THE SILVERSTEIN LAW FIRM
A Professional Corporation

215 NORTH MARENGO AVENUE, 3RD FLOOR
PASADENA, CALIFORNIA 91101-1504
PHONE: (626) 449-4200 FAX: (626) 449-4205
ROBERT@ROBERTSILVERSTEINLAW.COM
WWW.ROBERTSILVERSTEINLAW.COM

April 29, 2020

VIA OVERNIGHT DELIVERY

Mindy Nguyen
City of Los Angeles, Department of City Planning
221 North Figueroa Street, Suite 1350
Los Angeles, CA 90012

Re: Objection to Denial of Request for Extension of 45-Day Comment Period for Hollywood Center Project Draft Environmental Impact Report ("DEIR"); Case Number ENV-2018-2116-EIR; State Clearinghouse Number 2018051002

Attachment to the letter of the above-referenced subject.

Administrative Record from StopTheMillenniumHollywood.com vs. City of Los Angeles (LASC Case No. BS144606 ("Original Millennium Case")

4 of 6

HOLLYWOOD MILLENNIUM PROJECT
SCOPE OF DEVELOPMENT: DESIGN GUIDELINES AND STANDARDS

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1. PURPOSE AND OBJECTIVES

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria which serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

d. Permit design flexibility while establishing a set of controls that will guide the development for the Project site.

e. Ensure compliance with the Development Objectives.

1.2 Development Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure new development on the Project Site is consistent with these objectives.

1.2.2 The objectives for new development on the Project Site are to:

a. Preserve Capitol Records Tower and Gogerty Building.

b. Preserve public views to the Capitol Records Tower by creating grade level open space, civic

plazas, on the east site adjacent to the Jazz Mural and Capitol Records Tower and west site across from the Capitol Records Tower.

c. Create civic plazas that are activated by retail, landscaped and enhance the Hollywood Walk of Fame by providing it as an urban node; creating The Hollywood Walk of Fame Plaza. Reinforce the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

d. Preserve existing view corridors to the Hollywood hills.

e. Encourage street life by the creation of a new exclusive pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

f. Create vibrant urban spaces which permit active and passive recreational facilities for both the on-site and off-site population.

g. Create a 24 hr community by the creation of a Thriving Mixed-Use Development.

h. Eliminate the visual impact of the current on site parking.

i. Establish where feasible pedestrian linkages to existing public transportation routes in the area.

j. Establish of a standard intended to promote architectural excellence.

k. Provide designs that take into account the context and make an effort to respect it and fit in visually.

l. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

m. Create buildings that emphasize the vertical architecture and become visible icons.

n. Develop a visual gateway to Hollywood Boulevard from the Hollywood Freeway.

1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose strict compliance or measures for new development. For example, the Regulations include specific setback requirements along Vine Street. There are also mandatory requirements or standards for minimum open space on the ground floor as well as maximum building heights. By comparison, the guidelines are measures that may include a range of choices and require a degree of interpretation by the architect and design team to achieve compliance with the Regulations. The purpose of these guidelines is to create a principal design theme or objective without comprising high quality design. The purpose is to provide a range of flexibility to permit the selection of the most appropriate design feature based on the final development scenario. For instance, façade treatments for new development may take different form depending on the final design plans. The Regulations will guide the ultimate façade treatment by providing a limited range of choices in the use of material and color for the façades.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 They are approved by the City of Los Angeles City Council and are incorporated in the Development Agreement between the City of Los Angeles and _____ ("Millennium Development Agreement").

1.4.2 Wherever the Regulations contain provisions which establish regulations that are different from or more or less restrictive than the zoning or land use regulations in the Los Angeles Municipal Code ("LAMC") the Regulations that apply to the Project Site, the Regulations shall prevail pursuant to the Millennium Development Agreement approved by the City Council.

2. BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street. The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Street is the East Site.

The East Site and the West Site make up the Project Site.

2.1.2 The Project Site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 13 feet from Vine Street to Argyle Avenue and 11 feet from Vine Street to Ivar Avenue. The existing sidewalk elevations will not be altered as part the Project.

2.2 Site Zoning and Permitted Floor Area

2.2.1 Project Site is zoned Commercial (C2). City General Plan land use designation: Regional Center commercial.

2.2.2 Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.

2.2.3 Floor Area Ratio: 6:1

2.2.4 Height District: No. 2

proposed

3:1 under d limit

zoning when approved.

3. DENSITY

3.1 Transfer of Floor Area

Owner may transfer floor area from one site to the other, as long as the minimum and maximum building heights are maintained. Either site can exceed the 6:1 FAR, as long as the FAR of the combined sites averaged together is no more than 6:1.

3.2 Maximum OESF Density Per Area

[To be completed as part of the EIR.]

3.3 Use Coordination / Use Compatibility

[To be completed.]

We have done as part of unified

4. HEIGHT

4.1 Building Height Standards

The maximum permitted height for any building on the Project Site is _____. Refer to Figure __. Bulk Control Plan for specific permitted maximum building heights on each parcel.

4.2 Projections

The following are obstructions that can exceed the maximum building height: roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building, skylights, towers, steeples, flagpoles, wireless masts, water tanks, silos, solar energy devices, or similar structures.

use code def?.

screening

height varies on site

5. BUILDING AND STREET EXPERIENCE

5.1 Tower Massing Standards

5.1.1 The Tower Standards apply to the portion of a building located 150 feet above curb level.

5.1.2 Maximum lot coverage of tower floor plate:

a. 150 – 220 feet: 48%

b. 221 – 400 feet: 28%

c. 221 – 550 feet: 15%

d. 221 – 585 feet: 11.5%

drawing for each w/ dimensions so we can see

5.1.3 At least 50% of total floor area must be located below 220 feet.

5.1.4 Setback and articulation of tower walls and crown:

a. Towers are not required to step back.

b. Minimum 10% of tower to articulate

where did articulation elements on tower go?

5.2 Street Walls

A street wall is a wall or portion of a wall of a building facing a street or a grade level open space. Street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation.

5.3 Street Wall Standards

5.3.1 Location of a required street wall:

a. Parcels with a grade level open space: the required street wall shall be located minimum 5 feet from the property line. (S)

b. Parcels or portions of parcels without a grade level open space: the required street wall shall be located on the property line. (S)

Setback stepback

5.3.2 Height of required street wall and dimension of initial setback:

a. Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b) below.

b. 40% of aggregate width of required street wall frontage on each street can exceed maximum street wall height up to the maximum tower height.

5.3.3 Amount of articulation of required street wall:

The aggregate width of required street wall articulation at the level of any story above the level of the second story ceiling or 28'-0" above curb level, whichever is less, shall not exceed 50% of the required street wall.

5.3.4 Types of permitted articulation of a required street wall:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break should be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

5.3.5 Other permitted projections: elements which project beyond the property line from a required street wall shall comply with the Building Code.

a. Architectural facade elements such as expression bands, cornices; eaves, gutters, and downspouts may project from a required street wall over a grade level open space.

b. Steps and ramps may project from a required street wall over a grade level open space.

c. Marquees, canopies and awnings.

d. Retail storefronts: may project from a required street wall over a grade level open space by a maximum depth of 5'-0". The maximum height of

these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

5.4 Street Wall Guidelines

5.4.1 Pedestrian pass-through, public plazas, entry forecourts, permitted vehicular access driveways, hotel drop-offs and loading entries and exits are permitted; steps, ramps, marquees, canopies, awnings and retail storefronts are permitted.

5.4.2 [Insert new guidelines.]

5.5 Yard Standards

5.5.1 [Insert definition of yard.]

5.5.2 Commercial Use: no front, side or rear yard set backs are required

5.5.3 Residential Use:

a. Front Yard: none

b. Side Yard: Minimum 5 feet, for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.

c. Rear Yard: Minimum 15 feet, for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

5.6 Building Materials and Color Guidelines

5.6.1 Building materials and color will be subject to the following guidelines. These guidelines also address the façade treatment for both residential and commercial portions of buildings.

5.6.2 Building shall Feature long-lived and sustainable materials. The material palette should provide variety, reinforce massing and changes in the horizontal or vertical plane.

5.6.3 Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

5.6.4 Podium levels up to 150 feet will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents. There will be clear contrast between the buildings surface material and the building's glazed areas.

5.6.5 The building's skin, especially for towers, should be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required achieving energy efficiency standards.

5.6.6 In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style.

5.6.7 To provide visual variety and depth, layer the building skin and provide a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin should reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

5.6.8 Rooftop mechanical equipment: shall be screened with materials and design consistent with the building architecture.

5.6.9 Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

5.7 Grade Level Standards

5.7.1 The purpose of the grade level standards is to promote pedestrian-scaled architecture by regulating street wall massing, articulation and detail, street level entrances and storefront windows and doors, as well as the use of quality materials and decorative details. Architectural features that reinforce the retail character of the ground street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and should be integral to the architecture of the building.

5.7.2 Ground floor height

a. Minimum 12'-0" height floor to ceiling.

5.7.3 Building entrances:

a. The primary entrance to a street level tenant that has frontage along a public street shall be provided from that street. The primary entrance to a tenant that does not have its frontage along a public street shall be

provided from a courtyard, *grade level open space*, or *PAP*. Entries <18 inches from the property line shall not be higher than 12 inches above the elevation of the sidewalk; entries >18" from property line shall be within 30 inches of the adjacent grade level along the street frontages. Where possible entries shall be marked through the use of architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

b. Main building entrances should read differently from retail storefronts, restaurants and commercial entrances.

5.7.4 Ground floor glazing

a. Use of clear, colorless and transparent glazing is required within the first 30 feet of grade.

b. Use of reflective glass is prohibited.

c. Along street frontages with a required build-to line less than or equal to 18 inches from the property line, glazing should constitute a minimum of 30% of the area of a building face and should not exceed 80% of the area of a building face.

5.7.5 Arcades

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0 foot candles.

5.7.6 Service and refuse

a. Storage areas within the building of a size sufficient for that development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible to a curb cut.

5.7.7 Retail storefronts

a. Storefronts shall comprise a minimum of 70% of the building's street level façade and be recessed where necessary.

b. Storefront glazing should comprise a minimum of 60 percent of the storefront area along Vine Street and 40% glazing along all other streets.

Specify 3-8 feet? Height bands.

? CRA guidelines?

c. Ground floor retail space will be a minimum of 40 feet deep along Vine Street and 25 feet deep along all other streets; all retail shall have a minimum 12 feet clearance in height.

d. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet.

e. Storefront sills shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

f. Security grills will be located behind glass and be at minimum 70% open.

g. At-grade storefront glazing at, or adjacent to, and/or facing any public right-of-way shall incorporate transparent, clear, colorless glazing with no reflectivity.

5.8 Podium Standards

5.8.1 The purpose of the Podium Standards it to provide a modern interpretation of the historical context of Hollywood by establishing different treatment from the building's base, middle and top; through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

5.8.2 Podium height

Minimum 30'-0" to a maximum of 150 feet.

5.9 Podium Guidelines

5.9.1 Provide an identifiable break between the building's ground floors and upper floors. This break may include a change in material, change in fenestration pattern or similar means.

5.9.2 Podium level windows shall be vertically oriented.

5.9.3 Podium levels shall be predominantly light in color.

5.9.4 Expression band shall be provided at the highest story within the podium.

5.9.5 While blank street wall façades shall be avoided, an exception may be made for integration of public art or an articulated façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade should be a maximum of four floors high, and should have variation in its surface plane (using cut outs,

insets or pop-outs). It should employ different scales of elements as viewed when seeing the entire building massing.

5.9.6 Louvers and wall openings shall be designed to integrate with building architecture.

5.10 Street and Sidewalk Standards

5.10.1 The cohesiveness and variety of public open spaces and streets are key features of the Project. The combination of landscaped plazas, PAP and landscaped streets creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

5.10.2 Hotel and Commercial / Office / Retail that abut an alley Code language

a. Every required loading space shall be located and arranged that delivery vehicles may be driven upon or into said space from the alley. Such loading space shall have a minimum height of 14 feet and directly accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

b. Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.

c. Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet, a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet, and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

5.10.3 Condominiums

a. None

5.10.4 Rental

a. None

5.11 Screening Standards

a. Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

b. Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

6. TOWERS

can come back to this section

6.1 Purpose

6.1.1 Towers should have their massing designed to reduce overall bulk and to appear slender.

6.1.2 Towers should be designed to achieve a simple faceted geometry and exhibit big, simple moves. They should not appear overwrought or to have over-manipulated elements.

6.1.3 Towers that emulate a more streamline modern style should provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.

6.1.4 If a project has more than one tower, the towers should be complementary to each other and employ the same architectural design approach.

6.1.5 Generally, buildings over 150 feet tall (the historic datum for Hollywood) should not be historicized. They are contemporary interventions in the skyline and should appear as such.

6.2 General Tower Standards

6.2.1 A tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

6.2.2 Distinctive tower crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

6.3 Wall Standards

6.3.1 wall required to be articulated.

6.3.2 Types of permitted articulation of a tower wall:

a. Recess

b. Balcony: a balcony shall be integral to the façade and shall not create a relentless horizontal and vertical stacking pattern. They are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations.

c. Standard balconies may be projecting or recessed or a combination of both.

d. Bay windows

6.4 Spacing Standards

6.4.1 Towers should be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

6.4.2 Generally, the portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except the following which will meet code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled.

Q: reasoning behind to ensure towers spaced ok?

6.5 Rooftops Guidelines

6.5.1 Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and to be visually attractive when viewed from locations adjacent and above.

6.5.2 For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, [Insert Section No.__].

6.5.3 All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors.

6.5.4 All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

6.6 Parapets, Handrails, Roof Mechanical Equipment Screening Standards

6.6.1 Parapets and handrails shall be finished in a distinctive manner if part of an expression band or expression line.

6.6.2 Materials and design for roof mechanical equipment to be consistent with the building architecture and will utilize similar colors and materials as in other portions of the building.

6.6.3 Roof mechanical equipment shall be screened.

6.6.4 Enclosures for bulkheads shall not count against building height.

what does this mean?

ties into projections & recesses.

7. OPEN SPACE

7.1 Grade Level Open Space Standards

7.1.1 Grade level open space is a continuous open space fronting the street and open to the sky. The purpose of a grade level open space is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records and accentuate the low scale character.

7.1.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet.

7.1.3 An additional 3% of open space (total 8%) required for buildings between 221 feet and 400 feet.

7.1.4 An additional 5% (total 10%) of open space to be required for buildings between 401 feet and 550 feet

7.1.5 An additional 7% (total 12%) of open space required for buildings taller than 550 feet.

7.1.6 Location

a. East site: adjacent to the Jazz Mural and Capitol Records Tower; West site: across from the Capitol Records Tower along Vine Street.

b. Minimum depth: no horizontal dimension less than 5 feet when measured perpendicular from any point on each of the boundaries of the open space area.

7.2 Residential Open Space Standards

7.2.1 Common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above.

a. Requirements:

(i) Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.

(ii) Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein.

7.3 Common Open Space Standards

LAmC

7.3.1 [Insert definition.]

7.3.2 Be open to the sky and have no structures that project into the common open space area, except as permitted in the zoning code.

7.3.3 Be readily accessible to all the residents of the site.

7.3.4 Have a minimum area of 400 sq. ft. with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area,

7.3.5 Constitute at least 50% of the total required usable open space in developments built.

passage + plazas at jazz mind, etc.

7.3.6 Common open space areas shall incorporate recreational amenities including but not limited to, swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

7.3.7 Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use shall be considered as common open space.

7.4 Private Open Space Standards

LAmC

7.4.1 A private open space area is an area contiguous to and immediately accessible from a single dwelling unit. [Is it open to the sky?]

7.4.2 Contain a minimum of 50 square feet of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.

7.4.3 Have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

code language?

7.4.4 Provide a minimum eight foot vertical clearance under any projection, except as provided in zoning code.

7.4.5 That portion of a balcony which extends or projects into a required front yard in compliance with zoning code may qualify as usable open space provided it meets each of the above specified requirements noted in items i-iii.

7.5 Passageway Standards

7.5.1 *A publicly accessible passageway (PAP)**[rename PAP]*** is a continuous through block public connection between two parallel streets, located on privately owned land. The passageway may either be enclosed or open to the sky or a combination of both.

7.5.2 Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

7.5.3 Location and Size standards:

a. The major portion of a *PAP* is the largest area of the *PAP* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total PAP area and shall not be less than 20'-0" wide.

b. Minor portions of *PAP* are secondary areas that allow for additional flexibility in the shape and configuration of a *PAP*. Minor portions shall not occupy more than 25 percent of the total area of the *PAP*. The minor portion shall have a minimum width of 10 feet.

c. The minor portion must be directly adjacent to the major portion.

7.5.4 Permitted Obstructions:

a. *PAP* open air minimum requirements shall be as follows:

(i) Development with maximum building height of 150 feet: 0%

(ii) Development with maximum building height of 220 feet: 20%

(iii) Development with maximum building height of 400 feet: 30%

(iv) Development with maximum building height of 550 feet: 40%

(v) Development with maximum building height of 585 feet: 50%

b. Permitted obstructions within major portion of an open air *PAP*: any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions; balconies, bay windows; awnings, canopies and marquees; stairs, ramps and bollards.

7.5.5 Kiosk

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Buildings in conformance with the Building Code. Kiosks, including roofed areas, shall not exceed 3% of the total area of the *PAP* and no one kiosk shall occupy an area of more than 250 square feet.

b. A kiosk may be freestanding or may be attached on only one side to a wall of the building.

c. Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, and food preparation for open air cafes, flower stands or public service/information booths.

7.5.6 Open Air Cafe

a. Where an open air cafe is provided it shall be an unenclosed restaurant or eating or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies.

b. An open air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the *PAP*. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers.

c. An open air cafe may occupy an aggregate area not more than 20% of the total area of the *PAP*. No cooking equipment shall be installed within an

open air cafe. Cooking equipment may be contained in a kiosk adjoining the open air cafe. An open air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

7.5.7 Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on *PAP* through open windows.

7.5.8 Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No buildings refuse storage areas or refuse storage from a kiosk or open air café are permitted on any *PAP*.

b. No exhaust vents are permitted on any PAP or on any building wall of the development fronting upon the PAP except where such vents are more than 10'•6" above the level of the *PAP*.

7.5.9 Frontages

a. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a *PAP* shall be allocated for occupancy by permitted retail, restaurants and cultural uses.

b. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the *PAP* with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

7.5.10 Maintenance:

a. Responsibility: the building owner shall be responsible for the maintenance of the *PAP* including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the parcel and in the street sidewalk: area adjacent to the parcel.

b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of *PAP* area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000

square feet of *PAP* in connection with outdoor eating services or other uses permitted on *PAP* which generate litter.

7.6 Observation Deck Standards

7.6.1 Buildings above 550 feet to include an observation deck.

7.6.2 Observation to include roof-top open space and viewing deck accessible to the public.

8. LANDSCAPE

8.1 Grade Level Open Space Standards

8.1.1 Planting requirements: Minimum 10% of grade level open space shall be landscaped with softscape or water features.

8.1.2 Landscaped area(s) shall be planted with seasonally diverse plant material.

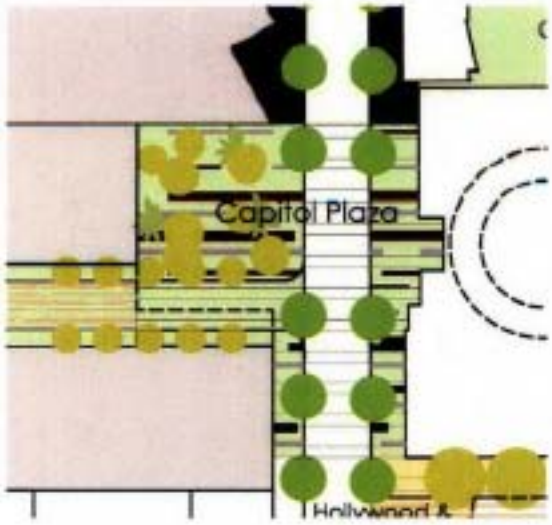
8.1.3 The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

8.1.4 The minimum soil depths for planting are:

a. Trees: 42"

b. Shrubs: 30"

c. Lawns, ground cover: 18"



8.1.5 Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

8.1.6 Permitted obstructions: the following are permitted obstructions which may occur in the *grade level open space*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining; and

b. retail storefronts.

8.1.7 Open air publicly accessible passageways (PAP) are not to be included in the grade level open space requirements.

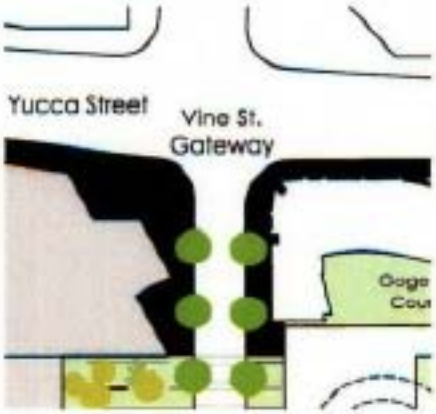
8.2 Common Open Space Standards

8.2.1 A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

8.2.2 At least one 24-inch box tree for every four dwelling units shall be provided on site and may include street trees in the parkway.

8.2.3 For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

residents? not common to all?



8.2.4 All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

8.3 Standards For Open Air Portions of *PAP*

8.3.1 The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

8.3.2 The minimum soil depths for planting are:

a. Trees: 42"

b. Shrubs: 30"

c. Lawns, ground cover: 18"

Standards for non-open parts of passage

8.3.3 Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

8.3.4 Planting requirements:

a. Minimum of 10% of open air *PAP* shall be landscaped.

b. For each 400 square feet of landscaped area there shall be at least one (l) major shade tree or two (2) minor ornamental trees.

- add Standards for non open air parts

9. PARKING

9.1 Automobile Standards

9.1.1 Commercial / Office / Retail/Sports Club:

At least two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot.

9.1.2 Condominiums

a. At least two parking spaces per each dwelling unit

b. One quarter parking spaces per each dwelling unit for guest parking

c. One quarter parking spaces per each dwelling unit for guest parking

d. Development is located within in a parking congested area

9.1.3 Rental

At least one parking space for each dwelling unit of less than three habitable rooms, one and one-half parking space for each dwelling unit of three habitable rooms, and two parking spaces for each dwelling unit of more than three habitable rooms.

9.1.4 Combination of uses

Where there is a combination of uses of a lot, the number of parking spaces required shall be the sum of the requirements of the various uses.

9.1.5 Shared parking

a. Shared parking may be applied on the site when the uses have different parking requirements and different demand patterns in a 24-hour cycle. The intent is to maximize efficient use of the site by matching parking demand with complimentary uses.

b. Calculating Shared Parking:

(i) Step I: Determine the aggregate minimum number of spaces required pursuant to the Code requirements for all land uses.

(ii) Step II: Based on the hourly variation in parking demand, determine the peak parking demand for the combined demand of all the land uses in the development.

(iii) Step III: Compare the calculations in Steps I and II, and the lesser of the two parking demands shall be used as the minimum number of parking spaces to be provided.

c. When a sports club is located in an office building with 50,000 square feet of office space, the general commercial use parking requirements apply and one parking space is required for 500 square feet of floor area for the building.

9.1.6 Additional regulations:

a. Location of accessory commercial / office / retail off-street spaces: may be located on the same parcel as the use to which they are accessory, or on the opposing development.

b. The automobile parking spaces required by Paragraphs (b), (c), (d) and (e) hereof, shall be provided either on the same lot as the use for which they are intended to serve or on another lot not more than 750 feet distant there from; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

c. Curb cuts shall be located no closer than 50 feet to the intersection of two streets.

d. Access driveways to parking facilities will not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

e. Parking and loading access will be shared where feasible.

9.1.7 Screening

a. Above grade parking shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible or shall be designed to blend in with the form and massing and designed to look

like an integral part of the building. The interior of a parking structure will be designed to be screened from the view of streets and sidewalks.

9.2 Bicycle Standards

9.2.1 Requirements for each use:

a. Commercial / Office / Retail:

Any portion of a building used for non-residential purposes which contains a floor area in excess of 10,000 square feet, bicycle parking spaces shall be provided at the rate of two percent of the number of automobile parking spaces required by this section for such non-residential uses; provided, however, that at least one bicycle parking space shall be provided for any such building having a floor area in excess of 10,000 square feet of non-residential use. If the calculation of the number of required spaces results in a number including a fraction, the next highest whole number shall be the number of spaces required.

shared shower facility—office retail etc...

b. Condominiums

At least one secure bicycle parking space shall be provided for every two residential units.

c. Rental

None

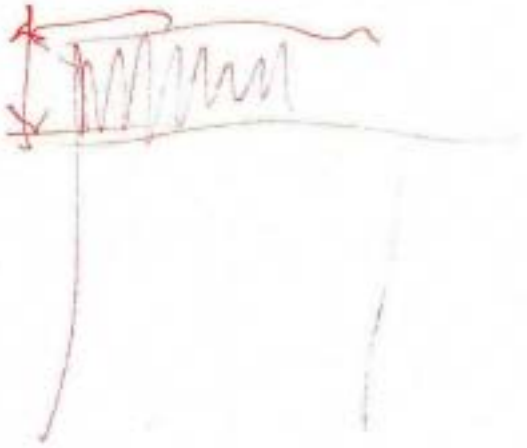
10. SIGNAGE

10.1 Hollywood Signage Supplemental Use District

Signage shall be subject to Ordinance No. 176172: Hollywood Signage Supplemental Use District pursuant to Section 13.11 of the Los Angeles Municipal Code.

10.2 Modification to Guidelines

Notwithstanding Section 10.1, high-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted.



11. SUSTAINABILITY

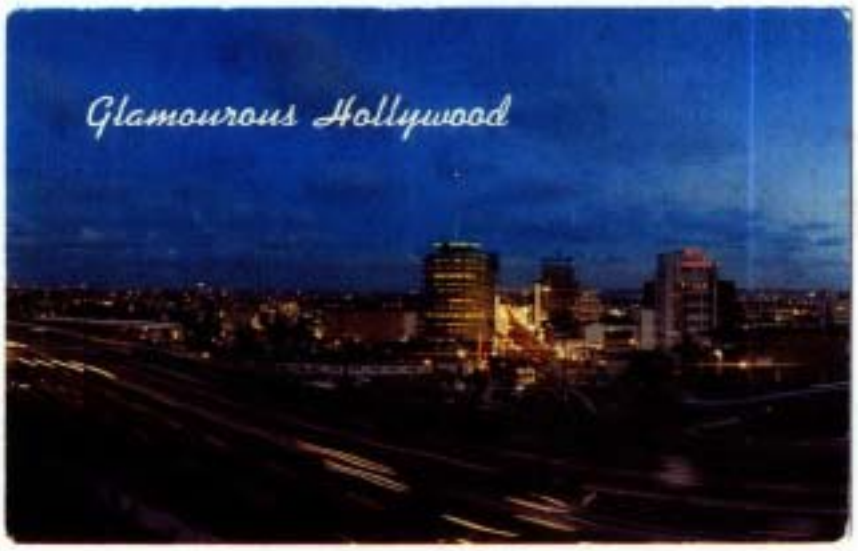
11.1 Nonresidential Projects

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

silver?

11.2 Other Projects

The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.



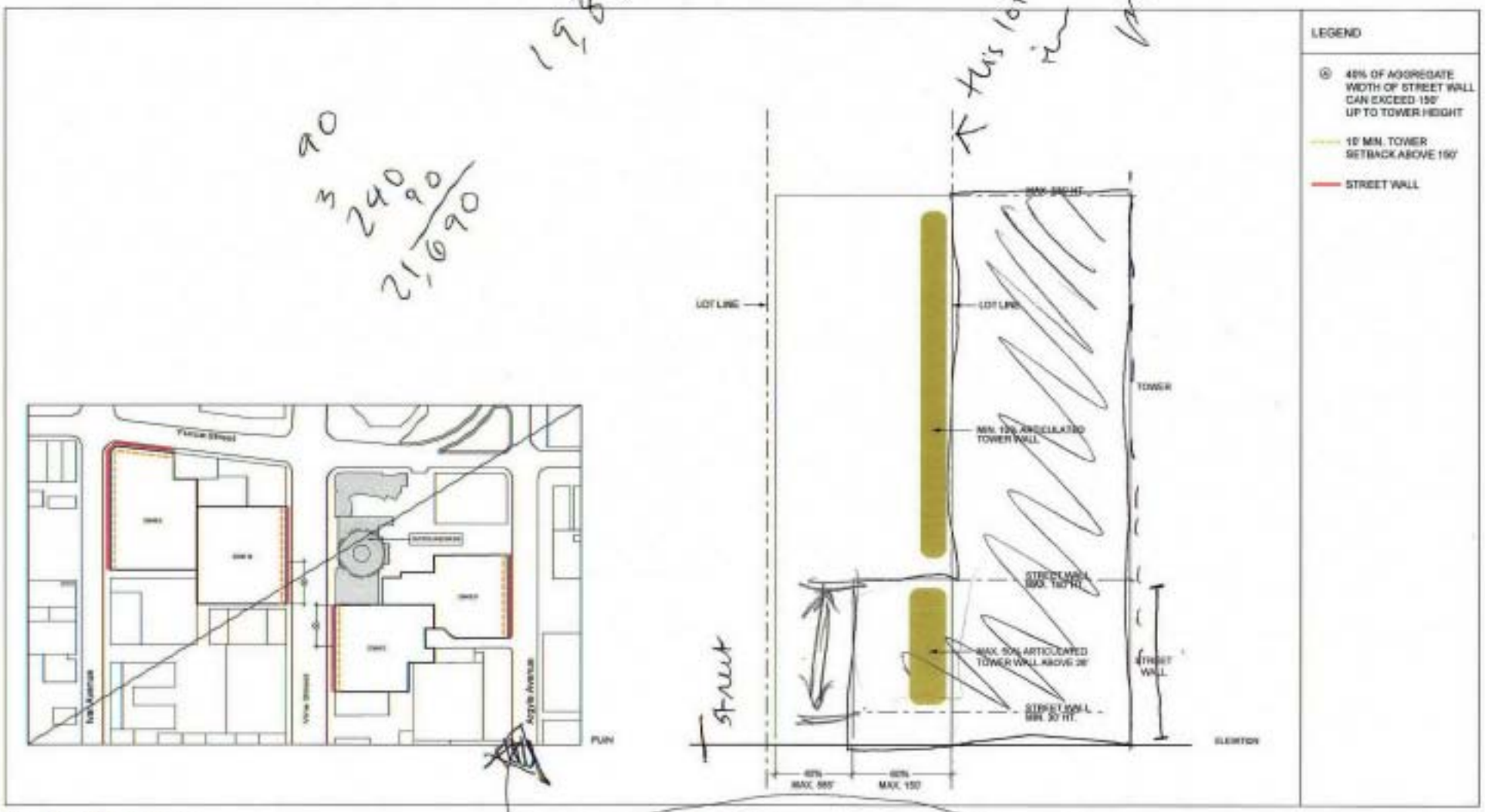
- flexibility
- what people get no matter what
- some of design images - (entitlement details)?
- further design ideas?

- can flexibility be narrowed down in order to further limit design choices
- Town level of change may be unacceptable
CRA issues about diagonal

20,000 sf office plate for eg

how to think about visualizing the entitled development w/ sketch up.

- entitlement
- flexibility / modality
- Idaeing
- Sketch up special places



HANDEL ARCHITECTS LLP
MARCH 24, 2010

STREET WALL

10% of length or square footage - how is % calculated linear or sf of total facade aggregated

Where is open space? is 10% OK?

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HANDEL ARCHITECTS LLP
MARCH 24, 2010

OPEN SPACE

talk to Kip and Allison - are open space numbers enough?

AR0067475

CO-0001-460

HANDEL ARCHITECTS
MARCH 26, 2013

OFFICE PROGRAM - 220'

CO-0001-461

AR0067476

HANDEL ARCHITECTS LLP
MARCH 24, 2010

OFFICE PROGRAM - 400'

CO-0001-462

AR0067477

DANIEL ARCHITECTS LLP
MARCH 24, 2010

RESIDENTIAL PROGRAM - 150'

CO-0001-463

AR0067478

HASOT ARCHITECTS LLP
MARCH 24, 2010

RESIDENTIAL PROGRAM - 220'

TRANSFER 36,600 SF TO WEST PARCEL

CO-0001-464

AR0067479

HANDEL ARCHITECTS LLP
MARCH 28, 2018

RESIDENTIAL PROGRAM - 400'

TRANSFER 22,200 SF TO WEST PARCEL

CO-0001-465

AR0067480

RESIDENTIAL PROGRAM - 550'

HANDEL ARCHITECTS
MARCH 24, 2010

CO-0001-466

AR007481

HANDEL ARCHITECTS LLP
MARCH 24, 2010

RESIDENTIAL PROGRAM - 585'

CO-0001-467

AR007482

OFFICE PROGRAM - 150'

TRANSFER 17,400 SF TO WEST PARCEL

CO-0001-468

AR007483

Design Guidelines
March 1, 2010
Revised April 8, 2010

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Design Guidelines
March 1, 2010
Revised April 8, 2010

1. INTRODUCTION

1.1. Purpose of Guidelines

1.1.1. The Design Guidelines ("Guidelines") have been prepared to regulate new development on the site with design guidelines and controls for development.

a. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project. The Design Guidelines establish basic site-wide design standards and criteria which serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole

b. Permit design flexibility while establishing a vocabulary which will guide the development for the Project site

c. Consolidate and illustrate the implications of the established practices which will govern the physical development of the two sites, defining the standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

1.2 Goals and Objectives

1.2.1. The Design Guidelines serve to reinforce the design principles which will contribute to the shape of a successful project.

1.2.2. These principles are as follows:

a. Preservation of the Capitol Records Tower and Gogerty Building.
b. Preserve public views to the Capitol Records Tower by creating *grade level* setbacks, civic plazas, on the east site adjacent to the Jazz Mural and Capitol Records Tower and west site across from the Capitol Records Tower.
c. Create civic plazas that are activated by retail, landscaped and enhance the Hollywood Walk of Fame by providing it as an urban room; creating The Hollywood Walk of Fame Plaza.
d. The reinforcement of the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.
e. The preservation of existing view corridor to the Hollywood hills.
f. The encouragement of street life by the creation of a new exclusive pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue
g. The creation of vibrant urban spaces which permit active and passive recreational facilities for both the on site and off-site population.
h. The creation of a 24 hr community by the creation of a Thriving Mixed-Use Development.
i. Eliminate the visual impact of the current on site parking.
j. [TRANSPORTATION – awaiting comments from CPDI]
k. The establishment of a standard intended to promote architectural excellence.
l. Provide designs that take into account the context and make an effort to respect it and fit in visually.

m. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space
n. The creation of two buildings that emphasize the vertical architecture and become a visible icon and gateway to Hollywood Boulevard from the Hollywood Freeway.

1.3 Relationship to the Los Angeles Municipal Code

1.3.1. The Guidelines were prepared in coordination with the Los Angeles City Planning Department and approved by the City Council.

1.3.2. Wherever the Guidelines contain provisions which establish regulations that are different from or more or less restrictive than allowed in the Los Angeles Municipal Code (LAMC) the Guidelines shall prevail pursuant to the Development Agreement approved by the City Council for the Project.

2. PROJECT BACKGROUND

2.1. Existing Site

2.1.1. The Project site consists of eight parcels on 4.47acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street. The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site. The area bounded by Yucca Street, Vine Street and Argyle Street is the East Site. The East Site and the West Site make up the Project Site. The Project site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 13 feet from Vine Street to Argyle Avenue and 11 feet from Vine Street to Ivar Avenue. The existing sidewalk elevations will not be altered as part the Project.

2.2. Zoning Classification

2.2.1. Classification: C2-2-SN (Proposed) within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.
- Currently zoned as a C4-2D-SN

2.2.2. The City General Plan land use designation: Regional Center commercial.

2.2.3. FAR: 6:1 (proposed)
- FAR 3:1 under "D" development limitation
- 4.5:1 under CRA Redevelopment Plan

2.3. Transfer of Floor Area

2.3.1. Owner may transfer floor area from one site to the other, as long as the minimum and maximum building heights are maintained. Either parcel can exceed the 6:1 FAR, as long as the FAR of the combined sites averaged together is no more than 6:1

2.4. Maximum OESF Density Per Area

2.5. Use Coordination / Use Compatibility

3. BUILDING HEIGHT AND MASSING

3.1. Street Wall

3.1.1. Definition of *street wall*: a wall or portion of a wall of a building facing a street or *a grade level setback*.

3.1.2. Design intent: required *street walls* determine the scale and character of the pedestrian environment. Articulation of the required *street wall* within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation.

3.1.3. Location of a required *street wall*:

a. Parcels with a *grade level setback*: the required *street wall* shall be located minimum 5 feet from the property line.
b. Parcels or portions of parcels without a *grade level setback*: the required *street wall* shall be located on the property line.

3.1.2. Height of required *street wall* and dimension of initial setback:

a. *Street walls* shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b) and (c) below.
b. 40% of aggregate width of required *street wall* frontage on each street can exceed maximum *street wall* height up to the maximum *tower* height.
c. 40% of aggregate width of required *street wall* frontage on a *publicly accessible private space* can exceed maximum *street wall* height up to the maximum *tower* height.

3.1.3. Amount of articulation of required *street wall*:

a. The aggregate width of required *street wall* articulation at the level of any story shall not exceed 30% of the required *street wall* above the level of the second story ceiling or 28'-0" above curb level, whichever is less, to the floor level of the penultimate floor within the required *street wall* height. Within the lesser of 2 stories or 28'-0" above curb level, recesses, balconies and bay windows shall not be permitted. Pedestrian pass-through, public plazas, entry forecourts, permitted vehicular access driveways, hotel drop-offs and loading entries and exits are permitted; steps, ramps, marquees, canopies, awnings and retail storefronts are permitted.

3.1.4 Types of permitted articulation of a required *street wall*:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0" with a 1:2 maximum depth to width ratio.

b. Balcony: a balcony may project a minimum of 3'-0" from a required *street wall* over a *grade level setback*.
c. Bay window: a bay window may project from a required *street wall* over a grade level setback.
d. Expression band: an identifiable break should be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

3.1.5. Other permitted projections: elements which project beyond the property line from a required *street wall* shall comply with the Building Code.

a. Architectural façade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required *street wall* over a *grade level setback*.
b. Steps and ramps may project from a required street wall over a *grade level setback*.
c. Marquees, canopies and awnings.
d. Retail storefronts may project from a required street wall over a *grade level setback* by a maximum depth of 5'-0". The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

3.2. Yards

3.2.1. Commercial Use: no front, side or rear yard set backs are required.

3.2.2. Residential Use:
a. Front Yard – none (proposed)
   - Code requires: There shall be a front yard of not less than 15 feet; provided, however, that on key lots the minimum front yard shall be 10 feet.
b. Side Yard: Minimum 5 feet, for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.
c. Rear Yard: Minimum 15 feet, for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

3.3. Maximum Building Height

3.3.1. Height District No. 2

3.3.2. The total floor area contained in all the buildings on a lot in Height District No. 2 shall not exceed six times the buildable area of said lot.
   - FAR 3:1 under "D" development limitation
   - 4.5:1 under CRA Redevelopment Plan

3.3.3. Refer to Figure xx Bulk Control Plan for permitted maximum building height on each parcel.

3.3.4. The following are permitted obstructions which may penetrate the maximum building height: roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building, skylights, towers, steeples, flagpoles, wireless masts, water tanks, silos, solar energy devices, or similar structures.

- [discuss] LAMC SEC. 12.21.B.2: "for each foot such structure exceeds the height limit, an equal setback from the roof perimeter is provided, except that stairways, chimneys and ventilation shafts shall not be required to be set back from the roof perimeter. No portion of any roof structure as provided for above shall exceed the specified height limit by more than five feet."

(Insert) Figures for Tower Zone and Massing Diagrams

3.4. Tower Controls

3.4.1. Definition of *tower*: the portion of a building located 150 feet above curb level.

3.4.2. Maximum lot coverage of *tower*:
a. 150 – 220 feet: 48%
b. 221 – 400 feet: 28%
c. 221 – 550 feet: 15%
d. 221 – 585 feet: 14.5%

3.4.3. Refer to 4.1.3 open space requirements for corresponding ground level open space that is determined by tower height.

3.4.4 50% of total floor area must be located below 220 feet.

3.4.5 Tower location: a tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

3.4.6. Setback and articulation of *tower* walls and crown:

a. *Towers* are not required to setback.
b. Minimum 10% of *tower* wall required to be articulated.
c. Distinctive *tower* crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

3.4.7 Types of permitted articulation of a *tower* wall:

a. Recess
b. Balcony: a balcony shall be integral to the façade and shall not create a relentless horizontal and vertical stacking pattern. They are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations.
   i) Standard balconies may be projecting or recessed or a combination of both.
c. Bay windows

3.4.8 Tower spacing

e. Towers should be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.
b. Generally, the portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except the following which will meet code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled.

4. OPEN SPACE

4.1. Grade Level Setback

4.1.1. Definition of *grade level setback*: a continuous open space fronting the street.

4.1.2. Design intent: the purpose of a *grade level setback* is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records and accentuate the low scale character.

4.1.3 Open space requirements:

a. Minimum ground floor open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet.
b. An additional 3% of open space (total: 8%) required for buildings between 221 feet and 400 feet.
c. An additional 3% (total: 10%) of open space to be required for buildings between 401 feet and 550 feet.
d. An additional 2% (total: 12%) of open space required for buildings taller than 550 feet.

4.1.4. Location

a. East site: adjacent to the Jazz Mural and Capitol Records Tower; West site: across from the Capitol Records Tower along Vine Street.
b. Minimum depth: no horizontal dimension less than 5 feet when measured perpendicular from any point on each of the boundaries of the open space area.

4.1.5. Landscape requirements:

a. Planting requirements: Minimum 10% of *grade level setback* shall be landscaped.
b. Landscaped area(s) shall be planted with seasonally diverse plant material.
c. The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.
d. The minimum soil depths for planting are:
   (1) Shrubs: 30"
   (2) Lawns, ground cover: 18"
e. Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

4.1.6 Permitted obstructions: the following are permitted obstructions which may occur in the *grade level setback*.

a. Building entries, steps, ramps, balconies, bay windows, architectural façade details, marquees, canopies, awnings, outdoor dining, and retail storefronts

4.2. Residential Open Space

4.2.1. Design intent: a common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children, and to be visually attractive when viewed from apartments adjacent and above.

a. Requirements.
(i) Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.
(ii) Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein.

4.2.2. Common Open Space

a. Requirements:
(i) Be open to the sky and have no structures that project into the common open space area, except as permitted in the zoning code.
(ii) Be readily accessible to all the residents of the site.
(iii) Have a minimum area of 400 sq. ft. with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area,
(iv) Constitute at least 50% of the total required usable open space in developments built.
(v) Common open space areas shall incorporate recreational amenities including but not limited to, swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center
(vi) A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.
(i) At least one 24 inch box tree for every four dwelling units shall be provided on site and may include street trees in the parkway.
(ii) For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.
(iii) All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

b. Location of common open space:

(i) Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use shall be considered as common open space.

4.2.3. Private Open Space

a. Definition: a private open space area contiguous to and immediately accessible from a single dwelling unit.

b. Requirements:
   (i) Contain a minimum of 50 square feet of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.
   (ii) Have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.
   (iii) Provide a minimum eight foot vertical clearance under any projection, except as provided in zoning code.
   (iv) That portion of a balcony which extends or projects into a required front yard in compliance with zoning code may qualify as usable open space provided it meets each of the above specified requirements noted in items 1-3.

4.3. Publicly Accessible Private Space (PAPS)

4.3.1. Definition of *publicly accessible private space (PAPS)*: a continuous through block connection, located on privately owned land.

4.3.2. Design intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

4.3.3. Location and size requirements:

a. The major portion of a *PAPS* is the largest area of the *PAPS* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total PAPS area and shall not be less than 20'-0" wide.
b. Minor portions of *PAPS* are secondary areas that allow for additional flexibility in the shape and configuration of a *PAPS*. Minor portions shall not occupy more than 25 percent of the total area of the *PAPS*. The minor portion shall have a minimum average width of 10 feet.
c. The minor portion must be directly adjacent to the major portion.

4.3.4. Permitted obstructions:

a. *PAPS* open air minimum requirements shall be as follows:

(i)	Development with maximum building height of 150 feet:	0%
(ii)	Development with maximum building height of 220 feet:	20%
(iii)	Development with maximum building height of 400 feet:	30%
(iv)	Development with maximum building height of 550 feet:	40%
(v)	Development with maximum building height of 585 feet:	50%

b. Permitted obstructions within open air *PAPS*: any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art,

arbors, trellises, benches, seats, trees, planting beds, other receptacles, drinking fountains, and bicycle racks; open air cafes; kiosks, outdoor furniture; lights and lighting stanchions, flag poles, public telephones, temporary exhibitions; balconies, bay windows; awnings, canopies and marquees; stairs, ramps and bollards. Metro station access?

4.3.5. Kiosk:

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Buildings in conformance with the Building Code. Kiosks, including roofed areas, shall not exceed 3%of the total area of the PAPS and no one kiosk shall occupy an area of more than 250 square feet. A kiosk may be freestanding or may be attached on only one side to a wall of the building. Any area occupied by a kiosk shall be excluded from the definition of floor area [needs to be confirmed with CPD], and may be occupied by news or magazine stands, candy stores, food preparation for open air cafes, flower stands or public service/information booths.

4.3.6. Open air cafe

a. Where an open air cafe is provided it shall be an unenclosed restaurant or eating or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies. An open air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the PAPS. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers. An open air cafe may occupy an aggregate area not more than 20%of the total area of the PAPS. No cooking equipment shall be installed within an open air cafe. Cooking equipment may be contained in a kiosk adjoining the open air cafe. An open air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

4.3.7. Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on PAPS through open windows.

4.3.8. Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No buildings refuse storage areas or refuse storage from a kiosk or open air cafe are permitted on any PAPS.
b. No exhaust vents are permitted on any PAPS or on any building wall of the development fronting upon the PAPS except where such vents are more than 10'-6" above the level of the PAPS.

4.3.9. Landscape requirements

a. The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.
b. The minimum soil depths for planting are:
   (i) Trees: 36"

(ii) Shrubs: 30"
(iii) Lawns, ground cover: 18"

c. Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

d. Planting requirements.
(i) Minimum of 10% of open air PAPS shall be landscaped.
(ii) For each 400 square feet of landscaped area there shall be at least one (1) major shade tree or two (2) minor trees.
(iii) The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

e. Seating.
1. There shall be a minimum of one linear foot of seating for each 300 square feet of PAPS excluding the area of an open air cafe.
(i) One seat shall equal two linear feet
2. Not more than 50% of the linear seating capacity may be in moveable seats which may be stored between the hours of 7 p.m. and 7 a.m. Seating shall meet the following standards:
(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count double provided there is access to both sides.
(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.
(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.
(iv) Moveable seating or chairs, excluding seating of open air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open air cafes do not count toward meeting the seating requirements.

4.3.10. Lighting:

a. A PAPS shall be illuminated throughout with an overall minimum average level of illumination of not less than one maintained foot candle (lumens per square foot) on the horizontal plane at grade. Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

4.3.11. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of all building walls of the development fronting on a PAPS shall be allocated for occupancy by permitted retail, restaurants and cultural uses. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the PAPS with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

4.3.12. Maintenance:

a. Responsibility: the building owner shall be responsible for the maintenance of the PAPS including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the parcel and in the street sidewalk area adjacent to the parcel.
b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of PAPS area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of PAPS in connection with outdoor eating services or other uses permitted on PAPS which generate litter.

4.4. Rooftop Observation Deck

4.4.1. Buildings above 550 feet to include a public roof-top open space and viewing deck.

5 ARCHITECTURAL ELEMENTS

5.1. Building Materials and Color

5.1.1. Design intent: define the general design objectives for the material and color of distinct portions of the buildings and prescribe the treatment required for both residential and commercial portions of the building.

5.1.2. Guidelines:

a. Feature long-lived and sustainable materials. The material palette should provide variety, reinforce massing and changes in the horizontal or vertical plane.
b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.
c. Podium levels up to 150 feet ~~must include surfaces of masonry~~ will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents. There will be clear contrast between the buildings surface material and the building's glazed areas.
d. The building's skin, especially for towers, should be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.
e. In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style.
f. To provide visual variety and depth, layer the building skin and provide a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin should reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.
g. Rooftop mechanical equipment: shall be screened with materials and design consistent with the building architecture; ~~see Section 10, Tower crown~~.
h. Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

5.2. Grade Level Controls

5.2.1. Design intent: street wall massing, articulation and detail, street level building entrances and storefront windows and doors, as well as the use of quality materials and decorative details, shall be used to promote pedestrian-scaled architecture along the street. Architectural features that reinforce the retail character of the ground street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and should be integral to the architecture of the building.

5.2.2. Ground floor height:

a. Minimum 12' 0" height floor to ceiling.

5.2.3. Building entrances:

a. The primary entrance to a street level tenant that has frontage along a public street shall be provided from that street. The primary entrance to a tenant that does not have its frontage along a public street shall be provided from a courtyard, *grade level setback*, or *PAPS*. Entries shall not be higher than 4 feet above the elevation of the sidewalk at its nearest point to the entry. Where possible entries shall be marked through the use of architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.
b. Main building entrances should read differently from retail storefronts, restaurants and commercial entrances.
~~c. See Section xx marquees, canopies, awnings; Section xx for signage controls, and Section xx for lighting controls~~

5.2.4. Ground floor glazing. [CPD sending text from CRA]

5.2.5. Arcades:

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0 foot candles.

5.2.6. Service and refuse:

a. Storage areas within the building of a size sufficient for that development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible to a curb cut; refer to Section xx Loading.

5.2.7 Retail storefronts:

a. Openings for storefronts, windows and doors shall comprise a minimum of 40% of the building's street level façade and be recessed where necessary.
b. Ground floor retail space will be a minimum of 20 feet deep and 12 feet clearance in height and have storefronts openings a minimum of 10 feet in height. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet.
c. Security grills will be located behind glass and be at minimum 80% open.
d. Storefront glazing will be transparent.

5.3. Podium Controls

5.3.1. Design intent: provide a modern interpretation of the historical context of Hollywood by establishing different treatment from the building's base, middle and top through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

5.3.2 Podium height:

a. Minimum 30'-0" to a maximum of 150 feet, ~~exclusive of the ground floor level.~~

5.3.3. Guidelines:

a. Provide an identifiable break between the building's ground floors and upper floors. This break may include a change in material, change in fenestration pattern or similar means
b. Podium level windows shall be vertically oriented
c. Podium levels shall be predominantly light in color.
d. Expression band shall be provided at the highest story within the podium.
e. While blank street wall façades are prohibited, an exception may be made for integration of public art or a graphic based façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade should be a maximum of four floors high, and should have variation in its surface plane (using cut outs insets or pop-outs). It should employ different scales of elements as viewed when seeing the entire building massing.

5.4. Fenestration

5.4.1. Louvers, wall openings shall be designed to integrate with building architecture

5.5. Tower

5.5.1. Design Intent:

a. Towers should have their massing designed to reduce overall bulk and to appear slender.
b. Towers should be designed to achieve a simple faceted geometry and exhibit big, simple moves. They should not appear overwrought or to have over articulated elements.
c. Towers that emulate a more streamline modern style should provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.
d. If a project has more than one tower, they should be complementary to each other and employ the same architectural design approach.
e. Generally, buildings over 150 feet tall (the historic datum for Hollywood) should not be historicized. They are contemporary interventions in the skyline and should appear as such.

5.6. Rooftops and Setbacks

5.6.1. General requirements:

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a. Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and to be visually attractive when viewed from locations adjacent and above.
b. For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section xxx
c. All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colours. All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

5.7. Parapets, Handrails, Roof Mechanical Equipment Screening

5.7.1. Parapets and handrails: if part of an expression band or expression line, shall be finished in a distinctive manner.

5.7.2. Roof mechanical equipment shall be screened, materials and design to be consistent with the building architecture and will utilize similar colors and materials as in other portions of the building. Enclosures for bulkheads shall not count against building height.

6. STREETSCAPE

6.1. Streets and Sidewalks

6.1.1. Design intent: the cohesiveness and variety of public open spaces and streets are key features of the Project. The combination of landscaped plazas and *PAPS* and landscaped streets creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings

(i) Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

(ii) Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree planting pattern

6.1.2 Tree planting guidelines

a. It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module

for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

7. PARKING

7.1. Automobile Parking

7.1.1 Requirements for each use:

a. Commercial / Office / Retail.
   i) At least two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot.

b. Condominiums
   i) At least two parking spaces per each dwelling unit
   ii) One quarter parking spaces per each dwelling unit for guest parking
   iii) One quarter parking spaces per each dwelling unit for guest parking
      - Development is located within a parking congested area

c. Rental
   i) At least one parking space for each dwelling unit of less than three habitable rooms, one and one half parking spaces for each dwelling unit of three habitable rooms, and two parking spaces for each dwelling unit of more than three habitable rooms.

d. Combination of uses:
   i) Where there is a combination of uses of a lot, the number of parking spaces required shall be the sum of the requirements of the various uses.

7.1.2. Additional regulations:

a. Location of accessory commercial / office / retail off street spaces: may be located on the same parcel as the use to which they are accessory, or on the opposing development.
   (i) (g) Location of Parking Area. The automobile parking spaces required by Paragraphs (b), (c), (d) and (e) hereof, shall be provided either on the same lot as the use for which they are intended to serve or on another lot not more than 750 feet distant there from; said distance to be measured horizontally along the streets between the two lots, except that; where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

b. Curb cuts shall be located no closer than 50 feet to the intersection of two streets.

c. Access driveways to parking facilities will not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

d. Parking and loading access will be shared where feasible.

7.1.3 Screening

a. Above grade parking shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible or shall be designed to blend in with the form and massing and designed to look like an integral part of the building. The interior of a parking structure will be designed to be screened from the view of streets and sidewalks

7.2. Employee Bicycle Parking

7.2.1 Requirements for each use:

a. Commercial / Office / Retail:
   (i) Any portion of a building used for non-residential purposes which contains a floor area in excess of 10,000 square feet, bicycle parking spaces shall be provided at the rate of two percent of the number of automobile parking spaces required by this section for such non-residential uses, provided, however, that at least one bicycle parking space shall be provided for any such building having a floor area in excess of 10,000 square feet of non-residential use. If the calculation of the number of required spaces results in a number including a fraction, the next highest whole number shall be the number of spaces required.

b. Condominiums
   (i) At least one secure bicycle parking space shall be provided for every two residential units.

c. Rental
   (i) None

7.3 Circulation

8. SERVICE AND LOADING

8.1. Requirements

a. Hotel and Commercial / Office / Retail that abut an alley
   (i) Every required loading space shall be located and arranged that delivery vehicles may be driven upon or into said space from the alley. Such loading space shall have a minimum height of 14 feet and directly accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.
   (ii) Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.
   (iii) Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet, a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet, and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

b. Condominiums

(i) None
c. Rental
(i) None

8.2. Screening

a. Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.
b. Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

8.3. Circulation

9. SIGNAGE

9.1. Guidelines

a. Refer to Ordinance No. 176171 Hollywood Signage Supplemental Use District pursuant to Section 13.11 of the Los Angeles Municipal Code

9.2. Modification to Guidelines

a. High-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted.

10. SUSTAINABILITY

10.1. LEED Certification

10.1.1 Standard of Sustainability (Mandatory for large projects)

a. Threshold: The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.
b. Requirement: The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level Formal certification by the USGBC is not required.

10.1.2 Standard of Sustainable Excellence (Voluntary for projects of any size - large and small)

a. Threshold: The Standard of Sustainable Excellence establishes an incentive program for projects that register with the USGBC's LEED® program, maintain

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with a LEED® AP, and can demonstrate how the project will achieve LEED® certification at a Silver or higher level.

c. Incentives: The ordinance will establish expedited service within the Department of City Planning and the Bureau of Engineering. Other incentives already in place including those from the Department of Water and Power and the Department of Building and Safety, remain unchanged.

11. LIGHTING

11.1. Design intent. Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, illumination, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually articulate the night time streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

11.2 Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade *level setback and open PAPS*.
b. Lighting will be operated from dusk to dawn.
c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.
d. Steps and ramps will be lighted with a minimum of 1.0 foot candles on a horizontal plane.
e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

11.3 Responsibility for maintenance: building owner is responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

11.4 Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building owner.

11.5. Lighting for areas located inside the lot line and visible from the street: such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

11.6. Lighting for above-grade parking garage facilities, shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

12. NOISE

13. OPERATIONAL STANDARDS

13.1 Pet Controls

13.2. Antennas
a. Transmission facilities
b. Cable antennas

13.3 Wireless Facilities

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MILLENNIUM TOWERS DEVELOPMENT AGREEMENT

February 18, 2010

Millennium Partners
Argent Ventures
Handel Architects
Roschen Van Clove Architects

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MILLENNIUM TOWERS DEVELOPMENT AGREEMENT

February 18, 2010

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MILLENNIUM TOWERS DEVELOPMENT AGREEMENT

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Vine Street & Yucca Street - Design Guideline Outline

1. Introduction

a. Purpose of Guidelines

The Design Guidelines have been prepared to provide information describing the Project's design intent and specific controls affecting the two sites as a whole as well as its individual development. The Design Guidelines serve two functions:

i. They establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project. The Design Guidelines establish basic site-wide design standards and criteria which serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole. These Design Guidelines are intended to permit design flexibility while establishing a vocabulary which will guide the development team for each of the two sites.

ii. They consolidate and illustrate the implications of the established practices which will govern the physical development of the two sites, defining the standards for use, bulk, parking and loading, architectural features, landscape treatment, signage and lighting. The Design Guidelines are to be approved by the Los Angeles City Planning Department. Once accepted the Design Guidelines will apply in lieu of the City of Los Angeles Municipal Code & the City of Los Angeles Planning and Zoning Code. Compliance with the Design Guidelines will replace the usual zoning review by the Los Angeles City Planning Department. Compliance with the current City of Los Angeles Building Code will continue to be reviewed by the City of Los Angeles Department of Buildings and Safety.

b. Goals and Objectives

The Design Guidelines serve to reinforce the design principles which will contribute to the shape of a successful project. These principles are as follows:

1. *Preservation of the Capitol Records Tower and Gogerty Building.*
2. *Preserve public views to the Capitol Records Tower.*
3. *Civic plazas located on the east site adjacent to Vine Street to preserve views of the Jazz Mural and Capitol Records Tower and west site across from the Capitol Records Tower.*
4. *The establishment of a standard intended to promote architectural excellence.*
5. *The creation of two iconic towers as the entrance to Hollywood Boulevard from the Hollywood Freeway.*
6. *The reinforcement of the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.*
- *The enhancement of the Hollywood Walk of Fame by providing it an urban node with the creation of The Hollywood Walk of Fame Plaza.*
- *The encouragement of street life by the creation of a new exclusive pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.*
- *The creation of vibrant urban spaces which permit active and passive*

Want taller building in exchange for more open space relationship w/ adjacent bldgs - setback height, buffer, landscaping

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recreational facilities for both the on-site and off-site population.

- *The creation of a 24 hour community by the creation of a thriving Mixed-Use Development.*
- *The preservation of existing view corridor to the Hollywood Hills.*
- *Eliminate the visual impact of the current parking on site parking.*
- *Insure sustainability by the creation of two development sites that offer flexibility to respond to market conditions and development phasing.*

Substantial portion of open space is contiguous

2. Location

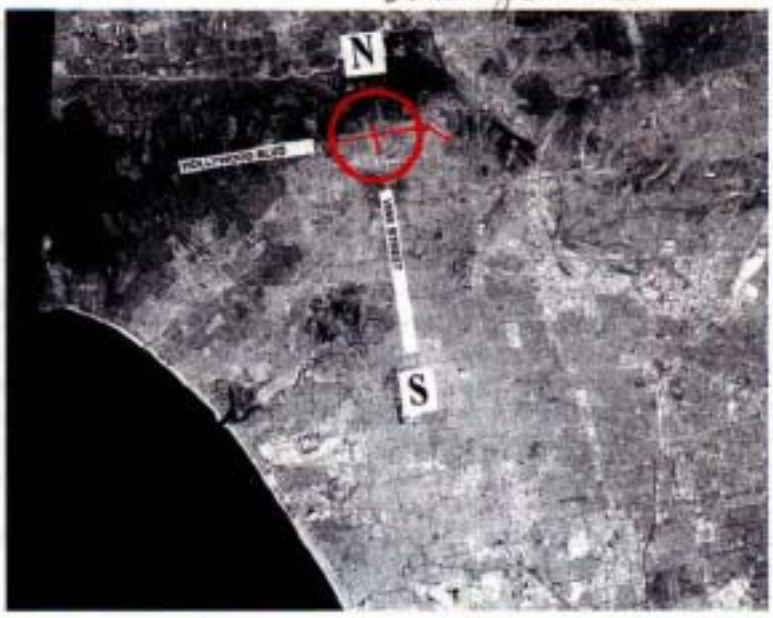


Figure 2.1

Figure 2.2

DRAFT

3. Building Height and Massing

a. Street wall

(a) Design intent: required street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation.

(b) Location of a required street wall:

- *The required street wall shall be located within 3'-0" from the street line, except as noted in Item 4. Open Space and or through block passages.*

(c) Height of required street wall and dimension of initial setback:

- *Street walls shall be built to a height of at least 30 feet.*

b. Yards and Setbacks

Notwithstanding the requirements set forth in the LA Municipal Code, no building shall be required to provide front, side or rear yards or building setbacks.

c. Tower width controls

Tower location: a tower 400 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets. why 400 feet?

d. Tower height

Designated Tower Zones, see Figure 3.1.

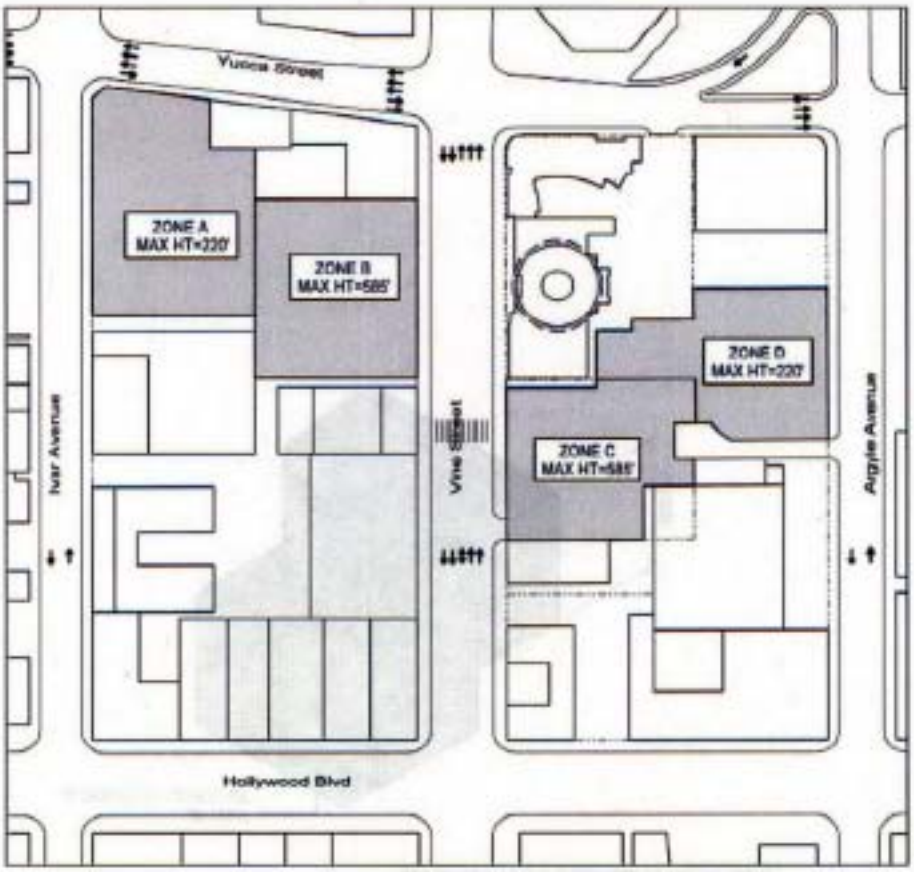


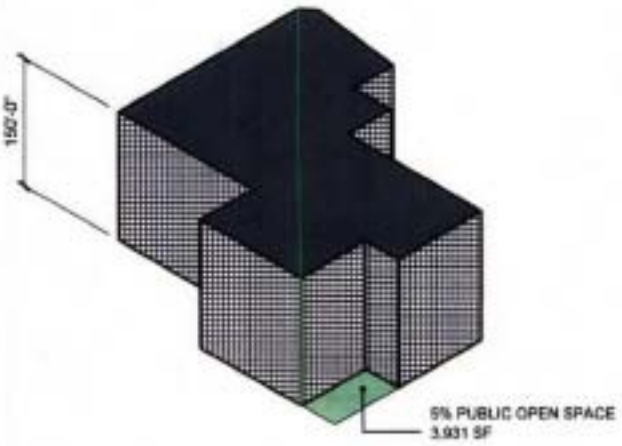
Figure 3.1

(a) Building Heights up to 150 feet:

- *Massing established by protected view corridors and fire access*
- *Street wall and facade modulation up to 150 feet*

West Site:

WEST SITE - SITE PLAN



AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.2

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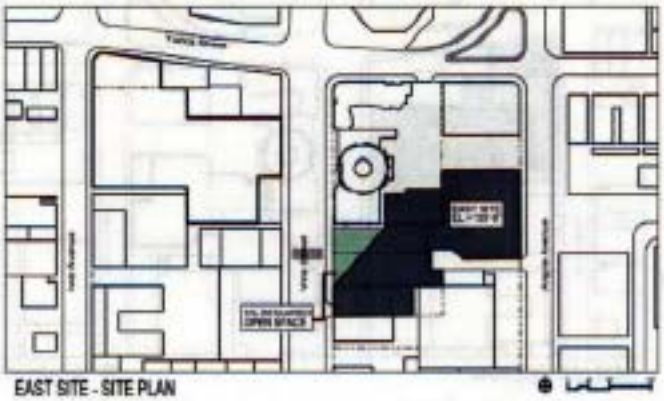
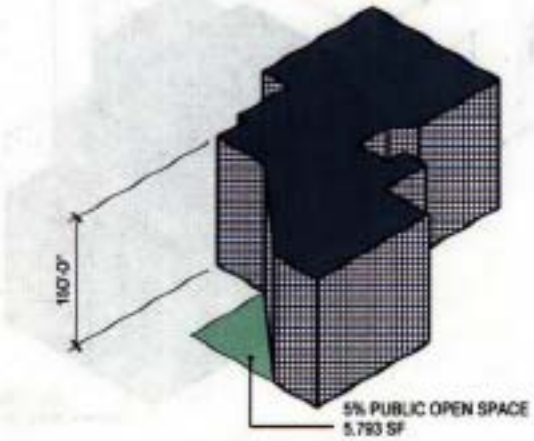
East Site



EAST SITE - SITE PLAN



AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.3

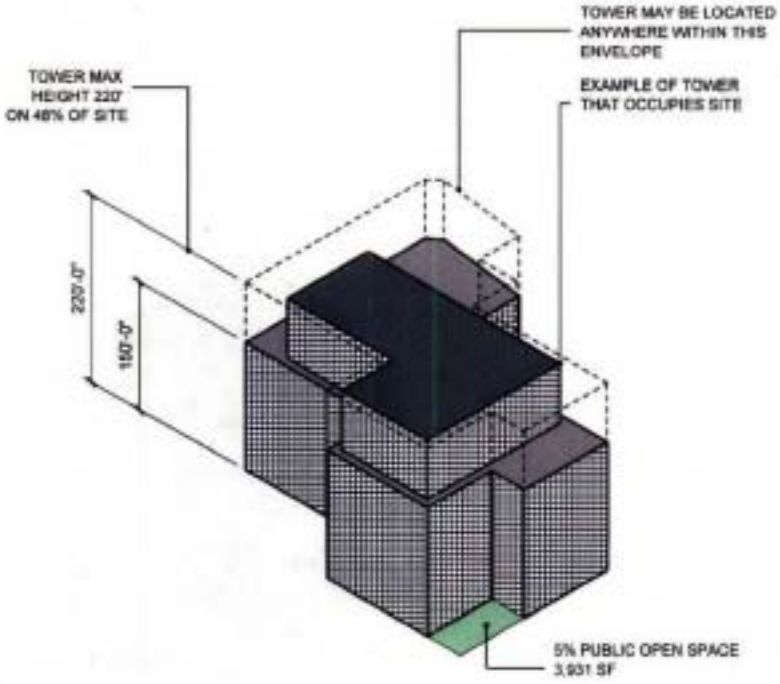
DRAFT

(b) Building Heights up to 220 feet:

- *Building floor plate not to exceed 48% of lot coverage in designated zones*

West Site

WEST SITE - SITE PLAN



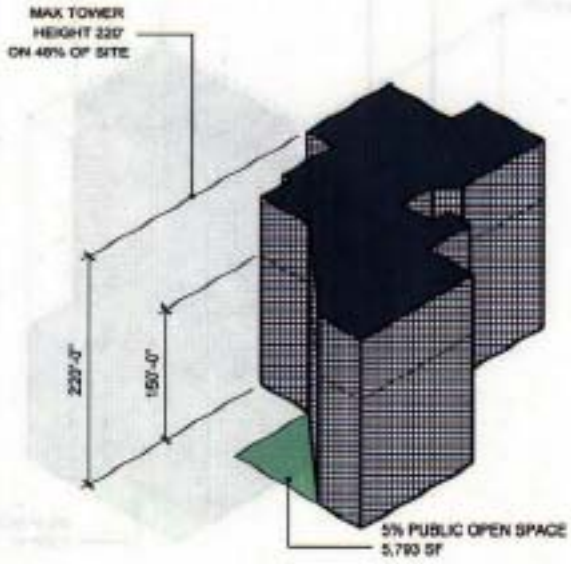
AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.4

DRAFT

East Site:

EAST SITE - SITE PLAN



AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.5

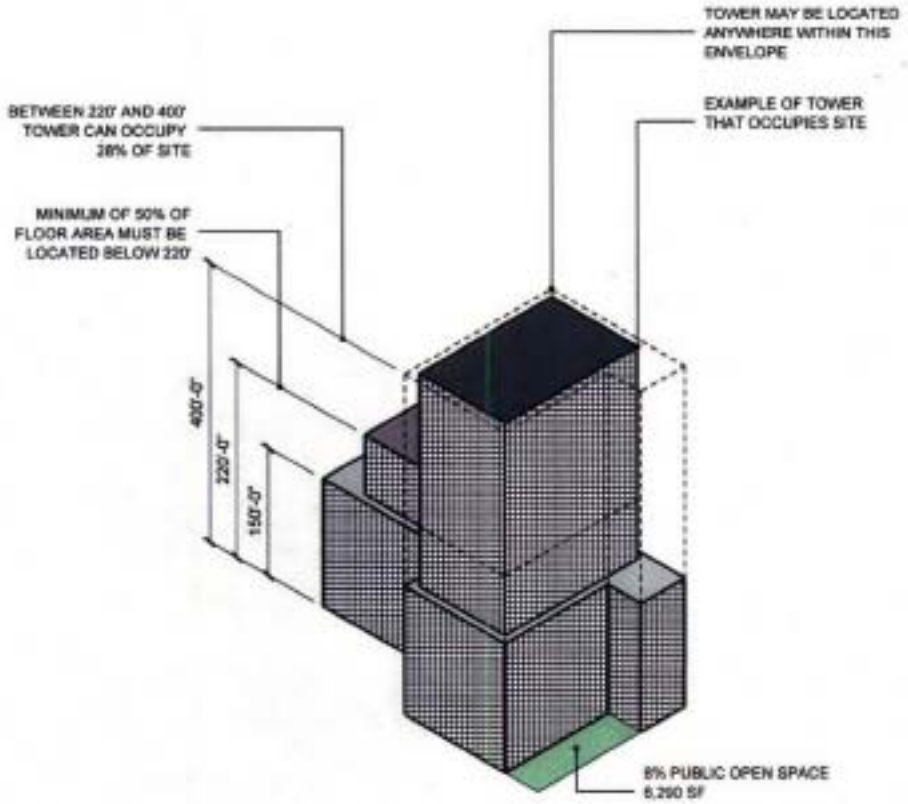
DRAFT

(c) Building Heights up to 400 feet:

- *50% of floor area must be located below 220 feet.*
- *Building floor plate not to exceed 28% of lot coverage in designated zones between 220 feet and 400 feet.*

West Site:

WEST SITE - SITE PLAN



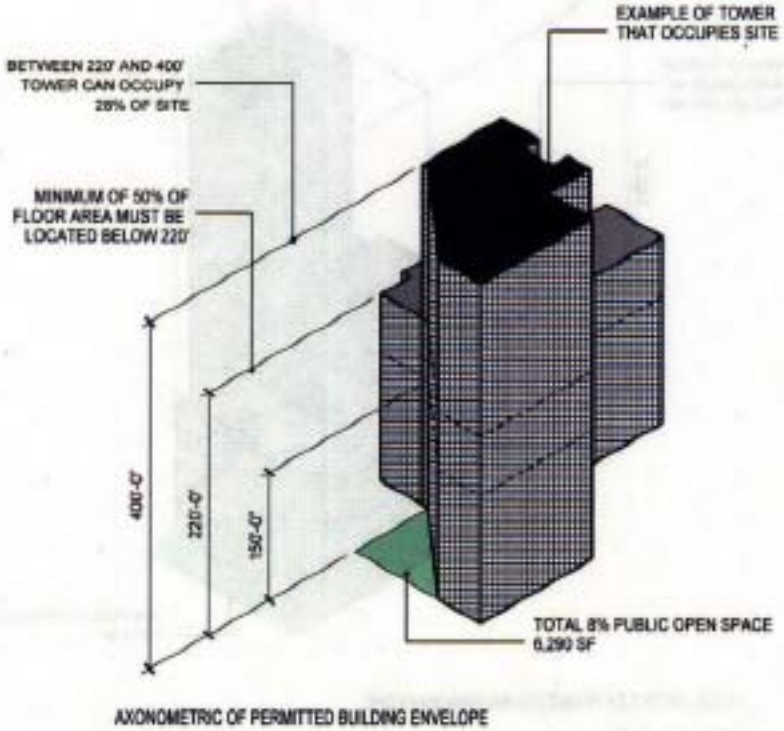
AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.6

DRAFT

East Site:

EAST SITE - SITE PLAN



AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.7

DRAFT

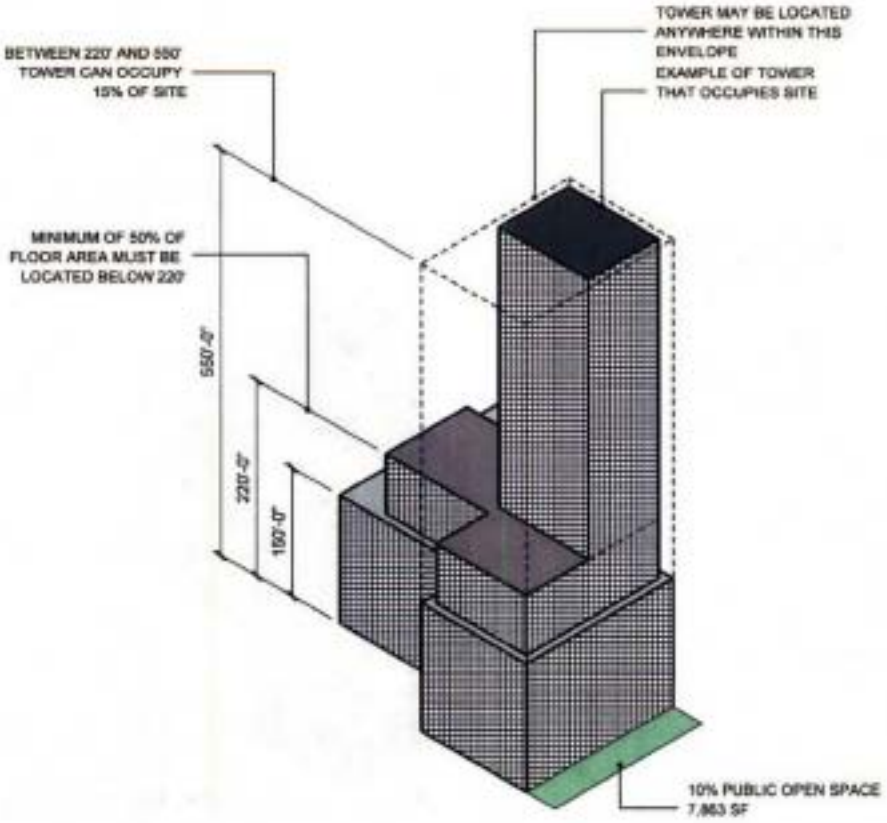
balance need to OS w/ need to create ~~open~~ green

3d) Building Heights up to 550 feet:

- *Building floor plate not to exceed 15% of lot coverage in designated zones between 220 feet and 550 feet.*

West Site:

WEST SITE - SITE PLAN



AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.8

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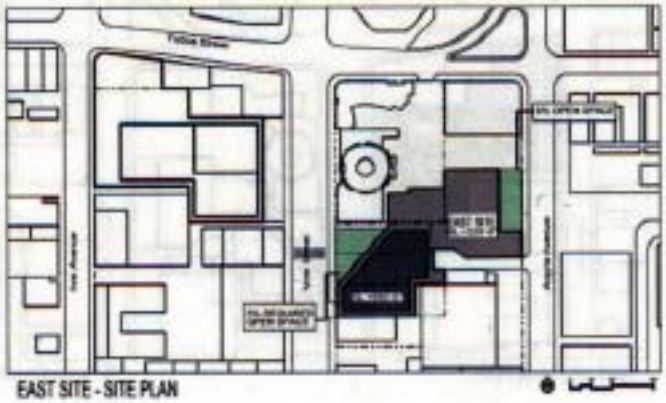
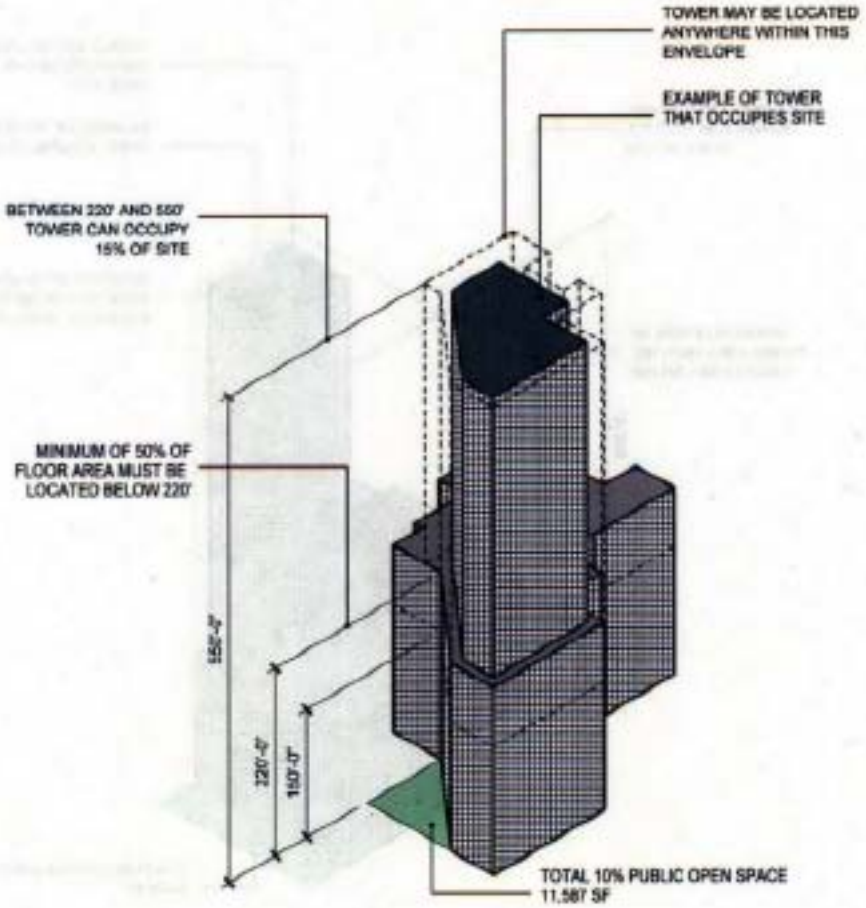
East Site:



EAST SITE - SITE PLAN



AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.9

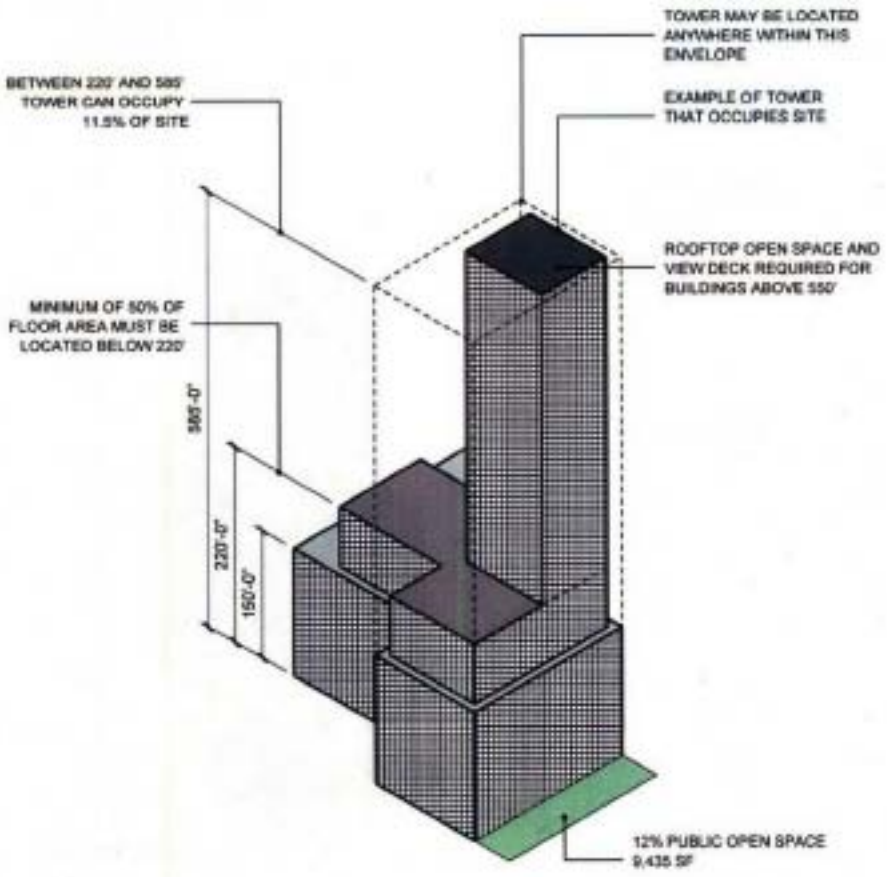
DRAFT

(e) Building Heights up to 585 feet:

- *Building floor plate not to exceed 11.5% of lot coverage in designated zones between 220 feet and 585 feet.*

West Site:

WEST SITE - SITE PLAN

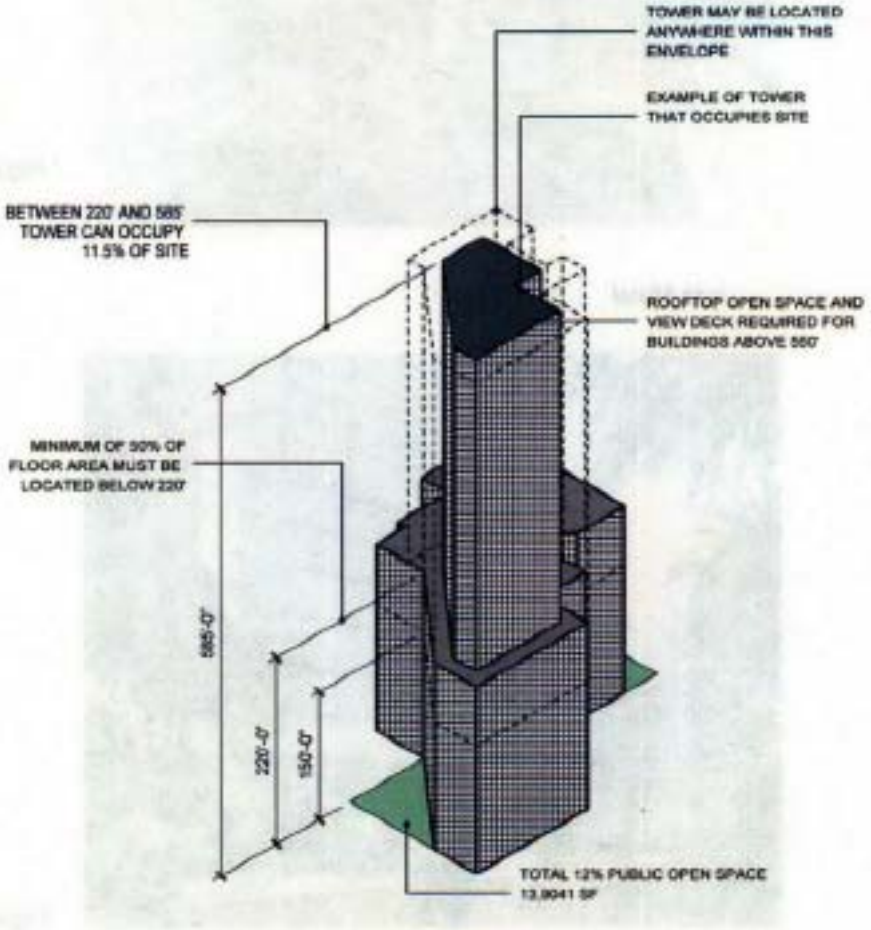


AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.10

DRAFT

East Site:



AXONOMETRIC OF PERMITTED BUILDING ENVELOPE

Figure 3.11

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4. **Open Space**

a. **Public open space**

Minimum ground floor open space will be 5% of total lot area of the Development Site for buildings up to a height of 220 feet. An additional 3% of open space (total 8%) required for buildings between 221 feet and 400 feet. An additional 5% (total 10%) of open space to be required for buildings between 401 feet and 550 feet and an additional 7% (total 12%) of open space required for buildings taller than 550 feet.

do they want to go higher?

i. *Across from Capitol Records*

Figure 4.1

ii. *Jazz Mural*

Figure 4.2

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how do we decide what is integral?

b. Residential open space

i. Balconies

- *Balconies shall be integral to the buildings form, mass, and or articulation.*

Figure 4.3

ii. Roof decks / viewing deck

- *Roof of parking structures will be landscaped to provide outdoor space were possible with consideration for use as public or privately accessible open space.*
- *Buildings above 550 feet to include roof-top open space and viewing deck.*

open space lower than 550 ft + want viewing deck

Figure 4.4

How do we deal w/ guidelines + non-discretionary.

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5. **View Corridor**

a. **Capitol Records**

Preserve public views to the Capitol Records Tower.

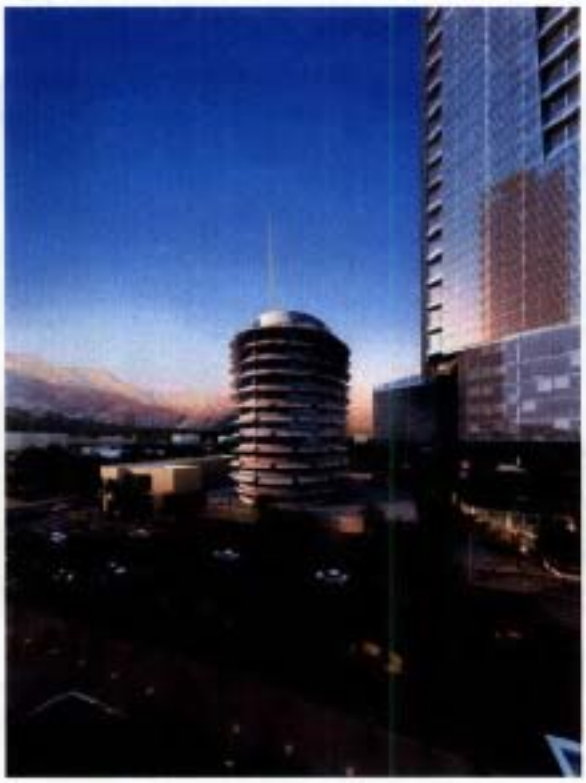

Figure 4.5

Figure 4.6

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6. Articulation and Fenestration

a. Grade Level

i. Building Entries: The primary entrance to a street level tenant that has frontage along a public street shall be provided from that street. The primary entrance to a tenant that does not have its frontage along a public street shall be provided from a courtyard, plaza, or through block passage. Entries shall not be higher than 9 feet above the elevation of the sidewalk at its nearest point to the entry. Where possible entries shall be marked through the use of architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

ii. Canopies and Awnings: Canopies will be provided for primary residential entrances. 10 feet minimum and 20 feet maximum clearance will be maintained above sidewalks, plazas, or walkways. A minimum of 2 feet will be provided from the face of canopy to the face of curb. The maximum width of a single canopy will be 30 feet.

iii. Arcades: Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0 foot candles.

iv. Drop-offs: Drop-offs shall be located along the curb or entirely within the site to maintain sidewalk continuity.

v. Exhaust: Building exhaust will be located at least 10 feet above a public side walk, plaza, or through block passages where possible.

vi. Public Walkways: Public walkways will be a minimum of 15 feet wide and be at least 50% open to the sky. Walkways will be lined with public open space or commercial spaces used for retail, restaurants, cultural uses, and lobbies along at least 40% of its frontage.

vii. Storefront: Openings such as storefronts, windows and doors shall comprise a minimum of 40% of the building's street level façade and be recessed where necessary. Ground floor retail space will be a minimum of 10 feet clearance in height and have storefronts openings a minimum of 10' feet in height. Security grills will be located behind glass and be at minimum 80% open. Storefront glazing will be transparent.

b. Podium – Up to 150 feet

i. Modulation: New building facades, located directly on a property line and facing a street, will predominantly incorporate the use of regular modulation horizontally along a street wall. Modulation might be incorporated by the use of recesses, projecting bays, changes in massing, color, material or fenestration. Extensive blank walls will be avoided. Ground floors shall have a different architectural expression than upper floors and feature durable materials that add scale, texture and variety.

ii. Materials and Colors: Materials, color, and fenestration of building frontages, located on or within 3' of a lot line facing a street, shall be similar to those found elsewhere in Hollywood. The buildings masonry surfaces will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather that the application of color to the surface.

Darker accent colors may be used to delineate building entrances and accents. There will be clear contrast between the buildings surface material and the building's glazed areas.

iii. *Windows and Glazing: Window proportion, grouping and arrangement will be an integral aspect of the design of the buildings. Above the ground floor the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of* reflectivity or tinting required to achieve energy efficiency standards. what does ed mean?

c. Tower – Over 150 feet

what about under 150 feet?

i. *Design intent: Buildings over 150' will not be historicized. They will be treated as contemporary interventions in the skyline and will appear simple yet elegant. Towers will be complementary to one another and may employ the same architectural design approach. Tower's primary entrances shall be scaled appropriately to the overall size of the tower and mediate the transition to the pedestrian scale. Buildings tops will be articulated with a change in massing or detail.*

ii. *Windows and Glazing: In buildings other than curtain wall buildings windows will be recessed, except where inappropriate to a building's architectural style.*

iii. *Roofs and Bulkheads: Roofs used for mechanical purposes will be designed to minimize attention by incorporating non reflective and low contrasting colors. Mechanical equipment shall be screened from lateral and pedestrian views. Mechanical penthouses will be designed to be consistent with the buildings architecture and will utilize similar colors and materials as in other portions of the building. Enclosures for bulkheads shall not count against building height.*

7. Landscape

a. Street Elements

i. *New trees, planting beds, and grates will be provided along Vine Street, Ivar Avenue, Yucca Street, and Argyle Avenue. Jacaranda Mimosifiolias will be interspaced with Washingtonia Robusta palms along Vine Street. Palms will be spaced on 40 foot centers. Jacaranda Mimosifiolias will also be planted along Yucca Street frontages. Evergreen trees will be planted along Ivar and Argyle Avenues.*

ii. *Sizable and healthy existing trees not conforming to the above will be removed and relocated on site if possible.*

Softscape

b. Public Areas

i. *Plant material will be selected for diversity, neat appearance, suitability to solar orientation, and relationship to fenestration. The mature size of any plants shall not project more than 12 feet beyond the face of planters below the height of 10 feet relative to the adjacent sidewalk.*

ii. *Kiosks, carts and temporary structures may be permitted within public open spaces. No roofs of such structure shall extend more than 4' in any one direction.*

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8. **Pedestrian Linkage**

a. **Through block connections**

i. Provide through block connections on both sites along Vine Street.

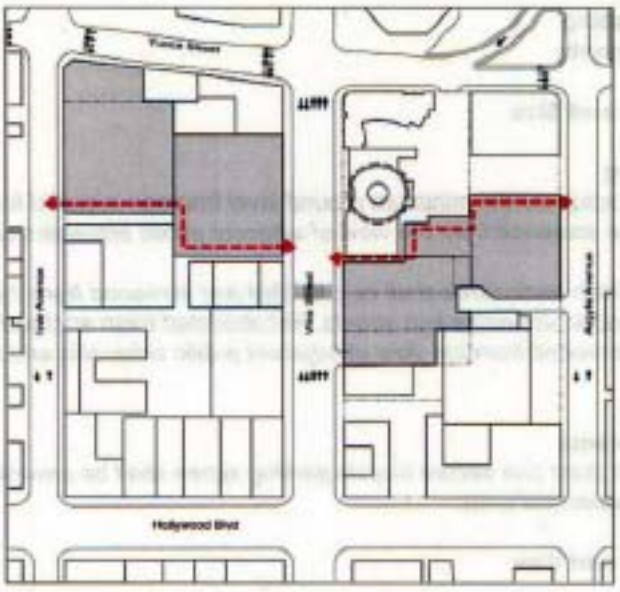

Figure 8.1

b. **Circulation**

i. Ingress into buildings

ii. Connection between city and site

9. **Parking**

a. **Requirements**

i. Required commercial parking may be transferred to an adjacent site located within 1000 feet.

ii. Shared parking strategies may be employed.

b. **Location and Size**

i. Curb cuts shall be located no closer than 50 feet to the intersection of two streets.

ii. Access driveways to parking facilities will not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

iii. Parking and loading access will be shared where feasible.

iv. The maximum floor to floor height of above grade parking shall not be greater than 9 feet except where parking is screened with dwelling units.

c. **Screening**

i. Above grade parking shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible or shall be designed to blend in with the form and massing and designed to look like an integral part of the building. The interior of a parking structure will be designed to be screened from the view of streets and sidewalks.

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d. Circulation

i. Ingress into parking facility

ii. Connection between city and site

10. Service and Loading

a. Requirements

b. Location and Size

c. Screening

i. Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

ii. Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

11. Bicycle Parking

a. Requirements

i. At least one secure bicycle parking space shall be provided for every two residential units.

b. Location and Size

12. Signage

a. Types

i. Retail tenants shall be allowed to install one exterior sign limited to name and logo only.

ii. No pole type signage shall be used.

iii. No more than one rooftop/skyline sign shall be used per building.

iv. Opaque message surfaces shall be avoided.

Knock out panel

Add minimal logo sign

b. Location

i. Retail Sign: shall be located within a permitted signage band and limited to area of 20 square feet. The total length of the sign shall not exceed 3/4 of the width of the tenant exterior wall surface and shall be equally spaced. One logo or emblem will be allowed. Interior signs shall permit an unobstructed view into tenant space.

ii. Projecting Sign: shall align with major building elements. The width of projecting signs shall not exceed 4 feet. The spacing of such signs shall be no less than 20 feet with the exception that each individual retail tenant may be allowed one projecting sign not to exceed 2 feet in width.

iii. Rooftop Signs: shall be setback at least 10 feet from property lines or building lines. Spacing between rooftop signs shall be at least 50 feet. Signs shall be oriented towards and parallel to Hollywood Boulevard or at corners at 45 degree angels to the Boulevard district grid.

c. Heights/Sizes

d. Illumination

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13. Green / LEED

LEED Certification

Standard of Sustainability (Mandatory for large projects)

Threshold:

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

Requirement: The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

Standard of Sustainable Excellence (Voluntary for projects of any size - large and small)

Threshold:

The Standard of Sustainable Excellence establishes an incentive program for projects that register with the USGBC's LEED® program, contract with a LEED® AP, and can demonstrate how the project will achieve LEED® certification at a Silver or higher level.

Incentives:

The ordinance will establish expedited service within the Department of City Planning and the Bureau of Engineering. Other incentives already in place, including those from the Department of Water and Power and the Department of Building and Safety, remain unchanged.

14. Lighting

a. *Exterior building lighting will be provided on all sides of the development to supplement street lighting.*
b. *Lighting will be operated from dusk to dawn.*
c. *Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater.*
d. *Steps and ramps will be lighted with a minimum of 1.0 foot candles on a horizontal plane.*
e. *Lighting approach will be consistent on each parcel with not more than 30 feet between elements.*
f. *Building owner will be responsible for maintaining all lighting used to meet these requirements. No luminaires used to meet these requirements shall be out of commission for more than 10 days.*
g. *Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building owner.*

15. Noise Controls

16. Land Use

a. **FAR**
b. **Equivalency / Transfer of floor area**
   Owner may transfer floor area from one site to the other, as long as the minimum and maximum building heights are maintained.
c. **Maximum OESF Density Per Area**
d. **Maximum Height**
e. **Use Coordination / Use Compatibility**

AR0067529

17. Operational Standards
    a. Pets
    b. Antennas
    c. Wireless Facilities (facades and parapets)

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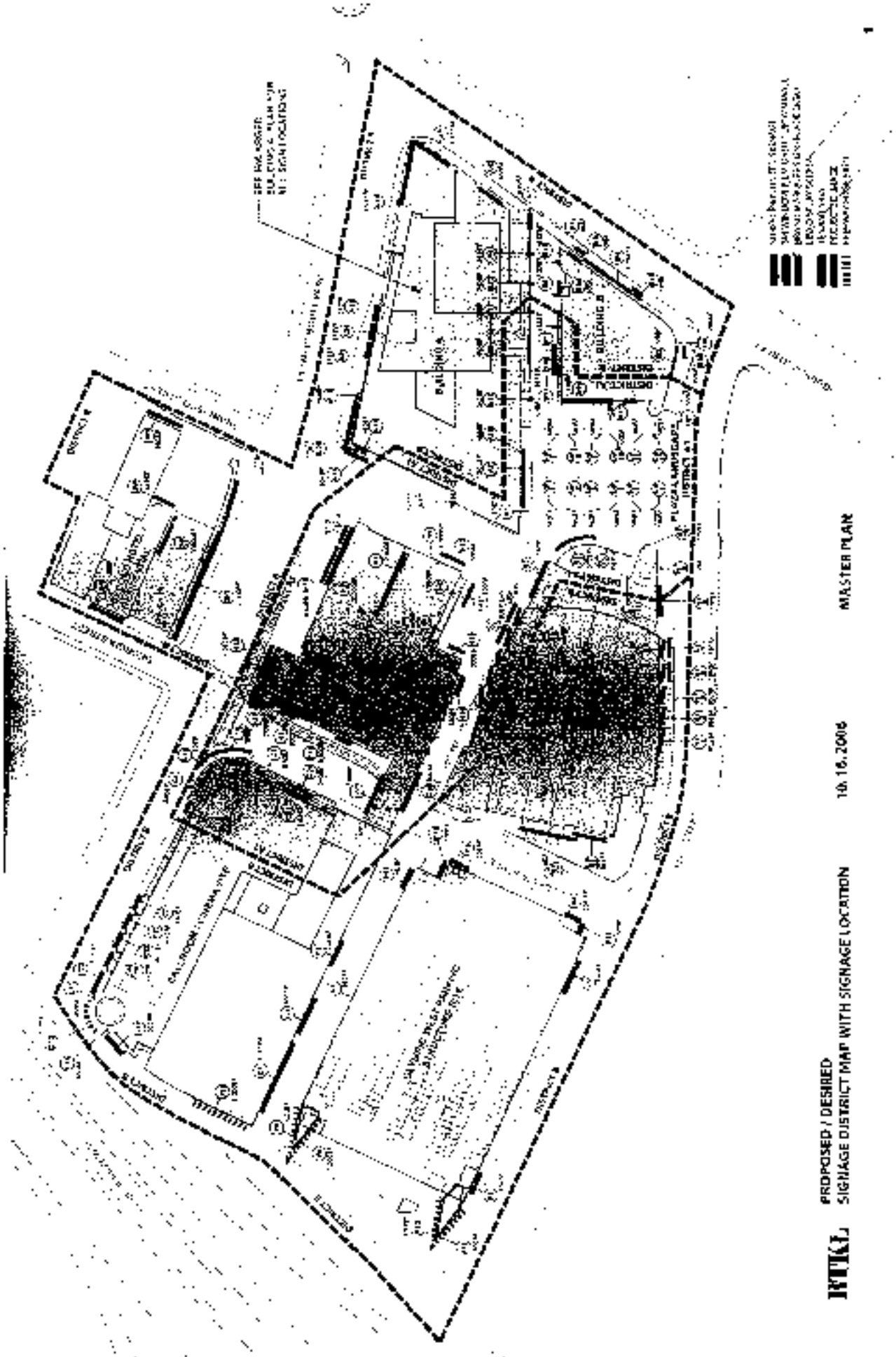
EXHIBIT B-5

LA LIVE!

CONCEPTUAL SIGN PLAN EXHIBITS

OCTOBER 2006


PROPOSED / DESIRED
SIGNAGE DISTRICT MAP WITH SIGNAGE LOCATION
10.16.2006
MASTER PLAN

PROPOSED / DESIRED
SIGNAGE DISTRICT MAP WITH SIGNAGE LOCATION

10.09.2006

BUILDING A - ENLARGED PLAN

2

CO-0001-520

AR0067535

CO-0001-521

AR0067536

AR0067537

NOKIA THEATRE ALLOWABLE SIGNAGE STUDY 10.10.2006

CO-0001-523

AR0067538

NOKIA
WEST ELEVATION
NORTH ELEVATION
NOKIA THEATRE ALLOWABLE SIGNAGE STUDY 10.12.2006

NOKIA THEATRE ALLOWABLE SIGNAGE STUDY 10.12.2004

RTKL LA LIVE! BUILDING A ALLOWABLE SIGNAGE STUDY 10.09.2006

B

CO-0001-526

AR0067541

CO-0001-527

AR0067542

11TH ST. & FIGUEROA ST. ELEVATION

CO-0001-528

AR0067543

PLAZA ELEVATION

PASEO ELEVATION

RTKL LA LIVE! BUILDING B ALLOWABLE SIGNAGE STUDY 10.09.2006

CO-0001-529

AR0067544

BUILDING A : NORTH ELEVATION
BUILDING A : WEST ELEVATION
ELEVATION B
KTGY
LA LIVE BUILDING A ALLOWABLE SIGNAGE STUDY 10.16.2006
12

BUILDING B : NORTH ELEVATION

BUILDING B : WEST ELEVATION

SECTION A
BUILDING A : SOUTH ELEVATION
BUILDING B : SOUTH / EAST ELEVATION
BUILDING A : EAST ELEVATION
LA LIVE! BUILDING A + B ALLOWABLE SIGNAGE STUDY 10.16.2006
14

EAST ELEVATION

WEST ELEVATION @ GEORGIA ST.

Gensler LA LIVE! HOTEL AND RESIDENCES 09.27.2006

CO-0001-533

AR0067548

Gensler LA LIVE! HOTEL AND RESIDENCES 10.05.2006

CO-0001-534

AR0067549

CO-0001-535

NORTH ELEVATION

AR0067550

SOUTH ELEVATION
Gensler
L.A. LIVE! HOTEL AND RESIDENCES 10.12.2006

NORTH ELEVATION

CO-0001-537

AR0067552

WEST ELEVATION @ GEORGIA ST.

EAST ELEVATION

Gensler LA LIVE! HOTEL AND RESIDENCES 10.12.2006

EAST ELEVATION @ GEORGIA ST.

WEST ELEVATION

CO-0001-539

AR0067554

EAST ELEVATION @ GEORGIA ST.

WEST ELEVATION

CO-001-540

AR0067555

SOUTH ELEVATION

NORTH ELEVATION

WEST ELEVATION

EAST ELEVATION

Gensler LA LIVE! OLYMPIC WEST PARKING GARAGE 10.02.2006

CO-0001-541

AR0067556

WEST ELEVATION
SOUTH ELEVATION

EAST ELEVATION
NORTH ELEVATION
25
Gensler LA LIVE! OLYMPIC WEST PARKING GARAGE 10.12.2006

Gensler
LA LIVE! OLYMPIC WEST PARKING GARAGE 10.16.2006

CO-0001-545

AR0067560

CO-0001-546

AR0067561

FRANCISCO STREET ELEVATION

OLYMPIC BLVD. ELEVATION

GEORGIA STREET ELEVATION

NORTH ELEVATION

RIOS CLEMENTI HALE STUDIOS

LA LIVE! PLAZA TOWERS

TOTAL POTENTIAL SIGNAGE AREA PERMITTED AND REQUESTED

09.26.2006

CO-0001-549

AR0067564

AR0067565

NORTH ELEVATION

EAST ELEVATION

WEST ELEVATION

SOUTH ELEVATION

ELS

NOKIA THEATRE

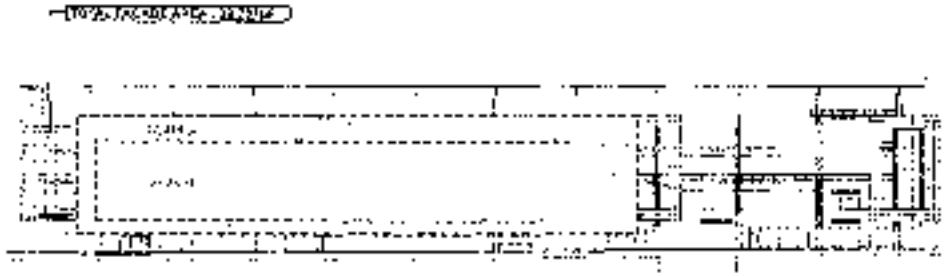
TOTAL POTENTIAL SIGNAGE AREA
PERMITTED AND REQUESTED

9.26.2006

CO-0001-550

NORTH ELEVATION

WEST ELEVATION



SOUTH ELEVATION

EAST ELEVATION

TOTAL POTENTIAL SIGNAGE AREA PERMITTED (BASED ON 2007 SPECIFIC PLAN)

PROPOSED TOTAL POTENTIAL SIGNAGE AREA

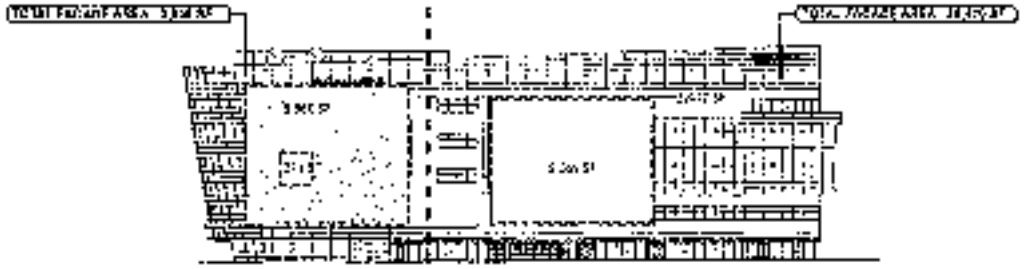
NOTE: The signage depicted on these drawings is illustrative only and is not approved as part of this application. All signage is subject to separate review and approval.

RITKA LA LIVE! BUILDING A TOTAL POTENTIAL SIGNAGE AREA PERMITTED AND REQUESTED 10.09.2008

33

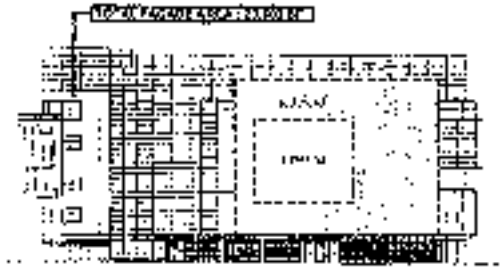
CO-0001-551

AR0067566

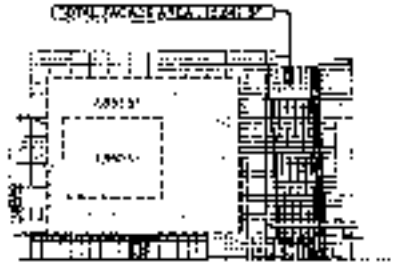


SOUTH ELEVATION

EAST ELEVATION



NORTH ELEVATION



WEST ELEVATION

TOTAL POTENTIAL SIGNAGE AREA PERMITTED UNDER THE 2001 SPECIFIC PLAN

PROPOSED TOTAL POTENTIAL SIGNAGE AREA

RFKL

LA LIVE! BUILDING B

TOTAL POTENTIAL SIGNAGE AREA
PERMITTED AND REQUESTED

10.09.2008

CO-0001-552

AR0067567

NORTH ELEVATION

WEST ELEVATION

SOUTH ELEVATION

EAST ELEVATION

TOTAL POTENTIAL SIGNAGE AREA PERMITTED PER CODE SECTION 22A.20.070

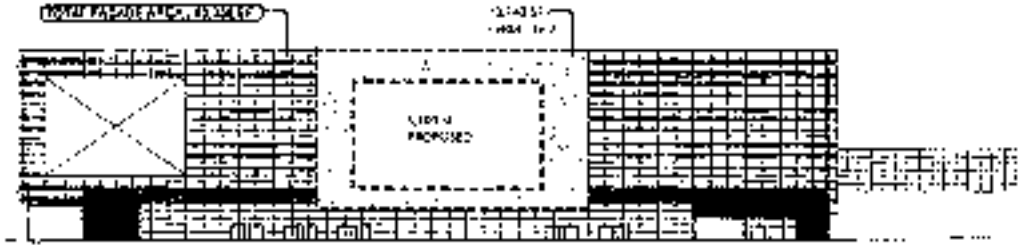
PROPOSED TOTAL POTENTIAL SIGNAGE AREA

NOTE: [illegible]

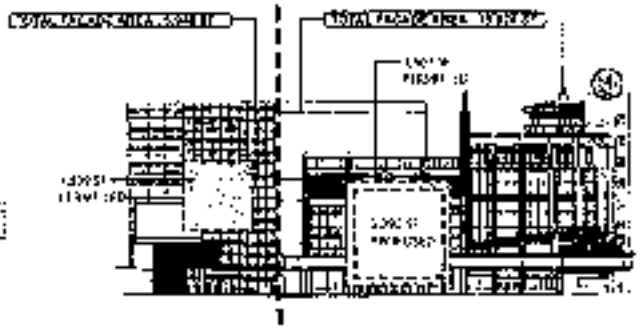
Gensler LA LIVE! HOTEL AND RESIDENCES TOTAL POTENTIAL SIGNAGE AREA PERMITTED AND REQUESTED 09.27.2006

CO-0001-553

AR0067568

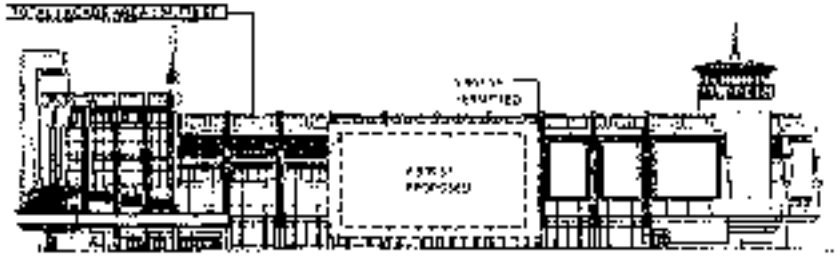


SOUTH ELEVATION - BALLROOM

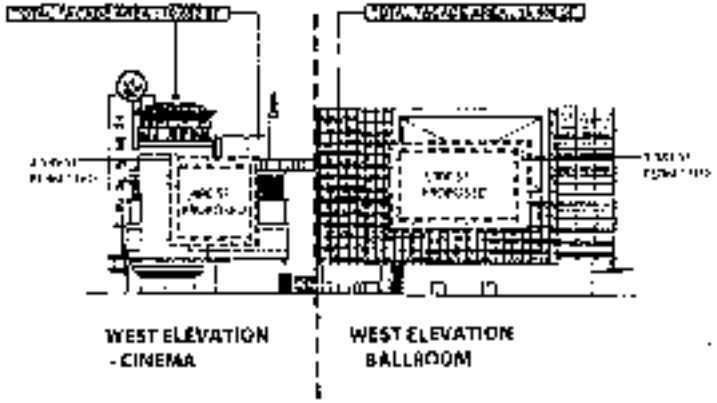


EAST ELEVATION - BALLROOM

EAST ELEVATION - CINEMA



NORTH ELEVATION - CINEMA



WEST ELEVATION - CINEMA

WEST ELEVATION BALLROOM

Gensler

LA LIVE! BALLROOM AND CINEMA TOTAL POTENTIAL SIGNAGE AREA PERMITTED AND REQUESTED 10.05.2006

36

CO-0001-554

AR0067569

NORTH ELEVATION

EAST ELEVATION

WEST ELEVATION

SOUTH ELEVATION

Gensler LA LIVE! OLYMPIC WEST PARKING TOTAL POTENTIAL SIGNAGE AREA PERMITTED AND REQUESTED 10.02.2006

37

CO-0001-555

AR0067570

NORTH ELEVATION

WEST ELEVATION

SOUTH ELEVATION

EAST ELEVATION

TOTAL POTENTIAL SIGNAGE AREA PROHIBITED (BASED ON 2007 SPECIFIC PLAN)

PROPOSED TOTAL POTENTIAL SIGNAGE AREA

RTKL LA LIVE! OLYMPIC / NORTH TOTAL POTENTIAL SIGNAGE AREA PERMITTED AND REQUESTED 10.09.2008

38

CO-0001-556

AR0067571

JULY

9th open

12th open

13th 11 – 2:30

14th open + 11 2 pm

next cell

2 weeks from Today @ 10:30

From: Kevin Keller
To: Alan Bell; Tanner Blackman
CC: Blake Lamb
Date: 8/21/2009 4:47 PM
Subject: PUD tool

Hi Alan, Hi Tanner

Following up on our meeting a few weeks ago on the "flexible entitlements" issue, I had a call with the Milenium folks. We advised them to draft a DA which basically tracks the same entitlements they are requesting, and leave the only "new" aspects in the DA as potentially some design review process language and an equivalency table. This leaves the bigger "flexibility" question for the future, and lets the project proceed using the standard entitlements.

How exactly the DA handles the design review process and the equivalency process (possibly 2-3 different variations of the same square footages) remains to be seen. Part of this language may drift over from the actual DA to become part of the enabling ordinance. This minimizes the "newness" factor of the proposal and tracks normal entitlements to the best of our ability.

I recommended that Milleni um may want to meet with you folks at some point to discuss the option of the new PUD tool to keep that option moving forward as well. Alfred Frelio says they abbolutely would like to do that when you are ready. We are meeting with them in about 3 weeks to go over a draft of the DA and that might be a good time to check in again on this.

Just wanted to keep everyone in the loop. Please let me know if you have any thoughts or ideas as we vigorously coordinate on all things planning!

Thanks,
Kevin

Design Guidelines
March 1, 2010
Revised April 8, 2010

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7.3. Circulation

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From: Rogelio Flores
To: Bell, Alan
CC: Roble, Faisal
Date: 6/21/2010 5:44 PM
Subject: Transfer of DIR-2010-1131-RAO (3455 Percy St) to ZA's Office
Attachments: 3455 E Percy St.pdf

Alan,

Thank you for meeting with me earlier today. Following on our chat, I have transferred the subject file on PCTS to your office, and have initiated a hold on PCTS pending the determination of the appropriate regulatory pathway for the requested actions.

The two prior variances for the property will be requested from Piper Tech (I'll bring them by you as soon as they are delivered to Auto Records). In case they may be useful to you, below is some draft background information for the subject property and attached are some aerial photographs (note: the Zoning Investigator will need to verify this information against primary records, as necessary).

Please let me know if I can provide further information / input from my end. Thanks.

-Rogelio

Background Information
3455 Percy St, LA CA 90023

2007 to present
Facility operates as a 68-room state licensed residential care facility providing a residential treatment program for up to 136 individuals with mental disabilities.

May 5, 2010
Applicant's representative files request for Reasonable Accommodation (pursuant to LAMC 12.22.A.27) in order to conform the Variance on the property (ZA-1992-707-ZV) to the existing use.

March 17th, 2010
LADBS Inspector John Stephens (213-252-3051) begins investigation re: 'Building or Property Converted to Another Use.'

2007
Owner modifies State License to adult residential care facility.

2005
Owner obtains State License for residential care facility for the elderly

1995
Certificate of Occupancy issued, allowing for a 68-room rest home.

May 5th, 1993 (ZA-1992-707-ZV):
"a variance to permit the construction, use and maintenance of a 20,000 square foot addition containing 20 rooms, plus 17 additional parking spaces, in conjunction with an existing 48 room retirement hotel for senior citizens, as not permitted in the R3 Zone under Sections 12.10-A and 12.21-A,4(b) and (u) of the Municipal Code. (This facility was previously approved as a retirement hotel under Case No. ZA 21469)."

Feb 27th, 1991

Zone change (pursuant to AB283) from R3-1 to RD1.5-1 becomes effective (this zone change may not have been implemented until after ZA-1992-707-ZV was issued, since that variance is dated 1993 and references R3 rather than RD1.5 as the subject zone).

1982-1988
Owner obtains State License to provide residential care for 96 elderly persons.

Nov 18, 1976
Building Permit No. 76LA35556 - for a one and two-story apartment home for the aged.
Building permit No. 76LA35557 issued November 18, 1976 for an application for a grading permit.
Building Permit No. 76LA35558 issued November 18, 1976 for a retaining wall.

Nov. 9, 1976:
Affidavit No. 42753 recorded for covenant and agreement to hold property as one parcel that includes Lots 20-23 of the Schmitt Tract.

October 29, 1974: (ZA-21463):
'conditionally approved on October 29, 1974, for the construction, use and maintenance of a two-story, 48 bedroom hotel for senior citizens including central dining facilities, lounge, reading room, beauty shop and with provisions for only 15 parking spaces instead of the approximate 48 spaces required.'

CO-0001-562

AR0067577

ENCLOSED PAPS

ENCLOSED PAPS

OPEN PAPS

OPEN PAPS

NOTE

PAPS open air minimum requirements shall be as follows:

(i)	Development with maximum building height of 150 feet:	0%
(ii)	Development with maximum building height of 220 feet:	20%
(iii)	Development with maximum building height of 400 feet:	30%
(iv)	Development with maximum building height of 550 feet:	40%
(v)	Development with maximum building height of 595 feet:	50%

HANDEL ARCHITECTS LLP
MARCH 24, 2010

PUBLICLY ACCESSIBLE PRIVATE SPACE (PAPS)

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MILLENNIUM PARTNERS/ARGENT VENTURES

The following Sections take the general concepts described above and propose a basic template for application to the Project proposed by Millennium/Argent. We recognize that the development of a plan for this approach requires greater discussion among the stakeholders and greater definition to the elements that will enable the proposed flexibility. The intent is to encourage a meaningful dialogue regarding how these general concepts may apply to a specific development. Further, we acknowledge that both the development agreement and the Design Guidelines for the Project would be developed and finalized by the City after significant community input.

I. The Contract

Taking the general concepts discussed above, a development agreement for the Project would consist of the following major components setting forth the terms of development for the Site:

1. Enabling Statute and Definition of Terms
2. Property Description
3. Project Description
   a. Major Project Components
   b. Permitted Uses and Equivalency Program (See Section V)
   c. Mandatory Infrastructure Improvements
   d. Permitted Density to 6.0 F.A.R.
   e. Maximum Height to 585 feet in Specified Zones
4. Time of Performance
   a. Development Schedule
   b. Minimum Performance by Developer based on Time Certain
5. CEQA Review
   a. Environmental Impact Report
   b. Equivalency Thresholds
6. Community Redevelopment Agency Approval/Owner Participation Agreement
7. Public Objectives
   a. Comprehensive Planning

b. Public Benefits

c. Mitigation Measures

8. Agreement and Assurances on the part of Applicant

a. Inclusionary Housing

b. Prevailing Wage

c. Public Art

d. Public Street Improvements

e. No Off-site Advertisement

f. Publicly-accessible Open Space

g. Conditions on Development

h. Minimum LEED Certification

i. Public Parking

9. Agreement and Assurances on the part of the City

a. Cooperation and Implementation

b. Entitlements to Develop

c. Consistency with Existing Rules

d. Subsequent Development Review

10. General Provisions

a. Effective Date

b. Term of 30 years

11. Exhibits

a. Legal Description

b. Location Map

c. Authorized Uses

d. Equivalency Program (from EIR)

e. Scope of Development

f. Design Guidelines (see Section IV)

II. The Guidelines

A comprehensive list of design guidelines and standards in the development agreement will serve as the overarching plan that controls development on the Site, from permitted density, massing and zoning standards to design and architecture. They are intended to maximize flexibility while preserving and promoting urban planning goals for the City. Rigorous design principles underlie the Design Guidelines, including historic preservation, public open space and civic space, pedestrian circulation, preservation of view corridors, maintenance of setbacks from Vine Street and establishment of zones where height is appropriate.

The Design Guidelines will include minimum design and development standards applicable to all new development, no matter the density, height or type of use (the "Development Guarantees"). Additionally, the Guidelines will include standards that are triggered depending, on the height and density of the new structures. Below is an overview of the Guidelines:

1. Development Guarantees

   a. Preservation of Capitol Records Tower and Gogerty Building

   b. Preserve public views to Capitol Records

   c Create unique retail at ground level to enliven all sidewalks and open space

   d. Minimum set backs from Vine Street to preserve views of Capitol Records and create public open space

   e. Civic plazas located on the east site adjacent to Vine Street and west site across from Capitol Records Tower

   f. Open space preserved along Vine Street frontage of east site to preserve views of the Jazz Mural and Capitol Records Tower

   g. Through-block connections on both sites

   h. Create a genuine Hollywood environment with lush landscaping for locals and visitors

   i Minimum ground floor open space will be 5% of lot area

2. General Open Space Strategy

   a. Emphasize green space networks

   b. Open space connections to existing open space

3. Based on Height Datum's

   a. Building Heights Up to 150 Feet

      i. Massing established by protected view corridors and fire access

      ii Subject to Zoning Standards (Section 4) and Building Design Parameters (Section 5)

   b. Building Heights Up to 220 Feet

      i. Permitted for buildings with a maximum floor plate of 42% to 48% of lot coverage in designated zones up to 220 feet

      ii. Subject to Zoning Standards (Section 4) and Architectural Guidelines (Section 5)

   c. Building Heights Up to 400 Feet

      i. An additional 3% of open space must be provided

      ii. At least 50% of the floor area must be located below 220 feet

      iii. Permitted for buildings with a maximum floor plate of approximately 22% to 28% of lot coverage between 220 feet and 400 feet

      iv Subject to Zoning Standards (Section 4) and Building Design Parameters (Section 5)

   d. Building Heights Up to 510 Feet

      i. An additional 2% of open space must be provided

      ii. Permitted for buildings with a maximum floor plate of approximately 10% to 15% of lot coverage between 220 feet and 550 feet

      iii. Building above 550 feet to include roof-top open space and viewing deck

iv. Subject to Zoning Standards (Section 4) and Building Design Parameters (Section 5)

e. Building Heights Up to 585 Feet

i. An additional 2% of open space must be provided

ii. Permitted for buildings with a maximum floor plate of approximately 6.5% to 11.5% of lot coverage between 220 feet and 585 feet

iii. Buildings above 550 feet to include roof-top open space and viewing deck

iv. Subject to Zoning Standards (Section 4) and Building Design Parameters (Section 5)

4. Zoning Standards

a. Parking

i. Spaces Per Use

ii. Combination of Uses

iii. Design

iv. Bicycle Parking

b Setbacks

i. Side yard

ii. Rear yard

iii. Front yard

iv. Alleys

v. Lot Area

c. Open Space

i. Public Open Space minimum 5% open space on ground floor

ii Private Open Space

iii. Balcony Configuration

d. Loading

e. Access Driveways

5. Building Design Parameters

a. Materials

b. Rooftop and Parapets

c. Balconies

d. Storefronts

e. Lighting

f. Arcades

g. Roof Treatments

h. Relief of Scale

i. Canopies and Awnings

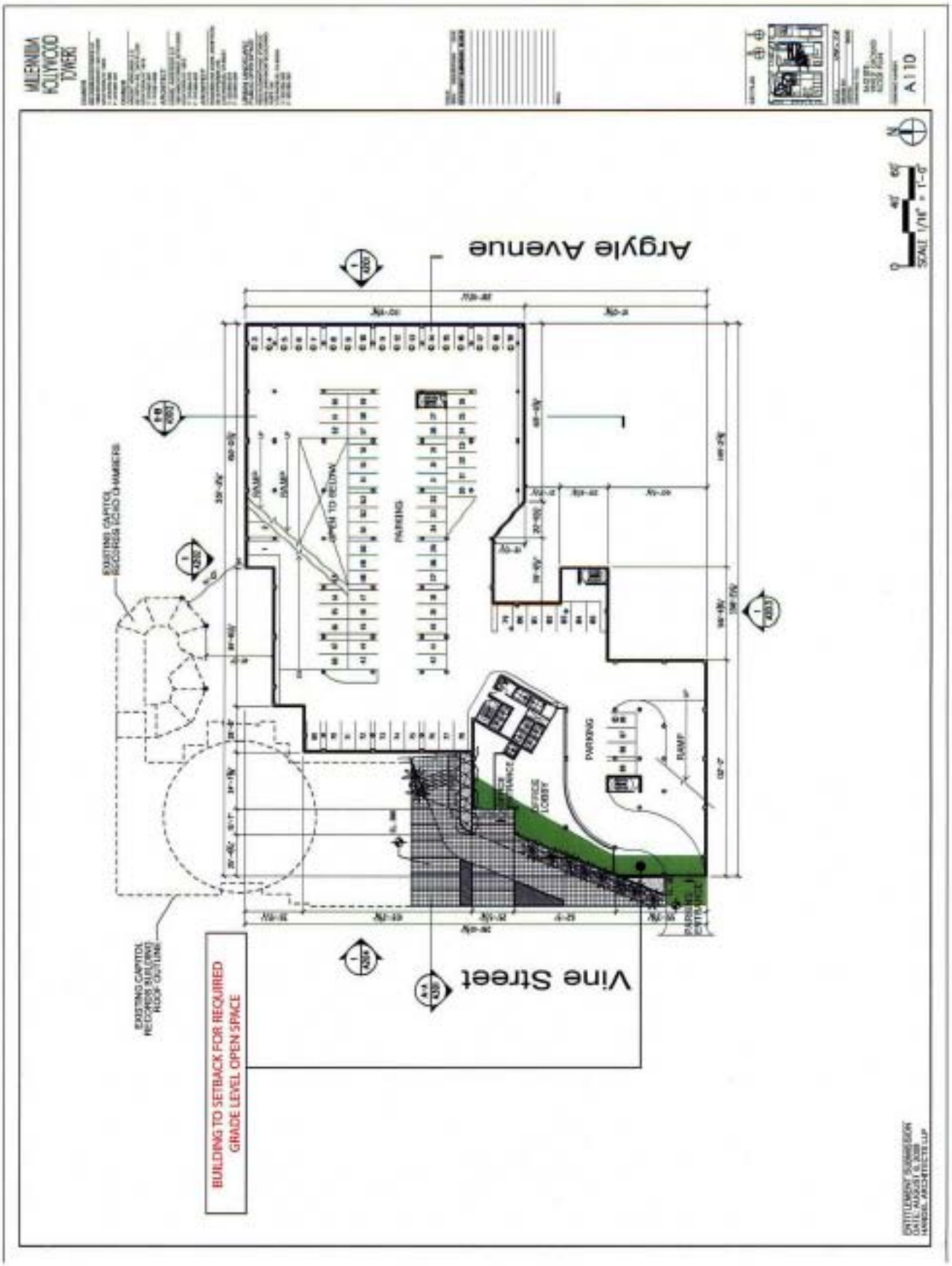
j. Landscape

k. Maintenance

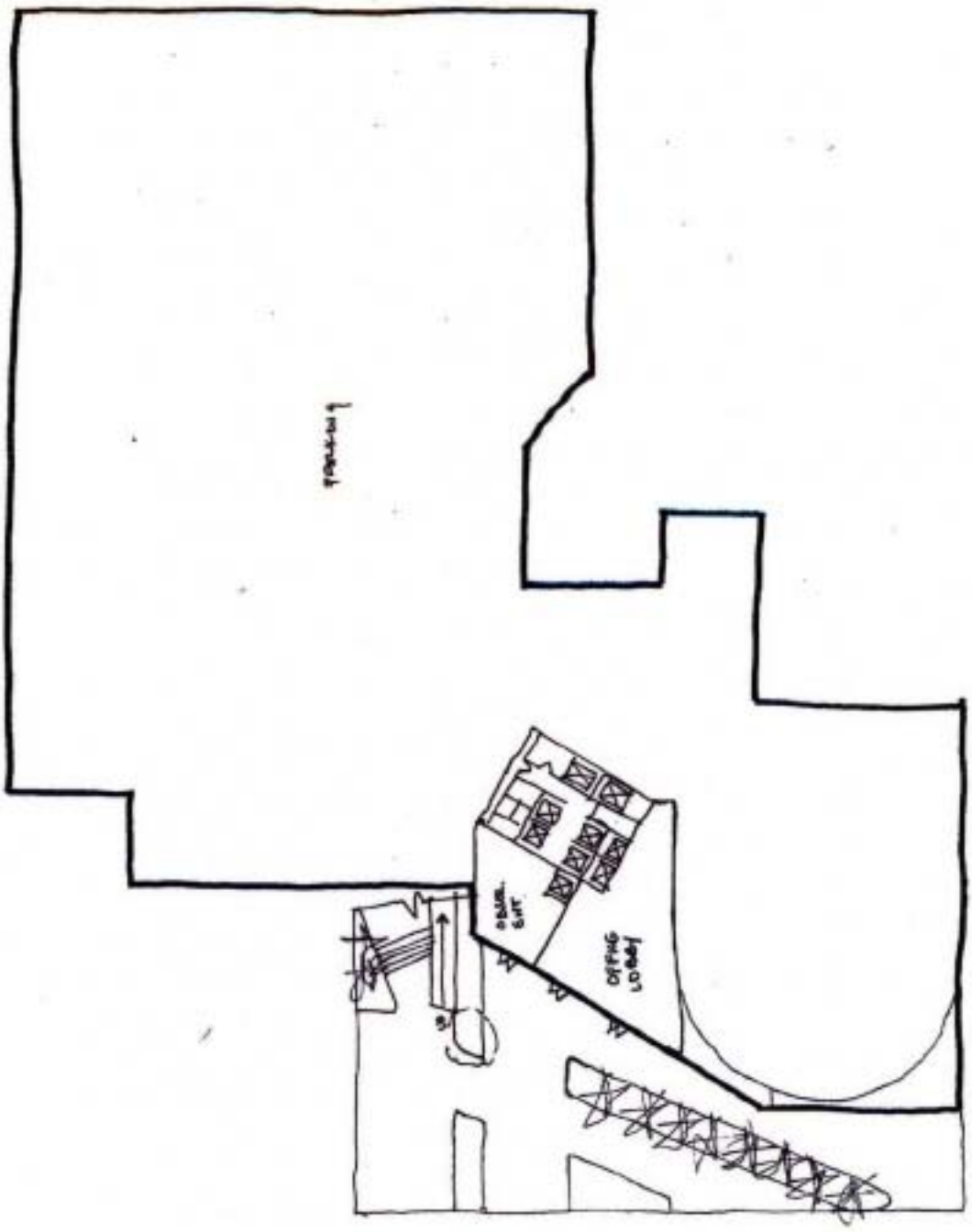
6. Signage

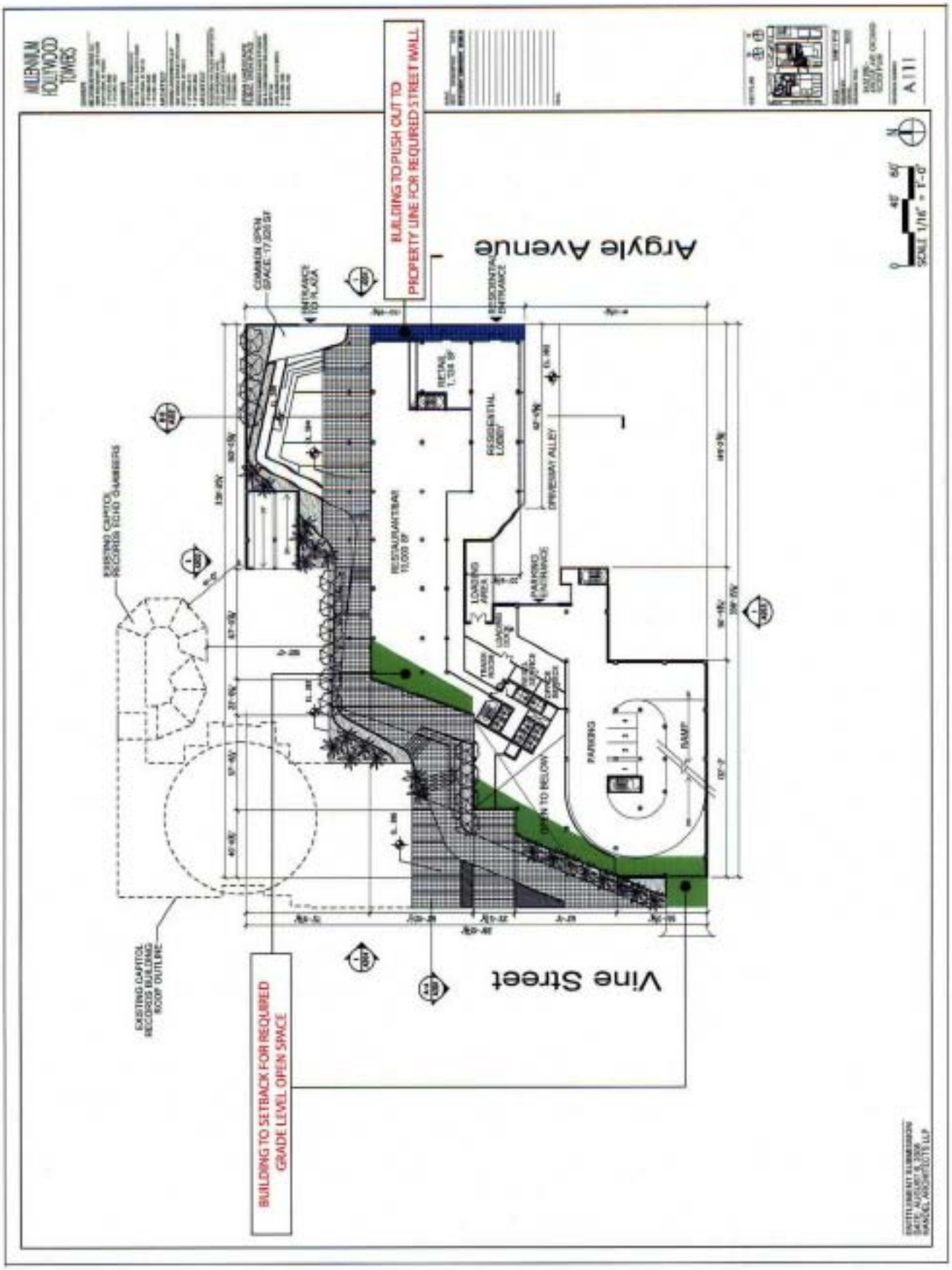
a. Wayfinding

b. No Off-site Advertising

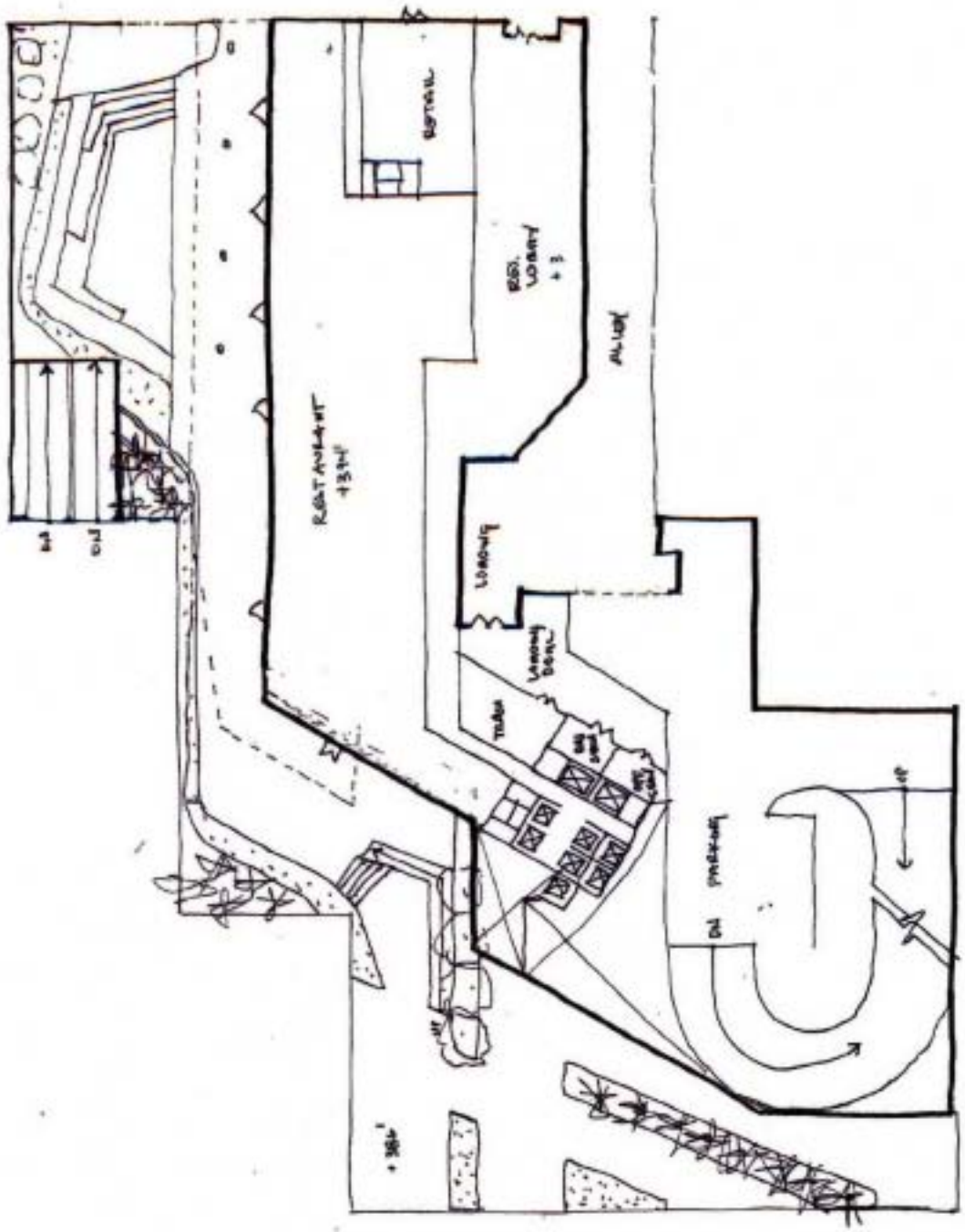

Argyle Avenue
Vine Street
BUILDING TO SETBACK FOR REQUIRED GRADE LEVEL OPEN SPACE
EXISTING CAPITOL RECORDS BUILDING ROOF OUTLINE
EXISTING CAPITOL RECORDS BUILDING ECHO CHAMBERS
RAMP TO BELOW
PARKING
RAMP
OFFICE LOBBY
SCALE 1/16" = 1'-0"
A110

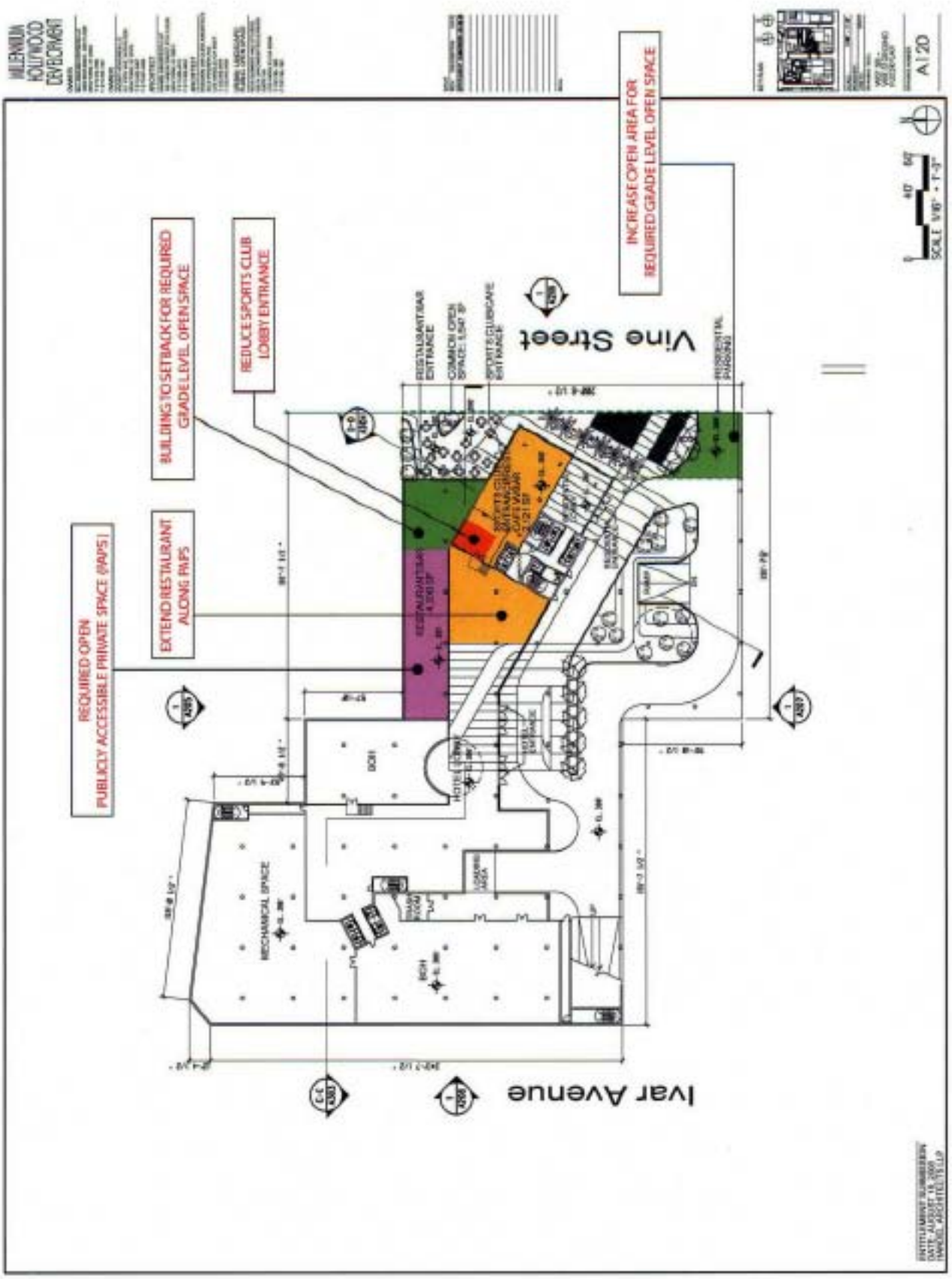
SK1 1D



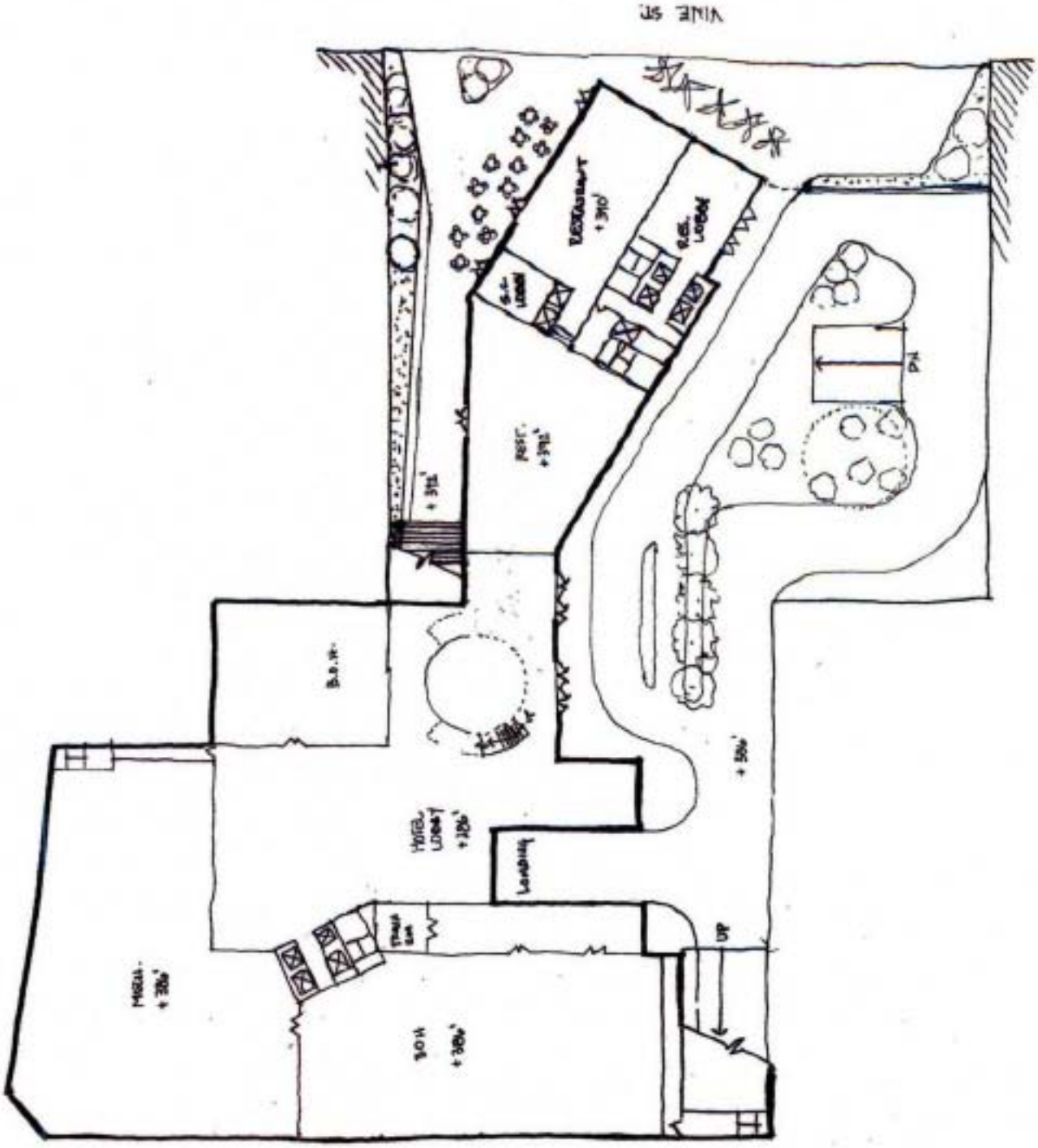

MILLENNIUM HOLLYWOOD TOWERS
A111
BUILDING TO PUSH OUT TO PROPERTY LINE FOR REQUIRED STREET WALL
Argyle Avenue
Vine Street
BUILDING TO SETBACK FOR REQUIRED GRADE LEVEL OPEN SPACE
EXISTING CAPITOL RECORDS BUILDING ROOF OUTLINE
EXISTING CAPITOL RECORDS ECHO CHAMBERS
COMMON OPEN SPACE: 17,820 SF
ENTRANCE TO PLAZA
RESIDENTIAL ENTRANCE
RETAIL 1,134 SF
RESIDENTIAL LOBBY
RESTAURANT/BAR 10,000 SF
DRIVEWAY ALLEY
LOADING AREA
PARKING ENTRANCE
TRASH ROOM
PARKING
RAMP
OPEN TO BELOW
SCALE 1/16" = 1'-0"

SK111




MILLENNIUM HOLLYWOOD DEVELOPMENT
A1.20
INCREASE OPEN AREA FOR REQUIRED GRADE LEVEL OPEN SPACE
BUILDING TO SETBACK FOR REQUIRED GRADE LEVEL OPEN SPACE
REDUCE SPORTS CLUB LOBBY ENTRANCE
EXTEND RESTAURANT ALONG PAPS
REQUIRED OPEN PUBLICLY ACCESSIBLE PRIVATE SPACE (PAPS)
Vine Street
Ivar Avenue
RESTAURANT/BAR ENTRANCE
COMMON OPEN SPACE: 5,547 SF
SPORTS CLUB/CAFE ENTRANCE
RESIDENTIAL PARKING
RESTAURANT/BAR 4,300 SF
SPORTS CLUB/CAFE 2,215 SF
HOTEL ENTRANCE
MECHANICAL SPACE
BOH
SCALE 1/16" = 1'-0"

SK120



MILLENNIUM HOLLYWOOD DEVELOPMENT

A121

CO-0001-575

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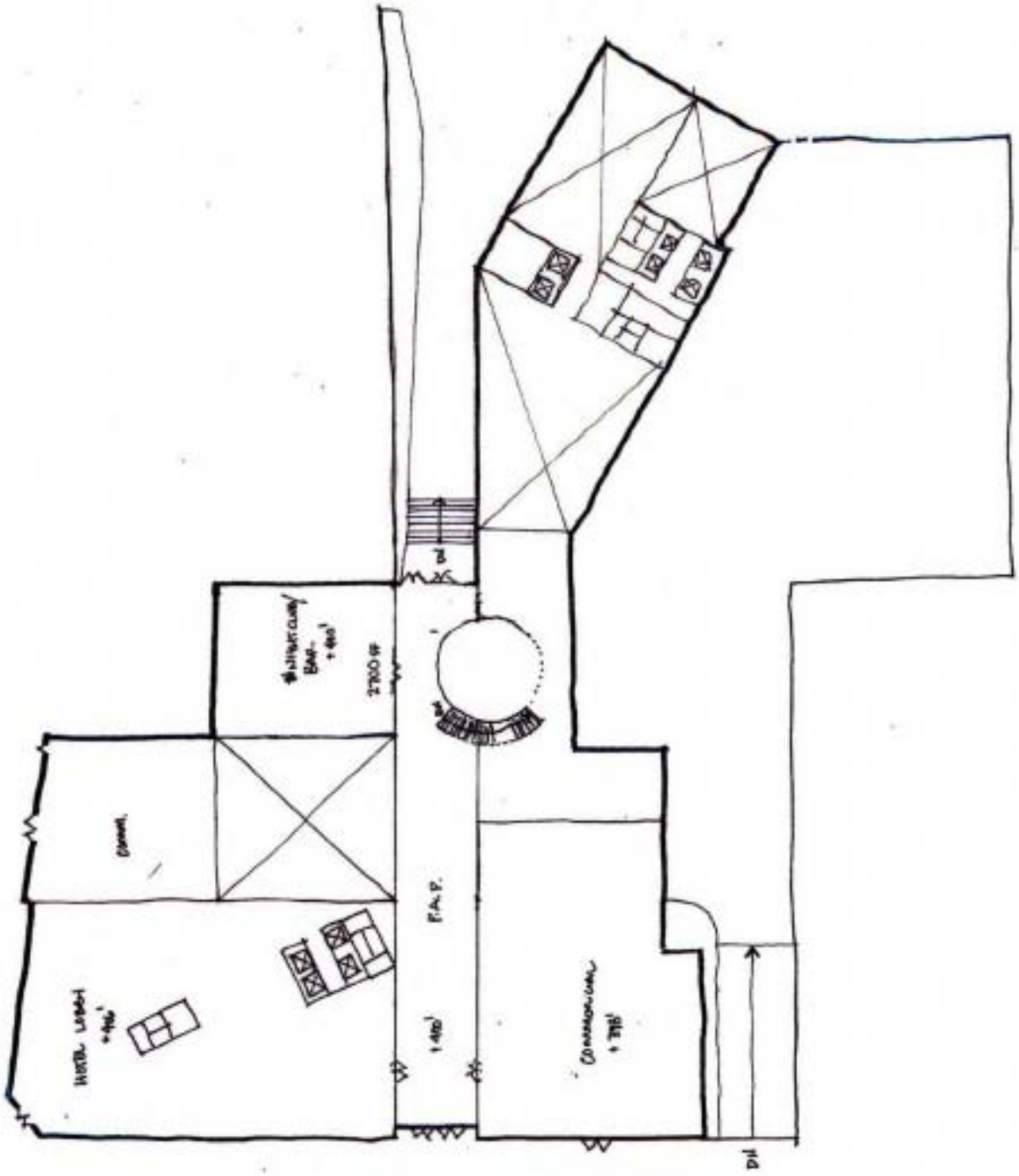
SK 121



EXAMPLE A

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria which serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

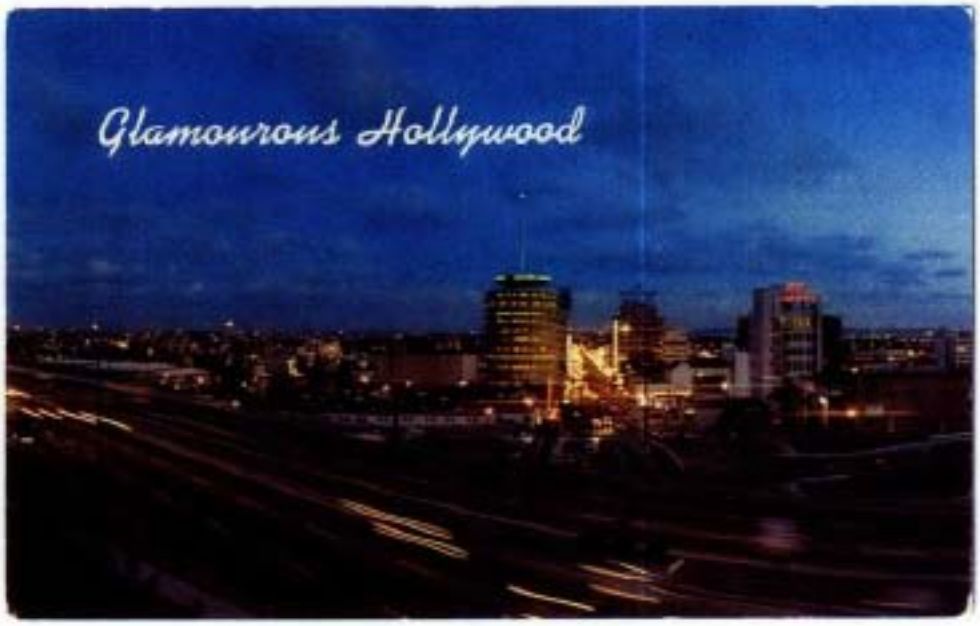
d. Permit design flexibility while establishing a set of controls that will guide the development for the Project site.

e. Ensure compliance with the Development Objectives, below.

EXAMPLE B

1.2 Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure new development on the Project Site is consistent with these objectives.



1.2.2. The objectives for new development on the Project Site are to:

a. Preserve Capitol Records Tower and Gogerty Building.

b. Preserve public views to the Capitol Records Tower by creating grade level open space, civic plazas, on the east site adjacent to the Jazz Mural and Capitol Records Tower and west site across from the Capitol Records Tower.

c. Create civic plazas that are activated by retail, landscaped and enhance the Hollywood Walk of Fame by providing it as an urban node; creating The Hollywood Walk of Fame Plaza.

d. Reinforce the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

e. Preserve existing view corridors to the Hollywood hills.

f. Encourage street life by the creation of a new exclusive pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

g. Create vibrant urban spaces which permit active and passive recreational facilities for both the on-site and off-site population.

h. Create a 24 hr community by the creation of a Thriving Mixed-Use Development.

j. Eliminate the visual impact of the current on site parking.

k. Establish of a standard intended to promote architectural excellence.

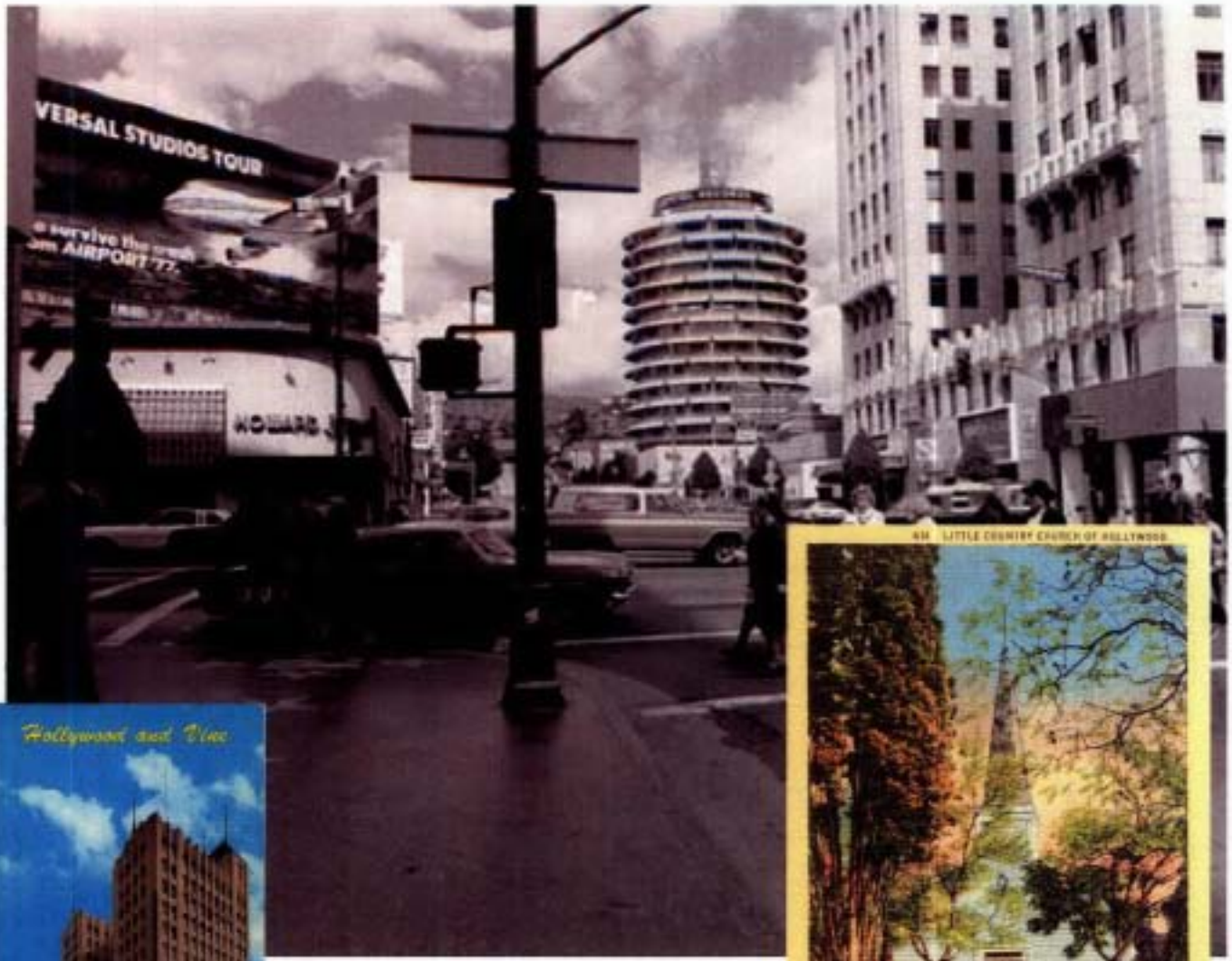
l. Mention transportation priority with linkages to public transportation.

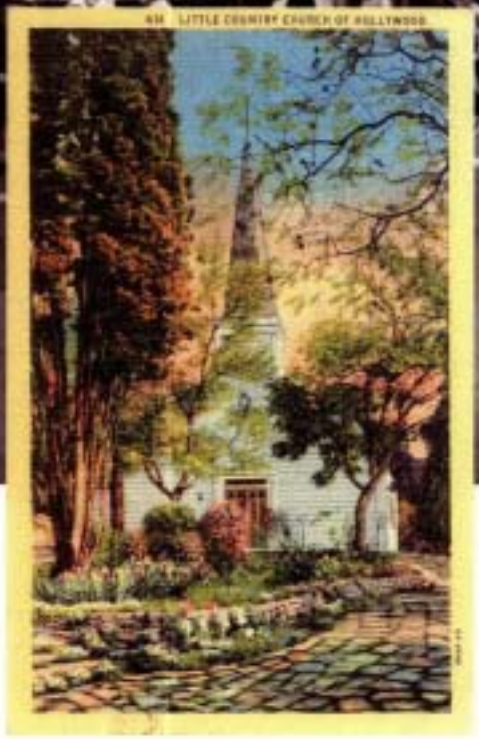
m. Provide designs that take into account the context and make an effort to respect it and fit in visually.

n. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

o. Create buildings that emphasize the vertical architecture and become visible icons.

p. Develop a visual gateway to Hollywood Boulevard from the Hollywood Freeway.

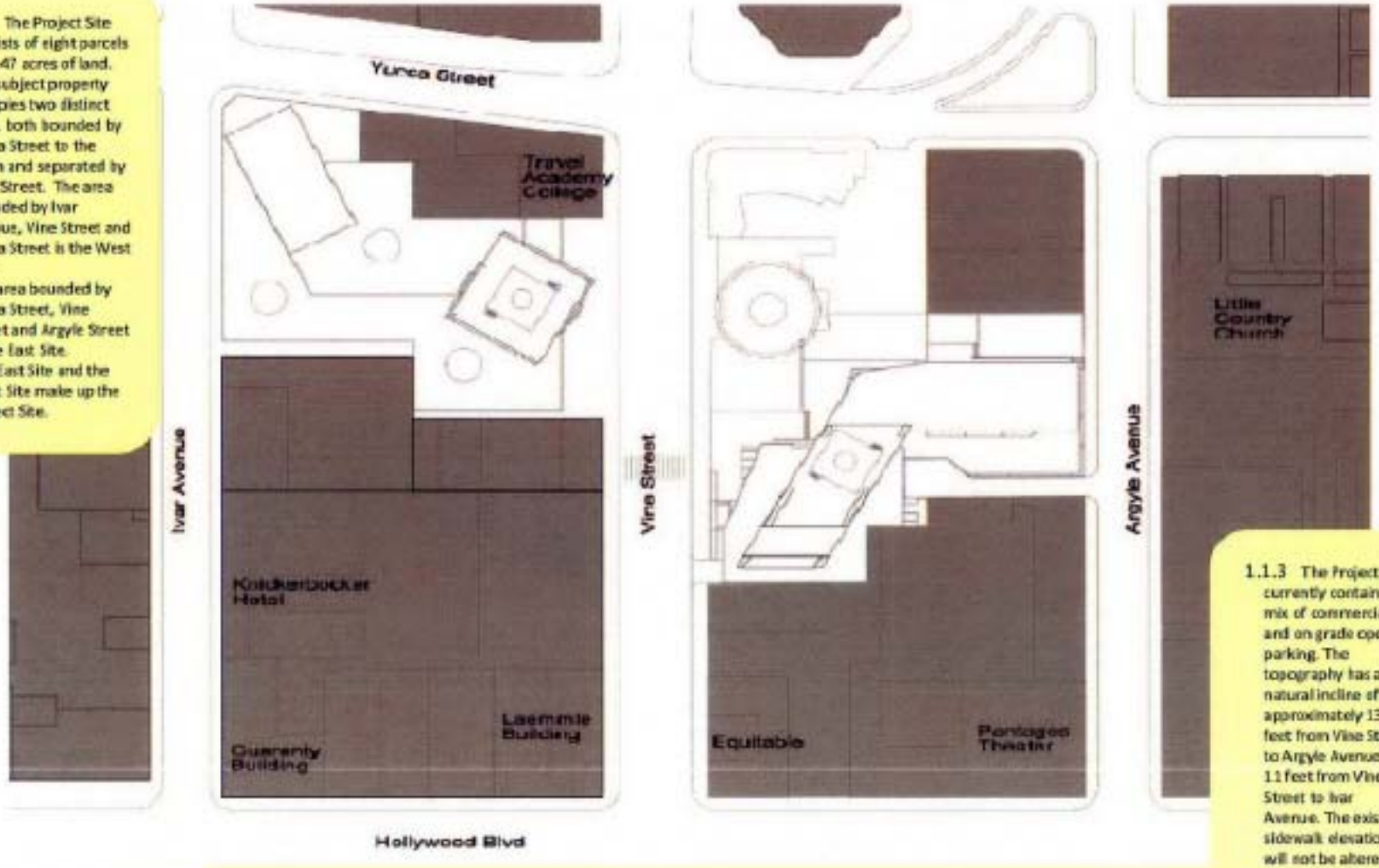




EXAMPLE C

1. PROJECT SITE

1.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street. The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.
The area bounded by Yucca Street, Vine Street and Argyle Street is the East Site.
The East Site and the West Site make up the Project Site.



1.1.3 The Project site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 13 feet from Vine Street to Argyle Avenue and 11 feet from Vine Street to Ivar Avenue. The existing sidewalk elevations will not be altered as part the Project.

1.2 Site Zoning and Permitted Floor Area

- 1.2.1 Project Site is zoned Commercial (C2). City General Plan land use designation: Regional Center commercial.
- 1.2.2 Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.
- 1.2.3 Floor Area Ratio: 6:1
- 1.2.4 Height District: No. 2

CO-0001-580

AR0067595

7/22/13

Meeting w/ Sen De Leon staff
(Dayasar Thomasian)

- DCP (Michael La Grande, Lisa Webber)
- DoT (me)

- meeting to ~~expand to~~ discuss 7/11/13 letter from Sen. De Leon

- we described issues w/ Caltrans on Millennium & most projects, which are:
  - Caltrans traffic study guide not practical
  - City & County define "significant" traffic impacts but Caltrans does not
  - Caltrans guide not administered consistently
  - freeway studies often become subjective exercise to extract funds for improvements w/o proven nexus
  - CEQA clearly defines lead agency's roles but Caltrans often tries to overstep
  - Caltrans does not accept the State-mandated CMP methodology which is used by all cities to assess impacts on SHS
  - Caltrans ignored 2001/2002 Task Force recommendations to fix their guide (issues pointed out 10+ yrs ago)

- IDEAS: → Caltrans should update their guidelines as LA City does to reflect technical updates, case law, policy changes, state legislation, etc.

→ LADOT/Caltrans should establish filter to determine which projects need fwy analysis & should be sent to Caltrans & which projects should just prepare CMP

→ Caltrans should establish impact thresholds

→ " should receive training to better understand trip generation and impact studies in urban areas (Caltrans' current guide was established for Fresno in the early '90's then adopted for entire state w/o consideration of land use, environment, urban setting, transit availability, etc.)

213-473-7734
FAX TO MARIE

CAPITOL OFFICE
STATE CAPITOL, ROOM 5108
SACRAMENTO, CA 95814
TEL (916) 651-4022
FAX (916) 327-6617

DISTRICT OFFICE
TEL (213) 612-9566
FAX (213) 612-9591

California State Senate

SENATOR
KEVIN DE LEÓN
DEMOCRATIC CAUCUS CHAIR
TWENTY-SECOND SENATE DISTRICT

COMMITTEES
APPROPRIATIONS
ELECTIONS & CONSTITUTIONAL AMENDMENTS
ENERGY, UTILITIES & COMMUNICATIONS
GOVERNMENTAL ORGANIZATION
HEALTH
RULES

JOINT COMMITTEES
LEGISLATIVE AUDIT
RULES

July 11, 2013

Michael LoGrande
Director of Planning
City of Los Angeles Planning Department
200 N. Spring Street, Executive Office
Los Angeles, CA 90012

RE: Millennium Hollywood Project
Vic. LA-101, PM 7.37
SCH#2100041094

Dear Mr. LoGrande:

My office has been in communications with the California Department of Transportation regarding concerns the agency has expressed about the impact of the proposed Millennium Hollywood Project to the 101 Freeway.

I understand that Caltrans has made several attempts to communicate their concerns to the City in an effort to ensure an appropriate focus of environmental study and to identify adequate mitigations. They have indicated no response has been received.

It is paramount that consistent and clear communications occur amongst government entities. I would like to set up a meeting as soon as possible for all relevant parties of the Millennium Hollywood Project to resolve concerns.

Please contact my Deputy, Baydsar Thomasian, to arrange the meeting. She can be reached at (213) 483-9300

Sincerely,

Kevin de Leon
Senator, Twenty Second District

Cc: Eric Garcetti, Mayor, City of Los Angeles
City Councilmember, Mitch O'farrell
City Councilmember, Tom LaBonge
Michael Gargano, Millennium Hollywood

presented/listed at 7/22/13 mtg

Millennium Hollywood Project

Traffic Study Summary

- LADOT guided the preparation of the traffic study for the Millennium Hollywood project – the study was prepared by a transportation engineering and planning firm hired by the developer
- The study was prepared consistent with LADOT's traffic study policies and procedures
- The study evaluated to potential impacts of the project's traffic on City streets and intersections, on the transit system, on freeway ramp and on the 101 freeway
- To off-set the traffic impacts resulting from the project's anticipated traffic, LADOT developed a comprehensive and multi-modal transportation mitigation program (summarized below)

Transportation Mitigation Program Summary

As conditions of project approval, the applicant will implement the following transportation mitigation measures:

- Implement a Transportation Demand Management Plan (i.e., Trip Reduction Program) which includes the following key measures:

    1. Internal Transportation Management Coordination Program with on-site transportation coordinator
    2. On-site car share services
    3. Parking as an option only for all leases and sales (unbundled parking)
    4. On-site bike repair area with shared tools for residents/employees
    5. Coordinate with DOT to provide space for a future Integrated Mobility Hub (car-share, bike-share and secure bike parking services)
    6. Contribute $250,000 to City Bike Plan Trust Fund
    7. On-demand van or shuttle services connecting project residents, employees and visitors to major transit stops
    8. To expand the reach of this plan beyond the project site, the applicant will also join or help create a Transportation Management Organization for the Hollywood area

- Improve sidewalk conditions (pavement reconstruction and added amenities) along Ivar Street and Argyle Avenue linking the project to the Hollywood/Vine Red Line Station.

- Improve the operations and safety of the intersection of Franklin Avenue and Argyle Avenue.

- Upgrade the traffic signal equipment at 33 intersections surrounding the project including along Highland Avenue, Hollywood Boulevard, Sunset Boulevard and Vine Street.

7/19/13

LADOT / Caltrans / Millennium Hollywood

(*) → adjust guidelines to include unsignalized I/S if it is a fwy ramp

→ analyze fwy ramps in our guidelines
↳ apply LADOT's filter in an off-line analysis

→ developer proposing to provide funds to Caltrans to prepare analysis &/or implement improvements

↳ $400K* offered to Caltrans for studies / mitigation →

↳ does Caltrans already know where deficiencies are?

(*) — how many cars is Millennium adding to the fwy system?

CURRENT HOLLYWOOD FAULT ZONE PROJECTS

1 Reports reviewed but not approved:
1600 Argyle Ave (correction letter issued requiring fault investigation)

1605 Highland Ave (correction letter issued for fault investigation report)

1720 Vine St. Millenium project; subdivision reviewed; however waiting for additional fault investigation for building

1769 Sycamore Ave; (correction letter issued requiring fault investigation)

2. Reports approved, but project not submitted for plan check:

6200 Hollywood Blvd (soil report approved; fault investigation will be required before issuance of permit)

7930 Hollywood Blvd (soil report approved, fault investigation will be required before issuance of permit)

1840 Highland Ave (has approved fault investigation)

3 Reports approved and in plan check: No projects
4 Permits issued, but construction not started: No projects

5 Permits issued and under construction(no fault investigation and no action recommended):
4454 Avocado St (3-story cut-grade; soil engineer site inspection only, without geologist, so no opinion of fault activity possible) (has approved inspections for framing (12/17/13), drywall and insulation(both 1/9/14))

2131 Hilhurst Ave (2 story – basement) (OK for TCO; 7/30/13)(soil engineer inspection only, without geologist, so no opinion of fault activity possible)

6201 Hollywood Blvd (6 story – several basement levels) (letter from on-site geologist states no evidence of Hollywood fault)

1751 Las Palmas Ave (all of the site except for the northern 24 feet is located outside of the A-P study zone, so no fault evaluation required) (foundation is partially completed)

6. Permits issued and under construction with approved fault investigation:

1811 Orchid Ave

CURRENT HOLLYWOOD FAULT ZONE PROJECTS

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1500 Argyle Ave (correction letter issued requiring fault invest gation)

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7930 Hollywood Blvd (soil report approved; fau t investigation will be required before issuance of permit)

1840 Highland Ave (has aporoved fau t investigation)

3 Reports approved and in plan check

No projects

4. Permits issued, but construct on not started:
No oro,erts

5. Permits issued and under construction(no fault investigation):
4414 Averacn St (3-story on-grade) (has aporoved inspections for framing (12/17/13), drywall and insulation(both 1/9/14))

2131 Hilhurst Ave (2-story + basement) (OK for TCO, 7/30/13)

6201 Ho lywood Bl (6-story - several basement leve s) (letter from on-site geologist states no evidence of Hol ywood fault)

6 Permits issued and under construction with approved fault investigat on

1811 Orchid Ave

In April 2012 Langan submitted a soil report (dated 11/22/12) for LADBS review The report was prepared for the purpose of the tentative tract process.

In May 2012, LADBS issued a correction letter requesting detail geotechnical study and geologic investigation for potential surface displacement on the Hollywood Fault

In October 2012, Langan proposed to use the boring method to do the fault investigation. The boring method is one of the few most commonly used methods for this type of investigation LADBS agreed with using the boring method

In Dec 2012, Langan submitted two reports addressing the fault investigation (dated 11/30/12) and soil report (dated 12/0/12).

In Jan 2013, LADBS issued approval letter for both reports with a condition requiring a detailed geotechnical study to be provided at or to the building permits and/or recordation of the final tract map.

In June 2013, Dr James Dolan requested for a copy of the fault investigation report for his review. Subsequently, Dr Dolan expressed his concern to LADBS that based on his interpretation of the data, there is a lack of correlation between bore holes. Please note that Dr Dolan concerns are related to interpretation of the data and not any new evidence that there is an active Hollywood Fault crossing the property which would otherwise invalidate our approval.

As is often the case, technical concerns can arise from other interested parties after the issuance of an approval (building permit, grading reports, etc.). It has always been LADBS' practice to investigate the concerns, refer the concerns to the project consultant, and meet with the consultant to evaluate the validity of the concerns. If it appears that the concerns may be valid, then LADBS will request additional information from the project consultant. If concerns are not addressed, then the approval will be rescinded

In this case, the Chief of LADBS Grading Division, Dana Prevost reviewed the concerns and left a message for Langan about the concerns and request for a discussion on 6/13/13

During Mr. Prevost's vacation (from 6/14/13 to 6/23/13), Langan called and spoke to the LADBS geologist who reviewed and approved the report. Langan did not agree with the concerns raised by Dr Dolan and LADBS.

Mr Prevost came back from his vacation on 6/24/13 and left a message with Langan explaining that if no additional information or explanation is provided to address the concern, then we would rescind our approval, which is our common practice

The traffic analysis in the EIR for the project studied 37 intersections. Under existing traffic conditions, (2011), all 37 intersections during the AM Peak Hour operate at acceptable levels of service (LOS) of A through D, as determined by DOT. During the PM Peak Hour, one intersection operates at a LOS E, defined as "Severe congestion with some long-standing lines on critical approaches. Blockage of intersection may occur if traffic signal does not provide for protected turning movements." Levels of Service of E or F are considered unacceptable. The addition of the project will increase the value of the Critical Movement Analysis (CMA) in the future at all study intersections during one or both peak hours. Per DOT policy, a significant impact is defined as an increase in the CMA value due to project-related traffic as 0.010 or more when the final LOS is E or F.

With and without the project (2020), levels of service at 22 of the 37 studied intersections would continue to operate at acceptable levels of A through D. The remaining 15 intersections are anticipated to operate at Levels of E or F during one or both peak hours with or without the project. With the addition of project and the project-related traffic mitigation measures, however, the intersections operating at LOS E or F would decrease from 15 to 13. Of these, five study intersections would remain significant project impacts ~~at a significant level~~ even with the implementation of mitigation measures, meaning there was minimal improvement to the CMA (less than 0.010).

In the Horizon Year 2035 Development Agreement analysis, 16 intersections would have significant project traffic impacts during one or both peak hours. In addition to the 13 intersections that would be impacted by the project (with mitigation) in 2020, three additional intersections, including Cahuenga Boulevard/Yucca Street, Vine Street/Selma Avenue, and Vine Street/De Longpre Avenue.

Although the study intersections are anticipated to operate with diminished levels of service ~~are anticipated to diminish~~ with and without the project, the traffic analysis has concluded that the implementation of traffic mitigation would reduce the affected intersections that operate with a level of service of E or F from 15 to 13 in the year 2020, and would only increase the number of affected intersections from 15 intersections (without the project) to 16 intersections with the project and project-related traffic and mitigation.

From: "Frajo, Alfred" <afrajo@allenmatkins.com>
To: Charmie Huynh
CC: Jerold Neuman, Kevin Keller, Jon Tanury, alfredsperez@laciv.org
Date: 11/19/2008 3:42:08 PM
Subject: Millennium Hollywood Development Balcony Discussion

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the

natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com
<<BALCONYS SKETCHES 2 (AF 11 19 08).pdf>> <<Screens.doc>>

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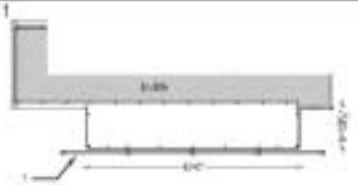
Attachments: BALCONYS SKETCHES 2 (AF 11 19 08).pdf, Screens.doc

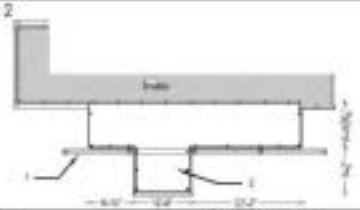
Balcony Type 1

Ref. SK 01



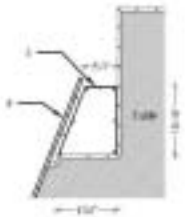
Balcony Type 2

Ref. SK 01

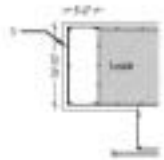


Balcony Type 7

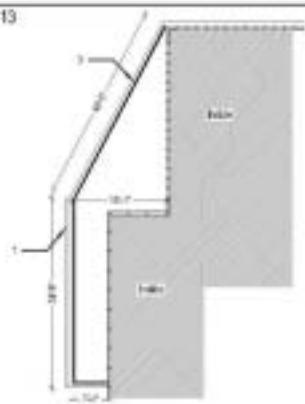
Ref. SK 04



Balcony Type 8



Balcony Type 13

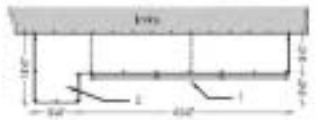


Balcony Type 3

Balcony Type 4

Balcony Type 9

Ref. SK 02



Balcony Type 10

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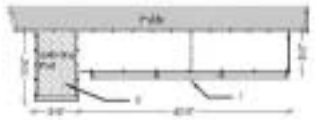
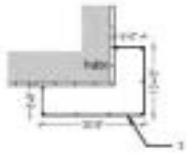
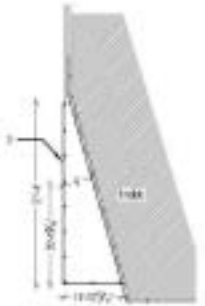


Balcony Type 14

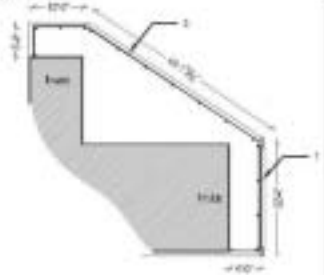


Balcony Type 15



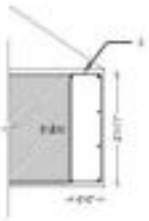
Balcony Type 5

Ref. SK 03

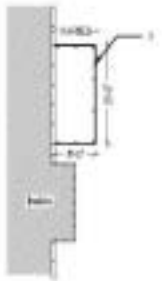


Balcony Type 6

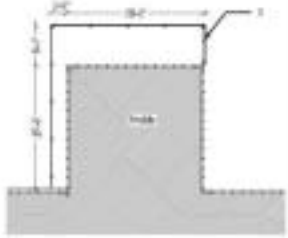
Ref. SK 04



Balcony Type 11



Balcony Type 12



LEGEND

1 - WOOD SCREEN

2 - PROJECTED BALCONY THROUGH LOUVER SYSTEM

3 - GLASS RAIL

4 - GLASS WIND BREAK (GLASS SCREEN)

5 - PROJECTED SWIMMING POOL

Millennium Hollywood

MILLENNIUM PARTNERS - ARGENT

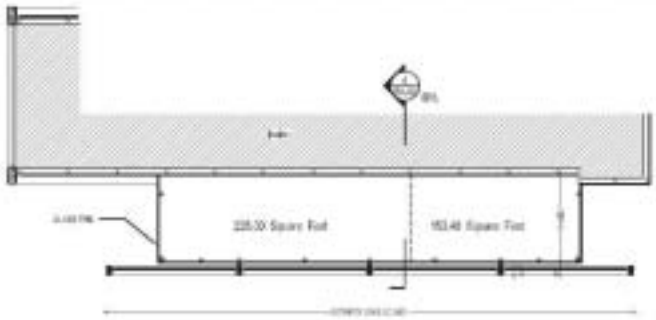
HANDEL ARCHITECTS LLP, &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-593

AR0067608

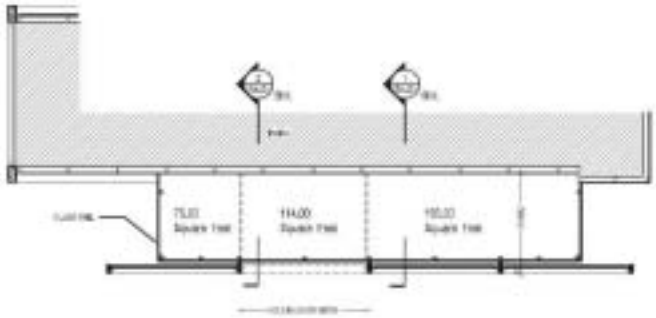
Franklin - Balcony Type 1

Case B

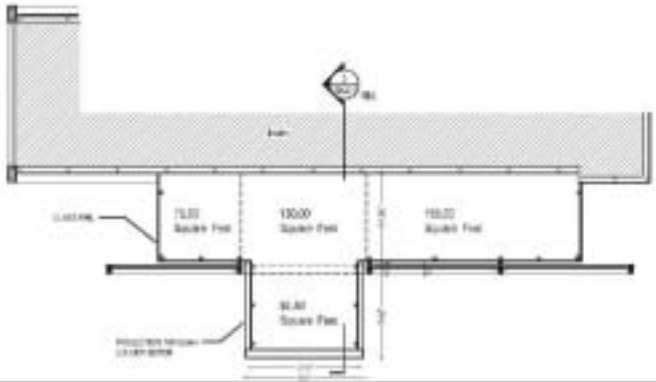


Franklin - Balcony Type 1

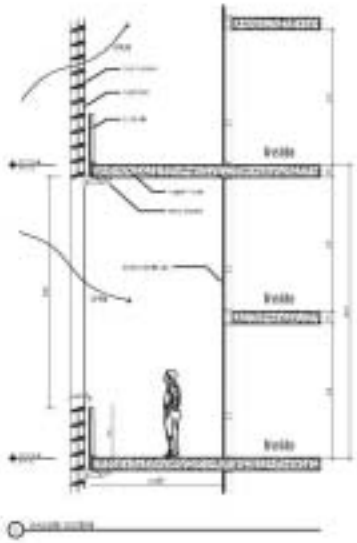
Case B

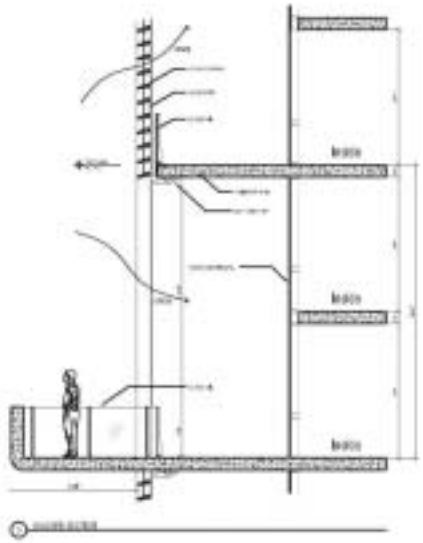


Franklin - Balcony Type 2



SK 01





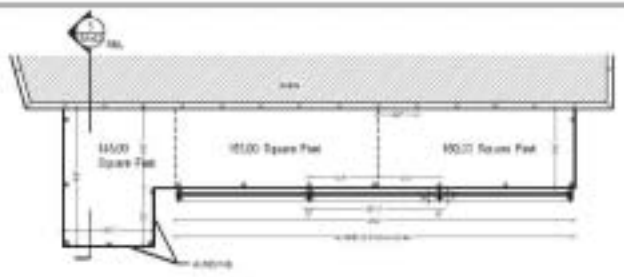
Millennium Hollywood

MILLENNIUM PARTNERS • ARGENT

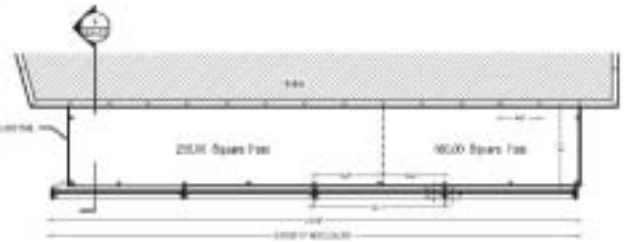
HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

Capitol - Balcony Type 9

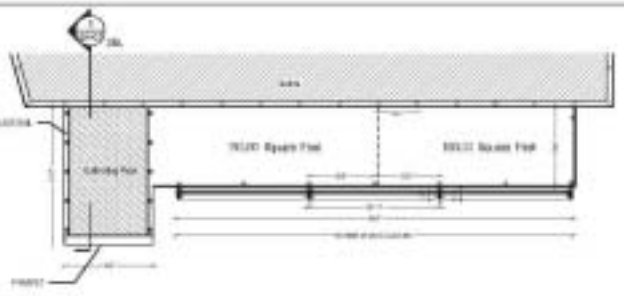
Case A



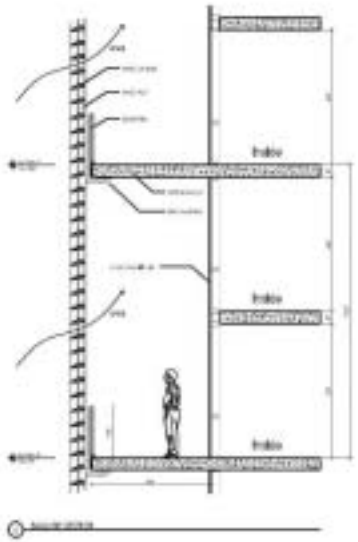
Capitol - Balcony Type 1

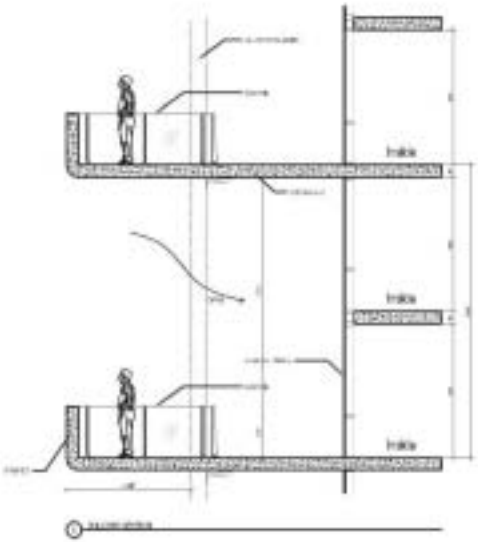


Capitol - Balcony Type 10



SK 02





Millennium Hollywood

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HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-596

AR0067611

Franklin - Balcony Type 5

Franklin - Balcony Type 6

SK 03

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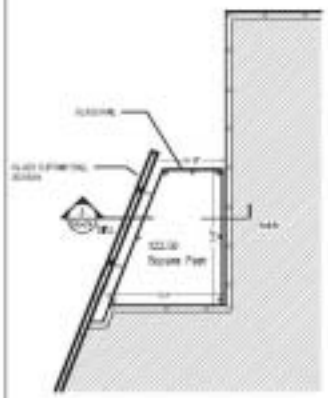
HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-597

AR0067612

Franklin - Balcony Type 7



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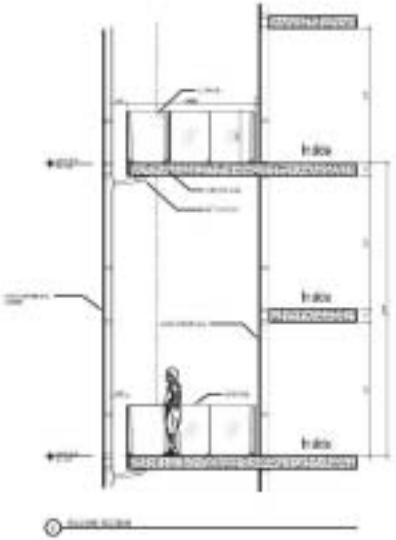

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CO-0001-598

AR0067613

Millennium Hollywood Los Angeles, CA
MP MILLENNIUM PARTNERS ARGENT

WOOD SCREEN

HANDEL ARCHITECTS LLP ROSCHEN VAN CLEVE ARCHITECTS

New York Times Building, Renzo Piano

New York Times Building, Renzo Piano

New York Times Building, Renzo Piano

Agbar Tower, Jean Nouvel

Wooden louvers

The New York Times

From: "Tachibana, Ed" etachibana@handelarchitects.com
To: Charmie Huynh
Date: 11/24/2008 11:37:43 AM
Subject: Capitol Records

Hi Charmie.

See if this helps. I have made a quick indication on "sketch 3" how the unit type distributions may work. Generally we are locating a living room at the end of each of the projecting "miradors". Other function may ultimately end up within that area. One possibility is an open loft style kitchen that would flow out to the primary living space.

Let me know if this helps or if you need further clarification.

Thanks

Best regards

EDWARD H TACHIBANA

HANDEL ARCHITECTS LLP

150 Varick Street, 8th Floor

New York, NY 10013

p 212 595 4112 f 212 595 9032

<<DS Balconies 2.pdf>>

Attachments: DS Balconies 2.pdf

Hi Ed,

Thanks for the pdf. Can you also email me the full level floor plan for the projecting living room and a full level floor plan for the balcony beneath it?

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Tachibana, Ed" <etachibana@handelarchitects.com> 11/24/2008 11:40 AM >>>

Hi Charmie,

See if this helps. I have made a quick indication on "sketch 3" how the unit type distributions may work. Generally we are locating a living room at the end of each of the projecting "miradors." Other function may ultimately end up within that area. One possibility is an open loft style kitchen that would flow out to the primary living space.

Let me know if this helps or if you need further clarification.

Thanks.

Best regards,

EDWARD H TACHIBANA

HANDEL ARCHITECTS LLP

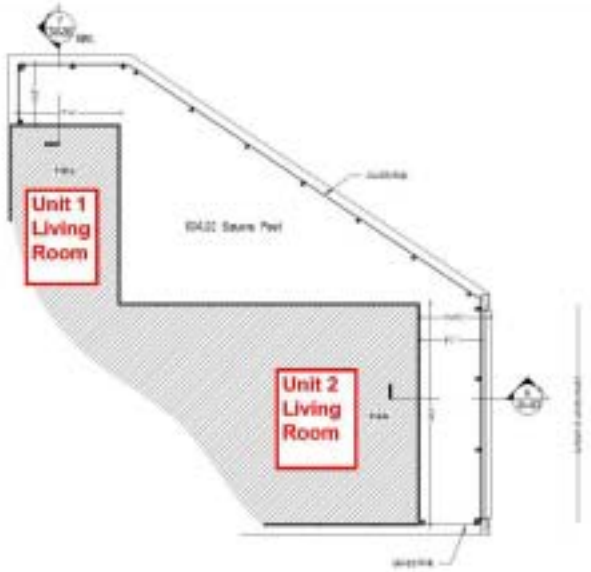
150 Varick Street, 8th Floor

New York, NY 10013

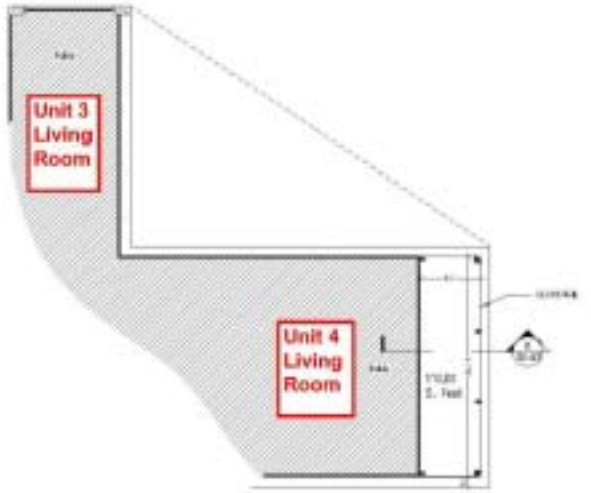
p. 212.595.4112 f. 212.595.9032

<<DS Balconies 2.pdf>>

Franklin - Balcony Type 5



Franklin - Balcony Type 6



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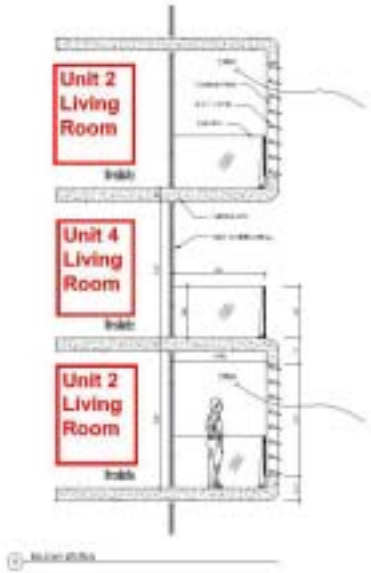

Millennium Hollywood

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ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-606

AR0067621

Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 3:38 PM >>>

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining

balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com
<<BALCONYS SKETCHES 2 (AF 11 19 08).pdf>> <<Screens.doc>>

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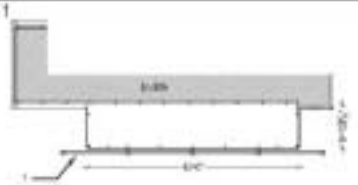
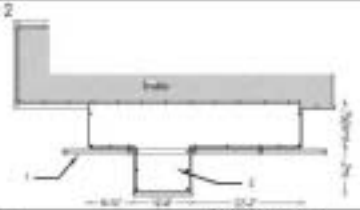
Balcony Type 1



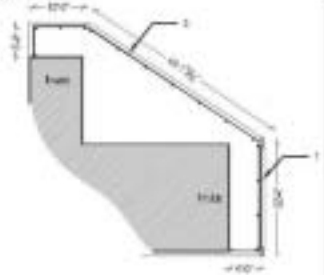
Balcony Type 2



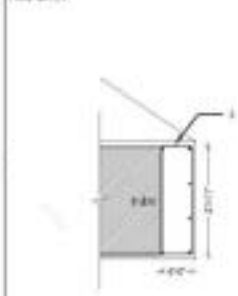
Balcony Type 3

Balcony Type 4

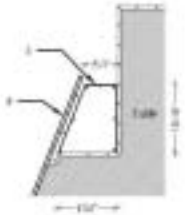
Balcony Type 5



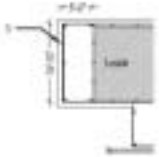
Balcony Type 6



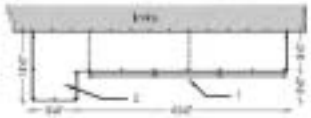
Balcony Type 7



Balcony Type 8

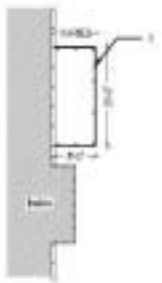


Balcony Type 9

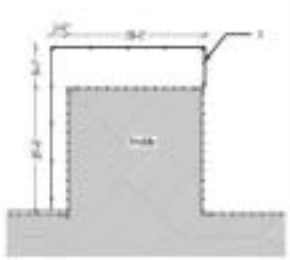


Balcony Type 10

Balcony Type 11



Balcony Type 12



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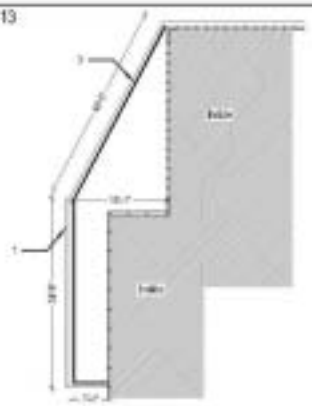

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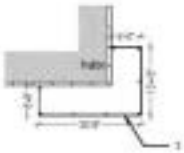
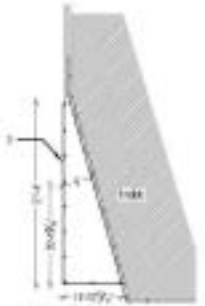


Balcony Type 15



LEGEND

1 - WOOD SCREEN

2 - PROJECTED BALCONY THROUGH LOUVER SYSTEM

3 - GLASS RAIL

4 - GLASS WIND BREAK (GLASS SCREEN)

5 - PROJECTED SWIMMING POOL

Millennium Hollywood

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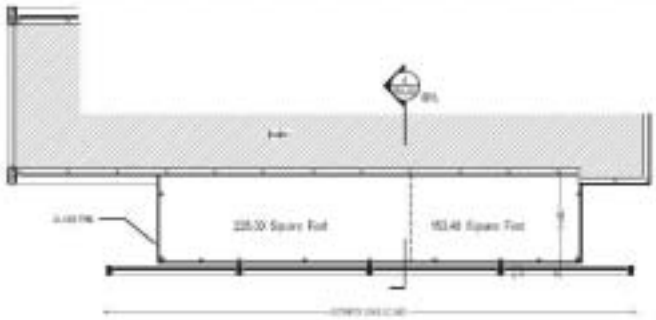
HANDEL ARCHITECTS LLP, &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-610

AR0067625

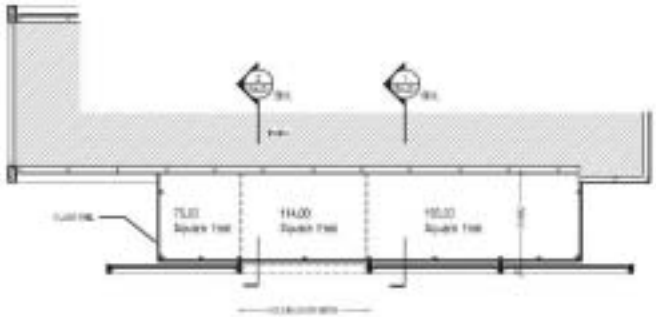
Franklin - Balcony Type 1

Case B

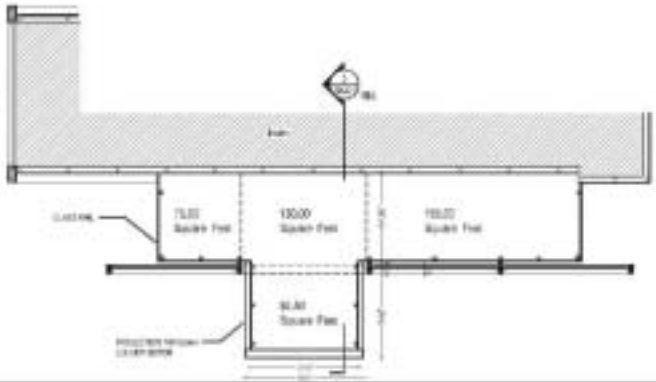


Franklin - Balcony Type 1

Case B



Franklin - Balcony Type 2



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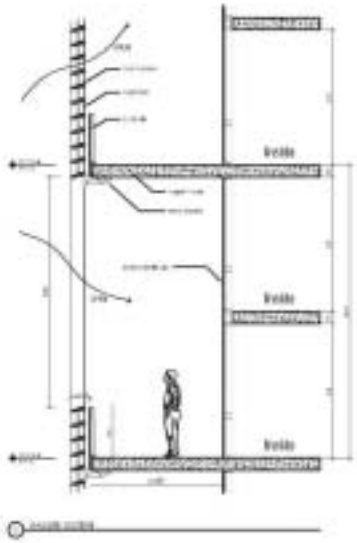

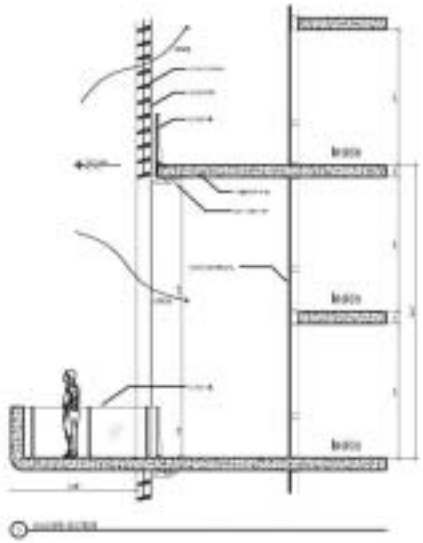

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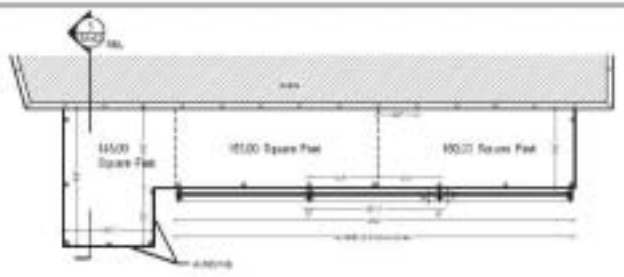
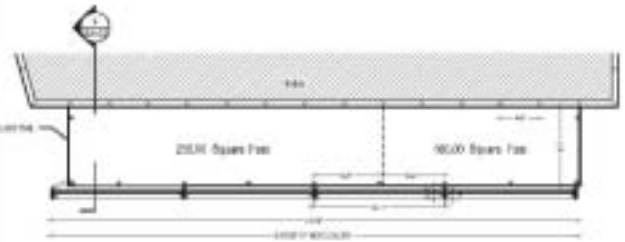
Capitol - Balcony Type 9

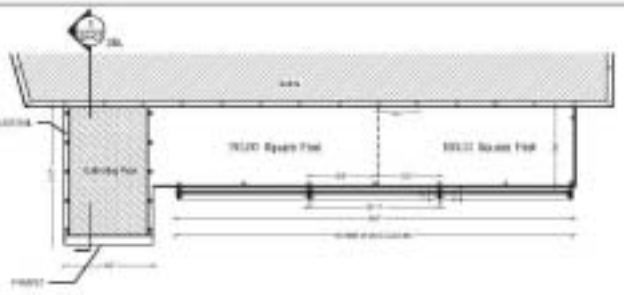
Case A



Capitol - Balcony Type 1



Capitol - Balcony Type 10



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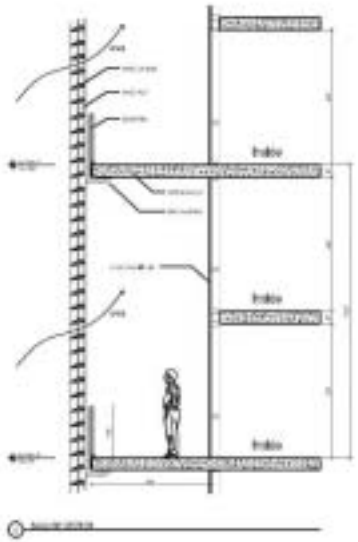

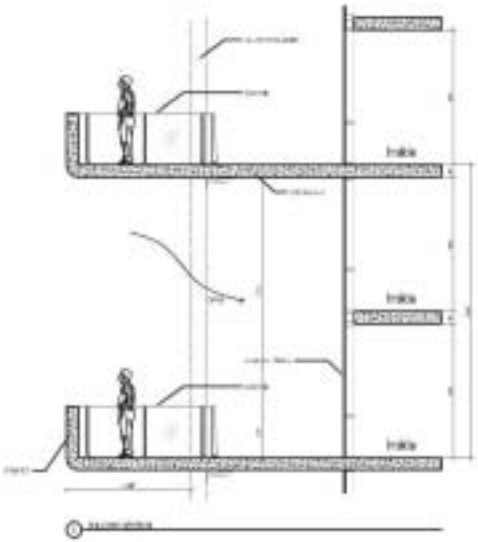

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ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-613

AR0067628

Franklin - Balcony Type 5

Franklin - Balcony Type 6

SK 03

Millennium Hollywood

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HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-614

AR0067629

Franklin - Balcony Type 7

SK 04

Millennium Hollywood

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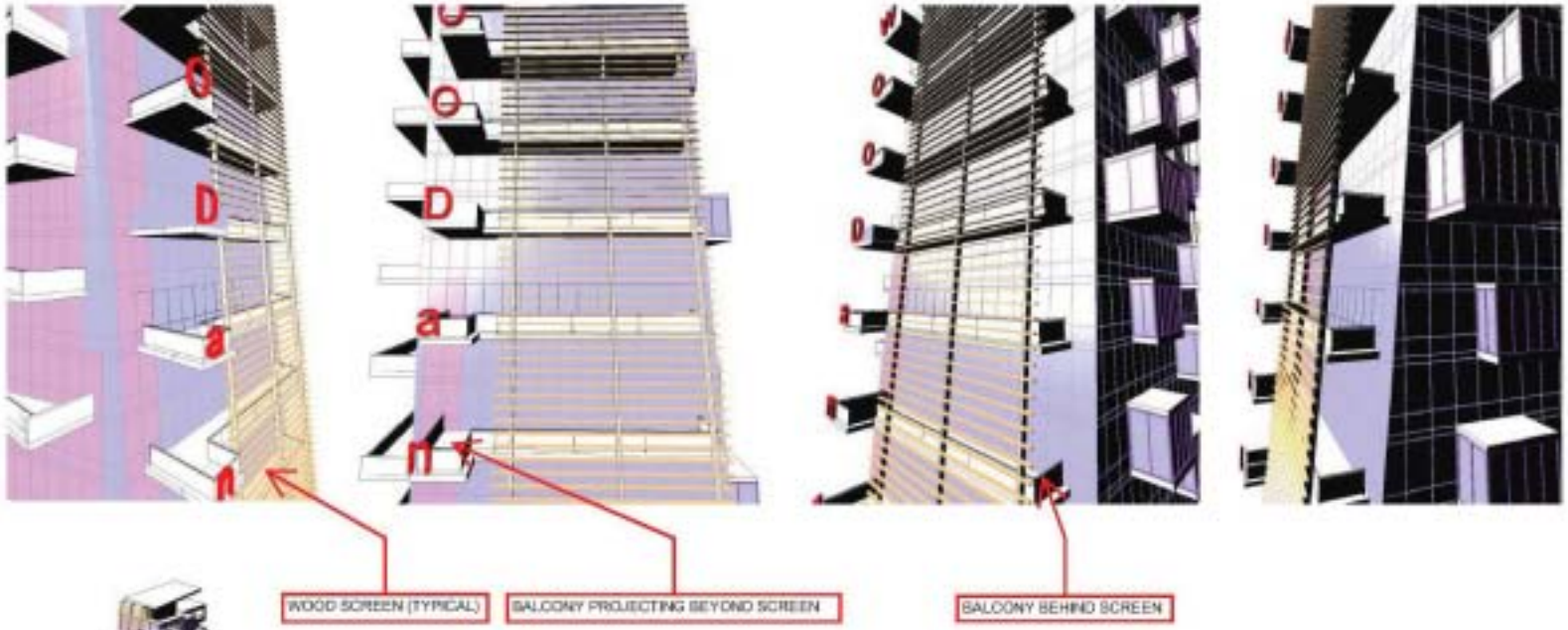
HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-615

AR0067630



Millennium Hollywood Los Angeles, CA
MP MILLENNIUM PARTNERS ARGENT

WOOD SCREEN

HANDEL ARCHITECTS LLP ROSCHEN VAN CLEVE ARCHITECTS

New York Times Building, Renzo Piano

New York Times Building, Renzo Piano

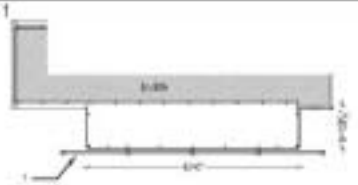
New York Times Building, Renzo Piano

Agbar Tower, Jean Nouvel

Wooden louvers

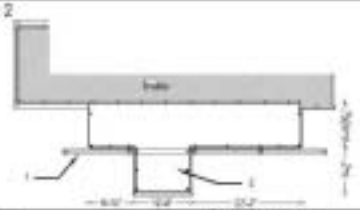
Balcony Type 1

Ref. SK 01



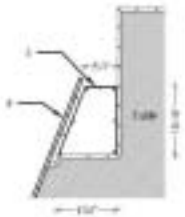
Balcony Type 2

Ref. SK 01

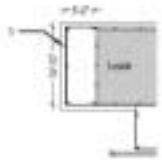


Balcony Type 7

Ref. SK 04



Balcony Type 8



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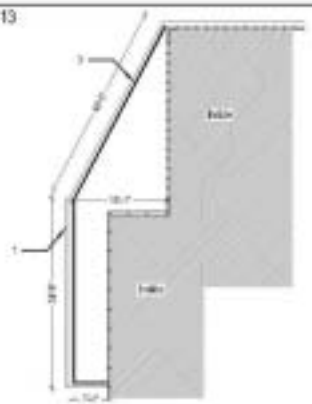


Balcony Type 3

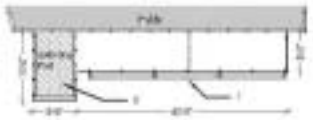
Balcony Type 4

Balcony Type 9

Ref. SK 02

Balcony Type 10

Ref. SK 02



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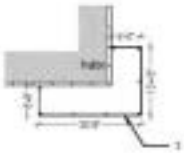

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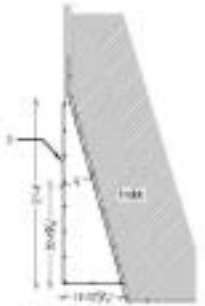
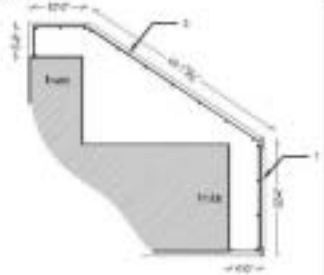


Balcony Type 5

Ref. SK 03



Balcony Type 6

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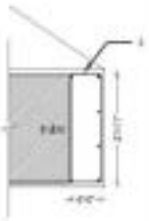
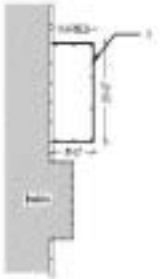
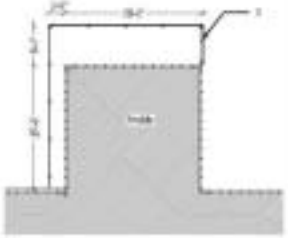


Balcony Type 11



Balcony Type 12



LEGEND

1 - WOOD SCREEN

2 - PROJECTED BALCONY THROUGH LOUVER SYSTEM

3 - GLASS RAIL

4 - GLASS WIND BREAK (GLASS SCREEN)

5 - PROJECTED SWIMMING POOL

Millennium Hollywood

MILLENNIUM PARTNERS - ARGENT

HANDEL ARCHITECTS LLP, &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-620

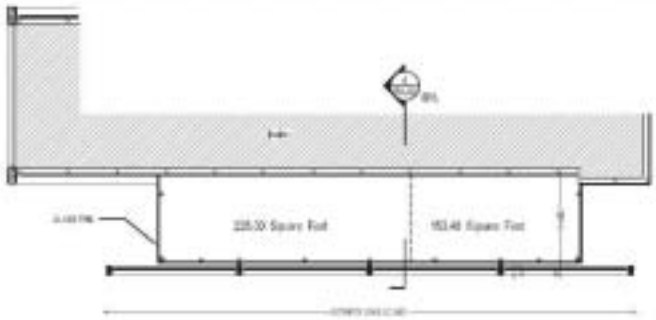
AR0067635

AR00067636

CO-0001-621

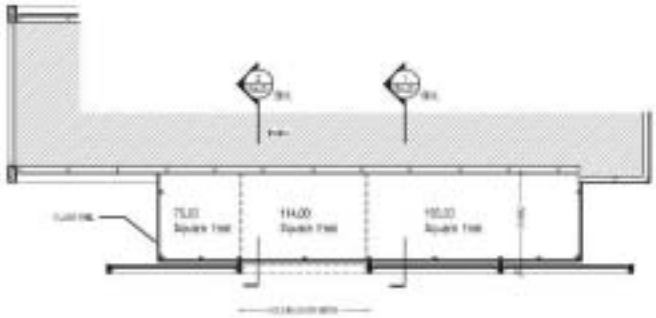
Franklin - Balcony Type 1

Case B

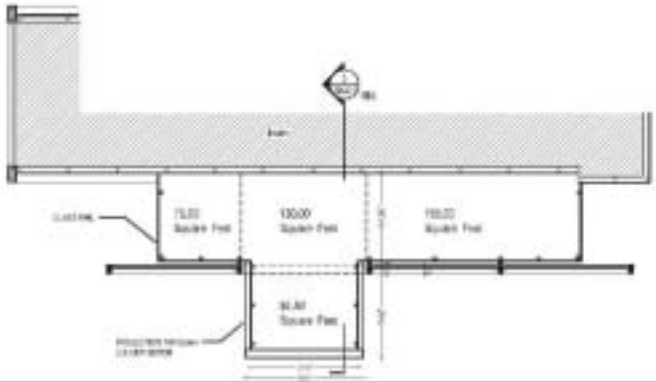


Franklin - Balcony Type 1

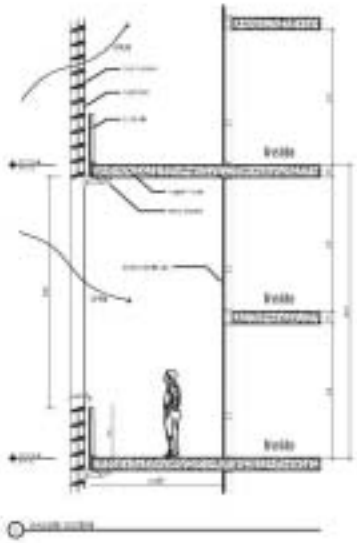
Case B

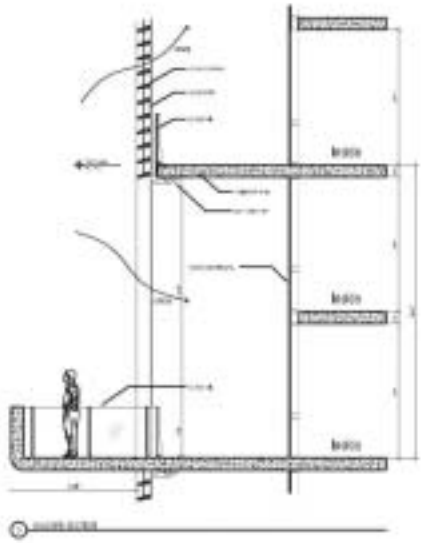


Franklin - Balcony Type 2



SK 01





Millennium Hollywood

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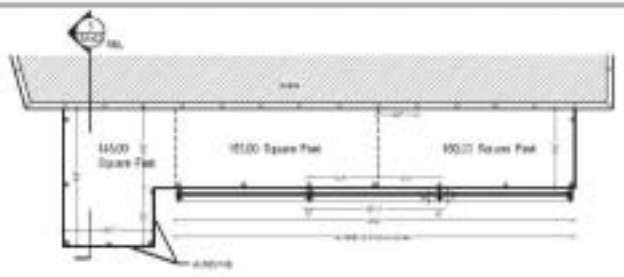
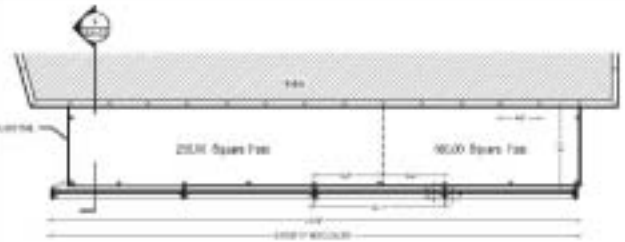
HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

Capitol - Balcony Type 9

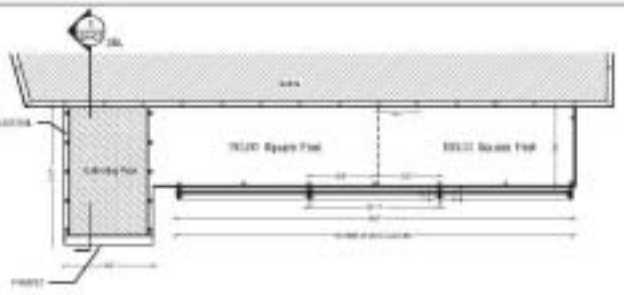
Case A



Capitol - Balcony Type 1



Capitol - Balcony Type 10



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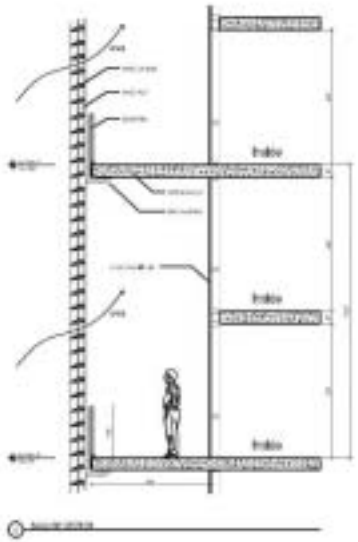

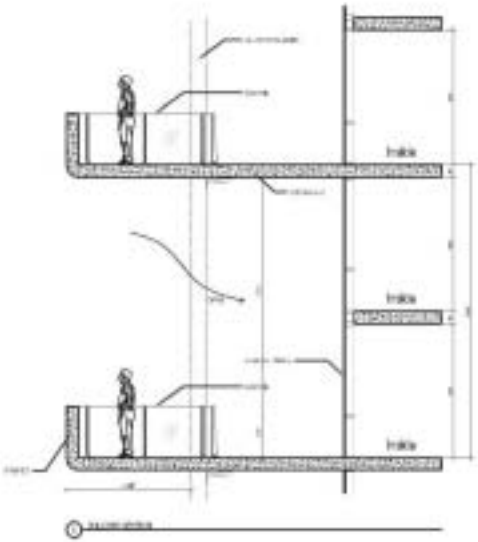

Millennium Hollywood

MILLENNIUM PARTNERS • ARGENT

HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-623

AR0067638

Franklin - Balcony Type 5

Franklin - Balcony Type 6

SK 03

Millennium Hollywood

MILLENNIUM PARTNERS • ARGENT

HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-624

AR0067639

Franklin - Balcony Type 7

SK 04

Millennium Hollywood

MILLENNIUM PARTNERS • ARGENT

HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-625

AR0067640

Millennium Hollywood Los Angeles, CA
MP MILLENNIUM PARTNERS ARGENT

WOOD SCREEN

HANDEL ARCHITECTS LLP ROSCHEN VAN CLEVE ARCHITECTS

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under 12.26. that said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Millenium Hollywood high rise project and the issue of FAR and Balconies. The topic at hand is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should make the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/24/2008 4:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

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221 N. Figueroa St, Suite 180

Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 3:38 PM >>>

Hi Charmie,
I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.
On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.
The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.
Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.
Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.
In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.
Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not

enclosed balconies and should be excluded from FAR.
Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com
allenmatkins.com
<<BALCONYS SKETCHES 2 (AF 11 19 08).pdf>> <<Screens.doc>>

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Charmie,

On the issue of space under a projection (i.e., ground floor or balcony space under a habitable room) that would be counted as FAR, can you refer us to the related Building or Zoning Code section for reference?

Thanks in advance.

From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Monday, December 01, 2008 3:49 PM
To: Fraijo, Alfred
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

>>> Alan Bell 12/1/2008 10:49 AM >>>
Hi Charmie - I've reviewed the material you sent me concerning the Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

The proposed additional screening above the guard rail encloses space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular wing walls and privacy screens discussed on p. 4 of the ZAI, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1322
(213) 978-1334 fax
alan.bell@lacity.org

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213.955.5607 D
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213.620.8816 F
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allenmatkins.com
<<BALCONYS SKETCHES 2 (AF 11 19 08).pdf>> <<Screens.doc>>

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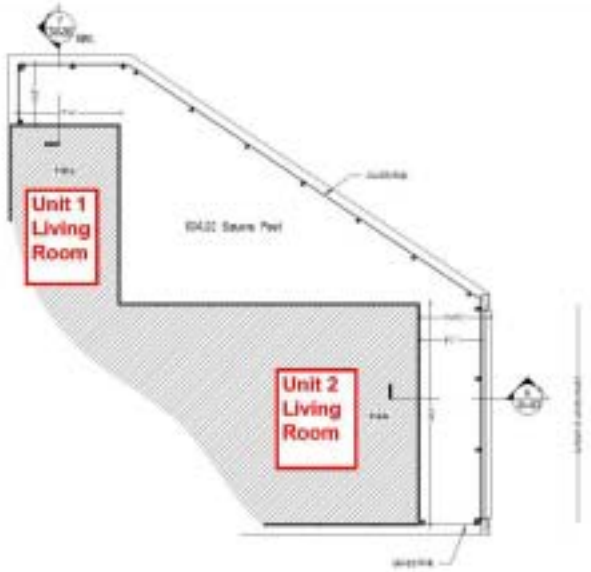
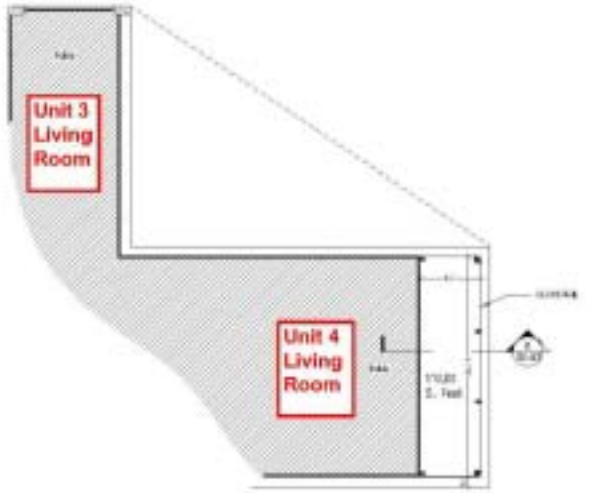
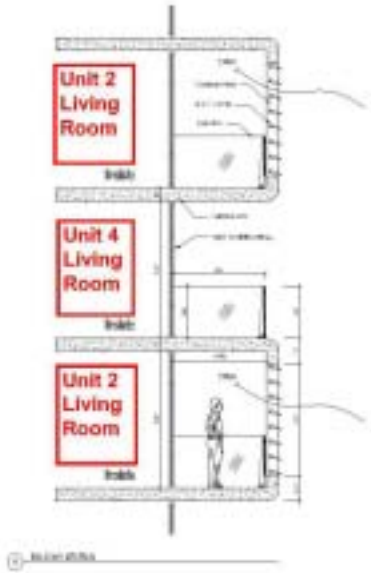
Franklin - Balcony Type 5



Franklin - Balcony Type 6



SK 03



Millennium Hollywood

MILLENNIUM PARTNERS - ARGENT

HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-633

AR0067648

From: Alan Bell
To: Charmie Huynh
CC: Michael McGeary; Maya Zaltzevsky; Arnaldo Perez; Jameson Lee
Date: 12/1/2008 10:49:42 AM
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

Hi Charmie - I've reviewed the material you sent me concerning the Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #3, which is that the balcony or deck remains "unenclosed except for the guardrails required by the Building Code."

The proposed additional screening above the guardrail encloses space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular end walls and privacy screens discussed on p. 4 of the ZAI, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1322
(213) 978-1334 fax
alan.bell@lacity.org

>>> Charmie Huynh 12/1/2008 10:27 AM >>>

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be LADBS's call as to how to apply the ZAI to a specific project, since LADBS is responsible for interpreting and enforcing the city's zoning ordinances (refer 12.26). That said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Millennium Hollywood high rise project and the issue of FAR and balconies. The report basically is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Arnaldo that you feel that LADBS should make the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZAI's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back on Monday. I'd love to get your feedback on this. Jameson and Arnaldo are cc'd on this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate - Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St. Suite 180
Los Angeles, CA 90012

T. (213) 482-6825
F. (213) 482-6870
Channie.Huynh@lacity.org

>>> Channie Huynh 10/2/2008 10:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification of these screens for your project. Basically, LADBS cannot provide clarification on an existing ZAI interpretation.

Please let me know if you have any questions.

Thanks

Channie Huynh, P.E.
Structural Engineering Associate - Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St. Suite 100
Los Angeles, CA 90012
T. (213) 482-6825
F. (213) 482-6870
Channie.Huynh@lacity.org

>>> Hong, Alfred <Alfred@jpcdevelopments.com> 10/29/2008 3:38 PM >>>

Hi Channie,
I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting. On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.
The Chief Zoning Administrators memo (ZAI) we reviewed at the pre-development meeting states that balcony wall not be included in FAR if it remains unenclosed except for the guardrails required by the Building Code. The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.
Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed on two or three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03). Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balconies as leave one or more wall areas open except for the required guardrails.
Additionally, the wooden louvers and glass breaks create a barrier against the natural elements and enhancing balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo (ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4). Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden planks (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the projects biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve views from the units. Accordingly,

the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the FAR regardless of height and do not function to enclose the balconies for FAR purposes.
In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are considered in addition to the required guardrails. The glass wind break can not be considered to enclose the balconies.
Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2005 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements."
As discussed above, the intent of the FAR was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are partially open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.
Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Hajjar, Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
ahajjar@allenmatkins.com
allenmatkins.com
<<BALCONY SKETCHES 2 (AF 11 13 08).pdf>> <<Screens.docx>>

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From: Charmie Huynh
To: afraijo@allenmatkins.com
Date: 12/1/2008 3:49:19 PM
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

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>>> Alan Bell 12/1/2008 10:49 AM >>>
Hi Charmie - I've reviewed the material you sent me concerning the Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

The proposed additional screening above the guard rail encloses space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular wing walls and privacy screens discussed on p. 4 of the ZAI, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1322
(213) 978-1334 fax
alan.bell@lacity.org

>>> Charmie Huynh 12/1/2008 10:27 AM >>>

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under 12.26. That said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Millenium Hollywood high rise project and the issue of FAR and Balconies. The topic at hand is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should make the call on this one. I've already spoken with Jamieson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this.

Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/24/2008 4:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 3:38 PM >>>

Hi Charmie,
I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.
On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.
The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening

must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.
Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.
Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.
In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.
Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.
Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com
allenmatkins.com
<<BALCONYS SKETCHES 2 (AF 11 19 08).pdf>> <<Screens.doc>>

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New York Times Building, Renzo Piano

New York Times Building, Renzo Piano

New York Times Building, Renzo Piano

Agbar Tower, Jean Nouvel

Wooden louvers

From: Charmie Hsieh
To: Alan Bell
Date: 12/1/2008 10:22:56 AM
Subject: balcony screens
Attachments: BALCONY SKETCHES 2 (AF 11-19-08).pdf; Screens.doc; DS Balconies 2.pdf

From: "Ord, Eleanor" <eord@allenmatkins.com>
To: Charmie Huynh
Date: 9/29/2008 3:43:05 PM
Subject: Capitol Records: FAR/Balcony

Hi Charmie,

We wanted to give you some information in advance of our meeting on Thursday to jumpstart our discussions. Attached below are renderings of the balcony configurations contemplated for the project and depictions of balconies in the finished structures. We're looking forward to seeing you on Thursday at 9:30 am.

Thanks,

Eleanor

Eleanor M. Ord
Attorney at Law
Allen Matkins
515 South Figueroa Street, 9th Floor
Los Angeles, CA 90071
Direct: 213-955-5653
Fax: 213-620-8816

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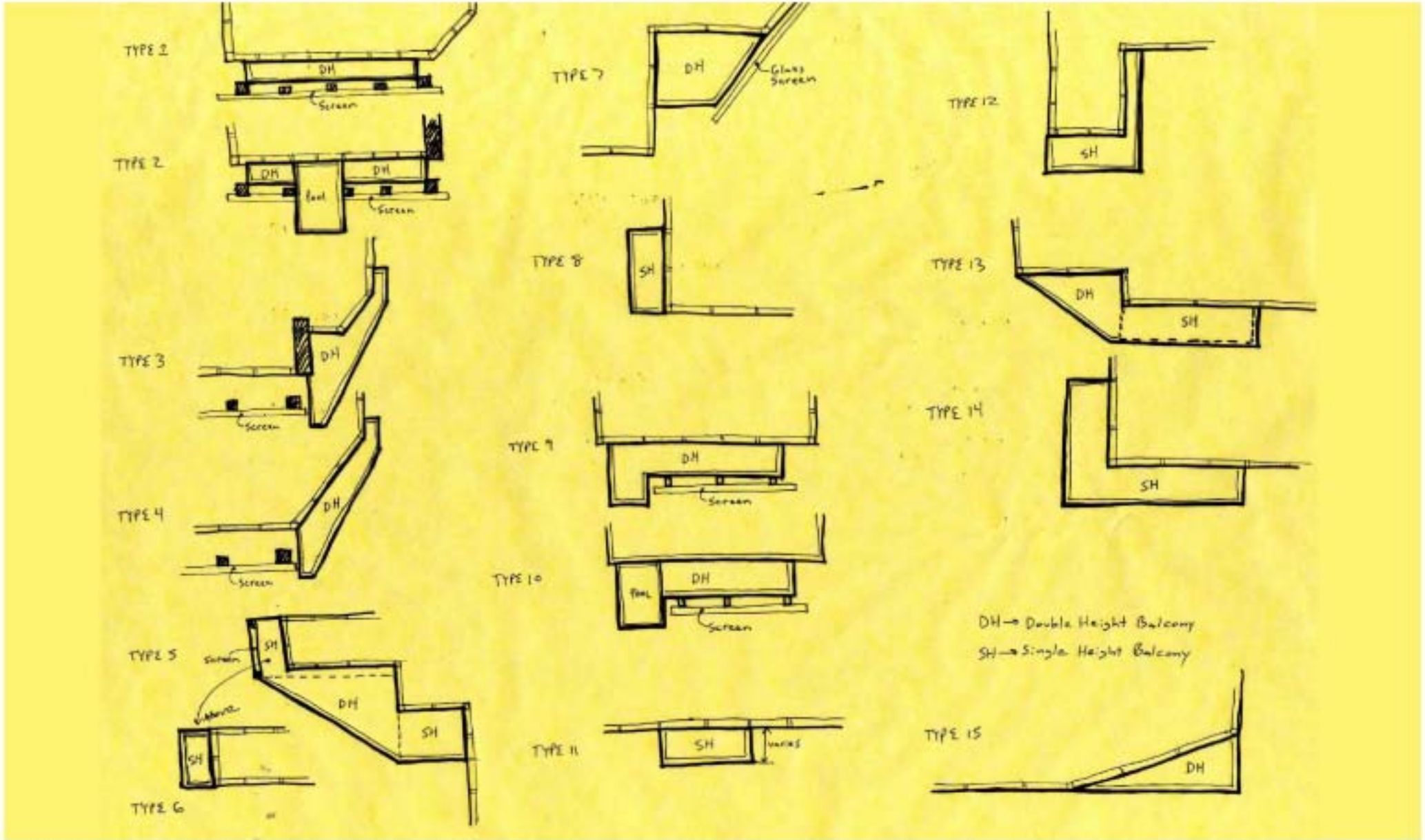
Attachments: Private Open Space - Types.pdf, crop of c011.jpg, crop of c005.jpg



Millennium Hollywood Los Angeles, CA

MP MILLENNIUM PARTNERS ARGENT

PRIVATE OPEN SPACE

HANDEL ARCHITECTS LLP | ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-650

AR0067665

From: Wes Pringle
To: Charmie Huynh
Date: 10/15/2008 2:36:27 PM
Subject: Millennium Project Meeting

Charmie

I will not be attending the meeting for this project. We have been working with the traffic consultant on the traffic study for this project and will comment on it when it comes out. If there are any other questions for DOT please forward my contact information (below).

Thanks

Weston Pringle
Department of Transportation
Metro Programs Division
100 S. Main St., 9th Floor
Los Angeles CA 90012
Phone: (213) 972-8482
Fax: (213) 972-8418
Stop 725

From: "Baluyot, Rene" <Rene.Baluyot@ladwp.com>
To: W.C. Byrd
CC: Charmie Huynh
Date: 10/20/2008 1:53:21 PM
Subject: RE: Request for Pre-Development Meeting for Millennium Hollywood -1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)

WC,

Would it be possible for you or your staff to attend this predevelopment meeting this Wednesday from 1PM to 3PM. Our group has a scheduled meeting with Councilmember Alarcon at the same time and I won't be able to attend the predev meeting. Please let me or Charmie know.

Charmie, I will forward the water info as soon as I get it from the water engineer.

Thanks!

Rene

From: Baluyot, Rene
Sent: Friday, October 17, 2008 12:52 PM
To: Byrd, W.C.; Spacht, Julie
Cc: Linard, Andrew; Moon, Marvin
Subject: RE: Request for Pre-Development Meeting for Millennium Hollywood -1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)

Julie/WC, << File: GROUND FLOOR PLAN 1.pdf >> << File: 1750 Zimas.pdf >> << File: LA-808560-v4-Pre-Development Meeting Project Description.pdf >> << File: Vicinity Map.pdf >> << File: A105 East Site Survey.pdf >> << File: LA-808370-v1-PDM Questions and Issues for City Departments.doc >>

The city case manager, Ms. Charmie Huynh, is requesting DWP to provide predevelopment assistance for the proposed Millenium Hollywood High-Rise project. Attached are the project files.

Will you please have your staff review the attached plans and requested DWP information and let me know the person in your group assigned to this project?

Thanks and have a great day!

Rene Baluyot

Economic Development Group

Los Angeles Department of Water and Power

213.367.1284

rene.baluyot@ladwp.com

-----Original Appointment-----
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Wednesday, October 08, 2008 4:47 PM
To: eord@allenmatkins.com; afraijo@allenmatkins.com; jneuman@allenmatkins.com; etachibana@handelarchitects.com; ghandel@handelarchitects.com; Ammar Eltawil; Carl Mills; Charmie Huynh; Frank Comfort; Kevin Keller; LADBS CMServiceRequest; LADBS_Fig221_180_Conf_A.po01.dom1@lacity.org; Lambert Giessinger; Michael Taylor; Richard Ferguson; Ron Lorenzen; Tomas Carranza; Win Pham; Baluyot, Rene; ttrynin@millenniumptrs.com
Cc: Jay Kim; Lemuel Paco
Subject: Request for Pre-Development Meeting for Millennium Hollywood -1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)
When: Wednesday, October 22, 2008 1:00 PM-3:00 PM (GMT-08:00) Pacific Time (US & Canada).
Where: 221 N Figueroa St., Suite 180, LA, CA 90012

Hello,

You are invited to a case management pre-development meeting for the proposed Millennium Hollywood High Rise projects at 1750 N Vine St (East Site) and 1751 N Vine St (West Site). The Project Narrative is attached to this email.

Date: Wednesday, October 22, 2008

Time: 1:00pm - 3:00pm

Location: 221 N Figueroa St., Suite 180, Los Angeles, CA 90012

Applicant: Alfredo Fraijo, Attorney at Law, Allen Matkins, 213-955-5607

Questionand Issues for the City Departments:

1.) Planning/Building & Safety:Confirmation of required entitlements with respect to the proposed

project (are any other entitlements required?); Confirmation of setbacks provided Are there minimum distance requirements between the two towers? Are there minimum distance requirements regarding light and air for windows facing windows, alleys or lot lines? Confirm loading spaces required for the project and their required dimensions Discuss balcony encroachment and screening issues (ZA 2007-3430(ZAI) Memo)

2.) Public Works:Are any offsite improvements required such as street widening, other than what a traffic study might suggest? Confirm sidewalk and street dedication requirements Sewer facility charge and credit Adequacy of storm drain system near project Confirmation of sewer capacity availability Are there any requirements for onsite storm water retention, treatment, discharge during construction and/or operation? What are the required public improvements regarding street trees etc? What are the required public improvements regarding street lights? How will the Walk of Fame be handled during construction? Task force to determine viability of underground tunnel and obtaining a franchise

3.) LAFD & Fire Hydrants and Access What are the type and location of desired Fire Dept turnarounds? Where should on-site hydrants be located? What fire lane access is required to the buildings? How do hydrant and fire equipment access requirements impact the layout of units? General review of and input related to the proposed site plan regarding Fire Department requirements. Observation deck fire access issues, including capacity, fire escape and elevator.

4.) DWP:Will we be required to provide public or private utilities? Requirements for undergrounding utilities, if any. How will project be metered relative to the air lot subdivision? Potential relocation of traffic island and right-hand turn lane at corner of Yucca and Argyle to create a park General review and input regarding the proposed site plan and DWP requirements, including water and power service availability, water and power connections and clear distance from existing or future power lines.

Your attendance is greatly appreciated. If you cannot attend, please reply to me via email with your comments and any information you can pass along to the Applicant to address their concerns/issues

Attached are some of the project files. I will be sending an additional 4 other emails containing the project files

Thank you

Charmie Huynh, P.E.

Structural Engineering Associate/Case Manager

City of Los Angeles/Department of Building and Safety

221 N. Figueroa St. Suite 180

Los Angeles, CA 90012

T: (213) 482-6875

F: (213) 482-6874

Charmie.Huynh@lacity.org << File: GROUND FLOOR PLAN 1.pdf >> << File: 1750 Zimas.pdf >> << File: LA-808560-v4-Pre-Development Meeting Project Description.pdf >>

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From: Charmie Huynh
To: Alfred Fraijo
Date: 11/19/2008 3:48:23 PM
Subject: Re: FW: Millennium Hollywood Development: Balcony Discussion

---

it's AV.Perez@lacity.org

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 3:43 PM >>>

Hi Charmie,

Do you happen to have Alfredo's correct email address? Thanks!

From: System Administrator
Sent: Wednesday, November 19, 2008 3:42 PM
To: Fraijo, Alfred
Subject: Undeliverable: Millennium Hollywood Development: Balcony Discussion

Your message did not reach some or all of the intended recipients.

Subject: Millennium Hollywood Development: Balcony Discussion
Sent: 11/19/2008 3:38 PM

The following recipient(s) could not be reached:

alfredo.perez@lacity.org on 11/19/2008 3:41 PM
The e-mail account does not exist at the organization this message was sent to. Check the e-mail address, or contact the recipient directly to find out the correct address.

< cwmsmtpx.ci.la.ca.us #5.1.1 SMTP; 550 No such recipient>

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From: Charmie Huynh
To: Alfred Fraijo
Date: 11/19/2008 4:16:06 PM
Subject: RE: Millennium Hollywood Development: Balcony Discussion

---

Alfred... you may want to include the attachments.

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 4:14 PM >>>

Alfredo,

I misspelled your email address - sorry. Please see original email below. Thanks!

Best regards,

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com

From: Fraijo, Alfred
Sent: Wednesday, November 19, 2008 3:38 PM
To: 'Charmie Huynh'
Cc: 'alfredo.perez@lacity.org'; 'jon.tanury@lacity.org'; 'Kevin Keller'; Neuman, Jerold
Subject: Millennium Hollywood Development: Balcony Discussion

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to

mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like

those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com
<< File: BALCONYS SKETCHES 2 (AF 11 19 08).pdf >> << File: Screens.doc >>

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From: Alan Bell
To: Charmie Huynh
CC: Alfredo Perez, Jameson Lee
Date: 11/25/2008 11:37:57 AM
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's call as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under 12.26. That said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Miller Hollywood high rise project and the issue of FAR and balconies. The report at hand is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should make the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The owners want LADBS to consider their interpretation on the ZAI (ZA2007-3401). However, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate - Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 100
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/24/2008 4:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3401(ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on another ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
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City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 100
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Feig, Alfred" <afeig@allenmatkins.com> 10/29/2009 3:38 PM >>>

Hi Glenn,
I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.
On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.
The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that balcony walls not be included in FAR if the walls are enclosed except for the guardrails required by the Building Code. The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with mesh screening." Since mesh screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.
Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean "closed in on all sides or surrounded on all sides." The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed on two or three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03). Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.
Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4). Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics of the buildings in line with similar concepts for other world-class structures (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical height of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (not unlike Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the projects biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve views from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered external walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.
In addition, the glass curtain wall is provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately five feet (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and do not form to the required guardrails. The glass wind break can not be considered to enclose the balconies.
Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.
Please let us know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Feig Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.273.6474 C
213.620.8816 F
afeig@allenmatkins.com
allenmatkins.com
Exhibit CONTRIBUTIONS 2 (Feb 11 19 08).pdf>> <<Screens.doc>>

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AR0067678

From: Charmie Huynh
To: Alfred Fraijo
CC: Jameson Lee
Date: 12/3/2008 9:42:13 AM
Subject: RE: Re: Millennium Hollywood Development: Balcony Discussion

---

Hi Alfred,

I don't believe there is a code section for this particular interpretation. Jameson said you can contact him if you need further clarification on this issue. Jameson's phone # is 213-482-6866.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 12/1/2008 4:15 PM >>>
Charmie,

On the issue of space under a projection (i.e., ground floor or balcony space under a habitable room) that would be counted as FAR, can you refer us to the related Building or Zoning Code section for reference?

Thanks in advance.

From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Monday, December 01, 2008 3:49 PM
To: Fraijo, Alfred
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

>>> Alan Bell 12/1/2008 10:49 AM >>>
Hi Charmie - I've reviewed the material you sent me concerning the Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

The proposed additional screening above the guard rail encloses space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular wing walls and privacy screens discussed on p. 4 of the ZAI, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1322
(213) 978-1334 fax
alan.bell@lacity.org

>>> Charmie Huynh 12/1/2008 10:27 AM >>>

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under 12.26. that said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

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I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
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F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/24/2008 4:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

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T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 3:38 PM >>>

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with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.
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Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

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Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com
allenmatkins.com
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H· Charmie.

I hope you are well.

The project is not on hold. We are taking add t onal time to review our design and planning approach w th our consultant team but we are still moving forward. We anticipate being able to visit with you and consider a submitta with LADBS in the new two months or so. I wi l keep you posted. Thank you for your follow up.

Best regards (and happy Cinco de Mayo!),

Alfred Fra.jo Jr.

Assoc ate

Allen Matkins Leck Gamule Ma lory & Narsh L P

515 South Figueroa Street, 9th Floor, Los Ange·es, CA 90071-3301

(213) 622-5555 (ma n)

(213) 955 5607 (direct)

(415) 225-6373 (mob.le)

(213) 620-8816 (fax)

www.allenmatk ns com

Allen Matkins

From: Charmie Huynh [mailto:Charmie.Huynh@ acity.org]

Sent: Tuesday, May 05, 2009 2:05 PM

To: Frajo, Alfred

Subject: 1750 N Vine St - Millennium Hollywood

Hi Alfred,

Hope you're doing well. It's been a while.

Just wanted to check in with you on the status of this project. Is it moving forward? And if so, do you know if they have an approximate plan check submittal date to LADBS?

Thanks

Charmie Huynh, P.E.

Case Manager/Structural Engineering Associate

City of Los Angeles

Department of Building and Safety - Case Management Unit

221 N. Figueroa St, Suite 180

Los Angeles, CA 90012

T. (213) 482-6875

F. (213) 482-6874

Charmie.Huynh@lacity.org

FW: Millennium Hollywood Development - revise WSA request letter

7 messages

From: Hwang, Jin
Sent: Monday, December 22, 2008 9:30 AM
To: 'wujor@cra.lacity.org'
Subject: Millennium Hollywood Development - revise WSA request letter

Ono,

Thank you for the Water Supply Assessment (WSA) request letter for the Millennium Hollywood Development Project. I have reviewed the letter and I would need some more information in order to be able to work on the WSA. Since some of the critical information are missing in the letter, I recommend sending a revised WSA request letter to DWP rather than providing the missing information in a separate letter or by e-mail. Please include the following information in the new revised letter:

1. Explain whether the project complies with the General Plan. You can provide a table similar to the one shown below. The purpose of comparing the General Plan to the proposed development is to see if the developer is proposing to build more than what is allowed. If the development will result in building more than what is allowed, that can translate into proposing more water demand than what is allowed. DWP is working on a fee structure for such "new unplanned water".

	Existing	Proposed Development
General Plan Land Use		
General Plan Land Use Max SF or FAR		
Zoning		
Zoning Max SF or FAR		

2. Please state what community plan this project is within.

3. Do the numbers in Tables 1 and 2 (Existing On-Site Water Consumption for West and East Sites) already include 18% and 28% of indoor water usage to calculate outdoor water usage? DWP has recently decided to stop using the 18 and 28 % method to calculate outdoor water usage. We're now using the actual square footage of landscaping to calculate outdoor water usage. Please revise Tables 1 and 2 (and also Table 3) to reflect this new method and include the square footage of landscaping for both existing and proposed.

4. Please provide the project location map and the address. The letter states that a vicinity map is attached, but there was no map attached to the letter.

Please call me if you have any questions. Thank you.

Jin Hwang

Civil Engineering Associate

Los Angeles Department of Water and Power

Water Resources Development Group

213-367-4845

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From: Hwang, Jin
Sent: Thursday, February 05, 2009 11:20 AM
To: 'wujor@cra.lacity.org'
Subject: FW: Millennium Hollywood Development - revise WSA request letter

Ono,

Please be reminded that I'm still waiting for the revised WSA request letter. The previously submitted WSA request letter is deemed incomplete, and I cannot start working on the WSA without the requested information. The date of the new submittal of the WSA request letter will be considered the official date the request letter was received by DWP. Thank you.

Jin Hwang

Civil Engineering Associate

Los Angeles Department of Water and Power

Water Resources Development Group

213-367-4845

[Quoted text hidden]
[Quoted text hidden]
[Quoted text hidden]

From: Ujor, W. Ono [mailto:oujor@cra.lacity.org]
Sent: Thursday, February 05, 2009 1:58 PM
To: Hwang, Jin
Subject: RE: Millennium Hollywood Development - revise WSA request letter

Hi Jin,

This is to acknowledge the receipt of your letter calling for revisions to the WSA request letter for the above referenced project. I was told by the consultant that the project is currently on hold because of the economic condition. Consequently, we hope to revise the WSA request letter whenever the developer is ready to proceed.

Thanks,

Ono

From: Hwang, Jin [mailto:Jin.Hwang@ladwp.com]
Sent: Thursday, February 05, 2009 11:20 AM
To: Ujor, W. Ono

[Quoted text hidden]

[Quoted text hidden]
[Quoted text hidden]

From: Hwang, Jin
Sent: Thursday, February 05, 2009 2:26 PM
To: 'Ujor, W. Ono'
Subject: RE: Millennium Hollywood Development - revise WSA request letter

Ok. Thank you for the update!

[Quoted text hidden]
[Quoted text hidden]

From: Ujor, W. Ono [mailto:oujor@cra.lacity.org]
Sent: Thursday, February 05, 2009 3:34 PM
To: Hwang, Jin
Subject: FW: Millennium Hollywood Development - revise WSA request letter

Hi Jin,

Here is the copy of the letter from the consultant for you to keep in your file.

Thanks,

Ono

From: Michael Brown [mailto:michael.brown@cajaeir.com]
Sent: Thursday, February 05, 2009 1:24 PM
To: Ujor, W. Ono
Subject: Re: Millennium Hollywood Development - revise WSA request letter

Hello Ono,

I am sorry that I have not returned your call, but I am in a jury this week.

I have been directed by the applicant to place my work on hold while they evaluate the current economic conditions. Please ask DWP to hold off on any additional analysis for the present time. I will let you know when I have been directed to proceed.

Michael Brown

Principal, Executive Director of Air Quality and Environmental Noise Programs

Christopher A. Joseph & Associates

Sent from my iPhone

On Feb 5, 2009, at 12:08 PM, "Ujor, W. Ono" <oujor@cra.lacity.org> wrote:

> Hi Michael,
>
> Here is a letter from Jim Hwang of DWP asking for the incorporation of additional information into the WSA request letter. Also, what is the status of the Draft Initial Study for the Millennium Hollywood Development?
>
> [Quoted text hidden]
>
> <Water Supply Assessment Request (Millennium Hollywood).doc>

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From: Hwang, Jin
Sent: Thursday, February 05, 2009 3:40 PM
To: 'Ujor, W. Ono'
Subject: RE: Millennium Hollywood Development - revise WSA request letter

[Quoted text hidden]
[Quoted text hidden]

From: Hwang, Jin
Sent: Tuesday, March 17, 2009 8:42 AM
To: 'Ujor, W. Ono'
Subject: RE: Millennium Hollywood Development - revise WSA request letter

Ono,

Please let me know if the applicant would like DWP to refund the WSA fee ($10,000), or keep it till a decision is made whether to proceed with the WSA. Thank you.

[Quoted text hidden]
[Quoted text hidden]

From: Jon Tanury
To: Lamb, Blake
Date: 4/12/2010 9:04:05 AM
Subject: Re: Millenium - go over recent stuff

Is this the "recent stuff" they've emailed us? The documents got corrupted in my email and I can't open them, so if you have them, please forward away.

From: Kevin Keller
To: Lamb, Blake; Tanury, Jon
Date: 3/25/2010 1:13:02 PM
Subject: Re: Fwd: APN 5546-004-006, 5546-004-020, 5546-004-021

I didn't realize this was millenium. Jon- if you can call this person and go over the FARs on the site and basic zones- that may help. He can do the rest. This may be related to millenium for financing purposes? If so, important- if not, normal importance only...
-----Original Message-----
From: Blake Lamb
To: Kevin Keller <Kevin.Keller@lacity.org>
To: Jon Tanury <Jon.Tanury@lacity.org>

Sent: 3/25/2010 1:07:05 PM
Subject: Re: Fwd: APN 5546-004-006, 5546-004-020, 5546-004-021

Yes they are some of the Millennium properties! Some financing, bank thing? Even though they are asking for discretionary actions this person must want to know what they can build by right. Which, as Kevin said, he can research himself with our help pointing him to the correct documents.

Blake

>>> Jon Tanury 3/25/2010 10:46 AM >>>
I'm a little lost, these are the Millenium properties, aren't they....?

>>> Kevin Keller 3/24/2010 6:34 PM >>>
Am forwarding your way. Jon, would this be something you could research BRIEFLY and then let him do his job researching all the entitlements? Thanks!

From: Kevin Keller
To: Yuan-McDaniel, Eva; Zatorski, Jan
CC: Bertoni, Vince; Zaitzevsky, Maya; Yeh, Livea
Date: 12/7/2009 5:01:16 PM
Subject: Re: fee recovery issue

Thanks Eva.

Jan, Eva's email sparked a lead- the DA was recently filed as part of an existing CPC case: CPC-2008-3440. Hopefully the new fee cost recovery number can be based on the case?

Many thanks,

Kevin

>>> Eva Yuan-McDaniel 12/4/09 8:53 AM >>>
Kevin,

We need a separate work order number for the M. project. I assume you do not yet have a case number. Let me check with Jan next week and get back to you.

You are correct; we definitely need to tighten up fee recovery for large projects. Much staff time is spent before we have a case, and sometimes that cost is not charged to the developer. We will include this in our discussion.

Thanks.

>>> Kevin Keller 12/3/2009 6:07 PM >>>
Hi Eva, Hi Vince-

There are a couple of issues on the horizon I wanted to flag re: fee recovery. For information only. I can assist on the Millenium issue.

Wilshire Grand Project
DOT would like to work in a fee recovery mode to expedite Wilshire Grand, but cannot. My understanding is that they only can recover costs through our supplemental fee agreement and through our expedited section. The project is not in expedited. Planning is full cost recovery using the EIR process.

I agree with Maya that it would be problematic to use expediting for only fee recovery on this project. She and I are in conversations on this. DOT is looking for help. It may be that DOT will need to solve this using their own resources.

Millenium Hollywood Project
This is a major Development Agreement project for Hollywood that community planning staff will begin spending time on. Currently the CRA is preparing the EIR, but as a development agreement project I believe we can still use full cost recovery.

Eva- Can we issue a E###### number for this type of situation for FMIS, or should we work to establish a stand alone new number? Please point me in the right direction and I will take care of the rest.

Next Steps
I'm eager to look for ways to help us better implement better fee recovery for community planning's work on these large projects- especially after the recent budget talks. I would be happy to work to streamline the establishment and transfer of EIR fee numbers generated at the counter at time of case filing to community planning staff- currently I think we miss many opportunities to charge our time on these larger cases.

-Kevin

From: Blake Lamb
To: Keller, Kevin
Date: 4/1/2010 8:37:45 AM
Subject: Re: April 13

Oh of course! I totally forgot about the conference. :(Wish I could go, boo.
Blake

>>> Kevin Keller 3/31/2010 6:09 PM >>>
thanks but no, I'll be at APA, returning Wednesday.

I also got a note from Alfred saying Phil Aarons is in town- I'll let him know that if they are interested in stopping by he can inquire with you. Thanks for all your work on this project!

-Kevin

>>> Blake Lamb 3/31/10 8:46 AM >>>
Hi kevin,
The Millenium architects are interested in coming to pay us a visit April 13. I notice you have APA all day on your calender - are you free at all that day?
Blake

From: Kevin Keller
To: Lamb, Blake
Date: 11/30/2009 4:53:58 PM
Subject: millenium city attorney meeting

Hi Blake-

I wanted to invite you to the development agreement meeting with the city attorneys office on millenium- it got moved to 3pm on Wednesday. I talked to Courtney and she seemed excited about the Country Club Park tour- so I leave it in your hands. Jon and Mariana will join (we will also be talking Wilshire Grand) so we can cover... but I wanted to see if you could make it.

-Kevin

From: Kevin Keller
To: Lamb, Blake
Date: 12/21/2009 3:34:41 PM
Subject: handle handel

I talked to Gary Handel today re: millenium architecture. I told him we'd contact him to set up a conf call the first week in January. In the meantime we will send him (email or mail) a copy of related design examples. I'm thinking LASED guidelines, and LASED conceptual sign program . (hard copy only , craig has a copy). Can you prepare a packet and mail to him while I'm out. You have his email and work address is online. Thanks - can explain more over email if you have questions.

From: Kevin Keller
To: Lamb, Blake; Tanury, Jon
Date: 12/7/2009 5:01:48 PM
Subject: Fwd: Re: fee recovery issue

I am working on getting us a fee cost recovery number for Millenium and the DA.

Attachments: Re: fee recovery issue

MILLENNIUM HOLLYWOOD PROJECT

DEVELOPMENT REGULATIONS: GUIDELINES AND STANDARDS

ORDINANCE NUMBER _____; EFFECTIVE DATE _____

MILLENNIUM HOLLYWOOD PROJECT

SCOPE OF DEVELOPMENT: DESIGN GUIDELINES AND STANDARDS

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1. PURPOSE AND OBJECTIVES

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria that serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

d. Permit design flexibility while establishing a set of controls that will guide the development for the Project Site.

e. Ensure compliance with the Development Objectives.

1.2 Development Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure that new development on the Project Site is consistent with these objectives.

1.2.2 The objectives for new development on the Project Site are to:

a. Preserve the Capitol Records Building and the Gogerty Building according to established preservation guidelines (the *Secretary of the Interior's Standards for Rehabilitation* and guidance provided by Office of Historic Resources).

b. Preserve public views from certain key vantage points to the Capitol Records Tower by creating grade level open space / civic plazas on the East Site adjacent to the Jazz Mural and Capitol Records Building and West Site across from the Capitol Records Building.

c. Preserve existing view corridors from certain key vantage points to the Hollywood Hills.

fig. 1.2.2.b-c: Capitol Records View Corridors

d. Create civic plazas that are activated by retail, landscaped, and enhance the Hollywood Walk of Fame by providing it as an urban node. Reinforce the urban and historical

importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

e. Encourage street life by the creation of a new pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

f. Create vibrant urban spaces that permit open and green spaces for both the on-site and off-site population.

fig 1.2.2.d: View North Along Vine Street

g. Create a 24 hr community by the creation of a Thriving Mixed-Use Development.

h. Eliminate the visual impact of current on-site parking.

i. Establish where feasible pedestrian linkages to existing public transportation routes in proximity to the Project Site, including the Metro Red Line Station at Hollywood Boulevard and Vine Street, and existing bus routes.

j. Establish standards to address architectural excellence.

k. Provide designs that address, respect and complement the existing context, including standards for ground-level open space, podium heights and massing setbacks that minimize impacts to the historic setting.

l. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

m. Create buildings that emphasize the vertical architecture and become visible icons.

n. Develop a visual gateway to Hollywood from the Hollywood Freeway.

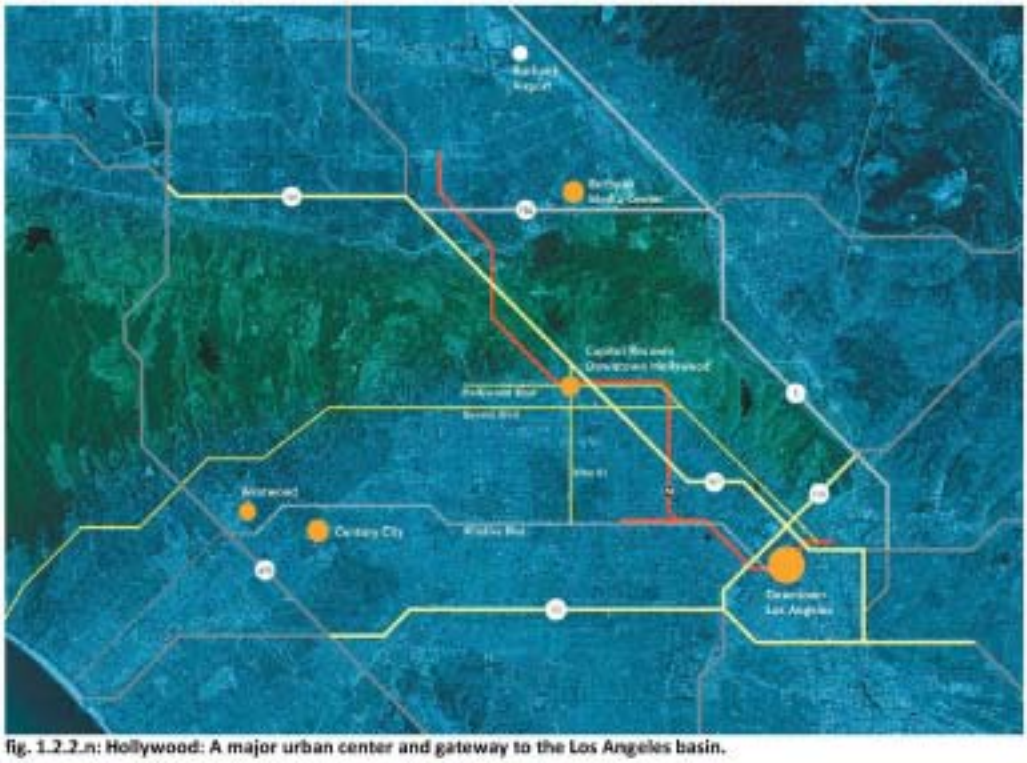


fig. 1.2.2.n: Hollywood: A major urban center and gateway to the Los Angeles basin.

1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose strict requirements for new development. For example, the Regulations include specific setback requirements along Vine Street. There are also mandatory requirements or standards for minimum open space on the ground floor as well as maximum building heights. By comparison, the guidelines are measures that may include a range of choices and require a degree of interpretation by the architect and design team to achieve compliance with the Regulations. The purpose of these guidelines is to create a principal design theme or objective without comprising high quality design. The purpose is to provide a range of flexibility to permit the selection of the most appropriate design feature based on the final development scenario. For instance, façade treatments for new development may take different form depending on the final design plans. The Regulations will guide the ultimate façade treatment by providing a limited range of choices in the use of material and color for the façades.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 The Development Regulations are approved by the City of Los Angeles City Council and are incorporated in the Development Agreement, authorized pursuant to California Government Code 65864, et seq., entered into by the City of Los Angeles and _____ ("Millennium Development Agreement") on _____.

1.4.2 The following sections in the Regulations differ from corresponding provisions (as written at the time of approval) in the LAMC: 2.2.1, 2.2.3, 5.5.3.a, 7.3.4.b, 9.1.6.a and 10.2.

1.4.3 Wherever the Regulations contain provisions which establish regulations that are different from or more or less restrictive than the zoning or land use regulations in the Los Angeles Municipal Code ("LAMC") that apply to the Project Site, the Regulations shall prevail pursuant to the Millennium Development Agreement approved by the City Council.

2. BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street.

The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Avenue is the East Site.

The East Site and the West Site make up the Project Site.

The Project Site currently contains a mix of commercial and on-grade open parking. The topography has a natural incline of approximately 21 feet (NE to SW) from Vine Street to Argyle Avenue and 21 feet (NW to SE) from Ivar Avenue to Vine Street. The existing sidewalk elevations will not be altered as part the Project.

fig. 2.1. Site Plan

2.2 Site Zoning and Permitted Floor Area

2.2.1 The Project Site is zoned Commercial (C2). The City General Plan land use designation is Regional Center commercial.

2.2.2 The Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.

2.2.3 Floor Area Ratio: 6:1

2.2.4 Height District: No. 2

3. HISTORIC RESOURCES AND SETTING

3.1 Overview

The Project Site is located in a historically rich area of Hollywood that contains a number of recognized historic resources. This Project is a preservation project in that its ambition is to respect, respond to, and preserve the Capitol Records Building and to continue the urban character of Vine Street on the Project Site. The Project is designed to be observant of historic settings and buildings. Two buildings located on the Project Site, the Capitol Records Building and the Gogerty Building, are historically significant. Other historic buildings, located on adjacent parcels, are the Pantages Theater, the Equitable Building, the Hollywood Palace, and the Art Deco commercial building at 6316-6324 Yucca Street. Several of these historic resources are located within the Hollywood Boulevard Commercial and Entertainment District, a National Register listed historic district located just south of the Project Site.

Composed of commercial properties from the first half of the 20th Century, contributing properties to the Hollywood Boulevard Commercial and Entertainment District include a wide variety of property types including single-story storefronts, two-story commercial blocks, department stores, theaters, high-rise office buildings and hotels.

The Capitol Records Building is a unique building whose cylindrical form has always been visible from portions of Hollywood, Vine Street from the south, and the freeway from the north. The Capitol Records Building and the iconic buildings in the Hollywood Boulevard Commercial and Entertainment District (the Hollywood Palace, Pantages Theater, Equitable Building) will maintain their prominence after implementation of the Project. Portions of the Hollywood Walk of Fame (L.A. Historic Cultural Monument #194) are located along Vine Street between Yucca Street and Sunset Boulevard and will be protected.
The protection of Hollywood's historic resources and unique character is an important objective of the Project. The guidelines and standards contained in this document were created in part to ensure the protection of historic resources within the Project Site and minimize potential adverse affects to historic resources from new development. Key Project objectives regarding historic resources include:

1) Preservation, maintenance, and rehabilitation of the Capitol Records Building and the Gogerty Building in accordance with the Secretary of the Interior's Standards. See sections 1.2.2a and 1.2.2b of this document.

2) Protection and preservation of the portions of the Hollywood Walk of Fame (LA Historic Cultural Monument #194) will need to be temporarily removed during construction and replaced after construction is completed. A preservation plan, outlined in the Hollywood Walk of Fame Terrazzo Pavement and Repair Guidelines (March, 2011) will be prepared for this aspect of the Project.

3) Incorporation of ground-floor open space and building setback requirements to moderate the overall massing of new development in a manner that preserves important views to and from the Capitol Records Building, the Hollywood Boulevard Commercial and Entertainment District, and important view corridors to the Hollywood Hills. See sections 1.2.2 c, 6.1, 6.9, 7.1, 7.5, 8.1 and 8.2 of this document.

4) Incorporation of ground-floor open space and building setback requirements to reduce massing at the street level and limit the visual crowding of adjacent historic resources. See sections 1.2.2c, 6.1, 7.1, 7.5,

5) 8.1 and 8.2 of this document.

6) Requirement that design of new buildings be in a manner that is differentiated from but compatible with adjacent historic resources. See sections 6.6, 6.8, 7.1.5, and 7.4 of this document.

One means of creating compatible new buildings in an urbanized setting is to incorporate qualities of vertical and horizontal visual complexity in world class design. The general characteristics, proportions, and details of older buildings may serve as a reference for the Project. The Project's intent is to allow old and new to mix, recognizing that Hollywood sustains its image through both the rehabilitation of existing historic structures and the design of creative and contemporary architecture.

4. DENSITY

4.1 Floor Area Ratio Averaging and Density Transfer

The Owner may transfer density and buildable floor area from one parcel within the Project Site to another parcel within the Project Site, as long as the minimum and maximum building heights in the Regulations are maintained and the entire Project does not exceed the cumulative, allowable density and floor area of the zoning for the sum of the individual parcels.

To allow for the spatial distribution of the development on the Project Site and ensure relationship and sensitivity with the uses surrounding the Project Site, parking, open space and related development requirements for any component of the Project may be developed in any location within the Project Site.

4.2 Maximum OEGSF Density Per Area

A land use equivalency program ("Equivalency Program") to provide flexibility for a thoughtful range of modifications to the land use and square footages within the West Site and East Site and across the Sites will be developed in connection with the environmental review for the Project and is authorized by the Regulations. The Equivalency Program would permit a transfer of floor area among parcels in the West Site and East Site whereby square footage increases in one land use category can be exchanged for corresponding decreases in other permitted land use categories as long as the environmental considerations of land uses in the ultimate development scenario was analyzed in the Environmental Impact Report for the Project. Rate of conversation between land uses will be based on a maximum office-equivalent gross square feet ("OEGSF") to maintain vehicular trip totals equivalent to and not exceeding those studied in the Environmental Impact Report for the Project. The total density permitted in the West Site and East Site is further limited by the development zones A, B, C and D (see Fig. 5.1).

4.3 Use Coordination / Use Compatibility

[To be completed.]

5. HEIGHT

5.1 Building Height Standards

The Regulations establish heights zones (A, B, C and D) to limit maximum building heights and control bulk in response to the Development Objectives including context with the built environment and to reinforce view corridors to the Capital Records Building.

Fig. 5.1 Height Zones

6. BUILDING AND STREET EXPERIENCE

6.1 Tower Massing Standards

6.1.1 The Tower Massing Standards apply to the portion of a building located 150 feet above curb level – see Table 6.1.1.

Tower Height (feet)	Maximum Tower Lot Coverage (%)	Minimum Floor Area Below 220 Feet (%)	Maximum Tower Floor Plate (sq. ft.)	Minimum Tower Setback (feet)	Minimum Public Open Space (%)	Figures
151 – 585	11.5	50	13,325 East Site 9,042 West Site	10 15[1]	12	6.1.2.d.1 6.1.2.d.2
151 – 550	15	50	17,380 East Site 11,794 West Site	10 15[1]	10	6.1.2.c.1 6.1.2.c.2
151 – 400	28	50	22,745 East Site 22,016 West Site	10 15[1]	8	6.1.2.b.1 6.1.2.b.2
150 – 220	48	n/a	55,616 East Site 37,742 West Site	10 15[1]	5	6.1.2.a.1 6.1.2.a.2

Table 6.1.1

Note 1: 15' tower setback required for any tower fronting Vine Street on West parcel. See Figure 6.3.2.

6.1.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Figs. 6.1.2.a.1 – 2.)

6.1.3 At least 50% of total floor area must be located below 220 feet.

6.1.4 Tower wall articulation:

a. Minimum 10% of tower aggregate area shall be articulated.

6.1.5 Types of permitted articulations for tower walls:

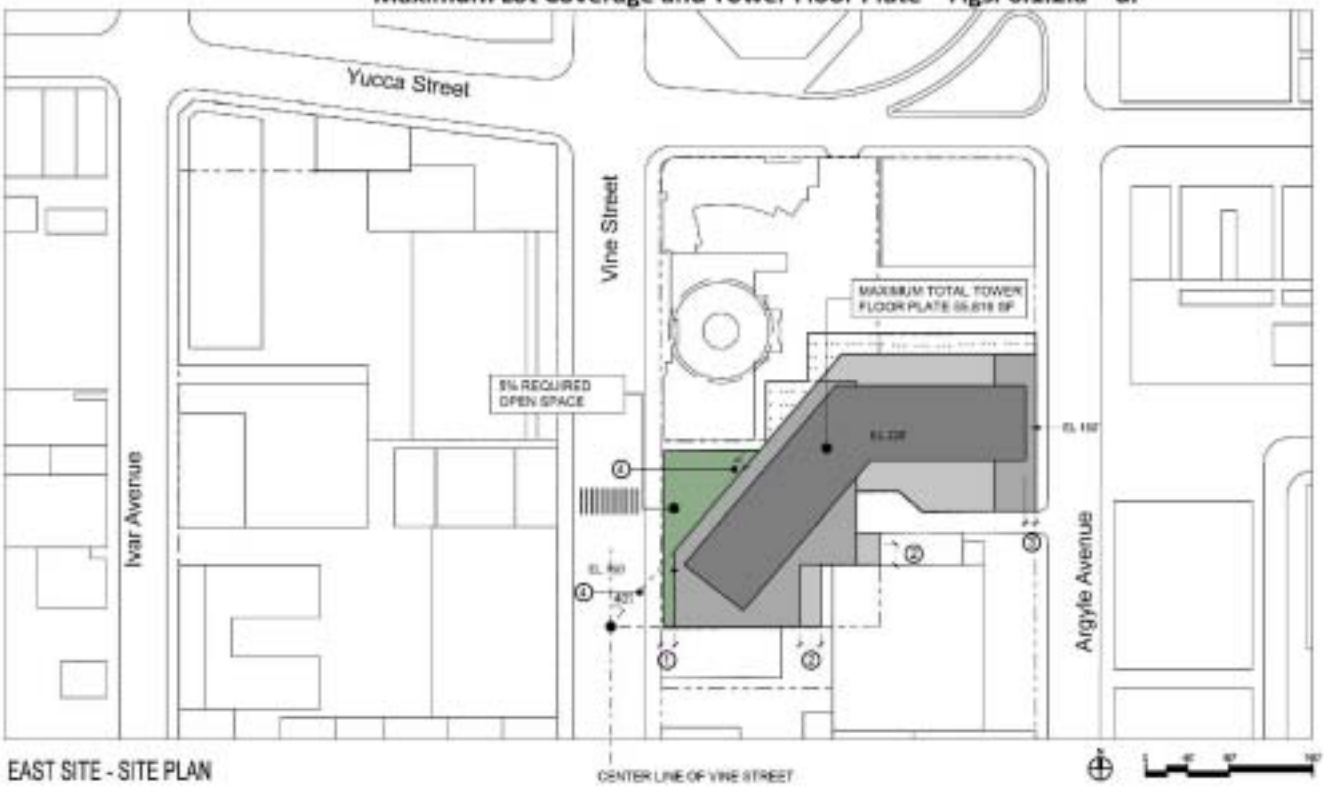
a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

The following developments are for illustrative purposes only.
Maximum Lot Coverage and Tower Floor Plate – Figs. 6.1.2.a – d.



EAST SITE - SITE PLAN

① MINIMUM 10' SETBACK ALONG VINE STREET
② MINIMUM 20' SETBACK ABOVE 150'
③ MINIMUM 10' SETBACK ABOVE 150'
④ 10' EASEMENT FROM CAPITOL RECORDS TOWER

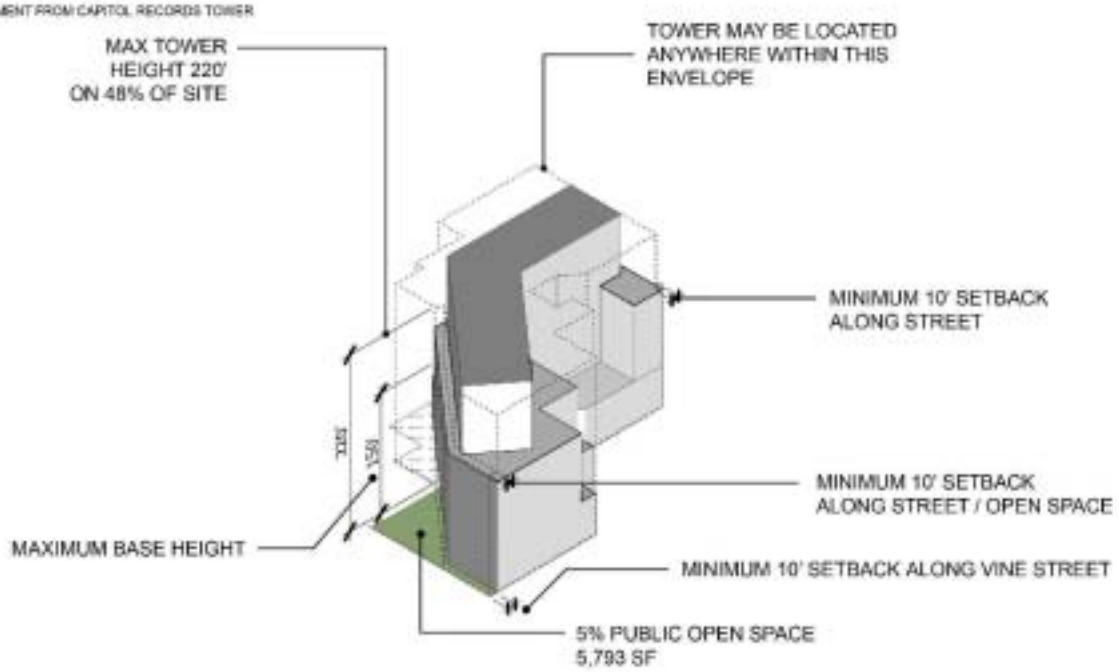
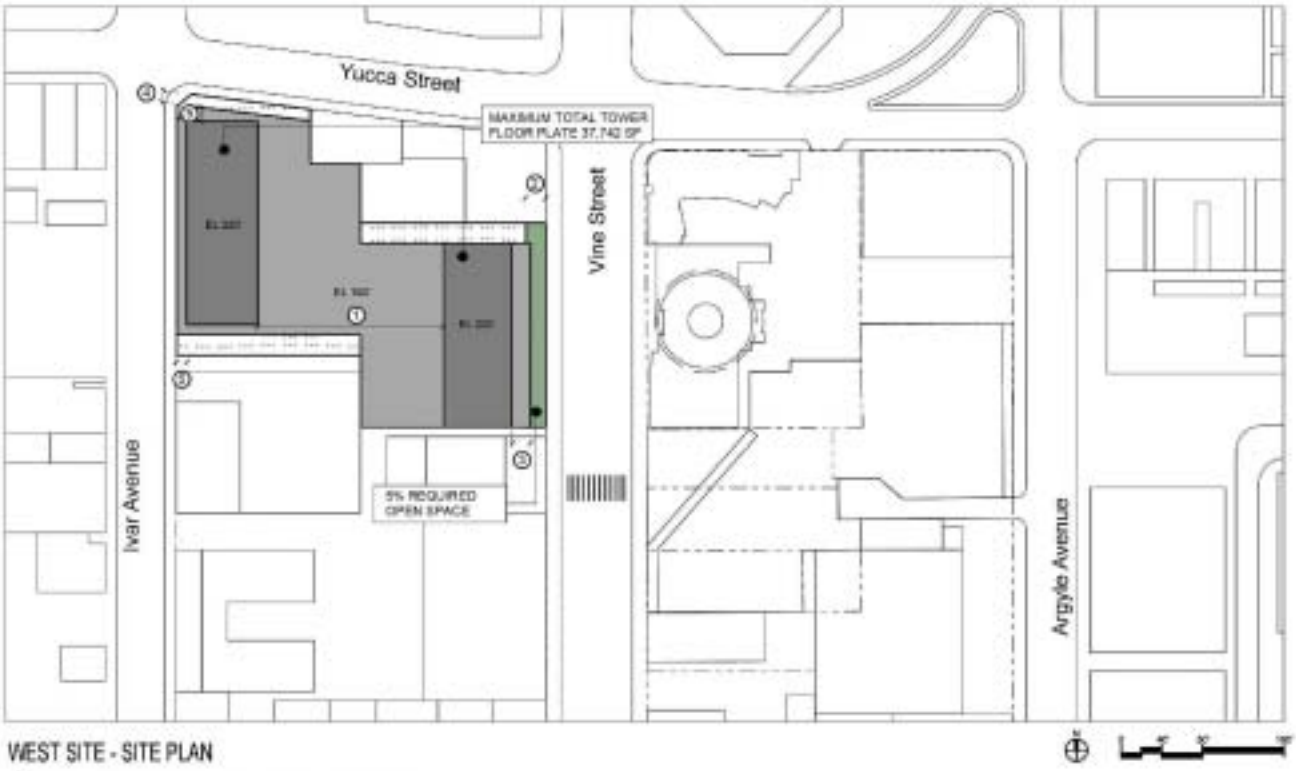


fig. 6.1.2.a.1: East Site – 220 Feet Maximum Tower Height



WEST SITE - SITE PLAN

① MINIMUM 60' SEPARATION BETWEEN "TOWERS" ON SAME SITE
② MINIMUM 15' SETBACK ALONG VINE STREET
③ MINIMUM 15' SETBACK ABOVE 40'
④ MINIMUM 10' SETBACK ALONG YUCCA STREET
⑤ MINIMUM 10' SETBACK ABOVE 150'

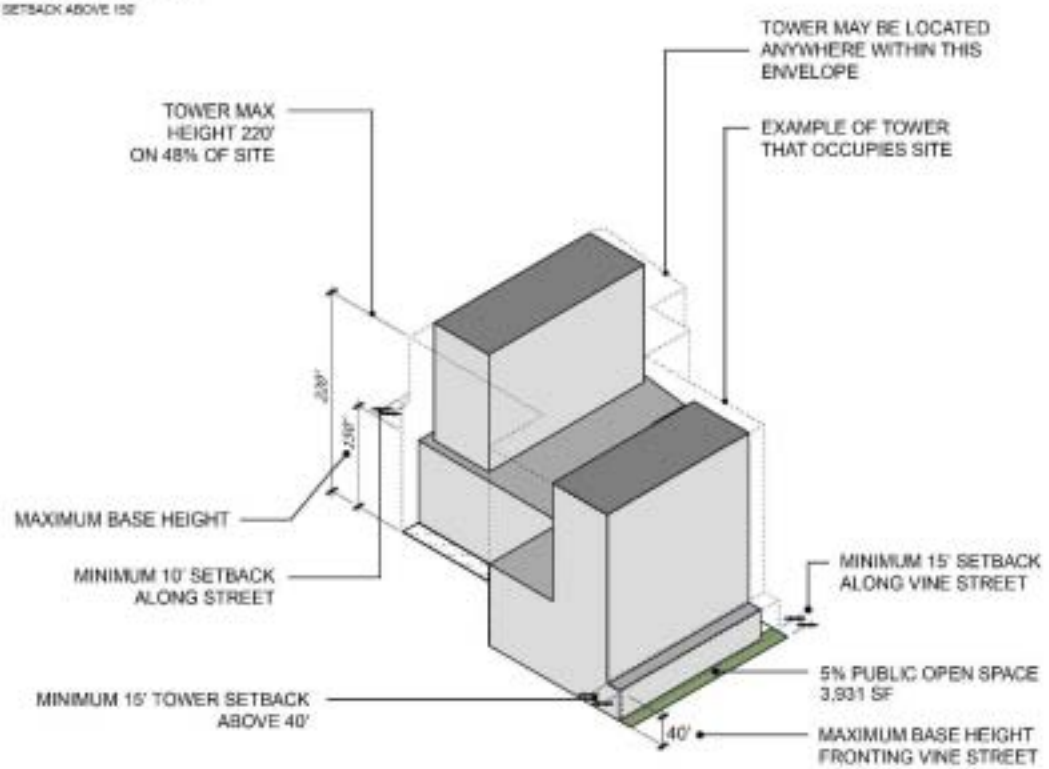
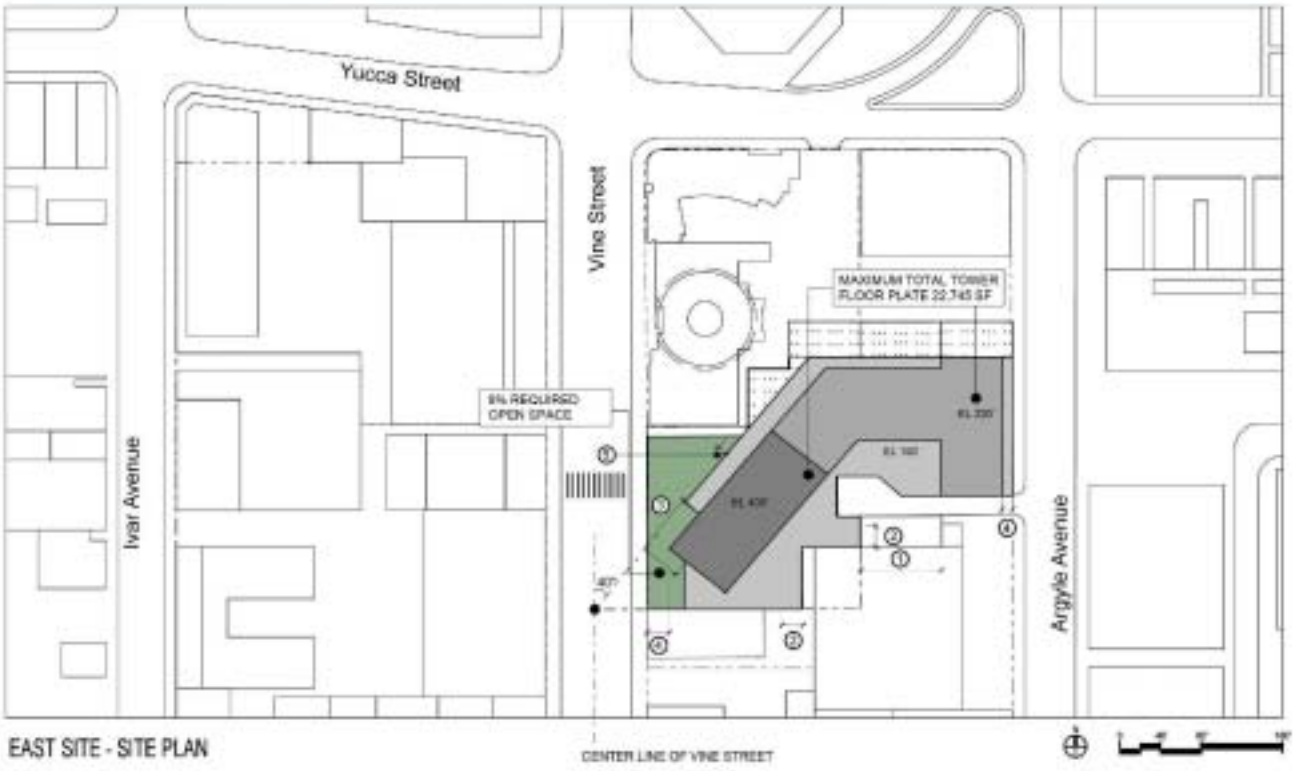


fig. 6.1.2.a.2: West Site - 220 Feet Maximum Tower Height.



EAST SITE - SITE PLAN

① MINIMUM 60' SEPARATION BETWEEN "TOWERS" ON SAME SITE
② MINIMUM 20' SETBACK ABOVE 155'
③ MAXIMUM 40% OF STREETWALL CAN EXCEED MAXIMUM STREETWALL HEIGHT
④ MINIMUM 10' SETBACK ABOVE 155'
⑤ 10' EASEMENT FROM CAPITOL RECORDS TOWER

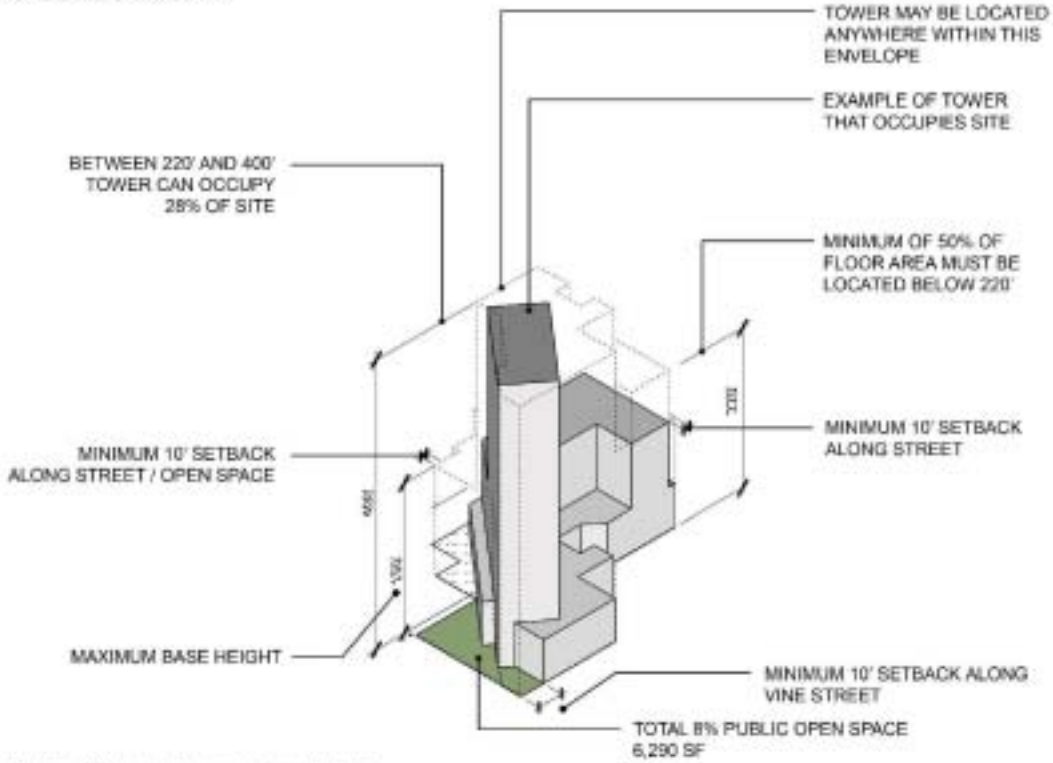
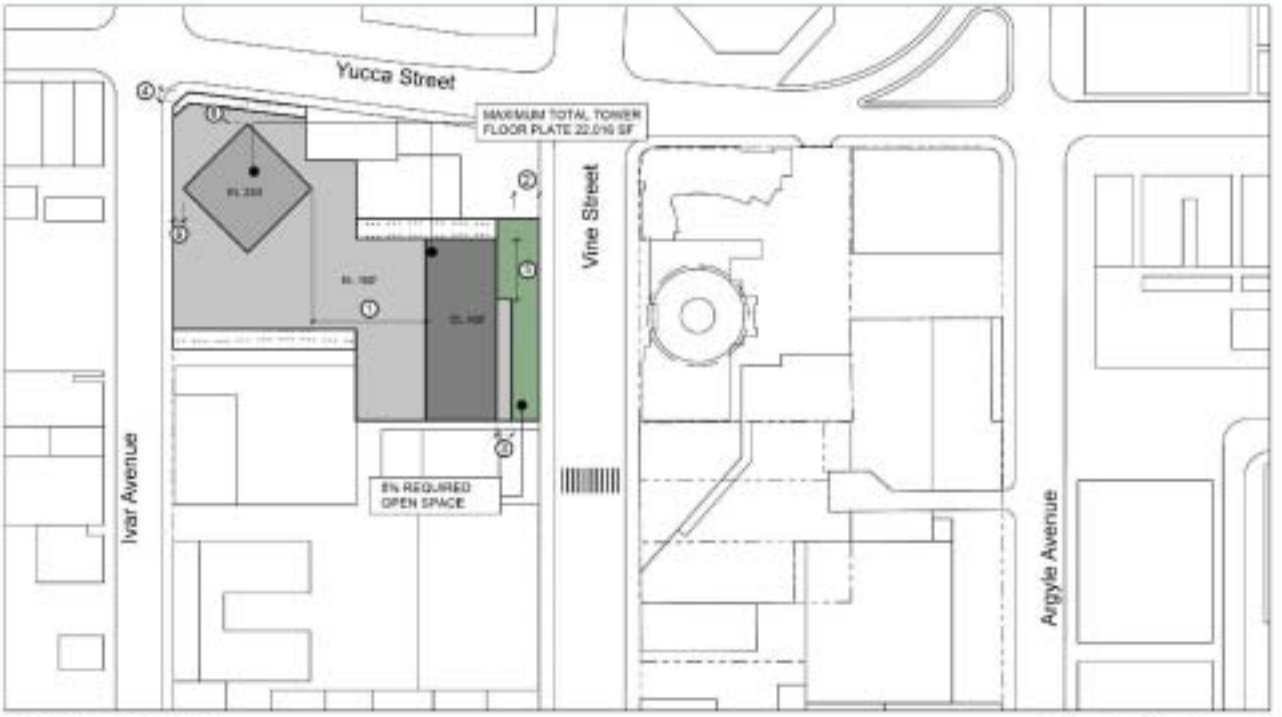


fig. 6.1.2.b.1: East Site – 400 Feet Maximum Tower Height



WEST SITE - SITE PLAN

① MINIMUM 80' SEPARATION BETWEEN "TOWERS" ON SAME SITE
② MINIMUM 15' SETBACK ALONG VINE STREET
③ MINIMUM 15' SETBACK ABOVE 40'
④ MINIMUM 10' SETBACK ALONG YUCCA STREET
⑤ MAXIMUM 40% OF STREET WALL CAN EXCEED MAXIMUM STREET WALL HEIGHT
⑥ MINIMUM 15' SET BACK ABOVE 150'

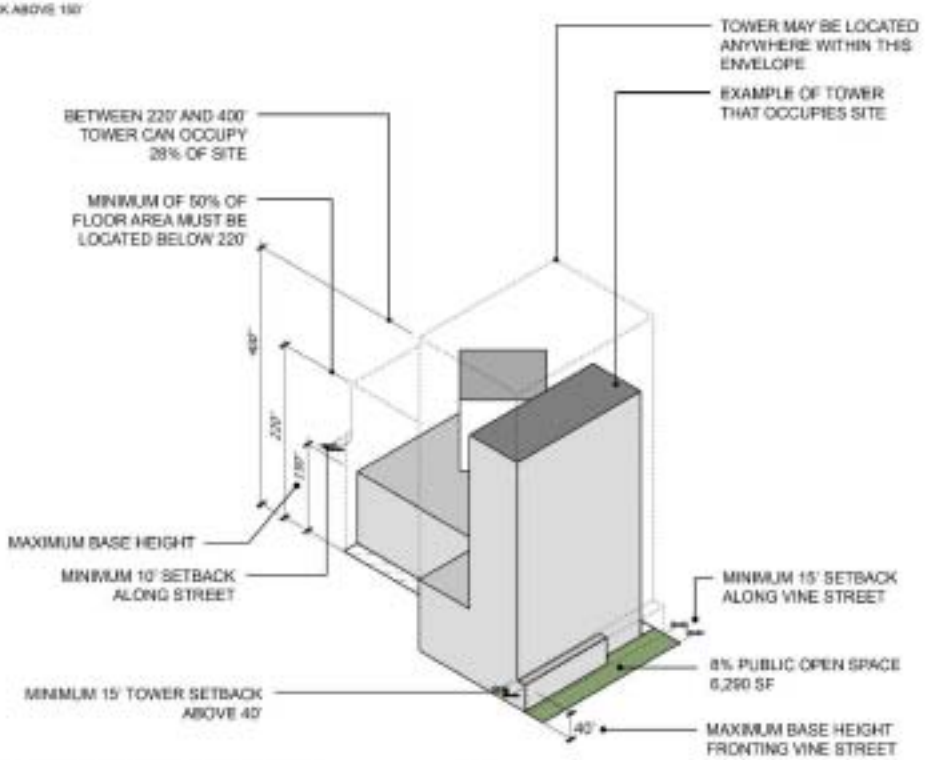


fig. 6.1.2.b.2: West Site – 400 Feet Maximum Tower Height

EAST SITE - SITE PLAN

① MINIMUM 80' SEPARATION BETWEEN "TOWERS" ON BASE SITE
② MINIMUM 20' SETBACK ABOVE 150'
③ MAXIMUM 40% OF STREETWALL CAN EXCEED MAXIMUM STREETWALL HEIGHT
④ MINIMUM 10' SETBACK ABOVE 150'
⑤ 10' EASEMENT FROM CAPITOL RECORDS TOWER

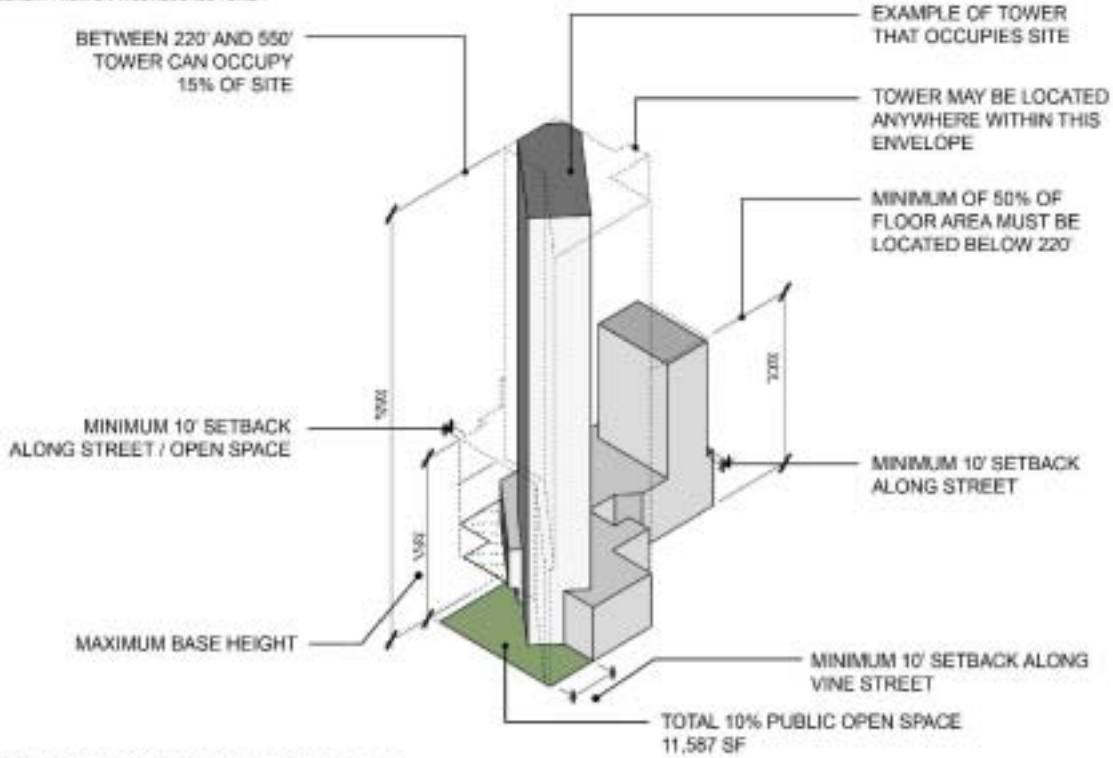
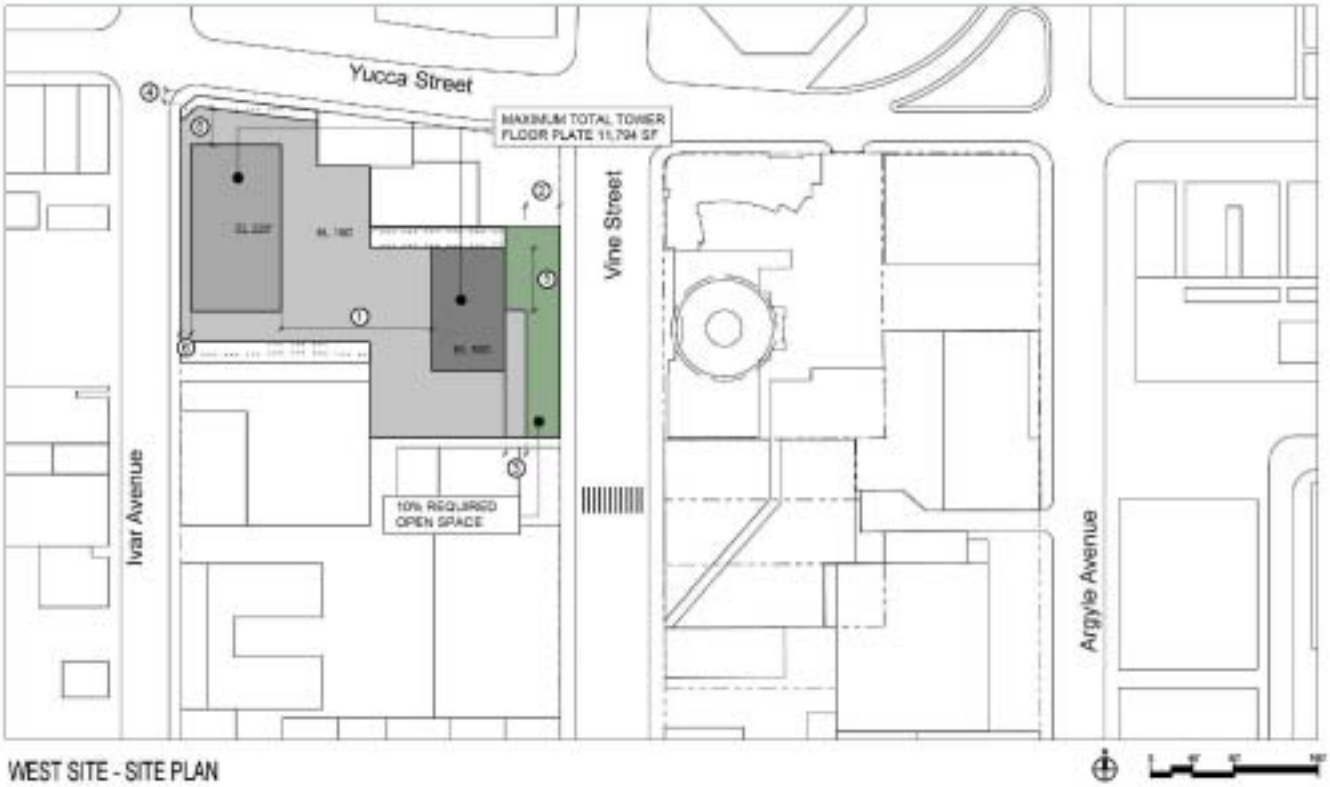


fig. 6.1.2.c.1: East Site – 550 Feet Maximum Tower Height



WEST SITE - SITE PLAN

① MINIMUM 60' SEPARATION BETWEEN "TOWERS" ON SAME SITE
② MINIMUM 15' SETBACK ALONG VINE STREET
③ MINIMUM 15' SETBACK ABOVE 40'
④ MINIMUM 10' SETBACK ALONG YUCCA STREET
⑤ MAXIMUM 40% OF STREET WALL CAN EXCEED MAXIMUM STREET WALL HEIGHT
⑥ MINIMUM 10' SETBACK ABOVE 150'

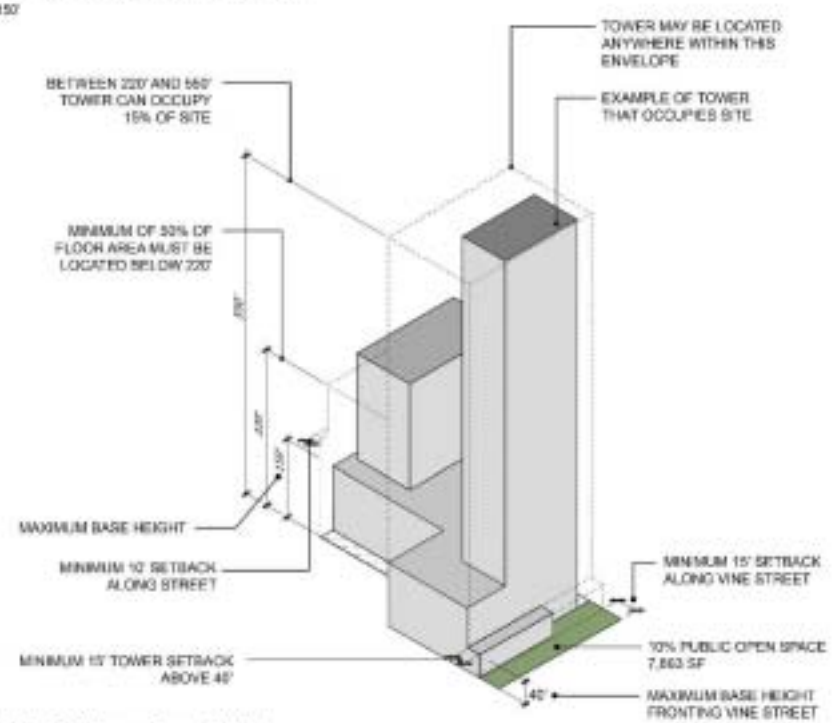


fig. 6.1.2.c.2: West Site – 550 Feet Maximum Tower Height

EAST SITE - SITE PLAN

① MINIMUM 90' SEPARATION BETWEEN "TOWERS" ON SAME SITE
② MINIMUM 25' SETBACK ABOVE 150'
③ MAXIMUM 40% OF STREETWALL CAN EXCEED MAXIMUM STREETWALL HEIGHT
④ MINIMUM 10' SETBACK ABOVE 150'
⑤ 10' EASEMENT FROM CAPITOL RECORDS TOWER

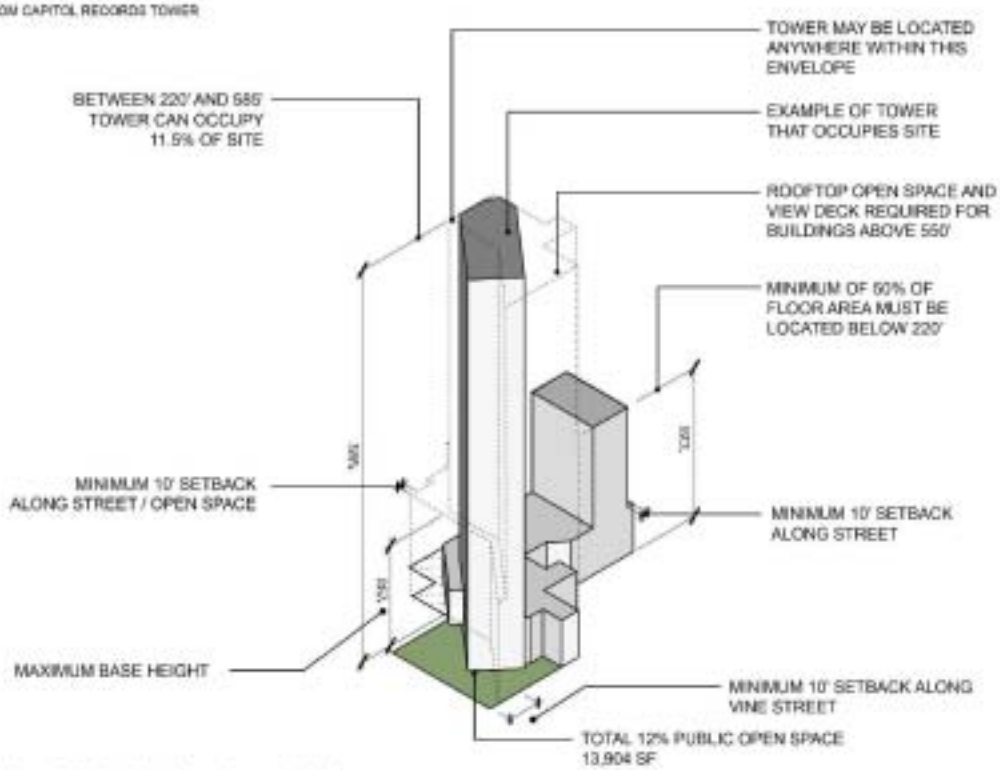
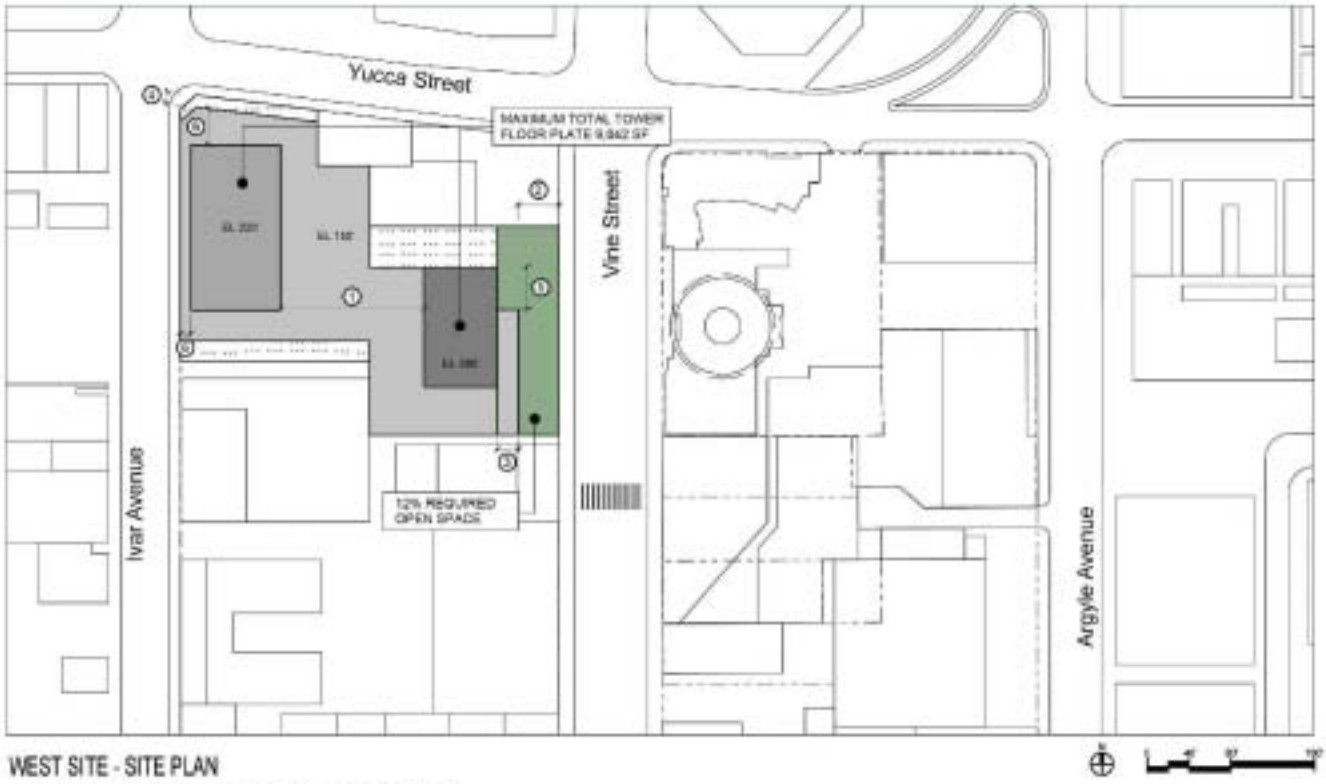


fig. 6.1.2.d.1: East Site – 585 Feet Maximum Tower Height



WEST SITE - SITE PLAN

① MINIMUM 80' SEPARATION BETWEEN "TOWERS" ON SAME SITE
② MINIMUM 15' SETBACK ALONG VINE STREET
③ MINIMUM 15' SETBACK ABOVE 40'
④ MINIMUM 10' SETBACK ALONG YUCCA STREET
⑤ MAXIMUM 40% OF STREET WALL CAN EXCEED MAXIMUM STREET WALL HEIGHT
⑥ MINIMUM 10' SETBACK ABOVE 150'

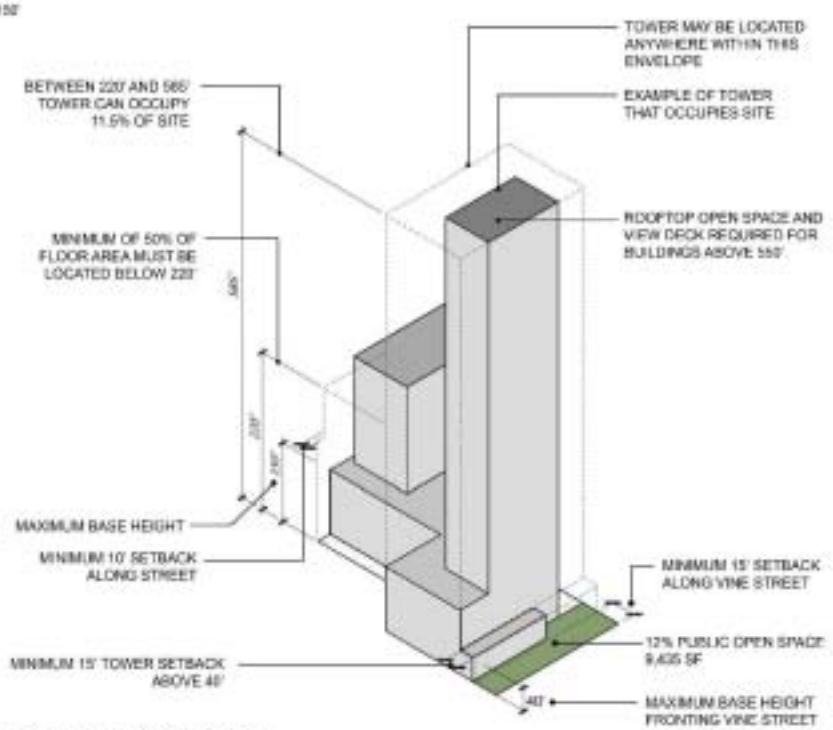


fig. 6.1.2.d.2: West Site – 585 Feet Maximum Tower Height

6.2 Street Walls

6.2.1 A street wall is a wall or portion of a wall of a building facing a street or a grade level open space. Street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation. The street wall shall have proportions and architectural building details which emphasize and reflect the presence and importance of the pedestrian environment; massing offsets, fenestration, varied textures, openings, recesses, and design accents are strongly encouraged to ensure there are no un-articulated walls and monolithic roof forms, and architectural elements such as balconies, verandas, and porches that add architectural character are encouraged.

6.3 Street Wall Standards

6.3.1 Location of a required street wall:

a. Parcels with a grade level open space: the required street wall shall be located a minimum 10 feet from the property line along Vine Street on the East Site and 15 feet along Vine Street on the West Site.

b. A grade level open space is required for any building fronting Yucca Street with a minimum 10 feet setback from the property line.

c. Parcels or portions of parcels without a grade level open space: the required street wall shall be located on the property line.

6.3.2 Height of required street wall:

a. Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b) and (c) below.

b. Street walls fronting Vine Street on the East Site shall be built to a maximum height of 40 feet above curb level except as noted in item (c) below.

c. 40% of the aggregate width of the required street wall frontage on each street can exceed the maximum street wall height up to the maximum tower height.

fig 6.3.2: Street Wall

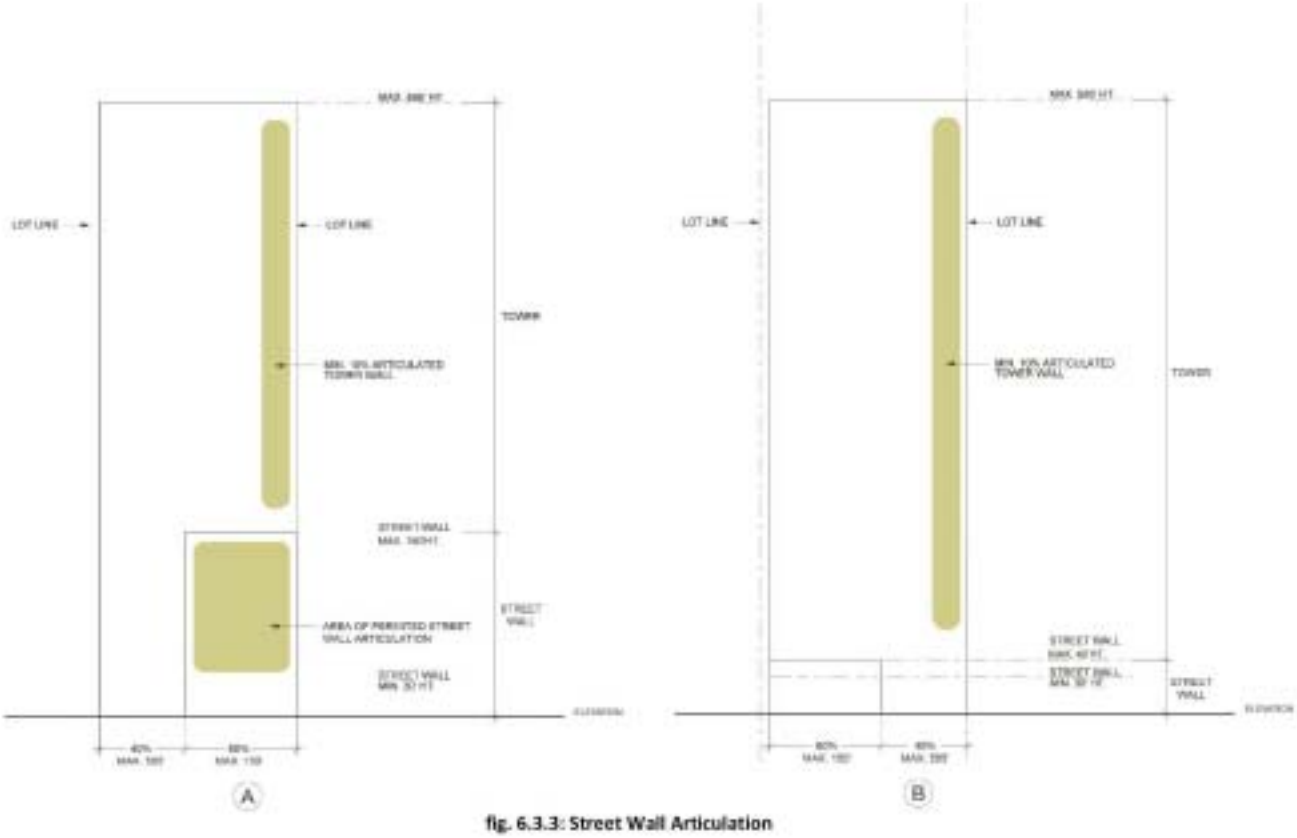


fig. 6.3.3: Street Wall Articulation

6.3.3 Types of permitted articulation of a required street wall:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

6.3.4 Other permitted projections: elements which project beyond the property line from a required street wall shall comply with the Building Code.

a. Architectural facade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required street wall over a grade level open space.

b. Steps and ramps may project from a required street wall over a grade level open space.

c. Commercial marquees, canopies and awnings.

d. Retail storefronts: may project from a required street wall over a grade level open space by a maximum depth of 5'-0'. The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

6.4 Street Wall Guidelines

6.4.1 Pedestrian pass-through areas, public plazas, marquees, canopies, awnings and retail storefronts are permitted within the street wall area.

6.4.2 Pedestrian steps and ramps, entry forecourts, hotel drop-offs and loading entries and exits and vehicular access driveways are also permitted within the street wall area on the Project Site.

6.5 Yard Standards

6.5.1 Yard is an open space other than a court that is unoccupied and unobstructed from the ground upward.

6.5.2 Commercial Use: no front, side or rear yard setbacks are required.

6.5.3 Residential Use:

a. Front Yard: none.

b. Side Yard: Minimum 5 feet; for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.

c. Rear Yard: Minimum 15 feet; for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

6.6 Building Materials and Color Guidelines

6.6.1 The goal of the building materials and colors is to reinforce the character of the Hollywood area and provide a design that is compatible yet avoids any appearance that the building is being historicized. These guidelines will address the façade treatment for both residential and commercial portions of buildings.

a. Buildings shall feature long-lived and sustainable materials. The material palette shall provide variety, reinforce massing and changes in the horizontal or vertical plane.

b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

c. Podium levels up to 150 feet will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents.

d. The architecture of the building shall clearly delineate an architectural style, and shall not appear as a simplified version thereof, with appropriate fenestration patterns, architectural features, proportions and materials.

e. The building's skin, especially for towers, shall be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.

f. In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style. There will be clear contrast between the building's surface material and the building's glazed areas.

g. In general, the overall massing, roof forms, materials, and architectural style of new structures shall provide a variety of forms, depth and texture, and encourage a cohesive character. Building massing shall include a variation in wall planes and height as well as roof forms to promote architectural excellence, a pedestrian friendly environment and take into account the context.

h. To provide visual variety and depth, the building skin shall be layered and designed with a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin shall reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

i. Rooftop mechanical equipment shall be screened with materials and the design shall be consistent with the building's architecture.

j. Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

6.7 Grade Level Standards

6.7.1 The purpose of the grade level standards is to promote pedestrian-scaled architecture by regulating street wall massing, articulation and detail, street level entrances and storefront windows and doors, as well as the use of quality materials and decorative details. Architectural features that reinforce the retail character of the ground floor street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and shall be integral to the architecture of the building.

6.7.2 Ground floor height:

a. Minimum 12'-0" height floor to ceiling.

6.7.3 Building entrances:

a. The primary entrance to a street level tenant space that has frontage along a public street shall be provided from that street. The primary entrance to a tenant space that does not have its frontage along a public street shall be provided from a courtyard, *grade level open space*, or *publicly accessible passageway*. Entries less than 18 inches from the property line shall not be higher than 12 inches above the elevation of the sidewalk; entries greater than 18 inches from the property line shall be within 30 inches of the adjacent grade level along street frontages. Where possible entries shall be marked using architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

b. All retail spaces shall be accessed primarily from a ground floor, single-tenant entry along a street, plaza or passageway. Where reasonably practicable given architecture and tenant requirements, access to different tenant spaces shall occur at a maximum interval of 60 feet.

c. Main building entrances shall read differently from retail storefronts, restaurants and commercial entrances.

d. In addition to the building's required primary entrance(s), there may be ancillary entrances to the building from parking garages.

6.7.4 Ground Floor Glazing

a. Use of clear, colorless and transparent glazing is required within the first 30 feet above curb level.

b. Use of reflective glass is prohibited.

c. Along street frontages with a required build-to line less than or equal to 18 inches from the property line, glazing shall constitute a minimum of 30% of the area of a building face and shall not exceed 80% of the area of a building face.

6.7.5 Arcades

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0-foot candles.

6.7.6 Service and Refuse Requirements

Hotel and Commercial / Office / Retail that abuts an alley

a. Every required loading space shall be located and arranged such that delivery vehicles may be driven upon or into said space from an alley. Such loading space shall have a minimum height of 14 feet and be accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

b. Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.

c. Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet; a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet; and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

Condominiums (Residential)

d. None

Rental (Residential)

e. None

6.7.7 Service and Refuse Guidelines

a. Storage areas shall be provided within the building of a size sufficient for the development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible from a curb cut.

b. Service, utility, and mechanical functions, including retail loading, shall be located in alleys whenever present. When alleys are not present, service functions shall be placed within buildings.

c. Service, utility, and mechanical equipment that is visible from the street shall be screened from view with landscaping or enclosures. Back flow and fire standpipes, along with utility box transformers, shall be screened.

d. All screening devices shall be compatible with the architecture, materials and colors of adjacent buildings.

e. Trash and storage enclosures shall be architecturally compatible with the project design and landscaping shall be provided adjacent to the enclosure(s) to screen them and deter graffiti.

f. Trash enclosures and retail loading areas shall be sited to minimize nuisance to adjacent properties.

g. The location of trash enclosures shall be easily accessible for trash collection and should not impede general site circulation patterns during loading operations.

h. Mechanical equipment shall vent to an alley wherever possible.

i. Roof-vent penetrations and mechanical equipment shall be located at least 10 feet from any exterior Building Face.

j. Gutters and downspouts shall be made of galvanized steel, copper (not copper coated), or aluminum.

6.7.8 Retail Storefronts

a. Storefronts shall comprise a minimum of 70% of the building's street level façade and be recessed where necessary.

b. Storefront glazing shall comprise a minimum of 60% of the storefront area along Vine Street and 40% glazing along all other streets.

c. All retail space shall have a minimum 12 feet finished ceiling clearance.

d. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet. Storefront sills shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

e. Storefront openings shall be no shorter than 12 feet above the adjoining grade for 90% of the required storefront frontage.

f. Security grilles will be located behind glass and be at minimum 70% open.

g. At-grade storefront glazing at, or adjacent to, and/or facing any public right-of-way shall incorporate transparent, clear, colorless glazing with no reflectivity.

h. Awnings shall not obscure storefront signage. Vinyl awnings are not permitted.

6.8 Podium Standards

6.8.1 The purpose of the Podium Standards is to provide a modern interpretation of the historical context of Hollywood by establishing different treatment of the building's base, middle and top through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

6.9 Podium Guidelines

6.9.1 Podiums shall have fenestration that establishes a clear pattern on the façade (with special attention paid to facades that are visible from a public street) and that provides depth and additional articulation.

6.9.2 An identifiable break between the building's ground floors and upper floors shall be provided. This break may include a change in material, change in fenestration pattern or similar means.

6.9.3 Podium level windows shall be vertically oriented.

6.9.4 Podium levels shall be predominantly light in color.

6.9.5 An expression band shall be provided at the highest story within the podium.

6.9.6 While blank street wall façades shall be avoided, an exception may be made for integration of public art or an articulated façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade shall be a maximum of four floors high, and shall have variation in its surface plane (using cutouts, insets or pop-outs). It shall employ different scales of elements as viewed when seeing the entire building massing.

6.9.7 Louvers and wall openings shall be designed to integrate with building architecture.

6.10 Street and Sidewalk Standards

6.10.1 The Site is comprised of a variety of public elements that include open spaces, streets and sidewalks. The Hollywood Walk of Fame is an integral element that fronts open spaces on both East and West Sites. Its adjacency to the public plazas requires a compatibility and cohesiveness.

6.10.2 The combination of landscaped plazas, publicly accessible passageways and landscaped streets and sidewalks creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

6.11 Screening Standards

6.11.1 Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

6.11.2 Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

7. TOWERS

7.1 Purpose

7.1.1 Towers shall have their massing designed to reduce overall bulk and to appear slender.

7.1.2 Towers shall be designed to achieve a simple faceted geometry and exhibit big, simple moves. They shall not appear overwrought or to have over-manipulated elements.

7.1.3 Towers that emulate a more streamlined modern style shall provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.

7.1.4 If a project has more than one tower, the towers shall be complementary to each other and employ the same architectural design approach.

7.1.5 Generally, buildings over 150 feet tall (the historic datum for Hollywood) shall not be historicized. They are contemporary forms in the skyline and shall appear as such.

7.2 Projections

7.2.1 The following building elements and operations equipment can project beyond the maximum permitted building height:

a. Roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building;

b. Skylights, towers, steeples, flagpoles, water tanks, silos;

c. Wireless masts; and

d. Solar energy devices and similar structures.

7.2.2 Permitted building elements or equipment in Section 7.2.1 shall be screened as practical and based on building design except if such projections – e.g., flagpoles or steeples – are part of the architecture or design. The use of creative materials and forms for screening is encouraged.

7.2.3 Enclosures for bulkheads shall not count against building height.

7.3 General Standards

7.3.1 A tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

7.3.2 Distinctive tower crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

7.4 Wall Standards

7.4.1 All walls are required to be articulated.

7.4.2 The following types of articulation of a tower wall are permitted:

a. Recess;

b. Standard balconies may be projecting or recessed or a combination of both; and

c. Bay windows.

fig. 7.4.2.a: Balcony/Recess

fig. 7.4.2.b: Bay Window

7.4.3 Balcony: a balcony shall be integral to the façade (see figs. 7.4.3.a and b) and shall not create a relentless horizontal and vertical stacking pattern. Balconies are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations and shall be a minimum 75% transparent.. Balconies are encouraged on buildings facing major public spaces such as plazas, passageways and open spaces. Long balconies resembling corridors are prohibited.

fig. 7.4.3.a: Recess/Balcony: Integral Balcony

fig. 7.4.3.b: Bay Window: Integral Balcony

7.5 Spacing Standards

7.5.1 Towers shall be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

7.5.2 Generally, any portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except for the following which will meet Planning Code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled. See fig. 7.5.2.

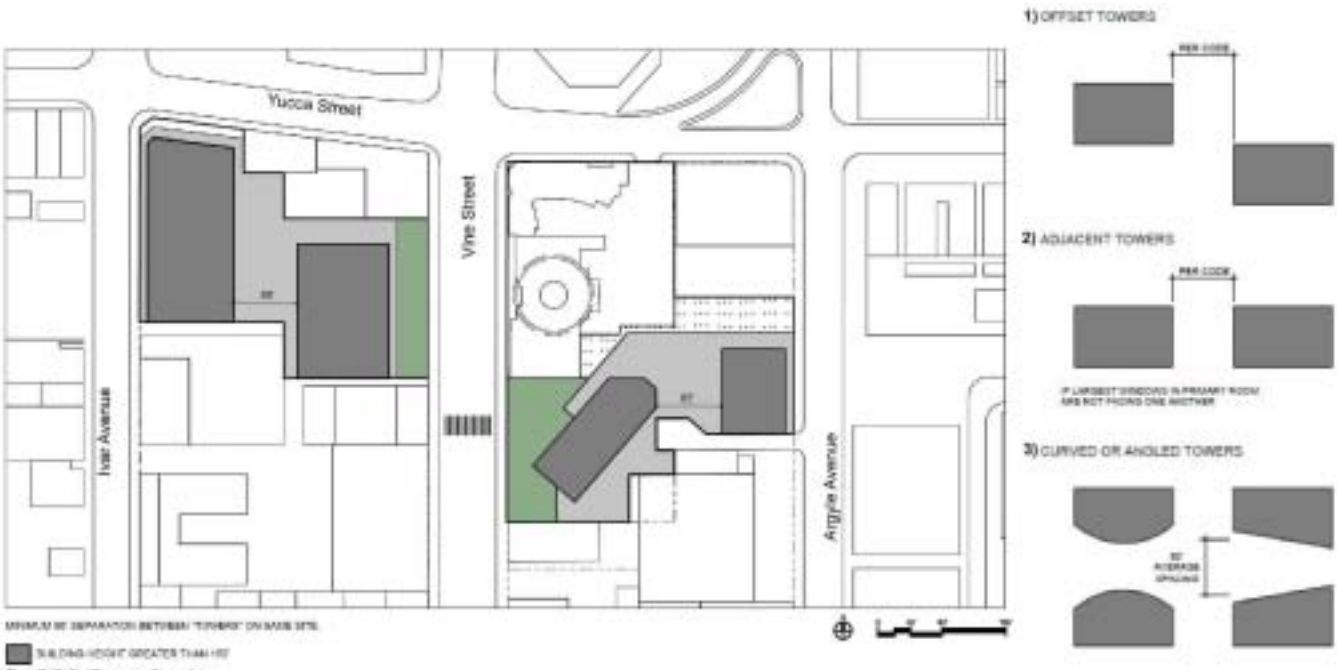


Fig. 7.5.2: Tower Spacing

7.6 Rooftops Guidelines

7.6.1 Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and be visually attractive when viewed from locations adjacent and above.

7.6.2 For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section 8.5.

7.6.3 All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors.

7.6.4 All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

7.7 Parapets, Handrails, Roof Mechanical Equipment Screening Standards

7.7.1 Parapets and handrails shall be finished in a distinctive manner if part of an expression band or expression line.

7.7.2 Materials and design for roof mechanical equipment shall be consistent with the building architecture and shall utilize similar colors and materials as in other portions of the building.

7.7.3 Roof mechanical equipment shall be screened.

8. OPEN SPACE

8.1 Overview

The development of open space is an important objective for the overall Project design. Open space will be used to enhance the experience of the visitor and resident. Open space also will enable important pedestrian linkages and through-block connections for the Project. Grade level open space also will be designed to showcase the Capital Records Building and Jazz Mural and will include design features and outdoor furniture to activate the ground floor amenities.

This section sets forth the standards and guidelines for all open space areas for the Project: areas to be accessible to the public (Grade Level Open Space, Publicly Accessible Passageways and Rooftop Open Space) and areas to be designed for the residential uses (Common Open Space and Private Open Space).

8.2 Grade Level Open Space Standards

8.2.1 Grade level open space is a continuous open space fronting the street and open to the sky. The purpose of a grade level open space is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records Building and accentuate the low scale character.

8.2.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Fig. 6.1.2.a.1 – 2)

8.2.3 An additional 3% of open space (total 8%) shall be required for buildings between 221 feet and 400 feet. (See Fig. 6.1.2.b.1 – 2)

8.2.4 An additional 5% (total 10%) of open space shall be required for buildings between 401 feet and 550 feet (See Fig. 6.1.2.c.1 – 2)

8.2.5 An additional 7% (total 12%) of open space shall be required for buildings taller than 550 feet. (See Fig. 6.1.2.d.1 – 2)

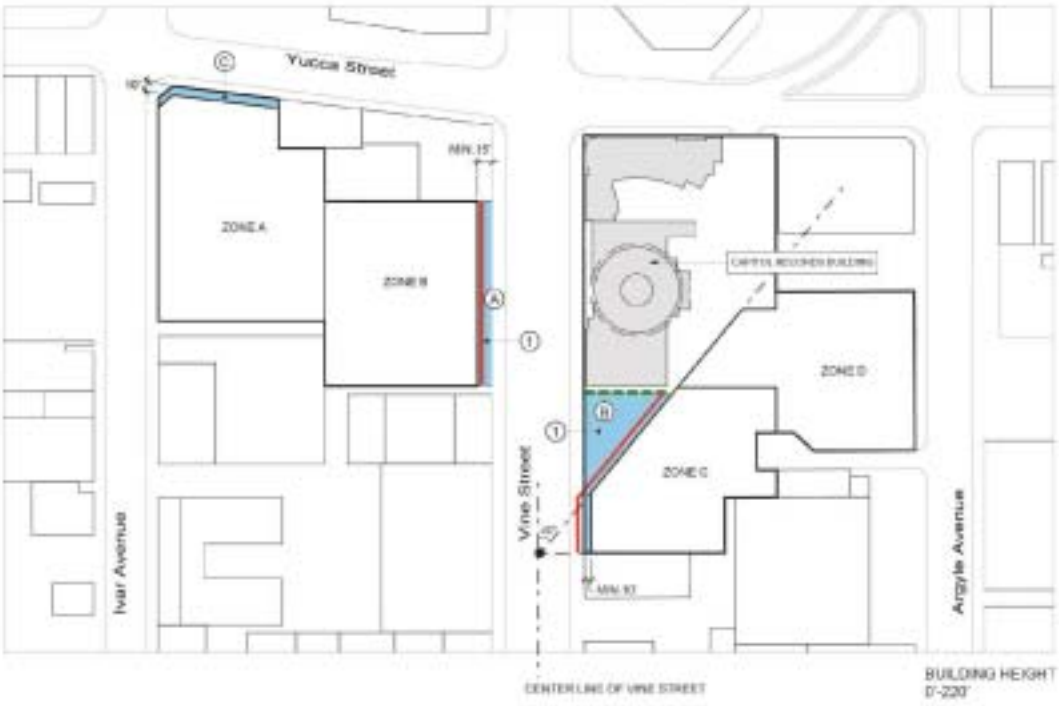
8.2.6 Location

a. East Site: adjacent to the Jazz Mural and Capitol Records Building; West Site: across from the Capitol Records Building along Vine Street.

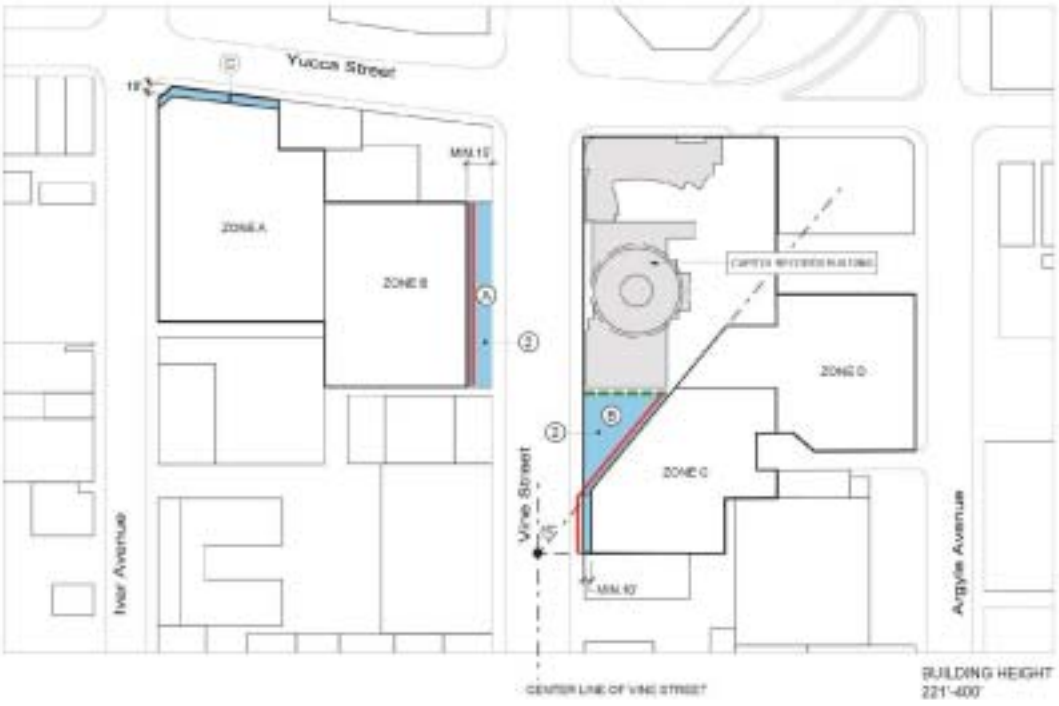
b. Minimum depth: no horizontal dimension less than 10 feet when measured perpendicular from any point on each of the boundaries of the open space area, except when contiguous with larger open space a portion can be less than 10 feet but for a distance no longer than 7 feet.

Figs 8.1.1 – 8.1.4: Grade Level Open Space

figs 8.1.1 Open Space Requirements for Maximum Building Height at 220 Feet

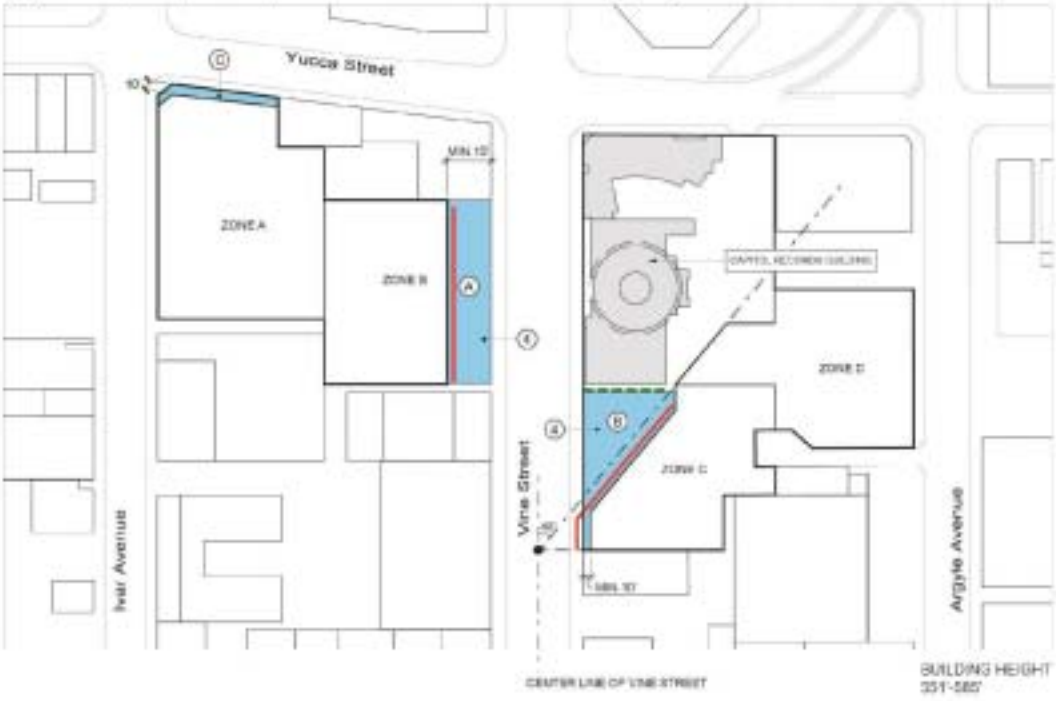


figs 8.1.2 Open Space Requirements for Maximum Building Height at 400 Feet



figs 8.1.3 Open Space Requirements for Maximum Building Height at 550 Feet

figs 8.1.4 Open Space Requirements for Maximum Building Height at 585 Feet



8.3 Passageway Standards

8.3.1 *A publicly accessible passageway* is a continuous through-block public connection between two parallel streets, located on privately owned land. The passageway may be either enclosed or open to the sky or a combination of both.

8.3.2 Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

8.3.3 Location and Size standards:

a. The major portion of a *publicly accessible passageway* is the largest area of the *passageway* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total passageway area and shall not be less than 20'-0" wide.

b. Minor portions of *publicly accessible passageway* are secondary areas that allow for additional flexibility in the shape and configuration of a passageway. Minor portions shall not occupy more than 25 percent of the total area of the *passageway*. The minor portion shall have a minimum width of 10 feet.

c. The minor portion must be directly adjacent to the major portion.

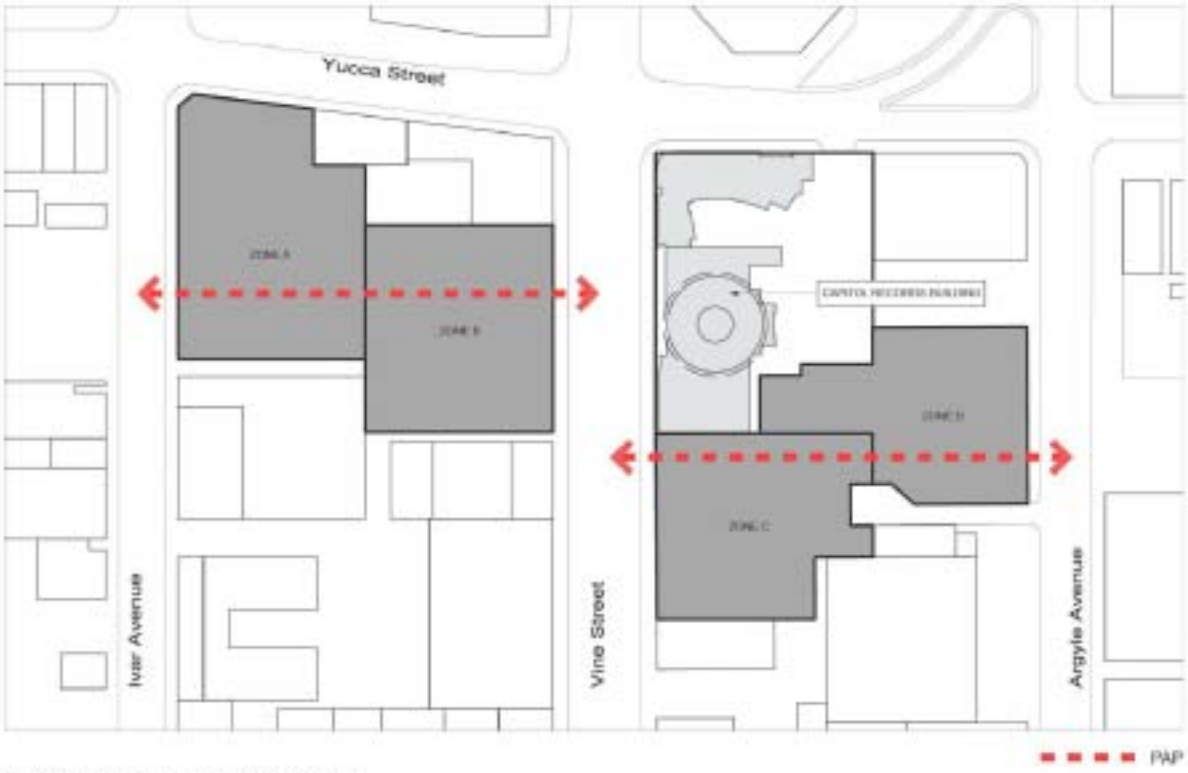


fig. 8.3.3: Publicly Accessible Passageway

8.3.4 Permitted Obstructions:

a. The minimum percentage of *publicly accessible passageway* area to be open to the sky (East and West Sites combined) shall be as follows:

(i) Development with maximum building height of 150 feet: 0%

(ii) Development with maximum building height of 220 feet: 20%

(iii) Development with maximum building height of 400 feet: 30%

(iv) Development with maximum building height of 550 feet: 40%

(v) Development with maximum building height of 585 feet: 50%

b. Permitted obstructions within the major portion of an open air *publicly accessible passageway* are any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open-air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions; balconies and bay windows; awnings, canopies and marquees; stairs, ramps

fig. 8.3.4: View from Argyle Avenue Along PAP Towards Capitol Records

and bollards.

8.3.5 Kiosk:

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Building in conformance with the Building Code. Kiosks, including roofed areas, shall not count as floor area, exceed 3% of the total area of the *publicly accessible passageway*, or occupy an area of more than 250 square feet.

b. A kiosk may be freestanding or may be attached on only one side to a wall of the building.

c. Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, and food preparation for open-air cafes, flower stands or public service/information booths.

d. All kiosks greater than 250 square feet are permitted but will count as floor area.

8.3.6 Open-Air Café:

a. Where an open-air cafe is provided it shall be an unenclosed restaurant or open-air seating for an enclosed restaurant, eating, or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies.

b. An open-air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the *publicly accessible passageway*. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers.

c. An open-air cafe may occupy an aggregate area not more than 20% of the total area of the *publicly accessible passageway*. No cooking equipment shall be installed within an open-air cafe. Cooking equipment may be contained in a kiosk adjoining the open-air cafe. An open-air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

8.3.7 Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on the *publicly accessible passageway* through open windows.

8.3.8 Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No building refuse storage areas or refuse storage from a kiosk or open-air café are permitted on any *publicly accessible passageway*.

b. No exhaust vents are permitted on any *publicly accessible passageway* or on any building wall of the development fronting upon the passageway except where such vents are more than 10'-6" above the level of the *passageway*.

8.3.9 Frontages:

a. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a *publicly accessible passageway* shall be allocated for occupancy by permitted retail, restaurants and cultural uses.

b. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the *publicly accessible passageway* with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

8.3.10 Maintenance:

a. The building owner shall be responsible for the maintenance of the *publicly accessible passageway* including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the passageway and in the street sidewalk area adjacent to the passageway.

b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of *publicly accessible passageway* area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of *passageway* in connection with outdoor eating services or other uses permitted on *passageway* which generate litter.

8.4 Roof-top Open Space

8.4.1 Buildings above 550 feet shall include roof-top open space.

8.4.2 Roof-top open space shall include an observation area (i.e., viewing deck) accessible to the public.

8.4.3 Roof-top open space may include a café.

8.5 Residential Common Open Space

8.5.1 Common open space is intended to be: a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above. The publicly accessible passageway cannot be used to meet the residential common open space requirements.

8.5.2 Common Open Space Standards

a. Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.

b. Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein.

c. Open space shall be open to the sky and have no structures that project into the common open space area, except as permitted in the Zoning Code.

d. Common open space shall be readily accessible to all the residents of the Site.

e. Common open space shall have a minimum area of 400 square feet with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

f. Common open space shall constitute at least 50% of the total required usable open space in the built development.

g. Common open space areas shall incorporate recreational amenities including but not limited to swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

h. Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use may be considered as common open space.

i. Refer to LAMC 12.21.G for additional open space requirements.

8.6 Residential Private Open Space

8.6.1 A private open space area is an area contiguous to and immediately accessible from a single dwelling unit.

8.6.2 Residential Open Space Standards:

a. Private open space shall contain a minimum area of 50 square feet, of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.

b. Private open space shall have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

c. Private open space shall provide a minimum eight-foot vertical clearance under any projection, except as permitted in the Zoning Code.

d. That portion of a balcony which extends or projects into a required front yard in compliance with Zoning Code may qualify as usable open space provided it meets each of the above specified requirements noted in items a-c.

9. LANDSCAPE

9.1 Grade Level Open Space Standards

9.1.1 Planting requirements: a minimum of 10% of grade level open space shall be landscaped with softscape or water features.

9.1.2 Landscaped area(s) shall be planted with seasonally diverse plant material. [LACP to provide language 30% California native]

9.1.3 The landscaped portion of open space may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.1.4 The minimum soil depths for planting are:

a. Trees: 42".

b. Shrubs: 30".

c. Lawns, ground cover: 18".

9.1.5 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.1.6 Permitted obstructions: the following are permitted obstructions which may occur in the *grade level open space*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining, and retail storefronts.

9.1.7 Open-air *publicly accessible passageways* are not to be included in the grade level open space requirements.

9.2 Common Open Space Standards

9.2.1 A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

9.2.2 At least one 36-inch box tree for every four dwelling units shall be provided on-site and may include street trees in the parkway, sidewalks adjoining the property, open space, *publicly accessible passageway* and common roof decks.

9.2.3 For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

9.2.4 All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

fig. 9.3.a: Movable Seating

fig. 9.3.b: Open Air Café

9.3 Standards For Open Air Portions of Publicly Accessible Passageway

9.3.1 The landscaped portion of open air passageways may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.3.2 The minimum soil depths for planting are:

a. Trees: 42".

b. Shrubs: 30".

c. Lawns, ground cover: 18".

9.3.3 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.3.4 Planting requirements:

a. A minimum of 10% of open air *publicly accessible passageway* shall be landscaped.

b. For each 400 square feet of landscaped area there shall be at least one (l) major shade tree or two (2) minor ornamental trees.

c. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

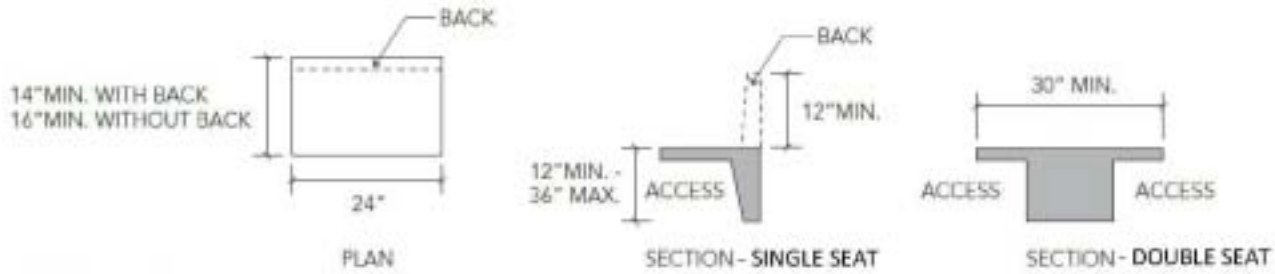


fig. 9.3.5: Seating Standards

9.3.5 Seating

a. There shall be a minimum of one linear foot of seating for each 500 square feet of *publicly accessible passageway* excluding the area of an open-air cafe.

b. One seat shall equal 2 linear feet.

c. Not more than 50% of the linear seating capacity may be in moveable seats. Seating shall meet the following standards:

(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons, a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count as double seating provided there is access to both sides.

(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.

(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

d. Moveable seating or chairs, excluding seating of open-air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open-air cafes do not count toward meeting the seating requirements.

9.4 Tree Planting Guidelines

9.4.1 It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

9.4.2 Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

9.4.3 Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree-planting pattern.

9.5 Lighting Standards

9.5.1 Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

9.5.2 Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade level open space and open *publicly accessible passageway*.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d. Steps and ramps will be lighted with a minimum of 1.0-foot candles on a horizontal plane.

e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

f. All exterior lighting shall be shielded or directed toward the areas to be lit to limit spill-over onto off-site uses.

g. Light quality shall not be harsh, glaring, blinking or shed beyond property boundaries.

9.5.3 Responsibility for maintenance:

a. The Building Owner shall be responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

b. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building Owner.

9.5.4 Lighting for areas located inside the lot line and visible from the street, such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

9.5.5 Lighting for above-grade parking garage facilities shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

9.6 Publicly Accessible Passageway Lighting Standards

9.6.1 A *publicly accessible passageway* shall be illuminated throughout with an overall minimum average level of illumination of not less than 1.0 maintained foot candle (lumens per square foot) on the horizontal plane at grade.

9.6.2 Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

9.7 Continuity of Design

9.7.1 Design elements and architectural clues that reinforce where appropriate continuity between open and enclosed spaces at grade level is encouraged. Continuity of design may reinforce pedestrian circulation and support the Project's way-finding features.

9.7.2 Where possible, materials, lighting, site elements and landscape shall be similar between different open and enclosed public spaces at the grade level.

10. PARKING

10.1 Automobile Standards

10.1.1 Base Standards

The following standards shall apply for the base level of parking to be provided as the minimum for each use in the project area. The Regulations set forth below incorporate the parking requirements in the LAMC, where applicable, and supersede the LAMC requirements for development in the Development Agreement area.

a. Commercial / Office / Retail:

Two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot. The Regulation incorporate applicable parking requirements in the LAMC as set forth below.

b. Sports Club:

When a sports club is located in a building with 50,000 office equivalent square feet of non-sports club space, the general commercial use parking requirements apply and two parking spaces are required for every one thousand square feet of floor area for the building. If the sports club is not in such a building, one space is required for one hundred square feet of floor area for the sports club portion of the building.

c. Condominiums (Residential):

Two parking spaces per dwelling unit.

One-quarter parking space per dwelling unit for guest parking.

d. Rental (Residential):

One parking space for each dwelling unit of less than three habitable rooms; one-and-one-half parking spaces for each dwelling unit of three habitable rooms; and two parking spaces for each dwelling unit of more than three habitable rooms.

e. Combination of Uses:

Where there is a combination of uses on a lot, the base number of parking spaces required shall be the sum of the requirements of the various uses.

10.1.2 Shared Parking:

a. Shared parking may be applied to the Section 10.1.1 base rates for the Site when the uses have different parking requirements and different demand patterns in a 24-hour cycle or between weekends and weekdays. The intent is to maximize efficient use of the site by matching parking demand with complimentary uses. The calculation of the parking requirements shall be based on a detailed assessment prior to its construction.

b. Calculating Shared Parking:

(i) The individual land use parking requirements for each component of a phase of development shall be calculated from Section 10.1.1. above to establish the "Base Demand."

(ii) The Base Demand will be adjusted by the number of bicycle spaces required per section 10.4. The following internal use reduction factors shall also be applied when 10,000 office equivalent square feet each of office, residential and other commercial uses will all be active on the Site:

Internal Use Reduction Factors	
Residential	5%
Hotel	5%
Office	15%
Other Commercial	15%

The resulting minimum automobile parking rates shall be applied to the proposed building(s) to be constructed in each phase of development.

(iii) For parking spaces that are to be shared between uses, the calculated minimum parking requirement for the Site, including that new phase of construction, is to be adjusted based on the procedures in *Shared Parking*, Urban Land Institute, 2nd Edition (2005).

10.2 Additional Regulations

10.2.1 The automobile parking spaces required shall be provided either on the same lot as the use for which they are intended to serve or on another lot located within 750 feet of the lot; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

10.2.2 Curb cuts for driveways shall be located no closer than 50 feet to the intersection of two streets unless approved by The Department of Transportation to be a leg of the intersection.

10.2.3 Access driveways to parking facilities not at signalized intersections shall not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

10.2.4 Parking and loading access shall be shared where feasible.

10.2.5 Priority placement within parking structures shall be given to bike parking, car-share parking, and other alternative ride vehicles.

10.2.6 Pedestrian entrances to all parking shall be directly from the street, except that underground parking garages may be entered directly from a building.

10.3 Screening

10.3.1 Above grade parking shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible, or shall be designed to blend in with the form and massing and to look like an integral part of the building, or by landscaping, or a combination thereof. The interior of a parking structure shall be designed to be screened from the view of streets and sidewalks.

10.4 Bicycle Standards

10.4.1 Requirements for each use:

a. Commercial / Office / Retail:

For uses listed below a minimum of 2 short-term and 2 long-term bicycle parking spaces shall be provided.

Land Use	Short Term Bicycle Parking	Long Term Bicycle Parking
Office	1 per 10,000 sq. ft.	1 per 5,000 sq. ft.
Health Clubs	1 per 2,000 sq. ft.	1 per 2,000 sq. ft.
Restaurant and Bars	1 per 2,000 sq. ft.	1 per 2,000 sq. ft.
Restaurant (less than 1,000 square feet)	2 per restaurant	2 per restaurant
Retail (General)	1 per 2,000 sq. ft.	1 per 2,000 sq. ft.
Retail (Furniture)	1 per 10,000 sq. ft.	1 per 10,000 sq. ft.
Hotel	1 per 20 guestrms	1 per 20 guestrms
All other commercial uses	1 per 10,000 sq. ft.	1 per 10,000 sq. ft.

COMBINATION OF USES. Where there is a combination of uses on a lot, the number of bicycle parking spaces required shall be the sum of the requirements of the various uses.

b. Residential:

For all residential buildings containing more than three dwelling units, or more than five guest rooms, long- and short-term bicycle parking shall be provided. Long-term bicycle parking shall be provided at a rate of one space per dwelling unit or guest room. In

addition, short-term bicycle parking shall be provided at one space per ten dwelling units or guest rooms. A minimum of two short-term bicycle parking spaces shall be provided in such cases.

(i) In instances where a building may contain both dwelling units and guest rooms, the sum of dwelling units and guest rooms shall be used to determine the amount of long and short-term parking. Any combination that results in more than five combined dwelling units and guest rooms will require bicycle parking.

10.5 Transportation Demand Management Plan

10.5.1 The Project shall incorporate a comprehensive transportation demand management plan.

10.5.2 The transportation demand management plan shall set forth best practices that relate to the Project Site and the Project's building design features in order to:

a. Promote bicycle and pedestrian circulation within the Project Site.

b. Promote alternative modes of transportation.

c. Create pedestrian linkages to public and private amenities outside the Project Site.

d. Provide convenient and attractive onsite pedestrian linkages for routes to the Metro Red Line Station at Hollywood Boulevard and Vine Street.

e. Provide adequate parking, but provide incentives to tenants and residents to utilize alternative modes of travel. The incentives shall include bicycle facilities, car sharing, discounted subway passes, and parking spaces as an only optional part of all lease and sale agreements.

11. SIGNAGE

11.1 Hollywood Signage Supplemental Use District

Signage shall be subject to Ordinance No. 176172: Hollywood Signage Supplemental Use District pursuant to Section 13.11 of the Los Angeles Municipal Code.

11.2 Modification to Guidelines

Notwithstanding Section 11.1, high-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted. See fig. 11.2.

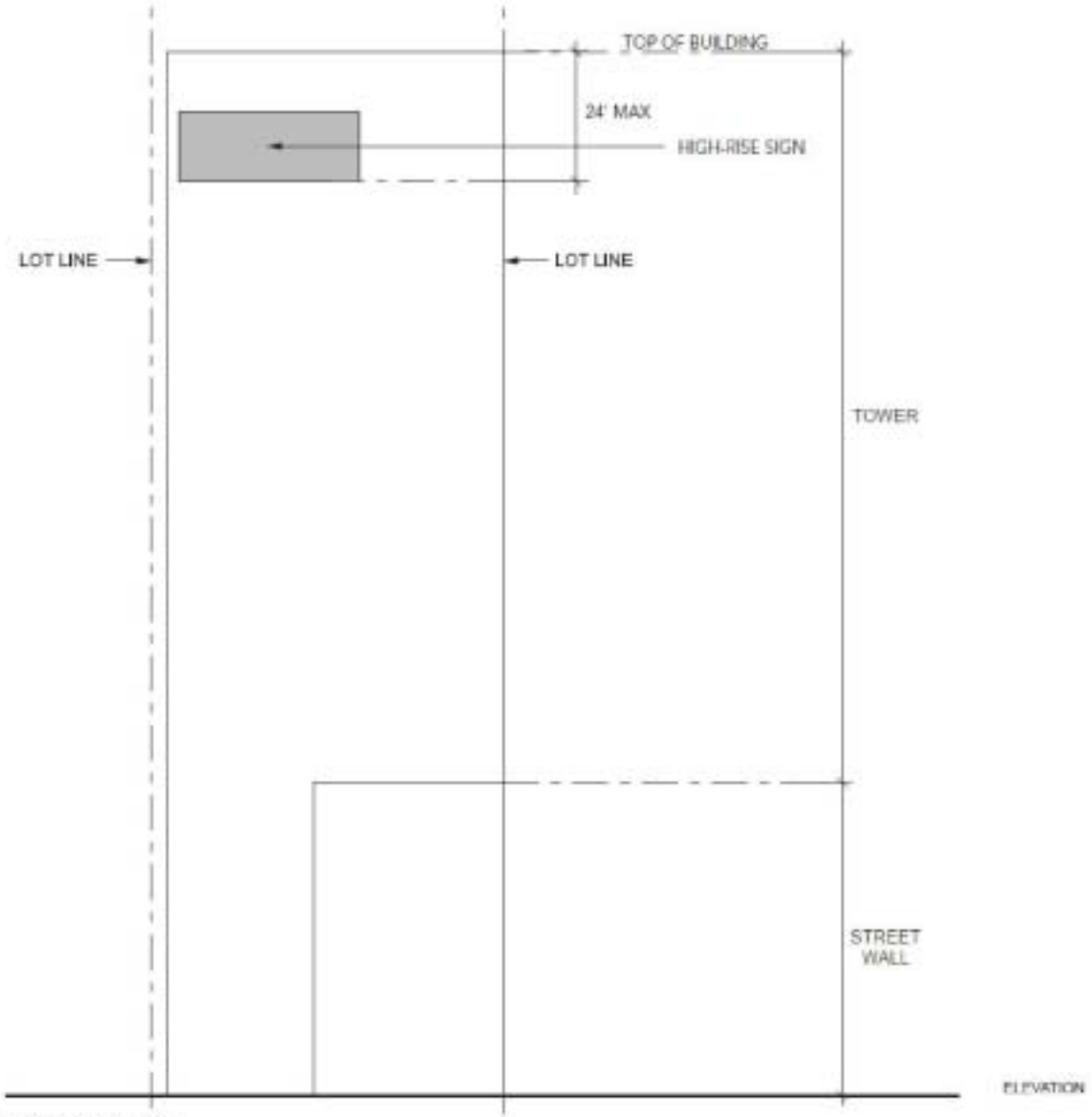


fig. 11.2: High Rise Sign

12. SUSTAINABILITY

12.1 Non-Residential Projects

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

12.2 Other Projects

The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

13. DEFINITIONS

Awning: glazing or fabric on metal frame structure supported entirely by the building to provide weather protection at doors, windows and/or storefronts; may be retractable.

Base: the lower portion of a building located at or within 150' above curb level.

Canopy: glazing, fabric and/or metal structure with vertical supports located on the sidewalk to provide weather protection at a building's primary entrance.

Expression band: a distinctive linear architectural element occurring on the building base facade at the highest floor. The band shall be contrasting in color, texture, material and/or fenestration from the adjacent building base facade. Projections may occur within an expression band.

Grade level open space: a continuous open space fronting the street and open to the sky.

Maximum building height: the maximum height permitted, measured from the adjacent street curb level.

Maintenance: the ongoing repair, care and upkeep of a property.

Open space use: active and passive recreational areas accessible to the general public, and as noted herein. Open spaces can occur in publicly accessible passageways, grade level open space, residential common open space and residential private open space, which are defined herein.

Preservation: the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property.

Publicly accessible passageway: a continuous through-block public connection between two parallel streets, located on privately owned land and designated for and designed to encourage public pedestrian circulation and other appropriate public uses.

Rehabilitation: the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values.

Required street wall: a wall or portion of a wall of a building facing a street or grade level open space which must be built to a minimum height above curb level.

Required street wall articulation, aggregate width of: the sum of the maximum widths of all segments of required street wall articulation on a street at the level of any story. The width of a required street wall articulation is measured in plan as the width of the street line from which perpendicular lines may be drawn to such required street wall articulation.

Residential common open space: a "rear yard" providing light and air to apartments on the interior of a parcel located at any story above curb level, and accessible only to residents.

Residential private open space: open space that is contiguous to and immediately accessible only from a single dwelling unit.

Setting: the area or environment in which a historic property is found. It may be an urban or suburban neighborhood or a natural landscape in which a building has been constructed. Elements of setting can include the relationship of buildings to each other, setbacks, views, sidewalks, and street trees.

Storefront: the architectural facade, including doorways, of any tenant-leased premise perimeter adjacent to public circulation areas. Storefronts refers to all permitted retail uses including retail, service, restaurants and cultural establishments.

Tower: the portion of a building located above 150' above curb level.

Notes:

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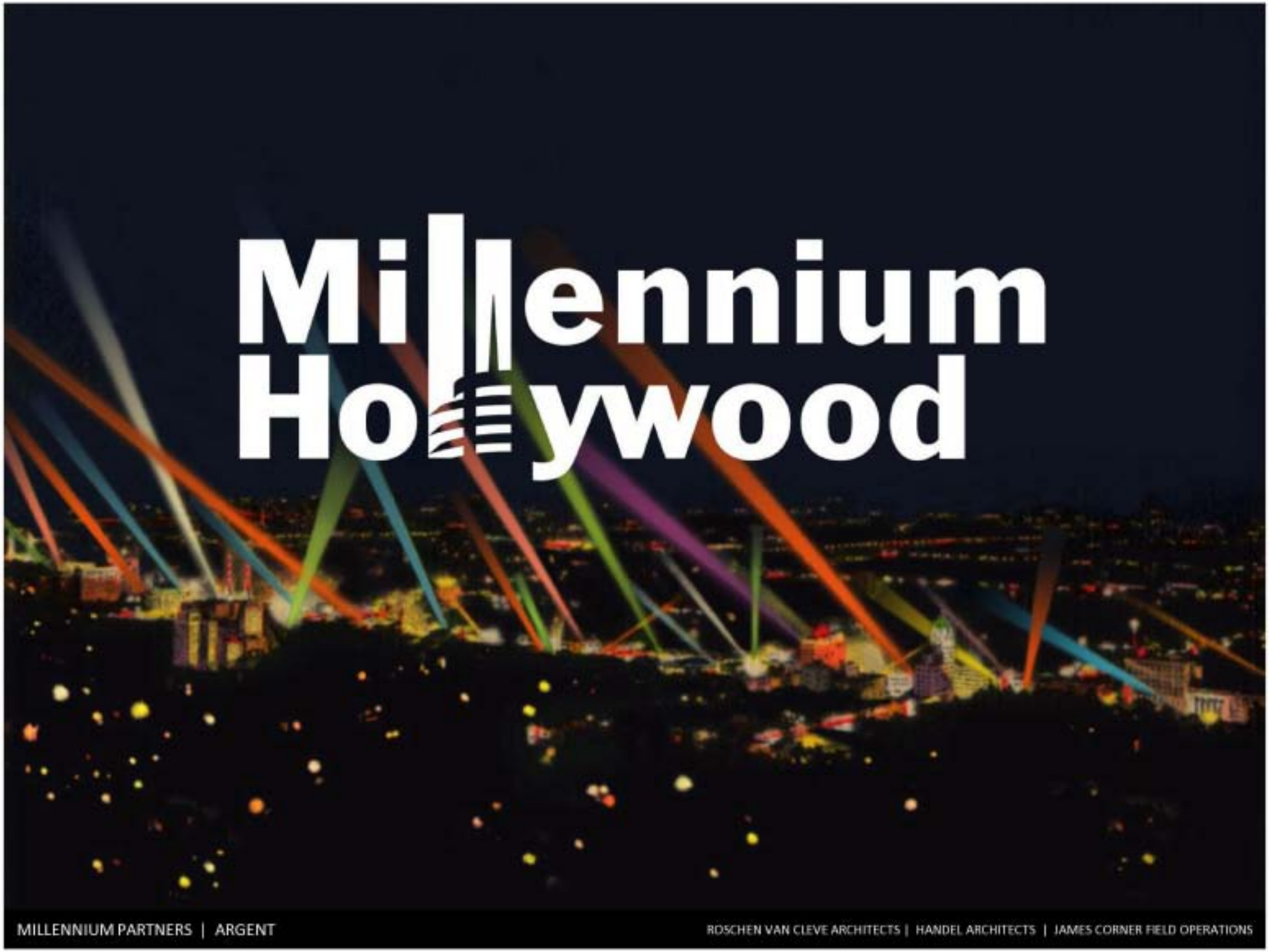

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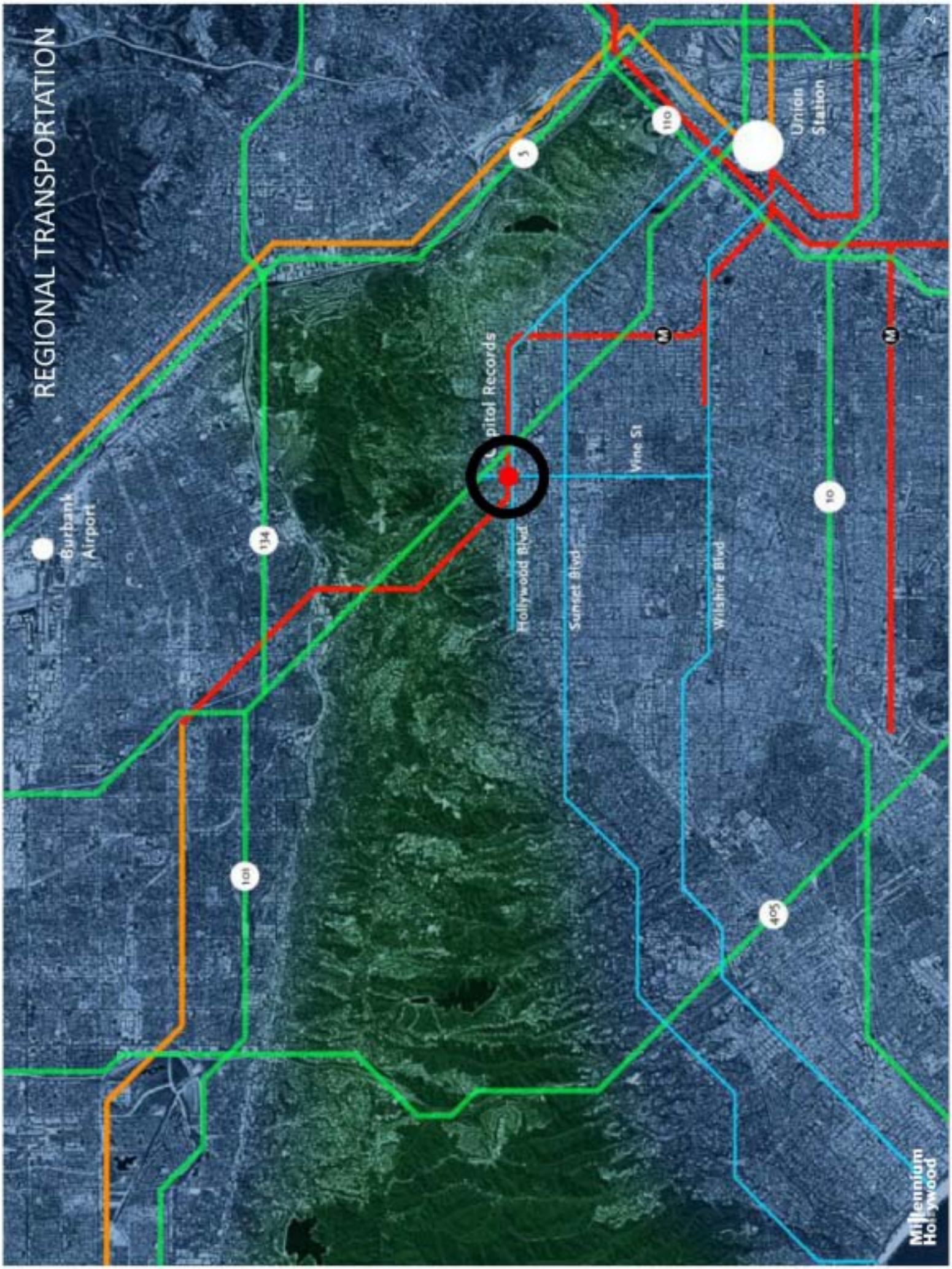
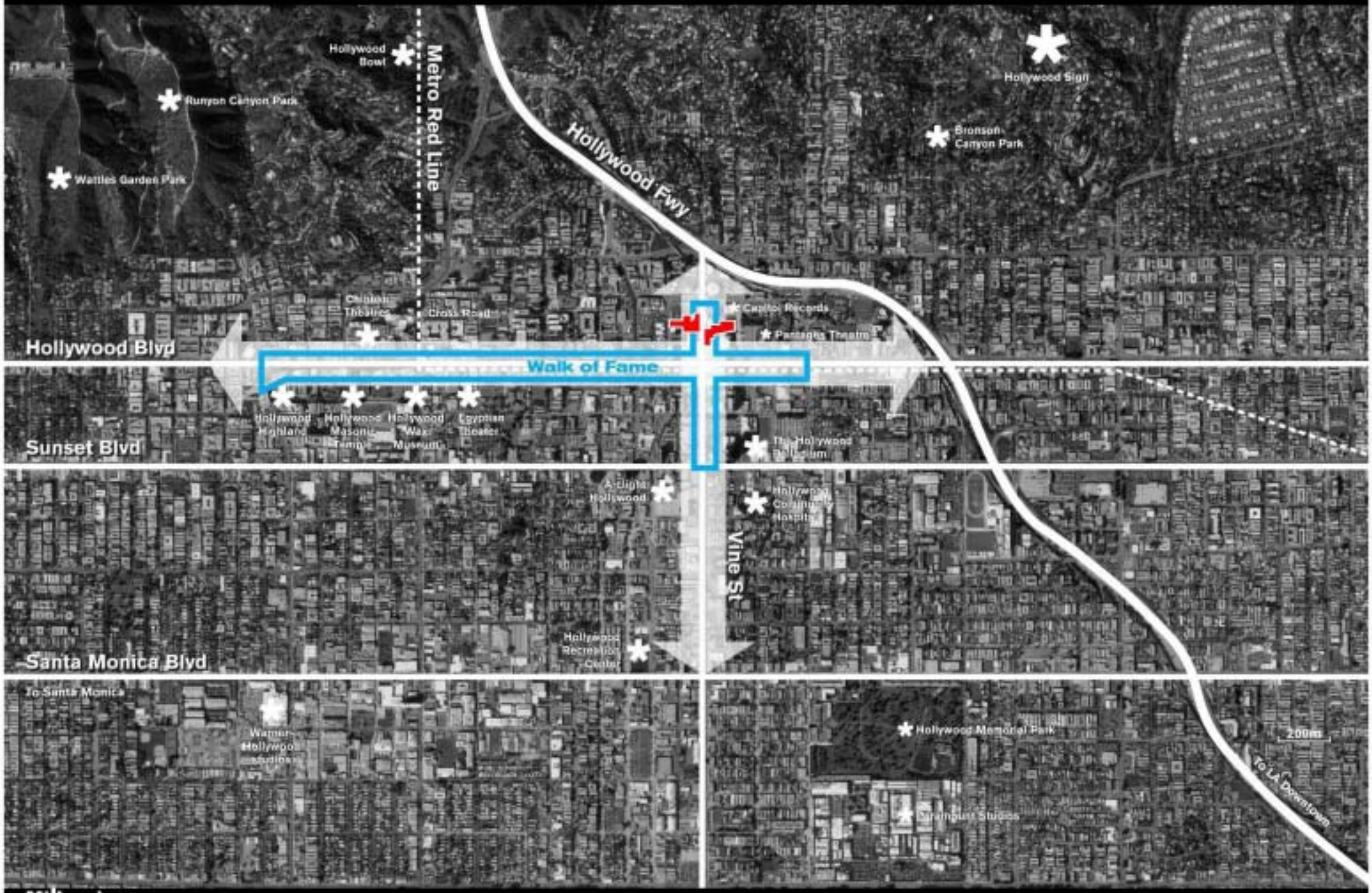

REGIONAL TRANSPORTATION
Union Station
Capitol Records
Vine St
Hollywood Blvd
Sunset Blvd
Wilshire Blvd
Burbank Airport
Millennium Hollywood
2
5
10
101
110
134
405
M
M

NEIGHBORHOOD CROSSROADS



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CO-0001-746

PRESERVE SITE LINES

HOLLYWOOD TRADITIONS: BUILDINGS

CO-0001-748

AR0067763

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HOLLYWOOD TRADITIONS: BUILDINGS

AR0067764

CO-0001-749

HISTORIC HOLLYWOOD OPEN SPACES
Little Country Church

AR0067765

CO-0001-750

HISTORIC HOLLYWOOD OPEN SPACES
Walk of Fame

AR0067766
CO-0001-751

NEW COURTYARD SEQUENCE

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CO-0001-752

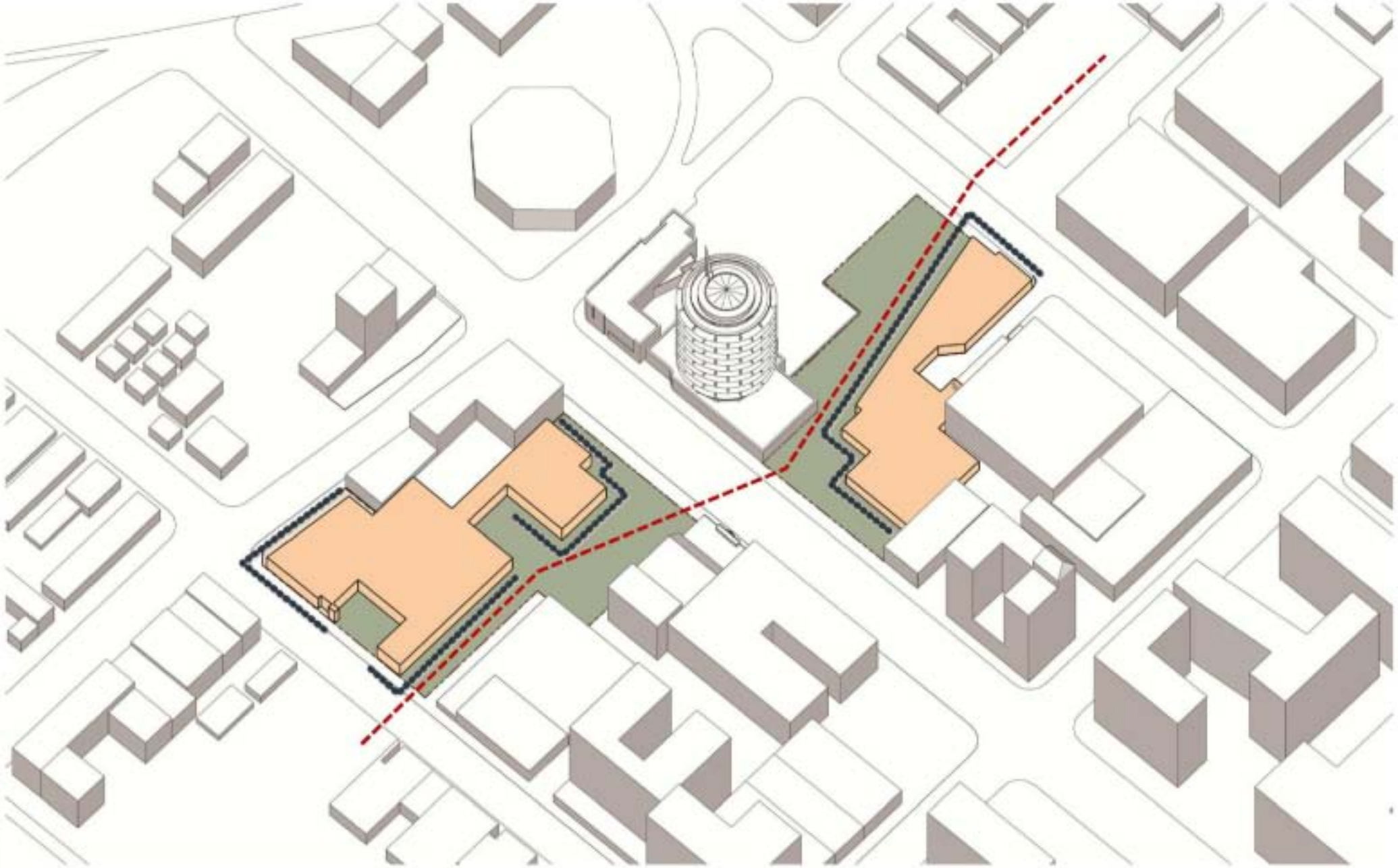
SCALE COMPARISONS

CO-0001-753

AR0067768

Millennium Hollywood

ACTIVE GROUND FLOOR



NEIGHBORHOOD OPEN SPACE AND LINKAGES

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NEW PLAN

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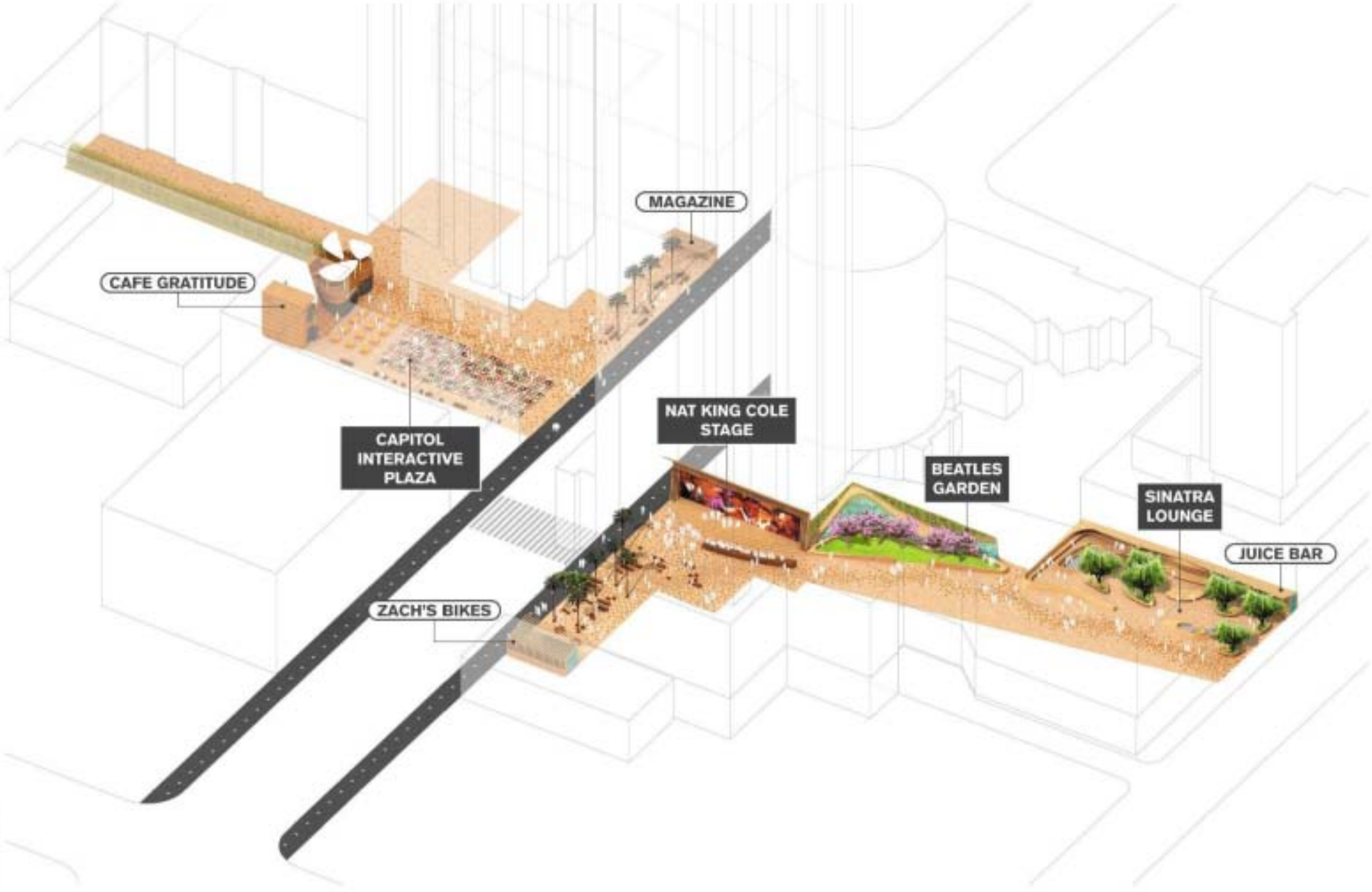
AR0067771

Millennium Hollywood

OVERALL VIEW



CO-0001-757

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Millennium Hollywood

THE LOUNGE

Outdoor Fire Place

Outdoor Library

Lime Trees

CO-0001-758

AR0067773

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THE LOUNGE

AR0067774

CO-0001-759

THE GARDEN

Water Wall

Vines

Lawn

Crape Myrtle

CO-0001-760

AR0067775

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THE GARDEN

AR0067776

CO-0001-761

THE STAGE

Seating Steps

Jazz Mural Stage

King Palm

Bike Shop

CO-0001-762

AR0067777

Millennium Hollywood

CO-0001-763

AR0067778

CO-0001-764

AR0067779

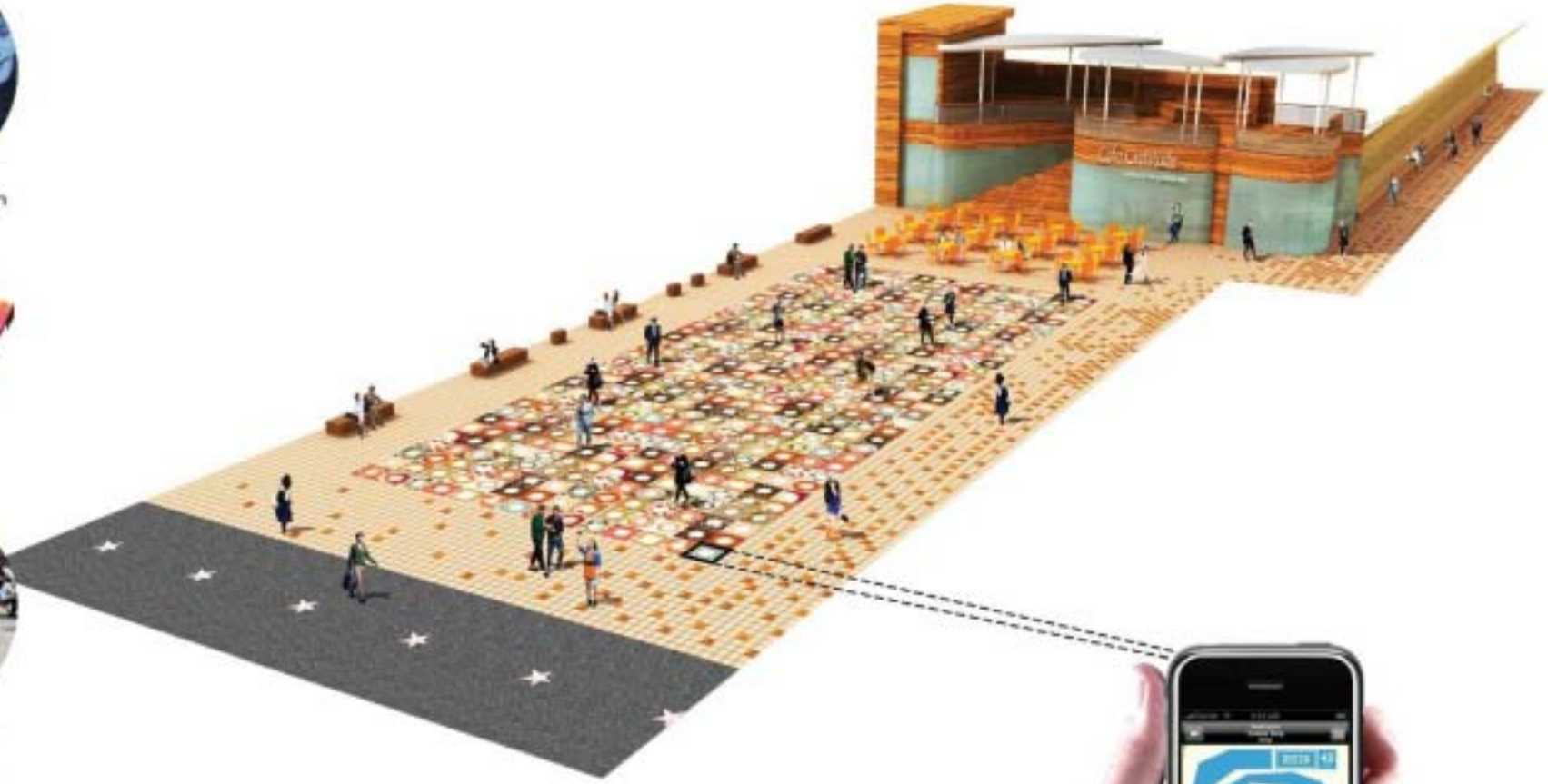
THE PLAZA

Cinema Projection

LED Paver

Rotating Events

Cafe



"Interactive Apps"

CO-0001-765

AR0067780

Millennium Hollywood

THE PLAZA

THE PLAZA
TYPICAL DAY

CO-0001-767

AR0067782

Millennium Hollywood

THE PLAZA
FOOD TRUCKS

THE PLAZA
FARMER'S MARKET

THE PLAZA
DANCE PERFORMANCE

CO-0001-770

AR0067785

Millennium Hollywood

AGGREGATE FORM

CO-0001-771

AR0067786

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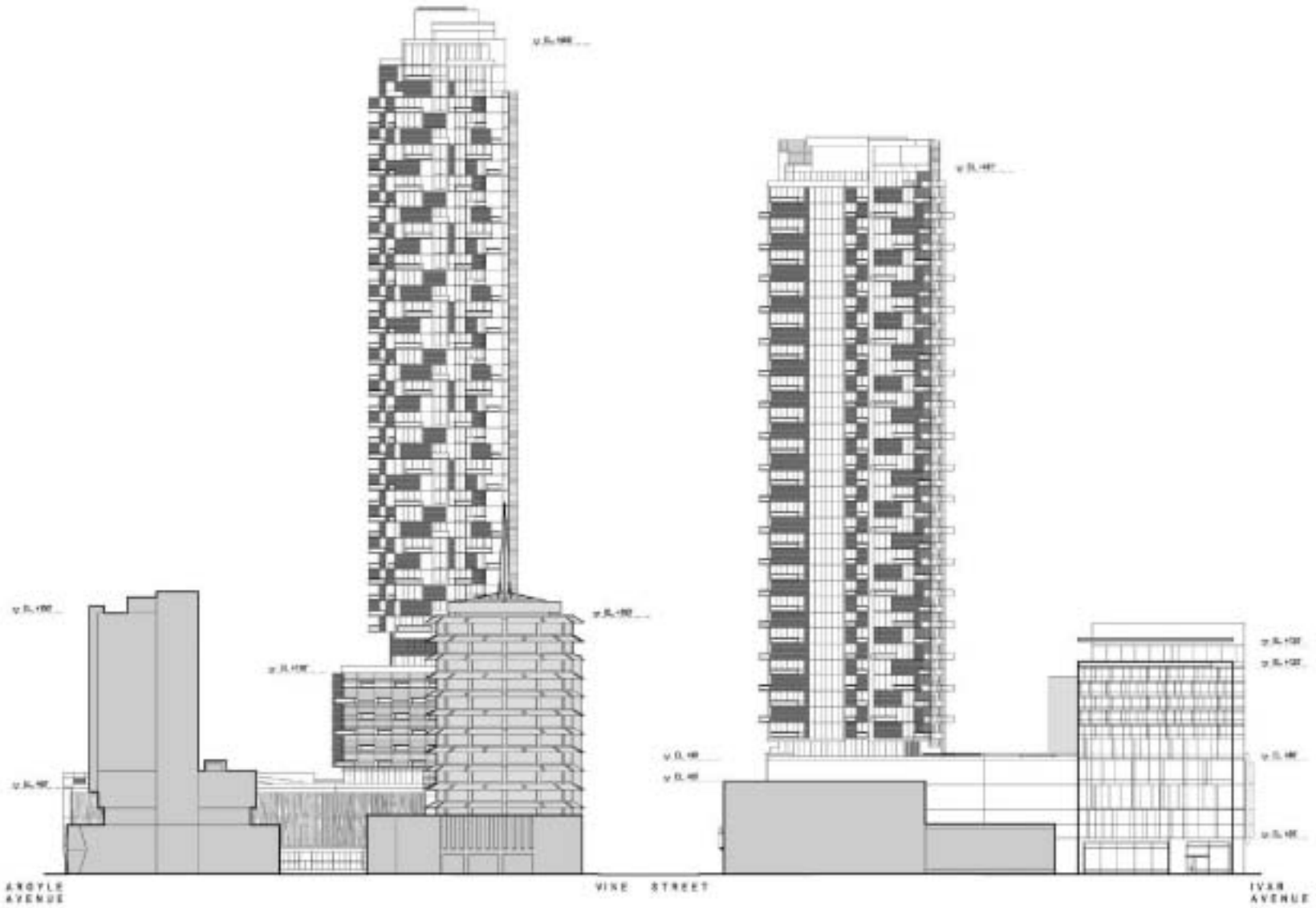
Millennium Hollywood

Millennium Hollywood



NOTE: ALL ELEVATIONS ON CONTEXT BUILDINGS ARE APPROXIMATED OR ESTIMATED

MILLENNIUM HOLLYWOOD
HANDEL ARCHITECTS LLP

NORTH ELEVATION

January 3, 2013

Millennium Hollywood

AR0067792

CO-0001-777

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102:—WORLD FAMOUS HOLLYWOOD BOULEVARD ON A PREMIERE NIGHT.
HOLLYWOOD, CALIFORNIA.

AR0067799
CO-0001-784
Millennium Hollywood

MILLENNIUM HOLLYWOOD PROJECT

DEVELOPMENT REGULATIONS: GUIDELINES AND STANDARDS

ORDINANCE NUMBER _____; EFFECTIVE DATE _____

MILLENNIUM HOLLYWOOD PROJECT

SCOPE OF DEVELOPMENT: DESIGN GUIDELINES AND STANDARDS

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1. PURPOSE AND OBJECTIVES

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria that serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

d. Permit design flexibility while establishing a set of controls that will guide the development for the Project Site.

e. Ensure compliance with the Development Objectives.

1.2 Development Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure that new development on the Project Site is consistent with these objectives.

1.2.2 The objectives for new development on the Project Site are to:

a. Preserve the Capitol Records Building and the Gogerty Building according to established preservation guidelines (the *Secretary of the Interior's Standards for Rehabilitation* and guidance provided by Office of Historic Resources).

b. Preserve public views from certain key vantage points to the Capitol Records Tower by creating grade level open space / civic plazas on the East Site adjacent to the Jazz Mural and Capitol Records Building and West Site across from the Capitol Records.

c. Preserve existing view corridors from certain key vantage points to the Hollywood Hills.

fig. 1.2.2.b-c: Capitol Records View Corridors

d. Create civic plazas that are activated by retail, landscaped, and enhance the Hollywood Walk of Fame by providing it as an urban node. Reinforce the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

e. Encourage street life by the creation of a new pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

f. Create vibrant urban spaces that permit open and green spaces for both the on-site and off-site population.

fig 1.2.2.d: View North Along Vine Street

g. Create a 24 hr community by the creation of a Thriving Mixed-Use Development.

h. Eliminate the visual impact of current on-site parking.

i. Establish where feasible pedestrian linkages to existing public transportation routes in proximity to the Project Site, including the Metro Red Line Station at Hollywood Boulevard and Vine Street, and existing bus routes.

j. Establish standards to address architectural excellence.

k. Provide designs that address, respect and complement the existing context, including standards for ground-level open space, podium heights and massing setbacks that minimize impacts to the historic setting.

l. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

m. Create buildings that emphasize the vertical architecture and become visible icons.

n. Develop a visual gateway to Hollywood from the Hollywood Freeway.

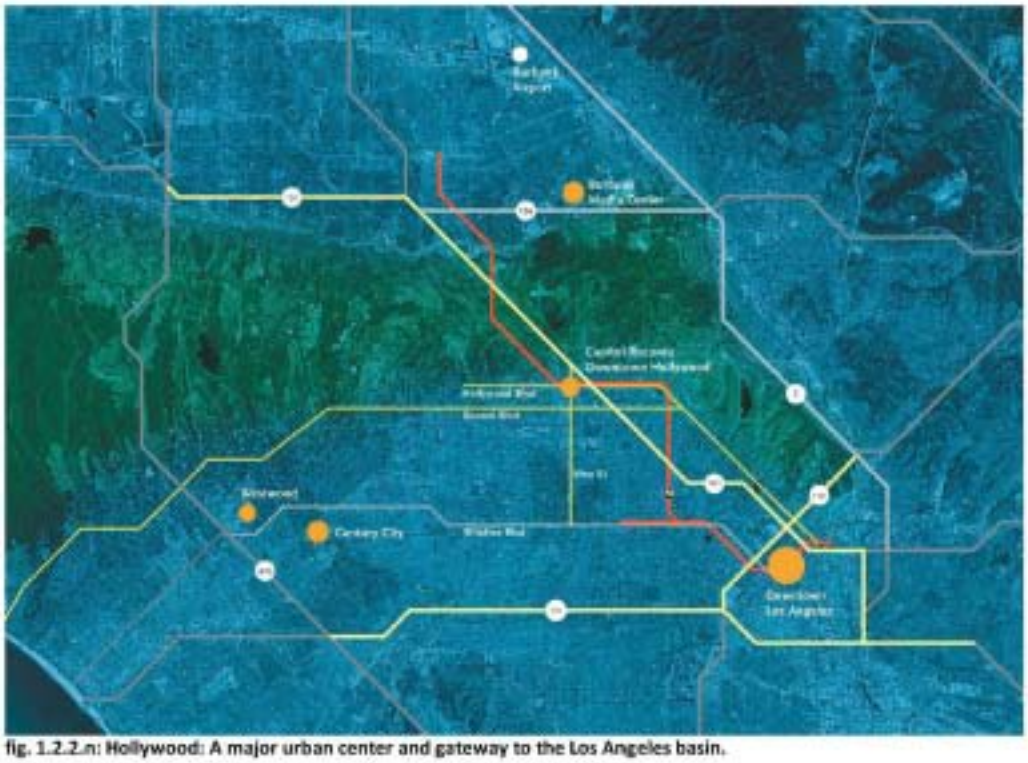


fig. 1.2.2.n: Hollywood: A major urban center and gateway to the Los Angeles basin.

1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose strict requirements for new development. For example, the Regulations include specific setback requirements along Vine Street. There are also mandatory requirements or standards for minimum open space on the ground floor as well as maximum building heights. By comparison, the guidelines are measures that may include a range of choices and require a degree of interpretation by the architect and design team to achieve compliance with the Regulations. The purpose of these guidelines is to create a principal design theme or objective without comprising high quality design. The purpose is to provide a range of flexibility to permit the selection of the most appropriate design feature based on the final development scenario. For instance, façade treatments for new development may take different form depending on the final design plans. The Regulations will guide the ultimate façade treatment by providing a limited range of choices in the use of material and color for the façades.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 The Development Regulations are approved by the City of Los Angeles City Council and are incorporated in the Development Agreement, authorized pursuant to California Government Code 65864, et seq., entered into by the City of Los Angeles and _____ ("Millennium Development Agreement") on _____.

1.4.2 Wherever the Regulations contain provisions which establish regulations that are different from or more or less restrictive than the zoning or land use regulations in the Los Angeles Municipal Code ("LAMC") that apply to the Project Site, the Regulations shall prevail pursuant to the Millennium Development Agreement approved by the City Council.

2. BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street.

The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Avenue is the East Site.

The East Site and the West Site make up the Project Site.

The Project Site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 21 feet (NE to SW) from Vine Street to Argyle Avenue and 21 feet (NW to SE) from Ivar Avenue to Vine Street. The existing sidewalk elevations will not be altered as part the Project.

fig. 2.1. Site Plan

2.2 Site Zoning and Permitted Floor Area

2.2.1 The Project Site is zoned Commercial (C2). The City General Plan land use designation is Regional Center commercial.

2.2.2 The Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.

2.2.3 Notwithstanding any provision in these Regulations, residential floor area is not permitted within 500 feet of any freeway .

2.2.4 Floor Area Ratio: 6:1

2.2.5 Height District: No. 2

3. HISTORIC RESOURCES AND SETTING

3.1 Overview

The Project Site is located in a historically rich area of Hollywood that contains a number of recognized historic resources. This Project is a preservation project in that its ambition is to respect, respond to, and preserve the Capitol Records Building and to continue the urban character of Vine Street on the Project Site. The Project is designed to be observant of historic settings and buildings. Two buildings located on the Project Site, the Capitol Records Tower and the Gogerty Building, are historically significant. Other historic buildings, located on adjacent parcels, are the Pantages Theater, the Equitable Building, the Hollywood Palace, and the Art Deco commercial building at 6316-6324 Yucca Street. Several of these historic resources are located within the Hollywood Boulevard Commercial and Entertainment District, a National Register listed historic district located just south of the Project Site.

Composed of commercial properties from the first half of the 20th Century, contributing properties to the Hollywood Boulevard Commercial and Entertainment District include a wide variety of property types including single-story storefronts, two-story commercial blocks, department stores, theaters, high-rise office buildings and hotels.

The Capitol Records Building is a unique building whose cylindrical form has always been visible from portions of Hollywood and Vine from the south and the freeway from the north. The Capitol Records Tower and the iconic buildings in the Hollywood Boulevard Commercial and Entertainment District (the Hollywood Palace, Pantages Theater, Equitable Building) will maintain their prominence after implementation of the Project.
Portions of the Hollywood Walk of Fame (L.A. Historic Cultural Monument #194) are located along Vine Street between Yucca Street and Sunset Boulevard and will be protected.
The protection of Hollywood's historic resources and unique character is an important objective of the Project. The guidelines and standards contained in this document were created in part to ensure the protection of historic resources within the Project Site and minimize potential adverse affects to historic resources from new development. Key Project objectives regarding historic resources include:

1) Preservation, maintenance, and rehabilitation of the Capitol Records Building and the Gogerty Building in accordance with the Secretary of the Interior's Standards. See sections 1.2.2a and 1.2.2b of this document.

2) Protection and preservation of the portions of the Hollywood Walk of Fame (LA Historic Cultural Monument #194) will need to be temporarily removed during construction and replaced after construction is completed. A preservation plan, outlined in the Hollywood Walk of Fame Terrazzo Pavement and Repair Guidelines (March, 2011) will be prepared for this aspect of the Project.

3) Incorporation of ground-floor open space and building setback requirements to moderate the overall massing of new development in a manner that preserves important views to and from the Capitol Records Building, the Hollywood Boulevard Commercial and Entertainment District, and important view corridors to the Hollywood Hills. See sections 1.2.2 c, 6.1, 6.9, 7.1, 7.5, 8.1 and 8.2 of this document.

4) Incorporation of ground-floor open space and building setback requirements to reduce massing at the street level and limit the visual crowding of adjacent historic resources. See sections 1.2.2c, 6.1, 7.1, 7.5,

8.1 and 8.2 of this document.

5) Requirement that design of new buildings be in a manner that is differentiated from but compatible with adjacent historic resources. See sections 6.6, 6.8, 7.1.5, and 7.4 of this document.

One means of creating compatible new buildings in an urbanized setting is to incorporate qualities of vertical and horizontal visual complexity in world class design. The general characteristics, proportions, and details of older buildings may serve as a reference for the Project. The Project's intent is to allow old and new to mix, recognizing that Hollywood sustains its image through both the rehabilitation of existing historic structures and the design of creative and contemporary architecture.

4. DENSITY

4.1 Floor Area Ratio Averaging and Density Transfer

The Owner may transfer density and buildable floor area from one parcel within the Project Site to another parcel within the Project Site, as long as the minimum and maximum building heights in the Regulations are maintained and the entire Project does not exceed the cumulative, allowable density and floor area of the zoning for the sum of the individual parcels.

To allow for the spatial distribution of the development on the Project Site and ensure relationship and sensitivity with the uses surrounding the Project Site, parking, open space and related development requirements for any component of the Project may be developed in any location within the Project Site.

4.2 Maximum OEGSF Density Per Area

A land use equivalency program ("Equivalency Program") to provide flexibility for a thoughtful range of modifications to the land use and square footages within the West Site and East Site and across the Sites will be developed in connection with the environmental review for the Project and is authorized by the Regulations. The Equivalency Program would permit a transfer of floor area among parcels in the West Site and East Site whereby square footage increases in one land use category can be exchanged for corresponding decreases in other permitted land use categories as long as the environmental considerations of land uses in the ultimate development scenario was analyzed in the Environmental Impact Report for the Project. Rate of conversation between land uses will be based on a maximum office-equivalent gross square feet ("OEGSF") to maintain vehicular trip totals equivalent to and not exceeding those studied in the Environmental Impact Report for the Project. The total density permitted in the West Site and East Site is further limited by the development zones A, B, C and D (see Fig. 5.1).

5. HEIGHT

5.1 Building Height Standards

The Regulations establish heights zones (A, B, C and D) to limit maximum building heights and control bulk in response to the Development Objectives including context with the built environment and to reinforce view corridors to the Capital Records Tower.

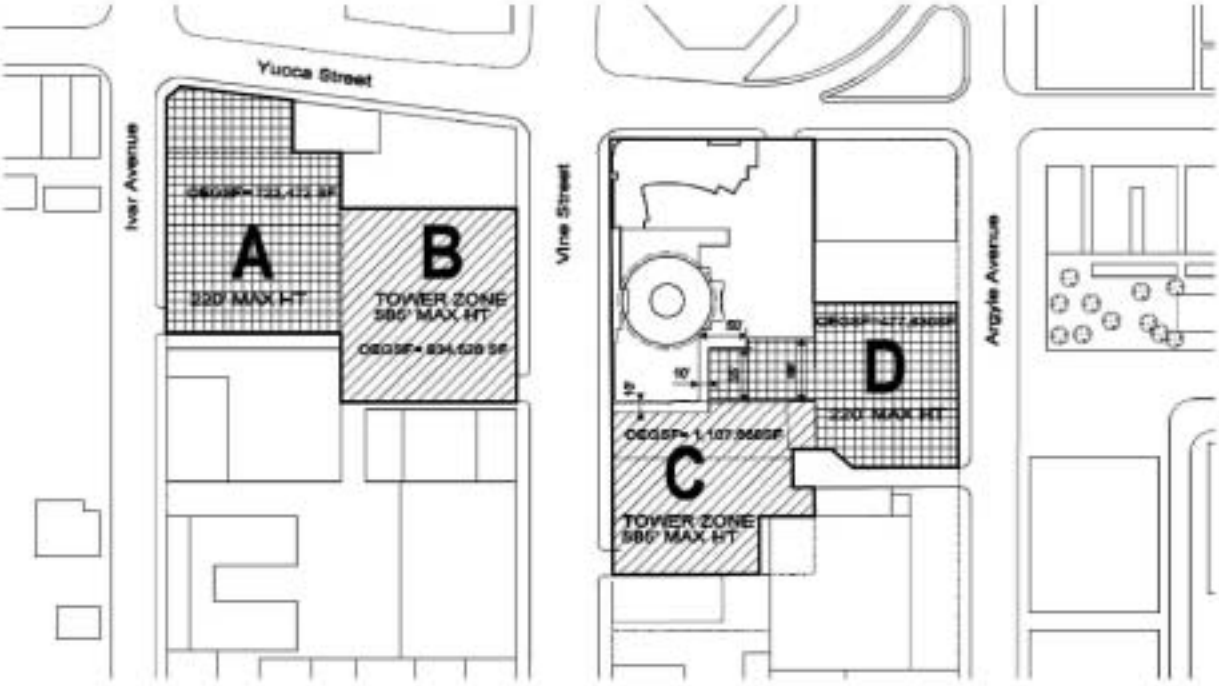


Fig. 5.1 Height Zones

6. BUILDING AND STREET EXPERIENCE

6.1 Tower Massing Standards

6.1.1 The Tower Massing Standards apply to the portion of a building located 150 feet above curb level – see Table 6.1.1.

Tower Height (feet)	Maximum Tower Lot Coverage (%)	Minimum Floor Area Below 220 Feet (%)	Maximum Tower Floor Plate (sq. ft.)	Minimum Tower Setback (feet)	Minimum Public Open Space (%)	Figures
151 – 585	11.5	50	13,325 East Site 9,042 West Site	10 15[1]	12	6.1.2.d.1 6.1.2.d.2
151 – 550	15	50	17,380 East Site 11,794 West Site	10 15[1]	10	6.1.2.c.1 6.1.2.c.2
151 – 400	28	50	22,745 East Site 22,016 West Site	10 15[1]	8	6.1.2.b.1 6.1.2.b.2
150 – 220	48	n/a	55,616 East Site 37,742 West Site	10 15[1]	5	6.1.2.a.1 6.1.2.a.2

Table 6.1.1

Note 1: 15' tower setback required for any tower fronting Vine Street on West parcel. See Figure 6.3.2.

6.1.2 For the purpose of calculating the maximum lot coverage the total lot area is equal to the total lot area for each of the sites, the West Site and the East Site. If there is more than one tower on a site, the maximum lot coverage requirement in Table 6.1.1 is calculated based on the combined area of all towers on each site. The total lot coverage applies to the aggregate floor plate(s) of the tower or towers on each site.

6.1.3 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Figs. 6.1.2.a.1 – 2.)

6.1.4 At least 50% of total floor area must be located below 220 feet.

6.1.5 Tower wall articulation:

a. Minimum 10% of tower aggregate area shall be articulated.

6.1.6 Types of permitted articulations for tower walls:

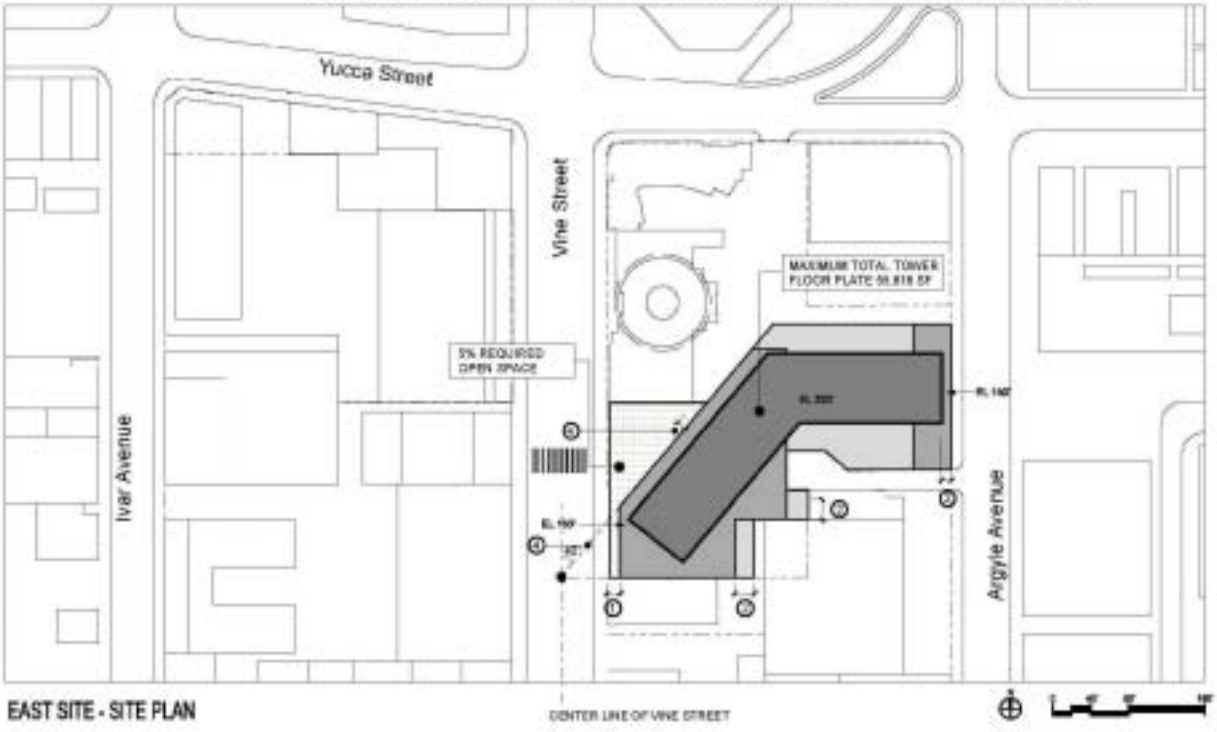
a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

The following developments are for illustrative purposes only.
Maximum Lot Coverage and Tower Floor Plate – Figs. 6.1.2.a – d.



EAST SITE - SITE PLAN

① MINIMUM 10' SETBACK ALONG VINE STREET
② MINIMUM 20' SETBACK ABOVE 150'
③ MINIMUM 10' SETBACK ABOVE 150'
④ 10' EASEMENT FROM CAPITOL RECORDS TOWER

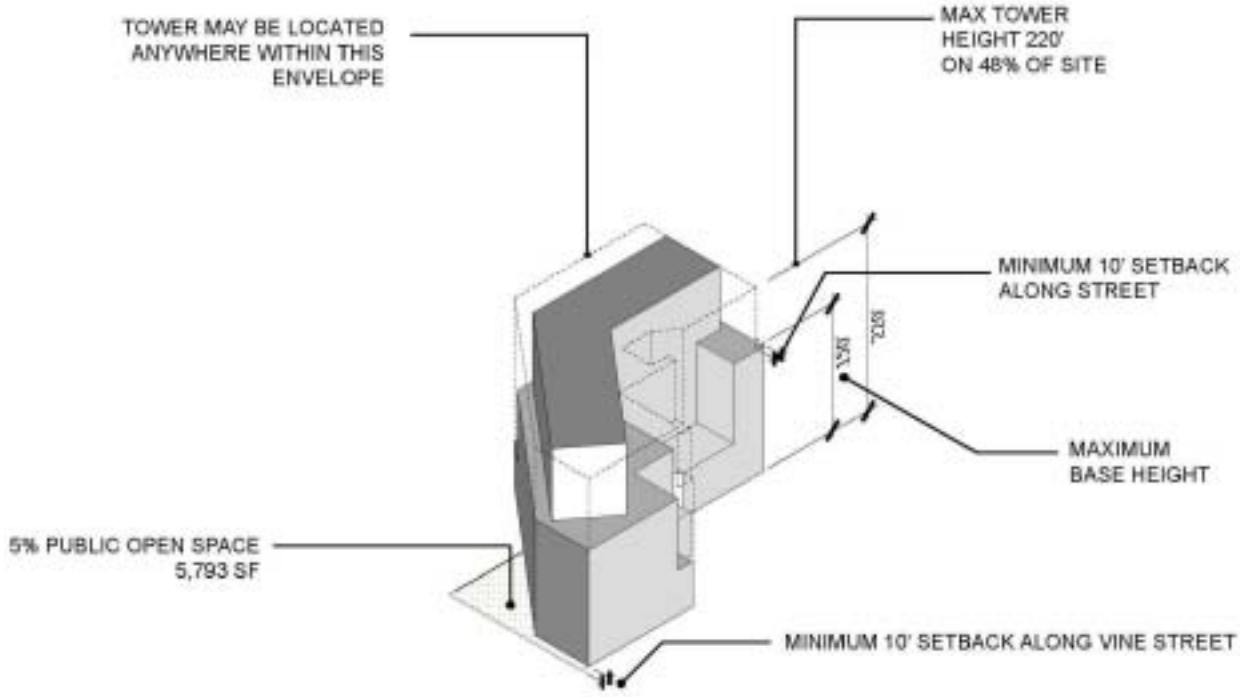
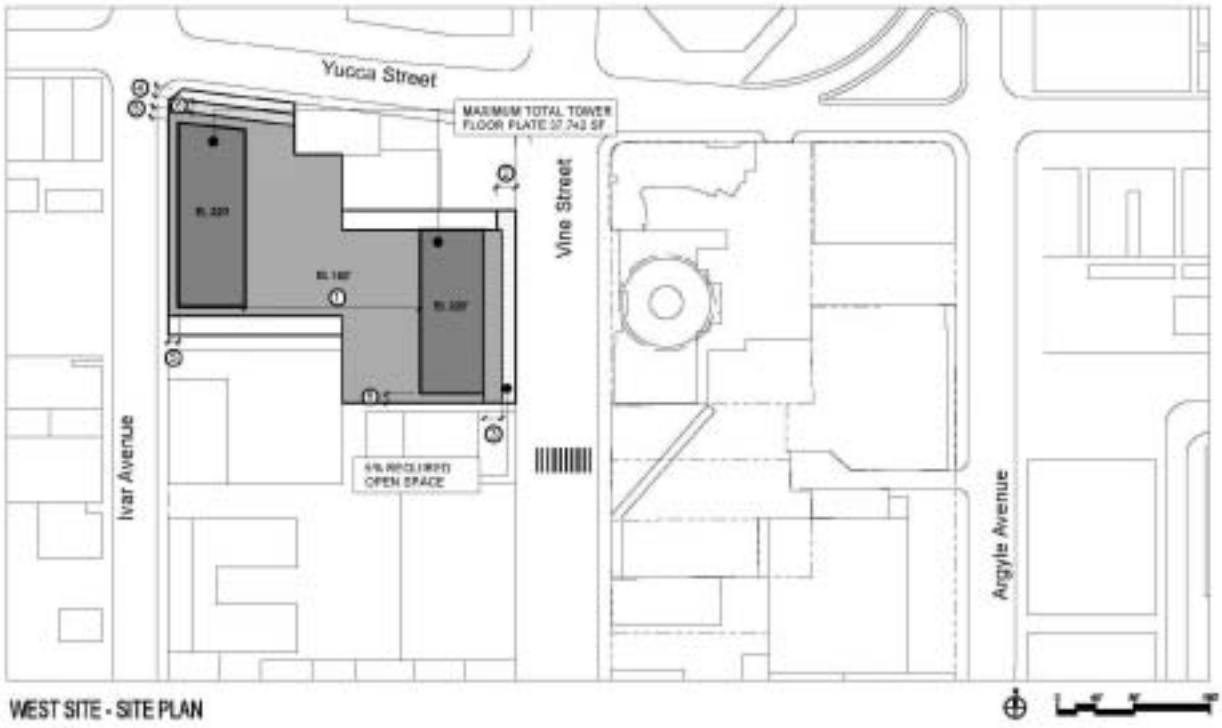


fig. 6.1.2.a.1: East Site – 220 Feet Maximum Tower Height



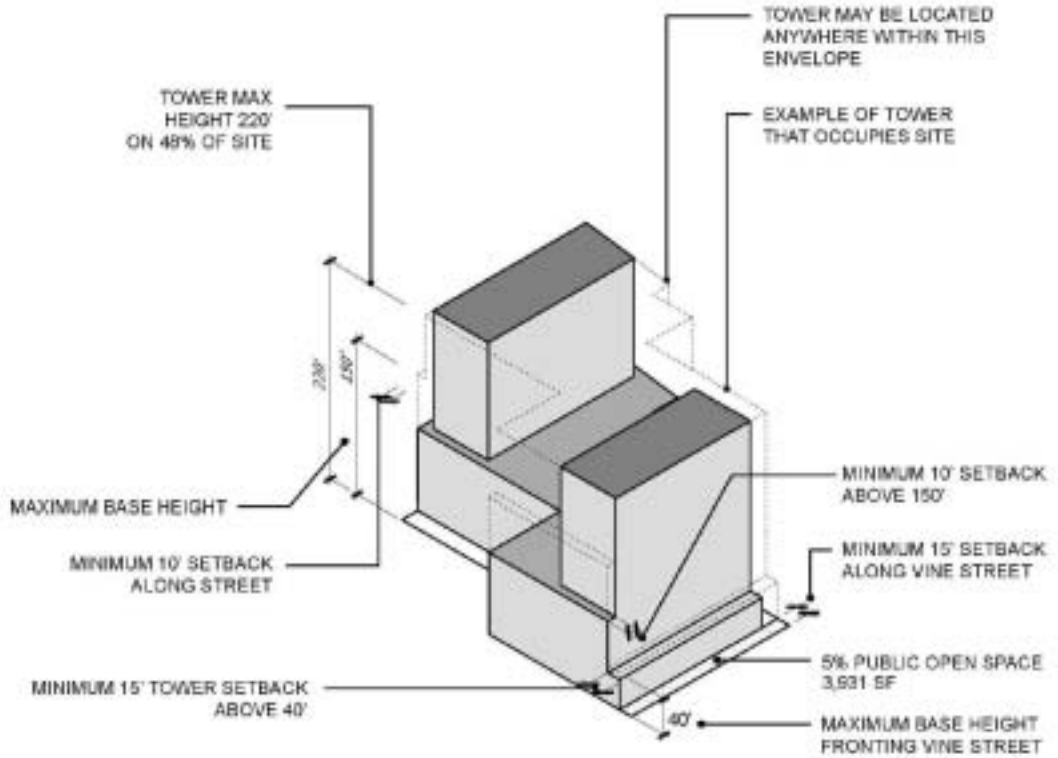
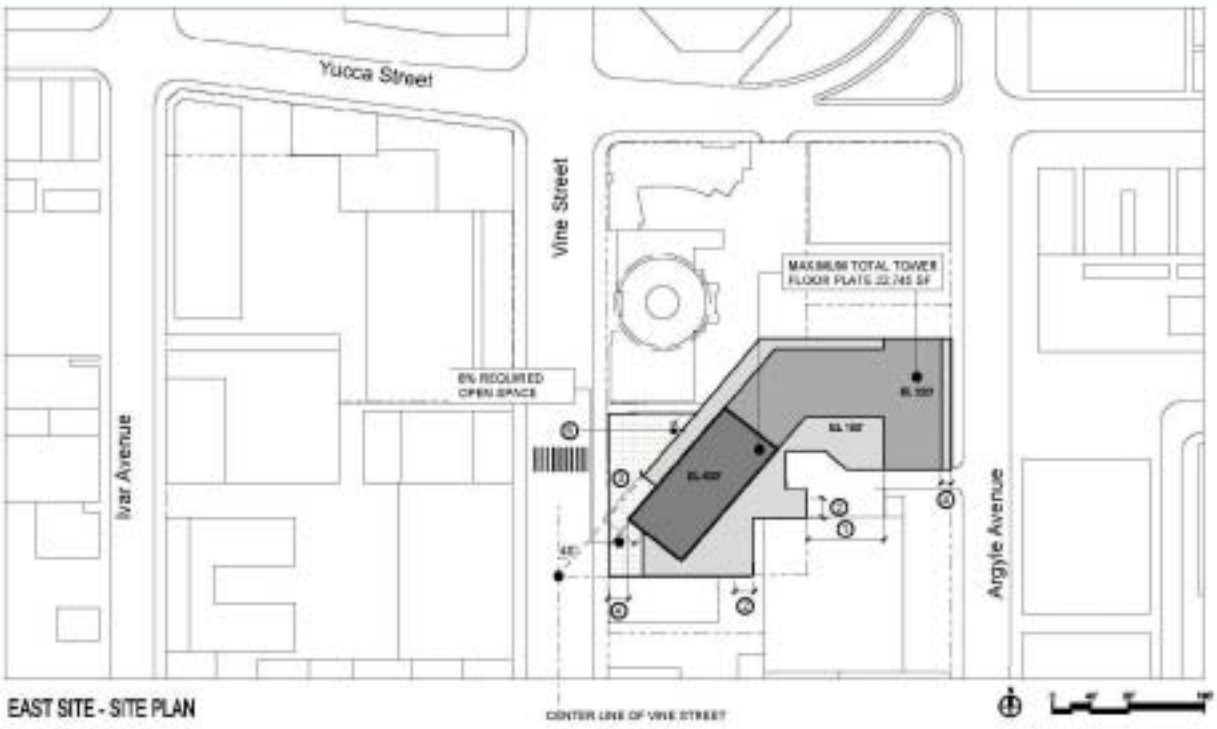


fig. 6.1.2.a.2: West Site - 220 Feet Maximum Tower Height.



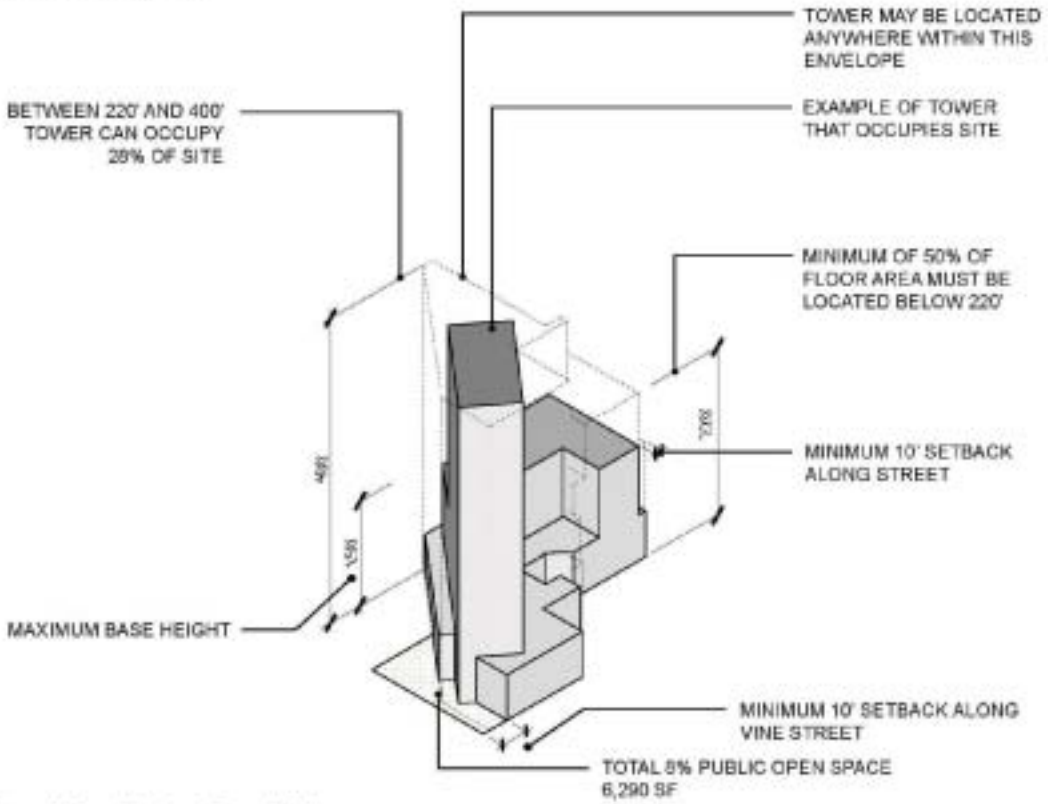


fig. 6.1.2.b.1: East Site – 400 Feet Maximum Tower Height

WEST SITE - SITE PLAN

1. MINIMUM 60' SEPARATION BETWEEN "TOWERS" ON SAME SITE
2. MINIMUM 15' SETBACK ALONG VINE STREET
3. MINIMUM 15' SETBACK ABOVE 40'
4. MINIMUM 10' SETBACK ALONG YUCCA STREET
5. MAXIMUM 40% OF STREET WALL CAN EXCEED MAXIMUM STREET WALL HEIGHT
6. MINIMUM 10' SET BACK ABOVE 150'
7. MINIMUM 10' SET BACK ABOVE 30'

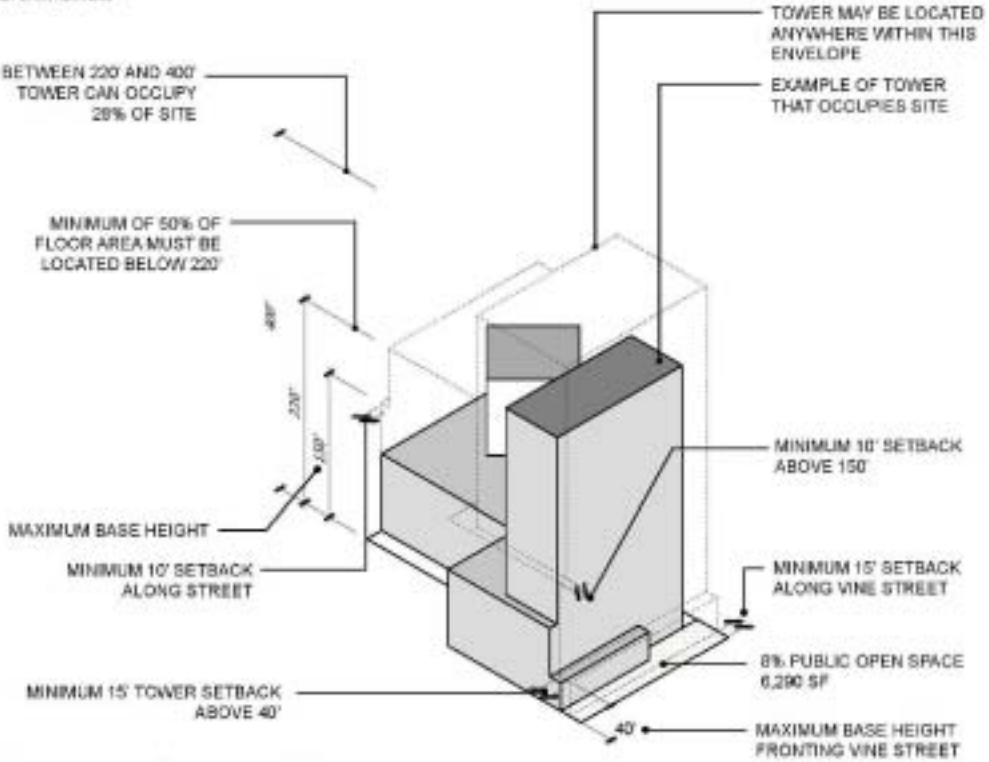
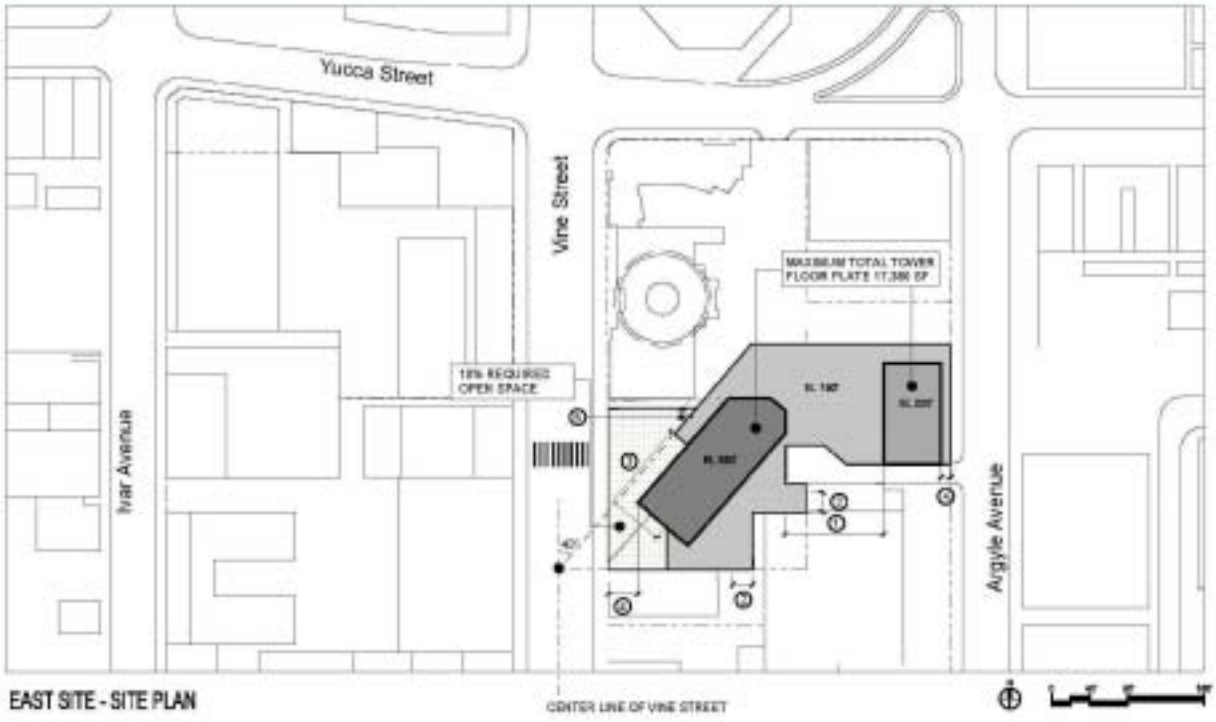


fig. 6.1.2.b.2: West Site – 400 Feet Maximum Tower Height



EAST SITE - SITE PLAN

① MINIMUM 80' SEPARATION BETWEEN "TOWERS" ON SAME SITE
② MINIMUM 25' SETBACK ABOVE 150'
③ MAXIMUM 40% OF STREETWALL CAN EXCEED MAXIMUM STREETWALL HEIGHT
④ MINIMUM 10' SETBACK ABOVE 150'
⑤ 10' EASEMENT FROM CAPITOL RECORDS TOWER

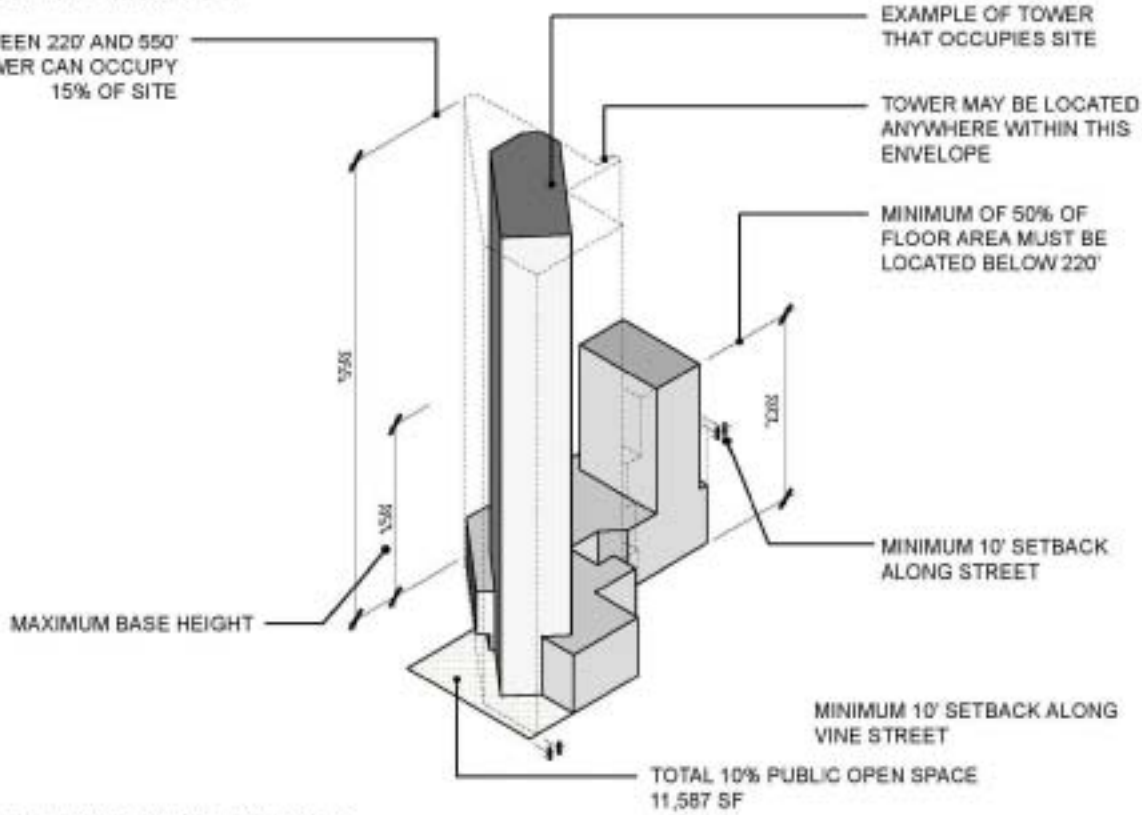
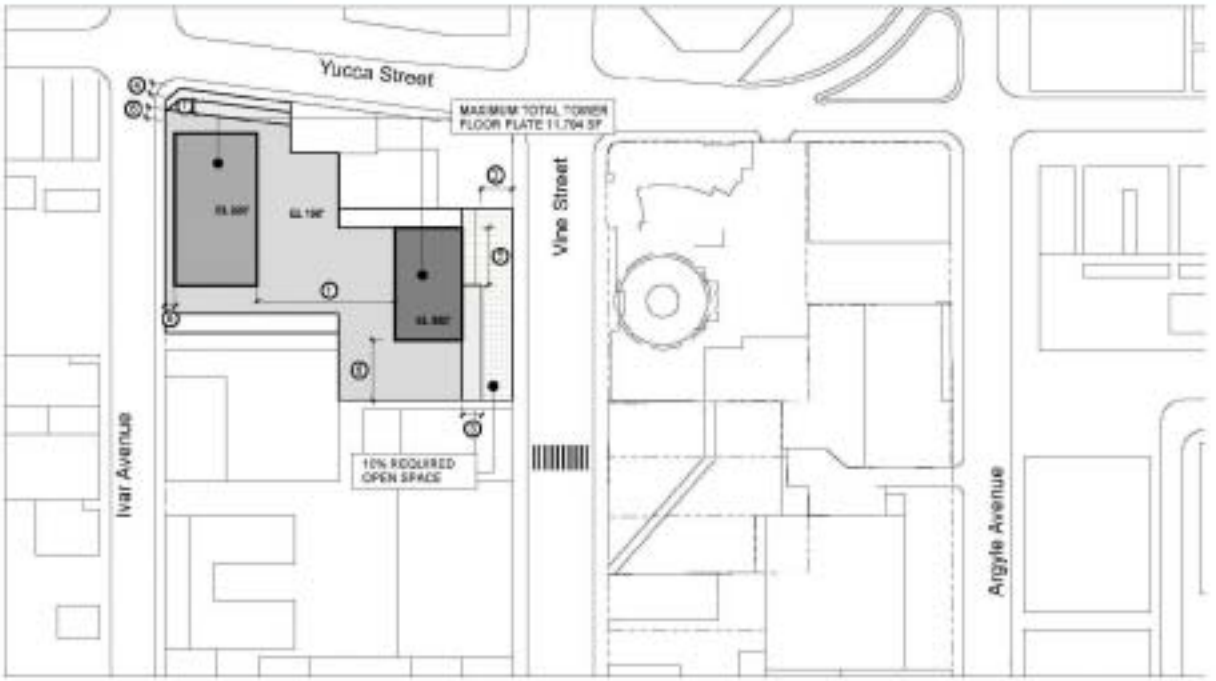


fig. 6.1.2.c.1: East Site – 550 Feet Maximum Tower Height



WEST SITE - SITE PLAN

1. MINIMUM 90' SEPARATION BETWEEN "TOWERS" ON SAME SITE
2. MINIMUM 15' SETBACK ALONG VINE STREET
3. MINIMUM 15' SETBACK ABOVE 40'
4. MINIMUM 10' SETBACK ALONG YUCCA STREET
5. MAXIMUM 40% OF STREET WALL CAN EXCEED MAXIMUM STREET WALL HEIGHT
6. MINIMUM 10' SETBACK ABOVE 156'
7. MINIMUM 10' SETBACK ABOVE 30'

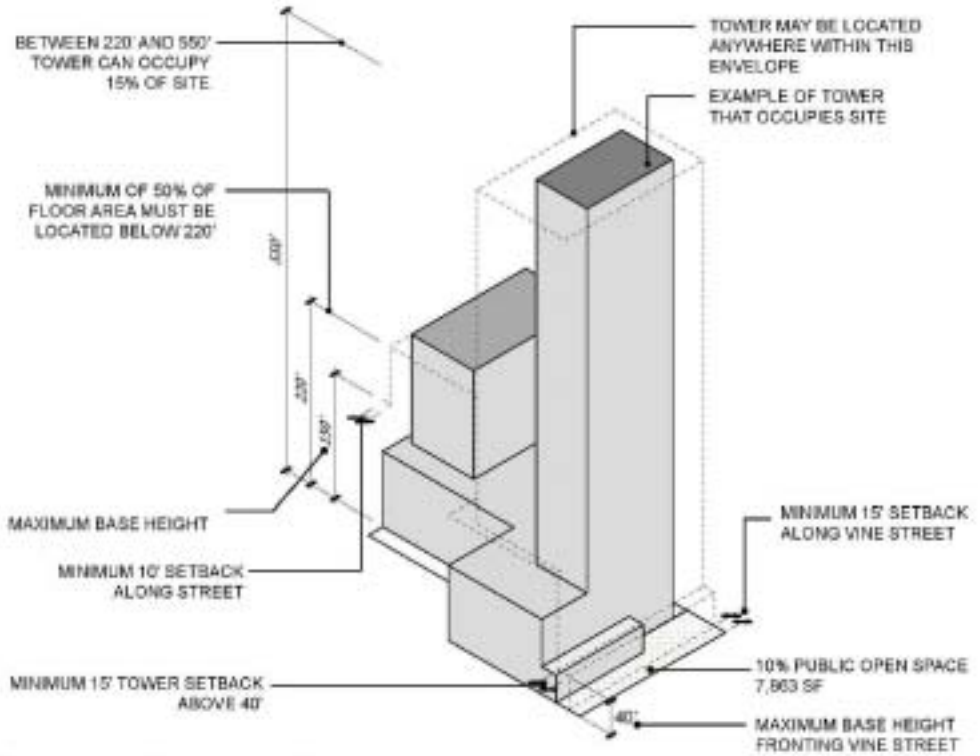
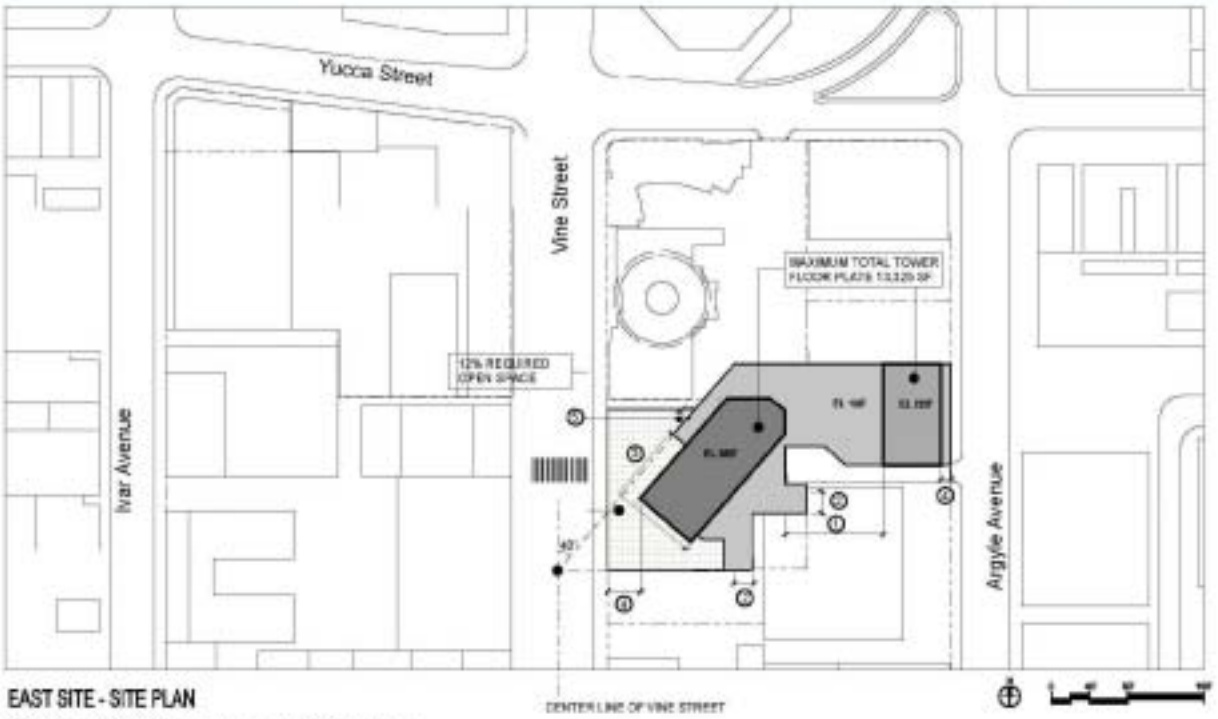


fig. 6.1.2.c.2: West Site – 550 Feet Maximum Tower Height



EAST SITE - SITE PLAN

- (C) MINIMUM 80' SEPARATION BETWEEN "TOWERS" ON SAME SITE
- (E) MINIMUM 20' SETBACK ABOVE 180'
- (F) MAXIMUM 48% OF STREETWALL CAN EXCEED MAXIMUM STREETWALL HEIGHT
- (G) MINIMUM 10' SETBACK ABOVE 180'
- (H) 10' EASEMENT FROM CAPITOL RECORDS TOWER

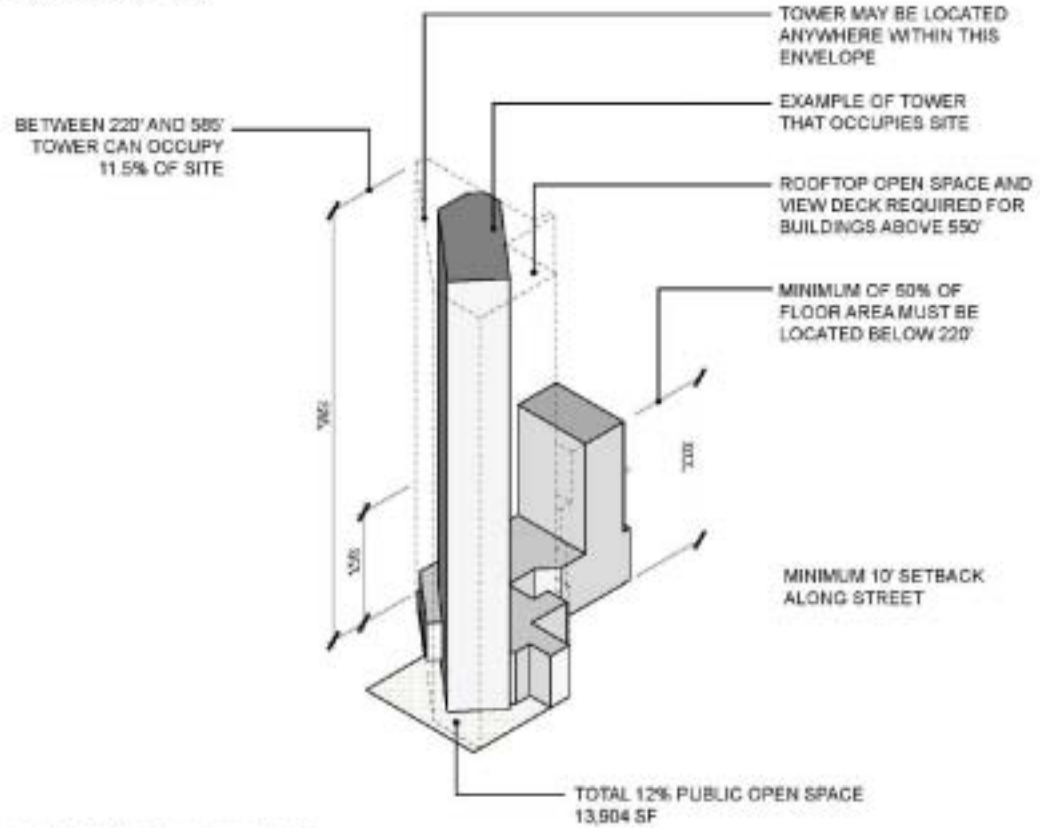
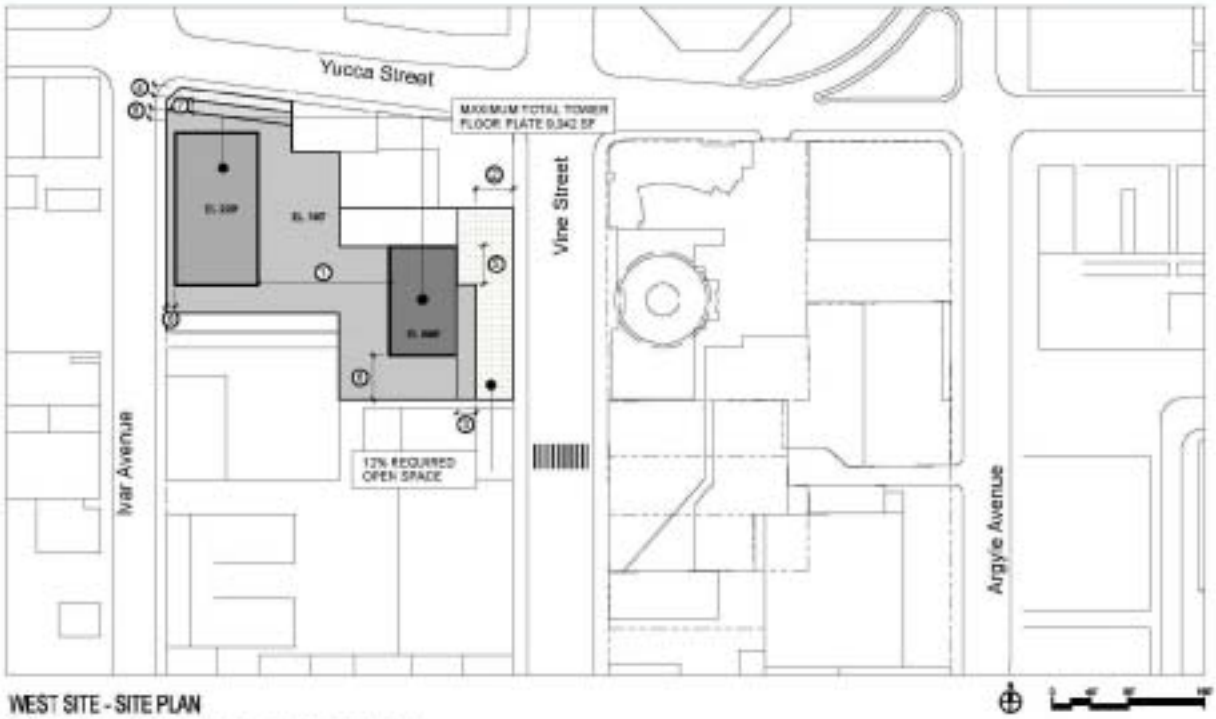


fig. 6.1.2.d.1: East Site – 585 Feet Maximum Tower Height



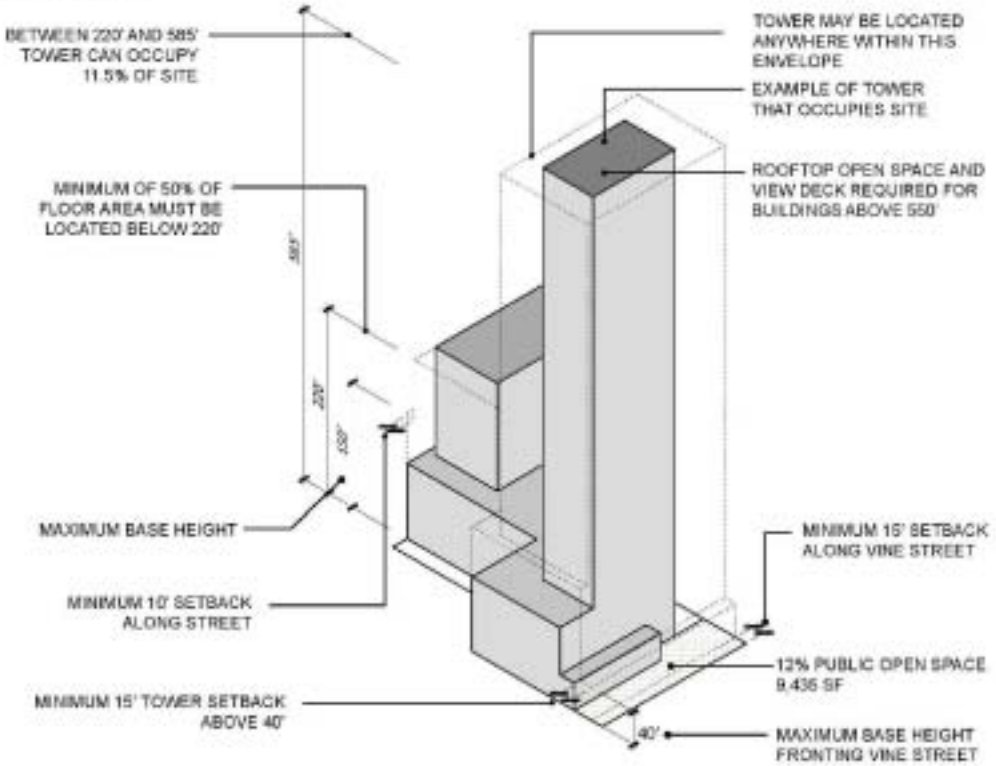


fig. 6.1.2.d.2: West Site – 585 Feet Maximum Tower Height

6.2 Street Walls

6.2.1 A street wall is a wall or portion of a wall of a building facing a street or a grade level open space. Street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation. The street wall shall have proportions and architectural building details which emphasize and reflect the presence and importance of the pedestrian environment. Massing offsets, fenestration, varied textures, openings, recesses, and design accents are strongly encouraged to ensure there are no un-articulated walls and monolithic roof forms, and architectural elements such as balconies, verandas, and porches that add architectural character are encouraged.

6.3 Street Wall Standards

6.3.1 Location of a required street wall:

a. Parcels with a grade level open space: the required street wall shall be located a minimum 10 feet from the property line along Vine Street on the East Site and 15 feet along Vine Street on the West Site.

b. A grade level open space is required for any building fronting Yucca Street with a minimum 10 feet setback from the property line.

c. Parcels or portions of parcels without a grade level open space: the required street wall shall be located on the property line.

6.3.2 Height of required street wall:

a. Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b), (c) and (d) below.

b. Street walls fronting Vine Street on the West Site shall be built to a maximum height of 40 feet above curb level except as noted in item (d) below.

c. Street walls fronting Yucca Street shall be built to a maximum height of 30 feet. Building can extend to a maximum height of 150 feet with a 10 foot setback above 30 feet except as noted in item (d) below.

d. 40% of the aggregate width of the required street wall frontage on each street can exceed the maximum street wall height up to the maximum tower height.

fig 6.3.2: Street Wall

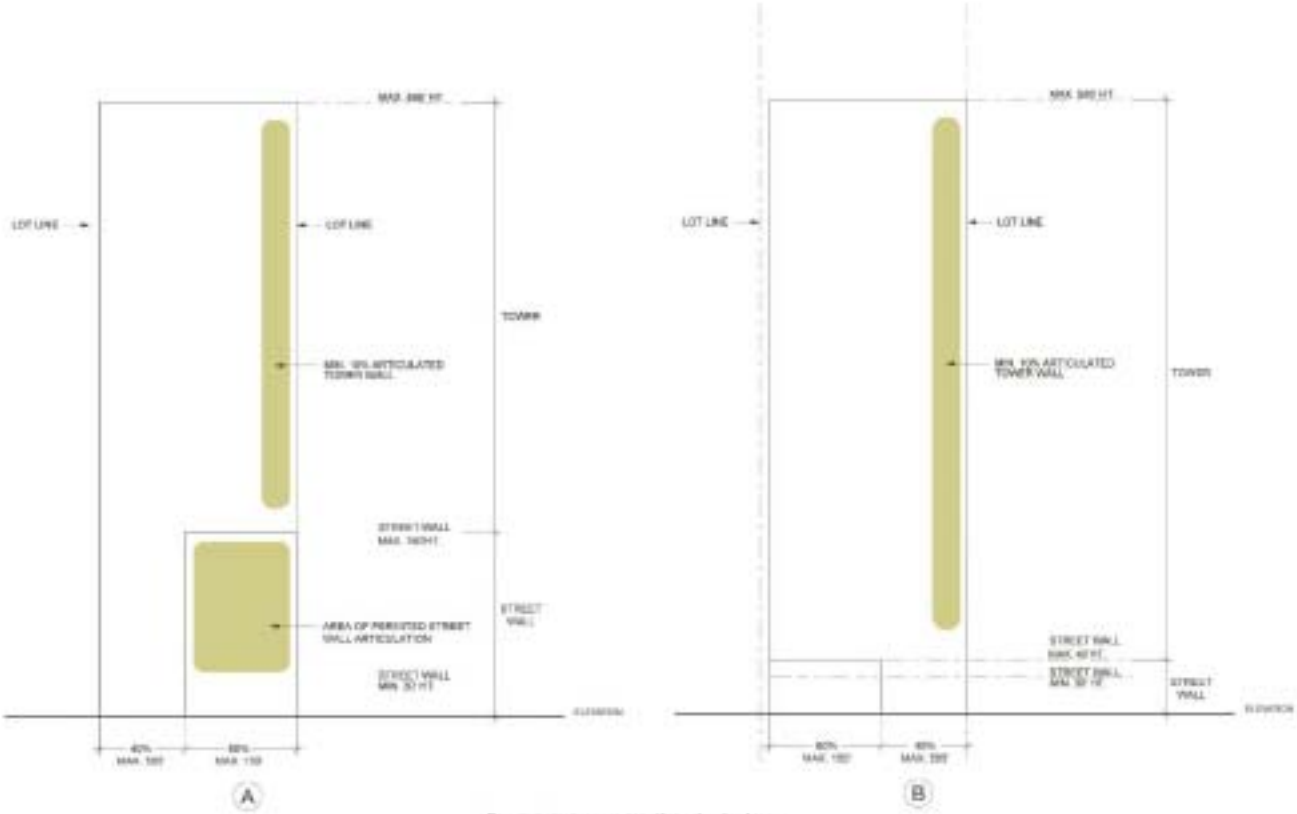


fig. 6.3.3: Street Wall Articulation

6.3.3 Types of permitted articulation of a required street wall:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

6.3.4 Other permitted projections: elements which project beyond the property line from a required street wall shall comply with the Building Code.

a. Architectural facade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required street wall over a grade level open space.

b. Steps and ramps may project from a required street wall over a grade level open space.

c. Commercial marquees, canopies and awnings.

d. Retail storefronts: may project from a required street wall over a grade level open space by a maximum depth of 5'-0'. The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

6.4 Street Wall Guidelines

6.4.1 Pedestrian pass-through areas, public plazas, marquees, canopies, awnings and retail storefronts are permitted within the street wall area.

6.4.2 Pedestrian steps and ramps, entry forecourts, hotel drop-offs and loading entries and exits and vehicular access driveways are also permitted within the street wall area on the Project Site.

6.5 Yard Standards

6.5.1 Yard is an open space other than a court that is unoccupied and unobstructed from the ground upward.

6.5.2 Commercial Use: no front, side or rear yard setbacks are required.

6.5.3 Residential Use:

a. Front Yard: none.

b. Side Yard: Minimum 5 feet; for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.

c. Rear Yard: Minimum 15 feet; for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

6.6 Building Materials and Color Guidelines

6.6.1 The goal of the building materials and colors is to reinforce the character of the Hollywood area and provide a design that is compatible yet avoids any appearance that the building is being historicized. These guidelines will address the façade treatment for both residential and commercial portions of buildings.

a. Buildings shall feature long-lived and sustainable materials. The material palette shall provide variety, reinforce massing and changes in the horizontal or vertical plane.

b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

c. Podium levels up to 150 feet will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents.

d. The architecture of the building shall clearly delineate an architectural style, and shall not appear as a simplified version thereof, with appropriate fenestration patterns, architectural features, proportions and materials.

e. The building's skin, especially for towers, shall be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.

f. In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style. There will be clear contrast between the building's surface material and the building's glazed areas.

g. In general, the overall massing, roof forms, materials, and architectural style of new structures shall provide a variety of forms, depth and texture, and encourage a cohesive character. Building massing shall include a variation in wall planes and height as well as roof forms to promote architectural excellence, a pedestrian friendly environment and take into account the context.

h. To provide visual variety and depth, the building skin shall be layered and designed with a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin shall reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

i. Rooftop mechanical equipment screening shall be designed to be integral with the building architecture and the visual impact shall be minimized by using materials that are complimentary or consistent with the building.

j. Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

6.7 Grade Level Standards

6.7.1 The purpose of the grade level standards is to promote pedestrian-scaled architecture by regulating street wall massing, articulation and detail, street level entrances and storefront windows and doors, as well as the use of quality materials and decorative details. Architectural features that reinforce the retail character of the ground floor street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and shall be integral to the architecture of the building.

6.7.2 Ground floor height:

a. Minimum 12'-0" height measured from floor to ceiling.

6.7.3 Building entrances:

a. The primary entrance to a street level tenant space that has frontage along a public street shall be provided from that street. The primary entrance to a tenant space that does not have its frontage along a public street shall be provided from a courtyard, *grade level open space*, or *publicly accessible passageway*. Entries less than 18 inches from the property line shall not be higher than 12 inches above the elevation of the sidewalk; entries greater than 18 inches from the property line shall be within 30 inches of the adjacent grade level along street frontages. Where possible entries shall be marked using architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

b. All retail spaces shall be accessed primarily from a ground floor, single-tenant entry along a street, plaza or passageway. Where reasonably practical given architecture and tenant requirements, access to different tenant spaces shall occur at a maximum interval of 60 feet.

c. Main building entrances shall read differently from retail storefronts, restaurants and commercial entrances which could include but are not limited to material change, architectural elements or elevation change.

d. In addition to the building's required primary entrance(s), there may be ancillary entrances to the building from parking garages.

6.7.4 Ground Floor Glazing

a. Use of clear, colorless and transparent glazing is required within the first 30 feet above curb level.

b. Use of reflective glass is prohibited.

c. Along street frontages with a required build-to line less than or equal to 18 inches from the property line, glazing shall constitute a minimum of 30% of the area of a building face and shall not exceed 80% of the area of a building face.

6.7.5 Arcades

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0-foot candles.

6.7.6 Service and Refuse Requirements

Hotel and Commercial / Office / Retail that abuts an alley

a. Every required loading space shall be located and arranged such that delivery vehicles may be driven upon or into said space from an alley. Such loading space shall have a minimum height of 14 feet and be accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

b. Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.

c. Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet; a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet; and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

Condominiums (Residential)

d. None

Rental (Residential)

e. None

6.7.7 Service and Refuse Guidelines

a. Storage areas shall be provided within the building of a size sufficient for the development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible from a curb cut.

b. Service, utility, and mechanical functions, including retail loading, shall be located in alleys whenever present. When alleys are not present, service functions shall be placed within buildings.

c. Service, utility, and mechanical equipment that is visible from the street shall be screened from view with landscaping or enclosures. Back flow and fire standpipes, along with utility box transformers, shall be screened.

d. All screening devices shall be compatible with the architecture, materials and colors of adjacent buildings.

e. Trash and storage enclosures shall be architecturally compatible with the project design and landscaping shall be provided adjacent to the enclosure(s) to screen them and deter graffiti.

f. Trash enclosures and retail loading areas shall be sited to minimize nuisance to adjacent properties.

g. The location of trash enclosures shall be easily accessible for trash collection and should not impede general site circulation patterns during loading operations.

h. Mechanical equipment shall vent to an alley wherever possible.

i. Roof-vent penetrations and mechanical equipment shall be located at least 10 feet from any exterior Building Face.

j. Gutters and downspouts shall be made of galvanized steel, copper (not copper coated), or aluminum.

6.7.8 Storefronts

a. Storefront (residential, retail, restaurant and commercial) requirements shall include frontage along streets and grade level open spaces.

b. Storefronts shall comprise a minimum of 70% of the building's street level façade along Vine Street and 40% along all other streets and be recessed where necessary.

c. Storefront glazing shall comprise a minimum of 60% of the storefront area along Vine Street and 40% glazing along all other streets.

d. All retail space shall have a minimum 12 feet finished ceiling clearance.

e. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet. Storefront sills shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

f. Storefront openings shall be no shorter than 12 feet above the adjoining grade for 90% of the required storefront frontage.

g. Security grilles will be located behind glass and be at minimum 70% open.

h. At-grade storefront glazing at, or adjacent to, and/or facing any public right-of-way shall incorporate transparent, clear, colorless glazing with no reflectivity.

i. Awnings shall not obscure storefront signage. Vinyl awnings are not permitted.

6.8 Podium Standards

6.8.1 The purpose of the Podium Standards is to provide a modern interpretation of the historical context of Hollywood by establishing different treatment of the building's base, middle and top

through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

6.9 Podium Guidelines

6.9.1 Podiums shall have fenestration that establishes a clear pattern on the façade (with special attention paid to facades that are visible from a public street) and that provides depth and additional articulation.

6.9.2 An identifiable break between the building's ground floors and upper floors shall be provided. This break may include a change in material, change in fenestration pattern or similar means.

6.9.3 Podium level windows shall be vertically oriented.

6.9.4 Podium levels shall be predominantly light in color.

6.9.5 An expression band shall be provided at the highest story within the podium.

6.9.6 While blank street wall façades shall be avoided, an exception may be made for integration of public art or an articulated façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade shall be a maximum of four floors high, and shall have variation in its surface plane (using cutouts, insets or pop-outs). It shall employ different scales of elements as viewed when seeing the entire building massing.

6.9.7 Louvers and wall openings shall be designed to integrate with building architecture.

6.10 Street and Sidewalk Standards

6.10.1 The Site is comprised of a variety of public elements that include open spaces, streets and sidewalks. The Hollywood Walk of Fame is an integral element that fronts open spaces on both East and West Sites. Its adjacency to the public plazas requires compatibility and cohesiveness.

6.10.2 The combination of landscaped plazas, publicly accessible passageways and landscaped streets and sidewalks creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

6.11 Screening Standards

6.11.1 Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

6.11.2 Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

7. TOWERS

7.1 Purpose

7.1.1 Towers shall have their massing designed to reduce overall bulk and to appear slender.

7.1.2 Towers shall be designed to achieve a simple faceted geometry and exhibit big, simple moves. They shall not appear overwrought or to have over-manipulated elements.

7.1.3 Towers that emulate a more streamlined modern style shall provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.

7.1.4 If a project has more than one tower, the towers shall be complementary to each other and employ a similar architectural design approach.

7.1.5 Generally, buildings over 150 feet tall (the historic datum for Hollywood) shall not be historicized. They are contemporary forms in the skyline and shall appear as such.

7.2 Projections

7.2.1 The following building elements and operations equipment can project beyond the maximum permitted building height:

a. Roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building;

b. Skylights, towers, steeples, flagpoles, water tanks, silos;

c. Wireless masts; and

d. Solar energy devices and similar structures.

7.2.2 Permitted building elements or equipment in Section 7.2.1 shall be screened as practical and based on building design except if such projections – e.g., flagpoles or steeples – are part of the architecture or design. The use of creative materials and forms for screening is encouraged.

7.2.3 Enclosures for bulkheads shall not count against building height.

7.3 General Standards

7.3.1 A tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

7.3.2 Distinctive tower crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

7.3.3 Towers shall be set back from maximum street wall height a minimum of 10 feet except for towers fronting Vine Street on the West site, these towers shall be setback 15 feet from the maximum street wall height.

7.3.4 Towers shall be setback on West Site from shared property line with Hollywood Playhouse a minimum of 10 feet above 150 feet.

7.4 Wall Standards

7.4.1 All walls are required to be articulated.

7.4.2 The following types of articulation of a tower wall are permitted:

a. Recess;

b. Standard balconies may be projecting or recessed or a combination of both; and

c. Bay windows.

fig. 7.4.2.a: Balcony/Recess

fig. 7.4.2.b: Bay Window

7.4.3 Balcony: a balcony shall be integral to the façade (see figs. 7.4.3.a and b) and shall not create a relentless horizontal and vertical stacking pattern. Balconies are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations and shall be a minimum 75% *transparent*. Balconies are encouraged on buildings facing major public spaces such as plazas, passageways and open spaces. Long balconies resembling corridors are prohibited.

fig. 7.4.3.a: Recess/Balcony: Integral Balcony

fig. 7.4.3.b: Bay Window: Integral Balcony

7.5 Spacing Standards

7.5.1 If two towers are located on a single site the towers shall be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

7.5.2 Generally, any portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except for the following which will meet Planning Code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled. See fig. 7.5.2.

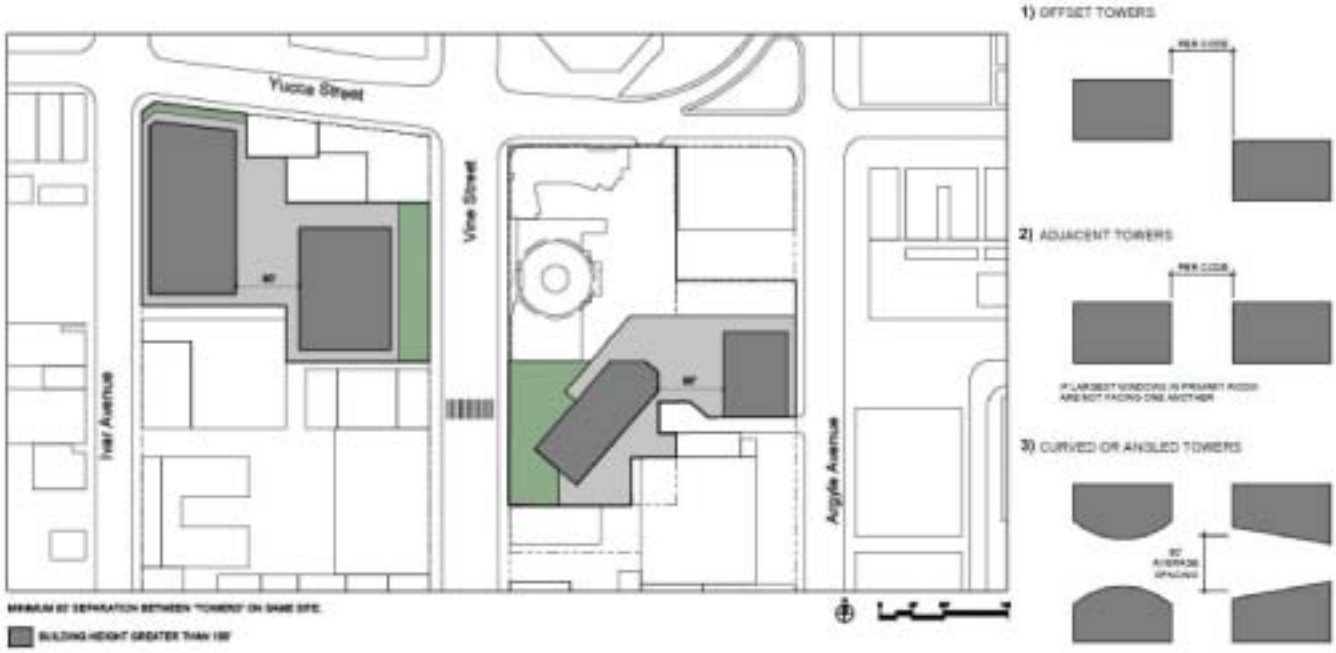


Fig. 7.5.2: Tower Spacing

7.5.3 Since a tower is defined as any building above 150 feet, all buildings above 150 feet shall be spaced at least 80 feet from any portion of any adjacent or separate building on the site, exceeding 150 feet, excluding a project within the height range of 150 to 220 feet, as shown in figures 6.1.2.a.1 and 6.1.2.a.2.

7.5.4 Spires, signage, parapets, and mechanical enclosures are excluded from the tower spacing regulations.

7.6 Rooftops Guidelines

7.6.1 Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and be visually attractive when viewed from locations adjacent and above.

7.6.2 For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section 8.5.

7.6.3 All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors.

7.6.4 All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

7.7 Parapets, Handrails, Roof Mechanical Equipment Screening Standards

7.7.1 Parapets and handrails shall be finished in a distinctive manner if part of an expression band or expression line.

7.7.2 Materials and design for roof mechanical equipment shall be consistent with the building architecture and shall utilize similar colors and materials as in other portions of the building.

7.7.3 Roof mechanical equipment shall be screened.

8. OPEN SPACE

8.1 Overview

The development of open space is an important objective for the overall Project design. Open space will be used to enhance the experience of the visitor and resident. Open space also will enable important pedestrian linkages and through-block connections for the Project. Grade level open space also will be designed to showcase the Capital Records Building and Jazz Mural and will include design features and outdoor furniture to activate the ground floor amenities.

This section sets forth the standards and guidelines for all open space areas for the Project: areas to be accessible to the public (Grade Level Open Space, Publicly Accessible Passageways and Rooftop Open Space) and areas to be designed for the residential uses (Common Open Space and Private Open Space).

8.2 Grade Level Open Space Standards

8.2.1 Grade level open space is a continuous open space fronting the street and open to the sky. The purpose of a grade level open space is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records Building and accentuate the low scale character.

8.2.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Fig. 6.1.2.a.1 – 2)

8.2.3 An additional 3% of open space (total 8%) shall be required for buildings between 221 feet and 400 feet. (See Fig. 6.1.2.b.1 – 2)

8.2.4 An additional 5% (total 10%) of open space shall be required for buildings between 401 feet and 550 feet (See Fig. 6.1.2.c.1 – 2)

8.2.5 An additional 7% (total 12%) of open space shall be required for buildings taller than 550 feet. (See Fig. 6.1.2.d.1 – 2)

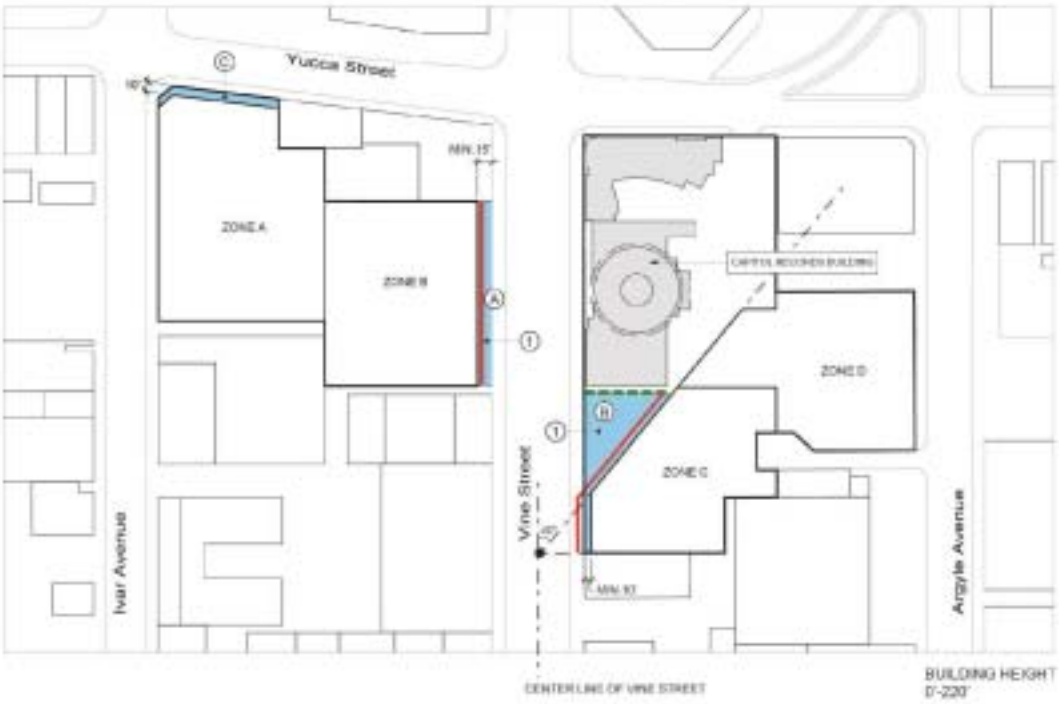
8.2.6 Location

a. East Site: adjacent to the Jazz Mural and Capitol Records Building; West Site: across from the Capitol Records Building along Vine Street and along Yucca Street.

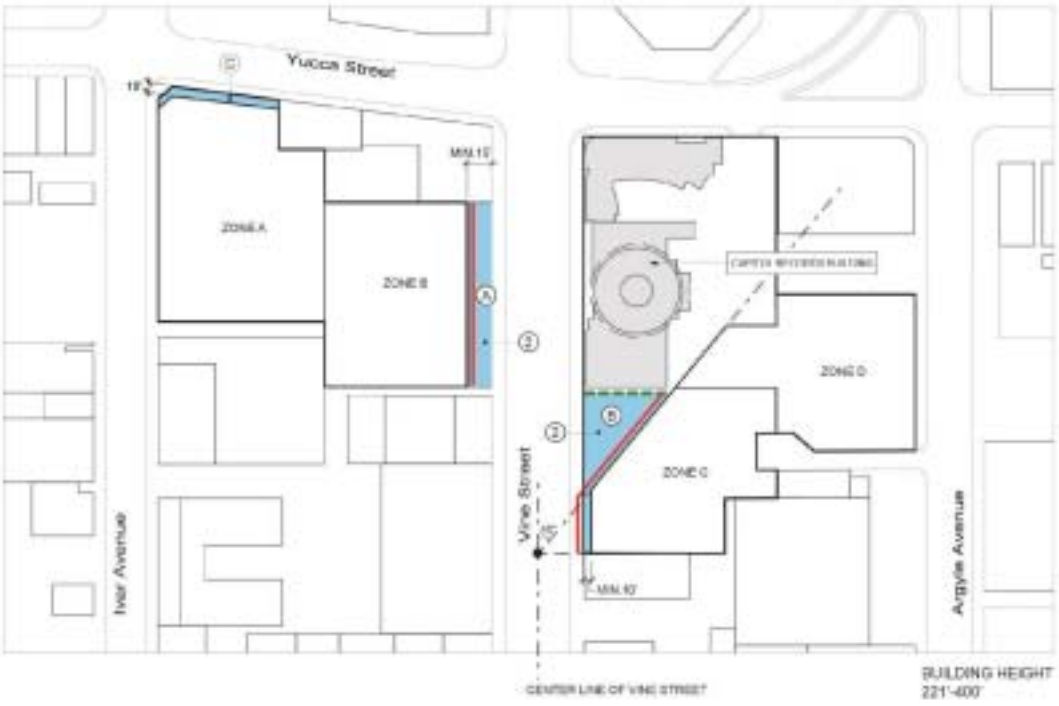
b. Minimum depth: no horizontal dimension less than 10 feet when measured perpendicular from any point on each of the boundaries of the open space area. Open space on West Site fronting Vine Street shall have a horizontal dimension no less than 15 feet when measured perpendicular from any point.

Figs 8.1.1 – 8.1.4: Grade Level Open Space

figs 8.1.1 Open Space Requirements for Maximum Building Height at 220 Feet

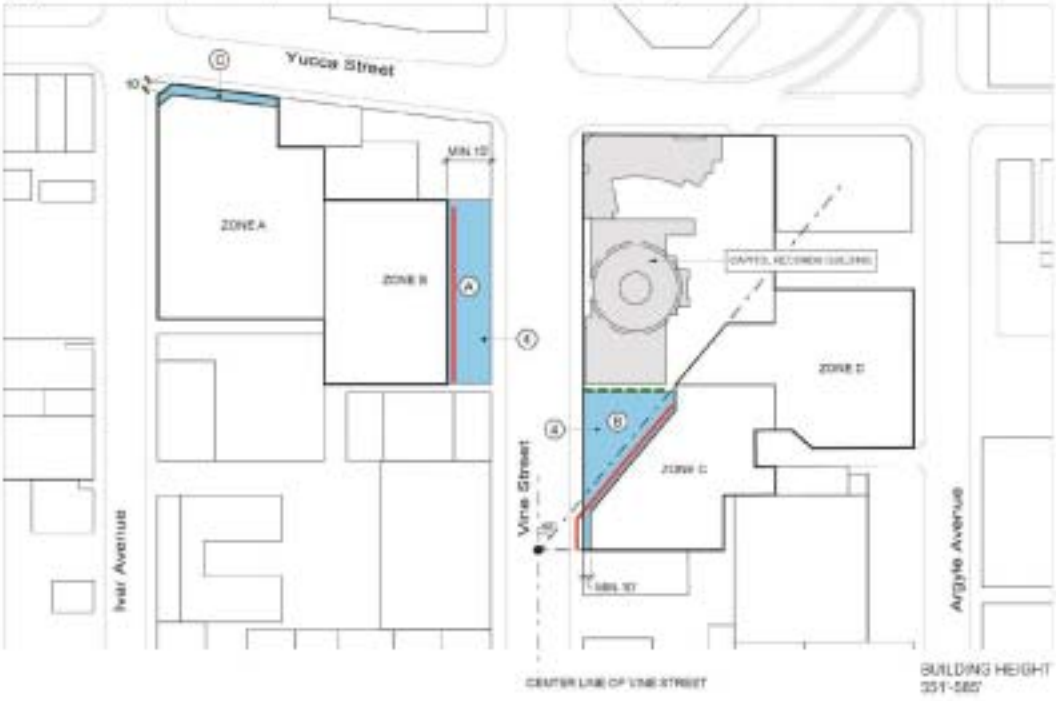


figs 8.1.2 Open Space Requirements for Maximum Building Height at 400 Feet



figs 8.1.3 Open Space Requirements for Maximum Building Height at 550 Feet

figs 8.1.4 Open Space Requirements for Maximum Building Height at 585 Feet



Ⓐ OPEN SPACE REQUIRED ACROSS FROM CAPITOL RECORDS BUILDING ALONG VINE STREET

Ⓑ OPEN SPACE REQUIRED ADJACENT TO JAZZ MURAL

Ⓒ OPEN SPACE REQUIRED FRONTING YUCCA STREET

JAZZ MURAL

STREET WALL

OPEN SPACE

① MINIMUM 4% OPEN

② MINIMUM 8% OPEN

③ MINIMUM 10% OPEN

④ MINIMUM 12% OPEN

8.3 Passageway Standards

8.3.1 *A publicly accessible passageway* is a continuous through-block public connection between two parallel streets, located on privately owned land. The passageway may be either enclosed or open to the sky or a combination of both.

8.3.2 Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

8.3.3 Location and Size standards:

a. The major portion of a *publicly accessible passageway* is the largest area of the *passageway* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total passageway area and shall not be less than 20'-0" wide.

b. Minor portions of *publicly accessible passageway* are secondary areas that allow for additional flexibility in the shape and configuration of a passageway. Minor portions shall not occupy more than 25 percent of the total area of the *passageway*. The minor portion shall have a minimum width of 10 feet.

c. The minor portion must be directly adjacent to the major portion.

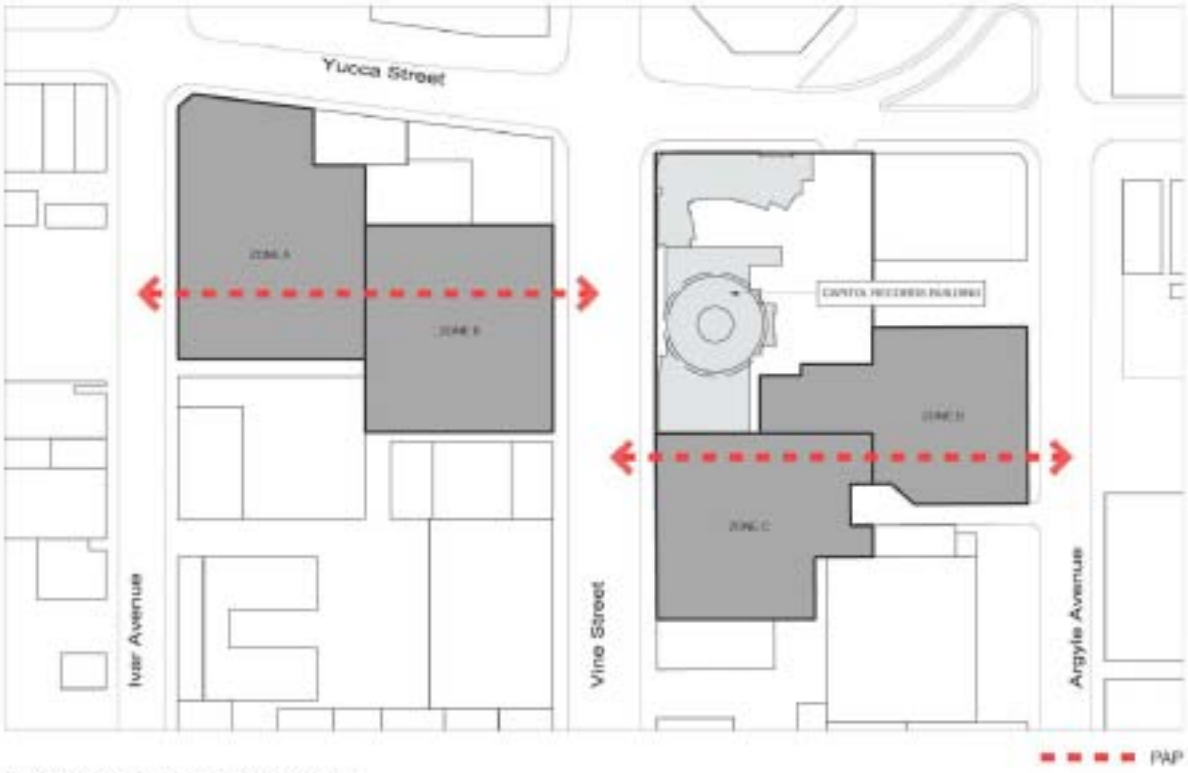


fig. 8.3.3: Publicly Accessible Passageway

8.3.4 Permitted Obstructions:

a. The minimum percentage of *publicly accessible passageway* area to be open to the sky (East and West Sites combined) shall be as follows:

(i) Development with maximum building height of 150 feet: 0%

(ii) Development with maximum building height of 220 feet: 20%

(iii) Development with maximum building height of 400 feet: 30%

(iv) Development with maximum building height of 550 feet: 40%

(v) Development with maximum building height of 585 feet: 50%

b. Permitted obstructions within the major portion of an open air *publicly accessible passageway* are any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open-air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions; balconies and bay windows; awnings, canopies and marquees; stairs, ramps

fig. 8.3.4: View from Argyle Avenue Along PAP Towards Capitol Records

and bollards.

8.3.5 Kiosk:

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Building and Safety in conformance with the Building Code. Kiosks, including roofed areas, shall not count as floor area, exceed 3% of the total area of the *publicly accessible passageway*, or occupy an area of more than 250 square feet.

b. A kiosk may be freestanding or may be attached on only one side to a wall of the building.

c. Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, and food preparation for open-air cafes, flower stands or public service/information booths.

d. All kiosks greater than 250 square feet are permitted but will count as floor area.

8.3.6 Open-Air Café:

a. Where an open-air cafe is provided it shall be an unenclosed restaurant or open-air seating for an enclosed restaurant, eating, or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies.

b. An open-air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the *publicly accessible passageway*. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers.

c. An open-air cafe may occupy an aggregate area not more than 20% of the total area of the *publicly accessible passageway*. No cooking equipment shall be installed within an open-air cafe. Cooking equipment may be contained in a kiosk adjoining the open-air cafe. An open-air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

8.3.7 Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on the *publicly accessible passageway* through open windows.

8.3.8 Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No building refuse storage areas or refuse storage from a kiosk or open-air café are permitted on any *publicly accessible passageway*.

b. No exhaust vents are permitted on any *publicly accessible passageway* or on any building wall of the development fronting upon the passageway except where such vents are more than 10'-6" above the level of the *passageway*.

8.3.9 Frontages:

a. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a *publicly accessible passageway* shall be allocated for occupancy by permitted retail, restaurants and cultural uses.

b. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the *publicly accessible passageway* with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

8.3.10 Maintenance:

a. The building owner shall be responsible for the maintenance of the *publicly accessible passageway* including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the passageway and in the street sidewalk area adjacent to the passageway.

b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of *publicly accessible passageway* area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of *passageway* in connection with outdoor eating services or other uses permitted on *passageway* which generate litter.

8.4 Roof-top Open Space

8.4.1 Buildings above 550 feet shall include roof-top open space.

8.4.2 Roof-top open space shall include an observation area (i.e., viewing deck) accessible to the public.

8.4.3 Roof-top open space may include a café.

8.5 Residential Common Open Space

8.5.1 Common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above. The publicly accessible passageway cannot be used to meet the residential common open space requirements.

8.5.2 Common Open Space Standards

a. Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.

b. Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein.

c. Open space shall be open to the sky and have no structures that project into the common open space area, except as permitted in the Zoning Code.

d. Common open space shall be readily accessible to all the residents of the Site.

e. Common open space shall have a minimum area of 400 square feet with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

f. Common open space shall constitute at least 50% of the total required usable open space in the built development.

g. Common open space areas shall incorporate recreational amenities including but not limited to swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

h. Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use may be considered as common open space.

i. Refer to LAMC 12.21.G for additional open space requirements.

8.6 Residential Private Open Space

8.6.1 A private open space area is an area contiguous to and immediately accessible from a single dwelling unit.

8.6.2 Residential Open Space Standards:

a. Private open space shall contain a minimum area of 50 square feet, of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.

b. Private open space shall have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

c. Private open space shall provide a minimum eight-foot vertical clearance under any projection, except as permitted in the Zoning Code.

d. That portion of a balcony which extends or projects into a required front yard in compliance with Zoning Code may qualify as usable open space provided it meets each of the above specified requirements noted in items a-c.

9. LANDSCAPE

9.1 Grade Level Open Space Standards

9.1.1 Planting requirements: a minimum of 10% of grade level open space shall be landscaped with softscape or water features.

9.1.2 Landscaped area(s) shall be planted with seasonally diverse plant material and 30% of all landscaping shall be California Natives or drought tolerant.

9.1.3 The landscaped portion of open space may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.1.4 The minimum soil depths for planting are:

a. Trees: 42"

b. Shrubs: 30"

c. Lawns, ground cover: 18"

9.1.5 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.1.6 Permitted obstructions: the following are permitted obstructions which may occur in the *grade level open space*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining, and retail storefronts.

9.1.7 Open-air *publicly accessible passageways* are not to be included in the grade level open space requirements.

9.2 Common Open Space Standards

9.2.1 A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

9.2.2 At least one 36-inch box tree for every four dwelling units shall be provided on-site and may include street trees in the parkway, sidewalks adjoining the property, open space, *publicly accessible passageway* and common roof decks.

9.2.3 For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

9.2.4 All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

fig. 9.3.a: Movable Seating

fig. 9.3.b: Open Air Café

9.3 Standards For Open Air Portions of Publicly Accessible Passageway

9.3.1 The landscaped portion of open air passageways may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.3.2 The minimum soil depths for planting are:

a. Trees: 42".

b. Shrubs: 30".

c. Lawns, ground cover: 18".

9.3.3 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.3.4 Planting requirements:

a. A minimum of 10% of open air *publicly accessible passageway* shall be landscaped.

b. For each 400 square feet of landscaped area there shall be at least one (l) major shade tree or two (2) minor ornamental trees.

c. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

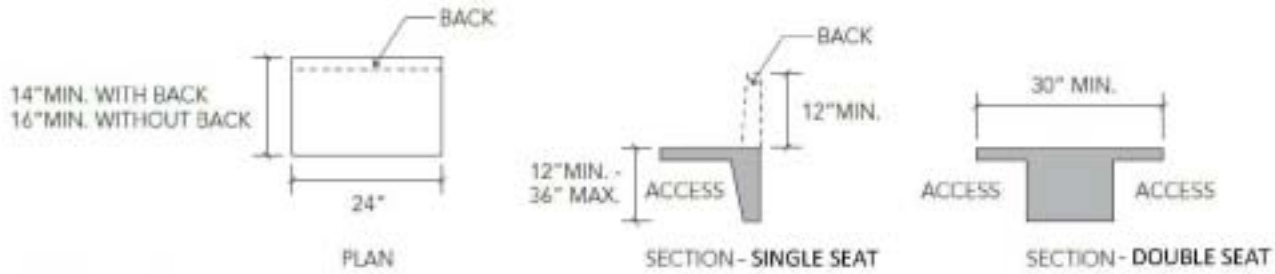


fig. 9.3.5: Seating Standards

9.3.5 Seating

a. There shall be a minimum of one linear foot of seating for each 500 square feet of *publicly accessible passageway* excluding the area of an open-air cafe.

b. One seat shall equal two linear feet.

c. Not more than 50% of the linear seating capacity may be in moveable seats. Seating shall meet the following standards:

(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons, a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count as double seating provided there is access to both sides.

(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.

(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

d. Moveable seating or chairs, excluding seating of open-air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open-air cafes do not count toward meeting the seating requirements.

9.4 Tree Planting Guidelines

9.4.1 It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

9.4.2 Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

9.4.3 Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree-planting pattern.

9.5 Lighting Standards

9.5.1 Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

9.5.2 Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade level open space and open *publicly accessible passageway*.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d. Steps and ramps will be lighted with a minimum of 1.0-foot candles on a horizontal plane.

e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

f. All exterior lighting shall be shielded or directed toward the areas to be lit to limit spill-over onto off-site uses.

g. Light quality shall not be harsh, glaring, blinking or shed beyond property boundaries.

9.5.3 Responsibility for maintenance:

a. The Building Owner shall be responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

b. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building Owner.

9.5.4 Lighting for areas located inside the lot line and visible from the street, such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

9.5.5 Lighting for above-grade parking garage facilities shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

9.6 Publicly Accessible Passageway Lighting Standards

9.6.1 A *publicly accessible passageway* shall be illuminated throughout with an overall minimum average level of illumination of not less than 1.0 maintained foot candle (lumens per square foot) on the horizontal plane at grade.

9.6.2 Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

9.7 Continuity of Design

9.7.1 Design elements and architectural clues that reinforce where appropriate continuity between open and enclosed spaces at grade level is encouraged. Continuity of design may reinforce pedestrian circulation and support the Project's way-finding features.

9.7.2 Where possible, materials, lighting, site elements and landscape shall be similar between different open and enclosed public spaces at the grade level.

10. PARKING

10.1 Automobile Standards

10.1.1 Base Standards

The following standards shall apply for the base level of parking to be provided as the minimum for each use in the project area. The Regulations set forth below incorporate the parking requirements in the LAMC, where applicable, and supersede the LAMC requirements for development in the Development Agreement area.

a. Commercial / Office / Retail:

Two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot. The Regulations incorporate applicable parking requirements in the LAMC as set forth below.

b. Sports Club:

Two parking spaces for every one thousand square feet of combined gross floor area.

c. Hotel

One parking space for each individual guest room or suite of rooms for the first 30;

One additional parking space for each two guest rooms or suites of rooms in excess of 30 but not exceeding 60; and

One additional parking space for each three guest rooms or suites of rooms in excess of 60.

d. Condominiums (Residential):

Two parking spaces per dwelling unit.

One-quarter parking space per dwelling unit for guest parking.

e. Rental (Residential):

One parking space for each dwelling unit of less than three habitable rooms; one-and-one-half parking spaces for each dwelling unit of three habitable rooms; and two parking spaces for each dwelling unit of more than three habitable rooms.

f. Combination of Uses:

Where there is a combination of uses on a lot, the base number of parking spaces required shall be the sum of the requirements of the various uses.

10.1.2 Shared Parking:

a. Shared parking may be applied to the Section 10.1.1 base rates for the Site when the uses have different parking requirements and different demand patterns in a 24-hour cycle or between weekends and weekdays. The intent is to maximize efficient use of the site by matching parking demand with complimentary uses. The calculation of the parking requirements shall be based on a detailed assessment prior to its construction.

b. Calculating Shared Parking:

(i) The individual land use parking requirements for each component of a phase of development shall be calculated from Section 10.1.1. above to establish the "Base Demand."

(ii) The Base Demand will be adjusted by the number of bicycle spaces required per section 10.4. The following internal use reduction factors shall also be applied when 10,000 office equivalent square feet each of office, residential and other commercial uses will all be active on the Site:

Internal Use Reduction Factors	
Residential	**5%**
Hotel	**5%**
Office	**15%**
Other Commercial	**15%**

The resulting minimum automobile parking rates shall be applied to the proposed building(s) to be constructed in each phase of development.

(iii) For parking spaces that are to be shared between uses, the calculated minimum parking requirement for the Site, including that new phase of construction, is to be adjusted based on the procedures in *Shared Parking*, Urban Land Institute, 2nd Edition (2005) or another source as determined by the Director of Planning.

10.2 Additional Regulations

10.2.1 The automobile parking spaces required shall be provided either on the same lot as the use for which they are intended to serve or on another lot located within 750 feet of the lot; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

10.2.2 Curb cuts for driveways shall be located no closer than 50 feet to the intersection of two streets unless approved by The Department of Transportation to be a leg of the intersection.

10.2.3 Access driveways to parking facilities not at signalized intersections shall not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

10.2.4 Parking and loading access shall be shared where feasible.

10.2.5 Priority placement within parking structures shall be given to bike parking, car-share parking, and other alternative ride vehicles.

10.2.6 Pedestrian entrances to all parking shall be directly from the street, except that underground parking garages may be entered directly from a building.

10.3 Screening

10.3.1 Above grade parking for the first 20 feet shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible and shall be designed to blend in with the form and massing and to look like an integral part of the building, with the use of windows and/or cladding, or by landscaping, or green screens, or a combination thereof. The interior of a parking structure shall be designed to be screened from the view of streets and sidewalks.

10.4 Bicycle Standards

10.4.1 Requirements for each use:

a. Commercial / Office / Retail:

For uses listed below a minimum of 2 short-term and 2 long-term bicycle parking spaces shall be provided.

Land Use	Short Term Bicycle Parking	Long Term Bicycle Parking
Office	1 per 10,000 sq. ft.	1 per 5,000 sq. ft.
Health Clubs	1 per 2,000 sq. ft.	1 per 2,000 sq. ft.
Restaurant and Bars	1 per 2,000 sq. ft.	1 per 2,000 sq. ft.
Restaurant (less than 1,000 square feet)	2 per restaurant	2 per restaurant
Retail (General)	1 per 2,000 sq. ft.	1 per 2,000 sq. ft.
Retail (Furniture)	1 per 10,000 sq. ft.	1 per 10,000 sq. ft.
Hotel	1 per 20 guestrooms	1 per 20 guestrooms
All other commercial	1 per 10,000 sq. ft.	1 per 10,000 sq. ft.

uses

COMBINATION OF USES. Where there is a combination of uses on a lot, the number of bicycle parking spaces required shall be the sum of the requirements of the various uses.

b. Residential:

For all residential buildings containing more than three dwelling units, or more than five guest rooms, long- and short-term bicycle parking shall be provided. Long-term bicycle parking shall be provided at a rate of one space per dwelling unit or guest room. In addition, short-term bicycle parking shall be provided at one space per ten dwelling units or guest rooms. A minimum of two short-term bicycle parking spaces shall be provided in such cases.

(i) In instances where a building may contain both dwelling units and guest rooms, the sum of dwelling units and guest rooms shall be used to determine the amount of long and short-term parking. Any combination that results in more than five combined dwelling units and guest rooms will require bicycle parking.

10.5 Transportation Demand Management Plan

10.5.1 The Project shall incorporate a comprehensive transportation demand management plan.

10.5.2 The transportation demand management plan shall set forth best practices that relate to the Project Site and the Project's building design features in order to:

a. Promote bicycle and pedestrian circulation within the Project Site.

b. Promote alternative modes of transportation.

c. Create pedestrian linkages to public and private amenities outside the Project Site.

d. Provide convenient and attractive onsite pedestrian linkages for routes to the Metro Red Line Station at Hollywood Boulevard and Vine Street.

e. Provide adequate parking, but provide incentives to tenants and residents to utilize alternative modes of travel. The incentives shall include bicycle facilities, car sharing, discounted subway passes, and parking spaces as an only optional part of all lease and sale agreements.

11. SIGNAGE

11.1 Hollywood Signage Supplemental Use District

Signage shall be subject to Ordinance No. 176172: Hollywood Signage Supplemental Use District pursuant to Section 13.11 of the Los Angeles Municipal Code.

11.2 Modification to Guidelines

Notwithstanding Section 11.1, high-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted. See fig. 11.2.

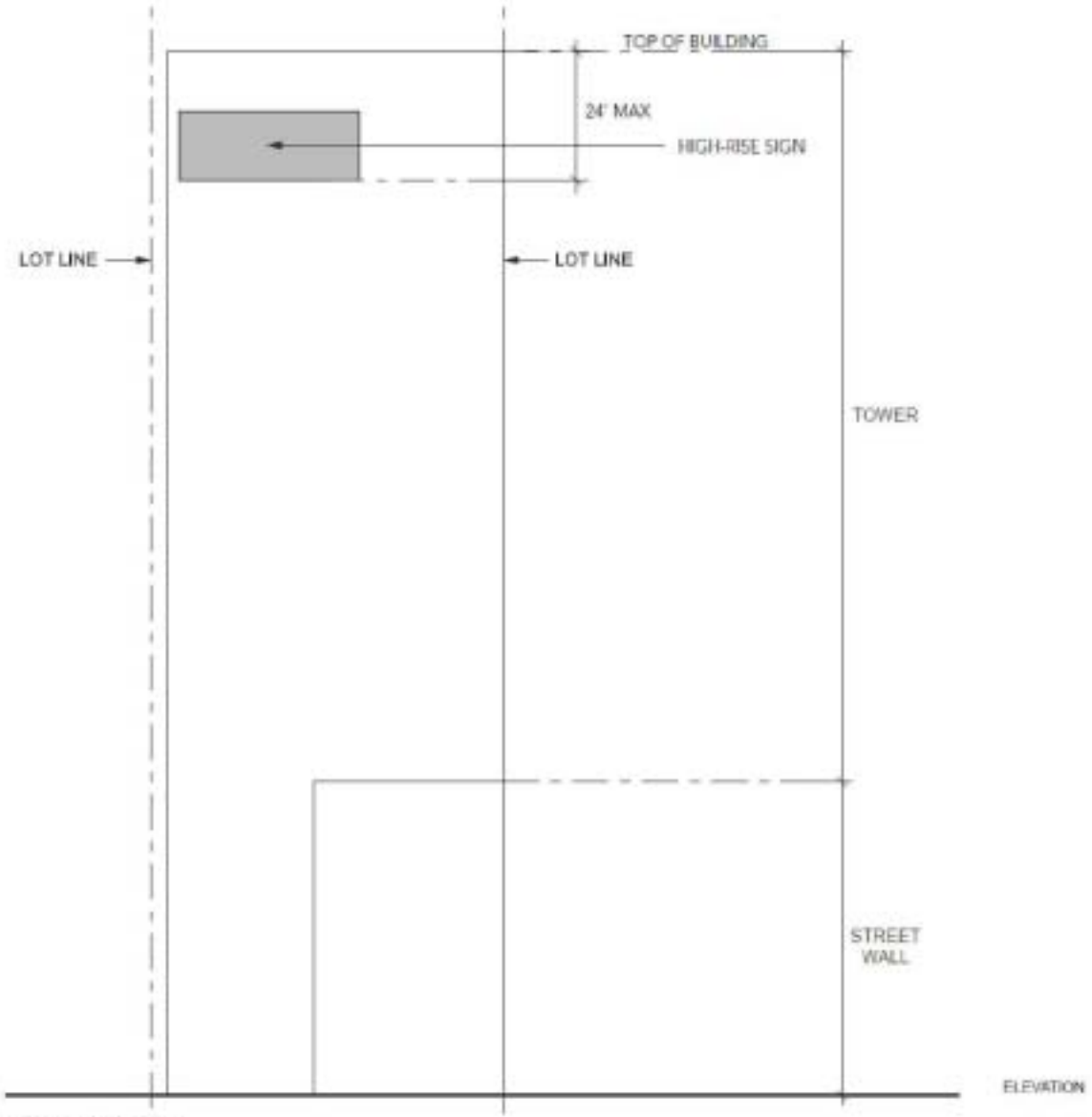


fig. 11.2: High Rise Sign

12. SUSTAINABILITY

12.1 Non-Residential Projects

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

12.2 Other Projects

The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

13. DEFINITIONS

Awning: glazing or fabric on metal frame structure supported entirely by the building to provide weather protection at doors, windows and/or storefronts; may be retractable.

Base: the lower portion of a building located at or within 150' above curb level.

Canopy: glazing, fabric and/or metal structure with vertical supports located on the sidewalk to provide weather protection at a building's primary entrance.

Expression band: a distinctive linear architectural element occurring on the building base facade at the highest floor. The band shall be contrasting in color, texture, material and/or fenestration from the adjacent building base facade. Projections may occur within an expression band.

Grade level open space: a continuous open space fronting the street and open to the sky.

Maximum building height: the maximum height permitted, measured from the adjacent street curb level.

Maintenance: the ongoing repair, care and upkeep of a property.

Open space use: active and passive recreational areas accessible to the general public, except as noted herein. Open spaces can occur in publicly accessible passageways, grade level open space, residential common open space and residential private open space which are defined herein.

Preservation: in conformance with standards and guidelines of the Secretary of the Interior, the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property.

Publicly accessible passageway: a continuous through-block public connection between two parallel streets, located on privately owned land and designated for and designed to encourage public pedestrian circulation and other appropriate public uses.

Rehabilitation: in conformance with standards and guidelines of the Secretary of the Interior, the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values.

Required street wall: a wall or portion of a wall of a building facing a street or grade level open space which must be built to a maximum height above curb level.

Required street wall articulation, aggregate width of: the sum of the maximum widths of all segments of required street wall articulation on a street at the level of any story. The width of a required street wall articulation is measured in plan as the width of the street line from which perpendicular lines may be drawn to such required street wall articulation.

Residential common open space: a "rear yard" providing light and air to apartments on the interior of a parcel located at any story above curb level.

Residential private open space: open space that is contiguous to and immediately accessible only from a single dwelling unit.

Setting: the area or environment in which a historic property is found. It may be an urban or suburban neighborhood or a natural landscape in which a building has been constructed. Elements of setting can include the relationship of buildings to each other, setbacks, views, sidewalks, and street trees.

Storefront: the architectural facade, including doorways, of any tenant-leased premise perimeter adjacent to public circulation areas. Storefronts refers to all permitted residential, retail uses including retail, service, restaurants and cultural establishments and commercial uses, including but not limited to hotels and sports clubs.

Tower: the portion of a building located above 150' above curb level.

Transparent: architectural elements that can be seen through or allows light to emit through, including but not exclusively glass, trellis and wire mesh.

Notes:

All images and figures used in the Regulations were prepared for exclusive use by Millennium Hollywood LLC unless otherwise noted.

LA DBS

DEPARTMENT OF BUILDING AND SAFETY

Development Services "Concierge" Program

We are with you all the way to build safe, build well, and build fast!

CO-0001-001

AR0067859

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Every year LADBS issues approximately 130,000 permits:

- 85,000 permits are Express Permits
  - No plan review required
  - Minor alterations (reroof, replace AC, kitchen remodel, etc.)
  - Issued at Express Counter or through e-Permit
- 45,000 permits require plans to be drawn and reviewed

These 45,000 projects can be categorized into five project types:

- Major (high rise building, shopping center, hotel, etc.)
- Midsize (35-unit apartment, low rise office building, etc.)
- Small Business (tenant improvement, retail shop, etc.)
- Small Residential (single family addition and alteration)
- Special (restaurant, high tech facilities, etc.)

All five types of projects have to go through three phases of the development process:

- Design Phase
- Permitting Phase
- Construction Phase

CO-0001-003

AR0067861

Mission Statement Prior to 2009

"The mission of the Department of Building and Safety is to protect the lives and safety of the residents and visitors of Los Angeles, preserve the City's quality of life, and contribute to the City's economic development. This is accomplished through implementation of the Zoning, Building, Plumbing, Mechanical, and Electrical Codes, as well as Engineering, Energy, and Disabled Access regulations, and local and State laws for construction and maintenance of commercial, industrial, and residential buildings."

Then, the culture of LADBS focused around safety more than quality customer assistance.

CO-0001-004

AR0067862

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

In 2009, LADBS modified our mission statement to foster a change in culture and place emphasis on customer assistance:

Mission Statement Since 2009

"The mission of the Department of Building and Safety is to protect the lives and safety of the residents and visitors of the City of Los Angeles and enhance the quality of life, housing, economic prosperity, and ***job creation****. This is accomplished through* ***advising, guiding, and assisting customers to achieve compliance*** *with the Building, Zoning, Plumbing, Mechanical, Electrical, Disabled Access, Energy, and Green Codes; and local and State laws,* ***through a timely, cooperative, and transparent process for the facilitation*** *of construction and maintenance of commercial, industrial, and residential buildings throughout the City"*

CO-0001-005

AR0067863

Our commitment to this mission is evident in our three added programs:

1. **Development Services Case Management (DSCM)**
   We plan your project with you!
2. **Parallel Design-Permitting Process (PDPP)**
   We issue your permit when you complete the design!
3. **Restaurant & Hospitality Express Program (RHEP)**
   Open on Schedule!

CO-0001-006

AR0067864

CO-0001-007

AR0067865

Prior to the establishment of the Development Services Case Management (DSCM), case management functions were housed in different departments and not formally coordinated.

On July 2011, the citywide DSCM was formed and comprised of staff from:

- 7 Building & Safety
- 3 Planning
- 1 Bureau of Engineering (part-time)
- 1 Water & Power (part-time)
- 1 Transportation (part-time)
- 1 Bureau of Street Lighting (part-time)
- 1 Urban Forestry Division (part-time)

CO-0001-008

AR0067866

In collaboration with the Construction Liaison Network (representatives from Fire, Bureau of Street Services, Bureau of Street Lighting, Housing, and Recreation and Park), DSCM act as advisors and pathfinders to provide consultation facilitation, and problem solving services to major projects:

- Performing project feasibility studies.
- Conducting pre-development meetings with other agencies.
- Conducting preliminary plan reviews to identify potential building site and code issues.
- Resolving code issues from design considerations.
- Assisting applicants with plan check corrections and the citywide clearance processes process.

CO-0001-009

AR0067867

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Feasibility Study Report

Development Services Case Management — Feasibility Study Form (Zoning)

Project Address:	Case Manager:	Case No:	Date:
400 S. Broadway	Jameson Lee	CM 2013-0205	7-1-13

Scope of Work: A new 36 story mixed-use project. 449 units with 459 Parking spaces 7450 SF of Retail space on ground floor

Information from ZIMAS:

Zoning: (Q)C4-4D-CDO
Lot area:
Alley: Yes
Building line:
- ☐ CZCA
- ☐ HPOZ
- ☑ ZI 145:
- ☑ Greater Downtown Incentive Area
- ☑ POD/CDO/NSO: Broadway

Information from ZIMAS:

CRA: City Center Redevelopment
Enterprise Zone: LA State Enterprise
Specific Plan:
Easement:
Legal (Lot cut): 4 Parcels
ZA,CPC: See ZIMAS
Downtown Design Guide Area
ZI: See ZIMAS
AFF:

Information from ZIMAS:

- ☐ Methane
- ☐ Oil and Gas
- ☑ Fire District 1
- ☐ LRM
- ☐ LIQ/LAN
- ☐ Hillside Area (ZONING)
- ☐ Special Grading Area (BOE)
- ☐ Flood:
- ☐ Environmentally Sensitive Area
- ☐ Very High Fire Hazard Severity Zone
- ☐ Seismic Fault Zone
- ☐ Alquist Priolo Fault Zone
- ☐ Airport Hazard Height Limit

Item to be Addressed	Per Zoning Code requirement	Requirement Per: (a) ☑ (b) ☑ (c) ☐ Specific Plan: ☑ Greater Downtown Housing Incentive Area	Comment / Proposed	Planning Action
1. Use	☑ By Right ☐ CUP Required per section _____ ☐ Public benefit projects per section 1400 ☐ (Discontinued) non conforming use	OK		☐
2. Height	☐ Height District: C4-4 (unlimited) ☐ Transitional height (12.21.1A10): ☐ Project is subject to the Commercial Corner/Mini Mall max 45' for height district 1 and 1VL	[Q]: min 150'		☐
3. FAR (Floor Area Ratio)	☐ Per Height District: 4 13x1 Note: Buildable area = lot area for residential or mixed use if project on C2,C4 and C5 zone	[D] limited to 6x1	Need TFAR approval. CRA.	☑

CO-0001-010

AR0067868

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Feasibility Study Report

Item to be Addressed	Per Zoning Code Requirements	Requirement Per:	Comment/Proposed	Planning Action
		☑ (Q) ☑ (D) (Q) ☐ Specific Plan: ☑ Greater Downtown Housing Incentive area		
4. Number of Stories	☐ Per Height District (12.21.1): C4-4 unlimited	no limit.		☐
5. Setback Note: FY is required for CR*,C1*, C1.5* MR1,MR2 Side is req'd for CR, C1, C1.5 *not req'd for mini mall/comm..	Front Side Rear Building Line ☐ 5' Landscape required for street frontage and parking area next to residential zone per Commercial Corner/Mini Mall 12.22A23(a)(10) (not req'd for st frontage for project in downtown bus. District) ☐ Mixed Use Yard Exception per 12.22A18(c)(3)	No setback req'd. per greater Downtown housing Incentive.	Front Side Rear Broadway CDO has different setback requirement.	☑
6. Parking Note: Non-Conforming Parking is lost once Ceiling Joists are removed.	Use / AUTOMOBILE PKG Factor and Code Section / Floor Area, # of Units/Guestrooms, Etc. / # of Req'd Auto Spaces / # of Req'd Bicycle ☐ Parking Bonuses/Exceptions: CRA, Enterprise Zone, Central City, Downtown Plg. Aff. Hsg Parking Options, Historical Guest Parking per tract conditions		Proposed # of Parking Spaces: Auto: Bicycle: per 12.21A16 Comments: per Central City Exception one per unit (Except if more than 6 units > 3 habitable Room	☑
7. Density	Base Lot Area (Inc Half Alley if any): / Required Hwy Dedication: / Net Lot Area (Condo): / Proposed # of Units: Base Density: Requirement per General Code, Q, or Specific Plan / Density Factor / # of Units Allowed: Density Bonus (Affordable Housing) (12.22A25(c)): Type of Low Income Units (Very Low, Low, Moderate) / % Density Bonus / # of Units Allowed with Density Bonus:		Comments: No limit. Project is in greater Downtown Incentive area.	☐

CO-0001-011

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LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Feasibility Study Report

8. Open Space (12.21G)	# of Habitable Rooms	# of Units	Req'd Open Space (sf)	Total Open Space Req'd:	Need to comply with 12.21G (there is exception for affordable housing incentive)	☐
	< 3		X 100sf =			
	= 3		X 125sf =			
	> 3		X 175sf =			
9. Passageway, Space bet Bldgs						☐
10. Loading Area	Per section 12.21C6					☐
11. Trash & Recycling	Per section 12.21A19					☐

Others:

- ☐ Coastal Zone (CZCA)
- ☐ Alley, Street vacation action required
- ☐ Commercial Corner/Mini Mall (12.22A23)(a mixed use project as defined in 13.09B3 or residential project conforms to Downtown Design Guide are exempted)
- ☐ Ch 34, all (E) CMU bldg is treated as ordinary shear wall
- ☐ Landscape
- ☐ Yards for Churches, Institutions, Schools etc in RA or R zones (12.21C3)

Others:

- ☑ Site Plan review (16.05)(>=50,000sf; >=50 units; and Increase "trips" and any **residential project in Greater downtown housing incentive area (unless complies with downtown design guide 12.22A30 per 16.05D (7)**
- ☐ Major development (12.24U14)(>=250,000sf warehouse; >=250 guest rooms; >=100,000sf for other non residential, non warehouse area in C2,C4,CS,CM,M1,M2,M3 and **Home improvement store,**
- ☑ Subdivision Action Required
- ☐ ANY Grading on a Site > 60,000sf requires Planning Department Signoff

Inform applicant that project requires planning entitlement action needs to follow the "City Design Guidelines" developed by Planning Department. Refer to Planning website: select "Policy Initiatives", then "Urban Design Studio"

Additional Comments:

1. Project needs to comply with Broadway CDO.
2. total lot area = (2740 + 328) + 1205 + 6261 = 34,338.
3. Broadway street scape compliance.
4. Applicant may seek "street vacation" for the area along 4th St & Broadway due to the street width standards is less

7/8/2013

CO-0001-012

AR0067870

Feasibility Study Report

HOUSING DEPARTMENT
- ☐ Demo of rental unit
- ☐ Housing density bonus
- ☐ Housing rent stabilization

DEPARTMENT OF WATER AND POWER (DWP)
- ☐ Construction within 10' of power line or easement
- ☐ Construction within a DWP utility easement
- ☐

STATE DEPT OF OIL & GAS
- ☐ Abandoned Oil Well
- ☐

Clearances/Fees required from the City's/State Agencies as indicated

Project Address:	Case Manager	Case No.	Date:
400 S. Broadway	Jameson Lee	CPC 2013-[illegible]	7-1-13

Scope of Work: 36 Story highrise condo

CITY PLANNING
- ☐ Specific Plan
- ☐ Design Review Board
- ☐ HPOZ
- ☐ Coastal Zone (CZCA)
- ☑ Site Plan Review
- ☐ Major Development
- ☐ Commercial Corner
- ☑ Q or D or T Conditions
- ☑ Landscape
- ☐ Conditional Use for _____
- ☐ CPC
- ☐ CEQA for proposed grading
- ☐ Certificate for compliance for illegal lot cut
- ☑ Historical
- ☐ Plan approval
- ☑ POD/CDO/NOD/TOD Broadway
- ☐ private street
- ☐ >9 dwelling units in CZCA (Mello Bill)
- ☐ Grading on site in BOE Special Grading Area having an area in excess of 60,000 sq ft per 91.7006.8.2
- ☐ Downtown Design Guide Project Area

Tract for subdivision

BUILDING AND SAFETY
- ☑ Disabled Access Division
- ☐ Private Sewage
- ☐ GPI
- ☐ DPI
- ☐ SPI
- ☐ Grading bond
- ☐ Green Building
- ☐ Haul Route

Fees: for building permit fee, art's development fee and school district fees, see: http://netinfo.ladbs.org/feecalc.nsf

FIRE DEPARTMENT
- ☑ Title 19 building
- ☐ Div 5 permit
- ☐ Fire Lane
- ☑ Fire Hydrant Access
- ☐ 150' driveway
- ☐ VHFHSZ
- ☐ Distance to fire station
- ☐ Underground Fuel Tank
- ☐ High Storage Rack >12'
- ☐ Methane Detection/Ventilation /Alarms
- ☐ Motion picture studio
- ☐ Asbestos Removal

PUBLIC WORKS (Bureau of Engineering)
- ☐ New Address
- ☐ Street Use
- ☐ Revocable Permit
- ☑ Street/Alley Vacation
- ☐ Flood
- ☑ Highway Dedication
- ☑ Removal of Lateral Support for Street
- ☐ Sewer
- ☑ Driveway/Curb Cut/Sidewalk
- ☐ Site Drainage to a storm drain easement
- ☐ Encroachment in public way
- ☑ Engineering clearance processing fee
- ☐ Construction within natural watercourse
- ☑ Roof/site drainage to street
- ☐ Board for construction marquee

PUBLIC WORKS (Bureau of Sanitation)
- ☑ SUSMP
- ☐ Industrial Waste
- ☐

STATE AQMD

restaurant with char-broiler, use or store acids, body shop, CFC recycling machine, use any chemical process, use solvent or clean-up, combustion equipment rated > 2,000,000BTU/Hr, on site dry cleaner, generating dust or smoke, gasoline station, use internal combustion engine > 50HP, for organic liquids/gases/ oven drying or curing, part coater, plating/coating, primer, refining/reclaiming, solvents/adhesives/paints, solvents/fuels and spray-paint booth

CTRC RAIL

Construction within Metro Rail Project Area

COUNTY FIRE

Hazardous Waste Control License Required

CALOSHA
- ☑ >3 Stories or > 35'
- ☑ Excavation > 5'
- Demo

PUBLIC WORKS (STREET LIGHT and STREET TREES)
- ☐ Street Lighting
- ☑ Urban Forestry Division

COMMUNITY REDEVELOPMENT AGENCY (CRA)
- ☑ Project located in CRA area
- ☑ Historical monument

LA COUNTY HEALTH DEPARTMENT
- ☐ Food establishment
- ☐ Public swimming pool
- ☐ Water well construction/monitoring/destruction
- ☐ Approval for portable chemical toilet prior to installation

CO-0001-013

AR0067871

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Pre-development Meeting

All relevant agencies meet with project representatives to:

- Establish department contacts for the project.
- Provide a clear, transparent road map of the permitting process.
- Identify and resolve foreseeable issues with each agency.

CO-0001-014

AR0067872

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Since its inception in July 2011, DSCM has assisted more than 2,400 projects including many significant job creation projects:

- LAX Modernization
- Emerson College
- Lucky Brand Jeans – West Coast Headquarter
- Forever 21 Headquarter
- Conversion of Old Post Office on Jefferson Blvd
- Hercules Campus at Playa Vista
- USC Health Science Building
- Gensler 's Office
- Caruso's Nordstrom at Grove
- Mini Cooper of Universal City and more dealerships
- Many High-Rises

Due to the consultation, facilitation, and problem solving services that DSCM provided, these projects were **completed with significant time and cost savings.**

CO-0001-015

AR0067873

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Testimonials

Brad Box, Senior Managing Director, Trammell Crow

"The case management approach has transformed our experience of working with the City. You go to one place, have one point person, and get answers quickly. We're moving forward faster thanks to this change."

William McGregor, Project Director, McGregor Company

"It is no overstatement to say that had it not been for Case Management, One Santa Fe would not be a reality today"

Ronald Kaleta, Project Director, Brookfield Properties

"The case management's suggestions and scheduling help in resolving signage issues has allowed the project to maintain its momentum with leasing, which is the life-blood of the project."

Jonathan Lonner, Project Director, Burns & Bouchard

"Both the developer and I felt that saving this enormous investment of public subsidy was impossible. However, in large part due to the work and coordination of case management, we were proved wrong and the City was able to maintain $20M in subsidy and gain 63 new affordable units in South Los Angeles."

CO-0001-016

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LA DBS
DEPARTMENT OF BUILDING AND SAFETY

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project > 50 units > 50,000 sq. ft > $10 million > 50 jobs	Dev. Services Case Mgmt. *We plan your project w/ you.* • Feasibility Study • Preliminary Plan Review • Pre-development Meeting	Dev. Services Case Mgmt. • Project Navigation	assistance not available
Midsize Project	assistance not available	assistance not available	assistance not available
Small Business	assistance not available	assistance not available	assistance not available
Small Single Dwelling	assistance not available	assistance not available	assistance not available
Special Project	assistance not available	assistance not available	assistance not available

CO-0001-017

AR0067875

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

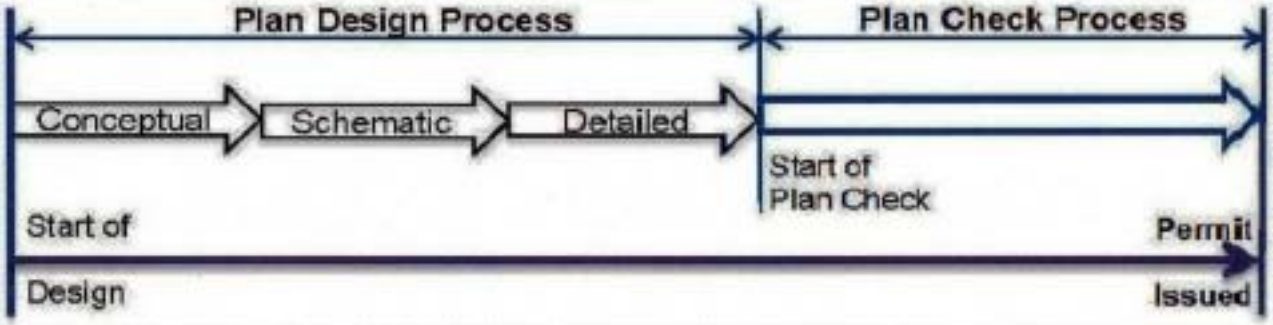
Parallel Design-Permitting Process (PDPP)

We issue your permits when you complete the design!

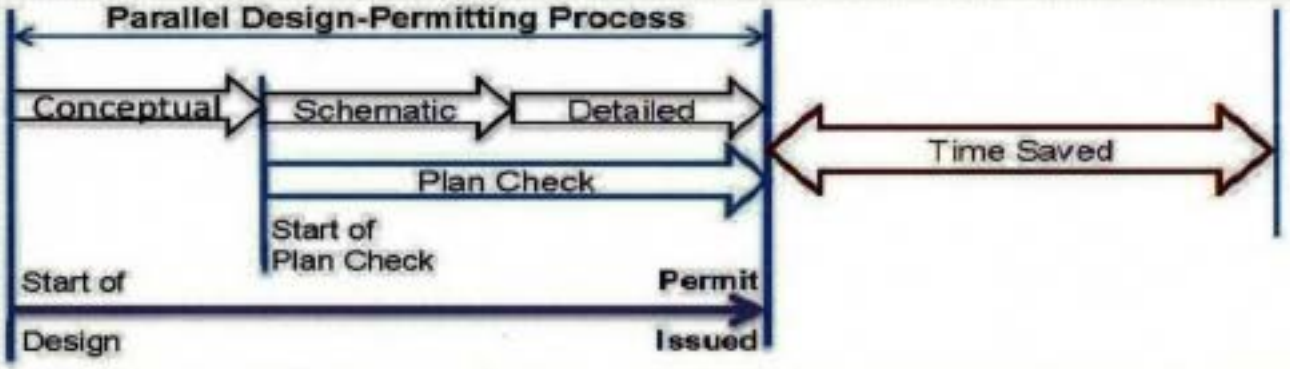
AR0067876

CO-0001-018

Traditionally, the plan design process and the plan check process are **sequential**; that is, projects are submitted to LADBS for plan check only after the project design is entirely complete.



PDPP allows the design process to run **concurrently** with the plan check process. We issue the permit when the design in complete.



CO-0001-019

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LA DBS
DEPARTMENT OF BUILDING AND SAFETY

1st Step – Zoning Plan Check & Clearances

- Only require plot plan, elevations, floor plans and parking.
- The Plan Check Engineer reviews conceptual plans:
  - generates correction Sheet identifying major issues
  - generates clearance sheet for other agencies' signoffs
- Resolve major issues and process clearances at early stage.

2nd Step – Architectural & Fire Life-safety Plan Check

- "Same" Plan Check Engineer reviews architectural plans:
  - identify all detail violations
  - issue modification for code deviations
- Building code issues are resolved at Design Phase.

3rd Step – Engineering Plan Check

- "Same" Plan Check Engineer reviews engineering plans.
- Building code issues are resolved at Design Phase.

NO MORE LATE HIT!

CO-0001-020

AR0067878

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Clearance Summary Sheet

CLEARANCE AGENCY "ADDRESS CODES"

(NOTE: Address Code 3 not in use at this time - Contact your plan check engineer for instructions)

Code	Agency Name	Agency Address	(Call First)
1	**Bureau of Engineering**	- Address Approval	(213) 482-7030
	(Within Central District)	- Highway Dedication / Hillside Ord.	(213) 482-7030
	Figueroa Plaza:	- Flood/Drainage: 1149 S. Broadway	(213) 485-4820
	201 N. Figueroa Street	Appointment required - call first	
	(See NOTE at bottom right.)	- Sewer / Driveway	(213) 482-7030
		- Excavation/Shoring: 201 N. Fig. St., 3rd Floor	(213) 482-7048
1	**Bureau of Engineering**	**Harbor District:** - (7:30 am to 4:30 pm)	(310) 732-4677
	(Outside Central District)	638 S. Beacon St., Suite 427, San Pedro	
		Valley District:	(818) 374-5090
		6262 Van Nuys Blvd., Room 251, Van Nuys	
		West Los Angeles District	(310) 575-8384
		1828 Sawtelle Blvd., 3rd Floor, West LA	
1	**Street Use Permits**	1149 S. Broadway, 3rd Floor	(213) 847-6000
2	**City Planning Department**		
	Development Services Center (DSC) - All City Planning Questions & Clearances via walk-in. All Case Filing, Case Condition Clearing via appointment. Hours: Mon, Tue, Thu, Fri from 7:30 AM to 4:30 PM. Wed from 9:00 AM to 4:30 PM.		
	DSC Metro Counter	Fig. Plaza: 201 N. Figueroa St., 7th Floor, Los Angeles, 90012	(213) 482-7677
	DSC Valley Counter	Marvin Braude Bldg., 6262 Van Nuys Blvd., Rm. 251, Van Nuys	(818) 374-5050
	Office of Historic Resources (OHR) - HPOZ/Historic-Cultural Monuments/Mills Act		**APPOINTMENT REQUIRED**
	Historic Monuments & Mills Act	City Hall: 200 N. Spring St., Room 620, Los Angeles, 90012	(213) 978-1200
	HPOZ	City Hall: 200 N. Spring St., Room 621, Los Angeles, 90012	(213) 978-1198
	Plan Implementation Division Billing/Invoice Request - Specific Plan/DRB/CDO/CUGU/Historic/HPOZ/CRA		**APPOINTMENT REQUIRED**
	Metro Neighborhood Projects	City Hall: 200 N. Spring St., Room 621, Los Angeles, 90012	(213) 978-1160
	Valley Neighborhood Projects	Marvin Braude Bldg: 6262 Van Nuys Blvd., Rm. 430, Van Nuys	(818) 374-5072
	Schedule Case Filing or Case Condition Clearance - Codes: Department Hours Directory - Codes:	city.planning.lacity.org/ Click on "Development Services Center" then "Make Appointment" city.planning.lacity.org/ Click on "Planning Contacts"	
4	**Building & Safety**	**Disabled Access:** See DA corrections	Call plan checker
	Figueroa Plaza: 201 N. Figueroa Street	**Hold / ZI:** See plan check engineer	Call plan checker
	(See NOTE at bottom right)	**Grading:** Go to District Office for project	(213) 482-0480
5	**Fire Department**	**Construction Services Unit:**	(213) 482-6500
		201 N. Figueroa St., Suite 300	
	Figueroa Plaza:	**Hydrants and Access Unit:**	(213) 482-6543
	201 N. Figueroa Street	221 N. Figueroa St., Suite 1500	
	(See NOTE at bottom right)	Van Nuys: 6262 Van Nuys Blvd., Room 251	(818) 374-5005
		West LA: 1828 Sawtelle Blvd., 2nd Floor	(310) 575-8271
6	**Transportation Department**	**Fig. Plaza:** 201 N. Fig. St. - (See NOTE)	(213) 482-7024
	ZI 1729, 1870 = West Valley	**(Only check payments accepted)**	
	ZI 1448,1874,1887,2192 = WLA	**West Valley:** 6262 Van Nuys Blvd., #320	(818) 374-4699
	ZI 2351 = DOT @ CalTrans Building	**West L.A.:** 7166 W. Manchester Ave.	(213) 485-1062
	(All others = Fig. Plaza)	- Additional Phone # for WLA	(310) 524-8253
		Cal Trans: 100 S. Main St., 9th Floor	(213) 972-8485

Code	Agency Name	Agency Address	(Call First)
7	**Los Angeles County Health**	3530 Wilshire Blvd., 9th Floor, LA 90010	(213) 351-7352
	Department	6851 Lennox Ave., 3rd Floor, Van Nuys	(818) 902-4470
	Admin. HQ: 5050 Commerce Dr.	6053 Bristol Pkwy., 2nd Floor, Culver City	(310) 665-8483
	Baldwin Park, (626) 430-5560	122 W. 8th St., Room 20-A, San Pedro	(310) 519-4081
8	**Community Redevelopment Agency**	**Figueroa Plaza:** 201 N. Figueroa St.	(213) 482-6595
	(CRA)	(See NOTE at bottom right)	
9	**Calif. Div. of Occupational Safety**	320 W. 4th St., Suite 860, LA	(213) 576-7451
	and Health	6150 Van Nuys Blvd, Room 405, Van Nuys	(818) 901-5403
	Appointment required - call first		
10	**South Coast Air Quality**	21865 E. Copley Dr., Diamond Bar	(909) 396-2000
	Management District (SCAQMD)	Hours: Tuesday - Friday, 7:30 am-5:00 pm	** Call first **
11	**Department of Conservation,**	5816 Corporate Ave., Room 200, Cypress	(714) 816-6847
	Division of Oil and Gas		
12	**Cultural Affairs Department**	City Property/Plazas (Public Way), Arts	(213) 202-5569
	201 N. Figueroa St., 14th Floor, LA	Development Fees, and Mural Signs	
13	**Department of Water and Power,**	111 N. Hope St., Room 1031	(213) 367-0562
	Real Estate Division	Los Angeles, CA 90012	
16	**Housing Department**	Density bonus/parking incentive	(213) 808-8806
	3550 Wilshire Blvd., #1500, Koreatown	Demo/reduction of unit/rooms	(213) 808-8537
		Tenant Habitability Plan	(213) 252-1464
17	**Metro. Trans. Authority (MTA)**	MTA, Project Engineering Facilities	**Call for appoint**
	Primary Contact: Thao Win	One Gateway Plaza - 16th Floor	(213) 922-1465
	Email: vint@metro.net	Los Angeles, CA 90012	
18	**Port of Los Angeles**	425 S. Palos Verdes St., San Pedro	(310) 732-3850
19	**Bureau of Sanitation**	Industrial Waste: Mgmt. Div. (Fats/Oils/Grease)	**Call for appoint**
		2714 Media Center Dr., Glassell Park	(323) 342-6138
		Watershed Project Division (Stormwater)	
		Recycling Division (Waste Hauler)	(213) 482-7066
		201 N. Figueroa St., 5th Floor	
20	**LA County Fire Department**	5825 Rickenbacker Rd., Commerce	(323) 890-4106
		Hours: Monday - Thursday, 8:30 am-1:30 pm	** Call First **
21	**Los Angeles World Airport**	1 World Way	(424) 646-7600
	Email: LAXPlanning@lawa.org	Administration East, Room 169	or Email
22	**Office of Finance**	**Fig. Plaza:** 201 N. Fig. St. - (See NOTE)	(213) 482-7032
		Van Nuys: 6262 Van Nuys Blvd, Room 116	(818) 374-6830
		West LA: 1828 Sawtelle Blvd., Room 102	(310) 575-8308
		City Hall: 200 N. Spring St., Room 101	(213) 473-5901
23	**Bureau of Street Services,**	1149 S. Broadway, 4th Floor	(213) 847-3077
	Urban Forestry Division	Los Angeles, CA 90015	

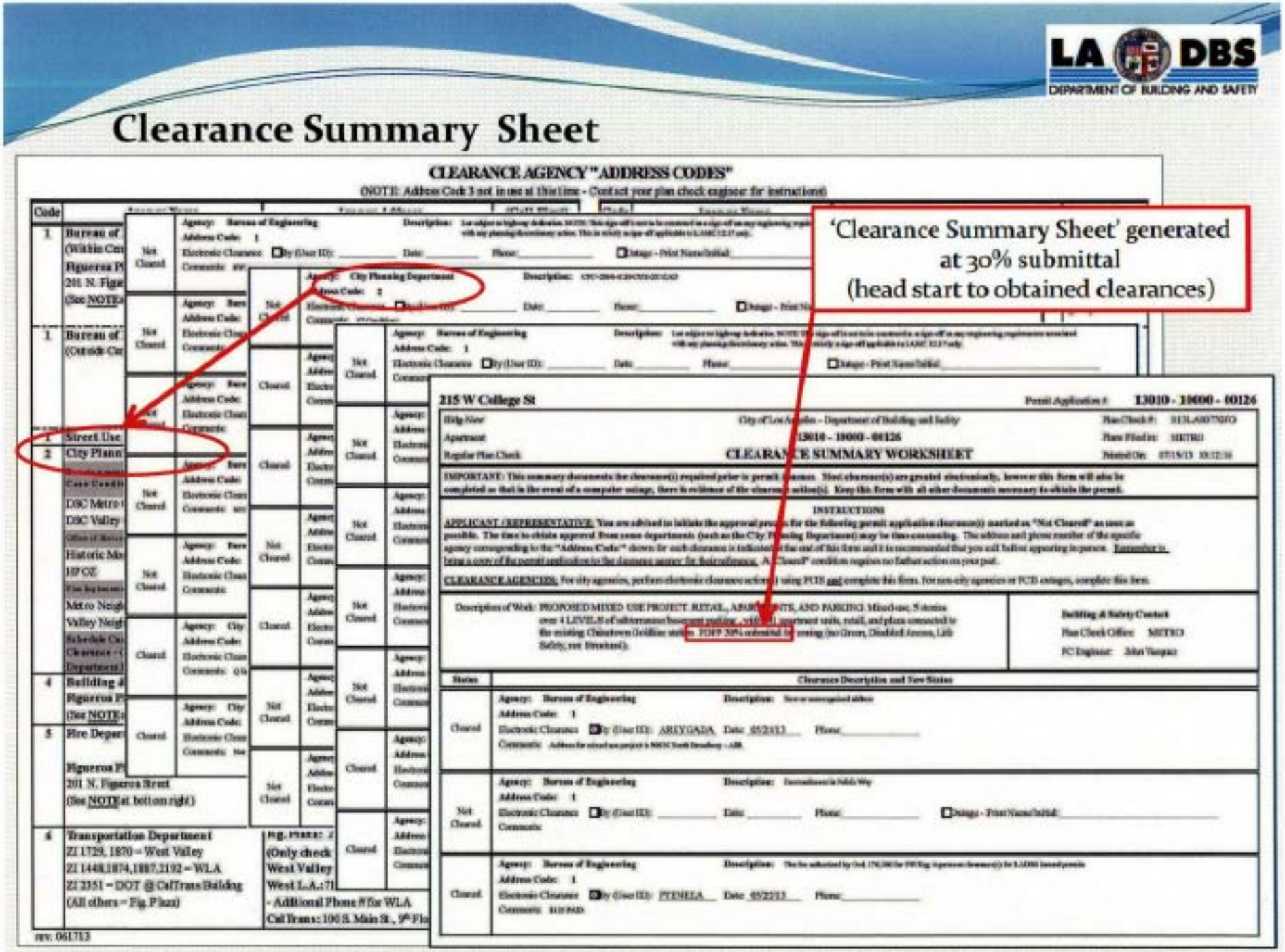
NOTE: Face harvesters required from agencies located at 201 N. Figueroa Street (between Temple Street and Los Angeles) sign-in at the "Fig. Plaza" reception counter for a "Q-Matic" referral to the appropriate floor counter.

rev. 061713

CO-0001-021

AR0067879

Clearance Summary Sheet



CO-0001-022

AR0067880

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Permitting Time for PDPP Projects

Project Description	Project Valuation	Conceptual Plans Submittal Date	Plan Approval Date	Total Time Conceptual to Permit
60-unit Affordable Housing	$11 mil	11/16/2011	3/29/2012	5 months
Broadway Charter School	$12 mil	8/19/2011	1/12/2012	5 months
USC Office Building	$17 mil	2/22/2010	7/14/2010	5 months
Sherman Oaks Ralphs Market	$22 mil	4/18/2011	5/25/2012	13 months
Facy Medical Group	$14 mil	6/29/2010	5/12/2011	10 months
78-unit Affordable Housing	$12 mil	8/3/2011	6/13/2012	10 months
2-story Charter School	$10 mil	8/17/2011	1/31/2012	6 months
102-unit apt. / Mixed Use	$12 mil	5/6/2011	11/28/2011	7 months
Rocketdyne - Test Facility & Office	$12 mil	4/20/2012	10/4/2012	6 months

CO-0001-023

AR0067881

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Benefits for PDPP Projects

- No more "late hits:"
  - Code issues are identified and resolved during Design Phase to avoid late revisions.
  - Early start on clearances and avoid unexpected "*Got You.*"
- LADBS Plan Check engineer acts as "Project Consultant" throughout Design-Permitting Phase.
- Reduce permitting time by 6 to 12 months.
- Start and complete construction ahead of schedule.
- Reduce significant project cost due to time savings.

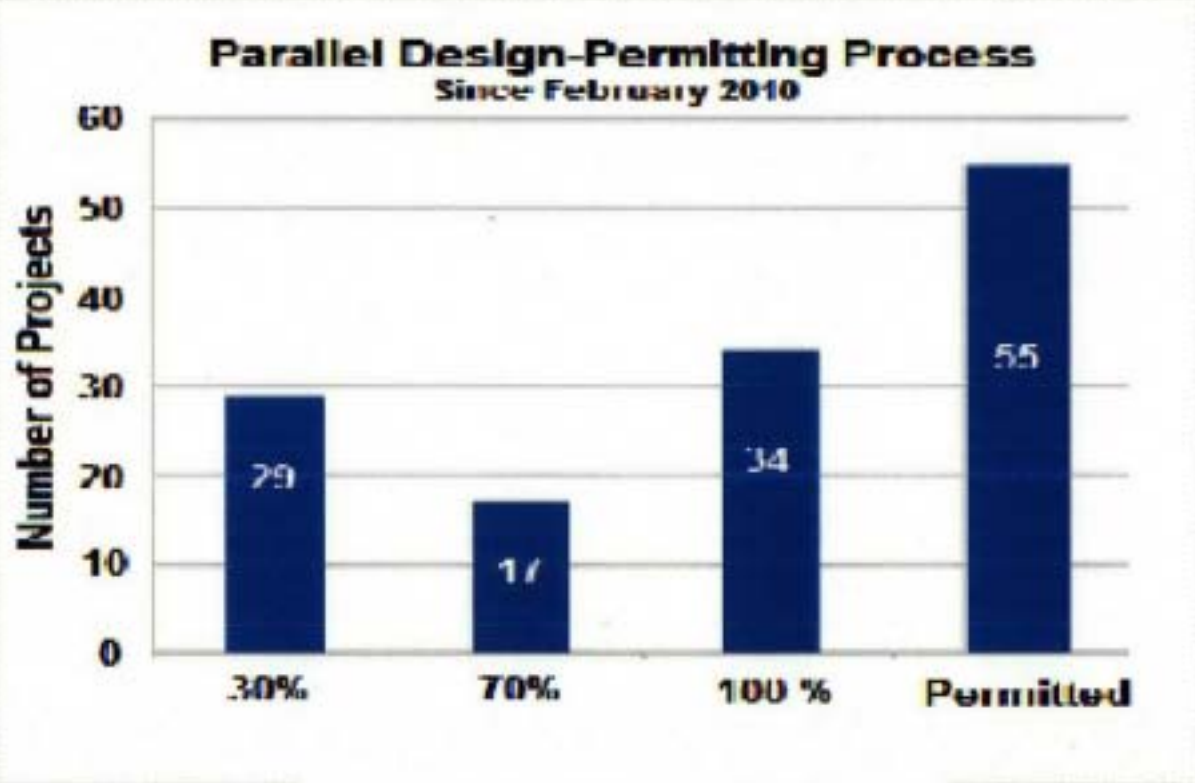
CO-0001-024

AR0067882

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

PDPP Projects since 2010:

- Permits issued: 55 projects with $3.6 billion valuation
- Permits soon be issued: 34 projects with 2.1 billion
- Halfway designed and checked: 17 projects with 2.0 billion
- Just started: 29 with 1.4 billion



CO-0001-025

AR0067883

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Testimonials

Arpy Hatzikian, Principal, Gensler Group

"I think that this procedure is a hit. 15% were saved for the last project."

David Weaver, Architect, DRW ASSOCIATES

"It does away with a lot is scheduling frustration beginning with releasing the clearance summary worksheet early in the plan checking process."

Mark Armbruster, Armbruster Goldsmith & Delvac LLP

"By decreasing the amount of time spent on corrections-resubmittals, this does save time and money, at least 30% in savings."

Tina Y. Choi-Nelson, Principal, Tchoi & Associates

"The parallel permitting program is a significant improvement over the standard plan check process and estimated time saving 20-25%, estimated dollars saving 5-15%."

Christian Kienapfel, Architect, LEED, Dipl.-Ing. Architekt, Germany

"Sense of partnership with the plan checker. Sense of "first class" assistance. It saves a great deal of time over the standard, non-expedited, plan check process. On scale of 1 to 10, my experience with the program has been a 10!"

CO-0001-026

AR0067884

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project > 50 units > 50,000 sq. ft > $10 million > 50 jobs	Dev. Services Case Mgmt. *We plan your project w/ you.* • Feasibility Study • Preliminary Plan Review • Pre-development Meeting	Dev. Services Case Mgmt. • Project Navigation Parallel Design-Permitting *We issue the permit when you complete the design.* • Design and Plan Check simultaneously • Early resolution of issues • Early start on clearance	**assistance not available**
Midsize Project	**assistance not available**	**assistance not available**	**assistance not available**
Small Business	**assistance not available**	**assistance not available**	**assistance not available**
Small Dwelling	**assistance not available**	**assistance not available**	**assistance not available**
Special Project	**assistance not available**	**assistance not available**	**assistance not available**

CO-0001-027

AR0067885

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Restaurant & Hospitality Express Program (RHEP)

Open on Schedule!

AR0067886

CO-0001-028

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Running a restaurant is difficult but opening a restaurant is worse. Prior to the Restaurant & Hospitality Express Program (RHEP), very few restaurants opened on schedule due to the permitting and construction complexities.

RHEP, comprised of 5 LADBS staff (4 inspectors and 1 engineer), was created to provide an assistance program tailored to streamline the permitting and inspection approval process for food service establishments to ensure TIMELY OPENING.

A multi-agency network led by LADBS (4 LADBS inspectors and 1 with the following agencies works collaboratively with the design/construction teams:

- County Health
- Sanitation
- Fire
- Planning
- Bureau of Engineering

CO-0001-029

AR0067887

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

RHEP has improved the procedure :

- Developed an over-the-counter plan check review.
- Created policies to eliminate inspection inconsistencies.
- Standardized referral procedures among agencies.

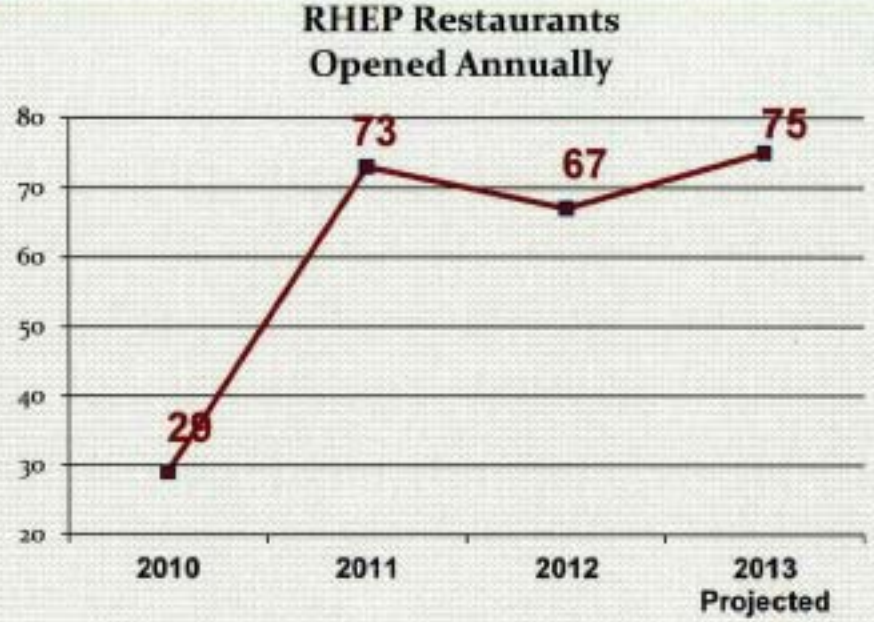
RHEP also assists restaurant projects throughout the entire development process:

- **Design Phase:**
  - Clarify code requirements and solve foreseeable issues
  - Determine permit cost.
- **Permitting Phase:**
  - Assign one plan check staff to perform counter plan check.
  - Assist project to obtain signoffs from other agencies.
- **Construction Phase:**
  - Resolve construction issues and conflicts.
  - Schedule inspection to meet completion timeline.

CO-0001-030

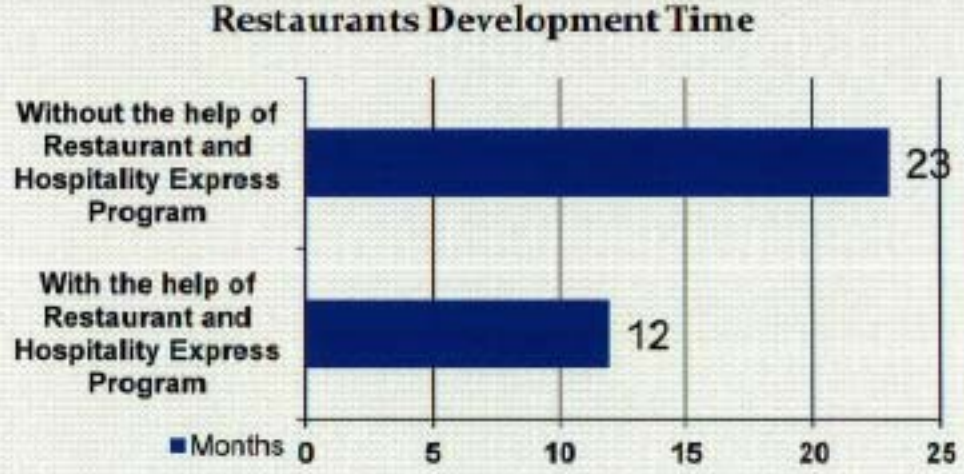
AR0067888

LA DBS
DEPARTMENT OF BUILDING AND SAFETY



206 RHEP restaurants were opened on schedule stimulating the economy and creating new jobs.

These RHEP restaurants saved approximately 6 to 18 months during the Design, Permitting, and Construction phases.



CO-0001-031

AR0067889

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Testimonials

Due to its success, RHEP has been featured in many publications including the L.A. Times, L.A. Business Journal, and Contra Costa Times.

Keith Glassman, Starbucks

"I want to Thank you for all the great work and tremendous customer assistance experience you provide all year long... the LADBS Hospitality program has been instrumental in expediting the plans review process and resolving issues..."

Frank Leon, Chef/Owner

"I wanted to express my personal gratitude as your hospitality program has helped small business owners like myself... Your guidance has truly been instrumental in keeping us on par throughout this entire process"

Matt Karatz, Former Deputy Mayor

"Awesome work Restaurant Express. The Mayor uses your group as a model for better customer assistance in many speeches across town."

CO-0001-032

AR0067890

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project > 50 units > 50,000 sq. ft > $10 million > 50 jobs	Dev. Services Case Mgmt.	Dev. Services Case Mgmt. Parallel Design-Permitting	**assistance not available**
Midsize Project	**assistance not available**	**assistance not available**	**assistance not available**
Small Business	**assistance not available**	**assistance not available**	**assistance not available**
Small Dwelling	**assistance not available**	**assistance not available**	**assistance not available**
Special Project (Restaurants)	Restaurant Express • Clarify code requirements • Solve foreseeable issues • Determine permit cost	Restaurant Express • Counter Plan Check • Assist to obtain signoffs	Restaurant Express • Inspection scheduling • Resolve construction issues • Meet completion deadline
Other Special Project	**assistance not available**	**assistance not available**	**assistance not available**

CO-0001-033

AR0067891

Although LADBS has made great strides at instilling a customer friendly culture, more needs to be done.

New Proposed Mission Statement

> *"The mission of the Department of Building and Safety is to protect the lives and safety of the residents and visitors of the City of Los Angeles and enhance the quality of life, housing, economic prosperity, and job creation. Through a timely, cooperative, and transparent process, the department advises, guides, and assists customers to achieve compliance with Building, Zoning, Plumbing, Mechanical, Electrical, Disabled Access, Energy, and Green Codes; and local and State laws.* ***The collaboration fosters the goal to build safe, build well, and build fast."***

LADBS will establish an all inclusive program to provide systematic and comprehensive assistance to all project types at all development phases."

CO-0001-034

AR0067892

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Development Services "Concierge" Program

We are with you all the way to build safe, build well, and build fast!

CO-0001-035

AR0067893

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project > 50 units > 50,000 sq. ft > $10 million > 50 jobs	Dev. Services Case Mgmt.	Dev. Services Case Mgmt. Parallel Design-Permitting	**assistance not available**
Midsize Project	**assistance not available**	**assistance not available**	**assistance not available**
Small Business	**assistance not available**	**assistance not available**	**assistance not available**
Small Dwelling	**assistance not available**	**assistance not available**	**assistance not available**
Special Project (Restaurants)	Restaurant Express	Restaurant Express	Restaurant Express
Other Special Project	**assistance not available**	**assistance not available**	**assistance not available**

There are many 'boxes' with 'assistance not available.'
DSCP will fill those 'boxes' with services to assist all of our customers.

CO-0001-036

AR0067894

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

The proposed Development Services "Concierge" Program will provide consultation, facilitation, and problem solving services to all Major, Midsize, Small and Special projects throughout the Design, Permitting, and Construction phases. DSCP will include:

Three existing programs:

- Development Services Case Management (DSCM)
- Parallel Design-Permitting Process (PDPP)
- Restaurant & Hospitality Express Program (RHEP)

Two EXPANDED existing programs:

- Expanded DSCM (to cover Midsize and Small projects)
- Expanded PDPP (to cover Midsize projects)

Three NEW programs:

- Inspection Case Management (ICM)
- Weekend Inspection for Single Family Dwellings
- High Tech Fast Track (HTFT)

CO-0001-037

AR0067895

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Expanded Development Services Case Management

Development Services Case Management Services will be expanded to include Midsize Projects, Small Businesses, and Small Single Dwellings.

Case managers will be available to perform project feasibility studies, coordinate pre-development meetings with other departments, conduct preliminary plan reviews to identify potential building site and code issues, resolve issues arising from design considerations and code requirements, and assist applicants with plan check corrections and the citywide clearance processes.

In addition a **Help Center** will be created to provide Ad Hoc assistance to property owners with their home improvements and additions. The Help Center will provide the same service to small business owners.

CO-0001-038

AR0067896

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Expanded Parallel Design-Permitting Process

PDPP services will be expanded to include Midsize projects.

With this expansion, the construction valuation of all PDPP projects will be approximately 70% of the total valuation of all development projects.

These PDPP projects , the ones that would contribute the most to jump start the economy and create the most jobs, will be built at least 6 to 9 months faster!

CO-0001-039

AR0067897

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project	Dev. Services Case Mgmt.	Dev. Services Case Mgmt. Parallel Design-Permitting	**assistance not available**
Midsize Project > 30 units > 30,000 sq. ft > $ 5 million > 30 jobs Affordable Housing Charter School	Expanded DSCM • Feasibility Study • Preliminary Plan Review • Pre-development meeting w/ involved agencies	Expanded DSCM • Project Navigation Expanded PDPP • Design & Plan Check simultaneously • Early resolution of issues • Early start on clearance	**assistance not available**
Small Business	Expanded DSCM • Clarify code requirements • Solve foreseeable issues	Expanded DSCM • Help Center	**assistance not available**
Small Single Dwelling	Expanded DSCM • Help Center	Expanded DSCM • Help Center	**assistance not available**
Special Project (Restaurants)	Restaurant Express	Restaurant Express	Restaurant Express
Other Special Project	**assistance not available**	**assistance not available**	**assistance not available**

CO-0001-040

AR0067898

Inspection Case Management (ICM)

The Development Service Case Management assists projects at their Design and Permitting phases.

The ICM program carries the case management concept into the Construction Phase for Major, Midsize, and Small Business projects.

ICM creates a partnership with developers and contractors to facilitate project construction and utilizes a series of "all-hands" meetings to collaborate on solutions to issues standing in the way of project completion.

CO-0001-041

AR0067899

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

ICM Pre-construction Meeting

Before construction starts, the construction team meets with LADBS inspection team to discuss issues such as construction timelines, overlapping inspection disciplines, trade specific questions, off-hour inspections, etc.

ICM Construction Facilitation Meeting

During construction, the two teams meet regularly to discuss and resolve issues such as technical details, plan inconsistencies, code interpretations, correction notices, etc.

ICM Certificate of Occupancy (C/O) Meeting

When a project nears completion and either a Temporary C/O or C/O is on a tight timeline, the two teams meet to discuss final inspections scheduling, fire and life safety systems testing and approvals, equipment listings, etc.

CO-0001-042

AR0067900

Construction Coordinator (funded by the development project)

In construction, time is money. While there are many reasons for construction delay, one common cause is not knowing where or who to contact to resolve an on-site problem when it arises. For examples, the approval of the usage of unapproved materials, unexpected change of inspection scheduling, etc.

The ICM includes the assignment of a Construction Coordinator (an LADBS senior inspector) to a project who will provide full time , on-site service to the construction teams.

The ICM Coordinator will be a facilitator, pathfinder, and problem-solver, who serves the project by accessing and coordinating a variety of departmental resources to resolve any construction and inspection related issues within a minimal amount of time.

The Construction Coordinator will be funded by the project.

CO-0001-043

AR0067901

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project	Dev. Services Case Mgmt.	Dev. Services Case Mgmt. Parallel Design-Permitting	Inspection Case Management • Network between construction team and inspection team • Construction Facilitation • Certificate of Occupancy Facilitation • Construction-Inspection Liaison
Midsize Projects	Expanded DSCM	Expanded DSCM Expanded PDPP	
Small Business	Expanded DSCM	Expanded DSCM	Inspection Case Management • Solve foreseeable issues
Small Single Dwelling	Expanded DSCM	Expanded DSCM	**assistance not available**
Special Project (Restaurants)	Restaurant Express	Restaurant Express	Restaurant Express
Other Special Project	**assistance not available**	**assistance not available**	**assistance not available**

CO-0001-044

AR0067902

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Weekend Inspection for Single Family Dwellings

Currently, inspections for single-family dwellings are available only during normal business hours from Monday through Friday.

Owners or tenants may have to take time off work or assign someone to wait at home for the inspectors to show up.

With Weekend Inspection, inspection services will be available on weekends for minor construction work:

- building, plumbing, mechanical and electrical repairs
- replacement of fixtures and mechanical equipment

This program will give single family dwelling owners or tenants the flexibility of receiving inspection service during weekends instead of taking time off work.

CO-0001-045

AR0067903

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project	Dev. Services Case Mgmt.	Dev. Services Case Mgmt. Parallel Design-Permitting	Inspection Case Management
Midsize Projects	Expanded DSCM	Expanded DSCM Expanded PDPP	Inspection Case Management
Small Business	Expanded DSCM	Expanded DSCM	Inspection Case Management
Small Single Dwelling	Expanded DSCM	Expanded DSCM	Weekend Inspection • Minor repair • Replacement of fixtures
Special Project (Restaurants)	Restaurant Express	Restaurant Express	Restaurant Express
Other Special Project	**assistance not available**	**assistance not available**	**assistance not available**

CO-0001-046

AR0067904

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

High Tech Fast Track (HTFT)

With the best weather and a large talent pool educated by the many outstanding universities in the region, L. A. is becoming a hot spot for High Tech companies (clean energy, information, telecommunications).

HTFT can help to attract these High Tech companies through its services (similar to the RHEP's):

- **Design Phase:**
  - Clarify code requirements and solve foreseeable issues
  - Determine permit cost.
- **Permitting Phase:**
  - Assign 1 plan check staff to perform counter plan check.
  - Assist project to obtain signoffs from other agencies.
- **Construction Phase:**
  - Resolve construction issues and conflicts.
  - Schedule inspection to meet completion timeline.

CO-0001-047

AR0067905

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

LADBS Assistance Provided to Projects

	Design Phase	Permitting Phase	Construction Phase
Major Project	Dev. Services Case Mgmt.	Dev. Services Case Mgmt. Parallel Design-Permitting	Inspection Case Management
Midsize Projects	Expanded DSCM	Expanded DSCM Expanded PDPP	Inspection Case Management
Small Business	Expanded DSCM	Expanded DSCM	Inspection Case Management
Small Single Dwelling	Expanded DSCM	Expanded DSCM	Weekend Inspection
Special Project (Restaurants)	Restaurant Express	Restaurant Express	Restaurant Express
Special Project (High Tech)	High Tech Fast Track	High Tech Fast Track	High Tech Fast Track

CO-0001-048

AR0067906

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

Development Services "Concierge" Program

We are with you all the way to build safe, build well, and build fast!

The Development Services "Concierge" Program brings services to projects of all sizes and throughout all phases of the development process.

Provides a vehicle for all LADBS employees to go beyond simply processing applications to partnering with our development customers to build safe, build well, and build fast.

DSCP is a comprehensive solution to foster development, jump start the economy, and create jobs.

CO-0001-049

AR0067907

Millennium Hollywood Project
Table of Public Benefits

DA Section and Page Number	Benefit Component	Timing	First Phase	Initial East Parcel/West Parcel Phase
	Labor/Hiring and Wage Components			
§3.1.3.1 Pg. 11	1. **Project Labor Agreement** – Developer shall enter into a "Project Labor Agreement" that will identify the construction trade union(s) as the primary source of all craft labor employed on the Project.	Developer must enter into agreement prior to issuance of a building permit for each Phase of the Project.		
§3.1.3.2 Pg. 11	2. **Local Hiring** – For each Phase of the Project Developer shall implement an apprenticeship and zip code identification program to prioritize local source hiring for Project construction from the 13th Council District.	A report detailing demographic information on the Project's workers shall be included as a part of the Annual Review.	Program shall be prepared no later than six months before start of construction of First Phase.	
§3.1.3.3 Pg. 12	3. **Construction Trades Prevailing Wage** - Construction workers employed in the construction of each Phase of the Project shall be paid no less than the prevailing wage as determined by the provisions of Sections 1770 et seq. of the California Labor Code	Proof of compliance shall be submitted prior to the issuance of any certificate of occupancy for the Project.		
	Transportation Improvements			
§3.1.3.5(a) Pg. 12	4. **Circulation Shuttle** Developer shall operate a shuttle service, providing "on call" service between the Project and residential areas within a two mile radius. Developer shall not be obligated to spend more than $50,000 per year for the operation of service.	The Developer shall demonstrate how it has implemented the program in the Annual Review.	Prior to issuance of final certificate of completion for the first Phase, Developer shall procure the shuttle service. Service shall operate during the Term of the Development Agreement (the "DA")	

CO-0001-050

AR0067908

DA Section and Page Number	Benefit Component	Timing	First Phase	Initial East Parcel/West Parcel Phase
§3.1.3.5(b) Pg. 13	5. **Bicycle Amenities Plan** Developer shall maintain a kiosk or tenant space of at least 200 square feet for bicycle repair services. This space is in addition to bicycle parking facilities required by the Development Regulations.	Developer shall demonstrate to the Planning Director how it has implemented the program in the Annual Review.	Provision of bicycle amenities shall commence upon issuance of a final certificate of occupancy for First Phase and thereafter for the Term of the DA	The East and West Portion Phase shall include dedicated bicycle ways and wayfinding signage between public streets and the facilities.
§3.1.3.5(c) Pg. 13	E. **Linkages to future public transit services** – Developer shall: a. Install directional signage showing pedestrian routes to all public transportation access points within a four block radius of the Project. b. Provide $20,000 to the Department of Transportation for the installation of directional signage at the DASH access point nearest the Project, and c. Provide $25,000 to Metro for directional signage for pedestrian routes between public transportation access points and the Project.		Proof of payment of the Transit Linkage Payments shall be submitted to the Planning Director prior to the issuance of a final certificate of occupancy for the First Phase of the Project.	

CO-0001-051
AR0067909

Millennium Hollywood Project
Table of Public Benefits

DA Section and Page Number	Benefit Component	Timing	First Phase	Initial East Parcel/West Parcel Phase
§3.1.3.5(e) Pg. 13	7. **Parking Tracking Services** - Developer shall contribute $50,000 to the Department of Transportation's Express Park program for new parking meter technology, vehicle sensors, a central management system and real-time parking guidance for motorists in the vicinity of the Project.		Contribution shall be paid to the City Department of Transportation prior to issuance of the final certificate of occupancy for the First Phase	
§3.1.3.5(e) Pg. 14	8. **Vine Street Metro Connection** – Developer shall engage an urban planning and architectural firm to study a portal north of Hollywood Boulevard into the Hollywood Boulevard/Vine Street Metro Station		Study shall be completed before the issuance of the first building permit for the first Phase.	
§3.1.3.5(f) Pg. 14	9. **Metro Passes** – Developer shall provide for the sale of Metro passes to Project residents, tenants and their employees and shall purchase at least 25 Metro passes for residents and tenants of the Project.	Developer shall demonstrate to the Planning director how it has implemented such program as part of the Annual Review.	Provision of Metro passes will begin upon issuance of final certificate of occupancy for the First Phase and thereafter during the Term of DA.	
§3.1.3.5(g) Pg. 14	10. **Monthly Parking Leases for Metro Commuters** – Developer shall provide 10 "park and ride" spaces for monthly lease to persons who are not tenants or occupants of the Project and establish a monitoring program of the park and ride spaces.	The results of the monitoring program shall be submitted as part of the Annual Review.	Beginning upon issuance of a final certificate of occupancy for the First Phase, and thereafter during the Term of the DA.	

CO-0001-052

AR0067910

Millennium Hollywood Project
Table of Public Benefits

DA Section and Page Number	Benefit Component	Timing	First Phase	Initial East Parcel/West Parcel Phase
§3.1.3.5(h) Pg. 14	11. **Shared Vehicle Parking** – Developer shall maintain 10 parking spaces within non-residential parking areas of the Project for shared vehicle services.	As part of the Annual Review, Developer shall demonstrate to the Planning Director how it has implemented such program	Commencing upon issuance of a final certificate of occupancy for the First Phase and thereafter during the Term of the DA.	
	Local Community Benefits			
§3.1.3.4 Pg. 12	12. **Community Organization Meeting Space** – Developer shall provide not less than 1,200 square feet of meeting space at the Project for use by Hollywood and community non-profit groups.		Developer shall establish and operate a reservation system commencing upon issuance of a certificate of occupancy for the First Phase.	
§3.1.3.6 Pg. 14	13. **Protection of Capitol Records Building, Recording Studios and Echo Chambers** – Developer shall prepare a written adjacent structure monitoring plan to ensure that construction will not damage the Capitol Records Building, including the recording studios and underground echo chambers therein	As part of the Annual Review, Developer shall demonstrate to the Planning Director how it has implemented such monitoring program.		Issuance of a building permit for the Initial East Parcel Phase is conditioned on submission of written adjacent structure monitoring plan to the Department of Building and Safety..

AR0067911

CO-0001-053

Millennium Hollywood Project
Table of Public Benefits

DA Section and Page Number	Benefit Component	Timing	First Phase	Initial East Parcel/West Parcel Phase
§3 1.3.7 Pg. 15	14. **Public Performances, Music, and Arts Programming** – Developer shall conduct at least four public events per year in the Art Plaza and pay costs associated with events.	Developer shall provide a schedule and conduct public events for Term of DA.		
§3.1.3.8 Pg. 15	15. **Parking Access Management System** – Developer shall provide a parking access management system.			
§3 1 3 9 Pg. 15	16. **Pedestrian Improvements Contribution** Developer shall provide funding in the amount of $50,000 to the Hollywood Chamber of Commerce Walk of Fame Committee, or as otherwise directed by the City, for renovation and upkeep of the Walk of Fame stars and terrazzo, sidewalks and other public streetscape improvements.		First half of payment is a condition of issuance of a building permit for the First Phase. Proof of payment of the balance shall be a condition to issuance of the final certificate of occupancy for the First Phase.	
§3.1.3.10 Pg. 15	17. **Music Appreciation Exhibit** – Developer shall install publicly accessible artwork and/or changeable exhibition cabinets and/or platforms. The Music Appreciation Exhibit shall be maintained at Developers sole cost.	Developer shall demonstrate how it has programmed the Music Appreciation Exhibit as part of the Annual Review.	The Music Appreciation exhibit shall be installed within the First Phase of the Project.	
§3 1 3.11 Pg. 16	18. **Hollywood Central Park** – Developer shall make contribution to the Friends of Hollywood Central Park in the amount of $50,000. Thereafter, Developer shall make an annual contribution in the amount of $50,000 for the operation and maintenance of the Hollywood Central Park.	Annual contribution shall be made on April 1 following the issuance of a final certificate of occupancy and on April 1 of each year during remaining term of the DA.	Proof of payment shall be a condition to the issuance of the building permit for the First Phase.	

AR0067912

CO-0001-054

Millennium Hollywood Project

Table of Public Benefits

DA Section and Page Number	Benefit Component	Timing	First Phase	Initial East Parcel/West Parcel Phase
	Affordable Housing			
§3.1.3.22 Pg. 16	19. **Affordable Housing Payment** – Developer shall pay $4,800,000 for the development of 100 new affordable housing units. The affordable housing Projects are (a) the Westlake Theater Project, and (b) the Coronet Project (the "HCHC Projects"). a. **Developer HCHC Project Contributions** – Within 90 days of as receipt of written notice from LAHD that the HCHC Project Commitment Date has occurred for each HCHC Project, Developer shall pay $2,400,000 to LAHD for the development HCHC Project. b. **Developer LAHD Contribution** – If the HCHC Project Commitment Date has not occurred for HCHC Project, by the date Developer submits an application for a building permit for a building that includes residential units, Developer shall pay an equal amount to LAHD as a condition to the issuance of the building permit. c. **LAHD Use of Developer LAHD Contribution** - LAHD is authorized to pay all or part of the Developers contribution to HCHC for costs associated with the remaining unfunded HCHC Project, other HCHC affordable housing projects, expenses, and costs associated with production of affordable housing.	Developer HCHC Project Contributions shall be paid within 90 days of receipt of written notice from LAHD that HCHC Project commitment Date has occurred		

CO-001-055

AR0067913

I. **Additional Benefits Proposed to be Included in the Conditions of Approval**

Benefit Component	Requested by:
1. **Pedestrian Improvements Contribution** – Developer shall provide funding in the amount of $50,000 to the Bureau of Street Services, or as otherwise directed by the City, for renovation and upkeep of the Walk of Fame stars and terrazzo, sidewalks and other public streetscape improvements.	*Planning, CD 13 Council Office*
2. **Skate Park** – Developer contribute lesser of estimated cost or $50,000 toward improvement of a community skate park, subject to City's acquisition of a site.	*CHNC*
3. **Central Hollywood Design Overlay** – If requested by City, Developer will contribute $125,000 toward completion of Central Hollywood Design Overlay pursuant to Hollywood Community Plan Policy LU 2.5.1 or other Planning undertaking	*CHNC*

Benefit Component	Requested by:
4. **Hollywood Sign Protection Fund –** Following installation of 410+ foot building, Developer shall make contributions to the Hollywood Sign Trust, a California non-profit corporation, in the amount of $500 per residential dwelling unit in such Phase and subsequent Phases, which contribution shall be payable with respect to each unit within thirty (30) days after the earlier of the initial sale or lease thereof.	*CHNC, CD 4 Council Office, CD 13 Council Office, Planning*
5. **Music and Arts Programming –** For a fifteen (15) year term starting upon issuance of the certificate of occupancy for the final phase of construction for the Project, Developer shall work with the 13th Council District to develop a plan for publicly accessible music and arts programming within the Project which may include such elements as art installations, whether temporary or permanent, changeable exhibition cabinets, or other artistic and musical performances at the Project Site. Programming will be developed in consultation with the City's Cultural Affairs Department, the Hollywood Arts Council, and the Hollywood Business Improvement District. Developer will pay for all costs associated with such programming.	*CD 13 Council Office, Planning*

Benefit Component	Requested by:
1. **Project Information** - Upon issuance of building permits but no less than sixty (60) days prior to the commencement of construction of new improvements. Developer will notify the 13th Council District of the development activity for which permits have been issued including proposed uses for such improvements and anticipated duration of construction. To the extent requested by the 13th Council District, Developer shall hold a public meeting for interested members of the public regarding the construction schedule for and ultimate uses of such improvements for which permits have been issued.	***CD 13 Council Office***

RECORDING REQUESTED BY AND
WHEN RECORDED MAIL TO:

Sheppard Mullin Richter & Hampton LLP
333 South Flower Street
43rd Floor
Los Angeles, CA 90071
Attn: Alfred Fraijo, Jr., Esq.

NO RECORDING FEE – PUBLIC AGENCY – GOVERNMENT CODE §6103

(Space above for Recorder's Use)

DEVELOPMENT AGREEMENT

by and among

THE CITY OF LOS ANGELES,

1720 NORTH VINE LLC,

1749 NORTH VINE STREET LLC,

1750 NORTH VINE LLC,

1733 NORTH ARGYLE LLC,

and

MILLENNIUM HOLLYWOOD LLC

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DEVELOPMENT AGREEMENT

This DEVELOPMENT AGREEMENT ("**Agreement**") is executed this _____day of _____, _____, 2013, by and among the CITY OF LOS ANGELES, a municipal corporation (the "**City**"), 1720 NORTH VINE, LLC, a Delaware limited liability company ("**1720 Owner**"), 1749 NORTH VINE STREET LLC, a Delaware limited liability company ("**1749 Owner**"), 1750 NORTH VINE LLC, a Delaware limited liability company ("**Capitol Records Building Owner**"), 1733 NORTH ARGYLE LLC, a Delaware limited liability company ("**Argyle Owner**"; and collectively with the 1720 Owner, the 1749 Owner, and the Capitol Records Building Owner, the "**Property Owners**"), and MILLENNIUM HOLLYWOOD LLC, a Delaware liability company (collectively with the Property Owners, "**Developer**"), pursuant to California Government Code Section 65864 et seq., and the implementing procedures of the City, with respect to the following:

RECITALS

WHEREAS, the City and Developer recognize that the further development of the Property will create significant opportunities for economic growth in the City of Los Angeles, the Southern California region and California generally;

WHEREAS, Developer wishes to obtain reasonable assurances that the Project, as defined below, may be developed in accordance with the Project Approvals, as defined below, and the terms of this Agreement;

WHEREAS, Developer will implement public benefits above and beyond the necessary mitigation for the Project, including benefits and other consideration as noted in Section 2.3.1,

WHEREAS, this Agreement is necessary to assure Developer that the Project will not be reduced in density, height, or use, or be subjected to new rules, regulations, ordinances, or policies unless otherwise allowed by this Agreement;

WHEREAS, by entering into this Agreement, the City is encouraging the development of the Project as set forth in this Agreement in accordance with the goals and objectives of the City, while reserving to the City the legislative powers necessary to remain responsible and accountable to its residents; and

WHEREAS, Developer intends to redevelop the 4.46-acre site (the "**Property**"), as set forth in **Exhibits A-1** and **A-2** attached hereto, located at 1720, 1722, 1724, 1730, 1740, 1745, 1749, 1750, 1751, 1753, 1760, 1762, 1764, 1766, 1768, and 1770 N. Vine Street; 6236, 6270, and 6334 W. Yucca Street; 1733 and 1741 N. Argyle Avenue; and 1746, 1748, 1754, 1760, and 1764 N. Ivar Avenue, Los Angeles, California 90028;

WHEREAS, Developer anticipates that the Project will be completely built-out and operational by the year 2020, but is requesting a longer term in this Agreement to allow sufficient time for development in the unlikely event of delays caused by unforeseen economic conditions and other unforeseen factors such as, but not limited to, unanticipated site conditions and the unavailability of materials or labor shortages;

WHEREAS, for the foregoing reasons, the Parties desire to enter into a development agreement for the Project pursuant to the Development Agreement Act, as defined below, and the City's charter powers upon the terms and conditions set forth herein.

AGREEMENT

NOW, THEREFORE, pursuant to the authority contained in the Development Agreement Act, as it applies to the City, and in consideration of the premises and mutual promises and covenants herein contained and other valuable consideration the receipt and adequacy of which the Parties hereby acknowledge, the Parties agree as follows:

1. DEFINITIONS.

For all purposes of this Agreement, except as otherwise expressly provided or unless the context requires:

1.1 "**Agreement**" means this Development Agreement, including all exhibits attached hereto and all amendments and modifications hereto.

1.2 "**Applicable Rules**" means all of the rules, regulations, ordinances and officially adopted policies of the City in force as of the Effective Date, including, but not limited to, the Municipal Code, this Agreement (including the Development Regulations and all other attachments hereto) and Project Approvals. Additionally, notwithstanding the language of this Section or any other language in this Agreement, all specifications, standards and policies regarding the design and construction of public works facilities, if any, shall be those that are in effect at the time the applicable Project plans are being processed for approval and/or under construction but only to the extent not inconsistent with the Development Regulations or this Agreement.

1.3 "**Argyle Owner**" means 1733 North Argyle LLC, a Delaware limited liability company.

1.4 "**Assignment Agreement**" means a written agreement between Developer (or any of them) and a Transferee of Developer (or any of them), consistent with the terms of this Agreement, in which the parties agree to specific obligations of this Agreement being transferred from such Developer to such Transferee. An Assignment Agreement may, but shall not be required to, allocate to the Transferee for its portion of the Property a defined portion of the Maximum Floor Area.

1.5 "**Capitol Records Building Owner**" means 1750 North Vine LLC, a Delaware limited liability company.

1.6 "**CEQA**" means the California Environmental Quality Act (Cal. Public Resources Code Sections 21000 et seq.) and the State CEQA Guidelines (Cal. Code of Regs., Title 14, Sections 15000 et seq.).

1.7 "**City**" means the City of Los Angeles, a charter City and municipal corporation.

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1.8 "**City Agency**" means each and every agency, department, board, commission, authority, employee, and/or official acting under the authority of the City, including without limitation, the City Council and the Planning Commission.

1.9 "**City Council**" means the City Council of the City and the legislative body of the City pursuant to Section 65867 of the California Government Code.

1.10 "**Conditions of Approval**" means the conditions of approval issued in connection with the Project Approvals.

1.11 "**Development Parameters**" means, collectively, the Development Regulations and the Equivalency Program.

1.12 "**Development Regulations**" means the Millennium Hollywood, Development Regulations: Design Guidelines and Standards attached as **Exhibit B**.

1.13 "**Developer**" means, collectively or individually, as applicable, 1720 Owner, 1749 Owner, Capitol Records Building Owner, and Millennium Hollywood LLC, a Delaware liability company, and all of their respective Transferees.

1.14 "**Development Agreement Act**" means Article 2.5 of Chapter 4 of Division 1 of Title 7 (Sections 65864 et seq.) of the California Government Code.

1.15 "**Discretionary Action**" means an action which requires the exercise of judgment, deliberation, or a decision on the part of the City and/or any City Agency, including any board, commission, or department or any officer or employee thereof, in the process of approving or disapproving a particular activity, as distinguished from an activity which merely requires the City and/or any City Agency, including any board, commission or department or any officer or employee thereof, to determine whether there has been compliance with statutes, ordinances, or regulations.

1.16 "**EIR**" means the Environmental Impact Report for the Project, State Clearinghouse No. ENV-2012-____-EIR-__, certified by the City in accordance with the requirements of CEQA.

1.17 "**Effective Date**" is the date on which this Agreement is attested by the City Clerk of the City of Los Angeles after execution by Developer and the Mayor of the City of Los Angeles.

1.18 "**Equivalency Program**" means the land use equivalency program, as more fully described in Section 3.2.5 of this Agreement and the Project Approvals, which allows land uses to be developed on the Property to be exchanged among the permitted land uses so long as the limitations of such equivalency program are satisfied and do not exceed the analyzed upper levels of environmental impacts that are identified in the EIR or exceed the Maximum Floor Area. All permitted land use increases can be exchanged for corresponding decreases of other permitted land uses on the Property under the Equivalency Program once the maximum FAR is reached.

1.19 "**Existing Improvements**" means the existing buildings, structures and improvements located within the Property, consisting only of the Capitol Records Building, the Gogerty Building, and parking facilities as of the Effective Date or replaced pursuant to this Agreement.

1.20 "**Fees**" means Impact Fees, Processing Fees and Charges and any other fees or charges imposed or collected by the City.

1.21 "**Floor Area**" means the floor area of the improvements, as measured by the City pursuant to Section 12.03 of the Los Angeles Municipal Code.

1.22 "**General Plan**" means the General Plan of the City.

1.23 "**Impact Fees**" means impact fees, linkage fees, exactions, assessments or fair share charges or other similar impact fees or charges imposed on and in connection with new development by the City pursuant to rules, regulations, ordinances and policies of the City set forth in the Applicable Rules. Impact Fees do not include (i) Processing Fees and Charges or (ii) other City-wide fees or charges of general applicability, provided that such City-wide fees or charges are not imposed on impacts of new development.

1.24 "**include**","**including**", "**includes**" in each instance will be deemed to be followed by the phrase "without limitation".

1.25 "**Litigation**" means any lawsuit (including any cross-action) filed against the City and/or Developer to the extent such lawsuit challenges the validity, implementation or enforcement of or seeks any other remedy directly relating to, all or any part of this Agreement, the EIR and/or the Project Approvals.

1.26 "**Ministerial Permits and Approvals**" means the permits, approvals, plans, inspections, certificates, documents, licenses, and all other actions required to be taken by the City in order for Developer to implement and construct the Project. Ministerial Permits and Approvals shall not include any Discretionary Actions.

1.27 "**Mitigation Measures**" means the mitigation measures set forth in the EIR for each potential environmental impact of the Project and set forth in the mitigation monitoring program adopted as a condition of approval of the EIR and/or Project Approvals.

1.28 "**Mortgage**" means any mortgage, deed of trust, pledge, encumbrance, sale leaseback, or other security interest granted to a person, made in good faith and for fair value, encumbering all or any part of the Developer Property or Developer's interest in this Agreement, given by Developer for the purpose of obtaining Financing for the acquisition of land within the Property or any portion thereof, the construction of any improvements thereon, or any other purpose.

1.29 "**Mortgagee**" means any (i) the holder of any Mortgage (including, as applicable, any administrative agent), (ii) beneficiary under any Mortgage, and/or (iii) with respect to any parcel in the Project which is the subject of a sale-leaseback transaction, the person acquiring fee title under a Mortgage who has delivered a Mortgagee Notice to the City as provided in Section

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6.1.4 of this Agreement, including the successors and assigns of any such holder, beneficiary or lessor.

1.30 "**Mortgagee Successor**" is defined in Section 6.1.4 of this Agreement.

1.31 "**Municipal Code**" means, as applicable, the Los Angeles Municipal Code as the same may exist from time to time during the term of this Agreement, or, when used in the context and within the meaning of the Applicable Rules, the Los Angeles Municipal Code as of the Effective Date of this Agreement.

1.32 "**Parties**" means collectively Developer and the City.

1.33 "**Party**" means any one of Developer or the City.

1.34 "**Phase**" shall have the meaning described in Section 3.2.1 of this Agreement.

1.35 "**Planning Commission**" means the City Planning Commission and the planning agency of the City pursuant to Section 65867 of the California Government Code (Development Agreement Act).

1.36 "**Planning Director**" means the Director of Planning for the City or his or her designee.

1.37 "**Proceeding**" is defined in Section 7.9.1.

1.38 "**Processing Fees and Charges**" means all processing fees and charges required by the City or any City Agency including, but not limited to, fees for land use applications, project permits, building application, building permits, grading permits, encroachment permits, tract or parcel maps, lot line adjustments, air right lots, street vacations and certificates of occupancy which are necessary to accomplish the intent and purpose of this Agreement. Expressly exempted from Processing Fees and Charges are all Impact Fees which may be imposed by the City on development projects pursuant to laws enacted after the Effective Date, except as specifically provided for in this Agreement. Processing Fees and Charges include those linkage fees, impact fees, and exactions which are in effect as of the Effective Date, the amounts of which are subject to ongoing annual increases which shall be calculated at time of payment. The amount of the Processing Fees and Charges to be applied in connection with the development of the Project shall be the amount which is in effect on a City-wide basis at the time an application for the City action is made unless an alternative amount is established by the City in a subsequent agreement.

1.39 "**Project**" means a mixed-use development described in greater detail in the Project Approvals and the Development Regulations.

1.40 "**Project Approvals**" those Discretionary Actions authorizing the Project which have been requested by Developer and approved by the City and which are comprised of (1) Vesting Zone Change and Height District removal of the "D" Limitation from C4-2D-SN to C2-2-SN per Municipal Code Section 12.32 F and 12.32Q and Ordinance 165,659-SA 180; (2) Vesting Conditional Use Permit to allow a hotel use within five hundred feet of a R Zone per

Municipal Code Section 12.24.W.24 and 12.24.T; (3) Conditional Use Permit for floor area ratio averaging in a unified development per Municipal Code Section 12.24.W.19; (4) the Conditional Use Permit for beverage with full alcohol, live entertainment and dancing per Municipal Code Sections 12.24.W.1 and 12.24.W.18.a; (5) Variance from Municipal Code Section 12.14.A.1(a)(10) for restaurants with outdoor eating areas above the ground floor per Municipal Code § 12.27; (6) Variance from Municipal Code Section 12.21.A.4(c)(2) to reduce parking required for sports club facility per Municipal Code § 12.27; (7) Authority for Reduced On-Site Parking with Remote Off-site Parking or Transportation Alternatives; (8) Site Plan Review for a project that creates a maximum of 1,116,000 square feet of development on a 4.4 acre site; and (9) the subdivision of the Property pursuant to the Vesting Tentative Tract Map dividing the Property into 2 grounds lots and 39 "air space" lots, and providing for further subdivision of up to 4 such air space lots into a maximum 897 condominium units.

1.41 "**Property**" shall have the meaning in the sixth Recital, is depicted on the Development Site Map attached hereto as **Exhibit** A-1, and is legally described in **Exhibit A-2** attached hereto. Notwithstanding the foregoing, prior to acquisition of the Third Party Property by Developer, the Property shall not include the Third Party Property.

1.42 "**Reserved Powers**" means the rights and authority excepted from this Agreement's restrictions on the City's police powers and which are instead reserved to the City. The Reserved Powers include the powers to enact regulations or take future Discretionary Actions after the Effective Date of this Agreement that may be in conflict with the Applicable Rules and Project Approvals, but: (1) are necessary to protect the public health and safety, and are generally applicable on a City-wide basis (except in the event of natural disasters as found by the City Council such as floods, earthquakes and similar acts of God); (2) are amendments to Chapter IX of the Los Angeles Municipal Code Section 91.0101 et seq. (Building Code) or Chapter V of the Los Angeles Municipal Code Section 57.01.01 et(Fire Code) regarding the construction, engineering and design standards for private and public improvements and which are (a) necessary to the health and safety of the residents of the City, and (b) are generally applicable on a Citywide basis (except in the event of natural disasters as found by the Mayor or The City Council such as floods, earthquakes, and similar acts of God); (3) are necessary to comply with state or federal laws and regulations (whether enacted previous or subsequent to the Effective Date of this Agreement) as provided in Section 3.2.3.3 or; (4) constitute Processing Fees and Charges imposed or required by the City to cover its actual costs in processing applications, permit requests and approvals of the Project or in monitoring compliance with permits issued or approvals granted for the performance of any conditions imposed on the Project, unless otherwise waived by the City.

1.43 "**Term**" means the period of time for which this Agreement shall be effective in accordance with Section 7.2 hereof.

1.44 "**Third Party Property**" means the portion of the Property that is not owned by Developer as of the Effective Date, which property is depicted on the Development Site Map attached hereto as **Exhibit A-1** and is legally described on **Exhibit A-3** attached hereto.

1.45 "**Transferee**" means individually or collectively, Developer's successors in interest, assignees, or transferees of all or any portion of the Property, which may include Mortgagees and/or Mortgagee Successors.

1.46 "**Vesting Tentative Tract Map**" means Vesting Tentative Tract Map No. 17834 approved by the City on _____, ____, _____, ___, 2053, dividing the Property into 2 grounds lots and 39 "air space" lots, and providing for further subdivision of up to 4 such air space lots into a maximum 897 condominium units.

1.47 "**1720 Owner**" means 1720 North Vine LLC, a Delaware limited liability company.

1.48 "**1749 Owner**" means 1749 North Vine LLC, a Delaware limited liability company.

2. RECITALS OF PREMISES, PURPOSE, AND INTENT.

2.1 State Enabling Statute. To strengthen the public planning process, encourage private participation in comprehensive planning and reduce the economic risk of development, the Legislature of the State of California adopted the Development Agreement Act which authorizes any the City to enter into binding development agreements establishing certain development rights in real property with persons having legal or equitable interests in this property. Section 65864 of the Development Agreement Act expressly provides as follows:

> "The Legislature finds and declares that:
>
> "(a) The lack of certainty in the approval of development projects can result in a waste of resources, escalate the cost of housing and other development to the consumer, and discourage investment in and a commitment to comprehensive planning which would make maximum efficient utilization of resources at the least economic cost to the public.
>
> (a) (b) Assurance to the applicant for a development project that upon approval of the project, the applicant may proceed with the project in accordance with existing policies, rules and regulations, and subject to conditions of approval will strengthen the public planning process, encourage private participation in comprehensive planning, and reduce the economic cost of development.
>
> (b) (c) The lack of public facilities, including, but not limited to, streets, sewerage, transportation, drinking water, school, and utility facilities, is a serious impediment to the development of new housing. Whenever possible, applicants and local governments may include provisions in agreements whereby applicants are reimbursed overtime for financing of public facilities."

Notwithstanding the foregoing, to ensure that the City remains responsive and accountable to its residents while pursuing the benefits of development agreements contemplated by the

Legislature, the City: (1) accepts restraints on its police powers contained in development agreements only to the extent and for the duration required to achieve the mutual objectives of the Parties; and (2) to offset these restraints, seeks public benefits which go beyond those obtained by traditional City controls and conditions imposed on development project applications.

2.2 **City Procedures and Actions.The City Planning Commission Action**. The City Planning Commission held a duly noticed public hearing, and recommended approval of this Agreement on _____ , 2013.

2.2.2 The City Council Action. The City Council on _____, 2013, after conducting a duly-noticed public hearing, adopted Ordinance No. _____, to become effective on the thirty-first day after publication, or on the forty-first day after posting, approving this Agreement, found that its provisions are consistent with the City's General Plan, the Hollywood Community Plan, and the Municipal Code, and authorized the execution of this Agreement.

2.3 Purpose of This Agreement.

2.3.1 Public Benefits. This Agreement provides assurances that the public benefits identified below, which are additional consideration for this Agreement, will be achieved and developed in accordance with the Applicable Rules and Project Approvals and with the terms of this Agreement and subject to the City's Reserved Powers. The Project will provide local and regional public benefits to the City, including without limitation (i) promote Hollywood and its commercial corridor; (ii) increased sales tax, property tax, and future transient occupancy tax revenues; (iii) promote tourism and business expansion and relocation in Hollywood, the City and the region; (iii) provide temporary and permanent jobs to improve the local and regional economy; (iv) provide the density necessary to support a new mix of uses in close proximity to mass transit; and other benefits as contained in Section 3.1.4. The Project will contribute positively to the City by providing a vibrant project with a variety of land uses, which will serve to increase the level of activity necessary to sustain Hollywood as a regional center and create new jobs and increase City tax revenues.

2.3.2 Developer Objectives. In accordance with the legislative findings set forth in the Development Agreement Act, and with full recognition of the City's policy of judicious restraints on its police powers, Developer wishes to obtain reasonable assurances that the Project may be developed in accordance with the Applicable Rules and Project Approvals and with the terms of this Agreement and subject to the City's Reserved Powers. In the absence of this Agreement, Developer would have no assurance that it can complete the Project for the uses and to the density and intensity of development set forth in this Agreement and the Project Approvals. This Agreement, therefore, is necessary to assure Developer that the Project will not be (1) reduced or otherwise modified in density, intensity or use from what is set forth in the Project Approvals, (2) subjected to new rules, regulations, ordinances, or official policies or plans which are not adopted or approved pursuant to the City's Reserved Powers, or (3) subjected to delays for reasons other than Citywide health and safety enactments related to critical situations such as, but not limited to, the lack of water availability or sewer or landfill capacity.

2.3.3 **Mutual Objectives.** Development of the Project in accordance with this Development Agreement will provide for the orderly development of the Property in accordance with the objectives set forth in the General Plan. Moreover, a development agreement for the Project will eliminate uncertainty in planning for and securing orderly development of the Property, assure installation of necessary improvements, assure attainment of maximum efficient resource utilization within the City at the least economic cost to its citizens and otherwise achieve the goals and purposes for which the Development Agreement Act was enacted. The Parties believe that such orderly development of the Project will provide public benefits, as described in Section 2.3.1, to the City through the imposition of development standards and requirements under the provisions and conditions of this Agreement, including without limitation: increased tax revenues, installation of on-site and off-site improvements, redevelopment of an underutilized site, preservation of the historic Capitol Records building, a grade level pedestrian plaza, a mix of land uses including some or all of the following uses: residential, commercial and office within an existing activity center offering direct proximity to existing public transit and transportation infrastructure, the addition of retail and restaurant uses, approximately 2,900 construction-related jobs, and creation and retention of 1,257 to 3,635 direct and indirect jobs for the City of Los Angeles. Additionally, although development of the Project in accordance with this Agreement will restrain the City's land use or other relevant police powers, this Agreement provides the City with sufficient Reserved Powers during the term hereof to remain responsible and accountable to its citizens. In exchange for these and other benefits to the City, Developer will receive assurance that the Project may be developed during the term of this Agreement in accordance with the Applicable Rules, Project Approvals and Reserved Powers, subject to the terms and conditions of this Agreement.

2.4 **Applicability of the Agreement.** This Agreement does not: (1) grant height, density, or intensity in excess of that otherwise established in the Applicable Rules and Project Approvals; (2) eliminate future Discretionary Actions relating to the Project if applications requiring such Discretionary Action are initiated and submitted by the owner of the Property after the Effective Date of this Agreement; (3) guarantee that Developer will receive any profits from the Project; (4) prohibit the Project's participation (with the consent of Developer, to the extent required under Applicable Rules) in any benefit assessment district that is generally applicable to surrounding properties; or (5) amend the City's General Plan. This Agreement has a fixed Term. Furthermore, in any subsequent Discretionary Actions applicable to the Property or any portion thereof, the City may apply the new rules, regulations and official policies as are contained in its Reserved Powers.

3. AGREEMENT AND ASSURANCES.

3.1 **Agreement and Assurance on the Part of Developer.** In consideration for the City entering into this Agreement, and as an inducement for the City to obligate itself to carry out the covenants and conditions set forth in this Agreement, and in order to effectuate the premises, purposes, and intentions set forth in Section 2.3 of this Agreement, Developer hereby agrees as follows:

3.1.1 **Project Development.** Developer agrees that it will use its commercially reasonable efforts, in accordance with its own business judgment and taking into account market conditions and economic considerations, to undertake development of the Project in accordance

with the terms and conditions of this Agreement, including the Applicable Rules and the Project Approvals. Nothing in this Agreement shall be construed to require Developer to proceed with the construction of or any other implementation of the Project or any portion thereof. In addition, Developer agrees to the following:

(1) Dedication of Land for Public Street Purposes. Provisions for the dedication of land for public purposes are set forth in the conditions of approval of the Project Approvals.

(2) Description of Transportation Improvements. The transportation improvements to be included within the scope of the Project are set forth in the Project Approvals.

(3) Maximum Height of the Project. The maximum height of the Project shall not exceed 585 feet and the Project shall comply with and be limited as set forth in the Project Approvals.

(4) Maximum Floor Area of the Project. The maximum Floor Area ("**Maximum Floor Area**") of the Project shall not exceed 1,166,970 net square feet (inclusive of Existing Improvements that are retained) and the Project shall comply with and be limited as set forth in the Project Approvals.

3.1.2 Timing of Development. Developer may construct the Project in any number of phases (each a "**Phase**") as Developer determines on the Property, consistent with the Applicable Rules and the Project Approvals. The parties acknowledge that Developer cannot at this time predict when or at what rate the Property would be developed. These decisions depend upon numerous factors that are not all within the control of Developer, such as market orientation and demand, availability of financing, and competition. Because the California Supreme Court held in Pardee Construction Co. v. The City of Camarillo, 37 Cal. 3d 465 (1984), that the failure of the parties therein to provide for the timing of development permitted a later adopted initiative restricting the timing of development and controlling the Parties' agreement, Developer and the City do hereby acknowledge and provide for the right of Developer to develop the Project in an order and at a rate and times as Developer deems appropriate within the exercise of its sole and subjective business judgment, subject to any restrictions that may exist in the Project Approvals. The City acknowledges that this right is consistent with the intent, purpose, and understanding of the Parties to this Agreement.

3.1.3 Additional Obligations of Developer as Consideration for this Agreement. In addition to the obligations identified in Sections 2.3.1 and 3.1.1 of this Agreement, in consideration for the City entering into this Agreement, and as an inducement for the City to obligate itself to carry out the covenants and conditions set forth in this Agreement, and in order to effectuate the premises, purposes and intentions set forth in Section 2 of this Agreement, Developer hereby agrees as follows:

3.1.3.1 Project Labor Agreement. Developer shall, or shall cause its Contractor to, enter into a "**Project Labor Agreement**" (herein so called) with the Building and Construction Trades Council for each Phase of the Project prior to the issuance of a building

permit for such Phase. The purpose of each Project Labor Agreement will be to promote efficiency of construction operation during the construction of such Phase and provide for the orderly settlement of labor disputes and grievances without strikes or lockouts, thereby assuring timely and economical completion of such Phase and the balance of the Phase. Additionally, the Project Labor Agreement will reflect a commitment by all parties to diversity in the workforce hiring that reflects levels of minority, women and other worker utilization at levels which are representative of the relevant workforce of these groups in the Greater Los Angeles Area. The Project Labor Agreement will serve to identify the construction trade union(s) as the primary source of all craft labor employed on the Phase of the Project. The union(s) will use their best efforts to recruit and identify individuals, particularly residents of the City of Los Angeles, for entrance into joining labor/management apprenticeship programs and to assist individuals in qualifying and becoming eligible for such programs.

3.1.3.2 Local Hiring. Developer shall work with the local construction trades and implement an apprenticeship and zip code identification program to prioritize local source hiring for Project construction from the 13th Council District of the City of Los Angeles, with priority given to construction workers from such area. This program shall be prepared in consultation with the Planning Department, no later than six months prior to the commencement of construction of the first Phase of the Project. Thereafter, on an annual basis as part of the required Annual Review for any year during which construction activity occurred, a report detailing the demographic and geographic information of the Project's construction workers shall be included.

3.1.3.3 Construction Trades Prevailing Wage. Construction workers employed in connection with the construction of the Project including core and shell construction shall be paid no less than the prevailing rate of wages as determined pursuant to the provisions of Sections 1770 et seq. of the California Labor Code. Developer shall submit proof of compliance with this obligation prior to the issuance of any certificate of occupancy for the Project.

3.1.3.4 Community Organization Space. Developer shall provide up to 1,200 square feet of meeting space at the Project for use by Hollywood and community non-profit groups including, but not limited to, the local Neighborhood Council and other civic organizations, during reasonable business hours, as available. Subject to availability, meeting space shall be provided to accommodate small gatherings, such as regularly scheduled community meetings, for a maximum of 50 occurrences per year. Subject to availability, groups shall be provided with access to such space if they schedule at least 30 days in advance, pay a refundable $500 deposit to hold the space, and provide a nominal flat clean up fee of $300. Developer shall establish and operate a reservation system whereby community groups can reserve the meeting space as available. This requirement shall include only the use of space and shall not include Developer's provision of security, food, beverage, equipment or other materials. The meeting space will be included in one of the Project buildings and, subject to availability, may also be used by residents, tenants, or others in the Project. The foregoing requirement is not intended to create a property right for any group or the City with respect to any particular space within the Project, and the location of any meeting space in the Project may be changed at Developer's discretion from time to time.

3.1.3.5 Transportation Improvements. Developer shall provide the following transportation related benefits:

(a) Circulator Payment. Developer shall provide funding in the amount of One Hundred Thousand Dollars ($100,000) (the "**Circulator Payment**") to the City or its designee toward development of local small bus shuttle service to promote multi-modal transportation alternatives and facilitate pedestrian traffic among the Project and designated areas within the Hollywood area including publicly accessible parking lots and structures in Hollywood and the hillside community north of the Project Site. Proof of payment of the Circulator Payment shall be submitted to the Planning Director prior to issuance of a final certificate of occupancy for the first Phase of the Project.

(b) Bicycle Amenities Plan. Commencing upon issuance of a final certificate of occupancy for the second Phase of the Project, thereafter during the Term of this Agreement, Developer shall provide or cause to be provided bicycle amenities within the second Phase of Project, including short term bicycle storage racks, long term bicycle storage, a kiosk or tenant space of not less than 100 square feet for the provision by a tenant of bicycle repair services, dedicated bicycle ways between the public streets and such facilities, and wayfinding signage directing bicycle users to such facilities. The final location of such bicycle facilities shall be mutually agreeable to Developer and the Director of Planning, in their reasonable discretion.

(c) Linkages to Future Public Transit Services. Developer shall provide funding in the amount of Fifty Thousand Dollars ($50,000) (the "**Transit Linkage Payment**") to the City or its designee toward development of connection mechanisms from the Project to public transit services constructed or implemented after the Effective Date, including wayfinding signage, within 1,000 yards of the Property. Such payment will be a condition to the next Phase of the Project constructed by Developer following the earlier to occur of (i) commencement of construction by City, Metro or otherwise of any such connection mechanisms that are improvements or (ii) commencement of service City, Metro or otherwise of any such connection mechanisms that are services, such as bus routes. Proof of payment of the Transit Linkage Payment shall be submitted to the Planning Director prior to issuance of a final certificate of occupancy for such Phase of the Project.

(d) Parking Tracking Services. Developer shall provide a fixed-fee contribution to supplement the City Department of Transportation's Express Park program that will provide new parking meter technology, vehicle sensors, a central management system, and real-time parking guidance for motorists in the vicinity of the Project. The contribution shall be in the amount of Fifty Thousand Dollars ($50,000) to be paid to the City Department of Transportation and made prior to issuance of the final certificate of occupancy for the second Phase of the Project.

(e) Vine Street and Metro Connections. Developer shall engage an urban planning and architectural firm reasonably acceptable to the Director of Planning and the 13th Council District Councilmember to prepare a study of the design, efficacy, potential cost, feasibility and impact on vehicular and pedestrian circulation of a portal north of Hollywood Boulevard into the Hollywood Boulevard/Vine Street Metro Station. Such study shall be completed and delivered to the Department of Planning not later than, and as a condition to, the issuance of the first building permit for the first Phase of the Project.

(f) Metro Passes. Commencing upon issuance of a final certificate of occupancy for the first Phase of the Project, thereafter during the Term of this Agreement, Developer shall provide within the Project, either by machine or through its management office, for the sale of Los Angeles County Metropolitan Transportation Authority ("**Metro**") passes to Project residents, tenants and their employees. Developer will use its commercially reasonable efforts to obtain a discount from Metro for such passes.

(g) Monthly Parking Leases for Metro Commuters. Commencing upon issuance of a final certificate of occupancy for the first Phase of the Project, thereafter during the Term of this Agreement, Developer shall provide, within each publicly accessible parking area in the Project, not less than ten (10) "Park and Ride" spaces for monthly lease to persons who are not tenants or occupants of the Project who use the spaces and then transfer to Metro commuter train or bus for transportation to their place of employment. Developer shall establish and maintain a monitoring and reporting program to reasonably assure that such parking continue to meet such condition.

3.1.3.6 Protection of Capitol Records Building, Recording Studios and Echo Chambers. As a condition to issuance of a building permit for the first Phase of the Project on the East Parcel (which area is depicted on Exhibit A-1 attached hereto), Developer shall prepare and submit to the Department of Building and Safety for its approval a written adjacent structure monitoring plan to ensure that construction will not damage the Capitol Records Building, including the recording studios and underground echo chambers therein. Approval of such plan may be issued by the Director of Building and Safety, in his or her reasonable discretion. The Director shall not withhold its approval of the proposed plan if an officer of EMI Music Ltd. dba Capitol Records, or the then tenant of the portions of the Capitol Records Building containing such recording studios and echo chambers ("**Capitol Records**") submits written confirmation that Capitol Records has approved such plan. Following its approval, such plan shall be implemented during construction of all improvements on the East Parcel.

3.1.3.7 Public Performances, Music and Arts Programming. After issuance of a final certificate of completion for the Phase of the Project which includes the open public space to be constructed adjacent to the existing Jazz Mural (the "**Art Plaza**"), for a period equal to the lesser of ten (10) years or the remaining term of this Agreement, Developer shall conduct within the Art Plaza at least four (4) public events per year, which may include musical, dramatic, comedic and/or dance performances, and art exhibitions. Developer will pay for all

costs associated with such public events, including planning, promotion, security, cleanup and insurance. Developer will obtain all permits required pursuant to applicable law, including assembly permits as may be required by the Municipal Code, in connection with each such public event. Developer will reasonably consider, but will not be bound to conduct, public events suggested by City and/or City Agencies. An annual schedule of such public events will be provided by Developer to the City Agency designated by the City to oversee such events. The foregoing will all be conducted at Developer's sole cost and expense.

3.1.3.8 Parking Access Management System. Developer shall provide a parking access management system containing, among other things, overhead illuminated signs for each exit/entry driveway from public streets into non-residential parking areas of the Project. The final size and design of such parking access management system shall be mutually agreeable to Developer and the Director of Planning, in their reasonable discretion.

3.1.3.9 Pedestrian Improvements Contribution. Developer shall provide funding in the amount of Fifty Thousand Dollars ($50,000) to the Hollywood Chamber of Commerce Walk of Fame Committee or otherwise as directed by the City (the "**Pedestrian Payment**") toward the renovation and upkeep of the Walk of Fame stars and terrazzo, sidewalks and other public streetscape improvements along Vine Street between the Project and Hollywood Boulevard. Such renovation and upkeep is intended to enhance the pedestrian experience for people in the vicinity of the Property. Proof of payment of the Pedestrian Payment shall be submitted to the Planning Director prior to issuance of a final certificate of occupancy for the first Phase of the Project.

3.1.3.10 Music Appreciation Exhibit. Developer shall install publicly accessible artwork and/or changeable exhibition cabinets and/or platforms within the first Phase of the Project (collectively, the "**Music Appreciation Exhibit**"). The Music Appreciation Exhibit shall be designed, decorated and programmed in a manner so as to celebrate music and entertainment. The Music Appreciation Exhibit plans shall be reviewed by the Director of Planning, in consultation with the Council Office, and approved by the Director of Planning, in his or her reasonable discretion. Developer's shall be entitled to credit to the Art Developments Fee otherwise payable by Developer under the Applicable Rules in connection with the Project for Developer's cost of installing such Music Appreciation Exhibit. The Music Appreciation Exhibit shall be maintained by Developer, at its sole cost, to a standard at least as high as the balance of the Project.

3.1.3.11 Hollywood Central Park. Commencing upon the April 15 following the later of (a) issuance of a final certificate of occupancy for the first Phase of the Project or (b) the completion and commencement of operation of the proposed Hollywood Central Park, and thereafter on April 1 of each year during the remaining Term of this Agreement, Developer shall make an annual contribution, in the amount of $50,000 to the City Department of Recreation and Parks or otherwise as directed by the City for the operation and maintenance of the Hollywood Central Park.

3.1.3.12 Retail/Restaurant Discount Program. During the Term of this Agreement, Developer will use its commercially reasonable efforts to establish, with

tenants of the Project, a discount program offered by retail and/or restaurant tenants for the benefit of employees and residents of the Project.

3.1.3.13 Electrical Car Recharging Station. Developer shall construct, maintain and operate within the parking facilities of the Project, ten (10) 208/240 V 40 amp, grounded AC outlets, in addition to the outlets required by applicable provisions of the Municipal Code.

3.1.3.14 Affordable Housing. Prior to the issuance of any final certificate of occupancy for any residential dwelling units in any Phase of the Project, Developer shall provide evidence to the Director of Planning that it has either:

(a) **Affordable Housing Payment**. Contributed a fixed-fee payment to the City Housing Authority to support affordable housing (each and collectively, the "**Affordable Housing Payment**") in an amount equal to Seventy Five Thousand Dollars ($75,000) multiplied by fifteen percent (15%) of the total number of market rate residential dwelling units in such Phase as shown on the final approved building plans for such Phase, or

(b) **Affordable Project Contribution** Contributed an amount equal to the Affordable Housing Payment for such Phase to a developer of a Transit Affordable Housing Project. As used herein, the term "**Transit Affordable Housing Project**" means a multifamily development project located within 1,000 yards of a commuter rail station or bus route containing "Affordable Units" (as defined below) in the amount of no less than fifteen percent (15%) of the total number of market rate residential dwelling units in such Project Phase. As used herein, the term "**Affordable Units**" means multifamily units subject to a regulatory agreement with the City and/or other governmental agency limiting rental thereto to low and/or very low income families, as defined in Section 8 of the United States Housing Act of 1937, as amended from time to time.

3.2 Agreement and Assurances on the Part of the City. In consideration for Developer entering into this Agreement, and as an inducement for Developer to obligate itself to carry out the covenants and conditions set forth in this Agreement and in order to effectuate the premises, purpose, and intentions set forth in Section 2.3 of this Agreement, the City hereby agrees as follows:

3.2.1 Entitlement to Develop. Developer has the vested right to develop the Project containing up to Maximum Floor Area in, on, under and/or above the Property as contemplated by the EIR subject to the terms and conditions of this Agreement, the Applicable Rules, Project Approvals, the Equivalency Program and the Reserved Powers. The 114,303 square feet of existing Floor Area in the Existing Improvements shall be included as part of such maximum permitted density of the Project. The density of certain portions of the Property may exceed the pro-rata or average per acre density for the Property as a whole provided that (a) such density shall be subject to maximum height limitations applicable to each portion of the Property as set forth in the Project Approvals and Development Regulations, and (b) the total density for the Property shall not exceed Maximum Floor Area. Developer's vested rights under this

Agreement shall include, without limitation, the right to remodel, renovate, rehabilitate, rebuild, or replace the Project or any portion thereof throughout the applicable Term for any reason, including, without limitation, in the event of damage, destruction, or obsolescence of the Project or any portion thereof, subject to the Applicable Rules, Project Approvals, and Reserved Powers. Any and/or all Existing Improvements which comply with the Applicable Rules on the Property as of the Effective Date which are damaged or destroyed during the Term may be remodeled, renovated, rehabilitated, repaired, rebuilt or replaced subject to the Applicable Rules (other than the Project Description set forth on **Exhibit B**) and the Reserved Powers. To the extent that all or any portion of the Project is remodeled, renovated, rehabilitated, rebuilt, or replaced, Developer may locate that portion of the Project at any other location of the Property, subject to the requirements of the Project Approvals, the Applicable Rules, and the Reserved Powers.

3.2.2 Consistency in Applicable Rules. Based upon all information made available to the City up to or concurrently with the execution of this Agreement, the City finds and certifies that no Applicable Rules prohibit or prevent or encumber the full completion and occupancy of the Project in accordance with the uses, densities, designs, heights, signage regulations, permitted demolition, and other development entitlements incorporated and agreed to herein and in the Project Approvals

3.2.3 Changes in Applicable Rules.

3.2.3.1 Non-Application of Changes in Applicable Rules. Any change in, or addition to, the Applicable Rules, including, without limitation, any change in any applicable General Plan, zoning or building regulation, adopted, or becoming effective after the Effective Date of this Agreement, including, without limitation, any such change by means of ordinance including but not limited to adoption of a specific plan or overlay zone, The City Charter amendment, initiative, referendum, resolution, motion, policy, order or moratorium, initiated, or instituted for any reason whatsoever and adopted by the City, the Mayor, City Council, Planning Commission or any other Board, Commission, Department or Agency of the City, or any officer or employee thereof, or by the electorate, as the case may be, which would, absent this Agreement, otherwise be applicable to the Project and which would conflict in any way with the Applicable Rules, Project Approvals, or this Agreement, shall not be applied to the Project unless these changes represent an exercise of the City's Reserved Powers, or are otherwise agreed to in this Agreement. Notwithstanding the foregoing, Developer may, in its sole discretion, give the City written notice of its election to have any subsequent change in the Applicable Rules applied to some portion or all of the Property as it may own, in which case such subsequent change in the Applicable Rules shall be deemed to be contained within the Applicable Rules insofar as that portion of the Property is concerned. In the event of any conflict or inconsistency between this Agreement and the Applicable Rules, the provisions of this Agreement shall control.

3.2.3.2 Changes in Building and Fire Codes. Notwithstanding any provision of this Agreement to the contrary, development of the Project shall be subject to changes occurring from time to time in the California Building Code and other uniform construction codes. In addition, development of the Project shall be subject to changes occurring from time to time in Chapters V and IX of the Municipal Code regarding the construction, engineering, and design standards for both public and private improvements provided that these

changes are (1) necessary to the health and safety of the residents of the City, and (2) are generally applicable on a Citywide basis (except in the event of natural disasters as found by the Mayor or City Council, such as floods, earthquakes and similar disasters).

3.2.3.3 Changes Mandated by Federal or State Law. This Agreement shall not preclude the application to the Project of changes in, or additions to, the Applicable Rules, including rules, regulations, ordinances, and official policies, to the extent that these changes or additions are mandated to be applied to developments such as this Project by state or federal regulations, pursuant to the Reserved Powers. In the event state or federal laws or regulations prevent or preclude compliance with one or more provisions of this Agreement, these provisions shall be modified or suspended as may be necessary to comply with state or federal laws or regulations.

3.2.4 Subsequent Development Review. The City shall not require Developer to obtain any approvals or permits for the development of the Project in accordance with this Agreement other than those permits or approvals that are required by the Applicable Rules, the Reserved Powers, and/or the Project Approvals. Except as permitted by the Equivalency Program and by those changes and modifications as described in Section 3.2.5, any subsequent Discretionary Action initiated by Developer that is not permitted by the Project Approvals or Applicable Rules, which changes the uses, intensity, density, building height, or timing of the Project, or decreases the lot area, setbacks, yards, parking, or which increases entitlements allowed under the Project Approvals, shall be subject to rules, regulations, ordinances, and official policies of the City then in effect. The Parties agree that this Agreement does not modify, alter or change the City's obligations pursuant to CEQA and acknowledge that future Discretionary Actions may require additional environmental review pursuant to CEQA. In the event that additional environmental review is required by CEQA, the City agrees to utilize tiered environmental documents to the fullest extent permitted by law, as determined by the City, and as provided in California Public Resources Code Sections 21093 and 21094.

3.2.5 Development Parameters.

3.2.5.1 Development Flexibility. The City acknowledges that the Development Parameters provide flexibility regarding modifications to Project's final development layout so that the Project can be built with a mix of uses and layout that responds to market demand and changing needs of the Southern California economy while maintaining design quality and consistency. Developer shall have the right to modify the Project within the limits set forth in the Development Parameters. Implementation of the Development Parameters will not require any new or additional Discretionary Approvals from the City.

3.2.5.2 Development Regulations. The Development Regulations permit design flexibility within a set of site-wide guidelines and standards that ensure the integrity of an overall master plan concept for the Site and protect the visual and environmental quality of the Project as a whole. The Development Regulations establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting and sustainability.

3.2.5.3 Equivalency Program. The Equivalency Program is intended to provide flexibility in land uses for the Project while ensuring that a change in land uses would

not result in new significant environmental impacts or a substantial increase in the severity of significant environmental impacts identified in the EIR.

3.2.5.4 EIR Analysis. Implementation of the Development Parameters will not result in any new significant environmental impacts or a substantial increase in the severity of previously identified significant environmental impacts as analyzed in the EIR. The Project including the development flexibility set forth in the Development Parameters were fully analyzed in the EIR.

3.2.6 Special Taxes and Assessments. Developer shall have the right, to the extent permitted by law, to protest, oppose, and vote against any and all special taxes, assessments, levies, charges, and/or fees imposed with respect to any assessment districts, infrastructure financing, Mello-Roos or community facilities districts, community taxing districts, maintenance districts, or other similar districts. If Developer requests the formation of any such districts in connection with the Project, the City agrees to cooperate fully in their formation.

3.2.7 Effective Development Standards. The City agrees that it is bound to permit the uses, intensity of use and density on this Property which are permitted by this Agreement and the Project Approvals, insofar as this Agreement and the Project Approvals so provide or as otherwise set forth in the Applicable Rules or the Reserved Powers. The City hereby agrees that it will not unreasonably withhold or unreasonably condition any Discretionary Action which must be issued by the City in order for the Project to proceed, provided that Developer reasonably and satisfactorily complies with all City-wide standard procedures, actions, payments of Processing Fees and Charges, and criteria generally required of developers by the City for processing Requests for development consistent with this Agreement.

3.2.8 Interim Use. The City agrees that Developer may use the Property during the Term of this Agreement for any use which is otherwise permitted by the applicable zoning regulations and the General Plan in effect at the time of the interim use, except as expressly provided in this Development Agreement, or pursuant to any approvals, permits, other agreements between the City and Developer, or other entitlements previously granted and in effect as of the Effective Date.

3.2.9 Moratoria or Interim Control Ordinances. In the event an ordinance, resolution, policy, or other measure is enacted, whether by action of the City, by initiative, or otherwise, which relates directly or indirectly to the Project or to the rate, amount, timing, sequencing, or phasing of the development or construction of the Project on all or any part of the Property, the City agrees that such ordinance, resolution, or other measure shall not apply to the Property or this Agreement, unless such changes: (1) are found by the City to be necessary to the public health and safety of the residents of the City, and (2) are generally applicable on a Citywide basis (except in the event of natural disasters as found by the Mayor or the City Council, such as floods, earthquakes and similar disasters).

3.2.10 Time Period of Tentative Tract Map and Project Approvals. The City acknowledges that the construction of the Project may be subject to unavoidable delays due to factors outside Developer's control. Pursuant to California Government Code Section

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66452.6(a), the City agrees that the duration of the Vesting Tentative Tract Map and any new tract or parcel map which are consistent with the Project Approvals, shall automatically be extended for the Term of this Agreement. The City further agrees that the duration of all of the Project Approvals shall automatically be extended for the Term of this Agreement.

3.2.11 Processing Fees and Charges. Developer shall pay all Processing Fees and Charges for Ministerial Permits and Approvals.

3.2.12 Timeframes and Staffing for Processing and Review. The City agrees that expeditious processing of Ministerial Permits and Approvals and Discretionary Actions, if any, and any other approvals or actions required for the Project are critical to the implementation of the Project. In recognition of the importance of timely processing and review of Ministerial Permits and Approvals, the City agrees to work with Developer to establish time frames for processing and reviewing such Ministerial Permits and Approvals and to comply with timeframes established in the Project Approvals. The City agrees to expedite all Ministerial Permits and Approvals and Discretionary Actions requested by Developer, if any.

3.2.13 Other Governmental Approvals. Developer may apply for such other permits and approvals as may be required for development of the Project in accordance with the provisions of this Agreement from other governmental or quasi-governmental agencies having jurisdiction over the Property. The City shall cooperate with Developer in its endeavors to obtain such permits and approvals. Each Party shall take all actions and do all things, and execute, with acknowledgment or affidavit, if required, any and all documents and writings that may be necessary or proper to achieve the purposes and objectives of this Agreement.

3.2.14 Administrative Changes and Modifications. The Parties may determine as the development of the Project proceeds that refinements and changes are appropriate with respect to certain details of the Project and the performance of the Parties under this Agreement. The Parties desire to retain a certain degree of flexibility with respect to the details of the Project development and with respect to those items covered in general terms under this Agreement and under the Project Approvals. If and when the Parties find that "Substantially Conforming Changes," as herein defined, are necessary or appropriate, they shall, unless otherwise required by law, effectuate such changes or adjustments through administrative modifications approved by the Parties. As used herein, "**Substantially Conforming Changes**" are changes, modifications or adjustments that are substantially consistent with the Project Approvals, and that do not materially alter the overall nature, scope or design of the Project including, without limitation, minor changes to the Vesting Tentative Tract Map, minor changes in building footprint configurations, locations, size or heights of buildings, architectural features or other Development Parameters (subject in all cases to the maximum intensity and height restriction set forth in the Applicable Rules), signage or configuration and size of parcels or lots (including lot line adjustments). Such Substantially Conforming Changes would not be considered Discretionary Actions, and would therefore not require a public hearing.

3.3 **Third Party Property.** The Third Party Property, which may be acquired by Developer after the Effective Date, shall be subject to this Agreement upon acquisition thereof by Developer (or any of them or any entity controlled by, controlling or under common control with any of them), including without limitation the Development Parameters. Developer shall

provide to the City (a) notice pursuant to Section 6.2 and Section 7.12 of this Agreement of the acquisition of the Third Party Property by Developer, and (ii) evidence of Developer's ownership or leasehold interest in the Third Party Property. Developer is in no way obligated to acquire or attempt to acquire the Third Party Property, and in the event that Developer does not acquire the Third Party Property, neither Developer nor the owner of the Third Party Property shall have any rights or obligations under the terms of this Agreement with respect to the Third Party Property.

4. ANNUAL REVIEW.

4.1 Annual Review. During the Term of this Agreement, the City shall review annually Developer's compliance with this Agreement by Developer, and/or any Transferee. This periodic review shall be limited in scope to good faith compliance with the provisions of this Agreement as provided in the Development Agreement Act and Developer, and/or any Transferee, shall have the burden of demonstrating such good faith compliance relating solely to such parties' portion of the Property and any development located thereon. The Annual Review shall be in the form of an Annual Report prepared and submitted by the Planning Director. The Report shall include, the number, type and square footage of and the status of Project; any transfers of floor area; the total number of parking spaces developed; provisions for open space; any equivalency transfers; status of activities relating to streetscape improvements; summary of performance of Developer's obligations.

4.2 Pre-Determination Procedure Submission by Developer, and/or Transferee, of evidence of compliance with this Agreement with respect to each such Party's portion of the Property, in a form which the Planning Director may reasonably establish, shall be made in writing and transmitted to the Planning Director not later than sixty (60) days prior to the yearly anniversary of the Effective Date. The public shall be afforded an opportunity to submit written comments regarding compliance to the Planning Director at least sixty (60) days prior to the yearly anniversary of the Effective Date. All such public comments and final staff reports shall, upon receipt by the City, be made available as soon as possible to Developer, and/or any Transferees.

4.2.1 Special Review. The City may order a special review of compliance with this Agreement, at any time.

4.3 Planning Director's Determination. On or before the yearly anniversary of the Effective Date of the Agreement, the Planning Director shall make a determination regarding whether or not Developer, and/or any Transferee, has complied in good faith with the provisions and conditions of this Agreement. This determination shall be made in writing with reasonable specificity, and a copy of the determination shall be provided to Developer, and/or any Transferee, in the manner prescribed in Section 7.12(i).

4.4 Appeal by Developer. In the event the Planning Director makes a finding and determination of non compliance, Developer, and/or any Transferee as the case may be, shall be entitled to appeal that determination to the Planning Commission. After a public hearing on the appeal, the Planning Commission shall make written findings and determinations, on the basis of substantial evidence, whether or not Developer, and/or any Transferee as the case may be, has complied in good faith with the provisions and conditions of this Agreement. Nothing in this

Section or this Agreement shall be construed as modifying or abrogating Los Angeles City Charter Section 245 (City Council review of Commission and Board actions).

4.5 Period to Cure Non-Compliance. If, as a result of this Annual Review procedure, it is found and determined by the Planning Director or the Planning Commission or The City Council, on appeal, that Developer, and/or any Transferee, as the case may be, has not complied in good faith with the provisions and conditions of this Agreement, the City, after denial of any appeal or, where no appeal is taken, after the expiration of the appeal period described in Section 7.3, shall submit to Developer, and/or any Transferee, as the case may be, by registered or certified mail, return receipt requested, a written notice of default in the manner prescribed in Section 7.8 L, stating with specificity those obligations of Developer and/or any Transferee, as the case may be, which have not been performed. Upon receipt of the notice of non-compliance, Developer, and/or any Transferee, as the case may be, shall promptly commence to cure the identified default(s) at the earliest reasonable time after receipt of the notice of default and shall complete the cure of the default(s) not later than sixty (60) days after receipt of the notice of default, or any longer period as is reasonably necessary to remedy such items of the default(s), by mutual consent of the City and Developer provided that Developer shall continuously and diligently pursue the remedy at all times until the item of default(s) is cured.

4.6 Failure to Cure Non-Compliance Procedure. If the Planning Director finds and determines that Developer (or any one of them) or a Transferee (or any one of them) has not cured a default pursuant to this Section, and that the City intends to terminate or modify this Agreement or those transferred or assigned rights and obligations, as the case may be, the Planning Director shall make a report to the Planning Commission. The Planning Director shall then set a date for a public hearing before the Planning Commission in accordance with the notice and hearing requirements of Government Code Sections 65867 and 65868. If after the public hearing, the Planning Commission finds and determines, on the basis of substantial evidence, that (i) such Developer, or such Transferee has not cured a default pursuant to this Section, and (ii) subject to Sections 5.1.1 and 5.1.4, the City may terminate or modify this Agreement, or those transferred or assigned rights and obligations, as the case may be, the finding and determination shall be appealable to the City Council in accordance with Section 7.3 hereof. In the event of a finding and determination of compliance, there shall be no appeal by any person or entity. Nothing in this Section or this Agreement shall be construed as modifying or abrogating Los Angeles City Charter Section 245 (City Council's review of Commission and Council actions).

4.7 Termination or Modification of Agreement. Subject to Sections 5.1.1 and 5.1.4, the City may terminate or modify this Agreement, or those transferred or assigned rights and obligations, as the case may be, after the final determination of noncompliance by the City Council or, where no appeal is taken, after the expiration of the appeal periods described in Section 7.3. There shall be no modifications of this Agreement unless the City Council acts pursuant to Government Code Sections 65867.5 and 65868, irrespective of whether an appeal is taken as provided in Section 7.3.

4.8 Reimbursement of Costs. Developer shall reimburse the City for its actual costs, reasonably and necessarily incurred, to accomplish the required annual review.

4.9 Evidence of Compliance Applicable to a Particular Portion of the Property. Notwithstanding anything to the contrary in this Section 4 or any other provision of this Agreement, a Transferee of all or any portion of the Property shall only be responsible for submitting evidence of compliance with this Agreement as it relates solely to that portion of the Property transferred, assigned, or conveyed to such Transferee in an Assignment Agreement authorized by Section 6.2 of this Agreement.

4.10 The City's Rights and Remedies Against a Developer. The City's rights in Section 4 of this Agreement relating to compliance with this Agreement by Developer shall be limited to only those rights and obligations assumed by Developer under this Agreement and as expressly set forth in the applicable Assignment Agreement authorized by Section 6.2 of this Agreement.

4.11 Developer Written Request for Confirmation. From time to time, Developer of any portion of the Property may, separate from the annual review process, submit a written request for confirmation from the Planning Director that certain obligations of this Agreement have been satisfied. Subject to the time limits and process requirements of Section 4.3, the Planning Director shall issue a written confirmation stating either that such obligations have been satisfied or setting forth the reasons why subject obligation have not been satisfied.

5. DEFAULT PROVISIONS.

5.1 Default by Developer.

5.1.1 Default. In the event Developer (or any one of them) or a Transferee of any portion of the Property fails to perform its obligations under this Agreement applicable to its portion of the Property as specified in the applicable Assignment Agreement, in a timely manner and in compliance pursuant to Section 4 of this Agreement, the City shall have all rights and remedies provided for in this Agreement, including, without limitation, modifying or terminating this Agreement, provided that (a) such modification or termination shall relate solely and exclusively to the property of the defaulting Developer or Transferee, and (b) the City has first complied with all applicable notice and opportunity to cure provisions in Sections 5.1.2 and 6.1.5 and given notice as provided in Sections 4.3, 4.6, 6.1.4 and/or 7.11 hereof, and (c) Developer may appeal such declaration in the manner provided in, and subject to all terms and provisions of, Sections 4.4 and 4.5. In no event shall a default by a Developer or a Transferee of any portion of the Property constitute a default by any non defaulting Developer or Transferee with respect to such non-defaulting parties' obligations hereunder nor affect such non-defaulting parties' rights hereunder, or respective portion of the Property.

5.1.2 Notice of Default. The City through the Planning Director shall submit to Developer (or any one of them) or a Transferee, as applicable, by registered or certified mail, return receipt requested, a written notice of default in the manner prescribed in Section 7.11, identifying with specificity those obligations of such Developer or Transferee, as applicable, which have not been performed. Upon receipt of the notice of default, Developer or Transferee, shall promptly commence to cure the identified default(s) at the earliest reasonable time after receipt of the notice of default and shall complete the cure of the default(s) not later than sixty (60) days after receipt of the notice of default, or a longer period as is reasonably necessary to

remedy the default(s), provided that Developer or Transferee, as applicable, shall continuously and diligently pursue the remedy at all times until the default(s) is cured.

5.1.3 Failure to Cure Default Procedures. If after the cure period has elapsed (Section 4.6), the Planning Director finds and determines that Developer (or any of them), or a Transferee, as the case may be, remains in default and that the City intends, subject to Section 5.1.1 and 5.1.4 of this Agreement, to terminate or modify this Agreement, or those transferred or assigned rights and obligations, as the case may be, the Planning Director shall make a report to the Planning Commission and then set a public hearing before the Commission in accordance with the notice and hearing requirements of Government Code Sections 65867 and 65868. If after public hearing, the Planning Commission finds and determines, on the basis of substantial evidence, that such Developer or Transferee, as applicable, remain(s) in default and that the City intends to terminate or modify this Agreement, or those transferred or assigned rights and obligations, as the case may be, such Developer and such Transferee shall be entitled to appeal that finding and determination to the City Council in accordance with Section 7.3. In the event of a finding and determination that all defaults are cured, there shall be no appeal by any person or entity. Nothing in this Section or this Agreement shall be construed as modifying or abrogating Los Angeles City Charter Section 245 (City Council review of Commission and Board actions).

5.1.4 Termination or Modification of Agreement. Upon default by Developer (or any of them) or a Transferee and the delivery of notice and expiration of all applicable cure periods, the City may terminate or modify this Agreement, or those transferred or assigned rights and obligations hereunder, as the case may be, relating solely to the defaulting Developer or Transferee and such defaulting party's portion of the Property, after such final determination of the City Council or, where no appeal is taken, after the expiration of the appeal periods described in Section 7.3 relating to the defaulting parties rights and obligations. There shall be no termination or modification of this Agreement unless the City Council acts pursuant to Section 7.3.

5.2 Default by the City.

5.2.1 Default. In the event the City does not accept, process, or render a decision on necessary development permits, entitlements, or other land use or building approvals for use as provided in this Agreement upon compliance with the requirements thereof, or as otherwise agreed to by the Parties, or the City otherwise defaults under the provisions of this Agreement, Developer, and any Transferee, shall have all rights and remedies provided herein or by applicable law, which shall include compelling the specific performance of the City's obligations under this Agreement; provided that Developer or Transferee, as the case may be, has first complied with the procedures in Section 5.2.2. No part of this Agreement shall be deemed to abrogate or limit any immunities or defenses the City may otherwise have with respect to claims for monetary damages.

5.2.2 Notice of Default. Developer or Transferee, as the case may be, shall first submit to the City a written notice of default stating with specificity those obligations that have not been performed. Upon receipt of the notice of default, the City shall promptly commence to cure the identified default(s) at the earliest reasonable time after receipt of the notice of default

and shall complete the cure of the default(s) not later than one hundred and twenty (120) days after receipt of the notice of default, or a longer period as is reasonably necessary to remedy such default(s), provided that the City shall continuously and diligently pursue the remedy at all times until the default(s) is cured. In the case of a dispute as to whether the City has cured the default, the Parties shall submit the matter to arbitration pursuant to Section 7.5 of this Agreement.

5.3 **No Monetary Damages.** It is acknowledged by the Parties that the City would not have entered into this Agreement if it were liable in monetary damages under or with respect to this Agreement or the application thereof. The Parties agree and recognize that, as a practical matter, it may not be possible to determine an amount of monetary damages which would adequately compensate Developer for its investment of time and financial resources in planning to arrive at the kind, location, intensity of use, and improvements for the Project, nor to calculate the consideration the City would require to enter into this Agreement to justify the exposure. Therefore, the Parties agree that each of the Parties may pursue any remedy at law or equity available for any breach of any provision of this Agreement, except that the Parties shall not be liable in monetary damages and the Parties covenant not to sue for or claim any monetary damages for the breach of any provision of this Agreement.

6. MORTGAGEE RIGHTS.

6.1.1 Encumbrances on the Property The Parties hereto agree that this Agreement shall not prevent or limit Developer (or any of them), or any Transferee, from encumbering the Property or any estate or interest therein, portion thereof, or any improvement thereon, together with the rights of Developer hereunder, in any manner whatsoever by one or more Mortgages with respect to the construction, development, use or operation of the Project and parts thereof. The City acknowledges that the Mortgagees may require certain Agreement interpretations and modifications and agrees, upon request, from time to time, to meet with Developer and representatives of such lender(s) to negotiate in good faith any such request for interpretation or modification. The City will not unreasonably withhold its consent to any such requested interpretation or modification, provided such interpretation or modification is consistent with the intent and purposes of this Agreement.

6.1.2 Mortgagee Protection. To the extent legally permissible, this Agreement shall be superior and senior to any lien placed upon the Property, or any portion thereof, including the lien of any Mortgage. Notwithstanding the foregoing, no breach of this Agreement shall defeat, render invalid, diminish, or impair the lien of any Mortgage made in good faith and for value. Any acquisition or acceptance of title or any right or interest in or with respect to the Property or any portion thereof by a Mortgagee, pursuant to foreclosure, trustee's sale, deed in lieu of foreclosure, lease or sublease termination or otherwise, shall be subject to all of the terms and conditions of this Agreement applicable to the Property or such portion, as applicable, except that any such Mortgagee, including its affiliate, or any other entity (a "**Mortgagee Successor**") which acquires the Property or any portion thereof a result of the foreclosure of such Mortgage, by power of sale granted thereunder, by acceptance of a deed in lieu of foreclosure, pursuant to a bankruptcy proceeding or other such similar proceedings or otherwise as a result of the exercise of remedies under any Mortgage, shall be entitled to the benefits arising under this Agreement provided Mortgagee complies with Section 6.1.3 below.

6.1.3 Mortgagee Not Obligated. Notwithstanding the provisions of this Section 6, Mortgagee will not have any obligation or duty pursuant to the terms set forth in this Agreement to perform the obligations of Developer or other affirmative covenants of Developer hereunder, or to guarantee such performance, except that the Mortgagee or its Mortgagee Successor shall have no vested right to develop the Project without fully complying with the terms of this Agreement and executing and delivering to the City, in a form and with terms reasonably acceptable to the City, an assumption agreement of Developer's obligations hereunder relating to the portion of the Property acquired by such Mortgagee or Mortgagee Successor.

6.1.4 Request for Notice to Mortgage. The Mortgagee of any Mortgage or deed of trust encumbering the Property, or any part or interest thereof, who has submitted a request in writing to the City in the manner specified herein for giving notices shall be entitled to receive written notification from the City of any notice of non-compliance by Developer in the performance of Developer's obligations under this Agreement. As of the date hereof, HSBC Bank USA, National Association, as administrative agent for itself and certain other lenders ("**Existing Mortgagagee**") is the Mortgagee of the entire Property and there are no other Mortgagees. The City acknowledges that Existing Mortgagee has requested notices pursuant to this Section 6.1.4 and that Existing Mortgagee's addresses for notices are as follows:

HSBC Bank USA, National Association
545 Washington Boulevard, 10th Floor
Jersey City, New Jersey 07310
Attention: Commercial Mortgage Servicing Department

with a copy to:

HSBC Bank USA, National Association
601 Montgomery Street, 10th Floor
San Francisco, California 94111
Attention: Ms. Mee Mee Kiong

6.1.5 Mortgagee's Time to Cure. If the City timely receives a request from a Mortgagee requesting a copy of any notice of non-compliance given to Developer under the terms of this Agreement, the City shall provide a copy of that notice to the Mortgagee within ten (10) days of sending the notice of non-compliance to Developer. The Mortgagee shall have the right, but not the obligation, to cure the non-compliance for a period of one hundred twenty (120) days after the Mortgagee receives written notice, or a longer period as is reasonably necessary to acquire possession of the Property or portion thereof (to the extent necessary to cure the default) and remedy the default(s), provided that Mortgagee shall continuously and diligently pursue the remedy at all times until the default(s) is cured..

6.1.6 Disaffirmation. If this Agreement is terminated as to any portion of the Property by reason of (i) any default or (ii) as a result of a bankruptcy proceeding, or if this

Agreement is disaffirmed by a receiver, liquidator, or trustee for Developer or its property, the City, if requested by any Mortgagee, shall negotiate in good faith with such Mortgagee (or if more than one Mortgage encumbers such portion of the Property, the Mortgagee holding the highest, or most senior priority Mortgage) for a new development agreement in substantially the same form as this Agreement for the Project or such portion of the Property acquired by such Mortgagee or its Successor Mortgagee. This Agreement does not require any Mortgagee to enter into a new development agreement pursuant to this Section.

6.2 Assignment. The Property, as well as the rights and obligations of Developer under this Agreement, may be transferred or assigned in whole or in part by Developer to a Transferee without the consent of the City, subject to the conditions set forth below in Sections 6.2.1 and 6.2.2.

6.2.1 Conditions of Assignment. No such assignment shall be valid until and unless the following occur:

(a) Written Notice of Assignment Required. Developer, or any successor transferor, gives prior written notice to the City of its intention to assign or transfer any of its interests, rights or obligations under this Agreement; and a complete disclosure of the identity of the assignee or Transferee, including copies of the Articles of Incorporation in the case of corporations, the trust declaration in the case of non-public trusts, the names of individual members in the case of a limited liability company, and the names of individual partners in the case of partnerships. Any failure by Developer or any successor transferor to provide the notice shall be curable in accordance with the provisions in Section 5.1.

(b) Automatic Assumption of Obligations. Unless otherwise stated elsewhere in this Agreement to the contrary, a Transferee of Property or any portion thereof expressly and unconditionally assumes all of the rights and obligations of this Agreement (including an allocation of the Transferee's share of the Maximum Floor Area) transferred or assigned by Developer and which are expressly set forth in the applicable Assignment Agreement.

6.2.2 Liability Upon Assignment. Each Developer of any portion of the Property shall be solely and only liable for performance of such Developer's obligations applicable to its portion of the Property under this Agreement as specified in the applicable Assignment Agreement. Upon the assignment or transfer of any portion of the Property together with any obligations assignable under this Agreement, the Transferee shall become solely and only liable for the performance of those assigned or transferred obligations so assumed and shall have the rights of a "Developer" under this Agreement; which such rights and obligations shall be set forth specifically in the Assignment Agreement, executed by the transferring Developer, and the Transferee, as of the date of such transfer, assignment or conveyance of the applicable portion of the Property. The failure of a Developer of any portion of the Property to perform such Developer's obligation set forth in the applicable Assignment Agreement may result, at the City's option, in a declaration that this Agreement has been breached and the City may, but shall not be obligated to, exercise its rights and remedies under this Agreement solely as it relates to the defaulting Developer's portion of the Property as provided for in Section 5.1 hereof, subject

to such defaulting Developer's right to notice and opportunity to cure the default in accordance with provisions of Section 5.1 hereof.

6.2.3 Release of Developer. With respect to a transfer and assignment of all or a portion of a Developer's interest in the Property and the related rights and obligations hereunder, upon the effective date of any such transfer and assignment, as evidenced by the execution of an Assignment Agreement pursuant to this Section 6.2 between such Developer and the Transferee and delivery of such Assignment Agreement to the City, such Developer shall automatically be released from any further obligations to the City under this Agreement with respect to the portion of the Property so transferred.

6.2.4 Release of Property Transferee. A Transferee shall not be liable for any obligations to the City under this Agreement relating to any portion of the Property other than that portion transferred to such Transferee, and no default by a Developer under this Agreement with respect to such other portions of the Property shall be deemed a default by such Transferee with respect to the portion of the Property transferred to such Transferee.

7. GENERAL PROVISIONS.

7.1 Effective Date. The Effective Date of this Agreement shall be the date on which this Agreement is attested by the City Clerk of the City of Los Angeles after execution by Developer and Mayor of the City of Los Angeles.

7.2 Term. The Term of this Agreement shall commence on the Effective Date and shall extend to December 31, 2035, unless said Term is otherwise terminated or modified by circumstances set forth in this Agreement or by mutual consent of the Parties hereto. Following the expiration of this Term, this Agreement shall terminate and be of no further force and effect, provided, however, that this termination shall not affect any right or duty arising from entitlements or approvals, including the Project Approvals on the Property, approved concurrently with, or subsequent to, the Effective Date of this Agreement. The Term of this Agreement shall automatically be extended for the period of time of any actual delay resulting from any enactments pursuant to the Reserved Powers or moratoria, or from legal actions or appeals which enjoin performance under this Agreement or act to stay performance under this Agreement (other than bankruptcy or similar proceedings), or from any actions taken pursuant to Section 7.5 (Dispute Resolution), or from any litigation related to the Project Approvals, this Agreement or the Property.

7.3 Appeals to City Council. Where an appeal by Developer, or its Transferees, as the case may be, to the City Council from a finding and/or determination of the Planning Commission is created by this Agreement, such appeal shall be taken, if at all, within twenty (20) days after the mailing of such finding and/or determination to Developer, or its successors, Transferees, and/or assignees, as the case may be. The City Council shall act upon the finding and/or determination of the Planning Commission within eighty (80) days after such mailing, or within such additional period as may be agreed upon by Developer, or its Transferees, as the case may be, and the City Council. The failure of the City Council to act shall not be deemed to be a denial or approval of the appeal, which shall remain pending until final the City Council action.

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7.4 **Enforced Delay; Extension of Time of Performance**. In addition to specific provisions of this Agreement, whenever a period of time, including a reasonable period of time, is designated within which either Party hereto is required to do or complete any act, matter or thing, the time for the doing or completion thereof shall be extended by a period of time equal to the number of days during which such Party is actually prevented from, or is unreasonably interfered with, the doing or completion of such act, matter or thing because of causes beyond the reasonable control of the Party to be excused, including: war; insurrection; riots; floods; earthquakes; fires; casualties; acts of God; litigation and administrative proceedings against the Project (not including any administrative proceedings contemplated by this Agreement in the normal course of affairs (such as the Annual Review)); any approval required by the City (not including any period of time normally expected for the processing of such approvals in the ordinary course of affairs); restrictions imposed or mandated by other governmental entities; enactment of conflicting state or federal laws or regulations; judicial decisions; the exercise of the City's Reserved Powers; or similar bases for excused performance which are not within the reasonable control of the Party to be excused (financial inability excepted). This Section shall not be applicable to any proceedings with respect to bankruptcy or receivership initiated by or on behalf of Developer or, if not dismissed within ninety (90) days, by any third parties against Developer. If written notice of such delay is given to either Party within thirty (30) days of the commencement of such delay, an extension of time for such cause will be granted in writing for the period of the enforced delay, or longer as may be mutually agreed upon.

7.5 **Dispute Resolution**.

7.5.1 **Dispute Resolution Proceedings**. The Parties may agree to dispute resolution proceedings to fairly and expeditiously resolve disputes or questions of interpretation under this Agreement. These dispute resolution proceedings may include: (a) procedures developed by the City for expeditious interpretation of questions arising under development agreements; or (b) any other manner of dispute resolution which is mutually agreed upon by the Parties.

7.5.2 **Arbitration**. Any dispute between the Parties that is to be resolved by arbitration shall be settled and decided by arbitration conducted by an arbitrator who must be a former judge of the Los Angeles County Superior Court or Appellate Justice of the Second District Court of Appeals or the California Supreme Court. This arbitrator shall be selected by mutual agreement of the parties.

7.5.2.1 **Arbitration Procedures**. Upon appointment of the arbitrator, the matter shall be set for arbitration at a time not less than thirty (30) nor more than ninety (90) days from the effective date of the appointment of the arbitrator. The arbitration shall be conducted under the procedures set forth in Code of Civil Procedure Section 638, et seq., or under such other procedures as are agreeable to both Parties, except that provisions of the California Code of Civil Procedure pertaining to discovery and the provisions of the California Evidence Code shall be applicable to such proceeding.

7.5.3 **Extension of Term**. The Term of this Agreement as set forth in Section 7.2 shall automatically be extended for the period of time in which the Parties are engaged in dispute resolution to the degree that such extension of the Term is reasonably

required because activities which would have been completed prior to the expiration of the Term are delayed beyond the scheduled expiration of the Term as the result of such dispute resolution.

7.5.4 **Legal Action**. Either Party may, in addition to any other rights or remedies, institute legal action to cure, correct, or remedy any default, enforce any covenant or agreement herein, enjoin any threatened or attempted violation, or enforce by specific performance the obligations and rights of the Parties hereto. Notwithstanding the above, the City's right to seek specific performance shall be specifically limited to compelling Developer to complete, demolish or make safe any particular improvement(s) on public lands which is required as a Mitigation Measure or Condition of Approval. Developer shall have no liability (other than the potential termination of this Agreement) if the contemplated development fails to occur.

7.5.5 **Applicable Law**. This Agreement shall be construed and enforced in accordance with the laws of the State of California, and the venue for any legal actions brought by any Party with respect to this Agreement shall be the County of Los Angeles, State of California for state actions and the Central District of California for any federal actions.

7.6 **Amendments**. This Agreement may be amended from time to time by mutual consent in writing of the Parties to this Agreement and each Mortgagee in accordance with Government Code Section 65868, and any Transferee of the Property or any portion thereof, in the event such amendment affects the rights and obligations of the Transferee under this Agreement in connection with the development, use and occupancy of its portion of the Property and/or any improvements located thereon. Any amendment to this Agreement which relates to the Term, permitted uses, substantial density or intensity of use, height, or size of buildings provisions (not otherwise permitted by the Development Parameters or changes and modifications pursuant to Section 3.2.5 or otherwise permitted by the Agreement) obligations for reservation and dedication of land, conditions, restrictions, and requirements relating to subsequent Discretionary Action or any conditions or covenants relating to the use of the Property, which are not provided for under the Applicable Rules or Project Approvals, shall require notice and public hearing before the Parties may execute an amendment thereto. Developer, or a Transferee as applicable, shall reimburse the City for its actual costs, reasonably and necessarily incurred, to review any amendments requested by Developer or a Transferee, including the cost of any public hearings.

7.7 **Covenants**. The provisions of this Agreement shall constitute covenants which shall run with the land comprising the Property for the benefit thereof, subject to the provisions of any Assignment Agreement (if applicable), and the burdens and benefits hereof shall bind and inure to the benefit of the Parties hereto and all successors and assigns of the Parties, including any Transferee of Developer.

7.8 **Cooperation and Implementation.Cooperation in the Event of Legal Challenge**. In the event of any legal action instituted by a third party or other governmental entity or official challenging the validity of any provision of this Agreement, the Parties hereby agree to affirmatively cooperate in defending said action. Developer and the City agree to cooperate in any legal action seeking specific performance, declaratory relief or injunctive relief,

to set court dates at the earliest practicable date(s) and not cause delay in the prosecution/defense of the action, provided such cooperation shall not require any Party to waive any rights.

7.8.2 Relationship of the Parties. It is understood and agreed by the Parties hereto that the contractual relationship created between the Parties hereunder is that Developer is an independent contractor and not an agent of the City. Further, the City and Developer hereby renounce the existence of any form of joint venture or partnership between them and agree that nothing herein or in any document executed in connection herewith shall be construed as making the City and Developer joint-venturers or partners.

7.9 Indemnification.

7.9.1 Obligation to Defend, Indemnify and Hold Harmless: Developer hereby agrees to defend, indemnify, and hold harmless the City and its agents, officers, and employees, from any claim, action, or proceeding ("**Proceeding**") against the City or its agents, officers, or employees (i) to set aside, void, or annul, all or any part of any Project Approval, or (ii) for any damages, personal injury or death which may arise, directly or indirectly, from such Developer or such Developer's contractors, subcontractors', agents', or employees' operations in connection with the construction of the Project, whether operations be by such Developer or any of such Developer's contractors, subcontractors, by anyone or more persons directly or indirectly employed by, or acting as agent for such Developer or any of such Developer's contractors or subcontractors. In the event that the City, upon being served with a lawsuit or other legal process to set aside, void or annul all or part of any Project Approval, fails to promptly notify Developer of the Proceeding, or fails to cooperate fully in the defense of the Proceeding, Developer shall thereafter be relieved of the obligations imposed in this Section 7.9. However, if Developer has actual notice of the Proceeding, it shall not be relieved of the obligations imposed hereunder, notwithstanding the failure of the City to provide prompt notice of the Proceeding. The City shall be considered to have failed to give prompt notification of a Proceeding if the City, after being served with a lawsuit or other legal process challenging the Approvals, unreasonably delays in providing notice thereof to the Applicant. As used herein, "unreasonably delays" shall mean any delay that materially adversely impacts Applicant's ability to defend the Proceeding. The obligations imposed in this Section 7.9 shall apply notwithstanding any allegation or determination in the Proceedings that the City acted contrary to applicable laws. Nothing in this Section shall be construed to mean that Developer shall hold the City harmless and/or defend it from any claims arising from, or alleged to arise from, intentional misconduct or gross negligence in the performance of this Agreement.

7.9.2 Defending the Project Approvals. Developer shall have the obligation to timely retain legal counsel to defend against any Proceeding to set aside, void, or annul, all or any part of any Project Approval. The City shall have the right if it so chooses, to defend the Proceeding utilizing in-house legal staff, in which case Developer shall be liable for all legal costs and fees reasonably incurred by the City, including charges for staff time charged. In the event of a conflict of interest which prevents Developer's legal counsel from representing the City, and in the event the City does not have the in-house legal resources to defend against the Proceeding, the City shall also have the right to retain outside legal counsel, in which case Developer shall be liable for all legal costs and fees reasonably incurred by the City. Provided that Developer is not in breach of the terms of this Section 7.9, the City shall not enter into any

settlement of the Proceeding which involves modification to any Project Approval or otherwise results in Developer incurring liabilities or other obligations, without the consent of Developer.

7.9.3 Breach of Obligations. Actions constituting a breach of the obligations imposed in this Section 7.9 shall include, but not be limited to: (i) the failure to timely retain qualified legal counsel to defend against the Proceedings; (ii) the failure to promptly pay the City for any attorneys' fees or other legal costs for which the City is liable pursuant to a judgment or settlement agreement in the Proceeding seeking to set aside, void or annul all or part of any Project Approval; or (iii) the breach of any other obligation imposed in this Section 7.9, in each case after written notice from the City and a reasonable period of time in which to cure the breach, not to exceed thirty-days. For purposes of this Section 7.9, Developer shall be considered to have failed to timely retain qualified legal counsel if such counsel is not retained within fourteen (14) days following the City's provision of the notice of Proceedings to Developer required hereunder. As used herein, qualified legal counsel shall mean competent counsel retained by Developer that does not have a conflict of interest with the City as a result of representing Developer in the Proceeding. In the event that Developer breaches the obligations imposed in this Section 7.9, the City shall have no obligation to defend against the Proceedings, and by not defending against the Proceedings, the City shall not be considered to have waived any rights in this Section 7.9.

7.9.4 Cooperation: The City shall cooperate with Developer in the defense of the Proceeding; provided however, that such obligation of the City to cooperate in its defense shall not require the City to (i) assert a position in its defense of the Proceeding which it has determined, in its sole discretion, has no substantial merit; (ii) advocate in its defense of the Proceeding legal theories which it has determined, in its sole discretion, lack substantial merit; or (iii) advocate in its defense of the Proceeding legal theories which it has determined, in its sole discretion, are contrary to its best interests, or to public policy. Nothing contained in this section shall require Developer to refrain from asserting in its defense of the Proceeding positions or legal theories that do not satisfy the foregoing requirements.

7.9.5 Contractual Obligation: Developer acknowledges and agrees that the obligations imposed in this Section 7.9 are contractual in nature, and that the breach of any such obligation may subject Developer to a breach of contract claim by the City.

7.9.6 Waiver of Right to Challenge: Developer hereby waives the right to challenge the validity of the obligations imposed in this Section 7.9.

7.9.7 Survival: The obligations imposed in this Section 7.9 shall survive any judicial decision invalidating the Project Approvals.

7.9.8 Preparation of Administrative Record: Developer and the City acknowledge that upon the commencement of legal Proceedings, the administrative record of proceedings relating to the Project Approvals must be prepared. Those documents must also be certified as complete and accurate by the City. Developer, as part of its defense obligation imposed in this Section 7.9, shall prepare at its sole cost and expense the record of proceedings in a manner which complies with all applicable laws; in accordance with reasonable procedures established by the City; and subject to the City's obligation to certify the administrative record of

proceedings and the City's right to oversee the preparation of such administrative record. Developer agrees that its failure to prepare the administrative record as set forth herein, and in compliance with all time deadlines imposed by law, shall constitute a breach of its obligation to defend the City. In the event that Developer fails to prepare the administrative record, the City may do so, in which event the City shall be entitled to be reimbursed by Developer for all reasonable costs associated with preparation of the administrative record, including reasonable charges for staff time.

7.9.9 **Termination**. Developer shall have the right, without City's prior approval but only with the prior written consent of all Mortgagees, in the event of and during the continuation of any Litigation, to terminate this Agreement or renounce the Project Approvals, provided, however, that the provisions of this Section 7.9 shall survive any such termination.

7.10 **Deposit** Following the filing of a lawsuit, or other legal process seeking to set aside, void or annul all or part of any Project Approval, Developer shall be required, following written demand by the City, to place funds on deposit with the City, which funds shall be used to reimburse the City for expenses incurred in connection with defending the Project Approvals. For Project Approvals which included the certification of an environmental impact report by the City, the amount of said deposit shall be ten thousand ($10,000) dollars. For all other Project Approvals, the amount of the deposit shall be five thousand ($5,000) dollars. The City, at its sole discretion, may require a larger deposit upon a detailed showing to Developer of the basis for its determination that the above stated amounts are insufficient. Any unused portions of the deposit shall be refunded to Developer within thirty (30) days following the resolution of the challenge to the Project Approvals. All Deposits must be paid to the City within thirty (30) days of Developer's receipt of the City's written demand for the Deposit.

7.11 **Notices** Any notice or communication required hereunder between the City or Developer must be in writing, and shall be given either personally or by registered or certified mail, return receipt requested. If given by registered or certified mail, the same shall be deemed to have been given and received on the first to occur of (i) actual receipt by any of the addressees designated below as the Party to whom notices are to be sent, or (ii) five (5) days after a registered or certified letter containing such notice, properly addressed, with postage prepaid, is deposited in the United States mail. If personally delivered, a notice shall be deemed to have been given when delivered to the Party to whom it is addressed. Any Party hereto may at any time, by giving ten (10) days' written notice to the other Party hereto, designate any other address in substitution of the address, or any additional address, to which such notice or communication shall be given. Such notices or communications shall be given to the Parties at their addresses set forth below:

If to the City:

Director of City Planning
The City of Los Angeles
200 N. Spring Street, 5th Floor
Los Angeles, CA 90012

with copies to

City Attorney
City of Los Angeles
Real Property/ Environment Division
700 The City Hall East, 200 N. Main Street
Los Angeles, CA 90012

If to Developer:

1720 North Vine LLC
1749 North Vine LLC
1750 North Vine LLC
1733 North Argyle LLC
Millennium Hollywood LLC
Suite 1000
1680 North Vine Street
Los Angeles, CA 90028
Attn: Mario Palumbo

with copies to

Millennium Partners
1195 Broadway, 3rd Floor
New York, NY 10023
Attn: Chief Financial Officer

And with copies to

Sheppard Mullin Richter & Hampton LLP
333 South Flower Street
43rd Floor
Los Angeles, CA 90071
Attn: Alfred Fraijo, Jr., Esq.

And with copies to

Paul Hastings Janofsky & Walker LLP
Real Property/ Environment Division
75 East 55th Street
New York, NY 10022
Attn: Eric R. Landau, Esq.

7.12 **Recordation**. As provided in Government Code Section 65868.5, this Agreement shall be recorded with the Registrar-Recorder of the County of Los Angeles within ten (10) days following its execution by all Parties. Developer shall provide the City Clerk with the fees for such recording prior to or at the time of such recording, should the City Clerk effectuate the recordation.

7.13 **Constructive Notice and Acceptance**. Every person who now or hereafter owns or acquires any right, title, interest in or to any portion of the Property, is and shall be conclusively deemed to have consented and agreed to every provision contained herein, whether or not any reference to this Agreement is contained in the instrument by which such person acquired an interest in the Property.

7.14 **Successors and Assignees.** The provisions of this Agreement shall be binding upon and shall inure to the benefit of the Parties any subsequent owner of all or any portion of the Property and their respective Transferees, successors, and assignees, subject to applicable Assignment Agreements.

7.15 **Severability**. If any provisions, conditions, or covenants of this Agreement, or the application thereof to any circumstances of either Party, shall be held invalid or unenforceable, the remainder of this Agreement or the application of such provision, condition, or covenant to persons or circumstances other than those as to whom or which it is held invalid

or unenforceable shall not be affected thereby and shall be valid and enforceable to the fullest extent permitted by law.

7.16 **Time of the Essence**. Time is of the essence for each provision of this Agreement of which time is an element.

7.17 **Waiver**. No waiver of any provision of this Agreement shall be effective unless in writing and signed by a duly authorized representative of the Party against whom enforcement of a waiver is sought and refers expressly to this Section. No waiver of any right or remedy with respect to any occurrence or event shall be deemed a waiver of any right or remedy with respect to any other occurrence or event.

7.18 **No Third Party Beneficiaries**. The only Parties to this Agreement are the City and Developer and their successors-in-interest. There are no third party beneficiaries (other than Mortgagees) and this Agreement is not intended, and shall not be construed to benefit or be enforceable by any other person whatsoever.

7.19 **Entire Agreement**. This Agreement sets forth and contains the entire understanding and agreement of the Parties and there are no oral or written representations, understandings or ancillary covenants, undertakings or agreements which are not contained or expressly referred to herein and no testimony or evidence of any such representations, understandings, or covenants shall be admissible in any proceedings of any kind or nature to interpret or determine the provisions or conditions of this Agreement.

7.20 **Legal Advice; Neutral Interpretation; Headings, Table of Contents**. Each Party acknowledges that it has received independent legal advice from its attorneys with respect to the advisability of executing this Agreement and the meaning of the provisions hereof. The provisions of this Agreement shall be construed as to their fair meaning, and not for or against any Party based upon any attribution to such Party as the source of the language in question. The headings and table of contents used in this Agreement are for the convenience of reference only and shall not be used in construing this Agreement.

7.21 **Estoppel Certificate**. At any time, and from time to time, Developer may deliver written notice to the City and the City may deliver written notice to Developer requesting that such Party certify in writing that, to the knowledge of the certifying Party (i) this Agreement is in full force and effect and a binding obligation of the Parties, (ii) this Agreement has not been amended, or if amended, the identity of each amendment, and (iii) the requesting Party is not in breach of this Agreement, or if in breach, a description of each such breach (an "**Estoppel Certificate**"). The Planning Director shall be authorized to execute, on behalf of the City, any Estoppel Certificate requested by Developer which complies with this Section 7.21. The City acknowledges that an Estoppel Certificate may be relied upon by Transferees or successors in interest to Developer who requested the certificate and by Mortgagees holding an interest in the portion of the Property in which that Developer has a legal interest.

7.22 **Counterparts**. This Agreement is executed in duplicate originals, each of which is deemed to be an original. This Agreement, not counting the Cover Page and Table of

Contents, consists of pages and 6 Attachments which constitute the entire understanding and agreement of the Parties.

[SIGNATURES ON FOLLOWING PAGES]

IN WITNESS WHEREOF, the Parties hereto have executed this Agreement as of the date first written above.

THE CITY OF LOS ANGELES, a municipal corporation of the State of California

By:_____
Antonio Villaraigosa, Mayor

DATE:

APPROVED AS TO FORM:

CARMEN A. TRUTANICH, City Attorney

By:
Deputy City Attorney

DATE:

ATTEST:
JUNE LAGMAY

By:_____
Deputy
DATE

AR0067958

1720 Owner

1720 NORTH VINE LLC,
a Delaware limited liability company

By: _____
Name:
Title:

DATE:

APPROVED AS TO FORM:

Attorney
By:
Alfred Fraijo, Jr., Esq.,
Sheppard Mullin Richter & Hampton LLP
Counsel to Developer

DATE:

1749 Owner

1749 NORTH VINE STREET LLC,
a Delaware limited liability company

By: _____
Name:
Title:

DATE:

APPROVED AS TO FORM:

Attorney

By:
Alfred Fraijo, Jr., Esq.,
Sheppard Mullin Richter & Hampton LLP
Counsel to Developer

DATE:

Capital Records Building Owner

1750 NORTH VINE LLC,
a Delaware limited liability company

By: _____
Name:
Title:

DATE:

APPROVED AS TO FORM:

Attorney

By: _____
Alfred Fraijo, Jr., Esq.,
Sheppard Mullin Richter & Hampton LLP
Counsel to Developer

DATE:

AR0067959

Argyle Owner

1733 NORTH ARGYLE LLC,
a Delaware limited liability company

By: _____
Name:
Title:

DATE:

APPROVED AS TO FORM:

Attorney

By: _____
Alfred Fraijo, Jr., Esq.,
Sheppard Mullin Richter & Hampton LLP
Counsel to Developer

DATE:

MILLENNIUM HOLLYWOOD LLC, a
Delaware limited liability company

By: _____
Name:
Title:

DATE

APPROVED AS TO FORM:

Attorney

By: _____
Alfred Fraijo, Jr., Esq.,
Sheppard Mullin Richter
& Hampton LLP
Counsel to Developer

DATE:

AR0067960

MORTGAGEE CONSENT AND SUBORDINATION

The undersigned, HSBC BANK USA, NATIONAL ASSOCIATION ("**Mortgagee**"), is the current beneficiary of record under the following deeds of trust (collectively, the "**Mortgages**"): (a) Deed of Trust, Assignment of Rents and Security Agreement dated as of December __, 2012, made by CPH 1750 North Vine LLC, a Delaware limited liability company ("**Capitol Records Building Ground Lessee**"), as trustor, in favor of _____ _____Title Company, as trustee ("**Trustee**"), for the benefit of Mortgagee, as beneficiary, and recorded on _____, 2012 as Instrument No. 2012-_____ in the Official Records of Los Angeles County, California ("**Official Records**"), (b) Deed of Trust, Assignment of Rents and Security Agreement dated as of December __, 2012, made by 1749 North Vine Street LLC, a Delaware limited liability company ("**1749 Owner**"), as trustor, in favor of Trustee, for the benefit of Mortgagee, as beneficiary, and recorded on _____, 2012 as Instrument No. 2012 - _____ in the Official Records; and (c) Deed of Trust, Assignment of Rents and Security Agreement dated as of December __, 2012, , made by 1733 North Argyle LLC, a Delaware limited liability company ("**Argyle Owner**"), 1720 North Vine LLC, a Delaware limited liability company ("**1720 Owner**"), 1750 North Vine LLC, a Delaware limited liability company ("**Capitol Records Building Owner**"), as trustors, in favor of Trustee, for the benefit of Mortgagee, as beneficiary, and recorded on _____, 2012 as Instrument No. 2012_-_____ in the Official Records.

The Mortgages encumber the "Property" other than the "Third Party Property", as such terms are defined in the attached Development Agreement dated as of _____ _____ __, 2013 (the "**Development Agreement**"), executed by and among the City of Los Angeles, a municipal corporation, 1749 Owner, Argyle Owner, 1720 Owner, Capitol Records Building Owner, and Millennium Hollywood LLC, a Delaware liability company.

Mortgagee has reviewed and approved the Development Agreement, and hereby consents to the recordation of the Development Agreement. Mortgagee further hereby subordinates the liens of the Mortgages to all of the terms, conditions, covenants, and easements contained in the Development Agreement.

Executed as of _____, 2013:

MORTGAGEE:

HSBC BANK USA, NATIONAL ASSOCIATION

By:_____
Name:_____
Title:_____

AR0067962

GROUND LESSEE CONSENT AND SUBORDINATION

The undersigned, CPH 1750 NORTH VINE LLC, a Delaware limited liability company ("**Capitol Records Building Ground Lessee**"), is the tenant of record under that certain Ground Lease dated December __, 2012 (the "**Ground Lease**"), between 1750 North Vine LLC, a Delaware limited liability company, as ground lessor ("**Capitol Records Building Owner**"), and Capitol Records Building Ground Lessee, as ground lessee, a memorandum of which was recorded on _____, 2012 as Instrument No. 2012-_____ in the Official Records of Los Angeles County, California.

The Ground Lease encumbers a portion (the "**Leased Premises**") of the "Property", as defined in the attached Development Agreement dated as of _____, 2013 (the "**Development Agreement**"), executed by among the City of Los Angeles, a municipal corporation (the "**City**"), 1720 North Vine, LLC, a Delaware limited liability company, 1749 North Vine, LLC, a Delaware limited liability company, Capitol Records Building Owner, 1735 North Argyle, LLC, a Delaware limited liability company, and Millennium Hollywood LLC, a Delaware liability company.

Capitol Records Building Ground Lessee has reviewed and approved the Development Agreement, and hereby consents to the recordation of the Development Agreement. Capitol Records Building Ground Lessee further hereby subordinates its leasehold interest in the Leased Premises to all of the terms, conditions, covenants, and easements contained in the Development Agreement.

Executed as of _____, 2013;

CAPITOL RECORDS BUILDING GROUND LESSEE:

CPH 1750 NORTH VINE LLC
a Delaware limited liability company

By: _____
Name: _____
Title: _____

EXHIBIT A-1

DIAGRAM OF THE PROPERTY

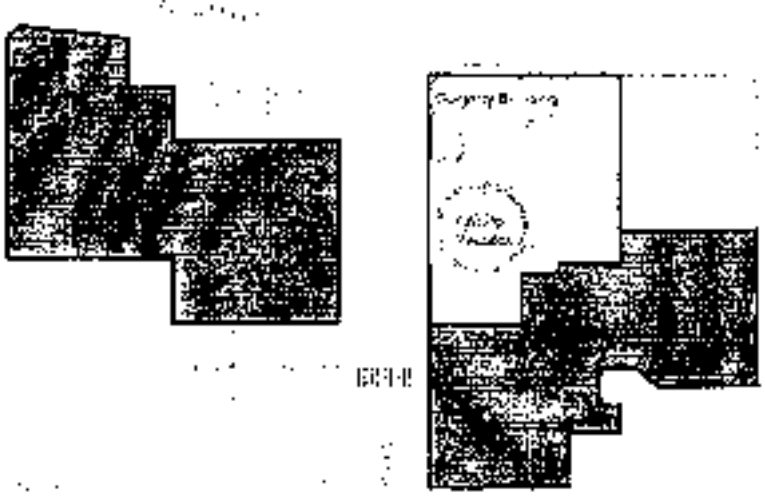

EXHIBIT A-2

LEGAL DESCRIPTION OF THE PROPERTY

EXHIBIT A-3

LEGAL DESCRIPTION OF THE THIRD PARTY PROPERTY

EXHIBIT B

DEVELOPMENT REGULATIONS
[*Attached*]

I. **Community Benefits Approved by City Planning Commission**

Included in entitlement approvals by the City Planning Commission and modified by the City Council PLUM Committee.

Benefit Component	Requested by:
1. **Observation Deck** – Developer to construct an open space observation area. (Required per the Development Regulations)	*CD 4 Council Office*
2. **Circulation Shuttle** – For 15 years, Developer shall operate a shuttle service, providing "on call" service between the Project and residential areas within a two mile radius. Developer shall not be obligated to spend more than $250,000 per year for the operation of service.	*City Planning*
3. **Bicycle Amenities Plan** – For 15 years, Developer shall maintain a kiosk or tenant space of at least 200 square feet for bicycle repair services. This space is in addition to bicycle parking facilities required by the Development Regulations.	*CHNC; City Planning*
4. **Parking Tracking Services** – Developer shall contribute $50,000 to the Department of Transportation's Express Park program for new parking meter technology, vehicle sensors, a central management system and real-time parking guidance for motorists in the vicinity of the Project.	*City Planning*
5. **Metro Passes** – Developer shall provide a fund of $500,000 over ten (10) years ($50,000 per year for ten (10) years) and work with Metro to create a program whereby the developer funds shall supplement 50% of the cost of 400 Metro passes per year over the ten (10) year period.	*City*

Benefit Component	Requested by:
6. **Monthly Parking Leases for Metro Commuters** – Developer shall provide fifty (50) "park and ride" spaces for monthly lease to persons who are not tenants or occupants of the Project and establish a monitoring program of the park and ride spaces. Monthly fees will not exceed $50 in first year (thereafter subject to increase by 3% per year)	*City, CHNC* ***Although an agreement with the Hollywood Dell Civic Association was not reached, these measures were included with input from the Dell Civic Association***
7. **Daily Discount Parking for Metro Commuters** – Developer will provide 10% parking rate discount to holders of Metro pass	*HSDNC, CHNC*
8. **Shared Vehicle Parking** Developer shall maintain 10 parking spaces within non-residential parking areas of the Project for shared vehicle services and lease same to Zipcar or other operator.	*City*
9. **Medians on Vine** – Developer will fund a study of the feasibility of installing landscaped medians on Vine Street between Franklin Avenue and Hollywood Boulevard	*CHNC*
10. **No Off-Site Signage** – Project shall not include any off-site revenue generating signage. (Required per the Development Regulations)	***Various stakeholder groups, CD 13 Council Office***

II. **Additional Benefits Proposed to be Included in the Development Agreement**

Additional community benefits to be [illegible] opment Agreement. Negotiations on additional benefi[illegible] completed prior to the Commission hearing.

Benefit Component	
Incorporated as Third Party Agreemen	
1. **Project Labor Agreement** – Developer shall enter into a "Project Labor Agreement" that will identify the construction trade union(s) as the primary source of all craft labor employed on the Project.	***Labor groups, CD 13 Council Office*** ***Completed through separate private agreement. Would be enforceable pursuant to the DA.***
2. **Local Hiring** – For each Phase of the Project Developer shall implement an apprenticeship and zip code identification program to prioritize local source hiring for Project construction from the 13th Council District. Thereafter, Developer shall implement an apprenticeship and zip code identification program to prioritize local source hiring for Project operation by Developer's employees.	***City, CHNC***
3. **Operation – Hotel Labor Agreement.** Developer shall enter into a labor agreement for the operation and maintance of the hotel.	***Labor groups, CD 13 Council Office*** ***Completed through separate private agreement. Would be enforceable pursuant to the DA.***
4. **Construction Trades Prevailing Wage** – Construction workers employed in the construction of each Phase of the Project shall be paid no less than the prevailing wage as determined by the provisions of Sections 1770 et seq. of the California Labor Code.	***City; Labor groups***

Benefit Component	Requested by:
Additional Benefits	
5. **Community Organization Meeting Space** – Developer shall provide not less than 1,200 square feet of meeting space at the Project for use by Hollywood and community non-profit groups.	*CHNC; HUNC; City Planning*
6. **Discount Parking for Local Area Residents** – Developer will provide 10% parking rate discount to car with occupant holding a driver's license showing address in Hollywood Central or Hollywood Hills zip code]	*CHNC*
7. **Public Performances, Music, and Arts Programming –** Developer shall conduct *at least 12 days of public events per year* in the Art Plaza and pay costs associated with events. *until 15th anniversary of Entitlement Date.*	*CD 13 Council Office, Planning*
8. **Parking Access Management System** – Developer shall provide a parking access management system.	*DOT, CD 13 Council Office, Planning*
9. **Pedestrian Improvements Contribution** – Developer shall provide funding in the amount of $50,000 to the Hollywood Chamber of Commerce Walk of Fame Committee, or as otherwise directed by the City, for renovation and upkeep of the Walk of Fame stars and terrazzo, sidewalks and other public streetscape improvements.	*Planning, CD 13 Council Office*

what is the Ask DOT

Benefit Component	Requested by:
10. **Music Appreciation Exhibit** – For 15 years. Developer shall install publicly accessible artwork and/or changeable exhibition cabinets and/or platforms. The Music Appreciation Exhibit shall be maintained at Developers sole cost.	***CD 13 Council Office***
11. **Hollywood Central Park** –shall make contribution to the Friends of Hollywood Central Park in the amount of $50,000. Thereafter, for 15 years, Developer Developer shall make an annual contribution in the amount of $50,000 for the operation and maintenance of the Hollywood Central Park.	***Planning, CHNC, CD 13 Council Office***
Additional Community Benefits	
12. **Dog Park** – Developer contribute lesser of estimated cost or $25,000 toward improvement of a community dog park, subject to City's acquisition of a site.	***CHNC***
13. **Franklin/Ivar Park –** Developer contribute lesser of estimated cost or $25,000 toward improvement of Franklin/Ivar Park.	***CHNC***
14. **Central Hollywood Design Overlay –** If requested by City, Developer will contribute $250,000 toward completion of Central Hollywood Design Overlay pursuant to Hollywood Community Plan Policy LU 2.5.1 or other Planning undertaking	***CHNC***

Benefit Component	Requested by:
15. **LAPD Hollywood Division Building** – Developer will (esser of estimated cost or $50,000 for the following improvements to 6501 Fountain Avenue: replacement of windows, refinishing façade facing Fountain Avenue, fabrication and installation of signage, and installation of a Wi-Fi system useable throughout the public portions of such building.	***CHNC***
16. **Grocer** – *Developer will use its commercially reasonable efforts to procure a grocery store tenant in any available, suitable retail area within the Project, subject to market conditions and demand, rent levels and competitive grocery facilities in the area.*	***CHNC***
17. **Hollywood Sign Protection Fund** – Following installation of 400+ foot building, Developer shall make contributions to the Hollywood Sign Trust, a California non-profit corporation, in the amount of $2,000 per residential dwelling unit in in such Phase and subsequent Phases, which contribution shall be payable with respect to each unit within thirty (30) days after the earlier of the initial sale or lease thereof.	***CHNC, CD 4 Council Office, CD 13 Council Office, Planning***
18. **Affordable Housing Payment** – Developer shall pay $4,800,000 for the development of 100 new affordable housing units. The affordable housing Projects are (a) the Westlake Theater Project, and (b) the Coronel Project (the "HCHC Projects"). If funds cannot be used or are not needed for HCHC Projects, LAHD can use for other affordable housing projects.	***To be completed by separate agreement. City/LAHD, CD 13 Council Office, Affordable housing advocates*** $2.4 mil HCHC $2.4 mil AHTF

III. **Mitigation Measures in Millennium Hollywood Project Environmental Impact Report (EIR) to Address Traffic and Circulation**

Benefit Component	Requested by:
Section IV.K.1 of the EIR:	
Transportation – Traffic	
K.1-1 To mitigate potential temporary traffic impacts of any necessary lane and/or sidewalk closures during the construction period, the Project Applicant shall, prior to construction, develop a Construction Management Plan/Worksite Traffic Control Plan (WTCP) to be approved by LADOT. The WTCP shall be designed to minimize the effects of construction on vehicular and pedestrian circulation and assist in the orderly flow of vehicular and pedestrian circulation on the public streets in the area of the Project. The WTCP shall include temporary roadway striping and signage for traffic flow as necessary, elements compliant with conditions xv through xvii in Measure K.1-3, and the identification and signage of alternative pedestrian routes in the immediate vicinity of the Project. The Plan shall show the location of any roadway or sidewalk closures, traffic detours, haul routes, hours of operation, protective devices, warning signs and access to abutting properties. Any construction related hauling traffic shall be restricted to off-peak hours.	***Planning, DOT***
K.1-2 In order to minimize peak period construction trips, construction related traffic shall be restricted to off-peak hours. The following language is to be incorporated into the WTCP: i On weekdays, work shifts shall not begin between 7:01 AM and 9:29 AM. ii Work shifts shall not end between 3:31 PM and prior to 6:29 PM. The WTCP shall also include Mitigation Measure K.1-3, Condition i, time restrictions for hauling.	***Planning, DOT***

Benefit Component	Requested by:
K.1-3 Prior to the issuance of a grading permit, the Project Applicant shall record and execute a Covenant and Agreement (Planning Department General Form CP-6770), binding the Project Applicant to the following haul route conditions: i All Project construction haul truck traffic shall be restricted to truck routes approved by the City of Los Angeles Department of Building and Safety, which shall avoid residential areas and other sensitive receptors to the extent feasible. ii Except under a permitted exception, all hauling (both delivery and export) shall be during the hours of 9:00 AM to 4:00 PM or 6:30 PM to 9:00 PM. Any exceptions to the above time limits shall be permitted by the Department of Building and Safety in consultation with the Department of Transportation. Exceptions to the haul activity time limits are to be permitted only when necessary, such as for the continuation of concrete pours that can not reasonably be completed otherwise. iii Permitted Days of the week shall be Monday through Saturday. No hauling activities are permitted on Sundays or Holidays. iv Project haul trucks shall be restricted to 18-wheel trucks or smaller. v The Traffic Bureau of the Los Angeles Police Department shall be notified prior to the start of hauling (213.485.3106). vi Streets shall be cleaned of spilled materials at the termination of each work day. vii The final approved haul routes and all the conditions of approval shall be available on the job site at all times. viii The Contractor shall keep the construction area sufficiently dampened to control dust caused by grading and hauling, and at all times provide reasonable control	***Planning, DOT***

Benefit Component	Requested by:
of dust caused by wind. ix Hauling and grading equipment shall be kept in good operating condition and muffled as required by law. x All loads shall be secured by trimming, watering or other appropriate means to prevent spillage and dust. xi All trucks are to be watered only when necessary at the job site to prevent excessive blowing dirt. xii All trucks are to be cleaned of loose earth at the job site to prevent spilling. Any material spilled on the public street shall be removed by the contractor. xiii The Project Applicant shall be in conformance with the State of California, Department of Transportation policy regarding movements of reducible loads. xiv All regulations set forth in the State of California Department of Motor Vehicles pertaining to the hauling of earth shall be complied with xv "Truck Crossing" warning signs shall be placed 300 feet in advance of the exit in each direction. xvi One flag person(s) shall be required at the job site to assist the trucks in and out of the Project area. Flag person(s) and warning signs shall be in compliance with Part II of the 1985 Edition of "Work Area Traffic Control Handbook." xvii The City of Los Angeles, Department of Transportation, telephone 213.485.2298, shall be notified 72 hours prior to beginning operations in order to have temporary "No Parking" signs posted along the route. xviii Any desire to change the prescribed routes shall be approved by the concerned governmental agencies by contacting the Street Use Inspection Division at 213.485.3711 before the change takes place. xix The permittee shall notify the Street Use	

Benefit Component	Requested by:
Inspection Division, 213.485.3711, at least 72 hours prior to the beginning of hauling operations and shall also notify the Division immediately upon completion of hauling operations. xx A surety bond by Contractor shall be posted in an amount satisfactory to the City Engineer for maintenance of haul route streets. The forms for the bond shall be issued by the Central District Engineering Office, 201 N. Figueroa Street, Room 770, Los Angeles, CA 90012. Further information regarding the bond may be obtained by calling 213.977.6039	
K.1-4 The Project Applicant shall contact the Metro Bus Operations Control Special Events Coordinator at 213-922-4632 regarding construction activities that may impact Metro bus lines.	***Planning, DOT, Metro***
K.1-5 Transportation Demand Management (TDM) – The Project is a mixed-use development, located within a quarter mile radius of the Hollywood/Vine Metro Red Line Transit Station and allows immediate access to the Metro Red Line rail system. Additionally, a number of Metro and LADOT bus routes are less than one-quarter mile (considered to be within reasonable walking distance) from the Project Site, providing access for Project employees, visitors, residents and guests. The Project Site is surrounded by numerous supporting and complementary uses, such as additional housing for employees and additional shopping for residents within walking distance. The Project shall take advantage of these opportunities through a pedestrian/bicycle friendly design and implementation of a TDM program. A preliminary TDM program shall be prepared and provided for LADOT review prior to the issuance of the first building permit for the Project and a final TDM program approved by LADOT is required prior to the issuance of the first certificate of occupancy for the Project. The TDM Program applies to the new land uses to be developed as part of the final development program for the Project. To the extent a TDM Program element is specific to a use, such element shall be implemented at such time that	***Planning, CD 13 Council Office, DOT, Metro, Caltrans, CHNC, and other stakeholder groups*** ***Although an agreement with the Hollywood Dell Civic Association was not reached, these measures were included with input from the Dell Civic Association***

Benefit Component	Requested by:
new land use is constructed. Both the pedestrian/bicycle friendly design and TDM program shall be acceptable to the Departments of Planning and Transportation. The TDM program shall include, but not be limited to, the following strategies: • Provide an internal Transportation Management Coordination Program with an on-site transportation coordinator; • A bicycle, transit, and pedestrian friendly environment; • Administrative support for the formation of carpools/vanpools; • Inclusion of business services to facilitate work-at-home arrangements for the proposed residential uses, if constructed; • Flexible/alternative work schedules and telecommuting programs; • Provide car share amenities (including a minimum of 5 parking spaces for shared car program); • Parking provided as an option only for all leases and sales; • A provision requiring compliance with the State Parking Cash-out Law in all leases; • Provision of a self-service bicycle repair area and shared tools for residents and employees; • Distribution of information to all residents and employees of the onsite pedestrian, bicycle and transit rider services, including shared car and shared bicycle services; • Coordinate with LADOT to provide space for a future Integrated Mobility Hub;	

Benefit Component	Requested by:
• Guaranteed ride home program potentially via the shared car program; • Transit routing and schedule information; • Transit pass sales; • Rideshare matching services; • Bike and walk to work promotions; • Visibility of the alternative commute options through a location on the central court of the Project Site; • Preferential rideshare loading/unloading or parking location; • Financial contribution to the City's Bicycle Plan Trust Fund that is currently being established (CF 10-2385-S5). In addition to these TDM measures, LADOT also recommends that the Project Applicant explore the implementation of an on-demand van, shuttle or tram service that connects the Project to off-site transit stops based on the transportation needs of the Project's employees, residents and visitors. Such a service shall be included as an additional measure in the TDM program if it is deemed feasible and effective by the Project Applicant.	
K.1-6 Hollywood Community Transportation Management Organization (TMO) – The Project shall join or help create a TMO serving the Hollywood Area by providing a meeting area and initial staffing for one year (free of charge). The Project owner shall participate in the TMO as a member. The TMO shall offer services to member organizations, which include: • Matching services for multi-employer carpools. • Multi-employer vanpools (to serve areas that are	***CD 13 Council Office, DOT, CHNC***

Benefit Component	Requested by:
identified as under served by transit, but contain the residences of the Hollywood area employees). • Help coordinating the Bicycle Share and Car Share programs. • Promotion and implementation of pedestrian, bicycle and transit stop enhancements (such as transit/bicycle lanes), and • Other efforts to encourage and increase the use of alternative transportation modes in the Hollywood area.	
K.1-7 Integrated Mobility Hubs – To support the goals of the Project's TDM plan and to expand the City's program, the Project Applicant shall coordinate with LADOT to provide space for a Mobility Hub in a convenient location within or near the Project Site. The Project Applicant has offered to provide on-site parking spaces for shared cars that could be a project-specific amenity or be linked with the larger Mobility Hubs program. The Project Applicant shall also provide space that shall accommodate bicycle parking, bicycle lockers, and shared bicycles. LADOT is currently working on an operating plan and assessment study for the Mobility Hubs project that shall include specific sites, designs, and blueprints for Mobility Hub stations. The results of this study shall assist in determining the appropriate location and space needed to accommodate a Mobility Hub at the Project Site.	***CD 13 Council Office, DOT, Metro, CHNC***
K.1-8 Transit Enhancements – The Project shall provide a pedestrian friendly environment through sidewalk pavement reconstruction/improvements, and improved amenities such as landscaping and shading particularly along the sidewalks on Ivar Avenue and Argyle Avenue linking the project to the Hollywood/Vine Metro Red Line Station. Enhancements shall include reconstructing damaged or missing pavement in the sidewalks along Ivar Avenue and Argyle Avenue between the Project Site and the Hollywood/Vine Metro Red Line Transit Station.	***CD 13 Council Office, DOT, CHNC***

Benefit Component	Requested by:
and installing up to four transit shelters with benches at stops within a block of the Project Site, as deemed appropriate by LADOT. The LADOT designation of locations shall be made in consultation with Los Angeles County Metropolitan Transportation Authority (Metro).	
K.1-9 Bike Plan Trust Fund – The Project Applicant shall contribute a one-time fixed-fee of $250,000 to be deposited into the City's Bicycle Plan Trust Fund that is currently being established (CF 10-2385-S5). These funds shall be used by LADOT, in coordination with the Department of City Planning and Council District 13, to implement bicycle improvements within the Hollywood area. However, improvements within Hollywood that are consistent with the City's complete streets and smart growth policies shall also be eligible expenses utilizing these funds. Any measures implemented by using the fund shall be consistent with the General Plan Transportation Element. Items beyond signing and striping, such as curb realignment and signal system modifications, may be included in the funded projects, to the degree necessary for safe and efficient operation. Should shuttle riders on the DASH system warrant an increase in capacity, the Project funding may instead be used for the purchase of a shuttle vehicle for the DASH system.	***CD 13 Council Office, DOT, CHNC***
K.1-10 Traffic Signal System Upgrades – The Project Applicant shall be required to implement the traffic signal upgrades identified in Attachment 3 to the LADOT's Correspondence to the Department of City Planning, dated August 16, 2012 (See Appendix K.2 to this Draft EIR). Should the project be approved, then a final determination on how to implement these traffic signal upgrades shall be made by LADOT prior to the issuance of the first building permit. These signal upgrades shall be implemented either by the Project Applicant through the B-permit process of the Bureau of Engineering (BOE), or through payment of a one-time fixed fee to LADOT to fund the cost of the upgrades. If LADOT selects the payment option, then the Project Applicant shall be required to pay LADOT the estimated cost to implement	***CD 13 Council Office, DOT***

Benefit Component	Requested by:
the upgrades, and LADOT shall design and construct the upgrades. If the upgrades are implemented by the Project Applicant through the B-Permit process, then these traffic signal improvements shall be guaranteed prior to the issuance of any building permit and completed prior to the issuance of any certificate of occupancy.	
K.1-11 Intersection Specific Improvements – Argyle Avenue/Franklin Avenue – US 101 Freeway Northbound On-Ramp – To mitigate the significant traffic impact at this intersection under both existing (2011) and future (2020) conditions, the Project Applicant shall restripe this intersection to provide a left-turn lane, two through lanes, and a right-turn lane for the southbound approach and two left-turn lanes and a shared through/right lane for the northbound approach. The final design of this improvement shall require the joint approval of Caltrans and LADOT.	***CD 13 Council Office, Planning, DOT***
K.1-12 Highway Dedication and Street Widening Requirements – The City Council recently adopted the updated Hollywood Community Plan. The new plan includes revised street standards that provide an enhanced balance between traffic flow and other important street functions including transit routes and stops, pedestrian environments, bicycle routes, building design and site access, etc. Vine Street has been designated as a Modified Major Highway Class II requiring a 35-foot half width roadway within a 50-foot half-width right-of-way. Yucca Street between Ivar Avenue and Vine Street is classified as a Secondary Highway, which requires a 35-foot half-width roadway within a 45-foot half-width right-of-way. Yucca Street between Vine Street and Argyle Avenue is classified as a Local Street. Ivar Avenue and Argyle Avenue are also classified as Local Streets. A Local Street requires a 20-foot half width roadway within a 30-foot half-width right-of way. The Project Applicant shall check with BOE's Land Development Group to determine if there are any highway dedication, street widening and/or sidewalk requirements for this project.	***Planning, DOT***

Benefit Component	Requested by:
K.1-13 Implementation of Improvements and Mitigation Measures. The Project Applicant shall be responsible for the cost and implementation of any necessary traffic signal equipment modifications and bus stop relocations associated with the proposed transportation improvements described above. Unless otherwise noted, all transportation improvements and associated traffic signal work within the City of Los Angeles shall be guaranteed through the B-Permit process of the Bureau of Engineering, prior to the issuance of any building permits and completed prior to the issuance of any certificates of occupancy. Temporary certificates of occupancy may be granted in the event of any delay through no fault of the Project Applicant, provided that, in each case, the Project Applicant has demonstrated reasonable efforts and due diligence to the satisfaction of LADOT. Prior to setting the bond amount, BOE shall require that the developer's engineer or contractor contact LADOT's B-Permit Coordinator, at (213) 928-9663, to arrange a pre-design meeting to finalize the proposed design needed for the project.	
K.1-14 East Site Residential Unit and Reserved Residential Parking Cap. On the East Site, residential development shall be limited to 450 residential units and 675 reserved residential parking spaces.	what is the rationale?
Section IV.K.2 of the EIR: **Transportation – Parking**	
K.2-1 No sidewalk in the pedestrian route along a public right-of-way shall be closed for construction unless an alternative pedestrian route is provided that is no more than 500 feet greater in length than the closed route.	***CD 13 Council Office, Planning, DOT***
K.2-2 Construction Related Parking. Off-street parking shall be provided for all construction-related employees generated by the Project. No employees or subcontractors shall be allowed to park on surrounding residential streets for the duration of all construction	***CD 13 Council Office, Planning, DOT***

Benefit Component	Requested by:
activities. There shall be no staging or parking of heavy construction vehicles on the surrounding street for the duration of all construction activities. There shall be no staging or parking of construction vehicles, including vehicles that transport workers, on any residential street in the immediate area. All construction vehicles shall be stored onsite unless returned to the base of operations.	

MILLENNIUM HOLLYWOOD PROJECT

DEVELOPMENT REGULATIONS: GUIDELINES AND STANDARDS

MILLENNIUM HOLLYWOOD PROJECT

SCOPE OF DEVELOPMENT: DESIGN GUIDELINES AND STANDARDS

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1. PURPOSE AND OBJECTIVES

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and ensure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria that serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

d. Permit design flexibility while establishing a set of controls that will guide the development for the Project Site.

e. Ensure compliance with the Development Objectives.

f. Ensure preservation of the Capitol Records Building and the Gogerty Building according to the *Secretary of the Interior's Standards for Rehabilitation*.

1.2 Development Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure that new development on the Project Site is consistent with these objectives.

1.2.2 The objectives for new development on the Project Site are to:

a. Preserve the Capitol Records Building and the Gogerty Building according to established preservation guidelines (the *Secretary of the Interior's Standards for Rehabilitation* and guidance provided by Office of Historic Resources).

b. Preserve public views from certain key vantage points to the Capitol Records Tower by creating grade level open space / civic plazas on the East Site adjacent to the Jazz Mural and Capitol Records Building and West Site across from the Capitol Records.

c. Preserve existing view corridors from certain key vantage points to the Hollywood Hills.

fig. 1.2.2.b-c: Capitol Records View Corridors

d. Create civic plazas that are activated by retail, landscaped, and enhance the Hollywood Walk of Fame by providing it as an urban node. Reinforce the urban and historical

importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

e. Encourage street life by the creation of a new pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

f. Create vibrant urban spaces that permit open and green spaces for both the on-site and off-site population.

fig 1.2.2.d: View North Along Vine Street

g. Create a 24 hr. community by the creation of a Thriving Mixed-Use Development.

h. Eliminate the visual impact of current on-site parking.

i. Establish where feasible pedestrian linkages to existing public transportation routes in proximity to the Project Site, including the Metro Red Line Station at Hollywood Boulevard and Vine Street, and existing bus routes.

j. Establish standards to address architectural excellence.

k. Provide designs that address, respect and complement the existing context, including standards for ground-level open space, podium heights and massing setbacks that minimize impacts to the historic setting.

l. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

m. Create buildings that emphasize the vertical architecture and become visible icons.

n. Develop a visual gateway to Hollywood from the Hollywood Freeway.

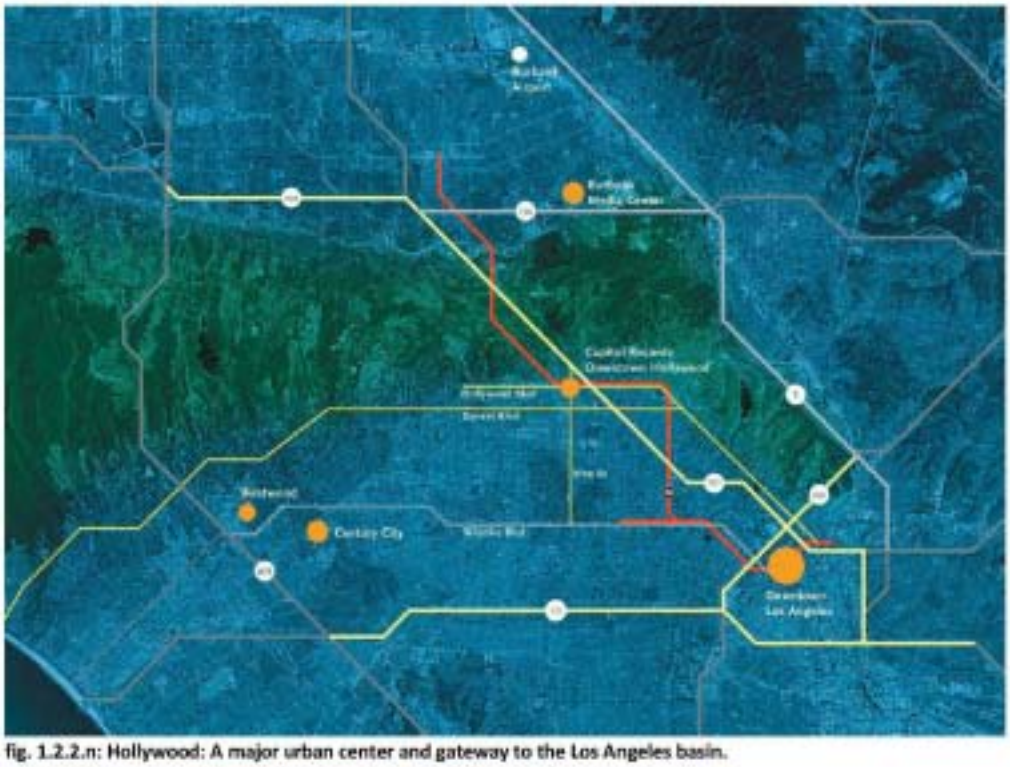


fig. 1.2.2.n: Hollywood: A major urban center and gateway to the Los Angeles basin.

1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose strict requirements for new development. For example, the Regulations include specific setback requirements along Vine Street. There are also mandatory requirements or standards for minimum open space on the ground floor as well as maximum building heights. By comparison, the guidelines are measures that may include a range of choices and require a degree of interpretation by the architect and design team to achieve compliance with the Regulations. The purpose of these guidelines is to create a principal design theme or objective without comprising high quality design. The purpose is to provide a range of flexibility to permit the selection of the most appropriate design feature based on the final development scenario. For instance, façade treatments for new development may take different form depending on the final design plans. The Regulations will guide the ultimate façade treatment by providing a limited range of choices in the use of material and color for the façades.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 The Development Regulations are approved by the City of Los Angeles City Council and are incorporated in the Development Agreement, authorized pursuant to California Government Code 65864, et seq., entered into by the City of Los Angeles and _____ ("Millennium Development Agreement") on _____.

1.4.2 Wherever the Regulations contain provisions which establish regulations that are different from or more or less restrictive than the zoning or land use regulations in the Los Angeles Municipal Code ("LAMC") that apply to the Project Site, the Regulations shall prevail pursuant to the Millennium Development Agreement approved by the City Council.

2. BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street.

The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Avenue is the East Site.

The East Site and the West Site make up the Project Site.

The Project Site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 21 feet (NE to SW) from Vine Street to Argyle Avenue and 21 feet (NW to SE) from Ivar Avenue to Vine Street. The existing sidewalk elevations will not be altered as part the Project.

fig. 2.1. Site Plan

2.2 Site Zoning and Permitted Floor Area

2.2.1 The Project Site is zoned Commercial (C2). The City General Plan land use designation is Regional Center commercial.

2.2.2 The Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.

2.2.3 Notwithstanding any provision in these Regulations, residential floor area is not permitted within 500 feet of any freeway.

2.2.4 Floor Area Ratio: 6:1

2.2.5 Height District: No. 2

3. HISTORIC RESOURCES AND SETTING

3.1 Overview

The Project Site is located in a historically rich area of Hollywood that contains a number of recognized historic resources. This Project is a preservation project in that its ambition is to respect, respond to, and preserve the Capitol Records Building and to continue the urban character of Vine Street on the Project Site. The Project is designed to be observant of historic settings and buildings. Two buildings located on the Project Site, the Capitol Records Tower and the Gogerty Building, are historically significant. Other historic buildings, located on adjacent parcels, are the Pantages Theater, the Equitable Building, the Hollywood Palace, and the Art Deco commercial building at 6316-6324 Yucca Street. Several of these historic resources are located within the Hollywood Boulevard Commercial and Entertainment District, a National Register listed historic district located just south of the Project Site.

Composed of commercial properties from the first half of the 20th Century, contributing properties to the Hollywood Boulevard Commercial and Entertainment District include a wide variety of property types including single-story storefronts, two-story commercial blocks, department stores, theaters, high-rise office buildings and hotels.

The Capitol Records Building is a unique building whose cylindrical form has always been visible from portions of Hollywood and Vine from the south and the freeway from the north. The Capitol Records Tower and the iconic buildings in the Hollywood Boulevard Commercial and Entertainment District (the Hollywood Palace, Pantages Theater, Equitable Building) will maintain their prominence after implementation of the Project.
Portions of the Hollywood Walk of Fame (L.A. Historic Cultural Monument #194) are located along Vine Street between Yucca Street and Sunset Boulevard and will be protected.

The protection of Hollywood's historic resources and unique character is an important objective of the Project. The guidelines and standards contained in this document were created in part to ensure the protection of historic resources within the Project Site and minimize potential adverse effects to historic resources from new development. Key Project objectives regarding historic resources include:

1) Preservation, maintenance, and rehabilitation of the Capitol Records Building and the Gogerty Building in accordance with the Secretary of the Interior's Standards. See sections 1.2.2a and 1.2.2b of this document.

2) Protection and preservation of the portions of the Hollywood Walk of Fame (LA Historic Cultural Monument #194) will need to be temporarily removed during construction and replaced after construction is completed. A preservation plan, outlined in the Hollywood Walk of Fame Terrazzo Pavement and Repair Guidelines (March, 2011) will be prepared for this aspect of the Project.

3) Incorporation of ground-floor open space and building setback requirements to moderate the overall massing of new development in a manner that preserves important views to and from the Capitol Records Building, the Hollywood Boulevard Commercial and Entertainment District, and important view corridors to the Hollywood Hills. See sections 1.2.2 c, 6.1, 6.9, 7.1, 7.5, 8.1 and 8.2 of this document.

4) Incorporation of ground-floor open space and building setback requirements to reduce massing at the street level and limit the visual crowding of adjacent historic resources. See sections 1.2.2c, 6.1, 7.1, 7.5,

8.1 and 8.2 of this document.

5) Requirement that design of new buildings be in a manner that is differentiated from but compatible with adjacent historic resources. See sections 6.6, 6.8, 7.1.5, and 7.4 of this document.

One means of creating compatible new buildings in an urbanized setting is to incorporate qualities of vertical and horizontal visual complexity in world class design. The general characteristics, proportions, and details of older buildings may serve as a reference for the Project. The Project's intent is to allow old and new to mix, recognizing that Hollywood sustains its image through both the rehabilitation of existing historic structures and the design of creative and contemporary architecture.

4. DENSITY

4.1 Floor Area Ratio Averaging and Density Transfer

The Owner may transfer density and buildable floor area from one parcel within the Project Site to another parcel within the Project Site, as long as the minimum and maximum building heights in the Regulations are maintained and the entire Project does not exceed the cumulative, allowable density and floor area of the zoning for the sum of the individual parcels.

To allow for the spatial distribution of the development on the Project Site and ensure relationship and sensitivity with the uses surrounding the Project Site, parking, open space and related development requirements for any component of the Project may be developed in any location within the Project Site.

4.2 Land Use Equivalency Program

The Land Use Equivalency Program is intended to provide flexibility in land uses for the Project while ensuring that a change in land uses would not result in new significant environmental impacts or a substantial increase in the severity of significant environmental impacts identified in the EIR, ENV-2011-0675-EIR (SCH No. 2011041094). With respect to any proposed Phase of the Project (an "Exchange Phase") that would result in a build out of the Project that is not consistent with at least one of the Project scenarios studied under the EIR, under the Land Use Equivalency Program, the developer may request a transfer or exchange of land uses, as well as modifications to the siting, massing or other development standard in so far as they are consistent with the provisions herein, for such Exchange Phase by a delivering written request therefore to the Planning Department of the City, which request shall be accompanied by (a) detailed information identifying the land use transfer/exchange that is being proposed for such Exchange Phase; (b) information documenting how the proposed land uses and densities in the Exchange Phase, together with the existing improvements and the other phases previously developed, are consistent with the overall AM and PM peak hour trip cap identified in Table II-3, Project Trip Cap from the EIR; and (c) supporting documentation to demonstrate that the Project including the proposed Exchange Phase would not exceed the maximum environmental impacts identified in the EIR (collectively, an "Equivalency Program Exchange Submission"). The Planning Director shall approve such request if the Equivalency Program Exchange Submission reasonably demonstrates that the Project including the proposed Exchange Phase is consistent with the overall AM and PM peak hour trip cap identified in such Table II-3, Project Trip Cap, does not conflict with the impacts analysis for the maxim Commercial and Residential Scenarios, and would not otherwise exceed the maximum environmental impacts identified in the EIR.

5. HEIGHT

5.1 Building Height Standards

The Regulations establish heights zones (A, B, C and D) to limit maximum building heights and control bulk in response to the Development Objectives including context with the built environment and to reinforce view corridors to the Capital Records Tower.

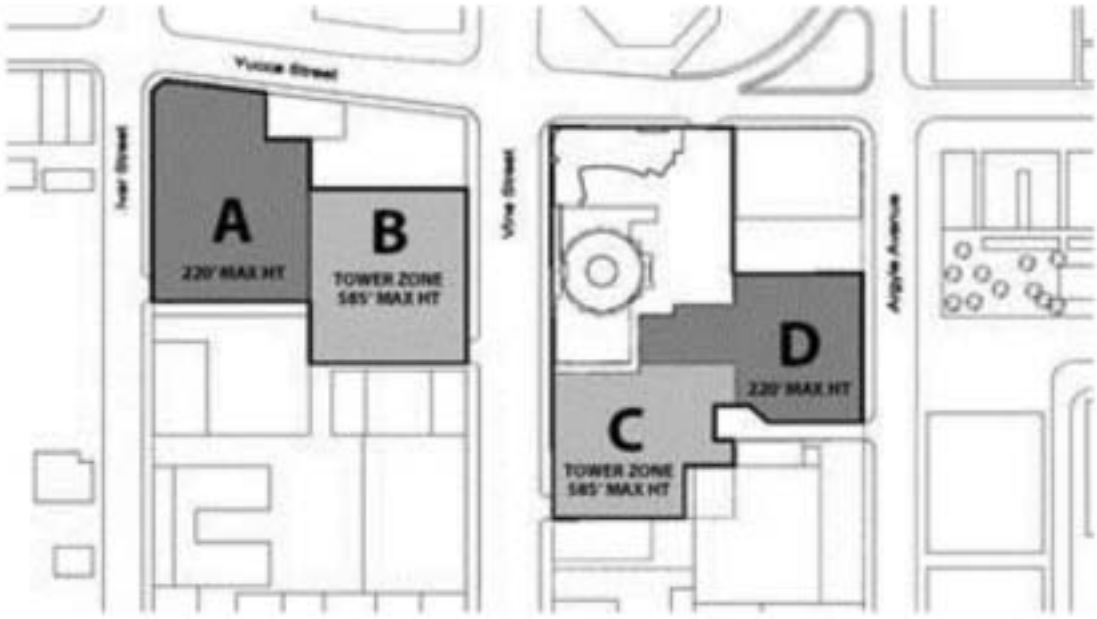


Fig. 5.1 Height Zones

6. BUILDING AND STREET EXPERIENCE

6.1 Tower Massing Standards

6.1.1 The Tower Massing Standards apply to the portion of a building located 150 feet above curb level – see Table 6.1.1.

Tower Height (feet)	Maximum Tower Lot Coverage (%)	Minimum Floor Area Below 220 Feet (%)	Maximum Tower Floor Plate (sq. ft.)	Minimum Tower Setback (feet)	Minimum Public Open Space (%)	Figures
151 – 585	11.5	50	13,325 East Site 9,042 West Site	10 15[1]	12	6.1.2.d.1 6.1.2.d.2
151 – 550	15	50	17,380 East Site 11,794 West Site	10 15[1]	10	6.1.2.c.1 6.1.2.c.2
151 – 400	28	50	22,745 East Site 22,016 West Site	10 15[1]	8	6.1.2.b.1 6.1.2.b.2
150 – 220	48	n/a	55,616 East Site 37,742 West Site	10 15[1]	5	6.1.2.a.1 6.1.2.a.2

Table 6.1.1

Note 1: 15' tower setback required for any tower fronting Vine Street on West parcel. See Figure 6.3.2.

6.1.2 For the purpose of calculating the maximum lot coverage the total lot area is equal to the total lot area for each of the sites, the West Site and the East Site. If there is more than one tower on a site, the maximum lot coverage requirement in Table 6.1.1 is calculated based on the combined area of all towers on each site. The total lot coverage applies to the aggregate floor plate(s) of the tower or towers on each site.

6.1.3 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Figs. 6.1.2.a.1 – 2.)

6.1.4 At least 50% of total floor area must be located below 220 feet.

6.1.5 Tower wall articulation:

a. Minimum 10% of tower aggregate area shall be articulated.

6.1.6 Types of permitted articulations for tower walls:

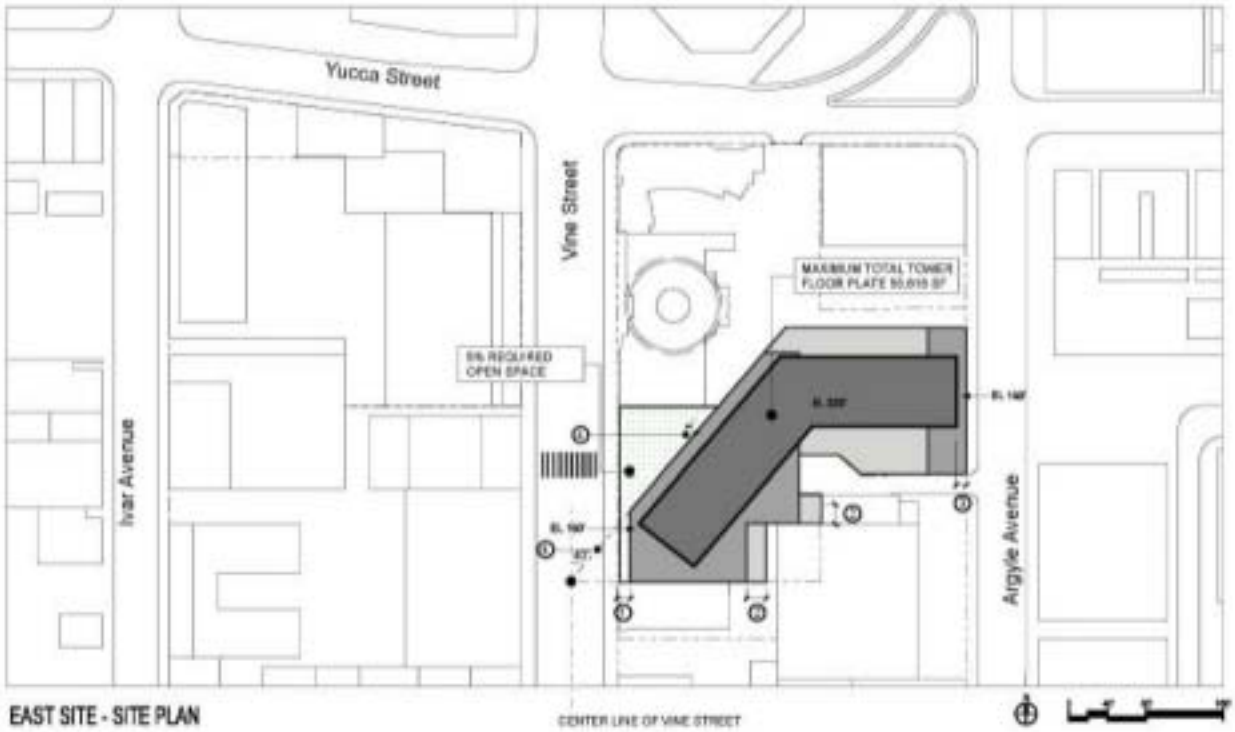
a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

The following developments are for illustrative purposes only.
Maximum Lot Coverage and Tower Floor Plate – Figs. 6.1.2.a – d.



EAST SITE - SITE PLAN

① MINIMUM 10' SETBACK ALONG VINE STREET
② MINIMUM 20' SETBACK ABOVE 150'
③ MINIMUM 10' SETBACK ABOVE 150'
④ 10' SETBACK FROM CAPITOL RECORDS TOWER

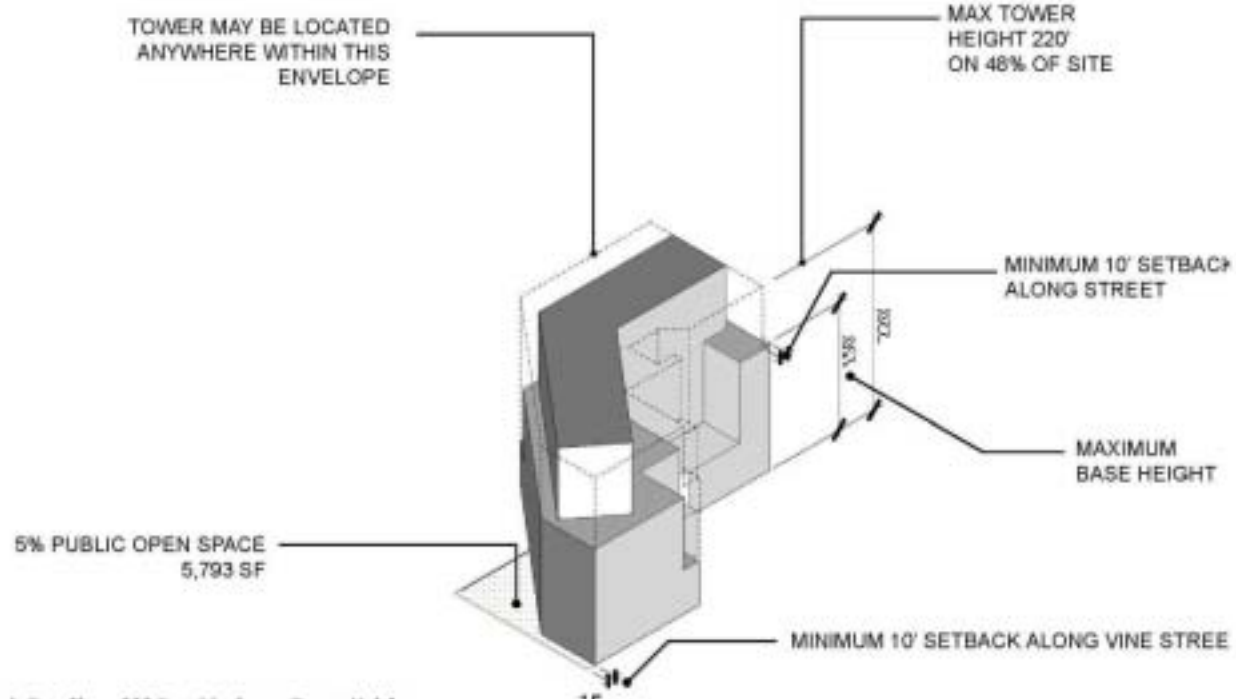


fig. 6.1.2.a.1: East Site – 220 Feet Maximum Tower Height

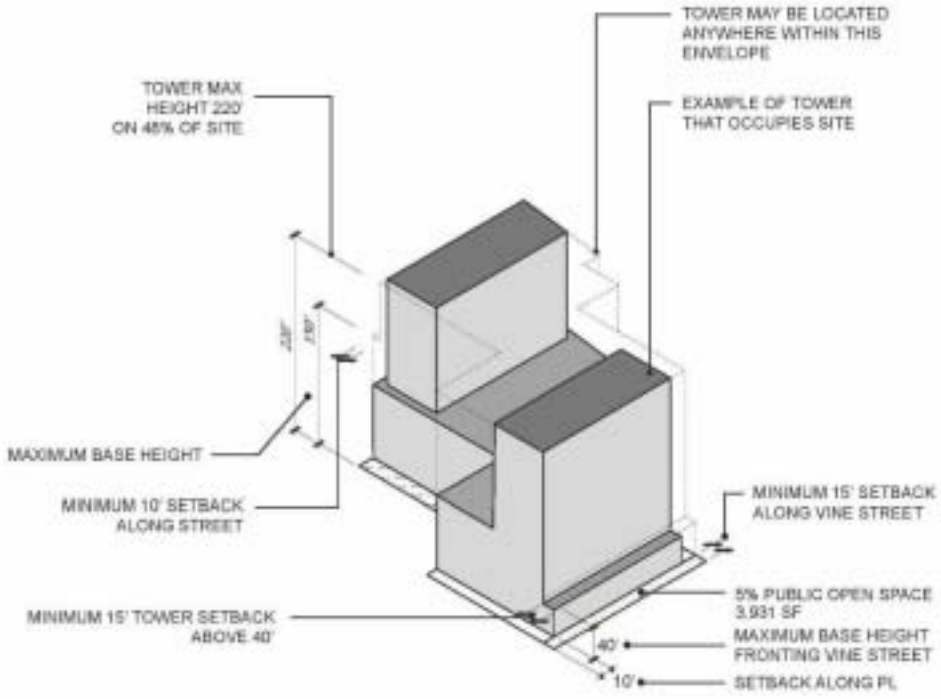
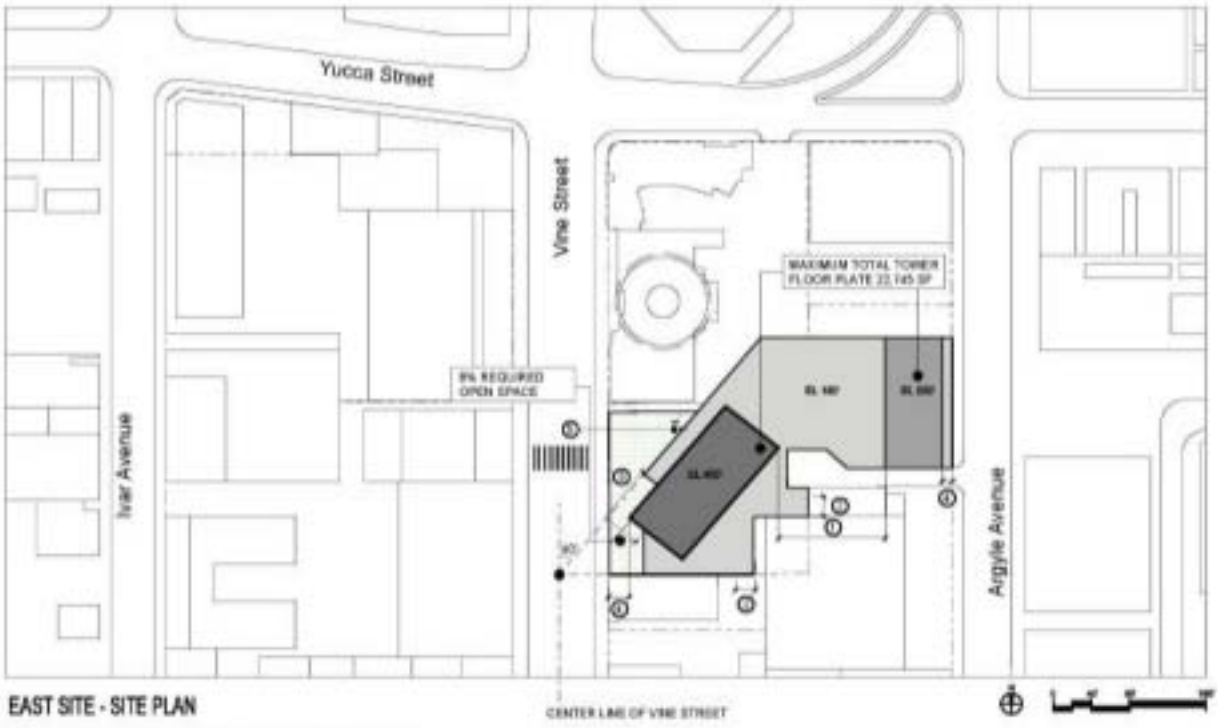


fig. 6.1.2.a.2: West Site - 220 Feet Maximum Tower Height.



EAST SITE - SITE PLAN

① MINIMUM 60' SEPARATION BETWEEN 'TOWERS' ON SAME SITE
② MINIMUM 20' SETBACK ABOVE 156'
③ MAXIMUM 40% OF STREETWALL CAN EXCEED MAXIMUM STREETWALL HEIGHT
④ MINIMUM 10' SETBACK ABOVE 156'
⑤ 10' SETBACK FROM CAPITOL RECORDS TOWER

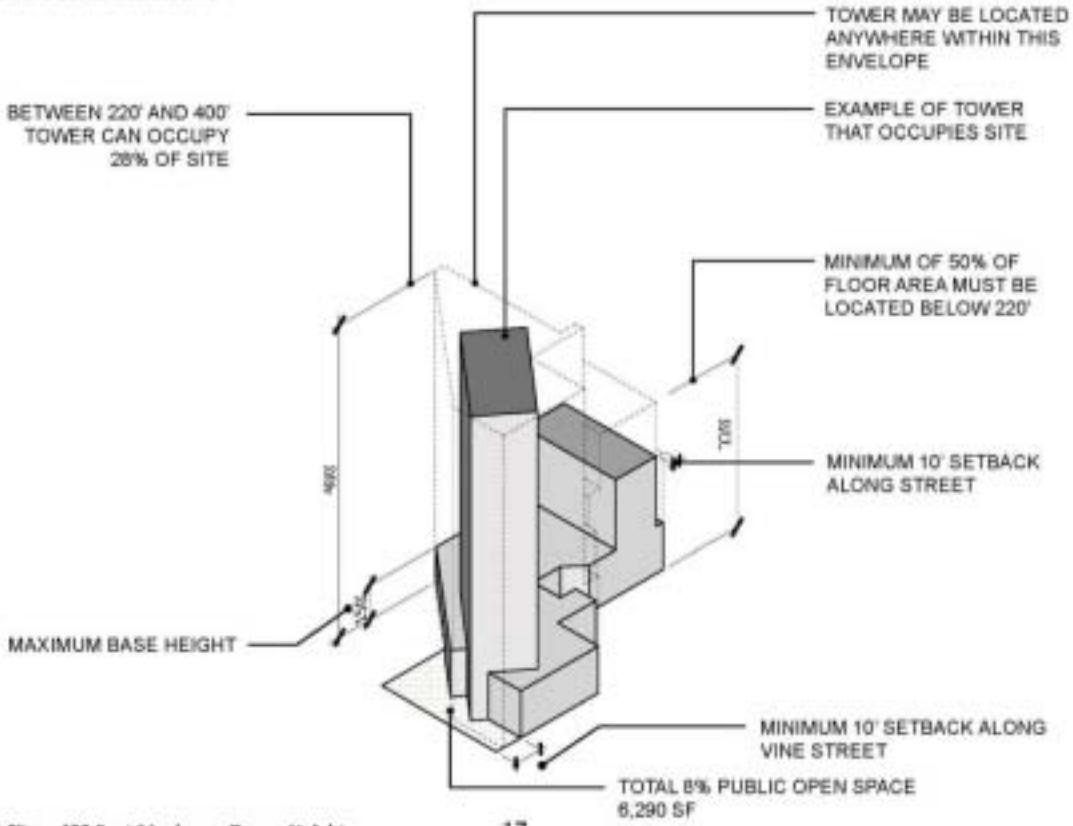


fig. 6.1.2.b.1: East Site – 400 Feet Maximum Tower Height

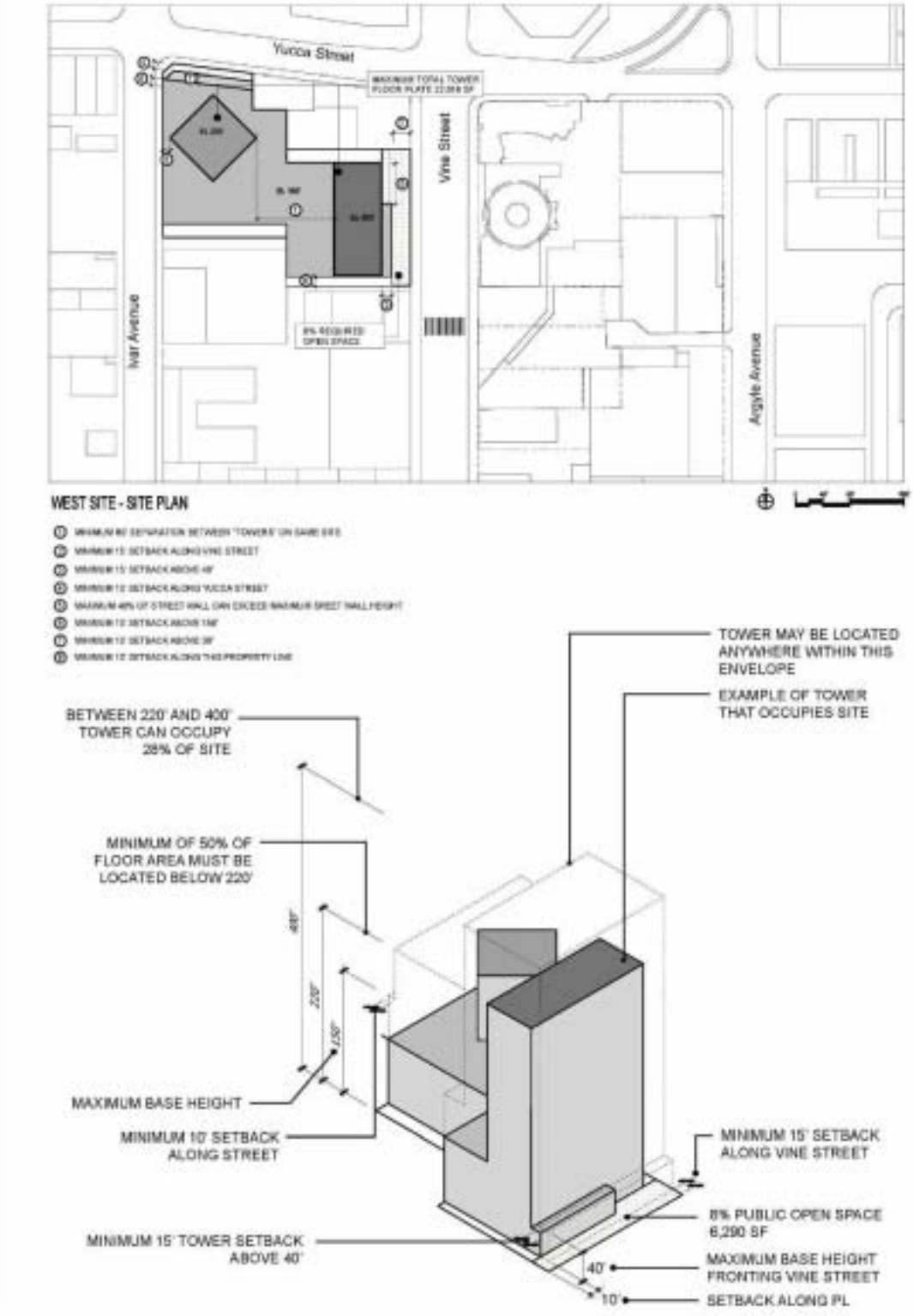


fig. 6.1.2.b.2: West Site – 400 Feet Maximum Tower Height

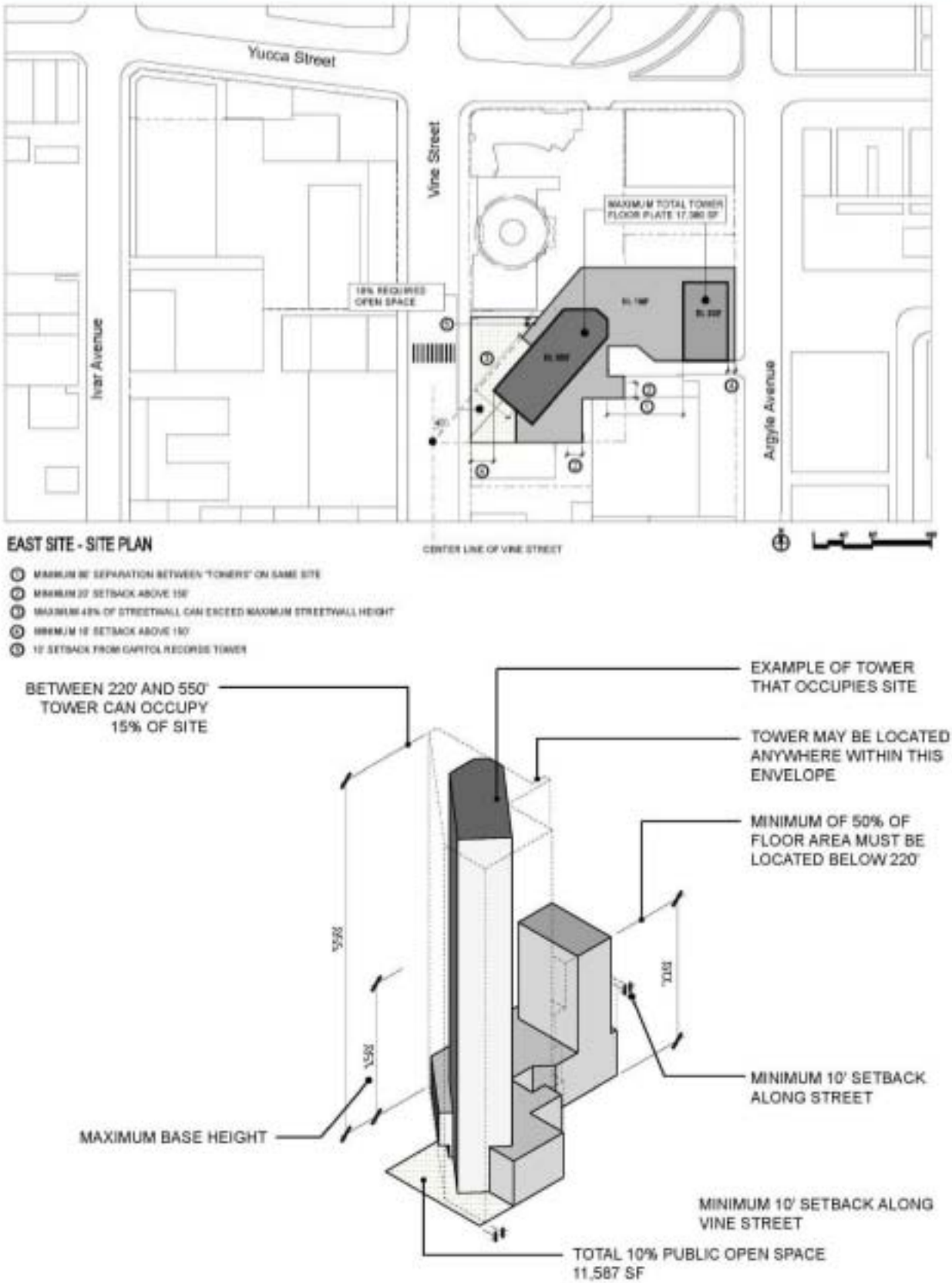


fig. 6.1.2.c.1: East Site – 550 Feet Maximum Tower Height

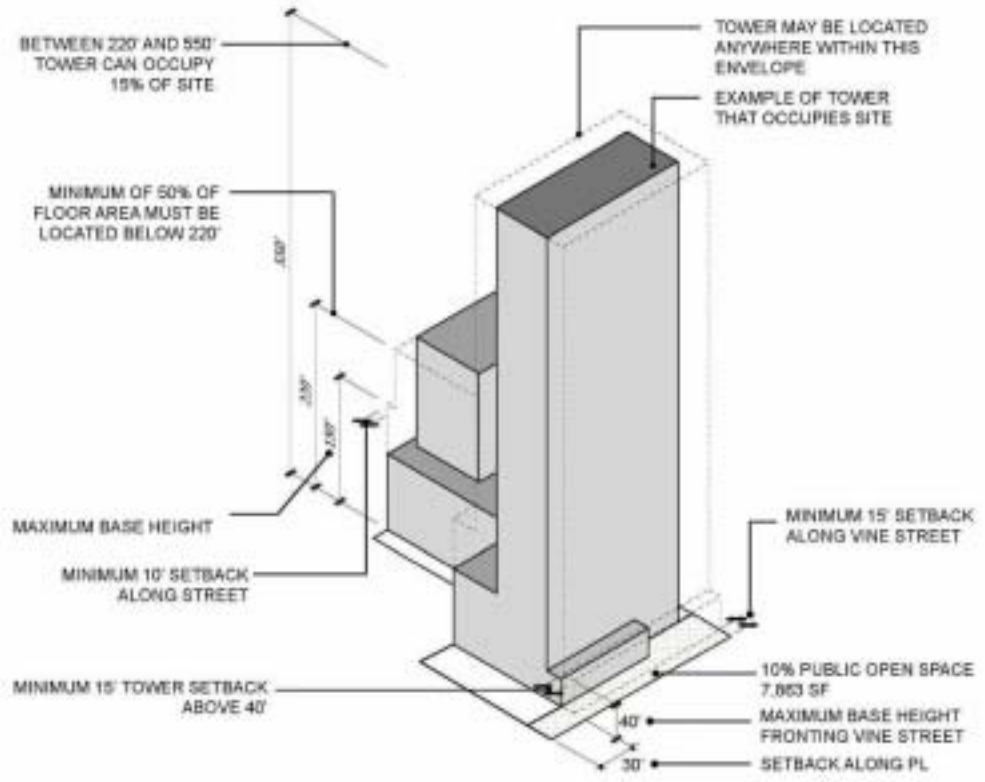
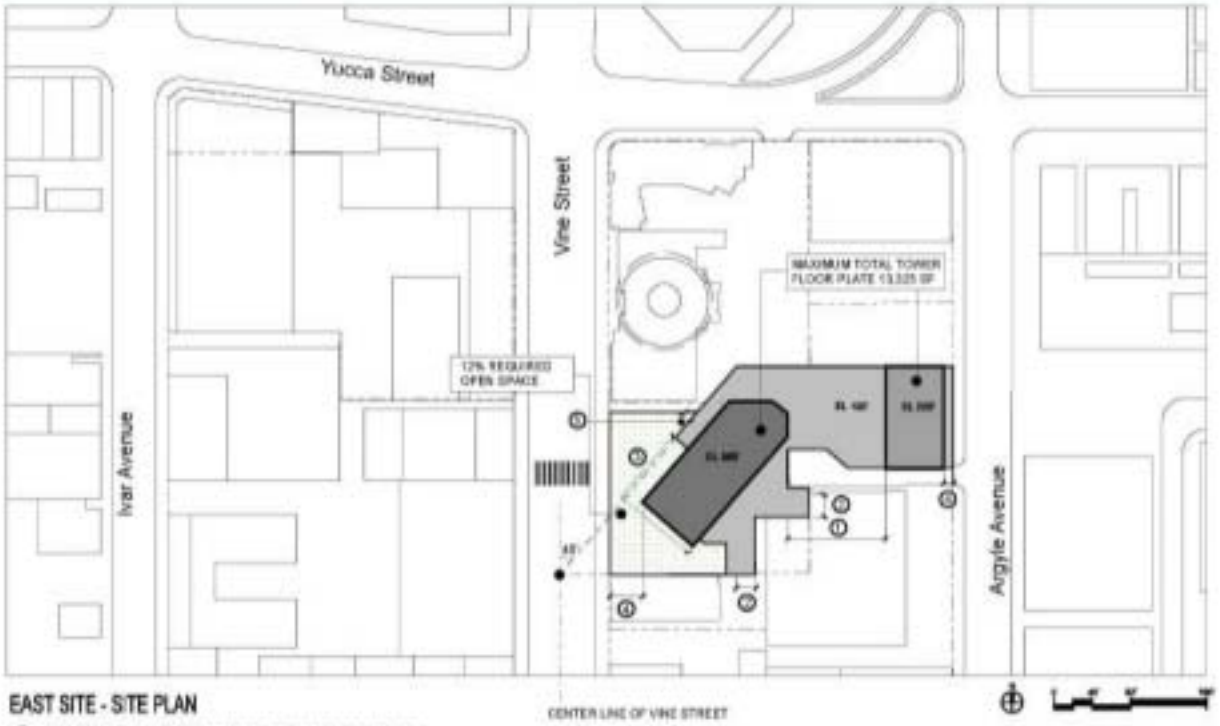


fig. 6.1.2.c.2: West Site – 550 Feet Maximum Tower Height



EAST SITE - SITE PLAN

1. MINIMUM 80' SEPARATION BETWEEN "TOWERS" ON SAME SITE
2. MINIMUM 20' SETBACK ABOVE 150'
3. MAXIMUM 40% OF STREETWALL CAN EXCEED MAXIMUM STREETWALL HEIGHT
4. MINIMUM 15' SETBACK ABOVE 150'
5. 10' SETBACK FROM CAPITOL RECORDS TOWER

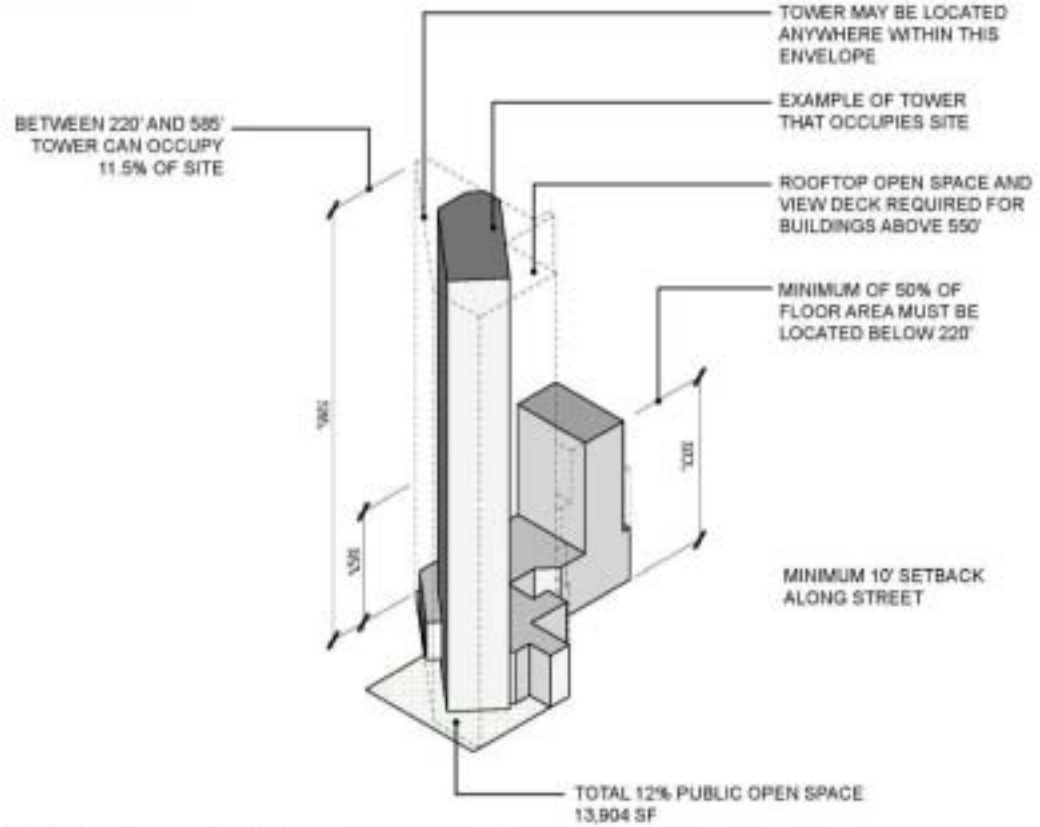


fig. 6.1.2.d.1: East Site – 585 Feet Maximum Tower Height

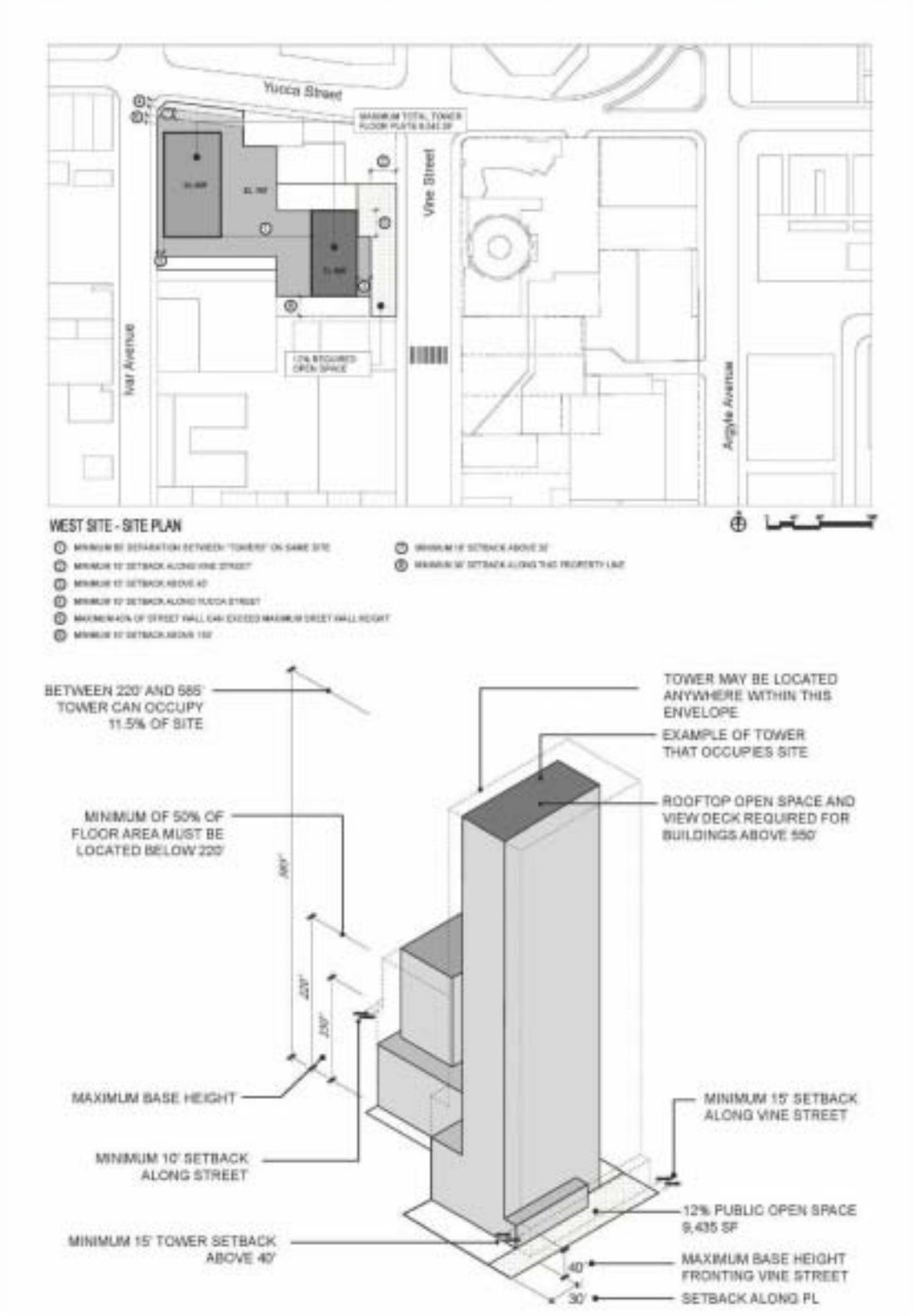


fig. 6.1.2.d.2: West Site – 585 Feet Maximum Tower Height

6.2 Street Walls

6.2.1 A street wall is a wall or portion of a wall of a building facing a street or a grade level open space. Street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation. The street wall shall have proportions and architectural building details which emphasize and reflect the presence and importance of the pedestrian environment. Massing offsets, fenestration, varied textures, openings, recesses, and design accents are strongly encouraged to ensure there are no un-articulated walls and monolithic roof forms, and architectural elements such as balconies, verandas, and porches that add architectural character are encouraged.

6.3 Street Wall Standards

6.3.1 Location of a required street wall:

a. Parcels with a grade level open space: the required street wall shall be located a minimum 10 feet from the property line along Vine Street on the East Site and 15 feet along Vine Street on the West Site.

b. A grade level open space is required for any building fronting Yucca Street with a minimum 10 feet setback from the property line.

c. Parcels or portions of parcels without a grade level open space: the required street wall shall be located on the property line.

6.3.2 Height of required street wall:

a. Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b), (c) and (d) below.

b. Street walls fronting Vine Street on the West Site shall be built to a maximum height of 40 feet above curb level except as noted in item (d) below.

c. Street walls fronting Yucca Street shall be built to a maximum height of 30 feet. Building can extend to a maximum height of 150 feet with a 10 foot setback above 30 feet except as noted in item (d) below.

d. 40% of the aggregate width of the required street wall frontage on each street can exceed the maximum street wall height up to the maximum tower height.

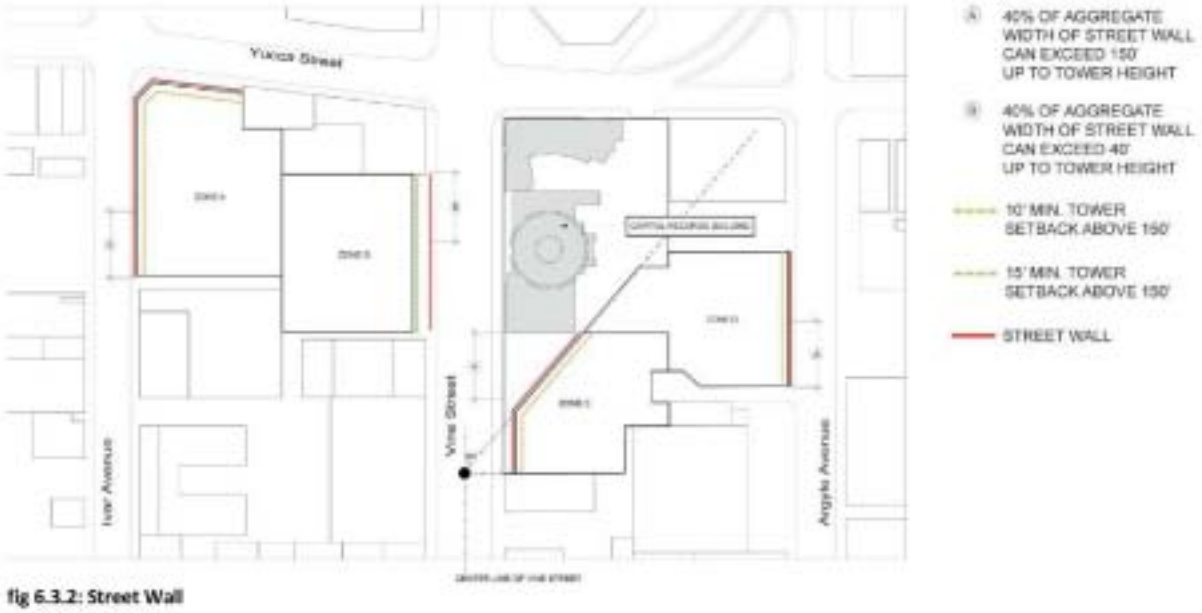


fig 6.3.2: Street Wall

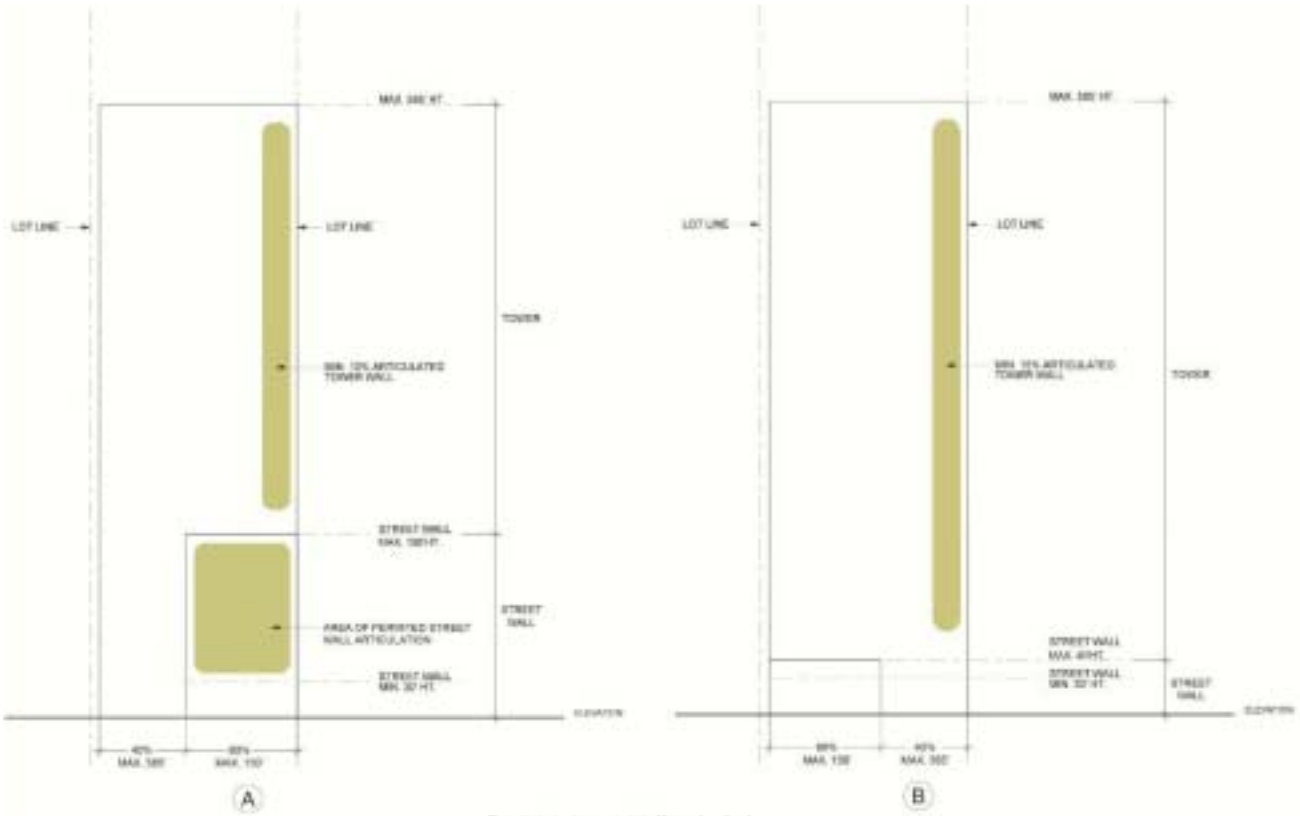


fig. 6.3.3: Street Wall Articulation

6.3.3 Types of permitted articulation of a required street wall:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

6.3.4 Other permitted projections: elements which project beyond the property line from a required street wall shall comply with the Building Code.

a. Architectural facade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required street wall over a grade level open space.

b. Steps and ramps may project from a required street wall over a grade level open space.

c. Commercial marquees, canopies and awnings.

d. Retail storefronts: may project from a required street wall over a grade level open space by a maximum depth of 5'-0'. The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

6.4 Street Wall Guidelines

6.4.1 Pedestrian pass-through areas, public plazas, marquees, canopies, awnings and retail storefronts are permitted within the street wall area.

6.4.2 Pedestrian steps and ramps, entry forecourts, hotel drop-offs and loading entries and exits and vehicular access driveways are also permitted within the street wall area on the Project Site.

6.5 Yard Standards

6.5.1 Yard is an open space other than a court that is unoccupied and unobstructed from the ground upward.

6.5.2 Commercial Use: no front, side or rear yard setbacks are required.

6.5.3 Residential Use:

a. Front Yard: none.

b. Side Yard: Minimum 5 feet; for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.

c. Rear Yard: Minimum 15 feet; for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

6.6 Building Materials and Color Guidelines

6.6.1 The goal of the building materials and colors is to reinforce the character of the Hollywood area and provide a design that is compatible yet avoids any appearance that the building is being historicized. These guidelines will address the façade treatment for both residential and commercial portions of buildings.

a. Buildings shall feature long-lived and sustainable materials. The material palette shall provide variety, reinforce massing and changes in the horizontal or vertical plane.

b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

c. Podium levels up to 150 feet will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents.

d. The architecture of the building shall clearly delineate an architectural style, and shall not appear as a simplified version thereof, with appropriate fenestration patterns, architectural features, proportions and materials.

e. The building's skin, especially for towers, shall be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.

f. In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style. There will be clear contrast between the building's surface material and the building's glazed areas.

g. In general, the overall massing, roof forms, materials, and architectural style of new structures shall provide a variety of forms, depth and texture, and encourage a cohesive character. Building massing shall include a variation in wall planes and height as well as roof forms to promote architectural excellence, a pedestrian friendly environment and take into account the context.

h. To provide visual variety and depth, the building skin shall be layered and designed with a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin shall reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

i. Rooftop mechanical equipment screening shall be designed to be integral with the building architecture and the visual impact shall be minimized by using materials that are complimentary or consistent with the building.

j. Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

Fig. 6.6.1

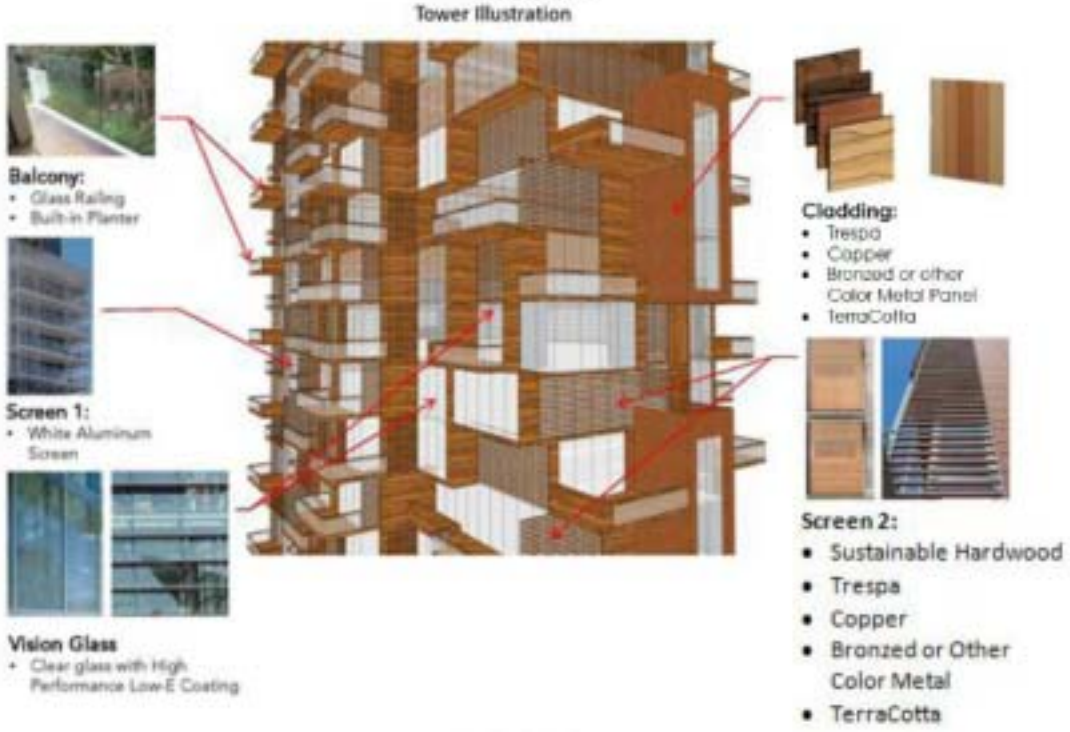


Fig. 6.6.2

k. Examples of acceptable materials are illustrated in Figures 6.6.1 – 2

6.7 Grade Level Standards

6.7.1 The purpose of the grade level standards is to promote pedestrian-scaled architecture by regulating street wall massing, articulation and detail, street level entrances and storefront windows and doors, as well as the use of quality materials and decorative details. Architectural features that reinforce the retail character of the ground floor street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and shall be integral to the architecture of the building.

6.7.2 Ground floor height:

a. Minimum 12'-0" height measured from floor to ceiling.

6.7.3 Building entrances:

a. The primary entrance to a street level tenant space that has frontage along a public street shall be provided from that street. The primary entrance to a tenant space that does not have its frontage along a public street shall be provided from a courtyard, *grade level open space*, or *publicly accessible passageway*. Entries less than 18 inches from the property line shall not be higher than 12 inches above the elevation of the sidewalk; entries greater than 18 inches from the property line shall be within 30 inches of the adjacent grade level along street frontages. Where possible entries shall be marked using architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

b. All retail spaces shall be accessed primarily from a ground floor, single-tenant entry along a street, plaza or passageway. Where reasonably practical given architecture and tenant requirements, access to different tenant spaces shall occur at a maximum interval of 60 feet.

c. Main building entrances shall read differently from retail storefronts, restaurants and commercial entrances which could include but are not limited to material change, architectural elements or elevation change.

d. In addition to the building's required primary entrance(s), there may be ancillary entrances to the building from parking garages.

6.7.4 Ground Floor Glazing

a. Use of clear, colorless and transparent glazing is required within the first 30 feet above curb level.

b. Use of reflective glass is prohibited.

c. Along street frontages with a required build-to line less than or equal to 18 inches from the property line, glazing shall constitute a minimum of 30% of the area of a building face and shall not exceed 80% of the area of a building face.

6.7.5 Arcades

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0-foot candles.

6.7.6 Service and Refuse Requirements

Hotel and Commercial / Office / Retail that abuts an alley

a. Every required loading space shall be located and arranged such that delivery vehicles may be driven upon or into said space from an alley. Such loading space shall have a minimum height of 14 feet and be accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

b. Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.

c. Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet; a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet; and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

Condominiums (Residential)

d. None

Rental (Residential)

e. None

6.7.7 Service and Refuse Guidelines

a. Storage areas shall be provided within the building of a size sufficient for the development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible from a curb cut.

b. Service, utility, and mechanical functions, including retail loading, shall be located in alleys whenever present. When alleys are not present, service functions shall be placed within buildings.

c. Service, utility, and mechanical equipment that is visible from the street shall be screened from view with landscaping or enclosures. Back flow and fire standpipes, along with utility box transformers, shall be screened.

d. All screening devices shall be compatible with the architecture, materials and colors of adjacent buildings.

e. Trash and storage enclosures shall be architecturally compatible with the project design and landscaping shall be provided adjacent to the enclosure(s) to screen them and deter graffiti.

f. Trash enclosures and retail loading areas shall be sited to minimize nuisance to adjacent properties.

g. The location of trash enclosures shall be easily accessible for trash collection and should not impede general site circulation patterns during loading operations.

h. Mechanical equipment shall vent to an alley wherever possible.

i. Roof-vent penetrations and mechanical equipment shall be located at least 10 feet from any exterior Building Face.

j. Gutters and downspouts shall be made of galvanized steel, copper (not copper coated), or aluminum.

6.7.8 Storefronts

a. Storefront (residential, retail, restaurant and commercial) requirements shall include frontage along streets and grade level open spaces.

b. Storefronts shall comprise a minimum of 70% of the building's street level façade along Vine Street and 40% along all other streets and be recessed where necessary.

c. Storefront glazing shall comprise a minimum of 60% of the storefront area along Vine Street and 40% glazing along all other streets.

d. All retail space shall have a minimum 12 feet finished ceiling clearance.

e. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet. Storefront sills shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

f. Storefront openings shall be no shorter than 12 feet above the adjoining grade for 90% of the required storefront frontage.

g. Security grilles will be located behind glass and be at minimum 70% open.

h. At-grade storefront glazing at, or adjacent to, and/or facing any public right-of-way shall incorporate transparent, clear, colorless glazing with no reflectivity.

i. Awnings shall not obscure storefront signage. Vinyl awnings are not permitted.

6.8 Podium Standards

6.8.1 The purpose of the Podium Standards is to provide a modern interpretation of the historical context of Hollywood by establishing different treatment of the building's base, middle and top

through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

6.8.2 Podiums shall comply as applicable with the minimum setback requirements set forth in Figures 6.1.2a – d.

6.9 Podium Guidelines

6.9.1 Podiums shall have fenestration that establishes a clear pattern on the façade (with special attention paid to facades that are visible from a public street) and that provides depth and additional articulation.

6.9.2 An identifiable break between the building's ground floors and upper floors shall be provided. This break may include a change in material, change in fenestration pattern or similar means.

6.9.3 Podium level windows shall be vertically oriented.

6.9.4 Podium levels shall be predominantly light in color.

6.9.5 An expression band shall be provided at the highest story within the podium.

6.9.6 While blank street wall façades shall be avoided, an exception may be made for integration of public art or an articulated façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade shall be a maximum of four floors high, and shall have variation in its surface plane (using cutouts, insets or pop-outs). It shall employ different scales of elements as viewed when seeing the entire building massing.

6.9.7 Louvers and wall openings shall be designed to integrate with building architecture.

6.9.8 Podiums are encouraged as feasible to be set back from Pantages to preserve sightlines and promote groundfloor open space.

6.10 Street and Sidewalk Standards

6.10.1 The Site is comprised of a variety of public elements that include open spaces, streets and sidewalks. The Hollywood Walk of Fame is an integral element that fronts open spaces on both East and West Sites. Its adjacency to the public plazas requires compatibility and cohesiveness.

6.10.2 The combination of landscaped plazas, publicly accessible passageways and landscaped streets and sidewalks creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

6.11 Screening Standards

6.11.1 Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

6.11.2 Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

7. TOWERS

7.1 Purpose

7.1.1 Towers shall have their massing designed to reduce overall bulk and to appear slender.

7.1.2 Towers shall be designed to achieve a simple faceted geometry and exhibit big, simple moves. They shall not appear overwrought or to have over-manipulated elements.

7.1.3 Towers that emulate a more streamlined modern style shall provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.

7.1.4 If a project has more than one tower, the towers shall be complementary to each other and employ a similar yet varied architectural design approach.

7.1.5 Generally, buildings over 150 feet tall (the historic datum for Hollywood) shall not be historicized. They are contemporary forms in the skyline and shall appear as such.

7.2 Projections

7.2.1 The following building elements and operations equipment can project beyond the maximum permitted building height:

a. Roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building;

b. Skylights, towers, steeples, flagpoles, water tanks, silos;

c. Wireless masts; and

d. Solar energy devices and similar structures.

7.2.2 Permitted building elements or equipment in Section 7.2.1 shall be screened as practical and based on building design except if such projections – e.g., flagpoles or steeples – are part of the architecture or design. The use of creative materials and forms for screening is encouraged.

7.2.3 Enclosures for bulkheads shall not count against building height.

7.3 General Standards

7.3.1 A tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

7.3.2 Distinctive tower crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

7.3.3 Towers shall be set back from maximum street wall height a minimum of 10 feet except for towers fronting Vine Street on the West site, these towers shall be setback a minimum of 15 feet from the maximum street wall height.

7.3.4 Towers shall be setback on West Site from shared property line with Hollywood Playhouse a minimum of 10 feet above 150 feet.

7.3.5 Adherence to minimum setbacks and other separation standards for towers is required as may be applicable to a specific tower and its location with the Project area. Please refer to standards for towers set forth in Figures 6.1.2.a – d.

7.3.6 Tower orientation and placement that enhances important sightlines is encouraged.

7.3.7 In no instance should the tower fronting Vine Street on the East site development have more than a 15% height differential from the tower on the West ste development .

7.4 Wall Standards

7.4.1 All walls are required to be articulated.

7.4.2 The following types of articulation of a tower wall are permitted:

a. Recess;

b. Standard balconies may be projecting or recessed or a combination of both; and

c. Bay windows.

fig. 7.4.2.a: Balcony/Recess

fig. 7.4.2.b: Bay Window

7.4.3 Balcony: a balcony shall be integral to the façade (see figs. 7.4.3.a and b) and shall not create a relentless horizontal and vertical stacking pattern. Balconies are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations and shall be a minimum 75% *transparent*. Balconies are encouraged on buildings facing major public spaces such as plazas, passageways and open spaces. Long balconies resembling corridors are prohibited.

fig. 7.4.3.a: Recess/Balcony: Integral Balcony

fig. 7.4.3.b: Bay Window: Integral Balcony

7.5 Spacing Standards

7.5.1 If two towers are located on a single site the towers shall be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

7.5.2 Generally, any portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except for the following which will meet Planning Code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled. See fig. 7.5.2.

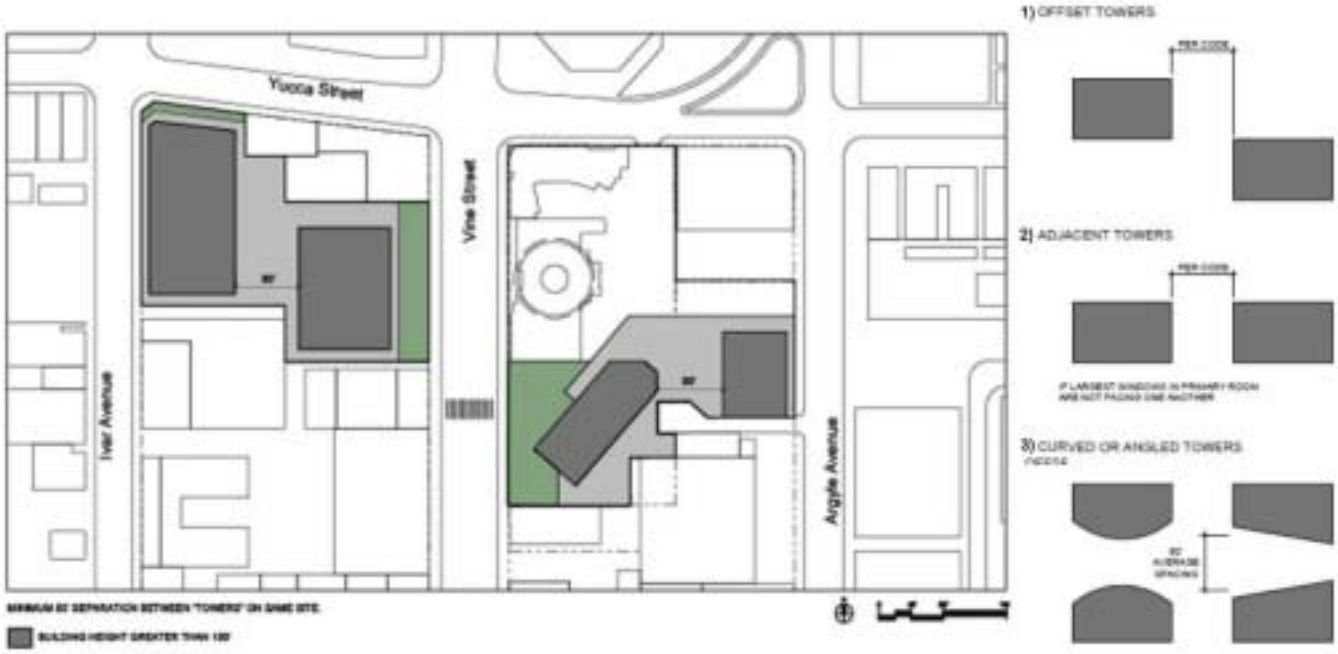


fig. 7.5.2: Tower Spacing

7.5.3 Since a tower is defined as any building above 150 feet, all buildings above 150 feet shall be spaced at least 80 feet from any portion of any adjacent or separate building on the site,

exceeding 150 feet, excluding a project within the height range of 150 to 220 feet, as shown in figures 6.1.2.a.1 and 6.1.2.a.2.

7.5.4 Spires, signage, parapets, and mechanical enclosures are excluded from the tower spacing regulations.

7.6 Rooftops Guidelines

7.6.1 Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and be visually attractive when viewed from locations adjacent and above.

7.6.2 For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section 8.5.

7.6.3 All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors.

7.6.4 All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

7.7 Parapets, Handrails, Roof Mechanical Equipment Screening Standards

7.7.1 Parapets and handrails shall be finished in a distinctive manner if part of an expression band or expression line.

7.7.2 Materials and design for roof mechanical equipment shall be consistent with the building architecture and shall utilize similar colors and materials as in other portions of the building.

7.7.3 Roof mechanical equipment shall be screened.

8. OPEN SPACE

8.1 Overview

The development of open space is an important objective for the overall Project design. Open space will be used to enhance the experience of the visitor and resident. Open space also will enable important pedestrian linkages and through-block connections for the Project. Grade level open space also will be designed to showcase the Capital Records Building and Jazz Mural and will include design features and outdoor furniture to activate the ground floor amenities.

This section sets forth the standards and guidelines for all open space areas for the Project: areas to be accessible to the public (Grade Level Open Space, Publicly Accessible Passageways and Rooftop Open Space) and areas to be designed for the residential uses (Common Open Space and Private Open Space).

8.2 Grade Level Open Space Standards

8.2.1 Grade level open space is a continuous open space fronting the street and open to the sky. The purpose of a grade level open space is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records Building and accentuate the low scale character.

8.2.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Fig. 6.1.2.a.1 – 2 and 8.1.1)

8.2.3 An additional 3% of open space (total 8%) shall be required for buildings between 221 feet and 400 feet. (See Fig. 6.1.2.b.1 – 2 and 8.1.2)

8.2.4 An additional 5% (total 10%) of open space shall be required for buildings between 401 feet and 550 feet (See Fig. 6.1.2.c.1 – 2 and 8.1.3)

8.2.5 An additional 7% (total 12%) of open space shall be required for buildings taller than 550 feet. (See Fig. 6.1.2.d.1 – 2 and 8.1.4)

8.2.6 Location

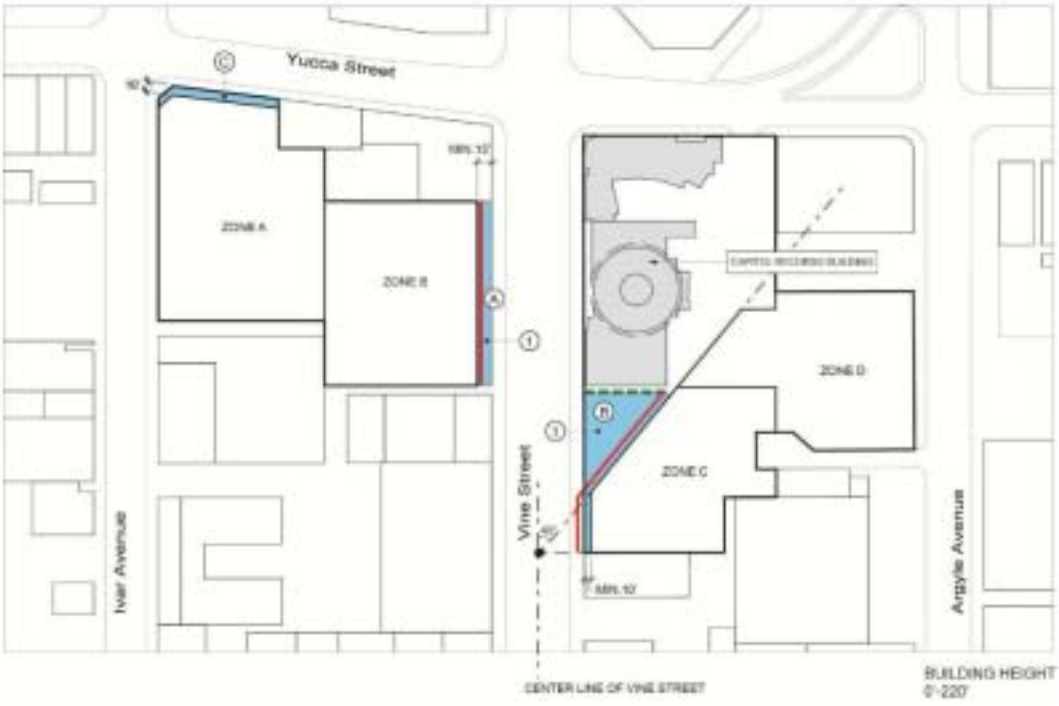
a. East Site: adjacent to the Jazz Mural and Capitol Records Building; West Site: across from the Capitol Records Building along Vine Street and along Yucca Street.

b. Minimum depth: no horizontal dimension less than 10 feet when measured perpendicular from any point on each of the boundaries of the open space area. Open space on West Site fronting Vine Street shall have a horizontal dimension no less than 15 feet when measured perpendicular from any point.

c. On West Site, open space must occupy the area to the west of a line struck at 40 degrees from center line of Vine Street ROW at alignment with the southern most property line and a minimum 10' setback from the southeast corner of the Capitol Records Building. (See Figs. 8.1.1 – 4)

Figs 8.1.1 – 8.1.4: Grade Level Open Space

figs 8.1.1 Open Space Requirements for Maximum Building Height at 220 Feet



figs 8.1.2 Open Space Requirements for Maximum Building Height at 400 Feet

figs 8.1.3 Open Space Requirements for Maximum Building Height at 550 Feet

figs 8.1.4 Open Space Requirements for Maximum Building Height at 585 Feet

8.3 Passageway Standards

8.3.1 *A publicly accessible passageway* is a continuous through-block public connection between two parallel streets, located on privately owned land. The passageway may be either enclosed or open to the sky or a combination of both.

8.3.2 Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

8.3.3 Location and Size standards:

a. The major portion of a *publicly accessible passageway* is the largest area of the *passageway* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total passageway area and shall not be less than 20'-0" wide.

b. Minor portions of *publicly accessible passageway* are secondary areas that allow for additional flexibility in the shape and configuration of a passageway. Minor portions shall not occupy more than 25 percent of the total area of the *passageway*. The minor portion shall have a minimum width of 10 feet.

c. The minor portion must be directly adjacent to the major portion.

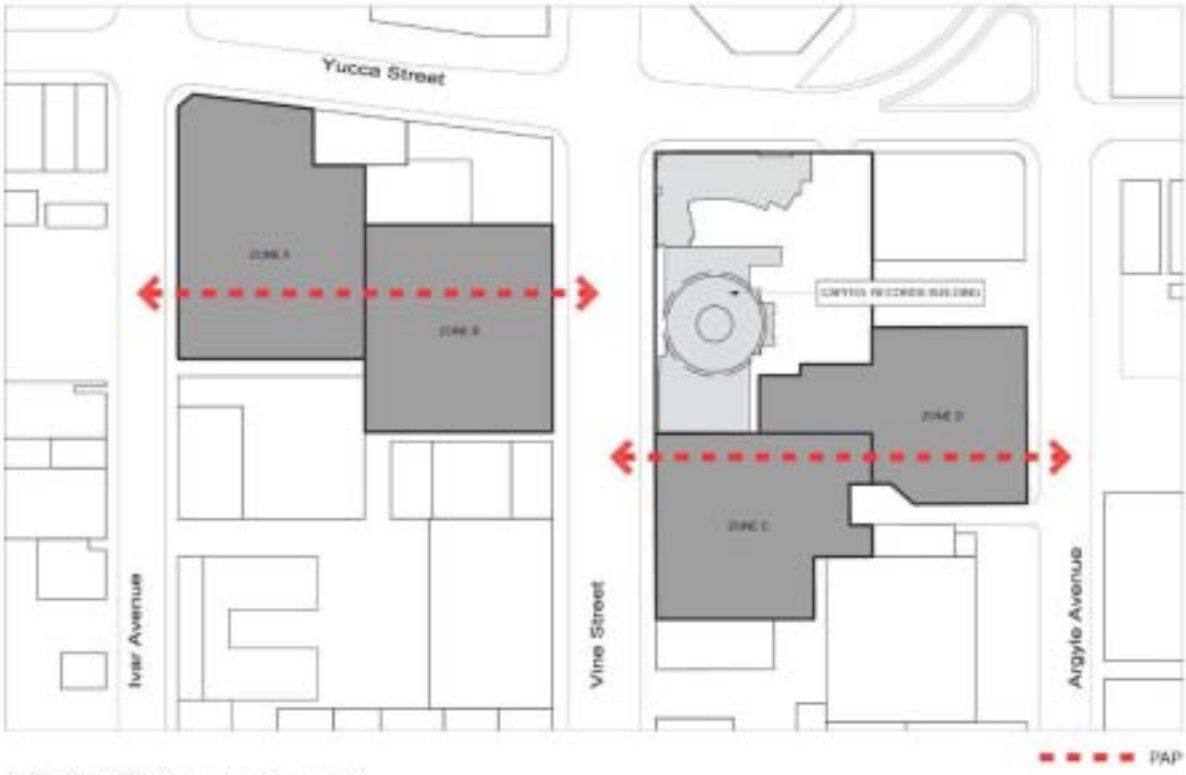


fig. 8.3.3: Publicly Accessible Passageway

8.3.4 Permitted Obstructions:

a. The minimum percentage of *publicly accessible passageway* area to be open to the sky (East and West Sites combined) shall be as follows:

(i) Development with maximum building height of 150 feet: 0%

(ii) Development with maximum building height of 220 feet: 20%

(iii) Development with maximum building height of 400 feet: 30%

(iv) Development with maximum building height of 550 feet: 40%

(v) Development with maximum building height of 585 feet: 50%

b. Permitted obstructions within the major portion of an open air *publicly accessible passageway* are any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open-air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions; balconies and bay windows; awnings, canopies and marquees; stairs, ramps

fig. 8.3.4: View from Argyle Avenue Along PAP Towards Capitol Records

and bollards.

8.3.5 Kiosk:

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Building and Safety in conformance with the Building Code. Kiosks, including roofed areas, shall not count as floor area, exceed 3% of the total area of the *publicly accessible passageway*, or occupy an area of more than 250 square feet.

b. A kiosk may be freestanding or may be attached on only one side to a wall of the building.

c. Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, and food preparation for open-air cafes, flower stands or public service/information booths.

d. All kiosks greater than 250 square feet are permitted but will count as floor area.

8.3.6 Open-Air Café:

a. Where an open-air cafe is provided it shall be an unenclosed restaurant or open-air seating for an enclosed restaurant, eating, or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies.

b. An open-air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the *publicly accessible passageway*. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers.

c. An open-air cafe may occupy an aggregate area not more than 20% of the total area of the *publicly accessible passageway*. No cooking equipment shall be installed within an open-air cafe. Cooking equipment may be contained in a kiosk adjoining the open-air cafe. An open-air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

8.3.7 Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on the *publicly accessible passageway* through open windows.

8.3.8 Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No building refuse storage areas or refuse storage from a kiosk or open-air café are permitted on any *publicly accessible passageway*.

b. No exhaust vents are permitted on any *publicly accessible passageway* or on any building wall of the development fronting upon the passageway except where such vents are more than 10'-6" above the level of the *passageway*.

8.3.9 Frontages:

a. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a *publicly accessible passageway* shall be allocated for occupancy by permitted retail, restaurants and cultural uses.

b. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the *publicly accessible passageway* with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

8.3.10 Maintenance:

a. The building owner shall be responsible for the maintenance of the *publicly accessible passageway* including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the passageway and in the street sidewalk area adjacent to the passageway.

b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of *publicly accessible passageway* area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of *passageway* in connection with outdoor eating services or other uses permitted on *passageway* which generate litter.

8.4 Roof-top Open Space

8.4.1 The Project shall include roof-top open space.

8.4.2 Roof-top open space shall include an observation area (i.e., viewing deck) accessible to the public.

8.4.3 The hotel, if developed, shall include an observation area (i.e., open space viewing area) accessible to the public.

8.4.4 The hotel observation area (i.e., viewing area), if developed, shall satisfy the requirement in section 8.4.1 above.

8.4.5 Roof-top open space may include a café.

8.5 Residential Common Open Space

8.5.1 Common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above. The publicly accessible passageway cannot be used to meet the residential common open space requirements.

8.5.2 Common Open Space Standards

a. Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.

b. Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein.

c. Open space shall be open to the sky and have no structures that project into the common open space area, except as permitted in the Zoning Code.

d. Common open space shall be readily accessible to all the residents of the Site.

e. Common open space shall have a minimum area of 400 square feet with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

f. Common open space shall constitute at least 50% of the total required usable open space in the built development.

g. Common open space areas shall incorporate recreational amenities including but not limited to swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

h. Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use may be considered as common open space.

i. Refer to LAMC 12.21.G for additional open space requirements.

8.6 Residential Private Open Space

8.6.1 A private open space area is an area contiguous to and immediately accessible from a single dwelling unit.

8.6.2 Residential Open Space Standards:

a. Private open space shall contain a minimum area of 50 square feet, of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.

b. Private open space shall have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

c. Private open space shall provide a minimum eight-foot vertical clearance under any projection, except as permitted in the Zoning Code.

d. That portion of a balcony which extends or projects into a required front yard in compliance with Zoning Code may qualify as usable open space provided it meets each of the above specified requirements noted in items a-c.

9. LANDSCAPE

9.1 Grade Level Open Space Standards

9.1.1 Planting requirements: a minimum of 10% of grade level open space shall be landscaped with softscape or water features.

9.1.2 Landscaped area(s) shall be planted with seasonally diverse plant material and 30% of all landscaping shall be California Natives or drought tolerant.

9.1.3 The landscaped portion of open space may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.1.4 The minimum soil depths for planting are:

a. Trees: 42"

b. Shrubs: 30"

c. Lawns, ground cover: 18"

9.1.5 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.1.6 Permitted obstructions: the following are permitted obstructions which may occur in the *grade level open space*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining, and retail storefronts.

9.1.7 Open-air *publicly accessible passageways* are not to be included in the grade level open space requirements.

9.2 Common Open Space Standards

9.2.1 A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

9.2.2 At least one 36-inch box tree for every four dwelling units shall be provided on-site and may include street trees in the parkway, sidewalks adjoining the property, open space, *publicly accessible passageway* and common roof decks.

9.2.3 For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

9.2.4 All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

fig. 9.3.a: Movable Seating

fig. 9.3.b: Open Air Café

9.3 Standards For Open Air Portions of Publicly Accessible Passageway

9.3.1 The landscaped portion of open air passageways may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.3.2 The minimum soil depths for planting are:

a. Trees: 42".

b. Shrubs: 30".

c. Lawns, ground cover: 18".

9.3.3 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.3.4 Planting requirements:

a. A minimum of 10% of open air *publicly accessible passageway* shall be landscaped.

b. For each 400 square feet of landscaped area there shall be at least one (l) major shade tree or two (2) minor ornamental trees.

c. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

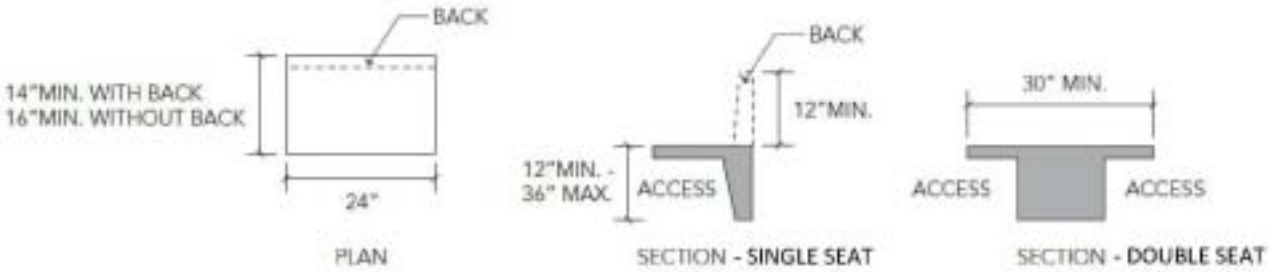


fig. 9.3.5: Seating Standards

9.3.5 Seating

a. There shall be a minimum of one linear foot of seating for each 500 square feet of *publicly accessible passageway* excluding the area of an open-air cafe.

b. One seat shall equal two linear feet.

c. Not more than 50% of the linear seating capacity may be in moveable seats. Seating shall meet the following standards:

(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons, a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count as double seating provided there is access to both sides.

(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.

(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

d. Moveable seating or chairs, excluding seating of open-air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open-air cafes do not count toward meeting the seating requirements.

9.4 Tree Planting Guidelines

9.4.1 It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

9.4.2 Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

9.4.3 Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree-planting pattern.

9.5 Lighting Standards

9.5.1 Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

9.5.2 Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade level open space and open *publicly accessible passageway*.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d. Steps and ramps will be lighted with a minimum of 1.0-foot candles on a horizontal plane.

e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

f. All exterior lighting shall be shielded or directed toward the areas to be lit to limit spill-over onto off-site uses.

g. Light quality shall not be harsh, glaring, blinking or shed beyond property boundaries.

9.5.3 Responsibility for maintenance:

a. The Building Owner shall be responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

b. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building Owner.

9.5.4 Lighting for areas located inside the lot line and visible from the street, such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

9.5.5 Lighting for above-grade parking garage facilities shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

9.6 Publicly Accessible Passageway Lighting Standards

9.6.1 A *publicly accessible passageway* shall be illuminated throughout with an overall minimum average level of illumination of not less than 1.0 maintained foot candle (lumens per square foot) on the horizontal plane at grade.

9.6.2 Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

9.7 Continuity of Design

9.7.1 Design elements and architectural clues that reinforce where appropriate continuity between open and enclosed spaces at grade level is encouraged. Continuity of design may reinforce pedestrian circulation and support the Project's way-finding features.

9.7.2 Where possible, materials, lighting, site elements and landscape shall be similar between different open and enclosed public spaces at the grade level.

10. PARKING

10.1 Automobile Standards

10.1.1 Base Standards

The following standards shall apply for the base level of parking to be provided as the minimum for each use in the project area. The Regulations set forth below incorporate the parking requirements in the LAMC, where applicable, and supersede the LAMC requirements for development in the Development Agreement area.

a. Commercial / Office / Retail:

Two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot. The Regulations incorporate applicable parking requirements in the LAMC as set forth below.

b. Sports Club:

Two parking spaces for every one thousand square feet of combined gross floor area.

c. Hotel

One parking space for each individual guest room or suite of rooms for the first 30;

One additional parking space for each two guest rooms or suites of rooms in excess of 30 but not exceeding 60; and

One additional parking space for each three guest rooms or suites of rooms in excess of 60.

d. Condominiums (Residential):

Two parking spaces per dwelling unit.

One-quarter parking space per dwelling unit for guest parking.

e. Rental (Residential):

One parking space for each dwelling unit of less than three habitable rooms; one-and-one-half parking spaces for each dwelling unit of three habitable rooms; and two parking spaces for each dwelling unit of more than three habitable rooms.

f. Combination of Uses:

Where there is a combination of uses on a lot, the base number of parking spaces required shall be the sum of the requirements of the various uses.

10.1.2 Shared Parking:

a. Shared parking may be applied to the Section 10.1.1 base rates for the Site when the uses have different parking requirements and different demand patterns in a 24-hour cycle or between weekends and weekdays. The intent is to maximize efficient use of the site by matching parking demand with complimentary uses. The calculation of the parking requirements shall be based on a detailed assessment prior to its construction.

b. Calculating Shared Parking:

(i) The individual land use parking requirements for each component of a phase of development shall be calculated from Section 10.1.1. above to establish the "Base Demand."

(ii) For parking spaces that are to be shared between uses, the calculated minimum parking requirement for the Site, including that new phase of construction, is to be adjusted from the Base Demand based on the procedures in *Shared Parking*, Urban Land Institute, 2nd Edition (2005) or another source as determined by the Director of Planning.

10.2 Additional Regulations

10.2.1 The automobile parking spaces required shall be provided either on the same lot as the use for which they are intended to serve or on another lot located within 750 feet of the lot; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

10.2.2 Curb cuts for driveways shall be located no closer than 50 feet to the intersection of two streets unless approved by The Department of Transportation.

10.2.3 Access driveways to parking facilities not at signalized intersections shall not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

10.2.4 Parking and loading access shall be shared where feasible.

10.2.5 Priority placement within parking structures shall be given to bike parking, car-share parking, and other alternative ride vehicles.

10.2.6 Pedestrian entrances to all parking shall be directly from the street, except that underground parking garages may be entered directly from a building.

10.3 Screening

10.3.1 Above grade parking for the first 20 feet shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible and shall be designed to blend in with the form and massing and to look like an integral part of the building, with the use of windows and/or cladding, or by landscaping, or green screens, or a combination thereof. The interior of a parking structure shall be designed to be screened from the view of streets and sidewalks.

10.4 Bicycle Standards

10.4.1 Bicycle parking shall be provided per Ordinance No.182386.

10.5 Transportation Demand Management Plan

10.5.1 The Project shall incorporate a comprehensive transportation demand management plan.

10.5.2 The transportation demand management plan shall set forth best practices that relate to the Project Site and the Project's building design features in order to:

a. Promote bicycle and pedestrian circulation within the Project Site.

b. Promote alternative modes of transportation.

c. Create pedestrian linkages to public and private amenities outside the Project Site.

d. Provide convenient and attractive onsite pedestrian linkages for routes to the Metro Red Line Station at Hollywood Boulevard and Vine Street.

e. Provide adequate parking, but provide incentives to tenants and residents to utilize alternative modes of travel. The incentives shall include bicycle facilities, car sharing, discounted subway passes, and parking spaces as an only optional part of all lease and sale agreements.

11. SIGNAGE

11.1 Hollywood Signage Supplemental Use District

Signage shall be subject to Ordinance No. 181340: Hollywood Signage Supplemental Use District (Amended) pursuant to Section 13.11 of the Los Angeles Municipal Code.

11.2 Modification to Guidelines

Notwithstanding Section 11.1, high-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted. See fig. 11.2.

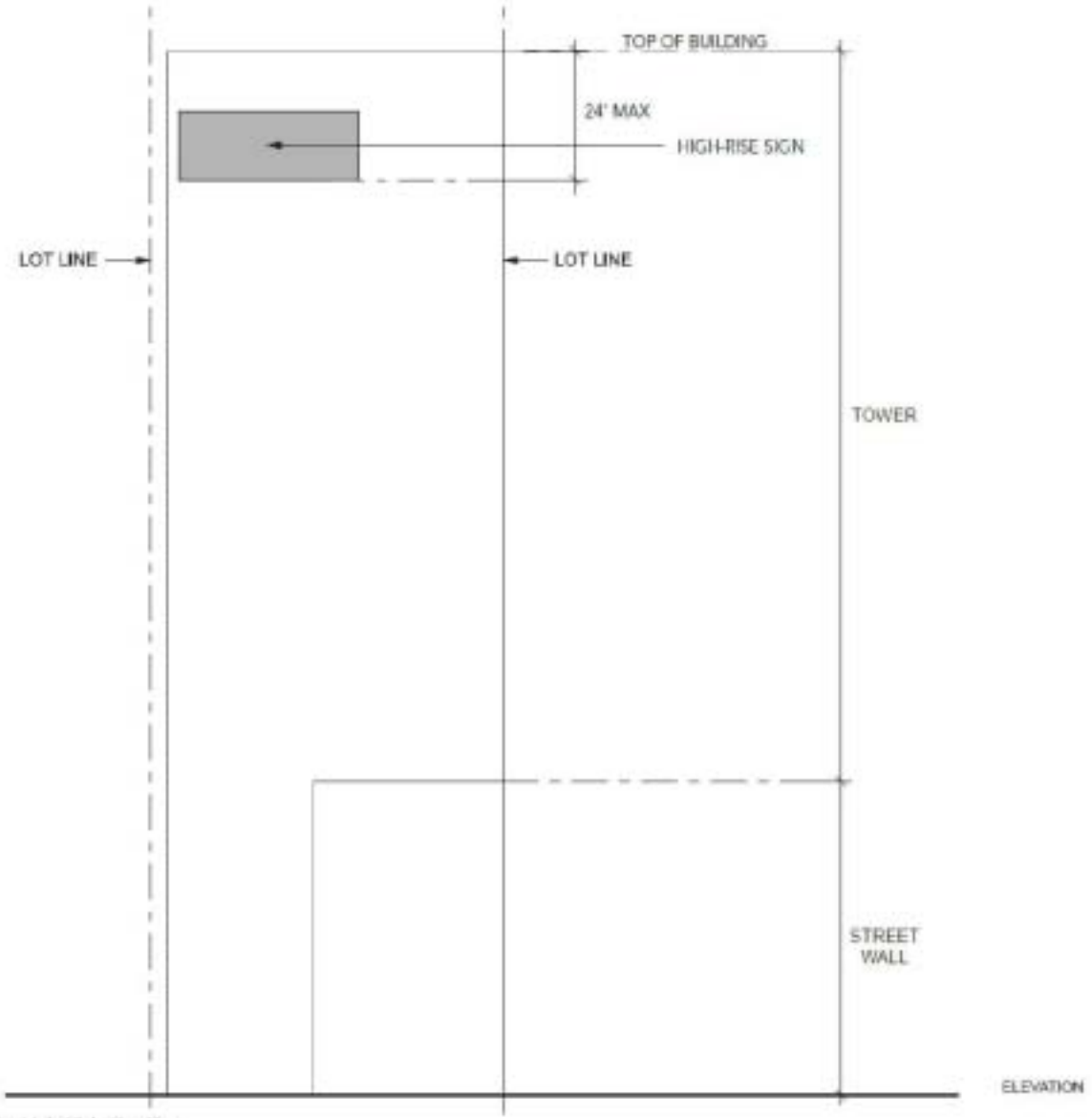


fig. 11.2: High Rise Sign

12. SUSTAINABILITY

12.1 Non-Residential Projects

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

12.2 Other Projects

The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

13. DEFINITIONS

Awning: glazing or fabric on metal frame structure supported entirely by the building to provide weather protection at doors, windows and/or storefronts; may be retractable.

Base: the lower portion of a building located at or within 150' above curb level

Canopy: glazing, fabric and/or metal structure with vertical supports located on the sidewalk to provide weather protection at a building's primary entrance.

Expression band: a distinctive linear architectural element occurring on the building base façade at the highest floor. The band shall be contrasting in color, texture, material and/or fenestration from the adjacent building base surface. Projections may occur within an expression band.

Grade level open space: a continuous open space fronting the street and open to the sky

Maximum building height: the maximum height permitted, measured from the adjacent street curb level

Maintenance: the ordinary repair, care and upkeep of a property

Open space use: active and passive recreational areas accessible to the general public, except as noted herein. Open spaces can occur in publicly accessible passageways, grade level open space, residential common open space and residential private open space which are defined herein.

Preservation: in conformance with standards and guidelines of the Secretary of the Interior, the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property

Publicly accessible passageway: a continuous through-block public connection between two parallel streets, located on privately owned land and designated for and designed to encourage public pedestrian circulation and other appropriate public uses

Rehabilitation: in conformance with standards and guidelines of the Secretary of the Interior, the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values.

Required street wall: a wall or portion of a wall of a building facing a street or grade level open space which must be built to a maximum height above curb level

Required street wall articulation, aggregate width of: the sum of the maximum widths of all segments of required street wall articulation on a street at the level of any story. The width of a required street wall articulation is measured in plan as the width of the street line from which perpendicular lines may be drawn to such required street wall articulation

Residential common open space: a "rear yard" providing light and air to apartments on the interior of a parcel located at any story above curb level.

Residential private open space: open space that is contiguous to and immediately accessible only from a single dwelling unit.

Setting: the area or environment in which an historic property is found. It may be an urban or suburban neighborhood or a natural landscape in which a building has been constructed. Elements of setting can include the relationship of buildings to each other, setbacks, views, sidewalks, and street trees.

Storefront: the architectural facade, including doorways, of any tenant-leased premise perimeter adjacent to public circulation areas. Storefronts refers to all permitted residential, retail uses including retail, service, restaurants and cultural establishments and commercial uses, including but not limited to hotels and sports clubs.

Tower: the portion of a building located above 150' above curb level.

Transparency: architectural elements that can be seen through or allows light to emit through, including but not limited to glass, trellis and wire mesh.

Notes

All images and figures used in the Regulations were prepared for exclusive use by Millennium Hollywood, LLC unless otherwise noted.

Millennium Hollywood

Millennium Hollywood Project
Meeting with Planning/Environmental
July 20, 2012
AGENDA

1. Status of Review
2. CEQA Outstanding:
   a. DOT – Determination Letter expected August 25, 2012
   b. Police - Will Serve Letter
3. Design Guidelines
   a. Finalize Revisions
   b. Tower Placement
   c. Code Overrides
4. Schedule (see below)
5. Design Presentation and Draft Development Agreement – Next Meeting(s)
6. Next Steps

	Milestone/Action	Date
1.	Master Land Use Application (MLUA) and Supplemental Submitted to City	**August 18, 2008; October 14, 2009**
2.	Circulation of NOP and IS (30-day public review period**)	**April 28, 2011 – May 31, 2011**
3.	Conduct Public Scoping Meeting (during NOP circulation period)	**May 11, 2011**
4.	Submit First Screencheck Draft EIR (DEIR) to the City	**January 17 – 24, 2012**
5.	File Vesting Tentative Tract Map (VTTM) with City	**February 23, 2012**
6.	City completes review of First Screencheck DEIR	**May 4, 2012**
7.	Submit Second Screencheck DEIR to City	**May 23, 2012**
8.	DOT approves Traffic Study	**July 25, 2012**
9.	City completes review of Second Screencheck DEIR	**Status Pending**
10.	Submit Final Screencheck for Review (Meeting with Srimal)	**Status Pending**
11.	Publish and mail DEIR for public review	**August 2012**
12.	Public review period for Draft EIR (45 days**)	**August – September**

How does the Hollywood Community Plan Improve Hollywood?

dcp Los Angeles Department of City Planning

The Plan directs growth around transit, away from hillsides and low density neighborhoods.

- maintains residential neighborhood zoning, directing future growth into the center of Hollywood adjacent to transportation choices
- maintains all parking requirements per the City code, encourages parking options
- downzones many residential areas with historic resources within the former Redevelopment Plan boundary
- implements stronger subdivision controls in the hills, promoting open space.
- maintains commercial development restrictions in hillside districts, such as Barham Avenue and Franklin Avenue

The Plan reinforces Hollywood's role as a media and entertainment jobs center – preserves industrial media lands.

- reserves M-zoned lands south of Santa Monica Boulevard in the Media District for industrial uses
- promotes tourism, entertainment, and media jobs
- promotes the expansion and modernization of Hollywood's studios

The Plan provides mobility choices, less dependence on automobiles.

- promotes transit-oriented development, design, and mixed-use amenities in the center of Hollywood
- raises standards for new building design, with an emphasis on pedestrian amenities
- implements city's Bike Plan, provides for expanded bike lanes on Fairfax and Fountain Avenues

The Plan establishes new lower height limits around historic districts, and integrates development into existing scale.

- lowers development heights north and south of Hollywood Boulevard along the National Register Historic District
- establishes lower height limits around the Melrose Hill Historic District and Spaulding Square Historic District
- maintains all existing height limits (a total of two parcels are proposed for a higher height limit, 60 feet, to make them consistent with neighborhood properties)

The Plan supports the Hollywood Central Park over the 101 Freeway, and expands park acreage.

- places the creation of such a park into the Community Plan policies, providing support for implementation funding
- rezones recent parkland acquisitions in the Hollywood Hills as permanent open space and expands number of neighborhood parks

The Plan protects hillsides from over development – strengthens development regulations for hillside subdivisions.

- expands the implementation of the "slope density" ordinance in the Community Plan
- applies restrictions to future parcel maps and tract maps in hillside areas
- promotes ridgeline protection and expanding retaining wall controls

Hollywood Community Plan, Continued

The Plan promotes streetscape plans and implements new street standards, wider sidewalks, pedestrian enhancements.

- develops sidewalk, landscaped parking, street tree, and lighting standards for major Hollywood thoroughfares (Santa Monica Boulevard, Melrose Avenue, La Brea Avenue, Western Avenue)
- expands sidewalks along major boulevards, including preservation of the Hollywood Walk of Fame
- preserves existing landscaped parkways and trees on significant thoroughfares, such as Los Feliz Boulevard
- balances pedestrian needs while maintaining roadway capacity

The Plan expands Historic Preservation Districts and preservation tools, including linking all incentives to historic preservation goals.

- expands historic resources in Hollywood
- supports the establishment and expansion of historic districts, including expansion of the Melrose Hill Historic District
- links the use of any incentive to historic preservation, and requires conformance with the Secretary of the Interior's standards

The Plan promotes the regulation of scale and design in the heart of Hollywood through a Hollywood Specific Plan or Community Plan Implementation Overlay.

- adds the development of specific scale, height, massing, and design requirements for the center of Hollywood to the Planning Department's work program

The Plan promotes mixed use along transit boulevards, limits density of mixed use development in Studio District and East Hollywood.

- emphasizes pedestrian friendly mixed-use development along commercial boulevards to maintain existing scale and character in residential neighborhoods
- proposals would limit mixed-use development density along Santa Monica Boulevard and Western Avenue
- maintains existing development limitations on Franklin Avenue, establishes more restrictive height limit on Hillhurst Avenue

The Plan establishes urban design guidelines for new development in Hollywood, reinforcing pedestrian friendly character of commercial districts.

- continues the ban on new supergraphics in Hollywood
- establishes expectations and guidelines for higher quality design, pedestrian orientation, active storefronts, and neighborhood cohesiveness for future development

The Plan funds a nexus study to establish trip fees on new development to finance regional mobility improvements.

- funds a study to establish a fee for new development based on how many car trips each project will generate, in addition to all currently required environmental analysis. Development fees would be used to finance regional transportation improvements in Hollywood

The Plan promotes pedestrian oriented design overlays for Historic Route 66, Hillhurst Avenue, and Melrose Avenues.

- calls for the establishment of pedestrian oriented development standards for Santa Monica Boulevard's Historic Route 66, the Melrose shopping district, and Hillhurst Avenue

dcp Los Angeles Department of City Planning

For More Information

Visit us online @ cityplanning.lacity.org
Email us @ Mary.Richardson@lacity.org
Phone us @ (213) 978-1478

c. Create new [illegible] that are activated by retail, restaurant, and entertainment uses and enhance the Hollywood experience by providing a safe, attractive, and pedestrian-friendly environment.

d. [illegible]

e. [illegible]

Fig. 1.1 [illegible]

f. [illegible]

g. [illegible]

h. [illegible]

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a. [illegible]

b. [illegible]

c. [illegible]

d. [illegible]

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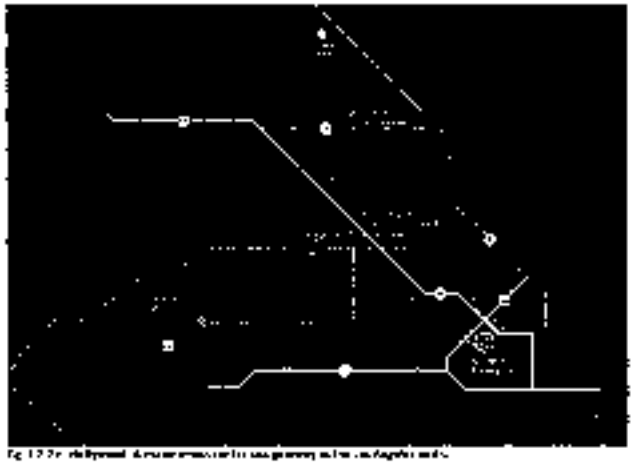

Fig. 1.2 [illegible]

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1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose certain requirements on development. For example, the Regulations establish height requirements along Vine Street. There are other standards, such as those that require open space for the project. Compliance with the standards is mandatory. The guidelines are suggestions that may include a range of choices and require a degree of discretion by the individuals charged with administering and complying with the Regulations. The purpose of these guidelines is to encourage high quality design. The purpose is to provide a range of flexible choices within the framework of the Regulations to allow for creativity in the development process. The Regulations require that ultimate design decisions must be determined by the Director of Planning, who may take different views on the total design proposal. The Regulations require ultimate discretionary review by providing a broad range of choices within the framework of the Regulations.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 The Development Regulations are approved by the City of Los Angeles City Council and are incorporated into the Development Agreement entered into pursuant to California Government Code Section 65864 et seq. entered into by the City and the Developer.

1.4.2 The following sections of the Regulations deviate from corresponding provisions in the Los Angeles Municipal Code (LAMC): 12.21, 12.21.1, 5.9.3.a, 12.4.a, 5.1.6 and 10.2.

1.4.3 Unless otherwise specifically provided in the Regulations, all words, terms and phrases shall have the meanings set forth in the Zoning Ordinance and Subdivision Ordinance of the Los Angeles Municipal Code (LAMC) that apply to the Project Site. Any capitalized terms shall have the meanings set forth in the Development Agreement, unless otherwise defined in this Document.

2 BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of approximately 4.47 acres of land. The subject property is generally bounded by Ivar Street to the north and bisected by Vine Street.

The area bounded by Ivar Avenue, Yucca Street, and Argyle Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Avenue is the East Site.

The East Site and the West Site make up the Project Site.

The Project Site currently contains a mix of commercial and/or public uses and parking. The topography of the site consists of approximately 25 feet (NE to SW) from the Vine Street to Argyle Avenue and 21 feet (NW to SE) from Ivar Avenue to Yucca Street. The existing uses will be demolished to allow for the development of the Project.

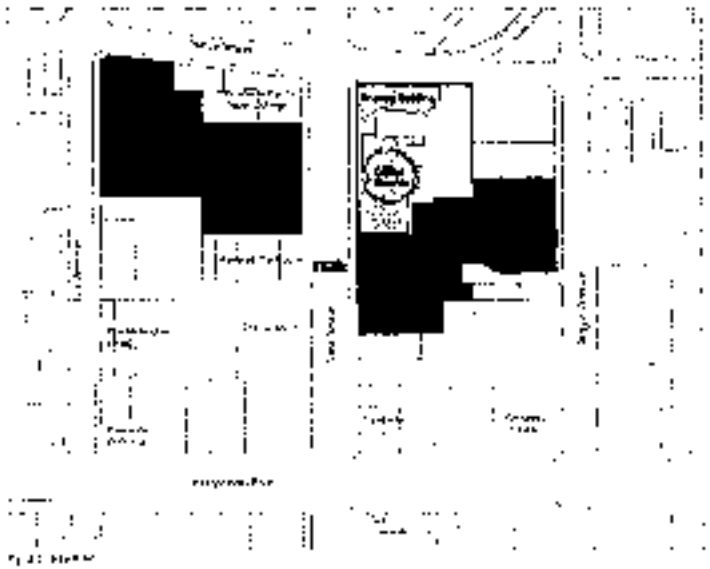

Figure 2.1: Site Plan

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[illegible]

[illegible]

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3.1 [illegible]

C) [illegible] Buildings [illegible] that will be established [illegible] with the adjacent [illegible] (see sections 5.1.1, 5.1.2, and 5.1.3 below).

Given the [illegible] the Project Site, the purpose of these [illegible] is to [illegible] a [illegible] and [illegible] that [illegible] the [illegible] and [illegible] of the Project. The Project [illegible] a [illegible] and [illegible] to [illegible] the [illegible] of the [illegible] and [illegible] the [illegible] of the [illegible] and [illegible] of the [illegible].

4. DENSITY

4.1 **Floor Area Ratio Averaging and Density Transfer**

The Development Parcels set by the Subdivision and Density Plan provide that the Project Site is to be developed with a [illegible] and [illegible] and [illegible] Building Heights in the Regulations, which [illegible] and the entire Project does not exceed the cumulative, allowable density, and [illegible] in the Regulations for the Project.

[illegible] for the [illegible] of the [illegible] on the Project Site and ensure [illegible] and density is within the [illegible] the Project Site, including [illegible] and related development requirements, [illegible] of the Project, as [illegible] with the Project Site.

4.2 **Maximum Gross Floor Area**

A mixed-use [illegible] ("Commercial Program") [illegible] as [illegible] and [illegible] uses [illegible] and [illegible] and across the Site [illegible] and [illegible] in the Environmental Impact Report for the Project. The [illegible] between land uses will be based on a maximum allowable building square footage [illegible] ("GSF") [illegible] applicable to and not exceeding [illegible] in the Environmental Impact Report for the Project. The total density [illegible] Gross Floor Area [illegible] Building [illegible] Gross Floor Area [illegible].

4.3 **Use Combination / Discretionary**

[illegible]

taken from another design guideline

5. HEIGHT

5.1 **Building Height Standards**

The Regulations establish Building Heights for [illegible] in response to the Upper Concept Diagram, providing guidance for the [illegible] and the varying [illegible] of the Capital Records Tower.

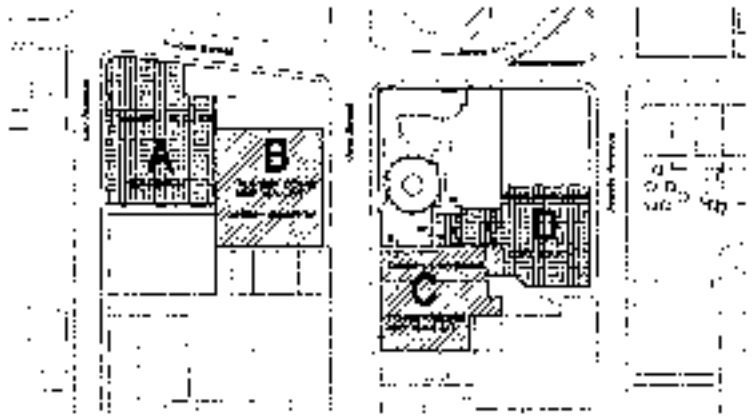

Figure 5.1 – Height Zones

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5 Building And Street Experience

5.1 Tower Massing Requirements

5.1.1 The Tower Massing Requirements apply to the portion of a building above 150 feet above curb level – see Table 5.1.1

150	90	17,150 East/West 11,500 North/South	10 15	12	5.1.2.a.1 5.1.2.a.2
250	90	17,150 East/West 11,500 North/South	10 15	10	5.1.2.b.1 5.1.2.b.2
400	90	17,150 East/West 11,500 North/South	10 15	8	5.1.2.c.1 5.1.2.c.2
450	90	17,150 East/West 11,500 North/South	10 15	5	5.1.2.d.1 5.1.2.d.2

5.1.2 Maximum gross floor area per floor is the 5% of total gross floor area of the development for the building above 150 feet to 250 feet. See Figure 5.1.2.a – d.1

5.1.3 Maximum floor plate size for portion of building above 250 feet

5.1.4 Tower separation

a. Minimum 80% of tower aggregate area shall be set back

5.1.5 Tower articulation

a. Recessed areas shall be provided for a minimum length of 30 feet

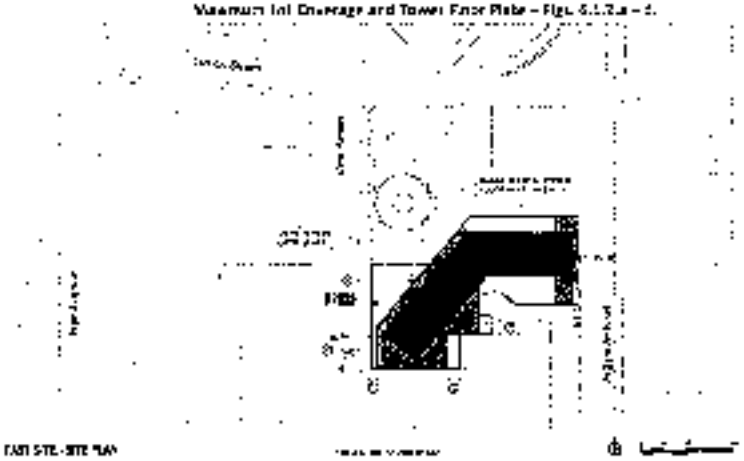
b. Recessed areas may project a maximum of 3 feet from the adjacent tower face and shall be a minimum width of 30 feet

c. Recessed areas shall be provided with a height of at least the adjacent ground floor ceiling height

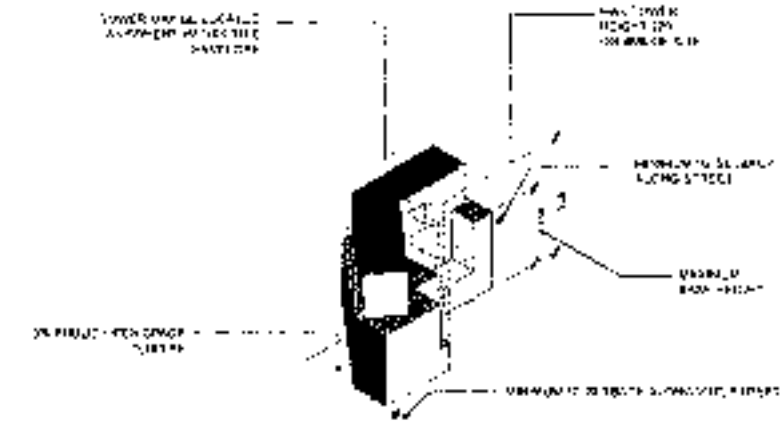
d. Recessed areas shall be provided for the purpose of providing separate parking, retail, residential and loading areas. The recessed area shall consist of a change in massing, materials or fenestration of the tower face.

The following developments are for illustrative purposes only.

Maximum Tot Coverage and Tower Floor Plate – Figs. 5.1.2.a – d.



EAST SITE - SITE PLAN



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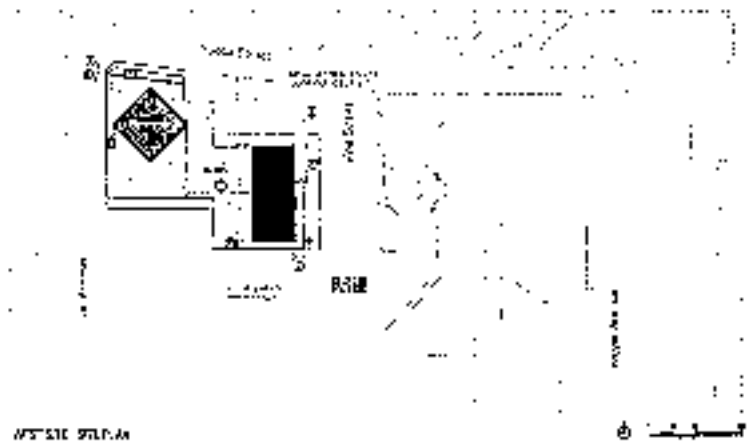

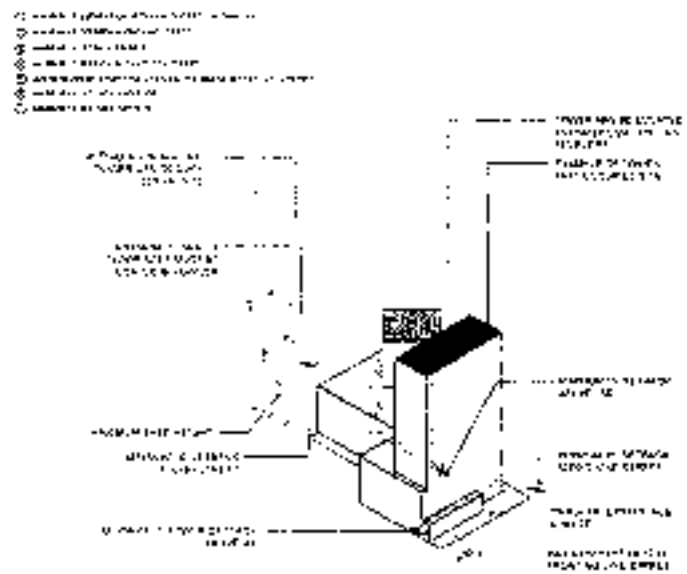

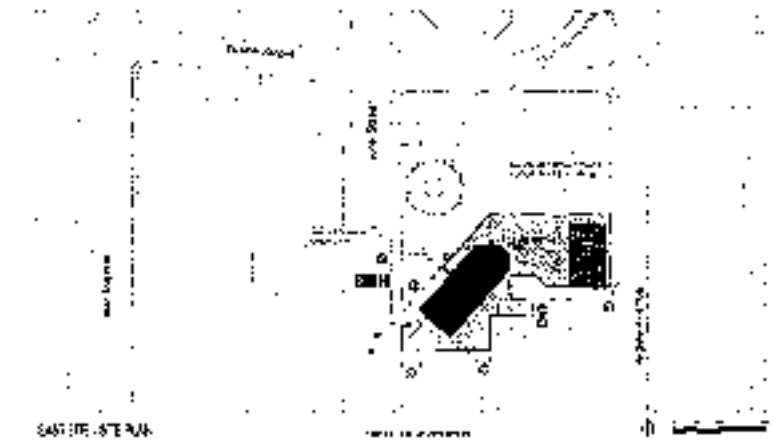

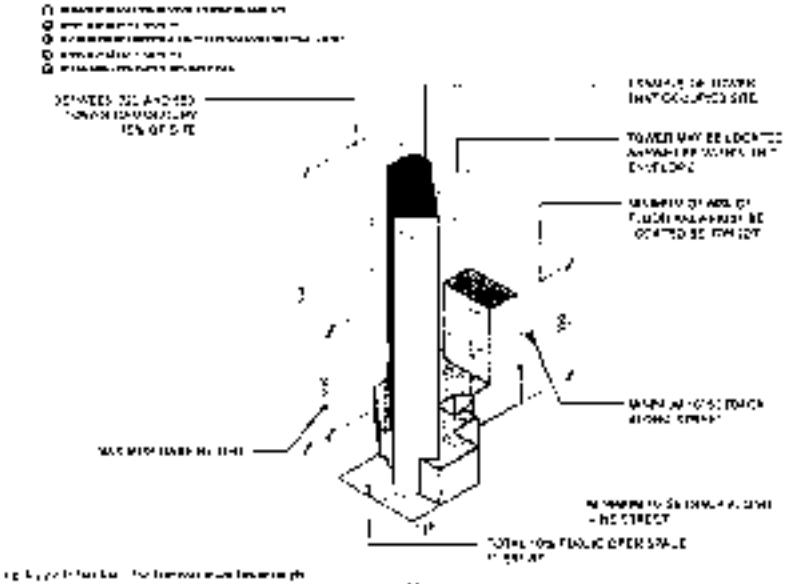

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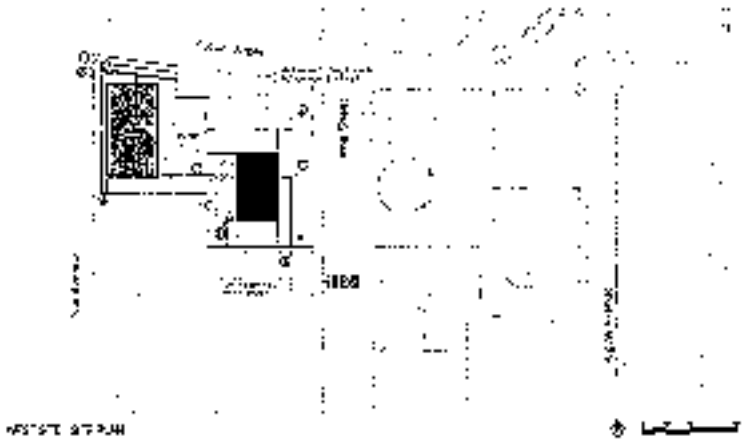
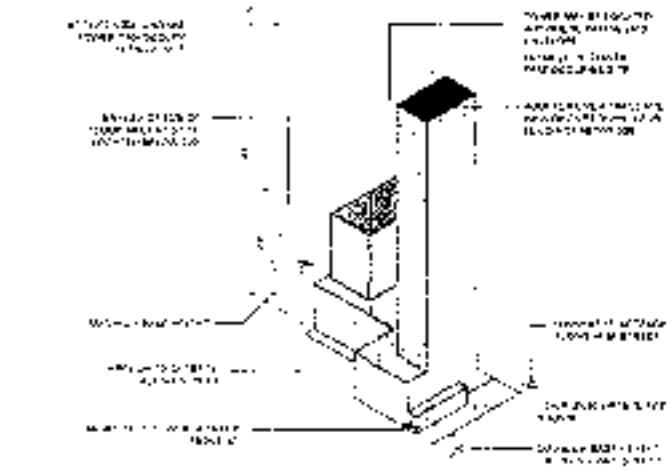




6.3 Street Walls

6.3.1 A street wall is the wall or portion of a wall of a building facing a public street or a public open space. Street wall requirements apply to new development and to the redevelopment or alteration of existing buildings. Street walls are to be designed to create a sense of definition and enclosure, and to contribute to a comfortable pedestrian environment. Building articulation, fenestration, varied materials, and high quality detailing are encouraged. Buildings are encouraged to provide these qualities at grade, podium levels, and the upper floors, and to include active uses at grade (such as retail, restaurants, and amenities) that add architectural character and are encouraged.

6.4 Street and Sidewalk

6.4.1 [illegible]

a Except for the grade level open space, the required street wall is to be located a minimum 10 feet from the property line along the Street on the East Side and 15 feet along the Street on the West Side.

b A grade level open space is required for any building fronting onto the West Side of the Street and is to be located on the property line.

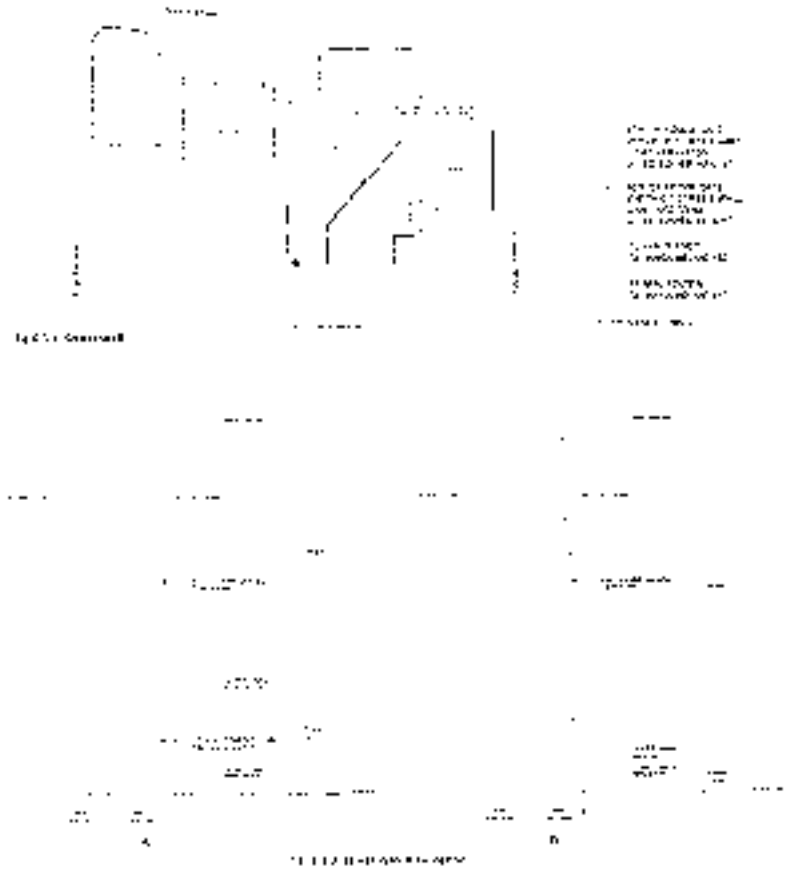
c Portions of the grade level open space may be located between the required street wall and the property line.

6.4.2 Height of required street wall

a Street walls shall be a minimum height of 10 feet above the curb height and a maximum height of 30 feet above curb level except as noted in items (b) and (c) below.

b Street walls fronting onto Street may exceed the 30 feet maximum height of the street wall to a maximum height of 150 feet with a 15 foot setback above 30 feet above curb level as noted in item (a) above.

c 50% of the aggregate width of the required street wall may exceed the maximum street wall height up to the maximum tower height.



5.3.3 Portion of Intermediate Level not required to be built:

a Recess rooftops that are not utilized to a minimum depth of 20'-0"

b Balcony, Bay Window or any projection of 3'-0" from required tower wall over a grade level open space

c Balcony, Bay Window may extend from a required flat roof over a grade level open space

d Permission based on condition that a breezeway be provided between building portion over and open space. This breezeway can not be enclosed and must be open to the sky

5.3.4 Other permitted projections above the height limit for the property for tower and podium wall that comply with the following:

a Architectural façade elements such as cornices or ornamentation, cornice lines, pilasters and downspouts may project from a required street wall over a grade level open space

b Projections may not project more than 6" from the street wall over a grade level open space

c [illegible]

d Tower Projections - may project from a required street wall over a grade level open space up to a maximum depth of 5'-0". The maximum height of these projections for each portion shall not exceed two courses or 28'-0" above curb level, whichever is less.

5.4 Street Wall Setbacks

5.4.1 Recesses or openings through ground floor, podium, balcony, canopy, awning and other projections are permitted subject to the above restrictions

5.4.2 Recessed doors and entrances, arcades, bay windows and landscaping are encouraged and other design elements that add interest along the street wall are encouraged on the Project Site

5.5 Roof Projections

5.5.1 Mechanical equipment, elevator overruns, roof access stairs and screening for such equipment are permitted above the maximum height limit

5.5.2 Communication devices may project above the maximum height limit

5.5.3 Parapet walls:

a Minimum 3'-6"

b Solid parapet walls greater than two courses in height over the roof shall be setback one additional foot for each additional course above the second course, but maximum setback required shall not exceed 10 feet.

c. Setback: Minimum 35 mm, for a building more than three storeys in height, one tier may be set back to the desired setback with the next tier. Additional tiers above the first setback may be set back by a minimum of 20 mm.

6.6 Building Materials and Colour Guidelines

6.6.1 The goal of the building materials and colours is to reinforce the character of the Bukit Ho Swee area and provide a design that complements the surrounding developments. The following guidelines should be addressed in the submission for Qualified Person certification:

a. Buildings should employ a harmonious range of colours. The range of colours should not be overly intrusive, but should complement the character of the residential conventional area.

b. Ground floors should have a minimum 4m2 of glazing on the upper floors and features high-quality durable materials that last long, (brick and stone).

c. Architectural expression of the ground level should be clearly defined and expressed through the choice of materials. Ground floor colours may be used to distinguish building entrances and access.

d. The architecture of the building should demonstrate architectural consistency in the use of materials, colours, and design features on all elevations, including those facing public streets, private streets, and open spaces.

e. The building should be designed to minimize the perception of bulk. The use of setbacks, articulation, and varying heights should be considered. Buildings should not exceed a height of 60 meters without setbacks or other design features to break up the mass.

f. Incorporate sustainable design principles, such as energy-efficient materials, natural ventilation, and renewable energy sources, where feasible. Consider the use of green roofs, solar panels, and rainwater harvesting systems.

g. Integrate the overall massing, roof forms, materials, and architectural style of new developments with the existing context. Respect the scale, rhythm, and character of adjacent buildings. Avoid abrupt changes in height or massing that may disrupt the visual harmony of the area. Consider the use of transitional elements, such as setbacks or stepped facades, to create a smooth transition between different building heights.

h. Incorporate the existing topography, landscaping, and natural features of the site into the design. Minimize excessive grading and earthworks. Use the site's natural contours to inform the building's massing and architectural elements. Consider the impact of the design on the surrounding landscape, including views, shadows, and wind patterns. Incorporate landscaping elements, such as trees, shrubs, and green roofs, to enhance the building's appearance and provide environmental benefits.

i. Design buildings that are easily accessible for people with disabilities, including ramps, elevators, and wide doorways. Provide clear and intuitive wayfinding signage throughout the building and its surroundings.

6.7 Guidelines Standards

6.7.1 The purpose of the guidelines and standards is to provide architects and developers with a clear understanding of the expectations for the development. These guidelines and standards are intended to ensure that the development is consistent with the overall vision for the area, while also allowing for flexibility and innovation in design. The guidelines and standards may be updated from time to time to reflect changing circumstances and best practices in urban development.

6.7.2 Building Height

a. Minimum 10 m or as per requirements by Qualified Person.

6.7.3 Building Articulation

a. The primary entrance to a commercial development shall be clearly visible and accessible from the street. The entrance should be designed to create a welcoming and inviting atmosphere, with features such as canopies, awnings, or overhangs. Consider the use of transparent materials to allow views into the building and create a sense of openness.

b. Buildings should be designed to provide a human scale, using elements such as windows, doors, and architectural details that are appropriate for pedestrians. Avoid large, blank walls and monotonous facades. Consider the use of setbacks, stepbacks, or articulation to break up the mass of the building and create visual interest.

c. Main building entrances shall be clearly defined, well-lit, and easily accessible from the street. Entrances should be designed to be welcoming and inviting, with features such as canopies, awnings, or overhangs. Consider the use of transparent materials to allow views into the building and create a sense of openness.

d. Incorporate public art installations, such as murals, sculptures, or interactive displays, to enhance the visual appeal and cultural significance of the development. Consider the use of local artists and themes that are relevant to the history and culture of the area.

6.7.4 Green Building Standards

a. Buildings should achieve a minimum Green Mark Gold rating or equivalent, with a target of Green Mark Platinum.

b. Incorporate sustainable design principles, such as passive cooling, natural ventilation, and daylighting, to reduce energy consumption.

c. Use energy-efficient lighting, HVAC systems, and appliances.

d. Implement water-saving measures, such as rainwater harvesting and greywater recycling.

e. Use sustainable materials, such as recycled content, low-VOC paints, and responsibly sourced timber.

f. Provide electric vehicle charging stations and encourage the use of electric vehicles.

g. Implement a waste management plan to minimize waste during construction and operation.

h. Consider the use of green roofs, solar panels, and other renewable energy technologies.

i. Aim for a minimum of 20% reduction in energy consumption compared to a baseline building.

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6.7.5 Articles

a Recreational activities and associated structures shall be set back a minimum of 2.0 feet from the

6.7.6 Setback and Height Requirements

Podium and Tower Setback Requirements

a Every required building setback shall be unobstructed from the ground to the sky except for the following projections: (a) cornices, eaves, sunshading devices, or other ornamental features projecting not more than 2 feet into the required setback; (b) balconies projecting from the building facade

b Every required building setback shall have a minimum area of 400 square feet, of which not less than 40% of it shall be open to the sky, and no dimension shall be less than the minimum required setback frontage for the zone

c Loading spaces shall have a minimum area of 300 square feet, where the gross floor area of the buildings on the site exceeds 50,000 square feet, but not more than 100,000 square feet, a minimum area of 600 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet, and the full requirement for additional 250 square feet for each additional 200,000 square feet or fraction thereof in excess of 200,000 square feet

Development Height Restrictions

a None

Podium Setback Line

a None

6.7.7 Structure and Setback Guidelines

a Vertical articulation shall be provided at the building facade to break up the massing of the building and to avoid the creation of long flat facades. Articulation shall be provided at intervals not exceeding 75 feet and may consist of a recessed or projected

b Service, storage and maintenance facilities, including related loading and manoeuvring areas, and refuse collection points shall be located within buildings

Service facilities, refuse collection points and loading areas shall be screened from the street and adjacent properties by enclosing them within buildings, or by using screening devices, planting, berms or a combination of these measures

c Architectural elements shall be consistent with the architectural vocabulary and character of the building

h Trash and storage enclosures shall be architecturally compatible with the principal building and shall be provided adjacent to the individual(s) it serves to the extent practicable

i Trash and service and refuse loading areas shall be located to minimize visibility from adjacent properties.

g Site location of trash enclosures shall be subject to review by the Director of Planning and Development to ensure proper functioning of loading operations

h Mechanical equipment and vents shall be screened by architectural elements and

Roof-level open-air recreational space shall be located at least 10 feet from the edge of the building face

i Curtain wall mullions shall be made of aluminum and steel, concealed spandrel panels shall be

6.7.8 Retail Standards

a Storefront glazing shall comprise a minimum of 70% of the length of the ground floor facade and be recessed where necessary

b Window glazing shall constitute a minimum of 30% of the total horizontal area along the street and shall be placed between the heights of

c Retail entrances shall be recessed a minimum of 3 feet to avoid swinging doors

d Storefront openings shall be no wider than 100 feet and no smaller than 15 feet. Storefronts shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

e Storefront openings shall be no more than 12 feet above the adjoining grade or 90% of the required minimum height

f Security grilles shall be located behind glazing and shall be minimum 75% open

g Any gate or roll up door shall be located behind the required minimum 75% open

6.8 City Open Standards

6.8.1 The purpose of the Podium Standards is to establish a model for implementation of the vision for a vibrant and enduring pedestrian environment at the ground level, as well as the upper levels of the podium, by the use of planning principles, regulations, implementing strategies and supporting documents

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5.0 Podium Locations

5.0.1 Podium(s) shall be provided on the Development Parcel(s) as identified on the Podium Locations Plan and may include a change in material, change in elevation, pavers or similar means.

5.0.2 Pedestrian breezeways between the building podium floors and upper floors shall be provided. This shall may include a change in material, change in elevation, pavers or similar means.

5.0.3 Podium projections shall be permitted, if desired.

5.0.4 Podium projections shall be permitted over public streets.

5.0.5 Podium projections shall be permitted over the highest floor within the podium.

5.0.6 Vehicle access and loading shall be provided, and exceptions may be made for integration of public art or architectural features such as screens or trellises that help to define the façade and add texture and depth to the building elevation. Vehicle access and loading shall be located off of Hall Street, Overton Street, Public Road A, Public Road B, Public Road C, or Public Road D, as applicable, and shall be screened from view from public streets, parks, and open spaces.

5.0.7 Louvers, vents and openings may be designed to integrate with building architecture.

5.1 Streets and Sidewalk Standards

5.1.1 The development shall be designed to provide a network of public streets that is safe, accessible, and well connected to the surrounding neighborhood. The network shall be designed to encourage walking, cycling, and transit use, and shall provide a high level of connectivity for pedestrians, cyclists, and motorists. Public streets shall be designed to accommodate a variety of uses, including vehicular travel, on-street parking, bicycle facilities, and pedestrian sidewalks.

5.1.2 The construction of new public streets shall be designed to provide a safe, comfortable, and attractive environment for pedestrians, cyclists, and motorists. This shall be achieved by providing features such as traffic calming measures, street trees, and landscaping, as well as ensuring that the streets are well-lit and visible. The use of high-quality materials and finishes shall also be encouraged to create a sense of place and enhance the overall aesthetic of the development.

5.1.3 Sidewalks shall be provided on both sides of all public streets, with a minimum width of 6 feet, except where otherwise specified in the Development Regulations. Sidewalks shall be designed to be accessible to all users, including those with disabilities, and shall be free of obstructions such as utility poles, signs, and vegetation that may impede pedestrian movement.

5.1.4 Street trees shall be planted at regular intervals along all public streets, with a minimum spacing of 30 feet on center. Trees shall be selected from a list of approved species that are suitable for the local climate and soil conditions, and shall be planted in accordance with the City's tree planting standards. Trees shall be provided with adequate soil volume, irrigation, and protection from damage, and shall be maintained in a healthy and vigorous condition.

5.1.5 Bicycle facilities, such as bike lanes, shared lanes, or cycle tracks, shall be provided on public streets as required by the Development Regulations. The design of bicycle facilities shall be consistent with the City's bicycle master plan and shall provide a safe and convenient connection to the surrounding bicycle network.

5.1.6 Public streets shall be designed to accommodate emergency vehicles, including fire trucks and ambulances, and shall provide adequate turning radii and clearance for these vehicles. The design of public streets shall also consider the needs of other users, such as pedestrians and cyclists, and shall incorporate features such as curb extensions, raised crosswalks, and speed humps to promote safe and slow traffic speeds.

5.1.7 Public streets shall be designed to be consistent with the City's street naming and numbering system, and shall be named in accordance with the City's street naming policy. The design of public streets shall also consider the integration of public art, such as sculptures, murals, or interactive installations, to enhance the pedestrian experience and create a sense of place.

5.2 Setback Standards

5.2.1 The minimum setback from a public street shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.2 The minimum setback from a property line that is not a public street shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.3 The minimum setback from a property line that is adjacent to a residential use shall be 10 feet, except where otherwise specified in the Development Regulations.

5.2.4 The minimum setback from a property line that is adjacent to a commercial use shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.5 The minimum setback from a property line that is adjacent to an industrial use shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.6 The minimum setback from a property line that is adjacent to a public park or open space shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.7 The minimum setback from a property line that is adjacent to a public street shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.8 The minimum setback from a property line that is adjacent to a private street shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.9 The minimum setback from a property line that is adjacent to a public alley shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.10 The minimum setback from a property line that is adjacent to a railroad right-of-way shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.11 The minimum setback from a property line that is adjacent to a utility easement shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.12 The minimum setback from a property line that is adjacent to a drainage easement shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.13 The minimum setback from a property line that is adjacent to a conservation easement shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.14 The minimum setback from a property line that is adjacent to a historic district shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.15 The minimum setback from a property line that is adjacent to a scenic corridor shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.16 The minimum setback from a property line that is adjacent to a wildlife habitat area shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.17 The minimum setback from a property line that is adjacent to a wetland area shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.18 The minimum setback from a property line that is adjacent to a floodplain shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.19 The minimum setback from a property line that is adjacent to a steep slope shall be 0 feet, except where otherwise specified in the Development Regulations.

5.2.20 The minimum setback from a property line that is adjacent to a cultural resource shall be 0 feet, except where otherwise specified in the Development Regulations.

7. Towers

7.1 Purpose

7.1.1 Towers are a unique architectural element that can help to define the skyline and create a sense of place. They can also be used to provide a sense of scale and proportion to the surrounding buildings and streets.

7.1.2 Towers can be used to create a sense of verticality and emphasize the height of a building, which can help to draw the eye upward and create a sense of grandeur.

7.1.3 Towers can be used to create a sense of enclosure and define the edges of a space, which can help to create a sense of intimacy and human scale.

7.1.4 Towers can be used to create a sense of rhythm and repetition, which can help to create a sense of order and harmony in the urban environment.

7.1.5 Towers can be used to create a sense of contrast and juxtaposition, which can help to create a sense of visual interest and excitement.

7.1.6 Towers can be used to create a sense of landmark and wayfinding, which can help to create a sense of place and identity.

7.1.7 Towers can be used to create a sense of transition and connection, which can help to create a sense of continuity and flow between different parts of the city.

7.1.8 Towers can be used to create a sense of mystery and intrigue, which can help to create a sense of curiosity and exploration.

7.1.9 Towers can be used to create a sense of drama and spectacle, which can help to create a sense of excitement and wonder.

7.1.10 Towers can be used to create a sense of tranquility and serenity, which can help to create a sense of peace and relaxation.

7.1.11 Towers can be used to create a sense of power and authority, which can help to create a sense of respect and admiration.

7.1.12 Towers can be used to create a sense of beauty and aesthetics, which can help to create a sense of pleasure and enjoyment.

7.1.13 Towers can be used to create a sense of history and culture, which can help to create a sense of connection and belonging.

7.1.14 Towers can be used to create a sense of community and social interaction, which can help to create a sense of belonging and identity.

7.1.15 Towers can be used to create a sense of environmental sustainability, which can help to create a sense of responsibility and stewardship.

7.2 Height Bonus

7.2.1 The following building elements are considered exempt from and may exceed the maximum permitted building height:

a. Rooftop structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment, required to operate and maintain the building;

b. Skylights, towers, steeples, flagpoles, water tanks, etc.;

c. Wireless masts; and

d. Solar energy devices and wind turbines.

7.2.2 Permitted building elements or appurtenances listed in Section 7.2.1 shall be limited to practical and necessary functional requirements (e.g., mechanical screening). Requests to exceed the permitted height for these elements shall be reviewed by the Director and may require additional documentation or screening.

7.2.3 No signage or graphics shall be permitted on exempt building elements.

7.3 Tower Standards

7.3.1 A tower 200 feet or greater in height above ground level shall be set back from the edge of the building by a minimum distance of 15 feet on all sides facing public streets.

7.3.2 Rooftop mechanical equipment and lighting fixtures shall not project more than 10 feet above the maximum permitted building height.

7.3.3 Towers shall be designed to minimize their visual impact on the surrounding neighborhood. This may include the use of setbacks, stepbacks, or other architectural features to reduce the perceived mass of the tower.

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7.1.A Towers that are attached to multi-family residential projects are to be limited to a maximum of 10 residential stories.

7.A Wall Standards

7.A.1 All walls shall be designed to be articulated.

7.A.2 The following guidelines shall be used to design all towers and all projects:

a. Reserved.

b. Standard solutions may be proposed, but must be supported by a comprehensive analysis of site, and

c. Each project.

Fig. 7.A.1a Bunker Hill Towers

Fig. 7.A.1b Los Feliz Towers

7.A.3 Balconies, balcony rails and railings at the facade (see figs. 7.A.3a and b) shall be designed to create a rich, three-dimensional, and vertical shading pattern. Balconies are encouraged to create a complex and varying pattern using multiple projections (minimum 6 projections) per facade (minimum 2 projections) and shall be a minimum 25% transparent. Balconies are encouraged to be designed to face public streets, open spaces, and common courtyards. Long continuous, monotonous, solid walls are discouraged.

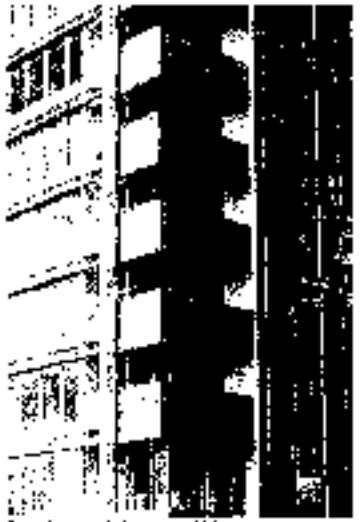

Fig. 7.A.3a Wilshire Rampart Building

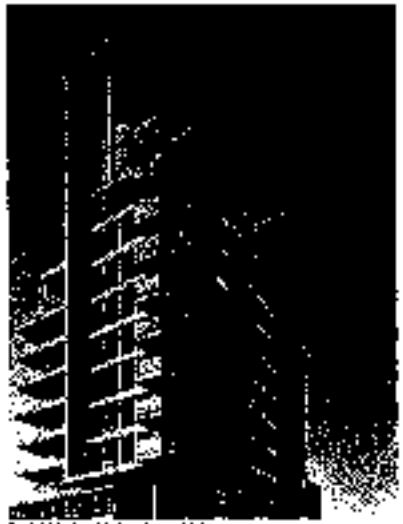

Fig. 7.A.3b Wilshire Wilcox Building

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7.5 Roofline Elements

7.5.1 [illegible]

7.5.2 [illegible]

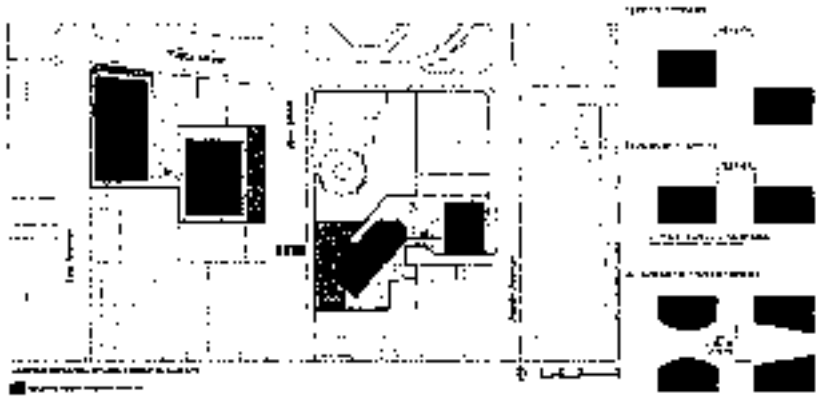

Fig 7.5.A [illegible]

7.6 [illegible]

7.6.1 [illegible]

7.6.2 [illegible]

7.6.3 [illegible]

7.6.4 [illegible]

7.7 Parapets, Handrails, Roof Penetration Equipment Screening Standards

7.7.1 [illegible]

7.7.2 [illegible]

7.7.3 [illegible]

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B. OPEN SPACE

B.0 Overview

The development of open space is an important objective for the Hollywood Project as an "Open space network" is required to address the open space needs of the community. Open space is an accessible, important feature of the Project and through-site connections for the Project. Grade level open space shall be designed to maximize the City of Beverly Building and Safety and shall include design features that activate the open space and the ground floor frontages.

The open space requirements in the Specific Plan guidelines for the Project are intended to be consistent with the Project's Grade Level Open Space Areas and Common Open Space Areas. Grade level open space shall be designed for the residential uses' Common Open Space and Private Open Space.

B.1 Grade Level Open Space Standards

B.1.1 Grade level open space shall be provided at or within 10 feet above the finished grade of the adjacent sidewalk. The grade level open space shall be designed to be accessible to the residents of the Project and open to the sky. This requirement may be satisfied by providing a portion of the required grade level open space as a roof deck, provided that the roof deck is accessible to the residents of the Project and is designed to be visually and physically integrated with the grade level open space.

B.1.2 Minimum grade level open space. As set forth in Table 6.3.2-1 of the Development Plan, for buildings up to and not exceeding 250 feet. (See Fig. 6.3.2-1 – B)

B.1.3 An additional 5% of open space shall be required for buildings above 250 feet and 400 feet. (See Fig. 6.3.2-1 – C)

B.1.4 An additional 5% (total 10%) of open space shall be required for buildings between 401 feet and 500 feet. (See Fig. 6.3.2-1 – D)

B.1.5 An additional 5% (total 15%) of open space shall be required for buildings greater than 500 feet. (See Fig. 6.3.2-1 – E)

B.1.6 Applicability.

a. Each use adjacent to the Las Palmas and Hollywood Boulevard Setback Area shall be setback from the Property Boundary along Vine Street and Yucca Street.

b. Minimum depth: no horizontal dimension less than 10 feet when measured perpendicular to the open space on each of the boundaries of the open space area. Open space shall be fronting on at least two (2) public streets or Private Streets, other than Alleys, and shall be improved pursuant to the Streetscape Plan.

Figure B.1.1 – B.1.4 Grade Level Open Space

Fig. B.1.1 Open Space Requirements for Maximum Building Height of 250 Feet

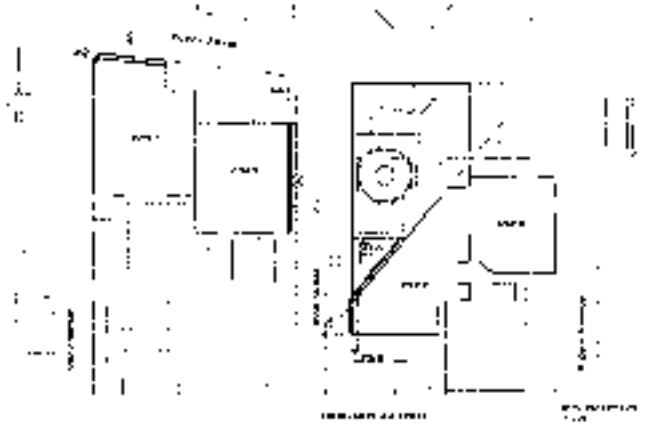
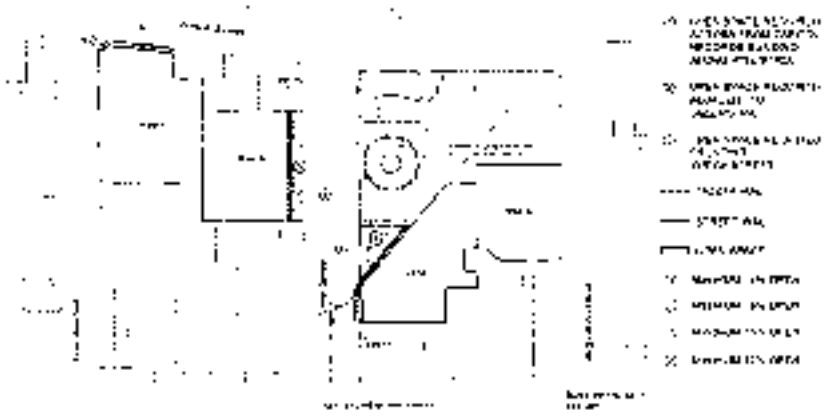


Fig. B.1.2 Open Space Requirements for Maximum Building Height of 400 Feet



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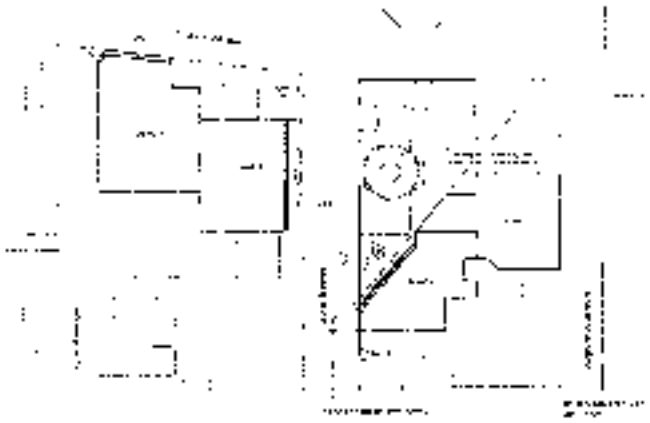
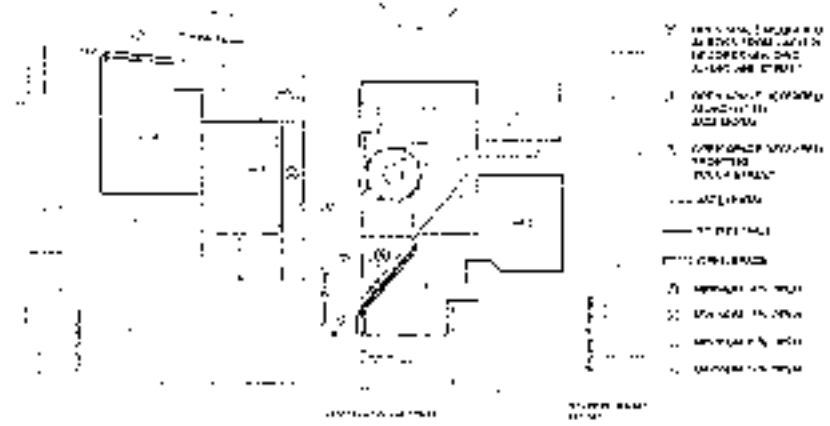




8.3 Passageway Standards

8.3.1 A publicly accessible passageway is a continuous through block public connection between two roads or streets, legible and readily understood. The passageway must be at least XXX metres wide by XXX metres high (or as otherwise specified).

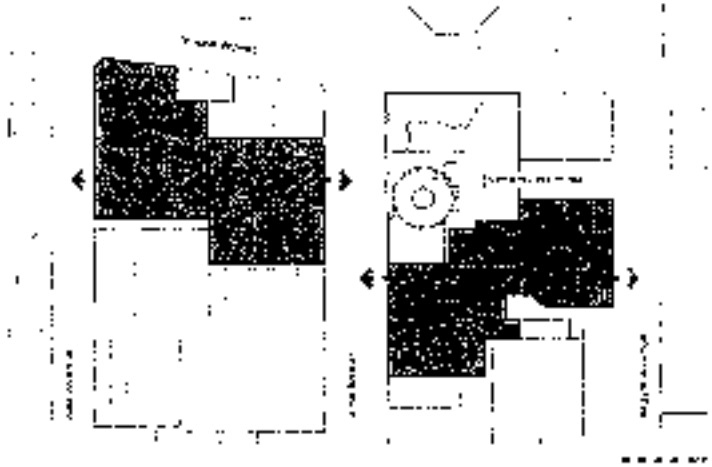
8.3.2 Design Provision to encourage public access and connection between and across appropriate public roads and streets along View Street.

8.3.3 Location and Size Requirements

a The minimum width of a publicly accessible passageway at the lowest level of the passageway and the rear of laneway are. Major publicly accessible parts adjoining buildings are public spaces. Major public spaces occupy no less than 75 percent of the total passageway area and shall not be less than 20 m² wide.

b Where a publicly accessible passageway and laneway does not align to create additional travel lines the shape and composition of a passageway. Where such lines shall not occupy more than 25 percent of the total area of the passageway. The minimum portion shall have a minimum width of 10 feet.

c The passageway shall be clear and open to the sky except as [illegible]



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5.2.4 Permitted Obstructions.

a. The minimum percentage of publicly accessible passageway area to be open to the sky [illegible] shall be as follows:

(1) Development with maximum building height of [illegible] feet: [illegible]

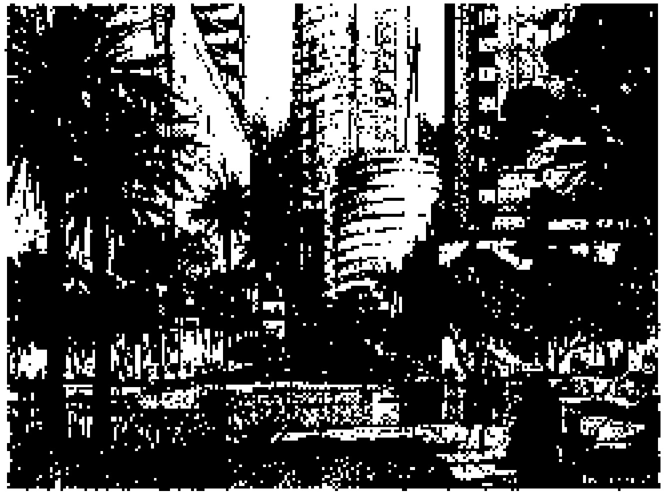
(2) Development with maximum building height of [illegible] feet: [illegible]

(3) Development with maximum building height of [illegible] feet: [illegible]

(4) Development with maximum building height of [illegible] feet: 40%

(5) Development with maximum building height of [illegible] feet: [illegible]

b. [illegible]



[illegible]

[illegible]

5.2.5 Kiosk

a. [illegible]

b. [illegible]

c. [illegible]

d. [illegible]

5.2.6 Open Air Café

a. [illegible]

b. [illegible]

c. [illegible]

5.2.7 [illegible]

a. [illegible]

5.2.8 [illegible]

a. [illegible]

b. [illegible]

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5.5.3 Frontages:

a. A minimum of [illegible] of the lot frontage for commercial uses and at least 40% of the lot frontage for [illegible] shall be occupied by buildings that are located close to the property line and [illegible]

b. Such [illegible] requirements shall not apply where the [illegible] provides, in the opinion of the City, that [illegible] from the existing or proposed streetscape [illegible] and [illegible] The remaining frontage may be occupied by other uses, [illegible] and parking facilities.

5.5.4 [illegible]

a. [illegible] that the responsibility for the maintenance of the publicly accessible parking area, including, but not limited to, the performance bond, the [illegible] and replacement of vegetation, and the care and replacement of vegetation within the passageway and on the adjacent sidewalk, boulevard, and adjacent street pavement.

b. [illegible] that all lands associated with the [illegible] shall be conveyed to the City at a rate of [illegible] square feet of public parking area for each [illegible] square feet of [illegible] gross floor area [illegible] and the [illegible] shall be provided for each 2,000 square feet of passageway in connection with the development, or [illegible] as otherwise determined through [illegible]

5.6 Rooftop Open Space

5.6.1 [illegible] square feet [illegible] rooftop [illegible] open space

5.6.2 [illegible] the [illegible] shall be considered private [illegible] accessible to the public

5.6.3 [illegible]

5.7 Neighbourhood Common Open Space

5.7.1 Common open space is [illegible] for the enjoyment, [illegible] and [illegible] of the residents of a parcel, [illegible] or the [illegible] and shall be [illegible] to the City and [illegible] such purposes. Where [illegible] from a commercial, [illegible] and [illegible] shall be [illegible] and the [illegible] common open space.

5.7.2 Common Open Space Standards

a. Provide a minimum of [illegible] open space per dwelling unit, [illegible] for each one bedroom dwelling unit, [illegible] for each two bedroom dwelling unit, and [illegible] for each unit containing three or more bedrooms.

b. Each common open space shall [illegible] and [illegible] to be used for active or passive recreation. Active open space may consist of private and/or semi-private [illegible] uses.

c. Open space may be used to satisfy [illegible] that [illegible] for common open space, except as [illegible] in the Zoning Code.

d. Common open space shall be readily accessible to all the residents of the site.

e. Common open space shall not include [illegible] of the site's landscaping, or areas [illegible] that [illegible] and [illegible] of the open space.

f. [illegible] open space shall comprise at least [illegible] of the total required open space on the [illegible].

g. Common open space shall [illegible] [illegible] including, but not limited to, [illegible] seating, [illegible], benches, children's play areas, ball courts, [illegible] areas, [illegible] and [illegible].

h. [illegible] open space shall be [illegible], any [illegible] above [illegible]. The [illegible] portion of a building used for [illegible] parking or [illegible] shall not be considered as common open space.

i. Refer to [illegible] for additional open space requirements.

5.8 Residential Private Open Space

5.8.1 [illegible] open space [illegible] for the [illegible] of residents of [illegible] by [illegible] dwellings.

5.8.2 Residential Open Space Standards

a. Private open space shall contain a minimum area of 10 square feet of which no more than 50 square feet may be [illegible] and shall be [illegible] to the dwelling unit it serves.

b. Private open space shall have a [illegible] of [illegible] that is [illegible] measured perpendicularly from any point on each of the boundaries of the open space area.

c. Private open space shall [illegible] with a minimum [illegible] clearance under any [illegible], except as [illegible] in the Zoning Code.

d. That portion of [illegible] which [illegible] or [illegible] may be [illegible] in connection with the Zoning Code may qualify as open space provided it meets each of the above-described requirements [illegible].

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9 LANDSCAPE

9.1 Ground Level Open Space Standards

9.1.1 [illegible]

9.1.2 [illegible]

9.1.3 [illegible]

9.1.4 [illegible]

a [illegible]

b [illegible]

c [illegible]

9.1.5 [illegible]

9.1.6 [illegible]

a [illegible]

9.1.7 [illegible]

9.2 Common Open Space Standards

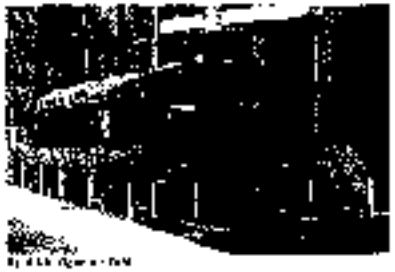
9.2.1 [illegible]

9.2.2 [illegible]

9.2.3 [illegible]

9.2.4 [illegible]

[illegible]



[illegible]

9.3 Standards For Open Air Forecourt Public/Accessible Passageway

9.3.1 [illegible]

9.3.2 [illegible]

a [illegible]

b [illegible]

c [illegible]

9.3.3 [illegible]

9.3.4 [illegible]

a [illegible]

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b. For each 500 square feet of landscaped area that is required, one tree shall be planted within the site. [Ord. No. 164,307, Eff. 10-1-89.]

c. Trees required by this section shall be planted within the following distance of the trunk:

Fig. 1 Tree Planting Requirements

3. Screening.

a. There shall be a minimum of one 5-gallon size shrub planting for each 500 square feet of landscaped area. Shrubs shall be planted within the following distance of the trunk of a tree:

b. Trees shall be planted in a manner that will not interfere with the use of fire hydrants.

c. Any more than 50% of the required planting area may be covered with walks, walking areas, or the following combinations:

(1) Walking surfaces constructed of materials with a minimum reflectance of 0.6, for the Society of Illuminating Engineers, a minimum of 50% of the required walking surface area shall be covered with lighting fixtures designed to provide an average maintained illumination level of at least two footcandles, measured at the walking surface.

(2) Walking surfaces constructed of materials with a minimum reflectance of 0.3, for the Society of Illuminating Engineers, a minimum of 100% of the required walking surface area shall be covered with lighting fixtures designed to provide an average maintained illumination level of at least two footcandles, measured at the walking surface.

d. Where walking surfaces, including parking areas, are located on a podium above the ground floor, the podium shall be screened from view by planting, trellis work, or other screening materials not less than 36 inches high.

D. Tree Planting Guidelines

1. Prior to the start of construction, the Project Developer shall submit a tree planting plan to the Director of Planning for review and approval. The tree planting plan shall show the species, location, and size of all trees proposed to be planted on the Project Site. The tree planting plan shall also show all existing trees proposed to be removed or relocated on the Project Site. The Director of Planning shall review the tree planting plan for consistency with the Hollywood Redevelopment Plan and the Hollywood Urban Design Guidelines.

2. Street trees shall be planted in accordance with the Project's approved tree planting plan. Street trees shall be planted in the parkway behind the curb, or in tree wells in the sidewalk, where no parkway exists. Street trees shall be planted at intervals of 20 feet, or as approved by the Director of Planning. Trees shall be planted in accordance with the Urban Forestry Division's standard tree planting procedures. Prior to planting, the Project Developer shall submit a street tree planting plan to the Urban Forestry Division for review and approval. The street tree planting plan shall show the species, location, and size of all trees proposed to be planted within the public right-of-way. Street trees shall be planted in accordance with the Urban Forestry Division's standard tree planting procedures.

3. Specific requirements for the planting of trees in the vicinity of overhead utility lines may be modified by the Urban Forestry Division to ensure adequate clearance for the trees at maturity.

E. Lighting Standards

1. Lighting located on the perimeter of each parcel is required to supplement the street lighting for the purpose of providing adequate illumination of sidewalks, bikeways, and pedestrian walkways. Lighting shall be provided along all publicly accessible areas within the Project Site, including but not limited to, parking areas, recreational areas, and pedestrian walkways. Lighting fixtures shall be energy efficient and shall be designed, located, and directed in such a manner as to prevent glare and excessive illumination on adjacent properties.

2. Decorative and security lighting shall meet the following minimum requirements:

a. Sufficient ornamental street lighting for pedestrians shall be provided along all sides of the project site adjacent to public streets. Such lighting shall be designed in conjunction with the street furniture and coordinated with the architectural theme of the project.

b. Lighting shall be energy efficient.

c. Lighting shall be designed to direct light downward and away from adjacent residential properties, so as not to create a nuisance or hazard to motorists on streets or highways.

d. Security lighting shall be provided in all parking areas, pedestrian walkways, and recreational areas.

e. Lighting poles shall not exceed the maximum height permitted by the Los Angeles Municipal Code.

f. All exterior lighting shall be architecturally integrated with the style, material and color of the buildings.

g. Lighting shall be designed, located, shielded or directed so as to prevent spillover onto adjacent properties.

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9.5.3 Requirements for Commercial Uses

a. The Building Owner shall be responsible for maintenance and repair of all lighting associated with the property, and shall ensure that all lighting used to meet these requirements does not cause glare or light pollution to adjacent properties or roadways, or impair the safe movement of traffic on adjacent roadways.

b. Additional lighting such as architectural lighting, colored lighting, signage lighting, etc. will be allowed. The operation of said additional lighting will be at the discretion of the Building Owner.

9.5.4 Lighting for commercial uses shall be limited to the minimum needed for security purposes, such as entrances, parking areas, loading areas, and pedestrian walkways. Lighting shall be directed downward and away from adjacent properties and streets. Lighting shall not blink, flash, oscillate, or be of unusually high intensity or brightness.

9.5.5 Lighting for above grade parking garages shall be limited to the minimum lighting necessary and the use of artificial brightness shall not be increased by use of the mixed or new residential lighting scale. This may be accomplished through the installation of motion sensors, security cameras, or limited hours of operation. Parking garages shall be exempt from the above requirements during hours when the building is not open for business.

9.6 Public Accessible Passageway Lighting Standards

9.6.1 A uniform, pedestrian-scale lighting system shall be provided throughout the public accessible passageways. Lighting shall be provided at a minimum average maintained illumination of 1.0 foot-candle (10.8 lumens per square foot) on the ground plane of the passageway.

9.6.2 Lighting shall be designed to minimize glare and to direct light downward and away from adjacent buildings.

9.7 Continuity of Design

9.7.1 Design guidelines for the Architectural Character shall be followed when appropriate to provide a consistent theme throughout the Development Regulations area. Variations to the guidelines may be allowed if the proposed architecture is equal to the guidelines and is approved by the Design Review Committee.

9.7.2 Where possible, similar materials, colors, and textures shall be used throughout the Development Regulations area to provide a consistent and cohesive appearance.

10 PARKING

10.1 Automobile Standards

10.1.1 Minimum Standards

The following standards shall be used to determine the minimum number of parking spaces required for each building. The Regulatory Authority shall have the authority to waive or modify the parking requirements for specific buildings or uses if the applicant can demonstrate that the proposed development is the Development Agreement Area.

a. Commercial / Office / Retail:

Two parking spaces for every one thousand square feet of commercial, office, business, retail, institutional, service, or mixed use space in the Development Agreement Area, unless otherwise specified in the Development Agreement. The Regulatory Authority may waive or modify the parking requirements for specific buildings or uses if the applicant can demonstrate that the proposed development is the Development Agreement Area.

b. Sports Club:

Where a sports club is located in a building with 50,000 gross square feet of contiguous, dedicated space, the general commercial use parking requirements apply and no parking spaces shall be required for any sports club use. Sports club uses in buildings with less than 50,000 square feet of contiguous, dedicated space shall provide parking at a rate of one space per one hundred square feet of floor area for the sports club portion of the building.

c. Condominiums (Residential):

Two parking spaces per dwelling unit.

One space for every guest parking lot and for guest parking.

d. Residential (Apartments):

One parking space for each dwelling unit of less than one habitable room, one and one-half parking spaces for each dwelling unit of two habitable rooms, and two parking spaces for each dwelling unit of more than two habitable rooms.

e. Combinations of Uses:

Where there is a combination of any two or more of the above uses, the total number of parking spaces required shall be the sum of the requirements of the various uses.

10.1.2 Shared Parking

a. Shared parking may be applied to the Section 10.1.1 base rates for the Site when the uses have different parking requirements and different demand periods, particularly when the uses are complementary or between weekdays and weekends. The intent is to minimize the creation of the total vehicle parking demand with its complementary uses. The calculation of the shared parking shall not be based on a detailed study or survey of actual conditions or

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[illegible]

Multimodal Reduction Factors

Residential	5%
Retail	5%
Office	15%
Other Commercial	[illegible]

[illegible]

10.2 Additional Regulations

[illegible]

[illegible]

10.3 Screening

[illegible]

10.4 Bicycle Standards

[illegible]

a. Commercial / Office Uses

[illegible]

Land Use	Short Term Bicycle Parking	Long Term Bicycle Parking
Office	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible]

b. [illegible]

[illegible]

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Additional restrictions on parking may be provided at the time of the building permit review process.

i. A minimum of one bicycle parking space shall be provided for each dwelling unit, guest room, or 10,000 square feet of floor area, whichever is greater. Bicycle parking spaces shall be provided in accordance with the requirements of Section 12.21 A.16 of the Los Angeles Municipal Code.

10.3 Transportation Demand Management Plan

10.3.1 The Project shall incorporate a comprehensive transportation demand management plan.

10.3.2 The transportation demand management plan shall set forth best practices that seek to reduce the Project's reliance on single occupancy vehicle trips and may include, but not be limited to, the following:

a. Promote bicycle and pedestrian circulation to and from the Project Site.

b. Promote alternative modes of transportation.

c. Provide preferential parking for high occupancy vehicles and electric vehicles on the Project Site.

d. Encourage carpool and ridesharing activity by designating passenger loading areas in the Project Site adjacent to Hollywood Boulevard and Vine Street.

e. Provide secure bicycle parking, bicycle racks and lockers in convenient locations on the Project Site in accordance with the requirements of Section 12.21 A.16 of the Los Angeles Municipal Code.

11 SIGNAGE

11.1 Hollywood Signage Supplemental Use District

Signage on the Project Site is governed by Ordinance No. 176,220, the Hollywood Signage Supplemental Use District, pursuant to Section 13.11 of the Los Angeles Municipal Code.

11.2 Modification to Guidelines

Notwithstanding Section 5.1, light emitting diode screens shall be permitted on the Project Site, subject to the requirements of the Hollywood Sign District. See Fig. 11.2.

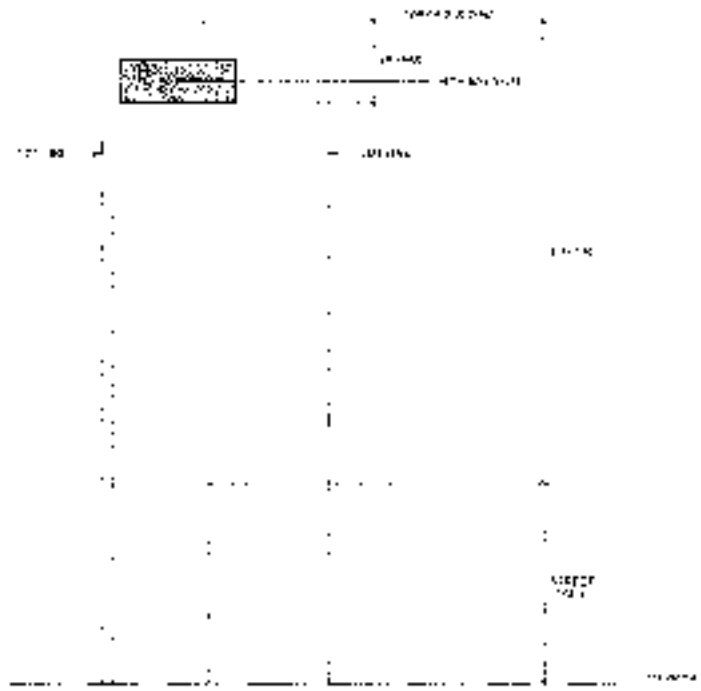

Fig. 11.2 Height Map Sign

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12. SUSTAINABILITY

12.1 Non-Residential Projects

[illegible] square feet of floor area, [illegible] square feet of floor area or more, [illegible] square feet of floor area, or [illegible] square feet of floor area or more [illegible] Energy and Environmental Design ("LEED") Certification level. The Standard and applicable rating system shall be the most recent [illegible] at the time of application for the applicable building permit.

12.2 Other Projects

[illegible]

13. DEFINITIONS

Awning, gating, or louver or other fixed structure projecting from the building to provide weather protection, identity or decoration, and may be illuminated by internal illumination.

Base: the lower portion of a building, defined as the first 150' above curb level.

Canopy: a rigid, fabric and/or metal structure with or without support, located on the sidewalk to provide weather protection for a building's entry and/or retail.

Expression band: a projecting or recessed architectural element occurring on the building base (typically at the height of the base) that runs the length of the building, usually aligning with floor lines, or floor to floor height of adjacent building base facade. Projections may occur in the expression band.

Grade level open space: a continuous open space located at street level and open to the sky.

Maximum: building height, the maximum height permitted, measured from the adjacent street curb level.

Maintenance: the ongoing repair, care and upkeep of a property.

Open space: usable and active recreational areas accessible to the general public except as noted herein. Open space can consist of publicly accessible passageways, grade level open space, terraces, courtyards, roof top open space, and other open space which are defined herein.

Preservation: the act or process of applying measures necessary to sustain the existing form, integrity and materials of an historic property.

Publicly accessible passageway: a covered or uncovered pedestrian connection between two parts of the site, which may be private or public, that is designed for and designated to allow safe, convenient and comfortable use by the general public.

Remediation: the act or process of removing or containing hazardous materials in order to protect the health of occupants of a property or the environment. Remediation activities are commonly associated with the cleanup of soil and groundwater contamination, but may also involve the removal of hazardous materials from buildings, such as asbestos, lead paint, and mold.

Required ground level retail: retail or restaurant space at the ground floor of a building, having a minimum depth and minimum square footage as set forth in the applicable Development Parcel Table.

Residential amenity: indoor or outdoor space within a residential building, including but not limited to fitness facilities, lounges, and recreational facilities, provided for the use of residents of the building and their guests.

Residential private open space: open space that is exclusively for the use of residents of a single residential unit.

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[illegible]	SCOPE OF DEVELOPMENT	DEFINITIONS

Setting: [illegible]

Street Wall: [illegible]

Tower: the portion of a building [illegible] above [illegible] level

Notes

All [illegible]

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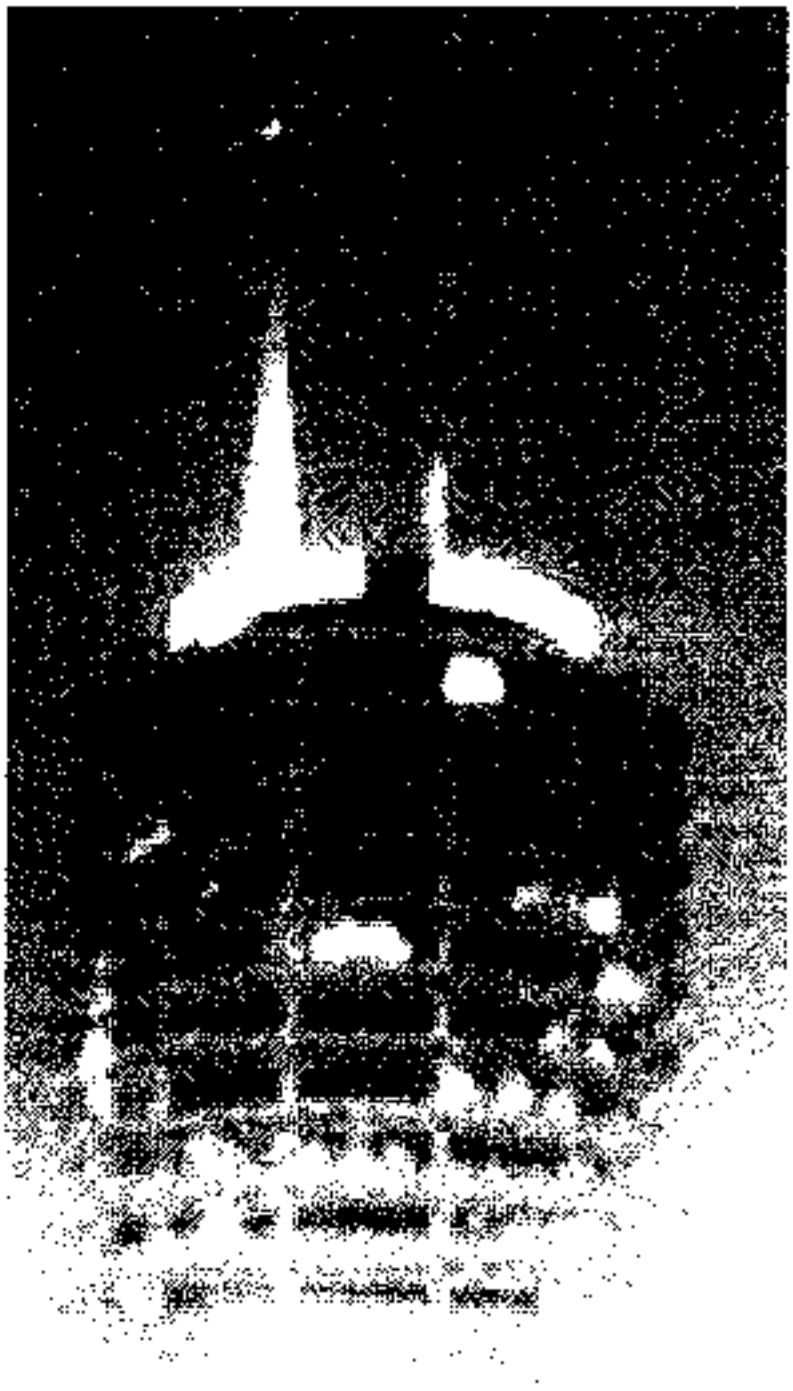

MILLENNIUM HOLLYWOOD PROJECT

DEVELOPMENT REGULATIONS: GUIDELINES AND STANDARDS

MILLENNIUM HOLLYWOOD PROJECT

SCOPE OF DEVELOPMENT: DESIGN GUIDELINES AND STANDARDS

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1. PURPOSE AND OBJECTIVES

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and ensure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria that serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

d. Permit design flexibility while establishing a set of controls that will guide the development for the Project Site.

e. Ensure compliance with the Development Objectives.

f. Ensure preservation of the Capitol Records Building and the Gogerty Building according to the *Secretary of the Interior's Standards for Rehabilitation*.

1.2 Development Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure that new development on the Project Site is consistent with these objectives.

1.2.2 The objectives for new development on the Project Site are to:

a. Preserve the Capitol Records Building and the Gogerty Building according to established preservation guidelines (the *Secretary of the Interior's Standards for Rehabilitation* and guidance provided by Office of Historic Resources).

b Preserve public views from certain key vantage points to the Capitol Records Tower by creating grade level open space / civic plazas on the East Site adjacent to the Jazz Mural and Capitol Records Building and West Site across from the Capitol Records

c. Preserve existing view corridors from certain key vantage points to the Hollywood Hills.

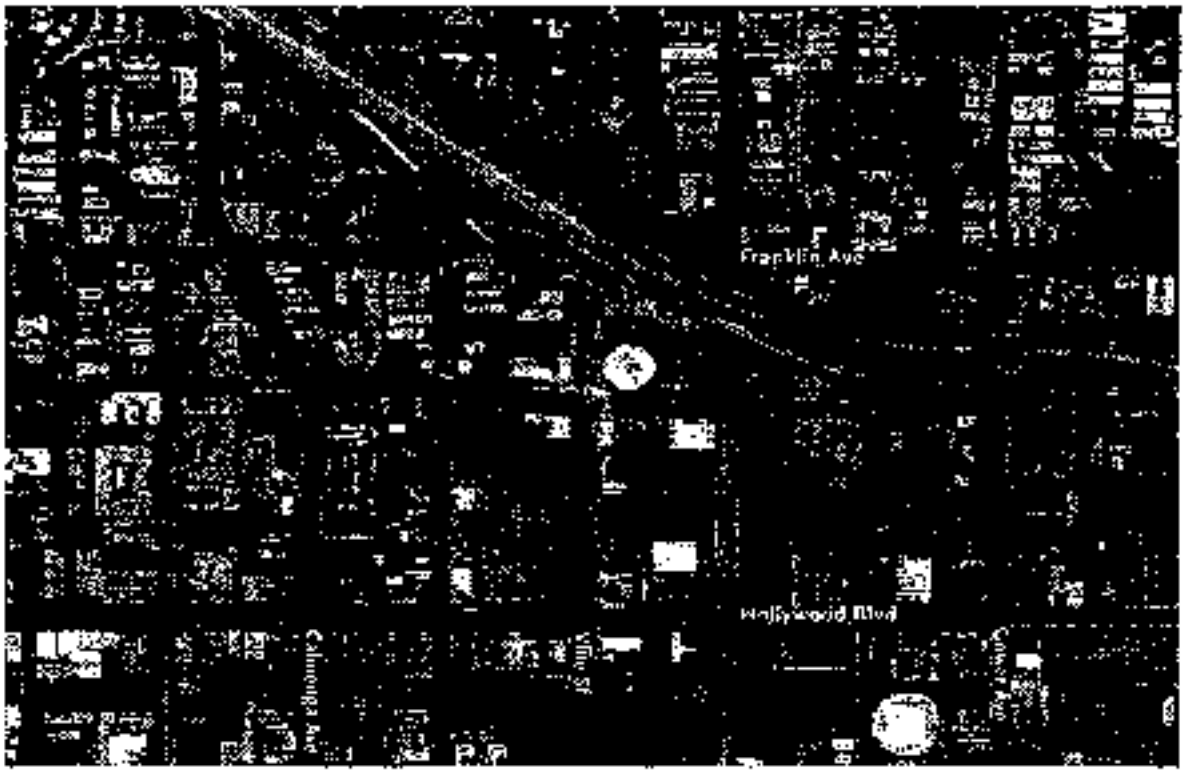


Fig. 1.2.2.b-c. Capitol Records View Corridors

d Create civic plazas that are activated by retail, landscaped, and enhance the Hollywood Walk of Fame by providing it as an urban node. Reinforce the urban and historical

importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

c. Encourage street life by the creation of a new pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

d. Create vibrant urban spaces that permit open and green spaces for both the on-site and off-site population.

fig I.2.2.d: View North Along Vine Street

e. Create a 24 hr community by the creation of a Thriving Mixed-Use Development.

f. Eliminate the visual impact of current on-site parking.

g. Establish where feasible pedestrian linkages to existing public transportation routes in proximity to the Project Site, including the Metro Red Line Station at Hollywood Boulevard and Vine Street, and existing bus routes.

h. Establish standards to address architectural excellence.

k. Provide designs that address, respect and complement the existing context, including standards for ground-level open space, podium heights and massing setbacks that minimize impacts to the historic setting.

l. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

m. Create buildings that emphasize the vertical architecture and become visible icons.

n. Develop a visual gateway to Hollywood from the Hollywood Freeway.

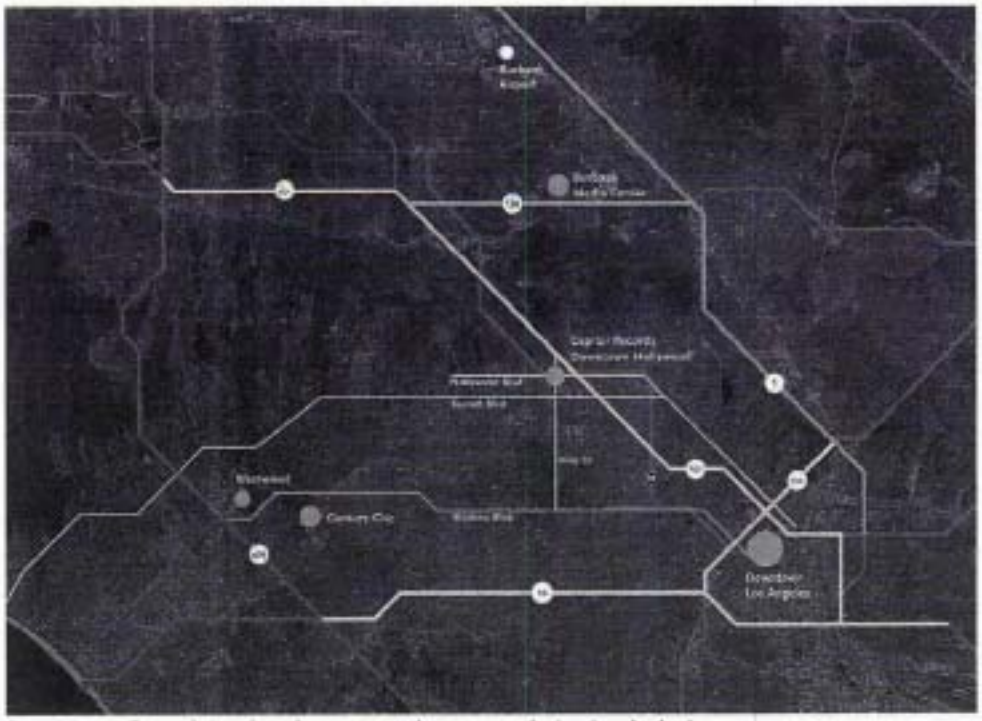


fig. 1.2.2.n: Hollywood: A major urban center and gateway to the Los Angeles basin.

1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose strict requirements for new development. For example, the Regulations include specific setback requirements along Vine Street. There are also mandatory requirements or standards for minimum open space on the ground floor as well as maximum building heights. By comparison, the guidelines are measures that may include a range of choices and require a degree of interpretation by the architect and design team to achieve compliance with the Regulations. The purpose of these guidelines is to create a principal design theme or objective without comprising high quality design. The purpose is to provide a range of flexibility to permit the selection of the most appropriate design feature based on the final development scenario. For instance, façade treatments for new development may take different form depending on the final design plans. The Regulations will guide the ultimate façade treatment by providing a limited range of choices in the use of material and color for the façades.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 The Development Regulations are approved by the City of Los Angeles City Council ~~and are incorporated~~ in the Development Agreement, authorized pursuant to California Government Code 65864, et seq., entered into by the City of Los Angeles and _____ ("Millennium Development Agreement") on _____.

1.4.2 Wherever the Regulations contain provisions which establish regulations that are different from or more or less restrictive than the zoning or land use regulations in the Los Angeles Municipal Code ("LAMC") that apply to the Project Site, the Regulations shall prevail pursuant to the Millennium Development Agreement approved by the City Council.

2. BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street.

The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Avenue is the East Site.

The East Site and the West Site make up the Project Site.

The Project Site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 21 feet (NE to SW) from Vine Street to Argyle Avenue and 21 feet (NW to SE) from Ivar Avenue to Vine Street. The existing sidewalk elevations will not be altered as part the Project.

fig. 2.1. Site Plan

2.2 Site Zoning and Permitted Floor Area

2.2.1 The Project Site is zoned Commercial (C2). The City General Plan land use designation is Regional Center commercial.

2.2.2 The Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.

2.2.3 Notwithstanding any provision in these Regulations, residential floor area is not permitted within 500 feet of any freeway.

2.2.4 Floor Area Ratio: 6:1

2.2.5 Height District: No. 2

3. HISTORIC RESOURCES AND SETTING

3.1 Overview

The Project Site is located in a historically rich area of Hollywood that contains a number of recognized historic resources. This Project is a preservation project in that its ambition is to respect, respond to, and preserve the Capitol Records Building and to continue the urban character of Vine Street on the Project Site. The Project is designed to be observant of historic settings and buildings. Two buildings located on the Project Site, the Capitol Records Tower and the Gogerty Building, are historically significant. Other historic buildings, located on adjacent parcels, are the Pantages Theater, the Equitable Building, the Hollywood Palace, and the Art Deco commercial building at 6916-6374 Yucca Street. Several of these historic resources are located within the Hollywood Boulevard Commercial and Entertainment District, a National Register listed historic district located just south of the Project Site.

Composed of commercial properties from the first half of the 20th Century, contributing properties to the Hollywood Boulevard Commercial and Entertainment District include a wide variety of property types including single-story storefronts, two-story commercial blocks, department stores, theaters, high-rise office buildings and hotels.

The Capitol Records Building is a unique building whose cylindrical form has always been visible from portions of Hollywood and Vine from the south and the freeway from the north. The Capitol Records Tower and the iconic buildings in the Hollywood Boulevard Commercial and Entertainment District (the Hollywood Palace, Pantages Theater, Equitable Building) will maintain their prominence after implementation of the Project.
Portions of the Hollywood Walk of Fame (L.A. Historic Cultural Monument #194) are located along Vine Street between Yucca Street and Sunset Boulevard and will be protected.

The protection of Hollywood's historic resources and unique character is an important objective of the Project. The guidelines and standards contained in this document were created in part to ensure the protection of historic resources within the Project Site and minimize potential adverse effects to historic resources from new development. Key Project objectives regarding historic resources include:

1) Preservation, maintenance, and rehabilitation of the Capitol Records Building and the Gogerty Building in accordance with the Secretary of the Interior's Standards. See sections 3.2.2a and 3.2.2b of this document.

2) Protection and preservation of the portions of the Hollywood Walk of Fame (LA Historic Cultural Monument #194) will need to be temporarily removed during construction and replaced after construction is completed. A preservation plan, outlined in the Hollywood Walk of Fame Terrazzo Pavement and Repair Guidelines (March, 2011) will be prepared for this aspect of the Project.

3) Incorporation of ground-floor open space and building setback requirements to moderate the overall massing of new development in a manner that preserves important views to and from the Capitol Records Building, the Hollywood Boulevard Commercial and Entertainment District, and important view corridors to the Hollywood Hills. See sections 3.2.2.c, E.1, 6.0, 7.1, 7.5, 8.1 and 8.2 of this document.

4) Incorporation of ground floor open space and building setback requirements to reduce massing at the street level and limit the visual crowding of adjacent historic resources. See sections 3.2.2c, G.1, 7.1, 7.5

8.1 and 8.2 of this document

v) Requirement that design of new buildings be in a manner that is differentiated from but compatible with adjacent historic resources. See Sections 6.6, 6.8, 7.1.5, and 7.4 of this document.

One means of creating compatible new buildings in an urbanized setting is to incorporate qualities of vertical and horizontal visual complexity in world-class design. The general characteristics, proportions, and details of older buildings may serve as a reference for the Project. The Project's intent is to allow old and new to mix, recognizing that Hollywood sustains its image through both the rehabilitation of existing historic structures and the design of creative and contemporary architecture.

4. DENSITY

4.1 Floor Area Ratio Averaging and Density Transfer

The Owner may transfer density and buildable floor area from one parcel within the Project Site to another parcel within the Project Site, as long as the minimum and maximum building heights in the Regulations are maintained and the entire Project does not exceed the cumulative, allowable density and floor area of the zoning for the sum of the individual parcels.

To allow for the spatial distribution of the development on the Project Site and ensure relationship and sensitivity with the uses surrounding the Project Site, parking, open space and related development requirements for any component of the Project may be developed in any location within the Project Site.

4.2 Land Use Equivalency Program

The Land Use Equivalency Program is intended to provide flexibility in land uses for the Project while ensuring that a change in land uses would not result in new significant environmental impacts or a substantial increase in the severity of significant environmental impacts identified in the EIR. ENV-2011-0675-EIR (SCH No. 2011041094). With respect to any proposed Phase of the Project (an "Exchange Phase") that would result in a build out of the Project that is not consistent with at least one of the Project scenarios studied under the EIR, under the Land Use Equivalency Program, the developer may request a transfer or exchange of land uses, as well as modifications to the siting, massing or other development standards in so far as they are consistent with the provisions herein, for such Exchange Phase by a delivering written request therefore to the Planning Department of the City, which request shall be accompanied by (a) detailed information identifying the land use transfer/exchange that is being proposed for such Exchange Phase, (b) information documenting how the proposed land uses and densities in the Exchange Phase, together with the existing improvements and the other phases previously developed, are consistent with the overall AM and PM peak hour trip cap identified in Table II-3, Project Trip Cap from the EIR; and (c) supporting documentation to demonstrate that the Project including the proposed Exchange Phase would not exceed the maximum environmental impacts identified in the EIR (collectively, an "Equivalency Program Exchange Submission"). The Planning Director shall approve such request if the Equivalency Program Exchange Submission reasonably demonstrates that the Project including the proposed Exchange Phase is consistent with the overall AM and PM peak hour trip cap identified in such Table II-3, Project Trip Cap, does not conflict with the impacts analysis for the maximum Commercial and Residential Scenarios, and would not otherwise exceed the maximum environmental impacts identified in the EIR.

5. HEIGHT

5.1 Building Height Standards

The Regulations establish heights zones (A, B, C and D) to limit maximum building heights and control bulk in response to the Development Objectives including context with the built environment and to reinforce view corridors to the Capitol Records Tower

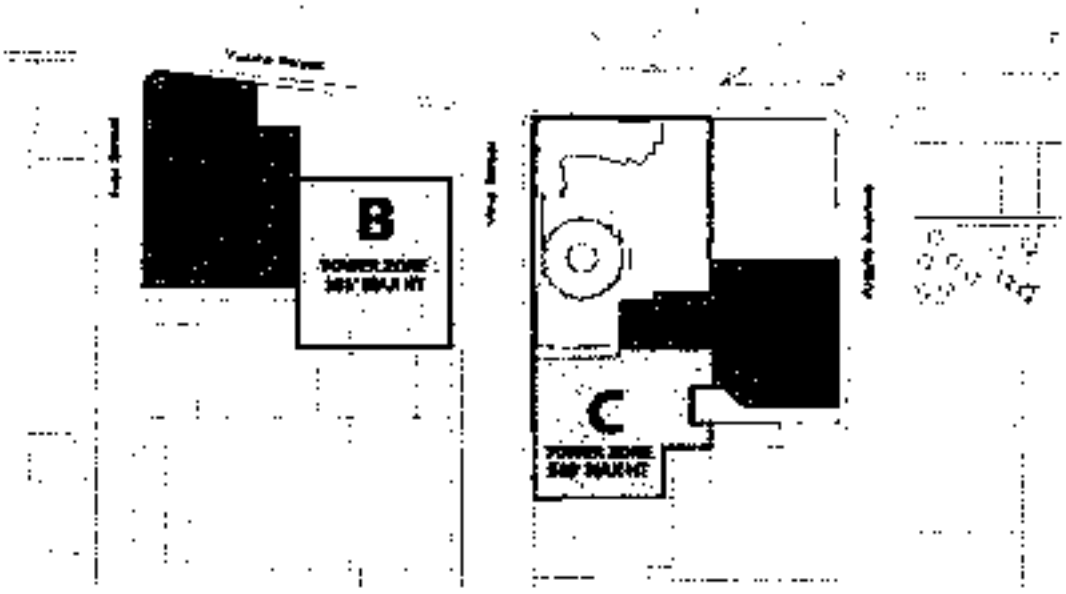


Fig. 5.1 Height Zones

5.1.1 - Number of stories to be counted by unit programmatic floor, excluding mechanical spaces.

5.1.2. Height of the building shall be measured from the curb of the primary street frontage

6. BUILDING AND STREET EXPERIENCE

6.1 Tower Massing Standards

6.1.1 The Tower Massing Standards apply to the portion of a building located 150 feet above curb level – see Table 6.1.1.

Tower Height (feet)	Maximum Tower Lot Coverage (%)	Minimum Floor Area Below 220 Feet (%)	Maximum Tower Floor Plate (sq. ft.)	Minimum Tower Setback (feet)	Minimum Public Open Space (%)	Figures
151 – 585	11.5	50	13,325 East Site 9,042 West Site	10 15[1]	12	6.1.2.d.1 6.1.2.d.2
151 – 550	15	50	17,380 East Site 11,794 West Site	10 15[1]	10	6.1.2.c.1 6.1.2.c.2
151 – 400	28	50	22,745 East Site 22,016 West Site	10 15[1]	8	6.1.2.b.1 6.1.2.b.2
150 – 220	48	n/a	55,616 East Site 37,742 West Site	10 15[1]	5	6.1.2.a.1 6.1.2.a.2

Table 6.1.1

Note 1: 15' tower setback required for any tower fronting Vine Street on West parcel. See Figure 6.3.2.

6.1.2 For the purpose of calculating the maximum lot coverage the total lot area is equal to the total lot area for each of the sites, the West Site and the East Site. If there is more than one tower on a site, the maximum lot coverage requirement in Table 6.1.1 is calculated based on the combined area of all towers on each site. The total lot coverage applies to the aggregate floor plate(s) of the tower or towers on each site.

6.1.3 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Figs. 6.1.2.a.1 – 2.)

6.1.4 At least 50% of total floor area must be located below 220 feet.

6.1.5 Tower wall articulation:

a. Minimum 10% of tower aggregate area shall be articulated.

6.1.6 Types of permitted articulations for tower walls:

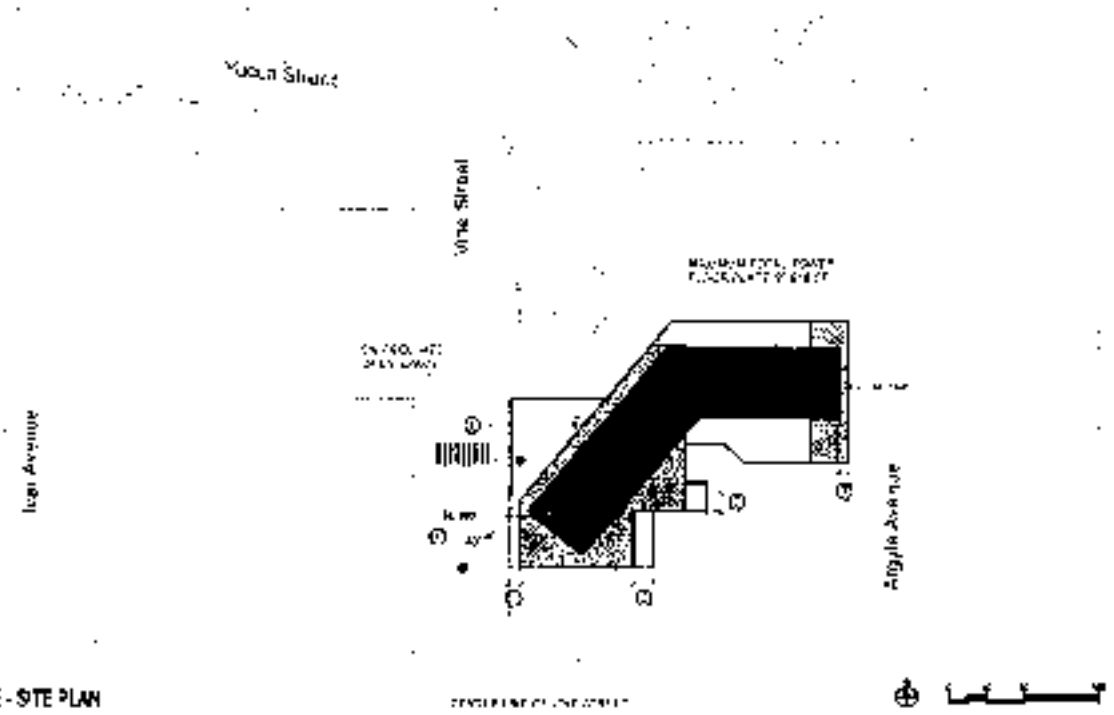
a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

The following developments are for illustrative purposes only.
Maximum Lot Coverage and Tower Floor Plate – Figs. 6.1.2.a – d.



EAST SITE - SITE PLAN

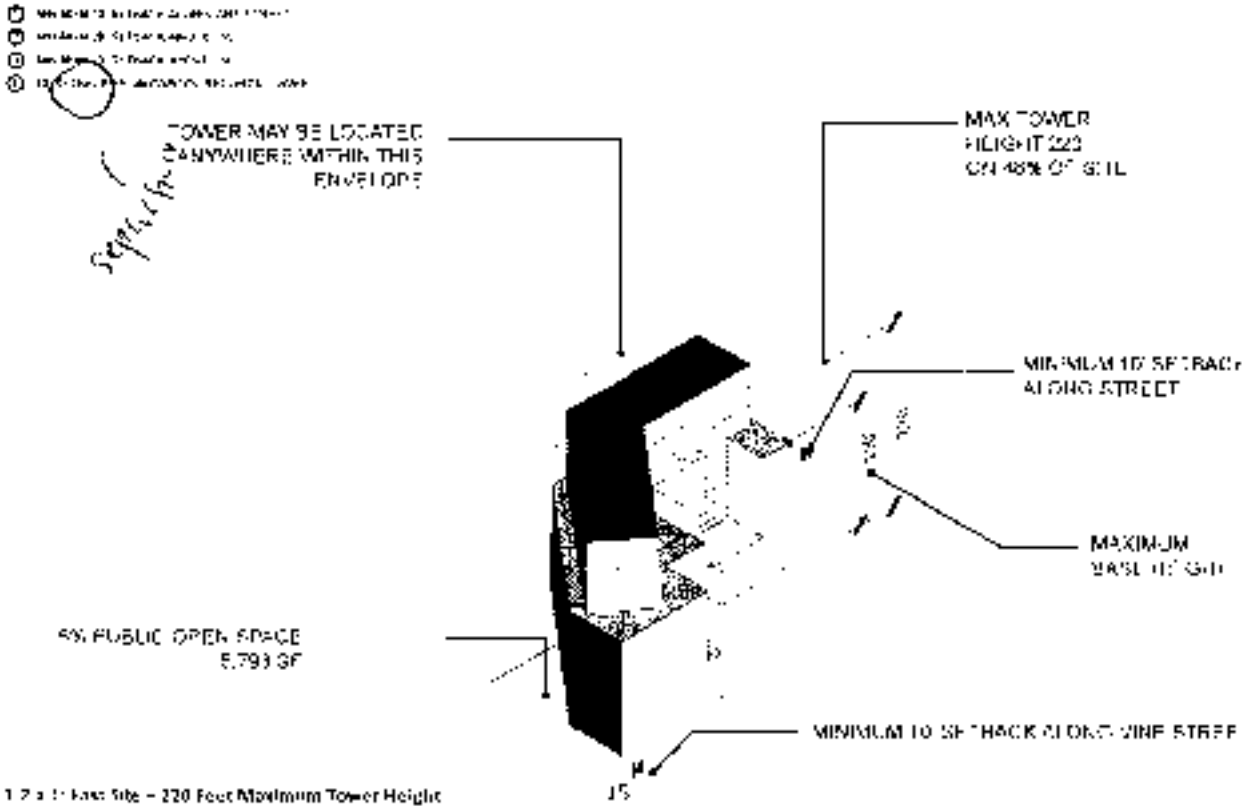


fig. 6.1.2.a.1: East Site – 220 Foot Maximum Tower Height

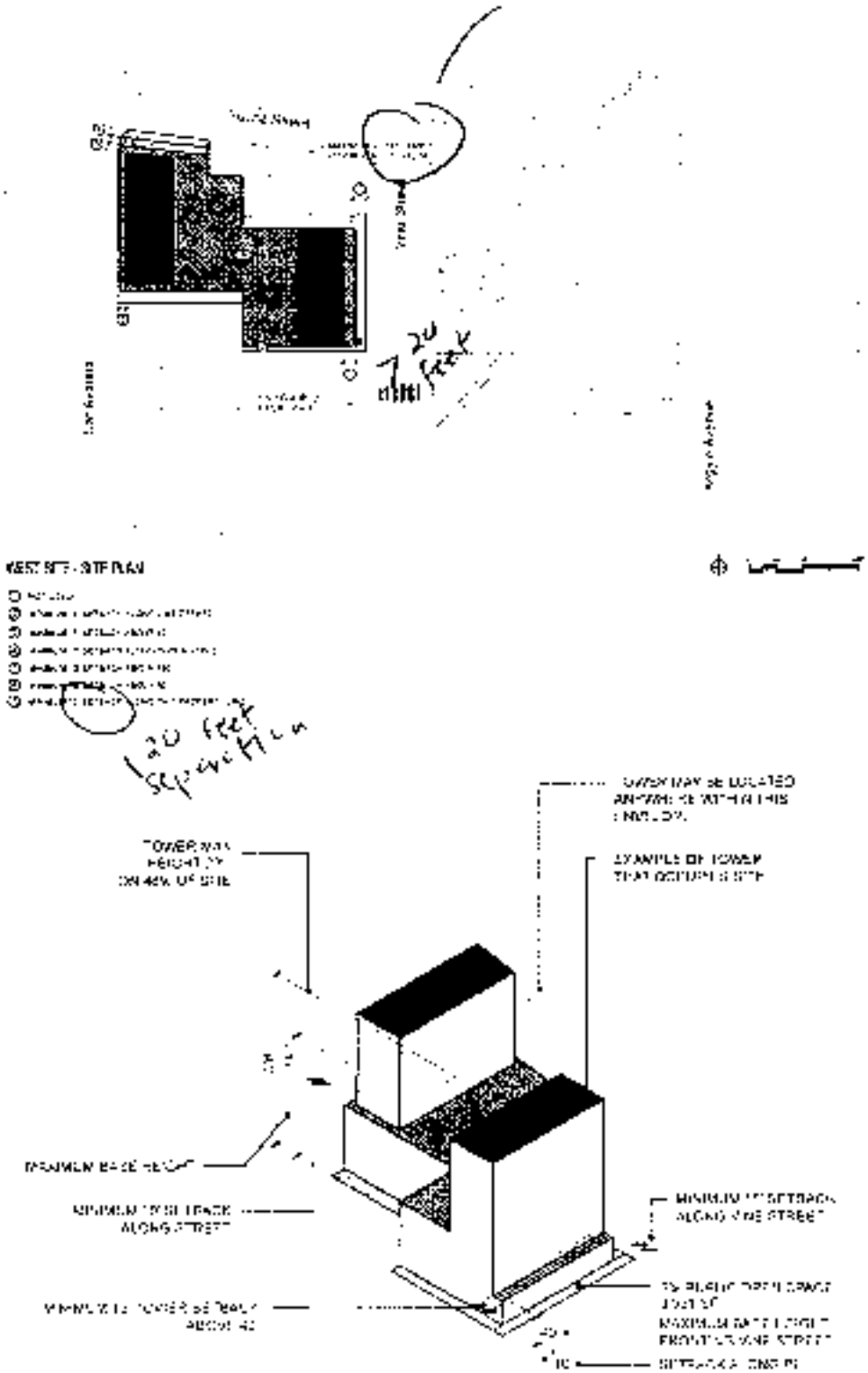


fig 6.1.2.a 2 West Site - 220 Foot Maximum Tower Height.

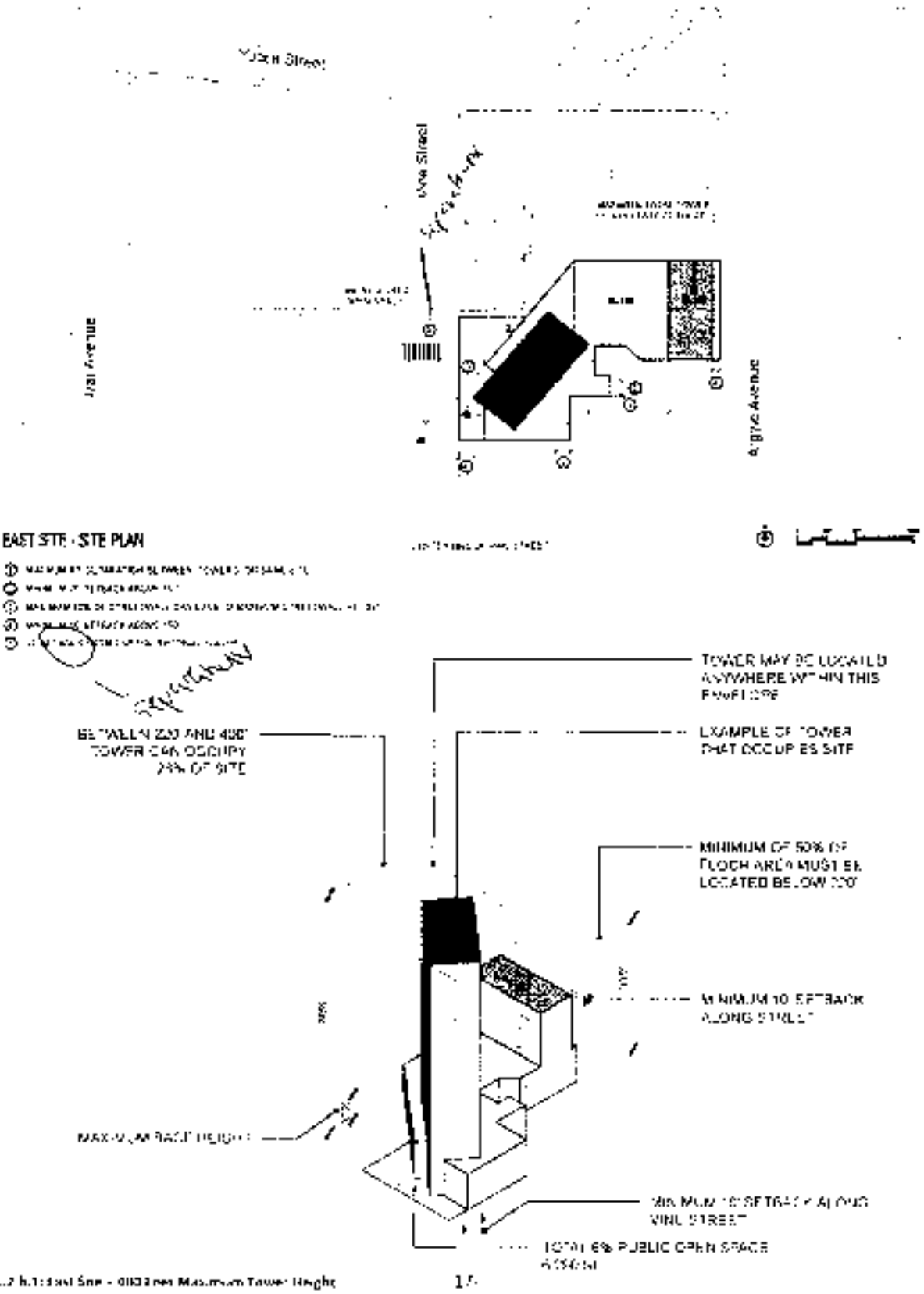
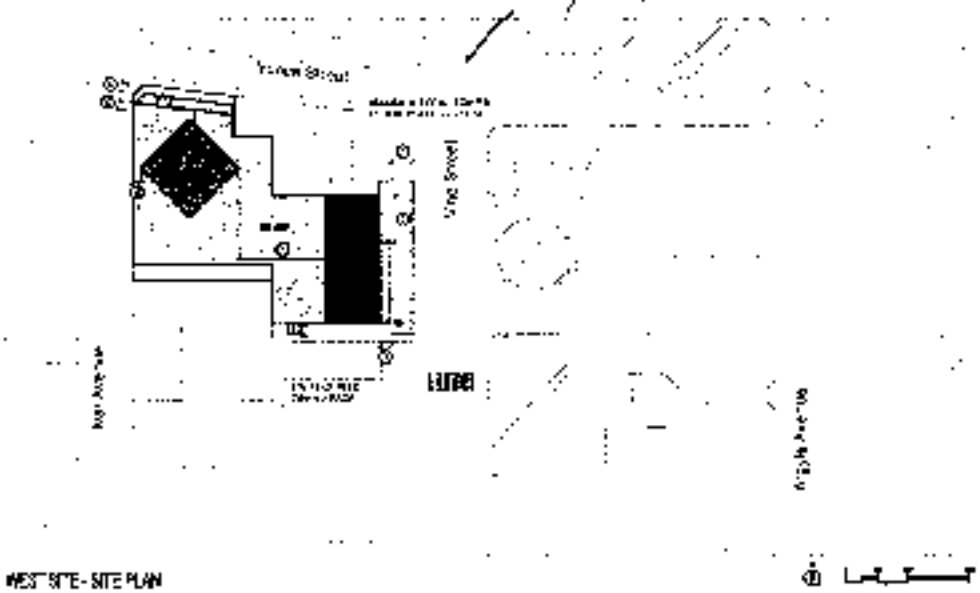


Fig. 6.1.2 h.1 East Site - 0833 feet Maximum Tower Height

32,443 (math)



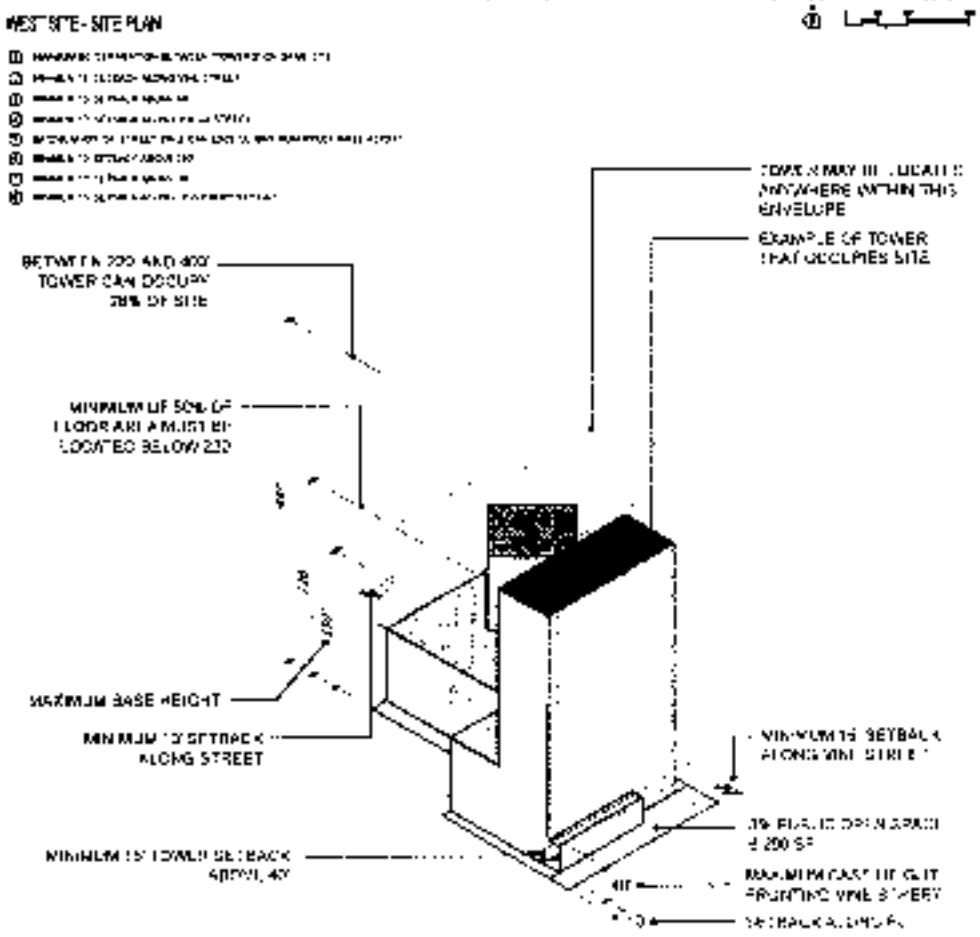


Fig. 6.1.2.b.2 West Site – 400 Feet Maximum Tower Height

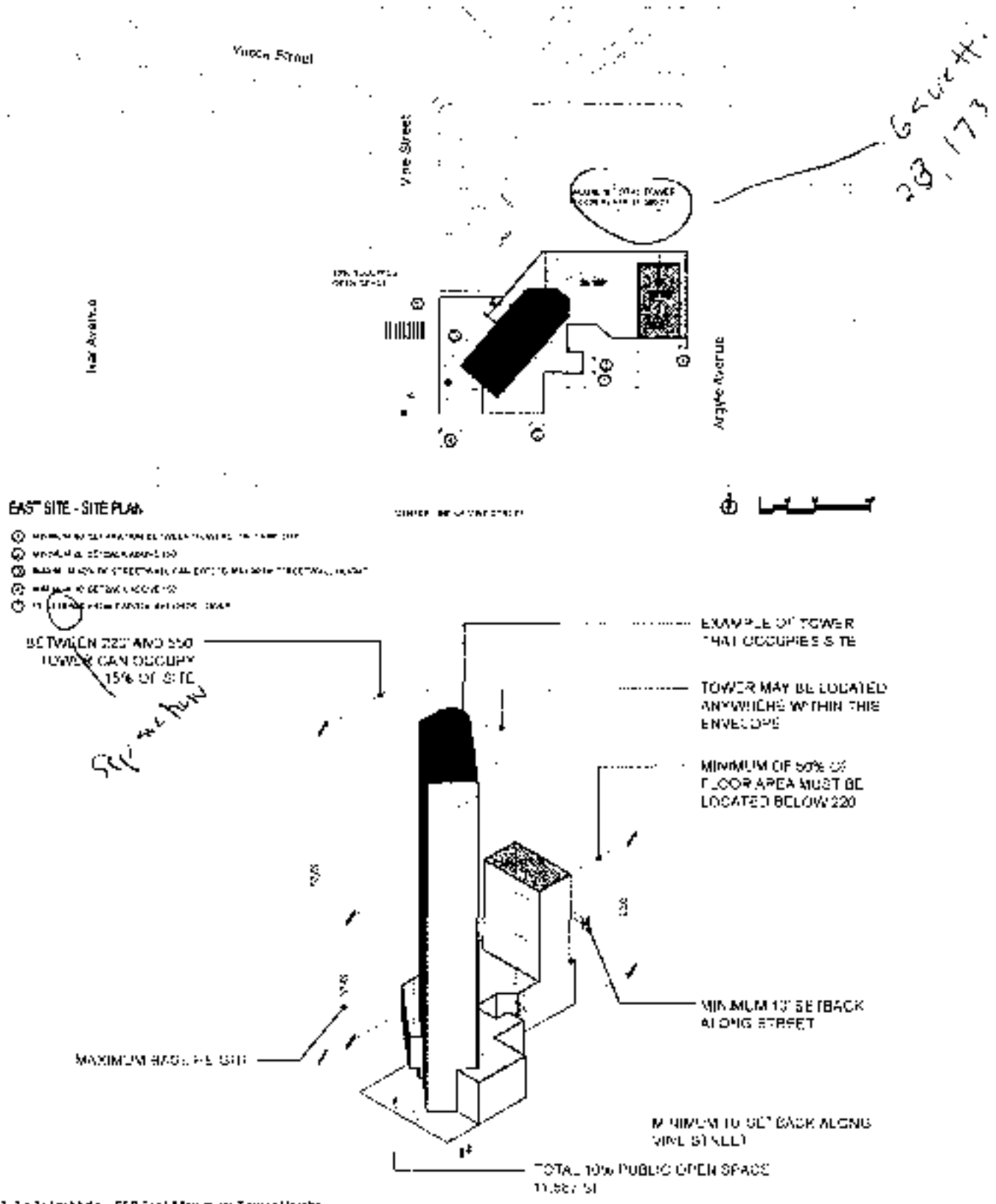
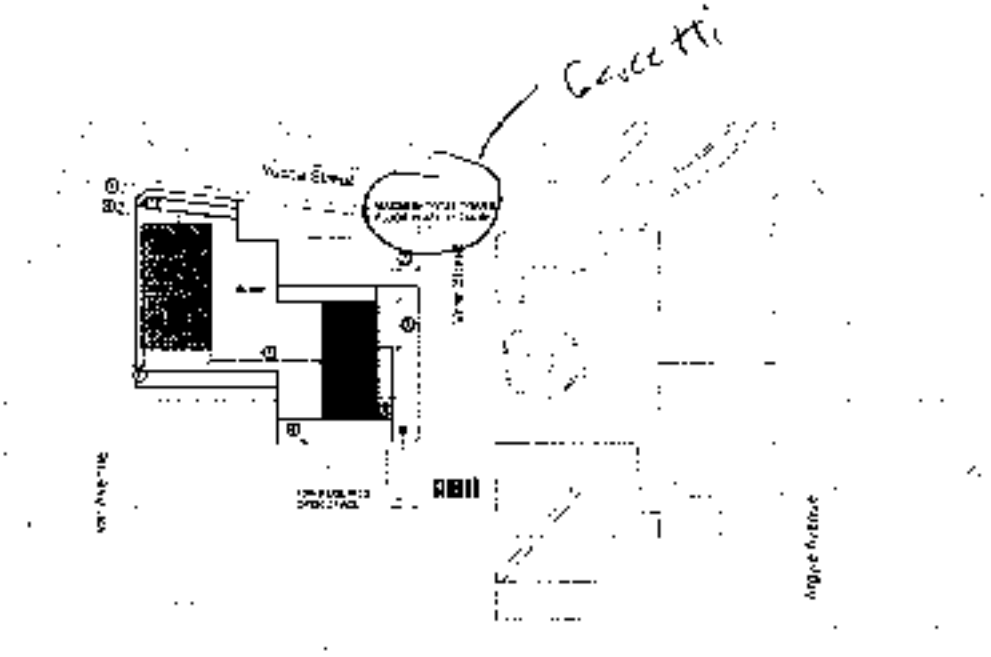


Fig. 6.1.2 c 1: East Site – 550 Feet Maximum Tower Height



WEST SITE - SITE PLAN

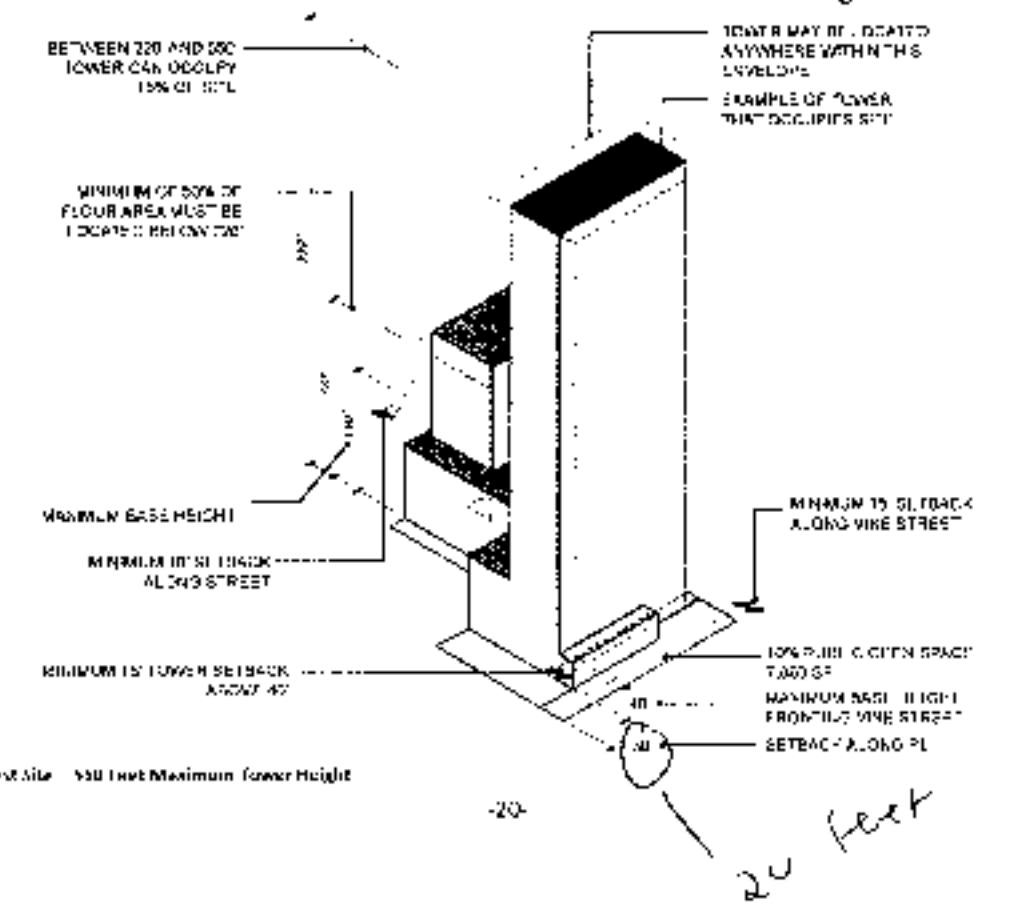
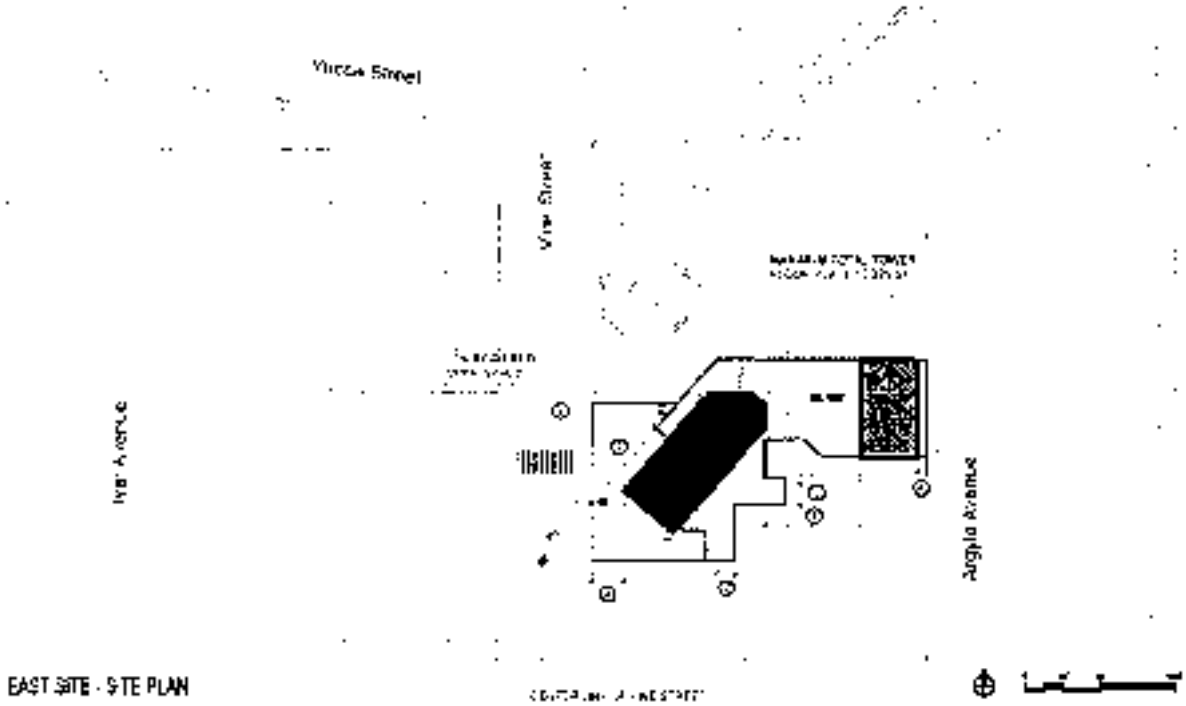


fig. 6.1.2.c.2: West Site - 550 Foot Maximum Tower Height



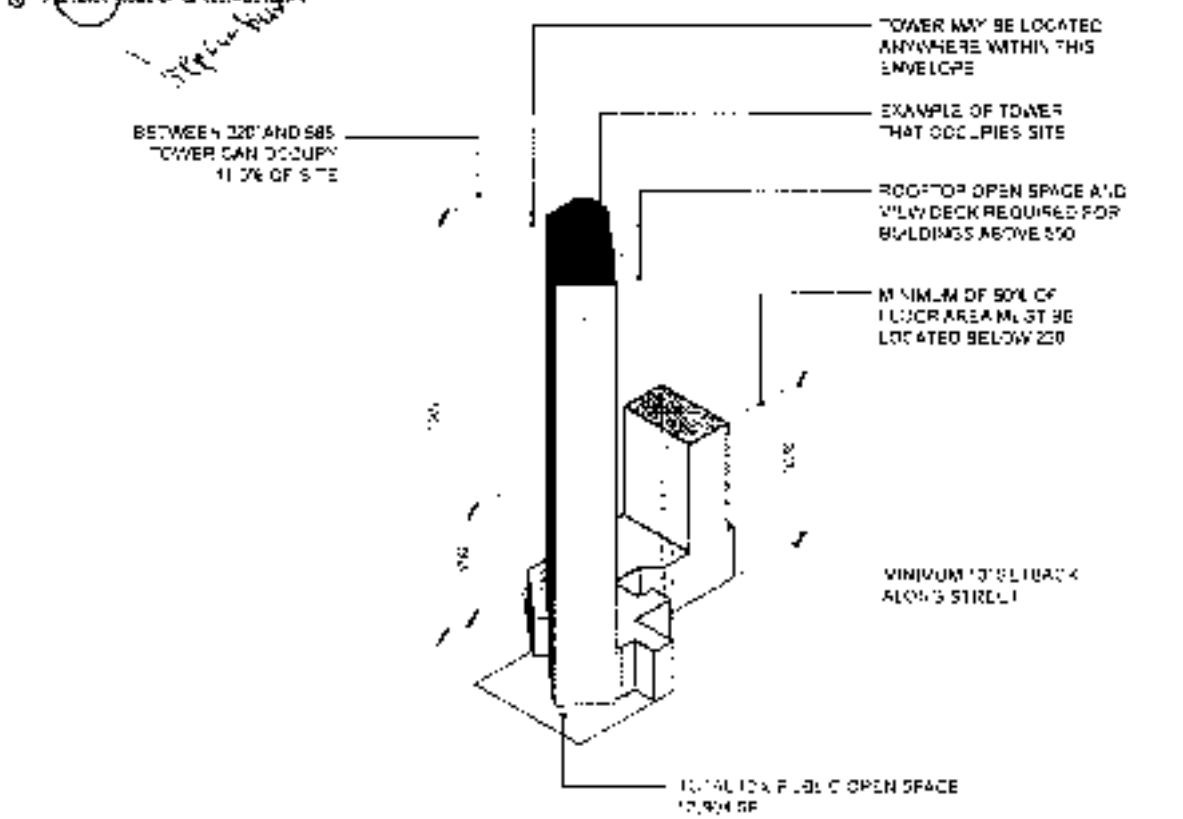


Fig. 4.1.2-1: East Site – 585 Foot Maximum Tower Height

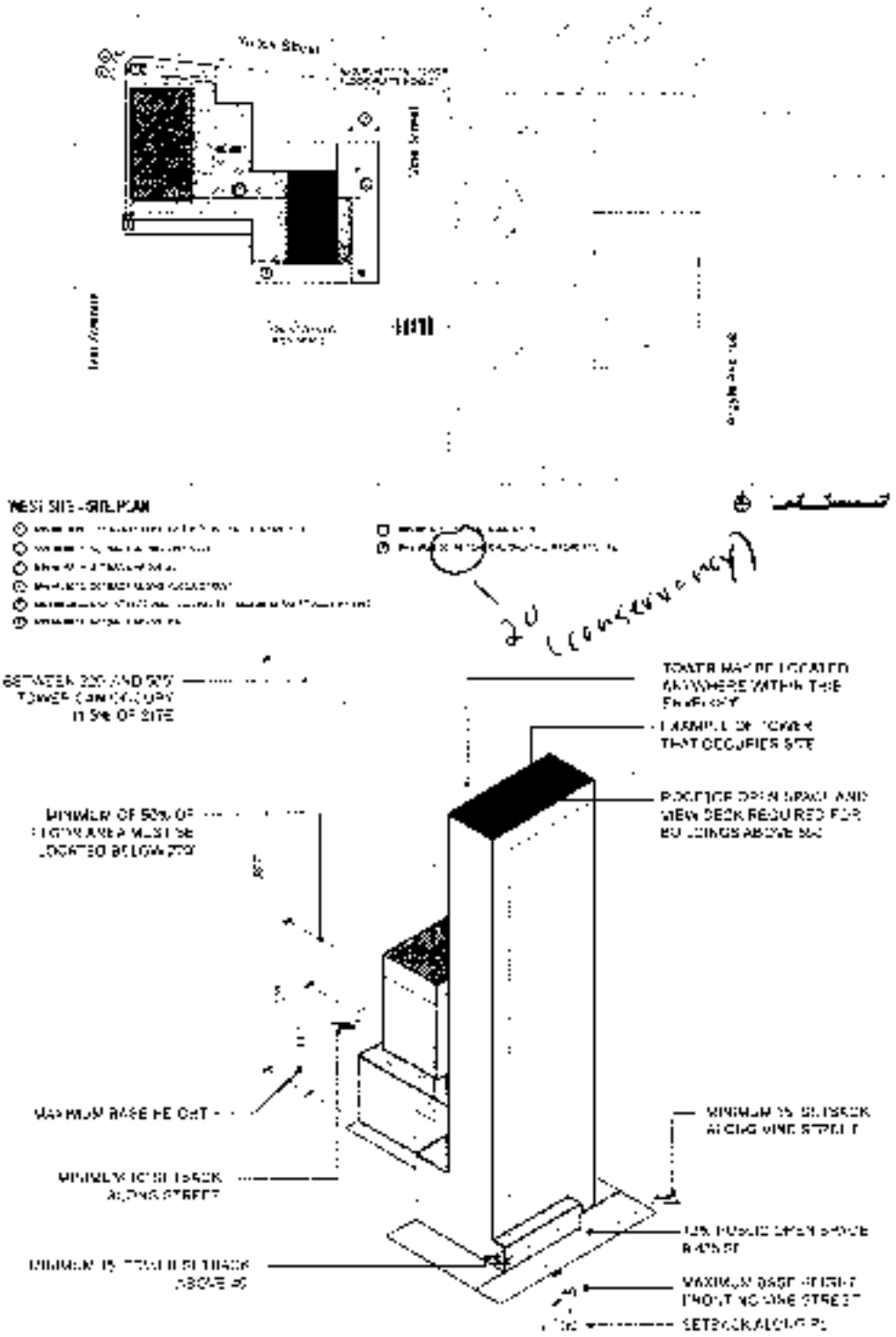


Fig. 6.1.2.d.2 West Side - 585 Feet Maximum Tower Height

6.2 Street Walls

6.2.1 A street wall is a wall or portion of a wall of a building facing a street or a grade level open space. Street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation. The street wall shall have proportions and architectural building details which emphasize and reflect the presence and importance of the pedestrian environment. Moving offsets, fenestration, varied textures, openings, recesses, and design accents are strongly encouraged to ensure there are no un-articulated walls and monolithic roof forms, and architectural elements such as balconies, verandas, and porches that add architectural character are encouraged.

6.3 Street Wall Standards

6.3.1 Location of required street wall

Parcels with a grade level open space: the required street wall shall be located a minimum 10 feet from the property line along Vine Street on the East Site and 15 feet along Vine Street on the West Site.

b. A grade level open space is required for any building fronting Yucca Street with a minimum 10 feet setback from the property line.

c. Parcels or portions of parcels without a grade level open space: the required street wall shall be located on the property line.

6.3.2 Height of required street wall

a. Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b), (c) and (d) below.

b. Street walls fronting Vine Street on the West Site shall be built to a maximum height of 40 feet above curb level except as noted in item (c) below.

c. Street walls fronting Yucca Street shall be built to a maximum height of 30 feet. Building can extend to a maximum height of 150 feet with a 10 foot setback above 40 feet except as noted in item (d) below.

d. 40% of the aggregate width of the required street wall frontage on each street can exceed the maximum street wall height up to the maximum tower height.

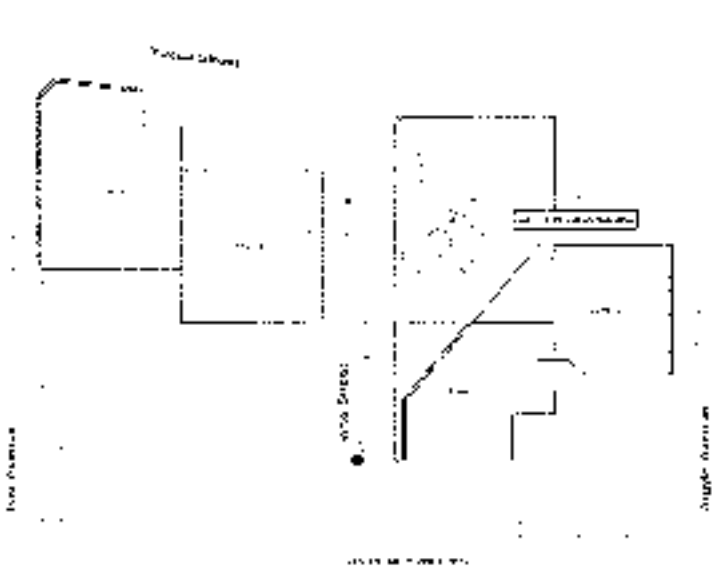


fig 6.3.2: Street Wall

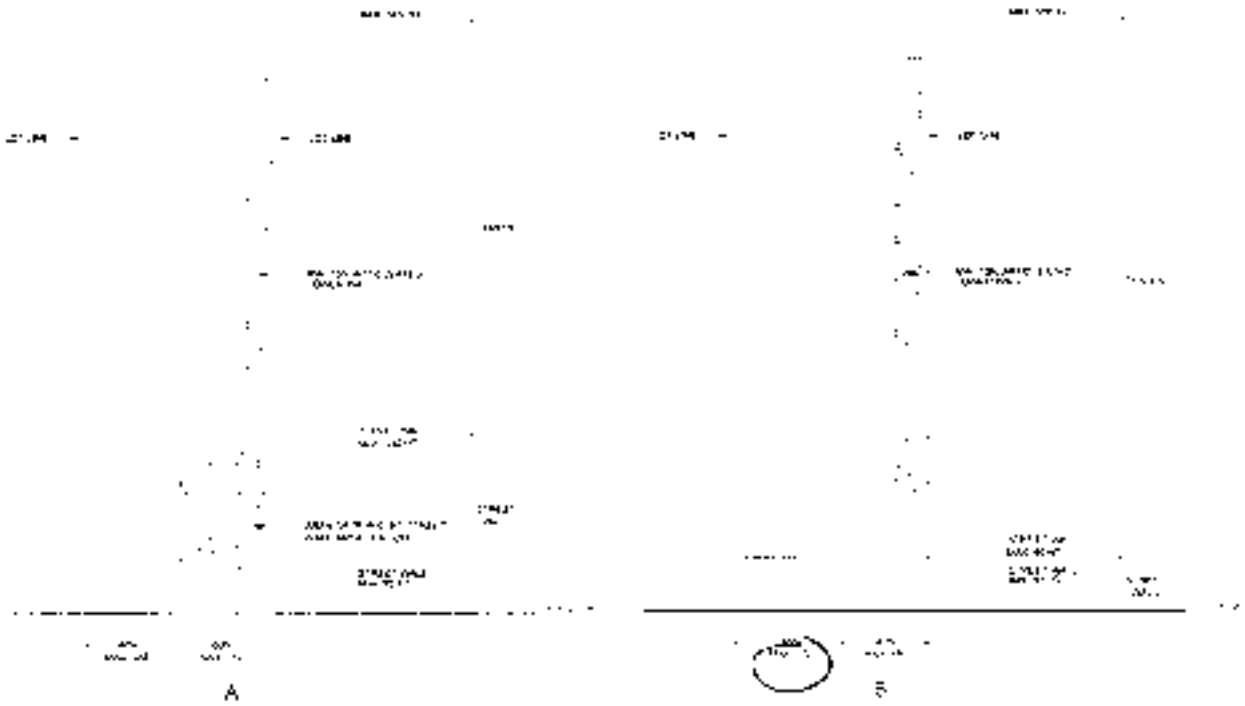


Fig. 6.4.1: Street Wall Articulation

6.3.4 Types of permitted articulation of a required street wall:

a Recess: recesses shall be permitted to a maximum depth of 15'-0".

b Balcony: a balcony may project a maximum of 8'-0" from a required street wall over a grade level open space.

c Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or a similar means.

6.3.4 Other permitted projections: elements which project beyond the property line from a required street wall shall comply with the Building Code.

a Architectural façade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required street wall over a grade level open space.

b. Steps and ramps may project from a required street wall over a grade level open space.

c. Commercial marquees, canopies and awnings.

d. Retail storefronts: may project from a required street wall over a grade level open space by a maximum depth of 5'-0". The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

6.4 Street Wall Guidelines

6.4.1 Pedestrian pass-through areas, public plazas, marquees, canopies, awnings and retail storefronts are permitted within the street wall area.

6.4.2 Pedestrian steps and ramps, entry forecourts, hotel drop-offs and loading entries and pedestrian and vehicular access driveways are also permitted within the street wall area on the Project Site.

6.5 Yard Standards

6.5.1 Yard is an open space other than a court that is unoccupied and unobstructed from the ground upward.

6.5.2 Commercial Use: no front, side or rear yard setbacks are required.

6.5.3 Residential Use:

a. Front Yard: None.

b. Side Yard: Minimum 5 feet, for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 10 feet in width be required.

c. Rear Yard. Minimum 15 feet, for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

6.5 Building Materials and Color Guidelines

6.6 1 The goal of the building materials and colors is to reinforce the character of the Hollywood area and provide a design that is compatible yet avoids any appearance that the building is being historicized. These guidelines will address the façade treatment for both residential and commercial portions of buildings.

a Buildings shall feature long-lived and sustainable materials. The material palette shall provide variety, reinforce massing and changes in the horizontal or vertical plane.

b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

c. Podium levels up to 150 feet will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents.

d. The architecture of the building shall clearly delineate an architectural style, and shall not appear as a simplified version thereof, with appropriate fenestration patterns, architectural features, proportions and materials.

e. The building's skin, especially for towers, shall be primarily transparent, the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.

f In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style. There will be clear contrast between the building's surface material and the building's glazed areas.

g. In general, the overall massing, roof forms, materials, and architectural style of new structures shall provide a variety of forms, depth and texture, and encourage a cohesive character. Building massing shall include a variation in wall planes and height as well as roof forms to promote architectural excellence, a pedestrian friendly environment and take into account the context.

h. To provide visual variety and depth, the building skin shall be layered and designed with a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin shall reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

i Rooftop mechanical equipment screening shall be designed to be integral with the building architecture and the visual impact shall be minimized by using materials that are complimentary or consistent with the building.

j Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

Tower Illustration

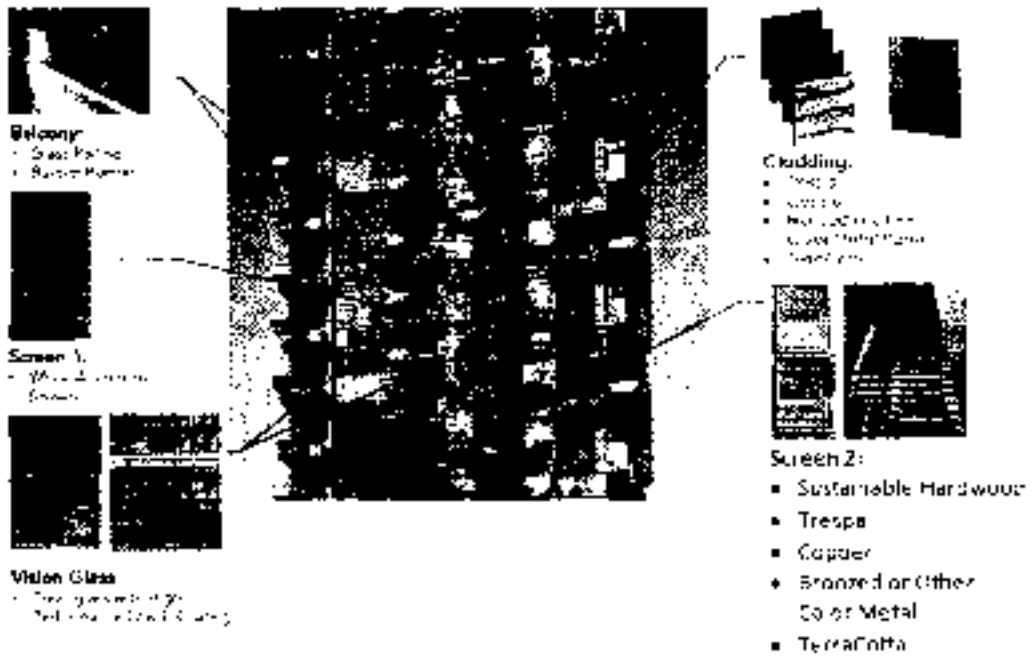


Fig. 6.6.1

Tower Illustration

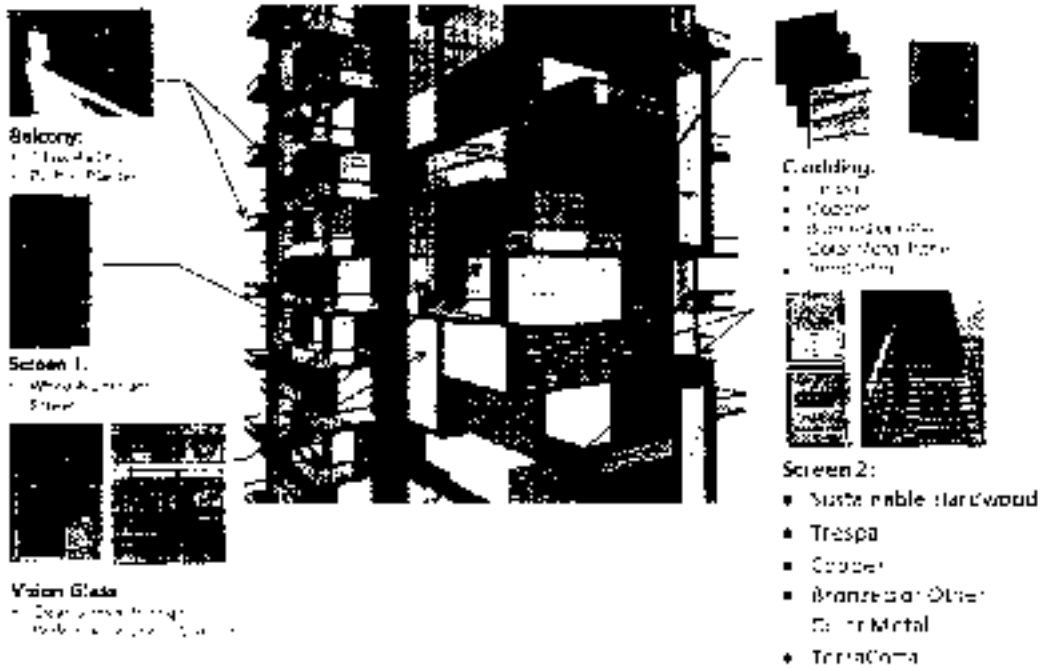


Fig. 6.6.2

c. Examples of acceptable materials are illustrated in Figures 6.6.1 – 2

6.7 Grade Level Standards

6.7.1 The purpose of the grade level standards is to promote pedestrian scaled architecture by regulating street wall massing, articulation and detail, street level entrances and storefront windows and doors, as well as the use of quality materials and decorative details. Architectural features that reinforce the retail character of the ground floor street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and shall be integral to the architecture of the building.

6.7.2 Ground floor height:

a Minimum 20'-0" height measured from floor to ceiling

6.7.3 Building entrances:

a. The primary entrance to a street level tenant space that has frontage along a public street shall be provided from that street. The primary entrance to a tenant space that does not have its frontage along a public street shall be provided from a courtyard, *grade level open space*, or *publicly accessible passageway*. Entries less than 18 inches from the property line shall not be higher than 12 inches above the elevation of the sidewalk; entries greater than 18 inches from the property line shall be within 30 inches of the adjacent grade level along street frontages. Where possible entries shall be marked using architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

b. All retail spaces shall be accessed primarily from a ground floor, single-tenant entry along a street, plaza or passageway. Where reasonably practical given architecture and tenant requirements, access to different tenant spaces shall occur at a maximum interval of 60 feet

c Main building entrances shall read differently from retail storefronts, restaurants and commercial entrances which could include but are not limited to material change, architectural elements or elevation change.

d In addition to the building's required primary entrance(s), there may be ancillary entrances to the building from parking garages.

6.7.4 Ground Floor Glazing

a. Use of clear, colorless and transparent glazing is required within the first 40 feet above curb level.

b. Use of reflective glass is prohibited.

c. Along street frontages with a required build-to-line less than or equal to 18 inches from the property line, glazing shall constitute a minimum of 30% of the area of a building face and shall not exceed 80% of the area of a building face

6.7.5 Arcades

e Arcades in graph will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0-foot candles.

6.7.6 Service and Refuse Requirements

Hotel and Commercial / Office / Retail that abuts an alley

a. Every required loading space shall be located and arranged such that delivery vehicles may be driven upon or into said space from an alley. Such loading space shall have a minimum height of 14 feet and be accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

b Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicular to the alley line

c Loading space shall have a minimum area of 800 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet; a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet, and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

Condominiums (Residential)

d None

Rental (Residential)

e. None

6.7.7 Service and Refuse Guidelines

a. Storage areas shall be provided within the building or site sufficient for the development to ensure that refuse is stored and loaded off street. Refuse storage areas shall be directly and conveniently accessible from a curb cut.

b. Service, utility, and mechanical functions, including retail loading, shall be located in alleys whenever present. When alleys are not present, service functions shall be planned within buildings.

c Service, utility, and mechanical equipment that is visible from the street shall be screened from view with landscaping or enclosures. Back flow and fire standpipes, along with utility box transformers, shall be screened

d All screening devices shall be compatible with the architecture, materials and colors of adjacent buildings

e. Trash and storage enclosures shall be architecturally compatible with the project design and landscaping shall be provided adjacent to the enclosure(s) to screen them and deter graffiti.

f. Trash enclosures and retail loading areas shall be sited to minimize nuisance to adjacent properties.

g. The location of trash enclosures shall be easily accessible for trash collection and should not impede general site circulation patterns during loading operations.

h. Mechanical equipment shall vent to an alley wherever possible.

i. Roof-vent penetrations and mechanical equipment shall be located at least 10 feet from any exterior Building Face.

j. Gutters and downspouts shall be made of galvanized steel, copper (not copper coated), or aluminum.

G.7.8 Storefronts

a. Storefront (residential, retail, restaurant and commercial) requirements shall include frontage along streets and grade level open spaces.

b. Storefronts shall comprise a minimum of 70% of the building's street level façade along Vine Street and 40% along all other streets and be recessed where necessary.

c. Storefront glazing shall comprise a minimum of 60% of the storefront area along Vine Street and 40% glazing along all other streets.

d. All retail space shall have a minimum 12 feet finished ceiling clearance.

e. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet. Storefront sills shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

f. Storefront openings shall be no shorter than 10 feet above the adjoining grade for 90% of the required storefront frontage.

g. Security grilles will be located behind glass and be at minimum 70% open.

h. At grade storefront glazing at, or adjacent to, and/or facing any public right-of-way shall incorporate transparent, clear, colorless glazing with no reflectivity.

i. Awnings shall not obscure storefront signage. Vinyl awnings are not permitted.

6.8 Podium Standards

G.8.1 The purpose of the Podium Standards is to provide a modern interpretation of the historical context of Hollywood by establishing different treatment of the building's base, middle and top

through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

6.8.2 Podiums shall comply as applicable with the minimum setback requirements set forth in Figures 6.1.2a – d.

6.9 Podium Guidelines

6.9.1 Podiums shall have fenestration that establishes a clear pattern on the façade (with special attention paid to facades that are visible from a public street) and that provides depth and additional articulation.

6.9.2 An identifiable break between the building's ground floors and upper floors shall be provided. This break may include a change in material, change in fenestration pattern or similar means.

6.9.3 Podium level windows shall be vertically oriented.

6.9.4 Podium levels shall be predominantly light in color.

6.9.5 An expression band shall be provided at the highest story within the podium.

6.9.6 While blank street wall façades shall be avoided, an exception may be made for integration of public art or an articulated façade that adds scale and interest to an otherwise bland frontage. In these cases, the façade shall be a maximum of four floors high and shall have variation in its surface plane (using cutouts, insets or pop-outs). It shall employ different scales of elements as viewed when seeing the entire building massing.

6.9.7 Louvers and wall openings shall be designed to integrate with building architecture.

6.9.8 Podiums are encouraged as feasible to be set back from frontages to preserve sightlines and promote ground floor open space.

6.10 Street and Sidewalk Standards

6.10.1 The Site is comprised of a variety of public elements that include open spaces, streets and sidewalks. The Hollywood Walk of Fame is an integral element that fronts open spaces on both East and West Sites. Its adjacency to the public realm requires compatibility and cohesiveness.

6.10.2 The combination of landscaped plazas, publicly accessible passageways and landscaped streets and sidewalks creates diversity, and at the same time forms a single unified system. Connections shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

6.11 Screening Standards

6.11.1 Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

6.11.2 Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

7. TOWERS

7.1 Purpose

7.1.1 Towers shall have their massing designed to reduce overall bulk and to appear slender.

7.1.2 Towers shall be designed to achieve a simple faceted geometry and exhibit big, simple moves. They shall not appear overwrought or to have over manipulated elements.

7.1.3 Towers that emulate a more streamlined modern style shall provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.

7.1.4 If a project has more than one tower, the towers shall be complementary to each other and employ a similar yet varied architectural design approach.

7.1.5 Generally, buildings over 150 feet tall (the historic datum for Hollywood) shall not be historicized. They are contemporary forms in the skyline and shall appear as such.

7.2 Projections

7.2.1 The following building elements and operations equipment can project beyond the maximum permitted building height:

a. Roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building.

b. Skylights, towers, steeples, flagpoles, water tanks, silos,

c. Wireless masts, and

d. Solar energy devices and similar structures.

7.2.2 Permitted building elements or equipment in Section 7.2.1 shall be screened as architectural and based on building design except if such projections (e.g., flagpoles or steeples) are part of the architecture or design. The use of creative materials and forms for screening is encouraged.

7.2.3 Enclosures for bulkheads shall not count against building height.

7.3 General Standards

7.3.1 A tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

7.3.2 Distinctive tower crowns and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

7.3.3 Towers shall be set back from the maximum street wall height a minimum of 15 feet except for towers fronting Vine Street on the West site, these towers shall be set back a minimum of 15 feet from the maximum street wall height.

7.3.4 Towers shall be setback on West Site from shared property line with Hollywood Playhouse a minimum of 20 feet above 150 feet

7.3.5 Adherence to minimum setbacks and other separation standards for towers is required as may be applicable to a specific tower and its location within the Project area. Please refer to standards for towers set forth in Figures 5.1.2.a – d.

7.3.6 Tower orientation and placement that enhances important sightlines is encouraged.

7.3.7 In no instance should the tower fronting Vine Street on the East site development have more than a 15% height differential from the tower on the West site development.

7.4 Wall Standards

7.4.1 All walls are required to be articulated.

7.4.2 The following types of articulation of a tower wall are permitted:

a. Recess,

b. Standard balconies may be projecting or recessed or a combination of both; and

c. Bay windows.

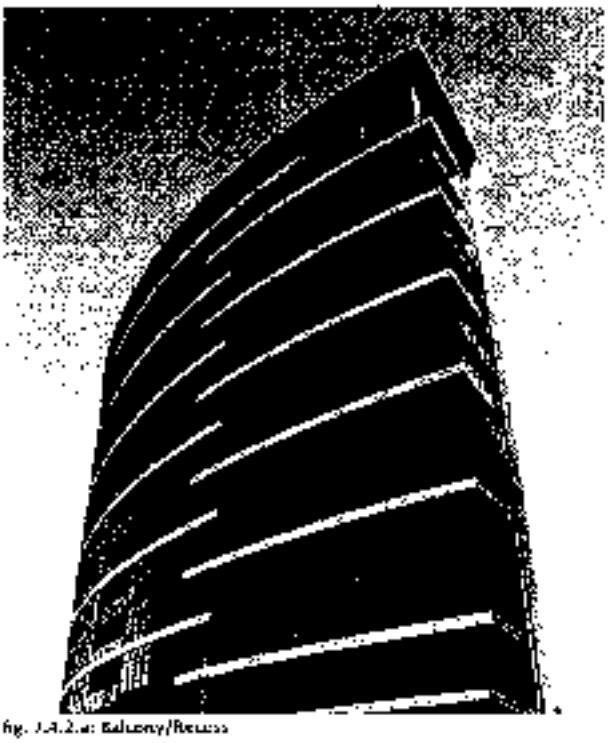


fig. 7.4.2.a: Balcony/Recess

fig. 7.4.2.b: Bay Window

7.4.3 Balcony: a balcony shall be integral to the façade (see Figs. 7.4.3.a and b) and shall not create a relentless horizontal and vertical stacking pattern. Balconies are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations and shall be a minimum 75% transparent. Balconies are encouraged on buildings facing major public spaces such as plazas, passageways and open spaces. Long balconies resembling corridors are prohibited.

Fig. 7.4.3.a: Recess/Balcony: Integral Balcony

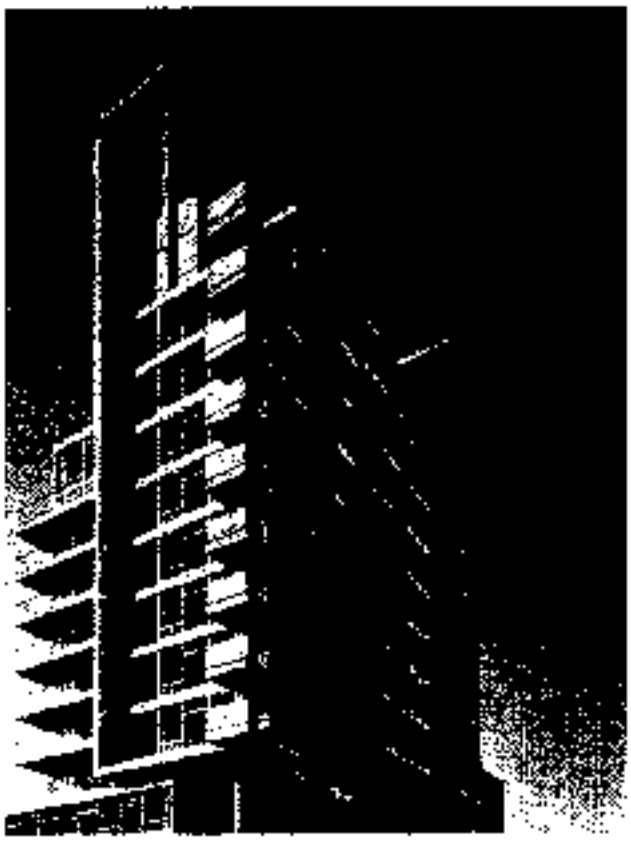


Fig. 7.4.3.b. Bay Window: Integral Balcony

7.5 Spacing Standards

7.5.1 If two towers are located on a single site the towers shall be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

7.5.2 Generally, any portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except for the following which will meet Planning Code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled. See fig. 7.5.2.

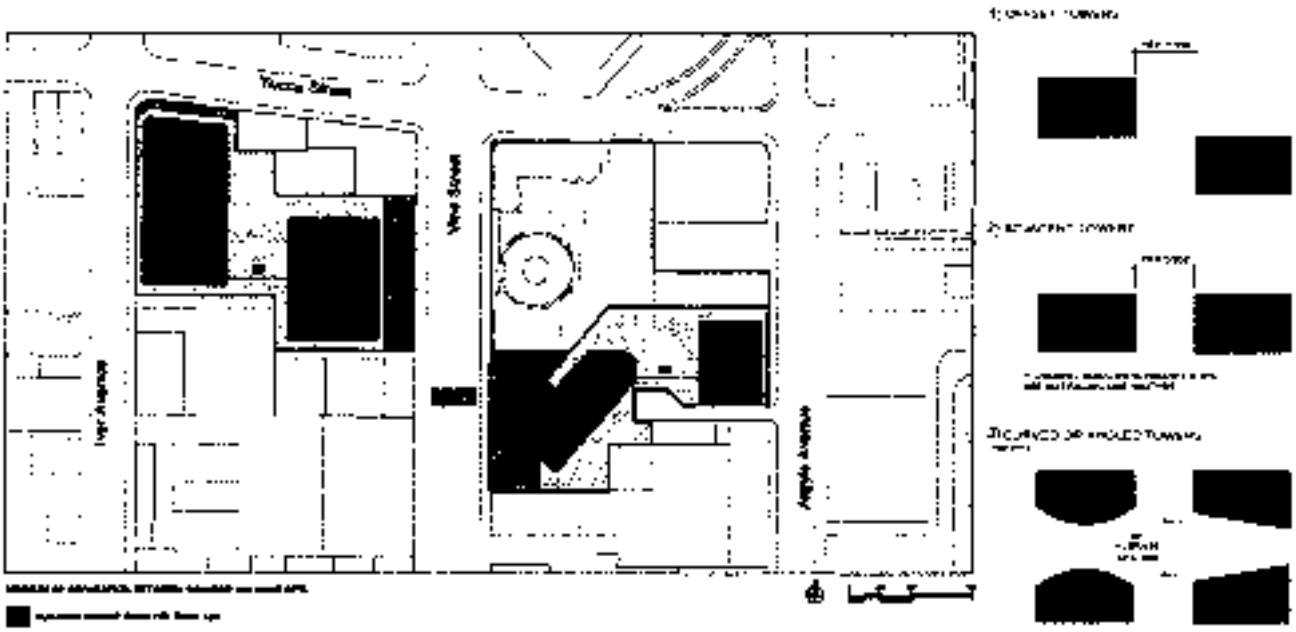


Fig. 7.5.2. Tower Spacing

7.5.3 Since a tower is defined as any building above 150 feet, all buildings above 150 feet shall be spaced at least 80 feet from any portion of any adjacent or separate building on the site.

exceeding 1[illegible] feet, excluding a project within the height range of 150 to 220 feet, as shown in figures 6.1.2.a.1 and 6.1.2.a.2.

7.5.4 Spires, signage, parapets, and mechanical enclosures are excluded from the tower spacing regulations.

7.6 Rooftops Guidelines

7.6.1 Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and be visually attractive when viewed from locations adjacent and above.

7.6.2 For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section 8.5.

7.6.3 All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors.

7.6.4 All obtrusive features such as vents, skylights and cooling units shall be screened from lateral and pedestrian views.

7.7 Parapets, Handrails, Roof Mechanical Equipment Screening Standards

7.7.1 Parapets and handrails shall be finished in a distinctive manner if part of an expression band or expression line.

7.7.2 Materials and design for roof mechanical equipment shall be consistent with the building architecture and shall utilize similar colors and materials as in other portions of the building.

7.7.3 Roof mechanical equipment shall be screened.

8. OPEN SPACE

8.1 Overview

The development of open space is an important objective for the overall Project design. Open space will be used to enhance the experience of the visitor and resident. Open space also will enable important pedestrian linkages and through-block connections for the Project. Grade level open space also will be designed to showcase the Capital Records Building and Jazz Mural and will include design features and outdoor furniture to activate the ground floor amenities.

This section sets forth the standards and guidelines for all open space areas for the Project: areas to be accessible to the public (Grade Level Open Space, Publicly Accessible Passageways and Rooftop Open Space) and areas to be designed for the residential uses (Common Open Space and Private Open Space).

8.2 Grade Level Open Space Standards

8.2.1 Grade level open space is a continuous open space fronting the street and open to the sky. The purpose of a grade level open space is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records Building and accentuate the low scale character.

8.2.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Fig. 8.1.2.a.1 – 2 and 8.1.1)

8.2.3 An additional 3% of open space (total 8%) shall be required for buildings between 221 feet and 400 feet. (See Fig. 8.1.2.b.1 – 2 and 8.1.2)

8.2.4 An additional 5% (total 10%) of open space shall be required for buildings between 401 feet and 550 feet (See Fig. 8.1.2.c.1 – 2 and 8.1.3)

8.2.5 An additional 7% (total 12%) of open space shall be required for buildings taller than 550 feet. (See Fig. 8.1.2.d.1 – 2 and 8.1.4)

8.2.6 Location

a. East Site: adjacent to the Jazz Mural and Capitol Records Building, West Site: across from the Capitol Records Building along Vine Street and along Yucca Street.

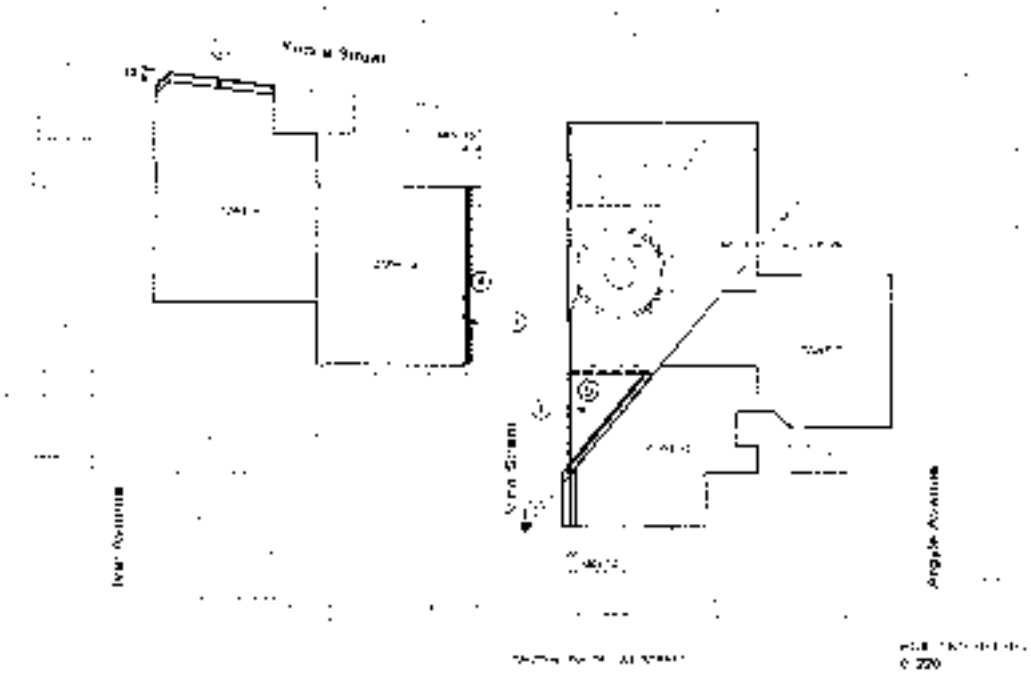
b. Minimum depth: no horizontal dimension less than 10 feet when measured perpendicular from any point on each of the boundaries of the open space area. Open space on West Site fronting Vine Street shall have a horizontal dimension of no less than 15 feet when measured perpendicular from any point.

c. On West Site, open space must occupy the area to the west of a line struck at 40 degrees from center line of Vine Street ROW at alignment with the southern most property line and a minimum 10' setback from the southeast corner of the Capitol Records Building. (See Figs. 8.1.1 – 4)

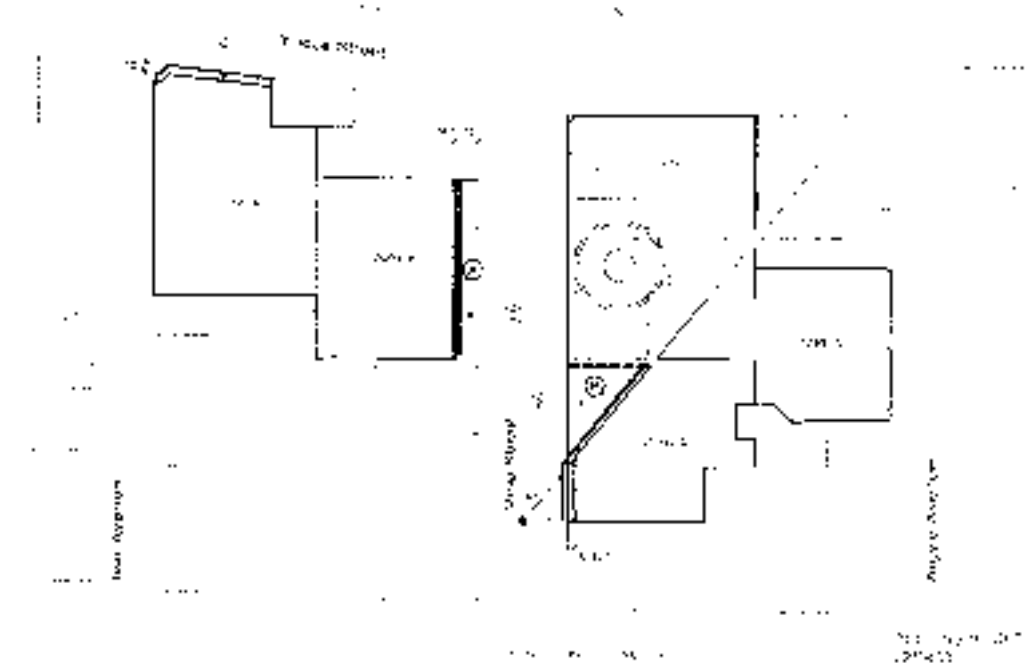
8.2.7 – Section 8.3.4 through 8.3.10 (excepting 8.3.4c) shall apply to grade level open space.

Figs 8.1.1 – 8.1.4: Grade-Level Open Space

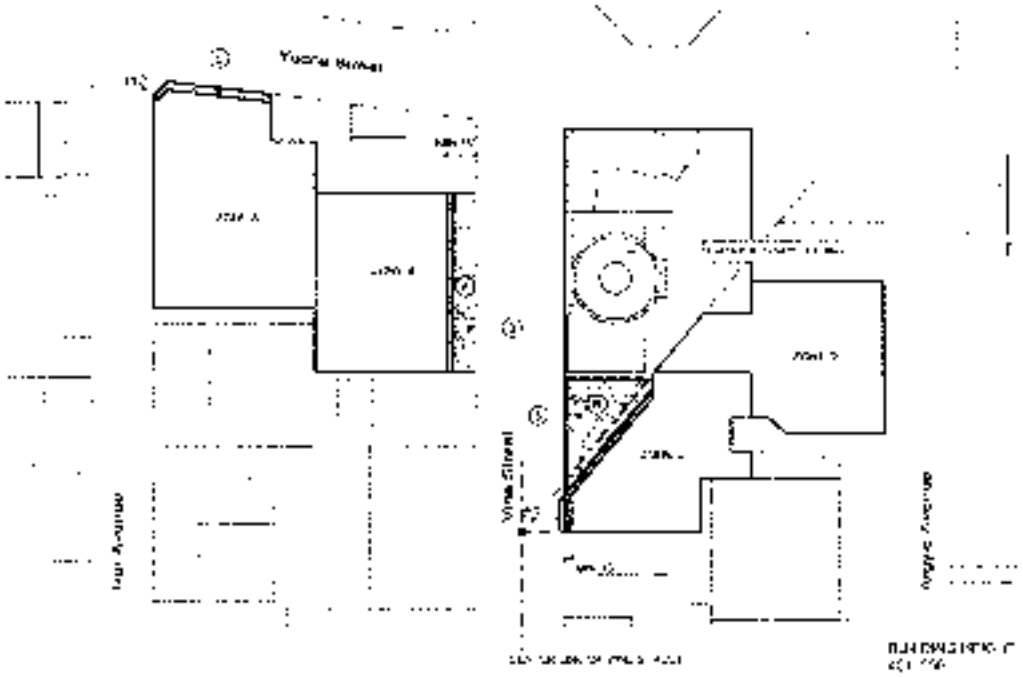
figs 8.1.1 Open Space Requirements for Maximum Building Height at 220 Feet



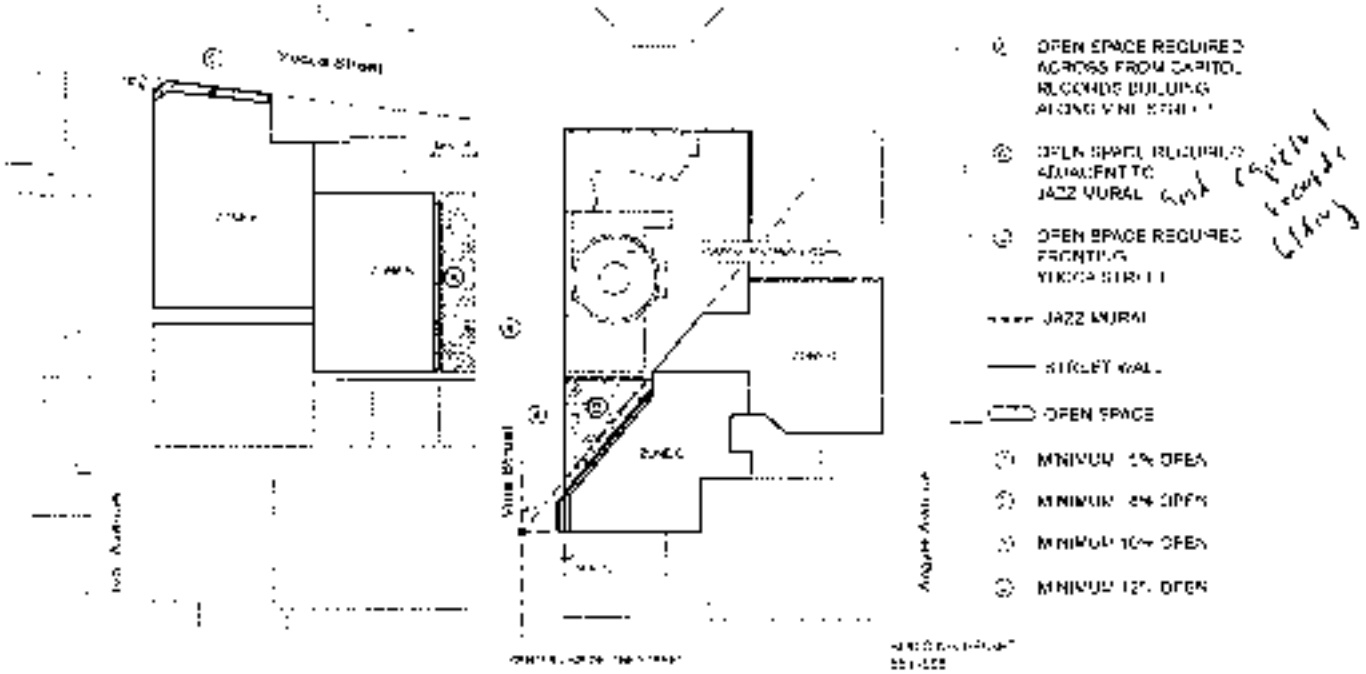
figs 8.1.2 Open Space Requirements for Maximum Building Height at 400 Feet



Figs 8.1.3 Open Space Requirements for Maximum Building Height at 350 Feet



figs 8.1.4 Open Space Requirements for Maximum Building Height at 585 Feet



8.3 Passageway Standards

8.3.1 *A publicly accessible passageway* is a continuous through block public connection between two parallel streets, located on privately owned land. The passageway may be either enclosed or open to the sky or a combination of both.

8.3.2 Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

8.3.3 Location and Size standards:

a The major portion of *a publicly accessible passageway* is the largest area of the *passageway* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total passageway area and shall not be less than 20'-0" wide.

b Minor portions of *publicly accessible passageway* are secondary areas that allow for additional flexibility in the shape and configuration of a passageway. Minor portions shall not occupy more than 25 percent of the total area of the *passageway*. The minor portion shall have a minimum width of 10 feet.

c. The minor portion must be directly adjacent to the major portion.

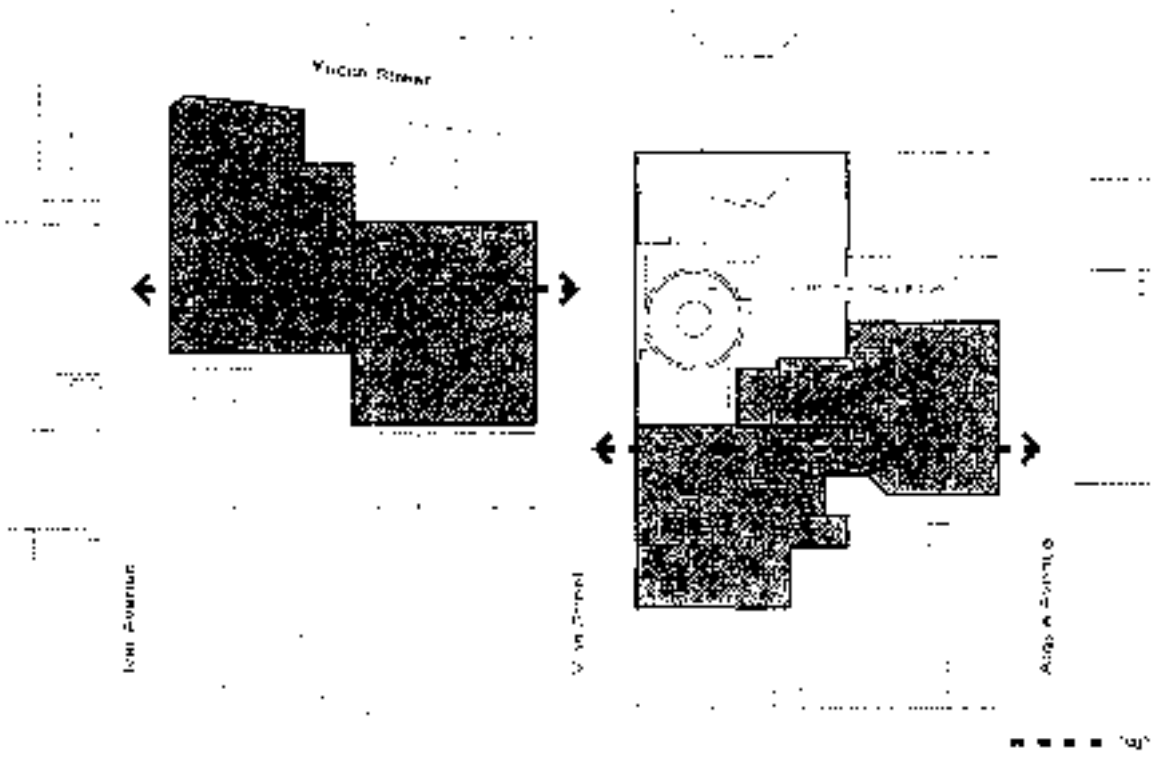


fig. 8.3.1: Publicly Accessible Passageway

8.3.4 Permitted Obstructions:

a. The minimum percentage of *publicly accessible passageway* area to be open to the sky (East and West Sites combined) shall be as follows:

(i) Development with maximum building height of 150 feet: 0%

(ii) Development with maximum building height of 220 feet: 20%

(iii) Development with maximum building height of 400 feet: 30%

(iv) Development with maximum building height of 550 feet: 40%

(v) Development with maximum building height of 585 feet: 50%

b. Permitted obstructions within the major portion of an open air *publicly accessible passageway* are any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open-air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions, balconies and bay windows; awnings, canopies and marquees, stairs, ramps

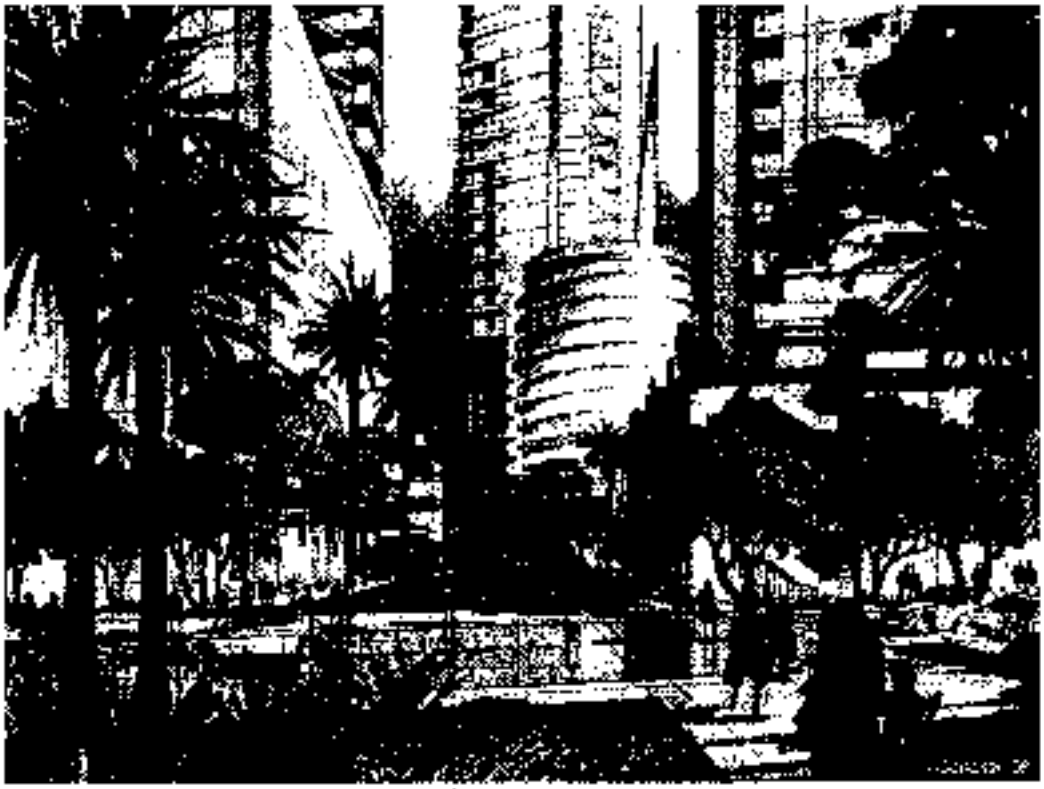


Fig. 8.3.4. View from Argyle Avenue Along PAP Towards Capitol Records

and bollards.

8.3.5 Kiosk.

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Building and Safety in conformance with the Building Code. Kiosks, including roofed areas, shall not count as floor area, exceed 3% of the total area of the *publicly accessible* passageway, or occupy an area of more than 250 square feet.

b. A kiosk may be freestanding or may be attached on only one side to a wall of the building.

c. Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, and food preparation for open air cafes, flower stands or public service/information booths.

d. All kiosks greater than 250 square feet are permitted but will count as floor area.

8.3.6 Open-Air Café

a. Where an open-air cafe is provided it shall be an unenclosed restaurant or open-air seating for an enclosed restaurant, eating, or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies.

b. An open air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the *publicly accessible passageway*. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers.

c. An open-air cafe may occupy an aggregate area not more than 20% of the total area of the *publicly accessible passageway*. No cooking equipment shall be installed within an open-air cafe. Cooking equipment may be contained in a kiosk adjoining the open-air cafe. An open-air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

8.3.7 Service through windows.

a. Outdoor eating services or uses occupying kiosks may serve customers on the *publicly accessible passageway* through open windows.

8.3.8 Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas.

a. No building refuse storage areas or refuse storage from a kiosk or open-air café are permitted on any *publicly accessible passageway*.

b. No exhaust vents are permitted on any publicly accessible passageway or on any building wall of the development fronting upon the passageway except where such vents are more than 10' 6" above the level of the passageway.

8.3.9 Frontages

a Mandatory allocation of frontages for permitted uses: at least 40% of the total frontage of building walls of the development fronting on a *publicly accessible passageway* shall be allocated for occupancy by permitted retail, restaurants and cultural uses.

b. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the *publicly accessible passageway* with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

8.3.10 Maintenance:

a The building owner shall be responsible for the maintenance of the *publicly accessible passageway* including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the passageway and in the street sidewalk area adjacent to the passageway.

b. Litter receptacles shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of *publicly accessible passageway* area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of *passageway* in connection with outdoor eating services or other uses permitted on *passageway* which generate litter.

8.4 Roof-top Open Space

8.4.1 The Project shall include roof-top open space.

8.4.2 Roof-top open space shall include an observation area (i.e., viewing deck) accessible to the public.

8.4.3 The hotel, if developed, shall include an observation area (i.e., open space viewing area) accessible to the public.

8.4.4 The hotel observation area (i.e., viewing area), if developed, shall satisfy the requirement in section 8.4.1 above.

8.4.5 Roof-top open space may include a café.

8.5 Residential Common Open Space

8.5.1 Common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children, and to be visually attractive when viewed from apartments adjacent and above. The publicly accessible passageway cannot be used to meet the residential common open space requirements.

8.5.2 Common Open Space Standards.

a. Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms, 125 square feet for each unit having three habitable rooms, and 175 square feet for each unit having more than three habitable rooms.

b. Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common areas as further defined and regulated herein.

c. Open space shall be open to the sky and have no structures that project into the common open space area, except as permitted in the Zoning Code.

d. Common open space shall be readily accessible to all the residents of the Site.

e. Common open space shall have a minimum area of 400 square feet with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

f. Common open space shall constitute at least 50% of the total required usable open space in the built development.

g. Common open space areas shall incorporate recreational amenities including but not limited to swimming pools, saunas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

h. Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use may be considered as common open space.

i. Refer to LAMC 12.21 G for additional open space requirements.

8.6 Residential Private Open Space

8.6.1 A private open space area is an area contiguous to and immediately accessible from a single dwelling unit.

8.6.2 Residential Open Space Standards.

a. Private open space shall contain a minimum area of 50 square feet, of which no more than 5ft square feet per dwelling unit shall be attributable to the total required usable open space.

b. Private open space shall have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

c. Private open space shall provide a minimum eight foot vertical clearance under any projection, except as permitted in the Zoning Code.

d. That portion of a balcony which extends or projects into a required front yard in compliance with Zoning Code may qualify as usable open space provided it meets each of the above specified requirements noted in items a - c.

9. LANDSCAPE

9.1 Grade Level Open Space Standards

9.1.1 Planting requirements. A minimum of 10% of grade level open space shall be landscaped with softscape or water features.

9.1.2 Landscape area(s) shall be planted with seasonally diverse plant material and 30% of all landscaping shall be California Natives or drought tolerant.

9.1.3 The landscaped portion of open space may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.1.4 The minimum soil depths for planting are:

a Trees: 42"

b Shrubs: 30"

c Lawns, ground cover: 18"

9.1.5 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.1.6 Permitted obstructions: The following are permitted obstructions which may occur in the *grade level open space*:

a Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining, and retail storefronts.

9.1.7 Open-air *publicly accessible* passageways are not to be included in the grade level open space requirements.

9.2 Common Open Space Standards

9.2.1 A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

9.2.2 At least one 36-inch box tree for every four dwelling units shall be provided on-site and may include street trees in the parkway, sidewalks adjoining the property, open space, *publicly accessible* passageways and common roof decks.

9.2.3 For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

9.2.4 All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

Fig. 9.3.a. Movable Seating

Fig. 9.3.b. Open Air Café

9.3 **Standards For Open Air Portions of Publicly Accessible Passageway**

9.3.1 The landscaped portion of open air passageways may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.3.2 The minimum soil depths for planting are:

a. Trees: 42".

b. Shrubs: 30".

c. Lawns, ground cover: 18".

9.3.3 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.3.4 Planting requirements.

a. A minimum of 10% of open air publicly accessible passageway shall be landscaped.

b. For each 400 square feet of landscaped area there shall be at least one (1) major shade tree or two (2) minor ornamental trees.

c. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

fig. 4.6 Seating Standards

9.8.5 Seating

a. There shall be a minimum of one linear foot of seating for each 500 square feet of *publicly accessible passage way* excluding the area of an open-air cafe.

b. One seat shall equal two linear feet.

c. Not more than 50% of the linear seating capacity may be in moveable seats. Seating shall meet the following standards:

(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons, a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count as double seating provided there is access to both sides.

(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.

(iii) The tops of walls or ledges but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

d. Moveable seating or chairs, excluding seating at open-air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open air cafes do not count toward meeting the seating % requirements.

9.4 Tree Planting Guidelines

9.4.1 It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

9.4.2 Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

9.4.3 Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree-planting pattern.

9.5 Lighting Standards

9.5.1 Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

9.5.2 Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade level open space and open *publicly accessible passageway*.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d Steps and ramps will be lighted with a minimum of 1.0 foot candles on a horizontal plane.

e Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

f All exterior lighting shall be shielded or directed toward the areas to be lit to limit spill over onto off site uses.

g. Light quality shall not be harsh, glaring, blinking or shed beyond property boundaries.

9.5.3 Responsibility for maintenance

a. The Building Owner shall be responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighting element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

b. Additional lighting such as plant lighting, covered lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the Building Owner.

9.5.4 Lighting for areas located inside the lot line and/or set back from the street, such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

9.5.5 Lighting for above grade parking garage facilities shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

9.6 Publicly Accessible Passageway Lighting Standards

9.6.1 A *publicly accessible passageway* shall be illuminated throughout with an overall minimum average level of illumination of not less than 1.0 maintained foot candle (lumens per square foot) on the horizontal plane at grade.

9.6.2 Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

9.7 Continuity of Design

9.7.1 Design elements and architectural clues that reinforce where appropriate continuity between open and enclosed spaces at grade level is encouraged. Continuity of design may reinforce pedestrian circulation and support the Project's way-finding features.

9.7.2 Where possible, materials, lighting, site elements and landscape shall be similar between different open and enclosed public spaces at the grade level.

10. PARKING

10.1 Automobile Standards

10.1.1 Base Standards

The following standards shall apply for the base level of parking to be provided as the minimum for each use in the project area. The Regulations set forth below incorporate the parking requirements in the LAMC, where applicable, and supersede the LAMC requirements for development in the Development Agreement area.

a Commercial / Office / Retail:

Two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot. The Regulations incorporate applicable parking requirements in the LAMC as set forth below.

b. Sports Club:

Two parking spaces for every one thousand square feet of combined gross floor area.

c. Hotel

One parking space for each individual guest room or suite of rooms for the first 30;

One additional parking space for each two guest rooms or suites of rooms in excess of 30 but not exceeding 60; and

One additional parking space for each three guest rooms or suites of rooms in excess of 60.

d. Condominiums (Residential):

Two parking spaces per dwelling unit

One quarter parking space per dwelling unit for guest parking

e. Rental (Residential):

One parking space for each dwelling unit of less than three habitable rooms, one-and-one half parking spaces for each dwelling unit of three habitable rooms; and two parking spaces for each dwelling unit of more than three habitable rooms.

f Combination of Uses

Where there is a combination of uses on a lot, the base number of parking spaces required shall be the sum of the requirements of the various uses.

10.1.2 Shared Parking

a Shared parking may be applied to the Section 10.2.1 base rates for the Site when the uses have different parking requirements and different demand patterns on a 24 hour cycle or between weekends and weekdays. The intent is to maximize efficient use of the Site by matching parking demand with complimentary uses. The calculation of the parking requirements shall be based on a detailed assessment prior to its construction.

b. Calculating Shared Parking

(i) The individual land use parking requirements for each component of a phase of development shall be calculated from Section 10.2.1 above to establish the "Base Demand."

(ii) For parking spaces that are to be shared between uses, the calculated minimum parking requirement for the Site, including that new phase of construction, is to be adjusted from the Base Demand based on the procedures in *Shared Parking*, Urban Land Institute, 2nd Edition (2005) or another source as determined by the Director of Planning.

10.2 Additional Regulations

10.2.1 The automobile parking spaces required shall be provided either on the same lot as the use for which they are intended to serve or on another lot located within 750 feet of the lot; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

10.2.2 Curb cuts for driveways shall be located no closer than 50 feet to the intersection of two streets unless approved by the Department of Transportation.

10.2.3 Access driveways to parking facilities not at signalized intersections shall not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

10.2.4 Parking and loading access shall be shared where feasible.

10.2.5 Priority placement within parking structures shall be given to bike parking, car-share parking, and other alternative ride vehicles.

10.2.6 Pedestrian entrances to all parking shall be directly from the street, except that underground parking garages may be entered directly from a building.

10.3 Screening

10.3.1 Above grade parking for the first 20 feet shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible and shall be designed to blend in with the form and massing and to look like an integral part of the building, with the use of windows and/or cladding, or by landscaping, or green screens, or a combination thereof. The interior of a parking structure shall be designed to be screened from the view of streets and sidewalks.

10.4 Bicycle Standards

10.4.1 Bicycle parking shall be provided per Ordinance No. 182386

10.5 **Transportation Demand Management Plan**

10.5.1 The Project shall incorporate a comprehensive transportation demand management plan.

10.5.2 The transportation demand management plan shall set forth best practices that relate to the Project Site and the Project's building design features in order to:

a. Promote bicycle and pedestrian circulation within the Project Site.

b. Promote alternative modes of transportation.

c. Create pedestrian linkages to public and private amenities outside the Project Site.

d. Provide convenient and attractive onsite pedestrian linkages for routes to the Metro Red Line Station at Hollywood Boulevard and Vine Street.

e. Provide adequate parking, but provide incentives to tenants and residents to utilize alternative modes of travel. The incentives shall include bicycle facilities, car sharing, discounted subway passes, and parking spaces as an only occasional part of all lease and sale agreements.

11. SIGNAGE

11.1 Hollywood Signage Supplemental Use District

Signage shall be subject to Ordinance No. 182340, Hollywood Signage Supplemental Use District (Amended) pursuant to Section 13.11 of the Los Angeles Municipal Code.

11.2 Modification to Guidelines

Notwithstanding Section 11.1, high-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted. See fig. 11.2.

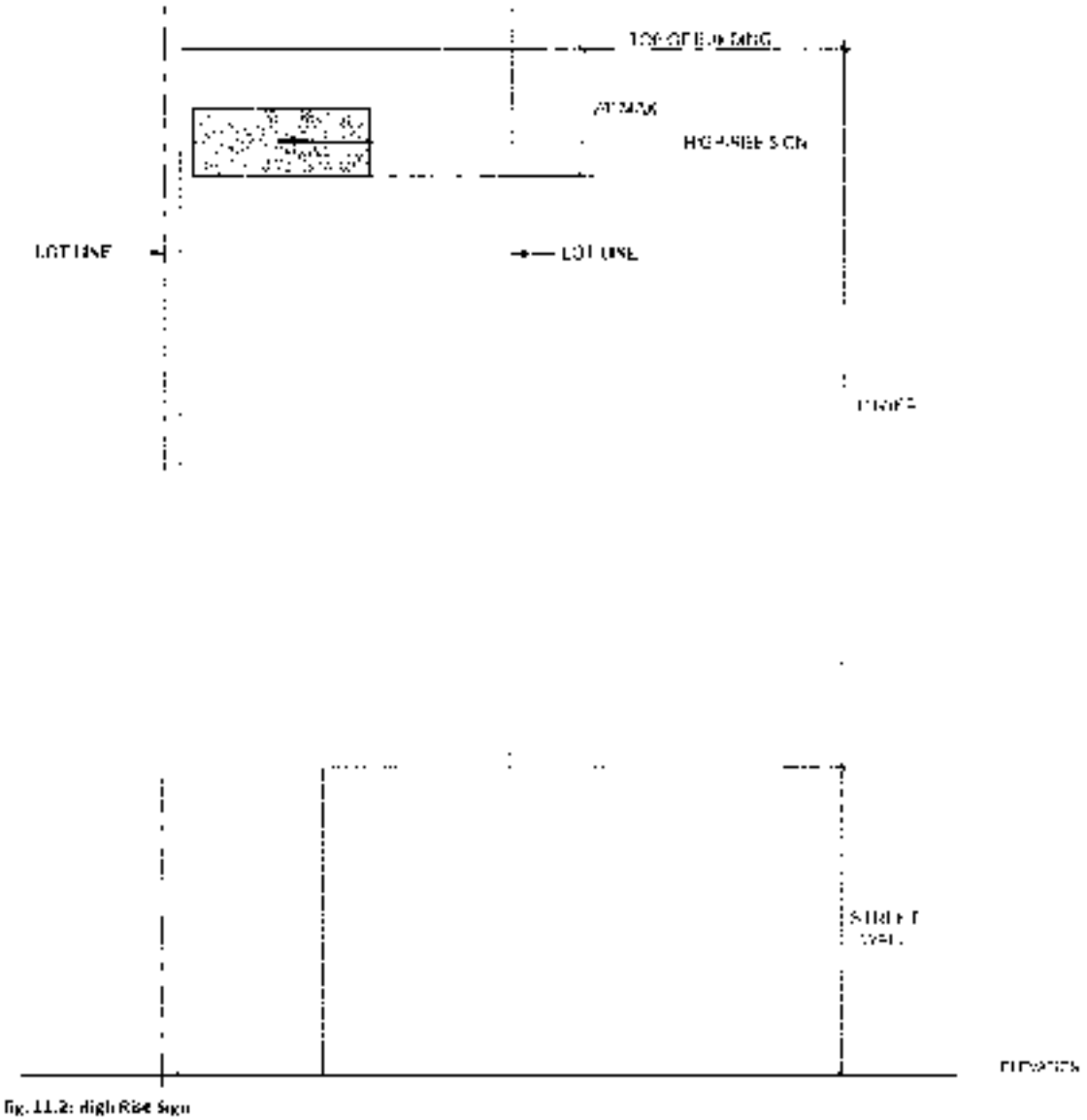


Fig. 11.2: High Rise Sign

12. SUSTAINABILITY

12.1 Non-Residential Projects

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds enumerated above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

12.2 Other Projects

The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

13. DEFINITIONS

Awning: glazing or fabric on metal frame structure supported entirely by the building to provide weather protection at doors, windows and/or storefronts; may be retractable.

Base: the lower portion of a building located at or within 150' above curb level.

Canopy: glazing, fabric and/or metal structure with vertical supports located on the sidewalk to provide weather protection at a building's primary entrance.

Expression band: a distinctive linear architectural element occurring on the building base facade at the highest floor. The band shall be contrasting in color, texture, material and/or fenestration from the adjacent building base facade. Projections may occur within an expression band.

Grade level open space: a continuous open space fronting the street and open to the sky.

Maximum building height: the maximum height permitted, measured from the adjacent street curb level.

Maintenance: the ongoing repair, care and upkeep of a property.

Open space use: active and passive recreational areas accessible to the general public, except as noted herein. Open spaces can occur in publicly accessible passageways, grade level open space, residential common open space and residential private open space which are defined herein.

Preservation: in conformance with standards and guidelines of the Secretary of the Interior, the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property.

Publicly accessible passageway: a continuous through-block public connection between two parallel streets, located on privately owned land and designated for and designed to encourage public pedestrian circulation and other appropriate public uses.

Rehabilitation: in conformance with standards and guidelines of the Secretary of the Interior, the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values.

Required street wall: a wall or portion of a wall of a building facing a street or grade level open space which must be built to a maximum height above curb level.

Required street wall articulation, aggregate width of: the sum of the maximum widths of all segments of required street wall articulation on a street at the level of any story. The width of a required street wall articulation is measured in plan as the width of the street line from which perpendicular lines may be drawn to such required street wall articulation.

Residential common open space: a "rear yard" providing light and air to apartments or the interior of a parcel located at any story above curb level.

Residential private open space: open space that is contiguous to and immediately accessible only from a single dwelling unit.

Setting: the area or environment in which a historic property is found. It may be an urban or suburban neighborhood or a natural landscape in which a building has been constructed. Elements of setting can include the relationship of buildings to each other, setbacks, views, sidewalks, and street trees.

Storefront: the architectural facade, including doorways, of any tenant-leased premise perimeter adjacent to public circulation areas. Storefronts refers to all permitted residential, retail uses including retail, service, restaurants and cultural establishments and commercial uses, including but not limited to hotels and sports clubs.

Tower: the portion of a building located above 150' above curb level.

Transparency: architectural elements that can be seen through or allows light to emit through, including but not limited to glass, grills and wire mesh.

Notes:

All images and figures cited in the Regulations were prepared for exclusive use by Millennium Hollywood, LLC unless otherwise noted.

صلى الله عليه وسلم

Alfred Fraijo Jr.
Allen Matkins
Allen Matkins Leck Gamble
Mallory & Natsis LLP
Los Angeles, CA 90067-3869
Phone: 213-622-5555
Fax: 213-620-8816
www.allenmatkins.com

Allen Matkins

MARATHON COMMUNICATIONS, INC.
Stockholder Communication

RICHARD LICHTENSTEIN
Personal

- Client
- Matter
- Phone
- Email

7/21/09 ①

- Millennium - Capitol Records

585 ft tall tower

over majority of two blocks

2 one drive to HD2 61
variances: outdoor dining above first floor
open health club on 2
parking sharing ZAD

want to get entire package approved at one time
CR - do equivalency. Swap retail, hotel, office, etc
Wexford did not FAR + they could move
air rights in any way

- equivalency - need decision on DA
Flexible massing - DA OK -
Design Review - DA OK
Development agreements can be entitlements
overlay legislation - does it allow this?
the agreed public benefits can be anything
don't "mandate" ordinance once done
adopt DA by overlay ordinance
can't search for DA on CFI index
need to adopt ordinance?
need new text to do this.

(2)

1120

DA - ~~max~~ Max massing
Max/Min massing
Phasing

Westfield - did model - rendering
concept designs

planned unit development ordinances - rather than doing a new development agreement could still be accompanied w/ DA
would be consistent w/ general plan
no larger district

12.04 - PUD ordinance intended to be used when
- 3 projects meet

A Bell wants PUD to be as small as single bldg
to deal w/ multiple entitlements

need to be involved w/ PUD ordinance?

is PUD a catch all?
what about catalog things you've missed?

Wilshire Grand wants higher FAR in downtown
can't go higher than 13:1
City council can do by ordinance to
add change. Way we count FAR
(and "close" goodly)

DA + entitlement
PUD - don't know when tool will be available
if we want to do

Want to file in a month
if want to do exc. redevelopment must be in EIR

other (incl) options to do specific plans (5)

"precise plan" in fountain valley

would use: need to provide height dist + zones
current gen count etc do about R-5'
could not to go above density
(7 - CH could go above R5 density

(1) work w/ PVP

(2) DA + enhancements
build design review into DA

MILLENNIUM HOLLYWOOD PROJECT

DEVELOPMENT REGULATIONS: GUIDELINES AND STANDARDS

ORDINANCE NUMBER _____; EFFECTIVE DATE _____

MILLENNIUM HOLLYWOOD PROJECT

SCOPE OF DEVELOPMENT: DESIGN GUIDELINES AND STANDARDS

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1. PURPOSE AND OBJECTIVES

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and ensure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria that serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

d. Permit design flexibility while establishing a set of controls that will guide the development for the Project Site.

e. Ensure compliance with the Development Objectives.

f. Ensure preservation of the Capitol Records Building and the Gogerty Building according to the *Secretary of the Interior's Standards for Rehabilitation*.

1.2 Development Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure that new development on the Project Site is consistent with these objectives.

1.2.2 The objectives for new development on the Project Site are to:

a. Preserve the Capitol Records Building and the Gogerty Building according to established preservation guidelines (the *Secretary of the Interior's Standards for Rehabilitation* and guidance provided by Office of Historic Resources).

b. Preserve public views from certain key vantage points to the Capitol Records Tower by creating grade level open space / civic plazas on the East Site adjacent to the Jazz Mural and Capitol Records Building and West Site across from the Capitol Records.

c. Preserve existing view corridors from certain key vantage points to the Hollywood Hills.

fig. 1.2.2.b-c: Capitol Records View Corridors

d. Create civic plazas that are activated by retail, landscaped, and enhance the Hollywood Walk of Fame by providing it as an urban node. Reinforce the urban and historical

importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

e. Encourage street life by the creation of a new pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

f. Create vibrant urban spaces that permit open and green spaces for both the on-site and off-site population.

fig 1.2.2.d: View North Along Vine Street

g. Create a 24 hr. community by the creation of a Thriving Mixed-Use Development.

h. Eliminate the visual impact of current on-site parking.

i. Establish where feasible pedestrian linkages to existing public transportation routes in proximity to the Project Site, including the Metro Red Line Station at Hollywood Boulevard and Vine Street, and existing bus routes.

j. Establish standards to address architectural excellence.

k. Provide designs that address, respect and complement the existing context, including standards for ground-level open space, podium heights and massing setbacks that minimize impacts to the historic setting.

l. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

m. Create buildings that emphasize the vertical architecture and become visible icons.

n. Develop a visual gateway to Hollywood from the Hollywood Freeway.

fig. 1.2.2.n: Hollywood: A major urban center and gateway to the Los Angeles basin.

1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose strict requirements for new development. For example, the Regulations include specific setback requirements along Vine Street. There are also mandatory requirements or standards for minimum open space on the ground floor as well as maximum building heights. By comparison, the guidelines are measures that may include a range of choices and require a degree of interpretation by the architect and design team to achieve compliance with the Regulations. The purpose of these guidelines is to create a principal design theme or objective without comprising high quality design. The purpose is to provide a range of flexibility to permit the selection of the most appropriate design feature based on the final development scenario. For instance, façade treatments for new development may take different form depending on the final design plans. The Regulations will guide the ultimate façade treatment by providing a limited range of choices in the use of material and color for the façades.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 The Development Regulations are approved by the City of Los Angeles City Council and are incorporated in the Development Agreement, authorized pursuant to California Government Code 65864, et seq., entered into by the City of Los Angeles and _____ ("Millennium Development Agreement") on _____.

1.4.2 Wherever the Regulations contain provisions which establish regulations that are different from or more or less restrictive than the zoning or land use regulations in the Los Angeles Municipal Code ("LAMC") that apply to the Project Site, the Regulations shall prevail pursuant to the Millennium Development Agreement approved by the City Council.

2. BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street.

The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Avenue is the East Site.

The East Site and the West Site make up the Project Site.

The Project Site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 21 feet (NE to SW) from Vine Street to Argyle Avenue and 21 feet (NW to SE) from Ivar Avenue to Vine Street. The existing sidewalk elevations will not be altered as part the Project.

fig. 2.1. Site Plan

2.2 Site Zoning and Permitted Floor Area

2.2.1 The Project Site is zoned Commercial (C2). The City General Plan land use designation is Regional Center commercial.

2.2.2 The Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.

2.2.3 Notwithstanding any provision in these Regulations, residential floor area is not permitted within 500 feet of any freeway.

2.2.4 Floor Area Ratio: 6:1

2.2.5 Height District: No. 2

3. HISTORIC RESOURCES AND SETTING

3.1 Overview

The Project Site is located in a historically rich area of Hollywood that contains a number of recognized historic resources. This Project is a preservation project in that its ambition is to respect, respond to, and preserve the Capitol Records Building and to continue the urban character of Vine Street on the Project Site. The Project is designed to be observant of historic settings and buildings. Two buildings located on the Project Site, the Capitol Records Tower and the Gogerty Building, are historically significant. Other historic buildings, located on adjacent parcels, are the Pantages Theater, the Equitable Building, the Hollywood Palace, and the Art Deco commercial building at 6316-6324 Yucca Street. Several of these historic resources are located within the Hollywood Boulevard Commercial and Entertainment District, a National Register listed historic district located just south of the Project Site.

Composed of commercial properties from the first half of the 20th Century, contributing properties to the Hollywood Boulevard Commercial and Entertainment District include a wide variety of property types including single-story storefronts, two-story commercial blocks, department stores, theaters, high-rise office buildings and hotels.

The Capitol Records Building is a unique building whose cylindrical form has always been visible from portions of Hollywood and Vine from the south and the freeway from the north. The Capitol Records Tower and the iconic buildings in the Hollywood Boulevard Commercial and Entertainment District (the Hollywood Palace, Pantages Theater, Equitable Building) will maintain their prominence after implementation of the Project.
Portions of the Hollywood Walk of Fame (L.A. Historic Cultural Monument #194) are located along Vine Street between Yucca Street and Sunset Boulevard and will be protected.

The protection of Hollywood's historic resources and unique character is an important objective of the Project. The guidelines and standards contained in this document were created in part to ensure the protection of historic resources within the Project Site and minimize potential adverse effects to historic resources from new development. Key Project objectives regarding historic resources include:

1) Preservation, maintenance, and rehabilitation of the Capitol Records Building and the Gogerty Building in accordance with the Secretary of the Interior's Standards. See sections 1.2.2a and 1.2.2b of this document.

2) Protection and preservation of the portions of the Hollywood Walk of Fame (LA Historic Cultural Monument #194) will need to be temporarily removed during construction and replaced after construction is completed. A preservation plan, outlined in the Hollywood Walk of Fame Terrazzo Pavement and Repair Guidelines (March, 2011) will be prepared for this aspect of the Project.

3) Incorporation of ground-floor open space and building setback requirements to moderate the overall massing of new development in a manner that preserves important views to and from the Capitol Records Building, the Hollywood Boulevard Commercial and Entertainment District, and important view corridors to the Hollywood Hills. See sections 1.2.2 c, 6.1, 6.9, 7.1, 7.5, 8.1 and 8.2 of this document.

4) Incorporation of ground-floor open space and building setback requirements to reduce massing at the street level and limit the visual crowding of adjacent historic resources. See sections 1.2.2c, 6.1, 7.1, 7.5,

8.1 and 8.2 of this document.

5) Requirement that design of new buildings be in a manner that is differentiated from but compatible with adjacent historic resources. See sections 6.6, 6.8, 7.1.5, and 7.4 of this document.

One means of creating compatible new buildings in an urbanized setting is to incorporate qualities of vertical and horizontal visual complexity in world class design. The general characteristics, proportions, and details of older buildings may serve as a reference for the Project. The Project's intent is to allow old and new to mix, recognizing that Hollywood sustains its image through both the rehabilitation of existing historic structures and the design of creative and contemporary architecture.

4. DENSITY

4.1 Floor Area Ratio Averaging and Density Transfer

The Owner may transfer density and buildable floor area from one parcel within the Project Site to another parcel within the Project Site, as long as the minimum and maximum building heights in the Regulations are maintained and the entire Project does not exceed the cumulative, allowable density and floor area of the zoning for the sum of the individual parcels.

To allow for the spatial distribution of the development on the Project Site and ensure relationship and sensitivity with the uses surrounding the Project Site, parking, open space and related development requirements for any component of the Project may be developed in any location within the Project Site.

4.2 Land Use Equivalency Program

The Land Use Equivalency Program is intended to provide flexibility in land uses for the Project while ensuring that a change in land uses would not result in new significant environmental impacts or a substantial increase in the severity of significant environmental impacts identified in the EIR, ENV-2011-0675-EIR (SCH No. 2011041094). With respect to any proposed Phase of the Project (an "Exchange Phase") that would result in a build out of the Project that is not consistent with at least one of the Project scenarios studied under the EIR, under the Land Use Equivalency Program, the developer may request a transfer or exchange of land uses, as well as modifications to the siting, massing or other development standard in so far as they are consistent with the provisions herein, for such Exchange Phase by a delivering written request therefore to the Planning Department of the City, which request shall be accompanied by (a) detailed information identifying the land use transfer/exchange that is being proposed for such Exchange Phase; (b) information documenting how the proposed land uses and densities in the Exchange Phase, together with the existing improvements and the other phases previously developed, are consistent with the overall AM and PM peak hour trip cap identified in Table II-3, Project Trip Cap from the EIR; and (c) supporting documentation to demonstrate that the Project including the proposed Exchange Phase would not exceed the maximum environmental impacts identified in the EIR (collectively, an "Equivalency Program Exchange Submission"). The Planning Director shall approve such request if the Equivalency Program Exchange Submission reasonably demonstrates that the Project including the proposed Exchange Phase is consistent with the overall AM and PM peak hour trip cap identified in such Table II-3, Project Trip Cap, and would not otherwise exceed the maximum environmental impacts identified in the EIR.

5. HEIGHT

5.1 Building Height Standards

The Regulations establish heights zones (A, B, C and D) to limit maximum building heights and control bulk in response to the Development Objectives including context with the built environment and to reinforce view corridors to the Capital Records Tower.

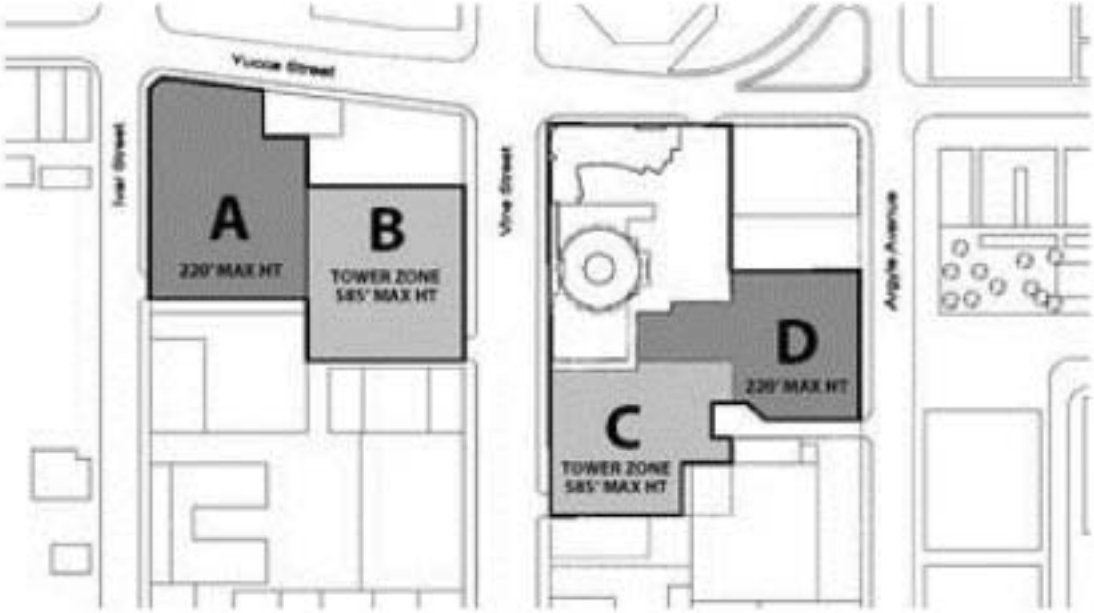


Fig. 5.1 Height Zones

6. BUILDING AND STREET EXPERIENCE

6.1 Tower Massing Standards

6.1.1 The Tower Massing Standards apply to the portion of a building located 150 feet above curb level – see Table 6.1.1.

Tower Height (feet)	Maximum Tower Lot Coverage (%)	Minimum Floor Area Below 220 Feet (%)	Maximum Tower Floor Plate (sq. ft.)	Minimum Tower Setback (feet)	Minimum Public Open Space (%)	Figures
151 – 585	11.5	50	13,325 East Site 9,042 West Site	10 15[1]	12	6.1.2.d.1 6.1.2.d.2
151 – 550	15	50	17,380 East Site 11,794 West Site	10 15[1]	10	6.1.2.c.1 6.1.2.c.2
151 – 400	28	50	22,745 East Site 22,016 West Site	10 15[1]	8	6.1.2.b.1 6.1.2.b.2
150 – 220	48	n/a	55,616 East Site 37,742 West Site	10 15[1]	5	6.1.2.a.1 6.1.2.a.2

Table 6.1.1

Note 1: 15' tower setback required for any tower fronting Vine Street on West parcel. See Figure 6.3.2.

6.1.2 For the purpose of calculating the maximum lot coverage the total lot area is equal to the total lot area for each of the sites, the West Site and the East Site. If there is more than one tower on a site, the maximum lot coverage requirement in Table 6.1.1 is calculated based on the combined area of all towers on each site. The total lot coverage applies to the aggregate floor plate(s) of the tower or towers on each site.

6.1.3 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Figs. 6.1.2.a.1 – 2.)

6.1.4 At least 50% of total floor area must be located below 220 feet.

6.1.5 Tower wall articulation:

a. Minimum 10% of tower aggregate area shall be articulated.

6.1.6 Types of permitted articulations for tower walls:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

The following developments are for illustrative purposes only.
Maximum Lot Coverage and Tower Floor Plate – Figs. 6.1.2.a – d.

EAST SITE - SITE PLAN

① MINIMUM 10' SETBACK ALONG VINE STREET
② MINIMUM 20' SETBACK ABOVE 150'
③ MINIMUM 10' SETBACK ABOVE 150'
④ 10' SETBACK FROM CAPITOL RECORDS TOWER

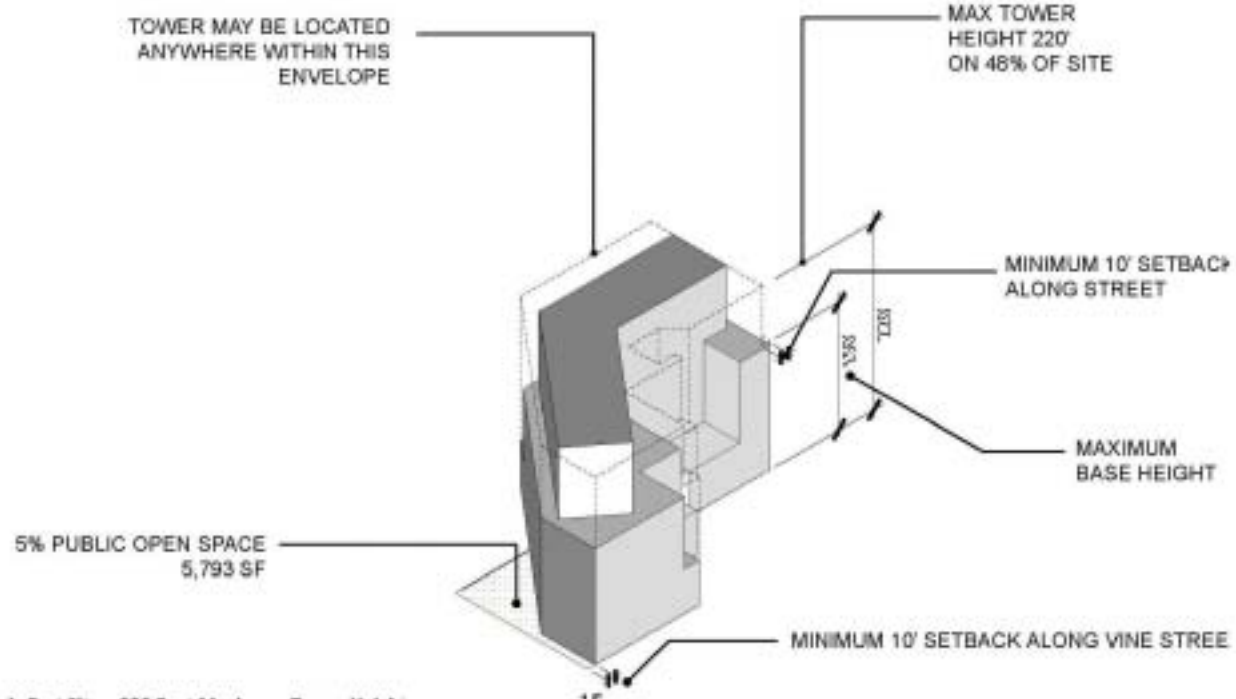
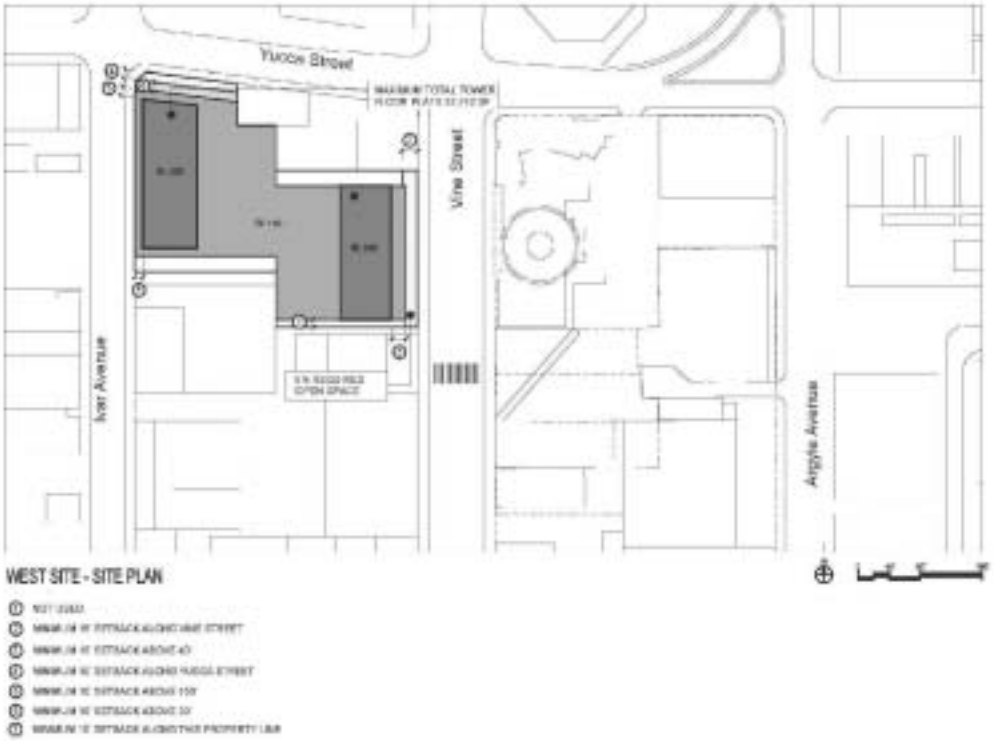


fig. 6.1.2.a.1: East Site – 220 Feet Maximum Tower Height



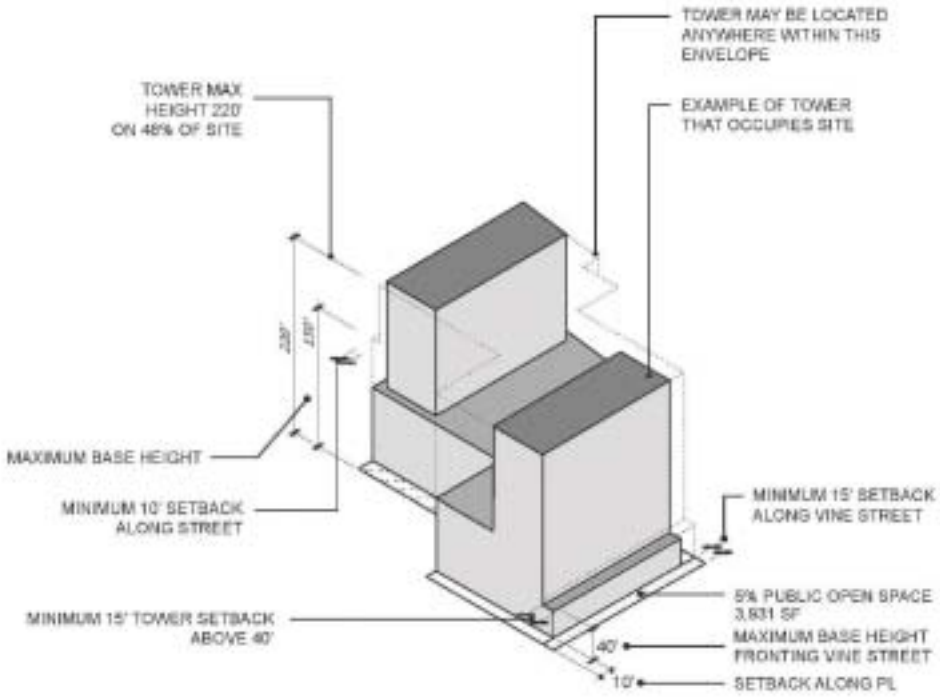
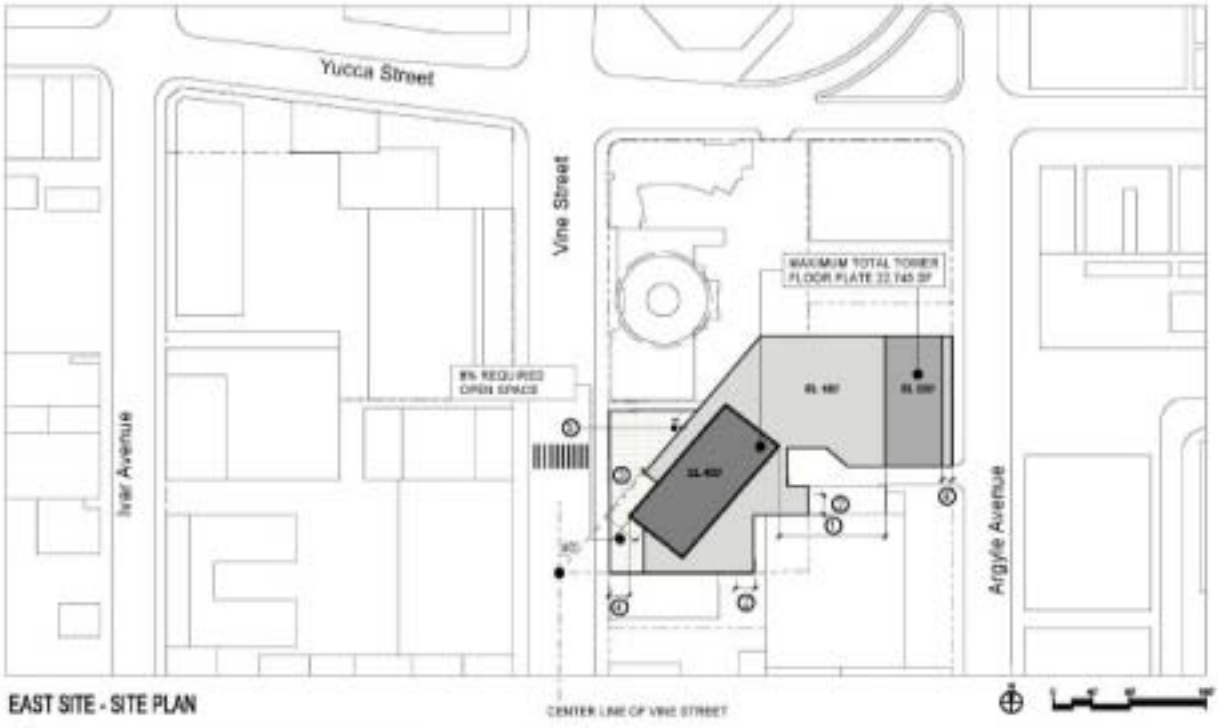


fig. 6.1.2.a.2: West Site - 220 Feet Maximum Tower Height.



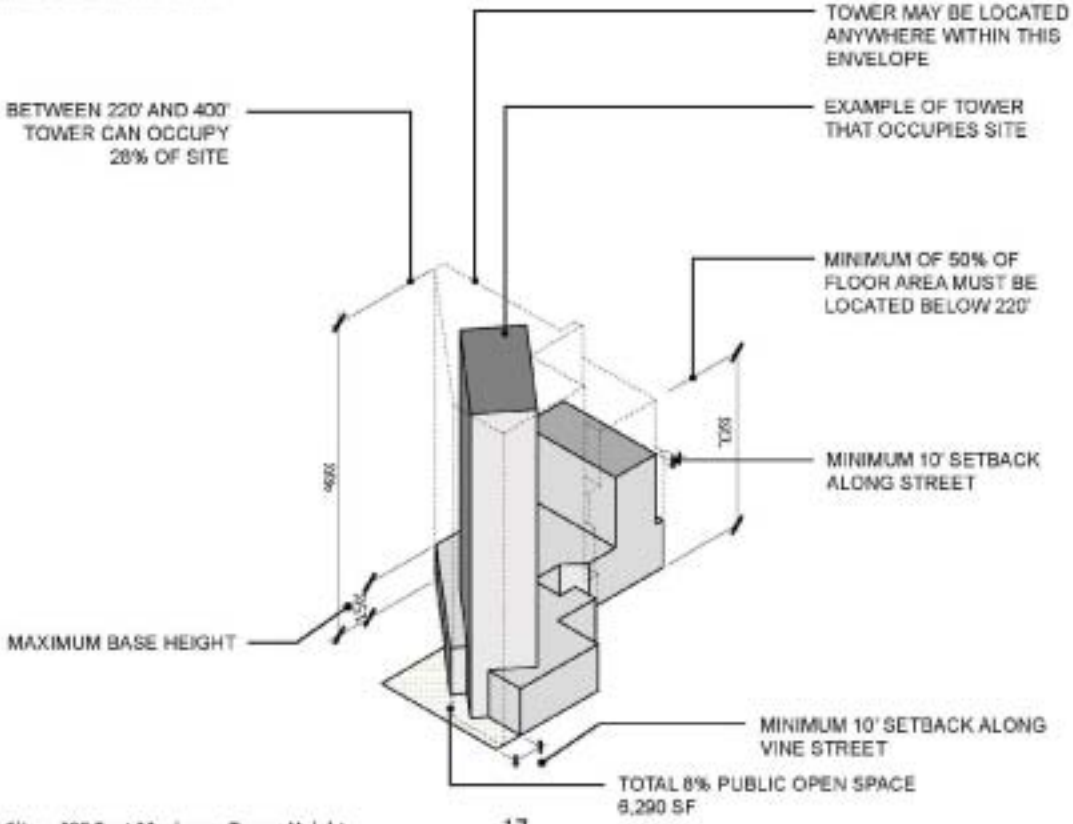


fig. 6.1.2.b.1: East Site – 400 Feet Maximum Tower Height

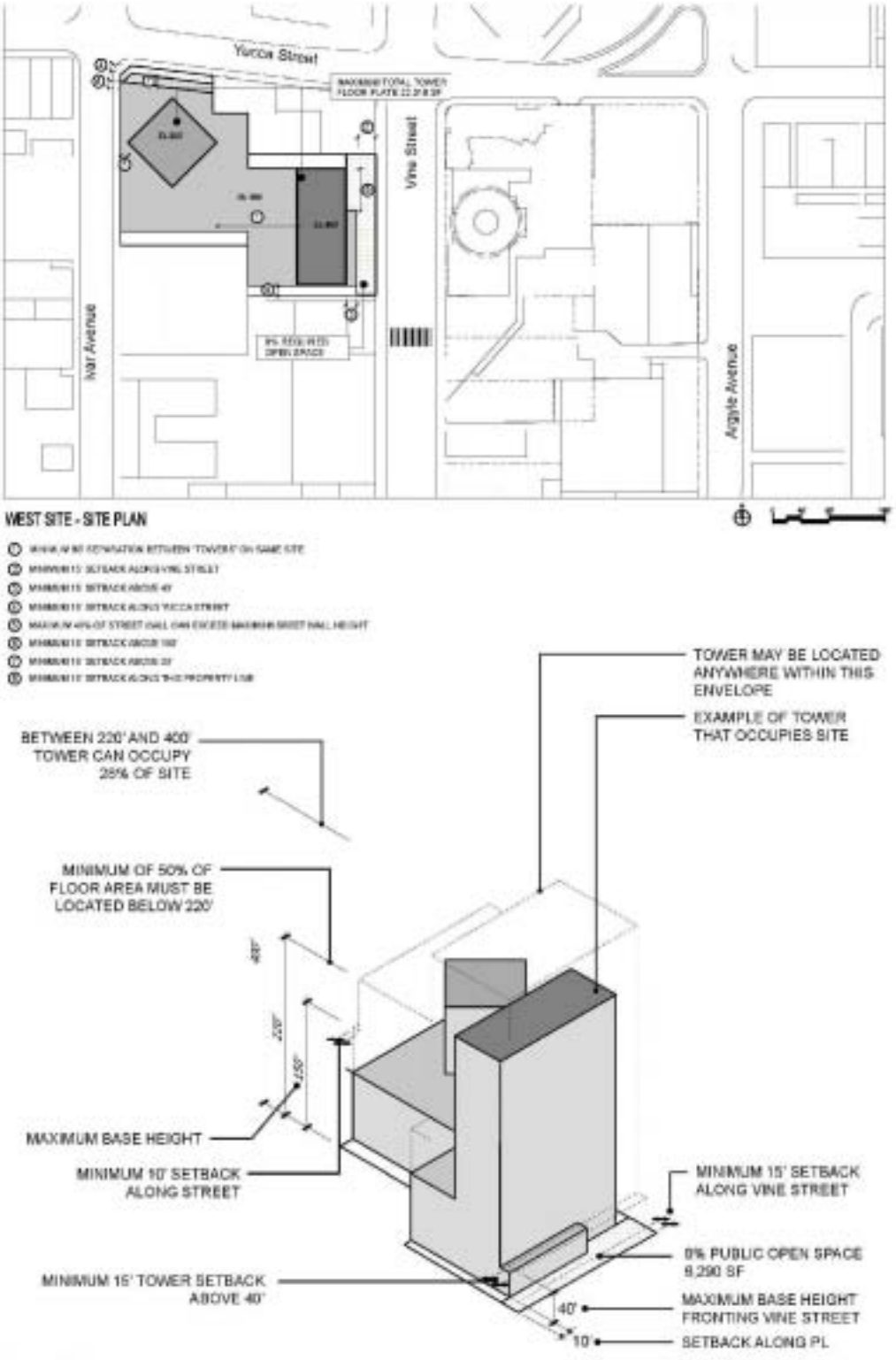
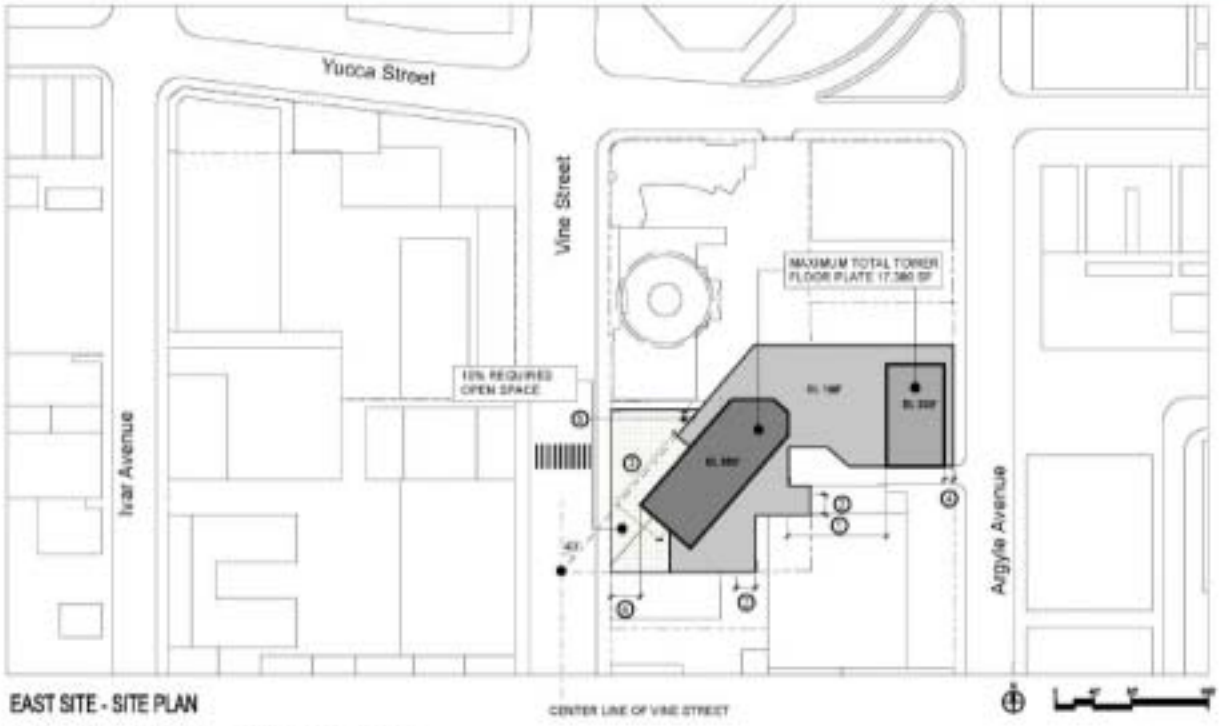


fig. 6.1.2.b.2: West Site – 400 Feet Maximum Tower Height



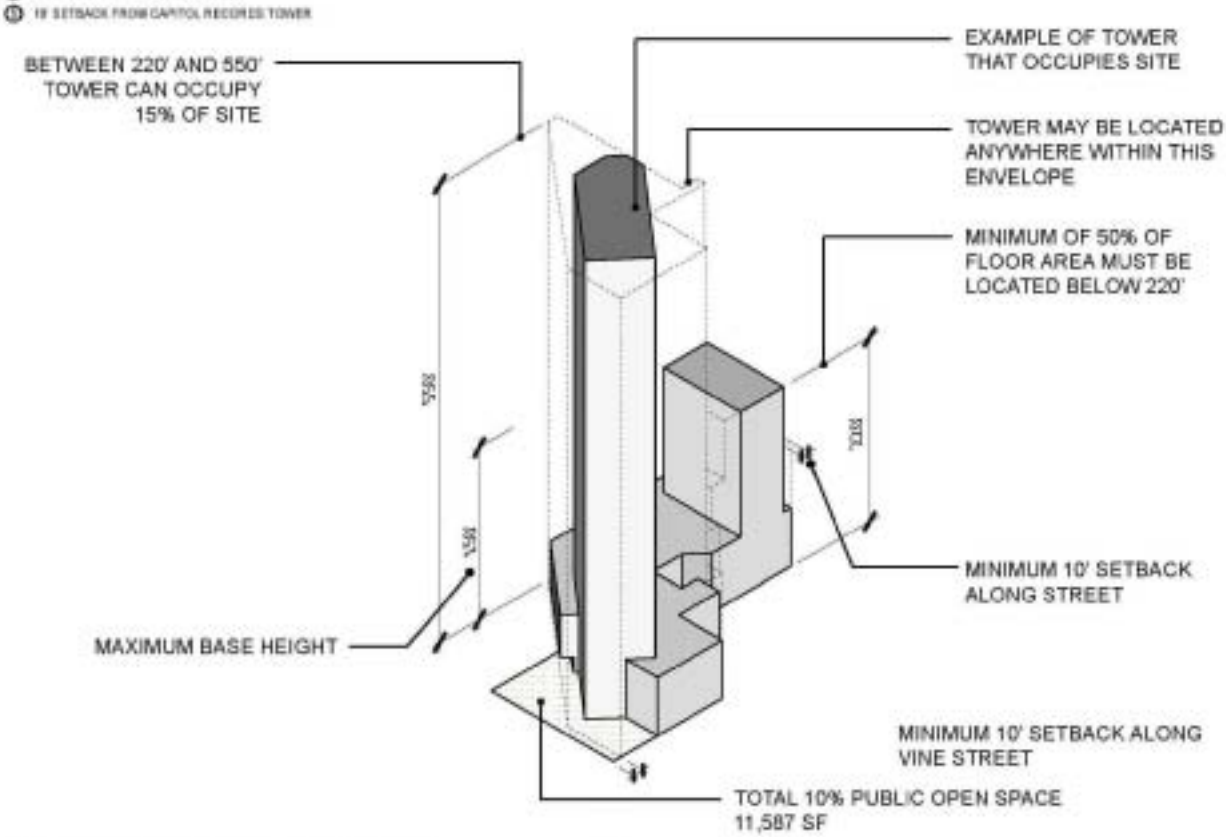
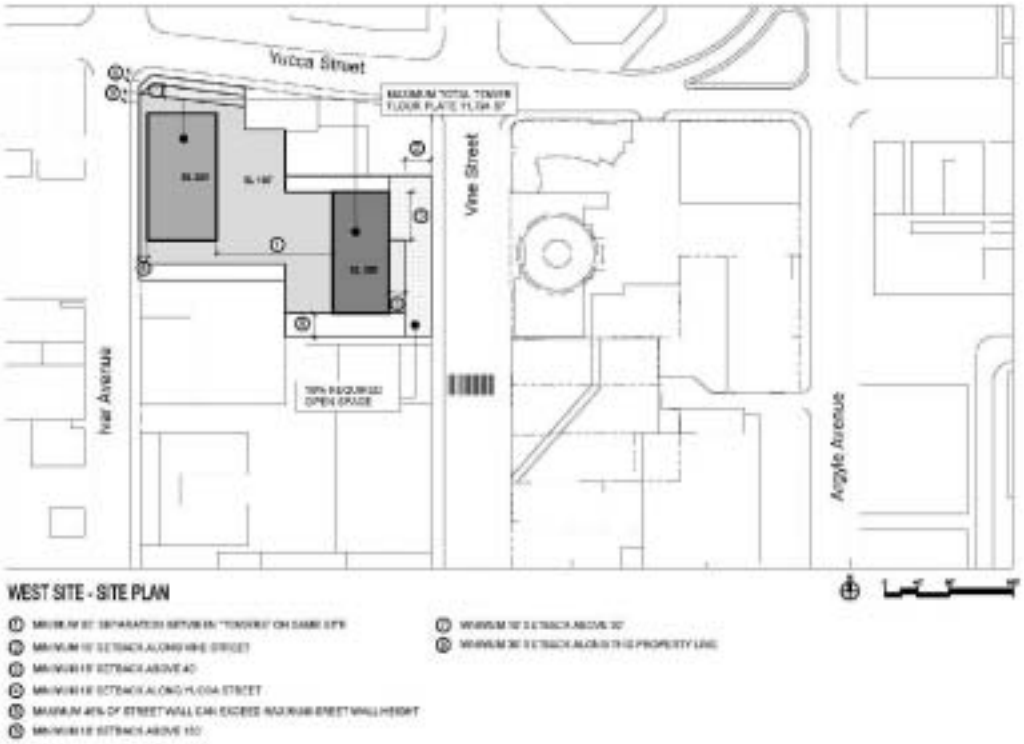


fig. 6.1.2.c.1: East Site – 550 Feet Maximum Tower Height



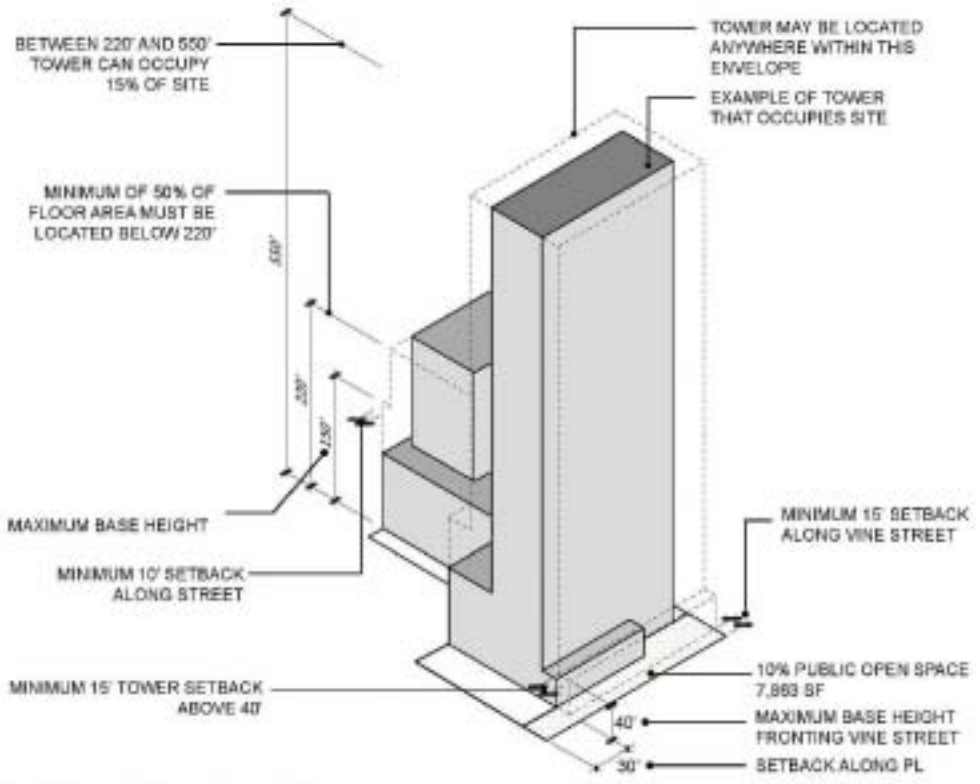
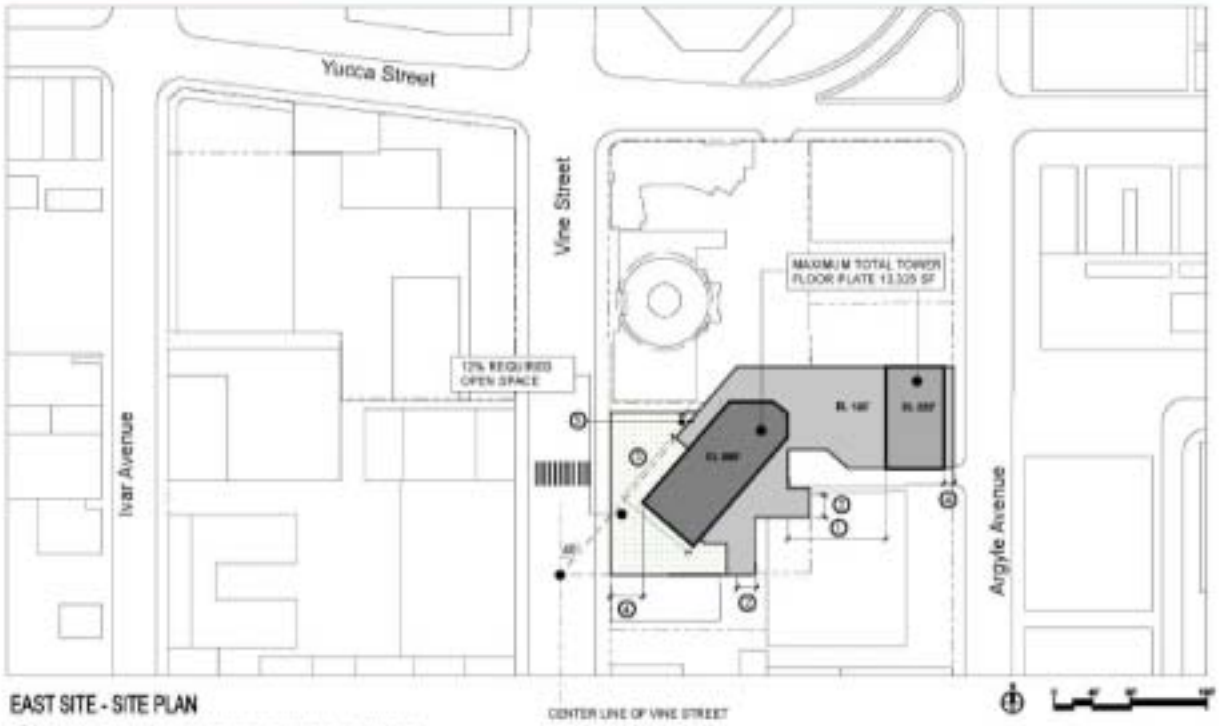


fig. 6.1.2.c.2: West Site – 550 Feet Maximum Tower Height



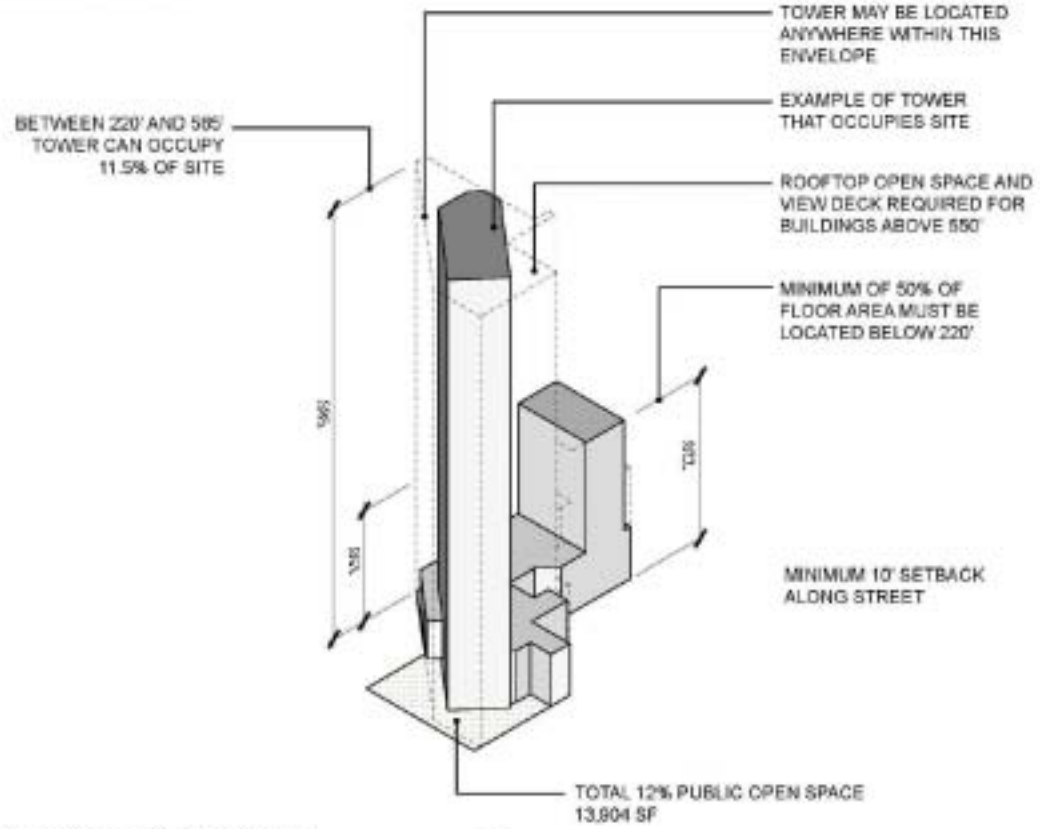


fig. 6.1.2.d.1: East Site – 585 Feet Maximum Tower Height

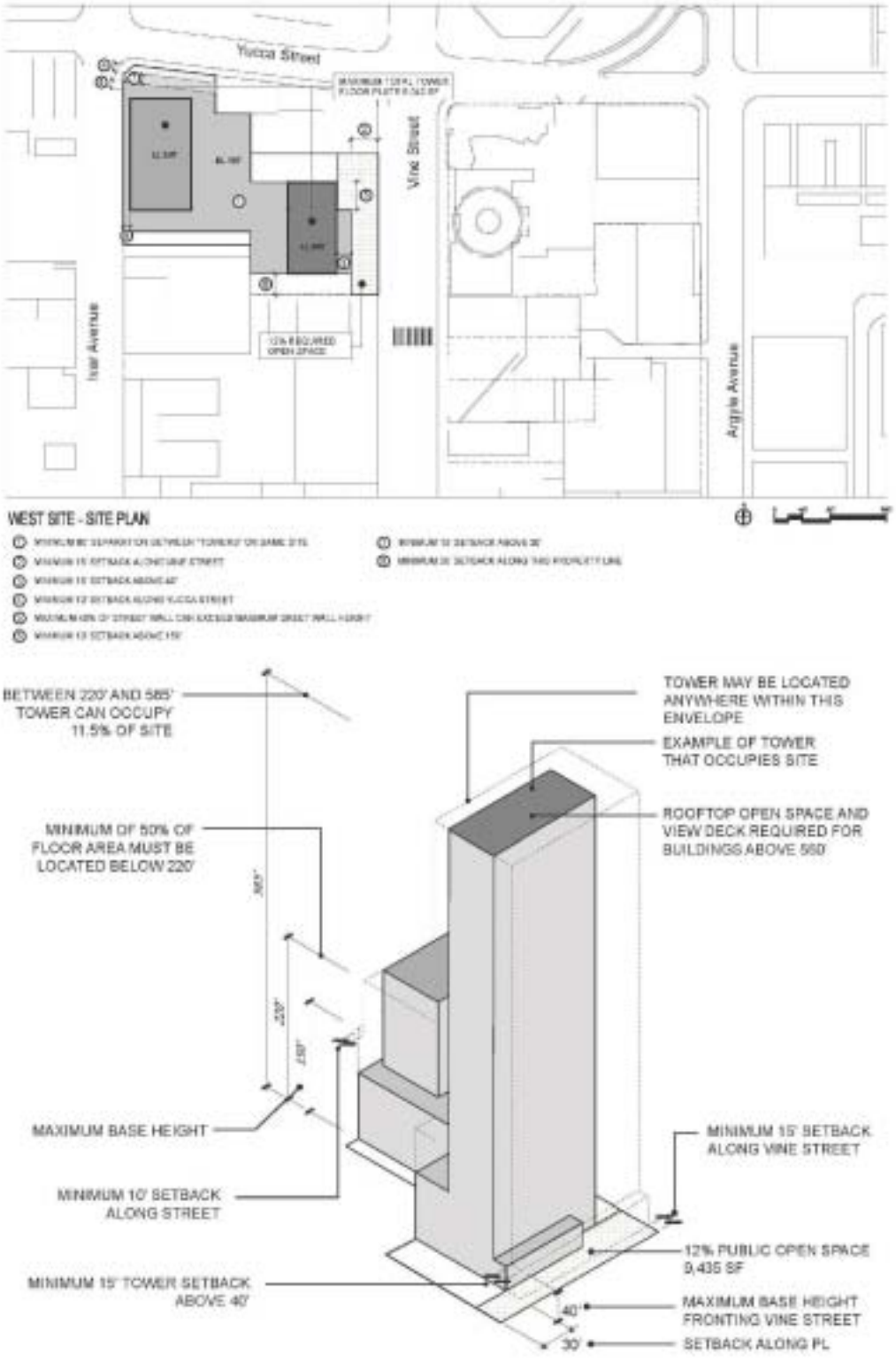


fig. 6.1.2.d.2: West Site – 585 Feet Maximum Tower Height

6.2 Street Walls

6.2.1 A street wall is a wall or portion of a wall of a building facing a street or a grade level open space. Street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation. The street wall shall have proportions and architectural building details which emphasize and reflect the presence and importance of the pedestrian environment. Massing offsets, fenestration, varied textures, openings, recesses, and design accents are strongly encouraged to ensure there are no un-articulated walls and monolithic roof forms, and architectural elements such as balconies, verandas, and porches that add architectural character are encouraged.

6.3 Street Wall Standards

6.3.1 Location of a required street wall:

a. Parcels with a grade level open space: the required street wall shall be located a minimum 10 feet from the property line along Vine Street on the East Site and 15 feet along Vine Street on the West Site.

b. A grade level open space is required for any building fronting Yucca Street with a minimum 10 feet setback from the property line.

c. Parcels or portions of parcels without a grade level open space: the required street wall shall be located on the property line.

6.3.2 Height of required street wall:

a. Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b), (c) and (d) below.

b. Street walls fronting Vine Street on the West Site shall be built to a maximum height of 40 feet above curb level except as noted in item (d) below.

c. Street walls fronting Yucca Street shall be built to a maximum height of 30 feet. Building can extend to a maximum height of 150 feet with a 10 foot setback above 30 feet except as noted in item (d) below.

d. 40% of the aggregate width of the required street wall frontage on each street can exceed the maximum street wall height up to the maximum tower height.

fig 6.3.2: Street Wall

fig. 6.3.3: Street Wall Articulation

6.3.3 Types of permitted articulation of a required street wall:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space.

d. Expression band: an identifiable break shall be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

6.3.4 Other permitted projections: elements which project beyond the property line from a required street wall shall comply with the Building Code.

a. Architectural facade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required street wall over a grade level open space.

b. Steps and ramps may project from a required street wall over a grade level open space.

c. Commercial marquees, canopies and awnings.

d. Retail storefronts: may project from a required street wall over a grade level open space by a maximum depth of 5'-0'. The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

6.4 Street Wall Guidelines

6.4.1 Pedestrian pass-through areas, public plazas, marquees, canopies, awnings and retail storefronts are permitted within the street wall area.

6.4.2 Pedestrian steps and ramps, entry forecourts, hotel drop-offs and loading entries and exits and vehicular access driveways are also permitted within the street wall area on the Project Site.

6.5 Yard Standards

6.5.1 Yard is an open space other than a court that is unoccupied and unobstructed from the ground upward.

6.5.2 Commercial Use: no front, side or rear yard setbacks are required.

6.5.3 Residential Use:

a. Front Yard: none.

b. Side Yard: Minimum 5 feet; for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.

c. Rear Yard: Minimum 15 feet; for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

6.6 Building Materials and Color Guidelines

6.6.1 The goal of the building materials and colors is to reinforce the character of the Hollywood area and provide a design that is compatible yet avoids any appearance that the building is being historicized. These guidelines will address the façade treatment for both residential and commercial portions of buildings.

a. Buildings shall feature long-lived and sustainable materials. The material palette shall provide variety, reinforce massing and changes in the horizontal or vertical plane.

b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

c. Podium levels up to 150 feet will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents.

d. The architecture of the building shall clearly delineate an architectural style, and shall not appear as a simplified version thereof, with appropriate fenestration patterns, architectural features, proportions and materials.

e. The building's skin, especially for towers, shall be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.

f. In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style. There will be clear contrast between the building's surface material and the building's glazed areas.

g. In general, the overall massing, roof forms, materials, and architectural style of new structures shall provide a variety of forms, depth and texture, and encourage a cohesive character. Building massing shall include a variation in wall planes and height as well as roof forms to promote architectural excellence, a pedestrian friendly environment and take into account the context.

h. To provide visual variety and depth, the building skin shall be layered and designed with a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin shall reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

i. Rooftop mechanical equipment screening shall be designed to be integral with the building architecture and the visual impact shall be minimized by using materials that are complimentary or consistent with the building.

j. Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

Fig. 6.6.1

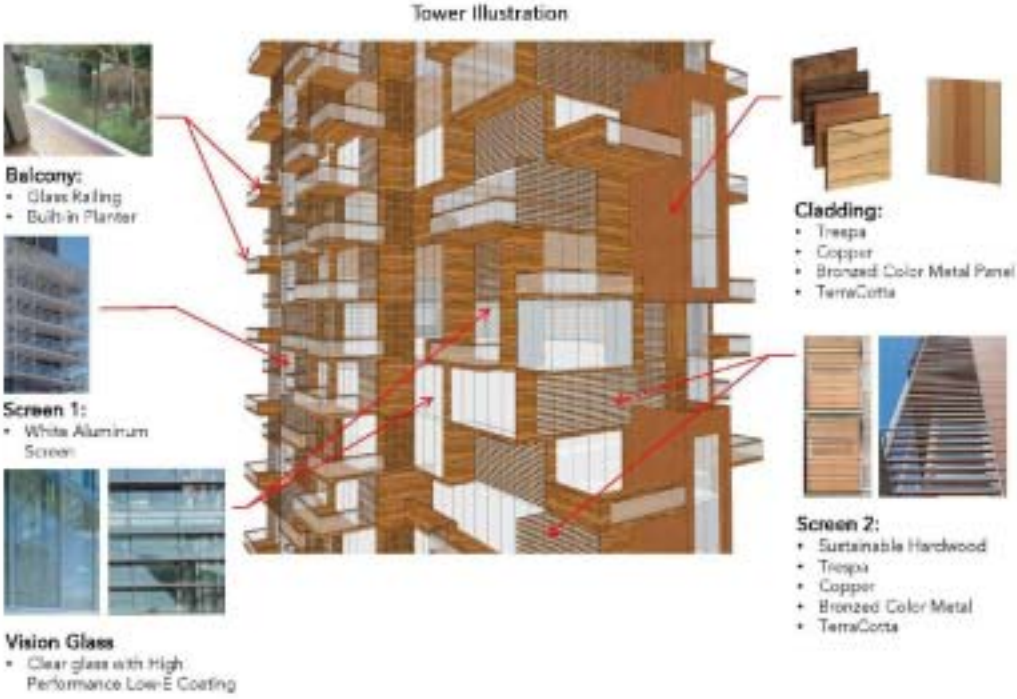


Fig. 6.6.2

k. Examples of acceptable materials are illustrated in Figures 6.6.1 – 2

6.7 Grade Level Standards

6.7.1 The purpose of the grade level standards is to promote pedestrian-scaled architecture by regulating street wall massing, articulation and detail, street level entrances and storefront windows and doors, as well as the use of quality materials and decorative details. Architectural features that reinforce the retail character of the ground floor street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and shall be integral to the architecture of the building.

6.7.2 Ground floor height:

a. Minimum 12'-0" height measured from floor to ceiling.

6.7.3 Building entrances:

a. The primary entrance to a street level tenant space that has frontage along a public street shall be provided from that street. The primary entrance to a tenant space that does not have its frontage along a public street shall be provided from a courtyard, *grade level open space*, or *publicly accessible passageway*. Entries less than 18 inches from the property line shall not be higher than 12 inches above the elevation of the sidewalk; entries greater than 18 inches from the property line shall be within 30 inches of the adjacent grade level along street frontages. Where possible entries shall be marked using architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

b. All retail spaces shall be accessed primarily from a ground floor, single-tenant entry along a street, plaza or passageway. Where reasonably practical given architecture and tenant requirements, access to different tenant spaces shall occur at a maximum interval of 60 feet.

c. Main building entrances shall read differently from retail storefronts, restaurants and commercial entrances which could include but are not limited to material change, architectural elements or elevation change.

d. In addition to the building's required primary entrance(s), there may be ancillary entrances to the building from parking garages.

6.7.4 Ground Floor Glazing

a. Use of clear, colorless and transparent glazing is required within the first 30 feet above curb level.

b. Use of reflective glass is prohibited.

c. Along street frontages with a required build-to line less than or equal to 18 inches from the property line, glazing shall constitute a minimum of 30% of the area of a building face and shall not exceed 80% of the area of a building face.

6.7.5 Arcades

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0-foot candles.

6.7.6 Service and Refuse Requirements

Hotel and Commercial / Office / Retail that abuts an alley

a. Every required loading space shall be located and arranged such that delivery vehicles may be driven upon or into said space from an alley. Such loading space shall have a minimum height of 14 feet and be accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

b. Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.

c. Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet; a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet; and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

Condominiums (Residential)

d. None

Rental (Residential)

e. None

6.7.7 Service and Refuse Guidelines

a. Storage areas shall be provided within the building of a size sufficient for the development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible from a curb cut.

b. Service, utility, and mechanical functions, including retail loading, shall be located in alleys whenever present. When alleys are not present, service functions shall be placed within buildings.

c. Service, utility, and mechanical equipment that is visible from the street shall be screened from view with landscaping or enclosures. Back flow and fire standpipes, along with utility box transformers, shall be screened.

d. All screening devices shall be compatible with the architecture, materials and colors of adjacent buildings.

e. Trash and storage enclosures shall be architecturally compatible with the project design and landscaping shall be provided adjacent to the enclosure(s) to screen them and deter graffiti.

f. Trash enclosures and retail loading areas shall be sited to minimize nuisance to adjacent properties.

g. The location of trash enclosures shall be easily accessible for trash collection and should not impede general site circulation patterns during loading operations.

h. Mechanical equipment shall vent to an alley wherever possible.

i. Roof-vent penetrations and mechanical equipment shall be located at least 10 feet from any exterior Building Face.

j. Gutters and downspouts shall be made of galvanized steel, copper (not copper coated), or aluminum.

6.7.8 Storefronts

a. Storefront (residential, retail, restaurant and commercial) requirements shall include frontage along streets and grade level open spaces.

b. Storefronts shall comprise a minimum of 70% of the building's street level façade along Vine Street and 40% along all other streets and be recessed where necessary.

c. Storefront glazing shall comprise a minimum of 60% of the storefront area along Vine Street and 40% glazing along all other streets.

d. All retail space shall have a minimum 12 feet finished ceiling clearance.

e. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet. Storefront sills shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

f. Storefront openings shall be no shorter than 12 feet above the adjoining grade for 90% of the required storefront frontage.

g. Security grilles will be located behind glass and be at minimum 70% open.

h. At-grade storefront glazing at, or adjacent to, and/or facing any public right-of-way shall incorporate transparent, clear, colorless glazing with no reflectivity.

i. Awnings shall not obscure storefront signage. Vinyl awnings are not permitted.

6.8 Podium Standards

6.8.1 The purpose of the Podium Standards is to provide a modern interpretation of the historical context of Hollywood by establishing different treatment of the building's base, middle and top

through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

6.8.2 Podiums shall comply as applicable with the minimum setback requirements set forth in Figures 6.1.2a – d.

6.9 Podium Guidelines

6.9.1 Podiums shall have fenestration that establishes a clear pattern on the façade (with special attention paid to facades that are visible from a public street) and that provides depth and additional articulation.

6.9.2 An identifiable break between the building's ground floors and upper floors shall be provided. This break may include a change in material, change in fenestration pattern or similar means.

6.9.3 Podium level windows shall be vertically oriented.

6.9.4 Podium levels shall be predominantly light in color.

6.9.5 An expression band shall be provided at the highest story within the podium.

6.9.6 While blank street wall façades shall be avoided, an exception may be made for integration of public art or an articulated façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade shall be a maximum of four floors high, and shall have variation in its surface plane (using cutouts, insets or pop-outs). It shall employ different scales of elements as viewed when seeing the entire building massing.

6.9.7 Louvers and wall openings shall be designed to integrate with building architecture.

6.9.8 Podiums are encouraged as feasible to be set back from Pantages to preserve sightlines and promote groundfloor open space.

6.10 Street and Sidewalk Standards

6.10.1 The Site is comprised of a variety of public elements that include open spaces, streets and sidewalks. The Hollywood Walk of Fame is an integral element that fronts open spaces on both East and West Sites. Its adjacency to the public plazas requires compatibility and cohesiveness.

6.10.2 The combination of landscaped plazas, publicly accessible passageways and landscaped streets and sidewalks creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

6.11 Screening Standards

6.11.1 Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

6.11.2 Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

7. TOWERS

7.1 Purpose

7.1.1 Towers shall have their massing designed to reduce overall bulk and to appear slender.

7.1.2 Towers shall be designed to achieve a simple faceted geometry and exhibit big, simple moves. They shall not appear overwrought or to have over-manipulated elements.

7.1.3 Towers that emulate a more streamlined modern style shall provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.

7.1.4 If a project has more than one tower, the towers shall be complementary to each other and employ a similar yet **varied** architectural design approach.

7.1.5 Generally, buildings over 150 feet tall (the historic datum for Hollywood) shall not be historicized. They are contemporary forms in the skyline and shall appear as such.

7.2 Projections

7.2.1 The following building elements and operations equipment can project beyond the maximum permitted building height:

a. Roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building;

b. Skylights, towers, steeples, flagpoles, water tanks, silos;

c. Wireless masts; and

d. Solar energy devices and similar structures.

7.2.2 Permitted building elements or equipment in Section 7.2.1 shall be screened as practical and based on building design except if such projections – e.g., flagpoles or steeples – are part of the architecture or design. The use of creative materials and forms for screening is encouraged.

7.2.3 Enclosures for bulkheads shall not count against building height.

7.3 General Standards

7.3.1 A tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

7.3.2 Distinctive tower crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

7.3.3 Towers shall be set back from maximum street wall height a minimum of 10 feet except for towers fronting Vine Street on the West site, these towers shall be setback a minimum of 15 feet from the maximum street wall height.

7.3.4 Towers shall be setback on West Site from shared property line with Hollywood Playhouse a minimum of 10 feet above 150 feet.

7.3.5 Adherence to minimum setbacks and other separation standards for towers is required as may be applicable to a specific tower and its location with the Project area. Please refer to standards for towers set forth in Figures 6.1.2.a – d.

7.3.6 Tower orientation and placement that enhances important sightlines is encouraged.

7.3.7 In no instance should the tower fronting Vine Street on the East site development have more than a 15% height differential from the tower on the West ste development .

7.4 Wall Standards

7.4.1 All walls are required to be articulated.

7.4.2 The following types of articulation of a tower wall are permitted:

a. Recess;

b. Standard balconies may be projecting or recessed or a combination of both; and

c. Bay windows.

fig. 7.4.2.a: Balcony/Recess

fig. 7.4.2.b: Bay Window

7.4.3 Balcony: a balcony shall be integral to the façade (see figs. 7.4.3.a and b) and shall not create a relentless horizontal and vertical stacking pattern. Balconies are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations and shall be a minimum 75% *transparent*. Balconies are encouraged on buildings facing major public spaces such as plazas, passageways and open spaces. Long balconies resembling corridors are prohibited.

fig. 7.4.3.a: Recess/Balcony: Integral Balcony

fig. 7.4.3.b: Bay Window: Integral Balcony

7.5 Spacing Standards

7.5.1 If two towers are located on a single site the towers shall be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

7.5.2 Generally, any portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except for the following which will meet Planning Code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled. See fig. 7.5.2.

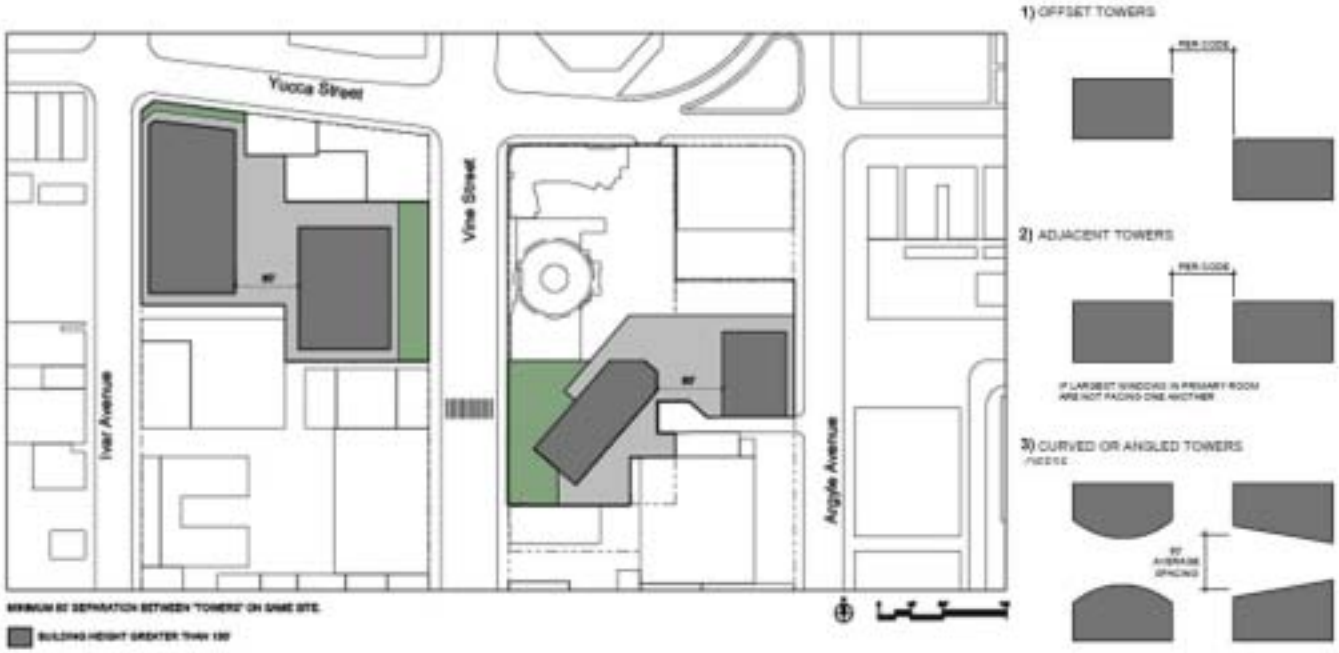


fig. 7.5.2: Tower Spacing

7.5.3 Since a tower is defined as any building above 150 feet, all buildings above 150 feet shall be spaced at least 80 feet from any portion of any adjacent or separate building on the site,

exceeding 150 feet, excluding a project within the height range of 150 to 220 feet, as shown in figures 6.1.2.a.1 and 6.1.2.a.2.

7.5.4 Spires, signage, parapets, and mechanical enclosures are excluded from the tower spacing regulations.

7.6 Rooftops Guidelines

7.6.1 Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and be visually attractive when viewed from locations adjacent and above.

7.6.2 For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section 8.5.

7.6.3 All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors.

7.6.4 All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

7.7 Parapets, Handrails, Roof Mechanical Equipment Screening Standards

7.7.1 Parapets and handrails shall be finished in a distinctive manner if part of an expression band or expression line.

7.7.2 Materials and design for roof mechanical equipment shall be consistent with the building architecture and shall utilize similar colors and materials as in other portions of the building.

7.7.3 Roof mechanical equipment shall be screened.

8. OPEN SPACE

8.1 Overview

The development of open space is an important objective for the overall Project design. Open space will be used to enhance the experience of the visitor and resident. Open space also will enable important pedestrian linkages and through-block connections for the Project. Grade level open space also will be designed to showcase the Capital Records Building and Jazz Mural and will include design features and outdoor furniture to activate the ground floor amenities.

This section sets forth the standards and guidelines for all open space areas for the Project: areas to be accessible to the public (Grade Level Open Space, Publicly Accessible Passageways and Rooftop Open Space) and areas to be designed for the residential uses (Common Open Space and Private Open Space).

8.2 Grade Level Open Space Standards

8.2.1 Grade level open space is a continuous open space fronting the street and open to the sky. The purpose of a grade level open space is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records Building and accentuate the low scale character.

8.2.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Fig. 6.1.2.a.1 – 2 and 8.1.1)

8.2.3 An additional 3% of open space (total 8%) shall be required for buildings between 221 feet and 400 feet. (See Fig. 6.1.2.b.1 – 2 and 8.1.2)

8.2.4 An additional 5% (total 10%) of open space shall be required for buildings between 401 feet and 550 feet (See Fig. 6.1.2.c.1 – 2 and 8.1.3)

8.2.5 An additional 7% (total 12%) of open space shall be required for buildings taller than 550 feet. (See Fig. 6.1.2.d.1 – 2 and 8.1.4)

8.2.6 Location

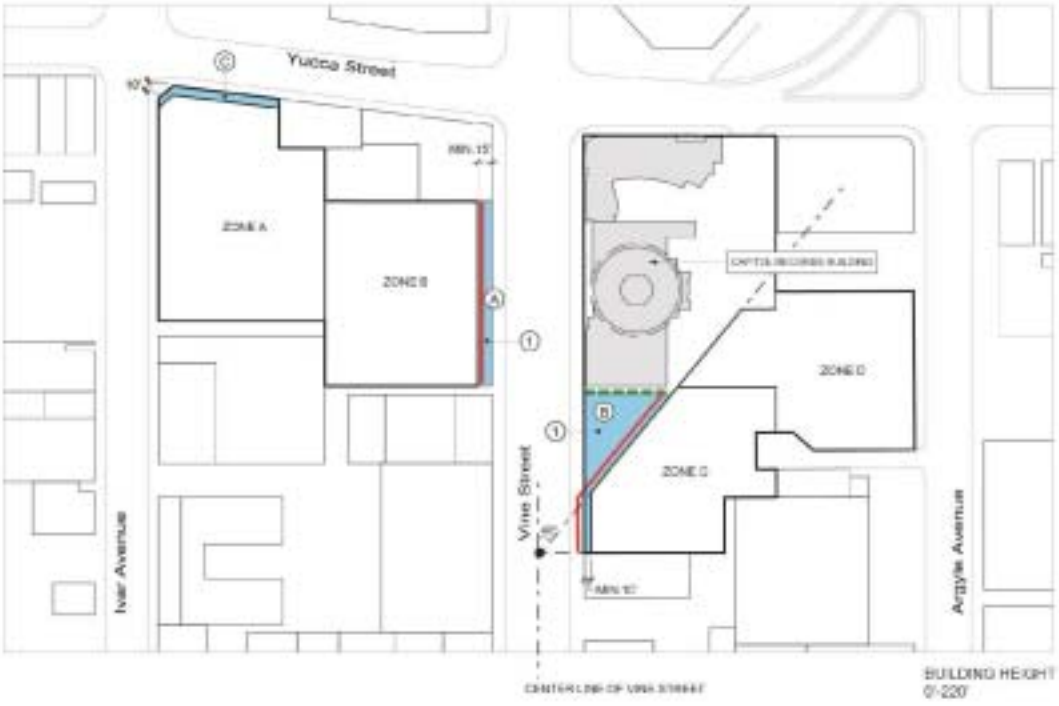
a. East Site: adjacent to the Jazz Mural and Capitol Records Building; West Site: across from the Capitol Records Building along Vine Street and along Yucca Street.

b. Minimum depth: no horizontal dimension less than 10 feet when measured perpendicular from any point on each of the boundaries of the open space area. Open space on West Site fronting Vine Street shall have a horizontal dimension no less than 15 feet when measured perpendicular from any point.

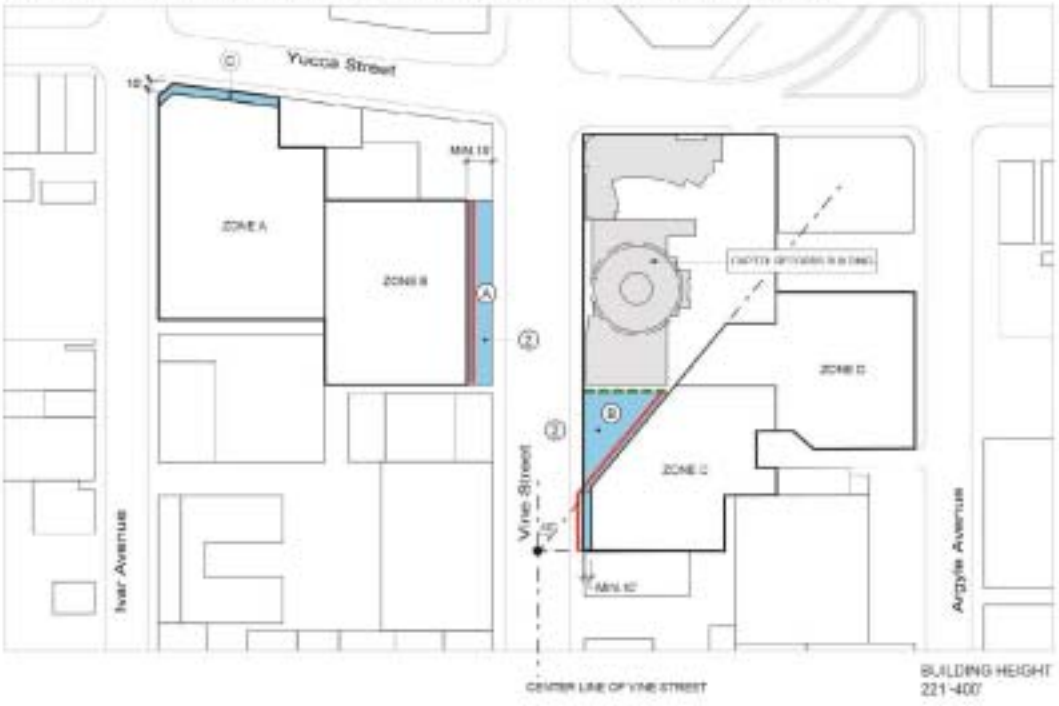
c. On West Site, open space must occupy the area to the west of a line struck at 40 degrees from center line of Vine Street ROW at alignment with the southern most property line and a minimum 10' setback from the southeast corner of the Capitol Records Building. (See Figs. 8.1.1 – 4)

Figs 8.1.1 – 8.1.4: Grade Level Open Space

figs 8.1.1 Open Space Requirements for Maximum Building Height at 220 Feet



figs 8.1.2 Open Space Requirements for Maximum Building Height at 400 Feet



figs 8.1.3 Open Space Requirements for Maximum Building Height at 550 Feet

figs 8.1.4 Open Space Requirements for Maximum Building Height at 585 Feet

8.3 Passageway Standards

8.3.1 *A publicly accessible passageway* is a continuous through-block public connection between two parallel streets, located on privately owned land. The passageway may be either enclosed or open to the sky or a combination of both.

8.3.2 Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

8.3.3 Location and Size standards:

a. The major portion of a *publicly accessible passageway* is the largest area of the *passageway* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total passageway area and shall not be less than 20'-0" wide.

b. Minor portions of *publicly accessible passageway* are secondary areas that allow for additional flexibility in the shape and configuration of a passageway. Minor portions shall not occupy more than 25 percent of the total area of the *passageway*. The minor portion shall have a minimum width of 10 feet.

c. The minor portion must be directly adjacent to the major portion.

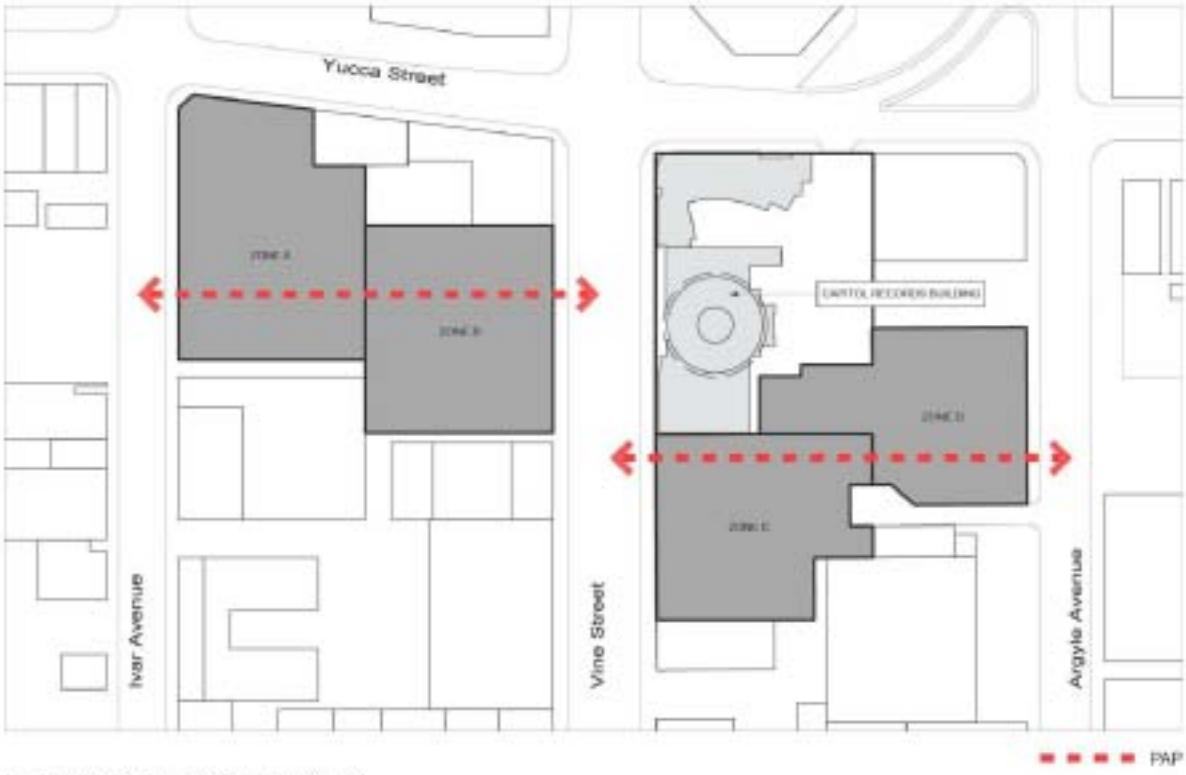


fig. 8.3.3: Publicly Accessible Passageway

8.3.4 Permitted Obstructions:

a. The minimum percentage of *publicly accessible passageway* area to be open to the sky (East and West Sites combined) shall be as follows:

(i) Development with maximum building height of 150 feet: 0%

(ii) Development with maximum building height of 220 feet: 20%

(iii) Development with maximum building height of 400 feet: 30%

(iv) Development with maximum building height of 550 feet: 40%

(v) Development with maximum building height of 585 feet: 50%

b. Permitted obstructions within the major portion of an open air *publicly accessible passageway* are any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open-air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions; balconies and bay windows; awnings, canopies and marquees; stairs, ramps

fig. 8.3.4: View from Argyle Avenue Along PAP Towards Capitol Records

and bollards.

8.3.5 Kiosk:

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Building and Safety in conformance with the Building Code. Kiosks, including roofed areas, shall not count as floor area, exceed 3% of the total area of the *publicly accessible passageway*, or occupy an area of more than 250 square feet.

b. A kiosk may be freestanding or may be attached on only one side to a wall of the building.

c. Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, and food preparation for open-air cafes, flower stands or public service/information booths.

d. All kiosks greater than 250 square feet are permitted but will count as floor area.

8.3.6 Open-Air Café:

a. Where an open-air cafe is provided it shall be an unenclosed restaurant or open-air seating for an enclosed restaurant, eating, or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies.

b. An open-air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the *publicly accessible passageway*. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers.

c. An open-air cafe may occupy an aggregate area not more than 20% of the total area of the *publicly accessible passageway*. No cooking equipment shall be installed within an open-air cafe. Cooking equipment may be contained in a kiosk adjoining the open-air cafe. An open-air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

8.3.7 Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on the *publicly accessible passageway* through open windows.

8.3.8 Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No building refuse storage areas or refuse storage from a kiosk or open-air café are permitted on any *publicly accessible passageway*.

b. No exhaust vents are permitted on any *publicly accessible passageway* or on any building wall of the development fronting upon the passageway except where such vents are more than 10'-6" above the level of the *passageway*.

8.3.9 Frontages:

a. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a *publicly accessible passageway* shall be allocated for occupancy by permitted retail, restaurants and cultural uses.

b. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the *publicly accessible passageway* with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

8.3.10 Maintenance:

a. The building owner shall be responsible for the maintenance of the *publicly accessible passageway* including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the passageway and in the street sidewalk area adjacent to the passageway.

b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of *publicly accessible passageway* area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of *passageway* in connection with outdoor eating services or other uses permitted on *passageway* which generate litter.

8.4 Roof-top Open Space

8.4.1 The Project shall include roof-top open space.

8.4.2 Roof-top open space shall include an observation area (i.e., viewing deck) accessible to the public.

8.4.3 The hotel, if developed, shall include an observation area (i.e., open space viewing area) accessible to the public.

8.4.4 The hotel observation area (i.e., viewing area), if developed, shall satisfy the requirement in section 8.4.1 above.

8.4.5 Roof-top open space may include a café.

8.5 Residential Common Open Space

8.5.1 Common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above. The publicly accessible passageway cannot be used to meet the residential common open space requirements.

8.5.2 Common Open Space Standards

a. Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.

b. Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein.

c. Open space shall be open to the sky and have no structures that project into the common open space area, except as permitted in the Zoning Code.

d. Common open space shall be readily accessible to all the residents of the Site.

e. Common open space shall have a minimum area of 400 square feet with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

f. Common open space shall constitute at least 50% of the total required usable open space in the built development.

g. Common open space areas shall incorporate recreational amenities including but not limited to swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

h. Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use may be considered as common open space.

i. Refer to LAMC 12.21.G for additional open space requirements.

8.6 Residential Private Open Space

8.6.1 A private open space area is an area contiguous to and immediately accessible from a single dwelling unit.

8.6.2 Residential Open Space Standards:

a. Private open space shall contain a minimum area of 50 square feet, of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.

b. Private open space shall have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

c. Private open space shall provide a minimum eight-foot vertical clearance under any projection, except as permitted in the Zoning Code.

d. That portion of a balcony which extends or projects into a required front yard in compliance with Zoning Code may qualify as usable open space provided it meets each of the above specified requirements noted in items a-c.

9. LANDSCAPE

9.1 Grade Level Open Space Standards

9.1.1 Planting requirements: a minimum of 10% of grade level open space shall be landscaped with softscape or water features.

9.1.2 Landscaped area(s) shall be planted with seasonally diverse plant material and 30% of all landscaping shall be California Natives or drought tolerant.

9.1.3 The landscaped portion of open space may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.1.4 The minimum soil depths for planting are:

a. Trees: 42"

b. Shrubs: 30"

c. Lawns, ground cover: 18"

9.1.5 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.1.6 Permitted obstructions: the following are permitted obstructions which may occur in the *grade level open space*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining, and retail storefronts.

9.1.7 Open-air *publicly accessible passageways* are not to be included in the grade level open space requirements.

9.2 Common Open Space Standards

9.2.1 A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

9.2.2 At least one 36-inch box tree for every four dwelling units shall be provided on-site and may include street trees in the parkway, sidewalks adjoining the property, open space, *publicly accessible passageway* and common roof decks.

9.2.3 For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

9.2.4 All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

fig. 9.3.a: Movable Seating

fig. 9.3.b: Open Air Café

9.3 Standards For Open Air Portions of Publicly Accessible Passageway

9.3.1 The landscaped portion of open air passageways may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

9.3.2 The minimum soil depths for planting are:

a. Trees: 42".

b. Shrubs: 30".

c. Lawns, ground cover: 18".

9.3.3 Each planted area shall have provision for proper drainage, and shall be equipped with an automatic irrigation system and waterproof electrical outlets.

9.3.4 Planting requirements:

a. A minimum of 10% of open air *publicly accessible passageway* shall be landscaped.

b. For each 400 square feet of landscaped area there shall be at least one (l) major shade tree or two (2) minor ornamental trees.

c. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

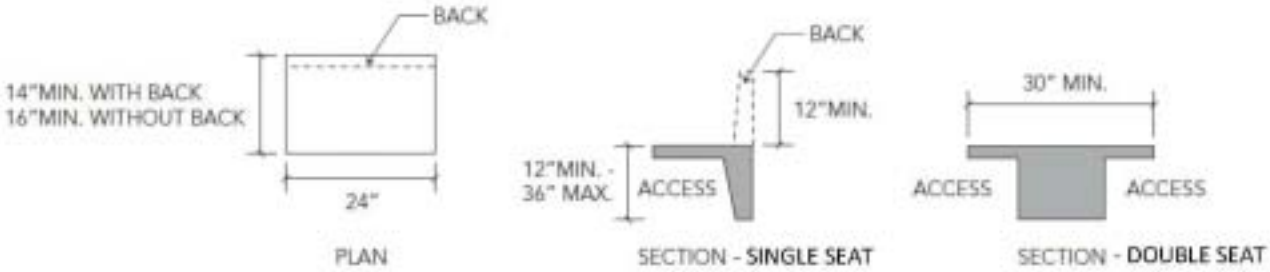


fig. 9.3.5: Seating Standards

9.3.5 Seating

a. There shall be a minimum of one linear foot of seating for each 500 square feet of *publicly accessible passageway* excluding the area of an open-air cafe.

b. One seat shall equal two linear feet.

c. Not more than 50% of the linear seating capacity may be in moveable seats. Seating shall meet the following standards:

(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons, a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count as double seating provided there is access to both sides.

(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.

(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

d. Moveable seating or chairs, excluding seating of open-air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open-air cafes do not count toward meeting the seating requirements.

9.4 Tree Planting Guidelines

9.4.1 It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

9.4.2 Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

9.4.3 Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree-planting pattern.

9.5 Lighting Standards

9.5.1 Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

9.5.2 Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade level open space and open *publicly accessible passageway*.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d. Steps and ramps will be lighted with a minimum of 1.0-foot candles on a horizontal plane.

e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

f. All exterior lighting shall be shielded or directed toward the areas to be lit to limit spill-over onto off-site uses.

g. Light quality shall not be harsh, glaring, blinking or shed beyond property boundaries.

9.5.3 Responsibility for maintenance:

a. The Building Owner shall be responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

b. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building Owner.

9.5.4 Lighting for areas located inside the lot line and visible from the street, such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

9.5.5 Lighting for above-grade parking garage facilities shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

9.6 Publicly Accessible Passageway Lighting Standards

9.6.1 A *publicly accessible passageway* shall be illuminated throughout with an overall minimum average level of illumination of not less than 1.0 maintained foot candle (lumens per square foot) on the horizontal plane at grade.

9.6.2 Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

9.7 Continuity of Design

9.7.1 Design elements and architectural clues that reinforce where appropriate continuity between open and enclosed spaces at grade level is encouraged. Continuity of design may reinforce pedestrian circulation and support the Project's way-finding features.

9.7.2 Where possible, materials, lighting, site elements and landscape shall be similar between different open and enclosed public spaces at the grade level.

10. PARKING

10.1 Automobile Standards

10.1.1 Base Standards

The following standards shall apply for the base level of parking to be provided as the minimum for each use in the project area. The Regulations set forth below incorporate the parking requirements in the LAMC, where applicable, and supersede the LAMC requirements for development in the Development Agreement area.

a. Commercial / Office / Retail:

Two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot. The Regulations incorporate applicable parking requirements in the LAMC as set forth below.

b. Sports Club:

Two parking spaces for every one thousand square feet of combined gross floor area.

c. Hotel

One parking space for each individual guest room or suite of rooms for the first 30;

One additional parking space for each two guest rooms or suites of rooms in excess of 30 but not exceeding 60; and

One additional parking space for each three guest rooms or suites of rooms in excess of 60.

d. Condominiums (Residential):

Two parking spaces per dwelling unit.

One-quarter parking space per dwelling unit for guest parking.

e. Rental (Residential):

One parking space for each dwelling unit of less than three habitable rooms; one-and-one-half parking spaces for each dwelling unit of three habitable rooms; and two parking spaces for each dwelling unit of more than three habitable rooms.

f. Combination of Uses:

Where there is a combination of uses on a lot, the base number of parking spaces required shall be the sum of the requirements of the various uses.

10.1.2 Shared Parking:

a. Shared parking may be applied to the Section 10.1.1 base rates for the Site when the uses have different parking requirements and different demand patterns in a 24-hour cycle or between weekends and weekdays. The intent is to maximize efficient use of the site by matching parking demand with complimentary uses. The calculation of the parking requirements shall be based on a detailed assessment prior to its construction.

b. Calculating Shared Parking:

(i) The individual land use parking requirements for each component of a phase of development shall be calculated from Section 10.1.1. above to establish the "Base Demand."

(ii) For parking spaces that are to be shared between uses, the calculated minimum parking requirement for the Site, including that new phase of construction, is to be adjusted from the Base Demand based on the procedures in *Shared Parking*, Urban Land Institute, 2nd Edition (2005) or another source as determined by the Director of Planning.

10.2 Additional Regulations

10.2.1 The automobile parking spaces required shall be provided either on the same lot as the use for which they are intended to serve or on another lot located within 750 feet of the lot; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

10.2.2 Curb cuts for driveways shall be located no closer than 50 feet to the intersection of two streets unless approved by The Department of Transportation.

10.2.3 Access driveways to parking facilities not at signalized intersections shall not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

10.2.4 Parking and loading access shall be shared where feasible.

10.2.5 Priority placement within parking structures shall be given to bike parking, car-share parking, and other alternative ride vehicles.

10.2.6 Pedestrian entrances to all parking shall be directly from the street, except that underground parking garages may be entered directly from a building.

10.3 Screening

10.3.1 Above grade parking for the first 20 feet shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible and shall be designed to blend in with the form and massing and to look like an integral part of the building, with the use of windows and/or cladding, or by landscaping, or green screens, or a combination thereof. The interior of a parking structure shall be designed to be screened from the view of streets and sidewalks.

10.4 Bicycle Standards

10.4.1 Bicycle parking shall be provided per Ordinance No.182386.

10.5 Transportation Demand Management Plan

10.5.1 The Project shall incorporate a comprehensive transportation demand management plan.

10.5.2 The transportation demand management plan shall set forth best practices that relate to the Project Site and the Project's building design features in order to:

a. Promote bicycle and pedestrian circulation within the Project Site.

b. Promote alternative modes of transportation.

c. Create pedestrian linkages to public and private amenities outside the Project Site.

d. Provide convenient and attractive onsite pedestrian linkages for routes to the Metro Red Line Station at Hollywood Boulevard and Vine Street.

e. Provide adequate parking, but provide incentives to tenants and residents to utilize alternative modes of travel. The incentives shall include bicycle facilities, car sharing, discounted subway passes, and parking spaces as an only optional part of all lease and sale agreements.

11. SIGNAGE

11.1 Hollywood Signage Supplemental Use District

Signage shall be subject to Ordinance No. 181340: Hollywood Signage Supplemental Use District (Amended) pursuant to Section 13.11 of the Los Angeles Municipal Code.

11.2 Modification to Guidelines

Notwithstanding Section 11.1, high-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted. See fig. 11.2.

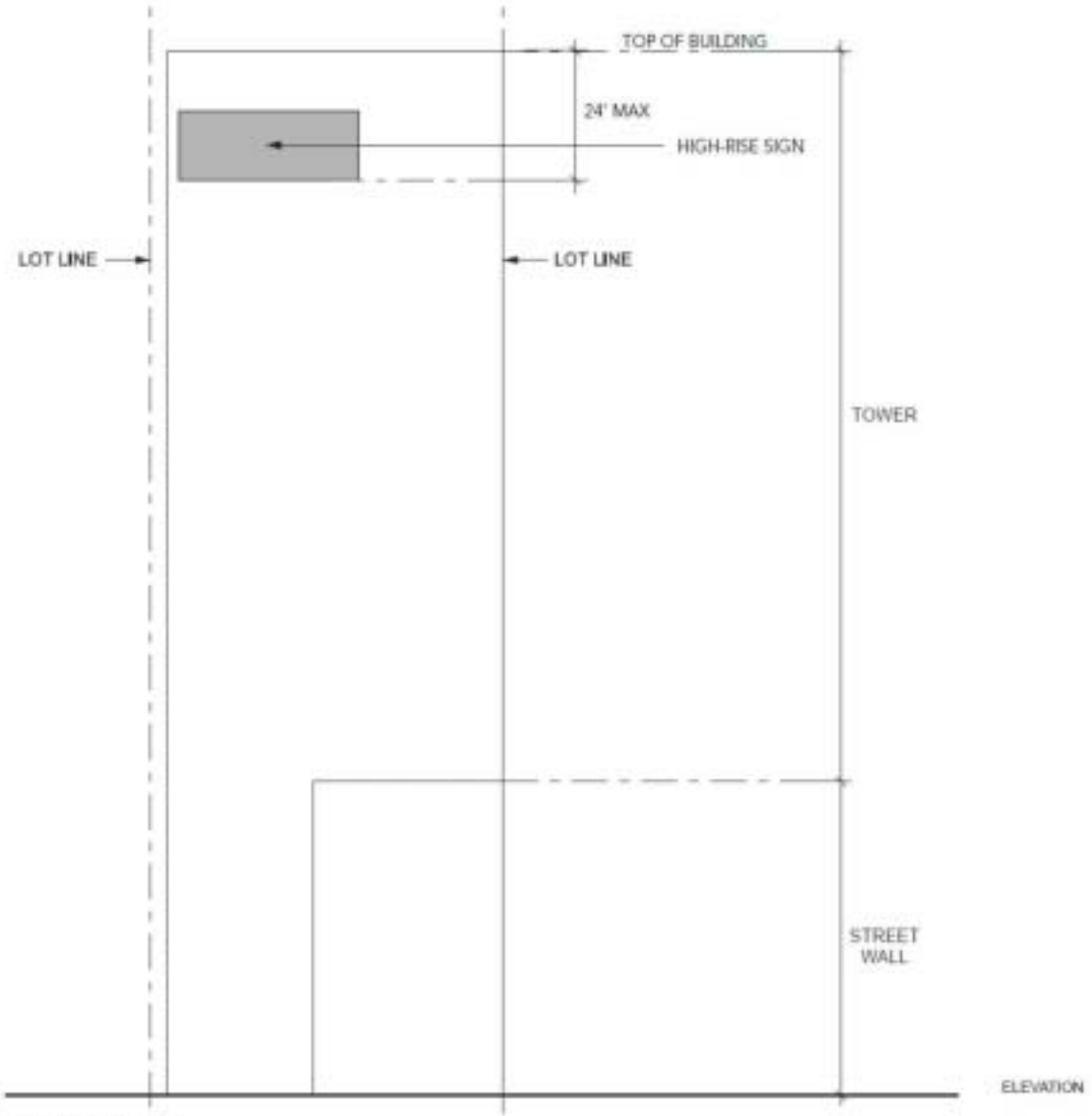


fig. 11.2: High Rise Sign

12. SUSTAINABILITY

12.1 Non-Residential Projects

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

12.2 Other Projects

The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

13. DEFINITIONS

Awning: glazing or fabric on metal frame structure supported entirely by the building to provide weather protection at doors, windows and/or storefronts, may be retractable.

Base: the lower portion of a building located at or within 150' above curb level.

Canopy: glazing, fabric and/or metal structure with vertical supports located on the sidewalk to provide weather protection at a building's primary entrance.

Expression band: a distinctive linear architectural element occurring on the building base façade at the highest floor. The band shall be contrasting in color, texture, material and/or fenestration from the adjacent building base façade. Projections may occur within an expression band.

Grade level open space: a continuous open space fronting the street and open to the sky.

Maximum building height: the maximum height permitted, measured from the adjacent street curb level.

Maintenance: the ongoing repair, care and upkeep of a property.

Open space use: active and passive recreational uses accessible to the general public, except as noted herein. Open spaces can occur in publicly accessible passageways, grade level open space, residential common open space and residential private open space which are defined herein.

Preservation: in conformance with standards and guidelines of the Secretary of the Interior, the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property.

Publicly accessible passageway: a continuous through-block public connection between two parallel streets, located on privately owned land and designated for and designed to encourage public pedestrian circulation and other appropriate public uses.

Rehabilitation: in conformance with standards and guidelines of the Secretary of the Interior, the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values.

Required street wall: a wall or portion of a wall of a building facing a street or grade level open space which must be built to a minimum height above curb level.

Required street wall articulation, aggregate width of: the sum of the maximum widths of all segments of required street wall articulation on a street at the level of any story. The width of a required street wall articulation is measured in plan as the width of the street line from which perpendicular lines may be drawn to such required street wall articulation.

Residential common open space: a "rear yard" providing light and air to apartments on the interior of a parcel located at any story above curb level.

Residential private open space: open space that is contiguous to and immediately accessible only from a single dwelling unit.

Setting: the area or environment in which a historic property is found. It may be an urban or suburban neighborhood or a natural landscape in which a building has been constructed. Elements of setting can include the relationship of buildings to each other, setbacks, views, sidewalks, and street trees.

Storefront: the architectural facade, including doorways, of any tenant-leased premise perimeter adjacent to public circulation areas. Storefronts refers to all permitted residential, retail uses including retail, service, restaurants and cultural establishments and commercial uses, including but not limited to hotels and sports clubs.

Tower: the portion of a building located above 150' above curb level

Transparency: architectural elements that can be seen through or allows light to emit through, including but not limited to glass, trellis and wire mesh

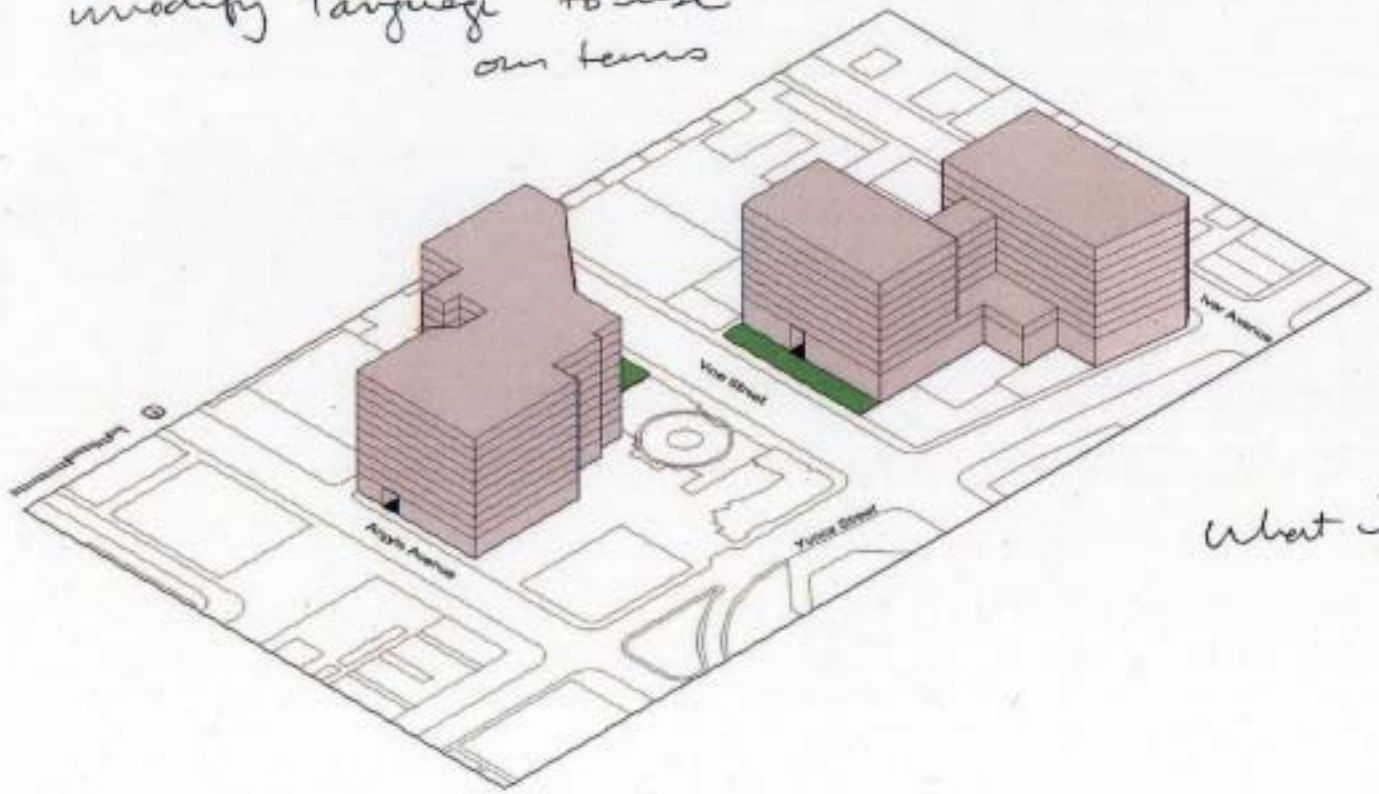
Notes

1. Images and figures used in the Regulations were prepared for exhibition use by Millennium Development LLC unless otherwise noted.

code open space
- private
- public
- PAPS - passage

better angle is this 6:1

look at code req. open space language
modify language to use our terms



what is PAPS

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MARCH 24, 2010

OFFICE PROGRAM - 150'

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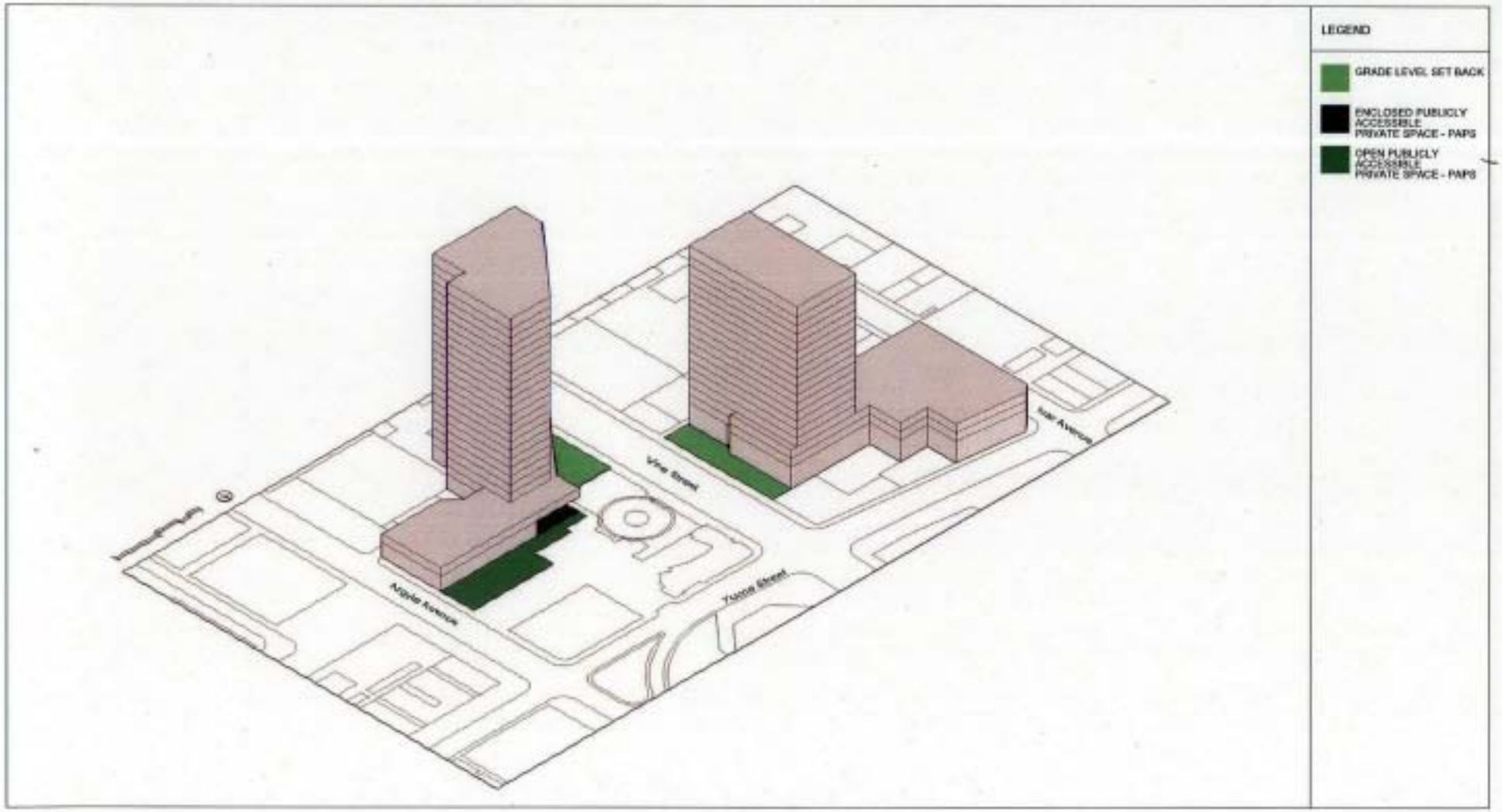
CO-0001-222

AR0068205

CO-0001-223

AR0068206



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MARCH 24, 2010

OFFICE PROGRAM - 400'

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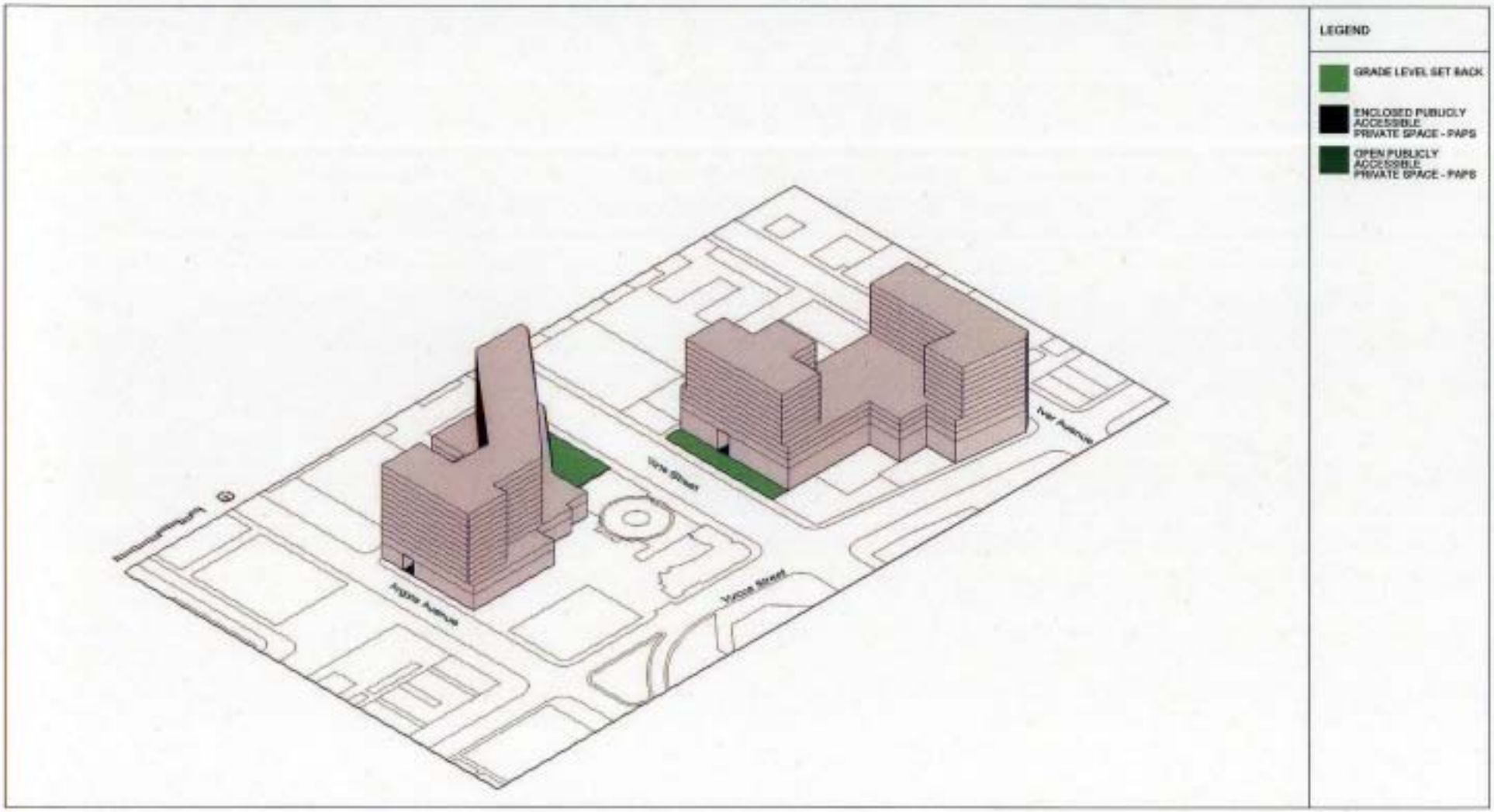
AR0068207



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RESIDENTIAL PROGRAM - 150'

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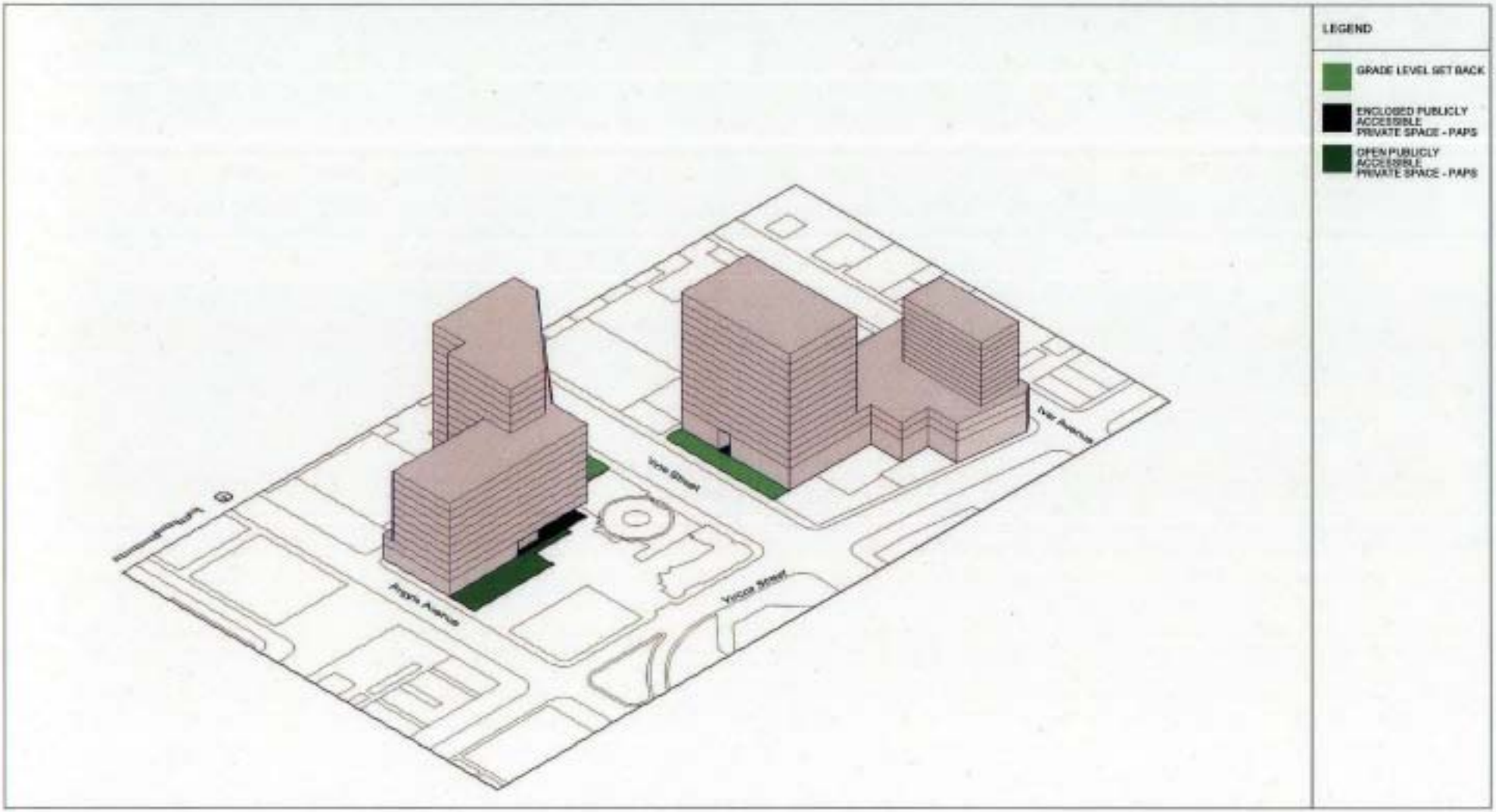

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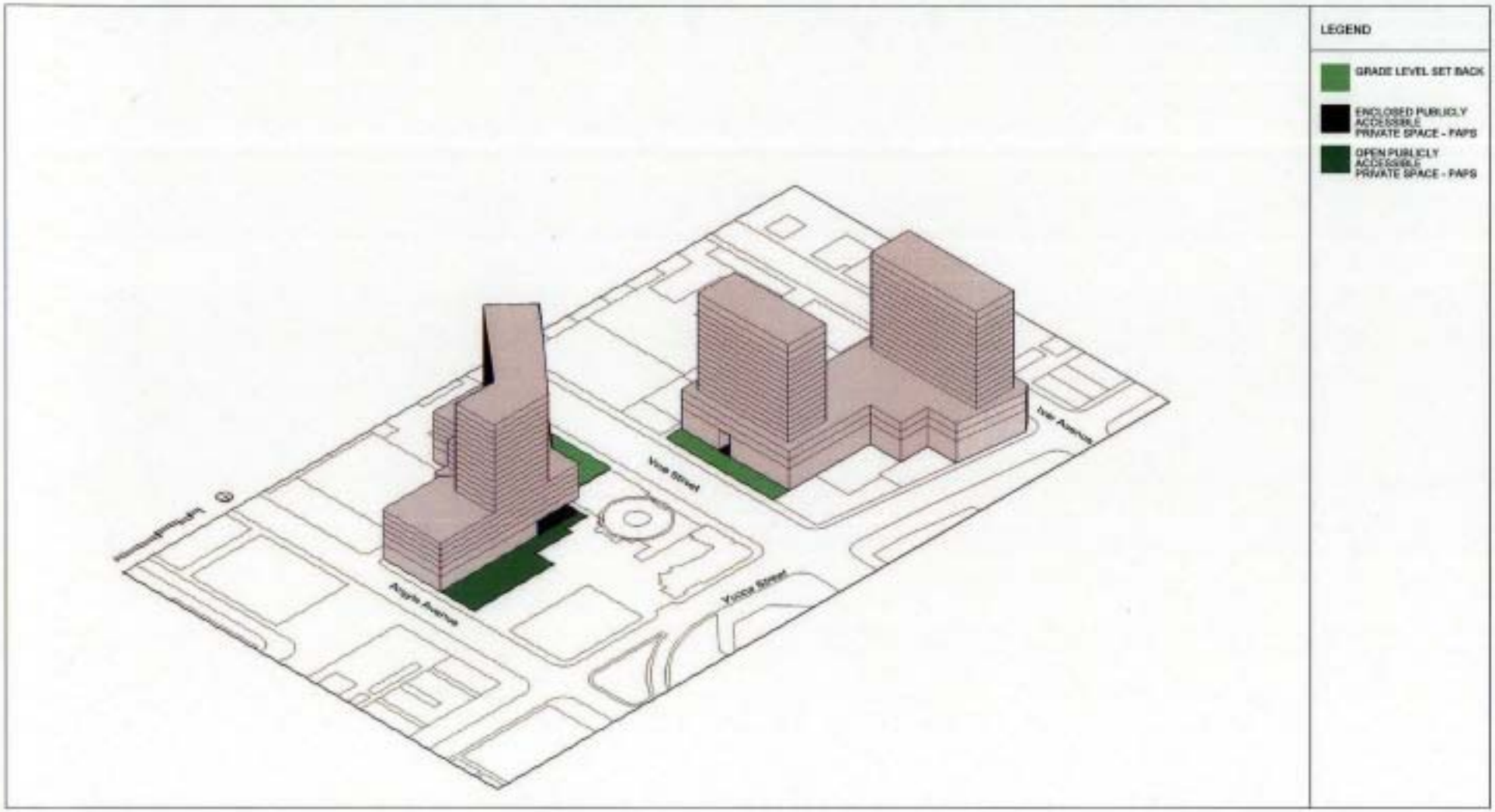
AR0068209



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MARCH 24, 2010

RESIDENTIAL PROGRAM - 220'

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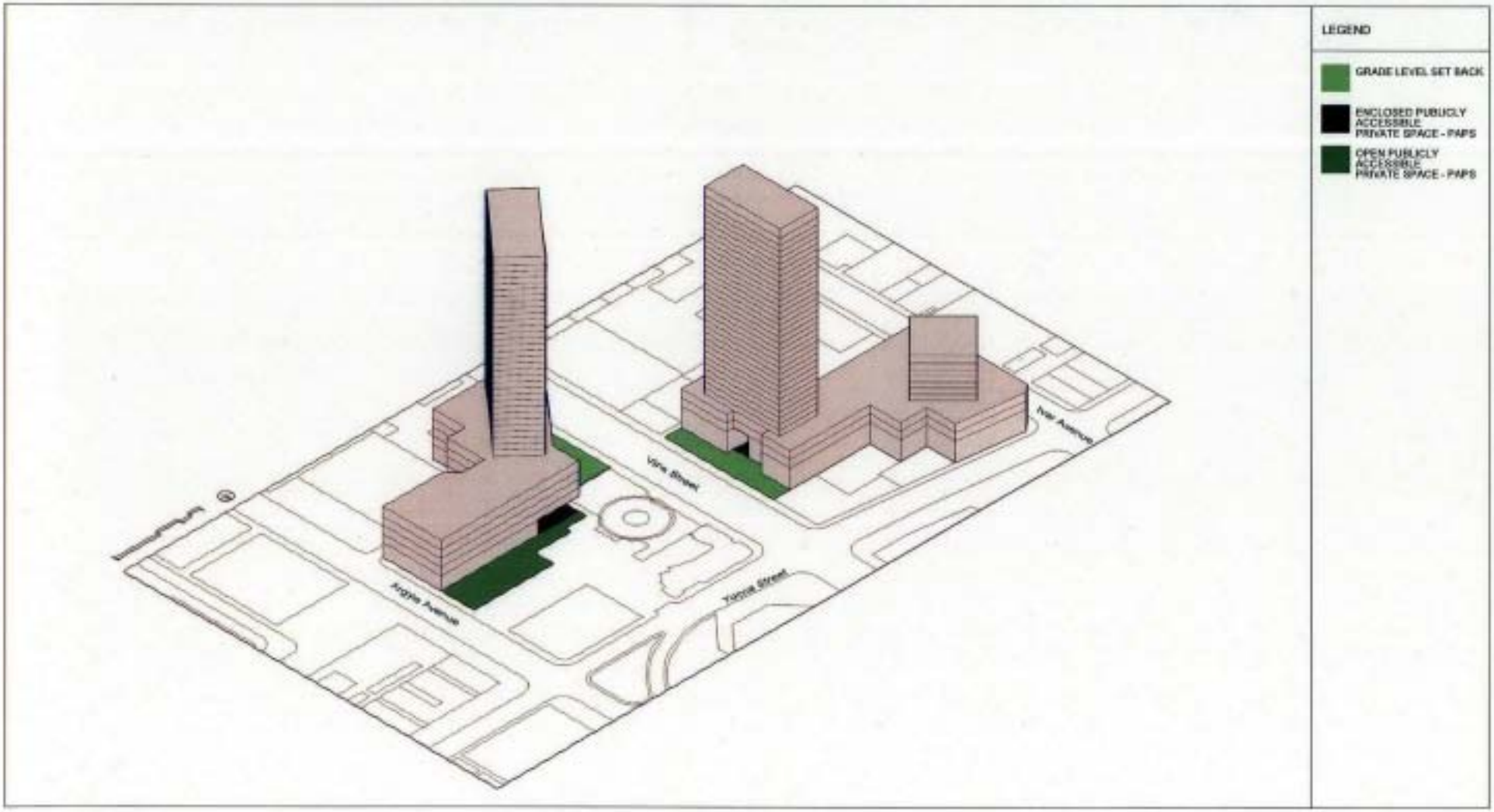
CO-0001-227

AR00068210



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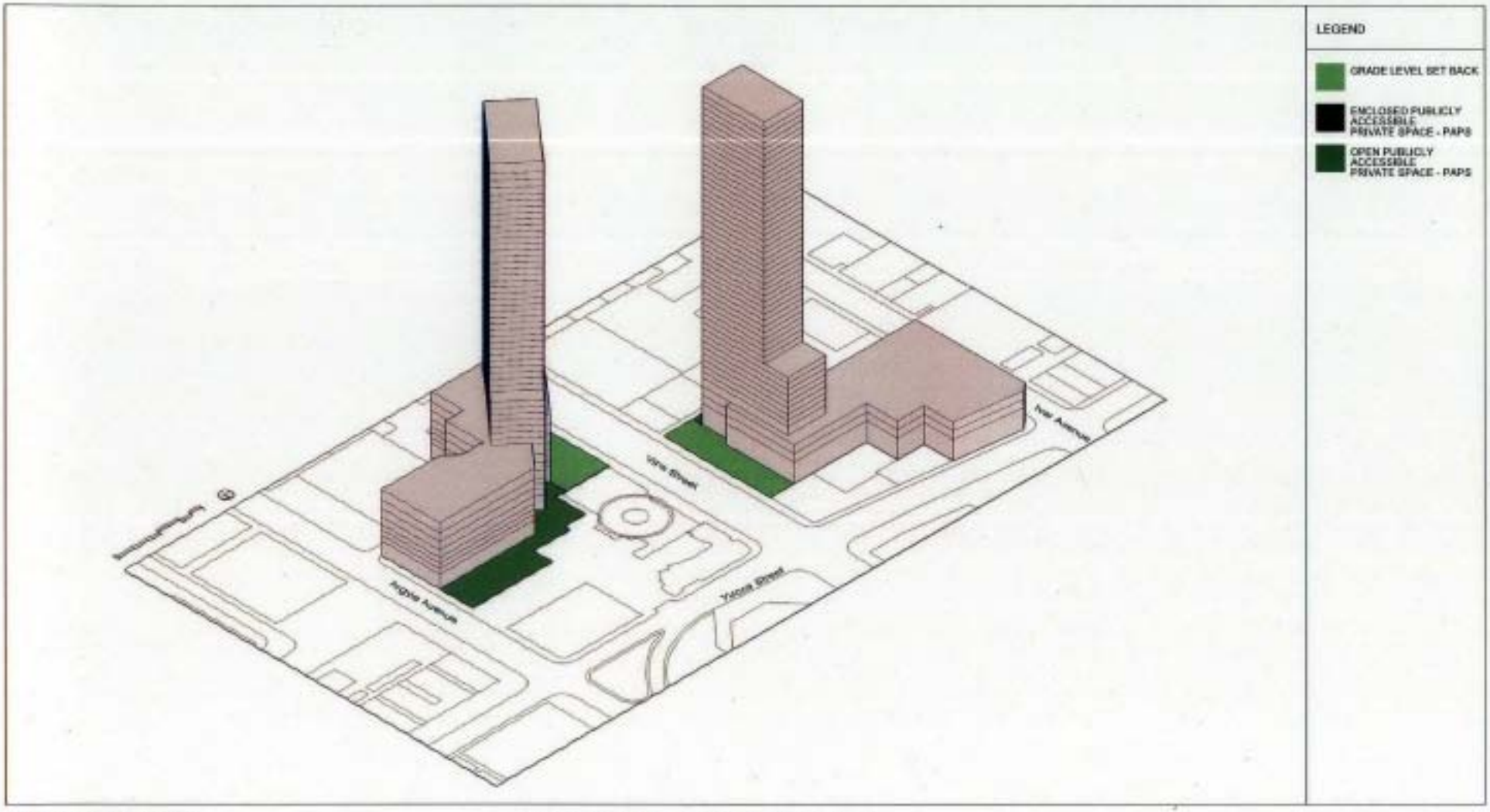
AR0068211



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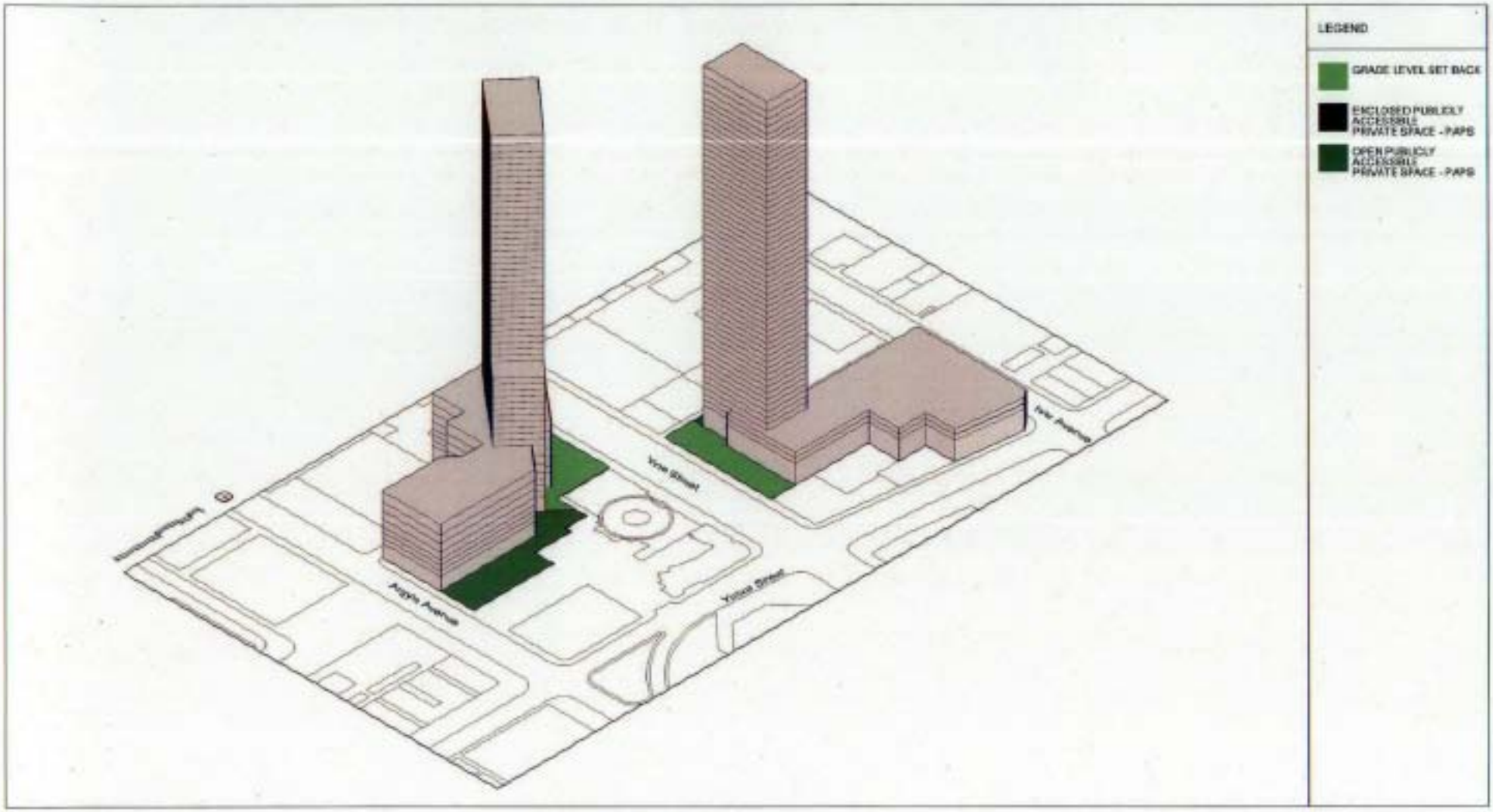
AR0068212



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MARCH 24, 2010

RESIDENTIAL PROGRAM - 585'

Blake Lamb - Millennium Hollywood Design Guidelines

From: "Kearns, Rick" <rkearns@handelarchitects.com>
To: "Blake Lamb" <Blake.Lamb@lacity.org>
Date: 7/7/2010 7:23 AM
Subject: Millennium Hollywood Design Guidelines
CC: "Kevin Keller" <Kevin.Keller@lacity.org>, "Handel, Gary" <ghandel@handelarchitects.com>
Attachments: Capital Records_ Millennium Design Guidelines.pdf; Capital Records Design Guidelines Exemplar.pdf

Blake – as promised, attached are the revised guidelines. We revised the text to distinguish the standards and the guidelines per our previous discussions and eliminated, to the extent possible (without compromising clarity), variant terminology. We organized the text under six major headings: density, height, massing (redefined to be community-oriented as "building and street experience"), tower, open space and landscape. We defined landscape to include all environmental aspects of the project to be experienced at eye level not including tower and massing provisions. Thus, rather than include a separate, general section for lighting, we thought that it was better organized under a subheading in landscape.

We have also included examples of how we can use graphics to help better illustrate the rules through renderings and photographs. Images in the examples are used as placeholders only.

We are confirmed for Friday, 9AM at Capitol Records. I will send out an email with room location later today.

See you on Friday

Best,

Rick

Rick Kearns
Senior Associate

HANDEL ARCHITECTS LLP
150 Varick Street
New York, NY 10013
t 212 595 4112
f 212 966 6632
www.handelarchitects.com

From: "Kearns, Rick" <rkearns@handelarchitects.com>
To: "Blake Lamb" <Blake.Lamb@lacity.org>
Date: 7/6/2010 12:04 PM
Subject: RE: Millennium/Argent Hollywood Meeting
Attachments: 20100615_SK.PDF; 20100615_SK.PDF

Hi Blake, We are confirming the meeting at Capitol - we should have a response by tomorrow.

We overlaid the proposed guidelines on the Entitlement Scheme and the attached documents show what is impacted on both sites. The grade level open space needs to increase on both sites and the pedestrian through block connection (PAP) needs to be added to the west site. We increased the amount of retail/restaurant area along the PAPs to meet the minimum retail frontage requirement. The hand sketch plans show the revised layout. We can discuss further at our meeting on Friday.

Regards,

Rick Kearns

Senior Associate

HANDEL ARCHITECTS LLP

<http://www.handelarchitects.com>

From: Blake Lamb [mailto:Blake.Lamb@lacity.org]
Sent: Friday, July 02, 2010 5:55 PM
To: Kearns, Rick
Subject: Re: Millennium/Argent Hollywood Meeting

Dear Rick,

That is a great idea. Either location is fine in Hollywood. Just let us know what you decide and see you then.

Have a great holiday weekend,

Blake

Millennium EIR Meeting 11/17/10

Chris Josephs
Rick Uchenatern
Alfred Francjo
Brian Parker

218 feet height - buses on Clean
update of staffing issues / changes to dept
since file EAL soon in 2010.

3rd party services? (Biaun) was done to test.

update tables
EAF fee ?

2/12

design guidelines - clear standards so we need less design review

equivalency matrix
- how to show flexibility?
- would it include a. alternative table. graphics of basic building envelope as well as "concept design"?

[equivalency concept design decision letter by right process for follow up.
- EHR

Charette or design meetings

idea is to allow shifting of permitted land use over life of project development

Gary, Rick

have a lot of materials they can share with us
in outline, any other specific

how will equivalency matrix?
- productive ideals to explore:
  - fact based numerical things
    - % of open space per bldg height
  - subjective things - qualitative based things more likely

how to show quality of design?

quantative - ok harder to define character

different ways to satisfy

→ limit flexibility - create architectural solutions or stick to quantative

could give examples
three diff. types of values

- could be a better palette
agree successful?
illustrative diff
- prescriptive with but leaving open loopcak + reasonable
create mechanism to vary from prescription
normative criteria + give examples
if have better value, there is a mechanism to do internal

did scheme before + ways change
use it as template, also may vary

massing studies

create set of parameters no matter what development
certain things triggered for certain heights, etc.
if go taller, need open space, less lot coverage.

building character is most tough

- Michael Gadamo
- Alfred
- Rick
- Gary

DBS Case No: CM2008-0257 12/9/2013

Address: 1750 N VINE ST

Comments: 39

Use Files:

Case Summary

Subject: Left voicemail message for Alfred Fraijo on 8/21 Created: 8/21/2008 4:35 PM
Modified: 8/21/2008 4:35 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Subject: Project Walk through: meeting Created: 9/4/2008
Modified: 9/4/2008 3:50 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Met with Alfredo Fraijo and Jerry Neuman from Allen Matkins

-Walked through project
-There are 2 sites
East Site (where the existing Capitol Records building will remain) will include a new 46-story (554') residential condo and office
-West Site (across the street) will include a new 38-story (482') residential condo, ground floor retail and restaurant, spa, and 16 story 200 room hotel.
-Still in design phase
-possible subsurface connection through vine street
-planning to make plan amendment in dec 08
-they have questions about balconies/viewdecks and FAR
-one parking variance for health club
some offsite parking already onsite for 40 spaces for a retail shop down the street
enterprise lot (sep ownership for now, but they want to obtain it)
-historic elements are not touched
-haul route hearing required
-kevin keller is the contact from city planning
-charlie (david) is from city planning

Subject: email to Celeste to update high rise list Created: 9/5/2008 9:33 AM
Modified: 9/5/2008 9:33 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Tower 1 (East Site) - 46 story residential condo, office, ground floor retail and parking
Tower 2 (West Site) - 38 Story residential condo, ground floor restaurant and retail, parking
Tower 3 (West Site) - 16 Story Hotel

Subject: Feasibility Study Meeting - WILL ADD DETAILS TO THIS ACTIVITY LATER. Created: 9/15/2008
Modified: 9/17/2008 9:13 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Subject: Spent time discussing project with Nick Trotta. (Will ADD DETAILS TO THIS ACTIVITY LATER)
Created: 9/19/2014
Modified: 9/19/2014 8:31 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Subject: My email to Alfred and Eleanor/Allen Matkins RE Follow Up Items to our Feasibility Study
Created: 9/17/2014 3:14 PM
Modified: 9/17/2014 3:14 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Hi Alfred and Eleanor,

I wanted to follow up with you on our meeting yesterday regarding the Capitol Records sites.

1. Regarding the yard designations we can consider all of the frontages on the streets as "Front Yards", and the rest of the lot lines as "Side Yards". However, we would also request that these "yard designations" be called out in your planning entitlement.

2. Regarding the residential and commercial parking combined on an above grade parking level: any floor level containing residential parking will have to observe residential yard setbacks (front yard not required in C zones) even if the residential parking is located in the interior of the floor and away from the lot lines. You will need a yard variance if you are proposing to have the above-grade parking levels containing residential parking all the to the property line.

3. Jamevon suggests that you speak to Greg Shoop at the City Planning Counter (4th Floor of 201 N Figueroa St). There may be creative ways to exceed the 6:1 FAR without the general plan amendment.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
201 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

Subject: Eleanor Cm/Allen Matkins acknowledged my follow up email sent on 9/17
Created: 9/25/2014 9:10 AM
Modified: 9/25/2014 9:10 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Hi Charmie,

Thanks for getting back to us before your trip. I hope you all have a great time, and we'll be in touch on your return.

Eleanor
-----Original Message-----
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Wednesday, September 17, 2008 5:16 PM
To: Fraija, Alfred; Ord, Eleanor
Cc: Jameson Lee
Subject: 1750 N Vine St - Capitol Records Site - CM2008-0287

Hi Alfred and Eleanor,

I wanted to follow up with you on our meeting yesterday regarding the Capitol Records sites.

1. Regarding the yard designations: we can consider all of the frontages on the streets as "Front Yards", and the rest of the lot lines as "Side Yards". However, we would also request that these "yard designations" be called out in your planning entitlement.

2. Regarding the residential and commercial parking combined on an above-grade parking level: any floor level containing residential parking will have to observe residential yard setbacks (front yard not required in C zones) even if the residential parking is located in the interior of the floor and away from the lot lines. You will need a yard variance if you are proposing to have the above-grade parking levels containing residential parking at 0' to the property line.

3. Jameson suggests that you speak to Greg Shoop at the City Planning Counter (4th floor of 201 N Figueroa St). There may be creative ways to exceed the 6:1 FAR without the general plan amendment.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-0875
F. (213) 482-6674
Charmie.Huynh@lacity.org

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AR0068220

Subject: Meeting with Project Team to discuss balconies and FAR
Created: 10/7/2008
Modified: 10/8/2008 10:01 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Spent time reviewing ZA2007-03430 (ZAI) prior to meeting

In attendance: Peggy Pallian (executive arch), Jerry Neuman/Allen Matkins, Alfred Fraijo/Allen Matkins, Gary Handel/design arch, Ed Tacyibana/design arch, and Tom Toynin/developer

Main issues:

-do the leftover spaces that are less than 6' in dimension count as FAR (ZAI 2007-3430 states that one of the conditions to benefit from this interpretation is that the balcony must qualify as Open Space as per 12.21-G,2(b)(2)

how do we measure the 6' measurement that qualifies a balcony as private open space

-will LADBS consider the wood lattice and the glass curtain wall as balcony enclosures?

We discussed the projecting living rooms, the area above the living rooms (open and unenclosed except for guardrails, and the measurements do qualify for private open space) are not FAR (confirmed this also with JL)

We discuss HOTEL Setbacks - hotel is defined as a residential building and must observe required setbacks. They will apply for a variance for the screen wall at the p.l. if it is attached to the building. I did not see a detail of this "screen wall".

Subject: Worked on coordinating the pre-development meeting, reviewed project files, phone conversations with the attorneys/applicants.
Created: 10/8/2008
Modified: 10/9/2008 7:27 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: Pre-Development

Thanks, Charmie. Attached below is the Project Description. Please let me know if you need anything else.

Eleanor
-----Original Message
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Wednesday, October 08, 2008 9:36 AM
To: Ord, Eleanor
Cc: Fraijo, Alfred; Neuman, Jerry
Subject: RE: Millennium Hollywood PDM Materials (Email 1)

Hi Eleanor,

Ok, I'll invite Lambert Giessinger to attend. Also, I'll need the project narrative before I send out the meeting invitation.

Thanks
Charmie

AR0068221

>>> "Ord, Eleanor" 10/7/2008 7:19 PM >>>

Charmie,

Yes, we'd like the Office of Historic Resources to attend.

Thanks,

Eleanor
-----Original Message-----
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Tuesday, October 07, 2008 7:18 PM
To: Ord, Eleanor
Cc: Hraljo, Alfred; Neuman, Jerold
Subject: Re: Millennium Hollywood PDM Materials (Email 2)

Also, would you need someone from the Office of Historic Resources (Planning) to attend this pdm?

Thanks
Charmie

>>> "Ord, Eleanor" 10/7/2008 12:08 PM >>>

Hi Charmie,

Because of the City limits on email file size, I'm going to send you the PDM materials for the Capitol Records project in a series of emails. Attached here are (1) our list of issues and questions for the City Departments and (2) a roof plan showing the project setbacks and sidewalk widths.

With regard to PDM attendees, we'd like Kevin Keller to attend from Planning and Tomas Carranza from DOT. We've been working with Kevin and Tomas and both are familiar with the project. It's not necessary to invite anyone from CRA to the PDM. We've been working with Kip Rudd and will schedule a separate CRA meeting with him.

Finally, we'd like to confirm October 22nd at 1:00 pm for the PDM. Thanks for being flexible with the time - 1:00 pm works well for everyone on our team.

Thanks,

Eleanor

Eleanor M. Ord
Attorney at Law
Allen Matkins
515 South Figueroa Street, 9th Floor
Los Angeles, CA 90071
Direct: 213-955-5653
Fax: 213-620-8816

Subject: My follow up email to project team and JL RE balconies and FAR — Created: 10/9/2008 11:18 AM, Modified: 10/9/2008 11:18 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMYGS

Hello All,

Here's a summary of my discussion with our director Jameson Lee regarding the questions you posed during our meeting last Thursday, Oct 2:

1. Leftover areas that are less than 5' in dimension, but are a part of the balconies that do qualify as private open space as per 12.21G2(b)(2); Are these counted as Zoning Code Floor Area as per ZA2007-3430(ZAI)?

No, we will not count these as Zoning Code Floor Area as long as these areas are a part of the balconies that do qualify as private open space per 12.21G2(b)(2).

2. Interpretation of the measurement of the 6' dimension:

You will need to measure the 6' dimension perpendicular to the boundaries of the open space area. However, you may still have the configuration of your balconies the way you have designed them so far if you have at least 50sf of qualified private open space (i.e., 6' measurement perpendicular, etc.) anywhere on the balcony. If so, then you can have the entire balcony benefit from ZA2007-3430(ZAI). This follows with our interpretation from #1 above.

3. Fixed Wood Lattice with Metal Frame that provide Sun Shade - Does this count as an enclosure for the balconies?

Yes, we will consider this an enclosure for the balconies. You may request to the Department of City Planning that they make the determination to not consider these screened balconies (be specific with the description of the screens) as "enclosed balconies" and thus not counting towards the FAR. You would need to have this request as part of your entitlement package.

4. Glass Curtain Wall as another "sun shade screen" for balcony areas

See #3 above.

5. REGARDING the wood lattice with metal frame (This issue was not discussed during our meeting):

I would like to mention that for Building Code purposes, Type I construction typically does not allow combustible material. Please look into this issue.

6. Another issue that was not discussed at our meeting:

Please contact Greg Shoop from City Planning regarding possible alternative ways to increase the allowable FAR w/o having to do a GPA. Greg can be reached at 213-482-7074. If there is another way around this max FAR issue, then most of your balcony issues would be solved.

Please let me know if you have any questions.

Thank you

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St. Suite 1180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6824
Charmie.Huynh@lacity.org

AR0068223

Subject: Worked on coordinating the pre-development meeting, reviewed project files, phone conversations with the attorneys/applicants. PART II

Created: 10/7/2008
Modified: 10/9/2008 7:27 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: Pre-Development

Thanks, Charmie. Attached below is the Project Description. Please let me know if you need anything else.

Eleanor
----- Original Message-----
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Wednesday, October 08, 2008 9:36 AM
To: Ord, Eleanor
Cc: Fralio, Alfred; Neuman, Jerold
Subject: RE: Millennium Hollywood PDM Materials (Email 1)

Hi Eleanor,

Ok, I'll invite Lambert Giesinger to attend. Also, I'll need the project narrative before I send out the meeting invitation.

Thanks
Charmie

>>> "Ord, Eleanor" 10/7/2008 7:19 PM >>>

Charmie,

Yes, we'd like the Office of Historic Resources to attend.

Thanks.

Eleanor
----- Original Message -----
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Tuesday, October 07, 2008 2:18 PM
To: Ord, Eleanor
Cc: Fralio, Alfred; Neuman, Jerold
Subject: Re: Millennium Hollywood PDM Materials (Email 1)

Also, would you need someone from the Office of Historic Resources (Planning) to attend this pdm?

Thanks
Charmie

>>> "Ord, Eleanor" 10/7/2008 (7:08 PM >>>

Hi Charmie,

Because of the City limits on email file size, I'm going to send you the PDM materials for the Capitol Records project in a series of emails. Attached here are (1) our list of issues and questions for the City Departments and (2) a roof plan showing the project setbacks and sidewalk widths.

With regard to PDM attendees, we'd like Kevin Keller to attend from Planning and Tomas Carranza

from DOT. We've been working with Kevin and Torres and both are familiar with the project. It's not necessary to invite anyone from CRA to the PDM. We've been working with Kip Rudd and will schedule a separate CRA meeting with him.

Finally, we'd like to confirm October 22nd at 1:00 pm for the PDM. Thanks for being flexible with the time - 1:00 pm works well for everyone on our team.

Thanks,

Eleanor

Eleanor M. Ord
Attorney at Law
Allen Matkins
515 South Figueroa Street, 9th Floor
Los Angeles, CA 90071
Direct: 213-955-5653
Fax: 213-620-8815

Subject: Worked on PDM. Sent out Mtg Invite and Project Files, Mtg scheduled for Wed., Oct 22 from 1-3pm

Created: 10/9/2008 7:25 AM
Modified: 10/9/2008 7:25 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: Pre Development

Hello,

You are invited to a case management pre-development meeting for the proposed Millennium Hollywood High Rise projects at 1750 N Vine St (East Site) and 1751 N Vine St (West Site). The Project Narrative is attached to this email.

Date: Wednesday, October 22, 2008
Time: 1:00pm - 3:00pm
Location: 221 N Figueroa St., Suite 160, Los Angeles, CA 90012

Applicant: Alfredo Fraija, Attorney at Law, Allen Matkins, 213-955-5607

Questions and Issues for the City Departments:

1.) Planning/Building & Safety:

Confirmation of required entitlements with respect to the proposed project (are any other entitlements required?)
Confirmation of setbacks provided
Are there minimum distance requirements between the two towers?
Are there minimum distance requirements regarding light and air for windows facing windows, alleys or lot lines?
Confirm loading spaces required for the project and their required dimensions
Discuss balcony enclosure and screening issues (ZA 2007-3430(ZAI) Memo)

2.) Public Works:

Are any offsite improvements required, such as street widening, other than what a traffic study might suggest?

Confirm sidewalk and street dedication requirements
Sewer facility charge and credit
Adequacy of storm drain system near project
Confirmation of sewer capacity availability
Are there any requirements for on-site storm water retention, treatment, discharge during construction and/or operation?
What are the required public improvements regarding street trees etc?
What are the required public improvements regarding street lights?
How will the Walk of Fame be handled during construction?
Task force to determine viability of underground tunnel and obtaining a franchise

3.) LAFD & Fire Hydrants and Access:

What are the type and location of desired Fire Dept. turnarounds?
Where should on-site hydrants be located?
What fire lane access is required to the buildings?
How do hydrant and fire equipment access requirements impact the layout of units?
General review of and input related to the proposed site plan regarding Fire Department requirements.
Observation deck fire access issues, including capacity, fire escape and elevator.

4.) DWP:

Will we be required to provide public or private utilities?
Requirements for undergrounding utilities, if any.
How will project be metered relative to the air lot subdivision?
Potential relocation of traffic island and right-hand turn lane at corner of Yucca and Argyle to create a park
General review and input regarding the proposed site plan and DWP requirements, including water and power service availability, water and power connections and clear distance from existing or future power lines.
Your attendance is greatly appreciated. If you cannot attend, please reply to me via email with your comments and any information you can pass along to the Applicant to address their concerns/issues.

Attached are some of the project files. I will be sending an additional 4 other emails containing the project files.

Thank you

Charmle Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmle.Huynh@lacity.org

4 Attachments:

Subject: Lamcert Giessinger from Office of Historic Resources will be out of town. He suggests I invite Ken Bernstein

Created: 10/8/2008 2:30 PM
Modified: 10/9/2008 7:39 AM

Last Modified by: Charmle Huynh

From: Department of Building and Safety

Subject: Pre-Development

Thanks Lambert. Can you forward the groupwise email invitation to Ken? And also all the project files? Please let me know.

Thanks
Charmie

>>> Lambert Giessinger 10/8/2008 5:11 PM >>>
Charmie,

I will be out of town. You may want to invite Ken Bernstein in my absence. Thank you.

Lambert

>>> Charmie Hoynh 10/8/2008 4:46 PM >>>
Hello,

You are invited to a case management pre development meeting for the proposed Millennium Hollywood High Rise projects at 1750 N Vine St (East Site) and 1751 N Vine St (West Site). The Project Narrative is attached to this email.

Date: Wednesday, October 22, 2008
Time: 1:00pm - 3:00pm
Location: 221 N Figueroa St., Suite 180, Los Angeles, CA 90012

Applicant: Alfredo Fraijo, Attorney at Law, Allen Matkins, 213 955-5607

Questions and Issues for the City Departments:

1.) Planning/Building & Safety: Confirmation of required entitlements with respect to the proposed project (are any other entitlements required?) Confirmation of setbacks provided Are there minimum distance requirements between the two towers? Are there minimum distance requirements regarding light and air for windows facing windows, alleys or lot lines? Confirm loading spaces required for the project and their required dimensions Discuss balcony enclosure and screening issues (ZA 2007-3430(ZAI) Memo)

2.) Public Works: Are any offsite improvements required, such as street widening, other than what a traffic study might suggest? Confirm sidewalk and street dedication requirements Sewer facility charge and credit Adequacy of storm drain system near project Confirmation of sewer capacity availability Are there any requirements for onsite storm water retention, treatment, discharge during construction and/or operation? What are the required public improvements regarding street trees etc? What are the required public improvements regarding street lights? How will the Walk of Fame be handled during construction? Task force to determine viability of underground tunnel and obtaining a franchise

3.) LAFD & Fire Hydrants and Access: What are the type and location of desired Fire Dept. turnarounds? Where should on-site hydrants be located? What fire lane access is required to the buildings? How do hydrant and fire equipment access requirements impact the layout of units? General review of and input related to the proposed site plan regarding Fire Department requirements. Observation deck fire access issues, including capacity, fire escape and elevator.

4.) DWP:Will we be required to provide public or private utilities? Requirements for under grounding utilities, if any. How will project be metered relative to the air lot subdivision? Potential relocation of traffic island and right-hand turn lane at corner of Yucca and Argyle to create a park General review and input regarding the proposed site plan and DWP requirements, including water and power service availability, water and power connections and clear distance from existing or future power lines.
Your attendance is greatly appreciated. If you cannot attend, please reply to me via email with your comments and any information you can pass along to the Applicant to address the concerns/issues.

Attached are some of the project files. I will be sending an additional 4 other emails containing the project files.

Thank you!

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

Subject: hector Banuelos / Street Tree will attend the pdr — Created: 10/6/2009 7:54 AM, Modified: 10/9/2009 7:54 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: Pre-Development

Hello Charmie,
No problem with the viewing. See you there.
Thanks

Hector M. Banuelos
Acting Street Tree Superintendent I
Bureau of Street Services
Urban Forestry Division

PH (213) 847-3077
Fax (213) 847-3033
hector.banuelos@lacity.org

>>> Charmie Huynh 10/9/2009 7:15 AM >>>

Thanks Ron. Hope you are well too.

Hector, please let me know if you have trouble viewing the project files.

Thanks
Charmie

>>> Ron Lorenzon 10/9/2009 5:46 AM >>>

Hector
Please attend
Thanks

Charmie
Hope you are well.
R

Subject: DOT contact (email from Tomas Carranza) Created: 10/10/2008 10:01 AM
Modified: 10/10/2008 10:05 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: Pre-Development

Hi Charmie,

I forwarded your invite to Wes and Eileen and requested that they cover it. I guess GroupWise automatically deletes invitations after I delegate them.

>>> Charmie Huynh 10/9/2008 11:08 AM >>>
Hi Tomas,

I saw that you deleted the groupwise pdm invitation I sent out yesterday for this project. The applicant would like to request that you attend this pdm since they have been working with you on this project already. Please advise if you can attend or if you will send someone else.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

Subject: DOT will not attend the PDM - I forwarded Wes Pringle's Email to Eleanor/Allen Matkins Created: 10/16/2008 9:13 AM
Modified: 10/16/2008 9:18 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: Pre-Development

FYI, Tomas Carranza from DOT delegated this project to Wes Pringle, who will not be able to attend. Please see attached.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org
****

Charmie,

I will not be attending the meeting for this project. We have been working with the traffic consultant on the traffic study for this project and will comment on it when it comes out. If there are any other questions for DOT, please forward my contact information (below).

Thanks,

Weston Pringle
Department of Transportation
Metro Programs Division
100 S. Main St, 9th Floor
Los Angeles CA 90012
Phone: (213) 972-8482
Fax: (213) 972-8418
Stop 725

Subject: Ken Bernstein/Office of Historic Resources will attend
Created: 10/16/2008 9:33 AM
Modified: 10/16/2008 9:33 AM
Last Modified by: Charmie Huynh
From: Department of Building and Safety
Folder: Pre-Development

Yes, I plan on attending, though it's possible I may be a few minutes late.

>>> Charmie Huynh 10/16/2008 8:18 AM >>>

Hi Ken,

Will you be able to attend Pre Case Management Meeting I am setting up for the Millenium Hollywood Project at 1750 N Vine St and 1751 N Vine St? I sent the original invitation to Lambert who unfortunately cannot attend. The meeting is scheduled for next Wednesday, October 22 from 1pm - 3pm. Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 150
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
Charmie.Huynh@lacity.org

Subject: PDM confirmations
Created: 10/16/2008 9:46 AM
Modified: 10/16/2008 9:46 AM
Last Modified by: Charmie Huynh
From: Department of Building and Safety
Folder: Pre-Development

Ken Bernstein confirmed, but he may be a couple minutes late.
Edmond Yew - Bureau of Engineering, Land Development Group, Public Works confirmed. He deals with street vacations.

Thanks
Charmie

>>> "Ord, Eleanor" 10/15/2008 8:48 AM >>>

Thanks, Charmie.

----- Original Message -----
From: Charmie Huynh
To: Ord, Eleanor
Cc: Fraijo, Alfred
Sent: Thu Oct 16 08:24:33 2008
Subject: Re: Millennium Hollywood: PDM

Hi Eleanor,

The following people have confirmed:

Armen ElRawli or his designated staff - Bureau of Sanitation, Stormwater Protection Division
Carl Mills - Bureau of Engineering, Public Works
Frank Comfort, Captain - Fire Department, Hydrants and Access Unit
Kevin Keller - City Planning
Richard Ferguson or his designated staff - City Planning, Enforcements Division
Hector Benuelos - Bureau of Street Trees, Public Works,
Rene Baluyot - DWP
Charmie Huynh - LADBS
(Tentative) Ken Bernstein - City Planning, Office of Historic Resources (Lambert will not be able to attend)

Basically, the agenda is as follows:

Self Introductions
Brief Project Overview by your group
Then, we will go around by each department to address the questions you have prepared for them.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 880
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@ladbs.org

>>> "Ord, Eleanor" 10/13/2008 1:22 PM >>>

Hi Charmie,

I'm just checking in to make sure you have all the information you need from us for the PDM next week. Also, can you provide us with a list of confirmed City attendees and with any agendas or other similar materials?

Thanks!

Eleanor

Eleanor M. Diaz
Attorney at Law
Allen Matkins
515 South Figueroa Street, 9th Floor
Los Angeles, CA 90071
Direct: 213-955-5653
Fax: 213-620-8816

Subject Sent Early Zoning Plan Review Service email to Alfred

Created: 10/10/2008 2:55 PM
Modified: 10/10/2008 3:05 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Dear Alfred,

As your LADBS Case Manager, I would like to introduce you to our new "Early Zoning Plan Review" program exclusively developed for high rise projects. Your project may benefit from this program.

The normal building plan check submittal will usually take place after the end of 9-12 months of the planning entitlement process and the completion of all the construction drawings. If any violation of a zoning related issue is revealed after regular plan check, major cost in time and money will be required to resolve the issues by re design and/or applications for additional planning entitlements approval.

The "Early Zoning Plan Review" service will allow an earlier confirmation of project compliance with the zoning requirements which includes, but not limited to; building setbacks, sidewalk height, maximum floor area ratio, open space, passageway, density, number of parking spaces required, parking layout...etc.

Due to the familiarity of your project, I will conduct the early zoning review for your project. Simply provide sufficient architectural design and draft of entitlement action approved by the Planning Department.

When this early zoning plan review is completed, typically after 2-3 weeks after submittal, you will receive a complete correction sheet identifying any zoning related violations. I will be responsible to verify zoning compliance after you make all necessary corrections. In addition, you will also receive a "Clearance Summary Sheet" listing all required sign-offs from other agencies enabling you to proceed with required clearances ahead of time.

The "Early Zoning Plan Review" fee is based on 30% of the project's total permit valuation. For your project, please contact me for the estimated zoning plan checking fee. This amount will be deducted from the plan check fee when you submit for the full building plan check.

For more information, please contact me at 213-482-6875

Thank you

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.huynh@ladbs.org

Subject: Rene Baluyot from DWP cannot attend. WC Byrd from Power may attend. **Created:** 10/20/2008 2:55 PM **Modified:** 10/20/2008 2:58 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: Pre-Development

WC,

Would it be possible for you or your staff to attend this predevelopment meeting this Wednesday from 1PM to 3PM. Our group has a scheduled meeting with Councilmember Alarcon at the same time and I won't be able to attend the predev meeting. Please let me or Charmie know.

Charmie, I will forward the water info as soon as I get it from the water engineer.

Thanks!

Rene

From: Baluyot, Rene
Sent: Friday, October 17, 2008 12:52 PM
To: Byrd, W.C.; Spaont, Julie
Cc: Linard, Andrew; Moon, Marvin
Subject: Re: Request for Pre-Development Meeting for Millennium Hollywood - 1750 N Vine St (East Site) and 1751 N Vine St (West Site)(email 1)

Julie/WC, << File: GROUND FLOOR PLAN 1.pdf >> << File: 1750 Zimas.pdf >> << File: LA-B08560-v4 Pre Development Meeting Project Description.pdf >> << File: Vicinity Map.pdf >> << File: A105 East Site Survey.pdf >> << File: LA-B08370 v1 PDM Questions and Issues for City Departments.doc >>

The city case manager, Ms. Charmie Huynh, is requesting DWP to provide predevelopment assistance for the proposed Millennium Hollywood High-Rise project. Attached are the project files.

Will you please have your staff review the attached plans and requested DWP information and let me know the person in your group assigned to this project?

Thanks and have a great day!

Rene Baluyot

Economic Development Group

Los Angeles Department of Water and Power

213.367.1284

rene.baluyot@ladwp.com

-----Original Appointment-----
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Wednesday, October 08, 2008 4:47 PM
To: cord@allenmatkins.com; afrajo@allenmatkins.com; jneuman@allenmatkins.com;

AR0068233

eSardiana@handelarchitects.com; ghandel@handelarchitects.com; Ammar Elfawii; Carl Mills; Charmie Huynh, Frank Comfort, Kevin Keller; LADBS CMServiceRequest; LADBS_Fig221_180_Conf_A.pc01.dom16@lacity.org; Lambert Giessinger; Michael Taylor; Richard Ferguson; Ron Lorenzen; Tomas Carranza; Will Priem; Balleyot, Rene; tcrynin@millercomputers.com Cc: Jay Kim; Leonel Paco
Subject: Request for Pre-Development Meeting for Millennium Hollywood -1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)
When: Wednesday, October 22, 2008 1:00 PM-3:00 PM (GMT-08:00) Pacific Time (US & Canada).
Where: 221 N Figueroa St., Suite 180, LA, CA 90012

Hello,

You are invited to a case management pre-development meeting, for the proposed Millennium Hollywood High Rise projects at 1750 N Vine St (East Site) and 1751 N Vine St (West Site). The Project Narrative is attached to this email.

Date: Wednesday, October 22, 2008

Time: 1:00pm - 3.00pm

Location: 221 N Figueroa St., Suite 180, Los Angeles, CA 90012

Applicant: Alfredo Fraijo, Attorney at Law, Allen Matkins, 213-955-5607

Questions and Issues for the City Departments:

1.) Planning/Building & Safety: Confirmation of required entitlements with respect to the proposed project (are any other entitlements required?) Confirmation of setbacks provided Are there minimum distance requirements between the two towers? Are there minimum distance requirements regarding light and air for windows facing windows, alleys or lot lines? Confirm loading spaces required for the project and their required dimensions Discuss balcony enclosure and screening issues (ZA 2007-3450(ZAI) Memo)

2.) Public Works: Are any offsite improvements required, such as street widening, other than what a traffic study might suggest? Confirm sidewalk and street dedication requirements Sewer facility charge and credit Adequacy of storm drain system near project Confirmation of sewer capacity availability Are there any requirements for onsite storm water retention, treatment, discharge during construction and/or operation? What are the required public improvements regarding street trees etc? What are the required public improvements regarding street lights? How will the Walk of Fame be handled during construction? Task force to determine viability of underground tunnel and obtaining a franchise

3.) LAFD & Fire Hydrants and Access: What are the type and location of desired Fire Dept. turnarounds? Where should on-site hydrants be located? What fire lane access is required to the buildings? How do hydrant and fire equipment access requirements impact the layout of units? General review of and input related to the proposed site plan regarding Fire Department requirements. Observation deck fire access issues, including capacity, fire escape and elevator

4.) DWP:W: I we be required to provide public or private infiltr os? Requirements for under grounding utilities, if any. How will project be metered relative to the air lot subdivision? Potential relocation of traffic island and right-hand turn lane at corner of Yucca and Argyle to create a park General review and input regarding the proposed site plan and DWP requirements, including water and power service availability, water and power connections and clear distance from existing or future power lines.

Your attendance is greatly appreciated. If you cannot attend, p ease reply to me via email with your comments and any information you can pass along to the Apol cant to address their concerns/issues.

Attached are some of the project files. I will be sending an additional 4 other emails containing the project files.

Thank you

Charmie Huynh, P.E.

Structural Engineering Associate Case Manager

City of Los Angeles/Department of Building and Safety

221 N. Figueroa St, Suite 180

Los Angeles, CA 90012

T. (213) 482-6875

F. (213) 482-6874

Charmie.Huynh@lacity.org << File: GROUND FLOOR PLAN 1.pdf >> << File: 1750 Vimas.pdf >> << File: LA-808560 v4-Pre-Development Meeting Project Description.pdf >>

Confidentiality Notice

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Subject: PDM Today

Created: 10/23/2008
Modified: 10/24/2008 9:09 AM

AR0068235

Last Modified by: Charmie Huynh
From: Department of Building and Safety
Folder: Pre-Development

-BOSS - Hector Bandelon mentioned that they govern less off-site. Onsite trees by City Planning
-BOS-WPD - Ammar Eltawil discussed the feasibility of the bio-swale option; possibilities for combination design. Gave requirements to Gary/arch. AE said they will need grading approval for OK to have onsite infiltration. During construction, they will need to prepare a SWPPP.
-BOE - Carl Mills said 2' Hwy Dedication req'd on Vine St, both sides. There are widening requirements that they could appeal during planning entitlements. Alley off of argyle, not sure if fully improved. They may have to dedicate some in the alley. Need to do SFC study now. Need formal council directive for the tunnel. Gregg Vandergriff is a contact for the Walk of Fame.
-DWP - Power - Rodolfo Monroy gave vault size reqts. Vaults need to be on private property.
Planning/LADBS - I confirmed that all street frontages are front yards, the rest are side yards, but they need to get this confirmed from Planning. Richard Ferguson said this can be done in the VBT, that they will designate the yards then. Kevin Keller advised them to get CM involved in the design of their signs. entitlements include FAR and hotel near R zones. Alfredo Perez said initially, they do not see a problem with the wood lattice and glass screens. However, they would like to have a discussion with Alan Bell on this. I asked that they include me in that mtg with Alan Bell.
-Fire Department Hydrants and Access - afterwards, we went to the FD counter (Hyd and Acc) to talk to Insp Lynn McClain. He gave them general requirements and a follow up detailed meeting will be needed at a later date.

Subject: Sent email to Alfred/attorney RE additional CM contacts (those who did not attend pdm)
Created: 10/24/2008 9:50 AM
Modified: 10/24/2008 9:50 AM

Last Modified by: Charmie Huynh
From: Department of Building and Safety
Folder: Pre-Development

Additional Case Management Contacts for your project:

1. Wil Pham - Bureau of Street Lighting, Public Works - 213-847-1348
2. Rene Baluyot - DWP - General CM contact within DWP who can put you in touch with the DWP Water Section - 213-367-1284, Rene.Baluyot@ladwp.com
3. Michael Taylor - Bureau of Sanitation, Industrial Waste Management Division, Public Works - 323-342-6121, Michael.Taylor@lacity.org

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

Subject: DWP Water Info for Project. Email from Rene Baluyot (I forwarded this to Alfred Frajo/Allen Matkins today)
Created: 10/29/2008 1:08 PM
Modified: 10/29/2008 1:08 PM

Last Modified by: Charmie Huynh
From: Department of Building and Safety
Folder: CM/GS

Chaine,

Here's the water info for the project. Did WC make the meeting?

Have a great day!

Rene

From: Patterson, Mark
Sent: Friday, October 24, 2008 11:18 AM
To: Bahuyot, Rene
Cc: Downs, Michael; Daneshmand, Neda
Subject: FW: Request for Pre-Development Meeting for Millennium Hollywood -1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)

Attached is the water information for the site.

<>

Mark Patterson

Los Angeles Department of Water and Power

Water Distribution

Western District Associate Engineer

Phone: (213) 367-1219

Fax: (213) 367-1168

e-mail: mark.patterson@ladwp.com

From: Downs, Michael
Sent: Thursday, October 23, 2008 1:58 PM
To: Patterson, Mark
Subject: FW: Request for Pre-Development Meeting for Millennium Hollywood -1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)

Mike Downs

Los Angeles Dept. Water & Power

Water Distribution

Western District Engineer

(213) 367-1218

(213) 367-1168 (FAX)

To/le/WC,

The city case manager, Ms. Charmie Huynh, is requesting DWP to provide predevelopment assistance for the proposed Millenium Hollywood High-Rise project. Attached are the project files.

Will you please have your staff review the attached plans and requested DWP information and let me know the person in your group assigned to this project?

Thanks and have a great day!

Rene Baluyot

Economic Development Group

Los Angeles Department of Water and Power

213.367.1284

rene.baluyot@ladwp.com

-----Original Appointment-----
From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Wednesday, October 08, 2008 4:47 PM
To: eord@allenmatkins.com; afraijo@allenmatkins.com; jneuman@allenmatkins.com; etachibana@handelarchitects.com; ghandel@handelarchitects.com; Ammar Elrawi; Carl Mills; Charmie Huynh; Frank Comfort; Kevin Keller; LADBS CMServiceRequest; LADBS_Fig221_180_Conf_A po01.dom1@lacity.org; Lambert Giessinger; Michael Taylor; Richard Ferguson; Ron Lorenzen; Tomas Carranza; Vin Pham; Baluyot, Rene; tbrytin@armbrustmetro.com
Cc: Jay Kim; Lemuel Paco
Subject: Request for Pre-Development Meeting for Millennium Hollywood - 1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)
When: Wednesday, October 22, 2008 1:00 PM-3:00 PM (GMT-08:00) Pacific Time (US & Canada).
Where: 221 N Figueroa St., Suite 180, LA, CA 90012

Hello,

You are invited to a case management pre development meeting for the proposed Millennium Hollywood High Rise projects at 1750 N Vine St (East Site) and 1751 N Vine St (West Site). The Project Narrative is attached to this email.

Date: Wednesday, October 22, 2008

Time: 1:00pm - 3:00pm

Location: 221 N Figueroa St., Suite 180, Los Angeles, CA 90012

Applicant: Alfredo Freija, Attorney at Law, Allen Matkins, 213 955 5607

Questions and Issues for the City Departments:

1.) Planning/Building & Safety: Confirmation of required entitlements with respect to the proposed project (are any other entitlements required?) Confirmation of setbacks provided Are there minimum distance requirements between the two towers? Are there minimum distance requirements regarding light and air for windows facing windows, alleys or lot lines? Confirm loading spaces required for the project and their required dimensions Discuss balcony enclosure and screening issues (ZA 2007-1430(ZAI) Memo)

2.) Public Works: Are any offsite improvements required, such as street widening, other than what a traffic study might suggest? Confirm sidewalk and street dedication requirements Sewer facility charge and credit Adequacy of storm drain system near project Confirmation of sewer capacity availability Are there any requirements for onsite storm water retention, treatment, discharge during construction and/or operation? What are the required public improvements regarding street trees etc? What are the required public improvements regarding street lights? How will the Walk of Fame be handled during construction? Task force to determine viability of underground tunnel and obtaining a franchise

3.) LAFD & Fire Hydrants and Access: What are the type and location of desired Fire Dept. turnarounds? Where should on-site hydrants be located? What fire lane access is required to the buildings? How do hydrant and fire equipment access requirements impact the layout of units? General review of and input related to the proposed site plan regarding Fire Department requirements. Observation deck fire access issues, including capacity, fire escape and elevator.

4.) DWP: Will we be required to provide public or private utilities? Requirements for undergrounding utilities, if any. How will project be metered relative to the air lot subdivision? Potential relocation of traffic island and right hand turn lane at corner of Yucca and Argyle to create a park General review and input regarding the proposed site plan and DWP requirements, including water and power service availability, water and power connections and clear distance from existing or future power lines

Your attendance is greatly appreciated. If you cannot attend, please reply to me via email with your comments and any information you can pass along to the Applicant to address their concerns/issues.

Attached are some of the project files. I will be sending an additional 4 other emails containing the project files.

Thank you

Charmie Huynh, P.E.

Structural Engineering Associate Case Manager

City of Los Angeles/Department of Building and Safety

221 N. Figueroa St, Suite 180

Los Angeles, CA 90012

T. (213) 482-6875

F. (213) 482-6874

Charmie.Huynh@lacity

1 Attachment:

Subject: Follow up - to do list - post PDM

Created: 10/24/2008 1:11 PM
Modified: 10/24/2008 1:11 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Hi Alfred,

You're welcome. I'm glad the meeting was productive for you el.

I will proceed with scheduling the fire safety meeting, but I need an agenda first before I set that one up. That meeting will be with LADBS (me) and the Fire Department Building Standards Group. Please provide me with an agenda as soon as possible.

You will need to schedule your meeting with Inspector Lynn McClain of Hydrants and Access separately.

I also will follow up with Richard Ferguson regarding the balconies once he speaks to Alan Bell.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 160
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Hrapo, Alfred" 10/24/2008 11:15 AM >>>

Charmie,

Thank you again for coordinating and facilitating such a productive meeting on Wednesday. We are grateful and look forward to more follow-up. Our immediate next step is to follow-up with additional information regarding the balconies with planning and schedule a follow-up meeting with fire safety

Best.
Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 O
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com

From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Friday, October 24, 2008 9:50 AM
To: Fraijo, Alfred; Ord, Eleanor; Neuman, Jerold
Subject: Additional Case Management Contacts - M Petition: HollywoodProject - CM2008-0287

Additional Case Management Contacts for your project:

1. Will Pham - Bureau of Street Lighting, Public Works - 213-847-1348
2. Rene Baluyot - DWP - General CM contact within DWP who can put you in touch with the DWP-Water Section - 213-367-1284, Rene.Baluyot@ladwp.com
3. Michael Taylor - Bureau of Sanitation, Industrial Waste Management Division, Public Works - 323-342-6121, Michael.Taylor@lacity.org

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.huynh@lacity.org

Subject: Left message for Alfred's assistant (applicant) to obtain floor area information per Ifa's request

Created: 10/31/2008 9:27 AM
Modified: 10/31/2008 9:30 AM

Last Modified by: Lily Teng

From: Department of Building and Safety

Folder: CMNGS

Subject: Email to Jameson for update of high rise list for Ifa

Created: 11/4/2008 9:14 AM
Modified: 11/4/2008 9:14 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Jameson,

East Site Tower 1 - 48 Story Residential Tower; 317 dwelling units, 80,000 sf of residential lofts, 365,000 sf of residential uses, 100,000sf of office uses, 17,000 sf of restaurant/cafe, retail and other commercial uses,

West Site Tower 2 - 38 Story Residential Tower. 175 dwelling units, 40,000 sf sports club, 10,000 sf of ground floor retail/restaurant and cafe uses.

West Site Tower 3 - 16 story,150,000 sf Hotel with 200 guest rooms.

>>> Jameson Lee 11/3/2008 7:40 AM >>>
Charmie:

Please provide detailed information (no of story, floor area for each use, no of units, no of guest rooms...etc) to me (as requested by Ifa) for:

1750 Vine St (3 new highrise towers)

(I remember you already did that, check your "sent" file first)

Ricardo:

Please provide detailed information (no of story, floor area for each use, no of units, no of guest rooms...etc) to me (as requested by Ifa) for:

11122 W Pico Bl

Subject: My email response to Alfred Trenjo/ RE: Balcony Discussion (also includes discussion with JL re balconies and certified louvered balconies)

Created: 11/24/2008 9:25 PM
Modified: 11/24/2008 9:27 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

AR0068242

CO-0001-995

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@ladbs.org

>>> "Feagin, Alfred" 11/19/2008 3:38 PM >>>

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "unenclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a bounding wall that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition; the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide sight screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view

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from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2006 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

****
time spent discussing with JL.

****Issue of the area above the cantilevered living rooms. Back on Oct, JL made the call that the area above the living rooms was not FAR and we can consider these as balconies. However, during my review with him today on this issue sent by Alfred re the wood screens and glass wind breaks, we revisited this area above the cantilvered living room.

Per JL, if Chief ZA is willing to make the interpretation on these louver screens, then we would accept the area above the cantilevered living rooms as balconies and not FAR. See attached file, sections 6 and 7. Section 6 shows louvered wood screen. Only difference with Section 7 is that the louvered screens are replaced with a glass wall. JL said if the ZA is going to let the louver screen go, then we would accept the situation in Section 7 because they are almost identical.

Attachment:

Subject: My email to Alan Bell, Alfredo Perez and Tamerein Lee RE Balconies, FAR and Screens
Created: 12/7/2012 8:07:7 AM
Mod Dat: 12/25/2012 10:07:7 AM
Last Modified by: Christine Huynh
From: Department of Building and Safety
Folder: CMNGS
Hi Alan,

I sent this email out yesterday regarding the Milenium Hollywood high rise project and the issue of FAR and Balconies. The topic at hand is rejecting the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should make the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/24/2008 4:13 PM >>>

Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" 11/19/2008 3:38 PM >>>

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guard rails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balcon es to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below,

The intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com
<> <>

Subject: Per phone conversation and email with Alan Bell, he concurs on ADBS Interpretation on the wood louvers and glass screens as enclosing balconies and counting as FAR.

Created: 12/1/2008 4:38 PM
Modified: 12/1/2008 4:41 PM

Last Modified by: Chermie Huynh

From: Department of Building and Safety

To/Cc: CMNGS

Hi Chermie - I've reviewed the material you sent me concerning the Millenium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

The proposed additional screening above the guard rail encloses space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular wing walls and privacy screens discussed on p. 4 of the ZAI, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1322
(213) 978-1334 fax
alan.bell@lacity.org

>>> Chermie Huynh 12/1/2008 10:27 AM >>>

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under 12.26. that said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Millenium Hollywood high rise project and the issue of FAR and Balconies. The topic at hand is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should make the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/24/2008 4:13 PM >>>
Hi Alfredo,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety

221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6870
F. (213) 482 6874
Channie.Huynh@lacity.org

>>> 'Franjo, Alfred" 11/19/2008 3:36 PM >>>

Hi Channie,
I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.
On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.
The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.
Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.
Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.
In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind breaks cannot be considered to enclose the balconies.
Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to

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buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.
Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8916 F
afraijo@allenmatkins.com
allenmatkins.com
<> <>

Subject: I forwarded Alan Bell's email to Alfred Fraijo/attorney - Also, discussed issue of cantilevering living rooms
Created: 12/1/2008 4:41 PM
Modified: 12/1/2008 4:41 PM
Last Modified by: Charmie Huynh
From: Department of Building and Safety
Holder: CMNGS

I discussed with alfred that LADBS will count these enclosed balconies (with wood screens and glass screens) as FAR. They need variance from Planning for this increased FAR. He will also explore option proposed by Greg Shoup that says it may be possible to go over the 6:1 w/o variance.

I also discussed that per my last conversation with JL, we now considers the area beneath the projection living rooms as FAR b/c the exterior wall to the living room defines the exterior wall for the building, and it is not longer considered a projection. These areas beneath the "alternating" living rooms (areas are open decks) shall be counted as FAR.

Subject: My email to Alfred regarding exterior wall interpretation (this relates to the cantilevered living rooms)
Created: 12/3/2008 9:42 AM
Modified: 12/3/2008 9:42 AM
Last Modified by: Charmie Huynh
From: Department of Building and Safety
Holder: CMNGS

Hi Alfred,

I don't believe there is a code section for this particular interpretation. Jameson said you can contact him if you need further clarification on this issue. Jameson's phone # is 213-482-6866.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 160
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

AR0068250

>>> "Frajo, Alfred" 12/1/2008 4:15 PM >>>

Charmie,

On the issue of space under a projection (i.e., ground floor or balcony space under a habitable room) that would be counted as FAR, can you refer us to the related Building or Zoning Code section for reference?

Thanks in advance.

From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Monday, December 01, 2008 3:49 PM
To: Frajo, Alfred
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

>>> Alan Bell 12/1/2008 10:49 AM >>>
Hi Charmie - I've reviewed the material you sent me concerning the Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZA1) concerning FAR and private open space is correct. As the ZA1 clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

The proposed additional screening above the guard rail encloses space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular wing walls and privacy screens discussed on p. 4 of the ZA1, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1322
(213) 978-1334 fax
alan.bell@lacity.org

>>> Charmie Huynh 12/1/2008 10:27 AM >>>

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under 12.26. That said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Millenium Hollywood high rise project and the issue of FAR and Balconies. The topic at hand is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should make the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/26/2008 4:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Kraig, Alfred" 11/19/2008 3:38 PM >>>

Hi Charmie,
I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.
On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.
The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.
Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.
Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.
In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.
Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2006 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.
Please let me know how we should proceed on this issue. And thanks again for your attention to the

CO-0001-1006

project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com
allenmatkins.com

Subject: email string with Alfred on 10/24/2008 regarding fire prelim meeting request

Created: 10/2008 3:25 PM
Modified: 10/2008 10:34 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folders: CMNGS

Hi Alfred,

You're welcome. I'm glad the meeting was productive for you all.

I will proceed with scheduling the fire safety meeting, but I need an agenda first before I set that one up. That meeting will be with LADBS (me) and the Fire Department Building Standards Group. Please provide me with an agenda as soon as possible.

You will need to schedule your meeting with Inspector Lynn McClain of Hydrants and Access separately.

I also will follow up with Richard Ferguson regarding the balconies once he speaks to Alan Bell.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
201 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6879
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" 10/24/2008 11:15 AM >>>

Charmie,

Thank you again for coordinating and facilitating such a productive meeting on Wednesday. We are grateful and look forward to more follow-up. Our immediate next step is to follow up with additional information regarding the balconies with planning and schedule a follow-up meeting with fire safety.

Best,
Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071

213.955.5607 D
415.925.6874 C
213.620.8816 F
afrajo@allenmatkins.com

allenmatkins.com

From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Friday, October 24, 2008 9:50 AM
To: Frajo, Alfred; Ord, Eleanor; Neuman, Jenoic
Subject: Additional Case Management Contacts - Millennium HollyWoodProject - CM2008-0287

Additional Case Management Contacts for your project:

1. Win Pham - Bureau of Street Lighting, Public Works - 213-847-1348
2. Rene Baluyot - DWP - General CM contact within DWP who can put you in touch with the DWP-Water Section - 213-367-1284, Rene.Baluyot@ladwp.com
3. Michael Taylor - Bureau of Sanitation, Industrial Waste Management Division, Public Works - 323-342-6121, Michael.Taylor@lacity.org

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate/Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

Subject: Project Status - INACTIVE-ON HOLD
Created: 9/12/2008 8:30 AM
Modified: 9/12/2008 8:30 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Hi Charmie,

I hope you are well.

The project is not on hold. We are taking additional time to review our design and planning approach with our consultant team but we are still moving forward. We anticipate being able to visit with you and consider a submittal with LADBS in the new two months or so. I will keep you posted. Thank you for your follow-up.

Best regards (and happy Cinco de Mayo!),
Alfred Frajo Jr.
Associate

Allen Matkins Leck Gamble Mallory & Natsis LLP
515 South Figueroa Street, 9th Floor, Los Angeles, CA 90071-3301
(213) 622-5555 (main)
(213) 955-5607 (direct)
(415) 225-0373 (mobile)
(213) 620-8816 (fax)

www.allenmatkins.com
Allen Matkins

From: Charmie Huynh [chuynh@lacity.org]
Sent: Tuesday, May 05, 2009 2:05 PM
To: Fraijo, Alfred
Subject: 1750 N Vine St - Millenium Hollywood

Hi Alfred,

Hope you're doing well. It's been a while.

Just wanted to check in with you on the status of this project. Is it moving forward? And if so, do you know if they have an approximate plan check submittal date to LADBS?

Thanks.

Charmie Huynh, P.E.
Case Manager/Structural Engineering Associate
City of Los Angeles
Department of Building and Safety - Case Management Unit
221 N. Figueroa St, Suite 280
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

Subject: Project may be coming back again - email from Blaxie Lamb/City Planning

Created: 4/7/2011 11:04 AM
Modified: 4/7/2011 11:05 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Yes of course. Please have them contact me.

Thanks,

Charmie Huynh, P.E.
Case Manager/Structural Engineering Associate
City of Los Angeles
Department of Building and Safety - Case Management Unit
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012

T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org
- Hide quoted text -

On Wed, Apr 6, 2011 at 5:36 PM, Blake Lamb wrote:
Hi Charmie,
I met yesterday with one of the applicant's for the Millennium project in Hollywood. I know that they had scheduled a case management meeting with you a while ago. He told me he wanted to "restart" that process with you and wasn't sure his next steps. It's a big project, 1 million SF at the Capitol Records site. Can you help?
Thanks!
Blake

--
Blake S. Lamb, AICP
City Planner
Plan Implementation Division
Neighborhood Projects, Central Section
Los Angeles Department of City Planning
200 N. Spring Street, Room 621
Los Angeles, CA 90012
(213) 978-1167

Subject: EQ Fault line/Zone

Created: 2/16/2011 9:35 AM
Modified: 2/16/2011 9:35 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folders: CMNGS

Hi Ray,

I spoke to Dana Prevost regarding the Millenium project at 1750 N Vine St. He mentioned that he met with the project team to discuss the Hollywood Fault line that could potentially be crossing the property. Here are some bullet points on what we discussed:

Currently, the Hollywood Fault line is not mapped and may be addressed by the State Geologist in the next 4-5 years min mum.
Per code section 1803.5.11, a geotechnical report shall be conducted for the site to address (among other things) surface displacement due to faulting or lateral spreading. Dana advised the project team that they need to do their own investigation to locate the fault per this code section
Per the Alquist Priolo Earthquake Fault Zoning Act, no structure for human occupancy shall be permitted to be placed on or across an active fault trace. I've attached a copy of our info bulletin and highlighted this condition (#2). It also describes a min 50' no build zone. However, Dana discussed with the project team that he has granted one modification in the past on another project that allowed them to build right adjacent to the fault line.
Please let me know if you have any questions.

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety

201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

On Thu, Mar 15, 2012 at 12:50 PM, Raymund C [illegible] wrote:
Hi Alfred,

We are working on this and will get back to you tomorrow.

Ray

On Thu, Mar 15, 2012 at 11:04 AM, Alfred Fraijo Jr. wrote:
Hi Ray,

Thank you for taking our call yesterday. The property address is 1750 North Vine Street.

We are looking for information on the building code regulations that apply to development within a fault zone or prohibitions on development related to fault areas. We were informed by Mr. Dana Prevost that a limited fault investigation would be required in the portion of the subject site. There is a Hollywood Fault trace mapped by the California Geological Survey that prompted the discussion with Mr. Prevost.

The property extends on two adjacent sites along Vine Street and is generally bounded by Yucca Street, Argyle Avenue and Ivar. Below is a general map of the site.

Thank you in advance for your assistance.

Subject: Project Status

Created: 4/1/2013 9:42 AM
Modified: 4/1/2013 9:42 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Thanks Alfred. I'm available to assist you with coordinating meetings with other departments, and especially regarding submittal to LADBS plan check. When will you submit to us for building permit?

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

On Mon, Apr 1, 2013 at 9:18 AM, Alfred Fraijo Jr. wrote:

Good morning Charmie,

We received approval from the City Planning Commission on Thursday. I will be meeting with Planning this week to review next steps. I will follow-up shortly.

Thank you.

From: Charmie Huynh [mailto:charmie.huynh@lacity.org]
Sent: Monday, April 01, 2013 9:18 AM
To: Alfred Fraija Jr.
Subject: Millenium

Hi Alfred,

How are you? Hope you're doing well.

I just wanted to see how this project is progressing and any status updates you can give me would be much appreciated.

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1070
Los Angeles, CA 90012
T: (213) 482-6975
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

Circular 230 Notice: In accordance with Treasury Regulations we notify you th

Subject: LA Times News Article

Created: 4/4/2013 4:04:10 PM
Modified: 4/4/2013 9:26 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

The Millennium Hollywood project, which recently won the approval of the Los Angeles City Planning Commission but still needs the backing of the City Council, would be splayed across 4.47 acres of Hollywood, bordering two sides of Vine Street, weaving around the historic Capitol Records building (Shimanaya Illustration / April 3, 2013)

By The Times editorial board
April 4, 2013
For far too long, development in Los Angeles has been approved based not on community plans and zoning codes but on a somewhat chaotic form of negotiation in which developers cajole, strong-arm or, um, financially incentivize city politicians into making concessions and giving breaks. It's time for that to stop. There is a reason why carefully thought out and democratically adopted zoning codes and strategic growth plans should be adhered to — especially in a city destined for its mish-mash of buildings.

Last summer, after a bitter but long overdue debate, the city approved a new and detailed Hollywood Community Plan. That plan went through years of public hearings and community comment, and was ultimately approved by the City Council, 13 to 0. Designed to guide Hollywood growth through 2030, it encouraged greater density around transit hubs. Among other things, it was

CO-0001-1012

well understood that it would lead to taller buildings in the neighborhood.

Now, just nine months later, an enormous and highly controversial project is wending its way through the process. The Millennium Hollywood project, which recently won the approval of the Los Angeles City Planning Commission but still needs the backing of the City Council, would be splayed across 4.47 acres of Hollywood, bordering two sides of Vine Street, weaving around the historic Capitol Records building. The complex would replace a scruffy tract of parking lots and nondescript buildings with two slender towers that at their highest (they will be deliberately asymmetrical) could rise four times the height of the iconic music building. The footprint of the project flanks portions of Vine Street but stretches all the way to Ivar Avenue on the western edge and from Vine to Argyle Avenue on the east.

Including the towers, the other new lower buildings and the existing space in the Capitol Records buildings, the developers say they will have more than a million square feet of residential, office, retail, hotel, dining and fitness center space. (And there will be about 2,000 underground parking spaces.)

Opponents, including numerous neighborhood groups, have extensive objections to the project, which they say would be out of scale with the neighborhood. Mayoral candidate Eric Garcetti has argued that it would be too tall. But despite the many understandable concerns, the Millennium project appears to conform substantially to the Hollywood Community Plan. If it does, it should be allowed to proceed.

That doesn't mean the opposition should stop monitoring the project (as if they would, no matter what we counseled them to do) or that the members of the City Council should not ask hard questions when the project and its developers come before that body seeking approval. For instance: Is the project's traffic study as extensive as it should be? The planning commission thought it was, but Caltrans did not.

There's no doubt that this is a startlingly expansive project, and its towers will do just that -- tower over the Capitol Records building. But height alone is not a deal breaker. There's no reason why an artful design cannot incorporate the historic building much the same way the downtown Central Library is not so much dwarfed by its skyscraping neighbors as it nestles like a jewel in the embrace of those buildings. From the projections on the developer's website, Millennium doesn't quite hover around the Capitol Records building that same way, but developer Philip Aarons speaks of the expansive ground level public spaces of the project as offering vantage points from which to view the building.

It's also worth remembering that when the Capitol Records building itself was erected in the 1950s, it, too, towered over most of the buildings that then existed in Hollywood.

The height of the new towers falls within the density limits of the Hollywood plan, which specifically allows the planning commission to approve an increase in the floor-to-area ratio for this part of Hollywood. The other, smaller variances and conditional-use permits the developers seek appear to be appropriate and reasonable. (For example, they've asked for a variance for above ground-floor outdoor dining.)

The project has benefits for the city, including many construction jobs. Developers have agreed to make this a union project and to offer local workers priority consideration for jobs. The developers are also contributing $4.8 million to the city housing department which will be put toward 106 units of affordable housing being built at two projects, one near Hollywood Boulevard and Western Avenue and the other in Westlake. The developers will give the city $2 million toward traffic mitigation.

This project furthers the goals of the Hollywood community plan without exceeding its specific limits. If the plan itself is unpopular or goes too far, it should be challenged (and, indeed, at least three lawsuits against it have already been filed). But for the moment, it is the best guide that exists to how Hollywood should be developed in the years ahead. Barring a powerful argument to the

AR0068260

contrary, a project that meets its requirements should be approved, and one that violates them should be rejected.

Not that all discretion should (or ever will be) done away with. There will always be an element of negotiation between developers, planners, communities and politicians, as there should be. But the process in recent years has been a mess; all the parties need greater certainty. The city has to stop treating land use approvals as individual transactions — a system that can be gamed — and instead should approach them in the context of smart, forward-looking planning law.

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Subject: Email to Kyndra/Land Use Attorney regarding allowable projections/balconies

Created: 5/20/2013 9:53 AM
Modified: 5/20/2013 9:53 AM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Hi Kyndra,

12.22C20(d) allows balconies not covered by a roof or canopy to project into a required rear yard not more than 4' and into a required front yard, passageway, other open space, or the side yard adjoining the street lot line of a reverse lot, not more than 30".

Vertical projections are those architectural projections that exceed 4' in vertical height. Please see the attached LADBS info bulletin regarding allowable projections. I've highlighted the reference made to vertical projections on page 2.

Please let me know if you have any further questions.

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

On Thu, May 16, 2013 at 2:29 PM, Kyndra Cooper wrote:
Charmie,

To follow-up on our brief discussion on Monday re balconies, here are the questions that the architects have regarding balconies/projections (below is an excerpt from the architect's email re balconies/projections:

"We need greater clarification from you on the applicable rules and if we can make the below assumptions or not.

Reviewing section 12.22.c.20 regarding projections into yards:

Does not refer to "balconies" specifically as far as I can tell. Does speak to other projections (eaves, sills or other such features - though explicitly excludes vertical projections which we would want in the sideyard)

If I'm reading this correct, gives the following rules:
2" for every 1' of sideyard. So for a 16' sideyard (req for res at this height) we could project max 32"). This is not enough for us.

We would like to project architectural features, including balconies, up to 6' into required side and rear yards.

Please confirm if we can make this assumption?

He also wanted clarification as to what "vertical projections" are in regard to LAMC section 12.22.C.20

Thank you for your help with this!

Best,
Kyndra

Subject: Email to Kyndra/land use attorney regarding balconies and FAR

Created: 6/4/2013 1:40 PM
Modified: 6/4/2013 3:40 PM

Last Modified by: Charmie Huynh

From: Department of Building and Safety

Folder: CMNGS

Hi Kyndra,

I've attached ZA2007-3438 (ZA1) that clarifies balconies and FAR here again for your reference. This document would answer the architect's questions.

Also, please see my responses below. They are italicized in blue.

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-6575
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

On Wed, May 29, 2013 at 4:39 PM, Kyndra Casper wrote:
Charmie-see attached and email below from architect. Thanks!

Kyndra-

Per our discussion last week, I might you please confirm this statement by your contact at Building department?

Our questions/assumptions:

Sketch 1:
1. No part of balcony counts towards FAR. - correct, since it is projecting from the exterior wall of the building.

2. So long as width does not exceed 5', length does not matter? - width can go beyond 5' as per ZA 2007-3430(2A1) as long as it projects beyond the perimeter of the building. And yes, length does not matter

Sketch 2:
1. Does any area greater than 5' in width count as floor area and thus create an assumed building wall even if not covered by a roof (only other balconies)? - See my answer above.

2. If so, how is this different than a roof terrace (public or private) or amenity terrace? Assume these do not count as floor area? FYI, roof terrace that are uncovered do not constitute floor area.

Sketch 3:
1. If there is an architectural feature beyond the balcony (such as a screen wall, horizontal or vertical expression band) does it affect what is considered floor area? If so, how? Yes, an architectural feature such as a screen covering stacking balconies would render the balconies as enclosed and count towards floor area.

AR0068263

From: "Ord, Eleanor" <ord@allenmatkins.com>
To: Charmie Huynh
Date: 9/29/2008 3:43:05 PM
Subject: Capitol Records: FAR/Balcony

Hi Charmie,

We wanted to give you some information in advance of our meeting on Thursday to jumpstart our discussions. Attached below are renderings of the balcony configurations contemplated for the project and depictions of balconies in the finished structures. We're looking forward to seeing you on Thursday at 9:30 am.

Thanks.

Eleanor

Eleanor M. Ord
Attorney at Law
Allen Matkins
515 South Figueroa Street, 9th Floor
Los Angeles, CA 90071
Direct: 213-955-5653
Fax: 213-620-8816

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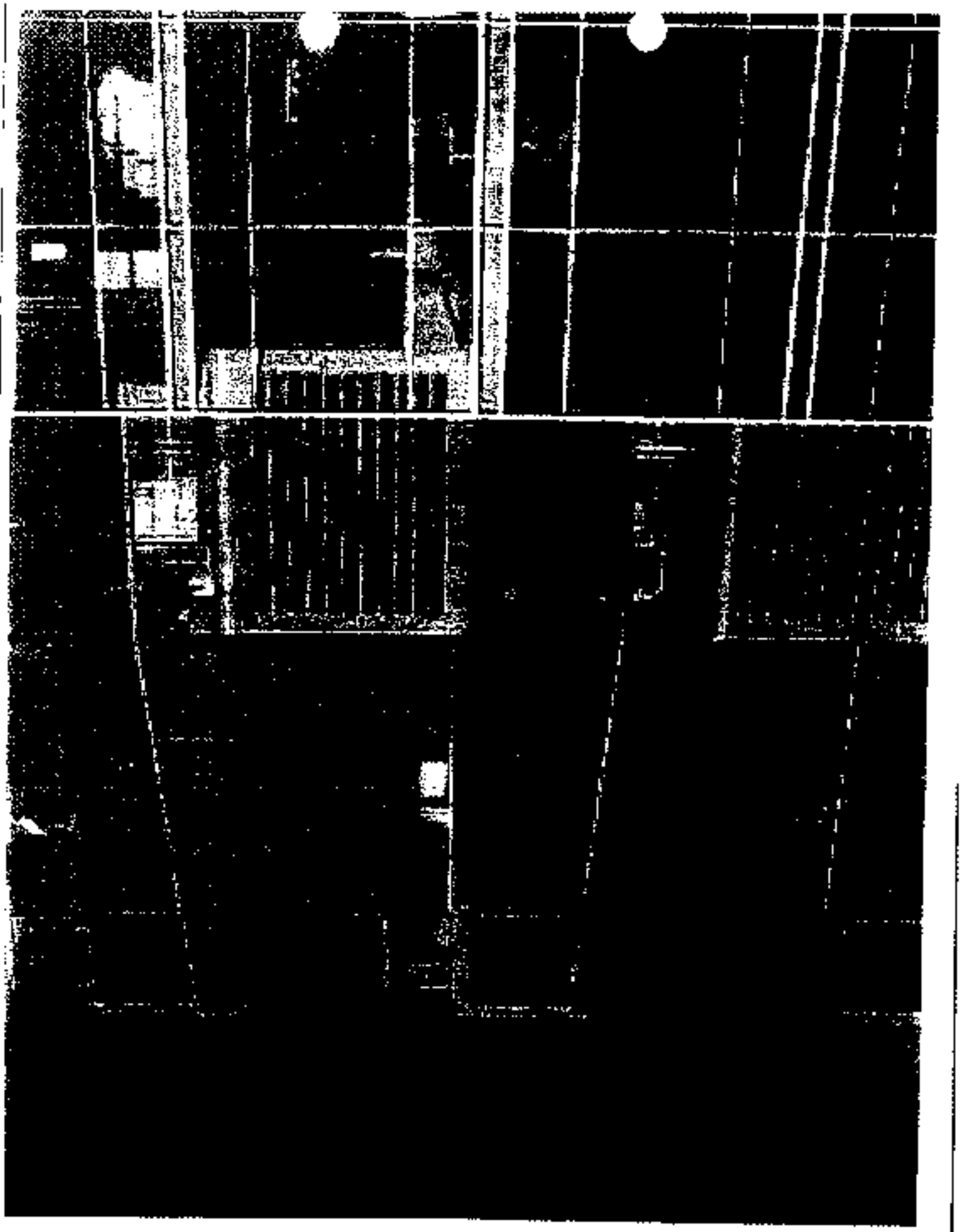
Attachments: Private Open Space_Types.pdf; crop of c01.jpg; crop of c05.jpg



From: Wes Pringle
To: Charmie Huynh
Date: 10/15/2008 2:36:27 PM
Subject: Milennium Project Meeting

Charmie,

I will not be attending the meeting for this project. We have been working with the traffic consultant on the traffic study for this project and will comment on it when it comes out. If there are any other questions for DOT, please forward my contact information (below).

Thanks,

Weston Pringle
Department of Transportation
Metro Programs Division
100 S. Main St, 9th Floor
Los Angeles CA 90012
Phone: (213) 972-8482
Fax: (213) 972-8410
Stop 725

CD-0001-1022

From: "Baluyot, Rene" <Rene.Baluyot@lacity.org>
To: W.C. Byrd
CC: Charmie Huynh
Date: 10/20/2008 1:53:21 PM
Subject: RE: Request for Pre-Development Meeting for Millennium Hollywood - 1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)

WC,

Would it be possible for you or your staff to attend this predevelopment meeting this Wednesday from 1PM to 3PM. Our group has a scheduled meeting with Councilmember Alarcon at the same time and I won't be able to attend the predev meeting. Please let me or Charmie know.

Charmie, I will forward the letter info as soon as I get it from the water engineer.

Thanks!

Rene

From: Baluyot, Rene
Sent: Friday, October 17, 2008 12:52 PM
To: Byrd, W.C.; Specht, Julie
Cc: Lueard, Andrew; Moon, Marvin
Subject: RE: Request for Pre-Development Meeting for Millennium Hollywood - 1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 2)

Julie/WC, << File: GROUND FLOOR PLAN 1.pdf >> << File: 1750 Vinas.pdf >> << File: LA-308360-v4-Pre-Development Meeting Project Description.pdf >> << File: Vicinity Map.pdf >> << File: ALTA Land Title Survey.pdf >> << File: LA-308370-v1 DWP Questions and Issues for City Departments.doc >>

The City case Analyst, Ms. Charmie Huynh, is requesting DWP to provide predevelopment assistance for the proposed Millennium Hollywood High-Rise project. Attached are the project files.

Will you please have your staff look at the attached plans and associated DWP information and let me know the person in your group assigned to this project?

Thanks And have a great day!

Rene Baluyot

Economic Development Group

Los Angeles Department of Water and Power

213.367.1284

rene.baluyot@ladwp.com

----- Original Appointment -----
From: Charnie Huynh [mailto:Charnie.Huynh@lacity.org]
Sent: Wednesday, October 08, 2008 4:47 PM
To: cerd@allenmatkins.com; afraijo@allenmatkins.com; jneuman@allenmatkins.com; etachibana@handelarchitects.com; gharder@handelarchitects.com; Ambrose Pitawi; Carl Mills; Charnie Huynh; Frank Comfort; Kevin Keller; LADBS CMServiceRequest; LADBS_Fig221_180_Conf_Apo01.dom1@lacity.org; Lambert Giessinger; Michael Taylor; Richard Ferguson; Rob Lorenzen; Tomas Carranza; Win Pham; Baluyot, Rene; thyne@millenniumpts.com
Cc: Jay Kim; Lemus, Paco
Subject: Request for Pre-Development Meeting for Millennium Hollywood -1750 N Vine St (East Site) and 1751 N Vine St (West Site)(Email 1)
When: Wednesday, October 22, 2008 1:00 PM-3:00 PM (GMT-08:00) Pacific Time (US & Canada).
Where: 221 N Figueroa St., Suite 180, LA, CA 90012

Hello,

You are invited to a case management pre development meeting for the proposed Millennium Hollywood High Rise projects at 1750 N Vine St (East Site) and 1751 N Vine St (West Site). The Project Narrative is attached to this email.

Date: Wednesday, October 22, 2008

Time: 1:00pm - 3:00pm

Location: 221 N Figueroa St. Suite 180, Los Angeles, CA 90012

Applicant: Alfredo Fraijo, Attorney at Law, Allen Matkins, 213 955-5607

Questionaire Issues for the City Departments.

AR0068271

CO-0001-1024

1.) Planning/Building & Safety:Confirmation of required entitlements with respect to the proposed project (are any other entitlements required?) Confirmation of setbacks provided Are there minimum distance requirements between the two towers? Are there minimum distance requirements regarding light and air for windows facing windows, alleys or lot lines? Confirm loading spaces required for the project and their required dimensions Discuss balcony enclosure and screening issues (ZA 2007-3450(ZAI) Memo)

2.) Public Works:Are any offsite improvements required, such as street widening, other than what a traffic study might suggest? Confirm sidewalk and street dedication requirements Sewer facility charge and credit Adequacy of storm drain system near project Confirmation of sewer capacity availability Are there any requirements for on-site storm water retention, treatment, discharge during construction and/or operation? What are the required public improvements regarding street trees etc? What are the required public improvements regarding street lights? How will the Walk of Fame be handled during construction? Task force to determine viability of underground tunnel and obtaining a franchise

3.) LAFD & Fire Hydrants and Access:What are the type and location of desired Fire Dept. turnarounds? Where should on-site hydrants be located? What fire lane access is required to the buildings? How do hydrant and fire equipment access requirements impact the layout of units? General review of and input related to the proposed site plan regarding Fire Department requirements. Observation deck fire access issues, including capacity, fire escape and elevator.

4.) DWP: Will we be required to provide public or private utilities? Requirements for undergrounding utilities, if any. How will project be metered relative to the air lot subdivision? Potential relocation of traffic stand and right-hand turn lane at corner of Yucca and Argyle to create a park. General review and input regarding the proposed site plan and DWP requirements, including water and power service availability, water and power connections and clear distance from existing or future power lines

Your attendance is greatly appreciated. If you cannot attend, please reply to me via email with your comments and any information you can pass along to the Applicant to address their concerns/issues.

Attached are some of the project files. I will be sending an additional 4 other emails containing the project files.

Thank you

Charmie Huynh P.E

Structural Engineering Associate Case Manager

City of Los Angeles/Department of Building and Safety

221 N. Figueroa St Suite 160

Los Angeles, CA 90012

T. (213) 482-6875

F. (213) 482-0874

Charmie.Huynh@lacity.org << File: GROUND FLOOR PLAN 1.pdf >> << File: 1750 Zimas.pdf >> << File: LA-8088660-v4-Pre-Development Meeting Project Description.pdf >>

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From: "Eraijo, Alfred" <afraijo@allenmatkins.com>
To: Charmie Blayzh
CC: Jerold Neuman; Kevin Keller; Jon Tootelian; alfredo.perez@lacity.org;
Date: 11/19/2008 1:42:08 PM
Subject: Millennium Hollywood Development: Balcony Discussion

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in or all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5597 D
415.225.0273 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com
<<BALCONYS SKETCHES 2 (AT 11 19 08).pdf>> <<Sateens.doc>>

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Attachments: BALCONYS SKETCHES 2 (AT 11 19 08).pdf, Sateens.doc

From: Charmie Huynh
To: Alfred Fraijo
Date: 11/19/2008 3:48:23 PM
Subject: Re: FW: Millennium Hollywood Development: Balcony Discussion

It's AV.Perez@lacity.org

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@alienmatxlns.com> 11/19/2008 3:43 PM >>>

Hi Charmie,

Do you happen to have Alfredo's correct email address? Thanks!

From: System Administrator
Sent: Wednesday, November 19, 2008 3:42 PM
To: Perez, Alfred
Subject: Undeliverable: Millennium Hollywood Development: Balcony Discussion

Your message did not reach some or all of the intended recipients.

Subject: Millennium Hollywood Development: Balcony Discussion
Sent: 11/19/2008 3:32 PM

The following recipient(s) could not be reached:

alfredo.perez@lacity.org on 11/19/2008 3:41 PM
The e-mail account does not exist at the organization this message was sent to. Check the e-mail address to be sure that you entered it correctly and resend the message. If the problem persists, contact the recipient by another method.

<alfredo.perez@lacity.org #5.1.1 SMTP; 550 No such recipient>

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From: "Fraijo, Alfred" <afraijo@allenmatkins.com>
To: Alfredo Perez
CC: Jerold Neuman; Kevin Keller; Jon Tamury; Charmie Hayph
Date: 11/19/2008 4:14:26 PM
Subject: RE: Millennium Hollywood Development: Balcony Discussion

Alfredo,

I misspelled your email address - sorry. Please see original email below. Thanks!

Best regards,
Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5602 D
415.273.8373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com

From: Fraijo, Alfred
Sent: Wednesday, November 19, 2008 3:55 PM
To: 'Charmie Hayph'
Cc: 'alfredo.perez@lacity.org'; 'jon.tamury@lacity.org'; 'Kevin Keller'; 'Neuman, Jerold'
Subject: Millennium Hollywood Development: Balcony Discussion

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it

"remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

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Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5602 D
415.225.0372 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com
<< File: BALCONY5 SKETCHES 2 (AF 11 19 08).pdf >> << File: Screens.doc >>

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CO-0001-1034

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AR0068282

From: Charmie Huynh
To: Alfred Fraijo
Date: 11/19/2008 4:16:06 PM
Subject: RE: Millennium Hollywood Development: Balcony Discussion

Alfred... you may want to include the attachments.

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 4:14 PM >>>

Alfredo,

I misspelled your email address - sorry. Please see original email below. Thanks!

Best regards,
Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8516 F
afraijo@allenmatkins.com

allenmatkins.com

From: Fraijo, Alfred
Sent: Wednesday, November 19, 2008 3:35 PM
To: 'Charmie Huynh'
Cc: 'afredo.gervacio@lacity.org'; 'jon.foster@lacity.org'; 'Kevin Keller'; Freeman, Tricia
Subject: Millennium Hollywood Development: Balcony Discussion

Hi Charmie,

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similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com

allenmatkins.com
<< File: BALCONYS SKETCH 55 2 (AF 11 19 06).pdf >> << File: Screens.doc >>

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CO-0001-1038

From: Charmie Huynh
To: Ed Tachibana
Date: 11/24/2008 1:25:07 PM
Subject: Re: Capitol Records

Hi Ed,

Thanks for the pdf. Can you also email me the full level floor plan for the projecting living room and a full level floor plan for the balcony beneath it?

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Tachibana, Ed" <etachibana@handelarchitects.com> 11/24/2008 11:40 AM >>>

Hi Charmie,

See if this helps. I have made a quick indication on "sketch 3" how the unit type distributions may work. Generally we are locating a living room at the end of each of the projecting "miradors." Other function may ultimately end up within that area. One possibility is an open loft style kitchen that would flow out to the primary living space.

Let me know if this helps or if you need further clarification.

Thanks

Best regards

EDWARD H TACHIBANA

HANDEL ARCHITECTS LLP

150 Varick Street, 8th Floor

New York, NY 10013

p 212.595.4112 f 212.595.9692

<[05] Balances 2.pdf>

From: "Tachibana, Ed" <etachibana@handelarchitects.com>
To: Charnie Huynh
Date: 11/24/2008 11:37:43 AM
Subject: Capitol Records

Hi Charnie,

See if this helps. I have made a quick indication on 'sketch 3' how the unit type distributions may work. Generally we are locating a living room at the end of each of the projecting "balconies." Other function may ultimately end up with in that area. One possibility is an open loft style kitchen that would flow out to the primary living space.

Let me know if this helps or if you need further clarification.

Thanks

Best regards

EDWARD H TACHIBANA

HANDEL ARCHITECTS LLP

150 Varick Street, 8th Floor

New York, NY 10013

p. 212.686.4112 f. 212.595.9832

<<US Balcon cs 2.pdf>>

Attachments: US Balconies 2.pdf

From: Charmie Huynh
To: Alfred Fraijo
CC: Jerold Neuman; Alfredo Perez; Kevin Keller; Jon Tanury; Jameson Lee
Date: 11/24/2008 4:13:34 PM
Subject: Re: Millennium Hollywood Development: Balcony Discussion

Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 160
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 11/19/2008 3:38 PM >>>

Hi Charmie,

I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre-development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.

On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.

The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the"

guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass certain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for

Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 O
415.215.6373 C
213.620.8816 F
AFraijo@allenmatkins.com

allenmatkins.com
<<BALCONYS SKETCHES 2 (AF 11 19 08).pdf>> <<Screens.doc>>

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Attachments: Screens.doc, BALCONYS SKETCHES 2 (AF 11 19 08).pdf

From: Charmie Huynh
To: Alan Bell
Date: 12/1/2008 10:27:40 AM
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under 12.26. that said, we should talk, and of course I'd be happy to give you my 2 cents.

>>> Charmie Huynh 11/25/2008 12:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Millenium Hollywood high rise project and the issue of FAR and Balconies. The topic at hand is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should take the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

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T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> Charmie Huynh 11/24/2008 4:13 PM >>>
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Please let me know if you have any questions.

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F. (213) 482-6874
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>>> "Fraijo, Alfred" <afraijo@elkinskins.com> 11/19/2008 2:38 PM >>>

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The Chief Zoning Administrators memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires guardrails for certain "projections or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.
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Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.
In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required

AR0068293

guardrails. The glass wind break cannot be considered to enclose the balconies.
Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.
Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5670 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com
allenmatkins.com
<<BALCONYS SKETCHES 2 (AT 11 19 08).pdf>> <<Screens.doc>>

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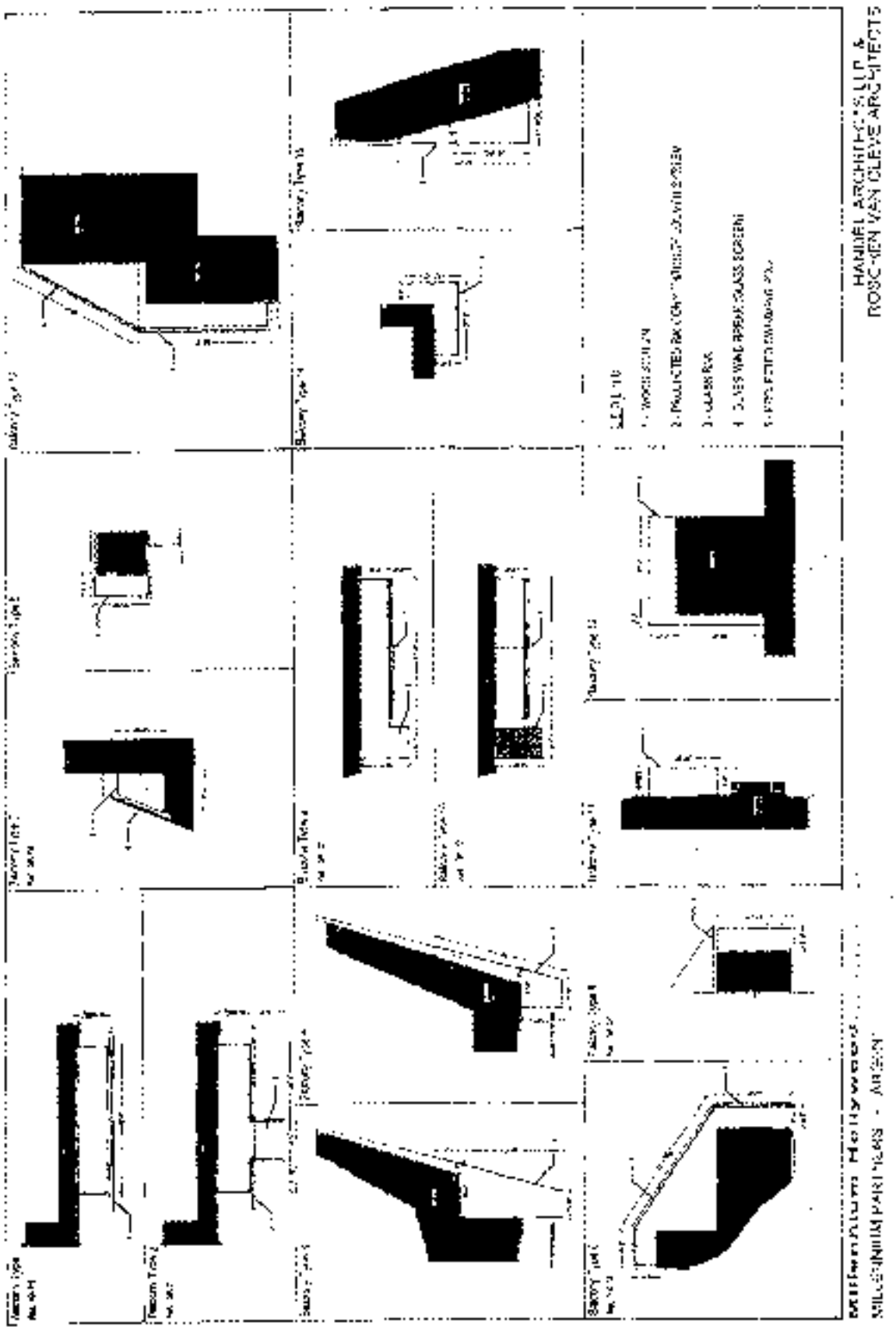

SK 01

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Millennium Hollywood

MILLENNIUM PARTNERS - ARGENT

HANDEL ARCHITECTS LLP. &
ROSCHEN VAN CLEVE ARCHITECTS

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CO-0001-1049

AR0068297

SK 03

SK 03

CO-0001-1051

MILLENNIUM PARTNERS - ARGENT

HANDEL ARCHITECTS LLP &
BOSA DI VAN CLEVE ARCHITECTS

AR0068299

SK 04

Millennium Hollywood

MILLENNIUM PARTNERS ARGENT

HANDEL ARCHITECTS LLP &
ROSCHEN VAN CLEVE ARCHITECTS

CO-0001-1052

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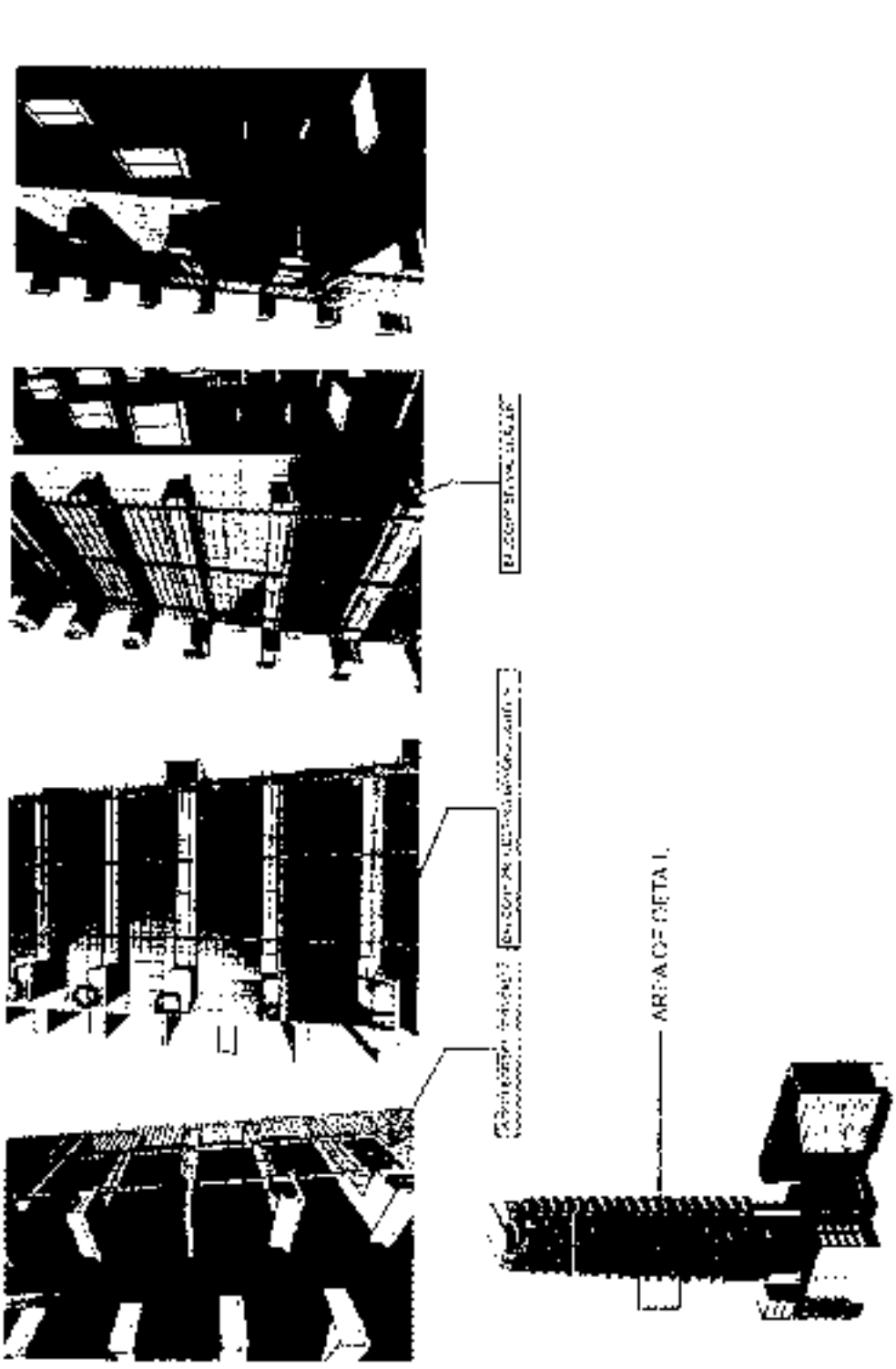
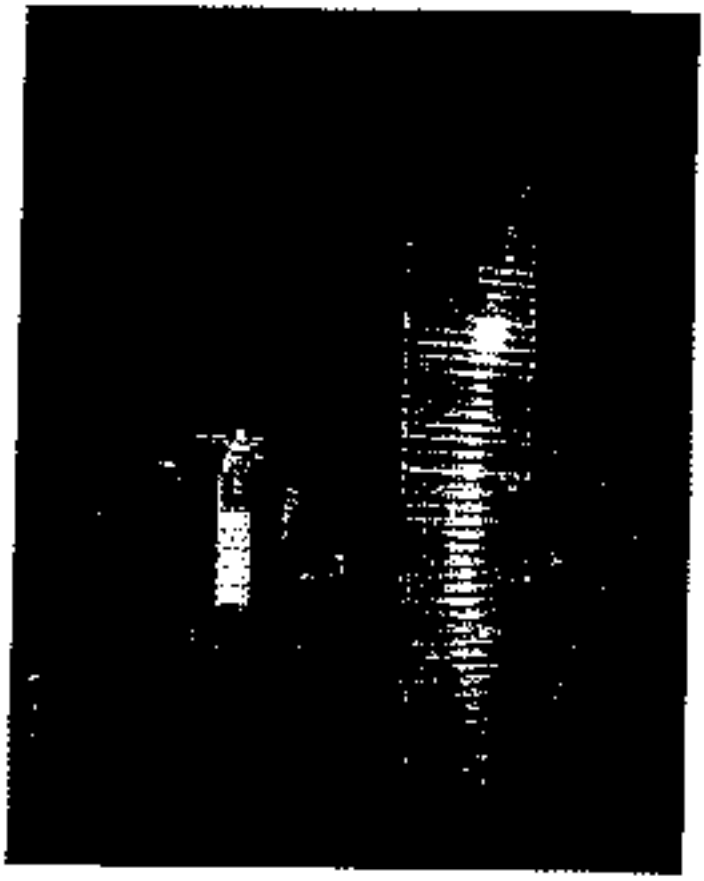
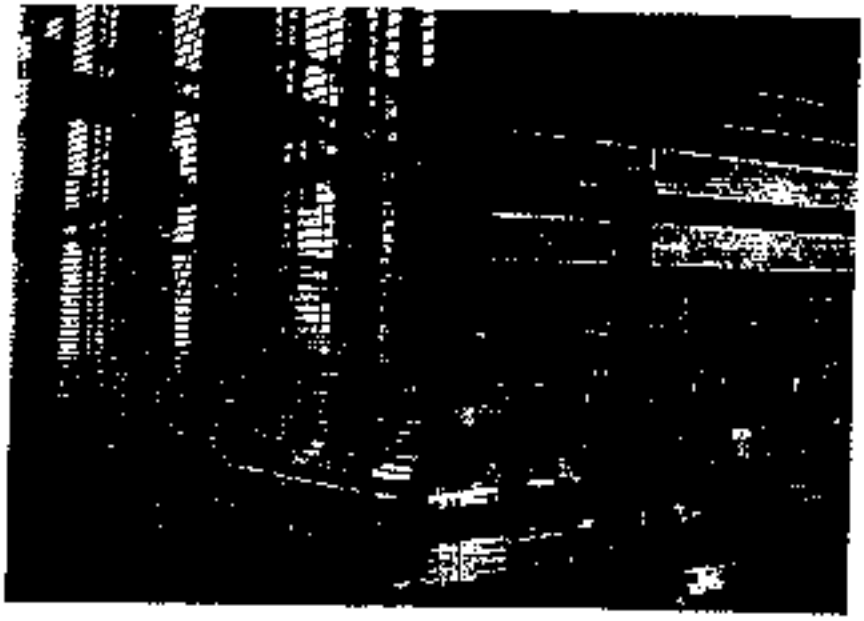
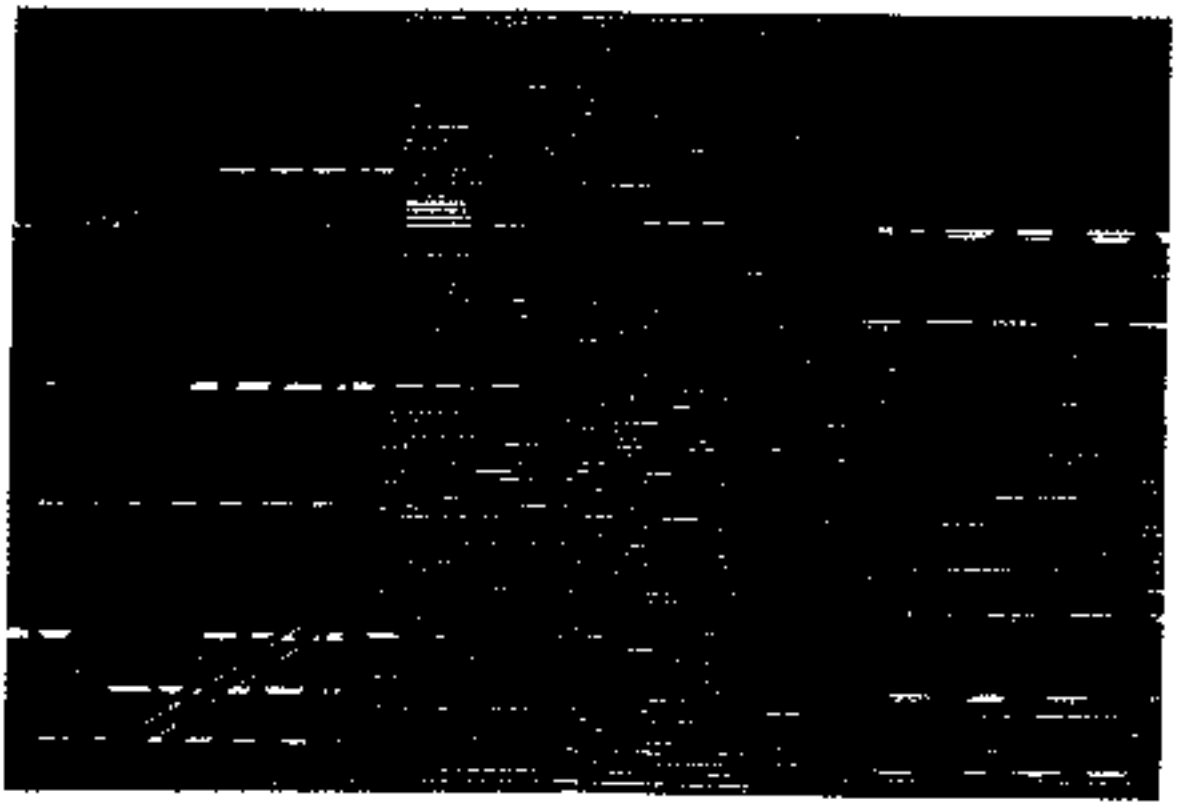




New York Times Building, Renzo Piano



New York Times Building, Renzo Piano



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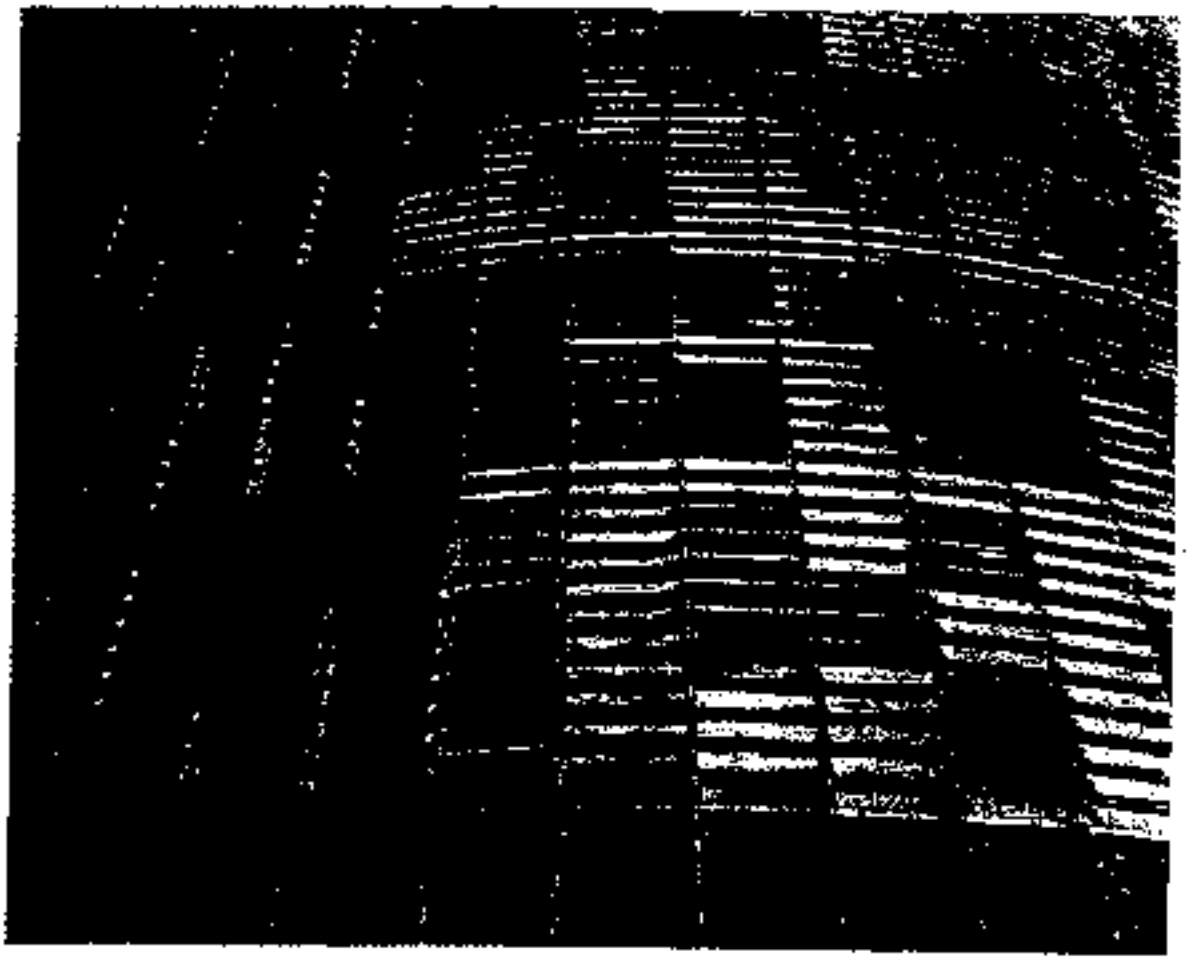

Agbar Tower, Jean Nouvel

Wooden drivers

From: Alan Bell
To: Charmie Huynh
CC: Michael Alexander; Maya Zaltzevsky; Alfredo Perez; Jamieson Lee
Date: 12/2/2009 10:49:42 AM
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

Hi Charmie. I've reviewed the materials you sent me (below) for Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

The proposed additional screening above the guard rail removes space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular wing walls and privacy screens discussed on p. 4 of the ZAI, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1272
(213) 978-1343 fax
alan.bell@lacity.org

>>> Charmie Huynh 12/1/2009 10:17 AM >>>

>>> Alan Bell 12/25/2008 11:07 AM >>>
possibly tomorrow or next week - really busy today dealing with appeals. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ordinances under LAMC 12.26. That said, we should talk, and of course I'd be happy to give you my 2 cents.

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I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jamieson and Alfredo are cc'd to this email as well.

Thanks and have a happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate - Case Manager
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221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6874
F. (213) 482-6874
Charnie.Huynh@ladbs.org

>>> Charnie Huynh 11/24/2008 4:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-4988-ZAI) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would not consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide certification on an existing ZAI interpretation.

Please let me know if you have any questions.

Thanks

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Los Angeles, CA 90012
T. (213) 482-6874
F. (213) 482-6874
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>>> "Trello, Alfred" <alfred.trello@nmbarons.com> 11/19/2008 10:38 PM >>>

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AR0068307

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Please give me a call to discuss this issue. And thanks again for your attention to this project.

Alonso Freija Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5697 D
415.999.6973 C
213.620.8816 F
afreija@allenmatkins.com
allenmatkins.com
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From: Charmie Huynh
To: afraijo@alleenatkins.com
Date: 12/1/2008 3:49:19 PM
Subject: Fwd: Re: Millennium Hollywood Development: Balcony Discussion

>>> Alan Bell 12/1/2008 10:49 AM >>>
Hi Charmie - I've reviewed the material you sent me concerning the Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3430 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

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>>> Charmie Huynh 11/24/2008 4:13 PM >>>
Hi Alfred,

I discussed this issue with Jameson Lee, our Case Management Director. We still feel that the ZAI (ZA2007-3430 (ZAI)) does not specifically address the project's wooden louvers and glass wind breaks. Thus, LADBS would still consider these elements as enclosing the balconies and making them count towards the project's FAR. I would suggest that you ask the Chief Zoning Administrator to provide an interpretation/clarification on these screens for your project. Basically, LADBS cannot provide clarification on an existing ZA's interpretation.

Please let me know if you have any questions.

Thanks

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fralo, Alfred" <afralo@[illegible]kins.com> 11/19/2008 3:38 PM >>>

Hi Charmie,
I'm following up with you and Planning regarding the balcony enclosures based on our brief discussion at the Pre development meeting. Attached are copies of the materials we shared with you and Planning during the meeting.
On the subject of whether the screens create an enclosure, we would like to submit the following information. In summary, the wooden louvers and glass wind breaks should not be considered building walls creating enclosures based on their design, construction and use.
The Chief Zoning Administrator's memo ("ZAI") we reviewed at the pre-development meeting states that a balcony will not be included in FAR if it "remains unenclosed except for the guardrails required by the Building Code." The term "enclosed" or "enclosure" is not defined in the LA Zoning or Building Codes. In considering when guards or guardrails are required, however, the 2007 California Building Code ("Building Code") uses the term enclosed to mean completely closed in or surrounded. Section 1013.4 of the Building Code requires

guardrails for certain "[p]orches or decks which are enclosed with insect screening." Since insect screening must completely surround a porch or deck to be effective, it is clear that the Building Code is using the term enclosed to mean closed in on all sides or surrounded.

Additionally, in the definition of habitable room, the LAMC also uses the term enclosed to mean closed in on all sides or surrounded on all sides. The LAMC defines a habitable room as "an enclosed subdivision in a residential building," and specifies that a recess from a room or an alcove, which is enclosed only on three sides, is considered a habitable room only if it exceeds certain square footage and can be partitioned off along the fourth side to form a habitable room. (LAMC Section 12.03) Here, none of the proposed balconies are closed in on all sides or surrounded by the glass curtain wind breaks or the fixed wood louvers as contemplated by the Building Code and the LAMC. Indeed, all balcony designs leave one or more wall areas open except for the required guardrails.

Additionally, the wooden louvers and glass breaks create a screen against the natural elements and adjoining balconies consistent with privacy screens defined in the Chief Zoning Administrator's memo ("ZAI"). The ZAI defines a privacy screen as "a decorative feature fastened to a building but that does not provide structural support." (ZAI, p. 4) Here, the fixed wooden louvers fully meet this definition: the louvers are decorative features that were added to the design to increase visual interest and improve aesthetics to the buildings, in line with similar concepts for other world-class buildings (see attached photos). They also do not provide structural support for the buildings and do not extend to the ground floor or occupy the total vertical length of the buildings. As the attached renderings show, the wooden louvers are attached or fastened to the building. They are constructed of widely spaced wooden panels (to be built to Building Code specifications) that provide solar screening but leave the majority of the balcony open to the elements. The views from the units and balconies are one of the project's biggest attractions and the louvers are specifically designed to create consistency or uniformity in the towers while leaving the balconies open to preserve view from the units. Accordingly, the fixed wooden louvers are privacy screens that are not considered exterior walls under the terms of the ZAI regardless of height and do not function to enclose the balconies for FAR purposes.

In addition, the glass curtain walls provided for a wind break cannot be considered to enclose the balconies. They would be separated from the balcony structures by a distance of approximately one foot (1'-0"). As can be seen from the attached section drawings, the glass curtain walls are outside and in addition to the required guardrails. The glass wind break cannot be considered to enclose the balconies.

Based on our research we also found that other local municipalities like City of Ventura use the term enclosed balconies to denote balconies that have been completely sealed off from the outdoors for the purpose of affording the occupant the use and enjoyment of the balcony in all weather and to buffer outside noise. The City of Ventura's 2008 Design Guidelines for Balconies provide that "standard balconies should not be completely enclosed to the natural elements." As discussed below, the intent of the ZAI was to prevent fully enclosed balconies, similar to atriums or sunrooms, from being excluded from FAR. Accordingly, balconies, like those proposed for the project, that are primarily open to the elements on at least one side or screened are not enclosed balconies and should be excluded from FAR.

Please let me know how we should proceed on this issue. And thanks again for your attention to the project.

Alfred Fraijo Jr., Esq.
Allen Matkins Leck Gamble Mallory & Natsis LLP
515 S. Figueroa Street, 9th Floor
Los Angeles, California 90071
213.955.5607 D
415.225.6373 C
213.620.8816 F
afraijo@allenmatkins.com
allenmatkins.com
<<BALCONYE SKETCH ES 7 (AF 11-19-08).pdf>> <<Screens.doc>>

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CO-0001-1065

From: Charmie Huynh
To: Alfred Fraijo
CC: Jameson Lee
Date: 12/3/2008 9:42:13 AM
Subject: RE: Re: Millennium Hollywood Development; Balcony Discussion

Hi Alfred,

I don't believe there is a code section for this particular interpretation. Jameson said you can contact him if you need further clarification on this issue. Jameson's phone # is 213-482-6806.

Thanks

Charmie Huynh, P.E.
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City of Los Angeles/Department of Building and Safety
221 N. Figueroa St, Suite 180
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org

>>> "Fraijo, Alfred" <afraijo@allenmatkins.com> 12/1/2008 4:15 PM >>>
Charmie,

On the issue of space under a projection (i.e., ground floor or balcony space under a habitable room) that would be counted as FAR, can you refer us to the related Building or Zoning Code section for reference?

Thanks in advance.

From: Charmie Huynh [mailto:Charmie.Huynh@lacity.org]
Sent: Monday, December 01, 2008 3:49 PM
To: Fraijo, Alfred
Subject: Fwd: Re: Millennium Hollywood Development; Balcony Discussion

>>> Alan Bell 12/1/2008 10:49 AM >>>
Hi Charmie - I've reviewed the material you sent me concerning the Millennium Hollywood Development. The Department of Building & Safety's interpretation and application of ZA 2007-3429 (ZAI) concerning FAR and private open space is correct. As the ZAI clearly states, balconies and decks shall not be considered "floor area" for purposes of calculating FAR, only so long as three conditions are met, including condition #2, which is that

the balcony or deck remains "unenclosed except for the guard rails required by the Building Code."

The proposed additional screening above the guard rail encloses space that would otherwise be open. The proposed screens, which are parallel to the building wall, do not serve the same purpose as the perpendicular wing walls and privacy screens discussed on p. 4 of the ZAI, which are intended to divide large balconies or decks shared by two or more residential dwelling units.

If you have any questions, please let me know.

Alan

Alan Bell, AICP
Senior City Planner
Office of Zoning Administration
Department of City Planning
(213) 978-1122
(213) 978-1334 fax
alan.bell@lacity.org

>>> Charmie Huynh 12/1/2008 10:27 AM >>>

>>> Alan Bell 11/25/2008 11:37 AM >>>
possibly tomorrow or next week - really busy today dealing with signs. I can provide you with my opinion, but I still think that technically it has to be DBS's "call" as to how to apply the ZAI to a specific project, since DBS is responsible for interpreting and enforcing the city's zoning ord nances under 12.26. that said, we should talk, and of course I'd be happy to g ve you my 2 cents.

>>> Charmie Huynh 11/25/2008 11:31 AM >>>
Hi Alan,

I sent this email out yesterday regarding the Millenium Hollywood high rise project and the issue of FAR and Balconies. The topic at hand is regarding the wood louvers and glass wind breaks. I understand from a voicemail message from Alfredo that you feel that LADBS should make the call on this one. I've already spoken with Jameson and we've made the decision to consider these "screens" as enclosures for the balconies and thus creating FAR for the project. We feel that the ZAI does not specifically address these types of wood louvers and glass wind break screens. The lawyers want LADBS to consider their interpretation on the ZAI (ZA2007-3430), however, LADBS cannot make an interpretation on a ZA's interpretation. That's why we have referred them to Planning for an interpretation on the ZAI.

I'll be out of the office starting this afternoon and back in on Monday. I'd love to get your feedback on this. Jameson and Alfredo are cc'd to this email as well.

Thanks and have a Happy Thanksgiving!

Charmie Huynh, P.E.
Structural Engineering Associate Case Manager
City of Los Angeles/Department of Building and Safety
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F. (213) 482-6874
Charmie.Huynh@lacity.org

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Charmie.Huynh@lacity.org

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213.955.5607 D
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<<BALCONYS SKETCHES 2 (AF 11 19 05).pdf>> <<Screens.doc>>

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Charmie Huynh <charmie.huynh@lacity.org>

Millennium project in Hollywood

3 messages

Blake Lamb <blake.lamb@lacity.org> Wed, Apr 6, 2011 at 5:36 PM
To: "Huynh, Charmie" <charmie.huynh@lacity.org>

Hi Charmie,
I met yesterday with one of the applicant's for the Millennium project in Hollywood. I know that they had scheduled a case management meeting with you a while ago. He told me he wanted to "restart" that process with you and wasn't sure his next steps. It's a big project. 1 million SF at the Capital Records site. Can you help?
Thanks!
Blake

--
Blake E. Lamb, AICP
City Planner
Plan Implementation Division
Neighborhood Projects, Central Section
Los Angeles Department of City Planning
200 N. Spring Street, Room 621
Los Angeles, CA 90012
(213) 978-1157

Charmie Huynh <charmie.huynh@lacity.org> Thu, Apr 7, 2011 at 11:01 AM
To: Blake Lamb <blake.lamb@lacity.org>

Yes of course. Please have them contact me.

Thanks,

Charmie Huynh, P.E.
Case Manager/Structural Engineering Associate
City of Los Angeles
Department of Building and Safety - Case Management Unit
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T. (213) 482-6875
F. (213) 482-6874
Charmie.Huynh@lacity.org
[Quoted text hidden]

Blake Lamb <blake.lamb@lacity.org> Fri, Apr 8, 2011 at 4:46 PM
To: Charmie Huynh <charmie.huynh@lacity.org>

Ok thanks Charmie.
Blake
[Quoted text hidden]

From:	Alfred Prago Jr. <aprago@sheppardmullin.com>
Sent:	Thursday, March 15, 2012 11:04 AM
To:	'Raymond.Chan@lacity.org'
Cc:	Jerry Neuman
Subject:	1750 North Vine Street
Attachments:	Outlook.jpg

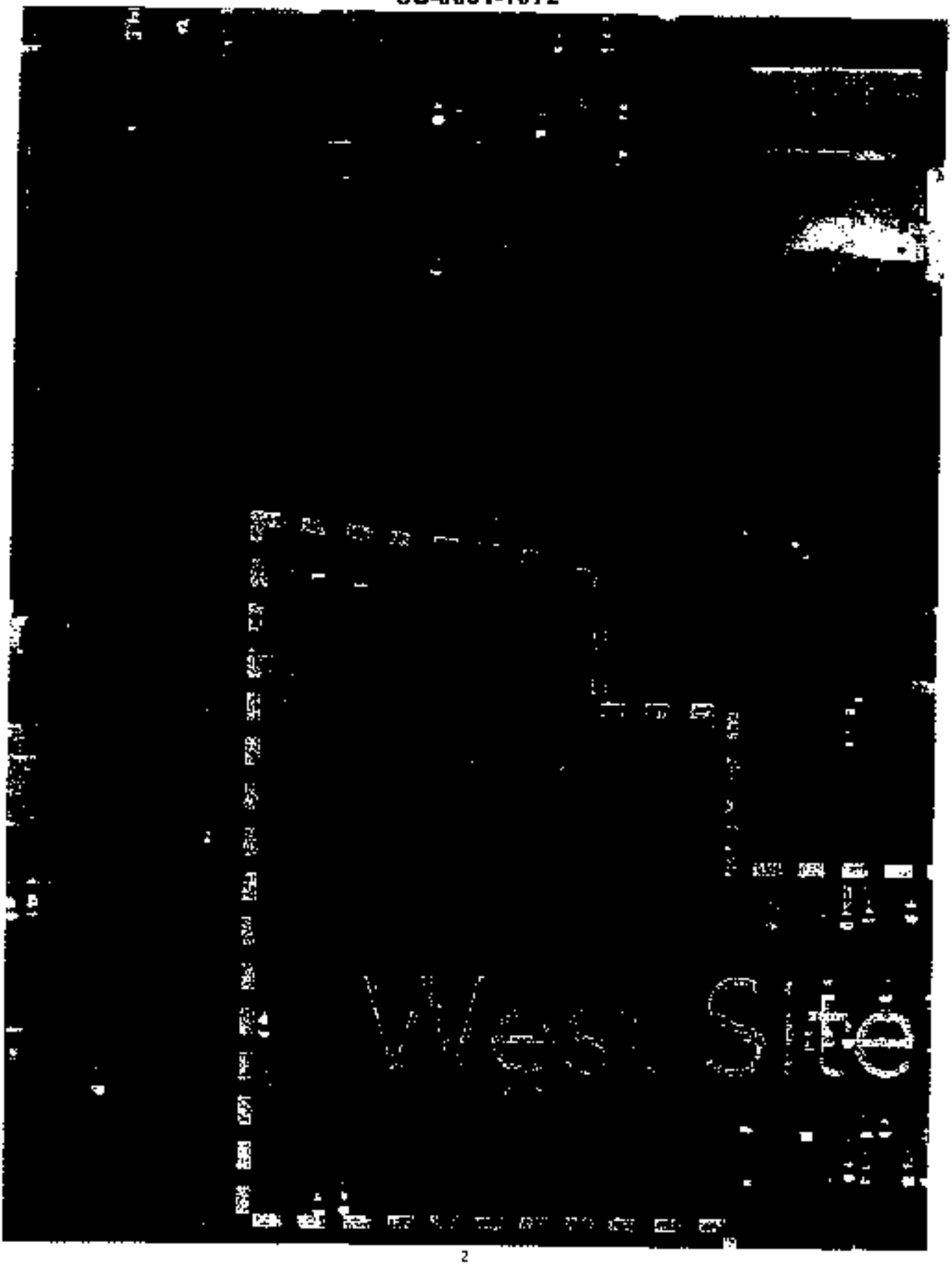
Hi Ray

Thank you for taking our call yesterday. The property address is 1750 North Vine Street.

We are looking for information on the building code regulations that apply to development within a fault zone or prohibitions on development related to fault areas. We were informed by Mr. Dave Prevost that a limited fault investigation would be required in the portion of the subject site. There is a Hollywood Fault trace mapped by the California Geological Survey that prompted the discussion with Mr. Prevost.

The property extends on two adjacent sites along Vine Street and is generally bounded by Yucca Street, Argyle Avenue and Vine. Below is a general map of the site.

Thanks you in advance for your assistance.


Web Site

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Sent: Thursday, March 15, 2012 11:04 AM
To: 'Raymond.Chan@lacity.org'
Cc: Jerry Neuman
Subject: 1750 North Vine Street
Attachments: Outlook (2)

R. Ray,

Thank you for taking our call yesterday. The property address is 1750 North Vine Street

We are looking for information on the building code regulations that apply to development within a fault zone or prohibitions on development related to fault areas. We were informed by Mr. Dane Prevost that a trench fault investigation would be required in the portion of the subject site. There is a Hollywood Fault trace mapped by the California Geological Survey that prompted the discussion with Mr. Prevost.

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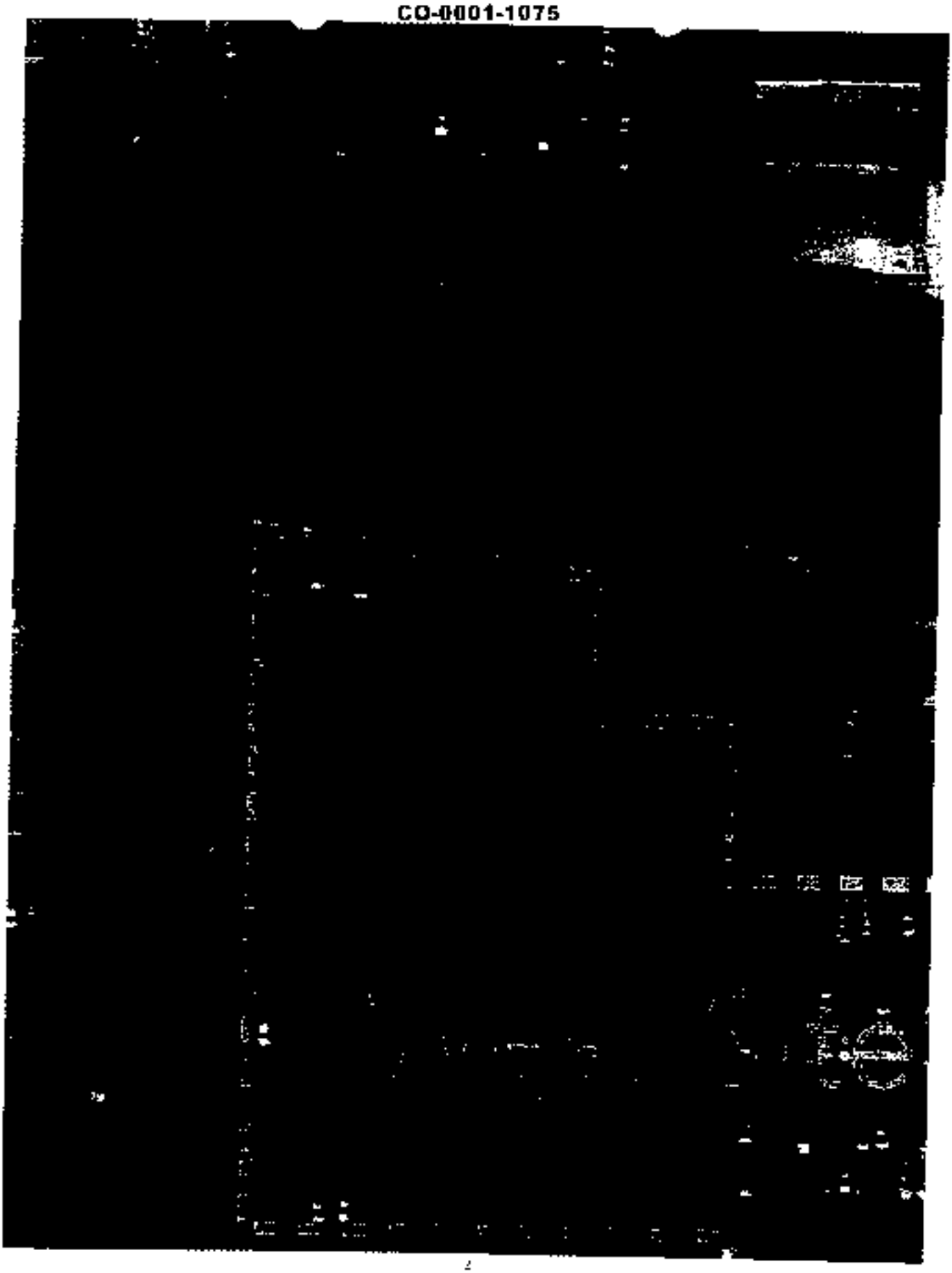
Thank you in advance for your assistance.



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From: Raymond Chan <raymond.chan@lacity.org>
Sent: Friday, March 16, 2012 2:16 PM
To: Charmie Huynh; jneuman@shepardmullin.com; ahajo@shepardmul...com
Subject: Re: 1750 North Vine Street
Attachments: Outlook.jpg

Thank you Charmie!!

On Fri, Mar 16, 2012 at 8:19 AM, Charmie Huynh <charmie.huynh@lacity.org> wrote:
Hi Ray,

I spoke to Dana Prevost regarding the Millenium project at 1750 N Vine St. He mentioned that he met with the project team to discuss the Hollywood Fault line that could potentially be crossing the property. Here are some bullet points on what we discussed.

- Currently, the Hollywood Fault line is not mapped and may be addressed by the State Geologist in the next 4-5 years minimum.
- Per code section 1803.5.13, a geotechnical report shall be conducted for the site to address (among other things) surface displacement due to faulting or lateral spreading. Dana advised the project team that they need to do their own investigation to locate the fault per this code section
- Per the Alquist Priolo Earthquake Fault Zoning Act, no structure for human occupancy shall be permitted to be placed on or across an active fault trace. I've attached a copy of an info bulletin and highlighted this condition (#2). It also describes a min 50' no build zone. However, Dana discussed with the project team that he has granted one modification in the past on another project that allowed them to build right adjacent to the fault line.

Please let me know if you have any questions.

Thanks.

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

On Thu, Mar 15, 2012 at 12:50 PM, Raymond Chan <raymond.chan@lacity.org> wrote:
Hi Alfred,

We are working on this and will get back to you tomorrow

Ray

On Thu, Mar 15, 2012 at 11:04 AM, Alfred Fraijo Jr. <afraijo@sheppardmullin.com> wrote:
Hi Ray,

Thank you for taking our call yesterday. The property address is 1750 North Vine Street.

We are looking for information on the building code regulations that apply to development within a fault zone or prohibitions on development related to fault areas. We were informed by Mr. Dana Prevost that a limited fault investigation would be required in the portion of the subject site. There is a Hollywood Fault trace mapped by the California Geological Survey that prompted the discussion with Mr. Prevost.

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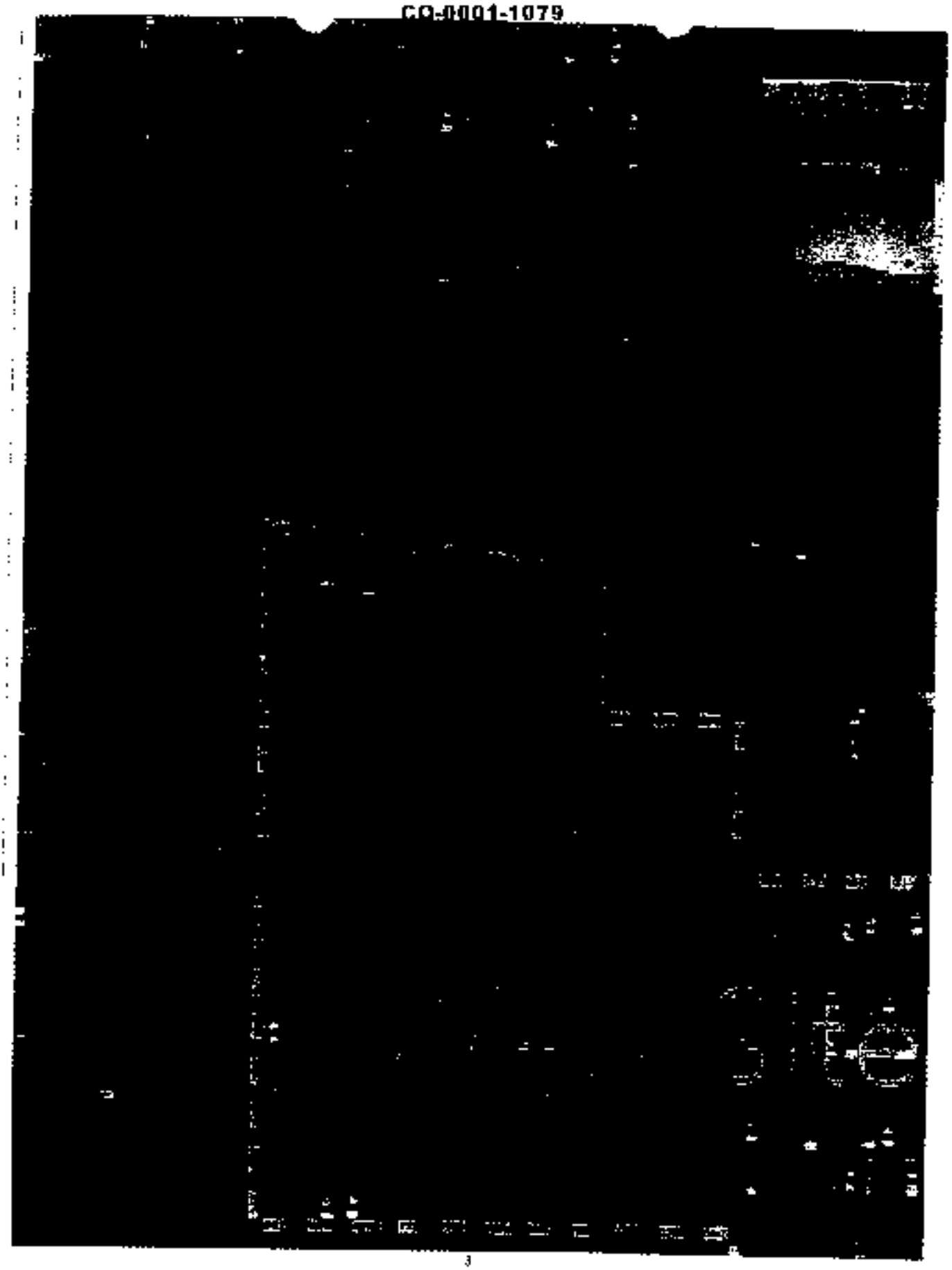
Thank you in advance for your assistance.



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On Tue, Mar 13, 2012 at 12:50 PM, Raymond Chan <raymond.chan@lacity.org> wrote:
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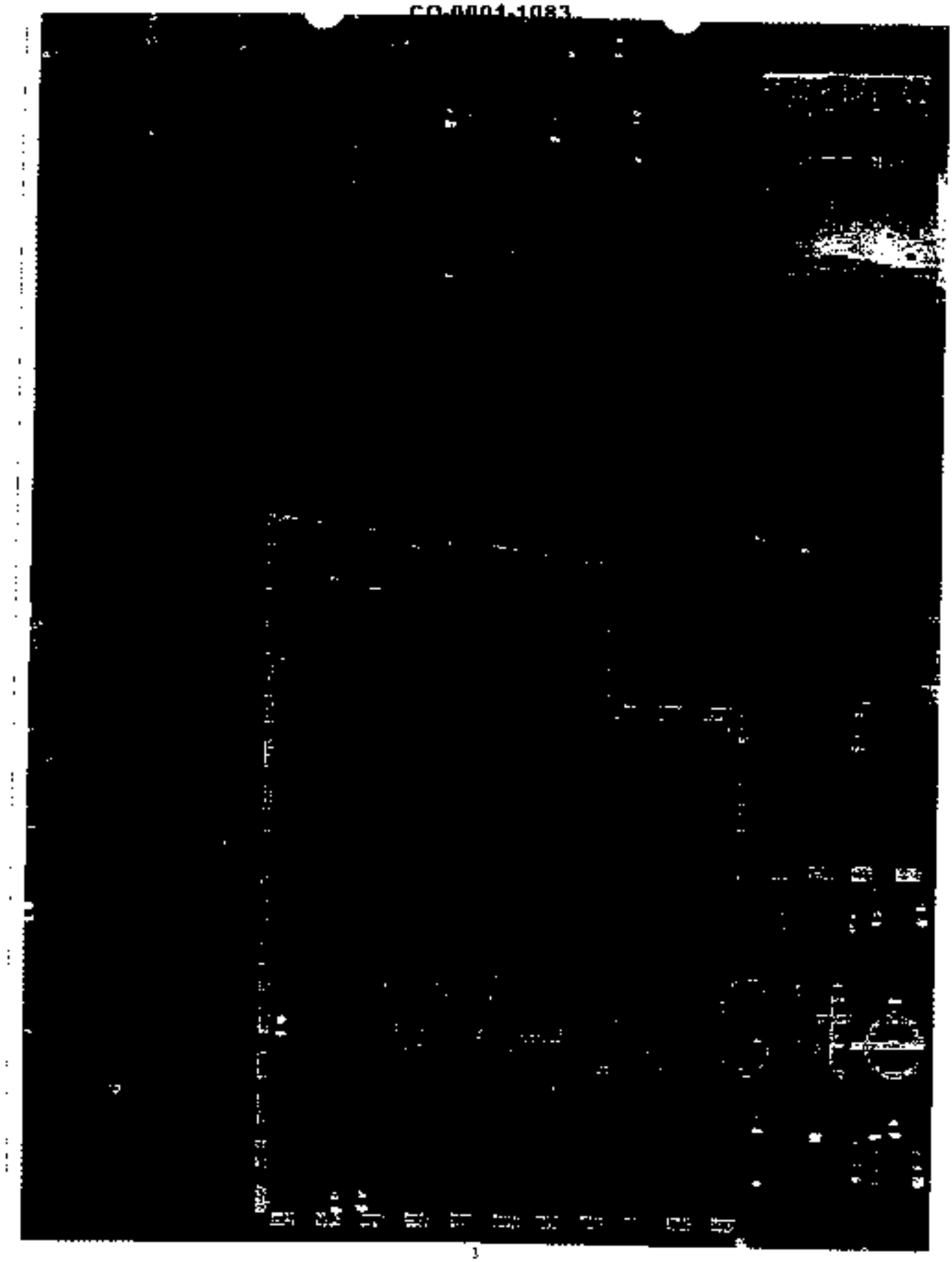

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Cc: Cheryle Huyhn
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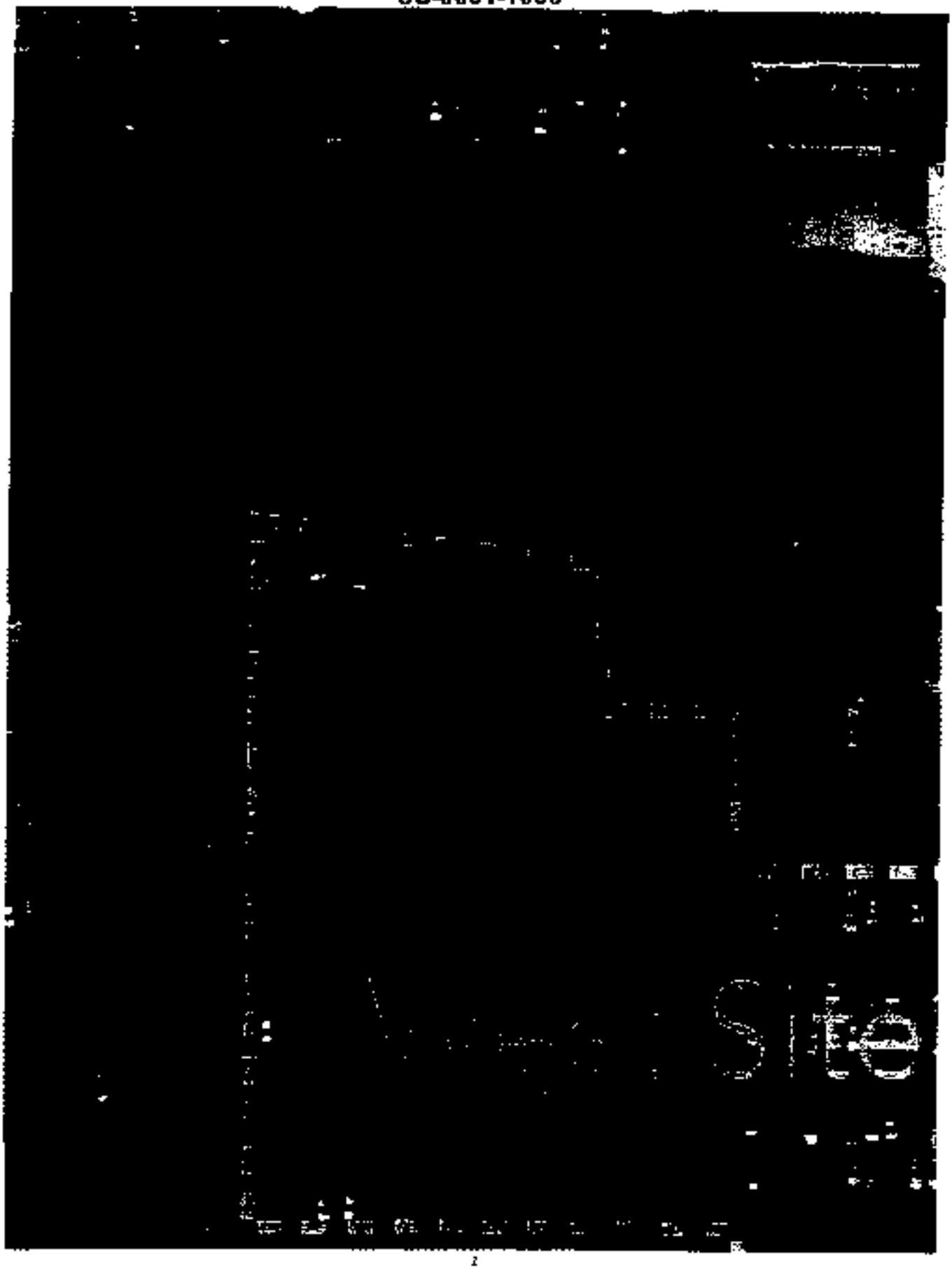
On Thu, Mar 15, 2012 at 11:04 AM, Alfred Fraijo Jr. <afraijo@sheppardmul...> wrote:
Hi Ray,

Thank you for taking our call yesterday. The property address is 1750 North Vine Street.

We are looking for information on the building code regulations that apply to development within a fault zone or prohibitions or development related to fault areas. We were informed by Mr. Dana Prevost that a limited fault investigation would be required in the portion of the subject site. There is a Hollywood Fault trace mapped by the California Geological Survey that prompted the discussion with Mr. Prevost

The property extends on two adjacent sites along Vine Street and is generally bounded by Yucca Street, Argyle Avenue and Ivar. Below is a general map of the site.

Thank you in advance for your assistance.


Site

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From:	Dana Prevost <dana.prevost@lacity.org>
Sent:	Tuesday, July 03, 2012 7:35 AM
To:	Dan Eberhart
Cc:	Jeffrey T. Wilson (jeffrey.wilson@lacity.org); shood@MillenniumPtrs.com; fluciano@MillenniumPtrs.com; kjonsar@MillenniumPtrs.com; pfalk@shopkick.com; lin.com; Rudy Svorcina; Diane Borelli; John Magnaverta
Subject:	Re: Millennium Hollywood Development - Tentative Tract 71497 - South of Yucca Street & East of Ivar Avenue

Dan:
Looks good. I would just like to note that full scope of the investigation will ultimately depend, of course, on the quality of the data from the borings. Also, the allowable building envelope will probably be some distance south of B-1, as I indicated in the meeting. We look forward to seeing the results.

Dana

On Tue, Jul 3, 2012 at 7:00 AM, Dan Eberhart <deberhart@langan.com> wrote:

Dana / Jeffrey

Thanks for meeting us yesterday. The following will summarize our meeting of 2 July 2012 at your office.

1. A fault investigation for the Hollywood fault will be required prior to approval of the tentative map. The investigation was agreed to be limited to the western parcel of the tentative map (that portion west of Vine Street).

2. The subsurface investigation scope as indicated on the attached map and section has been agreed to by the city.

3. Should the building envelope extend north of B1, additional subsurface investigation will be required prior to the issuance of building permits.

4. Should the investigation find evidence of recent fault activity, a restricted use area will be identified by Langan.

5. Should datable materials be found, carbon dating will be performed.

6. Langan will have a meeting with the city to discuss our findings from the fault investigation prior to report submittal.

7. The final geotechnical engineering study as recommended in the city review sheet dated May 23, 2012 is not required prior to approval of the vesting tentative map and will be deferred until the buildings have been designed. The report will be prepared prior to building permit issuance.

Regards,

Dan

Dan R. Eberhart, PG, CEG, CPG
Associate
Direct: 949.255.9661
Mobile: 714.695.6297

Langan Engineering & Environmental Services
Phone: 949.255.6545 Fax: 949.255.9641
18662 MacArthur Boulevard, Suite 455
Irvine, CA 92612-1720
www.langan.com

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--
Dana Prevost
Engineering Geologist III
Grading Division Chief
Building and Safety
City of Los Angeles
(213)482-0488

Jeffrey Wilson <jeffrey.wilson@lacity.org>

Log #: 77007-1 (1720-1770 N. Vine St, Hollywood)

1 message

Stephanie Montgomery <smontgomery@langan.com> Wed, Jan 2, 2013 at 4:10 PM
To: Jeffrey Wilson <jeffrey.wilson@lacity.org>

Jeff,

Langan's client elected to have the subject log expedited, thus an additional payment was made to the City for the fee difference between standard and expedited turn around. Please confirm you and Dana received such notice and advise where the report is within the queue of reports to be reviewed.

Once reviewed and prior to you and Dana issuing a review letter, Langan would like to meet with you and Dana to discuss your comments. Please advise when this meeting is feasible.
Thank you very much for your time and efforts.
Stephanie Montgomery
Senior Staff Geologist
Direct: 949.255.8667

WE HAVE MOVED! PLEASE NOTE OUR NEW ADDRESS BELOW

Langan Engineering & Environmental Services
Phone: 949.250.0410 Fax: 949.255.8641
30 Executive Park, Suite 100

Irvine, California 92614
www.langan.com

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(RRR)

From: Jeffrey Wilson [mailto:jeffrey.wilson@lacity.org]
Sent: Tuesday, November 06, 2012 11:42 AM
To: Stephanie Montgomery
Subject: Re: Log #77007, Tier 2, Various Tracts in Hollywood

Stephanie,

Thank you for the confirmation.

Jeff

On Tue, Nov 6, 2012 at 11:05 AM, Stephanie Montgomery <shmontgomery@langan.com> wrote:

Jeff,

Langan and Millennium Partners will meet with you and Donna on Thursday, November 8, 2012 at 10am to discuss Millennium's Hollywood Development.

Thank you,
Stephanie Montgomery
Senior Staff Geologist
Direct: 949.955.0667

Langan Engineering & Environmental Services
Phone: 949.250.0640 Fax: 949.250.0641
18552 MacArthur Boulevard, Suite 450
Irvine, CA 92612-1200
www.langan.com

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ABU DHABI ATHENS DOHA DUBAI ISTANBUL

Please consider the environment before printing this e-mail

From: Jeffrey Wilson [mailto:jeffrey.wilson@lacity.org]
Sent: Tuesday, November 06, 2012 8:08 AM
To: Stephanie Montgomery
Subject: Re: Log #77007, File-2, Various Tracts in Hollywood

Hi Stephanie,

This Thursday at 10 AM would be okay to meet with Donna Freeland and myself re: the Millennium project on Vine Street.

Thank you,

Jeff

On Mon, Nov 5, 2012 at 4:37 PM, Stephanie Montgomery <smontgomery@langan.com> wrote:

Jeff,

Per the meeting with yourself, Mr. Prevost, and personnel from Millennium Partners and Langan Engineering & Environmental Services in May 2012, we would like to discuss the findings of our fault investigation within the site that is discussed in the City's 'Geology and Soils Report Correction Letter for Log #77907, dated May 23, 2012. Please advise when you and Mr. Prevost are available that week to meet and discuss the findings.
Thank you.

Stephanie Montgomery
Senior Staff Geologist
Direct: 949.336.6662

Langan Engineering & Environmental Services
Phone: 949.295.5640 Fax: 949.295.6601
18662 MacArthur Boulevard, Suite 400
Irvine, CA 92612-1400
www.langan.com

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.

Jeffrey T. Wilson

Engineering Geologist

Grading Division

Department of Building & Safety

201 N. Figueroa St., 3rd Floor

Los Angeles, CA 90012

213 482-6539

213 482-0499 (fax)

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–

Jeffrey T. Wilson

Engineering Geologist I

Grading Division

Department of Building & Safety

201 N. Figueroa St., 3rd Floor

Los Angeles, CA 90012

213 482-6906

213 482-6930 (fax)

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From:	Stephanie Montgomery <smontgomery@langan.com>
Sent:	Monday, February 11, 2013 9:15 AM
To:	Mui Lay
Subject:	RE: 77007-01
Attachments:	C0001094.2 Response to City Comments 12-3-2012.pdf

Mui,
Please refer to the attached submittal you requested with the revised site addresses. Let me know if you need anything else for your files.
Thank you,
Stephanie Montgomery
Senior Staff Geologist
Direct: 949.255.6852
Mobile: 949.294.4175

WE HAVE MOVED. PLEASE NOTE OUR NEW ADDRESS BELOW.

LANGAN

CALIFORNIA NEW JERSEY NEW YORK CONNECTICUT PENNSYLVANIA VIRGINIA FLORIDA
ABU DHABI ATHENS DOHA DUBAI ISTANBUL

From: Mui Lay [mailto:mui.lay@lacity.org]
Sent: Thursday, February 07, 2013 4:18 PM
To: Stephanie Montgomery
Subject: Re: 77007-01

Stephanie,

Thank you. I received the package today.

Mui

On Tue, Feb 5, 2013 at 4:47 PM, Mui Lay <mui.lay@lacity.org> wrote:
Stephanie,

Please send it to my attention (Mui Lay) to the following address:

Building & Safety, Grading Division
201 N. Figueroa St., 3rd Floor, Station #15
Los Angeles, CA 90012

Thank you very much for your prompt attention to this matter.

Mui Lay

On Tue, Feb 5, 2013 at 4:36 PM, Stephanie Montgomery <smontgomery@langan.com> wrote:
Mui,

Please refer to the attached page which includes the additional site addresses for Log # 77007-01. Please provide the name and address to whom we send the 4 wet signed and stamped pages to your attention at the City.

Thank you,

Stephanie Montgomery
Senior Staff Geologist
Direct: 949 255.8552
Mobile: 949 764.1178

WE HAVE MOVED! PLEASE NOTE OUR NEW ADDRESS BELOW

LANGAN

CALIFORNIA NEW JERSEY NEW YORK CONNECTICUT PENNSYLVANIA VIRGINIA FLORIDA
ABU DHABI ATHENS DOHA DUBAI ISTANBUL

From: Mui Lay [mailto:mlay@langan.com]
Sent: Tuesday, February 05, 2013 4:14 PM
To: Stephanie Montgomery
Subject: 77007-01

Plse see attached.

Thank you.

Mui

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LANGAN

Environmental & Geotechnical Consultants

Technical Excellence
Project Experience
Client Responsiveness

3 December 2012

Mr. Dana Prevost
Engineering Geologist III
Department of Building and Safety
City of Los Angeles
201 N. Figueroa Street, 13th Floor
Los Angeles, CA 90012

Re: Response to City of Los Angeles Geology and Soils Report Correction Letter
Log # 77007, Soils/Geology File - 2
Vesting Tentative Tract 71837
Hollywood Development
1720 – 1770 N. Vine Street, 1745-1753 N. Vine Street, 6236-6334 W. Yucca Street, 1733-1741 N. Argyle Avenue & 1746-1764 Ivar Street
Hollywood, Los Angeles, California
Langan Project No.: 700019502

Dear Mr. Prevost,

Langan Engineering & Environmental Services (Langan) has prepared these comments as well as a Fault Investigation Report, dated 30 November 2012 in response to your Geology and Soils Report Correction Letter, dated 29 May 2012 for the Hollywood Development, Vesting Tentative Tract 71837.

City Comment 1: Provide a final geotechnical engineering study for the project development in accordance to Section 1803 of the Code and P/BC 2011-113, and as recommended by the consultant on page 9 of the report. The report shall include but not be limited to:

a. A geologic map and cross sections drawn to a suitable scale for a clearly legible reproduction or purposes showing top and bottom of slopes, formation contacts, locations of faults relative to the subject site, existing and proposed topographic profiles, existing and proposed structures and required Code setbacks (7006.3.2);
b. Additional borings, test pits and laboratory testing;
c. During and after construction groundwater control measures;
d. Temporary excavation recommendations considering groundwater, and potential removal of lateral support of adjacent structures, property and/or public way;
e. Allowable lateral shoring deflection;
f. Basement and retaining wall design recommendations considering hydrostatic conditions, surcharge loads and or seismic-induced lateral pressures;
g. Total and differential seismic and static settlements considering total dead and live loads;
h. Proper calculations to substantiate design recommendations.

Langan Response: The referenced geotechnical engineering report is a preliminary study that was prepared in support of ZAR. Per our discussion during the meeting on 2 July 2012, additional fieldwork will be performed and the corresponding geotechnical evaluations and substantiating data will be provided in a final design geotechnical report when the final design plans (building footprint area, height, below grade depths, and column loads) are available.

City Comment 2: Provide a geological investigation to evaluate surface displacement due to faulting. (1803.5.11)

Langan Response: Langan performed a fault rupture investigation within the southern portion of Site as requested and discussed with representatives of the City of Los Angeles Department of Building and Safety. The results of our investigation are presented in our report "Fault Investigation Report for the Hollywood Development, Hollywood, California," dated 30 November 2012. We concluded that active faulting was not present within the investigated portion of the Site.

The northwest portion of the Site, north of our fault investigation boring B4 is currently unexplored since the area is occupied by an Enterprise Rent-A-Car facility. If a structure or portion thereof is proposed for this area of the Site, a fault investigation will be performed within the unexplored portion of the Site. Currently, the unexplored portion of the Site is recommended to be a restricted use area until the absence/presence of active faulting is determined in this area.

City Comment 3: All testing is required to be conducted by a City of Los Angeles lab oratory testing agency. Provide evidence that all laboratory testing is performed by a City of Los Angeles approved testing agency. If soil testing is performed by a different consultant that is a City of Los Angeles approved testing agency a complete laboratory testing report shall be prepared, signed and stamped by the engineer in responsible charge of the testing and shall include testing description and procedure. In addition, a Statement of Responsibility by the Geotechnical Engineer of record concurring with the data stipulated in other consultant's reports and accepting the responsibility of using the data shall be provided.

Langan Response: The requested information will be included in the final geotechnical engineering design report after the building design has been finalized.

We are available to discuss any questions you may have regarding this submittal. Please contact us if you have any questions.

Sincerely,
Langan Engineering and Environmental Services, Inc.

PROFESSIONAL GEOLOGIST * STATE OF CALIFORNIA * DAN ROYDEN EBERHART No. 986 CERTIFIED ENGINEERING GEOLOGIST

Dan R. Eberhart, PG, CEG
Associate
CEG # 986

REGISTERED PROFESSIONAL ENGINEER DIANE M. FIORELLI C70591 EXP. 6/30/13 CIVIL * STATE OF CALIFORNIA *

Diane M. Fiorelli II, PE
Senior Project Manager
PE # C70591

DRE: DMF: cm

LA CITY BLDG & SFTY Fax:213-482-6497

CITY OF LOS ANGELES
INTER-DEPARTMENTAL CORRESPONDENCE

GEOLOGY AND SOILS REPORT CORRECTION LETTER

May 23, 2012

LOG # 77007
SOILS/GEOLOGY FILE - 2

To: Jim Tokunaga, Deputy Advisory Agency
Department of City Planning
200 N. Spring Street, 7th Floor, Room 750

From: Dana Prevost, Engineering Geologist II
Department of Building and Safety

Vesting Tentative Tract: 71837
LOT(S): 1-41 Mixed-Use Subdivision
LOCATION: 1720-1770 N. Vine Street, 1745-1753 N. Vine Street, 6236-6334 W. Yucca Street, 1733-1742 N. Argyle Avenue, 1746-1764 N. Ivar Street

CURRENT REFERENCE REPORT/LETTER(S)	REPORT No.	DATE(S) OF DOCUMENT	PREPARED BY
Soils Report	70001950	11/22/2011	Langan

The Grading Division of the Department of Building and Safety has reviewed the Vesting Tentative Tract 71837 and the referenced preliminary report concerning the proposed approximately 1,166,870 square feet of residential, commercial, retail, and hotel development. The site is bisected by Vine Street, which thereby creates two development sub-areas referred as the West Site and the East Site.

The East Site of the proposed development consists of the 13-story Capitol Records Building with a single-below grade vault chamber, and the two-story Gogerty office building to the north of the Capitol Records Building. The remainder of the East Site is an asphalt paved parking lot. The West Site is presently occupied by on-grade parking lots, with a one-story Enterprise Rent-A-Car building.

Proposed development includes up to 220-foot high towers on the northwest corner of the West Site of the development and up to 585-foot high towers on the east side of the East Site. Up to 4 levels of excavation beneath the West Site and up to 6 levels of excavation below the East Site are proposed.

Total depth of preliminary exploratory excavations was 101.5 feet below grade. Ground water was encountered at 57 feet below grade. The earth materials at the subsurface exploration locations consist of Holocene and Late Pleistocene Age alluvial deposits of gravel, sand and silt overlying older late to middle Pleistocene age alluvial deposits of silt, sand, and gravel. The consultants recommend to support the proposed towers and other heavily loaded structures on mat foundations and/or pile foundations. Lighter low-rise structures are recommended to be supported on conventional foundations. The native undisturbed soils is the recommended bearing material.

According to the Fault Activity Map of California, dated 2010, prepared by the California Geological Survey the Hollywood Fault is considered active and appears to exist in the vicinity of the subject

site. Therefore, a fault investigation report should be performed as required by Code Section 1803.5.11 of the Los Angeles Building Code.

The review of the subject report can not be completed at this time and will be continued upon submittal of an addendum to the report which shall include, but not be limited to, the following.

(Note: Numbers in parenthesis ( ) refer to applicable sections of the 2011 City of LA Building Code. LABC numbers refer the applicable Information Bulletin. Information Bulletins can be accessed on the Internet at LADBS.ORG.)

1. Provide a final geotechnical engineering study for the project development in accordance to Section 1803 of the Code and LABC 2011-113, and as recommended by the consultant on page 9 of their report. The report shall include but not to be limited to:
   a. a geologic map and cross sections drawn to a suitable scale for archiving and reproduction purposes showing top and bottom of slopes, lithologic contacts, locations of faults relative to the subject site, existing and proposed topographic profiles, existing and proposed structures and required Code setbacks (7006.3.2);
   b. additional borings, test pits, and laboratory testing;
   c. during and after construction groundwater control measures;
   d. temporary excavation recommendations considering groundwater, and potential removal of lateral support of adjacent structures, property and/or public way;
   e. allowable lateral shoring deflection;
   f. basement and retaining wall design recommendations considering hydrostatic conditions, surcharge loads and seismic-induced lateral pressures;
   g. total and differential seismic and static settlements considering total dead and live loads;
   h. proper calculations to substantiate design recommendations.

2. Provide a geological investigation to evaluate surface displacement due to faulting. (1803.5.11)

3. All testing is required to be conducted by a City of Los Angeles licensed testing agency. Provide evidence that all laboratory testing is performed by a City of Los Angeles approved testing agency. If soil testing is performed by a different consultant that is a City of Los Angeles approved testing agency, a complete laboratory testing report shall be prepared signed and stamped by the engineer in responsible charge of the testing and shall include testing description and procedure. In addition, a Statement of Responsibility by the Geotechnical Engineer of record concurring with the data stipulated in other consultants reports and accepting the responsibility of using these data shall be provided.

The geologist and soils engineer shall prepare a report containing the corrections indicated in this letter. The report shall be in the form of an itemized response. It is recommended that once all correction items have been addressed in a response report, to contact the report review engineer and/or geologist to schedule a verification appointment to demonstrate compliance with all the corrections. Do not schedule an appointment until all corrections have been addressed. Bring three

copies of the response report, including one unbound wet-signed original for microfilming in the event that the report is found to be acceptable.

JTW/JAA:jtw/jas
Log No. 77507
213 482-0432

cc: Millennium Hollywood, LLC, Owner
Paul Garry Pavlas, Applicant
Langan Engineering & Environmental Services, Project Consultant
LA District Office

From: Charmie Huynh <charmie.huynh@lacity.org>
Sent: Monday, April 01, 2013 9:18 AM
To: Alfred Frejo Jr.
Subject: Milestone

Hi Alfred,

How are you? Hope you're doing well!

I just wanted to see how this project is progressing and any status updates you can give me would be much appreciated.

Thanks.

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-6875
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

Charmie Huynh <charmie.huynh@lacity.org>

Balconies

7 messages

Kyndra Casper <KCasper@sheppardmullin.com> Thu, May 16, 2013 at 2:25 PM
To: "Charmie Huynh (charmie.huynh@lacity.org)" <charmie.huynh@lacity.org>

Charmie,

To follow-up on our brief discussion on Monday re balconies, here are the questions that the architects have regarding balconies/projections (below is an excerpt from the architect's email re balconies/projections:

"We need greater clarification from you on the applicable rules and if we can make the below assumptions or not.

Reviewing section 12.22.c.20 regarding projections into yards.

Does not refer to "balconies" specifically as far as I can tell. Does speak to other projections (eaves, sills or other similar features - though explicitly excludes vertical projections which we would want in the sideyard)

If I'm reading this correct, gives the following rules:

2" for every 1' of sideyard. So for a 16' sideyard (req for rest at this height) we could project max 32"? This is not enough for us.

We would like to project architectural features, including balconies, up to 6' into required side and rear yards.

Please confirm if we can make this assumption"

We also wanted clarification as to what "vertical projections" are in regard to LAMC section 12.22.c.20

Thank you for your help with this!

Best,

Kyndra

Kyndra Joy Casper
213.617.4157 | direct
213.443.3720 | direct fax
KCasper@sheppardmullin.com | Bio

SheppardMullin
Sheppard Mullin Richter & Hampton LLP
333 South Hope Street, 43rd Floor
Los Angeles, CA 90071-1422

213.620.1780 | main

www.sheppardmullin.com

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Charmie Huynh <charmie.huynh@lacity.org> Thu, May 16, 2013 at 3:44 PM
To: Kyndra Casper <KCasper@sheppardmullin.com>

Hi Kyndra,

I'm leaving the office soon and will not be back until this Monday. I'll take a look at your email then. Have a good weekend.

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
ph: (213) 482-0073

P: (213) 482-6874
E: Charmie.Huynh@lacity.org
[Quoted text hidden]

Kyndra Casper <KCasper@sheppardmullin.com> Thu, May 16, 2013 at 3:45 PM
To: "charmie.huynh@lacity.org" <charmie.huynh@lacity.org>

Thanks, Charmie!!

From: Charmie Huynh [mailto:charmie.huynh@lacity.org]
Sent: Thursday, May 16, 2013 03:44 PM
To: Kyndra Casper
Subject: Re: Balconies

[Quoted text hidden]

Charmie Huynh <charmie.huynh@lacity.org> Mon, May 20, 2013 at 9:50 AM
To: Kyndra Casper <KCasper@sheppardmullin.com>

Hi Kyndra,

12.22C20(d) allows balconies not covered by a roof or canopy to project into a required rear yard not more than 4' and into a required front yard, passageway, other open space, or the side yard adjoining the street lot line of a corner lot, not more than 30".

Vertical projections are those architectural projections that exceed 4' in vertical height. Please see the attached LADBS info bulletin regarding allowable projections. I've highlighted the reference made to vertical projections on page 2.

Please let me know if you have any further questions.

Thanks.

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N. Figueroa St, Suite 1036
Los Angeles, CA 90012
P: (213) 482-6875
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

On Thu, May 16, 2013 at 2:28 PM, Kyndra Casper <KCasper@sheppardmullin.com> wrote:
[Quoted text hidden]

---

2 attachments

12.22C20(d).pdf
21K

ts-F-ZD2002-006AllowableProjections.pdf

59K

Kyndra Casper <KCasper@sheppardmullin.com> Mon, May 20, 2013 at 11:02 AM
To: Charmie Huynh <charmie.huynh@lacity.org>

Thanks, Charmie! A couple more questions from the architects:

"Based on the zoning interpretation documents that we have available, it is unclear to us whether the portion of a balcony closest to the building on balconies greater than 5' in width constitutes floor area, and also 'assumed building wall' 5' in from the edge of balcony."

Thanks,

Kyndra

From: Charmie Huynh [mailto:charmie.huynh@lacity.org]
Sent: Monday, May 20, 2013 9:50 AM
To: Kyndra Casper
Subject: Re: Balconies

Hi Kyndra,

[Quoted text hidden]
[Quoted text hidden]

Charmie Huynh <charmie.huynh@lacity.org> Tue, May 21, 2013 at 9:20 AM
To: Kyndra Casper <KCasper@sheppardmullin.com>

Hi Kyndra,

I'm not clear on the architect's question. I've attached ZA-2007-3430-ZAI regarding floor area ratio and private open space. Perhaps you can send me a floor plan showing the balconies in question?

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1050
Los Angeles, CA 90012

CO-0001-1107

Charmie Huynh <charmie.huynh@lacity.org>

FW: Balcony Diagram

4 messages

Kyndra Casper <KCasper@sheppardmullin.com> Wed, May 29, 2013 at 4:38 PM
To: Charmie Huynh (charmie.huynh@lacity.org)" <charmie.huynh@lacity.org>

Charmie- see attached and email below from architect. Thanks!

Kyndra

Per our discussion last week, could you please run this diagram by your contact at Building department?

Our questions/assumptions:

Sketch 1:

1. No part of balcony counts towards FAR.
2. So long as wall does not exceed 5', length does not matter?

Sketch 2:

1. Does any area greater than 5' in width count as floor area and thus create an assumed building wall even if not covered by a roof (only other balconies)?
2. If so, how is this different than a roof terrace (public or private) or amenity terrace? Assume those do not count as floor area?

Sketch 3:

1. If there is an architectural feature beyond the balcony (such as a screen wall, horizontal or vertical expressor, band) does it affect what is considered floor area? If so, how?

We really appreciate your help with these issues.

Kyndra

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130528 Balcony Diagram.pdf
45K

Charmie Huynh <charmie.huynh@lacity.org> Thu, May 30, 2013 at 4:00 PM
To: Kyndra Casper <KCasper@shepardmullin.com>

Hi Kyndra,

I'll have to address your email next week. I'm out of the office tomorrow.

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N. Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-6975
F: (213) 482-6874
E: Charmie.Huynh@lacity.org
[Quoted text hidden]

Kyndra Casper <KCasper@shepardmullin.com> Thu, May 30, 2013 at 4:03 PM
To: Charmie Huynh <charmie.huynh@lacity.org>

Thanks, Charmie!

From: Charmie Huynh [mailto:charmie.huynh@lacity.org]
Sent: Thursday, May 30, 2013 4:00 PM
To: Kyndra Casper
Subject: Re: FW: Balcony Diagram

[Quoted text hidden]

Charmie Huynh <charmie.huynh@lacity.org> Tue, Jun 4, 2013 at 3:36 PM
To: Kyndra Casper <KCasper@shopparcmulti.com>

Hi Kyndra,

I've attached ZA2007-3430 (ZAI) that clarifies balconies and FAR item again for your reference. This document would answer the architect's questions.

Also, please see my responses below... they are colorized in blue.

Thanks,

Charmie Huynh, P.E.
Structural Engineering Associate / Case Manager
Development Services Case Management
City of Los Angeles - Department of Building and Safety
201 N Figueroa St, Suite 1030
Los Angeles, CA 90012
T: (213) 482-0075
F: (213) 482-6874
E: Charmie.Huynh@lacity.org

On Wed, May 29, 2013 at 4:35 PM, Kyndra Casper <KCasper@shopparcmulti.com> wrote:

> Charmie-See attached and email below from architect. Thanks!
>
> Kyndra-
>
> Per our discussion last week, could you please run this diagram by your contact at Building department?
>
> Our questions/assumptions.
>
> Sketch 1:
>
> 1. No part of balcony counts towards FAR - *correct, since it is projecting from the exterior wall of the building.*
>
> 2. So long as width does not exceed 5', length does not matter? - *width can go beyond 5' as per ZA-2007-3430(ZAI) as long as it projects beyond the perimeter of the building. And yes, length does not matter.*
>
> Sketch 2:
>
> 1. Does any area greater than 5' in width count as floor area and thus create an assumed building wall even if not covered by a roof (only other balconies)? - *See my answer above.*

2. If so, how is this different than a roof terrace (public or private) or amenity terrace? Assume these do not count as floor area? *FYI, roof terrace that are uncovered do not constitute floor area.*

Sketch 3:

1. Where is an architectural feature beyond the balcony (such as a screen wall, horizontal or vertical expression band) does it affect what is considered floor area? If so, how? *Yes, an architectural feature such as a screen covering stacking balconies would render the balconies as enclosed and count towards floor area.*

We really appreciate your help with these issues.

Kyrcra

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ZA-2007-3436-ZAI_F.A.R. & Pvt. Open Space_09-21-07.pdf
702K

Dana Prevost <dana.prevost@lacity.org>

millenium fault study

Dana Prevost <dana.prevost@lacity.org> Thu, Jun 13, 2013 at 3:23 PM
To: Jeffrey Wilson <jeffrey.wilson@lacity.org>

Jeff,
I tried to reach Dan eberhart but he didn't answer his phone. I left a long message explaining our concerns about the low slip recovery and that we would not approve exploration. He may try to call you when he gets back on until June 24.
Dana

Dana Prevost <Dana.Prevost@lacity.org>

Meeting re Millennium Hollywood Seismic Borings

Message

Jerry Neuman <jneuman@sheppardmullin.com> Wed, Jul 3, 2013 at 4:21 PM
To: "'raymond.chan@lacity.org' (raymond.chan@lacity.org)" <raymond.chan@lacity.org>, "Dana Prevost (Dana.Prevost@lacity.org)" <Dana.Prevost@lacity.org>, James Pugh <JPugh@sheppardmullin.com>
"debehart@jangan.com" <debehart@jangan.com>
Cc: "Catherine Nuezca Gaba (Catherine.NuezcaGaba@lacity.org)" <Catherine.NuezcaGaba@lacity.org>

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invite.ics
3K

Dana Prevost <dana.prevost@lacity.org>

Meeting re Millennium Hollywood Seismic Borings

Message

Jerry Neuman <jneuman@sheppardm.ulin.com> Mon, Jul 15, 2013 at 12:05 PM
To: "raymond.chan@lacity.org" (raymond.chan@lacity.org)" <raymond.chan@lacity.org>, "Dana Prevost (Dana.Prevost@lacity.org)" <Dana.Prevost@lacity.org>, James Pugh <JPugh@sheppardmullin.com>, "debenhart@Langan.com" <debenhart@langan.com>
Cc: "Catherine Nueza Gaba (Catherine.NuezaGaba@lacity.org)" <Catherine.NuezaGaba@lacity.org>, Dario Fiorelli <dfiorelli@langan.com>

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Attention: This message is sent by a law firm and may contain information that is privileged or confidential. If you received this transmission in error, please notify the sender by reply e-mail and delete the message and any attachments.

invite.ics
3K

Subject:	Meeting re Millennium Hollywood Project Settings
Location:	Dept. of Building & Safety 201 North Figueroa Street Suite 1000, Los Angeles, CA
Start:	Tue 7/16/2013 1:00 PM
End:	Tue 7/16/2013 2:00 PM
Show Time As:	Tentative
Recurrence:	(none)
Meeting Status:	Not yet responded
Organizer:	Jerry Neuman

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Attention: This message is sent by a law firm and may contain information that is privileged or confidential. If you received this transmission in error, please notify the sender by reply e-mail and delete the message and any attachments.

Subject:	Meeting re Millennium Hollywood Seismic Ratings
Location:	Dept of Building & Safety 201 North Figueroa Street, Suite 1000 Los Angeles CA
Start:	Tue 7/16/2013 1:00 PM
End:	Tue 7/16/2013 2:00 PM
Show Time As:	Tentative
Recurrence:	(none)
Meeting Status:	Not yet responded
Organizer:	Jerry Neuman

Circular 230 Notice: In accordance with Treasury Regulations we notify you that any tax advice given herein (or in any attachments) is not intended or written to be used, and cannot be used by any taxpayer, for the purpose of (i) avoiding tax penalties or (ii) promoting, marketing or recommending to another party any transaction or matter addressed herein (or in any attachments).

Attention: This message is sent by a law firm and may contain information that is privileged or confidential. If you received this transmission in error, please notify the sender by reply e-mail and delete the message and any attachments.

Subject:	Meeting re Millennium Hollywood Seismic Designs
Location:	Dept. of Building & Safety 201 North Figueroa Street, Suite 1008, Los Angeles, CA
Start:	Tue 7/16/2013 1:00 PM
End:	Tue 7/16/2013 2:00 PM
Show Time As:	Tentative
Recurrence:	(none)
Meeting Status:	Not yet responded
Organizer:	Jerry Neuner

Circular 230 Notice: In accordance with Treasury Regulations we notify you that any tax advice given herein (or in any attachments) is not intended or written to be used, and cannot be used by any taxpayer, for the purpose of (i) avoiding tax penalties or (ii) promoting, marketing or recommending to another party any transaction or matter addressed herein (or in any attachments).

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Subject:	Meeting re Mulholland Hollywood Seismic Savings
Location:	Dept. of Building & Safety 201 North Figueroa Street, Suite 1000 Los Angeles, CA
Start:	Tue 7/16/2013 1:00 PM
End:	Tue 7/16/2013 2:00 PM
Show Time As:	Tentative
Recurrence:	(none)
Meeting Status:	Not yet responded
Organizer:	Jerry Neuman

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Diego de la Garza <diego.delagarza@lacity.org>

LA Times Media Query: Millennium Hollywood

Jonathan Hui <jonathan.hui@lacity.org> Mon, Jun 17, 2013 at 10:29 AM
To: Bruce Gilman <bruce.gilman@lacity.org>
Cc: Manuel Porras <manuel.porras@lacity.org>, Diego de la Garza <diego.delagarza@lacity.org>, Zaki Mustafa <zaki.mustafa@lacity.org>, Jay Kim <jay.kim@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Lisa Webber <lisa.webber@lacity.org>, Lucralia Ibarra <lucralia.ibarra@lacity.org>

Hi Bruce

Just so FYI that Michael Ritzik interviewed Tomas Carranza today on the subject topic. He specifically was interested in Caltrans concerns that the project was not adequately addressing roadway impacts. Tomas emphasized the process which the department goes through to define and mitigate traffic impacts and how those became recommendations to the City Planning Department. He noted the mitigations the department recommended and referred Michael to Caltrans and the Planning department for information about Caltrans concerns. The planning and land use management committee meets on this particular project tomorrow.

Here is past editorial from the LA Times regarding this project which is generally neutral, but does mention Caltrans briefly:

http://articles.latimes.com/2013/apr/04/opinion/la-ed-0404-hollywood-20130404

Maximum size of the community is scheduled to run on Wednesday.

Please let me know if you have any questions.

Jonathan

--
Jonathan Hui
Los Angeles Department of Transportation
(213)972-8481
jonathan.hui@lacity.org

Fwd: Millennium/Caltrans

Council Member Gorsett <councilmember.gorsett@sdcity.org> Wed, Jun 19, 2013 at 8:00 PM
To: Marcel Ponce <marcel.ponce@sdcity.org>

---------- Forwarded message ----------
From: **Bill Miller** <mvc.bill@sbcglobal.net>
Date: Wed, Jun 19, 2013 at 1:45 PM
Subject: Millennium/Caltrans
To: councilmember.lightfoot@sdcity.org, councilmember.lightfoot@sdcity.org, councilmember.alvarez@sdcity.org, councilmember.cole@sdcity.org, councilmember.gloria@sdcity.org, councilmember.emerald@sdcity.org, councilmember.faulconer@sdcity.org, councilmember.zapf@sdcity.org, councilmember.kersey@sdcity.org, councilmember.sherman@sdcity.org, councilmember.gorsett@sdcity.org, councilmember.cole@sdcity.org
Cc: mayor@sandiego.gov, mayor@sandiego.gov

Only a few of the many unresolved problems with Millennium Projects

Caltrans never met them on Millennium Policy/Goal projects

Caltrans has made it clear that without significant changes in the plans

Millennium Policy/Goal projects, the Mitigation on the SR1 Freeway will be disastrous

Caltrans – Millennium Hollywood Issues
Department of City Planning Response

Main Issues

Caltrans issued a variety of concerns over the course of the two year environmental process (2011-2013) for the Millennium Hollywood Project with respect to the impacts the project will have on the US-101 Freeway.

1) The primary issue is that **Caltrans and LADOT use different methodologies** in analyzing impacts.

2) Another issue discussed is **Caltrans' belief that the project's adopted mitigation measures do not sufficiently address the anticipated impacts** on the freeway system.

Different Methodologies

The Department of City Planning (DCP) uses LADOT staff as the primary transportation engineering analysts for the environmental documents.

Caltrans uses much more conservative metrics that result in more vehicle trips and typically do not analyze alternative transportation options. LADOT uses methodologies that focus on alternative trips for urban infill projects as prescribed and adopted in the recent Hollywood Community Plan.

The following summarizes the different methodologies employed by the two agencies:

Caltrans	DCP/LADOT Response
Select Zone Analysis	Select Zone Analysis does not take intercepted trips into account, which are a major factor for urban infill projects. The project used a manual approach.
Trip Generation Tables	Land use code and independent variables dictate which formulas were to be used for trip generation. Tables were not used.
Highway Capacity Manual 85th Percentile Queuing	This methodology would be dependent on the area signal timing remaining fixed through 2035, whereas the City varies the signal timing on an instantaneous basis. LADOT also specifies the use of Critical Movement Analysis (CMA) as opposed to Caltrans' recommendation.

Mitigation Measures

Caltrans also identified several on- or off-ramp intersections that were not analyzed, as well as proposed mitigation measures that will not appropriately reduce traffic.

Caltrans – Millennium Hollywood Issues
Department of City Planning Response

DCP's response is that the locations where traffic impacts will be significant are the critical constraints that should be analyzed. The only locations identified in the study were local, signalized intersections of the area roadway system. The freeway ramps, including meters and weave sections, are not part of the roadway constraints in the Hollywood area.

DCP's response regarding mitigation measures is that the project has committed to significant upgrades to the regional transportation system by funding or implementing programs called for in MTA's Long Range Transportation Plan and the Hollywood Community Transportation Improvement and Mitigation Plan. This includes:

- Signal system upgrades
- Upgrades to the transit system (bus stops, ped linkages, etc)
- Transportation Demand Management program as part of the development

Also, given the robust transit system in the Project's vicinity, a main focus of the mitigation program is to reduce automobile trips by enhancing pedestrian and bicycle linkages to the transit system and investing in multi-modal transportation improvements (consistent with the Hollywood Community Plan update).

Discussion

Caltrans brings up appropriate issues regarding the existing conditions and future impacts of the Hollywood Project on the surrounding freeway system.

However, as they note in their Comment No 03-4, the freeway system is already currently operating at a Level of Service F.

It should not be the responsibility of the project to reduce congestion on the freeway, it should be the responsibility of the project to encourage new and existing residents to use alternative transportation options to reduce future impacts on the system.

The project accomplishes this with the variety of improvements provided through their mitigation program.

The project also appropriately analyzes and addresses the impacts to the surrounding residential streets using City of LA accepted methodologies and approaches.

Re: Caltrans Comment Letters - Millennium Hollywood Project

Jonathan Hui <jonathan.hui@lacity.org> Fri, Jun 21, 2013 at 9:58 AM
To: Dakota Smith <dakota.smith@dailynews.com>
Cc: Bruce Gillmer <bruce.gillmer@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Clinton Quan <clinton.quan@lacity.org>
Bcc: marcel.porras@lacity.org

Hi Dakota

See response below in blue box

> Does LADOT agree with Caltrans' assessment that many traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

> Also, LADOT met with planning and Caltrans in 2011. Did you expect then that a highway traffic project would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jonathan

> Thanks so much,
> Dakota
>
> ------ Forwarded message ------
> From: Rapisi, Marita C@DOT <marita.rapisi@dot.ca.gov>
> Date: Thu, Jun 20, 2013 at 2:47 PM
> Subject: Caltrans Comment Letters - Millennium Hollywood Project
> To: "dakota.smith@dailynews.com" <dakota.smith@dailynews.com>
> Cc: "Watson, Diana@DOT" <diana.watson@dot.ca.gov>

Notice of Preparation (NOP) Letter dated 3/19/11

Draft EIR (DEIR) Letter dated 12/10/12

Final EIR (FEIR) Letter dated 2/19/13

Letter to Councilmembers dated 3/7/13

Maria Boyce

Public Information Officer

Caltrans, District 07

100 So. Main Street, Los Angeles 90012

213-897-9372

maria.boyce@dot.ca.gov

Jonathan Hui
Los Angeles Department of Transportation
(213)972-8481
jonathan.hui@lacity.org

Marcel Porras <marcel.porras@lacity.org> Fri, Jun 21, 2013 at 9:55 AM
To: Yusef Robb <yusef.robb@lacity.org>

---------- Forwarded message ----------
From: "Jonathan Hui" <jonathan.hui@lacity.org>
Date: Jun 21, 2013 9:50 AM
Subject: Re: Caltrans Comment Letters - Millennium Hollywood Project
To: "Dakota Smith" <dakota.smith@latimes.com>
Cc: "Bruce Gilmore" <bruce.g.hui@lacity.org>, "Tomas Carranza" <tomas.carranza@lacity.org>, "Clinton Quan" <clinton.quan@lacity.org>

Hi Dakota

See response below in red

Does LADOT agree with Caltrans' assessment that more traffic studies should have been conducted?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

> Also, I ADOT met with planning and Caltrans in 2011. Did you expect then that a highway traffic project would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jim Gallan

> Thanks so much,
> Dakota
>
> ——— Forwarded message ———
> From: **Rapps, Maria C@DOT** <maria.rapps@dot.ca.gov>
> Date: Thu, Jun 20, 2013 at 2:47 PM
> Subject: Caltrans Comment Letters - Millennium Hollywood Project
> To: "dakota.smith@dailynews.com" <dakota.smith@dailynews.com>
> Cc: "Watson, D Anne@DOT" <dianne.watson@dot.ca.gov>
>
> Notice of Preparation (NOP) Letter dated 8/10/11
>
> Draft EIR (DEIR) Letter dated 12/10/12
>
> Final EIR (FEIR) Letter dated 2/19/13
>
> Letter to Commissioners dated 5/7/13
>
> Maria Rapps
>
> Public Information Officer
>
> Caltrans, District 7

100 S. Main Street, Los Angeles 90012

213 [illegible] 9372

marcel.porras@lacity.org

–
Jonathan Hui
Los Angeles Department of Transportation
(213)972 8481
jonathan.hui@lacity.org

Diego de la Garza <diego.delagarza@lacity.org> Fri, Jan 21, 2013 at 9:55 AM
To: yusef.robb@lacity.org, Marcel Porras <Marcel.Porras@lacity.org>

---------- Forwarded message ----------
From: Jonathan Hui <jonathan.hui@lacity.org>
Date: Fri, Jan 21, 2013 at 9:50 AM
Subject: Re: Caltrans Comment Letters - Millennium Hollywood Project
To: Dakota Smith <dakota.smith@dailynews.com>
Cc: Bruce Gillman <bruce.gillman@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Ci Ann Quan <cilinh.quan@lacity.org>

Hi Dakota,

See responses below in red bold

Does LADOT agree with Caltrans' assessment that more traffic studies should have been conducted?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

Also, LADOT met with planning and Caltrans in 2011. Did you expect then that a highway traffic analysis

project be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps,

Jonathan

Thanks so much
Dakota

---------- Forwarded message ----------
From: **Rapisarda, Maria C@DOT** <maria.rapisarda@dot.ca.gov>
Date: Thu, Jun 20, 2013 at 2:47 PM
Subject: Caltrans Comment Letters - Millennium Hollywood Project
To: "Dakota.smith@dailynews.com" <Dakota.smith@dailynews.com>
Cc: "Watson, DiAnna@DOT" <dianna.watson@dot.ca.gov>

Notice of Preparation (NOP) Letter-dated 9/9/11

Draft EIR (DEIR) Letter-dated 12/16/12

Final EIR (FEIR) Letter-dated 2/19/13

Letter re: Council motions-dated 5/7/13

Maria Rapisarda

Public Information Officer

Caltrans, District 7

100 So. Main Street, Los Angeles 90012

213-897-9172

maria.rapisarda@dot.ca.gov

Jonathan Hui
Los Angeles Department of Transportation
(213)977-6464

jonathan.hui@lacity.org

Marcel Porras <marcel.porras@lacity.org> Fri, Jun 21, 2013 at 9:57 AM
To: Diego de la Garza <diego.delagarza@lacity.org>
Cc: Marcel Porras <Marcel.Porras@lacity.org>, Yusef Robb <yusef.robb@lacity.org>

Yes

On Fri, Jun 21, 2013 9:56 AM, "Diego de la Garza" <diego.delagarza@lacity.org> wrote:
I received this as a blind copy. Did you get it too?

---------- Forwarded message ----------
From: **Jonathan Hui** <jonathan.hui@lacity.org>
Date: Fri, Jun 21, 2013 at 9:08 AM
Subject: Re: Caltrans Comment Letters - Millennium Hollywood Project
To: Dakota Smith <dakota.smith@dailynews.com>
Cc: Bruce G Shaw <bruce.glshaw@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Clinton Quan <clinton.quan@lacity.org>

Hi Dakota,

See response below in bold:

> Does LADOT agree with Caltrans' assessment that more traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

> And: LADOT met with planning and Caltrans in 2011. Did you expect then that a highway traffic project would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jonathan

> Thanks so much.
> Dakota

---------- Forwarded message ----------
From: **Raptis, Maria C@DOT** <maria.raptis@dot.ca.gov>
Date: Thu, Jun 20, 2013 at 2:47 PM
Subject: Caltrans Comment Letters - Millennium Hollywood Project
To: "steve.ta.smith@dailynews.com" <steve.ta.smith@dailynews.com>
Cc: "Watson, DiAnna@DOT" <dianna.watson@dot.ca.gov>

Notice of Preparation (NOP) Letter dated 5/7/11

Draft EIR (DEIR) Letter dated 12/10/12

Final EIR (FEIR) Letter dated 4/19/13

Letter to Council members dated 5/7/13

Maria Raptis

Public Information Officer

Caltrans, District 7

100 So Main Street, Los Angeles 90012

213-897-0371

maria.raptis@dot.ca.gov

Jonathan Hui
Los Angeles Department of Transportation
(213)972-8481
jonathan.hui@lacity.org

Marcel Porras <marcel.porras@lacity.org> Fri, Jun 21, 2013 at 10:01 AM
To: Jonathan Hui <jonathan.hui@lacity.org>
Cc: Clinton Quan <clinton.quan@lacity.org>, Thomas Carranza <thomas.carranza@lacity.org>, Bruce Gilman <Bruce.Gilman@lacity.org>, Yusef Robb <yusef.robb@lacity.org>, Diego de la Garza <diego.delagarza@sony.com>, Michael LaGrande <michael.lagrande@lacity.org>, Lisa Webber <lisa.webber@lacity.org>

Did you coordinate with planning? I want to make sure we are all on the same page. We got inquiries from dekots as well.

On Jun 21, 2013 9:53 AM, "Jonathan Hui" <jonathan.hui@lacity.org> wrote:
Hi Dakota

See response below in red bold

> Does LADOT agree with Caltrans' assessment that more traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

> Also, LADOT met with planning and Caltrans in 2011. Did you expect that a highway traffic project would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jonathan

> Thanks so much
> Dakota
>
> ---------- Forwarded message ----------
> From: Rapisi, Maria C@DOT <maria.rapisi@dot.ca.gov>
> Date: Thu, Jun 20, 2013 at 2:47 PM
> Subject: Caltrans Comment Letters - Millennium Hollywood Project
> To: "dakota.smith@dailynews.com" <dakota.smith@dailynews.com>
> Cc: "Watson, DiAnna@DOT" <dianna.watson@dot.ca.gov>
>
> Notice of Preparation (NOP) Letter dated 5/15/11
>
> Draft EIR (DEIR) Letter dated 12/13/12
>
> Final EIR (FEIR) Letter dated 3/19/13
>
> Letter to Councilmembers dated 5/7/13

Maria Rapisi

Public Information Officer

Caltrans, District 7

100 So. Main Street, Los Angeles 90012

213-897-0673

maria.rapisi@dot.ca.gov

Jonathan Hui
Los Angeles Department of Transportation
(213)972-8481
jonathan.hui@lacity.org

Tomas Carranza <tomas.carranza@lacity.org> Fri, Jun 21, 2013 at 10:05 AM
To: Marcel Porras <marcel.porras@lacity.org>
Cc: Jonathan Hui <jonathan.hui@lacity.org>, Clinton Quon <clinton.quon@lacity.org>, Bruce Gillmore <Bruce.Gillmore@lacity.org>, Yusef Robb <yusef.robb@lacity.org>, Diego de la Garza <diego.delagarza@lacity.org>, Michael LoGrande <michael.logrande@lacity.org>, Lisa Webber <lisa.webber@lacity.org>

Yes - Jaci came from Planning and I have coordinated our responses.

On Fri, Jun 21, 2013 at 10:01 AM, Marcel Porras <marcel.porras@lacity.org> wrote:

Did you coordinate with planning? I want to make sure we are all on the same page. We got inquiries from dakota as well

Marcel

On Jun 21, 2013 9:53 AM, "Jonathan Hui" <jonathan.hui@lacity.org> wrote:

Hi Dakota

See response below in bold

> Does LADOT agree with Caltrans' assessment that more traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

> Also, I/ADOT met with planning and Caltrans in 2011. Do you expect then that a highway traffic project would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jonathan

> Thanks so much,
> Dakota
>
> ---- Forwarded message ----
> From: Raptis, Maria C@DOT <maria.raptis@dot.ca.gov>
> Date: Thu, Jun 20, 2013 at 2:47 PM
> Subject: Caltrans Comment Letters - Millennium Hollywood Project
> To: "dakotaus.tn@dailynews.com" <dakota.smith@dailynews.com>
> Cc: "Watson, D'Anna@DOT" <dianna.watson@dot.ca.gov>
>
> Notice of Preparation (NOP) Letter dated 5/7/11
>
> Draft EIR (DEIR) Letter dated 12/10/12
>
> Final EIR (FEIR) Letter dated 7/19/13
>
> Letter to Councilmembers dated 5/7/13
>
> Maria Raptis
>
> Project Evaluation Officer
>
> Caltrans, District 7
>
> 100 S. Main Street, Los Angeles 90012
>
> 213-897-0372
>
> maria.raptis@dot.ca.gov

Jonathan Hui
Los Angeles Department of Transportation
(213)972-8561
jonathan.hui@lacity.org

Marcel Porras <marcel.porras@lacity.org> Fri, Jun 21, 2013 at 10:10 AM
To: Tomas Carranza <tomas.carranza@lacity.org>
Cc: Bruce Gillmer <Bruce.Gillmer@lacity.org>, Michael LoGrande <michael.logrande@lacity.org>, Diego Garza <diego.garza@lacity.org>, Jonathan Hui <jonathan.hui@lacity.org>, Yusef Robb <yusef.robb@lacity.org>, Lisa Webber <lisa.webber@lacity.org>, Clinton Owen <clinton.owen@lacity.org>, Lucinda Ibarra <lucinda.ibarra@lacity.org>

Thanks Tom. Luci, has planning issued a statement yet?

On Jun 21, 2013 10:05 AM, "Tomas Carranza" <tomas.carranza@lacity.org> wrote:
Yes - Luci leans from Planning and I have coordinated our responses.

On Fri, Jun 21, 2013 at 10:01 AM, Marcel Porras <marcel.porras@lacity.org> wrote:

Did you coordinate with planning? I want to make sure we are all on the same page. We got inquiries from Caltrans as well.

Marcel

On Jun 21, 2013 9:53 AM, "Jonathan Hui" <jonathan.hui@lacity.org> wrote:
Hi Gerald

See responses below in red bold

Does LADOT agree with Caltrans' assessment that more traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

Also, LADOT met with planning and Caltrans in 2011. Did you expect them that a highway traffic analysis would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jonathan

Thanks so much.
Dakota

---------- Forwarded message ----------
From: **Raptis, Maria C@DOT** <maria.raptis@dot.ca.gov>
Date: Thu, Apr 25, 2013 at 2:47 PM
Subject: Caltrans Comment Letters - Millennium Hollywood Project
To: "dakota.smith@dailynews.com" <dakota.smith@dailynews.com>
Cc: "Weiser, DAnna@DOT" <deanna.weiser@dot.ca.gov>

Notice of Preparation (NOP) Letter-dated 8/16/11

Draft EIR (DEIR) Letter-dated 12/10/12

Final EIR (FEIR) Letter-dated 2/28/13

Letter to Council members-dated 5/7/13

Maria Raptis

Public Information Officer

Caltrans, District 7

100 So. Main Street, Los Angeles 90012

213-897-9377

maria.raptis@dot.ca.gov

Jonathan Fox

Los Angeles Department of Transportation
(213)972-8482
jonathan.hui@lacity.org

Lucikarla Ibarra <lucikarla.ibarra@lacity.org> Fri, Jun 21, 2013 at 10:10 AM
To: Marcel Porras <marcel.porras@lacity.org>
Cc: Tomas Carranza <tomas.carranza@lacity.org>, Bruce Gillman <Bruce.Gillman@lacity.org>, Michael LoGrande <michael.logrande@lacity.org>, Diego de la Garza <diego.delagarza@lacity.org>, Jonathan Hui <jonathan.hui@lacity.org>, Yusef Robb <yusef.robb@lacity.org>, Lisa Webber <lisa.webber@lacity.org>, Colton Quan <colton.quan@lacity.org>

Hi everyone,
Planning got inquiries from Dakota yesterday. Tom and I worked on our response as he mentioned, and which was transmitted by Michael LoGrande.
Thank you.
Luci

On Fri, Jun 21, 2013 at 10:10 AM, Marcel Porras <marcel.porras@lacity.org> wrote:

Thanks Tom. Luci, has planning issued a statement yet?

On Jun 21, 2013 10:05 AM, "Tomas Carranza" <tomas.carranza@lacity.org> wrote:
Yes - Luci Ibarra from Planning and I have coordinated our responses.

On Fri, Jun 21, 2013 at 10:01 AM, Marcel Porras <marcel.porras@lacity.org> wrote:

Did you coordinate with planning? I want to make sure we are all on the same page. We got inquiries from dakota as well

Marcel

On Jun 21, 2013 9:58 AM, "Jonathan Hui" <jonathan.hui@lacity.org> wrote:
Hi Carolyn,

See response below for a hold:

> Does LADOT agree with Caltrans' assessment that more traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

Also, LADOT met with planning and Caltrans in 2011. Did you expect then that a highway traffic project would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jon Finn

Thanks so much.
Dakota

---------- Forwarded message ----------
From: **Raptis, Maria C@DOT** <maria.raptis@dot.ca.gov>
Date: Thu, Jun 20, 2013 at 2:47 PM
Subject: Caltrans Comment Letter - Millennium Hollywood Project
To: "dakota.smith@dailynews.com" <dakota.smith@dailynews.com>
Cc: "Watson, DiAnna@DOT" <dianna.watson@dot.ca.gov>

Notice of Preparation (NOP) Letter dated 5/19/11

Draft EIR (DEIR) Letter dated 12/30/12

Final EIR (FEIR) Letter dated 2/19/13

Letter to Council Members dated 3/7/13

Maria Raptis

Public Information Officer

Caltrans, District 7

100 So. Main Street, Los Angeles 90012

213-897-0172

maria.raptis@dot.ca.gov

Jonathan Hui

Los Angeles Department of Transportation
(213)972-8481
jonathan.hui@lacity.org

-

Lucas Ibarra
City Planner
Major Projects
Department of City Planning
200 N. Spring Street, Rm 750
Los Angeles, CA 90012
Ph: 213.978.1372
Fx: 213.978.1343

Marcel Porras <marcel.porras@lacity.org> Fri, Jun 21, 2013 at 10:27 AM
To: Lucas.Ibarra <lucas.ibarra@lacity.org>
Cc: Jonathan Hui <jonathan.hui@lacity.org>, Elise Wobber <elise.wobber@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Bruce Gillman <Bruce.Gillman@lacity.org>, Michael LoGrande <michael.logrande@lacity.org>, Diego de la Garza <diego.delagarza@lacity.org>, Yusef Robb <yusef.robb@lacity.org>, Clinton Quan <clinton.quan@lacity.org>

Thanks Luci.

On Jun 21, 2013 10:18 AM, "Lucas Ibarra" <lucas.ibarra@lacity.org> wrote:

Hi everyone,
Planning got inquiries from Dakota yesterday. Tom and I worked on our responses to be shared out, and which was transmitted by Michael LoGrande.
Thank you,
Luci

On Fri, Jun 21, 2013 at 10:10 AM, Marcel Porras <marcel.porras@lacity.org> wrote:

Thanks Tom. Luci, has planning issued a statement yet?

On Jun 21, 2013 10:05 AM, "Tomas Carranza" <tomas.carranza@lacity.org> wrote:

Yes - Luci Ibarra from Planning and I have coordinated our responses.

On Fri, Jun 21, 2013 at 10:01 AM, Marcel Porras <marcel.porras@lacity.org> wrote:

Did you coordinate with planning? I want to make sure we are all on the same page. We got inquiries from dakota as well

Marcel

On Jun 21, 2013 9:50 AM, "Jonathan Hui" <jonathan.hui@lacity.org> wrote:

Hi Dakota,

See response below inline today

Does LADOT agree with Caltrans' assessment that more traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state-mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

> Also, I ADOT met with planning and Caltrans in 2011. Did you expect then that a highway traffic project would be considered?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jonathan

> Thanks so much,
> Dakota
>
> ---------- Forwarded message ----------
> From: **Raptis, Maria C@DOT** <maria.raptis@dot.ca.gov>
> Date: Fri, Jun 28, 2013 at 2:47 PM
> Subject: Caltrans Comment Letters - Millennium Hollywood Project
> To: "Kakouris, Dakota" <dakouris@dailynews.com>
> Cc: "Watson, DiAnna@DOT" <dianna.watson@dot.ca.gov>
>
> Notice of Preparation (NOP) Letter-dated 5/16/11
>
> Draft EIR (DEIR) Letter-dated 12/10/12
>
> Final EIR (FEIR) Letter-dated 2/19/13
>
> Letter to Council members-dated 6/7/13
>
> Maria Raptis
>
> Public Information Officer
>
> Caltrans, District 7

100 S. Main Street, Los Angeles 90012

213 897 6372

[illegible]

Jonathan Hui
Los Angeles Department of Transportation
(213)972-8481
jonathan.hui@lacity.org

Lucas Ibana
City Planner
Major Projects
Department of City Planning
200 N. Spring Street, Rm. 750
Los Angeles, CA 90012
P: 213.978.1378
Fax: 213.978.1343

Diego de la Garza <diego.delagarza@lacity.org>

Re: Caltrans Comment Letters - Millennium Hollywood Project

Jonathan Hui <jonathan.hui@lacity.org> Fri, Jun 21, 2013 at 9:53 AM
To: Dakota Smith <dakota.smith@dailynews.com>
Cc: Bruce Gilman <bruce.gilman@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Clinton Quan <clinton.quan@lacity.org>
Bcc: diego.delagarza@lacity.org

Hi Dakota,

See response below. Hope that:

> Does LADOT agree with Caltrans' assessment that more traffic studies should have been completed?

The traffic impact study for the Millennium Hollywood project was prepared in accordance with LADOT's traffic study policies and procedures. These procedures are consistently used by all proposed development projects. LADOT's procedures were used to assess the project's potential impacts on the area's streets and intersections.

The traffic impact study also included a Congestion Management Program (CMP) analysis. The CMP is a state mandated program that was developed following the passage of Proposition 111 in 1990. One of the requirements of the CMP, which is administered by the Los Angeles County Metropolitan Transportation Authority (Metro), is for projects to analyze their potential impacts on the freeway systems. The traffic study for the Millennium Hollywood project included the required CMP analysis.

> Also, LADOT met with planning and Caltrans in 2011. Did you expect that that a highway traffic project would be completed?

Our staff does not recollect a meeting with planning and Caltrans in 2011 and are unsure what traffic project you are referring to. You may have to contact the Department of City Planning to see what scoping meetings were held with Caltrans prior to the EIR preparation.

Hope that helps.

Jonathan

> Thanks so much
> Dakota

> ---------- Forwarded message ----------
> From: Raptis, Maria C@DOT <maria.raptis@dot.ca.gov>
> Date: Thu, Jun 20, 2013 at 12:47 PM
> Subject: Caltrans Comment Letters - Millennium Hollywood Project
> To: "dakota.smith@dailynews.com" <dakota.smith@dailynews.com>
> Cc: "Watson, DiAnna@DOT" <dianna.watson@dot.ca.gov>

- Notice of Preparation (NOP) Letter dated 5/16/11
- Draft EIR (DEIR) Letter dated 12/12/12
- Final EIR (FEIR) Letter dated 2/19/13
- Letter to Councilmembers dated 5/7/13

Maria Kopsis
Public Information Officer
Caltrans, District 7
100 So. Main Street, Los Angeles 90012
213.897.3933
maria.kopsis@dot.ca.gov

Jonathan Ho
Los Angeles Department of Transportation
213.972.8401
jonathan.ho@lacity.org

Fwd: Millennium Traffic CALTRANS Response

Michael LoGrande <michael.logrande@lacity.org> Fri, Jun 21, 2013 at 10:45 AM
To: Marcel Porras <Marcel.Porras@lacity.org>

---------- Forwarded message ----------
From: "Michael LoGrande" <michael.logrande@lacity.org>
Date: Jun 20, 2013 7:17 PM
Subject: Millennium Traffic CALTRANS Response
To: "Dakota Smith" <dakota.smith@dailynews.com>
Cc:

Hi Dakota,
As the Lead Agency, we are tasked with choosing the appropriate methodology to analyze impacts. With respect to traffic on the city's streets and intersections, the project's transportation analysis was prepared consistent with LADOT's Traffic Study Policies and Procedures. The transportation study also utilized Metro's Congestion Management Program (CMP) to analyze the project's potential impacts to the transit and freeway systems. MTA (Metro) developed the state-mandated CMP following the passage of Prop 111 in 1990. The CMP directs all projects in the County that required to prepare an EIR to conduct transit and freeway impact analyses. While Caltrans argues that the CMP is insufficient, Caltrans' "Guide for the Preparation of Traffic Impact Studies" does not provide adequate clarity as to what constitutes an impact, which the CMP does. In the interest of transparency and consistency and to comply with the Metro's CMP requirements, the project's transportation study included the appropriate CMP analysis. The Planning Department is confident in the level of analysis and mitigation required of this development.

Marcel Porras <marcel.porras@lacity.org> Fri, Jun 21, 2013 at 10:46 AM
To: Yusef Robb <yusef.robb@lacity.org>, YUSEF ROBB <yusefrobb@gmail.com>

---------- Forwarded message ----------
From: "Michael LoGrande" <michael.logrande@lacity.org>
Date: Jun 21, 2013 10:45 AM
Subject: Fwd: Millennium Traffic CALTRANS Response
To: "Marcel Porras" <Marcel.Porras@lacity.org>
Cc:

---------- Forwarded message ----------
From: "Michael LoGrande" <michael.logrande@lacity.org>
Date: Jun 20, 2013 7:17 PM
Subject: Millennium Traffic CALTRANS Response
To: "Dakota Smith" <dakota.smith@dailynews.com>
Cc:

Hi Dakota,
As the Lead Agency, we are tasked with choosing the appropriate methodology to analyze impacts. With respect to traffic on the city's streets and intersections, the project's transportation analysis was prepared consistent with LADOT's Traffic Study Policies and Procedures. The transportation study also utilized Metro's Congestion Management Program (CMP) to analyze the project's potential impacts to the transit and freeway systems. MTA (Metro) developed the state-mandated CMP following the passage of Prop 111 in 1990. The CMP

directs all preparers in the County that required to prepare an EIR to conduct transit and freeway impact analysis. While Caltrans argues that the CMP is insufficient, Caltrans' "Guide for the Preparation of Traffic Impact Studies" does not provide adequate clarity as to what constitutes an impact, which the CMP does. In the interest of transparency and consistency and to comply with the Metro's CMP requirements, the project's transportation study included the appropriate CMP analysis. The Planning Department is confident in the level of analysis and mitigation required of this development.

THE SILVERSTEIN LAW FIRM
A Professional Corporation

215 North Marengo Avenue, 3rd Floor
Pasadena, California 91101-1504
Phone: (626) 304-3200 Fax: (626) 304-3211
rdiamond@RobertSilversteinLaw.com
www.RobertSilversteinLaw.com

June 25, 2013

VIA FACSIMILE (213) 482-6889
AND U.S. MAIL

Ms. Hazel Harris
Office of the Custodian of Records
Department of Building and Safety
201 N. Figueroa Street, Suite 782
Los Angeles, CA 90012

Re California Public Records Act Requests – Millennium Project

Dear Ms. Harris:

This request is made under the California Public Records Act pursuant to Government Code Section 6250, et seq. Please provide copies of the following from the City (as "City" is defined below).

For ease of reference in this document, please refer to the following **defined terms.**

The "City" shall refer to all officials, employees, consultants, and agents of the Department of Building and Safety, City of Los Angeles, including the City Attorney's office and any and all outside counsel retained by the City.

"Millennium Hollywood" shall refer to Millennium Hollywood, LLC, all related or affiliated companies, and all principals, including Phil Ahrens, officers, employees, attorneys, agents and/or consultants, including but not limited to Langan Engineering and Environmental Sciences, Inc., and the law firm of Sheppard, Mullin

"Project" shall refer to the proposed Millennium Hollywood Project as located at 1720-1770 N. Vine Street, 1745-1753 N. Vine Street, 6236-6334 W. Yucca Street, 1733-1741 N. Argyle Street, 1746-1764 N. Ivar Street, Hollywood, California

"Document," as defined in Govt. Code Section 6252(g), shall mean any handwriting, typewriting, printing, photostating, photographing, photocopying, transmitting by electronic mail or facsimile, and every other means of recording

upon any tangible thing any form of communication or representation, including letters, words, pictures, sounds, or symbols, or combinations thereof, and any record thereby created, regardless of the manner in which the record has been stored.

The public records requests include:

(1) All communications to or from any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara from May 1, 2012 through the date of your compliance with this request that relate in any way to the May 2013 Langan Engineering and Environmental Science's Preliminary Geotechnical Report for the Millennium Hollywood Project.

(2) All communications to or from any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara from May 1, 2012 through the date of your compliance with this request that relate in any way to the November 2012 Langan Engineering and Environmental Science's Fault Investigation Report for the Millennium Hollywood Project.

(3) All communications to or from any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara from May 1, 2012 through the date of your compliance with this request that relate in any way to the Millennium Hollywood Project.

(4) All communications from May 1, 2012 through the date of your compliance with this request between, on the one hand, any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara, and on the other hand, any and all email accounts of Millennium Hollywood, and of its EIR Consultants, or its Geotechnical Consultant Langan Engineering and Environmental Sciences, or any of its attorneys from the law firm of Sheppard, Mullin, Richter & Hampton, LLP, including but not limited to Phil Ahrens, CAJA Environmental Services, Dan Eberhart, Rudolph Frizzi, Alfred Fraijo, and/or Jerry Neuman.

I draw the City's attention to Government Code Section 6253.1, which requires a public agency to assist the public in making a focused and effective request by: (1) identifying records and information responsive to the request, (2) describing the information technology and physical location of the records, and (3) providing suggestions for overcoming any practical basis for denying access to the records or information sought.

If the City determines that any information is exempt from disclosure, I ask that the City reconsider that determination in view of Proposition 59 which amended the State Constitution to require that all exemptions be "narrowly construed." Proposition 59 may modify or overturn authorities on which the City has relied in the past.

If the City determines that any requested records are subject to a still-valid exemption, I request that the City exercise its discretion to disclose some or all of the records notwithstanding the exemption and with respect to records containing both exempt and non-exempt content, the City redact the exempt content and disclose the rest. Should the City deny any part of this request, the City is required to provide a written response describing the legal authority on which the City relies.

Please be advised that Government Code Section 6253(c) states in pertinent part that the agency "shall promptly notify the person making the request of the determination **and the reasons therefore**." (Emphasis added.) Section 6253(d) further states that nothing in this chapter "shall be construed to permit an agency to delay or obstruct the inspection or copying of public records. The **notification of denial** of any request for records required by Section 6255 shall set forth the names and titles or positions of each person responsible for the denial."

Additionally, Government Code Section 6255(a) states that the "agency shall justify withholding any record by demonstrating that the record in question is exempt under expressed provisions of this chapter or that on the facts of the particular case the public interest served by not disclosing the record clearly outweighs the public interest served by disclosure of the record." (Emphasis added.) This provision makes clear that the agency is required to justify withholding any record **with particularity as to "the record in question."** (Emphasis added.)

Please clearly state in writing pursuant to Section 6255(b): (1) if the City is withholding any documents, (2) if the City is redacting any documents; (3) what documents the City is so withholding and/or redacting, and (4) the alleged legal bases for

withholding and/or redacting as to the particular documents. It should also be noted that to the extent documents are being withheld, should those documents also contain material that is not subject to any applicable exemption to disclosure, then the discloseable portions of the documents must be segregated and produced.

We request that you preserve intact all documents and computer communications and attachments thereto, including but not limited to all emails and computer files, wherever originated, received or copied, regarding the subject matter of the above-referenced requests, including archives thereof preserved on tape, hard drive, disc, or any other archival medium, and including also any printouts, blowbacks, or other reproduction of any such computer communications.

If the copy costs for these requests do not exceed $200, please make the copies and bill this office. If the copy costs exceed $200, please contact me in advance to arrange a time and place where I can inspect the records. As required by Government Code Section 6253, please respond to this request within ten days. Because I am faxing this request on June 25, 2013, please ensure that your response is provided to me by no later than **July 5, 2013**. Thank you.

Very truly yours,

ROBERT P. SILVERSTEIN
FOR
THE SILVERSTEIN LAW FIRM

RPS:jcr

THE SILVERSTEIN LAW FIRM
A Professional Corporation

215 North Marengo Avenue, 3rd Floor
Pasadena, California 91101-1504
Phone: (626) 449-4200 Fax: (626) 449-4205
Robert@RobertSilversteinLaw.com
www.RobertSilversteinLaw.com

June 25, 2013

VIA FACSIMILE (213) 978-3310
AND U.S. MAIL

Ms. Laura Ito
Information Technology Agency
City of Los Angeles
200 N. Main Street, 16th Floor
Los Angeles, CA 90012

Re: California Public Records Act Request – Millennium Project

Dear Ms. Ito:

This request is made under the California Public Records Act pursuant to Government Code Section 6250, et seq. Please provide copies of the following from the City (as "City" is defined below).

For ease of reference in this document, please refer to the following defined terms.

The "City" shall refer to all officials, employees, consultants, and agents of the Department of Building and Safety, City of Los Angeles, including the City Attorney's office and any and all outside counsel retained by the City.

"Millennium Hollywood" shall refer to Millennium Hollywood, LLC, all related or affiliated companies, and all principals, including Phil Ahrens, officers, employees, attorneys, agents and/or consultants, including but not limited to Linyan Engineering and Environmental Sciences, Inc., and the law firm of Sheppard, Mullin.

"Project" shall refer to the proposed Millennium Hollywood Project at located at 1720-1770 N. Vine Street, 1745-1755 N. Vine Street, 6236-6154 W. Yucca Street, 1733-1741 N. Argyle Street, 1746-1764 N. Ivar Street, Hollywood, California.

"Document," as defined in Govt. Code Section 6252(g), shall mean any handwriting, typewriting, printing, photostating, photographing, photocopying, transmitting by electronic mail or facsimile, and every other means of recording

upon any tangible thing any form of communication or representation, including letters, words, pictures, sounds, or symbols, or combinations thereof, and any record thereby created, regardless of the manner in which the record has been stored.

The public records requests include:

(1) All communications to or from any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara from May 1, 2012 through the date of your compliance with this request that relate in any way to the May 2012 Langan Engineering and Environmental Science's Preliminary Geotechnical Report for the Millennium Hollywood Project.

(2) All communications to or from any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara from May 1, 2013 through the date of your compliance with this request that relate in any way to the November 2012 Langan Engineering and Environmental Science's Fault Investigation Report for the Millennium Hollywood Project.

(3) All communications to or from any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara from May 1, 2012 through the date of your compliance with this request that relate in any way to the Millennium Hollywood Project.

(4) All communications from May 1, 2012 through the date of your compliance with this request between, on the one hand, any and all email accounts (including alias accounts set up on the City's email system) of Dana Prevost, John Weight, Pascal Challita, Bud Ovrum, Ray Chan or David Lara, and on the other hand, any and all email accounts of Millennium Hollywood, and of its EIR Consultants, or its Geotechnical Consultant Langan Engineering and Environmental Sciences, or any of its attorneys from the law firm of Sheppard, Mullin, Richter & Hampton, LLP, including but not limited to Phil Ahrens, CAJA Environmental Services, Dan Eberhart, Rudolph Frizen, Alfred Fraijo and/or Barry Neuman.

I draw the City's attention to Government Code Section 6253.1, which requires a public agency to assist the public in making a focused and effective request by (1) identifying records and information responsive to the request, (2) describing the information technology and physical location of the records, and (3) providing suggestions for overcoming any practical basis for denying access to the records or information sought.

If the City determines that any information is exempt from disclosure, I ask that the City reconsider that determination in view of Proposition 59 which amended the State Constitution to require that all exemptions be "narrowly construed." Proposition 59 may modify or overturn authorities on which the City has relied in the past.

If the City determines that any requested records are subject to a still-valid exemption, I request that the City exercise its discretion to disclose some or all of the records notwithstanding the exemption and with respect to records containing both exempt and non-exempt content, the City redact the exempt content and disclose the rest. Should the City deny any part of this request, the City is required to provide a written response describing the legal authority on which the City relies.

Please be advised that Government Code Section 6253(c) states in pertinent part that the agency "shall promptly notify the person making the request of the determination **and the reasons therefore**." (Emphasis added.) Section 6253(d) further states that nothing in this chapter "shall be construed to permit an agency to delay or obstruct the inspection or copying of public records. The **notification of denial** of any request for records required by Section 6255 shall set forth the names and titles or positions of each person responsible for the denial."

Additionally, Government Code Section 6255(a) states that the "agency shall justify withholding any record by demonstrating that the record in question is exempt under expressed provisions of this chapter or that on the facts of the particular case the public interest served by not disclosing the record clearly outweighs the public interest served by disclosure of the record." (Emphasis added.) This provision makes clear that the agency is required to justify withholding any record **with particularity as to "the record in question."** (Emphasis added.)

Please clearly state in writing pursuant to Section 6255(b): (1) if the City is withholding any documents; (2) if the City is redacting any documents, (3) what documents the City is so withholding and/or redacting; and (4) the alleged legal bases for withholding and/or redacting as to the particular documents. It should also be noted that

to the extent documents are being withheld, should those documents also contain material that is not subject to any applicable exemption to disclosure, then the disclosable portions of the documents must be segregated and produced.

We request that you preserve intact all documents and computer communications and attachments thereto, including but not limited to all emails and computer files, wherever originated, received or copied, regarding the subject matter of the above-referenced requests, including archives thereof preserved on tape, hard drive, disc, or any other archival medium, and including also any printouts, blowbacks, or other reproduction of any such computer communications.

If the copy costs for these requests do not exceed $200, please make the copies and bill this office. If the copy costs exceed $200, please contact me in advance to arrange a time and place where I can inspect the records. As required by Government Code Section 6253, please respond to this request within ten days. Because I am faxing this request on June 25, 2013, please ensure that your response is provided to me by no later than **July 5, 2013**. Thank you.

Very truly yours,

ROBERT P. SILVERSTEIN
FOR
THE SILVERSTEIN LAW FIRM

RPS:lmt

Media Query: Hollywood Millenium

Jonathan Hui <jonathan.hui@lacity.org> Tue, Jul 2, 2013 at 2:55 PM
To: Vicki Curry <Vicki.Curry@lacity.org>
Cc: Bruce Gilman <bruce.gillman@lacity.org>, Jaime de la Vega <jaime.delavega@lacity.org>, Nat Gale <nat.gale@lacity.org>, Sonja Trauss <sonja.trauss@lacity.org>, Marcel Porras <marcel.porras@lacity.org>, Michael LoGrande <michael.logrande@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Jay Kim <jay.kim@lacity.org>

Hi Vicki,

I just wanted to keep you apprised of a media query we got regarding the Hollywood Millennium Project. You may already be aware that the Caltrans has sent letters to the City contesting the adequacy of the FEIR and LADOT's recommendations from the development traffic impact study.

In the past the department has consistently conveyed to both the LA Planning Department as well as the media that our traffic impact studies are in compliance with the City's requirements.

We have met with the Caltrans public relations office today and they have conveyed to the media that they have sent letters to the City without receiving any response.

The planning department's recommendations are scheduled to go to the full council July 24th.

Does the mayor's office have a preferred message to convey to the media about this project?

You can see the previous story here:

http://www.dailynews.com/ci_23521930/planned-hollywood-millennium-skyscrapers-project-courses-controversy

Please let me know if you have any questions.

Thanks,

Jonathan

>Hi Bruce and Jonathan
>Thanks for your help on the Millennium project.
>I spoke with Caltrans and they said they had a meeting with LADOT last week
>Would either of you have 10 minutes to talk today or tomorrow?
>Best,
>Dave

--
Jonathan Hui
Los Angeles Department of Transportation
(213)972-8461
jonathan.hui@lacity.org

https://mail.google.com/mail/u/0/?ui=2&ik=f0ab66c258&view=pt&q=jonathan.hui%40lacity.org&qs=true&search=query&th=13fd224f4f3f7f6a&siml=1 1/2

Vicki Curry <vicki.curry@lacity.org> Tue, Jul 2, 2013 at 4:32 PM
To: Jonathan Hui <jonathan.hui@lacity.org>
Cc: Bruce Gilman <bruce.gilman@lacity.org>, Jaime de la Vega <jaime.delavega@lacity.org>, hal gale <hal.gale@lacity.org>, Sonja Leon <sonja.leon@lacity.org>, Marcel Porras <marcel.porras@lacity.org>, Michael LoGrande <michael.logrande@lacity.org>, Tomas Carranza <tomas.carranza@lacity.org>, Jay Kim <jay.kim@lacity.org>, yusef rule <yusef.rule@lacity.org>

Jonathan,

Mayor Garcetti's office is happy with your current messaging. Thanks for keeping us posted.

Vicki

--

Vicki Curry
Communications Officer
Mayor Eric Garcetti
213-978-0741
vicki.curry@lacity.org

On Tue, Jul 2, 2013 at 2:58 PM, Jonathan Hui <jonathan.hui@lacity.org> wrote:

Hi Vicki

I just wanted to keep you apprised of a media query we got regarding the Hollywood Millennium Project. You may already be aware that the Caltrans has sent letters to the City contesting the findings of the FEIR, and LADOT's recommendations from the developer's traffic impact study.

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We have met with the Caltrans public relations office today and they have conveyed to the media that they have sent letters to the City without receiving any responses.

The planning department's recommendations are scheduled to go to the full council July 24th.

Does the mayor's office have a preferred message to convey to the media about this project?

You can see our previous story here:

http://www.dailynews.com/ci_23521933/[illegible]-millennium-hollywood-project-draws-concern

Please let me know if you have any questions.

Thanks,

Jonathan

>Hi Bruce and Jonathan:
>Thanks for your help on the Millennium project.
>I spoke with Caltrans and they said they had a meeting with LADOT last week.
>Would either of you have 10 minutes to talk today or tomorrow?
>Best,

> Dear Ms.

—
Jonathan Ha
Los Angeles Department of Transportation
(213)972-8467
jonathan.ha@lacity.org

yusef robb <yusef.robb@lacity.org>

Millennium Project

2 messages

Marie Ramsey <marie.ramsey@lacity.org> Wed, Jul 24, 2013 at 8:05 AM
To: yusef robb <yusef.robb@lacity.org>, Marcel Porras <marcel.porras@lacity.org>

Good morning.

Please see attached letter and FAQ from CM O'Farrell.

Marie

Marie Ramsey, Planning Director
Councilmember O'Farrell, District 13
213.473.2334
marie.ramsey@lacity.org

Find the Councilmember on Facebook, Twitter and YouTube!

2 attachments

Hollywood Millennium Project Letter - Mayor Garcetti.pdf
204K

Millennium Project FAQs.pdf
76K

Marcel Porras <marcel.porras@lacity.org> Wed, Jul 24, 2013 at 8:20 AM
To: Marie Ramsey <marie.ramsey@lacity.org>
Cc: YUSEF ROBB <yusef.robb@lacity.org>

Thanks Marie

[Quoted text hidden]

[redacted]

MITCH O'FARRELL
Councilmember
Thirteenth Council District

July 24, 2013

Honorable Eric Garcetti
Mayor
City of Los Angeles
200 N. Spring Street
Los Angeles, CA 90012

Re: Items 21 & 22, Hollywood Millennium Project

Dear Mayor Garcetti:

Today, we will be voting on a series of items related to the Millennium project in Council District 13. This is a mixed-use development in the heart of Hollywood that will transform underutilized surface parking lots into a center for office, retail, hospitality and residential uses. This project will act as the gateway to Hollywood and brings great economic development through the creation of 2,900 construction jobs and 1,257 full-time permanent jobs. These are good jobs that will give preference to local, City of Los Angeles residents through the implementation of a Project Labor Agreement and a Hotel Labor Agreement. Additionally, this project will bring an estimated $4.9 million in new tax revenue annually to the City's General Fund, which can support vital public services, such as police and fire.

Hollywood is a dynamic neighborhood and the ideal place to develop high-rise construction. The Millennium project will consist of two high rise towers; a 35 and a 39 story tower adjacent to mid-rise towers on opposite sides of Vine Street near the Capitol Records building. These building heights were significantly reduced from their original plans, as I requested, without sacrificing the public space below. The project will respect the historic Capitol Records building by making it the central focus of the project, maintaining view sheds through open space and setback requirements and imposing strict conditions throughout the construction process, so as to not disrupt recording sessions. The Millennium project recognizes the significant history of Hollywood and will pay tribute through the preservation and restoration of the Walk of Fame and the Jazz Mural, while embracing the future of Hollywood through new community area programming in the project's public plazas.

This project is consistent with the long range vision for Hollywood and will build upon the fact that Hollywood is a tourist destination, a business hub for entertainment related uses and a booming residential community served by an extensive network of public transit options, including the Metro Red Line. The Millennium project supports the idea of an all inclusive Hollywood through sustainable development principles and the provision of extensive community benefits to address issues such as traffic, affordable housing, park space and the promotion of the arts. To that end, the Millennium project is providing a comprehensive set of project features that support community goals and objectives.

CITY HALL: 200 N. Spring St., Room 450, Los Angeles, CA 90012-4801, PHONE: 213-473-7013, FAX: 213-473-7934
DISTRICT OFFICE: 6500 Hollywood Boulevard, Los Angeles, CA 90028, PHONE: 323-957-4500, FAX: 323-957-4520
www.cd13.lacity.org

Throughout the entitlement process the development team has engaged community stakeholders and the City family to determine necessary project mitigations and conditions. Specifically related to transportation enhancements, the project will support the improvement of more than 30 signalized intersections to enable them to respond to real-time traffic demands and the creation of a Transportation Management Organization, which will encourage transit solutions for the entire Hollywood area through partnerships with other major employment and housing centers. It will also support a mobility hub, pedestrian improvements at Ivar and Argyle Avenues, a $250,000 contribution to the Bike Plan Trust Fund, and improvements to the Argyle & Franklin–US 101 Northbound Freeway On-ramp. The project will provide funding to launch the Parking Express program in Hollywood, additional DASH routes with extended schedules, as well as a Neighborhood Circulation Shuttle. Traffic is always a primary concern when new development is proposed and I believe this project addresses the traffic issues through the utilization of public transit and new proposals such as the Parking Express program.

The Millennium project is utilizing the Land Use Equivalency Program (LUEP) and has strong Development Regulations in place to ensure a well-designed project. The LUEP is a planning tool that allows uses to be exchanged within a pre-determined building envelope while allowing flexibility of allowable uses. This program allows multi-phased developments to respond to market demands and community needs, as long as the project is consistent with the impacts analyzed in the Environmental Impact Report.

Under the LUEP, it can be challenging to assure community stakeholders of the final project with certainty, and in order to address that, I have worked with the development team to add a condition of approval that requires, upon the issuance of building permits, that the development team will work with my office to notify the public regarding the ultimate uses and related construction schedule. This provision, along with the Development Regulations, provides the necessary guidelines to feel confident that the Millennium project will be a well-designed development. The Development Regulations are extremely prescriptive and dictate everything from how the building relates to the street to the width and height of each tower per established standards. The Millennium project is the first major project in the City to use the LUEP in conjunction with Development Regulations.

There have also been significant concerns raised regarding seismic issues and Building and Safety representatives will be at today's Council meeting to address any questions related to this matter. I take all issues related to public safety very seriously and will continue to work with Building & Safety on this matter and make sure all information is available to the public.

I support the revised Millennium project and hope you agree that it is a grand-scaled ongoing project that will further establish Hollywood as a regional destination. It is a thoughtful project that embraces Hollywood and its future. It encourages multi-modal transit options, improves the area infrastructure and supports the development of new affordable housing through a $4.8 million contribution to the City's Affordable Housing Trust Fund. The revitalization of Hollywood will continue to be a priority of my administration and I will support development that advances this goal.

With Kind Regards,

MITCH O'FARRELL
Councilmember
City of Los Angeles, Thirteenth District
Los Angeles City Council

Cc: Mayor Eric Garcetti
Los Angeles City Council

Millennium Project
FAQ's

1. When will the project be built and completed?

It is a multi-phased project that is expected to be completed by year 2020

2. How does the Millennium Project utilize the Land Use Equivalency Program (LUEP)?

The LUEP provides development flexibility so that the project can respond to the growth of Hollywood and market conditions over the build-out duration of the development. It is a tool meant to address future needs and demands while defining the parameters for the land use types and intensity on the project site, all within the scope of analysis in the Environmental Impact Report (EIR).

The LUEP allows for modifications to the final development scenario but requires that the project's peak hour trip generation remain the same or decrease. To that end, the intensity and type of land uses on the project site including residential, commercial, retail, office, restaurant and fitness will be modified to meet market demand while NOT being permitted to exceed the trip cap of 1,498 total peak hour trips.

The proposed number of parking spaces included at the project will be dependent upon the ultimate configuration of land uses but will be in accordance with the number required by the Los Angeles Municipal Code.

3. What is the purpose of the Development Regulations?

The Development Regulations include guidelines and standards that establish minimum and maximum requirements with respect to height, massing, density, open space, landscaping, parking, setbacks and signage that ensures development is compatible with the district and nearby historic buildings. Additionally, the regulations include site wide development criteria and a set of controls that ensure a quality development including façade articulation and materials.

4. Why does this project utilize Floor Area Averaging (FAA)?

FAA will enable the project to provide an appropriate mix of uses across the two project sites on opposite sides of Vine Street. As a perfect development, the project will maximize open space, walkability and unify public improvements. In addition, the project will provide mid-block connections with pedestrian walkways and plazas. FAA supports a unified development concept.

5. Is the project height and density appropriate for Hollywood?

The project proposes to utilize 6:1 Floor Area Ratio (FAR) to provide a mixed-use development that includes residential, hotel, retail and offices uses to be consistent with the Regional Center designation. The provision of residential and commercial uses contributes to the jobs and housing balance intended for Regional Center areas served by extensive public transit.

The Hollywood Community and Redevelopment Plans (past and present) does not limit height and allows 6:1 FAR through discretionary approval. Additionally, the zoning of the project site allows a limitation of 200 sq. ft. per dwelling unit, or a maximum of 972 units for the 194,438 sq. ft. project site. The project is contemplating 492 residential units, which is well below the allowable density of the project site.

6. How does the proposed project respond to traffic issues?

Traffic for the project was analyzed in the same manner as comparable projects throughout the City. The project is improving 39+ signalized intersections with updated technology to allow real-time response to traffic demands. In addition, the project will be required to create an extensive Transportation Demand Management Plan and initiate the development of a Transportation Management Organization. Both of these programs are intended to support the utilization of public transit, vanpools, car sharing, bikes and other alternative means of transportation. The project will also provide critical funding to shuttle circulators, DASH buses, Express Picking technology and pedestrian linkages.

7. What impact will the development have on Public Safety resources?

The project will provide for on-site security personnel and a controlled access system for residents to minimize the demand on police and fire protection services. Furthermore, the EIR found no impact to public services. Additionally, the project will generate new revenue for the City's General Fund that could be applied towards the provision of new police and fire resources.

8. What is the economic impact associated with the Millennium Development?

The development will result in a long term increase of tax revenue for the City of Los Angeles by increasing the property tax base of the project site, generating additional sales tax and possible transit occupancy tax, if a hotel is built. All tax revenue will be allocated to the City's General Fund and can be used to fund basic City services such as police, fire, tree trimming, sidewalk repair and graffiti removal.

Further, the development creates new 2,500 construction jobs and 1,251 full-time permanent jobs. City of Los Angeles residents will be given preference for all employment opportunities.

9. What community benefits are associated with the development?

The community benefits include but are not limited to the provision of $4.8 million dedicated to the creation of affordable housing within the immediate area as well as funds to improve the Hollywood Sign, restore the Walk of Fame and the development of new park space.

10. How will the development respect the historic Capitol Records building?

The Capitol Records building will be maintained and view shafts will be protected. Additionally, the Cultural Recording Rooms associated with Capitol Records will be protected and given special consideration throughout construction. Setbacks are more restrictive than code requirements and have been designed to respect Capitol Records as a historic monument that is the centerpiece of the project.

11. There have been concerns raised regarding seismic issues, how is this being addressed?

The Department of Building & Safety will continue to review this project and additional studies to ensure public safety. All materials will be made available to the public upon request.

MILLENNIUM CHRONOLOGY
1720 - 1770 VINE STREET

1	03/23/2012	Fee paid, tract map (VTT71837) stamped and Langan report, dated 11/22/2011, taken in and placed in holding area pending receipt of letter map from City Planning.
2.	04/18/2012	Soil report by Langan, dated 11/22/2012, was keyed in for review.
3.	05/23/2012	LADBS Correction letter issued. Reviewed by Jeffrey Wilson and Jesus Acosta. Requested detailed geotechnical study and requested geologic investigation for potential surface displacement on the Hollywood Fault
4	07/02/2012	Meeting between Grading Division and Langan (Dan Eberhart) regarding the need for a fault investigation
5	11/08/2012	Meeting between Grading Division and Langan (Dan Eberhart) regarding proposed exploration plan for fault investigation
6.	12/17/2012	Reports by Langan, dated 11/30/2012 (fault investigation) and 12/03/2012 (soil report) submitted.
7	01/31/2013	LADBS issued approval letter for tentative tract and fault investigation report. Detailed geotechnical study to be provided prior to issuance of permits and/or recordation of tract map. Also additional fault studies to be done if development is proposed on northern portion of site, now occupied by Enterprise Car Rental.
8.	06/04/2013	Received first call from Dr. James Dolan (geology professor at USC) and recognized as expert on Hollywood Fault. Arranged for him to view fault report
9	06/05/2013	Received email from Dolan expressing concerns about the lack of correlation between boreholes. In phone conversation he requested that I take a look at the report.
10.	6/10/2013 to 6/13/2013	L.A. DBS Grading Division reviewed report again and had comments about lack of core recovery in addition to Dolan's concerns of lack of correlation between boreholes.
	06/11/2013	Received email from a George Abrahams requesting access to Langan report. (Did not know George Abrahams)
11.	6/13/2013	Left a message with Langan geologist, Dan Eberhart about concerns and

		indicated that we would like to discuss the investigation because based on a closer look at the report we may have to rescind our approval and require additional exploration
12	6/14/2013 to 6/23/2013	Dana Prevost on Vacation. Jeffrey Wilson spoke with Eberhart during this time and did not receive satisfactory answers to our concerns
13.	06/23/2013	Left message with Eberhart that due to concerns over the investigation and the lack of a satisfactory explanation it appeared that we would need to rescind our approval and require additional exploration.
14	06/25/2013	received email from George Abrahams, expressing his concern about the fault investigation. Attached to the email was the Silverstein Report dated 06/18/2013 that was part of an appeal being heard by PUCM
15.	06/28/2013	Received first phone call from George Abrahams, Director of Beachwood Canyon Neighborhood Assoc, expressing their concerns over the fault investigation.
16.	07/01/2013	Phone message from Eberhart that he wanted to meet.
17.	07/03/2013	Received email from SheppardMullin that Jerry Neuman would like to meet with Dana Prevost, Ray Chan and Dan Eberhart.
18	07/12/2013	Silverstein Law Firm issues Public Records Act Request to Hazel Hariz and Dana Prevost
19.	07/12/2013	Received call from John Parrish, Calif. State Geologist over the Calif Geologic Survey, expressing concerns about the Millennium Fault investigation.
20.	07/15/2013	Silverstein Law Firm issues letter to LADBS regarding "Objections to Millennium Hollywood Project: Inadequate Review of Geology/Seismology"
21.	07/16/2013	Meeting with Millennium geologists and attorneys. Ray Chan and Bob Steinbach also present at meeting. The result of the meeting is that Langan will do additional fault investigation.

CRA - Design Guidelines 6/22
redline in Sept
Env in October for Board

- what are additional guidelines

- have we let projects pool FAR across 2 sites across the street
  has been done - Lamation, CCW, downtown
  parcel gets redesignated as across the street

call it something besides design guideline
in July mtg w/ Herald.
walk us thru guidelines

6/27 fb EIR
Goldg 9 mtg w/ Agent + Pblic.
redesign
guidelines - change
mtg date
CRA meeting
7/29 CRA Staff meeting
design guideline packages
Chris Esser mtg
CRA joint design meeting in August

get the design package Goldg to make
sure meeting more efficient

will do sketchup renderings on July 9

Hollywood CRA guidelines and meetup on July 7.
How do they differ?

update file w/ added materials

Milestones 6/10/10

roll up Alfred Lewis

replus design plans

Conference room wants design plan

Phil wants to take old plans and fully illustrate

front version + then do vignettes of other versions

things that are flexible, do definitives to show

diagrammatic modeling software to show diff ideas

Case more casual meetings

quality + character

phil will also produce other material

to get us a sense of atmosphere

pass storefronts will get detail designs

Court show sketch up to committee

hire firm from LA Japan to do lots of modeling scene lighting

* full set
* plans of common areas. concrete
* set of chunky models

6/14

Meeting w/ Hassell + Bird

update on what we've been doing
w/ Blind and Alfred
design guidelines publicum
full set of plot - "exhibit and Shrine"
they have 3-D work
will i.d. what they have
send
(send them Emerson's design package)
design scheme, renderings, etc
they showed to Brad
will put together a package
have a call + then sit down
2 supplemental things
- graphic representation of design guide
- representation of common
elements
also will think small
assemblum, large
will get it by Thursday 10:30
2 weeks from today. Monday June 28

July 5th
- July 12th week for visit
decide on date for visit
July 6 July 9
July 12 7 (9?) Handed to
(1 July 13, 11-2:30) come to LA
50 50
July 14 - morning

4/21/10

CRA

Mtg w/ Rick, Alfred, ~~Richard~~ Richard

discuss CRA design guidelines, CRA issues, view diagram issues, etc.
parking above grade issue

parking issues for condo + rental, they are working out numbers
rental program - office + enterprise, need to look at parking for rentals

any deviations that are less restrictive should be tracked

how do we address transfer of floor area? entitlements

FAR averaging, can it jump the street? Charlie says ok so long as covenant as a unified development?

equivalency matrix
civic/gov't land use
also mangrove EIR - equivalency issue

what will package look like for commission

applicant

EQA comment - next steps

how to present visually for community & commission

visual representation will be important

Terry pushes more visions, plugging in diff items

Wishes and making progress w/ equivalency

4/13/10 ✓ ☺

Balcony: a balcony shall be integral to the façade and shall not create a relentless horizontal and vertical stacking pattern. They are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations.Standard balconies may be projecting or recessed or a combination of both.

Acceptable Balcony Options

Unacceptable Balcony Options

HANDEL ARCHITETS LLP
MARCH 24, 2010

BALCONY

2/18/09

meeting w/ Hewlett + Andy
Ruby,
Alfred,
Jolly, Michael

Millennium meeting

weekly calls w/ Hewlett, monthly face to face

-think about what elements create impacts, site height

will consider 4 different projects from Leo to consist entirely

series of design guidelines. how far do they go?
how to address issues w/ community

where we can steer in detail / how much for citizen discretionary actions

Need a list - are they missing anything
any questions about what I heard Dave?
what else do we need to discuss?
when does merged dist they get out of city?

then they can discuss and we can meet again to discuss these issues.

need to address what issues for CEQA purposes

get response in (10) days

March 3 10 am to discuss and issues w/ Hewlett

12/17/09

Jerry
Reid
Rick
Kevin
Jon
Blanche

to do

- follow up on EAF
- design guidelines
  - equiv. narrative, table, graphic. basic envelope
- meet w/ Gary to discuss format

Millenium, Capitol Records

City attorney meeting update
- OK w/ design review flexibility
- OK w/ density
- OK w/ equivalency concept in decision letter
- by urgent process for follow ups

show flexibility
Wilshire Grand - if only DA at same time similar
EIR with us (CRA OK) - file new EAF - some issues

files for unified dev. as part of project

public outreach - do we have our own city meeting
where we collect ideas + community
show what we are working w/ developers

public first part of discussion design guidelines?
then EIR scoping
then City Planning meeting
then hearing + CPC

Gary handle

how to show flexibility
narrative, table, photo graphics of envelope
concept design
guidelines + standards - need clear standards so
we need less design review at end of project

meet w/ Gary early to discuss
come up w/ "smart spot"

They will work up schedule

series of meetings in Jan

→ can they come in for check-in design mtg. in January

→ CEQA mtg in January

terms & DA discussion
↳ w/ performance standards

-parking issue
"undouble"
park. fees from code required

12/2/09

Millennium

Flexible entitlement
urban design review
- EIR by CRA - want to do equivalency in it
requires DA b/c over 6:1
- must do worst case analysis in terms of uses, etc.
max height, max sq-ft diff. uses, etc.
if they default on contract.

need "hook" to get them back in - if in DA, can default. Require a plan approval? too drawn out

matrix would not need a plan approval, should just be ministerial

how to do design as a public benefit in the DA?
doesn't have to be public benefit to go in DA
(contractual they agree to allow us to have oversight. Fixed contract limits our oversight

equivalency part of zone change as a condition

9123 · Millennium

Kevin

Vince

Richard

Mark

Jerry

---

pursue DA and entitlements along same time
need to include flexible wording + equivalency

OK to file

already filed CPC case, Nancy working on DA
will add to same case

Lender needs written statement that city
is interested in project
"planning to work on deal look forward to
working on it"

Letter indicating we agree w/ process, documentation, etc.
then they will take letter to Mayor + CD's
so they can also prepare letters.

our letter will dictate process / facts, etc.
they will limit it + Nancy's response

SHEPPARD MULLIN
ATTORNEYS AT LAW

333 South Hope Street 48th Floor | Los Angeles, CA 90071-1448
213 620-1780 office | 213-620-1398 fax | www.sheppardmullin.com

Jerry B. Neuman
Writer's Direct Line: 213-617-5565
jneuman@sheppardmullin.com

July 30, 2010

Our File Number: 23LV-152282

VIA E-MAIL AND U.S. MAIL

Leslie Lambert
Regional Administrator
Community Redevelopment Agency of the
City of Los Angeles
Hollywood/East Hollywood Office
6255 Sunset Boulevard, Suite 2206
Los Angeles, California 90028

Re: Comments to the Hollywood Boulevard District and Franklin Avenue Design District Urban Design Standards and Guidelines

Dear Ms. Lambert:

As you know, we represent Millennium Partners and Argent Ventures ("Millennium/Argent") in connection with their proposed redevelopment project on Vine Street that incorporates the Capitol Records Tower and Gogerty Building. The Millennium/Argent project extends on both east and west sides of Vine Street and proposes a transit oriented development with a mix of residential, commercial and office uses (the "Project"). The development objectives for the Project include realizing a new downtown Hollywood, supporting the expansion of entertainment businesses in Hollywood, and providing new day and evening amenities for current and future residents. A central priority also is to preserve the views and function of the Capitol Records Tower as a gateway to Hollywood through smart design that frames the iconic structure.

The Project site is within the Hollywood Redevelopment Project Area. Accordingly, the Project must consider the policies set forth by the Community Redevelopment Agency of the City of Los Angeles ("Agency"), including the development objectives in the Hollywood Redevelopment Plan ("Redevelopment Plan" or "Plan") and the 5-Year Implementation Plan ("5-Year Plan"). In this regard, we have reviewed the draft Hollywood Boulevard District and Franklin Avenue Design District Urban Design Standards and Guidelines ("Draft Guidelines" or "Guidelines") dated March 30, 2010.

We respectfully submit the following comments to the Guidelines. Though our letter responds to the Agency's request for written comments on or prior to July 30th, our intent is to open a dialogue with the community and the Agency about these important development issues. As a stakeholder and developer in Hollywood, Millennium/Argent wants to ensure that the final form of the Guidelines permit the kind of development that honors and continues Hollywood's legacy of innovation and its sense of place recognized worldwide.

INTRODUCTION

First and foremost, we are grateful for the Agency's efforts to prepare the Draft Guidelines and with their publication further a critical planning goal set forth in the Redevelopment Plan. Planning a vision for the future of Hollywood that incorporates its legacy and cultural and physical diversity is an extraordinary task. The Draft Guidelines attempt to marry complex design priorities in response to a range of development possibilities as broad as the points of view in Hollywood. We are very appreciative for the Agency's leadership in this endeavor.

In its current form, however, the Draft Guidelines fail to integrate the flexibility needed to build from rather than imitate the historic forms in Hollywood. This flexibility is important to ensure that new development reflects the kind of creativity and departures from tradition that influenced the most iconic structures in Hollywood. Including development flexibility and a range of compliance options furthers the Agency's core redevelopment objectives in Hollywood.

The Guidelines demand rigid adherence to traditional forms rather than enabling new design and ingenuity. Stated differently, the Guidelines reflect an emphasis on rules rather than opportunities. In so doing, they limit new construction that is forward thinking in terms of design and programming of uses. This approach also conflicts with the City's and Agency's plans and policies for Hollywood.

Our concerns are summarized below and addressed in detail in the following sections:

Comment 1. The Draft Guidelines do not embrace a vision of Hollywood as a regional center

Comment 2. The Draft Guidelines conflict with the Development Objectives in the Redevelopment Plan.

Comment 3. The Draft Guidelines encourage imitation instead of innovation.

Comment 4. The Draft Guidelines conflict with the Project and development trends in Hollywood.

Comment 5. The Draft Guidelines' strict standards regarding height, massing, and ground floor retail are in conflict with the encouragement of open urban spaces.

Comment 6 The Draft Guidelines should be a guide for development and not a platform for controversy.

COMMENTS

1. The Draft Guidelines Do Not Embrace a Vision of Hollywood as a Regional Center.

Hollywood is one of seven regional centers in the Los Angeles metro area that includes Downtown, the Wilshire Corridor and Century City. The Hollywood Boulevard District anchored by Hollywood Boulevard, Sunset Boulevard and Vine Street is recognized by the City as well as the Agency as an important commercial district or center. Similarly, businesses and developers see the district as a gateway to the Los Angeles basin with important regional commercial destinations.

Hollywood's extraordinary history with motion picture production and its status as the entertainment capital of the world fuels its regional importance but also supports a unique and diverse residential community. Yet, the Draft Guidelines do not clearly identify nor further the vision of Hollywood as a regional center with unique potential to attract and retain residents and world-class businesses. This approach overlooks the historical and current realities of Hollywood as well as broader planning goals set forth by the Agency and the City.

a. *The Draft Guidelines are inconsistent with the Hollywood Community Plan and the Redevelopment Plan because it does not identify the District as a regional center.*

The Guidelines, as drafted, are inconsistent with the policies and objectives of promoting Hollywood as a commercial regional center in the Redevelopment Plan and the City's Hollywood Community Plan update ("Draft Community Plan"). State law mandates consistency between redevelopment plans and the applicable local general plan. California Health and Safety Code § 33331. In this case, the Redevelopment Plan must be consistent with the planning priorities for Hollywood in the City of Los Angeles General Plan ("General Plan"). The Draft Community Plan furthers the General Plan priorities in the same way that the Draft Guidelines further the Agency's objectives for Hollywood in the Redevelopment Plan. It stands to bear, that these planning documents should reflect consistency in accordance with state law.

The Draft Community Plan designates the areas east of La Brea Avenue, south of Yucca Street, west of Gower Street and north of De Longpre Avenue in Hollywood as a "downtown regional center". This region, according to the Community Plan, is the "most intensely developed commercial area" in Hollywood and consequently functions as the "heart of Hollywood". Draft Community Plan, pp. 13, 38. The Draft Community Plan further describes the commercial regional center as a "highly urbanized area with considerable pedestrian activity" with resurging growth and a number of new mixed-use developments. *Id.* at 39.

Similarly, the Redevelopment Plan identifies the region of Hollywood along Vine Street and Sunset and Hollywood Boulevard as part of the Regional Center Commercial core, which

includes uses such as theatres, restaurants, hotels, offices and retail or other businesses. Redevelopment Plan, Section 506.2. Importantly, one of the goals of the Redevelopment Plan is to "promote the development of Hollywood Boulevard within the Hollywood commercial core." Redevelopment Plan, Section 300. In this sense, the Redevelopment Plan recognizes the Hollywood district as an important regional commercial center and promotes the development of new commercial and entertainment uses to continue current redevelopment trends in Hollywood.

The Draft Guidelines should identify and promote the District as a growing regional commercial center consistent with both the Redevelopment Plan and the Draft Community Plan. By contrast, as currently drafted, the Guidelines reflect a resistance to this vision and current trends with its demands for "conserving" existing settings and street scenes and "preserving" current street scenes. *See, e.g.*, Draft Guidelines, pp. and 8 – 11, 20 – 22. None of the provisions of the Draft Guidelines promote the policies of the Draft Community Plan or the objectives of the Redevelopment Plan to incentivize growth of the District as a regional commercial center. As currently proposed, the Draft Guidelines provide no explicit recognition in the Introduction or Vision sections (Sections 1.0 and 2.0) regarding the District's role as a growing commercial center for the region.

b. The Draft Guidelines do not promote new and innovative commercial growth in Hollywood as contemplated by the Draft Community Plan and the Redevelopment Plan.

Section 1.2 states that the purposes of the Guidelines are to "define compatibility of new construction and additions in relationship to existing historic and natural settings." Draft Guidelines, p. 6. There are no specific references, however, to new standards of design or efficiencies of space on the ground floor to promote pedestrian activity, new patterns of circulation, greater open space and new iconic structures. The sole objective appears to measure new development against the old. In this regard, the result of the Draft Guidelines is to restrict rather than incentivize dynamic growth in Hollywood.

We know adding new retail and commercial experiences to the eclectic tattoo parlors and t-shirt shops along the boulevard are important ingredients to bolstering Hollywood's evolving identity and support new and existing residents. Entertainment, media and other major businesses that would occupy new class-A office space in Hollywood must be supported with a new range of retail products and services. Attracting this broader range of ground floor retail experience requires innovative settings that may need to – indeed, should be permitted to – depart from traditional or historic forms. This is consistent with Hollywood's spirit of experimentation and innovation of place and design. The Guidelines should aim to keep the Hollywood tradition not the traditional form.

The Guidelines do not identify or promote, for example, ways in which developers can attract and retain new businesses with the built environment using dramatic variation in design

Yet, attracting new businesses and office tenants is an important goal in the Redevelopment Plan and the 5-Year Plan. An emphasis on established forms as precedent rather than context does little to engage developers in designing and developing the next generation of iconic structures and new open space that respond to a growing range of community needs. Consider for example, that new pedestrian and open space connections to the Hollywood Freeway Central Park and the Walk of Fame will be important considerations for future development. The Draft Guidelines should encourage and allow implementation of non-traditional building plans, publicly accessible open space and groundfloor design to connect new development to these important resources. By mostly measuring new development against the existing environment, the Draft Guidelines fail to allow new construction to respond to Hollywood's growth and broader contemporary trends in urban design and planning.

The Guidelines refer to the promotion of Hollywood as an "entertainment destination" and repeatedly refers to Hollywood's "golden era." Draft Guidelines, p. 8. However, the vision for Hollywood in 2030 appears to gravitate to a regular "tourists" haven rather than a gateway to the world. The Guidelines simply demand that new development "maintain" and "conserve the existing historic setting" (Draft Guidelines, pp. 10 and 20) and even limit extension of the skyline as discussed below. Instead of enabling novel concepts and providing guidance for new forms to expand Hollywood's regional commercial development with the built environment as

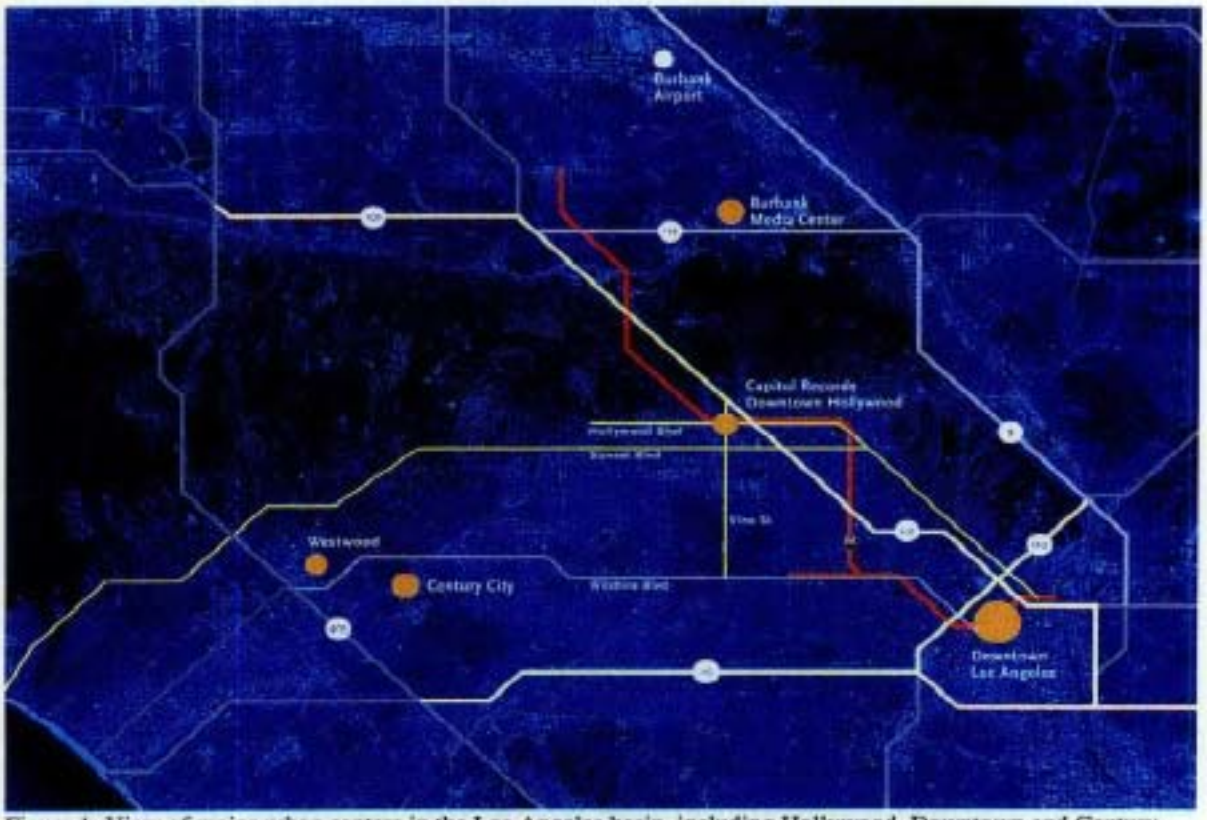


Figure 1: View of major urban centers in the Los Angeles basin, including Hollywood, Downtown and Century City regional centers. (Source: prepared for Millennium Partners.)

context, the restrictions in the Guidelines drop an anchor in the creative soul of Hollywood. The Hollywood community deserves more invention and vision from the Guidelines to match its current and future growth.

In Section 2.1, the Draft Guidelines envision Hollywood as a place to "live, work, walk and shop locally" but there are no planning references or suggestions for developing this mixed-use, regional center concept necessary to sustain a 24-hour lifestyle. Instead, the Draft Guidelines emphasize the need to protect the "quietude" in residential areas (a critical priority in itself) and increase "sidewalk activity." Should the vision for Hollywood in 2030 be mostly that the current "street scenes are conserved" as stated at Section 2.1?

Many stakeholders in Hollywood want to see new retailers and greater variety of commercial services and amenities as discussed above. In response, we are seeing the emergence of a new commercial and shopping experience along the Walk of Fame and other parts of Hollywood. Consider, for example, the current culinary renaissance thanks to top-notch restaurants sprouting all along Hollywood Boulevard from Highland to Vine. You may not need to sacrifice one type of retail for another but you need to acknowledge diversity and identify planning opportunities that encourage a broader range of retail experiences.

Additionally, the Draft Guidelines seem out of step with the Agency's own objectives. The 5-Year Plan specifically acknowledges the change in retail needs of the Hollywood community and identifies new opportunities for development in Hollywood. It calls for the creation of new office and retail uses to address "economic stagnation due to the lack of first-class office space and ***shifting commercial uses***." As set forth in Section 3 below, the Draft Guidelines should be designed with enough flexibility to accommodate a wide range of retail experiences and new ground floor urban spaces that reflect important changes in Hollywood. The build-to-property-line requirement along Hollywood Boulevard and the requirement that new buildings imitate or "maintain" current street walls, to name a few, will ensure that old forms will be duplicated without innovation.

Ironically, even historic Hollywood does not conform to the requirements in the Draft Guidelines. The historic Egyptian Theatre would violate many of the floor plate requirements for Hollywood Boulevard in Section 3.0. Yet, its open courtyard is a marvel of urban space enjoyed daily by hundreds of residents and visitors. The new Hollywood W Hotel development with its courtyard and entrance to the Metro station along Hollywood Boulevard similarly would violate certain requirements in the Draft Guidelines. The Draft Guidelines must permit a range of design opportunities and suggest priorities without the need for rigid requirements or triggering discretionary approval processes.

2. The Draft Guidelines Conflict with the Development Objectives in the Redevelopment Plan.

The Redevelopment Plan sets forth an array of goals that include encouraging economic development, promoting and retaining the entertainment industry, revitalizing the historic core, meeting social needs of area residents, providing urban design guidelines, and preserving historically significant structures. Regarding the Regional Commercial Center, new development must meet the following objectives:

1. Encourage preservation, restoration and appropriate reuse of historically or architecturally significant structures;
2. Assure that new development is sympathetic to and complements the existing scale of development;
3. Provide pedestrian oriented retail uses along the street level;
4. Encourage entertainment, theater and tourist related uses;
5. Provide adequate parking for new and existing uses; and
6. Reinforce and enhance the existing pedestrian environment.

Redevelopment Plan, Section 506.2.1.

The Redevelopment Plan requires the adoption of urban design guidelines to "achieve these objectives". *Id.* It is our understanding that the Draft Guidelines were developed by the Agency in response to this requirement. Unfortunately, the Draft Guidelines, as written, appear inconsistent with and deviate from these objectives.

As discussed above, development in the Regional Commercial Center must be "sympathetic to and

Figure 2: Heritage of tall structures in Hollywood – Taft Building, 1921.

complement[] the existing scale of development." *Id.* at Section 506.2.1. The terms "sympathetic" and "complementary" have no precise legal meaning or legal significance. It is, however, a well-established canon of statutory construction that legislative actions are to be interpreted according to the ordinary meaning of the words adopted by the body taking the action unless the meaning of the statute or ordinance is ambiguous or the words are unclear. *Kimmel v. Goland* (1990) 51 Cal. 3d 202, 208; *Kizer v. Hanna* (1989) 48 Cal. 3d 152, 155.

There is no reason to conclude that the Redevelopment Plan lacks clarity and the terms "sympathetic" and "complementary" should therefore be interpreted according to their ordinary definitions. Since courts will interpret statutory words and phrases in accordance with their plain meanings, we assume that the Agency deliberately chose the terms "complementary" and "sympathetic" in lieu of other equally significant design or architecture terms such as "compatible" or "consistent," which carry different meanings.

Figure 3: Variation in design and massing create a dynamic backdrop for activity along Hollywood Boulevard. (Source: www.yesterdayla.com/hollywood.html)

However, the Draft Guidelines introduce many terms that are inconsistent with the Redevelopment Plan. It shifts from "complementary" to "compatibility" (Section 2.2.4) and "sympathetic" to adherence (Section 2.2.3) with historic Hollywood. For example, Section 2.2.4 states that the height of new buildings and additions should "generally relate" to and "respect" the heights of historic districts and buildings. Draft Guidelines, pp. 11 and 12. Similarly, new buildings should "be observant" of historic settings while the existing buildings provide the framework for "conserving" existing settings. Section 2.2.4 states that new buildings should "respect" building heights in the Hollywood district. *Id.*, at p. 10.

Rather than track the adopted language in the Redevelopment Plan or provide a clear roadmap for complying with the objectives of the Plan, these new provisions set the stage for conflicting interpretations and create controversy over the application of the Draft Guidelines in relation to the Redevelopment Plan. It thwarts the objectives of the Agency's Plan and chills development efforts in the process. Instead of furthering the objectives of the Redevelopment Plan, the Draft Guidelines create competing objectives and requirements. The Draft Guidelines must therefore be revised to reflect the operative language in the Redevelopment Plan and set clearer standards for compliance.

3. The Draft Guidelines Encourage Imitation Instead of Innovation.

The Draft Guidelines attempt to honor Hollywood's rich history by requiring new construction to imitate the architectural styles and details of iconic Hollywood structures. While well intentioned, these requirements in fact make Hollywood's icons less iconic by encouraging imitation rather than contrast and distinction. Hollywood has been and should continue to be an environment for bold and experimental architecture. Building design pushed standard forms in the same way that tall buildings pushed standard conventions of verticality in Hollywood since the 1920s. For example, the Taft Building built in 1921 was a radical departure from the height datum that existed at the time in Hollywood (see Figure 2).

From the Egyptian Theatre to the Magic Castle, to the Crossroads of the World (see Figure 6) to the Grauman's Chinese Theatre (see Figure 4), diversity of design and eclecticism in experience defined Hollywood in its golden years. These developments turned Hollywood into a diverse design mosaic and world-class attraction by bucking contemporary trends. Although these and other buildings in Hollywood may have been controversial at the time of their construction we see them now as beloved icons. They are considered symbols of the spirit of adventure that defines Hollywood. The most important function of the Draft Guidelines should be to embrace and encourage new building forms and experimentation with a respect for the past.

New construction should not be forced to imitate or reproduce historic styles. It can compliment historic structures and datums with similarities as well as differences. The contrast between the modern, newer buildings and the historic structures allow the historic structures to

Figures 4 and 5: View of Grauman's Chinese Theatre (left) and Capitol Records Tower. Both trailblazers of design and building form were destined to become international attractions. (Source: historic postcards, circa 1950s.)

stand out as a monument to Hollywood's history against the backdrop of a thriving, modern commercial center that is Hollywood's future.

Section 4. below, addresses many of the provisions of the Draft Guidelines that require rigid imitation or adherence to historic design. The practical effect is a heavy handed document that discourages unique development forms and has the potential to permanently stall Hollywood's growth as an entertainment center.

4. The Draft Guidelines Conflict with the Project and Development Trends in Hollywood.

The following table describes specific provisions of the text that conflict with important design principles for new construction including the Millennium/Argent Project.

	Draft Guidelines	Comments
4.A	The height of new buildings and additions should be generally related to the heights of historic districts and buildings. Section 2.2 4.B.	Comment 4.A: Delete or revise this guideline. Without additional guidance the requirement is confusing and unnecessarily ambiguous. It suggests imitation and/or strict adherence to current height datum's in Hollywood although other sections in the Draft Guidelines acknowledge and encourage new height parameters. Refer also to Section 2, above.
4.B	Build to less than or equal to 18 inches from the property line. Figure 3-2.	Comment 4.B: Delete this standard. This requirement does not permit, much less encourage, the creation of publicly accessible open space on the ground floor. It would significantly restrict the creation of active pedestrian corridors and other important open space programming for new retail, commercial, office and residential uses along Hollywood Boulevard, Vine Street, Cahuenga Boulevard and Highland Avenue. The Draft Guidelines should encourage not restrict the creation of more open space for residents and visitors.

	Draft Guidelines	Comments
		Comment 4.B, continued The requirement also does not address the importance of considering setbacks whenever appropriate to address proximity to historic structures and to comply with other Agency requirements. For instance, the requirement would prohibit setbacks integrated in the Project's design to protect public view corridors to Capitol Records and views to the Hollywood Hills. These and other view corridors identified by the Agency for preservation could be negatively impacted if a strict adherence to this standard is required. The standard therefore conflicts with existing Agency policy.
4.C	A minimum twenty-four (24) foot high street wall shall be maintained along a minimum of 70 percent of the length of the property line adjoining the public right-of-way. Section 3.1.3.B.	Comment 4.C: Delete this standard. Generic and over-inclusive. Requirement constrains wide range of building types without exceptions. Overly restricts flexibility for buildings that are setback from the property line. See. also. Comment 6.B.
4.D	Maintain the integrity of heights, massing and bulk observed in the district Section 3.2.2.	Comment 4.D: Delete this guideline. Internally inconsistent and conflicts with other requirements in the Draft Guidelines, including the creation of new buildings "that imaginatively extend into the skyline and thereby strengthen the identity and spirit of Hollywood". Section 3.2.2. See. also. Comment 6.B above.

	Draft Guidelines	Comments
4.E	New buildings and additions may be developed to a maximum height of 220 provided that the gross lot coverage shall not exceed 70% of the lot area. Section 3.2.2.I.a.	Comment 4.E: Delete this standard. Does not reflect the range of development and design in Hollywood. Unnecessarily restricts existing property rights without accommodation for land use programming on the groundfloor, larger floor plates for office uses, diverse lot and parcel configuration or context to surrounding environment. Combined with other lot-line development standards it would result in lost groundfloor open space including potentially the formation of random alleyways without any connections to existing pedestrian corridors.
4.F	New buildings and additions may be developed to a maximum height of 220 provided that any floor area above a height of 150 feet shall have a maximum plan diagonal that does not exceed 155 feet in length. Section 3.2.2.I.b.	Comment 4.F: Delete this standard. Restriction is highly damaging and prohibitive for all future development including future development acknowledged in the Draft Guidelines. Unnecessarily restricts existing development rights without any accommodation for land use programming on the groundfloor, diverse lot and parcel configuration or context to surrounding environment.
4.G	The footprint of all architectural extensions shall not exceed 25% of the gross square footage of a building's top inhabited floor. Section 3.2.3.K.ii.	Comment 4.G. Delete or revise standard to allow for greater range of variation. Practical effect is to limit extension to small spires or narrow poles in best-case scenario. Instead, building form and type should dictate architectural extension. Limits seems arbitrary and narrow in perspective.

	Draft Guidelines	Comments
4.H	Variation or modulation in the design of architectural massing for street walls ≤ 18 in. from property line, facades facing these frontages shall express modulation or variation in the design of architectural massing and/or bulk at least once every 125 feet. > 18 in. from property line, every 75 feet Section 3.3.3.A.	Comment 4.H: Delete standard. Guidelines should emphasize variation of design. References to "architectural massing" are incompatible with standard interpretation of the terms "modulation" and "variation" in design for street wall and façade treatments. Change in material and design treatments cannot achieve the type of bulk or "massing" changes required.
4.I	Ground-Related Entries < 18 in. from property line at least once every 75 feet. Entry cannot be higher than 12" above sidewalk. > 18 in. from property line at least once every 50 feet. Entry cannot be higher than 30" above sidewalk. Section 3.3.3.B.	Comment 4.I: Revise standard to allow for a variety of commercial uses and tenant operations. The Plan should differentiate commercial building types and allow for flexibility without discretionary review or approval pursuant to Section 5. For example, for studio, entertainment or other uses, the Draft Guidelines must accommodate unique ground-floor designs to address security or related programming needs. Entrances, pedestrian visibility along primary streets, may need to be limited to accommodate for special security needs.
4.J	Maximum horizontal dimension of façade bays from center of bay to center of bay and the maximum horizontal dimension of un-subdivided glass expanses shall be thirty (30) feet within thirty (30) feet of grade. Section 3.3.3.C.i.	Comment 4.J: Delete or revise standard to allow for a variety of commercial uses and operations. For example, plan for use of glass and bays will vary based on commercial programming and tenant-type. See. also, Comment 4.I.

	Draft Guidelines	Comments
4.K	Balconies cannot project more than one foot from a building's façade surface. Section 3.3.3.G.i	Comment 4.K: Delete. Standard is overly restrictive. Inconsistent with current building and zoning standards for the City of Los Angeles. Substantially limits design and programming for residential and mixed-used building types. Has the practical effect of requiring all balconies to be recessed and may cause residential units to be unmarketable in an already challenged economy.
4.L	Minimum 40-foot deep storefront required along Vine Street Figure 3.4.3.C.	Comment 4.L: Delete or revise this standard consistent with the existing diversity of storefronts and building walls along Vine Street, Hollywood Boulevard, Cahuenga Boulevard. Many building operators and tenants (i.e., studio and entertainment uses) may have special programming and security needs for its operations.
4.M	Storefront requirements:	
a	Shall not be more than 12" higher than adjacent sidewalk. Section 3.4.3.	Comment 4.M.a: Revise this standard. Standard is overly restrictive. Storefront walls should be permitted to respond to site-specific elevations, adjoining building wall context and development intent. As with comments regarding other storefront requirements (see Comments 4.M.b – 4.M.e, below), the Draft Guidelines do not provide enough flexibility and are over inclusive. The standard constrains all buildings no matter the proposed building type or ground-floor use.
b.	Shall not exceed 30 feet in length and shall be separated from other storefronts by columns, pilasters, vertical separations, and/or other vertical architectural elements. Section 3.4.3	Comment 4.M.b: Delete or revise this standard. Overly rigid and does not permit changes to reflect context. Consider revising to require only that storefront opening be no wider than 100 feet and no smaller than 15 feet to permit flexibility as appropriate.

	Draft Guidelines	Comments
c.	The overall proportion of storefront bays should be approximately square and have a maximum ratio of 1.5 feet of height for each foot of length. Section 3.4.3.	Comment 4.M.c: Delete this standard as it is overly restrictive. Building wall should be permitted to respond to existing diverse building contexts along Hollywood Boulevard, Vine Street and Cahuenga Boulevard.
d.	Storefront sills shall be set a minimum of 18 inches and a maximum of 30 inches above the adjoining grade Section 3.4.3.	Comment 4.M.d: Revise this standard. It is overly restrictive and bears limited relationship to any community benefit compared to the design of a more flexible compliance matrix for street walls and storefronts design. For instance, as an alternative, limit standard to maximum and not minimum range to respond to historic and proposed context. Limit standard to maximum of 4 feet above adjoining grade to ensure proper flexibility. The current guidelines require only that storefront sills be set a maximum of 4 feet above the adjoining grade.
e.	Storefront glazing should comprise a minimum of 60 percent of the storefront area. Section 3.4.3.	Comment 4.M.e: Revise this standard. It is overly restrictive. Building wall should be permitted to respond to existing building wall context. Minimum standard should be reduced to reflect currently proposed development projects.
f.	Ground-related storefronts shall be set back from the exterior facade plane and/or an adjacent exterior wall surface of a structure a minimum of 3 inches. Section 3.4.3.	Comment 4.M.f: Revise or delete this standard. It is overly restrictive. Building wall should be permitted to respond to existing building wall context.

Draft Guidelines		Comments
4.N	Above-grade parking structures shall be set-back a minimum of sixty-five (65) feet from the property line and setback to be landscaped. Section 3.6.3.C.	Comment 4.N: Revise this standard to allow for modification as necessary based on cost considerations, programming and lot configuration. Best and highest use of a site consistent with community objectives should not be constrained. The standard should be rewritten to anticipate a range of options and may not be appropriate in every instance. Range of modifications or alternatives should be permitted to reflect site-specific realities (lot size, building orientation, use of lot space, etc.) and should not require discretionary approval or exceptions subject to Section 5.0. Insert "where feasible" language to standard Comments 4.R and 4.S are also incorporated by reference.
4.O	Above-grade parking structures shall not be "visible from" Vine Street Section 3.6.3.C.	Comment 4.O: Revise this standard to allow for modification as necessary based on cost, programming and lot configuration. Insert "where feasible" language to standard. May not be appropriate in every instance and range of modifications or alternations to reflect site-specific realities (lot size, building orientation, use of lot space, etc.) should not require discretionary approval or exceptions subject to Section 5.0 in the Guidelines.
4.P	Any portion of parking structures adjacent to streets (other than Vine Street) shall be architecturally treated and incorporate storefronts and uses (3.6.3.D)	Comment 4.P: Revise this standard to allow for modification as necessary based on cost, programming and lot configuration. May not be appropriate in every instance and range of modification should not require discretionary approval or exceptions subject to Section 5.0. Insert "where feasible" language to standard.

	Draft Guidelines	Comments
4.Q	Planting areas to be provided where front and rear yard setbacks are required. Section 3.7.3.	Comment 4.Q: Delete standard. Standard is ambiguous and lacks specificity. Planting may not be appropriate in every instance and planting for rear yard setbacks may be inappropriate from an urban design standpoint.
4.R	Any new or additional parking associated with new construction and/or additions within certain areas shall be located below or partially below grade Figure 3-72.	Comment 4.R: Delete this standard. This standard significantly restricts new development and in many certain instances may eliminate development rights altogether given the extraordinary cost associated with compliance. Below-grade parking construction is substantially more expensive than above-grade construction. The costs increase dramatically for construction of more than two levels below grade.
4.S	A minimum of one 36-inch box tree with mature height of 30 feet and canopy of 20 feet should be planted for each 1,000 square feet of on site ground related open space Figure 3-76.	Comment 4.S: Delete or revise this standard to permit a range of landscaping and planting scenarios to enhance the pedestrian experience. Standard is overly restrictive and does not permit a greater variety of open space and landscaping possibilities to reflect the needs of different land use programs and size of lots. The standard should be revised or deleted to reflect a range of possibilities.
4.T	Prior to approval, provide a materials and colors board and prepare a rendering or model illustrating the Project "in context". Sections 5.2.2.A and B.	Comment 4.T: Delete standard. Draft Guidelines set no justification why every project no matter the size should incur the expense of preparing renderings or models. See. also. Comment 2.

5. The Draft Guidelines' Standards Regarding Height, Massing, and Ground Floor Retail are in Conflict with the Encouragement of Open Urban Spaces.

We are pleased that one of the goals of the Draft Guidelines is to "realize new public and private open spaces." Draft Guidelines, p. 11. As you may know, Los Angeles is far below the national average of open space per citizen. Hollywood is the most deficient of any area in Los Angeles with approximately .5 acres per 1,000 residents or 0.005 acres of open space per resident – the lowest number in the nation. We are concerned that the compliance with numerous setback and massing requirements in the Draft Guidelines will result in the creation of less, not more, publicly accessible and pedestrian friendly open space in Hollywood.

Figure 6: Setbacks from property line create new urban open space in Crossroads of the World. (Source: www.yesterdayla.com/hollywood.html)

For example, the setback standards, including building to less than or equal to 18 inches from the property line, are contrary to the creation of open space along appropriate pedestrian corridors. Draft Guidelines, p. 15. This setback requirement may be appropriate in some instances but a developer should be encouraged to explore opportunities for creating publicly accessible open space on the ground floor as appropriate. As a general standard rather than a guideline, this requirement would restrict the creation of active pedestrian corridors and other important open space programming for new retail, commercial, office and residential uses along – for example – Hollywood Boulevard, Vine Street, Cahuenga Boulevard and Highland Avenue. It is another instance in the Guidelines that new opportunities for community benefits and smart design are sacrificed in favor of a rigid adherence to establish forms.

Other massing requirements in the Draft Guidelines (see, e.g., Section 3.2.2) also do not permit, much less, encourage, the development of new public and private open spaces on the ground floor. For example, "[n]ew buildings and additions may be developed to a maximum height of 220 provided that the gross lot coverage shall not exceed 70% of the lot area." Draft Guidelines, p. 25. Further, Section 3.2.2.I.b. allows development to a maximum height of 220 provided that any floor area above a height of 150 feet shall have a maximum plan diagonal that does not exceed 155 feet in length. *Id.* These requirements are unnecessarily restrictive and

combined with lot line development standards would result in lost ground floor open space including the formation of alleys without any circulation or connections to pedestrian corridors.

We applaud the Agency's efforts to promote the creation of open space in the Draft Guidelines. However, this intent conflicts with current setback and massing requirements. Revisions to the Draft Guidelines should resolve this internal inconsistency in favor of encouraging new public and private open spaces.

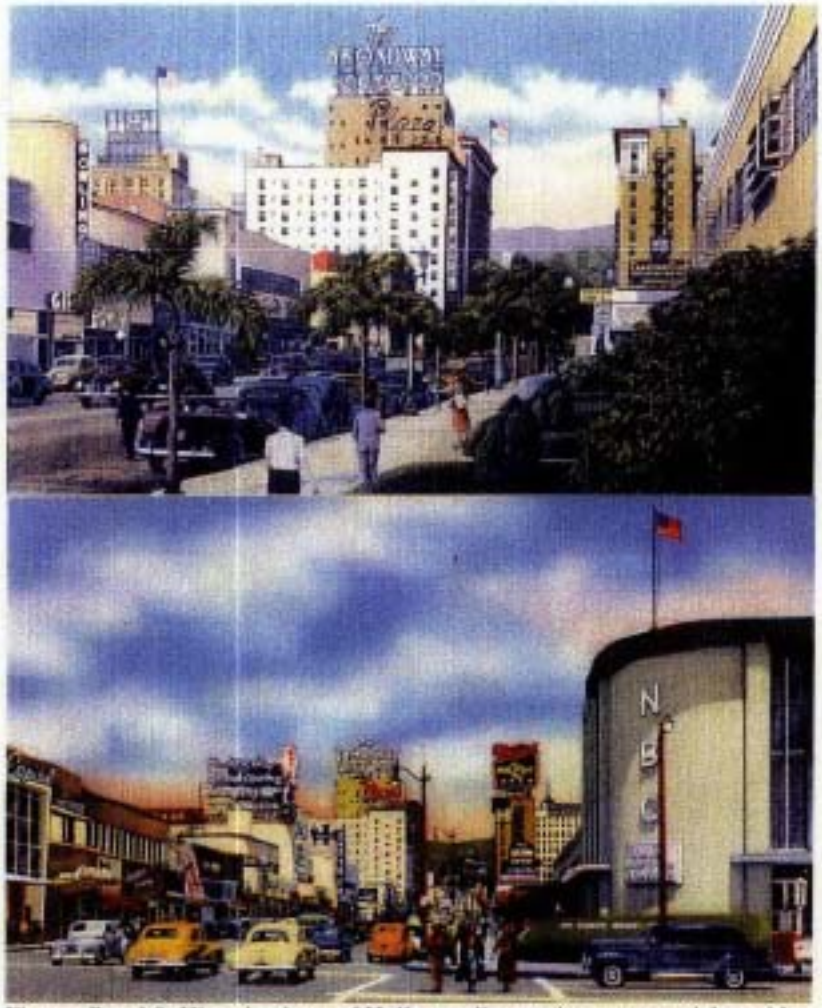
6. The Draft Guidelines Should be a Guide for Development and Not a Platform for Controversy.

The Draft Guidelines introduce a new review and approval process contrary to the intent of the Redevelopment Plan and in conflict with the City's mandate to streamline project approvals to promote economic development. Additionally, the Draft Guidelines set numerous strict standards for new projects rather than the flexibility to permit a range of options for new construction to comply with the guidelines. Revisions should be made to the Draft Guidelines to address the need for more flexibility.

a. *The Draft Guidelines create a new project approval framework that is inconsistent with the Redevelopment Plan, contrary to public policy and prohibitive.*

Imposing an additional project approval process is not the objective of the Draft Guidelines as set forth in the Redevelopment Plan. As discussed above, the Redevelopment Plan sets forth a number of objectives for the area and requires the CRA to adopt guidelines to ensure such objectives are met. Redevelopment Plan, Section 506.2.1. The creation of another discretionary review process in the Draft Guidelines are not mandated or contemplated by the Redevelopment Plan

Further, at a time when the City is trying to streamline development regulations and project review, the Draft Guidelines' imposition of another set of discretionary review procedures is counter-productive and creates another avenue for opposing a project. Sections 5.1 and 5.2 of the Draft Guidelines mandate that only projects in compliance with the standards of the Draft Guidelines will be approved by the Agency. Draft Guidelines, p. 54. The Draft Guidelines further state that "[i]f a project is not in compliance with the standards of this Plan, the project will not be cleared. In these cases the applicant can revise the Project design to bring it into compliance with the standards and guidelines of this Plan, or seek an exception." Draft Guidelines, p. 55. This is problematic because not only does it formalizes the Draft Guideline's mandatory nature as discussed below, but it also slows down the approval process and empowers opposition groups, the public, or City departments to stop projects even when the public interest would not be better served.



Figures 7 and 8: Historic views of Hollywood's growing commercial corridor with ground floor open space and variations in vertical and horizontal massing. Views of Vine Street looking north from Hollywood Boulevard (top) and from Sunset Boulevard (bottom). (Source: historic Hollywood postcards, Western Publishing & Novelty Co., circa 1940s.)

We understand that the Draft Guidelines allow "exceptions" for projects that may not comply. It provides that "[i]n certain extraordinary circumstances there may be situations where the intent of this Plan cannot be met through application of the design standards. In these cases the applicant may seek an exception to the Plan through an action of the CRA/LA." *Id.* We see at least two problems here. First, the Agency has set a very high and unrealistic bar (*i.e.*, "extraordinary circumstances") to qualify for an exception. Second, the Agency has developed yet another discretionary process that developers must trudge through for project approvals. In addition, the current finding statements are too open-ended and could allow the Agency unfettered discretion to approve or deny projects. We believe that these requirements are inappropriate given the current economic conditions and the fact that the Draft Guidelines were intended to ensure the objectives of the Redevelopment Plan are met, not to provide for additional barriers to development.

b. *Subject to limited exceptions, the Draft Guidelines should be guidelines for development not mandatory requirements.*

Besides creating a new approval process, the Draft Guidelines seem to impose mandatory requirements rather than guidelines as intended by Section 506.2.1 of the Redevelopment Plan as discussed above. The Introduction section of the Draft Guidelines established compliance with

the Draft Guidelines as a mandatory requirement for every project within the District. For example, Section 1.4 states that the Draft Guidelines "shall be used for all new construction, addition and conservation projects within the Hollywood Boulevard and Franklin Avenue Design Districts." Draft Guidelines, p. 6. In addition, it states that the Agency ". . .uses this Plan [the Draft Guidelines], as well as the Redevelopment Plan, and other CRA/LA policies, to review and approve proposed projects in these districts." Draft Guidelines, p. 6. Further, it provides that "a final clearance from CRA/LA will be required that ensures continued adherence to CRA/LA policies and these design standards and guidelines." Draft Guidelines, p. 6. Theses provisions expressly require strict compliance with the Draft Guidelines.

In contrast to the provisions above, we believe that the Draft Guidelines should guide development instead of control it. To be most effective in promoting innovation consistent with the historic and future growth of Hollywood, the Draft Guidelines cannot be primarily mandatory. We agree that as an implementation document the Draft Guidelines should establish requirements to ensure the objectives of the Redevelopment Plan are met. For example, requirements such as preserving historic icons and view corridors, maintaining historic storefronts, promoting new public and private open spaces and requiring ground floor development to engage the sidewalk should be created in the Draft Guidelines because those kinds of requirements ensure the objectives of the Redevelopment Plan are met. However, as drafted, the Draft Guidelines create mandatory provisions – a number of which conflict with the Redevelopment Plan – that do not allow for flexibility or a range of possible designs that would in fact fulfill the objectives of the Redevelopment Plan and further the public interest.

CONCLUSION

For the reasons set forth above, contrary to their fundamental objectives as a planning document for Hollywood, the Draft Guidelines do not succeed in encouraging bold development that honors Hollywood's rich architecture and historic environment. Instead, they appear anachronistic in their application rather than forward thinking. The Draft Guidelines cling to too many rigid and prescriptive measures that will stall rather than encourage development at a critical time in Hollywood. Sadly, the overall result of the Draft Guidelines is to under imagine and over prescribe.

Please do not hesitate to reach us with any questions. We look forward to your response. Thank you for considering these comments.

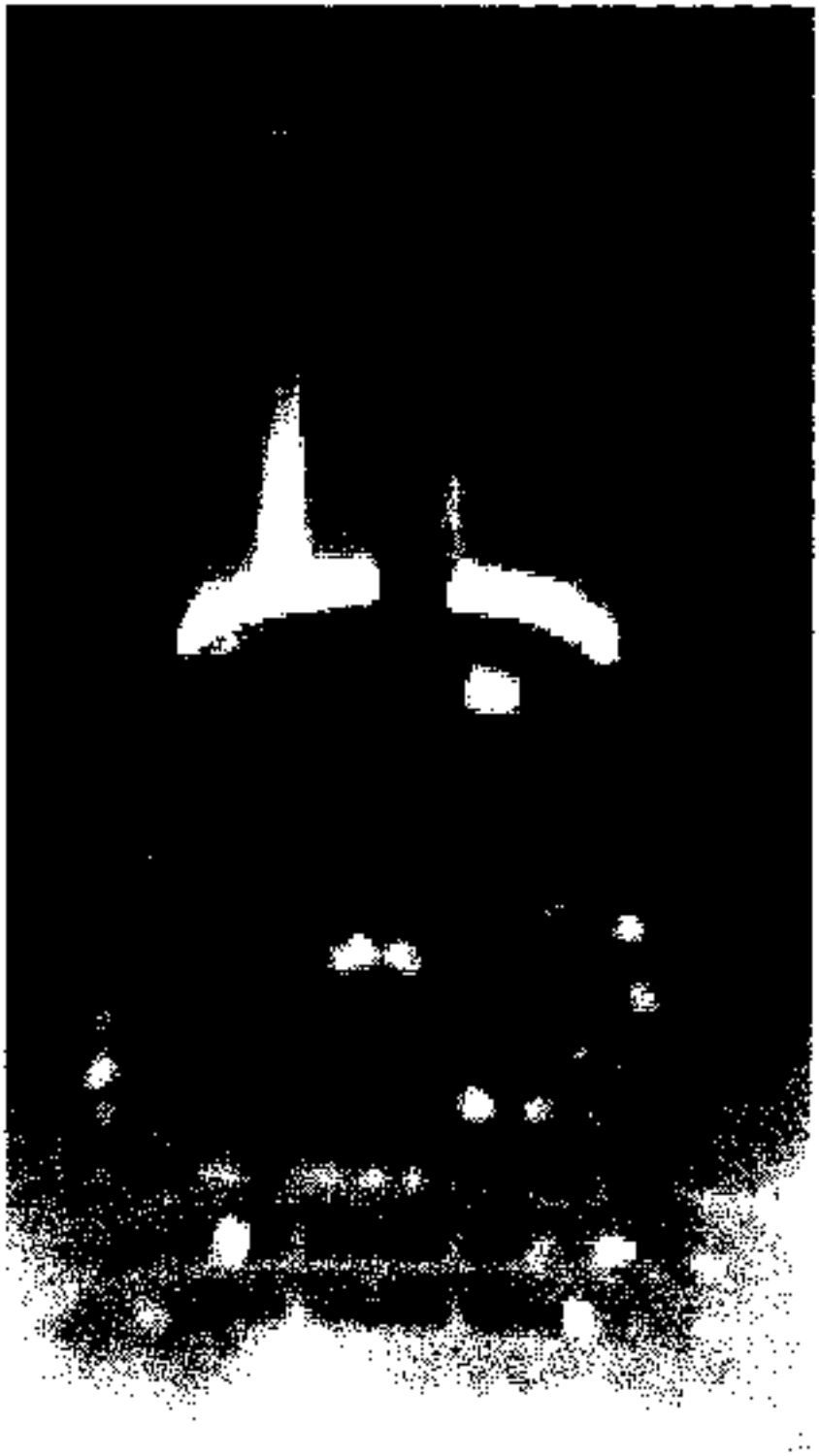
Very truly yours,

Jerry Neuman

for SHEPPARD, MULLIN, RICHTER & HAMPTON LLP

W02-WEST:1ALE\402236117.2

cc: Christopher Rudd and Alison Becker
Phil Aarons and Mario Palumbo, Millennium Partners
Michael Gargano, Argent Ventures
City of Los Angeles Council President, Eric Garcetti, Council District 13
Kevin Keller, City of Los Angeles Planning Department
Blake Lamb, City of Los Angeles Planning Department
Maureen B. Schultz, EMI Music North America
Alfred Fraijo Jr., Sheppard Mullin Richter & Hampton LLP



HOLLYWOOD MILLENNIUM PROJECT

DEVELOPMENT REGULATIONS: GUIDELINES AND STANDARDS

ORDINANCE NUMBER _____; EFFECTIVE DATE _____

HOLLYWOOD MILLENNIUM PROJECT

SCOPE OF DEVELOPMENT: DESIGN GUIDELINES AND STANDARDS

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7.1 The development of open space is an important objective for the overall Project design. Open space will be used to enhance the experience of the visitor and resident. Open space also will enable important pedestrian linkages and through-block connections for the Project. Grade level open space also will be designed to showcase the Capital Records Tower and Jazz Mural and will include design features and outdoor furniture to activate the ground floor amenities. This section sets forth the standards and guidelines for all open space areas for the Project: areas to be accessible to the public (Grade Level Open Space, Publicly Accessible Passageways and Rooftop Open Space) and areas to be designed for the residential uses (Common Open Space and Private Open Space) 34

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1. PURPOSE AND OBJECTIVES

1.1 Purpose

1.1.1 The Development Regulations ("Regulations") govern new development on the Project Site. Specifically, the Regulations:

a. Establish standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

b. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project.

c. Establish basic site-wide development standards and criteria that serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

d. Permit design flexibility while establishing a set of controls that will guide the development for the Project site.

e. Ensure compliance with the Development Objectives.

1.2 Development Objectives

1.2.1 The development objectives are intended to transform the Project Site consistent with the priorities and unique vision for the site shared by various Hollywood stakeholders. The Development Regulations will in turn ensure that new development on the Project Site is consistent with these objectives

1.2.2 The objectives for new development on the Project Site are to:

a. Preserve Capitol Records Tower and Gogerty Building

b. Preserve public views to the Capitol Records Tower by creating grade level open space, civic plazas, on the east site adjacent to the Jazz Mural and Capitol Records Tower and west site across from the Capitol Records Tower.

c. Preserve existing view corridors to the Hollywood hills.

Fig. 1.2.2.b-c: Capitol Records View Corridors

d. Create civic plazas that are activated by retail, landscaped and enhance the Hollywood Walk of Fame by providing it as an urban node; creating The Hollywood Walk of Fame Plaza. Reinforce the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.

e. Encourage street life by the creation of a new exclusive pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.

f. Create vibrant urban spaces that permit active and passive recreational facilities for both the on-site and off-site population

fig 1.2.2.d: View North Along Vine Street

g. Create a 24 hr community by the creation of a Thriving Mixed Use Development.

h. Eliminate the visual impact of the current on site parking.

i. Establish where feasible pedestrian linkages to existing public transportation routes in proximity of the Project Site, including the Metro Red Line Station at Hollywood Boulevard and Vine Street and existing bus routes.

j. Establish of a standard intended to promote architectural excellence.

k. Provide designs that take into account the context and make an effort to respect it and fit in visually.

l. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.

m. Create buildings that emphasize the vertical architecture and become visible icons.

n. Develop a visual gateway to Hollywood Boulevard from the Hollywood Freeway.

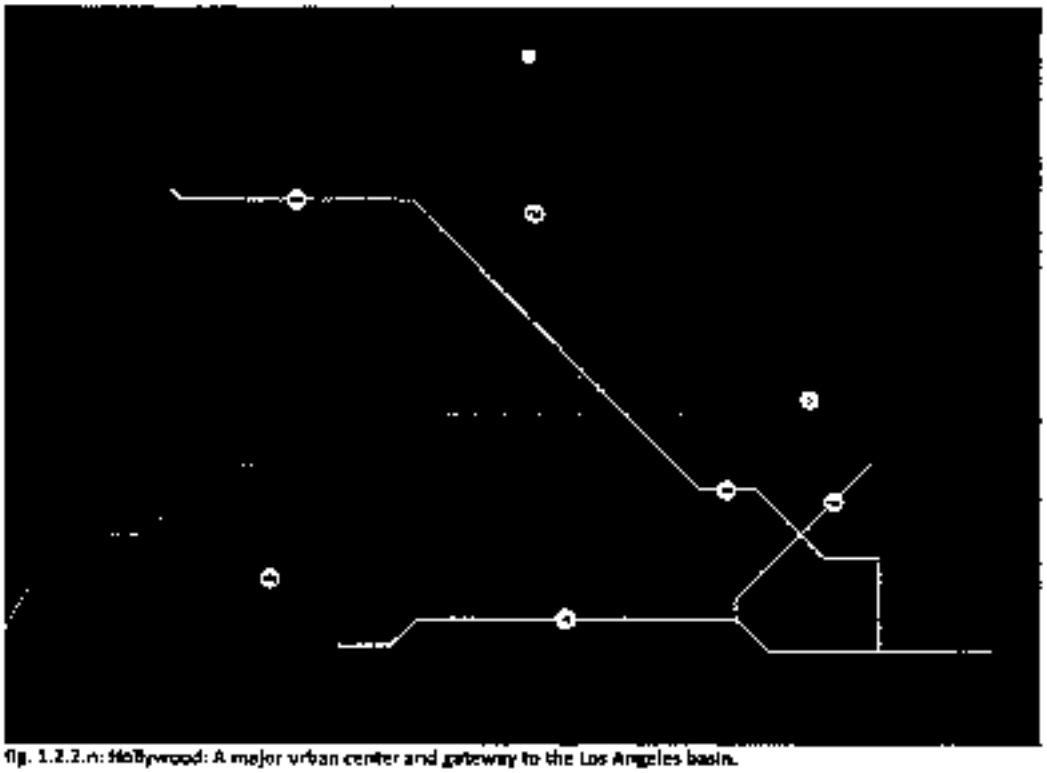


fig. 1.2.2.n: Hollywood: A major urban center and gateway to the Los Angeles basin.

1.3 Development Standards and Guidelines

The Development Regulations consist of standards and guidelines. The standards impose strict compliance or measures for new development. For example, the Regulations include specific setback requirements along Vine Street. There are also mandatory requirements or standards for minimum open space on the ground floor as well as maximum building heights. By comparison, the guidelines are measures that may include a range of choices and require a degree of interpretation by the architect and design team to achieve compliance with the Regulations. The purpose of these guidelines is to create a principal design theme or objective without comprising high quality design. The purpose is to provide a range of flexibility to permit the selection of the most appropriate design feature based on the final development scenario. For instance, façade treatments for new development may take different form depending on the final design plans. The Regulations will guide the ultimate façade treatment by providing a limited range of choices in the use of material and color for the façades.

1.4 Relationship to the Los Angeles Municipal Code

1.4.1 They are approved by the City of Los Angeles City Council and are incorporated in the Development Agreement, authorized pursuant to California Government Code 65864, et seq., entered into by the City of Los Angeles and __. ___. ___. ___ ___. ("Millennium Development Agreement") on __. ___. ___ __. .

1.4.2 The following sections in the Regulations differ from corresponding provisions (as written at the time of approval) in the LAMC. 2.2.1, 2.2.3, 5.5.3.a, 7.3.4.b, 9.1.6.a and 10.2.

1.4.3 Wherever the Regulations contain provisions which establish regulations that are different from or more or less restrictive than the zoning or land use regulations in the Los Angeles Municipal Code ("LAMC") the Regulations that apply to the Project Site, the Regulations shall prevail pursuant to the Millennium Development Agreement approved by the City Council

2. BACKGROUND

2.1 Project Site

2.1.1 The Project Site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street. The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site.

The area bounded by Yucca Street, Vine Street and Argyle Street is the East Site.

The East Site and the West Site make up the Project Site.

2.1.2 The Project Site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 13 feet from Vine Street to Argyle Avenue and 11 feet from Vine Street to Ivar Avenue. The existing sidewalk elevations will not be altered as part the Project.

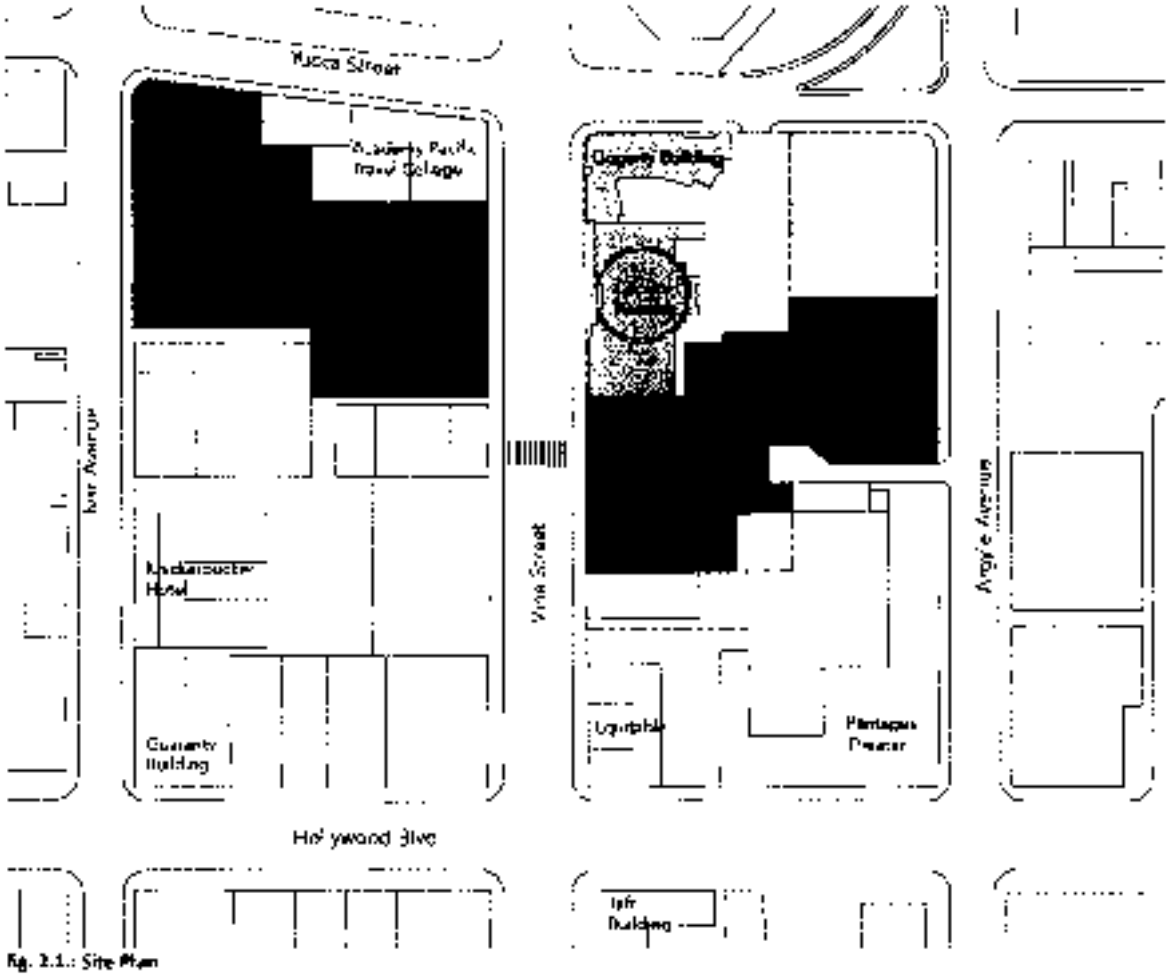


Fig. 2.1.: Site Plan

2.2 Site Zoning and Permitted Floor Area

2.2.1 Project Site is zoned Commercial (C2). City General Plan land use designation: Regional Center commercial.

2.2.2 Project Site is within the Special Sign District and within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.

2.2.3 Floor Area Ratio: 6:1

2.2.4 Height District: No. 2

3. DENSITY

3.1 Floor Area Ratio Averaging and Density Transfer

Owner may transfer density and buildable floor area from one parcel within the Project Site to another parcel within the Project Site, as long as the minimum and maximum building heights in the Regulations are maintained and the entire Project does not exceed the cumulative, allowable density and floor area of the zoning for the individual parcels.

To allow for the spatial distribution of the development on the Project Site and ensure relationship and sensitivity with the uses surrounding the Project Site, parking, open space and related development requirements for any component of the Project may be developed in any location within the Project Site.

3.2 Maximum QESF Density Per Area

[To be completed as part of the EIR.]

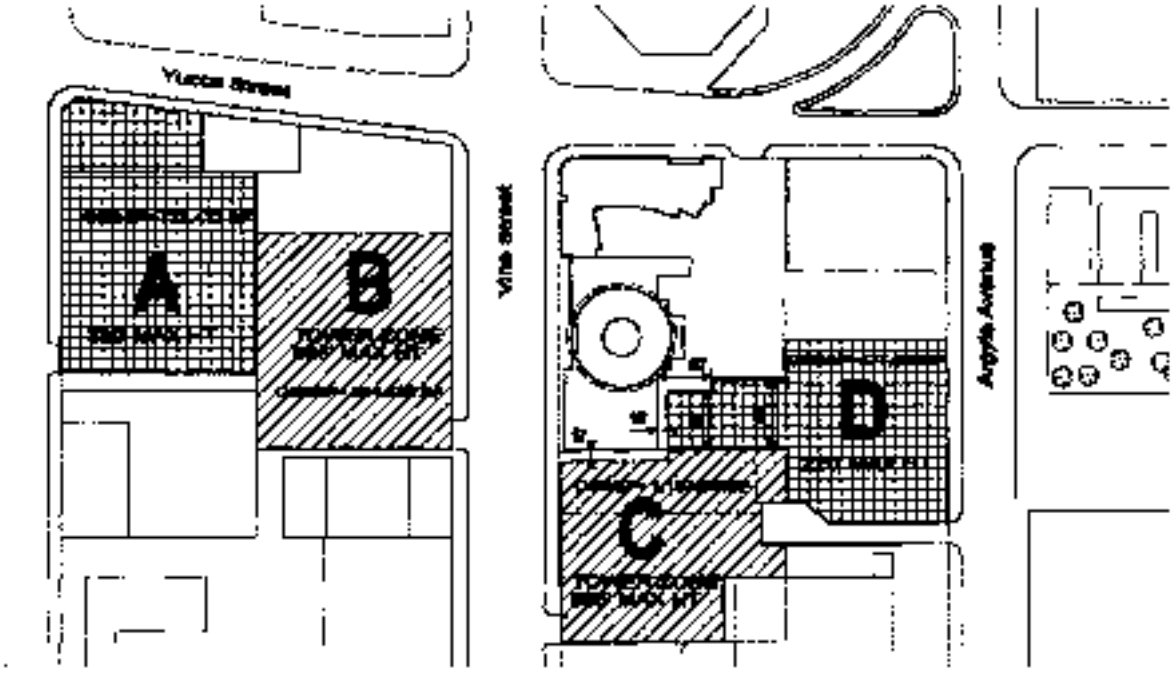
3.3 Use Coordination / Use Compatibility

[To be completed.]

4. HEIGHT

4.1 Building Height Standards

The Regulations establish heights zones (A, B, C and D) to limit maximum building heights and control bulk in response to the Development Objectives including context with the built environment and to reinforce view corridors to the Capital Records Tower.



5. BUILDING AND STREET EXPERIENCE

5.1 Tower Massing Standards

5.1.1 The Tower Massing Standards apply to the portion of a building located 150 feet above curb level – see Table 5.1.1

11.5	50	13,325 East Site 9,042 West Site	10	12	5.1.2.e.1 5.1.2.e.2
15	50	17,380 East Site 11,794 West Site	10	10	5.1.2.d.1 5.1.2.d.2
28	50	22,745 East Site 22,016 West Site	10	8	5.1.2.c.1 5.1.2.c.2
48	n/a	55,616 East Site 37,742 West Site	10	5	5.1.2.b.1 5.1.2.b.2

Table 5.1.1.

5.1.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See Figs. 5.1.2.a.1 – 2.)

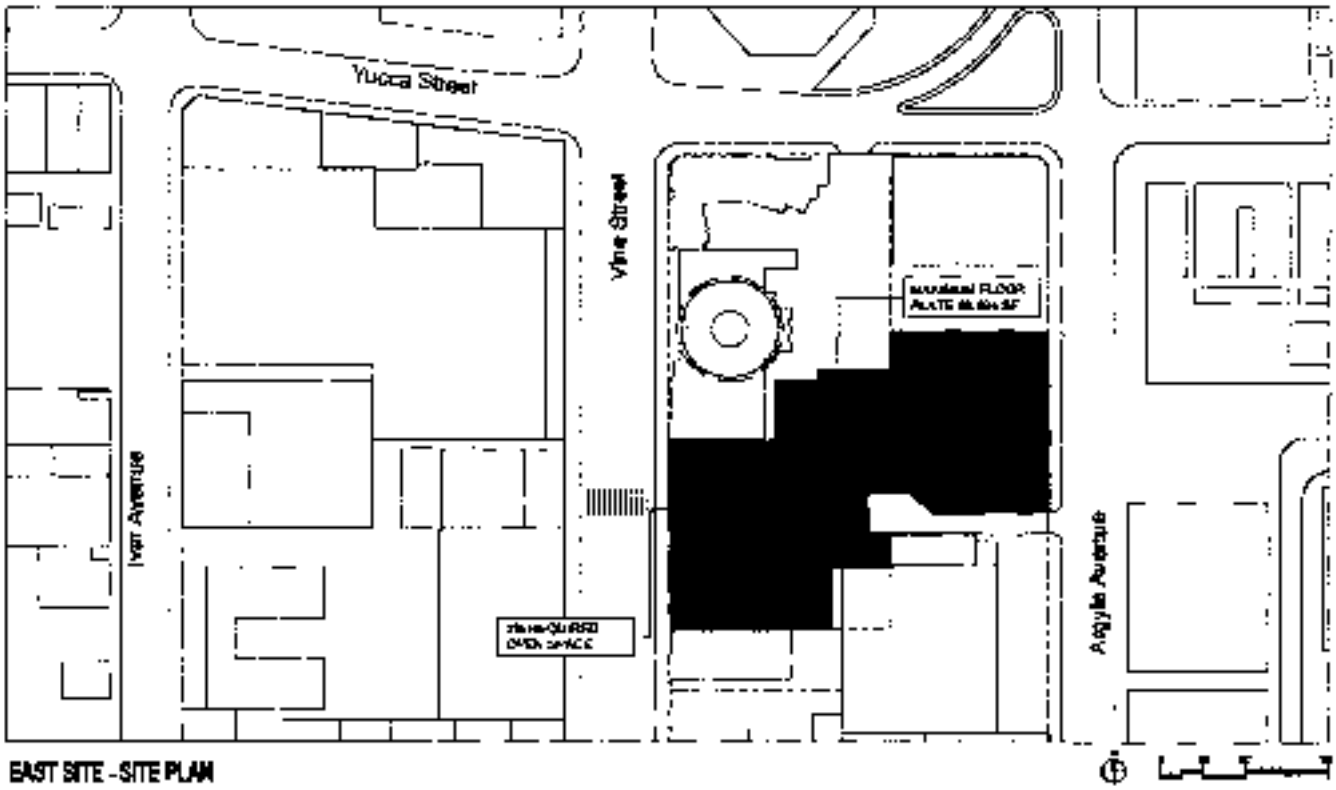
5.1.3 At least 50% of total floor area must be located below 220 feet

5.1.4 Setback and articulation of tower walls and crown

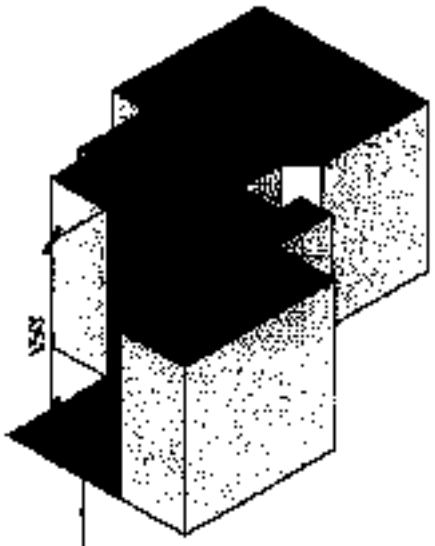
a. Towers are not required to step back

b. Minimum 10% of tower

Maximum Lot Coverage and Tower Floor Plate – Figs. 5.1.2.a – d.

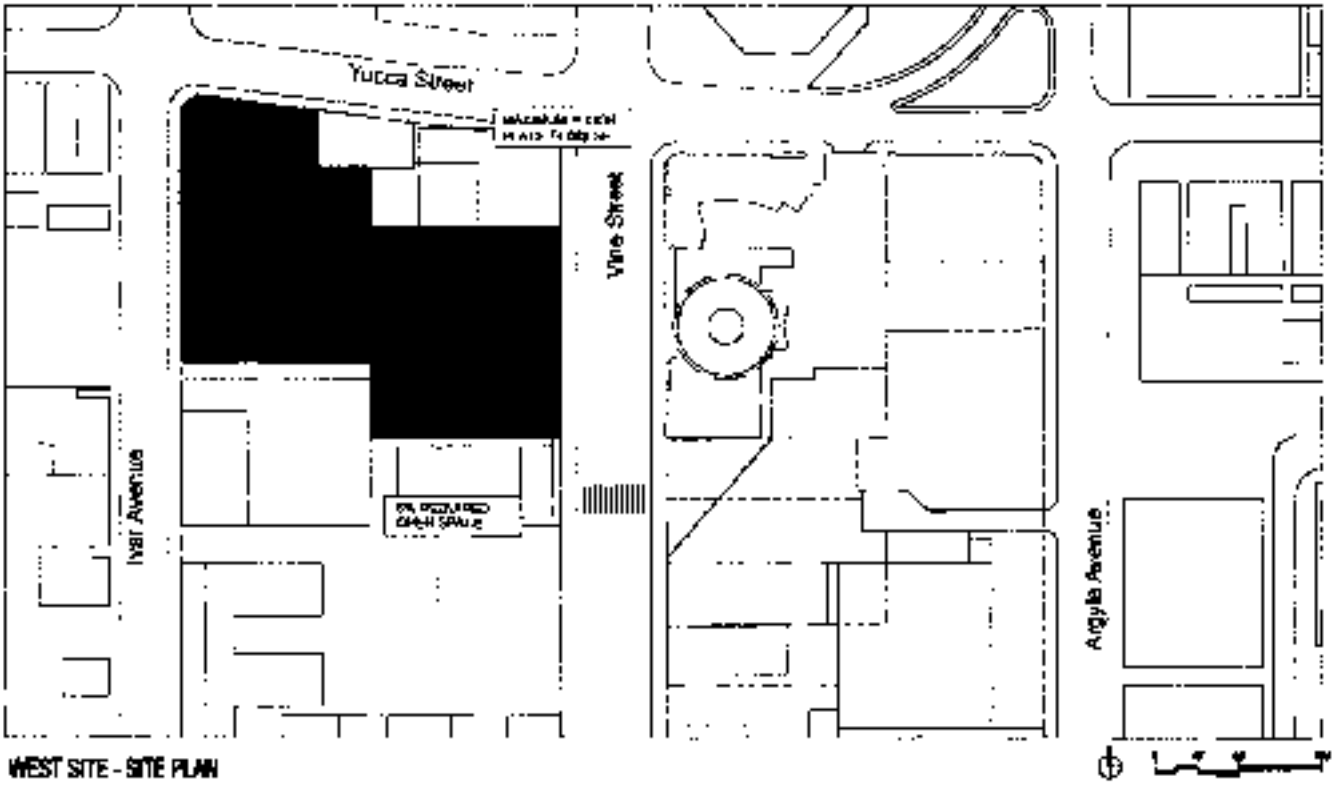


EAST SITE - SITE PLAN



5% PUBLIC OPEN SPACE
5,793 SF

Fig. 5.1.2.a.1: East Site



WEST SITE - SITE PLAN

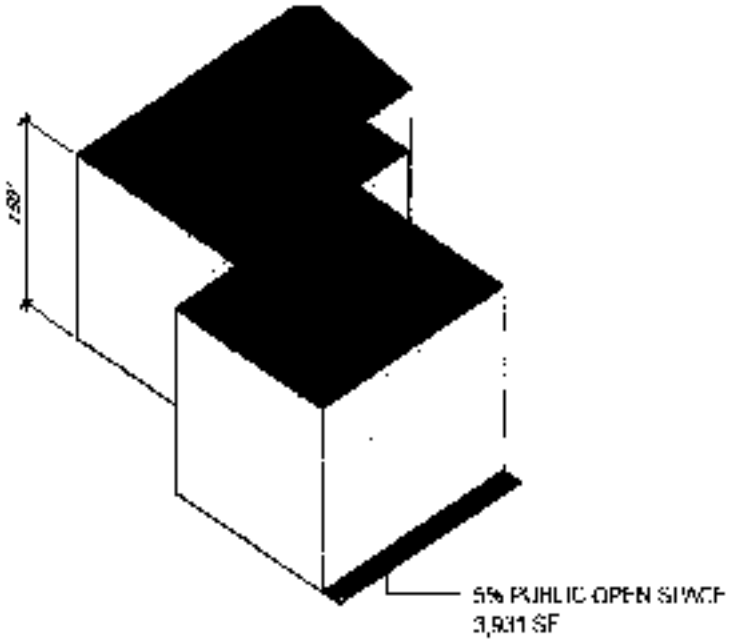
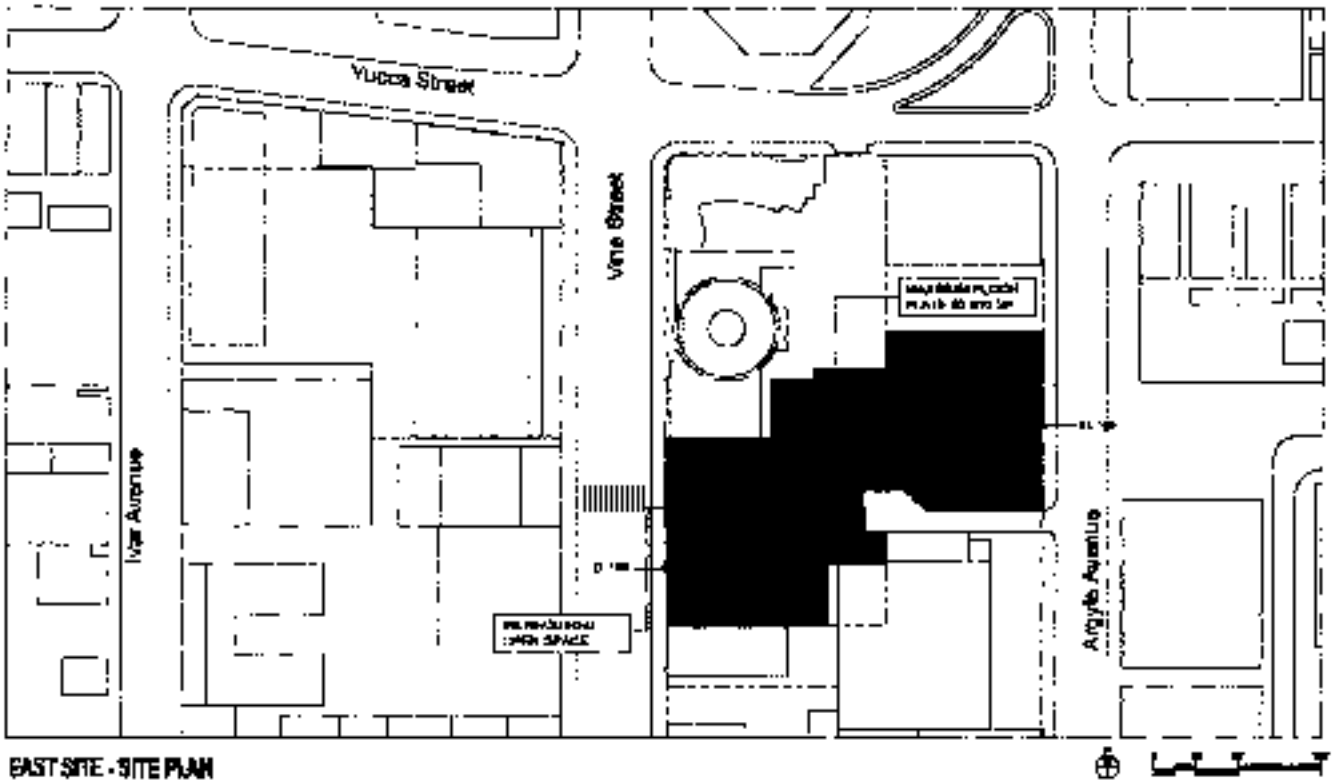


fig. 5.1.2.a.2: West Site



EAST SITE - SITE PLAN

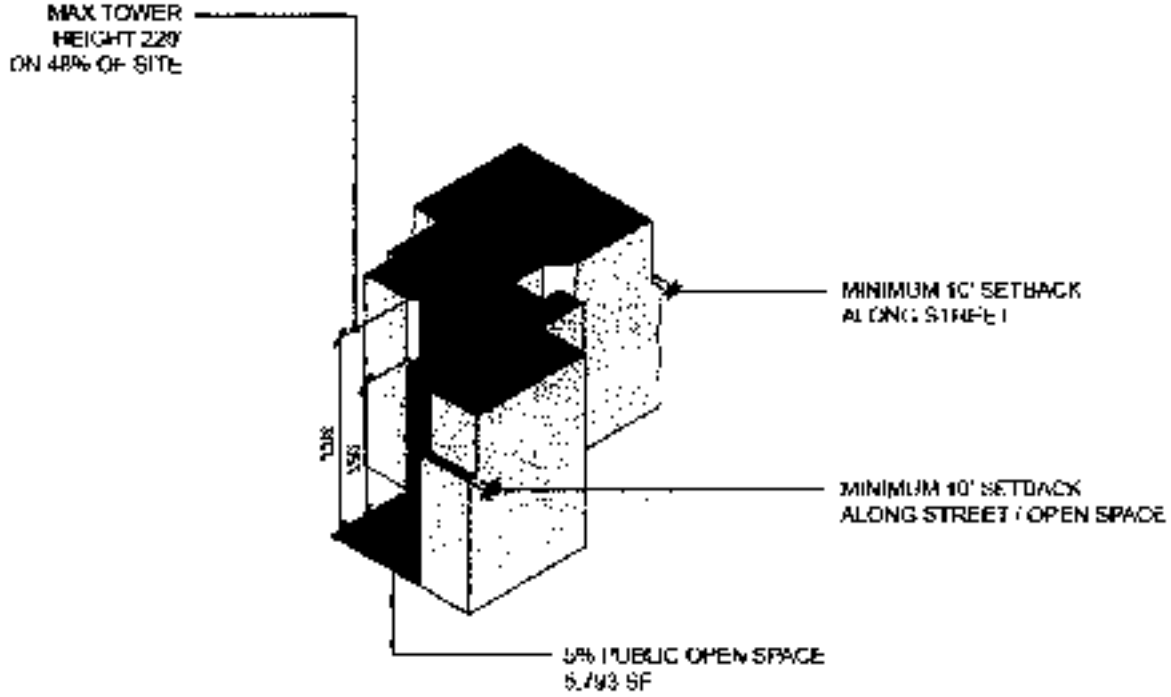
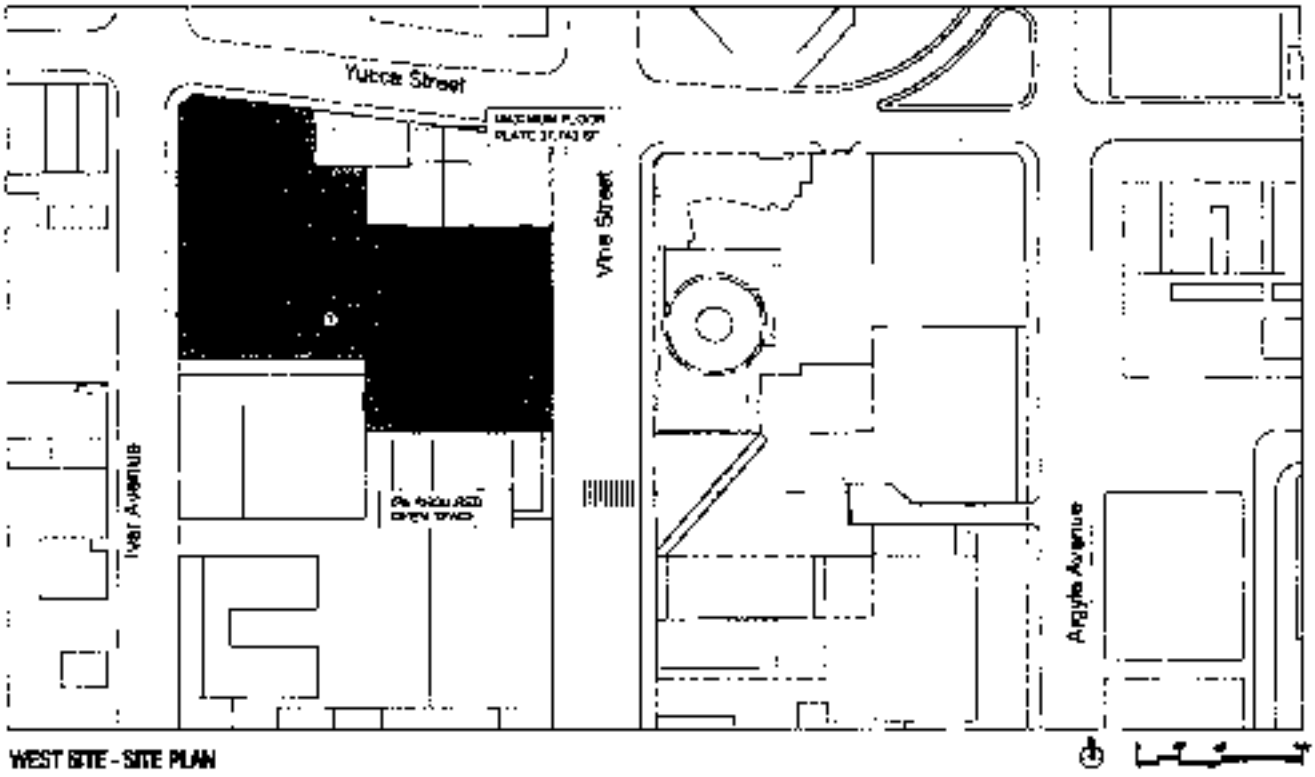


fig. 5.1.2.b.1: East Site



WEST SITE - SITE PLAN

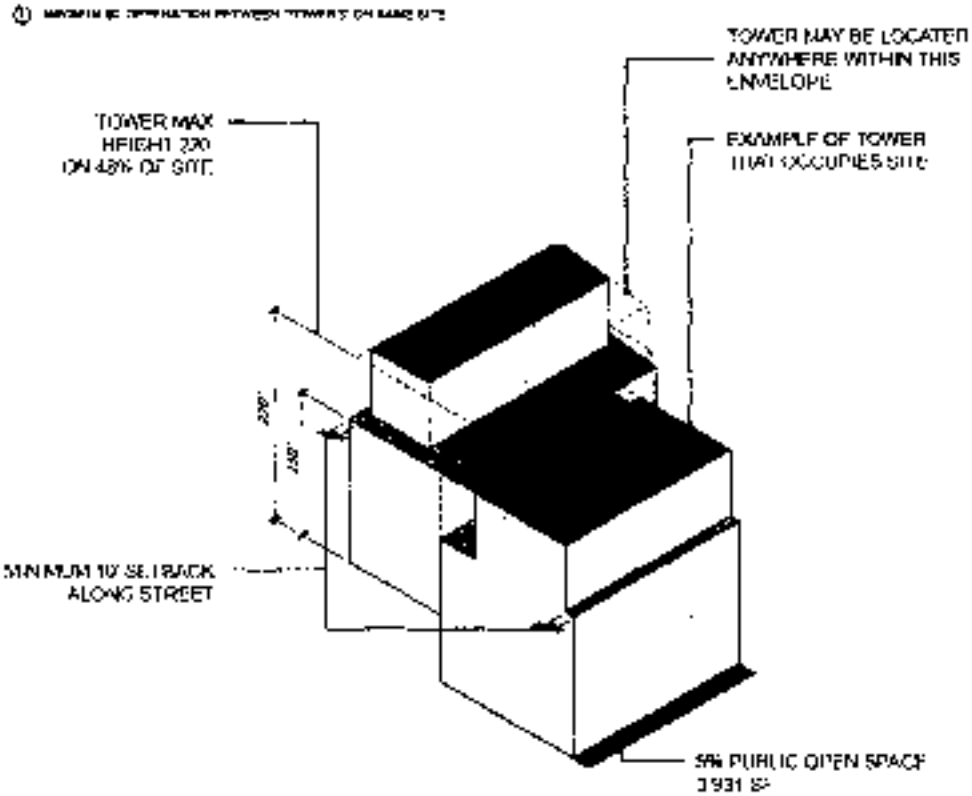
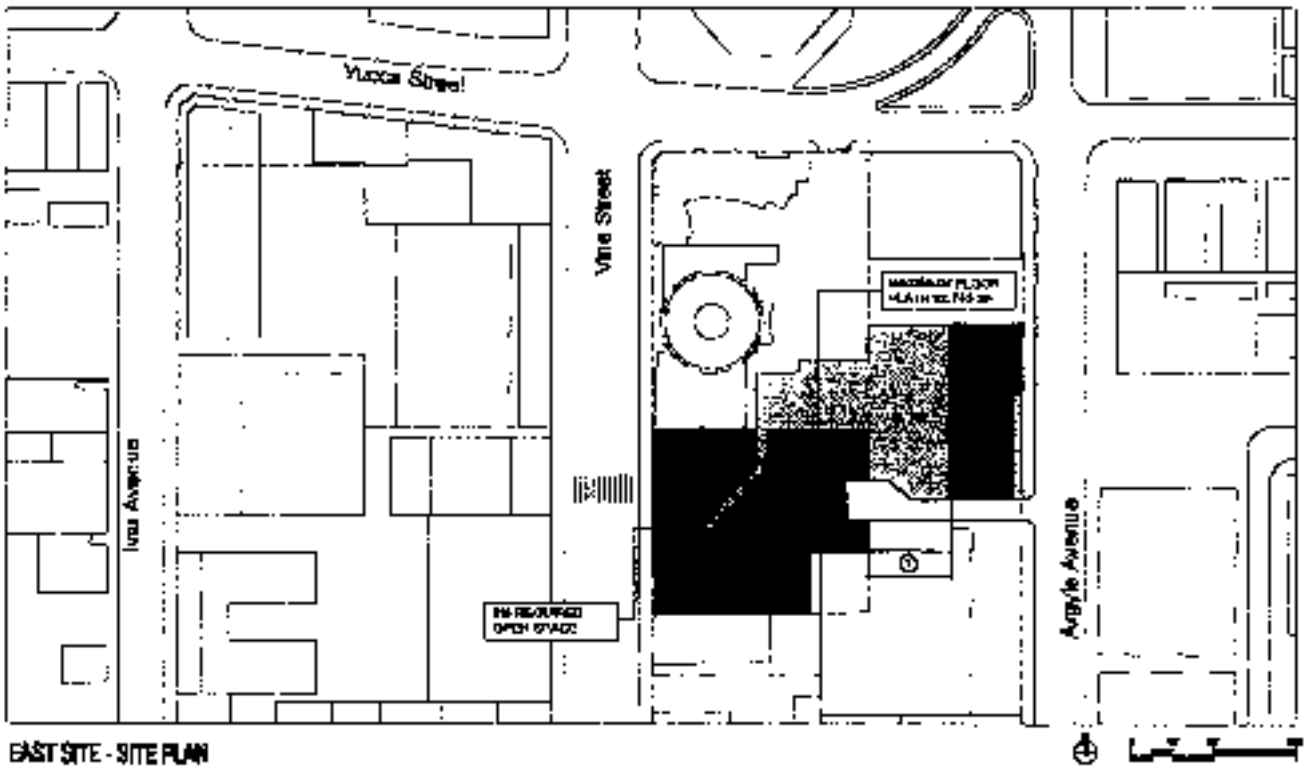


Fig. 5.1.2.b.2: West Site



EAST SITE - SITE PLAN

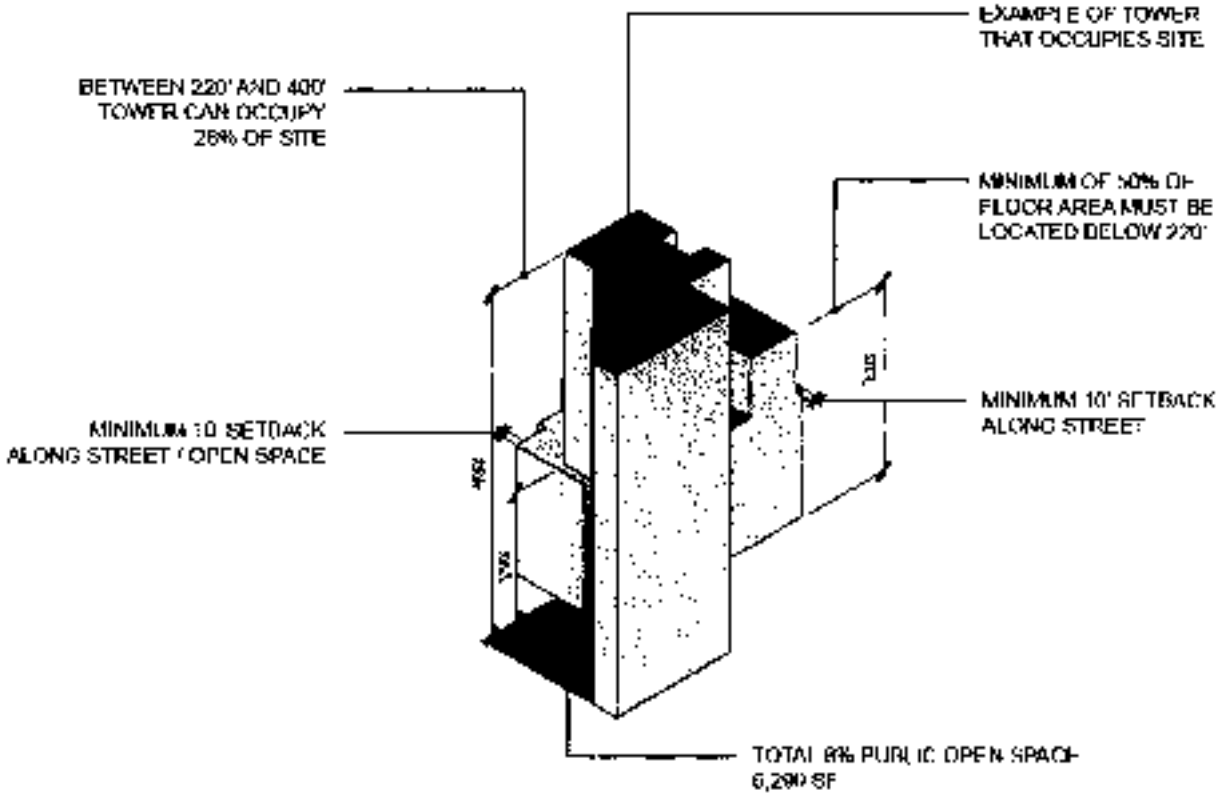
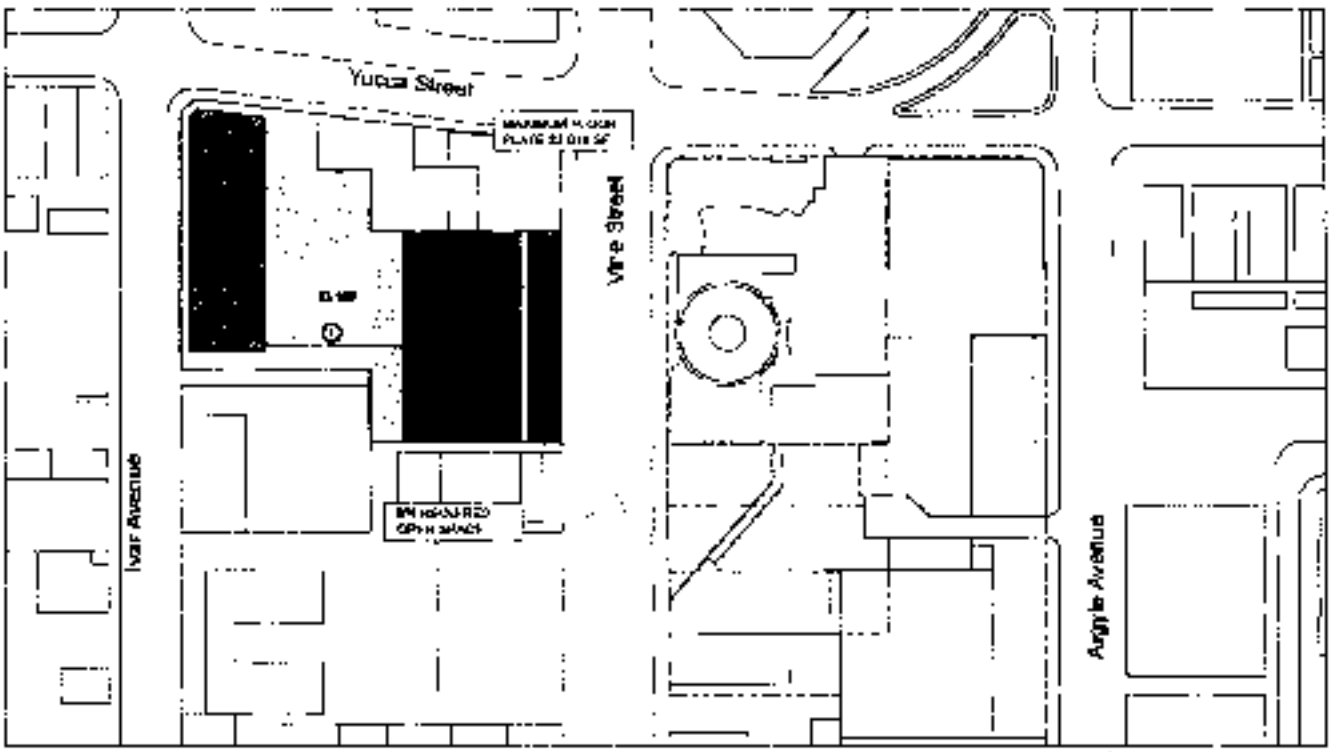


Fig. 5.1.2.c.1: East Site



WEST SITE - SITE PLAN

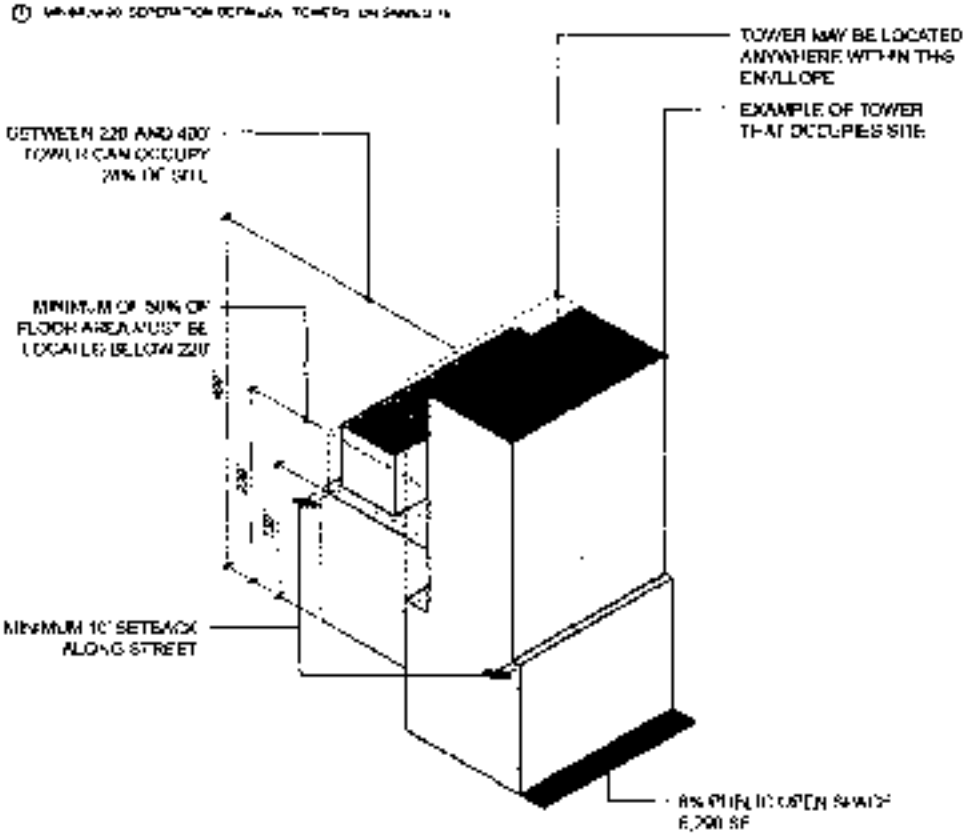
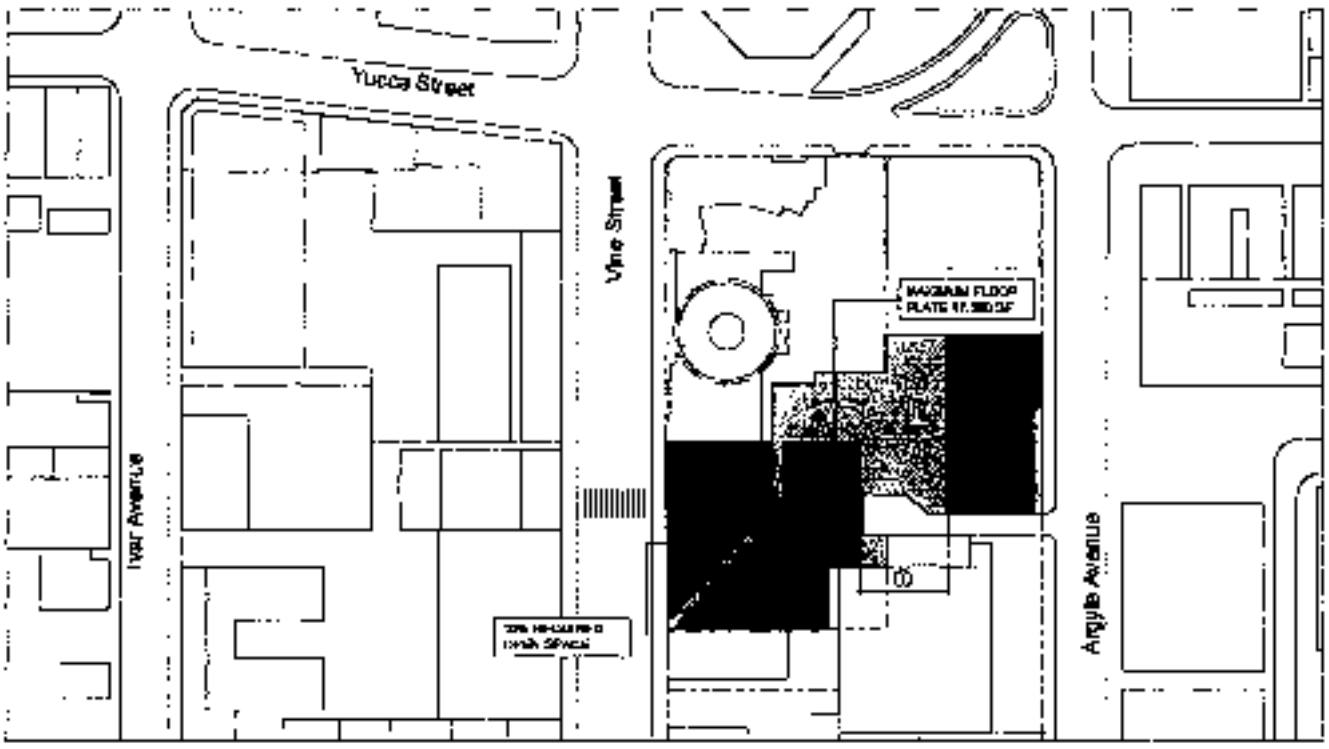


Fig. 5.1-2 c.2: West Site

HOLLYWOOD MILLENNIUM DEVELOPMENT REGULATIONS | SCOPE OF DEVELOPMENT | BUILDING AND STREET EXPERIENCE



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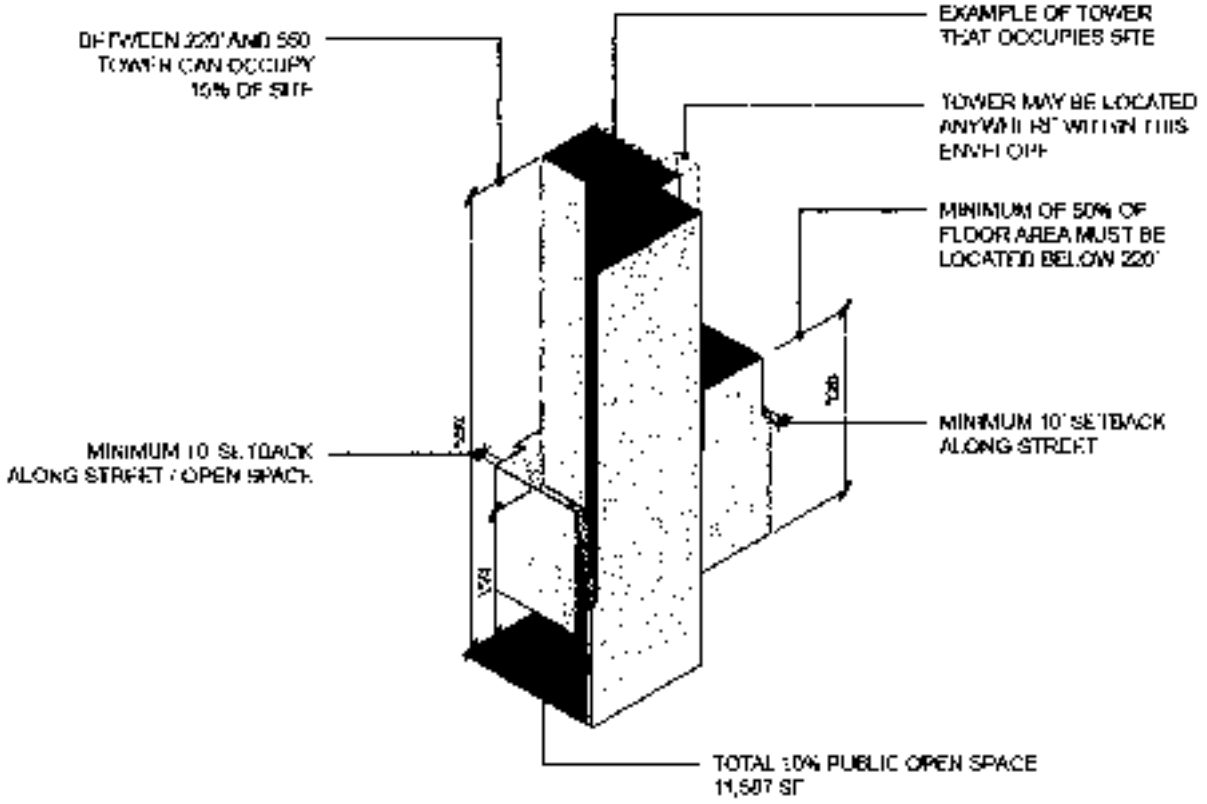
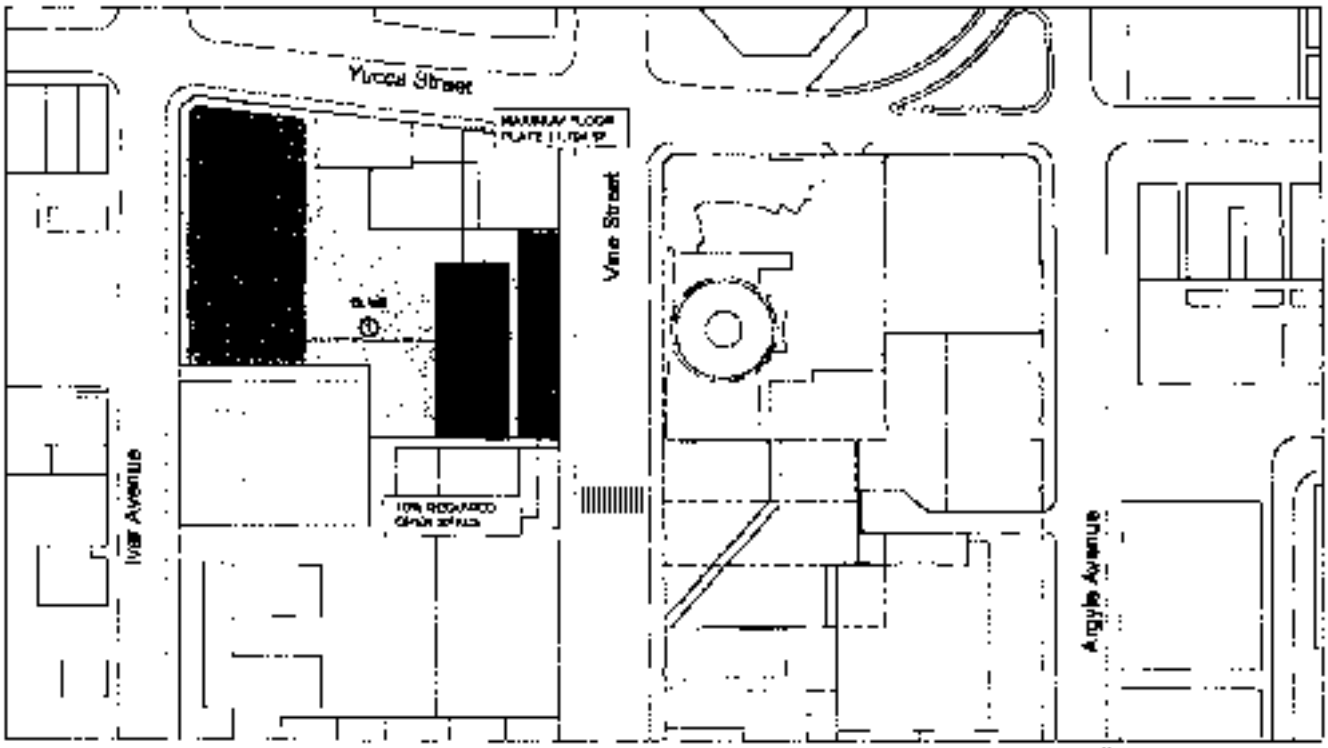


Fig. 5.1.2.d.1: East Site



WEST SITE - SITE PLAN

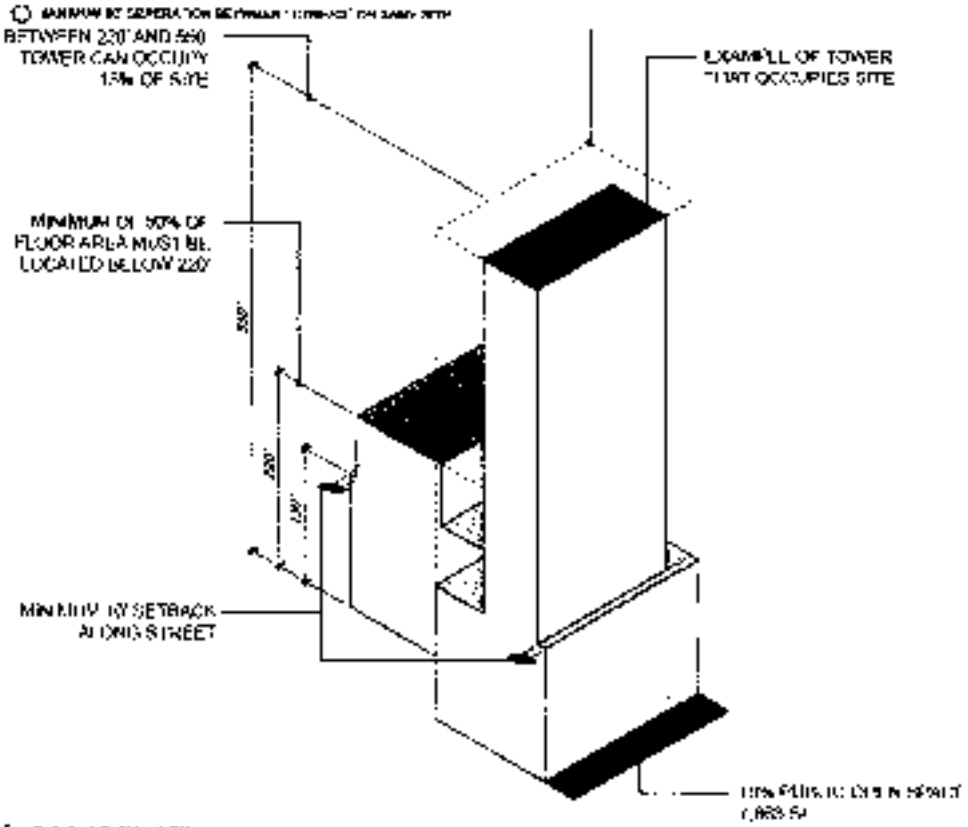
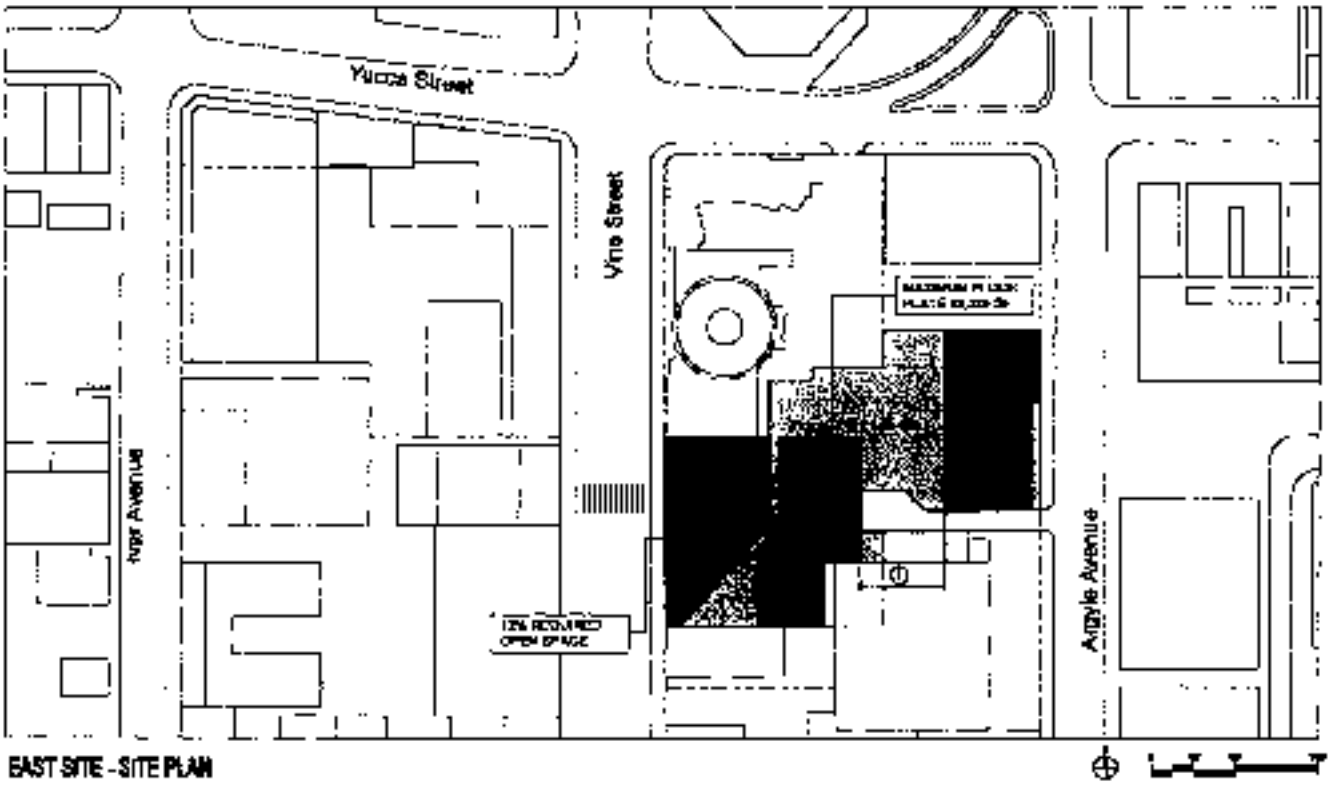


fig. 5.1.2.d.2: West Site



EAST SITE - SITE PLAN

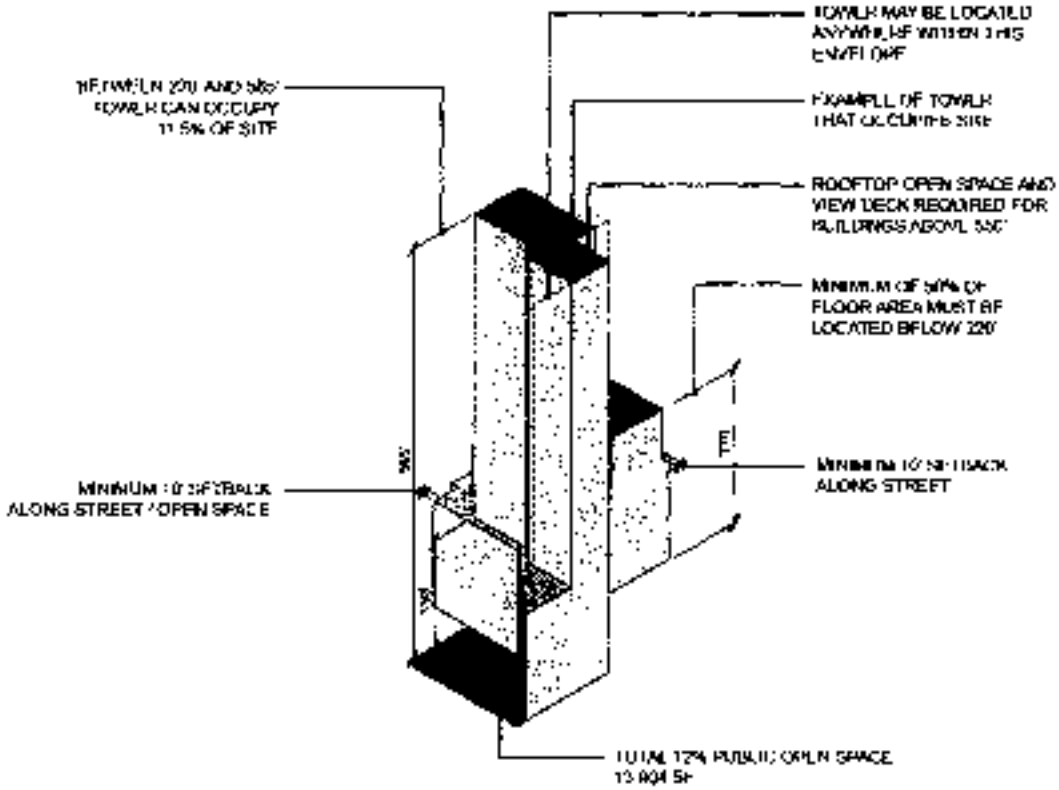
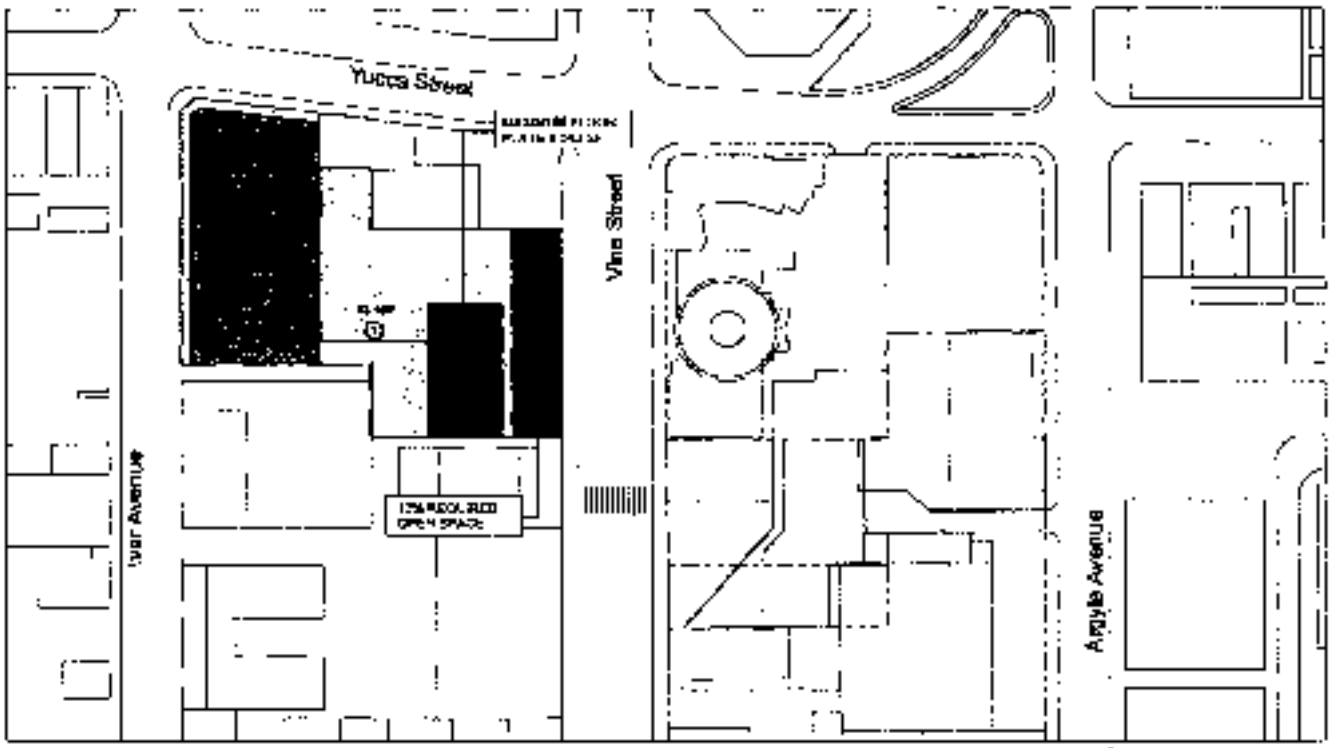


fig. 5-1.2.e.1: East Site



WEST SITE - SITE PLAN

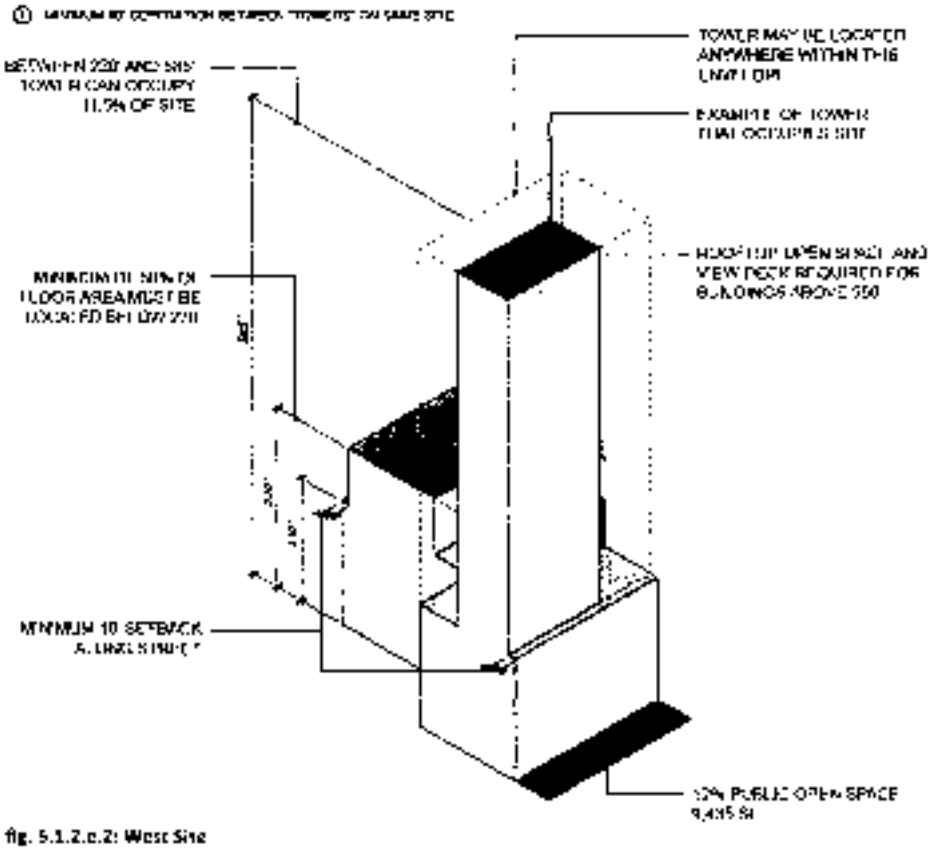


fig. 5.1.2.c.2: West Site

5.1.5 Types of permitted articulations for tower walls:

a Recess. recesses shall be permitted to a maximum depth of 15'-0".

b. Balcony: a balcony may project a minimum of 3'-0" from a required street wall over a grade level open space.

c. Bay window: a bay window may project from a required street wall over a grade level open space

d. Expression band: an identifiable break should be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

5.2 Street Walls

A street wall is a wall or portion of a wall of a building facing a street or a grade level open space. Street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation

5.3 Street Wall Standards

5.3.1 Location of a required street wall.

a. Parcels with a grade level open space, the required street wall shall be located minimum 5 feet from the property line.

b. Parcels or portions of parcels without a grade level open space: the required street wall shall be located on the property line.

5.3.2 Height of required street wall:

a Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b) below.

b. 40% of aggregate width of required street wall frontage on each street can exceed maximum street wall height up to the maximum tower height.

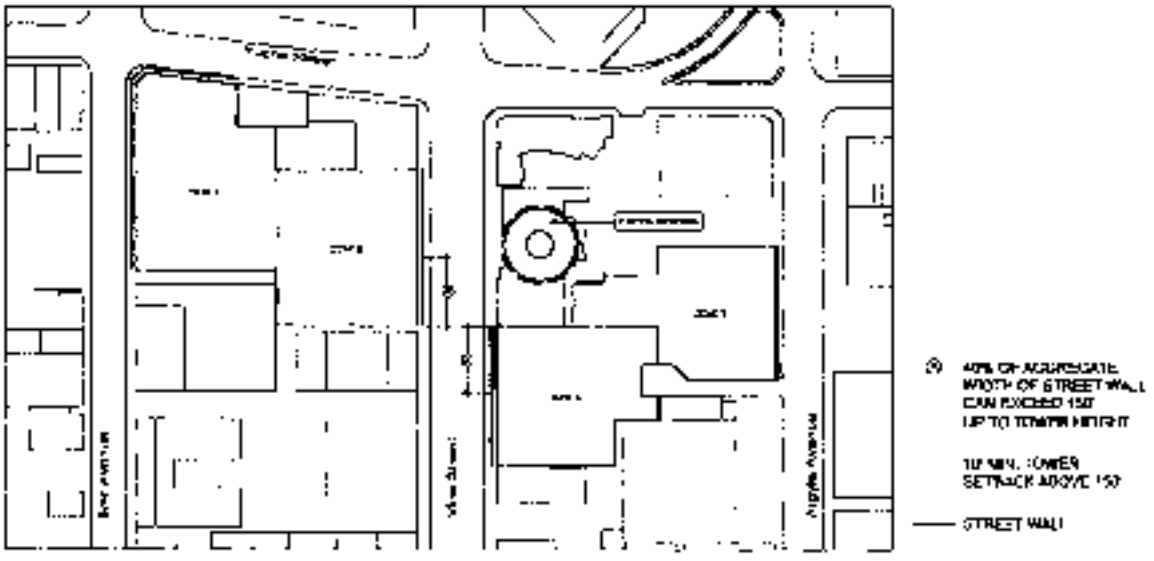


fig 5.3.2: Street Wall

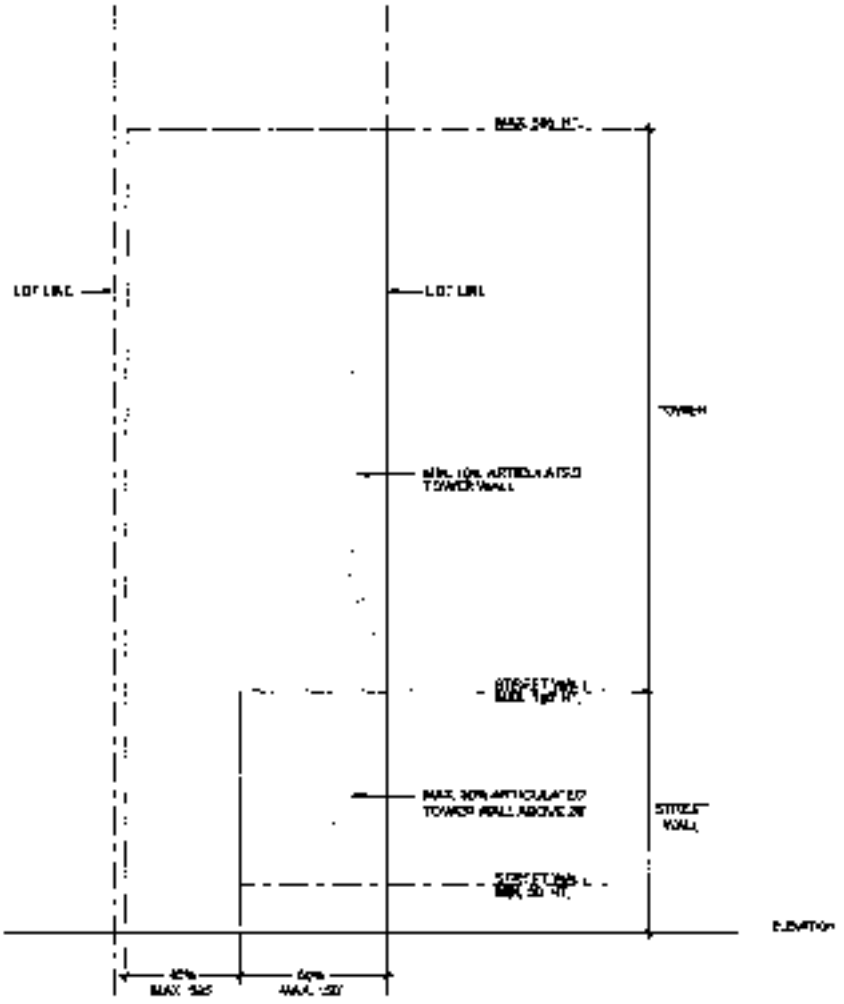


fig. 5.3.3: Street Wall Articulation

5.3.3 Amount of articulation of required street wall:

The aggregate width of required street wall articulation at the level of any story above the level of the second story ceiling or 28'-0" above curb level, whichever is less, shall not exceed 50% of the required street wall.

5.3.4 Other permitted projections: elements which project beyond the property line from a required street wall shall comply with the Building Code.

a Architectural facade elements such as expression bands, cornices; eaves, gutters, and downspouts may project from a required street wall over a grade level open space.

b. Steps and ramps may project from a required street wall over a grade level open space.

c. Marquees, canopies and awnings.

d. Retail storefronts: may project from a required street wall over a grade level open space by a maximum depth of 5' 0". The maximum height of these projections for each parcel shall not exceed two stories or 28' 0" above curb level, whichever is less.

5.4 Street Wall Guidelines

5.4.1 Pedestrian pass-through areas, public plazas, marquees, canopies, awnings and retail storefronts are permitted within the street wall area.

5.4.2 Pedestrian steps and ramps, entry forecourts, hotel drop offs and loading entries and exits and vehicular access driveways are also permitted within the street wall area.

5.5 Yard Standards

5.5.1 Yard is an open space other than a court that is unoccupied and unobstructed from the ground upward.

5.5.2 Commercial Use: no front, side or rear yard set backs are required

5.5.3 Residential Use.

a Front Yard: none

b. Side Yard: Minimum 5 feet, for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.

c. Rear Yard: Minimum 15 feet, for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet

5.6 Building Materials and Color Guidelines

5.6 1 Building materials and color will be subject to the following guidelines. These guidelines also address the façade treatment for both residential and commercial portions of buildings.

5.6.2 Building shall feature long-lived and sustainable materials. The material palette should provide variety, reinforce massing and changes in the horizontal or vertical plane

5.6.3 Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

5.6.4 Podium levels up to 150 feet will be predominantly light in color Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents. There will be clear contrast between the buildings surface material and the building's glazed areas

5 6.5 The building's skin, especially for towers, should be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required achieving energy efficiency standards.

5 6.6 In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style.

5.6.7 To provide visual variety and depth, layer the building skin and provide a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin should reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

5.6 8 Rooftop mechanical equipment: shall be screened with materials and design consistent with the building architecture.

5.6 9 Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

5.7 Grade Level Standards

5 7 1 The purpose of the grade level standards is to promote pedestrian-scaled architecture by regulating street wall massing, articulation and detail, street level entrances and storefront windows and doors, as well as the use of quality materials and decorative details. Architectural features that reinforce the retail character of the ground street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and should be integral to the architecture of the building.

5.7.2 Ground floor height

a. Minimum 12'-0" height floor to ceiling.

5.7 3 Building entrances:

a. The primary entrance to a street level tenant that has frontage along a public street shall be provided from that street. The primary entrance to a tenant that does not have its frontage along a public street shall be provided from a courtyard, grade level open space, or PAP. Entries <18 inches from the property line shall not be higher than 37 inches above the elevation of the sidewalk; entries >18" from property line shall be within 30 inches of the adjacent grade level along the street frontages. Where possible entries shall be marked using architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.

b. Main building entrances should read differently from retail storefronts, restaurants and commercial entrances.

5 7.4 Ground floor glazing

a. Use of clear, colorless and transparent glazing is required within the first 30 feet of grade

b. Use of reflective glass is prohibited.

c. Along street frontages with a required build-to line less than or equal to 18 inches from the property line, glazing should constitute a minimum of 30% of the area of a building face and should not exceed 80% of the area of a building face.

5.7.5 Arcades

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 5.0-foot candles.

5 7.6 Service and refuse

a Storage areas within the building of a size sufficient for that development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible to a curb cut.

5.7.7 Retail storefronts

a. Storefronts shall comprise a minimum of 70% of the building's street level façade and be recessed where necessary.

b. Storefront glazing should comprise a minimum of 60% of the storefront area along Vine Street and 40% glazing along all other streets. Glazed section shall comprise a calculated average of a minimum of 3 feet and 8 feet band of glazing measured from the ground floor.

c. All retail space shall have a minimum 12 feet finished ceiling clearance.

d. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet.

e. Storefront sills shall be a minimum of 18 inches and a maximum of 30 inches above the adjoining grade.

f. Security grills will be located behind glass and be at minimum 70% open

g. At-grade storefront glazing at, or adjacent to, and/or facing any public right-of-way shall incorporate transparent, clear, colorless glazing with no reflectivity.

5.8 Podium Standards

5.8.1 The purpose of the Podium Standards is to provide a modern interpretation of the historical context of Hollywood by establishing different treatment from the building's base, middle and top; through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

5.8.2 Podium height

Minimum 30'-0" to a maximum of 150 feet.

5.9 Podium Guidelines

5.9.1 Provide an identifiable break between the building's ground floors and upper floors. This break may include a change in material, change in fenestration pattern or similar means.

5.9.2 Podium level windows shall be vertically oriented.

5.9.3 Podium levels shall be predominantly light in color.

5.9.4 Expression band shall be provided at the highest story within the podium.

5.9.5 While blank street wall façades shall be avoided, an exception may be made for integration of public art or an articulated façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade should be a maximum of four floors high, and should have variation in its surface plane (using cutouts, insets or pop-outs). It should employ different scales of elements as viewed when seeing the entire building massing.

5.9.6 Louvers and wall openings shall be designed to integrate with building architecture.

5.10 Street and Sidewalk Standards

5.10.1 The cohesiveness and variety of public open spaces and streets are key features of the Project. The combination of landscaped plazas, PAP and landscaped streets creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

5.10.2 Hotel and Commercial / Office / Retail that abut an alley

a. Every required loading space shall be located and arranged that delivery vehicles may be driven upon or into said space from the alley. Such loading space shall have a minimum height of 14 feet and accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

b. Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.

c. Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet, a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet, and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building

5.10.3 Condominiums

a None

5.10.4 Rental

a. None

5.11 Screening Standards

5.11.1 Screen

5.11.2 Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets

5.11.3 Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets

6. TOWERS

6.1 Purpose

6.1.1 Towers should have their massing designed to reduce overall bulk and to appear slender.

6.1.2 Towers should be designed to achieve a simple faceted geometry and exhibit big, simple moves. They should not appear overwrought or to have over-manipulated elements

6.1.3 Towers that emulate a more streamline modern style should provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.

6.1.4 If a project has more than one tower, the towers should be complementary to each other and employ the same architectural design approach.

6.1.5 Generally, buildings over 150 feet tall (the historic datum for Hollywood) should not be historicized. They are contemporary interventions in the skyline and should appear as such.

6.2 Projections

6.2.1 The following building elements and operations equipment can project beyond the maximum permitted building height:

a. roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building;

b. skylights, towers, steeples, flagpoles, water tanks, silos;

c. wireless masts;

d. solar energy devices and similar structures.

6.2.2 Permitted building elements or equipment in Section 6.2.1 shall be screened as practical and based on building design except if such projections – i.e., flagpoles or steeples – are part of the architecture or design. The use of creative materials and forms for screening is encouraged.

6.2.3 Enclosures for bulkheads shall not count against building height

6.3 General Standards

6.3.1 A tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

6.3.2 Distinctive tower crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

6.4 Wall Standards

6.4.1 wall required to be articulated.

6.4.2 Types of permitted articulation of a tower wall:

a. Recess

b. Standard balconies may be projecting or recessed or a combination of both.

c. Bay windows

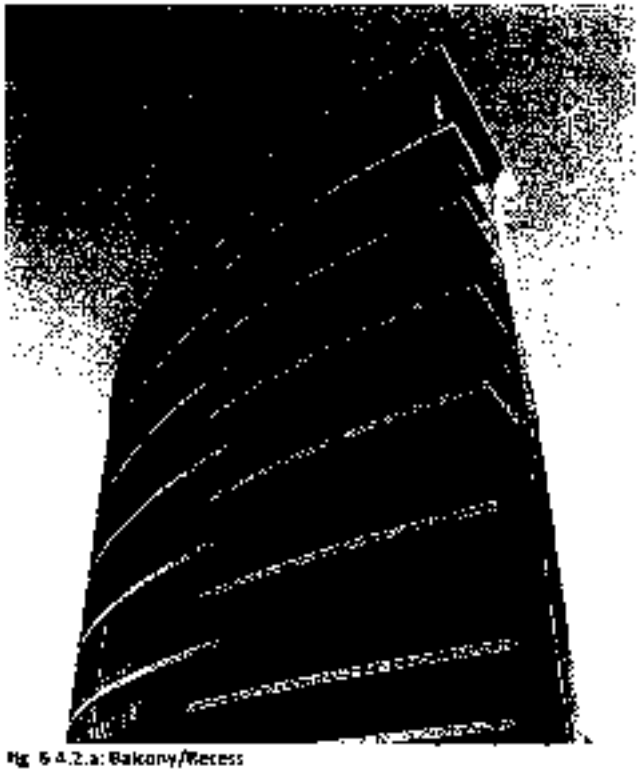


fig. 6.4.2.a: Balcony/Recess

fig. 6.4.2.b: Bay Window

6.4.3 Balcony: a balcony shall be integral to the façade (see figs. 6.4.3.a) and shall not create a relentless horizontal and vertical stacking pattern (see figs. 6.4.3.b). They are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations.

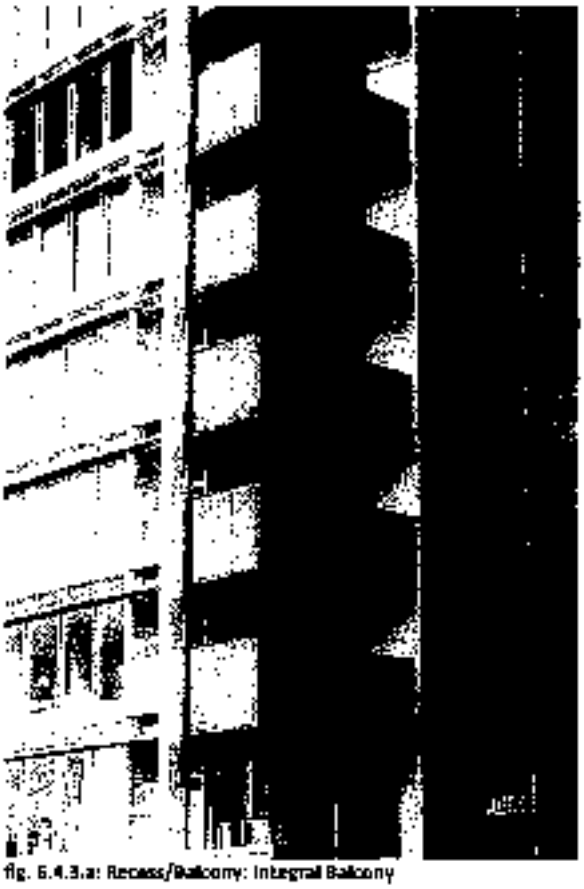


fig. 6.4.3.a: Recess/Balcony: Integral Balcony

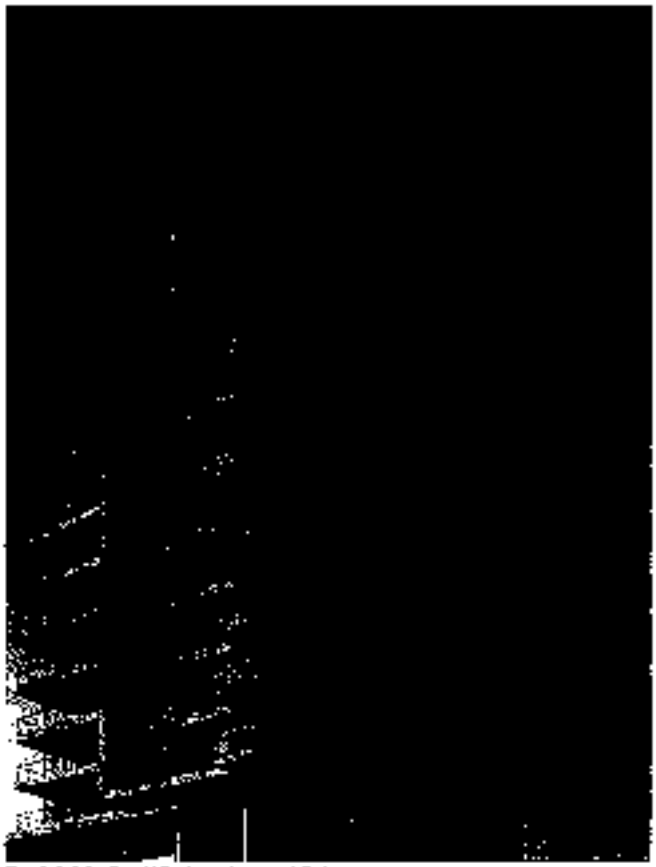


fig. 6.4.3.b: Bay Window: Integral Balcony

6.5 Spacing Standards

6.5.1 Towers should be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

6.5.2 Generally, the portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except the following which will meet code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled. See fig. 6.5.2.

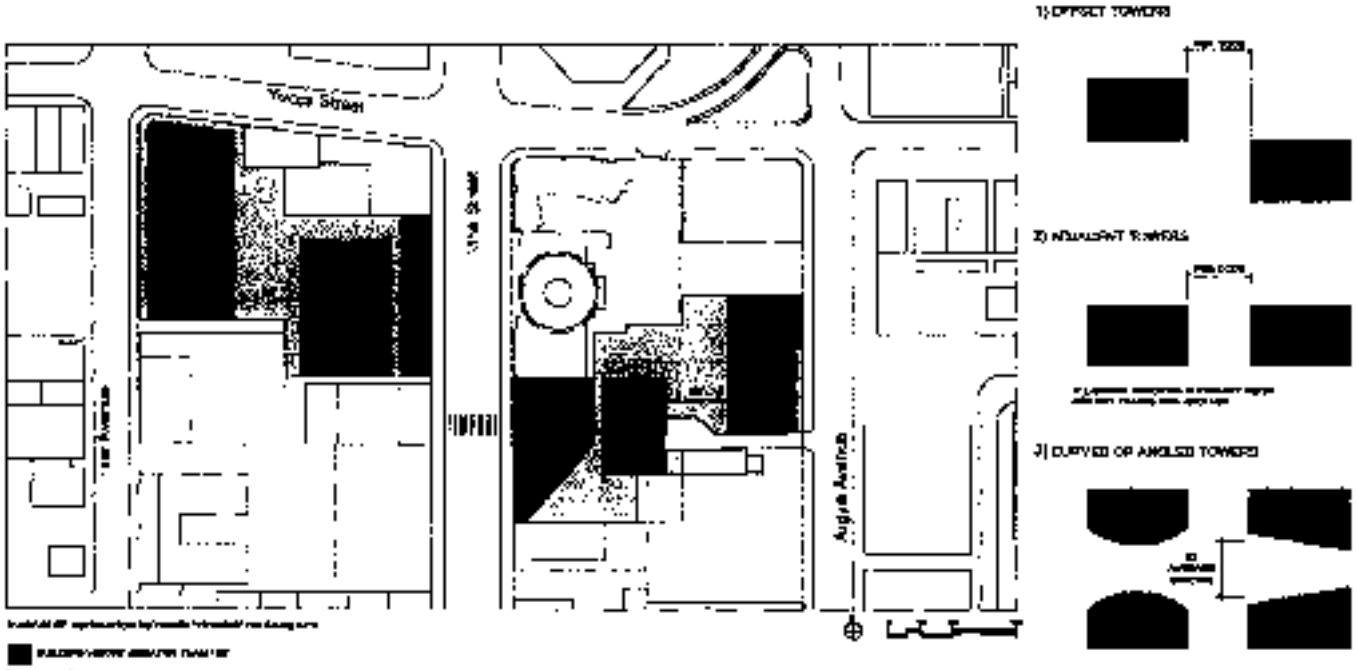


fig. 6.5.2: Tower Spacing

6.6 Rooftops Guidelines

6.6.1 Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and be visually attractive when viewed from locations adjacent and above.

6.6.2 For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section 7.2.

6.6.3 All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors.

6.6.4 All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

6.7 Parapets, Handrails, Roof Mechanical Equipment Screening Standards

6.7.1 Parapets and handrails shall be finished in a distinctive manner if part of an expression band or expression line.

6.7.2 Materials and design for roof mechanical equipment to be consistent with the building architecture and will utilize similar colors and materials as in other portions of the building

6.7.3 Roof mechanical equipment shall be screened.

7. OPEN SPACE

7.1 The development of open space is an important objective for the overall Project design. Open space will be used to enhance the experience of the visitor and resident. Open space also will enable important pedestrian linkages and through-block connections for the Project. Grade level open space also will be designed to showcase the Capital Records Tower and Jazz Mural and will include design features and outdoor furniture to activate the ground floor amenities.

This section sets forth the standards and guidelines for all open space areas for the Project, areas to be accessible to the public (Grade Level Open Space, Publicly Accessible Passageways and Rooftop Open Space) and areas to be designed for the residential uses (Common Open Space and Private Open Space).

7.2 Grade Level Open Space Standards

7.2.1 Grade level open space is a continuous open space fronting the street and open to the sky. The purpose of a grade level open space is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records and accentuate the low scale character.

7.2.2 Minimum grade level open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet. (See, Fig. 5.1.2.a.1 - 2.)

7.2.3 An additional 3% of open space (total 8%) required for buildings between 221 feet and 400 feet.

7.2.4 An additional 5% (total 10%) of open space to be required for buildings between 401 feet and 550 feet.

7.2.5 An additional 7% (total 12%) of open space required for buildings taller than 550 feet.

7.2.6 Location

a. East site: adjacent to the Jazz Mural and Capitol Records Tower; West site: across from the Capitol Records Tower along Vine Street.

b Minimum depth: no horizontal dimension less than 5 feet when measured perpendicular from any point on each of the boundaries of the open space area.

figs 7.1.2 – 7.1.5: Grade level Open Space

Fig 7.1.5

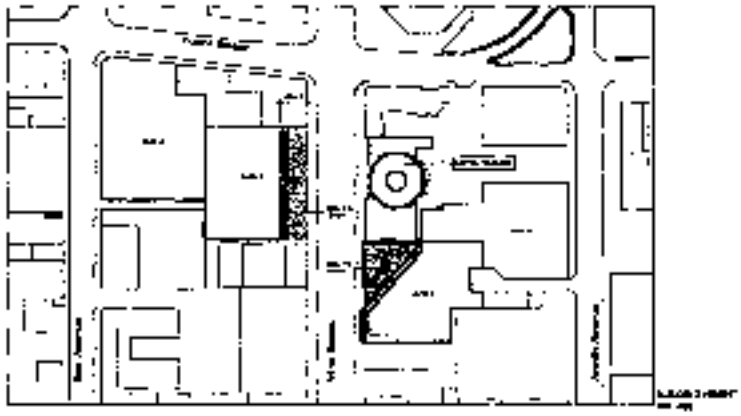


Fig 7.1.4

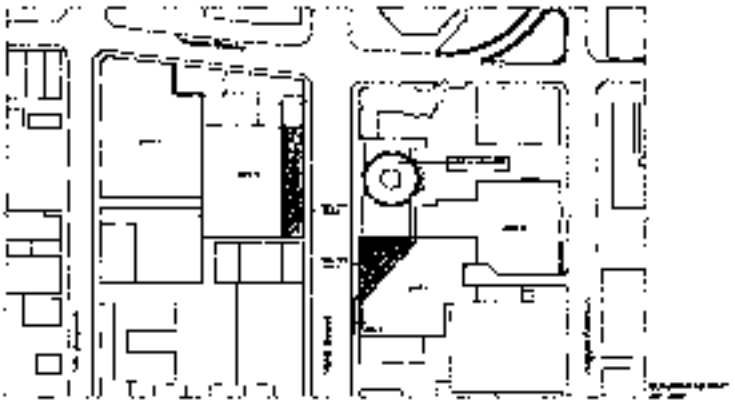


Fig 7.1.3

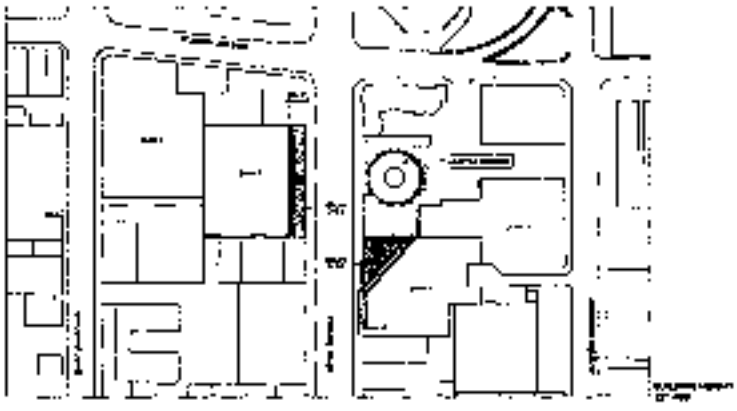
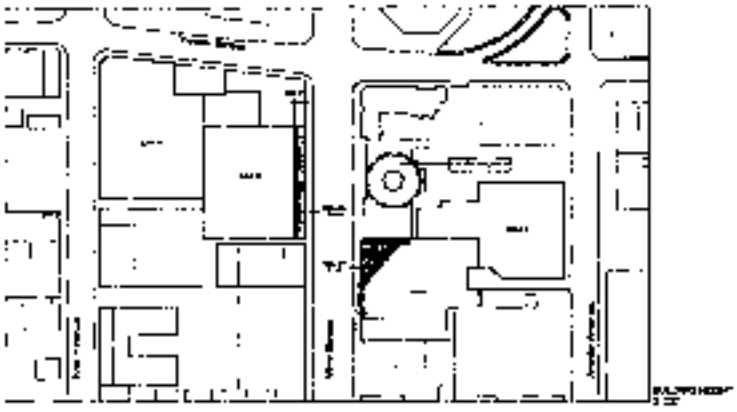


Fig 7.1.2



7.3 Passageway Standards

7.3.1 *A publicly accessible passageway (PAP)* is a continuous through block public connection between two parallel streets, located on privately owned land. The passageway may be either enclosed or open to the sky or a combination of both.

7.3.2 Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

7.3.3 Location and Size standards:

a. The major portion of a *PAP* is the largest area of the *PAP* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total *PAP* area and shall not be less than 20'-0" wide.

b Minor portions of *PAP* are secondary areas that allow for additional flexibility in the shape and configuration of a *PAP*. Minor portions shall not occupy more than 25 percent of the total area of the *PAP*. The minor portion shall have a minimum width of 10 feet.

c The minor portion must be directly adjacent to the major portion.

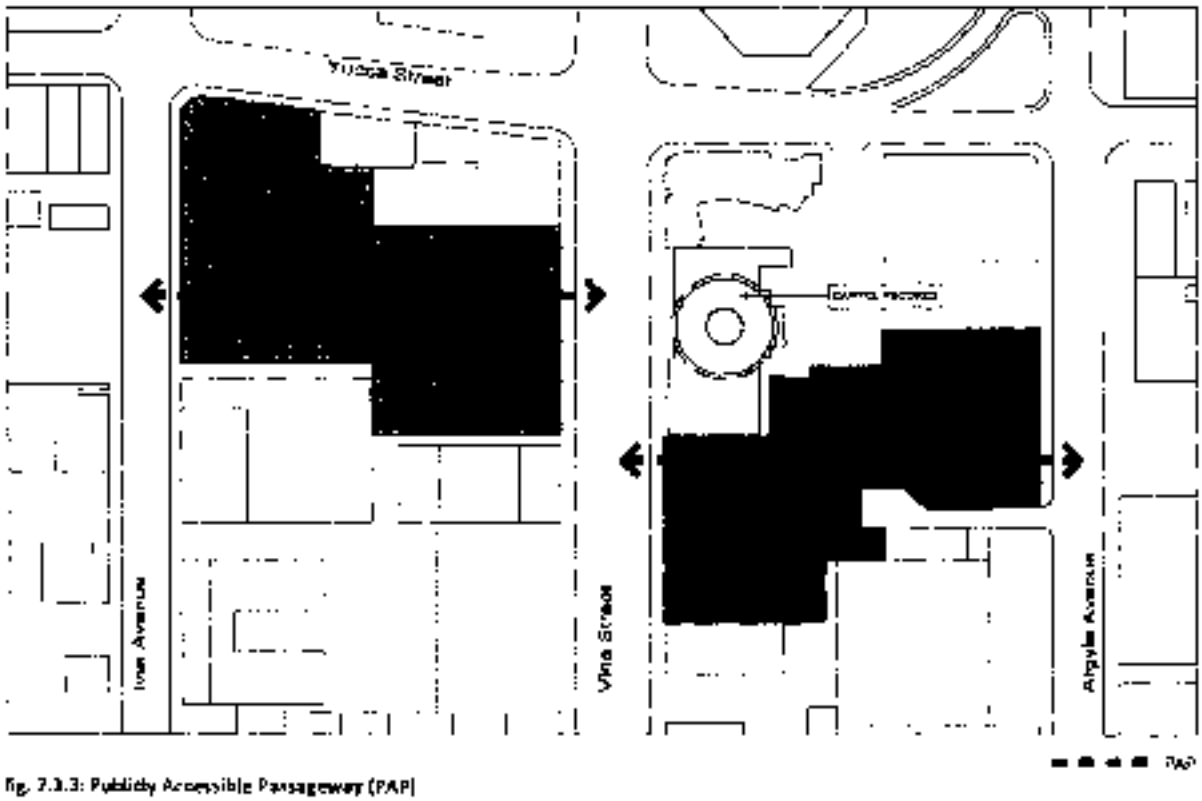


fig. 7.3.3: Publicly Accessible Passageway (PAP)

7.3.4 Permitted Obstructions:

a. Minimum percentage of PAP area to be open to the sky (East and West Sites combined) shall be as follows:

(i) Development with maximum building height of 150 feet: 0%

(ii) Development with maximum building height of 220 feet: 20%

(iii) Development with maximum building height of 400 feet: 30%

(iv) Development with maximum building height of 550 feet: 40% (at least __% of open air area to be on the East Site)

(v) Development with maximum building height of 585 feet: 50% (at least __% of open air area to be on the East Site)

b. Permitted obstructions within major portion of an open air PAP: any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions; balconies, bay windows, awnings, canopies and marquees; stairs, ramps and bollards.

fig. 7.3.4: View from Argyle Avenue Along PAP Towards Capitol Records

7.3.5 Kiosk

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Buildings in conformance with the Building Code. Kiosks, including roofed areas, shall not: count as floor area, exceed 3% of the total area of the *PAP*, and occupy an area of more than 250 square feet.

b. A kiosk may be freestanding or may be attached on only one side to a wall of the building.

c Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, and food preparation for open-air cafes, flower stands or public service/information booths.

d All kiosks exceeding 3% of total PAP area or greater than 250 square feet are permitted but will count as floor area.

7.3.6 Open Air Cafe

a. Where an open air cafe is provided it shall be an unenclosed restaurant, eating, or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies

b. An open air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the *PAP*. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers.

c. An open-air cafe may occupy an aggregate area not more than 20% of the total area of the *PAP*. No cooking equipment shall be installed within an open-air cafe. Cooking equipment may be contained in a kiosk adjoining the open-air cafe. An open-air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

7.3.7 Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on *PAP* through open windows

7.3.8 Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No buildings refuse storage areas or refuse storage from a kiosk or open-air café are permitted on any *PAP*

b. No exhaust vents are permitted on any PAP or on any building wall of the development fronting upon the PAP except where such vents are more than 10'-6" above the level of the *PAP*

7.3.9 Frontages

a Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a *PAP* shall be allocated for occupancy by permitted retail, restaurants and cultural uses.

b. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the *PAP* with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

7.3.10 Maintenance:

a Responsibility: the building owner shall be responsible for the maintenance of the *PAP* including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the parcel and in the street sidewalk area adjacent to the parcel.

b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of *PAP* area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of *PAP* in connection with outdoor eating services or other uses permitted on *PAP* which generate litter.

7.4 Roof-top Open Space

7.4.1 Buildings above 550 feet to include roof top open space.

7.4.2 Roof-top open space to include an observation area (i.e., viewing deck) accessible to the public.

7.4.3 Roof top open space may include a café.

RESIDENTIAL OPEN SPACE STANDARDS – COMMON AND PRIVATE OPEN SPACE

7.5 Residential Common Open Space

7.5.1 Common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above. The publicly accessible passageway cannot be used to meet the residential open space requirements.

7.5.2 Common Open Space Standards

a. Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms

b. Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein

c Be open to the sky and have no structures that project into the common open space area, except as permitted in the zoning code.

d. Be readily accessible to all the residents of the site.

e Have a minimum area of 400 sq. ft. with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

f Constitute at least 50% of the total required usable open space in developments built.

E Common open space areas shall incorporate recreational amenities including but not limited to, swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

h. Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use shall be considered as common open space.

7.6 Residential Private Open Space

7.6 1 A private open space area is an area contiguous to and immediately accessible from a single dwelling unit.

7.6 2 Residential Open Space Standards

a. Contain a minimum of 50 square feet of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.

b. Have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

c Provide a minimum eight-foot vertical clearance under any projection, except as provided in zoning code.

d. That portion of a balcony which extends or projects into a required front yard in compliance with zoning code may qualify as usable open space provided it meets each of the above specified requirements noted in items i-iii

B. LANDSCAPE

B.1 Grade Level Open Space Standards

B.1.1 Planting requirements. Minimum 10% of grade level open space shall be landscaped with softscape or water features.

B.1.2 Landscaped area(s) shall be planted with seasonally diverse plant material.

B.1.3 The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

B.1.4 The minimum soil depths for planting are:

a. Trees: 42"

b. Shrubs: 30"

c. Lawns, ground cover: 18"

B.1.5 Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

B.1.6 Permitted obstructions: the following are permitted obstructions which may occur in the *grade level open space*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining; and

b. retail storefronts.

B.1.7 Open-air publicly accessible passageways (PAP) are not to be included in the grade level open space requirements.

B.2 Common Open Space Standards

B.2.1 A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

B.2.2 At least one 24-inch box tree for every four dwelling units shall be provided on site and may include street trees in the parkway.

B.2.3 For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30 inches in depth, and lawn or ground cover shall be at least 12 inches in depth.

B.2.4 All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

Fig. 8.3-a: Movable Seating

fig. 8.3-b: Open Air Cafe

8.3 Standards For Open Air Portions of PAP

8.3.1 The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

8.3.2 The minimum soil depths for planting are:

a. Trees: 42"

b. Shrubs: 30"

c. Lawns, ground cover: 18"

8.3.3 Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation, and waterproof electrical outlets.

8.3.4 Planting requirements:

a Minimum of 10% of open air PAP shall be landscaped.

b For each 400 square feet of landscaped area there shall be at least one (1) major shade tree or two (2) minor ornamental trees.

c. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

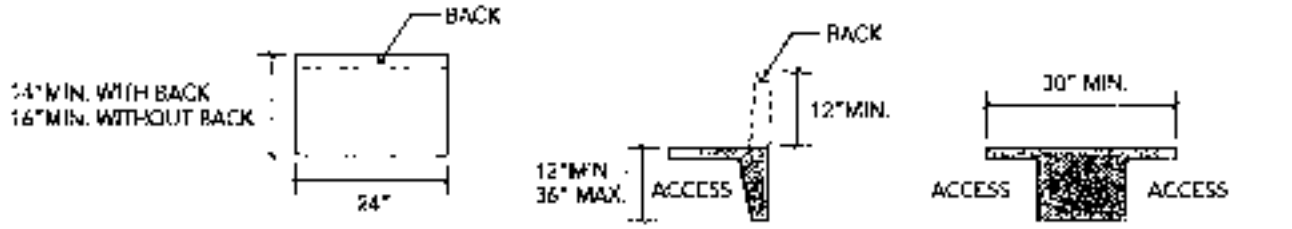


Fig. 8.3.5c Seating Standards

8.3.5 Seating

a. There shall be a minimum of one linear foot of seating for each 500 square feet of *PAP* excluding the area of an open-air cafe.

b. One seat shall equal 2 linear feet

c. Not more than 50% of the linear seating capacity may be in moveable seats. Seating shall meet the following standards:

(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons, a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count double provided there is access to both sides.

(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.

(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

d Moveable seating or chairs, excluding seating of open-air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open-air cafes do not count toward meeting the seating requirements.

8.4 Tree Planting Guidelines

8.4.1 It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

8.4.2 Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

8.4.3 Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree planting pattern.

8.5 Lighting Standards

8.5.1 Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain

8.5.2 Supplemental lighting shall meet the following minimum requirements

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade level open space and open PAP.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d. Steps and ramps will be lighted with a minimum of 1.0-foot candles on a horizontal plane.

e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements

8.5.3 Responsibility for maintenance

a. Building owner is responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

b. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building owner.

8.5.4 Lighting for areas located inside the lot line and visible from the street: such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires

8.5.5 Lighting for above grade parking garage facilities: shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

8.6 PAP Lighting Standards

8.6.1 A PAP shall be illuminated throughout with an overall minimum average level of illumination of not less than one maintained foot candle (lumens per square foot) on the horizontal plane at grade.

8.6.2 Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

8.7 Continuity of Design

8.7.1 Design elements and architectural clues that reinforce where appropriate continuity between open and enclosed spaces at grade level is encouraged. Continuity of design may reinforce pedestrian circulation and support the Project's way-finding features.

8.7.2 Where possible, materials, lighting, site elements and landscape should be similar between different open and enclosed public spaces at the grade level.

9. PARKING

9.1 Automobile Standards

9.1.1 Commercial / Office / Retail/Sports Club:

At least two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot. The Regulation incorporate applicable parking requirements in the LAMC as set forth below.

9.1.2 Condominiums

a. At least two parking spaces per each dwelling unit

b. One quarter parking spaces per each dwelling unit for guest parking

9.1.3 Rental

At least one parking space for each dwelling unit of less than three habitable rooms, one and one-half parking space for each dwelling unit of three habitable rooms, and two parking spaces for each dwelling unit of more than three habitable rooms.

9.1.4 Combination of uses

Where there is a combination of uses of a lot, the number of parking spaces required shall be the sum of the requirements of the various uses.

9.1.5 Shared parking

a. Shared parking may be applied on the site when the uses have different parking requirements and different demand patterns in a 24-hour cycle. The intent is to maximize efficient use of the site by matching parking demand with complimentary uses.

b. Calculating Shared Parking:

(i) Step I: Determine the aggregate minimum number of spaces required pursuant to the Code requirements for all land uses.

(ii) Step II: Based on the hourly variation in parking demand, determine the peak parking demand for the combined demand of all the land uses in the development.

(iii) Step III: Compare the calculations in Steps I and II, and the lesser of the two parking demands shall be used as the minimum number of parking spaces to be provided.

c. When a sports club is located in an office building with 50,000 square feet of office space, the general commercial use parking requirements apply and one parking space is required for 500 square feet of floor area for the building.

9.1.6 Additional regulations:

a. Location of accessory commercial, office and retail off-street spaces may be located on the same parcel as the use to which they are accessory or on the opposing development.

b. The automobile parking spaces required by Paragraphs (b), (c), (d) and (e) hereof, shall be provided either on the same lot as the use for which they are intended to serve or on another lot not more than 750 feet distant there from; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

c Curb cuts shall be located no closer than 50 feet to the intersection of two streets.

d Access driveways to parking facilities will not exceed 28 feet in width The minimum separation between drives located along the same frontage shall be 50 feet.

e. Parking and loading access will be shared where feasible.

9.1 7 Screening

a. Above grade parking shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible or shall be designed to blend in with the form and massing and designed to look like an integral part of the building. The interior of a parking structure will be designed to be screened from the view of streets and sidewalks.

9.2 Bicycle Standards

9.2.1 Requirements for each use:

a. Commercial / Office / Retail:

Any portion of a building used for non-residential purposes which contains a floor area in excess of 10,000 square feet, bicycle parking spaces shall be provided at the rate of two percent of the number of automobile parking spaces required by this section for such non-residential uses; provided, however, that at least one bicycle parking space shall be provided for any such building having a floor area in excess of 10,000 square feet of non-residential use. If the calculation of the number of required spaces results in a number including a fraction, the next highest whole number shall be the number of spaces required.

b. Condominiums

At least one secure bicycle parking space shall be provided for every two residential units

c Rental

None

9.3 Transportation Demand Management Plan

9.3.1 Project approvals to incorporate a comprehensive plan to manage vehicular and pedestrian circulation within the Project Site

9.3.2 The transportation demand management plan will promote smart onsite pedestrian and vehicular circulation and create linkages to public and private amenities outside the Project Site

10. SIGNAGE

10.1 Hollywood Signage Supplemental Use District

Signage shall be subject to Ordinance No. 176172: Hollywood Signage Supplemental Use District pursuant to Section 13.11 of the Los Angeles Municipal Code.

10.2 Modification to Guidelines

Notwithstanding Section 10.1, high-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted. See fig.

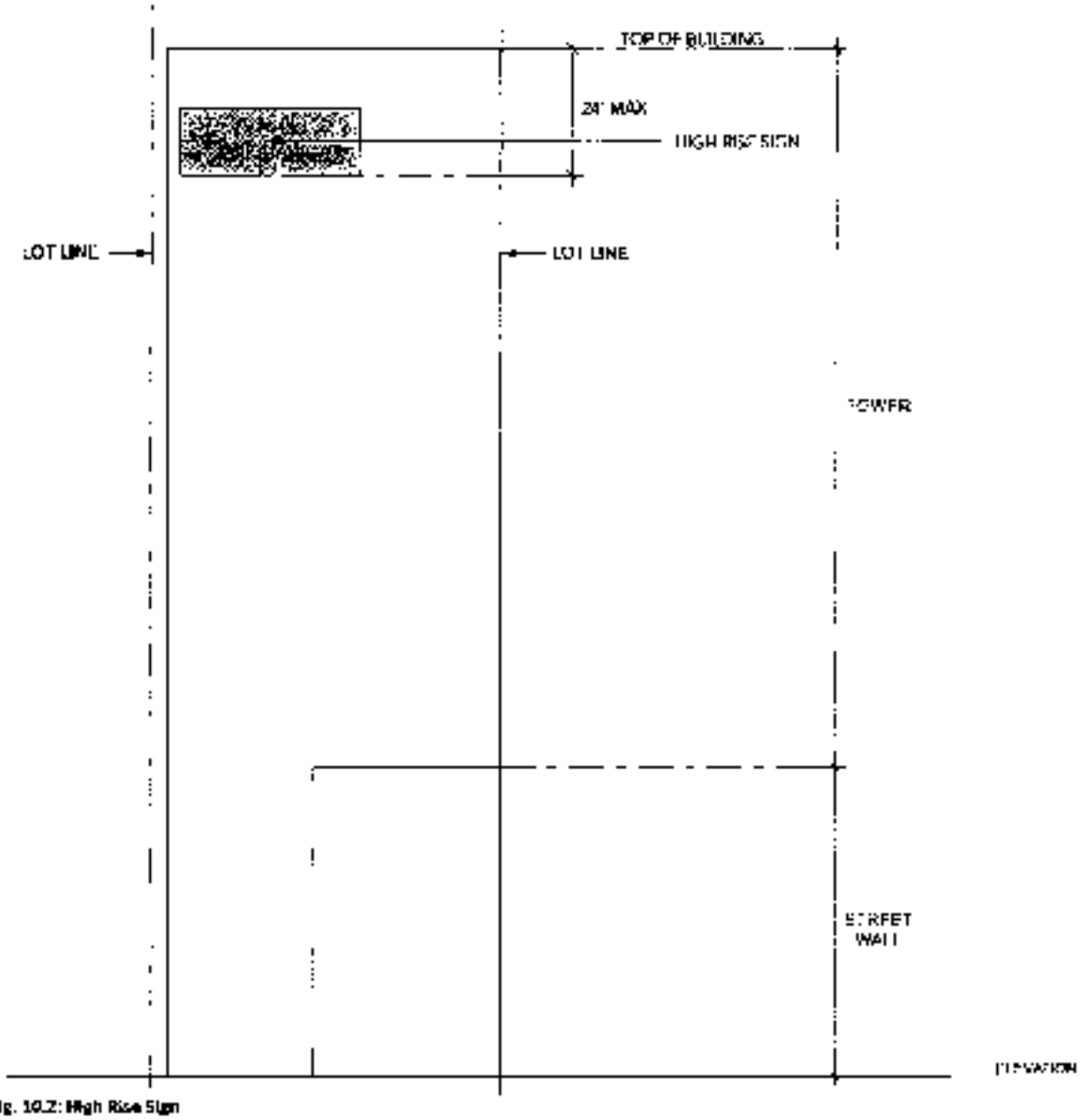


fig. 10.2: High Rise Sign

AR0068496

11. SUSTAINABILITY

11.1 Nonresidential Projects

The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.

11.2 Other Projects

The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required

Notes:

All images and figures used in the Regulations were prepared for exclusive use by Millennium Partners unless otherwise noted.

Hillsview Park 4/6/11

must be at least 35,000 sq-ft office use
EAC, but may want to allocate it to
community use.

want DA to allow to sit, but not to
exceed, not want to impede our EIR
that's the larger umbrella.

want the open to avoid impacts, per
EIR + DA but plans about one use

will be doing mitigation anyway should
use exist to

investigate what exact, that can
minimize impacts

* what is proposed is low, but what is
proposed is more

to start possible

restrictive document design guidelines
for document.

DA

schedule

* ask Deanna what they need to do to go on regarding the process of working with all departments

(C.C.)

* would like to be the first ones will keep one posted on timeline

~~update~~ ~~then update~~

* Update Nancy about case status

give update on Hollywood Blvd

Ariel to Jordan about schedule of Summit & IR.

Taylor Center on Vine
Over 100 people open house 5-8
stations, how it developed, number of
stations, entitlements.
Art work for next program

3. Entitlements Schedule
    a. CEQA Process
        ⇒ Coordination with Community Outreach
        ⇒ Q1 Milestones
            1. Filing Fees and Initial Study – February 2011
            2. Notice of Preparation of EIR – mid-March
            3. Scoping Meeting – April
    b. Approvals (*Hypothetical Outlook for 201[illegible] – 201[illegible]*)
        ⇒ EIR in circulation – March 2012
        ⇒ Responses to Comments – May/June
        ⇒ Planning Commission Hearing – July/August
        ⇒ PLUM/Council – September
        ⇒ CRA Commission – October
        ⇒ City Council – November/December

4 months

4. CRA
    a. Hollywood District Guidelines
    b. Joint Task Force
    c. State Reform – Update
5. Market Update
6. Next Steps/Other Business

AR0068500

CO-0001-326

4/18/11

- E.B. scoping meeting
- Cal law 35,000 ft not on private land
  (and DA is allowed)
- max agents models
  modern
- want to move forward w/ low management
  channel as study
- mail from Ft Lect emps
  - prepare discuss strategy & existing
    conditions & alts & timeline
    EIR -

May 11 scoping period

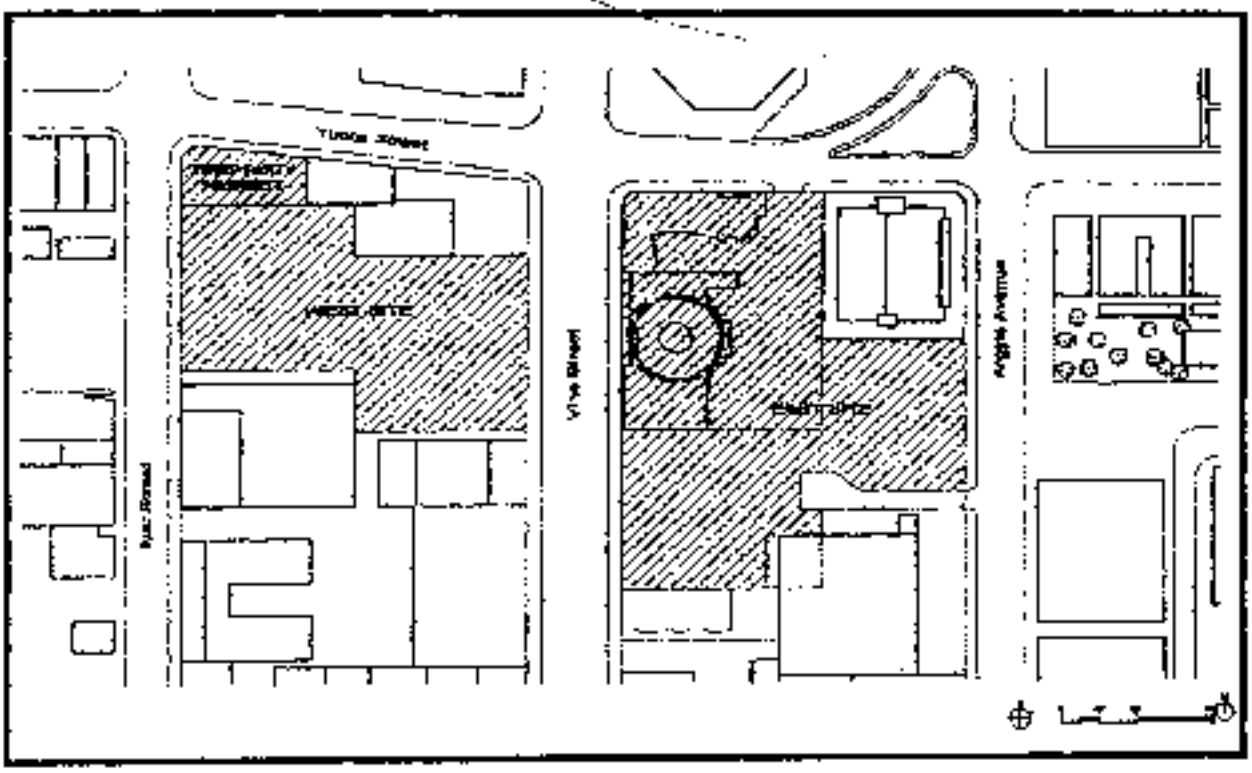
design guidelines use may part of project description?

DRAFT - FOR DISCUSSION PURPOSES ONLY

EXHIBIT "A-1"

DEVELOPMENT SITE MAP

DEVELOPMENT SITE MAP



DRAFT – FOR DISCUSSION PURPOSES ONLY

EXHIBIT "A-2"

DEVELOPER PROPERTY LEGAL DESCRIPTION

AR0068504

DEVELOPER PROPERTY LEGAL DESCRIPTION

APN 5546004006: 1746, 1748, 1754, 1760 and 1764 Ivar Street
APN 5546004020: 1745, 1749, 1751 and 1753 Vine Street
APN 5546004021: No Address

PARCEL 1:

LOTS 20, 21 AND THOSE PORTIONS OF LOTS 19 AND 22 IN BLOCK 21 OF HOLLYWOOD, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 28 PAGES 59 AND 60 OF MISCELLANEOUS RECORDS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, DESCRIBED AS FOLLOWS:

BEGINNING AT A POINT IN THE EAST LINE OF SAID LOT 19, DISTANT NORTHERLY THEREON, 400.23 FEET FROM THE NORTH LINE OF HOLLYWOOD BOULEVARD, 100.00 FEET WIDE, AS ESTABLISHED BY THE CITY ENGINEER OF SAID CITY, MEASURED ALONG THE EASTERLY LINES OF LOTS 13 TO 19 INCLUSIVE IN SAID BLOCK 21; THENCE WESTERLY IN A DIRECT LINE, A DISTANCE OF 181.50 FEET TO A POINT IN THE WEST LINE OF SAID LOT 19, DISTANT NORTHERLY, THEREON 400.39 FEET, MEASURED ALONG THE WESTERLY LINES OF SAID LOTS 13 TO 19 INCLUSIVE OF SAID BLOCK FROM THE NORTHERLY LINE OF SAID HOLLYWOOD BOULEVARD; THENCE NORTHERLY ALONG THE WESTERLY LINES OF SAID LOTS 19, 20, 21 AND 22; TO THE NORTHERLY LINE OF THE SOUTHERLY 17.00 FEET OF SAID LOT 22; THENCE EASTERLY ALONG SAID NORTHERLY LINE TO THE EASTERLY LINE OF SAID LOT 22; THENCE SOUTHERLY, ALONG THE EASTERLY LINES OF SAID LOTS 22, 21, 20 AND 19 TO THE POINT OF BEGINNING.

PARCEL 2:

LOTS 3, 4 AND THOSE PORTIONS OF LOTS 2 AND 5 IN BLOCK 21 OF HOLLYWOOD, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 28 PAGES 59 AND 60 OF MISCELLANEOUS RECORDS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, DESCRIBED AS A WHOLE AS FOLLOWS.

BEGINNING AT THE INTERSECTION OF THE NORTHERLY LINE OF THE SOUTH 16.80 FEET OF SAID LOT 5 WITH THE EASTERLY LINE THEREOF; THENCE WESTERLY ALONG SAID NORTHERLY LINE TO THE WESTERLY LINE OF SAID LOT 5; THENCE NORTHERLY ALONG THE WESTERLY LINES

OF SAID LOTS 5, 4, 3, AND 2 OF SAID BLOCK, TO THE NORTHERLY LINE OF THE SOUTHERLY 9.80 FEET OF SAID LOT 2; THENCE EASTERLY ALONG SAID NORTHERLY LINE TO THE EASTERLY LINE OF SAID LOT 2; THENCE SOUTHERLY ALONG THE EASTERLY LINES OF SAID LOTS 2, 3, 4 AND 5 TO THE POINT OF BEGINNING.

APN 5546030028: 6236 W. Yucca Street; 1740, 1750, 1760-1768 Vine Street
APN 5546030031: No Address
APN 5546030032: 1770 Vine Street

PARCEL 1: APN 5546-030-028 (PORTION)

THAT PORTION OF LOT 1 OF TRACT NO. 18237, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 529 PAGES 10 AND 11 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, LYING WESTERLY OF A LINE WHICH IS PARALLEL WITH AND DISTANT 260.00 FEET EASTERLY, MEASURED AT RIGHT ANGLES, FROM THE CENTER LINE OF VINE STREET, 100 FEET WIDE, AS SHOWN ON THE MAP OF SAID TRACT.

EXCEPT THAT PORTION OF SAID LAND LYING SOUTHERLY OF A LINE WHICH IS PARALLEL WITH THE MOST SOUTHERLY LINE OF SAID LOT 1 AND DISTANT 119.96 FEET NORTHERLY THEREFROM, MEASURED AT RIGHT ANGLES.

PARCEL 2: APN: 5546-030-028 (REMAINDER)

THE SOUTH 58 FEET OF LOT 12 OF CENTRAL HOLLYWOOD TRACT NO. 2, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 6 PAGE 144 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY.

PARCEL 3 APN: 5546-030-031

THE EAST 50 FEET OF THE NORTH 2 FEET OF LOT 12 OF CENTRAL HOLLYWOOD TRACT NO. 2, AND THE EAST 50 FEET OF LOT 13 OF SAID CENTRAL HOLLYWOOD TRACT NO. 2, WITH THE EXCEPT OF THAT PORTION DEEDED TO THE CITY FOR STREET PURPOSES OF LOS ANGELES, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 6 PAGE 144 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY.

PARCEL 4: APN: 5546-030-032

THE WEST 100 FEET OF LOTS 12 AND 13 OF CENTRAL HOLLYWOOD TRACT NO. 2, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 6 PAGE 144 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY.

EXCEPT THE SOUTH 58 FEET OF SAID LOT 12.

ALSO EXCEPT THEREFROM THAT PORTION OF SAID LAND INCLUDED WITHIN THE LINES OF YUCCA STREET AS DESCRIBED IN LOS ANGELES COUNTY SUPERIOR COURT CASE NO. 202550, NOTICE OF PENDENCY OF SAID ACTION WAS RECORDED ON AUGUST 6, 1926 AS INSTRUMENT NO. 1775, IN BOOK 6018 PAGE 270 OF OFFICIAL RECORDS IN SAID OFFICE OF THE COUNTY RECORDER.

SAID PROPERTY IS ALSO KNOWN AS AND IS DESCRIBED AS A WHOLE AS FOLLOWS:

BEGINNING AT THE MOST WESTERLY CORNER OF LOT 1; TRACT 18237, AS PER MAP RECORDED IN BOOK 529, PAGES 10 AND 11 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF LOS ANGELES COUNTY, CALIFORNIA, SAID POINT BEING ON THE EASTERLY RIGHT OF WAY OF VINE STREET 100' WIDE; THENCE N00 DEGREES 15'52"W 119.96' TO THE TRUE POINT OF BEGINNING. THENCE CONTINUING N00 DEGREES 15'52"W 297.05'; THENCE N89 DEGREES 52'48"E 150.002'; S00 DEGREES 15'52"E 24.00' TO THE SOUTHERLY RIGHT OF WAY OF YUCCA STREET 94' WIDE; THENCE N89 DEGREES 52'48'E 59.95'; THENCE S00 DEGREES 15'52"E 272.10'; THENCE S89 DEGREES 3721" W27.30' TO A POINT WHICH IS 232.67' PARALLEL WITH AND EASTERLY OF THE CENTERLINE OF VINE STREET 100' WIDE, THENCE S89 DEGREES 3721"W 182.67' TO THE POINT OF BEGINNING.

PARCEL 5:

A NON-EXCLUSIVE EASEMENT FOR PARKING SPACES AS SET FORTH IN THAT CERTAIN UNRECORDED PARKING EASEMENT AGREEMENT DATED AS OF MARCH 27, 2001, SUBJECT TO THE TERMS THEREIN PROVIDED, AS DISCLOSED BY THAT CERTAIN INSTRUMENT ENTITLED "MEMORANDUM OF PARKING EASEMENT AGREEMENT" RECORDED MARCH 30, 2001 AS INSTRUMENT NO. 01-528743, OFFICIAL RECORDS, AND SUBJECT TO THE TERMS AND PROVISION OF THAT CERTAIN "SUBORDINATION, NON-DISTURBANCE AND ATTORNMENT AGREEMENT" RECORDED MARCH 30, 2001 AS INSTRUMENT NO. 01-0528748 OF OFFICIAL RECORDS, SAID PARKING SPACES ARE LOCATED ON THE PROPERTY DESCRIBED IN EXHIBIT B ATTACHED TO SAID MEMORANDUM OF PARKING EASEMENT AGREEMENT.

APN 5546030033: 1733 and 1741 Argyle Avenue

PARCEL 1: APN: 5546-030-033

THAT PORTION OF LOT 1 OF TRACT NO. 18237, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 529 PAGES 10 AND 11 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY.

BEGINNING AT THE MOST WESTERLY SOUTHWEST CORNER OF SAID LOT; THENCE NORTHERLY ALONG THE WESTERLY LINE OF SAID LOT TO A LINE WHICH IS PARALLEL WITH THE MOST SOUTHERLY LINE OF SAID LOT 1 AND DISTANT 119.96 FEET NORTHERLY THEREFROM MEASURED AT RIGHT ANGLES, TO SAID SOUTHERLY LINE; THENCE EASTERLY ALONG SAID LAST MENTIONED PARALLEL LINE TO A LINE WHICH IS PARALLEL WITH AND DISTANT 260.00 FEET EASTERLY MEASURED A RIGHT ANGLES FROM THE CENTER LINE OF VINE STREET 100.00 FEET WIDE, AS SHOWN ON THE MAP OF SAID "TRACT NO. 18237; THENCE NORTHERLY ALONG SAID LAST MENTIONED PARALLEL LINE TO A POINT IN THE NORTHERLY LINE OF SAID LOT 1; THENCE NORTH 89° 52'27" EAST ALONG SAID LAST MENTIONED NORTHERLY LINE TO THE EASTERLY TERMINUS OF THAT CERTAIN COURSE IN THE NORTHERLY LINE OF SAID LOT SHOWN ON THE MAP OF SAID TRACT AS HAVING A BEARING AND LENGTH OF SOUTH 89° 52'27" WEST 195.04 FEET; THENCE SOUTHERLY ALONG A TANGENT CURVE IN THE BOUNDARY LINE OF SAID LOT CONCAVE TO THE SOUTHWEST HAVING A RADIUS OF 14.49 FEET AND AN ARC LENGTH OF 23.51 FEET TO THE END THEREOF; THENCE SOUTH 0° 16'00" EAST ALONG THE EASTERLY LINE OF SAID LOT, TO A POINT 171.50 FEET, NORTHERLY MEASURED ALONG SAID EASTERLY LINE FROM THE SOUTHEASTERLY CORNER OF SAID LOT, SAID POINT BEING THE TRUE POINT OF BEGINNING OF THIS DESCRIPTION; THENCE SOUTH 0° 16'00" EAST ALONG SAID EASTERLY LINE 171.50 FEET TO THE SOUTHEASTERLY CORNER OF SAID LOT; THENCE SOUTH 89° 37'45" WEST 109.50 FEET ALONG THE SOUTHERLY LINE OF SAID LOT TO AN ANGLE POINT THEREIN; THENCE CONTINUING ALONG SAID SOUTHERLY LINE NORTH 48° 55'41" WEST 30.21 FEET TO AN ANGLE POINT THEREIN; THENCE SOUTH 89° 37'45" WEST ALONG THE SOUTHERLY LINE OF SAID LOT AND ITS WESTERLY PROLONGATION SHOWN ON SAID MAP AS HAVING A BEARING OF SOUTH 89° 37'45" WEST AND A LENGTH OF 39.92 FEET TO A LINE WHICH IS PARALLEL WITH AND DISTANT 232.67 FEET EASTERLY MEASURED AT RIGHT ANGLES FROM THE CENTER LINE OF VINE STREET ABOVE DESCRIBED; THENCE NORTHERLY ALONG SAID LAST MENTIONED PARALLEL LINE TO A POINT ON THE LINE ABOVE DESCRIBED AS BEING PARALLEL WITH THE MOST SOUTHERLY LINE OF SAID LOT; THENCE EASTERLY ALONG SAID LINE TO THE LINE ABOVE DESCRIBED AS BEING PARALLEL WITH AND DISTANT 260.00 FEET EASTERLY OF THE CENTER

LINE OF VINE STREET; THENCE NORTHERLY ALONG SAID PARALLEL LINE TO THE INTERSECTION WITH A LINE PERPENDICULAR TO THE LINE ABOVE DESCRIBED AS THE EASTERLY LINE OF SAID LOT AT THE TRUE POINT OF BEGINNING; THENCE NORTH 89° 44' EAST ALONG SAID PERPENDICULAR LINE TO THE TRUE POINT OF BEGINNING.

SAID LAND IS ALSO KNOWN AS:

BEGINNING AT THE MOST WESTERLY CORNER OF LOT 1, TRACT NO. 18237, AS PER MAP RECORDED IN BOOK 529 PAGES 10 AND 11 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, CALIFORNIA; SAID POINT BEING ON THE EASTERLY RIGHT OF WAY OF VINE STREET 100' WIDE; THENCE N00 DEGREES 15'52"W 119.96'; THENCE N89 DEGREES 37'21"E 182.67 TO THE TRUE POINT OF BEGINNING, THENCE; N89 DEGREES 37'21"E 27.30'; THENCE N00 DEGREES 15'52"W 101.80'; THENCE N89 DEGREES 44'08"E 150.07 TO THE WESTERLY RIGHT OF WAY OF ARGYLE AVENUE 75' WIDE; THENCE SOUTHERLY ALONG SAID RIGHT OF WAY; S00 DEGREES 15'45"E 171.50' TO THE NORTHERLY RIGHT OF WAY OF A PUBLICLY DEDICATED ALLEY WAY BEING 20' WIDE THENCE ALONG SAID RIGHT OF WAY; S89 DEGREES 37'21" W 109.50' THENCE; N48 DEGREES 56'05"W 30.22' THENCE; S89 DEGREES 37'21"W 45.14' TO A POINT WHICH BEARS S00 DEGREES 15'52"E FROM THE POINT OF BEGINNING OF THIS DESCRIPTION; THENCE N00 DEGREES 15'52"E 49.99' RETURNING TO THE POINT OF BEGINNING.

PARCEL 2:

A NON-EXCLUSIVE EASEMENT FOR PARKING SPACES AT SET FORTH IN THAT CERTAIN UNRECORDED PARKING EASEMENT AGREEMENT DATED AS OF MARCH 27, 2001, SUBJECT TO THE TERMS THEREIN PROVIDED, AS DISCLOSED BY THAT CERTAIN INSTRUMENT ENTITLED "MEMORANDUM OF PARKING EASEMENT AGREEMENT" RECORDED MARCH 30, 2001 AS INSTRUMENT NO. 01-528743, OFFICIAL RECORDS, AND SUBJECT TO THE TERMS AND PROVISIONS OF THAT CERTAIN 'SUBORDINATION, NON-DISTURBANCE AND ATTORNMENT AGREEMENT' RECORDED MARCH 30, 2001 AS INSTRUMENT NO. 01-0528748 OF OFFICIAL RECORDS, SAID PARKING SPACES ARE LOCATED ON THE PROPERTY DESCRIBED IN EXHIBIT B ATTACHED TO SAID MEMORANDUM OF PARKING EASEMENT AGREEMENT.

APN 5546030034; 1723, 1724, and 1730 Vine Street

Real property in the City of Los Angeles, County of Los Angeles, State of California, described as follows:

THOSE PORTIONS OF LOT 1 OF TRACT NO. 18237, IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 529 PAGES 10 AND 11 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, AND LOT 6 OF CENTRAL HOLLYWOOD TRACT NO. 2 IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AS PER MAP RECORDED IN BOOK 6 PAGE 144 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, DESCRIBED AS FOLLOWS:

BEGINNING AT THE SOUTHWEST CORNER OF LOT 6 OF THE CENTRAL HOLLYWOOD TRACT NO. 2, PER MAP RECORDED IN BOOK 6 PAGE 144 OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, THENCE ALONG THE SOUTHERLY BOUNDARY OF SAID LOT 6, NORTH 89° 37'45" EAST 153.00 FEET, MORE OR LESS, TO THE WESTERLY LINE OF THE EASTERLY 87.00 FEET OF SAID LOT 6; THENCE NORTH 0° 15'52" WEST 60.00 FEET TO THE SOUTHERLY LINE OF LOT 1 OF TRACT NO. 18237, PER MAP RECORDED IN BOOK 529, PAGES 10 AND 11, OF MAPS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY; THENCE, ALONG THE BOUNDARY OF SAID LOT 1, NORTH 89° 37'45" EAST 57.00 FEET, NORTH 0° 16'00" WEST 30.00 FEET, SOUTH 89° 37'45" WEST 22.03 FEET, AND NORTH 0°22'15" WEST 40.00 FEET; THENCE SOUTH 89° 37'45" WEST 5.22 FEET, MORE OR LESS, ALONG THE WESTERLY PROLONGATION OF A COURSE IN THE SOUTHERLY BOUNDARY OF SAID LOT 1, TO A LINE WHICH IS PARALLEL WITH AND DISTANT 232.67 FEET EASTERLY MEASURED AT RIGHT ANGLES FROM THE CENTERLINE OF VINE STREET (100 FEET WIDE); THENCE NORTH 0° 15'52" WEST 49.97 FEET, MORE OR LESS, ALONG LAST SAID PARALLEL LINE TO A LINE WHICH IS PARALLEL WITH AND 119.96 FEET NORTHERLY, MEASURED AT RIGHT ANGLES, FROM THE MOST SOUTHERLY BOUNDARY LINE OF SAID LOT 1; THENCE SOUTH 89° 37'45" WEST 182.67 FEET TO THE EAST LINE OF VINE STREET; THENCE SOUTH 0°15'52" EAST 179.96 FEET TO THE POINT OF BEGINNING.

SAID LAND IS SHOWN ON THAT CERTAIN CERTIFICATE OF COMPLIANCE RECORDED MARCH 30, 2001 AS INSTRUMENT NO. 01 525740.

DRAFT – FOR DISCUSSION PURPOSES ONLY

EXHIBIT "A-3"

THIRD PARTY PROPERTY

THIRD PARTY PROPERTY LEGAL DESCRIPTION

APN 5546004029: 6334 Yucca Street
APN 5546004032: No Address

SAID LAND IS SITUATED IN THE CITY OF LOS ANGELES, COUNTY OF LOS ANGELES, STATE OF CALIFORNIA, AND IS DESCRIBED AS FOLLOWS:

THOSE PORTIONS OF LOTS 1 AND 2 IN BLOCK 21 OF HOLLYWOOD AS PER MAP RECORDED IN BOOK 28 PAGE(S) 59 AND 60 OF MISCELLANEOUS RECORDS, IN THE OFFICE OF THE COUNTY RECORDER OF SAID COUNTY, DESCRIBED AS A WHOLE AS FOLLOWS

BEGINNING AT THE NORTHWESTERLY CORNER OF SAID LOT 2, WHICH IS A POINT IN THE EAST LINE OF IVAR AVENUE, (70 FEET WIDE); THENCE ALONG THE WEST LINE OF SAID LOT 1 NORTH 0° 05' 30" EAST 5.31 FEET, MORE OR LESS, TO THE SOUTHERLY LINE OF YUCCA STREET, AS DESCRIBED IN PARCEL 117 OF DECREE OF CONDEMNATION ENTERED IN CASE NO. 202550 OF THE SUPERIOR COURT OF SAID COUNTY, A CERTIFIED COPY OF SAID DECREE BEING RECORDED ON OCTOBER 18, 1929 AS INSTRUMENT NO. 1085, IN BOOK 9421 PAGE 173 OF OFFICIAL RECORDS, IN THE OFFICE OF SAID RECORDER; THENCE ALONG SAID YUCCA STREET NORTH 48° 33' 16" EAST 13.26 FEET AND SOUTH 82° 58' 58" EAST 122.48 FEET, MORE OR LESS, TO THE WEST LINE OF THE EAST 50.00 FEET OF SAID LOTS 1 AND 2; THENCE SOUTHERLY ALONG THE LAST MENTIONED WEST LINE 54.50 FEET; MORE OR LESS, TO THE NORTH LINE OF THE SOUTH 9.89 FEET OF SAID LOT 2; THENCE WESTERLY ALONG SAID NORTH LINE 131.50 FEET TO THE WEST LINE OF SAID LOT 2; THENCE ALONG SAID WEST LINE 55.20 FEET, MORE OR LESS, TO THE POINT OF BEGINNING.

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EXHIBIT "B"

PROJECT APPROVALS

EXISTING DEVELOPMENT APPROVALS

- **Vesting Zone Change and Height District removal of the "D" Limitation from C4-2D-SN to C2-2-SN** per LAMC § 12.32 F and 12.32Q and Ordinance 165,659-SA 180
- **Vesting Conditional Use Approval to allow a hotel use within five hundred feet of a R Zone** per LAMC § 12.24.W.24 and 12.24.T
- **Conditional Use Approval for floor area ratio averaging in a unified development** per LAMC § 12.24.W.19
- **Conditional Use Approval for beverage with full alcohol, live entertainment and dancing** per LAMC §§ 12.24.W.1 and 12.24.W.18.a
- Variance from LAMC § 12.14.A.1(a)(10) for restaurants with outdoor eating areas above the ground floor per LAMC § 12.27
- Variance from LAMC § 12.21.A.4(c)(2) to reduce parking required for sports club facility per LAMC § 12.27

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EXHIBIT "C"

PUBLIC INFRASTRUCTURE

PUBLIC IMPROVEMENT LIST

OFF-SITE THRESHOLD IMPROVEMENTS

DEDSF THRESHOLDS	IMPROVEMENT		A	B	C
1,900,000	TRANSPORTATION				
	O-TR01	Victory/Riverside/Sonora Intersection			
	O-TR02	San Timoteo/Flower (SW) Intersection and Grade Crossing			
2,160,000	TRANSPORTATION				
	O-TR03	Riverside/Zoo Intersection			
2,200,000	SEWER				
	O-S.07	Down Pump Facility Rehabilitation			
	O-S.08	Upgrade Down Pump Station (Demand = 2,200 GPM)			
2,400,000	TRANSPORTATION				
	O-TR.04	Interchange Improvements - Phase II			
	O-TR.05	Flower(NS), Western to Sonora parkway			
	ITS				
	O-TR.03	ITS Improvements			
	ELECTRICAL				
	O-E.01	Winchester, Flower(NS) to Parcel 3027-093-017, Quickcore			
	LANDSCAPE				
	O-L.01	Flower (NS), Western to Sonora (west side only)			
	O-L.02	I-5 Phase II Additional Landscape			
	O-L.03	SR-91 Additional Landscape			
	SEWER				
	O-S.02	North Corridor Upgrade 2, Winchester to WestAm, 15" Main, (Demand = 277 GPM)			
	O-S.04	Flower NS, Maurice to Roberts, 15" Main, (Demand =570 GPM)			
	O-S.05	Flower NS, Roberts to Perrin, 15" Main, (Demand=295 GPM)			
	STORM DRAIN				
	O-SD.01	Winchester, Flower (NS) to Parcel 3027-093-017, 24" S/D			

PUBLIC IMPROVEMENT LIST

OFF-SITE THRESHOLD IMPROVEMENTS

DESIGN THRESHOLDS	IMPROVEMENT		A	B	C
4,030,000	SEWER				
	O-S-1A	Flower Extension to Doran Pump Station, 27" Main (Demand = 2,392 GPM)			
4,090,000	SEWER				
	O-S-11	Victory Trunk Blvd., Public to Flower N.E. 18" Main, (Demand =924 GPM)			
4,160,000	Maximum buildout				
TOTAL					

A - PROJECT MITIGATION AND DESIGN FEATURES
B - GENERAL REDEVELOPMENT AREA IMPROVEMENTS
C - REDEVELOPMENT AREA MITIGATIONS

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EXHIBIT "D"

SCOPE OF DEVELOPMENT

AR0068518

DESIGN STANDARDS FOR DEVELOPMENT

I. INTRODUCTION

The following design guidelines and standards (**"Design Guidelines"**) serve as the overarching plan controlling development of the Project. They are intended to enable the flexibility permitted in the Development Agreement while preserving and promoting comprehensive urban planning goals for the City and transportation-oriented development. They ensure that the transformation of the Development Site is compatible with the surrounding urban context by establishing parameters for all new physical improvements.

The Design Guidelines guarantee that the development of the entire Development Site is cohesive and developed as a unified development notwithstanding build-out over the Term of the Agreement.

The design principles underlying the Design Guidelines are:

a. historic preservation;

b. public open space and civic space;

c. pedestrian circulation;

d. preservation of view corridors to the Capital Records Building; and

e. maintenance of appropriate setbacks from Vine Street.

Further, the Design Guidelines establish standards specific to changes in the height of buildings whenever consistent with the permitted density as shown in Exhibit "E".

[The Development Guarantees and Development Guidelines will be completed with City and CRA input.]

II. OUTLINE OF DEVELOPMENT GUARANTEES

The Design Guarantees apply to any Phase of development permitted by the Agreement. Each Phase shall be developed to ensure compliance with the following Guarantees for the Project:

a Preservation of the Capitol Records Tower and Gogerty Building

b. Preserve public views to the Capitol Records Tower

c. Create unique retail at ground level to enliven all sidewalks and open space

d. Minimum set backs from Vine Street to preserve views of Capitol Records and create public open space

e. Civic plazas located on the east site adjacent to Vine Street and west site across from the Capitol Records Tower

f. Open space preserved along Vine Street frontage of east site to preserve views of the Jazz Mural and Capitol Records Tower

g. Through-block connections on both sites along Vine Street

h. Create a genuine Hollywood environment with lush landscaping for locals and visitors

i. Minimum ground floor open space will be 5% of total lot area of the Development Site

III. OUTLINE OF DEVELOPMENT GUIDELINES

1. Open Space

a. Emphasize green space networks

b. Open space connections to existing open space

2. Guidelines Based on Height

a. Building Heights Up to 150'

i. Massing established by protected view corridors and fire access

ii. Street wall and façade modulation up to 150'

iii. Subject to Zoning Standards (Section 3) and Building Design Parameters (Section 4)

b. Building Heights Up to 220'

i. Permitted for buildings with a maximum floor plate of 48% of lot coverage in designated zones up to 220'

ii. Subject to Zoning Standards (Section 3) and Architectural Guidelines (Section 5)

c. Building Heights Up to 400'

i. An additional 3% of open space must be provided. Minimum total open space is 8%.

ii. At least 50% of the floor area must be located below 220'

iii. Permitted for buildings with a maximum floor plate of approximately 28% of lot coverage between 220' and 400'

iv. Subject to Zoning Standards (Section 3) and Building Design Parameters (Section 4)

d. Building Heights Up to 510'

i. An additional 2% of open space must be provided. Minimum total open space is 10%.

ii. Permitted for buildings with a maximum floor plate of approximately 15% of lot coverage between 220' and 550'

iii. Subject to Zoning Standards (Section 3) and Building Design Parameters (Section 4)

e Building Heights Up to 585'

i. An additional 2% of open space must be provided. Minimum total open space is 12%.

ii. Permitted for buildings with a maximum floor plate of approximately 11.5% of lot coverage between 220' and 585'

iii. Buildings above 550' to include roof-top open space and viewing deck

iv. Subject to Zoning Standards (Section 3) and Building Design Parameters (Section 4)

3. Zoning Standards

a. Parking

i. Spaces Per Use

ii. Combination of Uses

iii. Design

iv. Bicycle Parking

1) At least one secure bicycle parking space shall be provided for every two residential units.

DESIGN STANDARDS FOR DEVELOPMENT

b. Setbacks

i. Side yard

ii. Rear yard

iii. Front yard

iv. Alleys

v. Lot Area

c. Open Space

i. Public Open Space – minimum 5% open space on ground floor

ii. Private Open Space

iii. Balcony Configuration

d. Loading

i. Except for the minimum ground level frontages required for all access, loading shall be screened from the view of adjacent public sidewalks and streets.

e. Access Driveways

4. Building Design Parameters

a. Materials and Colors

i. Materials, color, and fenestration of building frontages, located on or within 3' of a lot line facing a street, shall be similar to those found elsewhere in Hollywood.

ii. The building's masonry surfaces will be predominately light in color. Darker accent colors may be used to delineate building entrances and accents

iii. There will be clear contrast between the buildings surface materials and the building's glazed areas.

b. Rooftop and Parapets

c. Balconies

i. Balconies shall be integral to the building's form, mass, and or articulation.

d. Storefronts

e. Lighting

i. Exterior building lighting will be provided on all sides of the development to supplement street lighting.

ii. Lighting will be operated from dusk to dawn.

iii. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater.

iv. Steps and ramps will be lighted with a minimum of 1.0 foot candles on a horizontal plane.

v. Lighting approach will be consistent on each parcel with not more than 30' between elements.

vi. Building owner will be responsible for maintaining all lighting used to meet these requirements. No luminaries used to meet these requirements shall be out of commission for more than 10 days.

vii. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building owner.

f. Arcades

i. Arcades at grade will maintain a minimum of 10' clear height.

ii. Arcades will be lit with a minimum of 1.0 foot candles.

g. Roof Treatments

i. Roof of parking structures will be landscaped to the extent possible to provide outdoor space.

ii. Rooftops and setbacks will be designed to the extent possible with consideration for use as public or privately accessible open space.

iii. Roofs used for mechanical purposes will be designed to minimize attention by incorporating non-reflective and low contrasting colors.

iv. Mechanical equipment shall be completely screened from lateral and pedestrian views. Mechanical penthouses will be designed to be consistent with the building's architecture and will utilize similar colors and materials as in other portions of the building.

v. Enclosures for bulkheads shall not count against building height.

h. Relief of Scale

i. Canopies and Awnings

i. Canopies will be provided for primary residential entrances. 10' minimum and 20' maximum clearance will be maintained above sidewalks, plazas, or walkways. A minimum of 2' will be provided from the face of canopy to the face of curb. The maximum width of a single canopy will be 30'.

j. Landscape

i. Plant material will be selected for diversity, neat appearance, suitability to solar orientation, and relationship to fenestration. The mature size of any plants shall not project more than 12' beyond the face of planters below the height of 10' relative to the adjacent sidewalk.

ii. Kiosks, carts and temporary structures may be permitted within public open spaces. No roofs of such structure shall extend more than 4' in any one direction.

k. Maintenance

l. Exhausts

m. Trash Enclosures

5. Architectural Guidelines

a. Building Entries

b. Drop-offs

c. Windows and Glazing

d. Street Level Façade

e. Parking Garage Walls

f. Public Walkways

g. Street and Sidewalk Planting

6. Signage

a. Wayfinding

i. Projecting signs shall align with major building elements. The width of projecting signs shall not exceed 4'. The spacing of such signs shall be no less than 20' with the exception that each individual retail tenant may be allowed one projecting sign not to exceed 2' in width.

b. No Off-Site Advertising

i. No pole type signage shall be used.

ii. No more than one rooftop/skyline sign shall be used per building. Spacing between rooftop signs shall be at least 50'.

iii. Rooftop signs shall be setback at least 10' from property lines or building lines.

iv. Rooftop signs shall be oriented towards and parallel to Hollywood Boulevard or at corners at 45 degree angles to the Boulevard district grid.

v. Opaque message surfaces shall not be used.

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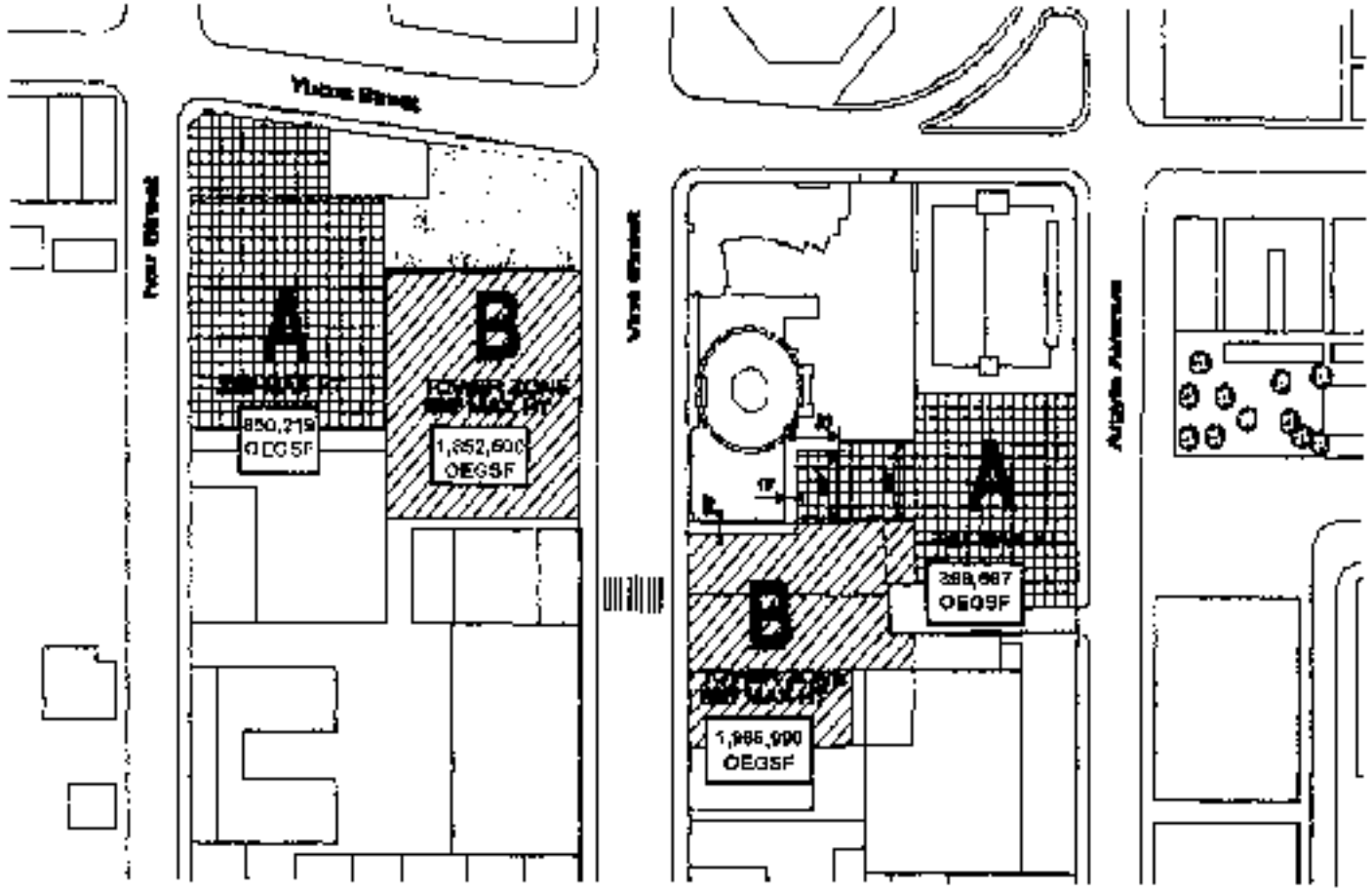
EXHIBIT "E"

MAXIMUM OEGSF DENSITY PER AREA

Arable
missing
per CASLD



Millennium Hollywood Towers

ZONE PLAN

HANDEL ARCHITECTS LLP &
KOHLBERG VAN CLEEF ARCHITECTS

NOTE: FOR DESCRIPTION ONLY – The square feet calculations shown are rough developments based on assumptions regarding number of floors and a building footprint equal to the boundaries of the zone. Regardless of the OEGSF amounts in each zone, the maximum allowable development for the Development Site will be 1,163,079 OEGSF.

CO-0001-353

AR0068527

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EXHIBIT "F"

AUTHORIZED USES

(To be provided.)

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EXHIBIT "G"

PROJECT DESIGN FEATURES

(To be provided.)

AR0068529

EXHIBIT "H"

DRAFT - FOR DISCUSSION PURPOSES ONLY

EXHIBIT "H"

ASSIGNMENT AND ASSUMPTION AGREEMENT

EXAMPLE FORM OF ASSIGNMENT AND ASSUMPTION
APPLICABLE TO ASSIGNMENTS OF LESS THAN ENTIRE DEVELOPMENT SITE

Recording Requested By and
When Recorded Mail To:

Allen, Matkins, Leck, Gamble & Mallory LLP
515 South Figueroa Street, 9th Floor
Los Angeles, California 90071-3398
Attn: Jerry Neuman, Esq.

Assignment And Assumption Agreement

This ASSIGNMENT AND ASSUMPTION AGREEMENT ("**Agreement**") is made and entered into by and between MILLENNIUM PARTNERS, _____ a _____ ("**Assignor**"), and _____, a _____ ("**Assignee**").

R E C I T A L S:

WHEREAS, the City of Los Angeles ("**City**") and Assignor entered into that certain Development Agreement dated as of _____, 2009 (the "**Development Agreement**"), and recorded in the Official Records of Los Angeles County, California (the "**Official Records**") on _____, 2009 as Instrument No. 00-_____, with respect to that certain real property located in the City of Los Angeles, State of California as more particularly described in Exhibit "A" attached hereto and incorporated herein by this reference which is referred to in the Development Agreement as the "**Development Site**;"

WHEREAS, pursuant to the Development Agreement, Assignor has obtained from the City certain development approvals and permits with respect to the development of the Development Site; and

WHEREAS, Assignor is entitled under Section 6.8 of the Development Agreement to assign all of its rights and obligations with respect to portions of the Development Site under the Development Agreement to Assignee; and

WHEREAS, the Community Redevelopment Agency of the City of Los Angeles ("**Agency**") and Assignor entered into that certain Owner Participation Agreement dated as of _____, 2009 (the "**OPA**"), a memorandum of which was recorded in the Official Records on _____, 2009 as Instrument No. 00-_____, with respect to the Development Site;

WHEREAS, pursuant to the Development Agreement and OPA, Assignor has obtained certain rights and benefits with respect to the development of the Development Site; and

WHEREAS, Assignor is entitled under Section _____ of the OPA to assign certain of its rights and obligations with respect to the Development Site or portion thereof under the OPA to Assignee: and

WHEREAS, Assignor desires to assign to Assignee all (except as provided below) of Assignor's right, title, and interest in and to the Development Agreement and the OPA with respect to that portion of the Development Site more particularly described in Exhibit "B" attached hereto and incorporated herein by this reference (the "**Property**"); and

WHEREAS, Assignee desires to accept such assignment from Assignor and assume the obligations of Assignor under the Development Agreement with respect to the Property;

NOW, THEREFORE, in consideration of the foregoing recitals and for good and valuable consideration, the receipt of which is hereby acknowledged, the parties hereto agree as follows:

1. ASSIGNMENT BY ASSIGNOR TO ASSIGNEE.

1.1 ASSIGNMENT. Assignor hereby assigns and transfers to Assignee Assignor's right, title, and interest in and to the Development Agreement with respect to the Property, and Assignee hereby agrees to and does accept such assignment from Assignor. Such assignment includes delegation to Assignee of all of Assignor's obligations with respect to the Property and the allocation from Assignee to Assignor of the following development rights under the Development Agreement and the OPA:

1.1.1 Density. Assignee, its successors and assigns shall be entitled during the Term of the Development Agreement to develop and construct not more than _____ thousand (___, ___) square feet of Improvements (as such term is defined in the Development Agreement) on the Property in accordance with the Development Agreement (the "**Entitled Density**"). Nothing herein shall prohibit the Assignee from constructing less improvements containing less than the Entitled Density or from agreeing with the City to a reduction in the Entitled Density of the Property;

1.1.2 OEGSF. For purposes of compliance with the EIR (as defined in the Development Agreement), _____ square feet of "office equivalent gross square footage" or "**OEGSF**" (as defined in the Project EIR) shall be allocated to the Property, notwithstanding that the actual uses of Improvements hereafter constructed on the Property in accordance with the Development Agreement may not be office uses (the "**Maximum OEGSF**"). The Maximum OEGSF constitutes the maximum allowable density which may be constructed on the Property in compliance with the Project EIR; however, Assignee shall not be prohibited from consuming less or from releasing unused OEGSF on the Property to the City or with the City's consent to the owners of other properties. Notwithstanding the foregoing, Assignor agrees that it shall have no further right to use any portion of the Maximum OEGSF in connection with the development on its retained property, if any, even if the Assignee uses less than the Maximum OEGSF for development of the Property;

1.1.3 Further Assurances regarding Allocations. Each of Assignor and Assignee hereby covenant that it will, at any time and from time to time, upon written request therefore,

execute and deliver to the other party, such other party's successors, nominees and assigns, any new or confirmatory instruments which such other party, such other party's successors, nominees and assigns may reasonably request in order to fully assign and transfer to and vest in such other party, or such other party's successors, nominees and assigns, and to protect such other party, or such other party's successors, nominees and assigns right, title and interest in and to the Entitled Density and the Maximum OEGSF and retained density and OEGSF and otherwise realize upon or enjoy such rights in and to the Entitled Density and the Maximum OEGSF and retained density and OEGSF.

1.1.4 Specific Rights under the OPA. This Assignment includes all of Assignor's rights as "Participant" under the OPA with respect to the Property except for the following rights of Assignor, which are hereby reserved:

_____

_____

_____

_____

1.2 ASSUMPTION. Assignee expressly assumes and agrees to keep, perform, and fulfill all of the terms, conditions, covenants, and obligations required to be kept, performed, and fulfilled by Assignor under the Development Agreement and the OPA with respect to the Property. Assignee agrees to indemnify and hold harmless Assignor from any cost, liability, damage or expense (including attorneys' fees) arising out of or relating to Assignee's failure to perform any of the foregoing obligations assumed by Assignee hereunder.

2. EFFECTIVE DATE OF ASSIGNMENT. Said assignment and assumption shall be effective upon the recordation of this Agreement in the Official Records. From and after such effective date, the Assignee shall be the Developer under Development Agreement with respect to the Property subject and the Participant under the OPA with respect to the Property, subject to all of the terms and conditions in each such agreement to the extent they relate to the Property.

3. AGENCY AND CITY THIRD PARTY BENEFICIARIES. The Agency and the City shall be third party beneficiaries of this Agreement.

4. MISCELLANEOUS. In the event of the bringing of any action or suit by a party hereto against another party hereunder by reason of any breach of any of the covenants, conditions, agreements or provisions on the part of the other party arising out of this Assignment, then in that event the prevailing party shall be entitled to have and recover from the other party all costs and expenses of the action or suit, including reasonable attorneys' fees. This Assignment shall be binding upon and inure to the benefit of the successors, assignees, personal representatives and heirs of all the respective parties hereto. This Assignment shall be governed by, interpreted under, and construed and enforceable in accordance with, the laws of the State of California.

IN WITNESS WHEREOF, the parties hereto have executed this Assignment and Assumption Agreement as of the dates set forth next to their signatures below.

[SIGNATURES CONTINUED ON NEXT PAGE]

"ASSIGNOR"
MILLENNIUM PARTNERS
_____, a _____

Date: _____, ____

By: _____
Its: _____

Date: _____, ____

By: _____
Its: _____

"ASSIGNEE"

Date: _____, ____

By: _____
Its: _____

Date: _____, ____

By: _____
Its: _____

DRAFT – FOR DISCUSSION PURPOSES ONLY

From: "Kearns, Rick" <rkearns@handelarchitects.com>
To: "Blake Lamb" <Blake.Lamb@lacity.org>
CC: "Jon Tanury" <Jon.Tanury@lacity.org>, "Handel, Gary" <ghandel@handelarch...
Date: 3/24/2010 9:17 AM
Subject: RE: Millennium Towers Hollywood
Attachments: FAR Axonometrics.pdf; FAR PLAN.pdf

Blake - here are the FAR studies for each height. We did layouts for residential use and office use to show how the bulk will differ - typically residential plates are only 70 feet wide and square footage between 9K - 12K. Office plates are 110 -120 feet wide and square footage between 20K - 25K. We did not produce office schemes above 400 feet because the lot coverage restrictions above 400 feet make an office tower impractical on either site.

17, 3rd to LA

We will send street wall diagrams later today

We are working out the schedule with our trip to LA, ownership had a conflict and is planning to be out the following week, April 13, but I am out of town that week. I will let you know after I had a chance to confirm schedules with all parties. If it does move to the 13th, would that work for you?

Thanks

Rick Kearns
Senior Associate

HANDEL ARCHITECTS LLP

----Original Message----
From: Blake Lamb [mailto:Blake.Lamb@lacity.org]
Sent: Tuesday, March 23, 2010 6:37 PM
To: Kearns, Rick
Cc: Handel, Gary; Jon Tanury
Subject: Re: Millennium Towers Hollywood

Hi Rick,
Actually I take back what I said about Weds - the best time would be April 6 around 1 pm. Thanks,
Blake

>>> "Kearns, Rick" <rkearns@handelarchitects.com> 3/23/2010 7:58 AM >>>
Blake - we are finishing up the diagrams you had requested (FAR massing at each height, street wall, through block connections) and will forward them to you within the next couple of days. We are also revising text pursuant to our meetings and follow-up discussions with ownership and should have them to you next week. We were planning another trip out to LA in early April and wanted to set up a meeting with you, John and Kevin. The purpose of the meeting would be to review any open items within the design guidelines and hopefully come to a mutual agreement on the text and diagrams. We would also use the meeting to outline our next steps.

Will April 6 or 7 work for you and your team?

Thanks

Rick Kearns

Senior Associate

HANDEL ARCHITECTS LLP

150 Varick Street

New York, NY 10013

t 212 595 4112

f 212 595 9032

www.handelarchitects.com

From: "Kearns, Rick" <rkearns@handelarchitects.com>
To: "Blake Lamb" <Blake.Lamb@lacity.org>
CC: "Jon Tanury" <Jon.Tanury@lacity.org>, "Handel, Gary" <ghandel@handelarch..
Date: 3/25/2010 8:23 AM
Subject: RE: Millennium Towers Hollywood
Attachments: Balcony.pdf; PAPS.pdf; Street wall.pdf; Open Space.pdf

Hi Blake - here are the diagrams for street wall, open space (grade level setbacks) and publically accessible private space (PAPS). The PAPS diagrams also include photo examples of an enclosed PAPS and an open air PAPS. We also included refined language for the balcony and photo examples to help clarify what integral means. Let me know if you want to call and discuss the diagrams.

Regards,

Rick Kearns
Senior Associate

HANDEL ARCHITECTS LLP

----Original Message----
From: Blake Lamb [mailto:Blake.Lamb@lacity.org]
Sent: Tuesday, March 23, 2010 6:07 PM
To: Kearns, Rick
Cc: Handel, Gary; Jon Tanury
Subject: Re: Millennium Towers Hollywood

Dear Rick,
That is great, we look forward to receiving them. April 6 looks a little better since Wednesdays here are often busy, but either one is ok.
Blake

>>> "Kearns, Rick" <rkearns@handelarchitects.com> 3/23/2010 7:58 AM >>>
Blake - we are finishing up the diagrams you had requested (FAR massing at each height, street wall, through block connections) and will forward them to you within the next couple of days. We are also revising text pursuant to our meetings and follow-up discussions with ownership and should have them to you next week. We were planning another trip out to LA in early April and wanted to set up a meeting with you, John and Kevin. The purpose of the meeting would be to review any open items within the design guidelines and hopefully come to a mutual agreement on the text and diagrams. We would also use the meeting to outline our next steps.

Will April 6 or 7 work for you and your team?

Thanks

Rick Kearns

Senior Associate

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New York, NY 10013

t 212 595 4112

f 212 595 9032

www.handelarchitects.com

HANDEL ARCHITECTS LLP

Millennium Towers
Vine Street & Yucca Street

Outline for the Development Agreement

1. Building Height and Massing
   a. Street wall
   b. Setbacks
   c. Tower width controls and Orientation
   d. Transitional Heights

2. Open Space
   a. Public open space
      i. Across from Capitol Records
      ii. Jazz Mural
   b. Residential open space
      i. Balconies
      ii. Roof decks / viewing park

3. View Corridor
   a. Capitol Records

4. Articulation and Fenestration
   a. Storefront
   b. Podium
   c. Tower

5. Landscape
   a. Street Elements
   b. Roof decks

6. Pedestrian Linkage
   a. Through block connections
   b. Circulation
      i. Ingress into buildings
      ii. Connection between city and site

7. Parking
   a. Requirements
   b. Location and Size
   c. Screening
   d. Circulation
      i. Ingress into parking facility
      ii. Connection between city and site

8. Service and Loading
   a. Requirements
   b. Location and Size
   c. Screening

9. Signage
   a. Types
   b. Location

materials, colors

Equivalency matrix
- table, graphics, concept design narrative

NEW YORK
SAN FRANCISCO
150 Varick St, 8th Fl New York, NY 10013 t 212 595 4112 f 212 595 9032 www.handelarchitects.com

3/9

Conference call w/ Rick Kenny

Design Guidelines
March 1, 2010

3. BUILDING HEIGHT AND MASSING

A. Street Wall

a. Design intent: required street walls determine the scale and character of the pedestrian environment. Articulation of the required street wall within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation.

b. Location of a required street wall:
   (i) Parcels with a grade level setback, the required street wall shall be located minimum 5 feet from the street line.
   (ii) Parcels or portions of parcels without a grade level setback, the required street wall shall be located on the street line.

c. Height of required street wall and dimension of initial setback
   (i) Street walls shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level with a minimum 10'-0" setback except as noted in item (ii) below.
   (ii) 40% of aggregate width of required street wall frontage on each street can exceed maximum street wall height up to the maximum building height.

d. Amount of articulation of required street wall.
   (i) The aggregate width of recessed street wall articulation at the level of any story shall not exceed 50% of the required street wall above the level of the second story ceiling or 28'-0" above curb level, whichever is less, to the floor level of the penultimate floor within the required street wall height within the lesser of 2 stories or 28'-0" above curb level. recesses, balconies and bay windows shall not be permitted. Pedestrian pass through, public plazas, entry forecourts, permitted vehicular access driveways, hotel drop-offs and loading entries and exits are permitted; steps, ramps, marquees, canopies, awnings and retail storefronts are permitted.

required street wall length?

e. Types of permitted articulation of a required street wall.
   (i) Recess, recesses shall be permitted to a maximum depth of 15'-0" with a 1:2 maximum depth to width ratio.
   (ii) Balcony, a balcony may project a maximum of 4'-0" from a required street wall over a grade level setback and each balcony may have a maximum length of 12'-0".
   (iii) Bay window: a bay window may project a maximum of 4'-0" from a required street wall over a grade level setback and each may have a maximum length of 12'-0".
   (iii) Expression band: an identifiable break should be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

f. Other permitted projections: elements which project beyond the street line from a required street wall shall comply with the Building Code.

req open space — what does it mean — exclusive of property line — consistent elsewhere?

(i) Architectural facade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required street wall over a grade level setback by a maximum depth of 3'-0".

(ii) Steps and ramps may project from a required street wall over a grade level setback by a maximum depth of 5'-0"

(iii) Marquees, canopies and awnings: see Section xx

(iv) Retail storefronts may project from a required street wall over a grade level setback by a maximum depth of 5'-0". The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less

why?

B. Yards

a. Notwithstanding the requirements set forth in the LA Municipal Code, no building shall be required to provide front, side or rear yards

? this means what setback is? open space, building

C. Tower Controls

a. Design Intent.

- Towers should have their massing designed to reduce overall bulk and to appear slender
- Towers should be designed to achieve a simple faceted geometry and exhibit big, simple moves. They should not appear overwrought or to have over-manipulated elements.
- Towers that emulate a more streamline modern style should provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.
- If a project has more than one tower, they should be complementary to each other and employ the same architectural design approach.
- Generally, buildings over 150 feet tall (the historic datum for Hollywood) should not be historicized. They are contemporary interventions in the skyline and should appear as such.

do we want this?

b. Tower location: a tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

c. Setback and articulation of tower walls and crown

(i) Towers may extend directly up from up from the property line at the street and are not required to setback.

(ii) Minimum 10% of tower wall required to be articulated.

(iii) Distinctive tower crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical-equipment enclosure.

maybe?

d. Types of permitted articulation of a tower wall.

(i) Recess
(ii) Balconies
(iii) Bay windows

same guidelines as for structure?

e. Tower spacing

(i) Towers should be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.

(ii) ~~Generally~~, the portion of a tower above 150 feet shall be spaced at least 80 feet from all existing or possible future towers, both on the same block and across the street, except where 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled.

(iii) Where there is an existing adjacent tower, the distance should be measured from the wall of the existing adjacent tower to the proposed tower. Where there is no existing adjacent tower, but one could be constructed in the future, the proposed tower must be 40 feet from an interior property line and 40 feet from the alley center line shared with the potential new tower.

D. Maximum Building Height

a. For permitted maximum building height on each parcel as established in Figure xx *Designated Tower Zones*. The following are permitted obstructions which may penetrate the maximum building height: chimneys or flues; elevator or stair bulkheads, roof water tanks or cooling towers (including enclosures), flagpoles or aerials; ornamental church towers having no habitable floor area; parapet walls not more than 4'-0", spires or cupolas, wire, chain link, or other transparent fences.

[Insert] Figures for Tower Zone and Massing Diagrams

4. OPEN SPACE

A Grade Level Setback

a. Design intent: the purpose of a grade level setback is to provide a landscape amenity across from Capitol Reef Park, preserve views of the Taos Mural, accentuate the low scale character and punctuate the rhythm of entries with projecting raised planting areas.

b. Open space requirements

(i) Minimum ground floor open space will be 5% of total lot area of the Development Site for buildings up to a height of 220 feet. An additional 3% of open space (total 8%) required for buildings between 221 feet and 400 feet. An additional 5% (total 10%) of open space to be required for buildings between 401 feet and 550 feet and an additional 2% (total 12%) of open space required for buildings taller than 550 feet.

c. Materials

(i) Raised planters shall be faced on all exposed sides with stone or masonry compatible with the building façade materials.

(ii) Plant material shall be selected for suitability to solar orientation, heat appreciation, relationship to fenestration and seasonal diversity. The mature size of any plant shall not project more than 12" beyond the faces of the planter below a height of 10 feet above the adjacent sidewalk.

d. Permitted obstructions: the following are permitted obstructions which may occur in the grade level setback:
   (i) Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, and retail storefronts.

e. Other requirements:
   (i) Each planted area shall have provision for proper drainage and shall be equipped with waterproof electrical outlets and exterior water sources at a maximum interval of 50 feet or a minimum of one in each setback area.

B. Common Open Space – Residential Use Only

a. Design intent: a common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children, and to be visually attractive when viewed from apartments adjacent and above.

b. Size of common open space:
   (i) To qualify as private open space, the area shall be primarily at one level, have no dimension less than 15 feet, and be structurally designed to accommodate weight loads required for landscaping.
   (ii) The landscaped area shall comprise a minimum of 25% of the total private open space square footage. The remaining area shall have a durable, attractive paved surface.

c. Location of common open space:
   (i) Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use shall be considered as private open space.
   (ii) Buildings above 550 feet to include roof-top open space and viewing deck.

d. Access to common open space:
   (i) Common open space shall be directly accessible to all residents on the parcel through a lobby connecting to each elevator core. Such spaces shall be accessible to the handicapped. Ramps, elevators, corridors and doors shall be designed to accommodate wheelchairs.
   (ii) Common open space shall be accessible only from the residential portion of the building.
   (iii) At least 35% of each door to a common open space shall be transparent.

e. Permitted obstructions: the following are permitted obstructions which may occur in a common open space.
   (i) Terraces, balconies, bay windows, architectural facade details, accessory noncommercial greenhouses, planting boxes, steps and ramps for access by the hand capped, vents, bulkheads or other mechanical equipment, projecting not more than 5'-0".
   (ii) Eaves, gutters, or downspouts projecting not more than 26",
   (iii) Arbors, trellises, fences, flag poles, awnings or canopies,
   (iv) Chimneys projecting not more than 3'-0"; and
   (v) Recreational equipment.

f. General requirements:

(i) For every twenty (20) apartments on the parcel one fixed seat with a back shall be provided in private open space.

(ii) Common open spaces shall be separated from all apartments and outdoor areas serving individual apartments by a 4 foot high opaque fence, wall or year round screen of densely planted shrubs located at least 6 feet from a window or door of an apartment.

(iii) Areas with play equipment for young children may be provided. Play areas shall not be located within 20 feet of a residential unit and shall be visually and acoustically buffered from residential units and other non planter areas.

(iv) Vents, bulkheads or other mechanical equipment penetrations shall be located so as not to obstruct access to and usefulness of the private open space.

(v) Surface finishes of projecting structures shall be finished with materials compatible with vertical building materials.

(vi) No exhaust vents are permitted unless such intakes and vents are more than 10'-6" above the level of the private open space.

g. Landscape requirements:

(i) The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.

(ii) The minimum soil depths for planting are:

- Trees: 36"
- Shrubs: 30"
- Lawns, ground cover: 18"

deepen ?

(iii) Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

(iv) Planting requirements:

1. For each 400 square feet of landscaped area there shall be at least one (1) major shade tree or two (2) minor trees.
2. The remaining landscaped area(s) shall be planted with seasonally diverse plant material appropriate for rooftops.
3. The landscaped area(s) shall be located such that they receive a minimum of 4 hours of direct sunlight as calculated on June 21.
4. The landscaped areas shall be contained by durable planters to accommodate the requirements specified in (i) above. Planters may be designed with a coping to provide additional seating if the coping is minimum 12" wide and does not exceed 18" in height. Planters may also be partially recessed into roof slab provided the overall requirements of (ii) above are met.

(v) Furnishings:

1. Furnishings such as seating, tables, gazebos or other shade structures are encouraged. Furnishings may be movable or fixed. If fixed, they shall be oriented to provide maximum variety in relationship to planted areas, sun and shade.

2. Surfacing beneath play equipment for young children shall comply with Federal safety standards and equipment shall be anchored in accordance with manufacturer's guidelines.
3. Provision for outdoor lighting: refer to Section xx.

C. Publicly Accessible Private Space (PAPS)

a. Design intent: a continuous through block connection, located on privately owned land, designated for and designed to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

b Location and size requirements:
i) 15'-0" minimum width and at least 50% open to the sky shall be provided along the entire southern side of western parcel and northern side of eastern parcel.

think about this width?

c Permitted obstructions:
i) Any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art; arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains and bicycle racks; open air cafes, kiosks, outdoor furniture, lights and lighting; stanchions, flag poles; public telephones; temporary exhibitions; balconies, bay windows, awnings, canopies and marquees; stairs, ramps and bollards.

Very well-proportioned

d Kiosk:
i) Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Buildings in conformance with the Building Code. Kiosks, including roofed areas, shall not exceed 3% of the total area of the PAPS and no one kiosk shall occupy an area of more than 250 square feet. A kiosk may be freestanding or may be attached on only one side to a wall of the building. Any area occupied by a kiosk shall be excluded from the definition of floor area, and may be occupied by news or magazine stands, candy stands, food preparation for open air cafes, flower stands or public service/information booths. Lighting and signage of kiosks shall conform to Section xx. Retail Guidelines

plazas?

e. Open air cafe:
i) Where an open air cafe is provided it shall be an unenclosed restaurant or eating or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies. An open air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the PAPS. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers. An open air cafe may occupy an aggregate area not more than 20% of the total area of the PAPS. No cooking equipment shall be installed within an open air cafe. Cooking equipment may be contained in a kiosk adjoining the open air cafe. An open air cafe qualifying as a permitted obstruction shall be

excluded from the definition of floor area. Lighting and signage of an open air cafe shall conform to Section xx, Retail Design Guidelines.

f. Service through windows:

(i) Outdoor eating services or just occupying kiosks may serve customers on PAPS through open windows.

g. Prohibition of parking spaces, loading bonths, exhaust vents and building refuse storage areas.

(i) No buildings refuse storage areas or refuse storage from a kiosk or open air cafe are permitted on any PAPS.

(ii) No exhaust vents are permitted on any PAPS or on any building wall of the development fronting upon the PAPS except where such vents are more than 10' 6" above the level of the PAPS.

h. Landscape requirements:

(i) The landscaped portion may be designed as a single area or multiple planter areas. The minimum size of a single planted area shall be 100 square feet.

(ii) The minimum soil depths for planting are:

- Trees: 36"
- Shrubs: 30"
- Lawns, ground cover: 18"

(iii) Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

(iv) Planting requirements:

1. Minimum of 10% of PAPS shall be landscaped.
2. For each 400 square feet of landscaped area there shall be at least one (1) major shade tree or two (2) minor trees.
3. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

(v) Seating:

1. There shall be a minimum of one linear foot of seating for each 1000 square feet of PAPS excluding the area of an open air cafe. Not more than 50% of the linear seating capacity may be in moveable seats which may be stored between the hours of 7 p.m. and 7 a.m. Seating shall meet the following standards.
2. Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count double provided there is access to both sides.
3. Seating higher than 35" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.
4. The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

5. Moveable seating or chairs, excluding seating of open air cafes may be credited as 30 inches of linear seating per chair. Stools and seating in open air cafes do not count toward meeting the seating requirements

h. Lighting:

(i) A PAPS shall be illuminated throughout with an overall minimum average level of illumination of not less than one maintained foot candle (lumens per square foot) on the horizontal plane at grade. Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

i. Electrical power:

(i) Electrical power shall be supplied by one or more outlets furnishing a total of at least 3,000 watts of power for every 4,000 square feet, or fraction thereof, of a PAPS for maintenance equipment, special events and retail uses (kiosks, open air cafes, carts).

j. Signs:

(i) A PAPS shall be treated as a street for the purpose of the applicable sign regulations. Signs are permitted only accessory to uses permitted within and abutting the PAPS.

k. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a PAPS shall be allocated for occupancy by permitted retail, restaurants and cultural uses. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the PAPS with an entrance required every 50' as a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

l. Maintenance:

(i) Responsibility: the building owner shall be responsible for the maintenance of the PAPS including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the parcel and in the street sidewalk area adjacent to the parcel.

(ii) Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of PAPS area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of PAPS in connection with outdoor eating services or other uses permitted on PAPS which generate litter.

6. ARCHITECTURAL ELEMENTS

A. Building Materials and Color

a. Design intent: these Design Guidelines define the general design objectives for the material and color of distinct portions of the buildings and prescribe the treatment required for both residential and commercial portions of the building.

b. Guidelines.

AR0068547

(i) Feature long-lived and sustainable materials. The material palette should provide variety, reinforce massing and changes in the horizontal or vertical plane.

(ii) Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.

(iii) Podium levels up to 150 feet that include surfaces of masonry will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents. There will be clear contrast between the buildings surface material and the building's glazed areas.

(iv) Expression band shall be provided at the highest story within the podium.

(v) The building's skin, especially for towers, should be primarily transparent, the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.

(vi) In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style.

(vii) To provide visual variety and depth, layer the building skin and provide a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin should reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.

(viii) Rooftop mechanical equipment shall be screened with materials and design consistent with the building architecture; see Section xx Tower crown.

(ix) Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

B. Grade Level Controls

a. Design intent:

(i) Street wall massing, articulation and detail, street level building entrances and storefront windows and doors, as well as the use of quality materials and decorative details, shall be used to promote pedestrian-scaled architecture along the street. Architectural features that reinforce the retail character of the ground street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings and overhangs, are encouraged and should be integral to the architecture of the building.

b. Ground floor height:

(i) Minimum 12'-0" height floor to ceiling.

c. Building entrances.

(i) The primary entrance to a street level tenant that has frontage along a public street shall be provided from that street. The primary entrance to a tenant that does not have its frontage along a public street shall be provided from a courtyard, plaza, or through block passage. Entries shall not be higher than 9 feet above the elevation of the sidewalk at its nearest

point to the entry. Where possible entries shall be marked through the use of architectural elements such as porches, gateways, entry alcoves, awnings, raincoles, or portals.

(b) Main building entrances should read differently from retail storefronts, restaurants and commercial entrances.

(c) See Section xx marquees, canopies, awnings; Section xx for signage controls, and Section xx for lighting controls.

d. Ground floor glazing:

(i) Where any building wall adjoins a street line or grade level setback, at least 25% of the total surface area of such wall between curb level and 12' above curb level or to the ceiling of the ground floor, whichever is higher, shall be transparent. Door or window openings or unglazed openings within such walls shall be considered as transparent. Such openings shall have a minimum width of 2'-0". The lowest point of any transparency that is provided to satisfy the requirements of this section shall not be higher than 4'-0" above the curb level. Retail store/and ground floor glazing requires at least 50% transparency.

(ii) Any portion of such building wall, 50' or more in length, which contains no transparent elements between curb level and 12' above curb level or the ceiling of the ground floor, whichever is higher, or to its full height, shall be covered with vines or similar planting or contain art work or be treated so as to provide visual relief.

e. Arcades:

(i) Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0 foot candles.

f. Service and refuse:

(i) Refer to Section xx Central Garbage Collection & Recycling

(ii) All refuse, except materials to be recycled, shall be mechanically compacted in accordance with applicable law. The storage of refuse shall occur entirely within an enclosed area on the parcel and appropriate locations within the parcel shall be delineated for this purpose: at least one for residential use and one for community facility and retail uses. Developments shall store compacted refuse in an on-site container acceptable to the Department of Sanitation. Each parcel shall have a minimum of one on-site loading berth; refer to Section xx Loading. A refuse disposal room meeting ADA requirements for access shall be provided on each story that has a corridor with two (2) or more entrances to apartments. The refuse disposal room shall contain vertical chute and bin containers and shelf space for the storage of recyclable materials. Each such refuse storage room and the central refuse storage and disposal room on each parcel shall be excluded from the definition of floor area.

(iii) Storage areas within the building of a size sufficient for that development to ensure that refuse is stored and loaded off street. Refuse storage areas shall be directly and conveniently accessible to a curb cut; refer to Section xx Loading.

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g. Retail storefronts:
   (i) Openings for storefronts. Windows and doors shall comprise a minimum of 40% of the building's street level façade and be recessed where necessary.
   (ii) Ground floor retail space will be a minimum of 20 feet deep and 12 feet clearance in height and have storefronts openings a minimum of 10 feet in height. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet.
   (iii) Security grills will be located behind glass and be at minimum 80% open.
   (iv) Storefront glazing will be transparent.

C. Podium Controls

a. Podium height.
   (i) Minimum 30' 0" to a maximum of 150 feet, exclusive of the ground floor level.

b. Guidelines
   (i) Provide an identifiable break between the building's ground floors and upper floors. This break may include a change in material, change in fenestration pattern or similar means.
   (ii) Facades directly on the property line and facing a street will be vertically articulated by establishing different treatments for the building's base, middle and top through the use of balconies, projections, recesses, fenestration, or other elements.
   (iii) While blank street wall façades are prohibited, an exception may be made for integration of public artwork or graphics based façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade should be a maximum of four floors high, and should have variation in its surface plane (inlay cut outs, insets or pop outs). It should employ different scales of elements as viewed when seeing the entire building massing.

D. Marquees, Canopies, Awnings

a. Location by use.
   (i) Residential use: marquee or canopy shall be provided at the primary building entrance, canopy or awning is permitted at secondary entrances.
   (ii) Community facility use and professional office: canopy or awnings permitted.
   (iii) Commercial use: marquees or canopies are discouraged and shall only be permitted for office use. Marquees or canopies shall be permitted for hotel use. Awnings shall be permitted for retail use.

b. Marquees
   (i) 10'-0" minimum clear height and a maximum height of 20 feet shall be provided above the sidewalk; 2'-0" minimum horizontal distance from face of curb. Maximum width permitted of a marquee is 30 feet.

c. Canopies, awnings.
   (i) 8' 0" minimum clear height and a maximum height of 20 feet shall be provided above the sidewalk; 2'-0" minimum horizontal distance from face

of curb. Maximum continuous length permitted is 15', with a minimum of 2'-0" spacing between awnings.

(i) Awnings and canopies shall be fabricated of woven fabric, glass, metal or other permanent material compatible with the building architecture. Internally illuminated, vinyl awnings are not permitted.

E. Fenestration

a. Louvers, wall openings, shall be designed to integrate with building architecture.

F Rooftops and setbacks

a. General requirements:

(i) Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and to be visually attractive when viewed from locations adjacent and above.

(ii) For rooftops to be developed as usable outdoor area refer to requirements specified under private open space, Section xxx.

(iii) All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors. All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

(iv) Rooftops and setbacks adjacent to residential units. (1) Rooftops and setbacks exceeding 50 square feet shall be finished with materials suitable for use and landscaping. (2) Paving materials shall be durable; slope of surface shall not exceed 3%. (3) Waterproof electrical outlets and exterior water source shall be provided for each residential unit or at 50' intervals if a single unit abuts a rooftop or setback greater than 50' in length.

G. Parapets, Handrails, Roof Mechanical Equipment Screening

a Parapets and handrails: if part of an expression band or expression line, shall be finished in a distinctive manner.

b. Roof mechanical equipment, shall be screened; materials and design to be consistent with the building architecture and will utilize similar colors and materials as in other portions of the building. Enclosures for bulkheads shall not count against building height.

8.1 Requirements
8.2. Location and Size
8.3. Screening
8.4. Circulation

9. SIGNAGE

9.1 Guidelines

10. SUSTAINABILITY

10.1. LEED Certification

11. LIGHTING

12. NOISE

13. OPERATIONAL STANDARDS

13.1 Pet Controls
13.2. Antennas
13.3 Wireless Facilities

Design Guidelines
March 1, 2010
Revised April 8, 2010

1. INTRODUCTION

1.1. Purpose of Guidelines

1.1.1. The Design Guidelines ("Guidelines") have been prepared to regulate new development on the site with design guidelines and controls for development.

a. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project. The Design Guidelines establish basic site-wide design standards and criteria which serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

b. Permit design flexibility while establishing a vocabulary which will guide the development for the Project site.

c. Consolidate and illustrate the implications of the established practices which will govern the physical development of the two sites, defining the standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

1.2. Goals and Objectives

1.2.1. The Design Guidelines serve to reinforce the design principles which will contribute to the shape of a successful project.

1.2.2. Those principles are as follows:

a. Preservation of the Capitol Records Tower and Gogerty Building.
b. Preserve public views to the Capitol Records Tower by creating *grade level setbacks*, civic plazas, on the east site adjacent to the Jazz Mural and Capitol Records Tower and west site across from the Capitol Records Tower.
c. Create civic plazas that are activated by retail, landscaped and enhance the Hollywood Walk of Fame by providing it as an urban node: creating The Hollywood Walk of Fame Plaza.
d. The reinforcement of the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.
e. The preservation of existing view corridor to the Hollywood hills.
f. The encouragement of street life by the creation of a new exclusive pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.
g. The creation of vibrant urban spaces which permit active and passive recreational facilities for both the on-site and off-site population.
h. The creation of a 24 hr community by the creation of a Thriving Mixed-Use Development.
i. Eliminate the visual impact of the current on site parking.
j. TRANSPORTATION – awaiting comments from CPDI
k. The establishment of a standard intended to promote architectural excellence.
l. Provide designs that take into account the context and make an effort to respect it and fit in visually.

m. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.
n. The creation of two buildings that emphasize the vertical architecture and become a visible icon and gateway to Hollywood Boulevard from the Hollywood Freeway.

1.3. Relationship to the Los Angeles Municipal Code

1.3.1. The Guidelines were prepared in coordination with the Los Angeles City Planning Department and approved by the City Council.

1.3.2. Whenever the Guidelines contain provisions which establish regulations that are different from or more or less restrictive than allowed in the Los Angeles Municipal Code (LAMC) the Guidelines shall prevail pursuant to the Development Agreement approved by the City Council for the Project.

2. PROJECT BACKGROUND

2.1. Existing Site

2.1.1 The Project site consists of eight parcels on 4.47 acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street. The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site. The area bounded by Yucca Street, Vine Street and Argyle Street is the East Site. The East Site and the West Site make up the Project Site. The Project site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 13 feet from Vine Street to Argyle Avenue and 11 feet from Vine Street to Ivar Avenue. The existing sidewalk elevations will not be altered as part the Project.

2.2. Zoning Classification

2.2.1. Classification: C2-2-SN (Proposed) within the Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency (CRA) of the City of Los Angeles.
- Currently zoned as a C4-2D-SN

2.2.2. The City General Plan land use designation: Regional Center commercial.

2.2.3. FAR: 6:1 (proposed)
- FAR 3:1 under "D" development limitation
- 4.5:1 under CRA Redevelopment Plan

2.3. Transfer of Floor Area

2.3.1. Owner may transfer floor area from one site to the other, as long as the minimum and maximum building heights are maintained. Either parcel can exceed the 6:1 FAR, as long as the FAR of the combined sites averaged together is no more than 6:1

2.4. Maximum OESF Density Per Area

2.5. Use Coordination / Use Compatibility

3. BUILDING HEIGHT AND MASSING

3.1. Street Wall

3.1.1. Definition of *street wall*: a wall or portion of a wall of a building facing a street or *a grade level setback*.

3.1.2 Design intent: required *street walls* determine the scale and character of the pedestrian environment. Articulation of the required *street wall* within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation.

3.1.3. Location of a required *street wall*:

a. Parcels with a *grade level setback*: the required *street wall* shall be located a minimum 5 feet from the property line.

b. Parcels or portions of parcels without a *grade level setback*: the required *street wall* shall be located on the property line.

3.1.2. Height of required *street wall* and dimension of initial setback:

a. *Street walls* shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b) and (c) below.

b. 40% of aggregate width of required *street wall* frontage on each street can exceed maximum *street wall* height up to the maximum *tower* height.

c. 40% of aggregate width of required *street wall* frontage on a *publicly accessible private space* can exceed maximum *street wall* height up to the maximum *tower* height.

3.1.3. Amount of articulation of required *street wall*:

a. The aggregate width of required *street wall* articulation at the level of any story shall not exceed 50% of the required *street wall* above the level of the second story ceiling or 28'-0" above curb level, whichever is less, to the floor level of the penultimate floor within the required *street wall* height. Within the lesser of 2 stories or 28'-0" above curb level, recesses, balconies and bay windows shall not be permitted. Pedestrian pass-through, public plazas, entry forecourts, permitted vehicular access driveways, porte cochere drop offs and loading entries and exits are permitted; steps, ramps, marquees, canopies, awnings and retail storefronts are permitted.

3.1.4. Types of permitted articulation of a required *street wall*:

a. Recess: recesses shall be permitted to a maximum depth of 15'-0" with a 1:2 maximum depth to width ratio.

iii. Balcony: a balcony may project a minimum of 3'-0" from a required *street wall* over a *grade level setback*
iv. Bay window: a bay window may project from a required *street wall* over a *grade level setback*.
d. Expression band: an identifiable break should be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

3.1.5 Other permitted projections: elements which project beyond the property line from a required *street wall* shall comply with the Building Code

a. Architectural façade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required *street wall* over a *grade level setback*
b. Steps and ramps may project from a required *street wall* over a *grade level setback*
c. Marquees, canopies and awnings
d. Retail storefronts, may project from a required street wall over a *grade level setback* by a maximum depth of 5'-0". The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

3.2. Yards

3.2.1. Commercial Use: no front, side or rear yard set backs are required

3.2.2. Residential Use:
a. Front Yard – none (proposed).
- Code requires: There shall be a front yard of not less than 15 feet; provided, however, that on key lots the minimum front yard shall be 10 feet
b. Side Yard: Minimum 5 feet, for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.
c. Rear Yard: Minimum 15 feet, for a building more than three stories in height one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

3.3. Maximum Building Height

3.3.1. Height District No. 2

3.3.2. The total floor area contained in all the buildings on a lot in Height District No. 2 shall not represent six times the buildable area of said lot.
- : AB 3.1 under "D" development limitation
- 4.5.1 under CRA Redevelopment Plan

3.3.3. Refer to Figure xx Bulk Control Plan for permitted maximum building height on each parcel.

3.3.4. The following are permitted obstructions which may penetrate the maximum building height: roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building; skylights, towers, steeples, flagpoles, wireless masts, water tanks, silos, solar energy devices, or similar structures.

- [discuss] CAMC SEC. 1.2.21.B.2 "For each foot such structure exceeds the height limit, an equal setback from the roof perimeter is provided, except that stairways, chimneys and ventilation shafts shall not be required to be set back from the roof perimeter. No portion of any roof structure as provided for above shall exceed the specified height limit by more than five feet."

[Insert] Figures for Tower Zone and Massing Diagrams

3.4. Tower Controls

3.4.1. Definition of *tower*: the portion of a building located 150 feet above curb level

3.4.2. Maximum lot coverage of *tower*:

a. 150 – 220 feet 48%
b. 221 – 400 feet 28%
c. 221 – 550 feet 15%
d. 221 – 585 feet 11.5%

3.4.3. Refer to 4.1.3 open space requirements for corresponding ground level open space that is determined by tower height

3.4.4. 50% of total floor area must be located below 220 feet.

3.4.5. Tower location: a tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets

3.4.6. Setback and articulation of tower walls and crown:

a. *Towers* are not required to setback.
b. Minimum 10% of *tower* wall required to be articulated.
c. Distinctive *tower* crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

3.4.7. Types of permitted articulation of a *tower* wall

a. Recess.
b. Balcony: a balcony shall be integral to the façade and shall not create a relentless horizontal and vertical stacking pattern. They are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations.
   (i) Standard balconies may be projecting or recessed or a combination of both
c. Bay windows

3.4.8. Tower spacing

a. Towers should be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.
b. Generally, the portion of a tower shall be spaced at least 80 feet from all other towers on the same parcel, except the following which will meet code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled.

4. OPEN SPACE

4.1. Grade Level Setback

4.1.1. Definition of *grade level setback*: a continuous open space fronting the street.

4.1.2. Design intent: the purpose of a *grade level setback* is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records and accentuate the low scale character.

4.1.3. Open space requirements.

a. Minimum ground floor open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet.
b. An additional 3% of open space (total 8%) required for buildings between 221 feet and 400 feet.
c. An additional 5% (total 10%) of open space to be required for buildings between 401 feet and 550 feet.
d. An additional 7% (total 12%) of open space required for buildings taller than 550 feet.

4.1.4. Location

a. East side: adjacent to the Jazz Mural and Capitol Records Tower; West side across from the Capitol Records Tower along Vine Street.
b. Minimum depth: no horizontal dimension less than 5 feet when measured perpendicular from any point on each of the boundaries of the open space area.

4.1.5. Landscape requirements:

a. Planting requirements. Minimum 10% of *grade level setback* shall be landscaped.
b. Landscaped area(s) shall be planted with seasonally diverse plant material.
c. The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.
d. The minimum soil depths for planting are:
    (i) Shrubs: 30"
    (ii) Lawns, ground cover: 18"
e. Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

4.1.6. Permitted obstructions: the following are permitted obstructions which may occur in the *grade level setback*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining, and retail storefronts

4.2. Residential Open Space

4.2.1. Design intent. A common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above.

a. Requirements:

(i) Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.

(ii) Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common areas as further defined and regulated herein.

4.2.2. Common Open Space

a. Requirements:

(i) Be open to the sky and have no structures that project into the common open space area, except as permitted in the zoning code.

(ii) Be readily accessible to all the residents of the site.

(iii) Have a minimum area of 400 sq. ft. with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

(iv) Constitute at least 50% of the total required usable open space in developments built.

(v) Common open space areas shall incorporate recreational amenities including but not limited to: swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

(vi) A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

(i) At least one 24-inch box tree for every four dwelling units shall be provided on site and may include street trees in the parkway.

(ii) For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

(iii) All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

b. Location of common open space:

(i) Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use shall be considered as common open space.

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4.2.3. Private Open Space

a. Definition: a private open space area contiguous to and immediately accessible from a single dwelling unit.

b. Requirements
(i) Contain a minimum of 50 square feet of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.
(ii) Have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.
(iii) Provide a minimum eight foot vertical clearance under any projection, except as provided in zoning code.
(iv) That portion of a balcony which extends or projects into a required front yard in compliance with zoning code may qualify as usable open space provided it meets each of the above specified requirements noted in items 1-3.

4.3. Publicly Accessible Private Space (PAPS)

4.3.1. Definition of *publicly accessible private space (PAPS)*: a continuous through block connection, located on privately owned land.

4.3.2. Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

4.3.3. Location and size requirements:

a. The major portion of a *PAPS* is the largest area of the *PAPS* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total PAPS area and shall not be less than 20'-0" wide.
b. Minor portions of *PAPS* are secondary areas that allow for additional flexibility in the shape and configuration of a *PAPS*. Minor portions shall not occupy more than 25 percent of the total area of the *PAPS*. The minor portion shall have a minimum average width of 10 feet.
c. The minor portion must be directly adjacent to the major portion.

4.3.4. Permitted obstructions.

a. *PAPS* open air minimum requirements shall be as follows.

(i)	Development with maximum building height of 150 feet.	0%
(ii)	Development with maximum building height of 220 feet.	20%
(iii)	Development with maximum building height of 400 feet.	30%
(iv)	Development with maximum building height of 550 feet.	40%
(v)	Development with maximum building height of 585 feet.	50%

b. Permitted obstructions within open air *PAPS*: any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art.

arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles, public telephones, temporary exhibitions; balconies, bay windows; awnings, canopies and marquises; stairs, ramps and bollards. Metro station access?

4.3.5. Kiosk:

a. Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Buildings in conformance with the Building Code. Kiosks, including roofed areas, shall not exceed 3%of the total area of the PAPS and no one kiosk shall occupy an area of more than 250 square feet. A kiosk may be freestanding or may be attached on only one side to a wall of the building. Any area occupied by a kiosk shall be excluded from the definition of floor area [needs to be confirmed with CPD], and may be occupied by news or magazine stands, candy stands, food preparation for open air cafes, flower stands or public service/information booths.

4.3.6. Open air cafe

a. Where an open air cafe is provided it shall be an unenclosed restaurant or eating or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies. An open air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the PAPS. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers. An open air cafe may occupy an aggregate area not more than 20%of the total area of the PAPS. No cooking equipment shall be installed within an open air cafe. Cooking equipment may be contained in a kiosk adjoining the open air cafe. An open air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area.

4.3.7. Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on PAPS through open windows

4.3.8. Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No building refuse storage areas or refuse storage from a kiosk or open air café are permitted on any PAPS.
b. No exhaust vents are permitted on any PAPS or on any building wall of the development fronting upon the PAPS except where such vents are more than 10' 6" above the level of the PAPS.

4.3.9. Landscape requirements:

a. The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.
b. The minimum soil depths for planting are:
   (i) Trees: 30"

(ii) Shrubs: 30"
(iii) Lawns, ground cover: 18"

c. Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets

d. Planting requirements:
(i) Minimum of 10% of open air PAPS shall be landscaped
(ii) For each 400 square feet of landscaped area there shall be at least one (1) major shade tree or two (2) minor trees
(iii) The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

e Seating:
1. There shall be a minimum of one linear foot of seating for each 500 square feet of PAPS excluding the area of an open air cafe.
(i) One seat shall equal two linear feet
2. Not more than 50% of the linear seating capacity may be of moveable seats which may be stored between the hours of 7 p.m. and 7 a.m. Seating shall meet the following standards:
(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count double provided there is access to both sides
(ii) Seating higher than 35" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.
(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.
(iv) Moveable seating or chairs, excluding seating of open air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open air cafes do not count toward meeting the seating requirements.

4.3.10. Lighting.

a. A PAPS shall be illuminated throughout with an overall minimum average level of illumination of not less than one maintained foot candle (lumens per square foot) on the horizontal plane at grade. Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

4.3.11. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a PAPS shall be allocated for occupancy by permitted retail, restaurants and cultural uses. Such building frontage use requirement shall apply to both the mezzanines, if provided, and the street level. All such uses shall be directly accessible from the PAPS with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

4.3.12. Maintenance.

a. Responsibility: the building owner shall be responsible for the maintenance of the PAPS including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the parcel and in the street sidewalk area adjacent to the parcel.
b. Litter receptacles shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of PAPS area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of PAPS in connection with outdoor eating services or other uses permitted on PAPS which generate litter.

4.4. Rooftop Observation Deck

4.4.1. Buildings above 550 feet to include a public roof-top open space and viewing deck.

5. ARCHITECTURAL ELEMENTS

5.1. Building Materials and Color

5.1.1. Design intent: define the general design objectives for the material and color of distinct portions of the buildings and prescribe the treatment required for both residential and commercial portions of the building.

5.1.2. Guidelines

a. Feature long-lived and sustainable materials. The material palette should provide variety, reinforce massing and changes in the horizontal or vertical plane.
b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.
c. Podium levels up to 150 feet ~~that include surfaces of masonry~~ will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents. There will be clear contrast between the buildings surface material and the building's glazed areas.
d. The building's skin, especially for towers, should be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.
e. In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style.
f. To provide visual variety and depth, layer the building skin and provide a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin should reinforce the integrity of the design concept and the building's structural elements, and not appear as surface application.
g. Rooftop mechanical equipment shall be screened with materials and design consistent with the building architecture; ~~see Section 5c Tower Crown~~.
h. Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

5.2. Grade Level Controls

5.2.1 Design intent: street wall massing, articulation and detail, street level building entrances and storefront windows and doors, as well as the use of quality materials and decorative details, shall be used to promote pedestrian-scaled architecture along the street. Architectural features that reinforce the retail character of the ground street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and should be integral to the architecture of the building.

5.2.2. Ground floor height:

a. Minimum 12'-0" height floor to ceiling.

5.2.3. Building entrances:

a. The primary entrance to a street level tenant that has frontage along a public street shall be provided from that street. The primary entrance to a tenant that does not have its frontage along a public street shall be provided from a courtyard, *grade level setback*, or *PMPS*. Entries shall not be higher than 4 feet above the elevation of the sidewalk at its nearest point to the entry. Where possible entries shall be marked through the use of architectural elements such as porticos, gateways, entry alcoves, awnings, canopies, or portals.
b. Main building entrances should read differently from retail storefronts, restaurants and commercial entrances.
c. ~~See Section xx for marquees, canopies, awnings, Section xx for signage controls, and Section xx for lighting controls.~~

5.2.4. Ground floor glazing: [CPD pending text from CRA]

5.2.5. Arcades:

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0 foot candles.

5.2.6. ~~Service~~ and refuse:

a. Storage areas within the building of a size sufficient for that development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible to a curb cut; refer to Section xx Loading.

5.2.7. Retail storefronts.

a. Openings for storefronts, windows and doors shall comprise a minimum of 40% of the building's street level façade and be recessed where necessary.
b. Ground floor retail space will be a minimum of 20 feet deep and 12 feet clearance in height and have storefronts openings a minimum of 10 feet in height. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet.
c. Security grills will be located behind glass and be at minimum 80% open.
d. Storefront glazing will be transparent.

5.3. Podium Controls

5.3.1. Design intent: provide a modern interpretation of the historical context of Hollywood by establishing different treatment from the building's base, middle and top through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

5.3.2. Podium height.

a. Minimum 30' 0" to a maximum of 150 feet, exclusive of the ground floor level.

5.3.3. Guidelines.

a. Provide an identifiable break between the building's ground floors and upper floors. This break may include a change in material, change in fenestration pattern or similar means.
b. Podium level windows shall be vertically oriented.
c. Podium levels shall be predominantly light in color.
d. Expression band shall be provided at the highest story within the podium.
e. While blank street wall façades are prohibited, an exception may be made for integration of public art or a graphic-based façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade should be a maximum of four floors high, and should have variation in its surface plane (using niches, reveals or pop-outs). It should employ different scales of elements as viewed when seeing the entire building massing.

5.4. Fenestration

5.4.1 Louvers, wall openings shall be designed to integrate with building architecture.

5.5. Tower

5.5.1. Design Intent:

a. Towers should have their massing designed to reduce overall bulk and to appear slender.
b. Towers should be designed to achieve a simple faceted geometry and exhibit big, simple moves. They should not appear overwrought or to have over-manipulated elements.
c. Towers that emulate a more streamline modern style should provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.
d. If a project has more than one tower, they should be complementary to each other and employ the same architectural design approach.
e. Generally, buildings over 150 feet tall (the historic datum for Hollywood) should not be historicized. They are contemporary interventions in the skyline and should appear as such.

5.6. Rooftops and Setbacks

5.6.1. General requirements:

a. Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and to be visually attractive when viewed from locations adjacent and above.
b. For rooftops to be developed as usable outdoor areas, refer to requirements specified under common open space, Section xxx.
c. All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors. All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.

5.7. Parapets, Handrails, Roof Mechanical Equipment Screening

5.7.1. Parapets and handrails: if part of an expression band or expression line, shall be finished in a distinctive manner.

5.7.2. Roof mechanical equipment: shall be screened; materials and design to be consistent with the building architecture and will utilize similar colors and materials as in other portions of the building. Enclosures for bulkheads shall not count against building height

6. STREETSCAPE

6.1. Streets and Sidewalks

6.1.1. Design Intent: the cohesiveness and variety of public open spaces and streets are key features of the Project. The combination of landscaped plazas and PARKS and landscape streets creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

(i) Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

(ii) Spacing of the street trees is critical to the overall image of the development, as their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree planting pattern.

6.1.2. Tree planting guidelines

a. It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module

for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

7. PARKING

7.1. Automobile Parking

7.1.1 Requirements for each use:

a. Commercial / Office / Retail:
   (i) At least two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail, restaurant, bar and related uses, trade schools, or research and development buildings on any lot.

b. Condominiums
   (i) At least two parking spaces per each dwelling unit
   (ii) One quarter parking spaces per each dwelling unit for guest parking
   (iii) One quarter parking spaces per each dwelling unit for guest parking
   - Development is located within in a parking exempt area

c. Rental
   (i) At least one parking space for each dwelling unit of less than three habitable rooms, one and one-half parking spaces for each dwelling unit of three habitable rooms, and two parking spaces for each dwelling unit of more than three habitable rooms.

d Combination of uses:
   (i) Where there is a combination of uses of a lot, the number of parking spaces required shall be the sum of the requirements of the various uses.

7.1.2 Additional regulations:

a. Location of accessory commercial / office / retail off street spaces may be located on the same parcel as the use to which they are accessory, or on the opposing development.
   (i) (g) **Location of Parking Area**. The automobile parking spaces required by Paragraphs (b), (c), (d) and (e) hereof, shall be provided either on the same lot as the use for which they are intended to serve or on another lot not more than 750 feet distant therefrom, said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750 foot distance may be measured along said alley, walk or easement.

b. Curb cuts shall be located no closer than 50 feet to the intersection of two streets.

c Access driveways to parking facilities will not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

d. Parking and loading access will be shared where feasible.

7.1.3. Screening

a. Above grade parking shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible or shall be designed to blend in with the form and massing and designed to look like an integral part of the building. The interior of a parking structure will be designed to be screened from the view of streets and sidewalks.

7.2. Employee Bicycle Parking

7.2.1. Requirements for each use.

a. Commercial / Office / Retail

(i) Any portion of a building used for non-residential purposes which contains a floor area in excess of 10,000 square feet, bicycle parking spaces shall be provided at the rate of two percent of the number of automobile parking spaces required by this section for such non-residential uses; provided, however, that at least one bicycle parking space shall be provided for any such building having a floor area in excess of 10,000 square feet of non-residential use. If the calculation of the number of required spaces results in a number including a fraction, the next highest whole number shall be the number of spaces required.

b. Condominiums

(i) At least one secure bicycle parking space shall be provided for every two residential units.

c. Rental

(ii) None

7.3. Circulation

8. SERVICE AND LOADING

8.1. Requirements

a. Hotel and Commercial / Office / Retail that abut an alley

(i) Every required loading space shall be located and arranged that delivery vehicles may be driven upon or into said space from the alley. Such loading space shall have a minimum height of 14 feet and directly accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.

(ii) Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.

(iii) Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet but not more than 100,000 square feet, a minimum area of 600 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet, and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

b. Condominiums

ii) None

c. Rental
i) None

8.2. Screening

a. Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.
b. Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

8.3. Circulation

9. SIGNAGE

9.1. Guidelines

a. Refer to Ordinance No. 176172: Hollywood Signage Supplemental Use District pursuant to Section 13.11 of the Los Angeles Municipal Code.

9.2. Modification to Guidelines

a. High-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted.

10. SUSTAINABILITY

10.1. LEED Certification

10.1.1. Standard of Sustainability (Mandatory for large projects)

a. Threshold: The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.
b. Requirement: The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

10.1.2. Standard of Sustainable Excellence (Voluntary for projects of any size - large and small)

a. Threshold: The Standard of Sustainable Excellence establishes an incentive program for projects that register with the USGBC's LEED® program, contract

with a LEED® AP, and can demonstrate how the project will achieve LEED® certification at a Silver or higher level.

b. Incentives. The ordinance will establish expedited service within the Department of City Planning and the Bureau of Engineering. Other incentives already in place, including those from the Department of Water and Power and the Department of Building and Safety, remain unchanged.

11. LIGHTING

11.1 Design intent: Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

11.2 Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the *grade-level setback and open PAPS*.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d. Steps and ramps will be lighted with a minimum of 1.0 foot candles on a horizontal plane.

e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

11.3. Responsibility for maintenance: Building owner is responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

11.4. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building owner.

11.5. Lighting for areas located inside the lot line and visible from the street such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

11.6. Lighting for above-grade parking garage facilities shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

12. NOISE

13. OPERATIONAL STANDARDS

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13.1. Pet Controls

13.2. Antennas
a. Transmission facilities
b. Cable antennas

13.3. Wireless Facilities

4/21/10

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Millennium Towers Development Agreement

LEGEND

Red Text: language City Planning would like to be added or modified

Blue Text: Zoning language that would need to be changed

Green Text: Additional information that was added after the March 1 issuance to ownership and City Planning.

~~Strikethrough~~ Text: Language City Planning does not view as necessary for the guidelines.

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1. INTRODUCTION

1.1. Purpose of Guidelines

1.1.1. The Design Guidelines ("Guidelines") have been prepared to regulate new development on the site with design guidelines and controls for development.

a. Establish a level of design quality and consistency for the entire development and insure design continuity will be carried through to the full implementation of the Project. The Design Guidelines establish basic site-wide design standards and criteria which serve to maintain the integrity of an overall master plan concept and protect the visual and environmental quality of the Project as a whole.

b. Permit design flexibility while establishing a vocabulary which will guide the development for the Project site.

c. Consolidate and illustrate the implications of the established practices which will govern the physical development of the two sites, defining the standards for use, bulk, parking and loading, architectural features, landscape treatment, signage, lighting, sound attenuation and sustainability.

1.2. Goals and Objectives

1.2.1. The Design Guidelines serve to reinforce the design principles which will contribute to the shape of a successful project.

1.2.2. These principles are as follows:

a. Preservation of the Capitol Records Tower and Gogerty Building.
b. Preserve public views to the Capitol Records Tower by creating *grade level setbacks*, civic plazas, on the east site adjacent to the Jazz Mural and Capitol Records Tower and west site across from the Capitol Records Tower.
c. Create civic plazas that are activated by retail, landscaped and enhance the Hollywood Walk of Fame by providing it as an urban node; creating The Hollywood Walk of Fame Plaza.
d. The reinforcement of the urban and historical importance of the intersection of Hollywood and Vine by the creation of an active street life focused on Vine Street.
e. The preservation of existing view corridor to the Hollywood hills.
f. The encouragement of street life by the creation of a new exclusive pedestrian connection between Ivar Avenue, Vine Street, and Argyle Avenue.
g. The creation of vibrant urban spaces which permit active and passive recreational facilities for both the on-site and off-site population.
h. The creation of a 24 hr community by the creation of a Thriving Mixed-Use Development.
i. ~~Insure sustainability by the creation of two development sites that offer flexibility to respond to market conditions and development phasing.~~
j. Eliminate the visual impact of the current on site parking.
k. [TRANSPORTATION – awaiting comments from CPD]
l. The establishment of a standard intended to promote architectural excellence.

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m. Provide designs that take into account the context and make an effort to respect it and fit in visually.
n. Create architecture that seeks to be a leader in minimizing the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space.
o. The creation of two buildings that emphasize the vertical architecture and become a visible icon and gateway to Hollywood Boulevard from the Hollywood Freeway.

want this document to trump code?

1.3. Relationship to the Los Angeles Municipal Code

1.3.1. The Guidelines were prepared in coordination with the Los Angeles City Planning Department and approved by the City Council.

1.3.2. Wherever the Guidelines contain provisions which establish regulations that are different from or more or less restrictive than allowed in the Los Angeles Municipal Code (LAMC) the Guidelines shall prevail pursuant to the Development Agreement approved by the City Council for the Project.

Alfred when there are deviations, want guidelines to control issue w/ standards/gdelns

track entitlements separately from guidelines?

2. PROJECT BACKGROUND

2.1. Existing Site

i.d. issues that this covers trumps

2.1.1. The Project site consists of eight parcels on 4.47acres of land. The subject property occupies two distinct sites, both bounded by Yucca Street to the north and separated by Vine Street. The area bounded by Ivar Avenue, Vine Street and Yucca Street is the West Site. The area bounded by Yucca Street, Vine Street and Argyle Street is the East Site. The East Site and the West Site make up the Project Site. The Project site currently contains a mix of commercial and on grade open parking. The topography has a natural incline of approximately 13 feet from Vine Street to Argyle Avenue and 11 feet from Vine Street to Ivar Avenue. The existing sidewalk elevations will not be altered as part the Project.

2.2. Zoning Classification

2.2.1. Classification: C2-2-SN (Proposed) within the ~~Hollywood Community Redevelopment Project Area of the Community Redevelopment Agency~~ (CRA) of the City of Los Angeles.
- Currently zoned as a C4-2D-SN

Comm Plan

2.2.2. The City General Plan land use designation: Regional Center commercial.

2.2.3. FAR: 6:1 (proposed)
- FAR 3:1 under "D" development limitation
- 4.5:1 under CRA Redevelopment Plan

2.3. Transfer of Floor Area

2.3.1. Owner may transfer floor area from one site to the other, as long as the minimum and maximum building heights are maintained. Either parcel can

exceed the 6:1 FAR, as long as the FAR of the combined sites averaged together is no more than 6:1

2.4. Maximum OESF Density Per Area

2.5. Use Coordination / Use Compatibility

3. BUILDING HEIGHT AND MASSING

3.1. Street Wall

3.1.1. Definition of *street wall*: a wall or portion of a wall of a building facing a street or *a grade level setback*.

3.1.2. Design intent: required *street walls* determine the scale and character of the pedestrian environment. Articulation of the required *street wall* within the permitted ranges is required in order to create a sense of different uses, visual interest and orientation.

3.1.3. Location of a required *street wall*:

a. Parcels with a *grade level setback*: the required *street wall* shall be located minimum 5 feet from the property line.
b. Parcels or portions of parcels without a *grade level setback*: the required *street wall* shall be located on the property line.

3.1.2. Height of required *street wall* and dimension of initial setback:

a. *Street walls* shall be built to a minimum height of 30 feet and a maximum height of 150 feet above curb level except as noted in item (b) and (c) below.
b. 40% of aggregate width of required *street wall* frontage on each street can exceed maximum *street wall* height up to the maximum *tower* height.
c. 40% of aggregate width of required *street wall* frontage on a *publicly accessible private space* can exceed maximum *street wall* height up to the maximum *tower* height.

3.1.3. Amount of articulation of required *street wall*:

a. The aggregate width of required *street wall* articulation at the level of any story shall not exceed 50% of the required *street wall* above the level of the second story ceiling or 28'-0" above curb level, whichever is less, to the floor level of the penultimate floor within the required *street wall* height. Within the lesser of 2 stories or 28'-0" above curb level, recesses, balconies and bay windows shall not be permitted. Pedestrian pass-through, public plazas, entry forecourts, permitted vehicular access driveways, hotel drop-offs and loading entries and exits are permitted; steps, ramps, marquees, canopies, awnings and retail storefronts are permitted.

3.1.4. Types of permitted articulation of a required *street wall*:

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a. Recess: recesses shall be permitted to a maximum depth of 15'-0" with a 1:2 maximum depth to width ratio.

~~b.~~ Balcony: a balcony may project a minimum of 3'-0" from a required *street wall* over a *grade level setback* ~~and each balcony may have a maximum length of 12'-0".~~

~~c.~~ Bay window: a bay window may project ~~a maximum of 4'-0"~~ from a required *street wall* over a grade level setback; ~~and each may have a maximum length of 12'-0".~~

d. Expression band: an identifiable break should be provided between a building's retail floors and upper floors. This break may consist of a change in material, change in fenestration, or similar means.

3.1.5. Other permitted projections: elements which project beyond the property line from a required *street wall* shall comply with the Building Code.

a. Architectural facade elements such as expression bands, cornices, eaves, gutters, and downspouts may project from a required *street wall* over a *grade level setback* ~~by a maximum depth of 3'-0".~~ DBS - so long as setback is code required

b. Steps and ramps may project from a required *street wall* over a *grade level setback* ~~by a maximum depth of 5'-0".~~ DBS

c. Marquees, canopies and awnings

d. Retail storefronts: may project from a required street wall over a *grade level setback* by a maximum depth of 5'-0". The maximum height of these projections for each parcel shall not exceed two stories or 28'-0" above curb level, whichever is less.

needs to be a request in entitlements?

3.2. Yards

3.2.1. Commercial Use: no front, side or rear yard set backs are required

3.2.2. Residential Use:

a. Front Yard – none (proposed)
- Code requires: There shall be a front yard of not less than 15 feet; provided, however, that on key lots the minimum front yard shall be 10 feet.

b. Side Yard: Minimum 5 feet, for a building more than two stories in height, one foot shall be added to the width of such side yard for each additional story above the second story, but in no event shall a side yard of more than 16 feet in width be required.

c. Rear Yard: Minimum 15 feet, for a building more than three stories in height, one foot shall be added to the depth of such rear yard for each additional story above the third story, but such rear yard need not exceed 20 feet.

3.3. Maximum Building Height

3.3.1. Height District: No. 2

3.3.2. The total floor area contained in all the buildings on a lot in Height District No. 2 shall not exceed six times the buildable area of said lot.
- FAR 3:1 under "D" development limitation
- 4.5:1 under CRA Redevelopment Plan

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3.3.3. Refer to Figure xx Bulk Control Plan for permitted maximum building height on each parcel.

3.3.4. The following are permitted obstructions which may penetrate the maximum building height: roof structures for the housing of elevators, stairways, tanks, ventilating fans or similar equipment required to operate and maintain the building, skylights, towers, steeples, flagpoles, wireless masts, water tanks, silos, solar energy devices, or similar structures.

- **[discuss]** LAMC SEC. 12.21.B.2: "for each foot such structure exceeds the height limit, an equal setback from the roof perimeter is provided, except that stairways, chimneys and ventilation shafts shall not be required to be set back from the roof perimeter. No portion of any roof structure as provided for above shall exceed the specified height limit by more than five feet."

[Insert] Figures for Tower Zone and Massing Diagrams

3.4. Tower Controls

3.4.1. Definition of *tower*: the portion of a building located 150 feet above curb level.

3.4.2. Maximum lot coverage of *tower*:

a. 150 – 220 feet 48%
b. 221 – 400 feet: 28%
c. 221 – 550 feet 15%
d. 221 – 585 feet 11.5%

3.4.3. Refer to 4.1.3 open space requirements for corresponding ground level open space that is determined by tower height.

3.4.4. 50% of total floor area must be located below 220 feet.

3.4.5. Tower location: a tower 220 feet or greater in height above curb level shall be located with its equal or longer dimension parallel to the north-south streets.

3.4.6. Setback and articulation of *tower* walls and crown:

a. *Towers* are not required to setback.
b. Minimum 10% of *tower* wall required to be articulated.
c. Distinctive *tower* crown and lighting permitted but not required at the highest one (1) story and rooftop mechanical equipment enclosure.

3.4.7. Types of permitted articulation of a *tower* wall:

a. Recess
b. Balcony: a balcony shall be integral to the façade and shall not create a relentless horizontal and vertical stacking pattern. They are encouraged to create a complex and varied pattern along the façade using various balcony sizes and architectural configurations.
   (i) Standard balconies may be projecting or recessed or a combination of both.
c. Bay windows

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3.4.8. Tower spacing

a. Towers should be spaced to provide privacy, natural light and air, as well as to contribute to an attractive skyline.
b. Generally, the portion of a *tower* shall be spaced at least 80 feet from all other *towers* on the same parcel, except the following which will meet code: 1) the towers are offset (staggered), 2) the largest windows in primary rooms are not facing one another, or 3) the towers are curved or angled.
c. ~~Where there is an existing adjacent tower, the distance should be measured from the wall of the existing adjacent tower to the proposed tower. Where there is no existing adjacent tower, but one could be constructed in the future, the proposed tower must be 40 feet from an interior property line and 40 feet from the alley center line shared with the potential new tower.~~

4. OPEN SPACE

4.1. Grade Level Setback

4.1.1. Definition of *grade level setback*: a continuous open space fronting the street.

4.1.2. Design intent: the purpose of a *grade level setback* is to provide a landscaped open space to preserve views of the Jazz Mural and Capitol Records and accentuate the low scale character.

4.1.3. Open space requirements:

a. Minimum ground floor open space will be 5% of total lot area of the development site for buildings up to a height of 220 feet.
b. An additional 3% of open space (total 8%) required for buildings between 221 feet and 400 feet.
c. An additional 5% (total 10%) of open space to be required for buildings between 401 feet and 550 feet
d. An additional 7% (total 12%) of open space required for buildings taller than 550 feet.

4.1.4. Location

a. East site: adjacent to the Jazz Mural and Capitol Records Tower; West site: across from the Capitol Records Tower along Vine Street.
b. Minimum depth: no horizontal dimension less than 5 feet when measured perpendicular from any point on each of the boundaries of the open space area.

4.1.5. Landscape requirements:

a. Planting requirements: Minimum 10% of *grade level setback* shall be landscaped.
b. Landscaped area(s) shall be planted with seasonally diverse plant material.
c. The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.
d. The minimum soil depths for planting are:

(i) Shrubs: 30"
(ii) Lawns, ground cover: 18"

e. Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

~~4.1.6. Materials:~~

~~a. Raised planters shall be faced on all exposed sides with stone or masonry compatible with the building facade materials.~~
~~b. Plant material shall be selected for suitability to solar orientation, neat appearance, relationship to fenestration and seasonal diversity. The mature size of any plant shall not project more than 12" beyond the faces of the planter below a height of 10 feet above the adjacent sidewalk.~~

4.1.7. Permitted obstructions: the following are permitted obstructions which may occur in the *grade level setback*:

a. Building entries, steps, ramps, balconies, bay windows, architectural facade details, marquees, canopies, awnings, outdoor dining, and retail storefronts.

~~4.1.8. Other requirements:~~

~~a. Each planted area shall have provision for proper drainage and shall be equipped with waterproof electrical outlets and exterior water sources at a maximum interval of 50 feet or a minimum of one in each setback area.~~

4.2. Residential Open Space

4.2.1. Design intent: a common open space is intended to be a "rear yard" providing light and air to apartments on the interior of a parcel; secure, primarily passive recreational open space for resident adults and play space for children; and to be visually attractive when viewed from apartments adjacent and above.

a. Requirements:
(i) Provide at a minimum the following usable open space per dwelling unit: 100 square feet for each unit having less than three habitable rooms; 125 square feet for each unit having three habitable rooms; and 175 square feet for each unit having more than three habitable rooms.
(ii) Usable open space shall mean an area which is designed and intended to be used for active or passive recreation. Usable open space may consist of private and/or common area as further defined and regulated herein.

4.2.2. Common Open Space

a. Requirements:
(i) Be open to the sky and have no structures that project into the common open space area, except as permitted in the zoning code.
(ii) Be readily accessible to all the residents of the site.
(iii) Have a minimum area of 400 sq. ft. with no horizontal dimension less than 15 feet when measured perpendicular from any point on each of the boundaries of the open space area.

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open space questions:

(iv) Constitute at least 50% of the total required usable open space in developments built.

(v) Common open space areas shall incorporate recreational amenities including but not limited to, swimming pools, spas, picnic tables, benches, children's play areas, ball courts, barbecue areas, sitting areas, gym and fitness center.

(vi) A minimum of 25 percent of the common open space area shall be planted with ground cover, shrubs or trees.

(i) At least one 24-inch box tree for every four dwelling units shall be provided on site and may include street trees in the parkway.

(ii) For a surface area not located directly on finished grade that is used for common open space, and located at ground level or the first habitable room level, shrubs and/or trees shall be contained within permanent planters at least 30-inches in depth, and lawn or ground cover shall be at least 12-inches in depth.

(iii) All required landscaped areas shall be equipped with an automatic irrigation system and be properly drained.

b. Location of common open space:

(i) Common open space shall be located at any story above curb level. The roof of any portion of a building used for accessory parking or for any permitted non-residential use shall be considered as common open space.

does restaurant w/seating count?

4.2.3. Private Open Space

a. Definition: a private open space area contiguous to and immediately accessible from a single dwelling unit.

b. Requirements:

(i) Contain a minimum of 50 square feet of which no more than 50 square feet per dwelling unit shall be attributable to the total required usable open space.

(ii) Have no horizontal dimension less than six feet when measured perpendicular from any point on each of the boundaries of the open space area.

(iii) Provide a minimum eight foot vertical clearance under any projection, except as provided in zoning code.

(iv) That portion of a balcony which extends or projects into a required front yard in compliance with zoning code may qualify as usable open space provided it meets each of the above specified requirements noted in items 1-3.

~~4.2.4. Access to common open space:~~

~~a. Common open space shall be directly accessible to all residents on the parcel through a lobby connecting to each elevator core. Such spaces shall be accessible to the handicapped. Ramps, elevators, corridors and doors shall be designed to accommodate wheelchairs.~~

~~b. Common open space shall be accessible only from the residential portion of the building.~~

~~c. At least 35% of each door to a common open space shall be transparent.~~

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~~4.2.5. Permitted obstructions: the following are permitted obstructions which may occur in a common open space:~~

~~a. Terraces, balconies, bay windows, architectural facade details, accessory noncommercial greenhouses, planting boxes, steps and ramps for access by the handicapped, vents, bulkheads or other mechanical equipment, projecting not more than 5'-0";~~
~~b. Eaves, gutters, or downspouts projecting not more than 16";~~
~~c. Arbors, trellises, fences, flag poles, awnings or canopies;~~
~~d. Chimneys projecting not more than 3'-0"; and~~
~~e. Recreational equipment.~~

~~4.2.6. General requirements:~~

~~a. For every twenty (20) apartments on the parcel one fixed seat with a back shall be provided in private open space.~~
~~b. Common open spaces shall be separated from all apartments, and outdoor areas serving individual apartments, by a 4 foot high opaque fence, wall or year round screen of densely planted shrubs located at least 6 feet from a window or door of an apartment.~~
~~c. Areas with play equipment for young children may be provided. Play areas shall not be located within 20 feet of a residential unit and shall be visually and acoustically buffered from residential units and other non-planted areas.~~
~~d. Vents, bulkheads or other mechanical equipment penetrations shall be located so as not to obstruct access to and usefulness of the private open space.~~
~~e. Surface finishes of projecting structures shall be finished with materials compatible with vertical building materials.~~
~~f. No exhaust vents are permitted unless such intakes and vents are more than 10'-6" above the level of the private open space.~~

~~4.2.7. Landscape requirements:~~

~~a. The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.~~
~~b. The minimum soil depths for planting are:~~
~~(i) Trees: 36"~~
~~(ii) Shrubs: 30"~~
~~(iii) Lawns, ground cover: 18"~~

~~c. Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.~~
~~d. Planting requirements:~~
~~(i) For each 400 square feet of landscaped area there shall be at least one (1) major shade tree or two (2) minor trees.~~
~~(ii) The remaining landscaped area(s) shall be planted with seasonally diverse plant material appropriate for rooftops.~~
~~(iii) The landscaped area(s) shall be located such that they receive a minimum of 4 hours of direct sunlight as calculated on June 21.~~
~~(iv) The landscaped areas shall be contained by durable planters to accommodate the requirements specified in (ii) above. Planters may be designed with a coping to provide additional seating if the coping is~~

~~minimum 12" wide and does not exceed 18" in height. Planters may also be partially recessed into roof slab provided the overall requirements of (ii) above are met.~~

~~e. Furnishings:~~

~~(i) Furnishings such as seating, tables, gazebos or other shade structures are encouraged. Furnishings may be movable or fixed. If fixed, they shall be oriented to provide maximum variety in relationship to planted areas, sun and shade.~~

~~(ii) Surfacing beneath play equipment for young children shall comply with Federal safety standards and equipment shall be anchored in accordance with manufacturer's guidelines.~~

~~(iii) Provision for outdoor lighting: refer to Section xx.~~

4.3. Publicly Accessible Private Space (PAPS)

4.3.1. Definition of *publicly accessible private space (PAPS)*: a continuous through block connection, located on privately owned land.

4.3.2. Design Intent: to encourage public pedestrian circulation and other appropriate public uses on both sides along Vine Street.

4.3.3. Location and size requirements:

a. ~~15'-0" minimum width and at least 50% open to the sky shall be provided on each parcel, along the entire southern side of western parcel and northern side of eastern parcel.~~

b. The major portion of a *PAPS* is the largest area of the *PAPS* and the area of primary use. Major portions shall be generally regular in shape, contiguous to each other, easily and directly accessible from adjoining buildings and public spaces. Major portions shall occupy no less than 75 percent of the total PAPS area and shall not be less than 20'-0" wide.

c. Minor portions of *PAPS* are secondary areas that allow for additional flexibility in the shape and configuration of a *PAPS*. Minor portions shall not occupy more than 25 percent of the total area of the *PAPS*. The minor portion shall have a minimum average width of 10 feet.

d. The minor portion must be directly adjacent to the major portion.

4.3.4. Permitted obstructions:

a. *PAPS* open air minimum requirements shall be as follows:

(i)	Development with maximum building height of 150 feet:	0%
(ii)	Development with maximum building height of 220 feet:	20%
(iii)	Development with maximum building height of 400 feet:	30%
(iv)	Development with maximum building height of 550 feet:	40%
(v)	Development with maximum building height of 585 feet:	50%

b. Permitted obstructions within open air *PAPS*: any features, equipment, and appurtenances normally found in public parks and playgrounds, such as fountains and reflecting pools, waterfalls, sculptures and other works of art, arbors, trellises, benches, seats, trees, planting beds, litter receptacles, drinking fountains, and bicycle racks; open air cafes; kiosks, outdoor furniture; lights and lighting stanchions; flag poles; public telephones; temporary exhibitions;

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balconies, bay windows; awnings, canopies and marquees; stairs, ramps and bollards. Metro station access?

4.3.5. Kiosk:

~~a.~~ Where a kiosk is provided, it shall be a one-story structure, predominantly of light materials, such as metal, glass, plastic, or fabric as approved by the Department of Buildings in conformance with the Building Code. Kiosks, including roofed areas, shall not exceed 3%of the total area of the PAPS and no one kiosk shall occupy an area of more than 250 square feet. A kiosk may be freestanding or may be attached on only one side to a wall of the building. Any area occupied by a kiosk shall be excluded from the definition of floor area [needs to be confirmed with CPD], and may be occupied by news or magazine stands, candy stands, food preparation for open air cafes, flower stands or public service/information booths. ~~Lighting and signage of kiosks shall conform to Section xx, Retail Guidelines.~~

4.3.6. Open air cafe:

a. Where an open air cafe is provided it shall be an unenclosed restaurant or eating or drinking place, which may have waiter or table service and is open to the sky except for permitted obstructions such as trees, arbors, awnings or canopies. An open air cafe shall be accessible from a minimum of two sides where there is a boundary with the remainder of the PAPS. The boundary shall be defined by planters or temporary decorative barricades. Seating may be reserved for customers. An open air cafe may occupy an aggregate area not more than 20%of the total area of the PAPS. No cooking equipment shall be installed within an open air cafe. Cooking equipment may be contained in a kiosk adjoining the open air cafe. An open air cafe qualifying as a permitted obstruction shall be excluded from the definition of floor area. ~~Lighting and signage of an open air cafe shall conform to Section xx, Retail Design Guidelines.~~

4.3.7. Service through windows:

a. Outdoor eating services or uses occupying kiosks may serve customers on PAPS through open windows.

4.3.8. Prohibition of parking spaces, loading berths, exhaust vents and building refuse storage areas:

a. No buildings refuse storage areas or refuse storage from a kiosk or open air café are permitted on any PAPS.
b. No exhaust vents are permitted on any PAPS or on any building wall of the development fronting upon the PAPS except where such vents are more than 10'-6" above the level of the PAPS.

4.3.9. Landscape requirements:

a. The landscaped portion may be designed as a single area or multiple planted areas. The minimum size of a single planted area shall be 100 square feet.
b. The minimum soil depths for planting are:

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(i) Trees: 36"
(ii) Shrubs: 30"
(iii) Lawns, ground cover: 18"

c. Each planted area shall have provision for proper drainage, and shall be equipped with automatic drip irrigation and waterproof electrical outlets.

d. Planting requirements:
   (i) Minimum of 10% of open air PAPS shall be landscaped.
   (ii) For each 400 square feet of landscaped area there shall be at least one (l) major shade tree or two (2) minor trees.
   (iii) The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

e. Seating:
   1. There shall be a minimum of one linear foot of seating for each 500 square feet of PAPS excluding the area of an open air cafe.
      (i) One seat shall equal two linear feet
   2. Not more than 50% of the linear seating capacity may be in moveable seats which may be stored between the hours of 7 p.m. and 7 a.m. Seating shall meet the following standards:
      (i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count double provided there is access to both sides.
      (ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.
      (iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.
      (iv) Moveable seating or chairs, excluding seating of open air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open air cafes do not count toward meeting the seating requirements.

4.3.10. Lighting:

a. A PAPS shall be illuminated throughout with an overall minimum average level of illumination of not less than one maintained foot candle (lumens per square foot) on the horizontal plane at grade. Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

~~4.3.11. Electrical power:~~

~~a. Electrical power shall be supplied by one or more outlets furnishing a total of at least 3,000 watts of power for every 4,000 square feet, or fraction thereof, of a PAPS for maintenance equipment, special events and retail uses (kiosks, open air cafes, carts).~~

~~4.3.12. Signs:~~

~~a. A PAPS shall be treated as a street for the purpose of the applicable sign regulations. Signs are permitted only accessory to uses permitted within and adjoining the PAPS.~~

4.3.13. Mandatory allocation of frontages for permitted use: at least 40% of the total frontage of building walls of the development fronting on a PAPS shall be allocated for occupancy by permitted retail, restaurants and cultural uses. Such building frontage use requirement shall apply to both the mezzanine, if provided, and the street level. All such uses shall be directly accessible from the PAPS with an entrance required every 50' at a minimum. The remaining frontage may be occupied by other uses, vertical circulation elements and building lobbies.

all at ground

4.3.14. Maintenance:

a. Responsibility: the building owner shall be responsible for the maintenance of the PAPS including, but not limited to, the confinement of permitted obstructions, litter control, and the care and replacement of vegetation within the parcel and in the street sidewalk: area adjacent to the parcel.
b. Litter receptacles: shall be provided with a minimum capacity of one cubic foot for each 2,000 square feet of PAPS area. An additional capacity of one cubic foot of litter receptacle shall be provided for each 2,000 square feet of PAPS in connection with outdoor eating services or other uses permitted on PAPS which generate litter.

don't want to go lower

4.4. Rooftop Observation Deck

lower?

4.4.1. Buildings above 550 feet to include a public roof-top open space and viewing deck.

~~5. VIEW CORRIDOR~~

6. ARCHITECTURAL ELEMENTS

6.1. Building Materials and Color

6.1.1. Design intent: define the general design objectives for the material and color of distinct portions of the buildings and prescribe the treatment required for both residential and commercial portions of the building.

6.1.2. Guidelines:

apply w/ equivalency to all facades

a. Feature long-lived and sustainable materials. The material palette should provide variety, reinforce massing and changes in the horizontal or vertical plane.
b. Ground floors shall have a different architectural expression than upper floors and feature high quality durable materials that add scale, texture and variety.
c. Podium levels up to 150 feet ~~that include surfaces of masonry~~ will be predominantly light in color. Colors will be achieved through the inherent color of the material, rather than the application of color to the surface. Darker accent colors may be used to delineate building entrances and accents. There will be

clear contrast between the buildings surface material and the building's glazed areas.

d. The building's skin, especially for towers, should be primarily transparent; the use of darkly colored or highly reflective glass will be avoided. Glazing will have the minimum amount of reflectivity or tinting required to achieve energy efficiency standards.
e. In buildings other than curtain wall buildings, windows will be recessed, except where inappropriate to a building's architectural style.
f. To provide visual variety and depth, layer the building skin and provide a variety of textures that bear a direct relationship to the building's massing and structural elements. The skin should reinforce the integrity of the design concept and the building's structural elements, and not appear as surface pastiche.
g. Rooftop mechanical equipment: shall be screened with materials and design consistent with the building architecture; ~~see Section xx Tower crown~~.
h. Design the color palette for a building to reinforce building identity and complement changes in the horizontal or vertical plane.

6.2. Grade Level Controls

6.2.1. Design intent: street wall massing, articulation and detail, street level building entrances and storefront windows and doors, as well as the use of quality materials and decorative details, shall be used to promote pedestrian-scaled architecture along the street. Architectural features that reinforce the retail character of the ground street wall and/or help define the pedestrian environment along the sidewalk, such as canopies, awnings, and overhangs, are encouraged and should be integral to the architecture of the building.

6.2.2. Ground floor height:

a. Minimum 12'-0" height floor to ceiling.

6.2.3. Building entrances:

Comm. use storefronts

a. The primary entrance to a street level tenant that has frontage along a public street shall be provided from that street. The primary entrance to a tenant that does not have its frontage along a public street shall be provided from a courtyard, *grade level setback*, or *PAPS*. Entries shall not be higher than 4 feet above the elevation of the sidewalk at its nearest point to the entry. Where possible entries shall be marked through the use of architectural elements such as porches, gateways, entry alcoves, awnings, canopies, or portals.
b. Main building entrances should read differently from retail storefronts, restaurants and commercial entrances.
c. ~~See Section xx marquees, canopies, awnings; Section xx for signage controls, and Section xx for lighting controls.~~

6.2.4. Ground floor glazing: (CPD sending text from CRA)

a. When any building wall adjoins a street line or grade level setback, at least 25% of the total surface area of such wall between curb level and 12' above curb level or to the ceiling of the ground floor, whichever is higher, shall be transparent. Door or window openings or unglazed openings within such walls shall be considered as transparent. Such openings shall have a minimum width

of 2'-0". The lowest point of any transparency that is provided to satisfy the requirements of this section shall not be higher than 4'-0" above the curb level. Retail storefront ground floor glazing requires at least 50% transparency.

b. Any portion of such building wall, 50' or more in length, which contains no transparent elements between curb level and 12' above curb level or the ceiling of the ground floor, whichever is higher, or to its full height, shall be covered with vines or similar planting or contain art work or be treated so as to provide visual relief.

6.2.5. Arcades:

a. Arcades at grade will maintain a minimum of 10 feet clear height and will be lit with a minimum of 1.0 foot candles.

6.2.6. Service and refuse:

a. ~~All refuse, except materials to be recycled, shall be mechanically compacted in accordance with applicable law. The storage of refuse shall occur entirely within an enclosed area on the parcel and appropriate locations within the parcel shall be delineated for this purpose: at least one for residential use and one for community facility and retail uses. Developments shall store compacted refuse in an on-site container acceptable to the Department of Sanitation. Each parcel shall have a minimum of one onsite loading berth; refer to Section xx Loading. A refuse disposal room meeting ADA requirements for access shall be provided on each story that has a corridor with two (2) or more entrances to apartments. The refuse disposal room shall contain vertical chute and two containers and shelf space for the storage of recyclable materials. Each such refuse storage room and the central refuse storage and disposal room on each parcel shall be excluded from the definition of floor area.~~

b. Storage areas within the building of a size sufficient for that development to ensure that refuse is stored and loaded off-street. Refuse storage areas shall be directly and conveniently accessible to a curb cut; refer to Section xx Loading.

6.2.7. Retail storefronts:

a. Openings for storefronts, windows and doors shall comprise a minimum of 40% of the building's street level façade and be recessed where necessary.
b. Ground floor retail space will be a minimum of 20 feet deep and 12 feet clearance in height and have storefronts openings a minimum of 10 feet in height. Storefront openings shall be no wider than 100 feet and no smaller than 15 feet.
c. Security grills will be located behind glass and be at minimum 80% open.
d. Storefront glazing will be transparent.

6.3. Podium Controls

6.3.1. Design intent: provide a modern interpretation of the historical context of Hollywood by establishing different treatment from the building's base, middle and top; through the vertical articulation of the street wall façade by the use of balconies, projections, recesses, fenestration and changes in massing, color, material or other elements.

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6.3.2. Podium height:

~~e.~~ Minimum 30'-0" to a maximum of 150 feet, ~~exclusive of the ground floor level.~~

6.3.3. Guidelines:

a. Provide an identifiable break between the building's ground floors and upper floors. This break may include a change in material, change in fenestration pattern or similar means.
b. Podium level windows shall be vertically oriented.
c. Podium levels shall be predominantly light in color.
d. Expression band shall be provided at the highest story within the podium.
e. While blank street wall façades are prohibited, an exception may be made for integration of public art or a graphic-based façade if it adds scale and interest to an otherwise bland frontage. In these cases, the façade should be a maximum of four floors high, and should have variation in its surface plane (using cut outs, insets or pop-outs). It should employ different scales of elements as viewed when seeing the entire building massing.

if bldg only 150 feet don't have podium

~~6.4. Marquees, Canopies, Awnings~~

~~6.4.1. Location by use:~~

~~a. Residential use: marquee or canopy shall be provided at the primary building entrance; canopy or awning is permitted at secondary entrances;~~
~~b. Community facility use and professional office: canopy or awning is permitted.~~
~~c. Commercial use: marquees or canopies are discouraged and shall only be permitted for office use; marquees or canopies shall be permitted for hotel use. Awnings shall be permitted for retail use.~~

~~6.4.2. Marquees:~~

~~a. 10'-0" minimum clear height and a maximum height of 20 feet shall be provided above the sidewalk. 2'-0" minimum horizontal distance from face of curb. Maximum width permitted of a marquee is 30 feet.~~

~~6.4.3. Canopies, awnings:~~

~~a. 8'-0" minimum clear height and a maximum height of 20 feet shall be provided above the sidewalk. 2'-0" minimum horizontal distance from face of curb. Maximum continuous length permitted is 15', with a minimum of 2'-0" spacing between awnings.~~
~~b. Awnings and canopies shall be fabricated of woven fabric, glass, metal or other permanent material compatible with the building architecture. Internally illuminated, vinyl awnings are not permitted.~~

6.5. Fenestration

6.5.1. Louvers, wall openings: shall be designed to integrate with building architecture.

6.6. Tower

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6.6.1. Design Intent:

a. Towers should have their massing designed to reduce overall bulk and to appear slender.
b. Towers should be designed to achieve a simple faceted geometry and exhibit big, simple moves. They should not appear overwrought or to have over-manipulated elements.
c. Towers that emulate a more streamline modern style should provide variety through subtle details in the curtain wall, and the articulation of a human-scaled base at the street level.
d. If a project has more than one tower, they should be complementary to each other and employ the same architectural design approach.
e. Generally, buildings over 150 feet tall (the historic datum for Hollywood) should not be historicized. They are contemporary interventions in the skyline and should appear as such.

6.7. Rooftops and Setbacks

6.7.1. General requirements:

a. Rooftops and setbacks are highly visible and provide a significant amenity. They shall be landscaped with consideration for use and to be visually attractive when viewed from locations adjacent and above.
b. For rooftops to be developed as usable outdoor area, refer to requirements specified under common open space, Section xxx.
c. All other roof surfaces and setbacks shall provide surface materials which are not reflective or high contrast colors. All obtrusive features such as vents, bulkheads and cooling units shall be screened from lateral and pedestrian views.
d. ~~Rooftops and setbacks adjacent to residential units: (1) Rooftops and setbacks exceeding 50 square feet shall be finished with materials suitable for use and landscaping. (2) Paving materials shall be durable; slope of surface shall not exceed 3%. (3) Waterproof electrical outlets and exterior water source shall be provided for each residential unit or at 50' intervals if a single unit abuts a rooftop or setback greater than 50' in length.~~

6.8. Parapets, Handrails, Roof Mechanical Equipment Screening

6.8.1. Parapets and handrails: if part of an expression band or expression line, shall be finished in a distinctive manner.

6.8.2. Roof mechanical equipment: shall be screened; materials and design to be consistent with the building architecture and will utilize similar colors and materials as in other portions of the building. Enclosures for bulkheads shall not count against building height.

7. STREETSCAPE

7.1. Streets and Sidewalks

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7.1.1. Design intent: the cohesiveness and variety of public open spaces and streets are key features of the Project. The combination of landscaped plazas and *PAPS* and landscaped streets creates diversity, and at the same time forms a single unified system. Cohesiveness shall be achieved by providing certain uniform elements such as lighting, paving, rhythmic tree plantings and continuous open spaces in a consistent palette of materials and furnishings.

Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree planting pattern.

7.1.2. Tree planting guidelines:

a. It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

~~7.1.3. New trees, planting beds, and grates will be provided along Vine Street, Ivar Avenue, Yucca Street, and Argyle Avenue. Jacaranda Mimosifiolias will be interspaced with Washingtonia Robusta palms along Vine Street. Palms will be spaced on 40 foot centers. Jacaranda Mimosifiolias will also be planted along Yucca Street frontages. Evergreen trees will be planted along Ivar and Argyle Avenues.~~

~~7.1.4. Sizable and healthy existing trees not conforming to the above will be removed and relocated on site if possible.~~

~~8. PEDESTRIAN LINKAGE~~

~~8.1. Provide through block connections on both sites along Vine Street.~~

9. PARKING

9.1. Automobile Parking

9.1.1. Requirements for each use:

a. Commercial / Office / Retail:

(i) At least two parking spaces for every one thousand square feet of combined gross floor area of commercial office, business, retail,

not a design feature needs to be in the DA instead of in TDM

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restaurant, bar and related uses, trade schools, or research and development buildings on any lot.

b. Condominiums
   (i) At least two parking spaces per each dwelling unit
   (ii) One quarter parking spaces per each dwelling unit for guest parking
   (iii) One quarter parking spaces per each dwelling unit for guest parking
   - Development is located within in a parking congested area

c. Rental
   (i) At least one parking space for each dwelling unit of less than three habitable rooms, one and one-half parking spaces for each dwelling unit of three habitable rooms, and two parking spaces for each dwelling unit of more than three habitable rooms.

d. Combination of uses:
   (i) Where there is a combination of uses of a lot, the number of parking spaces required shall be the sum of the requirements of the various uses.

9.1.2. Additional regulations:

a. Location of accessory commercial / office / retail off-street spaces: may be located on the same parcel as the use to which they are accessory, or on the opposing development.
   - (g) **Location of Parking Area.** The automobile parking spaces required by Paragraphs (b), (c), (d) and (e) hereof, shall be provided either on the same lot as the use for which they are intended to serve or on another lot not more than 750 feet distant there from; said distance to be measured horizontally along the streets between the two lots, except that where the parking area is located adjacent to an alley, public walk or private easement which is easily usable for pedestrian travel between the parking area and the use it is to serve, the 750-foot distance may be measured along said alley, walk or easement.

b. Curb cuts shall be located no closer than 50 feet to the intersection of two streets.

c. Access driveways to parking facilities will not exceed 28 feet in width. The minimum separation between drives located along the same frontage shall be 50 feet.

d. Parking and loading access will be shared where feasible.

e. ~~The maximum floor to floor height of above grade parking shall not be greater than 9 feet except where parking is screened with dwelling units.~~

9.1.3. Screening

a. Above grade parking shall be lined with habitable floor area having a minimum depth of 20 feet along street frontages where feasible or shall be designed to blend in with the form and massing and ~~designed to look~~ like an integral part of the building. The interior of a parking structure will be designed to be screened from the view of streets and sidewalks.

we will comply with

9.2. Employee Bicycle Parking

9.2.1. Requirements for each use:

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a. Commercial / Office / Retail:
   (i) Any portion of a building used for non-residential purposes which contains a floor area in excess of 10,000 square feet, bicycle parking spaces shall be provided at the rate of two percent of the number of automobile parking spaces required by this section for such non-residential uses; provided, however, that at least one bicycle parking space shall be provided for any such building having a floor area in excess of 10,000 square feet of non-residential use. If the calculation of the number of required spaces results in a number including a fraction, the next highest whole number shall be the number of spaces required.

b. Condominiums
   (i) At least one secure bicycle parking space shall be provided for every two residential units.

c. Rental
   (i) None

9.3. Circulation

10. SERVICE AND LOADING

10.1. Requirements

a. Hotel and Commercial / Office / Retail that abut an alley
   (i) Every required loading space shall be located and arranged that delivery vehicles may be driven upon or into said space from the alley. Such loading space shall have a minimum height of 14 feet and directly accessible through a usable door not less than three feet in width and not less than six feet six inches in height opening from the building it is to serve.
   (ii) Every required loading space shall have a minimum area of 400 square feet, a minimum width of 20 feet measured along the alley line, and a minimum depth of ten feet measured perpendicularly to the alley line.
   (iii) Loading space shall have a minimum area of 600 square feet where the gross floor area of all buildings on the lot exceeds 50,000 square feet, but not more than 100,000 square feet, a minimum area of 800 square feet where the gross floor area of all buildings is between 100,000 and 200,000 square feet, and shall be increased by an additional 200 square feet for each additional 200,000 square feet or fraction thereof of gross floor area in the building.

b. Condominiums
   (i) None

c. Rental
   (i) None

~~10.2. Location and Size~~

10.3. Screening

a. Except for the minimum ground level frontage required for access, loading shall be screened from the view of adjacent public sidewalks and streets.

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b. Trash enclosures shall be provided and screened from the view of adjacent public sidewalks and streets. Rehabilitated trash enclosures shall be screened from the view of adjacent public sidewalks and streets.

10.4. Circulation

~~11. BICYCLE PARKING~~

12. SIGNAGE

12.1. Guidelines

a. Refer to Ordinance No. 176172: Hollywood Signage Supplemental Use District pursuant to Section 13.11 of the Los Angeles Municipal Code.

need to adopt the SUD

12.2. Modification to Guidelines

a. High-rise signs located within 24 feet from the top of the building and meeting the requirements of the Building Code shall be permitted.

~~12.3. Types~~

~~a. Retail tenants shall be allowed to install one exterior sign limited to name and logo only.~~
~~b. No pole type signage shall be used.~~
~~c. No more than one rooftop/skyline sign shall be used per building.~~
~~d. Opaque message surfaces shall be avoided.~~

~~12.4. Location~~

~~a. Retail Sign: shall be located within a permitted signage band and limited to area of 20 square feet. The total length of the sign shall not exceed 3/4 of the width of the tenant exterior wall surface and shall be equally spaced. One logo or emblem will be allowed. Interior signs shall permit an unobstructed view into tenant space.~~
~~b. Projecting Sign: shall align with major building elements. The width of projecting signs shall not exceed 4 feet. The spacing of such signs shall be no less than 20 feet with the exception that each individual retail tenant may be allowed one projecting sign not to exceed 2 feet in width.~~
~~c. Rooftop Signs: shall be setback at least 10 feet from property lines or building lines. Spacing between rooftop signs shall be at least 50 feet. Signs shall be oriented towards and parallel to Hollywood Boulevard or at corners at 45 degree angels to the Boulevard district grid.~~

~~12.5. Heights/Sizes~~

~~12.6. Illumination~~

13. SUSTAINABILITY

13.1. LEED Certification

13.1.1. Standard of Sustainability (Mandatory for large projects)

Inventory what signs in EIR as aesthetic but don't put in project description

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a. Threshold: The Standard of Sustainability establishes a requirement for non-residential projects at or above 50,000 square feet of floor area, high-rise residential (above six stories) projects at or above 50,000 square feet of floor area, or low-rise residential (six stories or less) of 50 or more dwelling units within buildings of at least 50,000 square feet of floor area to meet the intent of the Leadership in Energy and Environmental Design® (LEED®) Certified level. The Standard also applies to existing buildings that meet the minimum thresholds described above when redevelopment construction costs exceed a valuation of 50% of the existing building's replacement cost.
b. Requirement: The project must include a LEED® Accredited Professional (LEED® AP) on the project team, and demonstrate that the project has met the intent of the US Green Building Council's (USGBC) LEED® Certified level. Formal certification by the USGBC is not required.

13.1.2. Standard of Sustainable Excellence (Voluntary for projects of any size - large and small)

a. Threshold: The Standard of Sustainable Excellence establishes an incentive program for projects that register with the USGBC's LEED® program, contract with a LEED® AP, and can demonstrate how the project will achieve LEED® certification at a Silver or higher level.
b. Incentives: The ordinance will establish expedited service within the Department of City Planning and the Bureau of Engineering. Other incentives already in place, including those from the Department of Water and Power and the Department of Building and Safety, remain unchanged.

14. LIGHTING

14.1. Design intent: lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

14.2. Supplemental lighting shall meet the following minimum requirements:

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade *level setback and open PAPS.*
b. Lighting will be operated from dusk to dawn.
c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.
d. Steps and ramps will be lighted with a minimum of 1.0 foot candles on a horizontal plane.
e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

14.3. Responsibility for maintenance: building owner is responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting

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c. The remaining landscaped area(s) shall be planted with seasonally diverse plant material.

8.3.5 Seating

a. There shall be a minimum of one linear foot of seating for each 500 square feet of *PAP* excluding the area of an open air cafe.

b. One seat shall equal 2 linear feet

c. Not more than 50% of the linear seating capacity may be in moveable seats. Seating shall meet the following standards:

(i) Seating without backs shall have a minimum depth of 16". For the benefit of handicapped persons a minimum of 20% of the required seating shall have backs at least 12" high and a minimum depth of 14". Seating 30" or more in depth shall count double provided there is access to both sides.

(ii) Seating higher than 36" and lower than 12" above the level of the adjacent walking surface shall not count toward meeting the seating requirements.

(iii) The tops of walls including but not limited to those which bound planting beds, fountains and pools may be counted as seating when they conform to the dimensional standards in subparagraphs (i) and (ii) above.

d. Moveable seating or chairs, excluding seating of open air cafes, may be credited as 30 inches of linear seating per chair. Steps and seating in open air cafes do not count toward meeting the seating requirements.

8.4 Tree Planting Guidelines

8.4.1 Purpose: [complete]

8.4.2 It is the intent to comply with the Urban Forestry Division standard guidelines regarding street tree locations and planting procedures. Regular spacing of the street trees is critical to the overall image of the Project, establishing the module for locating all of the other elements of the streetscape and certain building elements such as entrances, canopies, and utility connections.

8.4.3 Street trees play a very important role in the Project. To create a strong visual order, trees shall be planted in continuous, uniformly spaced rows along the streets. To acknowledge microclimatic variations and to avoid monoculture demise, different tree species shall be required on the designated hierarchy of street types. In all cases, the trees shall be planted in a single row on sidewalks leading to or abutting the development.

8.4.4 Spacing of the street trees is critical to the overall image of the development, so their regular spacing becomes the module for locating all of the other elements on the sidewalks such as light standards, pavement scoring patterns and curb cut zones. It is important that building elements affecting tree spacing, such as entrances, canopies, and utility connections, be coordinated at the outset to avoid conflict with the established tree planting pattern.

8.5 Lighting Standards

8.5.1 Lighting located at the perimeter of each parcel is required to supplement the street lighting. Its purpose is to improve color rendering, fill in shadows, light pedestrians' faces, articulate the building base-level facades, reinforce the residential and pedestrian character of the development and adjoining neighborhoods, increase security, and visually activate the nighttime streetscape. Lighting for this purpose shall be energy efficient, attractive, and easy to maintain.

8.5.2 Supplemental lighting shall meet the following minimum requirements

a. Supplemental sidewalk lighting for pedestrians shall be provided on all sides of the parcel and designed in conjunction with the grade level open space and open PAP.

b. Lighting will be operated from dusk to dawn.

c. Lighting will utilize a "white" light source with a color rendering index (CRI) of 65 or greater, i.e. metal halide, fluorescent, compact fluorescent, white cold cathode, white neon, or white HPS.

d. Steps and ramps will be lighted with a minimum of 1.0 foot candles on a horizontal plane.

e. Lighting approach will be consistent on each parcel with not more than 30 feet between elements.

8.5.3 Responsibility for maintenance

a. building owner is responsible for maintenance of all lighting associated with the property and for the maintenance of tenant lighting used to meet these requirements. No luminaire or lighted element which is to meet these requirements shall be out of commission for more than 10 consecutive days.

b. Additional lighting such as plant lighting, colored lighting, signage lighting, etc. will be used. The operation of additional lighting will be at the discretion of the building owner. - spotlights displays etc

8.5.4 Lighting for areas located inside the lot line and visible from the street: such as service yards, loading docks, service or garage entrances, shall be lighted with "white" light sources in attractive and/or concealed luminaires.

8.5.5 Lighting for above-grade parking garage facilities: shall utilize "white" light sources and the luminaires' brightness shall be shielded from view of the street or any residential living space. This may be accomplished through architectural screening, luminaire placement, or integral luminaire shielding. Parking garages which are entirely concealed from exterior view are exempt from this requirement.

8.6 PAP Lighting Standards

8.6.1 A *PAP* shall be illuminated throughout with an overall minimum average level of illumination of not less than one maintained foot candle (lumens per square foot) on the horizontal plane at grade.

8.6.2 Such level of illumination shall be maintained throughout the hours of darkness. Light sources shall be white light.

↳ COLOR TEMP

EPA United States Environmental Protection Agency

USER'S GUIDE FOR THE AMS/EPA REGULATORY MODEL - AERMOD

EPA-454/B-03-001

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USER'S GUIDE FOR THE AMS/EPA REGULATORY MODEL - AERMOD

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emissions Monitoring and Analysis Division
Research Triangle Park, North Carolina

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PREFACE

This User's Guide for the AMS/EPA Regulatory Model (AERMOD) provides user instructions for the AERMOD model. The technical description of the AERMOD algorithms is provided in a separate document (EPA, 2004a). The revised AERMOD model described in this user's guide includes the following modifications and enhancements: the PRIME building downwash algorithms based on the ISC-PRIME model, use of allocatable arrays for data storage, incorporation of EVENT processing for analyzing short-term source culpability, post-1997 PM10 processing; a non-regulatory default TOXICS option that includes optimizations for area sources and the Sampled Chronological Input Model (SCIM) option, explicit treatment of multiple-year meteorological data files and the ANNUAL average and options to specify emissions that vary by season, hour-of-day and day-of-week.

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1.0 INTRODUCTION

This section provides an overall introduction to the AERMOD model and to the AERMOD user's guide. Some suggestions are offered on how various users would best benefit from using the manuals. Also provided is an overview of the model's applicability, range of options, and basic input data and hardware requirements. The input file needed to run the AERMOD model is based on an approach that uses descriptive keywords and allows for a flexible structure and format.

1.1 HOW TO USE THE AERMOD MANUALS

The AERMOD model user's guide has been designed in an attempt to meet the needs of various types of users, depending on their level of experience with the model. This section describes briefly how different types of users would benefit most from their use of the manual.

1.1.1 Novice Users

Novice users are those whose exposure to or experience with the AERMOD model has been limited. They may be new to dispersion modeling applications in general, or new to the AERMOD model and therefore unfamiliar with the keyword/parameter approach utilized for the input file. These users should review the remainder of this Introduction to gain an overall perspective of the use of AERMOD model, particularly for regulatory modeling applications. They should then concentrate their review on Section 2, which provides a brief tutorial on setting up an input file that illustrates the most commonly used options of the AERMOD model. Section 2 provides a basic description of the input file structure and explains some of the advantages of the keyword/parameter approach to specifying modeling options and inputs. As the user becomes more familiar with the operation of the model and encounters the need to use more advanced features of the model, he/she will want to review the contents of Section 3, which provides a more detailed and complete reference of the

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various options for running the model

1.1.2 Experienced Modelers

Experienced modelers will have had considerable experience in applying the AERMOD model in a variety of situations. They should have basic familiarity with the overall goals and purposes of regulatory modeling in general, and with the scope of options available in the AERMOD model in particular. Experienced modelers who are new to the AERMOD model will benefit from first reviewing the contents of Section 2 of this volume, which will give them a basic orientation to the structure, organization and philosophy of the keyword/parameter approach used for the input runstream file. Once they have a basic grasp of the input file structure and syntax rules, they will benefit most from using Section 3 of this volume as a reference to learn the overall capabilities of the model, in order to understand the mechanics for implementing particular options. The information in Section 3 has a functional organization with detailed descriptions of each of the individual keyword options by functional pathway. Once they are familiar with most or all of the keywords, they may find the functional keyword reference provided in Appendix B useful to quickly review the proper syntax and available options/parameters for a particular keyword. They may also find the Quick Reference available at the end of the user's guide sufficient as a simple reminder of the available keywords for each pathway and to ensure the proper order of parameters for each input image.

Experienced modelers may also need to refer to the description of model formulation for AERMOD (EPA, 2009) in order to gain a more complete understanding of the technical basis for the AERMOD model.

1.1.3 Management/Decision Makers

Those involved in a management or decision-making role for dispersion modeling applications will be especially interested in the remainder of this section, which provides an

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overview of the model, including its role in various regulatory programs, a brief description of the range of available options, and basic input data and computer hardware requirements needed to run the model. From this information they should understand the basic capabilities of the AERMOD model well enough to judge the suitability of the model for particular applications. They may also want to review the brief tutorial provided in Section 2 to learn about the nature and structure of the input runstream file, in order to better be able to review the modeling results.

1.1.4 Programmers/Systems Analysts

Programmers and systems analysts, specifically those involved with installing the AERMOD code on other computer systems or charged with maintaining the code, should review the contents of Section 4 of this document. This will give specific details on compiling and linking the code for various situations, and explain in detail the memory storage requirements and control of input and output (I/O). They may also wish to review the remainder of this Introduction and the brief tutorial in Section 2 of this volume in order to have a basic understanding of the nature and overall capabilities of the model, and to understand the basic input runstream file structure and organization.

1.2 OVERVIEW OF THE AERMOD MODEL

This section provides an overview of the AERMOD model, including a discussion of the regulatory applicability of the model, a description of the basic options available for running the model, and an explanation of the basic input data and hardware requirements needed for executing the model.

1.2.1 Regulatory Applicability

The U.S. Environmental Protection Agency (EPA) maintains a *Guideline on Air Quality Models* (hereafter, Guideline) which is published as Appendix W to 40 CFR Part 51.

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as revised). The Guideline provides the agency's guidance on regulatory applicability of air quality dispersion models in general. In general, regulatory modeling applications should be carried out in accordance with a modeling protocol that is reviewed and approved by the appropriate agency prior to conducting the modeling. The modeling protocol should identify the specific model, modeling options and input data to be used for a particular application.

1.2.2 Basic Input Data Requirements

One of the basic inputs to AERMOD is the runstream setup file which contains the selected modeling options, as well as source location and parameter data, receptor locations, meteorological data file specifications, and output options. Another type of basic type of input data needed to run the model is the meteorological data. AERMOD requires two types of meteorological data files, that are provided by the AERMET meteorological preprocessor program (EPA, 2004b). One file consists of surface scalar parameters, and the other file consists of vertical profiles of meteorological data. These meteorological data files are described briefly later in this section, and in more detail in Sections 2 and 3. For applications involving elevated terrain effects, the receptor and terrain data will need to be processed by the AERMAP terrain preprocessing program (EPA, 2004c) before input to the AERMOD model.

1.2.3 Computer Hardware Requirements

The current version of the AERMOD model was developed on an IBM-compatible PC, and has been designed to run on PCs with an 80386 or higher central processing unit (CPU) chip, a minimum of 2 MB of RAM, a math coprocessor, and MS-DOS Version 3.2 or higher. In order to handle the input data files (runstream setup and meteorology) and the output files, it is required that the system have a hard disk drive. The amount of storage space required on the hard disk for a particular application will depend greatly on the output options selected. Some of the optional output files of concentration data can be rather large. More information on output file products is provided in Sections 2 and 3.

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1.2.4 Overview of Available Modeling Options

The AERMOD model includes a wide range of options for modeling air quality impacts of pollution sources, making it a popular choice among the modeling community for a variety of applications. The following sections provide a brief overview of the options available in the AERMOD model.

1.2.4.1 Dispersion Options

Since the AERMOD model is specially designed to support the EPA's regulatory modeling programs, the regulatory modeling options will be the default mode of operation for the model. These options include the use of stack-tip downwash, and a routine for processing averages when calm winds or missing meteorological data occur. The model also includes non-default options for suppressing the use of stack-tip downwash, and to disable the date checking for non-sequential meteorological data files. The latter option is needed to facilitate evaluation of the model. The user can specify several short term averages to be calculated in a single run of the AERMOD model, as well as requesting the overall period (e.g. annual) averages.

1.2.4.2 Source Options

The model is capable of handling multiple sources, including point, volume, and area source types. Line sources may also be modeled as a string of volume sources or as elongated area sources. Several source groups may be specified in a single run, with the source contributions combined for each group. This is particularly useful for PSD applications where combined impacts may be needed for a subset of the modeled background sources that consume increment, while the combined impacts from all background sources (and the permitted sources) are needed to demonstrate compliance with the National Ambient Air Quality Standards (NAAQS). The model contains algorithms for modeling the effects of

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aerodynamic downwash due to nearby buildings on point source emissions. AERMOD does include algorithms for modeling depositional effects on particulate emissions.

Source emission rates can be treated as constant throughout the modeling period, or may be varied by month, season, hour-of-day, or other optional periods of variation. These variable emission rate factors may be specified for a single source or for a group of sources. The user may also specify a separate file of hourly emission rates for some or all of the sources included in a particular model run.

4.3.2.4.3 Receptor Options.

The AERMOD model has considerable flexibility in the specification of receptor locations. The user has the capability of specifying multiple receptor networks in a single run, and may also mix Cartesian grid receptor networks and polar grid receptor networks in the same run. This is useful for applications where the user may need a coarse grid over the whole modeling domain, but a denser grid in the area of maximum expected impacts. There is also flexibility in specifying the location of the origin for polar receptors, other than the default origin at (0,0) in x,y, coordinates.

The user can input elevated receptor heights in order to model the effects of terrain above (or below) stack base, and may also specify receptor elevations above ground level to model flagpole receptors. There is no distinction in AERMOD between elevated terrain below release height and terrain above release height, as with earlier regulatory models that distinguished between simple terrain and complex terrain. For applications involving elevated terrain, the user must also input a hill height scale along with the receptor elevation. To facilitate the generation of hill height scales for AERMOD, a terrain preprocessor, called AERMAP, has been developed (EPA, 2004c).

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3.2.4.4 Meteorology Options.

The AERMOD model utilizes a file of surface boundary layer parameters and a file of profile variables including wind speed, wind direction, and turbulence parameters. These two types of meteorological inputs are generated by the meteorological preprocessor for AERMOD, which is called AERMET (EPA, 2004b). Both of these meteorological input files are sequential ASCII files, and the model automatically recognizes the format generated by AERMET as the default format. The model will process all available meteorological data in the specified input file by default, but the user can easily specify selected days or ranges of days to process.

3.2.4.5 Output Options.

The basic types of printed output available with AERMOD are:

- Summaries of high values (highest, second highest, etc.) by receptor for each averaging period and source group combination;
- Summaries of overall maximum values (e.g., the maximum 50) for each averaging period and source group combination; and
- Tables of concurrent values summarized by receptor for each averaging period and source group combination for each day of data processed. These "raw" concentration values may also be output to unformatted (binary) files, as described below.

The tables by receptor and maximum value tables can be output for the source group values or for the individual source values, or both. In addition, when maximum values for individual sources are output, the user has the option of specifying whether the maximum source values are to be the maximum values for each source independently, or the contribution of each source to the maximum group values, or both.

In addition to the tabular printed output products described above, the AERMOD model provides options for several types of file output products. One of these options for

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AERMOD is to output an unformatted ("binary") file of all concentration values as they are calculated. These files are often used for special postprocessing of the data. In addition to the unformatted concentration files, AERMOD provides options for two additional types of file outputs. One option is to generate a file of (X,Y) coordinates and design values (e.g., the second highest values at each receptor for a particular averaging period and source group combination) that can be easily imported into many graphics plotting packages to generate contour plots of the concentration values. Separate files can be specified for all of the averaging period and source group combinations of interest to the user.

Another output file option of the AERMOD model is to generate a file of all occurrences when a concentration value equals or exceeds a user-specified threshold. Again, separate files are generated for only those combinations of averaging period and source group that are of interest to the user. These files include the date on which the threshold violation occurred, the receptor location, and the concentration value.

AERMOD includes options for two types of output files that are designed to facilitate model evaluation. One type of file lists concentrations by rank, where only one value per date is included. This file may be used to generate Q-Q (quantile) plots of results, where values from different models and/or observed data are paired by rank. The other type of output file provides annual maximum results along with detailed information about the plume characteristics associated with the annual maximum.

1.2.4 Source Contribution Analyses

In air quality dispersion modeling applications, the user may have a need to know the contribution that a particular source makes to an overall concentration value for a group of sources. This section provides a brief introduction to how these types of source contribution (sometimes referred to as source culpability) analyses are performed using the AERMOD model. More detailed information about exercising these options is provided in Section 3.

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The AERMOD model provides the option of specifying source groups for which the model calculates high values independently. However, users may often have to run the model a second time selecting only specific days where the high values occurred, and setting up each source in its own source group in order to obtain source contribution results. Rather than running a separate EVENT model, as was done with ISCST2 (the original precursor to the AERMOD model), the EVENT processing has been incorporated into the AERMOD model

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2.0 GETTING STARTED - A BRIEF TUTORIAL

This section provides a brief tutorial for setting up a simple application problem with the AERMOD model, which serves as an introduction for novice users to the AERMOD model. The example illustrates the usage of the most commonly used options in the AERMOD model. A more complete description of the available options for setting up the AERMOD model is provided in Section 3.

The example problem presented in this section is a simple application of the AERMOD model to a single point source. The source is a hypothetical stack at a small isolated facility in a rural setting. Since the stack is below the Good Engineering Practice (GEP) stack height, the emissions from the source are subject to the influence of aerodynamic downwash due to the presence of nearby buildings. The tutorial leads the user through selection and specification of modeling options, specification of source parameters, definition of receptor locations, specification of the input meteorological data, and selection of output options. Since this discussion is aimed at novice users of the AERMOD model, a general description of the input file keyword/parameter approach is provided first.

2.1 DESCRIPTION OF KEYWORD/PARAMETER APPROACH

The input file for the AERMOD model makes use of a keyword/parameter approach to specifying the options and input data for running the model. The descriptive keywords and parameters that make up this input runstream file may be thought of as a command language through which the user communicates with the model what he/she wishes to accomplish for a particular model run. The keywords specify the type of option or input data being entered on each line of the input file, and the parameters following the keyword define the specific options selected or the actual input data. Some of the parameters are also input as descriptive secondary keywords.

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The runstream file is divided into five functional "pathways." These pathways are identified by a two-character pathway ID placed at the beginning of each runstream image. The pathways and the order in which they are input to the model are as follows:

CO - for specifying overall job **CO**ntrol options;

SO - for specifying **SO**urce information;

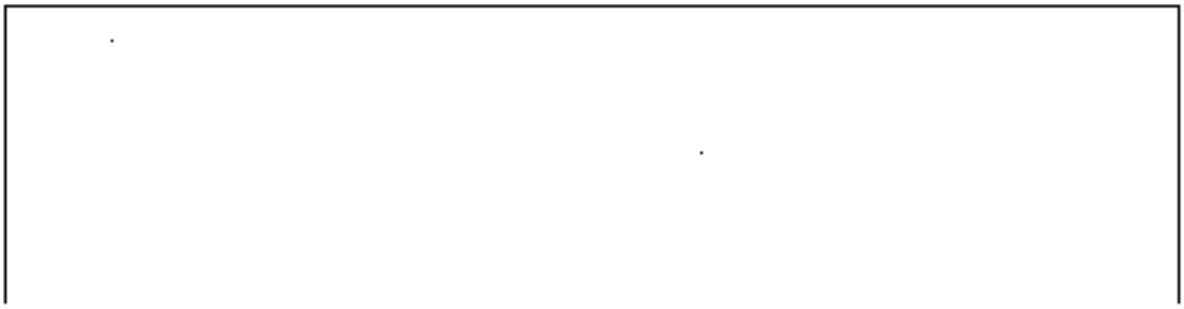
RE - for specifying **RE**ceptor information;

ME - for specifying **ME**teorology information;

EV - for specifying **EV**ent processing;

OU - for specifying **OU**tput options.

Each line of the input runstream file consists of a pathway ID, an 8-character keyword, and a parameter list. An example of a line of input from a runstream file, with its various parts identified, is shown below:



The following sections describe the rules for structuring the input runstream file, and explain some of the advantages of the keyword/parameter approach.

2.1.1 Basic Rules for Structuring Input Runstream Files

While the input runstream file has been designed to provide the user with considerable flexibility in structuring the input file, there are some basic syntax rules that need to be followed. These rules serve to maintain some consistency between input files generated by

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different users, to simplify the job of error handling performed by the model on the input data, and to provide information to the model in the appropriate order wherever order is critical to the interpretation of the inputs. These basic rules and the various elements of the input runstream file are described in the paragraphs that follow.

One of the most basic rules is that all inputs for a particular pathway must be contiguous, i.e., all inputs for the CO pathway must come first, followed by the inputs for the SO pathway, and so on. The beginning of each pathway is identified with a "STARTING" keyword, and the ending of the pathway with the "FINISHED" keyword. Thus the first functional record of each input file must be "CO STARTING" and the last record of each input file must be "OU FINISHED." The rest of the input images will define the options and input data for a particular run.

Each record in the input runstream file is referred to as a runstream "image." These records are initially read into the model as 132-character images. The information on each input image consists of a "pathway," a "keyword," and one or more "parameters." Each of these "fields" on the runstream image must be separated from other fields by at least one blank space. To simplify the interpretation of the runstream image by the model, the runstream file must be structured with the two-character pathway in columns 1 and 2, the eight-character keyword in columns 4 through 11, followed by the parameters in columns 13 through 132, as necessary. For most keywords, the <u>order</u> of parameters following the keyword <u>is</u> important -- the exact <u>spacing</u> of the parameters <u>is not</u> important, as long as they are separated from each other by at least one blank space and do not extend beyond the 132 character limit. The example of a runstream image from the CO pathway shown above is repeated here:

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Alphabetical characters can be input as either lower case or upper case letters. The model converts all character input to upper case letters internally, with the exception of the title fields and file names to be discussed later. Throughout this document, the convention of using upper case letters is followed. For numeric input data, it should be noted that all data are assumed to be in metric units, i.e., length units of meters, speed units of meters per second, temperature units of degrees Kelvin, and emission units of grams per second. In a few instances, the user has the option of specifying units of feet for length and the model will perform the conversion to meters. These exceptions are the input of receptor heights for elevated terrain and the specification of anemometer height, since these values are often more readily available in feet than in meters.

Certain keywords are mandatory and must be present in every runstream file, such as the MODELOPT keyword shown in the example above which identifies the modeling options. Other keywords are optional and are only needed to exercise particular options, such as the option to allow for the input of flagpole receptor heights. Some of the keywords are repeatable, such as the keywords to specify source parameters, while other keywords may only appear once. The keyword references in Section 3, Appendices A and B and the Quick Reference at the end of this volume identify each keyword as to its type, either mandatory or optional, and either repeatable or non-repeatable.

With a few exceptions that are described below, the order of keywords within each pathway is not critical. For the SO pathway, the LOCATION keyword must be specified before other keywords for a particular source, and the SRCGROUP keyword must be the last

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keyword before SO FINISHED. For keywords on the SO pathway that accept a range of source IDs, the source parameters specified by those keywords will only be applied to the sources already defined, and will exclude any sources that are specified latter in the input file.

The PARAMETER ILEN_FLD is used to specify the maximum length of individual fields on the input runstream image, and also to declare the length of all filename and format variables. This PARAMETER is initially assigned a value of 80, and is in MODULE MAIN1 in MODULES.FOR.

2.1.2 Advantages of the Keyword Approach

The keyword approach provides some advantages over the type of input file used by other models that require formatted input of several numeric switches. One advantage is that the keywords are descriptive of the options and inputs being used for a particular run, making it easier for a reviewer to ascertain what was accomplished in a particular run by reviewing the input file. Another advantage is that the user has considerable flexibility in structuring the inputs to improve their readability and understandability, as long as they adhere to the few basic rules described above.

Some special provisions have been made to increase the flexibility to the user in structuring the input files. One provision is to allow for blank records in the input file. This allows the user to separate the pathways from each other, or to separate a group of images, such as source locations, from the other images. Another provision is for the use of "comment lines," identified by a "**" in the pathway field. Any input image that has "**" for the pathway ID will be ignored by the model. This is especially useful for labeling the columns in the source parameter input images, as illustrated in the example problem later in this section. It may also be used to "comment out" certain options for a particular run without deleting the options and associated data (e.g., elevated terrain heights) completely from the input file. Because of the descriptive nature of the keyword options and the flexibility of the

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inputs it is generally much easier to make modifications to an existing input runstream file to obtain the desired result.

Another reason for improved "user-friendliness" is that detailed error-handling has been built into the model. The model provides descriptions of the location and nature of all of the errors encountered for a particular run. Rather than stopping execution at each occurrence of an input error, the model will read through and attempt to process all input records and report all errors encountered. If a fatal error occurs, then the model will not attempt to execute the model calculations.

2.2 REGULATORY MODELING OPTIONS

The regulatory default option is controlled from the MODELOPT keyword on the CO pathway. As its name implies, this keyword controls the selection of modeling options. It is a mandatory, non-repeatable keyword, and it is an especially important keyword for understanding and controlling the operation of the AERMOD model. Unless specified otherwise through the available keyword options, the AERMOD model implements the following default options:

- Use the elevated terrain algorithms requiring input of terrain height data.
- Use stack-tip downwash (except for building downwash cases).
- Use the calms processing routines.
- Use the missing data processing routines.
- Use a 4-hour half-life for exponential decay of SO_2 for urban sources.

The parameters used to specify options on the MODELOPT keyword are character strings, called "secondary keywords," that are descriptive of the option being selected. For example, to ensure that the regulatory default options are used for a particular run, the user would include the secondary keyword "DFAULT" on the MODELOPT input. The presence of this

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secondary keyword tells the model to override any attempt to use a non-regulatory default option. The model will warn the user if a non-regulatory option is selected along with the DFAULT option, but will not halt processing. For regulatory modeling applications, it is strongly suggested that the DFAULT switch be set, even though the model defaults to the regulatory options without it. The MODELOPT keyword is described in more detail in the Section 4.2.2.

For any application in which a non-regulatory option is to be selected, the DFAULT switch must not be set, since it would otherwise override the non-regulatory option. The non-regulatory options are also specified by descriptive secondary keywords, for example, "NOSTD" invokes the option not to use stack-tip downwash.

2.3 MODEL STORAGE LIMITS

The AERMOD model has been designed using a dynamic storage allocation approach, where the model allocates data storage as needed based on the number of sources, receptors, source groups, and input requirements, up to the maximum amount of memory available on the computer being used.

The AERMOD model uses dynamic arrays to allocate data storage at model runtime, rather than at compile time, as done by the previous version of AERMOD. The AERMOD model preprocesses the model runstream input file to determine the data storage requirements for a particular model run, and then allocates the input data arrays before processing the setup data. Once the setup processing is completed, the model allocates storage for the result arrays. When allocating data storage, the AERMOD model traps for errors, e.g., not enough memory available to allocate. If the allocation is unsuccessful, then an error message is generated by the model, and further processing is prevented. If the CO RUNORNOT NOT option is selected, the model will still go through all array allocations so that the user can determine if sufficient memory is available to complete the run. Also, an estimate of the total

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amount of memory needed for a particular run is printed out as part of the first page of printed output.

The parameters that are established at model runtime are as follows:

NSRC	Number of Sources
NREC	Number of Receptors
NGRP	Number of Source Groups
NAVE	Number of Short Term Averaging Periods
NVAL	Number of High Values by Receptor (RECTABLE Keyword)
NTYP	Number of Output Types (CONC currently is the only output type)
NMAX	Number of Overall Maximum Values (MAXTABLE Keyword)
NQF	Number of Variable Emission Rate Factors Per Source
NPDMAX	Number of Particle Diameter Categories Per Source
IXM	Number of X-coord (Distance) Values Per Receptor Network
IYM	Number of Y-coord (Direction) Values Per Receptor Network
NNET	Number of Cartesian and/or Polar Receptor Networks
NARC	Number of Receptor Arcs Used with EVALCART Keyword
NEVE	Number of Events for EVENT processing

In the case of NPDMAX, if no particle information is present in the input runstream, then NPDMAX is set to 1, otherwise it is set to 20. Other parameters are set to the actual numbers required for a particular model run.

There are several static array limits defined in AERMOD. These limits are controlled by PARAMETER statements in the Fortran source code. The variable name, description, and current value are defined in Section 4.2.2. If any of these static limits are changed, then AERMOD must be recompiled and linked. This process is described in Section 4.2.1.

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2.4 SETTING UP A SIMPLE RUNSTREAM FILE

This section goes through a step-by-step description of setting up a simple application problem, illustrating the most commonly used options of the AERMOD model. The example problem is based on a simple industrial source application. The input file for AERMOD for the example problem is shown in Figure 2-1. The remainder of this section explains the various parts of the input file for the AERMOD model, and also illustrates some of the flexibility in structuring the input file.

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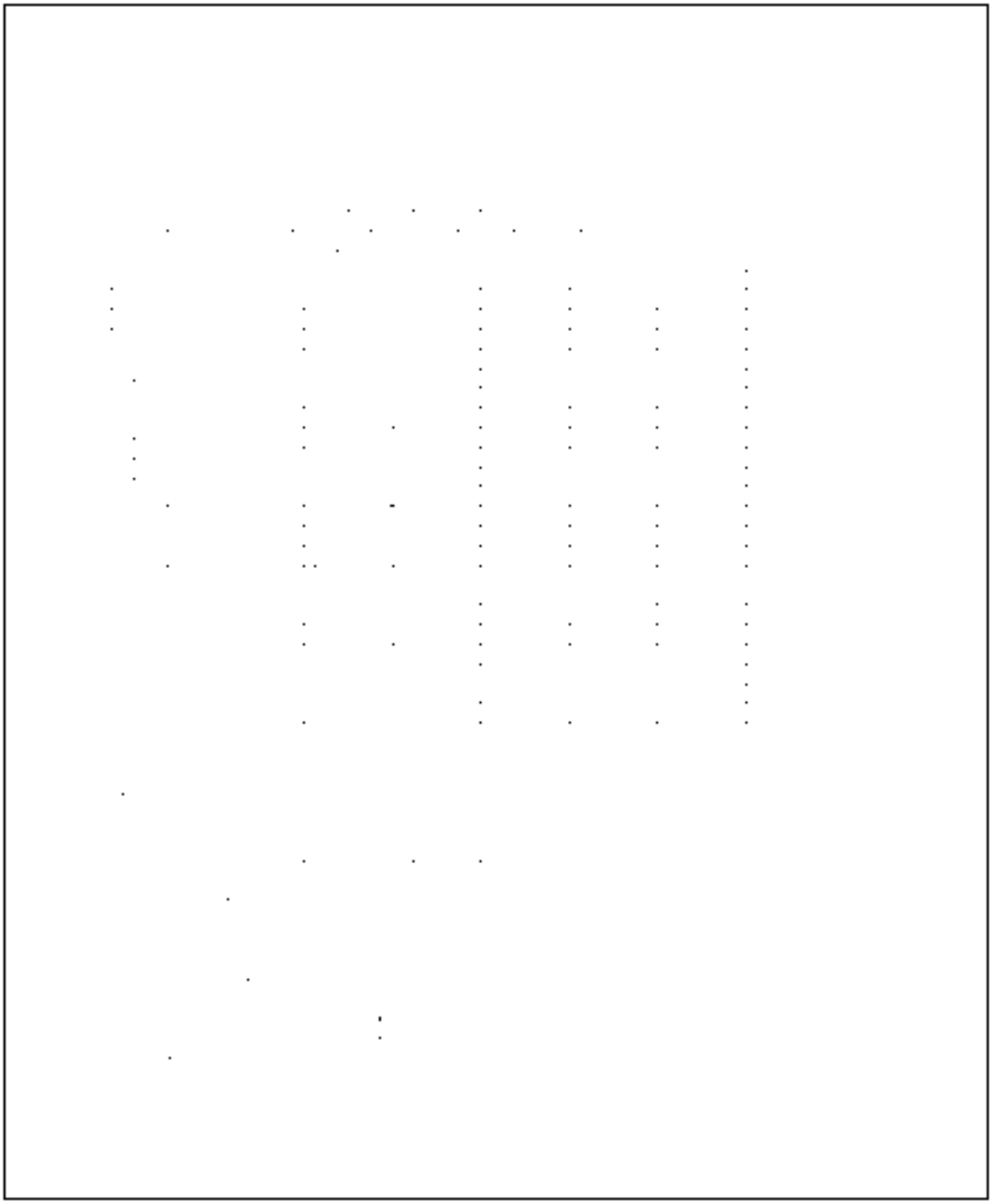

FIGURE 2-1 EXAMPLE INPUT FILE FOR AERMOD FOR SAMPLE PROBLEM

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2.4.1 A Simple Industrial Source Application

For this simple tutorial, an application is selected involving a single point source of SO_2 that is subject to the influences of building downwash. The source consists of a 50-meter stack with a buoyant release that is adjacent to a building. We will assume that the stack is situated in flat terrain in a rural setting. A polar receptor network will be placed around the stack location to identify areas of maximum impact.

2.4.2 Selecting Modeling Options - CO Pathway

The modeling options are input to the model on the Control pathway. The mandatory keywords for the CO pathway are listed below. A complete listing of all keywords is provided in Appendix B.

STARTING -	Indicates the beginning of inputs for the pathway; this keyword is mandatory on each of the pathways.
TITLEONE -	A user-specified title line (up to 68 characters) that will appear on each page of the printed output file (an optional second title line is also available with the keyword TITLETWO).
MODELOPT	Controls the modeling options selected for a particular run through a series of secondary keywords.
AVERTIME	Identifies the averaging periods to be calculated for a particular run.
POLLUTID	Identifies the type of pollutant being modeled. At the present time, this option has no influence on the results.
RUNORNOT -	A special keyword that tells the model whether to run the full model executions or not. If the user selects not to run, then the runstream setup file will be processed and any input errors reported, but no dispersion calculations will be made.
FINISHED -	Indicates that the user is finished with the inputs for this pathway; this keyword is also mandatory on each of the other pathways.

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The first two keywords are fairly self-explanatory. As discussed above in Section 2.2, the MODELOPT keyword on the CO pathway is pivotal to controlling the modeling options used for a particular run. For this example, we intend to use the regulatory default option, and have specified for the model to output concentration values. After the first three input records our input file will look something like this:

```
```

Note that the title parameter field does not need to be in quotations, even though it represents a single parameter. The model simply reads whatever appears in columns 13 through 80 of the TITLEONE card as the title field, without changing the lower case to upper case letters. Leading blanks are therefore significant if the user wishes to center the title within the field. Note also that the spacing and order of the secondary keywords on the MODELOPT card are not significant. A MODELOPT card that looked like this:

```
```

would have an identical result as the example above. It is suggested that the user adopt a style that is consistent and easy to read. A complete description of the available modeling options that can be specified on the MODELOPT keyword is provided in Section 4.

Since the pollutant in this example is SO_2, we will probably need to calculate average values for 3-hour and 24-hour time periods, and we also need to calculate averages for the full

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annual time period. Our runstream file might therefore look something like this after adding two more keywords:

Note again that the order of the parameters on the AVERTIME keyword is not critical, although the order of the short term averages given on the AVERTIME keyword will also be the order in which the results are presented in the output file. The order of the keywords within each pathway is also not critical in most cases, although the layout of the input runstream file may be easier to decipher if a consistent and logical order is followed. It is suggested that users follow the order in which the keywords are presented in Section 3, in Appendix B, and in the Quick Reference, unless there is a clear advantage to doing otherwise.

The only remaining mandatory keywords for the CO pathway are RUNORNOT and FINISHED. We will set the RUNORNOT switch to RUN for this example. If a user is unsure about the operation of certain options, or is setting up a complex runstream file to run for the first time, it may be desirable to set the model NOT to run, but simply to read and analyze the input file and report any errors or warning messages that are generated. Once the input file has been debugged using these descriptive error/warning messages, then the RUNORNOT switch can be set to RUN, avoiding a possible costly waste of resources generating erroneous results. Even if the model is set NOT to run, all of the inputs are summarized in the output file for the user to review.

Our complete runstream file for the CO pathway may look something like this:

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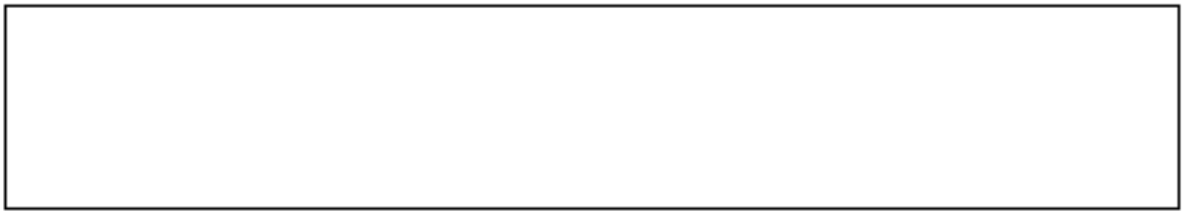

The following set of runstream images has a more structured look, but it is equivalent to the example above

Since the pathway ID is required to begin in column 1 (see Section 2.4.8 for a discussion of this restriction), the model will assume that the previous pathway is in effect if the pathway field is left blank. The model will do the same for blank keyword fields, which will be illustrated in the next section.

In addition to these mandatory keywords on the CO pathway, the user may select optional keywords to allow the use of receptor heights above ground-level for flagpole receptors, to specify a decay coefficient or a half-life for exponential decay, and to generate an input file containing events for EVENT processing. The user also has the option of having the model periodically save the results to a file for later re-starting in the event of a power failure or other interruption of the model's execution. These options are described in more detail in Section 4 of this volume.

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2.4.3 Specifying Source Inputs - SO Pathway

Besides the STARTING and FINISHED keywords that are mandatory for all pathways, the Source pathway has the following mandatory keywords:

LOCATION - Identifies a particular source ID and specifies the source type and location of that source.

SRCPARAM - Specifies the source parameters for a particular source ID identified by a previous LOCATION card.

SRCGROUP - Specifies how sources will be grouped for calculational purposes. There is always at least one group, even though it may be the group of ALL sources and even if there is only one source.

Since the hypothetical source in our example problem is influenced by a nearby building, we also need to include the optional keywords BUILDHGT and BUILDWID in our input file.

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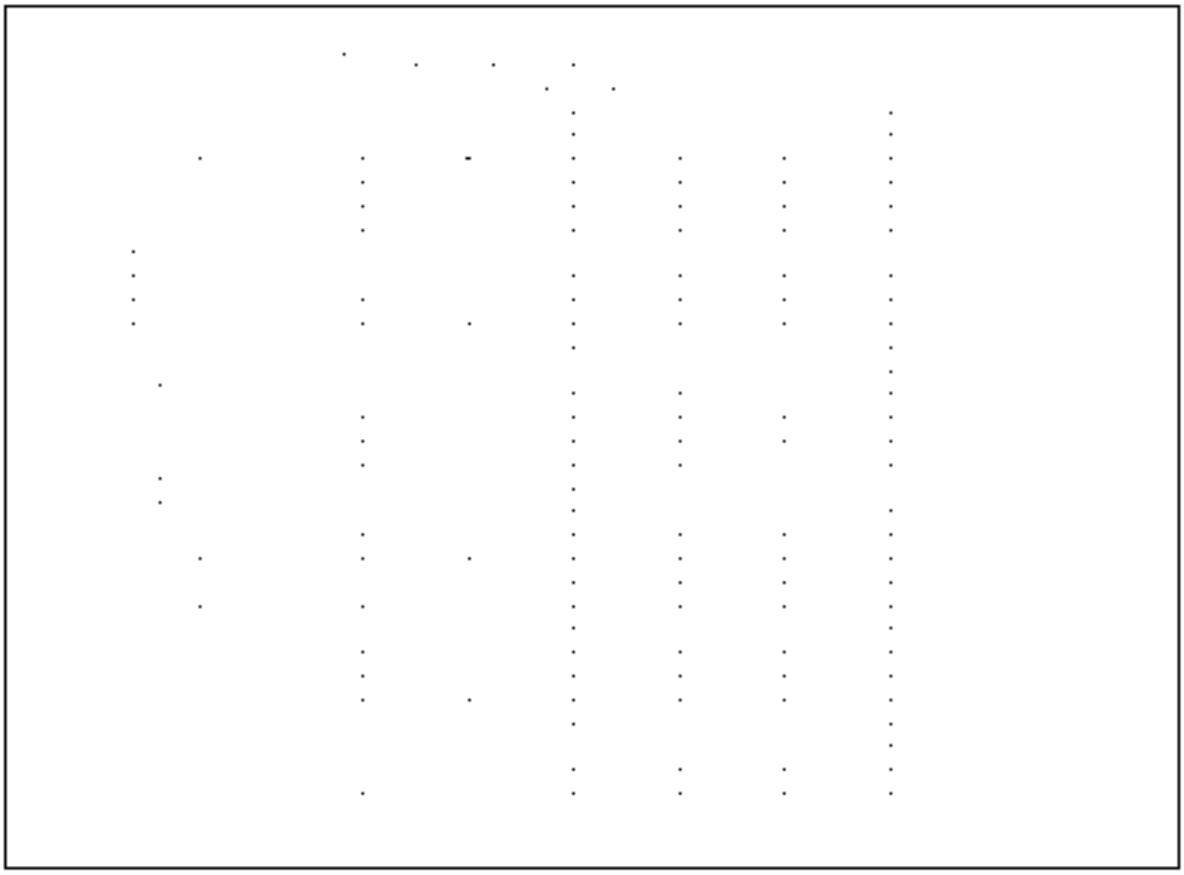
The input file for the SO pathway for this example will look something like this:



There are a few things to note about these inputs. Firstly, the source ID (STACK1 in this example) is an alphanumeric parameter (up to eight characters) that identifies the inputs for different keywords with a particular source. It is crucial that the source be identified with a LOCATION card before any other keyword makes reference to that source, since this identifies the source type (POINT in this case), and therefore which parameters the model will allow. Besides POINT sources, the current version of the ISCST3 model also allows VOLUME and AREA sources to be specified. Since the effects of elevated terrain are included in this analysis, it is important to specify the source base elevation above mean sea level (MSL) on the LOCATION card. For this example, the source base elevation is 0.0 meters MSL.

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Another thing to note is that since the model uses direction specific building dimensions for all sources with downwash, there are 36 building heights and 36 building widths entered on the appropriate keywords, one value for each 10 degree sector beginning with the 10 degree flow vector (direction toward which the wind is blowing), and continuing clockwise. Since the user could not fit all 36 values on a single record, the pathway, keyword and source ID were repeated as many times as were necessary. In this case there were 6 values given on each of 6 lines for each of the building dimensions. There could have been fewer or more lines as long as exactly 36 values were entered before starting with a new keyword. Since all of the building heights were the same across the sectors (fairly realistic for the height but not for widths, unless the structure was circular), there is a short cut available for specifying numeric input in the runstream files for the model. The user can specify "repeat values" by entering a field such as "36*50.0" as a parameter for the BUILDHGT keyword. The model will interpret this as "36 separate entries, each with a value of 50.0," and store the values in the appropriate arrays within the model. Since the model must identify this as a single parameter field, there must not be any spaces between the repeat value and the value to be repeated.

The final keyword before finishing the SO pathway must be the SRCGROUP keyword. In this example, since there is only one source, we have taken advantage of a short cut provided by the model by specifying a source group ID (which may be up to eight characters) of ALL. Whenever this card appears in an input file, it will generate a source group with a source-group ID of ALL, consisting of all sources defined for that run. The sources do not have to be explicitly identified. In a run involving multiple sources, the user may specify multiple source groups by repeating the SRCGROUP keyword. The use of the SRCGROUP card is explained in more detail in Section 3.

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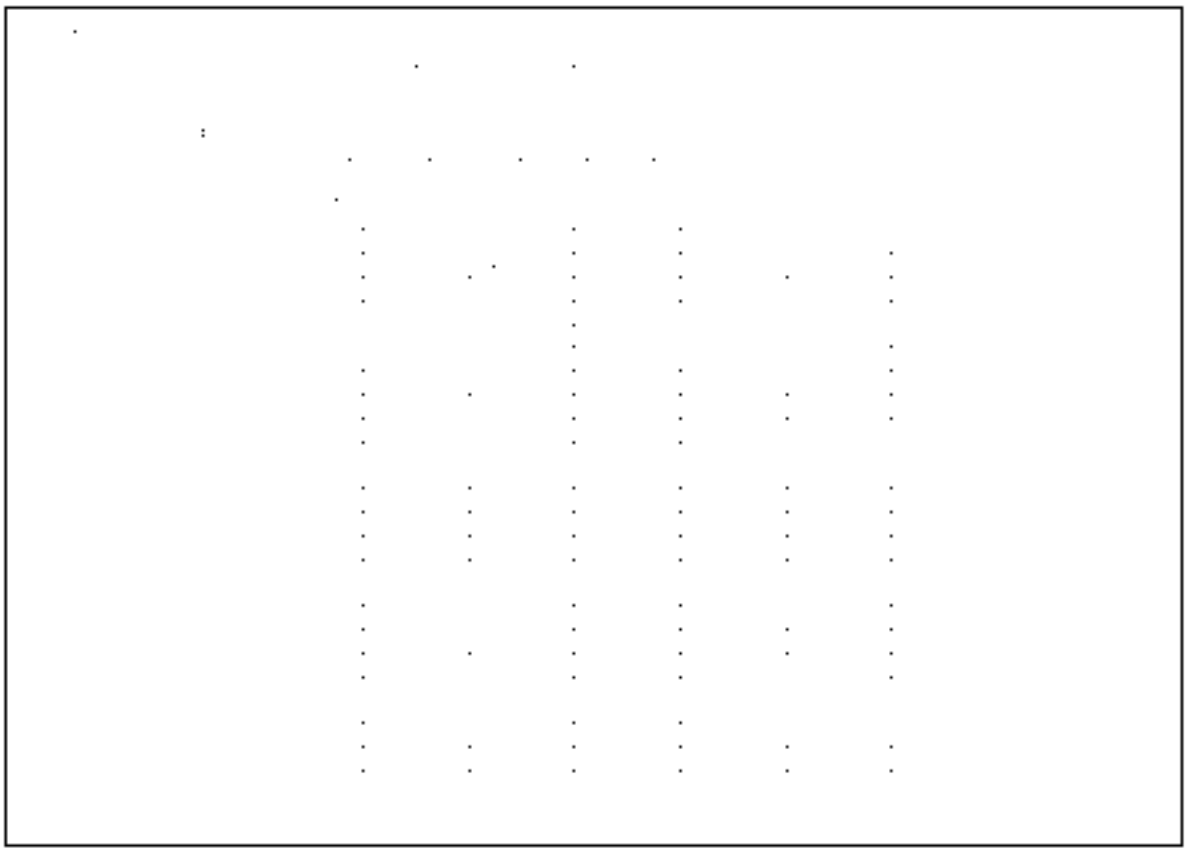
Using some of the formatting options discussed above, the SO pathway for our example may look like this, with the same result as above:



This version of the SO pathway inputs illustrates the use of the comment card to label the stack parameters on the SRCPARAM card, i.e., QS for emission rate (g/s), HS for stack height (m), TS for stack exit temperature (K), VS for exit velocity (m/s), and DS for stack diameter (m). A complete description of the source parameter card, with a list of parameters for each source type, is provided in Section 3.3 and in Appendix B.

Other optional inputs that may be entered on the SO pathway include specifying variable emission rate factors for sources whose emissions vary as a function of month, season, hour-of-day, or season and hour-of-day (see Section 3.3.4 for more details). The

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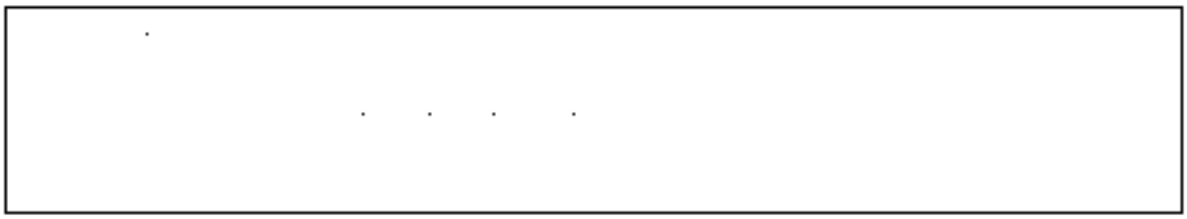
number of factors entered depends on the option selected, and factors may be input for single sources or for a range of sources.

2.4.4 Specifying a Receptor Network - RE Pathway

As mentioned above, this example will illustrate the use of a single polar receptor network centered on the stack location. Other options available on the RE receptor pathway include specifying a Cartesian grid receptor network, and specifying discrete receptor locations in either a polar or a Cartesian system. These other options are described in more detail in Section 3.4.

The RE pathway for this example will look like this:



Looking at the example for the RE pathway, the first thing to note about these inputs is that there is a new set of keywords, including something that looks like a STARting and ENDing. In fact the GRIDPOLR keyword can be thought of as a "sub-pathway," in that all of the information for a particular polar network must be in contiguous records, and that the starting and ending of the sub-pathway are identified. The order of secondary keywords within the sub-pathway is not critical, similar to the main pathways. Each card must be identified with a network ID (up to eight alphanumeric characters), in this case it's "POLR1". Multiple networks may be specified in a single model run. The model waits until the END secondary keyword is encountered to set the variables, which may include terrain heights for receptors on elevated terrain or flagpole receptor heights if those options are being exercised.

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by the user. The use of these optional secondary keywords is described in detail in Section 3.4

For this example, the ORIG secondary keyword specifies the location of the origin for the polar network being defined as being the location of the source STACK1. The origin can also be specified as X and Y-coordinates. The ORIG keyword is optional, and the model will default to an origin of (0.0, 0.0) if it is omitted. The DIST keyword identifies the distances along each direction radial at which the receptors will be located. In this case there are four distances. More distances could be added by adding values to that input card or by including a continuation card with the DIST keyword, if needed. The GDIR keyword specifies that the model will Generate DIRection radials for the network, in this case there will be 36 directions, beginning with the 10 degree flow vector and incrementing every 10 degrees clockwise. The user may elect to define Discrete DIRection radials instead by using the DDIR keyword in place of the GDIR keyword

2.4.5 Specifying the Meteorological Input - ME Pathway

The MEteorology pathway has the following four mandatory keywords (besides STARTING and FINISHED, of course)

SURFILE - Specifies the filename and format for the input surface meteorological data file

PROFILE - Specifies the filename and format for the input profile meteorological data file

SURFDATA - Specifies information about the surface meteorological data which will be used in the modeling

UAIRDATA - Specifies information about the upper air meteorological data which will be used in the modeling

PROFBASE - Specifies the base elevation above MSL for the potential temperature profile

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For the purposes of this example we will assume that the meteorological data files are for Albany, NY and that an on-site location called Hudson has also been used. We will also assume that the surface and profile data files were generated by the AERMET preprocessor, and are in the default format for AERMOD. The filename of the surface file is AERMET2.SFC and it consist of four days of data for Albany/Hudson from March 1988. The filename of the profile file is AERMET2.PFL. The data files used in this example correspond with the on-site example files used for the AERMET preprocessor program. The runstream images for the METeorology pathway would look something like this:

The first parameters on the SURFFILE and PROFFILE keywords are the filenames for the surface and profile data file, respectively, which can be entered as a full DOS pathname, including the drive specification and subdirectories, up to a total of 80 characters (with the maximum number of characters controlled by the FILE_FILD PARAMETER located in MODULE MAIN1 - see Section 2.1.3). Since there is no second parameter, the model will assume the default ASCII format for the data files. The format of the surface and profile data files is described in Appendix D.

The next two mandatory inputs identify the location and data period of the input meteorological data. A separate keyword is used for the surface meteorological data and for the upper air (mixing height) data. The parameters on these cards are the station number (e.g. WBAN number for NWS stations), the data period (years), and a station name. In order to identify potential errors in the model inputs, the model compares the station number from the runstream input file with values provided in the first record of the surface meteorology file, and issues warning messages if there are any mismatches. The user may also optionally input

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the (X,Y) coordinates for the location of the station(s), although these values are not currently used by the model. In this case, we have also included the optional SITEDATA keyword to identify the location for the on-site meteorological data that were preprocessed by AERMET.

The final mandatory keyword is PROFBASE, which is used to specify the base elevation (above MSL) for the potential temperature profile generated by AERMOD for use in the plume rise calculations. This should correspond to the base elevation for the main meteorological tower, which in this example is specified as 0.0 meters and is the same as the source base elevation.

Other optional keywords available on the ME pathway provide the user with options to specify selected days to process from the meteorological data file and a wind direction rotation correction term. These optional inputs are described in more detail in Section 3.5.

2.4.6 Selecting Output Options - OU Pathway

All of the keywords on the Output pathway are optional, although the model will warn the user if no printed outputs are requested and will halt processing if no outputs (printed results or file outputs) are selected. The user has considerable flexibility to select only the outputs that are needed for a particular application. The printed table keywords are:

RECTABLE - Specifies the selection of high value by receptor table output options

MAXTABLE - Specifies the selection of overall maximum value table output options

DAYTABLE - Specifies the selection of printed results (by receptor) for each day of data processed (this option can produce very large files and should be used with care)

The RECTABLE keyword provides the highest, second-highest and third-highest values by receptor. The MAXTABLE keyword provides the overall maximum 50 table. For both of these keywords, the user has additional flexibility to specify for which short term averaging periods the outputs are selected. For the MAXTABLE keyword the user can also

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specify the number of overall maximum values to summarize for each averaging period selected, up to a maximum number controlled by a parameter in the computer code. For this example problem we will select the highest and second-highest values by receptor, and the maximum 50 values for all averaging periods. These OU pathway inputs will look something like this:

To simplify the input for users who request the same printed table output options for all averaging periods, these keywords recognize the secondary keyword "ALL AVE" as the first parameter for that purpose. In order to obtain the overall maximum 10 values for the 24-hour averages only, then the OU pathway images would look like this:

It should also be noted that these output table options apply only to the short-term averaging periods, such as the 3-hour and 24-hour averages used in our example. If the user has selected that PERIOD averages be calculated (on the CO AVERTIME keyword), then the output file will automatically include a table of period averages summarized by receptor (the RECTABLE option does not apply since there is only one period value for each receptor). In addition, the printed output file will include tables summarizing the highest values for each averaging period and source group.

Other options on the OU pathway include several keywords to produce output files for specialized purposes, such as generating contour plots of high values, identifying occurrences

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of violations of a particular threshold value (e.g., a NAAQS), and for postprocessing of the raw concentration data. These options are described in detail in Section 3.7.

The complete input runstream file for this simple example is shown in Figure 2-2. Note that a consistent style has been used for formatting and structuring the file in order to improve its readability. This input file is comparable to the version shown earlier in Figure 2-1, which used a somewhat different style.

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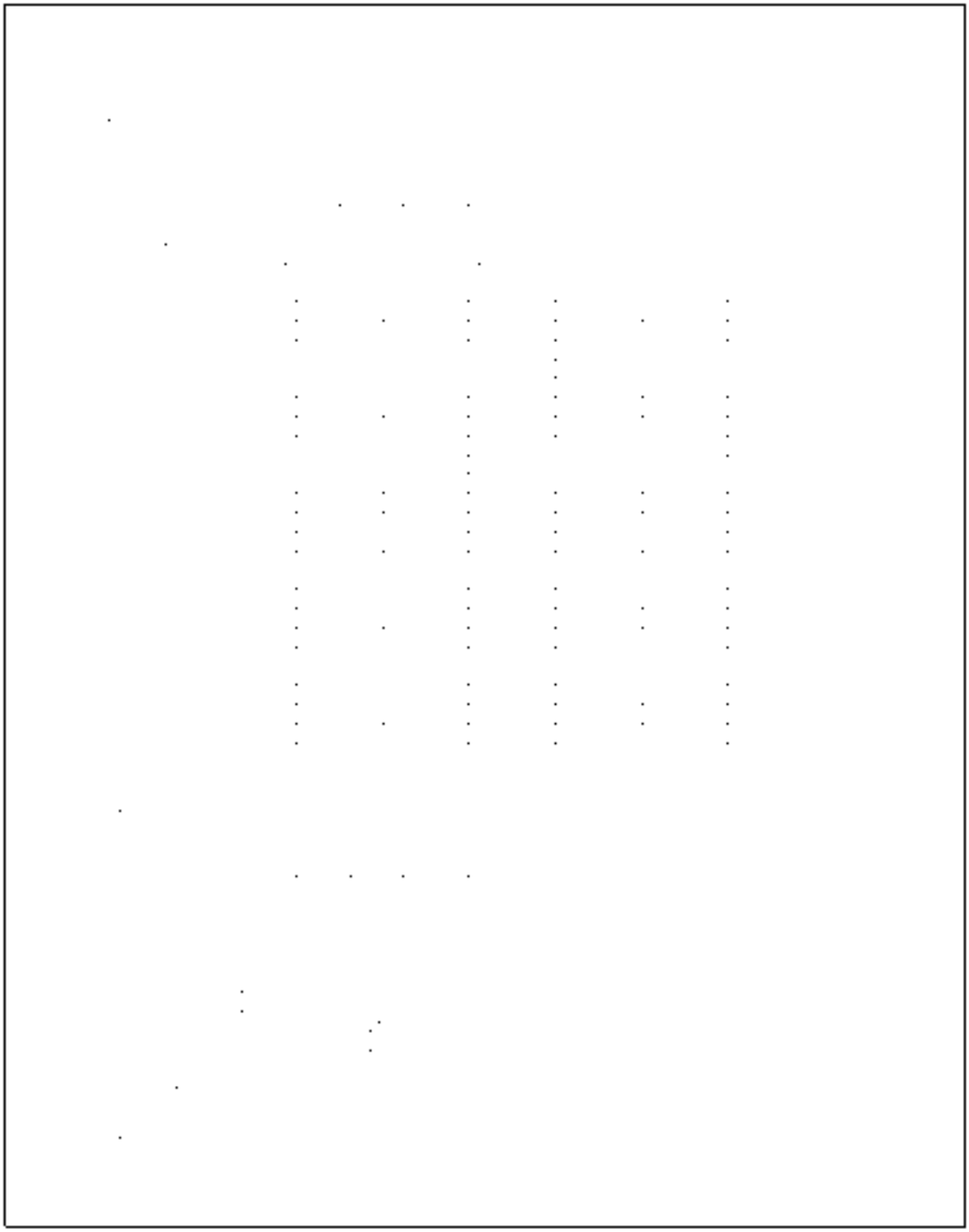

FIGURE 2-2 EXAMPLE INPUT RUNSTREAM FILE FOR SAMPLE PROBE EXT

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2.4.7 Using the Error Message File to Debug the Input Runstream File

The previous sections in this tutorial have lead through the step-by-step construction of a sample runstream input file for AERMOD. This simple example problem illustrated the usage of the most commonly used options of the AERMOD model. However, many real-time applications of the model will be much more complex than this example, perhaps involving multiple sources and source groups, multiple receptor networks, the addition of discrete receptor locations, and/or elevated terrain heights. Since humans are prone to make errors from time to time, an effort has been made to develop detailed error handling capabilities for the AERMOD model.

The error handling capabilities of the AERMOD model are designed to accomplish two things for the user. First, the model should read through the complete input file and report all occurrences of errors or suspect entries before stopping, rather than stopping on the first instance (and every instance thereafter) of an error in the input file. Second, the model should provide error and warning messages that are detailed and descriptive enough that they will help the user in his/her effort to debug the input file. The remainder of this section provides a brief introduction to the use of the model's error handling capabilities. Appendix C of this volume provides more details about the error handling provided by the AERMOD model, including a listing and explanation of all error and other types of messages generated by the model.

The AERMOD model generates messages during the processing of the input data and during the execution of model calculations. These messages inform the user about a range of possible conditions including:

- Errors that will halt any further processing, except to identify additional error conditions,
- Warnings that do not halt processing but indicate possible errors or suspect conditions, and

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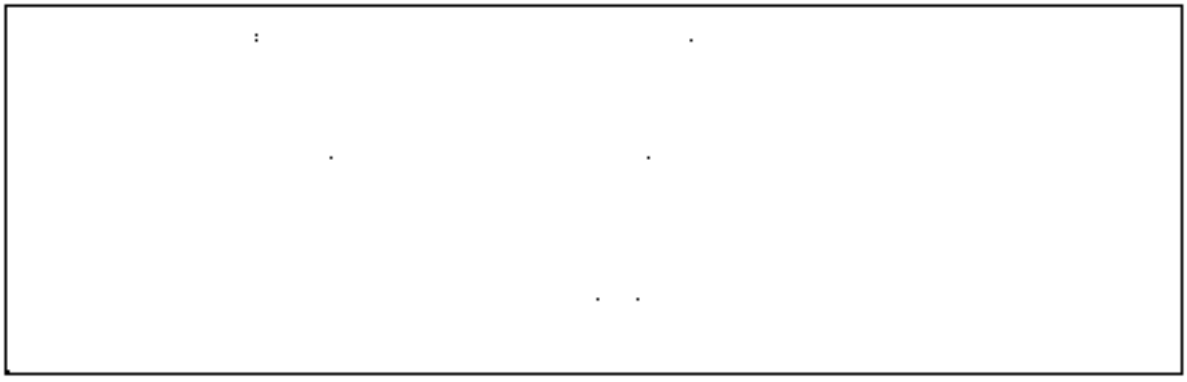
- Informational messages that may be of interest to the user but have no direct bearing on the validity of the results

As the model encounters a condition for which a message is generated, the model writes the message to a temporary storage file. At the completion of the setup processing for a run, and at the completion of the model calculations, the model rereads the message file and generates a summary of the messages which is included in the main printed output file. If the processing of the model setup information indicates no errors or warnings, and the user has selected the option to RUN the model calculations on the CO RUNORNOT card, then the model will simply write a statement to the print file that the model setup was completed successfully. Otherwise, the model will report a summary of the messages encountered. The summary of model setup messages that would be generated for the example problem if the option NOT to run was chosen is shown in Figure 2-4. This summary table reports the total number of occurrences for each of the message types, and lists the detailed message for any fatal errors or warning messages that were generated. In this case, since there were no errors or suspicious conditions in the setup file, there are no error or warning messages listed.

An example of the warning message that would have been generated had we left out the card on the RE pathway that specifies the origin of the polar receptor network is shown below.



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Since this is a warning message, it would have appeared at the end of the message summary table in the output file, but it would not have halted processing of the data. The last item on the message line, "Hints," may include such information as the keyword or parameter name causing the error, the source ID, group ID or (as in this case) the network ID involved, or perhaps the date variable identifying when the message occurred during the processing of the meteorological data, such as an informational message identifying the occurrence of a calm wind.

For new users and for particularly complex applications, it is strongly recommended that the model first be run with the RUNORNOT keyword (on the CO pathway) set NOT to run. In this way, the user can determine if the model is being setup properly by the runstream file before committing the resources to perform a complete run. The user should make a point of examining any warning messages carefully to be sure that the model is operating as expected for their application, since these messages will not halt processing by the model. In most cases, the detailed messages will provide enough information for the user to determine the location and nature of any errors in the runstream setup file. If the intent of the message is not immediately clear, then the user should refer to the more detailed descriptions provided in Appendix C for the particular error code generated.

In deciphering the error and warning messages, the line number provided as part of the message may be particularly helpful in locating the error within the input file. However, if it is an error of omission that is caught by the error checking performed at the completion of inputs for a pathway, then the line number will correspond to the last record for that pathway. The user may need to examine all of the messages carefully before locating the error or errors, especially since a single occurrence of certain types of errors may lead to other error conditions being identified later in the input file which do not really constitute errors in themselves. An example of this is provided in Figure 2-4, which shows some inputs for the SO pathway where the building dimension keywords have been typed incorrectly, and the associated list of error messages. Since continuation cards were being used for the building width inputs, and the keyword was entered incorrectly on the first line, the subsequent records

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were also taken by the model to be invalid keyword inputs. While the error messages are the same for these records, the message originates from a different part of the model (SUBROUTINE SOCARD) for the records with the blank keyword.

Since the detailed error and warning messages are listed in the output file as part of the message summary table, there will generally not be a need for the user to examine the contents of the detailed message file. For this reason, the default operation of the model is to write the messages that are generated by a particular run to a temporary file that is deleted when the run is completed. If the user wishes to examine the complete list of detailed messages for all to post, there is an optional keyword available on the CO pathway for that purpose. The ERRORFIL keyword, which is described in detail in Section 3.2.7, allows the user to save the complete list of detailed messages to a user-specified filename.

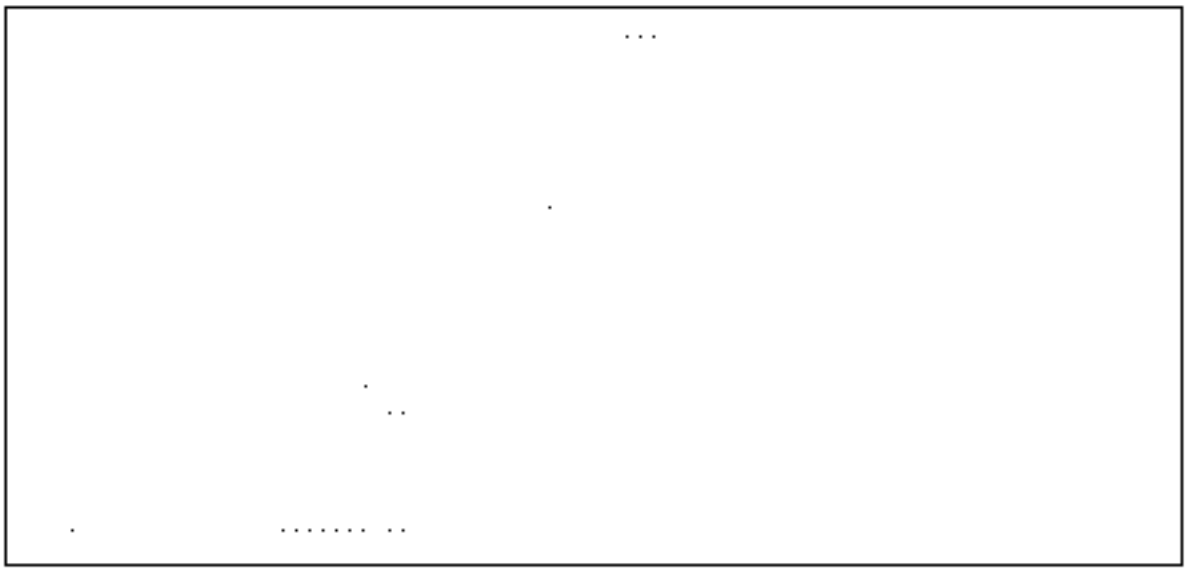

FIGURE 2-3 EXAMPLE MESSAGE SUMMARY TABLE FOR RUNSTREAM SETUP

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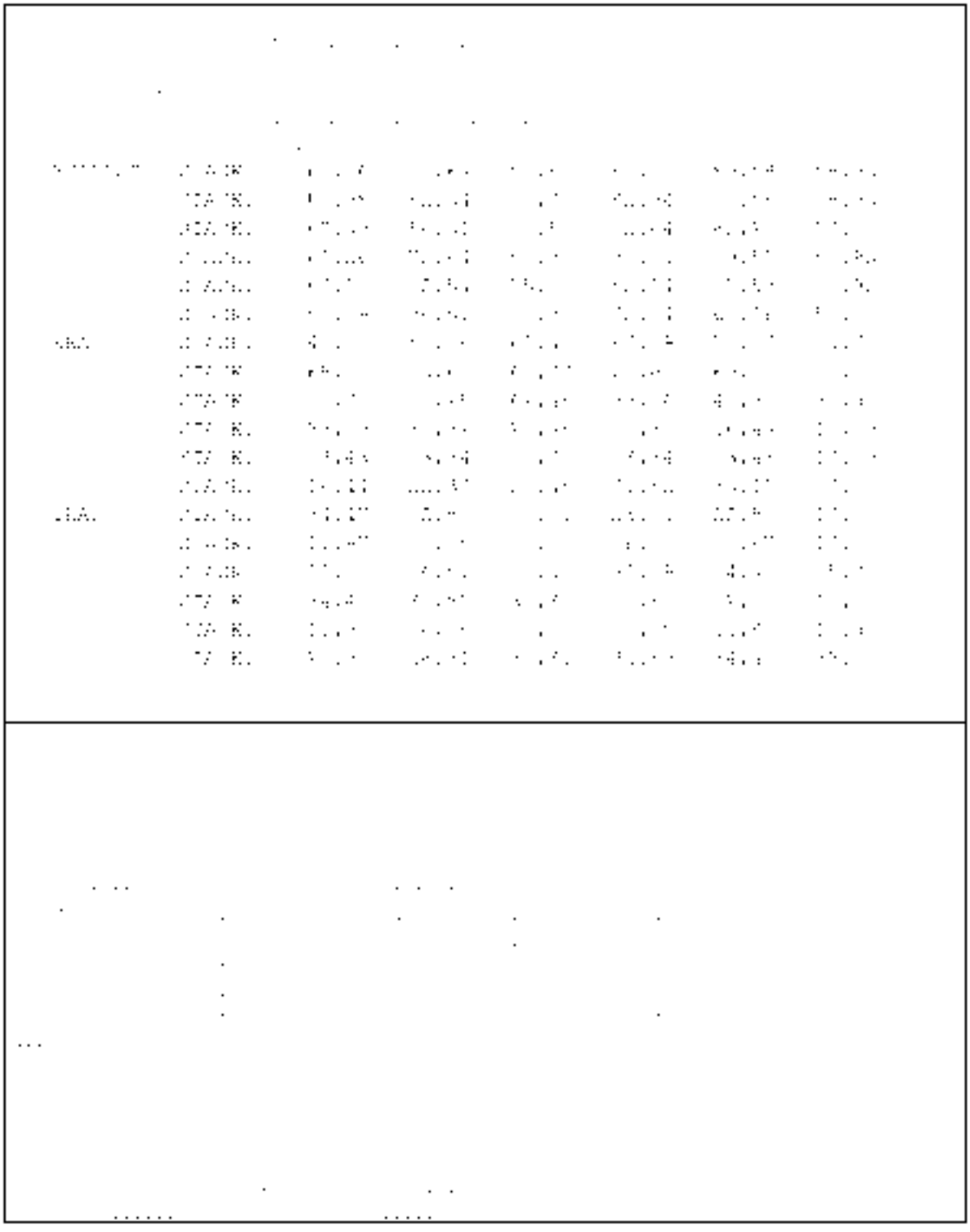

FIGURE 2-4 EXAMPLE OF KEYWORD ERROR AND ASSOCIATED MESSAGE SUMMARY TABLE

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2.4.8 Running the Model and Reviewing the Results

Now that we have a complete and error-free runstream input file, we are ready to run the model and then review the results. The PC-executable file available on the SCRAM website opens the runstream input and printed output files explicitly within the model using internally specified filenames of AERMOD.INP and AERMOD.OUT, respectively. The model can be executed from the command prompt by simply typing the name AERMOD, as follows:

C:>AERMOD

The "c-prompt" of DOS has been represented by the characters "C:>", but may appear different on different machines. The important points are that the AERMOD.EXE file either be in the directory from which you are attempting to run the model, or in a directory that is included on the DOS PATH command when the system is "booted up". The runstream input file (AERMOD.INP) must also be located in the directory from which the model is being executed. The model can also be executed by double clicking on the executable file from Windows Explorer.

As mentioned above, the SCRAM PC-executable file for AERMOD opens the input and output files explicitly. One reason for this is to allow for the model to write an update on the status of processing to the PC terminal screen. For the AERMOD model, the model first indicates that setup information is being processed and then gives the Julian day currently being processed. If no status message is seen then the model did not load into memory properly. If the model stops after completing the setup processing, then either the RUNORNOT option was set NOT to run. If a fatal error is encountered during the setup processing, then a message to that effect will be written to the screen and model execution will be stopped. Another reason for not sending the printed output to the default output device (i.e., to the screen or redirected to a file), is so that any DOS error messages will be visible on the screen and not be written to the printed file. One such message might be that

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there is insufficient memory available to run the program. Handling of DOS error messages may require some knowledge of DOS, unless the meaning of the message is obvious.

The order of contents and organization of the main output file for the AERMOD model is presented in Figure 2-5.

Echo of Input Runstream Images

Summary of Runstream Setup Messages

Summary of Inputs
- Summary of Modeling Options
- Summary of Source Data
- Summary of Receptor Data
- Summary of Meteorology Data

Model Results

- Daily Results for Each Averaging Period Selected for Each Day Processed (If Applicable)
  - DAYTABLE Keyword
- PERIOD Results for Each Source Group (If Applicable)
  - PERIOD Parameter on AVERTIME Keyword
- Short Term Average Results (High, Second High, etc.) by Receptor for Each Source Group (If Applicable)
  - RECTABLE Keyword
- Overall Maximum Short Term Average Results for Each Source Group (If Applicable)
  - MAXTABLE Keyword

Summary Tables of High Values for Each Averaging Period and Source Group (Always provided if PERIOD averages or the RECTABLE keyword are used)

Summary of Complete Model Execution Messages

FIGURE 2-5 ORGANIZATION OF AERMOD MODEL OUTPUT FILE

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Each page of the output file, except for the echo of the input file images, is labeled with the model name and version number, user-specified title(s), page number, and, for the PC version of the model, the date and time of the particular run. Also included as part of the header information for each page is a one-line summary of the modeling options used for that particular run. The modeling options are listed as the secondary keywords used to control the options, such as DEPLETE, CONC, etc. (Details about the date/time routines and other PC-specific features of the computer code are discussed in Section 4.0.)

Since the complete input file is normally echoed back as part of the output file, and since processing of the inputs stops when the OU FINISHED card is reached, the run can be duplicated by simply specifying the output filename as the input runstream file. Alternatively, the input records could be "cut and pasted" from the output file to a separate file using a text editor.

By default, the model will echo each line of the input runstream file to the printed output file. This provides a convenient record of the inputs as originally read into the model, without any rounding of numerical values that may appear in the input summary tables. As noted above, it also means that the output file can be used as an input file to the model to reproduce a particular application. However, for some applications, the length of the input runstream file may be too cumbersome to include the entire set of inputs at the beginning of each output file. This may happen, for example, if a large number of sources are being defined or if a large number of discrete receptor locations are used. For this reason, the user is provided with the option to "turn off" the echoing of the input file at any point within the runstream file. This is accomplished by entering the keywords "NO ECHO" in the first two fields anywhere within the runstream file. In other words, place NO in the pathway field, followed by a space and then ECHO. None of the input runstream images after the NO ECHO will be echoed to the output file. Thus, a user may choose to place NO ECHO after the Control pathway in order to keep the control options echoed, but suppress echoing the rest of the input file.

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The details of the message summary tables were discussed in the previous section. A portion of the summary of modeling option inputs is shown in Figure 2-6 for the simple example described in this section. The summary of source parameter input data includes separate tables for each source type, rather than combining all sources onto a single table. In this way the column headings are specific to the source type.

Figure 2-7 presents an example of the results output for the second highest values by receptor for our sample problem. These values are the second highest 3-hour averages at each receptor location. The number in parentheses following each concentration value is the date corresponding to each value. The date is given as an eight digit integer variable that includes the year (2-digits), month, day, and hour corresponding to the end of the averaging period.

For each of the different types of model result tables, the controlling keyword is identified in Figure 2-8 at the end of the description. All of the outputs of the same type (e.g. high values by receptor, are printed together, and the order of tables loops through all source groups for a particular averaging period, and then loops through all averaging periods. The summary tables of high values at the end of the model results follow the same order of loops. An example of the summary tables for our sample problem is shown in Figure 2-8. The summaries for all averaging periods have been combined onto a single figure, but would appear on separate pages of the actual output file.

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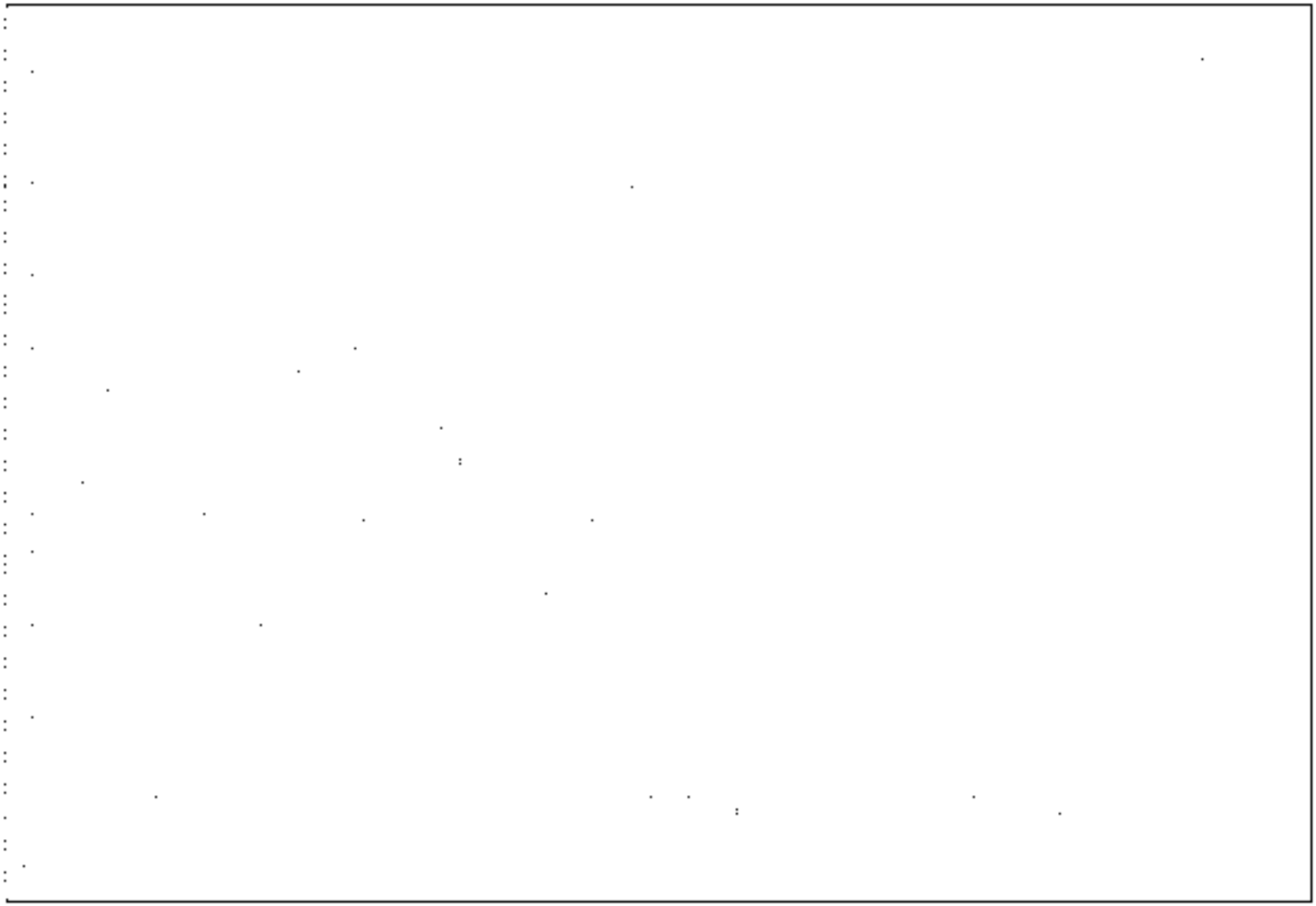

FIGURE 2-6. SAMPLE OF MODEL OPTION SUMMARY TABLE FROM AN AERMOD MODEL OUTPUT FILE

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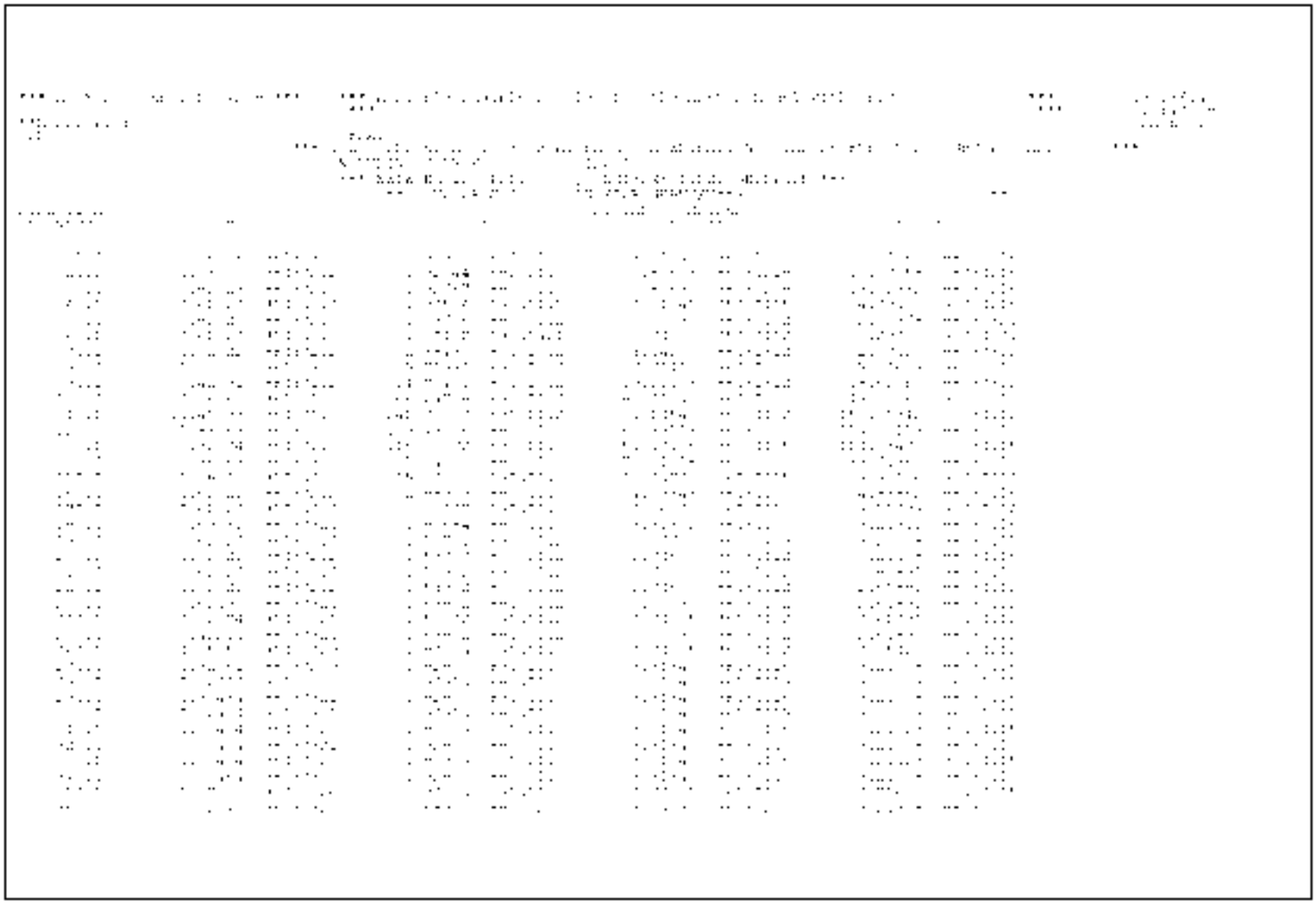

FIGURE 2-7. EXAMPLE OUTPUT USING DC HIGH VALUES BY DESCRIPTOR

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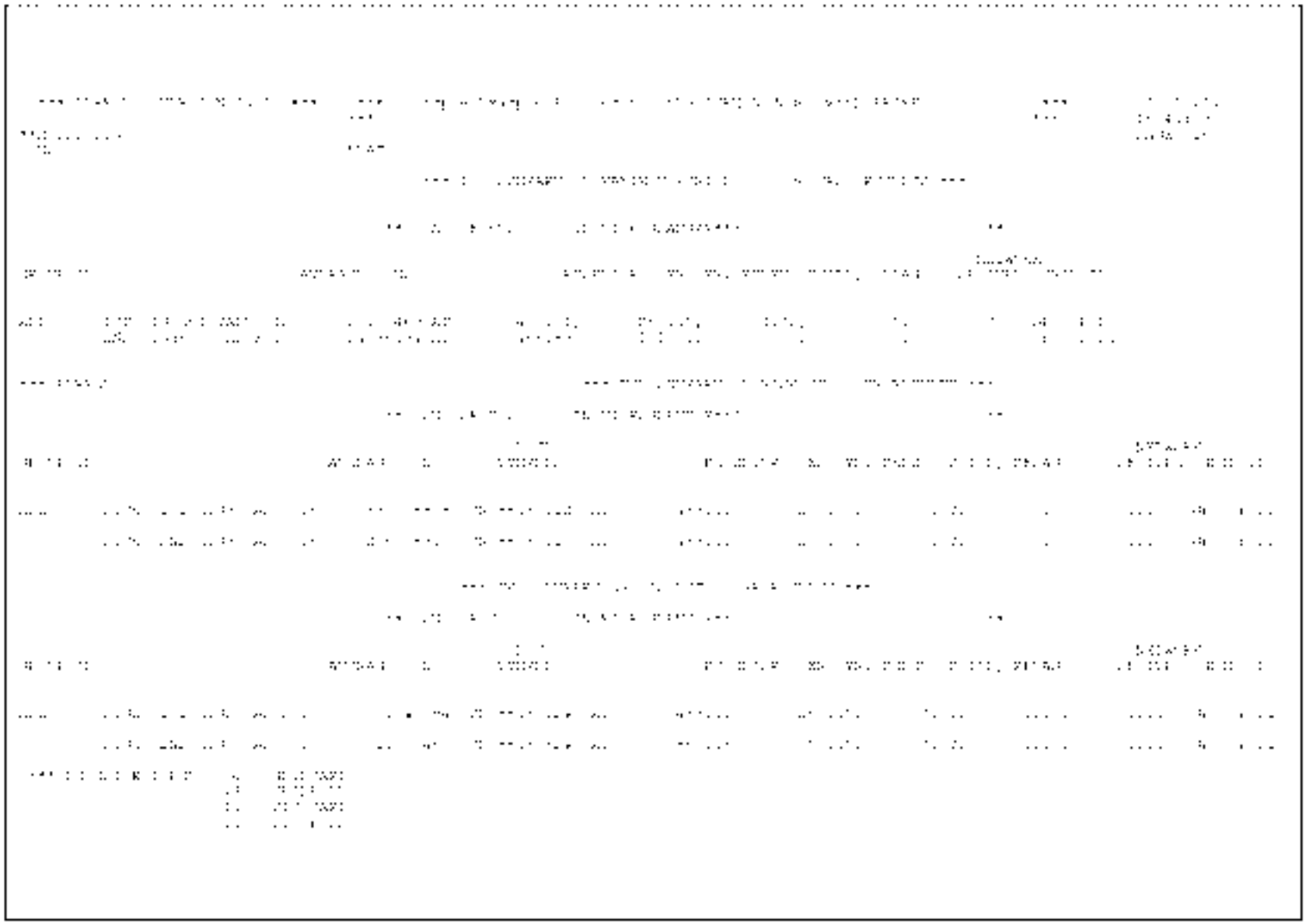

EXHIBIT 2-8. EXAMPLE OF RESULT SUMMARY TABLES FOR THE ADAMS2 MODEL

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2.5 MODIFYING AN EXISTING RUNSTREAM FILE

As noted earlier, one of the advantages of the keyword/parameter approach and the flexible format adopted for the input runstream file is that it will be easier for the user to make modifications to the runstream file and obtain the desired result. This section briefly illustrates some examples of how a runstream file can be modified. It is assumed that the reader is familiar with the operation of and basic editing commands for a text editor (i.e., a program that edits ASCII files), and is familiar with the previous sections of this tutorial.

2.5.1 Modifying Modeling Options

Depending on the type of analysis being performed, the user may need to modify the modeling options and run the model again. Because of the descriptive nature of the keywords and the secondary keywords used to control the modeling options, this can easily be done with the new runstream file, and usually without having to refer back to the user's guide each time a modification is attempted.

2.5.2 Adding or Modifying a Source or Source Group

Modifying the input file to add a source or a source group, or to add a source to a source group, is as simple as just adding it. There is no need to specify the total number of sources in the run, which would then have to be changed if more sources were added. The same applies to the number of groups, or the number of sources per group. If the user attempts to input more than the total number of sources or groups allowed for a particular run, an error message will be generated to that effect. Also, modifying a source group to delete a source is as easy as just deleting it from the input card, without having to change any other inputs.

Another way of "deleting" a source or a group from an input file is to place a "**" in the pathway field of the card or cards which define the source or group to "comment out" those inputs. This approach, which was discussed above in Section 2.1.2, has the advantage of leaving the input data for the source or group in the input file for possible later use. It doesn't matter

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whether the "*" is entered with the text editor in "insert" mode, in which case the other inputs of that line are moved over, or if it is in "overtype" mode, which would replace the pathway ID that was already there.

2.5.3 Adding or Modifying a Receptor Network

As with source data, adding to or modifying the receptor information in the AERMOD model is relatively straight forward. The problem of having to make several changes to accomplish one small modification, such as adding a distance to a polar receptor network, has been avoided in the new model. All that the user needs to do is to add the new distance on the appropriate input card, which is easily identifiable because of the use of descriptive keywords. The model checks to ensure that the user does not attempt to specify more than the maximum number of receptors for a particular run, and generates an appropriate message if too many are input.

2.5.4 Modifying Output Options

Modifying the output options involves many of the same principles that are described above. In addition, all of the output options are structured in a way that allows the user to select options for specific averaging periods, so that the user may find it useful to copy a record or group of records set up for one averaging period and simply change the averaging period parameter. The other important short cut that is available for the printed table output options is to use the secondary keyword ALL AVE to indicate that the option applies to all averaging periods that are calculated. In this way, there will be no need to change the output options if a new averaging period is added to a run or if one is deleted.

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3.0 DETAILED KEYWORD REFERENCE

This section of the AERMOD User's Guide provides a detailed reference for all of the input keyword options for the AERMOD model. The information provided in this section is more complete and detailed than the information provided in the Brief Tutorial in Section 2. Since this section is intended to meet the needs of experienced modelers who may need to understand completely how particular options are implemented in the model, the information for each keyword should stand on its own. This section assumes that the reader has a basic understanding of the keyword/parameter approach used by the model for specification of input options and data. Novice users should first review the contents of Section 2 in order to obtain that understanding.

3.1 OVERVIEW

The information in this section is organized by function, i.e., the keywords are grouped by pathway, and are in a logical order based on their function within the model. The order of keywords presented here is the same as the order used in the functional keyword reference in Appendix B, and the Quick Reference section at the end of the volume. The syntax for each keyword is provided, and the keyword type is specified - either mandatory or optional and either repeatable or non-repeatable. Unless noted otherwise, there are no special requirements for the order of keywords within each pathway, although the order in which the keywords are presented here and in Appendix B is recommended. Any keyword which has special requirements for its order within the pathway is so noted following the syntax and type description.

The syntax descriptions in the following sections use certain conventions. Parameters that are in all capital letters and underlined in the syntax description are secondary keywords that are to be entered as indicated for that keyword. Other parameters are given descriptive names to convey the meaning of the parameter, and are listed with an initial capital letter. Many of the parameter names used correspond to variable names used in the computer code of the model. Parentheses around a parameter indicate that the parameter is optional for that keyword. The default that is taken when an optional parameter is left blank is explained in the discussion for that keyword.

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3.2 CONTROL PATHWAY INPUTS AND OPTIONS

The COntrol pathway contains the keywords that provide the overall control of the model run. These include the dispersion options, averaging time options, terrain height options, and others that are described below. The CO pathway must be the first pathway in the runstream input file.

3.2.1 Title Information

There are two keywords that allow the user to specify up to two lines of title information that will appear on each page of the main output file from the model. The first keyword, TITLEONE, is mandatory, while the second keyword, TITLETWO, is optional. The syntax and type for the keywords are summarized below.

Syntax:	
Type:	

The parameters Title1 and Title2 are character parameters of length 68, which are read as a single field from columns 13 to 80 of the input record. The title information is taken as it appears in the runstream file without any conversion of lower case to upper case letters. If the TITLETWO keyword is not included in the runstream file, then the second line of the title in the output file will appear blank.

3.2.2 Dispersion Options

The dispersion options are controlled by the MODELOPT keyword of the CO pathway. The syntax, type, and order of the MODELOPT keyword are summarized below.

Syntax:	
Type:	

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where the secondary keyword parameters are described below (the order and spacing of these parameters is not critical).

DEFAULT - Specifies that the regulatory default options will be used.

CONC - Specifies that concentration values will be calculated (note that deposition algorithms have not been implemented in AERMOD yet).

FLAT - Specifies that the non-default option of assuming flat terrain will be used.

NOSTD - Specifies that the non-default option of no stack-tip downwash will be used.

NOCHKD - Specifies that the non-default option of suspending date checking will be used for non-sequential meteorological data files.

NOWARN - Specifies that the option of suppressing the detailed listing of warning messages in the main output file will be used (the number of warning messages is still reported, and warning messages are still included in the error file controlled by the CO ERRORFIL card described in Section 3.2.14).

SCREEN - Specifies that the non-default option for running AERMOD in a screening mode will be used.

TOXICS Specifies use of air toxics option(s), including SCIM and area source optimizations, and

SCIM - Sampled Chronological Input Model - used only with the ANNUAL average option to reduce runtime by sampling meteorology at a user-specified regular interval. SCIM sampling parameters must be specified on the MI pathway.

The regulatory default option in AERMOD includes the use of stack-tip downwash, incorporates the effects of elevated terrain, and includes the calms and missing data processing routines. The regulatory default option in AERMOD also forces the use of a 4-hour half life when modeling SO2 in an urban source, and does not allow for exponential decay for other applications.

The missing data processing routines that are included in the AERMOD model allow the model to handle missing meteorological data in the processing of short term averages. The model

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treats missing meteorological data in the same way as the calms processing routine, i.e., it sets the concentration values to zero for that hour, and calculates the short term averages according to EPA's calms policy, as set forth in the Guideline. Calms and missing values are tracked separately for the purpose of flagging the short term averages. An average that includes a calm hour is flagged with a 'c', an average that includes a missing hour is flagged with an 'm', and an average that includes both calm and missing hours is flagged with a 'b'. If the number of hours of missing meteorological data exceeds 10 percent of the total number of hours for a given model run, a cautionary message is written to the main output file, and the user is referred to Section 5.3.2 of "Meteorological Monitoring Guidance for Regulatory Modeling Applications" (EPA, 2000).

The screening mode of AERMOD, which is controlled by the SCREEN keyword on the MODELOPT card, forces the model calculations to represent values for the plume centerline, regardless of the source-receptor-wind direction orientation. This option is included in AERMOD to facilitate the use of the model with a Windows based AERMOD Screening Model interface (not yet developed) to estimate worst case impacts. Its use outside of that context is not recommended. Since the screening model is designed to be used with a non-sequential meteorological data file, representing a matrix of conditions, the SCREEN option also forces the use of the NOCHKD option described above, even if NOCHKD is not included on the MODELOPT card. The SCREEN option also restricts the averaging period options to 1-hour averages only on the AVERTIME card (see Section 3.2.3).

The AERMOD model includes the Sampled Chronological Input Model (SCIM) option for air toxics applications. In order to utilize this option, the user must include the TOXICS and SCIM keywords together on the CO MODELOPT card. Since the TOXICS option is a non-regulatory default option, the DEFAULT keyword should not be included on the MODELOPT card. If the DEFAULT keyword is present on the MODELOPT card, the DEFAULT option will override the TOXICS option if it is present, and any other enhancements dependent on the TOXICS option. The SCIM approach associated with the TOXICS option is described below.

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When the TOXICS option is specified, the area source integration routine is optimized to reduce model runtime. This is accomplished by incorporation of a three-tiered approach using the Romberg numerical integration, a 2-point Gaussian Quadrature routine for numerical integration, or a point source approximation based on the location of the receptor relative to the source. In the regulatory default mode the Romberg numerical integration is utilized for all receptors.

If the non-default TOXICS option is specified, the user may also use the SCIM option to reduce model runtime. The SCIM option can only be used with the ANNUAL average option, and is primarily applicable to multi-year model simulations. The approach used by the SCIM option is to sample the meteorological data at a user-specified regular interval to approximate the long-term (i.e., ANNUAL) average impacts. Studies have shown that the uncertainty in modeled results introduced by use of the SCIM option is generally lower for area sources than for point sources.

When only the regular sampling is selected, hourly concentrations are calculated in the normal fashion for each sampled hour. The annual average concentration is then simply calculated by dividing the cumulative concentration for the sampled hours by the number of hours sampled (arithmetic average), i.e.,

$$C = \sum C_N / N_S$$

where

C = Calculated concentration

$\sum C_N$ = Cumulatibe impacts for the sampled hours

N_S = Number of sampled hours

To use the SCIM option, the user must include the SCIM and TOXICS keywords on the CO MODELOPT card, and also specify the SCIM sampling parameters on the ME SCIMBYHR card. The format and syntax of the ME SCIMBYHR keyword are described in Section 3.5.7.

3.2.3 Averaging Time Options

The averaging periods for AERMOD are selected using the AVERTIME keyword. The syntax and type of the AVERTIME keyword are summarized below:

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Syntax:	
Type:	

where the parameters Time1 ... Time8 refer to the user-specified short term averaging periods of 1, 2, 3, 4, 6, 8, 12, or 24 hours, the secondary keyword MONTH refers to monthly averages (for calendar months), and the secondary keyword PERIOD refers to the average for the entire data period. Any of the short term averaging periods listed above may be selected for a given run, as long as the total data storage needed by the model does not exceed the available computer memory. Since the monthly averages are treated as short term averages, the user can select appropriate output options, such as the second highest values by receptor, on the OU pathway.

The location of the PERIOD keyword in the parameter list is not critical. The order of the short term averaging periods (including MONTH) is also not critical, although it does control the order of the averaging period result tables in the main output file. Generally, it is recommended that the short term averaging periods be input in increasing order, unless there is a clear advantage in doing otherwise.

3.2.4 Urban Modeling Option

The AERMOD model allows the user to incorporate the effects of increased surface heating from an urban area on pollutant dispersion under stable atmospheric conditions. The user defines the input parameters for the urban area with the URBANOPT keyword on the CO pathway, and then identifies which sources are to be modeled with urban effects using the URBANSRC keyword on the SO pathway (see Section 3.3.4). The syntax and type of the URBANOPT keyword are summarized below:

Syntax:	
Type:	

where the UrbPop parameter specifies the population of the urban area, the optional UrbName parameter may be used to identify the name of the urban area, and the optional UrbRoughness

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parameter may be used to specify the urban surface roughness length. Note the UrbName must be specified if the user wants to specify the urban roughness length. A default value of 1.0 meter will be used for the urban roughness length if the UrbRoughness parameter is omitted.

3.2.5 Specifying the Pollutant Type

The POLLUTID keyword is used to identify the type of pollutant being modeled for a particular run. The syntax, type, and order of the POLLUTID keyword are summarized below:

Syntax:	
Type:	

where the Pollut parameter may be name of up to eight characters. Examples include SO2, NOX, CO, PM10, TSP, and OTHER. The only choice that currently has any impact on the results is the selection of PM10 (or PM-10) with the multi-year option for generating the high-sixth-high in five years. Otherwise, the pollutant ID currently has no effect on the calculations made in AERMOD.

3.2.6 Modeling With Exponential Decay

The model provides the option to use exponential decay of the pollutant being modeled. Two keywords are available for this purpose, the HALFLIFE and DCAYCOEF keywords. The syntax, type, and order of these keywords are summarized below:

Syntax:	
Type:	

where the Halflf parameter is used to specify the half life for exponential decay in seconds, and the parameter Decay is used to specify the decay coefficient in units of s^{-1}. The relationship between these parameters is: DECAY = 0.693/HALFLIFE

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Only one of these keywords may be specified in a given run. If more than one is encountered, a non-fatal warning message is generated and the first specification is used in the modeling.

3.2.7 Flagpole Receptor Height Option

The FLAGPOLE keyword specifies that receptor heights above local ground level (i.e. flagpole receptors) are allowed on the Receptor pathway. The FLAGPOLE keyword may also be used to specify a default flagpole receptor height other than 0.0 meters. The syntax and type of the FLAGPOLE keyword are summarized below.

Syntax:	
Type:	

where Flagdf is an optional parameter to specify a default flagpole receptor height. If no parameter is provided, then a default flagpole receptor height of 0.0 meters is used. Any flagpole receptor heights that are entered on the Receptor pathway will override the default value, but are ignored if the FLAGPOLE keyword is not present on the Control pathway, and a non-fatal warning message is generated.

3.2.8 To Run or Not to Run - That is the Question

Because of the improved error handling and the "defensive programming" that has been employed in the design of the AERMOD model, it is intended that the model will read through all of the inputs in the runstream file regardless of any errors or warnings that may be encountered. If a fatal error occurs in processing of the runstream information, then further model calculations will be aborted. Otherwise, the model will attempt to run. Because of the great many options available in the AERMOD model, and the potential for wasted resources if a large run is performed with some incorrect input data, the RUNORNOT keyword has been included on the Control pathway to allow the user to specify whether to RUN the model and perform all of the

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calculations, or NOT to run and only process the input runstream data and summarize the setup information. The syntax and type of the RUNORNOT keyword are summarized below:

Syntax:	— —
Type:	

3.2.9 Generating an Input File for EVENT Processing

The AERMOD model contains the EVENTFIL keyword on the CO pathway to control whether or not the AERMOD model will generate an input file for EVENT processing. The syntax and type of the EVENTFIL keyword are summarized below:

Syntax:	
Type:	

where the optional Evfile parameter specifies the name of the EVENT input file to be generated (the maximum length of the file name is set by the FLEN_FILE parameter in MODULE MAIN1), and the optional parameter, Evopt, specifies the level of detail to be used in the EVENT output file. Valid inputs for the Evopt parameter are the secondary keywords of SOCONT and DETAIL (see the EVENTOUT keyword on the OUtput pathway, Section 3.7.2.1). The default filename used if no parameters are specified is EVENTS.INP, and the default for the level of detail is DETAIL. If only one parameter is present, then it is taken to be the Evfile, and the default will be used for Evopt.

The primary difference between routine AERMOD and EVENT processing is in the treatment of source group contributions. The AERMOD model treats the source groups independently. EVENT processing is designed to provide source contributions to particular events, such as the design concentrations determined from AERMOD, or user-specified events. The user may specify the "events" to process using the EVent pathway, which lists specific combinations of receptor location, source group, and averaging period. By specifying the EVENTFIL keyword, an input runstream file will be generated that can be used directly for

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EVENT processing. The events included in the generated EVENT processing input file are the design concentrations defined by the RECTABLE keyword and the threshold violations identified by the MAXIFILE keyword on the CO pathway.

3.2.10 The Model Re-start Capability

The AERMOD model has an optional capability to store intermediate results into an unformatted file, so that the model run can be continued later in case of a power failure or a user interrupt. This re-start option is controlled by the SAVEFILE and INITFILE keywords on the CO pathway. The syntax and type of these keywords are summarized below.

Syntax:
Type:

The SAVEFILE keyword instructs the model to save the intermediate results to a file, and controls the save options. All three parameters for this keyword are optional. If the user specifies only the Savfil parameter, then the intermediate results are saved to the same file (and overwritten) each time. If the user specifies both the Savfil and the Savfil2 parameters, then the model alternates between the two files for storing intermediate results. The latter approach requires additional disk space to handle two storage files. However, selecting two files avoids the potential problem that the power failure or interrupt might occur while the temporary file is open and the intermediate results are being copied to it. In such a case, the temporary results file would be lost.

The optional Daycnt parameter allows the user to specify the number of days between successive dumps. The default is to dump values at the end of each day, i.e., Daycnt = 1. For larger modeling runs, where the SAVEFILE option is most useful, the additional execution time required to implement this option is very small, compared to the total runtime. To be most effective, it is recommended that results be saved at least every 5 days.

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If no parameters are specified for the SAVEFILE keyword, then the model will store intermediate results at the end of each day using a default filename of TMP.FIL.

The INITFILE keyword works in conjunction with the SAVEFILE keyword, and instructs the model to initialize the results arrays from a previously saved file. The optional parameter, Initfil, identifies the unformatted file of intermediate results to use for initializing the model. If no Initfil parameter is specified, then the model assumes the default filename of TMP.FIL. If the file doesn't exist or if there are any errors encountered in opening the file, then a fatal error message is generated and processing is halted.

Note: It is important to note that if both the SAVEFILE and INITFILE keywords are used in a the same model run, then different filenames must be specified for the Savfil and Initfil parameters. Otherwise, the model will encounter an error in opening the files, and further processing will be halted.

3.2.11 Post-1997 PM_{10} Processing

A new NAAQS for modeling PM_{10} was promulgated in July 1997. This guidance utilizes the expected second high value of the 24-hour NAAQS replaced by a 3-year average of the 99th percentile value of the frequency distribution and a 3-year average of the annual mean. Since the Guideline on Air Quality Modeling precludes the use of a 3-year data set, a policy was established that uses unbiased estimates of the 3-year averages, utilizing all meteorological data (both single and multiple years of data) available. An unbiased estimate of the 99th percentile is the fourth highest concentration, if one year of meteorological data are input to the model, or the multi-year average of the fourth highest concentrations, if more than one year of meteorological data are input to the model. Similarly, an unbiased estimate of the 3-year average annual mean is simply the annual mean, if only one year of meteorological data are input to the model, or the multi-year average annual mean if multiple years of meteorological data are used. Analogously to the original NAAQS situation, the entire area is in compliance when the highest fourth high (or highest average fourth high) and the highest annual mean (or the highest average annual mean) are less than or equal to the NAAQS.

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AERMOD will process the 24-hour and annual averages for PM_{10} according to the new NAAQS if the pollutant ID specified on the CO POLLUTID card is PM10 or PM-10, and the CO MULTYEAR card is not present. In this case, the model will compute an average of the fourth highest concentrations at each receptor across the number of years of meteorological data being processed. For a single year of data, the model will report the fourth highest concentration at each receptor. For a five year period of data, the model will report the average of the five fourth-highest values at each receptor. Also, for multiple year data files, the annual average will first be calculated for each individual year of data, and the average of these across the number of years will be calculated. This processing of the annual average across multiple years may give slightly different results than the PERIOD average across the same time period, due to differences in the number of calms from year to year. In order to accommodate this difference, the new PM_{10} NAAQS makes use of the ANNUAL average keyword for specifying the long-term average.

Users should be aware of the following restrictions which are applied to the new PM_{10} NAAQS processing:

1. The averaging periods are limited to the 24-hour and ANNUAL averages. Use of the PERIOD average or a short term average other than 24-hour will result in a fatal error message being generated.

2. Only the FOURTH (or 4TH) highest value may be requested on the RECTABLE card for 24-hour averages. Specifying another high value on the RECTABLE card will result in a fatal error message being generated.

3. The model will only process complete years of meteorological data, although there is no restriction on the start date for the data. If less than one complete year of data is processed, a fatal error message will be generated. If additional meteorological data remains after the end of the last complete year of data, the remaining data will be ignored, and a non-fatal warning message will be generated specifying the number of hours ignored.

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4. The MULTYEAR card cannot be used with the new PM_{10} NAAQS. Multiple year analyses should be accomplished by including the multiple years of meteorology in a single data file.

5. Since the 24-hour average design values for post-1997 PM_{10} analyses may consist of averages over a multi-year period, they are incompatible with the EVENT processor. If the MAXIFILE option is used to output 24-hour average threshold violations, these may be used with the EVENT processor. Therefore, if the EVENTFIL option is used without the MAXIFILE option for post-1997 PM_{10} analyses, a non-fatal warning message will be generated, and the EVENTFIL option will be ignored.

3.2.12 Pre-1997 PM_{10} Processing

AERMOD may still be used to perform PM_{10} analyses according to the pre-1997 NAAQS. This may be accomplished as before by use of the MULTYEAR card on the CO pathway, except that the syntax for this keyword has been changed slightly. The syntax and type are now as follows:

Syntax:	
Type:	

where H61H is a new secondary keyword that identifies this as a pre-1997 analysis, the Savfil parameter specifies the filename for saving the results arrays at the end of each year of processing, and the Initfil parameter specifies the filename to use for initializing the results arrays at the beginning of the current year. The Initfil parameter is optional, and should be left blank for the first year in the multi-year series of runs. A non-fatal warning message will be generated if the MULTYEAR card is used for pre-1997 NAAQS analyses.

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3.2.13 Debugging Output Option

The DEBUGOPT keyword on the CO pathway allows the user to request detailed files of intermediate calculation results for debugging purposes. The syntax and type of the DEBUGOPT keyword are summarized below:

Syntax:	——— ———
Type:	

where the MODEL and METEOR secondary keywords specify the type of debug information to be provided, and the DbgFil and DbmFil parameters specify the names of the detailed message files. This option allows for two types of debug output files. The MODEL secondary keyword specifies that intermediate calculations related to the model results for each source and receptor, e.g., dispersion parameters, plume heights, etc., are to be output. The METEOR secondary keyword specifies that the gridded profiles of meteorological variables for each hour of data are to be output. Use the DEBUGOPT keyword with **CAUTION** - it can produce very large files! The METEOR profiles are printed to a separate file from the MODEL information. The filenames for each type of output are optional, and if provided must immediately follow the appropriate secondary keyword. The default filenames used if none are specified by the user are MODEL.DBG and METEOR.DBG. The model will overwrite these files, without warning, if they already exist.

3.2.14 Detailed Error Listing File

The ERRORFIL keyword on the CO pathway allows the user to request a detailed listing file of all the messages generated by the model. This includes the error and warning messages that are listed as part of the message summaries provided in the main output file, and also any informational messages (such as occurrences of calm winds) and quality assurance messages that are generated. The syntax and type of the ERRORFIL keyword are summarized below:

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Syntax:	
Type:	

where the Errfil parameter is the name of the detailed message file. If the optional Errfil parameter is left blank, then the model will use a default filename of ERRORS.LST. A complete description of the error and other types of messages generated by the model is provided in Appendix C.

3.3 SOURCE PATHWAY INPUTS AND OPTIONS

The **SO**urce pathway contains the keywords that define the source information for a particular model run. The model currently handles three source types, identified as point, volume or area sources. The input parameters vary depending on the source type. For point sources, the user can also identify building dimensions for nearby structure that cause aerodynamic downwash influences on the source. The user can also identify groups of sources for which the model will combine the results.

The LOCATION keyword, which identifies the source type and location, must be the first card entered for each source. The only other requirement for order of the keywords is that the SRCGROUP keyword must be the last keyword before the SOFINISHED card. The user may group all of the LOCATION cards together, then group the source parameter cards together, or they may want to group all input cards for a particular source together. All sources are given a source ID by the user, which is used to link the source parameter inputs to the correct source or sources. The source ID can be any alphanumeric string of up to eight characters.

As noted in Section 2.3, the number of sources is allocated dynamically at the time AERMOD is run. This value, in concert with the other dynamically allocated arrays and input requirements, is limited only by the amount of available memory.

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3.3.1 Identifying Source Types and Locations

The LOCATION keyword is used to identify the source type and the location of each source to be modeled. The LOCATION card must be the first card entered for each source since it identifies the source type, and dictates which parameters are needed and/or accepted. The syntax, type and order of the LOCATION keyword are summarized below:

Syntax:	
Type:	
Order:	

where the Srcid parameter is the alphanumeric source ID defined by the user (up to eight characters), Srctyp is the source type, which is identified by one of the secondary keywords - POINT, VOLUME, AREA, AREAPOLY, or AREACIRC - and Xs, Ys, and Zs are the x, y, and z coordinates of the source location in meters. All three of the area source types use the same numerical integration algorithm for estimating impacts from area sources, and are merely different options for specifying the shape of the area source. The AREA source keyword may be used to specify a rectangular-shaped area source with arbitrary orientation, the AREAPOLY source keyword may be used to specify an area source as an irregularly-shaped polygon of up to 20 sides; and the AREACIRC source keyword may be used to specify a circular-shaped area source (modeled as an equal-area polygon of 20 sides). Note that the source elevation, Zs, is an optional parameter. If the default option to include elevated terrain effects is used and the source elevation is omitted, a warning message will be generated and the source elevation will be given a value of 0.0. The source elevation is not used by the model if the non-default FLAT terrain option is used. While the default units of Zs are meters, the user may also specify source elevations to be in feet by adding the SO ELEVUNIT FEET card immediately following the SO STARTING card. The x (west-east) and y (north-south) coordinates are for the center of the source for POINT, VOLUME, and AREACIRC sources, and are for one of the vertices of the source for AREA and AREAPOLY sources. The source coordinates may be input as Universal Transverse Mercator (UTM) coordinates, or may be referenced to a user-defined origin.

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Certain types of line sources can be handled in AERMOD using either a string of volume sources, or as an elongated area source. The volume source algorithms are most applicable to line sources with some initial plume depth, such as conveyor belts and rail lines. Section 1.2.2 of the ISC Model User's Guide - Volume II (EPA, 1995) provides technical information on how to model a line source with multiple volume sources. The use of the AERMOD area source algorithm for elongated rectangles would be most applicable to near ground level line sources, such as a viaduct.

The source ID entered on the LOCATION card identifies that source for the remainder of the SO pathway inputs. Since the model accepts alphanumeric strings of up to eight characters for the source ID, the sources can be identified with descriptive names, such as STACK1, STACK2, BOILER3, SLAGPILE, etc. This may also be useful if line sources are being modeled as multiple volume or areas, as discussed above. Since they are part of the same physical source, they can be given names that will identify them as being related, such as LINE1A, LINE1B, LINE1C, etc.

3.3.2 Specifying Source Release Parameters

The main source parameters are input on the SRCPARAM card, which is a mandatory keyword for each source being modeled. Since the input parameters vary depending on the source type, the different source types handled by the AERMOD model are discussed separately.

3.3.2.1 POINT Source Inputs

The AERMOD POINT source algorithms are used to model releases from stacks and isolated vents, as well as other kinds of sources. The syntax, type and order for the SRCPARAM card for POINT sources are summarized below:

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Syntax:	
Type:	
Order:	

where the Srcid parameter is the same source ID that was entered on the LOCATION card for a particular source, and the other parameters are as follows:

Premis - point emission rate in g/s,

Stkhgt - release height above ground in meters,

Stktmp - stack gas exit temperature in degrees K,

Stkvel - stack gas exit velocity in m/s, and

Stkdia - stack inside diameter in meters

An example of a valid SRC PARAM input card for a point source is given below:

where the source ID is STACK1, the emission rate is 16.71 g/s, the release height is 35.0 m, the exit temperature is 444.8 K, the exit velocity is 22.7 m/s, and the inside stack diameter is 2.74 m. All of the parameters must be present on the input card.

If a value of 0.0 is input for the exit temperature, AERMOD will adjust the exit temperature for each hour to match the ambient temperature. This option allows the user to model a plume that is released at ambient temperature. The user may also model a plume with an exit temperature that exceeds the ambient temperature by a fixed amount by entering a negative value for exit temperature equal in magnitude to the temperature difference. The model will add the absolute value of a negative exit temperature to the ambient temperature for each hour to obtain the exit temperature used in computing the buoyancy flux of the plume. The AERMOD model does not include algorithms to model plumes that are released at temperatures below ambient temperature. Such releases should be modeled with a dense gas model.

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Since the AERMOD model uses direction-specific building dimensions for all sources subject to building downwash, there are no building parameters entered on the SRCPARAM card. Building dimensions are entered on the BUILDHGT, BUILDWID, BUILDLEN, XBADJ, and YBADJ cards described above in Section 3.4.3.

3.4.2.2 VOLUME Source Inputs

The AERMOD VOLUME source algorithms are used to model releases from a variety of industrial sources, such as building roof monitors, multiple vents, and conveyor belts. The syntax, type and order for the SRCPARAM card for VOLUME sources are summarized below:

Syntax:	
Type:	
Order:	

where the Srcid parameter is the same source ID that was entered on the LOCATION card for a particular source, and the other parameters are as follows:

Vlemis - volume emission rate in g/s,

Relhgt - release height (center of volume) above ground, in meters,

Syinit - initial lateral dimension of the volume in meters, and

Szinit - initial vertical dimension of the volume in meters.

The following table, which is explained in more detail in Section 1.2.2 of the ISC Model User's Guide - Volume II, summarizes the suggested procedures to be used for estimating the initial lateral and vertical dimensions for various types of volume and line sources.

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TABLE 3-1

SUMMARY OF SUGGESTED PROCEDURES FOR ESTIMATING

INITIAL LATERAL DIMENSIONS σ_{y_0} AND

INITIAL VERTICAL DIMENSIONS σ_{z_0} FOR VOLUME AND LINE SOURCES

Type of Source		Procedure for Obtaining Initial Dimension
(a) Initial Lateral Dimensions (σ_{y_0})		
Single Volume Source	σ_{y_0}	length of side divided by 4.3
Line Source Represented by Adjacent Volume Sources (see Figure 1-8(a) in EPA, 1995)	σ_{y_0}	length of side divided by 2.15
Line Source Represented by Separated Volume Sources (see Figure 1-8(b) in EPA, 1995)	σ_{y_0}	center to center distance divided by 2.15
(b) Initial Vertical Dimensions (σ_{z_0})		
Surface-Based Source (h_s = 0)	σ_{z_0}	vertical dimension of source divided by 2.15
Elevated Source (h_s > 0) on or Adjacent to a Building	σ_{z_0}	building height divided by 2.15
Elevated Source (h_s > 0) not on or Adjacent to a Building	σ_{z_0}	vertical dimension of source divided by 4.3

3.3.2.3 AREA Source Inputs

The AERMOD area source algorithm is used to model low level or ground level releases with no plume rise (e.g., storage piles, slag dumps, and lagoons). The AERMOD model uses a numerical integration approach for modeling impacts from area sources. When the TOXICS option is specified, the area source integration routine is optimized to reduce model runtime. This is accomplished by incorporation of a three-tiered approach using the Romberg numerical integration, a 2-point Gaussian Quadrature routine for numerical integration, or a point source approximation based on the location of the receptor relative to the source. In the regulatory default mode the Romberg numerical integration is utilized for all receptors.

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The AERMOD model includes three options for specifying the shape of an area source the AREA source type may be used to specify rectangular areas that may also have a rotation angle specified relative to a north-south orientation, the AREAPOLY source type may be used to specify an area source as an irregularly-shaped polygon of up to 20 sides; and the AREACIRC source keyword may be used to specify a circular-shaped area source (modeled as an equal-area polygon of 20 sides). The source parameter inputs for each of the area source types is described below.

AREA Source Type

The rotation angle for rectangular AREA sources is specified relative to the vertex used to define the source location on the SO LOCATION card (e.g., the southwest corner). The syntax, type and order for the SRCPARAM card for AREA sources are summarized below:

Syntax:
Type:
Order:

where the Srcid parameter is the same source ID that was entered on the LOCATION card for a particular source, and the other parameters are as follows:

Artemis - area emission rate in g/(s-m^2).

Relhgt - release height above ground in meters.

Xinit - length of X side of the area (in the east-west direction if Angle is 0 degrees) in meters.

Yinit - length of Y side of the area (in the north-south direction if Angle is 0 degrees) in meters (optional).

Angle - orientation angle for the rectangular area in degrees from North, measured positive in the clockwise direction (optional), and

Szinit - initial vertical dimension of the area source plume in meters (optional).

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It should be noted that the emission rate for the area source is an emission rate per unit area, which is different from the point and volume source emission rates, which are total emissions for the source.

If the optional Yinit parameter is omitted, then the model assumes that the area is a square, i.e., Yinit = Xinit. If the optional Angle parameter is omitted, then the model assumes that the area is oriented in the north-south and east-west directions, i.e., Angle = 0.0. If the Angle parameter is input, and the value does not equal 0.0, then the model will rotate the area clockwise around the vertex defined on the SOURCE card for this source. Figure 3-1 illustrates the relationship between the Xinit, Yinit, and Angle parameters and the source location, (Xs,Ys), for a rotated rectangle. The Xinit dimension is measured from the side of the area that is counterclockwise along the perimeter from the vertex defined by (Xs,Ys), while the Yinit dimension is measured from the side of the area that is clockwise from (Xs,Ys). The Angle parameter is measured as the orientation, relative to North, of the side that is clockwise from (Xs,Ys), i.e., the side with length Yinit. The Angle parameter may be positive (for clockwise rotation) or negative (for counterclockwise rotation), and a warning message is generated if the absolute value of Angle is greater than 180 degrees. The selection of the vertex to use for the source location is not critical, as long as the relationship described above for the Xinit, Yinit, and Angle parameters is maintained.

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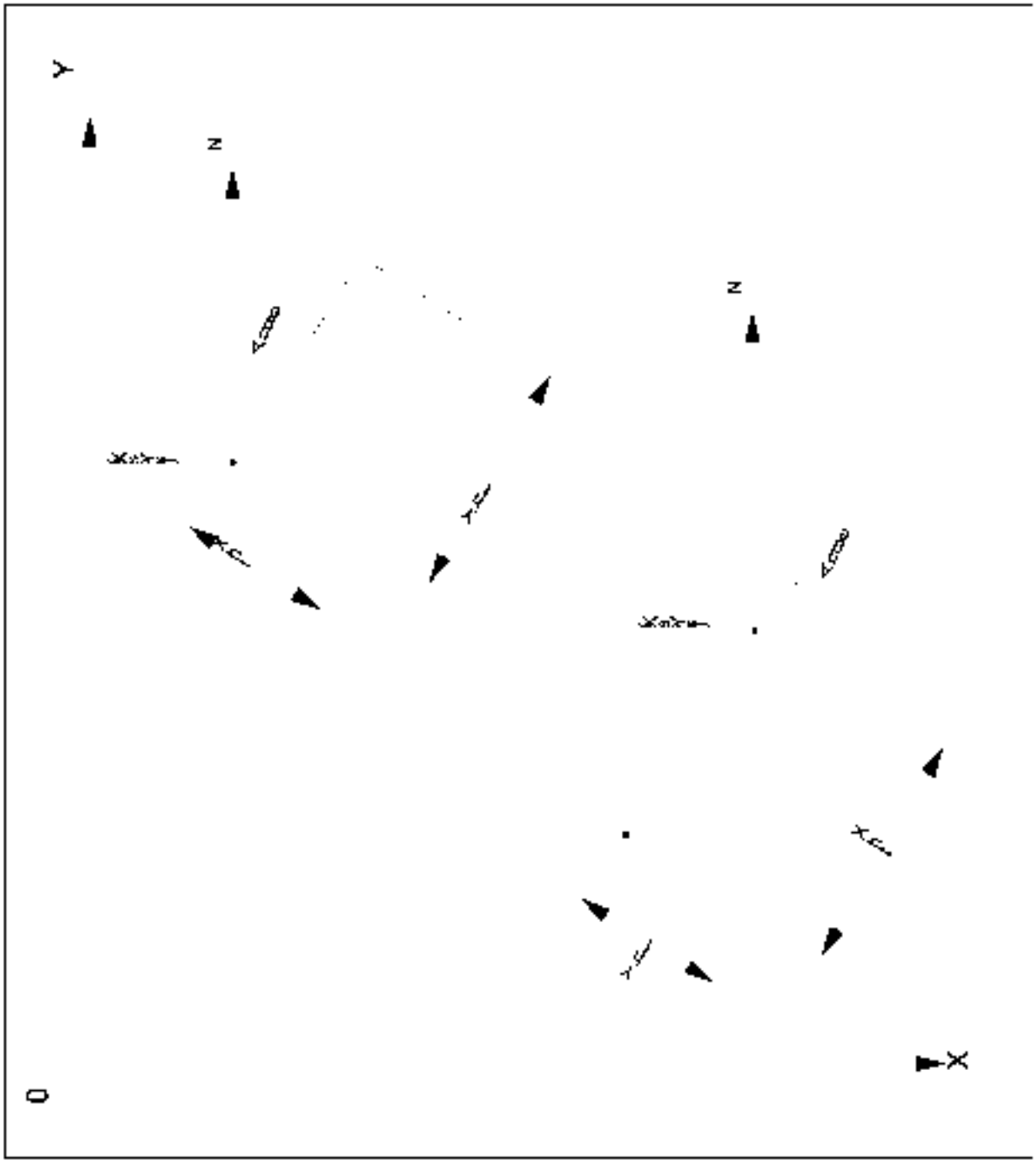

FIGURE 3-1 RELATIONSHIP OF AREA SOURCE PARAMETERS FOR ROTATED RECTANGLE

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By making the Yinit and Angle parameters optional, the area source input data for the previous versions of the ISC2 model can be used with the AERMOD model. The aspect ratio (i.e., length-width) for area sources should generally be less than about 10 to 1. If this is exceeded, then the model will generate a non-fatal warning message, and the user should consider subdividing the area to achieve a 10 to 1 aspect ratio (or less) for all subareas.

The optional Szinit parameter may be used to specify an initial vertical dimension to the area source plume, similar to the use of the Szinit parameter for volume sources. This parameter may be important when the area source algorithm is used to model mechanically generated emission sources, such as mobile sources. In these cases, the emissions may be turbulently mixed near the source by the process that is generating the emissions, and therefore occupy some initial depth. For more passive area source emissions, such as evaporation or wind erosion, the Szinit parameter may be omitted, which is equivalent to using an initial sigma-z of zero.

An example of a valid SRCPARAM input card for a rectangular area source is given below:

```
. . . .
```

where the source ID is SLAGPILE, the emission rate is 0.0025 g/(s-m^2), the release height is 5.0 m, the X-dimension is 50.0 m, the Y-dimension is 100.0 m, and the orientation angle is 30.0 degrees clockwise from North.

Since the numerical integration algorithm can handle elongated areas with aspect ratios of up to 10 to 1, the AERMOD area source algorithm may be useful for modeling certain types of line sources. There are no restrictions on the placement of receptors relative to area sources for the AERMOD model. Receptors may be placed within the area and at the edge of an area. The AERMOD model will integrate over the portion of the area that is upwind of the receptor. However, since the numerical integration is not performed for portions of the area that are closer than 1.0 meter upwind of the receptor, caution should be used when placing receptors within or

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adjacent to areas that are less than a few meters wide. More technical information about the application of the AERMOD area source algorithm is provided in Sections 1.2.3 and 2.2.3 of the ISC Model User's Guide - Volume II (EPA, 1995).

AREAPOLY Source Type

The AREAPOLY source type may be used to specify an area source as an arbitrarily-shaped polygon of between 3 and 20 sides (the number of sides allowed may be increased by modifying the NVMAX parameter in MODULE MAIN1). This source type option provides the user with considerable flexibility for specifying the shape of an area source. The syntax, type and order for the SRCPARAM card for AREAPOLY sources are summarized below.

Syntax:
Type:
Order:

where the Srcid parameter is the same source ID that was entered on the LOCATION card for a particular source, and the other parameters are as follows:

Arerris - area emission rate in g/(s-m^2),

Relhgt - release height above ground in meters,

Nverts - number of vertices (or sides) of the area source polygon,

Szinit - initial vertical dimension of the area source plume in meters (optional).

As with AREA sources, the emission rate for the source is an emission rate per unit area, which is different from the point and volume source emission rates, which are total emissions for the source. The number of vertices (or sides) used to define the area source polygon may vary between 3 and 20. The locations of the vertices are specified by use of the AREAVERT keyword, which applies only to AREAPOLY sources. The syntax, type and order for the AREAVERT keyword used for AREAPOLY sources are summarized below.

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Syntax:	
Type:	
Order:	

where the Xv(i) and Yv(i) are the x-coordinate and y-coordinate values of the vertices of the area source polygon. There must by Nverts pairs of coordinates for the area source, where Nverts is the number of vertices specified for that source on the SRCPARAM card. The first vertex, Xv(1) and Yv(1), must also match the coordinates given for the source location on the LOCATION card, Xs and Ys. The remaining vertices may be defined in either a clockwise or counter-clockwise order from the point used for defining the source location.

Since the numerical integration algorithm can handle elongated areas with aspect ratios of up to 10 to 1, the AERMOD area source algorithm may be useful for modeling certain types of line sources. There are no restrictions on the placement of receptors relative to area sources for the AERMOD model. Receptors may be placed within the area and at the edge of an area. The AERMOD model will integrate over the portion of the area that is upwind of the receptor. However, since the numerical integration is not performed for portions of the area that are closer than 1.0 meter upwind of the receptor, caution should be used when placing receptors within or adjacent to areas that are less than a few meters wide.

AREACIRC Source Type

The AREACIRC source type may be used to specify an area source as a circular shape. The model will automatically generate a regular polygon of up to 20 sides to approximate the circular area source. The polygon will have the same area as that specified for the circle. The syntax, type and order for the SRCPARAM card for AREACIRC sources are summarized below:

Syntax:	
Type:	
Order:	

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where the Srcid parameter is the same source ID that was entered on the LOCATION card for a particular source, and the other parameters are as follows:

Arsrris - area emission rate in g/(s-m^2),

Rellgt - release height above ground in meters,

Radius - radius of the circular area in meters,

Nverts - number of vertices (or sides) of the area source polygon (optional, 20 sides will be used if omitted),

Szinit - initial vertical dimension of the area source plume in meters (optional)

As with AREA sources, the emission rate for the source is an emission rate per unit area, which is different from the point and volume source emission rates, which are total emissions for the source.

3.4.3 Specifying Building Downwash Information

As noted above, the AERMOD model include algorithms to model the effects of buildings downwash on emissions from nearby or adjacent point sources. The building downwash algorithms do not apply to volume or area sources. For a technical description of the building downwash algorithms in AERMOD, the user is referred to Schulman, et al. (2000). The AERMOD model uses direction specific information for all building downwash cases.

There are five keywords that are used to specify building downwash information: BUILDHGT, BUILDWID, BUILDLEN, XBADJ, YBADJ. The syntax, type and order for the BUILDHGT keyword, used to input direction specific building heights, are summarized below:

Syntax:
Type:
Order:

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where the Srcid parameter is the same source ID that was entered on the LOCATION card for a particular source. The user also has the option of specifying a range of sources (the Srcrng parameter) for which the building heights apply, instead of identifying a single source. This is accomplished by two source ID character strings separated by a dash, e.g., STACK1-STACK10. Since the model reads the source range as a single input field there must not be any spaces between the source IDs. The model then places the building heights that follow (the Dsbh() parameter) into the appropriate arrays for all Srcid's that fall within that range, including STACK1 and STACK10.

When comparing a source ID to the range limits for a Srcrng parameter, the model separates the source IDs into three parts: an initial alphabetical part, a numerical part, and then the remainder of the string. Each part is then compared to the corresponding parts of the source range, and all three parts must satisfy the respective ranges in order for the source ID to be included. If there is no numeric part, then the ID consists of only one alphabetical part. If the ID begins with a numeric character, then the initial alphabetical part defaults to a single 'blank'. If there is no trailing alphabetical part, then the third part also defaults to a single blank part. If the trailing part consists of more than one alphabetical or numeric field, it is all lumped into one character field. For example, the source ID 'STACK2' consists of the parts 'STACK' plus '2' plus a single trailing blank, ' '. By comparing the separate parts of the source IDs, it can be seen that STACK2 falls between the range 'STACK1-STACK10'. For a three-part example, it can also be seen that VENT1B falls within the range of VENT1A-VENT1C. However, VENT2 does not fall within the range of VENT1A to VENT1B, since the third part of VENT2 is a single blank, which does not fall within the range of A to C. This is because a blank character will precede a normal alphabetical character. Normally, the source ranges will work as one would intuitively expect for simple source names. Most importantly, for names that are made up entirely of numeric characters, the source ranges will be based simply on the relative numerical values. The user is strongly encouraged to check the summary of model inputs to ensure that the source ranges were interpreted as expected, and also to avoid using complex source names in ranges, such as AA1B2C-AB3A3C. Since the order of keywords within the SO pathway is quite flexible, it is also important to note that the building heights will only be applied to those sources that have been defined previously in the input file.

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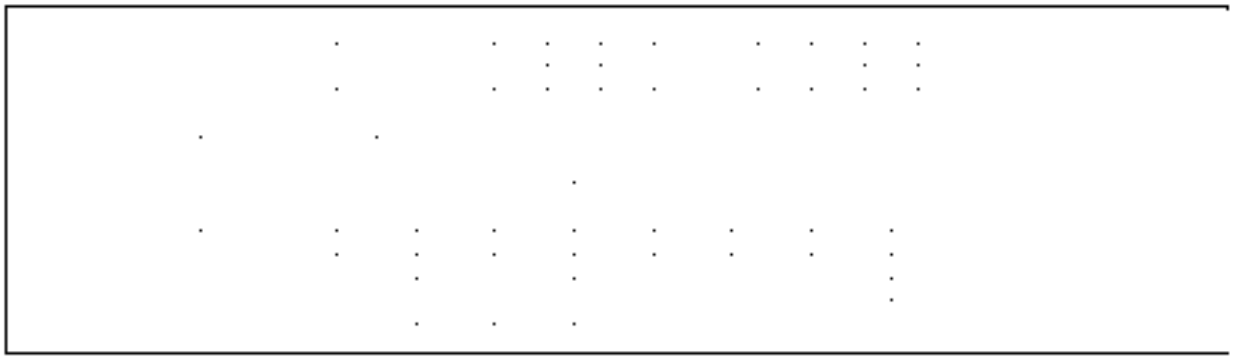
Following the Srcid or the Srcrng parameter, the user inputs 36 direction-specific building heights (Dsbh parameter) in meters, beginning with the 10 degree flow vector (wind blowing toward 10 degrees from north), and incrementing by 10 degrees in a clockwise direction. Some examples of building height inputs are presented below:



The first example illustrates the use of repeat cards if more than one card is needed to input all of the values. The values are processed in the order in which they appear in the input file, and are identified as being repeat cards by repeating the Srcid parameter. The first and second examples produce identical results within the model. The second one illustrates the use of a repeat value that can simplify numerical input in some cases. The field "36*3.0" is interpreted by the model as "repeat the value 3.0 a total of 36 times." This is also used in the third example where the building height is constant for directions of 10 degrees through 330 degrees, and then is set to 0.0 (e.g. the stack may be outside the region of downwash influence) for directions 340 through 360. The third example also uses a source range rather than a single source ID. The last example illustrates building heights which vary by direction, and shows that the number of values on each card need not be the same. For improved readability of the input file, the user may want to put the numerical inputs into "columns," but there are no special rules regarding the spacing of the parameters on this keyword.

The BUILDWID keyword is used to input direction-specific building widths for downwash analyses. The syntax for this keyword, which is very similar to the BUILDHGT keyword, is summarized below, along with the type and order information.

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Syntax:	
Type:	
Order:	

For a description of the Srcid and Srcng parameters, and for a discussion and examples of the numeric input options, refer to the **BUILDHGT** keyword above. The Dsbw(n) parameter contains the 36 direction-specific building widths. The directions proceed in a clockwise direction, beginning with the 10 degree flow vector.

The BUILDLEN keyword is used to input direction-specific along-flow building lengths for downwash analyses. Figure 3-2 shows the relationship of the projected building to this dimension. The syntax for this keyword, which is very similar to the BUILDHGT keyword, is summarized below, along with the type and order information.

Syntax:	
Type:	
Order:	

For a description of the Srcid and Srcng parameters, and for a discussion and examples of the numeric input options, refer to the **BUILDHGT** keyword above. The Dsbl(n) parameter contains the 36 direction-specific building lengths. The directions proceed in a clockwise direction, beginning with the 10 degree flow vector.

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Figure 3-2 shows the relationship of the projected building to these distances.

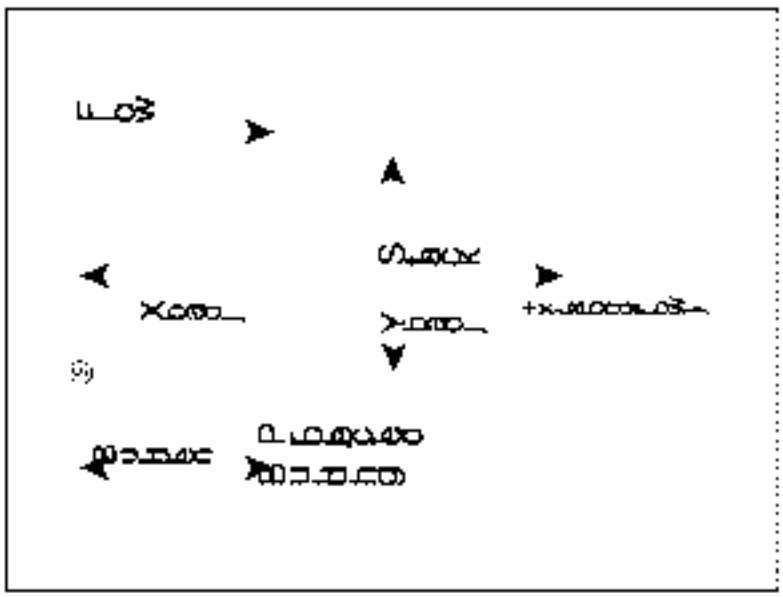

FIGURE 3-2 SCHEMATIC DIAGRAM IDENTIFYING NEW BUILDING DATA FOR PRIME DOWNWASH

The XBADJ and YBADJ keywords are used to input direction-specific along-flow and across-flow distances from the stack to the center of the upwind face of the projected building, respectively. Figure 3-2 shows the relationship of the projected building to these distances. The syntax for these keywords, which is very similar to the BUILDHGT keyword, are summarized below, along with the type and order information.

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Syntax:	
Type:	
Order:	

Syntax:	
Type:	
Order:	

For a description of the Srcid and Srcrng parameters, refer to the BUILDHGT keyword above. The Xbadj(i) parameter contains the 36 direction-specific along-flow distances from the stack to the center of the upwind face and the Ybadj(i) parameter contains the 36 direction-specific across-flow distances from the stack to the center of the upwind face. The directions proceed in a clockwise direction, beginning with the 10 degree flow vector.

3.4.4 Specifying Urban Sources

As discussed in Section 3.2.4, the AERMOD model allows the user to incorporate the effects of increased surface heating from an urban area on pollutant dispersion under stable atmospheric conditions. The user specifies the parameters for the urban area on the CO URBANOPT card (see Section 3.2.4), and identifies which sources are to be modeled with urban effects using the SO URBANSRC card. If a source is not included on the URBANSRC card, it will be modeled without the urban effects. The syntax, type and order for the URBANSRC keyword are summarized below:

Syntax:	
Type:	
Order:	

where the Srcid's and Srcrng's are the individual source IDs and/or source ranges that are to be modeled with urban effects. Source ranges, which are described in more detail in the description of the BUILDHGT keyword (Section 3.4.3), are input as two source IDs separated by a dash, e.g.,

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STACK1-STACK10. Individual source IDs and source ranges may be used on the same card. If more than one input card is needed to define the urban sources, then additional cards may be input.

3.3.5 Using Variable Emission Rates

The AERMOD model provide the option of specifying variable emission rate factors for individual sources or for groups of sources. The factors may vary on different time scales, such as by season, hour-of-day, etc. The EMISFACT keyword provides the user the option of specifying variable emission rate factors for sources modeled by the AERMOD model. The syntax, type and order of this keyword are summarized below:

Syntax:
Type: **Order:**

where the Srcid parameter is the same source ID that was entered on the LOCATION card for a particular source. The user also has the option of using the Srcrng parameter for specifying a range of sources for which the emission rate factors apply, instead of identifying a single source. This is accomplished by two source ID character strings separated by a dash, e.g., SRCID1-SRCID10. The use of the Srcrng parameter is explained in more detail in Section 3.3.3 above for the BUILDHGT keyword.

The parameter Qflag is the variable emission rate flag, and is one of the following secondary keywords:

SEASON - emission rates vary seasonally (n=4).

MONTH - emission rates vary monthly (n=12).

HRODDY - emission rates vary by hour-of-day (n=24).

WSPEED - emission rates vary by wind speed (n=6).

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SEASHR	emission rates vary by season and hour of day (nf = 96),
SHRDOW	emission rates vary by season, hour of day, and day of week (M-F, Sat, Sun; nf = 288), and
SHRDOW7	emission rates vary by season, hour-of-day, and the seven days of the week (M,Tu,W,Th,F,Sat,Sun) (nf = 672)

The Qfac array is the array of factors, where the number of factors is shown above for each Qflag option. The seasons are defined in the following order: Winter (Dec., Jan., Feb.), Spring (Mar., Apr., May), Summer (Jun., Jul., Aug.), and Fall (Sep., Oct., Nov.). The wind speed categories used with the WSPEED option may be defined using the MF-WINDCATS keyword. If the WINDCATS keyword is not used, the default wind speed categories are defined by the upper bound of the first five categories as follows (the sixth category is assumed to have no upper bound): 1.54, 3.09, 5.14, 8.23, and 10.8 m/s. The EMISFACT card may be repeated as many times as necessary to input all of the factors, and repeat values may be used for the numerical inputs. An example of each of these options is presented below, with column headers to indicate the order in which values are to be to input.

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3.3.6 Adjusting the Emission Rate Units for Output

The default emission rate units for the AERMOD model are grams per second for point and volume sources, and grams per second per square meter for area sources. By default, the model converts these input units to output units of micrograms per cubic meter for concentration calculations. This is accomplished by applying a default emission rate unit factor of 1.0E+06 for concentration.

The EMISUNIT keyword on the SO pathway allows the user to specify a different unit conversion factor, and to specify the appropriate label for the output units for either concentration calculations. The syntax and type of the EMISUNIT keyword are summarized below:

Syntax:
Type:

where the parameter Emsfac is the emission rate unit factor, Emslbl is the label for the emission units (up to 40 characters), and Conlbl is the output unit label (up to 40 characters) for concentration calculations. For example, to produce output concentrations in milligrams per cubic meter, assuming input units of grams per sec, the following card could be input:

since there are 1,000 milligrams per gram. The emission rate unit factor applies to all sources for a given run. Since the model uses one or more spaces to separate different fields on the input runstream images, it is important that there not be any spaces within the label fields on this card. Thus, instead of entering 'GRAMS PER SECOND' for the emission label, a label of 'GRAMS/SECOND', or 'GRAMS-PER-SECOND' or an equivalent variation should be used.

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3.3.7 Specifying Variables for Settling, Removal and Deposition Calculations

The current version of the AERMOD model does not include algorithms to handle the gravitational settling and removal by dry deposition of particulates.

3.3.8 Specifying Variables for Precipitation Scavenging and Wet Deposition Calculations

The current version of the AERMOD model does not include algorithms to handle the scavenging and removal by wet deposition (i.e., precipitation scavenging) of gases and particulates.

3.3.9 Specifying an Hourly Emission Rate File

The source (SO) pathway includes an option for inputting hourly emission rates for the AERMOD model, controlled by the HOUREMIS keyword. AERMOD currently allows for a single hourly emission file to be used with each model run. The syntax, type and order for this keyword are summarized below:

Syntax:
Type:
Order:

where the Hr-fil parameter specifies the filename (up to 40 characters) for the hourly emission file, and Srcid or Srcrng identify the source or sources for which hourly emission rates are included. Source ranges, which are described in more detail in the description of the BUILDHGT keyword (Section 3.3.3L) are input as two source IDs separated by a dash, e.g., STACK1-STACK10. The user may include more than one HOUREMIS card in a runstream file, if needed to specify additional sources, but there can be only one hourly emissions file, and therefore the filename must be the same on all HOUREMIS cards.

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The format of each record of the hourly emissions file includes a pathway and keyword (SO HOUREMIS), followed by the Year, Month, Day, Hour, Source ID, and emission rate (in the appropriate units). For point sources, the stack gas exit temperature (K), and stack gas exit velocity (m/s) are also specified. The hourly emissions file is processed using the same routines used to process the mainstream input file; therefore each of the parameters must be separated by at least one space, but otherwise the format is flexible. It is also not necessary to include the SO HOUREMIS on each line, as long as the parameters (Year, Month, etc.) do not begin before column 13.

The data in the hourly emission file must include the exact same dates as are included in the meteorological input files, and the source IDs must correspond to the source IDs defined on the SO LOCATION cards and be in the same order. Multiple records are required to define the emissions for one hour if more than one source is referenced. The model will check for a date mismatch between the hourly emissions file and the meteorological data, and also for a source ID mismatch. However, it is not necessary to process the entire hourly emissions file on each model run, i.e., the correct emissions data will be read if the ME DAYRANGE or the ME STARTEND cards (see Section 3.5.4) are used, as long as all the dates (including those that are processed and those that are skipped) match the meteorological data files. An example of several lines from an hourly emissions file for two point sources is provided below:

```
.          .          .
.          .          .
.          .
.          .
.          .          . .
.          .          . .
.          .          .
.          .          .
```

The model will use the stack release height and stack inside diameter defined on the SO SRCPARAM card, but will use the emission rate, exit temperature and exit velocity from the hourly emission file. If the emission rate, exit temperature and exit velocity are not included for a particular hour, i.e., any or all of those fields are blank, the model will interpret emissions data for

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that hour as missing and will set the parameters to zero. Since the emission rate will be zero, there will be no calculations made for that hour and that source.

3.4.10 Including Source Data From an External File

The user has the option of including source data from an external file by using the INCLUDED keyword on the source (SO) pathway. An SO INCLUDED card may be placed anywhere within the source pathway, after the STARTING card and before the FINISHED card (i.e., the SO STARTING and SO FINISHED cards cannot be included in the external file). The data in the included file will be processed as though it were part of the runstream file. The syntax and type of the INCLUDED keyword are summarized below:

Syntax:
Type:

where the Incfil parameter is a character field of up to 40 characters that identifies the filename for the included file. The contents of the included file must be valid runstream images for the source pathway. If an error is generated during processing of the included file, the error message will report the line number of the included file (see Appendix C). If more than one INCLUDED file is specified for the source pathway, the user will first need to determine which file the error occurred in. If the starting column of the main runstream input file is shifted from column 1 (see Section 2.4.8), then the runstream images in the included file must be offset by the same amount.

3.3.11 Using Source Groups

The AERMOD model allows the user to group contributions from particular sources together. Several source groups may be setup in a single run, and they may, for example, be used to model impacts from the source being permitted, the group of increment consuming PSD sources, and the group of all sources for comparison to a NAAQS in a single run. There is always at least one source group in a run, which may consist of all sources, so the SRCGROUP keyword

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has been made mandatory in the AERMOD model. The syntax, type and order of the SRCGROUP keyword are summarized below:

Syntax:	
Type:	
Order:	

where the Grpid parameter is an alphanumeric string of up to eight characters that identifies the group name. The Srcid's and Srcrng's are the individual source IDs and/or source ranges that make up the group of sources. Source ranges, which are described in more detail in the description of the BUILDHGT keyword (Section 3.3.5), are input as two source IDs separated by a dash, e.g., STACK1-STACK16. Individual source IDs and source ranges may be used on the same card. If more than one input card is needed to define the sources for a particular group, then additional cards may be input, repeating the pathway, keyword and group ID.

A special group ID has been reserved for use in specifying the group of all sources. When Grpid = ALL, the model will automatically setup a source group called ALL that includes all sources modeled for that particular run. If desired, the user can setup a group of all sources with a different group ID by explicitly specifying all sources on the input card(s).

As noted in Section 2.3, the number of source groups is allocated dynamically at the time AERMOD is run. This value, in concert with the other dynamically allocated arrays and input requirements, is limited only by the amount of available memory.

As discussed in Sections 1.2.4.b and 3.3.9, it is sometimes important for a user to know the contribution of a particular source to the total result for a group. These source contribution analyses are facilitated for short term averages by the use the EVENT processing capabilities in the AERMOD model. EVENT processing uses the same source groups that are identified by AERMOD (when the input file is generated using the COEVENTFIL option), but the model is structured in a way that it retains individual source results for particular events. Refer to the sections noted above for a more complete description of EVENT processing and its uses.

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3.4 RECEPTOR PATHWAY INPUTS AND OPTIONS

The **RE**ceptor pathway contains keywords that define the receptor information for a particular model run. The RE pathway contains keywords that allow the user to define Cartesian grid receptor networks and/or polar grid receptor networks, with either uniform or non-uniform grid spacing, as well as discrete receptor locations referenced to a Cartesian or a polar system. As noted in Section 2.3, the number of receptors and receptor networks are allocated dynamically at the time AERMOD is run. This value, in combination with the other dynamically allocated arrays and input requirements, is limited only by the amount of available memory.

All of the receptor options in AERMOD allow the user to input terrain elevations and hill height scales for each receptor, both of which are needed when applying AERMOD in an elevated terrain situation. To facilitate the generation of hill height scales for AERMOD, a terrain preprocessor, called AERMAP, has been developed (EPA, 2004e). The AERMAP terrain preprocessor, which uses U.S. Geological Survey (USGS) Digital Elevation Model (DEM) data as an input, may also be used to generate the terrain elevations for the receptor locations. The AERMAP program generates an output file that contains the receptor pathway data for AERMOD in the format described below. This file may either be cut and pasted into the AERMOD runstream file, or may be included as an external file using the RECEPTOR INCLUDED card (see Section 3.4.4).

The default units for receptor elevations for the AERMOD model are in meters, however, the user may specify receptor elevations to be in units of feet by adding the RE ELEVUNIT FEET card immediately after the RE STARTING card. Since the AERMAP terrain preprocessor outputs elevations in meters and includes the RE ELEVUNIT METERS card as the first record, the AERMAP data must be placed at the beginning of the receptor pathway.

3.4.1 Defining Networks of Gridded Receptors

Two types of receptor networks are allowed by the AERMOD model. A Cartesian grid network, defined through the GRIDCART keyword, includes an array of points identified by their

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x (east-west) and y (north-south) coordinates. A polar network, defined by the GRIDPOLR keyword, is an array of points identified by direction and distance from a user-defined origin. Each of these keywords has a series of secondary keywords associated with it that are used to define the network, including any receptor elevations for elevated terrain and flagpole receptor heights. The GRIDCART and GRIDPOLR keywords can be thought of as "sub-pathways," since their secondary keywords include a STArt and an END card to define the start and end of inputs for a particular network.

3.4.1.1 Cartesian Grid Receptor Networks

Cartesian grid receptor networks are defined by use of the GRIDCART keyword. The GRIDCART keyword may be thought of as a "sub-pathway" in that there are a series of secondary keywords that are used to define the start and the end of the inputs for a particular network, and to select the options for defining the receptor locations that make up the network. The syntax and type of the GRIDCART keyword are summarized below:

Syntax:	—
	—
	—
	—
Type:	

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where the parameters are defined as follows:

The ELEV, HILL, and FLAGr keywords are optional inputs, and are only needed if elevated terrain or flagpole receptor heights are to be used. If elevated terrain is being used, then both the ELEV and HILL inputs are needed for each receptor. If the ELEV and HILL keywords are used and the model is being run with the flat terrain option (see Section 3.2.2), then the elevated terrain height inputs will be ignored by the model, and a non-fatal warning message will be generated. If the elevated terrain option is selected, and no elevated terrain heights are entered,

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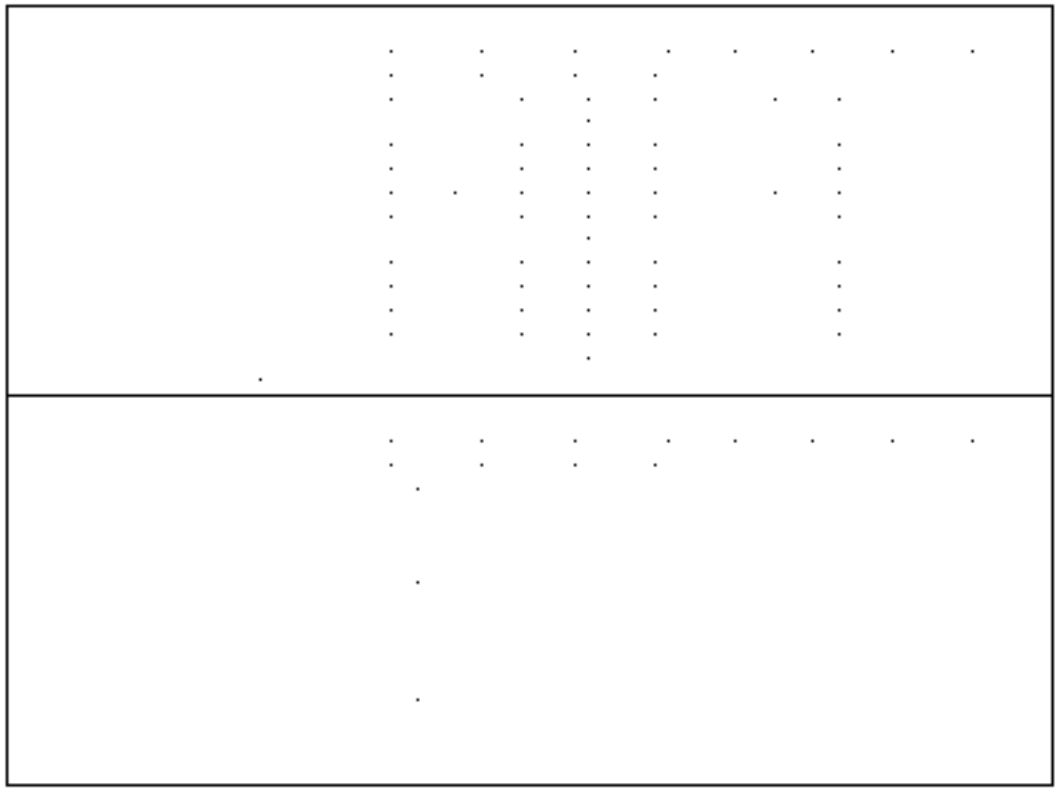
the elevations will default to 0.0 meters, and warning messages will also be generated. The model handles flagpole receptor height inputs in a similar manner.

The order of cards within the GRIDCART subpathway is not important, as long as all inputs for a particular network are contiguous and start with the STA secondary keyword and end with the END secondary keyword. It is not even required that all ELEV cards be contiguous, although the input file will be more readable if a logical order is followed. The network ID is also not required to appear on each upstream image (except for the STA card). The model will assume the previous ID if none is entered, similar to the use of continuation cards for pathway and keywords. Thus, the following two examples produce the same 8 X 4 Cartesian grid network:



The Row parameter on the ELEV, HILL, and FLAG inputs may be entered as either the row number (i.e., 1, 2, etc.) or as the actual y-coordinate value, e.g., -500., -250., etc. in the example above. The model sorts the inputs using Row as the index, so the result is the same. The

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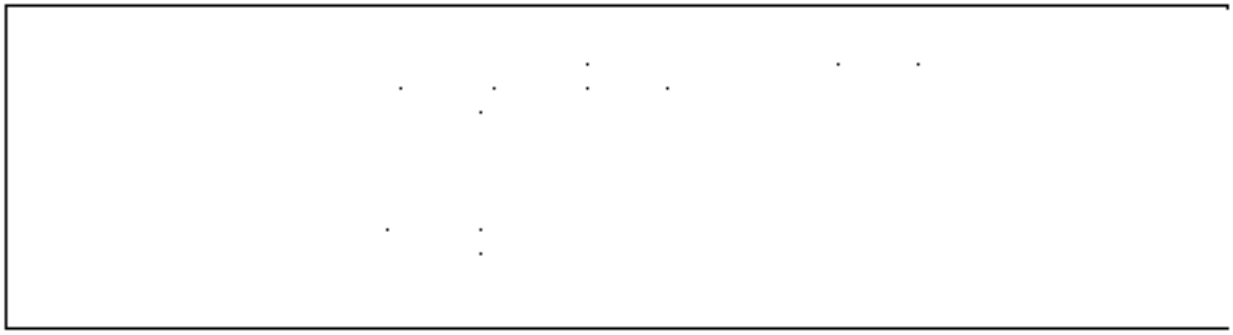
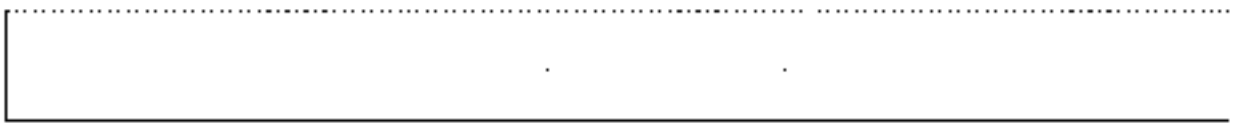
above example could therefore be entered as follows, with the same result:



Of course, one must use either the row number or x-coordinate value consistently within each network to have the desired result.

The following simple example illustrates the use of the XYINC secondary keyword to generate a uniformly spaced Cartesian grid network. The resulting grid is 11 x 11, with a uniform spacing of 1 kilometer (1000 meters), and is centered on the origin (0, 0). No elevated terrain heights or flagpole receptor heights are included in this example.



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3.4.1.2 Polar Grid Receptor Networks

Polar receptor networks are defined by use of the GRIDPOLR keyword. The GRIDPOLR keyword may also be thought of as a "sub-pathway," in that there are a series of secondary keywords that are used to define the start and the end of the inputs for a particular network, and to select the options for defining the receptor locations that make up the network. The syntax and type of the GRIDPOLR keyword are summarized below.

Syntax:	—
	—
	. .
	. . . .
	—
	—
	— .
	. .
	—
Type:	

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where the parameters are defined as follows:

The ORIG secondary keyword is optional for the GRIDPOLR inputs. If omitted, the model assumes a default origin of (0.0, 0.0) in x,y coordinates. The ELEV, HILL, and FLAG keywords are also optional inputs, and are only needed if elevated terrain or flagpole receptor heights are to be used. If elevated terrain is being used, then both the ELEV and HILL inputs are needed for each receptor. If the ELEV and HILL keywords are used and the model is being run with the flat terrain option (see Section 3.2.2), then the elevated terrain height inputs will be ignored by the model, and a non-fatal warning message will be generated. If the elevated terrain

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option is selected, and no elevated terrain heights are entered, the elevations will default to 0.0 meters, and warning messages will also be generated. The model handles flagpole receptor height inputs in a similar manner.

As with the GRIDCART keyword described above, the order of cards within the GRIDPOLR subpathway is not important, as long as all inputs for a particular network are contiguous and start with the SEA secondary keyword and end with the END secondary keyword. It is not even required that all ELEV cards be contiguous, although the input file will be more readable if a logical order is followed. The network ID is also not required to appear on each runstream image (except for the SEA card). The model will assume the previous ID if none is entered, similar to the use of continuation cards for pathway and keywords.

The following example of the GRIDPOLR keyword generates a receptor network consisting of 180 receptor points on five concentric distance rings centered on an assumed default origin of (0,0). The receptor locations are placed along 36 equal spaced radials, beginning with 10 degrees and incrementing by 10. degrees in a clockwise fashion.

```
. . . . . .
```

Another example is provided illustrating the use of a non-zero origin, discrete direction radials and the specification of elevated terrain and flagpole receptor heights.

```
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```


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The user has the option of specifying the radial number (e.g. 1, 2, 3, etc.) on the ELEV, HILL, and FLAG inputs, or the actual direction associated with each radial.

For purposes of model calculations, all receptor locations, including those specified as polar, are stored in the model arrays as x, y and z coordinates and flagpole heights. For the purposes of reporting the results by receptor in the main print file, the tables are labeled with the polar inputs, i.e., directions and distances.

3.4.2 Using Multiple Receptor Networks

For some modeling applications, the user may need a fairly coarsely spaced network covering a large area to identify the area of significant impacts for a plant, and a denser network covering a smaller area to identify the maximum impacts. To accommodate this modeling need, the AERMOD model allows the user to specify multiple receptor networks in a single model run. The user can define either Cartesian grid networks or polar networks, or both. With the use of the ORIG option in the GRIDPOLR keyword, the user can easily place a receptor network centered on the facility being permitted, and also place a network centered on another background source known to be a significant contributor to high concentrations. Alternatively, the polar network may be centered on a receptor location of special concern, such as a nearby Class I area.

As noted in the introduction to this section (3.4), the model dynamically allocates array storage based on the number of receptors and receptor networks when the AERMOD model is run, up to the maximum amount of memory available on the computer.

3.4.3 Specifying Discrete Receptor Locations

In addition to the receptor networks defined by the GRIDCART and GRIDPOLR keywords described above, the user may also specify discrete receptor points for modeling impacts at specific locations of interest. This may be used to model critical receptors, such as the locations of schools or houses, nearby Class I areas, or locations identified as having high concentrations by previous modeling analyses. The discrete receptors may be input as either

AR0068706

Cartesian x,y points (DISCCART keyword) or as polar distance and direction coordinates (DISCPOLR keyword). Both types of receptors may be identified in a single run. In addition, for discrete polar receptor points the user specifies the source whose location is used as the origin for the receptor.

3.4.3.1 Discrete Cartesian Receptors

Discrete Cartesian receptors are defined by use of the DISCCART keyword. The syntax and type of this keyword are summarized below.

Syntax:	
Type:	

where the Xcoord and Ycoord parameters are the x-coordinate and y-coordinate (m), respectively, for the receptor location. The Zelev parameter is an optional terrain elevation (m) and Zhill is a corresponding hill height scale for the receptor for use in elevated terrain modeling. Both the Zelev and Zhill parameters must be specified for use with the elevated terrain algorithms, and are referenced to the same reference elevation (e.g., mean sea level) used for source elevations. The Zflag parameter is the optional receptor height above ground (m) for modeling flagpole receptors. All of the parameters are in units of meters, except for Zelev and Zhill, which default to meters but may be specified in feet by use of the RE ELEVUNIT keyword.

If neither the elevated terrain option (Section 3.2.2) nor the flagpole receptor height option (Section 3.2.7) are used, then the optional parameters are ignored if present. If only the elevated terrain height option is used (no flagpoles), then the third parameter (the field after the Ycoord) is read as the Zelev parameter. If only the flagpole receptor height option is used (no elevated terrain), then the third parameter is read as the Zflag parameter. If both options are used, then the parameters are read in the order indicated for the syntax above. If the optional parameters are left blank, then default values will be used. The default value for Zelev is 0.0, and the default value for Zflag is defined by the COFLAGPOLE card (see Section 3.2.7). Note: If both the elevated terrain and flagpole receptor height options are used, then the third parameter will always be used

AR0068707

as Zelev, and it is not possible to use a default value for Zelev while entering a specific value for the Zflag parameter.

3.1.3.2 Discrete Polar Receptors

Discrete polar receptors are defined by use of the DISCPOLR keyword. The syntax and type of this keyword are summarized below.

Syntax:	
Type:	

where the Srcid is the alphanumeric source identification for one of the sources defined in the SO pathway which will be used to define the origin for the polar receptor location. The Dist and Direct parameters are the distance in meters and direction in degrees for the discrete receptor location. Degrees are measured clockwise from north. The Zelev parameter is an optional terrain elevation for the receptor and Zhill is the corresponding hill top elevation (m) for use in elevated terrain modeling. Both the Zelev and Zhill parameters must be specified for use with the elevated terrain algorithms, and are referenced to the same reference elevation (e.g., mean sea level) used for source elevations. The units of Zelev and Zhill are in meters, unless specified as feet by the RECEIVUNIT keyword. The Zflag parameter is the optional receptor height above ground (meters) for modeling flagpole receptors.

If neither the elevated terrain option (Section 3.2.2) nor the flagpole receptor height option (Section 3.2.7) are used, then the optional parameters are ignored if present. If only the elevated terrain height option is used (no flagpoles), then the third parameter (the field after the Ycoord) is read as the Zelev parameter. If only the flagpole receptor height option is used (no elevated terrain), then the third parameter is read as the ZFlag parameter. If both options are used, then the parameters are read in the order indicated for the syntax above. If the optional parameters are left blank, then default values will be used. The default value for Zelev is 0.0, and the default value for ZFlag is defined by the COFLAGPOLE card (see Section 3.2.7). Note: If both the elevated terrain and flagpole receptor height options are used, then fourth parameter will always be used as

AR0068708

Zelev, and it is not possible to use a default value for Zelev while entering a specific value for the Zflag parameter.

3.4.3.3 Discrete Cartesian Receptors for EVALFILE Output

The EVALCART keyword is used to define discrete Cartesian receptor locations, similar to the DISCCART keyword, but it also allows for grouping of receptors, e.g., along arcs. It is designed to be used with the EVALFILE option, described later for the output pathway, which outputs are maxima values to a separate file for evaluation purposes. The EVALCART keyword can be used without the use of the EVALFILE option, in which case the receptor groupings are ignored. The syntax and type for the modified EVALCART keyword are summarized below:

Syntax:	
Type:	

where the Xcoord and Ycoord parameters are the x-coordinate and y-coordinate (m), respectively, for the receptor location. The Zelev parameter is the terrain elevation (m) for the receptor and Zhill is the corresponding hill top elevation (m) for use in elevated terrain modeling. Both the Zelev and Zhill parameters must be specified for use with the elevated terrain algorithms, and are referenced to the same reference elevation (e.g., mean sea level) used for source elevations. The Zflag parameter is the receptor height above ground (m) for modeling flagpole receptors. All of the parameters are in units of meters, except for Zelev and Zhill, which default to meters but may be specified in feet by use of the RELEVUNIT keyword. The Arcid parameter is the receptor grouping identification, which may be up to eight characters long, and may be used to group receptors by arc. The Name parameter is an optional name field that may be included to further identify a particular receptor location. The Name parameter is ignored by the model. Unlike the DISCCART keyword, all of the parameters (except for the Name) must be present on each card with the EVALCART keyword. The terrain height and flagpole height inputs are ignored if the appropriate options are not specified on the CO TERRHGT and CO FLAGPOLE cards.

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3.4.4 Including Receptor Data From an External File

The user has the option of including receptor data from an external file by using the INCLUDED keyword on the receptor pathway. An RE INCLUDED card may be placed anywhere within the source pathway, after the STARTING card and before the FINISHED card (i.e., the RE STARTING and RE FINISHED cards cannot be included in the external file). The data in the included file will be processed as though it were part of the runstream file. The syntax and type of the INCLUDED keyword are summarized below:

Syntax:	
Type:	

where the Incfil parameter is a character field of up to 40 characters that identifies the filename for the included file. The contents of the included file must be valid runstream images for the receptor pathway. If an error is generated during processing of the included file, the error message will report the line number of the included file (see Appendix C). If more than one INCLUDED file is specified for the receptor pathway, the user will first need to determine which file the error occurred in. If the starting column of the main runstream input file is shifted from column 1 (see Section 2.4.8), then the runstream images in the included file must be offset by the same amount. The INCLUDED option allows the user to include receptor data that have been generated by the AERMOD Terrain Preprocessor, AERMAP, in the runstream file without having to cut and paste the AERMAP output file. Since AERMAP generates terrain elevations in meters and includes the RE ELEVUNIT METERS card as the first record, an AERMAP file must be INCLUDED at the beginning of the receptor pathway, immediately following the RE STARTING card. If more than one AERMAP output file is INCLUDED on the receptor pathway, the RE ELEVUNIT METERS card must be deleted from all but the first one.

3.5 METEOROLOGY PATHWAY INPUTS AND OPTIONS

The **ME**teorology pathway contains keywords that define the input meteorological data for a particular model run.

AR0068710

3.5.1 Specifying the Input Data Files and Formats

The AERMOD model uses hourly meteorological data from separate surface and profile data files as one of the basic model inputs. These input meteorological data filenames for AERMOD are identified by the SURFFILE and PROFFILE keywords on the ME pathway. The syntax and type of these keywords are summarized below:

Syntax:
Type:

where the Srstfil and Profil parameters are character fields of up to 40 characters that identify the filenames for the input meteorological data files. For running the model on an IBM compatible PC, the filename parameters may include the complete DOS pathname for the file, or will assume the current directory if only the filename is given. The optional Format parameter specifies the format of the meteorological data files. The default formats for the surface and profile data files corresponds with the format of the files generated by the AERMET meteorological preprocessor program. The user also has the option of specifying the Fortran read format for each of these files. The contents of the meteorological data files are described below, and the file formats are documented in Appendix D.

The surface meteorological data file consists of a header record containing information on the meteorological station locations, and one record for each hour of data. These data are delimited by at least one space between each element, i.e., the data may be read as free format. The contents of the surface file are as follows:

Year
Month (1 - 12)
Day (1 - 31)
Julian day (1 - 366)
Hour (1 - 24)
Sensible heat flux (W m^{-2})
Surface friction velocity, u_* (m s^{-1})
Convective velocity scale, w_* (m s^{-1})

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Vertical potential temperature gradient in the 500 m layer above the planetary boundary layer
Height of the convectively generated boundary layer (m)
Height of the mechanically-generated boundary layer (m)
Monin-Obukhov length, L, (m)
Surface roughness length, z_o (m)
Bowen ratio
Albedo
Wind speed (ms^{-1}) used in the computations
Wind direction (degrees) corresponding to the wind speed above
Height at which the wind above was measured (m)
Temperature (K) used in the computations
Height at which the temperature above was measured (m)

The sensible heat flux, Bowen ratio and albedo are not used by the AERMOD model, but are passed through by AERMET for information purposes only.

The profile meteorological data file consists of one or more records for each hour of data. As with the surface data file, the data are delimited by at least one space between each element and may be read as Fortran free format. The contents of the profile meteorological data file are as follows:

Year
Month (1 - 12)
Day (1 -31)
Hour (1 - 24)
Measurement height (m)
Top flag 1, if this is the last (highest) level for this hour,
0, otherwise
Wind direction for the current level (degrees)
Wind speed for the current level (ms^{-1})
Temperature at the current level (K)
Standard deviation of the wind direction, σ_θ (degrees)
Standard deviation of the vertical wind speed, σ_w (ms^{-1})

The data in this file include the on-site meteorological data that are processed by AERMET. Since AERMET was designed to be able to perform dispersion parameter calculations with NWS data only, i.e., no on-site data, the profile data may consist of a one-level "profile" based on the NWS winds and temperature.

AR0068712

3.5.2 Specifying Station Information

Three keywords are used to specify information about the meteorological stations. SURFDATA for the surface meteorological station, UAIRDATA for the upper air station, and the optional SITEDATA for any on-site meteorological data that may be used. The syntax and type of these keywords are summarized below:

Syntax:	
Syntax:	
Syntax:	
Type:	

where Stanum is the station number, e.g. the 5-digit WBAN number for NWS stations, Year is the year of data being processed (either 2- or 4-digits), Name is an optional character field (up to 40 characters with no blanks) specifying the name of the station, and Xcoord and Ycoord are optional parameters for specifying the x and y coordinates for the location of the stations. At the present time, the station locations are not utilized in the model. Therefore, no units are specified for Xcoord and Ycoord at this time, although meters are suggested in order to be consistent with the source and receptor coordinates. The AERMOD model compares the station numbers input using these keywords with the numbers included in the header record of the surface meteorological data file, and issues non-fatal warning messages if there are any mismatches.

3.5.3 Specifying the Base Elevation for Potential Temperature Profile

The AERMOD model generates a gridded vertical profile of potential temperatures for use in the plume rise calculations. Since potential temperature is dependent on the elevation above mean sea level (MSL), the user must define the base elevation for the profile with the PROFBASE keyword. The syntax and type for the PROFBASE keyword are summarized below:

AR0068713

Syntax:	
Type:	

where the BaseElev parameter specifies the base elevation above MSL for the potential temperature profile, and the optional Units parameter specifies the units of BaseElev. Valid inputs of Units are the secondary keywords METERS or FEET. The default units for BaseElev are in meters if Units is left blank. The base elevation should correspond with the base elevation of the primary meteorological tower.

3.5.4 Specifying a Data Period to Process

There are two keywords that allow the user to specify particular days or ranges of days to process from the sequential meteorological file input for the AERMOD model. The STARTEND keyword controls which period within the meteorological data file is read by the model, while the DAYRANGE keyword controls which days or ranges of days (of those that are read) for the model to process. The default for the model is to read the entire meteorological data file (up to a full year) and to process all days within that period.

The syntax and type for the STARTEND keyword are summarized below.

Syntax:	
Type:	

where the Styr, Smon, Sday parameters specify the year, month and day of the first record to be read (e.g., 87 01 31 for January 31, 1987), and the parameters Eyr, Emon, Eday specify the year, month and day of the last record to be read. The Shr and Ehr are optional parameters that may be used to specify the start and end hours for the data period to be read. If either Shr or Ehr is to be specified, then both must be specified. Any records in the data file that occur before the start date are ignored, as are any records in the data file that occur after the end date. In fact, once the end date has been reached, the model does not read any more data from the meteorological file. If Shr and Ehr are not specified, then processing begins with hour 1 of

AR0068714

the start date, and ends with hour 24 of the end date, unless specific days are selected by the DAYRANGE card described below.

Any PERIOD averages calculated by the model will apply only to the period of data actually processed. Therefore, if someone wanted to calculate a six-month average, they could select PERIOD averages on the CO-AVERTIME card, and then specify the period as follows:

for the period January 1, 1987 through June 30, 1987.

The syntax and type for the DAYRANGE keyword are summarized below.

Syntax:	
Type:	

where the Range parameters specify particular days or ranges of days to process. The days may be specified as individual days (e.g. 1 2 3 4 5) or as a range of days (e.g. 1-5). The user also has the option of specifying Julian day numbers, from 1 to 365 (366 for leap years), or specifying month and day (e.g., 1-31 for January 31). Any combination of these may also be used. For example the following card will tell the model to process the days from January 1 (Julian day 1) through January 31 (Day 31):

The DAYRANGE keyword is also repeatable, so that as many cards as needed may be included in the MI: pathway.

AR0068715

As with the STARTEND keyword, any PERIOD averages calculated by the model will apply only to the period of data actually processed. If the STARTEND keyword is also used, then only those days selected on the DAYRANGE cards that fall within the period from the start date to the end date will be processed. Thus, if the ME pathway included the following two cards

then no data would be processed, since the days 1 through 31 fall outside the period 2/1 to 12-31

3.3.3 Correcting Wind Direction Alignment Problems

The WDROTATE keyword allows the user to correct the input meteorological data for wind direction alignment problems. All input wind directions or flow vectors are rotated by a user-specified amount. Since the model results at particular receptor locations are often quite sensitive to the transport wind direction, this optional keyword should be used only with extreme caution and with clear justification.

The syntax and type of this keyword are summarized below.

Syntax:	
Type:	

where the Rotang parameter specifies the angle in degrees to rotate the input wind direction measurements. The value of Rotang is subtracted from the wind direction measurements. It may be used to correct for known (and documented) calibration errors, or to adjust for the alignment of a valley if the meteorological station is located in a valley with a different alignment than the source location.

AR0068716

3.5.6 Specifying Wind Speed Categories

Variable emission rate factors may be input to the model that vary by wind speed category. The model uses six wind speed categories, and these are defined by the upper bound wind speed for the first five categories (the sixth category is assumed to have no upper bound). The default values for the wind speed categories are as follows: 1.54, 3.09, 5.14, 8.23, and 10.8 m/s. The syntax and type of the WINDCATS keyword, which may be used to specify different category boundaries, are summarized below.

Syntax:	
Type:	

where the Ws1 through Ws5 parameters are the upper bound wind speeds of the first through fifth categories in meters per second. The upper bound values are inclusive, i.e., a wind speed equal to the value of Ws1 will be placed in the first wind speed category.

3.5.7 Specifying SCIM Parameters

The SCIM parameters on the SCIMBYHR card specify the starting hour and sampling interval for the regular sample and an optional file name. The syntax and type of the SCIMBYHR keyword are summarized below.

Syntax:	
Type:	

where the NRegStart and NRegInt parameters specify the first hour to be sampled and the sampling interval, respectively, when performing the regular sampling. The NWetStart and NWetInt parameters are used to specify the first wet hour (i.e., with non-zero precipitation) and the wet sampling interval for wet sampling. However, since the AERMOD model currently does not include wet deposition algorithms, the wet sampling option is not operational, and the user should enter a value of zero (0) for both NWetStart and NWetInt. Optionally, the user can create

AR0068717

output files containing the surface and profile meteorological data for the sampled hours by specifying the SfcFilnam and PflFilnam parameters. These output files are in the same format used in the summary of the first 24 hours of data included in the main output file.

In order to use the SCIM option, the user must specify the non-DEFAULT TOXICS option on the CO MODELOPT card, and also specify SCIM on the MODELOPT card. Although the MP SCIMBYHR is an optional card, it is required when using the SCIM option. NRegStart is required to have a value from 1 through 24, i.e., the first sampled hour must be on the first day in the meteorological data file. There are no restrictions for NRegInt, however, NRegInt would generally be greater than 1. For example, NRegInt could be based on the formula (24n + 1), where "n" is the number of days to skip between samples, in order to ensure a regular diurnal cycle to the sampled hours (e.g., 25 or 49).

3.6 EVENT PATHWAY INPUTS AND OPTIONS

EVENT processing is specifically designed to facilitate analysis of source contributions to specific events for short term averages (less than or equal to 24 hours). These events may be design concentrations generated by the AERMOD model, occurrences of violations of an air quality standard, or user-specified events. These events are input to the AERMOD model through the EVent pathway. Each event is defined by an averaging period and specific data period, a source group, and a receptor location. Since the locations are only of interest in combination with particular averaging and data periods, the REceptor pathway is not used with EVENT processing.

There are two keywords that are used to define the events on the EV pathway. The EVENTPER keyword defines the averaging period, data period and source group, while the EVENTLOC keyword defines the receptor location for the event. Each event is also given an alphanumeric name that links the two input cards for that event.

AR0068718

The syntax and type of the EVENTPER and EVENTLOC keywords are summarized below.

Syntax:	
Syntax:	
Type:	

where the parameters are as follows:

Evname - event name (an alphanumeric string of up to 8 characters).

Aveper - averaging period for the event (e.g. 1, 3, 8, 24 hr).

Grpid - source group ID for the event (must be defined on SO pathway).

Date - date for the event, input as an eight digit integer for the ending hour of the data period (YYYYMMDDHH), e.g. 84030324 defines a data period ending at hour 24 on March 3, 1984. The length of the period corresponds to Aveper.

XR - X-coordinate (m) for the event location, referenced to a Cartesian coordinate system.

YR - Y-coordinate (m) for the event location, referenced to a Cartesian coordinate system.

RNG - distance range (m) for the event location, referenced to a polar coordinate system with an origin of (0., 0.).

DIR - radial direction (deg.) for the event location, referenced to a polar coordinate system with an origin of (0., 0.).

Zelev - optional terrain elevation for the event location (m).

Zflag - optional receptor height above ground (flagpole receptor) for the event location (m).

Each event is defined by the two input cards EVENTPER and EVENTLOC, and these inputs are linked by the event name, which must be unique among the events being processed in a given run. There is no particular requirement for the order of cards on the EV pathway. Note that the

AR0068719

location for the event may be specified by either Cartesian coordinates or by polar coordinates. However, the polar coordinates must be relative to an origin of (0,0).

3.6.1 Using Events Generated by the AERMOD Model

The AERMOD model has an option (CO EVENTFIL, described in Section 3.2.9) to generate an input file for the AERMOD EVENT processing. When this option is used, the AERMOD model copies relevant inputs from the AERMOD runstream input file to the Event processing input file, and generates the inputs for the EVent pathway from the results of the modeling run. These events are the design concentrations identified by the OU RECTABLE keyword (see Section 3.8.1.1), such as the highest and high-second-high 24-hour averages, etc., and any threshold violations identified by the OU MAXTFILE keyword (see Section 3.8.1.2). The inputs generated by the AERMOD model correspond to the syntax described above for the EVENTPER and EVENTLOC keywords. The locations for events generated by the AERMOD model are always provided as Cartesian coordinates.

To easily identify the events generated by the AERMOD model, and to provide a mechanism for the AERMOD model to manage the events generated from the model run, a naming convention is used for the EVNAME parameter. The following examples illustrate the event names used by the AERMOD model:

H1H01001 - High-first-high 1-hour average for source group number 1

H2H24003 - High-second-high 24-hour average for source group number 3

TH03H010 - Threshold violation number 10 for 3-hour averages

TH24H019 - Threshold violation number 19 for 24-hour averages

The high value design concentrations are listed first in the EVENT processing input file, followed by the threshold violations (grouped by averaging period). To make it easier for the user to review the EVENT processing input file generated by the AERMOD model, and determine which events are of most concern, the actual concentration value associated with the event is included as

AR0068720

the last field on the EVENTPER card. This field is ignored by the AERMOD model, and is included only for informational purposes. The user should be aware that the same event may appear in the AERMOD model input file as both a design value and as a threshold violation, depending on the options selected and the actual results. Since the model processes the events by date sequence and outputs the results for each event as it is processed, the order of events in the output file will generally not follow the order of events in the input file, unless all of the events were generated by the MAXIFILE option.

3.6.2 Specifying Discrete Events

The user can specify discrete events by entering the EVENTPER and EVENTLOC cards as described above. The averaging period and source group selected for the event must be among those specified on the CO AVERTIME and SO SRCGROUP cards. If the EVENT processing input file was generated by the AERMOD model, the user may include additional events for those averaging periods and source groups used in the original AERMOD model run. They may also add averaging periods or define new source groups in the Event processing input file in order to define additional events.

3.6.3 Including Event Data From an External File

The user has the option of including event data from an external file by using the INCLUDED keyword on the source EVT pathway. An EV INCLUDED card may be placed anywhere within the event pathway, after the STARTING card and before the FINISHED card (i.e., the EV STARTING and EV FINISHED cards cannot be included in the external file). The data in the included file will be processed as though it were part of the runstream file. The syntax and type of the INCLUDED keyword are summarized below:

Syntax:	
Type:	

AR0068721

where the Infil parameter is a character field of up to 40 characters that identifies the filename for the included file. The contents of the included file must be valid runstream images for the event pathway. If an error is generated during processing of the included file, the error message will report the line number of the included file (see Appendix C). If more than one INCLUDED file is specified for the event pathway, the user will first need to determine which file the error occurred in. If the starting column of the main runstream input file is shifted from column 1 (see Section 2.4.8), then the runstream images in the included file must be offset by the same amount.

3.7 OUTPUT PATHWAY INPUTS AND OPTIONS

The OUTPUT pathway contains keywords that define the output options for the model runs. The AERMOD model has three keywords that control different types of tabular output for the main output file of the model, and seven keywords that control separate output file options for specialized purposes. The user may select any combination of output option for a particular application.

3.7.1 Selecting Options for Tabular Printed Outputs.

The three tabular printed output options are controlled by the following keywords:

RECTABLE - Controls output option for high value summary tables by receptor

MAXTABLE - Controls output option for overall maximum value summary tables; and

DAYTABLE Controls output option for tables of concurrent values summarized by receptor for each day processed

The keywords are described in more detail in the order listed above.

The syntax and type for the RECTABLE keyword are summarized below:

AR0068722

Syntax:	____ _____ ... ____ ____ ____ ... ____
Type:	

where the Aveper parameter is the short term averaging period (e.g. 1, 3, 8 or 24 hr or MONTH) for which the receptor table is selected, and the secondary keywords, FIRST, SECOND, etc., indicate which high values are to be summarized by receptor for that averaging period. The RECTABLE card may be repeated for each averaging period. For cases where the user wants the same RECTABLE options for all short term averaging periods being modeled, the input may be simplified by entering the secondary keyword ALLAVE for the Aveper parameter. The following example will select summaries of the highest, second highest and third highest values by receptor for all averaging periods.

The model will also recognize a range of high values on the RECTABLE input card, and therefore the following card will have the effect:

The output file will include tables for only the high values selected. Tables for all source groups for a particular averaging period are grouped together, and the averaging periods are output in the order that they appear the CO AVERTIME card. For each averaging period and source group combination, the tables of high values for the receptor networks (if any) are printed first, followed by any discrete Cartesian receptors, and any discrete polar receptors.

If the CO EVENTFIL keyword has been used to generate an input file for EVENT processing, then the design values identified by the RECTABLE options, e.g., the high-second-high 24-hour average, are included in the events that are defined in the EVENT processing input file.

AR0068723

The syntax and type for the MAXTABLE keyword are summarized below:

Syntax:
Type:

where the Aveper parameter is the short term averaging period (e.g. 1, 3, 8 or 24 hr or MONTH) for which the receptor table is selected, and the Maxnum parameter specifies the number of overall maximum values to be summarized for each averaging period. The MAXTABLE card may be repeated for each averaging period. As with the RECTABLE keyword, for cases where the user wants the same MAXTABLE options for all short term averaging periods being modeled, the input may be simplified by entering the secondary keyword ALLAVE for the Aveper parameter. The following example will select the maximum 50 table for all averaging periods:

A separate maximum overall value table is produced for each source group. The maximum value tables follow the RECTABLE outputs in the main print file. All source group tables for a particular averaging period are grouped together, and the averaging periods are output in the order that they appear on the CO AVERTIME card.

The syntax and type for the DAYTABLE keyword are summarized below:

Syntax:
Type:

where the Avperm parameters are the short term averaging periods (e.g. 1, 3, 8 or 24 hr or MONTH) for which the daily tables are selected. The DAYTABLE card is non-repeatable, but as with the RECTABLE and MAXTABLE keywords, for cases where the user wants daily tables for all short term averaging periods being modeled, the input may be simplified by entering the

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secondary keyword ALLAVE for the first parameter. The following example will select the daily tables for all averaging periods.

For each averaging period for which the DAYTABLE option is selected, the model will print the concurrent averages for all receptors for each day of data processed. The receptor networks (if any) are printed first, followed by any discrete Cartesian receptors, and any discrete polar receptors. Results for each source group are output. For example, if 1, 3, and 24-hour averages are calculated, and the OU DAYTABLE ALLAVE option is used, then for the first day of data processed, there will be 24 sets of tables of hourly averages (one for each hour in the day), eight sets of 3-hour averages (one for each 3-hour period in the day), and one set of 24-hour averages. The averages are printed as they are calculated by the model, but for hours where more than one averaging period is calculated (e.g., hour 24 is the end of an hourly average, a 3-hour average, and a 24-hour average), the order in which the averages are output will follow the order used on the OU AVERTIME card. Note: This option can produce very large output files, especially when used with a full year of data and very short period averages, such 1-hour and 3-hour. It should therefore be used with CAUTION.

3.7.2 Selecting Options for Special Purpose Output Files.

The AERMOD model provides options for seven types of output files for specialized purposes. These options are controlled by the following keywords:

MAXIFILE - Produces file with occurrences of violations of user-specified threshold value.

POSTFILE - Produces file of concurrent (raw) results at each receptor suitable for post-processing.

PLOTFILE - Produces file of design values that can be imported into graphics software for plotting contours.

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TOXXFILE	Produces unformatted files of raw results above a threshold value with a special structure for use with the TOXX model component of TOXST.
RANKFILE -	Produces file of output values by rank for use in Q-Q (quantile) plots.
EVALFILE -	Produces file of output values, including arc-maximum normalized concentrations suitable for model evaluation studies and
SEASONHR -	Produces file of output values by season and hour-of-day

The keywords are described in more detail in the order listed above.

The syntax and type for the MAXIFILE keyword are summarized below.

Syntax:	
Type:	

where the Aveper parameter is the short term averaging period (e.g. 3, 8, 24 for 3, 8 and 24-hour averages, or MONTH for monthly averages) and Grpid is the source group ID for which the MAXIFILE option is selected. The Thresh parameter is the user-specified threshold value and Filnam is the name of the file where the MAXIFILE results are to be written. The optional Funit parameter allows the user the option of specifying the Fortran logical file unit for the output file. The user-specified file unit must be in the range of 26-100, inclusive. By specifying the same filename and unit for more than one MAXIFILE card, results for different source groups and/or averaging periods may be combined into a single file. If the Funit parameter is omitted, then the model will dynamically allocate a unique file unit for this file (see Section 5.7.2).

The MAXIFILE card may be repeated for each combination of averaging period and source group, and a different filename should be used for each file. The resulting maximum value file will include several header records identifying the averaging period, source group and the threshold value for that file, and a listing of every occurrence where the result for that averaging period-source group equals or exceeds the threshold value. Each of these records includes the averaging period, source group ID, date for the threshold violation (ending hour of the averaging

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period, the x, y, z and flagpole receptor height for the receptor location where the violation occurred, and the concentration value.

Each of the threshold violations, except for monthly averages, identify events that may be modeled for source contribution information with EVENT processing by selecting the CO EVENTFIL option (see Sections 3.2.9 and 3.8). Each of the threshold violations is included as an event on the EV pathway, and is given a name of the form TTIxxyyyy, where xx is the averaging period, and yyyy is the violation number for that averaging period. For example, an event name of TTD-0019 identifies the 19th threshold violation for 24-hour averages. Monthly average threshold violations are included in the file specified on the MAXFILE card, but are not included in the EVENT processing input file since the AERMOD model currently handles only averaging periods of up to 24 hours.

The following examples illustrate the use of the MAXIFILE option:

```
                                .
                              .   .
                             .     .
                                .
```

where the 3-hour example illustrates the use of a DOS pathname for the PC, and the last example illustrates the use of monthly averages. The FILNAM parameter may be up to 40 characters in length. It should also be noted that only one MAXIFILE card may be used for each averaging period/source group combination. Note: The MAXIFILE option may produce very large files for runs involving a large number of receptors if a significant percentage of the results exceed the threshold value.

The syntax and type for the POSTFILE keyword are summarized below:

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Syntax:	
Type:	

where the Aveper parameter is the averaging period (e.g. 1, 8, 24 for 1, 8 and 24-hour averages, MONTH for monthly averages, PERIOD for period averages, or ANNUAL for annual averages) and Grpid is the source group ID for which the POSTFILE option is selected. The Format parameter specifies the format of the POSTFILE output, and may either be the secondary keyword UNFORM for unformatted concentration files, or the secondary keyword PLOT to obtain formatted files of receptor locations (x- and y-coordinates) and concentrations suitable for plotting contours of concurrent values. The Filnam parameter is the name of the file where the POSTFILE results are to be written. The optional Funit parameter allows the user the option of specifying the Fortran logical file unit for the output file. The user-specified file unit must be in the range of 20-100, inclusive. By specifying the same filename and unit for more than one POSTFILE card, results for different source groups and/or averaging periods may be combined into a single file. If the Funit parameter is omitted, then the model will dynamically allocate a unique file unit for this file (see Section 3.8.2).

The POSTFILE card may be repeated for each combination of averaging period and source group, and a different filename should be used for each file. If UNFORM is specified for the Format parameter, then the resulting unformatted file includes a constant-length record for each of the selected averaging periods calculated during the model run. The first variable of each record is an integer variable (4 bytes) containing the ending date (YYMMDDHH) for the averages on that record. The second variable for each record is an integer variable (4 bytes) for the number of hours in the averaging period. The third variable for each record is a character variable of length eight containing the source group ID. The remaining variables of each record contain the calculated average concentration values for all receptors, in the order in which they were defined in the input runstream.

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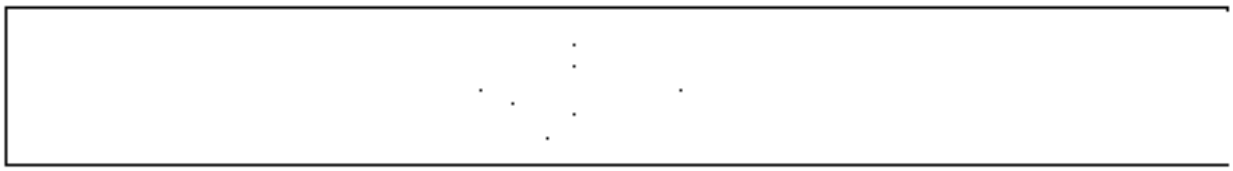
The following examples illustrate the use of the POSTFILE option:



where the 3-hour example illustrates the use of a DOS pathname for the PC, and the last example illustrates the use of monthly averages. The Filnam parameter may be up to 40 characters in length. The use of separate files for each averaging period/source group combination allows the user flexibility to select only those results that are needed for post-processing for a particular run, and also makes the resulting unformatted files manageable. Note: The POSTFILE option can produce very large files, and should be used with some caution. For a file of hourly values for a full year (8760 records) and 400 receptors, the resulting file will use about 14 megabytes of disk space. To estimate the size of the file (in bytes), use the following equation:

File Size (bytes) = (No. of Hours/Yr / (No. of Hours/Ave)) * No. of Receptors * 4

Divide the result by 1000 to estimate the number of kilobytes (KB) and divide by 1,0E6 to estimate the number of megabytes (MB).

The syntax and type for the PLOTFILE keyword are summarized below:

Syntax:
Type:

where the Aveper parameter is the averaging period (e.g. 3, 8, 24 for 3, 8 and 24-hour averages, MONTH for monthly averages, PERIOD for period averages, or ANNUAL for annual averages), Grpid is the source group ID for which the PLOTFILE option is selected, and Hivalu specifies which short term high values are to be output (FIRST for the first highest at each receptor, SECOND for the second highest at each receptor, etc.). Note that the Hivalu parameter is not

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specified for PERIOD or ANNUAL averages, since there is only one period or annual average for each receptor. The Filnam parameter is the name of the file where the PLOTFILE results are to be written. The optional Funit parameter allows the user the option of specifying the Fortran logical file unit for the output file. The user-specified file unit must be in the range of 26-100, inclusive. By specifying the same filename and unit for more than one PLOTFILE card, results for different source groups and/or averaging periods may be combined into a single file. If the Funit parameter is omitted, then the model will dynamically allocate a unique file unit for this file (see Section 3.8.2).

The PLOTFILE card may be repeated for each combination of averaging period, source group, and high value, and a different filename should be used for each file. The resulting formatted file includes several records with header information identifying the averaging period, source group and high value number of the results, and then a record for each receptor which contains the x and y coordinates for the receptor location, the appropriate high value at that location, and the averaging period, source group and high value number. The data are written to the file in the order of x-coord, y-coord, concentration so that the file can easily be imported into a graphics package designed to generate contour plots. Many such programs will read the PLOTFILEs directly without any modification, ignoring the header records, and produce the desired plots.

The following examples illustrate the use of the PLOTFILE option:

```
                                .
                                .
                              .
                            . .
                          .                 .
                              .
                            .
```

where the 3-hour example illustrates the use of a DOS pathname for the PC, and the last example illustrates the use of monthly averages. As illustrated by the second and third examples, the high

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value parameter may also be input as secondary keywords using the standard abbreviations of 1ST, 2ND, 3RD, . . . 10TH. The Filnam parameter may be up to 40 characters in length. The use of separate files for each averaging period, source group, high value combination allows the user flexibility to select only those results that are needed for plotting from a particular run.

The syntax and type for the TOXXFILE keyword are summarized below:

Syntax:	
Type:	

where the Aveper parameter is the short term averaging period (e.g. 1, 3, 8, 24 for 1, 3, 8 and 24-hour averages, or MONTH for monthly averages) for which the TOXXFILE option has been selected. The Cutoff (threshold) parameter is the user-specified threshold cutoff value in g/m^3, and Filnam is the name of the file where the TOXXFILE results are to be written. It is important to note that the units of the Cutoff parameter are g/m^3, regardless of the input and output units selected with the SO EMISUNIT card. The optional Funit parameter allows the user the option of specifying the Fortran logical file unit for the output file. The user-specified file unit must be in the range of 26-100, inclusive. If the Funit parameter is omitted, then the model will dynamically allocate a unique file unit for this file (see Section 5.8.2). While the TOXXFILE option may be specified for any of the short term averaging periods that are identified on the CO AVERTIME card for a particular run, a non-fatal warning message will be generated if other than 1-hour averages are specified. This is because the TOXST model currently supports only 1-hour averages.

The TOXXFILE card may be repeated for each averaging period, but a different filename should be used for each file since the structure of the output file generated by the TOXXFILE option does not allow for a clear way to distinguish between results for different averaging periods. The resulting output file for the AERMOD model is an unformatted file with several header records identifying the title, averaging period, receptor information, and the threshold value for that file, followed by records listing every occurrence where the result for any source group for that averaging period equals or exceeds the threshold value. When one of the source

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groups exceeds the threshold value, the results for all source groups for that averaging period and receptor location are output. Each concentration that is output through the TOXXFILE option is paired with an integer ID variable that identifies the averaging period (hour number of the year), the source group number, and the receptor number corresponding to that value. The concentration values and corresponding ID variables are stored in buffer arrays, and the arrays are then written to the unformatted output file when full. The size of the arrays is controlled by the NPAIR PARAMETER defined in MODULE MAIN1 and is initially set at 100. At the end of the modeling run, any values remaining in the buffer arrays are written to the file, padded on the right with zeroes. The structure of the output file generated by the TOXXFILE option is described in more detail in Section 3.8.2 and in Appendix D. When using the TOXXFILE option, the user will normally place a single source in each source group. The user should refer to the user's guide for TOXST for further instructions on the application of the TOXXFILE option of the AERMOD model.

The following examples illustrate the use of the TOXXFILE option:

:

The Filnam parameter may be up to 40 characters in length. It should be noted that only one TOXXFILE card may be used for each averaging period. Note: The TOXXFILE option may produce very large files for runs involving a large number of receptors if a significant percentage of the results exceed the threshold value.

The RANKFILE keyword outputs values by rank for use in Q-Q (quantile) plots. The MAXTABLE option must be specified first in order to use the RANKFILE option for a particular averaging period. However, the RANKFILE output differs from the results in the MAXTABLE output in that duplicate date/hour occurrences are removed. The syntax and type for the RANKFILE keyword are summarized below:

AR0068732

Syntax:
Type:

where the Aveper parameter is the averaging period (e.g., 3, 8, 24 for 3, 8, and 24-hour averages, or MONTH for monthly averages), and Hinum is the number of high values to be ranked. The RANKFILE keyword cannot be used with PERIOD averages. As noted above, the MAXTABLE option must be specified first for the particular Aveper, and the Hinum parameter on the RANKFILE card must be less than or equal to the Maxnum parameter on the corresponding MAXTABLE card. Since duplicate dates are removed from the RANKFILE output, the output file may contain less than the number of requested high values. The NMAX parameter, which controls the maximum number of values that can be stored, has been set initially to 400. The Filnam parameter is the name of the file (up to 40 characters) where the RANKFILE results are to be written. The optional Hunit parameter allows the user the option of specifying the Fortran logical file unit for the output file. The user-specified file unit must be in the range of 20-100, inclusive. By specifying the same filename and unit for more than one RANKFILE card, results for different averaging periods may be combined into a single file. If the Hunit parameter is omitted, the model will dynamically allocate a unique file unit for this file according to the following formula:

IRKUNT = 100 + IAVE

where IRKUNT is the Fortran unit number and IAVE is the averaging period number (the order of the averaging period as specified on the CO AVERTIME card).

The EVALFILE option is specifically designed for use in generating residuals for model evaluation studies. The EVALFILE output consists of the arc-maximum normalized concentration values for each hour of meteorology and for each source specified. The arc groupings of the receptors must be specified using the RE EVALCART keyword described above. The syntax and type for the EVALFILE keyword are summarized below:

AR0068733

Syntax:	
Type:	

where the Srcid parameter is the source ID for which EVMLFILE results are requested, the Filnam parameter is the name of the file (up to 40 characters) where the EVALFILE results are to be written, and the optional Funit parameter allows the user the option of specifying the Fortran logical file unit for the output file. The user-specified file unit must be in the range of 26-100, inclusive. By specifying the same filename and unit for more than one EVALFILE card, results for different sources may be combined into a single file. If the Funit parameter is omitted, the model will dynamically allocate a unique file unit for this file according to the following formula.

IFLUNT = 400 + ISRC*5

where IFLUNT is the Fortran unit number and ISRC is the source number (the order of the source as specified on the SO pathway).

For each hour of meteorological data processed and for each receptor grouping (e.g., arc), the EVMLFILE option outputs five records containing the source ID, date, arc ID, arc-maximum normalized concentration (χ/Q), emission rate, and other plume dispersion and meteorological variables associated with the arc-maximum. Since the EVALFILE option looks at receptor groupings, it must be used in conjunction with the EVALCART keyword described above for the RE pathway, and a fatal error is generated if no receptor groups are identified.

The SEASONHR option is used to output a file containing the average results by season and hour-of-day. To select this option, the user must include the SEASONHR keyword on the OU pathway. The syntax, type, and order for the SEASONHR keyword are summarized below.

Syntax:	
Type:	

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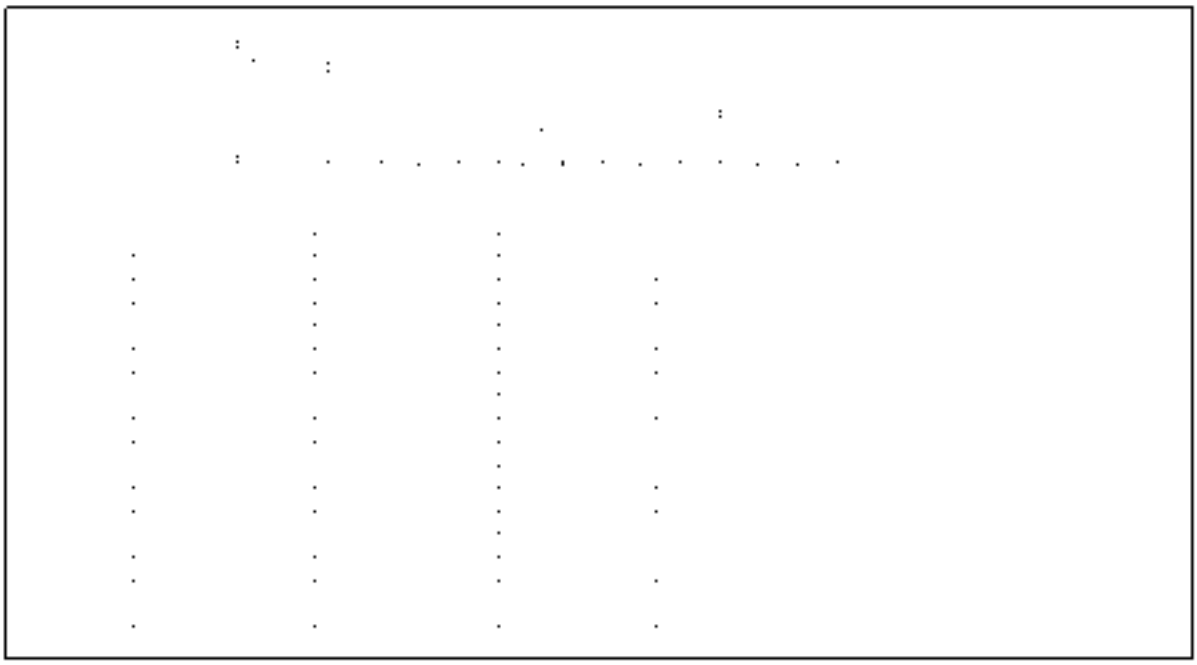
where the GroupID parameter specifies the source group to be output. FileName specifies the name of the output file, and the optional FileUnit parameter specifies an optional file unit and must be in the range 26-100, inclusive. If FileUnit is left blank, then the model will dynamically assign a file unit based on the formula 302 + IGRP*10, where IGRP is the group index number. A sample from a SEASONHR output file is shown below.



The NHRS column in the output file contains the number of non-calm and non-missing hours used to calculate the season-by-hour-of-day averages. The SEAS column is the season index, and is 1 for winter, 2 for spring, 3 for summer and 4 for fall. The records loop through hour-of-day first, and then through the seasons.

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3.7.3 EVENT Processing Options

EVENT processing in the AERMOD model is designed specifically to perform source contribution analyses for short term average (less than or equal to 24-hour) events. The events may either be generated by the AERMOD model, or they may be user-specified events, or both. Because of this rather narrow focus of applications, the output options are limited to a single keyword. The EVENTOUT keyword controls the level of detail in the source contribution output from the EVENT mode. The syntax and type of the EVENTOUT keyword are summarized below:

Syntax:	——— ———
Type:	

where the SOCONT secondary keyword specifies the option to produce only the source contribution information in the output file, and the DETAIL secondary keyword specifies the option to produce more detailed summaries in the output file. The SOCONT option provides the average concentration (or total deposition) value (i.e., the contribution) from each source for the period corresponding to the event for the source group. The basic source contribution information is also provided with the DETAIL option. In addition, the DETAIL option provides the hourly average concentration (or total deposition) values for each source for every hour in the averaging period, and a summary of the hourly meteorological data for the event period. In general, the DETAIL option produces a larger output file than the SOCONT file, especially if there are a large number of sources. There is no default setting for the EVENTOUT options.

3.8 CONTROLLING INPUT AND OUTPUT FILES

This section describes the various input and output files used by the AERMOD model, and discusses control of input and output (I/O) on the IBM compatible PC environment. Much of this discussion also applies to operating the model in other environments.

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3.8.1 Description of AERMOD Input Files

The two basic types of input files needed to run all of the AERMOD model are the input runstream file containing the modeling options, source data and receptor data, and the two input meteorological data files. Each of these is discussed below, as well as a special file that may be used to initialize the AERMOD model with intermediate results from a previous run.

3.8.1.1 Input Runstream File.

The input runstream file contains the user-specified options for running the various AERMOD model (called AERMOD INP), includes the source parameter data and source group information, defines the receptor locations, specifies the location and parameters regarding the meteorological data, and specifies the output options. Details regarding the keywords and parameters used in the input runstream file are provided in Section 5, and Appendix B.

For the PC-executable version of the model available on the SCRAM website, the runstream file is explicitly opened by the model using a Fortran OPEN statement, and the integer variable, INUNIT, specifies the unit number for the file. The variable INUNIT is initialized to a value of 7 in a DATA statement in MODULE MAIN1 and is therefore available to all of the necessary subroutines.

3.8.1.2 Meteorological Data Files.

The input meteorological data is read into the AERMOD model from two separate data files, one corresponding to surface (scalar) parameters, and the other corresponding to multi-level profiles of data. The meteorological data filenames and formats are specified within the input runstream file using the ME SURFFILE and PROFFILE keywords. The AERMOD model accepts meteorological data that has been preprocessed by the AERMET meteorological preprocessor program (EPA, 2004b). The data are read from formatted ASCII files of hourly sequential records.

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The meteorological data files are explicitly opened by the model using Fortran OPEN statements, and the integer variables MFUNIT for the surface/scalar file and MPUNIT for the profile file are used to specify the unit numbers for the files. The variable MFUNIT is initialized to a value of 19 and MPUNIT is initialized to a value of 20 in a DATA statement in MODULE MAIN1, and are therefore available to all of the necessary subroutines.

3.8.1.3 Initialization File for Model Re-start

The AERMOD model has an optional capability to store intermediate results to an unformatted (sometimes called binary) file for later re-starting of the model in the event of a power failure or user interrupt. This unformatted file may therefore be used as an input file to initialize the model. This option is controlled by the SAVEFILE (saves intermediate results to a file) and the INITFILE (initialize result arrays from a previously saved file) keywords on the CO pathway.

When initializing the model for the re-start option, the user specifies the name of the unformatted results file on the INITFILE keyword. The default filename used if no parameter is provided is INIT.FIL. The initialization file is explicitly opened by the AERMOD model, and the integer variable, IRSUNT, specifies the unit number for the file. The variable IRSUNT is initialized to a value of 15 in a DATA statement in MODULE MAIN1, and is therefore available to all of the necessary subroutines.

3.8.2 Description of AERMOD Output Files

The AERMOD model produce a variety of output files, including the main print file of model results, an unformatted file of intermediate results for later re-start of the model (AERMOD only), and several output data files for specialized purposes. These files are described in detail below.

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3.8.2.1 Output Print File

The AERMOD model produces a main output print file of model results called AERMOD.OUT. The contents and organization of this file were shown in Figure 2-5. This file includes an echo of the input runstream images at the beginning of the file (up until a NO ECHO input is encountered). A summary of runstream setup messages and a summary of the inputs follow the echo of inputs. The input summary includes a summary of modeling options, source data, receptor data, and meteorological data, following the same order as the pathways in the runstream file. If model calculations are performed, then the model results are summarized next. The content and order of the model result summaries depend on the output options selected and on the particular model being run. Following the detailed model results are summary tables of the high values for each averaging period and source group. The final portion of the main output print file is the summary of messages for the complete model run.

For the PC-executable version of the model available on the SCRAM website, the main print output file is explicitly opened by the model using a Fortran OPEN statement, and the integer variable, IOUNIT, specifies the unit number for the file. The variable IOUNIT is initialized to a value of 8 in a DATA statement in MODULE MAIN1, and is therefore available to all of the necessary subroutines.

By opening the printed output file explicitly, the outputs are not automatically formatted for the printer. This formatting is accomplished using the CARRIAGECONTROL specifier in the OPEN statement for the output file.

3.8.2.2 Detailed Error Message File

The user may select an option for the model to save a separate file of detailed error and other messages, through use of the CO ERRORFIL keyword. The format and syntax of these messages is described in Appendix C. The order of messages within the file is the order in which they were generated by the model. The file includes all types of messages that were generated.

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The error message file is explicitly opened by the model using a Fortran OPEN statement, and the integer variable, IERUNT, specifies the unit number for the file. The variable IERUNT is initialized to a value of 10 in a DATA statement in MODULE MAIN1, and is therefore available to all of the necessary subroutines.

3.8.2.3 Intermediate Results File for Model Re-start.

The AERMOD model has an optional capability to store intermediate results to an unformatted (sometimes called binary) file for later re-starting of the model in the event of a power failure or user interrupt. This unformatted file may therefore be used as an input file to initialize the model. This option is controlled by the SAVEFILE (saves intermediate results to a file) and the INITFILE (initialize result arrays from a previously saved file) keywords on the CO pathway.

When saving the intermediate results for the re-start option, the user specifies the name of the unformatted results file on the SAVEFILE keyword. The user has the option of specifying a single filename, two filenames (for alternate saves), or specifying no filename. The default filename used if no parameter is provided is TMP.FIL. If a single file is used, then the intermediate results file is overwritten on each successive dump, with the chance that the file will be lost if the interrupt occurs during the time that the file is opened. If two filenames are provided, then the model also saves to the second file on alternate dumps, so that the next most recent dump will always be available. The main save file is explicitly opened by the AERMOD model, and the integer variable, IDPUNT, specifies the unit number for the file. The variable IDPUNT is initialized to a value of 12 in a BLOCK DATA subprogram of the model. If a second save file is used, then it is also opened explicitly, and the integer variable IDPUN2, initialized to a value of 14, specifies the unit number.

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3.8.2.4 Maximum Value/Threshold File

The user may select an option for the AERMOD model to generate a file or files of concentration values exceeding a user-specified threshold. The OU MAXIFILE keyword controls this option. The user may select separate files for each averaging period and source group combination for which a list of threshold violations may be needed. Each file includes several records with header information identifying the averaging period, source group and threshold value, and then a record for every occurrence where the result for that averaging period/source group equals or exceeds the threshold value. Each of these records includes the averaging period, source group ID, date for the threshold violation (ending hour of the averaging period), the x, y, z and flagpole receptor height for the receptor location where the violation occurred, and the concentration value.

The structure of the threshold violation file is described in more detail in Appendix D. Each of the files selected by the user is opened explicitly by the model as an formatted file. The filenames are provided on the input runstream image. The user may specify the file unit on the MAXIFILE card through the optional FUNIT parameter. User-specified units must be greater than or equal to 26 and are recommended to be less than or equal to 100. If no file unit is specified, then the file unit is determined internally according to the following formula:

$$IMXUNT = 200 + IGRP*10 + IAVE$$

where IMXUNT is the Fortran unit number, IGRP is the source group number (the order in which the group is defined in the runstream file), and IAVE is the averaging period number (the order of the averaging period as specified on the CO AVERTIME card). This formula will not cause any conflict with other file units used by the model for up to 9 source groups and up to 9 short term averaging periods.

3.8.2.5 Sequential Results File for Postprocessing

The user may select an option for the AERMOD model to generate a file or files of

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concentration values suitable for postprocessing. The OU POSTFILE keyword controls this option. The user may select separate files for each averaging period and source group combination for which postprocessing may be needed. For each file requested, the user has the option of specifying whether to use unformatted files suitable for postprocessing or to use a plot format which could allow for importing the concentration files into a graphics package for plotting. For the unformatted file option, each file consists of sequential unformatted records of values at each receptor location for every averaging period calculated. For the plot file format option, each file consists of formatted records listing the x-coordinate, y-coordinate and concurrent concentration values for each receptor and for all averaging periods calculated. For certain applications, these files may become quite large, and should only be used when needed, especially when using the plot format.

The structure of both types of postprocessing file is described in more detail in Appendix D. Each of the postprocessing files selected by the user is opened explicitly by the model as either an unformatted or a formatted file, depending on the option selected. The filenames are provided on the input runstream image. The user may specify the file unit on the POSTFILE card through the optional FUNIT parameter. User-specified units must be greater than or equal to 20, and are recommended to be less than or equal to 100. If no file unit is specified, then the file unit is determined internally according to the following formulas.

IPSUNT = 200 + IGRP*10 + IAVE for short term averages
IAPUNT = 300 + IGRP*10 + 5 for PERIOD averages

where IPSUNT and IAPUNT are the Fortran unit numbers, IGRP is the source group number (the order in which the group is defined in the runstream file), and IAVE is the averaging period number (the order of the averaging period as specified on the AVERTIME card). This formula will not cause any conflict with other file units used by the model for up to 9 source groups and up to 9 short term averaging periods.

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3.8.2.6 High Value Summary File for Plotting

The user may select an option for the AERMOD model to generate a file or files of the highest concentration values at each receptor suitable for importing into a graphics package in order to generate contour plots. The OU PLOTFILE keyword controls this option. The user may select separate files for each averaging period, source group and high value combination for which a plot file may be needed. Each file includes several records with header information identifying the averaging period, source group and high value number of the results, and then a record for each receptor which contains the x and y coordinates for the receptor location, the appropriate high value at that location, and the averaging period, source group and high value number.

The structure of the plot file is described in more detail in Appendix D. Each of the plot files selected by the user is opened explicitly by the model as an formatted file. The filenames are provided on the input runstream image. The user may specify the file unit on the PLOTFILE card through the optional FUNIT parameter. User specified units must be greater than or equal to 26, and are recommended to be less than or equal to 100. If no file unit is specified, then the file unit is determined internally according to the following formulas:

IPLUNT = (IVAL - 3)*100 + IGRP*10 + IAVE for short term averages
IPPUNT = 300 + IGRP*10 for PERIOD averages

where IPLUNT and IPPUNT are the Fortran unit numbers, IVAL is the high value number (1 for FIRST highest, 2 for SECOND highest, etc.), IGRP is the source group number (the order in which the groups is defined in the runstream file), and IAVE is the averaging period number (the order of the averaging period as specified on the CO AVERTIME card). This formula will not cause any conflict with other file units used by the model for up to 9 source groups and up to 9 short term averaging periods.

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3.8.2.7 TOXX Model Input Files

The user may select an option for the AERMOD model to generate an unformatted file or files of concentration values exceeding a user-specified threshold for use with the TOXX model component of TOXST. The OU TOXXFILE keyword controls this option. The user may select separate files for each averaging period for which a threshold violation file may be needed. Each file includes several records with header information identifying the title, averaging period, threshold value, and receptor network information, and then records including every occurrence where the result of any source group for that averaging period equals or exceeds the threshold value. Records are also output that identify the averaging period (hour number of the year), source group number and receptor number corresponding to the concentration values.

The structure of the threshold exceedance file for use with the TOXX model component of TOXST is described in more detail in Appendix D. Each of the files selected by the user is opened explicitly by the model as an unformatted file. The filenames are provided on the input runstream image. The user may specify the file unit on the TOXXFILE card through the optional Funit parameter. User-specified units must be greater than or equal to 26, and are recommended to be less than or equal to 100. If no file unit is specified, then the file unit is determined internally according to the following formula:

$$ITXUNT = 300 + IAVE$$

where ITXUNT is the Fortran unit number, and IAVE is the averaging period number (the order of the averaging period as specified on the CO AVERTIME card). This formula will not cause any conflict with other file units used by the model for up to 4 short term averaging periods.

The user may also select an option for the AERMOD model to generate an output for use with the RISK model component of TOXST. The OU TOXXFILE keyword also controls this option. The user can specify a separate TOXXFILE for each long term averaging period and source group combination. The TOXXFILE option may also be used for PERIOD averages with

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the AERMOD model. The structure of the TOXXFILE output for AERMOD is very similar to the long term PLOTFILE output, except that results are output for each individual source in the specified source group. The structure of the long term TOXXFILE is described in more detail in Appendix D. Each of the files selected by the user is opened explicitly by the model as a formatted file. The filenames are provided on the input runstream image. The user may specify the file unit on the TOXXFILE card through the optional Furit parameter. User-specified units must be greater than or equal to 26, and are recommended to be less than or equal to 100. If no file unit is specified, then the file unit is determined internally according to the following formulas:

ITXUNT = 500 + IAVE*20 + IGRP for long term averages
IPXUNT = 700 + IGRP*10 for PERIOD averages

where ITXUNT and IPXUNT are the Fortran unit numbers, IAVE is the averaging period number (in the order of months, seasons or quarters, and annual), and IGRP is the source group number (in the order in which the groups are defined in the SO pathway). This formula will not cause any conflict with other file units used by the model for up to 9 source groups.

3.5.3 Control of File Inputs and Outputs (I/O)

3.5.3.1 Control of I/O on PCs.

The main input runstream file and the main output print file are specified internally by AERMOD as AERMOD.INP and AERMOD.OUT, respectively. Therefore, a standard command line to execute the AERMOD model might look something like this:

C:>AERMOD

where the "DOS prompt" has been given as "C:>", but may look different on different systems, or may include a subdirectory specification. The output file generated by the DOS version

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includes page feeds that are written directly to the file as part of the header for each page, rather than using the Fortran carriage control of '1'. This is accomplished by including a compiler-specific parameter to set CARRIAGECONTROL = 'Fortran' on the OPEN statement for the output file.

3.8.1.2 Controlling I/O on Other Computer Systems

Since the main input runstream file and the main output print file are specified internally by AERMOD, control of I/O on other computer systems will be the same, with the possible exception of the compiler-specific option to set CARRIAGECONTROL = 'Fortran' on the OPEN statement for the output file.

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4.0 REFERENCES

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APPENDIX A. ALPHABETICAL KEYWORD REFERENCE

This appendix provides an alphabetical listing of a l of the keywords used by the AERMOD model. Each keyword is identified as to the pathway for which it applies, the keyword type (either mandatory or optional, and either repeatable or non-repeatable), and with a brief description of the function of the keyword. For a more complete description of the keywords, including a list of associated parameters, refer to the Detailed Keyword Reference in Section 3 or the Functional Keyword/Parameter Reference in Appendix B

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Keyword	Path	Type	Keyword Description
AREAVERT	SO	M - R	Specifies location of vertices for an AREAPOLY source type (mandatory if AREAPOLY source is used)
AVERTIME	CO	M - N	Averaging time(s) to process (up to NAVE short term plus PERIOD or ANNUAL averages)
BUILDHGT	SO	O - R	Building height values for each wind sector
BUILDWID	SO	O - R	Building width values for each wind sector
DAYRANGE	ME	O - R	Specifies days or ranges of days to process (default is to process all data read in)
DAYTABLE	OU	O - N	Option to provide summaries for each averaging period for each day processed
DCAYCOEF	CO	O - N	Optional decay coefficient for exponential decay
DEBUGOPT	CO	O - N	Option to generate detailed result and meteorology files for debugging purposes
DISCCART	RE	O - R	Defines the discretely placed receptor locations referenced to a Cartesian system
DISCPOLR	RE	O - R	Defines the discretely placed receptor locations referenced to a polar system
ELEVUNIT	SO RE	O - N O - N	Defines input units for receptor elevations (RE path), or source elevations (SO path) (defaults to meters)
EMISFACT	SO	O - R	Optional input for variable emission rate factors
EMISUNIT	SO	O - N	Optional conversion factors for emission units and concentration units

Type: M - Mandatory N - Non-repeatable
O - Optional R - Repeatable

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Keyword	Path	Type	Keyword Description
ERRORFIL	CO	O - N	Option to generate detailed error listing file (error file is mandatory for CO RUNORNOT NOT case)
EVALCART	RE	O - R	Defines discretely placed receptor locations referenced to a Cartesian system, grouped by arc for use with the EVALFILE output option
EVALFILE	OU	O - R	Option to output file of normalized arc maxima for model evaluation studies
EVENTFIL	CO	O - N	Specifies whether to generate an input file for EVENT model
EVENTLOC	EV	M - R	Describes receptor location for an event
EVENTOUT	OU	M - N	Specifies the level of output information provided by the EVENT model
EVENTPER	EV	M - R	Describes data and averaging period for an event
FINISHED	ALL	M - N	Identifies the end of inputs for a particular pathway
FLAGPOLE	CO	O - N	Specifies whether to accept receptor heights above local terrain (m) for use with flagpole receptors, and allows for a default flagpole height to be specified
GRIDCART	RE	O - R	Defines a Cartesian grid receptor network
GRIDPOLR	RE	O - R	Defines a polar receptor network
HALFLIFE	CO	O - N	Optional half-life used for exponential decay
HOUREMIS	SO	O - R	Option for specifying hourly emission rates in a separate file
INCLUDED	SO, RE	O - R	Option to include input data from a separate file in the runstream for the SO and/or RE pathways
INITFILE	CO	O - N	Option to initialize model from file of intermediate results generated by SAVEFILE option
LOCATION	SO	M - R	Identifies coordinates for particular source location

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Keyword	Path	Type	Keyword Description
MAXFILE	OU	O - R	Option to list events exceeding a threshold value to File (if CO EVENT FILE option is used, these events are included in the input file generated for the EVENT model)
MAXTABLE	OU	O - R	Option to summarize the overall maximum values
MODELOPT	CO	M - N	Job control and dispersion options
MULTYEAR	CO	O - N	Specifies that run is part of a multi-year run, e.g., for PM-10 HiVol in five years
PLOTFILE	OU	O - R	Option to write certain results to a storage file suitable for input to plotting routines
POLLUTID	CO	M - N	Identifies pollutant being modeled
POSTFILE	OU	O - R	Option to write results to a mass storage file for postprocessing
PROFBASE	ME	M - N	Specifies the base elevation (above MSL) for the potential temperature profile
PROFFILE	ME	M - N	Describes input profile meteorological data file
RANKFILE	OU	O - R	Option to produce output file of ranked values for Q-Q plots

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Keyword	Path	Type	Keyword Description
RECTABLE	OU	O - R	Option to output value(s) by receptor
RUNORNOT	CO	M - N	Identifies whether to run model or process setup information only
SAVEFILE	CO	O - N	Option to store intermediate results for later restart of the model after user or system interrupt
SCIMBYHR	ME	O - N	Specifies sampling parameters for the SCIM option
SITEDATA	ME	O - N	Describes on-site meteorological station
SRCGROUP	SO	M - R	Identification of source groups
SRCPARAM	SO	M - R	Identifies source parameters for a particular source
STARTEND	ME	O - N	Specifies start and end dates to be read from input meteorological data file (default is to read entire file)
STARTING	ALL	M - N	Identifies the start of inputs for a particular pathway
SURFDATA	ME	M - N	Surface meteorological station
SURFFILE	ME	M - N	Describes input surface meteorological data file
TITLEONE	CO	M - N	First line of title for output
TITLETWO	CO	O - N	Optional second line of output title
TOXXFILE	OU	O - R	Creates output file formatted for use with TOXX model component of TOXST
UAIRDATA	ME	M - N	Upper air meteorological station
WDROTATE	ME	O - N	Wind direction rotation adjustment
WINDCATS	ME	O - N	Upper bound of wind speed categories

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APPENDIX B. FUNCTIONAL KEYWORD/PARAMETER REFERENCE

This appendix provides a functional reference for the keywords and parameters used by the input runstream files for the AERMOD model. The keywords are organized by functional pathway, and within each pathway the order of the keywords is based on the function of the keyword within the model. The pathways used by the model are as follows, in the order in which they appear in the runstream file and in the tables that follow:

CO - for specifying overall job **CO**ntrol options;
SO - for specifying **SO**urce information;
RE - for specifying **RE**ceptor information;
ME - for specifying **ME**teorology information and options;
EV - for specifying **EV**ent information and options;
OU - for specifying **OU**tput options.

The pathways and keywords are presented in the same order as in the Detailed Keyword Reference in Section 5, and in the Quick Reference at the end of the manual.

Two types of tables are provided for each pathway. The first table lists all of the keywords for that pathway, identifies each keyword as to its type (either mandatory or optional and either repeatable or non-repeatable), and provides a brief description of the function of the keyword. The second type of table, which takes up more than one page for most pathways, presents the parameters for each keyword, in the order in which they should appear in the runstream file where order is important, and describes each parameter in detail.

The following convention is used for identifying the different types of input parameters. Parameters corresponding to secondary keywords which should be input "as is" are listed on the tables with all capital letters and are underlined. Other parameter names are given with an initial capital letter and are not input "as is." In all cases, the parameter names are intended to be descriptive of the input variable being represented, and they often correspond to the Fortran variable names used in the model code. Parentheses around a parameter indicate that the parameter is optional for that keyword. The default that is taken when an optional parameter is left blank is explained in the discussion for that parameter.

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TABLE B-1
DESCRIPTION OF CONTROL PATHWAY KEYWORDS

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TABLE B-2

DESCRIPTION OF CONTROL PATHWAY KEYWORDS AND PARAMETERS

AR0068755

TABLE B-2 (CONT.)

DESCRIPTION OF CONTROL PATHWAY KEYWORDS AND PARAMETERS

AR0068756

TABLE B-2 (CONT.)

DESCRIPTION OF CONTROL PATHWAY KEYWORDS AND PARAMETERS

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TABLE B-3

DESCRIPTION OF SOURCE PATHWAY KEYWORDS

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TABLE B-1

DESCRIPTION OF SOURCE PATHWAY KEYWORDS AND PARAMETERS

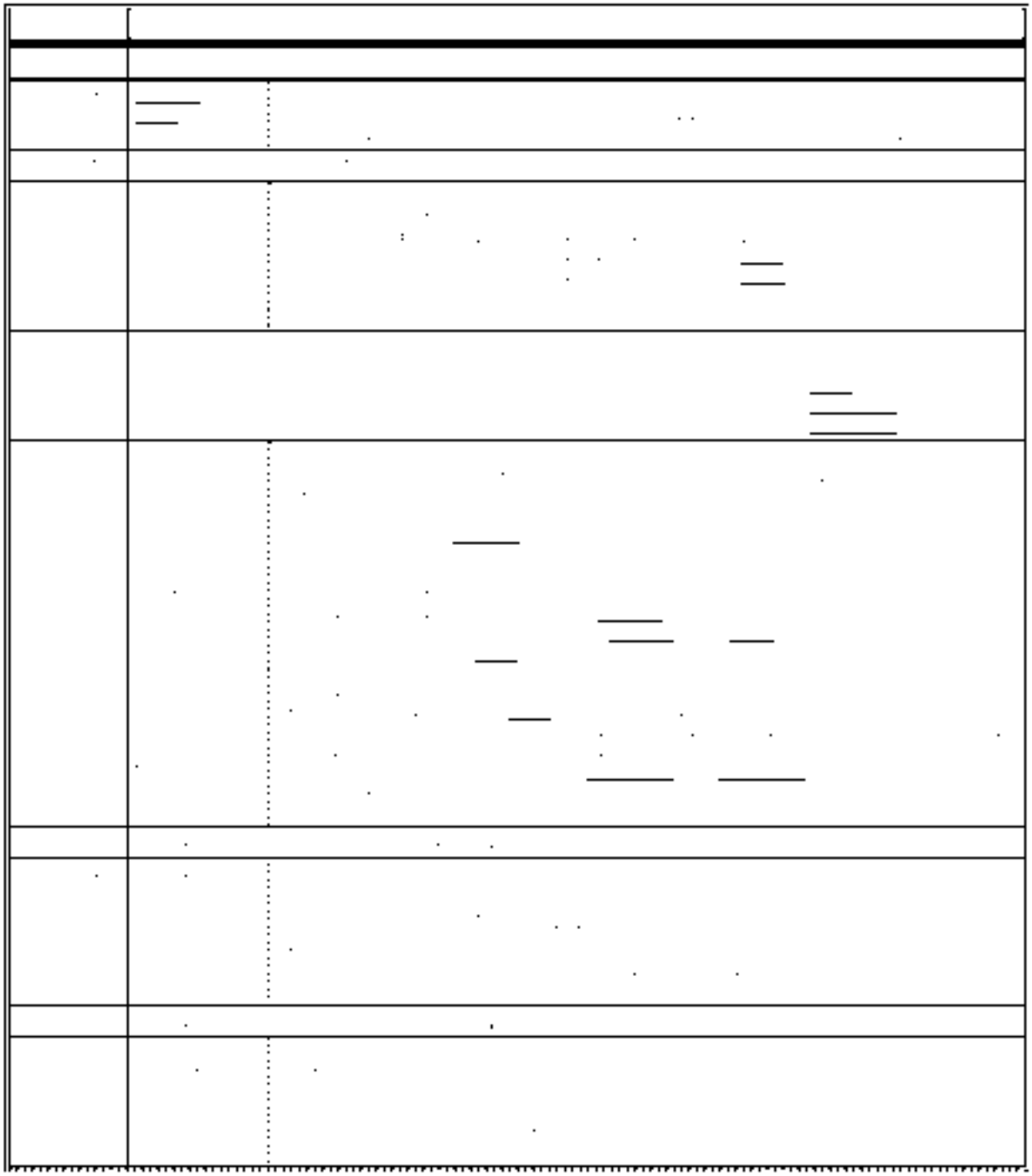

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TABLE B-3 (CONT.)
DESCRIPTION OF SOURCE PATHWAY KEYWORDS AND PARAMETERS

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TABLE B-3 (CONT'D)

DESCRIPTION OF SOURCE PATHWAY KEYWORDS AND PARAMETERS

AR0068761

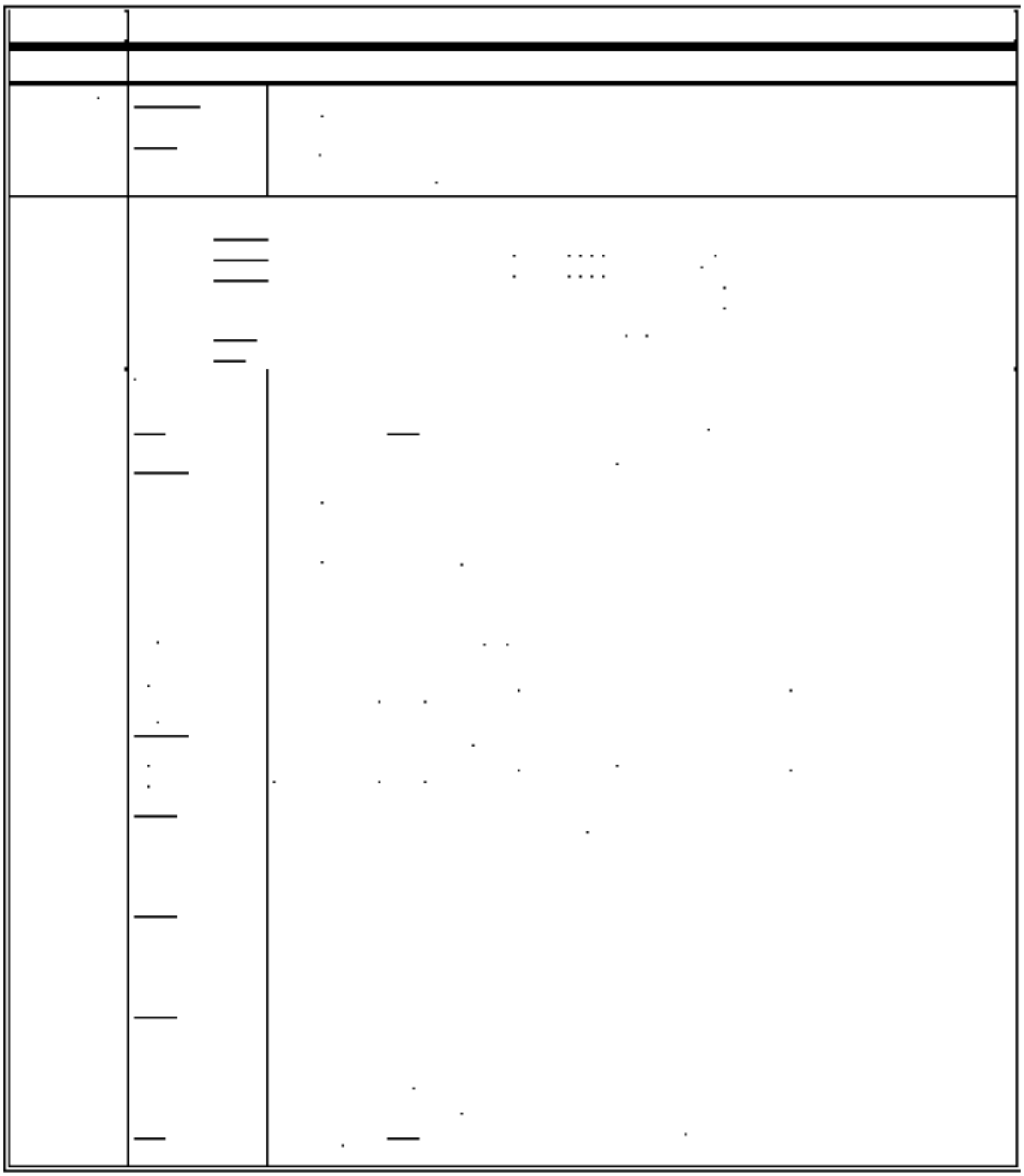
TABLE B-5

DESCRIPTION OF RECEPTOR PATHWAY KEYWORDS

AR0068762

TABLE B-6

DESCRIPTION OF RECEPTOR PATHWAY KEYWORDS AND PARAMETERS



AR0068763

TABLE B-6 (CONT)

DESCRIPTION OF RECEPTOR PATHWAY KEYWORDS AND PARAMETERS

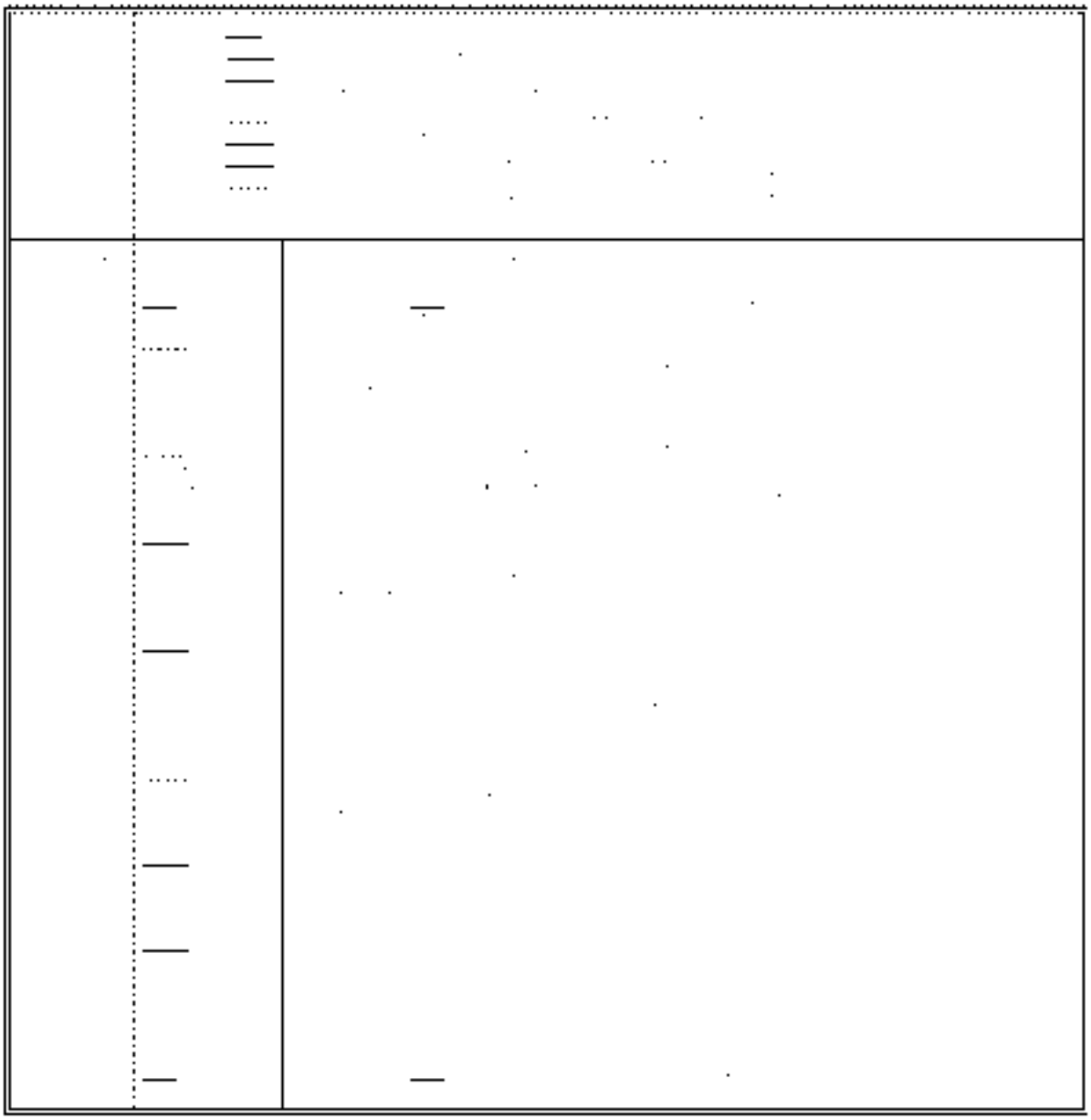


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TABLE B-6 (CONT)

DESCRIPTION OF RECEPTOR PATHWAY KEYWORDS AND PARAMETERS

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TABLE B-7

DESCRIPTION OF METEOROLOGY PATHWAY KEYWORDS

AR0068766

TABLE B-8

DESCRIPTION OF METEOROLOGY PATHWAY KEYWORDS AND PARAMETERS

AR0068767

TABLE B-8 (CONT'D)

DESCRIPTION OF METEOROLOGY PATHWAY KEYWORDS AND PARAMETERS

AR0068768

TABLE B-9

DESCRIPTION OF EVENT PATHWAY KEYWORDS

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

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TABLE B-10

DESCRIPTION OF EVENT PATHWAY KEYWORDS AND PARAMETERS

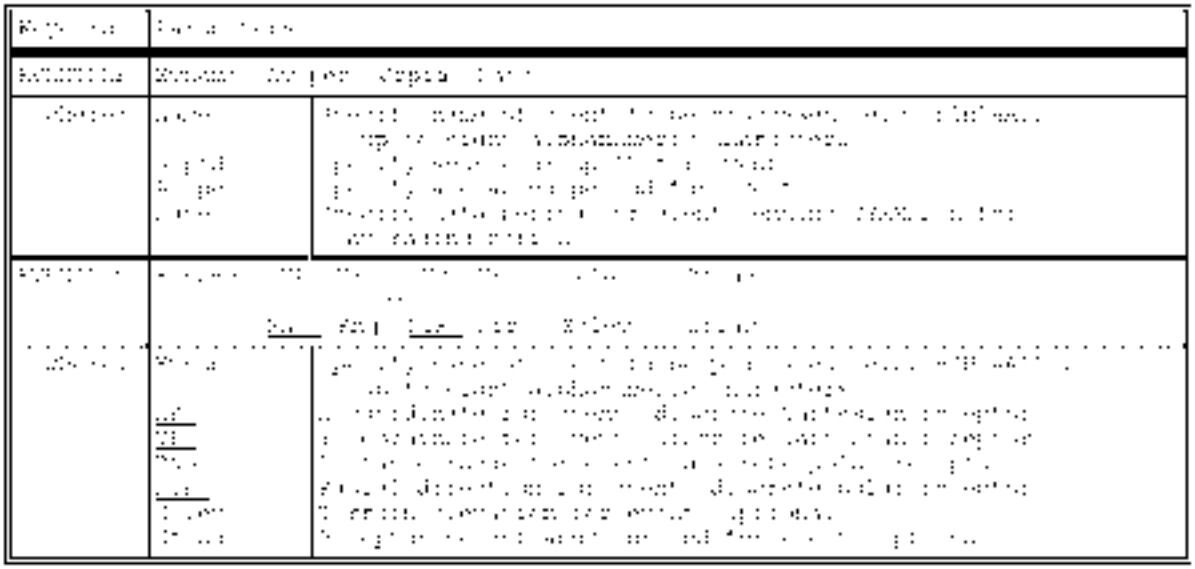

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TABLE B-11

DESCRIPTION OF OUTPUT PATHWAY KEYWORDS

AR0068771

TABLE B-12

DESCRIPTION OF OUTPUT PATHWAY KEYWORDS AND PARAMETERS

AR0068772

TABLE B-12 (CONT.)

DESCRIPTION OF OUTPUT PATHWAY KEYWORDS AND PARAMETERS

AR0068773

APPENDIX C EXPLANATION OF ERROR MESSAGE CODES

C.1 INTRODUCTION

The AERMOD input runstream is checked to identify parameters that are missing or potentially in error, and the input source and meteorological data are checked and flagged for possible erroneous values.

The AERMOD model uses a "defensive programming" approach to eliminate as much as possible of the user's work in debugging the input runstream file. Also, a great deal of effort has been made to eliminate the possibility of run time errors, such as "divide by zero," and to point out questionable input data. Error messages are reported to the user in two ways. A summary of messages is provided in the main output result file, and the user can also request a detailed message listing file.

Message Summary. Whether the user selects a detailed error listing file or not, the AERMOD model output a summary of messages within the output result file. This message table gives the number of messages of each type, together with a detailed list of all the fatal errors and warning messages. During setup processing, if no errors or warnings are generated, then the model simply reports to the user that "SETUP Finishes Successfully."

Detailed Message Listing File. The AERMOD model provide the option of saving a detailed list of all messages generated by the model to a separate output file. The user can select this option by specifying the keyword "ERRORFIL" followed by a filename inside the CONTROL pathway. For example, the following statements will save all the error messages to an ASCII text file named "errormsg.out":

```
CO STARTING
   ERRORFIL  errormsg.out
CO FINISHED
```


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C.2 THE OUTPUT MESSAGE SUMMARY

There are two message summaries provided in the standard output file of the AFRMOD model. The first one is located after the echo of input upstream file images and before the input data summary. This summary will take one of two forms, depending on whether any fatal error or non-fatal warning messages were generated, and also depending on whether the option to RUN or NOT to run was selected on the CO RUNORNOT card. If there are no errors or warnings generated during the setup processing, and the RUN option was selected, then the model simply reports that "SETUP Finishes Successfully." If any fatal errors or warning messages were generated during the setup processing, or if the option NOT to run was selected, then a more detailed summary is provided. This summary provides a message count for each type of message, and a detailed listing of each fatal error and warning message generated. The second message summary table is located at the very end of the standard output result file, and it sums up the messages generated by the complete model run - both setup processing and run-time processing.

An example of a setup processing message summary is shown in Figure C-1

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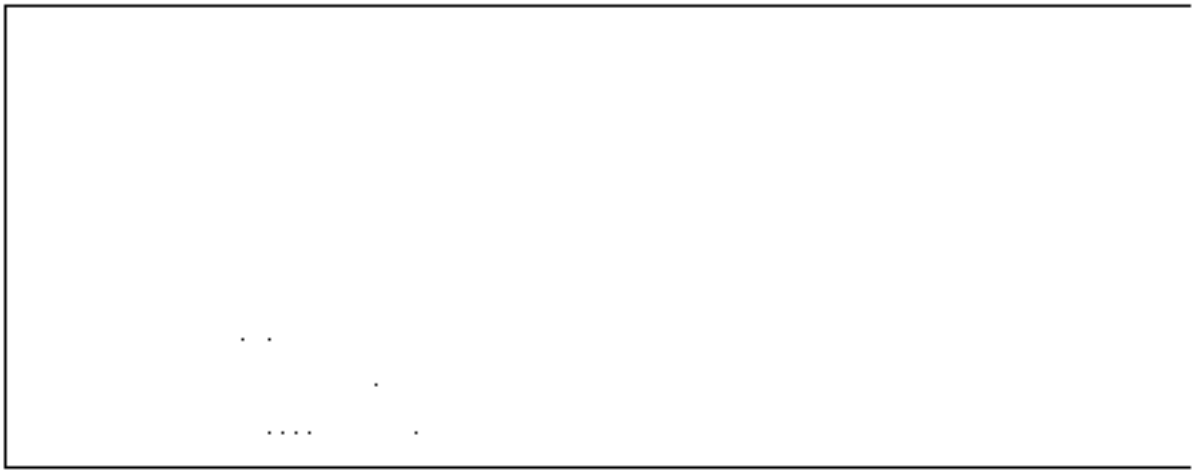

FIGURE C-1. EXAMPLE OF AN AERMOD MESSAGE SUMMARY

C.3 DESCRIPTION OF THE MESSAGE LAYOUT

Three types of messages can be produced by the model during the processing of input runstream images and during model calculations. These are described briefly below:

- Errors that will halt any further processing, except to identify additional error conditions (type E);
- Warnings that do not halt processing but indicate possible errors or suspect conditions (type W); and
- Informational messages that may be of interest to the user but have no direct bearing on the validity of the results (type I).

The messages have a consistent structure which contains the pathway ID, indicating which pathway the messages are generated from; the message type followed by a three-digit message number; the line number of the input runstream image file for setup messages (or the meteorology hour number for runtime messages); the name of the module (e.g. the subroutine name) from which the message is generated; a detailed message corresponding to the message code; and an 8-character simple hint to help the user spot the possible source of the problem.

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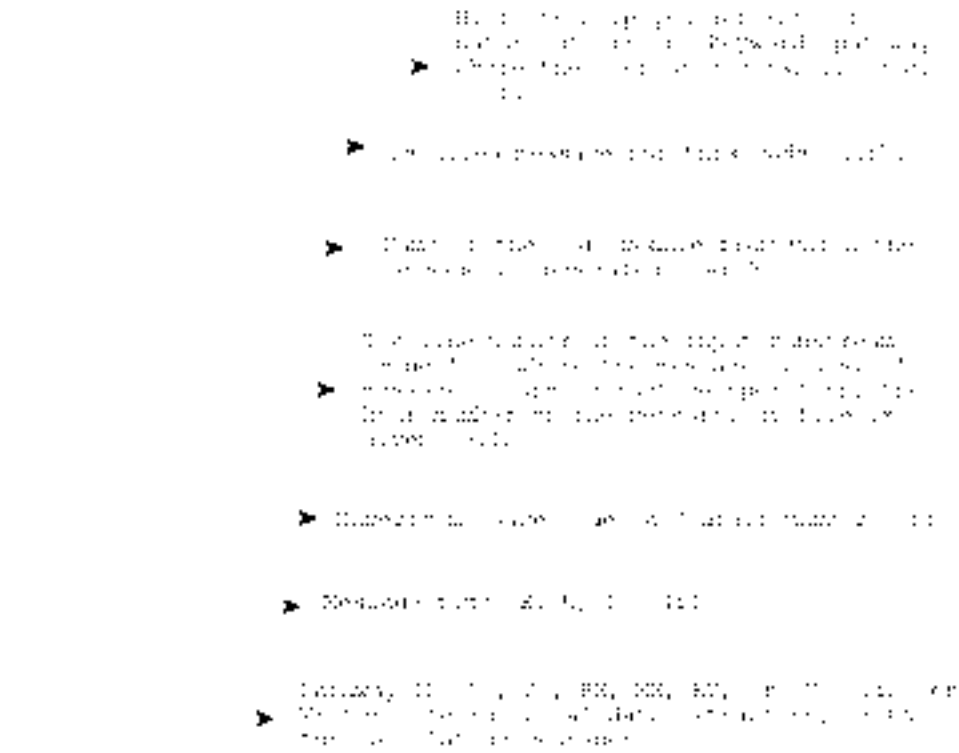
The following is an example of a detailed message generated from the CO pathway

```
:
```

The message syntax is explained in more detail below (values in parentheses give the column numbers within the message line for each element)

```
FW
```



If an error occurs during processing of an included file (either SO INCLUDED or RE INCLUDED), the line number will represent the line number of the included file. The line number of the runstream file is saved before processing the included data, and then restored when processing returns to the main runstream file.

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The three message types are identified with the letters F (for errors), W (for warnings), and I (for informational messages). The 3-digit message codes are grouped into general categories corresponding to the different stages of the processing. These categories are

100 - 199 Input Runstream Image Structure Processing
200 - 299 Parameter Setup Processing
300 - 399 Data and Quality Assurance Processing
400 - 499 Run Time Message Processing
500 - 599 Input/Output Message Processing

A detailed description of each of the message codes currently used in the model is provided in the next section

C.4 DETAILED DESCRIPTION OF THE ERROR/MESSAGE CODES

INPUT RUNSTREAM IMAGE STRUCTURE PROCESSING, 100-199

This type of message indicates problems with the basic syntax and/or structure of the input runstream image. Typical messages include errors like "Missing mandatory keyword" "Illegal Keyword", , etc. If a fatal error of this kind is detected in a runstream image, a fatal error message is written to the message file and any attempt to process data is prohibited, although the remainder of the runstream file is examined for other possible errors. If a warning occurs, data may still be processed, although the inputs should be checked carefully to be sure that the condition causing the warning does not indicate an error.

100 **Invalid Pathway Specified.** The pathway ID should be a 2 character string. It should be one of the following: CO for control pathway, SO for source pathway, RE for receptor pathway (or EV for event pathway for EVENT processing), ME for meteorology data setting pathway, and OU for output format pathway. Its position is normally confined to columns 1 and 2 (1:2) of the input runstream file. However, the model does allow for a shift of the entire input runstream file of up to 3 columns. If the inputs are shifted, then all input records must be shifted by the same amount. The invalid pathway is repeated at the end of the message

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105 Invalid Keyword Specified. The keyword ID should be an 8 character string. Its position is normally confined to columns 4 to 11 (4-11) of the input runstream file. However, the model does allow for a shift of the entire input runstream file of up to 3 columns. If the inputs are shifted, then all input records must be shifted by the same amount. There should be a space between keyword ID and any other data fields. For a list of valid keywords, refer to Appendix A or Appendix B. The invalid keyword is repeated at the end of the message.

110 Keyword is Not Valid for This Pathway. The input keyword is a valid 8-character string, but it is not valid for the particular pathway. Refer to Appendix A, Appendix B or Section 3 for the correct usage of the keyword. The invalid keyword is repeated at the end of the message.

115 Starting and Finishing Statements do not match. Only One STARTING and one FINISHED statement, respectively, is allowed at the very beginning and the very end of each pathway block. Check the position and frequency to make sure the input runstream file meets the format requirement. The pathway during which the error occurs is included at the end of the message.

120 Pathway is Out of Sequence. The pathways are not input in the correct order. The correct order is CO, SO, RE, ME, and OU for the AERMOD and AERMOD model and CO, SO, ME, EV, and OU for EVENT processing. The offending pathway is given as a hint.

125 Missing FINISHED Statement - Runstream file is incomplete. One or more FINISHED statements are missing. A 5-digit status variable is given as a hint. Each digit corresponds to a pathway in the appropriate order, and is a '1' if the pathway is complete and a '0' if the FINISHED is missing. For example, a status of '10111' indicates that the SO pathway was missing a FINISHED statement. Normally such an error will generate additional messages as well.

130 Missing Mandatory Keyword. To run the model, certain mandatory keywords must present in the input runstream file. For a list of mandatory keywords, see Appendix A or Appendix B. For more detailed information on keyword setup, see the description of message code 105. The missing keyword is included with the message.

135 Duplicate Non-repeatable Keyword Encountered. More than one instance of a non-repeatable keyword is encountered. For a list of non-repeatable keywords, see Appendix A or Appendix B. The repeated keyword is included with the message.

140 Invalid Placement of Keyword. A keyword has been placed out of the acceptable order, or a STARTING or FINISHED keyword has been placed in an INCLUDED file. The order for most keywords is not critical, but the relative order of a few keywords is important for the proper interpretation of the input data. The keyword reference in Section 3 identifies any requirements for the order of keywords. The keyword that was improperly placed is included with the message.

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145 Conflicting Options: MULTYEAR and Re Start Option. The multiple year option for processing PM-10 values makes use of the re-start routines in the model with some slight changes to handle the period averages from year to year. As a result, the MULTYEAR keyword cannot be specified with either the SAVEFILE or INITFILE keywords.

150 Conflicting Options: MULTYEAR for Wrong Pollutant. The multiple year option is provided specifically for the processing of PM-10 values to obtain the "high-sixth-high in five years" design value. Its treatment of the high short term values for multiple year periods is not consistent with existing air quality standards for other pollutants. To use the MULTYEAR option, the user must specify a pollutant type (on the CO POLLUTID card) of PM-10, PM10, or OTHER.

152 ELEVUNIT card must be first for this pathway. The ELEVUNIT card must be the first non-commented card after STARTING when used on the SO or RE pathway. This requirement is made in order to simplify reviewing upstream files to determine the elevation units used for sources and receptors.

154 Conflicting Options: SCIM option cannot be used with the specified option: causing a fatal error.

155 Conflicting Decay Keyword. The ISCMOD model allows for the user to specify the rate of exponential decay either in terms of the half-life (HALFLIFE keyword) or the decay coefficient (DCAYCOEF keyword). If both keywords are specified, then only the first one will be used, and inputs for the second one will be ignored.

156 Option ignored - not valid with SCIM. The specified option is not valid with the SCIM option and is ignored. This is not a fatal error.

157 Wet SCIM option is not operational yet and the input is ignored. Since the model does not include wet deposition algorithms yet, the wet SCIM option is not operational.

158 Wet SCIM option is not operational yet and the input is ignored. Since the model does not include wet deposition algorithms yet, the wet SCIM option is not operational.

160 Duplicate ORIG Secondary Keyword for GRIDPOLR. Only one origin card may be specified for each grid of polar receptors. The network ID for the effected grid is included with the message.

170 Invalid Secondary Key for Receptor GRID. The network ID for the effected grid is included with this message. Refer to Appendix B for the correct syntax of secondary keywords.

175 Missing Secondary Keyword END for Receptor Grid. The END secondary keyword is required for each grid of receptors input by the user (keywords GRIDCART and

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GRIDPOLAR). It signals the end of inputs and triggers the processing of data for that particular network.

180 Conflicting Secondary Keyword for Receptor Grid. Two incompatible secondary keywords have been input for the same grid of receptors, e.g. GDDR and DDDR for the keyword GRIDPOLAR, where GDDR specifies to generate directions with uniform spacing, and DDDR specifies that discrete non-uniform directions are being specified.

185 Missing Receptor Keywords - No Receptors Specified. Since none of the RE pathway keywords are mandatory, a separate error check is made to determine if any of the RE keywords are specified. At least one of the following keywords must be present: GRIDCART, GRIDPOLR, DISCCART, DISCPOLR, or EVALCART.

190 No Keywords for OU Pathway and No PERIOD or ANNUAL Averages. All of the OU pathway keywords are optional, and in fact the model will run if no keywords are specified on the OU pathway as long as PERIOD or ANNUAL averages are being calculated. However, if there are no OU keywords and no PERIOD or ANNUAL averages, then there will be no output generated by the model, and this fatal error message will be generated.

195 Incompatible Option Used With SAVEFILE or INITFILE. Either a non-fatal message to warn the user that DAYTABLE results will be overwritten if the model run is re-started, or a fatal error message generated if the TOXXFILE option is selected with either the SAVEFILE or INITFILE options.

197 Post-1997 PM_{10} processing option without the MAXIFILE option is incompatible with the EVENTFIL option. Threshold violations generated through the MAXIFILE option are the only events that are compatible with post-1997 PM_{10} processing for EVENT processing.

198 The non-default TOXICS option is required in order to use the specified option, such as the SCIM option.

PARAMETER SETUP PROCESSING, 200-299

This type of message indicates problems with processing of the parameter fields for the runstream images. Some messages are specific to certain keywords, while others indicate general problems, such as an invalid numeric data field. If a fatal error of this kind is detected in a runstream image, a fatal error message is written to the message file and any attempt to process data is prohibited, although the remainder of the runstream file is examined for other

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possible errors. If a warning occurs, data may still be processed, although the inputs should be checked carefully to be sure that the condition causing the warning does not indicate an error.

200 Missing Parameter(s). No options were selected for the indicated keyword. Check Appendix B for the list of parameters for the keyword in question.

201 Not Enough Parameters Specified For The Keyword. Check if there are any missing parameters following the indicated keyword. See Appendix B for the required keyword parameters.

202 Too Many Parameters Specified For The Keyword. Refer to Appendix B or Section 3 for the list of acceptable parameters.

203 Invalid Parameter Specified. The inputs for a particular parameter are not valid for some reason. Refer to Appendix B or Section 3. The invalid parameter is included with the message.

204 Option Parameters Conflict. Forced by Default to. Some parameters under the indicated keyword conflict with the other model parameters setting. Refer to Appendix B or Section 3 for the correct parameter usage. The default setting is specified with the message.

205 No Option Parameter Setting. Forced by Default to. No setting was specified for a particular parameter. Refer to Appendix B or Section 3 for the correct parameter usage. The default setting is specified with the message.

206 Regulatory DEAULT Specified With Non-default Option. The DEAULT option on the CO MODELOPT card always overrides the specified non-default option, and a warning message is generated.

207 No Parameters Specified. Default Values Used For. The keyword for which no parameters are specified is included with the message. Refer to Appendix B or Section 3 for a discussion of the default condition.

208 Illegal Numerical Field Encountered. The model may have encountered a non-numerical character for a numerical input, or the numerical value may exceed the limit on the size of the exponent, which could potentially cause an underflow or an overflow error.

209 Negative Value Appears For A Non-negative Variable. The effected variable name is provided with the message.

210 Number of Short Term Averages Exceeds Maximum. The user has specified more short term averages on the CO AVERTIM card than the model array limits allow.

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This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NAVE variable. While the model still performs this test, this message should never occur.

211 Duplicate Parameter(s) Specified for Keyword. A duplicate parameter or set of parameters has been specified for the indicated keyword. For example, if more than one POSTFILE keyword is included for the same averaging period and source group then this error message will be generated.

212 END Encountered Without (X,Y) Points Properly Set. This error occurs during setting up the grid of receptors for a Cartesian Network. This message may occur for example if X-coordinate points have been specified without any Y-coordinate points for a particular network ID.

213 ELEV Inputs Inconsistent With Option. Input Ignored. This happens when the user inputs elevated terrain heights for receptors when the FLAT option is specified. The input terrain heights are ignored and the model proceeds with FLAT terrain modeling.

214 ELEV Inputs Inconsistent With Option. Defaults Used. This happens when the user does not input elevated terrain heights for receptors when the default option of incorporating elevated terrain effects is used. The model assumes that the missing terrain heights are at 0.0 meters for those receptors and proceeds with ELEV terrain modeling.

215 FLAG Inputs Inconsistent With Option. Input Ignored. This happens when the user inputs receptor heights above ground for flagpole receptors when the FLAGPOLE keyword option has not been specified. The input flagpole heights are ignored in the model calculations.

216 FLAG Inputs Inconsistent With Option. Defaults Used. This happens when the user does not input receptor heights above ground for flagpole receptors when the FLAGPOLE keyword option has been specified. The model assumes that the missing flagpole heights are equal to the default value specified on the CO FLAGPOLE card. If no default height is specified on the FLAGPOLE card, then a default of 0.0 meters is assumed.

217 More Than One Delimiter In A Field. For example, 12-34 is an illegal input data item for the DAYRANGE card, and STACK1--STACK20 is an illegal specification for a range of sources.

218 Number of (X,Y) Points Not Match With Number Of ELEV Or FLAG. Check the number of elevated terrain heights or flagpole receptor heights for the gridded network associated with the indicated line number in the runstream file.

219 Number Of Receptors Specified Exceeds Maximum. The user has specified more receptors on the RE pathway than the model array limits allow. This array limit is

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dynamically allocated at model runtime based on model inputs, and is stored in the NREC variable. While the model still performs this test, this message should never occur.

220 Missing Origin (Use Default = 0,0) In GRIDPOLR. This is a non-fatal warning message to indicate that the ORIG secondary keyword has not been specified for a particular grid of polar receptors. The model will assume a default origin of (X=0, Y=0).

221 Missing Distance Setting In Polar Network. No distances have been provided (secondary keyword DIST) for the specified grid of polar receptors.

222 Missing Degree Or Distance Setting In Polar Network. Missing a secondary keyword for the specified grid of polar receptors.

223 Missing Distance or Degree Field. No data fields have been specified for the indicated secondary keyword.

224 Number of Receptor Networks Exceeds Maximum. The user has specified more receptor networks of gridded receptors on the RE pathway than the model array limits allow. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NNET variable. While the model still performs this test, this message should never occur.

225 Number of X-Coords Specified Exceeds Maximum. The user has specified more X-coordinate values for a particular grid of receptors than the model array limits allow. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the IXM variable. While the model still performs this test, this message should never occur.

226 Number of Y-Coords Specified Exceeds Maximum. The user has specified more Y-coordinate values for a particular grid of receptors than the model array limits allow. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the IYM variable. While the model still performs this test, this message should never occur.

227 No Receptors Were Defined on the RE Pathway. Either through lack of inputs or through errors on the inputs, no receptors have been defined.

228 Default(s) Used for Missing Parameters on Keyword. Either an elevated terrain height or a flagpole receptor height or both are missing for a discrete receptor location. Default value(s) will be used for the missing parameter(s).

229 Too Many Parameters - Inputs Ignored on Keyword. Either an elevated terrain height or a flagpole receptor height or both are provided when the corresponding option has not been specified. The unneeded inputs are ignored.

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231 Too Many Numerical Values Specified - Too many values have been specified for the type of input indicated

232 Number Of Specified Sources Exceeds Maximum - The user has specified more sources than the model array limits allow. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NSRC variable. While the model still performs this test, this message should never occur

233 Building Dimensions Specified for a Non-POINT Source - Building dimensions can only be specified for a POINT source, since the VOLUME and AREA source algorithms do not include building downwash

234 Too Many Sectors Input - For example, the user may have input too many building heights or widths for a particular source

235 Number of Source Groups Specified Exceeds Maximum - The user has specified more source groups than the model array limits allow. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NGRP variable. While the model still performs this test, this message should never occur

236 Not Enough BUILDHGTs Specified for a Source ID - There should be 36 building heights

237 Not Enough BUILDWIDs Specified for a Source ID. There should be 36 building widths.

239 Not Enough QFACTs Specified for a Source ID - The number of variable emission rate factors specified for a particular source is less than the model expects based on the variable emission rate flag. Check the EMISFACT keyword on the SO pathway in Appendix B of Section 3 for the appropriate number.

241 Not Enough BUILDLENs Specified for a Source ID - There should be 36 building lengths specified

246 Not Enough XBADJs Specified for a Source ID. There should be 36 along-flow distances from the stack to the center of the upwind face of building specified

247 Not Enough YBADJs Specified for a Source ID - There should be 36 across-flow distances from the stack to the center of the upwind face of building specified

248 No Sources Were Defined on the SO Pathway - There must be at least one LOCATION card and one SRCPARAM card to define at least one source on the SO pathway. Either no cards were input or there were errors on the inputs

250 Duplicate XPNTDIST or YPNTDIR Specified for GRID - One of the grid inputs, either an X-coordinate, Y-coordinate, polar distance range or polar direction, has been

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specified more than once for the same grid of receptors. This generates a non-fatal warning message.

252 Duplicate Receptor Network ID Specified. A network ID for a grid of receptors (GRIDCART or GRIDPOLR keyword) has been used for more that one network.

254 Number of Receptor Arcs Exceeds Maximum. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NARC variable. While the model still performs this test, this message should never occur.

256 EVALFILE Option Used Without EVALCART Receptors. The EVALFILE output option provides model results designed for model evaluation purposes based on receptors grouped by arc. Such receptors must be identified using the EVALCART keyword. If EVALFILE is selected without any EVALCART receptors, this fatal error message will be generated.

260 Number of Emission Factors Exceeds Maximum. The user has selected an option for variable emission rate factors that exceeds the array storage limit for emission rate factors. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NQF variable. While the model still performs this test, this message should never occur.

262 First Vertex Does Not Match LOCATION for AREAPOLY Source. The coordinates of the first vertex defined for an AREAPOLY source must match the source location coordinates provided on the SO LOCATION card.

264 Too Many Vertices Specified for an AREAPOLY Source. The number of vertices specified on the AREAVERT cards must match the number given on the SRCPARAM card for that source.

265 Not Enough Vertices Specified for an AREAPOLY Source. The number of vertices specified on the AREAVERT cards must match the number given on the SRCPARAM card for that source.

270 Number of High Values Specified Exceeds Maximum. The user has selected a high short term value on the OU RECTABLE card that exceeds the array storage limit for high values by receptor. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NVAL variable. While the model still performs this test, this message should never occur.

280 Number of Maximum Values Specified Exceeds Maximum. The user has selected a value for the number of overall maximum values on the OU MAXTABLE card that exceeds the array storage limit for overall maximum values. This array limit is dynamically allocated at model runtime based on model inputs, and is stored in the NMAX variable. While the model still performs this test, this message should never occur.

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294 PERIOD and ANNUAL averages are both selected on the AVERTIME card. The user can only specify one long-term averaging option, either PERIOD or ANNUAL average.

295 Invalid Averaging Period Specified for the SCREEN Mode. The SCREEN mode of AERMOD can only be used with 1-hour averages

298 Error Allocating Storage for Setup Arrays. An error occurred while allocating storage for the setup arrays, indicating that there is insufficient memory available on the computer for the model to run. Try closing other applications and/or reducing the size of the run. An estimate of memory requirements is provided on the first page of the output file

299 Error Allocating Storage for Result Arrays. An error occurred while allocating storage for the result arrays, indicating that there is insufficient memory available on the computer for the model to run. Try closing other applications and/or reducing the size of the run. An estimate of memory requirements is provided on the first page of the output file

SETUP DATA AND QUALITY ASSURANCE PROCESSING, 300-399

This type of message indicates problems with the actual values of the parameter data on the input runstream image. The basic structure and syntax of the input card is correct, but one or more of the inputs is invalid or suspicious. These messages include quality assurance checks on various model inputs. Typical messages will tell the consistency of parameters and data for the setup and run of the model. If a fatal error of this kind is detected in a runstream image, a fatal error message is written to the message file and any attempt to process data is prohibited. If a warning occurs, data may or may not be processed, depending on the processing requirements specified within the run stream input data.

300 Specified Source ID Has Not Been Defined Yet. The message indicates that the user attempts to use a source ID on a keyword before defining this source ID on a SO LOCATION card. It could indicate an error in specifying the source ID, an omission of a LOCATION card, or an error in the order of inputs

310 Attempt to Define Duplicate LOCATION Card for Source. There can be only one LOCATION card for each source ID specified. The source ID is included with the message

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313 Attempt to Define Duplicate EVENTPER Card for the specified EVENT. There can be only one EVENTPER card for each EVENT specified. The EVENT name is included with the message.

315 Attempt to Define Duplicate SRCPARAM Card for Source. There can be only one SRCPARAM card for each source ID specified. The source ID is included with the message.

319 No Sources Included in the Specified Source Group. This is a non-fatal warning message indicating that a source group has been defined that does not include any sources. The source group ID is provided.

320 Source Parameter May Be Out-of-Range for Parameter. The value of one of the source parameters may be either too large or too small. The name of the parameter is provided with the message. Use the line number provided to locate the card in question.

325 Negative Exit Velocity (Set 1.0E-5) for Source ID. The exit velocity for the specified source ID was input as a negative value. Since the model currently cannot handle sources with downward momentum, the exit velocity is set to a very small value (1.0E-5 m/s) and modeling proceeds. This non-fatal message is generated to warn the user that the input may be in error.

330 Mass Fraction Parameters Do Not Sum to 1.0 (within +/- 2 percent) for a particular source.

332 Mass Fraction Parameter Out-of-Range for a particular source. Must be between 0.0 and 1.0, inclusive.

334 Particle Density Out-of-Range for a particular source. Must be greater than 0.0.

340 Possible error in the PROFBASE input. The value input as the base elevation (above MSL) for the potential temperature file is less than zero.

342 Source ID Mismatch in the Hourly Emissions File. The source ID read from the hourly emissions file does not match what is expected based on the SO HOURFMS card. A source ID and/or date may be out of order or missing in the hourly emissions file. The source ID read from the file is provided with the error message.

344 Hourly Emission Rate is Zero. The emission rate read from the hourly emission file is zero for the specified date. This is written as an informational message, and does not halt processing of the data.

350 Julian Day Out Of Range. This error occurs if the Julian Day selected is less than zero or greater than 366. Check ME setups to ensure the Julian Day selection.

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352 Missing Field on MULTYEAR Card for Pre-1997 PM10. When using the MULTYEAR card for pre-1997 PM10 processing, the keyword 'HIGH' must be specified.

353 MULTYEAR Card for PM10 Processing Applies Only for Pre-1997 Applications. Use High-Fourth-High for Post-1997 PM10 Processing.

354 High-Fourth-High Only Required for Post-1997 PM10 Processing with the RFCTABLE Card.

360 2-digit Year Specified. Valid for the range 1950-2049. Four-digit years are valid for the entire range of Gregorian dates, but two digit years are accepted.

363 24-Hr and ANNUAL Averages Only are Allowed for Post-1997 PM10 Processing on the AVERTIME Card.

365 Year Input is Greater than 2147. A four-digit year greater than 2147 has been input to the model, which will cause an integer overflow.

370 Invalid Date, 2/29 for a Non-Leap Year. The year has been identified as a non-leap year, and a date of 2/29 (February 29) has been specified on the DAYRANGE card. Check the year and/or the date specification.

380 This Input Variable is Out-of-Range. The indicated value may be too large or too small. Use the line number to locate the card in question, and check the variable for a possible error.

381 Latitude in the Surface File is Not Valid. The latitude is read from the header record of the surface/scalar meteorological data file. If the value is not within the valid range of 0 to 90 degrees, then this error message is generated.

382 Error Decoding Latitude in the Surface File. The latitude is read from the header record of the surface/scalar meteorological data file. An error occurred trying to decode the latitude indicating a potential problem with the surface file.

385 Averaging period does not equal 1-hour averages for the TOXXFILE option for the AERMOD model. The AERMOD model will generate TOXXFILE outputs for other averaging periods, but the TOXX model component of TOXST currently supports only the 1-hour averages. This is a non-fatal warning message.

390 Averaging period specified on the EVENTPER card for EVENT processing must be less than or equal to 24.

391 Aspect ratio (length/width) of an area source is greater than 20. The area source algorithm in the AERMOD model allows for specifying area sources as elongated rectangles, however, if the aspect ratio exceeds 10 a warning message will be printed.

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eat. The user should subdivide the area so that each subarea has an aspect ratio of less than 10.

392 Error Decoding Latitude. The latitude is read from the header record of the surface/scalar meteorological data file. The value of the latitude should be followed by an 'N' or an 'S' for the northern or southern hemispheres. If the value cannot be decoded properly, then this error message is generated.

395 Met Data Error: Incompatible Version of AERMET. Based on the version date given in the header record of the surface meteorological data file, the meteorological data were generated by an older, incompatible version of AERMET.

396 Met Data Generated by Older Version of AERMET. Based on the version date given in the header record of the surface meteorological data file, the meteorological data were generated by an older version of AERMET. The data may be compatible with the current version of AERMOD, but should be updated with the current version of AERMET.

RUNTIME MESSAGE PROCESSING, 400-499

This type of message is generated during the model run. Setup processing has been completed successfully, and the message is generated during the performance of model calculations. Typical messages will tell the information and error during the model run. If a fatal error of this kind is detected during model execution, a fatal error message is written to the message file and any further processing of the data is prohibited. The rest of the meteorological data file will be read and quality assurance checked to identify additional errors. If a warning occurs, data may or may not be processed, depending on the processing requirements specified within the run stream input data.

405 The Value of PHEE Exceeds 1.0. If the value of PHEE, the fraction of the plume material below Heff, is greater than 1.0, then this informational message is generated. The value of PHEE is then set to 1.0 for the specified date.

406 Increase NVMAX for complex AREAPOLY source. The number of vertices for an AREAPOLY source exceeds the value of NVMAX, initially set to 20.

410 Flow Vector Out-of-Range. The flow vector must be between 0 and 360 degrees, inclusive. The date of occurrence is provided with the message (in the form of year, month, day, hour as YYMMDDHH).

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413 Number of Threshold Violation Events > 9999 for the Specified Averaging Period. This will result in duplicate event names being written to the EVENT.REC file. The duplicate events will have to be segregated before running the model in the EVENT processing mode.

420 Wind Speed Out-of-Range. The wind speed value may be either too large or too small. An error is generated if the speed is less than 0.0, and a warning is generated if the speed is greater than 30.0 m/s. The date of occurrence is provided with the message (in the form of year, month, day, hour as YYMMDDHH).

430 Ambient Temperature Data Out-of-Range. The ambient temperature value may be either too large or too small. A warning is generated if the temperature is less than 220.0 K or greater than 330 K. The date of occurrence is provided with the message (in the form of year, month, day, hour as YYMMDDHH).

432 Surface Friction Velocity Out-of-Range. The surface friction velocity may by too large. A warning is generated if the surface friction velocity is greater than 1.5 m/s. The date of occurrence is provided with the message (in the form of year, month, day, hour as YYMMDDHH).

438 Surface Roughness Length Out-of-Range. A warning is generated if the surface friction velocity is less than 0.001 meters, and the value is set to 0.001 meters to avoid a divide by zero. The date of occurrence is provided with the message (in the form of year, month, day, hour as YYMMDDHH).

448 Convective Velocity Scale Out-of-Range. The convective velocity scale may by too large. A warning is generated if the convective velocity scale is greater than 3.0 m/s. The date of occurrence is provided with the message (in the form of year, month, day, hour as YYMMDDHH).

460 Calm Hour Identified in Meteorology Data File. This message is generated if a calm hour is identified, and provides the date of occurrence (in the form of year, month, day, hour as YYMMDDHH). A calm hour is identified by a reference wind speed of 0.0 m/s in the surface meteorological data file.

450 Error in Meteorology File - Record Out of Sequence. There is an error in the sequence of the hourly meteorological data file. The message also provides the date of occurrence (in the form of year, month, day, hour as YYMMDDHH).

455 Date/Time Mismatch on Hourly Emission File. There is mismatch in the date/time field between the meteorological data file and the hourly emission file. The message also provides the date of the occurrence from the surface/scalar file (in the form of year, month, day, hour as YYMMDDHH).

456 Date/Time Mismatch on Scalar and Profile Data. There is mismatch in the date/time field between the surface/scalar and the profile meteorological data files. The message

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also provides the date of the occurrence from the surface/scalar file (in the form of year, month, day, hour as YYMMDDHH)

460 Missing Hour Identified in Meteorology Data File. At least one of the meteorological variables is missing or invalid for the hour specified (in the form of year, month, day, hour as YYMMDDHH). If the missing data processing option is not used, then this message will be generated and any further calculations with the data will be aborted. The model will continue to read through the meteorological data file and check the data.

465 Number of Profile Levels Exceeds the Maximum. The profile meteorological data file includes more than the maximum number of levels, specified by the MXPLVL PARAMETER in MODULE MAIN1. The value of MXPLVL is provided with the message.

470 Mixing Height Value is Less Than or Equal to 0.0. This is an informational message that may indicate an error in the meteorological data file. The message includes the hour of occurrence (in the form of year, month, day, hour as YYMMDDHH).

475 The Reference Height is Higher than 200 m. The reference height is read from the surface/scalar meteorological data file. This warning message is generated if the reference height is higher than 200 meters. Since data for the reference height are used in surface layer similarity profiles, the reference height should be within the surface layer (between about 7 and 100 times the surface roughness length).

480 Less Than 1 Year Found for ANNUAL Averages. The input meteorological data file consists of less than a full year of data. The ANNUAL average requires that a full year of data or multiple years be available.

485 Data Remaining After End of Year. The ANNUAL average requires full years of input data (not necessarily calendar years), and there are data remaining after the end of the year. The number of hours remaining is specified.

487 User-specified Start Date on STARTEND card is Earlier Than Start Date of Data File with the ANNUAL average or post 1997 PM10 processing option.

INPUT/OUTPUT MESSAGE PROCESSING, 500-599

This type of message is generated during the model input and output. Typical messages will tell the type of I/O operation (e.g., opening, reading or writing to a file), and the type of file. If a fatal error of this kind is detected in a runstream image, a fatal error message is written to the message file and any attempt to process data is prohibited. If a warning occurs,

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data may or may not be processed, depending on the processing requirements specified within the run stream input data.

500 Fatal Error Occurs During Opening of the Data File. The file specified can not be opened properly. This may be the runstream file itself, the meteorological data file, or one of the special purpose output files. This may happen when the file called is not in the specified path, or an illegal filename is specified. If no errors are found in the filename specification, then this message may also indicate that there is not enough memory available to run the program, since opening a file causes a buffer to be opened which takes up additional memory in RAM. For the special purpose output files, the hint field includes character string identifying the type of file and the file unit number, e.g., 'PLOTFILE:12'.

510 Fatal Error Occurs During Reading of the File. File is missing, incorrect file type, or illegal data field encountered. Check the indicated file for possible problems. As with error number 500, this message may also indicate that there is not enough memory available to run the program if no other source of the problem can be identified.

520 Fatal Error Occurs During Writing to the File. Similar to message 510, except that it occurs during a write operation.

540 CAUTION: Met Station ID Mismatch with SURFFILE for SURFDATA, UAIRDATA or SITEDATA. The surface, upper air, or optional on-site station ID numbers specified on the ME pathway do not agree with the values on the first record of the surface meteorological data file. This is a non-fatal warning message, but the input data should be checked carefully to ensure that the correct data file has been used.

549 No RECTABLE/MAXTABLE/DAYTABLE for Averaging Period. No printed output options selected for a particular averaging period. This is a non-fatal warning condition for the TERRAIN model.

550 File Unit/Name Conflict for the Output Option. This error indicates that a problem exists with the filename and file unit specification for one of the special purpose output files. The associated keyword is provided as a hint. The same filename may have been used for more than one file unit, or vice versa.

560 User Specified File Unit Less Than or Equal to 25 for OU Keyword. A file unit of less than or equal to 25 has been specified for the indicated special purpose output files. This is a fatal error condition. File units of less than or equal to 25 are reserved for system files. Specify a unit number in the range of 26 to 100.

565 Possible conflict With Dynamically Allocated FUNIT. A file unit specified for the indicated special purpose output files is in the range 1-100, and may therefore conflict

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with file units dynamically allocated for special purpose files by the model. This is typically a non-fatal warning condition

570 Problem Reading Temporary Event File for Event - The AERMOD model stores high value events in a temporary file that is used to create the input file for EVENT processing, if requested, and also to store the high values for the summary tables at the end of the printed output file. A problem has been encountered reading this file possibly because the concentration value was too large and overflowed the fixed format field of F14.5

580 End-of-File Reached Trying to Read a Data File - The AERMOD model has encountered an end-of-file trying the read the indicated file. This may appear when trying to "re-start" a model run with the CO INITFILE card if there is an error with the initialization file. Check the data file for the correct filename

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APPENDIX D. DESCRIPTION OF FILE FORMATS

D.1 AERMET METEOROLOGICAL DATA

Two files are produced for input to the AERMOD dispersion model by the AERMET meteorological preprocessor. The surface OUTPUT contains observed and calculated surface variables, one record per hour. The PROFILE file contains the observations made at each level of an on-site tower, or the one level observations taken from NWS data, one record per level per hour. The contents and format of each of these files is described below.

SURFACE OUTPUT

Header record

READ(1) *latitude, longitude, UA identifier, SF identifier, OS identifier, Version*

FORMAT (2(2X,A8),8X,' UA ID: ',A8,' SF ID: ',A8,' OS ID: ',A8,
8X,'VERSION: ',I5)

where *latitude* latitude specified in Stage 3 of AERMET

longitude longitude specified in Stage 3 of AERMET

UA identifier station identifier for upper air data, usually the WBAN number used to extract the data from an archive data set

SF identifier station identifier for hourly surface observations, usually the WBAN number used in extracting the data

OS identifier on-site identifier

Version version date of AERMET used to generate file

Data records

READ(1) *year, month, day, jday, hour, H, u*$_*$, *w*$_*$, *THETA*, Z_o, Z_{ref}, L, z_i, B, r, BV, $W_{sz_{ref}}$, *temp*, z_{ref}

FORMAT (3(I2,1X), I3,1X, I2,1X, F6.1,1X, 2(F6.3,1X), F5.0,1X, F8.1,1X, F5.2,1X, 2(F6.2,1X), F7.2,1X, F5.0, 3(1X,F6.2))

where *jday* Julian date

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H	sensible heat flux ($W \cdot m^{-2}$)
u_*	surface friction velocity (m/s)
w_*	convective velocity scale (m/s)
$dTdz$	vertical potential temperature gradient in the 500 m layer above PBL
z_i	height of convectively-generated boundary layer (m)
z_{im}	height of mechanically-generated boundary layer (m)
L	Monin-Obukhov length (m)
z_o	surface roughness length (m)
Bo	Bowen ratio
r	Albedo
WS	wind speed ($m \cdot s^{-1}$)
WD	wind direction (degrees)
z_{ref}	reference height for WS and WD (m)
temp	temperature (K)
z_{ref}	reference height for *temp* (m)

The sensible heat flux, Bowen ratio and albedo are not used by AERMOD, but are passed through by AERMET for information purposes only.

PROFILE

READ( ) *year, month, day, hour, height, top,* WD*nn*, WS*nn*, TT*nn*, SA*nn*, SW*nn*

FORMAT (4I2,1X, F6.1,1X, I1,1X, F5.0,1X, F7.2,1X, F7.1, 1X,F6.1, 1X,F7.2)

where	*height*	measurement height (m)
	top	1 if this is the last (highest) level for this *hour*, or 0 otherwise
	WD*nn*	wind direction at the current level (degrees)
	WS*nn*	wind speed at the current level (m/s)
	TT*nn*	temperature at the current level (° C)
	SA*nn*	σ_θ (degrees)
	SW*nn*	σ_w ($m \cdot s^{-1}$)

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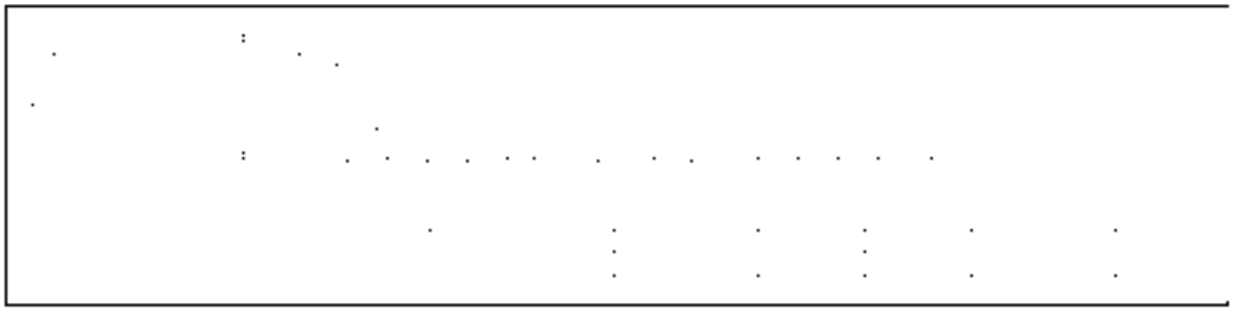
D.2 THRESHOLD VIOLATION FILES (MAXIFILE OPTION)

The OU MAXIFILE card for the AERMOD model allows the user the option to generate a file or files of threshold violations for specific source group and averaging period combinations. The file consists of several header records, each identified with an asterisk (*) in column one. The header information includes the model name and version number, the first line of the title information for the run, the list of modeling option keywords applicable to the results, the averaging period and source group included in the file, and the threshold value. Any value equal to or exceeding the threshold value will be included in the file. The header also includes the format used for writing the data records and column headers for the variables included in the file. The variables provided on each data record include the averaging period, the source group ID, the date (YYMMDDHH) for the end of averaging period, the X and Y coordinates of the receptor location, receptor terrain elevation, hill height scale, flagpole receptor height, and the concentration value that violated the threshold. The following example from a threshold file identifies the contents of the MAXIFILE:



D.3 POSTPROCESSOR FILES (POSTFILE OPTION)

The OU POSTFILE card for the AERMOD model allows the user the option of creating output files of concurrent concentration values suitable for postprocessing. The model offers two options for the type of file generated - one is an unformatted file, and the other is a formatted file of X, Y, CONC values suitable for inputting to plotting programs.

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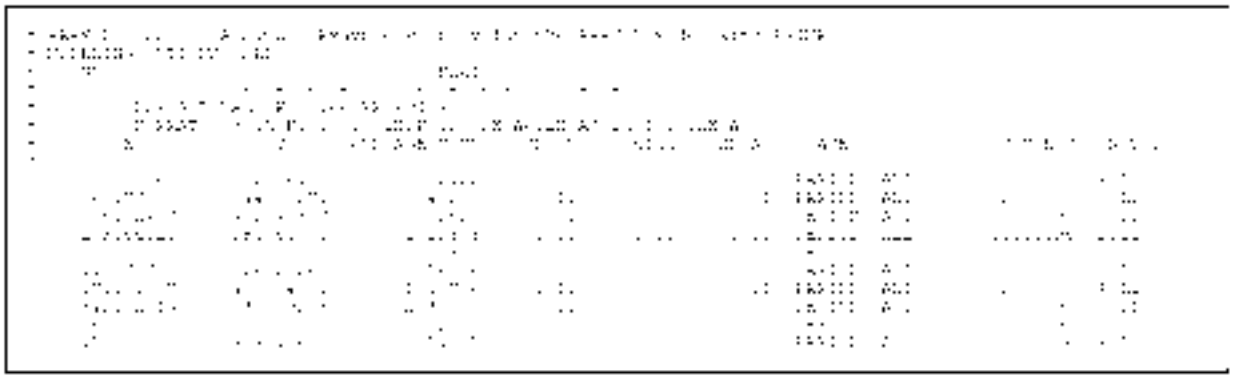
The unformatted POSTFILE option generates a separate unformatted data record of concurrent values for each averaging period and source group specified. The averaging period and source group combinations may be written to separate files, or combined into a single file. Each record begins with the date variable for the end of the averaging period (an integer variable of the form YYMMDDHH), the averaging period (e.g., an integer value of 3 for 3-hour averages), and the source group ID (eight characters). Following these three header variables, the record includes the concentration values for each receptor location, in the order in which the receptors are defined on the RE pathway. The results are output to the unformatted file or files as they are calculated by the model.

The formatted plot file option for the POSTFILE keyword includes several lines of header information, each identified with an asterisk (*) in column one. The header information includes the model name and version number, the first line of the title information for the run, the list of modeling option keywords applicable to the results, the averaging period and source group included in the file, and the number of receptors included. The header also includes the format used for writing the data records, and column headers for the variables included in the file. The variables provided on each data record include the X and Y coordinates of the receptor location, the concentration value for that location, receptor terrain elevation, hill height scale, flagpole receptor height, the averaging period, the source group ID, and the either the date variable for the end of the averaging period (in the form of YYMMDDHH) for short term averages or the number of hours in the period for PERIOD averages. The following example from a formatted postprocessor file for PERIOD averages identifies the contents of the POSTFILE:



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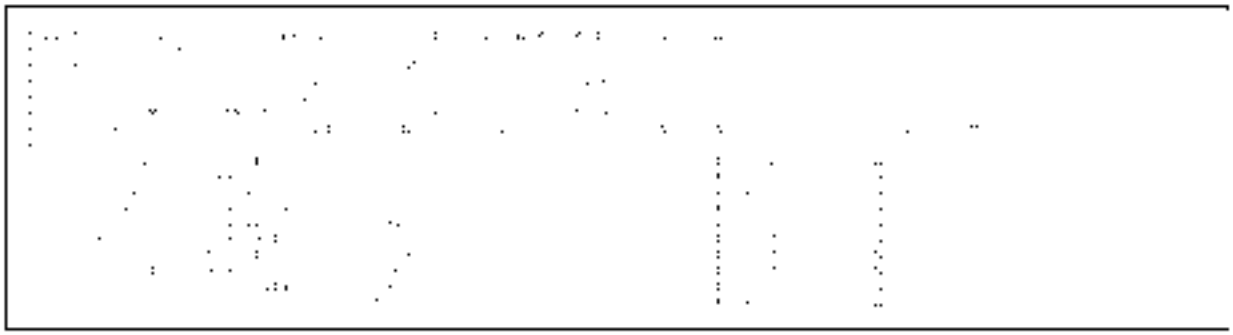
D.4 HIGH VALUE RESULTS FOR PLOTTING (PLOTFILE OPTION)

The OU PLOTFILE card for the AERMOD model allows the user the option of creating output files of highest concentration values suitable for importing into graphics software to generate contour plots. The formatted plot files generated by the PLOTFILE include several lines of header information, each identified with an asterisk (*) in column one. The header information includes the model name and version number, the first line of the title information for the run, the list of modeling option keywords applicable to the results, the averaging period and source group included in the file, the high value (e.g. 2ND highest) included for plotting, and the number of receptors included. The header also includes the format used for writing the data records and column headers for the variables included in the file. The variables provided on each data record include the X and Y coordinates of the receptor location, the concentration value for that location, receptor terrain elevation, hill height scale, flagpole receptor height, averaging period, the source group ID, and either the high value included for short term averages or the number of hours in the period for PERIOD averages. For short term averages, the PLOTFILE also includes the date variable for the end of the averaging period (in the form of YYMMDDHH). The PERIOD average PLOTFILE uses the same format for the data records as the PERIOD average formatted POSTFILE shown in the previous section. The following example from a plot file for high second highest 24-hour averages identifies the contents of the PLOTFILE:



The PLOTFILE output also includes a flag (**) identifying the receptor with the highest concentration. For short term averages, the flag precedes the date field. For period averages, the

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flag precedes the field with the number of hours in the period.

D.5 TOXX MODEL INPUT FILES (TOXXFILE OPTION)

The OU TOXXFILE card for the AERMOD model allows the user the option to generate an unformatted file or files of threshold violations for a specific averaging period for use with the TOXX model component of TOXST. The file consists of three header records, including the first line of the title information for the run, the number of source groups, receptors and averaging periods, information on the type of receptor network, and the threshold cutoff value. Following the header records are pairs of records identifying the specific averaging period, source group and receptor location and corresponding concentration value for the values exceeding the user-specified threshold. If any source group exceeds the threshold for a given averaging period and receptor location, then the concentrations for all source groups are output for that period and receptor. The structure of the unformatted file for the AERMOD model TOXXFILE option is described below.

Record	=	Description
1		Title (80 characters)
2		IYEAR, NUMGRP, NUMREC, NUMPER, ITAB, NXTOX, NYTOX, IDUM1, IDUM2, IDUM3
3		CUTOFF, RDUM1, . . ., RDUM9

where TITLE: First line of title (80 characters)
IYEAR Year of simulation
NUMGRP No. of source groups
NUMREC Total no. of receptors
NUMPER No. of averaging periods (e.g., number of hours in the year)
ITAB 1 for polar grid, 2 for Cartesian grid, 0 for discrete receptors or mixed grids
NXTOX No. of x-coordinates (or distances) in receptor network
NYTOX No. of y-coordinates (or directions) in receptor network
IDUM1, IDUM2, IDUM3 dummy integer variables, arbitrarily set equal to zero
CUTOFF User-specified threshold for outputting results (g/m^3)
RDUM1, . . ., RDUM9 Dummy real variables (nine) arbitrarily set equal to zero

Following the header records, the file consists of pairs of records including an ID variable

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identifying the data period, source group number and receptor number, and the corresponding concentration values. The number of values included in each record is controlled by the NPAIR PARAMETER, which is initially set at 100 in MODULE.MAIN1. The identification variable is determined as follows:

IDCONC = IPER*10000 + IGRP*1000 + IREC

where IPER = the year number for the year corresponding to the concentration value
IGRP = the source group number (the order in which the group was defined on the SO pathway)
IREC = the receptor number (the order in which the receptor was defined on the RE pathway)

D.6 MAXIMUM VALUES BY RANK (RANKFILE OPTION)

The OU RANKFILE card for the AERMOD model allows the user the option of creating output files of the maximum concentration values by rank, suitable for generating Q-Q or quantile plots. The data contained in the RANKFILE output is based on the MAXTABLE arrays, except that only one occurrence per data period is included. The formatted data files generated by the RANKFILE include several lines of header information, each identified with an asterisk (*) in column one. The header information includes the model name and version number, the first line of the title information for the run, the list of modeling option keywords applicable to the results, the averaging period included in the file, and the number of ranked values included. The header also includes the format used for writing the data records, and column headers for the variables included in the file. The variables provided on each data record include the rank, concentration value, X and Y coordinates of the receptor location, receptor terrain elevation, hill height scale, flagpole receptor height, and the source group ID. Each RANKFILE includes results for all of the source groups for a particular averaging period. Since the RANKFILE only include one occurrence per data period, the file may not include the number of ranked values requested, especially for evaluation data bases of limited duration. The following example identifies the contents of the RANKFILE:

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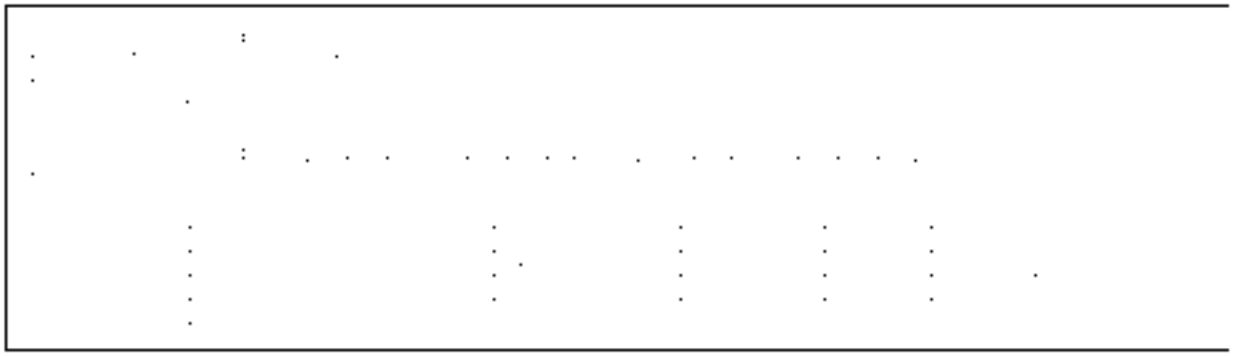

D.7 ARC-MAXIMUM VALUES FOR EVALUATION (EVALFILE OPTION)

The OU EVALFILE card for the AERMOD model allows the user the option of creating output files of the arc-maximum concentration values for individual sources suitable for use in model evaluation studies. The data contained in the EVALFILE output is based on the maximum value along arcs of receptors, identified using the RE EVALCART card. Receptors may be grouped on arcs based on their distance from the source, or other logical grouping. The formatted EVALFILE output includes five records of information for each selected source and each hour of meteorological data. The information provided is as follows:

Record 1
- Source ID (eight characters)
- Date variable (YYMMDDHH)
- Arc ID (eight characters)
- Arc maximum χ/Q
- Emission rate for arc maximum (including unit conversions)
- Crosswind integrated concentration based on true centerline concentration
- Normalized non-dimensional crosswind integrated concentration

Record 2
- Downwind distance corresponding to arc maximum (m)
- Effective wind speed corresponding to arc maximum (m/s)
- Effective σ_v corresponding to arc maximum (m/s)
- Effective σ_w corresponding to arc maximum (m/s)
- σ_z corresponding to arc maximum (m)
- Effective plume height corresponding to arc maximum (m)

Record 3
- Monin-Obukhov length for current hour (m)
- Mixing height for current hour (m)
- Surface friction velocity for current hour (m/s)
- Convective velocity scale for current hour if unstable (m/s), or σ_v for current hour if stable (m)

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Buoyancy flux for current hour (m^4/s^3)
Momentum flux for current hour (m^4/s^2)

Record 4 Bowen ratio for current hour
Plume penetration factor for current hour
Centerline χ/Q for direct plume
Centerline χ/Q for indirect plume
Centerline χ/Q for penetrated plume
Nondimensional downwind distance

Record 5 Plume height/mixing height ratio
Non-dimensional buoyancy flux
Source release height (m)
Arc centerline χ/Q
Developmental option settings place holder (string of 10 zeroes)
Flow vector for current hour (degrees)
Effective height for stable plume collections (m)

The following Fortran WRITE and FORMAT statements are used to write the results to the EVALFILE output

```
      WRITE(IFILE,9000) SRCID,SCAVDP,NUMDAT,AVGTIM,
     &                  ARCDIS(I),CHI(I),CHIDP(I),
     &                  CHIPEN(I),PCOF(I),PENDIS(I),
     &                  SYSTEP,ITEST,(DUMMY(I),I=1,10),
     &                  FLOW(I),TI,PLUHT,FSTAR,FS,FM,
     &                  BOWEN,DUM,(DUMMY(I),I=1,2),(DUMMY(I),I=1,2),
     &                  XNDIS,HSTAR,FSTAR,ZELEVREC,ARCDIS(I),
     &                  DFV,HSTACK(I)

9000  FORMAT(2X,A8,2X,A8,2X,A8,2X,A8,I10,2X,A8,
     &       4(2X,1PE12.5),2X,A8,2X,1PE12.5,
     &       4(2X,1PE12.5),2X,A8,2X,1PE12.5,
     &       2X,A8,2X,A8,2X,A8,2X,1PE12.5,
     &       2X,A8,2X,A8,2X,A8,2X,1PE12.5)
```

D.8 RESULTS BY SEASON AND HOUR-OF-DAY (SEASONHR OPTION)

The SEASONHR option is used to output a file containing the average results by season and hour-of-day. The formatted data files generated by the SEASONHR option include several lines of header information, each identified with an asterisk (*) in column one. The header information includes the model name and version number, the first line of the title information for the run, the list of modeling option keywords applicable to the results, the source group included in the file, and the number of receptors. The header also includes the format used for writing the

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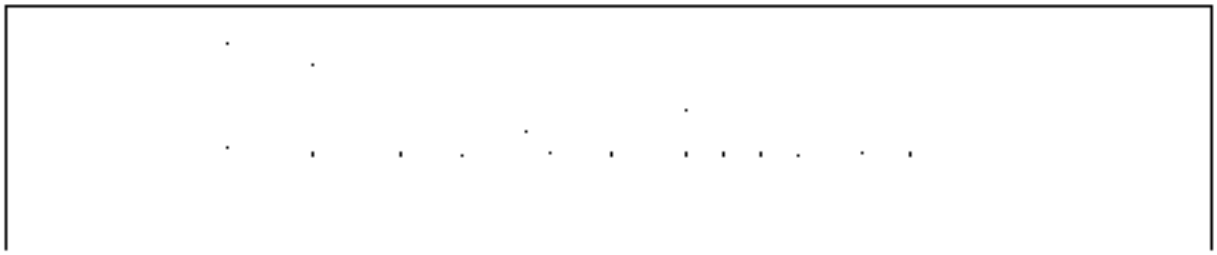
data records, and column headers for the variables included in the file. The variables provided on each data record include the X and Y coordinates of the receptor location, the average concentration value, receptor terrain elevation, hill height scale, flagpole receptor height, source group ID, number of non-calm and non-missing hours used to calculate the season-by-hour-of-day averages (the NHRS column), season index (the SEAS column with 1 for winter, 2 for spring, 3 for summer, and 4 for fall), and the hour-of-day for the concentration value. A sample from a SEASONHR output file is shown below.



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APPENDIX E.

QUICK REFERENCE FOR AERMOD

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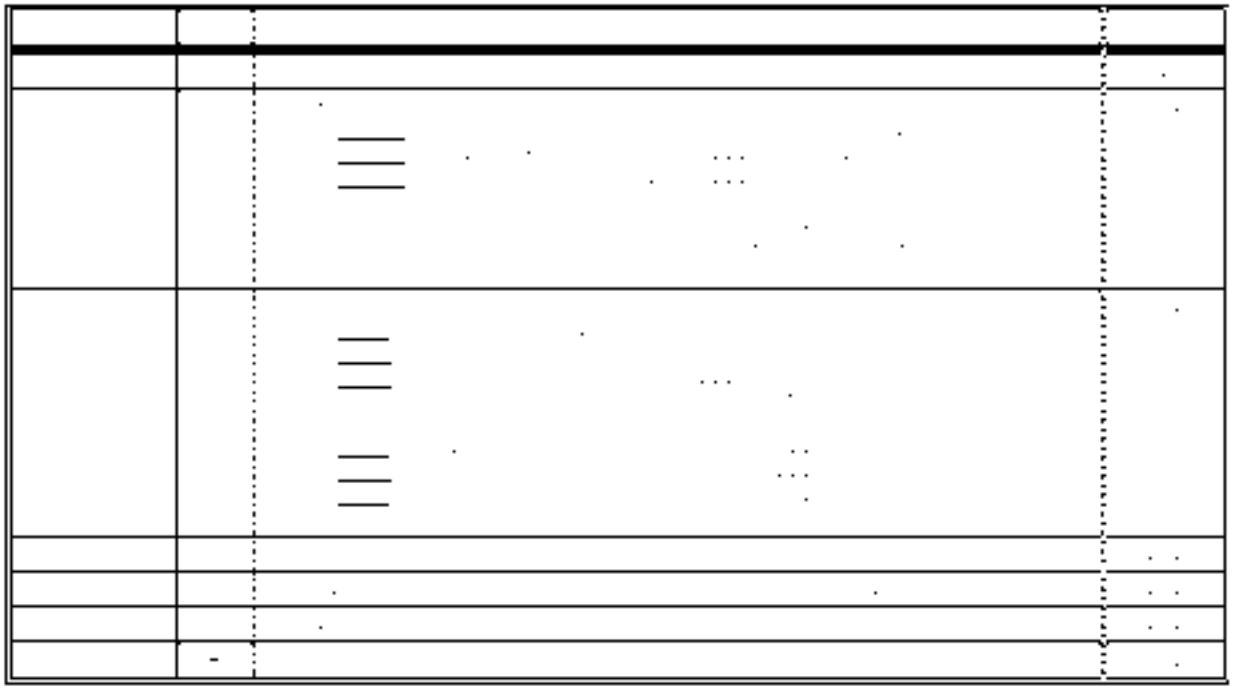

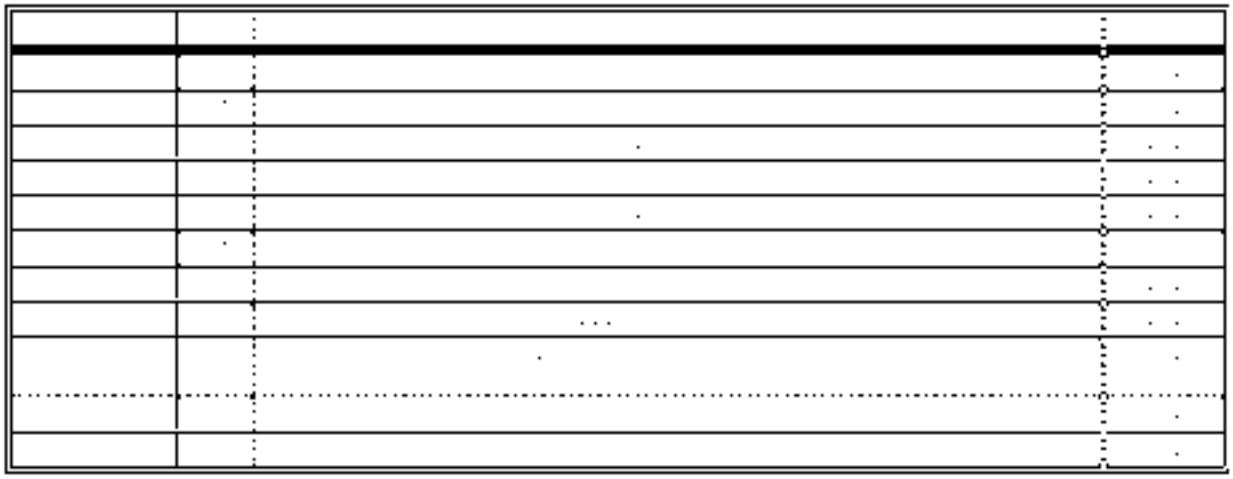

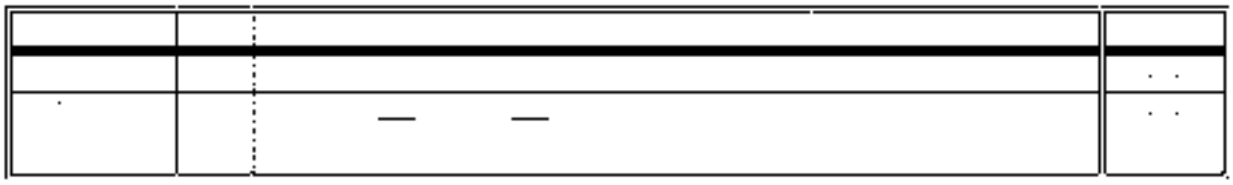

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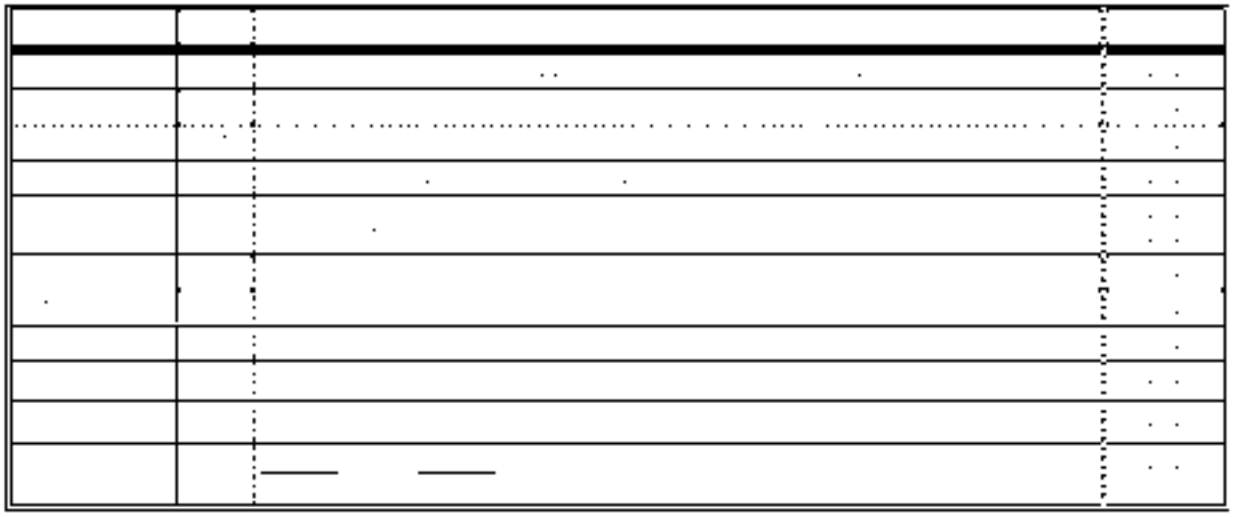

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GLOSSARY

AERMAP -- AMS/EPA Regulatory Model (AERMOD) Terrain Preprocessor

AERMET -- AMS/EPA Regulatory Model (AERMOD) Meteorological Preprocessor.

AERMOD -- AMS/EPA Regulatory Model

ASCII -- American Standard Code for Information Interchange, a standard set of codes used by computers and communication devices. Sometimes used to refer to files containing only such standard codes without any application-specific codes such as might be present in a document file from a word processor program.

CD-144 Format -- Card Deck-144 data format available from NCDC for National Weather Service surface observations commonly used for dispersion models. Each record represents an 80-column "card image"

CO -- **CO**ntrol, the 2-character pathway ID for input runstream images used to specify overall job control options

CO Pathway -- Collective term for the group of input runstream images used to specify the overall job control options, including files, dispersion options, terrain options, etc

Directory -- A logical subdivision of a disk used to organize files stored on a disk

Dispersion Model -- A group of related mathematical algorithms used to estimate (model) the dispersion of pollutants in the atmosphere due to transport by the mean (average) wind and small-scale turbulence

DOS -- Disk Operating System. Software that manages applications software and provides an interface between applications and the system hardware components, such as the disk drive, terminal, and keyboard

Echo of Inputs -- By default, the AERMOD model will echo the input runstream images, character by character, into the main printed output file. This serves as a record of the inputs as originally entered by the user, without any rounding of the numerical values. The echoing can be suppressed with the NO ECHO option

EOF -- End-of-File.

EPA -- U. S. Environmental Protection Agency

Error message -- A message written by the model to the error-message file whenever an error is encountered that will inhibit data processing

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Error Message File -- A file used for storage of messages written by the model.

EV -- EVent, the 2-character pathway ID for input runstream images used to specify event inputs for the Short Term EVENT model

EV Pathway -- Collective term for the group of input runstream images used to specify the event periods and locations for the Short Term EVENT model

EVENT Processing -- An option in the AERMOD model specifically designed to provide source contribution (culpability) information for specific events of interest, e.g., design values or threshold violations

Extended Memory -- Additional memory on 80386 and 80486 PCs that allows programs to address memory beyond the 640 KB limit of DOS. Special software is required to utilize this extra memory

Fatal Error -- Any error which inhibits further processing of data by the model. Model continues to read input images to check for errors during setup, and will continue to read input meteorological data during calculation phase

Flow Vector -- The direction towards which the wind is blowing

GMT -- Greenwich Mean Time, the time at the 0° meridian.

Informational Message -- Any message written to the error/message file that may be of interest to the user, but which have no direct bearing on the validity of the results and do not affect processing

Input Image -- User supplied input, read through the default input device, controlling the model options and data input. A single card or record from the input runstream file. Each input image consists of a pathway ID (may be blank indicating a continuation of the previous pathway), a keyword (may also be blank for continuation of a keyword), and possibly one or more parameter fields

Input Runstream File -- The basic input file to the AERMOD model controlling the modeling options, source data, receptor locations, meteorological data file specifications, and output options. Consists of a series of input images grouped into functional pathways.

Julian Day -- The number of the day in the year, i.e., Julian Day = 1 for January 1 and 365 (or 366 for leap years) for December 31

KB -- Kilobyte, 1000 bytes, a unit of storage on a disk

Keyword -- The 8-character codes that follow immediately after the pathway ID in the input run stream data

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LST Local Standard Time

Math Co processor A computer chip used to speed up floating point arithmetic in a personal computer

MB -- Megabyte, one million bytes, a unit of storage on a disk

ME -- **ME**teorology, the 2-character pathway ID for input runstream images used to specify meteorological data options

MF Pathway -- Collective term for the group of input runstream images used to specify the input meteorological data file and other meteorological variables, including the period to process from the meteorological file for the AERMOD model.

Meteorological Data File -- Any file containing meteorological data, whether it be mixing heights, surface observations or on-site data

Missing Value -- Alphanumeric character(s) that represent breaks in the temporal or spatial record of an atmospheric variable

Mixing Height -- The depth through which atmospheric pollutants are typically mixed by dispersive processes

NCDC -- National Climatic Data Center, the federal agency responsible for distribution of the National Weather Service upper air, mixing height and surface observation data

NO ECHO -- Option to suppress echoing of the runstream input images to the main printed output file

NWS -- National Weather Service.

On-site Data -- Data collected from a meteorological measurement program operated in the vicinity of the site to be modeled in the dispersion analysis

OU -- **OU**tput, the 2-character pathway ID for input runstream images used to specify output options

OU Pathway -- Collective term for the group of input runstream images used to specify the output options for a particular run

Overlay -- One or more subprograms that reside on disk and are loaded into memory only when needed

Pasquill Stability Categories -- A classification of the dispersive capacity of the atmosphere, originally defined using surface wind speed, solar insolation (daytime) and cloudiness

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(nighttime). They have since been reinterpreted using various other meteorological variables.

Pathway -- One of the six major functional divisions in the input runstream file for the AERMOD model. These are **CO**ntrol, **SO**urce, **RE**ceptor, **ME**teorology, **EV**ent, and **OU**tput (see these entries in this section for a description).

PC -- Personal Computer, a wide ranging class of computers designed for personal use, typically small enough to fit on a desktop.

Quality Assessment -- Judgment of the quality of the data.

Quality Assessment Check -- Determining if the reported value of a variable is reasonable (see also Range Check).

Quality Assessment Message -- Message written to the error/message file when a data value is determined to be suspect.

Quality Assessment Violation -- Occurrences when data values are determined to be suspect (see also Range Check Violation).

RAM -- Random Access Memory on a personal computer.

RAMMET -- Meteorological processor program used for regulatory applications capable of processing twice-daily mixing heights (TD-9689 format) and hourly surface weather observations (CD-144 format) for use in dispersion models such as AERMOD, CRSTER, MPTER and RAM.

Range Check -- Determining if a variable falls within predefined upper and lower bounds.

Range Check Violation -- Determination that the value of a variable is outside range defined by upper and lower bound values (see also Quality Assessment Violation).

RE -- **RE**ceptor, the 2-character pathway ID for input runstream images used to specify receptor locations.

RE Pathway -- Collective term for the group of input runstream images used to specify the receptor locations for a particular run.

Regulatory Applications -- Dispersion modeling involving regulatory decision-making as described in the Guideline on Air Quality Models, which is published as Appendix W of 40 CFR Part 51 (as revised).

Regulatory Model -- A dispersion model that has been approved for use by the regulatory offices of the EPA, specifically one that is included in Appendix A of the Guideline on Air Quality Models, (as revised), such as the AERMOD model.

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Runstream File -- Collectively, all input images required to process input options and input data for the AERMOD model

SCRAM -- Support Center for Regulatory Air Models - part of EPA's website on the internet, used by EPA for disseminating air quality dispersion models, modeling guidance, and related information

Secondary Keyword -- A descriptive alphabetical keyword used as a parameter for one of the main runstream keywords to specify a particular option

SO -- **SO**urce, the 2 character pathway ID for input runstream images used to specify input source parameters and source groups

SO Pathway -- Collective term for the group of input runstream images used to specify the source input parameters and source group information

Station Identification -- An integer or character string used to uniquely identify a station or site as provided in the upper air (TD-5600 and TD-6201), mixing height (TD-9689), and surface weather (CD-144 and TD-3280) data formats available from NCDC. There are no standard station numbers for on-site data or data image screening data, and the user may include any integer string.

Subdirectory -- A directory below the root, or highest level, directory or another subdirectory, used for organization of files on a storage medium such as a PC hard disk

Surface Weather Observations -- A collection of atmospheric data on the state of the atmosphere as observed from the earth's surface. In the U.S. the National Weather Service collect these data on a regular basis at selected locations

Surface Roughness Length -- Height at which the wind speed extrapolated from a near-surface wind speed profile becomes zero

Syntax -- The order, structure and arrangement of the inputs that make of the input runstream file, specifically, the rules governing the placement of the various input elements including pathway IDs, keywords, and parameters.

TD-1440 Format -- A format available from NCDC for summarizing NWS surface observations in an 80-column format; the CD-144 format is a subset of this format. This format has been superseded by the TD-3280 format

TD-3280 Format -- The current format available from NCDC for summarizing NWS surface weather observations in an elemental structure, i.e., observations of a single atmospheric variable are grouped together for a designated period of time

TD-5600 Format -- A format available from NCDC for reporting NWS upper air sounding data. This format has been superseded by the TD-6201 format

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TD-6201 Format -- The current format available from NCDC for reporting NWS upper air data. The file structure is essentially the same as the TD-5600 format except that there is more quality assurance information

TD-9689 Format -- The format available from NCDC for mixing heights estimated from morning upper air temperature and pressure data and hourly surface observations of temperature

Unformatted File -- A file written without the use of a FORTRAN FORMAT statement, sometimes referred to as a binary file

Upper Air Data (or soundings) -- Meteorological data obtained from balloon-borne instrumentation that provides information on pressure, temperature, humidity, and wind away from the surface of the earth

Vertical Potential Temperature Gradient -- The change of potential temperature with height, used in modeling the plume rise through a stable layer, and indicates the strength of the stable temperature inversion. A positive value means that potential temperature increases with height above ground and indicates a stable atmosphere.

Warning Message -- A message written by the model to the error message file whenever a problem arises that may reflect an erroneous condition, but does not inhibit further processing

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-454/B-03-001		

4. TITLE AND SUBTITLE	5. REPORT DATE
User's Guide for the AMS/EPA Regulatory Model - AERMOD	September 2004
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS See below.	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. 68D30032, 68D40001, 68D70069
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED Final technical report
	14. SPONSORING AGENCY CODE EPA/200/04

15. SUPPLEMENTARY NOTES

16. ABSTRACT: This User's Guide for the AMS/EPA Regulatory Model (AERMOD) provides user instructions for the AERMOD model. The technical description of the AERMOD algorithms is provided in a separate document. The revised AERMOD model described in this user's guide includes the following modifications and enhancements: the PRIME building downwash algorithms based on the ISC-PRIME model, use of allocatable arrays for data storage, incorporation of EVENT processing for analyzing short-term source culpability, post-1997 PM10 processing, a non-regulatory default TOXICS option that includes optimizations for area sources and the Sampled Chronological Input Model (SCIM) option, explicit treatment of multiple-year meteorological data files and the ANNUAL average, and options to specify emissions that vary by season, hour of day and day of week.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN-ENDED TERMS	c. COSATI Field/Group
AERMOD, user's guide, air dispersion model.	Air Pollution models	
18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 227
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APPENDIX "A"

Trip Generation Table

For purposes of this Table the floor area shall be the square footage confined by the outside surface of the exterior walls of a building, except for the square footage devoted to vehicle parking, necessary interior driveways and ramps.

LAND USE	P.M. PEAK TRIPS PER HOUR
Automobile Uses:	
*Car Wash	110.0 per car wash
*Gas Station	3.6 per pump
*Repair/Service	6.0 per service stall
Car rental/Used car sales	1.0 per 1,000 sq. ft. of lot size
New car sales	4.6 per 1,000 sq. ft. of floor area
Banking Uses	
*Walk-in Bank	16.7 per 1,000 sq. ft. of floor area
*With Drive-through	25.3 per 1,000 sq. ft. of floor area
*Savings & Loan	5.3 per 1,000 sq. ft. of floor area
*With Drive-through	6.8 per 1,000 sq. ft. of floor area
Shopping Center	
*Less than 30,000 sq. ft.	14.6 per 1,000 sq. ft. of floor area
30,000 sq. ft. or more	The trips per p.m. peak hour shall be determined by the following formula:

(-0.001A + (323.5/A) + 3.9) per 1,000 sq. ft. of floor area; Where A = Floor Area/1,000

Hospitals:	
General	1.2 per bed
Convalescent	0.2 per bed
Lodging:	
Hotel, Motel, or Apartment Hotel	0.7 per guest room
*Multi-Story Apartments, Condominiums, Townhomes or Single-Family Housing	0.7 per dwelling unit

*LOCAL SERVING USES

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Retail Uses:	
*Supermarket	6.8 per 1,000 sq. ft. of floor area
*Convenience Market	46.7 per 1,000 sq. ft. of floor area
*Specialty Retail (Free standing retail not in a shopping center excluding high Trip generating land uses)	5.0 per 1,000 sq. ft. of floor area
*Furniture Store (More than 30,000 sq. ft.)	0.4 per 1,000 sq. ft. of floor area
*Other Commercial (High Trip generating land uses such as video stores, bakeries, yogurt shops, etc.)	9.6 per 1,000 sq. ft. of floor area
*Entertainment Theater	0.15 per seat
Discount Stores (More than 50,000 sq. ft.)	6.1 per 1,000 sq. ft. of floor area
Industrial:	
Industrial Park	1.0 per 1,000 sq. ft. of floor area
Manufacturing	0.8 per 1,000 sq. ft. of floor area
Warehousing (50,000 sq. ft. or more)	1.6 per 1,000 sq. ft. of floor area
*Storage (Less than 50,000 sq. ft.)	0.3 per 1,000 sq. ft. of floor area
Airport Facilities, other than Passenger Terminals, such as maintenance or cargo facilities	0.8 per 1,000 sq. ft. of floor area
Mini-Warehouse (Less than 30,000 sq. ft.)	0.3 per 1,000 sq. ft. of floor area
Science Research & Development	0.9 per 1,000 sq. ft. of floor area

*LOCAL SERVING USES

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Offices:	
Commercial Office under 100,000 sq. ft.	2.6 per 1,000 sq. ft. of floor area
Commercial Office 100,000 sq. ft. or more	2.0 per 1,000 sq. ft. of floor area
Government Office	2.9 per 1,000 sq. ft. of floor area
Medical Office	3.9 per 1,000 sq. ft. of floor area
Parking Lot - Commercial:	0.0 Trips
Restaurants:	
*Low Turnover	6.1 per 1,000 sq. ft. of floor area
*High Turnover	10.5 per 1,000 sq. ft. of floor area
*Fast Food (A restaurant immediately adjacent to an automobile parking area, where patrons are served at a counter or a drive-through)	31.6 per 1,000 sq. ft. of floor area
***Child Care/Nursery**	12.3 per 1,000 sq. ft. of floor area
Health Club	3.6 per 1,000 sq. ft. of floor area

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WASTEWATER ENGINEERING SERVICES DIV.
2714 MEDIA CENTER DRIVE
LOS ANGELES, CA 90065
FAX: (323) 342-6210 OR 342-6211

September 27, 2011

Seth Wulkan, Assistant Environmental Planner
CAJA ENVIRONMENTAL SERVICES, LLC
11990 West San Vicente Blvd, Suite 200
Los Angeles, CA 90049

File: SC CE

Dear Mr. Wulkan:

Millennium Hollywood Project – Request for Wastewater Service Information

This is in response to your September 8, 2011 letter requesting wastewater service information for the proposed project. The Bureau of Sanitation, Wastewater Engineering Services Division (WESD), has conducted a preliminary evaluation of the potential impacts to the wastewater system for the proposed project.

Projected Wastewater Discharges for the Proposed Project:

Type Description	Average Daily Flow per Type Description (GPD/UNIT)	Proposed No. of Units	Average Daily Flow (GPD)
Existing			
Capital Records Complex	150 GPD/1000 SQ.FT	114,303 SQ.FT	(17,145)
Proposed			
Office	150 GPD/1000 SQ.FT	115,542 SQ.FT	17,331
Capital Records Complex	150 GPD/1000 SQ.FT	114,303 SQ.FT	17,145
Commercial Retail	80 GPD/1000 SQ.FT	115,000 SQ.FT	9,200
Food and Beverage	300 GPD/1000 SQ.FT	28,750 SQ.FT	8,625
Fitness/Sports Club	250 GPD/1000 SQ.FT	92,000 SQ.FT	23,000
Residential: Hotel	130 GPD/DU	200 DU	26,000
Residential: Studio/1-BR	120 GPD/DU	166 DU	19,920
Residential: 2-BR	160 GPD/DU	314 DU	50,240
Residential: 3-BR	200 GPD/DU	12 DU	2,400
Total			**156,716**

SEWER AVAILABILITY

The sewer infrastructure in the vicinity of the proposed project includes an existing 8-inch line on Argyle Ave, an 8-inch line on Vine St, and a 12-inch line on Yucca St. The sewage from the existing lines 8-inch lines on Argyle Ave and Vine St join at the intersection of Sunset Blvd and Vine St before discharging into a 33-inch line on Vine St. The sewage from the existing 12-inch line on Yucca St feeds into a 21-inch line on Cole Ave before splitting and discharging into a 27-inch line on Willoughby Ave and 20-inch line on Melrose Ave. Figure 1 shows the details of the sewer system within the vicinity of the project.

The current approximate flow level (d/D) and the design capacities at d/D of 50% in the sewer system are as follows:

Pipe Diameter (in)	Pipe Location	Current Gauging d/D (%)	50% Design Capacity
8	Argyle Ave	30	931,513 GPD
8	Vine St	48	725,182 GPD
12	Yucca St	14	676,120 GPD
33	Vine St	24	21.11 MGD
21	Cole Ave	11	5.46 MGD
27	Willoughby Ave	20	6.16 MGD
20	Melrose Ave	32	1.56 MGD

* No gauging available

Based on the estimated flows, it appears the existing sewer system with the exception of the one on Argyle Ave might be able to accommodate the total flow for your proposed project. Further detailed gauging and evaluation will be needed as part of the permit process to identify a specific sewer connection point. If the public sewer has insufficient capacity then the developer will be required to build sewer lines to a point in the sewer system with sufficient capacity. A final approval for sewer capacity and connection permit will be made at that time. Ultimately, this sewage flow will be conveyed to the Hyperion Treatment Plant, which has sufficient capacity for the project.

If you have any questions, please call Kwasi Berko of my staff at (323) 342-1562.

Sincerely,

Ali Poosti, Acting Division Manager
Wastewater Engineering Services Division
Bureau of Sanitation

Attachments: Figure 1 – Sewer Map

Div Files\SCAR\CEQA Review\Final CEQA Response Ltrs\Millennium Hollywood Project – Request for WWSI

Wastewater Engineering Services Division
Bureau of Sanitation
City of Los Angeles

FIGURE 1
Millennium Hollywood Project
Sewer Map

0 375 750 1,125 1,500 Feet

Thomas Brother Data reproduced with permission granted by THOMAS BROS MAP

CalRecycle

Waste Characterization

Service Sector: Estimated Solid Waste Generation and Disposal Rates

NOTE: More recent estimates for waste disposal, diversion, and generation rates are available for a limited number of business groups. These can be found in Table 2 of CalRecycle's *2006 Waste Disposal and Generation Studies for Selected Industry Groups*.

The data on this page is not official CalRecycle data; please read our disclaimer and background information.

Also see listings for Commercial / Industrial / Institutional / Residential establishments.

Waste Generation Source	Gen Rate	Units of Measure	Source Date	Source	Notes
Golf course	0.5	lb/golfer/day	Apr 1992	Stevenson Ranch Draft Environmental Impact Report (EIR) (Phase IV), LA County	EIR cites source as Ultrasystems
Hotel	2	lb/room/day	Apr 1992	Stevenson Ranch Draft EIR (Phase IV), LA County	EIR cites source as Ultrasystems
Hotel/motel	4	lb/room/day	Dec. 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source; assumes 750 SF/room
Hotel/motel	2	lb/room/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6, Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Motel	3.6	lb/room/day	Apr 1993	Draft EIR for South Gate Commercial Corridors Redevelopment Project	Cites City of LA Dept. of City Planning document "EIR Manual for Private Projects" as source
Other services*	3.12	lb/100 sq ft/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6, Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Restaurant	1	lb/seat/day	Apr 1992	Stevenson Ranch DEIR (Phase IV), LA County	EIR cites source as Ultrasystems; assumes 50% of restaurant is seating and 16 SF/seat
Restaurant	0.005	lb/sq ft/day	Dec 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source
Restaurant (fast food)	7	lb/employee/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6, Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"

* Includes museums, art galleries, theaters, recreational services, health clubs, repair services

CalRecycle does not officially endorse any of the waste generation rates in the preceding table, and cannot validate their accuracy. However, they may be useful in providing a general level of information for planning purposes.

The table contains information extracted from various sources, which are cited. Please note that several of the documents listed were developed by city or county planning or environmental departments. Your city or county planning or environmental agency may be a source of information for a local project.

Waste Generation Rates Home

Last Updated: January 16, 2013
Solid Waste Characterization: http://www.calrecycle.ca.gov/WasteChar/
Nancy Carr: NancyCarr@calrecycle.ca.gov (916) 341-6216

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

BULLETIN NO. 104

PLANNED UTILIZATION OF THE GROUND WATER BASINS OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

APPENDIX A
GROUND WATER GEOLOGY

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

BULLETIN NO. 104

PLANNED UTILIZATION OF THE GROUND WATER BASINS OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

APPENDIX A
GROUND WATER GEOLOGY

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FOREWORD

At present more than half of the water supply of the South Coastal area of Southern California is furnished by water from the ground water basins of the area. In general, the drafts on the ground water basins exceed the supply thereto, resulting in overdraft conditions that are expressed by the alarming decline of ground water levels. The lowered ground water levels result in higher costs of pumping, increased problems of maintaining proper salt balance, and in some basins, sea water or connate brine intrusion which threatens destruction of the utilization of the ground water basin.

The serious nature of this continuing and increasing overdraft of the ground water supply led many local water agencies and water users associations to request that detailed information on geology, hydrology, and basin operation be provided to assist them in overcoming or at least alleviating this dangerous condition. As a result of these requests, many by way of formal resolutions, the Southern District of the Department of Water Resources formulated a comprehensive program for an investigation of the planned utilization of the major ground water basins of Southern California.

The general objective of the basic program is to formulate a coordinated plan of operation that will permit the maximum utilization of these ground water basins in conserving the local water supply and in storing and distributing imported water. To attain this objective the work program for each basin investigation is divided into three phases: geology, hydrology, and operation and management. The first two phases provide the basic information required to develop a plan for coordinated ground water basin operation and will be detailed in interim reports as the studies are completed in each ground water basin. The final report on the planned utilization of

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each ground water basin will summarize the information contained in the interim reports and present and compare the alternative plans for coordinated operation of the ground water basin.

The Legislature provided funds during the 1959 General Session to initiate this program. The first ground water basins to be investigated underlie the Coastal Plain of Los Angeles County. The first phase of this investigation, the geologic study, has been completed and is presented in detail in this report.

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(Bound at end of report)

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1 Bibliography

2 Specific Yield Values and Transmissibility Tests

3 Well Numbering System and Definitions

AR0068845

EDMUND G. BROWN
GOVERNOR

WILLIAM E. WARNE
DIRECTOR

ADDRESS REPLY TO
P. O. BOX 388 SACRAMENTO
1120 N STREET HICKORY 5-

STATE OF CALIFORNIA

Department of Water Resources

SACRAMENTO

June 14, 1961

The Honorable Edmund G. Brown, Governor, and
Members of the Legislature of the
State of California

Gentlemen:

I have the honor to transmit herewith Appendix A, "Ground Water Geology", a portion of Bulletin No. 104, entitled "Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County".

This appendix presents data and conclusions on the extent, thickness, and lithology of the aquifers comprising the ground water basins of the Coastal Plain of Los Angeles County. It also describes the connections between the different aquifers, the areas where recharge to the aquifers are possible from the ground surface, and the effects of structural features on the movement of water through the basins. Geologic studies of this nature are required for proper operation of the ground water basins and for adequate planning and design of facilities for utilization of imported water.

Sincerely yours,

William E. Warne

Director

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ACKNOWLEDGMENTS

Valuable assistance and data used in this investigation were contributed by agencies of the Federal Government and of the State of California, by cities, counties, public districts, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

California Department of Public Works, Division of Highways

California Department of Natural Resources, Division of Mines and Division of Oil and Gas

Long Beach State College

Los Angeles County Engineers Office, Water Works Districts

Los Angeles County Flood Control District

Los Angeles Museum of History, Science, and Art; especially Theodore Downs, Curator of Vertebrate Paleontology and George P. Kanakoff, Curator of Invertebrate Paleontology

Richfield Oil Corporation

San Gabriel Valley Protective Association

Signal Oil and Gas Company

Standard Oil Company of California

Southwest Museum; especially Ruth D. Simpson, Assistant Curator

Texaco, Inc.

The Associated Colleges of Claremont

The California Institute of Technology

The University of California at Los Angeles, and at Riverside

The University of Southern California

United States Geological Survey, Ground Water Branch, Long Beach

Western Gulf Oil Company

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

Edmund G. Brown, Governor

William E. Warne, Director of Water Resources

SOUTHERN DISTRICT

John R. Teerink . . . . . District Manager

The investigation leading to this report
was conducted under the direction
of

Lloyd C. Fowler . . . . . Chief, Planning Branch

by

Robert G. Thomas . . . . . Senior Engineering Geologist
John J. Landry . . . . . Associate Engineering Geologist
Robert J. Turney . . . . . Assistant Engineering Geologist

Assisted by

John R. Cummings . . . . . Assistant Engineering Geologist
Joseph F. LoBue . . . . . Junior Engineering Geologist
John T. Scheliga . . . . . Junior Engineering Geologist
Ernest H. Gilmour . . . . . Junior Engineering Geologist

Staff review was provided
by

Laurence B. James . . . . . Chief Geologist

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CHAPTER I. INTRODUCTION

This report describes the geology of the water-bearing sediments and formations of the Coastal Plain of Los Angeles County, California. The information it contains will be used to support studies of the hydrology, water quality, and operational characteristics of the ground water basins in the area. The material presented includes a description of the geologic history of the area, the composition and extent of the aquifers of the coastal plain, the areas where recharge to the aquifers from the ground surface could occur, the geologic structure affecting the occurrence and movement of ground water through the area, and finally, a description of the individual ground water basins which comprise the coastal plain.

Description of Area

The area covered in this report is shown on Plate 1, entitled "General Geology and Location of Area of Investigation". In Los Angeles and Orange Counties there is a large coastal plain which extends inland from the Pacific Ocean. The ground water basins underlying this coastal plain are complex and the area is large; therefore, in order to adequately meet the objectives of this investigation within a reasonable period of time, the area was somewhat arbitrarily divided along the Los Angeles-Orange County line. This report considers only the northern portion of the coastal plain, that within Los Angeles County. The geology of the southern portion of the coastal plain within Orange County will be developed and reported upon subsequently.

The area of investigation is then the Coastal Plain of Los Angeles County. It is bounded by the Santa Monica Mountains on the north, the low-lying Elysian, Repetto, Merced, and Puente Hills on the northeast, the

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Los Angeles-Orange County line on the southeast, and the Pacific Ocean on the south and west. This 480 square mile portion of the coastal plain slopes gently from the bordering highlands on the north and northeast toward the ocean. The locations of these features are shown on Plate 2, entitled "Physiographic Features and Ground Water Basins".

Three main stream channels, the Los Angeles River, San Gabriel River, and Rio Hondo flow into the area from the interior valleys. The Los Angeles River drains the San Fernando Valley and flows southward across the coastal plain to discharge into the Pacific Ocean at San Pedro Bay. The San Gabriel River and Rio Hondo drain the San Gabriel Valley. The Rio Hondo flows southwesterly across the coastal plain and joines the Los Angeles River about midway in its journey across the coastal plain. The San Gabriel River flows southerly across the coastal plain and discharges into the Pacific Ocean about six miles southeast of the mouth of the Los Angeles River.

Authorization for Investigation

The Legislature, by Chapter 832, Statutes of 1929, directed that exploration and investigation be conducted to further a coordinated plan for the conservation, development, and utilization of the water resources of California. As a result of this legislation and pursuant to authorization contained in Sections 225 and 226 of the Water Code, a continuing hydrologic investigation of the Southern California area has been carried on. The work generally included, among other specific objectives, compilation of hydrologic data for use in a full scale investigation when needed and feasible.

Limited work on the investigation of the geology of the Coastal Plain of Los Angeles County was initiated in 1955 and carried on to the

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extent funds were available in the following years. During the 1959 session of the Legislature, responsible local agencies in Los Angeles County were instrumental in obtaining a $150,000 augmentation of the Department's 1959-60 budget to finance an intensive investigation of the ground water basins of Southern California. With these funds, it has been possible to finish this study of the geology of the area and concurrently carry forward hydrologic and operational studies which will lead to completion of plans for operation of the ground water complex underlying coastal Los Angeles County.

Previous Investigations

Because of the coordinated efforts of both oil company and academic geologists to unravel the complex structures involved in the oil fields within the Coastal Plain of Los Angeles County, the geologic history of the deeper and older consolidated sediments is better known than that of the shallower water-bearing materials. The younger shallower sediments have been studied where interest in ground water occurrence and movement has developed. Publications reporting those studies utilized in this investigation are listed in the bibliography.

W. C. Mendenhall of the United States Geological Survey first made a broad survey of wells and geology in the Upper Santa Ana Valley and the coastal plain in 1905. As ground water problems became apparent, interest in the younger alluvial deposits gained impetus and further geologic investigations were conducted.

In 1934, Bulletin No. 45, "South Coastal Basin Investigation, Geology and Ground Water Storage Capacity of Valley Fill", was published by the California Department of Public Works, Division of Water Resources. The fragmentary geologic work, both published and unpublished, which existed

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up to that time was reviewed, and original field and laboratory studies of the water-bearing sediments of the area were made.

After publication of Bulletin No. 45, relatively little work was accomplished on the water-bearing materials until the United States Geological Survey began an investigation which culminated in a series of open-file reports in the 1945-48 period. Some of these reports have been published in recent years. Both the published and unpublished Geological Survey reports are listed in the bibliography.

A report was prepared on an investigation of the West Coast Basin by the California Division of Water Resources, acting as Referee that was entitled "Report of Referee, California Water Service Company versus City of Compton, et al . . .", included considerable detailed geologic work in the West Coast Basin. This work was adopted, with minor modifications, for the purposes of this investigation.

Bulletin No. 170, "Geology of Southern California", published in 1954 by the California Department of Natural Resources, Division of Mines, contains many maps and articles on the geology of the coastal plain. One of the geologic contributions included in this bulletin is the "Geology of the Los Angeles Basin", by A. O. Woodford, J. E. Schoellhamer, J. G. Vedder, and R. F. Yerkes.

Scope of Report

The studies leading to this report began in 1955. At that time, it was planned to investigate only the area in and near Whittier Narrows. Field location of wells, both new and old, began in 1955 and continued sporadically in 1956. Interest in the geology of the coastal plain increased as the formation of the Central and West Basin Water Replenishment District

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was discussed and initiated. By 1957 it had become apparent that geologic studies would have to include a larger portion of the coastal plain than was originally planned, in order to make the geologic picture complete. Consequently, the geologic studies have included all of the Coastal Plain of Los Angeles County, with particular emphasis on the Central Basin.

Previous detailed data accumulated for the West Coast Basin reference study was utilized to the maximum extent. In addition, about 200 drillers logs and electric logs of oil wells, 3,500 water well drillers logs, and 20 electric logs of water wells were used in this study. Additional information was obtained from records of test holes and seismic work of various agencies and companies. The results of over 40 transmissibility tests made during this study and during the West Coast Basin reference study were used. (See Table C, Attachment 2). Outcrops of important water-bearing formations were visited in the field and descriptions of temporary excavations visited by department personnel were carefully studied. Paleontological data were used where possible to aid in correlation of subsurface strata. In all areas, ground water levels and water quality data were used to the extent available in checking the validity of these correlations.

Approximately 50 geologic sections were compiled from the logs of water and oil wells. Fifteen of these are shown on plates included with this report. The cross sections are oriented in north-south and east-west directions, since this follows the prevailing highway net and more wells are found adjacent to major thoroughfares. This also made it convenient to form a grid in order to trace aquifers across the coastal plain. Wells were used wherever possible for matching the cross sections at the points of intersection.

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This report contains six chapters in addition to this introduction. Chapter II, "Geologic History", relates the succession of geologic events for which evidence is present in the area of investigation. The chapter begins with the oldest known events and ends with Recent and presently active events. The third chapter, "Physiography", describes the land forms of the area of investigation. These land forms, or physiographic features, are the result of erosion combined with such transporting agents as water, gravity, and wind acting over a long period of time upon the sediments and rocks comprising the surface of the area. The present drainage system and the water-bearing quality of the physiographic features are discussed in this chapter.

Chapter IV, "Stratigraphy", describes the sediments and rocks now present in the coastal plain and the aquifers and aquicludes that have been identified in these sediments. The lithology of the more permeable Recent and Pleistocene sediments is discussed from the surface downward in some detail. The older underlying sediments and rocks, which are generally nonwater-bearing, are more briefly dealt with.

The fifth chapter, "Geologic Structure", is concerned with the structural features in the coastal plain and their relation to ground water movement. The structural features include anticlines, synclines, domes, and faults.

Chapter VI, "Description of Ground Water Basins", identifies the boundaries of the ground water basins contained within the coastal plain and takes up, basin by basin, the extent, thickness, and lithology of the aquifers and aquicludes within each. The connections between the different aquifers, the areas where recharge to the aquifers is possible from the

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ground surface, and the effects of structural features on the movement of ground water through the basins is also discussed.

The last chapter, "Concluding Remarks", presents a brief statement on the value of the data contained in this report, and recommendations on possible expansion of the data-collection activities.

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CHAPTER II. GEOLOGIC HISTORY

The geologic history of the coastal plain of Los Angeles County is exceedingly complex. Part of the area under study, the Santa Monica Mountains, is included in the Transverse Range geomorphic province, while the rest of the area is in the Peninsular Range province. Each of these two major geomorphic provinces has its own history of development and only large scale earth movements has affected both provinces simultaneously.

The physiography, structure, stratigraphy, and paleontology of an area must be carefully considered in any geologic history, and each subject is complex in its own way. The physiography or development of land forms and their relations to one another, are the product of periods of deformation, deposition of sediments, sea level changes, and erosional patterns. As for structure, pre-Pleistocene geologic structures are not always oriented in the same direction as structures formed since the Pleistocene began. The complex stratigraphy of the area has been further complicated by authors who have assigned different names to the same formation found in separate localities. Finally, paleontological data, in many cases essential to the proper identification of formations, are often lacking in critical areas, especially in sediments of Pleistocene age.

Succeeding sections of this chapter discuss the geologic history of the area of investigation and the broader scale regional geologic events which have played a role in that history. Some of the general features of the area of investigation and the surrounding region are shown on Plate 1, entitled "General Geology and Location of Area of Investigation". For the purposes of the discussion, four major periods are treated: pre-Miocene, Miocene-Pliocene, Pleistocene, and Recent. The geologic history as presented in this chapter is of a general nature, leaving much of the more detailed

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historical relationships of the various formations to be discussed in succeeding chapters. The time divisions employed in discussing geologic events is that employed in most standard geologic publications and is illustrated on Plates 3A and 3B, entitled "Areal Geology". These plates also delineate the detailed areal geology compiled from various sources for this investigation.

Pre-Miocene History

Sediments deposited during the Triassic period are found in the Santa Monica Mountains and other areas of Southern California. Rocks similar in lithology to Jurassic rocks in other parts of California have been identified in the offshore islands, on the Palos Verdes Hills, on the San Pedro shelf in San Pedro Bay, and in Orange County, suggesting relatively widespread deposition of materials in Jurassic time. These Triassic and possibly Jurassic sediments were metamorphosed as a result of rock deformation and intrusions of igneous rocks, perhaps in Jurassic time, and certainly in Cretaceous time. The early history of the region is summarized by E. S. Larsen, Jr. et al in United States Geological Survey Bulletin 1070-B, "Lead-Alpha Ages of the Mesozic Batholiths of Western North America", (1958), a portion of which is as follows:

> "In southern California, the succession of events bearing on the age of the batholith is deposition of fossiliferous Triassic rocks, folding and mild metamorphism during the Triassic, deposition of volcanic rocks and associated sediments of possible Jurassic age, folding and metamorphism of all these rocks, intrusion of the batholith, erosion to a mature surface, deposition of gravels, followed by deposition of fossiliferous Upper Cretaceous sediments (Larsen, 1948). The batholithic rocks are thus certainly younger than the Triassic rocks and older than the Upper Cretaceous sediments. On the basis of regional evidence Larsen (1948) considered them to be early Late Cretaceous."

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The Southern California batholith was intruded over a period of about nine million years ranging from 105 to 114 million years ago. This batholithic intrusion emplaced the granite and granodiorite which now underlie two large areas within the coastal plain. One of these is the "high", or upthrown block, underlying the Torrance Plain and the Palos Verdes Hills, and the other is the downdropped block beneath the Downey Plain; these features are shown on Plate 2 entitled "Physiographic Features and Ground Water Basins". The position of the basement rock has been verified in some areas by deep oil wells. The boundary between these two blocks is a fault system which lies beneath the Newport-Inglewood belt of hills.

Sediments of Early Cretaceous age have not been identified within the coastal plain. Lead-alpha dating of the granitic rock underlying the coastal plain indicates that this rock was probably being emplaced at that time and therefore that period was probably one of uplift and erosion. Portions of the Downey Plain, however, are believed to be underlain by Cretaceous sediments that were laid down upon the irregular surface of the crystalline basement. In the Torrance Plain, Cretaceous sediments are missing. Upper Cretaceous continental sediments, although not identified in the deeper parts of the coastal plain within Los Angeles County, were deposited unconformably on older formations in the Santa Monica and Santa Ana Mountains. In the Santa Monica Mountains an unconformity at the top of these basal continental Upper Cretaceous rocks indicates that some tilting occurred prior to the deposition of the overlying marine Upper Cretaceous sediments.

After minor structural deformation and erosion, marine sediments of Paleocene and Eocene age were deposited where the Santa Monica Mountains and the Santa Ana Mountains are now found, and probably on the coastal plain. During these two epochs, the area west of the Newport-Inglewood uplift was

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probably a physiographic "high" (Corey, 1954). After another period of deformation and erosion, continental sediments of Oligocene age were deposited in some areas. These continental beds indicate that at least part of the region was above sea level in Oligocene time. Geographic distribution of the highlands and the shorelines at that time are only vaguely known.

Miocene and Pliocene History

Deposition of marine sediments resumed in early Miocene time, accompanied by intrusion and extrusion of as much as 4,000 feet of basaltic material. An orogeny or series of orogenic movements during mid-Miocene time caused differential depression of the existing early Miocene features and further encroachment of the sea. The main embayment affecting the Los Angeles area, known as the Capistrano embayment (Reed, 1943), extended in a northwesterly direction across Orange County to the vicinity of Los Angeles. The landward end of this embayment has been referred to in geological literature as the Los Angeles Basin. The embayment served as a catchment area for materials being eroded from surrounding highlands. It reached a maximum size during middle and upper Miocene time. As sediments collected in the downwarped basin, areas around the margins were uplifted, exposing more material to weathering and erosional processes. Thus the elevation of the source areas controlled the rate of deposition.

Emery (1960) states that the series of ocean basins now found off Coastal Southern California also originated in the Miocene epoch. As the Los Angeles Basin filled with sediments, the excess material overflowed into adjacent, nearshore basins. As these nearshore basins filled, the sediments spilled into basins farther from shore. This process of filling and overtopping continues within the present offshore basins.

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Repeated unconformities in the sediments around the margins of the basin are primarily the result of the tectonic activity which accompanied the great downwarping of the basin and the rising of the adjacent highlands. By late Miocene or early Pliocene time the depth of the ocean embayment reached approximately 4,000 to 6,000 feet. Sediments approaching 5,000 feet in thickness were deposited during early Pliocene time. The shoreline extended to the east at least as far as Pomona and north as far as the San Gabriel Mountains. All features now on the coastal plain, including the Newport-Inglewood uplift, were probably minor subsea features, if indeed they existed at all. During late Pliocene time the downwarped Los Angeles basin became shallower and more limited in extent as it filled with another 3,500 feet of sediments. By the end of the Pliocene epoch the coastal plain had undergone repeated cycles of erosion and deposition accompanied by folding and faulting of the pre-existing sediments.

To summarize the geological events up to the end of Pliocene time: The Southern California batholith was emplaced during the Jurassic-Cretaceous epochs followed by further deposition and differential earth movements. During mid-Miocene time continued earth movement formed the embayment which contains the present coastal plain and raised the adjacent highlands. From mid-Miocene time until the end of Pliocene time the basin became shallower as it filled with sediments.

Sediments deposited during these early periods are for the most part nonwater-bearing. However, in some areas, potable water is present in the Pliocene sediments and in the older rocks.

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Pleistocene History

The Pleistocene epoch is generally considered to have begun approximately 1,000,000 years ago. Major glaciation occurred at least four times during this epoch and caused fluctuations in sea level of at least 400 feet. The geologic events of Pleistocene time are illustrated on Plate 4, entitled "Generalized Pleistocene Chronology, Coastal Plain of Los Angeles County". The interpretation of events shown on Plate 4 were based on data collected during the course of this investigation, and time unit and sea level changes are modified from previous work by Hinds (1952), Fairbridge (1958), Hopkins (1959), Flint (1957), and others.

The shoreline during early Pleistocene time extended along the south side of the Santa Monica Mountains, and probably across the San Gabriel Valley, north of the area now occupied by the Elysian, Repetto, Merced and Puente Hills. These hills were offshore features in the process of emerging from the sea. From here, the sea apparently extended in a southeasterly direction along the southwestern edge of the Santa Ana Mountains.

Depth of the water in the Whittier Narrows area, according to microfossil data, exceeded 500 feet. Location of the old shoreline in the vicinity of the present Elysian, Repetto, Merced, and Puente Hills is based on marine fossils found in lower Pleistocene deposits in the vicinities of Whittier and Los Angeles Narrows. The Palos Verdes Hills were also covered by the ocean during early Pleistocene time. As time progressed, all these areas were elevated above sea level. Such larger physiographic features as the Santa Monica Mountains, San Gabriel Mountains, and the Santa Ana Mountains in Orange County probably existed at least as subsea features

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since early Miocene time. During Pliocene and Pleistocene time these mountains were being uplifted to their present elevations.

Uplift, accompanied by erosion, was relatively rapid in some areas but slow in others. Meanwhile the downdropped areas continued to subside and the Coastal Plain of Los Angeles County was filled with more than 1,300 feet of sediments in early Pleistocene time. These sediments constitute the San Pedro formation. The Newport-Inglewood uplift is the only geologic feature on the coastal plain which may have occasionally risen above the surrounding flat-lying areas.

A very important unconformity separates lower and upper Pleistocene sediments throughout most of the California Coast Ranges. The orogeny suggested by this unconformity has been called the "Pasadena" or "Coast Range" disturbance (Reed, 1943b, p. 118). This hiatus, as shown on Plate 4, also referred to as the mid-Pleistocene orogeny, separates sediments which are of early and late Pleistocene age. The available evidence suggests, however, that several disturbances took place during the Pleistocene epoch and that the time of the unconformity could vary from area to area as erosion took place with each new uplift.

In spite of the relatively short span of geologic time involved, the rate of deformation in the coastal plain is adequate, if assumed continuous, to have formed most of the present features since the beginning of Pleistocene time. The assumption that tectonic activity has been continuous from the Pleistocene to the present time is supported by two pieces of geologic evidence. First, upper Pleistocene marine terraces are found on the Palos Verdes and Elysian Hills and on the Santa Monica Mountains at elevations varying from 200 feet to 1,000 feet above the present sea level. Equivalent terraces elsewhere are probably buried beneath the coastal plain

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or have been removed by erosion. Secondly, differential tilting and deformation of Pleistocene and Recent aquifers has occurred, and changes in drainage patterns, wind gaps, and other features may have been caused in part by tilting or by uplift.

At the beginning of late Pleistocene time the Santa Monica Mountains, the Elysian Hills, Repetto Hills, Merced Hills, and the Puente Hills apparently were not as high above sea level nor as rugged as they are at the present time. They did, however, form the ocean shoreline of late Pleistocene time.

Marine fossils in upper Pleistocene sediments near the cities of Santa Monica, Beverly Hills and Los Angeles indicate that at one time the ocean extended inland across the La Brea Plain. Physiographic features similar to those of the La Brea Plain are found in the Montebello Plain. Together, they suggest that an upper Pleistocene shoreline existed near the south edge of the Repetto and Merced Hills. No certain evidence has been found that upper Pleistocene marine sediments were deposited in the vicinity of the Coyote Hills, although one late Pleistocene marine fossil locality has been reported (Hoskins, 1954). The lack of upper Pleistocene marine terraces and the continental nature of the Pleistocene deposits within the inland valleys led Eckis (Calif. D.W.R., 1934) to infer that late Pleistocene seas never extended inland beyond the present margins of the coastal plain.

Throughout late Pleistocene time sediments were being deposited primarily in the downfolded areas of the coastal plain and, probably simultaneously, were being deformed to some extent along such uplifts as the Palos Verdes Hills, Repetto Hills, Puente Hills, and possibly the Santa

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Monica Mountains. These late Pleistocene sediments are named the Lakewood formation in this report. The period during which they were being deposited is illustrated on Plate 4. The Newport-Inglewood belt of hills may have existed as a line of very low hills in late Pleistocene time. These hills were undergoing continuous folding and faulting, but in general, deposition seems to have been the predominant process during this time. Outcrops clearly indicate that the basal portion of these upper Pleistocene deposits have been tilted as much as eleven degrees near areas of uplift, and have been downwarped beneath the present surface of the Downey Plain.

Although the western portion of the coastal plain was below sea level during at least part of late Pleistocene time, the nature of the upper Pleistocene deposits indicates that the shoreline apparently fluctuated and the resulting deposits are extremely complex.

World-wide changes of sea level during Pleistocene time caused the oceans to withdraw several times from the coastal plain. This was combined with intermediate periods of advance of the ocean onto the land. These recessions and advances occurred independently of the land movements. Plate 4 shows diagrammatically the possible fluctuations of sea level in Pleistocene and Recent times with suggested dates for each fluctuation. Withdrawals of the ocean caused erosion, and a rise in sea level caused deposition. That both of these conditions occurred at least once in late Pleistocene time is clearly seen in the stratigraphic sequences in the coastal plain. At least one deposit of marine sand (which now comprises the Gage aquifer) was exposed as the sea level fell, probably during the Illinoian glacial stage. A channel was eroded into these deposits by a river, or rivers, entering the coastal plain through the Los Angeles or Whittier Narrows or both. The resultant channel formed by these streams

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extended, not toward Dominguez Gap as does the present Los Angeles River, but westerly toward Gardena and Redondo Beach. This channel was backfilled, with coarse river gravels that form the present Gardena aquifer, as sea level rose because of the melting of the Illinoian stage glaciers.

As sea level continued to rise (probably during the beginning of the Sangamon interglacial period), portions of the Gardena aquifer inland from Lynwood were removed by wave action, and what remained was then covered by marine sands, silts, and clays. These new sand deposits cannot now be differentiated from the lower sands, and together they form the Gage aquifer.

All evidence of the stream which flowed through the Gardena and Redondo Beach areas, as well as the Gage aquifer, was eventually covered by deposition of shallow marine silts, clays and some sands. In the El Segundo Sand Hills these deposits (exposed in deep cuts in 1957 and 1958) consisted of beach sands. These beach sands extended across what is now Ballona Gap onto Ocean Park Plain where they were partly interfingered with later upper Pleistocene alluvial fans deposited by streams emanating from the Santa Monica Mountains. Erosion has subsequently removed the dunes and underlying materials from Ballona Gap. Further inland, alluvial material was being deposited concurrently by the major stream systems. Since deposition of the Gage and Gardena aquifers and the overlying fine-grained sediments, they have all been slightly folded and cut by minor faults along the Newport-Inglewood uplift.

During the last lowering of sea level, at the beginning of the Wisconsin glacial stage, it appears that the beach sands along the El Segundo-Redondo Beach area were exposed to the winds and blown inland to form the present El Segundo Sand Hills and part of the Ocean Park Plain. As sea level fell and the sea retreated, the Los Angeles and San Gabriel River

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systems eroded the upper Pleistocene sediments, forming Dominguez Gap. Streams draining the Santa Monica Mountains across the Sawtelle Plain and the Hollywood Piedmont Slope cut through the El Segundo Sand Hills and probably the Baldwin Hills to form Ballona Gap. At various times, the Los Angeles River and possibly the Rio Hondo-San Gabriel River system drained seaward through Ballona Gap. Since the last rise of sea level (post-Wisconsin or Recent time), the Los Angeles and San Gabriel River systems have reached the sea mainly through Dominguez and Alamitos Gaps, respectively.

Fluctuations of sea level associated with the last glacial stage have been rather complex in other portions of the world and available evidence indicates that such fluctuations were complex in this region as well. Because of these complexities it is almost impossible to tell at which period any given sand or gravel was deposited or when any given gap in the coastal plain was cut or backfilled.

Wind gaps in the Santa Monica Mountains, and the Elysian, Repetto, Merced, and Puente Hills indicate that streams other than those now existing have flowed from the San Fernando and San Gabriel Valleys across what are now the bordering highlands into the present coastal plain. Most of these streams probably were formed while the bordering highlands and mountains were being raised.

Recent History

Recent geologic time, as defined in this report, began with the melting of the last extensive world-wide glacial ice sheets. This event began about 15,000 years ago according to Shepard (1956) and Hopkins (1959), and evidently occurred rapidly, for the sea level rose at an accelerated rate. Coarse gravels were deposited or backfilled in the stream channels

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throughout the coastal plain. In Ballona Gap such material is found up to 60 feet below the present sea level. This stream aggradation was accompanied by wave erosion of the marine terrace deposits on exposed beaches and by marine deposition offshore. About 9,000 years ago the rate of sea level rise began to decrease and, as stream gradients decreased, finer materials were deposited in Dominguez and Ballona Gaps. Baymouth bars cut off the mouths of streams at various times, forming lagoons and playa lakes. At the present time Dominguez, Ballona, and Alamitos Gaps all contain considerable lagoonal deposits at shallow depth. The sea level was stabilized near its present level about 4,000 years ago, though a slight sea level rise occurred about 1200 A. D. which may have led to deposition of the peat now found in some areas near the coast.

Events that have occurred during the period of recorded history may help to reveal what has happened during the geologic past. Prior to 1825 and again during the flood of 1867-68, the Los Angeles River flowed westerly from the Los Angeles Narrows through Ballona Gap instead of south through Dominguez Gap. It is reasonable to assume that if rapid changes in the drainage patterns can occur in such a short time they may have occurred many times in the geologic past. The Santa Ana River is shown on older United States Geological Survey topographic maps as flowing westerly from the mouth of Santa Ana Canyon across Orange County in the direction of the present Coyote Creek drainage. The sediments which fill the basin, creating the flat, tilted plain that now exists, probably were deposited by streams migrating back and forth across the coastal plain.

Earthquakes occurring during historic times indicate that the coastal plain and surrounding highlands are still actively being folded and faulted. Deposition of active dune sands along the coast bordering

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Santa Monica Bay and erosion and deposition of sediments by streams and by the ocean, is continuing where not controlled by man.

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CHAPTER III. PHYSIOGRAPHY

This chapter describes the land forms or physiographic features in and surrounding the Coastal Plain of Los Angeles County. Within the area of investigation portions of two geomorphic provinces are present. The coastal plain is in the northwest corner of the Peninsular Range geomorphic province, which extends southward into San Diego County and Baja California. The Peninsular Range province consists of essentially northerly and northwesterly trending mountain ranges and associated valleys. This province is bordered on the north by the Transverse Range province, an east-west trending series of mountains which include the Santa Monica and San Gabriel Mountains. The northern portion of the coastal plain is a part of the transition area between these two major geomorphic provinces and the physiographic features reflect the complexity of the underlying structure caused by the abruptness of this transition.

The major land forms of the coastal plain consist of bordering highlands and foothills, older plains and hills, and younger alluvial plains, the rivers which drain the area, and the offshore topography. Names of land forms utilized by Poland, et al., (1945, 1956) are used herein except where additional features have been named, and their locations are shown on Plate 2.

Bordering Highlands and Foothills

Highland areas adjacent to the coastal plain include the Santa Monica Mountains, the Palos Verdes Hills, and the Puente Hills. All of these features are geologically young in origin, moderate to bold in relief, and generally mature in form.

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The highest elevations on these highlands within the area of investigation are: Santa Monica Mountains, 2,126 feet; Puente Hills, 1,387 feet; and the Palos Verdes Hills, 1,480 feet. The highland areas are more or less gullied and incised by streams, though extensive relatively smooth surfaces remain which have not been entirely removed. These smooth surfaces and their associated subdued hills and valleys are possibly remnants of an old erosion surface (Eldridge and Arnold, 1907), which has been deformed, uplifted, and removed in most areas by more recent erosion.

Thirteen wave-cut terraces on the Palos Verdes Hills, extending up to 1,300 feet above sea level, have been identified by Woodring, et al., (1946). Similar wave-cut terraces have been described in the Santa Monica Mountains and offshore islands (i.e., San Miguel, Santa Rosa, and Santa Cruz Islands) to the northwest and west of this area, but within the coastal plain only the equivalent of the lower terraces have been identified. As mentioned in the chapter on geologic history, these terraces indicate continued uplift of the highland areas in late Pleistocene time.

The highland areas generally consist of relatively impermeable rocks which yield little water to wells. Minor springs and seeps add to direct runoff from precipitation and are probably a negligible source of supply to adjacent water-bearing areas. Springs and seeps contribute to slope stability problems in certain areas.

The foothills are the Elysian, Repetto, and Merced Hills. These hills are mostly underlain by Tertiary rocks and may have been one continuous surface at some time in the past (Poland, et al., 1956). These features, like the highlands, are geologically young. The Elysian and Repetto Hills are now separated by the Los Angeles Narrows, and the Repetto and Merced

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Hills are separated by an abandoned stream channel along Potrero Grande Drive. Whittier Narrows separates the Merced Hills from the Puente Hills.

Maximum elevations in the foothills are: Elysian Hills, 757 feet; Repetto Hills, 735 feet; and the Merced Hills, 550 feet. These features have moderate relief and have been considerably eroded. Probable wind gaps are present in the Elysian Hills along Los Feliz and Silverlake Boulevards. Wind gaps are also present in the Repetto Hills north of Boyle Heights, east of City Terrace, and along Eastern Avenue, Monterey Pass Road, Atlantic Boulevard and Potrero Grande Drive.

The Tertiary sediments in these foothills are essentially nonwater-bearing. Water-bearing materials are present only in small thin patches and supply little water to wells.

Older Plains and Hills

Many physiographic features in the coastal plain are characteristically covered with a reddish, or brown, deeply weathered soil formed prior to Recent time. In some areas this soil and the surface which it forms may be in its original position, but in many areas both it and the underlying sediments have been warped, folded, faulted and at least partially eroded away. In other areas this deeply weathered soil has been downwarped and covered with younger alluvial material.

Land forms characterized by the red weathered soil include older dissected alluvial aprons, the Coyote Hills, older marine plains, the El Segundo Sand Hills, and the Newport-Inglewood belt of hills. Most of these land forms were formed at essentially the same time and have been deformed and eroded to about the same degree. The Coyote Hills, near the eastern boundary of the county, and the Baldwin and Signal Hills, which are part of

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the Newport-Inglewood belt of hills, have been uplifted and eroded to a greater degree than most of the other features included in this group. Available evidence suggests, however, that a deeply weathered soil was formed on these features before the latest erosional cycle began.

Older Dissected Alluvial Aprons

The older dissected alluvial aprons are located adjacent to the highlands and foothills previously described. In this category are the Santa Monica Plain, La Brea Plain, Montebello Plain, and the Santa Fe Springs Plain. Their locations are shown on Plate 2. Soils of deeply weathered, reddish material, 3 to 20 feet thick, have developed on the surface of these alluvial aprons. Within this soil profile, rock fragments, cobbles and boulders are commonly deeply weathered and soft. These soil features are easily recognized in most of the areas where they have been preserved from erosion. The older dissected alluvial aprons are generally underlain by water-bearing sediments of considerable thickness. Some parts of these areas are susceptible to recharge, and changes in ground water storage could occur in some underlying aquifers.

Santa Monica Plain. The Santa Monica Plain lies along the south flank of the Santa Monica Mountains and extends from the ocean inland to the Newport-Inglewood belt of hills. The plain has been dissected by streams draining the Santa Monica Mountains. Streams draining Sepulveda, Dry, Stone, and Brown Canyons have eroded and back-filled an area near Sawtelle, leaving a surface which slopes to the southeast and lies at a lower elevation than the Santa Monica Plain. This area, referred to as the Sawtelle Plain in this report, is

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discussed under a subsequent subheading - Alluvial Aprons. The Santa Monica Plain was originally deposited, however, in the form of several large alluvial fans which overlapped onto the Ocean Park Plain and Beverly Hills. Remnants of the surface of these fans are found 175 feet to about 500 feet above sea level. Gradients from apexes to the lower end of the surfaces average about 150 feet per mile.

La Brea Plain. The La Brea Plain is located east of the Newport-Inglewood belt of hills and west of the Elysian Hills. A surface was originally cut by the sea during Pleistocene time on lower Pleistocene and older formations. On this eroded surface 90 to 200 feet of alluvial sediments have been deposited, the top of which now forms the La Brea Plain.

The La Brea Plain has apparently been warped into an east-west anticlinal structure extending westerly from the Elysian Hills. Because of this warping and partial uplifting, the plain is being dissected and removed by erosion. A younger series of alluvial fans forming the Hollywood piedmont slope have buried the La Brea Plain from the north. Poland, et al., (1956) described the La Brea Plain and the Santa Monica Plain as being of similar origin, and additional exposures and close study of the land forms indicate that both of these forms are related in age to the Ocean Park Plain and the Torrance Plain.

Montebello Plain. The Montebello Plain extends south of the Repetto and Merced Hills between the Los Angeles River and the Rio Hondo and has been folded by an east-west anticlinal flexure extending westerly from the Montebello oil field. South of this anticlinal area, the Montebello

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Plain dips very gradually toward the Downey Plain and continues beneath a portion of it. In the area which has been affected or folded by the extension of the Montebello anticline, the Montebello Plain has been dissected by small streams draining southward from the Repetto Hills, forming deep gullies crossing the axis of the fold. Along the north side of the Montebello Plain near Boyle Heights, the physiographic relationships suggest that a marine-cut terrace was formed prior to deposition of the alluvial materials that now form the present surface of the Montebello Plain in that area. However, fossil evidence supporting this theory is absent.

Santa Fe Springs Plain. The Santa Fe Springs Plain is located south of Whittier and east of the San Gabriel River, in the area of the City of Santa Fe Springs, and is apparently a continuation of the Coyote Hills uplift to the southeast. The Santa Fe Springs Plain is only a low, slightly rolling topographic feature unlike the somewhat rugged Coyote Hills to the southeast. The Santa Fe Springs Plain has probably been warped by the Santa Fe Springs-Coyote Hills anticlinal system and dips gently both to the northeast toward Whittier and to the southeast toward the Downey Plain. The difference in elevation ranges from 100 to 175 feet above sea level.

Coyote Hills

The Coyote Hills, a youthful anticlinal feature, are most developed in Orange County. The feature continues northwesterly into Los Angeles County where it becomes a low hill dissected by streams and grades gradually into the Santa Fe Springs Plain.

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Maximum elevation in the Coyote Hills is 600 feet above sea level and occurs in Orange County. The hills that lie to the west of La Habra Road and in the area of investigation have elevations of approximately 25 feet to 325 feet above sea level. The north slope is steeper than the south, which grades gradually into the Downey Plain.

Older Marine Plains

The Older marine plains include the Torrance, Long Beach, and Ocean Park Plains, all of which have similar histories and are closely related to the Newport-Inglewood belt of hills. All of these plains are underlain by water-bearing sediments.

During upper Pleistocene time, it is probable that the Ocean Park Plain continued undisturbed southward and was united with the El Segundo Sand Hills and Torrance Plain. The Torrance and Long Beach Plains, originally one, have been separated by downcutting of the Los Angeles-Rio Hondo-San Gabriel River systems. Landing Hill, part of the Newport-Inglewood belt of hills, and Long Beach Plain have been separated because of erosion by Coyote Creek and possibly the Rio Hondo and San Gabriel River.

Much attention has been given to the fact that marine fossils are commonly found from 10 to 30 feet below the surface of the Long Beach, Torrance, and Ocean Park Plains. Fresh water fossils have also been observed in shallow deposits in the Torrance Plain near Dominguez Creek. Many remains of extinct land mammals have been found in this same thickness of sediments in the Long Beach and Torrance Plains. These fossils suggest that there were periods of complete or nearly complete emergence of the land between periods of subsidence so that both land and sea animals could have access to the area.

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Ocean Park Plain extends inland from the Pacific Ocean approximately three miles bordering on the north of Ballona Gap. Elevation on the plain ranges from sea level to 200 feet above sea level. Poland, et al., (1956) lists three physiographic areas within the plain: a bench on the eastern portion, a central unit with an undulating surface, and a ridge-and-trench area on the western portion. His ridge-and-trench area is equivalent to the El Segundo Sand Hills to the south. The Ocean Park Plain is slightly dissected by local streams.

The Torrance Plain parallels the Newport-Inglewood belt of hills from Ballona Gap southwest to Dominguez Gap. It is a broad featureless area only slightly dissected by local streams north of Centinela Creek and cut in the south by Dominguez Creek. The plain is immediately underlain by fine-grained materials of marine and nonmarine origin, and in small low lying areas the fine-grained materials are overlain by Recent alluvium.

The Long Beach Plain is located on the southwest side of the Newport-Inglewood belt of hills between Dominguez and Alamitos Gaps. This plain is underlain by the same kind of sediments as the Torrance Plain; however, no aquifers have been delineated in this area.

El Segundo Sand Hills

The El Segundo Sand Hills extend from Ballona Gap south to Torrance and the Palos Verdes Hills, and approximately three to four miles inland from the ocean. Remnants of similar hills are found on the western edge of Ocean Park Plain. The sand hills consist of a narrow strip of active or recent dunes along the coast and older stabilized sand dunes inland. The active dunes are up to one-half mile wide, with a maximum elevation of 185 feet above sea level. These active dunes have undergone

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at least two stages of development, as shown by excavations for the Scattergood Steam Plant of the Los Angeles Department of Water and Power near El Segundo. A earlier phase of the recent unweathered sand dunes had a surface which was inhabited by man and subsequently covered with over 30 feet of sand to form the present dunes.

The active dunes are underlain by older sand dunes of probable late Pleistocene age. In several areas of the El Segundo Sand Hills, fossils and sedimentary features in excavations indicate that these older sand dunes were originally beach deposits which have been altered in form by wind action and deeply weathered. These beach deposits resemble in many respects the marine and underlying portions of the Torrance and Long Beach Plains and are probably contemporaneous with them. The form of the older beach sands was modified by the wind so that the surface now has closed depressions. The closed depressions have been formed by a combination action of removing and piling up of sand. One to three miles inland, the older sand dunes overlie silts and clays which apparently were deposited on the landward side of the beach sands and which now form a portion of the Torrance Plain. Weathering and associated stabilizing processes have removed all but the gross features of dune topography in the older sand dune area. Thin remnants of similar dune sands have been observed in excavations for the Harbor Freeway on the Rosecrans Hills.

Newport-Inglewood Belt of Hills

The area of deformation that extends from the foot of the Santa Monica Mountains near Beverly Hills southeasterly as far as Newport Beach in Orange County is named the Newport-Inglewood belt of hills and plains. As originally defined by Poland, et al., (1956), this belt of hills and

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plains included the Torrance and Ocean Park Plains; however, in this report the term Newport-Inglewood belt of hills is used to delineate the area of deformation exclusive of the Torrance and Ocean Park Plains which have been described separately. The area of deformation varies in width from one to four miles and is underlain by a series of folds and faults which have given rise to most of the surface hills, plains, and mesas. For this reason, in discussions of structural geology this belt of hills is referred to as the Newport-Inglewood uplift. Poland's findings indicate that the many features of the Newport-Inglewood belt of hills and plains are of the same age as the Torrance and Ocean Park Plains. Observations during this investigation support this conclusion.

In the Newport-Inglewood belt of hills, the surface is frequently underlain by a highly weathered reddish colored soil which is itself underlain by sand and silt containing marine fossils. This sand and silt was deposited in a shallow sea or lagoonal environment. The original surface, after withdrawal of the sea, extended into Ocean Park Plain, Beverly Hills, and possibly the La Brea Plain. The marine-formed surface may have extended to the Montebello Plain, although fossil evidence has not been found to substantiate this theory. In general, the upper Pleistocene sediments have been strongly deformed in some areas along the uplift and completely removed by erosion in others.

The following paragraphs briefly describe the various features that comprise the Newport-Inglewood belt of hills, all of which are underlain by water-bearing sediments.

The Beverly Hills are the most northerly feature of the Newport-Inglewood belt of hills which have easily identifiable topographic characteristics. They range in elevation from 75 feet to 300 feet above sea level.

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The area displays a rolling topography, as a result of warping and of erosion by local streams. The marine upper Pleistocene deposits capping Beverly Hills were probably continuous with the Ocean Park and Torrance Plains and with remnants of similar sediments which now cap Baldwin Hills. The Beverly Hills apparently have been warped and faulted. In a small area near Cheviot Hills, which is a portion of Beverly Hills, lower Pleistocene marine sediments are exposed (Rodda, 1957); elsewhere they are overlain by marine upper Pleistocene deposits.

The Baldwin Hills, south of Ballona Gap, are a prominent feature extending some 513 feet above sea level and more than 400 feet above the central lowlands to the east and northeast. Sediments of the Baldwin Hills have been considerably warped and faulted. The north flank of the Baldwin Hills has been deeply incised by erosion, whereas the south flank slopes gently to the Torrance Plain and Rosecrans Hills.

The Rosecrans Hills, beginning near Inglewood and extending southward to Dominguez Hill, comprise a low swell about three miles wide with its crest ranging from 100 to 240 feet above sea level. The surface of the Rosecrans Hills is underlain by upper Pleistocene sediments which dip southwesterly toward and merge with the Torrance Plain and northeasterly toward and probably beneath the Downey Plain.

Dominguez Hill, an anticlinal dome with a northwest-southeast trending axis, is located just northwest of Dominguez Gap. On the west and north, Dominguez Hill grades into the Torrance Plain and the Rosecrans Hills. Elevations range from 20 feet to 195 feet above sea level. Little erosion has occurred on the hill to modify the surface topography, with the exception of the east flank where a local stream has cut a deep gully, and on the southeast where the Los Angeles River has eroded into the hill.

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Signal Hill, Bixby Ranch Hill and Bouton Plain were grouped by Poland, et al., (1956) as the Signal Hill uplift, but are considered to be separate though related features in this report. Signal Hill, southeast of Dominguez Gap, rises to an elevation of about 365 feet above sea level. Its southwesterly side is approximately bounded by a fault scarp. The north side of Signal Hill slopes gradually down to the Bouton Plain, which in turn slopes northerly toward the Downey Plain. On Signal Hill the upper Pleistocene sediments have been folded and eroded to such a degree that they have been removed, exposing the lower Pleistocene sediments in small areas. Southeast of Signal Hill is Bixby Ranch Hill, which is located to the northwest of Alamitos Gap. The south and north sides of Bixby Ranch Hill are apparently closely related to fault scarps.

Landing Hill, although just across Alamitos Gap in Orange County, is another feature of the Newport-Inglewood belt of hills. The surface slopes to the northeast beneath the Downey Plain and is capped with the same type of sediments as those on Signal Hill and the remainder of the Newport-Inglewood belt of hills.

Younger Alluvial Plains

Younger alluvial plains include those areas where alluvium has been deposited in Recent time. The alluvial material has buried parts of the older weathered surface. The younger alluvial plains have been grouped into alluvial aprons and the Downey Plain. All of these areas are underlain by water-bearing material.

Alluvial Aprons

The younger alluvial aprons consist essentially of coalescing alluvial fans or alluvial piedmont slopes which have overlapped in Recent

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time some of the older Pleistocene plains previously mentioned. These younger alluvial aprons include the Sawtelle Plain, Hollywood piedmont slope and the La Habra piedmont slope.

The Sawtelle Plain is essentially a thin sheet of alluvium deposited on an eroded surface in the area surrounded by the Santa Monica and Ocean Park Plains and Beverly Hills. Alluvium in the Sawtelle Plain appears to be relatively thin, possibly no more than 30 or 40 feet deep. The surface slope averages between 60 and 80 feet per mile.

The Hollywood piedmont slope lies south of the Santa Monica Mountains, north of the La Brea Plain, and east of the Newport-Inglewood belt of hills. This area consists of several small alluvial fans deposited by streams draining from the Santa Monica Mountains. These fans form a relatively flat surface, with minor undulations, that slopes to the south and southwest with a gradient of about 90 feet per mile. The small coalescing fans are approximately 100 feet thick near the base of the Santa Monica Mountains, but to the south near Beverly Hills, excavations indicate that they decrease to a thickness of 10 to 30 feet. The Hollywood piedmont slope has been deposited partly on the La Brea Plain, Beverly Hills, and the Elysian Hills. Along the north side of Ballona Gap, sediments from the Hollywood piedmont slope and from Sawtelle Plain have been deposited as small alluvial fans. These small fans are moderately thick and have overlapped and become interbedded with sediments of Recent age deposited by the Los Angeles River which, as late as 1868, flowed through Ballona Gap into the ocean near Venice.

The La Habra piedmont slope extends southeasterly along the southwest foot of the Puente Hills from Whittier Narrows into Orange County.

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This area consists of several small alluvial fans deposited by streams draining the Puente Hills. These fans coalesce forming an undulating surface that slopes to the south and southwest with a gradient of about 170 feet per mile. This area has been more extensively dissected than has the Hollywood piedmont slope. As a result of this dissection, the topographic expression of the La Habra piedmont slope is quite complex. Some of the exposed features are probably of the same age as the Santa Fe Springs Plain and the Montebello Plain, that is, of upper Pleistocene age. Many younger fans of shallow depth cover portions of the area.

Downey Plain and Related Features

The Downey Plain, the largest area of Recent alluvial deposition, is located south and southeast of the La Brea, Montebello, and Santa Fe Springs Plains, and of the Coyote Hills, and northeast of the Newport-Inglewood belt of hills (Poland, et al., 1956). It extends from Ballona Gap across the central lowland of the Coastal Plain of Los Angeles County into the Coastal Plain of Orange County nearly to Santa Ana. The Downey Plain ranges in elevation from 275 feet in the Los Angeles Narrows and 200 feet in the Whittier Narrows to sea level at the ocean near Dominguez Gap. The slope of the Downey Plain varies from 7 to 23 feet per mile, but is generally less than 18 feet per mile. It is essentially a depositional feature, although minor erosion has occurred. Alluvial fans formed by the Los Angeles and Rio Hondo-San Gabriel River systems have coalesced to form a very gentle plain. During past flood times these large rivers have swung over most of the area depositing their debris. Near the ocean some of the stream deposited sediments are interbedded with marine and tidal sands, gravels, and clays.

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Ballona Gap, located between the Baldwin Hills and Beverly Hills and extending to the ocean, was initially formed by headward erosion from the ocean, capturing drainage from the Sawtelle Plain and the Hollywood piedmont slope. Although the Los Angeles River has flowed through the Gap, available evidence indicates that it has caused less erosion than the smaller streams.

Dominguez Gap includes the lower portion of the Los Angeles River area between Dominguez and Signal Hills. It is about two miles wide and slopes toward the ocean at a gradient of about four feet per mile.

Alamitos Gap, separating Long Beach Plain and Bixby Ranch Hill from Landing Hill, has been eroded by Coyote Creek and presumably other streams. The surface slopes oceanward at the same gradient as Dominguez Gap.

The Los Angeles Narrows, located between the Elysian and Repetto Hills, is an erosional feature cut through a relatively weak portion of the Santa Monica Mountains by the Los Angeles River. Terraces and complex subsurface alluvial deposits indicate that erosion and deposition has been complex in the Narrows.

The Whittier Narrows separates the Merced and Puente Hills and forms the avenue through which drainage from the San Gabriel Valley and surrounding highlands passes to the coastal plain. The two major streams passing through Whittier Narrows are the Rio Hondo and the San Gabriel River. The width of the Whittier Narrows varies from 1.6 miles to 2 miles. Although generally flat with steep sides, the surface configuration of the Narrows is further complicated by terraces, alluvial fans from local small canyons, and abandoned stream courses and meanders. This physiographic

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feature appears to have been formed in late Pleistocene time, although Slosson (1958) suggests that the area was a submarine canyon in lower Pliocene time.

Drainage Systems

The Coastal Plain of Los Angeles County is drained primarily by the Los Angeles and Rio Hondo-San Gabriel River systems. Within historical times the Los Angeles River has flowed through Ballona Gap, and the Santa Ana River in Orange County has drained through Alamitos Gap. It is probable that all three river systems crossing the coastal plains of both counties have entered the ocean at various locations from Dominguez Gap on the north to Santa Ana Gap near Huntington Beach on the south.

Minor stream systems include Dominguez Creek on the Torrance Plain which drains to the ocean and Comptom Creek on the Downy Plain that enters the Los Angeles River northeast of Dominguez Hills. Coyote Creek, flowing through the Coyote Hills, now occupies a wide valley much larger than ncessary for its present flow. Physiographic evidence in the area north of Coyote Hills indicates that Brea Creek flowed down the present Coyote Creek channel in late geologic time, but has been diverted to its present channel southeast of Coyote Hills leaving the old channel to drain only its present small watershed.

Physiographic evidence is abundant that other streams have drained the San Gabriel Valley across the Repetto Hills to the coastal plain, and their courses have since been abandoned, forming wind gaps. What are probably wind gaps are also found in the Santa Monica Mountains; they may represent relatively old stream courses which drained the San Fernando Valley at the beginning of late Pleistocene time.

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Offshore Physiography

Physiography of the offshore area of Southern California is well described by Emery (1954), Shepard (1948), Terry, et al., (1956), Stevenson, et al., (1958), and Gorsline and Emery (1959). This large offshore area is described briefly in this report because of the close stratigraphic and physiographic relationship it has with the onshore area covered by this investigation. The offshore features are shown on Plate 2.

The first submarine physiographic province encountered is the continental shelf. The western boundary of the continental shelf, roughly delineated by the 50 fathom contour (300 feet), parallels the coastline at distances from shore varying from a few hundred feet to 8 or 10 miles. The continental shelf slopes seaward at a gradient of about 25 feet per mile in Santa Monica and San Pedro Bays. The shelf is generally smooth, though such minor irregularities as longshore troughs, mounds, bars, and depressions occur in water less than 20 feet deep where they are constantly changing position. Such features are known as micro-relief. Along the break in slope at the outer margins of the continental shelf are terraces, steps, and notches. Submarine canyons interrupt the shelf and may represent lines of weakness or remnants of pre-existing drainage channels. A zone of bedrock mounds, more than 2,000 feet in diameter, many of which are connected by steep-sided ridges, occur approximately five to six miles offshore in Santa Monica Bay on the continental shelf.

The second major offshore physiographic province is the basin slope. This slope extends from one to ten miles seaward from the rim of the continental shelf at about 300 feet to 2400 feet below sea level with an average 450 feet per mile gradient except where it steepens near submarine canyons.

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Beyond the basin slope for a distance of approximately 140 miles seaward lies a broad area of fault block structures, referred to by Shepard (1948) as the continental borderland. The downfaulted blocks are mostly closed basins separated by sills or upfaulted submarine ridges which rise about 2,000 feet above the floor of the basins. Included in the uplifted blocks are San Clemente, Santa Catalina, San Nicholas, San Miguel, Santa Rosa, and Santa Cruz Islands. Emery (1954) explains that this series of uplifted and downdropped structures may be due to faulting and/or folding.

The fourth of this series of physiographic provinces, the continental slope, begins at the edge of the continental borderland and plunges steeply to abyssal ocean depths of 12,000 feet or more.

Three subprovinces of the continental shelf named by Terry, et al., (1956) are the Santa Monica Shelf (Point Dume to Palos Verdes Point), the Palos Verdes Shelf (Palos Verdes Point to Point Fermin), and the San Pedro Shelf (Point Fermin to Corona Del Mar) are shown on Plate 2. The Santa Monica and San Pedro Shelves are significant in respect to the occurrence and movement of ground water.

The Santa Monica Shelf extends seaward about eight miles and is subdivided into three segments by two submarine canyons that cut transversely across it offshore from Santa Monica and Redondo Beaches.

The Palos Verdes Shelf is narrow and extends seaward about one mile from the coast of the Palos Verdes Hills. Because of the lack of water-bearing sediments in the southwestern Palos Verdes Hills and in the offshore area, the Palos Verdes Shelf is not significant for this study.

Located southeasterly from the Palos Verdes Hills is the San Pedro Shelf. This shelf extends seaward 2 miles from Point Fermin and

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achieves a maximum extension of 12 miles at its central projection, before it diminishes again to 2 miles off Corona Del Mar. Moore (1951) gives an account of the physiography, structure, and sediments in this area; the formations were also described by Stevenson, Uchupi, and Gorsline (1958). This flat, featureless plain slopes southward and southeastward toward the basin slope, which has here been named the San Pedro Escarpment by Shepard and Emery (1941). Erosion followed by deposition of Recent sediments has reduced both positive and negative topographic features, obliterating the ancient stream channels of the Los Angeles and San Gabriel Rivers that once crossed it.

The Santa Monica and Redondo Submarine Canyons occur along the basin slope extending westward off the Santa Monica Shelf. The Santa Monica Canyon begins about four miles offshore at a depth of 180 feet and assumes a curved and sinuous course into the Santa Monica Submarine Basin, the nearest closed basin of the continental borderland. The canyon is relatively smooth with only small tributaries entering from the south wall. The Redondo Canyon begins a few hundred feet offshore from the City of Redondo Beach, follows a straight course across the Santa Monica Shelf, and empties into the Santa Monica Submarine Basin. A steep gradient of about 400 feet per mile at the canyon head gradually decreases to about 130 feet per mile at its fan-like terminal approximately 2,200 feet below sea level. Tributaries along the north side contribute to the variable topography of the canyon walls. Slumping occurs within the canyons and along the basin slope and carries recently deposited sediments to greater depths offshore.

Subsurface evidence provides at least a partial history of the development of the Redondo Canyon. During a part of late Pleistocene

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time when the sea level was much lower, drainage from the San Gabriel River, and possibly the Los Angeles River, flowed across what is now the Downey Plain, Rosecrans Hills, Torrance Plain and El Segundo Sand Hills to the present head of Redondo Canyon and continued oceanward to the rim of the continental shelf. Downcutting probably occurred rapidly along the basin slope and further entrenched the stream channel landward. A rapid rise in sea level has since caused the backfilling of coarse debris in this entrenched channel.

The San Pedro Sea Valley, an east-west trending submarine canyon, begins on the San Pedro Shelf south of Point Fermin. A branch or tributary leads off from the northern side of the main valley and trends northeasterly toward the mouth of the San Gabriel River. Both the main valley and its tributary lose their identity above a depth of about 150 feet. At the eastern extremity of the San Pedro Shelf, about 10 miles south of Sunset Beach, two smaller valleys trend in a southerly direction from a depth of 150 feet. This valley system has been named the San Gabriel Canyon by Emery (1960).

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CHAPTER IV STRATIGRAPHY

This chapter describes the stratigraphy, or the physical characteristics of the natural groupings of the rocks and sediments, in the Coastal Plain of Los Angeles County, including the age of rocks and sediments, their order in relationship to each other, and their position in the area. In order to simplify the discussion of stratigraphy, the rocks and sediments in the coastal plain are divided into water-bearing deposits and nonwater-bearing rocks.

The water-bearing deposits include the unconsolidated and semiconsolidated marine and nonmarine alluvial sediments of Recent, Pleistocene, and Pliocene age which form ground water basins. These materials absorb, transmit, and yield water readily to wells. Sizes of individual particles may grade from coarse gravel and boulders to clay. Coarse sands and gravels form the conduits for transmission of ground water and are called aquifers, while the finer sands, silts and clays, which also transmit ground water, but very slowly, are known as aquicludes.

The types of materials encountered by surface and subsurface geologic exploration and water well drilling, as reported by various individuals and agencies, are summarized on Table 1, which is bound at the end in this report. Based upon this information, the areal extent, thickness, and depths of the various aquifers and aquicludes underlying the coastal plain were estimated. The aquifers were named and their stratigraphic positions are illustrated schematically on Plate 5, entitled "Generalized Stratigraphic Column, Coastal Plain of Los Angeles County". Since the aquicludes which separate aquifers are generally of secondary interest, and because of additional complications of nomenclature, only the surface aquiclude is named. An attempt has been made to bring together and clarify the nomenclature

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used by many individuals and agencies. Therefore Plate 5 also relates the nomenclature system utilized in this report with that employed by others in the past.

The term "nonwater-bearing rocks" used in this report should not be construed to mean rocks which contain no water, but rather materials from which wells produce relatively limited quantities of water. Nonwater-bearing rocks are the parent rocks from which alluvium is derived. These rocks flank, underlie, and sometimes form the limits of the ground water basins and provide watersheds for runoff or drainage to valley-fill areas. Nonwater-bearing rocks include granitic, metamorphic, volcanic, and consolidated sedimentary types. Locally, the sedimentary rocks may yield a small amount of brackish, saline, or other poor quality waters. Water which drains from these rocks may also affect the quality of water in the sediments of valley-fill areas. Even within the crystalline basement rocks, some extractable water is contained within the joints, fractures, and solution cavities. In the highland areas, wells in volcanic flows and breccias yield limited quantities of water. The yield of wells in the volcanics, however, is usually restricted either because there is a lack of connected interstices or because they are so situated topographically or structurally that cementation, folding and faulting interferes with the vertical and lateral flow of ground water.

The following sections describe the water-bearing deposits and nonwater-bearing rocks in detail beginning with the geologically most recent, and working backward in time to the oldest strata. The surface outcroppings of the various formations are delineated on Plate 3. The conclusions of this study relating to the depth and thickness of the various aquifers and aquicludes in the coastal plain are illustrated by a series of idealized

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geologic sections cutting the area in east-west and north-south directions. These sections are shown on Plates 6A through 6G, entitled "Idealized Geologic Sections"; and the geographic locations of the sections are indicated on Plate 3, together with the locations of wells and test holes from which the geologic sections were derived. In addition to the wells and test holes shown on these plates, there were two to three times as many wells and test holes that were studied. These data were used to assist in delineating the boundaries of the aquifers and aquicludes.

In constructing the geologic sections, it was much easier to correlate aquifers from well log to well log in the marine sediments found southwest of the Newport-Inglewood uplift than it was in the area to the northeast. Consequently, the correlations in the continental sediments, especially those adjacent to the high lands are more definitive than are those in the marine sediments closer to the ocean. Also, the geologic sections in the West Coast Basin (this basin is described in Chapter 6) were mainly based on data taken from the Report of Referee (Calif. D.W.R. 1952a), modified slightly by unpublished data obtained from the Los Angeles County Flood Control District.

Subsurface structure and positions of aquifers in the area downstream from Whittier Narrows are illustrated by a series of cut-away diagrams shown on Plate 7, entitled "Cut-Away Diagrams of Aquifers in Vicinity of Whittier Narrows". These diagrams are of assistance in following the discussion of stratigraphic relationships but are discussed in detail in Chapter V. Detailed discussions of structural features referred to in the following sections are also contained in Chapter V.

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Quaternary System

Sediments of Quaternary and late Pliocene age comprise the water-bearing formations in the coastal plain. The Quaternary deposits are divided into the Recent and Pleistocene series.

Alluvial materials and rocks of Recent and Pleistocene age usually are unconsolidated and have suffered deformation to a lesser degree than the older underlying rocks. These younger alluvial materials are generally more heterogeneous than the older sediments although this may be more apparent than real, since more detailed information is usually available for younger sediments than for those older in age. In the detailed studies of oil fields, by contrast, the heterogeneity of older sediments is apparent.

Ground water extracted from wells is obtained primarily from aquifers of Recent and Pleistocene age, with the exception of a few wells in the Lakewood and North Long Beach areas which are perforated in sediments of late Pliocene age.

Deposition of Quaternary sediments has been controlled by tectonic activity, geomorphic processes, changes in climate, and world-wide changes in sea level, as previously discussed. The physical characteristics of those water-bearing series that favor high production of ground water are: their unconsolidated and permeable nature, their relatively undeformed state, their low topographic position, which permits infiltration of drainage from higher surrounding areas, their freedom from obstructions to flow in most areas, the ease with which their materials may be dewatered, or drained, and the ease with which in certain areas they may be naturally or artificially recharged.

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Recent Series

Reade (1872) first defined the Recent epoch as that time which has elapsed since the beginning of the last major rise in sea level, and this definition has been adopted for use in this report. An approximate age of 15,000 years has been assigned to the Recent epoch by Shepard (1956) and Hopkins (1959).

Recent materials were laid down upon the erosional surface that existed toward the end of the last glacial stage. In most of the Coastal Plain of Los Angeles County these sediments are stream deposits but near the ocean they include tidal, marine, and wind-deposited materials.

Recent deposits are recognizable by:their generally coarse, unconsolidated or uncemented nature (however, on Recent flood plains, alluvial fans, and certain marine deposits, fine-grained silts and clays are common), their unconformable relationship with the underlying late Pleistocene and older deposits, their relationship to the present drainage system including numerous gaps along the coast and other physiographic features, and the youthful or poorly developed soil normally found on the surface. Little deformation of the Recent sediments has occurred except where they cross tectonically active areas, as in Dominguez and Ballona Gaps. Two major members of the Recent series are shown in the areal geology presented on Plate 3 namely, alluvium, represented by the symbol Qal and active dune sand represented by Qsr.

Alluvium. Recent Alluvium is primarily stream deposited gravel, sand, silt and clay with some interbedded littoral and estuary or bay deposits near the ocean. Geologic members found within the alluvial deposits include the Semiperched aquifer, Bellflower aquiclude, Gaspur aquifer, and

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Ballona aquifer. Portions of the Semiperched aquifer and Bellflower aquiclude are of late Pleistocene age, placing them in the Lakewood formation. They are described here, however, together with the deposits of Recent age.

Semiperched Aquifer. Coarse sands and gravels, called the Semiperched aquifer, are found on or near the surface of much of the Coastal Plain of Los Angeles County. These materials vary in thickness from 0 to 60 feet and may contain significant amounts of unconfined water where they are more than 20 feet thick. The most important areas where this aquifer appears are in the Los Angeles and Montebello Forebay Areas, and irregular patches occur throughout the rest of the coastal plain.

Where the underlying aquifers are confined, the Semiperched aquifer is generally separated from them by silts and clays or other material of relatively low permeability, called the Bellflower aquiclude. These materials inhibit the free percolation of water from the Semiperched aquifer to the underlying aquifers.

Permeable sediments of both Recent and late Pleistocene age are included within the Semiperched aquifer. Most of the sediments are probably remnants of abandoned stream channels, although marine deposits previously known as the Palos Verdes Sand are a part of the aquifer underlying portions of the Torrance Plain.

Little beneficial use is made of water in the Semiperched aquifer since wells perforated in it yield very small quantities of water. Furthermore, the poor quality of the water in some areas makes it undesirable for widespread use.

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Bellflower Aquiclude. Lying directly beneath the Semiperched aquifer are sediments of lesser permeability which restrict vertical movement of ground water. These relatively impermeable materials, referred to in numerous reports in generalized terms, have been designated the Bellflower aquiclude. Physical features and dimensions of this aquiclude are delineated on Plate 8, entitled "Lines of Equal Elevation on the Base of the Bellflower Aquiclude", and on Plate 9, entitled "Lines of Equal Thickness of the Bellflower Aquiclude". The Bellflower aquiclude comprises all of the fine grained sediments that extend from the ground surface, or from the base of the Semiperched aquifer, down to the first aquifer below. Other names that have been used to refer to these materials are: "Upper Division of the Alluvial Deposits of Recent Age" (Poland, et al 1956); "Upper Fine Grained Phase" in California D.W.R. 1952b; and "clay cap" in California D.W.R., 1952c, 1957a, and 1958b. The flood plain deposits referred to by Poland, (1959b) which are found in many portions of the Downey Plain may be equivalent, at least in part, to the Bellflower aquiclude as here defined. Although other reports refer to these sediments as Recent in geologic age, the Bellflower aquiclude, as defined in this report, is composed of both Recent sediments in some areas, and late Pleistocene deposits in others.

The Bellflower aquiclude extends throughout most of the Coastal Plain of Los Angeles County, except for the Los Angeles and Montebello Forebay Areas. According to drillers logs and from visual observation of exposed formations in excavations, this aquiclude is a heterogeneous mixture of fine grained continental, marine, and wind-blown sediments. In about a third of the coastal plain, the aquiclude consists only of clays and silty clays, but extensive lenses and pockets of sandy or gravelly clays occur in the remainder of the area, as shown on Plate 9. These predominantly

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sandy and gravelly clays may permit waters to percolate slowly to the underlying aquifer or aquifers, or ground water in these latter areas may move upward if pressure levels in the underlying aquifer are sufficiently high. Classification of materials from the descriptions usually found in well logs is difficult; however, in logs where descriptions of materials are more precise and presumably of greater reliability, the sand content is greater than has been generally assumed. Consequently, the aquiclude is believed to have a somewhat greater, though still restricted, permeability than has been supposed in the past.

That portion of the aquiclude of Recent age has not been appreciably faulted or folded; however, the portion of late Pleistocene age has been affected to some extent by tectonic movements.

The thickness of the Bellflower aquiclude, as shown on Plate 9, varies from zero to 200 feet. The areas of greatest thickness occur along the center and east flank of the Gardena Syncline in the West Coast Basin. Other areas of considerable thickness, ranging up to 140 feet, are generally aligned with the South Gate-Santa Ana Depression.

Gaspur Aquifer. The basal coarse phase of the Recent series has been referred to in previous reports as the Gaspur water-bearing zone. These sediments were described by Poland, et al (1956) and in California D.W.R. 1952a and 1952b. The term "aquifer" is used in this report rather than "water-bearing zone", the expression previously employed, as being more descriptive of the function of the deposits. According to Poland, et al (1956) the name of the aquifer is derived from the identification of a typical section in the log of a well near Gaspur Station at the coastal end of Dominguez Gap.

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The extent of the Gaspur aquifer is shown on Plate 10, entitled "Lines of Equal Elevation on the Base of the Gaspur, Ballona, Artesia, and Exposition Aquifers". Its westerly arm, extending southerly from the Los Angeles Narrows, joins the easterly arm extending southwesterly from the Whittier Narrows near Downey and continues southwesterly through Dominguez Gap to the ocean. Throughout the 23 mile length of the aquifer the width varies from one to five and a half miles.

The type cobbles and pebbles in the Gaspur aquifer indicate that they are derived from the San Gabriel Mountains and other highland areas surrounding the San Gabriel and San Fernando Valleys.

The continental stream deposits found in the Gaspur aquifer range in size from boulder gravel to silt and clay. In vertical section, the upper part is medium to coarse-textured sand while the lower part consists of sand, gravel, and cobbles as large as four or five inches in diameter. There is also a lateral variation in lithology. Well logs north of Rosecrans Boulevard generally show 80 to 90 percent coarse sands and gravels with 10 to 20 percent finer-grained materials. South of Rosecrans Boulevard, about 40 to 50 percent of the sediments comprising the Gaspur aquifer are fine-grained. The fine-grained patches are discontinuous within the Whittier Narrows, and occur as stringers, or elongated lenses. Variations in the thickness and width of the Gaspur aquifer seem to indicate that the stream or streams responsible for original deposition were meandering, braiding, eroding and aggrading. The absence of fine deposits in the lower portion suggests that they were removed by erosion during flood stages. Thickness of the Gaspur aquifer ranging up to about 120 feet, is delineated on Plate 11 entitled, "Lines of Equal Thickness of the Gaspur, Ballona, Artesia, and Exposition Aquifers".

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The Gaspur aquifer is merged with surface deposits in the Montebello Forebay between the Rio Hondo and San Gabriel River, extending as far south as Slauson Avenue. It also crops out in the Los Angeles Narrows in an area bounded by the Los Angeles River and the Harbor Freeway, and extends from the Narrows as far south as Firestone Boulevard. These two outcrops areas are shown on Plate 10A.

The gradient of the base of the westerly arm of the Gaspur aquifer is 44.5 feet per mile (a 300-foot drop in elevation in 6.75 miles). The gradient of the base of the Gaspur aquifer along the easterly arm is about 19 feet per mile (a drop of 200 feet in 10.5 miles). Between San Pedro Bay and the point where the two arms of the Gaspur aquifer join, the gradient is 10 feet per mile (a 60-foot drop in elevation in 6.0 miles). The steepness of the westerly arm may indicate uplift to the north and west, although greater rock hardness in Los Angeles Narrows and/or a difference in stream flow regimen caused by changing debris loads also may have caused this steep gradient. Minor warping of both the aquifer and overlying Recent deposits has probably occurred within the Whittier Narrows and Dominguez Gap. The Gaspur aquifer has apparently not been affected by faulting.

Water levels and well histories indicate that the Gaspur aquifer has been partially dewatered. The majority of new wells drilled in the area under which this aquifer lies do not depend solely on this aquifer but are usually drilled into and perforated in deeper aquifers as well. Many existing wells, however, depend only on this aquifer for their supply, and in these wells the yields are usually high. Permeabilities in this aquifer range up to 6000 gallons per day per square foot. (See Table D in Attachment 2 for general values of permeabilities used in the coastal plain).

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The Gaspur aquifer is merged with the deeper aquifers in the area immediately south of Los Angeles Narrows, which at one time served as a recharge area. However, this area is now completely covered by buildings and paved streets. Little, if any, direct percolation of water is possible; even the channel of the Los Angeles River is now lined where it passes through this area.

In the vicinity of Whittier Narrows, the deeper aquifers are also merged with the Gaspur aquifer and receive their natural recharge waters through it. Because percolation in the Los Angeles Narrows has been rendered infeasible, the Whittier Narrows is the most suitable remaining location for artificial recharge of the underlying aquifers. Consequently, the principal recharge basins and projects for recharging local surface flood waters and imported waters are located in this area, from whence natural percolation processes carry this water into the deeper aquifers.

Ballona Aquifer. The other principal aquifer of Recent age is the Ballona aquifer, which has previously been termed the "50-foot gravel". Poland, et al (1959a) originally assigned the name "50-foot gravel" to the lower divisions of the Recent series in Ballona Gap, because these occurred at an average depth of 50 feet below the surface. Although this aquifer is included within the Recent series it is believed that at least part of it may be of late Pleistocene age.

The Ballona aquifer lies north of the Ballona escarpment and extends inland to a point east of the Overland Avenue fault. The extent of this aquifer is shown on Plate 10. It is composed of coarse sand, rounded to subrounded gravel, and cobbles up to five inches in diameter that are of both granitic and metamorphic origin. Slate pebbles in this aquifer suggest

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that the Santa Monica Mountains were a possible source of material; on the other hand, granitic rocks and pebbles appear to come from the San Gabriel Mountains. The Los Angeles River has flowed north of the Baldwin Hills and along Ballona Creek channel in historic time, but no attempt has been made to determine the relative contribution to the Ballona aquifer from the two drainage systems.

The Ballona aquifer varies in thickness from less than 10 feet at the coast to 40 feet near Beverly Hills. Thickness of the Ballona aquifer is delineated on Plate 11.

The base of the Ballona aquifer drops from more than 100 feet above sea level beneath the Sawtelle Plain to 60 feet below sea level near the Ballona Escarpment, a gradient of about 40 feet per mile. There is a southward tilt to the base, which corresponds to the southerly dip into West Coast Basin of the San Pedro formation, and may be due to either erosion and depositional processes or to tilting, or possibly both.

Well yields from the Ballona aquifer are highly variable, ranging from 100 to 800 gpm (Poland, et al 1959a). This may be due to the irregularity and discontinuity of its composition and thickness.

Miscellaneous Alluvial Deposits. Other Recent alluvial deposits include beach deposits, playa lake deposits and lagoonal marshland deposits. These have been described more elaborately (Poland, et al 1959a), and are treated only briefly in this report.

Narrow strips of beach deposits, with materials ranging in size from fine sand to cobbles, are found adjacent to wave-cut cliffs along the coastline. They also exist as barrier beaches across the various gaps along the coast. The beach deposits act as a source for wind-blown material

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for the coastal-dune belt and may also serve as a permeable conduit for sea-water intrusion into aquifers near the surface along the coast.

Playa lake deposits found near the intersection of the Coast Highway and Vermont Avenue, about one mile west of Wilmington, have been deposited in shallow closed depressions. Standing water accumulates in these closed drainage areas after heavy rains. These deposits are usually fine-grained sands, silts, and clays.

Lagoonal marshlands extend along the coastal reaches of the Los Angeles and San Gabriel Rivers and Ballona Creek for a distance of one-half to three miles inland. Deposits in these areas appear to be heterogeneous in nature, lenticular, and mostly fine-grained. These sediments may also include medium sand, silty sand, clay and peat deposits.

Active Dune Sand. Wind-blown sands occur in a narrow strip 0.2 to 0.5 miles inland and parallel to the coast and continue from Ballona Escarpment southward to Redondo Beach for a distance of about nine miles. These deposits are known as the Active Dune Sands. Plate 3B shows the extent of these deposits which are identified by the symbol Qsr. These eolian deposits are lenticular, and composed of fine to medium, white or grayish sand, usually well sorted. These sediments may also include medium sand, silty sand, clay and peat deposits. The Active Dune Sands range up to 70 feet in thickness. Being above the zone of saturation, the sands do not yield water to wells. However, they are relatively permeable and water held in closed depressions after heavy rains does percolate vertically downward and laterally. The dune sands may therefore serve as recharge media to any water bodies that underlie this area.

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Pleistocene Series

The Pleistocene series is divided into upper Pleistocene and lower Pleistocene in most of coastal California, primarily because they are separated by an angular unconformity in many uplift areas. Fossils are used as an additional index to separation of the Pleistocene series. The boundary between deposits of Pliocene and Pleistocene age is difficult to determine and consequently is somewhat arbitrary in many areas.

In the coastal plain the upper Pleistocene is represented by the Older Dune Sands and the Lakewood formation, while the lower Pleistocene consists of the San Pedro formation (Poland, et al, 1956). Where they appear on the surface the Older Dune Sands, Lakewood formation, and the San Pedro formation are identified by the symbols Qso, Qlw, and Qsp, respectively. on Plate 3. A small zone of transitional material, cropping out between the San Pedro formation and the underlying Pico formation of Pliocene age is also shown on Plate 3 and identified by the symbol Qsp-Pp.

Older Dune Sand. Dune deposits occur in West Coast Basin which are older than those described under the Recent Series. These wind-blown materials are sufficiently significant in manner of deposition, lithology and topography, to be considered in this report as a separate unit. The term "Older Sand Dunes" has been previously used to designate these wind-blown deposits; however, in this report, the more descriptive term "Older Dune Sand" is used to identify these deposits.

The Older Dune Sand has been described by Poland, (1956, 1959b) and in Calif. D.W.R. 1952a and 1957c. Although these sediments have been previously classed as Recent materials, they are now considered to be of late Pleistocene age.

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The Older Dune Sand covers an area three to four miles wide and about 13 miles long extending along the Santa Monica Bay Coast line south of Ballona Escarpment. Surface exposures and well logs indicate that the dune sediments cover the Ocean Park Plain as well as a portion of the West Coast Basin. In the Ballona Creek area the older dunes have been removed. In the West Coast Basin the Older Dune Sand together with the Active Dune Sand form the El Segundo Sand Hills.

The Older Dune Sand consists of fine to medium sand with minor sandy silt, clay, and gravel lenses. Within the weathered zone the materials are yellow to brown in color although the unweathered formation in place is white, gray and black in color. The Older Dune Sand generally consists of three divisions: a deeply weathered surface, an intermediate horizon of clean sands and basal beach sands and gravels, and a lowermost horizon which apparently includes a zone of transition to the underlying Bellflower aquiclude.

Cross-bedding, and fossils in exposures near the Hyperion Sewage Treatment Plant at El Segundo and elsewhere, indicate that the sands were originally beach deposits with associated coarse gravels. These beach deposits were exposed to the wind by lowering of the sea level, resulting in formation of the present Older Dune Sand. Deep weathering has oxidized the iron minerals which, through cementation and leaching processes, have partially filled the interstices between individual grains, thus reducing the permeability of the weathered Older Dune Sand to some extent. Uplifting may have gently tilted these dunes toward the southwest.

Deep percolation of surface water occurs in most of the Older Dune Sand area, especially where closed depressions occur. Directly beneath these older dunes in part of the El Segundo Sand Hills, the fine sediments

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of the Bellflower aquiclude restrict downward movement of ground water. However, the aquiclude is missing along the ocean and ground water can move laterally into an area where downward percolation can again occur.

Lakewood formation. The Lakewood formation includes all upper Pleistocene deposits other than the Older Dune Sand. It includes what has previously been termed "terrace deposits", "Palos Verdes sand", and "unnamed upper Pleistocene deposits". Other names which have been used for upper Pleistocene deposits or parts of these deposits include the Sunny Hill formation (Hoskins, 1954,), and San Dimas formation (Eckis, 1928). These names, however, are awkward for use in the entire coastal plain since the named formations have been described as existing only in the limited associated area. The present designation was selected from a typical section indicated in the log of a well at Lakewood where this formation reaches a maximum thickness of approximately 400 feet.

In the upper part of the Lakewood formation lithologic changes are rapid, with discontinuous permeable zones and considerable variation in particle size. No shell zones have been found in the upper part of this formation. These features represent typical stream type alluviation with flood plain fine-grained sediments comprising from 40 to 80 percent of the total deposits. In the lower horizons the gravels and coarse sands are confined to a narrow belt extending over the Newport-Inglewood uplift. Gravels range from pea-size to cobbles, three to four inches in diameter. Over the balance of the coastal plain, coarse basal deposits of sand and gravel are fairly continuous with discontinuous lenses of sandy silt and clay. The basal part of the Lakewood formation in the Cheviot Hills area of Beverly Hills has been called the Medill sand by Rodda (1957)..

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The Lakewood formation extends beneath most of the coastal plain. In portions of the Baldwin Hills, Signal Hill, Palos Verdes Hills, and Coyote Hills, it has been eroded, exposing the underlying San Pedro and older formations. In the La Brea, Santa Monica, and Montebello Plains, and on the flanks of the Palos Verdes Hills and Puente Hills, the Lakewood formation unconformably overlies the lower Pleistocene San Pedro formation, the Pliocene Pico and Repetto formations, and the Miocene Puente formation.

The Lakewood formation is divided into the Artesia-Exposition aquifers, the Gage-Gardena aquifers, and the unnamed aquicludes between the aquifers. In some areas, portions of the Semiperched aquifer and the Bellflower aquiclude, described under Recent alluvium, are included. The base of the Lakewood formation generally coincides with the base of the Gage and Gardena aquifers. The aquifers of the Lakewood formation are discussed in the following paragraphs.

Artesia-Exposition Aquifers. The Artesia and Exposition aquifers, although located in separate geographical areas, are similar in composition and mode of deposition; this leads to the conclusion that they are contemporaneous. They are, therefore, jointly discussed in this section. The Artesia aquifer appears to be related to the San Gabriel River, Coyote Creek, and Santa Ana River systems, and the Exposition aquifer is related to the Los Angeles River drainage system. As shown on geologic section C-C'-C", Plate 6B, these aquifers extend beneath the Gaspur aquifer at which point they merge with each other and with the overlying Gaspur aquifer. On Plates 10 and 11, the contours on the base of the Artesia-Exposition aquifers and lines of equal thickness are not extended beneath the Gaspur aquifer since it is difficult to distinguish the separate aquifers.

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The Artesia aquifer extends from the middle of the Santa Fe Springs Plain southward, where it underlies the northern portions of the Bouton Plain, Signal Hill, and Bixby Ranch Hill. It follows the general trend of the present San Gabriel-Coyote Creek drainage as shown on Plate 10. The Artesia aquifer extends southeasterly from the Gaspur aquifer to and beyond the Los Angeles-Orange County line. However, since no study has been made of the extension of this or any other aquifer outside the area of investigation, it is terminated at the county line.

The Artesia aquifer is composed of coarse gravel, coarse to fine sand and interbedded silts and clays. In some areas, individual gravel members within the aquifer can be identified in drillers logs for considerable distances. The Artesia aquifer has a general southwesterly dip, and varies in thickness (Plate 11) and bottom configuration (Plate 10).

The ancestral San Gabriel and Santa Ana Rivers, and Coyote Creek, appear to have been the main source of the sediments comprising this aquifer. The Santa Ana River may have contributed sediments to the southern portion of the area since this river once flowed directly west and joined the San Gabriel River near its present confluence with Coyote Creek.

The geographical extent of the Exposition aquifer is shown on Plate 10. This aquifer consists of one to four discontinuous coarse members. Materials range in size from coarse gravels to clay, with the fine deposits separating the lenticular sandy and gravelly beds. Changes in lithology are frequent as evidenced by the many lenses of silt and clay encountered in the drillers logs.

Deposition of this material appears to have been controlled by the ancestral Los Angeles River, which may have flowed through the Silver Lake

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area (Riveroll, 1957) in the geologic past, as well as by tributary streams from the Santa Monica Mountains, Elysian Hills, and Repetto Hills. The configuration of the base of the Exposition aquifer, as well as the Artesia aquifer, is highly irregular and it appears that both were deposited on an erosional surface. A study of well logs indicates that the upper coarse members of the Exposition aquifer were either eroded and backfilled by Gaspur deposits or that some of the upper members were deposited contemporaneously with the formation of the Gaspur aquifer. Highway excavations in the vicinity of Boyle Heights and other areas along the south slope of the Repetto Hills and along the east bank of the Los Angeles River have exposed clean sands and gravels which are apparently an upper member of the Exposition aquifer.

The maximum thickness of the Exposition aquifer is 100 feet. Lines of equal thickness of the aquifer, including interbedded fine materials as well as the permeable zones, are shown on Plate 11.

Stratigraphically, the Artesia and Exposition aquifers lie above the Gage aquifer, described subsequently, and are generally deeper than the Gaspur aquifer, although some of the upper coarse members abut directly into the Gaspur aquifer and may be of the same age. At Boyle Heights and other places, the Artesia and Exposition aquifer have been uplifted and are now higher in elevation than the adjacent Gaspur aquifer. Lower members of the Exposition continue beneath the Gaspur aquifer and merge laterally with the Artesia aquifer. The Exposition aquifer merges with the underlying Gage aquifer approximately three miles northwest of downtown Los Angeles and also in the triangular area between the easterly and westerly arms of the Gaspur aquifer on the Montebello Plain,as shown on Plate 12, "Lines of Equal Elevation on the Base of the Gage and Gardena Aquifers".

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The Potrero fault is the only known structure that displaces the Exposition aquifer. However, both the Artesia and Exposition aquifers have been affected by folding and show slight warping near the Newport-Inglewood uplift and in the downwarped area of the Central Basin.

Gage Aquifer. The basal or lowest member of the Lakewood formation is termed the Gage aquifer. The name "200-foot sand" was applied to this aquifer by Poland, et al (1948 and 1959a), later by Richter (1950) and in the "Report of Referee", (Calif. D.W.R. 1952a). Originally the designation of the "200-foot sand" was used because the aquifer occurred about 200 feet below land surface in the syncline extending from Inglewood southeasterly through Gardena. In the Central Basin the base of the aquifer varies from 100 to over 350 feet below the surface; consequently the term "200-foot sand" is inapplicable. The lowest elevation this aquifer attains is in the vicinity of Lynwood, where an elevation of 350 feet below sea level occurs. The Gage aquifer extends over most of the Coastal Plain of Los Angeles County, although insufficient data is available to verify its extension beneath the Santa Monica Plain. Contours on the base of the aquifer are shown on Plate 12.

The composition of the Gage aquifer varies from a fine to medium sand with variable amounts of gravel, sandy silt, and clay in the West Cosst Basin, to a coarse yellow sand and minor gravel (two to four inches in diameter) in the center of the Central Basin, and to a fine yellow sand and gravel toward the Whittier Narrows region. The thickness varies from 10 feet to a maximum of 160 feet in the Torrance area. The thickness of the aquifer is shown on Plate 13, "Lines of Equal Thickness of the Gage and Gardena Aquifers".

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Deposits that comprise this aquifer are of both marine and continental origin. Along the northerly boundary of the Central Basin, that is, along the base of the Santa Monica Mountains and the Elysian and Repetto Hills, the deposits appear to be continental in origin. In the southeastern half of the coastal plain the aquifer consists mainly of mixed continental and marine, or in some areas, solely marine sediments.

Subsurface structures which either cut the aquifer or against which the aquifer terminates are shown on Plate 12. Areas where the aquifer is merged with overlying aquifers are also shown on this plate.

While this aquifer generally consists of sand, wells have been perforated in it only in areas where coarser materials exist. Approximately 200 wells have been drilled into the Gage aquifer in the West Coast Basin in the vicinity of Gardena but it is unimportant as a producing aquifer in other areas.

Gardena Aquifer. In 1950 Richter described the coarse deposits comprising this aquifer within the West Coast Basin under the term "Gardena Water-bearing Zone". In "Report of Referee" (Calif. D.W.R. 1952a) the description of the Gardena Water-bearing Zone was further elaborated. In the present investigation the extent of the Gardena water-bearing zone in the Central Basin was determined and these deposits have been designated the "Gardena aquifer". This term now applies to all of the coarse deposits that are contemporaneous with the Gage aquifer (fine grained deposits) in both the Central and West Coast Basins.

The Gardena aquifer extends inland from Redondo Beach beneath the City of Gardena, across the Newport-Inglewood uplift and into the Central Basin, where it loses its identity near Lynwood. Further inland, identical

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coarse deposits are again discernible underlying the Montebello Plain and within the Whittier Narrows. These two areas, however, are separated by the Gage aquifer which underlies that part of the Central Basin where the water-bearing deposits are deepest. In the western part of the coastal plain, the deposits form a strip one to four and one-half miles wide extending from Lynwood to the coast. Other coarse deposits, believed to be at the same stratigraphic horizon, extend southwesterly from the Whittier Narrows and then form two southeasterly trending lobes. One lobe reaches the area south of downtown Los Angeles and the Elysian Hills, and the other extends along the south side of the Santa Fe Springs Plain to the vicinity of Norwalk. The extent of these deposits is shown on Plate 12.

The lithology of the Gardena aquifer in the West Coast Basin is given by Richter (1950) as coarse sand and gravel with discontinuous lenses of sandy silt and yellow to blue clay, with the gravel sizes ranging from pea-size to cobbles three to four inches in diameter and the sand ranging from fine to coarse. Deposits in the Central Basin also contain coarse sands and gravels, with minor lenses of sand, silty clay, and clay. The deposits are similar in thickness and elevation to those of the Gage aquifer and are in direct continuity with the Gage materials. According to Richter (1950), the thickness within the West Coast Basin varies from 50 to 75 feet between the Avalon-Compton fault and the City of Gardena; from 75 to 100 feet west of Gardena, and is over 100 feet where it overlaps the merged Lynwood and Silverado aquifers near the coast. The present study indicates that the Gardena aquifer varies in thickness from 40 feet near Lynwood to 100 feet near Gardena and increases to 160 feet northwest of Torrance. Lines of equal thickness are shown on Plate 13.

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As shown on Plate 12, the lowest elevation of the base of this aquifer is 350 feet below sea level in the Central Basin and 200 feet below sea level in the West Coast Basin. On the Newport-Inglewood uplift, as well as in the merged area near the coast, the elevation of the base is 100 feet below sea level.

Richter (1950) indicated that this aquifer was one of fluvial origin since the alignment over the Newport-Inglewood uplift was narrow and perpendicular to probable ancient shore lines; furthermore, these deposits are similar to other Recent alluvial deposits in Dominguez and other Gaps. However, Poland (1959a) suggested that this coarse deposit may have been laid down beyond a shore line fringing the Newport-Inglewood uplift. Work in conjunction with this investigation, however, leads to the same conclusion outlined by Richter.

Some ancestral river flowing southwesterly incised a channel across the Newport-Inglewood uplift and eroded away most of the sediments comprising the Gage aquifer ("200-foot sand"). In this channel coarse fluvial deposits were laid down during a subsequent rise of sea level. Coastward from the uplift some shells have been found in wells drilled in this aquifer suggesting that fluvial action may have been affected by shallow lagoons or estuaries. From further study conducted during this investigation, it appears that the Rio Hondo-San Gabriel River systems have been the principal transporting agencies for sediments comprising the Gardena aquifer. However, because the two inland lobes of the Gardena aquifer extend parallel to the inland foothills there is a possibility that the Los Angeles River may have deposited portions of it.

In the Whittier Narrows, the Gardena aquifer is cut by the Rio Hondo fault shown on Plate 7, and it has been folded up to 11 degrees along

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the edge of the area near Boyle Heights. Recent uplift along the crest of the Rosecrans anticline has arched the Gardena aquifer, and this is shown on Plate 12 by contours plotted of the base of the aquifer.

The Gardena aquifer has yielded large quantities of water to wells. Because of its coarse texture and continuity, it is an important aquifer in the coastal plain. It is in hydraulic continuity with the Gage aquifer throughout most of its extent and for this reason the isopachs (lines of equal thickness) and elevation contours are plotted on the same maps as the Gage aquifer.

San Pedro Formation. The San Pedro formation has previously been defined to Poland, et al (1945, 1948, 1956, 1959a), as "that stratigraphic unit underlying the unnamed upper Pleistocene deposits and overlying the Pico formation of the late Pliocene age..... Essentially, the San Pedro formation embraces all strata of lower Pleistocene age." Richter (1950) defined the San Pedro formation as "all of the deposits of lower Pleistocene age which underlie West Basin." The original type section of the San Pedro formation contained San Pedro sand, Timms Point silt, and Lomita marl; however, Poland has stated that the San Pedro formation "includes some strata that are younger and may include some that are older than any exposed in the type section cited."

Eckis, (Calif. D.W.R., 1934) used the term "Fernando Group" for the lower Pleistocene and upper Pliocene strata that occurs along the inland foothills of the coastal plain. Since this term included the upper Pliocene deposits, not considered important fresh-water-bearing sediments, the designation "San Pedro formation" is used in this report for the heterogeneous materials comprising the lower Pleistocene horizons.

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The San Pedro formation underlies most, if not all, of the Coastal Plain of Los Angeles County as well as portions of the Santa Monica and San Pedro shelves offshore. In the type section along the north flank of the Palos Verdes Hills the San Pedro formation is composed of stratified sand with some beds of fine gravel, silty sand, and silt. Crossbedding occurs frequently in the outcrop. Some pebbles of limestone, siliceous Miocene shales and schist are also found. Away from the Palos Verdes Hills the percentage of granitic fragments increase. In 1950, Richter described the lithology of the San Pedro formation as it occurs in West Coast Basin as "gray sand, which weathers brown or reddish brown on exposure, and interbeds of small gravel are characteristic. Sand and gravel fragments are mainly granitic, indicating a common source area, probably the San Gabriel Mountains". Fine-grained members are generally marine type, blue to black clays, sea muds, or quicksand with abundant shells. The Anchor silt found in the Cheviot Hills (Rodda, 1957) is one of these members. It is correlative with the Timms Point silt, of lower Pleistocene age, and to the lower part of the San Pedro formation. The Coyote silt found in the Coyote Hills (Hoskins, 1954) is also of lower Pleistocene age and resembles the Anchor silt.

The thickness of the San Pedro formation is about 1050 feet beneath the Downey Plain along the South Gate-Santa Ana Depression, and increases to a maximum of 1350 feet in the area about two miles east and southeast of Norwalk along the Norwalk synclinal axis. Where section C-C'-C" (Plate 6b) crosses the Rosecrans anticline, the thickness is 570 feet. Within the West Coast Basin the thickness is greatest along the Gardena syncline, varying from 400 feet about 1 1/2 miles west of Inglewood to 500 feet 1 mile north of Hawthorne, 700 feet at Gardena, and to as much as 1050 feet near the intersection of Carson and Alameda Streets.

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The San Pedro formation crops out along the south side of the Repetto, Merced, and Puente Hills; on the Coyote Hills, Baldwin Hills, and Beverly Hills; along the north side of the Palos Verdes Hills; and on Signal Hill. Around the margins of the coastal plain, the San Pedro formation is upturned, and in some local areas is beveled and capped by younger strata.

Most of the structures encountered within the area of study affect at least part of the San Pedro formation. Elevation contour maps on the bases of the aquifers that comprise this formation indicate which fault or faults displace the aquifers. Much folding and warping, along with erosion, also has affected many of the aquifers. The structures affecting the San Pedro formation will be discussed in the descriptions of individual aquifers to follow.

On Plate 3 the San Pedro formation, where it appears at the ground surface, is represented by the symbol "Qsp". Although the formation is shown as one unit for convenience, it has been divided into various stratigraphic units or members. Only those members capable of storing or conveying ground water in suitable quantities have been named as aquifers, while the intervening finer-grained zones were not named. In downward succession, excluding the fine-grained interbedded layers, the aquifers are: The Hollydale aquifer, the Jefferson aquifer, the Lynwood aquifer ("400-foot gravel"), the Silverado aquifer, and the Sunnyside aquifer. Since most of the important aquifers used for production within the coastal plain are contained within the San Pedro formation, their complex water-bearing characteristics are discussed in Chapter VI rather than in the following description.

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Hollydale Aquifer. The uppermost aquifer within the San Pedro formation is named the Hollydale aquifer. Although discontinuous in extent, it reaches from the Newport-Inglewood uplift north and northeastward to the south line of the Elysian, Repetto, Merced, and Puente Hills, and eastward and southeastward to and beyond the Los Angeles-Orange County line. Plate 14, entitled "Lines of Equal Elevation on the Base of the Hollydale Aquifer", shows the sinuous irregular courses of this aquifer.

The lithology of this aquifer is variable and consists of yellow sands and gravels (pea-size to two inches) in the northeastern portion of the area, while grey, blue, and black sands, with muds, clays, and marine shells become more predominant toward the Newport-Inglewood uplift. Well log reports are the only means of determining the lithology for this aquifer because it does not crop out on the surface. The well logs indicate that some of the marine sands are mushy, while others are cemented and hard.

The irregular, sinuous, and meander-like courses of the aquifer suggests a stream deposition, but the lithology of the aquifer over three-fourths of the area indicates shallow marine deposition. Because the two main lobes of the aquifer open toward the Los Angeles and Whittier Narrows, it is assumed that streams flowing through these two narrows have controlled the deposition of those parts, while a part of the sediments were laid down beneath shallow water in lagoons or estuaries.

Lines of equal thickness of this aquifer are shown on Plate 15, "Lines of Equal Thickness of the Hollydale Aquifer". The thickness varies from less than 10 feet to a maximum of 100 feet near Lakewood.

In stratigraphic position the Hollydale aquifer is the first important aquifer beneath the Gage-Gardena aquifers. The Hollydale aquifer is overlain and underlain, in most areas, by fine-grained members or aquicludes

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of the San Pedro formation. Elevation contours on the base of the Hollydale aquifer and areas of mergence with overlying aquifers are shown on Plate 14. The aquifer attains its greatest depth at an elevation of 500 feet below sea level about two miles east of Compton. In the area between the towns of Norwalk and Bellflower, the depth is about 450 feet below sea level. The slope of the base of the Hollydale aquifer is generally toward these two areas of greatest depth.

Upfolding along the Newport-Inglewood uplift has apparently limited the depositional area of the Hollydale aquifer to the Central Basin. Within the Central Basin the aquifer does not exist in upfolded areas. Downfolding along the axis of the Paramount and Norwalk synclines has, however, placed the base of the aquifer at an elevation of 500 feet below sea level.

This aquifer apparently does not yield large quantities of water to wells, therefore few wells are perforated in this interval and even then only when producing horizons above and below are also perforated. Low productivity of the Hollydale aquifer may be due to the fineness of the materials of which it is composed and the lack of continuity in its extent.

Recharge of the Hollydale aquifer can be accomplished only where it merges with the overlying Gage or younger aquifers (Plate 14) because of the absence of outcrop areas.

Jefferson aquifer. Within the Central Basin, the second aquifer in downward succession within the San Pedro formation is designated the Jefferson aquifer. This aquifer extends over most of the Central Basin, although it is not known to reach the surface. Lobes of this aquifer extend into the Whittier Narrows, into the La Brea Plain, and south of the Coyote Hills through Buena Park into Orange County. Within the boundaries of

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the aquifer, some irregular areas exist where the aquifer has not been identified, as indicated on Plate 16, "Lines of Equal Elevation on the Base of the Jefferson Aquifer". This aquifer has not been located in the West Coast Basin. The Jefferson aquifer occurs in sinous courses extending from both the Los Angeles and Whittier Narrows into Orange County.

The lithology of the Jefferson aquifer is known only from drillers logs of water wells. The sediments comprising this aquifer are, for the greater part, fine-grained. Gravels are most extensive in the Whittier Narrows but also occur in scattered patches through the rest of the Central Basin. The remainder of the aquifer consists primarily of sand with some gravelly and clayey lenses.

From the pattern of distribution of sediments comprising this aquifer, source areas are assumed to have been the San Fernando and San Gabriel Valleys and their surrounding highlands. The Los Angeles and San Gabriel Rivers appear to have transported the material through the Los Angeles and Whittier Narrows into or through three possible areas: the La Habra Piedmont slope, the Buena Park area, and southward toward Seal Beach. Extensions of these areas into Orange County have not been determined.

The thickness of the Jefferson aquifer is shown on Plate 17, "Lines of Equal Thickness of the Jefferson Aquifer", and varies from a few feet to a maximum of 140 feet along the Los Alamitos fault. At Norwalk the Jefferson aquifer is 120 feet thick. The Jefferson aquifer has been considerably folded and its base varies in elevation from 700 feet below sea level to 50 feet above sea level.

Structures that affect the Jefferson aquifer are the Los Alamitos, Rio Hondo, Pico, and Cherry Hill faults, and possibly the Seal Beach fault.

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It is believed that the general upwarped area along the Newport-Inglewood uplift has controlled or confined to the Central Basin the deposition of sediments comprising this aquifer.

Although it does not crop out on the surface, the Jefferson aquifer does merge with the overlying Hollydale aquifer and also with the Gage aquifer along the Elysian Hills, Repetto Hills, and within the Whittier Narrows. These areas of mergence are shown on Plate 16.

Artificial recharge within the Whittier Narrows would have some effect on this aquifer. Since less than 10 percent of the wells in the Central Basin are perforated in this horizon, and then only in areas where coarse sandy and gravelly zones are found, it is not considered an important water producing aquifer.

Lynwood Aquifer. The Lynwood aquifer is the term used for the third aquifer in stratigraphic sequence within the San Pedro formation. The term "400-foot gravel" has been applied to this aquifer in the West Coast Basin. This latter term was first used by Poland (1948) and defined as "a distinct water-bearing zone in the upper part of the San Pedro formation .... its base is about 400 feet below land surface along the axis of the syncline" (southwest of the Newport-Inglewood uplift). Plate 18, "Lines of Equal Elevation on the Base of the Lynwood Aquifer", and Plate 19, "Lines of Equal Thickness of the Lynwood Aquifer" show the extent, elevation of the base, and thickness of this aquifer.

The Lynwood aquifer extends throughout the Central and West Coast Basins and its existence has been verified in the Hollywood Basin. There is no evidence to show that it exists in the Santa Monica Basin, nor has it been identified in the Baldwin Hills.

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Materials of which the Lynwood aquifer is composed appear to be both continental and marine in origin. Continental deposits, of yellow, brown, and red coarse gravels, sands, silts, and clays, are found in the vicinity of the Montebello Forebay Area. A line bounding this area extends from the Whittier Narrows to Bellflower, thence to Compton, South Gate, Huntington Park, and back to the Whittier Narrows. One arm of continental sediments extends from the area just described toward Hawthorne. Sediments of the Lynwood aquifer surrounding the Montebello Forebay Area are mostly marine deposits and are characterized by sand and gravel and blue, grey, and black silts and clays. Some of the sands and gravels have been cemented. The several areas where the marine deposits consist predominantly of fine-grained materials vary from less than 100 acres to about six or seven square miles in extent, and are shown on Plate 19.

From the study of well logs and the materials from wells drilled into this aquifer, it appears that the Rio Hondo and San Gabriel River systems have been the major contributing source for the continental sediments. Marine-type deposits appear to have been laid down when the area was covered by shallow seas.

The Lynwood aquifer ranges from less than 50 feet to about 200 feet in thickness near Wilmington, as shown on Plate 19. Near Lakewood, Torrance, Inglewood, and Montebello it is about 150 feet in thickness. The base contours and lines of equal thickness are not shown west of the Gardena syncline because of mergence with the Silverado aquifer.

In stratigraphic sequence the Lynwood aquifer is overlain and underlain in most of the area by fine-grained materials such as clays, silts, and sandy and silty clays. It is beneath the Jefferson aquifer and above the Silverado aquifer. Known areas of mergence with the overlying aquifers

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are shown on Plate 18, while the areas of mergence with the Silverado aquifer are shown on Plate 20, "Lines of Equal Elevation on the Base of the Silverado Aquifer".

Folding has been the primary structural factor affecting the Lynwood aquifer. Upfolding or upwarping has occurred along the coast in the West Coast Basin, over the Newport-Inglewood uplift, in the Artesia area over the Santa Fe Springs uplift, along the edge of the Elysian, Repetto, and Puente Hills, and within the Whittier Narrows. Downwarping has affected the aquifer in the Hawthorne-Long Beach depression extending to San Pedro, within the South Gate-Santa Ana depression (includes Paramount and Norwalk synclines), and within the La Habra syncline. Within the West Coast Basin the Charnock fault has offset the Lynwood aquifer. Along the Newport-Inglewood uplift, the Inglewood, Potrero, Avalon-Compton, Cherry Hill, Northeast Flank, and other associated transverse faults cut the aquifer. Within the Central Basin the Los Alamitos fault offsets the Lynwood aquifer as does the Rio Hondo and Pico faults within and south of Whittier Narrows.

The Lynwood aquifer is an important producer of ground water and is discussed in more detail in the descriptions of the ground water basins in Chapter VI. Most wells in the coastal plain drilled to or below this aquifer are perforated in it. Yields of wells perforated only in the Lynwood aquifer vary from 200 to 2100 gallons per minute.

Surface and subsurface flow of water through the Whittier Narrows moves downward through the shallow aquifers into the Lynwood aquifer. Water is also artificially spread in shallow pits below the Whittier Narrows where the Lynwood aquifer is in contact with the permeable materials extending upward into the pits, thus permitting this water to reach the Lynwood aquifer. This artificial method of recharging is not generally

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applicable in other areas where the Lynwood aquifer is merged with the overlying aquifers because of the greater depth of those aquifers as well as the Lynwood aquifer below the surface, the lack of continuous permeable materials to conduct water vertically downward, and the lack of available space for large surface pits. In these areas, therefore, other methods of recharge would be necessary, such as injection wells drilled into and perforated in this aquifer.

Silverado Aquifer. The Silverado aquifer is the name applied in this report to those water-bearing materials which are stratigraphic equivalents of the "Silverado Water-Bearing Zone" in the West Coast Basin. Originally named by Poland, et al (1956), from its typical occurrence in a well in Silverado Park, Long Beach, the Silverado Water-Bearing Zone has been found throughout the rest of the Coastal Plain of Los Angeles County and extends across the Los Angeles County line into Orange County. For the purpose of this report the term, "Silverado aquifer", will apply to these materials throughout the Coastal Plain of Los Angeles County. Areas of Pleistocene deposits occurring in the Santa Monica and San Pedro shelves offshore may be continuations of the Silverado and underlying Sunnywide aquifers. Plate 20 shows the known extent and elevation contours of the base of the Silverado aquifer.

Sediments comprising the Silverado aquifer are both continental and marine. Where continental deposits predominate, yellow to brown, coarse to fine sands and gravels are interbedded with yellow to brown silts and clays. Marine deposits which comprise the Silverado aquifer over the remainder of the basin are primarily blue to grey sand, gravel, silt, and clay. Some black sands, quicksand, marine shells, peat, and wood fragments

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are also shown on drillers logs of wells located in the area of marine sediments. In the West Coast Basin, Richter (1950) describes the lithology as fine to coarse, blue-black arkosic sand with the larger grains composed of granite, granodiorite, and diorite. Along the flanks of the Palos Verdes Hills, limestone and schist pebbles are abundant, while in the Ballona Gap area slate, schist, and volcanic pebbles are commonly found.

The ancestral Rio Hondo and San Gabriel River systems have been the major transporting agent for materials comprising the continental portion of the Silverado aquifer in Central Basin, although some contributions may have been added by the Santa Ana River flowing in one of its earlier courses. The regional evidence indicates that the Los Angeles River did not flow into the coastal plain during much of the lower Pleistocene time and probably did not contribute sediment to the Silverado aquifer. However, streams flowing from the Santa Monica Mountains, Elysian Hills, and Palos Verdes Hills have added debris from these areas. Much of this material was deposited beneath the shallow ocean that covered the coastal plain at this time. The continental deposits appear to have been laid down when the sea was retreating from the coastal plain.

The varying thickness of the Silverado aquifer is depicted on Plate 21, "Lines of Equal Thickness of the Silverado Aquifer". This aquifer reaches a maximum thickness of 500 feet between the Wilmington anticline and the Cherry Hill fault. One mile west of Lakewood, along Carson Street, the Silverado aquifer is 450 feet thick. Along the south side of the Santa Fe Springs Plain and also two miles southeast of Huntington Park it is 300 feet thick.

The maximum depth reached by the base of the Silverado aquifer, 1200 feet below sea level, is found southwest of the Cherry Hill fault

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within Dominguez Gap, along the north side of the Los Alamitos fault, and about three miles southeast of Norwalk. A depth of 1100 feet below sea level occurs near Long Beach Harbor.

The Silverado aquifer crops out along the northeast flank of the Palos Verdes Hills, possibly on the continental shelf beneath Santa Monica Bay, along the southern margin of the Baldwin Hills, in the Repetto and Merced Hills, along the south slope of the Puente Hills, and possibly in the Coyote Hills. Outcrops in the areas named are shown as the San Pedro formation, Qsp on Plate 3, because insufficient data are available to definitely identify the aquifer involved.

Areas where the Silverado aquifer merges with overlying aquifers are shown on Plate 20. In the Montebello Forebay Area and Whittier Narrows the Silverado aquifer is directly overlain by and merges with aquifers younger than the Lynwood aquifer. Merged areas are irregular in extent but are generally found along the Newport-Inglewood uplift, in the area from Huntington Park to Santa Fe Springs, and also within the Whittier Narrows. In the West Coast Basin the Silverado is merged with the overlying Lynwood aquifer everywhere except beneath the Gardena syncline and the Wilmington anticline. Near Santa Monica Bay the Silverado aquifer is in hydraulic continuity with the Gardena and Gage, as well as the Lynwood aquifers. In the Montebello Forebay Area the Silverado aquifer merges with the overlying Lynwood, Jefferson, Hollydale and Gardena aquifers, as delineated on Plate 20A.

The Silverado aquifer has suffered a greater degree of folding than the overlying Lynwood aquifer. It has been deformed by all of the major anticlinal and synclinal folds. All the major faults shown on Plate 3 seem to have affected this aquifer. After faulting occurred, the aquifer

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may be found at either different or the same elevation but separated by a region of altered permeability. Sufficient data is lacking to determine whether the geologic structure just south of Santa Fe Springs is a fault or downfold. On the basis of the data available it is believed that the postulation of a sharp downfold would explain the existing structure in a more adequate manner than the assumption of a fault.

This aquifer is one of the most important ground water producers in the coastal plain. Specific capacities of wells perforated in it range up to a maximum of 159 gallons per minute per foot of drawdown and yields range up to 4700 gallons per minute.

In the Whittier Narrows the Silverado aquifer is merged with many overlying aquifers and recharging the shallow aquifers in that area would cause additional water to reach the Silverado aquifer. Recharge from the surface in the Los Angeles Forebay Area may also reach the Silverado aquifer where it is truncated by the Gaspur. Other possible recharge areas for the Silverado aquifer are in the outcrop along the Coyote and Baldwin Hills, or in the Ballona Gap, where the Silverado aquifer is directly beneath the Ballona aquifer and close to the surface. Natural recharge takes place in those areas shown on Plate 3 where the San Pedro formation crops out on the surface.

Sunnyside Aquifer. The water-bearing materials occurring within the Central Basin beneath the Silverado aquifer but above the Pico formation have been termed the "Sunnyside aquifer" after a typical occurrence illustrated by the log of a well located in Sunnyside Cemetery in North Long Beach.

The Sunnywide aquifer extends throughout the Central Basin. Its extent and elevation of its base are shown on Plate 22, "Lines of Equal

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Elevation on the Base of the Sunnyside Aquifer". Recent drilling along the coastal region from Palos Verdes Hills to Ballona Escarpment has revealed a zone of coarse deposits approximately 500 feet thick occurring beneath the Silverado aquifer, but separated from it by silts and clays. These coarse materials are similar to the Sunnyside aquifer in the Central Basin and may be the extension of the Sunnyside aquifer in the West Coast Basin.

The materials comprising this aquifer are coarse-grained sands and gravels sepsrated by fine-grained interbeds of sandy clay and clay. The lithology shown on a typical well log near the intersection of Del Amo and Cherry Streets is compacted blue sand, coarse blue gravel (up to four inches in diameter), hard blue sandy clay, and clay. Toward the Los Angeles-Orange County line, mushy blue sands and coarse gravels with greater amounts of blue clay are found. At Spring Street and Bloomfield Avenue, well logs indicated that instead of clay, fine blue sand with minor clay streaks was present. Along the center of the coastal plain, about one mile north of Manchester and near Alameda Avenue, fine to medium gravel (one quarter to one inch in diameter), and partly cemented blue clay, and grey to brown shale are typical materials. In Whittier Narrows hard grey sands and gravels, boulders, and blue sandy shale are present.

From drillers descriptions of materials, it is believed that the aquifer is of marine origin and has been affected very little by weathering. Many well logs show marine shells included with the sediments in addition to the interbedded marine-type clays and shales.

The Sunnyside aquifer attains its maximum known thickness of about 300 feet about one to one and a half miles southeast of Maywood in the vicinity of Slauson Avenue and the Long Beach Freeway. Plate 23, "Lines of Equal Thickness of the Sunnyside Aquifer", gives the thickness of the

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Sunnyside aquifer. No data is available to determine thickness in the central downfolded area because none of the water wells have reached the aquifer in this area.

It is not definitely known whether the Sunnyside aquifer crops out in any particular location within the Central Basin; however, it is assumed that some of the outcrop areas shown as the San Pedro formation on Plate 3 include the Sunnyside aquifer also. The most likely areas for this to occur are along the south slope of the Repetto, Merced, and Puente Hills, and especially on the top of the Coyote Hills.

In stratigraphic position the Sunnyside aquifer is overlain by the fine-grained Timms Point silt and Lomita marl and underlain by the Pico formation. It may be correlated in age with the unit mapped by Hoskins (1954) as the Coyote silt, the Anchor silt of Rodda (1957), and the La Habra conglomerate of Eckis (Calif. D.W.R., 1934).

Structurally, the Sunnyside aquifer is offset by most, if not all, of the faults within the Central Basin. Some of the faults appear to act as boundaries for the aquifer. Northeast of the Los Alamitos fault the base of the Sunnyside aquifer occurs at a maximum depth of about 1500 feet below sea level.

The Sunnyside merges with the Silverado and other overlying aquifers in many areas delineated on Plate 22, "Lines of Equal Elevation on the Base of the Sunnyside Aquifer". In these merged areas hydraulic continuity is possible through a series of aquifers to the surface. The only known areas where this aquifer may be recharged are limited to outcrops of the San Pedro formation and merged areas where folds have lifted the Sunnyside aquifer near the surface of the ground.

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Yields of wells perforated in this aquifer range up to 1500 gallons per minute. Specific capacities of known wells using only this aquifer for production are only fair, ranging from 6 to 25 gallons per minute per foot of drawdown.

Undifferentiated Plio-Pleistocene Sediments

An area of sediments of either Pliocene or Pleistocene age, or possibly both, is shown on Plate 3 in the Repetto Hills southeasterly of Monterey Park. In the geologic literature these sediments have been classified variously as both Pliocene and Pleistocene. Although various fossils are present, age designation based upon them is uncertain. While these sediments are somewhat permeable they have relatively little significance as far as ground water in the coastal plain is concerned; therefore, no attempt was made to determine their age.

These undifferentiated sediments consist of thin bedded to massive silts, sands, and gravels that are locally well indurated and contain limited marine fossil remains. The sediments have been folded and many minor faults and fractures are seen in outcrops.

Although these sediments are considered to be relatively unimportant as far as ground water is concerned, a drainage well constructed in 1959 reportedly yields fair quantities of good quality water. Firm conclusions, however, cannot be drawn from this limited experience.

Tertiary System

Aquifers have not been differentiated in sediments and rocks older than Pleistocene age because of limited well log data. Few wells extend into these materials and little ground water of suitable quality is extracted from them. Some fresh water is now being extracted from the upper member

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of the Pico formation, discussed first in this section. For pre-Pleistocene materials in general, the sediments and rocks are described by formations or broad age classification.

Pliocene Series

The Pliocene series is divided into two formations, the Pico formation and the Repetto formation. In addition, the Pico formation is divided into upper, middle, and lower divisions.

Pico Formation. The Pico formation is shown, where it outcrops at the surface, on Plate 3 by the symbol "P_p". The upper division or upper member of the Pico formation is a potential source of ground water. It has not been exploited to date, though wells along Carson Street near Lakewood do obtain water from upper Pico aquifers. This member is thickest in the synclinal areas, and it outcrops on the hills surrounding the coastal plain.

The upper Pico formation is generally composed of sand, silt, and clay of marine origin interbedded with marine gravels. Beds of gravels and sands range in thickness from 20 to 100 feet and are separated by beds of micaceous siltstone and clays.

Unconformably beneath this upper member are the middle and lower members of the Pico formation, or in some areas, the Repetto formation. The middle and lower divisions of the Pico formation are differentiated from upper Pico sediments by the contained foraminiferal faunas. Lithologically, the middle and lower divisions are composed of greenish-grey micaceous siltstone and fine to coarse light grey feldspathic sandstone interbedded with claystone and shale. The thickness of these lower division materials ranges from 400 to more than 2,000 feet. Throughout most of the coastal plain these rocks are far below the depths reached by the deepest

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water wells. Oil well data indicate that, although portions of these sediments may be sufficiently permeable to transmit water in usable quantities, the water is of poor quality and unsuitable for general use.

Repetto Formation. The Repetto formation, of early Pliocene age, is exposed in several areas adjacent to the coastal plain. The outcrops of this formation are identified by the symbol "Pr" on Plate 3. These deposits are composed mostly of siltstone with layers of sandstone and conglomerate, containing fragmental marine shells locally. The Repetto formation is about 5,000 feet in thickness. Wissler (1943) states that the maximum thickness occurs in the Montebello-Santa Fe Springs area. Conrey (1958) and Slosson (1958) confirm this and discuss the distribution and thickness of the Repetto rocks in some detail.

Miocene Series

Rocks of Miocene age are shown on Plate 3 by the symbols "Ms" for sedimentary rocks and "Mv" for volcanic rocks. Nomenclature of the sediments of Miocene age is somewhat complicated; however, the relationship between the various names and brief descriptions of the various formations are presented in Table 1.

Sedimentary Rocks. Sedimentary rocks of middle and late Miocene age have been called the Monterey formation in the Palos Verdes Hills, the Modelo formation in the Santa Monica Mountains, and the Puente formation beneath the coastal plain and in the Repetto and Puente Hills. These formations, up to 11,000 feet thick, consist predominantly of clay shales but siliceous shales, sandstones, and conglomerates are common.

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The Topanga formation is of middle and possibly early Miocene age. It is interbedded with and lies below the Miocene volcanic rocks. The formation attains a thickness of 7,500 feet and consists of shale, sandstone, and conglomerate.

No wells are known to produce fresh water from these formations in the immediate area of the coastal plain. However, water wells in other parts of Southern California do obtain limited supplies from hard fractured shales and poorly consolidated sandstones and conglomerates of these formations.

Volcanic Rocks. Calcic andesite flows, tuffs, and breccias underlie at least parts of the coastal plain, and usually contain interbedded marine sand, conglomerate, and shale. Where these materials outcrop on the surface they are identified by the symbol "Mv" on Plate 3. Available data indicate that the fractured sills, dikes, and flows, along with interbedded sand and gravels, yield water to wells, while the conglomerates and agglomerates are relatively nonwater-bearing.

Older Tertiary Sedimentary Rocks

Rocks of Eocene and Oligocene age are missing beneath West Coast Basin, though they may underlie the Central Basin. Hoots (1931) gives some evidence for the presence of the Sespe and Vaqueros formations of Oligocene(?) or early Miocene age in the Santa Monica Mountains. Paleocene rocks crop out in the Santa Monica Mountains and may underlie a part of the coastal plain. Hoots (1931) termed these rocks the Martinez formation. Other exposures of Martinez sandstone and conglomerate were found in the Santa Monica Mountains by Durrell (1954) and others. Outcrops of Eocene and Oligocene rocks are shown on Plate 3 by the symbols "E" and "Ø", respectively, while outcrops of Paleocene rocks are marked by the symbol "E-K".

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Cretaceous System

A sequence of Upper Cretaceous sediments within the Santa Monica Mountains are differentiated and have been called the Chico formation by Hoots (1931). Durrell (1954) however, appears to have divided the same sequence into the Chico and Trabuco formations. The symbol "K_s" represents the areas of outcrops of these rocks on Plate 3.

Quartz dioritic intrusive rocks, shown by the symbol "K_g" on Plate 3 have previously been assumed to be Jurassic by comparison with similar rocks in the Sierra Nevada (Durrell, 1954). On the basis of dating by lead-alpha activity ratios of intrusive rocks in Southern California, Larsen, et al (1958) suggests that these rocks are of an early Late Cretaceous age rather than Jurassic.

Jurassic System

Rocks, called the Catalina schist, crop out on the Palos Verdes Hills and are identified on Plate 3 by the symbol "J". These have been also referred to as the Western bedrock complex because they underlie Miocene rocks of the West Coast Basin. The age of these schistose rocks is questionable and, according to Woodford, et al (1954), may be either Mesozoic (when compared to the Jurassic Franciscan formation of the coast ranges) or Precambrian (when compared with the Pelona schist of the San Gabriel Mountains). In this report they are mapped as Jurassic.

Triassic System

Metamorphosed black shale and sandstone crops out in the Santa Monica Mountains and have been called the Santa Monica slate (Hoots, 1931) and the Santa Monica formation (Durrell, 1954). Intrusion of these rocks

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by the quartz dioritic magma was responsible for changing these rocks into grey to black slates, mica schists, and spotted slates. These rocks are dated as Triassic by comparison with similar rocks of Triassic age in the Santa Ana Mountains. In the coastal plain, these are presumably the oldest rocks known, although the Cataline schist mentioned under the Jurassic System may possibly be older. These Triassic rocks are identified on Plate 3 by the symbol "T_R".

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CHAPTER V. GEOLOGIC STRUCTURE

Geologic structural features within the Coastal Plain of Los Angeles County have a pronounced effect upon ground water movement and storage. Faulting offsets aquifers, creates zones of cementation and low permeability, and generally disrupts the flow of subsurface waters. Folding and faulting raise aquifers either to or near the land surface, thereby enhancing the possibility of recharge. In some instances, uplifted fault blocks and folds are deterrents to ground water movement where structural highs of bedrock disrupt or change the course of ground water movement. Locally, aquifers are partially or entirely eroded away across these features, or are being dewatered because of the lowering of ground water levels. Elsewhere, ground water reservoirs are formed in structural lows created by faulting and synclinal folding of aquifers.

The tectonic forces which produced the structural deformation within and adjacent to the coastal plain were continuous throughout Tertiary time and possibly Quaternary time. This deformation, however, was most severe during mid-Miocene, Pliocene, and Pleistocene time. Sediments of Recent age have not been seriously disturbed, even though earth movements have been recorded during historic time.

Descriptions of individual geologic structures presented in this chapter are of necessity brief. Emphasis is given to those structures which influence ground water movement. Heretofore unrecognized or unpublished subsurface structural features have been noted during the course of this investigation. Most of these features are not evident from surface topography even though some of them affect relatively shallow sediments.

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The structural characteristics of Pleistocene and Recent aquifers were determined by constructing geologic cross sections and maps showing lines of equal elevation on the bases of aquifers. Available geologic maps and subsurface maps of oil field structures were used to help determine the structural patterns of the various aquifers and underlying Tertiary formations. The locations of faults and fold axes in these Tertiary formations, however, do not necessarily coincide with locations of similar structures in the Pleistocene sediments.

Those structures which have a surface expression or which affect water-bearing sediments are included in the areal geology shown on Plate 3.

Regional Features

Geologic structures within and bordering the coastal plain are generally aligned along regional uplifts and depressions. For descriptive purposes, these are herein grouped into the "Mountain and Foothill structures", "Transitional structures", the "South Gate-Santa Ana depression", the "Newport-Inglewood uplift", the "Hawthorne-Long Beach depression", and "Offshore structures". These structural systems are reasonably distinct, but where systems join, local structural features may be common to each of the systems.

The coastal plain is bordered to the north, northeast, and southwest by mountains and hills which have been uplifted by folding and faulting. The hills bordering the northeast margins of the coastal plain are flanked to the south by the Transitional structures consisting of partially buried anticlines and synclines. The Transitional structures do not constitute one structural system but are grouped together because of their

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relative positions. The South Gate-Santa Ana depression, a general northwest trending synclinal depression, underlies the Downey Plain and extends from the La Brea Plain to beyond the investigational area into Orange County. The South Gate-Santa Ana depression is bordered on the northeast by transitional structures and on the southwest by the Newport-Inglewood uplift, a system of echelon faults and anticlinal folds. In Los Angeles County, the Newport-Inglewood uplift is bordered on the southwest by the Hawthorne-Long Beach depression, a synclinal depression, which underlies the Torrance Plain and extends northwest from the City of Long Beach toward the Santa Monica Mountains. On the west side of the Hawthorne-Long Beach depression, beneath the El Segundo Sand Hills, water-bearing sediments of Pleistocene age rise gently as a homocline toward Santa Monica Bay. The Offshore structures affect the water-bearing sediments extending beneath the Santa Monica and San Pedro Bays.

Mountain and Foothill Structures

The northern and eastern margins of the coastal plain are bordered by the Santa Monica Mountains and the Elysian, Repetto, Merced, and Puente Hills. The Palos Verdes Hills border the plain to the southwest. These highlands are almost entirely composed of rocks of pre-Tertiary and Tertiary age and are essentially nonwater-bearing. Therefore, only brief mention of the structural nature of each of these areas will be made. Detailed description of geologic structures within these highlands may be found in many of the references listed in the Bibliography. Between the Merced and Puente Hills is the Whittier Narrows, an erosional gap. Since it is closely associated with the highlands and is the location of the

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major subsurface flow to the ground water basins of the Coastal Plain of Los Angeles County, the structures within it are described in detail in this section.

Santa Monica Mountains

The Santa Monica Mountains (Plate 2) are essentially a westerly plunging, asymetric anticline that has had a complex history of development. The anticline has been faulted, deformed by secondary folding, and further complicated by igneous intrusion. Important periods of deformation are recorded by several major unconformities between various formations of Cretaceous and Tertiary age. The Hollywood fault extends along the southern edge of the Santa Monica Mountains and at depth serves as the northerly edge of the Hollywood Basin, one of the ground water basins included in the coastal plain. The fault is buried by sediments of Pleistocene and Recent age.

Elysian Hills

Principal structures in the Elysian Hills include the Elysian Park anticline and secondary folding and faulting which deform its southern flank. The Elysian Park anticline extends southeast across the Los Angeles Narrows and through the Repetto Hills. In the Los Angeles Narrows, the structure has been cut by erosion and Miocene and Pliocene sediments are unconformably overlain by sediments of late Pleistocene and Recent age.

Repetto and Merced Hills

The Repetto and Merced Hills are essentially continuous but are structurally separated by a westerly trending syncline. In both uplift areas, angular unconformities locally exist between Tertiary sediments and the San Pedro formation, and between the San Pedro and Lakewood formations.

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North of the San Bernardino Freeway, the Repetto Hills are formed into three nearly parallel fold systems which trend slightly north of west. These consist of a syncline which separates the Highland Park-South Pasadena anticlinal system on the north from the Elysian Park anticline on the south. The Elysian Park anticline is flanked on the south by another syncline and then the Boston Heights anticline.

South of the San Bernardino Freeway, the Repetto Hills are a westerly trending, southerly dipping homocline that is cut by the Coyote Pass fault west of Atlantic Boulevard. The Coyote Pass fault extends westerly along the south flank of the hills, and brings sediments of Pliocene age into fault contact with those of Pleistocene age.

The Merced Hills are a westerly trending, structural high developed by faulting and anticlinal folding. Major structures include the North Montebello thrust fault and the Montebello anticline. These structures are exposed at the surface and are developed in sediments of Pliocene and Pleistocene age. The anticlinal structures containing the East and West Montebello oil fields are developed at depth in sediments of Tertiary age, and are not reflected in water-bearing sediments of Pleistocene and Recent age.

Whittier Narrows Area

The Whittier Narrows area is not itself an uplift, but is a structurally controlled erosional gap located between and structurally related to the adjacent Merced and Puente Hills. Beneath the Whittier Narrows, the sediments of the San Pedro formation, and possibly the Pico formation, are folded into a northeast trending, synclinal depression. Southwest of the Whittier Narrows Dam, the subsurface structure is further

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complicated by both block faulting and transverse folding. Sediments of the Lakewood formation unconformably overlie the syncline and are only slightly deformed (Section P-P', Plate 6G).

The synclinal structure underlying the Whittier Narrows separates the anticlinal form of the Merced Hills on the west from the essentially anticlinal structure of the Puente Hills on the east. These anticlinal structures have been cut through by erosion, and are locally interrupted by faulting. The Montebello anticline plunges east into the Whittier Narrows and is reflected in sediments of the San Pedro formation. The anticlinal structure of the Puente Hills, in its western extremity, is cut by the Cemetery fault, as hereafter presented.

The structure of that portion of Whittier Narrows lying directly southwest of the Whittier Narrows Dam is exceedingly complex, and the available data may be interpreted to derive two differing patterns of subsurface structure. One explanation of a portion of the data would picture sharp folding of the sediment parallel to the northeast-southwest trending synclinal axis, possibly coupled with the extension of the Whittier fault through Whittier Narrows perpendicular to the synclinal axis. After careful analysis, however, this theory was held to be inadequate in explaining all data.

This report therefore presents the subsurface structure of Whittier Narrows as being governed by three faults generally parallel to the axis of the syncline. The following discussion of the structural system in the Whittier Narrows is based on the presence of these assumed faults. These faults have been named, from east to west, the Cemetery, Pico, and Rio Hondo faults, and they divide the area into two fault blocks that are tilted to the west. (Plates 3, 6A, and 6G). The available evidence also

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indicates that within the Whittier Narrows, water-bearing sediments of Pleistocene and Recent ages are not offset by the Whittier fault. Vertical offsetting along the three parallel faults occurs primarily in the uppermost Pico and San Pedro formations; local displacement of the Lakewood formation occurs along the southern extent of the Rio Hondo fault (Section A-A'-A", Plate 6A). Sediments of Recent age are not disturbed by these faults. Considerable merging of aquifers occurs throughout the narrows and is related to displacement along faults and to unconformities among aquifers of Pleistocene and Recent ages. The pattern of the aquifers and their relationship to the fault system in this area are shown pictorially in the cut-away diagram on Plate 7.

The Rio Hondo fault is about four miles long and generally follows the east side of the Rio Hondo. West of the fault, aquifers of the San Pedro formation are raised close to the surface and are unconformably overlain by the Gardena and Gaspur aquifers (Section A-A'-A", Plate 6A).

The Pico fault, which can be traced for about three miles, is located about one mile east of, and essentially parallel to, the Rio Hondo fault. The fault block west of the Pico fault has been raised relative to that of the east side. The vertical displacement of the San Pedro formation brings different aquifers into hydraulic continuity with each other across the structure, as illustrated on Section A-A'-A", Plate 6A.

The Cemetery fault extends for about two miles along the east margin of the Whittier Narrows, and apparently displaces the west extent of the Puente Hills. The fault block west of the fault is downthrown relative to the east side. Available evidence suggests that the Cemetery fault terminates at the Whittier fault, and is possibly related to this major shear zone.

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Two complexly folded and tilted fault blocks are developed between the Rio Hondo, Pico and Cemetery faults. The western block is downthrown on the Rio Hondo fault, and upthrown on the Pico fault. Within this fault block, sediments of the upper Pico and San Pedro formations are folded into an anticline, which trends northeast and crests adjacent to the Pico fault. This high disrupts the synclinal depression in its southwest extremity, as shown by contours drawn on the base of the Sunnyside aquifer (Plate 22). The Gardena aquifer unconformably overlies the anticline and the truncated aquifers of the San Pedro formation. (Section P-P', Plate 6G).

The eastern fault block is downthrown between the Pico and Cemetery faults. Within this block, the San Pedro formation is gently folded as shown on Section N-N'-N", Plate 6F, and by contours drawn on the base of the Sunnyside, Silverado and Lynwood aquifers (Plates 22, 20, and 18). Sediments of the Lakewood formation unconformably overlie these gentle folds, and the Gardena Aquifer merges with the Jefferson aquifer locally across these flexures.

Puente Hills and Whittier Fault Zone

The Puente Hills are essentially a west trending anticline that is complicated by secondary folding and faulting. The predominant structural feature of the Puente Hills is the Whittier fault or fault zone. This major structure trends southeast along the south flanks of the Puente Hills and extends from the vicinity of the Whittier Narrows into Orange County. Northeast of the City of Whittier, the principal fault separates into a complex of smaller breaks and probably diminishes as it approaches the Whittier Narrows. Available oil well data indicate that it is a high angle reverse fault, with the north side rising over the south side at an angle of approximately 70 degrees. Offset drainage of La Mirada Creek and Turnbull and Brea Canyons

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in Orange County suggest that right lateral displacement has occurred along the fault in relatively late geologic time, the southwest side having moved several thousand feet northwest relative to the northeast side.

The Puente Hills have been uplifted by vertical displacement along the Whittier fault and by normal faulting along the Workman Hill, Handorf and Rowland fault systems. The hills are further characterized structurally by minor faults, unconformities, and tight and overturned folds in sediments of Miocene, Pliocene and Pleistocene age. South of the Whittier fault zone, an angular unconformity exists between Pico and overlying San Pedro sediments, but both formations have a general southerly homoclinal dip into the La Habra syncline.

Palos Verdes Hills

The Palos Verdes Hills are an uplifted fault block composed of Catalina schist basement and marine sediments of Tertiary and Quaternary age that have been folded into a general anticlinal form. This general anticlinal high extends through the central portion of the hills and may extend beneath alluvial cover into the San Pedro area; it may also continue as a subsea structure beneath the San Pedro Shelf (Moore, 1951).

A fault which extends in a northwest direction along the northern boundary of the hills has been termed the "Palos Verdes Fault Zone" by Woodford, et al (1954). This break, although only partially reflected at the surface by minor faults and steep northeast dipping sediments of Miocene, Pliocene and Pleistocene age, offsets Catalina schist basement at depth. Test drilling by the Los Angeles County Flood Control District has verified the continuity of this fault zone out into the Pacific Ocean near Redondo Beach.

The Gaffey anticline and the Gaffey syncline extend northwest along the northeastern portion of the Palos Verdes Hills. These folds plunge

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southeast and apparently extend beneath Recent alluvium east of the hills and into San Pedro Harbor where they may affect ground water movement.

Transitional Structures

Transitional structures are those structural features that lie along the generally south-dipping homoclinal flanks of those mountain and foothill structures to the north and east of the coastal plain. They are also north and northeast of the South Gate-Santa Ana depression. A few of these structures have topographic expression; the remainder are buried beneath upper Pleistocene and Recent sediments. These structures, like most on the coastal plain, are generally best developed in Miocene and Pliocene formations, and for the most part have been determined from subsurface oil exploration studies.

From northwest to southeast, the Transitional structures include the Hollywood syncline, La Brea high, Boyle Heights anticline, Bandini anticline, East Los Angeles anticline, the Santa Fe springs-Coyote Hills uplift, and La Habra syncline. Since the Bandini and East Los Angeles anticlines are developed at depth and do not appear to affect the overlying water-bearing sediments, they are not included in the following discussions of the other Transitional structures.

Hollywood Syncline

The Hollywood syncline is a downwarped area between the Santa Monica Mountains to the north and the La Brea Plain to the south. The syncline plunges to the southwest where it may be displaced by the Inglewood fault. Northeast of Western Avenue the flexure becomes ill defined and is apparently broken up by upfaulted blocks of Tertiary bedrock. The

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location of the synclinal axis, as shown by the areal geology on Plate 3A is inferred from available subsurface data.

Ground water moves south and west from the syncline. The Santa Monica Mountains and the Hollywood fault, which truncate the syncline's northern flank, are complete barriers to ground water movement to the north and east. To the south and southeast, ground water movement is impeded by the La Brea high.

La Brea High

The La Brea Plain is closely underlain by a structural high developed in sediments of Tertiary age and unconformably overlain by 100 to 200 feet of the Lakewood formation. The structural nature of the high is known in part. The northwestern portion of the high, which contains the Salt Lake oil field, includes a northwest plunging anticline, a northwest plunging syncline, and a southwest plunging anticline, all in Miocene rocks. South of these folds the structural configuration of bedrock is largely unknown. The south dipping monocline of Tertiary sediments in the Los Angeles oil field may extend west beneath the southern portion of the La Brea Plain and could be the upper expression of the east-west trending Santa Monica fault system described by Barbat (1958).

The crest of the La Brea high is located about one mile south of, and generally parallel to, Santa Monica Boulevard from Western Avenue to near the Inglewood fault. This feature plunges steeply in its western extremity, and the San Pedro formation is continuous from the south into the Hollywood syncline around the warped slope thus formed. Across the crest of the high, sediments of the San Pedro formation have been removed by erosion. Ground water movement from the Hollywood syncline south across

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the La Brea high is therefore limited to aquifers of the Lakewood formation, and to the San Pedro formation around the western nose of the La Brea high.

Boyle Heights Anticline

The Boyle Heights anticline contains the Boyle Heights oil field. This structure, developed in sediments of Miocene, Pliocene and Pleistocene age, is essentially a minor anticlinal flexure on the south dipping homoclinal flank of the western Repetto Hills. The anticlinal axis trends southeast: the crest approximately underlies the intersection of 4th and Soto Streets. The fold is asymetric with the north flank dipping more gently than the south flank. Well logs show that the San Pedro formation has been eroded from the crest of the anticline. The Lakewood formation, here approximately 250 feet thick, unconformably overlies the Repetto formation at the crest and the San Pedro formation along the southern flanks of the anticline. Ground water movement across the structure is restricted due to anticlinal folding, thinning of water-bearing section over the crest and the nonwater-bearing core of the Repetto formation.

Santa Fe Springs-Coyote Hills Uplift

The surface of the Santa Fe Springs Plain and the Coyote Hills reflects a structural high which trends northwest from the Coyote Hills in Orange County and is primarily developed in underlying formations of Miocene and Pliocene age. In these sediments, the uplift consists of anticlinal folds which contain the Santa Fe Springs, Leffingwell, and West Coyote oil fields. The San Pedro and Lakewood formations are similarly folded across the uplift, and the folds developed in these sediments generally correspond to the underlying structures.

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Santa Fe Springs Anticline. The Santa Fe Springs oil field is contained in an elongated anticlinal dome which trends northwest and underlies the Santa Fe Springs Plain. The fold is symmetrical and has gently dipping flanks. The San Pedro and Lakewood formations are folded over the structure and have a minimum combined thickness of 700 feet above the dome. Contours depicting the base of Pleistocene aquifers show that in the San Pedro and Lakewood formations the fold crest is located slightly north of the axis as defined by the Pliocene beds of the oil reservoir. Contours depicting the base of fresh-water materials correspond to the structural high and indicate that in this area the uppermost Pico sediments contain fresh water.

While some of the shallow aquifers thin out in the area of the Santa Fe Springs anticline, it does not otherwise affect movement of ground water.

Leffingwell Anticline. The Leffingwell oil field is located approximately two miles east of the Santa Fe Springs oil field and is contained in a faulted, eastward plunging, anticlinal nose developed in sediments of Tertiary age. The anticline is offset in its central portion by two northern trending faults which are not definable above sediments of Miocene age. Contours of the base of the Silverado aquifer (Plate 20) reflect the underlying high, but no effect on the movement of ground water is known.

West Coyote Anticline. The West Coyote anticline, an elongated dome, contains the West Coyote oil field and is defined in the outcropping San Pedro formation within that portion of the Coyote Hills immediately east

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of the Los Angeles-Orange County line. The anticline trends east-west and is complicated by faulting in the central and western portion and by secondary folding. Dips on the south flank are steeper than on the north flan. Contours of the base of lower Pleistocene aquifers show that the anticline plunges west into Los Angeles County. The coarse gravels exposed at the surface and across the crest are believed to be the Sunnyside aquifer. The uplifted, relatively impermeable upper Pico formation acts as a barrier to the movement of ground water across the anticline.

La Habra Syncline

This syncline is located between the Puente Hills on the north and Santa Fe Springs-Coyote Hills uplift on the south. The axis of the syncline trends slightly north of west and its location (Plate 3) is inferred from available subsurface data. Water-bearing materials extend up both limbs of the syncline and outcrop in the Puente Hills and the Coyote Hills. The syncline is closed at the eastern end by the northeast trending East Coyote anticline. Available data suggests that a saddle exists at the western end of the structure where it disappears into the Whittier Narrows area.

South Gate-Santa Ana Depression

The South Gate-Santa Ana depression is the generally downwarped area which underlies the Downey Plain. The depression trends northwest between the Baldwin Hills and the La Brea Plain and extends beyond the investigational area into Orange County. The Newport-Inglewood uplift borders the depression on the southwest in Los Angeles County. The La Brea Plain, Elysian Hills, Montebello Plain, Santa Fe Springs, Coyote Hills,

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and Santa Ana Mountains border the depression to the northeast. Minor anticlinal folds or warps lie along the limbs of this synclinal depression.

As shown on the geologic cross sections, sediments of lower Pleistocene age have been folded to a greater extent than upper Pleistocene and Recent materials. The trough in older sediments lies in the central portion of the plain, about one mile southwest of Huntington Park. In upper Pleistocene sediments it lies west of the central portion of the Downey Plain in the vicinity of Carson Street and Palo Verde Avenue. Recent alluvium is generally flat lying, although slight local folding occurs in the Whittier Narrows. The major structural features in the South Gate-Santa Ana depression are the Paramount Syncline and Los Alamitos fault, and the Norwalk Syncline.

Paramount Syncline and Los Alamitos Fault

The principal axis of the depression, determined from aquifers of the San Pedro formation, is named the Paramount syncline. This structure underlies the City of Paramount and extends northwesterly to the Inglewood fault. South of Huntington Park the trend of the synclinal axis changes from northwest to slightly north of west, as shown on Plate 3.

Southeast of the City of Paramount an extension of the axis of the Paramount syncline coincides with the Los Alamitos fault. This fault trends southeasterly from one mile north of the City of Lakewood and extends about six and one-half miles to the southwest limits of the Los Alamitos Naval Reservation. Apparent movement along the fault appears to have been vertical with the aquifers to the east of the fault having moved down relative to those of the west. Aquifers of late Pleistocene and Recent age apparently

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have not been displaced. Merging of differing aquifers occurs across the fault because of their vertical displacement. Water quality and water well logs on either side of the structure indicate that movement of ground water across the fault is only slightly affected.

The manner in which the Los Alamitos fault continues on as an apparent extension of the Paramount syncline suggests that the displacement of aquifers in this area might be a result of folding of the sediments rather than the postulated faulting. However, the available data are primarily derived from water well drillers logs and water quality data, indicate the presence of a fault, possibly the same fault believed by some petroleum geologists to exist in this area in the older sediment underlying the San Pedro formation. Subsequent drilling may resolve the question as to whether this feature is actually a fold or a fault.

Norwalk Syncline

The Norwalk syncline is located south of the Coyote Hills and extends southeast from the City of Norwalk into Orange County. As shown by contours depicting the base of the Silverado aquifer (Plate 20A), the syncline plunges northwesterly toward the City of Norwalk.

Newport-Inglewood Uplift

The Newport-Inglewood uplift is an important regional structure extending from Newport Mesa in Orange County northwesterly approximately 40 miles to its terminus in Beverly Hills. At depth, the uplift is considered a complex fault system that serves as the boundary between Catalina schist basement to the west and granitic basement to the east. At the surface it is characterized by a series of echelon faults and anticlinal folds and domes which underlie the Beverly, Baldwin, Rosecrans, Dominguez, Signal, Bixby Ranch and Landing Hills (Plate 2). Formations on both flanks of the uplift dip away from the axis. The anticlines are characteristically closed at

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both ends and are separated by structural saddles. The structures forming the uplift are deformed by high-angle normal and reverse faults at the surface and, at depth, Tertiary sediments are offset by low angle reverse faults.

The faults of the Newport-Inglewood uplift in some cases exert considerable barrier influence upon the movement of subsurface water. In other places sediments offset by the faults have been scoured and backfilled by ancient rivers and streams so that in these areas the faults offer little or no restraint to the movement of ground water. Offsetting of sediments along these faults is usually greater in the deeper, older formations. Displacement is less in younger, stratigraphically higher formations. In the Pleistocene deposits and on the surface, actual displacement by faulting is minor and folding is predominant.

The folds and faults of the Newport-Inglewood uplift, from north to south, include the Beverly Hills dome, Inglewood fault, the Baldwin Hills uplift, Potrero fault and dome, the Rosecrans anticline, Avalon-Compton fault, Dominguez and Long Beach anticlines, Cherry Hill, Northeast Flank, Pickler, and Reservoir Hill faults, and the Seal Beach structure. The structural features of the Newport-Inglewood uplift are described in the following sections.

Beverly Hills Dome

The Beverly Hills dome, a small fold developed at depth in sediments of Tertiary age, is the northernmost anticlinal structure of the Newport-Inglewood uplift. The dome, which contains the Beverly Hills oil field, is apparently not reflected in overlying sediments of Pleistocene and Recent age. Pleistocene formations in the area have reportedly been penetrated by only a few water wells on which data are not available. Available oil well information, however, indicates that Pleistocene sediments dip northwesterly away from the Baldwin Hills and toward the Santa Monica Mountains.

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Inglewood Fault

The Inglewood fault is approximately nine miles long, trends northwest-southeast, and extends from approximately one mile south of the City of Beverly Hills to nearly two miles southeast of the City of Inglewood. An eroded escarpment which is probably the surface expression of the Inglewood fault is present in the Cheviot Hills (Poland, et al 1949).

Beneath Ballona Gap, the fault offsets aquifers of Pleistocene age as shown on section A-A'-A", Plate 6A. In this area, the sediments east of the fault have dropped down relative to those on the west side and the fault forms a barrier to ground water movement. Between the Cheviot Hills and the Santa Monica Mountain front, the presence of the Inglewood fault and its probable effect on ground water is largely conjectural. Water level data for the vicinity of Beverly Hills, however, suggest that the fault does not affect water-bearing sediments in that area.

In the Baldwin Hills, the Inglewood fault is marked at the surface by an escarpment along which over 200 feet of vertical displacement has been measured (Driver, 1943). Available evidence indicates that displacement along the fault is both normal and right lateral, the latter being the principal movement. The fault dips steeply west and is offset by several cross faults which trend northeast. In the Baldwin Hills, the west block is dropped; between the Baldwin Hills and Ballona Gap, therefore, pivotal movement must have occurred as the west block is uplifted in Ballona Gap.

South of the Baldwin Hills, the Inglewood fault has also been called the Townsite fault (Willis and Ballantyne, 1943) and is offset by the Fairview Avenue and Centinela Creek faults which trend northeast. The

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Inglewood fault offsets aquifers of the San Pedro formation as shown on section B-B'-B", Plate 6A, and forms a partial barrier to ground water movement in the vicinity of the City of Inglewood.

Baldwin Hills Uplift

The Baldwin Hills, containing the Inglewood oil field, are underlain by a faulted, northwest-trending anticline which is developed in sediments of Tertiary and Pleistocene age. Two principal northwesterly trending, nearly parallel faults offset the central portion of the hills, developing a downdropped block or graben across the crest of the anticline. The more easterly of the two structures is the Inglewood fault, described in preceding paragraphs; the other fault is unnamed. Both faults are offset by secondary cross faults which trend northeast. The block east of the Inglewood fault is composed of sediments of Pliocene age and older and is cut by several small unnamed faults. One such fault extends along the northeast border of the Baldwin Hills and may be related to the prominent excarpment in that area. The Slauson Avenue fault extends northeast beyond the Baldwin Hills and offsets aquifers of the San Pedro formation.

The Baldwin Hills form a complete barrier to ground water movement where the essentially nonwater-bearing Pico formation crops out (Plate 3A).

Potrero Structures

This term is assigned to those structures of the Newport-Inglewood uplift which are located between the Baldwin Hills to the northwest and the Rosecrans anticline to the southeast. Principal structures include the Inglewood and Potrero faults and the Potrero dome. The faults are continuous from the Baldwin Hills to the Rosecrans anticline, but the dome is an independent structural feature.

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The Inglewood and Potrero faults extend southeast from the Baldwin Hills and border a linear, tilted block, approximately four miles long and several thousand feet wide, which is broken into smaller blocks by several nearly parallel, northeasterly trending cross faults (Plate 3A).

Potrero Fault. The Potrero fault is about four miles long and is expressed at the surface as an escarpment along the west flank of the Rosecrans Hills. It is essentially a fracture zone, 100 to 200 feet wide, that trends northwesterly and dips steeply to the west. Both normal and right lateral displacements have been observed, but the latter is more pronounced. In those areas where vertical displacement of aquifers exists, the fault acts as a barrier to subsurface flow, as was shown by a pumping test conducted in the Inglewood oil field.

A series of transverse faults cut both the Inglewood and Potrero faults and enclose a number of tilted, uplifted or downdropped blocks. From north to south these faults are: The Slauson Avenue fault, Fairview Avenue fault, Centinela Creek fault, Inglewood Park Cemetery fault, Manchester Avenue fault, and the Century Boulevard fault. These faults probably offset aquifers of Pleistocene age and are believed to act as partial barriers to ground water movement (Poland, et al 1959).

Potrero Dome. The Potrero dome, primarily developed at depth in sediments of Tertiary age, is located immediately east of the City of Inglewood and contains the Potrero oil field. The dome trends northwest and is offset by the Inglewood and Potrero faults. Dips along the flanks are gentle, becoming steepest to the north and east.

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Rosecrans Anticline

Defined by aquifers of the San Pedro formation, the Rosecrans anticline trends northwest and extends for approximately five miles near the middle of the Newport-Inglewood uplift in Los Angeles County and lies beneath the Rosecrans Hills. The Howard Townsite, Rosecrans, and South Rosecrans oil fields underlie this Pleistocene structure, and are developed in sediments of Tertiary age. These oil structures are offset and complicated by several nearly parallel, westerly trending thrust faults which do not affect sediments of Pleistocene age. Thinning and pinching out of the aquifers across the anticline may be a deterrent to ground water movement between the Central Basin and the West Coast Basin.

Avalon-Compton Fault

The Avalon-Compton fault is about two and one-half miles long and trends northwesterly from the north flank of Dominguez Hill to the south end of Rosecrans anticline. The normal displacement along the fault increases with depth, and the southwest block is dropped. The fault offsets the Silverado, Lynwood, and Gardena aquifers, as shown on Section D-D'-D", Plate 6B. Water level differences on either side of the fault indicate that this structure is an effective ground water barrier (Poland, et al 1959a).

Dominguez Anticline

The structure underlying Dominguez Hill and containing the Dominguez oil field has been described by Grinsfelder (1943) as an elliptical, northwesterly trending anticline. Similar to most structures on the Newport-Inglewood uplift, the anticline, fully developed in the deeper

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Tertiary formations, is also reflected in Pleistocene sediments at the surface. Dominguez Hill, rising about 150 feet above the surrounding land surface, is typical of this relationship. The anticline is offset by high angle normal faults and lower angle reverse faults at depth. This deformation does not appear to extend more than 4,000 feet below sea level. The base of Pleistocene sediments across the anticlinal crest is about 400 feet below sea level and it is believed that the aquifers are not affected by faulting across the anticline. The southwest flank of the anticline dips more steeply than the northeast flank. The extreme northwest flank of the structure is cut by the Avalon-Compton fault, described above.

Long Beach Anticline

The Long Beach anticline is a narrow, elongated, asymmetrical structure which trends northwest and is offset by several prominent faults. The structure extends approximately five miles through Signal Hill and Reservoir Hill and contains the Long Beach oil field. The plunge of the axis is less to the northwest than to the southeast. Dips on the southwest flanks are generally steeper away from the crest than dips on the northeast flanks. Three prominent faults, the Cherry Hill, Northeast Flank, and the Reservoir Hill faults, trend northwest along the crest of the anticline. A short, transverse fault, the Pickler fault. extends across the crest of the anticline from the northern expression of the Northeast Flank fault to the Cherry Hill fault. A surface scarp along the north side of the Bixby Ranch Hill may be a surface expression of a fault, but subsurface evidence available at this time does not clearly confirm this.

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Available data in the Signal Hill and Reservoir Hill areas and in that portion of the City of Long Beach adjacent to and west of the Resevoir Hill fault are insufficient for definition of aquifers in these areas and for correlation of aquifers across the Pickler, Northeast Flank, and Reservoir Hill faults. According to Poland, the Signal Hill area is a complete barrier to movement of ground water between the Long Beach Plain and the Downey Plain. No new evidence was available to confirm or disprove this assertion. Even though data are sparse, however, it is apparent that the structural character of Signal Hill and Reservoir Hill is sufficient to restrict ground water movement.

Cherry Hill Fault. Stolz (1943a) designated the fault that extends along the southwest flank of the Long Beach anticline as the Cherry Hill fault. Movement along the fault is up on the northeast side and down on the southwest side. Vertical displacement of water-bearing sediments is considerable for several miles along this fault. Along the southwest side, the Silverado aquifer, for example, has been displaced against older rocks of low permeability. Northeast of the structure at Signal Hill, these rocks of low permeability rise above the zone of saturation.

The Cherry Hill fault extends across Dominguez Gap and disappears along the northeast flank of Dominguez Hill. Although the fault does not act as a barrier to movement of ground water in the Gaspur aquifer, it does have a barrier effect in the underlying formations in Dominguez Gap (Poland, et al 1946b).

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Northeast Flank Fault. The Northeast Flank fault, also named by Stolz (1943), extends along the northeast flank of Signal Hill for about one mile. The northeast side of the fault is downdropped relative to Signal Hill, which is an uptilted block between this fault and the Cherry Hill fault. In this area, Pleistocene aquifers have apparently been entirely offset and ground water movement is impeded by the Northeast Flank fault.

Pickler Fault. The Pickler fault is a transverse fault which strikes southwest along the northwest margin of Signal Hill. Its existence was inferred largely from a difference in the productivity of oil wells on either side of the fault. The area northwest of the fault is downdropped relative to Signal Hill. The vertical displacement at the base of the San Pedro formation is believed to be about 150 feet. This displacement brings sediments of relatively low permeability in the block to the southeast into contact with the water-bearing sediments to the northwest.

Reservoir Hill Fault. The Reservoir Hill fault is a normal, steep, northeasterly dipping fault aligned with the northeast flank of Reservoir Hill. The fault trends southeast and is named the Seal Beach fault in Alamitos Gap and Landing Hill. It is in echelon with the Northeast Flank fault. The southwest side of the fault has moved up in relation to the northeast side. Vertical displacement along the fault, about opposite the crest of Reservoir Hill, is about 280 feet. Materials of the San Pedro and underlying Pico formation have been displaced by at least this amount; however, no displacement occurs within the uppermost alluvial deposits of Recent age. The fault is believed to restrict ground water movement in Alamitos Gap (Poland and Sinnott, 1959b).

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Seal Beach Structure

The Seal Beach structure, containing the Seal Beach oil field, consists of two elongated domes separated by a saddle. The domes are developed in underlying sediments of Tertiary age, trend northwesterly, and are offset by the Seal Beach fault, the local name applied to the southern portion of the Reservoir Hill fault. The more northerly dome underlies Bixby Ranch Hill; the southerly dome has its apex in Alamitos Gap under the present channel of the San Gabriel River. Bowes (1943) stated that the San Gabriel River is antecedent to the later periods of folding and its position may have been controlled by the saddle that exists between these two domes.

Hawthorne-Long Beach Depression

The Hawthorne-Long Beach depression is the downfolded area that underlies the El Segundo Sand Hills, Torrance Plain, Dominguez Gap, Long Beach Plain, and most of the Santa Monica and Sawtelle Plains, but only portions of Beverly Hills and Ballona Gap. The depression trends northwesterly and extends from its northwestern terminus at the base of the Santa Monica Mountains to the City of Long Beach and continues offshore beneath San Pedro Bay. It is bounded on the west by the Pacific Ocean, on the southwest by the Palos Verdes Hills and on the northeast by the Newport-Inglewood uplift.

The following structures lie within the depression and are briefly discussed in the succeeding paragraphs: Overland Avenue and Charnock faults, the Gardena syncline, the Torrance and Wilmington anticlines, the Lomita syncline, and unnamed structures beneath the Santa Monica Plain.

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Overland Avenue Fault

The Overland Avenue fault trends northwest and extends from Santa Monica Boulevard to the northwest flank of the Baldwin Hills. Displacement of the fault is believed to be vertical, with a magnitude of approximately thirty feet. The northeast side of the fault is raised relative to the southwest side. Over a 15-year period, water levels east of the fault have remained 60 to 100 feet higher than those west of the fault (Poland, et al 1959a), indicating its relative effectiveness as a barrier to the movement of ground water.

Charnock Fault

The Charnock fault extends southeast from near Venice Boulevard to the City of Gardena and runs parallel to the axis of the Gardena syncline for most of its length. The northeast side of the fault is downthrown relative to the southwest side. Because of the displacement of lower Pleistocene aquifers as shown on Section C-C'-C", Plate 6B, the fault acts as a partial barrier to ground water movement. This barrier effect increases as the fault approaches the Ballona Escarpment, and then apparently diminishes as it continues northwest beyond Ballona Gap into the Sawtelle Plain.

Gardena Syncline

The principal structure of the Hawthorne-Long Beach depression is the Gardena syncline, an elongated, northwesterly trending flexure extending from Culver City to the City of Long Beach. It parallels the Newport-Inglewood uplift which borders it on the northeast. Along the southwest border, beneath the El Segundo Sand Hills, Pleistocene sediments gently dip northeasterly into the syncline from beneath the Pacific Ocean. The syncline

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is best developed in Tertiary and lower Pleistocene sediments and is moderately defined in upper Pleistocene sediments. Its deepest part, as shown on the contour map of the Silverado aquifer (Plate 20B), lies beneath the intersection of Alameda Street and Carson Street. From the northwest, the synclinal axis plunges gently into this low. The axial plunge from the southeast is relatively steeper.

Northwest of the City of Gardena, lower Pleistocene aquifers along the southwest flank of the syncline are offset by the Charnock fault (Section C-C'-C", Plate 6B), though the Gardena aquifer of late Pleistocene age is not displaced. Further north, beginning at the south margin of the Ballona Gap, the northeast flank of the syncline is displaced by the Overland fault. Beneath Ballona Gap and continuing northwest to approximately the Santa Monica Plain, the syncline becomes a downfaulted block lying between the Charnock and Overland Avenue faults.

Torrance Anticline

The Torrance anticline, located in the southerly part of the Hawthorne-Long Beach depression, is a gentle fold which trends southeast from Redondo Beach and contains the Torrance oil field. In sediments of Tertiary age, several echelon faults trend diagonally across the principal fold, dividing it into three elements. The water-bearing formations are affected by the broad, gentle folding, but available evidence indicates that they are not offset by faulting.

Wilmington Anticline

The Wilmington anticline is essentially continuous with the Torrance anticline but the two are separated by a structural saddle developed

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in sediments of Tertiary age. The anticline plunges to the northwest and to the southeast and, according to Winterburn (1943), consists of five blocks developed by several faults. The San Pedro and Lakewood formations are not affected by these faults, and only the San Pedro formation is folded.

Lomita Syncline

The Lomita syncline is located between the Torrance-Wilmington anticlinal highs to the north, and the Palos Verdes fault zone and Gaffey anticline to the south. The syncline parallels the southeasterly trend of these bordering uplifts and extends southeast from the City of Redondo Beach. Similar to the Gardena syncline, it is best developed in San Pedro and older sediments.

Unnamed Structures

Hoots (1931) and Barbat (1958) indicate that there are structures under the alluvial cover of the Santa Monica Plain which trend east-west and parallel to the structural trend of the Santa Monica Mountains. Since there is little subsurface information available in this area, the geologic structure is inferred on Section G-G', Plate 6D. This section shows the San Pedro formation dipping gently to the south beneath Ballona Gap and the Torrance Plain.

Offshore Structures

Those structures that lie beneath Santa Monica and San Pedro Bays have a direct effect upon the water-bearing strata that extend into these areas. Much work remains to be done to determine the nature and extent of offshore folding and faulting and their effects on ground water. The

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general structure of the offshore region is discussed by Emery (1954) as follows:

> "In general, the region consists of many blocks of roughly equal size that bear a close resemblance to the fault blocks of the Basin Range province in Nevada and eastern California. . .The slopes that bound the blocks are fairly straight and steep (5° to 10° average and more than 40° locally), and some terminate downward in linear depressions similar to sag ponds. Earthquake epicenters are more frequent on the basin side of these slopes, suggesting that the slopes reflect the presence of normal faults that separate horsts and grabens, though later work may show that some of them are due to folding rather than to simple block faulting."

The Santa Monica shelf as a whole is a seaward continuation of the coastal plain, and available information suggests that the San Pedro formation becomes thinner there. The pattern of sea-water intrusion indicates that aquifers are exposed to the ocean all along the Santa Monica Bay.

The San Pedro shelf is underlain by the seaward extension of the anticline that comprises the Palos Verdes Hills, by the Gaffey syncline and anticline, by the Lomita syncline, and the Wilmington anticline. Available subsea data suggest that the extension of the main Palos Verdes Hills anticline beneath San Pedro Bay has resulted in uplift of the Lakewood and San Pedro formations, and possibly exposed them to the ocean floor south of the breakwater (Stevenson, et al 1958, Crouch, 1954, and Moore, 1954). Water levels in the Silverado aquifer, however, indicate little or no hydraulic continuity with the ocean beneath San Pedro Bay. The significance of this data is not clear, since no subsurface information is available seaward of the Wilmington oil field. It is not known, therefore, whether aquifers deeper than the Gaspur and above the Silverado are in hydraulic continuity with the ocean in San Pedro Bay.

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CHAPTER VI. DESCRIPTION OF GROUND WATER BASINS

This chapter describes the ground water basins in the Coastal Plain of Los Angeles County and discusses the occurrence and movement of ground water within each basin. Information regarding geologic features presented in earlier chapters is summarized here for each ground water basin to show what effect these features have on ground water flow into, through, and out of each basin. The relationships between the geologic features and the occurrence and movement of ground water as discussed in this chapter are intended to clarify the geologic setting of the area for future studies of hydrology, water quality, and problems involving the use of ground water.

Basin Boundaries

The ground water basin as herein used is defined as the area underlain by one or more permeable formations capable of furnishing a substantial water supply. It does not necessarily coincide with the surface drainage basins and is usually smaller in size because the essentially nonwater-bearing hills and mountains of the surface drainage basin (watershed) are excluded. Ground water basins are separated from adjacent basins by geologic features such as nonwater-bearing rock, faults, or other geologic structures which impede ground water movement, and by natural or artificial mounds or divides in the water table or piezometric surface. Geologic features generally establish well defined, fixed boundaries while ground water mounds are subject to change in time, particularly with changes in the development and use of ground water. However, both of these types of boundaries do define limits of ground water movement.

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Ground water basins also have been arbitrarily separated along political boundaries or surface features such as along topographic divides and across narrow gaps through a range of mountains or series of hills. Such arbitrary divisions may be useful but they do not really define the limit of ground water basins nor its movement as do geologic features. In many cases, the use of surface features to delimit a ground water basin has simplified hydrologic analysis, but this is seldom the case when political boundaries have been used.

The Coastal Plain of Los Angeles County consists mainly of unconsolidated sediments or alluvium underlain by and bounded on the north and east by essentially bedrock. On the west and south it is bounded by the Pacific Ocean. Ground water is stored within the interstices of these unconsolidated sediments and in the cracks or fractures of the nonwater-bearing rocks which bound the area.

The coastal plain has been divided into four ground water basins by geological and surface features. Two of these four ground water basins are southwest and two are northeast of the series of low hills formed by the folds and faults of the Newport-Inglewood uplift. The Santa Monica Basin ("West Coast Plain - North", Calif. D. W. R. 1934) and the West Coast Basin occupy what Mendenhall (1905b) called the "Western Coastal Plain" west and southwest of the Newport-Inglewood uplift (Plate 2). East and northeast of the Newport-Inglewood uplift are the Hollywood and Central Basins (Plate 2), which Mendenhall (1905a) considered together as the "Central Coastal Plain of Southern California".

The Santa Monica Basin is the northernmost of the two basins southwest of the Newport-Inglewood uplift; it extends south from the Santa

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Monica Mountains to the Ballona Escarpment between the uplift and the Pacific Ocean. The West Coast Basin extends southeast to the Palos Verdes Hills, San Pedro Bay, and Orange County. Although the Santa Monica and West Coast Basins have been divided at the Ballona Escarpment, the escarpment does not signify any geologic discontinuity in the water-bearing sediments. Rather, the separation was based on the existence of a ground water mound developed at this location as a result of ground water extractions. This ground water mound was carefully defined in the Report of Referee on the West Coast Basin (Calif. D. W. R. 1952a). The Newport-Inglewood uplift, which bounds these basins on the east, is a series of geologic features that exerts considerable influence on ground water movement along much of its length.

The Hollywood Basin is located south of the Santa Monica Mountains and east of the Newport-Inglewood uplift. It extends eastward to the Elysian Hills and south to the La Brea high, a complex subsurface structural feature. The Central Basin borders the Hollywood Basin on the south and occupies the rest of the Coastal Plain of Los Angeles County east of the Newport-Inglewood uplift. Historically, ground water moved from the Hollywood Basin across the La Brea high into the Central Basin. However, under present conditions, ground water levels are lower than the dome of this high so that it currently represents a barrier to ground water movement along the eastern section of the southern boundary. This feature plunges steeply at its western extremity, and the San Pedro formation is continuous from the Central Basin into the Hollywood Basin around the warped slope formed by the plunging anticline. A pumping depression or trough, developed in the vicinity of Culver City as the result of

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ground water extractions, now intercepts all flow from the Hollywood Basin, and has resulted in a ground water divide in the northern part of the Central Basin.

The southeast boundary of the Central Basin coincides with the Los Angeles-Orange County line. This boundary was originally defined (Calif. D. W. R. 1934) on the basis of a ground water mound generally paralleling the county line. Four areas are identified for descriptive purposes within the Central Basin: the Los Angeles and Montebello Forebay Areas, the Whittier Area, and the Central Basin Pressure Area (Plate 2). The boundaries of these areas are as described in Bulletin No. 45 (Calif. D. W. R. 1934). The forebay areas extend south from the Los Angeles and Whittier Narrows, two breaks in the hills which form the northern boundary of the basin. The Whittier area (formerly part of the La Habra Basin) is located in the northeastern part of the Central Basin, east of the Montebello Forebay Area. The Central Basin Pressure Area includes the rest of the Central Basin to the west and south of the other three areas.

Another basin, the "Los Angeles Narrows Basin" (Calif. D. W. R. 1934), was formerly recognized as part of the Coastal Plain of Los Angeles County. It extended from the Central Basin north to the San Fernando Basin, with an arm extending eastward along the Arroyo Seco into the San Gabriel Valley. Recent investigations have shown that the Los Angeles Narrows Basin should be divided; one part should be included with the San Fernando Basin and the remainder with the Central Basin. This change has been followed in this report and the boundary of the coastal plain in the vicinity of the Los Angeles Narrows was placed just north of and parallel

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to Figueroa Street across the narrowest portion of the alluvial fill. The area south of this new line and eastward along the Arroyo Seco is now included within the Central Basin.

Ground Water Occurrence

Poland (1948 and 1959a) divided the ground water contained in the alluvial sediments of the Coastal Plain of Los Angeles County into three categories, each of which may appear in any single ground water basin. In downward succession these are: (1) a body of shallow, unconfined, semiperched water which occurs in the upper part of the alluvial deposits in the Downey Plain and the Torrance Plain, (2) the principal body of fresh ground water, which occurs chiefly in deposits of Recent and Pleistocene age, and possibly in underlying Pliocene rocks, and (3) saline water underlying the principal fresh water body throughout the area.

The only use at the present time of the saline water underlying the coastal plain has been to repressurize areas where oil has been extracted. Since the primary interest is in the fresh ground water resources of the area, this chapter considers Poland's first and second categories of ground water, and omits further consideration of the saline waters.

Ground Water Movement

In all ground water basins, water moves from the point or points of recharge through the basin to the point or points of discharge. Ground water flow occurs because of differentials in pressure between the points of recharge and discharge, which establish a hydraulic gradient in the water surface. This flow will continue in one or more directions until

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the flow path is blocked by some structural barrier (i.e., fault, fold, unconformity, or a physical characteristic of the aquifer) or until the gradient of the water surface is altered by withdrawals or artificial recharge. The basin will generally discharge into another basin, or into a river, lake, or the ocean.

The ground water basins in the coastal plain are recharged by surface and subsurface inflow from the hills and mountains bordering the areas and from the adjacent San Gabriel and San Fernando Valleys, by downward percolation of the waters from the major streams crossing the area, by direct percolation of precipitation and other applied water, and by artificial recharge of either local or imported water through both spreading the water in specially prepared basins where it is impounded and allowed to percolate and injecting the water into wells.

The extensive paving of streets and construction of urban communities has greatly reduced the areas open to direct percolation of precipitation and applied water. Extension of sewer systems discharging through ocean outfalls, improvement in surface drains, and the lining of river channels to facilitate the runoff of floodwaters have all resulted in less water percolating into the ground water basins. In recent years the expansion of artificial recharge programs has tended to offset these reductions in the natural recharge to the ground waters of the coastal plain.

Discharge from the coastal plain under natural conditions has been to the Pacific Ocean. However, the increased withdrawals of ground water from the area, combined with the lower rate of replenishment during recent years, have reversed normal gradients as evidenced by sea

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water moving inland in the coastal portions of the aquifers and by the presence of "troughs" or pumping depressions in the ground water surface. At the present time, there is little subsurface outflow to the ocean.

Evapo-transpiration processes account for a minor amount of the ground water naturally discharged from the basins. The major discharge of ground water is presently by pumpage and eventual discharge to the ocean through sewers of the amount not consumptively used.

Rates of flow of ground water within the basins depend not only on the hydraulic gradient, but also on the cross-sectional area and permeability of the sediments. A very useful term in determining rates of flow is the coefficient of transmissibility, which is defined as coefficient of permeability multiplied by the saturated thickness, usually in gallons per day per foot of width or in cubic feet per second per foot of width. About 40 well tests have been conducted in the Coastal Plain of Los Angeles County to determine coefficients of transmissibility and storage. Selected references used in these computations are included on Page 1-10 of Attachment 1. Results of the tests are summarized in Table C in Attachment 2. In a few cases, it was possible to compute vertical permeability of the overlying aquiclude as indicated in this table.

Using results of the transmissibility tests, average values for permeability were computed and assigned to drillers logs. This procedure is discussed in Attachment 2 of this report and the values are shown in Table D. Using all well tests and several hundred well logs, transmissibility was then estimated for the major aquifers. Lines of equal transmissibility of the aquifers were generalized and drawn on Plates 26A

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through 26H. The values for all aquifers were later combined as shown on Plate 26I which is very generalized but is convenient to use in many hydrologic and operational studies.

Ground Water Storage

When discharge or outflow from a basin exceeds recharge or inflow, ground water is removed from storage in the basin. The amount of water in storage depends on the volume of sediments and their specific yield. Specific yield is defined as the ratio between the volume of stored water which a saturated sample of material will yield by gravity and the volume of that sample; it is customarily expressed in percent.

Specific yield values for the sedimentary deposits of Los Angeles County are given in Attachment 2, Table A. These specific yield values were compiled from available data, including work done by the State Water Rights Board for the San Fernando Valley Reference, and from Bulletin 45 (Calif. D. W. R. 1934). They were also checked against figures obtained from well tests but no new determinations were made during this investigation. Specific yield values are multiplied by the thickness and areal extent of the water-bearing sediments to determine the total storage capacity of these sediments. The variation in specific yield value over the coastal plain by elevational increments that were used in computations of storage are tabulated in Table B, Attachment 2.

Changes in the amount of ground water in storage in the ground water basins in the Coastal Plain of Los Angeles County have occurred mainly in the forebay areas. However, changes in storage have also occurred in other free ground water areas and in the pressure areas where water levels have been drawn below the base of the upper confining

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aquiclude. Additional limited changes of storage have occurred by dewatering of the confining aquicludes. The areas where changes in storage have occurred are discussed in the description of the individual basins; however, because of the general widespread nature, changes of storage in the Bellflower aquiclude are not delineated. Within the area as a whole, total storage to the base of the Sunnyside aquifer, or to the Silverado aquifer where the Sunnyside is missing, is approximately 22 million acre-feet. Ground water storage depletion since 1904 is about 1,200,000 acre-feet and the storage between historical high water levels which occurred in 1904 and sea level is about 1,600,000 acre-feet.

The discussion which follows treats the geology of each basin and its relation to ground water, the means by which the aquifers present are replenished, the areas of confined water, the barriers to ground water movement within or between basins, and the movement of water in each basin.

Santa Monica Basin

The Santa Monica Basin is bounded by the Santa Monica Mountains on the north and the Ballona Escarpment on the south. It extends eastward from the Pacific Ocean to the Inglewood fault (see Plate 2). This area was originally considered a part of the West Coast Basin, which now is limited to the area immediately south of the Santa Monica Basin. The Santa Monica Basin has also been referred to in prior publications as "West Basin Northern Area" (Calif. D. W. R. 1934); "West Coastal Plain - North" (Calif. D. W. R. 1947); and "West Coast Basin - North" (Calif. D. W. R. 1958a).

The majority of the water wells in the Santa Monica Basin lie south of Santa Monica Boulevard in an area covered by Recent alluvium

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(Plate 3B). North and northwest of Santa Monica Boulevard, where the Lakewood formation is exposed on the surface, and in the area covered by Older Dune Sand of late Pleistocene age, comparatively few wells have been drilled and little data are available. The area north of the Baldwin Hills, between the Overland Avenue and Inglewood faults (shown on Plate 3B), is also deficient in water well log data; however, oil well and electric log data indicate that fresh water is present in the undifferentiated Lakewood, San Pedro, and Pliocene formations. While no aquifers or aquicludes have been defined in either the northwest or northeast parts of the Santa Monica Basin, they do exist there.

Geologic Features

The Santa Monica Basin is overlain by six different physiographic features: Santa Monica Plain, Ocean Park Plain, Sawtelle Plain, part of the Beverly Hills, Ballona Gap, and the northern tip of the Baldwin Hills. These features are shown on Plate 2 and discussed in detail in Chapter III.

Recent alluvium, the Lakewood and San Pedro formations, and some older sediments have been identified in the Santa Monica Basin (Plate 3B). The known aquicludes and aquifers, however, are restricted to the Recent alluvium and the San Pedro formation. The Recent alluvium covers the Sawtelle Plain and Ballona Gap where it attains a maximum thickness of about 90 feet. Included within these sediments is a portion of the Bellflower aquiclude and the Ballona aquifer.

The Bellflower aquiclude (Plate 9B) within the Recent alluvium consists of 20 to 40 feet of clay and sandy clay extending to a maximum depth of about 50 feet (40 feet below sea level) below the surface (Plate 8B). It is also quite probable that the Bellflower aquiclude is present

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in the undifferentiated Lakewood formation in the Ocean Park Plain, the Santa Monica Plain, and the Beverly Hills area where it would partially restrict percolation of surface water.

The Ballona aquifer, called the "50-foot gravel" in a prior report (Calif. D. W. R. 1952a), consists of 30 to 50 feet of gravel and coarse sand (Plate 11B) and has a maximum depth of 70 feet (60 feet below sea level) below ground surface (Plate 10B).

The Lakewood formation and the Older Dune Sand of late Pleistocene age cover most of the northern half of the Santa Monica Basin. The Lakewood formation includes the weathered, reddish-brown continental deposits covering the Santa Monica Plain and the sands, clays and conglomerates of marine origin that form the Beverly Hills. The Older Dune Sand consists of sand and silt washed free of clay, which, according to Hoots (1931), "...probably represents sand bars and shore-line bluffs that were developed when the ocean stood at a higher level with relation to the land." These Older Dune Sands were later modified by wind action. The thickness of the Lakewood formation and the dune sand is uncertain in this basin, but it is known that the Lakewood formation thins out in the northern part of the basin where it overlies the older rocks of the Santa Monica Mountains.

The San Pedro formation is found beneath the Recent alluvium over the southern half of the Santa Monica Basin with no evidence of intervening Lakewood materials. In the northern part of the basin, the Lakewood formation is present and in the westerly portion appears to directly overlie Pliocene and older sediments with the San Pedro formation apparently missing. In the northeastern part of the basin, oil well and fossil

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data indicate that the San Pedro formation is at least 500 feet thick. In the Ballona Gap area available data indicate that the San Pedro formation has a thickness of about 300 feet.

The Silverado aquifer is the only member of the San Pedro formation identified in the Santa Monica Basin. It is mainly sand and gravel, with a small amount of clay. It ranges from 100 to 280 feet in thickness, and extends downward to elevation minus 420 feet, 450 feet below the ground surface (Plate 6D, Section G-G').

The San Pedro formation is underlain by sediments of Pliocene age in the southern and northeastern parts of the Santa Monica Basin. Oil well electric logs indicate that fresh water extends down several hundred feet below the base of the San Pedro formation in the western part of the Ballona Gap Area. In the northeastern part of the basin available oil well electric logs indicate that the San Pedro formation is underlain by saline water-bearing Pliocene sediments. Current subsurface work by oil companies in the northwestern portion of the basin may reveal the nature of the fresh water-bearing sediments there. Available outcrops suggest that the geology of the San Pedro and older formations is complex in that area. Plate 24, "Lines of Equal Elevation on the Base of Fresh Water-Bearing Sediments", indicate the spotty nature of the data in this basin by the limited number of elevations shown for this basin.

The major structural features of the Santa Monica Basin are the unconformity in the northern part, which brings the thin Lakewood formation into contact with the underlying Pliocene and Miocene deposits, and a number of faults in the area. Three of these faults, the Inglewood, Overland Avenue and Charnock faults, (Plate 3B) have been described previously. Several other faults in the basin have been reported in previous

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literature. Hoots (1931) shows a small fault extending into the basin near Potrero Canyon. In the "Guide to Geology and Oil Fields of the Los Angeles and Ventura Regions, Barbat (1958)", postulates an east-west fault system extending from north of Santa Monica to a point about four miles southeasterly of the Los Angeles civic center. Poland (1959a) also shows a small east-west fault located east of Santa Monica, which may possibly be related to Barbat's fault system. These faults described by Barbat and Poland are not shown on the geologic map in this report because there is no clear evidence that they affect water-bearing sediments.

The Inglewood fault, which forms the eastern boundary of the Santa Monica Basin, appears to be a barrier to the movement of ground water in the area between the Baldwin Hills and a point about one-half mile south of Santa Monica Boulevard. North of this point the presence of the fault is largely conjectural; electric logs of oil wells show a deep zone of fresh water west of where the Inglewood fault would be if it continued northward. Water level records in these sediments suggest that in this area the fault is either not present or does not act as a barrier.

The Overland Avenue fault in Ballona Gap also appears to act as a barrier to ground water movement since ground water levels on the east side of the fault are much higher than on the west side.

The Charnock fault, the westernmost of the three principal faults mentioned, appears to affect only slightly ground water movement in the Santa Monica Basin. It cuts the Silverado aquifer, which shows a displacement of about 180 feet (Plate 6A, Section A-A'), but leaves the water-bearing sediments still in juxtaposition. Ground water movement

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across the fault is still possible, though ground water levels are higher on the west side of the fault.

Occurrence of Ground Water

Ground water occurs in all sediments of the Santa Monica Basin from Recent alluvium to deposits of Miocene age. Water well information is available only where aquifers have been identified in the Sawtelle Plain and Ballona Gap areas. In these two areas ground water is found in deposits of Recent and lower Pleistocene age. In the area north of the Baldwin Hills between the Overland Avenue and Inglewood faults (Plate 3B), oil well data and electric logs indicate the presence of water in the undifferentiated Pleistocene and older formations as well.

Water levels in the Recent alluvium in the Sawtelle Plain are much higher than water levels in wells that penetrate the older sediments, suggesting that a perched or semiperched aquifer exists in this area.

Replenishment of ground water in the Santa Monica Basin is mainly by percolation of precipitation through sandy phases of the Bellflower aquiclude, the Lakewood formation and the Older Dune Sand, and by percolation of surface runoff into the basin from the mountains to the north. The Inglewood fault appears to inhibit replenishment from the Central Basin to the east. It is possible, however, that ground water does move between the Santa Monica and Hollywood Basins around the north end of the Inglewood fault.

Ground water in the Santa Monica Basin moves mainly toward the south, in the direction of Ballona Gap (Los Angeles County Flood Control District, 1958). Partial degradation of the ground water underlying the western part of Ballona Gap has taken place over the years (Calif. D. W. R.

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1958b) as evidenced by an increase in the chloride content. Part of the degradation may be due to sea-water intrusion into the aquifers because water levels have fallen below sea level. However, north of Ballona Creek in the City of Santa Monica, available data suggest that minor subsurface flow toward the ocean may occur.

Aquifers in Santa Monica Basin generally have transmissibility rates less than about 100,000 gallons per day per foot. In this basin, the Silverado aquifer has a maximum transmissibility rate of about 150,000 (see Plate 26G "Lines of Equal Transmissibility of the Silverado Aquifer"), and the Ballona aquifer has a maximum transmissibility rate of about 70,000 (see Plate 26A, "Lines of Equal Transmissibility of the Gaspur and Ballona Aquifers"). Because thickness of aquifers is poorly known in the north portion of the basin, transmissibility rates are not shown there, but they appear to be increasing in that direction. However, the rates would decrease as the Santa Monica Mountains are approached and the aquifers become thinner.

Changes in storage and free ground water conditions could possibly occur along the north edge of the Baldwin Hills and the south edge of the Santa Monica Mountains where the Lakewood and San Pedro formations crop out at the surface. Free ground water conditions also may exist near the coast in the Ballona Gap area where the Bellflower aquiclude is missing.

Total storage to the base of the Sunnyside aquifer, or Silverado aquifer where the Sunnyside is missing, amounts to about 1,100,000 acre-feet. Historically utilized storage is difficult to determine because of the paucity of information available. It probably has amounted to about 38,000 acre-feet since 1904, and occurs in both shallow and deep aquifers. Storage between historical high water levels which occurred in 1904 and sea level is about 36,000 acre-feet.

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West Coast Basin

The West Coast Basin extends southwesterly from the Newport-Inglewood uplift to Santa Monica Bay, to the drainage divide on the Palos Verdes Hills, and to San Pedro Bay. It extends from the Ballona Escarpment and Baldwin Hills on the northwest to the Los Angeles-Orange County line on the southeast. The basin boundaries are defined in the Report of Referee (Calif. D.W.R. 1952a).

Mendenhall (1905b) referred to this area as the "Western Coastal Plain Region". In Bulletin No. 45 (Calif. D.W.R. 1934) Eckis used the term "West Basin - Southern Area" for the West Coast Basin, which was slightly modified to "West Coastal Plain - South" in Bulletin No. 53 (Calif. D.W.R. 1947). The term "West Coast Basin" was officially accepted in the Report of Referee (Calif. D.W.R. 1952a, and has remained in use from that time.

Plates 6A and 6G and plates showing lines of equal elevation and lines of equal thickness of those aquifers in the West Coast Basin were based mainly on data taken from the Report of Referee (Calif. DWR, 1952a). However, in some areas, particularly along the coast line, the subsurface geology was modified pursuant to unpublished information obtained from the Los Angeles County Flood Control District. This district has undertaken extensive subsurface geologic exploration in connection with their studies of sea water barrier construction along Santa Monica Bay that will provide valuable detailed information on the geology of these areas. In the Long Beach Plain data are seriously lacking because only a few wells have been drilled.

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Geologic Features

Physiographic features of the West Coast Basin are the Torrance and Long Beach Plains, the El Segundo Sand Hills, the Dominguez and Alamitos Gaps, and portions of the Baldwin Hills, the Rosecrans Hills, Dominguez Hill, Signal Hill, and the Palos Verdes Hills (Plate 2). The continuity of the Newport-Inglewood belt of hills, which flanks the West Coast Basin on the northeast, is broken by Dominguez and Alamitos Gaps, which are stream-cut channels eroded and backfilled by ancestral rivers. Most of the basin consists of a gentle, poorly drained plain flanked by the partly eroded highland areas of the Newport-Inglewood belt of hills and the heavily eroded Palos Verdes Hills. Toward Santa Monica Bay, a wide belt of sand dunes, containing many closed depressions, form the El Segundo Sand Hills.

Sediments of the Recent Series and the Lakewood and San Pedro formations of the Pleistocene Series have been identified within the West Coast Basin. The principal aquifers in these series are discussed below.

The Recent Series has two main divisions - the Active Dune Sand and the Recent alluvium. The Active Dune Sand occurs along the coast bordering Santa Monica Bay and extends inland for a maximum distance of about one-half mile. Some of these dunes are 70 feet thick. The Recent alluvium occurs mainly in the Gardena area and within Dominguez Gap, with a lobe extending northwesterly from Dominguez Gap between Dominguez Channel and Dominguez Hill. Another small sinuous area of alluvium extends into Bixby Slough from San Pedro Harbor. Irregular patches also occur south of Torrance. Members of the Recent alluvium include the Semiperched aquifer, the Bellflower aquiclude, the Gaspur aquifer, and miscellaneous beach, playa lake, and lagoonal marshland deposits.

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The Recent portion of the Semiperched aquifer occurs only in Dominguez and Alamitos Gaps. It consists of sand, silty sand, silt and clay. The Semiperched aquifer can be detected in well logs, but water level measurements have been obtained from only a few test holes. Available evidence indicates that water levels in the Semiperched aquifer are generally above water levels in the Gaspur aquifer. Water in the Semiperched aquifer is generally of poor quality.

The Recent part of the Bellflower aquiclude occurs in Dominguez Gap where it overlies the Gaspur aquifer, and ranges in thickness from 40 to 80 feet (Plate 9B). The upper part of the aquiclude is sandy silt or sandy clay.

The Gaspur aquifer, entirely of Recent age, occurs only in Dominguez Gap. It has been slightly deformed over the Cherry Hill fault in such a manner that its base rises to an elevation of 80 feet below sea level. It reaches a maximum known depth of about 140 feet below sea level near Terminal Island (Plate 10B). Through the gap it is 40 to 80 feet thick (see Plate 11B). These coarse sands and gravels are confined and produce large quantities of water. Extensive sea-water intrusion into this aquifer is evidence that it is exposed to the ocean. The connection with the ocean may occur some distance offshore or may be through permeable overlying materials closer to shore or possibly both.

Upper Pleistocene deposits include the Older Dune Sand and the Lakewood formation. The Older Dune Sand occurs in a band from about three to four miles wide inland from Santa Monica Bay, extending from the Ballona Escarpment to the Torrance area. It forms the major part of the El Segundo

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Sand Hills. Since deposition, the Older Dune Sand has been tilted, weathered, eroded, and further altered by cementation and leaching processes. Surface water percolates into the dunes from closed depressions after heavy rains. Ground water is not, however, extracted from the Older Dune Sand although some perched water bodies may occur.

Divisions of the Lakewood formation in the West Coast Basin include the Semiperched aquifer, the Bellflower aquiclude, the Gardena aquifer, and the Gage aquifer. Those deposits previously known as Terrace Cover and the Palos Verdes sand constitute that part of the Semiperched aquifer that is of late Pleistocene age. These sediments may have been deposited at the same time as the Artesia-Exposition aquifers in the Central Basin.

Underlying both the Older Dune Sand and the Semiperched aquifer is that part of the Bellflower aquiclude which is of late Pleistocene age; it has been previously called the fine-grained phase of the Unnamed Upper Pleistocene Deposits. In the West Coast Basin, the Bellflower aquiclude overlies most of the Newport-Ingleood uplift and Torrance Plain though it is missing over the Baldwin Hills. It reaches a maximum depth of 140 feet below sea level (Plate 8B) and ranges up to 200 feet in thickness (Plate 9B). This heterogeneous mixture of continental, marine, and wind-blown sediments is generally fine-grained, consisting of silty clays and clays. It also contains lenses of sandy or gravelly clays which may be permeable enough to permit water to move vertically downward from the overlying Semi-perched aquifer to the underlying aquifers. It is not significant as a source of ground water. The Gardens and Gage aquifers are constituted of part of those sediments previously referred to as Unnamed Upper Pleistocene Deposits.

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The Gardena aquifer extends westward from Lynwood over the Newport-Inglewood uplift to Redondo Beach. It was deposited by an ancestral stream during a rise in sea level and has since been folded over the uplift. The aquifer is composed of sand and gravel with a few discontinuous lenses of sandy silt. It reaches a maximum depth of 200 feet below sea level (Plate 12B) and is as much as 160 feet in thickness (Plate 13B). Permeability is high in the Gardena aquifer, as evidenced by the many wells which tap this aquifer near the City of Gardena. Yields are high and range from 100 to 1,300 gallons per minute. Recharge to the aquifer occurs primarily in the Downey Plain and water is transmitted through the aquifer into the West Coast Basin. Some additional recharge is received by the Gardena aquifer from the overlying Semiperched aquifer and Active Dune Sand, and from the Gage aquifer, with which it is in hydraulic continuity.

The Gage aquifer (previously known as the "200-foot sand") extends over most of the West Coast Basin except for the Long Beach Plain. It is merged with the underlying aquifers near Torrance and south of the Ballona Escarpment along Santa Monica Bay. Except for local areas the Gage aquifer is confined by the Bellflower aquiclude. In the vicinity of Torrance, the Gage aquifer reaches a depth of 250 feet below sea level (Plate 12B) and attains a thickness of 160 feet (Plate 13B). It is composed chiefly of sand with minor amounts of gravel and thin beds of silt and clay. The aquifer exhibits moderate to low permeability and therefore is of secondary importance as a ground water producer in the West Coast Basin. The few wells extracting from this aquifer supply water for domestic and irrigation purposes.

Lower Pleistocene deposits are represented in the West Coast Basin by the San Pedro formation, which is of marine origin. The San Pedro

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formation includes two main aquifers, the Lynwood and the Silverado. Outcrops of the San Pedro formation occur on the Baldwin Hills, along the northeastern margin of the Palos Verdes Hills, and on Signal Hill. Portions of the Santa Monica and San Pedro shelves in the ocean are underlain by it. The San Pedro formation thickens along the Gardena syncline from 400 feet near Ballona Gap to more than a thousand feet in Dominguez Gap. It has been offset by the Charnock, Inglewood, Potrero, Avalon-Compton, Cherry Hill and Northeast Flank faults.

The uppermost aquifer of the San Pedro formation in West Coast Basin, the Lynwood aquifer (previously known as the "400-foot gravel"), is composed, in the northern and central parts of the basin, of sand and gravel with lesser amounts of sandy silt, silt, and clay. South of Gardena the gravel is missing and the aquifer consists mainly of sand and sandy silt. The Lynwood aquifer attains its maximum thickness of 200 feet one mile west of the intersection of Alameda Street and Sepulveda Boulevard (Plate 19B). Just one mile northwest of Gardena it reaches its greatest depth, 550 feet below sea level (Plate 18B). The Lynwood aquifer is confined throughout the West Coast Basin except in those areas where it merges with the overlying Gage aquifer (Plate 18B). It also merges with the underlying Silverado aquifer along Santa Monica Bay and along the Newport-Inglewood uplift.

About ten percent of the wells in West Coast Basin are perforated in the Lynwood aquifer. These wells are located primarily in the Torrance, Compton, and Inglewood areas. Few of them draw water solely from the Lynwood aquifer because they are usually perforated in other aquifers as well. Yields of 500 and 600 gallons per minute have been reported.

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Deposits of the Silverado aquifer, the lower defined aquifer of the San Pedro Formation in the West Coast Basin, consist of fine to coarse-grained, blue-grey sands and gravels that are continuous over most of the area but are interbedded in some places with discontinuous layers of relatively impermeable sandy silt, silt, and clay. These highly permeable marine deposits reach a maximum thickness of 500 feet (Plate 21B) between the Wilmington anticline and the Cherry Hill fault. The Silverado aquifer reaches its maximum depth at elevation 1,200 feet below sea level (Plate 20B), in Dominguez Gap. It also is most permeable in this area. The Silverado aquifer is merged with the overlying Lynwood aquifer along the coast from Ballona Gap to Redondo Beach, along the north flank of the Palos Verdes Hills, beneath the central and southern part of the Rosecrans Hills and the northern part of Dominguez Hill (Plate 20B). Near Redondo Beach and Hermosa Beach, the merged Lynwood-Silverado aquifers are in hydraulic continuity with the overlying Gardena aquifer; from Hermosa Beach to Ballona Gap, and along the north flank of the Palos Verdes Hills they are in continuity with the Gage aquifer.

Beneath the Silverado aquifer in some parts of the West Coast Basin are 500 to 700 feet of fresh water-bearing materials of the San Pedro and probable Pico formations which have not been identified as an aquifer or aquifers. The approximate elevation of these fresh water-bearing materials is shown on Plate 24B. Along the coast from Redondo Beach to the Ballona Escarpment these deposits are coarse sands and gravels which correspond in age and thickness to the Sunnyside aquifer in the Central Basin. Over the rest of the basin these deposits are fine-grained and act as an aquiclude. The upper division of the Pico formation consists of relatively impermeable

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micaceous silt and clay members interbedded with fresh water sands and lenses of gravel. Water contained in deeper Pliocene sediments is mostly saline.

As previously stated, the Newport-Inglewood uplift exerts a partial barrier effect on ground water movement from the Central Basin into the West Coast Basin, especially in the Pleistocene aquifers, by offsetting, elevating, or thinning of the aquifers which pass over it. Lithologic changes and thinning across the uplift have been due primarily to movement during deposition of aquifers and the faulting and elevation which followed. Because of its elevation this area apparently has acted as a boundary for the Artesia-Exposition, Hollydale, and Jefferson aquifers during their deposition by controlling alluviation and restricting the aquifers to the Central Basin.

Pleistocene and older formations that continue across the Newport-Inglewood uplift into West Coast Basin are sharply downwarped into a complex regional basin structure, the Hawthorne-Long Beach depression immediately to the west of the uplift. Many secondary structures interrupt the regularity of this regional downwarp. One of these secondary structures is the Gardena syncline, which parallels the Newport-Inglewood uplift. It plunges toward the southeast and is faulted in the northern part of the West Coast Basin by the Charnock fault. West of the Charnock fault, the water-bearing deposits rise toward the ocean with a gentle slope, while in the southern portion of the West Coast Basin they are deformed over the Torrance, Wilmington, and Gaffey anticlines and downwarped by the Gaffey syncline. Farther to the southwest the water-bearing materials lap onto the northeast slope of the Palos Verdes Hills, a structural highland composed of Miocene and older rocks.

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Occurrence of Ground Water

Ground water occurs in Recent and Pleistocene aquifers throughout the West Coast Basin, and some fresh water occurs in the underlying Pliocene sediments. The Semiperched aquifer of both Recent and late Pleistocene age is unconfined. The water in underlying aquifers is confined throughout most of the basin, though the Gage and Gardena aquifers are unconfined where water levels have dropped below the Bellflower aquiclude on the Newport-Inglewood belt of hills and in the northwest corner of the basin.

The major fresh water replenishment to the basin occurs by subsurface flow across the Newport-Inglewood uplift, also subsurface flows which have become increasingly saline occur from the seaward extensions of the aquifers under the influence of a landward hydraulic gradient. The merged Silverado-Lynwood-Gardena-Gage aquifers are in hydraulic continuity with Santa Monica Bay, while only the Gaspur aquifer appears to be in hydraulic continuity with San Pedro Bay. Subsurface flow occurs between the Santa Monica and West Coast Basins, with the direction of flow depending on the direction of the hydraulic gradient.

Subsurface flow across the Newport-Inglewood uplift is controlled by the difference in water levels between the Central Basin and West Coast Basin (which is itself influenced by the withdrawals, outflow, and replenishment measures taken in either basin), by the dewatering of the aquifers along the crest of the uplift, and by the degree to which the faults and folds act as barriers to ground water flow. The barrier effect may depend on cementation along fault zones, lithologic changes which in turn affect permeability, and the varying thicknesses of aquifers over the uplift.

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Subsurface inflow across the Newport-Inglewood uplift occurs in the Gaspur aquifer of Recent age and through the Gage, Gardena, Lynwood, and Silverado aquifers of late and early Pleistocene age.

The Baldwin Hills are an effective barrier to ground water movement. South of the Baldwin Hills, the Inglewood fault, in conjunction with the Potrero fault and other transverse faults associated with it, acts as a barrier, which, although relatively impervious, is not completely water tight. The Lynwood aquifer has not been delineated in this fault zone because of insufficient data. The Silverado aquifer continues through the most southerly block of this fault zone.

From the physical characteristics of the aquifers extending across the Rosecrans anticline, a barrier effect would not be expected; however, a differential in water levels does exist across the anticline indicating at least a partial structural barrier effect.

South of the Rosecrans anticline the Avalon-Compton fault acts as a barrier to ground water movement only in the deeper lower Pleistocene deposits. The younger, overlying Lynwood aquifer and aquifers of the Lakewood formation extend across this barrier without offset.

Both the Lakewood and San Pedro formations continue without interruption over the Dominguez anticline, though wells producing from the San Pedro formation show a discontinuity in water levels. Within Dominguez Gap, no barrier effects are found in the Gaspur and Semiperched aquifers. The Lakewood formation also appears to be continuous, although warped, across the Cherry Hill fault. The San Pedro formation is in partial continuity across the fault but wells utilizing the Silverado aquifer show a barrier effect.

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The Cherry Hill fault, along the west side of Signal Hill, has offset all aquifers. However, ground water movement across the fault is maintained and hydraulic continuity preserved by entirely different aquifers abutting against each other on opposite sides of the fault. Southeast of Signal Hill, the Cherry Hill and Reservoir Hill faults act as barriers to ground water movement in all aquifers. Poland (1959a), states that the barrier effect on Signal Hill may be interrupted by a gap 1,000 feet wide between the Northeast Flank and Reservoir Hill faults, an area in which sea-water intrusion may occur.

Within Alamitos Gap, the Seal Beach fault does not sever hydraulic communication within the Recent deposits, which extend to a depth of about 100 feet. Below this depth, the fault forms a substantial barrier to ground water movement through the aquifers of the Lakewood and San Pedro formations, which rise unconformably toward the fault on the inland side. Seaward from the Seal Beach fault, the Lakewood formation is absent, and aquifers of the San Pedro formation directly underlie Recent deposits.

Minor replenishment to the West Coast Basin occurs in the form of surface inflow from both the Los Angeles and San Gabriel Rivers which cross the Newport-Inglewood uplift through Dominguez and Alamitos Gaps, respectively. However, lining of the Los Angeles River in the West Coast Basin north of Willow Street (Sepulveda Boulevard) was completed in 1956, thereby eliminating recharge to the Basin in this area. Between Willow Street and Terminal Island, the bed of Los Angeles River is not lined and has a sandy bottom with riprap sides. Because the channel section and the wetted perimeter have been reduced, infiltration through the river sands has decreased.

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The San Gabriel River has not been lined although a program of such lining has been proposed. In Alamitos Gap, therefore, some infiltration of stream flow still may occur into the Recent alluvial deposits. However, because the reach between the Seal Beach fault and the Pacific Ocean is only one and one-quarter miles in length, the quantity of infiltration involved is probably minor.

Changes in ground water levels in the West Coast Basin do not generally reflect seasonal variations of precipitation. Therefore it is believed that the annual quantity of recharge effected by percolation of precipitation is small.

Other sources of recharge by infiltration from the surface include return irrigation water from fields and lawns, industrial waters, oil field brines, and other applied surface waters. Poor surface drainage in the past resulted in large expanses of swamp and slough, but these conditions have been improved by the channelization of Dominguez Creek and improved street drainage. At the present time, some surface drainage still collects in the low areas until it disappears by slow infiltration or evapo-transpiration processes.

Near surface replenishment is from infiltration of cesspool effluent and leakage from water distribution systems. These surface and near surface waters are somewhat restricted from moving downward by the Bellflower aquiclude and therefore may remain within the Semiperched aquifer. Some of this water also moves downward through permeable sections of abandoned wells which may serve as conduits between aquifers. Improper abandonment of such wells needs to be restricted to prevent poor quality surface water from gaining access to the deeper horizons.

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In the following discussion, the ground water movement throughout the West Coast Basin was derived from the most readily available ground water level contours which are reproduced in Appendix B, "Safe Yield Determinations", to Bulletin No. 104. Although "troughs" or "lows", which develop in both piezometric and free ground water areas, may migrate slightly from spring to fall in a given year, or from year to year, historical data from 1932 to the present show that the general pattern has not particularly changed.

In the spring of 1956, water levels of wells perforated in the Gaspur aquifer indicated ground water movement toward two pumping depressions in Dominguez Gap, one midway between the Cherry Hill fault and Long Beach Harbor and the other near Long Beach Harbor itself.

In 1959 subsurface inflow in the deeper aquifers occurred across the Ballona Escarpment from the Santa Monica Basin and moved southeasterly between the Charnock fault and the structures of the Newport-Inglewood uplift toward a pumping depression near Hawthorne. A general low or trough is aligned along the Gardena syncline and extends from Gardena southeastward toward Dominguez Gap. Piezometric levels reach a low elevation in the vicinity of Carson Street and Wilmington Avenue. Into this trough moves westerly flowing water which crosses the uplift between the Rosecrans anticline and the Avalon-Compton fault, and easterly flowing water from Redondo Beach and Hermosa Beach. A third major trough or pumping depression is centered just east of El Segundo. Water flows into it from that part of the coast between Manhattan Beach and the Ballona Escarpment.

Discharge of ground water from the basin under present conditions occurs primarily by pumping extractions. Some subsurface outflow has

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occurred historically to the north into the Santa Monica Basin and to the west and south to the ocean; however, with the prevailing below-sea-level water levels, the subsurface flow is into the basin and sea water has intruded along the coastline. Should the water levels be raised above sea level, subsurface outflow could once again occur.

Aquifers in West Coast Basin have extremely variable rates of transmissibility. The Silverado aquifer (Plate 26G) has the highest transmissibility rate, averaging about 150,000 gallons per day per foot of width with a maximum of about 400,000 gallons per day per foot near Torrance and near the intersection of Alameda and Sepulveda Boulevards. The other aquifers generally have lower transmissibility rates since they are thinner and have smaller grain sizes. The Gaspur (Plate 26A),Gage, and Gardena aquifers (Plate 26C) "Lines of Equal Transmissibility of the Gage and Gardena Aquifers", Lynwood aquifer (Plate 26F), "Lines of Equal Transmissibility of the Lynwood Aquifer" have transmissibility rates of about 50,000 to 100,000 gallons per day per foot, in West Coast Basin. In general, transmissibility rates near the ocean are lower than they are in the center of the basin. Although the combined transmissibility rates of all aquifers are low along some parts of the Newport-Inglewood uplift, they are relatively high in other portions, particularly in the Dominguez Gap north of Long Beach. This is shown on Plate 26I, "Generalized Lines of Equal Transmissibility of the Combined Aquifers."

Change in ground water storage occurs within the merged areas along the Newport-Inglewood uplift, near the Palos Verdes Hills, along the northwest corner of Torrance Plain, and to a minor extent within Alamitos and Dominguez Gaps. Change in ground water storage has also occurred in

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parts of the Semiperched aquifer and also the Bellflower aquiclude where piezometric levels have been lowered below its surface. Total storage to the base of the Silverado aquifer, the deepest aquifer delineated in the West Coast Basin, is about 6,500,000 acre-feet. Historically utilized storage since 1904 amounts to about 300,000 acre-feet. Most of this change in storage occurred in the Gage-Gardena aquifer, which is classified as a shallow aquifer. Small additional changes in storage have occurred in the deeper aquifers where they crop out along the northeastern side of the Palos Verdes Hills and along the southern slope of the Baldwin Hills. The storage capacity between the historical high water levels which occurred in 1904 and sea level is about 120,000 acre-feet.

Hollywood Basin

The Hollywood Basin extends from the Santa Monica Mountains southward to an arbitrary line which roughly parallels the crest of the La Brea high, a subsurface structural feature beneath the La Brea Plain. Its western and eastern boundaries are the Inglewood fault and the Elysian Hills, respectively (Plate 2). In Bulletin No. 45 (Calif. D.W.R. 1934) the name "Hollywood Basin" was first used for the area just described, although in more recent hydrologic studies, such as the State Water Resources Board Bulletin No. 8, "Central Basin Investigation", 1952, the basin was considered a part of the Central Basin.

Many water wells were present in the Hollywood Basin around the turn of the century, and ground water was the chief source of supply for irrigation and domestic use (Mendenhall, 1905b). Most of these wells have been since destroyed as land use changed from agricultural to urban. Most of the available water well data in the Hollywood Basin are restricted to

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the deep portion of the Hollywood syncline near the southern edge of the Santa Monica Mountains next to the Inglewood fault. Comparatively few wells have been drilled in other parts of the basin.

Geologic Features

The Hollywood Basin is overlain by the Hollywood Piedmont Slope and part of the La Brea Plain (Plate 2). The sediments containing known aquifers extend to a maximum depth of 650 feet (410 feet below sea level) and include Recent alluvium and the Lakewood and San Pedro formations of Pleistocene age.

The Recent alluvium covers about one-half of the basin; it ranges in thickness from about 5 to 35 feet (Plate 6G, section H-H'). Near the Santa Monica Mountains and in the western end of the basin, available well logs and excavations indicate that the alluvium consists of relatively coarse sand and gravel. Some Semiperched water may be present although aquifers have not been differentiated. Since the alluvium is thin over much of the area, it is improbable that any appreciable quantity of water could be withdrawn from it.

The Lakewood formation of late Pleistocene age extends over the whole of the Hollywood Basin and crops out at the surface in the southern half of the area. It includes the Bellflower aquiclude and the Exposition and Gage aquifers. The Bellflower aquiclude consists of silty clay and clay ranging from 5 to 35 feet in thickness (Plate 6G, Section H-H'). It extends upward from the top of the Exposition aquifer to the base of the Recent alluvium or to the surface in areas where no Recent sediments are present.

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The Exposition aquifer consists of 20 to 60 feet (Plate 11A) of sand and gravel with some interbedded clay, and attains a maximum depth of 150 feet (elevation 20 feet, Plate 10A).

The Gage aquifer is the major water-bearing member of the Lakewood formation in the Hollywood Basin; it consists of 20 to 80 feet (Plate 13A) of sand and gravel with interbedded clay, and attains a maximum depth of 260 feet (100 feet below sea level) in some areas (Plate 12A). The Gage aquifer is merged with the overlying Exposition aquifer over a large area in the northern and eastern part of the basin (Plate 12A).

The San Pedro formation of early Pleistocene age contains the Jefferson, Lynwood, Silverado, and Sunnyside aquifers in the Hollywood Basin. These aquifers have been identified only in the extreme western portion of the basin, south of the City of Beverly Hills. If additional well log information were available, some, if not all, of these aquifers probably could be defined in the northern portion of the basin along the axis of the Hollywood syncline.

The Jefferson aquifer consists of 20 to 40 feet (Plate 17) of gravel with some clay and attains a maximum depth of 380 feet (150 feet below sea level, Plate 16).

The Lynwood aquifer consists of about 50 feet (Plate 19A) of gravel with a small amount of interbedded clay, and reaches a depth of about 400 feet (200 feet below sea level, Plate 18A). It is merged with the overlying Jefferson aquifer in a small area in the southwestern part of the basin east of Beverly Hills (Plate 18A).

The Silverado aquifer consists of about 50 feet (Plate 21A) of sand and gravel with a small amount of clay, and reaches a maximum depth of about 500 feet (300 feet below sea level, Plate 20A).

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The Sunnyside aquifer consists of 40 to 50 feet (Plate 23) of sand and gravel with a small amount of clay, and attains a maximum depth of 660 feet (400 feet below sea level, Plate 22 and section H-H', Plate 6G).

The aquifers of the Lakewood formation are underlain by deposits of Miocene age in the eastern and southern part of the Hollywood Basin. In the extreme southwestern portion of the basin, the San Pedro formation has been identified beneath the Lakewood formation. Along the axis of the Hollywood syncline (Plate 3A), sediments of Pliocene age may underlie the San Pedro formation. These Pliocene and Miocene sediments also contain some fresh water, but no aquifers have been differentiated. They are relatively impervious and contain saline water at depth.

The major structural features of the Hollywood Basin are the Hollywood and Inglewood faults, the Hollywood syncline, and the La Brea high (Plate 3A). The Hollywood fault along the northern boundary of the basin brings Pleistocene deposits into contact with the Jurassic and younger rocks of the Santa Monica Mountains. The Inglewood fault, which forms the western boundary of the Hollywood Basin, appears to impede ground water movement between it and Santa Monica Basin. Available water level data suggest that the Hollywood Basin may be in hydraulic continuity with the Santa Monica Basin to the west along the northwestern part of the basin boundary where the presence of the Inglewood fault is largely conjectural.

The Hollywood syncline in the northern portion of the basin contains sediments of Recent, Pleistocene, and probably Pliocene age underlain by Miocene deposits. The southern flank of the syncline forms the

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La Brea high, a subsurface structural high extending from the Elysian Hills almost to the Inglewood fault where it plunges steeply westward and forms an anticlinal nose in the San Pedro formation. It acts as a partial barrier to ground water movement southward into the Central Basin. The San Pedro formation was originally folded up over the La Brea high and eroded off, and the Lakewood formation has been deposited unconformably on sediments of Miocene age and on what remains of the San Pedro formation.

Occurrence of Ground Water

Ground water in the Hollywood Basin occurs mainly in sediments of Recent and Pleistocene age. Some fresh ground water is present in the Pliocene deposits which underlie the San Pedro formation near the Inglewood fault. Mendenhall (1905b) reported flowing wells in what are now known to be Miocene sediments in the eastern part of the Hollywood Basin. Recently drilled oil wells also encounter fresh water at shallow depth in these rocks in the Elysian Hills.

Unconfined ground water conditions exist in the northern and eastern portions of the basin in the shallow aquifers. In the deeper aquifers and in the remainder of the basin ground water is confined, and clay members separate the aquifers over considerable areas.

Ground water in the Hollywood Basin is replenished by percolation of precipitation and stream flow from the higher areas to the north into Recent alluvial sands and gravels. Paving of streets and lining of drainage channels have decreased greatly the surface area open to direct percolation. Subsurface inflow may take place to a limited extent from the Santa Monica Mountains where the older crystalline rocks are sufficiently fractured to allow storage and passage of water.

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Ground water in the deeper aquifers of the Hollywood Basin can move to the southwest around the La Brea high, provided the ground water gradient is in that direction. Some ground water in the Lakewood formation probably moves south across the La Brea high. However, a pumping depression in the area southeast of Beverly Hills just east of the Inglewood fault causes water in the Hollywood Basin and water from the Central Basin to flow toward its center.

Aquifers in Hollywood Basin have relatively low transmissibility rates, generally being less than 40,000 gallons per day per foot of width. The Lynwood aquifer (Plate 26F) has the highest transmissibility rate (60,000 gallons per day per foot of width) in this basin. Because of the erosion of the aquifers in the San Pedro formation over the La Brea high, the overall transmissibility rate is quite low there. The area of highest combined transmissibility rate is near Beverly Hills because of the greater thickness of coarser materials (Plate 26I).

Changes in ground water storage occur in the areas of free ground water, which are primarily along the north and east portions of the basin. Total storage to the base of the Sunnyside aquifer is about 200,000 acre-feet. Historically utilized storage since 1904 amounts to about 30,000 acre-feet. The storage capacity between the historical high water level which occurred in 1904 and sea level is about 80,000 acre-feet.

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Central Basin

The Central Basin extends over most of the Coastal Plain of Los Angeles County east and northeast of the Newport-Inglewood uplift (Plate 2). It is bounded on the north by the Hollywood Basin and a series of low hills extending from the Elysian Hills on the northwest to the Puente Hills on the southeast. Where the Los Angeles and Whittier Narrows break the otherwise continuous line of hills, the Central Basin is separated from the ground water basins to its north by arbitrary lines. The Central Basin is bounded on the west and south by the Newport-Inglewood uplift and on the southeast by the Los Angeles-Orange County line. All of these boundaries do not coincide with the ones defined in earlier reports. In Bulletin No. 8 (Calif. D.W.R. 1952c) the Central Basin included the area referred to in this report as the Hollywood Basin. The present Central Basin includes part of the area formerly known as the Los Angeles Narrows Basin, and the Whittier Area which was formerly the western part of the La Habra Basin.

The Central Basin was historically divided internally into three areas (Calif. D.W.R. 1934): the Los Angeles and Montebello Forebay Areas and the Central Basin Pressure Area. This division is shown on Plate 2. The forebay areas have been described as intake areas (areas of free or unconfined ground water) where substantial infiltration of surface water could occur. In the pressure area, the aquifers were pictured as being confined between relatively impervious layers of considerable lateral extent that restricted percolation of water from the ground surface downward to the underlying aquifers. This investigation has shown that such a simplified division is not possible because aquicludes were found to extend into the so-called forebay areas and the pressure area aquicludes were found locally

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to contain large amounts of sandy and gravelly clay and silts where considerable deep percolation could occur. The area of essentially unrestricted percolation of surface waters to the underlying ground water is limited to small areas in the vicinity of the Los Angeles and Whittier Narrows (Plate 9A). These areas are considerably smaller in extent than the historically defined Los Angeles and Montebello Forebay Areas. However, in large portions of the remainder of the basin, including the pressure area, the upper aquiclude is only partly effective in restricting downward percolation. Because of the heterogeneous pattern of these relatively permeable areas in and around the more impermeable aquicludes and the general gradation from one to the other, an attempt to divide the basin into pressure and forebay areas along a definite line for purposes of hydrologic analysis would not only be difficult but would have to be completely arbitrary. Nevertheless, the old delineation of forebay and pressure areas are used in the discussion of the geology of the Central Basin to follow because of their historical significance and descriptive usefulness.

The Central Basin is divided into four parts for descriptive purposes: the Los Angeles Forebay Area, the Montebello Forebay Area, the Whittier Area, and the Central Basin Pressure Area. The Los Angeles and Montebello Forebay Areas are located in the northern part of the Central Basin immediately south of the two breaks in the line of low hills bordering the basin. Through these breaks the Los Angeles River and the Rio Hondo-San Gabriel River systems flow from the valleys to the north into the coastal plain (Plate 2). These forebay areas spread southward from the two narrows in irregular semicircles. The southern boundary of the two forebay areas roughly coincides with the northernmost limit of the line of flowing

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artesian wells delineated by Mendenhall in 1903. As explained above, these forebay areas are not true forebays in the academic sense of the word but are used herein for descriptive purposes.

The Whittier Area is located in the northeastern part of the Central Basin east of the Montebello Forebay Area, south of the Puente Hills and west of the Orange County line. The Whittier Area was described as part of the La Habra Basin in Bulletin 45 (Calif. D. W. R. 1934). However, since the aquifers present in this area, especially the deeper ones, are interconnected to varying degrees with the aquifers in the Central Basin, the area was renamed and treated as part of the Central Basin.

The Central Basin Pressure Area is the largest of the four divisions of the Central Basin. It encompasses all of the area east and northeast of the Newport-Inglewood uplift and northwest of the Orange County line that is not included in the other three areas. It is called a "pressure area" because the aquifers within it are confined by aquicludes or relatively impermeable layers of clay and silt over most of the area. One of the most important aquicludes is at or near the surface. As noted previously, this near surface aquiclude is missing in local areas and contains zones of relatively more permeable material in many places where water could move into or out of the underlying aquifer. Accordingly, completely confined conditions do not exist in the pressure area.

It should also be noted in this discussion of basin divisions that the pressure area could be further divided on the basis of a ground water mound which has existed in the northwestern portion of the basin since the early 1930's. This mound effectively divides the ground water movement in that portion of the basin into two parts; that which moves northward

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toward the Hollywood Basin and that which moves southeasterly toward the center of the old pressure area and the Los Angeles Forebay Area. This ground water mound was used in the formulation of a portion of the northern boundary of the Central and West Basin Water Replenishment District organized in 1959 (Calif. D.W.R. 1959).

In the sections which follow, the geologic features of the Los Angeles Forebay Area, the Montebello Forebay Area, the Whittier Area and finally the Central Basin Pressure Area are summarized. For each area these summaries include information about the aquifers present, the areas where these aquifers merge, and barriers to ground water movement. The flow of water into and out of the Central Basin as a whole, replenishment of the aquifers, and areas of free ground water and storage change are described in a separate section under the heading of "Occurrence of Ground Water in the Central Basin".

Geologic Features of the Los Angeles Forebay Area

The Los Angeles Forebay Area, located in the northern part of the Central Basin, is shown on Plate 2. In general it is a free ground water area; however, in the course of this investigation it became evident that the Bellflower aquiclude extends into the southerly portion of the forebay area. The aquiclude in this area contains a high percentage of sand, and vertical percolation of water is apparently more rapid here than in other portions of the basin covered by it. Where the Bellflower aquiclude is missing within the forebay area (see Plate 8A), the aquifers are in direct hydraulic continuity with the surface.

The Los Angeles Forebay Area is overlain by parts of the La Brea, Downey, and Montebello Plains. The known water-bearing sediments extend to

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a depth of 1600 feet (1440 feet below sea level) and include Recent alluvium, the Lakewood formation, and the San Pedro formation. Some fresh water also may be present in the Pliocene and Miocene rocks underlying these formations in this area.

Recent alluvium in the Los Angeles Forebay Area is found on the Downey Plain and in the Los Angeles Narrows. It attains a maximum thickness of 160 feet, and includes the western arm of the Gaspur aquifer and the parts of the Semiperched aquifer and Bellflower aquiclude lying west and south of the Los Angeles River.

The Semiperched aquifer is defined as the area where sand and gravel overlying the Bellflower aquiclude is more than 20 feet in thickness. This Semiperched aquifer is also present in the Lakewood formation just south of the Repetto Hills. Although the aquifer can be defined on well logs, water levels in wells indicate that it contains little or no water.

The Bellflower aquiclude consists of clay and sandy clay, ranging from 0 to 90 feet in thickness (Plate 9A) and attains a maximum depth of 100 feet (elevation 40 feet) in the southern part of the forebay area (Plate 8A). It is also present in the Lakewood formation in which it underlies the Semiperched aquifer east and north of the Los Angeles River and extends south into the Central Basin Pressure Area. In the Lakewood formation it varies from less than 40 feet to 50 feet or more in thickness, consists of clay and sandy clay, and attains a maximum depth of 80 feet (elevation 20 feet, Plate 9A). The lack of water in the Semiperched aquifer overlying the Bellflower aquiclude suggests that the Bellflower aquiclude is reasonably permeable in the forebay area.

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The Gaspur aquifer consists mainly of sand and gravel with a very small percentage of clay. It ranges from 10 to more than 80 feet in thickness (Plate 11A) and extends down to a depth of 160 feet (60 feet below sea level, Plate 10A). The Gaspur aquifer is overlain by the Bellflower aquiclude over part of the forebay area. However, in the smaller area open to direct percolation shown on Plate 10A, the Gaspur aquifer is either exposed at the surface or overlain by a thin layer of fine sand or soil.

The Lakewood formation is exposed on the surface of the La Brea and Montebello Plains and extends underneath the Recent alluvium on the Downey Plain. It is present in the Los Angeles Narrows, but aquifers have not been defined there. The Lakewood formation includes the portions of the Bellflower aquiclude and the overlying Semiperched aquifer east and north of the Los Angeles River and the Exposition, Gardena, and Gage aquifers. It ranges from 0 to more than 220 feet thick in the southern part of the area.

The Exposition aquifer has been delineated in that portion of the Los Angeles Forebay Area that is beyond the boundaries or limits of the Gaspur aquifer. The Expositon aquifer consists of as many as three sand and gravel members separated in some areas by discontinuous clay and silt lenses. It attains a maximum thickness of 80 feet (Plate 11) and varies in depth from 100 to 160 feet (elevation 200 to 20, Plate 10). Although the Exposition aquifer is known to extend beneath the Gaspur aquifer, it was not differentiated from the Gaspur aquifer, because the contact between the two is indistinct.

The Gardena aquifer is present over much of the Los Angeles Forebay Area. It consists mainly of sand and gravel with a little clay, and

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ranges from 0 feet to 60 feet thick (Plate 13A). The maximum depth is 290 feet (100 feet below sea level, Plate 12A).

The Gage aquifer is also present in the forebay area, but over a large part of the area it has been eroded away and subsequently replaced by the Gardena aquifer. The Gage aquifer consists of sand and sandy clay with some gravel. It ranges from 5 feet to 100 feet in thickness (Plate 13A) and extends to a depth of 375 feet (250 feet below sea level, Plate 12A). The Gage aquifer is the basal member of the Lakewood formation. It rests unconformably on the underlying San Pedro formation, except in the extreme northern part of the area, where the San Pedro is missing (Plate 6E, section K-K'-K").

The San Pedro formation is the lowest, stratigraphically, of the formations in the Los Angeles Forebay Area that contain known aquifers. It crops out along the southern edge of the Repetto Hills and extends over the whole of the forebay area except in the Los Angeles Narrows. The San Pedro formation is about 1,050 feet thick in the Los Angeles Forebay Area and includes the Hollydale, Jefferson, Lynwood, Silverado and Sunnyside aquifers.

The Hollydale aquifer is missing in the west end of the forebay. In the rest of the area, it consists of sand and sandy clay with some gravel. It ranges from 0 feet to 60 feet in thickness (Plate 15) and extends 475 feet (350 feet below sea level, Plate 14).

The Jefferson aquifer is missing in the extreme southern part of the forebay area. In the Central and northern portions of the area, it consists of sand with some gravel and clay. It ranges from 0 to 70 feet in thickness (Plate 17) and extends 640 feet down (450 feet below sea level, Plate 16).

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The Lynwood aquifer is present over all of the Los Angeles Forebay Area where the San Pedro formation occurs. It consists maily of sand and gravel with a little clay, ranges from 20 feet to 130 feet in thickness, (Plate 19A) and extends down to 720 feet (600 feet below sea level, Plate 18A).

The Silverado aquifer is found throughout most of the Los Angeles Forebay Area and consists of gravelly sand with some interbedded clay. It ranges from 20 feet to 150 feet in thickness (Plate 21A) and extends 1,070 feet down (880 feet below sea level, Plate 20A).

The Sunnyside aquifer also is found over most of the forebay area and consists mainly of sand with interbedded clays. It ranges from 50 to 430 feet in thickness (Plate 23) and extends down to 1,600 feet (1,440 feet below sea level, Plate 22).

The San Pedro formation is unconformably underlain by sediments of Pliocene age which probably contain fresh water in their upper portions.

Within the Los Angeles Forebay Area, the Miocene and Pliocene rocks and the San Pedro formation in the north limb of the Paramount syncline dip to the south. There is a sharp angular unconformity between the steeply dipping, truncated San Pedro formation, and the overlying gently dipping Lakewood formation. This unconformity permits water moving through the Recent and Lakewood formations to percolate downward into the aquifers of the San Pedro formation. (See sections J-J'-J", Plate 6D and K-K'-K", Plate 6E). To the north, in the narrows itself, the Recent alluvium rests directly upon Miocene rocks. Erosion has removed all of the San Pedro formation here, as well as parts of the Lakewood formation which occurs only as terrace remnants along the sides of the narrows.

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Movement and occurrence of ground water in the Los Angeles Forebay Area and the other areas in the Central Basin will be discussed later.

Geologic Features of the Montebello Forebay Area

The Montebello Forebay Area extends southward from the Whittier Narrows and presently is the most important area of recharge in the Central Basin. The boundary, shown on Plate 2, is the same as the Montebello Forebay Area boundary described in Bulletin No. 45 (Calif. D.W.R. 1934).

The Montebello Forebay Area is overlain by parts of the Montebello, Downey, and Santa Fe Springs Plains. The water-bearing sediments vary in age from Recent to early Pleistocene and extend to a maximum depth of about 1,050 feet (900 feet below sea level).

The Recent alluvium contains parts of the Semiperched aquifer and the Bellflower aquiclude, and the eastern arm of the Gaspur aquifer. The Semiperched aquifer consists of 20 to 60 feet of sand and gravel overlying the Bellflower aquiclude. The Semiperched aquifer is of Recent age over most of the area but in the northwest corner of the area it is part of the Lakewood formation of late Pleistocene age. The Bellflower aquiclude (Plates 8A and 9A) also is found both in Recent alluvium and the Lakewood formation in the Montebello Forebay Area. It consists of clay and sandy clay ranging in thickness from a few feet at its edge to about 60 feet northeast of Downey. Well logs and other data collected for this report show that where the Bellflower aquiclude extends into the forebay area, it contains a high percentage of sand and gravel. These data suggest that the permeability is sufficiently high to allow percolation through the aquiclude in portions of this area, and therefore it is not an aquiclude in fact in those areas. The areas where the Bellflower aquiclude is not present are shown on Plates 8A and 9A.

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The eastern arm of the Gaspur aquifer extends northeasterly through the Montebello Forebay Area and into the Whittier Narrows. It consists of coarse sand and gravel ranging from 40 to 100 feet in thickness (Plate 11A). The maximum thickness is found in the vicinity of the Whittier Narrows Dam, and the maximum depth of 125 feet (20 feet below sea level) occurs in the vicinity of Downey (Plate 10A). The Gaspur aquifer is exposed at the ground surface from Whittier Narrows south to Imperial Highway (Plate 10A). South of this point it is overlain by the Bellflower aquiclude.

The Lakewood formation in the Montebello Forebay Area contains parts of the Semiperched aquifer and the Bellflower aquiclude mentioned earlier, and the Artesia, Exposition, Gage, and Gardena aquifers.

The Artesia and Exposition aquifers, present over a limited area in the Montebello Forebay (Plates 10A and 11A), appear to be contemporaneous in age and mode of deposition. The name "Artesia aquifer" has been given to water-bearing sediments immediately underlying the Bellflower aquiclude east and south of the Gaspur aquifer. The Exposition aquifer consists of similar deposits extending west and north of the eastern arm of the Gaspur aquifer. The Artesia and Exposition aquifers consist of from 10 to 90 feet of sand and gravel with some clay. The sediments comprising these aquifers underlying the Gaspur aquifer had been mostly eroded away prior to deposition of the Gaspur aquifer, and no effort has been made to identify those portions of the aquifers that may remain beneath the Gaspur. The composite name, Artesia-Exposition aquifer, is used for these water-bearing deposits which underlie and are in hydraulic continuity with the Gaspur aquifer.

The Gage aquifer (Plates 12A and 13A) is composed mainly of sand ranging from 20 to 80 feet in thickness, and extends over approximately

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one-third of the forebay. The maximum thickness is found in the vicinity of Montebello. The maximum depth of 260 feet (150 feet below sea level) is southeast of Downey.

The Gardena aquifer (Plates 12A and 13A) is present over about two-thirds of the Montebello Forebay. This aquifer, deposited in channels incised into the Gage aquifer, is coarse sand and gravel and ranges from 20 to 140 feet in thickness. The maximum thickness is found just north of the Whittier Narrows Dam. The sediments extend down to a maximum depth of 265 feet (150 feet below sea level) north of Norwalk.

The San Pedro formation has been identified throughout the Montebello Forebay Area beneath the Lakewood formation. It also crops out on the south side of the Repetto Hills west of the Rio Hondo. All of the aquifers of the San Pedro formation are present in the Montebello Forebay Area. The Hollydale aquifer (Plates 14 and 15) is present over about one-half of the area and is compsed of about 20 to 60 feet of sand and gravel with a small amount of interbedded sandy clay and clay. The maximum depth of 260 feet (250 feet below sea level) occurs about one mile north of Norwalk. The Jefferson aquifer (Plates 16 and 17) has been identified over about three-quarters of the Montebello Forebay Area. It ranges in thickness from 20 to 60 feet and consists of sand and sandy clay. The maximum depth of 505 feet (300 feet below sea level) occurs about a mile north of Norwalk.

The Lynwood aquifer (Plates 18A and 19A) is found throughout the Montebello Forebay Area. It is mainly coarse sand and gravel ranging from 50 to 150 feet in thickness. The maximum depth of 705 feet (450 feet below sea level) occurs about one mile north of Norwalk. This aquifer yields water to many wells in the Montebello Forebay Area. The Silverado aquifer (Plates

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20A and 21A), identified throughout the Montebello Forebay Area, ranges from 50 to 200 feet in thickness, and is about half sandy gravel and half interbedded clay. The maximum depth of about 1,000 feet (900 feet below sea level) is also just north of Norwalk.

The Sunnyside aquifer (Plates 22 and 23) is the basal member of the San Pedro formation and is the deepest aquifer identified in the Montebello Forebay Area. It is generally sand with local areas of coarse gravel and ranges in thickness from 100 to 350 feet. The maximum depth of about 1,400 feet (1,300 feet below sea level) occurs north of Norwalk.

The San Pedro formation is underlain by Pliocene deposits which are water bearing in some areas. Electric logs of oil wells show that fresh water is present below the San Pedro formation in the Montebello Forebay Area but no aquifers have been delineated in these older sediments.

The major structural features of the Montebello Forebay Area are the unconformity between the Lakewood and San Pedro formation and the faulting and folding in the Whittier Narrows. Geologic sections A-A'-A", Plate 6A, M-M', and N-N', Plate 6F and P-P', Plate 6G, show the gently dipping formations in the Whittier Narrows, and Plate 7 shows cutaway views of the aquifers therein. The Rio Hondo, Pico, and Cemetery faults, all trending approximately northeast, have been postulated in the Whittier Narrows where they evidently bound two distinct, folded blocks (see section on Whittier Narrows Area in Chapter V).

The Rio Hondo fault follows approximately along the southwest side of the Rio Hondo. It displaces the Gardena, Lynwood, and Sunnyside aquifers. The Recent alluvium continues unaffected across the fault. On the northwest side of the Rio Hondo fault, the Sunnyside aquifer has been downdropped as

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much as 600 feet with respect to the aquifer on the southeast side. Northwest of the Rio Hondo fault near Whittier Narrows Dam, erosion has removed all aquifers between the Sunnyside and Gardena aquifers (geologic section P-P', Plate 6G).

The Pico fault extends parallel to the Rio Hondo fault and lies about one mile southeast of it. Only the aquifers of the San Pedro formation are cut by this fault, with the southeast side having been downdropped. The amount of offset varies along the fault and, for the Sunnyside aquifer, the maximum vertical offset is about 400 feet. This places the Sunnyside aquifer on the northwest side of the fault opposite the Lynwood and Jefferson aquifers on the southeast side, thus retaining some hydraulic continuity across the fault.

The Cemetery fault is located along the east side of Whittier Narrows and trends slightly east of north. No cross sections in this report cross through this fault. Because the fault coincides with the contact between the Recent alluvium of the Narrows and Pliocene formations of the Puente Hills and since data are not available to differentiate aquifers east of the fault in the Pliocene sediments, any displacement and the effect of the fault upon ground water movement cannot be ascertained.

Some idea of the complexity of the folding in the Whittier Narrows can be seen on geologic sections A-A'-A", M-M', N-N' and P-P' of Plates 6A, 6F, and 6G. Cutaway diagrams of aquifers in the vicinity of Whittier Narrows are shown on Plate 7, with the Gaspur, Gardena, and Silverado aquifers stripped off in succession. The fault displacement and folding can be understood particularly well with the use of this plate.

Ground water movement within the Whittier Narrows in a northwest-southeast direction would probably be impeded by these faults. Fortunately,

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the faults trend is essentially parallel to the main subsurface inflow to the Central Basin through the Whittier Narrows and apparently do not affect this ground water movement.

Geologic Features of the Whittier Area

The Whittier Area of the Central Basin extends from the Puente Hills south and southwest to the axis of the Santa Fe Springs-Coyote Hills uplift. The western boundary is an arbitrary line separating the Whittier Area from the Montebello Forebay Area; the eastern boundary is the Orange County line (see Plate 2). The name "Whittier Area" is used for the first time in this report. In prior publications this area was considered to be part of the La Habra Basin (Calif. D.W.R. 1934 and 1947), the southern boundary of which coincided with the southern edge of the Coyote Hills. The southern boundary of the Whittier Area used in this report was chosen because it is a drainage divide and water applied on the south flank of the Coyote Hills would drain into the Central Basin Pressure Area.

Water well data are almost entirely lacking for the sediments found in the east end of the Whittier Area and around the City of Whittier. However, it is reasonably certain that ground water is present in these areas. In the portion of the Whittier Area where aquifers have been defined, many of the old wells have been destroyed and water level data are no longer available. Consequently, the descriptions of the aquifers and aquicludes present in the Whittier Area are not complete.

The Whittier Area is overlain by the La Habra Piedmont Slope and part of the Santa Fe Springs Plain and the Coyote Hills (Plate 2). The known water-bearing sediments, extending to a depth of about 1,000 feet (800 feet below sea level), include Recent alluvium and the Lakewood and San

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Pedro formations. A part of the underlying Pliocene and older deposits may also contain water of good quality. Electric logs of oil wells in the Whittier Area indicate fresh water at greater depths than have been penetrated by water wells.

Recent alluvium in the Whittier Area consists of a thin finger of sand, gravel, and clay, which extends into the western portion of the area from the Montebello Forebay Area (Plate 3A). The sediments are 80 feet thick near the western boundary of the area, and thin out to the east. The Recent alluvium contains a portion of the Bellflower aquiclude and the Gaspur aquifer.

The Bellflower aquiclude in the Recent alluvium consists of clay and sandy clay ranging from 10 to over 40 feet in thickness (Plate 9A). It overlies the Gaspur aquifer in the extreme western part of the area. In much of the Whittier Area, the Bellflower aquiclude is part of the undifferentiated Lakewood formation. Lack of data in many parts of the area where the Lakewood formation is exposed at the surface makes it difficult to define the thickness, extent, and composition of this aquiclude. Where data are available, the Bellflower aquiclude is clay and sandy clay averaging 20 feet in thickness and extending down to a depth of about 70 feet below the ground surface (elevation 120 feet, Plate 8A). The degree to which the ground water can be transmitted through the Bellflower aquiclude depends on the thickness and composition of the aquiclude. While the aquiclude appears to be continuous over most of the Whittier Area, it may be either absent in some areas or so thin and discontinuous that ground water can be transmitted through it at an appreciable rate.

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The Gaspur aquifer is mainly sand and gravel with a small amount of interbedded clay. It ranges from 30 to 60 feet in thickness (Plate 11A) and attains a depth of 145 feet below the surface (elevation 60 feet, Plate 10A).

The Lakewood formation crops out over most of the Whittier Area (Plate 3A). It consists of continental deposits of late Pleistocene age and attains a maximum thickness of 70 feet. The Lakewood formation contains the Artesia and Gage aquifers and that part of the Bellflower aquiclude described above.

The Artesia aquifer extends a short distance into the southwest corner of the Whittier Area in the vicinity of Santa Fe Springs. It is mostly sand with some interbedded clay and has an average thickness of about 40 feet (Plate 11A) and a maximum depth of about 50 feet (elevation 60 feet, Plate 10A). This aquifer is near the surface and has been exposed in excavations on the Santa Fe Springs Plain.

The Gage aquifer is the major water-bearing member of the Lakewood formation in the Whittier Area. It has been delineated only in the southern portion of the area and near the Los Angeles-Orange County line, where it consists of about 30 feet (Plate 13A) of sand with some interbedded clay, and has a maximum depth of about 150 feet (elevation 50 feet, Plates 12A and 6A, section B-B'-B").

The San Pedro formation underlies the entire Whittier Area, where it attains a maximum thickness of about 850 feet and extends down to a depth of about 920 feet (850 feet below sea level). The formation is composed of sand and gravel with interbedded clay, all probably of marine origin. Clay members separate the sands and gravels comprising the aquifers over most of

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the basin. The San Pedro formation contains the Hollydale, Jefferson, Lynwood, Silverado, and Sunnyside aquifers. An extensive unconformity brings the aquifers of the San Pedro formation into contact with those of the Lakewood formation along the northern boundary of the area and along the edge of the Coyote Hills. Cross sections B-B'-B" and Q-Q' on Plates 6A and 6G show this relationship.

The Hollydale aquifer has been identified only in the western part of the Whittier Area. It may be present over the rest of the area, but data are lacking. It ranges in thickness from 10 to 25 feet (Plate 15) and consists of sand and gravel with a small amount of interbedded clay. It appears to reach a maximum depth of about 100 feet (elevation 50 feet, Plate 14). It is merged with the overlying Gage aquifer in the vicinity of South Whittier.

The Jefferson aquifer ranges in thickness from 20 feet to 40 feet (Plate 17) and consists of sand and gravel with a little interbedded clay. It extends over most of the Whittier Area and reaches a maximum depth of about 350 feet (100 feet below sea level, Plate 16). In the western part of the area, near the boundary with the Montebello Forebay, the Jefferson aquifer merges with the overlying Hollydale aquifer.

The Lynwood aquifer is present throughout the Whittier Area. It ranges in thickness from 50 to 100 feet (Plate 19A) and consists of sand and gravel with some interbedded clay. It extends to a maximum depth of about 460 feet (300 feet below sea level, Plate 18A).

The Silverado aquifer has been identified over all of the Whittier Area. It consists of 110 to 300 feet of sand and gravel with finer grained phases in some areas (Plate 21A). It extends to a depth of about 750 feet (600 feet below sea level, Plate 20A).

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The Sunnyside aquifer also has been identified throughout the Whittier Area. It consists of 200 to 300 feet of sand and gravel with some interbedded clay (Plate 23). It is the lowest of the aquifers identified, reaching a maximum depth of about 1,000 feet (700 feet below sea level, Plate 22). The gravels exposed in the Coyote Hills and along the north side of the area are believed to be surface outcrops of the Sunnyside aquifer.

The Pliocene and Miocene sediments below the San Pedro formation generally contain saline water in this area, but may locally contain fresh water. Plate 24A shows the approximate elevation of the base of fresh water-bearing sediments.

The available data suggest that some of the water-bearing sediments in the Whittier Area may have been faulted. However, the location of such faulting and its effect on ground water has not been determined.

The water-bearing sediments of the Whittier Area comprise part of the generally east-west trending La Habra syncline. The Recent deposits are essentially undisturbed. The Lakewood formation underlying the Recent alluvium is also generally flat-lying, though in some areas it is slightly tilted. The San Pedro formation, however, which unconformably underlies the Lakewood formation, has been folded sharply and its flanks are exposed in the Coyote Hills and on the south side of the Puente Hills. The effects of this unconformity and the outcrops of the moderately dipping San Pedro formation upon the occurrence and movement of ground water will be discussed later.

Geologic Features of the Central Basin Pressure Area

The Central Basin Pressure Area, previously known as the Central Coastal Plain Pressure Area, is overlain by the Downey Plain and parts of

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the Santa Fe Springs, Montebello, La Brea, and Bouton Plains. The area is generally flat and slopes gently to the south. Water-bearing sediments in the Central Basin Pressure Area range in age from Recent to Pliocene and extend to a probable maximum depth of 2,200 feet northeast of the City of Lakewood. Aquifers have been defined in the Recent alluvium and the Lakewood and San Pedro formations.

In this pressure area the aquifers are confined by many aquicludes, only one of which has been named. This is the near surface Bellflower aquiclude which restricts vertical percolation into the Gaspur and other underlying aquifers. Water levels in the confined area form a piezometric or pressure surface rather than a free ground water surface. As pressures change from aquifer to aquifer, the corresponding piezometric water levels in wells tend to vary according to which aquifer or aquifers are used for production. Also, as the aquicludes vary in extent, configuration, permeability, and thickness, their effectiveness as confining members also changes from place to place and with this change an exchange of water between aquifers may take place, depending on the direction of the pressure gradient.

The Recent alluvium covers most of the Central Basin Pressure Area, and attains a probable maximum depth of 200 feet near the City of Bellflower. It contains the Semiperched aquifer, the Bellflower aquiclude, and the Gaspur aquifer. The Semiperched aquifer consists of sands and gravels 20 to 60 feet thick overlying the Bellflower aquiclude.

The Bellflower aquiclude is found throughout the pressure area and is composed mainly of clay and silt; however, there are numerous areas where it consists mainly of clayey sands and gravels and where its effectiveness as an aquiclude is limited. It ranges from a few feet to 160 feet in

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thickness (Plate 9A). It extends downward to about 200 feet (140 feet below sea level) southwest of the City of Bellflower (Plate 8A). The Bellflower aquiclude is also present in the Lakewood formation but no effort has been made to define separately the areas where the aquiclude is identified with each age. The Gaspur aquifer extends south from the forebay areas in two separate arms which merge in the vicinity of the City of Lynwood and then extend south along the course of the Los Angeles River to the ocean. The Gaspur aquifer consists of coarse sand and gravel and ranges in thickness from 40 to 100 feet (Plate 11A). The maximum depth of about 190 feet (170 feet below sea level) occurs in the vicinity of Terminal Island in San Pedro Bay (Plate 10B).

The Lakewood formation, of late Pleistocene age, extends over all of the Central Basin Pressure Area. It contains part of the Bellflower aquiclude and the Artesia, Exposition, Gage, and Gardena aquifers. The water-bearing materials immediately underlying the Bellflower aquiclude west of the easterly arm of the Gaspur aquifer are called the Exposition aquifer. The water-bearing materials immediately underlying the Bellflower aquiclude east of this arm of the Gaspur aquifer are called the Artesia aquifer and are believed to be contemporary both in age and mode of deposition with the materials in the Exposition aquifer. The boundary between the Artesia and Exposition aquifers is somewhere in the center of the basin under the Gaspur aquifer. All three aquifers are in hydraulic continuity. Both the Artesia and Exposition aquifers consist of sand and gravel with local areas of interbedded clay. The Exposition aquifer ranges from 20 to over 100 feet in thickness (Plate 11A) and reaches a maximum depth of about 230 feet (120 feet below sea level) southeast of Huntington Park (Plate 10A).

AR0069017

The Artesia aquifer consists of 10 to 140 feet of sand and gravel with some interbedded clays (Plate 11A). It extends down to a maximum depth of 230 feet (220 feet below sea level) southeast of the City of Lakewood (Plate 10A).

The Gage and Gardena aquifers of the Lakewood formation are also considered to be the same age. Their relationship was discussed in this chapter in the section on the West Coast Basin. The Gage aquifer consists of fine-grained sand and silty sand ranging from 5 to 120 feet in thickness (Plate 13A). The maximum depth attained is 380 feet (350 feet below sea level) west of the City of Lakewood (Plate 12A). The Gardena aquifer consists of coarse-grained sand and gravel from 10 to 60 feet in thickness. It extends down to a depth of about 390 feet (350 feet below sea level) near the City of Lynwood. The Gage and Gardena aquifers mark the base of the Lakewood formation and along this base they abut the underlying San Pedro formation unconformably.

The San Pedro formation, present throughout the Central Basin Pressure Area, contains some of the most important aquifers in the area. In all, five aquifers, the Hollydale, Jefferson, Lynwood, Silverado, and Sunnyside, have been delineated.

Two relatively minor aquifers, the Hollydale and Jefferson aquifers, are present in the upper part of the San Pedro formation in the Central Basin Pressure Area. The Hollydale aquifer, uppermost of the two, (Plates 14 and 15) extends over approximately 60 percent of the area. It is mostly sand and silty sand with interbedded clays, though some gravel is found locally. It ranges from approximately 10 to 100 feet in thickness, and the maximum depth of about 570 feet (500 feet below sea level) is reached a few miles east of the City of Compton. The Jefferson aquifer (Plates 16 and 17)

AR0069018

is present over only 40 to 50 percent of the pressure area. It is mostly fine-grained sand with scattered lenses of gravel, and ranges in thickness from about 10 feet to over 140 feet. The maximum depth of approximately 720 feet (650 feet below sea level) is found near the Orange County line southeast of the City of Norwalk. Although these two aquifers are not continuous over the entire Central Basin Pressure Area, they are important sources of water in some localities.

Both the Lynwood and Silverado aquifers yield considerable water to wells in the Central Basin Pressure Area. The Lynwood aquifer (Plates 18A and 19A) is composed mainly of coarse-grained sands and gravels, ranging in thickness from less than 50 feet to over 150 feet. The maximum depth of about 1,030 feet (950 feet below sea level) occurs southeast of the City of Norwalk. The Silverado aquifer (Plates 20A and 21A) is composed largely of sands and gravels, ranging in thickness from about fifty feet to over 450 feet. The greatest depth is found north of the City of Lakewood, where its base is about 1,240 feet below the ground surface (1,200 feet below sea level). The base of the Silverado aquifer was thought to correspond to the base of the Pleistocene deposits and of fresh water in the West Coast Basin, where it was first named. In the Central Basin, however, the Sunnyside aquifer has been differentiated below the Silverado aquifer.

The Sunnyside aquifer (Plates 22 and 23) marks the base of the San Pedro formation in most parts of the Central Basin Pressure Area. It varies from about 70 feet to over 500 feet in thickness and consists of sand, and sand and gravel. The maximum depth of about 1,700 feet (1,660 feet below sea level) occurs east of the City of Lakewood.

AR0069019

Below the Sunnyside aquifer is a thick section of Pliocene deposits, the coarse zones of which contain fresh water, as indicated by electric logs of oil wells. Around the margins of the Central Basin Pressure Area, where many oil fields exist and more data are available, it is apparent that the fresh water was introduced into the Pliocene sediments by flushing the saline water toward the ocean. Much of the pressure area is in the South Gate-Santa Ana depression where only widely scattered exploratory type oil well data are available. No contours depicting the base of fresh water could be drawn through this area; however, the replacement of saline waters with fresh water appears to have occurred here as well.

The structural features which control or influence the occurrence and movement of ground water in the Central Basin Pressure Area are the South Gate-Santa Ana depression and the Newport-Inglewood uplift. The South Gate-Santa Ana depression extends from south of Beverly Hills into Orange County. It is bounded by transitional structures adjacent to the Puente and Repetto Hills on the northeast and the Newport-Inglewood uplift on the southwest. The Recent sediments in this depression are generally flat-lying as are the underlying deposits of the Lakewood formation. The San Pedro formation, however, is moderately folded and unconformably underlies the younger formations in most of the Central Basin.

The major structural features in the South Gate-Santa Ana depression are the Paramount syncline and Los Alamitos fault, and the Norwalk syncline. These structures appear to be developed only in the San Pedro formation, and they do not affect the overlying younger sediments. The Paramount syncline underlies the City of Paramount and extends northwesterly to the Inglewood fault north of the Baldwin Hills. The Los Alamitos fault

AR0069020

appears as an extension of the axis of the Paramount syncline southeast of the City of Paramount. The Norwalk syncline extends from the City of Norwalk southeasterly to the Orange County line. It is separated from the Los Alamitos fault by an unnamed anticlinal fold which extends into Orange County. None of these structural features appear to materially affect ground water movement in the Central Basin Pressure Area.

The faults and anticlinal folds of the Newport-Inglewood uplift mark the west and southwest boundary of the Central Basin Pressure Area and are partial barriers to movement of ground water from the Central Basin to the West Coast Basin, as has been previously discussed.

AR0069021

Occurrence of Ground Water in the Central Basin

In all four areas of the Central Basin ground water is found in the Recent alluvium, the Lakewood and San Pedro formations, and sometimes in the older sediments. The aquifers in these formations have been discussed above under separate headings for each area of the Central Basin. The paragraphs that follow will take up the movement of ground water into and through the Central Basin as a whole, rather than by separate areas.

Ground water enters the Central Basin through surface and subsurface flow and by direct percolation of precipitation, stream flow, and applied water. The main surface and subsurface flow into the basin is through the Los Angeles and Whittier Narrows from the ground water basins in the interior valleys. However, minor subsurface flow probably enters the area from the bordering relatively impermeable formations, and some subsurface flow can take place from the other surrounding ground water basins.

Replenishment of the aquifers by percolation of precipitation, stream flow, and applied water occurs in the forebay areas where permeable sediments are exposed at ground surface. In addition, some water also moves into the aquifers where they crop out on the surface against the surrounding highlands and in those portions of the pressure area where the Bellflower aquiclude is missing or contains considerable sand and gravel.

In the Los Angeles and Montebello Forebay Areas the aquifers are in hydraulic continuity in varying degrees, with each other and with the ground surface. In some instances this hydraulic continuity results from the aquifers being superposed one on another with no intervening clay members. Areas where each aquifer is merged with the overlying one are shown on the plates depicting lines of equal elevation on the base of each aquifer

AR0069022

(Plates 10A, 12A, 14, 16, 18A, 20A, and 22). In other portions of the forebay areas aquicludes present between the aquifers restrict direct movement of ground water between aquifers. However, these aquicludes are not continuous over the entire area; consequently, the hydraulic gradient controls the lateral movement of ground water to points where the aquifers are merged.

The areas of contact between aquifers and areas of contact with the ground surface are important because it is only through these areas that surface water can be introduced by spreading into the aquifers in major quantity. The most important area in this regard in the Coastal Plain of Los Angeles County is in the vicinity of the Whittier Narrows in the Montebello Forebay Area because of the interconnection of the deeper aquifers through the shallower ones to the ground surface. This condition also exists in the vicinity of the Los Angeles Narrows in the Los Angeles Forebay Area, but the paving of this area has essentially eliminated surface recharge to the aquifers below.

Plate 25, entitled "Areas Where Aquifers are Merged with Permeable Surface Deposits or Overlying Aquifers in Vicinity of Whittier Narrows" shows the generalized interconnections in and near the Whittier Narrows in the Montebello Forebay Area and the areas of essentially direct connection between the aquifers and the ground surface. This plate was derived from the detailed delineation of the areas of mergence shown on the plates depicting lines of equal elevation on the base of each aquifer.

Water applied on the surface can move directly into the Gaspur aquifer within the area shown on Plate 25. The Gage and Gardena aquifers immediately underlie the Gaspur aquifer and they are in hydraulic continuity. Below the Gage and Gardena aquifers are the Hollydale and Jefferson

AR0069023

aquifers which are generally merged with the Gage and Gardena aquifers. This relationship is shown on Plates 12A, 14, 16, and Plate 25. These interconnections provide essentially complete continuity with the surface through the Gaspur aquifer. The areas of mergence of the deeper aquifers with the overlying ones are much more restricted and these limited areas are shown on Plate 25 as well as on Plates 18A, 20A, and 22. It will be noted from Plate 25 that the area of direct vertical recharge from the ground surface to the Lynwood aquifer is about one-third of the area of the Gaspur in contact with the ground surface. The area of direct vertical recharge to the Silverado and Sunnyside aquifers is even more restricted and is limited to a very small area in the immediate vicinity of Whittier Narrows Dam. These limited areas of interconnection severely restrict the amount of recharge that can directly reach the deeper aquifers from the ground surface. Fortunately, the areas of mergence through which water can reach the lower aquifers by devious paths is considerably larger than shown on Plate 25 (see Plates 12A, 14, 16, 18A, 20A, and 22). Therefore, even though the direct downward infiltration may be restricted or entirely impeded by an intervening aquiclude, water can move laterally in one aquifer to a point where the aquifer is merged with a lower one, permitting water applied at the surface to reach and replenish the deeper aquifers.

The areas of mergence between aquifers in the Los Angeles Forebay also are shown on the plates depicting lines of equal elevation on the base of each aquifer. It is evident that considerable opportunity existed for infiltration of water from the ground surface into the Gaspur aquifer and on into the deeper aquifers of the basin. However, as noted before, this area now is essentially covered with impervious material and the opportunity for surface recharge of the aquifers is practically nonexistent.

AR0069024

This is unfortunate from the standpoint of ground water basin utilization since the available storage capacity in the Los Angeles Forebay is large.

Under present conditions, ground water in the Montebello Forebay Area moves into the Los Angeles Forebay Area, the Whittier Area, and the Central Basin Pressure Area. Ground water from the Los Angeles Forebay Area also moves into the Central Basin Pressure Area. In the northern portion of the pressure area a ground water mound exists which separates ground water movement into two parts. North of this mound ground water moves northward into the Hollywood Basin while south of this mound ground water moves southwesterly toward the West Coast Basin.

Ground water movement in the Whittier Area in July 1958 was to the west and southwest in both the deep and shallow aquifers. The Santa Fe Springs-Coyote Hills uplift, the axis of which serves as the southern boundary of the Whittier Area, appears to restrict ground water movement to the south into the Central Basin Pressure Area in the aquifers of the Lakewood formation. The aquifers of the San Pedro formation are continuous across the uplift and it is reasonable to assume that ground water movement to the south could take place if the hydraulic gradient sloped in that direction.

Historically, subsurface flow took place from the Central Basin across the Newport-Inglewood uplift into the West Coast Basin. However, pumping has lowered the water level in the Central Basin and at present water levels in some aquifers are about equal on both sides of the Newport-Inglewood uplift. Further lowering of water levels on either side of the uplift could result in a hydraulic gradient being established which would slope toward the point of the lower water level with a consequent flow of water in that direction. A relatively small amount of subsurface flow occurs out of the Central Basin Pressure Area because most of the ground

AR0069025

water moves to a series of pumping holes developed along the Newport-Inglewood uplift north of Dominguez Hill, along the Cherry Hill fault, north of Signal Hill and in the Lakewood area. From these areas the water is removed by pumping for industrial, irrigation, and domestic uses.

The movement of ground water across the Los Angeles-Orange County line, which forms the eastern boundary of the Central Basin, is entirely dependent on the hydraulic gradient in that area, as no physical barrier to ground water movement exists except for the Coyote Hills.

Transmissibility rates of aquifers in Central Basin as shown on Plates 26A through 26I are extremely variable, ranging up to 400,000 gallons per day per foot of width, although most of the aquifers have transmissibility rates of less than 100,000.

The Gaspur aquifer (Plate 26A) generally has a transmissibility rate of less than 200,000 gallons per day per foot, but has a maximum of 400,000 in a small area in Whittier Narrows. Transmissibility rates in the Artesia-Exposition aquifer average about 30,000 with a maximum transmissibility rate of about 70,000 in several small areas (see Plate 26B, "Lines of Equal Transmissibility of the Artesia-Exposition Aquifers"). The Gage and Gardena aquifers (Plate 26C) also have average rates of about 30,000 but reach a maximum value of about 100,000 near Long Beach and in the Whittier Narrows. The transmissibility rates of the Hollydale and Jefferson aquifers, shown on Plates 26D and 26E entitled, "Lines of Equal Transmissibility of the Hollydale Aquifer" and "Lines of Equal Transmissibility of the Jefferson Aquifer", respectively, have average values of about 20,000 gallons per day per foot of width. The Lynwood aquifer rates (Plate 26F) average about 40,000 but attain a maximum transmissibility rate of about 100,000 gallons per day per foot of width in several areas.

AR0069026

The Silverado aquifer (Plate 26G) averages about 60,000 but reaches a maximum of 400,000 near the intersection of Carson and Atlantic Boulevards. Data on the Sunnyside aquifer in the middle, deeper portion of Central Basin is not very complete, but it appears to have an average transmissibility rate of about 100,000 with a maximum of 300,000 in several areas as shown on Plate 26H, "Lines of Equal Transmissibility of the Sunnyside Aquifer".

The overall transmissibility of all aquifers in the Central Basin is of considerable importance. It may be noted on Plate 26I that high transmissibility rates exist from Whittier Narrows toward Long Beach and Compton, but that an area of low transmissibility separates the Montebello and Los Angeles Forebays. This low transmissibility partly explains the existence of the large pumping depression around Huntington Park and Vernon, where pumping rates are generally not much higher than in the Downey area but there no pumping depression exists.

While the Central Basin Pressure Area is, as its name signifies, essentially an area of confined aquifers, free ground water conditions exist in the Semiperched aquifer overlying the Bellflower aquiclude, and probably in the vicinity of Baldwin Hills where the San Pedro formation is exposed at the surface. In addition, changes in ground water storage have occurred immediately south of the two forebay areas in the upper aquifers directly underlying the Bellflower aquiclude.

In past ground water studies of the Central Basin, it was believed that the clay layer or cap covered all of the basin south of the forebay areas and effectively prevented any percolation of surface water into the aquifers below. Plate 9 shows places where this clay cap, the Bellflower aquiclude, contains considerable amounts of sand and gravel. In

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these areas, water applied on the surface could percolate down into the underlying aquifers and it is possible that free ground water conditions may exist from the surface down through one or more of the upper aquifers. These areas increase the total area of the Central Basin where changes in ground water storage can occur with changing water levels and where replenishment by deep percolation can occur. In addition, changes in storage in the Bellflower aquiclude itself is believed to occur as water levels are lowered. These changes in storage are relatively small however, because of the relatively low specific yield assigned to much of these sediments.

Total capacity to store ground water in the Central Basin above the base of the Sunnyside aquifer, or the Silverado aquifer where the Sunnyside is missing, is about 13,800,000 acre-feet. Historically utilized storage since 1904 amounts to about 780,000 acre-feet. As noted before, this change in storage has occurred primarily in the Montebello and Los Angeles Forebay Areas; however, some of the change in storage occurred in the pressure area immediately south of these areas where water levels were lowered below the base of the Bellflower aquiclude and near the Repetto and Whittier Hills where the San Pedro formation crops out at the surface. The storage capacity between high water levels, which occurred in 1904, and sea level amounts to about 1,340,000 acre-feet.

The storage and storage change for the Central Basin listed above may be broken down between the generalized areas delineated on Plate 2 as follows:

	Total storage to base of deepest aquifer	Storage between high water and sea level	Historically utilized storage
Los Angeles Forebay Area	1,800,000	430,000	190,000
Montebello Forebay Area	1,800,000	410,000	230,000
Whittier Area	600,000	60,000	20,000
Central Basin Pressure Area	9,600,000	440,000	340,000
Total	13,800,000	1,340,000	780,000

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CHAPTER VII. CONCLUDING REMARKS

This report has been compiled primarily for use in studies of ground water hydrology, quality, and basin operation. While it is true that considerable detail is shown on the plates and discussed in the text, the emphasis has been on general relationships between the aquifers, geologic structures, and ground water. Detailed investigations of small areas may indicate that there are, in reality, many more aquifers, and that their relationships are more complex than outlined here. It is to be expected that many of the details presented in this report will eventually be revised. However, it is believed that this report provides a foundation for further refinement and revision of the geology of the fresh water-bearing sediments.

Before additional refinements and revisions can be made it will be necessary to accumulate more basic data. Accordingly the following observations and recommendations are proffered:

1) This study has shown the value of the continuous collection of geologic and hydrologic data in order to better understand the physical limits of ground water basins, their aquifers and structures, and the movement and occurrence of their contained ground water. Where detailed information was available, the geologic interpretation was easier and certain, but not necessarily final. Areas that were deficient in data required an extension of basic concepts from known areas into unknown areas. It was here that the experience gained from similar studies in Southern California proved of value.

Development of highland areas is expanding and more wells are being drilled in volcanic rocks, older sediments, and the alluvium of

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mountain valleys. Although these areas are not in the principal ground water basins, the increased requests by the public for information on the ground water resources in the highlands have shown a need for more study of these upland areas.

It is therefore recommended that the data collection program be continued for areas both in the principal ground water basins as well as the lesser basins and highland areas. With more detailed information, the complex problems which will arise as ground water usage increases will be easier to analyze and perhaps solve. A continuous program of limited data collecting will also be necessary for a re-evaluation of areas already studied.

2) Similar studies of adjacent areas should clarify marginal basin features in the Coastal Plain of Los Angeles County. The regional interpretation sometimes sheds light on the local conditions. Conversely, information gained in this investigation will facilitate studies in these adjacent areas.

3) There is a need for more exploratory wells in areas where data is now deficient, in areas of sea-water intrusion, and in areas of complex geologic structures. These wells should be carefully logged by geologists, soil samples taken and examined for fossil or microfossil content, and water samples analyzed for water quality changes both in the vertical sequence of aquifers and laterally. Upon completion of the wells they should be pumped for transmissibility tests and to verify barrier effects, if any, of geologic structures.

4) There is a need for more control over the abandonment of water wells, such as the control that now exists in the oil well program,

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to protect the aquifers containing good quality water from degradation or contamination from the surface or from other aquifers of poorer quality water.

5) As more information becomes available for the deeper Pliocene water-bearing materials, aquifers should be delineated and identified.

6) The present communication and cooperation between agencies conducting geologic and ground water investigations in Southern California should be continued and improved. This reduces the cost of future studies and eliminates duplication of effort.

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TABLE I

)UNTY

	Signal Hill Area (After Delong, 1941)		Coastal Plain of Los Angeles County (this report)	
1954)				
ium and stream es 10 ft.	Not shown in report		Alluvium	Gravel, sands, silt and clay
			Active Dune sand	White or gray well sorted sand
lluvium of d sands, silts, and dark gumbo . thick	Palos Verdes sands	Micaceous sand and gray gravel 20 ft. thick	Older Dune sand	Fine-to-medium sand with sandy silt, and gravel lenses
			Lakewood formation	Marine and continental gravel, sand, sandy silt, silt, and clay with shale pebbles
	(Unconformity)			
e sand and l, cross-bed- slumping, clay with reeds t. thick	San Pedro sands	Unconsolidated brown-gray sand 15 ft. thick. Coarse gray-brown sand, brown gravel 20 ft. thick. Fine unconsolidated brown and gray sands 40 ft. thick	San Pedro formation	Marine and continental gravel, sand, sandy silt, silt and clay
rown silt and concretions, s abundant. t. thick			Undiff. San Pedro formation and/or Pico formation	Marine, partly consolidated gravel, sand, silt and clay
	(Unconformity)		Pico formation	Marine sand, silt, and clay interbedded with gravels
	Pico formation	Sandstone, sandy shale and shale 1300± ft. thick	Repetto formation	Marine siltstone with layers of sandstone and conglomerate
	Repetto formation	Sands and shales 2300± ft. thick		
missing	Hard black shale oil bearing		Miocene sediments and volcanics	Modelo formation (Santa Monica Mts.) Monterey formation (Palos Verdes Hills) Puente formation (Elysian, Repetto and Puente Hills)
	Not exposed or missing		Vaqueros and Sespe formations	Continental red conglomerate and sandstone
			Martinez formation	Marine conglomerate, sandstone, sandy shale and shale
			Undivided Martinez and Chico formations	
			Chico formation and intrusives	Marine hard conglomerate, sandstone and shale Continental conglomerate and sandstone
			Catalina schist	Varied schistose rocks
			Santa Monica slate	Slates, mica schists with quartz veins

AR0069033

SELECTED GEOLOGIC COLUMNAR SECTIONS IN AND NEAR THE COASTAL PLAIN OF LOS ANGELES COUNTY

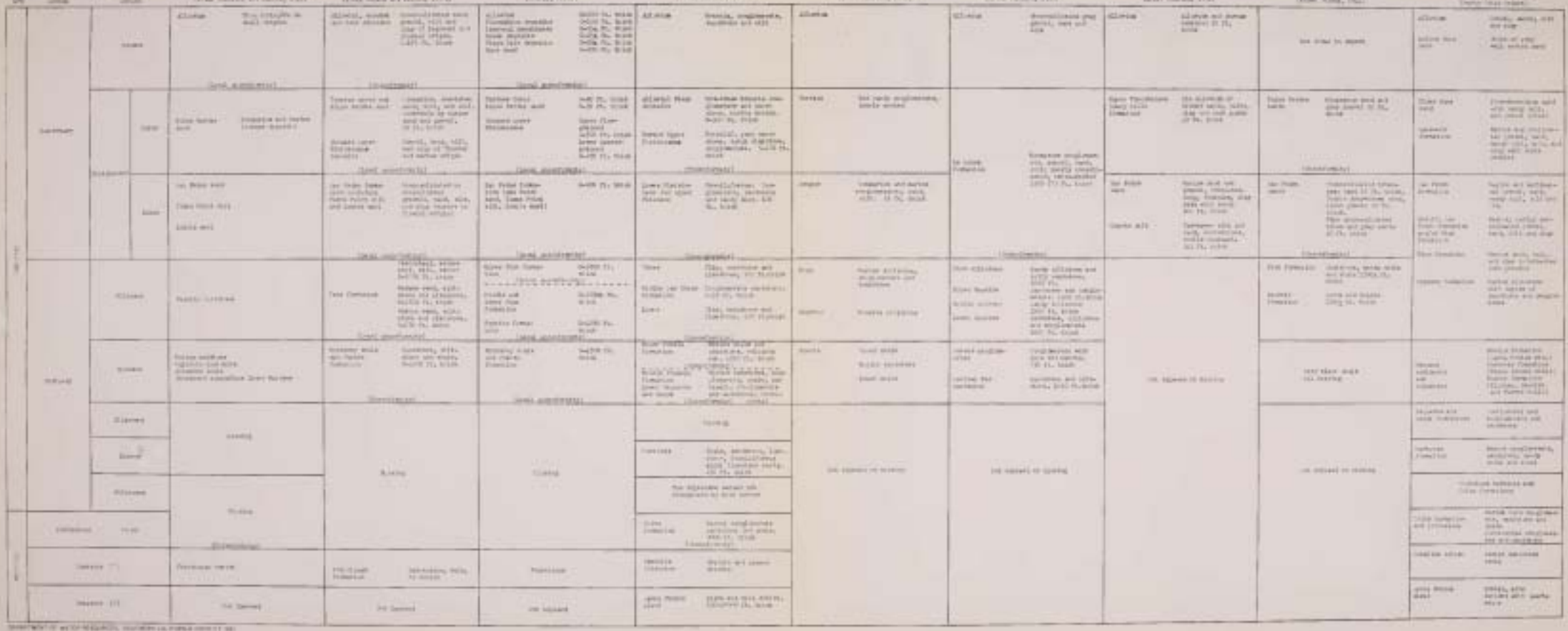

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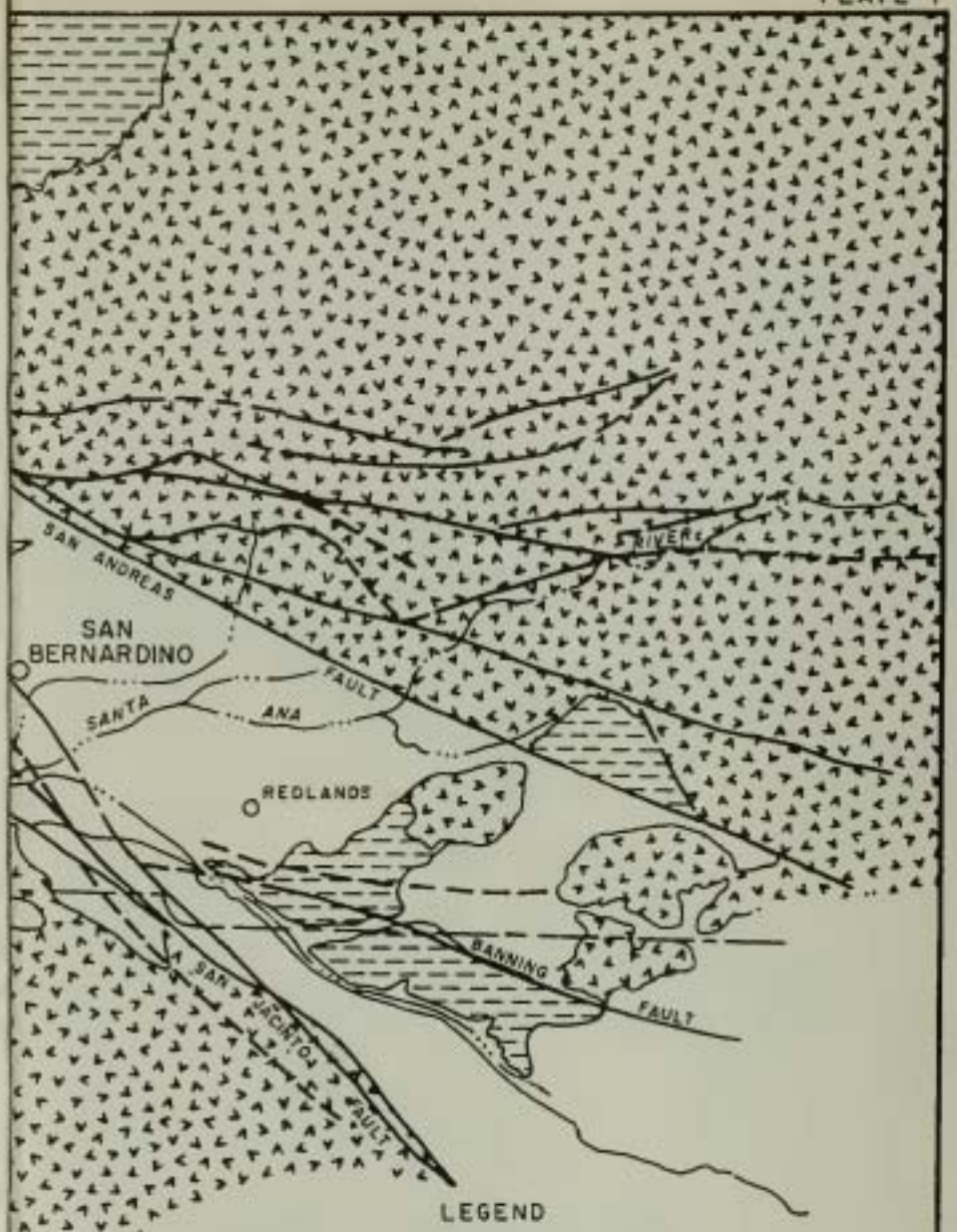
PLATE 1



STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

GENERAL GEOLOGY AND LOCATION OF AREA OF INVESTIGATION

SCALE OF MILES

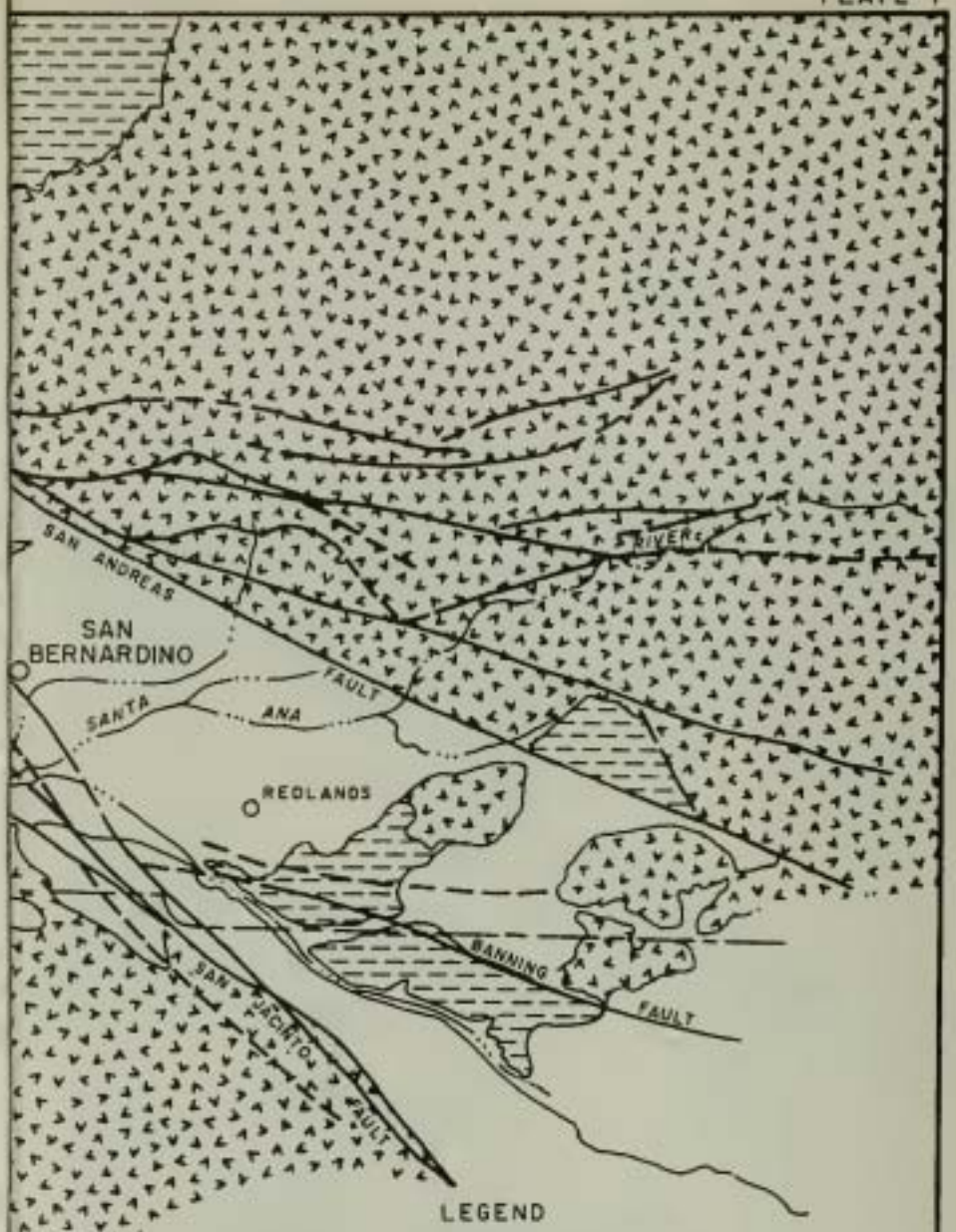
5 0 5 10

1961

AR0069035

AR0069036

PLATE 1



STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

GENERAL GEOLOGY AND LOCATION OF AREA OF INVESTIGATION

SCALE OF MILES

5 0 5 10

1961

AR0069037

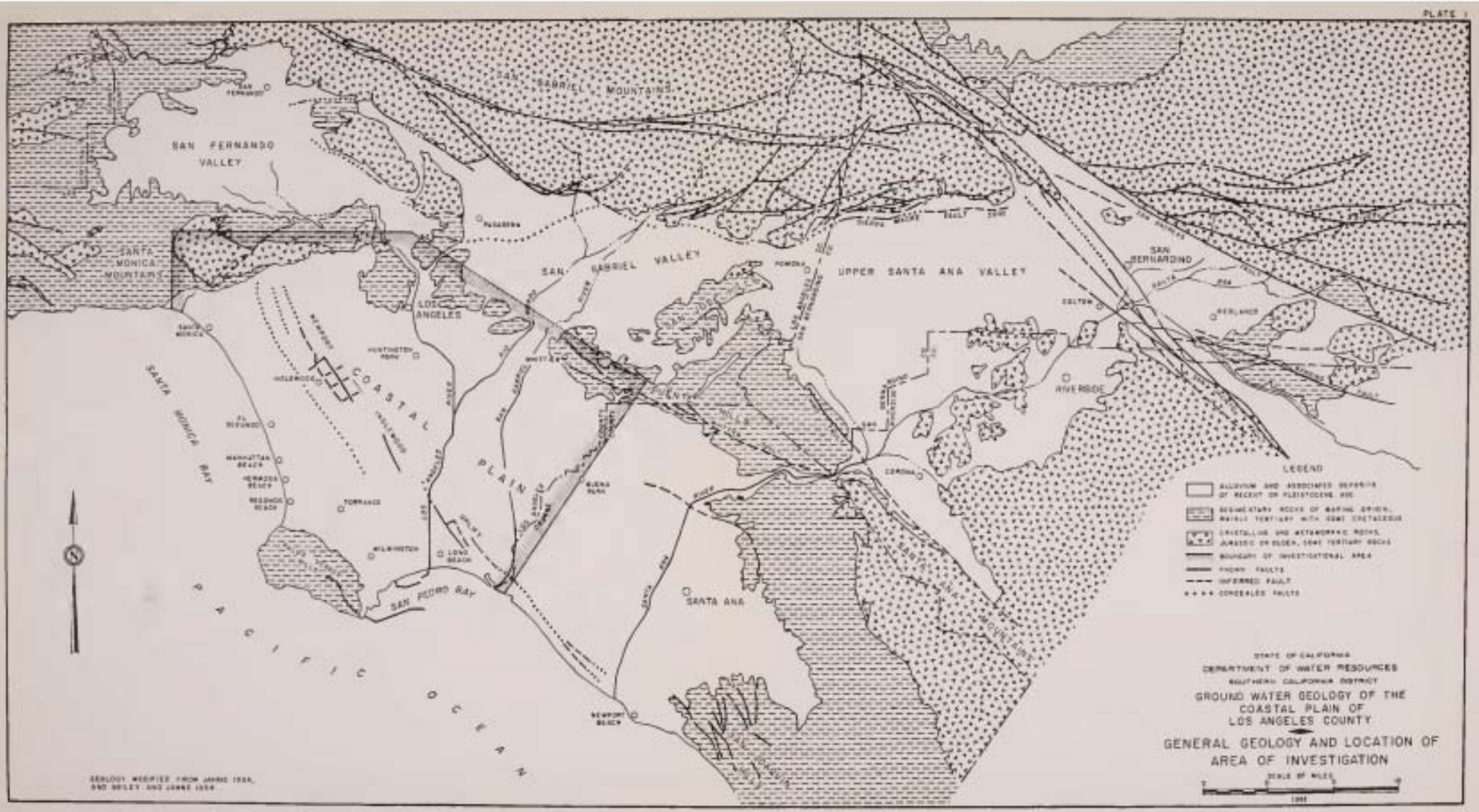


PLATE 1
SAN GABRIEL MOUNTAINS
SAN FERNANDO VALLEY
SANTA MONICA MOUNTAINS
SAN GABRIEL VALLEY
UPPER SANTA ANA VALLEY
SAN BERNARDINO
LOS ANGELES
COASTAL PLAIN
SANTA MONICA BAY
SAN PEDRO BAY
PACIFIC OCEAN
SANTA ANA
NEWPORT BEACH
RIVERSIDE
LEGEND
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY
GENERAL GEOLOGY AND LOCATION OF AREA OF INVESTIGATION

AR0069038

LEGEND

BOUNDARY BETWEEN PHYSIOGRAPHIC FEATURES (DOTTED WHERE APPROXIMATE OR POORLY DEFINED)

BOUNDARY OF GROUND WATER BASIN

BOUNDARY OF FOREBAY AND WHITTIER AREA

AXIS OF SUBMARINE CANYON

BOUNDARY BETWEEN FOREBAY AND PRESSURE AREA FROM BULLETIN 45 (CALIF. D.W.R. 1934)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

PHYSIOGRAPHIC FEATURES AND GROUND WATER BASINS

SCALE OF MILES

2 0 2 4

1961

AR0069039

AR0069040

LEGEND

BOUNDARY BETWEEN PHYSIOGRAPHIC FEATURES (DOTTED WHERE APPROXIMATE OR POORLY DEFINED)

BOUNDARY OF GROUND WATER BASIN

BOUNDARY OF FOREBAY AND WHITTIER AREA

AXIS OF SUBMARINE CANYON

BOUNDARY BETWEEN FOREBAY AND PRESSURE AREA FROM BULLETIN 45 (CALIF. D.W.R. 1934)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

PHYSIOGRAPHIC FEATURES AND GROUND WATER BASINS

SCALE OF MILES

2 0 2 4

1961

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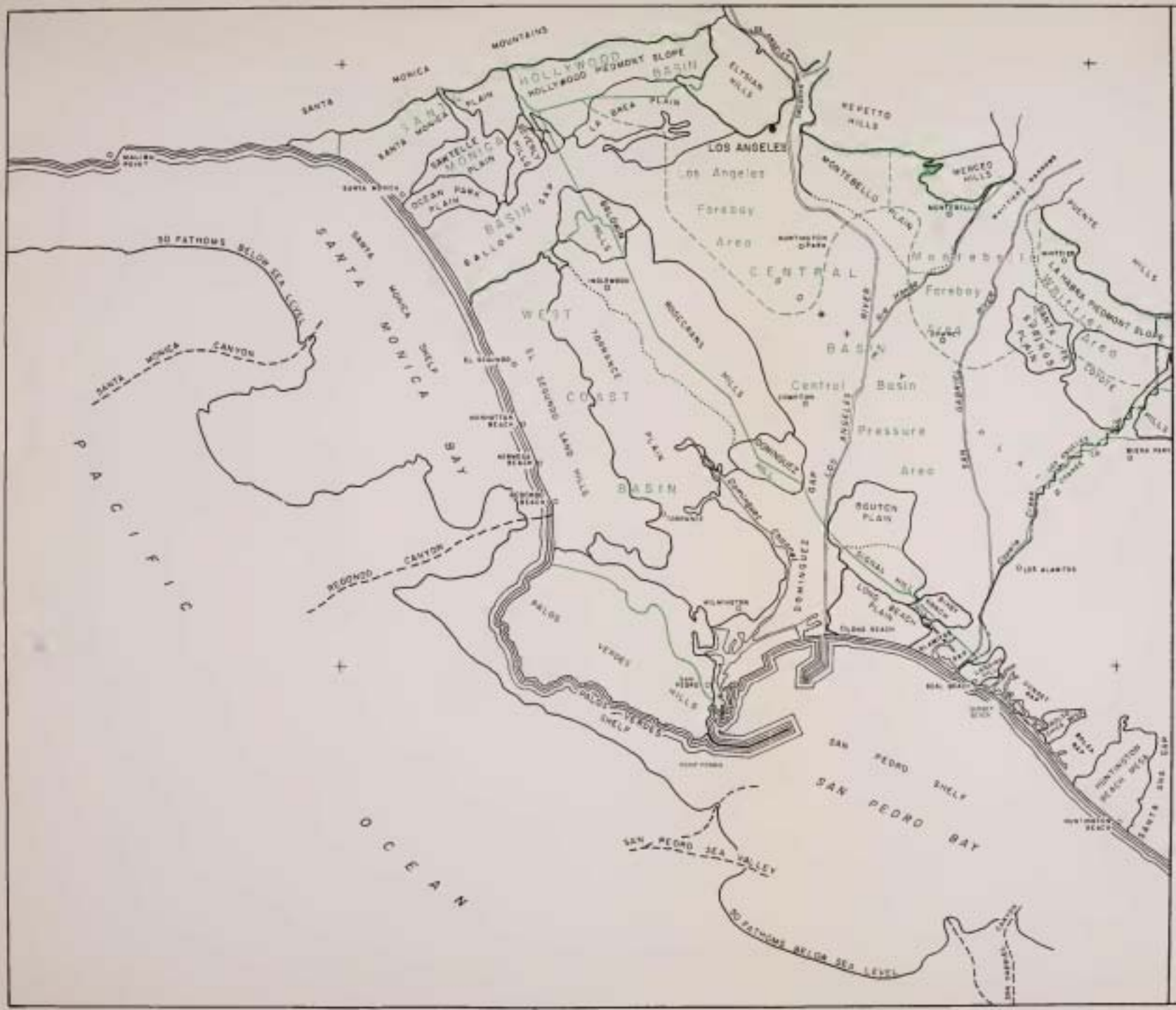


LEGEND

BOUNDARY BETWEEN PHYSIOGRAPHIC FEATURES (DOTTED WHERE APPROXIMATE OR POORLY DEFINED)

BOUNDARY OF GROUND WATER BASIN

BOUNDARY OF FOREBAY AND WHITTIER AREA

AXIS OF SUBMARINE CANYON

BOUNDARY BETWEEN FOREBAY AND PRESSURE AREA FROM BULLETIN 45 (U.S.G.S. D.W.R. 1961)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

PHYSIOGRAPHIC FEATURES AND GROUND WATER BASINS

SCALE OF MILES

1961

AR0069042

LOCATION MAP

LEGEND

SEDIMENTARY ROCKS

QUATERNARY	RECENT	Qal	ALLUVIUM GRAVEL, SAND, SILT, AND CLAY
		Qsr	ACTIVE DUNE SAND WHITE OR GREYISH, WELL SORTED SAND
	PLEISTOCENE — UPPER	Qss	OLDER DUNE SAND FINE TO MEDIUM SAND WITH SILT, AND GRAVEL LENSES
		Qlw	LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS," "PALOS VERDES SAND," AND "UNNAMED UPPER PLEISTOCENE DEPOSITS") MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY WITH SHALE PEBBLES
	PLEISTOCENE — LOWER	Qsp	SAN PEDRO FORMATION (INCLUDES "LA HABRA CONGLOMERATE" AND PART OF "SAUGUS FORMATION") MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY
		Qsp-Pp	UNDIFFERENTIATED SAN PEDRO FORMATION AND/OR PICO FORMATION MARINE, PARTIALLY CONSOLIDATED GRAVEL, SAND, SILT, AND CLAY
	PLIOCENE	Pp	PICO FORMATION MARINE SAND, SILT, AND CLAY INTERBEDDED WITH GRAVEL
		Pr	REPETTO FORMATION MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE
TERTIARY	MIOCENE	Ms	(SANTA MONICA MOUNTAINS) MODELO FORMATION MARINE CONGLOMERATIC SANDSTONE, SANDSTONE, AND SHALE TOPANGA FORMATION MARINE CONGLOMERATE, SANDSTONE, AND SHALE (PALOS VERDES HILLS) MONTEREY FORMATION MUDSTONE, DIATOMITE, AND SHALE (ELYSIAN HILLS, REPETTO HILLS, AND PUENTE HILLS) PUENTE FORMATION MARINE SILTSTONE, SANDSTONE, SHALE, CONGLOMERATE, LIMESTONE, AND TUFF
	OLIGOCENE(?)	T	VAQUEROS AND SESPE FORMATIONS CONTINENTAL RED CONGLOMERATE AND SANDSTONE
	EOCENE	E	MARTINEZ FORMATION MARINE CONGLOMERATE, SANDSTONE, SANDY SHALE, AND SHALE
	PALEOCENE(?)	E-K	UNDIVIDED MARTINEZ AND CHICO FORMATIONS
CRETACEOUS	UPPER	Kc	CHICO FORMATION UPPER MARINE MEMBER - HARD CONGLOMERATE, SANDSTONE, AND SHALE LOWER CONTINENTAL MEMBER - RED CONGLOMERATE AND SANDSTONE

IGNEOUS AND METAMORPHIC ROCKS

TERTIARY	MIOCENE	Mv	MIDDLE MIOCENE VOLCANIC ROCKS VOLCANIC FLOWS, BRECCIAS, TUFFS, AND INTRUSIVES, CHIEFLY ANDESITIC AND ANDESITIC WITH SEDIMENTAL ECHO ROCKS GENERALLY ASSOCIATED WITH TOPANGA, MODELO, OR PUENTE FORMATIONS
CRETACEOUS	UPPER	Kg	(SANTA MONICA MOUNTAINS) INTRUSIVES OF GRANITE AND GRANODIORITE
JURASSIC		J	(PALOS VERDES HILLS) CATALINA SCHIST COMPARED WITH FRANCISCAN FORMATION OF THE COAST RANGES, VARIED TYPES OF SCHISTOSE ROCKS
TRIASSIC		Ts	SANTA MONICA SLATE GREY TO BLACK SLATE, SPOTTED SLATE, MICA SCHIST WITH QUARTZ VEINS

LEGEND

- FAULT (DASHED WHERE APPROXIMATELY LOCATED; U - UPTHROWN SIDE; D - DOWNTHROWN SIDE)
- CONCEALED FAULT
- ANTICLINE (DASHED WHERE APPROXIMATELY LOCATED)
- SYNCLINE (DASHED WHERE APPROXIMATELY LOCATED)
- CONTACT (DASHED WHERE APPROXIMATELY LOCATED)
- ● 45 WELLS USED IN PREPARATION OF GEOLOGIC SECTIONS.
- A — A' LINE LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATES 6A THROUGH 6G

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

AREAL GEOLOGY

SCALE OF MILES
0 1 2 3

1961

AR0069043

AR0069044

LOCATION MAP

LEGEND

SEDIMENTARY ROCKS

QUATERNARY	RECENT	Qal	ALLUVIUM GRAVEL, SAND, SILT, AND CLAY
		Qsr	ACTIVE DUNE SAND WHITE OR GREYISH, WELL SORTED SAND
	PLEISTOCENE, UPPER	Qsg	OLDER DUNE SAND FINE TO MEDIUM SAND WITH SILT AND GRAVEL LENSES
		Qlw	LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS," "PALOS VERDES SAND," AND "UNNAMED UPPER PLEISTOCENE DEPOSITS") MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY WITH SHALE PEBBLES
	PLEISTOCENE, LOWER	Qsp	SAN PEDRO FORMATION (INCLUDES "LA HABRA CONGLOMERATE" AND PART OF "SAUGUS FORMATION") MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY
		Qsp-Fp	UNDIFFERENTIATED SAN PEDRO FORMATION AND/OR PICO FORMATION MARINE, PARTIALLY CONSOLIDATED GRAVEL, SAND, SILT, AND CLAY
	PLIOCENE	Pp	PICO FORMATION MARINE SAND, SILT, AND CLAY INTERBEDDED WITH GRAVEL
		Pr	REPETTO FORMATION MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE
TERTIARY	MIOCENE	M	(SANTA MONICA MOUNTAINS) MODELO FORMATION MARINE CONGLOMERATIC SANDSTONE, SANDSTONE, AND SHALE TOPANGA FORMATION MARINE CONGLOMERATE, SANDSTONE, AND SHALE (PALOS VERDES HILLS) MONTEREY FORMATION MUDSTONE, DIATOMITE, AND SHALE (PUENTE HILLS, REPETTO HILLS, AND PUENTE HILLS) PUENTE FORMATION MARINE SILTSTONE, SANDSTONE, SHALE, CONGLOMERATE, LIMESTONE, AND TUFF
	OLIGOCENE(?)	O	VAQUEROS AND SESPE FORMATIONS CONTINENTAL RED CONGLOMERATE AND SANDSTONE
	EOCENE	E	MARTINEZ FORMATION MARINE CONGLOMERATE, SANDSTONE, SANDY SHALE, AND SHALE
	PALEOCENE(?)	E-K	UNDIVIDED MARTINEZ AND CHICO FORMATIONS
CRETACEOUS	UPPER	Ks	CHICO FORMATION UPPER MARINE MEMBER—HARD CONGLOMERATE, SANDSTONE, AND SHALE LOWER CONTINENTAL MEMBER—RED CONGLOMERATE AND SANDSTONE

IGNEOUS AND METAMORPHIC ROCKS

TERTIARY	MIOCENE	Mv	MIDDLE MIOCENE VOLCANIC ROCKS VOLCANIC FLOWS, BRECCIAS, TUFFS, AND INTRUSIVES, CHIEFLY BASALTIC AND ANDESITIC WITH SEDIMENTARY BED ROCKS, GENERALLY ASSOCIATED WITH TOPANGA, MODELO, OR PUENTE FORMATIONS
CRETACEOUS	UPPER	Kg	(SANTA MONICA MOUNTAINS) INTRUSIVES OF GRANITE AND GRANODIORITE
JURASSIC		J	(PALOS VERDES HILLS) CATALINA SCHIST (COMPARED WITH FRANCISCAN FORMATION OF THE COAST RANGES, VARIOUS TYPES OF SCHISTOSE ROCKS
TRIASSIC		TrJs	SANTA MONICA SLATE GREY TO BLACK SLATE, SPOTTED SLATE, MICA SCHIST WITH QUARTZ VEINS

LEGEND

- FAULT (DASHED WHERE APPROXIMATELY LOCATED; U—UPTHROWN SIDE; D—DOWNTHROWN SIDE)
- CONCEALED FAULT
- ANTICLINE (DASHED WHERE APPROXIMATELY LOCATED)
- SYNCLINE (DASHED WHERE APPROXIMATELY LOCATED)
- CONTACT (DASHED WHERE APPROXIMATELY LOCATED)
- ● A5 WELLS USED IN PREPARATION OF GEOLOGIC SECTIONS.
- A—A' LINE LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATES 6A THROUGH 6G

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

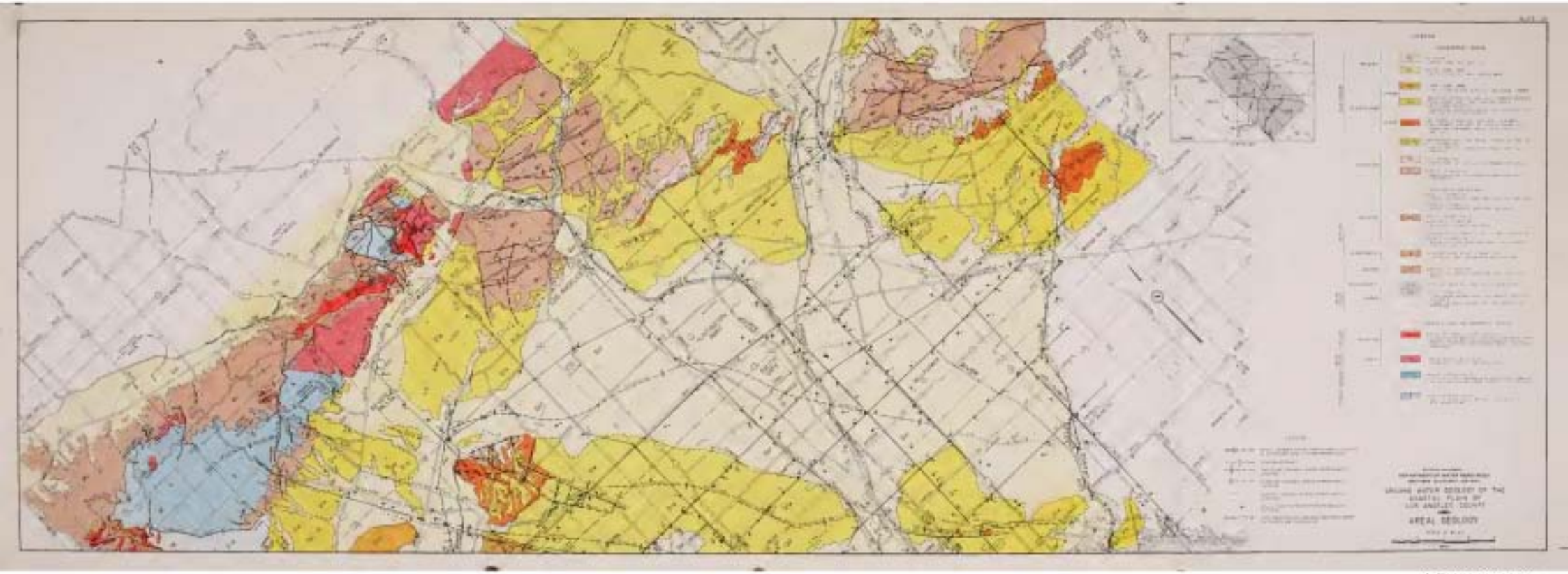
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

AREAL GEOLOGY

SCALE OF MILES
0 1 2 3

1961

AR0069045



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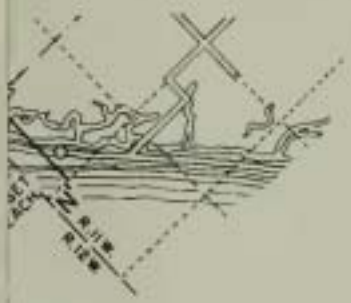
LOCATION MAP



LEGEND

- FAULT (DASHED WHERE APPROXIMATELY LOCATED; U-UPTHROWN SIDE; D-DOWNTHROWN SIDE)
- CONCEALED FAULT
- ANTICLINE (DASHED WHERE APPROXIMATELY LOCATED)
- SYNCLINE (DASHED WHERE APPROXIMATELY LOCATED)
- CONTACT (DASHED WHERE APPROXIMATELY LOCATED)
- WELLS USED IN PREPARATION OF GEOLOGIC SECTIONS.
- A-A' LINE LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATES 6A THROUGH 6G

LEGEND

SEDIMENTARY ROCKS

QUATERNARY

RECENT

- Qal — ALLUVIUM — GRAVEL, SAND, SILT, AND CLAY
- Qs — ACTIVE DUNE SAND — WHITE OR BROWN, WELL SORTED SAND

PLEISTOCENE

UPPER

- Qdo — OLDER DUNE SAND — FINE TO MEDIUM SAND WITH SILT, AND GRAVEL LENSES
- Ql — LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS" "PALOS VERDES SAND," AND "UNNAMED UPPER PLEISTOCENE DEPOSITS") — MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY WITH SHALE PEBBLES

LOWER

- Qsp — SAN PEDRO FORMATION (INCLUDES "LA HABRA CONGLOMERATE" AND PART OF "SAUGUS FORMATION") — MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY
- Qsp-Pp — UNDIFFERENTIATED SAN PEDRO FORMATION AND/OR PICO FORMATION — MARINE, PARTIALLY CONSOLIDATED GRAVEL, SAND, SILT, AND CLAY

PLIOCENE

- Pp — PICO FORMATION — MARINE SAND, SILT, AND CLAY INTERBEDDED WITH GRAVEL
- Pr — REPETTO FORMATION — MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE

TERTIARY

MIOCENE

- Mv — (SANTA MONICA MOUNTAINS) MODELO FORMATION — MARINE CONGLOMERATIC SANDSTONE, SANDSTONE, AND SHALE; TOPANGA FORMATION — MARINE CONGLOMERATE, SANDSTONE, AND SHALE
- Mv — (PALOS VERDES HILLS) MONTEREY FORMATION — MUDSTONE, DIATOMITE, AND SHALE
- Mv — (ELYSIAN HILLS, REPETTO HILLS, AND PUENTE HILLS) PUENTE FORMATION — MARINE SILTSTONE, SANDSTONE, SHALE, CONGLOMERATE, LIMESTONE, AND TUFF

OLIGOCENE(?)

- O — VAQUEROS AND SESPE FORMATIONS — CONTINENTAL RED CONGLOMERATE AND SANDSTONE

EOCENE

- E — MARTINEZ FORMATION — MARINE CONGLOMERATE, SANDSTONE, SANDY SHALE, AND SHALE

PALEOCENE(?)

- E-K — UNDIVIDED MARTINEZ AND CHICO FORMATIONS

CRETACEOUS

UPPER

- Kc — CHICO FORMATION — UPPER MARINE MEMBER—HARD CONGLOMERATE, SANDSTONE, AND SHALE; LOWER CONTINENTAL MEMBER—RED CONGLOMERATE AND SANDSTONE

IGNEOUS AND METAMORPHIC ROCKS

TERTIARY

MIOCENE

- Mv — MIDDLE MIOCENE VOLCANIC ROCKS — VOLCANIC FLOWS, BRECCIAS, TUFFS, AND INTRUSIVES CHIEFLY BASALTIC AND ANDESITIC WITH OCCASIONAL ACID ROCKS GENERALLY ASSOCIATED WITH TOPANGA, MODELO, OR PUENTE FORMATIONS

CRETACEOUS

UPPER

- Kg — (SANTA MONICA MOUNTAINS) INTRUSIVES OF GRANITE AND GRANODIORITE

JURASSIC

- J — (PALOS VERDES HILLS) CATALINA SCHIST COMPARED WITH FRANCISCAN FORMATION OF THE COAST RANGES VARIED TYPES OF SCHISTOSE ROCKS

TRIASSIC

- Ts — SANTA MONICA SLATE — GREY TO BLACK SLATE, SPOTTED SLATE, MICA SCHIST WITH QUARTZ VEINS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

AREAL GEOLOGY

SCALE OF MILES
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1961

AR0069047

AR0069048

LOCATION MAP

LEGEND

SEDIMENTARY ROCKS

QUATERNARY

RECENT

Qal — ALLUVIUM
GRAVEL, SAND, SILT, AND CLAY

Qsr — ACTIVE DUNE SAND
WHITE OR BROWN, WELL SORTED SAND

PLEISTOCENE

UPPER

Qso — OLDER DUNE SAND
FINE TO MEDIUM SAND WITH SILT, AND GRAVEL LENSES

Qlw — LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS" "PALOS VERDES SAND" AND "UNNAMED UPPER PLEISTOCENE DEPOSITS")
MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY WITH SHALE PEBBLES

LOWER

Qsp — SAN PEDRO FORMATION (INCLUDES "LA HABRA CONGLOMERATE" AND PART OF "SAUGUS FORMATION")
MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY

Qsp-Pp — UNDIFFERENTIATED SAN PEDRO FORMATION AND/OR PICO FORMATION
MARINE, PARTIALLY CONSOLIDATED GRAVEL, SAND, SILT, AND CLAY

PLIOCENE

Pp — PICO FORMATION
MARINE SAND, SILT AND CLAY INTERBEDDED WITH GRAVEL

Pr — REPETTO FORMATION
MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE

TERTIARY

MIOCENE

Mv — (SANTA MONICA MOUNTAINS)
MODELO FORMATION
MARINE CONGLOMERATIC SANDSTONE, SANDSTONE, AND SHALE
TOPANGA FORMATION
MARINE CONGLOMERATE, SANDSTONE, AND SHALE
(PALOS VERDES HILLS)
MONTEREY FORMATION
MUDSTONE, DIATOMITE, AND SHALE
(BALDWIN HILLS, REPETTO HILLS, AND PUENTE HILLS)
PUENTE FORMATION
MARINE SILTSTONE, SANDSTONE, SHALE, CONGLOMERATE, LIMESTONE, AND TUFF

OLIGOCENE(?)

Tv — VAQUEROS AND SESPE FORMATIONS
CONTINENTAL RED CONGLOMERATE AND SANDSTONE

EOCENE

E — MARTINEZ FORMATION
MARINE CONGLOMERATE, SANDSTONE, SANDY SHALE, AND SHALE

PALEOCENE(?)

E-K — UNDIVIDED MARTINEZ AND CHICO FORMATIONS

CRETACEOUS

UPPER

Ks — CHICO FORMATION
UPPER MARINE MEMBER - HARD CONGLOMERATE, SANDSTONE, AND SHALE
LOWER CONTINENTAL MEMBER - RED CONGLOMERATE AND SANDSTONE

IGNEOUS AND METAMORPHIC ROCKS

TERTIARY

MIOCENE

Mv — MIDDLE MIOCENE VOLCANIC ROCKS
VOLCANIC FLOWS, BRECCIAS, TUFFS, AND INTRUSIVES CHIEFLY BASALTIC AND ANDESITIC WITH OCCASIONAL RED ROCKS GENERALLY ASSOCIATED WITH TOPANGA, MODELO, OR PUENTE FORMATIONS

CRETACEOUS

UPPER

Kg — (SANTA MONICA MOUNTAINS)
INTRUSIVES OF GRANITE AND GRANODIORITE

JURASSIC

J — (PALOS VERDES HILLS)
CATALINA SCHIST COMPARED WITH FRANCISCAN FORMATION OF THE COAST RANGES VARIED TYPES OF SCHISTOSE ROCKS

TRIASSIC

Pzs — SANTA MONICA SLATE
GREY TO BLACK SLATE, SPOTTED SLATE, MICA SCHIST WITH QUARTZ VEINS

LEGEND

— FAULT (DASHED WHERE APPROXIMATLY LOCATED) U-UPTHROWN SIDE; D-DOWNTHROWN SIDE)

*** CONCEALED FAULT

— ANTICLINE (DASHED WHERE APPROXIMATLY LOCATED)

— SYNCLINE (DASHED WHERE APPROXIMATLY LOCATED)

— CONTACT (DASHED WHERE APPROXIMATLY LOCATED)

WELLS USED IN PREPARATION OF GEOLOGIC SECTIONS.

A — A' LINE LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATES 6A THROUGH 6G

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

AREAL GEOLOGY

SCALE OF MILES
1 0 1 2 3

1961

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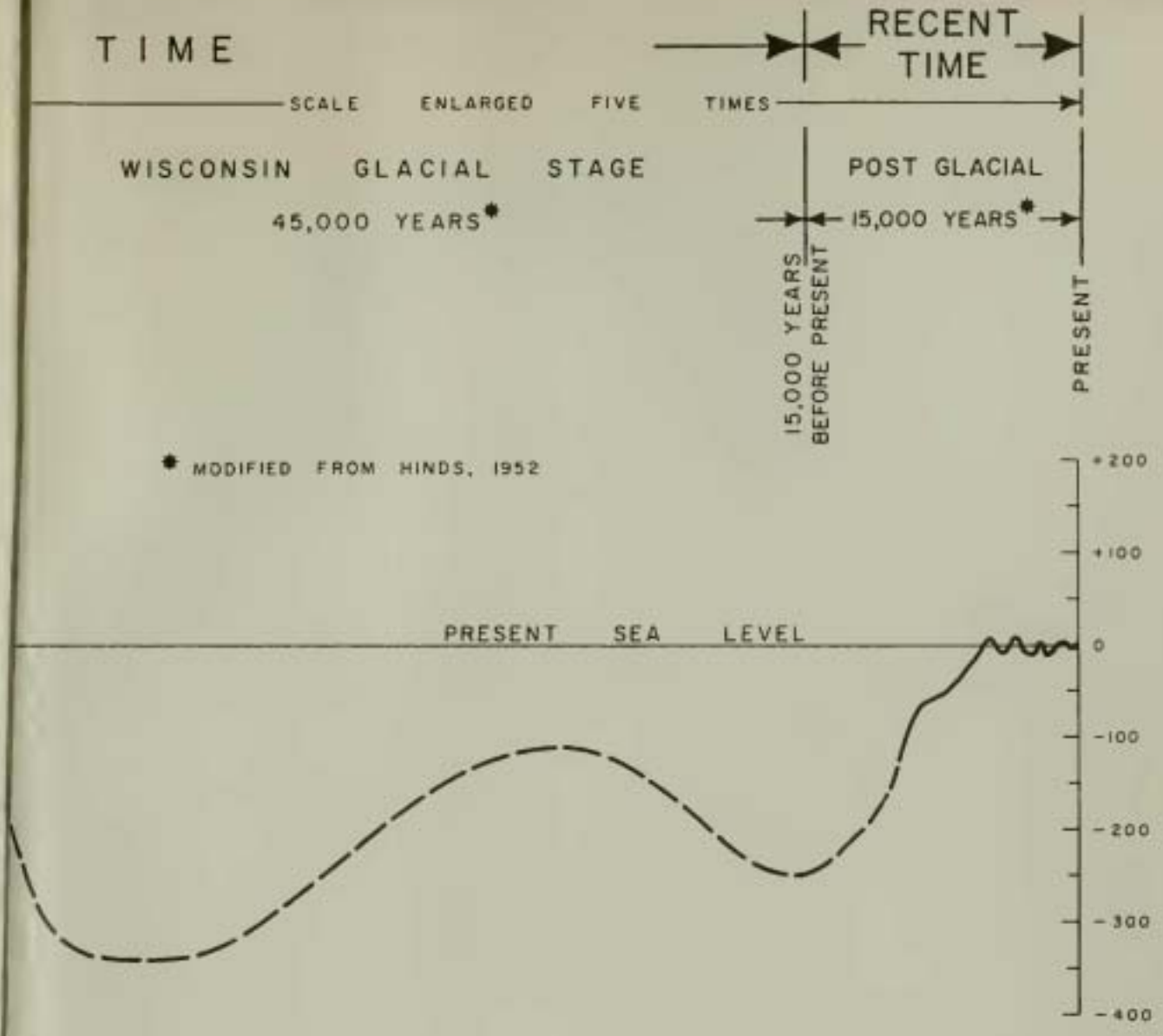

FORMATION			RECENT DEPOSITION	
UNE SAND O SAND HILLS) OSITED	EXPOSITION – ARTESIA AQUIFER DEPOSITED	DEPOSITION OF ACTIVE DUNE SAND INITIATED	GASPUR AQUIFER DEPOSITED	FINE – GRAINED ALLUVIUM EXPOSED OVER GASPUR AQUIFER
RTESIA UT, AND LTS D	LOS ANGELES AND SAN GABRIEL RIVERS ERODED UPPER PLEISTOCENE SEDIMENTS GAPS FORMED	GASPUR VALLEY CUT, STREAM EROSION OF UPPER PLEISTOCENE TERRACES		
N A	DEPRESSION	SUBSIDING		
PLEISTOCENE	SEDIMENTS		RECENT DEFORMATION	
	SHORELINE FURTHER OFFSHORE THAN AT PRESENT		SHORELINE ADVANCING TO PRESENT POSITION	

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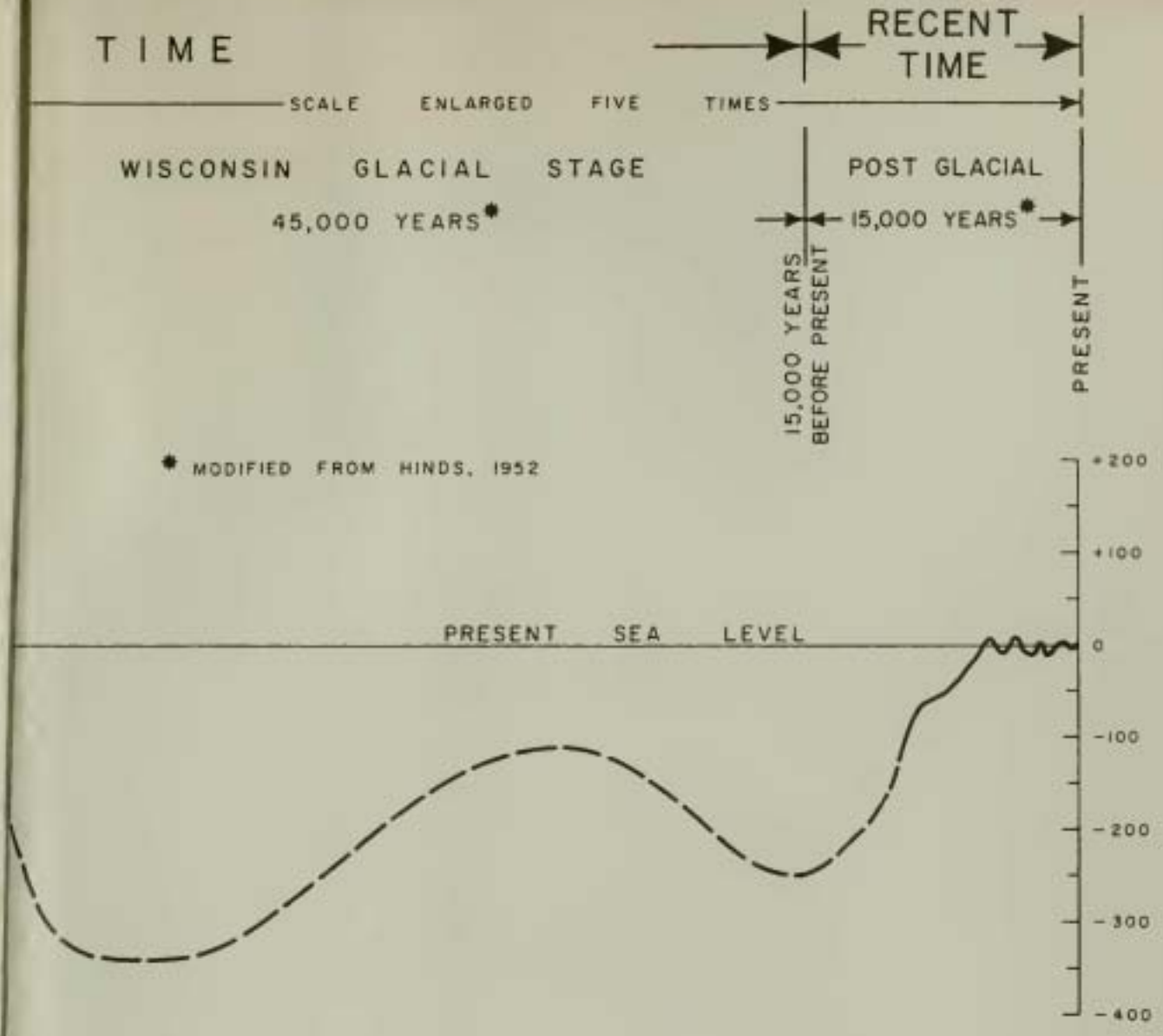

FORMATION			RECENT DEPOSITION	
UNE SAND O SAND HILLS) OSITED	EXPOSITION — ARTESIA AQUIFER DEPOSITED	DEPOSITION OF ACTIVE DUNE SAND INITIATED	GASPUR AQUIFER DEPOSITED	FINE — GRAINED ALLUVIUM EXPOSED OVER GASPUR AQUIFER
RTESIA UT, AND LTS)	LOS ANGELES AND SAN GABRIEL RIVERS ERODED UPPER PLEISTOCENE SEDIMENTS GAPS FORMED	GASPUR VALLEY CUT; STREAM EROSION OF UPPER PLEISTOCENE TERRACES		
N A	DEPRESSION SUBSIDING			
PLEISTOCENE SEDIMENTS			RECENT DEFORMATION	
	SHORELINE FURTHER OFFSHORE THAN AT PRESENT		SHORELINE ADVANCING TO PRESENT POSITION	

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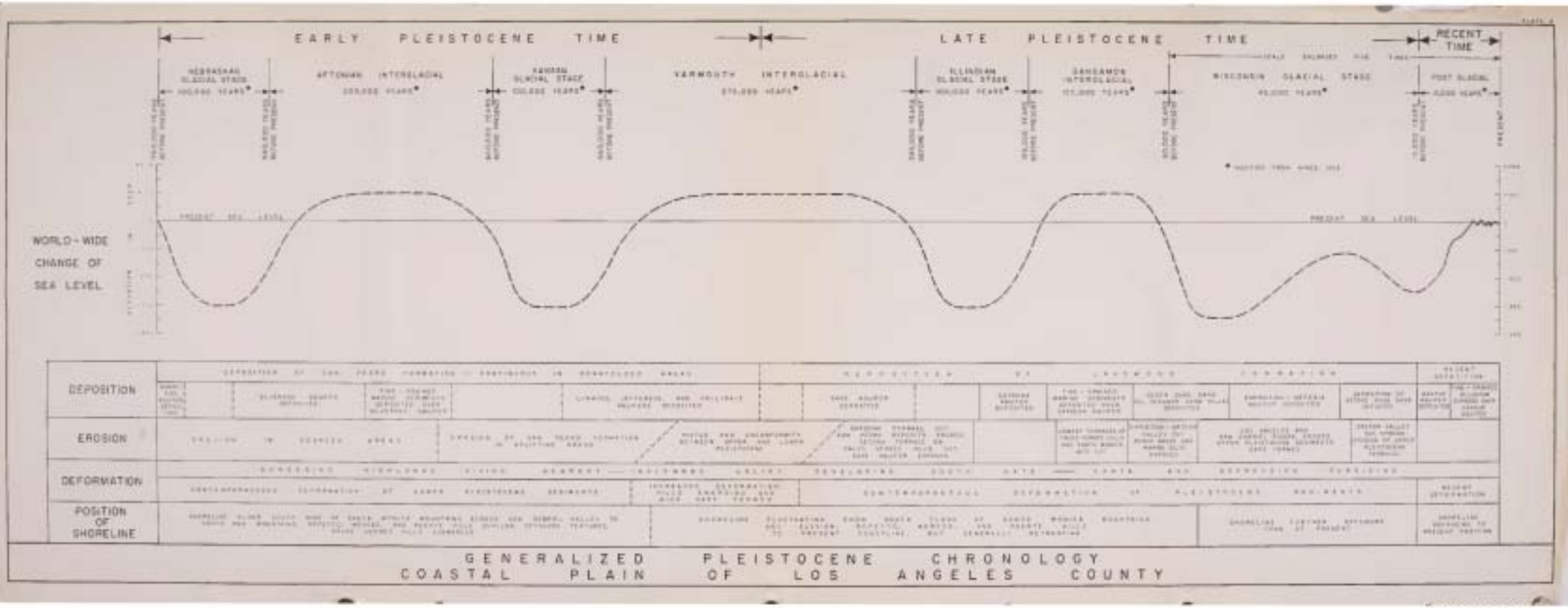
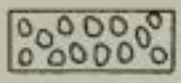


GENERALIZED PLEISTOCENE CHRONOLOGY
COASTAL PLAIN OF LOS ANGELES COUNTY

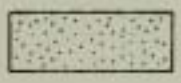
AR0069054

THICKNESS FEET)	PREVIOUS FORMATION NAMES*	PREVIOUS AQUIFER NAMES*
60	ALLUVIUM	SEMIPERCHED†
140		
120		GASPUR†
40	TERRACE COVER	"50 FOOT GRAVEL"
200	PALOS VERDES SAND	SEMIPERCHED†
140	UNNAMED UPPER PLEISTOCENE	GARDENA†
160		"200 FOOT SAND"
160	LOCAL UNCONFORMITY	
100	SAN PEDRO FORMATION	"400 FOOT GRAVEL"†
140		
200		SILVERADO†
500		
500	PICO FORMATION	

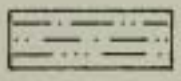
LEGEND OF LITHOLOGY



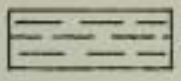
GRAVEL AND SAND



SAND



SILTY OR SANDY CLAY



CLAY OR SHALE

*DESIGNATIONS AND TERMS UTILIZED IN "REPORT OF REFEREE" DATED JUNE 1952 PREPARED BY THE STATE ENGINEER COVERING THE WEST COAST BASIN

†DESIGNATED AS "WATER BEARING ZONES" IN ABOVE NOTED REPORT OF REFEREE

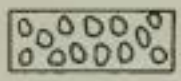
IGRAPHIC COLUMN
)S ANGELES COUNTY

AR0069055

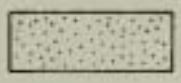
AR0069056

THICKNESS FEET)	PREVIOUS FORMATION NAMES*	PREVIOUS AQUIFER NAMES*
60	ALLUVIUM	SEMIPERCHED†
140		
120		GASPUR†
40	TERRACE COVER	"50 FOOT GRAVEL"
200	PALOS VERDES SAND	SEMIPERCHED†
140	UNNAMED UPPER PLEISTOCENE	GARDENA†
160		"200 FOOT SAND"
160	LOCAL UNCONFORMITY	
100	SAN PEDRO FORMATION	"400 FOOT GRAVEL"†
140		
200		
500		SILVERADO†
500		
	PICO FORMATION	

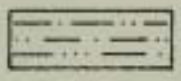
LEGEND OF LITHOLOGY



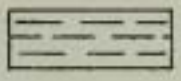
GRAVEL AND SAND



SAND



SILTY OR SANDY CLAY



CLAY OR SHALE

*DESIGNATIONS AND TERMS UTILIZED IN "REPORT OF REFEREE" DATED JUNE 1952 PREPARED BY THE STATE ENGINEER COVERING THE WEST COAST BASIN

†DESIGNATED AS "WATER BEARING ZONES" IN ABOVE NOTED REPORT OF REFEREE

IGRAPHIC COLUMN
)S ANGELES COUNTY

AR0069057

PLATE 5

SYSTEM	SERIES	FORMATION	AQUIFER AND AQUICLUDE	MAX. THICKNESS (FEET)	PREVIOUS FORMATION NAMES*	PREVIOUS AQUIFER NAMES*
QUATERNARY	RECENT	ACTIVE DUNE SAND	SEMIPERCHED	60	ALLUVIUM	SEMIPERCHED†
		ALLUVIUM	BELLFLOWER AQUICLUDE	140		
			GASPUR	120		GASPUR†
			BALLONA	40		"50 FOOT GRAVEL"
	UPPER PLEISTOCENE	OLDER DUNE SAND	SEMIPERCHED		TERRACE COVER	
			BELLFLOWER AQUICLUDE	200	PALOS VERDES SAND	SEMIPERCHED†
		LAKEWOOD FORMATION	EXPOSITION ARTESIA	140	UNNAMED UPPER PLEISTOCENE	
			GARDENA	160		GARDENA†
			GAGE	160		"200 FOOT SAND"
		UNCONFORMITY			LOCAL UNCONFORMITY	
	LOWER PLEISTOCENE	SAN PEDRO FORMATION	HOLLYDALE	100	SAN PEDRO FORMATION	"400 FOOT GRAVEL"†
			JEFFERSON	140		
			LYNWOOD	200		
			SILVERADO	500		SILVERADO†
			SUNNYSIDE	500		
		LOCAL	UNCONFORMITY			
TERTIARY	UPPER PLIOCENE	PICO FORMATION	UNDIFFERENTIATED		PICO FORMATION	

LEGEND OF LITHOLOGY

- GRAVEL AND SAND
- SAND
- SILTY OR SANDY CLAY
- CLAY OR SHALE

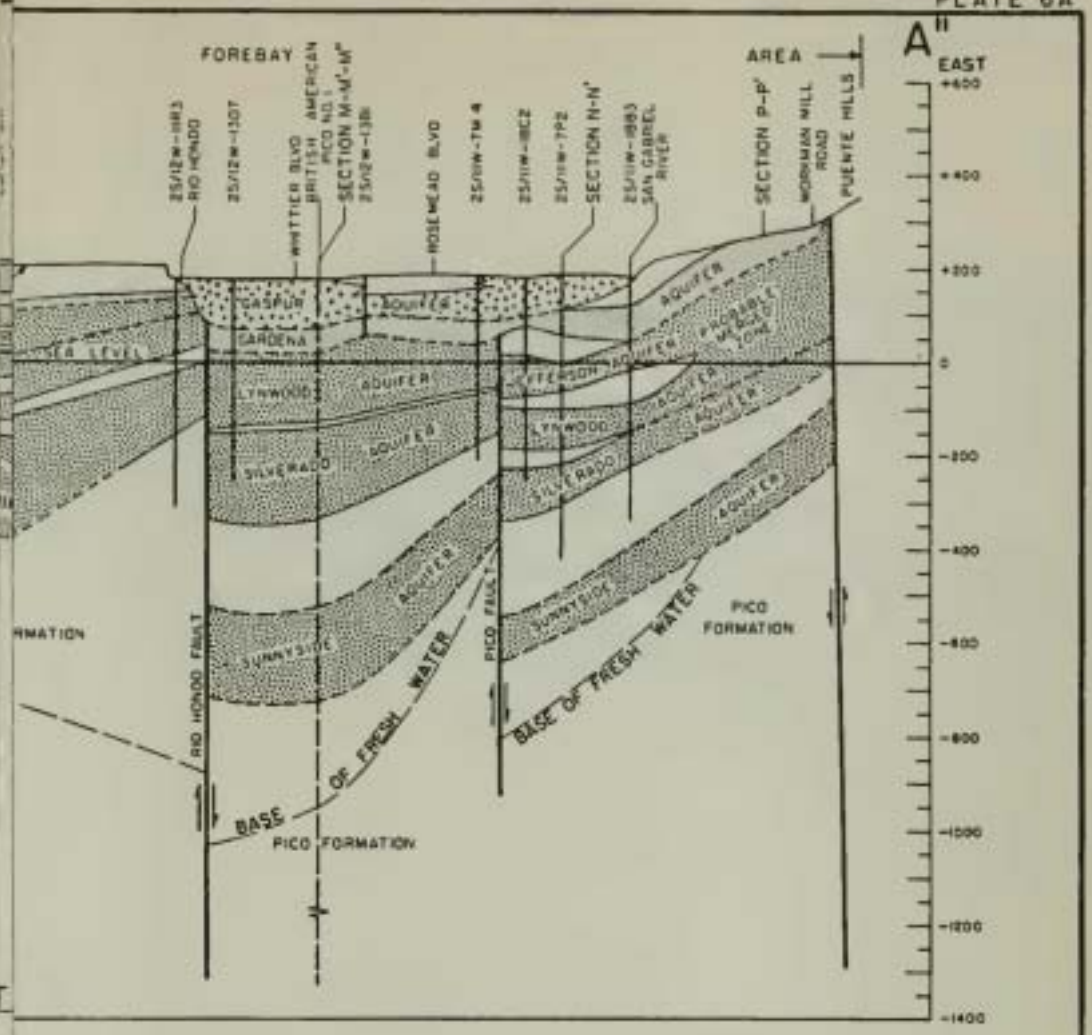
*DESIGNATIONS AND TERMS UTILIZED IN "REPORT OF REFEREE" DATED JUNE 1952 PREPARED BY THE STATE ENGINEER COVERING THE WEST COAST BASIN

†DESIGNATED AS "WATER BEARING ZONES" IN ABOVE NOTED REPORT OF REFEREE

GENERALIZED STRATIGRAPHIC COLUMN COASTAL PLAIN OF LOS ANGELES COUNTY

DEPARTMENT OF WATER RESOURCES 1961

AR0069058



LEGEND

- AQUICLUDES AND DEEPER UNDIFFERENTIATED FORMATIONS
- AQUIFERS IN RECENT ALLUVIUM (INCLUDES THE GASPUR AND BALLONA AQUIFERS)
- AQUIFERS IN LAKEWOOD FORMATION (INCLUDES THE ARTESIA, EXPOSITION, GAGE, AND GARDENA AQUIFERS)
- AQUIFERS IN SAN PEDRO FORMATION (INCLUDES THE HOLLYDALE, JEFFERSON, LYNWOOD, SILVERADO, AND SUNNYSIDE AQUIFERS)
- WATER WELLS
- OIL WELLS
- FAULTS

* BOUNDARY BETWEEN FOREBAY AND PRESSURE AREA AS SHOWN ON PLATE 2 OF THIS REPORT

NOTE LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 3A AND 3B

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

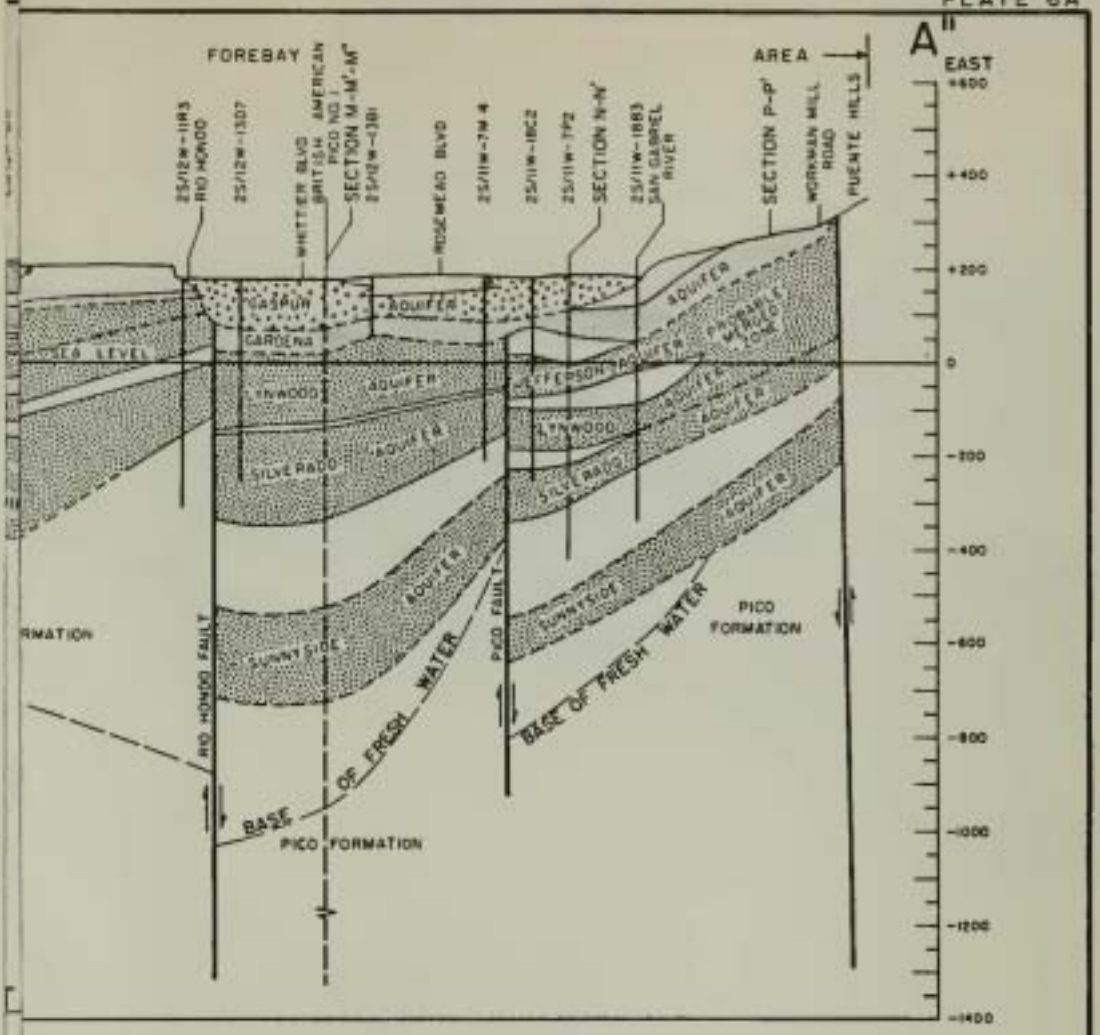
IDEALIZED GEOLOGIC SECTIONS A-A'-A" AND B-B'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069059

AR0069060



LEGEND

- AQUICLUDES AND DEEPER UNDIFFERENTIATED FORMATIONS
- AQUIFERS IN RECENT ALLUVIUM (INCLUDES THE GASPUR AND BALLONA AQUIFERS)
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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

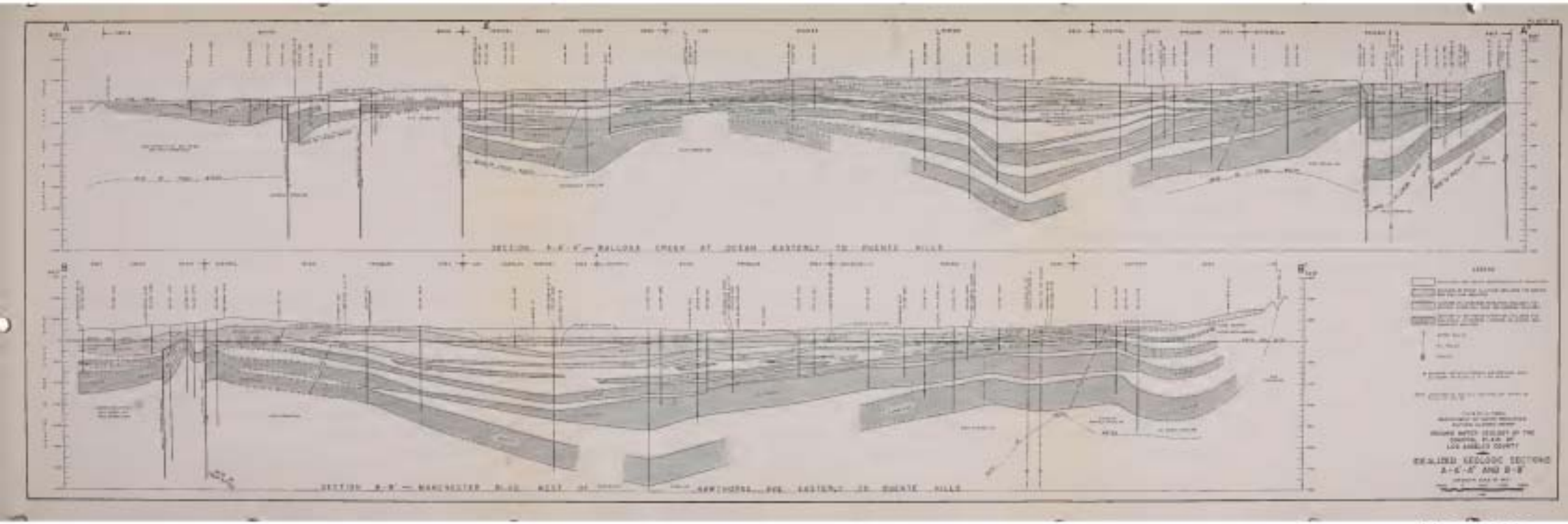
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS A-A'-A" AND B-B'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069061



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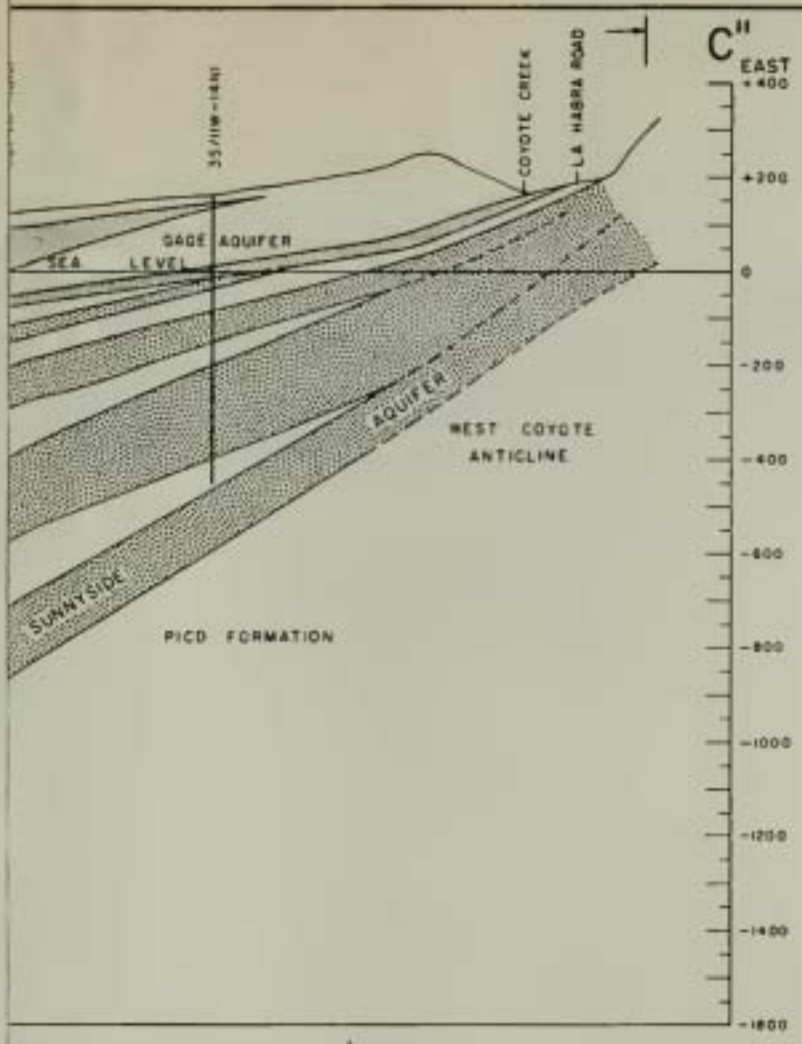

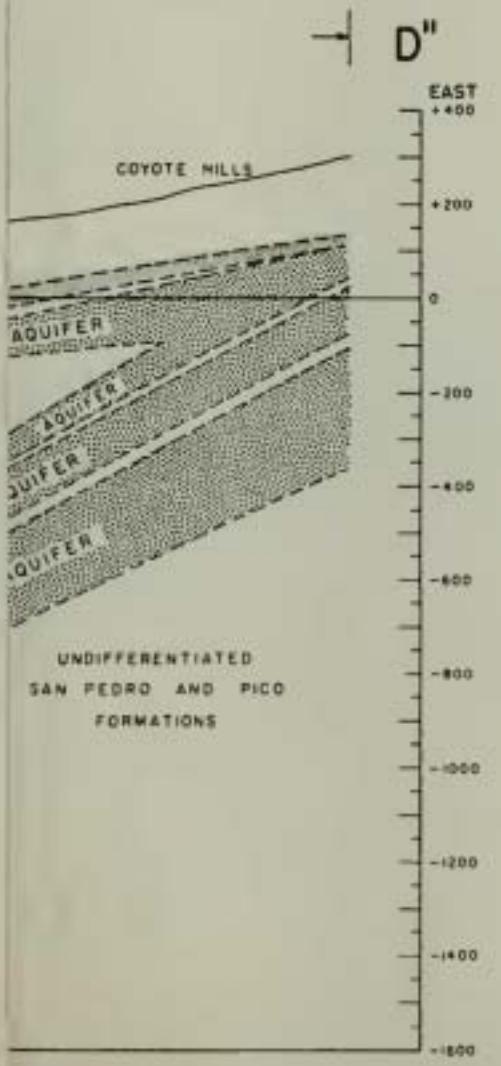

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

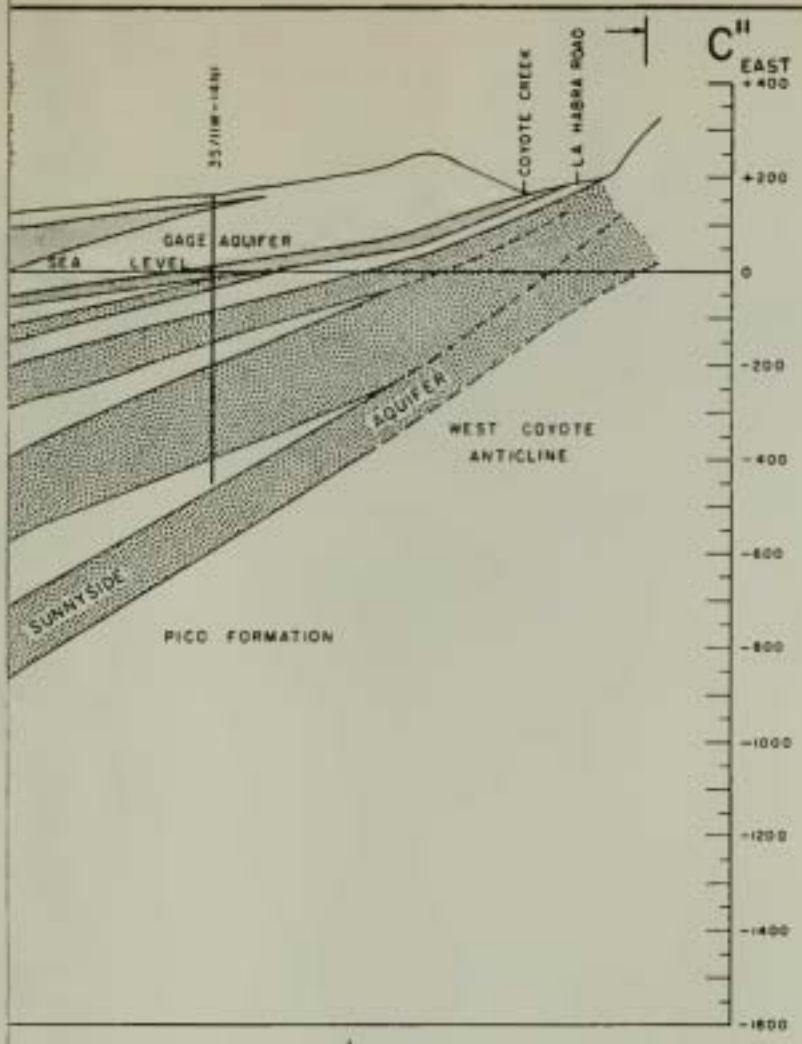
IDEALIZED GEOLOGIC SECTIONS C-C'-C" AND D-D'-D"

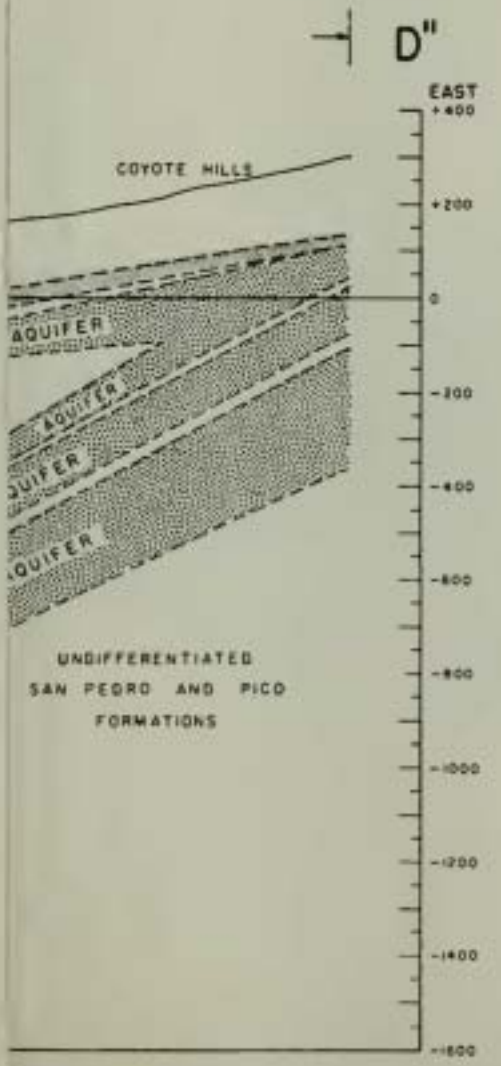
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069063

AR0069064





LEGEND

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

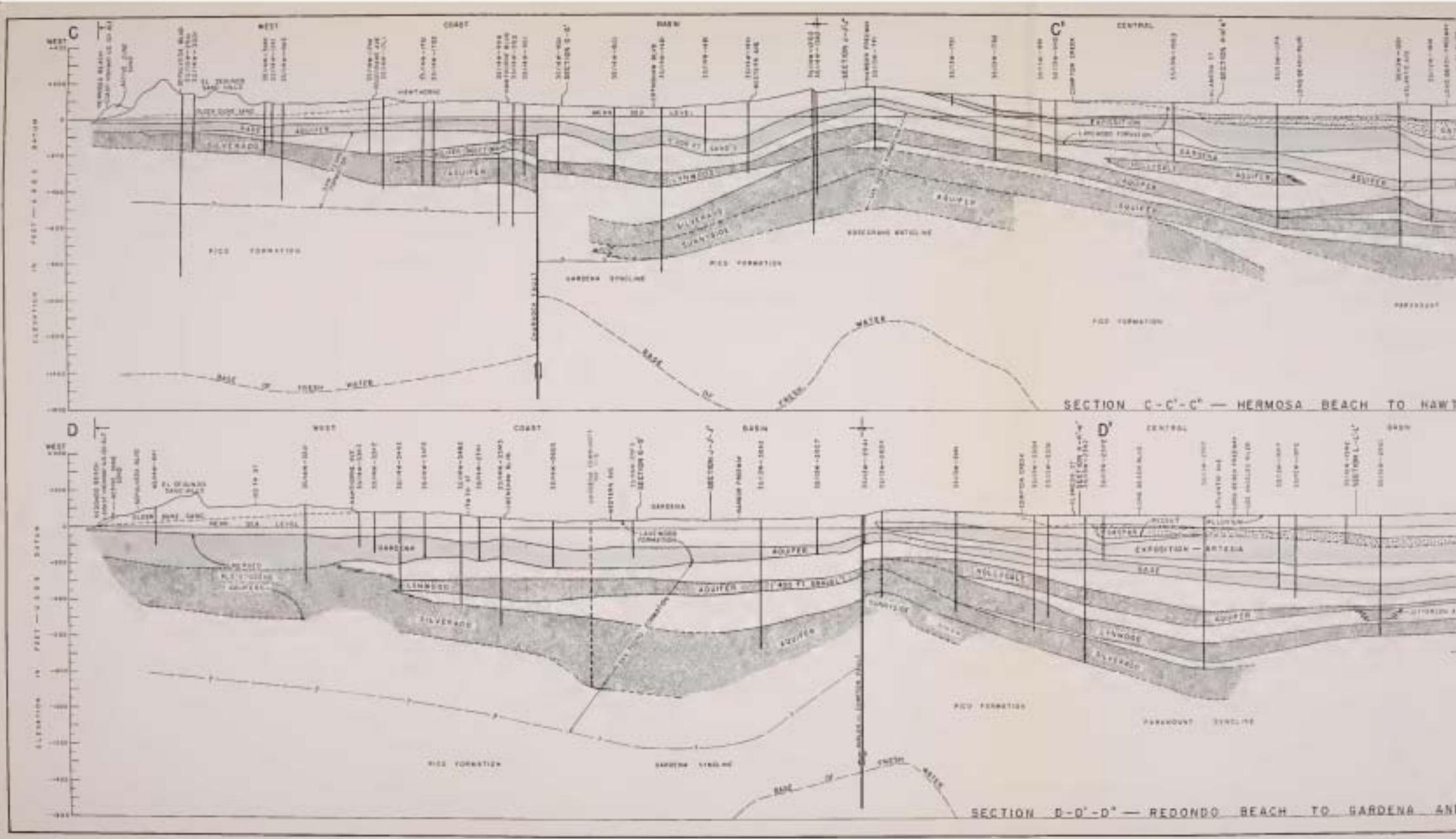
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS C-C'-C" AND D-D'-D"

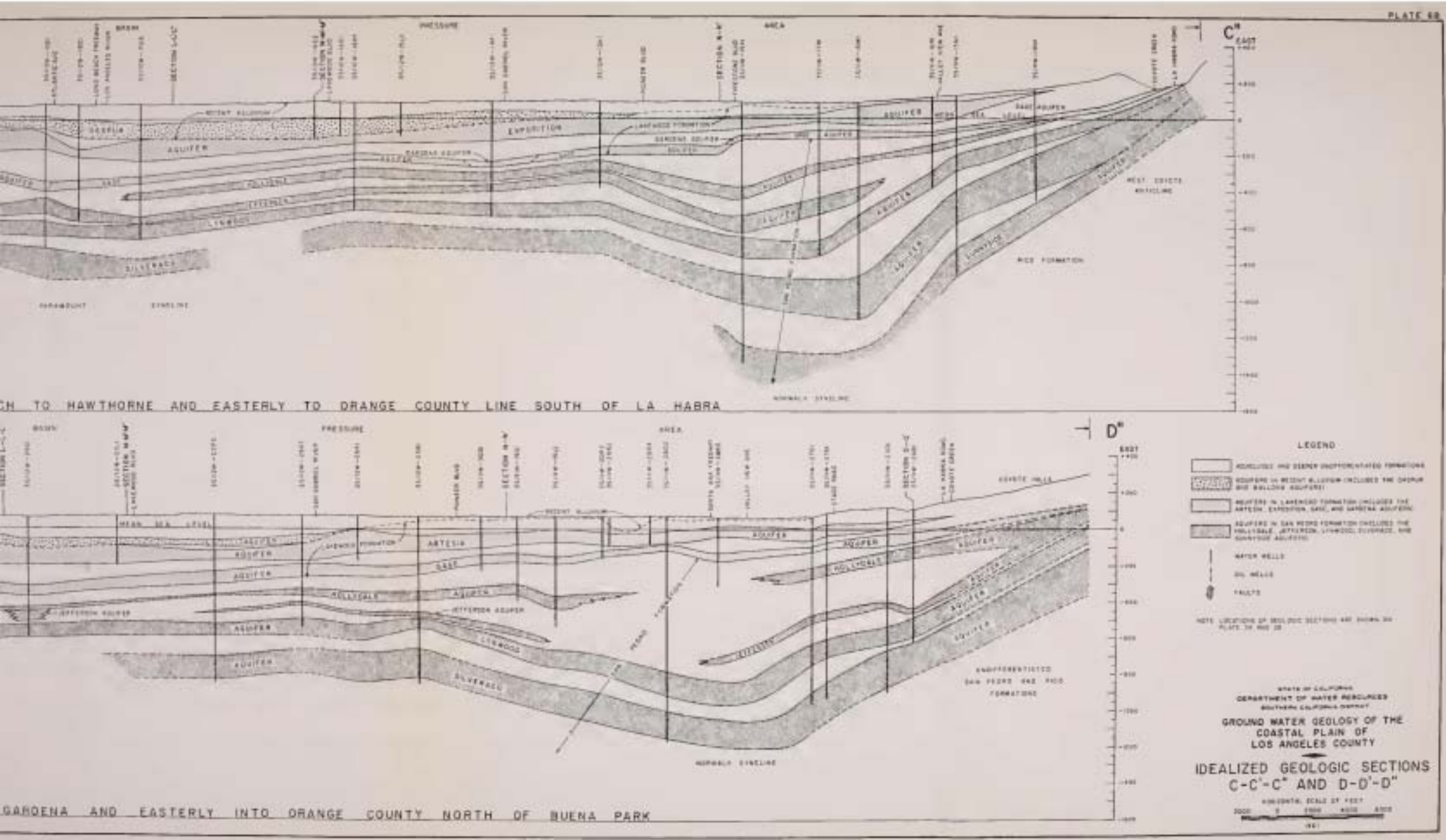
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069065


C
C'
WEST
COAST
BASIN
CENTRAL
SILVERADO AQUIFER
LYNWOOD AQUIFER
GAGE AQUIFER
ARTESIAN AQUIFER
PICO FORMATION
BASE OF FRESH WATER
SECTION C-C'-C" — HERMOSA BEACH TO HAWT
D
D'
EXPOSITION — ARTESIA
SECTION D-D'-D" — REDONDO BEACH TO GARDENA AN

AR0069066

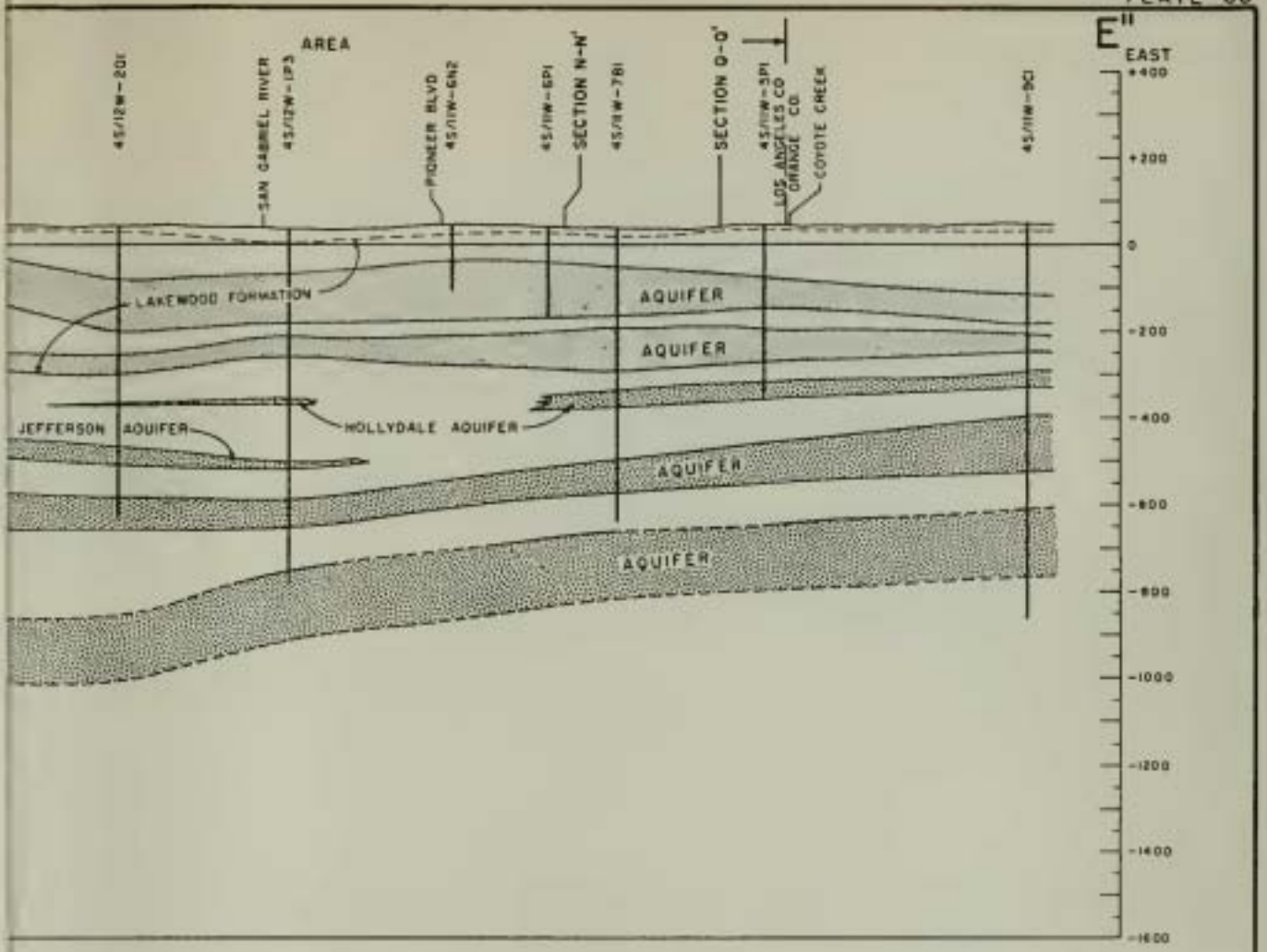


CH TO HAWTHORNE AND EASTERLY TO ORANGE COUNTY LINE SOUTH OF LA HABRA

GARDENA AND EASTERLY INTO ORANGE COUNTY NORTH OF BUENA PARK

AR0069067

AR0069068



LEGEND

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- AQUIFERS IN RECENT ALLUVIUM (INCLUDES THE GASPUR AND BALLONA AQUIFERS)
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- OIL WELLS
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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

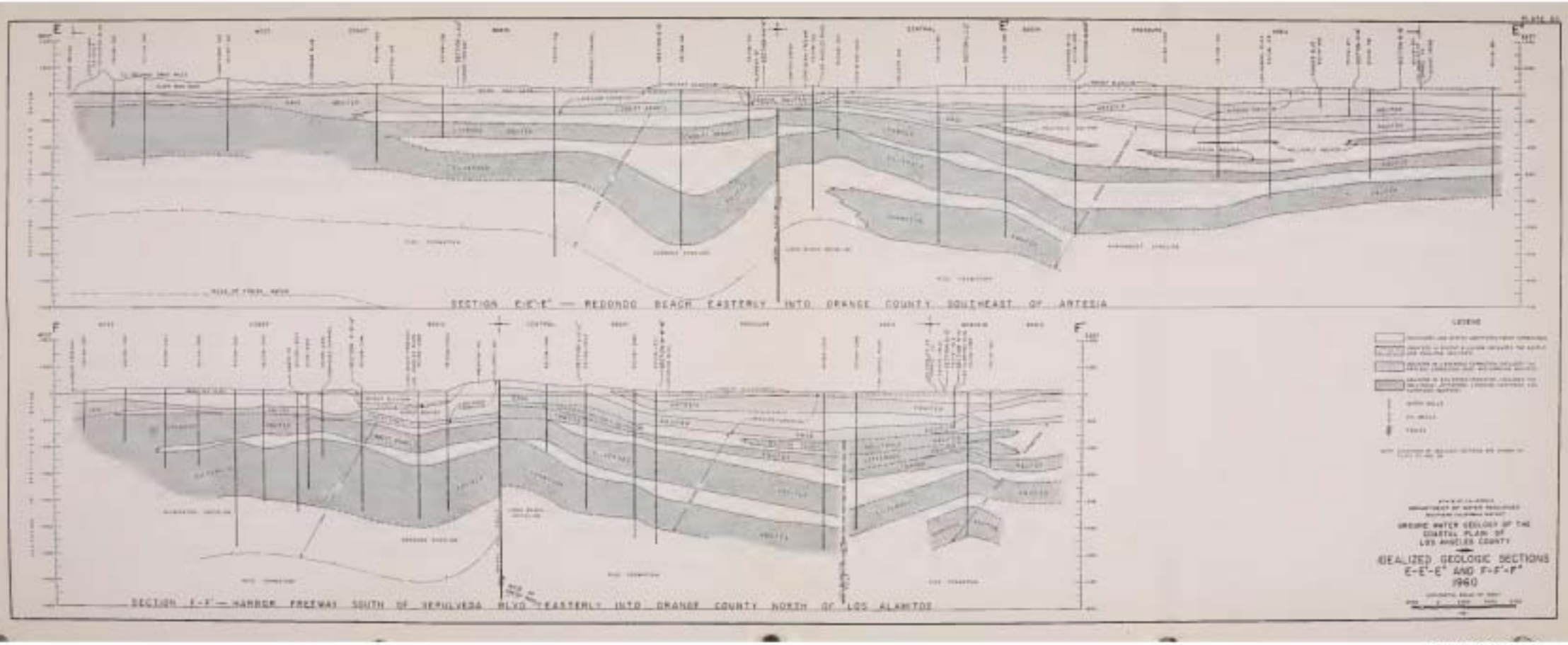
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS E-E'-E" AND F-F'-F" 1960

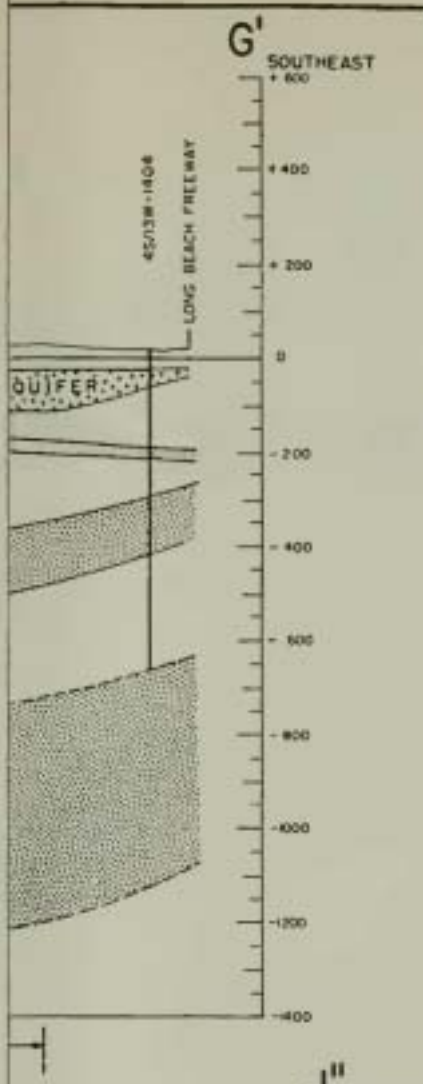
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

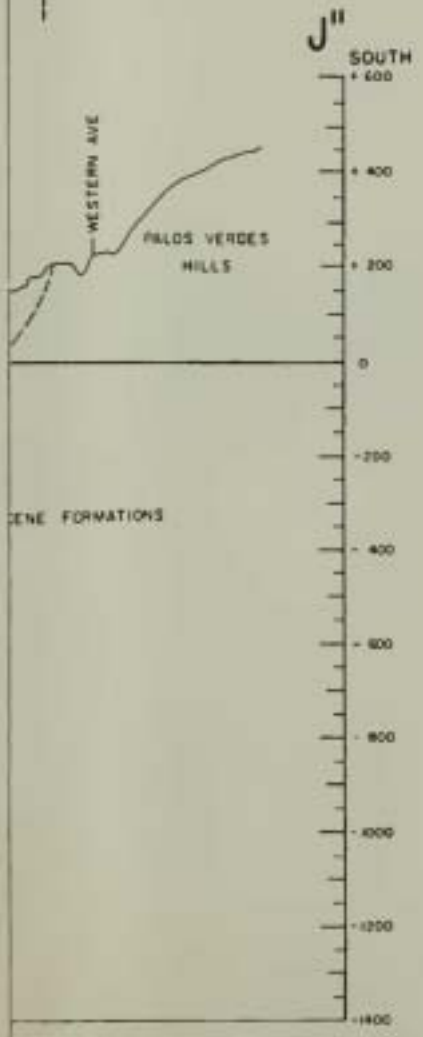
1961

AR0069069


SECTION E-E'-E" — REDONDO BEACH EASTERLY INTO ORANGE COUNTY SOUTHEAST OF ARTESIA
SECTION F-F' — HARBOR FREEWAY SOUTH OF SEPULVEDA BLVD EASTERLY INTO ORANGE COUNTY NORTH OF LOS ALAMITOS
LEGEND
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY
GENERALIZED GEOLOGIC SECTIONS E-E'-E" AND F-F'-F"
1960

AR0069070





LEGEND

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NOTE LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 3A AND 3B

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

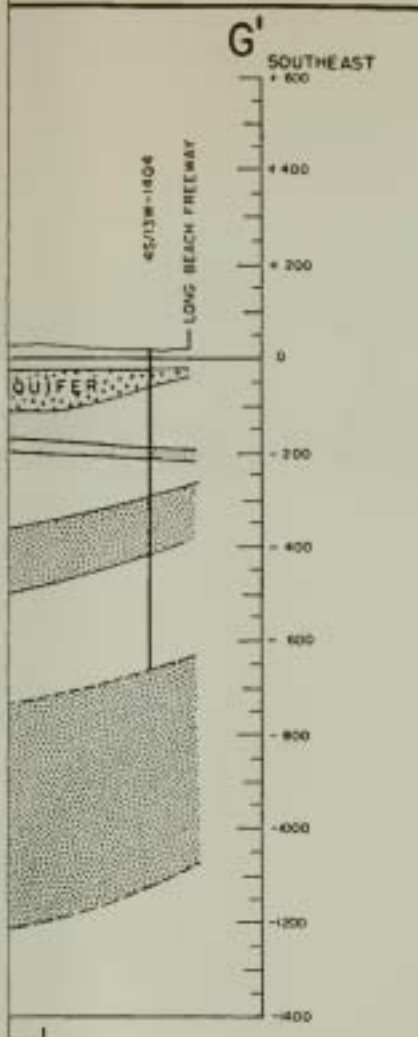
IDEALIZED GEOLOGIC SECTIONS G-G' AND J-J'-J"

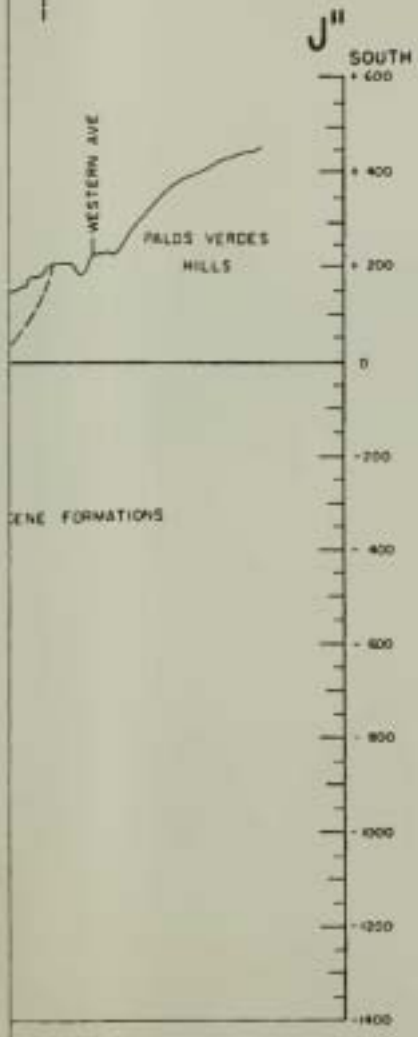
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069071

AR0069072





LEGEND

- AQUICLUDES AND DEEPER UNDIFFERENTIATED FORMATIONS
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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

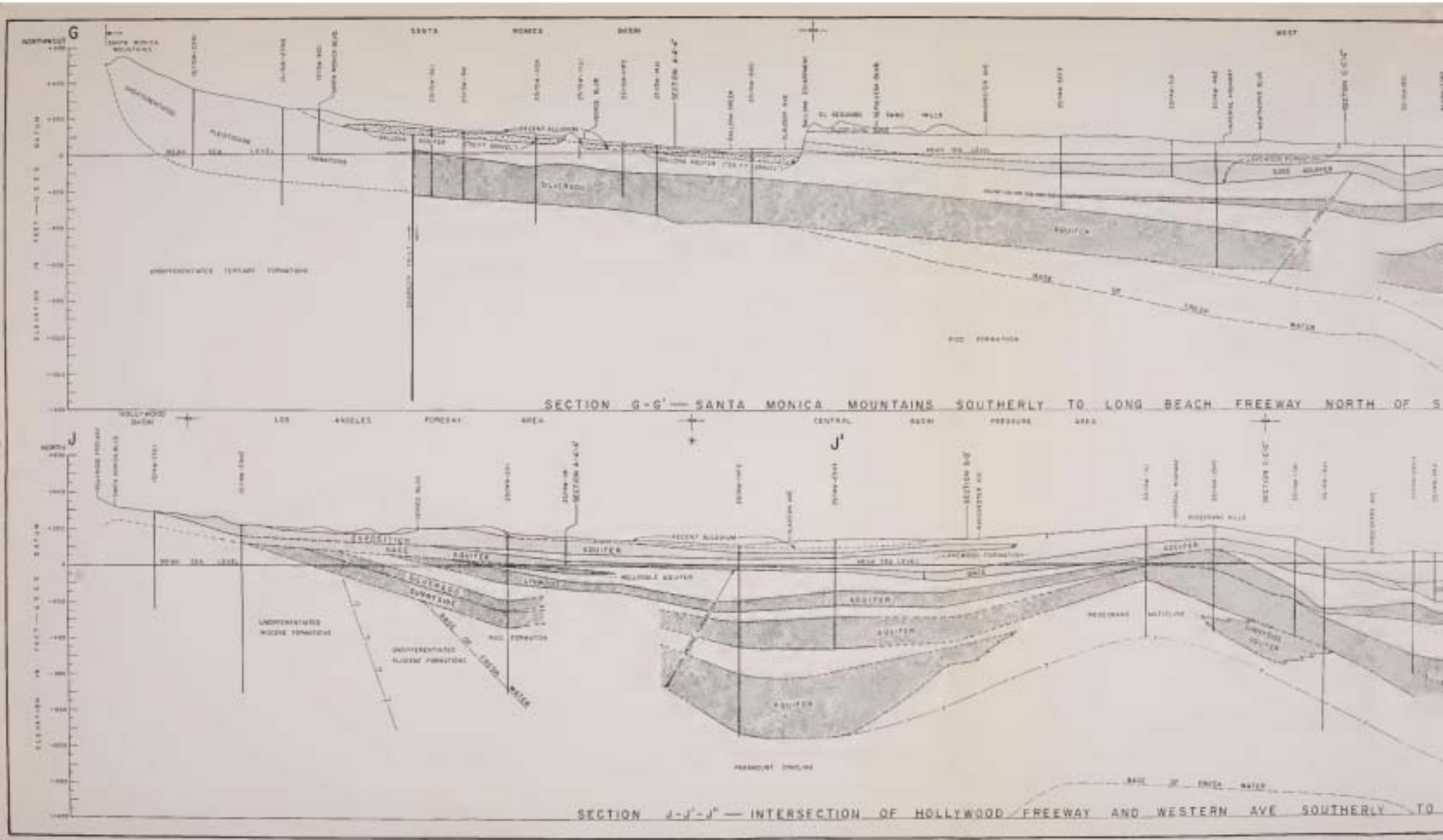
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS G-G' AND J-J'-J"

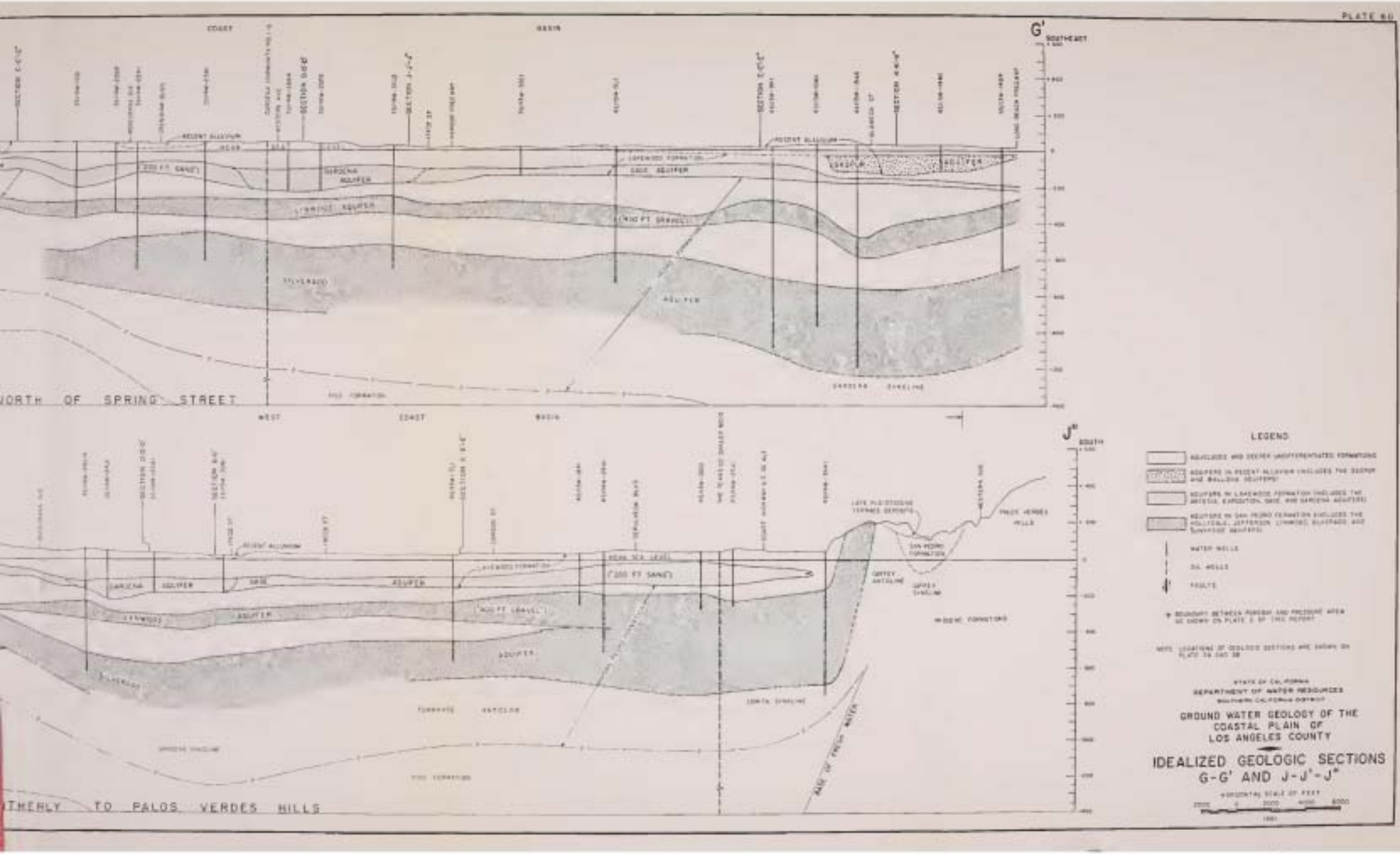
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069073


G
SANTA MONICA MOUNTAINS
SANTA MONICA BASIN
WEST
SECTION G-G' — SANTA MONICA MOUNTAINS SOUTHERLY TO LONG BEACH FREEWAY NORTH OF S
HOLLYWOOD BASIN
LOS ANGELES FOREBAY AREA
CENTRAL BASIN PRESSURE AREA
J
J'
SECTION J-J'-J" — INTERSECTION OF HOLLYWOOD FREEWAY AND WESTERN AVE SOUTHERLY TO

AR0069074



LEGEND

- ALLUVIUMS AND DEEPER UNDIFFERENTIATED FORMATIONS
- AQUIFERS IN RECENT ALLUVIUM (INCLUDES THE SILVERADO AND WILMINGTON AQUIFERS)
- AQUIFERS IN LAKEWOOD FORMATION (INCLUDES THE ARTESIA, EXPOSITION, GAGE, AND SARIDENA AQUIFERS)
- AQUIFERS IN SAN PEDRO FORMATION (INCLUDES THE HOLLYDALE, JEFFERSON, LYNWOOD, SILVERADO AND TORRANCE AQUIFERS)
- WATER WELLS
- OIL WELLS
- FAULTS

* BOUNDARY BETWEEN FRESH AND SALINE WATER AS SHOWN ON PLATE 3 OF THIS REPORT

NOTE: LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 3A AND 3B

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

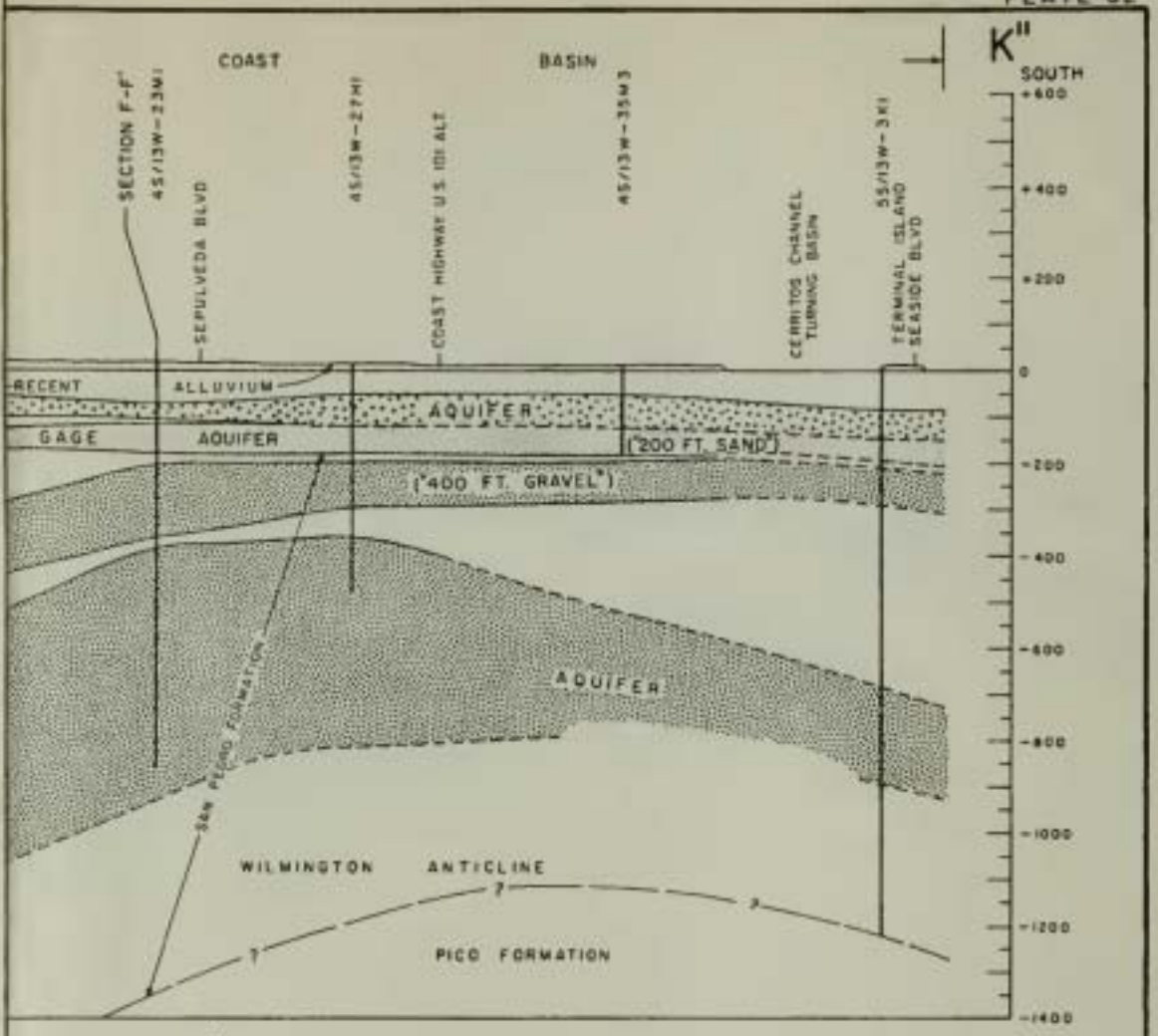
IDEALIZED GEOLOGIC SECTIONS G-G' AND J-J'-J"

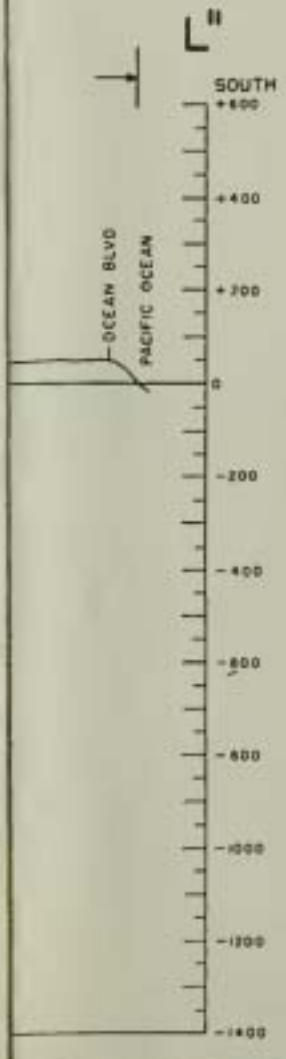
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069075

AR0069076





LEGEND

- INCLUDES AND DEEPER UNDIFFERENTIATED FORMATIONS
- AQUIFERS IN RECENT ALLUVIUM (INCLUDES THE GASPUR AND BALLONA AQUIFERS)
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NOTE: LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 3A AND 3B

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

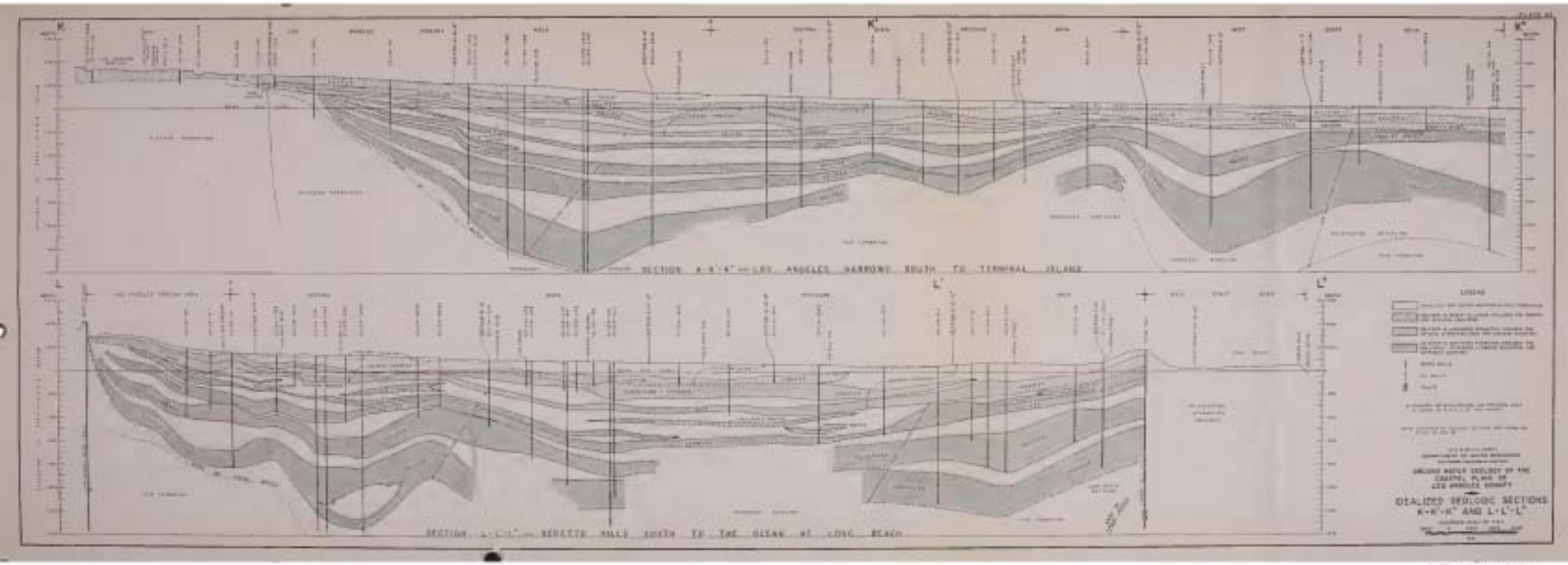
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS K-K'-K" AND L-L'-L"

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

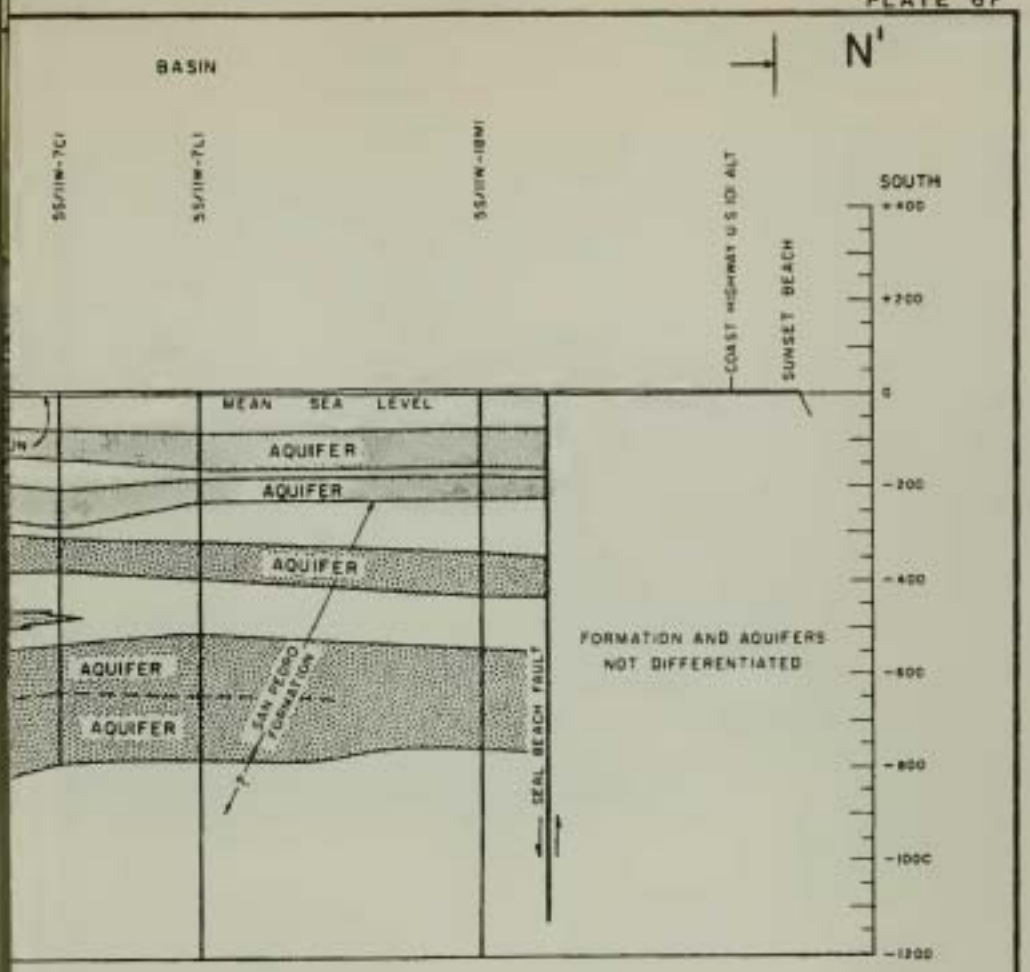
1961

AR0069077


K
K'
K"
SECTION K-K'-K" — LOS ANGELES HARBORS SOUTH TO TERMINAL ISLAND
L
L'
L"
SECTION L-L'-L" — BEVERLY HILLS SOUTH TO THE OCEAN AT LONG BEACH
LEGEND
GEOLOGIC SECTIONS
K-K'-K" AND L-L'-L"

AR0069078

PLATE 6F



LEGEND

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS M-M'-M" AND N-N'

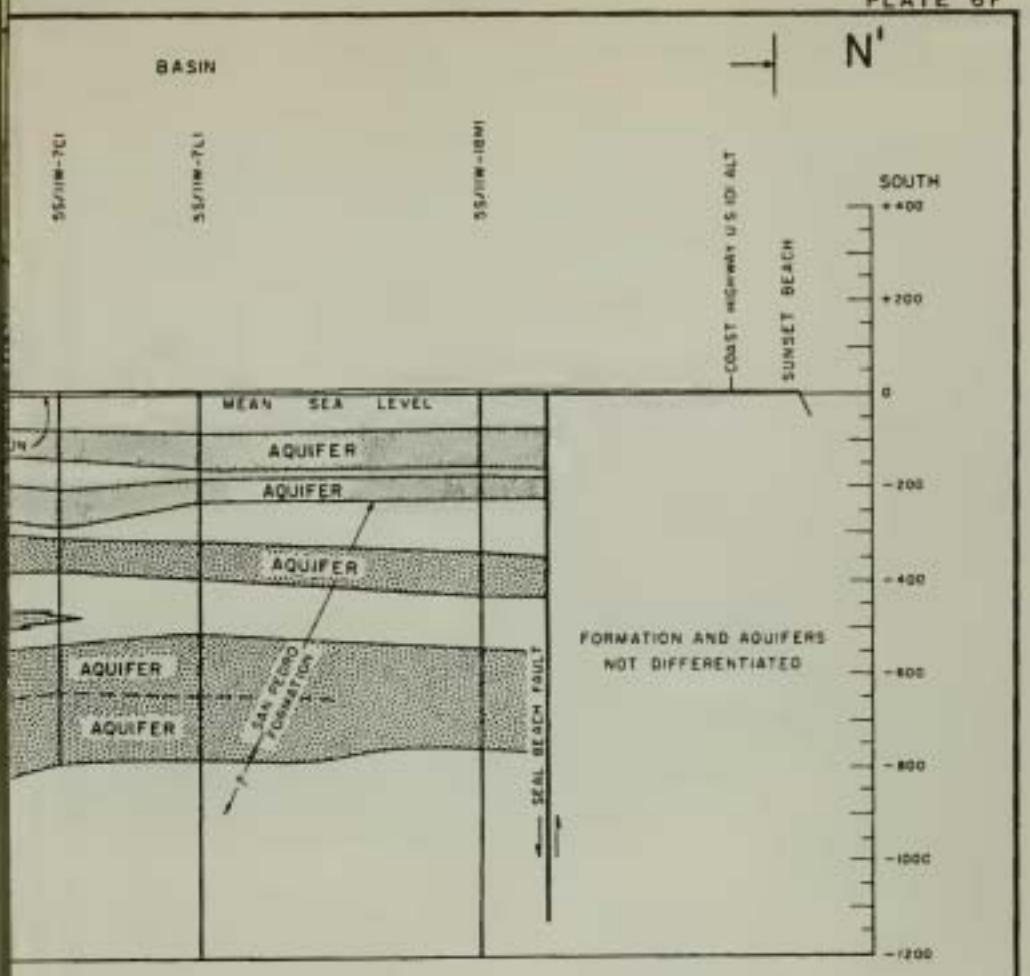
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069079

AR0069080

PLATE 6F



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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

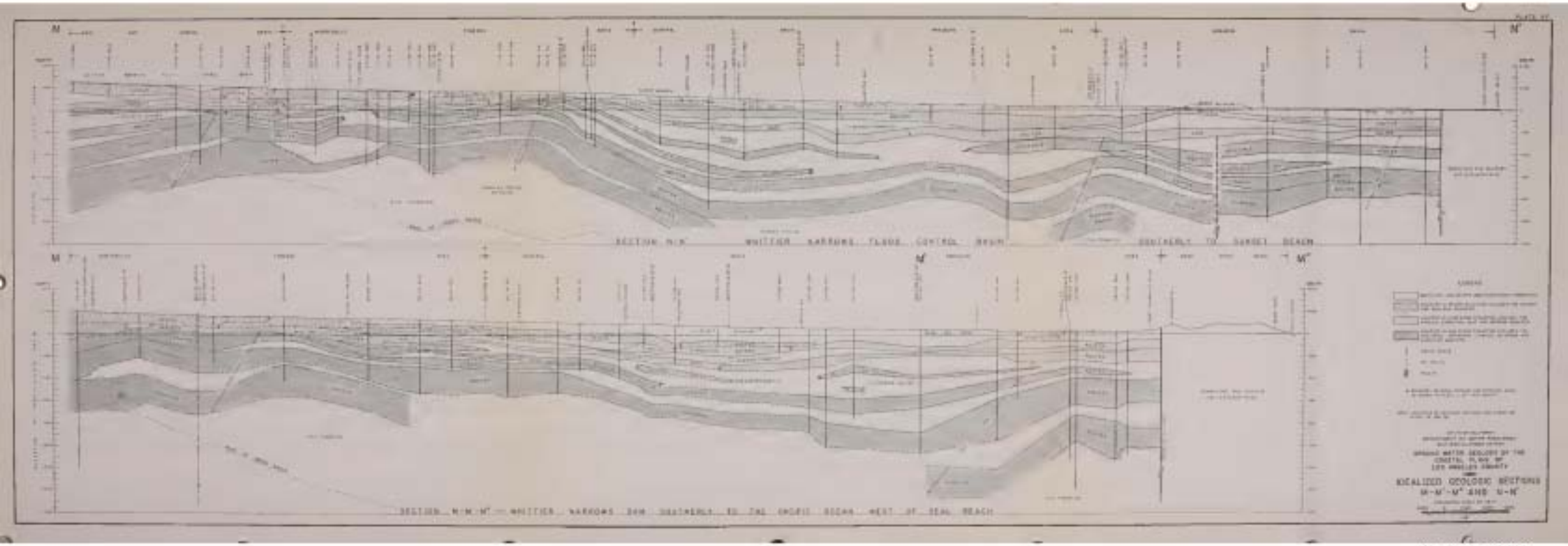
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS M-M'-M" AND N-N'

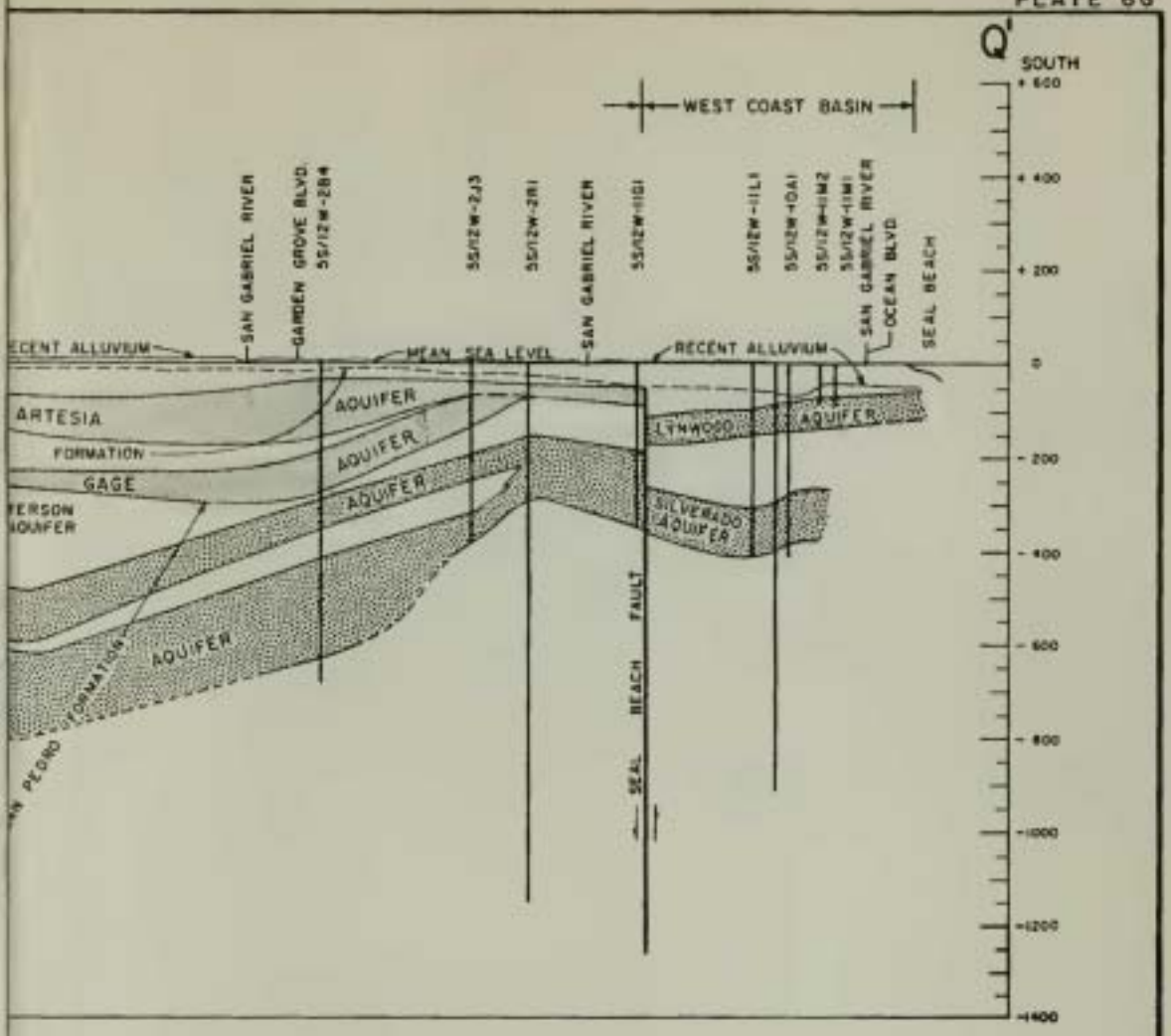
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069081


M
M'
M
M'
M"
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
REALIZED GEOLOGIC SECTIONS
M-M'-M" AND N-N'

AR0069082



LEGEND

- AQUICLUDES AND DEEPER UNDIFFERENTIATED FORMATIONS
- AQUIFERS IN RECENT ALLUVIUM (INCLUDES THE GASPUR AND BALLONA AQUIFERS)
- AQUIFERS IN LAKEWOOD FORMATION (INCLUDES THE ARTESIA, EXPOSITION, GAGE, AND GARDENA AQUIFERS)
- AQUIFERS IN SAN PEDRO FORMATION (INCLUDES THE HOLLYDALE, JEFFERSON, LYNWOOD, SILVERADO, AND SUNNYSIDE AQUIFERS)
- WATER WELLS
- OIL WELLS
- FAULTS

NOTE: LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 3A AND 3B

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

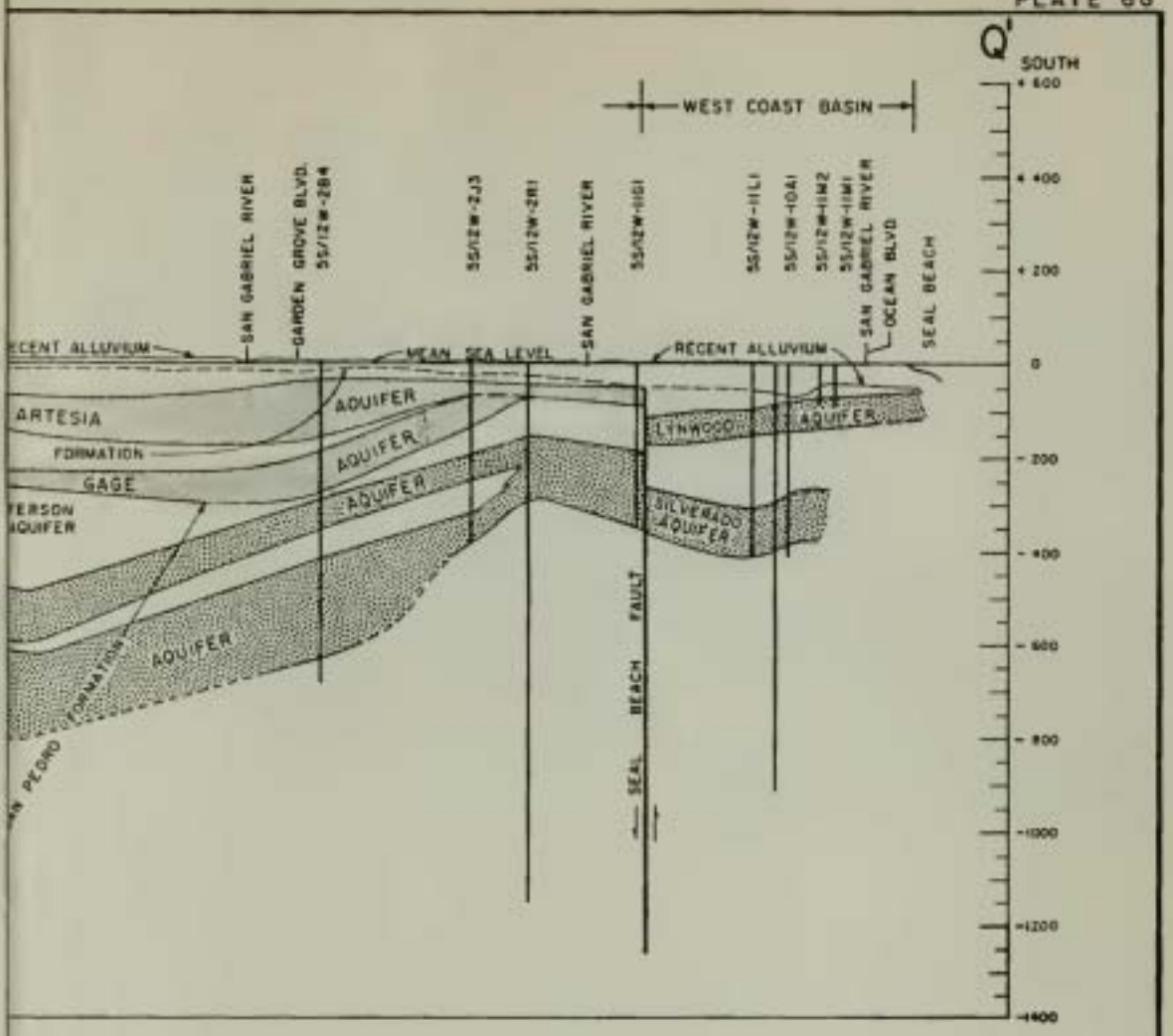
IDEALIZED GEOLOGIC SECTIONS H-H', P-P', AND Q-Q'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069083

AR0069084



LEGEND

- AQUICLUDES AND DEEPER UNDIFFERENTIATED FORMATIONS
- AQUIFERS IN RECENT ALLUVIUM (INCLUDES THE GASPUR AND BALLONA AQUIFERS)
- AQUIFERS IN LAKEWOOD FORMATION (INCLUDES THE ARTESIA, EXPOSITION, GAGE, AND GARDENA AQUIFERS)
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- WATER WELLS
- OIL WELLS
- FAULTS

NOTE: LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 3A AND 3B

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

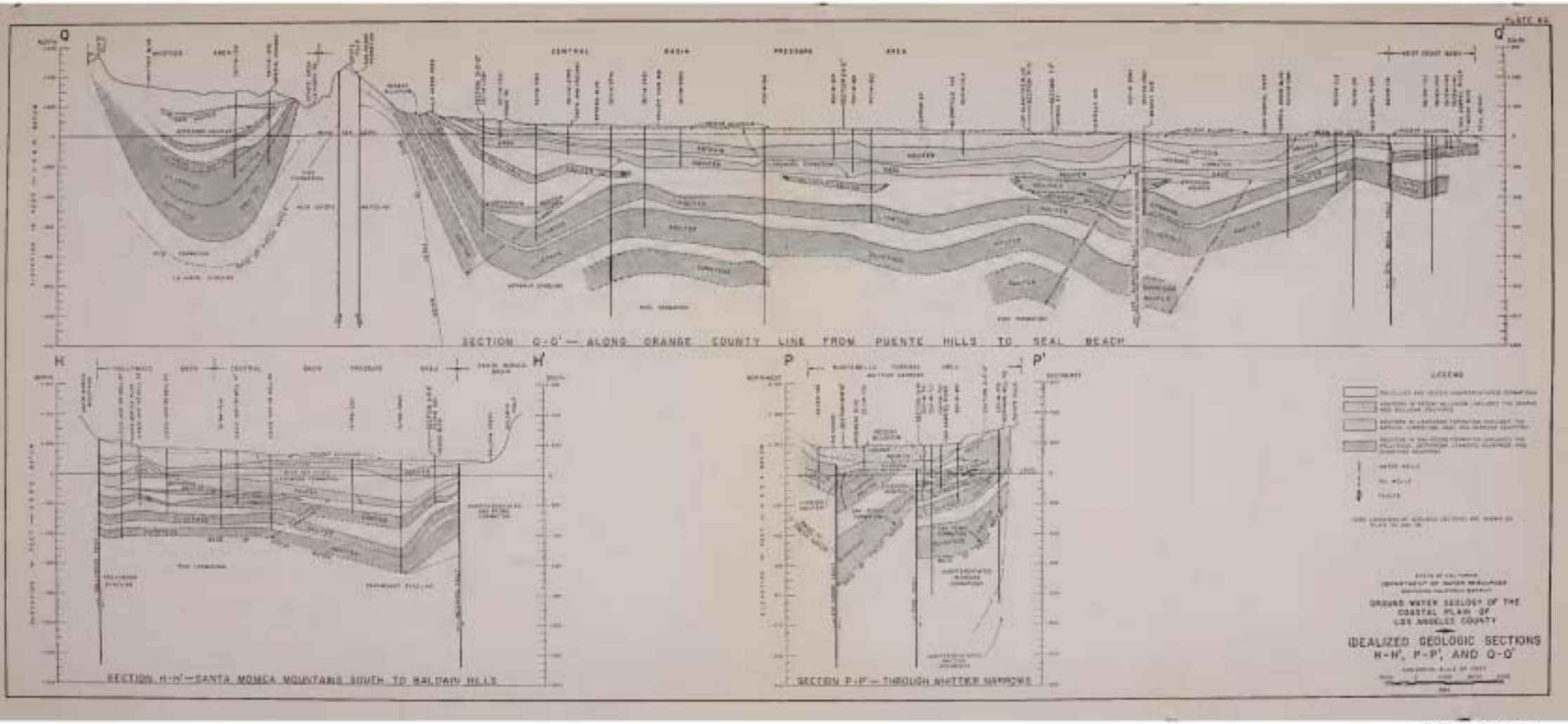
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

IDEALIZED GEOLOGIC SECTIONS H-H', P-P', AND Q-Q'

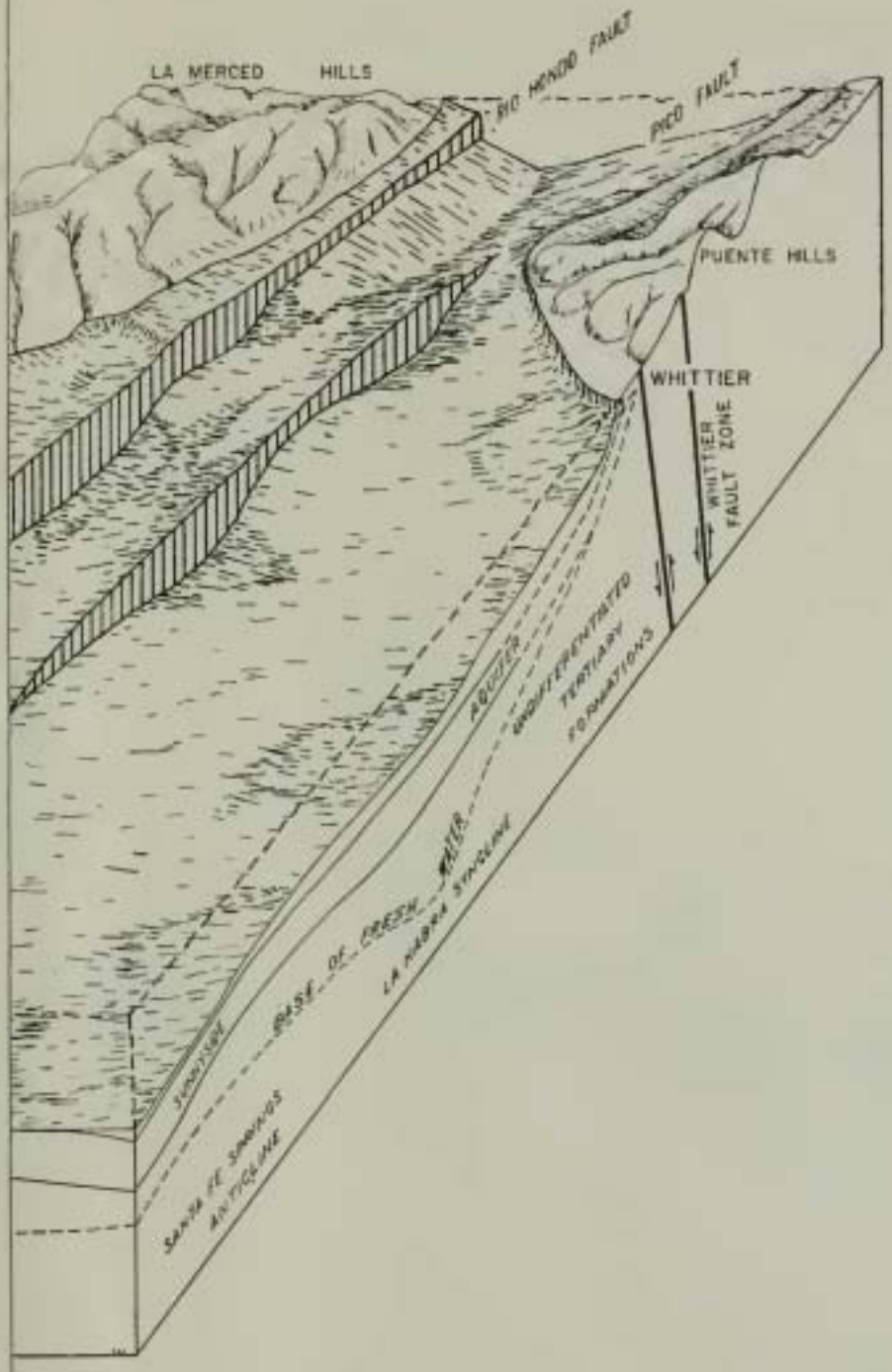
HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1961

AR0069085


Q
Q'
SECTION Q-Q' — ALONG ORANGE COUNTY LINE FROM PUENTE HILLS TO SEAL BEACH
H
H'
SECTION H-H' — SANTA MONICA MOUNTAINS SOUTH TO BALDWIN HILLS
P
P'
SECTION P-P' — THROUGH WHITTIER NARROWS
LEGEND
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY
IDEALIZED GEOLOGIC SECTIONS H-H', P-P', AND Q-Q'

AR0069086



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

CUT-AWAY DIAGRAMS OF AQUIFERS IN VICINITY OF WHITTIER NARROWS

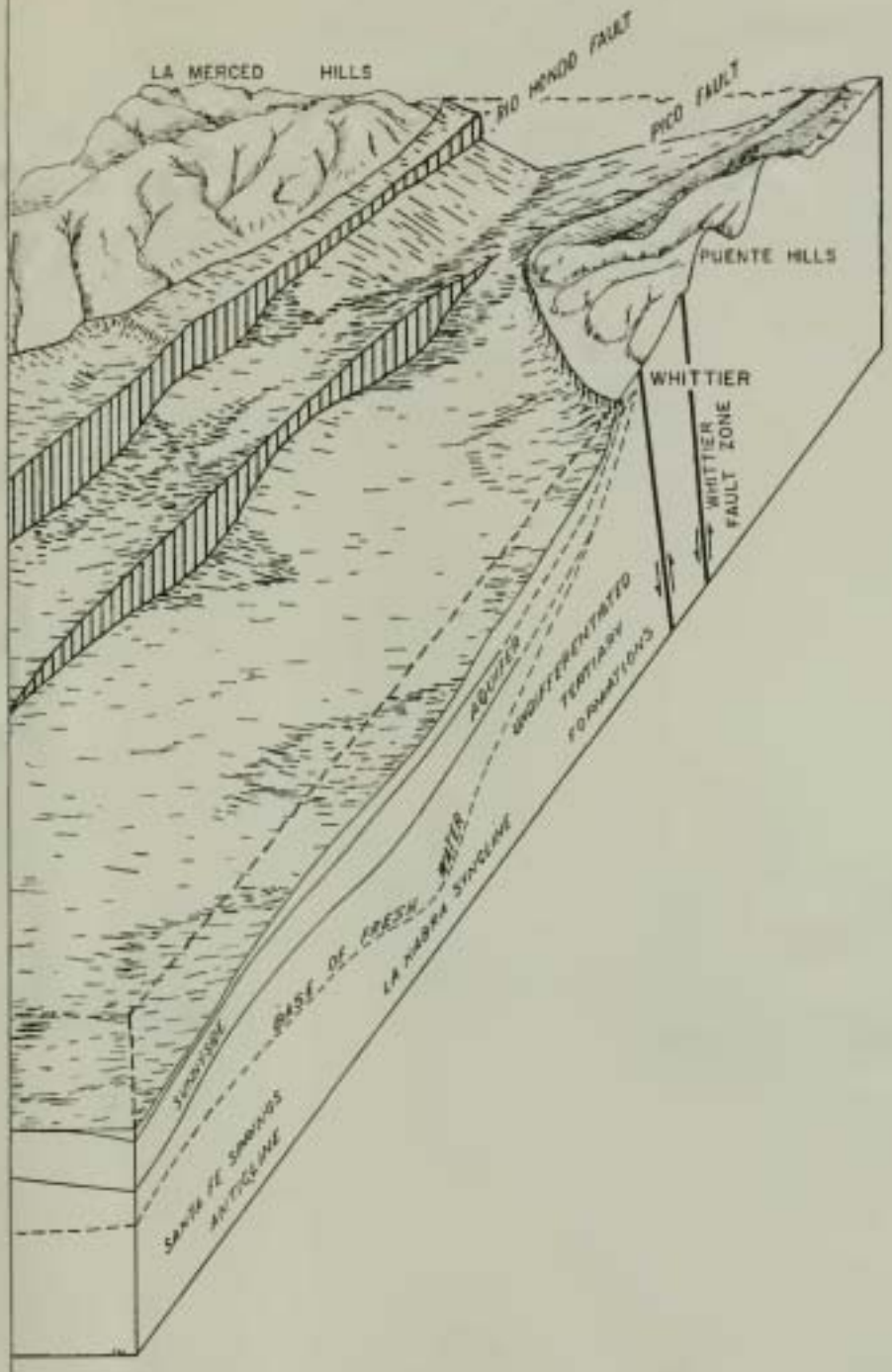
HORIZONTAL SCALE OF FEET

1000 0 1000 2000

1961

AR0069087

AR0069088



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

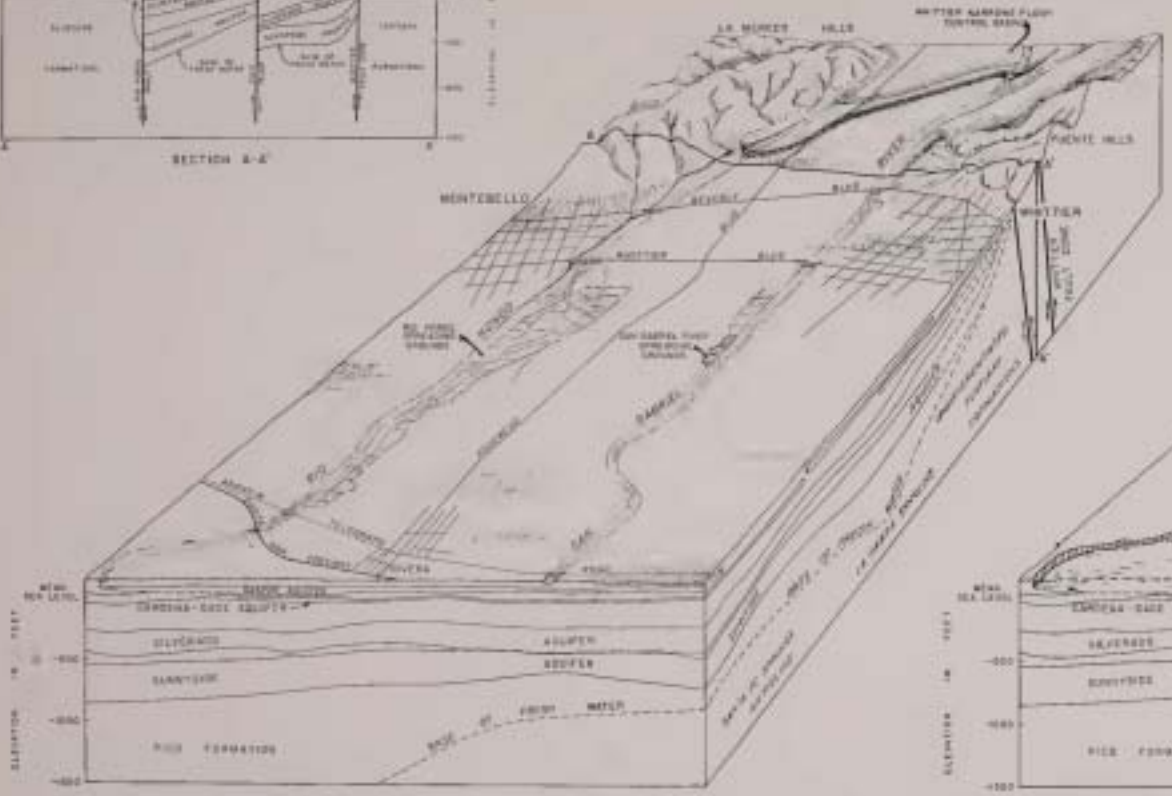
CUT-AWAY DIAGRAMS OF AQUIFERS IN VICINITY OF WHITTIER NARROWS

HORIZONTAL SCALE OF FEET

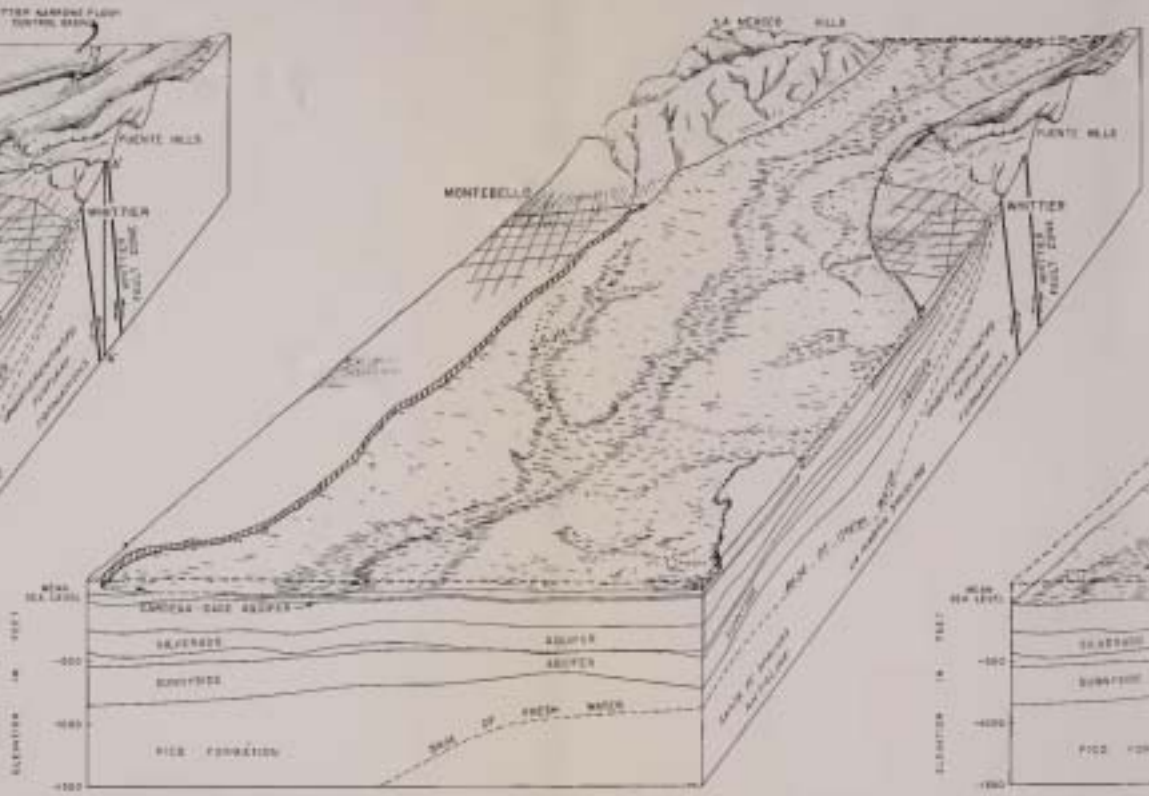
1000 0 1000 2000

1961

AR0069089



VIEW I PRESENT LAND SURFACE

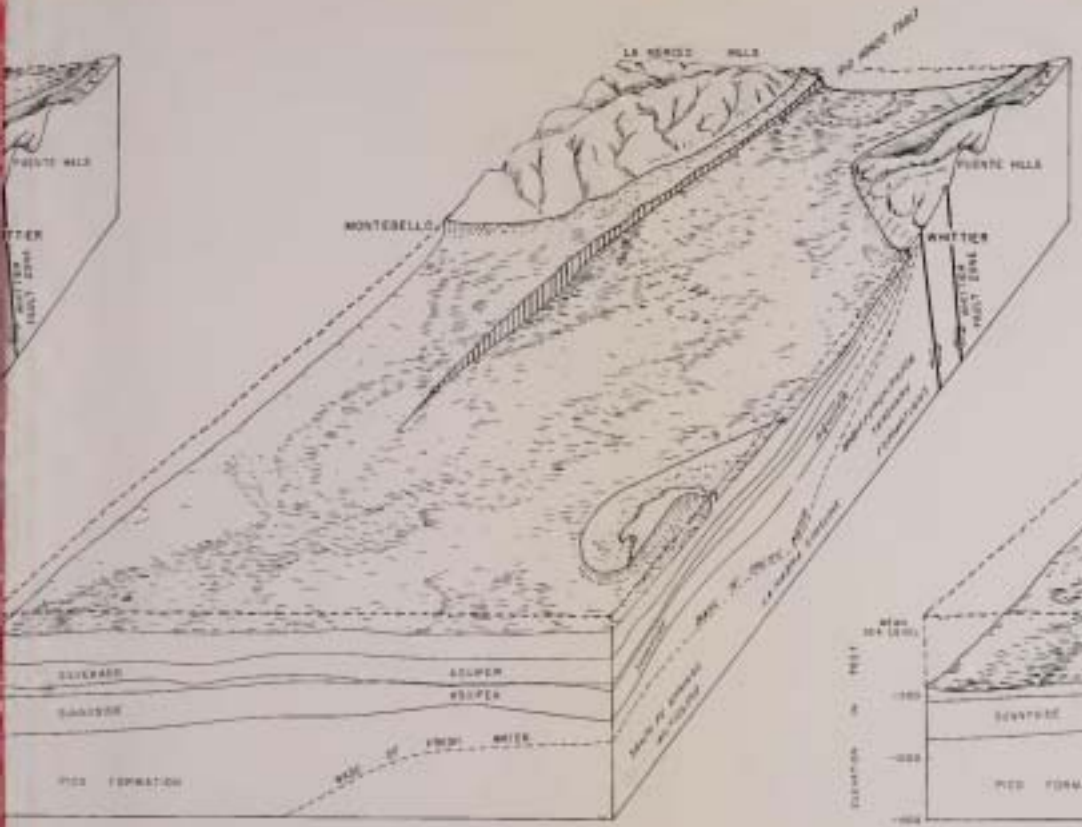


VIEW II BASE OF THE GASPUR AQUIFER
(OVERLYING SEDIMENTS REMOVED)

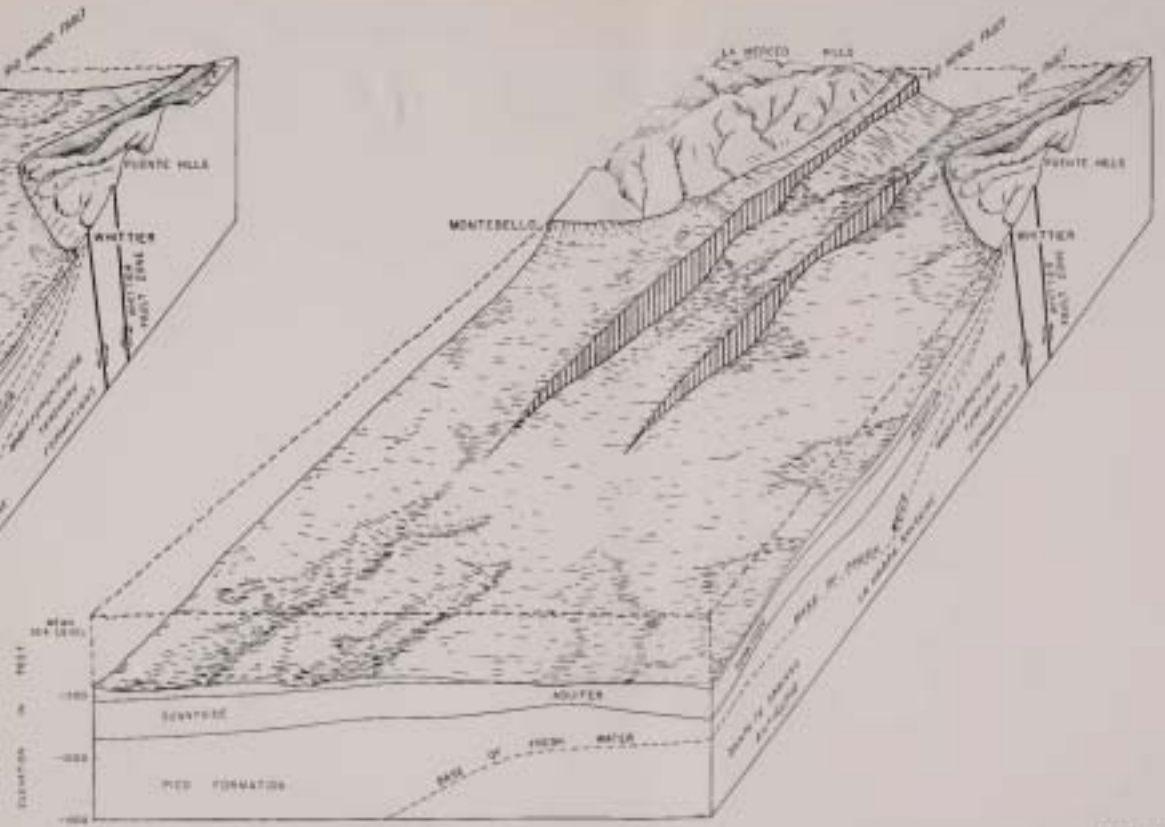
VIEW III BA
(OV

NOTE VERTICAL SCALE IS TWICE THE HORIZONTAL SCALE

AR0069090



VIEW III BASE OF THE GARDENA-GAGE AQUIFER
(OVERLYING SEDIMENTS REMOVED)



VIEW IV BASE OF THE SILVERADO AQUIFER
(OVERLYING SEDIMENTS REMOVED)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

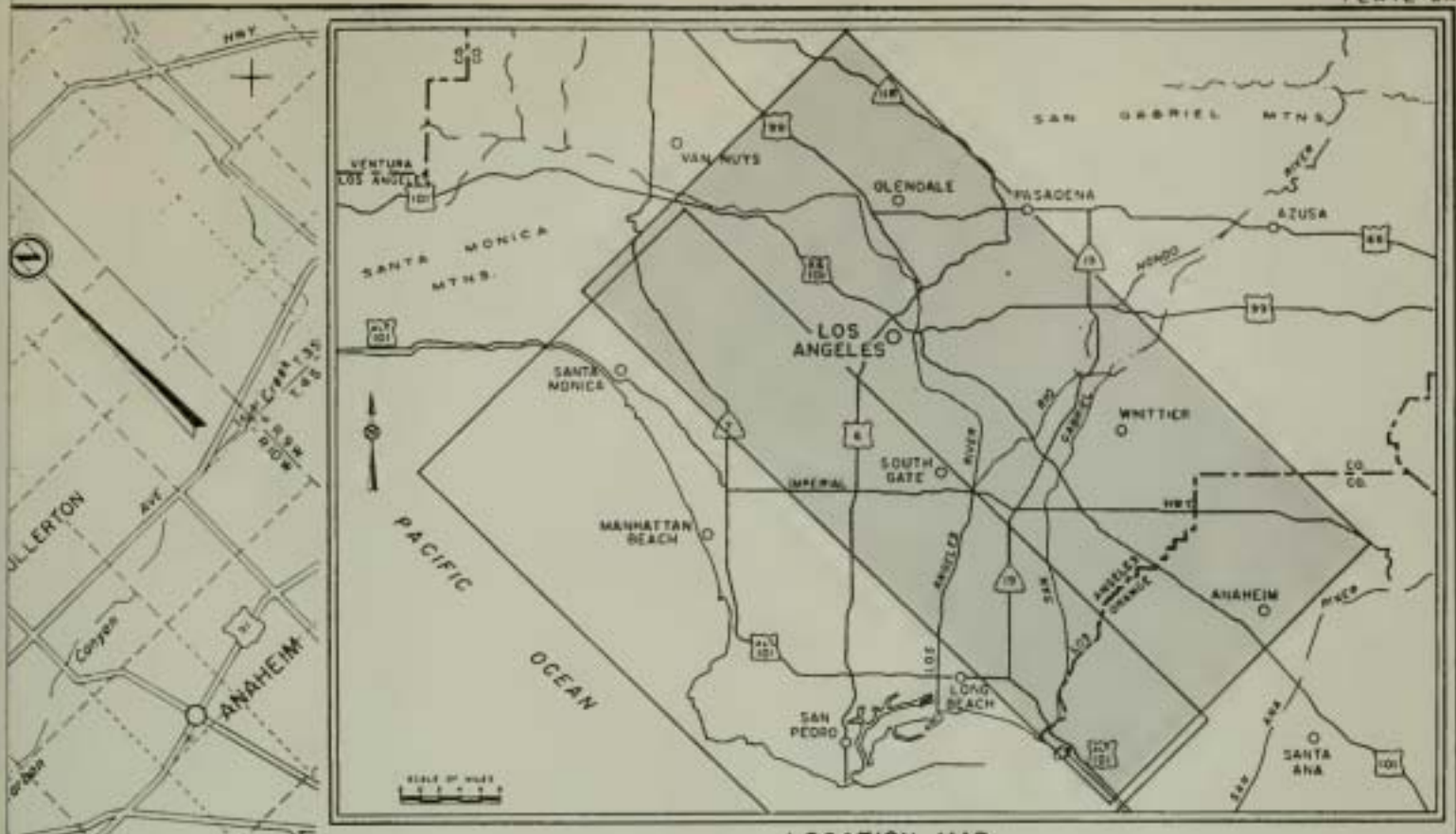
CUT-AWAY DIAGRAMS OF AQUIFERS IN VICINITY OF WHITTIER NARROWS

HORIZONTAL SCALE OF FEET

0 2000 4000

AR0069091

AR0069092



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF BELLFLOWER AQUICLUDE (DASHED WHERE LOCATION IS APPROXIMATE)
- -60- LINES OF EQUAL ELEVATION ON THE BASE OF THE BELLFLOWER AQUICLUDE (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE BELLFLOWER AQUICLUDE IS ABSENT AND THE AQUIFERS PRESENT ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE
- BOUNDARY OF THE GASPUR AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

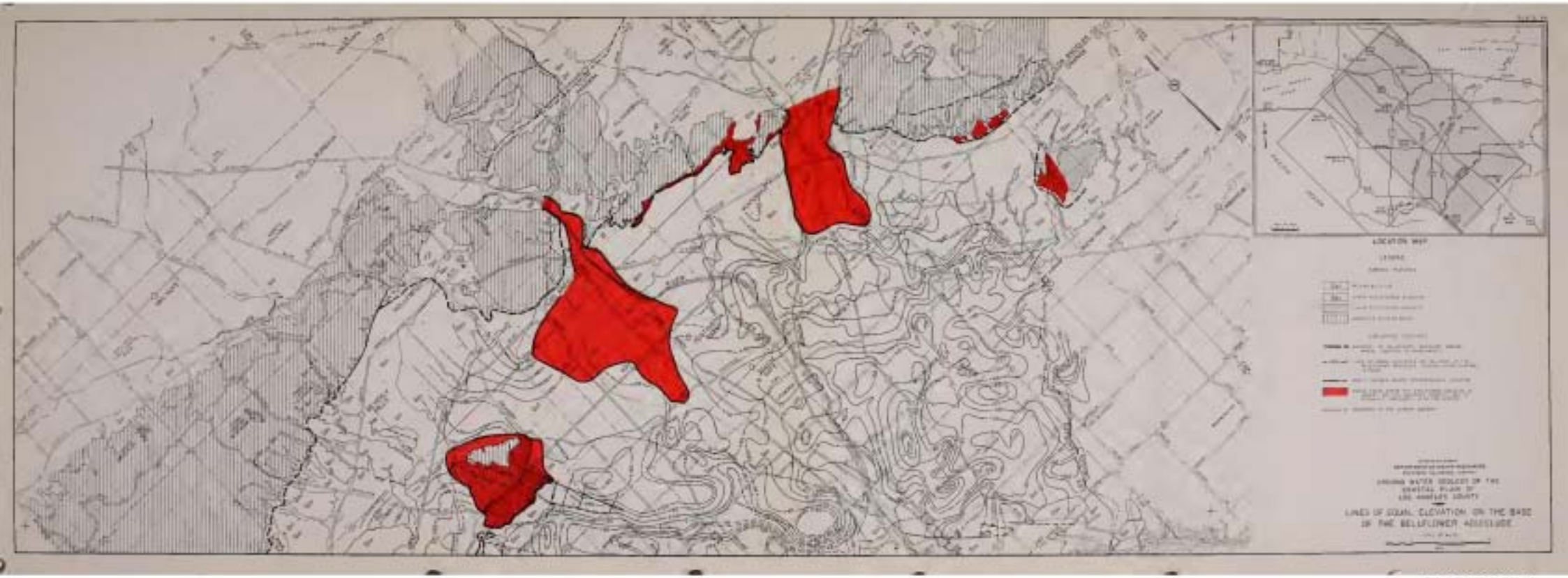
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE BELLFLOWER AQUICLUDE

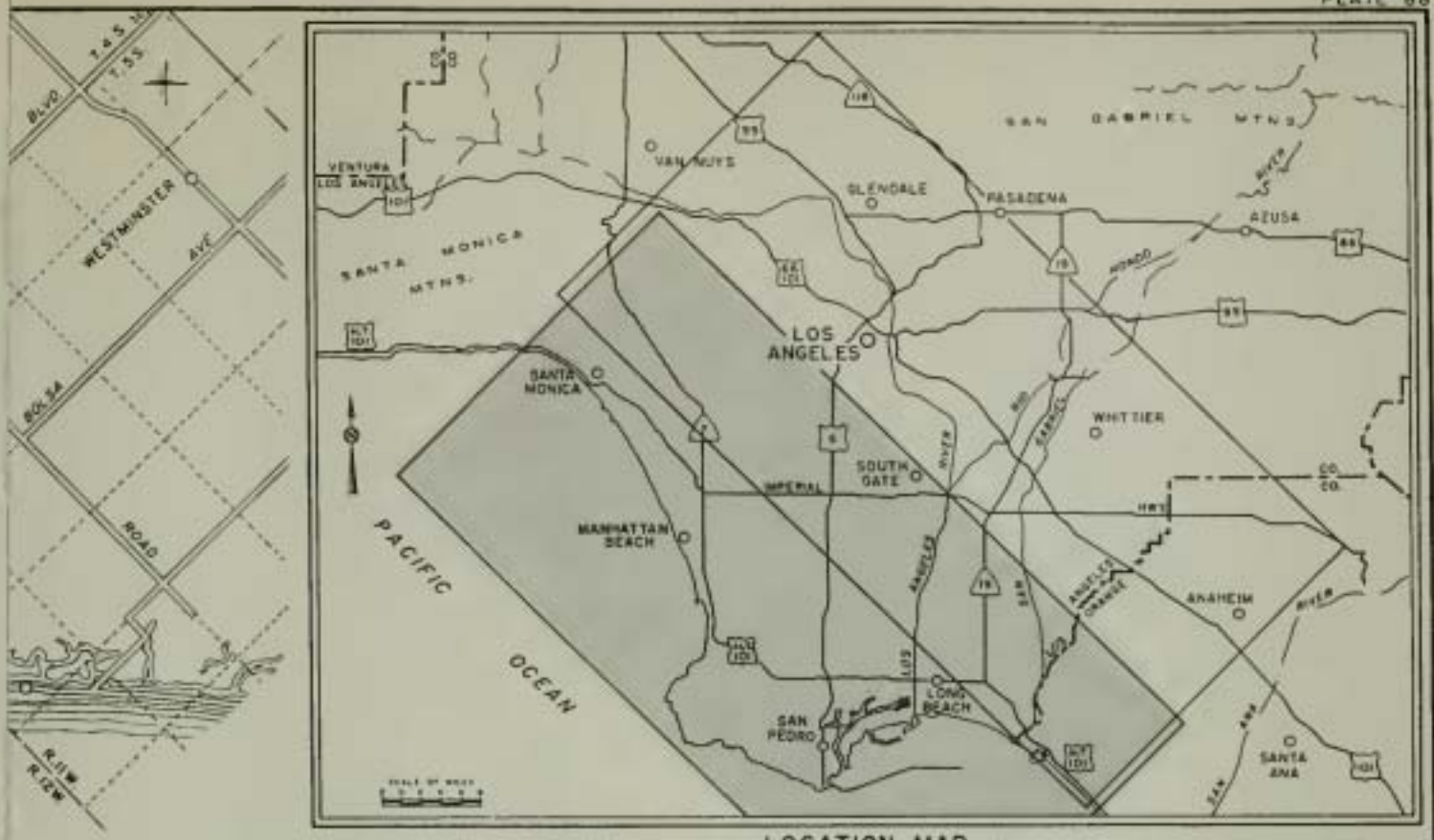
SCALE OF MILES
0 1 2 3

1961

AR0069093


LOCATION MAP
LINES OF EQUAL ELEVATION ON THE BASE OF THE BELLFLOWER AQUICLUDE

AR0069094



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF BELLFLOWER AQUICLUDE (DASHED WHERE LOCATION IS APPROXIMATE)
- -60- LINES OF EQUAL ELEVATION ON THE BASE OF THE BELLFLOWER AQUICLUDE (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE BELLFLOWER AQUICLUDE IS ABSENT AND THE AQUIFERS PRESENT ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE
- BOUNDARY OF THE GASPUR AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

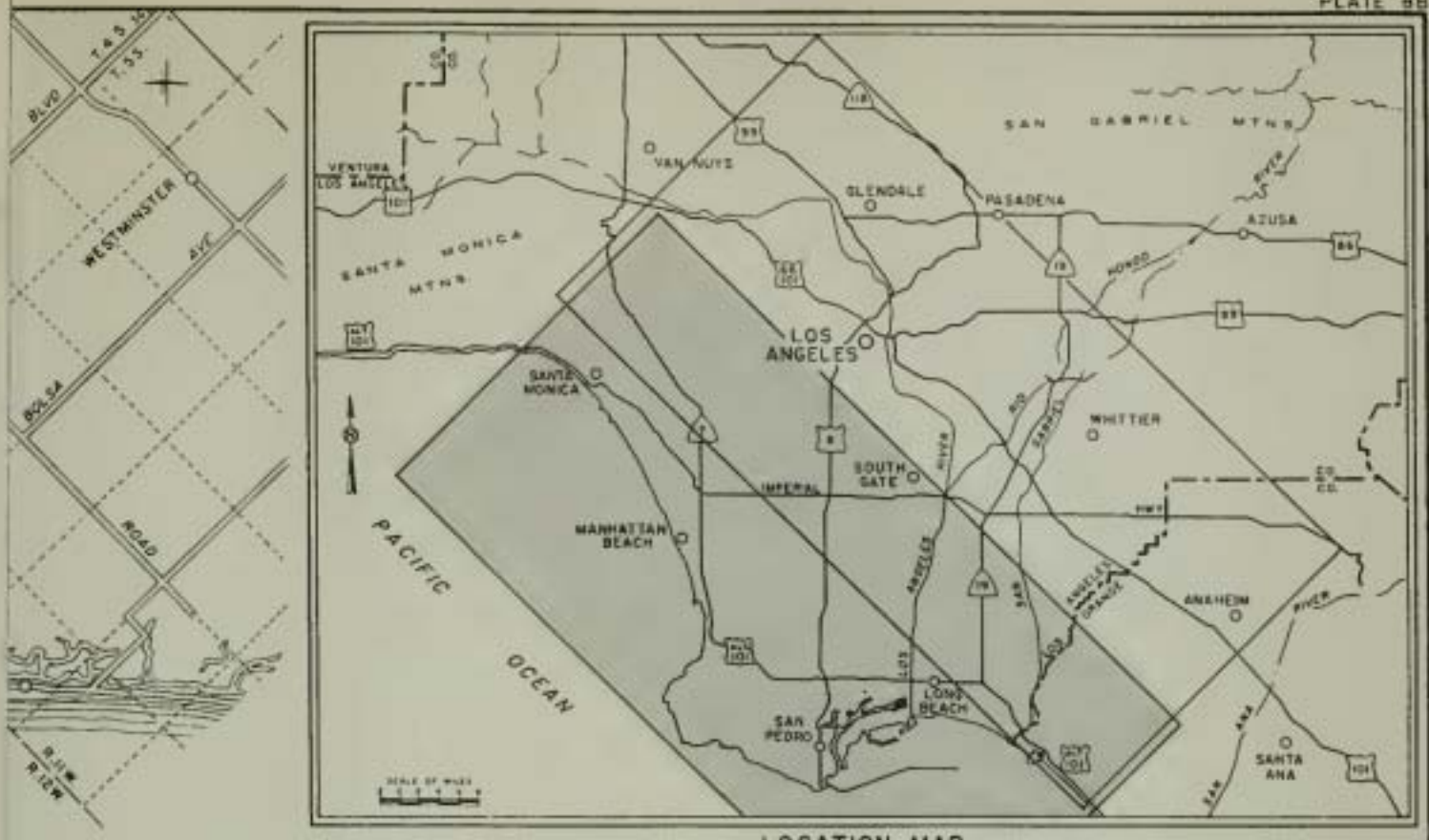
LINES OF EQUAL ELEVATION ON THE BASE OF THE BELLFLOWER AQUICLUDE

SCALE OF MILES
0 1 2 3

1961

AR0069095

AR0069096



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF BELLFLOWER AQUICLUDE (DASHED WHERE LOCATION IS APPROXIMATE)
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- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE BELLFLOWER AQUICLUDE IS ABSENT AND THE AQUIFERS PRESENT ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE
- BOUNDARY OF THE GASPUR AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

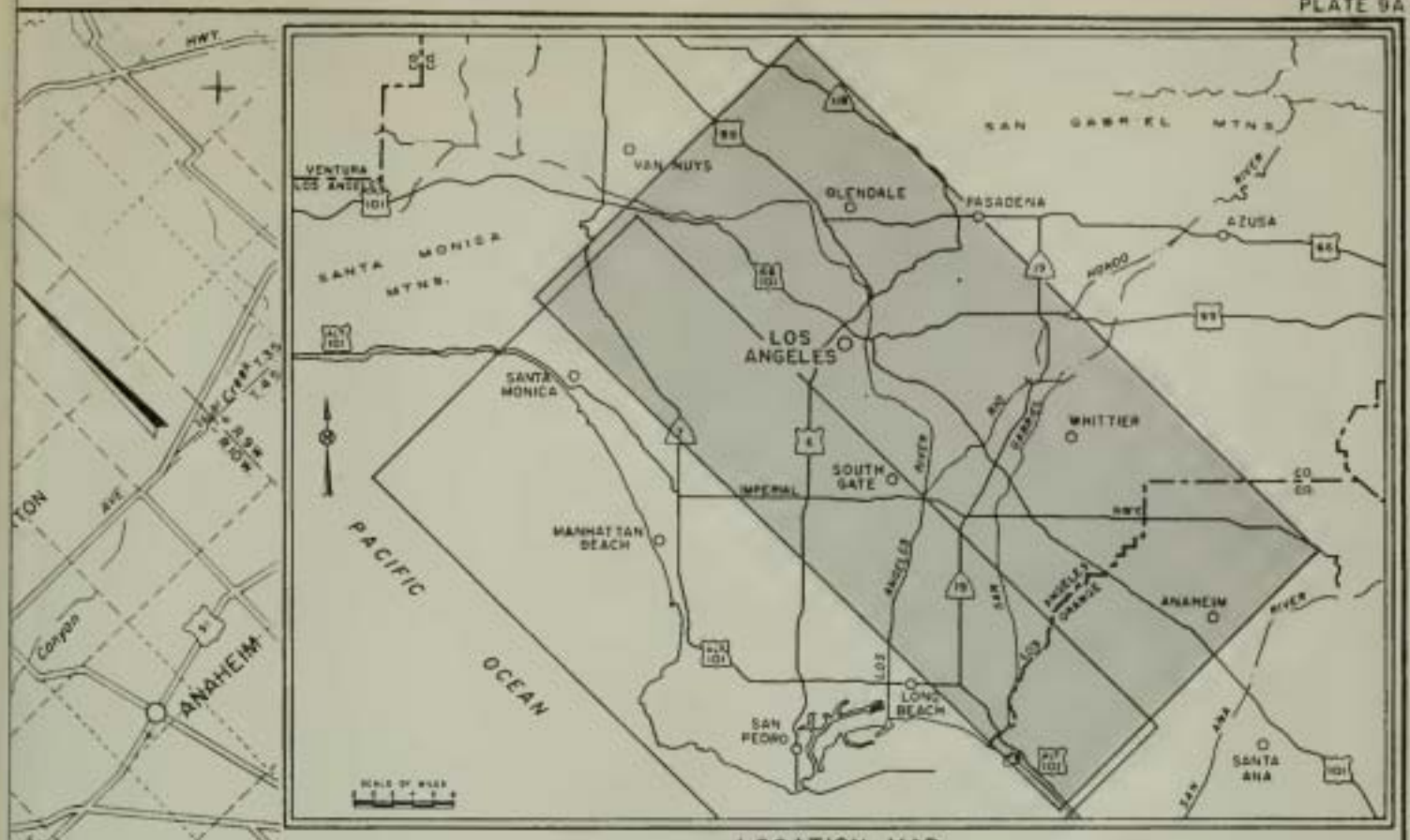
LINES OF EQUAL ELEVATION ON THE BASE OF THE BELLFLOWER AQUICLUDE

SCALE OF MILES
0 1 2 3

(DE)

AR0069097

AR0069098



LOCATION MAP

LEGEND

Groundwater Quality Monitoring Program,

GEOLOGIC FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF BELLFLOWER AQUICLUDE (DASHED WHERE LOCATION IS APPROXIMATE)
- 60 — LINES OF EQUAL THICKNESS OF THE BELLFLOWER AQUICLUDE (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE BELLFLOWER AQUICLUDE IS ABSENT AND THE AQUIFERS PRESENT ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE
- KNOWN AREAS WHERE THE BELLFLOWER AQUICLUDE IS COMPOSED LARGELY OF SANDY AND GRAVELLY CLAY
- BOUNDARY OF THE GASPUR AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

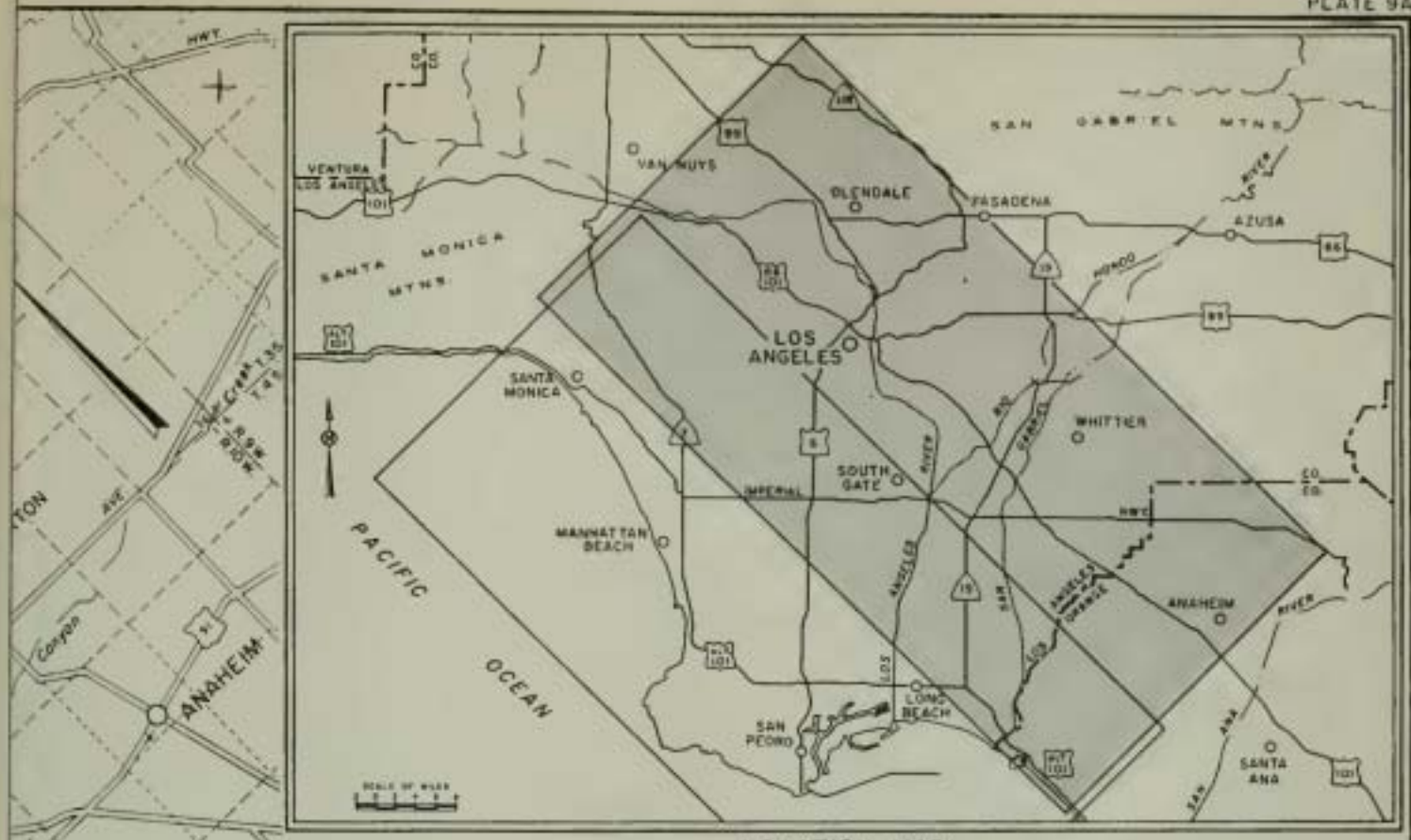
LINES OF EQUAL THICKNESS OF THE BELLFLOWER AQUICLUDE

SCALE OF MILES
1 0 1 2 3

(SE)

AR0069099

AR0069100



LOCATION MAP

LEGEND

Groundwater Quality Monitoring Program,

GEOLOGIC FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF BELLFLOWER AQUICLUDE (DASHED WHERE LOCATION IS APPROXIMATE)
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- KNOWN AREAS WHERE THE BELLFLOWER AQUICLUDE IS COMPOSED LARGELY OF SANDY AND GRAVELLY CLAY
- BOUNDARY OF THE GASPUR AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE BELLFLOWER AQUICLUDE

SCALE OF MILES

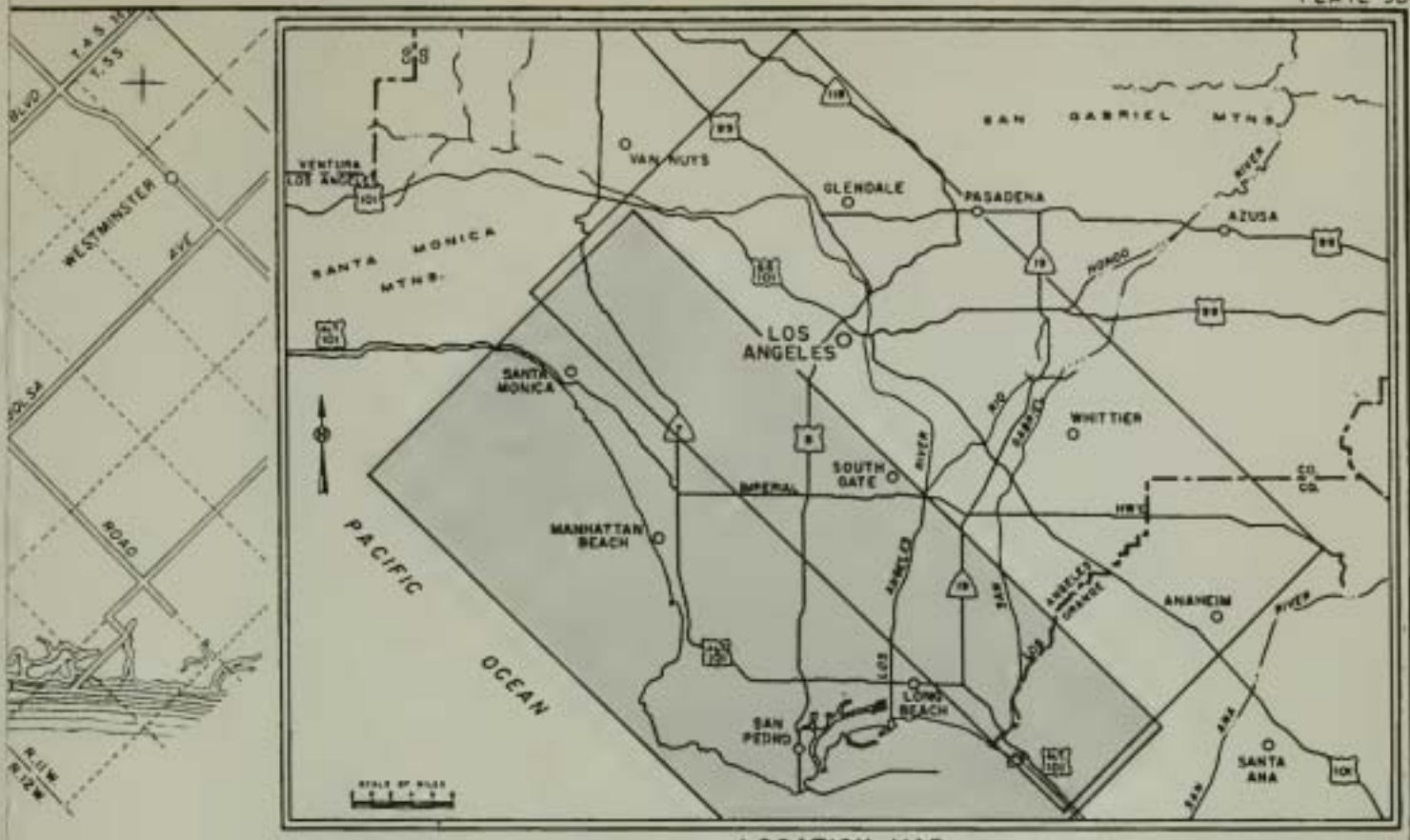
0 1 2 3

1961

AR0069101

Groundwater Quality Monitoring Program
GROUND WATER BASINS OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL THICKNESS
OF THE BELLFLOWER AQUICLUDE

AR0069102



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

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- KNOWN AREAS WHERE THE BELLFLOWER AQUICLUDE IS COMPOSED LARGELY OF SANDY AND GRAVELLY CLAY
- BOUNDARY OF THE GASPUR AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

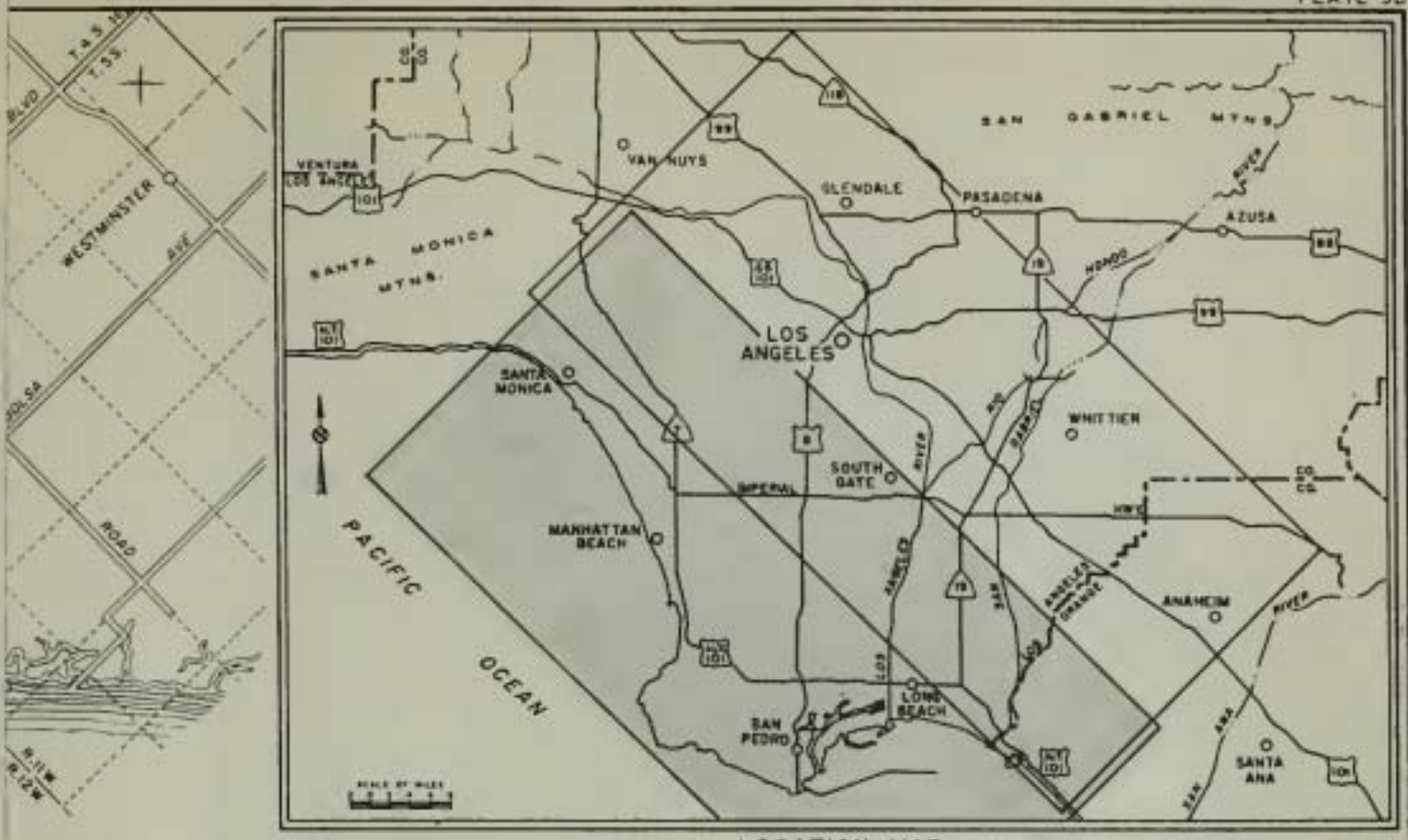
LINES OF EQUAL THICKNESS OF THE BELLFLOWER AQUICLUDE

SCALE OF MILES
1 0 1 2 3

1961

AR0069103

AR0069104



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

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- BOUNDARY OF THE GASPUR AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE BELLFLOWER AQUICLUDE

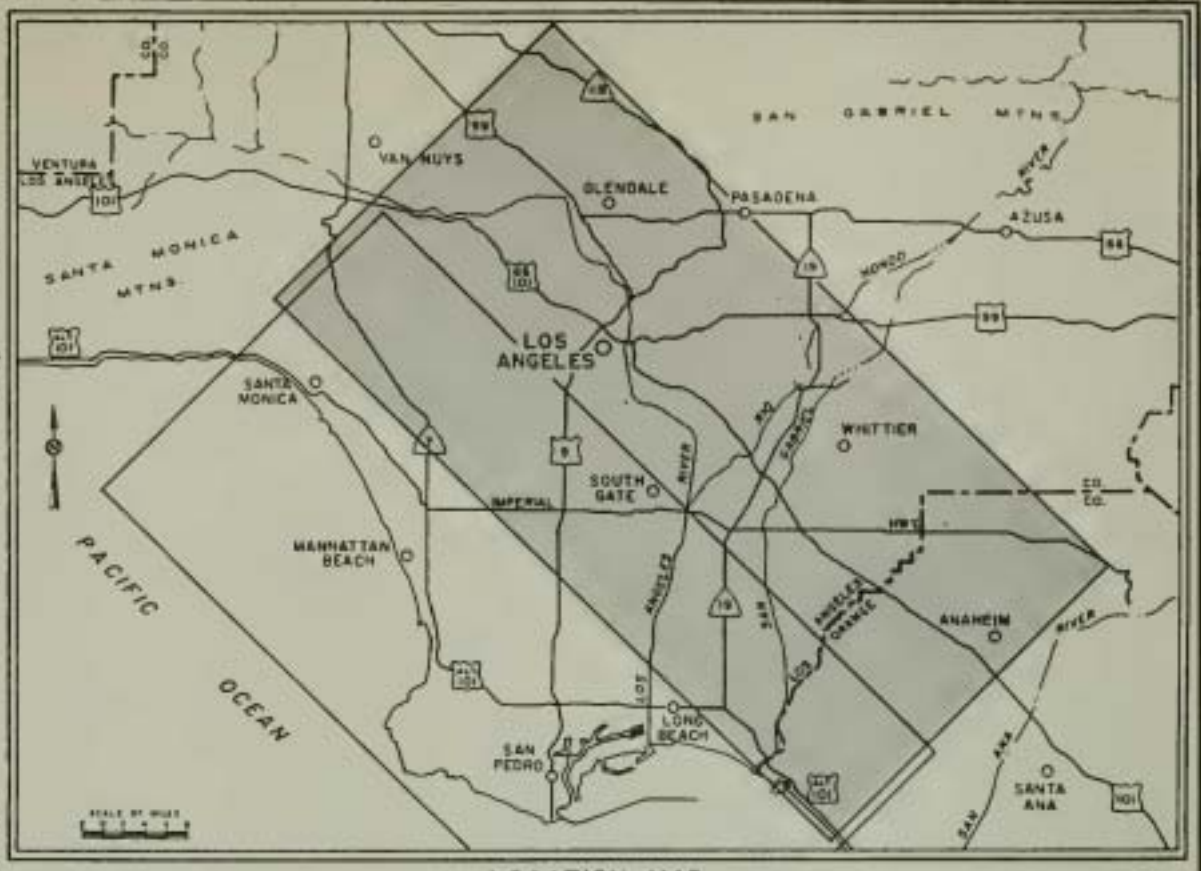
SCALE OF MILES
1 0 1 2 3

1961

AR0069105

PACIFIC
OCEAN
LOCATION MAP
LINES OF EQUAL THICKNESS
OF THE BELLFLOWER AQUICLUDE

AR0069106



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- -60- LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER
- KNOWN AREAS WHERE AQUIFERS ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

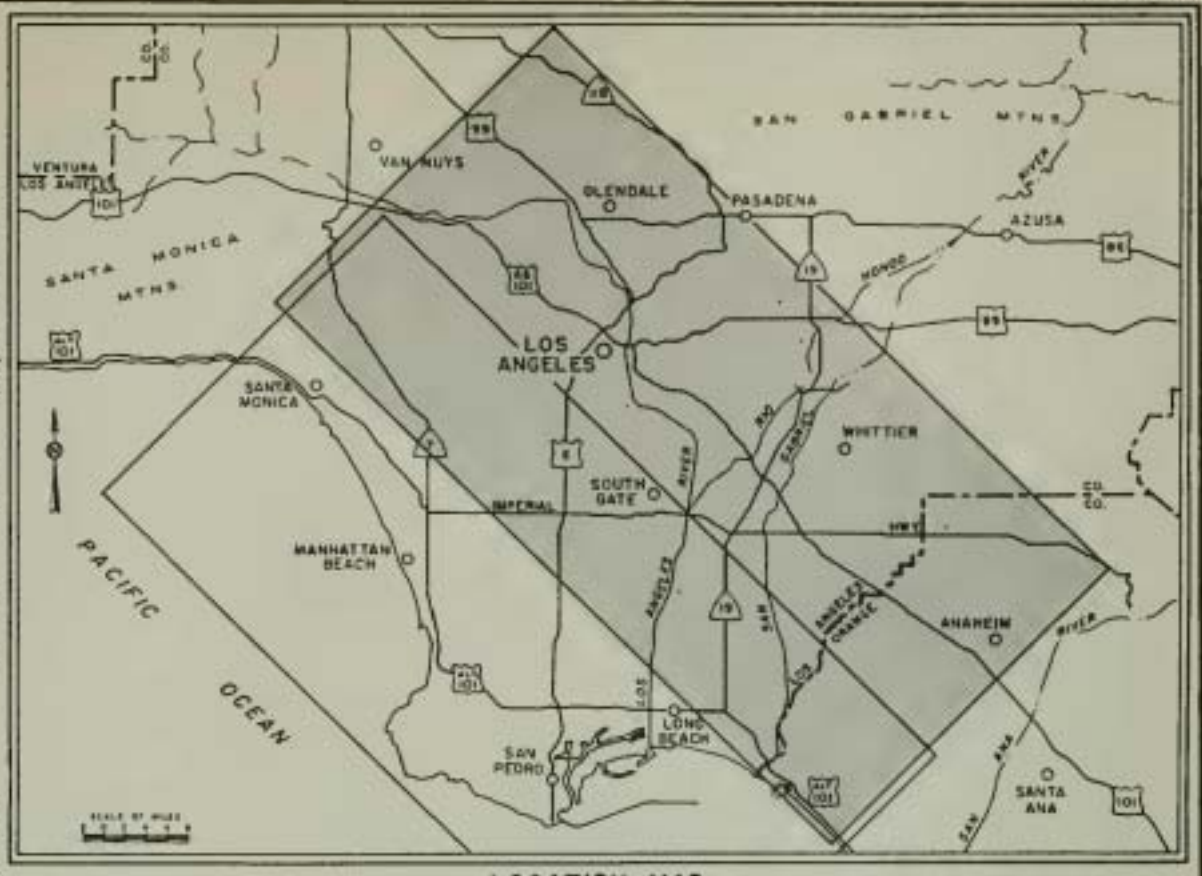
LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

SCALE OF MILES
0 1 2 3

1961

AR0069107

AR0069108



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- -60- LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER
- KNOWN AREAS WHERE AQUIFERS ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

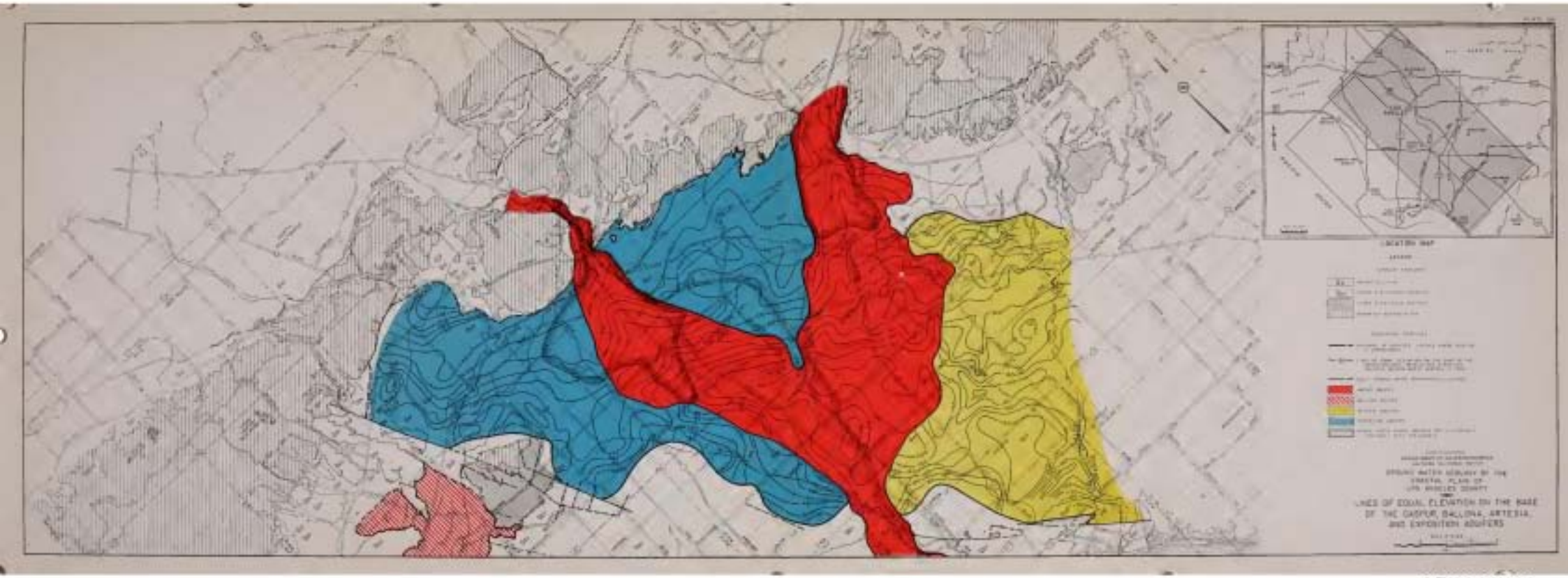
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

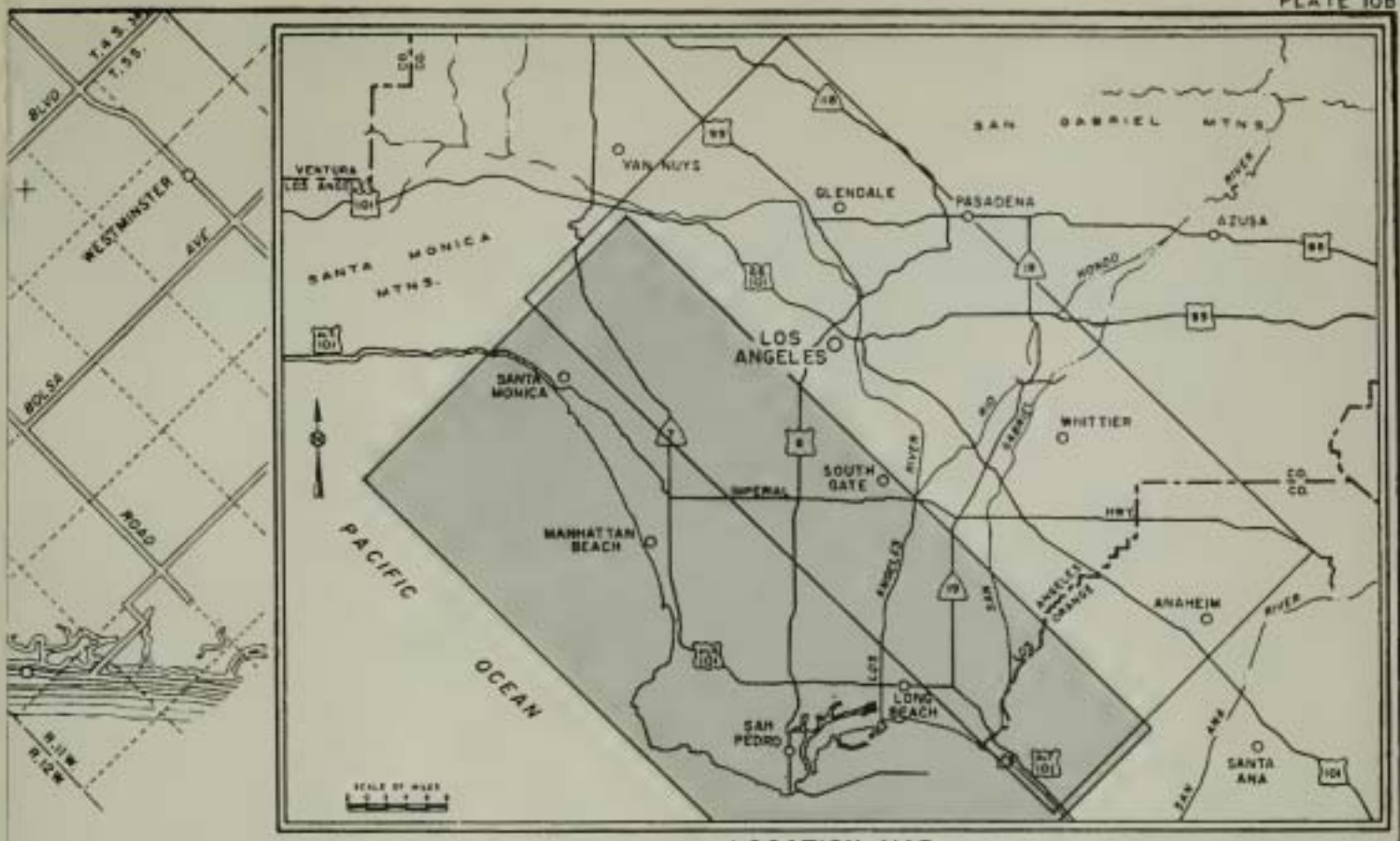
SCALE OF MILES
0 1 2 3

1961

AR0069109


LOCATION MAP
LINES OF EQUAL ELEVATION ON THE BASE
OF THE GAGE, BALDWIN, ARTESIA,
AND EXPOSITION AQUIFERS

AR0069110



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- ~60~ LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER
- KNOWN AREAS WHERE AQUIFERS ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

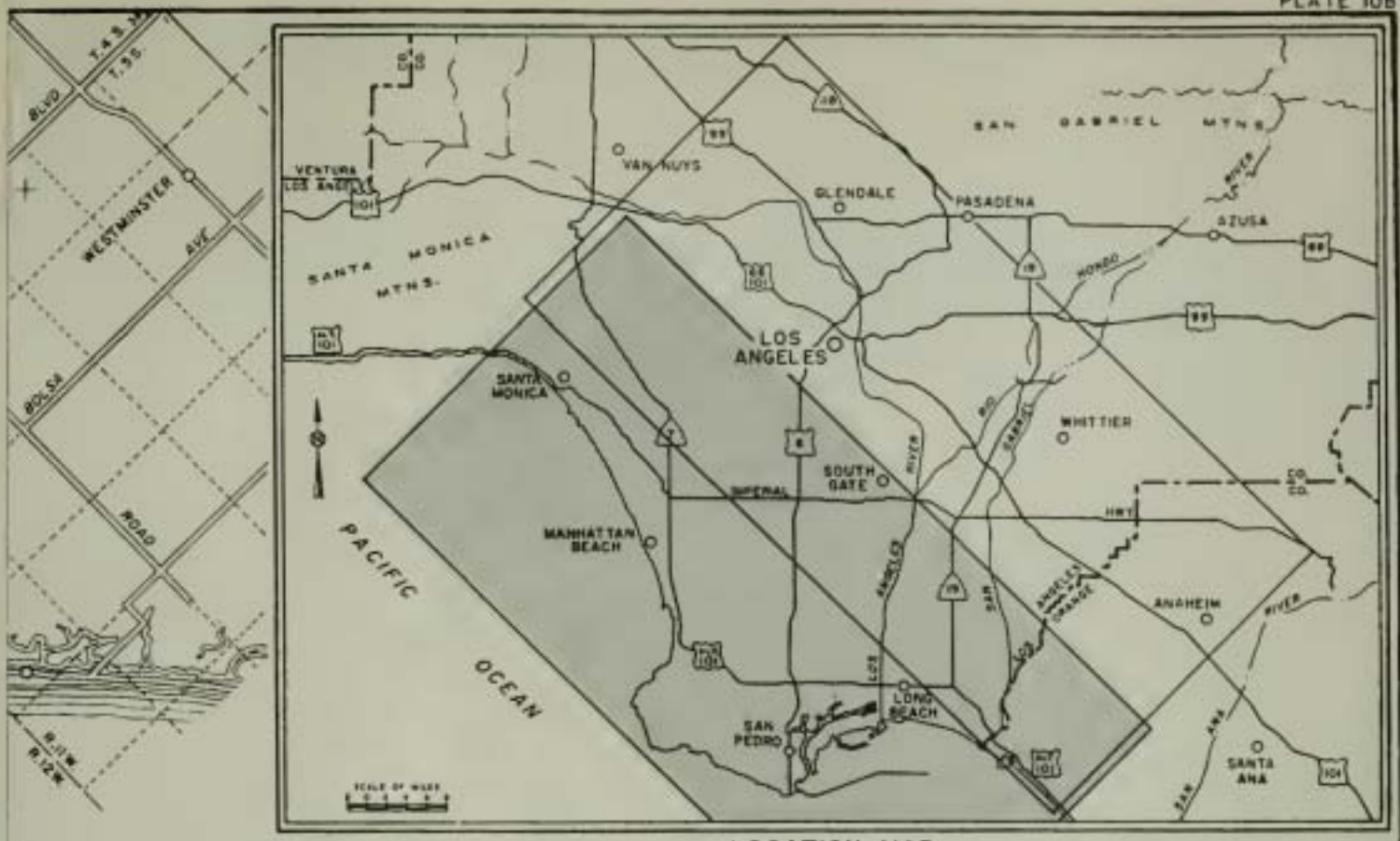
LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

SCALE OF MILES
1 0 1 2 3

1961

AR0069111

AR0069112



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- ~60~ LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER
- KNOWN AREAS WHERE AQUIFERS ARE IN HYDRAULIC CONTINUITY WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

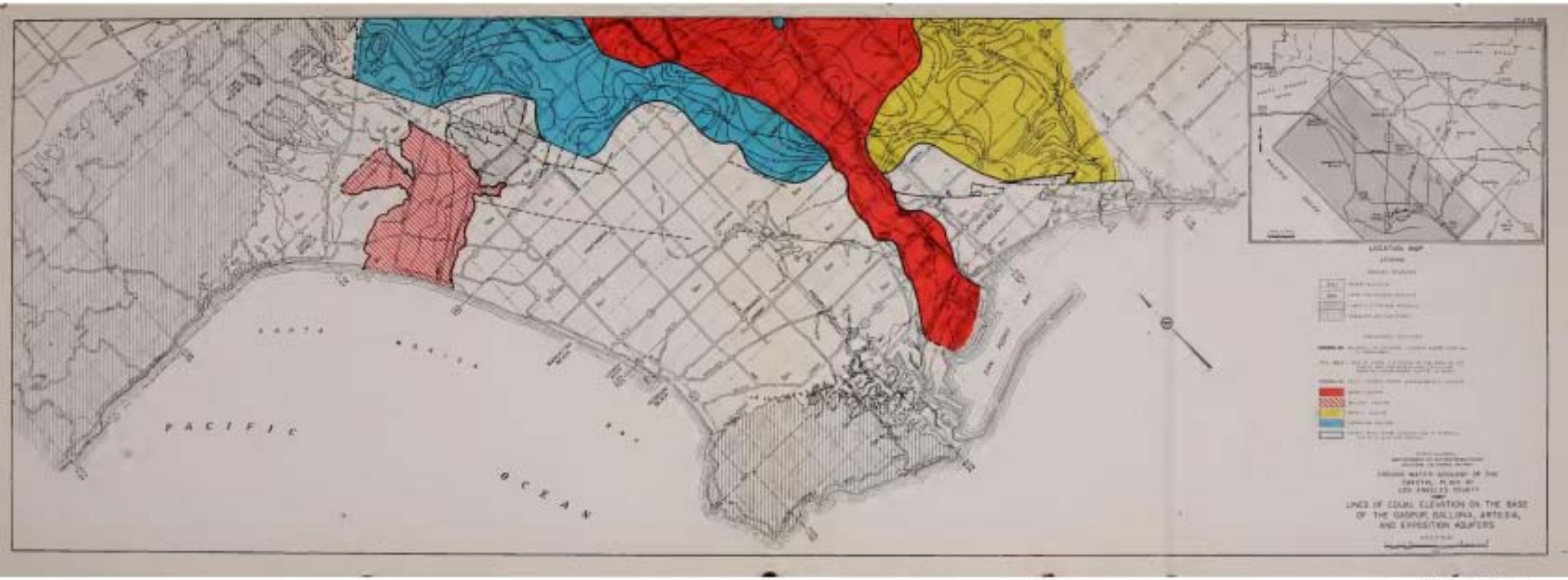
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

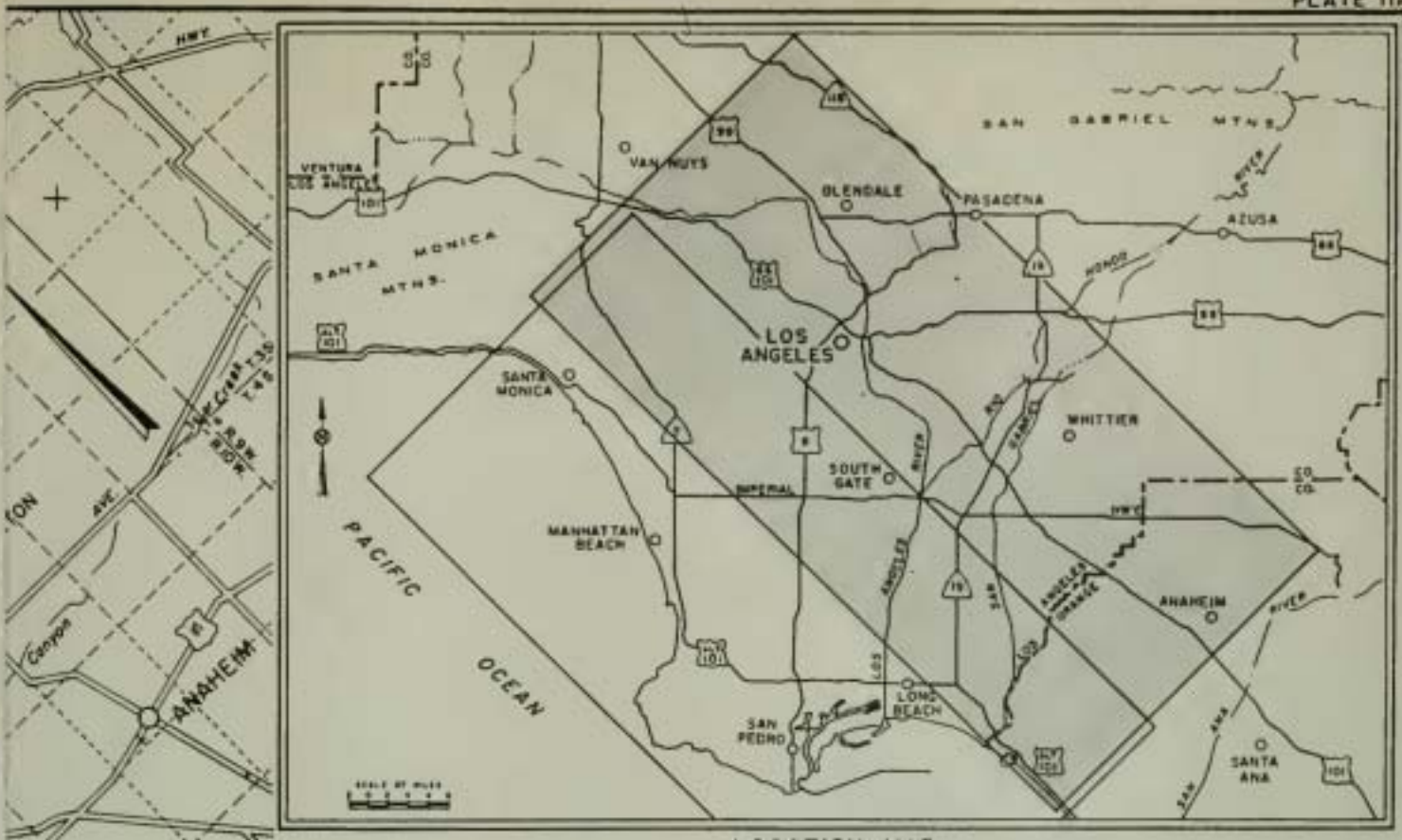
SCALE OF MILES
1 0 1 2 3

1961

AR0069113


PACIFIC
OCEAN
LOCATION MAP
LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE, BALDWIN, ARTESIA, AND EXPOSITION AQUIFERS

AR0069114



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 80 — LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

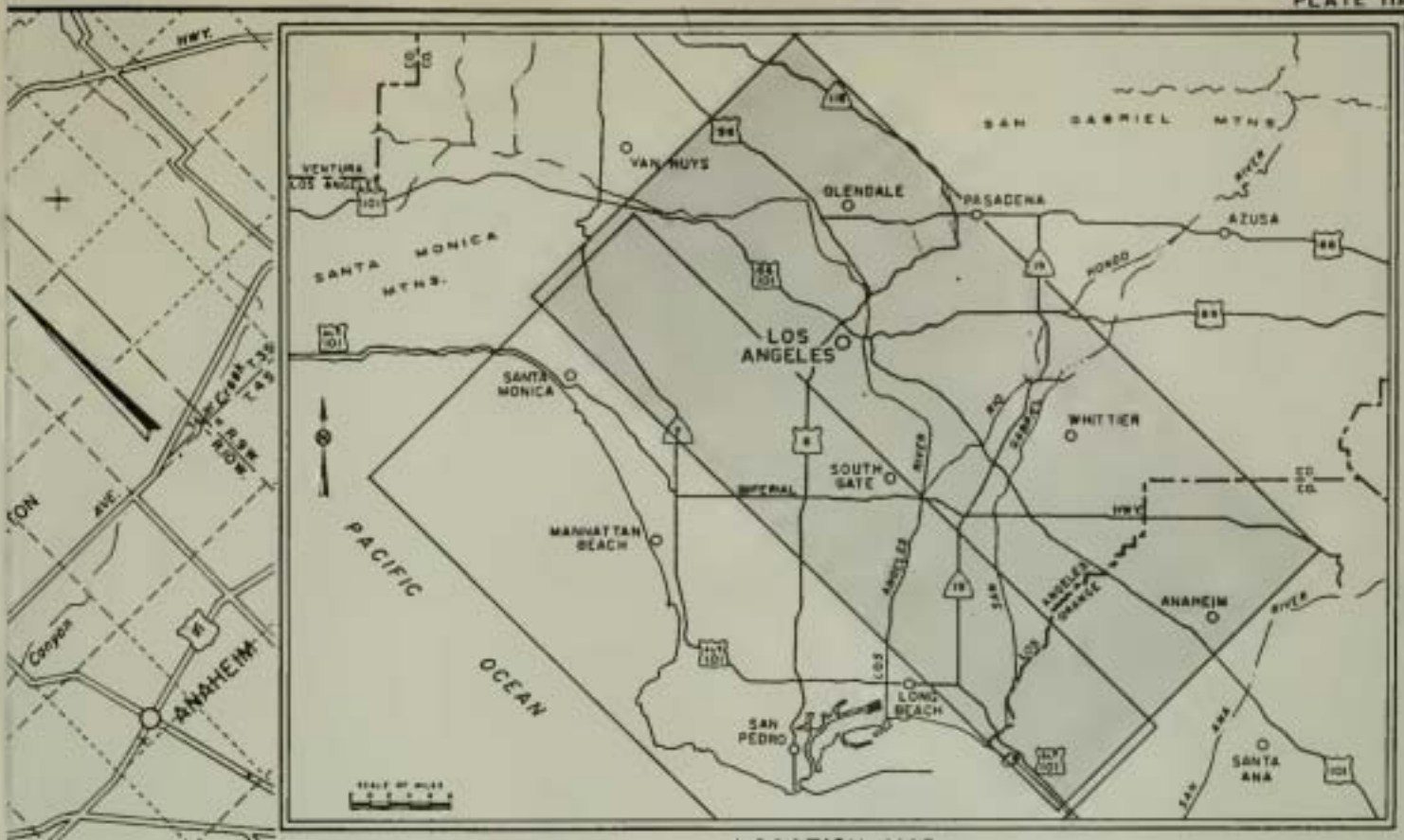
LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

SCALE OF MILES
0 1 2 3

1961

AR0069115

AR0069116



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 80 — LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

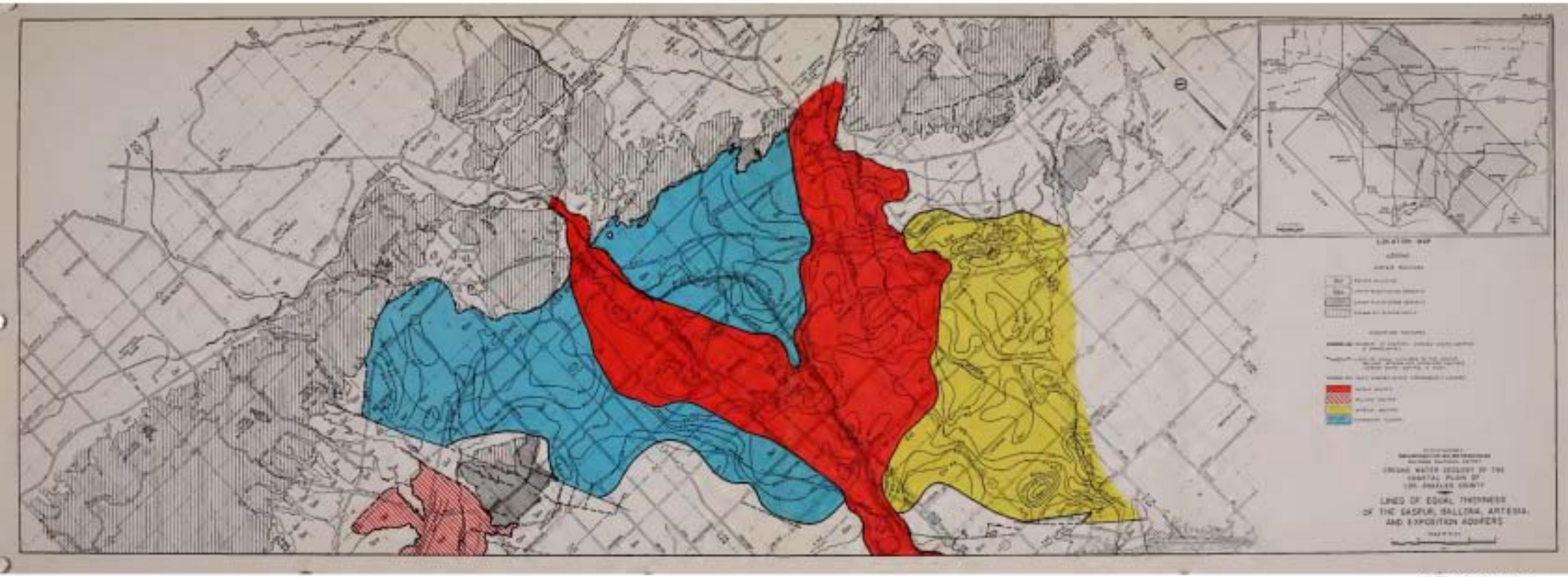
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

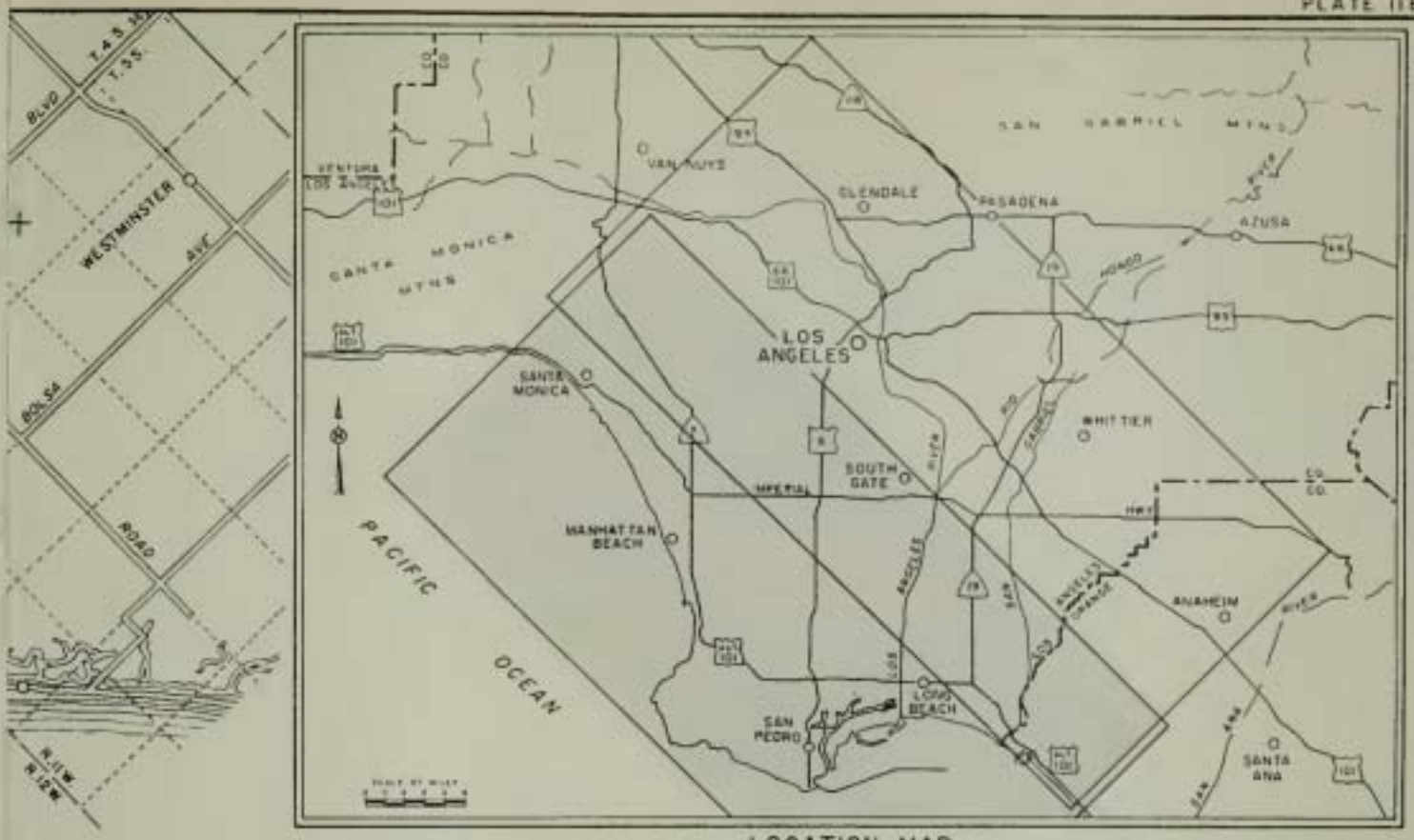
SCALE OF MILES
1 0 1 2 3

1961

AR0069117


LINES OF EQUAL THICKNESS
OF THE GASPUR, GALLONA, ARTESIA,
AND EXPOSITION AQUIFERS

AR0069118



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 80 — LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

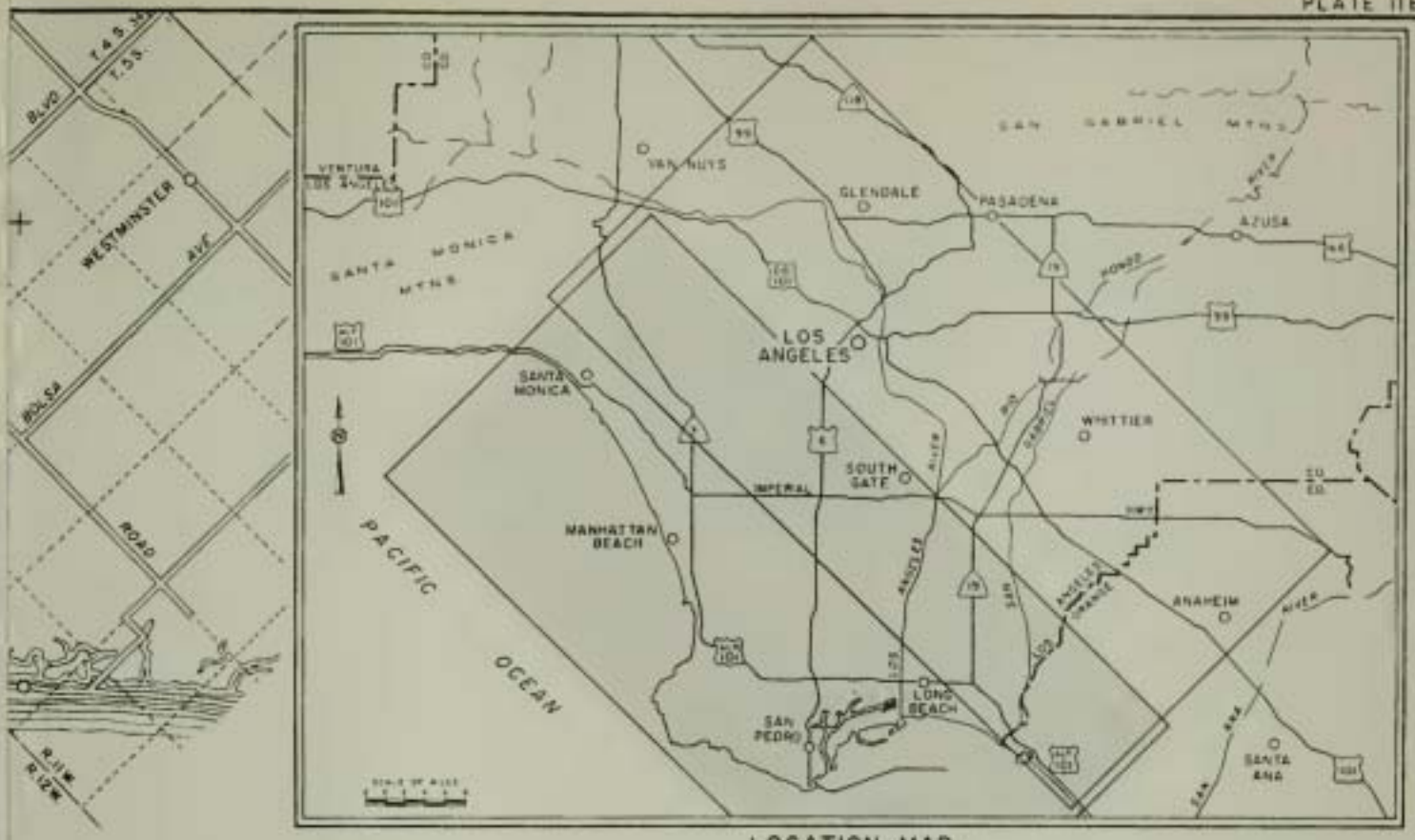
LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

SCALE OF MILES

1961

AR0069119

AR0069120



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 80 — LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GASPUR AQUIFER
- BALLONA AQUIFER
- ARTESIA AQUIFER
- EXPOSITION AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

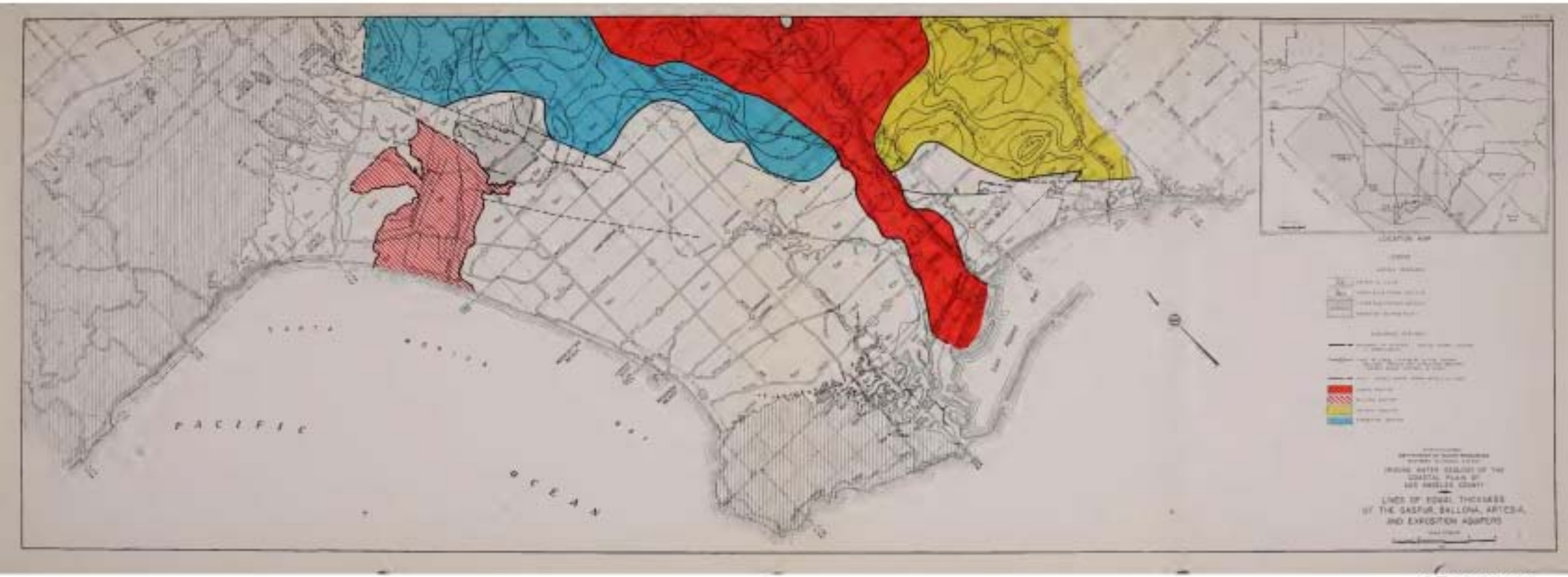
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE GASPUR, BALLONA, ARTESIA, AND EXPOSITION AQUIFERS

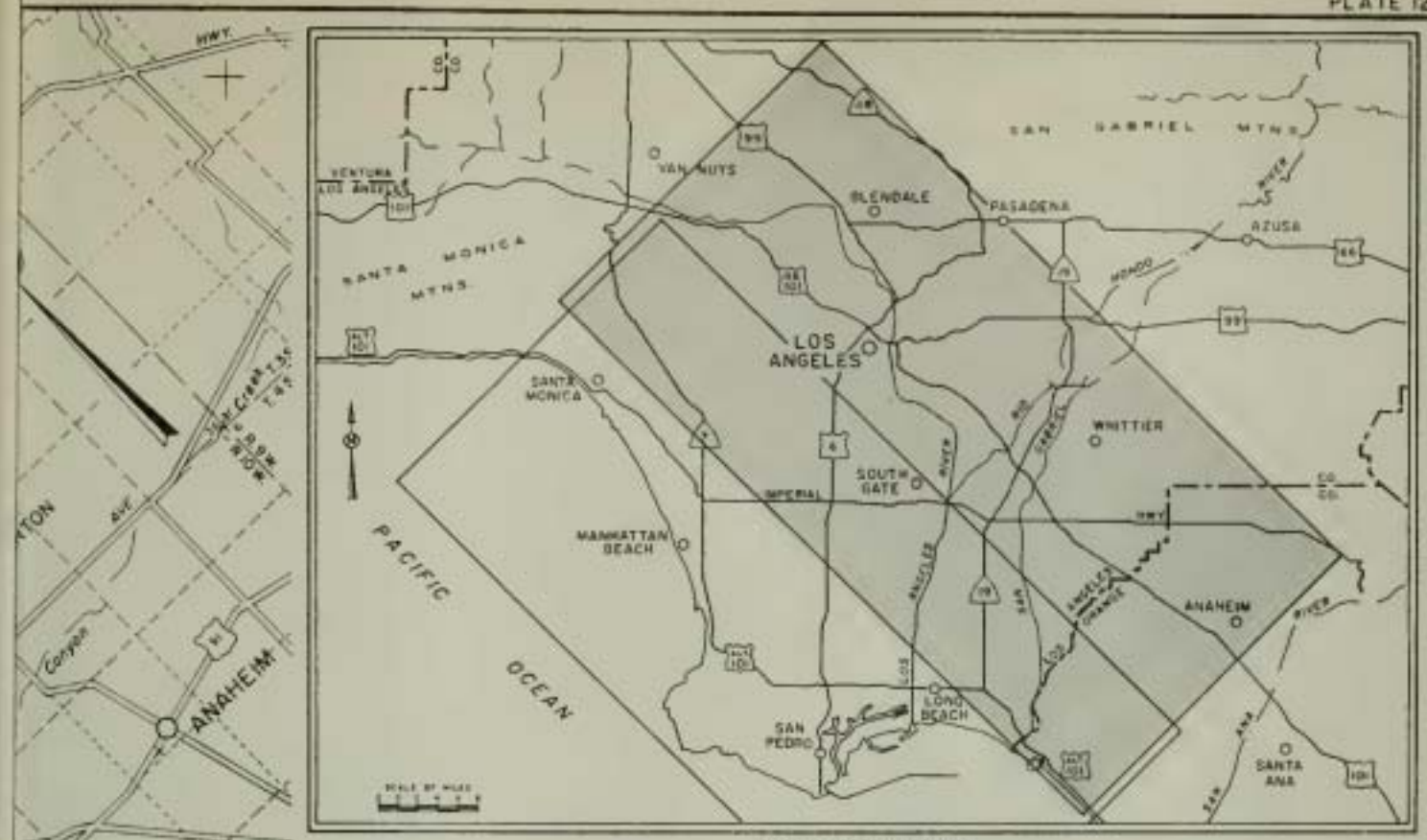
SCALE OF MILES
0 1 2 3

1961

AR0069121



AR0069122



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER
- KNOWN AREAS WHERE THE GAGE AND GARDENA AQUIFERS ARE MERGED WITH THE OVERLYING AQUIFER OR WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS

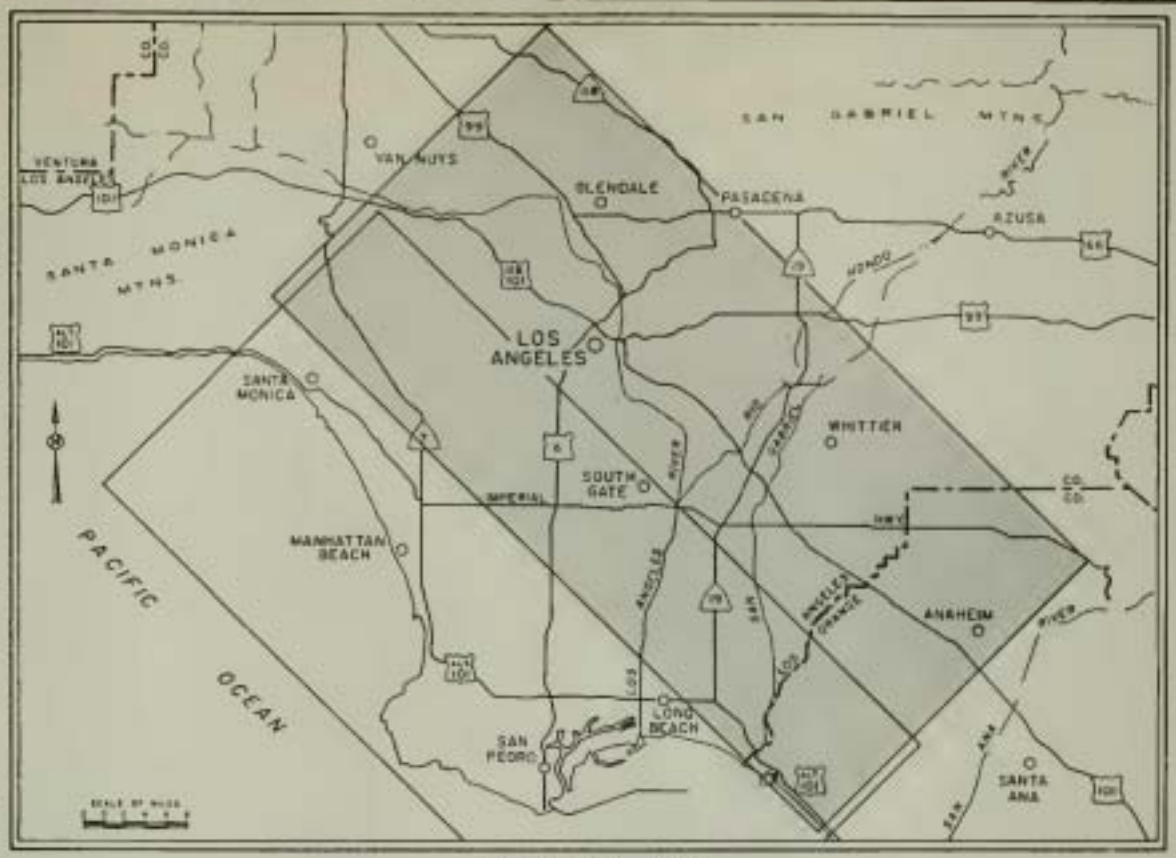
SCALE OF MILES

0 1 2 3

1961

AR0069123

AR0069124



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER
- KNOWN AREAS WHERE THE GAGE AND GARDENA AQUIFERS ARE MERGED WITH THE OVERLYING AQUIFER OR WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

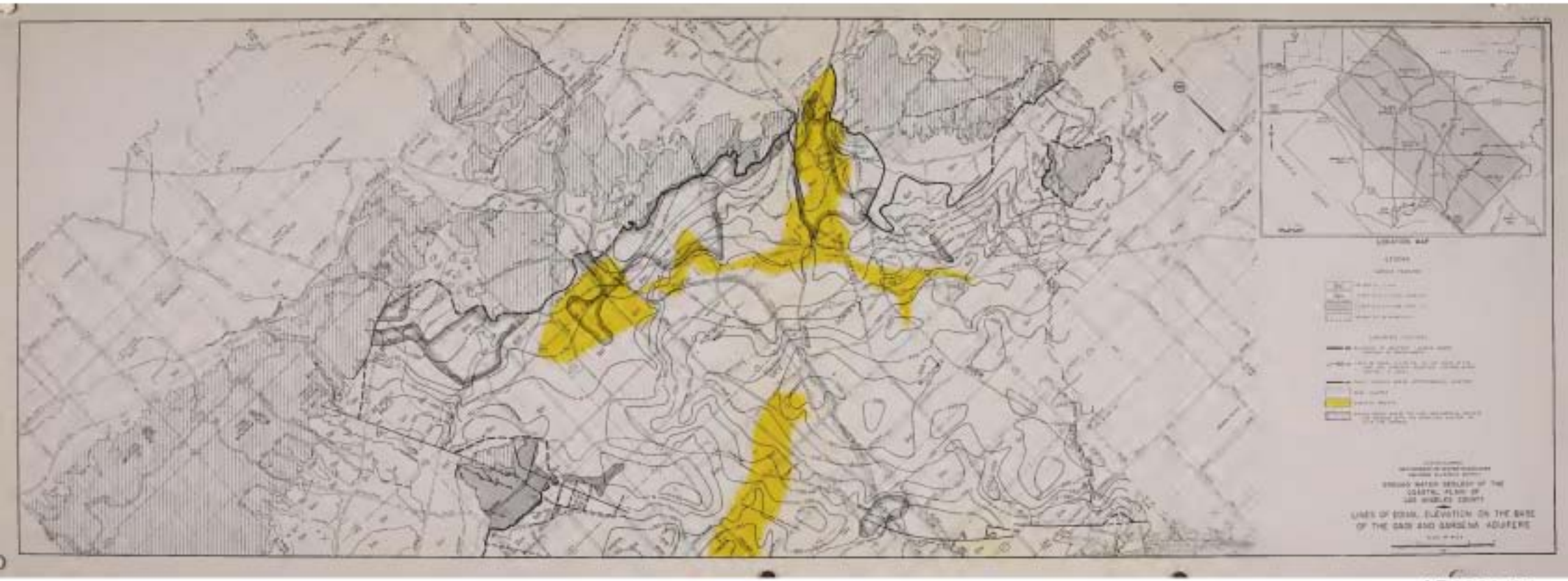
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS

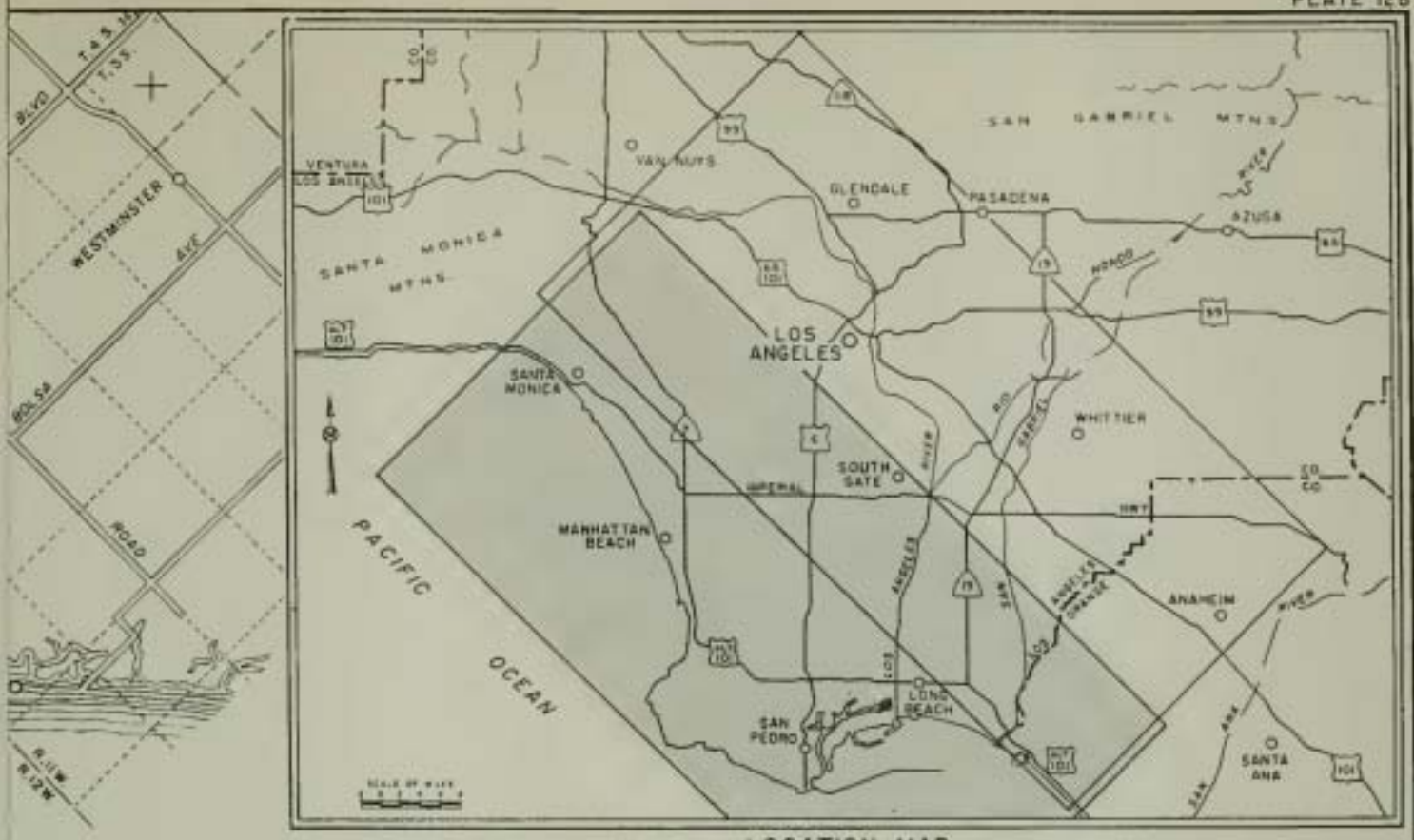
SCALE OF MILES
0 1 2 3

1961

AR0069125


LOCATION MAP
LEGEND
GROUND WATER BASINS OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL ELEVATION ON THE BASE
OF THE GAGE AND GAGE/HA AQUIFERS

AR0069126



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER
- KNOWN AREAS WHERE THE GAGE AND GARDENA AQUIFERS ARE MERGED WITH THE OVERLYING AQUIFER OR WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

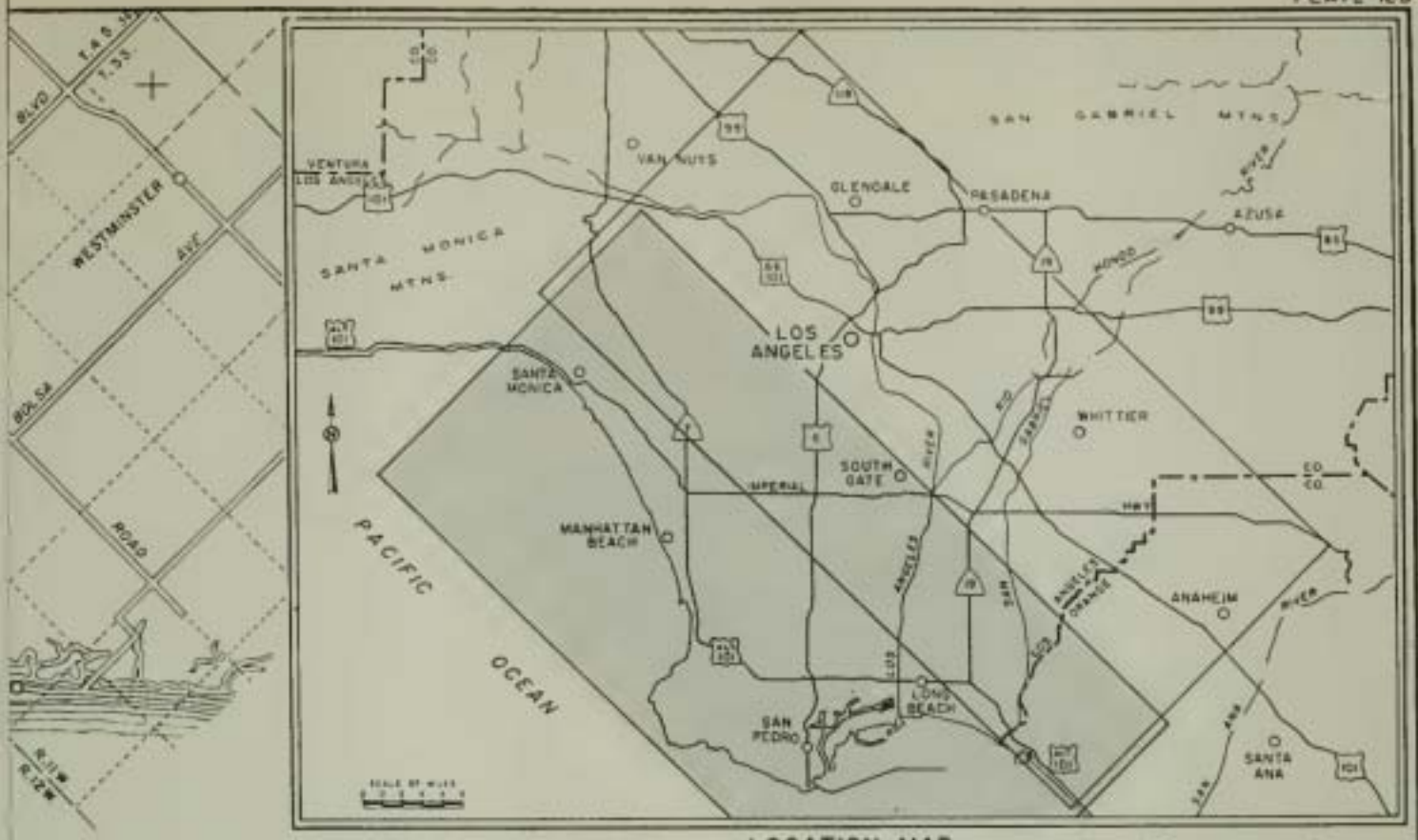
LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS

SCALE OF MILES
1 0 1 2 3

1961

AR0069127

AR0069128



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER
- KNOWN AREAS WHERE THE GAGE AND GARDENA AQUIFERS ARE MERGED WITH THE OVERLYING AQUIFER OR WITH THE SURFACE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

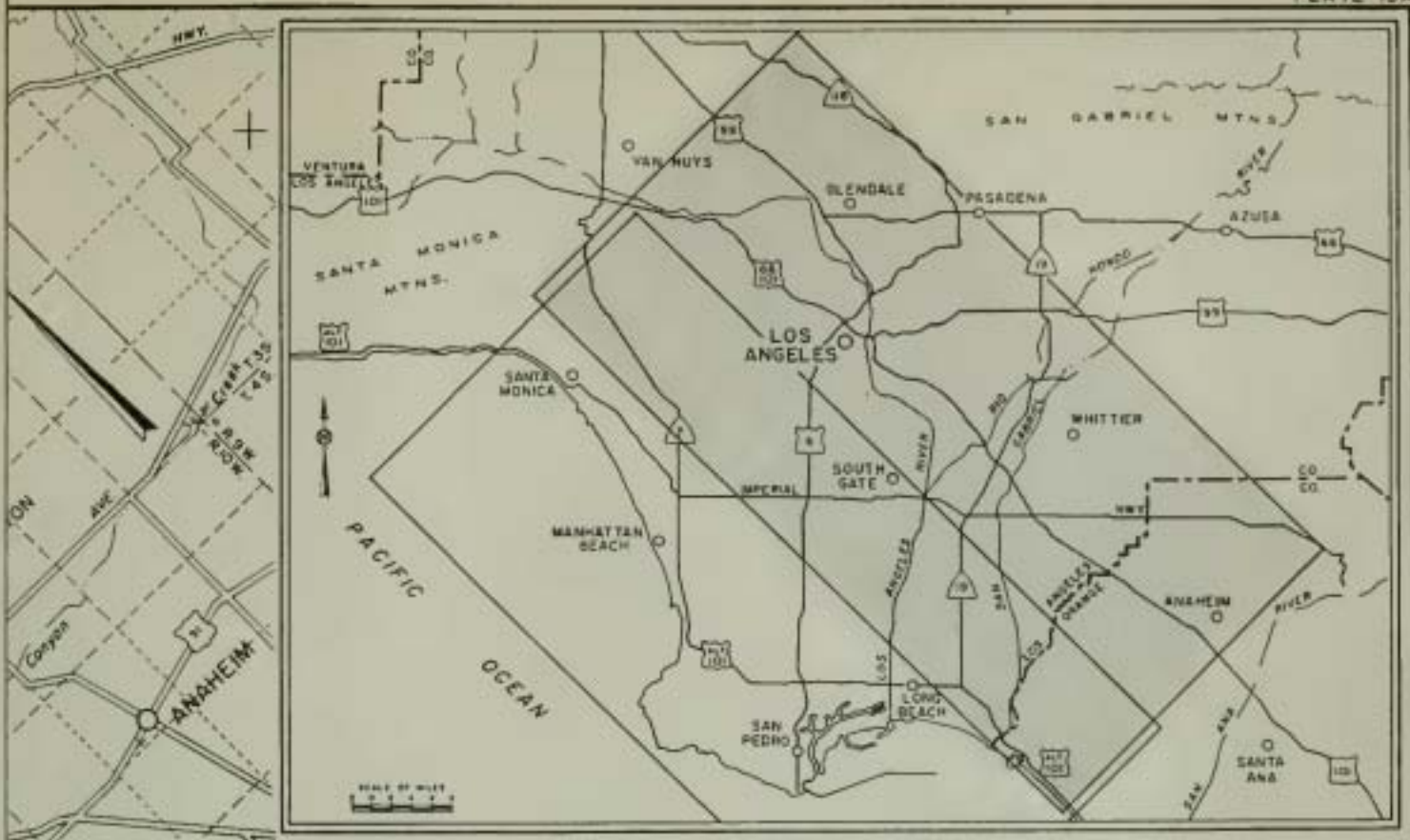
LINES OF EQUAL ELEVATION ON THE BASE OF THE GAGE AND GARDENA AQUIFERS

SCALE OF MILES
1 0 1 2 3

1961

AR0069129

AR0069130



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 60 — LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

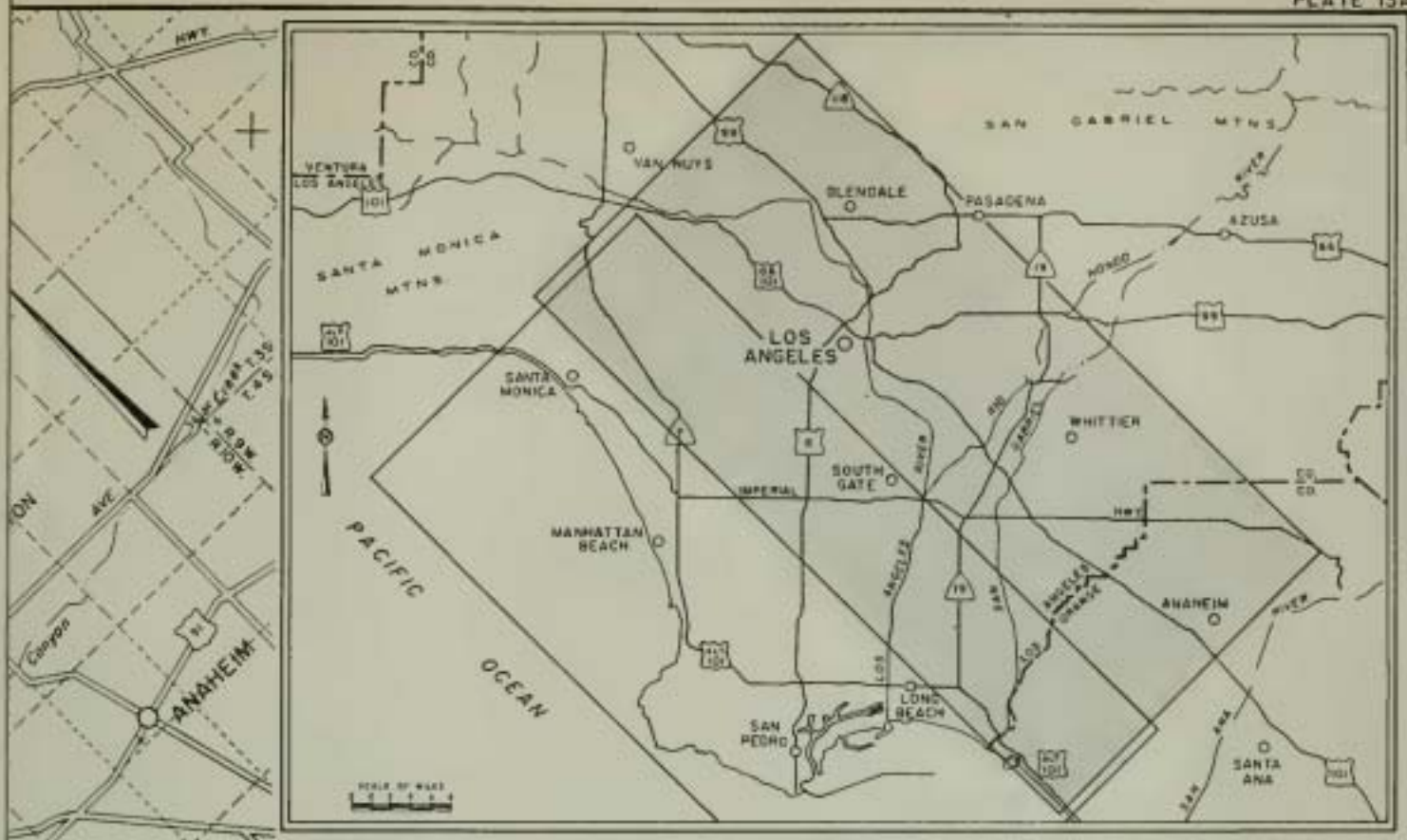
LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS

SCALE OF MILES
1 0 1 2 3

1961

AR0069131

AR0069132



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 60 — LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

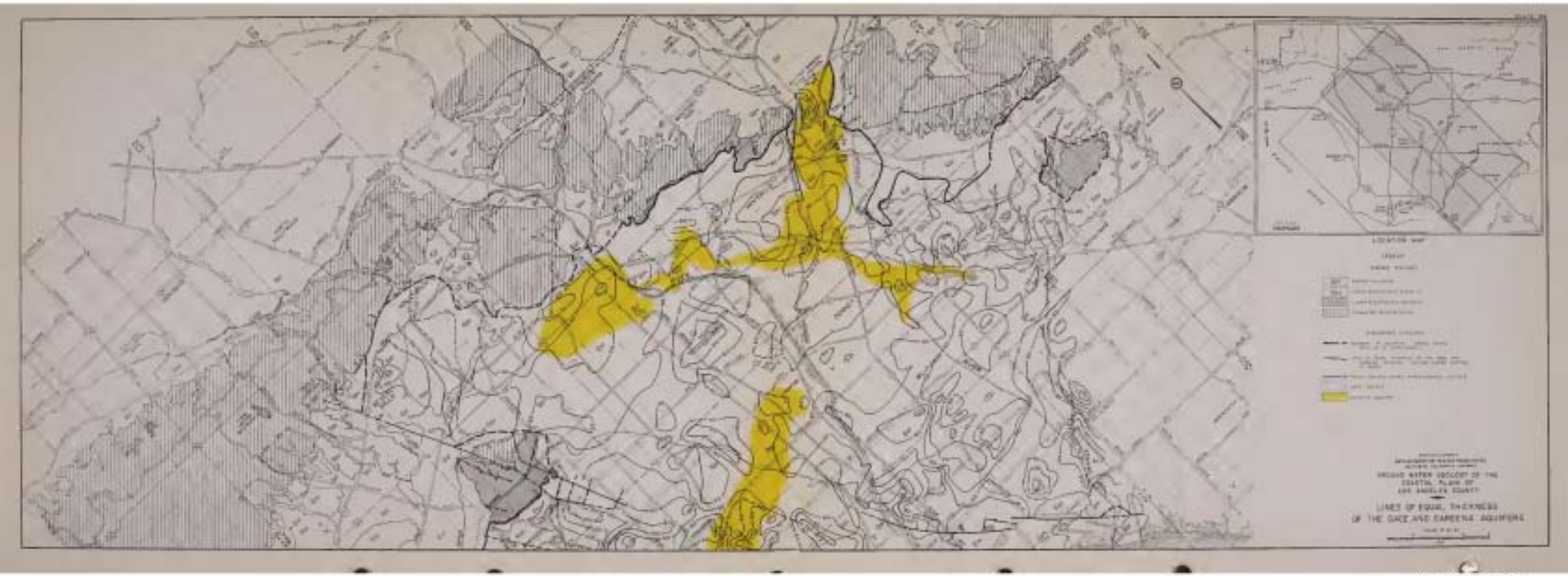
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS

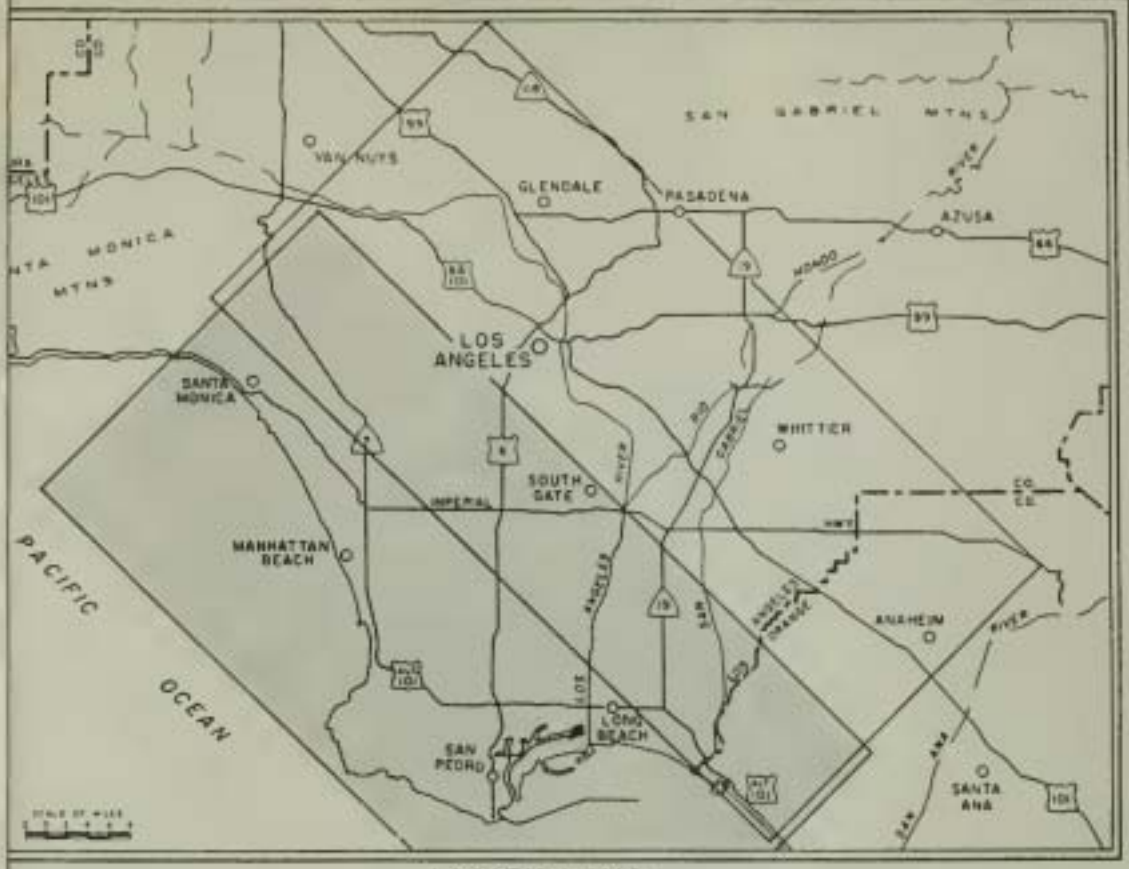
SCALE OF MILES
1 0 1 2 3

(961)

AR0069133



AR0069134



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 60 — LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

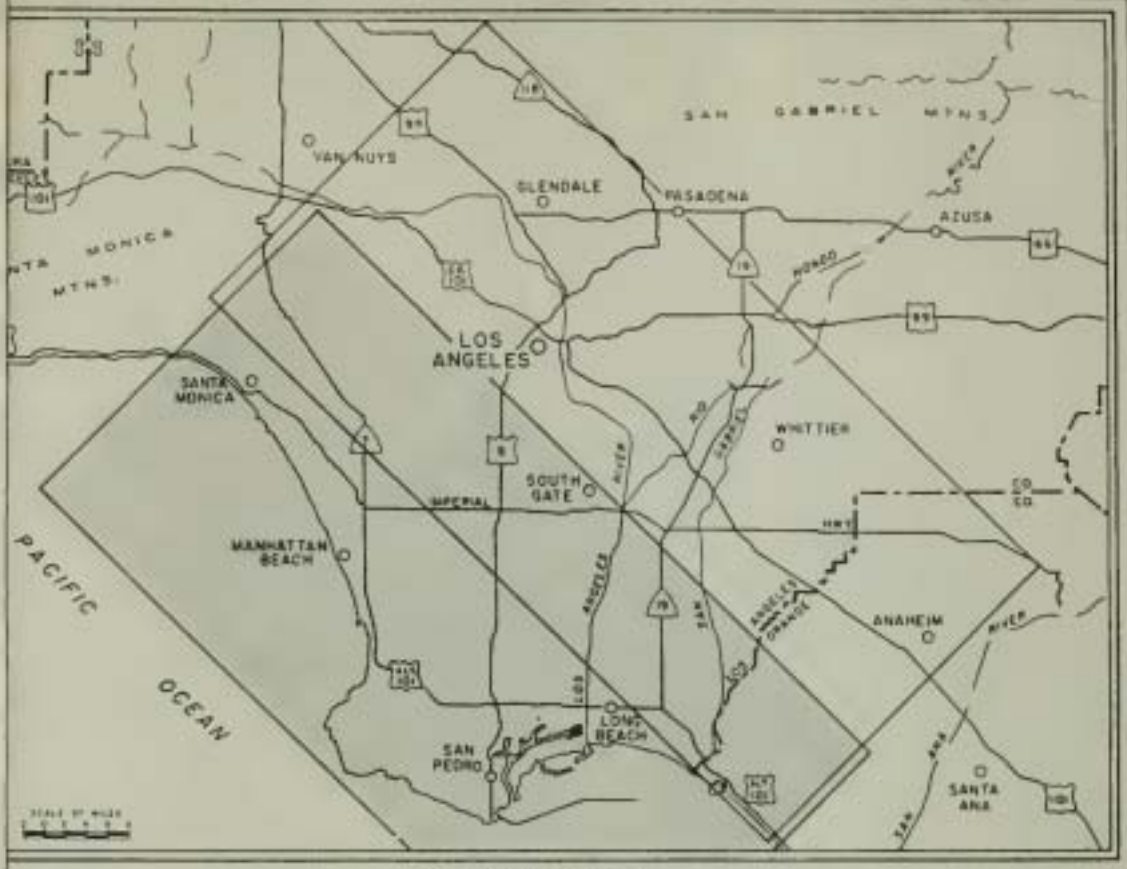
LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS

SCALE OF MILES
1 0 1 2 3

1961

AR0069135

AR0069136



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF AQUIFERS (DASHED WHERE LOCATION IS APPROXIMATE)
- 60 — LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- GAGE AQUIFER
- GARDENA AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE GAGE AND GARDENA AQUIFERS

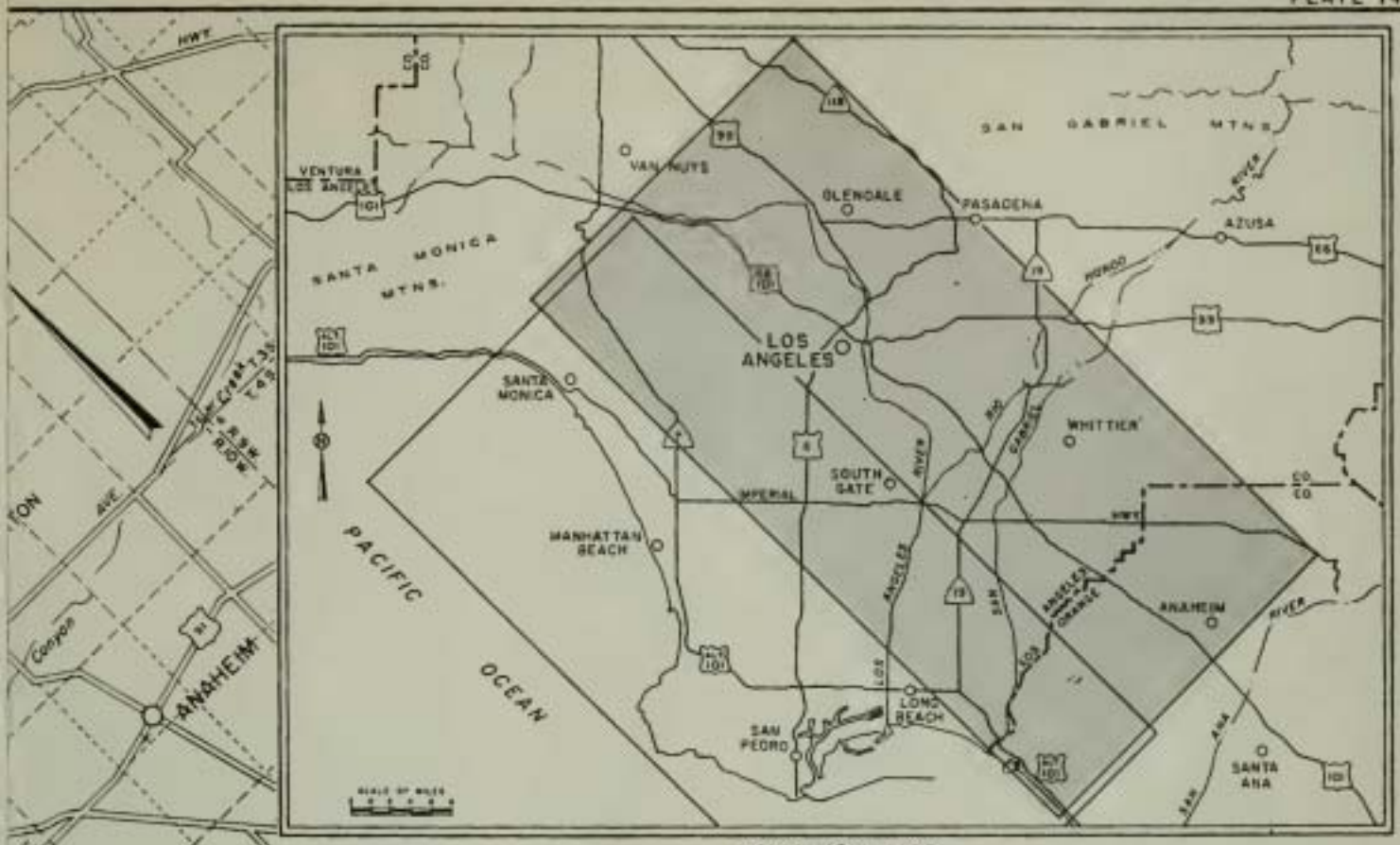
SCALE OF MILES
1 0 1 2 3

1961

AR0069137

PACIFIC
OCEAN
LINES OF EQUAL THICKNESS
OF THE SAND AND GARDENA AQUIFERS

AR0069138



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF HOLLYDALE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE HOLLYDALE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE HOLLYDALE AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

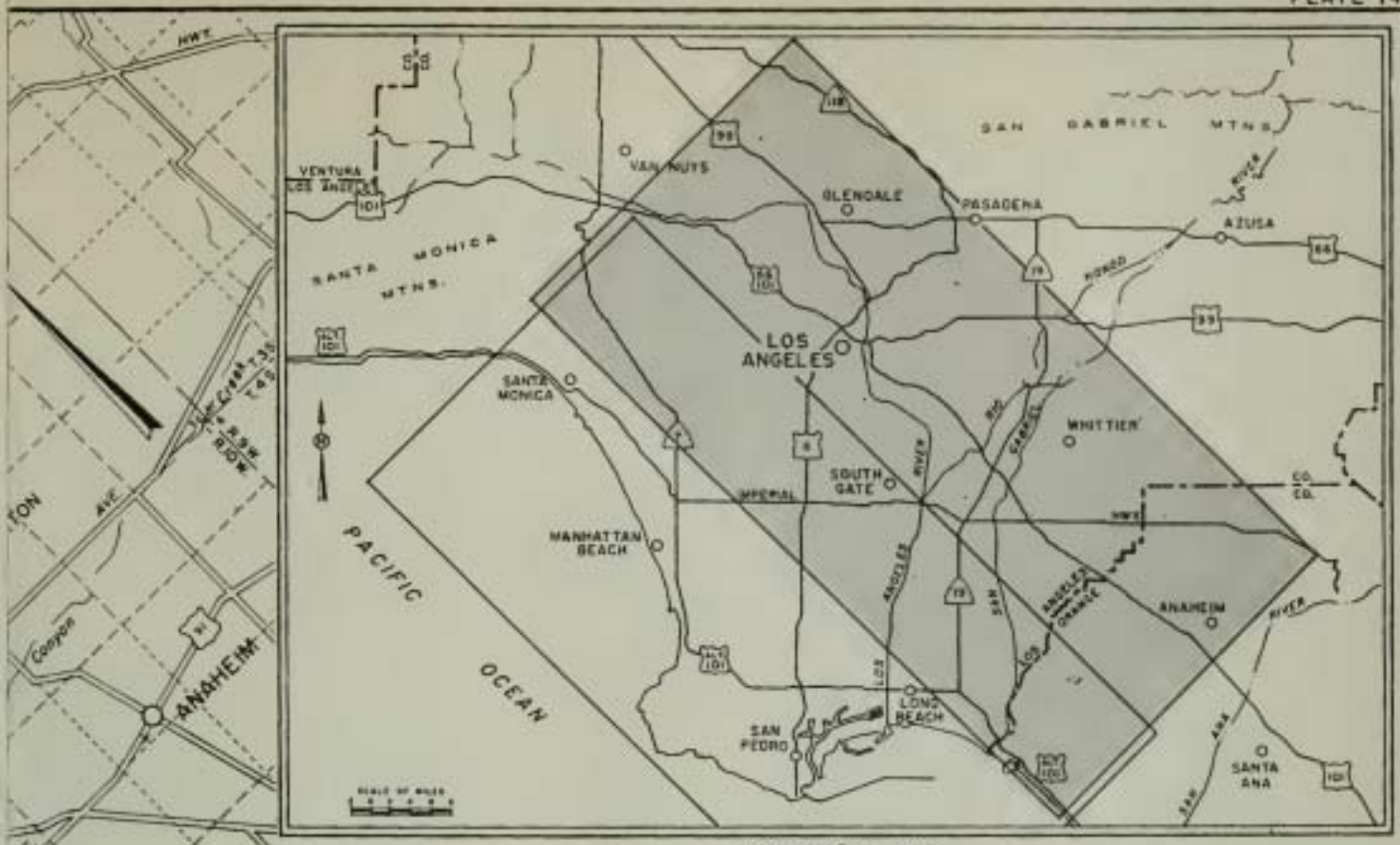
LINES OF EQUAL ELEVATION ON THE BASE OF THE HOLLYDALE AQUIFER

SCALE OF MILES
1 0 1 2 3

1961

AR0069139

AR0069140



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF HOLLYDALE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE HOLLYDALE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE HOLLYDALE AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE HOLLYDALE AQUIFER

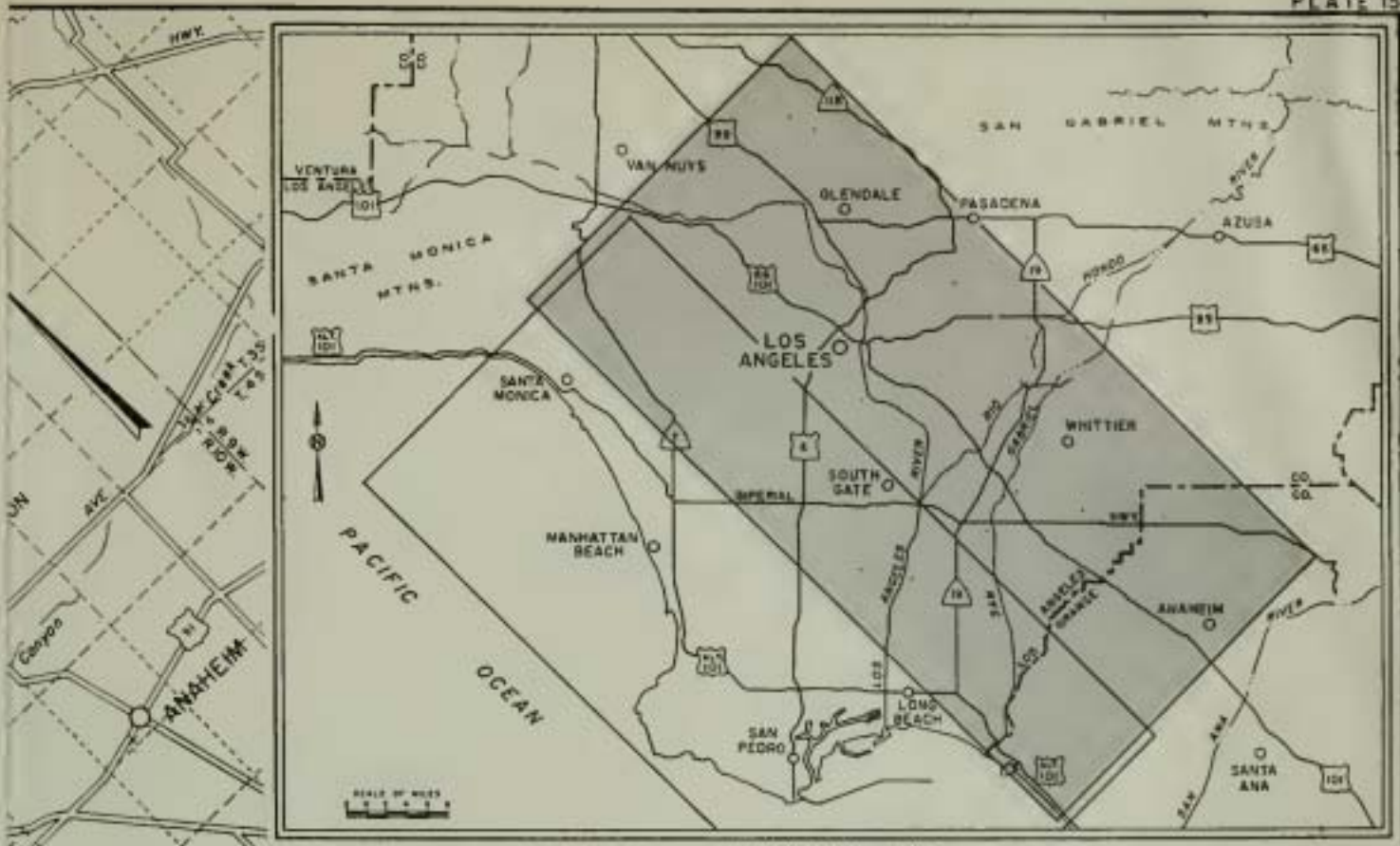
SCALE OF MILES
1 0 1 2 3

1961

AR0069141

LOCATION MAP
LEGEND
LINES OF EQUAL ELEVATION ON THE BASE
OF THE HOLLYDALE AQUIFER

AR0069142



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF HOLLYDALE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 80 — LINES OF EQUAL THICKNESS ON THE BASE OF THE HOLLYDALE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

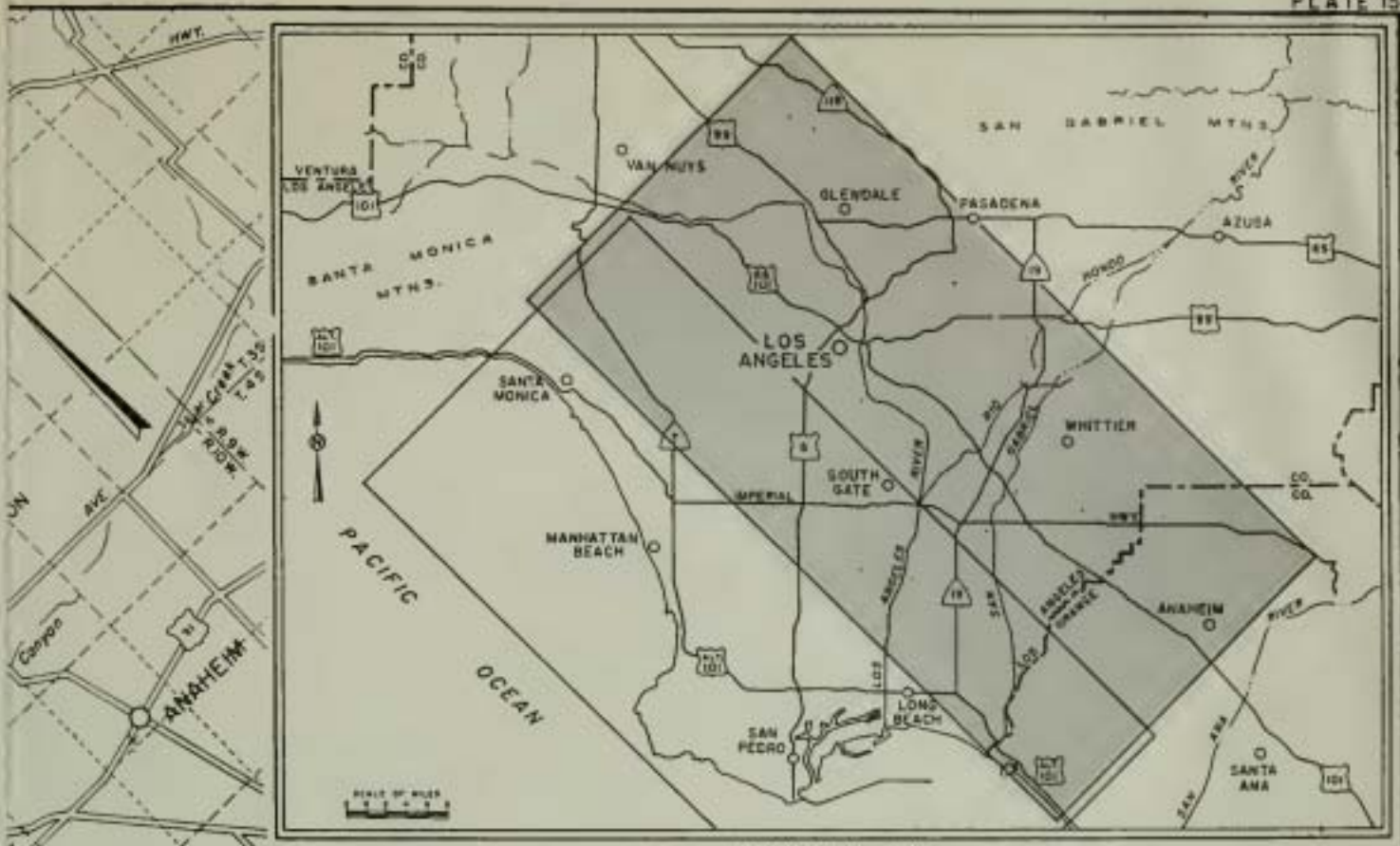
LINES OF EQUAL THICKNESS OF THE HOLLYDALE AQUIFER

SCALE OF MILES
1 0 1 2 3

1961

AR0069143

AR0069144



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF HOLLYDALE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 80 — LINES OF EQUAL THICKNESS ON THE BASE OF THE HOLLYDALE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE HOLLYDALE AQUIFER

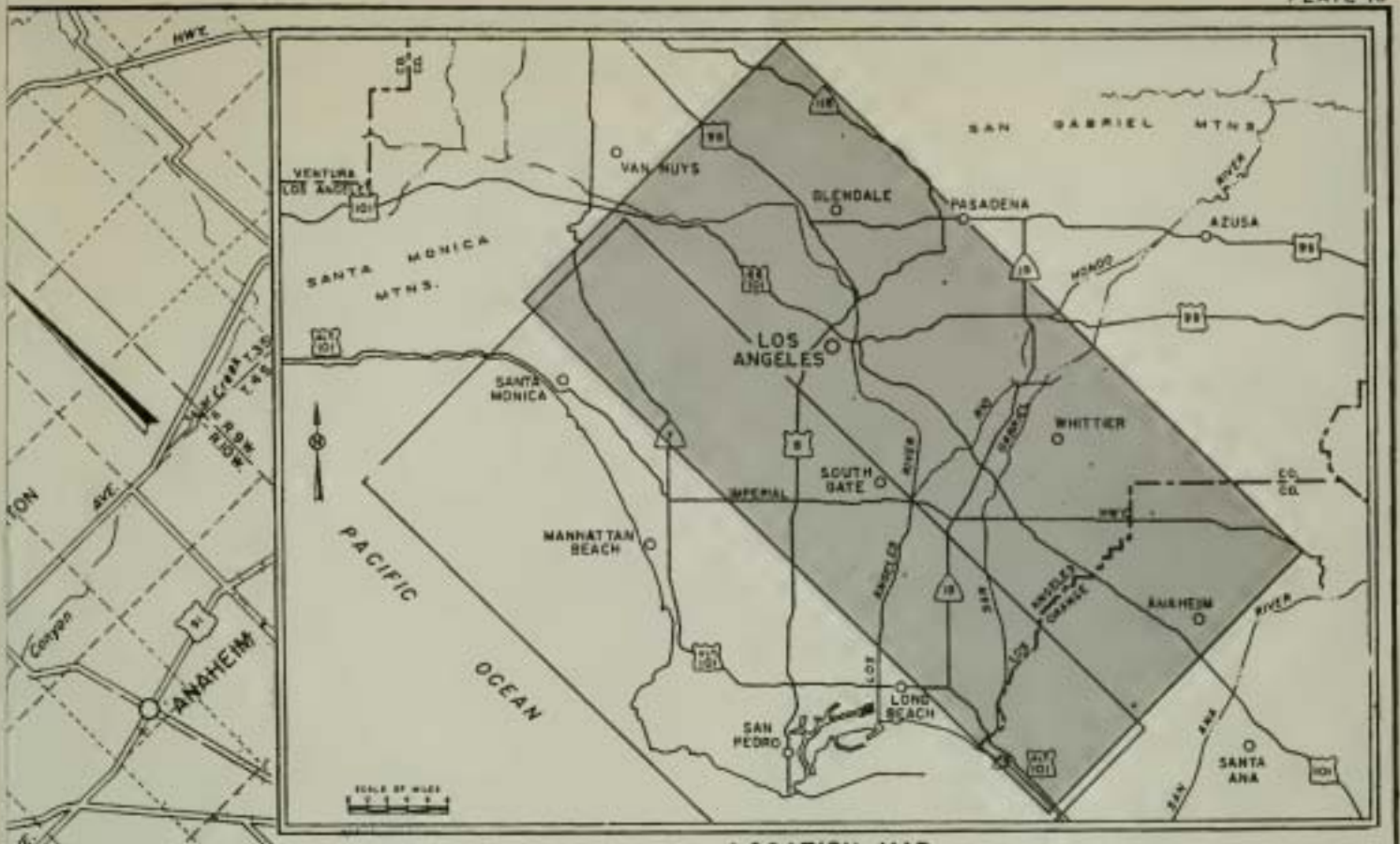
SCALE OF MILES
1 0 1 2 3

1961

AR0069145

LOCATION MAP
LINES OF EQUAL THICKNESS
OF THE HOLLYDALE SOURCE

AR0069146



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF JEFFERSON AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 50 — LINES OF EQUAL ELEVATION ON THE BASE OF THE JEFFERSON AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE JEFFERSON AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

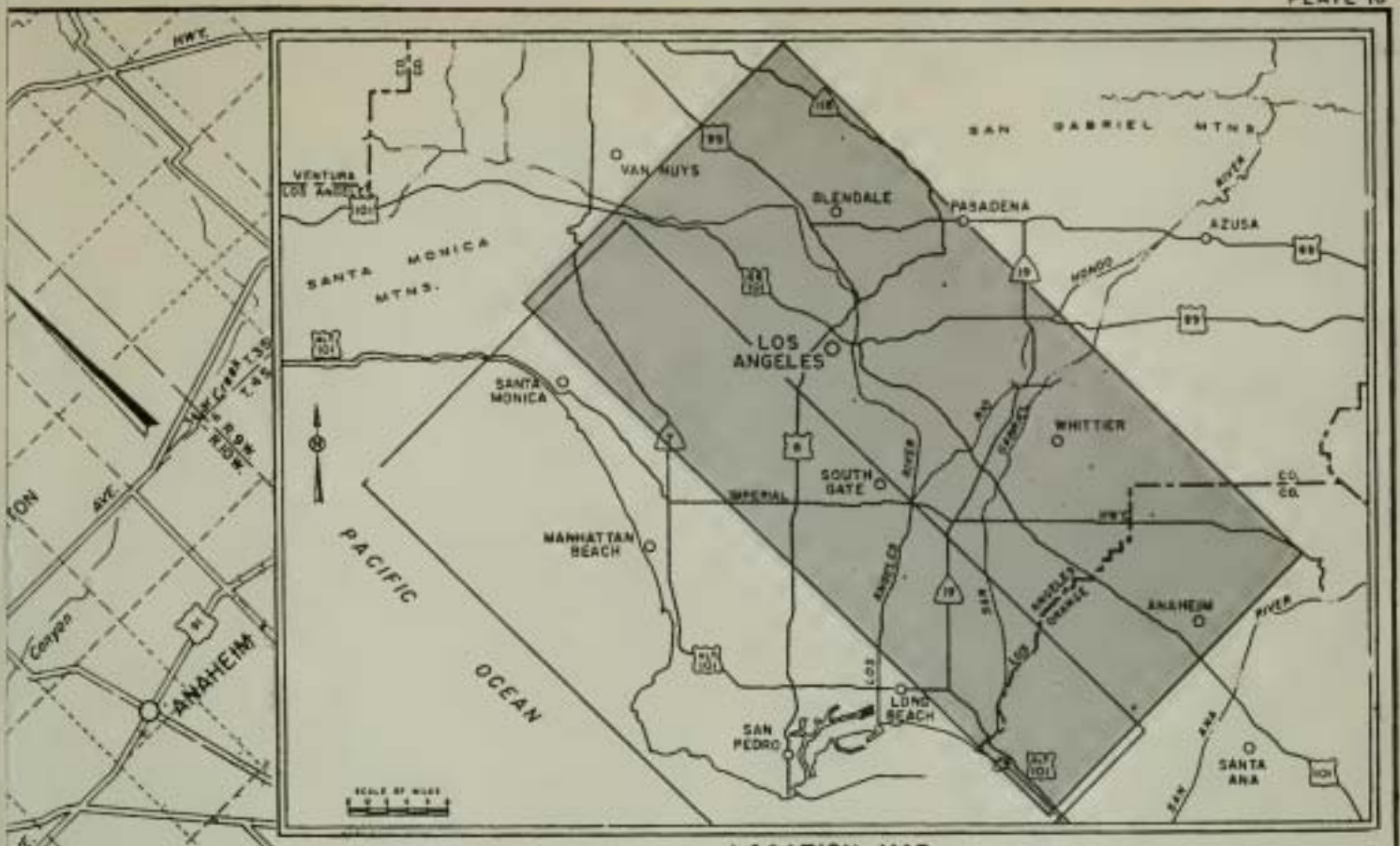
LINES OF EQUAL ELEVATION ON THE BASE OF THE JEFFERSON AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069147

AR0069148



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF JEFFERSON AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- —50— LINES OF EQUAL ELEVATION ON THE BASE OF THE JEFFERSON AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE JEFFERSON AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE JEFFERSON AQUIFER

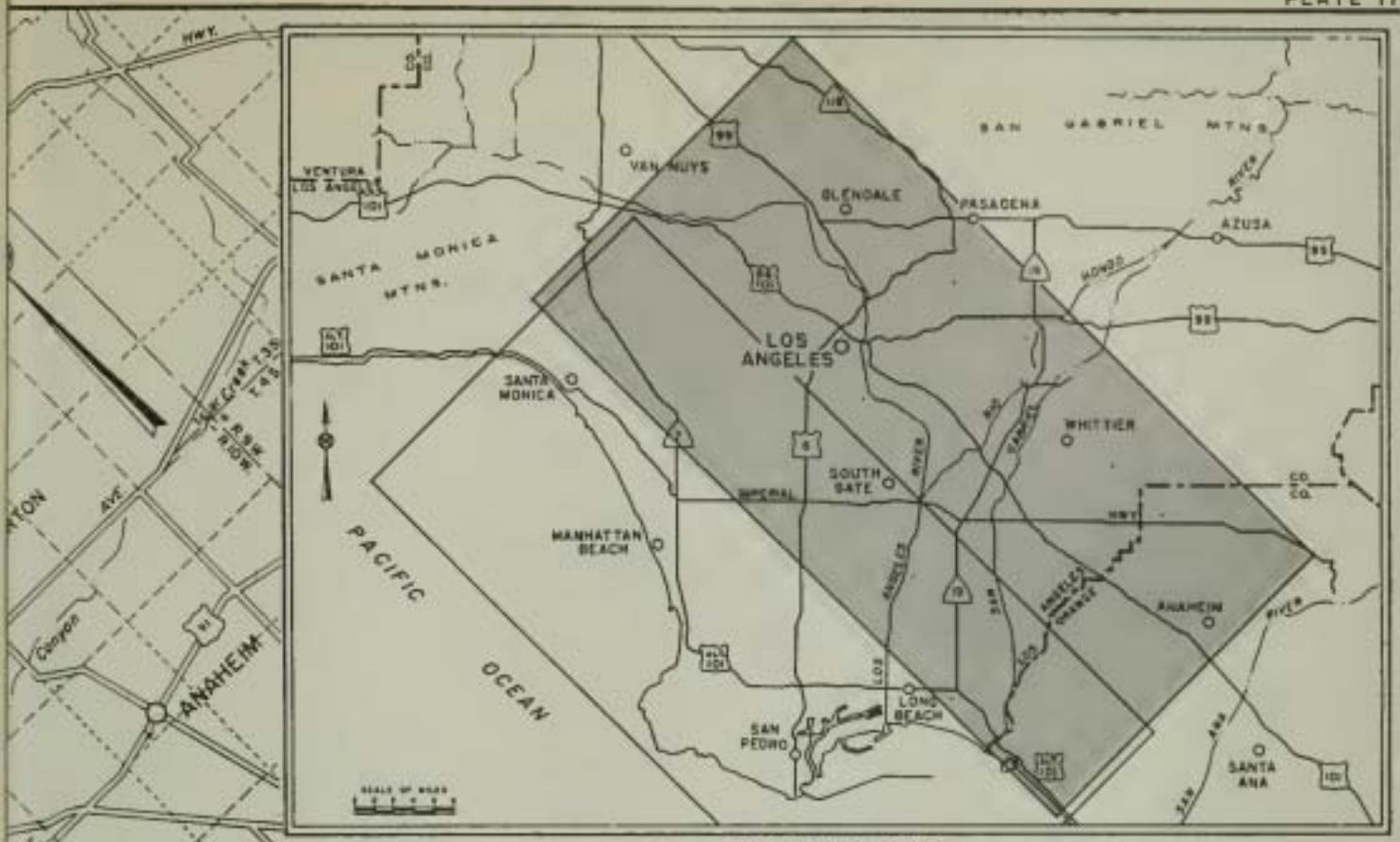
SCALE OF MILES
0 1 2 3

1961

AR0069149

LOCATION MAP
LINES OF EQUAL ELEVATION ON THE BASE
OF THE JEFFERSON AQUIFER

AR0069150



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF JEFFERSON AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 40 — LINES OF EQUAL THICKNESS OF THE JEFFERSON AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE JEFFERSON AQUIFER IS COMPOSED OF COARSE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

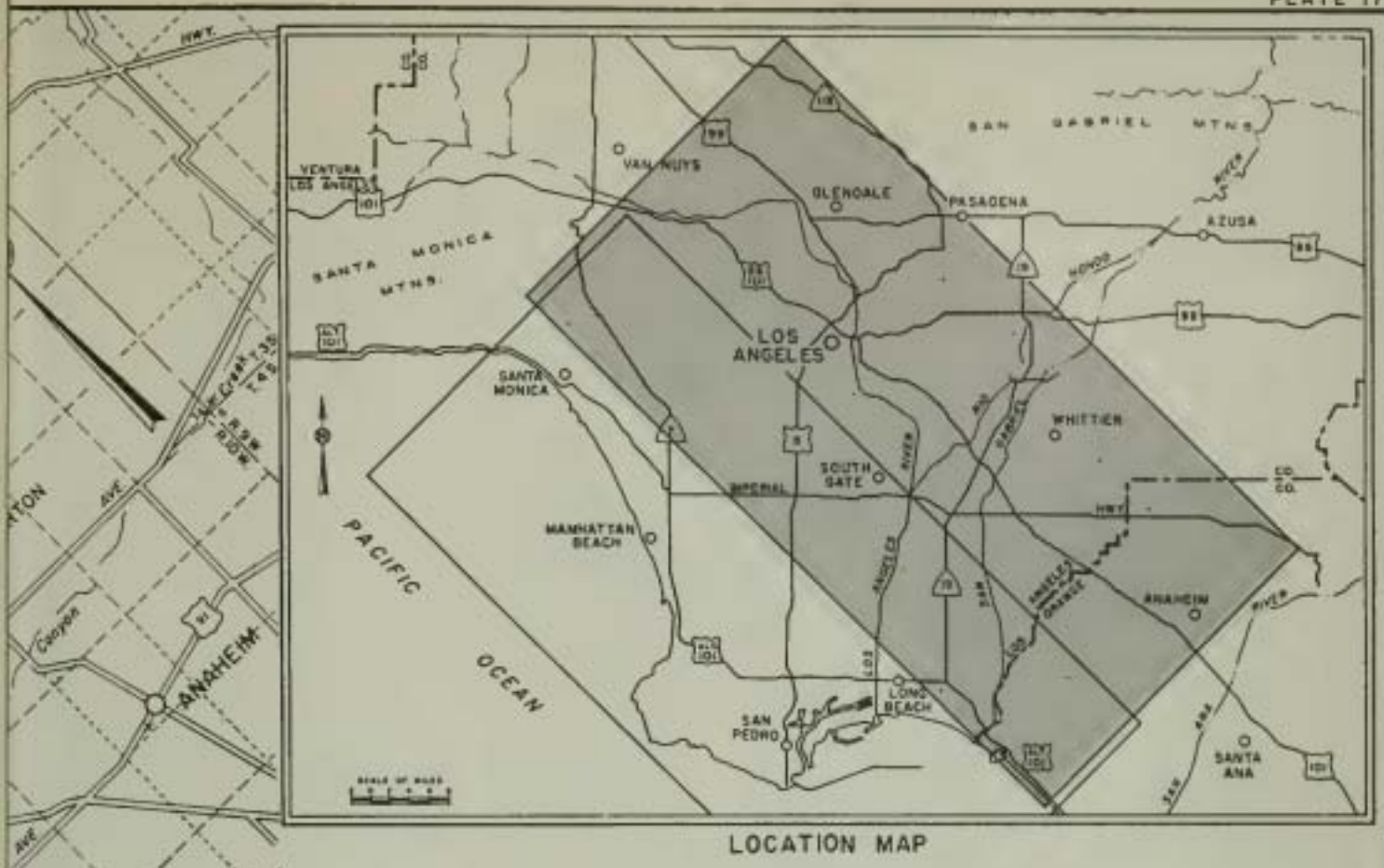
LINES OF EQUAL THICKNESS OF THE JEFFERSON AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069151

AR0069152



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF JEFFERSON AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- —40— LINES OF EQUAL THICKNESS OF THE JEFFERSON AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE JEFFERSON AQUIFER IS COMPOSED OF COARSE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE JEFFERSON AQUIFER

SCALE OF MILES

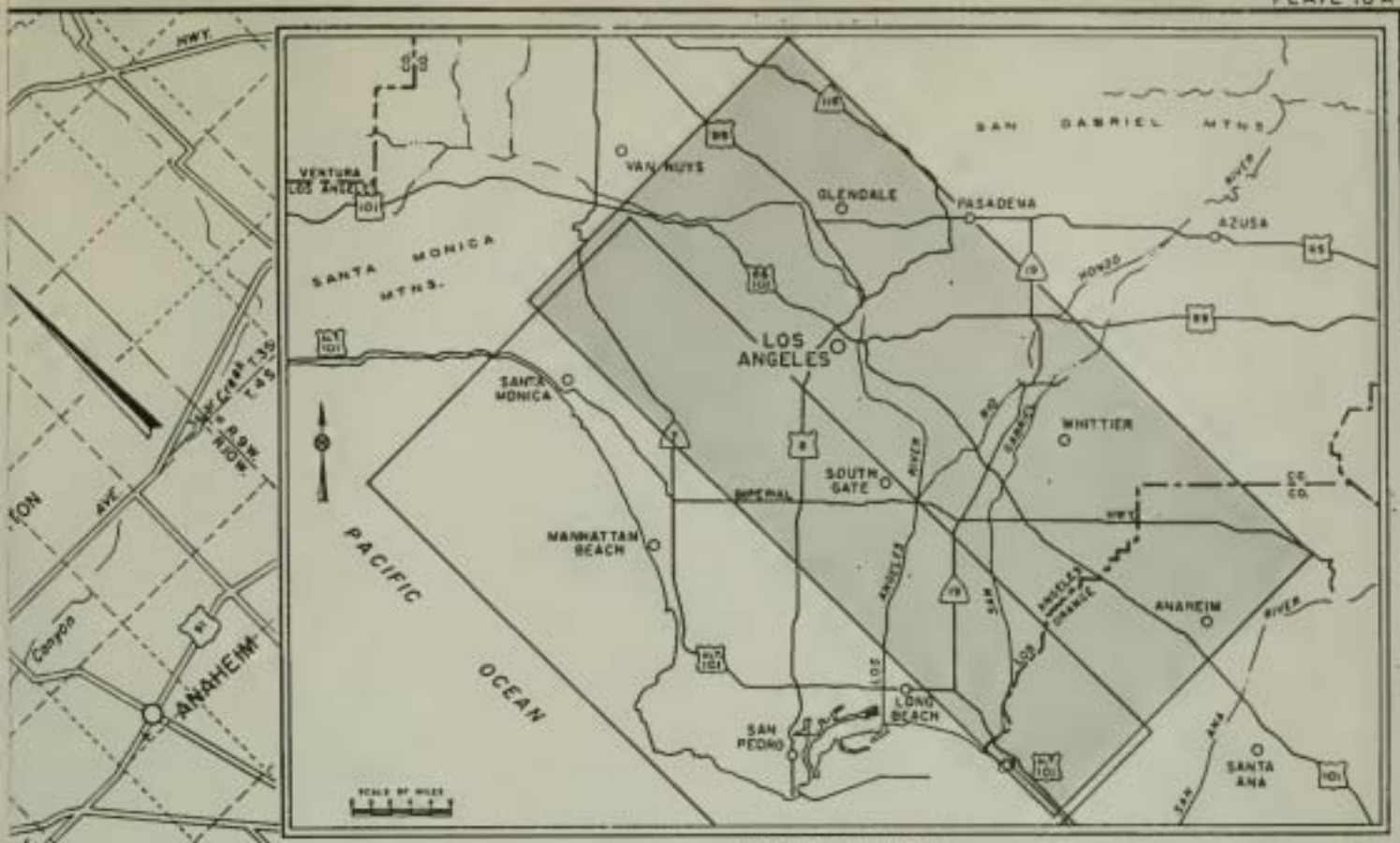
0 1 2 3

1961

AR0069153

LOCATION MAP
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
PART
LINES OF EQUAL THICKNESS
OF THE JEFFERSON AQUIFER

AR0069154



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

NOTE: IN WEST COAST BASIN THE LYNWOOD AQUIFER WAS PREVIOUSLY CALLED "400 FOOT GRAVEL"

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

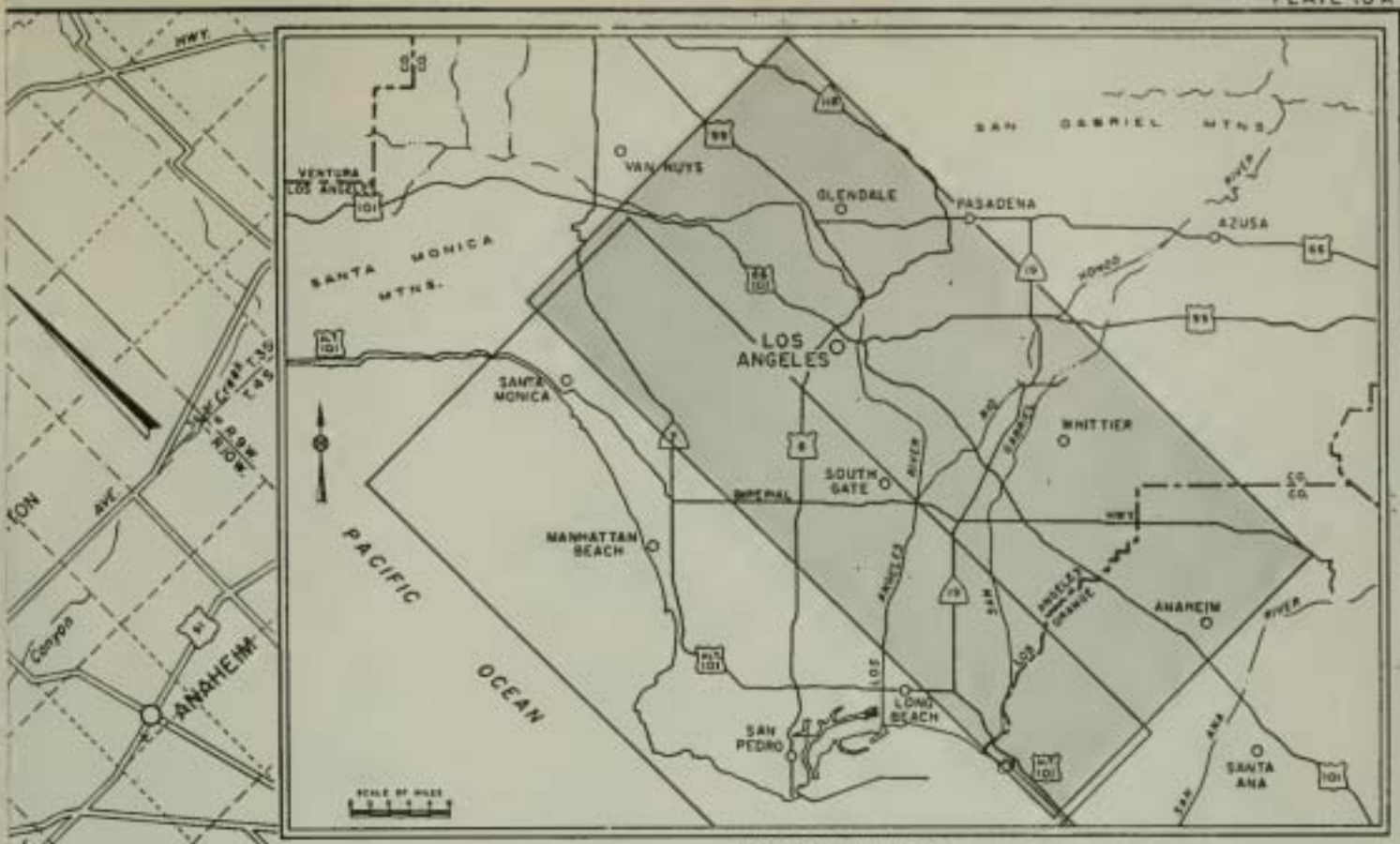
LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069155

AR0069156



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

NOTE: IN WEST COAST BASIN THE LYNWOOD AQUIFER WAS PREVIOUSLY CALLED "400 FOOT GRAVEL"

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER

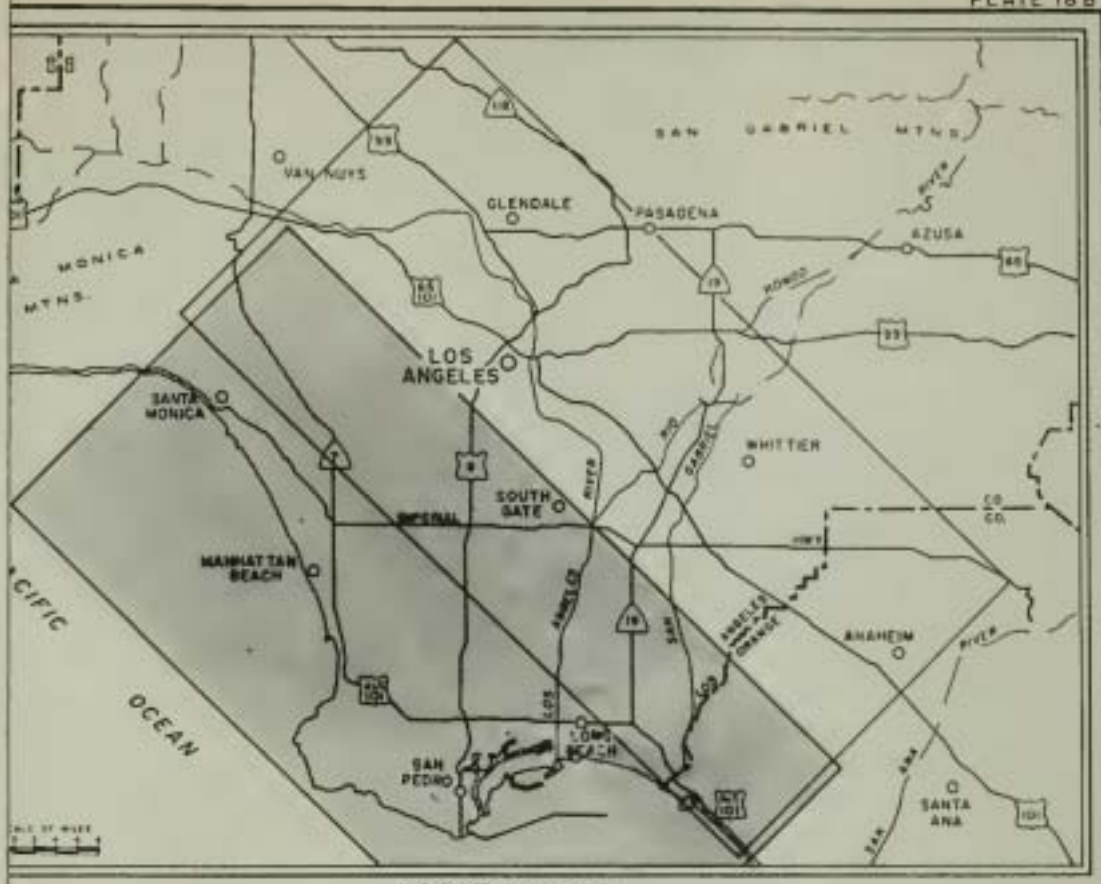
SCALE OF MILES
1 0 1 2 3

1961

AR0069157

LOCATION MAP
LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER

AR0069158



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

NOTE: IN WEST COAST BASIN THE LYNWOOD AQUIFER WAS PREVIOUSLY CALLED "400 FOOT GRAVEL"

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER

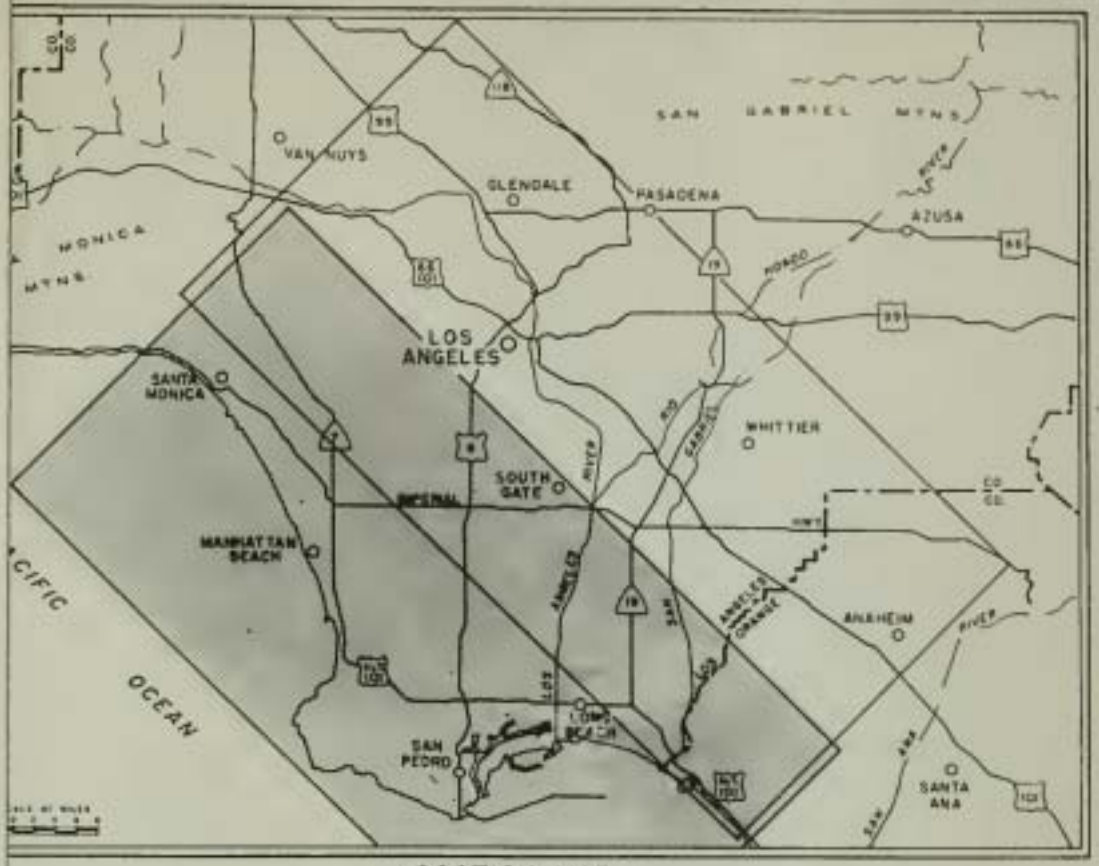
SCALE OF MILES

1 0 1 2 3

1961

AR0069159

AR0069160



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -50- LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

NOTE: IN WEST COAST BASIN THE LYNWOOD AQUIFER WAS PREVIOUSLY CALLED "400 FOOT GRAVEL"

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER

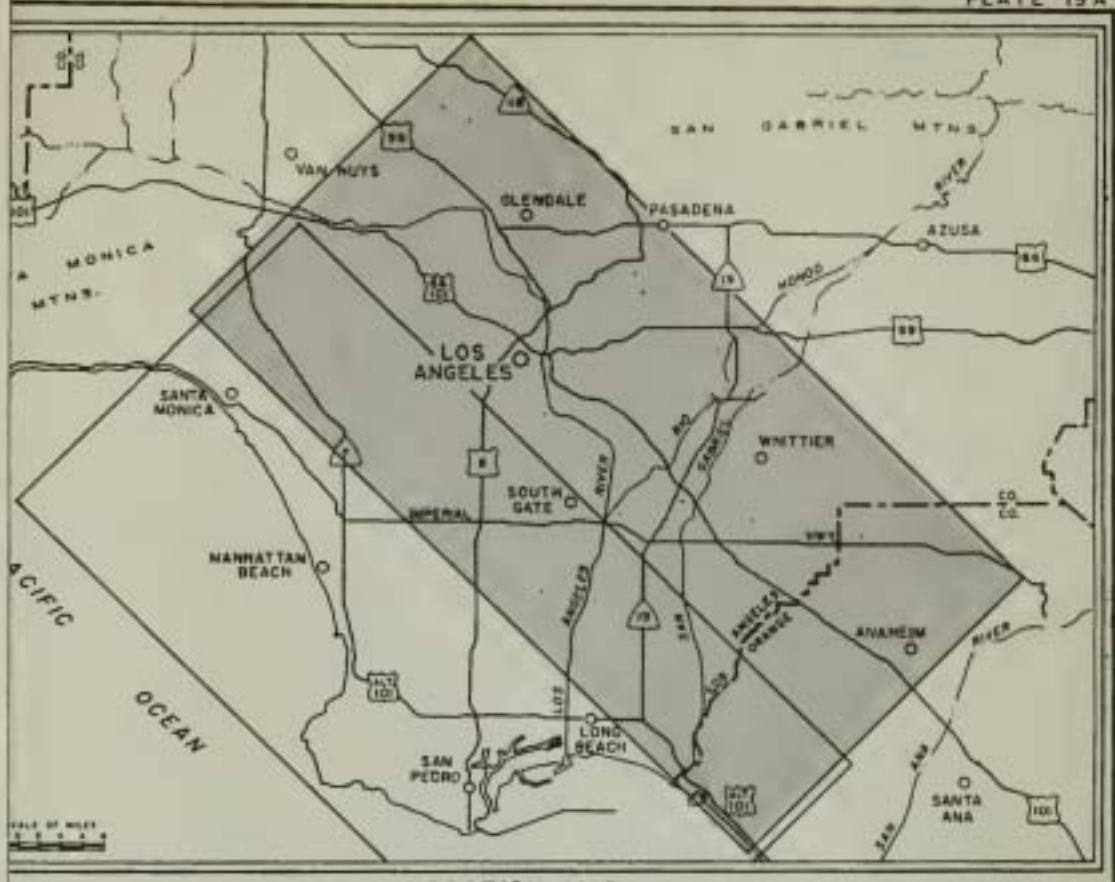
SCALE OF MILES
1 0 1 2 3

1961

AR0069161

PACIFIC
OCEAN
LOCATION MAP
LINES OF EQUAL ELEVATION ON THE BASE OF THE LYNWOOD AQUIFER

AR0069162



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 100 — LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

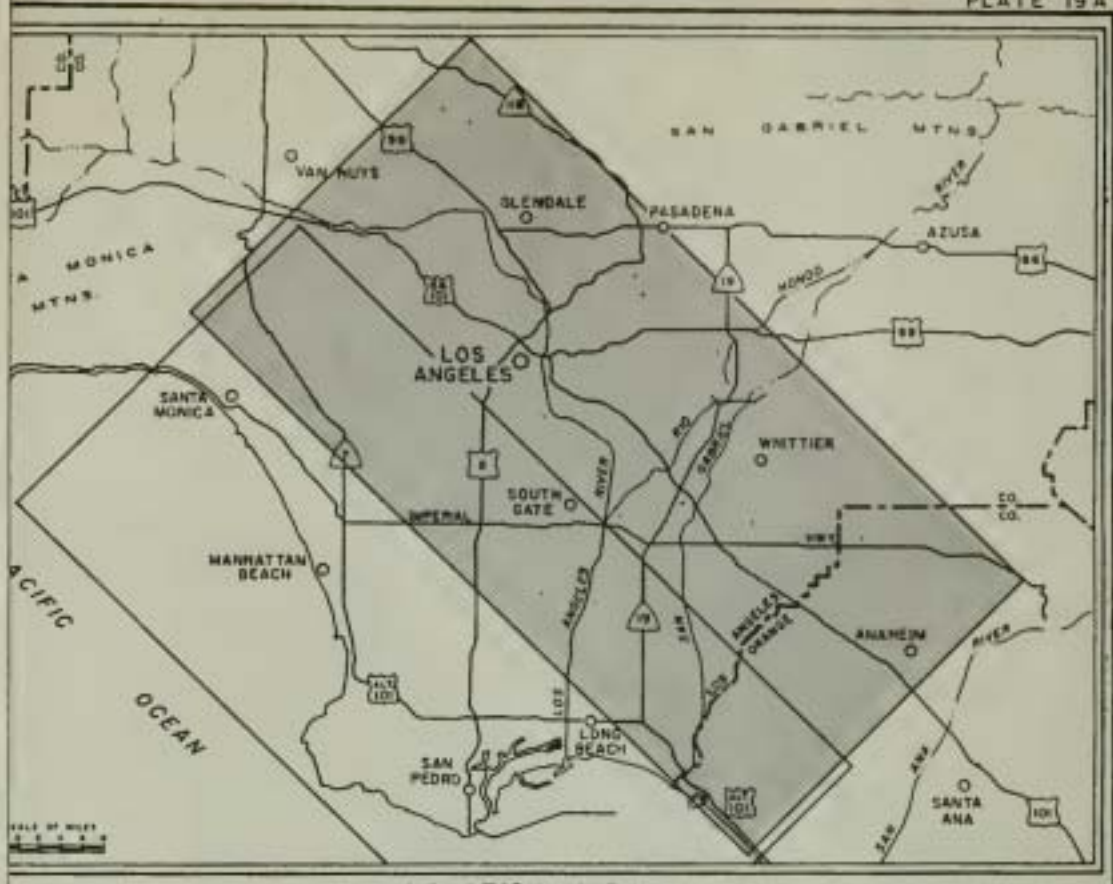
LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069163

AR0069164



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 100 LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER

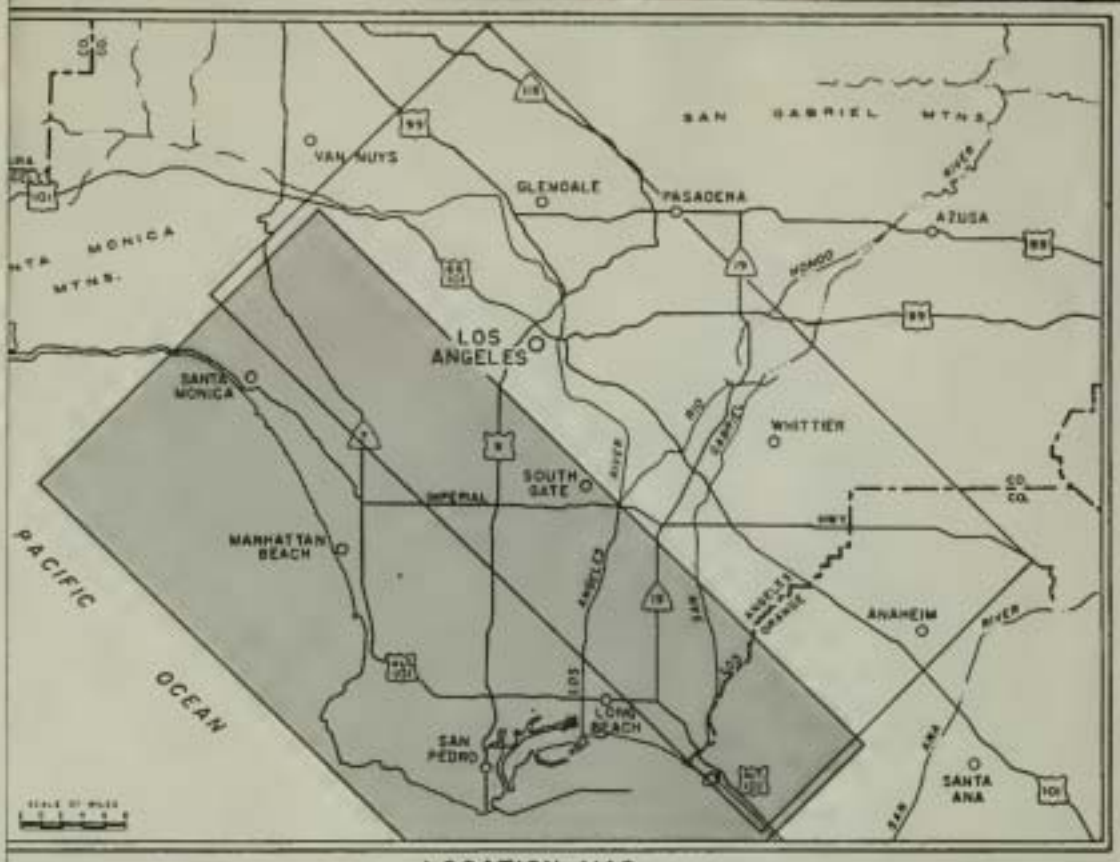
SCALE OF MILES

1961

AR0069165

LOCATION MAP
LINES OF EQUAL THICKNESS
OF THE LYNWOOD AQUIFER

AR0069166



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 50 — LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

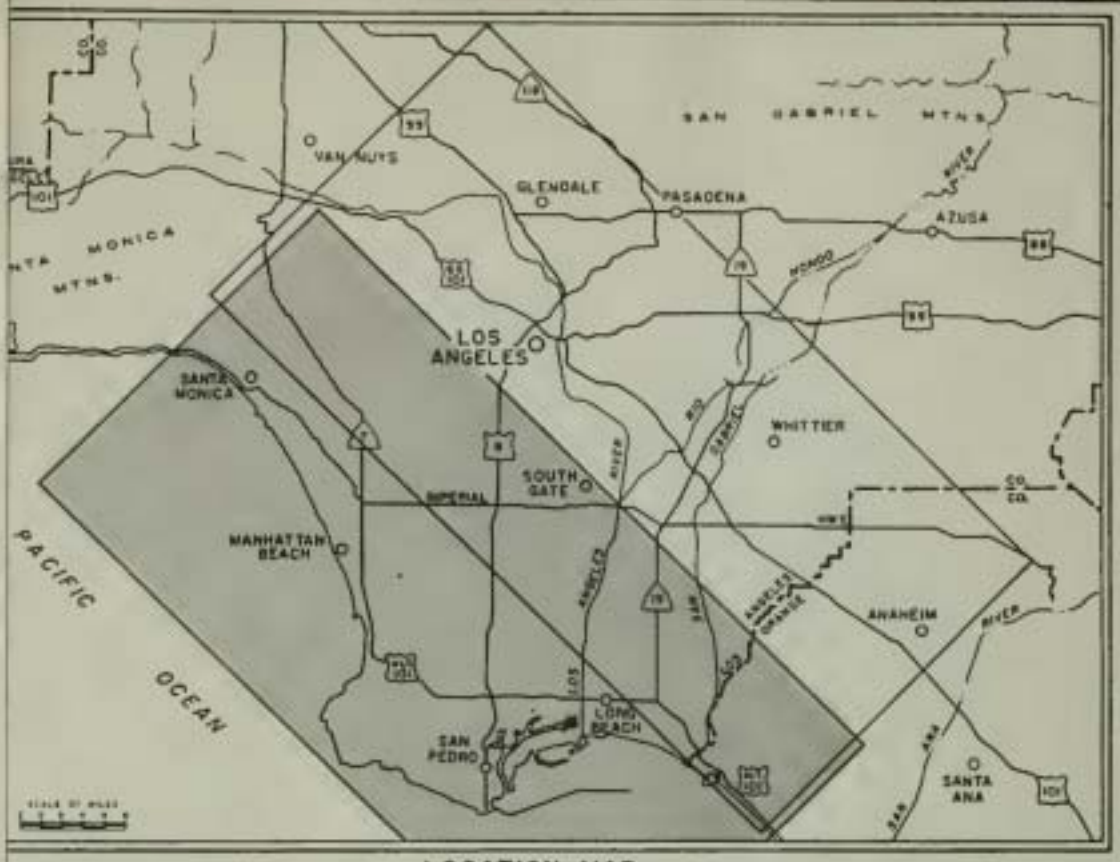
LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069167

AR0069168



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF LYNWOOD AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- —50— LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE LYNWOOD AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER

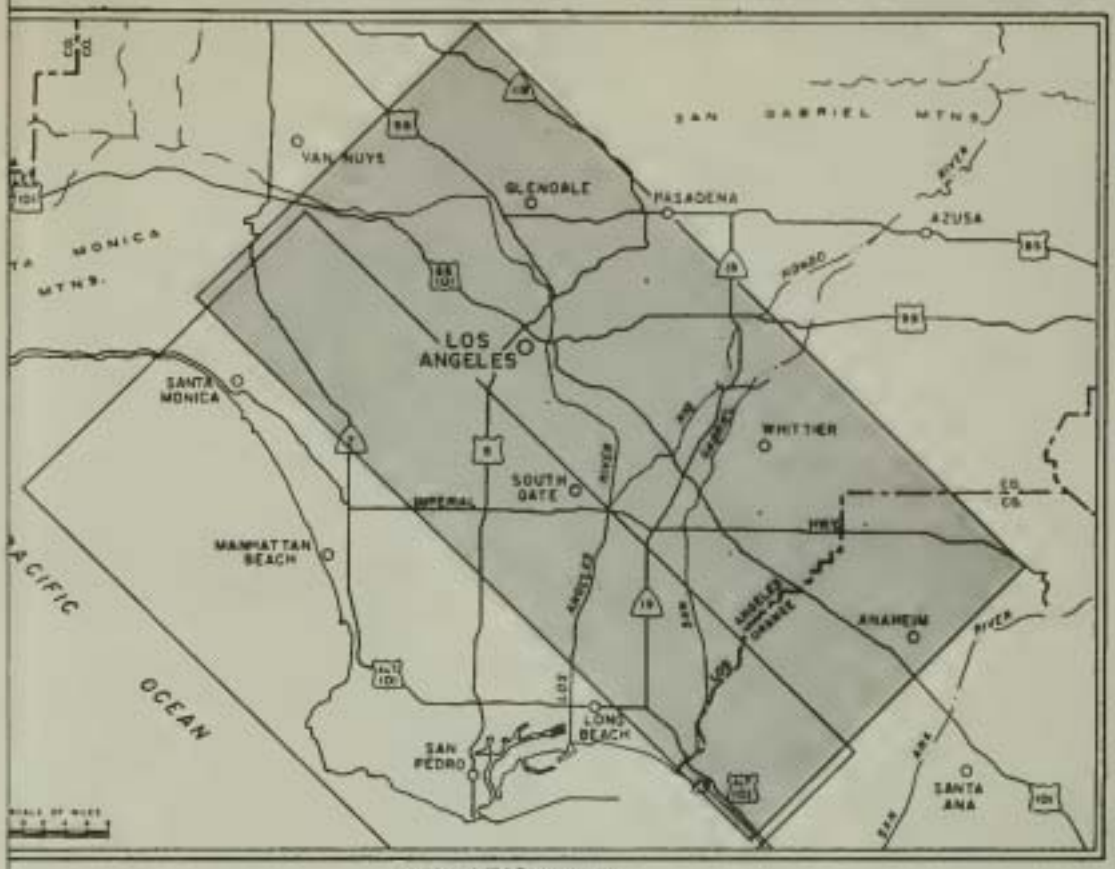
SCALE OF MILES
0 1 2 3

1961

AR0069169

PACIFIC
OCEAN
LOCATION MAP
LEGEND
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY
LINES OF EQUAL THICKNESS OF THE LYNWOOD AQUIFER

AR0069170



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- ~200~ LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

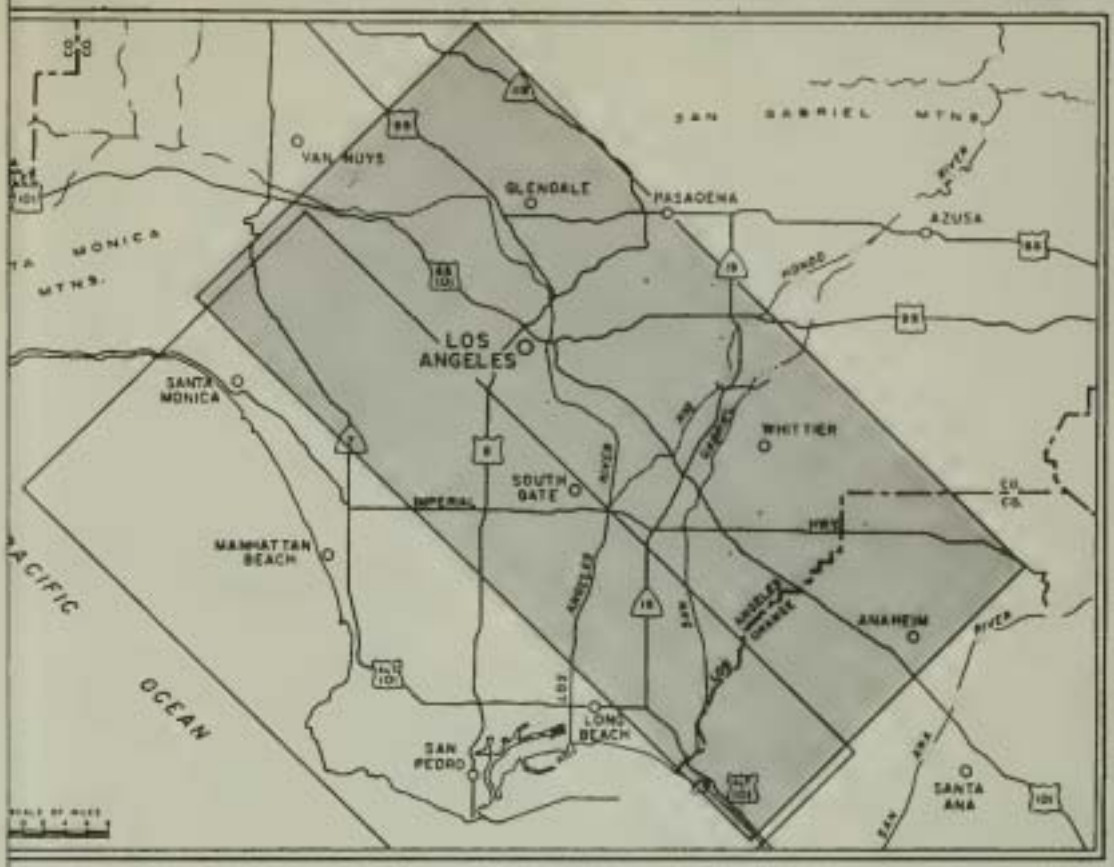
LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER

SCALE OF MILES
1 0 1 2 3

1961

AR0069171

AR0069172



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- ~200~ LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER

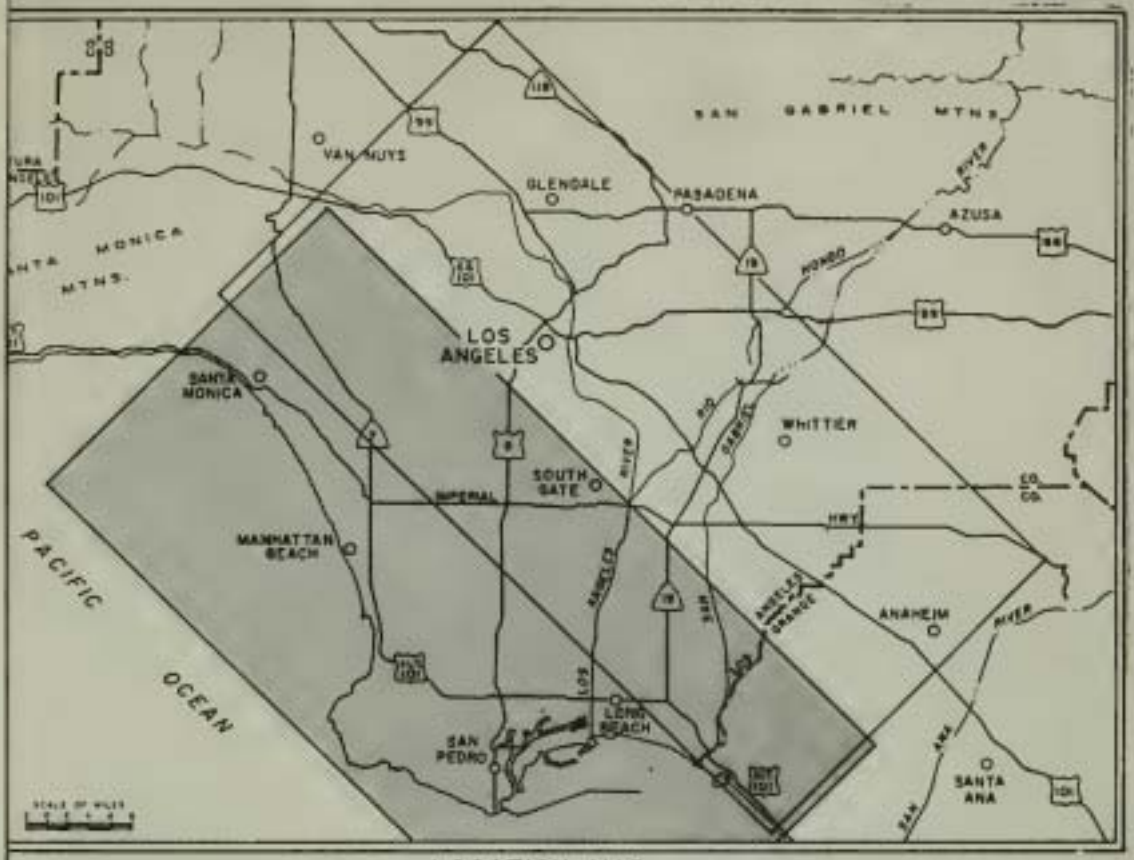
SCALE OF MILES
1 0 1 2 3

1961

AR0069173

LINES OF EQUAL ELEVATION ON THE BASE
OF THE SILVERADO AQUIFER

AR0069174



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF THE SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -700- LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

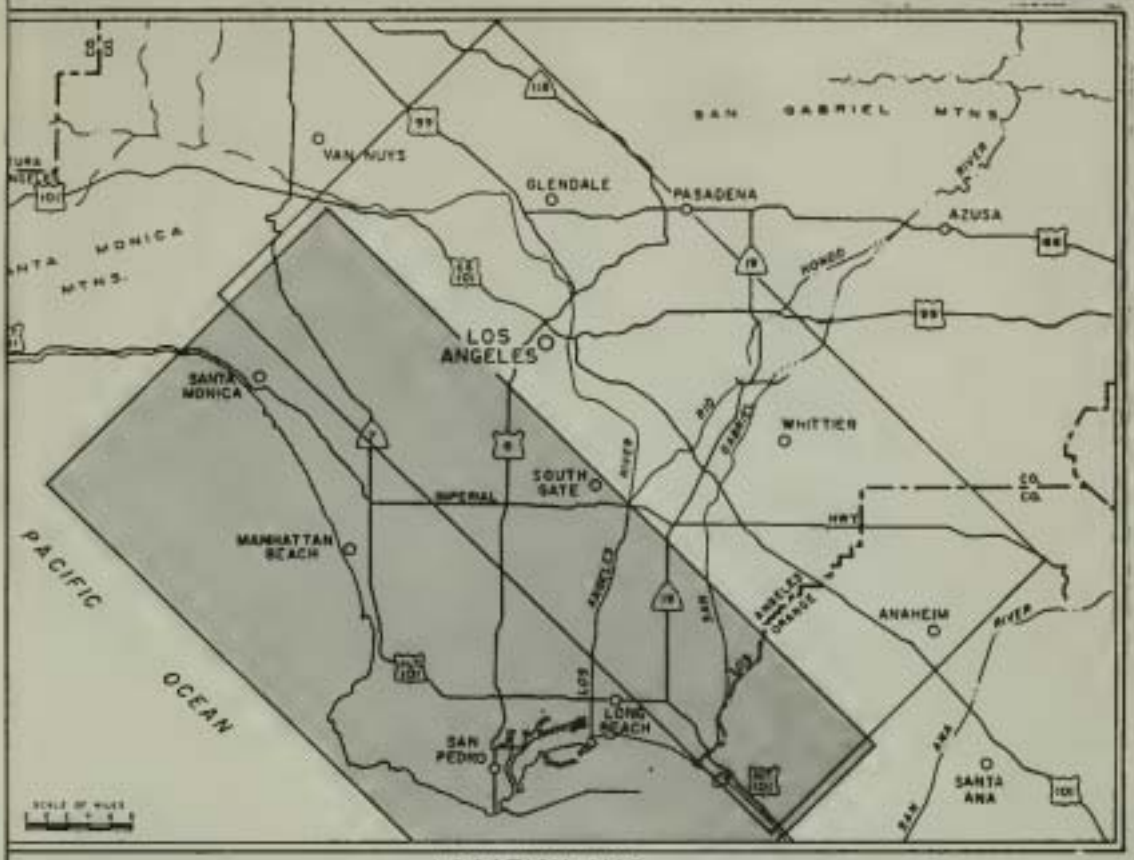
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER

SCALE OF MILES
0 1 2 3
1961

AR0069175

AR0069176



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF THE SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 700 — LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

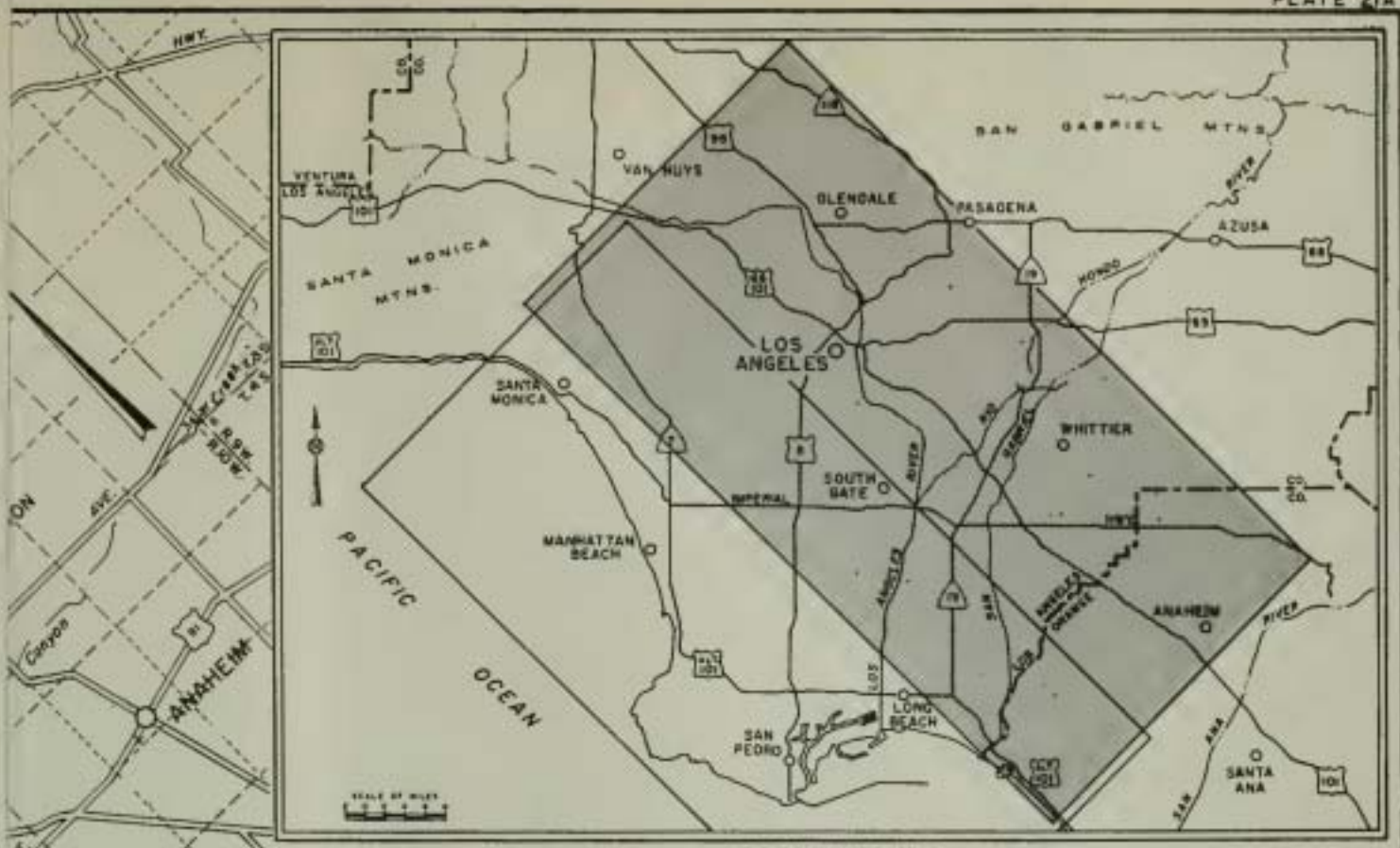
LINES OF EQUAL ELEVATION ON THE BASE OF THE SILVERADO AQUIFER

SCALE OF MILES
0 1 2 3
(SG)

AR0069177

PACIFIC
OCEAN
LINES OF EQUAL ELEVATION ON THE BASE
OF THE SILVERADO AQUIFER

AR0069178



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 100 — LINES OF EQUAL THICKNESS ON THE BASE OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

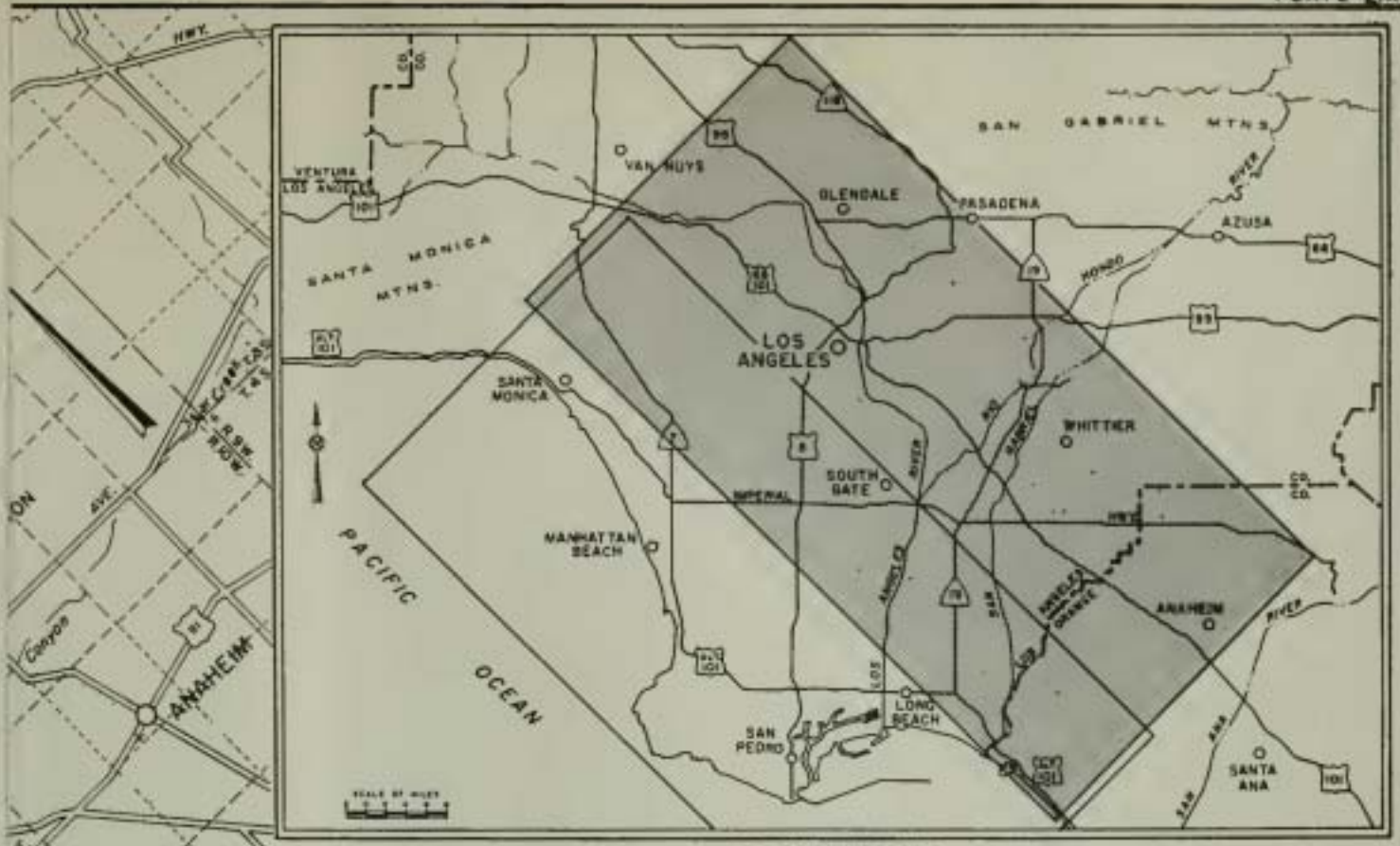
LINES OF EQUAL THICKNESS OF THE SILVERADO AQUIFER

SCALE OF MILES
1 0 1 2 3

1961

AR0069179

AR0069180



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 100 — LINES OF EQUAL THICKNESS ON THE BASE OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

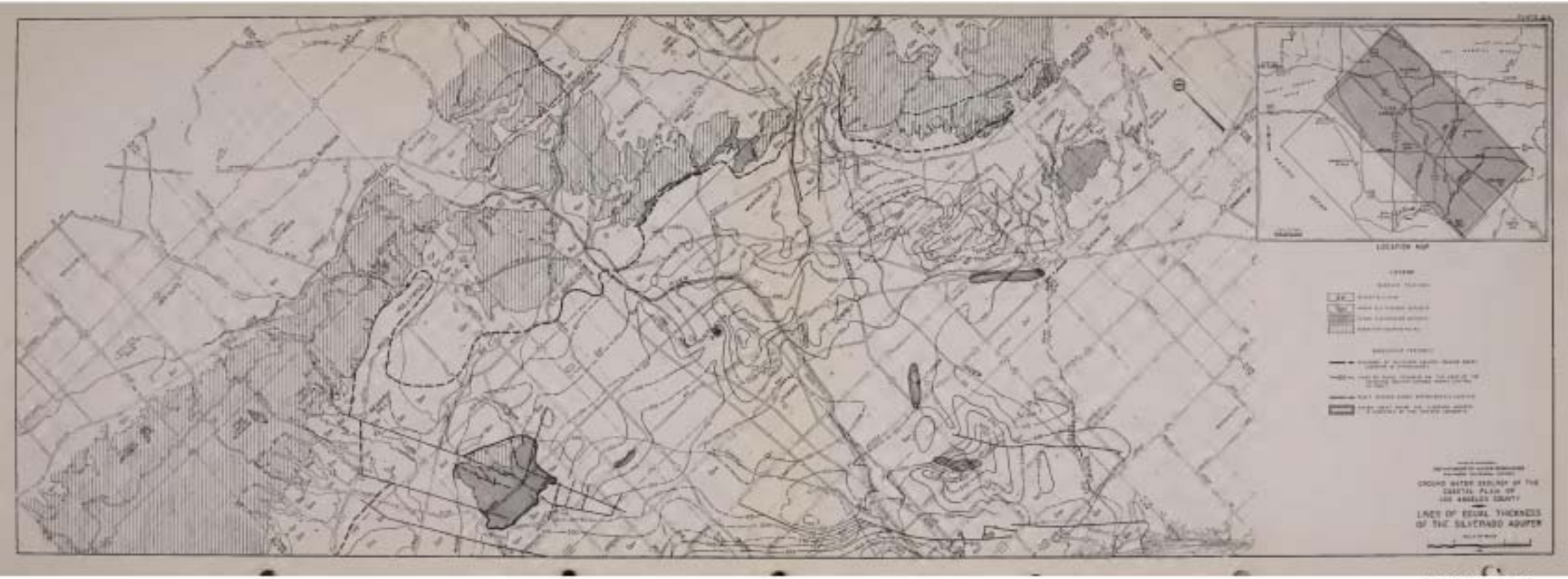
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE SILVERADO AQUIFER

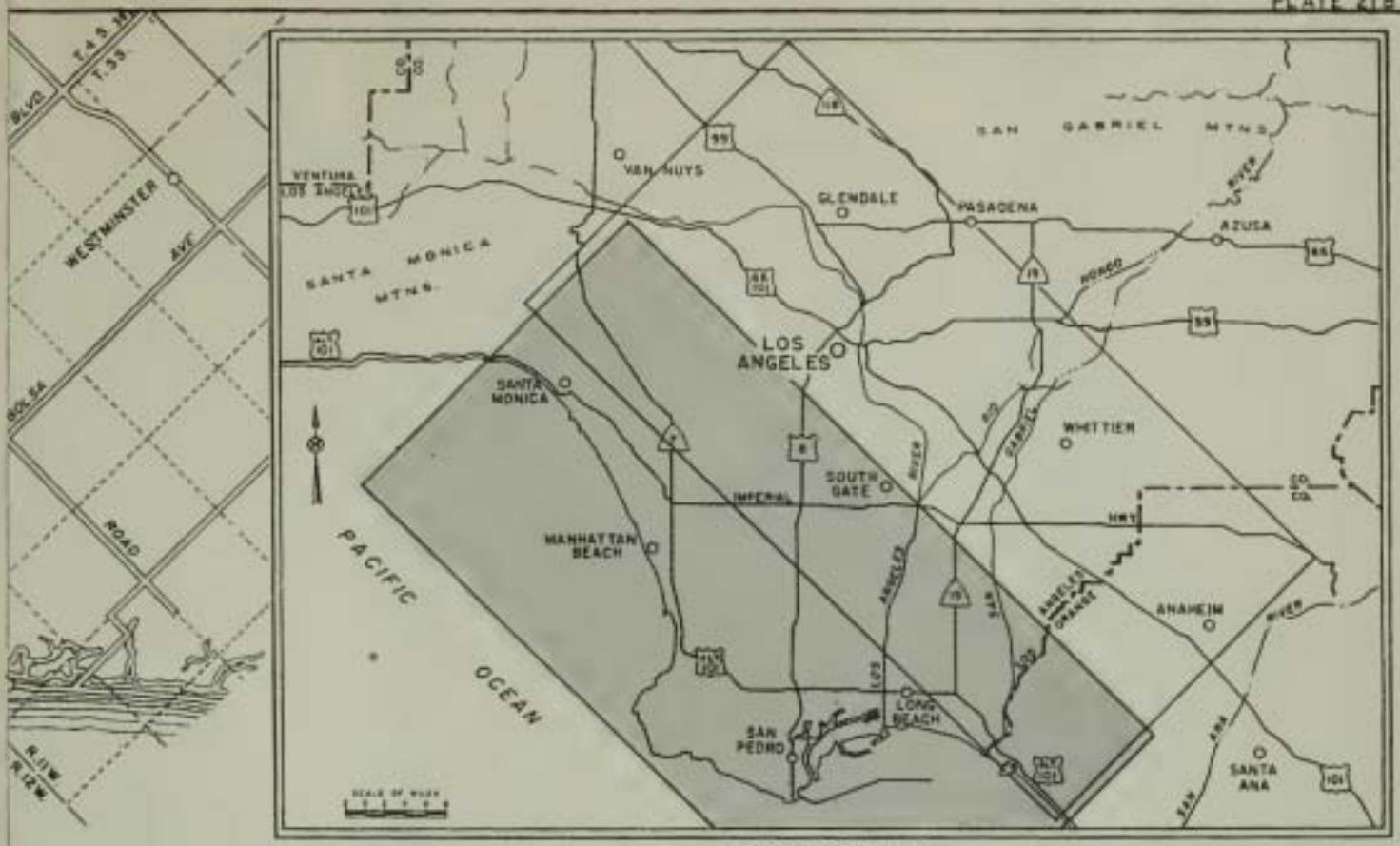
SCALE OF MILES
1 0 1 2 3

1961

AR0069181


LOCATION MAP
LINES OF EQUAL THICKNESS
OF THE SILVERADO AQUIFER

AR0069182



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 50 — LINES OF EQUAL THICKNESS OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

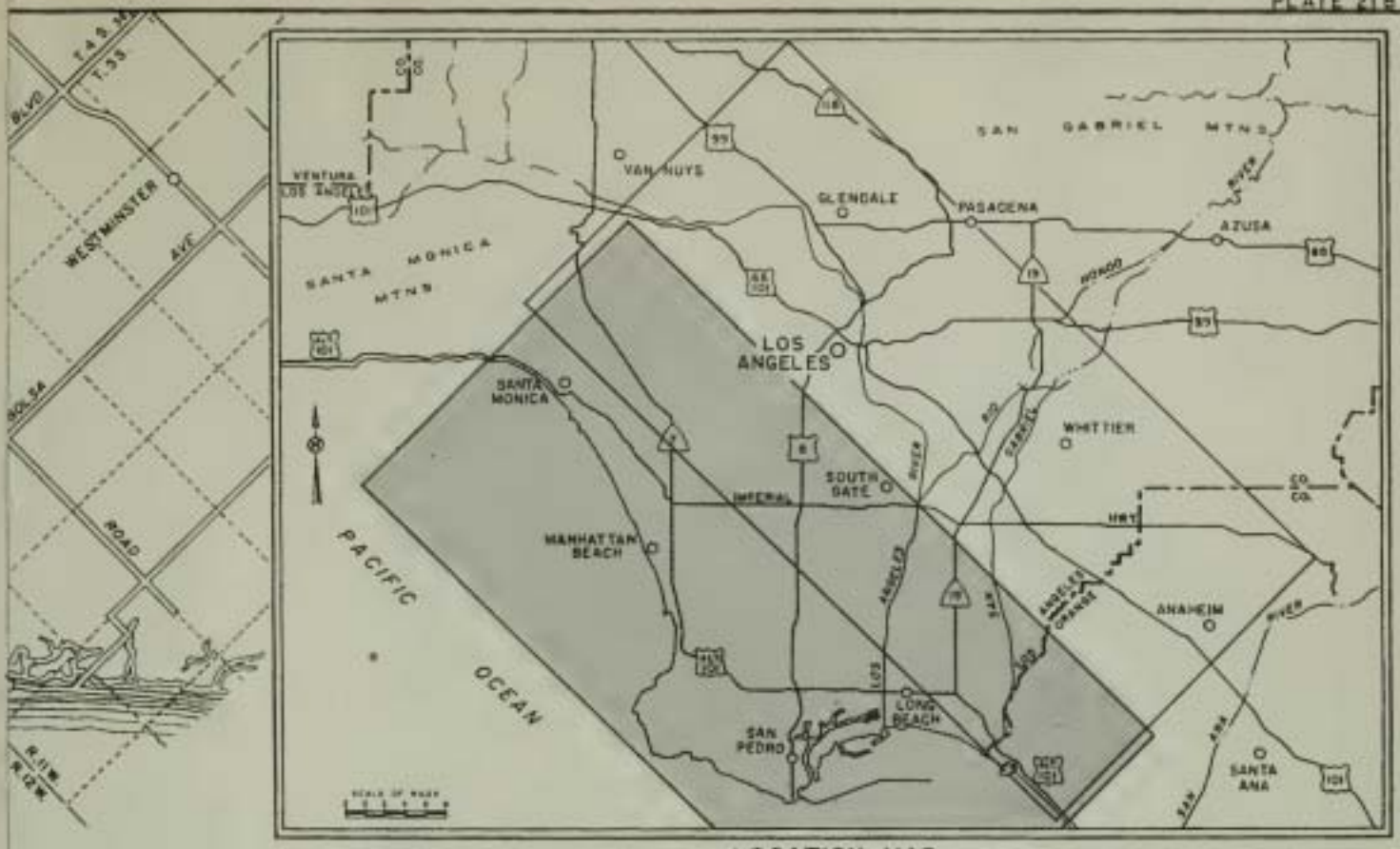
LINES OF EQUAL THICKNESS OF THE SILVERADO AQUIFER

SCALE OF MILES
1 0 1 2 3

1961

AR0069183

AR0069184



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SILVERADO AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 50 — LINES OF EQUAL THICKNESS OF THE SILVERADO AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SILVERADO AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL THICKNESS OF THE SILVERADO AQUIFER

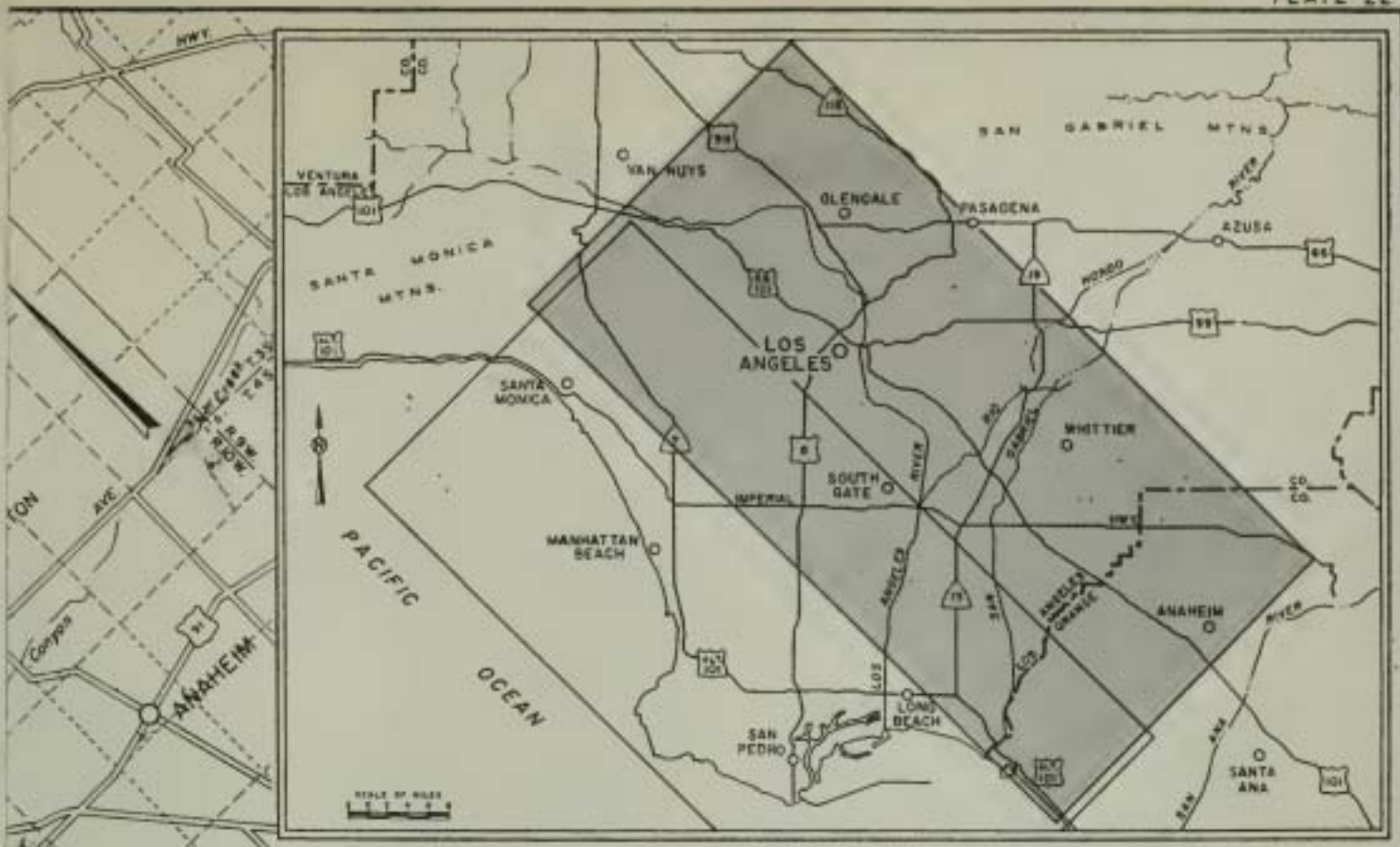
SCALE OF MILES
1 0 1 2 3

1961

AR0069185

PACIFIC
OCEAN
INDEX MAP
LEGEND
GROUND WATER BASINS OF THE COASTAL PLAIN OF LOS ANGELES COUNTY
LINES OF EQUAL THICKNESS OF THE SAN PEDRO AQUIFER

AR0069186



LOCATION MAP

LEGEND

SURFACE FEATURES

- Qal — RECENT ALLUVIUM
- Qpu — UPPER PLEISTOCENE DEPOSITS
- LOWER PLEISTOCENE DEPOSITS
- NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF THE SUNNYSIDE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -100- LINES OF EQUAL ELEVATION ON THE BASE OF THE SUNNYSIDE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SUNNYSIDE AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

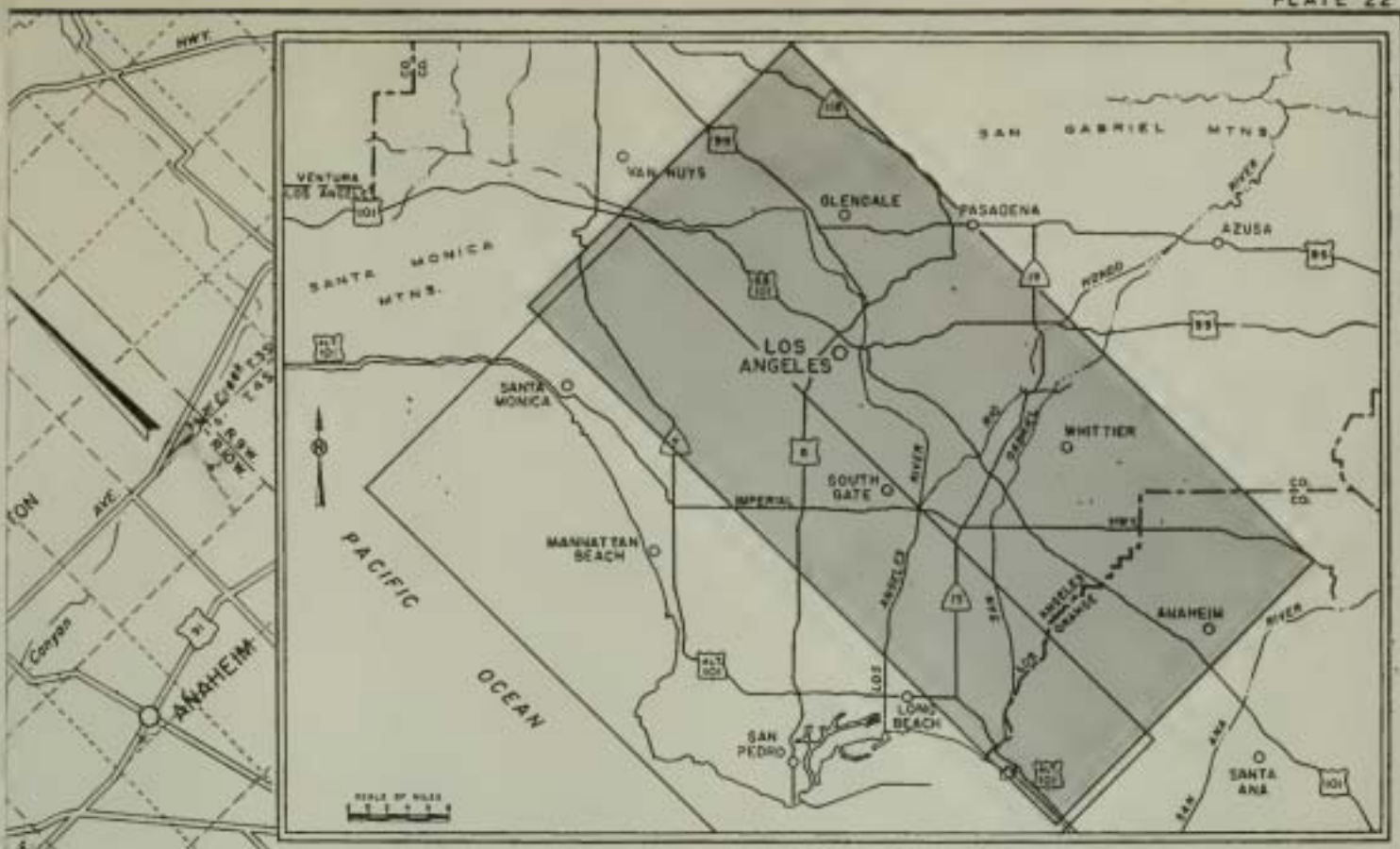
LINES OF EQUAL ELEVATION ON THE BASE OF THE SUNNYSIDE AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069187

AR0069188



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF THE SUNNYSIDE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- -100- LINES OF EQUAL ELEVATION ON THE BASE OF THE SUNNYSIDE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SUNNYSIDE AQUIFER IS MERGED WITH THE OVERLYING AQUIFER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF THE SUNNYSIDE AQUIFER

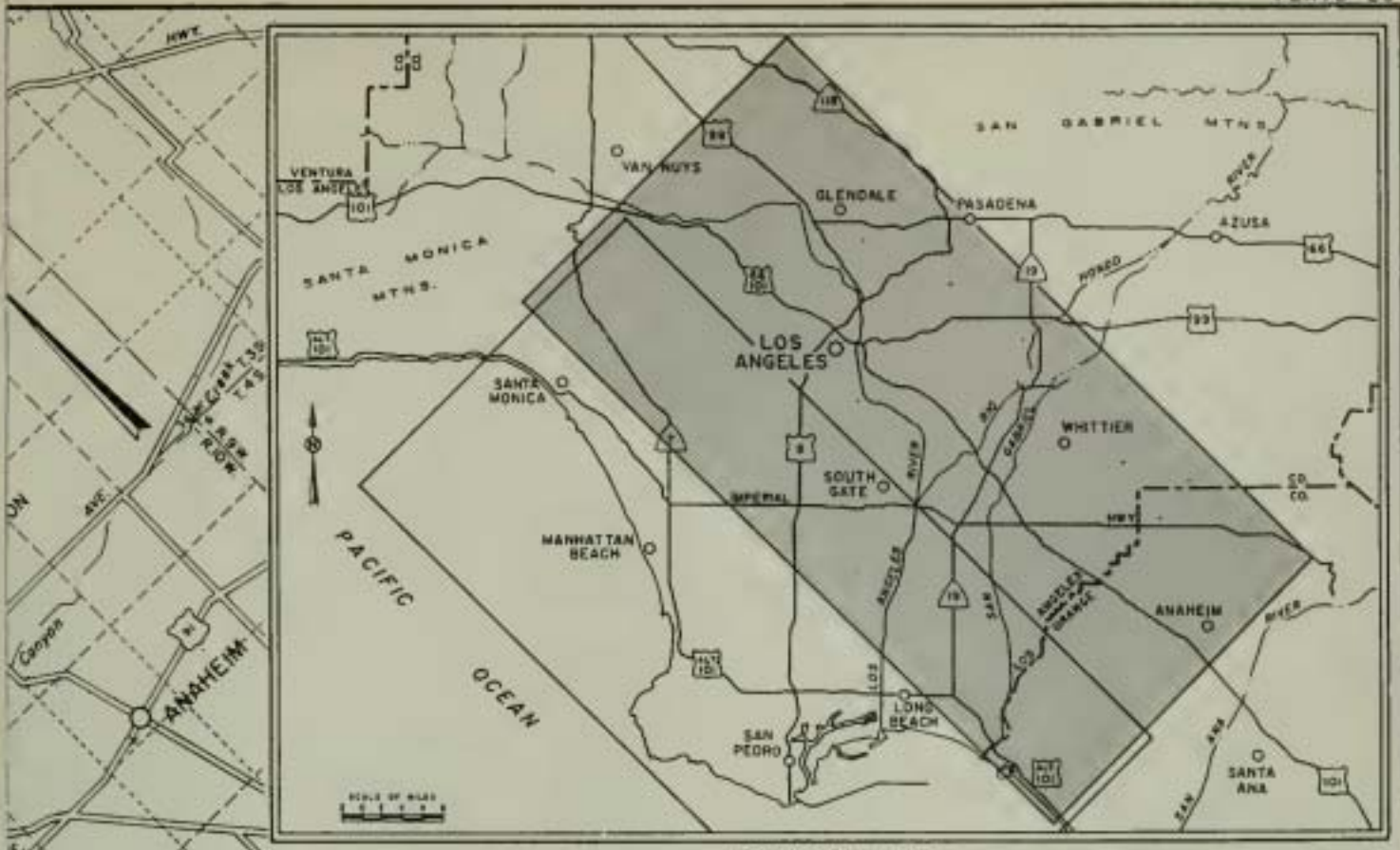
SCALE OF MILES
0 1 2 3

1961

AR0069189

LOCATION MAP
LEGEND
BASIN WATER VELOCITY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL ELEVATION ON THE BASE
OF THE SUNNYSIDE AQUIFER

AR0069190



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SUNNYSIDE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- ~150~ LINES OF EQUAL THICKNESS OF THE SUNNYSIDE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SUNNYSIDE AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

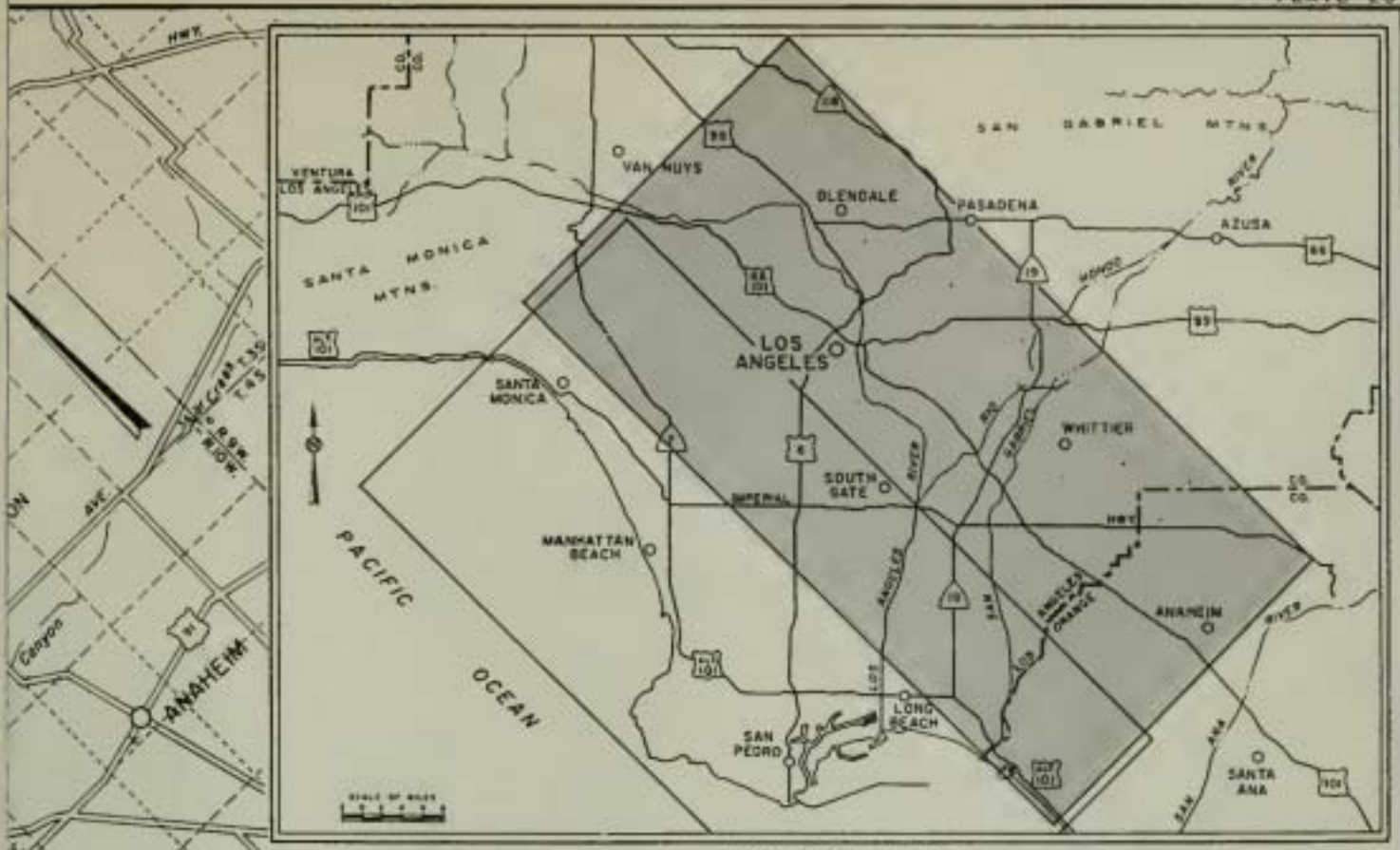
LINES OF EQUAL THICKNESS OF THE SUNNYSIDE AQUIFER

SCALE OF MILES
1 0 1 2 3

1961

AR0069191

AR0069192



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

- BOUNDARY OF SUNNYSIDE AQUIFER (DASHED WHERE LOCATION IS APPROXIMATE)
- 150 — LINES OF EQUAL THICKNESS OF THE SUNNYSIDE AQUIFER (DASHED WHERE CONTROL IS POOR)
- FAULT (DASHED WHERE APPROXIMATELY LOCATED)
- KNOWN AREAS WHERE THE SUNNYSIDE AQUIFER IS COMPOSED OF FINE GRAINED SEDIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

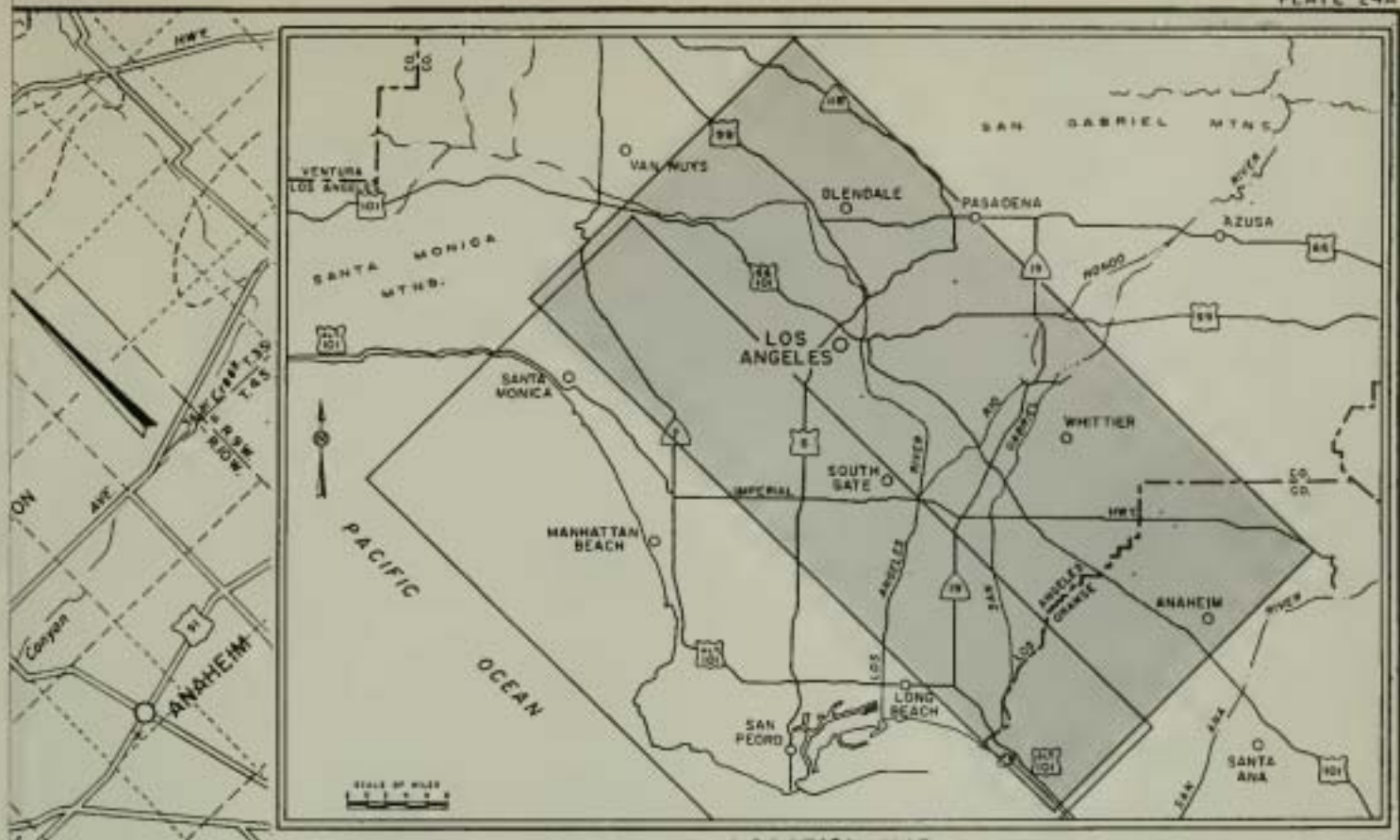
LINES OF EQUAL THICKNESS OF THE SUNNYSIDE AQUIFER

SCALE OF MILES
1 0 1 2 3

1961

AR0069193

AR0069194



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

—400—	LINES OF EQUAL ELEVATION ON THE BASE OF PRINCIPLE FRESH WATER-BEARING SEDIMENTS (DASHED WHERE CONTROL IS POOR)
○-50	KNOWN ELEVATION OF BASE OF FRESH WATER AT A WELL
○(-700)	MINIMUM ELEVATION OF FRESH WATER AT A WELL (BASE IS AT A GREATER DEPTH)
	FAULT (DASHED WHERE APPROXIMATELY LOCATED)
	OIL FIELDS (BOUNDARIES APPROXIMATE)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

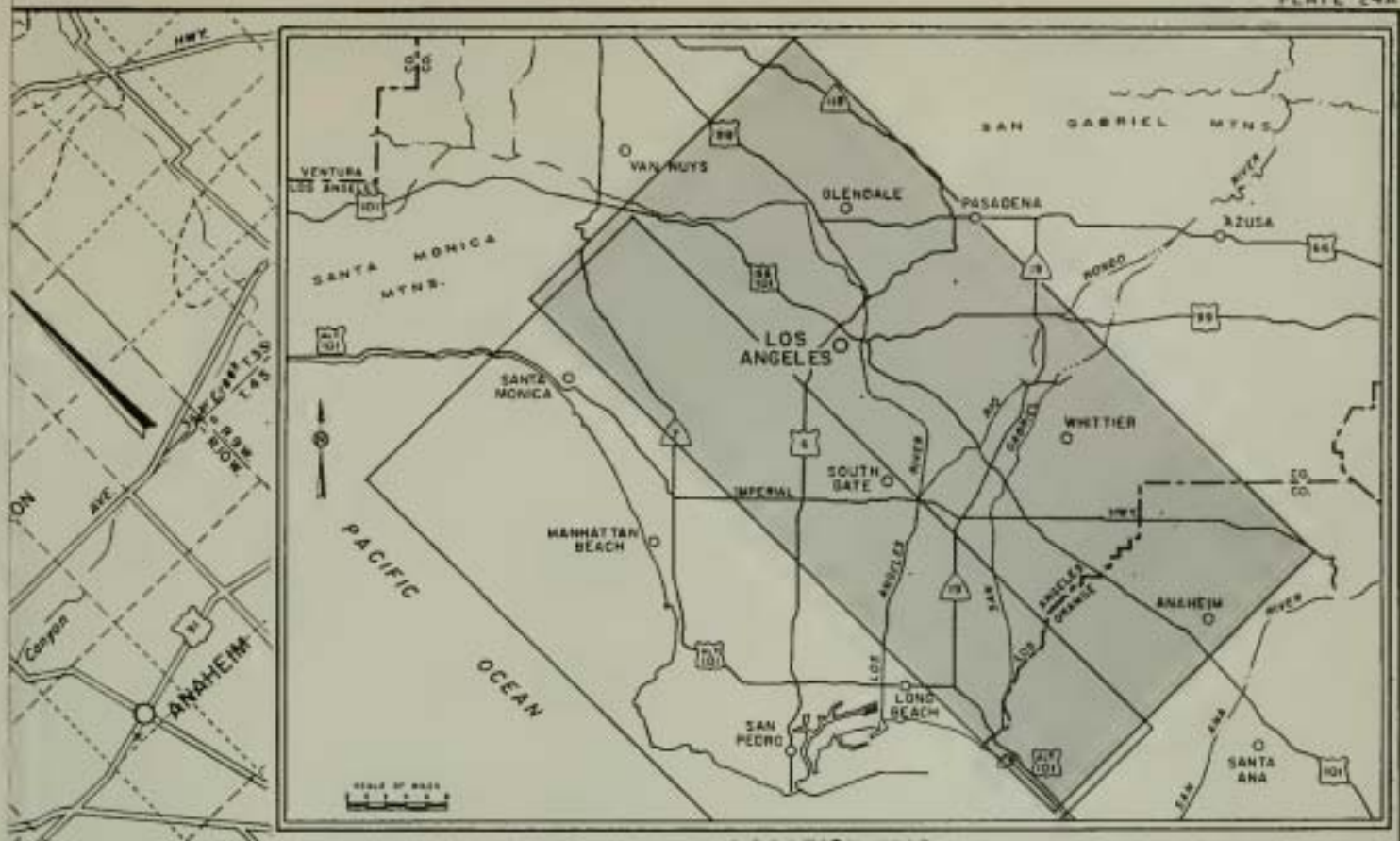
LINES OF EQUAL ELEVATION ON THE BASE OF FRESH WATER-BEARING SEDIMENTS

SCALE OF MILES
1 0 1 2 3

1961

AR0069195

AR0069196



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

--400--	LINES OF EQUAL ELEVATION ON THE BASE OF PRINCIPLE FRESH WATER-BEARING SEDIMENTS (DASHED WHERE CONTROL IS POOR)
○ -50	KNOWN ELEVATION OF BASE OF FRESH WATER AT A WELL
○ (-700)	MINIMUM ELEVATION OF FRESH WATER AT A WELL (BASE IS AT A GREATER DEPTH)
	FAULT (DASHED WHERE APPROXIMATELY LOCATED)
	OIL FIELDS (BOUNDARIES APPROXIMATE)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF FRESH WATER-BEARING SEDIMENTS

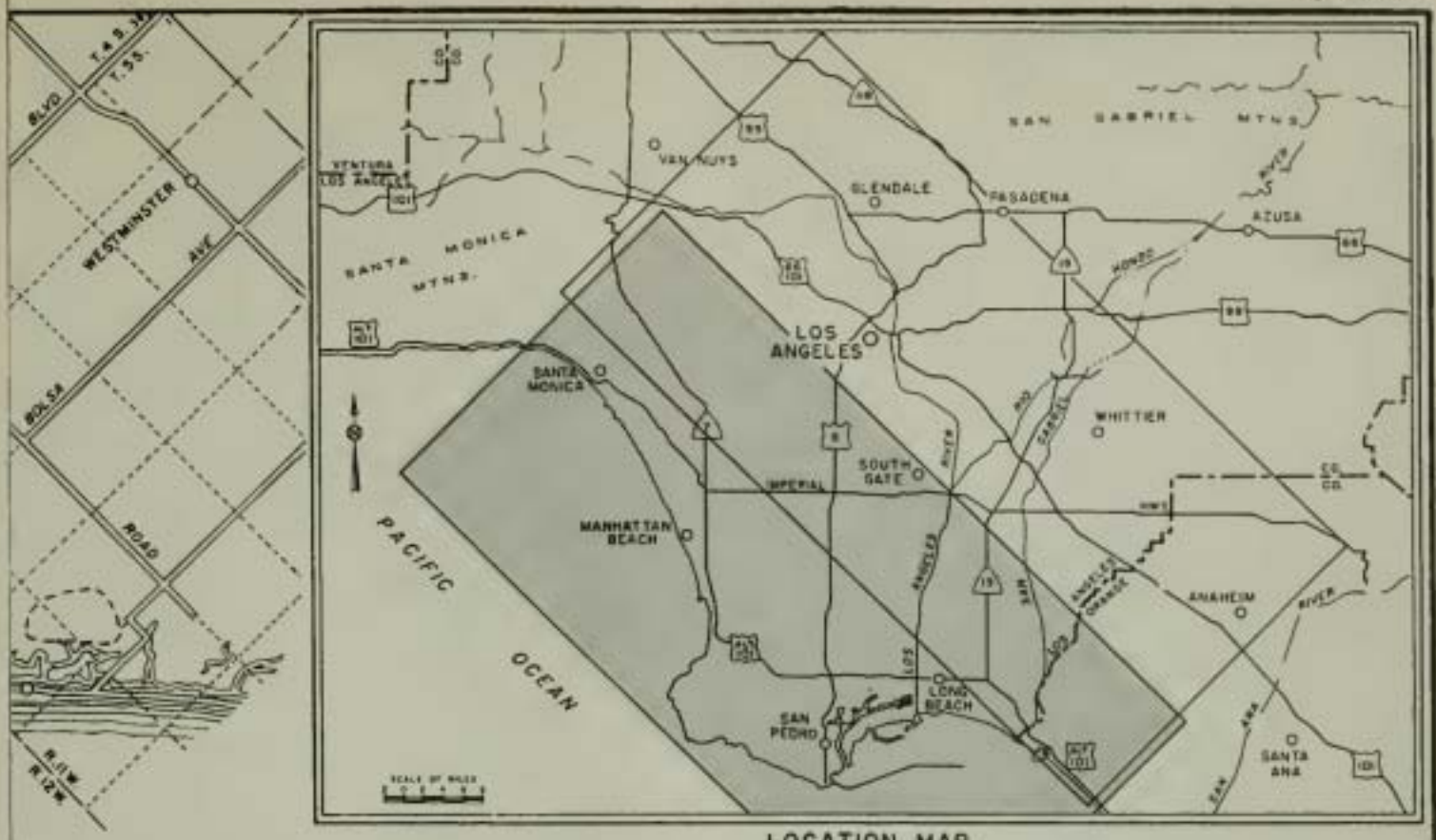
SCALE OF MILES
1 0 1 2 3

1961

AR0069197

LOCATION MAP
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY
LINES OF EQUAL ELEVATION ON THE BASE OF FRESH WATER-BEARING SEDIMENTS

AR0069198



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

—400— LINES OF EQUAL ELEVATION ON THE BASE OF PRINCIPLE FRESH WATER-BEARING SEDIMENTS (DASHED WHERE CONTROL IS POOR)

○-740 KNOWN ELEVATION OF BASE OF FRESH WATER AT A WELL

○(-700) MINIMUM ELEVATION OF FRESH WATER AT A WELL (BASE IS AT A GREATER DEPTH)

FAULT (DASHED WHERE APPROXIMATELY LOCATED)

OIL FIELDS (BOUNDARIES APPROXIMATE)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

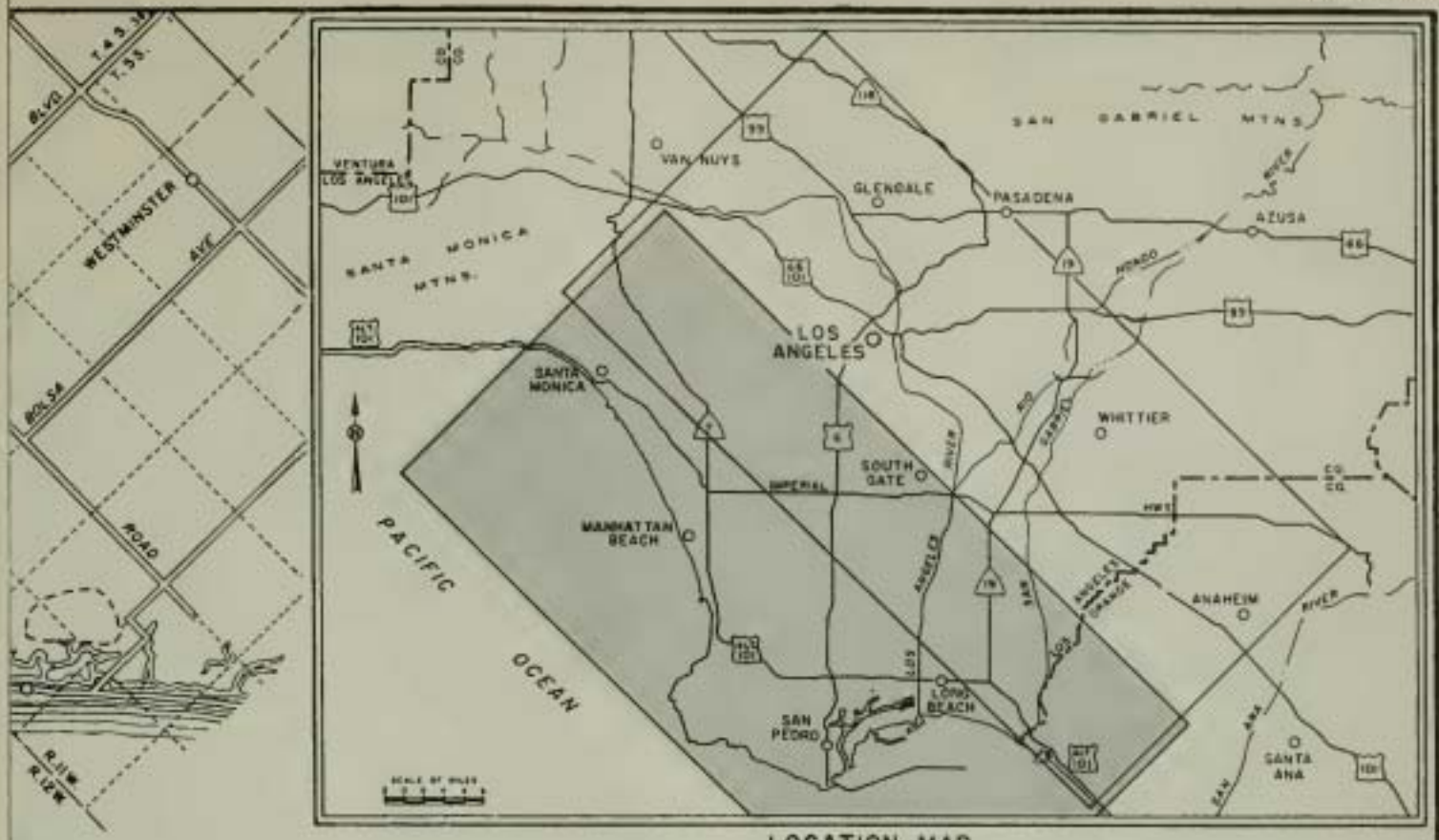
LINES OF EQUAL ELEVATION ON THE BASE OF FRESH WATER-BEARING SEDIMENTS

SCALE OF MILES
1 0 1 2 3

1961

AR0069199

AR0069200



LOCATION MAP

LEGEND

SURFACE FEATURES

Qal	RECENT ALLUVIUM
Qpu	UPPER PLEISTOCENE DEPOSITS
	LOWER PLEISTOCENE DEPOSITS
	NONWATER-BEARING ROCKS

SUBSURFACE FEATURES

--400--	LINES OF EQUAL ELEVATION ON THE BASE OF PRINCIPLE FRESH WATER-BEARING SEDIMENTS (DASHED WHERE CONTROL IS POOR)
O -740	KNOWN ELEVATION OF BASE OF FRESH WATER AT A WELL
♂ (-700)	MINIMUM ELEVATION OF FRESH WATER AT A WELL (BASE IS AT A GREATER DEPTH)
	FAULT (DASHED WHERE APPROXIMATELY LOCATED)
	OIL FIELDS (BOUNDARIES APPROXIMATE)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL ELEVATION ON THE BASE OF FRESH WATER-BEARING SEDIMENTS

SCALE OF MILES
0 1 2 3

1961

AR0069201

PACIFIC
OCEAN
LOCATION MAP
LINES OF EQUAL ELEVATION ON THE BASE
OF FRESH WATER-BEARING SEDIMENTS

AR0069202

AREA WHERE GASPUR AQUIFER IS MERGED WITH GROUND SURFACE.

AREA WHERE THE GAGE-GARDENA AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE HOLLYDALE AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE JEFFERSON AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE LYNWOOD AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE SILVERADO AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE SUNNYSIDE AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY

AREAS WHERE AQUIFERS ARE MERGED WITH PERMEABLE SURFACE DEPOSITS OR OVERLYING AQUIFERS IN VICINITY OF WHITTIER NARROWS

SCALE OF MILES
1 1/2 0

1961

AR0069203

AR0069204

AREA WHERE GASPUR AQUIFER IS MERGED WITH GROUND SURFACE.

AREA WHERE THE GAGE-GARDENA AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE HOLLYDALE AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE JEFFERSON AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE LYNWOOD AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE SILVERADO AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

AREAS WHERE THE SUNNYSIDE AQUIFER IS MERGED WITH AN OVERLYING AQUIFER.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

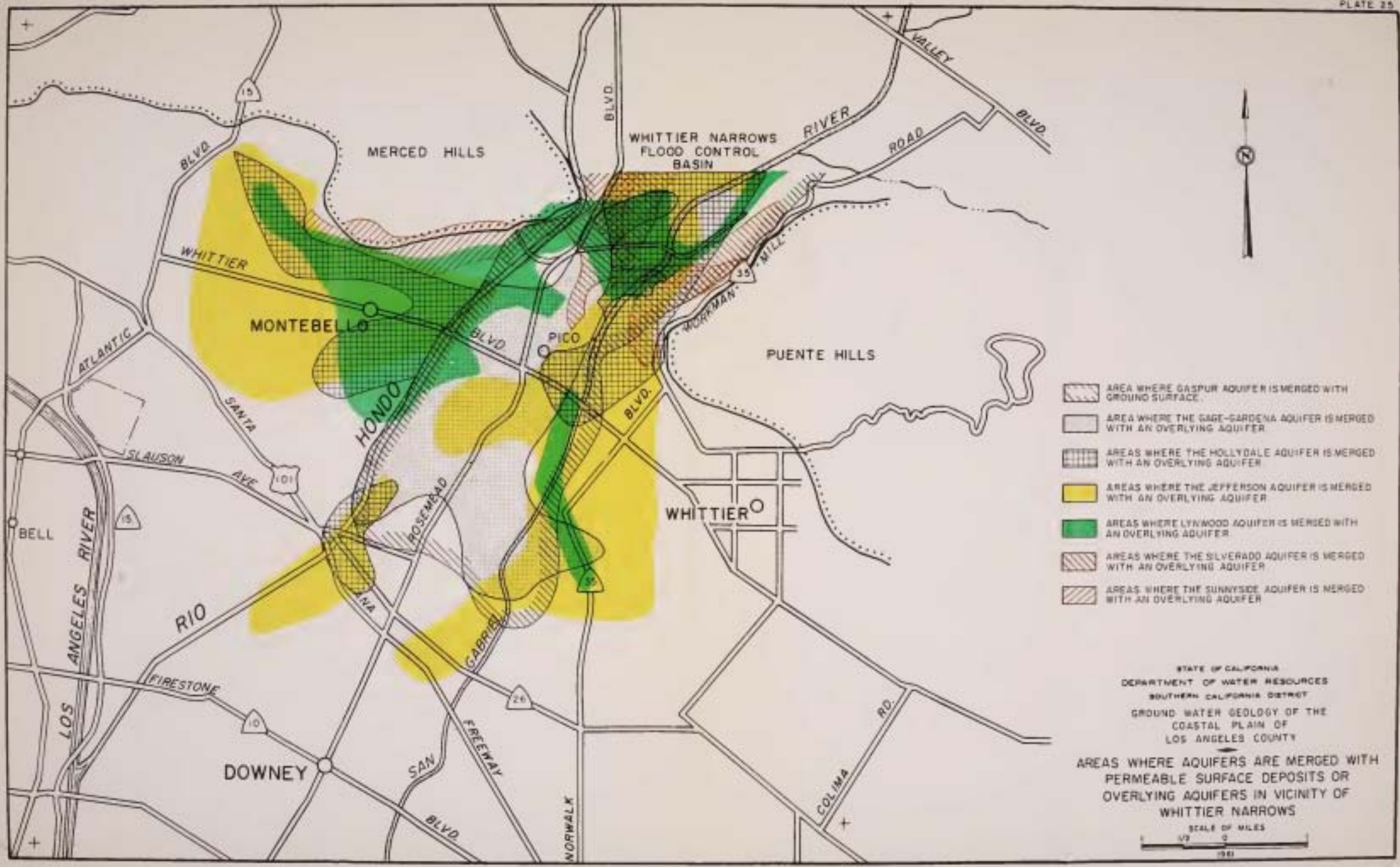
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY

AREAS WHERE AQUIFERS ARE MERGED WITH PERMEABLE SURFACE DEPOSITS OR OVERLYING AQUIFERS IN VICINITY OF WHITTIER NARROWS

SCALE OF MILES
1/2 0

1961

AR0069205


MERCED HILLS
WHITTIER NARROWS FLOOD CONTROL BASIN
RIVER
ROAD
VALLEY BLVD.
BLVD.
WHITTIER BLVD.
MONTEBELLO
PICO
HONDO
ATLANTIC
SANTA ANA
SLAUSON AVE
BELL
LOS ANGELES RIVER
RIO HONDO
ROSEMEAD BLVD.
WHITTIER
PUENTE HILLS
WORKMAN MILL
GABRIEL
FIRESTONE
DOWNEY
SAN GABRIEL FREEWAY
NORWALK BLVD.
COLIMA RD.
AREA WHERE GASPUR AQUIFER IS MERGED WITH GROUND SURFACE.
AREA WHERE THE GAGE-GARDENA AQUIFER IS MERGED WITH AN OVERLYING AQUIFER
AREAS WHERE THE HOLLYDALE AQUIFER IS MERGED WITH AN OVERLYING AQUIFER
AREAS WHERE THE JEFFERSON AQUIFER IS MERGED WITH AN OVERLYING AQUIFER
AREAS WHERE LYNWOOD AQUIFER IS MERGED WITH AN OVERLYING AQUIFER
AREAS WHERE THE SILVERADO AQUIFER IS MERGED WITH AN OVERLYING AQUIFER
AREAS WHERE THE SUNNYSIDE AQUIFER IS MERGED WITH AN OVERLYING AQUIFER
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY
AREAS WHERE AQUIFERS ARE MERGED WITH PERMEABLE SURFACE DEPOSITS OR OVERLYING AQUIFERS IN VICINITY OF WHITTIER NARROWS
SCALE OF MILES
1/2
0
1 (MI)

AR0069206

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

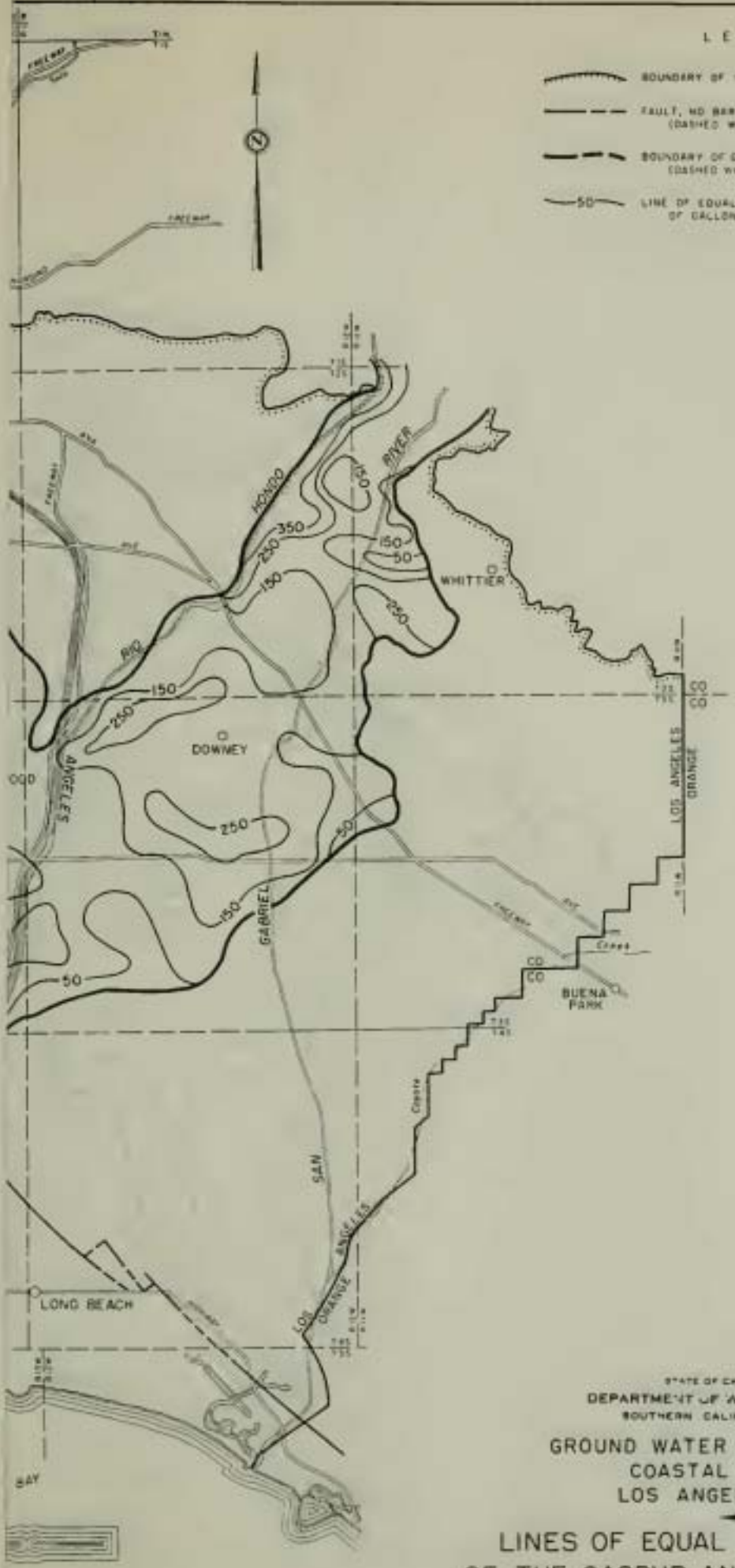
LINES OF EQUAL TRANSMISSIBILITY OF THE GASPUR AND BALLONA AQUIFERS

SCALE OF MILES
0 1 2 3

1961

AR0069207

AR0069208



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

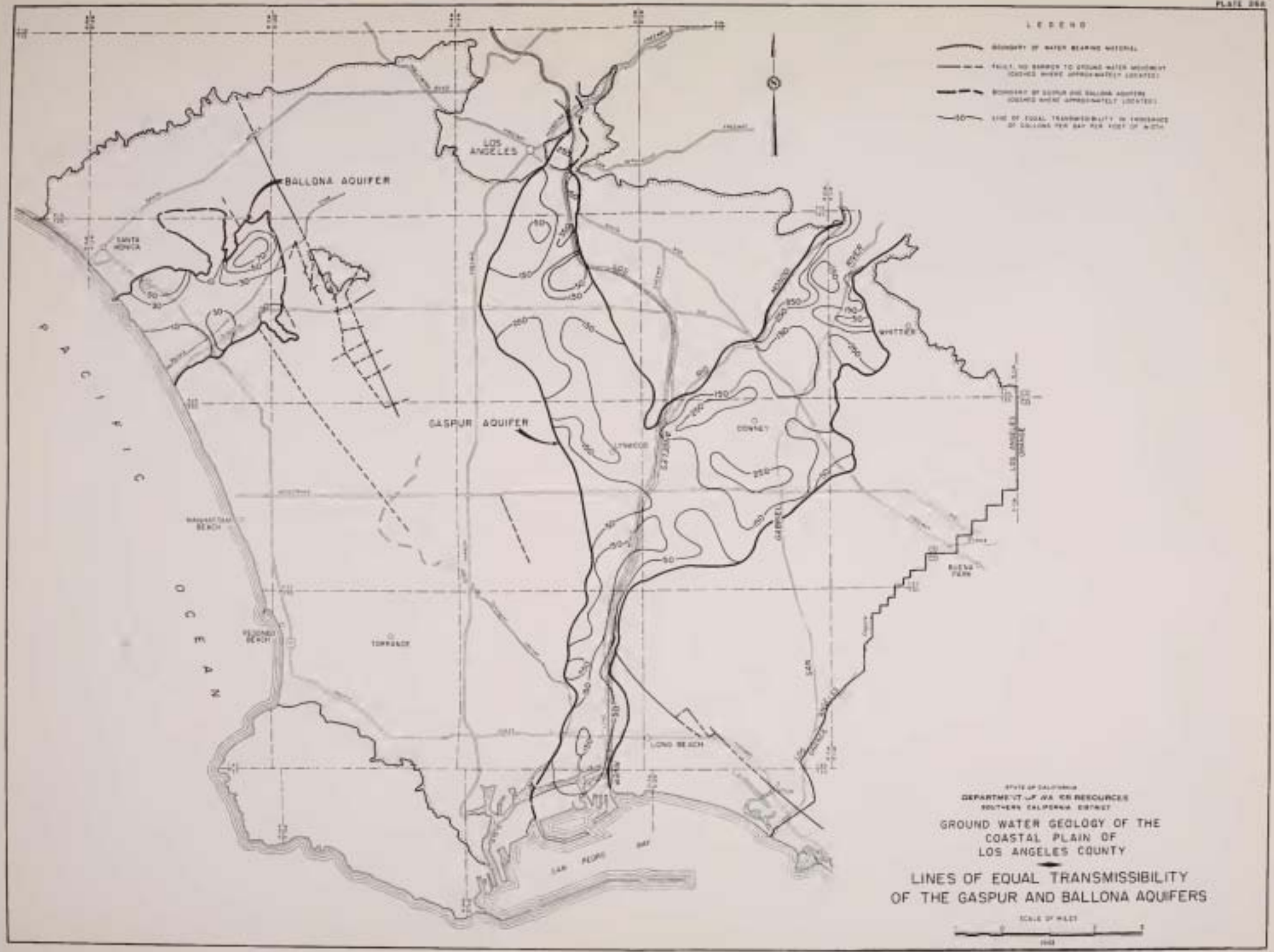
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE GASPUR AND BALLONA AQUIFERS

SCALE OF MILES
0 1 2 3

1961

AR0069209



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

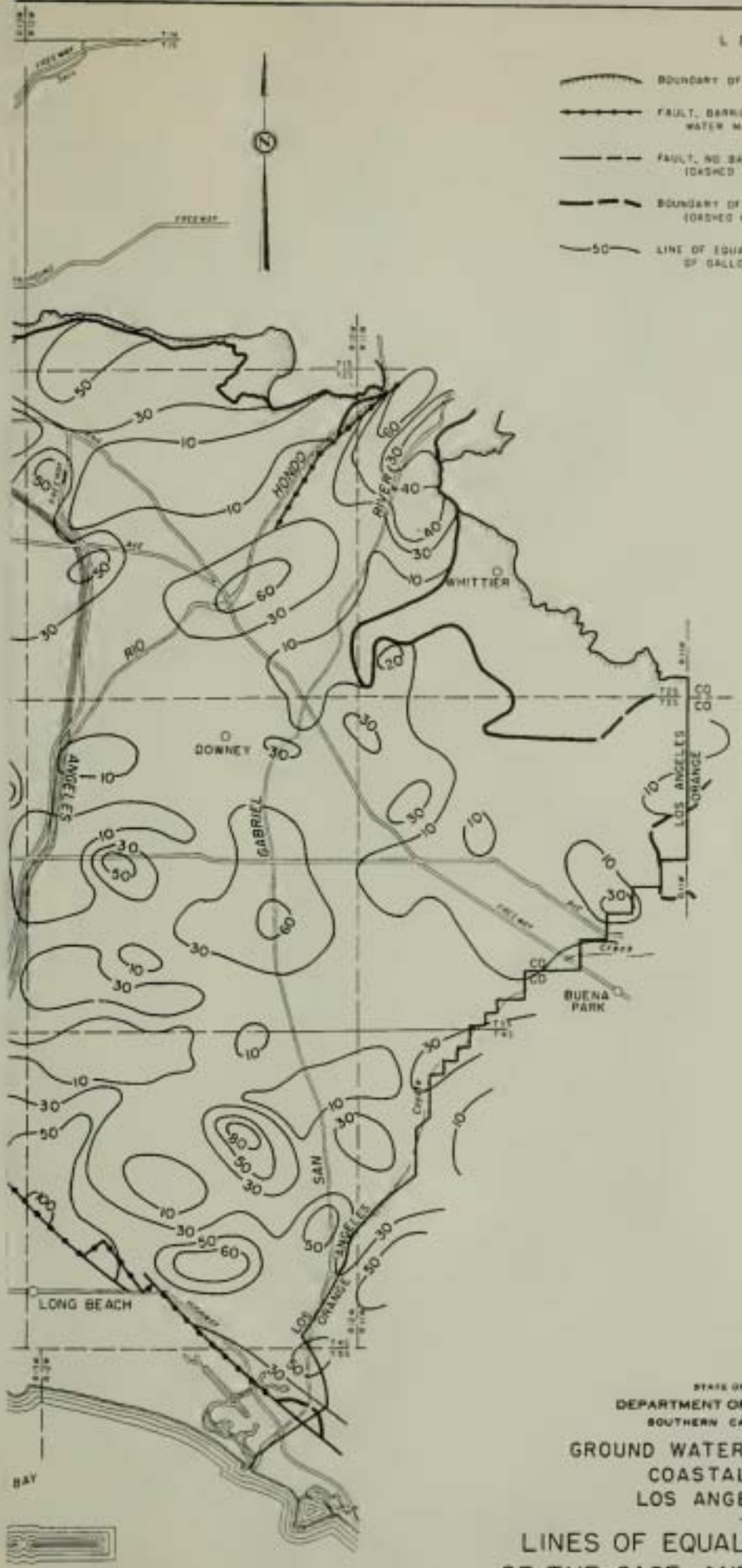
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY
OF THE GASPUR AND BALLONA AQUIFERS

SCALE OF MILES
0 1 2 3

1948

AR0069210



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

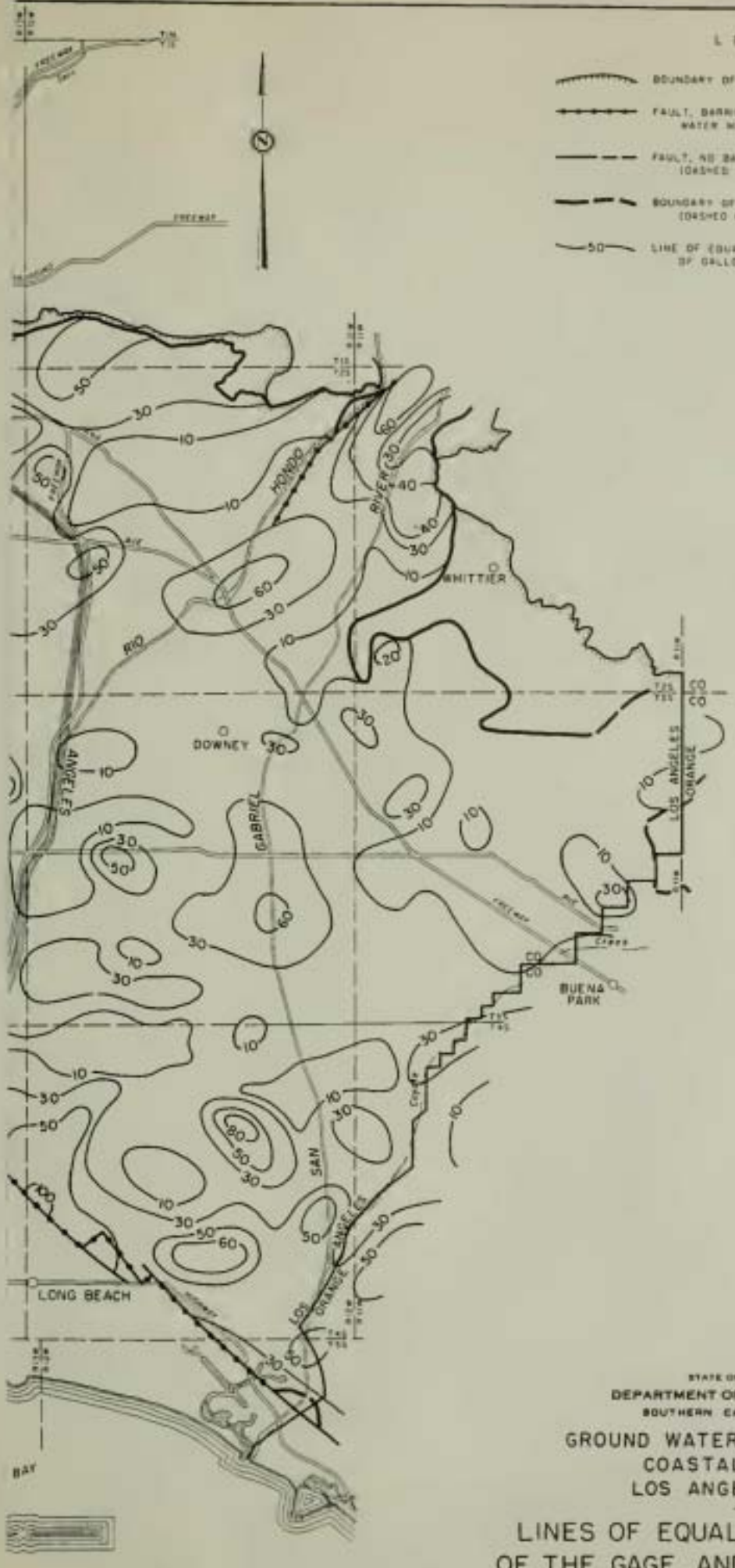
LINES OF EQUAL TRANSMISSIBILITY OF THE GAGE AND GARDENA AQUIFERS

SCALE OF MILES
0 1 2 3

1961

AR0069211

AR0069212



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

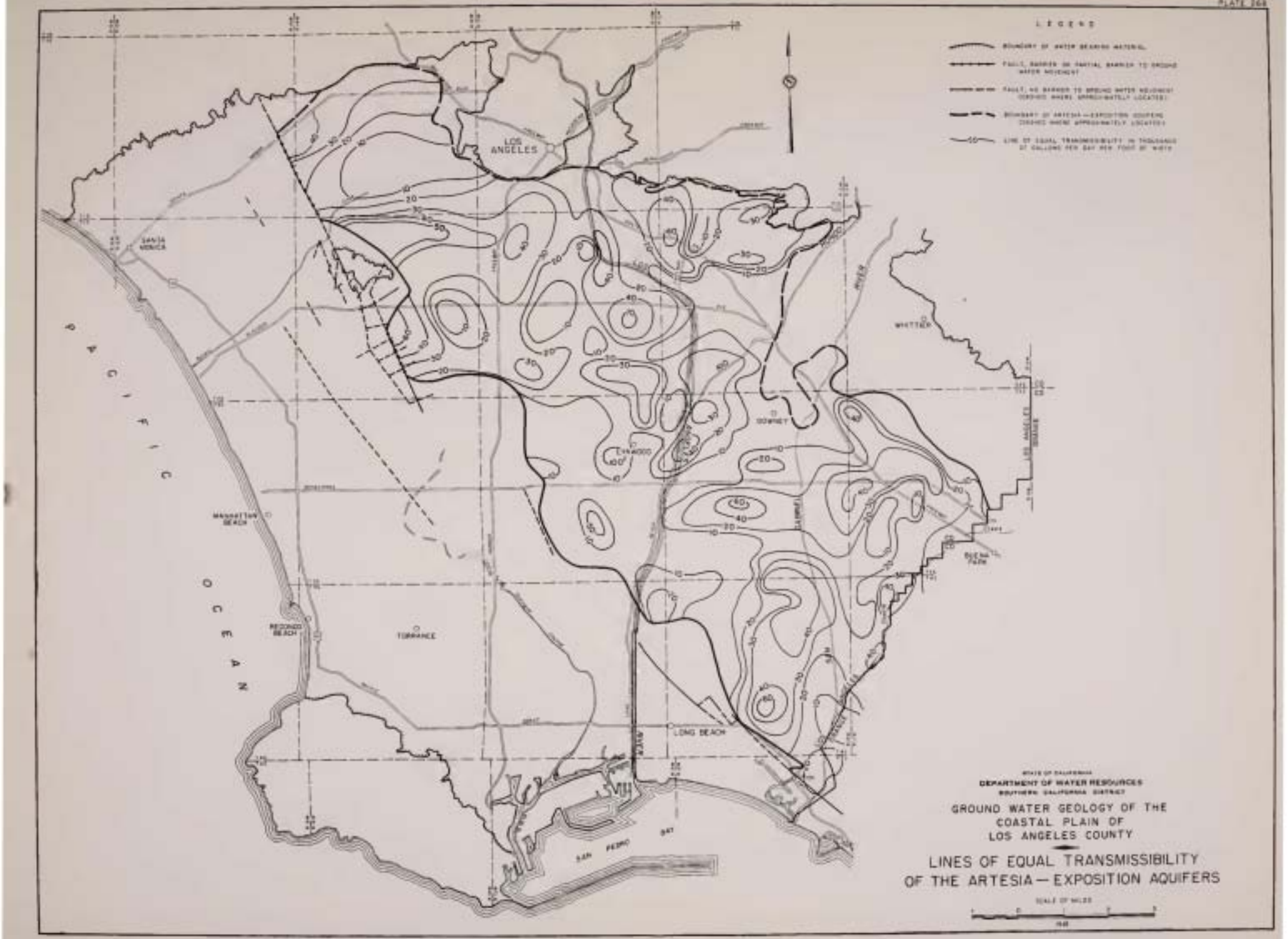
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE GAGE AND GARDENA AQUIFERS

SCALE OF MILES
1 0 1 2 3

1961

AR0069213



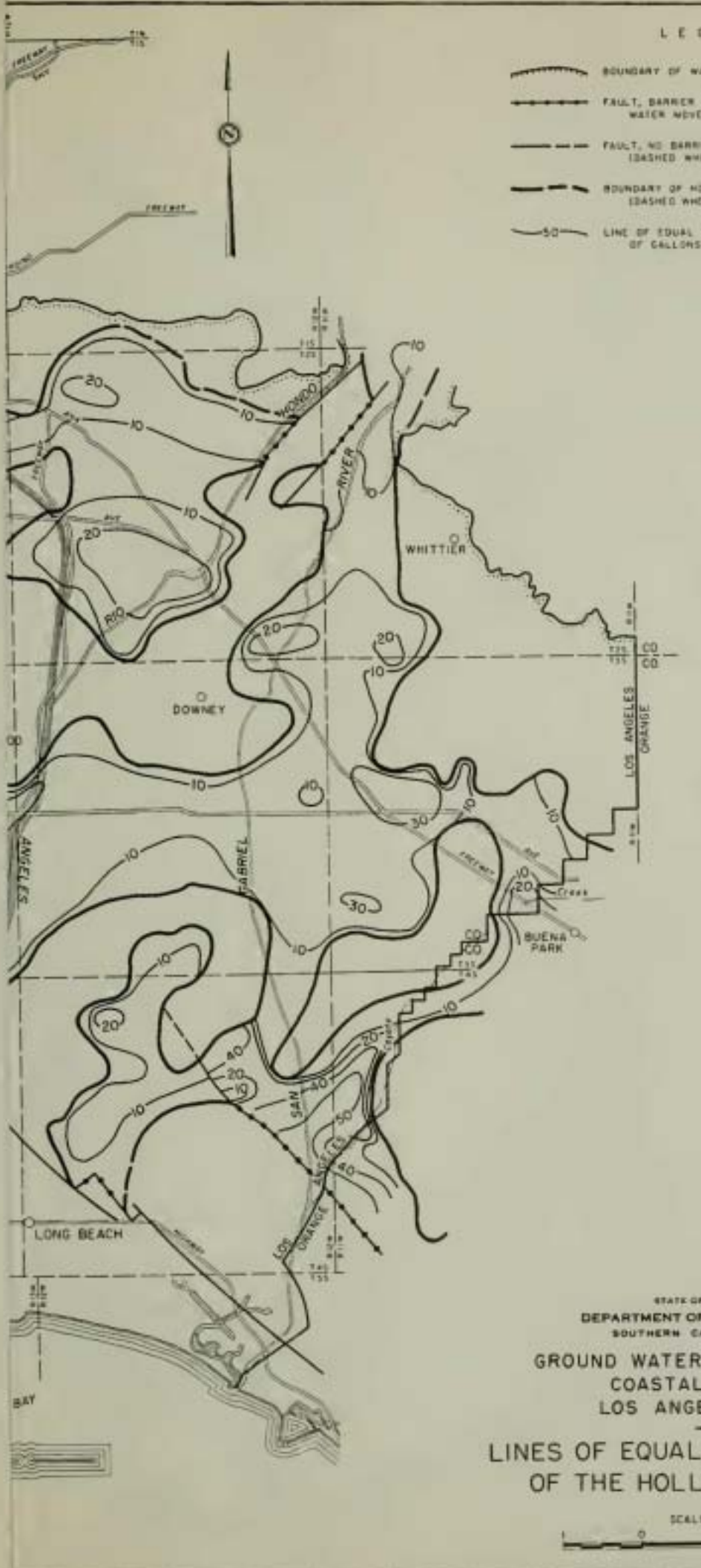
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY
OF THE ARTESIA — EXPOSITION AQUIFERS

SCALE OF MILES

AR0069214



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

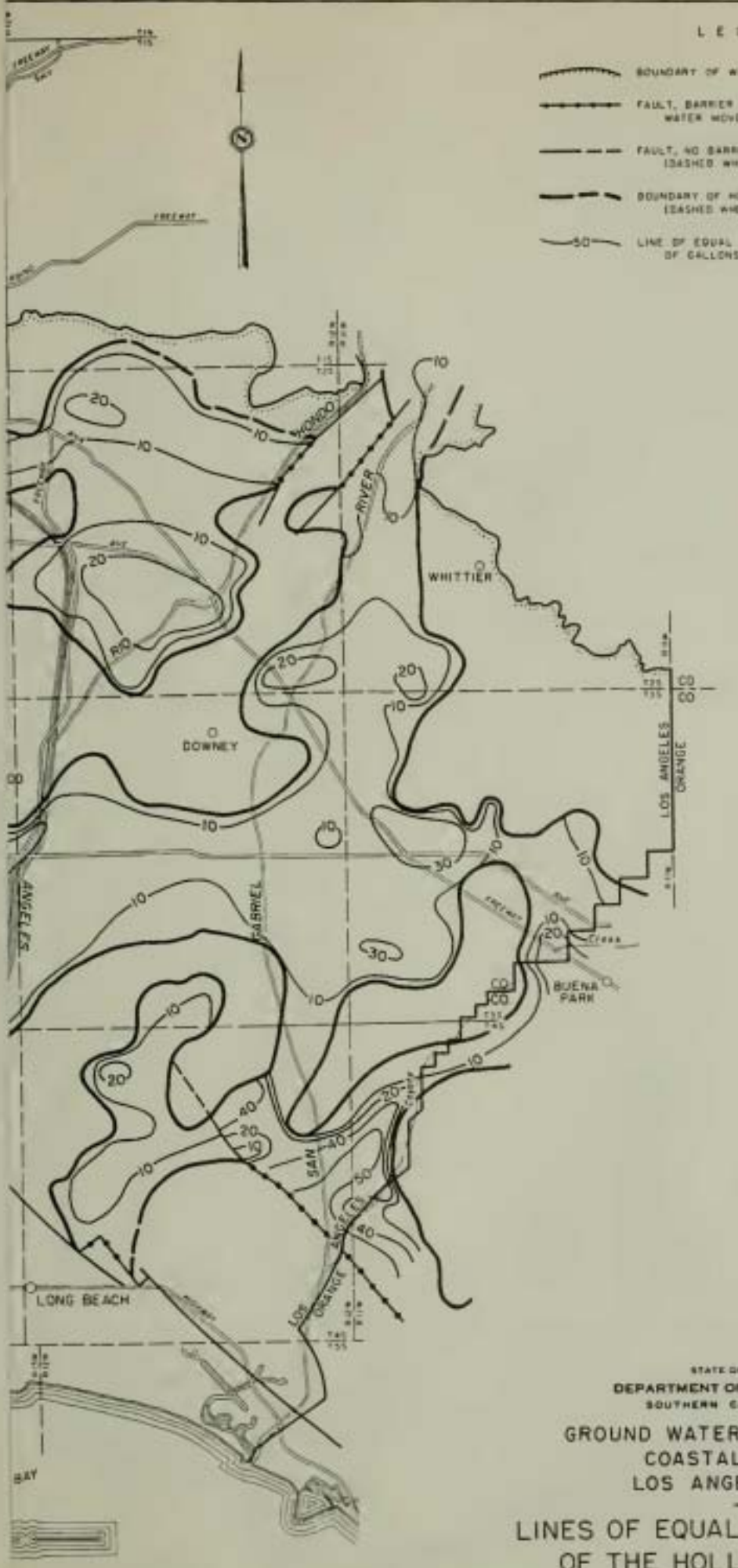
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE HOLLYDALE AQUIFER

SCALE OF MILES
1 0 1 2 3

AR0069215

AR0069216



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

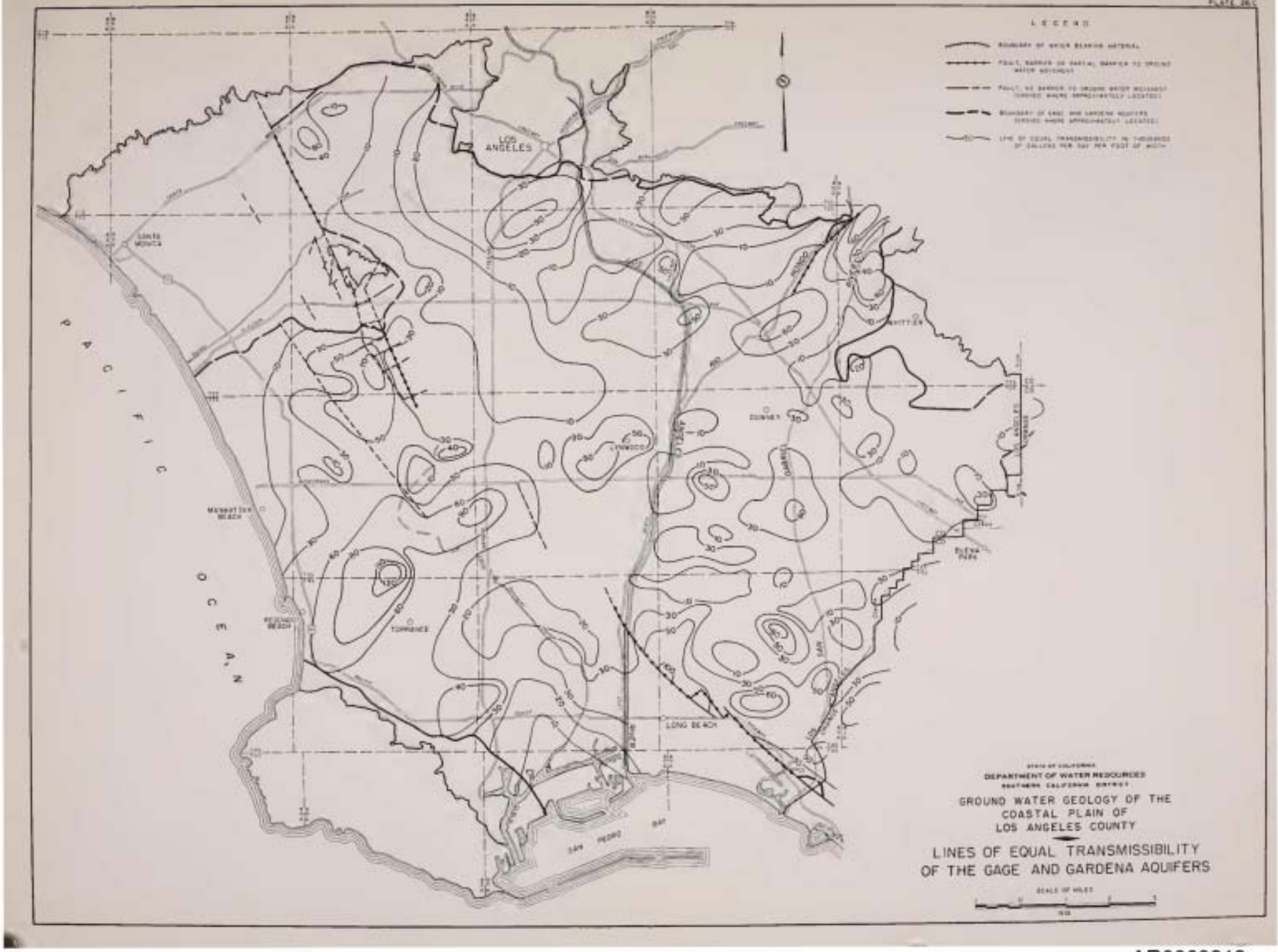
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE HOLLYDALE AQUIFER

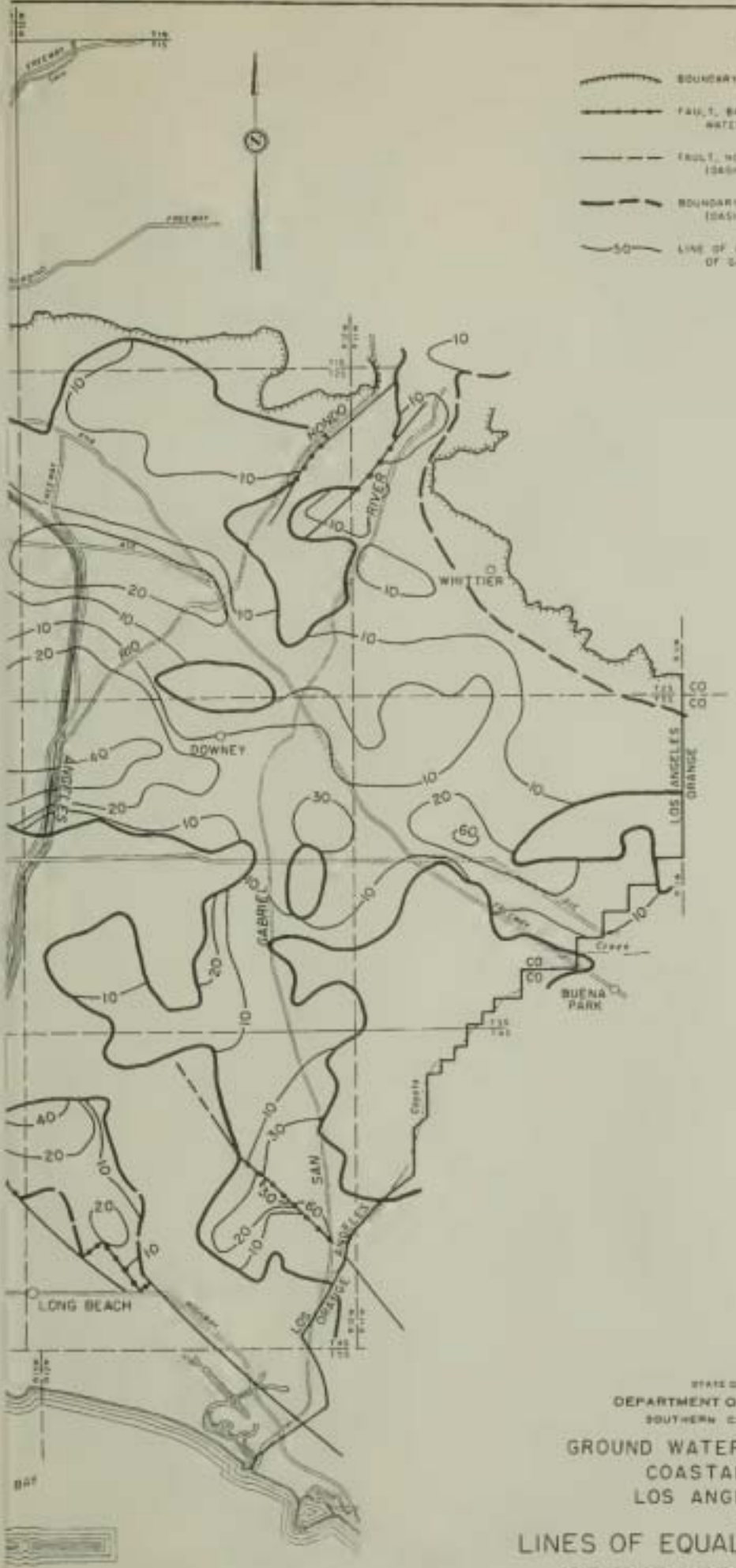
SCALE OF MILES

1961

AR0069217


LEGEND
LOS ANGELES
SANTA MONICA
PACIFIC OCEAN
MANHATTAN BEACH
REDONDO BEACH
TORRANCE
LONG BEACH
SAN PEDRO BAY
COMPTON
WHITTIER
DOWNEY
SOUTH GATE
PALOS VERDES
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL TRANSMISSIBILITY
OF THE GAGE AND GARDENA AQUIFERS
SCALE OF MILES

AR0069218



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE JEFFERSON AQUIFER

SCALE OF MILES
0 1 2 5

1961

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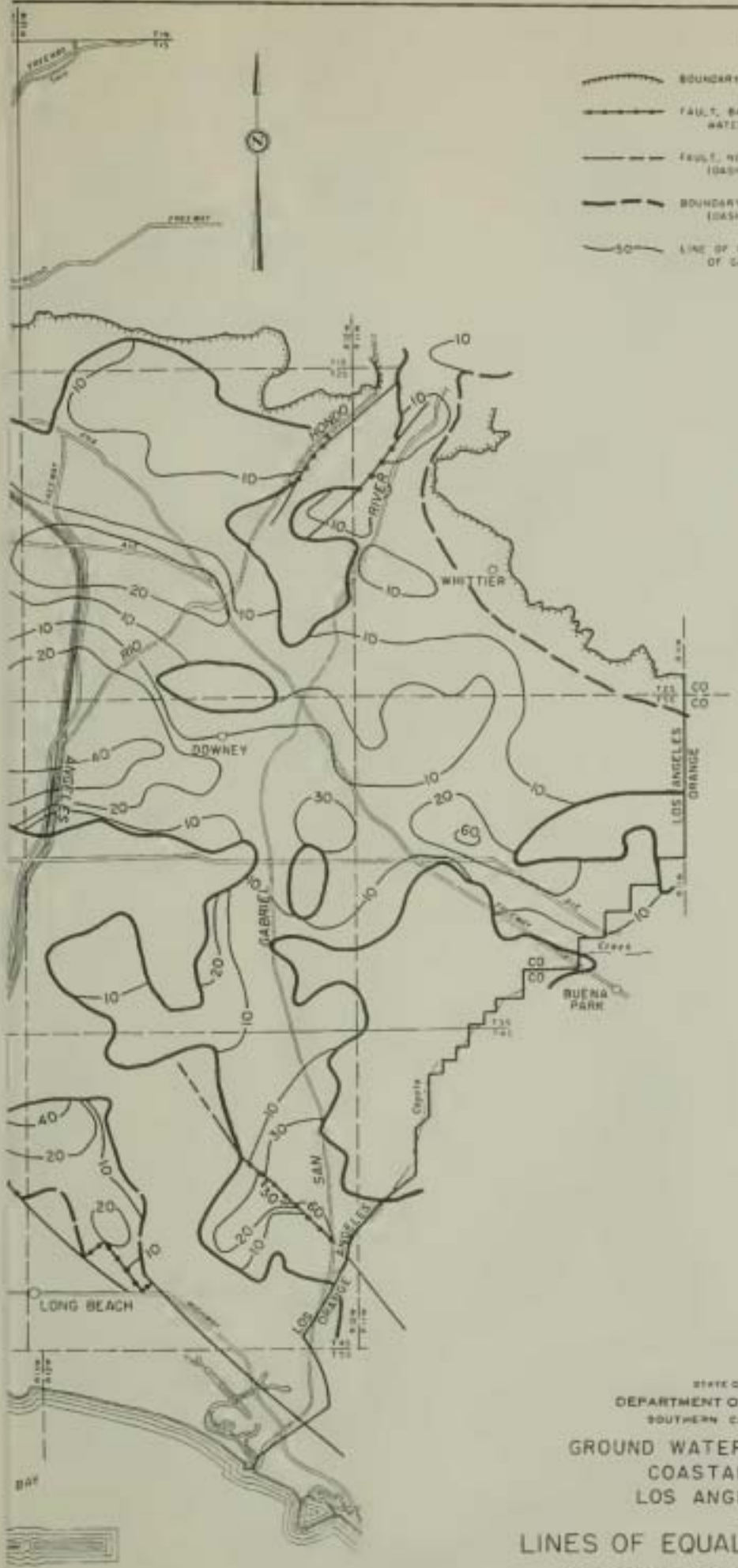


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE JEFFERSON AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069221

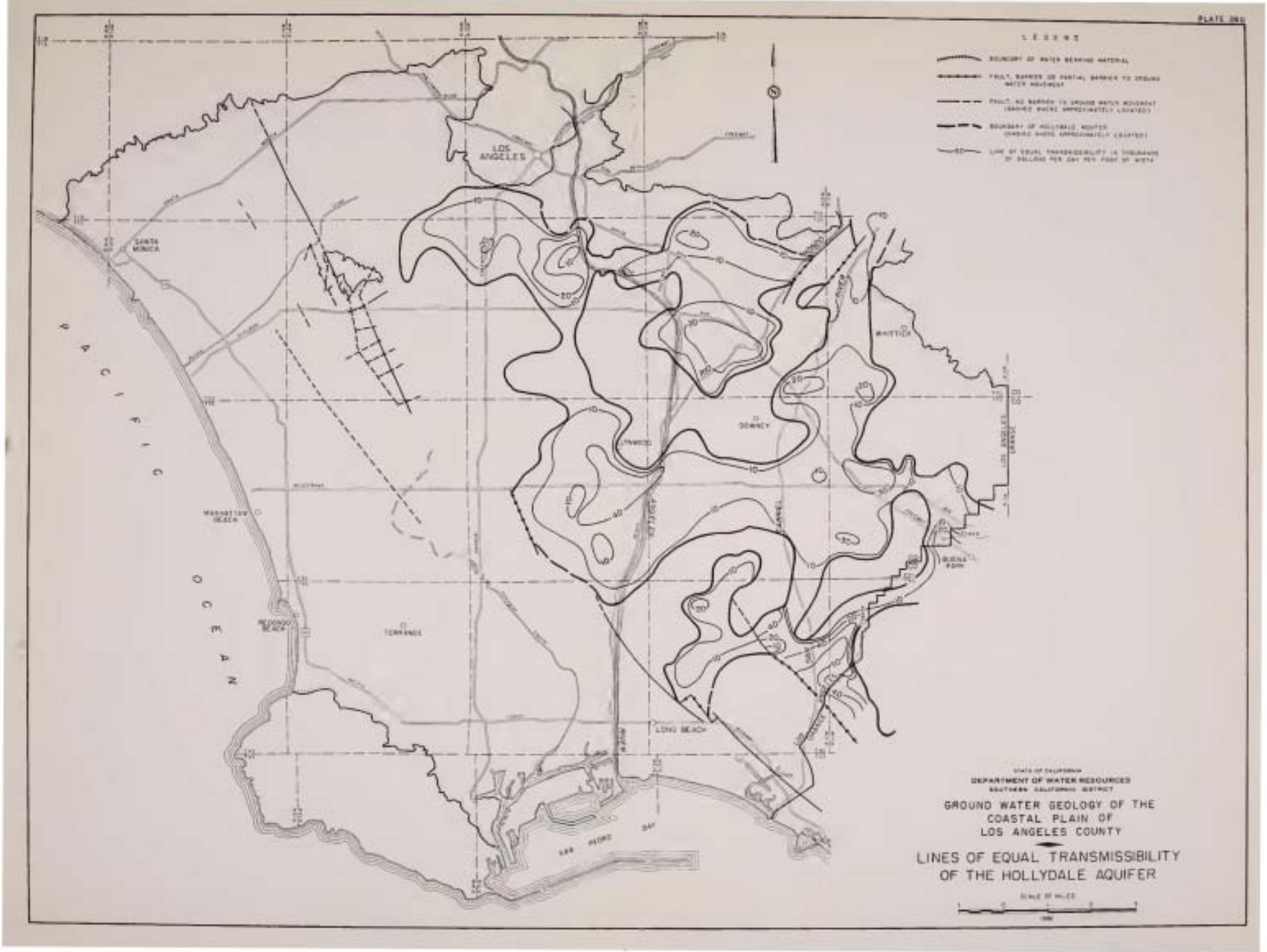
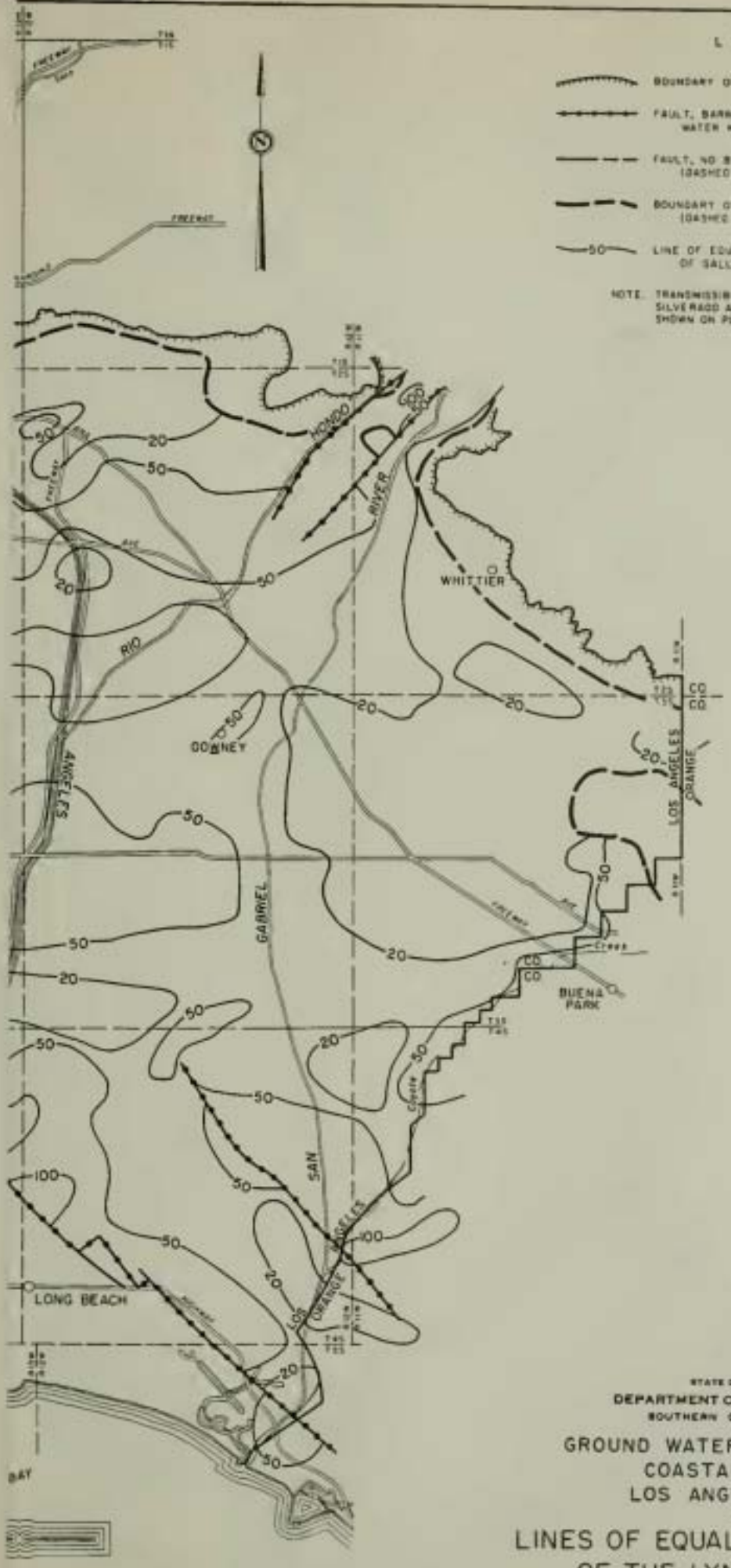


PLATE 2911
LEGEND
LOS ANGELES
SANTA MONICA
MANHATTAN BEACH
TORRANCE
LONG BEACH
SAN PEDRO BAY
WHITTIER
DOWNEY
BUENA PARK
PACIFIC OCEAN
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL TRANSMISSIBILITY
OF THE HOLLYDALE AQUIFER

AR0069222



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE LYNWOOD AQUIFER

SCALE OF MILES
0 1 2 3

1961

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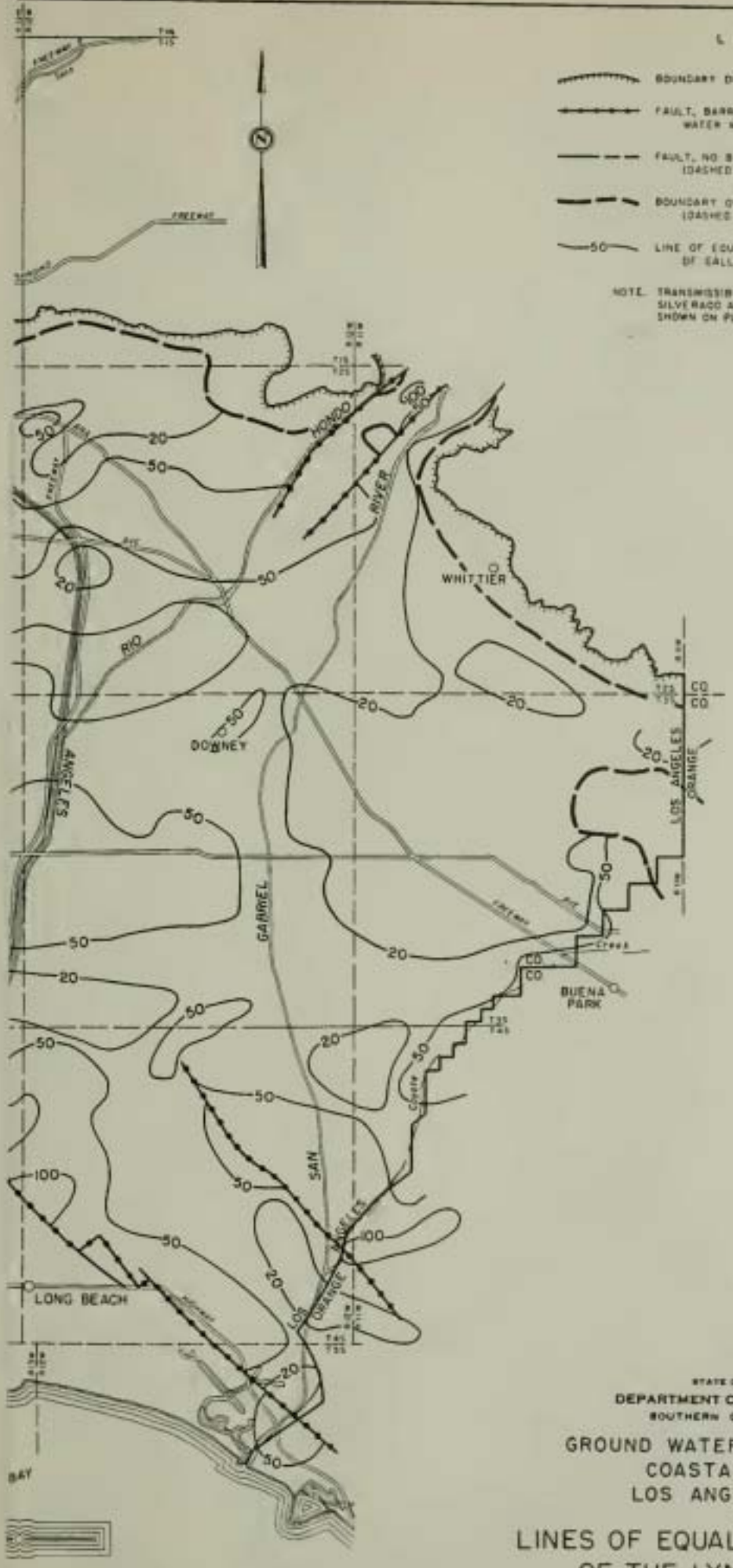


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE LYNWOOD AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069225

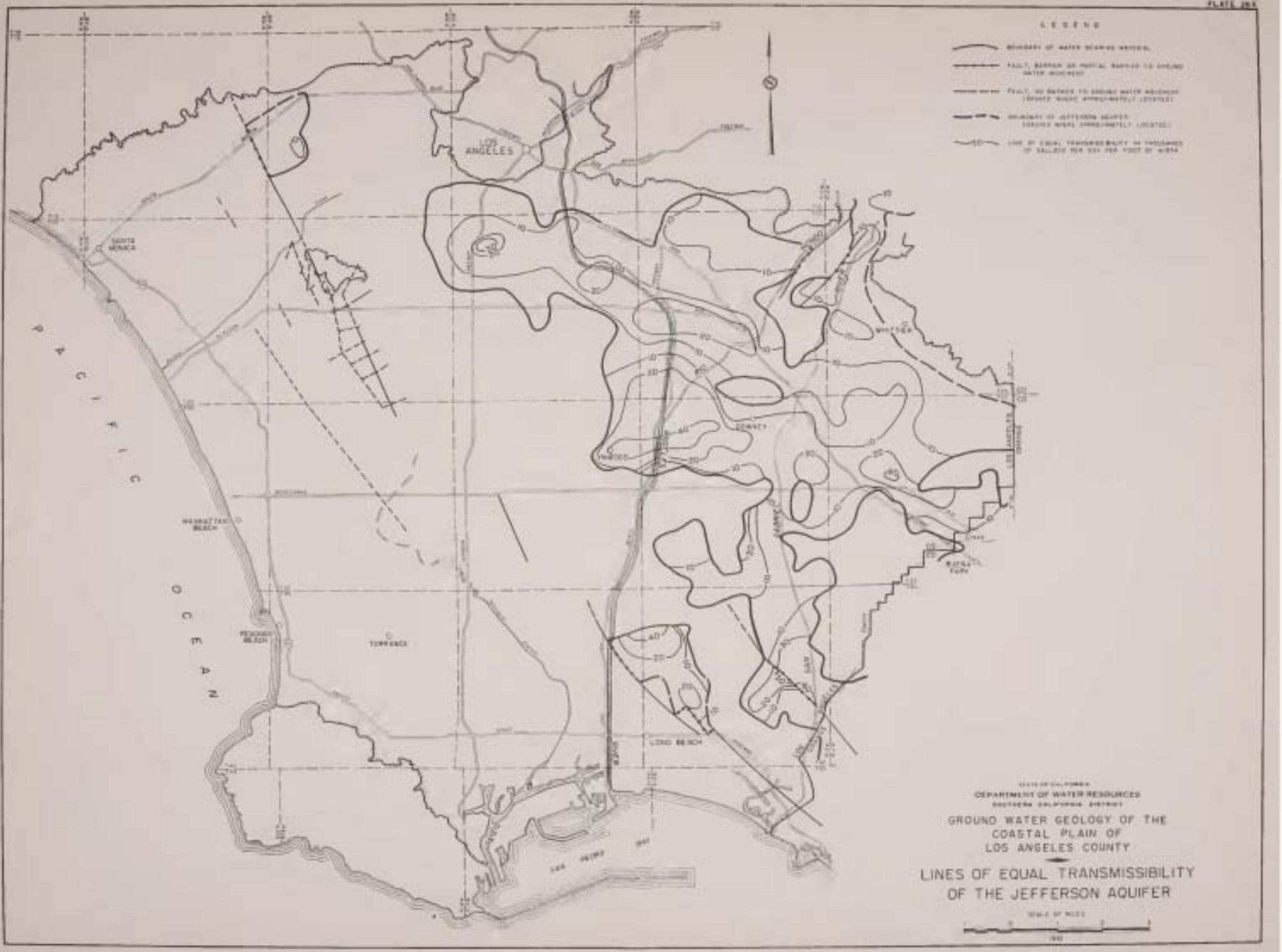
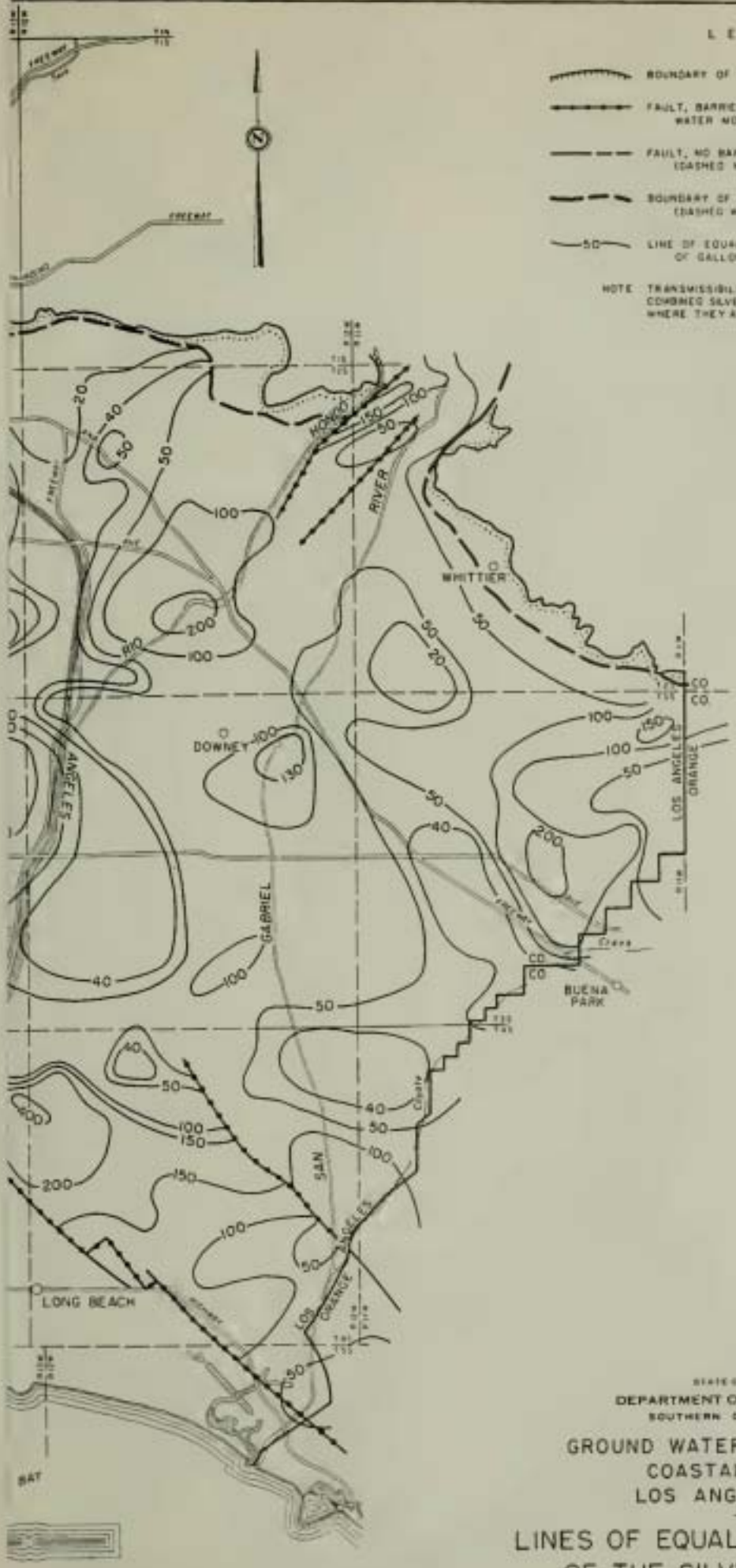


PLATE 28-E
LEGEND
LOS ANGELES
SANTA MONICA
MANHATTAN BEACH
REDONDO BEACH
TORRANCE
LONG BEACH
DOWNEY
PACIFIC OCEAN
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL TRANSMISSIBILITY
OF THE JEFFERSON AQUIFER

AR0069226



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE SILVERADO AQUIFER

SCALE OF MILES

1961

AR0069227

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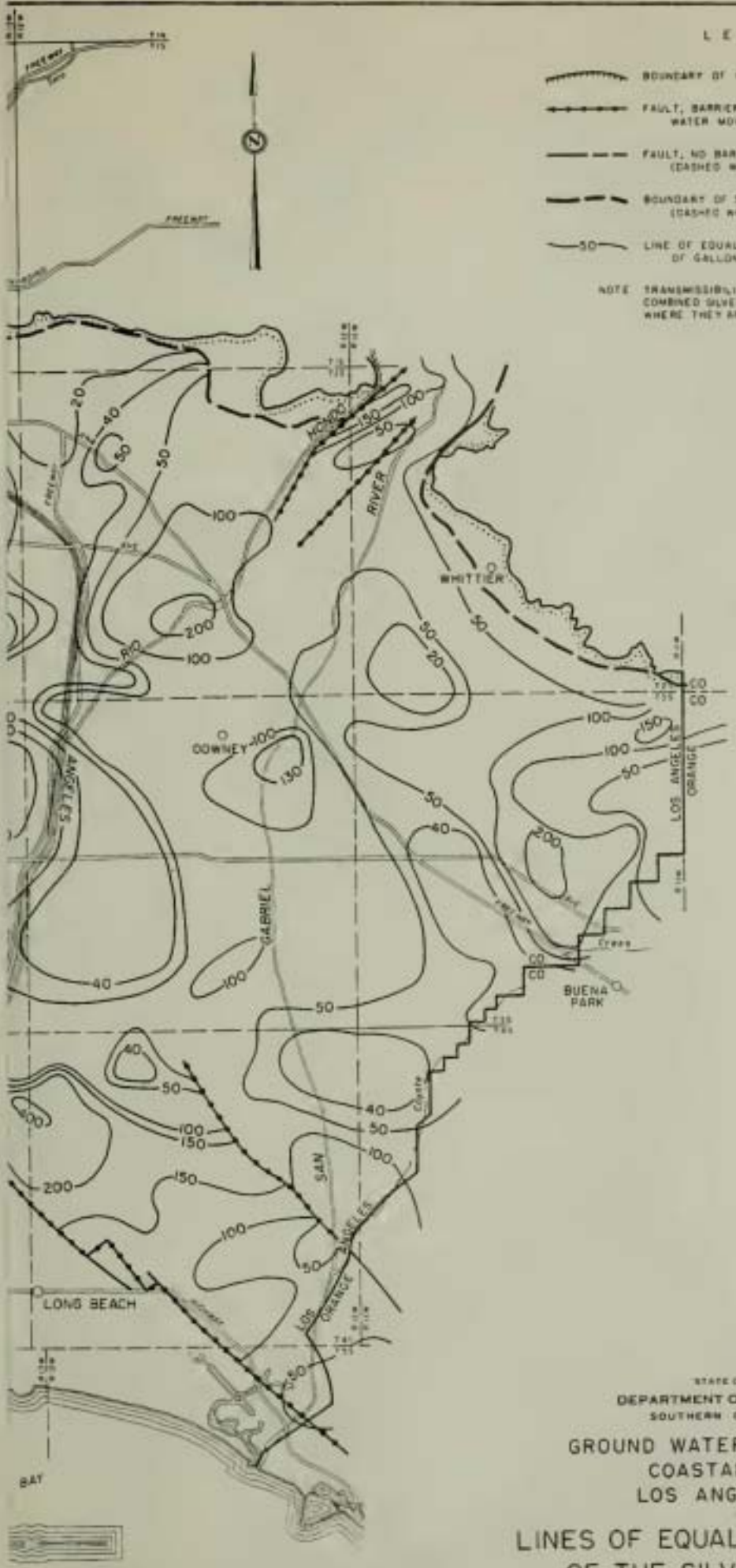


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

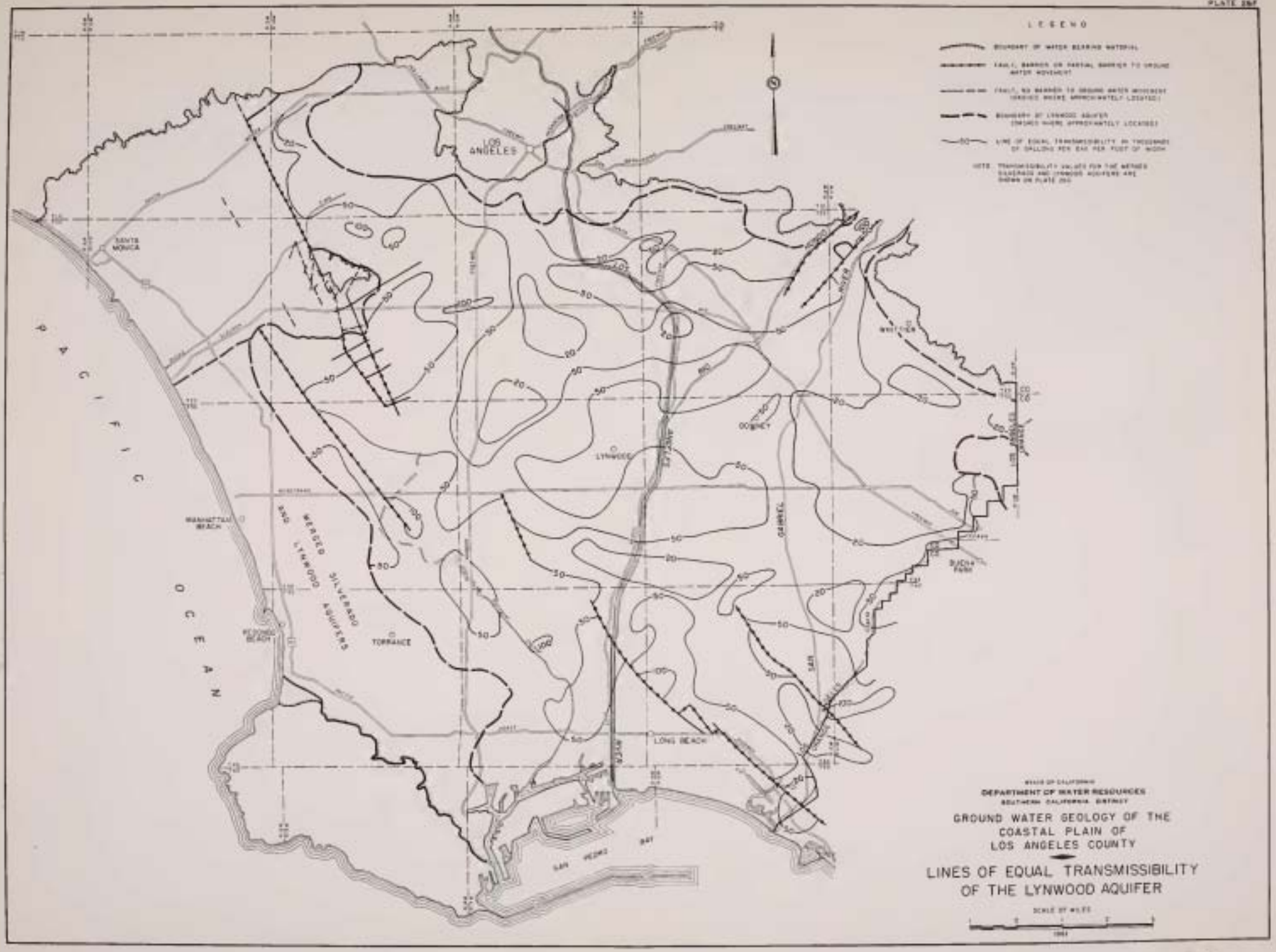
LINES OF EQUAL TRANSMISSIBILITY OF THE SILVERADO AQUIFER

SCALE OF MILES
0 1 2 3

1961

AR0069229

PLATE 26F



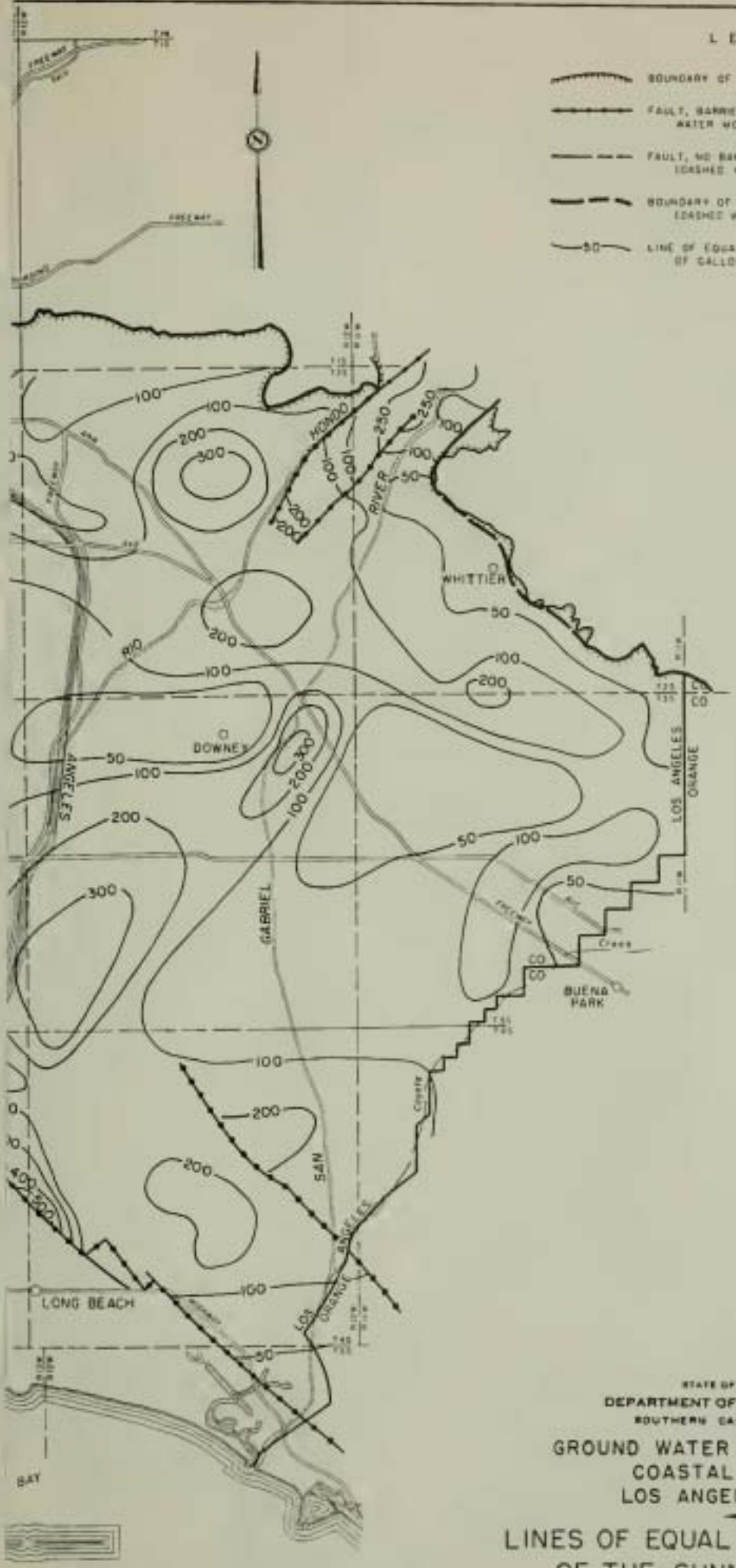
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE LYNWOOD AQUIFER

SCALE OF MILES

AR0069230



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

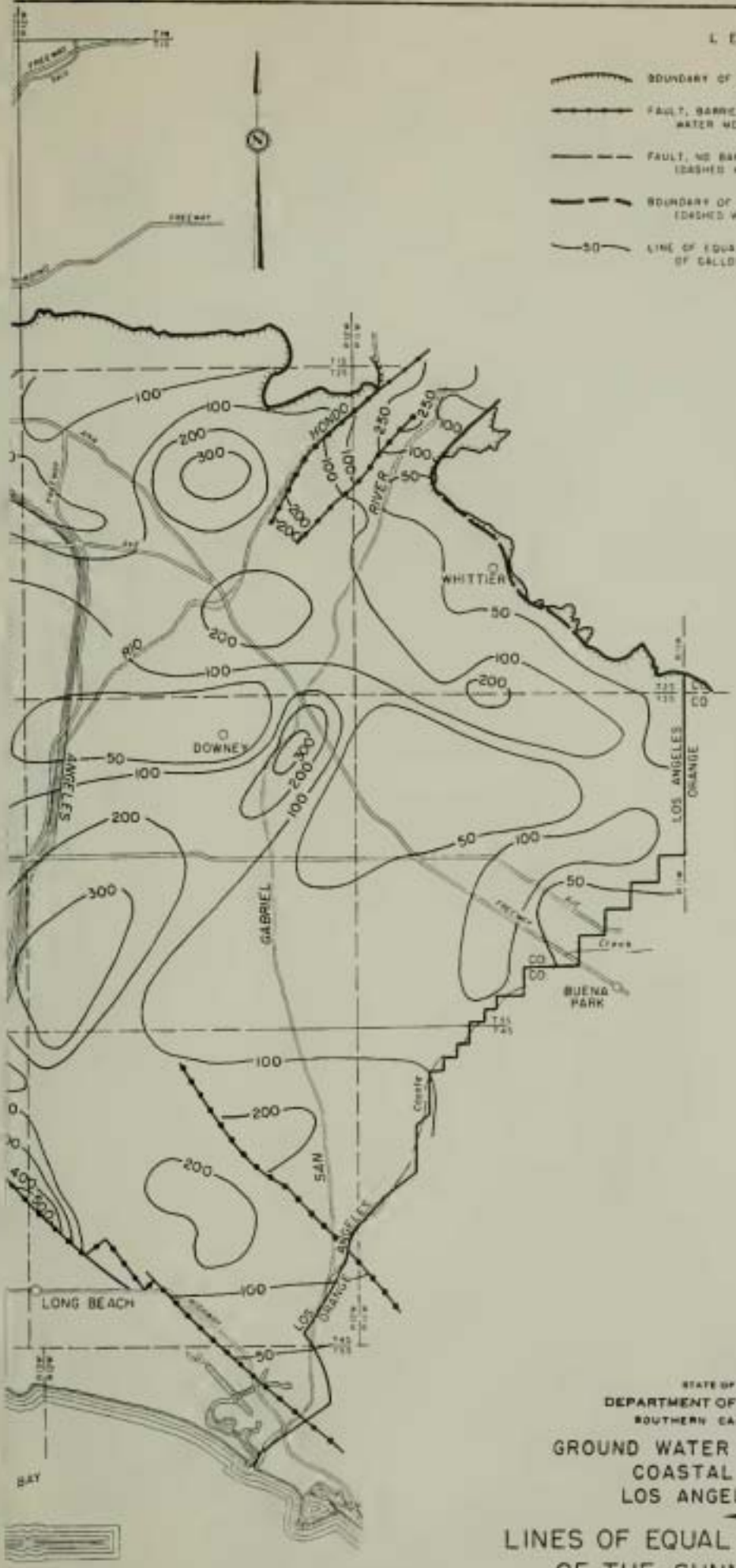
LINES OF EQUAL TRANSMISSIBILITY OF THE SUNNYSIDE AQUIFER

SCALE OF MILES

1961

AR0069231

AR0069232



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

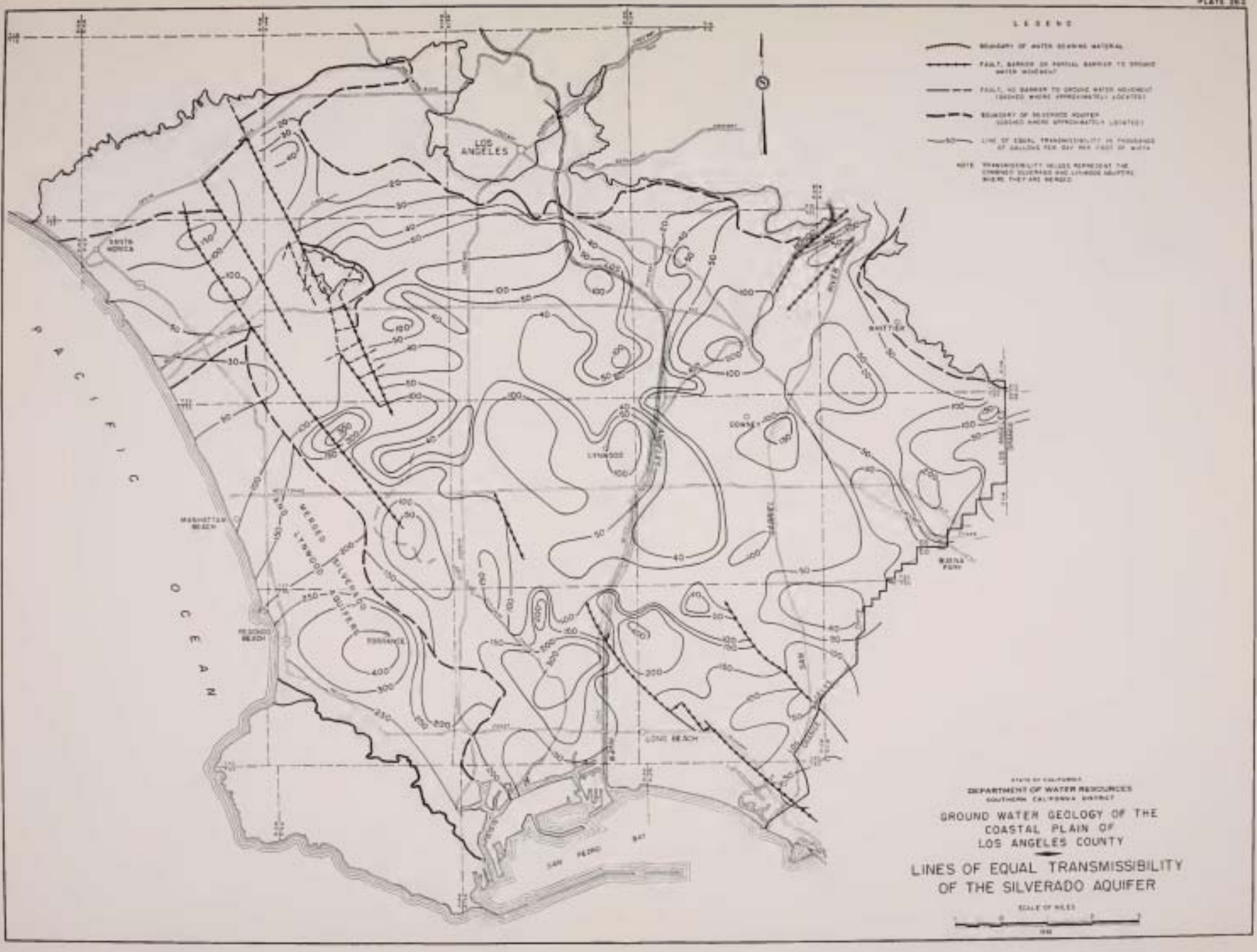
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE SUNNYSIDE AQUIFER

SCALE OF MILES

1961

AR0069233



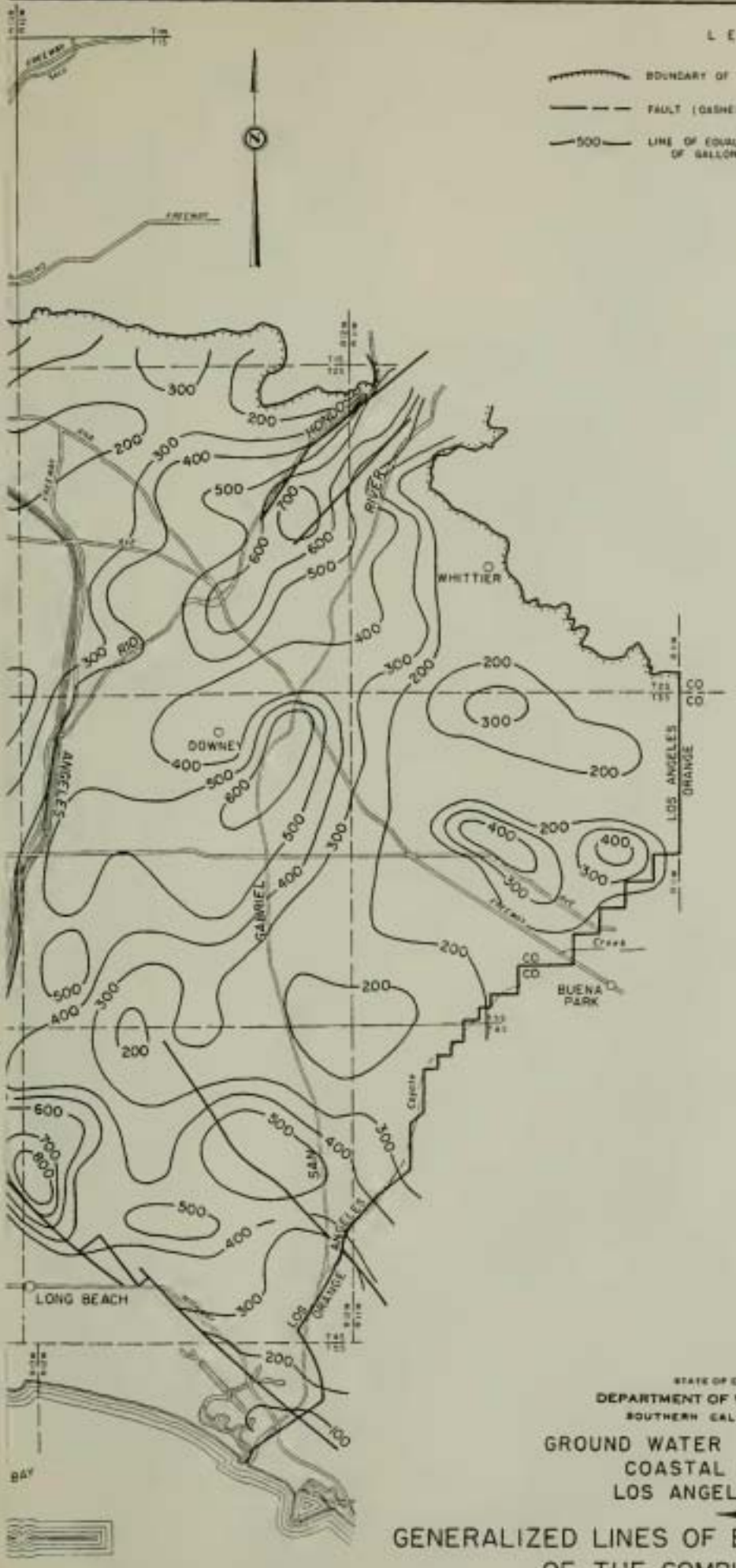
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

LINES OF EQUAL TRANSMISSIBILITY OF THE SILVERADO AQUIFER

SCALE OF MILES

AR0069234



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

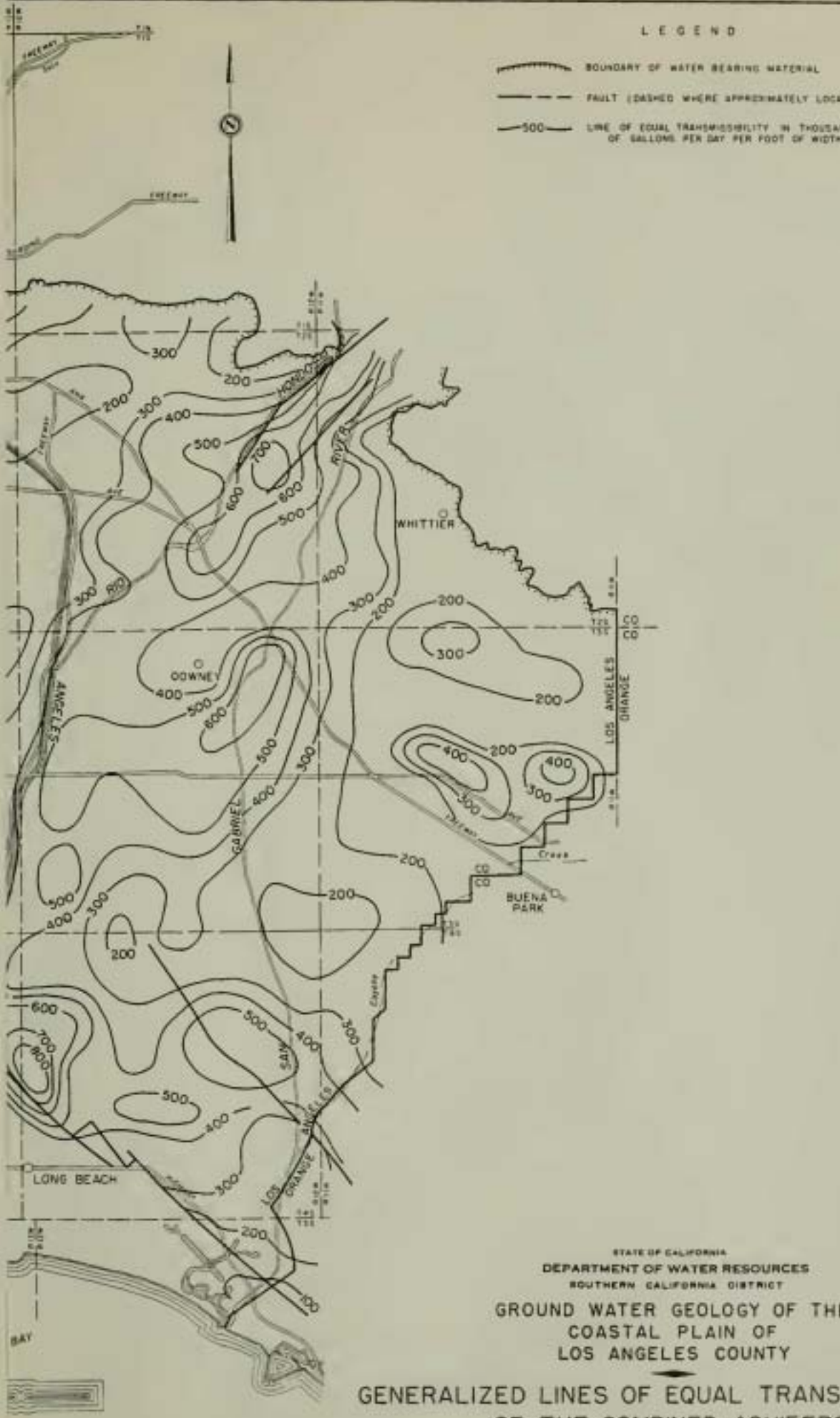
GENERALIZED LINES OF EQUAL TRANSMISSIBILITY OF THE COMBINED AQUIFERS

SCALE OF MILES
0 1 2 3

1961

AR0069235

AR0069236



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

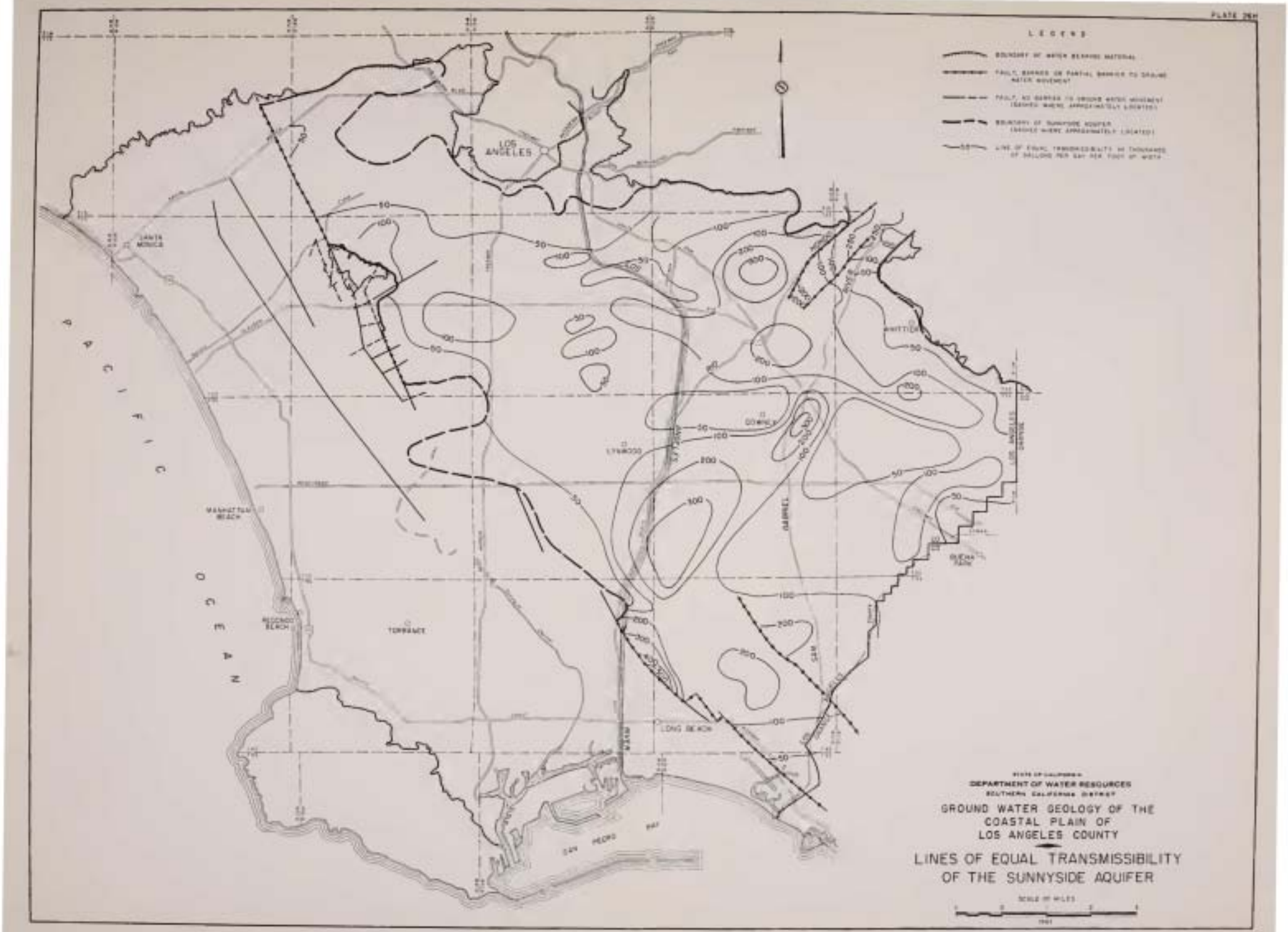
GROUND WATER GEOLOGY OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

GENERALIZED LINES OF EQUAL TRANSMISSIBILITY OF THE COMBINED AQUIFERS

SCALE OF MILES
0 1 2 3

1961

AR0069237


LEGEND
LOS ANGELES
SANTA MONICA
MANHATTAN BEACH
REDONDO BEACH
TORRANCE
LONG BEACH
SAN PEDRO BAY
WHITTIER
DOWNEY
LYNWOOD
COMPTON
GARDENA
PACIFIC OCEAN
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL TRANSMISSIBILITY
OF THE SUNNYSIDE AQUIFER

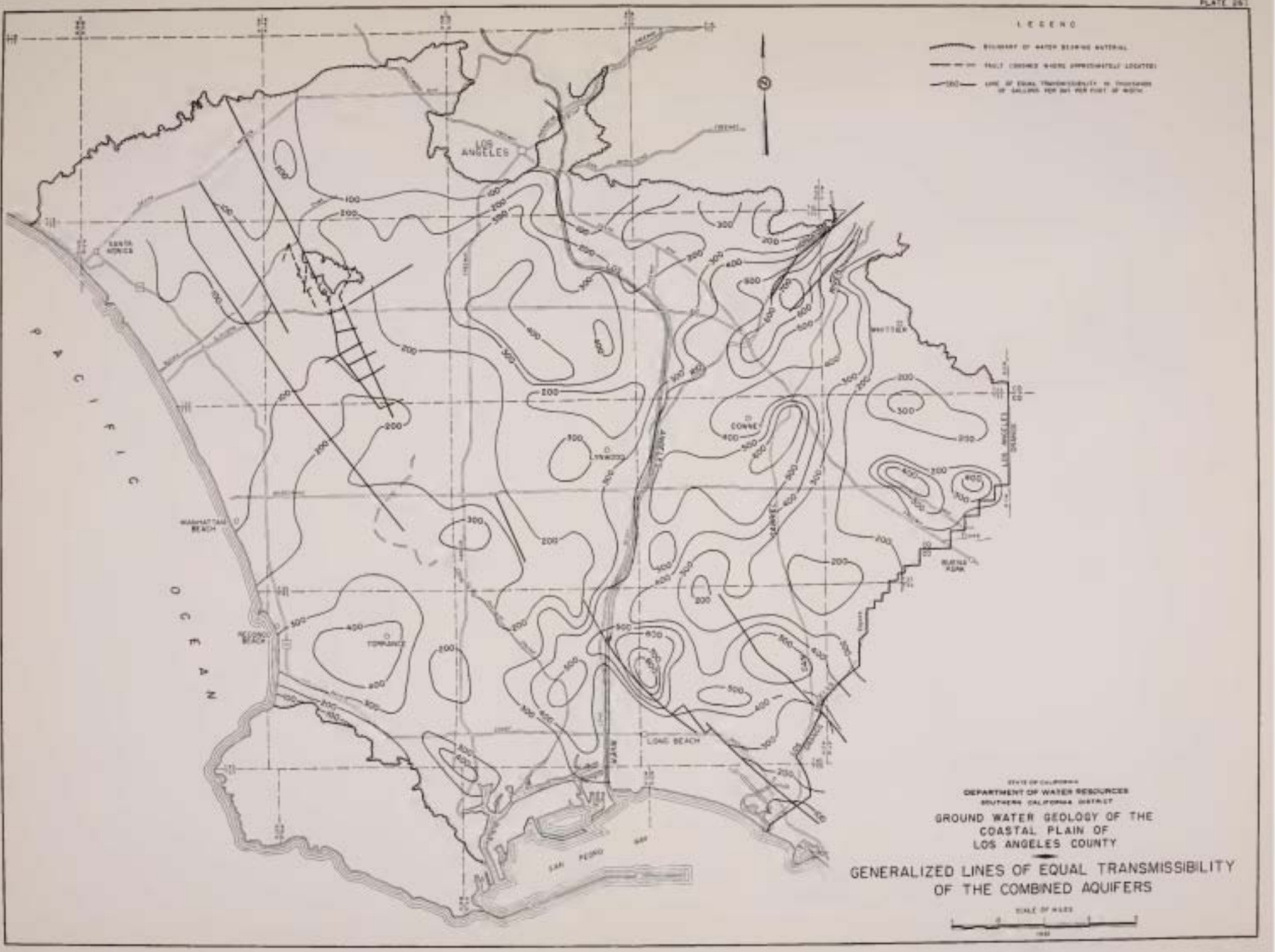
AR0069238

ATTACHMENT 1

BIBLIOGRAPHY

AR0069239

PLATE 26T



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY

GENERALIZED LINES OF EQUAL TRANSMISSIBILITY
OF THE COMBINED AQUIFERS

SCALE OF MILES

AR0069240

ATTACHMENT 1

BIBLIOGRAPHY

AR0069241

AR0069242

ATTACHMENT 1

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ATTACHMENT 2

SPECIFIC YIELD VALUES AND

TRANSMISSIBILITY TESTS

AR0069253

AR0069254

ATTACHMENT 2

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TABLE A

SPECIFIC YIELD VALUES
Used in Coastal Plain of Los Angeles County

(After State Water Rights Board Revised Values of
Specific Yield as used for San Fernando Valley Reference,
7/9/59, which is based on values used in Bulletin 45,
Geology and Ground Water Storage Capacity of Valley Fill)
*Specific yield values above base of Bellflower aquiclude = 00

*00 Percent - Bellflower Aquiclude

03 Percent - Clay and Shale

Adobe
Boulders in clay
Cemented clay
Clay
Clayey loam
Decomposed shale
Granite clay
Hard clay
Hard pan
Hard sandy shale
Hard shell
Muck
Shale
Shaley clay
Shell rock
Silty clay loam
Soapstone

05 Percent - Clayey Sand and Silt

Chalk rock
Clay and gravel
Clayey sand
Clayey silt
Conglomerate
Decomposed granite
Gravelly clay
Loam
Rotten conglomerate
Rotten granite
Sand and clay
Sand and silt
Sand rock
Sandstone
Sandy clay
Sandy silt
Sediment
Shaley gravel
Silt
Silty clay
Silty loam
Silty sand
Soil

10 Percent - Cemented or Tight Sand or Gravel

Caliche
Cemented boulders
Cemented gravel
Cemented sand
Cemented sand and gravel
Dead gravel
Dead sand
Dirty pack sand
Hard gravel
Hard sand
Heavy rocks
Soft sandstone
Tight boulders
Tight coarse gravel

14 Percent - Gravel and Boulders

Cobbles and gravel
Coarse gravel
Boulders
Broken rocks
Gravel and boulders
Heaving gravel
Heavy gravel
Large gravel
Rocks
Sand and gravel, silty
Silty sand
Tight fine gravel
Tight medium gravel
Muddy sand

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SPECIFIC YIELD VALUES
(continued)

16 Percent - Fine Sand

Fine sand	Quicksand	Sand, gravel and boulders
Heaving sand	Sand and boulders	Tight sand

21 - 23 Percent - Sand and Gravel

Dry gravel	Gravelly sand	Sand
Loose gravel	Medium gravel	Water gravel

26 Percent - Coarse Sand and Fine Gravel

Coarse sand	Fine gravel	Medium sand

Value of one added to given value where streaks of sand or gravel occur in clay or clayey material.

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TABLE B

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

SANTA MONICA BASIN

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
1/14-30											23	14	14	14	14	10	9	9	9	9	9	9	9	9	9	9
1/14-31											9	21	19	19	19	16	13	5	21	23	23	23	24	26	26	26
1/15-14						5	5	4	5	6	8	6	6	5	4	4	5	5	5	5	10	4	3	3	5	6
1/15-15	5	5	4	5	6	8	6	6	5	4	4	5	5	5	5	10	4	3	3	5	6	6	6	6	6	6
1/15-19	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5					
1/15-20	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5		
1/15-21	3	3	3	3	5	10	15	15	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
1/15-22	3	3	3	3	20	19	5	13	22	25	19	23	19	11	12	12	12	12	12	12	12	12	12	12	12	12
1/15-23			2	3	3	3	3	3	26	13	5	15	25	25	19	23	15	12	12	12	12	12	12	12	12	12
1/15-24					4	6	5	5	6	5	4	2	3	16	8	5	10	15	17	12	15	10	4	5	5	5
1/15-25					12	19	14	14	14	12	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
1/15-26					12	19	14	14	14	12	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
1/15-27				17	23	23	13	5	23	13	3	3	3	3	5	10	15	14	11	11	11	11	11	11	11	11
1/15-28	6	23	23	13	13	15	23	3	3	3	3	3	9	10	18	8	8	8	8	8	8	8	8	8	8	8
1/15-29				2	5	6	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	4	3	3	8	5
1/15-30			6	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1/15-31						4	5	5	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	4	3	5
1/15-32							3	7	8	5	10	12	12	10	9	7	4	3	7	6	7	4	4	4	4	4
1/15-33									20	23	21	13	7	23	11	3	3	3	3	6	10	12	12	12	12	12
1/15-34								23	23	18	13	10	23	8	3	3	3	3	7	10	18	13	13	13	13	13
1/15-35									17	23	23	13	5	23	13	3	3	3	3	5	10	15	15	12	12	12
1/15-36					12	19	14	14	14	12	10	14	14	14	14	14	14	14	14	14	14					
1/16-25		9	5	5	5	5	5	5	5	5	5	5	5	5	5	5										
1/16-26			4	3	3	5	8	3	3	3	3	3	3	3	3	3										
1/16-35								4	3	3	5	8	3	3	3	3										
1/16-36										5	3	4	5	8	3	10										
2/14-05											2	2	3	12	10	9	8	8	9	8	11	11	13	15	12	9
2/14-06														20	17	9	5	5	5	5	5					
2/14-07															18	18	9	5	5	5	5	5				
2/14-08														3	5	5	5	5	5	5	5					
2/14-17			6	14	12	10	12	20	19	12	13	15	5	5	5	5	5	4	5	5	15	11	6	3	3	3
2/14-18									2	3	6	4	12	12	10	17	19	22	22	19	15	15	13	10	7	8
2/14-19														2	2	5	15	18	10	12	9	9	14	14	16	14
2/15-01													1	12	9	7	5	5	5	5	5					
2/15-02													2	5	4	4	4	4	4	7	15					

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

SANTA MONICA BASIN (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																							
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
2/15-03											2	14	16	13	11	12	14	4	4	5	9	14	17	14	13	5
2/15-04										4	15	15	11	16	19	15	13	13	3	3	4	10	12	18	12	12
2/15-05											5	8	20	17	12	13	14	23	14	14	14					
2/15-06												1	12	12	20	19	21	13	14							
2/15-07															12	13										
2/15-08									5	17	17	17	17	18	18	20	23	21	21	21	21					
2/15-09																13	23	22	17	16	16	18	18	18		
2/15-10											7	12	10	16	15	12	12	10	13							
2/15-11													9	7	10	15	14	11	12	13	18	18	17	21	22	19
2/15-12															2	11	12	8	5	4	4	8	8	12	15	
2/15-13															1	7	18	12	11	11	10	13	14	11	9	11
2/15-14																9	9	15	18	18	17	17	19	17	17	14
2/15-15														1	6	13	11	11	17	21	15	12	11	10	16	12
2/15-16																11	15	13	21	21	22	21	18	18	20	20
2/15-17															5	15	16	16	18	21	18	16	15	5	11	14
2/15-18																17	23	23	23	21	21					
2/15-20																	14	12	15	18	22	20	16	16		
2/15-21																	21	19	15	19	19	20	16	14	14	11
2/15-22																2	11	14	18	20	17	17	14	16	11	5
2/15-23																1	5	11	18	20	19	17	11	9	7	8
2/15-24																	6	17	18	13	11	9	11	13	11	18
2/15-26																	2	8	16	13	11	10	9	9	9	8
2/15-27																		1	9	5	3	4				
2/15-28																8	16	16	16	16	16					
2/15-33																3	5	5	5							
2/16-01												13	14	22	11	12										
2/16-02									1	20	17	15	14	14	14	14										
2/16-12														21	23	10										

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

WEST COAST BASIN

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																							
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
2/14-08														3	5	5	5	5	5	5	5					
2/14-16				2	2	3	2	12	17	13	9	11	15	3	11	6	13	10	13	9	3					
2/14-17			6	14	12	10	12	20	19	12	13	15	5	5	5	5	5	4	5	5	15	11	6	3	3	3
2/14-18									2	3	6	4	12	12	10	17	19	22	22	19	15	15	13	10	7	8
2/14-19														2	2	5	15	18	10	12	9	9	14	14	16	14
2/14-20									5	5	4	3	3	22	19	3	14	15	9	5	5	5	4			
2/14-21									5	4	5	6	10	17	18	13	17	8	10	16	13	5	5	3	10	10
2/14-22										1	4	11	15	15	16	15	13	11	12	9	6	13	10	6	4	5
2/14-27								1	3	6	8	13	14	11	12	12	10	11	11	11	10	11	11	9	8	7
2/14-28								5	10	10	11	11	12	13	14	14	15	15	15	13	13	12	12	13	13	11
2/14-29																	7	16	13	16	5	3	3	7	23	11
2/14-30												1	1	2	6	2	9	9	9	12	12	12	13	19	15	10
2/14-31																			3	13	11	9	23	13	3	3
2/14-32																			5	15	22	12	11	8	4	5
2/14-33																2	12	7	7	18	16	18	10	3	10	10
2/14-34											2	9	18	19	15	15	11	8	8	8	8	15	18	20	19	14
2/15-24																	6	17	18	13	11	9	11	13	11	18
2/15-25																	17	23	15	23	23	18	18	18	18	18
2/15-26																	2	8	16	13	11	10	9	9	9	8
2/15-27																		1	9	5	3	4				
2/15-33																3	5	5	5							
2/15-34										1	4	4	8	8	6	9	9	18	18	14	14					
2/15-35											8	23	23	23	23	22	23	22	18	22	21	16	16	18	16	
2/15-36											3	8	8	8	12	15	14	9	13	20	13	14	14	11	10	3
3/13-17												1			1	6	10	8	11	8	10	12	13	9	11	15
3/13-18													1	1	2	5	4	4	9	8	11	9	14	13	15	18
3/13-19																4	7	6	9	11	10	11	11	12	17	14
3/13-20															1	1	7	18	17	15	11	8	17	10	9	6
3/13-28												4	5	5	6	6										
3/13-29																1	1	5	8	7	10	11	15	9	14	10
3/13-30															2	2	2	2	2	4	6	9	13	13	8	9
3/13-31																					6	8	6	13	9	10
3/13-32															1	1	1	1	1	1	2	6	5	3	3	4
3/13-33													9	15	16	16	14	16	15	16	17	12	11	15	4	4
3/13-34													1	5	13	17	7	8	10	9	10	16	9	14	17	18

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

WEST COAST BASIN (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
3/14-02											1	7	6	8	9	12	9	12	8	9	12	9	9	11	8	8
3/14-03														3	1	1	4	6	9	5	8	9	5	9	8	8
3/14-04																			10	18	16	11	8	12	9	4
3/14-05																			2	16	20	22	20	20	20	20
3/14-06																			17	17	18	19	17	17	17	17
3/14-07															1	5	11	13	15	14	14	10	10	9	10	12
3/14-08																	5	18	14	10	8	5	6	10	13	15
3/14-09																3	7	12	12	17	12	10	11	14	10	9
3/14-10													1	4	4	4	4	4	4	4	4	8	16	12	15	14
3/14-11											2	3	1	3	3	2	6	10	15	10	7	8	12	21	20	22
3/14-12										1	4	9	15	16	15	14	17	21	16	15	15	8	9	11	15	12
3/14-13														2	7	4	4	6	10	12	10	7	8	14	13	12
3/14-14																				2	7	11	5	8	8	12
3/14-15																		7	7	6	10	14	7	4	22	17
3/14-16															1	4	4	2	6	9	13	12	13	14	7	5
3/14-17																	3	11	10	10	10	6	4	4	4	9
3/14-18																		8	14	9	19	18	5	5	10	10
3/14-19														3	5	5	5	5	5	7	12	10	15	18	21	17
3/14-20																							23	14	5	5
3/14-21																				9	13	10	9	8	9	7
3/14-22																				5	9	12	12	15	12	7
3/14-23																					2	6	11	14	8	6
3/14-24														2	3	3	3	3	3	3	3	5	9	11	15	16
3/14-25																					4	16	19	16	13	10
3/14-26																					4	14	18	18	16	15
3/14-27																				4	11	17	21	18	16	8
3/14-28																3	4	4	9	15	15	17	15	11	12	15
3/14-29																		3	10	7	14	19	20	18	17	16
3/14-30																			4	11	13	14	18	16	13	12
3/14-31																		1	9	18	14	22	21	21	21	23
3/14-32																		6	21	23	23	9	19	23	23	23
3/14-33																		3	13	14	18	13	14	13	13	13
3/14-34																			9	14	18	17	16	17	12	9
3/14-35																			4	10	16	13	12	7	5	6
3/14-36																				1	4	7	6	5	5	6

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

WEST COAST BASIN (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
3/15-01											10	12	12	12	10	16	20	13	7	7	11	13	13	13	13	14
3/15-02											4	16	16	16	16	16	11	20	17	18	15	19	20	16		
3/15-03													12	20	20	19	19	16	7	22	17					
3/15-10													8	16	8	8	20	24	9							
3/15-11												19	16	18	15	13	15	17	15	21	14	5				
3/15-12																2	3	10	8	12	10	14	14	14	13	12
3/15-13								1	6	7	7	6	6	6	6	5	5	5	11	10	12	11	13	16	12	14
3/15-14											16	22	22	22	22	22	19	14	5	18						
3/15-23														7	20	20	19	19	18	8	19					
3/15-24												8	8	8	11	10	3	5	13	14	23	19	14	12	11	
3/15-25																	1	2	8	14	14	15	13	12	9	
3/15-36																			14	14	14	14	14	14	14	14
4/13-02														1	3	5	13	19	20	17	9	9	10	4	9	12
4/13-03																			3	16	18	16	9	3	3	3
4/13-04																						6	3	3	10	4
4/13-05																										8
4/13-06																			12	12	12	12	12	12	12	12
4/13-07																			1	2	6	12	16	13	9	4
4/13-08																				1	3	7	9	13	8	10
4/13-09																				2	7	8	2	2	2	6
4/13-10																	2	5	6	5	13	14	10	9	8	6
4/13-11																	2	13	14	17	8	10	9	9	9	9
4/13-14																1	1	5	14	17	23	23	15	21	18	23
4/13-15																	2	6	11	19	17	14	7	7	8	8
4/13-16															1	5	5	5	5	5	5	5	6	15	13	13
4/13-17									20	23	22	16	21	23	12	12	8	5	5	5	2	6	13	13	11	11
4/13-18																								4	8	21
4/13-19																				11	13	7	11	10	11	20
4/13-20																				1	12	16	11	19	21	21
4/13-21																					11	15	15	15	17	16
4/13-22																		2	3	4	6	5	15	16	12	13
4/13-23																		3	8	17	18	17	22	10	14	10
4/13-24																			5	14	15	8	18	8	9	6
4/13-25																2	3	2	4	6	12	16	21	19	17	16
4/13-26																	5	5	8	21	17	21	19	23	23	23

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

WEST COAST BASIN (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
4/13-27																2	3	3	3	8	12	13	12	13	11	12
4/13-28																					5	8	17	17	23	23
4/13-29																		4	6	13	20	16	15	17	23	23
4/13-30																		2	7	12	12	10	10	7	14	20
4/13-31																	4	6	14	13	10	9	10	8	12	12
4/13-32																			5	8	11	20	14	7	8	10
4/13-33																					1	4	9	6	5	4
4/13-34																					16	12	3	10	23	23
4/13-35																			5	18	18	14	13	12	12	12
4/14-01																				1	4	16	12	4	3	3
4/14-02																		3	6	11	19	22	13	13	13	9
4/14-03																		3	13	19	18	20	22	23	22	22
4/14-04																		8	20	9	5	14	19	18	20	21
4/14-05											13	23	23	22	18	23	23	9	21	19	19	20	20	20	20	20
4/14-06																	9	8	18	19	19	16	16	24	26	18
4/14-07												2	3	3	4	8	12	12	10	10	18	19	21	21	21	21
4/14-08									8	12	14	16	16	15	14	16	19	20	19	21	19	20	22	20	19	18
4/14-09																		7	21	13	8	26	24	21	21	21
4/14-10																2	11	18	13	18	21	22	22	22	21	18
4/14-11																5	12	17	18	19	21	18	18	9	11	10
4/14-12																					2	3	3	4	3	3
4/14-13															2	3	12	18	21	15	20	15	13	12	3	8
4/14-14																	10	16	16	16	16	16	18	16	17	26
4/14-15																1	1	5	5	6	5	10	6	12	16	16
4/14-16													1	6	10	14	17	15	14	13	14	16	15	21	20	21
4/14-17												2	7	9	17	14	18	19	13	12	22	19	23	21	20	19
4/14-18																			1	16	16	22	22	22	21	15
4/14-19																			4	5	5	8	13	10	12	21
4/14-20											7	23	9	17	10	13	17	17	18	18	5	4	7	21	23	16
4/14-21												3	6	5	12	19	17	15	16	19	20	18	18	17	19	18
4/14-22														1	6	9	13	15	16	19	16	15	16	17	19	20
4/14-23														1	12	17	16	18	19	18	18	19	18	16	15	10
4/14-24													5	5	5	10	16	22	23	19	16	13	13	11	9	20
4/14-25															5	8	9	11	16	16	16	16	15	12	13	14
4/14-26																1	2	5	5	10	14	12	14	16	16	7

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY
WEST COAST BASIN (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
4/14-27								8	7	6	5	4	3	3	6	9	13	15	16	16	16	10	15	19	19	18
4/14-28							1	2	3	4	3	5	3	5	6	10	16	18	18	21	21	20	22	22	15	17
4/14-29															4	2	2	3	7	7	8	15	14	13	17	22
4/14-34			3	5	5	5	5	23	23	23	23	18	3	3	12	12	12	12	12	12	12	12	12	12	12	12
4/14-35			5	5	5	5	6	13	11	15	15	15	17	17	17	18	20	21	19	18	19	16	15	17	19	18
4/14-36															4	4	10	12	11	10	11	16	16	17	18	18
4/15-01																			2	11	7	16	17	23	12	21
5/13-02																					1	3	4	19	25	14
5/13-03																			1	6	16	18	17	14	16	11
5/13-04																					12	19	14	12	12	9
5/13-05																			12	5	10	16	9	8	8	3
5/13-06																5	4	3	18	8	7	9	4	4	4	4
5/13-07																			23	9	9	12	3	3	3	3
5/13-08																			12	5	10	16	9	8	8	9
5/13-09																					21	20	14	13	13	3
5/13-10																					12	10	8	9	7	10
5/13-11																						1	3	3	4	18
5/13-17																					4	13	10	10	9	7
5/13-18																				8	13	10	9	8	8	9
5/14-01																14	11	5	4	10	6	5	5	5	5	
5/14-02									3	5	4	6	10	12	13	14										
5/14-11				2	3	3	3	3	3	3	3	3	3	3	3	3										
5/14-12												4	6	4	7	7										
5/14-13									2	3	10	7	6	6	10	10										

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

HOLLYWOOD BASIN

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
1/13-07					5	7																				
1/13-18							2	7	7																	
1/14-02					3	16																				
1/14-07	5	5	4	5	5	8	6	6	5	4	4	5	5	5	5	10	4	3	3	5	6					
1/14-08											11	11	11	11	11	11	11	11	11							
1/14-09												11	14	16	18	26	26	26	26							
1/14-10										3	16	16	16	23	26	26										
1/14-11				2	3	3	3	3	3																	
1/14-12					3	5																				
1/14-13								1	3																	
1/14-14																										
1/14-15								3	3	6	10															
1/14-16								8	7	7	4	3	3	3	3	5										
1/14-17													1	3	3	3	6	8	8	8	4					
1/14-18												8	9	3	2	3	4	7	4	5	6					
1/14-19							12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	22	26	19	23	19
1/14-20										7	12	12	12	4	5	9	18	17	10	12	9	7	6	3	3	3
1/14-21										6	23	21														
1/14-22								12	23	21																
1/14-23										1	3	3	3	3												
1/15-13								2	5	4	5	6	5	9	5	6	3	4	5	5	5	5	6	8	3	3
1/15-14						5	5	4	5	6	8	6	6	5	5	4	5	5	5	5	10	6	9	9	5	6
1/15-23			2	3	3	3	3	3	26	13	5	15	25	25	19	23	15	12	12	12	12	12	12	12	12	17
1/15-24					4	6	5	5	6	5	4	2	3	16	8	5	10	15	17	12	15	10	4	5	5	5

AR0069265

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

LOS ANGELES FOREBAY AREA

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
1/12-31			8	23	23	8	3	12	10	4	3	3	3	3	5	5	5	5	5	5	5	6	7	7	7	7
1/13-21	3	4	8	8	8	8																				
1/13-22	3	3																								
1/13-23		6	18	7																						
1/13-26	8	9	9	5	5	5																				
1/13-27			11	16	15	13	9	10	10																	
1/13-28	13	13	15	15	10	14																				
1/13-29	15	21	13	17	23	13	3	3	3	3	3															
1/13-30				2	19	8	10	21	16	15	21															
1/13-31						4	18	8	12	12	15	19	21	18	3	4	11	4	13	8	13					
1/13-32					3	13	13	14	17	17	17	19	14	10	13	12	7	13	12	3	11					
1/13-33				2	5	10	14	14	14	14	15	18	3	3	3	3	3									
1/13-34				7	13	14	10	19	10	9	4	3	3	3	3	3										
1/13-35									6	6	6	6	6	6	6	6										
1/13-36								8	5	3	3	3	3	4	5	5	5	5	5							
1/14-13								1	3																	
1/14-14																										
1/14-20										7	12	12	12	4	5	9	18	17	10	12	7	7	6	3	3	3
1/14-21										6	23	21														
1/14-22								12	23	21																
1/14-23										1	3	3	3	3												
1/14-24									2	3	3	3	3	3												
1/14-25												3	1	3	3	3	3	3	3							
1/14-26													1	3	3	3	3	3	3	3	3					
1/14-36								5	23	23	11	3	9	12	4	3	3	3	3	6	7	7	7	7		
2/12-06						7	12	12	12	20	20	22	14	14	7	7	16	6	4	4	4	4	4	3	4	12
2/12-07									14	21	21	15	5	5	10	17	21	21	21	13	5	5	5	5	5	5
2/13-01					2	3	3	3	3	4	16	16	16	16	16	16	16	16	10	16	11	4	3	6	3	7
2/13-02										3	9	12	14	20	21	18	15	20	19	23	15	10	9	11	10	12
2/13-03					8	16	16	16	16	18	4	7	3	8	18	3	4	16	4	3	3	3	3	3	9	9
2/13-04					14	21	16	10	10	9	6	12	10	14	17	12	10	15	3	3	3	4	4	4	6	3
2/13-05					4	14	19	13	19	19	13	14	13	12	12	9	4	11	9	11	6	16	15	12	12	12
2/13-06							8	21	7	14	3	14	23	21	17	3	6	18	7	22	14	23	23	18	18	18
2/13-07								9	8	4	5	4	17	14	13	6	3	9	6	9	13	6	13	13	13	3
2/13-08							1	7	11	20	18	14	16	11	17	12	17	5	5	6	6	8	8	10	20	21

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ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY
LOS ANGELES FOREBAY AREA (CONTINUED)
(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
2/13-09						1	11	12	14	23	16	21	20	19	16	17	17	17	17	17	17	17	17	17	17	17
2/13-10					2	5	14	12	12	12	12	14	14	13	11	11	8	5	5	5	5	8	8	10	8	-
2/13-11						1	6	5	5	6	7	9	10	9	7	11	9	9	8	7	6	6	-	8	10	9
2/13-12									1	1	1	3	9	10	7	4	5	11	6	9	9	6	6	6	-	-
2/13-14							4	10	9	3	5	12	9	6	6	7	8	11	8	10	12	15	19	20	20	21
2/13-15							7	19	17	16	16	11	14	13	10	9	9	9	8	11	24	26	29	18	11	11
2/13-16								6	16	18	15	9	3	5	9	16	7	8	6	3	21	26	17	12	7	7
2/13-17								5	8	6	7	5	9	6	9	11	5	4	4	6	4	6	6	4	4	4
2/13-18														13	10	3	3	3	3	3	3	4	4	5	5	5
2/13-20								1	1	2	8	11	12	14	12	7	5	4	4	6	12	5	5	9	7	-
2/13-21								3	9	19	21	21	20	13	14	10	5	7	4	4	12	16	20	19	12	12
2/13-22								13	11	11	10	7	14	15	10	10	7	4	5	4	20	13	20	14	17	17
2/13-23											1	1	4	7	8	8	6	8	6	6	17	17	18	19	10	10
2/13-24												3	11	11	7	3	8	3	5	5	7	12	16	8	8	13
2/13-25													6	8	5	6	7	6	7	4	11	12	17	17	14	20
2/13-26													4	4	4	4	4	6	4	4	14	17	21	20	21	17
2/13-27												1	2	3	6	8	8	7	8	9	12	20	12	10	12	20
2/14-01									7	9	22	8	20	3	3	21	11	11	11	11	11	11	11	11	11	11
2/14-12									13	14	12	17	11	3	12	17	9	9	9	9	9	9	9	9	6	6
2/14-13											2	2	7	6	12	5	4	6	3	3	4	4	3	3	3	3

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ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY
MONTEBELLO FOREBAY AREA
(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
1/12-32				5	8	7	1	2	13	6	9	12	12	7	5	5	11	11	8	10	13	11	14	8	3	11
1/12-33										7	21	13	21	21	21	9	5	10	23	23	8					
1/12-34	3	13	8	3	9	13	9	13	13	13	4	5	10	14	14	4	12	14	14	13	9					
1/12-35	14	13	10	13	9	9	13	6	11	11	6	9	7	7	8	5	8	13	16							
2/11-06						9	23	23	14	10	12	26	26	26	26	11	15	16	16	16	14	11	16	16	16	16
2/11-07			1	7	7		5	14	18	18	15	16	18	20	13	12	16	13	15	16	8	7	10	10	6	7
2/11-08					1	3	5	7	6	2	3	7	3	5	19	4	4	3	3	12	5	5	5	6	5	5
2/11-17				4	2	3	8	2	3	7	6	11	8	4	3	4	6	6	4	9	8	8	5	4	4	4
2/11-18								10	15	15	14	12	8	9	12	11	13	13	12	10	8	6	10	12	14	11
2/11-19								4	14	9	15	19	16	9	7	8	7	8	12	13	15	17	12	5	7	15
2/11-30									4	8	13	19	13	15	12	15	10	10	11	7	4	13	15	20	14	16
2/11-31										6	13	16	16	14	12	11	4	4	3	3	3	7	14	3	6	9
2/12-01							1	6	10	10	6	11	8	10	14	9	13	12	12	13	10	6	12	8	12	8
2/12-02	8	11	6	13	14	5	13	10	5	6	4	6	10	13	15	15										
2/12-03							13	26	9	5	5	5	5	5	5	3	4	5	5	5	5					
2/12-04								3	5	5	4	3	3	3	4	5	5	5	5	5	5	5	9	3	3	3
2/12-05															2	7	16	5	5	5	5	5	5	11	18	5
2/12-09														18	5	5	13	13	3	3	15	17	26	25	7	5
2/12-10							1	5	7	16	7	9	5	9	9	8	5	4	12	14	12	17	9	4	4	8
2/12-11								4	15	15	21	5	5	5	16	10	8	7	4	17	21	5	21	16	3	3
2/12-12							4	20	20	20	14	8	7	17	6	12	15	13	19	19	21	21	13	7	14	14
2/12-13							1	7	17	19	19	16	17	14	9	11	19	14	9	11	9	13	18	14	13	13
2/12-14							10	17	17	19	13	13	10	10	15	15	10	4	8	10	11	19	18	15	5	4
2/12-15										4	5	5	5	5	5	5	5	5	5	15	16	14	3	5	12	14
2/12-16										1	5	5	5	5	5	5	5	5	5	7	16	16	10	3	5	15
2/12-21											3	6	4	5	3	10	7	6	6	4	8	12	12	12	12	14
2/12-22								7	21	18	18	17	9	6	8	17	14	17	9	4	3	6	11	11	12	14
2/12-23								1	15	15	16	14	14	14	6	13	16	16	7	3	3	3	10	10	10	10
2/12-24									17	20	17	18	17	13	11	9	11	12	10	6	8	7	16	15	15	14
2/12-25									7	12	10	13	13	15	10	9	5	4	6	10	14	19	8	14	13	9
2/12-26												20	21	17	13	4	9	3	3	3	3	6	21	21	14	11
2/12-27									1	8	11	18	15	9	8	6	16	13	15	17	14	13	10	9	7	9
2/12-28										2	1	8	10	10	8	11	6	13	13	10	4	6	17	16	10	6
2/12-33											2	9	18	14	7	11	9	5	5	4	5	5	7	9	4	4
2/12-34											2	8	14	17	16	10	12	9	11	11	9	7	7	7	5	10

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ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY
MONTEBELLO FOREBAY AREA (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
2/12-35											2	7	19	15	11	16	9	14	12	8	6	8	13	11	15	12
2/12-36										5	23	22	5	3	13	5	5	5	4	5	7	21	15	14	14	5
3/11-06											2	7	10	16	16	14	9	7	7	8	7	4	5	5	4	5
3/12-01										1	2	9	15	15	16	13	13	12	13	13	11	16	14	14	9	12
3/12-02													5	13	18	20	12	12	12	11	9	8	7	8	10	8
3/12-03													3	8	19	12	20	11	5	10	6	7	12	10	10	17
3/12-11													1	11	16	14	16	10	5	3	5	15	12	9	7	12
3/12-12											1	4	10	16	15	10	10	12	8	12	11	11	8	11	5	13

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

WHITTIER AREA

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
2/10-31					1	5	5	5	4	3	3	5	5	3	3	5	21	5	4	17	10	8	5	9	9	5
2/11-16		7	8	4	12	4	4	3	7	7	4	4	6	6	4	3										
2/11-20											4	6	10	3	3	4	4	6	8	4	3	3	9	3	3	3
2/11-21					4	6	10	3	3	4	4	6	8	4	3	3	9	3	3	3	3	6	3	3	3	4
2/11-28						2	4	4	4	3	3	3	3	5	7	3	3	4	3	3	3	9	14	14	15	10
2/11-27	6	2	2	3	2	2	2	2	8	5	4	4	3	3	4	4	5	5	4	4	4	3	3	3	9	9
2/11-28					2	6	10	11	5	4	3	3	5	12	7	4	5	4	3	4	5	5	5	5	4	3
2/11-29											15	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
2/11-32									2	3	15	10	13	9	5	4	7	10	9	6	4	4	4	4	4	4
2/11-33											12	6	3	5	5	3	3	4	5	15	4	4	5	3	3	5
2/11-34					2	6	2	2	3	2	2	2	2	8	5	4	4	3	3	4	4	5	5	4	4	4
2/11-35														5	4	4	3	3	3	3	4	7	3	3	3	4
2/11-36	3	3	3	5	7	5	4	4	4	4	3	4	4	13	13	13										
3/10-06							2	5	5	5	3	3	4	5	4	3	3	8	18	4	7	15	9	7	5	12
3/10-07													1	3	3	18	21	22	17	4	14	23	19	13	6	13
3/11-01				2	1	7	8	6	3	3	3	5	5	7	5	4	4	5	5	3	3	4	20	11	10	18
3/11-02																2	3	3	3	3	5	5	3	4	3	3
3/11-03										1	3	2	2	2	2	2	6	2	4	4	3	6	11	6	10	5
3/11-04											7	15	3	8	9	11	3	12	3	4	5	3	8	17	7	16
3/11-05										3	9	6	10	7	3	4	6	6	6	6	3	3	6	13	7	17
3/11-10								6	3	2	4	4	4	4	4	3	3	3	4	3	4	3	4	3	4	5
3/11-11																5	4	5	10	9	11	6	4	11	10	9
3/11-12												2	3	6	23	18	24	10	4	21	22	16	8	13	13	13
3/11-13															3	5	3	11	23	8	5					

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(Continued)

ESTIMATED, AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

CENTRAL BASIN PRESSURE AREA

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
1/14-19							12	12	12	12	12	12	12	12	12	12	12	12	12	12	22	25	19	23	19
1/14-27										3	12	11	13	3	3	3	3	3	3						
1/14-28										6	11	11	9	2	9	5	3	9	4	6	6				
1/14-29															4	6	8	12	18	6	12	15	10	12	12	6
1/14-30											23	14	14	14	14	10	9	9	9	9	9	9	9	9	9	9
1/14-31											9	21	19	19	19	16	13	5	21	23	23	23	24	26	26	26
1/14-32													2	13	16	9	10	12	11	4	8	12	15	15	15	17
1/14-33													9	12	16	20	15	22	12	8	21	22	19	13	14	15
1/14-34									8	21	21	10	5	3	3	15	3	3	4	3	9	19	21	21	21	21
1/14-35							1	19	5	21	18	7	21	23	22	5	16	16	18	13	5	5	4	3	8	5
1/15-24					4	6	5	5	6	5	4	2	3	16	8	5	10	15	17	12	15	10	4	5	5	5
1/15-25					12	19	14	14	14	12	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
2/12-08										1	1	1	1	10	5	4	4	4	7	4	6	5	5	6	6	7
2/12-17										3	11	11	12	19	16	13	12	15	12	12	4	4	4	12	6	4
2/12-18										7	11	14	14	13	9	9	15	18	19	15	19	14	9	9	5	5
2/12-19															4	6	11	9	8	5	8	9	11	13	18	19
2/12-20																2	9	3	5	5	8	8	8	12	19	19
2/12-29													5	2	4	5	7	9	10	6	5	5	9	10	11	11
2/12-30															1	10	5	7	15	6	12	12	16	15	10	12
2/12-31																	4	9	7	7	14	12	15	13	11	6
2/12-32													10	5	6	16	11	13	10	5	8	5	5	10	6	4
2/13-13												3	4	3	2	7	12	8	6	6	9	9	11	7	7	9
2/13-19												3	9	6	14	5	17	9	9	9	9	9	9	9	9	9
2/13-28									3	11	10	9	12	18	18	22	22	8	3	3	12	4	5	5	9	9
2/13-29										5	5	2	9	11	10	10	9	5	3	3	3	6	3	3	5	
2/13-30											2	10	9	7	9	6	11	3	10	11	13	3	3	6	16	23
2/13-31											1	4	4	2	2	2	2	5	12	10	9	4	4	4	8	10
2/13-32												3	6	2	2	2	4	2	5	3	3	5	4	5	7	10
2/13-33													2	8	8	8	4	5	4	3	3	10	4	4	5	6
2/13-34												5	5	10	16	16	14	16	5	3	9	8	14	6	4	4
2/13-35															5	12	10	10	3	3	20	12	12	12	11	7
2/13-36														1	9	2	7	10	4	15	14	21	16	24	22	22
2/14-02									13	11	15	23	4	21	23	23	10	13	16	18	16	5	5	5	3	5
2/14-03												2	11	18	13	4	6	3	5	8	5	8	5	6	15	15
2/14-04													7	16	15	13	12	12	10	4	12	11	8	3	3	3

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

CENTRAL BASIN PRESSURE AREA (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
2/14-05											2	2	3	12	10	9	8	8	9	8	11	11	13	15	12	9
2/14-06														20	17	9	5	5	5	5	5					
2/14-08														3	5	5	5	5	5	5	5					
2/14-09			2	6	10	5	12	7	4	11	12	14	3	3	3	4	4	3	22	17	24	5	3	3	3	3
2/14-10												5	9	4	4	4	4	3	4	3	5	15	7	6	4	10
2/14-11											3	7	6	10	5	8	10	10	6	5	11	8	8	5	4	4
2/14-14												5	8	9	6	4	5	4	5	4	5	4	6	6	3	8
2/14-15														1	22	5	5	5	11	7	3	14	13	21	17	17
2/14-16				2	2	3	2	12	17	13	9	11	15	3	11	6	13	10	13	9	3					
2/14-21									5	4	5	6	10	17	18	13	17	8	10	16	13	5	5	3	10	10
2/14-22										1	4	11	15	15	16	15	13	11	12	3	6	13	10	6	4	5
2/14-23												1	4	6	7	7	7	9	7	7	4	4	6	12	17	12
2/14-24												2	12	9	18	4	5	13	4	4	4	7	7	7	7	7
2/14-25											17	14	5	21	12	12	12	12	12	12	12	12	12	12	12	12
2/14-26								2	8	3	7	6	3	4	4	6	3	4	4	5	13	8	10	6	10	10
2/14-27								1	3	6	8	13	14	11	12	12	10	11	11	11	10	11	11	9	8	7
2/14-34											2	9	18	19	15	15	11	8	8	8	8	15	18	20	19	14
2/14-35										9	11	11	10	16	16	15	12	13	20	19	20	21	19	19	16	12
2/14-36									1	10	6	4	7	3	8	8	16	15	16	12	8	9	9	13	13	11
3/11-07												4	14	20	12	12	13	12	19	6	6	8	11	9	6	6
3/11-08											3	8	11	10	15	21	18	16	7	12	12	12	12	12	12	12
3/11-09											7	5	4	5	4	5	5	4	4	3	3	4	4	4	3	3
3/11-14														2	4	9	10	12	9	10	14	9	14	13	10	10
3/11-15													4	5	4	3	3	3	3	3	3	3	3	4	3	3
3/11-16												4	9	9	11	6	10	9	8	9	23	18	12	16	18	19
3/11-17												3	1	3	5	8	12	8	7	6	13	14	13	13	11	13
3/11-18													5	5	4	8	10	8	9	12	15	15	20	20	13	13
3/11-19																2	6	12	9	7	11	12	9	9	9	8
3/11-20															1	2	6	10	9	9	11	10	11	7	9	9
3/11-21														1		1	4	11	7	11	11	12	11	10	10	10
3/11-22																			2	4	6	8	8	8	8	10
3/11-23											0	2	2	2	8	5	9	5	8	8	11	11	9	10	8	8
3/11-24									1	1	1	1	2	8	4	5	4	6	4	8	5	3	4	10	8	4
3/11-26															2	1	4	4	4	4	6	4	3	3	4	4
3/11-27																3	5	6	6	11	14	10	7	7	7	11

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

CENTRAL BASIN PRESSURE AREA (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
3/11-28													1	1			3	9	8	6	13	19	31	16	8	10
3/11-29																	2	8	8	8	15	15	15	17	11	13
3/11-30																		7	9	8	22	22	22	22	23	22
3/11-31																		2	4	4	17	20	19	11	11	10
3/11-32																			2	3	6	8	11	10	7	12
3/11-33																			6	5	6	10	4	5	8	6
3/12-04											2	3	4	10	20	20	19	14	10	13	11	11	11	11	10	10
3/12-05														1	4	12	20	15	11	14	6	10	14	9	4	6
3/12-06															1	4	10	11	9	10	16	15	12	12	11	12
3/12-07															1	9	8	16	19	17	27	27	32	33	38	38
3/12-08																	8	19	20	20	15	8	10	7	4	4
3/12-09															9	15	19	18	13	6	9	4	8	10	10	7
3/12-10														7	18	21	19	13	12	4	5	4	3	3	3	3
3/12-11														8	14	15	11	8	9	6	20	9	6	7	10	8
3/12-14															8	16	16	9	4	5	6	6	4	4	4	5
3/12-15															11	17	18	16	12	10	12	12	12	12	12	12
3/12-16															1	5	12	15	16	16	23	11	9	4	4	5
3/12-17																		4	11	12	16	14	12	20	21	20
3/12-18																3	7	15	15	16	21	20	19	18	24	21
3/12-19																	1	11	16	17	21	14	14	16	16	17
3/12-20																			2	18	23	15	17	15	11	15
3/12-21																		1	6	11	22	12	18	24	24	21
3/12-22																		5	5	9	22	14	17	24	18	15
3/12-23																	3	11	14	16	17	12	12	12	12	12
3/12-24															2	3	6	17	19	17	19	24	18	17	17	14
3/12-25																	1	3	10	15	26	19	12	15	15	12
3/12-26													1	2	2	2	4	8	11	10	18	17	13	16	20	14
3/12-27																		3	4	7	11	17	16	13	9	12
3/12-28																				6	19	11	8	11	8	8
3/12-29																			2	9	21	23	11	19	15	28
3/12-30															1	2	11	15	13	16	16	4	9	7	5	3
3/12-31																6	11	7	12	3	9	7	12	4	23	23
3/12-32													1	12	12	12	12	12	12	12	24	12	12	17	12	12
3/12-33																			4	3	10	14	11	13	12	16
3/12-34																		3	4	5	12	15	12	14	13	10

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

CENTRAL BASIN PRESSURE AREA (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																									
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
3/12-35													1		1	2	2	5	11	12	8	12	14	16	9	7
3/12-36																	3	6	8	10	8	20	16	25	10	11
3/13-01																		8	6	9	14	14	14	14	14	29
3/13-02																3	13	16	17	14	5	7	9	13	19	10
3/13-03														1	11	8	5	5	5	5	5	5	7	3	3	4
3/13-04														2	3	8	11	4	3	3	6	7	3	3	6	11
3/13-05												7	4	3	4	6	4	4	9	3	3	3	4	8	13	5
3/13-06										4	8	8	8	15	17	13	10	23	17	19	17	19	19	23	23	9
3/13-07											2	12	16	17	17	16	17	22	20	21	20	17	14	13	16	16
3/13-08																4	7	7	8	9	10	12	11	9	10	12
3/13-09															5	2	5	4	3	3	3	3	7	14	8	13
3/13-10														7	10	9	3	4	4	4	4	4	10	12	9	11
3/13-11															2	8	17	15	7	7	7	6	6	6	6	5
3/13-12																2	9	12	11	13	4	7	6	4	6	6
3/13-13																	13	17	14	7	14	6	4	4	4	7
3/13-14																	9	22	17	17	17	17	17	17	17	17
3/13-15															1	4	6	4	5	4	7	7	4	12	16	12
3/13-16														2	2	5	3	6	12	10	13	17	13	9	5	5
3/13-17												1			1	6	10	8	11	8	10	12	13	9	11	15
3/13-18													1	1	2	5	4	4	9	8	11	9	14	13	15	18
3/13-20															1	1	7	18	17	15	11	8	17	10	9	6
3/13-21												1	5	8	4	5	13	20	19	13	11	18	14	5	7	12
3/13-22																1	4	5	11	9	7	8	8	15	19	19
3/13-23													1	3	3	4	7	13	14	10	9	10	14	16	19	15
3/13-24																2	8	16	18	16	24	12	12	12	12	12
3/13-25																3	11	19	16	14	10	4	4	3	3	3
3/13-26																	4	13	10	10	6	8	3	7	4	8
3/13-27																9	8	11	12	9	9	13	14	11	12	14
3/13-28												4	5	5	6	6										
3/13-29																1	1	5	8	7	10	11	15	9	14	10
3/13-33													9	15	16	16	14	16	15	16	17	12	11	15	4	4
3/13-34													1	5	13	17	7	8	10	9	10	16	9	14	17	18
3/13-35																	7	19	18	12	6	8	6	7	7	8
3/13-36																	5	14	12	9	4	4	4	3	4	5
3/14-01											2	11	12	13	14	14	16	19	19	19	18					

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS
COASTAL PLAIN OF LOS ANGELES COUNTY
CENTRAL BASIN PRESSURE AREA (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																							
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
3/14-02											1	7	6	8	9	12	9	12	8	9	12	9	9	11	8	8
3/14-12										1	4	9	15	16	15	14	17	21	16	15	15	8	9	11	15	12
4/11-05																		1	2	2	9	11	13	7	7	14
4/11-06																	1	5	4	4	10	13	16	16	9	9
4/11-07																			1	2	8	8	8	9	11	17
4/11-08																			1	2	8	9	10	12	5	16
4/11-18																				2	16	18	29	37	36	30
4/11-19																	2	2	4	12	28	8	5	3	5	4
4/12-01																		1	6	7	13	17	17	17	17	11
4/12-02														1	2	1	1	1	1	3	12	15	15	19	14	10
4/12-03																		6	9	5	12	12	17	13	13	12
4/12-04														8	5	4	10	3	3	3	12	12	20	12	12	26
4/12-05																				3	12	12	12	17	8	7
4/12-06																				3	17	8	4	9	12	16
4/12-07																					28	20	28	30	30	11
4/12-08																			3	5	14	16	20	11	14	19
4/12-09																					7	11	21	22	26	10
4/12-10																	5	9	3	3	10	12	11	11	11	11
4/12-11																					23	16	16	19	34	22
4/12-12																		2	3	1	9	10	12	13	16	27
4/12-13															1	3	3	7	12	10	16	19	19	21	16	20
4/12-14																2	8	5	6	6	17	16	16	16	15	17
4/12-15															1	2	7	4	3	6	18	8	20	10	10	14
4/12-16																1	2	2	6	3	12	16	19	15	19	14
4/12-17																		3	6	8	22	21	19	21	22	24
4/12-18																1	23	23	23	16	27	16	16	17	10	4
4/12-19													1	1	2	5	11	18	15	11	11	14	13	14	16	14
4/12-20															1	3	4	7	11	7	8	11	11	8	8	8
4/12-21															2	3	5	6	9	13	9	11	10	12	12	12
4/12-22																8	8	8	8	8	16	16	16	16	8	8
4/12-23																	8	20	11	5	7	10	17	19	9	9
4/12-24																	1	8	9	6	19	18	16	17	16	20
4/12-25																		1	2	10	17	13	13	13	13	14
4/12-26																			2	8	20	18	14	19	19	23
4/12-27																	3	10	20	21	39	30	26	32	16	15

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(Continued)

ESTIMATED AVERAGE SPECIFIC YIELD VALUES[1] BY ELEVATIONAL INCREMENTS, COASTAL PLAIN OF LOS ANGELES COUNTY

CENTRAL BASIN PRESSURE AREA (CONTINUED)

(IN PERCENT)

LOCATION[2]	ELEVATIONAL INCREMENTS IN FEET ABOVE SEA LEVEL																								
	320 300	300 280	280 260	260 240	240 220	220 200	200 180	180 160	160 140	140 120	120 100	100 80	80 60	60 40	40 20	20 0	0 -20	-20 -40	-40 -60	-60 -80	-80 -100	-100 -120	-120 -140	-140 -160	-160 -180	-180 -200
4/12-28																			2	9	14	16	20	19	20	17
4/12-29																				2	5	5	5	10	3	3
4/12-33																							7	9	10	12
4/12-34																	1	10	15	16	15	10	12	7	10	15
4/12-35																					3	12	14	14	13	17
4/12-36																			5	1	3	9	8	4	3	6
4/13-01																1	4	3	4	10	6	5	7	13	10	10
4/13-02														1	3	5	13	19	20	17	9	9	10	4	9	12
4/13-03																			3	16	18	16	9	3	3	3
4/13-11																	2	13	14	17	8	10	9	9	9	9
4/13-12														5	2	2	6	12	15	15	16	7	7	7	7	14
4/13-13																			2	10	4	3	12	9	15	22
4/13-24																			5	14	15	8	18	8	9	6
5/12-01																			14	3	3	3	3	3	3	3
5/12-02																	1	5	16	15	11	10	7	6	6	7
5/12-11																2	5	11	15	11	25	10	10	9	9	10

Footnotes:

1. Where no value is shown specific yield was assumed to be zero or the elevational increment was above the ground surface or below the base of the deepest aquifer. For this tabulation all the deposits above the base of the Bellflower Aquiclude were considered to have zero specific yield. Also the tabulation was limited to the elevations between + 320 and -200 feet because it is within this range that change in ground water storage occurs.
2. Location is referenced to the U. S. Public Land Survey as projected into the Coastal Plain of Los Angeles County. 1/14 - 30 refers to Township 1 South, Range 14W, Section 30, San Bernardino Base and Meridian. The estimated average specific yield values given refer to the section or portion of a section lying within the boundary of the specified ground water basin.

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TRANSMISSIBILITY TEST PROCEDURES

The transmissibility rates of aquifers penetrated by wells in the Coastal Plain of Los Angeles County were determined by the use of drawdown and recovery tests, in addition to other available data. A drawdown test is one in which measurements of the ground water levels are taken starting the moment the well is turned on and continued as long as possible or until the water level stabilizes or draws down very slowly. The measurements are usually taken in an observation well perforated in the same aquifer as the pumping well, but the measurements may be taken in the pumping well. The quantity of ground water pumped is also measured.

A recovery test is essentially the reverse of a drawdown test. A well is pumped for a known amount of time and the discharge measured. Starting at the time the pump is shut off, ground water levels are measured at frequent intervals. The measurements are continued until the static level is approximately reached (the static water level is where the water level in the well would stand if not affected by pumping in the well or in nearby wells). The water level measurements are made in the pumping well, or in a nearby observation well perforated in the same aquifer as the pumping well.

In both tests, the change in water level can be plotted against the time required for the change. Using formulas previously determined, the transmissibility, horizontal permeability, storage coefficient, and vertical permeability can be computed when a pumping and observation well are used together. When a test is run in the pumping well, generally only transmissibility and horizontal permeability can be determined.

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The transmissibility rate, or the coefficient of transmissibility, is the flow of water, in gallons per day at the prevailing water temperature, through a vertical strip of the aquifer one foot wide having a height equal to the thickness of the aquifer and under a unit hydraulic gradient. It has also been described at "the field coefficient of permeability" multiplied by the thickness, in feet, of the saturated part of the aquifer.

The permeability of a material is its capacity for transmitting a fluid. The coefficient of permeability is the rate of flow of water in gallons a day through a cross section of one square foot under a unit hydraulic gradient. The standard coefficient is defined for water at a temperature of 60°F. The field coefficient requires no temperature adjustment and the units are stated in terms of the prevailing water temperature.

The horizontal permeability refers to the flow of water into a pumping well from an aquifer penetrated by the well.

Vertical permeability as used in this attachment refers to the movement of water through a confining bed into the underlying aquifer.

The leakage coefficient is used to describe the numerical quantity derived by dividing the vertical permeability of a confining bed by the thickness in feet through which this leakage occurs.

Storage coefficient, or the coefficient of storage, is the volume of water in cubic feet released from storage in each vertical column of water having a base one foot square when the water table or piezometric surface declines one foot. It is expressed as a decimal figure with no units.

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An aquifer is a geologic formation, group of formations, or part of a formation that transmits water in sufficient quantity to supply pumping wells or springs.

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TABLE C

TRANSMISSIBILITY TESTS IN THE
COASTAL PLAIN OF LOS ANGELES COUNTY

Observation well(s)	Pumping well(s)	Date of test	Type of test	Aquifer(s)	Transmissibility: gal./day/ft.	Estimated horizontal permeability: gal./day/sq.ft.	Storage coefficient	Leakage coefficient: gal./day/ft.	Estimated vertical permeability: gal./day/sq.ft.
	2S/11W- 7J2	4- 5-57	Recovery	Pleistocene and Recent	130,000	575			
	2S/11W- 8N1	4- 5-57	Recovery	Pleistocene and Recent	53,000	246			
2S/11W-18K2	2S/11W-18Q4	8-17-59	Drawdown	Recent and Lower Pleistocene	410,000	2,830	$1.7X10^{-3}$		
2S/11W-18P2	2S/11W-18Q2	2-24-59	Drawdown	Lower Pleistocene	690,000	3,300	$2.3X10^{-3}$		
2S/11W-18Q4	2S/11W-18Q2	2-24-59	Drawdown	Lower Pleistocene	190,000	1,195	$2.9X10^{-4}$		
2S/14W-19C1	2S/14W-19C2	6-26-50	Drawdown	Lower Pleistocene	170,000	600	$2.9X10^{-3}$	$1.2X10^{-7}$	$1.2X10^{-6}$
	2S/14W-27J1	7- 7-50	Recovery	Silverado	92,500	1,050			
2S/15W-34A3	2S/15W-34A1	6- 9-49	Recovery	Gardena and Lynwood	82,600	1,173	$4.2X10^{-5}$	$1.9X10^{-8}$	$1.2X10^{-6}$
	3S/11W-23P2	12-10-59	Recovery	Lynwood	2,410	160			
	3S/11W-26B5	12-11-59	Recovery	Silverado	21,000	420			
	3S/11W-27C1	12-21-59	Recovery	Silverado	11,000	212			
	3S/11W-27G3	12-22-59	Recovery	Lynwood	19,000	247			
	3S/12W-23C3	10-20-60	Recovery		34,254	952			
	3S/13W- 8R1	1-26-50	Recovery	Lynwood and Silverado	43,000	580			
	3S/13W-17A1	6-30-50	Recovery	Gardena and Silverado	110,000	1,908			
3S/13W-20H1 -20H3	3S/13W-20H7	12- -49 6- -50	Drawdown Recovery	Gardena	380,000	5,310	$1.6X10^{-2}$	$2.3X10^{-7}$	$3.7X10^{-6}$

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TRANSMISSIBILITY TESTS IN THE
COASTAL PLAIN OF LOS ANGELES COUNTY
(continued)

Observation well(s)	Pumping well(s)	Date of test	Type of test	Aquifer(s)	Transmissibility: gal./day/ft.	Estimated horizontal permeability: gal./day/sq.ft.	Storage coefficient	Leakage coefficient: gal./day/ft.	Estimated vertical permeability: gal./day/sq.ft.
	3S/13W-27E2	2- 2-50	Recovery	Silverado	126,000	3,730			
	3S/13W-28E2	6-22-50	Recovery	Lynwood and San Pedro	13,600	55			
3S/13W-29G6	3S/13W-29G3	1-30-58	Drawdown Recovery	Gardena	56,100	764	$9.0X10^{-4}$		
	3S/14W- 1G1	1-30-50	Recovery	Silverado	155,000	1,325			
3S/14W- 2D1	3S/14W- 3A1	6-27-50	Drawdown	Silverado	52,100	291	$1.0X10^{-4}$		
3S/14W- 4N1 - 4N2	3S/14W- 4M3	3-17-50	Drawdown	Lynwood and Silverado	220,000	934	$5.3X10^{-4}$		
3S/14W- 7Q2 - K2	3S/14W- 7Q3	3-17-50	Drawdown Recovery	Silverado	110,000	1,358	$2.8X10^{-4}$		
3S/14W-11G1	3S/14W-11C1	1-20-58	Drawdown	Lynwood, San Pedro Silverado	202,000	1,141	$2.95X10^{-3}$	$3X10^{-8}$	$1.51X10^{-6}$
3S/14W-10G1	3S/14W-10G2	4- 5-50	Drawdown	Lynwood and Silverado	153,000	735	$6.7X10^{-4}$		
	3S/14W-11J2	1- 2-58 1- 3-58	Recovery	Gage	157,000	1,743			
	3S/14W-25P4	12- 7-49	Recovery		409,000	4,350			
3S/15W-13H1 -13R1 -13R2	3S/15W-13A4	9-22-49	Drawdown Recovery	Lynwood and Silverado	103,000	495	$3.7X10^{-4}$	$5.3X10^{-9}$	$1.6X10^{-8}$
	4S/11W- 4H3	12- 8-59	Recovery	Artesia	30,000	1,500			
	4S/11W- 8J1	12-12-59	Recovery	Artesia	36,000	1,100			
	4S/11W-17H1	11-19-59	Recovery	Gage	4,700	362			
	4S/11W-17L2	11- 6-59	Recovery	Gage	11,000	1,068			

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TRANSMISSIBILITY TESTS IN THE
COASTAL PLAIN OF LOS ANGELES COUNTY
(continued)

Observation well(s)	Pumping well(s)	Date of test	Type of test	Aquifer(s)	Transmissibility: gal./day/ft.	Estimated horizontal permeability: gal./day/sq.ft.	Storage coefficient	Leakage coefficient: gal./day/ft.	Estimated vertical permeability: gal./day/sq.ft.
	4S/11W-20M1	11-24-60	Recovery	Lynwood	60,000	1,052			
4S/13W- 2J1	4S/13W- 2R2	7-19-49	Drawdown	Gaspur, Gardena Lynwood	177,000	2,602	$8.1X10^{-4}$	$1.1X10^{-8}$	$3.3X10^{-7}$
	4S/13W- 7H1	6-28-50	Recovery	Silverado	280,000	1,657			
	4S/13W-12A1	7- 6-50	Recovery	Plio-Pleistocene	79,500	530			
4S/13W-15C1	4S/13W-15B8	2- -50	Drawdown	Silverado	821,000	3,258	$5.47X10^{-5}$	$1X10^{-8}$	$3.8X10^{-7}$
4S/13W-15C1	4S/13W-15P3	6-20-50	Drawdown		326,000	1,294			
4S/13W-27M1	4S/13W-27N1	10-19-49	Drawdown	Silverado	750,000	1,404	$1.9X10^{-3}$	$3.2X10^{-8}$	$4.6X10^{-6}$
	4S/13W-27N1	10-20-49	Recovery	Silverado	650,000	2,070			
	4S/14W- 8F1	8-24-49	Recovery		775,000	2,250			
	4S/14W-17H1	3-28-50	Recovery	Gardena, Lynwood, Silverado	680,000	2,464			

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Assignment of Transmissibility Rates to Aquifer

The transmissibility rates for each aquifer and overall transmissibility rates for the coastal plain that were presented in this report were computed in the following manner:

1. All well logs used in the investigation were classified as to the aquifers intercepted and to the thickness of each aquifer at that well.

2. Permeability values of sediments were obtained from the transmissibility tests previously discussed. The results of these tests, summarized on Table C, were used as a basis for assigning representative values to the various materials encountered in the sediments. This simplification was necessary to reduce the amount of time that would otherwise have been necessary to evaluate each well log separately. The representative values of permeability used in the study are tabulated in Table D, following.

3. Using the values in Table D, a tabulation for each well log was completed that listed the materials encountered, the thickness of the material, and the permeability values used. By multiplying the thickness of each material by its permeability value, and adding together these products for the various materials found in each aquifer, the transmissibility rates of individual aquifers were computed for each well location.

4. The transmissibility values for each aquifer were plotted on maps of the coastal plain that also delineated lines of equal thickness of the particular aquifer in order to correlate the two. Contour lines of equal transmissibility rates were then drawn and interpolated and extrapolated into areas with only sparse data control. These contour lines are shown on Plates 26A to 26H for each aquifer.

5. Transmissibility rates at the northeast corner of each section for each aquifer were taken off the maps and tabulated. The values for each aquifer at each section corner were totaled, obtaining an overall transmissibility rate for that location. These overall rates were also plotted on a map and contours drawn representing lines of equal total transmissibility rates. This map of generalized lines of total transmissibility is presented as Plate 26I.

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TABLE D

PERMEABILITY VALUES

ASSIGNED TO DRILLERS LOGS

Sandy Clay (includes gravelly clay, clay and sand, clayey sand, etc.)	50gpd/ft^2
Sand	500gpd/ft^2
Gravel (includes sand and gravel)	
Gaspur Aquifer	4000gpd/ft^2
Ballona Aquifer	2000gpd/ft^2
Marine Gravels (Silverado, Sunnyside, and portion of Lynwood aquifers)	1500gpd/ft^2
Nonmarine Gravels (Gardena, Artesia, Exposition, Jefferson, Hollydale, and portion of Lynwood Aquifer)	1000gpd/ft^2
Gravel with Clay Streaks	one-half of above values for gravel
Clay	0

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ATTACHMENT 3

WELL NUMBERING SYSTEM AND DEFINITIONS

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ATTACHMENT 3

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Well Numbering System

The well numbering system employed herein is that utilized by the United States Geological Survey, according to the township, range, and section subdivision of the Federal Land Survey. It conforms to that used in all ground water investigations by the U. S. Geological Survey in California and has been adopted by the Department of Water Resources.

Under the system, each section is divided into sixteen 40-acre plots, which are lettered as follows:

Wells are numbered within each of these 40-acre plots according to the order in which they are located. For example, a well having the number 2S/11W-26B8 would be in Township 2 South, Range 11 West, Section 26, and would be further identified as the 8th well located in the 40-acre plot lettered B. Each well must be referenced to a particular Base and Meridian line, such as S. B. B. & M. for San Bernardino Base and Meridian (Southern California) or M. D. B. & M. for Mount Diablo Base and Meridian (Central California) and H. B. & M. for Humbolt Base and Meridian (Northern California).

Definitions

Anticline - Term applied to strata which dip in opposite directions from a common ridge or axis, like the roof of a house, and from what is

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termed an "anticline" or "saddleback" (Page D, Handbook of Geological Terms, London, 1859).

Aquiclude - A formation which, although porous and capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for a well or spring. (Tolman, 1937, p. 557).

Aquifer - A geologic formation, group of formations, or part of a formation that transmits water in sufficient quantity to supply pumping wells or springs.

Confined Ground Water - A body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying ground water except at the intake. Confined water moves in conduits under pressure due to the difference in head between the intake and discharge areas of the confined water body. (Tolman, 1937, p. 558).

Connate Water - Water entrapped in the interstices of a sedimentary rock at the time it was deposited. (Tolman, 1937, p. 558). These waters may be fresh, brackish, or saline in character. Because of the dynamic geologic and hydrologic conditions in California this definition has been altered in practice to apply to water in older formations, even though in these the water may have been altered in quality since the rock was originally deposited.

Free Ground Water - Water in interconnected interstices in the zone of saturation down to the first impervious barrier, moving under the control of the water-table slope. (Tolman, 1937, p. 559).

Graben - Fault block bounded on both sides by gravity faults, generally long compared to its width, that has been lowered relative to the blocks on either side. (Billings, 1954, p. 203).

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Horst - A block of the earth's crust, generally long compared to its width, bounded on both sides by gravity faults, that has been uplifted relative to the blocks on either side. (Billings, 1954, p. 203).

Impermeable - Impervious. Having a texture that does not permit water to move through it perceptibly under the head differences ordinarily found in subsurface water. (Meinzer, 1923, p. 20).

Isopach or Isopachous line - A line drawn on a map through points of equal thickness of a designated unit. (Glossary of Geology and Related Sciences, 1957).

Orogeny - The process of mountain building (Fay, 1920).

Perched Ground Water - Ground water occurring in a saturated zone separated from the main body of ground water by unsaturated rock (Tolman, 1937, p. 562).

Permeability - The permeability (or perviousness) of rock is its capacity for transmitting a fluid. Degree of permeability depends upon the size and shape of the pores, the size and shape of their interconnections, and the extent of the latter. (Glossary of Geology and Related Sciences, 1957, p. 217).

Permeability, field coefficient of - The amount of water moving through a unit area of aquifer per unit time under unit hydraulic gradient at the natural temperature. Ordinarily in gallons per day per square foot.

Permeability, coefficient of - Same as above, except that a reference temperature of 60 degrees Fahrenheit is defined. Other units are also used such as cubic feet per second per square foot, acre-feet per year per square foot, etc.

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Permeable - Pervious. Having a texture that permits water to move through it perceptibly under the head differences ordinarily found in subsurface water. (Meinzer, 1923, p. 29).

Piedmont Slope - "When two or more streams flow out from a highland and closely adjacent to one another they may build a sloping plain, which is relatively high near the highland and lower further out, and which is composed of a series of fans in whose growth there has been mutual interference. This process produces a piedmont slope or series of coalescing fans." (Bryan, Kirk, U.S.G.S.W.S.P., p. 28, 1923).

Piezometric Surface - The piezometric surface of an aquifer is an imaginary surface that everywhere coincides with the head of water in the aquifer. (Meinzer, 1942).

Specific Yield - The ratio of the water a saturated sediment will yield by gravity drainage to the total volume of the sediment and water prior to draining, customarily expressed in percent.

Storage Coefficient - Volume of water released from storage in each verticle column of aquifer having a base one foot square when the water level declines one foot. In an unconfined aquifer it approximates specific yield. In a confined aquifer it is related to elasticity of the aquifer and is usually very small.

Syncline - A fold in rocks in which the strata dip inward from both sides toward the axis. (Glossary of Geology and Related Sciences, 1957).

Transmissibility, coefficient of - The rate of flow of water, in gallons a day, at the prevailing water temperature through each vertical strip, one foot wide, having a height equal to the thickness of the aquifer and under a unit hydraulic gradient. (Glossary of Geology and Related Sciences, 1957).

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Unconformity - A surface of erosion or nondeposition, usually the former, that separates younger strata from older rocks. (Glossary of Geology and Related Sciences, 1957).

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From: Steven M Malkson [mailto:steven_m_malkson@dot.ca.gov]
Sent: Tuesday, November 08, 2011 5:02 PM
To: Brett Pomeroy
Subject: Re: 110/10 Fwy Ramp Data Request

Brett,

Volumes are as follows:

LOCATION #	AM PEAK HOUR	PM PEAK HOUR
1	1,600	1,200
2	650	480
3	180	200

Steve Malkson
Lead Transportation Engineer
Caltrans District 7 Traffic Monitoring
(323) 849-5028

Brett Pomeroy
<brett@parkerenvironmental.com>
11/08/2011 12:02 PM

To
Steven M Malkson
<steven_m_malkson@dot.ca.gov>
cc

Subject
Re: 110/10 Fwy Ramp Data Request

Hi Steven - If you recall, you helped me gather some traffic data in July (see below.) I have a new (and smaller) request. I was able to find all the ADT volumes, but not the peak hours for the ramps. Do you think you could fill in the blanks below? I would greatly appreciate your help!

101 Freeway, LA County

1. 101 South Off-Ramp to Vine Street
   Postmile 7.368
   AADT: 14,200
   Peak Hour: ____

2. 101 South Off-Ramp to Gower Street
   Postmile: 7.059
   AADT: 6,700
   Peak Hour: ____

3. 101 South On Ramp From Argyle Ave
   Postmile 6.969
   AADT: 3,100
   Peak Hour: ____

Traffic and Vehicle Data Systems Unit

2011 All Traffic Volumes on CSHS

Home View

Dist	Rte	CO	Post Mile	Description	Back Peak Hour	Back Peak Month	Back AADT	Ahead Peak Hour	Ahead Peak Month	Ahead AADT
7	101	LA	S 0	LOS ANGELES, JCT. RTE. 5				9000	138000	134000
7	101	LA	S 0.624	LOS ANGELES, FOURTH ST	9000	138000	134000	8000	125000	122000
7	101	LA	S 0.907	LOS ANGELES, FIRST ST	8000	125000	122000	7700	124000	120000
7	101	LA	S 1.329	LOS ANGELES, JCT. RTE. 10	7700	124000	120000	13700	215000	209000
7	101	LA	0.387	LOS ANGELES, VIGNES ST	13700	215000	209000	13200	212000	206000
7	101	LA	0.82	LOS ANGELES, ALAMEDA/LOS ANGELES	13200	212000	206000	12600	205000	200000
7	101	LA	1.007	LOS ANGELES, SPRING ST	12600	205000	200000	13500	222000	217000
7	101	LA	1.569	LOS ANGELES, JCT. RTE. 110	13500	222000	217000	15900	272000	265000
7	101	LA	2.483	LOS ANGELES, GLENDALE BLVD	15900	272000	265000	15400	265000	258000
7	101	LA	2.857	LOS ANGELES, JCT. RTE. 2 NE	15400	265000	258000	15900	270000	262000
7	101	LA	3.342	LOS ANGELES, BENTON/RAMPART	15900	270000	262000	15700	264000	256000
7	101	LA	3.76	LOS ANGELES, SILVER LAKE	15700	264000	256000	14200	251000	243000
7	101	LA	4.397	LOS ANGELES, VERMONT AVE	14200	251000	243000	13500	237000	229000
7	101	LA	4.851	LOS ANGELES, MELROSE AVE	13500	237000	229000	12800	223000	215000
7	101	LA	5.554	LOS ANGELES, JCT. RTE. 2 W	12800	223000	215000	11400	195000	189000

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AIR QUALITY AND LAND USE HANDBOOK: A COMMUNITY HEALTH PERSPECTIVE

April 2005

California Environmental Protection Agency
California Air Resources Board

Air Agency Contacts

Federal-

U.S. EPA, Region 9
Phone: (866)-EPA-WEST
Website: www.epa.gov/region09
Email: r9.info@epa.gov

-State-

California Air Resources Board
Phone: (916) 322-2990 (public info)
(800) 363-7664 (public info)
(800) 952-5588 (complaints)
(866)-397-5462 (env. justice)
Website: www.arb.ca.gov
Email: helpline@arb.ca.gov

-Local-

Amador County APCD
Phone: (209) 257-0112
Website: www.amadorapcd.org
E-Mail: jharris@amadorapcd.org

Antelope Valley AQMD
Phone: (661) 723-8070
Complaint Line: (888) 732-8070
Website: www.avaqmd.ca.gov
E-Mail: bbanks@avaqmd.ca.gov

Bay Area AQMD
Phone: (415) 749-5000
Complaint Line: (800) 334-6367
Website: www.baaqmd.gov
E-Mail: webmaster@baaqmd.gov

Butte County AQMD
Phone: (530) 891-2882
Website: www.bcaqmd.org
E-Mail: air@bcaqmd.org

Calaveras County APCD
Phone: (209) 754-6504
E-Mail: lgrewal@co.calaveras.ca.us

Colusa County APCD
Phone: (530) 458-0590
Website: www.colusanet.com/apcd
E-Mail: ccair@colusanet.com

El Dorado County AQMD
Phone: (530) 621-6662
Website:
www.co.el-dorado.ca.us/emd/apcd
E-Mail: mcctaggart@co.el-dorado.ca.us

Feather River AQMD
Phone: (530) 634-7659
Website: www.fraqmd.org
E-Mail: fraqmd@fraqmd.org

Glenn County APCD
Phone: (530) 934-6500
http://www.countyofglenn.net/air_pollution_control
E-Mail: ktokunaga@countyofglenn.net

Great Basin Unified APCD
Phone: (760) 872-8211
Website: www.gbuapcd.org
E-Mail: gb1@greatbasinapcd.org

Imperial County APCD
Phone: (760) 482-4606
E-Mail: reyesromero@imperialcounty.net

Kern County APCD
Phone: (661) 862-5250
Website: www.kernair.org
E-Mail: kcapcd@co.kern.ca.us

Lake County AQMD
Phone: (707) 263-7000
Website: www.lcaqmd.net
E-Mail: bobr@pacific.net

Lassen County APCD
Phone: (530) 251-8110
E-Mail: lassenag@psln.com

Mariposa County APCD
Phone: (209) 966-2220
E-Mail: air@mariposacounty.org

Mendocino County AQMD
Phone: (707) 463-4354
Website:
www.co.mendocino.ca.us/aqmd
E-Mail:
mcaqmd@co.mendocino.ca.us

Modoc County APCD
Phone: (530) 233-6419
E-Mail: modapcd@hdo.net

Mojave Desert AQMD
Phone: (760) 245-1661
(800) 635-4617
Website: www.mdaqmd.ca.gov

Monterey Bay Unified APCD
Phone: (831) 647-9411
(800) 253-6028 (Complaints)
Website: www.mbuapcd.org
E-Mail: dquetin@mbuapcd.org

North Coast Unified AQMD
Phone: (707) 443-3093
Website: www.ncuaqmd.org
E-Mail: lawrence@ncuaqmd.org

Northern Sierra AQMD
Phone: (530) 274-9360
Website: www.myairdistrict.com
E-Mail: office@myairdistrict.com

Northern Sonoma County APCD
Phone: (707) 433-5911
E-Mail: nsc@sonic.net

Placer County APCD
Phone: (530) 889-7130
Website:
http://www.placer.ca.gov/airpollution/airpolut.htm
E-Mail: pcapcd@placer.ca.gov

Sacramento Metro AQMD
Phone: (916) 874-4800
Website: www.airquality.org
E-Mail: kshearer@airquality.org

San Diego County APCD
Phone: (858) 650-4700
Website: www.sdapcd.org

San Joaquin Valley APCD
Phone: (559) 230-6000 (General)
(800) 281-7003
(San Joaquin, Stanislaus, Merced)
(800) 870-1037
(Madera, Fresno, Kings)
(800) 926-5550
(Tulare and Valley portion of Kern)
Website: www.valleyair.org
E-Mail: sjvapcd@valleyair.org

San Luis Obispo County APCD
Phone: (805) 781-5912
Website: www.slocleanair.org
E-Mail: info@slocleanair.org

Santa Barbara County APCD
Phone (805) 961-8800
Website: www.sbcapcd.org
Email us: apcd@sbcapcd.org

Shasta County AQMD
Phone: (530) 225-5789
Website:
www.co.shasta.ca.us/Departments/Resourcemgmt/drm/aqmain.htm
E-Mail: scdrm@snowcrest.net

Siskiyou County APCD
Phone: (530) 841-4029
E-Mail: ebeck@siskiyou.ca.us

South Coast AQMD
Phone: (909) 396-2000
Complaint Line: 1-800-CUT-SMOG
Website: www.aqmd.gov
Email: bwallerstein@aqmd.gov

Tehama County APCD
Phone: (530) 527-3717
Website: www.tehcoapcd.net
Email: general@tehcoapcd.net

Tuolumne County APCD
Phone: (209) 533-5693
E-Mail:
bsandman@co.tuolumne.ca.us

Ventura County APCD
Phone: (805) 645-1400
Complaint Line: (805) 654-2797
Website: www.vcapcd.org
E-Mail: info@vcapcd.org

Yolo-Solano AQMD
Phone: (530) 757-3650
Website: www.ysaqmd.org
Email: administration@ysaqmd.org

To My Local Government Colleagues....

I am pleased to introduce this informational guide to air quality and land use issues focused on community health. As a former county supervisor, I know from experience the complexity of local land use decisions. There are multiple factors to consider and balance. This document provides important public health information that we hope will be considered along with housing needs, economic development priorities, and other quality of life issues.

An important focus of this document is prevention. We hope the air quality information provided will help inform decision-makers about the benefits of avoiding certain siting situations. The overarching goal is to avoid placing people in harm's way. Recent studies have shown that public exposure to air pollution can be substantially elevated near freeways and certain other facilities. What is encouraging is that the health risk is greatly reduced with distance. For that reason, we have provided some general recommendations aimed at keeping appropriate distances between sources of air pollution and land uses such as residences.

Land use decisions are a local government responsibility. The Air Resources Board's role is advisory and these recommendations do not establish regulatory standards of any kind. However, we hope that the information in this document will be seriously considered by local elected officials and land use agencies. We also hope that this document will promote enhanced communication between land use agencies and local air pollution control agencies. We developed this document in close coordination with the California Air Pollution Control Officers Association with that goal in mind.

I hope you find this document both informative and useful.

Barbara Riordan

Mrs. Barbara Riordian
Interim Chairman
California Air Resources Board

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Acknowledgments

The ARB staff would like to acknowledge the exceptional contributions made to this document by members of the ARB Environmental Justice Stakeholders Group. Since 2001, ARB staff has consistently relied on this group to provide critical and constructive input on implementing the specifics of ARB's environmental justice policies and actions. The Stakeholders Group is convened by the ARB, and comprised of representatives from local land use and air agencies, community interest groups, environmental justice organizations, academia, and business. Their assistance and suggestions throughout the development of this Handbook have been invaluable.

Executive Summary

The Air Resources Board s (ARB) primary goal in developing this document is to provide information that will help keep California's children and other vulnerable populations out of harm s way with respect to nearby sources of air pollution. Recent air pollution studies have shown an association between respiratory and other non-cancer health effects and proximity to high traffic roadways. Other studies have shown that diesel exhaust and other cancer-causing chemicals emitted from cars and trucks are responsible for much of the overall cancer risk from airborne toxics in California. Also, ARB community health risk assessments and regulatory programs have produced important air quality information about certain types of facilities that should be considered when siting new residences, schools, day care centers, playgrounds, and medical facilities (i.e., sensitive land uses). Sensitive land uses deserve special attention because children, pregnant women, the elderly, and those with existing health problems are especially vulnerable to the non-cancer effects of air pollution. There is also substantial evidence that children are more sensitive to cancer-causing chemicals.

Focusing attention on these siting situations is an important preventative action. ARB and local air districts have comprehensive efforts underway to address new and existing air pollution sources under their respective jurisdictions. The issue of siting is a local government function. As more data on the connection between proximity and health risk from air pollution become available, it is essential that air agencies share what we know with land use agencies. We hope this document will serve that purpose.

The first section provides ARB recommendations regarding the siting of new sensitive land uses near freeways, distribution centers, rail yards, ports, refineries, chrome plating facilities, dry cleaners, and gasoline dispensing facilities. This list consists of the air pollution sources that we have evaluated from the standpoint of the proximity issue. It is based on available information and reflects ARB's primary areas of jurisdiction – mobile sources and toxic air contaminants. A key air pollutant common to many of these sources is particulate matter from diesel engines. Diesel particulate matter (diesel PM) is a carcinogen identified by ARB as a toxic air contaminant and contributes to particulate pollution statewide.

Reducing diesel particulate emissions is one of ARB's highest public health priorities and the focus of a comprehensive statewide control program that is reducing diesel PM emissions each year. ARB's long-term goal is to reduce diesel PM emissions 85% by 2020. However, cleaning up diesel engines will take time as new engine standards phase in and programs to accelerate fleet turnover or retrofit existing engines are implemented. Also, these efforts are reducing diesel particulate emissions on a statewide basis, but do not yet capture every site where diesel vehicles and engines may congregate. Because living or going to school too close to such air pollution sources may increase both cancer and non-cancer health risks, we are recommending that proximity be considered in the siting of new sensitive land uses.

AR0069311

There are also other key toxic air contaminants associated with specific types of facilities. Most of these are subject to stringent state and local air district regulations. However, what we know today indicates that keeping new homes and other sensitive land uses from siting too close to such facilities would provide additional health protection. Chrome platers are a prime example of facilities that should not be located near vulnerable communities because of the cancer health risks from exposure to the toxic material used during their operations.

In addition to source specific recommendations, we also encourage land use agencies to use their planning processes to ensure the appropriate separation of industrial facilities and sensitive land uses. While we provide some suggestions how to best achieve that goal is a local issue. In the development of these guidelines, we received valuable input from local government about the spectrum of issues that must be considered in the land use planning process. This includes addressing housing and transportation needs, the benefits of urban infill, community economic development priorities, and other quality of life issues. All of these factors are important considerations. The recommendations in the Handbook need to be balanced with other State and local policies.

Our purpose with this document is to highlight the potential health impacts associated with proximity to air pollution sources so planners explicitly consider this issue in planning processes. We believe that with careful evaluation, infill development, mixed use, higher density, transit-oriented development, and other concepts that benefit regional air quality can be compatible with protecting the health of individuals at the neighborhood level. One suggestion for achieving this goal is more communication between air agencies and land use planners. Local air districts are an important resource that should be consulted regarding sources of air pollution in their jurisdictions. ARB staff will also continue to provide updated technical information as it becomes available.

Our recommendations are as specific as possible given the nature of the available data. In some cases, like refineries, we suggest that the siting of new sensitive land uses should be avoided immediately downwind. However, we leave definition of the size of this area to local agencies based on facility specific considerations. Also, project design that would reduce air pollution exposure may be part of the picture and we encourage consultation with air agencies on this subject.

In developing the recommendations, our first consideration was the adequacy of the data available for an air pollution source category. Using that data, we assessed whether we could reasonably characterize the relative exposure and health risk from a proximity standpoint. That screening provided the list of air pollution sources that we were able to address with specific recommendations. We also considered the practical implications of making hard and fast recommendations where the potential impact area is large, emissions will be reduced with time, and air agencies are in the process of looking at options for additional emission control. In the end, we tailored our recommendations to minimize the highest exposures for each source category independently. Due to the large variability in relative risk in the source categories, we chose not to apply

AR0069312

a uniform quantified risk threshold as is typically done in air quality permitting programs. Instead, because these guidelines are not regulatory or binding on local agencies, we took a more qualitative approach in developing the distance-based recommendations.

Where possible, we recommend a minimum separation between a new sensitive land use and known air pollution risks. In other cases, we acknowledge that the existing health risk is too high in a relatively large area, that air agencies are working to reduce that risk, and that in the meantime, we recommend keeping new sensitive land uses out of the highest exposure areas. However, it is critical to note that our implied identification of the high exposure areas for these sources does not mean that the risk in the remaining impact area is insignificant. Rather, we hope this document will bring further attention to the potential air health risk throughout the impact area and help garner support for our ongoing efforts to reduce health risk associated with air pollution sources. Areas downwind of major ports, rail yards, and other inter-modal transportation facilities are prime examples.

We developed these recommendations as a means to share important public health information. The underlying data are publicly available and referenced in this document. We also describe our rationale and the factors considered in developing each recommendation, including data limitations and uncertainties. These recommendations are advisory and should not be interpreted as defined "buffer zones." We recognize the opportunity for more detailed site-specific analyses always exists, and that there is no "one size fits all" solution to land use planning.

As California continues to grow, we collectively have the opportunity to use all the information at hand to avoid siting scenarios that may pose a health risk. As part of ARB's focus on communities and children's health, we encourage land use agencies to apply these recommendations and work more closely with air agencies. We also hope that this document will help educate a wider audience about the value of preventative action to reduce environmental exposures to air pollution.

AR0069313

1. ARB Recommendations on Siting New Sensitive Land Uses

Protecting California's communities and our children from the health effects of air pollution is one of the most fundamental goals of state and local air pollution control programs. Our focus on children reflects their special vulnerability to the health impacts of air pollution. Other vulnerable populations include the elderly, pregnant women, and those with serious health problems affected by air pollution. With this document, we hope to more effectively engage local land use agencies as partners in our efforts to reduce health risk from air pollution in all California communities.

Later sections emphasize the need to strengthen the connection between air quality and land use in both planning and permitting processes. Because the siting process for many, but not all, air pollution sources involves permitting by local air districts, there is an opportunity for interagency coordination where the proposed location might pose a problem. To enhance the evaluation process from a land use perspective, section 4 includes recommended project related questions to help screen for potential proximity related issues.

Unlike industrial and other stationary sources of air pollution, the siting of new homes or day care centers does not require an air quality permit. Because these situations fall outside the air quality permitting process, it is especially important that land use agencies be aware of potential air pollution impacts.

The following recommendations address the issue of siting "sensitive land uses" near specific sources of air pollution, namely:

- High traffic freeways and roads
- Distribution centers
- Rail yards
- Ports
- Refineries
- Chrome plating facilities
- Dry cleaners
- Large gas dispensing facilities

The recommendations for each category include a summary of key information and guidance on what to avoid from a public health perspective.

AR0069315

Sensitive individuals refer to those segments of the population most susceptible to poor air quality (i.e., children, the elderly, and those with pre-existing serious health problems affected by air quality). Land uses where sensitive individuals are most likely to spend time include schools and schoolyards, parks and playgrounds, daycare centers, nursing homes, hospitals and residential communities (sensitive sites or sensitive land uses).

We are characterizing sensitive land uses as simply as we can by using the examples of residences, schools, day care centers, playgrounds, and medical facilities. However, a variety of facilities are encompassed. For example, residences can include houses, apartments, and senior living complexes. Medical facilities can include hospitals, convalescent homes, and health clinics. Playgrounds could be play areas associated with parks or community centers.

In developing these recommendations, ARB first considered the adequacy of the data available for each air pollution source category. We assessed whether we could generally characterize the relative exposure and health risk from a proximity standpoint. The documented non-cancer health risks include triggering of asthma attacks, heart attacks, and increases in daily mortality and hospitalization for heart and respiratory diseases. These health impacts are well documented in epidemiological studies, but less easy to quantify from a particular air pollution source. Therefore, the cancer health impacts are used in this document to provide a picture of relative risk. This screening process provided the list of source categories we were able to address with specific recommendations. In evaluating the available information, we also considered the practical implications of making hard and fast recommendations where the potential impact area is large, emissions will be reduced with time, and air agencies are in the process of looking at options for additional emission control. Due to the large variability in relative risk between the source categories, we chose not to apply a uniform, quantified risk threshold as is typically done in regulatory programs. Therefore, in the end, we tailored our recommendations to minimize the highest exposures for each source category independently. Additionally, because this guidance is not regulatory or binding on local agencies, we took a more qualitative approach to developing distance based recommendations.

Where possible, we recommend a minimum separation between new sensitive land uses and existing sources. However, this is not always possible, particularly where there is an elevated health risk over large geographical areas. Areas downwind of ports and rail yards are prime examples. In such cases, we recommend doing everything possible to avoid locating sensitive receptors within the highest risk zones. Concurrently, air agencies and others will be working to reduce the overall risk through controls and measures within their scope of authority.

AR0069316

The recommendations were developed from the standpoint of siting new sensitive land uses. Project-specific data for new and existing air pollution sources are available as part of the air quality permitting process. Where such information is available, it should be used. Our recommendations are designed to fill a gap where information about existing facilities may not be readily available. These recommendations are only guidelines and are not designed to substitute for more specific information if it exists.

A summary of our recommendations is shown in Table 1-1. The basis and references[1] supporting each of these recommendations, including health studies, air quality modeling and monitoring studies is discussed below beginning with freeways and summarized in Table 1-2. As new information becomes available, it will be included on ARB's community health web page.

[1]Detailed information on these references are available on ARB's website at: http://www.ARB.ca.gov/ch/landuse.htm.

AR0069317

Table 1-1

Recommendations on Siting New Sensitive Land Uses Such As Residences, Schools, Daycare Centers, Playgrounds, or Medical Facilities*

Source Category	Advisory Recommendations
Freeways and High-Traffic Roads	• Avoid siting new sensitive land uses within 500 feet of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day
Distribution Centers	• Avoid siting new sensitive land uses within 1,000 feet of a distribution center (that accommodates more than 100 trucks per day, more than 40 trucks with operating transport refrigeration units (TRUs) per day, or where TRU unit operations exceed 300 hours per week). • Take into account the configuration of existing distribution centers and avoid locating residences and other new sensitive land uses near entry and exit points
Rail Yards	• Avoid siting new sensitive land uses within 1,000 feet of a major service and maintenance rail yard. • Within one mile of a rail yard, consider possible siting limitations and mitigation approaches.
Ports	• Avoid siting of new sensitive land uses immediately downwind of ports in the most heavily-impacted zones. Consult local air districts or the ARB on the status of pending analyses of health risks.
Refineries	• Avoid siting new sensitive land uses immediately downwind of petroleum refineries. Consult with local air districts and other local agencies to determine an appropriate separation.
Chrome Platers	• Avoid siting new sensitive land uses within 1,000 feet of a chrome plater.
Dry Cleaners Using Perchloro-ethylene	• Avoid siting new sensitive land uses within 300 feet of any dry cleaning operation. For operations with two or more machines, provide 500 feet. For operations with 3 or more machines, consult with the local air district. • Do not site new sensitive land uses in the same building with perc dry cleaning operations.
Gasoline Dispensing Facilities	• Avoid siting new sensitive land uses within 300 feet of a large gas station (defined as a facility with a throughput of 3.6 million gallons per year or greater). A 50 foot separation is recommended for typical gas dispensing facilities.

*Notes

- These recommendations are advisory. Land use agencies have to balance other considerations, including housing and transportation needs, economic development priorities, and other quality of life issues.

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- Recommendations are based primarily on data showing that the air pollution exposures addressed here (i.e., localized) can be reduced as much as 80% with the recommended separation
- The relative risk for these categories varies greatly (see Table 1-2). To determine the actual risk near a particular facility, a site-specific analysis would be required. Risk from diesel PM will decrease over time as cleaner technology phases in
- These recommendations are designed to fill a gap where information about existing facilities may not be readily available and are not designed to substitute for more specific information if it exists. The recommended distances take into account other factors in addition to available health risk data (see individual category descriptions)
- Site-specific project design improvements may help reduce air pollution exposures and should also be considered when siting new sensitive land uses
- This table does not imply that mixed residential and commercial development in general is incompatible. Rather it focuses on known problems like dry cleaners using perchloroethylene that can be addressed with reasonable preventative actions
- A summary of the basis for the distance recommendations can be found in Table 1-2

AR0069319

Table 1-2

Summary of Basis for Advisory Recommendations

Source Category	Range of Relative Cancer Risk[1,2]	Summary of Basis for Advisory Recommendations
Freeways and High-Traffic Roads	300 – 1,700	• In traffic-related studies, the additional non-cancer health risk attributable to proximity was seen within 1,000 feet and was strongest within 300 feet. California freeway studies show about a 70% drop off in particulate pollution levels at 500 feet.
Distribution Centers[3]	Up to 500	• Because ARB regulations will restrict truck idling at distribution centers, transport refrigeration unit (TRU) operations are the largest onsite diesel PM emission source followed by truck travel in and out of distribution centers. • Based on ARB and South Coast District emissions and modeling analyses, we estimate an 80 percent drop-off in pollutant concentrations at approximately 1,000 feet from a distribution center.
Rail Yards	Up to 500	• The air quality modeling conducted for the Roseville Rail Yard Study predicted the highest impact is within 1,000 feet of the Yard, and is associated with service and maintenance activities. The next highest impact is between a half to one mile of the Yard depending on wind direction and intensity.
Ports	Studies underway	• ARB will evaluate the impacts of ports and develop a new comprehensive plan that will describe the steps needed to reduce public health impacts from port and rail activities in California. In the interim, a general advisory is appropriate based on the magnitude of diesel PM emissions associated with ports.
Refineries	Under 10	• Risk assessments conducted at California refineries show risks from air toxics to be under 10 chances of cancer per million.[4] • Distance recommendations were based on the amount and potentially hazardous nature of many of the pollutants released as part of the refinery process, particularly during non-routine emissions releases.
Chrome Platers	10-1,100	• ARB modeling and monitoring studies show localized risk of hexavalent chromium diminishing significantly at 300 feet. There are data limitations in both the modeling and monitoring studies. These include variability of plating activities and uncertainty of emissions such as fugitive dust. Hexavalent chromium is one of the most potent toxic air contaminants. Considering these factors, a distance of 1,000 feet was used as a precautionary measure.
Dry Cleaners Using Perchloro-ethylene (perc)	15-1,150	• Local air district studies indicate that individual cancer risk can be reduced by as much as 75 percent by establishing a 300 foot separation between a sensitive land use and a one-machine perc dry cleaning operation. For larger operations (2 machines or more), a separation of 500 feet can reduce risk by over 85 percent.

AR0069320

Source Category	Range of Relative Cancer Risk[1,2]	Summary of Basis for Advisory Recommendations
Gasoline Dispensing Facilities (GDF)[3]	Typical GDF: Less than 10 Large GDF: Between less than 10 and 120	• Based on the CAPCOA Gasoline Service Station Industry-wide Risk Assessment Guidelines, most typical GDFs (less than 3.6 million gallons per year) have a risk of less than 10 at 50 feet under urban air dispersion conditions. Over the last few years, there has been a growing number of extremely large GDFs with sales over 3.6 and as high as 19 million gallons per year. Under rural air dispersion conditions, these large GDFs can pose a larger risk at a greater distance.

[1] For cancer health effects, risk is expressed as an estimate of the increased chances of getting cancer due to facility emissions over a 70-year lifetime. This increase in risk is expressed as chances in a million (e.g., 10 chances in a million).

[2] The estimated cancer risks are a function of the proximity to the specific category and were calculated independent of the regional health risk from air pollution. For example, the estimated regional cancer risk from air toxics in the Los Angeles region (South Coast Air Basin) is approximately 1,000 in a million.

[3] Analysis based on refrigerator trucks.

[4] Although risk assessments performed by refineries indicate they represent a low cancer risk, there is limited data on non-cancer effects of pollutants that are emitted from these facilities. Refineries are also a source of non-routine emissions and odors.

[5] A typical GDF in California dispenses under 3.6 million gallons of gasoline per year. The cancer risk for this size facility is likely to be less than 10 in a million at the fenceline under urban air dispersion conditions.

[6] A large GDF has fuel throughouts that can range from 3.6 to 19 million gallons of gasoline per year. The upper end of the risk range (i.e., 120 in a million) represents a hypothetical worst case scenario for an extremely large GDF under rural air dispersion conditions.

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Freeways and High Traffic Roads

Air pollution studies indicate that living close to high traffic and the associated emissions may lead to adverse health effects beyond those associated with regional air pollution in urban areas. Many of these epidemiological studies have focused on children. A number of studies identify an association between adverse non-cancer health effects and living or attending school near heavily traveled roadways (see findings below). These studies have reported associations between residential proximity to high traffic roadways and a variety of respiratory symptoms, asthma exacerbations, and decreases in lung function in children.

One such study that found an association between traffic and respiratory symptoms in children was conducted in the San Francisco Bay Area. Measurements of traffic-related pollutants showed concentrations within 300 meters (approximately 1,000 feet) downwind of freeways were higher than regional values. Most other studies have assessed exposure based on proximity factors such as distance to freeways or traffic density.

These studies linking traffic emissions with health impacts build on a wealth of data on the adverse health effects of ambient air pollution. The data on the effects of proximity to traffic related emissions provides additional information that can be used in land use siting and regulatory actions by air agencies. The key observation in these studies is that close proximity increases both exposure and the potential for adverse health effects. Other effects associated with traffic emissions include premature death in elderly individuals with heart disease.

Key Health Findings

- Reduced lung function in children was associated with traffic density, especially trucks, within 1,000 feet and the association was strongest within 300 feet. (Brunekreef, 1997)
- Increased asthma hospitalizations were associated with living within 650 feet of heavy traffic and heavy truck volume. (Lin, 2002)
- Asthma symptoms increased with proximity to roadways and the risk was greatest within 300 feet. (Venn, 2001)
- Asthma and bronchitis symptoms in children were associated with proximity to high traffic in a San Francisco Bay Area community with good overall regional air quality. (Kim, 2004)
- A San Diego study found increased medical visits in children living within 550 feet of heavy traffic. (English, 1999)

In these and other proximity studies, the distance from the roadway and truck traffic densities were key factors affecting the strength of the association with adverse health effects. In the above health studies, the association of traffic-related emissions with adverse health effects was seen within 1,000 feet and was

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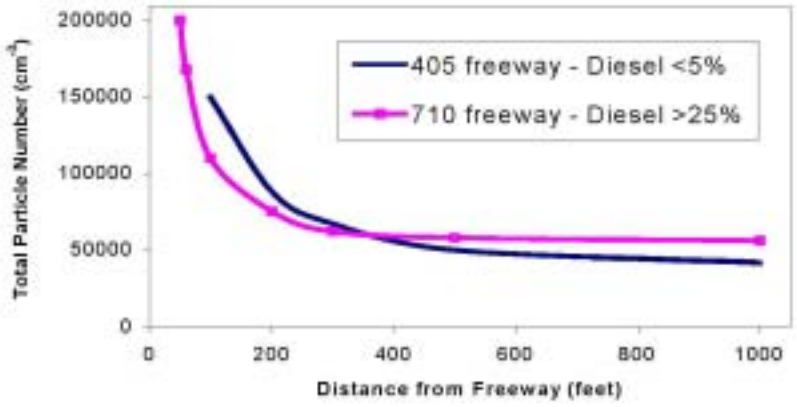
strongest within 300 feet. This demonstrates that the adverse effects diminished with distance.

In addition to the respiratory health effects in children, proximity to freeways increases potential cancer risk and contributes to total particulate matter exposure. There are three carcinogenic toxic air contaminants that constitute the majority of the known health risk from motor vehicle traffic – diesel particulate matter (diesel PM) from trucks, and benzene and 1,3-butadiene from passenger vehicles. On a typical urban freeway (truck traffic of 10,000-20,000/day), diesel PM represents about 70 percent of the potential cancer risk from the vehicle traffic. Diesel particulate emissions are also of special concern because health studies show an association between particulate matter and premature mortality in those with existing cardiovascular disease.

Distance Related Findings

A southern California study (Zhu, 2002) showed measured concentrations of vehicle-related pollutants, including ultra-fine particles, decreased dramatically within approximately 300 feet of the 710 and 405 freeways. Another study looked at the validity of using distance from a roadway as a measure of exposure

Figure 1-1
Decrease In Concentration of Freeway Diesel PM Emissions With Distance



to traffic related air pollution (Knape, 1999). This study showed that concentrations of traffic related pollutants declined with distance from the road, primarily in the first 500 feet.

These findings are consistent with air quality modeling and risk analyses done by ARB staff that show an estimated range of potential cancer risk that decreases with distance from freeways. The estimated risk varies with the local meteorology, including wind pattern. As an example, at 300 feet downwind from a freeway (Interstate 80) with truck traffic of 10,000 trucks per day, the potential cancer risk was as high as 100 in one million (ARB Roseville Rail Yard Study). The cancer health risk at 300 feet on the upwind side of the freeway was much

ess. The risk at that distance for other freeways will vary based on local conditions – it may be higher or lower. However, in all these analyses the relative exposure and health risk dropped substantially within the first 300 feet. This phenomenon is illustrated in Figure 1-1.

State law restricts the siting of new schools within 500 feet of a freeway, urban roadways with 100,000 vehicles/day, or rural roadways with 50,000 vehicles with some exceptions.[2] However, no such requirements apply to the siting of residences, day care centers, playgrounds, or medical facilities. The available data show that exposure is greatly reduced at approximately 300 feet. In the traffic-related studies the additional health risk attributable to the proximity effect was strongest within 1,000 feet.

The combination of the children's health studies and the distance related findings suggests that it is important to avoid exposing children to elevated air pollution levels immediately downwind of freeways and high traffic roadways. These studies suggest a substantial benefit to a 500-foot separation.

The impact of traffic emissions is on a gradient that at some point becomes indistinguishable from the regional air pollution problem. As air agencies work to reduce the underlying regional health risk from diesel PM and other pollutants, the impact of proximity will also be reduced. In the meantime, as a preventative measure, we hope to avoid exposing more children and other vulnerable individuals to the highest concentrations of traffic-related emissions.

Recommendation

- Avoid siting new sensitive land uses within 500 feet of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day.

References

- Brunekreef, B. et al. *"Air pollution from truck traffic and lung function in children living near motorways."* Epidemiology, 1997, 8:298-303.
- Lin, S. et al. *"Childhood asthma hospitalization and residential exposure to state route traffic."* Environ Res. 2002;88:73-81.
- Venn, et al. *"Living near a main road and the risk of wheezing illness in children."* American Journal of Respiratory and Critical Care Medicine, 2001, Vol.164, pp. 2177-2180.
- Kim, J. et al. *"Traffic-related air pollution and respiratory health: East Bay Children's Respiratory Health Study."* American Journal of Respiratory and Critical Care Medicine, 2004; Vol. 170, pp. 520-526.

[2] Section 17213 of the California Education Code and section 21151.8 of the California Public Resources Code. See also Appendix E for a description of special processes that apply to school siting.

- Zhu, Y et al. *"Study of Ultra-Fine Particles Near A Major Highway With Heavy-Duty Diesel Traffic."* Atmospheric Environment. 2002 ; 36:4323-4335
- Knape, M. *"Traffic related air pollution in city districts near motorways."* The Science of the Total Environment. 1999; 235:339-341
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Distribution Centers

Distribution centers or warehouses are facilities that serve as a distribution point for the transfer of goods. Such facilities include cold storage warehouses, goods transfer facilities, and inter-modal facilities such as ports. These operations involve trucks, trailers, shipping containers, and other equipment with diesel engines. A distribution center can be comprised of multiple centers or warehouses within an area. The size can range from several to hundreds of acres, involving a number of different transfer operations and long waiting periods. A distribution center can accommodate hundreds of diesel trucks a day that deliver, load, and/or unload goods up to seven days a week. To the extent that these trucks are transporting perishable goods, they are equipped with diesel-powered transport refrigeration units (TRUs) or TRU generator sets.

The activities associated with delivering, storing, and loading freight produces diesel PM emissions. Although TRUs have relatively small diesel-powered engines, in the normal course of business, their emissions can pose a significant health risk to those nearby. In addition to onsite emissions, truck travel in and out of distribution centers contributes to the local pollution impact.

ARB is working to reduce diesel PM emissions through regulations, financial incentives, and enforcement programs. In 2004, ARB adopted two airborne toxic control measures that will reduce diesel PM emissions associated with distribution centers. The first will limit nonessential (or unnecessary) idling of diesel-fueled commercial vehicles, including those entering from other states or countries. This statewide measure, effective in 2005, prohibits idling of a vehicle more than five minutes at any one location.[3] The elimination of unnecessary idling will reduce the localized impacts caused by diesel PM and other air toxics

[3] For further information on the Anti-Idling ATCM, please click on: http://www.arb.ca.gov/toxics/idling/outreach/factsheet.pdf

in diesel vehicle exhaust. This should be a very effective new strategy for reducing diesel PM emissions at distribution centers as well as other locations.

The second measure requires that TRUs operating in California become cleaner over time. The measure establishes in-use performance standards for existing TRU engines that operate in California, including out-of-state TRUs. The requirements are phased-in beginning in 2008, and extend to 2019.[4]

ARB also operates a smoke inspection program for heavy-duty diesel trucks that focuses on reducing truck emissions in California communities. Areas with large numbers of distribution centers are a high priority.

Key Health Findings

Diesel PM has been identified by ARB as a toxic air contaminant and represents 70 percent of the known potential cancer risk from air toxics in California. Diesel PM is an important contributor to particulate matter air pollution. Particulate matter exposure is associated with premature mortality and health effects such as asthma exacerbation and hospitalization due to aggravating heart and lung disease.

Distance Related Findings

Although distribution centers are located throughout the state, they are usually clustered near transportation corridors, and are often located in or near population centers. Diesel PM emissions from associated delivery truck traffic and TRUs at these facilities may result in elevated diesel PM concentrations in neighborhoods surrounding those sites. Because ARB regulations will restrict truck idling at distribution centers, the largest continuing onsite diesel PM emission source is the operation of TRUs. Truck travel in and out of distribution centers also contributes to localized exposures, but specific travel patterns and truck volumes would be needed to identify the exact locations of the highest concentrations.

As part of the development of ARB's regulation for TRUs, ARB staff performed air quality modeling to estimate exposure and the associated potential cancer risk of onsite TRUs for a typical distribution center. For an individual person, cancer risk estimates for air pollution are commonly expressed as a probability of developing cancer from a lifetime (i.e., 70 years) of exposure. These risks were calculated independent of regional risk. For example, the estimated regional cancer risk from air toxics in the Los Angeles region (South Coast Air Basin) is approximately 1,000 additional cancer cases per one million population.

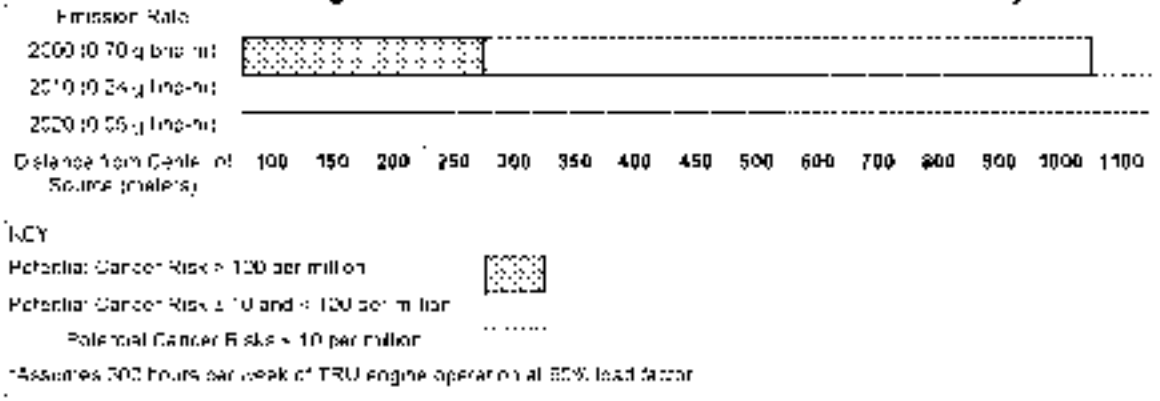
[4] For further information on the Transport Refrigeration Unit ATCM, please click on: http://www.arb.ca.gov/diesel/documents/trufaq.pdf

The diesel PM emissions from a facility are dependent on the size (horsepower), age, and number of engines, emission rates, the number of hours the truck engines and/or TRUs operate, distance, and meteorological conditions at the site. This assessment assumes a total on-site operating time for all TRUs of 300 hours per week. This would be the equivalent of 40 TRU-equipped trucks a day, each loading or unloading on-site for one hour, 12 hours a day and seven days a week.

As shown in Figure 1-2 below, at this estimated level of activity and assuming a current fleet diesel PM emission rate, the potential cancer risk would be over 100 in a million at 800 feet from the center of the TRU activity. The estimated potential cancer risk would be in the 10 to 100 per million range between 800 to 3,300 feet and fall off to less than 10 per million at approximately 3,600 feet. However, with the implementation of ARB's regulation on TRUs, the risk will be significantly reduced.[5] We have not conducted a risk assessment for distribution centers based on truck traffic alone, but on an emissions basis, we would expect similar risks for a facility with truck volumes in the range of 100 per day.

Figure 1-2

Estimated Risk Range versus Distance from Center of TRU Activity Area*



The estimated potential cancer risk level in Figure 1-2 is based on a number of assumptions that may not reflect actual conditions for a specific site. For example, increasing or decreasing the hours of diesel engine operations would change the potential risk levels. Meteorological and other facility specific parameters can also impact the results. Therefore, the results presented here are not directly applicable to any particular facility or operation. Rather, this information is intended to provide an indication as to the potential relative levels of risk that may be observed from operations at distribution centers. As shown in Figure 1-2, the estimated risk levels will decrease over time as lower-emitting diesel engines are used.

* These risk values assume an exposure duration of 70 years for a nearby resident and uses the methodology specified in the 2003 OEHHA health risk assessment guidelines.

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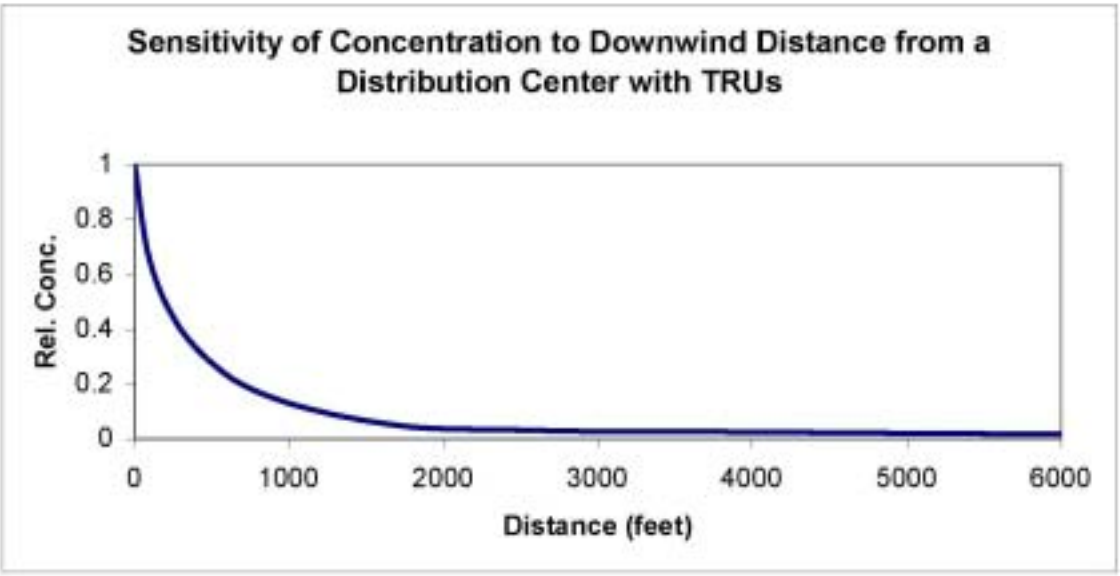
Another air modeling analysis, performed by the South Coast Air Quality Management District (South Coast AQMD), evaluated the impact of diesel PM emissions from distribution center operations in the community of Mira Loma in southern California. Based on dispersion of diesel PM emissions from a large distribution center, Figure 1-3 shows the relative pollution concentrations at varying distances downwind. As Figure 1-3 shows, there is about an 80 percent drop off in concentration at approximately 1,000 feet.

Figure 1-3
Decrease In Relative Concentration of Risk
With Distance



Both the ARB and the South Coast AQMD analyses indicate that providing a separation of 1,000 feet would substantially reduce diesel PM concentrations and public exposure downwind of a distribution center. While these analyses do not provide specific risk estimates for distribution centers, they provide an indication of the range of risk and the benefits of providing a separation. ARB recommends a separation of 1,000 feet based on the combination of risk analysis done for TRUs and the decrease in exposure predicted with the South Coast AQMD modeling. However, ARB staff plans to provide further information on distribution centers as we collect more data and implement the TRU control measure.

Taking into account the configuration of distribution centers can also reduce population exposure and risk. For example, locating new sensitive land uses away from the main entry and exit points helps to reduce cancer risk and other health impacts.

Recommendations

- Avoid siting new sensitive land uses within 1,000 feet of a distribution center (that accommodates more than 100 trucks per day, more than 40 trucks with operating TRUs per day, or where TRU unit operations exceed 300 hours per week).

- Take into account the configuration of existing distribution centers and avoid locating residences and other new sensitive land uses near entry and exit points.

References

- *Airborne Toxic Control Measure To Limit Diesel-Fueled Commercial Motor Vehicle Idling*. ARB (August 20, 2004). Rule effectiveness date awaiting submittal of regulation to the Office of Administration Law. http://www.arb.ca.gov/regact/idling/idling.htm

- *Revised Staff Report: Initial Statement of Reasons for Proposed Rulemaking. Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate*. ARB (October 28, 2003). http://www.arb.ca.gov/regact/trude03/revisor.doc

- *Health Risk Assessment Guidance for Analyzing Cancer Risks from Mobile Source Diesel Idling Emissions for CEQA Air Quality Analysis*. SCAQMD (August 2003) http://www.aqmd.gov/ceqa/handbook/diesel_analysis.doc

- *"Mira Loma Study: Analysis of the Impact of Diesel Particulate Emissions from Warehouse/Distribution Center Operations"*, PowerPoint presentation. SCAQMD (July 31, 2002)

Rail Yards

Rail yards are a major source of diesel particulate air pollution. They are usually located near inter-modal facilities, which attract heavy truck traffic, and are often sited in mixed industrial and residential areas. ARB, working with the Placer County air district and Union Pacific Railroad, recently completed a study[6] of the Roseville Rail Yard (Yard) in northern California that focused on the health risk from diesel particulate. A comprehensive emissions analysis and air quality modeling were conducted to characterize the estimated potential cancer risk associated with the facility.

[6] To review the study, please click on: http://www.arb.ca.gov/diesel/documents/rrstudy.htm

The Yard encompasses about 950 acres on a one-quarter mile wide by four-mile long strip of land that parallels Interstate 80. It is surrounded by commercial, industrial, and residential properties. The Yard is one of the largest service and maintenance rail yards in the West with over 30,000 locomotives visiting annually.

Using data provided by Union Pacific Railroad, the ARB determined the number and type of locomotives visiting the Yard annually and what those locomotives were doing - moving, idling, or undergoing maintenance testing. Union Pacific provided the annual, monthly, daily, and hourly locomotive activity in the yard including locomotive movements, routes for arrival, departure, and through trains, and locomotive service and testing. This information was used to estimate the emissions of particulate matter from the locomotives, which was then used to model the potential impacts on the surrounding community.

The key findings of the study are:

- Diesel PM emissions in 2000 from locomotive operations at the Roseville Yard were estimated at about 25 tons per year.

- Of the total diesel PM in the Yard, moving locomotives accounted for about 50 percent, idling locomotives about 45 percent, and locomotive testing about five percent.

- Air quality modeling predicts potential cancer risks greater than 500 in a million (based on 70 years of exposure) in a 30-40 acre area immediately adjacent to the Yard's maintenance operations.

- The risk assessment also showed elevated cancer risk impacting a larger area covering about a 10 by 10 mile area around the Yard.

The elevated concentrations of diesel PM found in the study contribute to an increased risk of cancer and premature death due to cardiovascular disease, and non-cancer health effects such as asthma and other respiratory illnesses. The magnitude of the risk, the general location, and the size of the impacted area depended on the meteorological data used to characterize conditions at the Yard, the dispersion characteristics, and exposure assumptions. In addition to these variables, the nature of locomotive activity will influence a risk characterization at a particular rail yard. For these reasons, the quantified risk estimates in the Roseville Rail Yard Study cannot be directly applied to other rail yards. However, the study does indicate the health risk due to diesel PM from rail yards needs to be addressed. ARB, in conjunction with the U.S. Environmental Protection Agency (U.S. EPA), and local air districts, is working with the rail industry to identify and implement short-term, mid-term and long-term mitigation strategies. ARB also intends to conduct a second rail study in southern California to increase its understanding of rail yard operations and the associated public health impacts.

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Key Health Findings

Diesel PM has been identified by ARB as a toxic air contaminant and represents 70 percent of the known potential cancer risk from air toxics in California. Diesel PM is an important contributor to particulate matter air pollution. Particulate matter exposure is associated with premature mortality and health effects such as asthma exacerbation and hospitalization due to aggravating heart and lung disease.

Distance Related Findings

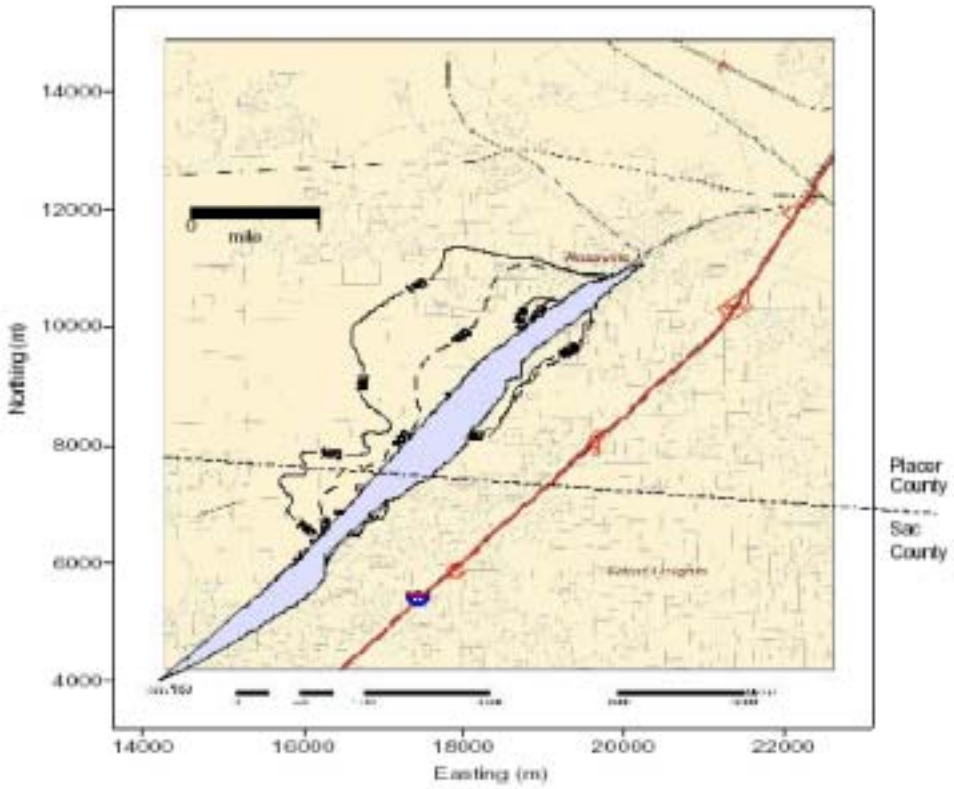
Two sets of meteorological data were used in the Roseville study because of technical limitations in the data. The size of the impact area was highly dependent on the meteorological data set used. The predicted highest impact area ranged from 10 - 40 acres with the two different meteorological data sets. This area, with risks estimated above 500 in a million, is adjacent to an area that includes a maintenance shop (see Figure 1-4). The high concentration of diesel PM emissions is due to the number of locomotives and nature of activities in this area, particularly idling locomotives.

The area of highest impact is within 1,000 feet of the Yard. The next highest impact zone as defined in the report had a predicted risk between 500 and 100 in one million and extends out between a half to one mile in some spots, depending on which meteorological conditions were assumed. The impact areas are irregular in shape making it difficult to generalize about the impact of distance at a particular location. However, the Roseville Rail Yard Study clearly indicates that the localized health risk is high, the impact area is large, and mitigation of the locomotive diesel PM emissions is needed.

For facilities like rail yards and ports, the potential impact area is so large that the real solution is to substantially reduce facility emissions. However, land use planners can avoid encroaching upon existing rail facilities and those scheduled for expansion. We also recommend that while air agencies tackle this problem, land use planners try not to add new sensitive individuals into the highest exposure areas. Finally, we recommend that land use agencies consider the potential health impacts of rail yards in their planning and permitting processes. Additional limitations and mitigation may be feasible to further reduce exposure on a site-specific basis.

Figure 1-4

Estimated Cancer Risk from the Yard
(100 and 500 in a million risk isopleths)



Notes: 100/Million Contours: Solid Line – Roseville Met Data; Dashed Line-McClellan Met Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities (23 TPY), 70-Year Exposure

Recommendation

- Avoid siting new sensitive land uses within 1,000 feet of a major service and maintenance rail yard[7].
- Within one mile of a rail yard, consider possible siting limitations and mitigation approaches.

References

- *Roseville Rail Yard Study*. ARB (2004)

[7] The rail yard risk analysis was conducted for the Union Pacific rail yard in Roseville, California. This rail yard is one of the largest in the state. There are other rail yards in California with comparable levels of activity that should be considered "major" for purposes of this Handbook.

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Ports

Air pollution from maritime port activities is a growing concern for regional air quality as well as air quality in nearby communities. The primary air pollutant associated with port operations is directly emitted diesel particulate. Port-related activities also result in emissions that form ozone and secondary particulate in the atmosphere. The emission sources associated with ports include diesel engine-powered ocean-going ships, harbor craft, cargo handling equipment, trucks, and locomotives. The size and concentration of these diesel engines makes ports one of the biggest sources of diesel PM in the state. For that reason, ARB has made it a top priority to reduce diesel PM emissions at the ports, in surrounding communities, and throughout California.

International, national, state, and local government collaboration is critical to reducing port emissions based on both legal and practical considerations. For example, the International Maritime Organization (IMO) and the U.S. EPA establish emission standards for ocean-going vessels and U.S.-flagged harbor craft, respectively. ARB is pursuing further federal actions to tighten these standards. In addition, ARB and local air districts are reducing emissions from ports through a variety of approaches. These include: incentive programs to fund cleaner engines, enhanced enforcement of smoke emissions from ships and trucks, use of dockside electricity instead of diesel engines, cleaner fuels for ships, harbor craft, locomotives, and reduced engine idling. The two ATCMs that limit truck idling and reduce emissions from TRUs (discussed under "Distribution Centers") also apply to ports.

ARB is also developing several other regulations that will reduce port-related emissions. One rule would require ocean-going ships to use a cleaner marine diesel fuel to power auxiliary engines while in California coastal waters and at dock. Ships that frequently visit California ports would also be required to further reduce their emissions. ARB has adopted a rule that would require harbor craft to use the same cleaner diesel fuel used by on-road trucks in California. In 2005, ARB will consider a rule that would require additional controls for in-use harbor craft, such as the use of add-on emission controls and accelerated turnover of older engines.

Key Health Findings

Port activities are a major source of diesel PM. Diesel PM has been identified by ARB as a toxic air contaminant and represents 70 percent of the known potential cancer risk from air toxics in California. Diesel PM is an important contributor to particulate matter air pollution. Particulate matter exposure is associated with premature mortality and health effects such as asthma exacerbation and hospitalization due to aggravating heart and lung disease.

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Distance Related Findings

The Ports of Los Angeles and Long Beach provide an example of the emissions impact of port operations. A comprehensive emissions inventory was completed in June 2004. These ports combined are one of the world's largest and busiest seaports. Located in San Pedro Bay, about 20 miles south of downtown Los Angeles, the port complex occupies approximately 16 square miles of land and water. Port activities include five source categories that produce diesel emissions. These are ocean-going vessels, harbor craft, cargo handling equipment, railroad locomotives, and heavy duty trucks.

The baseline emission inventory provides emission estimates for all major air pollutants. This analysis focuses on diesel PM from in-port activity because these emissions have the most potential health impact on the areas adjacent to the port. Ocean vessels are the largest overall source of diesel PM related to the ports, but these emissions occur primarily outside of the port in coastal waters, making the impact more regional in nature.

The overall in-port emission inventory for diesel particulate for the ports of Los Angeles and Long Beach is estimated to be 550 tons per year. The emissions fall in the following major categories: ocean-going vessels (17%), harbor craft (25%), cargo handling (47%), railroad locomotive (3%), and heavy duty vehicles (8%). In addition to in-port emissions, ship, rail and trucking activities also contribute to regional emissions and increase emissions in nearby neighborhoods. Off-port emissions associated with related ship, rail and trucking activities contribute an additional 660 tons per year of diesel particulate at the Port of Los Angeles alone.

To put this in perspective, the diesel PM emissions estimated for the Roseville Yard in ARB's 2004 study are 25 tons per year. The potential cancer risk associated with these emissions is 100 in one million at a distance of one mile, or one half mile, depending on the data set used. This rail yard covers one and a half square miles. The Los Angeles and Long Beach ports have combined diesel PM emissions of 550 tons per year emitted from a facility that covers a much larger area - 16 miles. The ports have about twice the emission density of the rail yard - 34 tons per year per square mile compared to 16 tons per year per square mile. However, while this general comparison is illustrative of the overall size of the complex, a detailed air quality modeling analysis would be needed to assess the potential health impact on specific downwind areas near the ports.

ARB is in the process of evaluating the various port-related emission sources from the standpoint of existing emissions, growth forecasts, new control options, regional air quality impacts, and localized health risk. A number of public processes - both state and local - are underway to address various aspects of these issues. Until more of these analyses are complete, there is little basis for recommending a specific separation between new sensitive land uses and ports.

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For example, the type of data we have showing the relationship between air pollutant concentrations and distance from freeways is not yet available.

Also, the complexity of the port facilities makes a site-specific analysis critical. Ports are a concentration of multiple emission sources with differing dispersion and other characteristics. In the case of the Roseville rail yard, we found a high, very localized impact associated with a particular activity: service and maintenance. By contrast, the location, size, and nature of impact areas can be expected to vary substantially for different port activities. For instance, ground level emissions from dockside activities would behave differently from ship stack level emissions.

Nonetheless, on an emissions basis alone, we expect locations downwind of ports to be substantially impacted. For that reason, we recommend that land use agencies track the current assessment efforts, and consider limitations on the siting of new sensitive land uses in areas immediately downwind of ports.

Recommendations

Avoid siting new sensitive land uses immediately downwind of ports in the most heavily impacted zones. Consult local air districts or the ARB on the status of pending analyses of health risks.

References

- *Roseville Rail Yard Study*. ARB (2004)
- Final Draft, "*Port-Wide Baseline Air Emissions Inventory*." Port of Los Angeles (June 2004)
- Final Draft, "*2002 Baseline Air Emissions Inventory*." Port of Long Beach (February 2004)

Petroleum Refineries

A petroleum refinery is a complex facility where crude oil is converted into petroleum products (primarily gasoline, diesel fuel, and jet fuel) which are then transported through a system of pipelines and storage tanks for final distribution by delivery truck to fueling facilities throughout the state. In California, most crude oil is delivered either by ship from Alaska or foreign sources, or is delivered via pipeline from oil production fields within the state. The crude oil then undergoes many complex chemical and physical reactions, which include distillation, catalytic cracking, reforming, and finishing. These refining processes have the potential to emit air contaminants and are subject to extensive emission controls by district regulations.

As a result of these regulations covering the production, marketing, and use of gasoline and other oil by products, California has seen significant regional air quality benefits both in terms of cleaner fuels and cleaner operating facilities. In

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the 1990s California refineries underwent significant modifications and modernization to produce cleaner fuels in response to changes in state law Nevertheless, while residual emissions are small when compared to the total emissions controlled from these major sources, refineries are so large that even small amounts of fugitive, uncontrollable emissions and associated odors from the operations, can be significant This is particularly the case for communities that may be directly downwind of the refinery. Odors can cause health symptoms such as nausea and headache Also, because of the size, complexity and vast numbers of refinery processes onsite, the occasional refinery upset or malfunction can potentially result in acute or short term health effects to exposed individuals

Key Health Findings

Petroleum refineries are large single sources of emissions. For volatile organic compounds (VOCs), eight of the ten largest stationary sources in California are petroleum refineries. For oxides of nitrogen (NOx), four of the ten largest stationary sources in California are petroleum refineries Both of these compounds react in the presence of sunlight to form ozone. Ozone impacts lung function by irritating and damaging the respiratory system. Petroleum refineries are also large stationary sources of both particulate matter under 10 microns in size (PM_{10}) and particulate matter under 2.5 microns in size ($PM_{2.5}$). Exposure to particulate matter aggravates a number of respiratory illnesses including asthma and is associated with premature mortality in people with existing cardiac and respiratory disease Both long-term and short-term exposure can have adverse health impacts Finer particles pose an increased health risk because they can deposit deep in the lung and contain substances that are particularly harmful to human health NOx are also significant contributors to the secondary formation of $PM_{2.5}$.

Petroleum refineries also emit a variety of toxic air pollutants These air toxics vary by facility and process operation but may include: acetaldehyde, arsenic antimony benzene, beryllium, 1,3-butadiene, cadmium compounds, carbonyl sulfide, carbon disulfide, chlorine, dibenzofurans, diesel particulate matter formaldehyde, hexane hydrogen chloride, lead compounds, mercury compounds nickel compounds phenol, 2,3,7,8-tetrachlorodibenzo-p-dioxin, toluene and xylenes (mixed) among others. The potential health effects associated with these air toxics can include cancer respiratory irritation, and damage to the central nervous system, depending on exposure levels

Distance Related Findings

Health risk assessments for petroleum refineries have shown risks from toxic air pollutants that have quantifiable health risk values to be around 10 potential cancer cases per million Routine air monitoring and several air monitoring studies conducted in the San Francisco Bay Area (Crockett) and the South Coast Air Basin (Wilmington) have not identified significant health risks specifically

associated with refineries. However, these studies did not measure diesel PM as no accepted method currently exists, and there are many toxic air pollutants that do not have quantifiable health risk values.

In 2002, ARB published a report on the results of the state and local air district air monitoring done near oil refineries. The purpose of this evaluation was to try to determine how refinery-related emissions might impact nearby communities. This inventory of air monitoring activities included 10 ambient air monitoring stations located near refineries in Crockett and four stations near refineries in Wilmington. These monitoring results did not identify significant increased health risks associated with the petroleum refineries. In 2002-2003, ARB conducted additional monitoring studies in communities downwind of refineries in Crockett and Wilmington. These monitoring results also did not indicate significant increased health risks from the petroleum refineries.

Consequently, there are no air quality modeling or air monitoring data that provides a quantifiable basis for recommending a specific separation between refineries and new sensitive land uses. However, in view of the amount and potentially hazardous nature of many of the pollutants released as part of the refinery process, we believe the siting of new sensitive land uses immediately downwind should be avoided. Land use agencies should consult with the local air district when considering how to define an appropriate separation for refineries within their jurisdiction.

Recommendations

- Avoid siting new sensitive land uses immediately downwind of petroleum refineries. Consult with local air districts and other local agencies to determine an appropriate separation.

References

- *Review of Current Ambient Air Monitoring Activities Related to California Bay Area and South Coast Refineries. ARB (March 2002)* http://www.arb.ca.gov/aaqm/qmosqual/special/mldrefinery.pdf
- *Community Air Quality Monitoring: Special Studies – Crockett. ARB (September 2004)* http://www.arb.ca.gov/ch/communities/studies/crockett/crockett.htm
- *Wilmington Study - Air Monitoring Results. ARB (2003)* http://www.arb.ca.gov/ch/communities/studies/wilmington/wilmington.htm

Chrome Plating Operations

Chrome plating operations rely on the use of the toxic metal hexavalent chromium, and have been subject to ARB and local air district control programs for many years. Regulation of chrome plating operations has reduced statewide emissions substantially. However, due to the nature of chrome plating

operations and the highly toxic nature of hexavalent chromium, the remaining health risk to nearby residents is a continuing concern.

Chrome plating operations convert hexavalent chromium in solution to a chromium metal layer by electroplating, and are categorized based upon the thickness of the chromium metal layer applied. In "decorative plating", a layer of nickel is first plated over a metal substrate. Following this step, a thin layer of chromium is deposited over the nickel layer to provide a decorative and protective finish, for example, on faucets and automotive wheels. "Hard chrome plating" is a process in which a thicker layer of chromium metal is deposited directly on metal substrates such as engine parts, industrial machinery, and tools to provide greater protection against corrosion and wear.

Hexavalent chromium is emitted into the air when an electric current is applied to the plating bath. Emissions are dependent upon the amount of electroplating done per year and the control requirements. A unit of production referred to as an ampere-hour represents the amount of electroplating produced. Small facilities have an annual production rate of 100,000 – 500,000 ampere-hours, while medium-size facilities may have a production rate of 500,000 to about 3 million ampere-hours. The remaining larger facilities have a range of production rates that can be as high as 80 million ampere-hours.

The control requirements, which reduce emissions from the plating tanks, vary according to the size and type of the operation. Facilities either install add-on pollution control equipment, such as filters and scrubbers, or in-tank controls, such as fume suppressants and polyballs. With this combination of controls, the overall hexavalent chromium emissions have been reduced by over 90 percent. Larger facilities typically have better controls that can achieve efficiencies greater than 99 percent. However, even with stringent controls, the lack of maintenance and good housekeeping practices can lead to problems. And, since the material itself is inherently dangerous, any lapse in compliance poses a significant risk to nearby residents.

A 2002 ARB study in the San Diego community of Barrio Logan measured unexpectedly high concentrations of hexavalent chromium near chrome platers. The facilities were located in a mixed-use area with residences nearby. The study found that fugitive dust laden with hexavalent chromium was an important source of emissions that likely contributed to the elevated cancer risk. Largely as a result of this study, ARB is in the process of updating the current requirements to further reduce the emissions from these facilities.

In December 2004, the ARB adopted an ATCM to reduce emissions of hexavalent chromium and nickel from thermal spraying operations through the installation of best available control technology. The ATCM requires all existing facilities to comply with its requirements by January 1, 2006. New and modified thermal spraying operations must comply upon initial startup. An existing thermal spraying facility may be exempt from the minimum control efficiency

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requirements of the ATCM if it is located at least 1,640 feet from the nearest sensitive receptor and emits no more than 0.5 pound per year of hexavalent chromium.[8]

Key Health Findings

Hexavalent chromium is one of the most toxic air pollutants regulated by the State of California. Hexavalent chromium is a carcinogen and has been identified in worker health studies as causing lung cancer. Exposure to even very low levels of hexavalent chromium should be avoided.

The California Office of Environmental Health Hazard Assessment has found that: 1) many epidemiological studies show a strong association between hexavalent chromium exposure in the work place and respiratory cancer; and 2) all short-term assays reported show that hexavalent chromium compounds can cause damage to human DNA.

Hexavalent chromium when inhaled over a period of many years can cause a variety of non-cancer health effects. These health effects include damage to the nose, blood disorders, lung disease, and kidney damage. The non-cancer health impacts occur with exposures considerably higher than exposures causing significant cancer risks. It is less likely that the public would be exposed to hexavalent chromium at levels high enough to cause these non-cancer health effects. Non-cancer health effects, unlike cancer health effects, have a threshold or exposure level below which non-cancer health effects would not be expected.

Distance Related Findings

ARB's 2002 Barrio Logan Study measured concentrations of hexavalent chromium in the air near two chrome plating facilities. The study was conducted from December 2001 to May 2002. There were two chrome platers on the street - one decorative and one hard plater. The purpose of the study was to better understand the near source impact of hexavalent chromium emissions. Air monitors were placed at residences next to the platers and at varying distances down the street. The monitors were moved periodically to look at the spatial distribution of the impact. Source testing and facility inspections identified one of the facilities as the likely source.

The first two weeks of monitoring results showed unexpectedly high levels of hexavalent chromium at a number of the monitoring sites. The high concentrations were intermittent. The concentrations ranged from 1 to 22 ng/m3 compared to the statewide average of 0.1 ng/m3. If these levels were to continue for 70 years, the potential cancer risk would be 150 in one million. The highest value was found at an air monitor behind a house adjacent to one of the

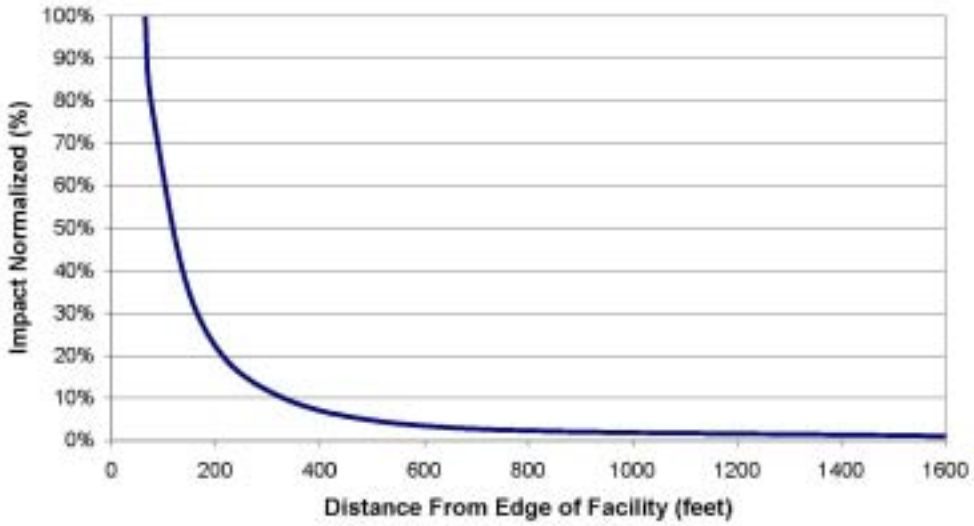
[8] For further information on the ATCM, please refer to: http://www.arb.ca.gov/regact/thermspr/thermalspr.htm

plating facilities–approximately 30 feet from the back entrance. Lower, but significant concentrations were found at an ambient air monitor 250 feet away.

The monitoring covered a period when the facility was not operating its plating tank. During this period, one of the highest concentrations was measured at an adjacent house. It appears that chromium-laden dust was responsible for high concentrations at this location since there was no plating activity at the time. Dust samples from the facility were tested and found to contain high levels of hexavalent chromium. On the day the highest concentration was measured at the house next door, a monitor 350 feet away from the plater's entrance showed very little impact. Similar proximity effects are shown in ARB modeling studies.

Figure 1-5 shows how the relative health risk varies as a function of distance from a chrome plater. This analysis is based on a medium-sized chrome plater with an annual production rate of 3 million ampere-hours. As shown in Figure 1- 5, the potential health risk drops off rapidly, with over 90 percent reduction in risk within 300 feet. This modeling was done in 2003 as part of a review of ARB's current air toxic control measure for chrome platers and is based on data from a recent ARB survey of chrome platers in California. The emission

Figure 1-5
Risk vs. Distance From Chrome Plater
(Based on plating tank emissions)



rates are only for plating operations. Because there are insufficient data available to directly quantify the impacts, the analysis does not include fugitive emissions, which the Barrio Logan analysis indicated could be significant.

Both the ARB Barrio Logan monitoring results and ARB's 2003 modeling analysis suggests that the localized emissions impact of a chrome plater diminishes significantly at 300 feet. However, in developing our recommendation, we also considered the following factors:

- some chrome platers will have higher volumes of plating activity
- potential dust impacts were not modeled
- we have only one monitoring study looking at the impact of distance and
- hexavalent chromium is one of the most potent toxic air contaminants ARB has identified

Given these limitations in the analysis, we recommend a separation of 1,000 feet as a precautionary measure. For large chrome platers, site specific information should be obtained from the local air district.

Recommendation

- Avoid siting new sensitive land uses within 1,000 feet of a chrome plater

References

- *Ambient Air Monitoring for Hexavalent Chromium and Metals in Barrio Logan May 2001 through May 2002*. ARB, Monitoring and Laboratory Division (October 14, 2003)
- *Draft Barrio Logan Report*. ARB, Planning and Technical Support Division (November 2004)
- *Proposed Amendments to the Hexavalent Chromium Control Measure for Decorative and Hard Chrome Plating and Chromic Acid Anodizing Facilities*. ARB (April 1998)
- Murchison, Linda, Suer, Carolyn, Cook, Jeff. "*Neighborhood Scale Monitoring in Barrio Logan*." (AWMA Annual Conference Proceedings, June 2003)

Dry Cleaners Using Perchloroethylene (Perc Dry Cleaners)

Perchloroethylene (perc) is the solvent most commonly used by the dry cleaning industry to clean clothes or other materials. The ARB and other public health agencies have identified perc as a potential cancer-causing compound. Perc persists in the atmosphere long enough to contribute to both regional air pollution and localized exposures. Perc dry cleaners are the major source of perc emissions in California.

Since 1990, the statewide concentrations and health risk from exposure to perc has dropped over 70 percent. This is due to a number of regulatory requirements on perc dry cleaners and other sources, including degreasing operations, brake cleaners, and adhesives. ARB adopted an Airborne Toxic Control Measure (ATCM) for Perc Emissions from Dry Cleaning Operations in 1993. ARB has also prohibited the use of perc in aerosol adhesives and automotive brake cleaners.

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Perc dry cleaners statewide are required to comply with ARB and local air district regulations to reduce emissions. However, even with these controls, some emissions continue to occur. Air quality studies indicate that there is still the potential for significant risks even near well-controlled dry cleaners. The South Coast AQMD has adopted a rule requiring that all new dry cleaners use alternatives to perc and that existing dry cleaners phase out the use of perc by December 2020. Over time, transition to non-toxic alternatives should occur. However, while perc continues to be used, a preventative approach should be taken to siting of new sensitive land uses.

Key Health Findings

Inhalation of perc may result in both cancer and non-cancer health effects. An assessment by California's Office of Environmental Health Hazard Assessment (OEHHA) concluded that perc is a potential human carcinogen and can cause non-cancer health effects. In addition to the potential cancer risk, the effects of long-term exposure include dizziness, impaired judgment and perception, and damage to the liver and kidneys. Workers have shown signs of liver toxicity following chronic exposure to perc, as well as kidney dysfunction and neurological effects. Non-cancer health effects occur with higher exposure levels than those associated with significant cancer risks. The public is more likely to be exposed to perchloroethylene at levels causing significant cancer risks than to levels causing non-cancer health effects. Non-cancer health effects, unlike cancer health effects, have a threshold or exposure level below which non-cancer health effects would not be expected. The ARB formally identified perc as a toxic air contaminant in October 1991.

One study has determined that inhalation of perc is the predominant route of exposure to infants living in apartments co-located in the same building with a business operating perc dry cleaning equipment. Results of air sampling within co-residential buildings indicate that dry cleaners can cause a wide range of exposures depending on the type and maintenance of the equipment. For example, a well-maintained state-of-the-art system may have risks in the range of 10 in one million, whereas a badly maintained machine with major leaks can have potential cancer risks of thousands in one million.

The California Air Pollution Control Officers Association (CAPCOA) is developing Industry-wide Risk Assessment Guidelines for Perchloroethylene Dry Cleaners which, when published, will provide detailed information on public health risk from exposure to emissions from this source.

Distance Related Findings

Risk created by perc dry cleaning is dependent on the amount of perc emissions, the type of dry cleaning equipment, proximity to the source, and how the emissions are released and dispersed (e.g., type of ventilation system, stack parameters, and local meteorology). Dry cleaners are often located near

residential areas and near shopping centers, schools, day-care centers, and restaurants.

The vast majority of dry cleaners in California have one dry cleaning machine per facility. The South Coast AQMD estimates that an average well-controlled dry cleaner uses about 30 to 160 gallons of cleaning solvent per year, with an average of about 100 gallons. Based on these estimates, the South Coast AQMD estimates a potential cancer risk between 25 to 140 in one million at residential locations 75 feet or less from the dry cleaner, with an average of about 80 in one million. The estimate could be as high as 270 in one million for older machines.

CAPCOA's draft industry-wide risk assessment of perc dry cleaning operations indicates that the potential cancer risk for many dry cleaners may be in excess of potential cancer risk levels adopted by the local air districts. The draft document also indicates that, in general, the public's exposure can be reduced by at least 75 percent by providing a separation distance of about 300 feet from the operation. This assessment is based on a single machine with perc use of about 100 gallons per year. At these distances, the potential cancer risk would be less than 10 potential cases per million for most scenarios.

The risk would be proportionately higher for large, industrial size, dry cleaners. These facilities typically have two or more machines and use 200 gallons or more per year of perc. Therefore, separation distances need to be greater for large dry cleaners. At a distance of 500 feet, the remaining risk for a large plant can be reduced by over 85 percent.

In California, a small number of dry cleaners that are co-located (sharing a common wall, floor, or ceiling) with a residence have the potential to expose the inhabitants of the residence to high levels of perc. However, while special requirements have been imposed on these existing facilities, the potential for exposure still exists. Avoiding these siting situations in the future is an important preventative measure.

Local air districts are a source of information regarding specific dry cleaning operations—particularly for large industrial operations with multiple machines. The 300 foot separation recommended below reflects the most common situation – a dry cleaner with only one machine. While we recommend 500 feet when there are two or more machines, site specific information should be obtained from the local air district for some very large industrial operations. Factors that can impact the risk include the number and type of machines, controls used, source configuration, building dimensions, terrain, and meteorological data.

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Recommendation

- Avoid siting new sensitive land uses within 300 feet of any dry cleaning operation. For operations with two or more machines provide 500 feet. For operations with 3 or more machines, consult with the local air district.

- Do not site new sensitive land uses in the same building with perc dry cleaning operations.

References

- *Proposed Amended Rule 1421 – Control of Perchloroethylene Emissions from Dry Cleaning Systems,* Final Staff Report. South Coast AQMD. (October 2002)
- *Air Toxic Control Measure for Emissions of Perchloroethylene from Dry Cleaning Operations.* ARB (1994) (http://www.arb.ca.gov/toxics/atcm/percatcm.htm)
- *"An Assessment of Tetrachloroethylene in Human Breast Milk"*, Judith Schreiber, New York State Department of Health – Bureau of Toxic Substance Assessment, Journal of Exposure Analysis and Environmental Epidemiology, Vol.2, Suppl.2, pp. 15-26, 1992.
- Draft *Air Toxics "Hot Spots" Program Perchloroethylene Dry Cleaner Industry-wide Risk Assessment Guidelines.* (CAPCOA (November 2002)
- *Final Environmental Assessment for Proposed Amended Rule 1421 – Control of Perchloroethylene Emissions from Dry Cleaning Systems.* South Coast AQMD. (October 18, 2002)

Gasoline Dispensing Facilities

Refueling at gasoline dispensing facilities releases benzene into the air. Benzene is a potent carcinogen and is one of the highest risk air pollutants regulated by ARB. Motor vehicles and motor vehicle-related activity account for over 90 percent of benzene emissions in California. While gasoline-dispensing facilities account for a small part of total benzene emissions, near source exposures for large facilities can be significant.

Since 1990, benzene in the air has been reduced by over 75 percent statewide, primarily due to the implementation of emissions controls on motor vehicle vapor recovery equipment at gas stations, and a reduction in benzene levels in gasoline. However, benzene levels are still significant. In urban areas, average benzene exposure is equivalent to about 50 in one million.

Gasoline dispensing facilities tend to be located in areas close to residential and shopping areas. Benzene emissions from the largest gas stations may result in near source health risk beyond the regional background and district health risk thresholds. The emergence of very high gasoline throughput at large retail or

wholesale outlets makes this a concern as these types of outlets are projected to account for an increasing market share in the next few years.

Key Health Findings

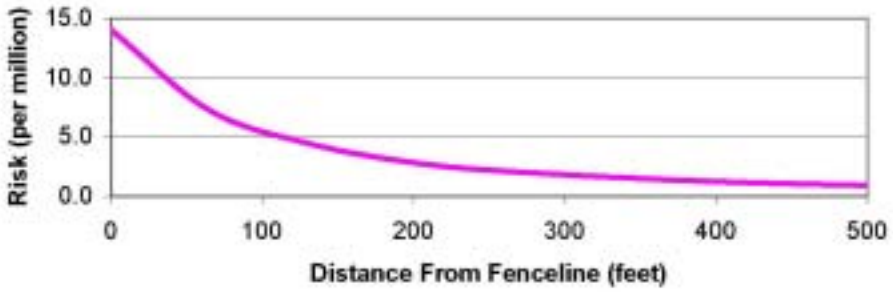
Benzene is a human carcinogen identified by ARB as a toxic air contaminant. Benzene also can cause non-cancer health effects above a certain level of exposure. Brief inhalation exposure to high concentrations can cause central nervous system depression. Acute effects include central nervous system symptoms of nausea, tremors, drowsiness, dizziness, headache, intoxication, and unconsciousness. It is unlikely that the public would be exposed to levels of benzene from gasoline dispensing facilities high enough to cause these non-cancer health effects.

Distance Related Findings

A well-maintained vapor recovery system can decrease emissions of benzene by more than 90% compared with an uncontrolled facility. Almost all facilities have emission control systems. Air quality modeling of the health risks from gasoline dispensing facilities indicate that the impact from the facilities decreases rapidly as the distance from the facility increases.

Statistics reported in the ARB's staff reports on Enhanced Vapor Recovery released in 2000 and 2002, indicated that almost 96 percent of the gasoline dispensing facilities had a throughput less than 2.4 million gallons per year. The remaining four percent, or approximately 450 facilities, had throughputs exceeding 2.4 million gallons per year. For these stations, the average gasoline throughput was 3.6 million gallons per year.

Figure 1-6
Gasoline Dispensing Facility Health Risk
for 3,600,000 gal/yr throughput



As shown in Figure 1-6, the risk levels for a gasoline dispensing facility with a throughput of 3.6 million gallons per year is about 10 in one million at a distance of 50 feet from the fenceline. However, as the throughput increases, the potential risk increases.

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As mentioned above, air pollution levels in the immediate vicinity of large gasoline dispensing facilities may be higher than the surrounding area (although tailpipe emissions from motor vehicles dominates the health impacts). Very large gasoline dispensing facilities located at large wholesale and discount centers may dispense nine million gallons of gasoline per year or more. At nine million gallons, the potential risk could be around 25 in one million at 50 feet, dropping to about five in one million at 300 feet. Some facilities have throughputs as high as 19 million gallons.

Recommendation

- Avoid siting new sensitive land uses within 300 feet of a large gasoline dispensing facility (defined as a facility with a throughput of 3.6 million gallons per year or greater). A 50 foot separation is recommended for typical gas dispensing facilities.

References

- *Gasoline Service Station Industry-wide Risk Assessment Guidelines*. California Air Pollution Control Officers Association. (December 1997 and revised November 1, 2001)
- *Staff Report on Enhanced Vapor Recovery*. ARB (February 4, 2000)
- *The California Almanac of Emissions and Air Quality*. ARB. (2004)
- *Staff Report on Enhanced Vapor Recovery Technology Review*. ARB (October 2002)

Other Facility Types that Emit Air Pollutants of Concern

In addition to source specific recommendations, Table 1-3 includes a list of other industrial sources that could pose a significant health risk to nearby sensitive individuals depending on a number of factors. These factors include the amount of pollutant emitted and its toxicity, the distance to nearby individuals, and the type of emission controls in place. Since these types of facilities are subject to air permits from local air districts, facility specific information should be obtained where there are questions about siting a sensitive land use close to an industrial facility.

Potential Sources of Odor and Dust Complaints

Odors and dust from commercial activities are the most common sources of air pollution complaints and concerns from the public. Land use planning and permitting processes should consider the potential impacts of odor and dust on surrounding land uses, and provide for adequate separation between odor and dust sources. As with other types of air pollution, a number of factors need to be considered when determining an adequate distance or mitigation to avoid odor or

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Table 1-3 – Examples of Other Facility Types That Emit[1] Air Pollutants of Concern

Categories	Facility Type	Air Pollutants of Concern
Commercial		
	Autobody Shops	Metals, Solvents
	Furniture Repair	Solvents[2], Methylene Chloride
	Film Processing Services	Solvents, Perchloroethylene
	Distribution Centers	Diesel Particulate Matter
	Printing Shops	Solvents
	Diesel Engines	Diesel Particulate Matter
Industrial		
	Construction	Particulate Matter, Asbestos
	Manufacturers	Solvents, Metals
	Metal Platers, Welders, Metal Spray (flame spray) Operations	Hexavalent Chromium, Nickel, Metals
	Chemical Producers	Solvents, Metals
	Furniture Manufacturers	Solvents
	Shipbuilding and Repair	Hexavalent chromium and other metals, Solvents
	Rock Quarries and Cement Manufacturers	Particulate Matter, Asbestos
	Hazardous Waste Incinerators	Dioxin, Solvents, Metals
	Power Plants	Benzene, Formaldehyde, Particulate Matter
	Research and Development Facilities	Solvents, Metals, etc.
Public		
	Landfills	Benzene, Vinyl Chloride, Diesel Particulate Matter
	Waste Water Treatment Plants	Hydrogen Sulfide
	Medical Waste Incinerators	Dioxin, Benzene, PAH, PCBs 1,3-Butadiene
	Recycling, Garbage Transfer Stations	Diesel Particulate Matter
	Municipal Incinerators	Dioxin, Benzene, PAH, PCBs 1,3-Butadiene
Transportation		
	Truck Stops	Diesel Particulate Matter
Agricultural Operations		
	Farming Operations	Diesel Particulate Matter, VOCs, NOx, PM10, CO, SOx, Pesticides
	Livestock and Dairy Operations	Ammonia, VOCs, PM10

[1] Note: for these air pollutants of concern due to process changes or chemical substitution. Consult the local air district regarding specific facilities.
[2] Some solvents may emit toxic air pollutants, but not all solvents are toxic air contaminants.

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dust complaints in a specific situation. Local air districts should be consulted for advice when these siting situations arise.

Table 1-4 lists some of the most common sources of odor complaints received by local air districts. Complaints about odors are the responsibility of local air districts and are covered under state law. The types of facilities that can cause odor complaints are varied and can range from small commercial facilities to large industrial facilities and may include waste disposal and recycling operations. Odors can cause health symptoms such as nausea and headache. Facilities with odors may also be sources of toxic air pollutants (See Table 1-3). Some common sources of odors emitted by facilities are sulfur compounds, organic solvents, and the decomposition/digestion of biological materials. Because of the subjective nature of an individual's sensitivity to a particular type of odor, there is no specific rule for assigning appropriate separations from odor sources. Under the right meteorological conditions, some odors may still be offensive several miles from the source.

Table 1-4
Sources of Odor Complaints

- Sewage Treatment Plants
- Landfills
- Recycling Facilities
- Waste Transfer Stations
- Petroleum Refineries
- Biomass Operations
- Autobody Shops
- Coating Operations
- Fiberglass Manufacturing
- Foundries
- Rendering Plants
- Livestock Operations

Sources of dust are also common sources of air pollution-related complaints. Operations that can result in dust problems are rock crushing, gravel production, stone quarrying, and mining operations. A common source of complaints is the dust and noise associated with blasting that may be part of these operations. Besides the health impacts of dust as particulate matter, thick dust also impairs visibility, aesthetic values, and can soil homes and automobiles. Local air districts typically have rules for regulating dust sources in their jurisdictions, but dust sources can still be a concern. Therefore, separation of these facilities from residential and other new sensitive land uses should be considered.

In some areas of California, asbestos occurs naturally in stone deposits. Asbestos is a potent carcinogenic substance when inhaled. Asbestos-containing dust may be a public health concern in areas where asbestos-containing rock is mined, crushed, processed, or used. Situations where asbestos-containing gravel has been used in road paving materials are also a source of asbestos exposure to the general public. Planners are advised to consult with local air pollution agencies in areas where asbestos-containing gravel or stone products are produced or used.

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2. Handbook Development

ARB and local air districts share responsibility for improving statewide air quality. As a result of California's air pollution control programs, air quality has improved and health risk has been reduced statewide. However, state and federal air quality standards are still exceeded in many areas of California and the statewide health risk posed by toxic air contaminants (air toxics) remains too high. Also, some communities experience higher pollution exposures than others - making localized impacts, as well regional or statewide impacts, an important consideration. It is for this reason that this Handbook has been produced – to promote better, more informed decision-making by local land use agencies that will improve air quality and public health in their communities.

Land use policies and practices, including planning, zoning, and siting activities, can play a critical role in air quality and public health at the local level. For instance, even with the best available control technology, some projects that are sited very close to homes, schools, and other public places can result in elevated air pollution exposures. The reverse is also true – siting a new school or home too close to an existing source of air pollution can pose a public health risk. The ARB recommendations in section 7 address this issue.

This Handbook is an informational document that we hope will strengthen the relationship between air quality and land use agencies. It highlights the need for land use agencies to address the potential for new projects to result in localized health risk or contribute to cumulative impacts where air pollution sources are concentrated.

Avoiding these incompatible land uses is a key to reducing localized air pollution exposures that can result in adverse health impacts, especially to sensitive individuals.

Individual siting decisions that result in incompatible land uses are often the result of locating "sensitive" land uses next to polluting sources. These decisions can be of even greater concern when existing air pollution exposures in a community are considered. In general terms, this is often referred to as the issue of "cumulative impacts." ARB is working with local air districts to better define these situations and to make information about existing air pollution levels (e.g. from local businesses, motor vehicles, and other areawide sources) more readily available to land use agencies.

In December 2001, the ARB adopted "Policies and Actions for Environmental Justice" (Policies). These Policies were developed in coordination with a group of stakeholders representing local government agencies, community interest

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groups, environmental justice organizations, academia, and business (Environmental Justice Stakeholders Group).

The Policies included a commitment to work with land use planners, transportation agencies, and local air districts to develop ways to identify, consider, and reduce cumulative air pollution emissions, exposure, and health risks associated with land use planning and decision-making. Developed under the auspices of the ARB's Environmental Justice Stakeholders Group, this Handbook is a first step in meeting that commitment.

ARB has produced this Handbook to help achieve several objectives:

- Provide recommendations on situations to avoid when siting new residences, schools, day care centers, playgrounds, and medical-related facilities (sensitive sites or sensitive land uses);

- Identify approaches that land use agencies can use to prevent or reduce potential air pollution impacts associated with general plan policies, new land use development, siting, and permitting decisions;

- Improve and facilitate access to air quality data and evaluation tools for use in the land use decision-making process;

- Encourage stronger collaboration between land use agencies and local air districts to reduce community exposure to source-specific and cumulative air pollution impacts; and

- Emphasize community outreach approaches that promote active public involvement in the air quality/land use decision-making process.

This Handbook builds upon California's 2003 General Plan Guidelines. These Guidelines, developed by the Governor's Office of Planning and Research (OPR), explain the land use planning process and applicable legal requirements. This Handbook also builds upon a 1997 ARB report, "The Land Use-Air Quality Linkage" ("Linkage Report").[9] The Linkage Report was an outgrowth of the California Clean Air Act which, among other things, called upon local air districts to focus particular attention on reducing emissions from sources that indirectly cause air pollution by attracting vehicle trips. Such indirect sources include, but are not limited to, shopping centers, schools and universities, employment centers, warehousing, airport hubs, medical offices, and sports arenas. The Linkage Report summarizes data as of 1997 on the relationships between land use, transportation, and air quality, and highlights strategies that can help to reduce the use of single occupancy automobile use. Such strategies

[9] To access this report, please refer to ARB's website or click on: http://www.arb.ca.gov/ch/programs/link97.pdf

complement ARB regulatory programs that continue to reduce motor vehicle emissions.

In this Handbook, we identify types of air quality-related information that we recommend land use agencies consider in the land use decision-making processes such as the development of regional, general, and community plans, zoning ordinances, environmental reviews, project siting, and permit issuance. The Handbook provides recommendations on the siting of new sensitive land uses based on current analyses. It also contains information on approaches and methodologies for evaluating new projects from an air pollution perspective.

The Handbook looks at air quality issues associated with emissions from industrial, commercial, and mobile sources of air pollution. Mobile sources continue to be the largest overall contributors to the state's air pollution problems, representing the greatest air pollution health risk to most Californians. Based on current health risk information for air toxics, the most serious pollutants on a statewide basis are diesel PM, benzene, and 1,3-butadiene, all of which are primarily emitted by motor vehicles. From a state perspective, ARB continues to pursue new strategies to further reduce motor vehicle-related emissions in order to meet air quality standards and reduce air toxics risk.

While mobile sources are the largest overall contributors to the state's air pollution problems, industrial and commercial sources can also pose a health risk, particularly to people near the source. For this reason, the issue of incompatible land uses is an important focus of this document.

Handbook Audience

Even though the primary users of the Handbook will likely be agencies responsible for air quality and land use planning, we hope the ideas and technical issues presented in this Handbook will also be useful for:

- public and community organizations and community residents,
- federal, state and regional agencies that fund, review, regulate, oversee, or otherwise influence environmental policies and programs affected by land use policies, and
- private developers.

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3. Key Community Focused Issues Land Use Agencies Should Consider

Two key air quality issues that land use agencies should consider in their planning, zoning, and permitting processes are:

1) **Incompatible Land Uses.** Localized air pollution impacts from incompatible land use can occur when polluting sources, such as a heavily trafficked roadway, warehousing facilities, or industrial or commercial facilities, are located near a land use where sensitive individuals are found such as a school, hospital, or homes.

2) **Cumulative Impacts.** Cumulative air pollution impacts can occur from a concentration of multiple sources that individually comply with air pollution control requirements or fall below risk thresholds, but in the aggregate may pose a public health risk to exposed individuals. These sources can be heavy or light-industrial operations, commercial facilities such as autobody shops, large gas dispensing facilities, dry cleaners, and chrome platers, and freeways or other nearby busy transportation corridors.

Incompatible Land Uses

Land use policies and practices can worsen air pollution exposure and adversely affect public health by mixing incompatible land uses. Examples include locating new sensitive land uses, such as housing or schools, next to small metal plating facilities that use a highly toxic form of chromium, or very near large industrial facilities or freeways. Based on recent monitoring and health-based studies, we now know that air quality impacts from incompatible land uses can contribute to increased risk of illness, missed work and school, a lower quality of life, and higher costs for public health and pollution control.[10]

Avoiding incompatible land uses can be a challenge in the context of mixed-use industrial and residential zoning. For a variety of reasons, government agencies and housing advocates have encouraged the proximity of affordable housing to employment centers, shopping areas, and transportation corridors, partially as a means to reduce vehicle trips and their associated emissions. Generally speaking, typical distances in mixed-use communities between businesses and industries and other land uses such as homes and schools, should be adequate to avoid health risks. However, generalizations do not always hold as we addressed in section 1 of this Handbook.

In terms of siting air pollution sources, the proposed location of a project is a major factor in determining whether it will result in localized air quality impacts. Often, the problem can be avoided by providing an adequate distance or setback

[10] For more information, the reader should refer to ARB's website on community health: http://www.arb.ca.gov/ch/ch.htm

between a source of emissions and nearby sensitive land uses. Sometimes, suggesting project design changes or mitigation measures in the project review phase can also reduce or avoid potential impacts. This underscores the importance of addressing potential incompatible land uses as early as possible in the project review process, ideally in the general plan itself.

Cumulative Air Pollution Impacts

The broad concept of cumulative air pollution impacts reflects the combination of regional air pollution levels and any localized impacts. Many factors contribute to air pollution levels experienced in any location. These include urban background air pollution, historic land use patterns, the prevalence of freeways and other transportation corridors, the concentration of industrial and commercial businesses, and local meteorology and terrain.

When considering the potential air quality impacts of polluting sources on individuals, project location and the concentration of emissions from air pollution sources need to be considered in the land use decision-making process. In section 4, the Handbook offers a series of questions that helps land use agencies determine if a project should undergo a more careful analysis. This holds true regardless of whether the project being sited is a polluting source or a sensitive land use project.

Large industrial areas are not the only land uses that may result in public health concerns in mixed-use communities. Cumulative air pollution impacts can also occur if land uses do not adequately provide setbacks or otherwise protect sensitive individuals from potential air pollution impacts associated with nearby light industrial sources. This can occur with activities such as truck idling and traffic congestion, or from indirect sources such as warehousing facilities that are located in a community or neighborhood.

In October 2004, Cal/EPA published its Environmental Justice Action Plan. In February 2005, the Cal/EPA Interagency Working Group approved a working definition of "cumulative impacts" for purposes of initially guiding the pilot projects that are being conducted pursuant to that plan. Cal/EPA is now in the process of developing a Cumulative Impacts Assessment Guidance document. Cal/EPA will revisit the working definition of "cumulative impacts" as the Agency develops that guidance. The following is the working definition:

> *"Cumulative impacts means exposures, public health or environmental effects from the combined emissions and discharges, in a geographic area, including environmental pollution from all sources, whether single or multi-media, routinely, accidentally, or otherwise released. Impacts will take into account sensitive populations and socio-economic factors, where applicable, and to the extent data are available."*

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4. Mechanisms for Integrating Localized Air Quality Concerns Into Land Use Processes

Land use agencies should use each of their existing planning, zoning, and permitting authorities to address the potential health risk associated with new projects. Land use-specific mechanisms can go a long way toward addressing both localized and cumulative impacts from new air pollution sources that are not otherwise addressed by environmental regulations. Likewise, close collaboration and communication between land use agencies and local air districts in both the planning and project approval stages can further reduce these impacts. Local agency partnerships can also result in early identification of potential impacts from proposed activities that might otherwise escape environmental review. When this happens, pollution problems can be prevented or reduced before projects are approved, when it is less complex and expensive to mitigate.

The land use entitlement process requires a series of planning decisions. At the highest level, the General Plan sets the policies and direction for the jurisdiction, and includes a number of mandatory elements dealing with issues such as housing, circulation, and health hazards. Zoning is the primary tool for implementing land use policies. Specific or community plans created in conjunction with a specific project also perform many of the same functions as a zoning ordinance. Zoning can be modified by means of variances and conditional use permits. The latter are frequently used to insure compatibility between otherwise conflicting land uses. Finally, new development usually requires the approval of a parcel or tract map before grading and building permits can be issued. These parcel or tract maps must be consistent with the applicable General Plan, zoning and other standards.

Land use agencies can use their planning authority to separate industrial and residential land uses, or to require mitigation where separation is not feasible. By separating incompatible land uses, land use agencies can prevent or reduce both localized and cumulative air pollution impacts without denying what might otherwise be a desirable project.[1] For instance:

- a dry cleaner could open a storefront operation in a community with actual cleaning operations performed at a remote location away from residential areas;
- gas dispensing facilities with lower fuel throughput could be sited in mixed-use areas;
- enhanced building ventilation or filtering systems in schools or senior care centers can reduce ambient air from nearby busy arterials; or
- landscaping and regular watering can be used to reduce fugitive dust at a building construction site near a school yard.

[1] It should be noted that such actions should also be considered as part of the General Plan or Plan element process.

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The following general and specific land use approaches can help to reduce potential adverse air pollution impacts that projects may have on public health.

General Plans

The primary purpose of planning, and the source of government authority to engage in planning, is to protect public health, safety, and welfare. In its most basic sense, a local government General Plan expresses the community's development goals and embodies public policy relative to the distribution of future land uses, forming the basis for most land use decisions. Therefore, the most effective mechanism for dealing with the central land use concept of compatibility and its relationship to cumulative air pollution impacts is the General Plan. Well before projects are proposed within a jurisdiction, the General Plan sets the stage for where projects can be sited, and their compatibility with comprehensive community goals, objectives, and policies.

In 2003, OPR revised its General Plan Guidelines, highlighting the importance of incorporating sustainable development and environmental justice policies in the planning process. The OPR General Plan Guidelines provides an effective and long-term approach to reduce cumulative air pollution impacts at the earliest planning stages. In light of these important additions to the Guidelines, land use agencies should consider updating their General Plans or Plan elements to address these revisions.

The General Plan and related Plan elements can be used to avoid incompatible land uses by incorporating air quality considerations into these documents. For instance, a General Plan safety element with an air quality component could be used to incorporate policies or objectives that are intended to protect the public from the potential for facility breakdowns that may result in a dangerous release of air toxics. Likewise, an air quality component to the transportation circulation element of the General Plan could include policies or standards to prevent or reduce local exposure to diesel exhaust from trucks and other vehicles. For instance, the transportation circulation element could encourage the construction of alternative routes away from residential areas for heavy-duty diesel trucks. By considering the relationship between air quality and transportation, the circulation element could also include air quality policies to prevent or reduce trips and travel, and thus vehicle emissions. Policies in the land use element of the General Plan could identify areas appropriate for future industrial, commercial, and residential uses. Such policies could also introduce design and distance parameters that reduce emissions, exposure, and risk from industrial and some commercial land uses (e.g., dry cleaners) that are in close proximity to residential areas or schools.

Land use agencies should also consider updating or creating an air quality element in the jurisdiction's General Plan. In the air quality element, local decision-makers could develop long-term, effective plans and policies to address

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air quality issues including cumulative impacts. The air quality element can also provide a general reference guide that informs local land use planners about regional and community level air quality, regulatory air pollution control requirements and guidelines, and references emissions and pollution source data bases and assessment and modeling tools. As is further described in Appendix C of the Handbook, new assessment tools that ARB is developing can be included into the air quality element by reference. For instance, ARB's statewide risk maps could be referenced in the air quality element as a resource that could be consulted by developers or land use agencies.

Zoning

The purpose of "zoning" is to separate different land uses. Zoning ordinances establish development controls to ensure that private development takes place within a given area in a manner in which:

- All uses are compatible (e.g., an industrial plant is not permitted in a residential area)
- Common development standards are used (e.g., all homes in a given area are set back the same minimum distance from the street); and
- Each development does not unreasonably impose a burden upon its neighbors (e.g., parking is required on site so as not to create neighborhood parking problems).

To do this, use districts called "zones" are established and standards are developed for these zones. The four basic zones are residential, commercial, industrial and institutional.

Land use agencies may wish to consider how zoning ordinances, particularly those for mixed-use areas, can be used to avoid exacerbating poor land use practices of the past or contributing to localized and cumulative air pollution impacts in the community.

Sometimes, especially in mixed use zones, there is a potential for certain categories of existing businesses or industrial operations to result in cumulative air pollution impacts to new development projects. For example:

- An assisted living project is proposed for a mixed-use zone adjacent to an existing chrome plating facility, or several dry cleaners.
- Multiple industrial sources regulated by a local air district are located directly upwind of a new apartment complex.
- A new housing development is sited in a mixed-use zone that is downwind or adjacent to a distribution center that attracts diesel-fueled delivery trucks and TRUs; or
- A new housing development or sensitive land use is sited without adequate setbacks from an existing major transportation corridor or rail yard.

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As part of the public process for making zoning changes, local land use agencies could work with community planning groups, local businesses, and community residents to determine how best to address existing incompatible land uses.

Land Use Permitting Processes

- **Questions to Consider When Reviewing New Projects**

Very often, just knowing what questions to ask can yield critical information about the potential air pollution impacts of proposed projects – both from the perspective of a specific project as well as in the nature of existing air pollution sources in the same impact area. Available land use information can reveal the proximity of air pollution sources to sensitive individuals, the potential for incompatible land uses, and the location and nature of nearby air pollution sources. Air quality data, available from the ARB and local air districts, can provide information about the types and amounts of air pollution emitted in an area, regional air quality concentrations, and health risk estimates for specific sources.

General Plans and zoning maps are an excellent starting point in reviewing project proposals for their potential air pollution impacts. These documents contain information about existing or proposed land uses for a specific location as well as the surrounding area. Often, just looking at a map of the proposed location for a facility and its surrounding area will help to identify a potential adjacent incompatible land use.

The following pages are a "pull-out" list of questions to consider along with cross-references to pertinent information in the Handbook. These questions are intended to assist land use agencies in evaluating potential air quality-related concerns associated with new project proposals.

The first group of questions contains project-related queries designed to help identify the potential for localized project impacts, particularly associated with incompatible land uses. The second group of questions focuses on the issue of potential cumulative impacts by including questions about existing emissions and air quality in the community, and community feedback. Depending on the answers to these questions, a land use agency may decide a more detailed review of the proposal is warranted.

The California Department of Education has already developed a detailed process for school siting which is outlined in Appendix E. However, school districts may also find this section helpful when evaluating the most appropriate site for new schools in their area. At a minimum, using these questions may encourage school districts to engage throughout their siting process with land use agencies and local air districts. The combined expertise of these entities can be useful in devising relevant design standards and mitigation measures that can

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reduce exposure to cumulative em ssions, exposure, and health risk to students and school workers

As indicated throughout the Handbook, we strongly encourage land use agencies to consult early and often with local air districts. Local air districts have the expertise many of the analytical tools, and a working know edge of the sources they regulate. It is also critical to fully involve the public and businesses that could be affected by the siting decision The questions provided in the chart below do not imply any particular action should be taken by land use agencies. Rather the questions are intended to improve the assessmen: process and facilitate informed decision-making

- **Project-Related Questions**

This section includes project-related questions that, in conjunction with the questions in the next section, can be used to tailor the project evaluation. These questions are designed to help identify the potential for incompatible land uses from localized project impacts.

Questions to Consider When Reviewing New Projects

Project-Related Questions	Cross-Reference to Relevant Handbook Sections
1. Is the proposed project: ▲ A business or commercial license renewal ▲ A new or modified commercial project ▲ A new or modified industrial project ▲ A new or modified public facility project ▲ A new or modified transportation project ▲ A housing or other development in which sensitive individuals may live or play	See Appendix A for typical land use classifications and associated project categories that could emit air pollutants
2. Does the proposed project: ▲ Conform to the zoning designation? ▲ Require a variance to the zoning designation? ▲ Include plans to expand operations over the life of the business such that additional emissions may increase the pollution burden in the community (e.g., from additional truck operations, new industrial operations or process lines, increased hours of operation, build-out to the property line, etc.)?	See Appendix F for a general explanation of land use processes. In addition, Section 3 contains a discussion of how land use planning, zoning, and permitting practices can result in incompatible land uses or cumulative air pollution impacts.
3. Has the local air district provided comments or information to assist in the analysis?	See Section 5 and Appendix C for a description of air quality-related tools that the ARB and local air districts use to provide information on potential air pollution impacts.
4. Have public meetings been scheduled with the affected community to solicit their involvement in the decision-making process for the proposed project?	See Section 7 for a discussion of public participation, information and outreach tools.
5. If the proposed project will be subject to local air district regulations: ▲ Has the project received a permit from the local air district? ▲ Would it comply with applicable local air district requirements? ▲ Is the local air district contemplating new regulations that would reduce emissions from the source over time? ▲ Will potential emissions from the project	See Appendix C for a description of local air district programs

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Project-Related Questions	Cross-Reference to Relevant Handbook Sections
trigger the local air district's new source review for criteria pollutants or air toxics emissions? ▲ Is the local air district expected to ask the proposed project to perform a risk assessment? ▲ Is there sufficient new information or public concern to call for a more thorough environmental analysis of the proposed project? ▲ Are there plans to expand operations over time? ▲ Are there land-use based air quality significance thresholds or design standards that could be applied to this project in addition to applicable air district requirements?	
6. If the proposed project will release air pollution emissions, either directly or indirectly, but is not regulated by the local air district ▲ Is the local air district informed of the project? ▲ Does the local air district believe that there could be potential air pollution impacts associated with this project category because of the proximity of the project to sensitive individuals? ▲ If the project is one in which individuals live or play (e.g., a home, playground convalescent home, etc.) does the local air district believe that the project's proximity to nearby sources could pose potential air pollution impacts? ▲ Are there indirect emissions that could be associated with the project (e.g., truck traffic or idling, transport refrigeration unit operations, stationary diesel engine operations, etc.) that will be in close proximity to sensitive individuals? ▲ Will the proposed project increase or serve as a magnet for diesel traffic? ▲ Are there land-use based air quality significance thresholds or design standards that could be applied to this project in addition to applicable air district requirements? ▲ Is there sufficient new information or public concern to call for a more thorough environmental analysis of the proposed project? ▲ Should the site approval process include identification and mitigation of potential	See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites)

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Project-Related Questions	Cross-Reference to Relevant Handbook Sections
direct or indirect emissions associated with the potential project?	
7. Does the local air district or land use agency have pertinent information on the source, such as: ▲ Available permit and enforcement data including for the owner or operator of the proposed source that may have other sources in the State. ▲ Proximity of the proposed project to sensitive individuals. ▲ Number of potentially exposed individuals from the proposed project. ▲ Potential for the proposed project to expose sensitive individuals to odor or other air pollution nuisances. ▲ Meteorology or the prevailing wind patterns between the proposed project and the nearest receptor, or between the proposed sensitive receptor project and sources that could pose a localized or cumulative air pollution impact	See Appendix C for a description of local air district programs See Appendix B for a listing of useful information that land use agencies should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts Also, do not hesitate to contact your local air district regarding answers to any of these questions that might not be available at the land use agency. See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites)
8. Based upon the project application, its location, and the nature of the source, could the proposed project: ▲ Be a polluting source that is located in proximity to, or otherwise upwind of, a location where sensitive individuals live or play? ▲ Attract sensitive individuals and be located in proximity to or otherwise downwind of a source or multiple sources of pollution including polluting facilities or transportation-related sources that contribute emissions either directly or indirectly? ▲ Result in health risk to the surrounding community?	See Section 3 for a discussion of what is an incompatible land use and the potential cumulative air pollution impacts See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites)
9. If a CEQA categorical exemption is proposed, were the following questions considered: ▲ Is the project site environmentally sensitive as defined by the project's location? (A project that is ordinarily insignificant in its impact on the environment may in a particularly sensitive environment be significant.) ▲ Would the project and successive future projects of the same type in the approximate location potentially result in cumulative impacts? ▲ Are there "unusual circumstances" creating the possibility of significant effects?	See CEQA Guidelines section 15300.2 and Public Resources Code section 21084 See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites) See also Section 5 and Appendix C for a description of air quality-related tools that the ARB and local air districts use to provide information on potential air pollution impacts.

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- **Questions Related to Cumulative Impact Assessment**

The following questions can be used to provide the decision-maker with a better understanding of the potential for cumulative air pollution impacts to an affected community. Answers to these questions will help to determine if new projects or activities warrant a more detailed review. It may also help to see potential environmental concerns from the perspective of the affected community. Additionally, responses can provide local decision-makers with information with which to assess the best policy options for addressing neighborhood-scale air pollution concerns.

The questions below can be used to identify whether existing tools and procedures are adequate to address land use-related air pollution issues. This process can also be used to pinpoint project characteristics that may have the greatest impact on community-level emissions, exposure, and risk. Such elements can include: the compliance record of existing sources including those owned or operated by the project proponent; the concentration of emissions from polluting sources within the approximate area of sensitive sites; transportation circulation in proximity to the proposed project; compatibility with the General Plan and General Plan elements; etc.

The local air district can provide useful assistance in the collection and evaluation of air quality-related information for some of the questions and should be consulted early in the process.

Questions Related to Cumulative Impact Assessment

	Technical Questions	Cross-Reference to Relevant Handbook Sections
1	Is the community home to industrial facilities?	See Appendix A for typical land use classifications and associated project categories that could emit air pollutants.
2	Do one or more major freeways or high-traffic volume surface streets cut through the community?	See transportation circulation element of your general plan. See also Appendix B for useful information that land use agencies should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts. See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites).
3	Is the area classified for mixed-use zoning?	See your general plan and zoning ordinances.
4	Is there an available list of air pollution sources in the community?	Contact your local air district.
5	Has a walk-through of the community been conducted to gather the following information:	See Appendix B for a listing of useful information that land use agencies

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Technical Questions	Cross-Reference to Relevant Handbook Sections
▲ Corroborate available information on land use activities in the area (e.g., businesses, housing developments, sensitive individuals, etc.)? ▲ Determine the proximity of existing and anticipated future projects to residential areas or sensitive individuals? ▲ Determine the concentration of emission sources (including anticipated future projects) to residential areas or sensitive individuals?	should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts. Also contact your local air district.
6. Has the local air district been contacted to obtain information on sources in the community?	See Section 7 for a discussion of public participation, information and outreach tools.
7. What categories of commercial establishments are currently located in the area and does the local air district have these sources on file as being regulated or permitted?	See Appendix A for typical land use classifications and associated project categories that could emit air pollutants. Also contact your local air district.
8. What categories of indirect sources such as distribution centers or warehouses are currently located in the area?	See Appendix A for typical land use classifications and associated project categories that emit air pollutants.
9. What air quality monitoring data are available?	Contact your local air district.
10. Have any risk assessments been performed on emission sources in the area?	Contact your local air district.
11. Does the land use agency have the capability of applying a G.I.S. spatial mapping tool that can overlay zoning, sub-development information, and other neighborhood characteristics, with air pollution and transportation data?	See Appendix B for a listing of useful information that land use agencies should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts. Also contact your local air district for tools that can be used to supplement available land use agency tools.
12. Based on available information, is it possible to determine if the affected community or neighborhood experiences elevated health risk due to a concentration of air pollution sources in close proximity, and if not, can the necessary information be obtained?	Contact your local air district. Also see Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites).
13. Does the community have a history of chronic complaints about air quality?	See Section 7 for a discussion of public participation, information and outreach tools. Also contact your local air district.
14. Is the affected community included in the public participation process for the agency's decision?	See Section 7 for a discussion of public participation, information and outreach tools.
15. Have community leaders or groups been contacted about any pre-existing or chronic community air quality concerns?	See Section 7 for a discussion of public participation, information and outreach tools. Also contact your local air district.

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- **Mitigation Approaches**

In addition to considering the suitability of the project location, opportunities for mitigation of air pollution impacts should be considered. Sometimes a land use agency may find that selection of a different project location to avoid a health risk is not feasible. When that happens, land use agencies should consider design improvements or other strategies that would reduce the risk. Such strategies could include performance or design standards, consultation with local air districts and other agencies on appropriate actions that these agencies should, or plan to, undertake, and consultation and outreach in the affected community. Potential mitigation measures should be feasible, cost-effective solutions within the available resources and authority of implementing agencies to enforce.[17]

- **Conditional Use Permits and Performance Standards**

Some types of land uses are only allowed upon approval of a conditional use permit (also called a CUP or special use permit). A conditional use permit does not re-zone the land but specifies conditions under which a particular land use will be permitted. Such land uses could be those with potentially significant environmental impacts. Local zoning ordinances specify the uses for which a conditional use permit is required, the zones they may be allowed in, and public hearing procedures. The conditional use permit imposes special requirements to ensure that the use will not be detrimental to its surroundings.

In the context of land use planning, performance standards are requirements imposed on projects or project categories through conditional use permits to ensure compliance with general plan policies and local ordinances. These standards could apply to such project categories as distribution centers, very large gas dispensing facilities, autobody shops, dry cleaners, and metal platers. Land use agencies may wish to consider adding land use-based performance standards to zoning ordinances in existing mixed-use communities for certain air pollution project categories. Such standards would provide certainty and equitable treatment to all projects of a similar nature, and reserve the more resource intensive conditional or special use permits to projects that require a more detailed analysis. In developing project design or performance standards, land use agencies should consult with the local air district. Early and regular consultation can avoid duplication or inconsistency with local air district control requirements when considering the site-specific design and operation of a project.

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[17] A land use agency has the authority to condition or deny a project based upon information collected and evaluated through the land use decision-making process. However, any denial would need to be based upon identifiable, generally applicable, articulated standards set forth in the local government's General Plan and zoning codes. One way of averting this is to conduct early and regular outreach to the community and the local air district so that community and environmental concerns can be addressed and accommodated into the project proposal.

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Examples of land use-based air quality-specific performance standards include the following:

- Placing a process vent away from the direction of the local playground that is nearby or increasing the stack height so that emissions are dispersed to reduce the emissions impact on surrounding homes or schools.
- Setbacks between the project fence line and the population center.
- Limiting the hours of operation of a facility to avoid excess emissions exposure or foul odors to nearby individuals.
- An ordinance that requires fleet operators to use cleaner vehicles before project approval (if a new business), or when expanding the fleet (if an existing business); and
- Providing alternate routes for truck operations that discourage detours into residential neighborhoods.

Outreach to Other Agencies

When questions arise regarding the air quality impacts of projects, including potential cumulative impacts, land use agencies should consult the local air district. Land use agencies should also consider the following suggestions to avoid creating new incompatible land uses:

- Consult with the local air district to help determine if emissions from a particular project will adversely impact sensitive individuals in the area, if existing or future effective regulations or permit requirements will affect the proposed project or other sources in the vicinity of the proposed project, or if additional inspections should be required.
- Check with ARB for new information and modeling tools that can help evaluate projects seeking to site within your jurisdiction.
- Become familiar with ARB's Land Use-Air Quality Linkage Report to determine whether approaches and evaluation tools contained in the Report can be used to reduce transportation-related impacts on communities.
- Contact and collaborate with other state agencies that play a role in the land use decision-making process, e.g., the State Department of Education, the California Energy Commission, and Caltrans. These agencies have information on mitigation measures and mapping tools that could be useful in addressing local problems.

- **Information Clearinghouse**

  - Land use agencies can refer to the ARB statewide electronic information clearinghouse for information on what measures other jurisdictions are using to address comparable issues or sources.[13]

[13] This information can be accessed from ARB's website by going to: http://www.arb.ca.gov/ch/clearinghouse.htm

The next section addresses available air quality assessment tools that land use agencies can use to evaluate the potential for localized or cumulative impacts in their communities

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5. Available Tools to Evaluate Cumulative Air Pollution Emissions and Risk

Until recently, California has traditionally approached air pollution control from the perspective of assessing whether the pollution was regional, category-specific, or from new or existing sources. This methodology has been generally effective in reducing statewide and regional air pollution impacts and risk levels. However, such an incremental, category-by-category, source-by-source approach may not always address community health impacts from multiple sources - including mobile, industrial, and commercial facilities.

As a result of air toxics and children's health concerns over the past several years, ARB and local air districts have begun to develop new tools to evaluate and inform the public about cumulative air pollution impacts at the community level. One aspect of ARB's programs now underway is to consolidate and make accessible air toxics emissions and monitoring data by region, using modeling tools and other analytical techniques to take a preliminary look at emissions, exposure, and health risk in communities.

ARB has developed multiple tools to assist local air districts perform assessments of cumulative emissions, exposure, and risk on a neighborhood scale. These tools include:

- Regional risk maps that show trends in potential cancer risk from toxic air pollutants in southern and central California between 1990 and 2010. These maps are based on the U.S. EPA's ASPEN model. These maps provide an estimate of background levels of toxic air pollutant risk but are not detailed enough to assess individual neighborhoods or facilities.[14]

- The Community Health Air Pollution Information System (CHAPIS) is a user-friendly, Internet-based system for displaying information on emissions from sources of air pollution in an easy to use mapping format. CHAPIS contains information on air pollution emissions from selected large facilities and small businesses that emit criteria and toxic air pollutants. It also contains information on air pollution emissions from motor vehicles. When released in 2004, CHAPIS did not contain information on every source of air pollution or every air pollutant. However, ARB continues to work with local air districts to include all of the largest air pollution sources and those with the highest documented air pollution risk. Additional facilities will be added to CHAPIS as more data become available.[15]

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[14] For further information on these maps, please visit ARB's website at: http://www.arb.ca.gov/toxics/cti/hlthrisk/hlthrisk.htm

[15] For further information on CHAPIS, please click on: http://www.arb.ca.gov/ch/chapis1/chapis1.htm

- The Hot Spots Analysis and Reporting Program (HARP) is a software database package that evaluates emissions from one or more facilities to determine the overall health risk posed by the facility(-ies) on the surrounding community. Proper use of HARP ensures that the risk assessment meets the latest risk assessment guidelines published by the State Office of Environmental Health Hazard Assessment (OEHHA). HARP is designed with air quality professionals in mind and is available from the ARB.

- The Urban Emissions Model (URBEMIS) is a computer program that can be used to estimate emissions associated with land development projects in California such as residential neighborhoods, shopping centers, office buildings, and construction projects. URBEMIS uses emission factors available from the ARB to estimate vehicle emissions associated with new land uses.

Local air districts and others can use these tools to assess a new project or plan revision. For example, these tools can be used to:

- Identify if there are multiple sources of air pollution in the community;
- Identify the major sources of air pollution in the area under consideration;
- Identify the background potential cancer risk from toxic air pollution in the area under consideration;
- Estimate the risk from a new facility and how it adds to the overall risk from other nearby facilities; and
- Provide information to decision-makers and key stakeholders on whether there may be significant issues related to cumulative emissions, exposure, and health risk due to a permitting or land use decision.

If an air agency wishes to perform a cumulative air pollution impact analysis using any of these tools, it should consult with the ARB and/or the local air district to obtain information or assistance on the data inputs and procedures necessary to operate the program. In addition, land use agencies could consult with local air districts to determine the availability of land use and air pollution data for entry into an electronic Geographical Information System (GIS) format. GIS is an easier mapping tool than the more sophisticated models described in Appendix C. GIS mapping makes it possible to superimpose land use with air pollution information so that the spatial relationship between air pollution sources, sensitive receptors, and air quality can be visually represented. Appendix C provides a general description of the impact assessment process and micro-scale, or community level modeling tools that are available to evaluate potential cumulative air pollution impacts. Modeling protocols will be accessible on ARB's website as they become available. The ARB will also provide land use agencies and local air districts with statewide regional modeling results and information regarding micro-scale modeling.

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6. ARB Programs to Reduce Air Pollution in Communities

ARB's regulatory programs reduce air pollutant emissions through statewide strategies that improve public health in all California communities. ARB's overall program addresses motor vehicles, consumer products, air toxics, air-quality planning, research, education, enforcement, and air monitoring. Community health and environmental justice concerns are a consideration in all these programs. ARB's programs are statewide but recognize that extra efforts may be needed in some communities due to historical mixed land-use patterns, limited participation in public processes in the past, and a greater concentration of air pollution sources in some communities.

ARB's strategies are intended to result in better air quality and reduced health risk to residents throughout California. The ARB's priority is to prevent or reduce the public's exposure to air pollution, including from toxic air contaminants that pose the greatest risk, particularly to infants and children who are more vulnerable to air pollution.

In October 2003, ARB updated its statewide control strategy to reduce emissions from source categories within its regulatory authority. A primary focus of the strategy is to achieve federal and state air quality standards for ozone and particulate matter throughout California, and to reduce health risk from diesel PM. Along with local air districts, ARB will continue to address air toxics emissions from regulated sources (see Table 6-1 for a summary of ARB activities). As indicated earlier, ARB will also provide analytical tools and information to land use agencies and local air districts to help assess and mitigate cumulative air pollution impacts.

The ARB will continue to consider the adoption of or revisions to needed air toxics control measures as part of the state's ongoing air toxics assessment program.[16]

As part of its effort to reduce particulate matter and air toxics emissions from diesel PM, the ARB has developed a Diesel Risk Reduction Program[17] that lays out several strategies in a three-pronged approach to reduce emissions and their associated risk:

- Stringent emission standards for all new diesel-fueled engines;
- Aggressive reductions from in-use engines; and
- Low sulfur fuel that will reduce PM and still provide the quality of diesel fuel needed to control diesel PM.

[16] For continuing information and updates on state measures, the reader can refer to ARB's website at http://www.arb.ca.gov/toxics/toxics.htm.
[17] For a comprehensive description of the program, please refer to ARB's website at http://www.arbB.ca.gov/diesel/dieselrrp.htm.

Table 6-1
ARB ACTIONS TO ADDRESS
CUMULATIVE AIR POLLUTION IMPACTS IN COMMUNITIES

Information Collection

- Improve emission inventories, air monitoring data, and analysis tools that can help to identify areas with high cumulative air pollution impacts
- Conduct studies in coordination with OEHHA on the potential for cancer and non-cancer health effects from air pollutants emitted by specific source categories
- Establish web-based clearinghouse for local land use strategies

Emission Reduction Approaches (2004-2006)*

- Through a public process, consider development and/or amendment of regulations and related guidance to reduce emissions, exposure, and health risk at a statewide and local level for the following sources:
  - Diesel PM sources such as stationary diesel engines, transport refrigeration units, portable diesel engines, on-road public fleets, off-road public fleets, heavy-duty diesel truck idling, harbor craft vessels, waste haulers
  - Other air toxics sources, such as formaldehyde in composite wood products, hexavalent chromium for chrome plating and chromic acid anodizing, thermal spraying, and perchloroethylene dry cleaning
- Develop technical information for the following:*
  - Distribution centers
  - Modeling tools such as HARP and CHAPIS
- Adopt rules and pollution prevention initiatives within legal authority to reduce emissions from mobile sources and fuels, and consumer products
- Develop and maintain Air Quality Handbook as a tool for use by land use agencies and local air districts to address cumulative air pollution impacts

Other Approaches

- Establish guidelines for use of statewide incentive funding for high priority mobile source emission reduction projects

*Because ARB will continue to review the need to adopt or revise statewide measures, the information contained in this chart will be updated on an ongoing basis.

A number of ARB's diesel risk reduction strategies have been adopted. These include measures to reduce emissions from refuse haulers, urban buses, transport refrigeration units, stationary and portable diesel engines, and idling trucks and school buses. These sources are all important from a community perspective.[18]

[18] The reader can refer to ARB's website for information on its mobile source-related programs at: http://www.arb.ca.gov/msprog/msprog.htm, as well as regulations adopted and under consideration as part of the Diesel Risk Reduction Program at: http://www.arb.ca.gov/diesel/dieselrrp.htm

The ARB will continue to evaluate the health effects of air pollutants while implementing programs with local air districts to reduce air pollution in all California communities.

Local air districts also have ambitious programs to reduce criteria pollutants and air toxics from regulated sources in their region. Many of these programs also benefit air quality in local communities as well as in the broader region. For more information on what is being done in your area to reduce cumulative air pollution impacts through air pollution control programs, you should contact your local air district.[19]

[19] Local air district contacts can be found on the inside cover to this Handbook.

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7. Ways to Enhance Meaningful Public Participation

Community involvement is an important part of the land use process. The public is entitled to the best possible information about the air they breathe and what is being done to prevent or reduce unhealthful air pollution in their communities. In particular, information on how land use decisions can affect air pollution and public health should be made accessible to all communities, including low-income and minority communities.

Effective community participation consistently relies on a two-way flow of information – from public agencies to community members about opportunities, constraints and impacts, and from community members back to public officials about needs, priorities, and preferences. The outreach process needed to build understanding and local neighborhood involvement requires data, methodologies and formats tailored to the needs of the specific community. More importantly, it requires the strong collaboration of local government agencies that review and approve projects and land uses to improve the physical and environmental surroundings of the local community.

Many land use agencies, especially those in major metropolitan areas, are familiar with, and have a long established public review process. Nevertheless public outreach can often be improved. Active public involvement requires engaging the public in ways that do not require their previous interest in or knowledge of the land use or air pollution control requirements, and a commitment to taking action where appropriate to address the concerns that are raised.

- **Direct Community Outreach**

In conjunction with local air districts, land use agencies should consider designing an outreach program for community groups, other stakeholders, and local government agency staffs that address the problem of cumulative air pollution impacts, and the public and government role in reducing them. Such a program could consider analytical tools that assist in the preparation and presentation of information in a way that supports sensible decision-making and public involvement. Table 7-1 contains some general outreach approaches that might be considered.

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Table 7-1
Public Participation Approaches

- Staff and community leadership awareness training on environmental justice programs and community-based issues
- Surveys to identify the website information needs of interested community-based organizations and other stakeholders
- Information materials on local land use and air district authorities
- Community-based councils to facilitate and invite resident participation in the planning process
- Neighborhood CEQA scoping sessions that allows for community input prior to technical analysis
- Public information materials on existing issues are under review including materials written for the affected community and in different media that widens accessibility
- Public meetings
- Identify other opportunities to include community-based organizations in the process

To improve outreach, local land use agencies should consider the following activities.

- Hold meetings in communities affected by agency programs, policies, and projects at times and in places that encourage public participation, such as evenings and weekends at centrally located community meeting rooms, libraries, and schools.
- Assess the need for and provide translation services at public meetings.
- Hold community meetings to update residents on the results of any special air monitoring programs conducted in their neighborhood.
- Hold community meetings to discuss and evaluate the various options to address cumulative impacts in their community.
- In coordination with local air districts, make staff available to attend meetings of community organizations and neighborhood groups to listen to and, where appropriate, act upon community concerns.
- Establish a specific contact person for environmental justice issues.
- Increase student and community awareness of local government land use activities and policies through outreach opportunities.
- Make air quality and land use information available to communities in an easily understood and useful format, including fact sheets, mailings, brochures, public service announcements, and web pages, in English and other languages.
- On the local government web-site, dedicate a page or section to what the land use program is doing regarding environmental justice and cumulative environmental impacts, and, as applicable, activities conducted with local air districts such as neighborhood air monitoring studies, pollution prevention, air pollution sources in neighborhoods, and risk reduction.

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- Allow, encourage, and promote community access to land use activities including public meetings, General Plan or Community Plan updates, zoning changes, special studies, CEQA reviews, variances, etc.
- Distribute information in multiple languages, as needed, on how to contact the land use agency or local air district to obtain information and assistance regarding environmental justice programs, including how to participate in public processes
- Create and distribute a simple, easy-to-read, and understandable public participation handbook, which may be based on the "Public Participation Guidebook" developed by ARB.

- **Other Opportunities for Meaningful Public Outreach**

  - Community-Based Planning Committees

Neighborhood-based or community planning advisory councils could be established to invite and facilitate direct resident participation into the planning process. With the right training and technical assistance, such councils can provide valuable input and a forum for the review of proposed amendments to plans, zone changes, land use permits, and suggestions as to how best to prevent or reduce cumulative air pollution impacts in their community.

  - Regional Partnerships

Consider creating regional coalitions of key growth-related organizations from both the private and public sectors, with corporations, communities, other jurisdictions, and government agencies. Such partnerships could facilitate agreement on common goals and win-win solutions tailored specifically for the region. With this kind of dialogue, shared vision, and collaboration barriers can be overcome and locally acceptable sustainable solutions implemented. Over the long term, such strategies will help to bring about clean air in communities as well as regionally.

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LAND USE CLASSIFICATIONS AND ASSOCIATED FACILITY CATEGORIES THAT COULD EMIT AIR POLLUTANTS

(1) Land Use Classifications – by Activity[1]	(2) Facility or Project Examples	(3) Key Pollutants[2,3]	(4) Air Pollution Permits[4]
COMMERCIAL/ LIGHT INDUSTRIAL: SHOPPING, BUSINESS, AND COMMERCIAL			
▲ Primarily retail shops and stores, office commercial activities, and light industrial or small business	Dry cleaners, drive-through restaurants, gas dispensing facilities, auto body/ auto mechanical, metal plating shops, photographic processing shops, textiles, apparel and furniture, upholstery, leather and leather products, appliance repair shops, mechanical assembly cleaning, printing shops	VOCs, air toxics including diesel PM, NOx, CO, SOx	Limited Rules for applicable equipment
▲ Goods storage or handling activities, characterized by loading and unloading goods at warehouses, large storage structures, movement of goods, shipping, and trucking	Warehousing, freight forwarding centers, drop off and loading areas, distribution centers	VOCs, air toxics including diesel PM, NOx, CO, SOx	No
LIGHT INDUSTRIAL/ RESEARCH AND DEVELOPMENT			
▲ Medical waste at research hospitals and labs	Incineration, surgical and medical instrument manufacturers, pharmaceutical manufacturing, biotech research facilities	Air toxics, NOx, CO, SOx	Yes
▲ Electronics, electrical apparatus, components, and accessories	Computer manufacturer, integrated circuit board manufacturer, semiconductor production	Air toxics, VOCs	Yes
▲ College or university lab or research center	Medical waste incinerators, lab chemicals handling, storage and disposal	Air toxics, NOx, CO, SOx, PM10	Yes
▲ Research and development labs	Satellite manufacturer, fiber optics manufacturer, defense contractors, space research and technology, new vehicles and fuels testing labs	Air toxics, VOCs	Yes
▲ Commercial testing labs	Consumer products, chemical handling, storage and disposal	Air toxics, VOCs	Yes

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(1) Land Use Classifications – by Activity[1]	(2) Facility or Project Examples	(3) Key Pollutants[2,3]	(4) Air Pollution Permits[4]
INDUSTRIAL: NON-ENERGY-RELATED			
▲ Assembly plants manufacturing facilities industrial machinery	Adhesives, chemical, textiles, apparel and furniture upholstery, clay, glass, and stone products production, asphalt materials, cement manufacturers, wood products, paperboard containers and boxes, metal coating, metal and canned food product fabrication, auto manufacturing, food processing, printing and publishing, drug, vitamins and pharmaceuticals, dyes, paints, pesticides, photographic chemicals, polish and wax, consumer products, metal and mineral smelters and foundries, fiberboard, floor tile and cover, wood and metal furniture and fixtures, rubber and leather products, general, industrial and metalworking machinery, musical instruments, office supplies, rubber products and plastics production, sawmills, solvent recycling, shingle and siding, surface coatings	VOCs, air toxics, including diesel PM, NOx, PM, CO, SOx	Yes
INDUSTRIAL: ENERGY AND UTILITIES			
▲ Water and sewer operations	Pumping stations, vents, treatment	VOCs, air toxics, NOx, CO, SOx, PM10	Yes
▲ Power generation and distribution	Power plant boilers and heaters, portable diesel engines, gas turbine engines	NOx, diesel PM, NOx, CO, SOx, PM10, VOCs	Yes
▲ Refinery operations	Refinery boilers and heaters, coke cracking units, valves and flanges, flares	VOCs, air toxics, including diesel PM, NOx, CO, SOx, PM10	Yes
▲ Oil and gas extraction	Oil recovery systems, uncovered wells	NOx, diesel PM, VOCs, CO, SOx, PM10	Yes
▲ Gasoline storage, transmission, and marketing	Above and below ground storage tanks, floating roof tanks, tank farms, pipelines	VOCs, air toxics, including diesel PM, NOx, CO, SOx, PM10	Yes
▲ Solid and hazardous waste treatment, storage, and disposal activities	Landfills, methane digester systems, process recycling facility for concrete and asphalt materials	VOCs, air toxics, NOx, CO, SOx, PM10	Yes
CONSTRUCTION (NON-TRANSPORTATION)			
	Building construction, demolition sites	PM (particulate road dust), asbestos, diesel PM, NOx, CO, SOx, PM10, VOCs	Limited state and federal off-road equipment standards

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(1) Land Use Classifications – by Activity[1]	(2) Facility or Project Examples	(3) Key Pollutants[2,3]	(4) Air Pollution Permits[4]
DEFENSE			
	Ordnance and explosives demolition range and testing activities, chemical production, degreasing, surface coatings, vehicle refueling, vehicle and engine operations and maintenance	VOCs, air toxics including diesel PM, NOx, CO, SOx, PM10	Limited prescribed burning, equipment and solvent rules
TRANSPORTATION			
▲ Vehicular movement	Residential area circulation systems, parking and idling at parking structures, drive-through establishments, car washes, special events, schools, shopping malls, etc.	VOCs, NOx, PM (re-entrained road dust), air toxics (e.g., benzene, diesel PM, formaldehyde, acetaldehyde, 1,3 butadiene), CO, SOx, PM10	No
▲ Road construction and surfacing	Street paving and repair, new highway construction and expansion	VOCs, air toxics including diesel PM, NOx, CO, SOx, PM10	No
▲ Trains	Railroads, switch yards, maintenance yards		
▲ Marine and port activities	Recreational sailing, commercial marine operations, refueling operations, loading and unloading, servicing, shipping operations, dredging, marina expansion, truck idling	VOCs, NOx, CO, SOx, PM10, air toxics, refueling diesel PM	Limited Applicable state and federal MV standards and possible equipment rules
▲ Aircraft	Takeoff, landing, and taxiing, aircraft maintenance, ground support activities		
▲ Mass transit and school buses	Bus repair and maintenance		
NATURAL RESOURCES			
▲ Farming operations	Agricultural burning, diesel operated engines and heaters, small food processors, pesticide application, agricultural off-road equipment	Diesel PM, VOCs, NOx, PM10, CO, SOx, pesticides	Limited[5], Agricultural burning requirements, applicable state and federal mobile source standards, pesticide rules
▲ Livestock and dairy operations	Dairies and feed lots	Ammonia, VOCs, PM10	Yes
▲ Logging	Off-road equipment (e.g., diesel fueled skippers, crush trackers, etc.)	Diesel PM, NOx, CO, SOx, PM10, VOCs	Limited Applicable state/federal mobile source standards
▲ Mining operations	Quarrying or stone cutting, mining, drilling or dredging	PM10, CO, SOx, VOCs, NOx, and asbestos in some geographical areas	Applicable equipment rules and dust controls

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(1) Land Use Classifications – by Activity[i]	(2) Facility or Project Examples	(3) Key Pollutants[ii,iii]	(4) Air Pollution Permits[iv]
RESIDENTIAL			
Housing	Housing developments; retirement developments; affordable housing	Fireplace emissions (PM10, NOx, VOCs, CO, air toxics); Water heater combustion (NOx, VOCs, CO)	No[vi]
ACADEMIC AND INSTITUTIONAL			
▲ Schools, including school-related recreational activities	Schools; school yards; vocational training labs/classrooms such as auto repair/painting and aviation mechanics	Air toxics	Yes/No[vii]
▲ Medical waste	Incineration	Air toxics, NOx, CO, PM10	Yes
▲ Clinics, hospitals, convalescent homes		Air toxics	Yes

[i] These classifications were adapted from the American Planning Association's "Land Based Classification Standards." The Standards provide a consistent model for classifying land uses based on their characteristics. The model classifies land uses by refining traditional categories into multiple dimensions, such as activities, functions, building types, site development character, and ownership constraints. Each dimension has its own set of categories and subcategories. These multiple dimensions allow users to have precise control over land-use classifications. For more information, the reader should refer to the Association's website at http://www.planning.org/LBCS/GeneralInfo/.

[ii] This column includes key criteria pollutants and air toxic contaminants that are most typically associated with the identified source categories.

Additional information on specific air toxics that are attributed to facility categories can be found in ARB's Emission Inventory Criteria and Guidelines Report for the Air Toxics Hot Spots Program (May 15, 1997). This information can be viewed at ARB's web site at http://www.arb.ca.gov/ab2588/final96/guide96.pdf.

Criteria air pollutants are those air pollutants for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Criteria pollutants include ozone (formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of sunlight), particulate matter, nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead.

Volatile organic compounds (VOCs) combine with nitrogen oxides to form ozone, as well as particulate matter. VOC emissions result primarily from incomplete fuel combustion and the evaporation of chemical solvents and fuels. On-road mobile sources are the largest contributors to statewide VOC emissions. Stationary sources of VOC emissions include processes that use solvents (such as dry-cleaning, degreasing, and coating operations) and petroleum-related processes (such as petroleum refining, gasoline marketing and dispensing, and oil and gas extraction). Areawide VOC sources include consumer products, pesticides, aerosols and paints, asphalt paving and roofing, and other evaporative emissions.

Nitrogen oxides (NOx) are a group of gaseous compounds of nitrogen and oxygen, many of which contribute to the formation of ozone and particulate matter. Most NOx emissions are produced by the combustion of fuels. Mobile sources make up about 80 percent of the total statewide NOx emissions. Mobile sources include on-road vehicles and trucks, aircraft, trains, ships, recreational boats, industrial and construction equipment, farm

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equipment, off-road recreational vehicles, and other equipment. Stationary sources of NOx include both internal and external combustion processes in industries such as manufacturing, food processing, electric utilities, and petroleum refining. Areawide sources, which include residential fuel combustion, waste burning, and fires, contribute only a small portion of the total statewide NOx emissions, but depending on the community, may contribute to a cumulative air pollution impact.

Particulate matter (PM) refers to particles small enough to be breathed into the lungs (under 10 microns in size). It is not a single substance, but a mixture of a number of highly diverse types of particles and liquid droplets. It can be formed directly, primarily as dust from vehicle travel on paved and unpaved roads, agricultural operations, construction and demolition.

Carbon monoxide (CO) is a colorless and odorless gas that is directly emitted as a by-product of combustion. The highest concentrations are generally associated with cold, stagnant weather conditions that occur during winter. CO problems tend to be localized.

An Air Toxic Contaminant (air toxic) is defined as an air pollutant that may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health. Similar to criteria pollutants, air toxics are emitted from stationary, areawide, and mobile sources. They contribute to elevated regional and localized risks near industrial and commercial facilities and busy roadways. The ten compounds that pose the greatest statewide risk are: acetaldehyde, benzene, 1,3-butadiene, carbon tetrachloride, diesel particulate matter (diesel PM), formaldehyde, hexavalent chromium, methylene chloride, para-dichlorobenzene, and perchloroethylene. The risk from diesel PM is by far the largest, representing about 70 percent of the known statewide cancer risk from outdoor air toxics. The exhaust from diesel-fueled engines is a complex mixture of gases, vapors, and particles, many of which are known human carcinogens. Diesel PM is emitted from both mobile and stationary sources. In California, on-road diesel-fueled vehicles contribute about 26 percent of statewide diesel PM emissions, with an additional 72 percent attributed to other mobile sources such as construction and mining equipment, agricultural equipment, and other equipment. Stationary engines in shipyards, warehouses, heavy equipment repair yards, and oil and gas production operations contribute about two percent of statewide emissions. However, when this number is disaggregated to a sub-regional scale such as neighborhoods, the risk factor can be far greater.

The level of pollution emitted is a major determinant of the significance of the impact.

[1] Indicates whether facility activities listed in column 4 are generally subject to local air district permits to operate. This does not include regulated products such as solvents and degreasers that may be used by sources that may not require an operating permit per se, e.g., a gas station or dry cleaner.

[2] Generally speaking, warehousing or distribution centers are not subject to local air district permits. However, depending on the district, motor vehicle fleet rules may apply to trucks or off-road vehicles operated and maintained by the facility operator. Additionally, emergency generators or internal combustion engines operated on the site may require an operating permit.

[3] Authorized by recent legislation SB700.

[4] Local air districts do not require permits for woodburning fireplaces inside private homes. However, some local air districts and land use agencies do have rules or ordinances that require new housing developments or home re-sales to install U.S. EPA–certified stoves. Some local air districts also ban residential woodburning during weather inversions that concentrate smoke in residential areas. Likewise, home water heaters are not subject to permits; however, new heaters could be subject to emission limits that are imposed by federal or local agency regulations.

[5] Technical training schools that conduct activities normally permitted by a local air district could be subject to an air permit.

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LAND USE-BASED REFERENCE TOOLS TO EVALUATE NEW PROJECTS FOR POTENTIAL AIR POLLUTION IMPACTS

Land use agencies generally have a variety of tools and approaches at hand, or accessible from local air districts that can be useful in performing an analysis of potential air pollution impacts associated with new projects. These tools and approaches include:

- Base map of the city or county planning area and terrain elevations.
- General Plan designations of land use (existing and proposed).
- Zoning maps.
- Land use maps that identify existing land uses, including the location of facilities that are permitted or otherwise regulated by the local air district. Land use agencies should consult with their local air district for information on regulated facilities.
- Demographic data, e.g., population location and density, distribution of population by income, distribution of population by ethnicity, and distribution of population by age. The use of population data is a normal part of the planning process. However, from an air quality perspective, socioeconomic data is useful to identify potential community health and environmental justice issues.
- Emissions, monitoring, and risk-based maps created by the ARB or local air districts that show air pollution-related health risk by community across the state.
- Location of public facilities that enhance community quality of life, including parks, community centers, and open space.
- Location of industrial and commercial facilities and other land uses that use hazardous materials, or emit air pollutants. These include chemical storage facilities, hazardous waste disposal sites, dry cleaners, large gas dispensing facilities, auto body shops, and metal plating and finishing shops.
- Location of sources or facility types that result in diesel on-road and off-road emissions, e.g., stationary diesel power generators, forklifts, cranes, construction equipment, on-road vehicle idling, and operation of transportation refrigeration units. Distribution centers, marine terminals and ports, rail yards, large industrial facilities, and facilities that handle bulk goods are all examples of complex facilities where these types of emission sources are frequently concentrated.[1] Very large facilities, such as ports, marine terminals, and airports, could be analyzed regardless of proximity to a receptor if they are within the modeling area.
- Location and zoning designations for existing and proposed schools, buildings, or outdoor areas where sensitive individuals may live or play.
- Location and density of existing and proposed residential development.
- Zoning requirements, property setbacks, traffic flow requirements, and idling restrictions for trucks, trains, yard hostlers[2], construction equipment, or school buses.
- Traffic counts (including diesel truck traffic counts), within a community to validate or augment existing regional motor vehicle trip and speed data.

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[1] The ARB is currently evaluating the types of facilities that may act as complex point sources and developing methods to identify them.

[2] Yard hostler means a tractor less than 300 horsepower that is used to transfer semi-truck or tractor-trailer containers in and around storage, transfer, or distribution yards or areas and is often equipped with a hydraulic lifting fifth wheel for connection to trailer containers.

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ARB AND LOCAL AIR DISTRICT INFORMATION AND TOOLS CONCERNING CUMULATIVE AIR POLLUTION IMPACTS

It is the ARB's policy to support research and data collection activities toward the goal of reducing cumulative air pollution impacts. These efforts include updating and improving the air toxics emissions inventory, performing special air monitoring studies in specific communities, and conducting a more complete assessment of non-cancer health effects associated with air toxics and criteria pollutants.[1] This information is important because it helps us better understand links between air pollution and the health of sensitive individuals – children, the elderly, and those with pre-existing serious health problems affected by air quality.

ARB is working with CAPCOA and OEHHA to improve air pollutant data and evaluation tools to determine when and where cumulative air pollution impacts may be a problem. The following provides additional information on this effort.

How are emissions assessed?

Detailed information about the sources of air pollution in an area is collected and maintained by local air districts and the ARB in what is called an emission inventory. Emission inventories contain information about the nature of the business, the location, type and amount of air pollution emitted, the air pollution producing processes, the type of air pollution control equipment, operating hours, and seasonal variations in activity. Local districts collect emission inventory data for most stationary source categories.

Local air districts collect air pollution emission information directly from facilities and businesses that are required to obtain an air pollution operating permit. Local air districts use this information to compile an emission inventory for areas within their jurisdiction. The ARB compiles a statewide emission inventory based on the information collected by the ARB and local air districts. Local air districts provide most of the stationary source emission data, and ARB provides mobile source emissions as well as some areawide emission sources such as consumer products and paints. ARB is also developing map-based tools that will display information on air pollution sources.

Criteria pollutant data have been collected since the early 1970's, and toxic pollutant inventories began to be developed in the mid-1980's.

[1] A criteria pollutant is any air pollutant for which EPA has established a National Ambient Air Quality Standard or for which California has established a State Ambient Air Quality Standard, including: carbon monoxide, lead, nitrogen oxides, ozone, particulates and sulfur oxides. Criteria pollutants are measured in each of California's air basins to determine whether the area meets or does not meet specific federal or state air quality standards. Air toxics or air toxic contaminants are listed pollutants recognized by California or EPA as posing a potential risk to health.

How is the toxic emission inventory developed?

Emissions data for toxic air pollutants is a high priority for communities because of concerns about potential health effects. Most of ARB's air toxics data is collected through the toxic "Hot Spots" program. Local air districts collect emissions data from industrial and commercial facilities. Facilities that exceed health-based thresholds are required to report their air toxics emissions as part of the toxic "Hot Spots" program and update their emissions data every four years. Facilities are required to report their air toxics emissions data if there is an increase that would trigger the reporting threshold of the hotspots program. Air toxics emissions from motor vehicles and consumer products are estimated by the ARB. These estimates are generally regional in nature, reflecting traffic and population.

The ARB also maintains chemical speciation profiles that can be used to estimate toxics emissions when no toxic emissions data is available.

What additional toxic emissions information is needed?

In order to assess cumulative air pollution impacts, updated information from individual facilities is needed. Even for sources where emissions data are available, additional information such as the location of emissions release points is often needed to better model cumulative impacts. In terms of motor vehicles, emissions data are currently based on traffic models that only contain major roads and freeways. Local traffic data are needed so that traffic emissions can be more accurately assigned to specific streets and roads. Local information is also needed for off-road emission sources, such as ships, trains, and construction equipment. In addition, hourly maximum emissions data are needed for assessing acute air pollution impacts.

What work is underway?

ARB is working with CAPCOA to improve toxic emissions data, developing a community health air pollution information system to improve access to emission information, conducting neighborhood assessment studies to better understand toxic emission sources, and conducting surveys of sources of toxic pollutants.

How is air pollution monitored?

While emissions data identify how much air pollution is going into the air, the state's air quality monitoring network measures air pollutant levels in outdoor air. The statewide air monitoring network is primarily designed to measure regional exposure to air pollutants, and consists of more than 250 air monitoring sites.

The air toxics monitoring network consists of approximately 20 permanent sites. These sites are supplemented by special monitoring studies conducted by ARB and local air districts. These sites measure approximately sixty toxic air pollutants. Diesel PM, which is the major driver of urban air toxic risk, is not monitored directly. Ten of the

60 toxic pollutants, not including diesel, account for most of the remaining potential cancer risk in California urban areas

What additional monitoring has been done?

Recently additional monitoring has been done to look at air quality at the community level. ARB's community monitoring was conducted in six communities located throughout the state. Most sites were in low-income, minority communities located near major sources of air pollution, such as refineries or freeways. The monitoring took place for a year or more in each community, and included measurements of both criteria and toxic pollutants.

What is being learned from community monitoring?

In some cases, the ARB or local air districts have performed air quality monitoring or modeling studies covering a particular region of the state. When available, these studies can give information about regional air pollution exposures.

The preliminary results of ARB's community monitoring are providing insights into air pollution at the community level. Urban background levels are a major contributor to the overall risk from air toxics in urban areas, and this urban background tends to mask the differences between communities. When localized elevated air pollutant levels were measured, they were usually associated with local ground-level sources of toxic pollutants. The most common source of this type was busy streets and freeways. The impact these ground-level sources had on local air quality decreased rapidly with distance from the source. Pollutant levels usually returned to urban background levels within a few hundred meters of the source.

These results indicate that tools to assess cumulative impacts must be able to account for both localized, near-source impacts, as well as regional background air pollution. The tools that ARB is developing for this purpose are air quality models.

How can air quality modeling be used?

While air monitoring can directly measure cumulative exposure to air pollution, it is limited because all locations cannot be monitored. To address this, air quality modeling provides the capability to estimate exposure when air monitoring is not feasible. Air quality modeling can be refined to assess local exposure, identify locations of potential hot spots, and identify the relative contribution of emission sources to exposure at specific locations. The ARB has used this type of information to develop regional cumulative risk maps that estimate the cumulative cancer air pollution risk for most of California. While these maps only show one air pollution-related health risk, it does provide a useful starting point.

What is needed for community modeling?

Air quality models have been developed to assess near-source impacts, but they have very exacting data requirements. These near-source models estimate the impact of local sources, but do not routinely include the contribution from regional air pollution background. To estimate cumulative air pollution exposure at a neighborhood scale, a modeling approach needs to combine features of both micro-scale and regional models.

In addition, improved methods are needed to assess near-source impacts under light and variable wind conditions, when high local concentrations are more likely to occur. A method for modeling long-term exposure to air pollutants near freeways and other high traffic areas is also needed.

What modeling work has ARB developed?

A key component of ARB's Community Health Program is the Neighborhood Assessment Program (NAP). As described later in this section, the NAP studies are being conducted to better understand pollution impacts at the community level. Through two such studies conducted in Barrio Logan (San Diego) and Wilmington (Los Angeles), ARB is refining community-level modeling methodologies. Regional air toxics modeling is also being performed to better understand regional air pollution background levels.

In a parallel effort, ARB is developing modeling protocols for estimating cumulative emissions, exposure, and risk from air pollution. The protocols will cover modeling approaches and uncertainties, procedures for running the models, the development of statewide risk maps, and methods for estimating health risks. The protocols are subject to an extensive peer review process prior to release.

How are air pollution impacts on community health assessed?

On a statewide basis, ARB's toxic air contaminant program identifies and reduces public exposure to air toxics. The focus of the program has been on reducing potential cancer risk, because monitoring results show potential urban cancer risk levels are too high. ARB has also looked for potential non-cancer risks based on health reference levels provided by OEHHA. On a regional basis, the pollutants measured in ARB's toxic monitoring network are generally below the OEHHA non-cancer reference exposure levels.

As part of its community health program, the ARB is looking at potential cancer and non-cancer risk. This could include chronic or acute health effects. If the assessment work shows elevated exposures on a localized basis, ARB will work with OEHHA to assess the health impacts.

What tools has ARB developed to assess cumulative air pollution impacts?

ARB has developed the following tools and reports to assist land use agencies and local air districts assess and reduce cumulative emissions, exposure, and risk on a neighborhood scale.

Statewide Risk Maps

ARB has produced regional risk maps that show the statewide trends for Southern and Central California in estimated potential cancer risk from air toxics between 1990 and 2010.[2] These maps will supplement U.S. EPA's ASPEN model and are available on the ARB's Internet site. These maps are best used to obtain an estimate of the regional background air pollution health risk and are not detailed enough to estimate the exact risk at a specific location.

ARB also has maps that focus in more detail on smaller areas that fall within the Southern and Central California regions for these same modeled years. The finest visual resolution available in the maps on this web site is two by two kilometers. These maps are not detailed enough to assess individual neighborhoods or facilities.

Community Health Air Pollution Information System (CHAPIS)

CHAPIS is an Internet-based procedure for displaying information on emissions from sources of air pollution in an easy to use mapping format. CHAPIS uses Geographical Information System (GIS) software to deliver interactive maps over the Internet. CHAPIS relies on emission estimates reported to the ARB's emission inventory database - California Emissions Inventory Development and Reporting System, or CEIDARS.

Through CHAPIS, air district staff can quickly and easily identify pollutant sources and emissions within a specified area. CHAPIS contains information on air pollution emissions from selected large facilities and small businesses that emit criteria and toxic air pollutants. It also contains information on air pollution emissions from motor vehicle and areawide emissions. CHAPIS does not contain information on every source of air pollution or every air pollutant. It is a major long-term objective of CHAPIS to include all of the largest air pollution sources and those with the highest documented air pollution risk. CHAPIS will be updated on a periodic basis and additional facilities will be added to CHAPIS as more data becomes available.

CHAPIS is being developed in stages to assure data quality. The initial release of CHAPIS will include facilities emitting 10 or more tons per year of nitrogen oxides, sulfur dioxide, carbon monoxide, PM10, or reactive organic gases; air toxics from refineries and power plants of 50 megawatts or more; and facilities that conducted health risk

[2]ARB maintains state trends and local potential cancer risk maps that show statewide trends in potential inhalable cancer risk from air toxics between 1990 and 2010. This information can be viewed at ARB's web site at http://www.arb.ca.gov/toxics/cti/hlthrisk/hlthrisk.htm)

assessments under the California Air Toxics "Hot Spots" Information and Assessment Program.[3]

CHAPIS can be used to identify the emission contributions from mobile, area, and point sources on that community.

"Hot Spots" Analysis and Reporting Program (HARP)

HARP[4] is a software package available from the ARB and is designed with air quality professionals in mind. It models emissions and release data from one or more facilities to estimate the potential health risk posed by the selected facilities on the neighboring community. HARP uses the latest risk assessment guidelines published by OEHHA.

With HARP, a user can perform the following tasks:

- Create and manage facility databases;
- Perform air dispersion modeling;
- Conduct health risk analyses;
- Output data reports; and
- Output results to GIS mapping software.

HARP can model downwind concentrations of air toxics based on the calculated emissions dispersion at a single facility. HARP also has the capability of assessing the risk from multiple facilities, and for multiple locations of concern near those facilities. While HARP has the capability to assess multiple source impacts, there had been limited application of the multiple facility assessment function in the field at the time of HARP's debut in 2003. HARP can also evaluate multi-pathway, non-inhalation health risk resulting from air pollution exposure, including skin and soil exposure, and ingestion of meat and vegetables contaminated with air toxics, and other toxics that have accumulated in a mother's breast milk.

Neighborhood Assessment Program (NAP)

The NAP[5] has been a key component of ARB's Community Health Program. It includes the development of tools that can be used to perform assessments of cumulative air pollution impacts on a neighborhood scale. The NAP studies have been done to better understand how air pollution affects individuals at the neighborhood level. Thus far, ARB has conducted neighborhood scale assessments in Barrio Logan and Wilmington.

As part of these studies, ARB is collecting data and developing a modeling protocol that can be used to conduct cumulative air pollution impact assessments. Initially these

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[3] California Health & Safety Code section 44300, et seq.
[4] More detailed information can be found on ARB's website at: http://www.arb.ca.gov/toxics/harp/harp.htm
[5] For more information on the Program, please refer to: http://www.arb.ca.gov/ch/programs/nap/nap.htm

assessments will focus on cumulative inhalation cancer health risk and chronic non-cancer impacts. The major challenge is developing modeling methods that can combine both regional and localized air pollution impacts, and identifying the critical data necessary to support these models. The objective is to develop methods and tools from these studies that can ultimately be applied to other areas of the state. In addition, the ARB plans to use these methods to replace the ASPEN regional risk maps currently posted on the ARB Internet site.

Urban Emissions Model (URBEMIS)

URBEMIS[6] is a computer program that can be used to estimate emissions associated with land development projects in California such as residential neighborhoods, shopping centers, office buildings, and construction projects. URBEMIS uses emission factors available from the ARB to estimate vehicle emissions associated with new land uses. URBEMIS estimates sulfur dioxide emissions from motor vehicles in addition to reactive organic gases, nitrogen oxides, carbon monoxide, and PM10.

Land-Use Air Quality Linkage Report[7]

This report summarizes data currently available on the relationships between land use, transportation and air quality. It also highlights strategies that can help to reduce the use of the private automobile. It also briefly summarizes two ARB-funded research projects. The first project analyzes the travel patterns of residents living in five higher density, mixed use neighborhoods in California, and compares them to travel in more auto-oriented areas. The second study correlates the relationship between travel behavior and community characteristics, such as density, mixed land uses, transit service, and accessibility for pedestrians.

[6] For more information on this model, please refer to ARB's website at http://www.arb.ca.gov/html/soft.htm.
[7] To access this report, please refer to ARB's website or click on: http://www.arb.ca.gov/ch/programs/link97.pdf

LAND USE AND AIR QUALITY AGENCY ROLES IN THE LAND USE PROCESS

A wide variety of federal, state, and local government agencies are responsible for regulatory, planning, and siting decisions that can have an impact on air pollution. They include local land use agencies, regional councils of government, school districts, local air districts, ARB, the California Department of Transportation (Caltrans), and the Governor's Office of Planning and Research (OPR) to name a few. This Section will focus on the roles and responsibilities of local and state agencies. The role of school districts will be discussed in Appendix E.

Local Land Use Agencies

Under the State Constitution, land use agencies have the primary authority to plan and control land use.[1] Each of California's incorporated cities and counties are required to adopt a comprehensive, long-term General Plan.[2]

The General Plan's long-term goals are implemented through zoning ordinances. These are local laws adopted by counties and cities that describe for specific areas the kinds of development that will be allowed within their boundaries.

Land use agencies are also the lead for doing environmental assessments under CEQA for new projects that may pose a significant environmental impact, or for new or revised General Plans.

Local Agency Formation Commissions (LAFCOs)

Operating in each of California's 58 counties, LAFCOs are composed of local elected officials and public members who are responsible for coordinating changes in local governmental boundaries, conducting special studies that review ways to reorganize, simplify, and streamline governmental structures, and preparing a sphere of influence for each city and special district within each county. Each Commission's efforts are directed toward seeing that local government services are provided efficiently and economically while agricultural and open-space lands are protected. LAFCO decisions strive to balance the competing needs in California for efficient services, affordable housing, economic opportunity, and conservation of natural resources.

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[1] The legal basis for planning and land use regulation is the "police power" of the city or county to protect the public's health, safety and welfare. The California Constitution gives cities and counties the power to make and enforce all local police, sanitary and other ordinances and regulations not in conflict with general laws. State law reference: California Constitution, Article XI §7.

[2] OPR General Plan Guidelines, 2003: http://www.opr.ca.gov/planning/PDFs/General_Plan_Guidelines_2003.pdf

Councils of Government (COG)

COGs are organizations composed of local counties and cities that serve as a focus for the development of sound regional planning, including plans for transportation, growth management, hazardous waste management, and air quality. They can also function as the metropolitan planning organization for coordinating the region's transportation programs. COGs also prepare regional housing need allocations for updates of General Plan housing elements.

Local Air Districts

Under state law, air pollution control districts or air quality management districts (local air districts) are the local government agencies responsible for improving air quality and are generally the first point of contact for resolving local air pollution issues or complaints. There are 35 local air districts in California[3] that have authority and primary responsibility for regional clean air planning. Local air districts regulate stationary sources of air pollutants within their jurisdiction, including but not limited to industrial and commercial facilities, power plants, construction activities, outdoor burning, and other non-mobile sources of air pollution. Some local air districts also regulate public and private motor vehicle fleet operators such as public bus systems, private shuttle and taxi services, and commercial truck depots.

- **Regional Clean Air Plans**

Local air districts are responsible for the development and adoption of clean air plans that protect the public from the harmful effects of air pollution. These plans incorporate strategies that are necessary to attain ambient air quality standards. Also included in these regional air plans are ARB and local district measures to reduce statewide emissions from mobile sources, consumer products, and industrial sources.

- **Facility-Specific Considerations**

Permitting. In addition to the planning function, local air districts adopt and enforce regulations, issue permits, and evaluate the potential environmental impacts of projects.

Pollution is regulated through permits and technology-based rules that limit emissions from operating units within a facility or set standards that vehicle fleet operators must meet. Permits to construct and permits to operate contain very specific requirements and conditions that tell each regulated source what it must do to limit its air pollution in compliance with local air district rules, regulations, and state law. Prior to receiving a permit, new facilities must go through a New Source Review (NSR) process that establishes air pollution control requirements for the facility. Permit conditions are typically contained in the permit to operate and specify requirements that businesses must follow; these may include limits on the amount of pollution that can be emitted, the

[3] Contact information for local air districts in California is listed in the front of this Handbook.

type of pollution control equipment that must be installed and maintained, and various record-keeping requirements.

Local air districts also notify the public about new permit applications for major new facilities, or major modifications to existing facilities that seek to locate within 1,000 feet of a school.

Local air districts can also regulate other types of sources to reduce emissions. These include regulations to reduce emissions from the following sources:

- hazardous materials in products used by industry such as paints, solvents, and de-greasers;
- agricultural and residential burning;
- leaking gasoline nozzles at service stations;
- public fleet vehicles such as sanitation trucks and school buses; and
- fugitive or uncontrolled dust at construction sites.

However, while emissions from industrial and commercial sources are typically subject to the permit authority of the local air district, sensitive sites such as a day care center, convalescent home, or playground are not ordinarily subject to an air permit. Local air district permits address the air pollutant emissions of a project but not its location.

Under the state's air toxics program, local air districts regulate air toxic emissions by adopting ARB air toxic control measures, or more stringent district-specific requirements, and by requiring individual facilities to perform a health risk assessment if emissions at the source exceed district-specific health risk thresholds[4], [5] (See the section on ARB programs for a more detailed summary of this program).

One approach by which local air districts regulate air toxics emissions is through the "Hot Spots" program.[6] The risk assessments submitted by the facilities under this

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[4] Cal/EPA's Office of Environmental Health Hazard Assessment has published "A Guide to Health Risk Assessment" for lay people involved in environmental health issues, including policymakers, businesspeople, members of community groups, and others with an interest in the potential health effects of toxic chemicals. To access this information, please refer to http://www.oehha.ca.gov/pdf/HRSguide2001.pdf

[5] Section 44306 of the California Health & Safety Code defines a health risk assessment as a detailed comprehensive analysis that a polluting facility uses to evaluate and predict the dispersion of hazardous substances in the environment and the potential for exposure of human populations, and to assess and quantify both the individual and population-wide health risks associated with those levels of exposure.

[6] AB-2588 (the Air Toxics "Hot Spots" Information and Assessment Act) requires local air districts to prioritize facilities by high, intermediate, and low priority categories to determine which must perform a health risk assessment. Each district is responsible for establishing the prioritization score threshold at which facilities are required to prepare a health risk assessment. In establishing priorities for each facility, local air districts must consider the potency, toxicity, quantity, and volume of hazardous materials released from the facility, the proximity of the facility to potential receptors, and any other factors that the district determines may indicate that the facility may pose a significant risk. All facilities within the highest category must prepare a health risk assessment. In addition, each district may require facilities in the intermediate and low priority categories to also submit a health risk assessment.

Table D-1
Local Sources of Air Pollution, Responsible Agencies, and Associated Regulatory Programs

Source	Examples	Primary Agency	Applicable Regulations
Large Stationary	Refineries, power plants, chemical facilities, certain manufacturing plants	Local air districts	Operating permit rules Air Toxics "Hot Spots" Law (AB 2588) Local district rules Air Toxic Control Measures (ATCMs)* New Source Review rules Title V permit rules
Small Stationary	Dry cleaners, auto body shops, welders, chrome plating facilities, service stations, certain manufacturing plants	Local air districts	Operating permit conditions. Air Toxics "Hot Spots" Law (AB 2588) Local district rules ATCMs* New Source Review rules
Mobile (non-fleet)	Cars, trucks, buses	ARB	Emission standards Cleaner-burning fuels (e.g., unleaded gasoline, low-sulfur diesel) Inspection and repair programs (e.g., Smog Check)
Mobile Equipment	Construction equipment	ARB, U.S. EPA	ARB rules U.S. EPA rules
Mobile (fleet)	Truck depots, school buses, taxi services	Local air districts, ARB	Local air district rules ARB urban bus fleet rule
Areawide	Paints and consumer products such as hair spray and spray paint	Local air district, ARB	ARB rules Local air district rules

*ARB adopts ATCMs, but local air districts have the responsibility to implement and enforce these measures or more stringent ones.

program are reviewed by OEHHA and approved by the local air district. Risk assessments are available by contacting the local air district.

Enforcement. Local air districts also take enforcement action to ensure compliance with air quality requirements. They enforce air toxic control measures, agricultural and residential burning programs, gasoline vapor control regulations, laws that prohibit air pollution nuisances, visible emission limits, and many other requirements designed to

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clean the air. Local districts use a variety of enforcement tools to ensure compliance. These include notices of violation, monetary penalties, and abatement orders. Under some circumstances, a permit may be revoked.

- **Environmental Review**

As required by the California Environmental Quality Act (CEQA), local air districts also review and comment on proposed land use plans and development projects that can have a significant effect on the environment or public health.[7]

California Air Resources Board

The ARB is the air pollution control agency at the state level that is responsible for the preparation of air plans required by state and federal law. In this regard, it coordinates the activities of all local air districts to ensure all statutory requirements are met and to reduce air pollution emissions for sources under its jurisdiction.

Motor vehicles are the single largest emissions source category under ARB's jurisdiction as well as the largest overall emissions source statewide. ARB also regulates emissions from other mobile equipment and engines as well as emissions from consumer products such as hair sprays, perfumes, cleaners, and aerosol paints.

Air Toxics Program

Under state law, the ARB has a critical role to play in the identification, prioritization, and control of air toxic emissions. The ARB statewide comprehensive air toxics program was established in the early 1980's. The Toxic Air Contaminant Identification and Control Act of 1983 (AB 1807, Tanner 1983) created California's program to reduce exposure to air toxics.[8] The Air Toxics "Hot Spots" Information and Assessment Act (Hot Spots program) supplements the AB 1807 program, by requiring a statewide air toxics inventory, notification of people exposed to a significant health risk, and facility plans to reduce these risks.

Under AB 1807, the ARB is required to use certain criteria to prioritize the identification and control of air toxics. In selecting substances for review, the ARB must consider criteria relating to emissions, exposure, and health risk, as well as persistence in the atmosphere, and ambient concentrations in the community. AB 1807 also requires the ARB to use available information gathered from the Hot Spots program when prioritizing compounds.

The ARB identifies pollutants as toxic air contaminants and adopts statewide air toxic control measures (ATCMs). Once ARB adopts an ATCM, local air districts must

[7] Section 4 of this Handbook contains more information on the CEQA process.
[8] For a general background on California's air toxics program, the reader should refer to ARB's website at http://www.arb.ca.gov/toxics/tac/appendxb.htm.

implement the measure, or adopt and implement district-specific measures that are at least as stringent as the state standard. Taken in the aggregate, these ARB programs will continue to further reduce emissions, exposure, and health risk statewide.

With regard to the land use decision-making process, ARB, in conjunction with local air districts, plays an advisory role by providing technical information on land use-related air issues.

Other Agencies

Governor's Office of Planning and Research (OPR)

In addition to serving as the Governor's advisor on land use planning, research, and liaison with local government, OPR develops and implements the state's policy on land use planning and coordinates the state's environmental justice programs. OPR updated its General Plan Guidelines in 2003 to highlight the importance of sustainable development and environmental justice policies in the planning process. OPR also advises project proponents and government agencies on CEQA provisions and operates the State Clearinghouse for environmental and federal grant documents.

California Department of Housing and Community Development

The Department of Housing and Community Development (HCD) administers a variety of state laws, programs and policies to preserve and expand housing opportunities, including the development of affordable housing. All local jurisdictions must update their housing elements according to a staggered statutory schedule, and are subject to certification by HCD. In their housing elements, cities and counties are required to include a land inventory which identifies and zones sites for future residential development to accommodate a mix of housing types, and to remove barriers to the development of housing.

An objective of state housing element law is to increase the overall supply and affordability of housing. Other fundamental goals include conserving existing affordable housing, improving the condition of the existing housing stock, removing regulatory barriers to housing production, expanding equal housing opportunities, and addressing the special housing needs of the state's most vulnerable residents (frail elderly, disabled, large families with children, farmworkers, and the homeless).

Transportation Agencies

Transportation agencies can also influence mobile source-related emissions in the land use decision-making process. Local transportation agencies work with land use agencies to develop a transportation (circulation) element for the General Plan. These local government agencies then work with other transportation-related agencies, such as the Congestion Management Agency (CMA), Metropolitan Planning Organization

(MPO), Regional Transportation Planning Agency (RTPA), and Caltrans to develop long and short range transportation plans and projects.

Caltrans is the agency responsible for setting state transportation goals and for state transportation planning, design, construction, operations and maintenance activities. Caltrans is also responsible for delivering California's multibillion-dollar state Transportation Improvement Program, a list of transportation projects that are approved for funding by the California Transportation Commission in a 4-year cycle.

When safety hazards or traffic circulation problems are identified in the existing road system, or when land use changes are proposed such as a new residential subdivision, shopping mall or manufacturing center, Caltrans and/or the local transportation agency ensure the projects meet applicable state, regional, and local goals and objectives.

Caltrans also evaluates transportation-related projects for regional air quality impacts, from the perspective of travel-related emissions as well as road congestion and increases in road capacity (new lanes).

California Energy Commission (CEC)

The CEC is the state's CEQA lead agency for permitting large thermal power plants (50 megawatts or greater). The CEC works closely with local air districts and other federal, state and local agencies to ensure compliance with applicable laws, ordinances, regulations and standards in the permitting, construction, operation and closure of such plants. The CEC uses an open and public review process that provides communities with outreach and multiple opportunities to participate and be heard. In addition to its comprehensive environmental impact and engineering design assessment process, the CEC also conducts an environmental justice evaluation. This evaluation involves an initial demographic screening to determine if a qualifying minority or low-income population exists in the vicinity of the proposed project. If such a population is present, staff considers possible environmental justice impacts including from associated project emissions in its technical assessments.[9]

Department of Pesticides Regulation (DPR)

Pesticides are industrial chemicals produced specifically for their toxicity to a target pest. They must be released into the environment to do their job. Therefore, regulation of pesticides focuses on using toxicity and other information to ensure that when pesticides are used according to their label directions, potential for harm to people and the environment is minimized. DPR imposes strict controls on use, beginning before pesticide products can be sold in California, with an extensive scientific program to ensure they can be used safely. DPR and county enforcement staff tracks the use of pesticides to ensure that pesticides are used properly. DPR collects periodic

[9] See California Energy Commission, "Environmental Performance Report," July 2001 at http://www.energy.ca.gov/reports/2001-11-20_700-01-001.PDF

measurements of any remaining amounts of pesticides in water, air, and on fresh produce. If unsafe levels are found, DPR requires changes in how pesticides are used, to reduce the possibility of harm. If this cannot be done - that is, if a pesticide cannot be used safely - use of the pesticide will be banned in California.[10]

Federal Agencies

Federal agencies have permit authority over activities on federal lands and certain resources, which have been the subject of congressional legislation, such as air, water quality, wildlife, and navigable waters. The U.S. Environmental Protection Agency generally oversees implementation of the federal Clean Air Act, and has broad authority for regulating certain activities such as mobile sources, air toxics sources, the disposal of toxic wastes, and the use of pesticides. The responsibility for implementing some federal regulatory programs such as those for air and water quality and toxics is delegated by management to specific state and local agencies. Although federal agencies are not subject to CEQA they must follow their own environmental process established under the National Environmental Policy Act (NEPA).

[10] For more information, the reader is encouraged to visit the Department of Pesticide Regulation web site at www.cdpr.ca.gov/docs/empm/pubs/tacmenu.htm.

SPECIAL PROCESSES THAT APPLY TO SCHOOL SITING

The California Education Code and the California Public Resources Code place primary authority for siting public schools with the local school district, which is the 'lead agency' for purposes of CEQA. The California Education Code requires public school districts to notify the local planning agency about siting a new public school or expanding an existing school. The planning agency then reports back to the school district regarding a project's conformity with the adopted General Plan. However, school districts can overrule local zoning and land use designations for schools if they follow specified procedures. In addition, all school districts must evaluate new school sites using site selection standards established in Section 14010 of Title 5 of the California Code of Regulations. Districts seeking state funding for school site acquisition must also obtain site approval from the California Department of Education.

Before making a final decision on a school site acquisition, a school district must comply with CEQA and evaluate the proposed site acquisition/new school project for air emissions and health risks by preparing and certifying an environmental impact report or negative declaration. Both the California Education Code section 17213 and the California Public Resources Code section 21151.8 require school districts to consult with administering agencies and local air districts when preparing the environmental assessment. Such consultation is required to identify both permitted and non-permitted "facilities" that might significantly affect health at the new site. These facilities include, but are not limited to, freeways and other busy traffic corridors, large agricultural operations, and rail yards that are within one-quarter mile of the proposed school site, and that might emit hazardous air emissions, or handle hazardous or acutely hazardous materials, substances, or waste.

As part of the CEQA process and before approving a school site, the school district must make a finding that either it found none of the facilities or significant air pollution sources, or alternatively, if the school district finds that there are such facilities or sources, it must determine either that they pose no significant health risks, or that corrective actions by another governmental entity would be taken so that there would be no actual or potential endangerment to students or school workers.

In addition, if the proposed school site boundary is within 500 feet of the edge of the closest traffic lane of a freeway or traffic corridor that has specified minimum average daily traffic counts, the school district is required to determine through specified risk assessment and air dispersion modeling that neither short-term nor long term exposure poses significant heath risks to pupils.

State law changes effective January 1, 2004 (SB352, Escutia 2003, amending Education Code section 17213 and Public Resources Code section 21151.8) also provides for cases in which the school district cannot make either of those two findings and cannot find a suitable alternative site. When this occurs, the school district must adopt a statement of over-riding considerations, as part of an environmental impact

report that the project should be approved based on the ultimate balancing of the merits.

Some school districts use a standardized assessment process to determine the environmental impacts of a proposed school site. In the assessment process, school districts can use maps and other available information to evaluate risk, including a local air district's database of permitted source emissions. School districts can also perform field surveys and record searches to identify and calculate emissions from non-permitted sources within one-quarter mile radius of a proposed site. Traffic count data and vehicular emissions data can also be obtained from Caltrans for major roadways and freeways in proximity to the proposed site to model potential emissions impacts to students and school employees. This information is available from the local COG, Caltrans, or local cities and counties for non-state maintained roads.

GENERAL PROCESSES USED BY LAND USE AGENCIES TO ADDRESS AIR POLLUTION IMPACTS

There are several separate but related processes for addressing the air pollution impacts of land use projects. One takes place as part of the planning and zoning function. This consists of preparing and implementing goals and policies contained in county or city General Plans, community or area plans, and specific plans governing land uses such as residential, educational, commercial, industrial, and recreational activities. It also includes recommending locations for thoroughfares, parks and other public improvements.

Land use agencies also have a permitting function that includes performing environmental reviews and mitigation when projects may pose a significant environmental impact. They conduct inspections for zoning permits issued, enforce the zoning regulations and issue violations as necessary, issue zoning certificates of compliance, and check compliance when approving certificates of occupancy.

Planning

- **General Plan**[1]

The General Plan is a local government "blueprint" of existing and future anticipated land uses for long-term future development. It is composed of the goals, policies, and general elements upon which land use decisions are based. Because the General Plan is the foundation for all local planning and development, it is an important tool for implementing policies and programs beneficial to air quality. Local governments may choose to adopt a separate air quality element into their General Plan or to integrate air quality-beneficial objectives, policies, and strategies in other elements of the Plan, such as the land use, circulation, conservation, and community design elements.

More information on General Plan elements is contained in Appendix D.

- **Community Plans**

Community or area plans are terms for plans that focus on a particular region or community within the overall general plan area. It refines the policies of the general plan as they apply to a smaller geographic area and is implemented by ordinances and other discretionary actions, such as zoning.

[1] In October 2003, OPR revised its General Plan Guidelines. An entire chapter is now devoted to a discussion of how sustainable development and environmental justice goals can be incorporated into the land use planning process. For further information, the reader is encouraged to obtain a copy of OPR's General Plan Guidelines, or refer to their website at: http://www.opr.ca.gov/planning/PDFs/General_Plan_Guidelines_2003.pdf

- **Specific Plan**

A specific plan is a hybrid that can combine policies with development regulations or zoning requirements. It is often used to address the development requirements for a single project such as urban infill or a planned community. As a result, its emphasis is on concrete standards and development criteria.

- **Zoning**

Zoning is the public regulation of the use of land. It involves the adoption of ordinances that divide a community into various districts or zones. For instance, zoning ordinances designate what projects and activities can be sited in particular locations. Each zone designates allowable uses of land within that zone, such as residential, commercial, or industrial. Zoning ordinances can address building development standards, e.g. minimum lot size, maximum building height, minimum building setback, parking, signage, density, and other allowable uses.

Land Use Permitting

In addition to the planning and zoning function, land use agencies issue building and business permits, and evaluate the potential environmental impacts of projects. To be approved, projects must be located in a designated zone and comply with applicable ordinances and zoning requirements.

Even if a project is sited properly in a designated zone, a land use agency may require a new source to mitigate potential localized environmental impacts to the surrounding community below what would be required by the local air district. In this case, the land use agency could condition the permit by limiting or prescribing allowable uses including operating hour restrictions, building standards and codes, property setbacks between the business property and the street or other structures, vehicle idling restrictions, or traffic diversion.

Land use agencies also evaluate the environmental impacts of proposed land use projects or activities. If a project or activity falls under CEQA, the land use agency requires an environmental review before issuing a permit to determine if there is the potential for a significant impact, and if so, to mitigate the impact or possibly deny the project.

- **Land Use Permitting Process**

In California, the authority to regulate land use is delegated to city and county governments. The local land use planning agency is the local government administrative body that typically provides information and coordinates the review of development project applications. Conditional Use Permits (CUP) typically fall within a land use agency's discretionary authority and therefore are subject to CEQA. CUPs are

intended to provide an opportunity to review the location, design, and manner of development of land uses prior to project approval. A traditional purpose of the CUP is to enable a municipality to control certain uses that could have detrimental environmental effects on the community.

The process for permitting new discretionary projects is quite elaborate, but can be broken down into five fundamental components:

- Project application
- Environmental assessment
- Consultation
- Public comment
- Public hearing and decision

Project Application

The permit process begins when the land use agency receives a project application with a detailed project description, and support documentation. During this phase, the agency reviews the submitted application for completeness. When the agency deems the application to be complete, the permit process moves into the environmental review phase.

Environmental Assessment

If the project is discretionary and the application is accepted as complete, the project proposal or activity must undergo an environmental clearance process under CEQA and the CEQA Guidelines adopted by the California Resources Agency.[2] The purpose of the CEQA process is to inform decision-makers and the public of the potential significant environmental impacts of a project or activity, to identify measures to minimize or eliminate those impacts to the point they are no longer significant, and to discuss alternatives that will accomplish the project goals and objectives in a less environmentally harmful manner.

What is a "Lead Agency"?

A lead agency is the public agency that has the principal responsibility for carrying out or approving a project that is subject to CEQA. In general, the land use agency is the preferred public agency serving as lead agency because it has jurisdiction over general land uses. The lead agency is responsible for determining the appropriate environmental document, as well as its preparation.

What is a "Responsible Agency"?

A responsible agency is a public agency with discretionary approval authority over a portion of a CEQA project (e.g., projects requiring a permit). As a responsible agency, the agency is available to the lead agency and project proponent for early consultation on a project to apprise them of applicable rules and regulations, potential adverse impacts, alternatives, and mitigation measures, and provide guidance as needed on applicable methodologies or other related issues.

What is a "Commenting Agency"?

A commenting agency is any public agency that comments on a CEQA document, but is neither a lead agency nor a responsible agency. For example, a local air district, as the agency with the responsibility for comprehensive air pollution control, could review and comment on an air quality analysis in a CEQA document for a proposed distribution center, even though the project was not subject to a permit or other pollution control requirements.

[2] Projects and activities that may have a significant adverse impact on the environment are evaluated under CEQA Guidelines set forth in title 14 of the California Code of Regulations, sections 15000 et seq.

To assist the lead agency in determining whether the project or activity may have a significant effect that would require the preparation of an EIR, the land use agency may consider criteria, or thresholds of significance, to assess the potential impacts of the project, including its air quality impacts. The land use agency must consider any credible evidence in addition to the thresholds, however, in determining whether the project or activity may have a significant effect that would trigger the preparation of an EIR.

The screening criteria to determine significance is based on a variety of factors, including local, state, and federal regulations, administrative practices of other public agencies, and commonly accepted professional standards. However, the final determination of significance for individual projects is the responsibility of the lead agency. In the case of land use projects, the lead agency would be the City Council or County Board of Supervisors.

A new land use plan or project can also trigger an environmental assessment under CEQA if, among other things, it will expose sensitive sites such as schools, day care centers, hospitals, retirement homes, convalescence facilities, and residences to substantial pollutant concentrations.[3]

CEQA only applies to "discretionary projects." Discretionary means the public agency must exercise judgment and deliberation when deciding to approve or disapprove a particular project or activity, and may append specific conditions to its approval. Examples of discretionary projects include the issuance of a CUP, re-zoning a property, or widening of a public road. Projects that are not subject to the exercise of agency discretion, and can therefore be approved administratively through the application of set standards are referred to as ministerial projects. CEQA does not apply to ministerial projects.[4] Examples of typical ministerial projects include the issuance of most building permits or a business license.

Once a potential environmental impact associated with a project is identified through an environmental assessment, mitigation must be considered. A land use agency should incorporate mitigation measures that are suggested by the local air district as part of the project review process.

Consultation

Application materials are provided to various departments and agencies that may have an interest in the project (e.g., air pollution, building, police, fire, water agency, Fish and Game, etc.) for consultation and input.

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[3] Readers interested in learning more about CEQA should contact OPR or visit their website at http://www.opr.ca.gov/.

[4] See California Public Resources Code section 21080(b)(1).

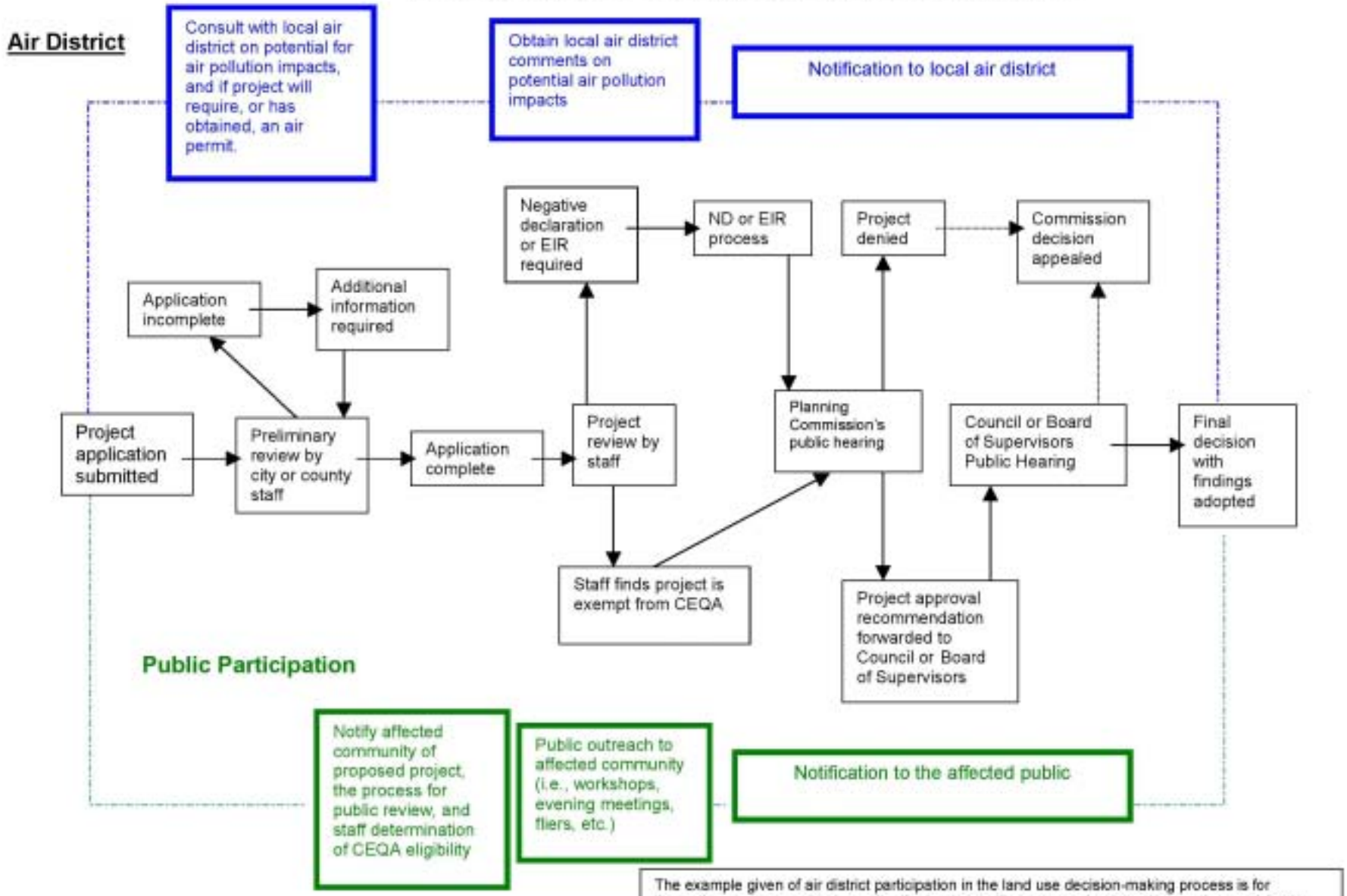
Pub ic Comment

Fo low ng the environmental rev ew process, the P anning Commission reviews application along with the staff's report on the project assessment and a public comment period is set and input s solicited.

Pub ic Hearing and Decis on

Permit rules vary depending on the particular permit authority in question but the process generally involves comparing the proposed project with the land use agency standards or policies The procedure usually leads to a pub ic hearing which is followed by a written decision by the agency or its designated off cer Typically, a project is approved denied, or approved subject to specified condit ons

USE PERMIT (DISCRETIONARY ACTION) REVIEW PROCESS*



The example given of air district participation in the land use decision-making process is for illustrative purposes only. In reality, the land use siting process involves the ongoing participation of multiple affected agencies and stakeholders throughout the process.

GLOSSARY OF KEY AIR POLLUTION TERMS

Air Pollution Control Board or Air Quality Management Board: Serves as the governing board for local air districts. It consists of appointed or elected members from the public or private sector. It conducts public hearings to adopt local air pollution regulations.

Air Pollution Control Districts or Air Quality Management Districts (local air district): A county or regional agency with authority to regulate stationary and area sources of air pollution within a given county or region. Governed by a district air pollution control board.

Air Pollution Control Officer (APCO): Head of a local air pollution control or air quality management district.

Air Toxic Control Measures (ATCM): A control measure adopted by the ARB (Health and Safety Code section 39666 et seq.), which reduces emissions of toxic air contaminants.

Ambient Air Quality Standards: An air quality standard defines the maximum amount of a pollutant that can be present in the outdoor air during a specific time period without harming the public's health. Only U.S. EPA and the ARB may establish air quality standards. No other state has this authority. Air quality standards are a measure of clean air. More specifically, an air quality standard establishes the concentration at which a pollutant is known to cause adverse health effects to sensitive groups within the population, such as children and the elderly. Federal standards are referred to as National Ambient Air Quality Standards (NAAQS), state standards are referred to as California ambient air quality standards (CAAQS).

Area-wide Sources: Sources of air pollution that individually emit small amounts of pollution, but together add up to significant quantities of pollution. Examples include consumer products, fireplaces, road dust, and farming operations.

Attainment vs. Nonattainment Area: An attainment area is a geographic area that meets the National Ambient Air Quality Standards for the criteria pollutants and a non-attainment area is a geographic area that doesn't meet the NAAQS for criteria pollutants.

Attainment Plan: Attainment plans lay out measures and strategies to attain one or more air quality standards by a specified date.

California Clean Air Act (CCAA): A California law passed in 1988, which provides the basis for air quality planning and regulation independent of federal regulations. A major element of the Act is the requirement that local air districts in violation of the CAAQS

must prepare attainment plans which identify air quality problems, causes, trends, and actions to be taken to attain and maintain California's air quality standards by the earliest practicable date.

California Environmental Quality Act (CEQA): A California law that sets forth a process for public agencies to make informed decisions on discretionary project approvals. The process helps decision-makers determine whether any potential, significant, adverse environmental impacts are associated with a proposed project and to identify alternatives and mitigation measures that will eliminate or reduce such adverse impacts.[1]

California Health and Safety Code: A compilation of California laws, including state air pollution laws, enacted by the Legislature to protect the health and safety of people in California. Government agencies adopt regulations to implement specific provisions of the California Health and Safety Code.

Clean Air Act (CAA): The federal Clean Air Act was adopted by the United States Congress and sets forth standards, procedures, and requirements to be implemented by the U.S. Environmental Protection Agency (U.S. EPA) to protect air quality in the United States.

Councils of Government (COGs): There are 25 COGs in California made up of city and county elected officials. COGs are regional agencies concerned primarily with transportation planning and housing; they do not directly regulate land use.

Criteria Air Pollutant: An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM10 and PM2.5. The term "criteria air pollutants" derives from the requirement that the U.S. EPA and ARB must describe the characteristics and potential health and welfare effects of these pollutants. The U.S. EPA and ARB periodically review new scientific data and may propose revisions to the standards as a result.

District Hearing Board: Hears local air district permit appeals and issues variances and abatement orders. The local air district board appoints the members of the hearing board.

Emission Inventory: An estimate of the amount of pollutants emitted into the atmosphere from mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year.

Environmental Impact Report (EIR): The public document used by a governmental agency to analyze the significant environmental effects of a proposed project, to identify

[1] To track the submittal of CEQA documents to the State Clearinghouse within the Office of Planning and Research, the reader can refer to CEQAnet at http://www.ceqanet.ca.gov.

alternatives and to disclose possible ways to reduce or avoid the possible negative environmental impacts

Environmental Justice: California law defines environmental justice as the "fair treatment of people of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (California Government Code sec.65040.12(c)).

General Plans: A statement of policies developed by local governments, including text and diagrams setting forth objectives, principles, standards, and plan proposals for the future physical development of the city or county

Hazardous Air Pollutants (HAPs): An air pollutant listed under section 112 (b) of the federal Clean Air Act as particularly hazardous to health. U.S. EPA identifies emission sources of hazardous air pollutants, and emission standards are set accordingly. In California, HAPs are referred to as toxic air contaminants

Land Use Agency: Local government agency that performs functions associated with the review, approval, and enforcement of general plans and plan elements, zoning, and land use permitting. For purposes of this Handbook, a land use agency is typically a local planning department

Mobile Source: Sources of air pollution such as automobiles, motorcycles, trucks, off-road vehicles, boats, and airplanes.

National Ambient Air Quality Standard (NAAQS): A limit on the level of an outdoor air pollutant established by the US EPA pursuant to the Clean Air Act. There are two types of NAAQS. Primary standards set limits to protect public health and secondary standards set limits to protect public welfare

Negative Declaration (ND): When the lead agency (the agency responsible for preparing the EIR or ND) under CEQA, finds that there is no substantial evidence that a project may have a significant environmental effect, the agency will prepare a "negative declaration" instead of an EIR.

New Source Review (NSR): A federal Clean Air Act requirement that state implementation plans must include a permit review process, which applies to the construction and operation of new or modified stationary sources in nonattainment areas. Two major elements of NSR to reduce emissions are best available control technology requirements and emission offsets.

Office of Planning and Research (OPR): OPR is part of the Governor's office. OPR has a variety of functions related to local land-use planning and environmental programs. It provides General Plan Guidelines for city and county planners, and coordinates the state clearinghouse for Environmental Impact Reports

Ordinance: A law adopted by a City Council or County Board of Supervisors. Ordinances usually amend, repeal or supplement the municipal code, provide zoning specifications, or appropriate money for specific purposes.

Overriding Considerations: A ruling made by the lead agency in the CEQA process when the lead agency finds the importance of the project to the community outweighs potential adverse environmental impacts.

Public Comment: An opportunity for the general public to comment on regulations and other proposals made by government agencies. You can submit written or oral comments at the public meeting or send your written comments to the agency.

Public Hearing: A public hearing is an opportunity to testify on a proposed action by a governing board at a public meeting. The public and the media are welcome to attend the hearing and listen to, or participate in, the proceedings.

Public Notice: A public notice identifies the person, business, or local government seeking approval of a specific course of action (such as a regulation). It describes the activity for which approval is being sought, and describes the location where the proposed activity or public meeting will take place.

Public Nuisance: A public nuisance, for the purposes of air pollution regulations, is defined as a discharge from any source whatsoever of such quantities of air contaminants or other material which cause injury, detriment, nuisance, or annoyance to any considerable number of persons or to the public, or which endanger the comfort, repose, health, or safety of any such persons or the public, or which cause, or have a natural tendency to cause, injury or damage to business or property. (Health and Safety Code section 41700)

Property Setback: In zoning parlance, a setback is the minimum amount of space required between a lot line and a building line.

Risk: For cancer health effects, risk is expressed as an estimate of the increased chances of getting cancer due to facility emissions over a 70 year lifetime. This increase in risk is expressed as chances in a million (e.g. 10 chances in a million).

Sensitive Individuals: Refers to those segments of the population most susceptible to poor air quality (i.e., children, the elderly, and those with pre-existing serious health problems affected by air quality).

Sensitive Sites or Sensitive Land Uses: Land uses where sensitive individuals are most likely to spend time, including schools and schoolyards, parks and playgrounds, day care centers, nursing homes, hospitals, and residential communities.

Setback: An area of land separating one parcel of land from another that acts to soften or mitigate the effects of one land use on the other.

State Implementation Plan (SIP): A plan prepared by state and local agencies and submitted to U.S. EPA describing how each area will attain and maintain national ambient air quality standards. SIPs include the technical information about emission inventories, air quality monitoring, control measures and strategies, and enforcement mechanisms. A SIP is composed of local air quality management plans and state air quality regulations.

Stationary Sources: Non-mobile sources such as power plants, refineries, and manufacturing facilities.

Toxic Air Contaminant (TAC): An air pollutant identified in regulation by the ARB, which may cause or contribute to an increase in deaths or in serious illness, or which may pose a present or potential hazard to human health. TACs are considered under a different regulatory process (California Health and Safety Code section 39650 et seq.) than pollutants subject to State Ambient Air Quality Standards. Health effects associated with TACs may occur at extremely low levels. It is often difficult to identify safe levels of exposure, which produce no adverse health effects.

Urban Background: The term is used in this Handbook to represent the ubiquitous elevated, regional air pollution levels observed in large urban areas in California.

Zoning ordinances: City councils and county boards of supervisors adopts zoning ordinances that set forth land use classifications, divides the county or city into land use zones as delineated on the official zoning maps, and set enforceable standards for future develop

Ambient Air Quality Standards

Pollutant	Averaging Time	California Standards [1]		National Standards [2]		
		Concentration [3]	Method [4]	Primary [3,5]	Secondary [3,6]	Method [7]
Ozone (O_3)	1 Hour	0.09 ppm (180 µg/m^3)	Ultraviolet Photometry	—	Same as Primary Standard	Ultraviolet Photometry
	8 Hour	0.070 ppm (137 µg/m^3)		0.075 ppm (147 µg/m^3)		
Respirable Particulate Matter (PM10)[8]	24 Hour	50 µg/m^3	Gravimetric or Beta Attenuation	150 µg/m^3	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	20 µg/m^3		—		
Fine Particulate Matter (PM2.5)[8]	24 Hour	—	—	35 µg/m^3	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	12 µg/m^3	Gravimetric or Beta Attenuation	12.0 µg/m^3	15 µg/m^3	
Carbon Monoxide (CO)	1 Hour	20 ppm (23 mg/m^3)	Non-Dispersive Infrared Photometry (NDIR)	35 ppm (40 mg/m^3)	—	Non-Dispersive Infrared Photometry (NDIR)
	8 Hour	9.0 ppm (10 mg/m^3)		9 ppm (10 mg/m^3)	—	
	8 Hour (Lake Tahoe)	6 ppm (7 mg/m^3)		—	—	
Nitrogen Dioxide (NO_2)[9]	1 Hour	0.18 ppm (339 µg/m^3)	Gas Phase Chemiluminescence	100 ppb (188 µg/m^3)	—	Gas Phase Chemiluminescence
	Annual Arithmetic Mean	0.030 ppm (57 µg/m^3)		0.053 ppm (100 µg/m^3)	Same as Primary Standard	
Sulfur Dioxide (SO_2)[10]	1 Hour	0.25 ppm (655 µg/m^3)	Ultraviolet Fluorescence	75 ppb (196 µg/m^3)	—	Ultraviolet Flourescence; Spectrophotometry (Pararosaniline Method)
	3 Hour	—		—	0.5 ppm (1300 µg/m^3)	
	24 Hour	0.04 ppm (105 µg/m^3)		0.14 ppm (for certain areas)[10]	—	
	Annual Arithmetic Mean	—		0.030 ppm (for certain areas)[10]	—	
Lead[11,12]	30 Day Average	1.5 µg/m^3	Atomic Absorption	—	—	High Volume Sampler and Atomic Absorption
	Calendar Quarter	—		1.5 µg/m^3 (for certain areas)[12]	Same as Primary Standard	
	Rolling 3-Month Average	—		0.15 µg/m^3		
Visibility Reducing Particles[13]	8 Hour	See footnote 13	Beta Attenuation and Transmittance through Filter Tape	No National Standards		
Sulfates	24 Hour	25 µg/m^3	Ion Chromatography			
Hydrogen Sulfide	1 Hour	0.03 ppm (42 µg/m^3)	Ultraviolet Fluorescence			
Vinyl Chloride[11]	24 Hour	0.01 ppm (26 µg/m^3)	Gas Chromatography			

See footnotes on next page …

1. California standards for ozone, carbon monoxide (except 8-hour Lake Tahoe), sulfur dioxide (1 and 24 hour), nitrogen dioxide, and particulate matter (PM10, PM2.5, and visibility reducing particles) are values that are not to be exceeded. All others are not to be equaled or exceeded. California ambient air quality standards are listed in the Table of Standards in Section 70200 of Title 17 of the California Code of Regulations.

2. National standards (other than ozone, particulate matter, and those based on annual arithmetic means) are not to be exceeded more than once per year. The ozone standard is attained when the fourth-highest 8-hour concentration measured at each site in a year, averaged over three years, is equal to or less than the standard. For PM10, the 24-hour standard is attained when expected number of days per calendar year with a 24-hour average concentration above 150 µg/m^3 is equal to or less than one. For PM2.5, the 24-hour standard is attained when 98 percent of the daily concentrations, averaged over three years, are equal to or less than the standard. Contact the U.S. EPA for further clarification and current national policies.

3. Concentration expressed first in units in which it was promulgated. Equivalent units given in parentheses are based upon a reference temperature of 25°C and a reference pressure of 760 torr. Most measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 torr; ppm in this standard refers to ppm by volume, or micromoles of pollutant per mole of gas.

4. Any equivalent measurement method which can be shown to the satisfaction of the ARB to give equivalent results at or near the level of the air quality standard may be used.

5. National Primary Standards: The levels of air quality necessary, with an adequate margin of safety, to protect the public health.

6. National Secondary Standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

7. Reference method as described by the U.S. EPA. An "equivalent method" of measurement may be used but must have a correlation, relationship, or conversion factor that has been approved by the U.S. EPA.

8. On December 14, 2012, the national annual PM2.5 primary standard was lowered from 15 µg/m^3 to 12.0 µg/m^3. The existing national 24-hour PM2.5 standards (primary and secondary) were retained at 35 µg/m^3, as was the annual secondary standard of 15 µg/m^3. The existing 24-hour PM10 standards (primary and secondary) of 150 µg/m^3 also were retained. The form of the annual primary and secondary standards is the annual mean, averaged over 3 years.

9. To attain the 1-hour national standard, the 3-year average of the annual 98th percentile of the 1-hour daily maximum concentrations at each site must not exceed 0.12 ppm. Note that the national 1-hour standard is in units of parts per million (ppm). To directly compare the national 1-hour standard to the California standards the units can be converted from ppm to pphm. To convert from ppm to pphm, move the decimal point one place to the right (0.12 ppm = 12 pphm).

10. On June 2, 2010, a new 1-hour SO2 standard was established and the existing 24-hour and annual primary standards were revoked. To attain the 1-hour national standard, the 3-year average of the annual 99th percentile of the 1-hour daily maximum concentrations at each site must not exceed 75 ppb. The 1971 SO2 national standards (24-hour and annual) remain in effect until 1 year after an area is designated for the 2010 standard, except that in areas designated nonattainment for the 1971 standard, the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.

   Note that the 1-hour national standard is in units of parts per billion (ppb). California standards are in units of parts per million (ppm). To directly compare the 1-hour national standard to the California standards the units can be converted to ppm. To convert from the 1-hour national standard of 75 ppb, move the decimal point three places to the left (75 ppb = 0.075 ppm).

11. The ARB has identified sulfates, hydrogen sulfide, vinyl chloride, and visibility reducing particles as toxic air contaminants with no threshold level of exposure for adverse health effects determined. These actions allow for the implementation of control measures at levels below the ambient concentrations specified for these pollutants.

12. The national standard for lead was revised on October 15, 2008 to a rolling 3-month average. The 1978 lead standard (1.5 µg/m^3 as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978 standard, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

13. In 1989, the ARB converted both the general statewide 10-mile visibility standard and the Lake Tahoe 30-mile visibility standard to instrumental equivalents, which are "extinction of 0.23 per kilometer" and "extinction of 0.07 per kilometer" for the statewide and Lake Tahoe Air Basin standards, respectively.

2010 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2010

Source/Receptor Area No.	Location	Station No.	Carbon Monoxide[a]			Ozone									Nitrogen Dioxide[b]				Sulfur Dioxide[c]		
										No. Days Standard Exceeded										
											Federal		State								
			No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 8-hour	No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 8-hour	Fourth High Conc. ppm 8-hour	Health Advisory ≥ 0.15 ppm 1-hour	Old > 0.12 ppm 1-hour	Current > 0.075 ppm 8-hour	Current > 0.09 ppm 1-hour	Current > 0.070 ppm 8-hour	No. Days of Data	Max. Conc. in ppb 1-hour	98th Percentile Conc. ppb 1-hour	Annual Average AAM Conc. ppb	No. Days of Data	Max. Conc. in ppb 1-hour	Max. Conc. in ppb 24-hour
LOS ANGELES COUNTY																					
1	Central LA	087	364	3	2.3	357	0.098	0.080	0.064	0	0	1	1	1	364	89.0	70.5	25.0	355	9.8	1.5
2	Northwest Coastal LA County	091	364	2	1.4	360	0.099	0.078	0.069	0	0	1	2	4	365	70.8	57.4	15.6	--	--	--
3	Southwest Coastal LA County	820	344	3	2.2	319	0.089	0.070	0.059	0	0	0	0	1	358	75.8	60.9	12.1	327	25.9	3.5
4	South Coastal LA County 1	072	358	3	2.1	358	0.101	0.084	0.057	0	0	1	1	1	360	92.8	70.2	19.8	329	40.0	6.0
4	South Coastal LA County 2	077	--	--	--	--	--	--	--	--	--	--	--	--	--			--	--	--	--
6	West San Fernando Valley	074	365	3	2.6	295	0.122	0.091	0.086	0	0	19	11	40	365	75.0	56.0	16.7	--	--	--
7	East San Fernando Valley	069	364	3	2.4	317	0.111	0.084	0.076	0	0	4	3	11	359	82.0	64.3	24.1	233*	14.9	4.1
8	West San Gabriel Valley	088	355	3	2.0	325	0.101	0.081	0.075	0	0	3	1	6	355	71.0	63.0	19.6	--	--	--
9	East San Gabriel Valley 1	060	355	3	1.3	356	0.104	0.081	0.075	0	0	3	5	10	364	77.2	59.6	18.5	--	--	--
9	East San Gabriel Valley 2	591	360	2	1.3	350	0.124	0.099	0.090	0	0	20	25	48	360	78.5	55.5	15.4	--	--	--
10	Pomona/Walnut Valley	075	365	3	1.8	342	0.115	0.082	0.076	0	0	4	9	20	365	97.0	72.5	26.2	--	--	--
11	South San Gabriel Valley	085	364	2	1.9	358	0.112	0.086	0.059	0	0	1	1	1	364	79.0	65.4	22.9	--	--	--
12	South Central LA County	112	353	6	3.6	358	0.081	0.062	0.050	0	0	0	0	0	364	76.8	68.8	17.9	--	--	--
13	Santa Clarita Valley	090	355	2	1.1	331	0.126	0.105	0.087	0	1	23	18	44	364	59.3	54.2	14.3	--	--	--
ORANGE COUNTY																					
16	North Orange County	3177	356	3	1.8	351	0.118	0.096	0.071	0	0	1	2	4	333	82.5	61.6	20.1	--	--	--
17	Central Orange County	3176	358	3	2.0	331	0.104	0.088	0.060	0	0	1	1	1	364	73.3	61.1	17.5	--	--	--
18	North Coastal Orange County	3195	364	2	2.1	353	0.097	0.076	0.060	0	0	1	1	2	364	70.0	56.0	11.3	348	9.5	2.1
19	Saddleback Valley	3812	362	1	0.9	353	0.117	0.082	0.069	0	0	2	2	2	--			--	--	--	--
RIVERSIDE COUNTY																					
22	Norco/Corona	4155	--	--	--	--	--	--	--	--	--	--	--	--	--			--	--	--	--
23	Metropolitan Riverside County 1	4144	364	3	1.8	341	0.128	0.098	0.092	0	1	47	31	78	333	64.5	57.0	16.8	349	17.6	4.6
23	Metropolitan Riverside County 2	4146	355	3	1.7	--	--	--	--	--	--	--	--	--	361	60.8	51.5	17.2	--	--	--
23	Mira Loma	4165	360	3	1.9	324	0.121	0.094	0.090	0	0	38	22	63	365	62.2	50.3	15.1	--	--	--
24	Perris Valley	4149	--	--	--	343	0.122	0.107	0.099	0	0	50	42	82	--			--	--	--	--
25	Lake Elsinore	4158	363	1	0.6	355	0.107	0.091	0.086	0	0	24	15	42	363	51.2	40.6	10.1	--	--	--
29	Banning Airport	4164	--	--	--	328	0.124	0.107	0.099	0	0	60	31	84	365	65.7	53.2	11.6	--	--	--
30	Coachella Valley 1**	4137	365	2	0.5	361	0.114	0.099	0.092	0	0	52	23	83	365	45.7	39.0	8.5	--	--	--
30	Coachella Valley 2**	4157	--	--	--	348	0.100	0.087	0.084	0	0	19	7	47	--			--	--	--	--
SAN BERNARDINO COUNTY																					
32	Northwest San Bernardino Valley	5175	353	2	1.8	349	0.131	0.097	0.090	0	1	39	31	59	365	78.9	58.0	20.4	--	--	--
33	Southwest San Bernardino Valley	5817	--	--	--	--	--	--	--	--	--	--	--	--	--			--	--	--	--
34	Central San Bernardino Valley 1	5197	359	3	1.4	350	0.143	0.100	0.094	0	2	33	28	55	363	71.9	64.8	23.1	330*	6.6	1.6
34	Central San Bernardino Valley 2	5203	326	2	1.7	354	0.129	0.105	0.095	0	1	40	27	63	365	69.2	56.6	18.8	--	--	--
35	East San Bernardino Valley	5204	--	--	--	363	0.128	0.112	0.097	0	1	61	43	86	--			--	--	--	--
37	Central San Bernardino Mountains	5181	--	--	--	364	0.142	0.123	0.109	0	6	74	52	101	--			--	--	--	--
38	East San Bernardino Mountains	5818	--	--	--	--	--	--	--	--	--	--	--	--	--			--	--	--	--
DISTRICT MAXIMUM				6	3.6		0.143	0.123	0.109	0	6	74	52	101		97.0	72.5	26.2		40.0	6.0
SOUTH COAST AIR BASIN				6	3.6		0.143	0.123	0.109	0	7	102	79	131		97.0	72.5	26.2		40.0	6.0

ppm - Parts Per Million parts of air, by volume ppb – Parts Per Billion parts of air, by volume AAM = Annual Arithmetic Mean --- Pollutant not monitored

** Salton Sea Air Basin

- In 2010, the State and Federal Ambient Air Quality Standards were met for the gaseous pollutants CO, NO2 and SO2 at all District regular monitoring sites, listed above.
  a) - The federal 8-hour standard is 8-hour average CO > 9 ppm and state 8-hour standard is 8-hour average CO > 9.0 ppm. The federal and state 1-hour standards are 35 ppm and 20 ppm.
  b) - The NO2 federal 1-hour standard is 100 ppb and the annual standard is annual arithmetic mean NO_2 > 0.0534 ppm. The state 1-hour and annual standards are 0.18 ppm and 0.030 ppm.
  c) - The federal SO2 1-hour standard is 75 ppb (0.075 ppm). The state standards are 1-hour average SO_2 > 0.25 ppm and 24-hour average SO_2 > 0.04 ppm.
- Revised/New Standards in 2010:
  -- U.S. EPA established the new NO2 1-hour federal standard of 100 ppb (0.100 ppm), effective April 7, 2010.
  -- U.S. EPA revised the SO2 federal standard by establishing the new 1-hour standard of 75 ppb (0.075 ppm) and revoking the existing annual (0.03 ppm) and 24-hour (0.14 ppm) standards, effective August 2, 2010.

South Coast Air Quality Management District
21865 Copley Drive
Diamond Bar, CA 91765-4182
www.aqmd.gov

2010 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2010

Source/Receptor Area No.	Location	Station No.	Suspended Particulates PM10 [d] No. Days of Data	Max. Conc. in µg/m³ 24-hour	No. (%) Samples Exceeding Standards Federal > 150 µg/m³ 24-hour	No. (%) Samples Exceeding Standards State > 50 µg/m³ 24-hour	Annual Average Conc. (AAM) µg/m³	Fine Particulates PM2.5 [e] No. Days of Data	Max. Conc. in µg/m³ 24-hour	98th Percentile Conc. in µg/m³ 24-hour	No. (%) Samples Exceeding Federal Std > 35 µg/m³ 24-hour	Annual Average Conc. (AAM) µg/m³	Particulates TSP [f] No. Days of Data [e]	Max. Conc. in µg/m³ 24-hour	Annual Average Conc. (AAM) µg/m³	Lead [f] Max. Monthly Average Conc. µg/m³	Max. Quarterly Average Conc. µg/m³	Sulfate [f] Max. Conc. in µg/m³ 24-hour	No. Days Exceeding State Std ≥ 25 µg/m³ 24-hour
LOS ANGELES COUNTY																			
1	Central LA	087	55	42	0	0	27.1	335	39.2	27.1	2(0.6%)	11.9	53	105	53.3	0.02	0.01	9.1	0
2	Northwest Coastal LA County	091	--	--	--	--	--	--	--	--	--	--	59	82	40.8	--	--	7.5	0
3	Southwest Coastal LA County	820	55	37	0	0	20.6	--	--	--	--	--	55	85	36.7	0.01	0.01	9.7	0
4	South Coastal LA County 1	072	58	44	0	0	22.0	338	35.0	28.3	0	10.5	60	129	45.5	0.01	0.01	11.8	0
4	South Coastal LA County 2	077	59	76	0	2(3.4%)	27.3	351	33.7	26.5	0	10.4	57	130	50.8	0.01	0.01	12.2	0
6	West San Fernando Valley	074	--	--	--	--	--	100	40.7	30.4	1(1.0%)	10.2	--	--	--	--	--	--	--
7	East San Fernando Valley	069	55	51	0	1(1.8%)	29.6	322	43.7	31.8	4(1.2%)	12.5	--	--	--	--	--	--	--
8	West San Gabriel Valley	088	--	--	--	--	--	97	35.2	24.0	0	10.2	58	58	36.4	--	--	7.7	0
9	East San Gabriel Valley 1	080	55	70	0	5(9.1%)	29.8	93	44.4	35.4	1(1.1%)	10.9	53	136	58.2	--	--	6.4	0
9	East San Gabriel Valley 2	591	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	Pomona/Walnut Valley	075	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	South San Gabriel Valley	085	--	--	--	--	--	117	34.9	32.0	0	12.5	59	263	86.1	0.02	0.01	8.5	0
12	South Central LA County	112	--	--	--	--	--	111	38.2	31.8	1(0.9%)	12.5	58	94	49.2	0.01	0.01	7.8	0
13	Santa Clarita Valley	090	57	40	0	0	21.0	--	--	--	--	--	--	--	--	--	--	--	--
ORANGE COUNTY																			
16	North Orange County	3177	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	Central Orange County	3176	57	43	0	0	22.4	331	31.7	25.2	0	10.2	--	--	--	--	--	--	--
18	North Coastal Orange County	3195	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	Saddleback Valley	3812	58	34	0	0	18.1	116	19.9	17.3	0	8.0	--	--	--	--	--	--	--
RIVERSIDE COUNTY																			
22	Norco/Corona	4155	61	50	0	0	27.2	--	--	--	--	--	--	--	--	--	--	--	--
23	Metropolitan Riverside County 1	4144	122	75	0	7(5.7%)	32.8	351	46.5	32.0	4(1.1%)	13.2	60	131	64.3	0.01	0.01	6.7	0
23	Metropolitan Riverside County 2	4146	--	--	--	--	--	115	43.7	27.3	2(1.7%)	11.0	59	88	45.0	0.01	0.01	5.0	0
23	Mira Loma	4165	60	89	0	25(41.7%)	42.3	340	54.2	36.1	8(2.4%)	15.2	--	--	--	--	--	--	--
24	Perris Valley	4149	61	51	0	1(1.6%)	28.0	--	--	--	--	--	--	--	--	--	--	--	--
25	Lake Elsinore	4158	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	Banning Airport	4164	60	55	0	1(1.7%)	21.8	--	--	--	--	--	--	--	--	--	--	--	--
30	Coachella Valley 1**	4137	61	37	0	0	18.7	111	12.8	12.6	0	6.0	--	--	--	--	--	--	--
30	Coachella Valley 2**	4157	119	107	0	6(5%)	29.3	112	16.0	12.2	0	6.8	--	--	--	--	--	--	--
SAN BERNARDINO COUNTY																			
32	Northwest San Bernardino Valley	5175	--	--	--	--	--	--	--	--	--	--	59	86	46.7	0.01	0.01	10.1	0
33	Southwest San Bernardino Valley	5817	60	87	0	3(5%)	31.8	112	46.1	31.2	1(0.9%)	13.0	--	--	--	--	--	--	--
34	Central San Bernardino Valley 1	5197	53	62	0	3(5.7%)	33.9	112	42.6	30.8	2(1.8%)	12.0	61	142	73.3	--	--	6.3	0
34	Central San Bernardino Valley 2	5203	59	63	0	3(5.1%)	32.4	119	39.3	29.7	2(1.7%)	11.1	60	106	57.7	0.01	0.01	11.4	0
35	East San Bernardino Valley	5204	58	57	0	1(1.7%)	25.8	--	--	--	--	--	--	--	--	--	--	--	--
37	Central San Bernardino Mountains	5181	57	39	0	0	18.9	--	--	--	--	--	--	--	--	--	--	--	--
38	East San Bernardino Mountains	5818	--	--	--	--	--	53	35.4	27.5	0	8.4	--	--	--	--	--	--	--
	DISTRICT MAXIMUM			107	0	25	42.3		54.2	36.1	8	15.2		265	86.1	0.02	0.01	12.2	0
	SOUTH COAST AIR BASIN			89	0	34	42.3		54.2	36.1	13	15.2		265	86.1	0.02	0.01	12.2	0

** Salton Sea Air Basin µg/m³ - Micrograms per cubic meter of air AAM = Annual Arithmetic Mean -- - Pollutant not monitored

- In 2010, Particulate Matter concentrations met the Ambient Air Quality Standard levels for the federal PM10 Standard, the State and Federal Lead Standards, and the State Sulfate standard at the regular monitoring sites, listed above.

d) - PM10 samples were collected every 6 days at all sites except for Station Numbers 4144 and 4157, where samples were collected every 3 days. The Federal annual PM10 standard (AAM > 50 µg/m³) was revoked in 2006. State standard is annual average (AAM) > 20 µg/m³.

e) - PM2.5 samples were collected every 3 days at all sites except for station numbers 069, 072, 077, 087, 3176, 4144 and 4165, where samples were taken daily, and station number 5818 where samples were taken every 6 days. Federal annual PM2.5 standard is annual average (AAM) > 15.0 µg/m³. State standard is annual average (AAM) > 12.0 µg/m³.

f) - TSP Particulate, Lead and Sulfate samples were taken every 6 days at all sites monitored.

- Federal Equivalent Method (FEM) continuous monitoring instruments were operated at some of the above locations for PM10 and PM2.5 monitoring. The Federal Reference Method (FRM) data is used for the above statistics.

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For information on the current standard levels and most recent revisions please refer to the previous year "Air Quality" summary card or access the "Ambient Air Quality Standards" chart at http://www.arb.ca.gov/research/aaqs/aaqs2.pdf.

Maps showing the source/receptor area boundaries can be accessed via the Internet by entering your address in the AQMD Current Hourly Air Quality Map, accessed from http://www2.aqmd.gov/webappl/pisaq2/VEMap3D.aspx or at http://www.aqmd.gov/map/MapAQMD2.pdf. A map is also available free of charge from the AQMD Public Information Center at 1-800-CUT-SMOG.

2009 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2009

Source/Receptor Area No.	Location	Station No.	Carbon Monoxide[a]			Ozone									Nitrogen Dioxide[d]				Sulfur Dioxide[e]		
										No. Days Standard Exceeded										
												Federal[b]		State[c]							
			No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 8-hour	No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 8-hour	Fourth High Conc. ppm 8-hour	Health Advisory ≥ 0.15 ppm 1-hour	Old > 0.12 ppm 1-hour	Current > 0.075 ppm 8-hour	Current > 0.09 ppm 1-hour	Current > 0.070 ppm 8-hour	No. Days of Data	Max. Conc. in ppm 1-hour	98th Percentile Conc. ppm 1-hour	Annual Average AAM Conc. ppm	No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 24-hour
LOS ANGELES COUNTY																					
1	Central LA	087	357	3	2.2	365	0.139	0.100	0.073	0	1	2	3	5	365	0.12	0.07	0.0281	365	0.01	0.002
2	Northwest Coastal LA County	091	365	2	1.5	365	0.131	0.094	0.075	0	1	3	6	5	355	0.08	0.06	0.0170	--	--	--
3	Southwest Coastal LA County	820	349	2	1.9	352	0.077	0.070	0.061	0	0	0	0	0	362	0.08	0.07	0.0159	362	0.02	0.006
4	South Coastal LA County 1	072	362	3	2.2	363	0.089	0.068	0.064	0	0	0	0	0	362	0.11	0.07	0.0212	361	0.02	0.005
4	South Coastal LA County 2	077	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	West San Fernando Valley	074	365	4	2.8	365	0.135	0.100	0.093	0	1	19	15	31	365	0.07	0.06	0.0171	--	--	--
7	East San Fernando Valley	069	365	3	2.9	365	0.145	0.096	0.086	1	1	14	16	28	353	0.09	0.07	0.0274	362	0.01	0.003
8	West San Gabriel Valley	008	365	4	2.1	365	0.176	0.114	0.095	1	3	12	12	19	365	0.08	0.06	0.0221	--	--	--
9	East San Gabriel Valley 1	060	357	3	1.7	365	0.150	0.107	0.091	1	4	17	23	32	365	0.10	0.07	0.0194	--	--	--
9	East San Gabriel Valley 2	591	351	3	2.1	352	0.150	0.118	0.108	3	7	42	45	64	350	0.09	0.06	0.0170	--	--	--
10	Pomona/Walnut Valley	075	365	3	1.8	365	0.138	0.099	0.095	0	1	23	25	37	365	0.10	0.08	0.0274	--	--	--
11	South San Gabriel Valley	085	365	3	2.1	365	0.131	0.101	0.072	0	1	3	8	6	361	0.10	0.07	0.0259	--	--	--
12	South Central LA County	112+	354	7	4.6	354	0.104	0.086	0.064	0	0	1	2	1	354	0.09	0.07	0.0214	--	--	--
13	Santa Clarita Valley	090	361	2	1.4	357	0.140	0.122	0.103	0	5	64	57	77	357	0.06	0.05	0.0151	--	--	--
ORANGE COUNTY																					
16	North Orange County	3177	365	4	2.3	365	0.115	0.082	0.075	0	0	3	4	9	365	0.10	0.06	0.0206	--	--	--
17	Central Orange County	3176	365	3	2.7	365	0.093	0.077	0.068	0	0	1	0	2	365	0.07	0.06	0.0179	--	--	--
18	North Coastal Orange County	3195	362	3	2.2	365	0.087	0.075	0.066	0	0	0	0	3	365	0.07	0.06	0.0130	364	0.01	0.004
19	Saddleback Valley	3812	362	2	1.0	362	0.121	0.095	0.084	0	0	10	7	14	--	--	--	--	--	--	--
RIVERSIDE COUNTY																					
22	Norco/Corona	4155	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
23	Metropolitan Riverside County 1	4144	364	2	1.9	346	0.116	0.100	0.089	0	0	35	25	57	357	0.08	0.06	0.0171	364	0.01	0.003
23	Metropolitan Riverside County 2	4146	365	3	1.8	--	--	--	--	--	--	--	--	--	365	0.08	0.06	0.0200	--	--	--
23	Mira Loma	4165	364	3	2.4	364	0.118	0.090	0.086	0	0	22	15	37	364	0.08	0.05	0.0158	--	--	--
24	Perris Valley	4149	--	--	--	354	0.125	0.108	0.101	0	1	67	53	88	--	--	--	--	--	--	--
25	Lake Elsinore	4158	365	1	0.7	365	0.128	0.105	0.096	0	1	37	24	65	365	0.06	0.04	0.0129	--	--	--
29	Banning Airport	4164	--	--	--	359	0.133	0.104	0.100	0	1	70	55	93	359	0.06	0.05	0.0109	--	--	--
30	Coachella Valley 1**	4137	365	2	0.7	365	0.120	0.098	0.096	0	0	53	28	73	349	0.05	0.04	0.0081	--	--	--
30	Coachella Valley 2**	4157	--	--	--	365	0.097	0.090	0.085	0	0	24	6	41	--	--	--	--	--	--	--
SAN BERNARDINO COUNTY																					
32	Northwest San Bernardino Valley	5175	365	2	1.5	365	0.146	0.121	0.102	1	3	49	51	71	363	0.11	0.07	0.0239	--	--	--
33	Southwest San Bernardino Valley	5817	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34	Central San Bernardino Valley 1	5197	363	2	1.5	365	0.142	0.128	0.100	0	3	48	45	65	365	0.11	0.07	0.0235	365	0.01	0.002
34	Central San Bernardino Valley 2	5203	363	3	1.9	363	0.150	0.126	0.101	1	2	62	53	79	363	0.08	0.06	0.0196	--	--	--
35	East San Bernardino Valley	5204	--	--	--	365	0.145	0.122	0.100	1	1	73	62	91	--	--	--	--	--	--	--
37	Central San Bernardino Mountains	5181	--	--	--	364	0.149	0.117	0.110	2	7	92	70	107	--	--	--	--	--	--	--
38	East San Bernardino Mountains	5818	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DISTRICT MAXIMUM				7	4.6		0.176	0.128	0.110	3	7	92	70	107		0.12	0.08	0.0281		0.02	0.006
SOUTH COAST AIR BASIN				7	4.6		0.176	0.128	0.110	6	15	113	102	133		0.12	0.08	0.0281		0.02	0.006

ppm - Parts Per Million parts of air, by volume. AAM = Annual Arithmetic Mean -- - Pollutant not monitored.

** Salton Sea Air Basin.

+ Site was relocated.

a) - The federal 8-hour standard (8-hour average CO > 9 ppm) and state 8-hour standard (8-hour average CO > 9.0 ppm) were not exceeded. The federal and state 1-hour standards (35 ppm and 20 ppm) were not exceeded, either.

b) - The federal 1-hour ozone standard was revoked and replaced by the 8-hour average ozone standard effective June 15, 2005. U.S. EPA has revised the federal 8-hour ozone standard from 0.084 ppm to 0.075 ppm, effective May 27, 2008.

c) - The 8-hour average California ozone standard of 0.070 ppm was established effective May 17, 2006.

d) - The federal standard is annual arithmetic mean NO_2 > 0.0534 ppm. California Air Resources Board has revised the NO_2 1-hour state standard from 0.25 ppm to 0.18 ppm and has established a new annual standard of 0.030 ppm, effective March 20, 2008. U.S. EPA has established a new NO2 1-hour standard of 100 ppb (0.100 ppm), effective April 7, 2010.

e) - The state standards are 1-hour average SO_2 > 0.25 ppm and 24-hour average SO_2 > 0.04 ppm. U.S. EPA has revised the federal standard by establishing a new SO2 1-hour standard of 75 ppb (0.075 ppm) and revoking the existing annual (0.03 ppm) and 24-hour (0.14 ppm) SO2 standards, effective August 2, 2010. The federal and state SO_2 standards were not exceeded.

South Coast Air Quality Management District
21865 Copley Drive
Diamond Bar, CA 91765-4182
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2009 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2009

Source/Receptor Area No.	Location	Station No.	Suspended Particulates PM10 [f]					Fine Particulates PM2.5 [g] [i]					Particulates TSP			Lead		Sulfate	
			No. Days of Data	Max. Conc. in µg/m³ 24-hour	No. (%) Samples Exceeding Standards: Federal > 150 µg/m³ 24-hour	No. (%) Samples Exceeding Standards: State > 50 µg/m³ 24-hour	Annual Average Conc. [h] (AAM) µg/m³	No. Days of Data	Max. Conc. in µg/m³ 24-hour	98th Percentile Conc. in µg/m³	No. (%) Samples Exceeding Federal Std > 35 µg/m³ 24-hour	Annual Average Conc. [i] (AAM) µg/m³	No. Days of Data	Max. Conc. in µg/m³ 24-hour	Annual Average Conc. (AAM) µg/m³	Max. Monthly Average Conc. [j] µg/m³	Max. Quarterly Average Conc. [j] µg/m³	Max. Conc. in µg/m³ 24-hour	No. Days Exceeding State Std ≥ 25 µg/m³ 24-hour
LOS ANGELES COUNTY																			
1	Central LA	087	60	72	0	4(6.7)	33.1	359	61.7	34.0	7(1.9)	14.3	61	148	66.8	0.02	0.01	9.8	0
2	Northwest Coastal LA County	091	--	--	--	--	--	--	--	--	--	--	59	99	50.8	--	--	9.1	0
3	Southwest Coastal LA County	820	60	52	0	1(1.7)	25.4	--	--	--	--	--	48	87	42.4	0.01	0.01	8.6	0
4	South Coastal LA County 1	072	57	62	0	3(5.3)	30.5	328	63.0	34.2	6(1.8)	13.0	60	128	55.4	0.01	0.01	13.6	0
4	South Coastal LA County 2	077	56	83	0	5(8.9)	33.2	350	55.8	30.5	4(1.1)	12.5	59	159	65.2	0.01	0.01	12.1	0
6	West San Fernando Valley	074	--	--	--	--	--	110	39.9	27.2	1(0.9)	11.4	--	--	--	--	--	--	--
7	East San Fernando Valley	069	60	80	0	11(18.3)	39.2	243	67.5	34.4	4(1.6)	14.4	--	--	--	--	--	--	--
8	West San Gabriel Valley	088	--	--	--	--	--	109	52.0	35.7	3(2.8)	12.3	59	151	48.5	--	--	8.8	0
9	East San Gabriel Valley 1	080	52	74	0	7(13.5)	32.0	153	72.1	42.9	6(3.9)	12.8	58	208	74.9	--	--	7.9	0
9	East San Gabriel Valley 2	591	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	Pomona/Walnut Valley	075	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	South San Gabriel Valley	085	--	--	--	--	--	118	71.1	35.4	2(1.7)	14.8	59	194	69.7	0.04	0.02	9.9	0
12	South Central LA County+	112+	--	--	--	--	--	114	69.2	37.7	3(2.6)	14.7	57	118	59.6	0.03	0.02	9.9	0
13	Santa Clarita Valley	090	53	56	0	1(1.9)	23.4	--	--	--	--	--	--	--	--	--	--	--	--
ORANGE COUNTY																			
16	North Orange County	3177	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	Central Orange County	3176	56	63	0	1(1.8)	30.9	334	64.6	32.1	4(1.2)	11.8	--	--	--	--	--	--	--
18	North Coastal Orange County	3195	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	Saddleback Valley	3812	60	56	0	1(1.7)	23.5	116	39.2	23.8	1(0.9)	9.5	--	--	--	--	--	--	--
RIVERSIDE COUNTY																			
22	Norco/Corona	4155	59	79	0	7(11.9)	35.6	--	--	--	--	--	--	--	--	--	--	--	--
23	Metropolitan Riverside County 1	4144	119	77	0	35(29.4)	42.5	347	54.5	39.6	13(3.7)	15.3	60	161	87.6	0.01	0.01	7.3	0
23	Metropolitan Riverside County 2	4146	--	--	--	--	--	114	42.2	34.0	2(1.8)	13.4	61	162	66.0	0.01	0.01	6.8	0
23	Mira Loma	4165	59	108	0	33(55.9)	53.4	229	49.2	40.6	14(6.1)	16.9	--	--	--	--	--	--	--
24	Perris Valley	4149	58	80	0	9(15.5)	34.8	--	--	--	--	--	--	--	--	--	--	--	--
25	Lake Elsinore	4158	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	Banning Airport	4164	59	99	0	1(1.7)	25.9	--	--	--	--	--	--	--	--	--	--	--	--
30	Coachella Valley 1**	4137	54	140	0	1(1.9)	22.6	112	21.8	14.6	0	6.7	--	--	--	--	--	--	--
30	Coachella Valley 2**	4157	120	132	0	9(7.5)	32.5	112	27.5	17.0	0	7.9	--	--	--	--	--	--	--
SAN BERNARDINO COUNTY																			
32	Northwest San Bernardino Valley	5175	--	--	--	--	--	--	--	--	--	--	59	123	58.5	0.01	0.01	6.8	0
33	Southwest San Bernardino Valley	5817	62	70	0	9(14.5)	35.6	114	46.9	35.9	3(2.6)	14.7	--	--	--	--	--	--	--
34	Central San Bernardino Valley 1	5197	60	75	0	13(21.7)	40.2	118	46.4	32.7	2(1.7)	14.3	58	185	84.3	--	--	6.7	0
34	Central San Bernardino Valley 2	5203	52	66	0	11(21.2)	41.5	110	37.8	35.2	2(1.8)	13.0	61	125	74.3	0.01	0.01	7.1	0
35	East San Bernardino Valley	5204	60	52	0	2(3.3)	30.2	--	--	--	--	--	--	--	--	--	--	--	--
37	Central San Bernardino Mountains	5181	51	57	0	1(2.0)	24.5	--	--	--	--	--	--	--	--	--	--	--	--
38	East San Bernardino Mountains	5818	--	--	--	--	--	56	40.8	29.4	1(1.8)	9.9	--	--	--	--	--	--	--
	DISTRICT MAXIMUM			140	0	35	53.4		72.1	42.9	14	16.9		208	87.6	0.04	0.02	13.6	0
	SOUTH COAST AIR BASIN			108	0	60	53.4		72.1	42.9	27	16.9		208	87.6	0.04	0.02	13.6	0

µg/m³ - Micrograms per cubic meter of air. AAM = Annual Arithmetic Mean -- = Pollutant not monitored.

** Salton Sea Air Basin.

+ Site was relocated.

f) - PM10 samples were collected every 6 days at all sites except for Station Numbers 4144 and 4157 where samples were collected every 3 days.

g) - PM2.5 samples were collected every 3 days at all sites except for the following sites: Station Numbers 069, 072, 077, 087, 3176, 4144 and 4165 where samples were taken every day, and Station Number 5818 where samples were taken every 6 days.

h) - Federal annual PM10 standard (AAM > 50 µg/m³) was revoked effective December 17, 2006. State standard is annual average (AAM) > 20 µg/m³.

i) - Federal PM2.5 standard is annual average (AAM) > 15.0 µg/m³. State standard is annual average (AAM) > 12.0 µg/m³.

j) - Federal lead standards are rolling 3-month average > 0.15 µg/m3, and quarterly average > 1.5 µg/m³. State standard is monthly average ≥ 1.5 µg/m³.

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Maps showing the source/receptor area boundaries can be accessed via the Internet by entering your address in the AQMD Current Hourly Air Quality Map, accessed from http://www2.aqmd.gov/webappl/ajaxqi2/YEMap3D.aspx or at http://www.aqmd.gov/map/Map/AQMD2.pdf. A map is also available free of charge from the AQMD Public Information Center at 1-800-CUT-SMOG.

2008 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2008

Source/Receptor Area		Station No.		Carbon Monoxide [a]			Ozone										Nitrogen Dioxide [d]			Sulfur Dioxide [e]			
											No. Days Standard Exceeded												
												Federal [b]			State [c]								
No.	Location	State Code	District Code	No. Days of Data	Max. Conc. in ppm 1-hour	Max Conc. in ppm 8-hour	No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 8-hour	Fourth High Conc. ppm 8-hour	Health Advisory ≥ 0.150 ppm 1-hour	Old > 0.12 ppm 1-hour	Old > 0.08 ppm 8-hour	Current > 0.075 ppm 8-hour	Current > 0.09 ppm 1-hour	Current > 0.070 ppm 8-hour	No. Days of Data	Max Conc. in ppm 1-hour	Annual Average AAM Conc. ppm	No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 24-hour	Annual Average AAM Conc. ppm
LOS ANGELES COUNTY																							
1	Central LA	70087	087	366	3	2.1	356	0.109	0.090	0.073	0	0	1	3	3	7	343	0.12	0.0275	366	0.01	0.002	0.0003
2	Northwest Coastal LA County	70091	091	366	3	2.0	366	0.11	0.097	0.073	0	0	1	2	3	8	364	0.09	0.0184	--	--	--	--
3	Southwest Coastal LA County	70111	820	358	4	2.5	360	0.086	0.075	0.065	0	0	0	0	0	1	359	0.09	0.0143	357	0.02	0.005	0.0014
4	South Coastal LA County 1	70072	072	366	3	2.6	366	0.093	0.074	0.064	0	0	0	0	0	1	366	0.13	0.0208	366	0.09	0.012	0.0022
4	South Coastal LA County 2	70110	077	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	West San Fernando Valley	70074	074	366	4	2.9	366	0.123	0.103	0.095	0	0	14	25	23	40	366	0.09	0.0180	--	--	--	--
7	East San Fernando Valley	70069	069	366	3	2.6	366	0.133	0.109	0.092	0	1	8	17	20	35	364	0.11	0.0285	366	0.01	0.003	0.0008
8	West San Gabriel Valley	70088	088	366	3	2.1	366	0.122	0.100	0.091	0	0	6	16	16	26	365	0.11	0.0235	--	--	--	--
9	East San Gabriel Valley 1	70060	060	366	2	1.6	366	0.135	0.111	0.101	0	7	14	28	34	39	366	0.10	0.0230	--	--	--	--
9	East San Gabriel Valley 2	70591	591	366	3	3.0	366	0.156	0.118	0.112	2	12	25	45	48	61	366	0.10	0.0182	--	--	--	--
10	Pomona/Walnut Valley	70075	075	366	3	2.0	366	0.141	0.110	0.100	0	5	19	35	32	47	366	0.11	0.0302	--	--	--	--
11	South San Gabriel Valley	70185	085	357	3	2.1	366	0.107	0.093	0.077	0	0	1	5	7	13	341	0.10	0.0263	--	--	--	--
12	South Central LA County+	70084+	084+	310*	6*	4.3*	310*	0.078*	0.060*	0.055*	0*	0*	0*	0*	0*	0*	305*	0.12*	0.0301*	--	--	--	--
13	Santa Clarita Valley	70090	090	363	2	1.1	363	0.160	0.131	0.108	2	8	35	60	54	81	363	0.07	0.0165	--	--	--	--
ORANGE COUNTY																							
16	North Orange County	30177	3177	366	5	2.9	366	0.104	0.084	0.078	0	0	0	5	7	15	361	0.08	0.0206	--	--	--	--
17	Central Orange County	30178	3176	366	4	3.6	366	0.105	0.086	0.076	0	0	1	4	2	10	366	0.09	0.0203	--	--	--	--
18	North Coastal Orange County	30195	3195	366	3	2.0	366	0.094	0.079	0.075	0	0	0	3	0	6	365	0.08	0.0132	366	0.01	0.003	0.0011
19	Saddleback Valley	30002	3812	365	2	1.1	365	0.118	0.104	0.092	0	0	6	15	9	25	--	--	--	--	--	--	--
RIVERSIDE COUNTY																							
22	Norco/Corona	33155	4155	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
23	Metropolitan Riverside County 1	33144	4144	366	3	2.0	366	0.146	0.116	0.111	0	8	38	64	54	88	366	0.09	0.0192	366	0.01	0.003	0.0009
23	Metropolitan Riverside County 2	33146	4146	366	7	2.0	--	--	--	--	--	--	--	--	--	--	70*	0.09*	0.0258*	--	--	--	--
23	Mira Loma	33165	5214	366	3	1.9	366	0.135	0.107	0.104	0	4	23	47	38	62	366	0.10	0.0174	--	--	--	--
24	Perris Valley	33149	4149	--	--	--	366	0.142	0.114	0.106	0	4	41	77	65	94	--	--	--	--	--	--	--
25	Lake Elsinore	33158	4158	365	1	1.0	365	0.139	0.118	0.108	0	6	32	69	49	92	362	0.08	0.0129	--	--	--	--
29	Banning Airport	33164	4164	--	--	--	365	0.149	0.120	0.108	0	10	45	74	57	95	366	0.08	0.0128	--	--	--	--
30	Coachella Valley 1**	33137	4137	366	1	0.6	366	0.11	0.101	0.098	0	0	20	51	26	70	366	0.05	0.0093	--	--	--	--
30	Coachella Valley 2**	33157	4157	--	--	--	355	0.12	0.092	0.090	0	0	11	27	11	44	--	--	--	--	--	--	--
SAN BERNARDINO COUNTY																							
32	Northwest San Bernardino Valley	36175	5178	365	2	1.6	365	0.155	0.122	0.111	2	9	30	50	51	65	365	0.09	0.0235	--	--	--	--
33	Southwest San Bernardino Valley	36025	5817	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34	Central San Bernardino Valley 1	36197	5197	363	2	1.9	364	0.162	0.124	0.111	1	8	35	58	55	82	364	0.10	0.0207	364	0.01	0.003	0.0018
34	Central San Bernardino Valley 2	36203	5203	366	2	1.8	366	0.157	0.122	0.113	2	11	43	62	62	90	366	0.09	0.0217	--	--	--	--
35	East San Bernardino Valley	36204	5204	--	--	--	366	0.154	0.120	0.112	1	12	50	75	72	100	--	--	--	--	--	--	--
37	Central San Bernardino Mountains	36181	5181	--	--	--	362	0.176	0.126	0.120	2	16	67	97	78	115	--	--	--	--	--	--	--
38	East San Bernardino Mountains	36001	5818	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DISTRICT MAXIMUM				366	7	4.3	366	0.176	0.131	0.120	2	16	67	97	78	115		0.13	0.0302		0.09	0.012	0.0022
SOUTH COAST AIR BASIN					7	4.3		0.176	0.131	0.120	7	28	80	120	102	140		0.13	0.0302		0.09	0.012	0.0022

ppm - Parts Per Million parts of air, by volume. AAM = Annual Arithmetic Mean -- - Pollutant not monitored.

* Less than 12 full months of data; may not be representative. ** Salton Sea Air Basin.

\+ Site was relocated.

a) - The federal 8-hour standard (8-hour average CO > 9 ppm) and state 8-hour standard (8-hour average CO > 9.0 ppm) were not exceeded. The federal and state 1-hour standards (35 ppm and 20 ppm) were not exceeded, either.

b) - The federal 1-hour ozone standard was revoked and replaced by the 8-hour average ozone standard effective June 15, 2005. U.S. EPA has revised the federal 8-hour ozone standard from 0.084 ppm to 0.075 ppm, effective May 27, 2008.

c) - The 8-hour average California ozone standard of 0.070 ppm was established effective May 17, 2006.

d) - The federal standard is annual arithmetic mean NO_2 > 0.0534 ppm. California Air Resources Board has revised the NO_2 1-hour state standard from 0.25 ppm to 0.18 ppm and has established a new annual standard of 0.030 ppm, effective March 20, 2008.

e) - The state standards are 1-hour average SO_2 > 0.25 ppm and 24-hour average SO_2 > 0.04 ppm. The federal standards are annual arithmetic mean SO_2 > 0.03 ppm, 24-hour average > 0.14 ppm, and 3-hour average > 0.50 ppm. The federal and state SO_2 standards were not exceeded.

South Coast Air Quality Management District
21865 Copley Drive
Diamond Bar, CA 91765-4182
www.aqmd.gov

Maps showing the source/receptor area boundaries can be accessed via the Internet by entering your address in the AQMD Current Hourly Air Quality Map, accessed from http://www2.aqmd.gov/webappl/gisaqi2/VEMap3D.aspx or at http://www.aqmd.gov/map/MapAQMD2.pdf. A map is also available free of charge from the AQMD Public Information Center at 1-800-CUT-SMOG.

AR0069419

2008 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2008

Source/Receptor Area No.	Location	Station No. State Code	Station No. District Code	Suspended Particulates PM10[f] No. Days of Data	Max. Conc. in µg/m³ 24-hour	No. (%) Samples Exceeding Standards Federal > 150 µg/m³ 24-hour	No. (%) Samples Exceeding Standards State > 50 µg/m³ 24-hour	Annual Average Conc.[h] (AAM) µg/m³	Fine Particulates PM2.5[g] No. Days of Data	Max. Conc. in µg/m³ 24-hour	98th Percentile Conc. in µg/m³	No. (%) Samples Exceeding Federal Standard Current > 35[j] µg/m³ 24-hour	No. (%) Samples Exceeding Federal Standard Old > 65[j] µg/m³ 24-hour	Annual Average Conc.[k] (AAM) µg/m³	Particulates TSP[h] No. Days of Data	Max. Conc. in µg/m³ 24-hour	Annual Average Conc. (AAM) µg/m³	Lead[h] Max. Monthly Average Conc.[l] µg/m³	Lead[h] Max. Quarterly Average Conc.[l] µg/m³	Sulfate[h] Max. Conc. in µg/m³ 24-hour	Sulfate[h] %Samples Exceeding State Standard > 25 µg/m³ 24-hour
LOS ANGELES COUNTY																					
1	Central LA	70087	087	45*	66*	0*	2(4%)*	30.9*	337	78.3	40.4	10(3.0)	1(0.3)	15.7	63	112	65.6	0.02	0.02	14.4	0
2	Northwest Coastal LA County	70091	091	--	--	--	--	--	--	--	--	--	--	--	56	88	45.9	--	--	11.1	0
3	Southwest Coastal LA County	70111	820	60	50	0	0(0%)	25.6	--	--	--	--	--	--	54	85	42.4	0.01	0.01	14.0	0
4	South Coastal LA County 1	70072	072	57	62	0	1(2%)	29.1	346	57.2	38.9	8(2.3)	0	14.2	61	117	55.7	0.01	0.01	11.0	0
4	South Coastal LA County 2	70110	077	58	81	0	9(16%)	35.8	349	60.9	36.4	7(2.0)	0	13.7	59	130	61.2	0.01	0.01	13.2	0
6	West San Fernando Valley	70074	074	--	--	--	--	--	113	50.5	26.2	2(1.8)	0	11.9	--	--	--	--	--	--	--
7	East San Fernando Valley	70069	069	54	66	0	7(13%)	35.6	116	57.5	34.6	2(1.7)	0	14.1	--	--	--	--	--	--	--
8	West San Gabriel Valley	70088	088	--	--	--	--	--	118	66.0	32.1	2(1.7)	1(0.9)	12.9	55	108	46.7	--	--	14.1	0
9	East San Gabriel Valley 1	70060	060	49	98	0	13(27%)	35.3	321	53.1	34.8	5(1.6)	0	14.1	59	146	74.9	--	--	18.7	0
9	East San Gabriel Valley 2	70591	591	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	Pomona/Walnut Valley	70075	075	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	South San Gabriel Valley	70185	085	--	--	--	--	--	114	47.3	38.0	4(3.5)	0	15.0	57	119	63.2	0.02	0.02	10.1	0
12	South Central LA County+	70084+	084+	--	--	--	--	--	118	44.2	36.5	3(2.5)	0	15.5	51	103	70.4	0.03	0.02	10.6	0
13	Santa Clarita Valley	70090	090	57	91	0	2(4%)	25.8	--	--	--	--	--	--	--	--	--	--	--	--	--
ORANGE COUNTY																					
16	North Orange County	30177	3177	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	Central Orange County	30178	3176	58	61	0	3(5%)	28.6	336	67.9	39.4	13(3.9)	1(0.3)	13.7	--	--	--	--	--	--	--
18	North Coastal Orange County	30195	3195	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	Saddleback Valley	30002	3812	55	42	0	0(0%)	22.6	120	32.6	27.1	0	0	10.4	--	--	--	--	--	--	--
RIVERSIDE COUNTY																					
22	Norco/Corona	33155	4155	61	86	0	9(15%)	34.4	--	--	--	--	--	--	--	--	--	--	--	--	--
23	Metropolitan Riverside County 1	33144	4144	120	115	0	49(41%)	46.6	348	57.7	41.5	14(4.0)	0	16.4	59	222	100.6	0.01	0.01	9.1	0
23	Metropolitan Riverside County 2	33146	4146	--	--	--	--	--	116	43.0	39.1	4(3.4)	0	13.4	63	130	69.4	0.01	0.01	7.1	0
23	Mira Loma	33165	5214	61	135	0	35(57%)	57.4	111	50.9	47.1	10(9.0)	0	18.2	--	--	--	--	--	--	--
24	Perris Valley	33149	4149	45*	85*	0*	12(27%)*	38.3*	--	--	--	--	--	--	--	--	--	--	--	--	--
25	Lake Elsinore	33158	4158	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	Banning Airport	33164	4164	56	51	0	1(2%)	26.1	--	--	--	--	--	--	--	--	--	--	--	--	--
30	Coachella Valley 1**	33137	4137	47*	75*	0*	4(9%)*	23.2*	110	18.1	17.1	0	0	7.2	--	--	--	--	--	--	--
30	Coachella Valley 2**	33157	4157	112	128	0	25(22%)	39.9	113	21.6	18.8	0	0	8.4	--	--	--	--	--	--	--
SAN BERNARDINO COUNTY																					
32	Northwest San Bernardino Valley	36175	5175	--	--	--	--	--	--	--	--	--	--	--	54	87	52.2	0.01	0.01	8.4	0
33	Southwest San Bernardino Valley	36025	5817	62	90	0	15(24%)	38.8	113	54.2	45.0	6(5.3)	0	15.8	--	--	--	--	--	--	--
34	Central San Bernardino Valley 1	36197	5197	60	75	0	14(23%)	40.3	112	49.0	47.1	6(5.4)	0	15.4	57	139	80	--	--	9.5	0
34	Central San Bernardino Valley 2	36203	5203	60	76	0	19(32%)	42.7	110	43.5	40.1	3(2.7)	0	13.5	59	166	83.6	0.02	0.02	8.6	0
35	East San Bernardino Valley	36204	5204	61	58	0	4(7%)	29.0	--	--	--	--	--	--	--	--	--	--	--	--	--
37	Central San Bernardino Mountains	36181	5181	39*	41*	0*	0(0%)*	23.9*	--	--	--	--	--	--	--	--	--	--	--	--	--
38	East San Bernardino Mountains	36001	5818	--	--	--	--	--	58	36.8	33.3	1(1.7)	0	9.2							
DISTRICT MAXIMUM					135	0	49	57.4		78.3	47.1	14	1	18.2		222	100.6	0.03	0.02	18.7	0
SOUTH COAST AIR BASIN					135	0	68	57.4		78.3	47.1	28	2	18.2		222	100.6	0.03	0.02	18.7	0

µg/m³ - Micrograms per cubic meter of air. AAM = Annual Arithmetic Mean -- - Pollutant not monitored.

* Less than 12 full months of data; may not be representative. ** Salton Sea Air Basin.

\+ Site was relocated.

f) - PM10 samples were collected every 6 days at all sites except for Station Numbers 4144 and 4157 where samples were collected every 3 days.

g) - PM2.5 samples were collected every 3 days at all sites except for the following sites: Station Numbers 060, 072, 077, 087, 3176, and 4144 where samples were taken every day, and Station Number 5818 where samples were taken every 6 days.

h) - Total suspended particulates, lead, and sulfate were determined from samples collected every 6 days by the high volume sampler method, on glass fiber filter media.

i) - Federal annual PM10 standard (AAM > 50 µg/m³) was revoked effective December 17, 2006. State standard is annual average (AAM) > 20 µg/m³.

j) - U.S. EPA has revised the federal 24-hour PM2.5 standard from 65 µg/m³ to 35 µg/m³; effective December 17, 2006.

k) - Federal PM2.5 standard is annual average (AAM) > 15 µg/m³. State standard is annual average (AAM) > 12 µg/m³.

l) - Federal lead standard is quarterly average > 1.5 µg/m³; and state standard is monthly average ≥ 1.5 µg/m³. U.S. EPA has established the federal standard of 0.15 ug/m3, rolling 3-month average, as of October 15, 2008.

Maps showing the source/receptor area boundaries can be accessed via the Internet by entering your address in the AQMD Current Hourly Air Quality Map, accessed from http://www2.aqmd.gov/webappl/gissql2/VEMap3D.aspx or at http://www.aqmd.gov/map/MapAQMD2.pdf . A map is also available free of charge from the AQMD Public Information Center at 1-800-CUT-SMOG.

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AR0069420

2009 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2009

Source/Receptor Area No.	Location	Station No.	Carbon Monoxide[a]			Ozone									Nitrogen Dioxide[d]				Sulfur Dioxide[e]		
										No. Days Standard Exceeded										
											Federal[b]		State[c]								
			No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 8-hour	No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 8-hour	Fourth High Conc. ppm 8-hour	Health Advisory ≥ 0.15 ppm 1-hour	Old > 0.12 ppm 1-hour	Current > 0.075 ppm 8-hour	Current > 0.09 ppm 1-hour	Current > 0.070 ppm 8-hour	No. Days of Data	Max. Conc. in ppm 1-hour	98th Percentile Conc. ppm 1-hour	Annual Average AAM Conc. ppm	No. Days of Data	Max. Conc. in ppm 1-hour	Max. Conc. in ppm 24-hour
LOS ANGELES COUNTY																					
1	Central LA	087	357	3	2.2	365	0.139	0.100	0.073	0	1	2	3	5	365	0.12	0.07	0.0281	365	0.01	0.002
2	Northwest Coastal LA County	091	365	2	1.5	365	0.131	0.094	0.075	0	1	3	6	5	355	0.08	0.06	0.0170	--	--	--
3	Southwest Coastal LA County	820	349	2	1.9	352	0.077	0.070	0.061	0	0	0	0	0	362	0.08	0.07	0.0159	362	0.02	0.006
4	South Coastal LA County 1	072	362	3	2.2	363	0.089	0.068	0.064	0	0	0	0	0	362	0.11	0.07	0.0212	361	0.02	0.005
4	South Coastal LA County 2	077	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	West San Fernando Valley	074	365	4	2.8	365	0.135	0.100	0.093	0	1	19	15	31	365	0.07	0.06	0.0171	--	--	--
7	East San Fernando Valley	069	365	3	2.9	365	0.145	0.096	0.086	1	1	14	16	28	353	0.09	0.07	0.0274	362	0.01	0.003
8	West San Gabriel Valley	008	365	4	2.1	365	0.176	0.114	0.095	1	3	12	12	19	365	0.08	0.06	0.0221	--	--	--
9	East San Gabriel Valley 1	060	357	3	1.7	365	0.150	0.107	0.091	1	4	17	23	32	365	0.10	0.07	0.0194	--	--	--
9	East San Gabriel Valley 2	591	351	3	2.1	352	0.150	0.118	0.108	3	7	42	45	64	350	0.09	0.06	0.0170	--	--	--
10	Pomona/Walnut Valley	075	365	3	1.8	365	0.138	0.099	0.095	0	1	23	25	37	365	0.10	0.08	0.0274	--	--	--
11	South San Gabriel Valley	085	365	3	2.1	365	0.131	0.101	0.072	0	1	3	8	6	361	0.10	0.07	0.0259	--	--	--
12	South Central LA County	112+	354	7	4.6	354	0.104	0.086	0.064	0	0	1	2	1	354	0.09	0.07	0.0214	--	--	--
13	Santa Clarita Valley	090	361	2	1.4	357	0.140	0.122	0.103	0	5	64	57	77	357	0.06	0.05	0.0151	--	--	--
ORANGE COUNTY																					
16	North Orange County	3177	365	4	2.3	365	0.115	0.082	0.075	0	0	3	4	9	365	0.10	0.06	0.0206	--	--	--
17	Central Orange County	3176	365	3	2.7	365	0.093	0.077	0.068	0	0	1	0	2	365	0.07	0.06	0.0179	--	--	--
18	North Coastal Orange County	3195	362	3	2.2	365	0.087	0.075	0.066	0	0	0	0	3	365	0.07	0.06	0.0130	364	0.01	0.004
19	Saddleback Valley	3812	362	2	1.0	362	0.121	0.095	0.084	0	0	10	7	14	--	--	--	--	--	--	--
RIVERSIDE COUNTY																					
22	Norco/Corona	4155	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
23	Metropolitan Riverside County 1	4144	364	2	1.9	346	0.116	0.100	0.089	0	0	35	25	57	357	0.08	0.06	0.0171	364	0.01	0.003
23	Metropolitan Riverside County 2	4146	365	3	1.8	--	--	--	--	--	--	--	--	--	365	0.08	0.06	0.0200	--	--	--
23	Mira Loma	4165	364	3	2.4	364	0.118	0.090	0.086	0	0	22	15	37	364	0.08	0.05	0.0158	--	--	--
24	Perris Valley	4149	--	--	--	354	0.125	0.108	0.101	0	1	67	53	88	--	--	--	--	--	--	--
25	Lake Elsinore	4158	365	1	0.7	365	0.128	0.105	0.096	0	1	37	24	65	365	0.06	0.04	0.0129	--	--	--
29	Banning Airport	4164	--	--	--	359	0.133	0.104	0.100	0	1	70	55	93	359	0.06	0.05	0.0109	--	--	--
30	Coachella Valley 1**	4137	365	2	0.7	365	0.120	0.098	0.096	0	0	53	28	73	349	0.05	0.04	0.0081	--	--	--
30	Coachella Valley 2**	4157	--	--	--	365	0.097	0.090	0.085	0	0	24	6	41	--	--	--	--	--	--	--
SAN BERNARDINO COUNTY																					
32	Northwest San Bernardino Valley	5175	365	2	1.5	365	0.146	0.121	0.102	1	3	49	51	71	363	0.11	0.07	0.0239	--	--	--
33	Southwest San Bernardino Valley	5817	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34	Central San Bernardino Valley 1	5197	363	2	1.5	365	0.142	0.128	0.100	0	3	48	45	65	365	0.11	0.07	0.0235	365	0.01	0.002
34	Central San Bernardino Valley 2	5203	363	3	1.9	363	0.150	0.126	0.101	1	2	62	53	79	363	0.08	0.06	0.0196	--	--	--
35	East San Bernardino Valley	5204	--	--	--	365	0.145	0.122	0.100	1	1	73	62	91	--	--	--	--	--	--	--
37	Central San Bernardino Mountains	5181	--	--	--	364	0.149	0.117	0.110	2	7	92	70	107	--	--	--	--	--	--	--
38	East San Bernardino Mountains	5818	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DISTRICT MAXIMUM				7	4.6		0.176	0.128	0.110	3	7	92	70	107		0.12	0.08	0.0281		0.02	0.006
SOUTH COAST AIR BASIN				7	4.6		0.176	0.128	0.110	6	15	113	102	133		0.12	0.08	0.0281		0.02	0.006

ppm - Parts Per Million parts of air, by volume. AAM = Annual Arithmetic Mean -- - Pollutant not monitored.

** Salton Sea Air Basin.

+ Site was relocated.

a) - The federal 8-hour standard (8-hour average CO > 9 ppm) and state 8-hour standard (8-hour average CO > 9.0 ppm) were not exceeded. The federal and state 1-hour standards (35 ppm and 20 ppm) were not exceeded, either.

b) - The federal 1-hour ozone standard was revoked and replaced by the 8-hour average ozone standard effective June 15, 2005. U.S. EPA has revised the federal 8-hour ozone standard from 0.084 ppm to 0.075 ppm, effective May 27, 2008.

c) - The 8-hour average California ozone standard of 0.070 ppm was established effective May 17, 2006.

d) - The federal standard is annual arithmetic mean NO_2 > 0.0534 ppm. California Air Resources Board has revised the NO_2 1-hour state standard from 0.25 ppm to 0.18 ppm and has established a new annual standard of 0.030 ppm, effective March 20, 2008. U.S. EPA has established a new NO2 1-hour standard of 100 ppb (0.100 ppm), effective April 7, 2010.

e) - The state standards are 1-hour average SO_2 > 0.25 ppm and 24-hour average SO_2 > 0.04 ppm. U.S. EPA has revised the federal standard by establishing a new SO2 1-hour standard of 75 ppb (0.075 ppm) and revoking the existing annual (0.03 ppm) and 24-hour (0.14 ppm) SO2 standards, effective August 2, 2010. The federal and state SO_2 standards were not exceeded.

South Coast Air Quality Management District
21865 Copley Drive
Diamond Bar, CA 91765-4182
www.aqmd.gov

2009 AIR QUALITY
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

2009

Source/Receptor Area No.	Location	Station No.	Suspended Particulates PM10 [f]					Fine Particulates PM2.5 [g] [i]					Particulates TSP			Lead		Sulfate	
			No. Days of Data	Max. Conc. in µg/m³ 24-hour	No. (%) Samples Exceeding Standards: Federal > 150 µg/m³ 24-hour	No. (%) Samples Exceeding Standards: State > 50 µg/m³ 24-hour	Annual Average Conc. [h] (AAM) µg/m³	No. Days of Data	Max. Conc. in µg/m³ 24-hour	98th Percentile Conc. in µg/m³ 24-hour	No. (%) Samples Exceeding Federal Std > 35 µg/m³ 24-hour	Annual Average Conc. [i] (AAM) µg/m³	No. Days of Data	Max. Conc. in µg/m³ 24-hour	Annual Average Conc. (AAM) µg/m³	Max. Monthly Average Conc. [j] µg/m³	Max. Quarterly Average Conc. [j] µg/m³	Max. Conc. in µg/m³ 24-hour	No. Days Exceeding State Std ≥ 25 µg/m³ 24-hour
LOS ANGELES COUNTY																			
1	Central LA	087	60	72	0	4(6.7)	33.1	359	61.7	34.0	7(1.9)	14.3	61	148	66.8	0.02	0.01	9.8	0
2	Northwest Coastal LA County	091	--	--	--	--	--	--	--	--	--	--	59	99	50.8	--	--	9.1	0
3	Southwest Coastal LA County	820	60	52	0	1(1.7)	25.4	--	--	--	--	--	48	87	42.4	0.01	0.01	8.6	0
4	South Coastal LA County 1	072	57	62	0	3(5.3)	30.5	328	63.0	34.2	6(1.8)	13.0	60	128	55.4	0.01	0.01	13.6	0
4	South Coastal LA County 2	077	56	83	0	5(8.9)	33.2	350	55.8	30.5	4(1.1)	12.5	59	159	65.2	0.01	0.01	12.1	0
6	West San Fernando Valley	074	--	--	--	--	--	110	39.9	27.2	1(0.9)	11.4	--	--	--	--	--	--	--
7	East San Fernando Valley	069	60	80	0	11(18.3)	39.2	243	67.5	34.4	4(1.6)	14.4	--	--	--	--	--	--	--
8	West San Gabriel Valley	088	--	--	--	--	--	109	52.0	35.7	3(2.8)	12.3	59	151	48.5	--	--	8.8	0
9	East San Gabriel Valley 1	080	52	74	0	7(13.5)	32.0	153	72.1	42.9	6(3.9)	12.8	58	208	74.9	--	--	7.9	0
9	East San Gabriel Valley 2	591	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	Pomona/Walnut Valley	075	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	South San Gabriel Valley	085	--	--	--	--	--	118	71.1	35.4	2(1.7)	14.8	59	194	69.7	0.04	0.02	9.9	0
12	South Central LA County+	112+	--	--	--	--	--	114	69.2	37.7	3(2.6)	14.7	57	118	59.6	0.03	0.02	9.9	0
13	Santa Clarita Valley	090	53	56	0	1(1.9)	23.4	--	--	--	--	--	--	--	--	--	--	--	--
ORANGE COUNTY																			
16	North Orange County	3177	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	Central Orange County	3176	56	63	0	1(1.8)	30.9	334	64.6	32.1	4(1.2)	11.8	--	--	--	--	--	--	--
18	North Coastal Orange County	3195	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	Saddleback Valley	3812	60	56	0	1(1.7)	23.5	116	39.2	23.8	1(0.9)	9.5	--	--	--	--	--	--	--
RIVERSIDE COUNTY																			
22	Norco/Corona	4155	59	79	0	7(11.9)	35.6	--	--	--	--	--	--	--	--	--	--	--	--
23	Metropolitan Riverside County 1	4144	119	77	0	35(29.4)	42.5	347	54.5	39.6	13(3.7)	15.3	60	161	87.6	0.01	0.01	7.3	0
23	Metropolitan Riverside County 2	4146	--	--	--	--	--	114	42.2	34.0	2(1.8)	13.4	61	162	66.0	0.01	0.01	6.8	0
23	Mira Loma	4165	59	108	0	33(55.9)	53.4	229	49.2	40.6	14(6.1)	16.9	--	--	--	--	--	--	--
24	Perris Valley	4149	58	80	0	9(15.5)	34.8	--	--	--	--	--	--	--	--	--	--	--	--
25	Lake Elsinore	4158	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	Banning Airport	4164	59	99	0	1(1.7)	25.9	--	--	--	--	--	--	--	--	--	--	--	--
30	Coachella Valley 1**	4137	54	140	0	1(1.9)	22.6	112	21.8	14.6	0	6.7	--	--	--	--	--	--	--
30	Coachella Valley 2**	4157	120	132	0	9(7.5)	32.5	112	27.5	17.0	0	7.9	--	--	--	--	--	--	--
SAN BERNARDINO COUNTY																			
32	Northwest San Bernardino Valley	5175	--	--	--	--	--	--	--	--	--	--	59	123	58.5	0.01	0.01	6.8	0
33	Southwest San Bernardino Valley	5817	62	70	0	9(14.5)	35.6	114	46.9	35.9	3(2.6)	14.7	--	--	--	--	--	--	--
34	Central San Bernardino Valley 1	5197	60	75	0	13(21.7)	40.2	118	46.4	32.7	2(1.7)	14.3	58	185	84.3	--	--	6.7	0
34	Central San Bernardino Valley 2	5203	52	66	0	11(21.2)	41.5	110	37.8	35.2	2(1.8)	13.0	61	125	74.3	0.01	0.01	7.1	0
35	East San Bernardino Valley	5204	60	52	0	2(3.3)	30.2	--	--	--	--	--	--	--	--	--	--	--	--
37	Central San Bernardino Mountains	5181	51	57	0	1(2.0)	24.5	--	--	--	--	--	--	--	--	--	--	--	--
38	East San Bernardino Mountains	5818	--	--	--	--	--	56	40.8	29.4	1(1.8)	9.9	--	--	--	--	--	--	--
	DISTRICT MAXIMUM			140	0	35	53.4		72.1	42.9	14	16.9		208	87.6	0.04	0.02	13.6	0
	SOUTH COAST AIR BASIN			108	0	60	53.4		72.1	42.9	27	16.9		208	87.6	0.04	0.02	13.6	0

µg/m³ - Micrograms per cubic meter of air. AAM = Annual Arithmetic Mean -- = Pollutant not monitored.

** Salton Sea Air Basin.

+ Site was relocated.

f) - PM10 samples were collected every 6 days at all sites except for Station Numbers 4144 and 4157 where samples were collected every 3 days.

g) - PM2.5 samples were collected every 3 days at all sites except for the following sites: Station Numbers 069, 072, 077, 087, 3176, 4144 and 4165 where samples were taken every day, and Station Number 5818 where samples were taken every 6 days.

h) - Federal annual PM10 standard (AAM > 50 µg/m³) was revoked effective December 17, 2006. State standard is annual average (AAM) > 20 µg/m³.

i) - Federal PM2.5 standard is annual average (AAM) > 15.0 µg/m³. State standard is annual average (AAM) > 12.0 µg/m³.

j) - Federal lead standards are rolling 3-month average > 0.15 µg/m3, and quarterly average > 1.5 µg/m³. State standard is monthly average ≥ 1.5 µg/m³.

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Maps showing the source/receptor area boundaries can be accessed via the Internet by entering your address in the AQMD Current Hourly Air Quality Map, accessed from http://www2.aqmd.gov/webappl/ajaxqi2/YEMap3D.aspx or at http://www.aqmd.gov/map/Map/AQMD2.pdf. A map is also available free of charge from the AQMD Public Information Center at 1-800-CUT-SMOG.

AR0069422

APPENDIX C

MAPS AND TABLES OF AREA DESIGNATIONS FOR STATE AND NATIONAL AMBIENT AIR QUALITY STANDARDS

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APPENDIX C

MAPS AND TABLES OF AREA DESIGNATIONS FOR STATE AND NATIONAL AMBIENT AIR QUALITY STANDARDS

This attachment fulfills the requirement of Health and Safety Code section 40718 for ARB to publish maps that identify areas where one or more violations of any State ambient air quality standard (State standard) or national ambient air quality standard (national standard) have been measured. The national standards are those promulgated under section 109 of the federal Clean Air Act (42 U.S.C. 7409).

This attachment is divided into three parts. The first part comprises a table showing the levels, averaging times, and measurement methods for each of the State and national standards. This is followed by a section containing maps and tables showing the 2012 area designations for each pollutant for which there is a State standard in the California Code of Regulations, title 17, section 70200. The last section contains maps and tables showing the most current area designations for the national standards.

AR0069425

Ambient Air Quality Standards

Pollutant	Averaging Time	California Standards [1]		National Standards [2]		
		Concentration [3]	Method [4]	Primary [3,5]	Secondary [3,6]	Method [7]
Ozone (O_3)	1 Hour	0.09 ppm (180 µg/m³)	Ultraviolet Photometry	—	Same as Primary Standard	Ultraviolet Photometry
	8 Hour	0.070 ppm (137 µg/m³)		0.075 ppm (147 µg/m³)		
Respirable Particulate Matter (PM10)	24 Hour	50 µg/m³	Gravimetric or Beta Attenuation	150 µg/m³	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	20 µg/m³		—		
Fine Particulate Matter (PM2.5)	24 Hour	—	—	35 µg/m³	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	12 µg/m³	Gravimetric or Beta Attenuation	15 µg/m³		
Carbon Monoxide (CO)	1 Hour	20 ppm (23 mg/m³)	Non-Dispersive Infrared Photometry (NDIR)	35 ppm (40 mg/m³)	—	Non-Dispersive Infrared Photometry (NDIR)
	8 Hour	9.0 ppm (10 mg/m³)		9 ppm (10 mg/m³)	—	
	8 Hour (Lake Tahoe)	6 ppm (7 mg/m³)		—	—	
Nitrogen Dioxide (NO_2)[8]	1 Hour	0.18 ppm (339 µg/m³)	Gas Phase Chemiluminescence	100 ppb (188 µg/m³)	—	Gas Phase Chemiluminescence
	Annual Arithmetic Mean	0.030 ppm (57 µg/m3)		53 ppb (100 µg/m³)	Same as Primary Standard	
Sulfur Dioxide (SO_2)[9]	1 Hour	0.25 ppm (655 µg/m³)	Ultraviolet Fluorescence	75 ppb (196 µg/m³)	—	Ultraviolet Flourescence; Spectrophotometry (Pararosaniline Method)
	3 Hour	—		—	0.5 ppm (1300 µg/m³)	
	24 Hour	0.04 ppm (105 µg/m³)		0.14 ppm (for certain areas)[9]	—	
	Annual Arithmetic Mean	—		0.030 ppm (for certain areas)[9]	—	
Lead[10,11]	30 Day Average	1.5 µg/m³	Atomic Absorption	—	—	High Volume Sampler and Atomic Absorption
	Calendar Quarter	—		1.5 µg/m³ (for certain areas)[11]	Same as Primary Standard	
	Rolling 3-Month Average	—		0.15 µg/m³		
Visibility Reducing Particles[12]	8 Hour	See footnote 12	Beta Attenuation and Transmittance through Filter Tape	No National Standards		
Sulfates	24 Hour	25 µg/m³	Ion Chromatography			
Hydrogen Sulfide	1 Hour	0.03 ppm (42 µg/m³)	Ultraviolet Fluorescence			
Vinyl Chloride[16]	24 Hour	0.01 ppm (26 µg/m³)	Gas Chromatography			

See footnotes on next page ...

For more information please call ARB-PIO at (916) 322-2990

California Air Resources Board (2/7/12)

AR0069426

1. California standards for ozone, carbon monoxide (except 8-hour Lake Tahoe), sulfur dioxide (1 and 24 hour), nitrogen dioxide, and particulate matter (PM10, PM2.5, and visibility reducing particles), are values that are not to be exceeded. All others are not to be equaled or exceeded. California ambient air quality standards are listed in the Table of Standards in Section 70200 of Title 17 of the California Code of Regulations.

2. National standards (other than ozone, particulate matter, and those based on annual arithmetic mean) are not to be exceeded more than once a year. The ozone standard is attained when the fourth highest 8-hour concentration measured at each site in a year, averaged over three years, is equal to or less than the standard. For PM10, the 24 hour standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 $\mu g/m^3$ is equal to or less than one. For PM2.5, the 24 hour standard is attained when 98 percent of the daily concentrations, averaged over three years, are equal to or less than the standard. Contact the U.S. EPA for further clarification and current national policies.

3. Concentration expressed first in units in which it was promulgated. Equivalent units given in parentheses are based upon a reference temperature of 25°C and a reference pressure of 760 torr. Most measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 torr; ppm in this table refers to ppm by volume, or micromoles of pollutant per mole of gas.

4. Any equivalent measurement method which can be shown to the satisfaction of the ARB to give equivalent results at or near the level of the air quality standard may be used.

5. National Primary Standards: The levels of air quality necessary, with an adequate margin of safety to protect the public health.

6. National Secondary Standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

7. Reference method as described by the U.S. EPA. An "equivalent method" of measurement may be used but must have a "consistent relationship to the reference method" and must be approved by the U.S. EPA.

8. To attain the 1-hour national standard, the 3-year average of the annual 98th percentile of the 1-hour daily maximum concentrations at each site must not exceed 100 ppb. Note that the national standards are in units of parts per billion (ppb). California standards are in units of parts per million (ppm). To directly compare the national standards to the California standards the units can be converted from ppb to ppm. In this case, the national standards of 53 ppb and 100 ppb are identical to 0.053 ppm and 0.100 ppm, respectively.

9. On June 2, 2010, a new 1-hour SO_2 standard was established and the existing 24-hour and annual primary standards were revoked. To attain the 1-hour national standard, the 3-year average of the annual 99th percentile of the 1-hour daily maximum concentrations at each site must not exceed 75 ppb. The 1971 SO_2 national standards (24-hour and annual) remain in effect until one year after an area is designated for the 2010 standard, except that in areas designated nonattainment for the 1971 standards, the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standards are approved.

   Note that the 1-hour national standard is in units of parts per billion (ppb). California standards are in units of parts per million (ppm). To directly compare the 1-hour national standard to the California standard the units can be converted to ppm. In this case, the national standard of 75 ppb is identical to 0.075 ppm.

10. The ARB has identified lead and vinyl chloride as 'toxic air contaminants' with no threshold level of exposure for adverse health effects determined. These actions allow for the implementation of control measures at levels below the ambient concentrations specified for these pollutants.

11. The national standard for lead was revised on October 15, 2008 to a rolling 3-month average. The 1978 lead standard (1.5 $\mu g/m^3$ as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978 standard, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

12. In 1989, the ARB converted both the general statewide 10-mile visibility standard and the Lake Tahoe 30-mile visibility standard to instrumental equivalents, which are "extinction of 0.23 per kilometer" and "extinction of 0.07 per kilometer" for the statewide and Lake Tahoe Air Basin standards, respectively.

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AR0069428

Area Designations for the State Ambient Air Quality Standards

The following maps and tables show the area designations for each pollutant with a State standard set forth in the California Code of Regulations Title 17 section 60200. Each area is identified as attainment, nonattainment, nonattainment-transitional, or unclassified for each pollutant, as shown below:

Attainment	A
Nonattainment	N
Nonattainment-Transitional	NA-T
Unclassified	U

In general, ARB designates areas by air basin for pollutants with a regional impact and by county for pollutants with a more local impact. However, when there are areas within an air basin or county with distinctly different air quality deriving from sources and conditions not affecting the entire air basin or county, ARB may designate a smaller area. Generally, when boundaries of the designated area differ from the air basin or county boundaries, the description of the specific area is referenced at the bottom of the summary table.

AR0069429

FIGURE 1

2012
Area Designations for State
Ambient Air Quality Standards
OZONE

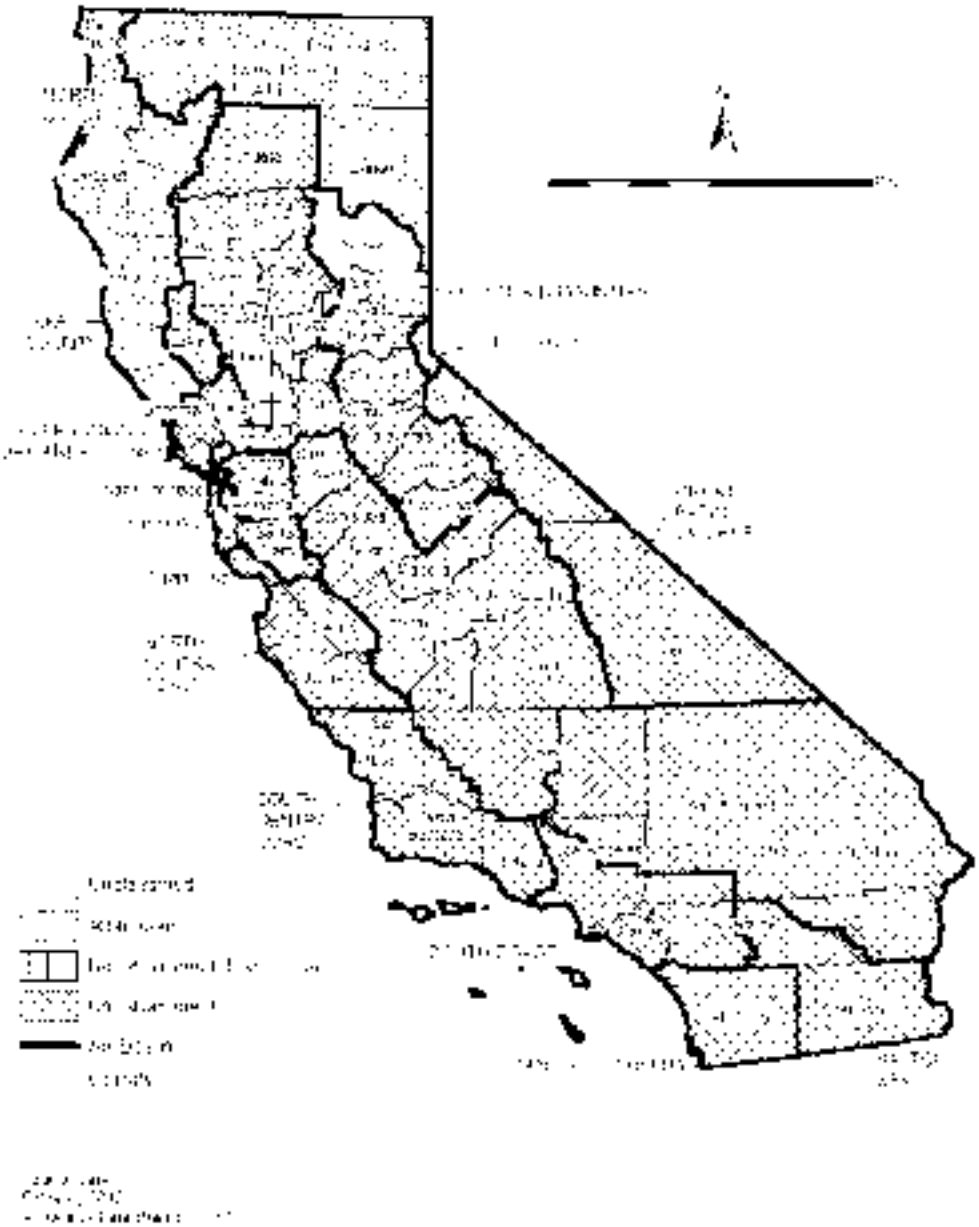


TABLE 1

California Ambient Air Quality Standards
Area Designations for Ozone [1]

	N	NA-T	U	A
GREAT BASIN VALLEYS AIR BASIN				
Alpine County			X	
Inyo County	X			
Mono County	X			
LAKE COUNTY AIR BASIN				X
LAKE TAHOE AIR BASIN		X		
MOJAVE DESERT AIR BASIN	X			
MOUNTAIN COUNTIES AIR BASIN				
Amador County	X			
Calaveras County	X			
El Dorado County (portion)	X			
Mariposa County	X			
Nevada County	X			
Placer County (portion)	X			
Plumas County			X	
Sierra County			X	
Tuolumne County	X			
NORTH CENTRAL COAST AIR BASIN	X			

	N	NA-T	U	A
NORTH COAST AIR BASIN				X
NORTHEAST PLATEAU AIR BASIN				X
SACRAMENTO VALLEY AIR BASIN				
Colusa and Glenn Counties		X		
Solano, Sutter, Yolo, and Yuba Counties		X		
Remainder of Air Basin	X			
SALTON SEA AIR BASIN	X			
SAN DIEGO AIR BASIN	X			
SAN FRANCISCO BAY AREA AIR BASIN	X			
SAN JOAQUIN VALLEY AIR BASIN	X			
SOUTH CENTRAL COAST AIR BASIN	X			
SOUTH COAST AIR BASIN	X			

(1) AB 3548 (Connelly and AB 7021 (Mobley), signed into law in 1988, made changes to Health and Safety Code section 40925.5. One of the changes directs districts to become operational nonattainment areas for ozone by operation of law.

AR0069431

FIGURE 2

2012
Area Designations for State
Ambient Air Quality Standards
PM10

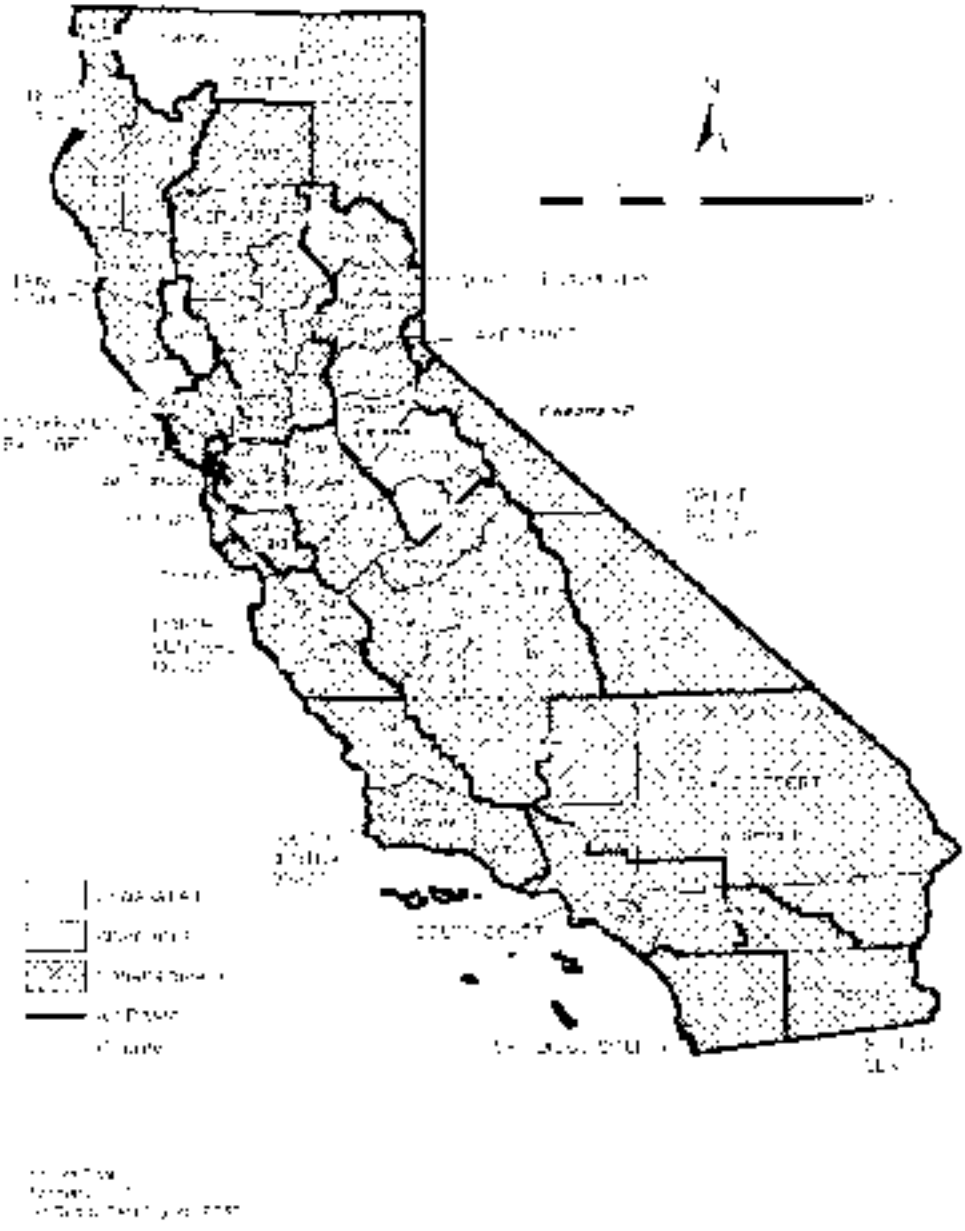


TABLE 2

California Ambient Air Quality Standards
Area Designation for Suspended Particulate Matter (PM10)

	N	U	A
GREAT BASIN VALLEYS AIR BASIN	X		
AKE COUNTY A R BASIN			X
LAKE TAHOE A R BASIN	X		
MOJAVE DESERT A R BASIN	X		
MOUNTAIN COUNTIES A R BASIN			
Alpine County		X	
Calaveras County	X		
El Dorado County (portion)	X		
Mariposa County			
- Yosemite National Park	X		
- Remainder of County		X	
Nevada County	X		
Placer County (portion)	X		
Plumas County	X		
Sierra County	X		
Tuolumne County		X	

	N	U	A
NORTH CENTRAL COAST AIR BASIN	X		
NORTH COAST AIR BASIN			
Sonoma County (portion)			X
Remainder of Air Basin	X		
NORTHEAST PLATEAU AIR BASIN			
Siskiyou County			X
Remainder of Air Basin	X		
SACRAMENTO VALLEY AIR BASIN	X		
SALTON SEA A R BASIN	X		
SAN DIEGO AIR BASIN	X		
SAN FRANCISCO BAY AREA AIR BASIN	X		
SAN JOAQUIN VALLEY AIR BASIN	X		
SOUTH CENTRAL COAST AIR BASIN	X		
SOUTH COAST AIR BASIN	X		

AR0069433

FIGURE 3

2012
Area Designations for State
Ambient Air Quality Standards
PM2.5
N
0
50
100
200
Miles
NORTHEAST PLATEAU
NORTH COAST
SACRAMENTO VALLEY
Portola Valley
MOUNTAIN COUNTIES
LAKE COUNTY
LAKE TAHOE
SAN FRANCISCO BAY AREA
GREAT BASIN VALLEYS
SAN JOAQUIN VALLEY
NORTH CENTRAL COAST
SOUTH CENTRAL COAST
County Portion of Federal Ozone AQMR
MOJAVE DESERT
SOUTH COAST
SAN DIEGO COUNTY
SALTON SEA
Unclassified
Attainment
Nonattainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 3

California Ambient Air Quality Standards
Area Designations for Fine Particulate Matter (PM2.5)

	N	U	A
GREAT BASIN VALLEYS AIR BASIN			X
Alpine County			X
LAKE TAHOE AIR BASIN			X
MOJAVE DESERT AIR BASIN			
San Bernardino County			
- County portion of Federal Southeast Desert Modified AQMA (1)	X		
Remainder of Air Basin		X	
MOUNTAIN COUNTIES AIR BASIN			
Plumas County			
- Portola Valley (2)	X		
Remainder of Air Basin		X	
NORTH CENTRAL COAST AIR BASIN			X
NORTH COAST AIR BASIN			X
NORTHEAST PLATEAU AIR BASIN			X
SACRAMENTO VALLEY AIR BASIN			
Butte County	X		
Colusa County			X
Placer County (portion)			X
Sacramento County	X		
Shasta County			X
Sutter and Yuba Counties			X
Remainder of Air Basin		X	

	N	U	A
SALTON SEA AIR BASIN			
Imperial County			
- City of Calexico (3)	X		
Remainder of Air Basin		X	
SAN DIEGO AIR BASIN	X		
SAN FRANCISCO BAY AREA AIR BASIN	X		
SAN JOAQUIN VALLEY AIR BASIN	X		
SOUTH CENTRAL COAST AIR BASIN			
San Luis Obispo County			X
Santa Barbara County		X	
Ventura County			X
SOUTH COAST AIR BASIN	X		

(1) California Code of Regulations, title 17, section 60200(b)
(2) California Code of Regulations, title 17, section 60200(c)
(3) California Code of Regulations, title 17, section 60105(a)

AR0069435

FIGURE 4

2012
Area Designations for State
Ambient Air Quality Standards
CARBON MONOXIDE
N
0
50
100
200
Miles
NORTH COAST
NORTHEAST PLATEAU
SACRAMENTO VALLEY
LAKE COUNTY
MOUNTAIN COUNTIES
LAKE TAHOE
SAN FRANCISCO BAY AREA
GREAT BASIN VALLEYS
SAN JOAQUIN VALLEY
NORTH CENTRAL COAST
SOUTH CENTRAL COAST
MOJAVE DESERT
SOUTH COAST
SAN DIEGO COUNTY
SALTON SEA
Unclassified
Attainment
Nonattainment-Transitional
Nonattainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 4

California Ambient Air Quality Standards
Area Designation for Carbon Monoxide*

	N	NA-T	U	A
GREAT BASIN VALLEYS AIR BASIN				
Alpine County			X	
Inyo County				X
Mono County				X
LAKE COUNTY AIR BASIN				X
LAKE TAHOE AIR BASIN				X
MOJAVE DESERT AIR BASIN				
Kern County (portion)			X	
Los Angeles County (portion)				X
Riverside County (portion)			X	
San Bernardino County (portion)				X
MOUNTAIN COUNTIES AIR BASIN				
Amador County			X	
Calaveras County			X	
El Dorado County (portion)			X	
Mariposa County			X	
Nevada County			X	
Placer County (portion)			X	
Plumas County				X
Sierra County			X	
Tuolumne County				X
NORTH CENTRAL COAST AIR BASIN				
Monterey County				X
San Benito County			X	
Santa Cruz County			X	
NORTH COAST AIR BASIN				
Del Norte County			X	
Humboldt County				X
Mendocino County				X
Sonoma County (portion)			X	
Trinity County			X	
NORTHEAST PLATEAU AIR BASIN			X	

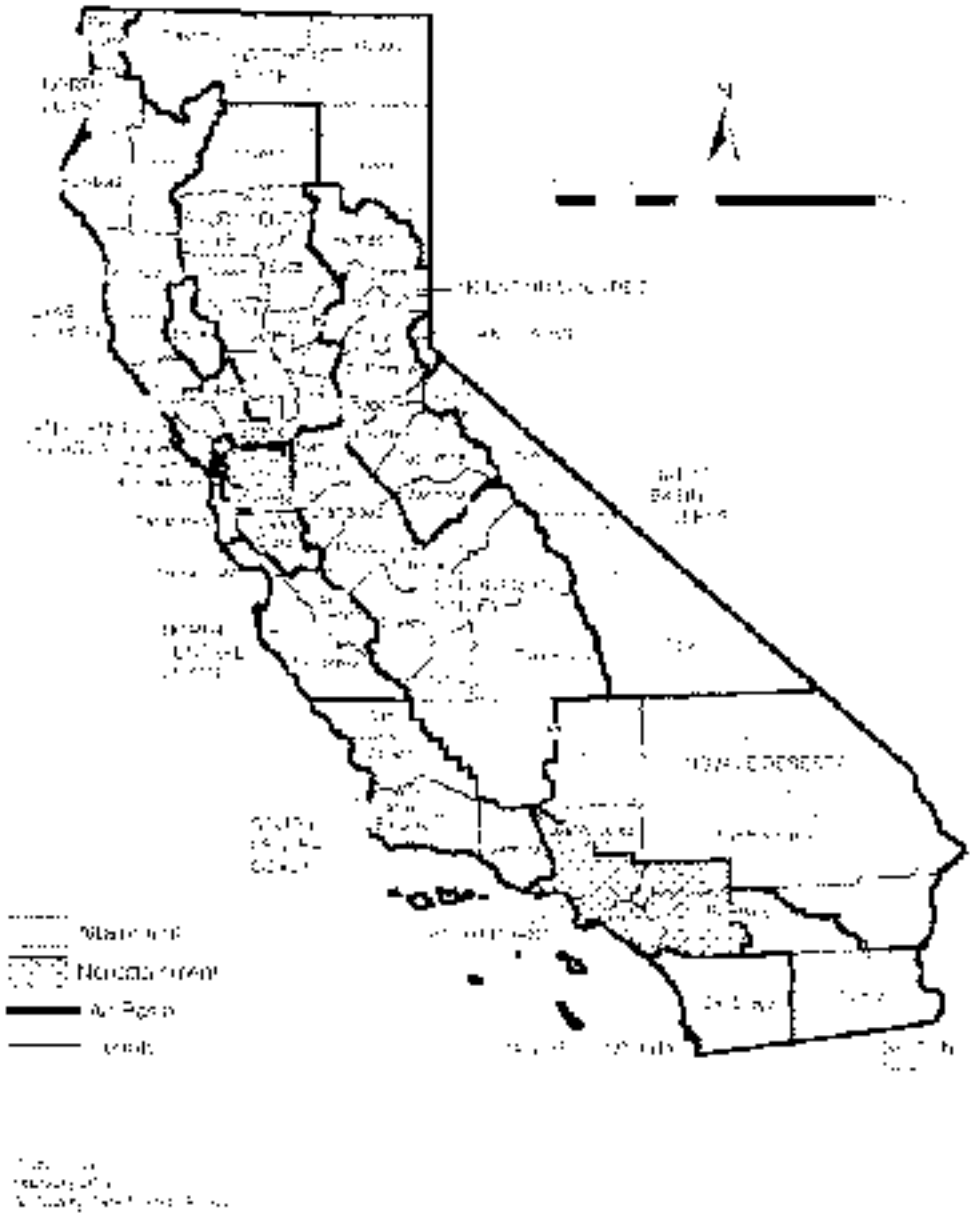
	N	NA-T	U	A
SACRAMENTO VALLEY AIR BASIN				
Butte County				X
Colusa County			X	
Glenn County			X	
Placer County (portion)				X
Sacramento County				X
Shasta County			X	
Solano County (portion)				X
Sutter County				X
Tehama County			X	
Yolo County				X
Yuba County			X	
SALTON SEA AIR BASIN				
Imperial County				X
Riverside County (portion)				X
SAN DIEGO AIR BASIN				X
SAN FRANCISCO BAY AREA AIR BASIN				X
SAN JOAQUIN VALLEY AIR BASIN				
Fresno County				X
Kern County (portion)				X
Kings County			X	
Madera County			X	
Merced County			X	
San Joaquin County				X
Stanislaus County				X
Tulare County				X
SOUTH CENTRAL COAST AIR BASIN				X
SOUTH COAST AIR BASIN				
Los Angeles County (portion)				X
Orange County				X
Riverside County (portion)				X
San Bernardino County (portion)				X

* The area designated for carbon monoxide is a county or portion of a county.

AR0069437

FIGURE 5

2012
Area Designations for State
Ambient Air Quality Standards
NITROGEN DIOXIDE



AR0069438

TABLE 5

California Ambient Air Quality Standards
Area Designation for Nitrogen Dioxide

	N	U	A
GREAT BASIN VALLEYS AIR BASIN			X
LAKE COUNTY AIR BASIN			X
LAKE TAHOE AIR BASIN			X
MOJAVE DESERT AIR BASIN			X
MOUNTAIN COUNTIES AIR BASIN			X
NORTH CENTRAL COAST AIR BASIN			X
NORTH COAST AIR BASIN			X
NORTHEAST PLATEAU AIR BASIN			X
SACRAMENTO VALLEY AIR BASIN			X
SALTON SEA AIR BASIN			X
SAN DIEGO AIR BASIN			X
SAN FRANCISCO BAY AREA AIR BASIN			X
SAN JOAQUIN VALLEY AIR BASIN			X
SOUTH CENTRAL COAST AIR BASIN			X
SOUTH COAST AIR BASIN	X		

AR0069439

FIGURE 6

2012
Area Designations for State
Ambient Air Quality Standards
SULFUR DIOXIDE

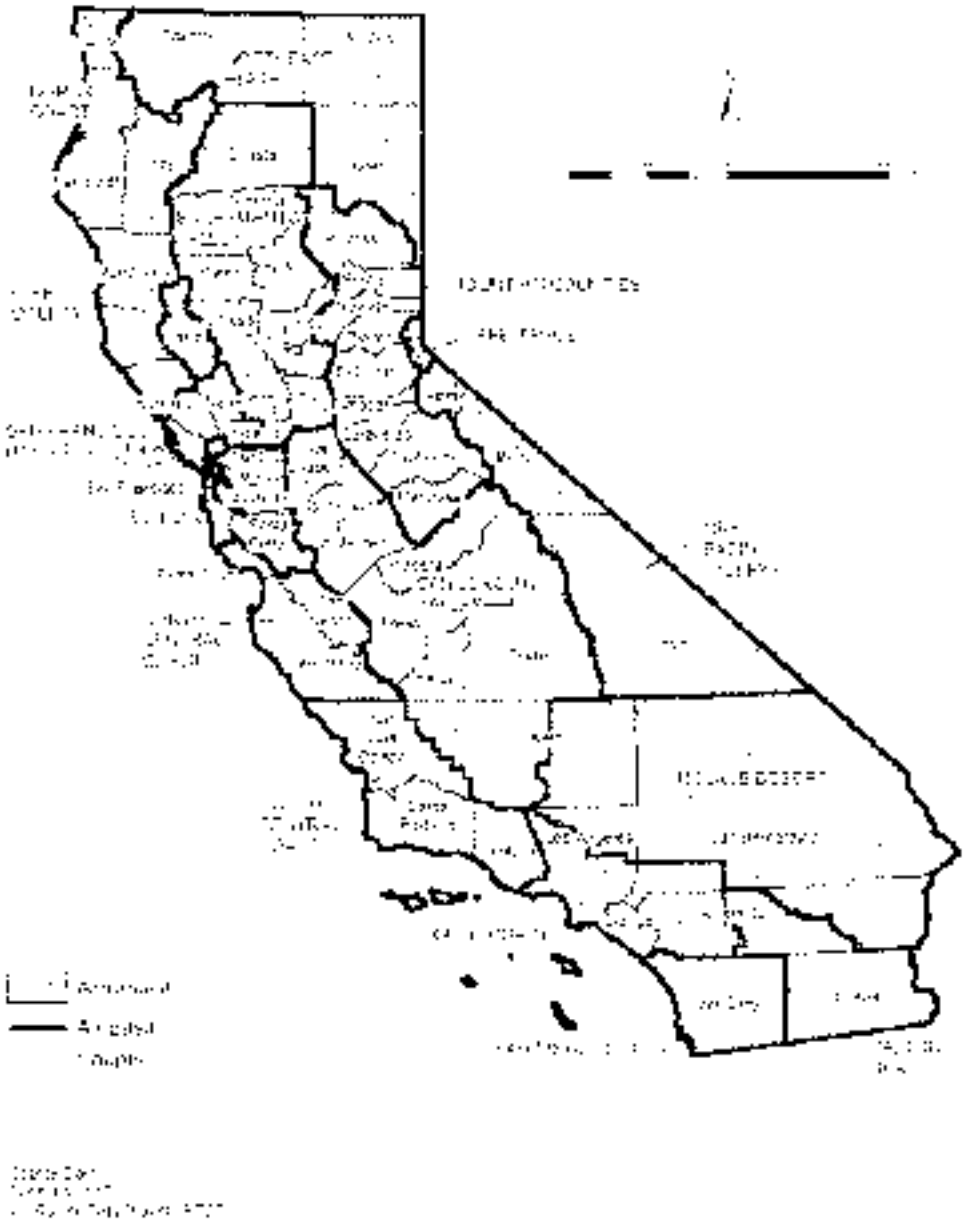


TABLE 6

California Ambient Air Quality Standards
Area Designation for Sulfur Dioxide*

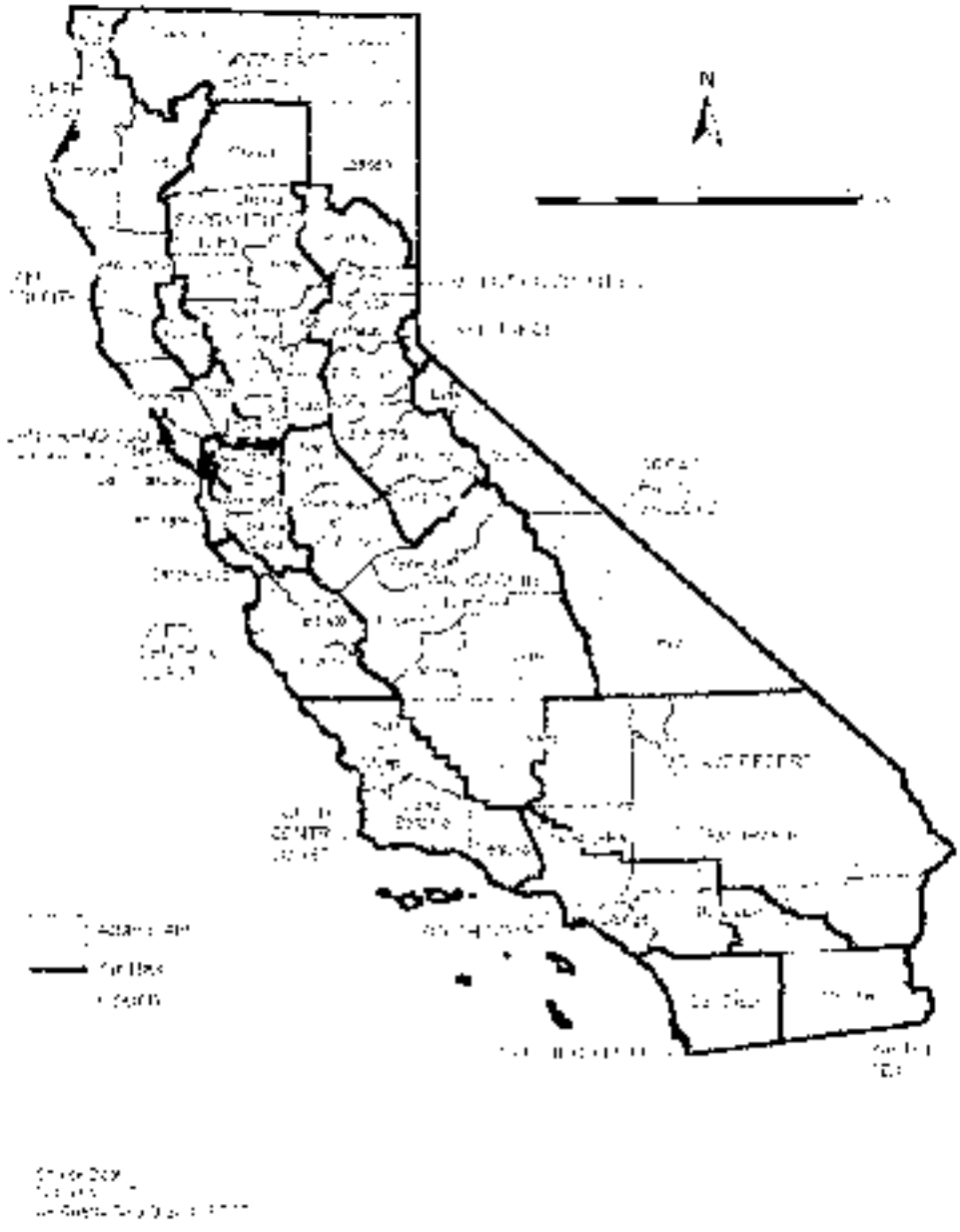
	N	U	A		N	U	A
GREAT BASIN VALLEYS AIR BASIN			X	SACRAMENTO VALLEY AIR BASIN			X
LAKE COUNTY AIR BASIN			X	SALTON SEA AIR BASIN			X
LAKE TAHOE AIR BASIN			X	SAN DIEGO AIR BASIN			X
MOJAVE DESERT AIR BASIN			X	SAN FRANCISCO BAY AREA AIR BASIN			X
MOUNTAIN COUNTIES AIR BASIN			X	SAN JOAQUIN VALLEY AIR BASIN			X
NORTH CENTRAL COAST AIR BASIN			X	SOUTH CENTRAL COAST AIR BASIN			X
NORTH COAST AIR BASIN			X	SOUTH COAST AIR BASIN			X
NORTHEAST PLATEAU AIR BASIN			X				

* The area designated for sulfur dioxide is a county or portion of a county.

AR0069441

FIGURE 7

2012
Area Designations for State
Ambient Air Quality Standards
SULFATES



AR0069442

TABLE 7

California Ambient Air Quality Standards
Area Designation for Sulfates

	N	U	A		N	U	A
GREAT BASIN VALLEYS AIR BASIN			X	SACRAMENTO VALLEY AIR BASIN			X
LAKE COUNTY AIR BASIN			X	SALTON SEA AIR BASIN			X
LAKE TAHOE AIR BASIN			X	SAN DIEGO AIR BASIN			X
MOJAVE DESERT AIR BASIN			X	SAN FRANCISCO BAY AREA AIR BASIN			X
MOUNTAIN COUNTIES AIR BASIN			X	SAN JOAQUIN VALLEY AIR BASIN			X
NORTH CENTRAL COAST AIR BASIN			X	SOUTH CENTRAL COAST AIR BASIN			X
NORTH COAST AIR BASIN			X	SOUTH COAST AIR BASIN			X
NORTHEAST PLATEAU AIR BASIN			X				

AR0069443

FIGURE 8

2012
Area Designations for State Ambient Air Quality Standards
LEAD

Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 8

California Ambient Air Quality Standards
Area Designations for Lead (particulate)*

	N	U	A
GREAT BASIN VALLEYS AIR BASIN			X
LAKE COUNTY AIR BASIN			X
LAKE TAHOE AIR BASIN			X
MOJAVE DESERT AIR BASIN			X
MOUNTAIN COUNTIES AIR BASIN			X
NORTH CENTRAL COAST AIR BASIN			X
NORTH COAST AIR BASIN			X
NORTHEAST PLATEAU AIR BASIN			X
SACRAMENTO VALLEY AIR BASIN			X

	N	U	A
SALTON SEA AIR BASIN			X
SAN DIEGO AIR BASIN			X
SAN FRANCISCO BAY AREA AIR BASIN			X
SAN JOAQUIN VALLEY AIR BASIN			X
SOUTH CENTRAL COAST AIR BASIN			X
SOUTH COAST AIR BASIN			
Los Angeles County	X		
Remainder of Air Basin			X

* The area designated for lead is a county or portion of a county

AR0069445

FIGURE 9

2012
Area Designations for State
Ambient Air Quality Standards
HYDROGEN SULFIDE
N
0
50
100
200
Miles
NORTHEAST PLATEAU
NORTH COAST
SACRAMENTO VALLEY
MOUNTAIN COUNTIES
LAKE COUNTY
LAKE TAHOE
Geyser Geothermal
City of Sutter Creek
SAN FRANCISCO BAY AREA
GREAT BASIN VALLEYS
SAN JOAQUIN VALLEY
NORTH CENTRAL COAST
Searles Valley
MOJAVE DESERT
SOUTH CENTRAL COAST
SOUTH COAST
SAN DIEGO COUNTY
SALTON SEA
Unclassified
Attainment
Nonattainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 9

California Ambient Air Quality Standards
Area Designation for Hydrogen Sulfide*

	N	NA-T	U	A
GREAT BASIN VALLEYS AIR BASIN				
Alpine County			X	
Inyo County				X
Mono County				X
LAKE COUNTY AIR BASIN				X
LAKE TAHOE AIR BASIN			X	
MOJAVE DESERT AIR BASIN				
Kern County (portion)			X	
Los Angeles County (portion)			X	
Riverside County (portion)			X	
San Bernardino County (portion)				
- Searles Valley Planning Area (1)	X			
Remainder of County			X	
MOUNTAIN COUNTIES AIR BASIN				
Amador County				
City of Sutter Creek	X			
Remainder of County			X	
Calaveras County			X	
El Dorado County (portion)			X	
Mariposa County			X	
Nevada County			X	
Placer County (portion)			X	
Plumas County			X	
Sierra County			X	
Tuolumne County			X	

	N	NA-T	U	A
NORTH CENTRAL COAST AIR BASIN			X	
NORTH COAST AIR BASIN				
Del Norte County			X	
Humboldt County				X
Mendocino County			X	
Sonoma County (portion)				
Geyser Geothermal Area (2)				X
Remainder of County			X	
Trinity County			X	
NORTHEAST PLATEAU AIR BASIN			X	
SACRAMENTO VALLEY AIR BASIN			X	
SALTON SEA AIR BASIN			X	
SAN DIEGO AIR BASIN			X	
SAN FRANCISCO BAY AREA AIR BASIN			X	
SAN JOAQUIN VALLEY AIR BASIN			X	
SOUTH CENTRAL COAST AIR BASIN				
San Luis Obispo County				X
Santa Barbara County				X
Ventura County			X	
SOUTH COAST AIR BASIN			X	

* The area designated for hydrogen sulfide is a county or portion of a county.

(1) 52 Federal Register 29381 (August 7, 1987).

(2) California Code of Regulations, title 17, section 80235(c).

AR0069447

FIGURE 10

2012
Area Designations for State
Ambient Air Quality Standards
VISIBILITY REDUCING
PARTICLES
Del Norte
Siskiyou
Modoc
NORTHEAST PLATEAU
NORTH COAST
Trinity
Shasta
Lassen
Humboldt
Tehama
SACRAMENTO VALLEY
Plumas
Mendocino
Glenn
Butte
Sierra
MOUNTAIN COUNTIES
Nevada
LAKE COUNTY
Colusa
Yuba
Placer
LAKE TAHOE
Lake
Sutter
Yolo
El Dorado
Sonoma
Napa
Sac
Amador
Alpine
SAN FRANCISCO BAY AREA
Solano
Calaveras
Marin
Contra Costa
San Joaquin
Tuolumne
Mono
San Francisco
Alameda
Stanislaus
Mariposa
GREAT BASIN VALLEYS
San Mateo
Santa Clara
Merced
Madera
Santa Cruz
SAN JOAQUIN VALLEY
San Benito
Fresno
Inyo
NORTH CENTRAL COAST
Monterey
Kings
San Luis Obispo
Kern
MOJAVE DESERT
Santa Barbara
SOUTH CENTRAL COAST
Ventura
Los Angeles
San Bernardino
Orange
Riverside
SOUTH COAST
San Diego
Imperial
SAN DIEGO COUNTY
SALTON SEA
N
0
50
100
200
Miles
Unclassified
Attainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 10

California Ambient Air Quality Standards
Area Designation for Visibility Reducing Particles

	N	NA-T	U	A		N	NA-T	U	A
GREAT BASIN VALLEYS AIR BASIN			X		SACRAMENTO VALLEY AIR BASIN			X	
LAKE COUNTY AIR BASIN				X	SALTON SEA AIR BASIN			X	
LAKE TAHOE AIR BASIN			X		SAN DIEGO AIR BASIN			X	
MOJAVE DESERT AIR BASIN			X		SAN FRANCISCO BAY AREA AIR BASIN			X	
MOUNTAIN COUNTIES AIR BASIN			X		SAN JOAQUIN VALLEY AIR BASIN			X	
NORTH CENTRAL COAST AIR BASIN			X		SOUTH CENTRAL COAST AIR BASIN			X	
NORTH COAST AIR BASIN			X		SOUTH COAST AIR BASIN			X	
NORTHEAST PLATEAU AIR BASIN			X						

AR0069449

Area Designations for the National Ambient Air Quality Standards

The following maps and tables show the area designations for each pollutant with a national ambient air quality standard. Additional information about the federal area designations is available on the U.S. EPA website

http://www.epa.gov/airprogm/oar/oaqps/greenbk

Over the last several years U.S. EPA has been reviewing the levels of the various national standards. The agency has already promulgated new standard levels for some pollutants and is considering revising the levels for others. Information about the status of these reviews is available on the U.S. EPA website:

http://epa.gov/airquality/urbanair/

Designation Categories

Ozone and Suspended Particulate Matter (PM_{10}). The U.S. EPA uses three categories to designate areas with respect to ozone and PM_{10}

- Attainment
- Nonattainment
- Unclassifiable

The national 1-hour ozone standard was revoked effective June 15, 2005, and the current area designations reflect the 2008 national 8-hour ozone standard of 0.075 ppm. These designations were finalized on April 30, 2012.

Fine Suspended Particulate Matter ($PM_{2.5}$), Carbon Monoxide (CO), and Nitrogen Dioxide (NO_2). The U.S. EPA uses two categories to designate areas with respect to these standards

- Nonattainment
- Unclassifiable/Attainment

New national area designations for $PM_{2.5}$ became effective December 14, 2009. These designations reflect both the annual average standard of 15 $\mu g/m^3$ and the recently revised (December 2006) 24-hour standard of 35 $\mu g/m^3$.

On January 22, 2010, the U.S. EPA established a new national 1-hour NO_2 standard of 100 parts per billion (ppb) and retained the annual average standard of 53 ppb. New designations for the primary NO_2 standard became effective on February 29, 2012. All areas of California meet this standard.

AR0069450

Sulfur Dioxide (SO_2) The U.S. EPA uses four categories to designate areas with respect to the 24-hour and annual average sulfur dioxide standards. These designation categories are

- Does not meet the primary standards.
- Does not meet the secondary standards,
- Cannot be classified and
- Better than the national standards

In California, the first two designation categories listed above are not applicable because all areas of California either meet the primary and secondary standards or are unclassifiable. The map and summary table for sulfur dioxide show areas that cannot be classified as "U" for unclassifiable and areas that are better than the national standards as "A" for attainment.

On June 2, 2010, the U.S. EPA established a new primary 1-hour SO_2 standard of 75 parts per billion (ppb). At the same time, U.S. EPA revoked the 24-hour and annual average standards. U.S. EPA is currently in the process of designating areas for the 2010 national 1-hour SO_2 standard of 75 ppb. However, these designations are not expected to be finalized until June 2012.

Lead (particulate) The U.S. EPA promulgated a new lead standard in October 2008 of 0.15 $\mu g/m^3$ for a 3 month average. This new standard is ten times lower than the former lead standard. Effective December 31, 2010, several areas in the nation became nonattainment for lead, based on data collected during 2007 through 2009. All other areas were designated as unclassified. These unclassified designations will be resolved over the next several years as data from a new, source-oriented monitoring network become available.

Designated Areas

From time to time, the boundaries of the California air basins have been changed to facilitate the planning process. ARB generally initiates these changes, and they are not always reflected in the U.S. EPA's area designations. For purposes of consistency, the maps in this attachment reflect area designation boundaries and nomenclature as promulgated by the U.S. EPA. In some cases, these may not be the same as those adopted by ARB. For example, the national area designations reflect the former Southeast Desert Air Basin. In accordance with Health and Safety Code section 39606.1, ARB redefined this area in 1996 to be the Mojave Desert Air Basin and Salton Sea Air Basin. The definitions and boundaries for all areas designated for the national standards can be found in Title 40, Code of Federal Regulations (CFR) Chapter I, Part 81.305. They are available on the web at:

http://www.access.gpo.gov/nara/cfr/waisidx_05/40cfr81_05.html

Once at this website, scroll down to Part 81.305 to view the California area designations.

AR0069451

FIGURE 11

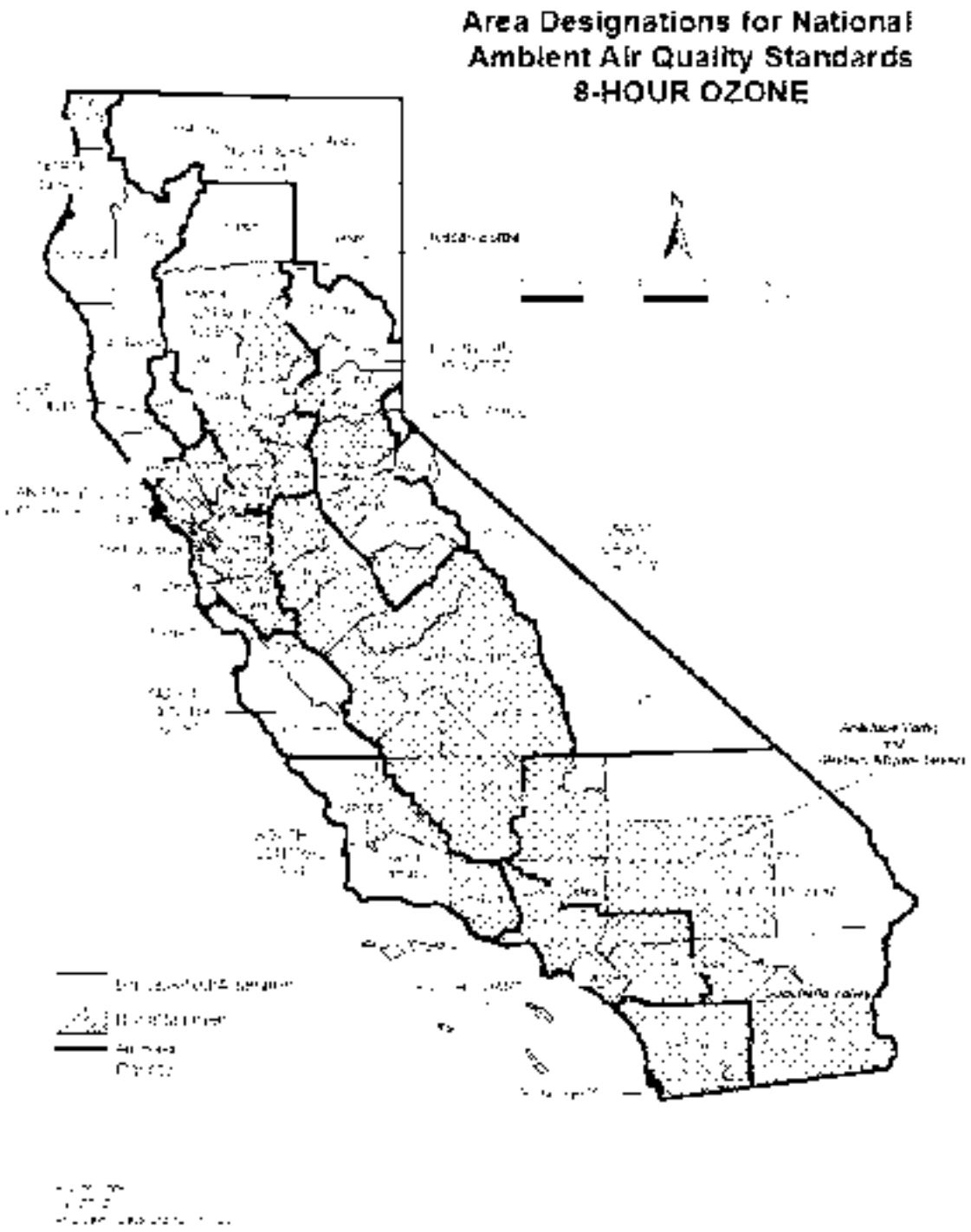

Area Designations for National
Ambient Air Quality Standards
8-HOUR OZONE

TABLE 11

National Ambient Air Quality Standards
Area Designations for 8-Hour Ozone*

	N	U/A		N	U / A
GREAT BASIN VALLEYS AIR BASIN		X	SACRAMENTO VALLEY AIR BASIN (cont.)		
LAKE COUNTY AIR BASIN		X	Yolo County (2)	X	
LAKE TAHOE AIR BASIN		X	Yuba County		X
MOUNTAIN COUNTIES AIR BASIN			SAN DIEGO COUNTY	X	
Amador County		X	SAN FRANCISCO BAY AREA AIR BASIN	X	
Calaveras County	X		SAN JOAQUIN VALLEY AIR BASIN	X	
El Dorado County (portion) (2)	X		SOUTH CENTRAL COAST AIR BASIN (1)		
Mariposa County	X		San Luis Obispo County		
Nevada County			- Eastern San Luis Obispo County	X	
- Western Nevada County	X		- Remainder of County		X
- Remainder of County		X	Santa Barbara County		X
Placer County (portion) (2)	X		Ventura County		
Plumas County		X	- Area excluding Anacapa and San Nicolas Islands	X	
Sierra County		X	- Channel Islands (1)		X
Tuolumne County		X	SOUTH COAST AIR BASIN (1)	X	
NORTH CENTRAL COAST AIR BASIN		X	SOUTHEAST DESERT AIR BASIN		
NORTH COAST AIR BASIN		X	Kern County (portion)	X	
NORTHEAST PLATEAU AIR BASIN		X	- Indian Wells Valley		X
SACRAMENTO VALLEY AIR BASIN			Imperial County	X	
Butte County	X		Los Angeles County (portion)	X	
Colusa County		X	Riverside County (portion)		
Glenn County		X	- Coachella Valley	X	
Sacramento Metro Area (2)	X		- Non-AQMA portion		X
Shasta County		X	San Bernardino County		
Sutter County			- Western portion (AQMA)	X	
- Southern portion of Sutter County (2)	X		- Eastern portion (non-AQMA)		X
- Remainder of Sutter County		X			
Tehama County					
- Tuscan Buttes	X				
- Remainder of Tehama County		X			

* Definitions and references for all areas can be found in 40 CFR, Chapter I, Part 81.305.
Areas may include Indian country of tribes listed in the tables located on the U.S. EPA website at:
http://www.epa.gov/airquality/ozonepollution/designations/2008standards/final/tribalf.htm and
http://www.epa.gov/airquality/ozonepollution/designations/2008standards/documents/20120430desfr.pdf.

(1) South Central Coast Air Basin Channel Islands:
Santa Barbara County includes Santa Cruz, San Miguel, Santa Rosa, and Santa Barbara Islands.
Ventura County includes Anacapa and San Nicolas Islands.
South Coast Air Basin:
Los Angeles County includes San Clemente and Santa Catalina Islands.

(2) For this purpose, the Sacramento Metro Area comprises all of Sacramento and Yolo Counties, the Sacramento Valley Air Basin portion of Solano County, the southern portion of Sutter County, and the Sacramento Valley and Mountain Counties Air Basins portions of Placer and El Dorado counties.

FIGURE 12

Area Designations for National Ambient Air Quality Standards PM10
N
NORTH COAST
NORTHEAST PLATEAU
SACRAMENTO VALLEY
MOUNTAIN COUNTIES
LAKE COUNTY
LAKE TAHOE
SAN FRANCISCO BAY AREA
GREAT BASIN VALLEYS
NORTH CENTRAL COAST
SAN JOAQUIN VALLEY
SOUTH CENTRAL COAST
SOUTHEAST DESERT
SOUTH COAST
SAN DIEGO COUNTY
Unclassified
Attainment
Nonattainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 12

National Ambient Air Quality Standards
Area Designations for Suspended Particulate Matter (PM10)*

	N	U	A
GREAT BASIN VALLEYS AIR BASIN			
Alpine County		X	
Inyo County			
- Owens Valley Planning Area	X		
Coso Junction			X
- Remainder of County		X	
Mono County			
- Mammoth Lake Planning Area	X		
- Mono Lake Basin	X		
- Remainder of County		X	
LAKE COUNTY AIR BASIN		X	
LAKE TAHOE AIR BASIN		X	
MOUNTAIN COUNTIES AIR BASIN			
Placer County (portion)(2)		X	
Remainder of Air Basin		X	
NORTH CENTRAL COAST AIR BASIN		X	
NORTH COAST AIR BASIN		X	
NORTHEAST PLATEAU AIR BASIN		X	
SACRAMENTO VALLEY AIR BASIN			
Butte County		X	
Colusa County		X	
Glenn County		X	
Placer County (portion)(2)		X	
Sacramento County (1)	X		
Shasta County		X	
Solano County (portion)		X	
Sutter County		X	
Tehama County		X	
Yolo County		X	
Yuba County		X	

	N	U	A
SAN DIEGO COUNTY		X	
SAN FRANCISCO BAY AREA AIR BASIN		X	
SAN JOAQUIN VALLEY AIR BASIN			X
SOUTH CENTRAL COAST AIR BASIN		X	
SOUTH COAST AIR BASIN (1)	X		
SOUTHEAST DESERT AIR BASIN			
Eastern Kern County			
- Indian Wells Valley			X
- Portion within San Joaquin Valley Planning Area	X		
- Remainder of County		X	
Imperial County			
- Imperial Valley Planning Area	X		
- Remainder of County		X	
Los Angeles County (portion)		X	
Riverside County (portion)			
- Coachella Valley (1)	X		
Non AQMA portion		X	
San Bernardino County			
- Trona	X		
Remainder of County	X		

* Definitions and references for Areas can be found in 40 CFR, Chapter I, Part 81.305.
(1) Air quality in Sacramento, South Coast, and Coachella Valley meets the national PM10 standards. Requests for redesignation
may be considered once have been submitted to U.S. EPA.
(2) U.S. EPA designation puts the Sacramento Valley Air Basin portion of Placer County in the Mountain Counties Air Basin.

AR0069455

FIGURE 13

Area Designations for National Ambient Air Quality Standards PM2.5
N
0 40 80 120 160 Miles
NORTH COAST
Siskiyou
Modoc
NORTHEAST PLATEAU
Humboldt
Trinity
Shasta
Lassen
Tehama
Plumas
SACRAMENTO VALLEY
Glenn
Butte
Sierra
MOUNTAIN COUNTIES
Mendocino
LAKE COUNTY
Colusa
Yuba
Nevada
Placer
LAKE TAHOE
Lake
Yolo
Sutter
Yuba
El Dorado
Alpine
Napa
Solano
Amador
Calaveras
GREAT BASIN VALLEYS
Tuolumne
Mono
SAN FRANCISCO BAY AREA
Marin
Contra Costa
Alameda
Mariposa
San Mateo
Santa Clara
Merced
Stanislaus
Fresno
NORTH CENTRAL COAST
San Benito
SAN JOAQUIN VALLEY
Kings
Inyo
Monterey
Tulare
Kern
San Luis Obispo
San Bernardino
SOUTH CENTRAL COAST
Santa Barbara
SOUTHEAST DESERT
Ventura
Riverside
SOUTH COAST
Orange
San Diego
Imperial
SAN DIEGO COUNTY
Unclassified/Attainment
Nonattainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 13

National Ambient Air Quality Standards
Area Designations for Fine Particulate Matter (PM2.5)*

	N	U/A
GREAT BASIN VALLEYS AIR BASIN		X
LAKE COUNTY AIR BASIN		X
LAKE TAHOE AIR BASIN		X
MOUNTAIN COUNTIES AIR BASIN		X
NORTH CENTRAL COAST AIR BASIN		X
NORTH COAST AIR BASIN		X
NORTHEAST PLATEAU AIR BASIN		X
SACRAMENTO VALLEY AIR BASIN		
Butte County (portion) (1)	X	
Sacramento Metro Area (2)	X	
Sutter County (3)	X	
Yuba County (portion) (3)	X	
Remainder of Air Basin		X

	N	U/A
SAN DIEGO COUNTY		X
SAN FRANCISCO BAY AREA AIR BASIN	X	
SAN JOAQUIN VALLEY AIR BASIN	X	
SOUTH CENTRAL COAST AIR BASIN		X
SOUTH COAST AIR BASIN (4)	X	
SOUTHEAST DESERT AIR BASIN		
Imperial County (portion) (5)	X	
Remainder of Air Basin		X

* Definitions and references for all areas can be found in 40 CFR, Chapter I, Part 81.306.

(1) City of Chico and surrounding areas.
(2) For this purpose, Sacramento Metro Area comprises all of Sacramento and portions of El Dorado, Placer, Solano, and Yolo Counties.
(3) Comprises all of Sutter and western portion of Yuba County.
(4) Those lands of the Santa Rosa Band of Cahuilla Mission Indians in Riverside County are designated Unclassifiable Attainment.
(5) That portion of Imperial County encompassing the urban and surrounding areas of Brawley, Calexico, El Centro, Heber, Holtville, Imperial, Seeley, and Westmorland.

AR0069457

FIGURE 14

Area Designations for National Ambient Air Quality Standards
CARBON MONOXIDE
N
0 50 100 150 200 Miles
Del Norte
Siskiyou
Modoc
NORTHEAST PLATEAU
NORTH COAST
Humboldt
Trinity
Shasta
Lassen
Tehama
SACRAMENTO VALLEY
Plumas
Mendocino
Glenn
Butte
Sierra
Nevada
MOUNTAIN COUNTIES
Colusa
Yuba
Placer
LAKE TAHOE
Lake
Sutter
LAKE COUNTY
Yolo
El Dorado
Napa
Sac
Amador
Alpine
Sonoma
SAN FRANCISCO BAY AREA
Solano
Calaveras
Marin
Contra Costa
San Joaquin
Tuolumne
Mono
GREAT BASIN VALLEYS
San Francisco
Alameda
Stanislaus
Mariposa
San Mateo
Santa Clara
Merced
Santa Cruz
Madera
SAN JOAQUIN VALLEY
San Benito
Fresno
NORTH CENTRAL COAST
Inyo
Tulare
Monterey
Kings
San Luis Obispo
Kern
SOUTH CENTRAL COAST
SOUTHEAST DESERT
Santa Barbara
Ventura
Los Angeles
San Bernardino
Orange
Riverside
SOUTH COAST
San Diego
Imperial
SAN DIEGO COUNTY
Unclassified/Attainment
Nonattainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 14

National Ambient Air Quality Standards
Area Designations for Carbon Monoxide*

	N	U/A		N	U/A
GREAT BASIN VALLEYS AIR BASIN		X	SACRAMENTO VALLEY AIR BASIN		X
LAKE COUNTY AIR BASIN		X	SAN DIEGO COUNTY		X
LAKE TAHOE AIR BASIN		X	SAN FRANCISCO BAY AREA AIR BASIN		X
MOUNTAIN COUNTIES AIR BASIN		X	SAN JOAQUIN VALLEY AIR BASIN		X
NORTH CENTRAL COAST AIR BASIN		X	SOUTH CENTRAL COAST AIR BASIN		X
NORTH COAST AIR BASIN		X	SOUTH COAST AIR BASIN		X
NORTHEAST PLATEAU AIR BASIN		X	SOUTHEAST DESERT AIR BASIN		X

* Definitions and references for all areas can be found in 40 CFR, Chapter I, Part 81, 305

AR0069459

FIGURE 15

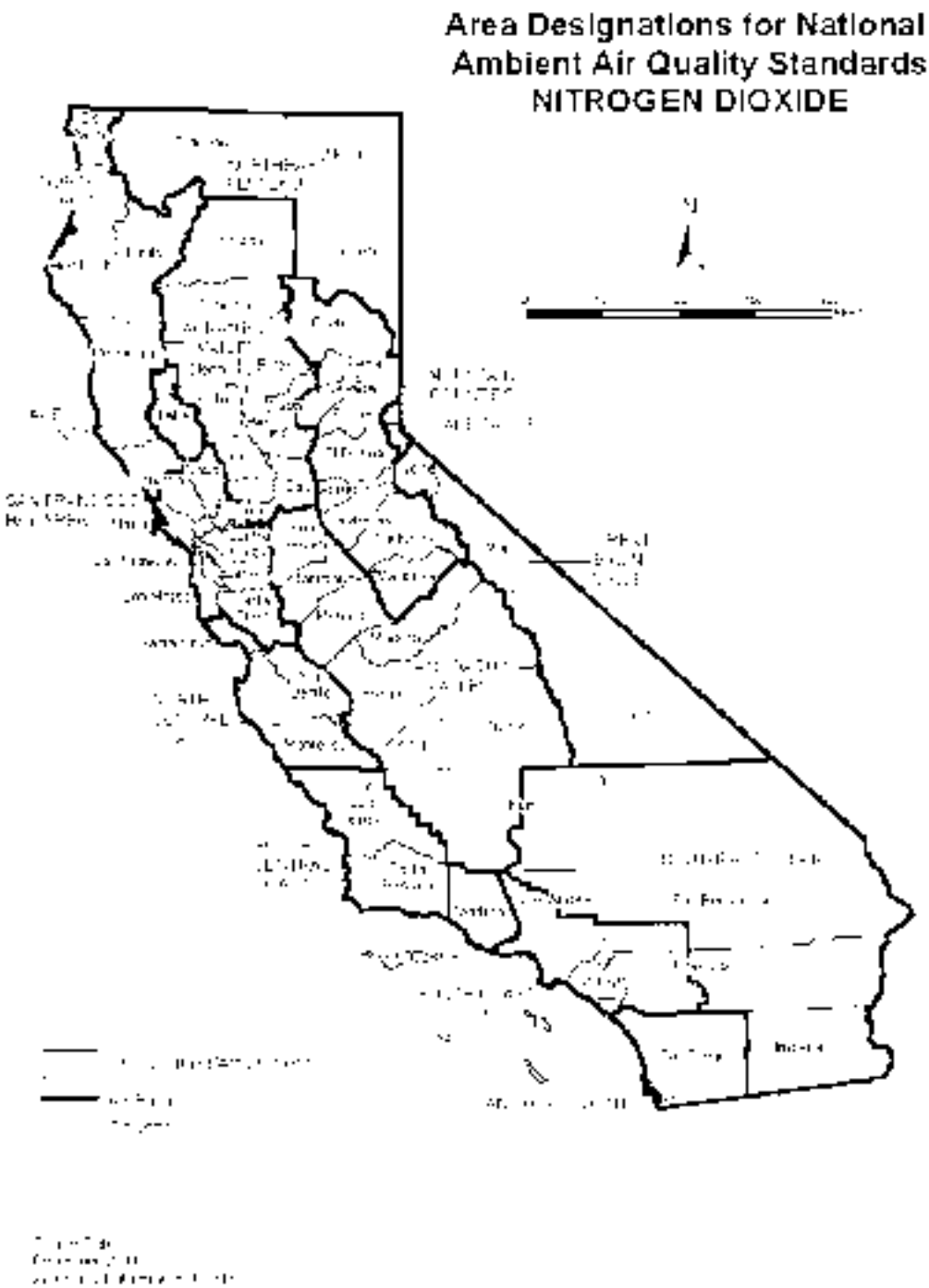

Area Designations for National
Ambient Air Quality Standards
NITROGEN DIOXIDE

TABLE 15

National Ambient Air Quality Standards
Area Designations for Nitrogen Dioxide*

	N	U/A		N	U/A
GREAT BASIN VALLEYS AIR BASIN		X	SACRAMENTO VALLEY AIR BASIN		X
LAKE COUNTY AIR BASIN		X	SAN DIEGO COUNTY		X
LAKE TAHOE AIR BASIN		X	SAN FRANCISCO BAY AREA AIR BASIN		X
MOUNTAIN COUNTIES AIR BASIN		X	SAN JOAQUIN VALLEY AIR BASIN		X
NORTH CENTRAL COAST AIR BASIN		X	SOUTH CENTRAL COAST AIR BASIN		X
NORTH COAST AIR BASIN		X	SOUTH COAST AIR BASIN		X
NORTHEAST PLATEAU AIR BASIN		X	SOUTHEAST DESERT AIR BASIN		X

* Definitions and references for all areas can be found in 40 CFR, Chapter I, Part 81, 329.

AR0069461

FIGURE 16

Area Designations for National Ambient Air Quality Standards
SULFUR DIOXIDE

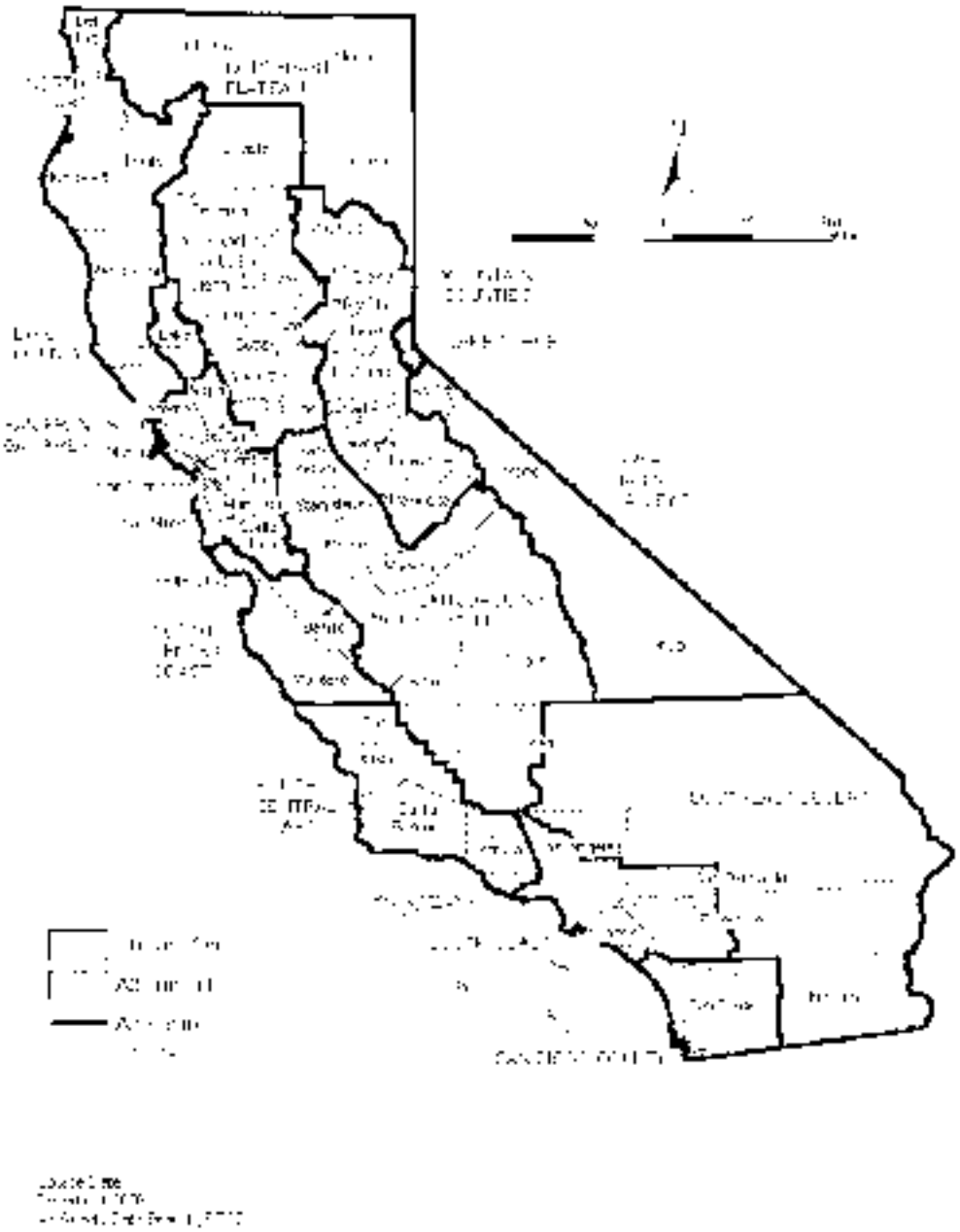


TABLE 16

National Ambient Air Quality Standards
Area Designations for Sulfur Dioxide*

	A	U		A	U
GREAT BASIN VALLEYS AIR BASIN		X	SOUTH CENTRAL COAST AIR BASIN		
LAKE COUNTY AIR BASIN		X	San Luis Obispo County		X
LAKE TAHOE AIR BASIN	X		Santa Barbara County		X
MOUNTAIN COUNTIES AIR BASIN		X	Ventura County	X	
NORTH CENTRAL COAST AIR BASIN		X	Channel Islands (1)		X
NORTH COAST AIR BASIN		X	SOUTH COAST AIR BASIN	X	
NORTHEAST PLATEAU AIR BASIN		X	SOUTHEAST DESERT AIR BASIN		
SACRAMENTO VALLEY AIR BASIN		X	Imperial County	X	
SAN DIEGO COUNTY	X		Remainder of Air Basin		X
SAN FRANCISCO BAY AREA AIR BASIN	X				
SAN JOAQUIN VALLEY AIR BASIN					
Fresno County		X			
Kern County (portion)	X				
Kings County		X			
Madera County		X			
Merced County		X			
San Joaquin County		X			
Stanislaus County		X			
Tulare County		X			

* Definitions and references for Areas can be found in 40 CFR, Chapter I, Part 81.300.
Although U.S. EPA established a new 1-hour standard of 75 ppb for SO2, current area designations still reflect the revoked 24-hour and annual average standards as U.S. EPA has not finalized the designations for the revised standard.

(1) South Central Coast Air Basin Channel Islands:

Santa Barbara County includes Santa Cruz, San Miguel, Santa Rosa and Santa Barbara Islands.

Ventura County includes Anacapa and San Nicolas Islands.

Note that the San Clemente and Santa Catalina Islands are considered part of Los Angeles County, and therefore are included as part of the South Coast Air Basin.

AR0069463

FIGURE 17

Area Designations for National Ambient Air Quality Standards
LEAD
N
0 40 80 120 160 Miles
NORTH COAST
NORTHEAST PLATEAU
SACRAMENTO VALLEY
MOUNTAIN COUNTIES
LAKE COUNTY
LAKE TAHOE
SAN FRANCISCO BAY AREA
GREAT BASIN VALLEYS
SAN JOAQUIN VALLEY
NORTH CENTRAL COAST
SOUTH CENTRAL COAST
SOUTHEAST DESERT
SOUTH COAST
SAN DIEGO COUNTY
Del Norte
Siskiyou
Modoc
Humboldt
Trinity
Shasta
Lassen
Tehama
Plumas
Mendocino
Glenn
Butte
Sierra
Nevada
Lake
Colusa
Yuba
Placer
Yolo
El Dorado
Alpine
Napa
Sonoma
Sac
Amador
Solano
Calaveras
Marin
Contra Costa
San Joaquin
Tuolumne
Mono
San Francisco
Alameda
Stanislaus
Mariposa
San Mateo
Santa Clara
Merced
Santa Cruz
Madera
San Benito
Fresno
Tulare
Inyo
Monterey
Kings
San Luis Obispo
Kern
Santa Barbara
Ventura
Los Angeles
San Bernardino
Orange
Riverside
San Diego
Imperial
Unclassified/Attainment
Nonattainment
Air Basin
County
Source Date:
February 2012
Air Quality Data Branch, PTSD

TABLE 17

National Ambient Air Quality Standards
Area Designations for Lead (particulate)

	N	U/A		N	U/A
GREAT BASIN VALLEYS AIR BASIN		X	SAN DIEGO COUNTY		X
LAKE COUNTY AIR BASIN		X	SAN FRANCISCO BAY AREA AIR BASIN		X
LAKE TAHOE AIR BASIN		X	SAN JOAQUIN VALLEY AIR BASIN		X
MOUNTAIN COUNTIES AIR BASIN		X	SOUTH CENTRAL COAST AIR BASIN		X
NORTH CENTRAL COAST AIR BASIN		X	SOUTH COAST AIR BASIN		
NORTH COAST AIR BASIN		X	Los Angeles County (portion) (1)	X	
NORTHEAST PLATEAU AIR BASIN		X	Remainder of Air Basin		X
SACRAMENTO VALLEY AIR BASIN		X	SOUTHEAST DESERT AIR BASIN		X

(1) Portion of County in Air Basin - not including Channel Islands

AR0069465

APPENDIX H:

LAFD File Review Requests and Permits

LOS ANGELES FIRE DEPARTMENT
UNDERGROUND TANKS REQUEST FOR FIRE PREVENTION RECORDS
NEW ADDRESS: 221 NORTH FIGUEROA ST., 15TH FLR., SUITE 1500
NEW OFFICE# - 213/482-7115 NEW FAX# - 213/482-6511

ONE ADDRESS ONLY - PER SHEET

↓ COMPLETE THIS BOX, ONE FOR EACH PROPERTY CONCERNED ↓

PHONE NO: (818) 841-2575 FAX NO: (818) 841-2576

NAME OF REQUESTER (PLEASE PRINT): RICHARD O'NEIL

REPRESENTING (COMPANY NAME): Building Analytics

SIGNATURE: _____ DATE: XX / XX / 2006

DRIVER LIC NO.: C2089759 EXP.: 07-03-09

ADDRESS FOR WHICH RECORDS ARE REQUESTED: 1753, 1755, 1757 North Vine Street

REASON FOR REQUEST: Phase I ESA

FOR OFFICE USE ONLY:

- [ ] REVIEW ONLY (NO COPIES)
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NUMBER OF COPIES: _____

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= _____

+ $11.00

TOTAL FEE AMOUNT: _____

BILLING & ACCOUNTS RECEIVABLE
4TH FLOOR, 201 N. Figueroa (REV CODE #3887)

NO FILE FOUND

LOS ANGELES FIRE DEPARTMENT
UNDERGROUND TANKS REQUEST FOR FIRE PREVENTION RECORDS
NEW ADDRESS: 221 NORTH FIGUEROA ST., 15TH FLR., SUITE. 1500
NEW OFFICE# - 213/482-7115 NEW FAX# - 213/482-6511

ONE ADDRESS ONLY - PER SHEET

↓ COMPLETE THIS BOX. ONE FOR EACH PROPERTY CONCERNED ↓

PHONE NO: (818) 841-2575 FAX NO: 818) 841-2576

NAME OF REQUESTER (PLEASE PRINT): RICHARD O'NEIL

REPRESENTING (COMPANY NAME): Building Analytics

SIGNATURE: _____ DATE 02 / 01 / 2007

DRIVER LIC NO C2089759 EXP. 07-03-09

ADDRESS FOR WHICH RECORDS ARE REQUESTED: 1749 Vine Street
Hollywood, CA

REASON FOR REQUEST: Phase I ESA

FOR OFFICE USE ONLY:

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+ $11.00

TOTAL FEE AMOUNT: _____

BUILDING & ACCOUNTS RECEIVABLE
4TH FLOOR, 201 N. Figueroa (REV CODE #3387)

NO FILE FOUND

NAME 420 South Spring Street Corporation CANCELLATION DATE January 17, 1950 No. [illegible]

DBA Walt's Auto Parks and Garages ADDRESS 1179 Cahuenga Street Code 3-03

ON East Side of Street between Hollywood and Yucca

BOARD OF FIRE COMMISSIONERS, CITY OF LOS ANGELES:

In conformance with the Ordinances of the City of Los Angeles and under the supervision of the Chief Engineer of the Fire Department or his duly authorized representative, application is hereby made for

AN ORIGINAL PERMIT [ ] A RENEWAL OF PERMIT [X] A TRANSFER OF PERMIT [ ] to install or maintain

[ ] AIRCRAFT FUELING POST
[ ] AIR VEHICLE FACTORY
[ ] AIR VEHICLE HANGAR
[X] AUTO FILLING STATION
[ ] AUTO PARKING STATION
[ ] PUBLIC FILLING STATION
[ ] PUBLIC GARAGE
[ ] PUBLIC OIL DEPOT
[ ] TENANT GARAGE

Applicant is a CORPORATION—ASSOCIATION—PARTNERSHIP—INDIVIDUAL (Indicate by placing an X above type of organization.)

Signature Lee S. Nickerson Title General Manager Applicant's Phone MUtual 8137

Mail Address 240 South Hill Street, Los Angeles 12, California

SPACE BELOW THIS LINE FOR DEPARTMENTAL USE ONLY

Perimeter of property in linear feet: [illegible]

and to install or maintain in connection therewith TANKS AND DISPENSING APPARATUS AS FOLLOWS:

No. of Tanks	Capacity	Contents	Make & Symbol	LAFC No.	Location

CANCELLATION

1 TANKS 550 GALS. UNDERGROUND STORAGE—AND [illegible] PORTABLE TANKS OF [illegible] Gallons Capacity.

First Inspection Date 2-6-50 Last Inspection Date 2-6-50 Inspector [signature]

Recommendation: APPROVAL DISAPPROVAL CANCELLATION Violation of Ordinance No. [illegible] Section [illegible]

Previous Permit Granted 9-1-49 (date) To Detail 1-23-50 (date) By [signature]

Former Permittee Hunt—Richmond Station (for use on transfer of permit only) Inspector Completed 2-6-50 (date)

Prepared for Comm. [illegible] (date) By [illegible]

Remarks: Duplication of permit #9608

OK for auto filling station on appl. 9608

P-154 (12 Sec 1-40)

AR0069469

NAME Walter M. Briggs DATE 7-22-49

DBA Walt's Auto Parts ADDRESS 1154 N. Ivar

No. 3018

Code 3.4

ON E. Side of Street between Hollywood and Ivar

BOARD OF FIRE COMMISSIONERS, CITY OF LOS ANGELES:

In conformance with the Ordinances of the City of Los Angeles and under the supervision of the Chief Engineer of the Fire Department or his duly authorized representative, application is hereby made for

AN ORIGINAL PERMIT ☑ A RENEWAL OF PERMIT ☐ A TRANSFER OF PERMIT ☐ to install or maintain

☐ AIRCRAFT FUELING POST	☑ AUTO FILLING STATION	☐ PUBLIC GARAGE
☐ AIR VEHICLE FACTORY	☐ AUTO PARKING STATION	☐ PUBLIC OIL DEPOT
☐ AIR VEHICLE HANGAR	☐ PUBLIC FUELING STATION	☐ TENANT GARAGE

Applicant is a CORPORATION—ASSOCIATION—PARTNERSHIP—INDIVIDUAL (Indicate by placing an X above type of organization.)

Signature Peter Hudson Title Attendant Applicant's Phone No. 20547

Mail Address 240 So. Ivar St. (12)

SPACE BELOW THIS LINE FOR DEPARTMENTAL USE ONLY

Perimeter of property in linear feet: 602 ft.

and to install or maintain in connection therewith TANKS AND DISPENSING APPARATUS AS FOLLOWS:

No. of Tanks	Capacity	Contents	Make & Symbol	LAFC No.	Location
1	1000	Gas			30' E of W P/L x 30' S of N P/L
1	1000	Gas			40' E of W P/L x 30' S of N P/L
1	1000	Gas			50' E of W P/L x 30' S of N P/L
1	250	Waste Oil			30' E of W P/L x 5' S of N P/L

4 TANKS 3250 GALS. UNDERGROUND STORAGE AND PORTABLE TANKS OF Gallons Capacity.

First Inspection Date 8-1-49 Last Inspection Date 8-1-49 Inspector Gordon E. Hostetter

Recommendation: (APPROVAL)—DISAPPROVAL—CANCELLATION—Violation of Ordinance No. Section

Previous Permit Granted (date) To Detail By

Former Permittee (for use on transfer of permit only) Inspector Completed (date) 8-1-49 Gordon E. Hostetter (date)

Prepared for Comm. (date) By

Remarks: Tanks formerly used for gasoline exclusively

AR0069470

FIRE DEPARTMENT — CITY OF LOS ANGELES

APPLICATION FOR PERMIT

Hotel

Rec. No. —

Date 8-24-65

Name of Owner: Continental Parking Corp.

Doing Business As:

Address of Owner: 240 S Ref LA 12

Owner's Phone:

Address of Installation: 175 ½ North Ivar Street

Phone of Installation:

Mail Permit to: Charles Albert 620 N. Mission Road LA 33

Signature of Applicant: Charles G. Albert

Title: contractor

Contractor's Phone: CA 5-1371

Do Not Write Below This Line

NO.	ITEM	FEE
1	abandonment	10

Filled with approved seal

PERMIT GRANTED

Thomas F Luby

24 AUG 1965

Total Fee	Approved	Disapproved	Date	Inspector
$ 10.00	☑	☐	11-8-65	Leo H. Lemon

Gr Prob

AR0069471

Granted 8-24-65

Expires

Fire Department
City of Los Angeles

PERMIT

Reg'D No. 6949

Fee Paid $10.00

In accordance with terms of the application on file with the Fire Prevention Bureau, permission is granted to:

Name

Continental Parking Corporation

Mail: Clarice Gilbert
600 N. Mission Road
Los Angeles, California 90033

Permit to abandon 1 stno tank as per specifications submitted to the Fire Prevention Bureau.

Location 1754 N. Ivar Street

WILLIAM L. MILLER, CHIEF ENGINEER

By: [signature]
Fire Marshal

AR0069472

LOS ANGELES FIRE DEPARTMENT
UNDERGROUND TANKS REQUEST FOR FIRE PREVENTION RECORDS
NEW ADDRESS: 221 NORTH FIGUEROA ST., 15TH FLR., SUITE. 1500
NEW OFFICE# 213/482-7115 NEW FAX# 213/482-6511

ONE ADDRESS ONLY - PER SHEET

↓ COMPLETE THIS BOX. ONE FOR EACH PROPERTY CONCERNED ↓

PHONE NO: (818) 841-2575 FAX NO: (818) 841-2576

NAME OF REQUESTER (PLEASE PRINT): GREG HARGLEROAD

REPRESENTING (COMPANY NAME): Building Analytics

SIGNATURE: [signature] DATE: 01 / 02 / 2007

DRIVER LIC NO: N8983278 EXP. 09-29-07

ADDRESS FOR WHICH RECORDS ARE REQUESTED: 1720 Vine Street
Hollywood (City of Los Angeles)

REASON FOR REQUEST: Phase I ESA

FOR OFFICE USE ONLY:

☐ REVIEW ONLY (NO COPIES)

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NUMBER OF COPIES: ____

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TOTAL FEE AMOUNT: ____

BILLING & ACCOUNTS RECEIVABLE
4th FLOOR, 201 N. Figueroa (REV CODE #3887)

NO FILE FOUND

LOS ANGELES FIRE DEPARTMENT
UNDERGROUND TANKS REQUEST FOR FIRE PREVENTION RECORDS
NEW ADDRESS: 221 NORTH FIGUEROA ST., 15TH FLR., SUITE 1500
NEW OFFICE# - 213/482-7115 NEW FAX# - 213/482-6511

ONE ADDRESS ONLY - PER SHEET

COMPLETE THIS BOX, ONE FOR EACH PROPERTY CONCERNED

PHONE NO: (818) 841-2575 FAX NO: 818) 841-2576

NAME OF REQUESTER (PLEASE PRINT): GREG HARGLEROAD

REPRESENTING (COMPANY NAME): Building Analytics

SIGNATURE: [signature] DATE: 01 / 02 / 2007

DRIVER LIC NO: N8983278 EXP. 09-29-07

ADDRESS FOR WHICH RECORDS ARE REQUESTED: 1722 Vine Street
Hollywood (City of Los Angeles)

REASON FOR REQUEST: Phase I ESA

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TOTAL FEE AMOUNT: _____

BILLING & ACCOUNTS RECEIVABLE
4TH FLOOR, 201 N. Figueroa (REV CODE #3887)

NO FILE FOUND

LOS ANGELES FIRE DEPARTMENT
UNDERGROUND TANKS REQUEST FOR FIRE PREVENTION RECORDS
NEW ADDRESS: 221 NORTH FIGUEROA ST., 15TH FLR., SUITE. 1500
NEW OFFICE# - 213/482-7115 NEW FAX# - 213/482-6511

ONE ADDRESS ONLY - PER SHEET

↓ COMPLETE THIS BOX. ONE FOR EACH PROPERTY CONCERNED ↓

PHONE NO: (818) 841-2575 FAX NO: 818) 841-2576

NAME OF REQUESTER (PLEASE PRINT): GREG HARGLEROAD

REPRESENTING (COMPANY NAME) Building Analytics

SIGNATURE: [signature] DATE: 01 / 02 / 2007

DRIVER LIC NO: N8983278 EXP: 09-29-07

ADDRESS FOR WHICH RECORDS ARE REQUESTED: 1724 Vine Street
Hollywood (City of Los Angeles)

REASON FOR REQUEST: Phase I ESA

FOR OFFICE USE ONLY:

[ ] REVIEW ONLY (NO COPIES)

[ ] REQUEST COPIES

NUMBER OF COPIES: ____

x 10 ¢

____

+ $11.00

TOTAL FEE AMOUNT: ____

BILLING & ACCOUNTS RECEIVABLE
4th FLOOR, 200 N. Figueroa (REV CODE #3887)

NO FILE FOUND

LOS ANGELES FIRE DEPARTMENT
UNDERGROUND TANKS REQUEST FOR FIRE PREVENTION RECORDS
NEW ADDRESS: 221 NORTH FIGUEROA ST., 15TH FLR., SUITE 1500
NEW OFFICE# - 213/482-7115 NEW FAX# - 213/482-6511

ONE ADDRESS ONLY - PER SHEET

COMPLETE THIS BOX, ONE FOR EACH PROPERTY CONCERNED

PHONE NO: (818) 841-2575 FAX NO: 818) 841-2576

NAME OF REQUESTER (PLEASE PRINT): GREG HARGLEROAD

REPRESENTING (COMPANY NAME): Building Analytics

SIGNATURE: [signature] DATE: 01 / 02 / 2007

DRIVER LIC NO: N8983278 EXP 09-29-07

ADDRESS FOR WHICH RECORDS ARE REQUESTED: 1730 Vine Street
Hollywood (City of Los Angeles)

REASON FOR REQUEST Phase I ESA

FOR OFFICE USE ONLY:

☐ REVIEW ONLY (NO COPIES)

☐ REQUEST COPIES

NUMBER OF COPIES: ____

x .10 ¢

= ____

+ $11.00

TOTAL FEE AMOUNT: ____

BILLING & ACCOUNTS RECEIVABLE
4th FLOOR, 201 N. Figueroa (REV CODE #3887)

NO FILE FOUND

Research Request Form

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

DATE: February 01, 2007

Q-MATIC TICKET # (office use only)

NAME: Richard O'Neil COMPANY NAME: Building Analysts

TELEPHONE #: 818-841-2575 FAX #: 818-841-2576

FAXING OPTIONS: Service Counter: LADBS Fax to one of the numbers below (check one):

☐ (213) 482-6552
Main Office
201 N. Figueroa St., 1st Flr, Rm 110
Los Angeles, CA 90012

☑ (818) 374-5313
Van Nuys Office
5262 Van Nuys Blvd.
Van Nuys, CA 91401

PROPERTY ADDRESS(ES): Please research the following addresses (IN PERSON: One Address submitted at a time; FAXING: Up to 3 addresses per request)

1749 Vine Street, Hollywood

Use of Existing Building:

COMMENTS: Reason for Records Request

Phase I ESA

Information Requested:

Copies of All Documents are $1.50 per page (excluding blueprint copies)

Select from the following by checking the box next to it – for further clarification of request, use comments box

☒ BUILDING PERMITS	☐ CERTIFICATES OF OCCUPANCY	☒ GRADING DOCUMENTS	For Office Use Only: ____PCS ____IDS
☐ MECHANICAL PERMITS 1985 - 1990 and 1997 - Present	☐ VIOLATIONS	☐ MODIFICATIONS/BOARD FILES	
☐ AFFIDAVITS/LAO:			

☐ BLUEPRINTS ($8.00 for the Service Fee and $1.00 per page*)

*If Blueprints are sent to a graphics company for copying, the Service Fee is $15.00 and the cost per page is determined by that company.
No plans available for Single Family Dwellings and Commercial buildings 3 stories and under, prior to 1978

To obtain copies of blueprints on file, the following must be submitted:
1. A release letter from the current owner
2. A release letter from the architect and engineer whose stamps on the plans.
   Letters must be on Letterhead and have engineer/architect's stamp
3. A copy of the current owner's Grant Deed.

Research Request Form

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

DATE: February 01, 2017

Q-MATIC TICKET #
(office use only)

NAME: Richard O'Neil

COMPANY NAME: Building Analytics

TELEPHONE #: 818-841-2575

FAX #: 818-841-2576

FAXING OPTIONS: Records Counter, LADBS Fax to one of the numbers below (check one)

- (213) 482-6282, Metro Office, 201 N. Figueroa St., 1st Flr, Rm 110, Los Angeles, CA 90012
- (818) 374-5912, Van Nuys Office, 5262 Van Nuys Bl., Van Nuys, CA 91401

PROPERTY ADDRESS(ES): Please research the following addresses (IN PERSON: One Address submitted at a time) (FAXING: Up to 3 addresses per request)

1754 Ivar Ave, Hollywood

1754 ½ Ivar Ave, Hollywood

Use of Existing Building:

COMMENTS: Reason for Records Request:

Phase I ESA

Information Requested:

Copies of All Documents are $1.50 per page (excluding blueprint copies)

Select from the following by checking the box next to it - for further clarification of request, use comments box

☒ BUILDING PERMITS	☐ CERTIFICATES OF OCCUPANCY	☒ GRADING DOCUMENTS	For Office Use Only
☐ MECHANICAL PERMITS 1965 - 1980 and 1987 - Present	☐ VIOLATIONS	☐ VOID CATIONS-BOARD FILES	____PCIS ____IDIS
☐ AFFIDAVITS/Z.I.NO.			

☐ BLUEPRINTS ($8.00 for the Service Fee and $1.00 per page*)

*If Blueprints are sent to a graphics company for copying, the Service Fee is $15.00 and the cost per page is determined by that company
No plans available for Single Family Dwellings and Commercial buildings 3 stories and under, prior to 1978

To obtain copies of blueprints on file, the following must be submitted:

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3. A copy of the current owner's Grant Deed

AR0069478

Research Request Form

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

DATE: February 01, 2007

Q-MATIC TICKET # (office use only)

NAME: Richard O'Neil COMPANY NAME: Building Analytics

TELEPHONE #: 818-841-2575 FAX #: 818-841-2576

FAXING OPTIONS: Records Counter, LADBS Fax to one of the numbers below (check one):

☐ (213) 482-6662
Metro Office
201 N. Figueroa St., 1st Flr, Rm 110
Los Angeles, CA 90012

☒ (818) 374-5012
Van Nuys Office
6262 Van Nuys Bl
Van Nuys, CA 91401

PROPERTY ADDRESS(ES): Please research the following addresses: (IN PERSON: One Address submitted at a time; FAX/MAIL: Up to 3 addresses per request)

1753 Vine Street, Hollywood

1755 Vine Street, Hollywood

1757 ~~7797~~ Vine Street, Hollywood

Use of Existing Building:

COMMENTS: Reason for Records Request:

Phase I ESA

Information Requested:

Copies of A1 Documents are $1.50 per page (excluding blueprint copies)

Select from the following by checking the box next to it - for further clarification of request, use comments box

☒ BUILDING PERMITS	☐ CERTIFICATES OF OCCUPANCY	☒ GRADING DOCUMENTS	For Office Use Only: PCIS ____ IDIS ____
☐ MECHANICAL PERMITS 1955 - 1990 and 1997 - Present	☐ VIOLATIONS	☐ MODIFICATIONS/BOARD FILES	
☐ AFFIDAVITS? ; NO			

☐ BLUEPRINTS ($8.00 for the Service Fee and $1.00 per page*)

* Blueprints are sent to a graphics company for copying. The Service Fee is $15.00 and the cost per page is determined by that company. No plans available for Single Family Dwellings and Commercial Buildings 5 stories and under prior to 1978.

To obtain copies of blueprints on file, the following must be submitted:

1. A release letter from the current owner
2. A release letter from the architect and engineer whose stamp is on the plans. Letters must be on Letterhead and have engineer/architect's stamp
3. A copy of the current owner's Grant Deed

Research Request Form

LA DBS
DEPARTMENT OF BUILDING AND SAFETY

DATE: February 01, 2007

Q-MATIC TICKET # (office use only)

NAME: Richard O'Neal COMPANY NAME: Building Analysts

TELEPHONE #: 818-841-2575 FAX #: 818-841-2576

FAXING OPTIONS: Records Counter, LADBS Fax to one of the numbers below (check one)

- ☐ (213) 482-6961 Metro Office 201 N. Figueroa St., 1st Floor, Rm 110 Los Angeles, CA 90012
- ☒ (818) 374-5613 Van Nuys Office 6262 Van Nuys Bl Van Nuys, CA 91401

PROPERTY ADDRESS(ES): Please research the following addresses (IN PERSON. One Address submitted at a time) (FAXING: Up to 3 addresses per request)

1746 Ivar Ave, Hollywood

1746 ½ Ivar Ave, Hollywood

1764 Ivar Ave, Hollywood

Use of Existing Building:

COMMENTS: Reason for Records Request.

Phase I ESA

Information Requested:

Copies of All Documents are $1.50 per page (excluding blueprint copies)

Select from the following by checking the box next to it - for further clarification of request use comments box

☒ BUILDING PERMITS	☐ CERTIFICATES OF OCCUPANCY	☒ GRADING DOCUMENTS	For Office Use Only
☐ MECHANICAL PERMITS 1985, 1990 and 1997 - Present	☐ VIOLATIONS	☐ MODIFICATIONS/BOARD FILES	____POS ____IDIS
☐ AFFIDAVITS/2 INO ____			

☐ BLUEPRINTS ($8.00 for the Service Fee and $1.00 per page*)

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No plans available for Single Family Dwellings and Commercial buildings 3 stories and under, prior to 1978

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www.ladbs.org LADBS-REQFRM.1

AR0069480

Historic-Cultural Monument (HCM) List

City Declared Monuments

No.	Name	Address	CHC No.	CF No.	Adopted	Notes
1	Lopez Adobe	23937 Cavalleri Road			04/1962	
2	Bolton Hall	10110 Commerce Avenue			04/1962	
3	Nuestra Senora la Reina de Los Angeles (Plaza Church)	100-110 Cesar E. Chavez Ave & 535 N. Main St 535 N. Main Street & 100-110 Cesar Chavez Ave			04/1962	
4	Angels Flight	4th Street & Hill			04/1962	Dismantled 05/1969 Relocated to Hill Street Between 3rd St. & 4th St in 1996
5	The Fun Box (Former Site of)	359 S. Hamburger Avenue (Now Japan Street)			04/1962	Relocated to Heritage Square in 1969. Destroyed by Fire 10/29/1969
6	Bradbury Building	216-224 W. 3rd Street 300-310 S. Broadway			04/1962	
7	Rancho Rio Adobe (Rancho Romulo)	19040 Sepulveda Boulevard			04/1962	
8	Pay House	1335-1341 1/2 Carroll Avenue			04/1962	
9	Shields Ranch House	22653 Vanowen Street			11/20/1962	
10	Eagle Rock	72-77 Persian Way 7000-7004 School Canyon Road Eagle Rock View Drive North Figueroa (Terminus)			11/15/1962	
11	West Temple Apartments (The Rochester)	1012-20 Temple Street			04/1963	
12	Hollyhock House	4800 Hollywood Boulevard			1/24/1963	
13	Bolton House	2400 Shenandoah Street			02/27/1963	
14	Chatsworth Community Church (Oakwood Memorial Park)	22601 Lassen Street			2/15/1963	
15	Towers of Simon Rodia (Watts Towers)	10619-10623 Graham Avenue 1727-1765 E. 107th Street			3/1/1963	
16	Saint Joseph's Church (site of)	1200-1210 S. Los Angeles Street 1200-1215 Santee Street 200-226 E. 12th Street			5/10/1963	Destroyed by fire 08/24/1963
17	Saint Vibiana's Cathedral	110-136 E. 2nd Street 200-248 S. Main Street 200-214 S. Los Angeles Street			5/10/1963	
18	Hyde Park Congregational Church (site of) Hyde Park Congregational Church (Former Site of)	3435-3445 Hyde Park Boulevard 6501 Crenshaw Boulevard			5/10/1963	Demolished 1964
19	Moreton Bay Fig Tree	1100 Natural Boulevard			5/10/1963	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
19	Moreton Bay Fig Tree	1101 S Olive Avenue 3310 Trousdale Avenue			5/10/1963	
20	Two Stone Gates (also Westshire & Bellagio Drives)	Bellagio Drive			5/24/1963	
	Two Stone Gates (also Beverwood & Westshire Drives)	Westshire Drive				
21	Drum Barracks and Officers Quarters	1051-1053 Cary Avenue			6/7/1963	
22	Palms - Southern Pacific Railroad Depot	2400 Hoover Street			8/9/1963	
23	San Fernando Rey Mission (site of)	15151 San Fernando Mission Boulevard			9/6/1963	
24	Oak Tree (Former Site of)	Lemon Avenue			9/6/1963	Relocated by Item 02/07/1966.
25	General Phineas Banning Residence	401 E 7th Street - Street			10/11/1963	
26	First Cathedral of the Angels (site of)	521 N Main Street			3/20/1964	
27	The Castle (Former Site of)	331 S Runkle Hill Avenue (New Hope Street)			5/8/1964	
28	William Andrews Clark Memorial Library	2150-2200 W 23rd Street 2150-2210 W Adams Boulevard 2600-2628 Cimarron Street 2701 Cimarron Place			10/5/1964	
29	Campo De Cahuenga (site of)	3919 Lankershim Boulevard			11/23/1964	
30	Oliver G. Hasley - Edward L. Doheny Residence	8 Chester Place			2/5/1965	
31	Original Ranch Horticultural Center (Rancho San Pascual Roble)	26555 Jackson Street			1/22/1965	
32	Saint Saviour's Church (Harvard School)	2700-2740 Cahuenga Boulevard West			2/5/1965	
33	Barnsdall Park Arts Center (Residence A)	4800 Hollywood Boulevard			2/26/1965	
34	Barnsdall Art Park	4800 Hollywood Boulevard			2/26/1965	
35	Sculpture of Adlai E. Stevenson III (Site of)	2939 Monticello Avenue			5/28/1965	
36	Watts Station	1686-1690 E 103rd St (C)			7/23/1965	
37	Fire Station No. 23	225 E 5th Street			8/27/1965	
38	Site of Engelhorn Oak	Hawthorne Avenue			8/27/1965	Cut down. Located between Street & Avenue
39	Residence	1425 Miramar Street			8/15/1966	
40	Dale House (Ivy Deco Square)	2800 Banner Street			8/15/1966	
41	114 Cedar Trees	White Oak Avenue			6/3/1969	
42	San Antonio Winery	737-741 Lamar Street 738-744 Gregorio Street			9/14/1969	
43	California Club Building	538-538 S Flower Street			11/21/1969	
44	Hangar No. 1 Building	5701 W Imperial Hwy S 5801 W Imperial Hwy			11/21/1969	

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No	Name	Address	CHC No.	CF No	Adopted	Notes
44	Hangar No. 1 Building	6801 W. Imperial Hwy & 5701 W. Imperial Hwy			11/16/1900	
45	Residence	816-822 S. Victoria River Street			2/6/1967	
46	Los Angeles Central Library Building and Grounds	530 W. 5th Street			3/1/1967	
47	Saint John's Episcopal Church	1020-1032 Neptune Avenue			3/7/1967	
48	Cleaves Ravine Arboretum	Elysian Park			4/20/1967	
49	76 Mature Olive Trees (Pioneer Topanga Canyon and Penfield)	Jason Street			5/1/1967	Between Topanga Canyon and Penfield
50	Division Weir and Settling Basin (Area C)	Brewer Street & Havana Avenue Havana Avenue & Becker Street			5/15/1967	
51	Residence	1300 Carol Avenue			5/1/1967	
52	Residence	1330 Carol Avenue			5/24/1967	
53	Saint Peter's Episcopal Church	2320-2338 Grand Avenue			12/6/1967	2411 and San Pedro
	Saint Peter's Episcopal Church (2420 and San Pedro)	Harbor View Memorial Park (2411 S. Grand Ave)				
54	Old 6th Street Viaduct Bridge (Former Site of)	Across Hollenbeck Park Lake			6/26/1968	Demolished 1994
55	Grauman's Chinese Theater	6801-6927 Hollywood Boulevard			8/6/1968	
56	Hubbell Wilshire Building	2973-2985 W. 7th Street 3550-3570 Wilshire Boulevard 565-585 Vermont Place 568-570 Wright Road Avenue			8/7/1968	
57	Second Church of Christ Scientist of Los Angeles	930-948 W. Adams Boulevard			9/17/1968	
58	A & M Records Studio (formerly Charlie Chaplin Studio) Charlie Chaplin Studios	1416 N. La Brea Avenue 7053-7067 De Longpre Avenue			2/5/1969	A & M Records Studio
59	Eagle Rock City Hall	2031-2035 Colorado Boulevard 5110 Maywood Avenue			2/26/1969	
60	Biltmore Hotel	506-508 S. Olive Street 512 W. 5th Street 514-530 S. Grand Avenue			7/2/1969	
61	Philharmonic Auditorium (Former Site of)	427 W. 5th Street			7/27/1969	Demolished 1989
62	Judson Studios	200-204 S. Avenue 58			8/13/1969	
63	McConaghy Hall and Grounds	7570 McConaghy Terrace			2/4/1970	
64	Los Angeles Plaza Park	Cesar E. Chavez Avenue Los Angeles Street N. Main Street Plaza Park			9/17/1970	
65	Valley Knudsen Garden and Residence (Pershing Square)	3900 Wilshire Boulevard			11/5/1970	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
66	Saint Paul's Cathedral - Former Site of)	815 S. Figueroa Street			5/5/1970	Demolished 1979
	Saint Paul's Cathedral (Current)	401-815 Wilshire Boulevard				Demolished
67	Cedar Trees	Los Feliz Boulevard			5/5/1970	Between Riverside Dr. and Western Ave.
68	Charles Lummis Residence and Surrounding Gardens	200 & 212 N. Avenue 43 201-231 N. Avenue 43 4750, 4751 Casitas Pass Road			5/21/1970	
69	Los Angeles Athletic Club Building	431-437 W. 7th Street 648-660 S. Olive Street			6/16/1970	
70	Adams House (Wesley Hall)	650 W. 36th Street			12/15/1970	
71	First African Methodist Episcopal Church Building (Former Site of)	754-760 E. 8th Street 801 S. Towne Avenue			1/4/1971	Destroyed by fire 3/04/1972
72	Automobile Club of Southern California	2601 S. Figueroa Street 670 W. Adams Boulevard 661 W. 27th Street			2/2/1971	
73	Residence	1321 Carroll Avenue			2/8/1971	
74	Residence	1345 Carroll Avenue			2/8/1971	
75	Residence	1355 Carroll Avenue			2/8/1971	
76	Residence	1318 Carroll Avenue			2/8/1971	
77	Residence	1330 Carroll Avenue			2/8/1971	
78	Residence	1304 Carroll Avenue			2/8/1971	
79	Residence	1344 Carroll Avenue			2/8/1971	
80	Farm Court (Alexandria Hotel)	210 W. 5th Street & 501-511 S. Spring Street 501-511 S. Spring Street & 210 W. 5th Street			3/8/1971	
81	Memorial Bronco L. Shaw	4920 W. Olympic Boulevard			4/1/1971	
82	River Station Area	1231 N. Spring Street			6/15/1971	San Pedro Railroad
83	Doyle - Penrose Residence	1211-1231 Alvarado Terrace			7/7/1971	
84	Cain Residence	1235 Alvarado Terrace			7/7/1971	
85	Gillet Residence	1333 Alvarado Terrace			7/7/1971	
86	Powers Residence	1341 Alvarado Terrace			7/7/1971	
87	Raphael Residence	1368 Alvarado Terrace			7/7/1971	
88	Kinney - Eyerly Residence	1401 Alvarado Terrace			7/7/1971	
89	Central Spanish Seventh Day Adventist Church	1356 Alvarado St. & 1447-1459 Alvarado Ter. 1447-1465 Alvarado Ter. & 1308 Alvarado St.			7/7/1971	
90	Saint Vincent de Paul Church	821 W. Adams Boulevard			7/21/1971	
91	Korean Presbyterian Presbyterian Church (Temple Street East)	401-407 N. Vermont Canyon Avenue			7/7/1971	
92	Old Stage Coach Inn Property	Scott Griffith Park			1/5/1972	
93	Pepper Trees Avenue Boulevard to Saltair Street)	Canyon Avenue			1/5/1972	

AR0069484

No.	Name	Address	CHC No.	CF No	Adopted	Notes
94	Palm Trees (Queen & Washingtonia Robusta) and the Median Strip	Highland Avenue			12/8/1972	
95	Bungalow - Frederick Hastings House	1941 W. 25th Street 2247-2271 S. Harvard Boulevard			2/23/1973	
96	Storer House	8161 Hollywood Boulevard			2/23/1973	
97	Residence at 1520 Pleasant Avenue (Former Site of)	1520 Pleasant Avenue			2/23/1973	Demolished 05/1973
98	Mount Pleasant Picnic Grounds (Heritage Square)	3800 Homer Street			3/16/1973	
99	Residence	1035-1039 S. Orange Grove Street			4/6/1973	
100	General Douglas MacArthur Park (Formerly Westlake Park)	2130-2250 W. 6th Street 601-651 S. Alvarado Street 610-650 Park View Street			5/1/1973	
101	Los Angeles Union Station Passenger Terminal and Grounds	357 Arcadia Street 540-650 N. Alameda Street			5/2/1973	
102	Residence	1030 Cesar E. Chavez Avenue			10/4/1973	
103	Pantheon House (Demolished)	1102-1114 28th St. & 2801-2803 Hoover St. 2801-2803 Hoover St. & 1102-1114 W. 28th St.			10/4/1973	
	Pantheon Carriage House (Original location)	679 W. 18th Street				Relocated to 512 E. Edgeware Road in 2017
	Pantheon Carriage House (New Site)	512 North Edgeware	CHC 2017-1801-HCM			
104	Security Pacific National Bank Building	609-634 S. 6th Street 600-616 S. Main Street 601-619 S. Los Angeles Street			12/17/1973	
105	Hunt House	4755-4757 N. Figueroa Street			11/15/1973	
106	San Encino Abbey	6201-6211 Arroyo Glen 6204 Marmion Way			11/15/1973	
107	Residence	432-438 N. Avenue 50			11/15/1973	
108	Security Avenue House	9800 Hoover Street			12/1973	
109	Residence	1314-1320 Kellam Avenue 1325 Carroll Avenue			12/1973	
110	Los Angeles Police Academy Rock Garden	1880 N. Academy Drive			1/31/1974	
111	Hollywood Sign & Hollywood Forever (Gully) Park (Portion)	Mount Lee			2/7/1974	
112	Gallery (Site)	Fuji Gallery (Site)			3/7/1974	
113	Young's Market Building Young's Market	1003-1014 W. 7th Street 711-719 S. Afton Avenue			3/7/1974	
114	Wilshire United Methodist Church	4260-4300 Wilshire Boulevard 708 S. Lucerne Boulevard 711-717 Plymouth Boulevard			3/7/1974	
115	Evans Residence	410 S. Lorraine Boulevard			3/24/1974	

AR0069485

No.	Name	Address	CHC No.	CF No.	Adopted	Notes
116	Wilshire Boulevard Temple Wilshire Boulevard Temple	3541-3663 Wilshire Boulevard 618-648 S. Hobart Avenue 625-647 S. Harvard Boulevard			3/31/1973	
117	Residence	2216-2222 La Salle Avenue 2215 S. Harvard Boulevard			4/4/1973	
118	Hollyhock Building and Millard Theater	3760-3780 Wilshire Boulevard 681-697 Oxford Avenue 652-676 S. Western Avenue			4/16/1973	
119	Cobb - Cornwall Building	1145-1149 San Julian Street 525 E. 12th Street			5/10/1973	
120	Saint Sophia Cathedral	1324-1400 S. Normandie Avenue			6/6/1973	
121	Garfield Building	401-415 W. 3rd Street 757-759 S. Hill Street			9/12/1973	
122	Buck House	5800-5810 W. 8th Street 515 S. Genesee Avenue			10/1/1974	
123	Lloyd House	467 E. Juanita Drive			10/2/1974	
124	Norman House	2322 Micheltorena Street			10/2/1974	
125	Fine Arts Building	307-315 W. 7th Street			10/2/1974	Cross Manor Hotel
126	Franklin Avenue Bridge (Shake Spears Bridge)	Franklin Avenue			10/2/1974	
127	Residence (Colonial House)	3950 Mount Ashmun			10/2/1974	
128	Southwest Museum	3816 Jonesboro Avenue			10/2/1974	
129	Residence	7574-7576 Coral Avenue			10/9/1974	
130	Garcia - Navarro House	2255 Valley Oak Drive 5009 Valley Oak Drive			10/9/1974	
131	Dunbar Hotel (Somerville Hotel)	1007 E. 42nd Place 4225-4235 S. Central Avenue			9/4/1974	
132	Stoney Point Outcroppings	North Chatsworth			11/20/1974	
133	Pyramids Shed Orange Hill Pioneer Restaurant	2220 Governor Drive	CHC 1974-4082-HCM	07-0705	11/20/2007 11/20/1974	
134	Crossroads of the World	1578-1587 Cassil Place 1510-1535 N. Las Palmas Avenue 667-6675 Prospect Boulevard 6676-6684 Argyle Avenue			12/4/1974	
135	Carnegie Museum Gallery	2431 Sherman Way			12/4/1974	
136	Saint Mary of the Angels	4510 Finley Avenue			12/4/1974	
137	Pinney's Gallery	217-219 W. 6th Street			1/15/1975	
138	Coca Cola Building	1200-1334 S. Olive Avenue 1211-1265 Wall Street 1300-1422 E. 12th Street			2/5/1975	
139	Shrine Auditorium	3216-3244 Royal Street 647-665 W. Jefferson Boulevard 700 W. 32nd Street			3/5/1975	
140	Castruccio Commercial Building	611 Agatha Street Also 740 S. San Pedro Street			3/19/1975	

AR0069486

No.	Name	Address	CHC No.	CF No	Adopted	Notes
141	Stevenson Reservoir Arch Site	Valley Circle Woodley Canyon Drive			4-2-1975	
142	Smith Estate	5805-5810 Pickup Drive			4/16/1976	
143	Residence	6025 Hayes Avenue			4/16/1976	
144	Residence	2054-2056 Griffith Avenue			5/21/1976	
145	Residence	3537 Griffith Avenue			5/21/1976	
146	Municipal Ferry Building (Maritime History Museum)	Main Channel (San Pedro Harbor) San Pedro Harbor			6/7/1976	
147	James H. Dobson Residence	859-863 W. 15th Street			9/17/1976	
148	Cork Trees (Erythrina Caffra, Between 20th & Dingman)	San Vicente Boulevard			3/3/1976	
149	Davis - Brown House	2807 Glendower Avenue			3/3/1976	
150	Los Angeles City Hall	200 N. Spring Street			3/24/1976	
151	Chateau Marmont	8217-8221 Sunset Boulevard 8225 Marmont Lane 8244 Crescent Road			3/24/1976	
152	Faith Ultra Church	10521 Gresham Street			4/7/1976	
153	Lincoln Park Carousel (Former Site of)	Mission Road & Valley Boulevard Valley Boulevard & Mission Road			4/21/1976	Destroyed by Fire 1976
154	Precinct No. 3 and Firehouse No. 112 (Barn 27)	Old Dock Street - San Pedro			5/5/1976	
155	Memorial Chapel (Calvary Presbyterian Church)	1146-1160 N. Marine Avenue			5/5/1976	
156	Fire Station No. 1	2230 Fletcher & Avenue 26			7/7/1976	
157	Residence	1110 N. Broadway			7/7/1976	
158	Mary Andrews Clark Residence at the YWCA	308 Loma Drive			7/7/1976	
159	Ralph J. Bunche House	1221-1223 E. 43rd Place			7/23/1976	
160	Monument (Boyle County)	Highway 395 (Inyo County)			9/15/1976	
161	Walter Parking Company Building	301-311 Mission Road 416-420 S. Weir Street			9/15/1976	
162	Willard Millard Memorial Fountain	Los Feliz Boulevard & Riverside Drive Riverside Drive & Los Feliz Boulevard			10/6/1976	
163	Animation School for the Walt Disney Studios from 1926-1940	2649 Griffith Park Blvd	CHC-2006-3167-HCM	CF-07-0715	7/26/2006	
		2653 Griffith Park Blvd 2689 Griffith Park Blvd				
	Site of First Walt Disney Studio	2701-2733 Hyperion Avenue 2710-2746 Griffith Park Boulevard			10/6/1976	
	Animation School for the Walt Disney Studios from 1926-1940	3027 Angus St	CHC-2006-3167-HCM	CF-07-0715	7/26/2006	
		3031 Angus St 3033 Angus St				
	Site of First Walt Disney Studio	2616-2618 Manor Street			10/6/1976	
164	Glendale - Hyperion Bridge	Los Angeles River			10/20/1976	

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No.	Name	Address	CHC No	CF No.	Adopted	Notes
165	Fire Station No. 27	1052 N. Cahuenga Boulevard & 1033 Cole Place			10/20/1978	
166	Carriage House	1411-1417 Kellam Avenue			1/2/1979	
167	Residence	629 S. Coronado Street			1/17/1979	
168	Griffith Observatory	2800 E. Observatory Road Griffith Park			1/17/1979	
169	Woman's Club Hall Residence	1272 Victoria Avenue			12/1/1976	
170	Paul R. Williams Residence	1640 Victoria Avenue			12/1/1978	
171	Site of Timm's Landing (exhibited part of Fishermen's Co-op)	Terminal Island (San Pedro Harbor)			2/1/1977	
172	Stonehurst Recreation Center Building	8801 Stonehurst Street			3/5/1977	
173	Welsh Presbyterian Church	1152 S. Valencia Street 1531 W. 12th Street			4/20/1977	
174	Village Green	5112-5606 Village Green			5/4/1977	
175	YWCA Hollywood Studio Club	1215-1233 Lodi Place			5/4/1977	
176	Residence	1312-1316 Kellam Avenue 1321 Carroll Avenue			7/13/1977	
177	Pathway Terminal Building	415-419 S. Hill Street 416-424 S. Olive Street			7/27/1977	
178	Los Angeles Herald Examiner Building	111-121 S. Broadway 146 S. Los Angeles Street			9/14/1977	
179	Residence (Former Site of)	919 W. 20th Street			9/14/1977	Demolished 05/1978
180	Site of the Filming of First Talking Film	1424-1458 Bronson Avenue 5900-5958 Sunset Boulevard			9/21/1977	
181	Site of Burial Place of Chief Tarkashlar (Name Lost)	Nichols Canyon Road			10/6/1978	
182	Ivy Court Substation	2000-2031 Glendale Boulevard			2/11/1975	
183	West Parade of Pan Pacific Auditorium (Former Site of)	7600 Beverly Boulevard			3/11/1975	Destroyed by Fire 06/24/1989 Demolished 04/1992
184	Tower of Wooden Palace (Former Site of)	15357 Magnolia Boulevard	CHC-2004-3515-HCM		4/19/1978	Demolished 2005
185	President's House (Carriage House & Formal Gardens - Former Site of)	7551 Hollister Avenue			4/19/1978	Demolished 1988
186	Conquistador Clubhouse (Harbor Area YMCA)	437 S. 6th Street			5/3/1978	
187	Korean Pavilion Belfry of Friendship (Angel's Gate Park)	37th Street & Gaffey Street Gaffey Street & 37th Street			5/3/1978	
188	USS Los Angeles Naval Monument (John S. Gibson Jr. Park)	Harbor Boulevard			5/31/1978	
189	Residence	1407 Carroll Avenue			5/9/1979	
190	Residence and Carriage House	1411 Carroll Avenue			5/31/1979	
191	Residence	1441-1443 1/2 Carroll Avenue			5/31/1979	
192	Franklin Garden Apartments (Former Site of)	6015-6035 Franklin Avenue			6/27/1979	Demolished 1984
193	Pantages Theater	1709-1715 Argyle Avenue			7/5/1979	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
193	Pantages Theater	6225-6249 Hollywood Boulevard			7/5/1978	
194	Hollywood Walk of Fame (Portions of Gower & Sycamore)	Hollywood Boulevard			7/27/1978	
						Expansion to include Hollywood Boulevard between Sycamore Avenue and La Brea Avenue Adopted by Council on 8/16/2017
		Vine Street				Part of the 1978 designation between Sunset Blvd. and Yucca Street
195	James Oviatt Building	615-617 S. Olive Street			7/19/1978	
196	Variety Arts Center Building	940-948 S. Figueroa Street			8/8/1978	
197	Shrine Mansion and Formal Gardens	2141-2151 W. Adams Boulevard 2528 S. Arlington Place			8/23/1978	
198	KCET Studios	4827-4835 N. Hoover Street 4951-4421 Sunset Boulevard			9/20/1978	
199	Dave Brubeck Christian Temple Activities Hall	12014-12024 Ventura Boulevard 5540 Laurel Canyon Boulevard			9/20/1978	
200	Second Baptist Church Building	1400 W. 24th Street 2408-2412 S. Hoover Avenue			10/18/1978	
201	West Adams Heritage Association Building	14632-14636 Sylvan Street			10/18/1978	
202	Valley Municipal Building (West Adams City Hall)	14401-14441 Sylvan Street (Mail) 14410-14448 Sylvan Street			10/18/1978	
203	Bard House (Columbian Heights Community Center)	14003-14007 Gurdula Street			10/18/1978	
204	Lederer Residence and Immediate Environments	23134 Sherman Way			11/15/1978	
205	Los Angeles State Orphanage Building	310-318 S. Spring Street			1/3/1979	
206	Residence	724 E. Edgeware Road			1/3/1979	
207	Residence	1964 Nolan Avenue			1/17/1979	
208	Residence and Carriage House	841-845 S. Lake Street			1/17/1979	
209	Wilshire Christian Church Building	3461 Wilshire Boulevard 334-348 S. Normandie Avenue			1/17/1979	
210	Terrace Park and Powers Place	Powers Place and 16th Street			2/21/1979	
211	Security Bank Building (Between Alameda and N. Main St.)	Arcola Street			3/7/1979	
212	Silverado House	2421 S. Figueroa Street			3/30/1979	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
213	S.S. Catalina (The Great White Steamship)	Port of Ensenada, Baja California, Mexico			5/15/1979	Demolished 2008
214	Mount Carmel High School Building (Former Site of) Mount Carmel High School Building (site of)	7014 S. Hoover Street 814 W. 70th Street			5/5/1978	Demolished 1983
215	Isaac Market	1232-1234 Broadway Avenue			5/5/1978	
216	Residence	915-917 Douglas Street			5/5/1978	
217	Residence	1101 Douglas Street 874-880 W. Adams Boulevard			5/5/1978	
218	Residence	949 E. Edgeware Road			5/5/1978	
219	Residence	1238-1247 Boston Street			5/5/1978	
220	Residence	1343 Kellam Avenue			5/5/1978	
221	Residence and Garage House	1347-1349 Kellam Avenue			5/5/1978	
222	Residence	1401-1411 Kellam Avenue			5/5/1978	
223	Residence	822-826 E. Washington Place			5/26/1978	
224	Main Street Viaduct (between Mission & Vignes)	Cesar E. Chavez Avenue			5/1/1978	
226	Los Angeles Theatre	609-615 S. Broadway			5/15/1979	
230	Mesquiers Job Building (site of)	1766 N. Sycamore Avenue			5/29/1979	
237	Janss House	6541 Hollywood Boulevard			4/3/1980	
238	Laurelwood Apartments	11833-11847 Laurelwood Drive			4/24/1980	
239	Wilshire Free Methodist Church	2925-2933 W. Jefferson Boulevard			5/11/1980	
240	Villa Maria (Quinn House)	2425 N. Glendale Avenue			5/12/1980	
241	El Greco Apartments	417-423 N. Hayworth Avenue			4/30/1981	
242	Department of Water and Power Building	5103-5138 Lankershim Boulevard			5/14/1980	
243	Sunset Plaza Apartments (Former Site of)	8215-8229 Sunset Plaza Drive			10/28/1980	Demolished 1987
244	Tait House (Former Site of)	2771-2791 Sunset Boulevard			11/25/1980	Demolished 1982
245	Hollman House	1531 - 534 N. Fuller Drive			11/25/1980	
246	Sunset Boulevard Bridge (crossing over Silver Lake Boulevard)	Silver Lake Boulevard			4/3/1981	
247	First Baptist Church of Los Angeles	2875 W. 8th Street 2960-2962 Orchard Avenue 760 S. Westmoreland Avenue			4/3/1981	
248	Crossroads Shopping & Studios Building	566-572 S. Lafayette Park Place			4/3/1981	
249	L.S. Ayres & Co. Company	350-374 N. Lake Street			4/3/1981	
250	Residence	1110 W. 27th Street 2703-2707 S. Hoover Street			4/3/1981	
251	Sunshine Mission	2830 S. Hoover Street 954-1008 W. Adams Boulevard			4/3/1981	
252	Miguel Figueroa Adobe	1147-1163 W. 27th Street 2670-2676 Magnolia Avenue			4/3/1981	
253	Garden Court Apartments (Former Site of)	7021 Hollywood Boulevard			4/24/1981	Demolished 1987
254	Residence	1432 Marvern Avenue			4/24/1981	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
244	Residence	1956 W. 34th Street			4/20/1981	
245	Lincoln Avenue Church Building (Frontage Façade)	3600 Homer Street			6/4/1981	
246	Residence	1443-1447 N. Vista Avenue			11/25/1981	
247	Freeman House	1962 Glencoe Way			11/25/1981	
248	First Living Methodist Church of Hollywood	6817 Franklin Avenue			12/4/1981	
249	Pacific Magazine (Can) Depot	1001 Dubois Avenue & 501 E. Opp Street 561 E. Opp Street & 1000 Locust Avenue			9/15/1982	
250	Lord of Los Angeles Building	4435 Wilshire Boulevard 741-743 Lucerne Boulevard			8/25/1982	
251	Junior Theatre (Warner Brothers)	475 W. 8th Street			8/25/1982	
252	Harbor View House	907-945 Beacon Street 913-925 Palos Verdes Street			8/25/1982	
253	Muller House	1542 S. Beacon Street			8/25/1982	
	Muller House (partial)	475 W. 16th Street				
254	Marymount High School Main Admin Bldg. and Chapel & Auditorium	101 - 21 Marymount Place			9/28/1982	
		10643-10681 Sunset Boulevard				
255	Original Hardy	809 817 W. 8th Street 870-877 S. Figueroa Street			10/5/1982	
256	Mack Sennett Studios	1712 Glendale Boulevard 2 1/2 Aaron Street			11/5/1982	
257	Residence	817-821 N. Glendale Boulevard			11/5/1982	
258	Fitzgerald House	2525 S. Arlington Avenue 3119-3125 W. Adams Boulevard			11/17/1982	
259	Dayton Theater	6700 Melrose Avenue 6708-6810 S. Serrano Boulevard			12/17/1982	
260	Schindler House	1842 Kelly Glen Drive			5/17/1983	
261	Echo Heights Branch Library	2538 Glendale Boulevard			3/3/1983	
262	Residence	2705 Eagle Street			3/3/1983	
263	Villa Raphael	5123 Hercules Avenue			3/3/1983	
264	Vermont Square Branch Library	1201 W. 48th Street			3/7/1983	
265	Bridge at Fourth and Lorena Streets	4th Street Lorena Street			3/7/1983	
266	Old Ice Residence	600-602 W. Kensington Road			5/10/1983	
267	Park Plaza Hotel	2400-2410 W. 8th Street 602-607 Park View Street			5/24/1983	
268	La Fonda Restaurant Building	2501-2511 Wilshire Boulevard			5/24/1983	
269	Mount Washington Cable Car Station	200-202 N. Avenue 43			5/26/1983	
270	Venice Canal System	Carroll Canal Eastern Canal Grand Canal Howland Canal Linnie Canal			7/15/1983	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
270	Venice Canal System	Ocean Avenue Strongs Canal Grand Canal Venice Boulevard Washington Boulevard			7/15/1999	
271	Fire Station No. 30 and Police Station Building	401-411 S. Main Street			8/6/1980	
272	Pool House	1135 S. Serrano Boulevard			9/21/1993	
273	Bungalow House	1301-1307 W. 24th Street 2311 Toberman Avenue			6/4/1984	
274	Northeast Police Station	6045 York Boulevard			6/4/1984	
275	Hollywood Recording Company Building	7471-7627 Beverly Boulevard			6/4/1984	
276	Pacific Palisades Business Block	15000-15016 Sunset Boulevard 15001-15327 Antioch Street 304-313 Via de la Paz			4/24/1986	
277	Hollywood Masonic Temple	6840 Hollywood Boulevard			9/27/1994	
278	Title Guarantee & Trust Company Building	401-411 W. 6th Street	CHC-1986-0253-HCM	CF 86-0469	6/18/2003 7/11/1994	Existing HCM expanded to include interior
279	Greenacres Thomas Mayou Lloyd Estate	1055 North Mayfield Drive 1741 Green Acres Place			7/24/1994	
280	Chaplin Park Studio Building	2501-2519 W. 5th Street			7/24/1994	
281	Cathedral High School	1253 Dishman Road			8/7/1984	
282	Masonic Temple Highland Park	104-112 N. Avenue 56 & 5567 N Figueroa St 5567 N. Figueroa St and 5 104 N. Avenue 56			9/28/1984	
283	Southwest Museum	234 Museum Drive	CHC-1984-3284-HCM		8/21/1984	
284	Highland Park Lodge Building	125-131 S. Avenue 57			8/21/1984	
285	C.C. Boeseman Estate	1847 Camino Palmero			10/31/1984	
286	Mayflower Hotel	531-535 S. Grand Avenue			10/31/1984	
287	Vendome Hotel	1400-1414 S. Vermont			1/31/1985	
288	Radisson Hotel	1703-1707 W. 4th Street			2/1/1985	
289	Fire Station No. 38	1401 S. Central Avenue			2/15/1985	
290	La Reina Theatre	14029 Ventura Boulevard			2/27/1985	
291	Highland - Camrose Bungalow Village	2105-2115 1/2 N. Highland Avenue 6814-6836 Alta Loma Terrace 6819 Camrose Drive & 2103-15 N. Highland Ave			4/3/1985	
292	Old Eagle Rock Branch Library	2225 Colorado Boulevard			6/5/1985	
293	The Magnolia	13242 Magnolia Boulevard			6/5/1985	
294	Fashion Square Building	241 W. 9th Street 843-853 S. Broadway			6/26/1985	
295	Art Deco Entry Registered	1160-1198 W. Adams Boulevard			7/12/1985	
296	John C. Lynch Residence	1154-1166 W. 27th Street			7/12/1985	

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No.	Name	Address	CHC No	CF No.	Adopted	Notes
297	West Adams Gardens	1150-1176 W. Adams Boulevard			9/13/1985	
298	Crocker Bank Building	256-270 S. Western Avenue 4359-4363 W. 3rd Street			9/20/1985	
299	Pantages Auditorium and Lobby	531 W. 9th Street 838-851 S. Grand Avenue			10/4/1985	
300	Casa Bianca Pool	1823 S. Cox Street Washington Boulevard			10/29/1985	
301	Andrew Morgan Residence	2249 Mountain Oak Drive			10/29/1985	
302	Angelus Parish Branch (North Hollywood Branch Library)	5211 N. Tujunga Avenue			8/27/1986	
303	John C. Fremont Branch Library	6121 Melrose Avenue			8/27/1986	
304	Malabar Branch Library	2801 E. Wabash Avenue			8/27/1986	
305	John Muir Branch Library	1005 W. 64th Street			8/27/1986	
306	Original Vernon Branch Library (Former Site of)	4501 S. Central Avenue			8/27/1986	Demolished 1986
307	Washington-Irving Branch Library	1803 S. Arlington Avenue			8/27/1986	
308	Wilmington Branch Library	1301-1307 N. Figueroa Avenue 309 W. Opp Street			8/27/1986	
309	El Royale Apartments	450 N. Rossmore Avenue			9/2/1986	
310	Fire Station No. 39	750 S. Western Avenue			10/1/1986	
311	Los Altos Apartments	4117-4127 Wilshire Boulevard			10/17/1986	
312	Japanese Union Church of Los Angeles	120-122 N. San Pedro Street			10/24/1986	
313	Los Angeles Pagoda (Hongwanji) Buddhist Temple	109-119 N. Central Avenue 356-366 E. 1st Street			10/24/1986	
314	Canoga Branch Library	4850 N. Sepulveda Boulevard			10/24/1986	
315	Villa Carlotta	1913-1915 Tamarind Avenue 5850 Franklin Avenue			10/29/1986	
316	William Stromberg Block	6435 Hollywood Boulevard			1/7/1987	
317	Young Apartments	1016-1021 S. Grand Avenue 303-311 W. 10th Street			1/7/1987	
318	Hornby House	1221-1225 Hornby Avenue			2/3/1987	
319	The Crow	10960-10965 Santa Monica Boulevard			3/11/1987	
320	Landfair Apartments	10640-10664 Comr Drive			5/20/1987	
321	Eastlake Inn	1007 W. Edgeware Road 1442 Kellam Avenue			5/20/1987	
322	Fletcher Drive Bridge over the Los Angeles River	Fletcher Drive			5/21/1987	
323	Church of the Open Door (Former Site of)	550 S. Hope Street			7/28/1987	Demolished 1988
324	The Lindbrook	10800-10806 Lindbrook Drive			8/14/1987	
325	Shulman House	7875-7877 Woodrow Wilson Drive			8/26/1987	
326	McKinley Mansion (Former Site of)	310-312 S. LaFayette Park Place			9/9/1987	Destroyed by Fire 05/24/1994
327	Thomas Potter Residence	1135-1141 S. Alvarado Street			9/23/1987	

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No.	Name	Address	CHC No	CF No	Adopted	Notes
327	August Wahlstrom Residence	1147 S. Alvarado Street			3/22/1987	
328	Chatwood Duplex	1830-1836 Tamarind Avenue 5820-5828 Yucca Street 5820-5830 Hudson Avenue			3/23/1987	
330	Rosedale Cemetery	1831 W. Washington Boulevard 1888 Venice Boulevard			12/17/1987	
331	Pacific Bell Building	2749-2765 W. 15th Street			12/3/1987	
332	Wilshire Tower	5600-5622 Wilshire Boulevard			12/3/1987	
333	Grier - Musser House	403 S. Bonnie Brae Street			12/16/1987	
334	Security Trust and Savings Building	1728 Cahuenga Boulevard 6367-6385 Hollywood Boulevard			12/16/1987	
335	Perry L. Pelton Residence	920-924 W. 23rd Street			12/30/1987	
336	Hollywood Western Building	5520-5610 Hollywood Boulevard			1/6/1988	
337	Engine Company No. 56	2838 Roscoe Avenue			1/12/1988	
338	Drake House	210-220 S. Avenue 60			1/26/1988	
339	Santa Fe Arroyo Seco Railroad Bridge	102 S. Avenue 61			1/26/1988	
340	Standard Oil Company	601-635 Olympic Boulevard & 950 S. Hope St. 953 S. Hope Street & 605 W. Olympic Blvd.			1/26/1988	
341	First African Methodist Episcopal Zion Cathedral & Community Center	1435-1457 W. Adams Boulevard			1/22/1988	
342	Masonic Temple	221-227 N. Avalon Boulevard			1/22/1988	
343	Avocado Tree Station Block	4400 Avocado Street			1/22/1988	
344	Institute of Musical Art	321 W. 54th Street 5401 10th Avenue			2/2/1988	
345	Harris Newmark Building	121 E. 6th Street			2/22/1988	
346	Coast Federal Savings Building	316 W. 3rd Street 855 S. Hill Street			3/1/1988	
347	Old Bunker Hill Building	458 S. Grand Avenue 601-611 5th Street			3/25/1988	
348	Fire Station No. 20	644-646 S. Figueroa Street			3/30/1988	
349	Fire Station No. 10	2610 S. Hoover Boulevard			3/30/1988	
350	Irving Tabelson House and Modern Boy Flagpole	1180-1190 W. Adams Boulevard 2642 Magnolia Avenue			3/30/1988	
351	Shelmore Apartments	11005-11013 1/2 Rochester Drive			4/8/1988	
352	Los Angeles Athletic Club	1431 Maple Street 245 S. Lucas Avenue			4/6/1988	
353	Monterey Apartments	4600-4602 Los Feliz Boulevard			5/17/1988	
354	Security - Bank of America Security - Bank of America Building	626 W. 7th Street 648 S. Olive Street			4/20/1988	
355	Roosevelt Building	648-654 S. Flower Street 716-736 W. 7th Street			4/20/1988	
356	Baker Brothers Building	700-726 S. Figueroa Street 705-715 S. Flower Street 630-648 W. 7th Street & 709-711 S. Flower St.			4/20/1988	

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No.	Name	Address	CHC No	CF No	Adopted	Notes
357	Rose Building W. Robinson's	600-602 W. 7th Street 700-716 S. Grand Avenue 715-723 S. Hope Street			4/26/1988	
358	Brock Jewelers - Gilbert's	513-515 W. 7th Street			4/13/1988	
359	Broad Street Shul	241-247 N. Broad Street			6/7/1988	
360	Wiltshire - Egyptian Theater (Ralphs Grocery Store)	10835-10857 Lindbrook Drive 1142-1164 Weyburn Boulevard			6/21/1988	
361	Fox Bruin Theater	10915-10940 Weyburn Avenue 925-935 Broxton Avenue			6/21/1988	
362	Fox Village Theater	10960-10961 Weyburn Avenue 945-961 Broxton Avenue			6/21/1988	
363	Gayley Terrace	956 Gayley Avenue			6/21/1988	
364	Janss Investment Company Building	1045-1055 Westwood Boulevard			6/21/1988	
365	Kelton Apartments	644-648 Kelton Avenue			6/21/1988	
366	Lallier House and Arroyo Stone Wall	137-151 S. Avenue 57			6/21/1988	
367	Sheets Apartments	1010 Strathmore Drive			6/21/1988	
368	Tilray Apartments	638-642 Kelton Avenue			6/21/1988	
369	Johnson Terrace & Arroyo Stone Wall	4096 N. Figueroa Street 4905-4909 N. Sycamore Terrace			7/5/1988	
370	Herbert Terrace & Arroyo Stone Wall	4979-4987 N. Sycamore Terrace 4970-4985 N. Figueroa Street			7/5/1988	
371	Tustin House & Arroyo Stone Wall	4967-4973 N. Figueroa Street 4973-4977 N. Sycamore Terrace			7/5/1988	
372	Mary M. Todd House & Arroyo Stone Wall	4967-4971 N. Sycamore Terrace 4957-4970 N. Figueroa Street			7/5/1988	
373	Arroyo Stone House & Arroyo Stone Wall	4099 N. Figueroa Street 4920 N. Sycamore Terrace			7/5/1988	
374	Guy E. Griffith House	5915-5919 Dana Street			7/5/1988	
375	Putnam House	5044-5048 Hayes Avenue			7/5/1988	
376	William J. Smith House & Arroyo Stone Wall	142-142 S. Avenue 57			7/5/1988	
377	Site Tree (except for 7) - Landscaping Elements & Structure Site Tree (except Structure for 138 S. Avenue 57)	126-138 S. Avenue 57 5731-5731 Monte Vista			7/5/1988	
378	Orlando - Smith House	5675-5680 Ash Street			7/5/1988	
379	Worrell House	215 N. Avenue 53			7/5/1988	
380	Reeves House	219 N. Avenue 53			7/5/1988	
381	The Lemle House (Studio at Orlando, Greek Study House #5)	203 One Gaucho Bar Overd			7/5/1988	
382	Falcon Studios	5624 Hollywood Boulevard			7/25/1988	Rear Stucco Building Demolished 1995

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No.	Name	Address	CHC No.	CF No	Adopted	Notes
383	Residence	1203-1207 Kipling Avenue			9/5/1986	
384	Department of Water and Power Building	2417 Daly Street			8/5/1986	
385	Title Insurance & Trust Company Building and Annex	433 S. Spring Street			9/5/1986	
386	Chapman Park Market Building	3451 W. 6th Street			9/30/1986	
387	Gas Station	1100 S. Barrington Avenue			9/2/1986	
388	Edison Electric Company (Los Angeles #3 Steam Power Plant)	950 S. Avenue 21			10/21/1986	
389	C. M. Church House	5507 Echo Street			12/4/1986	
390	Jardinette Apartments	5120 Marathon Street			12/4/1986	
391	Garland - Warner Estate	1923 Whitley Court			10/4/1986	
392	Freshaven Guest House and Grounds	4211 Glenalbyn Drive			11/4/1986	
393	Wiles House and Grounds	4224 Glenalbyn Drive			11/4/1986	
394	Lindley Dent / Florence Dent Halstead House and Grounds	4200 Glenalbyn Drive			11/4/1986	
395	H. Stanley Dent House and Carriage House and Horse Fountain)	4201 Glenalbyn Drive			11/4/1986	
396	Federal Bank Building	220 S. Broadway			11/13/1986	
397	Romer Gardens	2000 N. Highland Avenue			11/21/1986	
398	Pacific Mutual Building	523 W. 6th Street			11/13/1986	
399	Bates House	1415 Cahuenga Avenue			11/20/1986	
400	Sunset Court	5721-5725 Monte Vista Street			11/13/1986	
401	Patz Adobe	4730 Cypress Springs Drive			11/13/1986	
402	Frederic M. Ashley House	745-747 N. Avenue 56			12/9/1986	
403	Higgins - Workman - Prism Mansion	607 S. Catalina Boulevard			12/4/1986	
404	Los Angeles Railway Huron Substation	6540 W. Huron Street			12-2-1986	
405	Pacific Electric Power Railway Station (Interior Space)	1671 0 Station Way			1/21/1987	Destroyed by Fire 05/04/1990
406	Mayo Center	7001 Franklin Avenue			1-7-1987	
407	Bayer Residence	2326 South Street			1/20/1987	
408	Mitchell - Spargo House	2341 South Street			1/20/1987	
409	Burkhart Residence	2305-2311 Orwell Street			1/20/1987	
410	Distribution Station No. 31	1035 W. 24th Street			1/20/1987	
411	Robert Edington/Williams House (Halfway Home for Orphans)	942 N. Avenue 66			1/7/1987	
412	Garvanza Pumping Station and site of High Level Reservoir	420 N. Avenue 62			1/20/1987	
413	Octagon House (Heritage Square)	3800 Homer Street			1-20-1987	
414	Workington Cemetery	801-725 F. O Street			1-24-1987	
415	Virginia Avenue Library	149 N. Saint Andrews Place			2-1-1987	
416	Ringer House	4021 N. Figueroa Street			2-27-1987	
417	Colonel E. McDonough House	2232 9th Avenue			2-27-1987	
418	George W. Wilcox House (Former Site of)	916 N. Avenue 66			2-27-1987	Destroyed by Fire 12/15/1985
419	Gilker Mansion	3330 W. Adams Boulevard			3/3/1987	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
420	Milbank - Mellon Estate	1120 Arlington Avenue & 3340 Country Club Dr 3340 Country Club Drive & 1120 Arlington Ave			12/3/1969	
421	Lake Hollywood Reservoir (including Mulholland Dam)	2460 Lake Hollywood Drive			3/31/1983	
422	Silverlake and Ivanhoe Reservoir	Armstrong Avenue & Scott & Silverlake Dr Silverlake Blvd & Silverlake & Armstrong Ave W. Silverlake Dr & Silverlake & Armstrong Ave			3/31/1983	
423	Apartment Building	607 Burnside Avenue			3/31/1983	
424	Apartment Building	625 Burnside Avenue			3/31/1983	
425	Apartment Building	635 Burnside Avenue			3/31/1983	
426	Apartment Building	654 Burnside Avenue			3/31/1983	
427	Apartment Building	364 Cloverdale Avenue			4/7/1983	
428	Villa Sierra	430 Cloverdale Avenue			4/7/1983	
429	Apartment Building	631 Cloverdale Avenue			4/7/1983	
430	Carlton Apartments	633 Cloverdale Avenue			4/7/1983	
431	Residence	1561 W. 11th Street			5/5/1983	Exterior only
432	Dana Apartments	1600-1604 W. Pico Boulevard			5/5/1983	
433	Alphabet Tongue Residence	1047 S. Bonnie Brae Street			5/5/1983	Exterior only
434	Colonel John P. Stevens Residence	27 San Clemente Park			5/5/1983	
435	Anastasia Apartments	1471-1475 Beachwood Drive			5/16/1983	
436	Howard - Nagel Residence	145 S. Fuller Avenue			5/19/1983	
437	A. H. Judson Estate (Former Site of)	4909-4919 N. Sycamore Terrace 4911 Pasadena Avenue Terrace			5/19/1983	Demolished 2/4/2002
438	Apartments	445 S. Detroit Street			5/19/1983	
439	Apartments	450-458 S. Detroit Street			5/19/1983	
440	Eastern Star Home and Long Beach Chapter and Courtyard	11725 Sunset Boulevard			5/10/1984	
441	Dunning House	1000-1018 Saint Andrews Pl & 5567 Carlton Way 1552 Carlton Way & 1000-1018 Saint Andrews Pl			9/21/1984	
442	Allan Colleges - Avalon Village Market	1801-1813 Micheltorena Street			8/23/1989	
443	Sherman Residence	2425 Gilda Avenue			8/23/1989	Exterior only
444	Columbia Savings Residence	179-181 S. Avenida Cabrillo Boulevard			8/23/1989	
445	Courtney Conservatories	1531-1541 Courtney Avenue			8/23/1989	
446	Courtyard Apartments Complex	10500 Lindbrook Drive			9/1/1989	
447	Courtyard Apartments Complex	10838-10840 Lindbrook Drive			9/1/1989	
448	Whitley Court	1720-1728 Whitley Avenue			10/13/1989	
449	Avalon Theater	330-340 S. Broadway			8/15/1990	
450	Tower Theater	219-233 W. 8th Street & 800-834 S. Broadway 835-834 S. Broadway & 219-233 W. 8th Street			8/15/1990	
451	Residence (Façade only)	5370 Wilshire Boulevard			11/1/1990	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
452	Fernando Nava Branch Library	2823-2833 W. 6th Street			10/17/1989	
453	Artisan's Plaza Complex	6727-6733 Hollywood Boulevard			10/17/1979	
454	Chouinard Institute of the Arts	2301 W. 6th Street 707-747 Grand View Street			10/24/1969	
455	Margaret T. and Gotlieb Mesta Craftsman Residence	2342 Scarff Street			10/24/1989	
456	Irma T. Johnson House	838 W. Adams Boulevard			10/24/1989	
457	Freeman D. Tyrrell House	2885-2887 Scarff Street			10/24/1989	
458	Wells - Halliday Mansion	2148 W. Adams Boulevard			11/3/1964	
459	Hamburger's Department Store	330-332 W. 8th Street 800-838 S. Hill Street 801-829 S. Broadway			12/7/1959	
460	Mayan Theatre	1038-1044 S. Hill Street			12/7/1959	
461	Meyers House Palmer Residence	4345 Eagle Rock Boulevard			11/3/1958	Relocated to 4340 Eagle Rock Blvd. in 1982. Destroyed by fire 4/30/1992
462	Hollywood American Legion Post 43	2035 N. Highland Avenue			11/3/1958	
463	Allen Arms Apartments	6141 Allen Place			11/3/1989	
464	Fargo House	200 Fargo Street			11/3/1958	
465	Sycamore Trees	Bienveneda Avenue			10/27/1959	
466	Harry J. Foster Residence	1030-1036 1/2 W. 23rd Street			10/17/1963	
467	Chanel Apartments	2275 Scarff Street			10/27/1989	
468	Sacred Heart Church	2210-2212 Sichel Street 2401 Baldwin Street			12/6/1989	
469	Ivar Phillips Dwelling	4230 N. Figueroa Street			12/20/1966	
470	Ivar Phillips Residence	4204 N. Figueroa Street			12/20/1966	
471	Argus Court	1760-1768 Cochran Boulevard			12/20/1966	
472	Rialto Theater Building	806-812 S. Broadway			12/20/1966	
473	Apartment	610 Ridgeley Drive			12/8/1967	
474	Little Niagara (Revel Town - Echo Park)	2200 Echo Drive			1/29/1969	
475	Highland Towers Apartments	1520-1530 N. Highland Avenue			12/18/1979	
476	Belasco Theater	1046-1054 S. Hill Street			1/30/1980	
477	Biggs Residence	3734 W. Adams Boulevard			8/30/1990	
478	Guest Villa - Braby Berkley Estate	3500-3520 1/2 W. Adams Boulevard			8/30/1990	
479	Dr. Grandison Matthews Home	3722-3728 W. Adams Boulevard			1/30/1990	
480	Spanish - American War Memorial (Pershing Square)	5th Street & Olive Street Olive Street & 6th Street 6th Street & Hill Street Hill Street & 5th Street			9/28/1990	
481	Murphy House	932 Bonita Drive			9/28/1990	
482	Arthur S. Aiken House	104-108 S. Avenue 49			5/1/1987	
483	J. B. Morin House	615 Dyke Drive			9/28/1990	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
484	Oakridge and Grounds	18550 Devonshire Street	CHC-2005-1399-HCM		3/23/1995	
485	Rudolph Palazzo	414 Santa Monica Road			4/6/1990	
486	Huntington Center of Los Angeles Chinese Community Pillars	204 N. Hewitt Street			6/21/1990	
487	Sanchez Ranch	3733 San Feliciano Drive			5/1/1990	
488	Omega Palm Lighting Coachhouse Southern Pacific R/R Station	2355 Sherman Way			5/30/1990	
489	Tyrrell-Alexander Residence	2110 Peralta Avenue			5/30/1990	
490	SAANGNA (Sacred Indian Soil of Gabrielino Indians)	4221-4265 S. Lincoln Boulevard			6/1/1990	
491	Charles H. Boerr Residence and Carriage House	824 826 S. Hobart Boulevard			7/13/1990	
492	Arroyo Seco Dairy Building	5199-5199 York Boulevard 5201-5211 N. Figueroa Street			7/13/1990	
493	Casa de Adobe	4603-4613 Figueroa St & 4610 4616 Woodcrest 4611-4617 Woodcrest & 4603 4613 Figueroa			7/13/1990	
494	Kohner Residence and Carriage Barn	9824 Bonhill Road			7/13/1990	
495	El Capitan Theatre Building	6834 6838 Hollywood Boulevard			8/10/1990	
496	Lycurgus Lindsay Mansion	3424 3426 W. Adams Boulevard			9/13/1990	
497	Charles Coffee Gibbons Residence	2124 Portello Avenue			9/13/1990	
498	Lois Fisher Arnold Residence	1937 Estrella Avenue			9/13/1990	
499	Agnes Bennington Residence	1969 Portello Avenue			9/13/1990	
500	John D. Kane Residence	2127 Portello Avenue			9/13/1990	
501	Michael Shannon Residence	1970 Portello Avenue			9/13/1990	
502	Dennis Hathaway Mansion (Mansion City)	3681 3801 Tennessee Avenue			9/26/1990	
503	Wachtel Studio - Home & Eucalyptus Grove	315 W. Avenue 43 & 4308 Glenmuir Avenue 4308 Glenmuir Avenue & 315 W. Avenue 43			10/4/1990	
504	Barlow Sanitarium	1300 Scott Avenue & 2000 Sichel Way 2000 Sichel Way & 1300 Scott Avenue			10/4/1990	
505	First Baptist Church of San Pedro (Facade & Stained Glass Window)	555 W. 7th Street			9/29/1990	
506	Bachrach Residence	175 Glenfiddich Avenue			10/31/1990	
507	William W. Shoaf Residence	2108-2110 1/2 Portello Avenue			11/2/1990	
508	Chinese Consolidated Service Station	8500 Willoughby Ave & 553-559 N. Highland Ave 553-559 N. Highland Ave & 8500 Willoughby Ave			3/25/1991	
509	Camphor Trees	1208 1208 Lakme Avenue			12/19/1990	
510	Residence	1157 W. 58th Street 5426 Building Avenue			1/11/1991	
511	Residence	1138 W. 60th Street			1/11/1991	
512	Church of The Advent	2014 Longwood Ave & 4970 4976 W. Adams Blvd			1/15/1991	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
512	Church of The Advent	4570-4550 W. Adams Blvd & 2634 Longwood Ave			1/16/1991	
513	Southern California Edison Service Yard Structure	315 E. 16th Street			1/15/1991	
514	Residence	351-353 12th Street			1/22/1991	
515	Barney Ragget / Turley	5321 Barney Street Leesworth Drive			1/22/1991	
516	Saint Johns Episcopal Church	514-518 W. Adams Boulevard			1/22/1991	
517	Residence	317 E. 43rd Place			1/16/1991	
518	Residence	1287 E. 55th Street			1/16/1991	
519	Cookie House	2353 S. Hoover Street			2/1/1991	
520	El Rey Theatre	5515-5519 Wilshire Boulevard			2/26/1991	
521	Teggie House	2150-2158 Live Oak Drive & 5423 Black Oak Dr 5423 Black Oak Drive & 2150-2158 Live Oak Dr			3/4/1991	
522	Stock Exchange Building	300-314 W. 7th Street 701-725 S. Broadway & 300-314 W. 7th Street			3/20/1991	
523	United Artists Theater Building	931-933 S. Broadway			3/20/1991	
524	Cameo Theater (aka Ivy Cinema Broadway	935-939 S. Broadway			3/20/1991	
525	Arcade Theater (formerly Rampage Theater)	937-939 S. Broadway			3/20/1991	
526	Rialto Theater	812-824 S. Broadway			3/20/1991	
527	Residence	1437 N. Wade Avenue			4/2/1991	
528	Dr. Franklin S. Worley Residence	6431 Crescent Street			4/23/1991	
529	Montecito Vista Duplex	4415 Brunswick Place			4/23/1991	
530	John Palenza House (Olive Knoll House #5)	205 Chadwick Boulevard			4/30/1991	
531	Wilshire Ward Chapel	1239 S. Manhattan Place			5/10/1991	
532	Venice Arcades (including Columns and Capitals)	67-77 Windward Avenue			4/23/1991	
533	Residence	2003 Scott Street			5/1/1991	
534	J. Magnin & Company Building	3240 Wilshire Blvd & 550 New Hampshire Ave 550-560 New Hampshire Ave/3240 Wilshire Blvd			5/1/1991	
535	Hollywoodland's Historic Granite Retaining Walls and Stairs	Hollywoodland			5/1/1991	
536	Eagle Rock Playground Clubhouse	1100 Eagle Vista Drive			7/2/1991	
537	Eagle Rock Women's Twentieth Century Clubhouse	1841-1855 Colorado Blvd/5105 Hermosa Ave 5101-5105 Hermosa Ave/1841-1855 Colorado Blvd			7/2/1991	
538	David J. Wilmer Family Houses and Complex	1422 W. 2nd Street & 208-210 N. Wilmer St 208-210 N. Wilmer Street & 1422 W. 2nd St			7/2/1991	
539	J. C. Stowell Residence	211 S. Avenue 52			7/19/1991	
540	Viper House (Former Site of)	326 N. Avenue 53			7/19/1991	Destroyed by Fire 09/20/1995

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No.	Name	Address	CHC No	CF No.	Adopted	Notes
641	Rosalyne Wirtz Thomson Residence	215 S. Avenue 52			7/15/1991	
642	Sisson House	2273 Addison Way			7/24/1991	
643	Farmers Market	Gilmore Lane West 3rd Street & West Fairfax Avenue West Fairfax Avenue & West 3rd Street			9/24/1991	
644	Home Dyment Building	249-259 S. Broadway & 301 W. 3rd Street 301 W. 3rd Street & 249-259 S. Broadway			8/2/1991	
645	Hollywood Roosevelt Hotel and Fox	7000-7034 Hollywood Boulevard 7001-7009 Hawthorn Avenue			8/13/1991	
646	Avalon Theater	634-642 S. Avalon Street			9/24/1991	
647	Camp Osceola Nellie Lodge	3033 Rustic Canyon Road			10/22/1991	
648	Korean Independence Memorial Building	1368 W. Jefferson Boulevard			10/2/1991	
649	Highland Theatre Building	103 E. Avenue 66 & 5933-5939 N. Figueroa 5933-5939 N. Figueroa Street & 103 E. Ave 66			10/2/1991	
650	A. J. Madison House	48-100 S. Avenue 66			10/2/1991	
651	Thomas W. Phillips Residence	2715 S. Harvard Boulevard			11/13/1991	
652	Frank C. Patterson Studio Court	4350-4357 1/2 Rosemary Road			11/13/1991	
653	Midlevel School	4101 Russell Avenue			11/13/1991	Site plus four Joint Launer Buildings
654	La Belloma	357-359 N. Avenue 53 & 5300-5320 Granada St 5300-5320 Granada St & 357-359 N. Avenue 53			2/6/1992	
655	Mother Trust Superior Market	2506-2522 W. 3rd Street			3/5/1992	
656	Charles and Nellie Williams Home	212-214 N. Avenue 57			4-21/1992	
657	Arthur L. Wood House	4027-4029 Dahlia Place			4/21/1992	
658	Department of Water and Power Distributing Station No. 2	211-235 N. Avenue 61 6100-6114 Mount Angelus Drive 6112 Monte Vista Street			4-21/1992	
659	Hollywood Church of Christ Scientist	1748-1760 N. Edgemont Street			4/21/1992	
660	Wright House	2121-2123 Berkeley Avenue			6/26/1992	
661	Allen House	2125 Berkeley Avenue			6/26/1992	
662	Eagle Rock Women's Christian Temperance Union Home	2222-2244 Laverna Ave & 2225-2245 Norwalk Av 2225-2245 Norwalk Ave & 2222-2244 Laverna Av			9/25/1992	
663	Lloyd Wright's Hardley - Handley House	3008 Runyon Canyon Road			7-14/1992	
664	E. A. Spencer Estate	5660 Ash Street			9/25/1992	
665	Charles H. Greenaway Residence	1102-1114 Laverna Dr & 2121-2381 Rockway Ter 6171-6187 Rockwood Ter & 1102-1114 Laverna Dr			8/27/1992	
666	May Company Wilshire	6067 Wilshire Boulevard			9/25/1992	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
567	Little Church of Hollywood	1750 N. Argyle Avenue & 6151 Carlos Ave 6151-6161 Carlos Avenue & 1750 N. Argyle Ave	CHC-1992-1518-HCM		10/27/1992	
568	Thomas A. Garland Sr. Residence	275 S. Vernon Place			10/27/1992	
569	Van De Kamp's Holland Dutch Bakery	2930-2930 Fletcher Dr & 3015-3015 San Fernando Rd 3015-3023 San Fernando Rd & 2930-2930 Fletcher			5/12/1993	
570	Argyle Theatre Building	901 Cahuenga Way			12/18/1995	Colors Only
571	Outside Beach Bathhouse	3730 Stephen White Drive			12/18/1995	
572	Warner Brothers Hollywood Theater	1700-1718 Wilcox Ave & 6423-6445 Hollywood			2/9/1993	
	Warner Brothers Hollywood Theater Building	6423-6445 Hollywood Blvd & 1700-1718 Wilcox				
573	El Portal Theater	11239-11239 Weddington/5355-5371 Lankershim 5355-5371 Lankershim/11239-11239 Weddington			2/9/1993	
574	Pierce Brothers Mortuary	1900-1928 Barrington Ave/714-720 Washington Bl 714-720 Washington Bl/1900-1928 Barrington Ave			2/9/1993	
575	Security First National Savings Bank (Digitoria Park branch)	101-107 N. Avenue 56/5600-5608 N Figueroa St 5601-5633 N. Figueroa St/101-107 N. Ave 56			2/9/1993	
576	Sheraton Town House Hotel	2959-2973 Wilshire Bl/840 Commonwealth 2959-2999 Wilshire Bl/ 615-625 N. Virgil Ave 606-620 S. Virgil Ave & 2980-2990 Wilshire 607-645 Commonwealth Av/2959-2973 Wilshire 840 Commonwealth Av/2959-72 Wilshire Blvd			4/21/1993	
577	Burgess House	441-445 Bryson Way			5/21/1993	
578	Immanuel Congregational Lutheran Church	4254-4260 3rd Avenue			5/25/1993	
579	Western Pacific Railroad Depot	1701-1715 Santa Barbara/1611 Hollywood Blvd 1624-1650 N. Gower Avenue 1601 Hollywood Blvd/1611-1755 Santa Barbara			5/25/1993	
580	Golden State Mutual Life Insurance Building	4261-4265 1/2 S. Central Avenue			6/29/1993	
581	York Boulevard State Bank - Bank of America and Residence	5301-5313 N. Avenue 51 & 5317-5061 York Blvd 5013-5061 York Blvd & 5301-5315 N. Avenue 51			8/ 3/1993	
582	Wolf Apartments	123 N. Avenue 54			8/10/1993	
583	Arbelian Estate	3731-3731 S. Hower St/458-458 W. 38th St 458-458 W. 38th St & 3731-3731 S. Hower St			9/21/1993	
584	Egyptian Theater and Forecourt Appurtenants	1613-1654 McCadden Pl/6706-6712 Hollywood			9/21/1993	

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No.	Name	Address	CHC No.	CF No	Adopted	Notes
554	Egyptian Theater and Forecourt Signage	6708 6712 Hollywood Blvd; 1654 McCadden Place			8/27/1998	
555	Jane Reed College Hall of Letters Building (Savoy Apartments)	111-129 7/8 N. Avenue 50			12/15/1998	
556	San Fernando Roman Memorial Cemetery	1440 Eastern Place; 1440-1450 Gladys St 1445-1455 Gladys St; 1440 Eastern Place			11/30/1998	
557	Lincoln Heights Jail (Los Angeles City Jail)	401 449 N. Avenue 19			12/30/1998	
558	Wilshire Investment Company Uptown Branch (Bank Bldg./Retail Bldg.)	4761-4775 Maplewood Ave; 500-508 Western Ave 500 508 N. Western; 4761-4775 Maplewood Ave			11/30/1998	
559	Schoenberger House - Villa Aurora	520 Paseo Marcia			2/2/1994	
560	Brooklyn Avenue Neighborhood Corridor	Cesar E. Chavez Avenue			3/3/1994	
561	Derker Estate	3620 W. Adams Boulevard			3/3/1994	
562	Philosophical Research Society	3341 3351 Griffith Park; 3910 3916 Los Feliz 3910 3916 Los Feliz; 3441-3451 Griffith Park			3/3/1994	
563	Max Factor Make Up Salon	1660 N. Highland Avenue			4/21/1994	
564	Bradbury House	68 137 Ocean Way			4/20/1994	
565	Venice Division Police Station	652 Venice Boulevard			4/20/1994	
566	Petroleum Building	700 710 S. Hazel St; 700 714 W. Olympic Bl 700 714 W. Olympic Bl; 701 707 S. Hazel St			4/20/1994	
567	Raymond Chandler Square	Cahuenga Ave & Hollywood Blvd Intersection Hollywood Blvd & Cahuenga Ave Intersection			6-3/1994	
568	Benjamin J. Davies Residence	2226 W. 25th Street			6/27/1994	
569	Louis Bench Residence	1818 E. Discovery Place			6-27/1994	
570	Hudson and Bonnie Day Residence	2516 2518 4th Avenue			6/27/1994	
571	Discovery Homestead Park	2058-2102 W. 24th Street 2400-2402 Discovery Park			6/27/1994	
572	Augusto R. Vargas Residence (Filipino Federation of America)	2300-2312 W. 25th St/2301 S Arlington Ave 2301 S. Arlington Ave/2300-2312 W. 25th St			6/27/1994	
573	Villa Valombrosa	2341 Westerly Terrace			6-27/1994	
574	Hollywood School for Girls (Women's Club of Hollywood)	1741 1751 N. La Brea Avenue			11/1/1994	
575	Old Fire Station No.	534 E. Edgewood Road			11/1/1994	
576	Kershaw House	725 W. 27th Street; 730-740 W. Adams Blvd 730-740 W. Adams Boulevard; 725 W. 27th St			11/1/1994	
577	Powers Apartment #1	2525-2529 Scarff Street			11/1/1994	
578	Powers Apartment #2	13 Saint James Park; 2520-2527 Scarff St. 2525 2532 Scarff St; 13 Saint James Park			11/1/1994	

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No.	Name	Address	CHC No	CF No.	Adopted	Notes
609	Powers Apartment #3	2508-2512 1/2 Scott Street			11/1/1994	
610	Shackleford House	715 W. 28th Street			11/1/1994	
611	Mansion Residence	4151 4157 Sea View Drive & 4150 Sea View Ln 4151 Sea View Ln & 4151 4157 Sea View Drive			11/1/1994	
612	Britcher - Shaw Residence	4200-4216 Sea View Drive & 4234 Sea View Ln 4231 Sea View Ln & 4220 4218 Sea View Drive			11/1/1994	
613	Schofield House	4222-4230 Sea View Drive & 4252 Sea View Ln 4257 Sea View Ln & 4222-4230 Sea View Drive			11/1/1994	
614	Wofford House	4242 Sea View Drive & 4230 Sea View Lane 4250 Sea View Ln & 4242 Sea View Drive	CHC 1994 137 HCM		11/1/1994	
615	San Pedro Fire Building	108 116 N. San Pedro Street			11/8/1995	
616	The Triangle and Neon Eagle Sign	1750 1754 N. Serrano Ave			8/23/1995	
617	Hollywood Pilgrimage Memorial Monument	2580 Cahuenga Blvd			12/1/1995	
618	McDonnell Residence Foundation Home, Urban Academy	601 N. Wilcox Ave			11/22/1995	
619	Wolff-Ehlers House	111 N. June Street			9/21/1998	Demolished
620	Lemuel Hicks	4339 Lennox Blvd			2/1/1996	
621	Alice Lynch Residence	2414 4th Ave			3/1/1996	
622	Tait House and Landscaping	10745 San Fernando Mission Blvd			4/18/1996	
623	Kappe Residence	715 Broadway Road			4/15/1996	
624	Lawrence and Martha Joseph Residence and Apartments	3610-3607 Dunn Drive			4/15/1996	
626	Thomas Butler Perry Residence	1402 S. Manhattan Place			6/21/1996	
628	Eyraud Residence	1323 S. Manhattan Place			6/21/1996	
627	John F. Powers Residence	1347 S. Manhattan Place			6/21/1996	
625	Jack Doyle Residence	823 S. Irving Blvd			7/9/1996	
629	Adams Residence	7400 Fareda Ave			12/4/1996	
630	Fleming Residence	3124 Belden Drive			11/13/1996	
631	Bonis-Hartley Building	634 S. Spring Street			1/14/1997	
632	Gottfurcht House	810 Bienveni Way			2/4/1997	
633	Haas House	12434 Rochester Ave			2/4/1997	
634	Kalmus House	12527 Rochester Ave			2/4/1997	
635	Winkler House	12434 Rochester Ave			2/4/1997	
636	C. A. Nelson Residence	1215 Manchester Place			3/18/1997	
637	The Carmelli Condominium Complex	1150 Brockton Drive			3/18/1997	
638	The Parasol	11406 Dona Cecilia Drive			3/18/1997	
639	Rustic Art Club	800 S. Plymouth Blvd			3/18/1997	
640	Richard and Dion Neutra VDL Research House	2300 Silver Lake Blvd			3/18/1997	
641	Bronson Apartments Neon Roof Sign	422 426 S. New Hampshire Ave			6/4/1997	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
642	Embassy Apartments Neon Roof Sign	732-738 S. Mariposa Ave			8/4/2017	
643	Superba Apartments Incandescent Roof Sign	535 S. Berendo Street			8/4/2017	
644	Rose Court	4642 Sunland Blvd			12/16/1997	
645	Harvester Farms	22045 Devonshire Street			12/19/1997	
646	Villa Serrano	536-540 S. Serrano Ave			12/19/1997	
647	Grand Avenue Guest Residence	126 Mandy Road			12/19/1997	
648	Owner's Residence	2731 Woodbury Drive			12/9/1997	
649	Dana D. Henderson House	132 S. Wilton Place			4/7/1998	
650	Montenegro House	139 S. Wilton Drive			4/7/1998	
651	Regina Christian Church	201 N. Grand Avenue			5/5/1998	
652	Junipero Recreation Center and Electric Roof Sign	1700 W. Sunset Boulevard			8/18/1998	
653	Bryson Apartments	2701 W. Wilshire Boulevard			9/16/1998	
654	Chatsworth Mansion	4319 Woodley Park Place			9/16/1998	
655	George R. Reed House	2337 Benedict Canyon Drive			9/16/1998	
656	"Hillsdale"	340 Main Street			10/14/1998	
657	Los Feliz Heights Steps	Cromwell Ave & Rowena Ave			10/14/1998	
658	Harry & Grace Warner House	996 Longwood Avenue			11/4/1998	
659	Pacific Electric Building Theatre and Marquee	6360 Sunset Boulevard			12/16/1998	
660	Rosenheim Mansion	1140 S. Westmoreland Place			6/22/1999	
661	Kuhn Mansion	1130 S. Westmoreland Place			6/22/1999	
662	Perino House	2229 S. Gramercy Place			6/22/1999	
663	Del Rey Clubhouse	801 Latimer Road			8/10/1999	
664	Broadway Department Store and Neon Sign	6300 W. Hollywood Boulevard			8/25/1999	
665	Hollywood Plaza Hotel and Neon Sign	1633 Vine Street			8/25/1999	
666	Taft Building and Neon Sign	6280 W. Hollywood Boulevard			8/25/1999	
667	The Theater Building Rooftop Neon Sign	344-346 N. Heliotrope Avenue			8/25/1999	
668	Pierce House by Carl Maston	9707 St. Ives Drive			9/29/1999	
669	Bailey House - Case Study House #21	9038 Wonder and Park Avenue			11/9/1999	
670	Stahl House - Case Study House #22	1635 Woods Drive			11/9/1999	
671	Security Bank	535-541 South Spring Street			11/9/1999	
672	Perry H. Clark Residence	2550 South Van Ness Place			11/9/1999	
673	The Colonnade II	1801 Colorado Drive			11/17/1999	
674	Jacobson House	4626 Dundee Drive			2/25/2000	
675	Villa Elaine	1241-1249 N. Vine Street			2/25/2000	
676	Neutra Office Building	2379 N. Glendale Boulevard			4/25/2000	
677	Hunter Oppen House	1244 S. Van Ness Avenue			4/25/2000	
678	The Turnberry House	2567 S. Van Buren Place			4/25/2000	
679	Maryland's Flat	4220-4222 1/2 S. Crenshaw Boulevard			4/25/2000	

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No.	Name	Address	CHC No	CF No.	Adopted	Notes
680	Mutual Housing Association Site Office	960 Hanley Avenue			5/6/2000	
681	S.H. Woodruff Residence	3186 N. Tyrone Drive			6/14/2000	
682	School House	967 N. Hanley Avenue			6/14/2000	
683	Chase Knolls Garden Apartments	1340* W. Riverside Drive	CHC 2000-3446-HCM		7/11/2000	
684	Heart House	112 N. Bernard Boulevard			10/3/2000	
685	Pierce Methodist Family Cemetery	631 N. San Fernando Court			10/17/2000	
686	Southern Oil Company Building	550 S. Flower Street			12/24/2000	
687	Tamarind House	1019 N. Tamarind Avenue			12/24/2000	
688	Holiday Bowl	3730 S. Crenshaw Boulevard	CHC 2000-3228-HCM		12/19/2000	
689	Philip Chandler House	2501 N. Catalina Street			2/6/2001	
690	Stuart House	4237 Noakdale Drive			2/6/2001	
691	Carl C. Wehlow Residence	875 N. Norma Drive			3/23/2001	
692	Dan A. Kimball Building	1047 W. Colorado Boulevard			4/24/2001	
693	Isaac House	814 N. Bluegrass Lane			4/24/2001	
694	Emmons House	881 N. Brockman Road			4/24/2001	
695	Cross House	900 N. Hanley Avenue			4/24/2001	
696	Jones & Emmons Building	1224 W. Santa Monica Boulevard			4/24/2001	
697	Kamm House	900 N. Stanford Lane			4/24/2001	
698	Sherwood House	947 N. Stanford Lane			4/24/2001	
699	August House	1684 N. Mariposa Avenue			5/23/2001	
700	Saratoga Park Branch Library	4760 N. Overland Avenue			5/23/2001	
701	Burnside Manor	620 S. Burnside Avenue			7/31/2001	
702	Howe Residence	1542 N. Curson Avenue			7/31/2001	
703	Chyzow Cabins	10341-10335 Wilshire Blvd			7/31/2001	
704	John R. Berg House	2255 N. West Silver Lake Drive			10/23/2001	
705	Dryden Residence	3825 West Adams Boulevard			10/19/2001	
706	First Congregational Church of Los Angeles	540 S. Commonwealth Ave			2/15/2002	
707	Weber House	3522 W. 3rd Street			3/15/2002	
708	Dairy Building	310 E. Los Angeles Street			4/5/2002	
709	Dairy Building	324 E. Los Angeles Street			4/5/2002	
710	M. J. Connell Buildings 1, 2, 3 & 4	714, 710, 720 & 724 S. Los Angeles St.			4/5/2002	
711	M. J. Connell Building 5, 6 & 8	736 & 746 S. Los Angeles St and 743 Sanborn St			4-5-2002	
712	Tropico Dairy Building	316 E. 8th St.			4-5-2002	
713	Santa Fe Hospital	610 S. St. Louis St			4-5-2002	
714	Don Carlos Apartments	5225 Hollywood Blvd			4/24/2002	
715	Jorman House	2720 Belden Drive			5/16/2002	
716	Cliff May Experimental House	1931 Old Ranch Road	CHC 2004-4845-HCM		5/17/2002	
717	Pilot House	735 Rome Drive			7/30/2002	
718	Ward House	1450 Mulholland Dr			7/30/2002	
719	L.A.K. Hackett House	1317 S. Westlake Avenue			10/1/2002	
720	Ennis House	1240 Glendower Lane			10/1/2002	

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No.	Name	Address	CHC No	CF No.	Adopted	Notes
721	Sidwell House	1239 Beethoven Lane			10/1/2002	
722	Volk House	1241 W. Beethoven Lane			10/1/2002	
723	Wurlele House	946 Sonsini Lane			10/1/2002	
724	Venice of America Home	1323 Cabrillo Avenue			10/2/2002	
725	John C. Jones Lodge	5500 South Broadway			9/1/2002	
726	Ginger W. Lackey Home	774 East 52nd Place			9/1/2002	
727	Founder's Church of Religious Science	3281 West 8th St			10/2/2002	
728	San Fernando Building	400 S. Main Street			10/18/2002	
729	Hellman Building	417 S. Main St (410 S. Spring St.			9/18/2002	
730	Continental Building	408 S. Spring St			10/18/2002	
731	Westwood Village Memorial Park	1218 Glendon Ave			9/19/2002	
732	San Pedro Municipal Building	638 S Beacon St			10/22/2002	
733	The Garden	539 N Sycamore Ave			10/3/2002	
734	Bell Commercial Block	1946-1950 West Colorado Blvd			10/29/2002	
735	Jeffries House	571 Cypress Avenue			10/29/2002	
736	Monterey Trailer Park	8441 Monterey Rd			11/2/2002	
737	Gans Brothers Building	814 S. Spring St			11/22/2002	
738	Albert Wigand Greene Estate Residence	2430 W Ridgeview Ave			11/22/2002	
739	J.W. Hall 4-Plex	1121 W. Marion Avenue			12/17/2002	
740	The Scudder House	3547 Mandeville Road			12/17/2002	
741	Security Building	800-810 S. Spring Street			2/4/2003	
742	First Los Angeles Aqueduct Cascades	Highway 5 (Symbol)			2/4/2003	
743	Commerce Presbyterian Church	2300 Wilshire Blvd			2/4/2003	
744	Lincoln Theatre	2300 S Central Ave			3/18/2003	
745	Durham House	1651 Kelton Avenue			3/28/2003	
746	Ferneby House	1645 Kelton Avenue			3/28/2003	
747	Sicle House	1041 Kelton Avenue			3/28/2003	
748	South Park Loft Building	916 Maple Ave			6/4/2003	
749	Venice City Hall	681 C Venice Blvd			6/27/2003	
750	The Mayan Club	2153-2161 W Beverly Blvd			6/6/2003	
751	Redmen's Hall	543 Shamel St			4/23/2003	
752	Hanson-Purcell House	5961 Calleys View Ave			4/23/2003	
753	L. W. Ames House	3002 San Rafael Ave			4/23/2003	
754	First Presbyterian Church of Los Angeles	1809 West Blvd			5/2/2003	
755	Vista Del Mar Steps	Vista Del Mar Ave & Holly Mount Dr			6/3/2003	
756	Henry W. O'Melveny House	901 Plymouth			5/13/2003	
757	Joseph Dupy Residence - South Side Preservation	2201 to 2241 St			7/23/2003	
758	Ayres Residence	2501 Waverly Dr			6/3/2003	
759	Gerst Residence	3437 Adina Dr			6/23/2003	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
760	Casa Adobe Cafe	2400 West 6th St			7/29/2003	
761	Pleasant House	1402 W 28th St		CF 1407	7/29/2003	
762	Sweden House	5121 Franklin Ave			8/19/2003	
763	Studio Theatre at the Dorothy Building	3403 Cahuenga Blvd West			9/19/2003	
764	Lady Ellen's Tea Parlor	450 E Adams Blvd			10/1/2003	
765	Bullocks/Macy's Department Store	801 S Broadway			11/7/2003	
766	General Petroleum Building	612 S Flower St			11/7/2003	
767	Temple Methodist Church	770 Main St			11/7/2003	
768	Ravenswood Apartments	570 S Rossmore Ave			11/7/2003	
769	Doberman House	1749 Harvard Blvd			10/29/2003	
770	Red Car Trestle Footings	Fletcher Dr & Riverside Dr			12/17/2003	
771	J.T. Hoops Residence	2229 N Mt Royal Dr			12/19/2003	
772	Title Insurance Building	433 S Spring St			12/19/2003	
773	El Cabrillo Apartments	1632 - 1650 Grace Ave			12/19/2003	
774	Angelus Funeral Home	1026 - 1030 E 1st/Pecan Blvd			1/2/2004	
775	El Cortez Apartments	1721 N Sycamore Ave			4/2/2004	
776	Ray Charles Worldwide Offices and Studios	2107 W Washington Blvd			1/21/2004	
777	Wonder Residence	4640 Melrose Ave			4/14/2004	
778	Murdock Residence	4219 N Figueroa St		04-0095	5/18/2004	
779	Michael J. Connell Carriage House	934 W 23rd St		04-0500	6/10/2004	
780	Dennys House	1806 W 25th St		03-0072	5/7/2004	
781	Mia Cottage	4740 Tolaire Way		04-0351	6/15/2004	
782	El Encanto	1700 Chase St		04-0348	6/1/2004	
783	Covert Cottages Bungalow Court	939 - 944 1/2 N Vista Ave		04-0210	3/24/2004	
784	Paul Revere House	3965 Clayton Ave		04-1292	8/10/2004	
785	Chamberlain House	7776 Torreyson Drive		04-1296	8/10/2004	
786	Edwards-Dilley Building	830 S Grand Ave		04-1291	8/10/2004	
787	Fire Station 21	1187 E 52nd St		04-1287	8/10/2004	
788	Sears, Roebuck & Company Mail Order Building	2650 E Olympic Blvd		04-1251	8/10/2004	
789	Southern California Gas Company	830, 810, and 820 S Flower St		04-1224	8/10/2004	
790	Baldwin Tunnel / Detroit Substation and Yard	1304 W 3rd St	CHC-2004-5668-HCM	05-0114	2-23/2005	
791	Billy Hill House	1356 W 37th P	CHC-2004-6830-HCM	05-0248	4/13/2005	
792	Bl[illegible] House	215 S Mansfield Pl	CHC-2004-6870-HCM	05-0663	5/4/2005	
793	La Casa Nueva Jewelry Store Ranch	5700 N Rhodes Ave	CHC-2004-6732-HCM	05-0664	5/4/2005	
794	Carolyn Rumsey Energy House	1949 Eden Ave	CHC-2004-6734-HCM	05-0665	5/4/2005	
795	Santa Fe Transport Freight House	555 South Santa Fe	CHC-2004-5809-HCM	05-0666	5/4/2005	
796	Jacobson Duplex	1200-1202 S Lighthouse Ave	CHC-2004-5685-HCM	05-0667	5/4/2005	
797	Gamma House	12401 W Deerbrook Lane	CHC-2004-7296-HCM	05-0668	5/4/2005	
798	Mary C. Smith House	1138 W 24th St	CHC-2004-6741-HCM	05-0618	5/18/2005	
799	Chateau Des Fleurs	6825 Franklin Ave	CHC-2004-6740-HCM	05-0619	5/18/2005	
800	Margaret Hogg Shotwell	307 Foothill Drive	CHC-2004-6760-HCM	05-0675	5/25/2005	

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No.	Name	Address	CHC No	CF No	Adopted	Notes
801	The Courtyard Apartments	1670 [illegible] Ave	CHC-2004-0297-HOM	05-0885	6/1/2005	
802	Hazel Residence and Tea House	6503, 6512, 6513 N. Vesper Ave 6511, 6515, 6519 N. Short Way	CHC-2004-0230-HOM	05-0903	6/1/2005	
803	A. W. Buck Residence	652 S Dunsmuir Ave	CHC-2005-1154-HOM	05-0978	6/1/2005	
804	Olive Apartments	317 S Kenmore Ave	CHC-2004-0221-HOM	05-0979	6/1/2005	
805	J.A. Holmby Realty	221 S Manhattan P	CHC-2005-0385-HOM	05-0980	6/1/2005	
806	Kinsell Building and Annex	131, 133 E 6th St 653 S. Los Angeles St 658, 664 S Main St	CHC-2005-0475-HOM	05-0981	6/1/2005	
807	Church of the Epiphany	2856 N Alpine St	CHC-2005-0739-HOM	05-0520	6/15/2005	
808	Wave House	476 North Rowing Canal Way	CHC-2006-1118-HOM	03-2048	7/5/2005	Re-posted 6/22 [illegible] Ridgecrest Road in 2005
809	Franklin J Dales Residence	151 N Berendo St	CHC-2005-0824-HOM	05-0590	7/8/2005	
810	Edward J. Torgerson House	138 S Manhattan P	CHC-2005-1310-HOM	05-1148	7/8/2005	
811	Tate - McCoy Residence	1453 - 1459 S Norton Ave	CHC-2005-1020-HOM	05-1149	7/8/2005	
812	Wave House	2972 Glendower Ave	CHC-2005-1114-HOM	05-1151	7/8/2005	
813	Security First National Bank	5207 5209 Wilshire Blvd	CHC-2005-1146-HOM	05-1152	7/8/2005	
814	The Barker Block	324 - 334 1/2 W 10th St	CHC-2005-1975-HOM	05-1220	7/8/2005	
815	The French Chateau Apartments	3248 3250 W James M. Wood Blvd French Chateau Apartments 300 S Rober[illegible] Ave	CHC-2005-2404-HOM	05-1250	7/8/2005	
816	Kinsella Apartments	1779, 1781 N Orange Dr	CHC-2005-2446-HOM	05-1648	7/13/2005	
817	La Loyanda Apartments	1735 1737 N Vermont Ave	CHC-2005-2672-HOM	05-1650	7/13/2005	
818	J. R. Donahoe House	1515 S Harvard Blvd	CHC-2005-2671-HOM	05-1651	7/13/2005	
819	Viola Magnolia Court	1201-1215 W 27th St 2671 S Magnolia Ave	CHC-2005-1974-HOM	05-1652	7/13/2005	
820	William J. Doran Residence	1134 W 27th St	CHC-2005-2885-HOM	05-1653	7/13/2005	
821	Las Pitchas	1833 N Orchid Ave	CHC-2005-2554-HOM	05-1661	8/4/2005	
822	Pellman House	1946 N Cahuenga Ave	CHC-2005-2481-HOM	05-1663	8/4/2005	
823	Marsha I Pass	792 795 N Kensington Rd	CHC-2005-1428-HOM	05-1780	11/2/2005	
824	Mary P. Pierson Residence	1045 W Kensington Rd	CHC-2005-1444-HOM	05-1781	11/2/2005	
825	Chinatown West Gate	954 N Hill St	CHC-2005-1487-HOM	05-1782	11/2/2005	
826	Chinatown East Gate	845 N Broadway	CHC-2005-1515-HOM	05-1783	11/2/2005	
827	Arthur D. Gerson Residence	301 305 E Kensington Rd	CHC-2005-1421-HOM	05-1785	11/2/2005	
828	Harry J. Wahl House	4000 N Sunnyslope Ave	CHC-2005-2458-HOM	05-1825	11/9/2005	
829	James Goodwin Office	Suite 2000 of 10100 West Santa Monica Blvd	CHC-2005-3781-HOM	05-2164	12/14/2005	
830	Disney Castle	1021 S Tujunga Canyon Blvd	CHC-2005-3484-HOM	05-2564	1/13/2006	
831	Lucy and Anastasia Rotesko Apartments	2039-2049 Cotner Park Blvd	CHC-2005-5035-HOM	05-2562	1/25/2006	
832	Casa Laguna	1345 - 1353 S Kingsley Dr 5200 W Franklin Ave	CHC-2005-5080-HOM	05-2563	1/25/2006	
833	Crest House	2630 Hollyridge Dr	CHC-2005-5057-HOM	05-2011	1/25/2006	
834	Charles R. Rich House	669 N Oxford Ave	CHC-2005-6084-HOM	05-2014	1/25/2006	
835	Pellish Dees Residence	545 S Plymouth Blvd	CHC-2005-5179-HOM	05-2016	1/25/2006	

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No.	Name	Address	CHC No	CF No.	Adopted	Notes
835	Dana Park	751 N Arlington Park Ave	CHC-2005-[illegible]-HCM	05-0015	2/7/2006	
837	Brooke House	2075 N Kenilworth Ave	CHC-2005-[illegible]-HCM	05-0235	2/7/2006	
838	Oak Glen Ranch	7281 W Sunset Blvd 7264 W St Felipe St 9501-11 N Hillgreen Ave 9510-9530 W Oak Glen Dr	CHC-2005-[illegible]-HCM	05-0377	3/17/2006	
839	Paul Landacre Cabin And Grounds	2008 W El Moran St	CHC-2005-[illegible]-HCM	05-0105	3/17/2006	
840	Anderson A. Dyer House	9870 Holly Oak Dr	CHC-2005-[illegible]-HCM	05-0309	3/17/2006	
841	Westside Welder Cluster	10034 N Commerce Ave 10032 N Commerce Ave	CHC-2005-[illegible]-HCM	05-1111	5/3/2006	
842	Dyer Apartments	1929-1933 N Whitley Ave	CHC-2006-[illegible]-HCM	06-0347	5/16/2006	
843	[illegible] Brown Duplex	4630 W Los Feliz Blvd	CHC-2006-[illegible]-HCM	06-0697	5/19/2006	
844	Polyphase Residence	914-944 1/2 N Mansfield Ave	CHC-2005-[illegible]-HCM	05-1271	5/31/2006	
845	Mount Washington Home Self Realization Fellowship International Headquarters	3880 & 3840 San Rafael Ave 701 & 721 W Washington Dr	CHC-2006-[illegible]-HCM	06-1642	8/10/2006	
846	R. A. S. Fuller Residence	0667 West Alta Loma Terrace	CHC-2006-1442-HCM	06-1668	8/16/2006	
847	Richardson Apartments	3919 West 8th Street 715 South Gramercy Drive	CHC-2006-1544-HCM	06-1671	8/16/2006	
848	Turner Homes-Foster Residence	17145 Deer Ranch Street	CHC-2006-[illegible]-HCM	06-1672	8/16/2006	
849	Michael Henry Mansion	2523 E Thorpe Ave 901 & 903 N Isabel St	CHC-2006-[illegible]-HCM	06-1673	8/16/2006	
850	William Hubbard Residence	811 S Norton Avenue	CHC-2006-2247-HCM	06-1818	9/13/2006	
851	28th Street Y.W.C.A. Building	1009 E 28th Street	CHC-2006-[illegible]-HCM	06-1881	9/27/2006	
852	Wolf Residence	8530 W Hedges Place	CHC-2006-2276-HCM	06-1847	9/27/2006	
853	La Marquise	535 S Gramercy Place	CHC-2006-[illegible]-HCM	06-1810	9/27/2006	
854	Chin Residence and Museum	1401-1407 South Gramercy Place	CHC-2006-2308-HCM	06-0040	10/11/2006	
855	Scallon Residence	1415 South Gramercy Place	CHC-2006-2069-HCM	06-0095	10/11/2006	
856	Skinner House	1500 North Easterly Terrace	CHC-2006-2417-HCM	06-2161	10/25/2006	
857	Capitol Tower and Rooftop Sign	1740 - 1750 N Vine St 6230 W Yucca Street	CHC-2006-2562-HCM	06-2361	11/15/2006	
858	One Hundred Sycamore	102 N Sycamore Avenue	CHC-2006-[illegible]-HCM	06-2102	11/22/2006	
859	Orchard Cabins Cottage Orchard Cabins Cottage	1211 North Wilcox Avenue 6516 West Fountain Avenue	CHC-2006-2585-HCM	06-2005	2/9/2007	
860	Kahn House	2563 North McIlwee Dr	CHC-2006-[illegible]-HCM	06-2003	2/9/2007	
861	Monsignor O'Brien House	120 North California Ave	CHC-2006-[illegible]-HCM	06-2009	2/9/2007	
862	Willer House	12420 West Rochelle Lane	CHC-2006-[illegible]-HCM	07-0246	3/7/2007	
863	Los Tiempos - The Chandler Homes	465 South Lorraine Boulevard	CHC-2006-[illegible]-HCM	07-0256	3/7/2007	
864	The Niagara/Belmont Park House	3692 S Olmsted Ave	CHC-2006-[illegible]-HCM	07-0259	3/9/2007	
865	Joseph L. Starr Farmhouse	2601 S Arlington Ave	CHC-2006-[illegible]-HCM	07-0275	4/11/2007	
866	Glen Lukens Home and Studio	3403 West 27th Street	CHC-2006-[illegible]-HCM	07-0277	4/11/2007	
867	Mayfair Apartments and Rooftop Neon Sign	1260 North Wilcox Avenue	CHC-2006-[illegible]-HCM	07-1056	4/27/2007	
868	Orbell Duplex No. 1	2042-2044 West Cove Avenue	CHC-2006-[illegible]-HCM	07-1070	5/15/2007	
869	Bakman House	10623 Riverside Drive	CHC-2006-[illegible]-HCM	07-1071	5/15/2007	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
870	San Marino Villas	3300-3396 West San Marino Street	CHC-2006-8549-HCM	07-0660	9/19/2007	
871	510 South Spring Street Building	510 South Spring Street	CHC-2006-8786-HCM	07-1351	9/20/2007	
872	Reinforced Concrete Block Building (Now Nate Bergreder Factory-Gail Steve Co Company)	1639-1927 North Spring Street	CHC-2006-8773-HCM	07-1742	9/20/2007	
873	Higgins Building	108 West 2nd Street	CHC-2006-10153-HCM	07-1153	9/27/2007	
874	Gable House	6000 Scenic Avenue (0058 Highland Hills)	CHC-2006-8212-HCM	07-1249	9/6/2007	
875	Wall/Wenger Apartments	854 South Oxford Ave.	CHC-2006-8181-HCM	07-1250	9/6/2007	
876	Hollywood Professional Building	7046 Hollywood Boulevard	CHC-2006-10207-HCM	07-1275	9/6/2007	
877	Wilcox House	6150-6152 North Avenue 57	CHC-2006-10206-HCM	07-1263	7/3/2007	
878	Avery Manor	3035 West 6th Street 745 South Manhattan Place	CHC-2006-8452-HCM	07-1842	9/7/2007	
879	Louise Hall House	2706-2708 South Menlo Street	CHC-2007-0442-HCM	07-1843	9/7/2007	
880	Pigeon Wood Residence	2905 South Hoover Street	CHC-2006-10232-HCM	07-1846	9/7/2007	
881	Jackson Rose Building	424 South Broadway	CHC-2006-10090-HCM	07-1847	9/7/2007	
882	The Parsonage	1811 North Valley Avenue	CHC-2006-9084-HCM	07-1844	9/25/2007	
883	Waddington House	11025 W Weddington Street	CHC-2007-0335-HCM	07-1965	9/19/2007	
884	Weems - Snow Family Residence	2700 S Severance Street	CHC-2007-0702-HCM	07-1941	9/19/2007	
885	Holmes Shannon House	4011 W Dorcas Park Drive	CHC-2007-0018-HCM	07-1888	9/19/2007	
886	Gould Guthrie House	12258 W Channel Road	CHC-2007-0468-HCM	07-1887	9/19/2007	
887	Barry Building	11973 W San Vicente Boulevard	CHC-2007-1585-HCM	07-2057	10/2/2007	
888	National Postal Company Building	1810 Industrial Street	CHC-2007-1321-HCM	07-2276	10/9/2007	
889	Delaney House	4777 Eagle Rock Blvd	CHC-2006-10192-HCM	07-2506	10/12/2007	
890	Wade Residence	2431 4th Floor	CHC-2007-1656-HCM	07-2557	10/12/2007	
891	Boyle Hotel - Cummings Block	101-105 North Boyle Avenue 1760-1768 East 1st Street	CHC-2007-0671-HCM	07-3028	10/24/2007	
892	Kite-Pole Residence	2335 Hidalgo Ave	CHC-2007-1892-HCM	07-3010	10/30/2007	
893	Cedars Residence	551 North Silver Way	CHC-2007-2377-HCM	07-3029	10/30/2007	
894	Munnell Cottage	5310 Crescent St	CHC-2007-1830-HCM	07-3386	10/30/2007	
895	Lion House	2427 N Silver Ridge Ave	CHC-2006-9111-HCM	07-3112	11/7/2007	
896	Draper House #1	2764 West Tennyson Drive	CHC-2007-2077-HCM	07-3540	12/5/2007	
897	Haven of Rest	2432 North Hyperion Avenue	CHC-2007-2215-HCM	07-3542	12/5/2007	
898	Van Nuys Building	204, 210 & 212 West 7th Street 701 South Spring Street	CHC-2007-3575-HCM	07-3541	12/5/2007	
899	Charles C. Chapman Building	756 South Broadway	CHC-2007-2216-HCM	07-3543	12/5/2007	
900	North Spring Street Bridge, No. 53C0559	N Spring St between Ardmore Ave/N Broadway and Ave 19	CHC-2007-4864-HCM	07-4143	1/30/2008	
901	North Main Street Bridge, No. 53C0170	N Spring St between Chavez ST and Arcadia St	CHC-2007-4864-HCM	07-4144	1/30/2008	
902	Olympic Boulevard Bridge, No. 53C0183	E Olympic Blvd between Soto Ave and Santa Fe Ave	CHC-2007-4031-HCM	07-4145	1/30/2008	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
903	Washington Boulevard Bridge No. 53C1378	e Washington Boulevard between Soto Street L 2nd St	CHC-2007-4850-HCM	07-1145	1/30/2008	
904	Seventh Street Bridge, No. 53C1721	C 7th St between Santa Fe Ave and Mayers St	CHC-2007-4852-HCM	07-4147	1/30/2008	
905	Sixth Street Bridge, No. 53C1850	e 6th St between Mateo St and S Boyle Ave	CHC-2007-4856-HCM	07-4152	1/30/2008	
906	Fourth Street Bridge, No. 53C0044	L 4th St between Santa Fe Ave and Mission Rd	CHC-2007-4855-HCM	07-4153	1/30/2008	
907	North Broadway Buena Vista Street Bridge, No. 53C0546	N Broadway between Lyon Park Dr and Forester Ave	CHC-2007-4858-HCM	07-4154	1/30/2008	
908	Riverside/Figueroa Bridge No. 53C0192	Riverside Dr between Glendale Blvd and N San Fernando Rd	CHC-2007-4857-HCM	07-4155	1/30/2008	
909	First Street Bridge, No. 53C1100	E 1st St between Mateo St and Mission Rd	CHC-2007-4860-HCM	07-4163	1/30/2008	
910	Riverside Zoo Drive Bridge, No. 53C1298	Zoo Dr from Western Heritage Way to the west of Zoo Dr	CHC-2007-4870-HCM	07-4167	1/30/2008	
911	Van Nuys Branch Library	14555 Sylvan Street	CHC-2007-4299-HCM	06-0181	2/13/2008	
912	Rukavina Court	5124 West De Longpre Avenue	CHC-2007-4270-HCM	06-0189	2/26/2008	
913	Blackburn Residence	4701 Glencoe Avenue	CHC-2007-4676-HCM	06-0757	4/8/2008	
914	Avalon Blvd Mexican Folk Pharmacy	Avalon Blvd between Florida Blvd and W 1st St	CHC-2007-4121-HCM	06-0730	4/15/2008	
915	Vivian Rassall Residence	2155 North Berendo Drive	CHC-2007-5209-HCM	08-0729	4/15/2008	
916	Rabinis Residence	4510 West Carlton Drive	CHC-2008-1054-HCM	08-0701	4/15/2008	
917	Edward H. Hill House	3206 Mount Vernon Drive	CHC-2007-5437-HCM	08-0730	4/23/2008	
918	Lybecker Bishop House	3820 Rowena Park Drive	CHC-2007-5948-HCM	08-0627	5/14/2008	
919	LOJA Crest Theater	1262 South Westmoore Boulevard	CHC-2008-125-HCM	08-0888	5/14/2008	
920	Aoyama Tree	135 North Central Avenue	CHC-2008-471-CM	08-0980	5/21/2008	
921	Residence	1999 Sycamore Avenue	CHC-2007-4401-CM	08-1172	6/11/2008	
922	Edward A. Dickson Adams House	2301 West Cove Ave	CHC-2008-511-HCM	08-1450	7/2/2008	
923	Kennedy School House	5626 Maryland Drive	CHC-2008-512-HCM	08-1457	7/2/2008	
924	Bryant Residence	1548 South Ridgeley Avenue	CHC-2008-523-HCM	08-1476	7/2/2008	
926	212 South Wilton Place Residence	212 South Wilton Place	CHC-2008-750-HCM	08-1498	7/9/2008	
926	Kinney Tabor House	1310 South Sixth Avenue	CHC-2008-521-HCM	08-1531	7/9/2008	
927	Sturdevant Bungalow	721 East Arroyo Terrace	CHC-2008-661-HCM	08-1559	7/9/2008	
928	Chester Apts.	916-920 1/2 South Serrano Avenue	CHC-2008-526-HCM	08-1592	7/9/2008	
929	Oliver Flats	427-429 North Orange Drive	CHC-2008-878-HCM	08-1581	7/9/2008	
932	Garment Center Building	217-231 East 8th Street	CHC-2008-1161-HCM	08-1775	7/29/2008	
931	Carlile Bldg.	5327 W Virginia Avenue	CHC-2008-1177-CM	08-1778	7/29/2008	
932	Clarence D. Badger Residence	2128 Wyndham Place	CHC-2008-1160-HCM	08-1776	7/29/2008	
933	Kramer House	12550 Mount Holiday Place	CHC-2008-1064-HCM	08-1925	9/25/2008	
934	Park Wilshire Building	2424 Wilshire Boulevard	CHC-2008-1062-HCM	08-1923	9/25/2008	
935	Santa Monica Forestry Station Eucalyptus Grove	001 North Canyon Blvd 901 North Latimer Road	CHC-2008-3009-HCM	08-2042	10/28/2008	
936	Archangel/Ave Maya - I.O.O.F. Lodge	925 North Haverford Avenue	CHC-2008-134-HCM	08-2043	10/28/2008	
937	Westinghouse Electric Building	420 South San Pedro Street	CHC-2008-2120-HCM	08-2655	10/28/2008	
938	Scott Avenue Court	1463-69 N. Scott Avenue	CHC-2008-2716-HCM	08-2658	11/7/2008	
939	The Black Cat	2909 West Sunset Boulevard	CHC-2008-2705-HCM	08-2659	11/7/2008	

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No.	Name	Address	CHC No.	CF No.	Adopted	Notes
940	North Vermont Avenue Monster Day Fig Tree	N. Vermont between Los Feliz Blvd. and Alexandria Ave.	CHC-2008-3804-HCM	08-2937	1/14/2009	
941	Stahl House	1002 North Sweetzer Avenue	CHC-2008-3084-HCM	08-2938	1/14/2009	
942	Dalton Park	2716 N. Vermont Avenue 3201 Riverside Drive 3210 Riverside Drive 3401 Riverside Drive 4730 Crystal Springs Drive 5333 Fire Drive	CHC-2008-2724-HCM	08-3085	1/27/2009	
943	Mountain Palace	525 South Van Ness Avenue	CHC-2008-3554-HCM	08-3089	1/28/2009	
944	Harmon Car Wash	400 Block of Duncan Avenue	CHC-2008-3950-HCM	08-3242	1/28/2009	
945	The Rialto Theatre	336 North Sycamore Avenue	CHC-2008-4395-HCM	09-0236	2/25/2009	
946	Verdugo Hills Memorial Park Pioneer Cemetery	7300 Paraiso Trail	CHC-2008-4385-HCM	09-0263	3/4/2009	
947	CBS Columbia Square Studios	6121 Sunset Boulevard	CHC-2008-3850-HCM	09-0188	3/10/2009	
948	Silvey House	1881 North Heather Court	CHC-2008-4460-HCM	09-0175	3/10/2009	
949	Bank of America - Echo Park Branch	1572 W. Sunset Blvd.	CHC-2008-4094-HCM	09-0480	4/1/2009	
950	Original Echo Park Clubhouse	1004 North Echo Park Ave.	CHC-2008-4084-HCM	09-0487	4/1/2009	
951	James P. Real Estate Office	77 Paloma Way	CHC-2008-4717-HCM	09-0405	4/22/2009	
952	Kaye Residence	4754 Vanalden Avenue	CHC-2008-4718-HCM	09-0406	4/22/2009	
953	Chapman and Clark Building	701 South Hill Street	CHC-2009-4978-HCM	09-0825	5/20/2009	
954	Dunsmuir Flats	1279 South Bunsher Avenue	CHC-2006-4975-HCM	09-0824	5/20/2009	
955	Dickinson and Gillespie Drive	220 East Outer Boulevard	CHC-2008-4984-HCM	09-0826	5/20/2009	
956	Villa Bonita	1517 North Hobart Road	CHC-2008-4976-HCM	09-0711	5/20/2009	
957	Great Republic Life Building	756 South Spring Street	CHC-2009-198-HCM	09-0723	5/20/2009	
958	Bob Baker Marionette Theater	1345 West First Street	CHC-2009-199-HCM	09-0724	6/3/2009	
959	Jacks Country Shop and Kitchen No. 1	12535 Nano Western Avenue	CHC-2009-210-HCM	09-0727	6/24/2009	
960	Ashby Apartments	806 South Hobart Boulevard	CHC-2008-402-HCM	09-1630	8/6/2009	
961	Marshall Kline Residence	2037 South Tarvale Boulevard	CHC-2008-607-HCM	09-1621	8/6/2009	
962	Colley Mitchell Residence	2648 South Carlton Boulevard	CHC-2008-248-HCM	09-1851	9/23/2009	
963	Linda Scott Residence	1910 South Harvard Boulevard	CHC-2009-1258-HCM	09-1852	9/23/2009	
964	Kass House	2173 North Valentine Street	CHC-2009-1304-HCM	09-1846	9/23/2009	
965	Wilson House	2090 North Bronte Street	CHC-2009-1387-HCM	09-1853	9/23/2009	
966	Douglas Building	257 South Spring Street	CHC-2009-1373-HCM	09-1850	9/23/2009	
967	Lipetz House	1943 North Orion Street	CHC-2009-1391-HCM	09-1849	9/23/2009	
968	Bethlehem Baptist Church	4901 South Compton Avenue	CHC-2009-2110-HCM	09-1957	12/15/2009	
969	Clara T. Flanigan Residence	1004 South Gramercy Place	CHC-2009-2432-HCM	09-2052	1/27/2010	
970	844 South Plymouth Apartments	844 South Plymouth Boulevard	CHC-2009-2056-HCM	09-2923	1/27/2010	
971	Vista Peterson Lagrier	2506 Mayberry Street	CHC-2009-1059-HCM	09-3010	1/27/2010	
972	Brice Art House	2564 South Vista Bonita Drive	CHC-2009-2026-HCM	09-3015	1/27/2010	
973	Henry Silva Pes Junior	2205 North Princeton Avenue	CHC-2009-1047-HCM	09-3020	1/27/2010	
974	Van Dekker House	19950 West Outer Street	CHC-2009-3041-HCM	09-3067	2/25/2010	
975	Separate Unitarian Universalist Society Sanctuary	9550 N. Fraser Avenue	CHC-2009-3526-HCM	10-0166	2/26/2010	
976	Cobble Palms House	5118 Marguerite Avenue	CHC-2009-3511-HCM	10-0167	2/26/2010	
977	Hot Hour Cafe	4824 Vermont Avenue	CHC-2009-3812-HCM	10-0170	2/26/2010	

AR0069513

No.	Name	Address	ENC No.	CE No.	Adopted	Notes
978	Lankershim Boarding House	10940 North Sepulveda Boulevard	CHC-2009-3667-HCM	10-0171	3/30/2010	
979	Venice West Cafe	321 S. Ocean Front Walk	CHC-2009-2840-HCM	10-0163	3/19/2010	
980	Frank C. Hill House	201 South Coronado Street	CHC-2009-3542-HCM	10-0229	5/3/2010	
981	Margaret and Harry Hay House	5139 North Oakcrest Drive	CHC-2009-3585-HCM	10-0227	5/3/2010	
982	Gross Farmhouse	101 South Foyle Street	CHC-2010-771-HCM	10-0560	6/10/2010	
983	Rancho House	900 North Muse Road	CHC-2010-98-HCM	10-0559	6/10/2010	
984	Sandoval Building	322-24 West Seventh St. and 739-45 South Hill St.	CHC-2010-805-HCM	10-0717	9/9/2010	
985	Sun Realty Company Building	529-33 South Hope Street	CHC-2010-902-HCM	10-0714	9/8/2010	
986	Lento Brick Oven	1258 West Sunset Boulevard	CHC-2010-534-HCM	10-0646	7/13/2010	
987	St. Philip the Evangelist Church	2710 South Western Avenue	CHC-2010-1097-HCM	10-0833	10/5/2010	
988	St. Philip the Evangelist Church Parish Hall	2800 South Gramercy Avenue	CHC-2010-1098-HCM	10-0834	10/5/2010	
989	Owens House	2071 West Escarpa Drive	CHC-2010-1800-HCM	0-1066	10/6/2010	
990	Hatsuyasu Kobayashi Residence	3741 West 27th Street	CHC-2010-1179-HCM	10-1067	10/27/2010	
991	Lucy C. Wheeler-Martin L. Wise House	2175 Cambridge Street	CHC-2010-1837-HCM	10-1606	11/3/2010	
992	TR Craig Residence ("Hacienda Ranch")	9401 Wheeler Drive	CHC-2010-2342-HCM	11-0205	3/9/2011	
993	Cross of Four Points	7570 McGroarty Terrace	CHC-2010-3058-HCM	11-0201	3/11/2011	
994	Adelsberg Stenbom Home Gallery	7065 Hillside Avenue	CHC-2010-2940-HCM	11-0570	4/20/2011	
995	8097 West Alden Drive Apartments	8097 West Alden Drive	CHC-2011-631-HCM	11-0559	5/11/2011	
996	Garden of Oz	3040 North Edgewood Drive	CHC-2011-70-HCM	11-0560	5/11/2011	
997	Collard Chalet Residence	5470 W. Los Feliz Blvd	CHC-2011-1054-HCM	11-0708	5/18/2011	
998	Hardison House	1605 S. 9th Avenue	CHC-2011-170-HCM	11-0707	6/1/2011	
999	Majestic Square	130-141 S. Westmoreland Ave.	CHC-2011-1038-HCM	11-0705	5/18/2011	
1000	Golden State Mutual Life Insurance Company Home Office	1999 W. Adams Boulevard	CHC-2011-221-HCM	11-0711	6/1/2011	
1001	May Company Garage	900 S. Hill Street	CHC-2011-1221-HCM	11-0710	6/1/2011	
1002	Gertrude and Harry Keys Building	320 S. Alvarado Drive	CHC-2011-68-HCM	11-0565	5/5/2011	
1003	Ralph L. Chandler Residence	1928 N. Hobart Blvd.	CHC-2011-510-HCM	11-1498	9/14/2011	
1004	Richard Henry Dana Branch Library	3320 Hooper Street	CHC-2011-511-HCM	11-1499	9/14/2011	
1005	Gabrielle Grant Post House	220 S. Wilton Place	CHC-2011-506-HCM	11-1497	9/14/2011	
1006	Kuh Residence	1960 Glenroy Drive	CHC-2011-1349-HCM	11-1085	11/15/2011	
1007	Evening Star Missionary Baptist Church	5892 S. Normandie Street	CHC-2011-1690-HCM	11-0560	11/15/2011	
1008	Lincoln Place Apartments	1000-1058 S. Gaffey Place 1030-1070 S. Cabrillo Street 1035-1135 E. Lake Street 1402-1542 S. Lakeview Avenue 1505-1751 S. Mansfield Avenue 5300-5781 E. Walnut Place	CHC-2011-2009-HCM	11-1681	12/16/2011	
1009	Heritage Square Museum	3800 Homer Street	CHC-2011-2206-HCM	11-1650	12/16/2011	
1010	350 N. Sycamore Apartments (Sycamore Chateau)	350 N. Sycamore Avenue	CHC-2011-2155-HCM	11-1503	12/16/2011	
1011	McArthur House	2217 W. Waverly Drive	CHC-2011-2157-HCM	11-1570	01/4/2012	
1012	Gerald House	232 S. Andrews Place	CHC-2011-2708-HCM	11-2147	2/14/2012	

AR0069514

No.	Name	Address	CHC No	CF No	Adopted	Notes
1013	Normandie Ivory	305 S. Normandie Ave	CHC-2011-2743-HCM	11-2148	2/14/2012	
1014	Capt. Ralph Prose	3166 N. Lake Drive	CHC-2011-2016-HCM	11-2145	2/14/2012	
1015	Stahl House	966 Sunset Blvd	CHC-2011-2045-HCM	11-2150	2/14/2012	
1016	Schindler House	835 North Kings Road	CHC-2011-2053-HCM	11-2157	2/14/2012	
1017	Young Drilling Residence	3320 N. Griffith Ave	CHC-2012-630-HCM	12-0374	4/25/2012	
1018	Lautner Residence	1635 N. Ridgewood Place	CHC-2012-629-HCM	12-0375	4/25/2012	
1019	Metropolitan Building	315 W. 9th Street	CHC-2012-551-HCM	12-0383	4/27/2012	
1020	Broadway Building	600 S. Broadway Ave	CHC-2012-1951-HCM	12-0640	5/9/2012	
1021	Bowers Museum Annex	2002 North Main Street	CHC-2012-1064-HCM	12-1064	6/26/2012	
1022	Los Angeles Department of Water and Power General Office Building (John Ferraro Building)	111 N. Hope Street	CHC-2012-1044-HCM	12-936	3/21/2012	
1023	Vista Boulevard Bridge	Crossing Venice Boulevard between 16th Place and Victoria Park Drive	CHC-2012-XXXX-HCM	12-2041	12/19/2012	
1024	Lautner House	11000 W. Amanda Drive	CHC-2012-2029-HCM	12-1951	2/5/2013	
1025	Jones Model Home	340 N. Amalfi Dr	CHC-2012-2951-HCM	12-1952	2/5/2013	
1026	Shenwood House	342 N. Amalfi Dr	CHC-2012-2044-HCM	12-1953	2/5/2013	
1027	John Anson Ford Residence	1976 N. Normandie Ave	CHC-2012-2927-HCM	12-0104	2/27/2013	
1028	Stewart Farmhouse	511 W. 21st Street	CHC-2012-2953-HCM	12-0105	2/27/2013	
1029	Stowell Hotel	410 S. Spring St	CHC-2012-2957-HCM	12-0217	4/5/2013	
1030	Union Bank and Trust Company	400 S. Hill St.	CHC-2012-2955-HCM	12-0218	4/5/2013	
1031	Frederick A. Hanson Residence	5807 Tuxedo Terrace	CHC-2013-514-HCM	12-0615	5/22/2013	
1032	Emma Wood House	245 S. Wilson Place	CHC-2013-510-HCM	12-0616	5/22/2013	
1033	Goodyear Tract Home #1	310 E. 59th Place	CHC-2013-804-HCM	12-1692-S1	6/18/2013	
1034	Goodyear Tract Home #2	314 E. 59th Place	CHC-2013-830-HCM	12-1692-S2	6/18/2013	
1035	Goodyear Tract Home #3	427 E. 60th Place	CHC-2013-833-HCM	12-1692-S3	6/18/2013	
1036	Goodyear Tract Home #4	510 E. 59th Place	CHC-2013-834-HCM	12-1692-S4	6/18/2013	
1037	Soudraver	4421 N. Atwater Circle	CHC-2013-500-HCM	12-0614	6/26/2013	
1038	Abbott De Rio Residence	757 Bringham Ave.	CHC-2013-510-HCM	13-0017	6/26/2013	

AR0069515

Office of
HISTORIC RESOURCES

Frequently Asked Questions (FAQs)

FREQUENTLY ASKED QUESTIONS (FAQs) ABOUT THE HISTORIC-CULTURAL MONUMENT DESIGNATION PROCESS

Who may submit a nomination?

A nomination for City of Los Angeles Historic-Cultural Monument status may be submitted by any person or organization. The City Council may also nominate a resource for Monument status, typically through the introduction of a motion by an individual Councilmember. The Cultural Heritage Commission itself may also initiate a nomination.

The application requires considerable research to determine the age of buildings and structures, property ownership history, former inhabitants, past uses, and other known facts about the resource. Many applicants choose to retain historic preservation consultants to prepare nominations, but it is also possible for non-professionals to research and prepare successful nominations. The Los Angeles Conservancy has prepared a helpful guide to researching and preparing Historic-Cultural Monument applications, at Los Angeles Conservancy.

Is there an age requirement?

In the City of Los Angeles, there is no requirement that a resource be a certain age before it can be designated. In general, enough time needs to have passed since the resource's completion to provide sufficient perspective that would allow an evaluation of its significance within a historical context. The youngest structure to be designated in Los Angeles was built in 1909 – it is Claes Oldenburg and Coosje van Bruggen's Binoculars at the Chiat/Day Building in Venice (the rest of the building, designed by Frank Gehry, is not yet designated).

What can be nominated?

The criteria for designation allow for numerous types of Monuments. Buildings make up the great majority of Historic-Cultural Monuments – including many examples of residential, commercial, institutional, and industrial structures. Structures like bridges, stairways, and median strips have also become Monuments. Open spaces such as Echo Park and Banning Park (which, in these cases, also feature historic structures) have been declared Monuments, as have individual trees or groups of trees, and natural features such as Eagle Rock.

What makes a resource historically significant?

See What Makes a Resource Historic for information on the criteria for Historic-Cultural Monument status and for the types of questions that help staff and the Cultural Heritage Commission evaluate a nomination for Historic-Cultural Monument status.

Must the property owner be notified about the nomination?

Under the City of Los Angeles' Cultural Heritage Ordinance, the property owner is not required to support the nomination, but the owner typically does participate in the designation process. To avoid preemptive demolition or alteration before the nomination can be heard, the Commission does not notify the owner that an application has been filed until after the first hearing. If the Commission takes the nomination under consideration at that hearing, no permits for demolition or significant alterations may be issued. Even if a demolition permit has already been issued when the Commission takes the nomination under consideration, no actual demolition may occur while the nomination is being considered by the Commission and City Council.

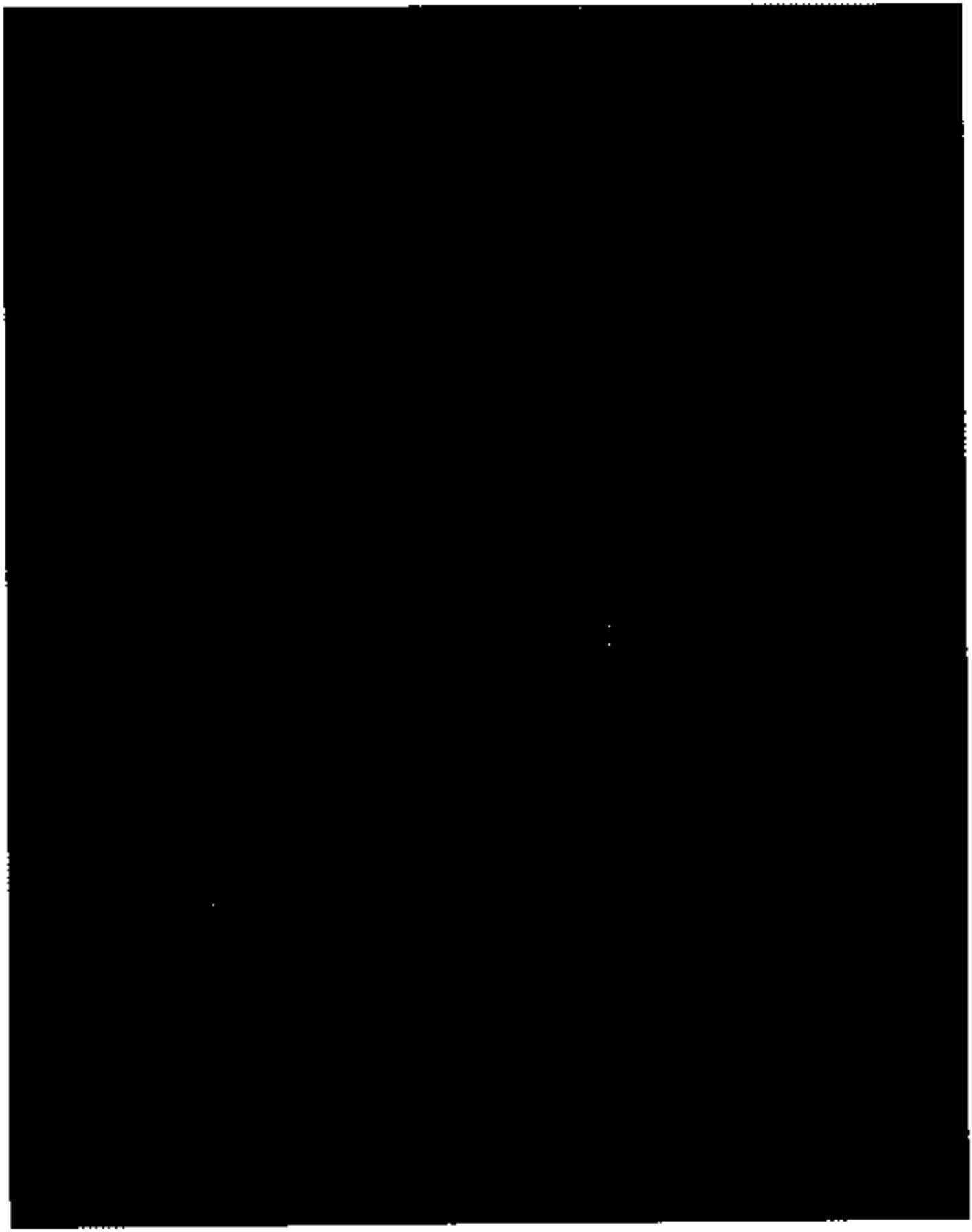
What happens when a building is designated? Is it protected forever?

In Los Angeles, designation as a Historic-Cultural Monument does not guarantee that the building cannot be demolished, but it does allow the Commission to delay demolition in order to create opportunities for preservation solutions to emerge. The ordinance allows the Cultural Heritage Commission to object formally to the issuance of a demolition permit, delaying the demolition for up to 180 days, plus another possible 180-day extension if approved by the City Council, to allow for time to preserve the monument. Designation also ensures that Office of Historic Resources staff trained in preservation and architecture reviews and approves proposals for work on HCMs before any permits for alteration are issued. A Monument is also presumed to be a significant historical resource under the California Environmental Quality Act (CEQA), triggering the requirement to perform an environmental review that could lead to the preparation of an Environmental Impact Report (EIR) before demolition can occur. For more information on what Historic-Cultural Monument status accomplishes, visit Historic-Cultural Monument Status. [illegible]

IN THIS SECTION

- What Does Historic-Cultural Monument Status Mean?
- What Makes a Resource Historically Significant?
- The Historic Designation Process
- Cultural Heritage Ordinance
- Historic-Cultural Monument Application
- Guide to Bronze Plaque Program for Historic-Cultural Monuments
- Designated Historic-Cultural Monuments
- Photo Gallery
- Frequently Asked Questions (FAQs)

AR0069517



Los Angeles City Planning Department

221 North Figueroa
16th Floor

Date: May 24, 2000

To: Licensed Engineers, Surveyors and Subdivision Consultants

From: Emily Gabel-Luddy
Deputy Advisory Agency

Subject: Residential Parking Policy for Division of Land - No. AA 2000-1

Attached is a parking policy addressing standards for new condominiums and condominium conversions.

Please retain for your files. If you have any questions do not hesitate to contact me at (213) 580-5529.

EGL:oss

Attachment: AA 2000-1 (Parking Policy)

No. AA 2000-1
RESIDENTIAL PARKING POLICY

New Condominiums:

A. Up to 5 units

1. 2 per du
2. Minimum 1/4 guest per du[1]

B. Six units or more

1. 2 per du
2. 1/4 guest in non-parking congested areas[1]
   1/2 guest in parking congested areas[1]
3. For side-by-side parking in private garages with direct entries into the units, 1/4 guest parking per unit will be permitted in parking congested areas.

Condominium Conversions:

A. Minimum of 2 parking spaces per unit for projects if the building is more than five years old from a temporary issuance of its Certificate of Occupancy.

B. For projects where the building is five or less years old from the Certificate of Occupancy, standards for new condominiums will apply.

EXCEPTIONS

Exceptions will be considered by the Advisory Agency pursuant to LAMC Section 12.22-A.26 ("Adaptive Reuse Projects in the Greater Downtown Los Angeles Area," Ordinance No. 172,571). Stock Cooperative Conversions will be considered on case-by-case basis.

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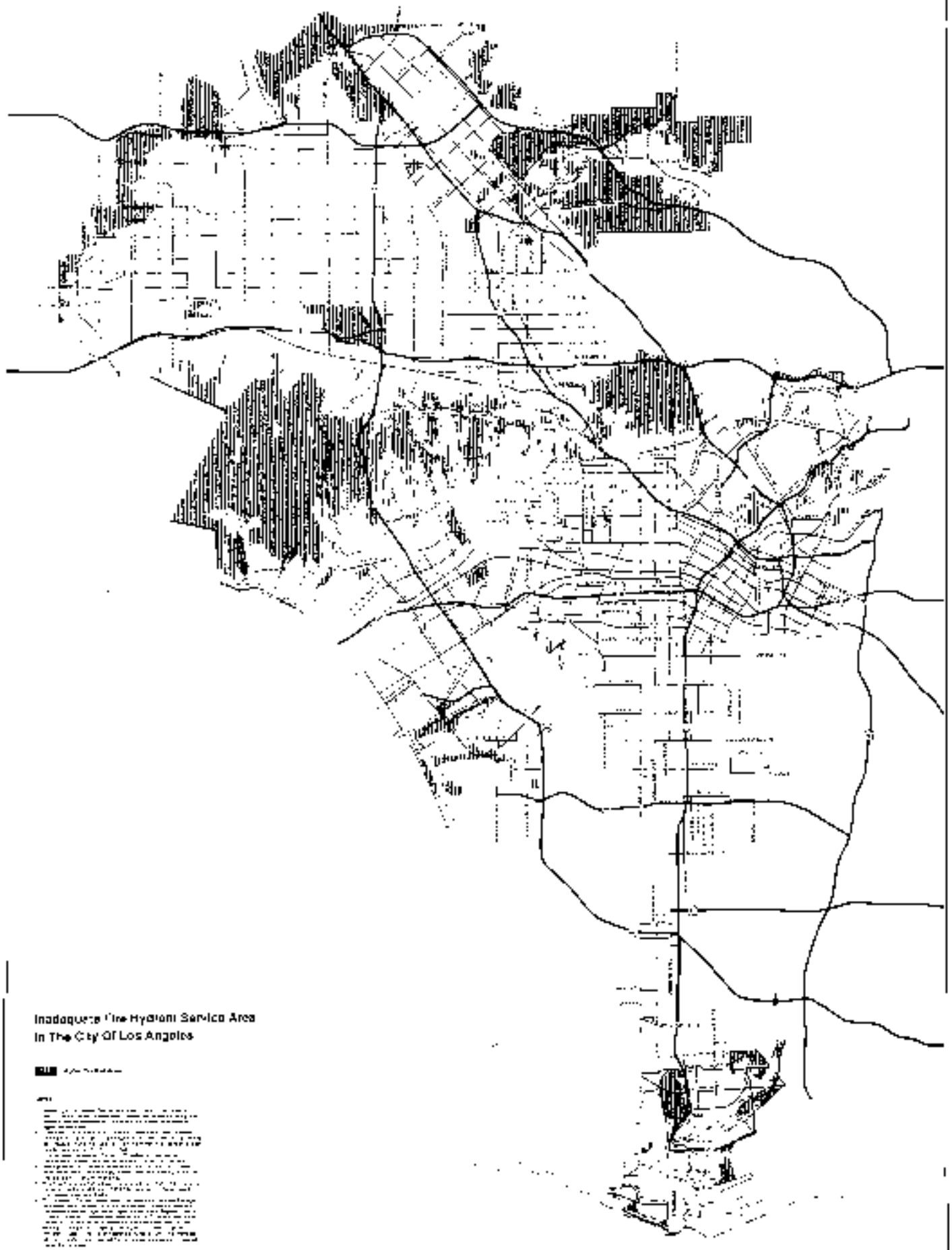
[1]Determinations on required parking by the Advisory Agency are not intended to supercede more restrictive requirements contained in other adopted City ordinances such as adopted specific plans and "Q" conditions. Further, additional guest parking will be considered in special areas of the City which are either subject to unusual public access demands (such as the beach areas) or areas where on-street parking is highly restricted (Major highways, such as Barham Boulevard).

Issued by Deputy Advisory Agency MAY 2 4 2000



Inadequate Fire Hydrant Service Area
In The City Of Los Angeles

Figure F-7

AR0065

CIVIL CITATION
COUNTY OF ORANGE, CODE ENFORCEMENT

1. TO COMPLY:

A. PAYMENT MUST BE MADE WITHIN TEN CALENDAR DAYS OF THE ISSUANCE OF THIS CITATION. PAYMENT MAY BE SENT TO, AND MADE PAYABLE TO, "COUNTY OF ORANGE – CODE ENFORCEMENT". DO NOT SEND CASH. PAYMENT MAY ALSO BE MADE IN PERSON AT THE COUNTY OF ORANGE. PLEASE NOTE A NOTICE OF VIOLATION MAY BE RECORDED ON YOUR PROPERTY. PAYMENT MAY ALSO BE MADE VIA ONLINE BY CREDIT CARD AT WWW.OCAPPSERVICES.COM/CODE OR BY CALLING (800) 290-6155. USE THE CITATION NUMBER AS YOUR REFERENCE NUMBER. PAYMENT MUST BE FOLLOWING ADDRESS:

COUNTY OF ORANGE
C/O CITATION PROCESSING CENTER
P.O. BOX 2935
ANAHEIM, CA 92803

B. IF THIS CIVIL CITATION IS YOUR FIRST NOTICE, YOU ARE NOT REQUIRED TO PAY ANY PENALTY IF YOU CORRECT THE VIOLATION WITHIN THE TIME GIVEN ON THE FRONT OF THIS CITATION. YOU MAY BE CITED FOR ADDITIONAL VIOLATIONS FOR EACH DAY THE VIOLATION EXISTS AFTER THE END OF THE 30-DAY CORRECTION PERIOD. YOU CAN FILE A REQUEST IN WRITING FOR AN EXTENSION OF THIS 30-DAY CORRECTION PERIOD WITH THE ISSUING DEPARTMENT. SUBMIT A COPY OF THIS CIVIL CITATION AND A LETTER STATING WHY THE EXTENSION IS REQUESTED. MAIL TO CODE ENFORCEMENT, 1501 E. EDINGER #E, SANTA ANA, CA 92705 OR P.O. BOX 1438, SANTA ANA, CA 92702. EXTENSIONS MAY BE GRANTED IN UNUSUAL CIRCUMSTANCES WHERE REASONABLE.

2. TO CONTEST:

A. ADMINISTRATIVE REVIEW: YOU MAY REQUEST AN ADMINISTRATIVE REVIEW TO CONTEST THE CIVIL CITATION WITHIN 10 DAYS OF THE DATE OF ISSUANCE BY MAILING A SIGNED COPY OF THIS CIVIL CITATION WITH THE REQUESTED CHANGES TO CODE ENFORCEMENT, 1501 E. EDINGER #E, SANTA ANA, CA 92705 OR P.O. BOX 1438, SANTA ANA, CA 92702. YOU MUST SPECIFY IN WRITING WHY YOU ARE REQUESTING AN ADMINISTRATIVE REVIEW BY CLICKING ON ONE OF THE BOXES IN ITEM 2.C. BELOW. WITHIN 10 DAYS TO OBTAIN A HEARING YOU MUST DEPOSIT THE FULL AMOUNT OF THE FINE WITH YOUR REQUEST UNLESS YOU ALSO REQUEST A FINANCIAL HARDSHIP WAIVER ON THE FORM BELOW AND THE WAIVER IS GRANTED PRIOR TO THE LOCATION OF THE HEARING IS APPEALED. IF THE CITATION IS NOT APPEALED IN THIS MANNER, THE CITATION IS FINAL. YOU ARE REQUIRED TO ATTEND THE HEARING SCHEDULED FOR YOU AT THE TIME YOU CONTACT THE CODE ENFORCEMENT OFFICER. IF THE HEARING OFFICER WILL BE IN THE FIELD, THEIR CONTACT INFORMATION WILL BE PROVIDED AT THE TIME OF THE HEARING. IF THE HEARING OFFICER DECIDES THAT THERE WAS A CODE VIOLATION AND THAT YOU ARE RESPONSIBLE FOR THE VIOLATION, NOTICE OF A VIOLATION MAY BE RECORDED ON THE PROPERTY. THE CITATION AMOUNT MAY BE INCREASED WHICH MUST BE PAID BY YOU.

B. COURT APPEAL: YOU MAY APPEAL FROM THE DECISION OF THE HEARING OFFICER TO THE SUPERIOR COURT WITHIN 90 DAYS AFTER THE DATE OF THE DECISION. TO APPEAL, YOU MUST PAY A $25 FILING FEE TO THE COURT. IMPORTANT: NOT ALL UNPAID PENALTIES AND/OR ORIGINAL CITATION AMOUNTS CAN BE SUSPENDED AS A CONDITION TO APPEAL. YOU MAY BE RESPONSIBLE FOR PAYING ALL OR PART OF THE ORIGINAL CITATION AMOUNT. UNPAID ASSESSMENTS CAN RESULT IN A LIEN ON YOUR PROPERTY THAT LASTS FOR THREE YEARS OR LONGER. YOU MAY BE CHARGED INTEREST AT 10% PER YEAR ON THE CITATION AMOUNT. A FULL EXPLANATION OF THE CIVIL PENALTY PROCEDURES FOR CODE ENFORCEMENT CITATIONS AND VIOLATIONS AND YOUR RIGHTS TO CONTEST ARE AVAILABLE IN ORANGE COUNTY CODE SECTION 1-6-81 THROUGH 1-6-101.

1

C. IF YOU NEED FURTHER CLARIFICATION ABOUT PAYMENT, APPEAL OF THIS CITATION, PLEASE CALL (800) 290-6155. IF YOU NEED FURTHER INFORMATION ABOUT HOW TO COMPLY WITH THE ORANGE COUNTY CODIFIED ORDINANCE VIOLATIONS, PLEASE CONTACT THE COUNTY CODE ENFORCEMENT AT (714) 796-0177.

FORM TO CONTEST THIS CIVIL CITATION (FILL OUT SECTIONS 1 AND 2)

1. ☐ I HEREBY REQUEST AN ADMINISTRATIVE REVIEW OF THE CIVIL CITATION. I HAVE ATTACHED A COPY OF THE CITATION WITH THE REQUESTED CHANGES TO THE CITATION.

☐ I HEREBY REQUEST A HEARING BEFORE A HEARING OFFICER.

☐ I HAVE ATTACHED A REQUEST FOR A FINANCIAL HARDSHIP WAIVER.

2. ☐ I HAVE ENCLOSED THE FULL AMOUNT OF THE CITATION WITH THIS REQUEST.

☐ I HEREBY REQUEST A FINANCIAL HARDSHIP WAIVER OF THE DEPOSIT REQUIREMENT.

SIGNATURE OF PERSON CONTESTING CITATION

DATE

AR0069522

Power Consumption Chart for Tools

Power Consumption Chart

Electrical Energy Charges are expressed in kWh.

Circular Saw	2400	1200
Drill	1000	720
Edger	2400	960
Electric Chainsaw	2400	1200
Electric Lawn Mower	4320	1440
Electric Pressure Washer	3600	1200
Electric String Trimmer	1500	600
Jig Saw	1800	720
Miter Saw	2160	840
Orbital Sander	1800	600
Paint Sprayer	1000	360
Planer	2400	960
Router	1500	6000
Water Pump	2000	1000
Wet/Dry Vacuum	2500	850
Winch	2400	1800
Furnace Fan, gas/fuel oil furnace		
1/3 horsepower (hp)	500	300
1/2 horsepower (hp)	750	500
3/4 horsepower (hp)	1000	800
2/3 horsepower (hp)	1400	700
3/3 horsepower (hp)	2250	1125
Central Air Conditioner		
10,000 BTU	2200	1800
20,000 BTU	3300	2500
24,000 BTU	4950	3800
32,000 BTU	6500	5000
60,000 BTU	9200	8000
1/4" Drill	200	200
Jigsaw	300	300
Electric Weed Trimmer	500	500
Belt Sander	1000	1000
Disc Sander	1200	1200
Circular Saw	1300	1400
Worm Drive Saw	1600	1500
12" Concrete Cutter	3600	1500
7 1/4" Circular Saw	3000	1500
Disc Grinder	4000	2000
Air Compressor (Average)	4000	2000

P&E

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General Enquiries:

USP&E Companies:

US Office:

SA Office:

Ernst & Young Entrepreneur Of The Year

Inc. 50

AR0069524

CTL Environmental Services

May 16, 1997

Via Facsimile: (213) 871-5058

Mr. John Piro
CAPITAL RECORDS
1750 North Vine Street
Hollywood, California 90028

RE: PROFESSIONAL CONSULTING SERVICES AGREEMENT
CLIENT-DIRECTED BULK SAMPLING FOR ASBESTOS
1750 NORTH VINE, HOLLYWOOD, CA 90028
CTL PROPOSAL #A-057-3485

Dear Mr. Piro:

CTL is pleased to present the following consulting services agreement for the above-referenced project. CTL understands the scope of work to include the following:

SCOPE OF WORK

- Provision of client-directed bulk sampling for asbestos at the above-referenced property, with 24 hour verbal results with fax transmittal and submission of report 1 week from authorization. CTL will collect bulk samples of suspect asbestos-containing material from the subject property. If additional building area is requested to be surveyed, you will be contacted for authorization prior to any additional work.

FEE SCHEDULE

ASBESTOS SAMPLING		
Technician	4 @ $50.00/hr	$200.00
Project Manager	.50 @ $80.00/hr	$40.00
PLM Sample Analysis	3 @ $15.00/ea*	$45.00
Report	Lump Sum	$35.00
TOTAL		**$320.00**

*Estimated maximum of 3 samples. Additional samples can be collected and analyzed at $15.00 each.

This proposal is valid for 60 days from correspondence date.

Should you have any questions regarding the information contained herein, please do not hesitate to contact me directly at (310) 530-5006. Thank you for allowing CTL the opportunity to be of service to Capital Records.

Respectfully Submitted,

CTL Environmental Services

Douglas W. Coburn

Douglas W. Coburn
Project Manager
Hazardous Materials Division

Accepted By:

Capital Records

John Piro

Authorized Signature and Date

John Piro Chief Building Eng.

Print Name and Title

Attachment

CTL Environmental Services
24404 S. Vermont Ave., Ste 307 • Harbor City, CA 90710 • TEL: (310) 530-5000 • FAX: (310) 530-0792

REPORTED: October 24, 1996 **CTL JOB NO.:** 96-1478

CLIENT: Capitol Records
1750 N. Vine Street
Hollywood, California 90025

ATTENTION: Mr. John Piru

REF: Bulk Sample Analysis
Mail Room

PROJECT SUMMARY

CTL Environmental Services (CTL) collected and analyzed bulk samples for asbestos content from the Capitol Records facility located at 1750 N. Vine Street, Hollywood, California. The sampling was conducted on October 17, 1996 by Perry Adams, a Certified Site Surveillance Technician employed by CTL.

ANALYTICAL METHODOLOGY

The samples collected for analysis of asbestos content were analyzed by Polarized Light Microscopy (PLM). Analysis was conducted as described in United States Environmental Protection Agency (EPA) Method for the Determination of Asbestos in Bulk Building Materials: EPA/600/R-93/116, July 1993, at our NVLAP-accredited laboratory in South Gate, California.

RESULTS

The following samples were collected and analyzed for asbestos content:

MATERIAL	SAMPLE #	MATERIAL LOCATION	ASBESTOS CONTENT
Off-White/Gray Fibrous Material	56254	Sample Collected by Client	10% Chrysotile 25% Amosite <1% Crocidolite
Off-White/Gray Fibrous Material	56255	Sample Collected by Client	15% Chrysotile 25% Amosite
Off-White/Gray Fibrous Material	56256	North Wall by Pipe Penetration	5% Chrysotile 30% Amosite <1% Crocidolite
Off-White Fibrous Material	56257	Pipe Insulation Above Duct in Mail Room	12% Chrysotile
Off-White Fibrous Material	56258	Pipe Insulation Above Duct in Mail Room	10% Chrysotile

This report applies only to the samples or samples investigated and is not representative of the quality or condition of apparently identical or similar materials. As a mutual protection to clients, the public and these laboratories, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from these laboratories.

CTL ENVIRONMENTAL SERVICES • 2995 E. Century Blvd. • South Gate, CA 90280 • (213) 564-2842

POLARIZED LIGHT MICROSCOPY SUMMARY REPORT

CLIENT : **Capitol Records**

Project Name : 1750 N. Vine St., Hollywood

CTL Lab # : **113663** CTL Project # : **96-1478**

Analytical Method: EPA/ 600/ R-93/ 116, July 1993

Client Sample # / CTL sample #	Sample Remarks Or Description	Total Asbestos %	Asbestos Type(s) present
56254 96-30466	Off-white/gray fibrous material, collected by client	35 %	Chrysotile Amosite Crocidolite
56255 96-30467	Off-white/gray fibrous material, collected by client	40 %	Chrysotile Amosite
56256 96-30468	Off-white/gray fibrous material, N. wall pipe penetration	36 %	Chrysotile Amosite Crocidolite
56257 96-30469	Off-white fibrous material, pipe ins. above duct, mail rm.	12 %	Chrysotile
56258 96-30470	Off-white fibrous material, pipe ins. above duct, mail rm.	10 %	Chrysotile

Supervisor Signature: Cynthia Tabatt

Analyst initial : FDC

Date Received 10 / 18 / 96

Date Analyzed: 10 / 18 / 96

When a sample is "layered", the Total Asbestos % represents the composite percentage of all sample layers. If the asbestos percentage of an individual layer is required, the detailed lab report should be referenced, or the layer should be reanalyzed as a separate sample. Samples reported as Not detected, or less than 1% (<1%), are non-asbestos containing according to PLM method definitions.

The report applies only to the sample, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar materials or products. As a mutual protection to clients, the public and these Laboratories, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from these Laboratories.

CTL Environmental Services

113863

Page 1 of 1

CHAIN OF CUSTODY RECORD

Client: Capital Records Date: 10-17-96

Address: 1750 N. Vine Street, Hollywood

Project Name: Capitol Records

Project Number: 96-1496

Project Manager: Marie Tullai Phone #: 530-5006 Pager: —

TESTS REQUIRED

- ☒ PLM
- ☐ PCM
- ☐ TEM - Bulk
- ☐ TEM - Water
- ☐ TEM - AHERA
- ☐ TEM - EPA Level II

CTL will store sample for 30 days (beginning with the date the samples were received in the laboratory at no charge)

1. Client will pick up _____ by _____
2. Lab Disposal _____ by _____

Sample #	Material Description (not to exceed 15 characters)	Sample Location (not to exceed 25 characters)
56254	8 FA - White/Gray Fibrous Material	Floor - Sample Collected by Client
56255	" " " " "	Floor - Sample Collected by Client
56256	" White/Gray Fibrous Material	North wall by Pipe penetration
56257	" White Fibrous Material	Pipe insulation - Above Duct - Mech.
56258	" White Fibrous Material	Pipe insulation - Above duct - Mech.

Special Instructions (including turn around time): < 8 hr TAT

The client is Requesting - Results By noon

Documentation Attached:

Received By	Received By	Received By
Relinquished By	Relinquished By	Relinquished By
Date/Time: 10-17-96 / 08:23	Date/Time:	Date/Time:

Received for Laboratory: Date/Time: 10-18-96 9:30am

24404 S. Vermont Avenue, Suite #307 • Harbor City, CA 90710 • TEL: (310) 530-5006 • FAX (310) 530-0792

AR0069529

If you have any questions regarding these samples, please feel free to contact me at (310) 530-5006.

Respectfully submitted,
CTL Environmental Services

Marie Tultai

Marie Tultai
Project Manager
Certified Asbestos Consultant
Cal-OSHA Cert. #92-0218

MT:mak

Attachment

CTL Environmental Services
24404 S. Vermont Ave., Ste. 307 · Harbor City, CA 90710 · TEL (310) 530-5906 · FAX (310) 530-0792

PROJECT NO.: 96-1478 **REPORTED:** November 1, 1996

CLIENT: Capitol Records
1750 North Vine Street
Hollywood, California 90028

ATTENTION: Mr John Piru

RE: **Clearance Air Sampling**
Mail Room

INTRODUCTION

CTL Environmental Services performed clearance air sampling, following the removal of asbestos contaminated ceiling tile from the mail room of the Capitol Records facility at 1750 North Vine Street, Hollywood, California. Clearance air sampling was conducted on October 24, 1996

Samples were collected and analyzed in accordance with the National Institute of Occupational Safety and Health (NIOSH) Method 7400 utilizing Phase Contrast Microscopy (PCM).

All samples were consistent at less than 0.01 fibers per cubic centimeter (f/cc) of air, the level recommended by the Environmental Protection Agency (EPA) for reoccupancy of non-protected personnel following an asbestos response action

CTL Environmental Services is an environmental consulting firm, registered to practice under the State of California Department of Safety and Health. Its laboratories are accredited by the American Industrial Hygiene Association (AIHA) and the National Voluntary Laboratory Accreditation (NVLAP) programs.

Sincerely,
CTL Environmental Services

Marie Tullai

Marie Tullai
Project Manager
Certified Asbestos Consultant
Cal-OSHA Cert. #92-0218

MT:rtak

This report relates only to the samples investigated and is not necessarily indicative of the quality of apparently identical or similar materials or products. Any unauthorized publication or use of the name of this laboratory, or reports or statements based upon or referring to its findings or opinions, may be subject to claims for damages. The client should inform CTL promptly if these findings or opinions are misquoted or misinterpreted.

TO

QHI / STEVENS

cc: Capitol Records

FROM Perry Adams

CTL Environmental Services
24404 So. Vermont Ave., Suite #307
Harbor City, CA 90710
(310) 539-5036

SUBJECT Final Air Testing - Capitol Records (Mailroom)

DATE 05-24-96 (06:15)

MESSAGE

At the request of QHI-Stevens, CTL conducted final air testing after the cleaning and removal of asbestos contaminated ceiling tile. The area appears to be clear of all dust and debris. The area appears to have been encapsulated and allowed to dry.

CTL have conducted air testing in the work area and, found the sample to be 0.01 f/cc or less. The samples were collected using PCM (Phase Contrast Microscopy). The samples were analyzed using the NIOSH 7400 method. The level of airborne fibers are below the 0.1 f/cc which is the permissible exposure level set by the OSHA (Occupational Safety and Health Administration).

Sample No.	Location	Results (f/cc)
001-CAP	Mailroom - South	0.002
002-CAP	Mailroom - North	0.002

Time 06:10

TECHNICIAN

CERTIFICATION NO. 93-1159

RECEIVED BY

RESPONSE:

CTL Environmental Services
24404 S Vermont Ave., Ste 307 Harbor City, CA 90710 TEL (310) 530-5006 FAX (310) 530-0792

AIR SAMPLING FORM

Project Name: Capitol Records Project Number:

Technician: Perry D. Adams Date: 10-24-96 Shift: Night Floor/Area: Mailroom

Sampling Method or Sample Type: PCM X TEM NIOSH X AHERA EPA II

Microscope Number: 3010 Reticle Field Area: 0.00785 Filter Area: 385

Blank Count Average Amount: (Note: Min. of 2 or 10%) 0 Rotometer Number: 00566

Microscopist: Perry Adams Data Entered: 10-24-96 Checked By:

Sample Number	Pump #	Location	Type	Start Time	Stop Time	Total Minutes	LPM Average	Volume	Fibers Counted	Fields Counted	F/CC
Blank 001		Blank - Lab	B						0	100	
Blank 002		Blank - Field	B						0	100	
001 - CAP	1058	IWA - NORTH	C	4:39	6:00	81	15	1215	4	100	0.002
001 - CAP	1045	IWA - SOUTH	C	4:40	6:00	80	15	1200	5	100	0.002

Comment:

AR0069533

CTL Environmental Services
24404 S. Vermont Ave., Ste. 907 • Harbor City, CA 90710 • TEL: (310) 530-5006 • FAX: (310) 530-0782

REPORTED: October 30, 1996 **CTL JOB NO.: 96-1478**

CLIENT: Capitol Records
1750 N. Vine Street
Hollywood, California 90025

ATTENTION: Mr. John Piru

REF: Bulk Sample Analysis
Mail Room

PROJECT SUMMARY

CTL Environmental Services (CTL) analyzed bulk samples of plaster and wall packing from the mail room of the Capitol Records facility located at 1750 N. Vine Street, Hollywood, California. The samples were submitted to CTL by a Capitol Records representative on October 24, 1996.

ANALYTICAL METHODOLOGY

The samples collected for analysis of asbestos content were analyzed by Polarized Light Microscopy (PLM). Analysis was conducted as described in United States Environmental Protection Agency (EPA) Method for the Determination of Asbestos in Bulk Building Materials: EPA/600/R-93/116, July 1993, at our NVLAP-accredited laboratory in South Gate, California.

RESULTS

The following samples were analyzed for asbestos content:

MATERIAL	SAMPLE #	SAMPLE LOCATION	MATERIAL LOCATION	ASBESTOS CONTENT
Off-White Crumbly Packing & Plaster with Black Paint	001	In Pipe Penetration, North Side of Mail Room	Recreation Room	9% Chrysotile 15% Amosite <1% Crocidolite
Plaster with Light Green Paint	002	Boiler Room Stack Wall, North Side of Mail Room	Recreation Room	None Detected
Plaster with Black Paint	003	West Wall of Mail Room	Recreation Room	None Detected

This report applies only to the samples, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar materials or products. As a mutual protection to clients, the public and these laboratories, this report is submitted and accepted for the exclusive use of the client to which it is addressed and upon the condition that it is not to be [illegible]

If you have any questions regarding these samples, please feel free to contact me at (310) 530-5006.

Respectfully submitted,
CTL Environmental Services

Marie Tullai

Marie Tullai
Project Manager
Certified Asbestos Consultant
Cal-OSHA Cert. #92-0218

MT:mak

Attachment

CTL ENVIRONMENTAL SERVICES • 2995 E. Century Blvd. • South Gate, CA 90280 • (213) 564-2642

POLARIZED LIGHT MICROSCOPY SUMMARY REPORT

CLIENT : **Capitol Records**

Project Name : Mail Room

CTL Lab # : **113697** CTL Project # : **96-1478**

Analytical Method: EPA/ 600/ R-93/ 116, July 1993

Client Sample # / CTL sample #	Sample Remarks Or Description	Total Asbestos %	Asbestos Type(s) present
1 96-30959	Off white crumbly w/black paint, penetration north side # of layers in sample 2	24 %	Chrysotile Amosite Crocidolite
2 96-30960	Plaster, w/light green paint, boiler room stack wall N. side # of layers in sample 2	Not detected	———
3 96-30961	Plaster w/black paint, west wall # of layers in sample 2	Not detected	———

Supervisor Signature: Cynthia Tibbett

Analyst Initial : FDC

Date Received 10 / 25 / 96

Date Analyzed: 10 / 25 / 96

When a sample is "layered", the Total Asbestos % represents the composite percentage of all asbestos layers. If the asbestos percentage of an individual layer is required, the detailed lab report should be referenced, or the layer should be reanalyzed as a separate sample. Samples reported as Not detected, or less than 1% (<1%), are non-asbestos containing according to PLM method definitions.

This report applies only to the samples, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar material or products. As a mutual protection to clients, the public and these Laboratories, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without our written authorization from these Laboratories.

CTL Environmental Services

113897

Page 1 of 1

CHAIN OF CUSTODY RECORD

Client: CAPITOL RECORDS Date: 10-25-96

Address: N. VINE STREET / Hollywood, CA

Project Name: MAILROOM

Project Number: 96-1478

Project Manager: MARIO TELLEZ Phone #: 530-5006 Pager: ———

TESTS REQUIRED

- ☒ PLM
- ☐ PCM
- ☐ TEM - Bulk
- ☐ TEM - Water
- ☐ TEM - AHERA
- ☐ TEM - EPA Level II

CTL will store sample for 30 days (beginning with the date the samples were received in the laboratory at no charge)

1. Client will pick up _____ by _____
2. Lab Disposal _____ by _____

Sample #	Material Description (not to exceed 15 characters)	Sample Location (not to exceed 25 characters)
001	Off white crumbly knock Block Paint	Rec. From Client: Ceiling and Plaster to the West side mailroom
002	Plaster with Light Green Paint	Rec From Client: Boiler Room Directly North side of mailroom
003	Plaster with Black Paint	Rec. From Client: West wall of mailroom

Special Instructions (including turn around time):
Samples Received From Client.
Regular Turn Around Time.

Documentation Attached:

Received By	Received By	Received By
Relinquished By	Relinquished By	Relinquished By
Date/Time: 10-24-96	Date/Time:	Date/Time:

Received for Laboratory: Date/Time: 10-25-96 9:30am

24404 So. Vermont Avenue, Suite 207 • Harbor City, CA 90710 • TEL: (310) 530-5006 • FAX: (310) 530-0792

AR0069537

CTL Environmental Services 24404 S. Vermont Ave., Ste. 307 * Harbor City, CA 90710 * (213) 530-6006

PROJECT NO: 92-0553 **REPORTED:** January 29, 1992

CLIENT: Capital Records
1750 North Vine Street
Hollywood, California 90028

ATTENTION: Mr. John McKenna

REF: **Investigation for asbestos-containing materials of the Capital Records Building located at 1750 North Vine Street, Hollywood, California.**

A. Introduction

On January 25th, 1992, CTL Environmental Services (CTL) conducted a limited asbestos investigation survey of the property located at 1750 North Vine Street, in Hollywood, California for Capital Records.

The survey was conducted by Doug Coburn, an EPA accredited building inspector employed by CTL. The purpose of the survey was to identify and sample all accessible friable and non-friable building materials suspected to contain asbestos that may be impacted by the installation of fire sprinklers in the building.

At the request of the building management, sampling was to be conducted in a discrete and non-destructive manner. Also, to provide the description and locations of these materials and provide estimated quantities of those materials found to contain asbestos.

This document is intended to identify the asbestos-containing materials in the building as a result of this asbestos survey. The quantity estimates given herein are **estimates only** and should not be used for asbestos removal bidding purposes.

B. Description of Survey Site

The Property surveyed is located at 1750 North Vine Street, in Hollywood, California. The Building consists of thirteen stories, constructed on a concrete foundation with concrete slabs separating floors and supported by concrete columns and beams. Interior walls are constructed of drywall and plaster.

C. Field Survey and Analytical Methods

Prior to sampling suspect material, a visual inspection was conducted during which accessible areas of the building were visited.

This report applies only to the samples tested and is not necessarily representative of other similar or dissimilar materials.

methods cont...

By request of the building management, sampling was conducted in an non-destructive manner to preserve the current integrity of all building materials. As a result, some areas were not readily accessible unless destructive means were employed to gain access. These areas were considered inaccessible and are considered exempt from this report. Examples of such areas include: areas under carpeting, between walls, wall pipe chases, elevator and air shafts, areas between suspended gypsum board ceilings and hard decks, adhesives between acoustic tiles and substrates, and materials behind wall coverings (i.e. wallpaper, wood paneling).

Prior to any renovation or demolition that may affect these areas, it is recommended that further investigating be conducted for suspect materials by a qualified building inspector.

Samples were collected from suspect materials and subsequently analyzed by Polarized Light Microscopy (PLM) in accordance with U.S. Environmental Protection Agency Interim Method of the Determination of Asbestos in Bulk Insulation Samples: Polarized Light Microscopy, 40 CFR Ch. 1 Pt. 763, Subpart. F, Appendix A, 7/1/87 edition.

D. Survey Results

A complete listing of all samples collected is in the following section of this report. The materials listed below were determined to contain asbestos. Quantities are approximations only and should not be used for bidding purposes.

ASBESTOS-CONTAINING MATERIAL	LOCATION	EST. QTY.
Acoustic spray on ceiling	1st floor, elevator lobby	500 square ft.
White gasket material (plugging holes in walls)	Mezzanine, walls	10 sq. ft.
Pipe insulation S-2 (Chill water)	Above 1st floor in crawlspace	100 linear feet
Pipe insulation S-1 (Hot water)	Mail room, above dropped ceiling	100 linear feet
Pipe insulation S-2 (Hot water)	1st floor, boiler room	75 linear feet

E. Discussion

Currently, the Environmental Protection Agency E.P.A. considers those materials that contain more than one (1) percent of asbestos by volume to be treated as asbestos-containing material (ACM).

As previously discussed, this survey was conducted in a non-destructive manner. Although every attempt was made to access friable suspect materials in the buildings, the possibility exists that additional materials may be exposed during renovation and/or demolition activities. Visually suspect materials not listed in this report and exposed during renovation or demolition should be sampled and analyzed prior to further disturbance.

Prior to the demolition of the building or any other activity that may disturb known asbestos containing materials (ACM), removal of such materials is advised. Removal should be performed by a qualified and licensed asbestos removal contractor.

Should you have any further questions regarding this investigation report or would like more information describing our wide range of environmental services, please feel free to contact me at (310) 530-5006.

Respectfully submitted,
CTL Environmental Services,

David R. Schack
Sr. Project Coordinator

Reviewed/approved:

Todd W. Ellertson
Project Manager

DRS/dwc
ref:92-0553.rpt

HOMOGENEOUS MATERIAL SAMPLE LOG

MATERIAL SAMPLED	SAMPLE NUMBERS
2'x4' White ceiling panel	65649
2'x2' White ceiling panel	65651
12"x12" White ceiling tile	65652
Sprayed-on acoustic ceiling material	65650
White gasket material	65662
1'x2' Perforated ceiling tile	65655
Pipe insulation debris	65653
12"x12" Smooth ceiling tiles (3rd floor)	65654
S-3 Pipe elbow insul. (Chill Water)	65664
S-3 Boiler flue insulation (roof)	65665
12"x12" Coarse hole ceiling tile E-floor south of womens restroom	65657
12"x12" Ceiling tile (E-floor conf. rm.)	65658
12"x12" Perforated ceiling tile	65659
Plaster ceiling/wall	65663
Drywall	65656
Pipe insulation S-2 Chill water	65660
Pipe insulation S-1 Hot water	65648
Pipe insulation S-2 Hot water	65661

CTL ENVIRONMENTAL SERVICES - 2995 E. Century Blvd. - South Gate, CA 90280 - (213) 564-2642

POLARIZED LIGHT MICROSCOPY SUMMARY REPORT

CLIENT NAME : Capitol Records

Client Reference# N/A Location/Description: Capitol Records Bldg. / John McKenna

CTL Lab# : 102935 CTL Project # : 92-0553

Analytical Method: EPA/NVLAP PLM Method (Federal Register --40 CFR Ch. 1, Pt. 763, Subpt. F, Appendix A, 7/1/91)

Client Sample # / CTL Lab #	Sample Remarks Or Description	Total Asbestos %	Asbestos Type(s) present
65648 92-00690	Pipe ins. H water, S-1, mail room, above ceil.	15 %	amosite crocidolite
65649 92-00691	2X4 white ceiling panel, Mail room, below air handler	Not detected	----------
65650 92-00692	Sprayed-on acoustic ceiling, 1st elevator lobby # of layers in sample = 2	10 %	chrysotile
65651 92-00693	2X2 ceiling panel, 1st floor, studio office # of layers in sample = 2	Not detected	----------
65652 92-00694	12X12 white C.T. 1st fl., security desk # of layers in sample = 2	Not detected	----------
65653 92-00695	Pipe ins. debris, office 3rd floor, soffet, N/E	< 1 %	chrysotile
65654 92-00696	12X12 smooth C.T. 3rd floor hall, E. office # of layers in sample = 2	Not detected	----------
65655 92-00697	1X2 C.T. perforated, 3rd floor, E. office # of layers in sample = 2	Not detected	----------
65656 92-00698	Drywall, 9th Floor conference room, kitchen # of layers in sample = 4	Not detected	----------
65657 92-00699	12X12 C.T. coarse hole, E floor, office S of women's R.R. # of layers in sample = 2	Not detected	----------

Supervisor Signature: Cristina Ritchie Review Date: 2/13/92

Data Entry Initials : CR

* When a sample is "layered", the *Total Asbestos %* represents the composite percentage of all sample layers. If the asbestos percentage of an individual layer is required, the detailed lab report should be referenced, or the layer should be reanalyzed as a separate sample. Samples reported as *Not detected*, or less than 1% (<1%), are non-asbestos containing according to PLM method detection limits.

This report applies only to the samples, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar material or products. As a mutual protection to clients, the public and these Laboratories, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from these Laboratories.

CTL ENVIRONMENTAL SERVICES • 2995 E. Century Blvd. • South Gate, CA 90280 • (213) 564-2542

POLARIZED LIGHT MICROSCOPY SUMMARY REPORT

CLIENT NAME : Capitol Records

Client Reference# N/A Location/Description: Capitol Records Bldg. / John McKenna

CTL Lab# : 102935 CTL Project # : 92-0553

Analytical Method: EPA/NVLAP PLM Method (Federal Register --40 CFR Ch. 1, Pt. 763, Subpt. F, Appendix A, 7/1/91)

Client Sample # / CTL Lab #	Sample Remarks Or Description	Total Asbestos %	Asbestos Type(s) present
65658 92-00700	12X12 C.T. E floor, conference room # of layers in sample = 2	Not detected	———
65659 92-00701	12X12 perforated tile, E. floor, copier room # of layers in sample = 2	Not detected	———
65660 92-00702	Pipe insul., S-2 crawlspace, chill water # of layers in sample = 6	10 %	chrysotile
65661 92-00703	Pipe insulation, S-2 boiler room, 1st floor	15 %	amosite crocidolite
65662 92-00704	White gasket materia, mezzanine	60 %	chrysotile
65663 92-00705	Plaster, wall ceiling, Mezzanine, door # of layers in sample = 2	Not detected	———
65664 92-00706	Elbow pipe insulation, S-3, chill water	< 1 %	chrysotile
65665 92-00707	Boiler flue on roof, S-3, insulation	Not detected	———

Supervisor Signature: Cristina Estrada Review Date: 2 13 92

Data Entry Initials : CR

* *When a sample is "layered", the Total Asbestos % represents the combinate percentage of all sample layers. If the asbestos percentage of an individual layer is required, the detailed lab report should be referenced, or the layer should be reanalyzed as a separate sample. Samples reported as Not detected, or less than 1% (<1%), are non-asbestos containing according to PLM method deadlines.*

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CTL Environmental Services, Inc.

FACSIMILE COVER SHEET

DATE: 11/14/2003 **FAX #:** (714) 982-5843

TIME: 2:43 PM **NO. OF PAGES:** 4 (Including cover)

CTL Job Number 103-0352

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COMPANY: Sycle Hennessy

FROM: Naomi Arakawa for Marie Tullai

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Naomi
Operator/Sender

24814 So. Vermont Avenue, Suite 307, Harbor City, CA 90710 – Tel: (310) 530-5006 Fax: (310) 530-0792

MATERIAL INVENTORY
ASBESTOS

CLIENT: Syska Hennessy Group
PROJECT NO: 103-0352
PROJECT NAME: Capital Records building

MATERIAL	SAMPLE NUMBER	ASBESTOS CONTENT	SAMPLE LOCATION	MATERIAL LOCATION	APPROX. QTY.	FRIABLE	DAMAGE
10" O.D. TSI cork elbow	8866	None Detected	Northwest side, 6 feet from north wall, 3 feet from west wall	Chiller room	4 elbows	No	No
10" O.D. TSI cork run	8867	7% Chrysotile	Southwest side approximately 18 feet from east wall, 3 feet from south wall	Chiller room	40 ln. ft.	No	No
6" O.D. TSI cork elbow	8868	5% Chrysotile	Southeast side approximately 10 feet from east wall, 8 feet from south wall	Chiller room	6 elbows	No	No
6" O.D. TSI cork run	8869	None Detected	Southeast side approximately 10 feet from east wall, 5 feet from south wall	Chiller room	30 ln. ft.	No	No
6.5" O.D. TSI elbow	8870	10% Amosite 10% Crocidolite	4 feet northeast of southwest	Boiler room	12 elbows	Yes	No
6.5" O.D. TSI run	8871	10% Amosite 10% Crocidolite	4 feet northeast of southwest	Boiler room	90 ln. ft.	Yes	Yes
5.5" O.D. TSI elbow	8872	10% Amosite 10% Chrysotile 10% Crocidolite	5 feet north from south center	Boiler room	9 elbows	Yes	No
5.5" O.D. TSI run	8873	5% Amosite 5% Crocidolite	5 feet north from south center	Boiler room	56 ln. ft.	Yes	Yes
8.5" O.D. TSI elbow	8874	10% Amosite 20% Chrysotile 10% Crocidolite	8 feet south of northwest	Boiler room	17 elbows	Yes	No
8.5" O.D. TSI run	8875	15% Amosite 5% Crocidolite	8 feet south of northwest	Boiler room	190 ln. ft	Yes	Yes
Furnace insulation	8876	None Detected	South furnace vent, 5 feet north of south wall	Boiler room	2 units	No	No
Gray rolled-on roof core	8877	None Detected	Southwest corner from chiller unit above chiller room	Roof - chiller room	400 sq. ft.	No	No
Gray roof mastic	8878	None Detected	Southwest corner from chiller unit on penetration	Roof - chiller room	25 sq. ft.	No	No

NOTE: TSI = thermal system insulation

CTL Environmental Services

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MATERIAL INVENTORY
ASBESTOS

CLIENT: Sysko Hennessy Group
PROJECT NO: 103-0352
PROJECT NAME: Capitol Records building

MATERIAL	SAMPLE NUMBER	ASBESTOS CONTENT	SAMPLE LOCATION	MATERIAL LOCATION	APPROX. QTY.	FRIABLE	DAMAGE
2x4 fissured ceiling panel	8879	None Detected	North center, 3rd floor office	Outer perimeter soffit in offices of floors 2 through 5	160 sq. ft.	Yes	No
3" O.D. TSI run (light gray)	8880	10% Chrysotile	North center, 3rd floor office	Soffit space, perimeter offices in floor 3	300 ln. ft.	No	No
Flexible collar	8881	None Detected	North center, 3rd floor office	Soffit space of perimeters of floors 3 through 5	33 collars	No	No
4" black cove base and glue	8882	None Detected	Southwest corner, storage room, 3rd floor (exterior)	Floors 2 through 5	80 ln. ft.	No	No
Drywall	8883	None Detected	Southwest corner, storage room, 3rd floor (exterior)	Sporadic locations on columns of floors 2 through 5 and all interior dividing walls of building	400 sq. ft.	No	No
Drywall joint compound	8884	None Detected	South center, storage room, 4th floor	Sporadic locations on columns of floors 2 through 5 and all interior dividing walls of building	400 sq. ft.	No	No
	8885	None Detected	South center, storage room, 5th floor				
	8886	None Detected	Southeast corner, storage room, 7th floor				
	8887	None Detected	Column 2 on 9th floor				
	8888	None Detected	Column 1 on 12th floor				
12x12 black with white dots floor tile and mastic	8889	None Detected	Southwest corner, storage room, 3rd floor (exterior)	Lobby and core area, floors 3 through 11	1500 sq. ft.	No	No
4" O.D. TSI elbow	8893	None Detected	East center, room 6, 3rd floor	Riser on outer perimeter, 3rd floor	6 elbows	No	No
2x2 ceiling panel and mastic	8894	None Detected	Center storage room, 3rd floor	Floors 3 through 10	300 sq. ft.	No	No
Smooth plaster	8890	None Detected	3rd floor, east center, office 6	Outer perimeter walls of all floors and columns throughout the building	1500 sq. ft.	No	No
	8891	None Detected	South center, storage room, 4th floor				
	8892	None Detected	Column 1 on 10th floor				

CTL Environmental Services

AR0069546

MATERIAL INVENTORY
ASBESTOS

CLIENT: Sydex Hennessy Group
PROJECT NO: 103-0392
PROJECT NAME: Capital Records building

MATERIAL	SAMPLE NUMBER	ASBESTOS CONTENT	SAMPLE LOCATION	MATERIAL LOCATION	APPROX. QTY.	FRIABLE	DAMAGE
Smooth plaster	8895	None Detected	East center on column 6, 10th floor	Outer perimeter walls of all floors and columns throughout the building	1540 sq. ft.	No	No
	8896	None Detected	Column 2, 12th floor				
12x12 fissured ceiling tile	8897	None Detected	North center core, 11th floor	11th floor	30 sq. ft.	Yes	No

NOTES: ***Boiler room/chiller room***

All TSI runs have open ends with some gouges in sporadic locations.
No walls, floors, or ceilings will be impacted in the boiler room.
Wall east of the chiller room is the only wall impacted. This wall is concrete
No floors, ceilings impacted in the chiller room.

3rd floor

4" O.D. run consists of fiberglass

Throughout building

Columns consists of concrete with combination drywall and plaster shells
9th floor floor consists of terrazo (green)
9th floor ceilings and walls of south side on 12th floor consists of drywall.
Floor E consists of drywall walls and ceilings.
Floor E floor consists of beige terrazo.

All materials sampled and quantities were based on the affected areas as per information supplied by the client's field representative. This inspection was limited to areas in the building affected by the installation of the new riser.

AR0069547

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Los Angeles Department of Water & Power

2009 Annual Water Quality Report

It really is that good!

A Message to our Customers 2
Water Treatment Processes 3
Water Quality News and Updates 4
City Water Sources 6
Report for All Water Quality Areas 8
About this Report & Contact Information 15

AR0069548

1 Beginning of L.A. Aqueducts

Lee Vining Intake

The beginning of the Los Angeles Aqueducts. Water is collected from creeks in the Mono Basin and the Owens River in the Owens Valley and then carried to the City of Los Angeles by the Los Angeles Aqueducts, which operate completely by gravity, making clean hydroelectric energy along the way.

A Message to Our Customers

In 2009, the 200 billion gallons of water supplied to the City's 4.1 million residents met or surpassed all health-based drinking water standards. These standards are set by the U.S. Environmental Protection Agency (USEPA) and the State of California Department of Public Health (CDPH) Drinking Water Program.

Year after year, LADWP proves that it has what it takes to provide the City of Los Angeles with high-quality, low cost drinking water. It's no easy task to achieve such high quality water. Hundreds of employees and countless hours are spent protecting our water sources, managing state-of-the-art water treatment processes, maintaining and operating our facilities, and vigilantly monitoring and testing the water we serve. We continuously strive to surpass the legal requirements and do so in an effective and affordable way for our customers.

In 2009, LADWP collected over 25,000 water samples across the city, and performed more than 240,000 water quality tests—not just for compliance, but also for research and operational improvements. We tested for over 200 different contaminants throughout the year including both, regulated contaminants such as arsenic, chromium, lead, and disinfection by-products, as well as unregulated contaminants of concern such as sodium and boron.

This report summarizes the results of the water quality tests conducted in 2009 and provides specific information about the quality of water served in your neighborhood. You will see that most contaminants have not been detected in our water sources and those that are (see tables I-IV) are safely within the regulatory limits for drinking water.

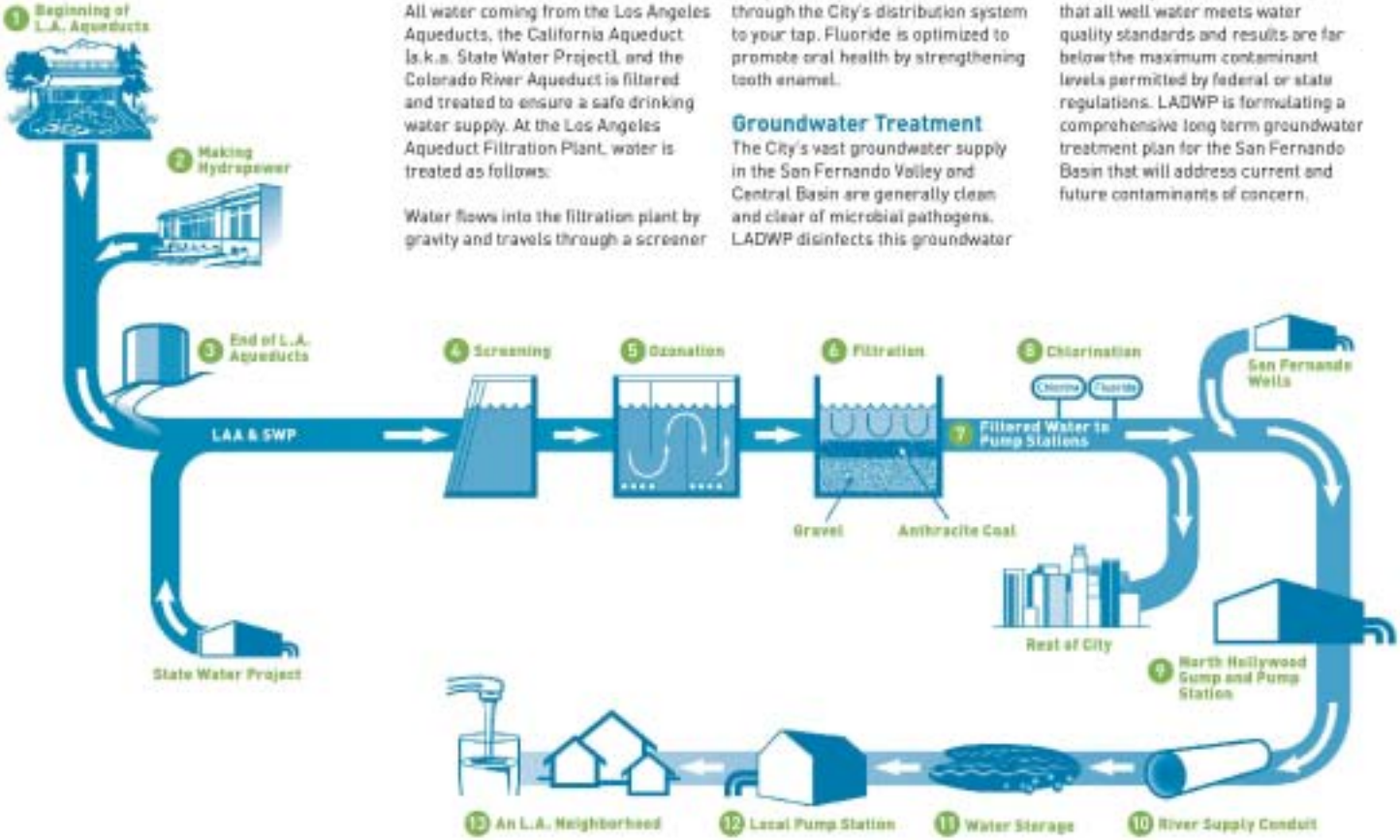
James B. McDaniel
Senior Assistant General Manager - Water

Dr. Pankaj Parekh
Director of Water Quality

The Journey of a Drop of a Water

From the Mountains to Your Tap...

A drop of melted snow trickles into a stream and gathers strength as it travels down mountains and into streams and rivers in a land of blue skies. This is where City of Los Angeles drinking water comes from. To most people, the journey water takes to get to their business or residence is a mystery. The photos in this report will reveal the mystery by sharing snapshots of where a drop of water travels before it splashes over your baby's head at bathtime or streams into your water bottle before your evening walk. Because, when it's all said and done, **it really is that good!**



Water Treatment Processes

Surface Water Treatment

LADWP water comes from four very different water sources—three are from surface water sources like lakes and rivers, and the other is groundwater from local wells and springs. The taste and appearance of surface water can vary seasonally and groundwater generally contains more minerals. All these factors make for different tasting water. Despite these variations, LADWP water meets all drinking water standards for health and aesthetics.

All water coming from the Los Angeles Aqueducts, the California Aqueduct (a.k.a. State Water Project), and the Colorado River Aqueduct is filtered and treated to ensure a safe drinking water supply. At the Los Angeles Aqueduct Filtration Plant, water is treated as follows:

Water flows into the filtration plant by gravity and travels through a screener to remove environmental debris such as twigs and dead leaves. The process injects ozone, a super-charged oxygen molecule and a powerful disinfecting agent into the water to destroy bacteria and other impurities that affect taste, odor and color. Treatment chemicals are quickly dispersed into the water to make fine particles called floc. A six-foot-deep filter (crushed coal over gravel) removes the floc and previously added chemicals. Chlorine added during the final step ensures lasting disinfection and protects the water as it travels through the City's distribution system to your tap. Fluoride is optimized to promote oral health by strengthening tooth enamel.

Groundwater Treatment

The City's vast groundwater supply in the San Fernando Valley and Central Basin are generally clean and clear of microbial pathogens. LADWP disinfects this groundwater with chlorine as a safeguard against microorganisms and adds optimal amounts of fluoride to promote oral health. In December, 2009, the federal Ground Water Rule went into effect. This regulation now requires all water agencies across the country to disinfect groundwater sources, a standard practice that LADWP has had for decades.

Because of man-made contaminants found in San Fernando Valley groundwater wells, LADWP continuously monitors and ensures that all well water meets water quality standards and results are far below the maximum contaminant levels permitted by federal or state regulations. LADWP is formulating a comprehensive long term groundwater treatment plan for the San Fernando Basin that will address current and future contaminants of concern.

AR0069549

Making Hydropower 2

San Francisquito Power Plant 1

Water generates electricity as it passes through the hydroelectric plant.

Water Quality News and Updates

Safeguarding Our Surface Water

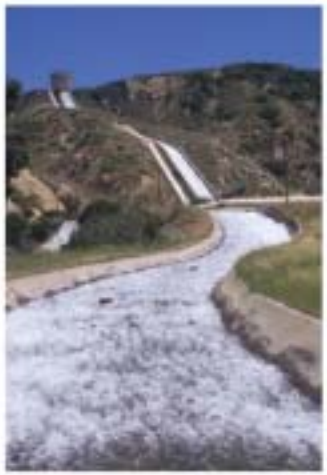
The Surface Water Treatment Rule (SWTR), administered by CDPH, is a drinking water regulation designed to help safeguard reservoir supplies from microbiological contamination that may occur when rain runoff from nearby hillsides and slopes enters the water. In Los Angeles, SWTR applied to four open water reservoirs – Lower Stone Canyon, Encino, and Upper and Lower Hollywood.

LADWP successfully met the compliance deadlines and treatment requirements for all four open reservoirs that were subject to SWTR. Upper and Lower Hollywood Reservoirs were successfully removed in July 2001 and replaced with two 30 million gallon buried tanks. New support facilities were successfully commissioned to serve filtered water from Encino Reservoir in January, 2006 and Lower Stone Canyon Reservoir in September, 2008.

The latest drinking water regulation related to the treatment of surface water is the Long Term 2 Enhanced Surface Water Treatment Rule (LT2). This rule requires that LADWP cover or remove from service the remaining six uncovered distribution reservoirs, or provide additional treatment to achieve prescribed inactivation or removal of viruses, Cryptosporidium, and Giardia by April 1, 2009 or be in compliance with a state-approved schedule to meet the same requirements. The six reservoirs are Los Angeles, Upper Stone Canyon, Santa Ynez, Ivanhoe, Silver Lake, and Elysian Reservoirs.

On April 1, 2008, LADWP notified CDPH that it is fully committed to complying with the new regulations and requested an extension of the April 1, 2009 deadline. LADWP submitted an interim operations plan, a schedule for the required reservoir improvements, and executed a Compliance Agreement with CDPH on March 31, 2009. LADWP is working diligently to bring all reservoirs into compliance as quickly as possible and will provide the public with project updates in the annual water quality report. The estimated cost to modify the six reservoirs is $1.65 billion.

LT2 improves on the SWTR by requiring further protection of open distribution reservoirs from microbial pathogens like Cryptosporidium and Giardia. In preparation for compliance with this rule, LADWP has been routinely monitoring its water sources for microbial pathogens since 2005. Cryptosporidium and Giardia are occasionally detected in very low numbers in some of our reservoirs and in the L.A. Aqueduct and we are fully committed to achieving compliance with the LT2. To further educate our customers on this topic, we have included a statement from CDPH regarding Cryptosporidium.



End of LA Aqueducts 3

The Cascades

Seen along Interstate 5, this is the terminus (end) of the Aqueducts. Water flows over the "steps" to release some of the water's energy.

"Cryptosporidium is a microbial pathogen found in surface water throughout the U.S. Although filtration removes Cryptosporidium, the most commonly used filtration methods cannot guarantee 100 percent removal. Our monitoring indicates the presence of these organisms in our source water and finished water. Current test methods do not allow us to determine if the organisms are dead or if they are capable of causing disease. Ingestion of Cryptosporidium may cause cryptosporidiosis, an abdominal infection. Symptoms of infection include nausea, diarrhea, and abdominal cramps. Most healthy individuals can overcome the disease within a few weeks. However, immunocompromised persons are at greater risk of developing life-threatening illness. We encourage immunocompromised individuals to consult their doctor regarding appropriate precautions to take to avoid infection. Cryptosporidium must be ingested to cause disease, and it may be spread through means other than drinking water."

Water Quality Team Regulatory Affairs

Among the employees responsible for the maintenance and compliance of the City's drinking water, is a little known group of highly trained and educated water quality experts. Known as the LADWP Regulatory Affairs Unit, this elite group knows everything there is to know about the implementation and adherence to all drinking water regulations to protect our water quality. They field hundreds of calls each year from customers and provide input to management about everything water quality.

A diverse group of employees, the unit includes chemists, biologists, environmental specialists, and environmental engineers who work closely with State and County public health departments on ongoing and emerging public health issues related to water quality. They implement

Screening 4

Los Angeles Aqueduct Filtration Plant (LAAFP) Inlet Structure

Water flows through the inlet of the LAAFP, where large pieces of debris or algae are removed by screens.

Ozonation 5

Ozone Contact Chamber, LAAFP

Water is exposed to ozone gas, a disinfectant that prepares the water for filtration.

Filtration 6

Anthracite Coal Filters, LAAFP

Water passes through 60 inches of anthracite coal filters, which remove particles as small as microns.

AR0069550

City Water Sources

San Fernando Valley Communities
Sources: Los Angeles Aqueduct, local groundwater, and MWD State Water Project.

Arleta
Canoga Park
Chatsworth
Encino
Granada Hills
Hollywood Hills
Lake View Terrace
Mission Hills
North Hills
North Hollywood
Northridge
Olive View
Pacoima
Panorama City
Porter Ranch
Reseda
Sherman Oaks
Studio City
Sun Valley
Sunland
Sylmar
Tarzana
Toluca Lake
Tujunga
Valley Village
Van Nuys
Warner Center
West Hills
Winnetka
Woodland Hills

Western Los Angeles Communities
Sources: Los Angeles Aqueduct and MWD State Water Project.

Bel Air Estates
Beverly Glen
Brentwood
Castellamare
Century City
Cheviot Hills
Culver City*
Mar Vista
Pacific Palisades
Palisades Highlands
Palms
Playa del Rey
Sawtelle
Venice
West Los Angeles
Westchester
Westwood

Eastern Los Angeles Communities
Sources: MWD State Water Project and Colorado River Aqueduct.

Atwater Village
Boyle Heights
Cypress Park
Eagle Rock
Echo Park
El Sereno
Glassell Park
Highland Park
Lincoln Heights
Montecito Heights
Monterey Hills
Mt. Washington

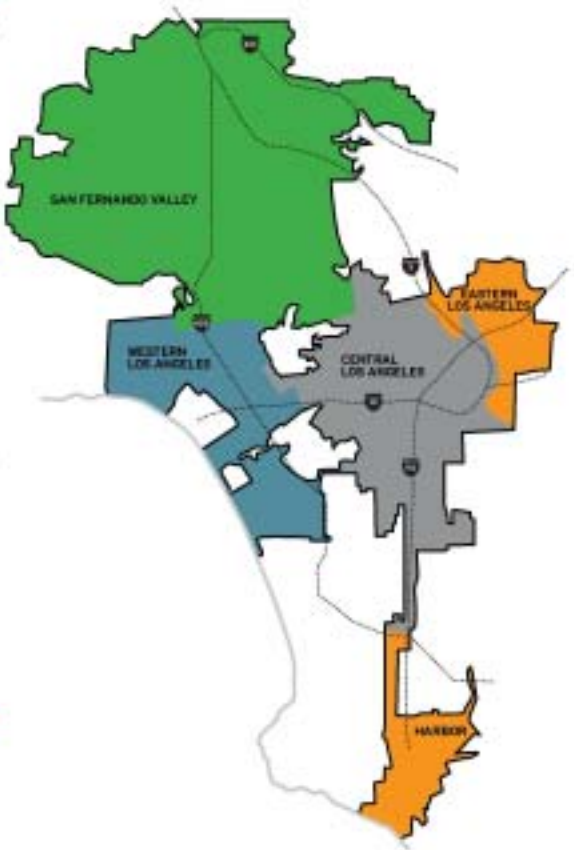
Central Los Angeles Communities
Sources: Los Angeles Aqueduct, MWD State Water Project, and local groundwater.

Baldwin Hills
Chinatown
Country Club Park
Crenshaw
Griffith Park
Hancock Park
Hollywood
Hyde Park
Koreatown
L.A. City Strip*
Little Tokyo
Los Feliz
Mid City
Mt. Olympus
Park La Brea
Rancho Park
Silverlake
Watts
West Hollywood*
Westlake

Harbor Communities
Sources: MWD State Water Project and Colorado River Aqueduct.

East San Pedro (Terminal Island)
Harbor City
Harbor Gateway*
L.A. City Strip*
San Pedro
Wilmington

*parts of



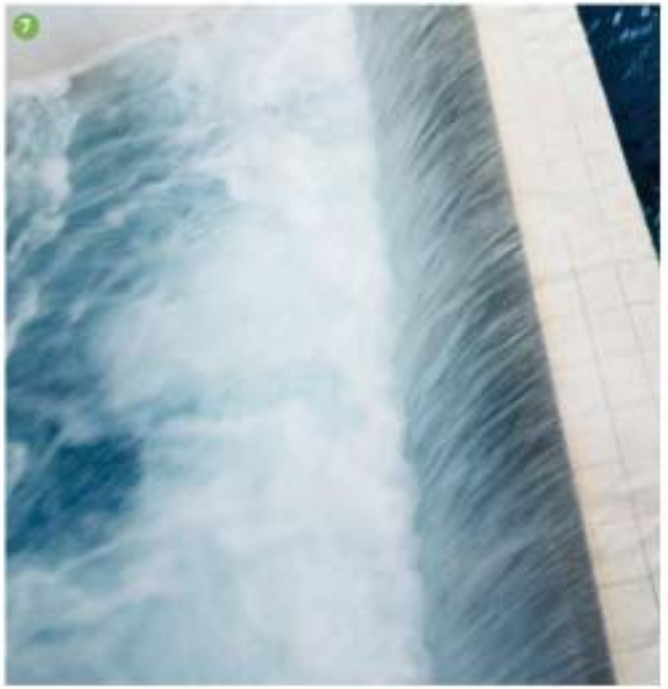
new regulations as well as perform annual and multi-year compliance activities for the City of Los Angeles including: Residential Lead and Copper monitoring; the Watershed Sanitary Survey of the Owens Valley and Mono Basin; system-wide changes to improve water quality, and the updating of water quality data and statistics at ladwp.com. The team works continuously to find new ways to improve water quality above and beyond what is currently required by law.

As LADWP customers themselves, the Regulatory Affairs group has a first-hand understanding of the importance of water quality in our daily lives. It takes a team to complete the various jobs related to water quality.

A Better Understanding of Radon

Radon is a naturally occurring radioactive gas that is not a significant issue in most of California. In 2009, very low levels of radon were detected in some of our water supplies that serve the Central Los Angeles area (see Table III on page 12). There is no established drinking water standard or monitoring requirement for radon. In general, radon entering a home through tap water is a very small contributor to radon in indoor air. Although the radon levels were well below what the EPA currently considers as standard, the EPA has asked us to share the following general information with you to help you better understand radon.

"Radon is a radioactive gas that you can't see, taste, or smell. It is found throughout the U.S. Radon can move up through the ground and into a home through cracks and holes in the foundation. Radon can build up to high levels in all types of homes. Radon can also get into indoor air when released from tap water from showering, washing dishes, and other household activities. Compared to radon entering the home through soil, radon entering the home through tap water is, in most cases, a small source of radon in indoor air. Radon is a known human carcinogen. Breathing air containing radon can lead to lung cancer. Drinking water containing radon may also cause increased risk of stomach cancer. If you are concerned about radon in your home, test the air in your home. Testing is inexpensive and easy. Fix your home if the level of radon in your air is 4 picoCuries per liter of air (pCi/L) or higher. There are simple ways to fix a radon problem that aren't too costly. For additional information, call your State radon program or call EPA's Radon Hotline (800-SOS-RADON)."



7 Filtered Water to Pump Stations

Filter Weir
Water from each of the 24 filters combine at the Filter Weir before leaving the Filtration Plant.

8 Chlorination

Chlorination Station
Chlorinator controls the amount of chlorine added to protect against bacteria and pathogens as water travels through the distribution system.

AR0069551

Report for All Water Quality Areas

Tables I–IV list the results of water tests performed by LADWP and MWD from January to December 2009. LADWP tests for over 200 contaminants. These tables include only contaminants with values that are equal to or greater than the limit of detection.

How to Read the Tables

The constituents/contaminants found in the water served in your area are listed as follows:

- For San Fernando Valley Area – water test results are under the Los Angeles Aqueduct Filtration Plant, the Northern Combined Wells, and MWD Jensen Filtration Plant columns
- For Western Los Angeles Area – water test results are under the Los Angeles Aqueduct Filtration Plant column
- For Central Los Angeles Area – water test results are under the Los Angeles Aqueduct Filtration Plant and the Southern Combined Wells columns
- For Harbor/Eastern Los Angeles Area – water test results are under the MWD Jensen, Weymouth, and Diemer Filtration Plants columns

Some constituents/contaminants detected are reported on a citywide basis as required by the California Department of Public Health.
The unregulated contaminants reported on an area-wide basis are included for additional information on the water served in your area.

Shade Balls Minimize Bromate in City Reservoirs

LADWP continues to minimize bromate levels in open reservoirs, keeping them within regulatory requirements. A creative short-term intervention LADWP recently implemented was the use of "shade balls" to decrease the formation of Bromate. In 2008, shade balls were used to shade the water surfaces of Elysian and Ivanhoe Reservoirs. As a result, bromate levels have been consistently well below the current drinking water standard of 10 parts per billion.

In the long term, LADWP intends to permanently cover or replace all remaining uncovered reservoirs by 2022 as required by the LT2 regulation (please see Safeguarding our Surface Water, page 4). Meanwhile, all water served to our customers continues to meet all public health standards.

Public Health Goals Report

Prepared once every three years, the Public Health Goals Report focuses on drinking water contaminants found at levels above a California Public Health Goal (PHG). A PHG is a level identified as having no adverse health effects. PHGs are not strict standards, but are used in the regulatory process to establish a drinking water standard for contaminants that are currently

9 North Hollywood Sump and Pump Station

Well Water Blending

Water flows by gravity from the LAAFP to the North Hollywood Pump Station. Well water from the San Fernando Valley mixes with the aqueduct water in the North Hollywood Sump before it is sent by large pumps to the central city.

Table I Calendar Year 2009 Water Quality Monitoring Results

Health-Based Primary Drinking Water Standards (MCLs) Constituents/Contaminants Detected in Treated Water

Constituents/ Contaminants	Units	Los Angeles Aqueduct Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Weymouth Filtration Plant		MWD Diemer Filtration Plant		MWD Jensen Filtration Plant		State and Federal Primary Standard (MCL) or [MRDL]	Meet Primary Standard?	State PHG or Federal (MCLG) or [MRDLG]	Major Sources in Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average				
Aluminum	µg/L	<50	<50	<50	<50	<50	<50	110-340	160 (a)	100-230	170 (a)	<50-100	76 (a)	1000	YES	600	Erosion of natural deposits; residue from surface water treatment processes
Arsenic	µg/L	2-5	4 (a)	<2-3	2	<2-3	2	<2-3	2 (a)	<2-3	2 (a)	3-4	3 (a)	10	YES	0.004	Erosion of natural deposits; runoff from orchards; glass and electronics production wastes
Barium	µg/L	<100	<100	<100	<100	<100-116	<100	110-140	120	120-140	130	<100	<100	1000	YES	2000	Erosion of natural deposits
Bromate (a, bi)	µg/L	<5-13	<5 (a)	NA	NA	NA	NA	NA	NA	NA	NA	<5-12	7 (a)	10	YES	0.1	By-product of ozone disinfection; formed under sunlight
Gross Alpha Particle Activity (c)	pCi/L	4	4	5-5.2	5	<3-5	5	<3-8	5	4-9	6	<3-9	3	15	YES	(0)	Naturally present in environment
Gross Beta Particle Activity (c)	pCi/L	7	7	<4-4	4	<4-5	4	<4-10	4	<4-6	4	<4-5	<4	50	YES	(0)	Naturally present in environment
Nitrate (as NO_3)	mg/L	<2-3	2	<3-23	9	<2-16	9	4-8	8	4-8	8	11-18	16	45	YES	45	Erosion of natural deposits; runoff and leaching from fertilizer use
Nitrate + Nitrite (as N)	mg/L	<0.4-0.7	0.5	0.4-3	2	<0.4-4	2	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	10	YES	10	Erosion of natural deposits; runoff and leaching from fertilizer use
Tetrachloroethylene (PCE)	µg/L	<0.5	<0.5	<0.5-2	<0.5	<0.5-0.8	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	YES	0.06	Discharge from factories, dry cleaners, auto shops (metal degreaser)
Trichloroethene (TCE)	µg/L	<0.5	<0.5	<0.5-5	1	<0.5-2	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	YES	1.7	Discharge from metal degreasing sites and other factories
Turbidity (d)	NTU	0.8	100%	NA	NA	NA	NA	0.08	100%	0.08	100%	0.08	100%	TT	YES	none	Soil runoff
Uranium (c)	pCi/L	3-4	3	2-4	4	<1-5	4	2-3	3	3-4	3	1.6-2	2	20	YES	0.5	Erosion of natural deposits

Health-Based Primary Drinking Water Standards (MCLs) Constituents/Contaminants Detected in Treated Water and Reported on City-Wide Basis

Constituents/Contaminants	Units	Range	Average	State and Federal Primary Standard (MCL) or [MRDL]	Meet Primary Standard ?	State PHG or Federal (MCLG) or [MRDLG]	Major Sources of Contaminants in Our Drinking Water
Bromate (f)	µg/L	Range = <5-8	City-wide Average = <5	10	YES	0.1	By-product of ozone disinfection; formed under sunlight
Copper (at the tap) AL = 1300 (e)	µg/L	number of samples exceeding AL = 0 out of 110	90th Percentile value = 576	TT	YES	300	Internal corrosion of household water plumbing systems
Fluoride	mg/L	Range = 0.7-0.9	Average = 0.8	2	YES	1	Erosion of natural deposits; water additive that promotes strong teeth
Lead (at the tap) AL = 15 (e)	µg/L	number of samples exceeding AL = 3 out of 110	90th Percentile value = 5.6	TT	YES	0.2	Internal corrosion of household water plumbing systems
Chlorine Residual, Total	mg/L	Range = 1.7 - 1.9	Average = 1.8 (a)	[4]	YES	[4]	Drinking water disinfectant added for treatment
Total Coliform Bacteria	% Positives	Range: 0 – 0.5% Coliform positive samples	Average = 0.2% Coliform positive samples	5% of monthly samples are coliform positive	YES	(0)	Naturally present in the environment
Total Haloacetic Acids (HAA5)	µg/L	Range = 2-98	City-wide Average = 29 (a)	60	YES	none	By-product of drinking water disinfection
Total Trihalomethanes (TTHM)	µg/L	Range = 14-106	City-wide Average = 61 (a)	80	YES	none	By-product of drinking water chlorination

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Table II

Calendar Year 2009 Water Quality Monitoring Results

Aesthetic-Based Secondary Drinking Water Standards (SMCLs) Constituents/Contaminants Detected in Treated Water

Constituents/ Contaminants	Units	Los Angeles Aqueduct Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Weymouth Filtration Plant		MWD Diemer Filtration Plant		MWD Jensen Filtration Plant		State and Federal Secondary MCL	Meet Secondary Standard?	Major Sources in Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average			
Aluminum	µg/L	<50	<50	<50	<50	<50	<50	110-240	160 (a)	100-230	170 (a)	<50-100	76 (a)	200	YES	Erosion of natural deposits; residue from some surface water treatment processes
Chloride	mg/L	48-71	60	40-64	48	24-63	48	89-100	98 (a)	89-98	97 (a)	77-82	79 (a)	500	YES	Runoff/leaching from natural deposits; seawater influence
Color (unfiltered)	ACU	3	3	3-5	3	3-7	3	1-2	2 (a)	1-2	2 (a)	1-2	2(a)	15	YES	Naturally-occurring organic materials
Manganese (MCL = 500	µg/L	<20	<20	<20	<20	<20-51	<20	<20	<20	<20	<20	<20	<20	50	YES	Leaching from natural deposits
Odor	TON	<1	<1	<1-1	<1	<1-1	<1	2	2	2	2	2	2	3	YES	Naturally occurring organic materials
Specific Conductance	µS/cm	432-527	488	448-754	648	448-797	648	850-1100	1000 (a)	880-1100	1000 (a)	570-610	590 (a)	1600	YES	Substances that form ions when in water; seawater influence
Sulfate	mg/L	39-54	47	41-150	104	41-150	104	180-260	240 (a)	190-250	240 (a)	56-70	66 (a)	500	YES	Runoff/leaching from natural deposits
Total Dissolved Solids (TDS)	mg/L	242-311	274	260-501	400	275-511	400	510-660	620 (a)	530-640	610 (a)	310-340	330 (a)	1000	YES	Runoff/leaching from natural deposits
Turbidity (g)	NTU	0.1	0.1	0.1-0.3	0.1	<0.1-0.5	0.1	0.05-0.06	0.06 (a)	0.04-0.05	0.05 (a)	0.04-0.05	0.04 (a)	5	YES	Soil runoff
Zinc	µg/L	<50	<50	<50	<50	<50-1000	<50	<50	<50	<50	<50	<50	<50	5000	YES	Run off/leaching from natural deposit

Abbreviations and Footnotes

mg/L = milligrams per liter (equivalent to ppm)
µg/L = micrograms per liter (equivalent to ppb)
ng/L = nanograms per liter (equivalent to ppt)
pCi/L = picoCuries per liter
% = percentage
µS/cm = microSiemens per centimeter
NTU = nephelometric turbidity unit
TON = threshold odor number
CFU = colony-forming unit
ACU = apparent color unit
< = less than

NA = not applicable
NT = not tested
HRAA = highest running annual average

(a) Values reflect Highest Running Annual Average (HRAA). HRAA is the highest of all Running Annual Averages (RAAs). RAA is a calculated average of all the samples collected within twelve months period.

(b) Bromate is tested in water treated with ozone. Bromate has also been found in chloraminated treated water of some LADWP reservoirs exposed to sunlight. Metropolitan Water District of Southern California (MWD) only tests bromate at Jensen Filtration Plant.

(c) Radiological monitoring is performed in cycles of various periods of time. LADWP performed all radiological testing in 2009 for samples collected at Los Angeles Aqueduct Filtration Plant, Northern Combined Wells blend points, and Southern Combined Wells blend points. MWD performed all radiological testing in 2008 for samples collected at Weymouth, Diemer, and Jensen Filtration Plants.

(d) Turbidity is a measure of the cloudiness of the water and is a good indicator of water quality and filtration performance. High turbidity can hinder the effectiveness of disinfectants. The Primary Drinking Water Standard for turbidity level at water filtration plants is less than or equal to 0.3 NTU in at least 95% of the measurements taken in any month and shall not exceed 1.0 NTU at any time. The reporting requirement for treatment plant turbidity is: report the highest single measurement in the calendar year and the lowest monthly percentage of measurements that are less than or equal to 0.3 NTU.

(e) At-the-tap monitoring of lead and copper is conducted every three years as required by the Lead and Copper Rule. LADWP performed at-the-tap testing in 2009. A system is out of compliance if the Regulatory Action Level is exceeded in the 90th percentile of all samples at the customers' taps. Although the City's treated water has little, if any, detectable lead, studies were conducted and corrosion control is scheduled for implementation.

(f) Values reflect annual range and average of samples collected from six open reservoirs: Elysian, Ivanhoe, Los Angeles, Santa Ynez, Silver Lake, and Upper Stone.

(g) Values reflect testing at entry to distribution system.

10 River Supply Conduit

Water Travels through the City

Water from the pump station is carried through a 78" water main to Ivanhoe Reservoir in the Silver Lake area of the City.

unregulated, and are used to revise standards for regulated contaminants. While PHGs are based solely on health effects, primary drinking water standards are based on health effects, technical feasibility and cost.

The report includes health effects from exposure to the contaminant, the relative risk associated with each contaminant, the best available treatment technology to remove or reduce the contaminant down to the PHG, and the cost associated with such treatments. For Los Angeles, the contaminants in water that pose the highest risks are arsenic and disinfection by-products. By prioritizing water quality improvements on contaminants that pose the greatest risks to health, LADWP effectively and efficiently achieves the highest risk reduction at the lowest cost.

LADWP's 2009 Public Health Goals report was completed in July 2010 and can be downloaded from www.ladwp.com or mailed to customers upon request.

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11 Water Storage

Ivanhoe Reservoir

Shade balls filling the reservoir will protect the water from sunlight as the water travels onto nearby neighborhoods.

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Table III Calendar Year 2009 Water Quality Monitoring Results

Unregulated Drinking Water Constituents/Contaminants Detected in Treated Water

Constituents/Contaminants	Units	Los Angeles Aqueduct Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Weymouth Filtration Plant		MWD Diemer Filtration Plant		MWD Jensen Filtration Plant		Major Sources in Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	
Alkalinity	mg/L	92 - 106	100	102 - 176	146	100 - 200	146	100 - 130	120 (a)	98 - 120	120 (a)	84 - 93	90 (a)	Erosion of natural deposits
Bicarbonate (as HCO_3)	mg/L	112 - 129	122	124 - 215	178	124 - 244	178	NT	NT	NT	NT	NT	NT	Naturally occurring dissolved gas; erosion of natural deposits
Boron NL = 1000	µg/L	264 - 420	355	161 - 374	272	108 - 374	272	120 - 140	140 (a)	120-140	140 (a)	190-220	200 (a)	Erosion of natural deposits
Bromide	µg/L	35 - 67	50	34 - 55	45	22 - 88	45	NT	NT	NT	NT	NT	NT	Runoff/leaching from natural deposits; seawater influence
Calcium	mg/L	26 - 30	28	26 - 77	60	29 - 82	60	54 - 78	68 (a)	50 - 75	68 (a)	27 - 33	31 (a)	Erosion of natural deposits; natural hot springs
Chromium, Hexavalent	µg/L	<1	<1	<1 - 3	<1	<1 – 4	<1	<1	<1	<1	<1	<1	<1	Industrial discharge; erosion of natural deposits
Dibromomethane	µg/L	<0.5	<0.5	<0.5-0.7	<0.5	<0.5	<0.5	NT	NT	NT	NT	NT	NT	Industrial discharge
Hardness, Total (as $CaCO_3$)	mg/L	104 - 118	110	103 - 276	214	153 - 279	214	230 - 310	280 (a)	240 - 300	280 (a)	120 - 130	130 (a)	Erosion of natural deposits
Heterotrophic Plate Count Bacteria (HPC)	CFU/mL	NT	NT	NT	NT	NT	NT	<1 - 2	<1	<1 - 1	<1	<1 - 20	<1	Naturally present in the environment
Magnesium	mg/L	9 - 11	9	9 - 20	16	9 - 22	16	23 - 30	27 (a)	23 - 29	27 (a)	11 - 12	13 (a)	Erosion of natural deposits
Methyl Ethyl Ketone (MEK, 2-Butanone)	µg/L	<5 - 9	<5	<5	<5	<5	<5	NT	NT	NT	NT	NT	NT	Industrial discharge
N-Nitrosodimethylamine (NDMA) NL=10	ng/L	<2	<2	<2	<2	<2	<2	<2 - 3	<2	<2	<2	<2 - 5	3	By-product of chloramination
pH	Unit	7.3-7.8	7.5	7.2-7.8	7.5	7.2-7.9	7.5	7.8-8.0	7.9	7.8-8.0	7.9	8.1-8.3	8.2	Naturally occurring dissolved gases and minerals
Phosphate (as PO_4)	µg/L	49 - 60	55	17 - 110	89	26 - 360	89	NT	NT	NT	NT	NT	NT	Erosion of natural deposits, agricultural run-off
Potassium	mg/L	3 - 4	4	3 - 4	4	3 - 5	4	4 - 5	5 (a)	4 - 5	5 (a)	2 - 4	3 (a)	Erosion of natural deposits
Radon (C)	pCi/L	<100	<100	175 - 176	176	143 - 506	176	<100	<100	<100	<100	<100	<100	Decay of natural deposits
Silica (as SiO)	mg/L	14 - 20	16	15 - 22	20	19 - 23	20	NT	NT	NT	NT	NT	NT	Erosion of natural deposits
Sodium	mg/L	50 - 56	53	38 - 55	49	43 - 85	49	84 - 100	93 (a)	86 - 100	98 (a)	68 - 74	68 (a)	Erosion of natural deposits
Total Organic Carbon (TOC)	mg/L	1 - 2	2	0.4 - 1	0.9	<0.3 - 1	0.9	1.9 – 2.4	2	2 - 3	2	1 - 2	2	Erosion of natural deposits
Vanadium NL = 50	µg/L	<3	<3	<3 - 7	<3	<3 - 4	<3	<3 -4	3	<3 - 3	3	6 - 7	6	Erosion of natural deposits

Commonly Used Terms

Compliance: A drinking water standard based on the health risk (primary standards) and aesthetic (secondary standards) exposure of a contaminant to consumers. For example, bacteria and nitrate have strict limits that must be met at all times due to the acute effects they can cause. Other standards, like small amounts of disinfection by-products and man-made chemicals, have standards that are based on a lifetime of exposure because the risk to consumers is very low. Compliance with most standards is based on an average of samples collected within a year. This allows for some fluctuation above and below the numerical standard, while still protecting public health.

Detection Limit for Reporting Purpose (DLR): DLR means the designated minimum level at or above which any analytical finding of a contaminant in drinking water resulting from monitoring required under Title 22 Code of Regulations shall be reported to the California Department of Public Health (CDPH).

Maximum Contaminant Level (MCL): MCL is the highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the Public Health Goals (PHGs) or Maximum Contaminant Level Goals (MCLGs) as is economically and technologically feasible. Secondary MCLs are set to protect odor, taste, and appearance of drinking water. For certain contaminants, compliance with the MCL is based on the average of all samples collected throughout the year.

Maximum Contaminant Level Goal (MCLG): MCLG is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. Environmental Protection Agency (USEPA).

Maximum Residual Disinfectant Level (MRDL): MRDL is the highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal (MRDLG): MRDLG is the level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants. MRDLGs are set by the USEPA.

Notification Level (NL): NL is the Health-based advisory levels established by CDPH for chemicals in drinking water that lack maximum contaminant levels (MCLs).

Primary Drinking Water Standard (PDWS): MCLs and MRDLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.

Public Health Goal (PHG): PHG is the level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (OEHHA).

Regulatory Action Level (AL): AL is the concentration of a contaminant which, if exceeded, triggers treatment or other requirements that a water system must follow. ALs are set by the USEPA.

Treatment Technique (TT): TT is a required process intended to reduce the level of a contaminant in drinking water. For example, the filtration process is a treatment technique used to reduce turbidity (the cloudiness in water) and microbial contaminants from surface water. High turbidities may be indicative of poor or inadequate filtration.

Table IV Calendar Year 2009 Water Quality Monitoring Results

Drinking Water Disinfection By-Products Reported on Area-Wide Basis

Constituents/ Contaminants	Units	Central Los Angeles		San Fernando Valley		Western Los Angeles		Harbor / Eastern Los Angeles		Major Sources in Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	
Bromodichloromethane (BDCM)	µg/L	4 - 30	12	5 - 42	14	3 - 44	22	2 - 26	12	By-product of chlorine/ chloramine disinfection
Bromoform	µg/L	2 – 24	8	1 - 42	12	1 - 38	12	4 - 23	6	By-product of chlorine/ chloramine disinfection
Chlorate NL = 800	µg/L	118 - 255	172	54 - 863	465	176 - 978	571	ND - 74	47	By-product of chlorine disinfection
Chloroform	µg/L	2 - 23	7	2 - 28	7	2 - 43	17	1 - 25	10	By-product of chlorine/ chloramine disinfection
Dibromochloromethane (DBCM)	µg/L	6 - 41	17	6 - 50	23	5 - 45	27	6 - 41	14	By-product of chlorine/ chloramine disinfection
Dibromoacetic Acid (DBAA)	µg/L	<1 - 16	7	<1 - 23	9	3 - 23	13	<1 - 19	4	By-product of chlorine/ chloramine disinfection
Dichloroacetic Acid (DCAA)	µg/L	<1 - 20	8	<1 - 28	7	2 - 48	18	<1 - 13	6	By-product of chlorine/ chloramine disinfection
Monobromoacetic Acid (MBAA)	µg/L	<1 - 3	1	<1 - 5	1	<1 -5	2	<1 - 4	<1	By-product of chlorine/ chloramine disinfection
Monochloroacetic Acid (MCAA)	µg/L	<2 - 3	<2	<2 - 6	<2	<2 - 9	3	<2 - 3	<2	By-product of chlorine/ chloramine disinfection
Trichloroacetic Acid (TCAA)	µg/L	<1 - 7	3	<1 - 10	2	<1 - 51	8	<1 - 8	4	By-product of chlorine/ chloramine disinfection

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12 Local Pump Station

Fletcher Pump Station

Additional chlorine is added before large pumps send the water to L.A. neighborhoods, east of Ivanhoe Reservoir.

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Impact of Public Water System Contaminants

Lead Exposure from Plumbing Materials

LADWP monitors lead contents in source water and the distribution system and has not found detectable amounts. If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with lead service lines and home plumbing. The LADWP is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting in the pipes for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. This water can be collected and used to water plants. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at http://www.epa.gov/safewater/lead.

Pharmaceutical and Personal Care Products

Very low levels of pharmaceutical and personal care products (PPCPs) are increasingly being detected in U.S. drinking water supplies. PPCPs include medicines, shampoos, soaps, detergents, lotions, and perfumes. Currently, neither the state or federal government require LADWP to test for PPCPs. However, as a forward looking utility, LADWP conducts its own monitoring for these compounds.

In 2009, LADWP tested its source and treated waters for PPCPs. The amount of PPCPs detected was so minute that no adverse health effect from exposure has been reported. LADWP continues to study the issue with several other utilities and the Water Research Foundation. Customers can do their part by disposing unwanted medications into a waste receptical—not down a toilet or drain.

13 An L.A. Neighborhood

The Journey Ends

Water passes through the interior plumbing of a home to be used for many purposes, including drinking, cooking, bathing, laundry, toilet flushing and as an eco-friendly alternative to bottled water.

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About This Report

The 2009 Water Quality Report was prepared by the Los Angeles Department of Water and Power (LADWP). This report is required by the California Department of Public Health (CDPH) and was prepared in accordance with CDPH guidelines. It was prepared, printed and mailed to you at a cost of 35 cents.

Contact Information

LADWP, the largest municipal utility in the nation, was established more than 100 years ago to provide a reliable and safe water and electric supply to the City's 4 million residents and businesses.

LADWP is governed by a five-member Board of Water and Power Commissioners, appointed by the Mayor and confirmed by the City Council. The Board meets regularly on the first and third Tuesdays of each month at 1:30 p.m. Meetings are held at:

Los Angeles Department of Water and Power
111 North Hope Street, Room 1555H
Los Angeles, CA 90012-2694

The meeting agenda is available to the public on the Thursday prior to the week of the meeting. You can access the Board agenda at www.ladwp.com or by calling (213) 367-1351.

For general information about LADWP, call 1-800-DIAL DWP (1-800-342-5397) or visit www.ladwp.com.

For questions regarding water quality, call the LADWP Water Quality Customer Services Group at (213) 367-3182.

For questions regarding this report, please call Dr. Langford Book at (213) 367-3199.

Want to know more about your drinking water and related regulations?

Los Angeles Department of Water and Power	www.ladwp.com
California Department of Public Health (CDPH)	www.cdph.ca.gov
U.S. Environmental Protection Agency (USEPA)	www.epa.gov

This report is printed on recycled paper.

This Message for Non-English Speaking Customers

This report contains important information about your drinking water. If you have any questions regarding this report, please contact us at (800) 342-5397.

Spanish

Este informe contiene información importante sobre su agua potable. Si tiene alguna pregunta sobre este informe, por favor comuníquese con nosotros llamando al (800) 342-5397.

Russian

В этом отчете содержится важная информация о вашей питьевой воде. Если у вас есть вопросы по этому отчету, вы можете позвонить по телефону (800) 342-5397.

Farsi

این گزارش حاوی اطلاعات مهمی در مورد آب آشامیدنی شماست. چنانچه سوالی در مورد این گزارش دارید لطفا با شماره تلفن (800)342-5397 با ما تماس بگیرید.

Japanese

この報告書には皆さんの飲料水に関する重要な情報が含まれています。この報告書に関して何かご質問があれば(800) 342-5397 までお問い合わせください。

Armenian

Այս զեկույցը պարունակում է կարևոր տեղեկություններ ձեր խմելու ջրի մասին. Այս խնդրի մասին որևէ հարցում ունենալու պարագայում կարող եք հեռախոսել մեզ՝ (800) 342-5397 հեռախոսահամարով:

Arabic

يحتوي هذا التقرير على معلومات هامة عن مياه الشرب في لوس انجلوس. اذا كان لديك أسئلة عن هذا التقرير ترجو الاتصال بنا على الرقم (800) 342-5397 .

Korean

이 보고서는 여러분의 수돗물에 관한 중요한 정보를 포함하고 있습니다. 이 보고서에 관해 질문이 있으시면, (800) 342-5397 로 연락 주십시오.

Chinese

本报告包含有关您饮用水的重要资讯。您对本报告如有任何疑问，请致电：(800) 342-5397。

Vietnamese

Báo cáo này có tin tức quan trọng về nguồn nước uống của quý vị. Nếu quý vị có thắc mắc về báo cáo này, xin liên lạc với chúng tôi tại số (800) 342-5397.

Thai

รายงานนี้ประกอบด้วยข้อมูลสำคัญเกี่ยวกับน้ำดื่มของท่าน ถ้าหากท่านมีคำถามใดๆเกี่ยวกับรายงานนี้ กรุณาติดต่อเราได้ที่ (800) 342-5397

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Los Angeles
Department of
Water & Power

2009 Annual Water Quality Report
Los Angeles Department of Water and Power
P.O. Box 51111 Room 1213
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Water Quality Report

AR0069556

Solid Resources Infrastructure Strategy
Facilities Plan

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Solid Resources Program

Prepared by: Karen Coca
Solid Resources
Infrastructure Development

November, 2000

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AR0069558

Introduction

The City through its Bureau of Sanitation in the Department of Public Works has provided solid resources management services to residential households within the City of Los Angeles since 1890. Every week three collection vehicles visit each of our 720,000 customers to separately collect recyclables, yard trimmings and refuse at curbside. The Bureau also provides special residential collection services such as bulky item, appliance and bulky brush collection.

The City's collection of solid waste has changed dramatically since its inception in 1890 when the first solid waste crematory (incinerator) was constructed and the City provided disposal service. In later years food and organic waste was collected for delivery to hog ranches, metals and other materials were reused or recycled, and combustible rubbish was burned in backyard incinerators or collected and disposed by private contractors.

In 1943, residential collection was turned over to City forces. In 1957 after backyard incineration was banned as a part of the smog control program, the City added the collection and disposal of combustible rubbish as part of its refuse collection program. Beginning in 1957 the City used only landfill disposal sites located in and around the City to dispose of all materials collected at curbside.

In 1961, Sam Yorty was elected Mayor of Los Angeles. Part of his campaign platform was the promise that, if elected, he would end the requirement to separate refuse at the curb. He accused his opponent, the incumbent Norris Poulson, of *"forcing Los Angeles housewives to perform coolie labor for a salvage firm."* After his election, in 1964 all household refuse was then collected in a single container and disposed in local City, County and private landfills rather than being recycled. During the 1970s and 1980s, local City landfills began closing and new landfill sites became harder to secure. In the early 1980s the Bureau of Sanitation began investigating recycling and waste to energy technology as a way to reduce our reliance on landfills.

City Rubbish Collection 1943

A waste to energy facility was authorized for study in 1979, but in 1987, after eight years of development, the project was canceled. Also, during this time pilot curbside recycling operations were initiated in West Los Angeles in 1985 and expanded to the San Fernando Valley in 1987 and into all Council Districts in 1989, finally reaching a total of 95,000 households.

In order to control the growing waste stream and improve operational efficiency, the Mayor and City Council approved the implementation of a full curbside recycling and automated refuse and yard trimmings collection program in early 1990, with the program roll out starting later that same year. The yellow bin recycling program and the automated collection system became a Citywide program in 1995. In 1997, just two years after the five year implementation of the yellow bin system, the City embarked on the next generation of curbside recycling and began the implementation of the automated blue container recycling system. This new system, which is the state of the art in recycling, was completely rolled out Citywide by December 1998 in a record 18 month period of time.

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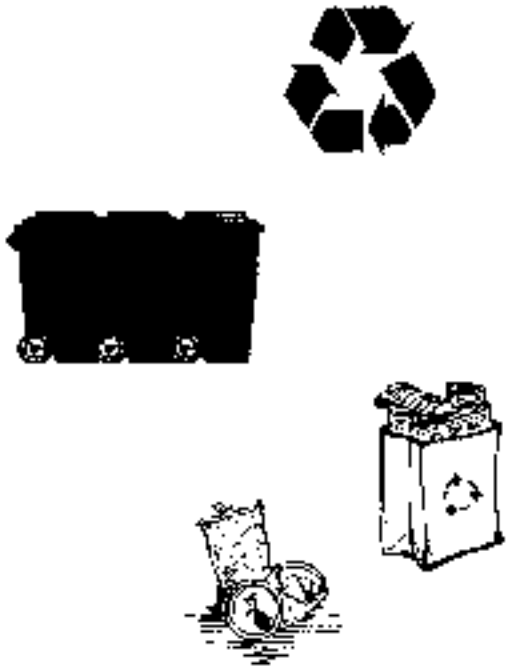
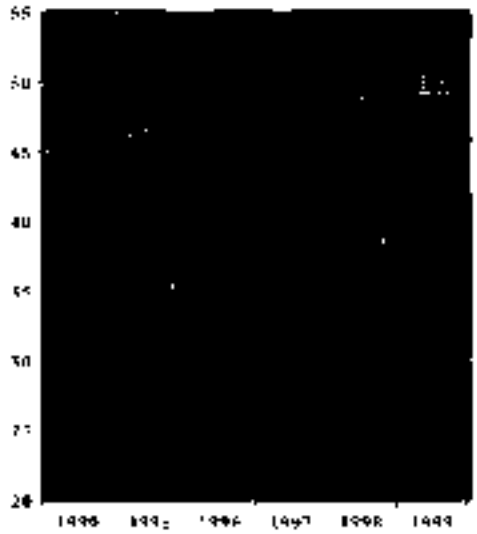
Current Solid Resources Operations



The City's solid waste management practices have come a long way since 1890 and have transitioned from a collection and disposal oriented structure to a recycling operation back to a disposal operation and since 1990 returning whole heartedly back to recycling. Even the term for the materials we collect and manage has changed from solid *waste* to solid *resources*. Programs have been established throughout the City that have contributed to a Citywide waste diversion rate of 49% in 1999, and the City is expected to surpass the mandated 50% diversion rate in 2000. Innovative programs must be implemented to reach the City's 70% diversion goal in 2020.

The shift in emphasis in the Bureau's solid resources business has also affected our need for support facilities. Where, for example, the City used to own and operate several landfills which provided disposal services to our collection staff, the Bureau now disposes of the remaining refuse it collects in three landfills, two operated by private entities and one by the Los Angeles County Sanitation Districts. The City's involvement in its landfills is now focused on closure, maintenance, and ultimate restoration of the six inactive City owned landfills. Recycling and Transfer facilities provide the necessary link between the collection of solid waste and its ultimate disposal.



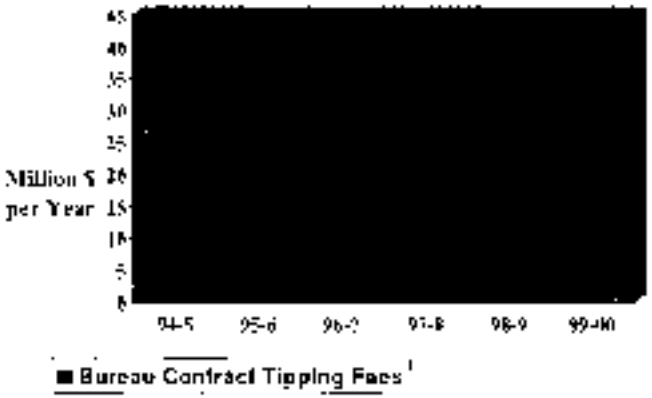
Diversion increases yearly

The doubling of the recyclables collected at curbside has resulted in the City contracting with several Material Recovery Facilities owned and operated by the private sector to receive, clean, process, and market the recyclables. The Bureau also has three City operations and several contracts with private contractors to accept, clean, grind, and mulch or compost our yard trimmings which is a significant element in our achieving such a high recycling rate. The City now needs to invest in infrastructure to support these new solid resources management activities. Acquiring City-owned and operated facilities may provide more control over future cost increases and more options for managing the materials we collect at curbside. The development of infrastructure, in most cases, could result in a net cost savings when compared to future private sector contract costs.

AR0069560

Current issues in solid resources management

The waste management industry has recently experienced unprecedented consolidation, transitioning from many companies to a few mega-companies. For example, after the merger between giants Waste Management, inc and USA Waste, a trade paper reported that prices have been raised at many Waste Management disposal facilities across the nation--- increases such as 40 percent in Pennsylvania, 29 percent in Virginia, and 136 percent at a landfill in Ohio! Analysts predict that other companies will follow with price hikes. Also, Allied Industries, a waste management giant based in Phoenix, Arizona, acquired Browning Ferris Industries, the owners of the Falcon Transfer Station and Sunshine Canyon Landfill (both used by the City), for a price totaling about $9.1 *billion* dollars. **Future prices for transfer and disposal in Los Angeles are expected to only go higher.**



The City does not own the supporting infrastructure facilities such as transfer stations and Material Recovery Facilities which are critical to support our core business of servicing 720,000 households with waste management services. This situation exposes the City to capricious changes in prices and control by these large private waste management companies. The Bureau's attempt to exercise its purchase option for the Central Los Angeles Recycling and Transfer Station was met by the owner reporting that a sale of the facility was made to Republic Industries for over $70 million! Through the sale of the property at that price, the new owner will need to recoup its costs through higher contract rates in the future. City ownership of facilities could provide us with both cost control and greater operating efficiencies. **We must aggressively pursue cost effective contract services or the siting and construction of City-owned facilities to contain costs to City residents.**

AR0069561

Solid Resources Plan Development

Plan Development

On July 28, 1995, the Bureau was directed by the City Council to prepare an Action Plan to examine: (1) the waste disposal alternatives available when the Lopez Canyon Landfill closed, (2) measures to increase waste diversion, and (3) revenue raising alternatives to finance new solid resources projects. On December 13, 1995 the Action Plan prepared by the Bureau was considered by the City Council and the Bureau was directed by the City Council to develop a plan to procure/construct City-owned transfer facilities in the West Los Angeles, Valley, and Central City areas so that the City could gain greater control over the management of its waste stream and future cost increases.

After investigating the City's long-term needs for these solid resources management services, the Bureau presented a preliminary report (August 27 1997) to the Board of Public Works containing several recommendations recommending the acquisition and development of City-owned solid resources management facilities, and other capital improvements. Upon review of that report the Board directed the Bureau to hold a series of public workshops in October, 1997 to gather additional input and foster discussion of the items with concerned agencies, the industry and the public. The Bureau also formed a Process Action Team (PAT) composed of staff, union representatives, and Solid Waste Citizens Advisory Group (SWCAG) members to discuss and provide direction concerning the proposed recommended actions.

In response to the comments received at the workshops and further investigation by the Bureau, the previous report and recommendations were revised to reflect the changing emphasis of waste management and recycling within the City and the industry.

AR0069562

Plan Objectives

As a result of further review and the comments received on the draft Solid Resources Infrastructure Plan, the following twelve key strategies were identified.

(1) *Develop a Transfer facility and/or Recycling Center in the Central Los Angeles area.* The Bureau has launched an aggressive program to acquire, permit and construct a state of the art transfer facility in the downtown Los Angeles area which is environmentally sound and cost effective.

(2) *Develop a Transfer and/or Recycling facility to serve the West Los Angeles area.* This state of the art, cost-effective facility will serve the West Los Angeles area, possibly other nearby City collection routes and may serve other area cities by contract to manage recyclables collected in their curbside programs.

(3) *Relocate the East Valley Collection Yard. Develop a new East Valley collection yard facility as approved by the Mayor and Council on August 5, 1998 (CF 96-0705-S2).* This larger site will allow collection yard operations, truck maintenance shops, container warehouse facilities and residential drop-off.

(4) *Develop permanent Household Hazardous Waste (HHW) drop-off facilities for City residents to provide year-round services and encourage safe disposal of these materials.* These new facilities will ultimately replace the existing Mobile Program.

(5) *Continue to pursue the development of yard trimmings processing, mulching and shipping facilities and marketing of the finished product within the City.* Successful programs have already been established in the San Fernando Valley and Harbor areas.

(6) *Continue to research and develop the use of Material Recovery Facilities to preprocess all residual waste prior to delivery to a disposal site.*

(7) *Establish a capital improvement expenditure program to upgrade all collection yard facilities to meet current environmental and health and safety standards, and to provide an adequate working environment for our employees.* New regulations requiring treatment of stormwater runoff and purchase of alternative fuel collection trucks will drive the cost of yard upgrades.

(8) *Perform closure construction at all six inactive landfill sites owned by the City within the next four years. Post-Closure monitoring and maintenance will continue after closure construction.*

(9) *Acquire the minimal long-term disposal capacity that the City will need beyond the year 2001.*

(10) *Develop a financing plan with the assistance of the Office of Administrative and Research Services for the recommended Solid Resources capital improvement program.*

(11) *Identify a method of receiving Citywide public review of plans and actions in the Solid Resources programs similar to the Solid Waste Citizen's Advisory Group.*

(12) *Develop a comprehensive and continual Public Education & Community Outreach program designed to educate and inform the public about the City's solid resources programs and strategies.* The Bureau will report back with the plan and budget costs.

These are the key objectives of the Plan that will provide the City with the necessary solid resources management infrastructure to serve our customers into the next Century. As other changes take place over time further actions will be necessary to bring the City the best possible services at the lowest cost.

AR0069563

2.0 Solid Resources Programs And Facilities Objectives

2.1 Plan Objective No. 1 - Central Los Angeles Transfer Station Development

Although the amount of refuse collected and disposed by the Bureau has decreased from over 1,200,000 tons in fiscal year 1993-94 to 863,500 tons in fiscal year 1999-00, the City must still maintain disposal contracts to provide guaranteed disposal capacity. Although our disposal needs will continue to decrease with the implementation of more intensive recycling efforts, disposal capacity needs will continue for the foreseeable future.

The City no longer owns and operates its own landfills. To provide cost containment and control for the future, the Bureau believes that a publicly owned and operated transfer station is essential. This facility can be used as a focal point for the gathering and shipping of materials to more remote landfills. On July 28, 1995, the Bureau was directed by the City Council to prepare an Action Plan with an examination of the waste disposal alternatives available when the Lopez Canyon Landfill closed, measures to increase waste diversion, and revenue raising alternatives to finance new solid resources projects. The Action Plan was considered by the City Council on December 13, 1995. On December 19, 1995, the Bureau was directed by the City Council to procure/construct City-owned transfer facilities in the West Los Angeles, Valley, and Central City areas so that the City can maintain greater control over its waste stream (Council File #95-0859). The Bureau is involved in the following projects in response to the Council directive:

2.1.1 Central Los Angeles Recycling and Transfer Station

To reduce contract costs of transfer services and increase our flexibility in providing services in the Central City area, the City is seeking to establish a recycling and transfer facility in Central Los Angeles.

In August, 1997, the Board of Public Works as a result of a report from the Bureau began consideration of recommendations to develop recycling and transfer facilities in the Central Los Angeles and Valley areas of the City. The recommendations included the acquisition of the Central Los Angeles Recycling and Transfer Station (Central L.A.) currently under contract to the City. The current contract includes a buy-out clause that gave the City the option to purchase the facility under certain conditions in December 1998, and again in December 2003. The buy-out clause includes procedures for valuation of the property.

AR0069564

On June 16, 1998, the City Council approved the issuance of Letters of Interest to BLT Enterprises, the owner, and Browning-Ferris Industries, the operator, stating that the City intended to exercise its purchase option with respect to the Central L.A. facility. The City followed up by conducting a land and business appraisal of the facility. The owner in a separate action negotiated an option and sale of the Central L.A. facility to Republic Industries. The owner has stated that the sale price was approximately $70 million. The sale of the facility at this price has excluded the City from the sale process.

A task force was formed within the Bureau to examine the potential for City operation of the Central L.A. facility. The Task Force recommended several actions in its final report to make the implementation of City owned and operated transfer facilities a success. Task Force staff also worked with employee unions and other City departments.

Estimated costs for operation of a City-owned facility, as of late 1999, are as follows:

City Operation of Recycling and Transfer Station
2,000 tons per day

Personnel	Salary	Benefits	Indirect	Cost per year
Full Time City Staff	$1,601,095	$605,578	$758,758	$3,965,431
Scheduled Overtime				$200,419
Operating Costs within Transfer Station				$284,929
Hauling Costs				$661,170
Equipment Maintenance				$1,178,257
Capital Costs - Equipment				$632,714
Retipping (Any Top)				$26,867
Total Yearly Estimated Cost				$6,887,525
Total Cost per Ton				$11.28

New Transfer Station
(Oxnard, California)

AR0069565

The Task Force also recommended that staff investigate the procurement of suitable land/property in downtown Los Angeles to construct a City-owned and operated recycling and/or transfer facility. The Bureau estimates that the permitting, design and construction of a new transfer facility to manage City-collected material would be approximately $12 million with an additional $5 million for equipment including transfer vehicles, significantly lower than the stated purchase price of the Central L.A. facility.

The Bureau is now on an aggressive course to site and develop a recycling and transfer station within the Central L.A. service area. In late 1999, the Bureau was approached by the L.A. County Sanitation Districts to discuss the development of a potential joint recycling and transfer facility. The resulting Joint Powers Agreement (JPA) will lay the groundwork for a facility that will serve the City as well as private haulers well into the 21st century through a cooperative equity partnership.

The development of a transfer station would be approximately $17 million as shown above. If the development of the facility was through a JPA with the L.A. County Sanitation Districts, the City may be able to reduce its up-front investment costs by paying capital development costs through tipping fees, while remaining an equity partner.

2.1.2 Other Transfer Station Services

The Bureau will also continue to procure or acquire transfer station services throughout the City as needed. For example:

(1) The Bureau currently contracts with the Falcon/BFI transfer station in the Harbor for refuse transfer services.

(2) The Bureau currently contracts with Southern California Disposal for refuse transfer services at their facility in Santa Monica.

(3) To further serve the West Los Angeles area, the Bureau has a new program to use direct transfer trailers - where the material is pushed directly from the collection vehicle into a trailer without the need for a transfer facility. This small scale transfer activity could serve as a bridge during development of larger, permanent transfer facilities.

(4) The Bureau is investigating the potential of developing a recycling and/or transfer facility at 5000 West Jefferson to serve the West Los Angeles area.

(5) To serve the San Fernando Valley when local disposal is not available, the Bureau will continue the planning process for a City-owned transfer station.

(6) The Bureau will continue to investigate options to procure cost-effective transfer station services through contract.

AR0069566

2.2 Plan Objective No. 2 - Western Facility Development

The Bureau should develop a Recycling and/or Transfer Center in the Western portion of the City to process and/or transfer the materials collected in this area. Siting is the greatest challenge in the Western area of Los Angeles, as the amount of industrial zoned land is limited. In 1996, the Bureau acquired a five acre parcel of land on Jefferson Boulevard zoned M1-1, located in the City and less than one mile from the Culver City transfer station. Three acres of the site have been graded and paved for parking of recycling and employee vehicles, and a temporary office trailer has been installed.

Prior to 1994 there was no Recycling Center located in the Western District. The recyclables from this District were transported to Recycling Centers located in either downtown L.A. or the San Fernando Valley. The current contractor built a Recycling Center on Jefferson Boulevard near the City property which transfers the recyclables collected in the Western District. Currently the recyclables are shipped from the contractor's facility to another location to be processed.

The Bureau has run pilot programs to utilize both the City of Culver City transfer station and the Southern California Disposal transfer station in Santa Monica. Both are currently utilized for about 100 tons per day of the refuse and 50 tons per day of the yard trimmings collected in the Western District.

Develop a Transfer and Recycling Center to serve the West Los Angeles area.

-Prepare a feasibility report and construction estimate for services to be provided at the site.

-Acquire financing and begin site assessments of available properties.

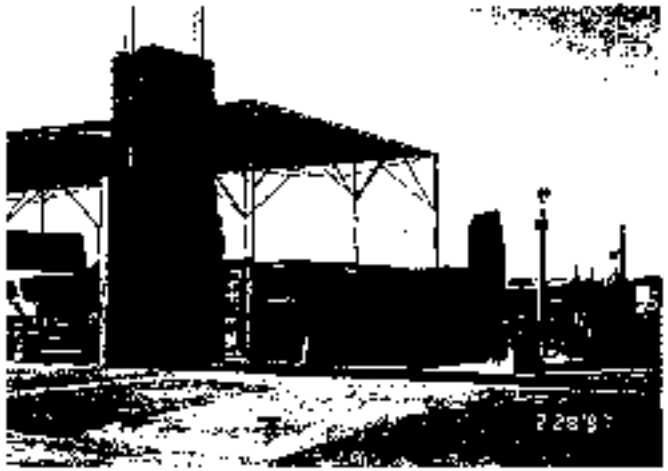
AR0069567

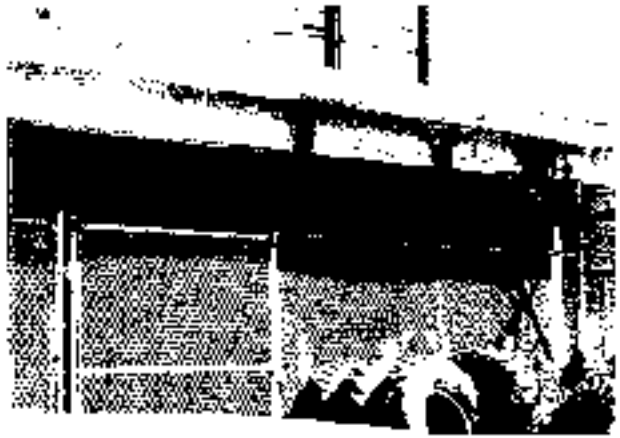
2.3 Plan Objective No. 3- East Valley Solid Resources Yard Relocation

The Northridge Earthquake in January 1994 caused an estimated $25 billion in damage. The current East Valley Collection Yard, located on San Fernando Road in Sun Valley, was damaged by the event as follows:

The entrance gate wall was damaged beyond repair;
The Maintenance/repair garage was partly demolished, and a 'temporary' carport-type building erected in its place;
Roof structures were deformed;
Employee parking was structurally damaged; and
I-beam and wall connections in the tire store and garage buildings were damaged.

The City qualified for reimbursement of approximately $750,000 from the Federal Emergency Management Agency (FEMA) for the replacement and repair of earthquake-damaged buildings at the East Valley Collection Yard. This money will be used for construction of a new yard at another site. The City has chosen to relocate the yard to a new site which is larger and more suitable for this use, leaving the site on San Fernando road available for development.





East Valley Earthquake Damage

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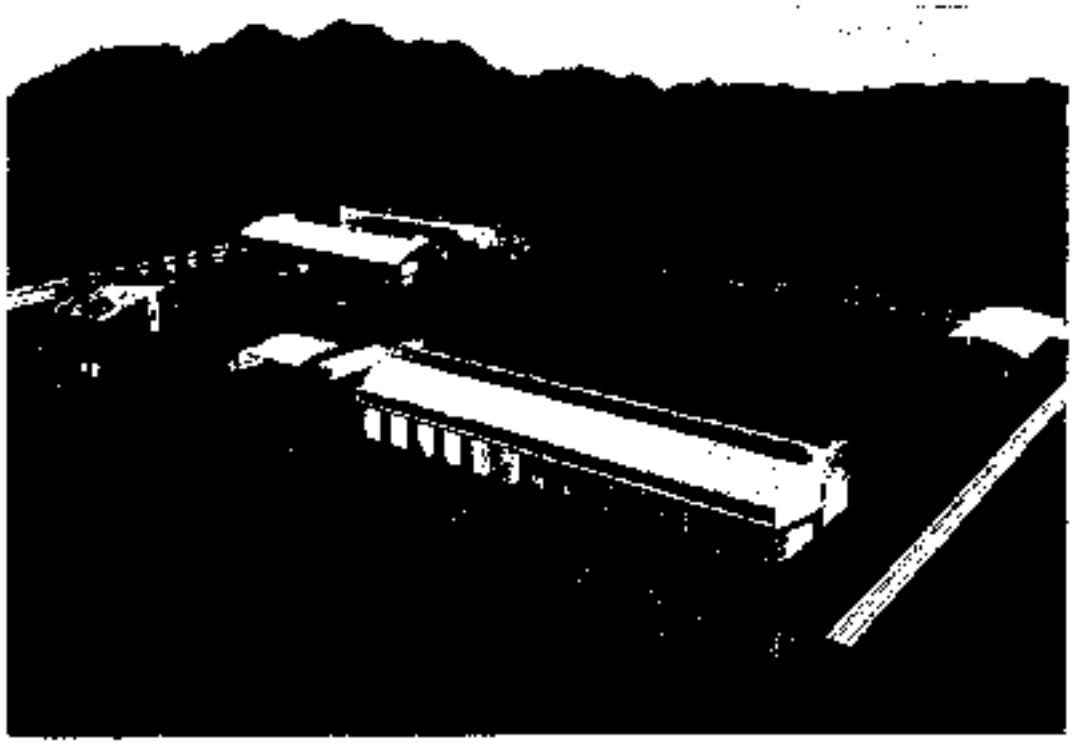
The Bureau investigated the potential for using another site to develop a new East Valley collection yard facility, and a site was found in Sun Valley at 11050 Pendleton Street which is properly zoned and large enough (about 14 acres) to provide other services on the same site that will result in increased efficiency for our collection programs and expanded services to the local residents. The Bureau has acquired the property from the Department of Water and Power (DWP) to on Pendleton Street to develop as a new East Valley collection yard.

The expanded services to residents will include the development of residential drop-off facilities for recyclables, bulky items, and a special area for Household Hazardous Waste (HHW). A transfer facility can be developed if it becomes necessary. Both the development and the operation of the site are cost-effective when compared to the redevelopment of the current site on San Fernando Road.

East Valley Administration Building
Conceptual Design



On August 5th, 1998, the City Council authorized the Department of General Services to negotiate with the DWP for lease and transfer of jurisdiction for the property at 11050 Pendleton Street to the Department of Public Works. An authorization was also given to the Bureaus of Sanitation and Engineering to begin the environmental review process for the development of the new collection yard.

The Bureaus of Sanitation and Engineering have worked together to prepare the design for the site and to prepare required environmental documentation and permits. Development of the site is proceeding on schedule, with site preparation/excavation (to be performed by City crews) scheduled to begin in mid 2000, and construction beginning in mid 2001. Estimated capital needs for the relocation of the East Valley Collection Yard is approximately $25 million.

AR0069569

2.4 Plan Objection No. 4 - Permanent Household Hazardous Waste Facilities

Under the agreement with the County of Los Angeles, the Bureau has been operating its Household Hazardous Waste (HHW) collection program since 1989, serving over 150,000 households and disposing of 12 million pounds of HHW. Through this agreement, the City educates and informs City and County residents about HHW and local collection events. The City is reimbursed for its costs through a $.34 per ton fee on each ton of refuse disposed in the County, administered by the County Department of Public Works. At the request of the Mayor's Office, the Bureau began the Conditionally Exempt Small Quantity Generator program (CESQG) in 1998. The CESQG program provides small businesses with a legal and affordable solution to hazardous waste disposal,as the generators pay only the fees charged to the City by our HHW contractors.

The City conducts approximately two multi-day collection events per month. Three full-time City personnel handle the planning, siting, permitting, and logistics and two contractors handle the on-site operations at each event. Public notifications is done using event flyers and mailing of postcards. Public Service Announcements are sent to radio and television stations and press releases are mailed to newspapers, both dailies and non-dailies. All of these efforts are documented and used to request reimbursement from the County.

In order to meet the needs of residents and businesses and remove HHW from refuse and landfills, the Bureau will develop up to five HHW/Used Oil facilities throughout the City. These facilities will complement and in some areas replace the existing Mobile Program. Some of the potential facilities are as follows:

(1) The City of Santa Monica has an existing HHW drop-off facility for their residents. A Memorandum of Understanding is being drafted to allow City and County residents to dispose of HHW at this site.

(2) A grant of $290,000 was awarded to the City and six other jurisdictions including the cities of Bell, Bell Garden, Cudahy, Huntington Park, South Gate and Vernon by the California Integrated Waste Management Board for the development of a permanent HHW facility. This facility must be on-line by mid-2001 due to the grant restrictions. The Bureau is proposing to site a facility at the South Central District Yard.

(3) Through the relocation of the East Valley Collection yard, the Bureau has included in the design a permanent HHW facility. Construction is scheduled to take place in mid 2001.

(4) Other potential sites may be in the West Valley and Harbor areas, possibly in conjunction with other Bureau Solid Resources projects.

AR0069570

2.5 Plan Objective No. 5 - Yard Trimmings Processing Facilities

The Bureau currently uses a combination of contract and City-owned facilities to process and beneficially reuse the yard trimmings collected by City crews at curbside. Successful new programs operated by City employees in partnership with the Bureau of Street Services and the Harbor Department now process an average of 250 tons of yard trimmings per day at the Van Norman Reservoir in the North San Fernando Valley and a similar mulching site in the Harbor area. To further reduce contract costs associated with processing and transportation of yard trimmings for beneficial reuse, the Bureau intends to take positive steps to reduce the City's dependence on private service contracts when such use will lower program costs.

The Bureau collects over 400,000 tons of yard trimmings per year separated at curbside by our residents. Over the last several years, yard trimmings diversion programs have contributed 30% to the diversion rate for residents receiving curbside service. The 1,600 tons of yard trimmings collected per day are taken to several processors which clean the material of residue, chip it into small pieces, and either mulch the material on-site or transport it to other distant locations where the material is beneficially reused. Currently, nine contracts are held by the Bureau for a range of services to handle yard trimmings. The estimated cost for yard trimmings processing and reuse in the 2000 - 01 Fiscal Year budget is over $16 million dollars, even with the cost savings provided by the City operated facilities.

Acquire and Develop sites for the Processing, Mulching and/or Composting of Yard Trimmings

- Expand Processing Operations to Provide material.

- Develop joint programs for processing and/or spreading mulch with other agencies or private contractors where possible.

- Pursue other contractual opportunities to lower program costs for yard trimmings.

Several actions have been taken to lower the Bureau's contract costs and to control future cost increases. Actions include a new contract with a transfer station in the Central L.A. area that allows material that had a high cost due to 'double transfer' to now be received by one processor at a lower cost, reducing the Bureau's contract costs by over $700,000 per year. Other yard trimmings contract costs have been renegotiated at a lower rate to remain competitive in the current marketplace.

AR0069571

2.5.1 Van Norman Joint Processing Facility

A joint mulching operation with the Bureau of Street Services at the Van Norman Dam receives Sanitation-collected yard trimmings delivered to the site where it is cleaned, processed, and spread at the site for weed and erosion control or transported to farms for use as mulch. The site manages approximately 200 tons per day of Sanitation collected yard trimmings for a contract cost savings over $1.4 million per year. Staff is also accomplishing the objective of using mulch from the site at City parks and facilities whenever possible.

2.5.2 Harbor Processing Facility

The Bureau has established a yard trimmings processing site located on Harbor Department property. 50-70 tons per day of yard trimmings from the Harbor area collected by the Bureau are cleaned, processed and delivered by the Bureau for use as weed and erosion control in the Harbor area. This program reuses material from the immediate area, provides aesthetic benefits for the Harbor Beautification Project, and saves over $600,000 per year in contract costs.

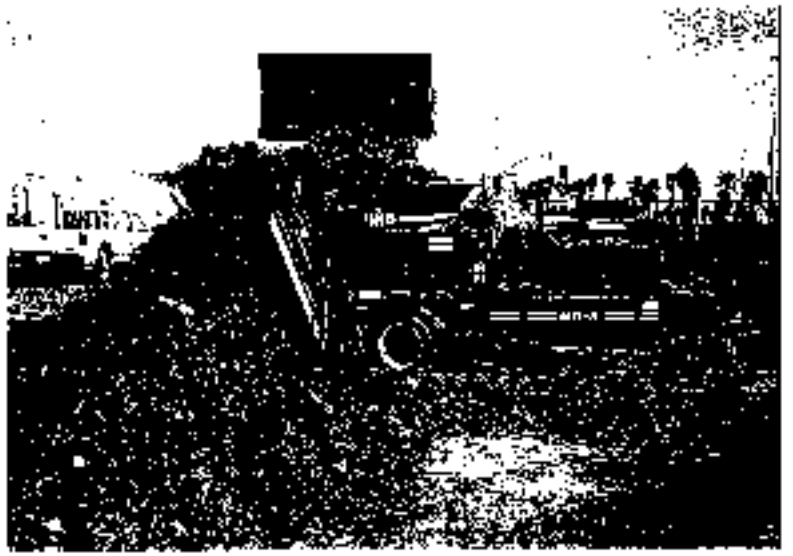
2.5.3 Sites for Mulch Application

After the yard trimmings collected at curbside are cleaned and processed, the material can be used as a soil amendment, or for erosion and dust control. The Bureau has established a Process Action Team (PAT) to work with other agencies to locate additional sites to spread the mulch created by the Van Norman facility and other potential sources. These sites may include:

(1) City Parks - The Department of Recreation and Parks has tested mulch application at several sites and is interested in using the material, which is shipped from the Van Norman site. The demand for this material is expected to increase. The Bureau also provides the department with 50% of the TopGro produced at the Griffith Park Composting Facility.

(2) CalTrans. The Bureau is delivering mulch to freeway right-of-ways.

(3) Harbor - The Harbor Department allows the Bureau to compost mulch on a site near Anchorage Street. This compost material is delivered to CalTrans, will also be made available to Rec and Parks for soil amendment and eventually to the general public through composting workshops.



City Yard Trimmings-Grindor Operation

AR0069572

(4) City golf courses - The Bureau is pursuing the use of mulch at City golf courses

(5) L.A. County Sanitation - has designated small pilot sites in landscaped areas for application of mulch

(6) Palmdale Airport site - The City's Department of Airports owns twenty-six square miles of unimproved property east of the City of Palmdale. Some small acreage is leased for agriculture. The cleaned, processed yard trimmings could be applied and/or tilled into the soil to anchor sand dunes and provide nutrients to the soil to increase the agricultural value of the property

(7) Owens Valley revegetation project - The use of cleaned, processed yard trimmings as a soil amendment could decrease soil erosion due to wind and increase the soil's moisture retaining ability, therefore increasing the success rate of revegetation of a portion of the dry lake bed. The Bureau is working with the Department of Water and Power to develop an initial pilot test to determine the suitability of the TopGro compost and yard trimmings material for use in the revegetation project. Initial tests show that mulch is chemically clean and able to be land-applied for this purpose.

2.5.4 Opportunities for Public/Private partnership

The Bureau has successfully utilized contractors for the beneficial reuse of the majority of the yard trimmings collected from City residents. The private contractors have provided excellent service to the City. Recently, the contract cost to the City for management of yard trimmings has dropped due to both the City-operated mulching facilities and the increases in the markets for end use of the material. The Bureau will continue to utilize private contractors for a portion of the yard trimmings collected using the City's competitive bid process and will continue to seek potential facilities to receive, clean, process and ship to end use, and/or receive and mulch or compost the material. The Bureau will continue to beneficially reuse all yard trimmings collected in the Curbside Yard Trimmings Program.

2.5.5 Other Potential Programs

Processed yard trimmings have many applications. The demand for the material is increasing due to its soil enhancing properties. Development of processing operations will provide more material for mulching or composting. Some other potential programs include:

(1) The development of a Recycling and Transfer facility in the central Los Angeles area can provide yard trimmings processing capacity if space is available.

(2) A small-scale project with the City of Culver City provides a lower price for shipping and processing 50 tons per day of the yard trimmings collected in the Western area of the City. This program could be expanded to provide more processing services.

(3) Yard Trimmings may be used to remediate 'brownfields', or areas of vacant land which have been contaminated by petroleum. Studies have indicated that blending yard trimmings into the soil helps release hydrocarbons and possibly remediate the contamination.

(5) The Bureau can pursue the establishment of more composting or vermicomposting facilities to create a compost product with our processed yard trimmings

(4) The Bureau will pursue the marketing of mulch and compost products to help offset the cost of processing yard trimmings.

AR0069573

2.6 Plan Objective No.6 – Material Recovery Facility Development

The Bureau of Sanitation, through the Curbside Recycling Program, collects over 800 tons per day of commingled, source separated recyclables. Through existing contracts, these materials are taken to private contractors to sort, bale and market. Although opportunities exist for residents and businesses to recycle, many are unable to provide source separation because of location, size, or other impediments. To increase the recycling rate in the City, the Bureau believes that the City should promote and support the development of Material Recovery Facilities (MRF) which can accept mixed loads of construction/demolition debris, office and commercial bin waste, and potentially mixed residential waste. The City in October 1993 adopted the goal of 70% diversion Citywide by 2020. This goal has received continued support from the Mayor and City Council.

Inert landfills accept only rocks, dirt, etc., not organic materials such as wood and paper. Any 'mixed loads' which contain some organic material, are disposed at the same landfills used by the City for residential waste (Class III). By pre sorting this material, it reduces the amount sent to the Class III landfills and can preserve space for more appropriate materials. From commercial and industrial customers, a mixed waste MRF can recover mixed paper, cardboard, metals, and other easily marketed materials. Sorting waste from residences such as those in apartment complexes with a large trash bin can increase the recovery of glass, plastics and all types of paper.

A series of pilot programs are being implemented by the Bureau to study additional potential recovery using mixed waste processing. This information, along with the comprehensive waste characterization study now underway, will allow the Bureau to target specific mixed wastestreams and types of MRF's which will be the most cost-effective in diverting material from disposal. Funding for the development of MRF's accesible to both the public and private sector could be made available through both private and public sources. A portion of the money collected from a hauler permitting system could be directed towards such development.

Facility in Oxnard, California

AR0069574

2.7 Plan Objective No.7 - Upgrade Collection Yard Facilities to meet health and safety standards

Our fleet of collection vehicles are parked and maintained at a total of six collection yards located throughout the City. North Central, South Central, Harbor, East Valley, West Valley, and Western. The collection yards have all been used continually for up to 40 years, with only minor repair and maintenance done to the facilities. Repaving of the parking areas to collect and treat stormwater runoff and prevent petroleum from reaching the storm drains is one of several major improvements needed at these yards. Also, the need for modern facilities and clean vehicles is a Bureau priority.

To create a better working environment for our staff and reduce environmental impacts, the Bureau should undertake a series of small capital improvements at the Sanitation collection yards to refurbish and provide more modern facilities

Below are listed the types of upgrades and repairs needed in the short term at the Solid Resources Collection yards:

General Improvements

Stormwater Management improvements will decrease the amount of contamination reaching the storm drain system and, ultimately, the Pacific Ocean. Stormwater improvements will be made to all yards including, canopy covers over fuel dispensing areas, clarifiers to treat oily-water run-off and drainage improvements such as regrading and repaving to facilitate collection of run-off

Improved truck wash facilities will be installed at all yards including structural modifications to the existing facility at Western, West Valley and Harbor yards and asbestos abatement at West Valley and Harbor yards. A new truck wash structure will be constructed at the North Central yard. Truck wash improvements at the South Central yard are in process.

Specific Improvements by Collection yard are as follows:

AR0069575

Yard Specific Improvements needed at Solid Resources Collection Yards

West Valley
Repair Facility: Construct additional repair bays and enclosed parts storage area.
Truck Parking Area: Replace existing deteriorated asphalt pavement with concrete surface.

South Central Satellite Yard
Reconstruction/evaluation after completion of Alameda Corridor project

Harbor
Reconstruct substandard yard facilities to improve operational efficiency
Replace repair facilities which are inadequate for current needs

Harbor Yard Example:
Automated Collection Vehicles do not fit into maintenance bays

Western Yard Example - Trucks and cars share parking space

North Central
Reconstruct existing Street Services transfer station to add operational capacity for curbside collected material

Western
Provide additional employee parking either by acquiring additional property or construction of a parking structure.

East Valley
Relocation and reconstruction in progress (See 2.2)

Western Satellite Yard
Redevelopment for use as a Recycling and/or Transfer Center (See 2.3)

AR0069576

2.7.1 Alternative Fueling for City Collection Vehicles

In June 2000, the South Coast Air Quality Management District voted to impose new regulations on all refuse collection fleets of 15 or more vehicles. These regulations require the City to begin purchasing either dual-fuel or alternative fuel collection vehicles beginning in 2001 to reduce diesel pollutants in Los Angeles. The Bureau of Sanitation has 18 months to prepare their collection yards to receive the first deliveries of new dual-fuel vehicles arriving in December 2001. In addition a recently adopted Council motion requires all diesel powered City over-the- road vehicles over a two year period be retrofitted with particulate exhaust traps and use low sulfur diesel.

Specialized infrastructure must be installed to fuel these vehicles with one of the alternative fuel compounds allowed by the California Air Resources Board. Also, these types of fuel require specialized safety equipment and modifications to the maintenance facilities to repair and maintain these trucks. The estimated cost per collection yard for the new fueling infrastructure is $1.7 million per facility, and maintenance facility improvements are estimated to reach $1 million per collection yard.

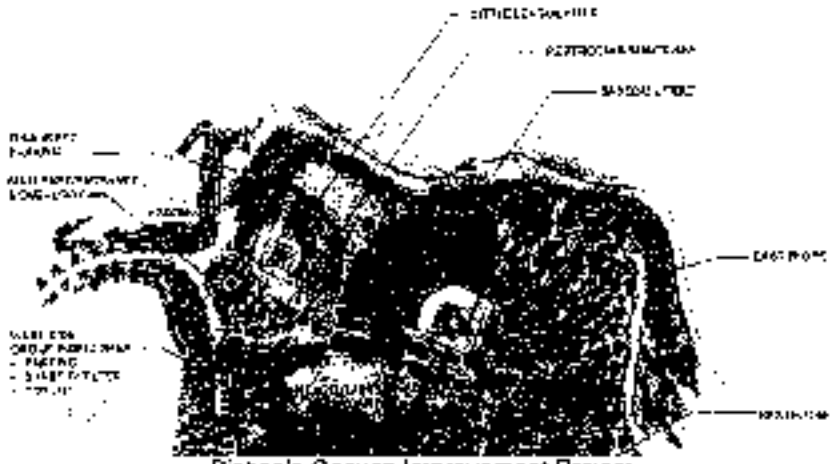
The preliminary plan will entail ordering 400 new dual-fuel collection vehicles over the next two fiscal years and modifying two of our existing collection yards for these vehicles. Also, the new collection facility to be constructed in Sun Valley has been designed to accommodate dual-fuel vehicles and is expected to be in use at the end of 2002 (Objective No.3).

The Bureau is procuring the services of a consultant to evaluate the needs for each facility and the feasibility of installing and using alternative fuels. At the same time, we will be testing several dual-fuel collection vehicles to make sure that they can be used to collect materials at curbside in Los Angeles. These additional costs will be included in the financing plan developed for all Solid Resources capital needs (see Objective No.9).

AR0069577

2.8 Plan Objective No.8 - Closure of Inactive City Owned Landfills

The City of Los Angeles owns and maintains six inactive landfill sites. In accordance with State regulations, all landfills that ceased accepting refuse after November 1984 are required to completed final closure in compliance with prescribed minimum standards. The minimum standards for closure include a multiple layer final cover typically consisting of a foundation soil layer, a low permeable layer, with a vegetative soil layer on top. The regulations allow an alternative final cover design if it is shown to be equivalent or superior to the prescribed final cover.



Bishop's Canyon Improvement Project

2.8.1 Lopez Canyon and Toyon Canyon

Since both the Lopez Canyon and Toyon Canyon Landfills ceased accepting refuse after November 1984, they must be formally closed in compliance with State regulations. Each of these landfills is currently undergoing closure construction. The Bureau has received Regional Water Quality Control Board (RWQCB) approval to use an alternative engineered cover system known as a monolithic or single layer system at both the Lopez Canyon and Toyon Canyon landfills. The monolithic system will perform better, and cost less to construct and maintain as compared to the prescriptive cover system. It will also be easier and quicker to construct, thus reducing the closure time line. Lopez Canyon and Toyon Canyon closure construction are expected to be completed by mid 2002.

2.8.2 Four Other Landfills

The City also owns and maintains four other inactive landfills: Bishops Canyon, Branford, Gaffey Street, and Sheldon-Arleta. These landfills ceased accepting refuse prior to November 1984 and are not subject to current closure regulations. However, the RWQCB has advised the Bureau that these landfills are still required to formally close in compliance with the requirements stipulated in each facility's Waste Discharge Requirements (WDRs) issued by the RWQCB. It is also be prudent for the City to formally close these landfills to minimize any liabilities the City may have for owning unofficially closed landfills. In order to formally rescind the WDRs and officially close each landfill, the City must show the RWQCB that the landfill does not impact the local groundwater by a Solid Waste Assessment Test (SWAT), and that it satisfies the requirements for soil cover and drainage. The City must also satisfy health and safety concerns of the CIWMB and the Local Enforcement Agency (LEA).

AR0069578

Phase I of the Bishops Canyon Site Improvements Project was completed in mid 1997, with the installation of recreational baseball fields on the north edge of the site and surface drainage improvements on the front face. Phase II of the project will include additional park facilities, landscaping and irrigation. Plans for Phase II were finalized, with construction anticipated to begin in the spring of 2000 and to be completed by January 2001. An estimated total of $2,500,000 is needed to complete the Phase II construction. Bond funds of $600,000 are available for Bishops Canyon Landfill Closure. The Bureau received a grant of $1,900,000 from the Los Angeles County Park and Open Space District, as one of the projects approved in the 1996 Proposition A, Safe Neighborhood Parks.

Since the SWAT indicates no impact to the groundwater, the Bureau will, at the completion of the Phase II project, request the RWQCB to officially rescind the WDR for Bishops Canyon. The Bureau will also identify for the CIWMB and LEA the actions addressing any potential health and safety concerns. No additional closure work is anticipated in order for the regulatory agencies to acknowledge the official closure of the Bishops Canyon Landfill.

For the Gaffey Street Landfill, closure plans were prepared and submitted to the RWQCB and the Local Enforcement Agency. In February 1999, the office of Councilman Rudy Svorinich requested the Bureau to investigate the possibility of reclaiming the landfill site into an active recreational facility. The Bureau performed a technical evaluation and found it to be feasible for park development.

Lopez Canyon - Monofill Construction
Toyon Canyon will receive similar closure
Estimated completion date 2002

AR0069579

Currently, the Caffey Landfill is undergoing closure construction in accordance with detailed closure plans that provide for the following mitigation and improvements:

(1) A final cover with a minimum thickness of six feet over the entire landfill boundary.
(2) A subdrain system to prevent the percolation of the rain and irrigation water into the system.
(3) Drainage collection system for controlling surface runoff and minimizing erosion.
(4) Installation of a gas migration control system.
(5) Reclamation of the landfill into an active recreational facility known as the "Field of Dreams Athletic Complex"

At the conclusion of the closure construction, scheduled for completion in late 2000, the Bureau will turn over the 15-acre site to the Department of Recreation and Parks for development. The estimated cost for closure is $708,000. Bond funds are available for the closure construction materials

Closure plans for the Branford Landfill were prepared and submitted to the LEA & RWQCB. The SWAT indicates no impacts on the groundwater, however, there is the need for proper drainage of the site. The Bureau is in the process of purchasing a different site for the relocation of the existing adjacent East Valley Yard. Once this relocation is complete, the drainage at the Branford site can be improved to formally close the landfill Closure construction cost is estimated at $875,000, and could begin in FY 2001-02. The Mayor's Office of Economic Development is also in the process of negotiating with a private developer to purchase the landfill site and the current East Valley Collection yard site for development into an industrial complex

Since the SWAT for the Sheldon-Arleta Landfill is outdated, the Bureau has prepared the closure plans to include additional groundwater sampling and analysis. This sampling should be completed by January 2001. If the results are satisfactory, an official request can then be submitted to the RWQCB to rescind the WDR. Closure construction is necessary to correct some drainage problems and gas migration areas. This construction cost is estimated at $1,000,000, and could begin in FY 2002-03.

AR0069580

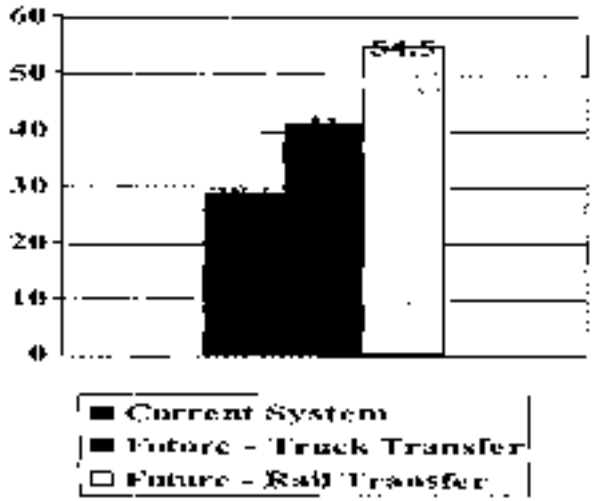
2.9 Plan Objective No. 9 - Disposal Options

The Bureau currently disposes about 3,300 tons per day of refuse in two landfill sites, down from 5,500 tons per day in 1990 as discussed below

The Bradley Landfil, owned and operated by Waste Management, Inc. (WMX), receives approximately 2,200 tons per day of refuse under a contract with the City which expires July 1, 2001

The Sunshine Canyon Landfill owned and operated by Browning Ferris Industries (BFI), receives approximately 1,100 tons per day of refuse under a contract which expires in February, 2004.

The South East Resources Recovery Facility in Long Beach, through a pilot program, receives about 100 tons per day of the refuse collected in the Harbor area. This pilot has a potential tip fee savings over $160,000 per year.



TIP FEE ESTIMATES PER OPTION
(in Million $ per year)

The future availability of close-in refuse disposal facilities can affect the timing of development of a transfer facility in the San Fernando Valley

The Bradley Landfill does not have a closure date, but will close when it reaches a final elevation and capacity This may allow the facility to remain open past mid-2001 for 1-2 more years, thus delaying the need for a transfer facility at this time;

The Sunshine Canyon Landfill has received a General Plan amendment and zone change to expand their disposal facility into the City of Los Angeles. This will allow landfilling to take place at a higher rate for a longer period than the previous landfill site in the County of Los Angeles

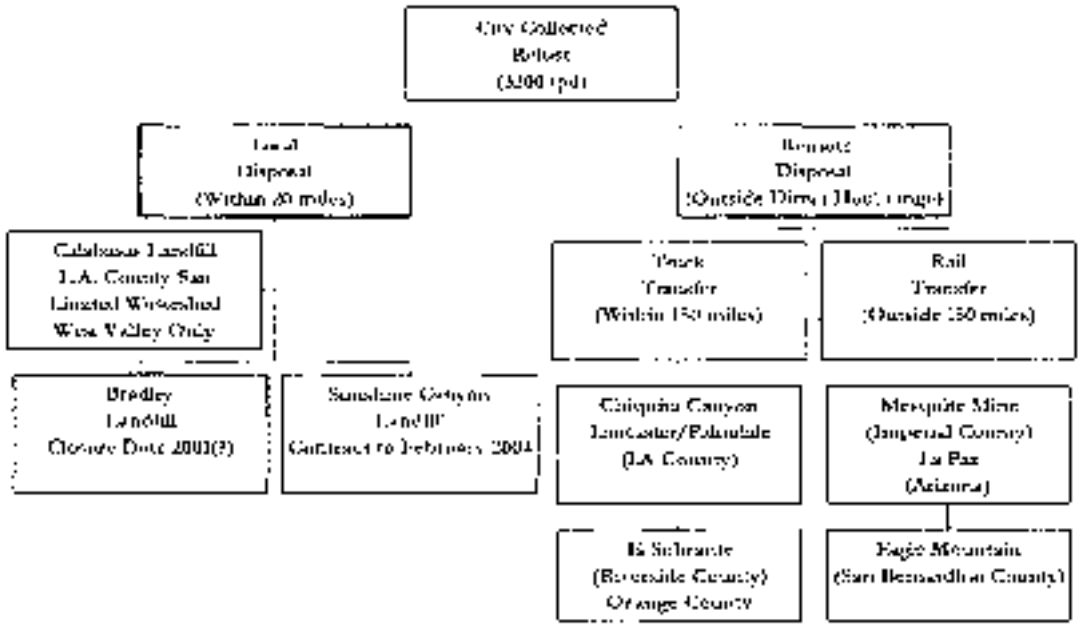
The Bureau must acquire additional disposal capacity for approximately 2,300 tons per day of refuse before 2001, and another 1,000 tons per day by 2004. Disposal capacity in the region is affected both by permit restrictions and the difficulty in siting new facilities Permitting of new disposal facilities can take 15 years, with no guarantee of success.

After the Bradley Landfill is closed for refuse disposal, and if Sunshine Canyon is not available to the City after the current contract expires, the Bureau will be faced with higher transportation costs to transfer refuse to more distant disposal facilities As an example, the Chiquita Canyon landfill will have available capacity, but is 19 miles further from the Central L.A. facility than the Bradley Landfill, thus increasing transportation costs Other facilities such as El Sobrante Landfil in Riverside, Lancaster Landfill in the Antelope Valley, and Bowerman Landfill in south Orange County could have available disposal capacity but it will cost considerably more because the average distance from the central Los Angeles area to these more remote located landfills is 60-70 miles (one way).

AR0069581

A contract amendment to extend the current refuse disposal contract for the Sunshine Canyon Landfill will extend local disposal in five year increments at the City's sole option until 2021.

To prepare for long-term disposal capacity after local capacity is exhausted, the Bureau has recommended a Joint Powers Agreement with the Los Angeles County Sanitation Districts (County San) to develop a transfer station in the central Los Angeles area that will allow Los Angeles access to desert rail-haul disposal facilities (Objective #1). County San announced in August 2000 that it had acquired both the fully permitted Mesquite Mine and almost permitted Eagle Mountain landfills. This acquisition gives the agency control over long term rail disposal options for the Southern California area well into this century



County San may begin in the next fiscal year to levelize the tip fees it charges to users of its disposal options to begin to create a resource to fund future cost increases associated with rail haul. County San may add several dollars per ton for disposal at the Puente Hills landfill to create this resource fund that will make the transition from the current $18 per ton disposal fee at Puente Hills to the $55 or more per ton for rail haul disposal more gradual. The agency expects to have rail disposal fully operational by 2013. The agency will continue to build and/or acquire rail-compatible transfer facilities to serve all Los Angeles County haulers, including those within the City of Los Angeles

The City should also consider establishing a sinking fund to set aside monies now to pay for the significant cost impact of rail haul in the future.

AR0069582

2.10 Plan Objective No.10 - Develop a Financing Strategy with the assistance of the Office of Administrative and Research Services (OARS) for the Solid Resources Capital Improvement Program

Prior to 1983 the City has historically provided the bulk of the funding for its Solid Resources program activites through the General Fund. In 1983 the Sanitation Equipment Charge (SEC), a fee used for the purchase and maintenance of collection/disposal vehicles/equipment was adopted. The SEC rate is currently $6 per single family residence and $4 per multi-family unit per month.

The funds generated by the SEC are limited in use for the following purposes:

1. Purchase of collection and disposal vehicles (including alternative fuel trucks), other equipment, and collection containers;
2. Maintenance of these vehicles, equipment and collection containers;
3. Purchase of real property to park and maintain the vehicles, equipment and collection containers, and
4. Landfill improvements and closure construction

The Solid Resources Program Objectives identified in this Plan could require funds of over $200 million over the next 7 to 10 years. It is unlikely that the Sanitation Equipment Charge can provide this level of funding needed to provide the Solid Resources Management infrastructure needed for the future. Because of these realities, the Bureau believes that the funding for these infrastructure needs be generated through a combination of debt financing using the SEC, an increase in the SEC and possible reallocation of existing SEC revenues from related costs to infrastructure needs as the mechanisms to finance the proposed infrastructure improvements and facilities development. Other sources of funds may include grants, loan programs, and federal appropriations

The Bureau recommends with the assistance of the Office of Administrative and Research Services, the development of a comprehensive financing plan that over the next 7 to 10 years can accommodate the proposed capital improvements. The great majority of the proposed solid resources infrastructure projects will have 20+ years of useful life and as such any debt payments of the principle and interest can be spread over the life of the facilities, thus minimizing yearly debt payments. The amount of debt that the current SEC revenues can support are not sufficient to finance the projects identified in this Plan.

AR0069583

2.11 Plan Objective No. 11 - Solid Waste Citizens Advisory Group (SWCAG)

The City has in the past utilized the Solid Waste Citizen's Advisory Group (SWCAG) formed by the City Council with representatives from each Council district as a forum for the presentation of information concerning the City's Solid Resources Management Program. This group has been consulted many times in the past and has provided comments on many solid resources issues. The Bureau believes that a public review panel should exist in some form for the presentation and review of Citywide solid resources issues. This panel could be a group similar to the SWCAG or could be incorporated with the community input process resulting from the City Charter reform.

AR0069584

2.12 Plan Objective No.12 - Public Education/Community Outreach

The Solid Resources Public Outreach program began in 1990 with the implementation of the automated collection system. At that time seven City staff members handled outreach with a budget of $3.5 million. Over time the public education staff within the Bureau were absorbed into the Department of Public Works, but several public information functions have remained with Bureau staff.

Outreach programs in the Bureau include those administered by the Solid Resources Citywide Recycling Division, as follows: the Used Oil Collection Program, the Household Hazardous Waste mobile collection program, Business and Technical outreach for AB939 mandated diversion goals, home Composting workshops, seasonal programs such as grasscycling, clean your files, etc., and program-specific information which has been developed for each of these programs. Other current Solid Resources education and outreach programs of the Solid Resource Collection Division include the Service Request Line which can be accessed by any resident, information programs such as the development of a new comprehensive service brochure mailed to all 720,000 residential customers and informational signs on all City solid resources collection vehicles. The City's various webpages describe programs, services, and information. Outreach to schools and community groups are currently limited to request only, based on the total educational budget of $500,000 for printing and contractual services.

The Bureau will investigate other successful programs within the City and seek partnering opportunities with other similar programs. Integration of environmental protection messages will help maximize their impact and can potentially reduce the overall cost of programs.

The Bureau can reach more residents with an expansion of existing programs. Additional staff is needed to provide hands on technical assistance to private sector generators to help increase diversion. The Bureau would like to increase the schools program to reach all schools in the City, and provide information on other City environmental programs as well. Another asset would be the development of a Speaker's Bureau, including collection truck operators, to participate in community meetings. A team is needed to provide one-on-one interaction with City residents to reduce contamination and increase diversion through the Blue Container recycling program.

A comprehensive report is being prepared for the potential implementation of a private hauler fee which could finance the above programs. The Bureau will present this report intended to increase our ability to reach residents with the specific information they need to make our environmental programs a success.

AR0069585

CalRecycle

Waste Characterization

Commercial Sector: Estimated Solid Waste Generation and Disposal Rates

NOTE: More recent estimates for waste disposal, diversion, and generation rates are available for a limited number of business groups. These can be found in Table 2 of CalRecycle's *2006 Waste Disposal and Diversion Findings for Selected Industry Groups.*

The data on this page is not official CalRecycle data; please read our disclaimer and background information.

Also see listings for Industrial / Institutional / Residential / Service establishments.

Waste Generation Source	Gen. Rate	Units of Measure	Source Date	Source	Notes
Commercial	10.53	lb/employee/day	2006	City of Los Angeles CEQA Thresholds Guide: Your Resource for Preparing CEQA Analyses in Los Angeles	Does not include generation of construction debris
Commercial	5	lb/1000 sq ft /day	Aug. 1992	Co. of Los Angeles Dept. of Regional Planning, Vesting Tentative Tract No. 47905, etc.	EIR cites City of LA Dept. of City Planning doc "EIR Manual for Private Projects" as source
Commercial	13	lb/1000 sq ft /day	Apr. 1993	Draft Environmental Impact Report (EIR) for South Gate Commercial Corridors Redevelopment Project	EIR cites CIWMB Resource Manual, May 1989
Commercial	25	lb/gross sq ft /day	Jan. 1996	Draft Program EIR for Rye Canyon Business Part, Santa Clarita	EIR cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Santa Clarita SRRE, 1990
Commercial retail	0.046	lb/sq ft/day	n/a	Draft EIR for the Central Commercial Redevelopment Project (Monterey Park Redevelopment Agency)	EIR cites Athens Disposal Co. and GRC Redevel. Consultants, 1992 as source
Commercial retail	0.006	lb/sq ft/day	Dec. 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source
Commercial retail	2.5	lb/1000 sq ft /day	Apr. 1992	Stevenson Ranch Draft EIR (Phase IV) , LA County	EIR cites source as Ultrasystems
Office	6	lb/1000 sq ft /day	Apr. 1992	Stevenson Ranch Draft EIR (Phase IV) , LA County	EIR cites source as Ultrasystems
Office	0.006	lb/sq ft/day	Dec. 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source
Office	100	lb/gross sq ft /day	Jan. 1996	Draft Program EIR for Rye Canyon Business Park, Santa Clarita	EIR cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Santa Clarita SRRE, 1990
Office	1.24	lb/employee /day	Jul. 1993	Final Report: 1992 Washington State Waste Characterization Study, Volume 3: Generator Survey Approach (Washington State Department of Ecology)	
Offices	11.5	lb./100 sq ft /daylb /employee /day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and

				(Santa Barbara County Public Works Department)	Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Professional office	0.084	lb/sq ft/day	n/a	Draft EIR for the Central Commercial Redevelopment Project and the Freeway ... (Monterey Park Redevel. Agency)	EIR cites Athens Disposal Co. and GRC Redevel. Consultants, 1992 as source
Commercial retail (dry goods)	4.75	lb/emp/day	Jul. 1993	Final Report: 1992 Washington State Waste Characterization Study: Volume 3: Generator Survey Approach (Washington State Department of Ecology)	
Auto dealer and service station	0.9	lb/100 sq ft/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Department store	3.12	lb/100 sq ft/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Shopping center	2.5	lb/100 sq ft/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Supermarket	3.12	lb/100 sq ft/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"

CalRecycle does not officially endorse any of the waste generation rates in the preceding table, and cannot validate their accuracy. However, they may be useful in providing a general level of information for planning purposes.

The table contains information extracted from various sources, which are cited. Please note that several of the documents listed were developed by city or county planning or environmental departments. Your city or county planning or environmental agency may be a source of information for a local project.

Waste Generation Rates Home

Last updated: January 14, 2013
Solid Waste Characterization, http://www.calrecycle.ca.gov/WasteChar/
Nancy Carr: Nancy.Carr@calrecycle.ca.gov (916) 341-6216

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Waste Characterization

Industrial Sector: Estimated Solid Waste Generation Rates

NOTE: More recent estimates for waste disposal, diversion, and generation rates are available for a limited number of business groups. They can be found in Table 2 of CalRecycle's *2006 Waste Disposal and Diversion Findings for Selected Industry Groups.*

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Industrial	8.93	lb/employee/day	2006	City of Los Angeles CEQA Thresholds Guide: Your Resource for Preparing CEQA Analyses in Los Angeles.	Does not include generation of construction debris
Industrial	62.5	lb/1000 sq ft/day	Apr. 1993	Draft Environmental Impoact Report (EIR) for South Gate Commercial Corridors Redevelopment Project	EIR cites City of LA Manual for Private Projects (rate for manufacturing uses)
Industrial	5	lb/1000 sq ft/day	Apr. 1992	Stevenson Ranch Draft EIR (Phase IV) , LA County	EIR cites source as Ultrasystems
Industrial	0.006	lb/sq ft/day	Dec. 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source
Industrial	3	lb/employee /1000 sq ft/day	Jan. 1996	Draft Program EIR for Rye Canyon Business Part, Santa Clarita	EIR cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Santa Clarita SRRE, 1990
Light industrial	41.64	lb/employee/day	Aug. 1992	Co. of Los Angeles Dept. of Regional Planning, Vesting Tentative Tract No. 47905, etc.	Cites City of LA Dept. of City Planning document "EIR Manual for Private Projects" as source
Manufacturing/ warehouse	1.42	lb/100 sq ft/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Transportation,/ communication/ utilities	1.4 9.2	lb/100 sq ft/day lb/employee/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Warehouse	13.82	lb/emp/day	Jul. 1993	Final Report: 1992 Washington State Waste Characterization Study: Volume 3: Generator Survey Approach (Washington State Department of Ecology)	

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Nancy Carr: Nancy.Carr@calrecycle.ca.gov (916) 341-6216

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CalRecycle

Waste Characterization

Public Sector and Institutions: Estimated Solid Waste Generation Rates

The data on this page is not official CalRecycle data; please read our disclaimer and background information.

Also see listings for Commercial / Industrial / Residential / Service establishments.

Waste Generation Source	Gen. Rate	Units of Measure	Source Date	Source	Notes
Education	3.55	lb/emp/day	Jul. 1993	Final Report: 1992 Washington State Waste Characterization Study, Volume 3: Generator Survey Approach (Washington State Department of Ecology)	
Educational facilities	0.5	lb/student/day	Apr. 1992	Stevenson Ranch Draft Environmental Impact Report (EIR) (Phase IV), LA County	EIR cites source as Ultrasystems
Educational institutions	0.12	tons/emp/year	1990	Environmental Thresholds and Guidelines Manual (Santa Barbara County Department of Resource Management)	Cites Matrix Management Group, et al. "Best Management Practices Analysis for Solid Waste", 1988.
Government	0.59	tons/emp/year	1990	Environmental Thresholds and Guidelines Manual (Santa Barbara County)	Cites Matrix Management Group, et al. "Best Management Practices Analysis for Solid Waste", 1988.
Hospital	16	lb/bed/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Nursing/ retirement home	5	lb/person/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Public/ institutional	0.007	lb/sq ft /day	n/a	Draft EIR for the Central Commercial Redevelopment Project (Monterey Park Redevelopment Agency)	EIR cites Athens Disposal Co. and GRC Redevel. Consultants, 1992 as source
School	0.007	lb/sq ft/day	Dec. 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source; assumes 22.5 sq.ft./student
School	0.6	lb/person/day	May 1997	Guide to Solid Waste and Recycling Plans for Development Projects (Santa Barbara County Public Works Department)	Cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Matrix Mgmt Group, "Best Management Practices Analysis for Solid Waste"
Schools	1	lb/student/day	Jan. 1996	Draft Program EIR for Rye Canyon Business Park, Santa Clarita	EIR cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Santa Clarita SRRE, 1990

CalRecycle does not officially endorse any of the waste generation rates in the preceeding table, and cannot validate their accuracy. However, they may be useful in providing a general level of information for planning purposes.

The table contains information extracted from various sources, which are cited. Please note that several of the documents listed were developed by city or county planning or environmental departments. Your city or county planning or environmental agency may be a source of information for a local project.

Waste Generation Rates Home

Last updated: January 14, 2013
Solid Waste Characterization, http://www.calrecycle.ca.gov/WasteChar/
Nancy Carr: Nancy.Carr@calrecycle.ca.gov (916) 341-6216

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CalRecycle

Waste Characterization

Residential Developments: Estimated Solid Waste Generation Rates

The data on this page is not official CalRecycle data; please read our disclaimer and background information.

Also see listings for Commercial / Industrial / Institutional / Service establishments.

Waste Generation Source	Gen. Rate	Units of Measure	Source Date	Source	Notes
Residential	12.23	lb/household/day	2006	City of Los Angeles CEQA Thresholds Guide: Your Resource for Preparing CEQA Analyses in Los Angeles (DRAFT)	Does not include generation of construction debris
Multifamily	4	lb/dwelling unit /day	Aug. 1992	Co. of Los Angeles Dept. of Regional Planning, Vesting Tentative Tract No. 47905, etc.	Cites City of LA Dept. of City Planning document "EIR Manual for Private Projects" as source
Multifamily	8.6	lb/dwelling unit /day	n/a	Draft Environmental Impact Report (EIR) for the Central Commercial Redevelopment Project (Monterey Park Redevelopment Agency)	EIR cites Athens Disposal Co. and GRC Redevel. Consultants, 1992, as source
Multifamily	3.6	lb/unit/day	Apr. 1993	Draft EIR for South Gate Commercial Corridors Redevelopment Project	EIR cites City of LA Dept. of City Planning document "EIR Manual for Private Projects" as source
Multifamily	4	lb/dwelling unit /day	Dec. 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source
Multifamily	5.31	lb/dwelling unit /day	Jan. 1996	Draft Program EIR for Rye Canyon Business Park, Santa Clarita	EIR cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Santa Clarita SRRE, 1990
Residential	12	lb/person/day	Apr. 1992	Stevenson Ranch Draft EIR (Phase IV) , LA County	EIR cites source as Ultrasystems
Single Family	10	lb/dwelling unit /day	Aug. 1992	Co. of Los Angeles Dept. of Regional Planning, Vesting Tentative Tract No. 47905, etc.	EIR cites City of LA Dept. of City Planning doc "EIR Manual for Private Projects" as source
Single Family	11.4	lb/dwelling unit /day	n/a	Draft EIR for the Central Commercial Redevelopment Project (Monterey Park Redevelopment Agency)	EIR cites Athens Disposal Co. and GRC Redevel. Consultants, 1992, as source
Single Family	7.8	lb/unit/day	Apr. 1993	Draft EIR for South Gate Commercial Corridors Redevelopment Project	EIR cites City of LA Manual for Private Projects
Single Family	10	lb/dwelling unit /day	Dec. 1991	Draft EIR for North Hills Development (Santa Clarita)	EIR cites City of LA Bureau of Solid Waste, 1989, as source
Single Family	9.8	lb/dwelling unit /day	Jan. 1996	Draft Program EIR for Rye Canyon Business Park, Santa Clarita	EIR cites SWANA Tech. Bull. 85-6; Recovery Sciences, 1987; and Santa Clarita

					SRRE, 1990

CalRecycle does not officially endorse any of the waste generation rates in the preceding table, and cannot validate their accuracy. However, they may be useful in providing a general level of information for planning purposes.

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Nancy Carr: Nancy.Carr@calrecycle.ca.gov (916) 341-6216

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DUE DILIGENCE REPORT
For the Capitol Records Tower
1750 N. Vine Street
Hollywood, Ca.
January 24, 1994

DUE DILIGENCE REPORT

CAPITOL RECORDS TOWER
1750 N. Vine St.
Hollywood, CA.

FOR

CAPITOL RECORDS INC.
1750 N. Vine St.
Hollywood, CA.
ATTN: Mr. Charles Goldstuck

BY

DON PROHASKA & ASSOCIATES

January 24, 1994

AR0069595

APPENDIX 1

The appendix contains copies of all permits, variances and other documents on file with the Los Angeles Department of Building and Safety. The original core & shell building permit could not be located and therefore was not on file. The approved soils report was on file. There are two documents which should be given attention.

1) A 1988 zoning memorandum which requires all properties listed to obtain written clearance from the Cultural Heritage Commission for any applications to obtain a building permit or perform any demolition. 1750 N. Vine Street is listed.

2) An unapproved request for a 2 year extension to provide elevator lobby vestibules. Such extension expired on December 20, 1993. Another extension should be applied for to avoid an Order to Comply from the Fire Safety Division.

BUILDING PROFILE

1. ARCHITECTURAL FINISHES:
   a. Exterior: Painted concrete, glass in aluminum frames and porcelain-enameled metal louvers.
   b. Interior:
      1. Lobby: Marble walls and floor, painted plaster ceiling.
      2. Typical floor: Plaster on concrete, gypsum board, carpet and acoustic ceiling tile

2. BUILDING DATA:
   a. Floor-to-floor Height:
      1. Ground Floor: Varies from 16'-6" to 22'-0"
      2. Typical tower floor: 10'-9".

   b. Floor-to-ceiling Height:
      1. Ground floor: Varies 14'-6" (lobby) to 26'-0" (Studio A&B).
      2. Typical tower floor: 9'-0".

   c. Window Height:
      1. Floor-to-sill: 2'-11"
      2. Window height: 5'-0"
      3. Window head to ceiling: 2'-1"

   d. Perimeter Window Module: 3'-6" on center.

   e. Perimeter Column Module: 22'-11" on center

3. ROOFING:
   a. Type: Asphaltic built-up membrane (installed 1984) at T-2 and Penthouse levels.
   b. Condition: Fair

FINDINGS:
Exterior finishes are in good condition. No rust is evident on the porcelain-enameled metal louvers. Painted concrete walls have no significant cracks or spalling. Aluminum windows have some corrosion which can be easily cleaned.

The roofs have considerable ponding due to inadequate slope to drains. This will lead to premature failure of the membrane. The 10 year joint and several guarantee of the roof by the manufacturer expires in 1994. At time of next re-roof, consider providing sloped insulation and additional drains to eliminate ponding and prolong roof life.

AR0069597

BUILDING STATISTICS

1. GROSS LOT AREA: 43,460 SF
   FAR: 2.12:1

2. BUILDING AREAS:
   a. Gross Area: 92,246 SF / 86,617 RSF
      (reverb chambers below grade not included)

   b. Typical Floor Area:
      T2: 4,915 GSF / 4,415 RSF
      T3-T8: 6,030 GSF / 6,030 RSF
      P2: 1,697 GSF

   c. Ground Floor Area: 15,006 GSF / 14,076 RSF
      Studios A & B: 5,535 GSF
      Studio C: 1,880 GSF

3. BUILDING DATA:
   a. Number of floors:
      The building contains 12 floors of offices (T2-T8) in the tower above a ground floor base structure containing recording studios and support areas, lobby, mailroom and physical plant. A mechanical penthouse is located on the roof. There are 8 subterranean reverberation chambers under the parking lot connected by a corridor. Each chamber is approximately 336 SF.

   b. Parking Spaces: 374 Total (4.3/1000 RSF)
      On-site: 97 spaces
      Off-site: 277 spaces

4. DESIGN CONSULTANTS
   a. Architect:
      Base Building: Welton Becket
      Space Planner: Tichenor & Thorp/Others

   b. Structural Engineer
      Base Building: Murray Erick Associates

   c. Mechanical/Electrical/Plumbing
      Base Building: Welton Becket

5. YEAR COMPLETED: 1956

AR0069598

ELECTRICAL PROFILE

1. SERVICE ENTRANCE:
   Electrical service is provided by the Department of Water and Power through transformers located under the parking lot near the Yucca St. entrance. Service entrance is underground at northeast corner of ground floor.

2. SERVICE CAPACITY:
   a. 1 - 800 A, 480Y 3P, 3 wire. Main switchboard servicing the physical plant and some equip. in Studio A.
   b. 5 - 800 A, 120/240V 1P, 3 wire. Main switchboards providing lighting and power for offices and studios. Wattage per square foot (demand) distributed in risers equals approximately 5.4 w/sf. 2.4 w/sf lighting and 3 w/sf convenience power.

3. DISTRIBUTION:
   a. Floor duct system (flrs. 2-8 only): 3 concentric rings of floor duct with outlet inserts 24" o.c. Top of duct 2-7/8" below top of slab.
   b. Conduit: All conductors are in rigid steel conduit, EMT or flexible armored cable.
   c. Conductors: All wire sizes No. 8 AWG or smaller is type TH (heat-resistant thermoplastic insulation). All wire sizes No. 6 AWG or larger is type RHW (heat and moisture-resistant rubber insulated).

5. EMERGENCY POWER:
   a. Capacity: 150 kw, 3P.
   b. Fuel: 100 gallons (diesel)
   c. Cummins driver/Onan generator.

FINDINGS:
The convenience power capacity as calculated in watts/sf is not ample by present standards (5.4 watts/sf). Expansion of the building which adds electrical equipment or demand on the power system may require adding additional capacity. However, it may be that with diversity, that actual power usage is much less than the connected load and service switch capacity. Consider taking measured readings from the service panels to determine actual usage.

AR0069599

ELEVATOR PROFILE

1. ELEVATORS:
   a. Mfgr. / Type: Otis / gearless passenger
   b. Number / Capacity: 3 / 2500 lb.
   c. Speed: 500 feet per minute
   d. Dedicated freight elevator: None
   e. Control System: Otis Autotronic original group supervisory control system utilizing six basic traffic programs:
      1. Up Peak
      2. Two-Way - Balanced
      3. Two-Way - Heavier Down
      4. Two Way - Heavier Up
      5. Down Peak
      6. Light and Intermittent
   f. Platform Dimensions: 5' x 7'
   g. Entrance Size: 3'-6" wide x 7'-0" high
   h. Freemans' Service: Phase I & Phase II
   i. Alternate Floor Recall: No
   j. Disabled Access Compliance: Poor
   k. Floors Served: All

NOTE: **See attached Elevator Report by Lerch, Bates & Associates dated April 23, 1993.**

2. DUMBWAITER
   a. Mfgr / Type: Otis / geared
   b. Number / Capacity: 1 / 300 lb.
   c. Speed: 100 feet per minute
   d. Floors Served: All

3. DOCK LIFT:
   a. Mfgr / Type: Unknown/ hydraulic
   b. Size / Capacity: 6' x 6' / 6,000 lb.
   c. Speed / Travel: 7 feet per minute / 4 feet

FINDINGS:
The Lerch Bates report recommends a modernization program to upgrade the system dispatch controls, motor controls, motor generators, door operation components and cab finishes. This office concurs with their recommendations. Much of the existing elevator system components have reached the end of their useful lives and will require higher and costlier levels of maintenance and repair to keep operating.

Title 24/ADA requirements for disabled access are mandated by state law and are required in order to obtain building permits for remodeling. These are considerably more limited and less costly to provide than a modernization program. Consider doing this required work during the modernization of such a program is undertaken. Otherwise, the existing equipment can be retrofitted to comply.

ENVIRONMENTAL PROFILE

1. ASBESTOS CONTAINING MATERIALS:
   ACM was detected in piping insulation in various locations and spray-on acoustic ceiling of the ground floor lobby. **See attached report by CTL Environmental Services dated January 29, 1992.**

2. UNDERGROUND FUEL TANK:
   None known to exist.

3. OTHER:
   Some older fluorescent light fixture ballasts may contain PCB's. These fixtures are being replaced over time.

FINDINGS:
It does not appear that hazardous materials such as asbestos will be encountered during the remodeling program contemplated.

MECHANICAL PROFILE

1. STANDARD HOURS OF OPERATION:
   6:30 am to 1 am Weekdays

2. DESIGN CONDITIONS:
   a. Cooling
      1. Inside: 72° DB / 50% RH
      2. Outside: 90° DB / 70° WB
   b. Heating:
      1. Inside: 70°
      2. Outside: 35°

3. HEATING/COOLING SYSTEM:
   a. 3-3 - 7FGround floor
      Generic Type: 4 - pipe air and water using compressive refrigeration.
      A central plant produces chilled and heated water which are pumped to fan coils of both central and individual air handlers. Central air handlers are double-duct type and serve the interior zones and ground floor. Individual units at the periphery are single-duct type and serve perimeter zones in the Tower.

   b. Studios/T-2 Editing rooms
      Generic type: Direct refrigerant package units. Studio units are single package type and are located on the 1st floor roof. Editing room units are split system type with the fan coils in the perimeter soffit and the compressors located outside on the 1st floor roof.

   c. Refrigeration Plant
      1. Number of machines and tonnage:
         1 - 160 ton chiller (installed 1978)
         1 - 40 ton chiller (installed 1990)
         (chilled and condensing water circulated by 2 Worthington centrifugal pumps (10 hp) each. Pumps were installed in 1988.
         Type: reciprocating
         Manufacturer: Carrier
         Cooling Tower: Baltimore Air Coil, 200 ton capacity (installed 1982).
         Automatic Controls: Johnson Controls pneumatic temperature control system.
      2. Package units
         Studio A: 1 - Trane 6 ton unit (installed 1991) for performance area
                   1 - Trane 5 ton unit (installed 1991) for control room.
                   1 - Trane 3 ton unit (installed 1991) for lounge area/electrical room.
         Studio B: 1 - Carrier 5 ton unit (installed 1985) in performance area only. Control room on central system.
         Studio C: 1 - Carrier 5 ton unit (installed 1981) for performance area and control room.

   d. Heating Plant
      2 - 1,250,000 BTU gas fired boilers with 2 circulating pumps by Chicago Pump
      Manufacturer: Aerco
      Efficiency: 80%

   e. Air Handling Equipment
      1. Number and location of central fan coils and served areas:
         1 - 13,955 CFM unit at ground floor. Serving ground floor areas including Studio B performing area (all other studio areas on package units).

AR0069602

1 - 6,030 CFM unit at ground floor. Serving interior zones of floors T2-T6.
1 - 10,265 CFM unit at penthouse. Serving interior zones of floors T7-TE.
Manufacturer/Model: Westinghouse/AHZ

2. Individual fan-coil units at periphery vary in size from 350 CFM to 880 CFM. Units (zones) per floor vary from 6 to 11 depending on office layout.
Manufacturer/Model: Wat International. Units on floors T-9 (1992) and TE (1990) were replaced by MagicAire units in 1993.

3. Exhaust fans
Location/size and served areas:

E-1 Ground floor	780 CFM	Gr. flr. areas on north side
E-2 Ground floor	12,950 CFM	Gr. flr. recirculation
E-3 Penthouse	13,400 CFM	Tower toilets
E-4 Penthouse	250 CFM	Kitchen on TE
E-5 Penthouse	2,500 CFM	Elevator room
E-6 Ground floor	1,060 CFM	Reverberation chambers
E-7 Ground floor	280 CFM	Record. studio toilets

4. PLUMBING SYSTEM
   a. Domestic water system: Cold water riser to 2500 gallon pressure storage tank on roof. Hot water riser pumped from 2 - 100 gallon (4 years old) hot water heaters on T-1 to TE. Individual hot and cold supply drops feed men's and women's restroom fixtures. 4 floor shut off valves on T-9 and T-12 only. All water supply distribution piping was originally installed as Schedule 40 galvanized steel pipe with threaded joints. The hot water riser and drops have been replaced with copper piping. The old piping was abandoned and the janitorial sinks on each floor removed.

   b. Hydronic / Condenser water loops: There are 6 hot / chilled water supply and return risers at the tower perimeter. The condenser riser runs one story to the new cooling tower on the roof of T-1. The original installation located the cooling tower on the Penthouse level and condenser riser piping was located in stairwell #2. Hydronic loop piping is Schedule 40 black steel pipe.

FINDINGS:

HVAC:

The system is generally in good condition. The refrigeration plant and some fan coil unit in the tower are relatively new. The balance of the system is nearly 40 years old and reaching the end of its useful life. The double duct system provides superior comfort control to VAV and is still considered to be the "Cadillac" system. Where system upgrading should be considered is in the automatic controls. The existing system does not allow the plant to be as efficient or as flexible as it could be. The condition of the controls particularly at the penthouse fan coil unit is fair to poor.

Plumbing:

The cold water distribution piping and hydronic loop piping has chronic leaking problems due to the age of the steel piping. Consider replacing this piping with new copper piping and providing floor shut-off valves at the hot and cold water drops.

STRUCTURAL PROFILE

1. GENERIC TYPE: Reinforced Concrete
The round Tower is constructed as a reinforced concrete frame. The floor slabs, perimeter columns and spandrels are of 3000 psi, poured-in-place concrete. The first floor rectangular "base" structure is composed of two systems: 1) the round tower structure flanked by (2), a rectangular steel frame and concrete structure for the studios and mechanical/support areas.

The Tower floor slabs are cantilevered from 8 1/4" at the center to 8" at the column line and 7 1/2" at the perimeter slab edge.

2. DESIGN LIVE LOADS
   a. Tower floors: 50 PSF.
   b. Ground floor roof areas: 20 PSF

3. CONTROL DIMENSIONS
   a. Slab-to-slab height
      Tower: 10'-9"
      Ground floor: varies between 16'-6"(north side) and 22'-0"(south side)
   b. Slab thickness
      Tower: 8"- 8 1/4"
      Ground floor: 6 1/2"
      "L roof": 7 1/2"
   c. Tower floor plate size: 95'-6" diameter (90'-8" enclosed).

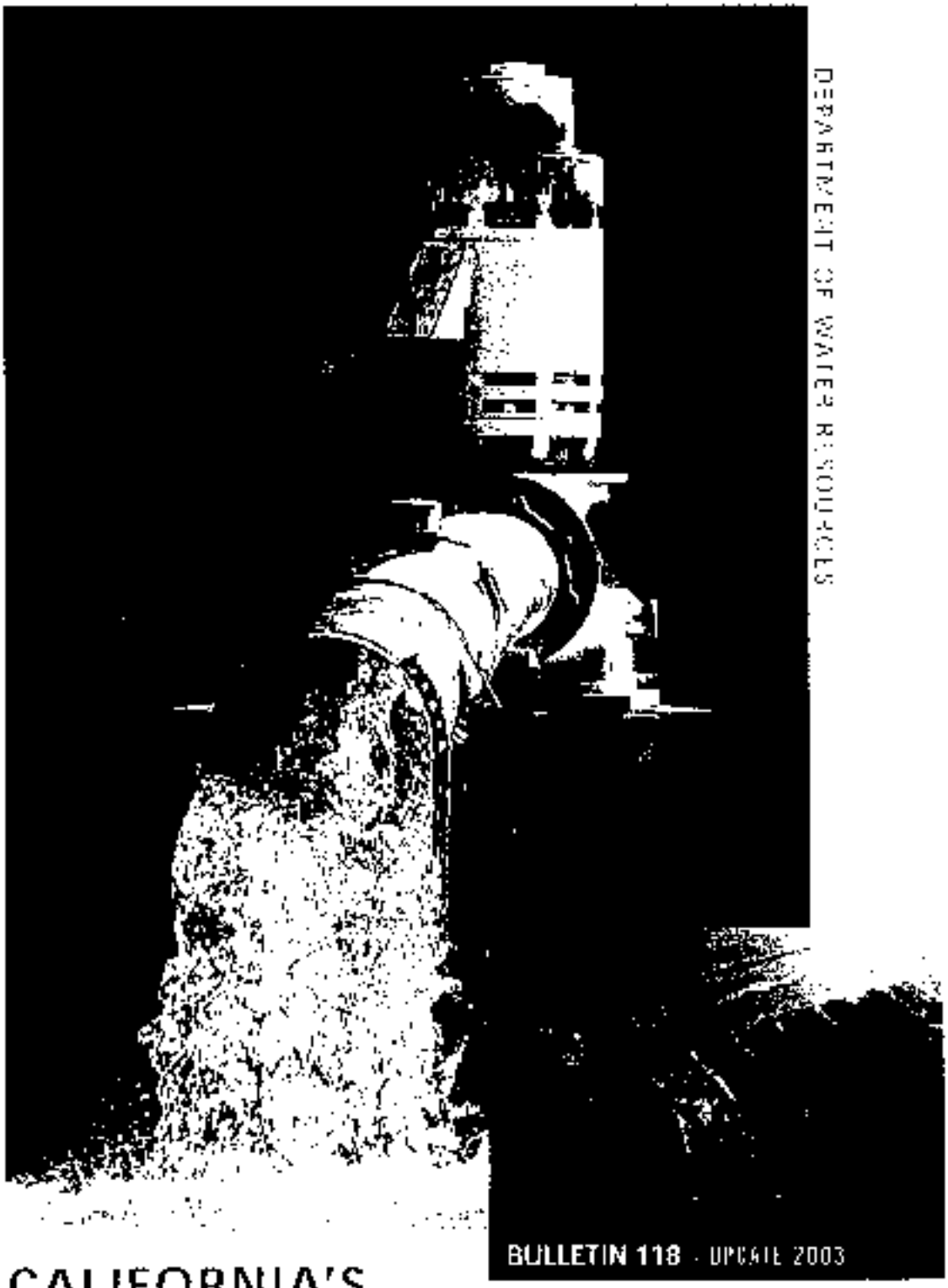
4. SEISMIC
   a. Seismic zone: 4
   b. Seismic upgrades: none

FINDINGS:
The building is constructed as two independent structures: the base and the tower. The tower is a very rigid frame designed to resist large lateral forces from wind and earthquake. The base has considerable resistance as well due the shear capacity of long windowless walls. The perimeter spandrel beam system is designed to span continuously from column to column. Any perceptions of this beam to accomodate new traffic patterns on the 2nd floor must compensate for the loss in continuity.

Consider reviewing seismic capability with a structural engineer specializing in such design. As the recent Northridge earthquake has shown, even recently designed buildings have areas of vulnerability which only a disaster will reveal. Further, even if the main building frame is found to be satisfactory, there may be secondary yet important members and connections which need reinforcement. For example, while the tower and base are shown on the drawings to have a separation joint between them, this may not be adequate to prevent the separate structures from 'banging' against one another in a larger or closer earthquake and causing significant damage in the studio areas.

This report is a qualitative evaluation based upon a general review of the architectural and structural drawings. Not calculations or other quantitative analysis was performed. Such analysis should be done by a structural engineer.

AR0069604



DEPARTMENT OF WATER RESOURCES

BULLETIN 118 - UPDATE 2003

CALIFORNIA'S GROUNDWATER

AR0069605

Cover photograph:
A typical agricultural well with the water discharge pipe and the electric motor that drives the pump.

Inset photograph:
Groundwater recharge ponds in the Upper Coachella Valley near the Whitewater River that use local and imported water. Recharge ponds are also called spreading basins or recharge basins.

AR0069606

State of California
The Resources Agency
Department of Water Resources

CALIFORNIA'S
GROUNDWATER

BULLETIN 118 *Update 2003*

October 2003

GRAY DAVIS
Governor
State of California

MARY D. NICHOLS
Secretary of Resources
The Resources Agency

MICHAEL J. SPEAR
Interim Director
Department of Water Resources

AR0069607

If you need this publication in an alternate form, contact the Department's Office of Water Education at
-800-272-8Rev.

AR0069608

Foreword

Groundwater is one of California's greatest natural resources. In an average year, groundwater meets about 30 percent of California's urban and agricultural water demands. In drought years, this percentage increases to more than 40 percent. In 1995, an estimated 12 million Californians, nearly 45 percent of the State's population, were served by groundwater. The demand on groundwater will increase significantly as California's population grows to a projected 46 million by the year 2020. In many basins, our ability to optimally use groundwater is affected by overdraft and water quality impacts, or limited by a lack of data, management, and coordination between agencies.

Over the last few years, California voters and the Legislature have provided significant funding to local agencies for conjunctive use projects, groundwater recharge facilities, groundwater monitoring, and groundwater basin management activities under Proposition 13 and the Local Groundwater Management Assistance Act of 2000. Most recently, the 2002 passage of Propositions 50 will result in additional resources to continue recent progress toward sustaining our groundwater resources through local agency efforts. We are beginning to see significant benefits from these investments.

The State Legislature recognizes the need for groundwater data in making sound local management decisions. In 1969, the Legislature approved funding and directed the Department of Water Resources (DWR) to update the inventory of groundwater basins contained in Bulletin 118 (1975), *California's Ground Water* and Bulletin 118-80 (1980), *Ground Water Basins in California*. In 2001, the Legislature passed AB 599, requiring the State Water Resources Control Board to establish a comprehensive monitoring program to assess groundwater quality in each groundwater basin in the State and to increase coordination among agencies that collect groundwater contamination information. In 2002, the Legislature passed SB 1938, which contains new requirements for local agency groundwater management plans to be eligible for public funds for groundwater projects.

Effective management of groundwater basins is essential because groundwater will play a key role in meeting California's water needs. DWR is committed to assisting local agencies statewide in developing and implementing effective, locally planned and controlled groundwater management programs. DWR is also committed to federal and State interagency efforts and to partnerships with local agencies to coordinate and expand data monitoring activities that will provide necessary information for more effective groundwater management. Coordinated data collection at all levels of government and local planning and management will help to ensure that groundwater continues to serve the needs of Californians.

Michael J. Spear
Interim Director

State of California
Gray Davis, *Governor*

The Resources Agency
Mary D. Nichols, *Secretary for Resources*

Department of Water Resources
Michael J. Spear, *Interim Director*

Lester Snow
Deputy Director

Peggy Bernardy
Chief Counsel

Stephen Verigin
Acting Chief Deputy Director

James Mitton	**Peter Garris**	**Vernon T. Glover**
Deputy Director	*Deputy Director*	*Deputy Director*

Division of Planning and Local Assistance
Mark Cowin, Chief

Statewide Water Planning Branch
Kamyar Guivetchi, Chief

Conjunctive Water Management Branch
John Woodling, Chief

This Bulletin was prepared under direction of
Doug Osugi
by
Robert Swartz, *Senior Engineering Geologist*
and
Carl Hauge, *Chief Hydrogeologist*

Final coordination by
Mary Scruggs and **Joe Yun**
with assistance from
Tom Hawkins **Derrick Lottie**
Tom Luttenman **Darby Vickery** **Rene Wellman-Barbree** **Judy Calvin**

AR0069610

Data collection, regional information and basin descriptions provided by Department district offices

Northern District

Dwight Russell, *District Chief*

William Mendenhall, *Chief, Resource Assessment Branch*

Lacey Dudley, *Chief, Groundwater Section*

Mike Ward, *Engineer WR, technical lead*

Todd Hillmire **Noel Eaves** **Dan McManus** **Bill Elkins** **Debbie Spangler**
Kelley Staton **Dott Watkins** **Charlene Sundermann** **Bruce Ross**

Central District

Karl Winkler, *District Chief*

Emil Calzascia, *Chief, Water Management*

Bob Niblack, *Chief, Geology and Groundwater Section*

Chris Bonds, *Engineering Geologist, technical lead*

Sandra Maxwell **Mark Souverville** **Tanya Meerb** **Bill Waggoner** **Solomon Meseghina**
Bill Brewster **Anne Roth**

San Joaquin District

Paula J. Landis, *District Chief*

Brian Smith, *Chief, Resource Assessment*

Ben Igawa, *Chief, Groundwater Section*

Al Steele, *Engineering Geologist, technical lead*

Bruce Myers **Anna Mancillas** **Ken Winden** **Amanda Mayes** **Norm Bara**

Southern District

Mark Stuart, *District Chief*

Bob Pierotti, *Chief, Groundwater Section*

Tim Ross, *Engineering Geologist, technical lead*

Gary Giacci **Richard Lewy** **Dan Gamon** **Brian Moniz** **Randall Davis** **Jun Wong**
Nuna Jetsabahian **Monica Lee** **Jeremy Lancaster** **Tammy Suren** **Mark Stuhlman**

Editorial, design and production services were provided by

Brenda Main, *Supervisor of Technical Publications*

Linda Sinnwell, *Art Director*

Marilee Talley **Alice Dyer** **Xiunjun Li** **Gretchen Goettl** **Jeannie Pierce**

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California Department of Pesticide Regulation
California Department of Toxic Substances Control
California Department of Health Services
California State Water Resources Control Board
California Regional Water Quality Control Boards
United States Geological Survey
United States Bureau of Reclamation

We also wish to thank numerous reviewers who provided valuable comments on the April 2009 public review draft of this [illegible]

AR0069612

Acronyms and abbreviations

AB Assembly Bill
BMO Basin management objective
CAS California Aquifer Susceptibility
CVP Central Valley Project
DBCP Dibromochloropropane
DCE Dichloroethylene
DHS California Department of Health Services
DPR California Department of Pesticide Regulation
DTSC California Department of Toxic Substances Control
DWR California Department of Water Resources
DWSAP Drinking Water Source Assessment Program
EDB Ethylene dibromide
EC Electrical conductivity
EMWD Eastern Municipal Water District
EWMP Efficient water management
EPA U.S. Environmental Protection Agency
ESA Federal endangered species Act
ET Evapotranspiration
ETAW Evapotranspiration of applied water
EWA Environmental Water Account
GAMA Groundwater Ambient Monitoring and Assessment
GIS Geographic information system
GMA Groundwater Management Agency
gpm Gallons per minute
GRID Groundwater Resources Information Database
GRIST Groundwater Resources Information Sharing Tools
H & S Health and Safety Code
HR Hydrologic region
ISI Integrated Storage Investigations
ITF Interagency Task Force
JPA Joint powers agreement
maf Million acre-feet
MCL Maximum contaminant level
mg/L Milligrams per liter
MOU Memorandum of understanding
MTBE Methyl tertiary-butyl ether
OCWD Orange County Water District
PAC Public Advisory Committee
PCE Tetrachloroethylene
PCA Pesticide contamination activity
PPIC Public Policy Institute of California
ROD Record of Decision
RWQCB Regional Water Quality Control Board
SB Senate Bill
SGA Sacramento Groundwater Authority
SVOC Semi-volatile organic compound
SVWD Santa Valley Water District
SWRCB State Water Resources Control Board

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taf Thousand acre-feet
TCE Trichloroethylene
TDS Total dissolved solids
UWMP Urban water management plan
USACE U.S. Army Corps of Engineers
USBR U.S. Bureau of Reclamation
USC United States Code
USGS U.S. Geological Survey
VOC Volatile organic compound
WQCP Water Quality Control Plan

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Findings

Major Findings

1. **Groundwater provides about 30% of the State's water supply in an average year, yet in many basins the amount of groundwater extracted annually is not accurately known.**
   - In some regions, groundwater provides 60% or more of the supply during dry years.
   - Many small to moderate sized towns and cities are entirely dependent on groundwater for drinking water supplies.
   - 40% to 90% of Californians rely on groundwater for part of their water supply.
   - In many basins, groundwater use is indirectly estimated by assessing crop evapotranspiration demands and surveying the acreage of each crop type.

2. **Opportunities for local agencies to manage their groundwater resources have increased significantly since the passage of Assembly Bill 3030 in 1992. (Water Code § 10750 et seq.). In the past several years more agencies have developed management programs to facilitate conjunctive use, determine the extent of the resource, and protect water quality.**
   - The act provides the authority for many local agencies to manage groundwater.
   - The act has resulted in more than 200 local agencies adopting groundwater management plans to date.
   - The act encourages regional cooperation in basins and allows private water purveyors to participate in groundwater management through memorandums of understanding with public agencies.
   - Many local agencies are recognizing their responsibility and authority to better manage groundwater resources.

3. **Agencies in some areas have not yet developed groundwater management plans.**
   - Concerns about cooperative management, governance, and potential liabilities have kept some agencies from developing management plans.
   - Development of management programs to the basin's sustainable groundwater supply for local use has not been accomplished throughout the State.

4. **A comprehensive assessment of overdraft in the State's groundwater basins has not been conducted since Bulletin 118-80, but it is estimated that overdraft is between 1 million and 2 million acre-feet annually.**
   - Historical overdraft in many basins is evident in hydrographs that show a steady decline in groundwater over a number of years.
   - Other basins may be subject to overdraft in the future if current water management practices are continued.
   - Overdraft can result in increased water production costs, land subsidence, water quality impairment, and environmental degradation.
   - Few basins have detailed water budgets by which to estimate overdraft.
   - While the most extensively developed basins tend to have information, many basins have insufficient data for effective management or the data have not been evaluated.
   - The extent and impacts of overdraft must be fully evaluated to determine whether groundwater will provide a sustainable water supply.
   - Modern computer hardware and software enable rapid manipulation of data to develop and test conditions such as groundwater storage changes or groundwater extraction, but a lack of essential data limits the ability to make such calculations.
   - Adequate statewide land use data for making groundwater extraction estimates are not available in electronic format.

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5. Surface water and groundwater are connected and can be effectively managed as integrated resources
   - Groundwater originates as surface water.
   - Groundwater extraction can affect flow in streams.
   - Changes in surface water flow can affect groundwater levels.
   - Legal systems for surface water and groundwater rights can make coordinated management complex.

6. Groundwater quality and groundwater quantity are interdependent and are increasingly being considered in an integrated manner.
   - Groundwater quantity and groundwater quality are inseparable.
   - Groundwater in some aquifers may not be usable because of contamination with chemicals either from natural or human sources.
   - Unmanaged groundwater extraction may cause migration of poor quality water.
   - Monitoring and evaluating groundwater quality provides managers with the necessary data to make sound decisions regarding storage of water in the groundwater basin.
   - State agencies conduct several legislatively mandated programs to monitor different aspects of groundwater quality.
   - California Department of Water Resources (DWR) monitors general groundwater quality in many basins throughout the State for regional evaluation.

7. Land use decisions affecting recharge areas can reduce the amount of groundwater in storage and degrade the quality of that groundwater.
   - In many basins, little is known about the location of recharge areas and their effectiveness.
   - Protection and preservation of recharge areas are seldom considered in land use decisions.
   - If recharge areas are altered by paving, channelizing, or other land use changes, available groundwater will be reduced.
   - Potentially contaminating activities can degrade the quality of groundwater and require well-head treatment or aquifer remediation before use.
   - There is no coordinated effort to inform the public that recharge areas should be protected against contamination and preserved so that they function effectively.

Additional Important Findings

8. Funding to assist local groundwater management has recently been available in unprecedented amounts.
   - Proposition 13 (Water Code § 79000 et seq.) authorized $230 million in loans and grants for local groundwater programs and projects, almost all of which has been allocated.
   - The Local Groundwater Management Assistance Act of 2000 (Water Code § 10795) has resulted in more than $15 million in grants to local agencies in fiscal years 2001, 2002, and 2003.
   - Proposition 50 (Water Code, § 79500 et seq.) will provide funding for many aspects of water management, including groundwater management and groundwater recharge projects.
   - Funding for the California Bay-Delta program has provided technical and facilitation assistance to numerous local groundwater planning efforts.

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9. **Local governments are increasingly involved in groundwater management.**
   - Twenty-four of the 27 existing county groundwater management ordinances have been adopted since 1990.
   - Most ordinances require the proponents of groundwater export to demonstrate that a proposed export will not cause subsidence, degrade groundwater quality, or deplete the water supply before the county will issue an export permit.
   - While the ordinances generally require a permit for export of groundwater, most do not require a comprehensive groundwater management plan designed to ensure a sustainable water resource for local use.
   - Some local governments are coordinating closely with local water agencies that have adopted groundwater management plans.
   - Many local governments are monitoring and conducting studies in an effort to better understand groundwater resources.

10. **Despite the increased groundwater management opportunities and activities, the extent of local efforts is not well known.**
    - There is no general requirement that groundwater management plans be submitted to DWR, so the number of adopted plans and status of groundwater management throughout the State are not currently known.
    - There are no requirements for evaluating the effectiveness of adopted plans other than during grant proposal review.
    - No agency is responsible for tracking implementation of adopted plans.
    - Unlike urban water management plans, groundwater management plans are not required to be submitted to DWR, making such information unavailable for updating the California Water Plan.

11. **Despite the fact that several agencies often overlie each groundwater basin, there are few mechanisms in place to support and encourage agencies to manage the basin cooperatively.**
    - Some local agencies have recognized the benefits of integrating basin-wide and regional planning for groundwater management and have recorded many successes.
    - Regional cooperation and coordination depends on the ability of local agencies to form such efforts.
    - There is no specific State or federal program to fund and support coordination efforts that would benefit multiple water users in a region and statewide.

12. **The State Legislature has recognized the need to consider water supplies as part of the local land use planning process.**
    - Three bills—Senate Bill 221[1], SB 610[2], and AB 901[3]—were enacted in 2001 to improve the assessment of water supplies. The new laws require the verification of sufficient water supply as a condition for approving certain developments and compel urban water suppliers to provide more information on the reliability of groundwater as an element of supply.
    - The Government Code does not specifically require local governments to include a water resources element in their general plans.

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[1] Business and Professions Code Section 11010, Government Code Sections 65867.5, 66455.3, and 66473.7
[2] Public Resources Code Section 21151.9, Water Code Sections 10631, 10656, 10657, 10910-10912, 10915
[3] Water Code Sections 10910-12, 10631, 10604

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13. The need to monitor groundwater quality and contamination of groundwater continues to grow
    - As opportunities for developing additional surface water supplies become more limited, subsequent growth will increasingly rely on groundwater.
    - Human activities are likely the cause of more than half the exceedances of a basin plan contaminant level in public water supply wells.
    - New contaminants are being regulated and standards are becoming more stringent, for others, requiring more load monitoring and better management of water quality.

14. Monitoring networks for groundwater levels and groundwater quality have not been evaluated in all basins to ensure that the data accurately represent conditions in the aquifer(s).
    - Groundwater levels are monitored in about 10,000 active wells, including those basins where most of the groundwater is used.
    - Groundwater levels are not monitored in approximately 200 basins where population is sparse and groundwater use is generally low.
    - Groundwater quality monitoring networks are most dense near population centers and may not be representative of the basin as a whole.
    - Many of the wells being monitored are not ideally constructed to provide water level or water quality information that is representative of a specific aquifer.
    - Many wells are too deep to monitor changes in the unconfined (water table) portion of basins.

15. The coordination of groundwater data collection and evaluation by local, State, and federal agencies is improving.
    - The State Water Resources Control Board (SWRCB) recently formed the Groundwater Resources Information Sharing Team (GRIST) consisting of several State and federal agencies with groundwater-related programs.
    - DWR established a website in 1998 that has provided water level data and hydrographs for more than 35,000 active and inactive wells monitored by DWR and cooperating agencies.
    - DWR collects and maintains water level data in part through partnerships with local agency cooperators.
    - DWR staff consulted with many local, State, and federal agencies in developing this update of Bulletin 118.
    - SWRCB recently formed an interagency task force to develop a comprehensive groundwater quality monitoring program for assessing every groundwater basin in the State as required by the Groundwater Quality Monitoring Act of 2001 (AB 599, Water Code, § 10780 et seq.).
    - Water purveyors have concerns about balancing public access to data with water supply security.

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16. **Boundaries of groundwater basins have been determined using the best available geologic and hydrologic information. These boundaries are important in determining the availability of local water supplies.**
    - Basin boundaries were developed primarily by identifying alluvial sediments on geologic maps using the best available information, but are subject to change when new information becomes available
    - The Water Code requires the use of basin boundaries defined in Bulletin 118 in groundwater management plans and urban water management plans.
    - The location of basin boundaries will become more critical as the demand for water continues to increase.
    - Subbasin boundaries may be delineated for management convenience rather than based on hydrogeologic conditions.

17. **Little is known about the stream-aquifer interaction in many groundwater basins.**
    - Groundwater and surface water are closely linked in the hydrologic cycle.
    - The relationship between stream flow and extraction of groundwater is not fully understood in most basins and is generally not considered.
    - Groundwater extraction in many basins may affect stream flow.
    - Interaction of groundwater flow and surface water may affect environmental resources in the hyporheic zone.
    - An understanding of stream aquifer interaction will be essential to evaluating water transfers in many areas of the State.

18. **Although many new wells are built in fractured rock areas, insufficient hydrogeologic information is available to ensure the reliability of groundwater supplies.**
    - Population is increasing rapidly in foothill and mountain areas in which groundwater occurs in fractured rock.
    - The cumulative effect of groundwater development may reduce the yield of individual wells, lower the flow of mountain streams, and impact local habitat.
    - Characterization of groundwater resources in fractured rock areas can be very expensive and complex.
    - Many groundwater users in these areas have no other water supply alternatives.
    - Recent dry years have seen many wells go dry in fractured rock areas throughout the State.
    - Groundwater management in these areas is beginning, but there is insufficient data to support quantitative conclusions about the long-term sustainable yield.

19. **When new wells are built, drillers are required to file a Well Completion Report with DWR. That report contains a lithologic log, the usability of which varies considerably from driller to driller.**
    - The Well Completion Reports are confidential and not available to the public, as stipulated by the Water Code, unless the owner's permission is obtained.
    - The usefulness of the information in Well Completion Reports varies but is not fully realized.
    - Public access to Well Completion Reports would increase understanding of groundwater conditions and issues.
    - There is no provision in the Water Code that requires submission of geophysical logs, which would provide an accurate log of the geologic materials within the aquifer.
    - Geophysical logs would provide a greatly improved database for characterization of aquifers.

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Recommendations

Major Recommendations

1. Local or regional agencies should develop groundwater management plans if groundwater constitutes part of their water supply. Management objectives should be developed to maintain a sustainable long-term supply for multiple beneficial uses. Management should integrate water quantity and quality, groundwater and surface water, and recharge area protection.
   - Groundwater management in California is a local agency responsibility.
   - In basins where there is more than one management agency, those agencies should coordinate their management objectives and program activities.
   - A water budget should be completed that includes recharge, extraction and change in storage in the aquifer(s).
   - Changes in groundwater quality should be monitored and evaluated.
   - Stakeholders should be identified and included in development of groundwater management plans.

2. The State of California should continue programs to provide technical and financial assistance to local agencies to develop monitoring programs, management plans, and groundwater storage projects to more efficiently use groundwater resources and provide a sustainable supply for multiple beneficial uses. DWR should:
   - Post information about projects that have successfully obtained funding through various grant and loan programs.
   - Provide additional technical assistance to local agencies in the preparation of grant and loan applications.
   - Continue outreach efforts to inform the public and water managers of grant and loan opportunities.
   - Participate, when requested, in local efforts to develop and implement groundwater management plans.
   - Continue to assess, develop, and modify its groundwater programs to provide the greatest benefit to local agencies.
   - Develop grant criteria to ensure funding supports local benefits as well as Statewide priorities, such as development of the California Water Plan and meeting Bay-Delta objectives.

3. DWR should continue to work with local agencies to more accurately define historical overdraft and to more accurately predict future water shortages that could result in overdraft.
   - A water budget should be developed for each basin.
   - The annual change in storage should be determined for each basin.
   - The amount of annual recharge and discharge, including pumping, should be determined.
   - Changes in groundwater quality that make groundwater unusable or could allow additional groundwater to be used should be included in any evaluation of overdraft.

4. Groundwater management agencies should work with land use agencies to inform them of the potential impacts various land use decisions may have on groundwater, and to identify, prioritize, and protect recharge areas.
   - Local planners should consider recharge areas when making land use decisions that could reduce recharge or pose a risk to groundwater quality.
   - Recharge areas should be identified and protected from land uses that limit recharge rates, such as paving or lining of channels.

AR0069630

- Both local water agencies and local governments should pursue education and outreach to inform the public of the location and importance of groundwater.
- DWR should inform local agencies of the availability of grant funding and technical assistance that could support these efforts.

5. DWR should publish a report by December 31, 2004 that identifies those groundwater basins or subbasins that are being managed by local or regional agencies and those that are not, and should identify how local agencies are using groundwater resources and protecting groundwater quality.
   - Such information will be necessary to confirm whether agencies are meeting the requirements of SB 1938 (Water Code Section 10753.7).
   - Collection and summary of existing groundwater management plans will provide a better understanding of the distribution and coordination of groundwater management programs throughout the State.
   - Successful strategies employed by specific local agencies should be highlighted to assist others in groundwater management efforts.
   - Similarly, the impact of groundwater management ordinances throughout the State should be evaluated to provide a better understanding of the effect of ordinances on groundwater management.

6. Water managers should include an evaluation of water quality in a groundwater management plan, recognizing that water quantity and water quality are inseparable.
   - Local water managers should obtain groundwater quality data from federal, state, and local agencies that have collected such data in their basin.
   - Local agencies should evaluate long-term trends in groundwater quality.
   - Local agencies should work closely with the SWRCB and DWR in evaluating their groundwater basins.
   - Local agencies should establish management objectives and monitoring programs that will maintain a sustainable supply of good quality groundwater.

7. Water transfers that involve groundwater (or surface water that will be replaced with groundwater) should be consistent with groundwater management in the source area that will assure the long-term sustainability of the groundwater resource.

8. Continue to support coordinated management of groundwater and surface water supplies and integrated management of groundwater quality and groundwater quantity.
   - Future bond funding should be provided for conjunctive use facilities to improve water supply reliability.
   - Funding for feasibility and pilot studies, in addition to construction of projects will help maximize the potential for conjunctive use.
   - DWR should continue and expand its efforts to form partnerships with local agencies to investigate and develop locally controlled conjunctive use programs.

9. Local, State, and federal agencies should improve data collection and analyses to better estimate groundwater basin conditions used in Statewide and local water supply reliability planning. DWR should:
   - Assist local agencies in the implementation of SB 221, SB 610, and AB 901 to help determine water supply reliability during the local land use planning process.
   - Provide and continue to update information on groundwater basins, including basin boundaries, groundwater levels, monitoring data, aquifer yield, and other aquifer characteristics.

AR0069631

- Identify areas of rapid development that are heavily reliant on groundwater and prioritize monitoring activities in these areas to identify potential impacts on these basins.
- Evaluate the existing network of wells monitored for groundwater elevations, eliminate wells of questionable value from the network, and add wells where data are needed.
- Work cooperatively with local groundwater managers to evaluate the groundwater basins of the State with respect to overdraft and its potential impacts. Beginning with the most heavily used basins.
- Expand DWR and its cooperating monitoring programs to provide a better understanding of the interaction between groundwater and surface water.
- Work with SWRCB to investigate temporal trends in water quality to identify areas of water quality degradation that should receive additional attention.
- Estimate groundwater extraction using a land use based method for over 200 basins with little or no groundwater budget information.
- Integrate groundwater budgets into the California Water Plan Update process.

10 **Increase coordination and sharing of groundwater data among local, State, and federal agencies and improve data dissemination to the public. DWR should:**

- Use the established website to continually update new groundwater basin data collected after the publication of California's Groundwater (Bulletin 118-Update 2003).
- Publish a summary update of Bulletin 118 every five years coincident with the California Water Plan (Bulletin 160).
- Publish in cooperation with SWRCB, a biennial groundwater report that addresses current groundwater quantity and quality conditions.
- Coordinate the collection and storage of its groundwater quality monitoring data with programs of SWRCB and other agencies to ensure maximum coverage statewide and reduce duplication of effort.
- Make groundwater basin information more compatible with other Geographic Information System-based resource data to improve local integrated resources planning efforts.
- Compile data collected by projects funded under grant and loan programs and make data available to the public on the DWR website.
- Encourage local agency cooperators to submit data to the DWR database.
- Maximize the accuracy and usefulness of data and develop guidelines for quality assurance and quality control, consistency, and format compatibility.
- Expand accessibility of groundwater data by the public after considering appropriate security measures.
- State, federal, and local agencies should expand accessibility of groundwater data by the public after considering appropriate security measures.
- Local agencies should submit copies of adopted groundwater management plans to DWR.

Additional Important Recommendations

11 **Local water agencies and local governments should be encouraged to develop cooperative working relationships at basinwide or regional levels to effectively manage groundwater. DWR should:**

- Provide technical and financial assistance to local agencies in the development of basinwide groundwater management plans.
- Provide a preference in grant funding for groundwater projects for agencies that are part of a regional or basinwide planning effort.
- Provide Proposition 50 funding preferences for projects that are part of an integrated regional water management plan.

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12. Groundwater basin boundaries identified in Bulletin 118 should be updated as new information becomes available and the basin becomes better defined. DWR should:
    - Identify basin boundaries that are based on limited data.
    - List the kind of information that is necessary to better define basin boundaries.
    - Develop a systematic procedure to obtain and evaluate stakeholder input on groundwater basin boundaries.

13. Improve the understanding of groundwater resources in fractured rock areas of the State.
    - DWR, in cooperation with local and federal agencies, should conduct studies to determine the amount of groundwater that is available in fractured rock areas, including water quality assessment, identification of recharge rates and amounts, and if water can be obtained when needed.
    - Local agencies and local governments should conduct studies in their areas to quantify the local demands on groundwater and project future demands.
    - The Legislature should consider expanding the groundwater management authority in the Water Code to include areas outside of alluvial groundwater basins.
    - DWR should include information on the most significant fractured rock groundwater sources in future updates of Bulletin 118.

14. Develop a program to obtain geophysical logs in areas where additional data are needed.
    - DWR should encourage submittal of geophysical logs, when they are conducted, as a part of the Well Completion Report.
    - The geophysical logs would be available for use by public agencies to better understand the aquifer, but would be confidential as stipulated by the Water Code.
    - DWR should seek funding to work with agencies and property owners to obtain geophysical logs of new wells in areas where additional data are needed.
    - Geophysical logs would be used to better characterize the aquifers within each groundwater basin.

15. Educate the public on the significance of groundwater resources and on methods of groundwater management.
    - DWR should continue to educate the public on statewide groundwater issues and assist local agencies in their public education efforts.
    - Local agencies should expand their outreach efforts during development of groundwater management plans under AB 3030 and other authority.
    - DWR should develop educational materials to explain how they quantify groundwater throughout the State as well as the utility and limitations of the information.
    - DWR should continue its efforts to educate new dug well owners and small water systems that are entirely dependent on groundwater.

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Introduction

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Introduction

Groundwater is one of California's greatest natural resources. In an average water supply year, groundwater meets about 30 percent of California's urban and agricultural demand. In drought years, this percentage increases to 40 percent or even higher (DWR 1998). Some cities, such as Fresno, Davis, and Lodi, rely solely on groundwater for their drinking water supply. In 1995, an estimated 13 million Californians (nearly 43 percent of the State's population) used groundwater for at least a portion of their public supply needs (Solley and others 1998). With a projected population of nearly 46 million by the year 2020, California's demand on groundwater will increase significantly. In many basins, our ability to optimally use groundwater is affected by overdraft and water quality, or limited by a lack of data, lack of management, and coordination between agencies.

In the last few years, California has provided substantial funds to local agencies for groundwater management. For example, the nearly $2 billion Water Bond 2000 (Proposition 13) approved by California voters in March 2000 specifically authorizes funds for two groundwater programs: $200 million for grants for feasibility studies, project design, and the construction of conjunctive use facilities; and $50 million for loans for local agency acquisition and construction of groundwater recharge facilities and grants for feasibility studies for recharge projects. Additionally, the Local Groundwater Management Assistance Act of 2000 (AB 303) resulted in $15 million in fiscal years 2001, 2002, and 2003 for groundwater studies and data collection intended to improve basin and subbasin groundwater management. These projects focus on improving groundwater monitoring, coordinating groundwater basin management, and conducting groundwater studies.

The State Legislature has increasingly recognized the importance of groundwater and the need for monitoring in making sound groundwater management decisions. Significant legislation was passed in 2000, 2001 and 2002. AB 303 authorizes grants to help local agencies develop better groundwater management strategies. AB 599 (2001) requires, for the first time, that the State Water Resources Control Board (SWRCB), in cooperation with other agencies, develop a comprehensive monitoring program capable of assessing groundwater quality in every basin in the State with the intent of maintaining a safe groundwater supply. SB 610 (2001) and SB 901 (2001) together require urban water suppliers, in their urban water management plans, to determine the adequacy of current and future supplies to meet demands. Detailed groundwater information is required for those suppliers that use groundwater. SB 221 (2001) prohibits approval of certain developments without verification of an available water supply. These bills are significant with respect to groundwater because much of California's new development will rely on groundwater for its supply.

Finally, SB 1938 (2002) was enacted to provide incentives to local agencies for improved groundwater management. The legislation modified the Water Code to require that specific elements be included in a groundwater management plan for an agency to be eligible for certain State funding administered by the Department of Water Resources for groundwater projects. AB 303 is exempt from that requirement.

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History of Bulletin 118

DWR has long recognized the need for collection, summary, and evaluation of groundwater data as tools in planning optimal use of the groundwater resource. An example of this is DWR's Bulletin 118 series. Bulletin 118 presents the results of groundwater basin evaluations in California. The Bulletin 118 series was preceded by Water Quality Investigations Report No. 3, *Ground Water Basins in California* (referred to in this bulletin as Report No. 3), published in 1952 by the Department of Public Works, Division of Water Resources (the predecessor of DWR). The purpose of Report No. 3 was to create a base/index map of the "more important ground water basins" for carrying out DWR's mandate in Section 229 of the Water Code. Sect on 229 directed Public Works to

> ... investigate conditions of the quality of all waters within the State, including saline waters, coastal and inland, as related to all sources of pollution of whatever nature and shall report thereon to the Legislature and to the appropriate regional water pollution control board annually, and may recommend any steps which might be taken to improve or protect the quality of such waters.

Report No. 3 identified 233 alluvium-filled valleys that were believed to be basins with usable groundwater in storage. A statewide numbering system was created in cooperation with the State Water Pollution Control Board (now the State Water Resources Control Board) based on the boundaries of the nine Regional Water Quality Control Boards. In 1992, Water Code Section 229 was amended, resulting in the elimination of the annual reporting requirements.

In 1975, DWR published Bulletin 118, *California's Ground Water* (referred to in this report as Bulletin 118-75). Bulletin 118-75 summarized available information from DWR, U.S. Geological Survey, and other agencies for individual groundwater basins to "help those who must make decisions affecting the protection, additional use, and management of the State's ground water resources."

Bulletin 118-75 contains a summary of technical information for 248 of the 461 identified groundwater basins, subbasins, and what were referred to as "areas of potential ground water storage" in California as well as maps showing their location and extent. The Bulletin 118-75 basin boundaries were based on geologic and hydrogeologic conditions except where basins were defined by a court decision.

In 1976, Section 12924 was added to the California Water Code:

> The Department shall, in cooperation with other public agencies, conduct an investigation of the State's groundwater basins. The Department shall identify the State's groundwater basins on the basis of geologic and hydrogeologic conditions and consideration of political boundary lines whenever practical. The Department shall also investigate existing general patterns of groundwater pumping and groundwater recharge within such basins to the extent necessary to identify basins which are subject to critical conditions of overdraft.

DWR published the report in 1980 as *Ground Water Basins in California, A Report to the Legislature in Response to Water Code Section 12924* (referred to in this report as Bulletin 118-80). The bulletin included 36 groundwater basins with boundaries different from Bulletin 118-75. The changed boundaries resulted by combining several basins based on geologic or political considerations and by dividing the San Joaquin Valley groundwater basin into many smaller subbasins based primarily on political boundaries. These changes resulted in the identification of 447 groundwater basins, subbasins, and areas of potential groundwater storage. Bulletin 118-80 also identified 11 basins as subject to critical conditions of overdraft.

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Box A: Which Bulletin 118 Do You Mean?

Mention of an update to Bulletin 118 causes some confusion about which Bulletin 118 the California Department of Water Resources (DWR) has updated. In addition to the statewide Bulletin 118 series (Bulletin 118-75, Bulletin 118-80, and Bulletin 118-03), DWR released several other publications in the 118 series that evaluate groundwater basins in specific areas of the State. Regional specific Bulletin 118 reports are listed below:

- Bulletin 118-1: Evaluation of Ground Water Resources: South San Francisco Bay
  - Appendix A: Geology, 1967
  - Volume 1: Fremont Study Area, 1968
  - Volume 2: Additional Fremont Study Area, 1973
  - Volume 3: Northern Santa Clara County, 1975
  - Volume 4: South Santa Clara County, 1991
- Bulletin 118-2: Evaluation of Ground Water Resources: Livermore and Sunol Valleys, 1974
  - Appendix A: Geology, 1966
- Bulletin 118-3: Evaluation of Ground Water Resources: Sacramento County, 1974
- Bulletin 118-4: Evaluation of Ground Water Resources: Sonoma County
  - Volume 1: Geologic and Hydrologic Data, 1975
  - Volume 2: Santa Rosa Plain, 1982
  - Volume 3: Petaluma Valley, 1982
  - Volume 4: Sonoma Valley, 1982
  - Volume 5: Alexander Valley and Healdsburg Area, 1983
- Bulletin 118-5: Bulletin planned but never completed
- Bulletin 118-6: Evaluation of Ground Water Resources: Sacramento Valley, 1978

The Need for Bulletin 118 Update 2003

Despite California's heavy reliance on groundwater, basic information for many of the groundwater basins is lacking. Particular essential data necessary to provide for both the protection and optimal use of this resource is not available. To this end, the California Legislature mandated in the Budget Act of 1999 that DWR prepare:

> "...the statewide update of the inventory of groundwater basins contained in Bulletin 118-80, which includes, but is not limited to, the following: the review and summary of boundaries and hydrographic features, hydrogeologic units, yield data, water budgets, well production characteristics, and water quality and active monitoring data; development of a water budget for each groundwater basin; development of a format and procedures for publication of water budgets on the Internet; development of the model groundwater management ordinance; and development of guidelines for evaluating local groundwater management plans."

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The information on groundwater basins presented in Bulletin 118 Update 2003 is mostly limited to the acquisition and compilation of existing data previously developed by federal, State, and local water agencies. While this bulletin is a good starting reference for basic data on a groundwater basin, more recent data and more information about the basin may be available in recent studies conducted by local water management agencies. Those agencies should be contacted to obtain the most recent data.

Report Organization

Bulletin 118 Update 2003 includes this report and supplemental material consisting of individual descriptions and a Geographic Information System-compatible map of each of the delineated groundwater basins in California. The basin descriptions will be updated as new information becomes available, and can be viewed or downloaded at http://www.waterplan.water.ca.gov/groundwater/118index.htm (Appendix A). Basin descriptions will not be published in hard copy.

This report is organized into the following topics:

- Groundwater is one of California's most important natural resources, and our reliance on it has continued to grow (Chapter 1).
- Groundwater has a complex legal and institutional framework in California that has shaped the groundwater management system in place today (Chapter 2).
- Groundwater management occurs primarily at the local water agency level, but may also be instituted at the local government level. At the request of the Legislature, DWR has developed some recommendations for a model groundwater management ordinance and components for inclusion in a groundwater management plan (Chapter 3).
- Groundwater has had a flurry of activity in the Legislature and at the ballot box in recent years that will affect the way groundwater is managed in California (Chapter 4).
- Groundwater programs with a variety of objectives exist in many State and federal agencies (Chapter 5).
- Groundwater concepts and definitions should be made available to a wide audience (Chapter 6).
- Groundwater basins with a wide range of characteristics and concerns exist in each of California's 10 hydrologic regions (Chapter 7).

AR0069639

Chapter 1
Groundwater California's Hidden Resource

Chapter 1
Groundwater – California's Hidden Resource

In 1975, *California's Ground Water – Bulletin 118* described groundwater as "California's hidden resource." Today, those words ring as true as ever. Because groundwater cannot be directly observed, except under a relatively few conditions such as at a spring or a wellhead, most Californians do not give much thought to the value that California's vast groundwater supply has added to the State. It is unlikely that California could have achieved its present status as the largest food and agricultural economy in the nation and fifth largest overall economy in the world without groundwater resources. Consider that about 43 percent of all Californians obtain drinking water from groundwater. California is not only the single largest user of groundwater in the nation, but the estimated 14.5 million acre-feet (maf) of groundwater extracted in California in 1995 represents nearly 20 percent of all groundwater extracted in the entire United States (Solley and others 1998).

California's Hydrology

California's climate is dominated by the Pacific storm track. Numerous mountain ranges cause orographic lifting of clouds, producing precipitation mostly on the western slopes and leaving a rain shadow on most eastern slopes (Figure 1 and Figure 2). These storms also leave tremendous accumulations of snow in the Sierra Nevada during the winter months. While the average annual precipitation in California is about 23 inches (DWR 1998), the range of annual rainfall varies greatly from more than 140 inches in the northwestern part of the State to less than 4 inches in the southeastern part of the State.

Snowmelt and rain falling on the mountains flow into creeks, streams, and rivers. The average annual runoff in California is approximately 71 maf (DWR 1998). As these flows make their way into the valleys, much of the water percolates into the ground. The vast majority of California's groundwater that is accessible in significant amounts is stored in alluvial groundwater basins. These alluvial basins, which are the subject of this report, cover nearly 40 percent of the geographic area of the State (Figure 3).

This bulletin focuses on groundwater resources, but in reality groundwater and surface water are inextricably linked in the hydrologic cycle. As an example, groundwater may be recharged by spring runoff in streams, but later in the year the base flow of a stream may be provided by groundwater. So, although the land surface is a convenient division for categorizing water resources, it is a somewhat arbitrary one. It is essential that water managers recognize and account for the relationship between groundwater and surface water in their planning and operations.

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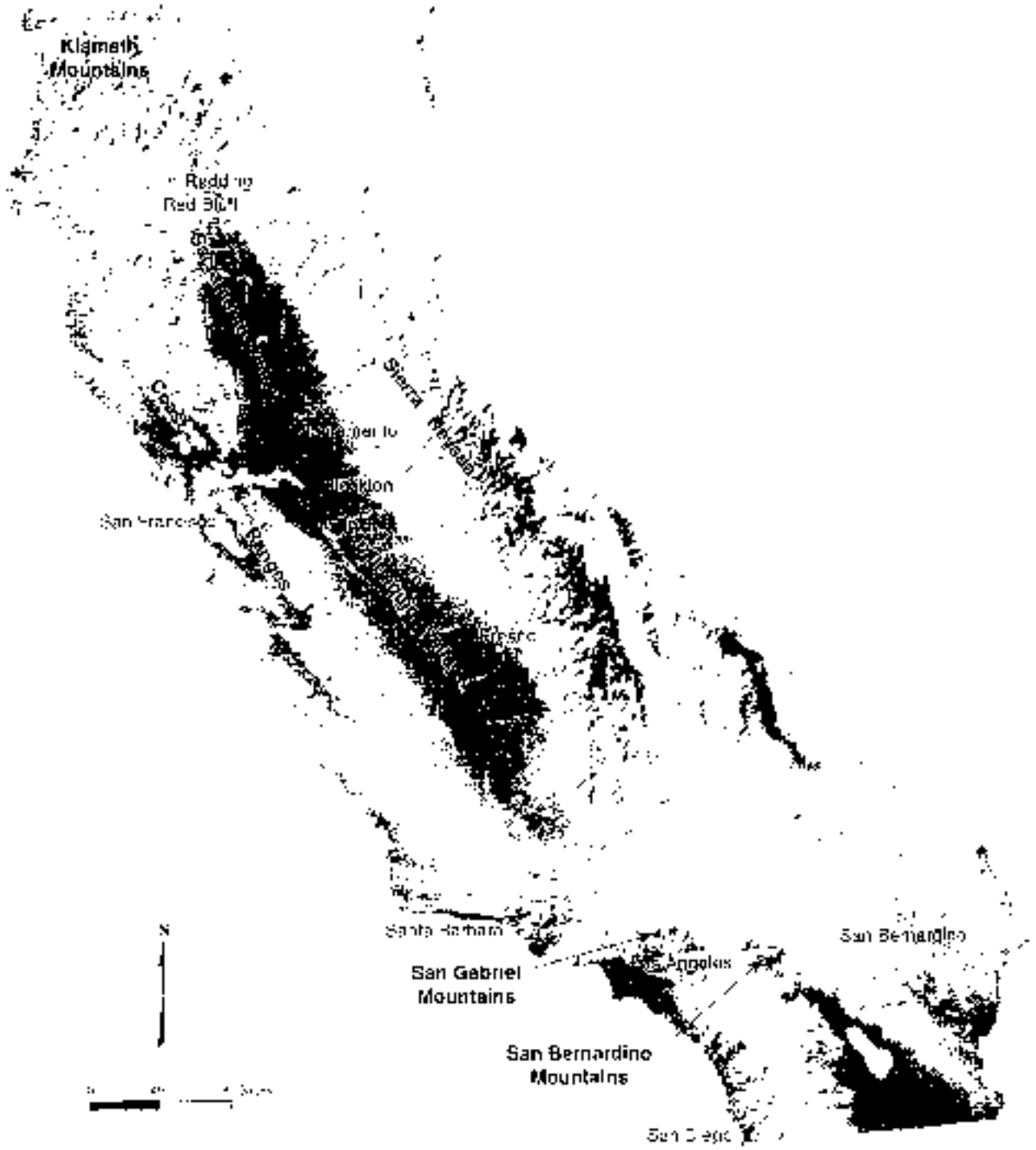

Figure 1 Shaded relief map of California

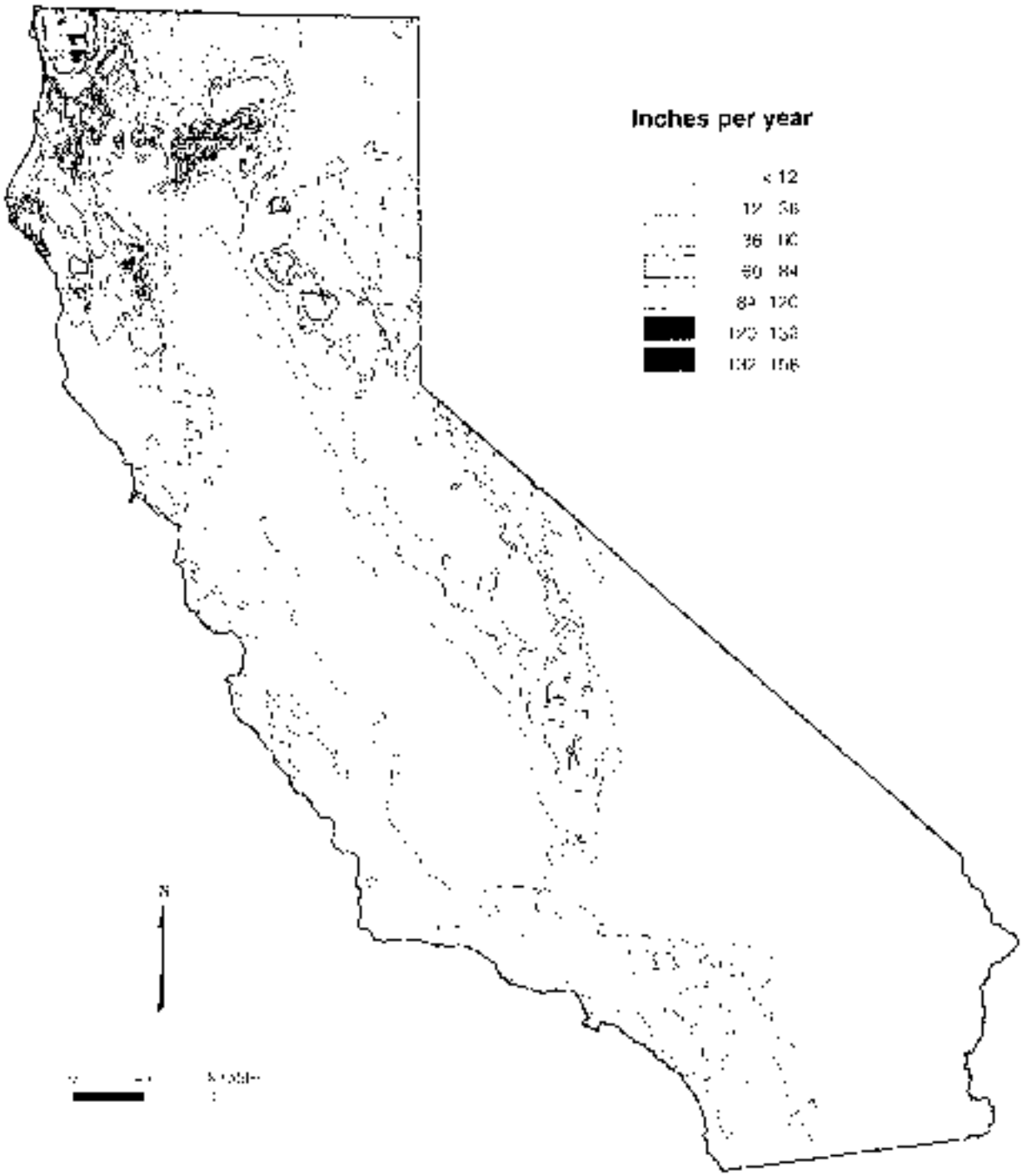

Figure 2. Mean annual precipitation in California, 1961 to 1990

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Figure 3 Groundwater basins, subbasins and hydrologic regions

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California's Water Supply System

The economic success achieved in California could not have been foreseen a century ago. California's natural hydrologic system appeared too limited to support significant growth in population, industry, and agriculture. The limitations revolved around not only the relative aridity of the State, but the geographic, seasonal, and climatic variability that influences California's water supply. Approximately 70 percent of the State's average annual runoff occurs north of Sacramento, while about 75 percent of the State's urban and agricultural water needs are to the south. Most of the State's precipitation falls between October and April with half of it occurring December through February in average years. Yet, the peak demand for this water occurs in the summer months. Climatic variability includes dramatic deviations from average supply conditions by way of either droughts or flooding. In the 20th century alone, California experienced multi-year droughts in 1912–1913, 1918–1920, 1922–1924, 1929–1934, 1947–1950, 1959–1961, 1976–1977, and 1987–1992 (DWR 1998).

California has dealt with the limitations resulting from its natural hydrology and achieved its improbable growth by developing an intricate system of reservoirs, canals, and pipelines under federal, State and local projects (Figure 4). However, a significant portion of California's water supply needs is also met by groundwater. Typically, groundwater supplies about 30 percent of California's urban and agricultural uses. In dry years, groundwater use increases to about 40 percent statewide and 60% or more in some regions.

The importance of groundwater to the State's development may have been underestimated at the beginning of the 20th century. At that time, groundwater was seen largely as just a convenient resource that allowed for settlement in nearly any part of the State, given groundwater's widespread occurrence. Significant artesian flow from confined aquifers in the Central Valley allowed the early development of agriculture. When the Water Commission Act defined the allocation of surface water rights in 1914, it did not address allocation of the groundwater resource. In the 1950s, the development of the deep-well turbine pump and the increased availability of electricity led to a tremendous expansion of agriculture, which used these high-volume pumps and increased forever the significance of groundwater as a component of water supply in California.

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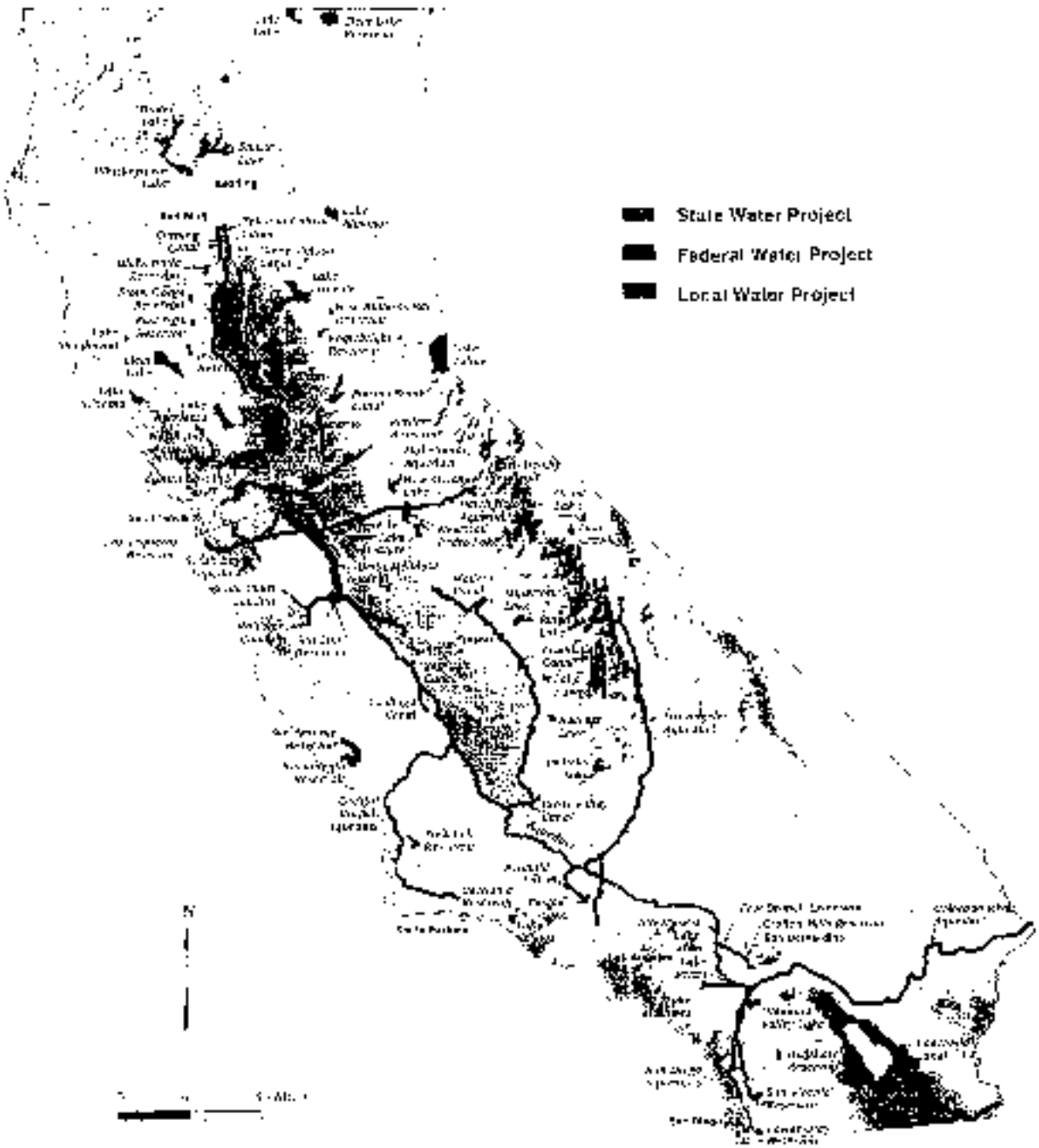

Figure 4 Water projects in California

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Box 8 Will Climate Change Affect California's Groundwater?

California's water storage and delivery system can be thought of as including three reservoir systems—the snowpack of the Sierra Nevada, an extensive system of dams, lakes, and conveyance systems for surface water, and finally the aquifers that store groundwater. Precipitation in the form of snow is stored in the Sierra in winter and early spring and under ideal conditions melts in a manner that allows dams to capture the water for use during California's dry season. When snow melts faster, the dams act as flood control structures to prevent high runoff from flooding lowland areas. Water storage and delivery infrastructure—dams and canals—has been designed largely around the historical snowpack, while aquifers have played a less formal and less recognized role.

What will be the affect of climate change on California's water storage system? How will groundwater basins and aquifers be affected?

The latest report of the Intergovernmental Panel on Climate Change (2001) reaffirms that climate is changing in ways that cannot be accounted for by natural variability and that "global warming" is occurring. Studies by the National Water Assessment Team for the U.S. Global Change Research Program's National Assessment of the Potential Consequences of Climate Variability and Change identify potential changes that could affect water resources systems. For California, these include higher snow levels leading to more precipitation in the form of rain (or runoff) and rise in sea level, and possibly larger floods. In addition to affecting the balance between storage and flood control of our reservoirs, such changes in hydrology would affect wetlands, resulting in fauna and flora displacement and resulting changes in vegetative water consumption. These changes would also affect patterns of both irrigated and dryland farming.

A warmer, wetter winter would increase the amount of runoff available for groundwater recharge, however this additional runoff in the winter would be occurring at a time when some basins, particularly in Northern California, are either being recharged at their maximum capacity or are already full. Conversely, reductions in spring runoff and higher evapotranspiration because of warmer temperatures could reduce the amount of water available for recharge and surface storage.

The extent to which climate will change and the impact of that change are both unknown. A reduced snowpack, coupled with increased seasonal rainfall and earlier snowmelt, may require a change in the operating procedures for existing dams and conveyance facilities. Furthermore, these changes may require more active development of successful conjunctive management programs in which the aquifers are more effectively used as storage facilities. Water managers might want to evaluate their systems to better understand the existing snowpack surface water/groundwater relationship and identify opportunities that may exist to optimize groundwater and other storage capability under a new hydrologic regime that may result from climate change. If more water was stored in aquifers or in new or reoperated surface storage, the additional water could be used to meet water demands when the surface water supply was not adequate because of reduced snowmelt.

AR0069648

Recent Groundwater Development Trends

While development of California's surface water storage system has slowed significantly, groundwater development continues at a strong pace. A review of well completion reports submitted to the California Department of Water Resources (DWR) provides data on the number and type of water wells drilled in California since 1987. For the 14-year period, DWR received 127,616 well completion reports for water supply wells that were newly constructed, reconditioned, or deepened — an average of 9,115 annually[1]. Of these, 82 percent were drilled for individual domestic uses; 14 percent for irrigation; and about 4 percent for a combined group of municipal and industrial uses (figure 5). Although domestic wells predominate, individual domestic use makes up a small proportion of total groundwater use in the State.

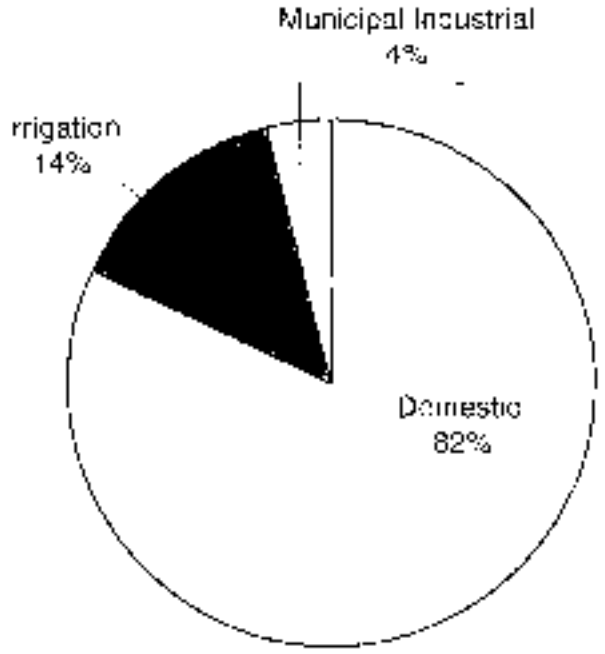

Figure 5 Well completion reports filed with DWR from 1987 through 2000

The most evident influence on the number of wells constructed is hydrologic conditions. The number of wells constructed and modified increases dramatically with drought conditions (figure 6). The number of wells constructed and modified annually from 1987 through 1992 is more than double the annual totals for 1993 through 2000. Each year from 1987 through 1992 was classified as either dry or critically dry; water years 1993 through 2000 were either above normal or wet, based on measured unimpaired runoff in the Sacramento and San Joaquin valleys. In addition to providing an indication of the growth of groundwater development, well completion reports are a valuable source of information on groundwater basin conditions.

[1] DWR also received an average of 1,225 well completion reports for monitoring, which were not included above because they do not extract groundwater for supply purposes.

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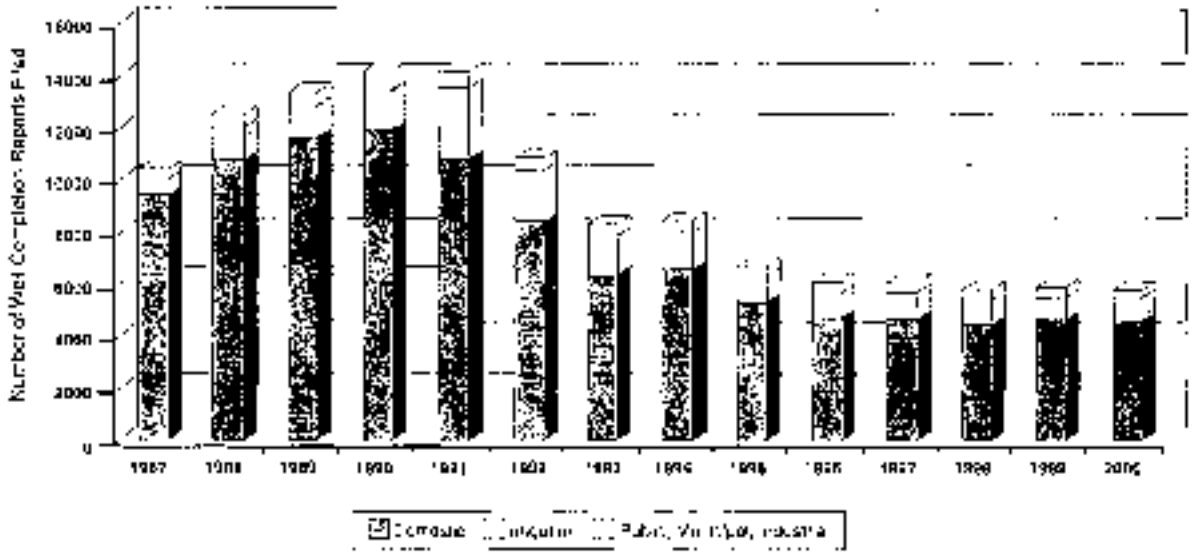

Figure 6 Well completion reports filed annually from 1987 through 2000

The Need for Groundwater Monitoring and Evaluation

Some 34 million people called California their home in the year 2000, and a population of nearly 46 million is expected by 2020. The increased population and associated commercial, industrial, and institutional growth will bring a substantially greater need for water. This need will be met in part by improved water use efficiency, opportunities to reoperate or expand California's surface water system, and increased desalination and recycling of water sources not currently considered usable. This need will also be met by storing and extracting additional groundwater. However, the sustainability of the groundwater resource, both in terms of what is currently used and future increased demand, cannot be achieved without effective groundwater management. In turn, effective groundwater management cannot be achieved without a program of groundwater data collection and evaluation.

Perhaps surprising to many, California does not have a comprehensive monitoring network for evaluating the health of its groundwater resource, including quantity and quality of groundwater. The reasons for this are many with the greatest one being that information on groundwater levels and groundwater quality is primarily obtained by drilling underground, which is relatively expensive. Given that, delineated groundwater basins cover about 40 percent of the State's vast area, the cost of a dedicated monitoring network would be prohibitive. The other important reason for the lack of a comprehensive network is that, as will be discussed later in this report, groundwater is a locally controlled resource. State and federal agencies become involved only when a groundwater issue is directly related to the mission of a particular agency or if a local agency requests assistance. For these and other reasons, California lacks a cohesive, dedicated monitoring network.

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Box C What about Overdraft?

Overdraft is the condition of a groundwater basin in which the amount of water withdrawn by pumping over the long term exceeds the amount of water that recharges the basin. Overdraft is characterized by groundwater levels that decline over a period of years and do not fully recover even in wet years. Overdraft can lead to increased pumping costs, land subsidence, water quality degradation, and environmental impacts.

The California Water Plan Update, Bulletin 160-98 (DWR 1998) estimated that groundwater overdraft in California in 1995 was nearly 1.5 million acre-feet annually, with most of the overdraft occurring in the Tulare Lake, San Joaquin River, and Central Coast hydrologic regions. The regional and statewide estimates of overdraft are currently being revised for the 2003 update of Bulletin 160. While these estimates are useful from a regional and statewide planning perspective, the basin water budgets calculated for this update of Bulletin 118 clearly indicate that information is insufficient in many basins to quantify overdraft, track how it has occurred, project future impacts on groundwater storage, and effectively manage groundwater. Further technical discussion of overdraft is provided in Chapter 6 of this bulletin.

When DWR and other agencies involved in groundwater began to collect data in the first half of the 20th century, it quickly became evident that there were insufficient funds to install an adequate number of monitoring wells to accurately determine changes in the condition of groundwater basins. Consequently, to create a serviceable monitoring network, the agencies asked owners of irrigation or domestic wells for permission to measure water levels and to a lesser extent to monitor water quality. These have been called "wells of opportunity." In many areas, this approach has led to a network of wells that provide adequate information to gain a general understanding of conditions in the subsurface and to track changes through time. In some areas, groundwater studies were conducted and often included the construction of a monitoring well network. These studies have gradually contributed to a more detailed understanding of some of California's groundwater basins, particularly the most heavily developed basins.

Given the combination of monitoring wells of opportunity and dedicated monitoring wells, it might be assumed that an adequate monitoring network in California will eventually accumulate. However, several factors contribute to reducing the effectiveness of the monitoring network for data collection and evaluation: (1) The funding for data programs in many agencies, which was generally insufficient in the first place, has been reduced significantly. (2) When private properties change ownership, some new owners rescind permission for agency personnel to enter the property and measure the well. (3) The appropriateness of using these private wells is questionable because they are often screened over long intervals encompassing multiple aquifers in the subsurface, and in some cases construction details for the well are unknown. (4) Some wells with long-term records actually reach the end of their usefulness because the casing collapses or something falls into the well, making it unusable. In some cases, groundwater levels may drop below the well depth. (5) As water quality or water quantity conditions change, the monitoring network may no longer be adequate to provide necessary data to manage groundwater.

AR0069651

The importance of long-term monitoring networks cannot be overstated. Sound groundwater management decisions require observation of trends in groundwater levels and groundwater quality. Only through these long-term evaluations can the question of sustainability of groundwater be answered. For example, this report contains a summary of groundwater contamination in public water supply wells throughout the State collected from 1994 through 2000. While this provides a "snap-shot" of the suitability of the groundwater currently developed for public supply needs, it does not address sustainability of groundwater for public uses. Sustainability can only be determined by observing groundwater quality over time. If conditions worsen, local managers will need to take steps to prevent further harm to groundwater quality. Long-term groundwater records require adequate funding and staff to develop groundwater monitoring networks and to collect, summarize, and evaluate the data.

AR0069652

Chapter 2
Groundwater Management in California

Chapter 2
Groundwater Management in California

Groundwater management, as defined in this report, is the planned and coordinated monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of long-term sustainability of the resource. Throughout the history of water management in California, local agencies have practiced an informal type of groundwater management. For example, since the early 20th century, when excess surface water was available, some agencies intentionally recharged groundwater to augment their natural water supply. In 1947, the amount of groundwater used was estimated at 8 million to 10 million acre-feet. By the beginning of the 21st century, the amount of groundwater used had increased to an estimated 15 million acre-feet. Better monitoring would provide more accurate information. This increased demand on California's groundwater resources, when coupled with estimates of population growth, has resulted in a need for more intensive groundwater management.

In 1914, California created a system of appropriating surface water rights through a permitting process (Stats. 1913, ch. 586), but groundwater use has never been regulated by the State. Though the regulation of groundwater has been considered on several occasions, the California Legislature has repeatedly held that groundwater management should remain a local responsibility (Sax 2002). Although they are treated differently legally, groundwater and surface water are closely interconnected in the hydrologic cycle. Use of one resource will often affect the other, so that effective groundwater management must consider surface water supplies and uses.

Figure 7 depicts the general process by which groundwater management needs are addressed under existing law. Groundwater management needs are identified at the local water agency level and may be directly resolved at the local level. If groundwater management needs cannot be directly resolved at the local agency level, additional actions such as enactment of ordinances by local governments, passage of laws by the Legislature, or decisions by the courts may be necessary to resolve the issues. Upon implementation, local agencies evaluate program success and identify additional management needs. The State's role is to provide technical and financial assistance to local agencies for their groundwater management efforts, such as through the Local Groundwater Assistance grant program (see Chapter 4, AB 303).

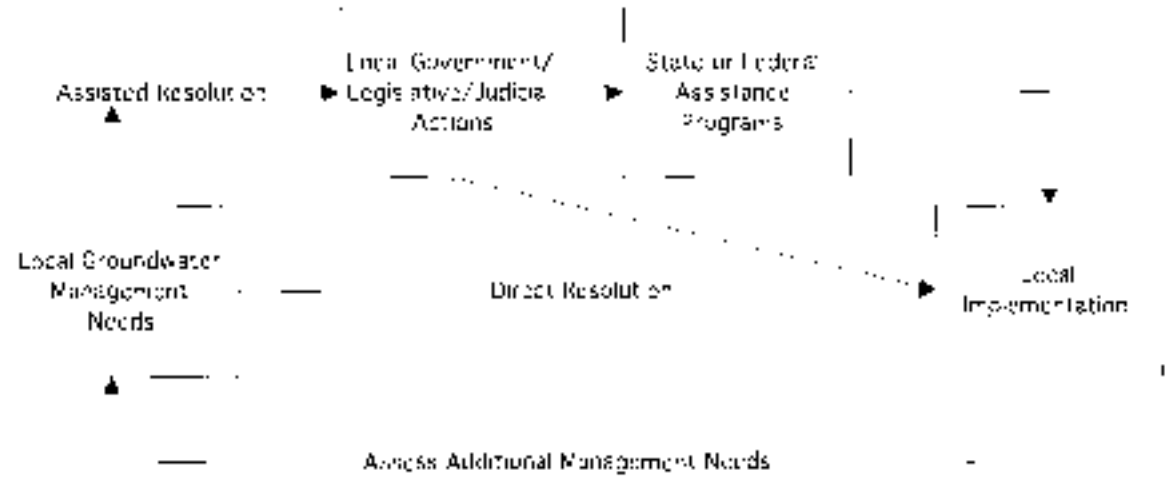

Figure 7 Process of addressing groundwater management needs in California

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How Groundwater is Managed in California

There are three basic methods available for managing groundwater resources in California: (1) management by local agencies under authority granted in the California Water Code or other applicable State statutes, (2) local governmental groundwater ordinances or joint powers agreements, and (3) court adjudications. Table 1 shows how often each of these methods has been used, and each method is discussed briefly below. No law requires that any of these forms of management be applied in a basin. Management is often instituted after local agencies or landowners recognize a specific groundwater problem. The level of groundwater management in any basin or subbasin is often dependent on water availability and demand.

Table 1. Groundwater management methods

Method	Frequency of use[a]
Local water agencies	Undetermined number of agencies with authority to manage some types of groundwater under general powers associated with particular types of districts.
	Thirteen agencies with specially legislated authority to limit or regulate extraction.
	Seven agencies with adopted groundwater ordinances under Water Code Section 10750 et seq.[b] (As of 1991).
	More than 300 agencies with adopted plans with authority from Water Code Section 10753 et seq. (As of 1991).
Local ordinances, management and taxes	Currently adopted in 27 counties.
Court adjudication	Currently decided in 19 groundwater basins, mostly in Southern California. Three more basins are in court.

a. These figures do not include the many instances (typically within the California Department of Water Resources) in which
b. Section 10750 et seq. was amended in 1992.

Groundwater Management through Authority Granted to Local Water Agencies

More than 20 types of local agencies are authorized by statute to provide water for various beneficial uses. Many of these agencies also have statutory authority to institute some form of groundwater management. For example, a Water Replenishment District (Water Code, § 60000 et seq.) is authorized to establish groundwater replenishment programs and collect fees for that service. A Water Conservation District (Water Code, § 75500 et seq.) can levy groundwater extraction fees. Table 2 lists these and other types of local agencies that deliver water and may have authority to institute some form of groundwater management. Most of these agencies are identified in the Water Code, but their specific authority related to groundwater management varies. The Water Code does not require that the agencies report their activities to the California Department of Water Resources (DWR).

AR0069655

Table 2 Local agencies with authority to deliver water for beneficial uses, which may have authority to institute groundwater management

Local agency	Authority	Number of agencies[a]
Community Services District	Gov. Code § 61000 et seq.	115
County Sanitation District	Health and Safety Code § 4700 et seq.	91
County Service Area	Gov. Code § 25210.1 et seq.	307
County Water Authority	Water Code App. 45.	30
County Water District	Water Code § 30000 et seq.	174
County Waterworks District	Water Code § 55000 et seq.	34
Flood Control and Water Conservation District	Water Code App. 38.	19
Irrigation District	Water Code § 20500 et seq.	97
Metropolitan Water District	Water Code App. 109.	1
Municipal Utility District	Pub. Util. Code § 11501 et seq.	5
Municipal Water District	Water Code § 71000 et seq.	91
Public Utility District	Pub. Util. Code § 15501 et seq.	54
Reclamation District	Water Code § 50000 et seq.	152
Recreation and Park District	Pub. Resources Code § 5780 et seq.	110
Resort Improvement District	Pub. Resources Code § 13000 et seq.	-
Resource Conservation District	Pub. Resources Code § 9001 et seq.	96
Water Conservation District	Water Code App. 34; Wat. Code § 74000 et seq.	13
Water District	Water Code § 34000 et seq.	241
Water Replenishment District	Water Code § 60000 et seq.	1
Water Storage District	Water Code § 39000 et seq.	8

a From State Controller's Office Special Districts Annual Report, 1991 Edition.

Greater authority to manage groundwater has been granted to a small number of local agencies or districts created through special acts of the Legislature. For example, the Sierra Valley Groundwater Basin Act of 1980 (Water Code, App. 119) created the first two groundwater management districts in California. Currently, 13 local agencies have specific groundwater management authority as a result of being special act districts. The specific authority of each agency varies, but they can generally be grouped into two categories. Most of the agencies formed since 1980 have the authority to limit export and even control some in basin extraction upon evidence of overdraft or the threat of overdraft. These agencies can also generally levy fees for groundwater management activities and for water supply replenishment. Agencies formed prior to 1980 do not have authority to limit extraction from a basin. However, the groundwater users in these areas are generally required to report extractions to the agency, and the agency can levy fees for groundwater management or water supply replenishment. Some of these agencies have effectively used a tiered fee

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structure to discourage excessive groundwater extraction in the basin. Table 1 lists the names of special act districts with legislative authority to manage groundwater.

Table 3 Special act districts with groundwater management authority in California

District or agency	Water Code citation[a]	Year agency established or Code[b]
Desert Water Agency	App. 100	1961
Fox Canyon Groundwater Management Agency	App. 121	1982
Honey Lake Groundwater Management District	App. 129	1989
Long Valley Groundwater Management District	App. 119	1980
Mendocino City Community Services District	Section 10700 et seq.	1987
Monte Vista/Lone Valley Groundwater Management District	App. 79	1989
Monterey Peninsula Water Management District	App. 118	1977
Ojai Groundwater Management Agency	App. 151	1991
Orange County Water District	App. 40.	1933
Pajaro Valley Water Management Agency	App. 120	1984
Santa Clara Valley Water District	App. 60.	1951
Sierra Valley Groundwater Management District	App. 119	1980
Willow Creek Groundwater Management Agency	App. 155	1993

a. Refers to West's Annotated California Codes (Deering's).
b. This is the year the agency was established. Also, Water Code Specific authorities, such as those for groundwater management activities, may have been granted through later amendments.

In 1992, AB 255 (Stats. 1991, Ch. 903) was enacted authorizing local agencies overlying basins subject to critical conditions of overdraft, as defined in DWR's Bulletin 118-80, to establish programs for groundwater management within their service areas. Water Code section 10750 et seq. provided these agencies with the powers of a water replenishment district to raise revenue for facilities to manage the basin for the purposes of extraction, recharge, conveyance, and water quality. Seven local agencies adopted plans under this authority.

The provisions of AB 255 were repealed in 1992 with the passage of AB 3030 (Stats. 1992, Ch. 947). This legislation was significant in that it greatly increased the number of local agencies authorized to develop a groundwater management plan and set forth a common framework for management by local agencies throughout California. AB 3030, which is codified in Water Code section 10750 et seq., provides a systematic procedure to develop a groundwater management plan by local agencies overlying the groundwater basins defined by Bulletin 118-75 (DWR 1975) and updates. Upon adoption of a plan, these agencies could possess the same authority as a water replenishment district to "fix and collect fees and assessments for groundwater management" (Water Code, § 10754). However, the authority to fix and collect these fees and assessments is contingent on receiving a majority of votes in favor of the proposal in a local election (Water Code, § 10754.3). More than 200 agencies have adopted an AB 3030 groundwater management plan. None of these agencies is known to have exercised the authority of a Water Replenishment District.

Water Code section 10753.2 expands groundwater management opportunities by encouraging coordinated plans and by authorizing public agencies to enter into a joint powers agreement or memorandum of understanding with public or private entities that provide water service. At least 20 coordinated plans have been prepared to date involving nearly 120 agencies, including cities and private water companies.

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Local Groundwater Ordinances

A second general method of managing groundwater in California is through ordinances adopted by local governments such as cities or counties. Twenty-seven counties have adopted groundwater ordinances, and others are being considered (Figure 8). The authority of counties to regulate groundwater has been challenged, but in 1995 the California Supreme Court declined to review an appeal of a lower court decision, *Baldwin v. County of Tehama* (1994) that holds that State law does not occupy the field of groundwater management and does not prevent cities and counties from adopting ordinances to manage groundwater under their police powers. However, the precise nature and extent of the police power of cities and counties to regulate groundwater is uncertain.

The Public Policy Institute of California recently performed a study of California's water transfer market, which included a detailed investigation of the nature of groundwater ordinances by counties in California. The report found that 22 counties had adopted ordinances requiring a permit to export groundwater. In all but three cases, restricting out-of-county uses appears to be the only purpose (Hanak 2003). One ordinance, adopted recently in Glenn County (Box D, "Basin Management Objectives for Groundwater Management"), takes a comprehensive approach by establishing management objectives for the county's groundwater basins. Several other counties in Northern California are considering adopting similar management objective based ordinances.

Ordinances are mostly a recent trend in groundwater management, with 24 of the 27 ordinances enacted since 1990. Local ordinances passed during the 1990s have significantly increased the potential role of local governments in groundwater management. The intent of most ordinances has been to hold project proponents accountable for impacts that may occur as a result of proposed export projects. Because adoption of most of these ordinances is recent, their effect on local and regional groundwater management planning efforts is not yet fully known. However, it is likely that future groundwater development will take place within the constraints of local groundwater management ordinances. Table 4 lists counties with groundwater management ordinances and their key elements.

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Figure 8 Counties with groundwater ordinances

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Box D Basin Management Objectives for Groundwater Management

Most county groundwater management ordinances require that an export proponent prove the project will not deplete groundwater, cause groundwater quality degradation, or result in land subsidence. Although these factors could be part of any groundwater management plan, these ordinances do not require that a groundwater management plan be developed and implemented.

The only ordinance requiring development and adoption of objectives to be accomplished by management of the basin was adopted by the Glenn County Board of Supervisors in 2000. This action came after a citizen's committee spent five years working with stakeholders. The process of developing a groundwater management ordinance for Glenn County began in 1995 when local landowners and county residents became concerned about plans to export groundwater or substitute groundwater for exported surface water. Control of exports was the focus of early ordinance discussions.

After many discussions and technical advice from groundwater specialists, the committee realized that goals and objectives must be identified for effective management of groundwater in the county. What do the county want to accomplish by managing groundwater within the county? What did groundwater management really mean?

The concept of establishing basin management objectives emerged (BMOs). BMOs would establish threshold values for groundwater levels, groundwater quality, and land surface subsidence. When a threshold level is reached, the rules and regulations require that groundwater extraction be adjusted or stopped to prevent exceeding the threshold.

The Glenn County Board of Supervisors has adopted BMOs, which were developed by an advisory committee, for groundwater levels throughout the county. While currently there are 17 BMOs representing the 17 management areas in the county, the goal is to begin managing the entire county as a unit that benefits each of the local agencies and their landowners, as well as landowners outside of an Agency boundary. The committee is now developing BMOs for groundwater quality and land surface subsidence.

There is no single set of management objectives that will be successful in all areas. Groundwater management must be adapted to an area's political, institutional, legal, and technical constraints and uncertainties. Groundwater management must be tailored to each basin or subbasin's conditions and needs. Even within a single basin, the management objectives may change as more is learned about managing the resource within that basin. Flexibility is the key, but that flexibility must operate within a framework that ensures public participation, monitoring, evaluation, feedback on management alternatives, rules and regulations, and enforcement.

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Table 4 Counties with ordinances addressing groundwater management

County	Year enacted	Key elements (refer to ordinances for exemptions and other details)
Butte	1990	Export permit required (extraction & substitute pumping), Water Commission and Technical Advisory Committee, groundwater planning reports (every 5 yrs monitoring program)
Calaveras	2007	Export permit required (extraction & substitute pumping)
Colusa	1998	Export permit required (extraction & substitute pumping)
Fresno	2008	Export permit required (extraction & substitute pumping)
Glenn	1998 ex. 2008	Water Advisory Committee and Technical Advisory Committee, basin management objectives and monitoring network, export permit required (1998)
Imperial	1996	Conservation district established to manage groundwater, discharge monitoring reports (permit required) over-draft, artificial recharge, and development projects
Inyo	1998	Regulates Owens Valley transfers pursuant to Water Code Section 1810, (2) cycles of control of the City of Los Angeles from within Inyo Co., (3) transfer or transport of water from basins within Inyo Co. to another basin with the County, and (4) transfers of water from basins within Inyo Co. to any area outside the County
Kern	1998	Conjunctive use permit for export of waters both outside county and within watershed area of underlying aquifer in question. Only applies to southeastern drainage of Sierra Nevada and Tehachapi mountains
Lake	1999	Export permit required (extraction & substitute pumping)
Lassen	1999	Export permit required (extraction & substitute pumping)
Madera	1999	Permit required for export, groundwater banking, and import for groundwater banking, purposes to areas outside local water agencies
Mendocino	1995	Mining of groundwater regulated for new developments in Town of Mendocino
Merced	2003	Export permit required for transfers out of basin
Mono	1998	Permit required for transfers out of basin
Monterey	1995	Water Resources Agency strictly regulates extractions facilities in zones with groundwater problems
Napa	1996	Permits for basin groundwater extractions. Exemptions for single parcels and agricultural use
Sacramento	1952 ex. 1986	Water Agency created to manage and protect groundwater management zones' replenishment charges
San Benito	1995	Mining groundwater (overdraft) for export prohibited, permit required for off-parcel use, affect up to 200 feet, influence of well for pump restrictions
San Bernardino	2007	Permit required for any new groundwater well within the desert region of the county
San Diego	1997	Provides for managing of groundwater impacted basins (drought), projects within impacted basins require groundwater investigations
San Joaquin	1996	Export permit required (extraction & substitute pumping)
Shasta	1997	Export permit required (extraction & substitute pumping)
Sierra	1998	Export permit required for off-parcel use
Siskiyou	1998	Permit required for transfers out of basin
Tehama	1995	Mining groundwater (overdraft) for export prohibited, permit required for off-parcel use, influence of well pumping restrictions
Tuolumne	2001	Export permit required (extraction & substitute pumping)
Yolo	1996	Export permit required (extraction & substitute pumping)

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Adjudicated Groundwater Basins

A third general form of groundwater management in California is court adjudication. In some California groundwater basins, as the demand for groundwater exceeded supply, landowners and other parties turned to the courts to determine how much groundwater can rightfully be extracted by each user. The courts study available data to arrive at a distribution of the groundwater that is available each year, usually based on the California law of overlying use and appropriation. This court-directed process can be lengthy and costly. As noted in Table 5, the longest adjudication took 24 years. Many of these cases have been resolved with a court approved negotiated settlement, called a stipulated judgment. Unlike overlying and non-overlying rights to groundwater, such decisions guarantee to each party a proportionate share of the groundwater that is available each year. The intense technical focus on the groundwater supply and restrictions on groundwater extraction for all parties make adjudications one of the strongest forms of groundwater management in California.

There are 19 court adjudications for groundwater basins in California, mostly in Southern California (see Table 5). Eighteen of the adjudications were undertaken in State Superior Court and one in federal court. For each adjudicated groundwater basin, the court usually appoints a watermaster to oversee the court judgment. In 15 of these adjudications, the court judgment limits the amount of groundwater that can be extracted by all parties based on a court-determined safe yield of the basin. The basin boundaries are also defined by the court. The Santa Margarita Basin was adjudicated in federal court. That decision requires water users to report the amount of surface water and groundwater they use, but groundwater extraction is not restricted.

Most basin adjudications have resulted in either a reduction or no increase in the amount of groundwater extracted. As a result, agencies often import surface water to meet increased demand. The original court decisions provided watermasters with the authority to regulate extraction of the quantity of groundwater; however, they omitted authority to regulate extraction to protect water quality or to prevent the spread of contaminants in the groundwater. Because water quantity and water quality are inseparable, watermasters are recognizing that they must also manage groundwater quality.

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Box F. Adjudication of Groundwater Rights in the Raymond Basin

The first basin-wide adjudication of groundwater rights in California was in the Raymond Basin in Los Angeles County in 1949 (*Pasadena v. Alhambra*). The first water well in Raymond Basin was drilled in 1887; 20 years later, the number of operating wells grew to about 140. Because of this pumping, the City of Pasadena began spreading water in 1914 to replenish the groundwater and during the next 10 years the city spread more than 20,000 acre-feet.

Pumping during 1930 through 1937 caused water levels to fall 30 to 60 feet in wells in Pasadena. After attempting to negotiate a reduction of pumping on a cooperative basis, the City of Pasadena, on September 25, 1937, filed a complaint in Superior Court against the City of Alhambra and 29 other purveyors to quiet title to the water rights within Raymond Basin. The court ruled that the city must amend its complaint, making defendants of all entities pumping more than 100 acre-feet per year, and that it was not a simple quiet title suit but a general adjudication of the water rights in the basin.

In February 1939, a court-ordered reference procedure under the State Water Code directed the State Division of Water Resources, Department of Public Works (predecessor to the Department of Water Resources) as referee to review all physical facts pertaining to the basin, determine the safe yield, and ascertain whether there was a surplus or an overdraft. The study took 2 1/2 years to complete and cost more than $53,000, which was paid by the parties. The resulting Report of Referee submitted to the court in July 1943 found that the annual safe yield of the basin was 21,900 acre-feet but that the actual pumping and claimed rights were 29,400 acre-feet per year.

Most parties agreed to appoint a committee of seven attorneys and engineers to work out a stipulated agreement. In 1944, the court designated the Division of Water Resources to serve as watermaster for the stipulated agreement, which all but one of the parties supported. On December 23, 1944, the judge signed the judgment that adopted the stipulation.

The stipulation provided that (1) the water was taken by each party openly, notoriously, and under a claim of right, which was asserted to be and was adverse to each and to other parties; (2) the safe yield would be divided proportionally among the parties; and (3) each party's right to a specified proportion of the safe yield would be declared and protected. It also established an arrangement for the exchange of pumping rights among parties.

Based on the stipulation, the court adopted a program of proportionate reductions. In so doing, the court developed the doctrine of mutual prescription, whereby the rights were essentially based on the highest continual amount of pumping during the five years following the beginning of the overdraft, and under conditions of overdraft, all of the overlying and appropriative water users had acquired prescriptive rights against each other, that is, mutual prescription."

In 1946, one party appealed the judgment, and in 1947, the District Court of Appeals reversed and remanded *Pasadena v. Alhambra*. However, on June 3, 1948, the State Supreme Court overturned the appellate court's decision and affirmed the original judgment. In 1950, the court granted a motion by the City of Pasadena that there be a review of the determination of safe yield, and in 1955, the safe yield and the total decreed rights were increased to 32,822 acre-feet per year. In 1984, watermaster responsibilities were assigned to the Raymond Basin Management Board.

In *City of Los Angeles v. City of San Fernando* (1975), the California Supreme Court rejected the doctrine of mutual prescription and held that a groundwater basin would be adjudicated based on the correlative rights of overlying users and prior appropriation among non-overlying users. For further discussion, see Appendix B.

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Table 5 List of adjudicated basins

Court name	Relationship to DWR Bulletin 118 basin name; county	Basin No.	Filed in court	Final decision	Watermaster and/or website
1 Scott River Stream System	Scott River Valley, Siskiyou	1-5	1970	1980	Two local cooperative districts
2 Santa Paula Basin	Subbasin of Santa Clara River, Ventura	4-4	1991	1996	Three person technical advisory committee from United Water Cd, City of Ventura, and Santa Paula Basin Pumpers Association, www.unitedwater.org
3 Central Basin	Northeast part of Coastal Plain of Los Angeles County Basin; Los Angeles	4-11	1962	1965	DWR - Southern District www.dpla.water.ca.gov/sd/watermaster-watermaster.html
4 West Coast Basin	Southwest part of Coastal Plain of Los Angeles County Basin; Los Angeles	4-11	1946	1961	DWR - Southern District, www.dpla.water.ca.gov/sd/watermaster-watermaster.html
5 Upper Los Angeles River Area	San Fernando Valley Basin (entire watershed); Los Angeles	4-12	1955	1979	Superior Court appointee
6 Raymond Basin	Northwest part of San Gabriel Valley Basin; Los Angeles	4-13	1937	1944	Raymond Basin Management Board
7 Main San Gabriel Basin	San Gabriel Valley Basin, excluding Raymond Basin; Los Angeles	4-13	1968	1973	Water purveyors and water districts elect a nine member board, www.watermaster.org
Puente Narrows Addendum to Main San Gabriel Basin decision			1972	1977	Five consulting engineers
8 Pomona	San Gabriel Valley Basin, excluding Raymond Basin; Los Angeles	4-13	1987	1989	Five consultants
9 Cummings Basin	Cummings Valley Basin; Kern	5-2	1964	1972	Tehachapi-Cummings County Water District, www.tcwd.com/pcm.htm
10 Tehachapi Basin	Tehachapi Valley West Basin and Tehachapi Valley East Basin; Kern	5-28 6-45	1966	1973	Tehachapi-Cummings County Water District, www.tcwd.com/gwm.htm
11 Brite Basin	Brite Valley, Kern	5-48	1964	1970	Tehachapi-Cummings County Water District, www.tcwd.com/gwm.htm

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Table 5 List of adjudicated basins (continued)

Court name	Relationship to DWR Bulletin 118 basin name / subbasin	Basin No.	Filed in court	Final decision	Watermaster and/or website
12 Mojave Basin Area Adjudication	Lower, Middle & Upper Mojave River Valley Basins, el Mirage & Lucerne valleys, San Bernardino	6-40, 6-41, 6-42	1990	1996	Mojave Water Agency, www.mojavewater.org/mwa50th.html
13 Warren Valley Basin	Part of Warren Valley Basin, San Bernardino	8-17	1976	1977	Mr. Dewey Water District, www.mojavewater.org
14 Chino Basin	Northwest part of Upper Santa Ana Valley Basin, San Bernardino and Riverside	8-2	1972	1978	Nine people, recommended by producers and appointed by Court — www.cbwm.org
15 Cucamonga Basin	North central part of Upper Santa Ana Valley Basin, San Bernardino	8-2	1975	1978	Not yet appointed; operated as part of Chino Basin
16 San Bernardino Basin Area	Northeast part of Upper Santa Ana Basin, San Bernardino and Riverside	8-2	1963	1969	One representative each from: Western Municipal Water District of Riverside County & San Bernardino Valley Municipal Water District
17 Six Basins	Six subbasins in northwest upper Santa Ana Valley, Upper & Lower Claremont Heights, Canyon, Pomona, Live Oak & Ganesha - Los Angeles. Small portions of Upper Claremont Heights and Canyon are in San Bernardino County	4-11, 8-2	1968	1978	Nine-member board representing all parties to the judgment
18 Santa Margarita River watershed	The Santa Margarita River watershed, including 3 groundwater basins: Santa Margarita Valley, Temecula Valley and Cahuilla Valley Basins, San Diego and Riverside	9-1, 9-5, 9-6	1951	1966	U.S. District Court appointee
19 Goleta	Goleta Central Basin; judgment reduces North Basin. Santa Barbara	3-16	1975	1989	No watermaster appointed; the court retains jurisdiction

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How Successful Have Groundwater Management Efforts Been?

This chapter describes the opportunities for local agencies to manage their groundwater resources. Many have questioned whether these opportunities have led to an overall successful system of groundwater management throughout California. How successful groundwater management has been throughout the State is a difficult question and cannot be answered at present. While there are many examples of local agency successes (see Box B, "Managing through a Joint Powers Agreement," Box C, "Managing a Basin through Integrated Water Management," and Box G, "Managing Groundwater Using both Physical and Institutional Solutions"), there are neither mandates to prepare groundwater management plans nor reporting requirements when plans are implemented, so a comprehensive assessment of local planning efforts is not possible. Additionally, many plans have been adopted only recently, during a period of several consecutive wet years, so many of the plan components are either untested or not implemented.

At a minimum, successful groundwater management should be defined as maintaining and maximizing long-term reliability of the groundwater resource, focused on preventing significant depletion of groundwater in storage over the long term and preventing significant degradation of groundwater quality. A review of some of the groundwater management plans prepared under AB 3030 reveals that some plans are simply brief recitations about continuing the agency's existing programs. Not all agencies that enacted groundwater management plans under AB 3030 are actively implementing the plan.

Despite this apparent lack of implementation of groundwater management plans prepared under AB 3030, the bill has certainly increased interest in more effective groundwater management. With more than 200 agencies participating in plans and more than 120 of those involved in coordinated plans with other agencies, AB 3030 has resulted in a heightened awareness of groundwater management. Additionally, annual reports published by a few water agencies indicate that they are indeed moving toward better coordination throughout the basin and more effective management of all water supplies. Given the history of groundwater management in California, these seemingly small steps toward better management may actually represent giant strides forward.

More recently, financial incentives have played a large role in driving groundwater management activities. For example, under grant and loan programs resulting from Proposition 13 of 2000 (see description in Chapter 4), local agencies submitted applications proposing a total increase in annual water yield of more than 300,000 acre-feet through groundwater storage projects. Additional projects and programs would be developed with sufficient funding for feasibility and pilot studies. Unfortunately, not enough funding exists for all of the proposed projects, and many other legal and institutional barriers remain (see Box E, "Impediments to Conjunctive Management Programs in California"). It is clear, however, that further incentives would help agencies move ahead more aggressively in their groundwater management planning efforts.

Additional progress in groundwater management is reflected by passage of amendments to the Water Code (§§ 10753.4 and 10795.4 as amended, §§ 10753.7, 10753.8, and 10753.9 as amended and renumbered, and §§ 10753.1 and 10753.7 as added) through SB 1938 of 2002. The amendments require that groundwater management plans include specific components for agencies to be eligible for some public funds for groundwater projects. The provisions of SB 1938 (2001) are fully described in Chapters 3 and 4.

This evaluation of groundwater management success has not really considered ordinances and adjudications. Adjudications have been successful at maintaining the groundwater basin conditions, often restricting pumping for all basin users. In some cases, adjudication provides the necessary framework for more proactive management as well. Ordinances have successfully restricted exports from basins, but have not

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Box F Managing through a Joint Powers Agreement

In 1993, representatives from business, environmental, public, and water purveyor interests formed the Sacramento Area Water Forum to develop a plan to protect the region's water resources from the effects of prolonged drought as the demand for water continues to grow. The Water Forum was founded on two co-equal objectives: (1) to provide a reliable and safe water supply for the region's economic health and planned development to the year 2030 and (2) to preserve the fishery, wildlife, recreational and aesthetic values of the lower American River.

After a six-year consensus-based process of education, analysis and negotiation, the participants signed a Water Forum agreement to meet these objectives. The agreement provides a framework for avoiding future water shortages, environmental degradation, groundwater contamination, threats to groundwater reliability, and limits to economic prosperity.

The Sacramento Groundwater Authority (SGA) was formed to fulfill a key Water Forum goal of protecting and managing the north-area groundwater basin. The SGA is a joint powers authority formed for the purpose of collectively managing the region's groundwater resources. This authority permits SGA to make contractual arrangements required to implement a conjunctive use program, and also provides potential partners with the legal and political certainty for entering into long-term agreements.

SGA's regional banking and exchange program is designed to provide long-term supply benefits for local needs, but also will have the potential to provide broader statewide benefits consistent with American River environmental needs. Water stored in Folsom Lake would be conjunctively used with groundwater in order to reduce surface water diversions in dry years and to achieve in-lieu recharge of the basin in wet years. The conjunctive use program participants include 16 water providers in northern Sacramento and southern Placer counties that serve water to more than half a million people.

Two of three implementation phases of the program are complete. In the first phase, program participants identified long-term water supply needs and conducted an inventory of existing infrastructure that could be used to implement the program. In the second phase, SGA completed two pilot banking and exchange projects, demonstrating the technical, legal, and institutional viability of a regional conjunctive use program. In the first pilot study, water agencies worked with the U.S. Bureau of Reclamation and the Sacramento Area Flood Control Agency to bank 2,100 acre-feet of groundwater, providing additional flood storage capacity in Folsom Lake. In the second pilot study, Citrus Heights and Fair Oaks water districts and the city of Sacramento extracted and used 7,143 acre-feet of groundwater, forgoing a portion of their rights to surface water, making this water available to the Environmental Water Account. The third phase of the SGA program is to further solidify the institutional frameworks and construct facilities to implement a full-scale regional conjunctive use program. These facilities, that will result in an average annual yield of 21,400 acre-feet, are currently under construction, funded in part by a $21.6 million grant under Proposition 13 of 2000.

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Box C: Managing a Basin through Integrated Water Management

Orange County Water District (OCWD) was established in 1933 by an uncodified Act (Water Code App. 40) to manage Orange County's groundwater basin and protect the Santa Ana River rights of water users of north-central Orange County. The district manages the groundwater basin, which provides as much as 75 percent of the water supply for its service area. The district strives for a groundwater-based water supply with enough reserves to provide a water supply through drought conditions. An integrated set of water management practices helps achieve this, including the use of recharge, alternative sources, and conservation.

Recharge

The Santa Ana River provides the main natural recharge source for the county's groundwater basin. Increased groundwater use and lower than average rainfall during the late 1980s and early 1990s forced the district to rely on an aggressive program to enhance recharge of the groundwater basin. Programs used today to optimize water use and availability include:

- Construction of levees in the river channel to increase infiltration.
- Construction of additional recharge basins within the forebay.
- Development of an underwater basin cleaning vehicle that removes a clogging layer at the bottom of the recharge basin and extends the time between draining the basin for cleaning by a bulldozer.
- Use of stormwater captured behind Prado Dam that would otherwise flow to the ocean.
- Use of imported water from the State Water Project and Colorado River.
- Injection of treated recycled water to form a seawater intrusion barrier.

Alternative Water Use and Conservation

OCWD has successfully used nontraditional sources of water to help satisfy the growing need for water in Orange County. Projects that have added to the effective supply of groundwater are:

- Use of treated recycled water for irrigation and industrial use.
- In-lieu use to reduce groundwater pumping.
- Change to low-flow toilets and showerheads.
- Participation of 70 percent of Orange County hotels and motels in water conservation programs.
- Change to more efficient computerized irrigation.

Since 1975, Water Factory 21 has provided recycled water that meets all primary and secondary drinking water standards set by the California Department of Health Services. OCWD has proposed a larger, more efficient membrane purification project called the Groundwater Replenishment System (GWRS), which is scheduled to begin operating at 70,000 acre-feet per year in 2007. By 2020 the system will annually supply 131,000 acre-feet of high-quality water for recharge, for injection into the seawater intrusion barrier, and for direct industrial uses.

This facility will use a lower cost, microfiltration and reverse osmosis treatment process that produces water of near-distilled quality, which will help reverse the trend of rising total dissolved solids (TDS) in groundwater caused by the recharge of higher TDS-content Santa Ana River and Colorado River waters. The facility will use about half the energy required to import an equivalent amount of water to Orange County from Northern California. The GWRS will be funded, in part, by a $30 million grant under Proposition 13 of 2000.

Source: Orange County Water District

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Box H Managing Groundwater using both Physical and Institutional Solutions

Four agencies share responsibility for groundwater management in Ventura County. Coordination and cooperation between these agencies focus on regular meetings, attendance at each other's board meetings, joint projects, watershed committees, and ongoing personal contacts to discuss water-related issues. The agencies and their areas of responsibility are:

- United Water Conservation District – physical solutions: monitoring, modeling, recharging, administering management plans and adjudication;
- Fox Canyon Groundwater Management Agency – pumping allocations, credits and penalties, abandoned well destruction, data for irrigation efficiency
- County of Ventura – well permits, well construction regulations, tracking abandoned wells; and
- Calleguas Municipal Water District – groundwater storage of imported water

In Ventura County 75% to 80% of the extracted groundwater is for agriculture, the remainder is for municipal and industrial use. Seawater intrusion into the aquifers was recognized in the 1930s and was the driving force behind a number of groundwater management projects and policies in the county's groundwater basins. As groundwater issues became more complicated at the end of the 20th century, these groundwater management projects and policies were useful in solving a number of problems.

Physical Solutions

Physical solutions substitute supplemental surface water for groundwater pumping near coastal areas, increase basin recharge, and increase the reliability of imported water. Projects include:

- Winter flood-flow storage for dry season release
- Wells and pipelines to move pumping for drinking water away from the coast
- Diversion structures to supply surface water to spreading grounds and irrigation
- Pipelines to convey surface water to coastal areas
- Las Posas Basin Aquifer Storage and Recovery project

Institutional Solutions

Institutional solutions focus on developing and implementing effective groundwater management programs, reducing pumping demands, tracking groundwater levels and water quality, managing groundwater pumping patterns, and destroying abandoned wells to prevent cross-contamination of aquifers. Solutions include:

- Creation of Fox Canyon Groundwater Management Agency (GMA), which represents each major pumping constituency
- Use of irrigation efficiency (agricultural water conservation) and alternative sources of water (urban) to reduce pumping by 25%
- Manage pumping in the GMA area through an AB 3030 plan and a court adjudication
- Limit new permits for wells in specific aquifers to avoid seawater intrusion
- Creation of a program to destroy abandoned wells
- Creation of a database of historical groundwater levels and quality information collected since the 1920s
- Development of a regional groundwater flow model and a regional master plan for groundwater projects
- Creation of an irrigation weather station to assist in irrigation efficiency

Implementation of these physical and institutional management tools has resulted in the reversal of seawater intrusion in key coastal monitoring wells. These same tools are being used to mitigate saline intrusion (not seawater) in two inland basins and to reduce seasonal nitrate problems in the recharge area. Work is being expanded to help reduce loading of agricultural pesticides and nutrients. Without close coordination and cooperation of the county's water-related agencies, municipalities, and landowners, it would have been very difficult to implement most of these solutions. Although such coordination takes time, the investment has paid off in solutions that help provide a sustainable water supply for all water users in Ventura County.

Source: United Water Conservation District

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necessarily improved groundwater management. The primary intent of most ordinances is to ensure that proponents of projects are held accountable for potential impacts of the proposed export projects. As studies lead to a better understanding of local water resources, development of pilot export and transfer projects, with appropriate monitoring, may lead to greater certainty in managing groundwater resources. Areas managed under adjudications and ordinances will continue to develop more active management approaches. Population growth and its accompanying increased demand on the resources is a certainty. Most geographic areas in California are not immune to this growth. As strategies for more than just maintaining existing groundwater supply through extraction or export restrictions need to be implemented.

Box I Impediments to Conjunctive Management Programs in California

In 1996 the National Water Research Institute in cooperation with the Association of Ground Water Agencies and the Metropolitan Water District of Southern California, conducted a workshop to determine the biggest impediments to implementing a cost effective conjunctive water management program in California.

Since that time, some steps have been taken to overcome those impediments, but several important barriers remain. Workshop participants identified the 10 most significant obstacles:

1) Inability of local and regional water management governance entities to build trust, resolve differences (internally and externally), and share control.
2) Inability to match benefits and funding burdens in ways that are acceptable to all parties, including third parties.
3) Lack of sufficient federal, State, and regional financial incentives to encourage groundwater conjunctive use to meet statewide water needs.
4) Legal constraints that impede conjunctive use, regarding storage rights, basin judgments, area of origin, water rights, and adjudication.
5) Lack of statewide leadership in the planning and development of conjunctive use programs as part of comprehensive water resources plans which recognize local, regional, and other stakeholders' interests.
6) Inability to address quality differences in "old" versus "new" standards for injection, export, and reclaimed water and unforeseeable future groundwater degradation.
7) Risk that water stored cannot be extracted when needed because of infrastructure, water quality or water level policies, and institutional or contractual provisions.
8) Lack of assurances to prevent third-party impacts and uncertainties to increase willingness of local citizens to participate.
9) Lack of creativity in developing "win-win" conjunctive use projects, agreements, and programs.
10) Supplemental suppliers and basin managers have different roles and expectations in relation to conjunctive use.

[Editor's note: The California Department of Water Resources' Conjunctive Water Management program has been significant steps to overcome several of these impediments, using a combination of California Bay-Delta Authority, IRWM, Proposition 13, and AB 303 funds to promote locally planned and controlled conjunctive use programs.]

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Future Groundwater Management in California

Trying to predict what will happen with groundwater management in California is difficult given that actions by all of the involved groups—landowners, local governments, local, State, and federal agencies, and the courts—will continue to shape groundwater management in the future. However, the increasing population and the demands on California's water supply will accelerate the rate at which groundwater management issues become critical and require resolution. Some general conclusions are:

- Groundwater management will continue to be a local responsibility with increasing emphasis on how actions in one part of a basin impact groundwater resources throughout the basin. Regional cooperation and coordination of groundwater management activities will increase.

- As the State's population continues to grow, the increased reliance on groundwater will keep the topic of groundwater management at the forefront of legislative interest.

- Coordinated management of groundwater and surface water resources, through further development of conjunctive water management programs and projects, will become increasingly important.

- The increased reliance on groundwater in the future will necessitate a more direct link between land use planning, watershed management, floodplain management, and groundwater management plans.

- Current trends indicate that financial incentives in the form of loans and grants are increasing groundwater management planning and implementation at the local level. These successes will only continue at the current pace with increased funding to local agencies.

- Management of groundwater will increasingly include consideration of groundwater quality and groundwater quantity.

- Groundwater will be an important element in the trend toward an integrated water management approach that considers the full range of demand management and supply alternatives.

- Understanding of the relationship of groundwater and surface water and the role of groundwater in the environment will continue to grow.

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Box 3 Managing Groundwater Quantity and Quality

When people hear the words "groundwater monitoring" they may think either of measuring groundwater levels or of analyzing for groundwater quality. In reality, monitoring and management of groundwater quantity and groundwater quality are inseparable components of a management plan.

Although the primary focus of the California Department of Water Resources (DWR) is on groundwater quantity and the measures taken by local agencies to manage supply, management must also consider groundwater quality. Natural or anthropogenic contamination and pumping patterns that are not managed to protect groundwater quality may limit the quantity of groundwater that is available for use in a basin.

Several State programs provide useful data as well as regulatory direction on groundwater quality that managers can use in managing their groundwater supply. One program is the Drinking Water Source Assessment and Protection Program prepared by the California Department of Health Services in response to 1996 amendments to the federal Safe Drinking Water Act. The DWSAP requires water purveyors to assess sources of drinking water, develop zones indicating direction of travel of groundwater, and identify potentially contaminating activities around supply wells. The goal is to ensure that the quality of drinking water sources is maintained and protected. Other useful water quality data for groundwater managers is collected by the agencies within the California Environmental Protection Agency, including the State Water Resources Control Board, Department of Pesticide Regulation and the Department of Toxic Substances Control, which are discussed in more detail in Chapter 5. Each of these agencies has a specific statutory responsibility to collect groundwater quality information and protect water quality.

Protection of Recharge Areas

Groundwater recharge areas, and the human activities that can reduce their ingestion, are an example of the need to coordinate land use activities to protect both groundwater quality and quantity. Protection of recharge areas, whether natural or man-made, is necessary if the quantity and quality of groundwater in the aquifer are to be maintained. Existing and potential recharge areas must be protected so that they remain functional, that is they continue to provide recharge to the aquifer and they are not contaminated with chemical or microbial constituents. Land-use practices should be implemented so that neither the quantity nor quality of groundwater is reduced. A lack of protection of recharge areas could decrease the availability of usable groundwater and require the substitution of a more expensive water supply.

Many potentially contaminating activities have routinely been practiced in recharge areas, leading to the presence of contaminants in groundwater. In many areas, groundwater obtained from aquifers now requires remediation. Recent studies in some areas show that recharge areas are contaminated, but down gradient wells are not, indicating that it is only a matter of time before contaminants in wells reach concentrations that require treatment of the groundwater.

In addition to quality impacts, urban development, consisting of pavement and buildings on former agricultural land, lining of flood control channels, and other land use changes have reduced the capacity of recharge areas to replenish groundwater, effectively reducing the safe yield of some basins.

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Box 1 Managing Groundwater Quantity and Quality (continued)

To ensure that recharge areas continue to replenish high quality groundwater, water managers and land use planners should work together to:

- Identify recharge areas so the public and local zoning agencies are aware of the areas that need protection from paving and from contamination;
- Include recharge areas in zoning categories that diminish the possibility of contaminants entering the subsurface;
- Standardize guidelines for pre-treatment of the recharge water, including recycled water;
- Build monitoring wells to collect data on changes in groundwater quality that may be caused by recharge; and
- Consider the functions of recharge areas in land use and development decisions.

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Chapter 3
Groundwater Management Planning and Implementation

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Chapter 3
Groundwater Management Planning and Implementation

The 1990s were a very important decade in the history of groundwater management in California. In 1992, the State Legislature provided an opportunity for more formal groundwater management with the passage of AB 3030 (Water Code § 10750 et seq.). More than 200 agencies have adopted an AB 3030 groundwater management plan. Additionally, 24 of the 27 counties with ordinances related to groundwater management adopted these laws during the 1990s. Plans prepared under AB 3030 certainly brought unprecedented number of water agencies into the groundwater management arena, and counties are now heavily involved in groundwater management, primarily through ordinances. However, many plans prepared under AB 3030 have had little or no implementation, and many counties focus primarily on limiting exports rather than on a comprehensive management program. As a result, the California Budget Act of 1999 (Stats. 1999, ch. 50), which authorized this update to Bulletin 118, directed the California Department of Water Resources (DWR) to complete several tasks, including developing criteria for evaluating groundwater management plans and developing a model groundwater management ordinance. This chapter presents the results of these directives. The intent is to provide a framework that will assist local agencies in proactively planning and implementing effective groundwater management programs.

Criteria for Evaluating Groundwater Management Plans—Required and Recommended Components

In 2002, the Legislature passed SB 1938 (Stats 2002, ch 603), which amended Water Code section 10750 et seq to require that groundwater management plans adopted by local agencies include certain components to be eligible for public funds administered by DWR for construction of groundwater projects. The statute applies to funds authorized or appropriated after September 1, 2002. In addition to the required components, DWR worked with representatives from local water agencies to develop a list of additional recommended components that are common to effective groundwater management.

Both the "required" and the "recommended" components are tools that local agencies can use either to institute a groundwater management plan for the first time or to update existing groundwater management plans. These components are discussed below and listed in Appendix C, which can be used as a checklist by local agencies to assess whether their groundwater management plans are addressing these topics.

Required Components of Local Groundwater Management Plans

As of January 1, 2005, amendments to Water Code Section 10750 et seq. resulting from the passage of SB 1938, require new groundwater management plans prepared under section 10750, commonly referred to as AB 3030 plans, to include the first component listed below.

Groundwater management plans prepared under any statutory authority must include components 2 through 7 to be eligible for the award of public funds administered by DWR for the construction of groundwater projects or groundwater quality projects. These requirements apply to funds authorized or appropriated after September 1, 2002. Funds appropriated under Water Code section 10795 et seq. (AB 303 – Local Groundwater Assistance Fund) are specifically excluded.

1) Documentation that a written statement was provided to the public "describing the manner in which interested parties may participate in developing the groundwater management plan" (Water Code, § 10753.1(b)).

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2) Basin management objectives (BMOs) for the groundwater basin that is subject to the plan (Water Code, § 10753.7 (a)(1)).
3) Components relating to the monitoring and management of groundwater levels, groundwater quality, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping (Water Code, § 10753.7 (a)(1)).
4) A plan by the managing entity to "involve other agencies that enables the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin" (Water Code, § 10753.7 (a)(2)). A local agency includes "any local public agency that provides water service to all or a portion of its service area" (Water Code, § 10752 (g)).
5) Adoption of monitoring protocols (Water Code, § 10753.7 (a)(4)) for the components in Water Code section 10753.7 (a)(3). Monitoring protocols are not defined in the Water Code, but the section is interpreted to mean developing a monitoring program capable of tracking changes in conditions for the purpose of meeting BMOs.
6) A map showing the area of the groundwater basin as defined by DWR Bulletin 118 with the area of the local agency subject to the plan as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a groundwater management plan (Water Code, § 10753.7 (a)(3)).
7) For local agencies not overlying groundwater basins, plans shall be prepared including the above listed components and using geologic and hydrologic principles appropriate to those areas (Water Code, § 10753.7 (a)(5)).

Recommended Components of Groundwater Management Plans

Although the seven components listed above are required only under certain conditions, they should always be considered for inclusion in any groundwater management planning process. In addition to the required components of a groundwater management plan resulting from the passage of SB 1938, it is recommended that the components listed below be included in any groundwater management plan adopted and implemented by a local managing entity. These additional components were developed in accord with the Budget Act of 1999 and with the assistance of stakeholder groups. The components should be considered and developed for specific application within the basin, subbasin, or agency service area covered by the plan. Additional components will likely be needed in specific areas. The level of detail for each component will vary from agency to agency. None of the suggested data reporting in the components should be construed to require disclosure of information that is confidential under State law. Local agencies should consider both the benefits of public dissemination of information and water supply security in developing reporting requirements.

Manage with the Guidance of an Advisory Committee

The managing entity should establish an advisory committee of interested parties that will help guide the development and implementation of the plan. The committee can benefit management in several ways. First, the committee can bring a variety of perspectives to the management team. As the intent of local groundwater management is to maintain and expand local benefits from the availability of the resource, it makes sense that the intended beneficiaries are a part of the management process. Second, the committee is free to focus on the specifics of groundwater management without being distracted by the many operational activities that the managing entity (such as a water district) must complete. Third, some parties could be negatively impacted by certain groundwater management decisions, and these actions and potential adverse impacts should be a part of the decision-making process to help reduce future conflicts. Finally, the advisory committee helps the managing entity gain the confidence of the local constituency by providing the opportunity for interested parties to participate in the management process.

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Many managing entities have already elected to use advisory committees for implementation of their groundwater management plans. The composition of these committees varies widely. Some groups consist entirely of stakeholders; others add local or State government representatives or academic members as impartial third parties, and some have included consultants as technical advisors. Some plans use multiple advisory committees to manage unique subareas. Some plans appoint advisory committees with different objectives, such as one that deals with technical issues and another that deals with policy issues. There is no formula for the composition of an advisory committee because it should ultimately be based on local management needs and should include representation of diverse local interests.

The Tulare Lake Bed Coordinated Management Plan provides an example of the benefit of an advisory committee. The plan includes nine groups of participants, making coordination and communication a complicated issue. To allow for greater communication, an executive committee was established consisting of one voting member from each public agency participating in the plan and one voting member representing a combined group of private landowner plan participants. The committee administers groundwater management activities and programs for the plan (TLBWSD 2002).

Describe the Area to Be Managed under the Plan
The plan should include a description of the physical setting and characteristics of the aquifer system underlying the plan area in the context of the overall basin. The summary should also include a description of historical data, including data related to groundwater levels, groundwater quality, subsidence, and groundwater–surface water interaction, known issues of concern with respect to the above data, and a general discussion of historical and projected water demands and supplies. All of these data are critical to effective groundwater management because they demonstrate the current understanding of the system to be managed and serve as a point of departure for monitoring activities as part of plan implementation.

Create a Link Between Management Objectives and Goals and Actions of the Plan
The major goal of any groundwater management plan is to maintain a reliable supply of groundwater for long-term beneficial uses of groundwater in the area covered by the plan. The plan should clearly describe how each of the adopted management objectives helps attain that goal. Further, the plan should clearly describe how current and planned actions by the managing entity help meet the adopted management objectives. The plan will have a greater chance of success by developing an understanding of the relationship between each action, management objectives, and the goal of the groundwater management plan.

For example, prevention of contamination of groundwater from the land surface is a management objective that clearly supports the goal of groundwater sustainability. Management actions that could help support this objective include (1) educating the public through outreach programs that explain how activities at the surface ultimately impact groundwater, (2) developing wellhead protection programs or re-evaluating existing programs, (3) working with the local responsible agency to ensure that permitted wells are constructed, abandoned, and destroyed according to State well standards, (4) investigating whether local conditions necessitate higher standards than those adopted by the local permitting agency for the construction, abandonment, or destruction of wells, and (5) working with businesses engaged in practices that might impact groundwater to reduce the risks of contamination.

The concept of having a management objective is certainly not new. While many existing plans do not clearly include management objectives nor specifically identify actions to achieve objectives, some plans indirectly include these components. As an example, Eastern Municipal Water District's (EMWD) Groundwater Management Plan states that its goal includes maximizing "the use of groundwater for all beneficial uses in such a way as to lower the cost of water supply and to improve the reliability of the total

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water supply for all users." To achieve this goal, EMWD has listed several issues to be addressed. One is the prevention of long-term depletion of groundwater. This can be defined as a management objective even though it is not labeled as such. Where this management objective is currently unmet in the North San Jacinto watershed portion of the plan area, EMWD has identified specific actions to achieve that objective, including the reduction of groundwater extraction coupled with pursuing the construction of a pipeline to act as an alternative source of surface water for the impacted area (EMWD 2002).

Describe the Plan Monitoring Program

The groundwater management plan should include a map indicating the locations of any applicable monitoring sites for groundwater levels, groundwater quality, subsidence, stream gaging, and other applicable monitoring. The groundwater management plan should summarize the type of monitoring (for example, groundwater level, groundwater quality, subsidence, streamflow, precipitation, evaporation, tidal influence), type of measurements, and the frequency of monitoring for each location. Site specific monitoring information should be included in each groundwater management plan. The plan should include the well depth, screened interval(s) and aquifer zone(s) monitored, and the type of well (public, irrigation, domestic, industrial, monitoring). These components will serve as a tool for the local managing entity to assess the adequacy of the existing monitoring network in tracking the progress of plan activities.

The groundwater management plan developed for the Scotts Valley Water District (SVWD) provides a detailed description of the monitoring program in Santa Cruz County (Todd Engineers 1994). Table 6 is SVWD's monitoring table, which serves as an example of the level of detail that is useful in a plan (Todd Engineers 2000a). Figure 9 shows the locations and types of monitoring points for each monitoring site. The monitoring table specifies in detail the data available and the planned monitoring. These serve as useful tools for SVWD to visualize the types and distribution of data available for their groundwater management activities. In addition to the minimum types of monitoring, SVWD summarizes other types of data that are relevant to their groundwater management effort.

Describe Integrated Water Management Planning Efforts

Water law in California treats groundwater and surface water as two separate resources with the result that they have largely been managed separately. Such management does not represent hydrologic reality. Recently, managers of a number of resources are becoming increasingly aware of how their planning activities could impact or be impacted by the groundwater system. Because of this, the local managing entity should describe any current or planned actions to coordinate with other land use, zoning, or water management planning entities.

Integrated management is addressed in existing groundwater management plans in several ways, including cooperatively managing groundwater with surface water supplies, recharging water from municipal sewage treatment plants, and working with local planning agencies to provide comments when a project is proposed that could impact the groundwater system.

Examples of planning efforts that should be integrated with groundwater management may include watershed management, protection of recharge areas, agricultural water management, urban water management, flood management, drinking water source assessment and protection, public water system emergency and disaster response, general plans, urban development, agricultural land preservation, and environmental habitat protection or restoration. Another example that may appear insignificant is transportation infrastructure. However, local impacts on smaller aquifers could be significant when landscaping of medians and interchanges requires groundwater pumping for irrigation or when paved areas are constructed over highly permeable sediments that act as recharge zones for the underlying aquifer.

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Table 6 Scotts Valley Water District's Groundwater Monitoring Plan

Monitoring type	Location	Measurement type	Date started	Frequency and Author	Notes
Precipitation	El Pueblo Yard	5-minute recording	Feb 85	Daily-District, Manchle/City	Other historic gages (1) Bldr site on Granite Ck. Rd (Jan. 1973 - Dec. 1980) (2) Hacienda Dr (Jul. 1954 - May 1979) (3) El Pueblo Yard historic gage (Jan. 1961 - Jan. 1965)
	WWTP	5 minute recording	1990	Daily City	
Evaporation	El Pueblo Yard	Pan	Jan 86	Daily/District	Evaporation pan raw data not compiled after July 1990
Evapotranspiration	De Laveaga Park, Santa Cruz	Automated active weather station	Sep-90	California Irrigation Management Information System/Monthly	Data available on-line through UCDS
Stream Flow	Carbonera Ck at Scotts Valley @ Calpella Way Bridge (#11161080)	15-minute recording	Jan-85	USGS Daily	Other historic gages (1) Carbonera Ck @ Santa Cruz (#11161400) 100 feet upstream from mouth (1974-1979 partial data)
	Bean Ck near Scotts Valley @ Bennett Crossing (#11160430)	15 minute recording	Dec 88	USGS Daily	(2) Bean Ck near Felton (#11160520) (1963-1978 partial data) flow flows at same location (1983-1988)
	Eagle Creek In Henry Cowell Redwoods State Park	Bucket Fill, Flow Meter-Spring	Mar 01	Semi annually/ Todd Engineers	(3) Carbonera Creek @ Glen Canyon (1990-1994?)
Well Inventory	T10S-R01E Sections 6-9, 16-20, 30 and T10S-R02E, Sections 1, 11-14, 23-26, 36	Over 400 wells location, log, type, capacity, etc. stored in GIS and Access database	1985	Logs from DWR maintained by Todd Engineers	
Groundwater Levels	~35 Santa Margarita aquifer and ~14 Lompico formation wells	Depth to water	1968	Quarterly/ District and cooperators	Data from over 35 wells, as early as 1968 bi monthly 1983-1988
Pumpage	T10S-R01E Sections 6-9, 16-20, 30 and T10S-R02E Sections 1, 11-14, 23-26, 36 District wells in production and on standby	Metered	1975	Monthly/ Scotts Valley Water District, Mt. Hermon Association, Hanson Aggregates West, Soquel Creek Water District	Other historic pumpage data: Mattson Woods (1988-1990 partial data)

Table 6 Scotts Valley Water District's Groundwater Monitoring Plan (continued)

Monitoring type	Location	Measurement type	Date started	Frequency - maintainer	Notes
Groundwater Quality	TTES-RDF Sections 1-9, 16-20, 29 and Post Rock Sections 1, 11-14, 23-26, 36 District wells in production	Title 22 constituents	1965	At least semi-annually- District and others	Data from over 50 wells, as early as 1965 monitoring frequency similar to groundwater level program
	North Scotts Valley 3 shallow monitoring wells	Metals, nitrogen species, general minerals	Mar 01	Semi-annually- Todd Engineers	
Surface Water Quality	4 sites on Carbonero and 3 sites on Bean Creek	Grab samples - metals, nitrogen species, general minerals	Mar 01	Semi-annually- Todd Engineers	
Wastewater Outflows	City of Scotts Valley WWTP to Lunsey Lane	Wastewater outflow volume and effluent quality	1965	Daily-City of Scotts Valley	Plant operational in 1965 (septic systems pre-1965)
Recycled Water Production	Scotts Valley WWTP	Recycled water production volume and quality	2002	At least quarterly-WWTP	

Source: Todd Engineering 2003a

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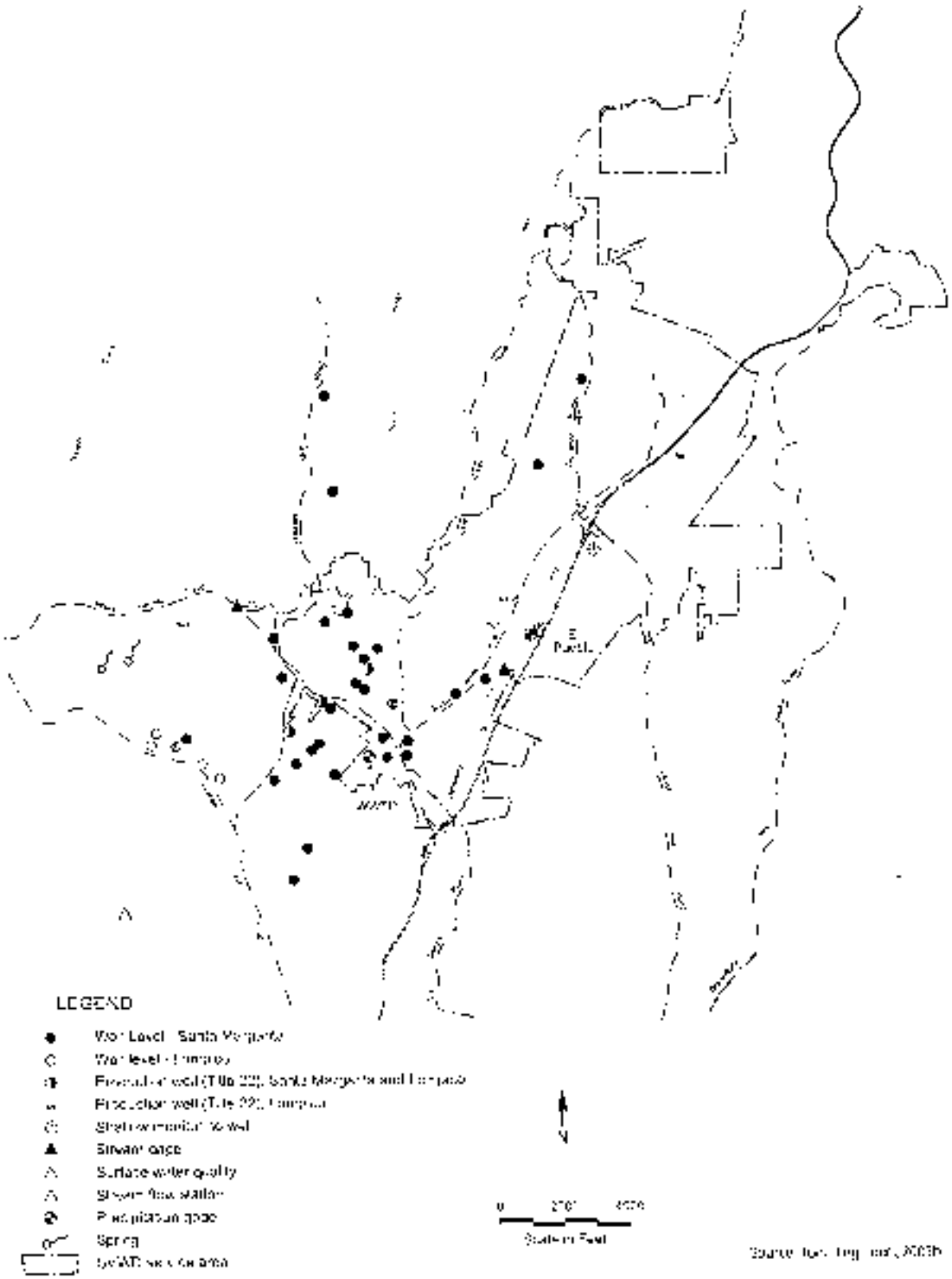

Figure 9 Scotts Valley Water District's Groundwater Management Plan monitoring locations

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Box K: What are Management Objectives?

Management objectives are the local managing entity's way of identifying the most important issues in meeting local resource needs. They can be seen as establishing a "value system" for the plan area. There is no fixed set of management objectives for any given plan area. Some of the more commonly recognized management objectives include the monitoring and managing of groundwater levels, groundwater quality, inelastic land subsidence, and changes in streamflow and surface water quality where they impact or are impacted by groundwater pumping. Management objectives may range from being entirely qualitative to strictly quantified.

Each management objective would have a locally determined threshold value associated with it which can vary greatly. For example, in establishing a management objective for groundwater quality, one area may simply choose to establish an average value of total dissolved solids as the indicator of whether a management objective is met, while another agency may choose to have no constituents exceeding the maximum contaminant level for public drinking water standards. While there is great latitude in establishing management objectives, local managers should remember that the objectives should serve to support the goal of a sustainable supply for the beneficial use of the water in their jurisdictional area.

An example of an alternative management objective is Orange County Water District's (OCWD) objective of maintaining available storage space in its management area at 200,000 acre-feet. The objective does not require that groundwater elevations be used at any particular location, although managing to this objective would likely have the net benefit of stabilizing water levels. Groundwater storage is a dynamic value, so attempting to meet this management objective is an ongoing challenge. OCWD has implemented many management actions directly aimed at managing the basin to meet this objective.

The Deer Creek and Tule River Authority provides an excellent example of how groundwater management activities can be coordinated with other resources. The authority, in conjunction with the U.S. Bureau of Reclamation, has constructed more than 200 acres of recharge basins as part of the Deer Creek Recharge-Wildlife Enhancement Project. When available, the project takes surplus water during winter months and delivers it to the basins, which serve as winter habitat for migrating waterfowl, creating a significant environmental benefit. Most of the water also recharges into the underlying aquifer, thereby benefiting the local groundwater system.

Report on Implementation of the Plan

The managing entity should produce periodic reports -- annually or at other frequencies determined by the local managing entity -- summarizing groundwater basin conditions and groundwater management activities for the period since the previous update. The reports should include:

- A summary of monitoring results, including historical trends,
- A summary of actual management actions,
- A summary, supported by monitoring results, of whether management actions are achieving progress in meeting management objectives,
- A summary of proposed management actions, and
- A summary of any plan component changes, including addition or modification of management objectives.

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Unfortunately, many plans were prepared in the mid-1990s with little or no follow-up documentation of whether the plan is actually being implemented. This makes it difficult to determine what progress has been achieved in managing the groundwater resource. Periodic reports will serve as a tool for the managing entity to organize its many activities to implement the plan, act as a driving force for plan implementation, and help interested parties understand the progress made by local entities in managing their groundwater resource.

Progress reports on SVWD (Todd Engineers 2002) and EMWD (2002) groundwater management plans serve as excellent examples of the value of such an exercise. Both reports effectively portray the results of management actions, progress toward achieving objectives and specific recommendations for future management actions. An example of reporting on the modification of a management objective for water quality can be found in EMWD's 2000 Annual Report (EMWD 2001). A task force of more than 20 water suppliers and wastewater agencies, including EMWD, worked to update the Regional Water Quality Control Board's Region 8 Basin Plan objectives for nitrogen and total dissolved solids in water, effectively changing EMWD's management objectives for those constituents.

Evaluate the Plan Periodically

The managing entity and advisory committee should re-evaluate the entire plan. Periodic evaluation of the entire management plan is essential to delineate successes and failures under the plan and identify changes that may be needed. Additionally, re-evaluation of the plan should include assessment of changing conditions in the basin that may warrant modification of the plan or management objectives. Adjustment of components in the plan should occur on an ongoing basis if necessary. The re-evaluation of the plan should focus on determining whether the actions under the plan are meeting the management objectives and whether the management objectives are meeting the goal of sustaining the resource.

While there are several examples of existing groundwater management plans that demonstrate ongoing changes to plan activities, there are no known examples of such an approach to entirely re-evaluate an existing plan. This is likely due in part to the occurrence of several consecutive wet years in the mid- and late-1990s. The abundant surface water supplies reduced the need to actively manage groundwater supplies in many cases. More recent dry conditions and the recent passage of SB 1938 will create an excellent opportunity for managing entities to begin a re-evaluation of existing plans.

Model Groundwater Management Ordinance

As discussed in the previous chapter, ordinances are groundwater management mechanisms enacted by local governments through exercise of their police powers to protect the health and safety of their citizens. In Baldwin v. Tehama County (1994), the appellate court declared that State law does not preempt the field of groundwater management.

In the mid- to late-1990s, many counties adopted ordinances that effectively prevented export of groundwater from the county, even though none specifically prohibited export. The intent of most of these ordinances is to sustain groundwater as a viable local resource. To ensure that no local an export project proponent is required by most of the ordinances to show that the proposed project will not cause depletion of the groundwater, degradation of groundwater quality, or subsidence before a permit to export groundwater can be issued. Although these ordinances do not specifically require thresholds/limits for each of these potential negative impacts, a project proponent can really only show that these negative effects will not occur if the proponent develops a groundwater management plan.

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Many of these ordinances were developed in response to the plans of some agencies or landowners to export groundwater or develop a groundwater substitution project where surface water is exported and groundwater is substituted for local use. In some cases, short-term export actually took place, leading to a number of claims of negative third party impacts. Residents of some counties became concerned because no one knew how much groundwater was available for local use and how much groundwater was available for export. In short, details of the hydrology of the basin, including surface water and groundwater availability, water quality, and the interaction of surface water and groundwater were not known. This lack of detailed knowledge about the operating potential of their groundwater resources led counties to take what they viewed as protective action, which consisted of requiring a permit before anyone could export groundwater from the county.

From the perspective of DWR, groundwater should be managed in a manner that ensures long-term sustainability of the resource for beneficial uses. Those beneficial uses are to be decided by the local stakeholders within the basin. In some areas there may be an ample supply of water, so groundwater exports or substitution projects are feasible while local beneficial uses of the water supply are maintained. In other areas, limiting exports may be necessary to maintain local beneficial uses. Such determinations can be made only after the data are collected and evaluated and the results are used to develop management objectives for the basin.

While developing both the criteria for evaluating groundwater management plans and the model groundwater management ordinance, DWR staff has some two principles in mind. First, the goal of groundwater management, whether accomplished by a plan or by an ordinance, is to sustain and often expand a groundwater resource. Second, groundwater management, whether accomplished by a plan or by an ordinance, requires that local agencies address and resolve the same or similar issues within the boundaries of the agencies. To say it in different words, whether it is a plan or an ordinance, good groundwater management should address the same issues and problems and arrive at the same conclusions and solutions to satisfy the needs of the local area. While some areas may allow or promote exports, others may not.

As stated above, the Legislature required a model ordinance as one of the elements of this update of Bulletin 118. The model ordinance is included as Appendix D and can be used by local governments that have identified a need to adopt a groundwater management ordinance. The model is an example of what a local ordinance might include. Local conditions will require some additions, modifications, or deletions. The variety of political, institutional, legal, technical, and economic opportunities and constraints throughout California guarantees that there will be differences in which the model will have to be adapted. Local governments interested in adopting a groundwater management ordinance are encouraged to consider all components included in the model.

Water Code section 10753.7(b)(1)(A) allows an agency to participate in or consent to be subject to a groundwater management plan, a basin-wide management plan, or other integrated regional water management plan in order to meet the funding eligibility requirements that resulted from passage of SB 1938 (2002). A local government that adopts an ordinance should consider whether or not it will have local agencies that do not have their own groundwater management plan, but consent to be managed under the ordinance. If this situation is anticipated, the ordinance should include the required components described in the Water Code so State funding can be pursued.

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Chapter 4

Recent Actions Related to Groundwater Management

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Chapter 4
Recent Actions Related to Groundwater Management

The past few years have seen significant actions that impact groundwater management in California. Below are several examples of recent actions including legislation, ballot measures, and executive orders that show the State Legislature and the citizens of California clearly recognize the importance of groundwater and its appropriate management in meeting the present and future water supply needs of the State.

Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act of 2000 (Proposition 13)

On March 7, 2000, California voters approved a $1.97-billion general obligation bond known as the Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act (Proposition 13). Of the nearly $2 billion, $230 million was earmarked for groundwater programs. The act authorizes $200 million for grants for feasibility studies, project design, and construction of conjunctive use facilities (Water Code, § 79170 et seq.) and $30 million in loans for local agency acquisition and construction of groundwater recharge facilities and feasibility study grants for projects potentially eligible for the loan program (Water Code, § 79160 et seq.). More than $120 million have been awarded in grants and loans to local agencies in the first two years of implementation of these programs.

California Bay-Delta Record of Decision

The goal of the California Bay-Delta (formerly CALFED) program is to restore ecosystem health and improve water management in the Bay-Delta system. The program has four primary objectives:

- Provide good water quality for all beneficial uses
- Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species
- Reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system
- Reduce the risk to land use and associated economic activities, water supply infrastructure, and the ecosystem from catastrophic breaching of Delta levees

The Record of Decision (ROD), released in August 2000, sets forth a 30-year plan to address ecosystem health and water supply reliability problems in the Bay-Delta system. The ROD lays out specific actions and investments over the first seven years to meet program goals. Most important, with respect to groundwater is the California Bay-Delta program's commitment to local groundwater management. The ROD states, "CALFED will work with local governments and affected stakeholders to develop legislation to strengthen AB 3030 and provide technical and financial incentives to encourage more effective basin-wide groundwater management plans ..." (CALFED 2000). The ROD encourages basin management that is developed at the subbasin level so that it addresses local needs, but is coordinated at the basin-wide level so that it considers impacts to other users in the basin. The ROD also commits Bay–Delta agencies to "facilitate and fund locally supported, managed, and controlled groundwater and conjunctive use projects with a total of 500,000 acre-feet to 1 million acre-feet (maf) of additional storage capacity by 2007" (CALFED 2000).

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Local Groundwater Management Assistance Act of 2000 (AB 303, Water Code Section 10795 et seq.)

The goal of the Local Groundwater Management Assistance Act is to help local agencies better understand how to manage groundwater resources effectively to ensure the safe production, quality and proper storage of groundwater in the State. The act created the Local Groundwater Assistance Fund, which must be appropriated annually. In three years, more than $15 million in grants were awarded for 71 projects. Grants went to local agencies for groundwater studies and projects that contribute to basin and subbasin management objectives, including but not limited to groundwater monitoring and groundwater basin management. Grants are available to all geographic areas of the State. This act serves to emphasize that groundwater is recognized as an important local resource and, to the extent that groundwater is properly managed at the local level, serves to benefit all Californians.

Groundwater Quality Monitoring Act of 2001 (AB 599, Water Code Section 10780 et seq.)

Assembly Bill 599, known as the Groundwater Quality Monitoring Act of 2001, set a goal to establish comprehensive groundwater monitoring and increase the availability of information about groundwater quality to the public. The objective of the program is to highlight those basins in which contamination has occurred or is likely to occur and provide information that will allow local managers to develop programs to curtail, treat, or avoid additional contamination. The act required the State Water Resources Control Board (SWRCB), in coordination with an Interagency Task Force (ITF) and a Public Advisory Committee (PAC), to integrate existing monitoring programs and design new program elements, as necessary, to establish a comprehensive statewide groundwater quality monitoring program.

Through the ITF and PAC, the Comprehensive Groundwater Quality Monitoring Program was developed. The program will seek to:

- Accelerate the monitoring and assessment program already established by the SWRCB,
- Implement monitoring and assessment in accordance with a prioritization of basins/subbasins,
- Increase coordination and data sharing among groundwater agencies, and
- Maintain groundwater data in a single repository to provide useful access by the public while maintaining appropriate security measures.

The Comprehensive Groundwater Quality Monitoring Program is expected to provide the following key benefits:

- A common base communications medium for agencies to utilize and supply groundwater quality data at multiple levels,
- A mechanism to unite local, regional and statewide groundwater programs in a common effort,
- Better understanding of local, regional and statewide water quality issues and concerns that in turn can provide agencies at all levels with better information to deal with the concerns of consumers and consumer advocate groups,
- Groundwater agencies with near- and long-term forecasting information, essential for groundwater management plan preparation and implementation, and
- The motivation for small- and medium-sized agencies to begin or improve their own groundwater monitoring and management programs.

AR0069689

Water Supply Planning

Three bills enacted by the Legislature to improve water supply planning processes at the local level became effective January 1, 2002. In general, the new laws are intended to improve the assessment of water supplies during the local planning process before land use projects that depend on water are approved. The new laws require the verification of sufficient water supplies as a condition for approving developments, and they compel urban water suppliers to provide more information on the reliability of groundwater if used as a supply.

SB 221 (Gov. and Prof. Code, § 11010 as amended, Gov. Code, § 65867.5 as amended, Gov. Code, §§ 66455.3 and 66473.7) prohibits approval of subdivisions consisting of more than 500 dwelling units unless there is verification of sufficient water supplies for the project from the applicable water supplier(s). This requirement also applies to increases of 10 percent or more of service connections for public water systems with less than 500 service connections. The law defines criteria for determining "sufficient water supply," such as using normal, single-dry, and multiple-dry year hydrology and identifying the amount of water that the supplier can reasonably rely on to meet existing and future planned uses. Rights to extract additional groundwater must be substantiated if used for the project.

SB 610 (Water Code §§ 10631, 10656, 10910, 10911, 10912, and 10915 as amended; Pub. Resources Code, § 21151.9 as amended) and AB 901 (Water Code, §§ 10610.2 and 10631 as amended; Water Code § 10634) make changes to the Urban Water Management Planning Act to require additional information in Urban Water Management Plans (UWMPs) if groundwater is identified as a source available to the supplier. Required information includes a copy of any groundwater management plan adopted by the supplier, proof that the developer or agency has rights to the groundwater, a copy of the adjudication order or decree for adjudicated basins, and if not adjudicated, whether the basin has been identified as being overdrafted or projected to be overdrafted in the most current DWR publication on the basin. If the basin is in overdraft, the UWMP must include current efforts to eliminate any long-term overdraft. A key provision in SB 610 requires that any project subject to the California Environmental Quality Act supplied with water from a public water system be provided a water supply assessment, except as specified in the law. AB 901 requires the plan to include information relating to the quality of existing sources of water available to an urban water supplier over given periods and include the manner in which water quality affects water management strategies and supply reliability.

Emergency Assistance to the Klamath Basin

On May 1, 2001, the Governor proclaimed a State of Emergency in the Klamath Basin in Siskiyou and Modoc counties. The proclamation included disaster assistance of up to $5 million under authority of the State Natural Disaster Assistance Act. This assistance went directly into constructing wells to extract groundwater for use on cover crops to avoid loss of critical topsoil. The Governor's proclamation also included $1 million for a study of the Klamath River Basin to determine the long-term water supply in the California portion of the basin.

Governor's Drought Panel

The Governor's Advisory Drought Planning Panel was formed in 2000 to develop a contingency plan to address the impacts of critical water shortages in California. The panel formed with the recognition that critical water shortages may severely impact the health, welfare, and economy of California. Panel recommendations included securing funding for the Local Groundwater Management Assistance Act (described above), continued support of critical groundwater monitoring in basins with inadequate data, and the formation of a technical assistance and education program for "rural homeowners and small domestic water systems relying on self-supplied groundwater" (GADPP 2000).

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Sacramento Valley Water Management Agreement

On May 22, 1995, SWRCB adopted the "Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary" (the 1995 WQCP). Following its action, SWRCB initiated a water rights hearing process with the intent of allocating responsibility for meeting the standards of the 1995 WQCP among water right holders in areas tributary to the Delta. The water rights hearing was conducted in phases with all phases being resolved with the exception of Phase 8, which involved water rights holders in the Sacramento Valley.

Proceeding with Phase 8 may have involved litigation and judicial review for years. That extended process could have resulted in adverse impacts to the environment and undermined progress on other statewide water management initiatives. To avoid the consequences of delay, the Sacramento Valley Water Users, DWR, the U.S. Bureau of Reclamation (USBR), and expert water users developed the Sacramento Valley Water Management Agreement. The agreement became effective April 20, 2001. At that time SWRCB issued an order staying the Phase 8 hearing for 18 months. The parties negotiated a short-term settlement agreement that obligated DWR and USBR to continue to fully meet the Bay Delta water quality standards while providing for the development of conjunctive use and system improvement projects by participating upstream water rights holders that would make water available to help meet water quality standards while improving the reliability of local water supplies. SWRCB has subsequently dismissed the Phase 8 proceedings, and work is being undertaken on both short-term and long-term activities included in the Sacramento Valley Water Management Agreement.

Groundwater Management Water Code Amendments

In September 2002, SB 1938 (Water Code, § 10753.4 and § 10795.4 as amended; Water Code, § 10753.7, § 10753.8 and § 10753.9 as amended and renumbered; Water Code, § 10753.1 and § 10753.7 as added) was signed into law. The act amends existing law related to groundwater management by local agencies. The law requires any public agency seeking State funds administered through DWR for the construction of groundwater projects or groundwater quality projects to prepare and implement a groundwater management plan with certain specified components. Prior to this, there were no required plan components. New requirements include establishing basin management objectives, preparing a plan to involve other local agencies in a cooperative planning effort, and adopting monitoring protocols that promote efficient and effective groundwater management. The requirements apply to agencies that have already adopted groundwater management plans as well as agencies that do not overlie groundwater basins identified in Bulletin 118 and its updates when these agencies apply for state funds. The requirements do not apply to funds administered through the AB 303 Local Groundwater Management Assistance Act (Water Code, § 10795 et seq.) or to funds authorized or appropriated prior to September 1, 2002. Further discussion of the requirements is included in Chapter 3 and Appendix C.

Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (Proposition 50)

California voters approved the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (Proposition 50; Water Code, § 79500 et seq.) on the November 2002 elections. The initiative provides for more than $3.4 billion of funding, subject to appropriation by the Legislature, for a number of land protection and water management activities.

Several chapters of Proposition 50 allocate funds for specified water supply and water quality projects, including:

- Chapter 3 Water Security. Provides $50 million to protect State, local, and regional drinking water systems from terrorist attack or deliberate acts of destruction or degradation.

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- Chapter 4 Safe Drinking Water. Provides $435 million for grants and loans for infrastructure improvements to meet safe drinking water standards.
- Chapter 5 Clean Water and Water Quality. Provides $390 million for a number of water quality and environmental improvements.
- Chapter 6 Contaminant and Salt Removal Technologies. Provides $100 million for desalination of ocean or brackish waters as well as treatment and removal of contaminants.
- Chapter 7 California Bay-Delta program. Provides $825 million for continuing implementation of all elements of the program.
- Chapter 8 Integrated Regional Water Management. Provides $500 million for many categories of water management projects that will protect communities from drought, protect and improve water quality, and reduce dependence on imported water supplies.
- Chapter 9 Colorado River. Provides $70 million for canal-lining projects necessary to reduce water use and to meet commitments related to California's allocation of water from the Colorado River.

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Chapter 5

The Roles of State and Federal Agencies in California Groundwater Management

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Even though groundwater management is a local responsibility and mostly voluntary, several State and federal agencies have key roles in California groundwater management. Some of these roles may not be immediately recognized, but because they work toward the goal of maintaining a reliable groundwater supply, they are closely related to groundwater management. Some of the programs available through the California Department of Water Resources (DWR) and other agencies that assist local agencies in managing groundwater resources are described below.

Local Groundwater Management Assistance from DWR

DWR's role in groundwater management begins with the fundamental understanding that groundwater management is locally driven and management programs should respond to local needs and concerns. DWR recognizes that when groundwater is effectively managed at the local level, benefits are realized at a statewide level.

DWR has historically maintained many programs that directly benefit local groundwater management efforts including:

- Providing assistance to local agencies to assess basin hydrogeologic characteristics,
- Assisting local agencies to identify opportunities to develop additional groundwater supply,
- Monitoring groundwater levels and quality,
- Providing watermaster services for court-adjudicated basins,
- Providing standards for well construction and destruction,
- Managing the State's extensive collection of well completion reports, and
- Reviewing proposals and distributing grant funds and low-interest loans for conjunctive use projects, as well as local groundwater management and monitoring programs.

Conjunctive Water Management Program

DWR's Conjunctive Water Management Program consists of a number of integrated efforts to assist local agencies in improving groundwater management and increasing water supply reliability.

One goal of the Integrated Storage Investigations (ISI) Program, an element of the Bay-Delta program, is to increase water supply reliability statewide through the planned, coordinated management and use of groundwater and surface water resources. The effort emphasizes forming working partnerships with local agencies and stakeholders to share technical data and costs for planning and developing locally controlled and managed conjunctive water management projects.

Toward that end, the Conjunctive Water Management Program has:

- Developed a vision in which DWR would assist local agencies throughout the State so that these agencies can effectively manage groundwater resources,
- Adopted a set of working principles to ensure local planning, local control, operation, and management of conjunctive use projects; voluntary implementation of projects; and local benefits from the proposed projects,
- Executed memoranda of understanding with 30 local agency partners and provided technical and financial assistance to study groundwater basins and assess opportunities for conjunctive water management.

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- Provided technical assistance in the form of groundwater monitoring, groundwater modeling, and local water management planning, as well as a review of numerous regional and statewide planning efforts on a variety of water issues, and
- Provided facilitation assistance to promote broad stakeholder involvement in regional water management planning processes.

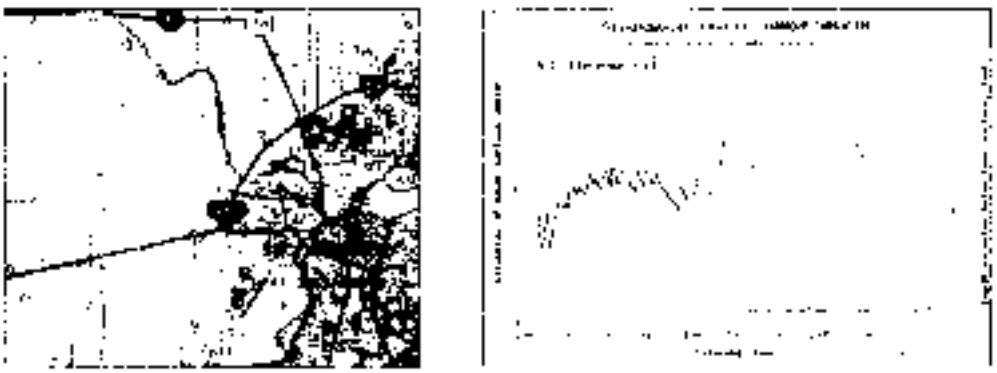
DWR staff review proposals and distribute grants pursuant to the Local Groundwater Management Assistance Act of 2000 (AB 303). To date, DWR has awarded more than $1.5 million to local agencies to fund 71 projects dealing with groundwater investigation, monitoring, or management.

With funds provided under Proposition 13, DWR has awarded more than $170 million in loans and grants for groundwater recharge and storage studies and projects to local agencies throughout the State. Applicant estimates of the water supply reliability increases that will be realized from these projects exceeds 150 thousand acre-feet annually. Recipients of loans and grants must provide progress reports to allow an evaluation of the successes of the various programs. Figure 16 shows the distribution of loan and grant awards throughout the State.

Both grant programs have active outreach efforts to inform and to assist agencies in preparation of applications. Selection of projects for funding relies in part on input from advisory committees composed of stakeholders from throughout the State.

Box L: Providing Data:
The Internet Makes Groundwater Elevation Data Readily Accessible to the Public

In 1995, the California Department of Water Resources (DWR) began providing Internet access to groundwater level data and hydrographs for wells in groundwater basins throughout California. The website, which distributes historical data for more than 35,000 wells monitored by DWR and its many cooperators has proven very popular with more than 60,000 visits to date. Options include a form or map interface to locate wells with water level data and the ability to download long-term water levels for specific wells or seasonal measurements for specific areas to create groundwater contour maps. The availability of this data makes it a significant resource for local agencies making sound groundwater management decisions. The address of the site is http://well.water.ca.gov/



Wells can be located with a map interface. By clicking on a well, a hydrograph with the latest data available is automatically generated.

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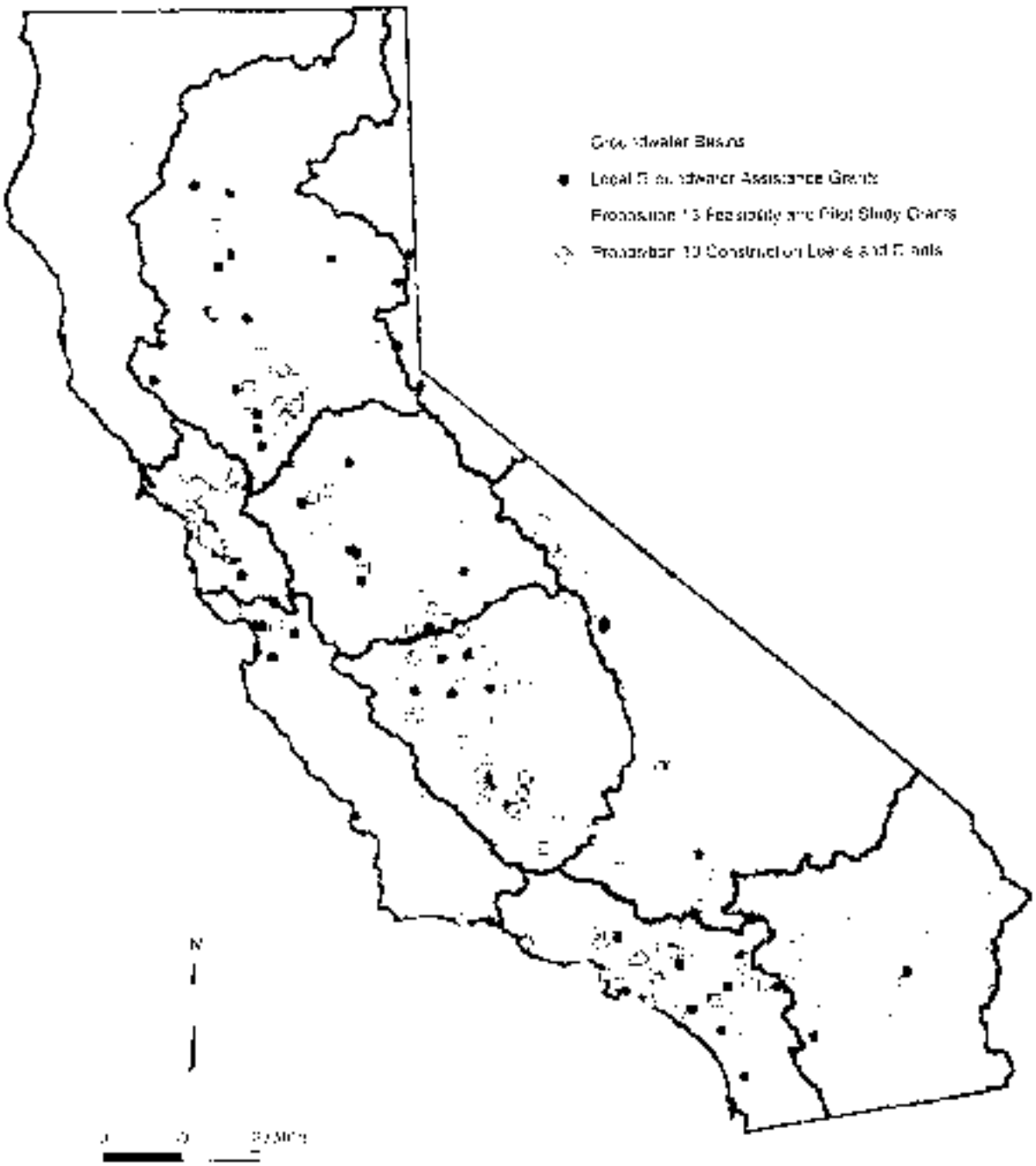

Figure 19 Broad distribution of grant and loan awardees for 2001 through 2003

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Assistance from Other State and Federal Agencies

Many other State and federal agencies provide groundwater management assistance to local agencies. Some of those roles are described below. For more information on the roles of various agencies in protecting the groundwater resource, see the California Department of Health Services' Drinking Water Source Assessment and Protection Program Document (DHS 2000), California Groundwater Management (Jachens and others 1997), or the individual agency websites.

State Water Resources Control Board and Regional Water Quality Control Boards

http://www.swrcb.ca.gov The mission of the State Water Resources Control Board (SWRCB) is to ensure the highest reasonable quality of waters of the State, while allocating those waters to achieve the optimum balance of beneficial uses. In turn, the nine Regional Water Quality Control Boards (RWQCB) develop and enforce water quality objectives and implement plans to protect the beneficial uses of the State's waters, recognizing differences in climate, topography, geology, and hydrology.

SWRCB has many responsibilities regarding the protection of the groundwater resource. One of the more notable is the GroundWater Ambient Monitoring and Assessment (GAMA) Program. GAMA is a recently enacted program that will provide a comprehensive assessment of water quality in water wells throughout the state. GAMA has two main components: the California Aquifer Susceptibility (CAS) Assessment and the Voluntary Domestic Well Assessment Project.

The CAS combines age dating of water and sampling for low-level volatile organic compounds (VOCs), such as methyl tertiary-butyl ether (MTBE), to assess the relative susceptibility of all of approximately 16,000 public supply wells throughout the State. Age dating provides a general assessment of how quickly groundwater is moving through the system, while the sampling of low-level VOCs allows greater reaction time for potential remediation strategies before contaminants reach action levels. Sampling is being conducted by staff from the U.S. Geological Survey (USGS) and Lawrence Livermore National Laboratory. The CAS Assessment was developed cooperatively with DHS and DWR.

The Voluntary Domestic Well Assessment Project will provide a previously unavailable sampling of water quality in domestic wells, which will assist in assessing the relative susceptibility of California's groundwater. Because water quality in individual domestic wells is unregulated, the program is voluntary and will focus, as resources permit, on specific areas of the state. Constituents to be analyzed include nitrate, total and fecal coliform bacteria, MTBE, and minerals. Additional constituents will be added in areas with known water quality problems.

Other SWRCB/RWQCB activities related to groundwater protection include developing basin plans that identify existing and potential beneficial uses of marine water, groundwater, and surface waters; regulating the discharge of waste that may affect water quality in California; monitoring of landfills and hazardous waste facilities; establishing standards for the construction and monitoring of underground storage tanks; establishing management plans for control of nonpoint source pollutants; and issuing cleanup and abatement orders that require corrective actions by the responsible party for a surface water or groundwater pollution problem or nuisance.

The Groundwater Quality Monitoring Act of 2001 (AB599, Water Code, § 10780 et seq.) required the SWRCB to develop a comprehensive monitoring program in a report to the Legislature. See Chapter 4 for details.

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California Department of Health Services

http://www.dhs.ca.gov/ps/ddwem The DHS Drinking Water Program, part of the Division of Drinking Water and Environmental Management, is responsible for DHS implementation of the federal Safe Drinking Water Act, as well as California statutes and regulations related to drinking water. As part of this responsibility, DHS inspects and provides regulatory oversight of approximately 8,500 public water systems (and approximately 16,000 drinking water wells) to assure delivery of safe drinking water to all California consumers.

Public water system operators are required to regularly monitor their drinking water sources for microbiological, chemical and radiological contaminants to show that drinking water supplies meet regulatory requirements (called primary maximum contaminant levels - MCLs). Among these contaminants are approximately 80 specific inorganic and organic chemical contaminants and six radiological contaminants that reflect the natural environment as well as human activities.

Public water system operators also monitor their water for a number of other contaminants and characteristics that deal with the aesthetic properties of drinking water (known as secondary MCLs). They are also required by regulation to analyze for certain unregulated contaminants (to allow DHS to collect information on emerging contaminants, for example), and to report findings of other contaminants that may be detected during routine monitoring. The DHS water quality monitoring database contains the results of analyses since 1984. These data, collected for purposes of regulatory compliance with drinking water laws, also provide an extensive body of information on the quality of groundwater throughout the State.

California Department of Pesticide Regulation

http://www.cdpr.ca.gov/dprprograms.htm The California Department of Pesticide Regulation (DPR) protects human health and the environment by regulating pesticide sales and use, and by promoting reduced-risk pest management. DPR plays a significant role in monitoring for the presence of pesticides and in preventing further contamination of the groundwater resource.

DPR conducts six types of groundwater monitoring:

1) Monitoring for pesticides on a DPR-determined Ground Water Protection List, which lists pesticides with the potential to pollute groundwater;
2) Post-sanitary survey monitoring to verify a reported detection and to help determine if a detected pesticide resulted from legal agricultural use;
3) Areal extent monitoring to identify the extent of contaminated wells;
4) Adjacent-section monitoring to identify additional areas sensitive to pesticide movement to groundwater;
5) Monitoring to repeatedly sample a network of wells to determine whether pesticide residues are declining; and
6) Special project monitoring.

When pesticides are found in groundwater, they are normally regulated in one-square-mile areas identified in regulation as sensitive to groundwater pollution. These pesticides are subject to permitting by the county agricultural commissioner and to use restrictions specified in regulation. DPR maintains an extensive database of pesticide sampling in groundwater and reports a summary of annual sampling and detections to the State Legislature.

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California Department of Toxic Substances Control

http://www.dtsc.ca.gov The California Department of Toxic Substances Control (DTSC) has two programs related to groundwater resources protection: the Hazardous Waste Management Program and the Site Mitigation Program. These programs are authorized under Division 20 of the California Health and Safety Code, and implementing regulations are codified in Title 22 of the California Code of Regulations.

A critical element of both programs is maintaining environmental quality and economic vitality through the protection of groundwater resources. This is accomplished through hazardous waste facility permitting and design; oversight of hazardous waste handling, removal, and disposal; oversight of remediation of hazardous substances releases; funding of emergency removal actions involving hazardous substances, including the cleanup of illegal drug labs; cleanup of abandoned hazardous waste sites; oversight of the closure of military bases; and pollution prevention.

If groundwater is threatened or impacted by a hazardous substance release, DTSC provides technical oversight for the characterization and remediation of soil and groundwater contamination. DTSC and the nine RWQCBs coordinate regulatory oversight of groundwater remediation. To ensure site-specific groundwater quality objectives are met, DTSC consults with RWQCB staff and appropriate groundwater basin plans.

Box M: Improving Coordination of Groundwater Information

California's groundwater resources are addressed by an array of different State and federal agencies. Each agency approaches groundwater from a unique perspective, based on its individual statutory mandate. As a result, each agency collects different types of groundwater data and information. To facilitate the effective and efficient exchange of groundwater resource information, the State Water Resources Control Board (SWRCB) is coordinating the Groundwater Resources Information Sharing Team (GRIST), which is composed of representatives from various groundwater agencies. Agencies currently participating in GRIST are:

- State Water Resources Control Board
- Department of Health Services
- Department of Water Resources
- Department of Pesticide Regulation
- Lawrence Livermore National Laboratory
- U.S. Geological Survey

One of the tasks of the GRIST is to identify data relevant to California groundwater resources. A listing of the data, along with the appropriate agency contacts and Internet links, will be maintained by SWRCB on the Groundwater Resources Information Database. In addition, to facilitate effective information sharing and communication among stakeholders, groundwater data will be made available on the SWRCB GeoTracker system. GeoTracker is a geographic information system that provides Internet access to environmental data. The centralization of environmental data through GeoTracker will enable more in-depth geospatial and statistical analyses of groundwater data in the future. For more information about GeoTracker, visit the GeoTracker Internet site at http://geotracker.arsenault.egy.com.

California Bay-Delta Authority

http://calwater.ca.gov The California Bay-Delta program was initiated in 1994 to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Sacramento-San Joaquin Bay-Delta System. The partnership currently consists of more than 20 State and federal agencies. An important element of the program is to increase storage by developing an additional 500,000 acre-feet to 1.0 million acre-feet of groundwater storage capacity by the year 2020 (CALFED 2000).

Effective January 1, 2003, a newly formed State agency assumed responsibility for overseeing implementation of the Bay-Delta program. The California Bay-Delta Authority provides a permanent governance structure for the collaborative state-federal effort. The authority was established by enactment of Senate Bill 1653 in 2002. The legislation calls for the authority to sunset on January 1, 2006, unless federal legislation has been enacted authorizing the participation of appropriate federal agencies in the authority.

U.S. Environmental Protection Agency

http://www.epa.gov/safewater The U.S. Environmental Protection Agency (EPA) Office of Ground Water and Drinking Water, together with states, tribes, and many partners, protects public health by ensuring safe drinking water and protecting groundwater. The EPA's role in California groundwater is primarily related to protection of the resource and comes in the form of administering several federal programs in close coordination with State agencies such as SWRCB, DHS, and DTSC.

U.S. Geological Survey

http://ca.water.usgs.gov USGS has published results of many studies of California groundwater basins. USGS maintains an extensive groundwater level and groundwater quality monitoring network and has compiled this data in a database. The California District is working on cooperative programs with local, State, and other federal agencies. The most notable programs include three regional studies of the San Joaquin-Tulare Basin, the Sacramento River Basin, and the Santa Ana River Basin under the National Water Quality Assessment Program. Results were published for the San Joaquin-Tulare Basin in 1995 and the Sacramento River Basin in 2000. The Santa Ana River basin study is in progress.

U.S. Bureau of Reclamation

http://www.usbr.gov The U.S. Bureau of Reclamation (USBR) operates the Central Valley Project (CVP), an extensive network of dams, canals, and related facilities that delivers about 7 mat during normal years for agricultural, urban, and wildlife use. USBR's role with respect to groundwater is generally limited to monitoring for impacts to the groundwater systems adjacent to its CVP facilities. Through the cooperative efforts of USBR, DWR, irrigation districts, farmers, and other local entities, groundwater level data have been collected continuously since project conception in the 1930s and 1940s.

In addition to CVP monitoring, USBR monitors groundwater levels to identify potential impacts as a result of two other projects in California. That monitoring includes the Santa Ynez basin as part of the Cachuma Project on the central coast, and the Butte Creek Cone as part of the Sutter Project in the southwest Sacramento Valley. Both monitoring efforts are required as part of permitting for the projects.

USBR is planning to implement a groundwater information system to collect and distribute to the public the large volume of historical groundwater level data associated with its projects.

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Chapter 6

Basic Groundwater Concepts

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Basic Groundwater Concepts

This chapter presents general concepts relating to the origin, occurrence, movement, quantity, and quality of groundwater. The concepts will be useful in providing the nontechnical reader with a basic understanding of groundwater. For more experienced readers, many topics are discussed specifically as they apply to California or as the terms are used in this report. A glossary of terms is included at the end of this report. For additional reading on basic groundwater concepts see *Basic Ground-Water Hydrology* (Heath 1983).

Origin of Groundwater

Groundwater is a component of the hydrologic cycle (Figure 1), which describes locations where water may occur and the processes by which it moves or is transformed to a different phase. In simple terms, water or one of its forms—water vapor and ice—can be found at the earth's surface, in the atmosphere, or beneath the earth's surface. The hydrologic cycle is a continuum, with no beginning or end, however, it is often thought of as beginning in the oceans. Water evaporates from a surface water source such as an ocean, lake, or through transpiration from plants. The water vapor may move over the land and condense to form clouds, allowing the water to return to the earth's surface as precipitation (rain or snow). Some of the snow will end up in polar ice caps or in glaciers. Most of the rain and snowmelt will either become overland flow in channels or will infiltrate into the subsurface. Some of the infiltrated water will be transpired by plants and returned to the atmosphere, while some will cling to particles surrounding the pore spaces in the subsurface, remaining in the vadose (unsaturated) zone. The rest of the infiltrated water will move gradually under the influence of gravity into the saturated zone of the subsurface, becoming groundwater. From here, groundwater will flow toward points of discharge such as rivers, lakes, or the ocean to begin the cycle anew. This flow from recharge areas to discharge areas describes the groundwater portion of the hydrologic cycle.

The importance of groundwater in the hydrologic cycle is illustrated by considering the distribution of the world's water supply. More than 97 percent of all earth's water occurs as saline water in the oceans (Lattet 1988). Of the world's fresh water, almost 75 percent is in polar ice caps and glaciers, which leaves a very small amount of fresh water readily available for use. Groundwater accounts for nearly all of the remaining fresh water (Alley and others 1999). All of the fresh water stored in the world's rivers and lakes accounts for less than 1 percent of the world's fresh water.

Occurrence of Groundwater

Groundwater is the water occurring beneath the earth's surface that completely fills (saturates) the void space of rocks or sediment. Given that all rock has some open space (voids), groundwater can be found underlying nearly any location in the State. Several key properties help determine whether the subsurface environment will provide a significant, usable groundwater resource. Most of California's groundwater occurs in material deposited by streams, called alluvium. Alluvium consists of coarse deposits, such as sand and gravel, and finer-grained deposits such as clay and silt. The coarse and fine materials are usually coalesced in thin lenses and beds in an alluvial environment. In this environment, coarse materials such as sand and gravel deposits usually provide the best source of water and are termed aquifers; whereas, the finer-grained clay and silt deposits are relatively poor sources of water and are referred to as aquitards. California's groundwater basins usually include one or a series of alluvial aquifers with interfingered aquitards. Less frequently, groundwater basins include aquifers composed of unconsolidated marine sediments that have been flushed by fresh water. We include the marine-deposited aquifers in the discussion of alluvial aquifers in this bulletin.

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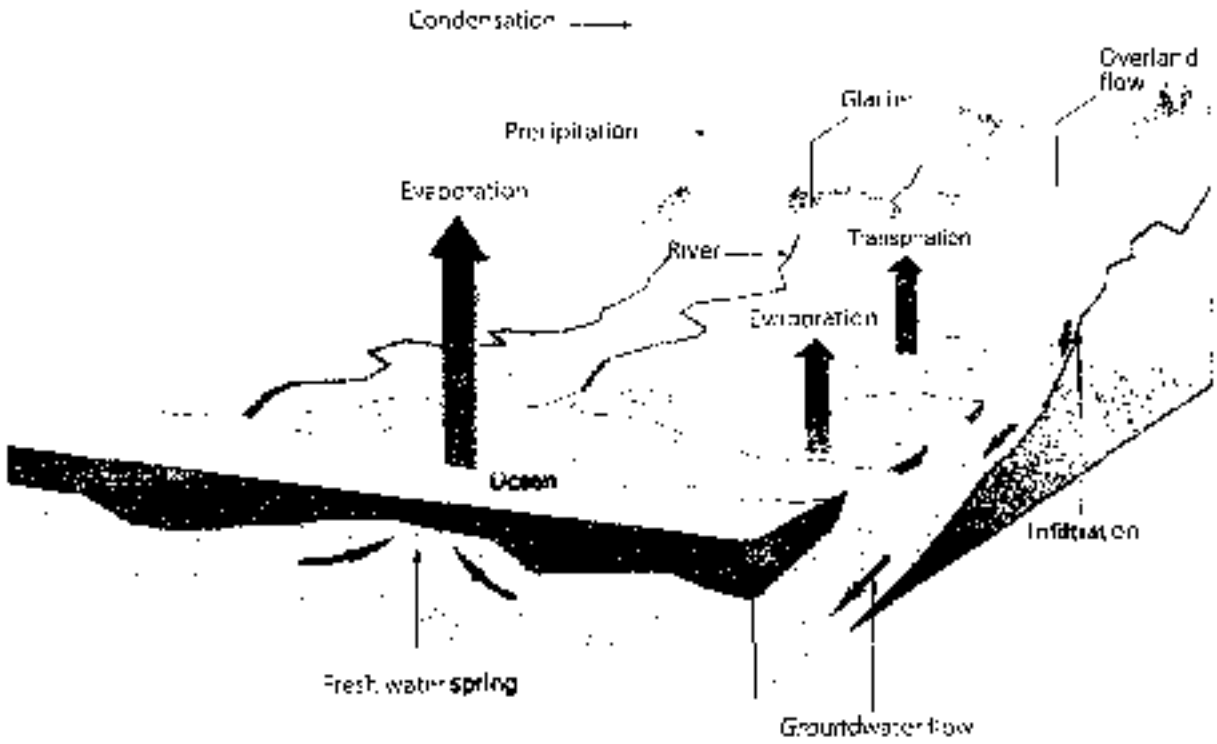

Figure 11 The Hydrologic Cycle

Although alluvial aquifers are most common in California, other groundwater development occurs in fractured crystalline rocks, fractured volcanics, and limestones. For this report, these non-alluvial areas that provide groundwater are referred to as "groundwater source areas," while the alluvial aquifers are called groundwater basins. Each of these concepts is discussed more fully below.

Groundwater and Surface Water Interconnection

Groundwater and surface water bodies are connected physically in the hydrologic cycle. For example, at some locations or at certain times of the year, water will infiltrate the bed of a stream to recharge groundwater. At other times or places, groundwater may discharge, contributing to the base flow of a stream. Changes in either the surface water or groundwater system will affect the other, so effective management requires consideration of both resources. Although this physical interconnection is well understood in general terms, details of the physical and chemical relationships are the topic of considerable research.

These details are the subject of significant recent investigations into the hyporheic zone, the zone of sand and gravel that forms the channel of a stream. As surface water flows downstream it may enter the gravels in the

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Box M One Resource, Two Systems of Law

In California, two distinct legal regimes govern the appropriation of surface water and subterranean streams, and percolating groundwater. The California Water Code requires that water users taking water for beneficial use from surface watercourses and "subterranean streams flowing through known and definite channels" obtain water right permits or licenses from the State Water Resources Control Board (SWRCB) (Water Code § 1200 et seq.). Groundwater classified as percolating groundwater is not subject to the Water Code provisions concerning the appropriation of water, and a water user can take percolating groundwater without having a State-issued water right permit or license. Current Water Code section 1200 is derived from a provision in the Water Commission Act of 1913, which became effective on December 19, 1914.

The SWRCB developed a test to identify groundwater that is in a subterranean stream flowing through a known and definite channel and is therefore subject to the SWRCB's permitting authority. The physical conditions that must be present in a subterranean stream flowing in a known and definite channel are: (1) a subsurface channel must be present; (2) the channel must have relatively impermeable bed and banks; (3) the course of the channel must be known or capable of being determined by reasonable diligence; and (4) groundwater must be flowing in the channel. Whether groundwater is subject to the SWRCB's permitting authority under this test is a factual determination. Water that does not fit this test is "percolating groundwater" and is not subject to the SWRCB's permitting authority.

The SWRCB has issued decisions that find that groundwater under the following streams constitutes a "subterranean stream flowing through known and definite channels" and is therefore subject to the SWRCB's permitting authority (Murphey 2003 pers. com.):

Los Angeles River in Los Angeles County
Sheep Creek in San Bernardino County
Mission Basin of the San Luis Rey River in San Diego County
Bonsall Basin of the San Luis Rey River in San Diego County
Pala Basin of the San Luis Rey River in San Diego County
Carmel River in Monterey County
Carmelita Creek in Monterey County
Big Sur River in Monterey County
Russian River
Chorro Creek in San Luis Obispo County
Morro Creek in San Luis Obispo County
North Fork Cuyama River in Mendocino County

Contact the SWRCB, Division of Water Rights for specific stream regimes and other details of these decisions.

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hyporheic zone, mix with groundwater, and re-enter the surface water in the stream channel. The effects of this interchange between surface water and groundwater can change the dissolved oxygen content, temperature, and mineral concentrations of the water. These changes may have a significant effect on aquatic and riparian biota.

Significantly, the physical and chemical interconnection of groundwater and surface water is not well represented in California's water rights system (see Box N "One Resource, Two Systems of Law").

Physical Properties That Affect Groundwater

The degree to which a body of rock or sediments will function as a groundwater resource depends on many properties, some of which are discussed here. Two of the more important physical properties to consider are porosity and hydraulic conductivity. Transmissivity is another important concept to understand when considering an aquifer's overall ability to yield significant groundwater. Throughout the discussion of these properties, keep in mind that sediment size in alluvial environments can change significantly over short distances, with a corresponding change in physical properties. Thus, while these properties are often presented as average values for a large area, one might encounter different conditions on a more localized level. Determination of these properties for a given aquifer may be based on lithologic or geophysical observations, laboratory testing, or aquifer tests with varying degrees of accuracy.

Porosity

The ratio of voids in a rock or sediment to the total volume of material is referred to as porosity and is a measure of the amount of groundwater that may be stored in the material. Figure 12 gives several examples of the types of porosity encountered in sediments and rocks. Porosity is usually expressed as a percentage and can be classified as either primary or secondary. Primary porosity refers to the voids present when the sediment or rock was originally formed. Secondary porosity refers to voids formed through fracturing or weathering of a rock or sediment after it was formed. In sediments, porosity is a function of the uniformity of grain size (sorting) and shape. Finer-grained sediments tend to have a higher porosity than coarser sediments because the finer-grained sediments generally have greater uniformity of size and because of the tabular shape and surface chemistry properties of clay particles. In crystalline rocks, porosity becomes greater with a higher degree of fracturing or weathering. As alluvial sediments become consolidated, primary porosity generally decreases due to compaction and cementation, and secondary porosity may increase as the consolidated rock is subjected to stresses that cause fracturing.

Porosity does not tell the entire story about the availability of groundwater in the subsurface. The pore spaces must also be interconnected and be large enough so that water can move through the ground to be extracted from a well or discharged to a water body. The term "effective porosity" refers to the degree of interconnectedness of pore spaces. For coarse sediments, such as the sand and gravel often stored in California's alluvial groundwater basins, the effective porosity is often nearly equal to the overall porosity. In finer-sediments, effective porosity may be low due to water that is tightly held in small pores. Effective porosity is generally very low in crystalline rocks that are not highly fractured or weathered.

While porosity measures the total amount of water that may be contained in void spaces, there are two related properties that are important to consider: specific yield and specific retention. Specific yield is the fractional amount of water that would drain freely from rocks or sediments due to gravity and describes the portion of the groundwater that could actually be available for extraction. The portion of groundwater that is retained either as a film on grains or in small pore spaces is called specific retention. Specific yield and specific retention of the aquifer material together equal porosity. Specific retention increases with decreasing

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grain size. Table 7 shows that clays, while having among the highest porosities, make poor sources of groundwater because they yield very little water. Sand and gravel, having much lower porosity than clay, make excellent sources of groundwater because of the high specific yield, which allows the groundwater to flow to wells. Rocks such as limestone and basalt yield significant quantities of groundwater if they are well-weathered and highly fractured.

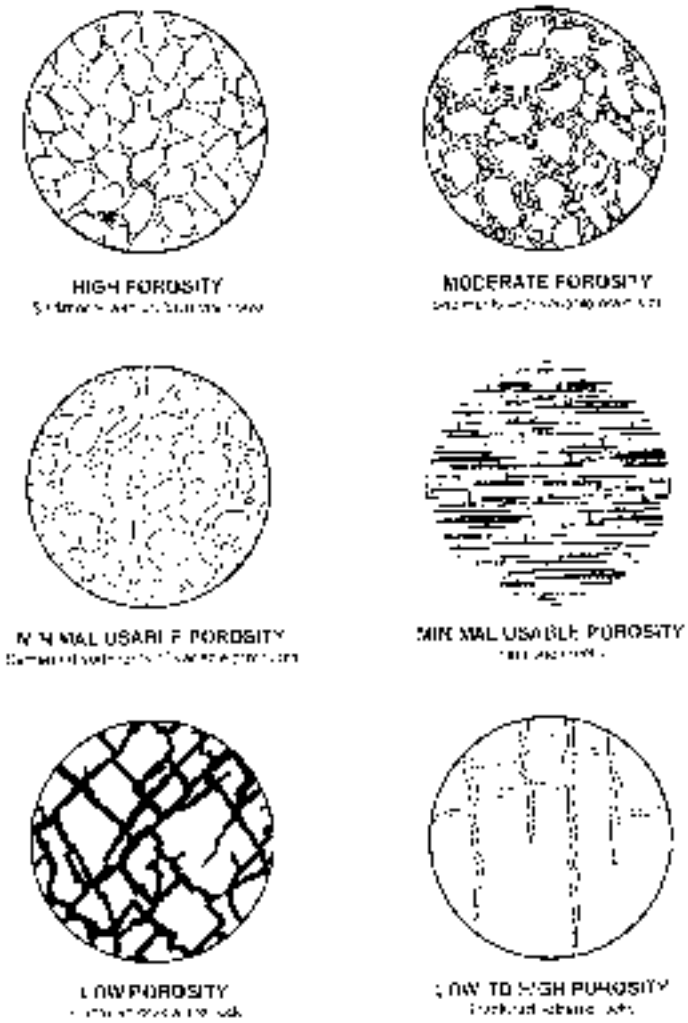

Figure 12 Examples of porosity in sediments and rocks

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Table 7 Porosity (in percent) of soil and rock types

Material	Porosity	Specific yield	Specific retention
Clay	50	2	48
Sand	25	23	2
Gravel	20	19	1
Limestone	20	18	2
Sandstone (unconsolidated)	21	6	5
Granite	0.1	0.09	0.01
Basalt (young)	11	8	3

Modified from Heath (1983)

Hydraulic Conductivity

Another major property related to understanding water movement in the subsurface is hydraulic conductivity. Hydraulic conductivity is a measure of a rock or sediment's ability to transmit water and is often used interchangeably with the term permeability. The size, shape, and interconnectedness of pore spaces affect hydraulic conductivity (Driscoll, 1986).

Hydraulic conductivity is usually expressed in units of length/time: feet/day, meters/day, or gallons/day/square-foot. Hydraulic conductivity values in rocks range over many orders of magnitude from a low permeability unfractured crystalline rock at about 10^{-6} feet/day to a highly permeable well-sorted gravel at greater than 10^{5} feet/day (Heath 1983). Clays have low permeability, ranging from about 10^{-7} to 10^{-3} feet/day (Heath 1983). Figure 13 shows hydraulic conductivity ranges of selected rocks and sediments.

Transmissivity

Transmissivity is a measure of the aquifer's ability to transmit groundwater through its entire saturated thickness and relates closely to the potential yield of wells. Transmissivity is defined as the product of the hydraulic conductivity and the saturated thickness of the aquifer. It is an important property to understand because a given area could have a high value of hydraulic conductivity but a small saturated thickness, resulting in limited overall yield of groundwater.

Aquifer

An aquifer is a body of rock or sediment that yields significant amounts of groundwater to wells or springs. In many definitions, the word "significant" is replaced by "economic." Of course, either term is a matter of perspective, which has led to disagreement about what constitutes an aquifer. As discussed previously, coarse-grained sediments such as sands and gravels deposited in alluvial or marine environments tend to function as the primary aquifers in California. These alluvial aquifers are the focus of this report. Other aquifers, such as those found in volcanics, igneous intrusive rocks, and carbonate rocks are described briefly in the section Groundwater Source Areas.

Aquitard

An aquitard is a body of rock or sediment that is typically capable of storing groundwater but does not yield it in significant or economic quantities. Fine-grained sediments with low hydraulic conductivity, such as clays and silts, often function as aquitards. Aquitards are often referred to as confining layers because they retard the vertical movement of groundwater and under the right hydrogeologic conditions confine groundwater that is under pressure. Aquitards are capable of transmitting enough water to allow some flow between adjacent aquifers, and depending on the magnitude of this transfer of water, may be referred to as leaky aquitards.

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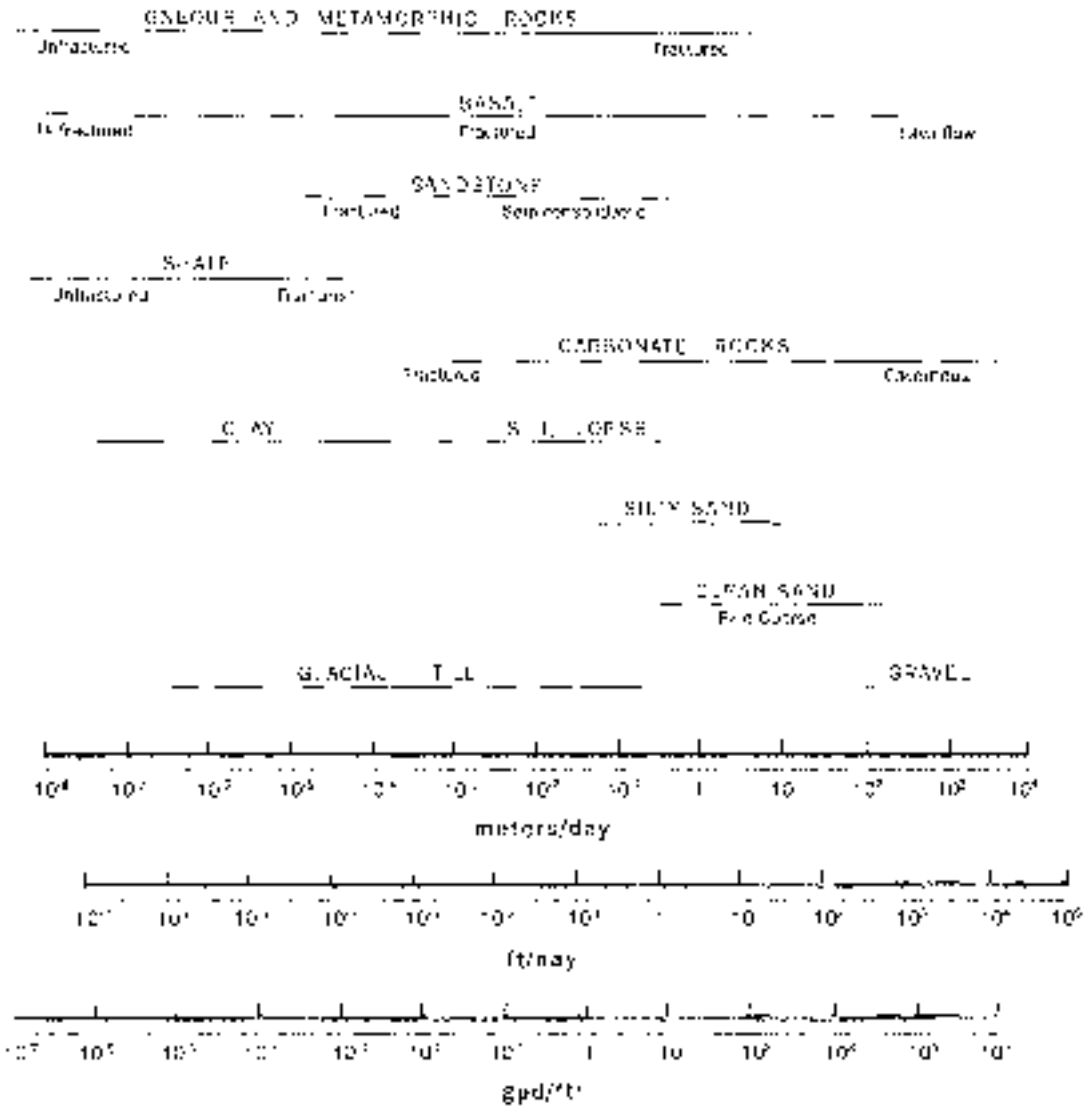

Figure 13 Hydraulic conductivity ranges of selected rocks and sediments

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Unconfined and Confined Aquifers

In most depositional environments, coarser-grained deposits are interbedded with finer-grained deposits creating a series of aquifers and aquitards. When a saturated aquifer is bounded on top by an aquitard (also known as a confining layer), the aquifer is called a confined aquifer (Figure 14). Under these conditions, the water is under pressure so that it will rise above the top of the aquifer if the aquitard is penetrated by a well. The elevation to which the water rises is known as the potentiometric surface. Where an aquifer is not bounded on top by an aquitard, the aquifer is said to be unconfined. In an unconfined aquifer, the pressure on the top surface of the groundwater is equal to that of the atmosphere. This surface is known as the water table, so unconfined aquifers are often referred to as water table aquifers. The arrangement of aquifers and aquitards in the subsurface is referred to as hydrostratigraphy.

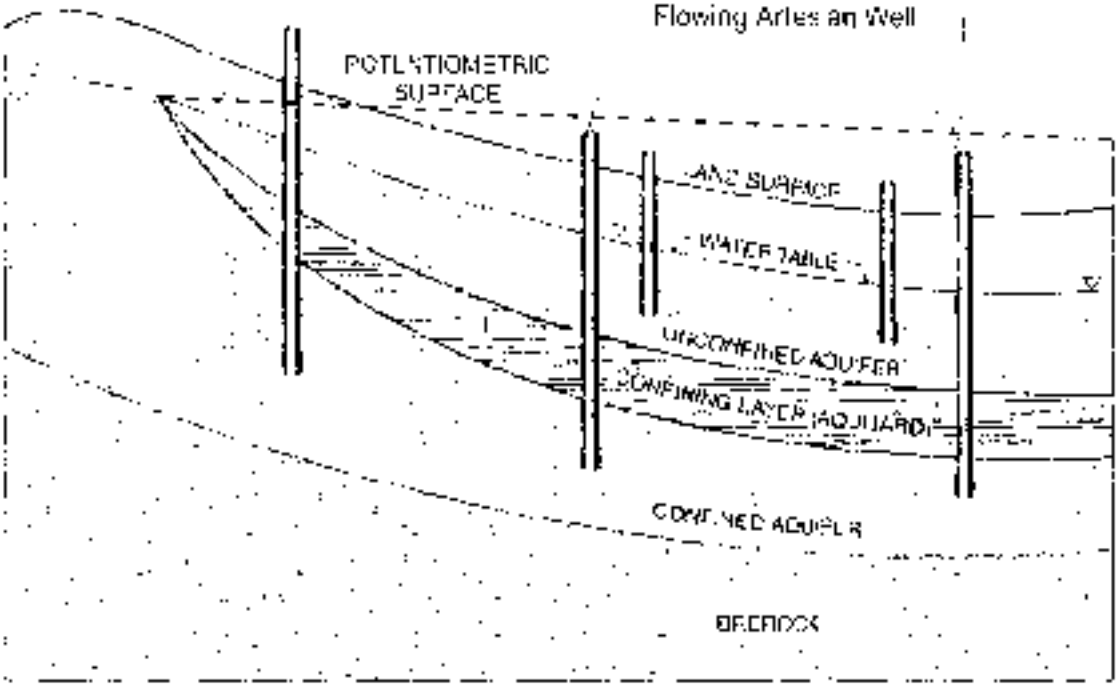

Figure 14 Interbedded aquifers with confined and unconfined conditions

With the notable exception of the Corcoran Clay of the Tulare Formation in the San Joaquin Valley and the equivalent in West Coast Basin in Los Angeles County, there are no clearly recognizable regional aquitards in California alluvial basins. Instead, due to the complexity of alluvial environments, it is the cumulative effect of multiple thin lenses of fine-grained sediments that causes increasing confinement of groundwater with increasing depth, creating what is often referred to as a semiconfined aquifer.

In some confined aquifers groundwater appears to defy gravity, but that is not the case. When a well penetrates a confined aquifer with a potentiometric surface that is higher than land surface, water will flow naturally to the surface. This is known as artesian flow, and results from pressure within the aquifer. The pressure results when the recharge area for the aquifer is at a higher elevation than the point at which discharge is occurring (Figure 14). The confining layer prevents the groundwater from returning to the surface until the confining layer is penetrated by a well. Artesian flow will discontinue as pressure in the aquifer is reduced and the potentiometric surface drops below the land surface elevation.

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Groundwater Basin

A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom. Lateral boundaries are features that significantly impede groundwater flow such as rock or sediments with very low permeability or a geologic structure such as a fault. Bottom boundaries would include rock or sediments of very low permeability if no aquifers occur below those sediments within the basin. In some cases, such as in the San Joaquin and Sacramento Valleys, the base of fresh water is considered the bottom of the groundwater basin. Table 8 is a generalized list of basin types and the features that define the basin boundaries.

Table 8 Types and boundary characteristics of groundwater basins

Characteristics of groundwater basins	
Groundwater basin	An aquifer or an aquifer system that is bounded laterally and at depth by one or more of the following features that affect groundwater flow: • Rock or sediments of lower permeability • A geologic structure, such as a fault • Hydrologic boundaries, such as a stream, lake, ocean, or groundwater divide
Types of basins and their boundaries	
Single alluvial basin	Basin surrounded, laterally overlain by less permeable rock Higher permeability near the periphery. Clays near the center. Unconfined around the periphery. Confined near the center. May have artesian flow near the center
Basin open to one or more places by other basins	May depict basins Merged alluvial fans. Topographic boundaries only. Includes some hydrologic boundaries.
Basin open to Pacific Ocean	Extends along the coast Water-bearing materials extend offshore May have contact with salt water Vulnerable to seawater intrusion.
Single complex basin	Basin rocks are surrounded by older water bearing materials and water bearing volcanics. Quantification is difficult because of lack knowledge between different rock types within the basin.
Groundwater in consolidated volcanic rocks	Basin concepts rarely applicable in volcanic rocks Volcanic rocks are highly variable in permeability.
Groundwater in weathered crystalline rocks (fractured rock) and unconsolidated deposits	Small quantities of groundwater Low-yielding wells Most wells are completed in the crystalline rock and rely on fractures to obtain groundwater
Potential hydraulic or management boundaries	Usually not selected as hydrologic boundaries for water-budget purposes, usually for managing surface water storage and delivery

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Although only the upper surface of a groundwater basin can be shown on a map, the basin is three-dimensional and includes all subsurface fresh water-bearing material. These boundaries often do not extend straight down, but are dependent on the spatial distribution of geologic materials in the subsurface. In fact, in a few areas near California's coastal areas, aquifers in the subsurface are known to extend beyond the mapped surface of the basin and may actually be exposed under the ocean. Under natural conditions, fresh water flows from these aquifers into the ocean. If groundwater levels are lowered, sea water may flow into the aquifer. This has occurred in Los Angeles, Orange, Ventura, Santa Cruz and Monterey Counties, and some areas around San Francisco Bay. Depiction of a groundwater basin in three dimensions requires extensive subsurface investigation and data evaluation to delineate the basin geometry. Figure 15 is a cross section showing how a coastal basin might appear in the subsurface.

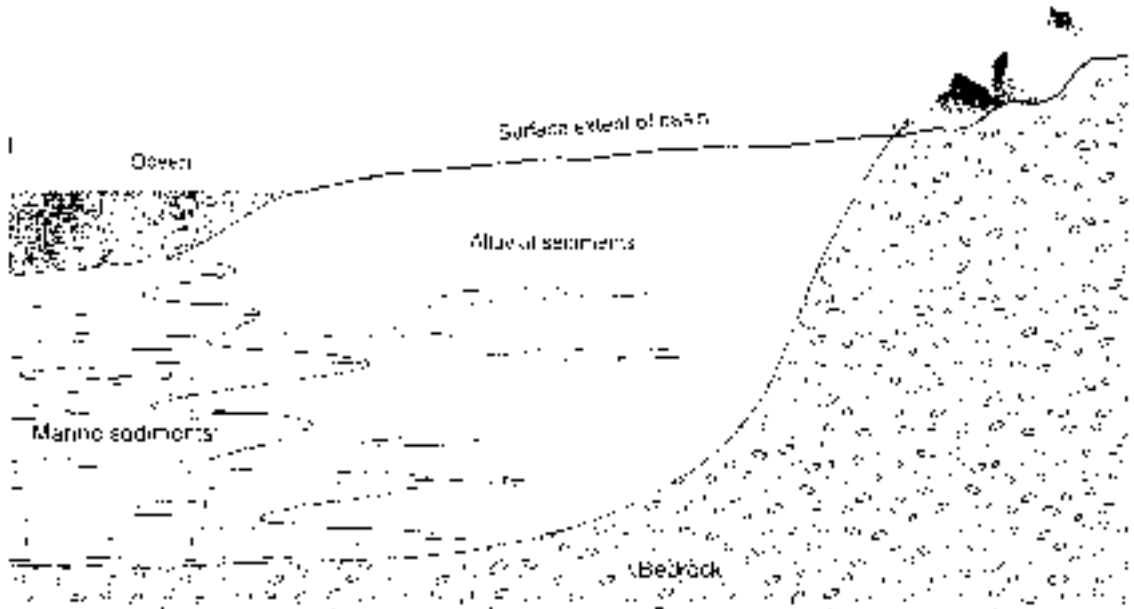

Figure 15 Groundwater basin near the coast with the aquifer extending beyond the surface basin boundary

Groundwater basin and subbasin boundaries shown on the map included with this bulletin are based on evaluation of the best available information. In basins where many studies have been completed and the basin has been operated for a number of years, the basin response is fairly well understood and the boundaries are fairly well defined. Even in these basins, however, there are many unknowns and changes in boundaries may result as more information about the basin is collected and evaluated. In many other basins where much less is known and understood about the basin, boundaries will probably change as a better understanding of the basin is developed. A procedure for collecting information from all the stakeholders should be developed for use statewide so that agreement on basin boundaries can be achieved.

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Groundwater Subbasin

A subbasin is created by dividing a groundwater basin into smaller units using geologic and hydrologic barriers or, more commonly, institutional boundaries (see Table 8). These subbasins are created for the purpose of collecting and analyzing data, managing water resources, and managing adjudicated basins. As the definition implies, the designation of a subbasin boundary is flexible and could change in the future. The limiting rule for a subbasin is that it should not cross over a groundwater basin boundary.

An example of a hydrologic subbasin boundary would be a river or stream that creates a groundwater divide. While hydrologic boundaries may limit groundwater flow in the shallow subsurface, data indicate significant groundwater flow may occur across the boundary at greater depths. In addition, the location of the boundary may change over time if pumping or recharge patterns change. Institutional subbasin boundaries could be based on a political boundary, such as a county line or a water agency service area, or a legally mandated boundary, such as a court adjudication basin.

Groundwater Source Areas

Groundwater in California is also found outside of alluvial groundwater basins. Igneous extrusive (volcanic), igneous intrusive, metamorphic, and sedimentary rocks are all potential sources of groundwater. These rocks often supply enough water for domestic use, but in some cases can also yield substantial quantities. In this report the term groundwater source area is used for rocks that are significant in terms of being a local groundwater source, but do not fit the category of basin or subbasin. The term is not intended to imply that groundwater actually originates in these rocks, but that it is withdrawn from rocks underlying a generally definable area. Because of the increased difficulty in defining and understanding the hydrogeologic properties of these rocks, the limited data available for the areas in which these rocks occur, and the relatively small, though rapidly growing, segment of the population served by these water supplies, they are discussed separately from groundwater basins.

Volcanics

Groundwater in volcanics can occur in fractures that result from cooling or changes in stress in the crust of the Earth, lava tubes, tree molds, weathering surfaces, and porous tuff beds. Additionally, the volcanics could overlie other deposits from an alluvial environment. Flow in the fractures may approach the same velocities as that of surface water, but there is often very limited storage potential for groundwater. The tuff beds can act similarly to alluvial aquifers.

Some of the most productive volcanic rocks in the State include the Modoc Plateau volcanics in the northeast and the Napa-Sonoma volcanics northeast of San Francisco Bay (Figure 16). Wells in Modoc Plateau volcanics are commonly reported to yield between 100 and 1,000 gallons per minute, with some yields of 4,000 gpm (Planert and Williams 1995). Bulletin 118-75 assigned identification numbers to these volcanic rocks throughout the State (for example, Modoc Plateau Recent Volcanic Areas, 1-23). The numbers led some to misinterpret them as being groundwater basins. In this update, the numbers corresponding to the volcanics are being retired to eliminate this confusion.

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Figure 16 Significant volcanic groundwater source areas

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Igneous Intrusive, Metamorphic, and Sedimentary Rocks

Groundwater in igneous intrusive, metamorphic, and consolidated sedimentary rocks occurs in fractures resulting from tectonism and expansion of the rock as overburden pressures are relieved. Groundwater is extracted from fractured rock in many of the mountainous areas of the State, such as the Sierra Nevada, the Peninsular Range, and the Coast Ranges. Rocks in these areas often yield only enough supply for individual domestic wells, stock water wells, or small community water systems. Availability of groundwater in such formations can vary widely, even over a distance of a few yards. Areas of groundwater production from consolidated rocks were not defined in previous versions of Bulletin 118 and are not included in this update.

As population grows in areas underlain by these rocks, such as the foothills of the Sierra Nevada and southern California mountains, many new wells are being bored in fractured rock. However, groundwater data are often insufficient to accurately estimate the long-term reliability of groundwater supplies in these areas. Additional investigation, data evaluation, and management will be needed to ensure future sustainable supplies. The Legislature recognized both the complexity of these areas and the need for management in SB 1938 (2002), which amended the Water Code to require groundwater management plans with specific components be adopted for agencies to be eligible for certain funding administered by DWR for construction of groundwater projects. Water Code section 10753.7(a)(5) states:

> Local agencies that are located in areas outside the groundwater basins delineated on the latest edition of the department's groundwater basin and subbasin map shall prepare groundwater management plans incorporating the components in this subdivision, and shall use geologic and hydrologic principles appropriate to those areas.

In carbonate sedimentary rocks such as limestone, groundwater occurs in fractures and cavities formed as a result of dissolution of the rock. Flow in the largest fractures may approach the velocities of surface water, but where these rocks occur in California there is limited storage potential for groundwater. Carbonate rocks occur mostly in Inyo County near the Nevada border (USGS 1995), in the Sierra Nevada foothills, and in some parts of the Sacramento River drainage north of Redding. The carbonates near the Nevada state border in Inyo County are part of a regional aquifer that extends northeastward into Nevada. Springs in Nevada and in the Death Valley region in California are dependent on groundwater flow in this regional aquifer. In other parts of the country, such as Florida, carbonate rocks constitute significant sources of groundwater.

Movement of Groundwater

The movement of groundwater in the subsurface is quite complex, but in simple terms it can be described as being driven by potential energy. At any point in the saturated subsurface, groundwater has a hydraulic head value that describes its potential energy, which is the combination of its elevation and pressure. In an unconfined aquifer, the water table elevation represents the hydraulic head, while in a confined aquifer the potentiometric surface represents the hydraulic head (Figure 14). Water moves in response to the difference in hydraulic head from the point of highest energy toward the lowest. On a regional scale this results in flow of groundwater from recharge areas or discharge areas. In California, pumping depressions around extraction wells often create the discharge points to which groundwater flows. Groundwater may naturally exit the subsurface by flowing into a stream, lake, or ocean, by flowing to the surface as a spring or seep, or by being transpired by plants.

The rate at which groundwater flows is dependent on the hydraulic conductivity and the rate of change of hydraulic head over some distance. In the mid-19th century, Henry Darcy found through his experiments on sand filters that the amount of flow through a porous medium is directly proportional to the difference

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between hydraulic head values and inversely proportional to the horizontal distance between them (Fetter 1988). His conclusions extend to flow through aquifer materials. The difference between hydraulic heads divided by the distance between them is referred to as the hydraulic gradient. When combined with the hydraulic conductivity of the porous medium and the cross-sectional area through which the groundwater flows, Darcy's law states:

$$Q = KA(dh/dl) \quad \text{(volume/time)}$$

Where:

Q = flow discharging through a porous medium
K = hydraulic conductivity (length/time)
A = cross-sectional area (length^2)
dh = change in hydraulic head between two points (length)
dl = distance between two points (length)

This version of Darcy's law provides a volumetric flow rate. To calculate the average linear velocity at which the water flows, the result is divided by the effective porosity. The rate of movement of groundwater is very slow, usually less than 1,000 feet per year because of the great amount of friction resulting from movement through the spaces between grains of sand and gravel.

Quantity of Groundwater

Because groundwater is a precious resource, the questions of how much there is and how more can be made available are important. There are many terms and concepts associated with the quantity of groundwater available in a basin, and some controversy surrounding their definition. Some of these include groundwater storage capacity, usable storage capacity, groundwater budget, change in storage, overdraft, and safe yield. This section discusses some of the more common terms used to represent groundwater quantity in California.

Groundwater Storage Capacity

The groundwater storage capacity of an individual basin or within the entire State is one of the questions most frequently asked by private citizens, water resource planners, and politicians alike. Total storage capacity seems easy to understand. It can be seen as how much physical space is available for storing groundwater. The computation of groundwater storage capacity is quite simple if data are available: capacity is determined by multiplying the total volume of a basin by the average specific yield. The total storage capacity is constant and is dependent on the geometry and hydrogeologic characteristics of the aquifer(s) (Figure 17).

Estimates of total groundwater storage capacity in California are staggering. Previous estimates of total storage range from 850 million acre-feet (maf) to 1.3 billion acre-feet (DWR 1975, DWR 1994). However, due to incomplete information about many of the groundwater basins, there has never been an accurately quantified calculation of total storage capacity statewide. Even if such a calculation were possible, the utility of such a number is questionable because total storage capacity might lead to overly optimistic estimates of how much additional groundwater development can contribute to meeting future demands.

Total groundwater storage capacity is misleading because it only takes into account one aspect of the physical character of the basin. Many other factors limit the ultimate development potential of a groundwater basin. These limiting factors may be physical, chemical, economic, environmental, legal, and institutional (Table 9). Some of these factors, such as the economic and institutional ones, can change with time. However, there may remain significant physical and chemical constraints that will limit groundwater development.

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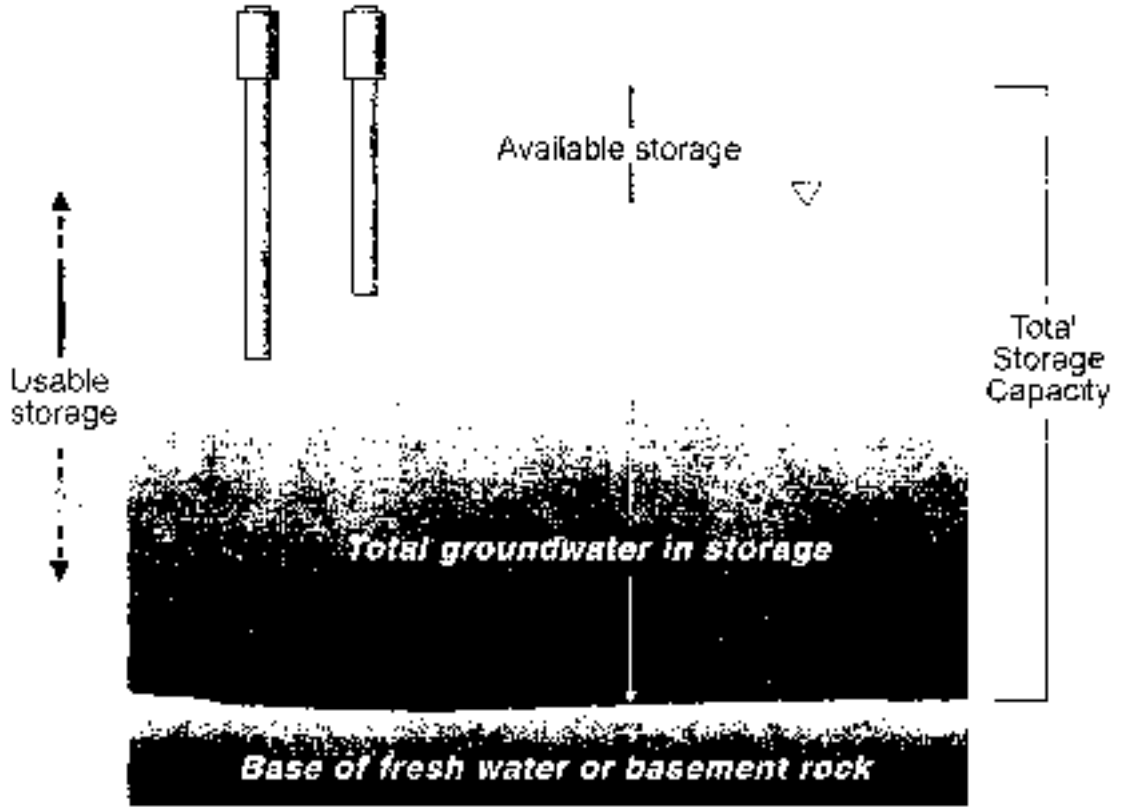

Figure 17 Schematic of total, usable, and available groundwater storage capacity

Table 9 Examples of factors that limit development of a groundwater basin

Limiting factor	Examples
Physical	Basin recharge area not adequate to sustain development; pumping too concentrated in a portion of basin; well yields too low for intended use.
Quality	Water quality not suitable for intended use; increased potential for seawater intrusion in coastal areas; upconing of poorer quality water in deeper parts of basin
Economic	Excessive costs associated with increased pump lifts and deepening of wells; cost of treating water if it does not meet requirements for intended use
Environmental	Need to maintain groundwater levels for wetlands, stream base flow, or other habitat.
Institutional	Court groundwater management plans or ordinances restrictions (e.g., basin adjudication); impacts on surface water rights of others.

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Usable Groundwater Storage Capacity

Usable storage capacity is defined as the amount of groundwater of suitable quality that can be economically withdrawn from storage. It is typically computed as the product of the volume of the basin to some basin-specific depth that is considered economically available and the average specific yield of the basin (see Figure 17).

As more groundwater is extracted, groundwater levels may fall below some existing wells, which may then require replacement or deepening. This may be a consideration in management of the basin and will depend on the cost of replacement, the cost of pumping the water from deeper zones, and whether managers are willing to pay that cost. Other impacts that may increase the cost include subsidence and groundwater quality degradation. The usable storage may change because of changes in economic conditions.

Estimates of usable storage represent only the total volume of groundwater assumed to be usable in storage, not what would be available for sustained use on an annual basis. Previous estimates of usable groundwater storage capacity range from 143 to 450 maf (DWR 1975, DWR 1994). Unfortunately, the term "usable storage" is often used to indicate the amount of water that can be used from a basin as a source of long-term annual supply. However, the many limitations associated with total groundwater storage capacity discussed above may also apply to usable storage.

Available Groundwater Storage Capacity

Available storage capacity is defined as the volume of a basin that is unsaturated and capable of storing additional groundwater. It is typically computed as the product of the empty volume of the basin and the average specific yield of the unsaturated part of the basin (see Figure 17). The available storage capacity does not include the uppermost portion of the unsaturated zone in which saturation could cause problems such as crop root damage or increased liquefaction potential. The available storage will vary depending on the amount of groundwater taken out of storage and the recharge. The total groundwater in storage will change inversely as the available storage changes.

Available storage has often been used as a number to represent the potential for additional yield from a particular basin. Unfortunately, many of the limitations that exist in developing existing supply discussed above also limit taking advantage of available storage. Although limitations exist, looking only at available groundwater storage capacity may underestimate the potential for groundwater development. Opportunities to use groundwater already in storage and create additional storage space would be overlooked by this approach.

Groundwater Budget

A groundwater budget is an analysis of a groundwater basin's inflows and outflows to determine the change in groundwater storage. Alternatively, if the change in storage is known, the value of one of the inflows or outflows could be determined. The basic equation can be expressed as:

INFLOWS − OUTFLOWS = CHANGE IN STORAGE

Typical inflows include:

- natural recharge from precipitation;
- seepage from surface water channels;
- intentional recharge via ponds, ditches, and injection wells;
- net recharge of applied water for agricultural and other irrigation uses;
- unintentional recharge from leaky conveyance pipelines; and
- subsurface inflows from outside basin boundaries.

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Outflows include:

- groundwater extraction by wells;
- groundwater discharge to surface water bodies and springs;
- evapotranspiration; and
- subsurface outflow across basin or subbasin boundaries.

Groundwater budgets can be useful tools to understand a basin, but detailed budgets are not available for most groundwater basins in California. A detailed knowledge of each budget component is necessary to obtain a good approximation of the change in storage. Absence or inaccuracy of one or more parameters can lead to an analysis that varies widely from a positive to a negative change in storage or vice versa. Since much of the data needed requires subsurface exploration and monitoring over a series of years, the collection of detailed field data is time-consuming and expensive. A management plan should develop a monitoring program as soon as possible.

Change in Groundwater Storage

As stated above, a groundwater budget is one potential way of estimating the change in storage in a basin, although it is limited by the accuracy and availability of data. There is a simpler way – by determining the average change in groundwater elevation over the basin, multiplied by the area overlying the basin and the average specific yield (or storativity in the case of a confined aquifer). The time interval over which the groundwater elevation change is determined is study specific, but annual spring-to-spring changes are commonly used. A change in storage calculation does not attempt to determine the volume of water in storage at any time interval, but rather the change from a previous period or baseline condition.

A change in storage calculation is a relatively quick way to represent trends in a basin over time. If change in storage is negligible over a representative period, the basin is in equilibrium under current use. Changes in storage calculations are more often available for a groundwater basin than groundwater budgets because water level measurements are available in many basins. Specific yield and storativity are readily estimated based on knowledge of the hydrogeologic setting and geologic materials or through aquifer pumping tests. Although simple, change in storage calculations have potential sources of error, so it is important to treat change in storage as just one of many tools in determining conditions in a groundwater basin. Well data sets must be carefully evaluated before use in these calculations. Mixing of wells constructed in confined and unconfined portions of the basin and measurement of different well sets over time can result in significant errors.

Although the change in storage calculation is a relatively quick and inexpensive method of measuring changes in the groundwater system, the full groundwater budget is preferable. A detailed budget describes an understanding of the physical processes affecting storage in the basin, which the simple change in storage calculation does not. For example, the budget takes into account the relationship between the surface water and the groundwater system. If additional groundwater extraction induced additional infiltration of surface water, the calculated change in storage could be minimal. However, if the surface water is used as a source of supply downstream, the impact of reduced flows could be significant.

Overdraft

Groundwater overdraft is defined as the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions (DWR 1998). Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. If overdraft continues for a number of years, significant adverse impacts may occur, including increased extraction costs, costs of well deepening or replacement, land subsidence, water quality degradation, and environmental impacts.

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Despite its common usage, the term overdraft has been the subject of debate for many years. Groundwater management is a local responsibility; therefore, the decision whether a basin is in a condition of overdraft is the responsibility of the local groundwater or water management agency. In some cases local agencies may choose to deliberately extract groundwater in excess of recharge in a basin (known as "groundwater mining") as part of an overall management strategy. An independent analysis of water levels in such a basin might conclude that the basin is in overdraft. In other cases, where basin management is less active or nonexistent, declining groundwater levels are not considered a problem until levels drop below the depth of many wells in the basin. As a result, overdraft may not be reported for many years after the condition began.

Water quality changes and subsidence may also indicate that a basin has been overdrafted. For example, when groundwater levels decline in coastal aquifers, seawater fills the pore spaces in the aquifer that are vacated by the groundwater, indicating that the basin is being overdrafted. Overdraft has historically led to as much as 30 feet of land subsidence in some areas of the State and lesser amounts in other areas.

The word "overdraft" has been used to designate two unrelated types of water shortages. The first is "historical overdraft" similar to the type illustrated in Figure 18, which shows that ground water levels began to decline in the mid 1950s and then leveled off in the mid 1980s, indicating less groundwater extraction or more recharge. The second type of shortage is "projected overdraft" as used in the *California Water Plan Update* (DWR 1998). In reality, this is an estimate of future water shortages based on an assumed management program within the basin, including projected supply and projected demand. If water management practices change in those basins in which a water shortage is projected, the amount of projected shortage will change.

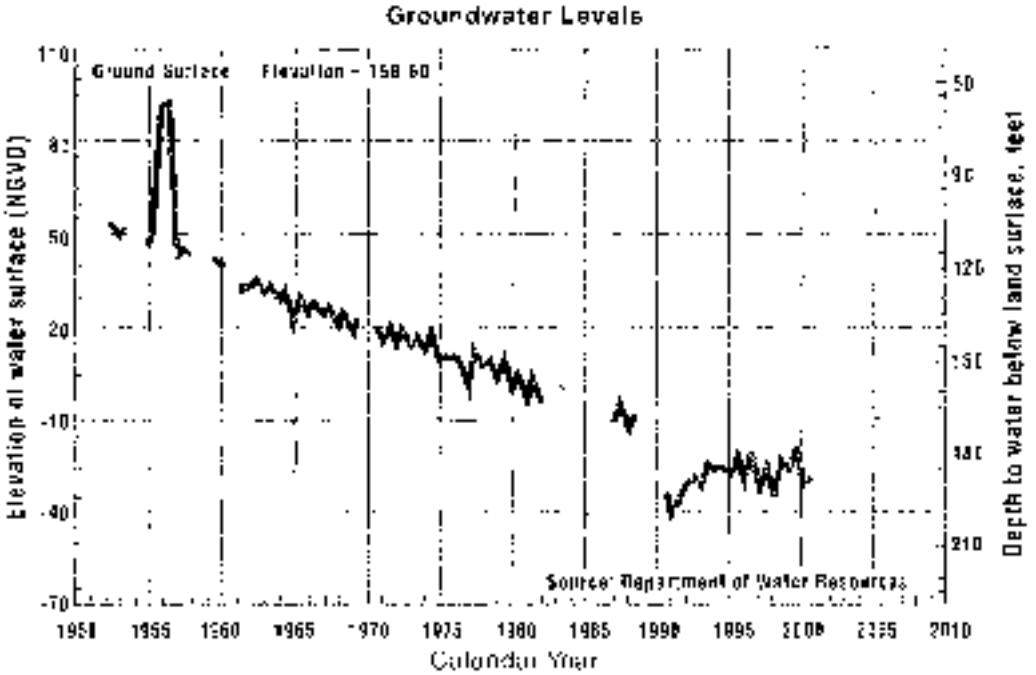

Figure 18 Hydrograph Indicating Overdraft

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In some basins or subbasins, groundwater levels declined steadily over a number of years as agricultural or urban use of groundwater increased. In response, managing agencies developed surface water import projects to provide expanded water supplies to alleviate the declining groundwater levels. Increasing groundwater levels or refilling of the aquifer demonstrate the effectiveness of this approach in long-term water supply planning. In some areas of the State, the past overdraft is now being used to advantage. When the groundwater storage capacity that is created through historical overdraft is used in coordination with surface water supplies in a conjunctive management program, local and regional water supplies can be augmented.

In 1978 DWR was directed by the legislature to develop a definition of critical overdraft and to identify basins that were in a condition of critical overdraft (Water Code § 12924). The process that was followed and the basins that were deemed to be in a condition of critical overdraft are discussed in Box O, "Critical Conditions of Overdraft." This update to Bulletin 118 did not include similar direction from the legislature, nor funding to undertake evaluation of the State's groundwater basins to determine whether they are in a state of overdraft.

Box O Critical Conditions of Overdraft

In 1978 DWR was directed by the legislature to develop a definition of critical overdraft and to identify those basins in a critical condition of overdraft (Water Code § 12924). DWR held public workshops around the State to obtain public and water managers' input on what the definition should include, and which basins were critically overdrafted. Bulletin 118-80, *Ground Water Basins in California* was published in 1980 with the results of that local input. The definition of critical overdraft is:

> *A basin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts.*

No time is specified in the definition. Definition of the time frame is the responsibility of the local water managers, as is the definition of significant adverse impacts, which would be related to the local agency's management objectives.

Eleven basins were identified as being in a critical condition of overdraft. They are:

Pajaro Basin	Cuyama Valley Basin
Ventura Central Basin	Eastern San Joaquin County Basin
Chowchilla Basin	Madera Basin
Kings Basin	Kaweah Basin
Tulare Lake Basin	Tule Basin
Kern County Basin	

The task was not identified by the legislature, nor was the funding for this update (2003) sufficient to consult with local water managers and fully re-evaluate the conditions of the 11 critically overdrafted basins. Funding and duration were not sufficient to evaluate additional basins with respect to conditions of critical overdraft.

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If a basin lacks existing information, the cost of a thorough evaluation of overdraft conditions in a single basin could exceed $1 million. In this update of Bulletin 118, DWR has included groundwater budget information for each basin description, where available. In most cases, however, sufficient quantitative information is not available, so conditions of overdraft or critical overdraft were not reported.

While this bulletin does not specifically identify overdrafted basins (other than the 11 basins from Bulletin 118-80), the negative effects of overdraft are occurring or may occur in the future in many basins throughout the State. Declining water levels, diminishing water quality, and subsidence threaten the availability of groundwater to meet current and future demands. A thorough understanding of overdraft can help local groundwater managers minimize the impacts and take advantage of the opportunity created by available groundwater storage capacity. Local groundwater managers and DWR should seek funding and work cooperatively to evaluate the groundwater basins of the State with respect to overdraft and its potential impacts. Beginning with the most heavily used basins and relying to the extent possible on available data collected by DWR and through local groundwater management programs, current or projected conditions of critical overdraft should be identified. If local agencies take the lead in collecting and analyzing data to fully understand groundwater basin conditions, DWR can use the information to update the designations of critically overdrafted basins. This can be a cost effective approach since much of the data needed to update the overdraft designations are the same data that agencies need to effectively manage groundwater.

Safe Yield

Safe yield is defined as the amount of groundwater that can be continuously withdrawn from a basin without adverse impact. Safe yield is commonly expressed in terms of acre-feet per year. Depending on how it is applied, safe yield may be an annual average value, or may be calculated based on changed conditions each year. Although safe yield may be indicated by stable groundwater levels measured over a period of years, a detailed groundwater budget is needed to accurately estimate safe yield. Safe yield has commonly been determined in groundwater basin adjudications.

Proper application of the safe yield concept requires that the value be modified through time to reflect changing practices within the basin. One of the common misconceptions is that safe yield is a static number. That is, once it has been calculated, the amount of water can be extracted annually from the basin without any adverse impacts. An example of a situation in which this assumption could be problematic is when land use changes. In some areas, where urban development has replaced agriculture, surface pavement, storm drains, and sewers have increased runoff and dramatically reduced recharge into the basin. If extraction continues at the predetermined safe yield of the basin, water level decline and other negative impacts could occur.

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Figure 19 Photograph of extensometer

An extensometer is a well with a concrete foundation and a steel wire suspended from the bottom of the well. A pipe extends from the concrete base to the land surface. As subsidence of the fine-grained sediments occurs, leading to land surface subsidence, the pipe in the well will appear to extend out of the well casing, while the wire remains in contact with the stationary bottom of the well. The land surface has moved down with the land surface has moved.

Subsidence

When groundwater is extracted from some aquifers in sufficient quantity, compaction of the fine-grained sediments can cause subsidence of the land surface. As the groundwater level is lowered, water pressure decreases and many of the weight of the overlying sediments is supported by the sediment grains within the aquifer. If these sediments have not previously been surcharged with an equivalent load, the overlying load will compact them. Compaction decreases the porosity of the sediments and decreases the overall volume of the finer grain sediments, leading to subsidence at the land surface. While the finer sediments within the aquifer system are compacted, the usable storage capacity of the aquifer is not greatly decreased.

Data from extensometers (Figure 19) show that as groundwater levels decline in an aquifer, the land surface falls slightly. As groundwater levels rise, the land surface also rises to its original position. This component of subsidence is called elastic subsidence because it recovers. Inelastic subsidence, the second component of subsidence, is what occurs when groundwater levels decline to the point that the finer sediments are compacted. This compaction is not recoverable.

Conjunctive Management

Conjunctive management in its broadest definition is the coordinated and combined use of surface water and groundwater to increase the overall water supply of a region and improve the reliability of that supply. Conjunctive management may be implemented to meet other objectives as well, including reducing groundwater overdraft and land subsidence, protecting water quality, and improving environmental conditions. Although surface water and groundwater are sometimes considered to be separate resources, they are connected in the hydrologic cycle. By using or storing additional surface water when it is plentiful, and relying more heavily on groundwater during dry periods, conjunctive management can change the timing and location of water so it can be used more efficiently.

Although a specific project or program may be extremely complex, there are several components common to conjunctive management projects. The first is to recharge surplus surface water when it is available to increase groundwater in storage. Recharge may occur through surface spreading, by injection wells, or by reducing groundwater use by substituting surface water. The surplus surface water used for recharge may be local runoff, imported water, stored surface water, or recycled water. The second component is to reduce surface water use in dry years or dry seasons by switching to groundwater. This use of the stored groundwater may take place through direct extraction and use, pumping back to a conveyance facility, or through exchange of another water supply. A final component that should be included is an ongoing monitoring program to evaluate conditions and allow water managers to respond to changes in groundwater, surface water, or environmental conditions that could violate management objectives or impact other water users.

AR0069722

Quality of Groundwater

All water contains dissolved constituents. Even rainwater, often described as being naturally pure, contains measurable dissolved minerals and gases. As it moves through the hydrologic cycle, water dissolves and incorporates many constituents. These include naturally occurring and man-made constituents.

Most natural minerals are harmless up to certain levels. In some cases, higher mineral content is preferable to consumers for taste. For example, minerals are added to many bottled drinking waters after going through a filtration process. At some level, however, most naturally occurring constituents, along with those introduced by human activities, are considered contaminants. The point at which a given constituent is considered a contaminant varies depending on the intended use of the groundwater and the toxicity level of the constituents.

Beneficial Uses

For this report, water quality is a measure of the suitability of water for its intended use, with respect to dissolved solids and gases and suspended material. An assessment of water quality should include the investigation of the presence and concentration of any individual constituent that may limit the water's suitability for an intended use.

The SWRCB has identified 23 categories of water uses, referred to as beneficial uses. The beneficial use categories and a brief description of each are presented in Appendix C. The actual criteria that are used to evaluate water quality for each of the beneficial uses are determined by the nine Regional Water Quality Control Boards, resulting in a range of criteria for some of the uses. These criteria are published in each of the Regional Boards' Water Quality Control Plans (Basin Plans).[1]

A summary of water quality for all of the beneficial uses of groundwater is beyond the scope of this report. Instead, water quality criteria for two of the most common uses—municipal supply (referred to as public drinking water supply in this report) and agricultural supply—are described below.

Public Drinking Water Supply

Standards for maximum contaminant levels (MCLs) of constituents in drinking water are required under the federal Safe Drinking Water Act of 1974 and its updates. There are primary and secondary standards. Primary standards are developed to protect public health and are legally enforceable. Secondary standards are generally for the protection of aesthetic qualities such as taste, odor, and appearance, and cosmetic qualities, such as skin or tooth discoloration, and are generally nonenforceable guidelines. However, in California secondary standards are legally enforceable for all new drinking water systems and new sources developed by existing public water suppliers (DWR 1997). Under these primary and secondary standards, the U.S. Environmental Protection Agency regulates more than 90 contaminants, and the California Department of Health Services regulates about 120. Federal and State primary MCLs are listed in Appendix F.

Agricultural Supply

An assessment of the suitability of groundwater as a source of agricultural supply is much less straightforward than that for public water supply. An evaluation of water supply suitability for use in agriculture is difficult because the impact of an individual constituent can vary depending on many factors, including soil chemical and physical properties, crop type, drainage, and irrigation method. Elevated levels of constituents usually do not result in an area being taken entirely out of production, but may lower crop yields. Management decisions will determine appropriate land use and irrigation methods.

[1] Digital versions of these plans are available online at http://www.swrcb.ca.gov/plnspls/index.html

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There are no regulatory standards for water applied on agriculture. Criteria for crop water have been provided as guidelines. Many constituents have the potential to negatively impact agriculture, including more than a dozen trace elements (Ayers and Westcot 1985). Two constituents that are commonly considered with respect to agricultural water quality are salinity -- expressed as total dissolved solids (TDS) -- and boron concentrations.

Increasing salinity in irrigation water inhibits plant growth by reducing a plant's ability to absorb water through its roots (Pratt and Suarez 1996). While the impact will depend on crop type and soil conditions, it is useful to look at the TDS of the applied water as a general assessment tool. A range of values for TDS with their estimated suitability for agricultural uses is presented in Table 10. These ranges are modified from criteria developed for use in the San Joaquin Valley by the San Joaquin Valley Drainage Program. However, they are similar to values presented in Ayers and Westcot (1985).

Table 10 Range of TDS values with estimated suitability for agricultural uses

Range of TDS (mg/L)	Suitability
<500	Generally no restrictions on use
500 – 1,500	Generally slight restrictions on use
1,500 – 2,500	Generally moderate restrictions on use
>2,500	Generally severe restrictions on use

Modified from SJVDP (1990)
TDS = total dissolved solids

High levels of boron can present toxicity problems in plants by damaging leaves. The boron is absorbed through the root system and transported to the leaves. Boron then accumulates during plant transpiration, resulting in leaf burn (Ayers and Westcot 1985). Boron toxicity is highly dependent on a crop's sensitivity to the constituent. A range of values of dissolved boron in irrigation water, with their estimated suitability on various crops is presented in Table 11. These ranges are modified from Ayers and Westcot (1985).

Table 11 Range of boron concentrations with estimated suitability on various crops

Range of dissolved boron (mg/L)	Suitability
<0.5	Suitable for all but most highly boron sensitive crops
0.5 – 1.0	Suitable for most boron sensitive crops
1.0 – 2.0	Suitable for most moderately boron sensitive crops
>2.0	Suitable for only moderately to highly boron tolerant crops

Source: Modified from Ayers and Westcot 1985

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Contaminant Groups

Because there are so many potential individual constituents to evaluate, researchers have often summarized contaminants into groups depending on the purpose of the study. Recognizing that there are exceptions to any classification scheme, this update considered groups according to their common sources of contamination—those naturally occurring and those caused by human activities (anthropogenic). Each of these sources includes more than one contaminant group. A listing of the contaminant groups and the individual constituents belonging to those groups, summarized in this report, is included in Appendix B.

Naturally Occurring Sources

In this report, naturally occurring sources include three primary groups: (1) inorganic constituents with primary MCLs, (2) inorganic constituents with secondary MCLs, and (3) radiological constituents. Inorganics primarily include naturally occurring minerals such as arsenic or mercury, although human activities may certainly contribute to observed concentrations. Radiological constituents include primarily naturally occurring constituents such as radon, gross alpha, and uranium. Although radioactivity is not considered a significant contaminant statewide, it can be locally important, particularly in communities in the Sierra Nevada.

Anthropogenic Sources

Anthropogenic contaminants include pesticides, volatile organic compounds (VOCs), and nitrates. Pesticides and VOCs are often grouped together into an organic contaminant group. However, separating the two gives a general idea of which contaminants are primarily from agricultural activities (pesticides) and which are primarily from industrial activities (VOCs). One notable exception to the groupings is dibromochloropropane (DBCP). Even though this compound is a VOC, DBCP is a soil fumigant and is included with pesticides. Nitrates are a surprising anthropogenic class to some observers. Nitrogen is certainly a naturally occurring inorganic constituent. However, because most nitrates are associated with agriculture (see Box F, "Focused on Nitrates: Detailed Study of a Contaminant") and nitrates are among California's leading contaminants, it is appropriate to consider them separately from inorganics.

Box F: Focused on Nitrates: Detailed Study of a Contaminant

Because water has so many potential uses, the study of water quality means different things to different people. Thomas Harter, a professor at the University of California at Davis, has chosen to focus on nitrates as one of his research interests. Harter's monitoring network consists of 70 wells on 8 dairies in the San Joaquin Valley.

A common result of dairy activities is the release of nitrogen into the surroundings, which changes to nitrate in groundwater. Nitrates are notorious for their role in interfering with oxygen transport in babies, a condition commonly referred to as "blue baby syndrome." Nitrates are also of interest because more public supply wells have been closed due to nitrate contamination than from any other contaminant (Bachman and others 1997).

Harter's study has focused on two primary activities. The first is a meticulous examination of nitrogen at the surface and nitrates in the uppermost 25 feet of the subsurface. This monitoring has been ongoing since 1993, and has shown that a significant amount of nitrate can reach shallow groundwater. The second focus of the study has been to change management practices to reduce the amount of nitrogen available to reach groundwater, along with continued monitoring. This has occurred since 1996. Results of the study use better management practices that significantly reduce the amount of nitrogen available to groundwater. This will help minimize the potential adverse impacts to groundwater quality from nitrates.

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Chapter 7

Inventory of California's Groundwater Information

Chapter 7
Inventory of California's Groundwater Information

The groundwater information in this chapter summarizes the available information on statewide and regional groundwater issues. For more detailed information on specific groundwater basins see the supplement to this report that is available on the California Department of Water Resources (DWR) website, http://www.waterplan.water.ca.gov/groundwater/index.htm. See Appendix A for information on accessing individual basin descriptions and the map delineating California's groundwater basins.

Statewide Groundwater Information

There is a large amount of data available for many of the State's most heavily developed groundwater basins. Conversely, there is relatively little data available on groundwater in the undeveloped areas. The information in this report is primarily limited to a compilation of the information readily available to DWR staff and may not include the most up-to-date data generated by studies that have been completed recently by water management agencies. For this reason, the collection of additional, more recent data on groundwater basins should be continued and integrated into the basin descriptions. Statewide summaries are included below.

Groundwater Basins

There are currently 431 groundwater basins delineated, underlying about 40 percent of the surface area of the State. Of these, 24 basins are subdivided into a total of 268 subbasins, giving a total of 515 distinct groundwater systems described in this report (Figure 20). Basin delineation methods are described in Appendix C. Additionally, many of the subbasin boundaries were developed or modified with public input, but little physical data. These boundaries should not be considered as precisely defining a groundwater basin boundary; the determination of whether any particular area lies within a groundwater basin boundary should be determined only after detailed local study.

Groundwater basin and subbasin boundaries shown on the map included with this bulletin are based on evaluation of the best available information. In basins where many studies have been completed and the basin has been operated for a number of years, the basin response is fairly well understood and the boundaries are fairly well defined. Even in these basins, however, there are many unknowns and changes in boundaries may result as more information about the basin is collected and evaluated.

Groundwater Budgets

Rather than simply providing all groundwater budget data collected during this update, the budget information was classified into one of three categories indicating the relative level of detail of information available. These categories, types A, B, and C, are discussed in Box B, "Explanation of Groundwater Data Tables." A type A budget indicates that much of the information needed to characterize the groundwater budget for the basin or subbasin was available. DWR staff did not verify these type A budgets, so DWR cannot address the accuracy of the data provided by them. Type B indicates that enough data are available to estimate the groundwater extraction to meet local water use needs. This is useful in understanding the reliance of a particular area on groundwater. Type C indicates a low level of knowledge of any of the budget components for the area.

Figure 21 depicts where these type A, B, and C budgets occur. In general, there is a greater level of understanding (type A or B) in the more heavily developed areas in terms of groundwater use. These include the Central Valley and South Coast. The lowest level of knowledge of groundwater budget data is in the southeast desert area. A discussion of groundwater use in each region is included below.

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Box Q How Does the Information in This Report Relate to the Recently Enacted Laws Senate Bill 221 and Senate Bill 610 (2002)?

Recently enacted legislation requires developers of certain new housing projects to demonstrate an adequate water supply for that development. If a part of that proposed water supply is groundwater, urban water suppliers must provide additional information on the availability of an adequate supply of groundwater to meet the projected demand and show that they have the legal right to extract that amount of groundwater. SB 610 (2002) amended the Water Code to require, among other things, the following information (Section 10631 (b)(2)):

> *For basins that have not been adjudicated, information as to whether the department has identified the basin or basins as overdrafted or has projected that the basin will become overdrafted if present management conditions continue, in the most current official departmental bulletin that characterizes the condition of the groundwater basin, and a detailed description of the efforts being undertaken by the urban water supplier to eliminate the long-term overdraft condition.*

The hydrogeologic information contained in the basin descriptions that supplement this update of Bulletin 118 includes only the information that was available in California's recent past of Water Resources (DWR) files through reference searches and through limited contact with local agencies. Local agencies may have conducted more recent studies that have generated additional information about water budgets and aquifer characteristics. Unless the agency notifies DWR, or provided a copy of the recent reports to DWR staff, that recent information has not been included in the basin descriptions. Therefore, although SB 610 refers to groundwater basins identified as overdrafted in Bulletin 118, it would be prudent for local water suppliers to evaluate the potential for overdraft of any basin included as a part of a water supply assessment.

Persons interested in collecting groundwater information in accordance with the Water Code as amended by SB 221 and SB 610 may start with the information in Bulletin 118, but should follow up by consulting the references listed for each basin and contacting local water agencies to obtain any new information that is available. Otherwise, evaluation of available groundwater resources as mandated by SB 221 and SB 610 may not be using the most complete and recent information about water budgets and aquifer characteristics.

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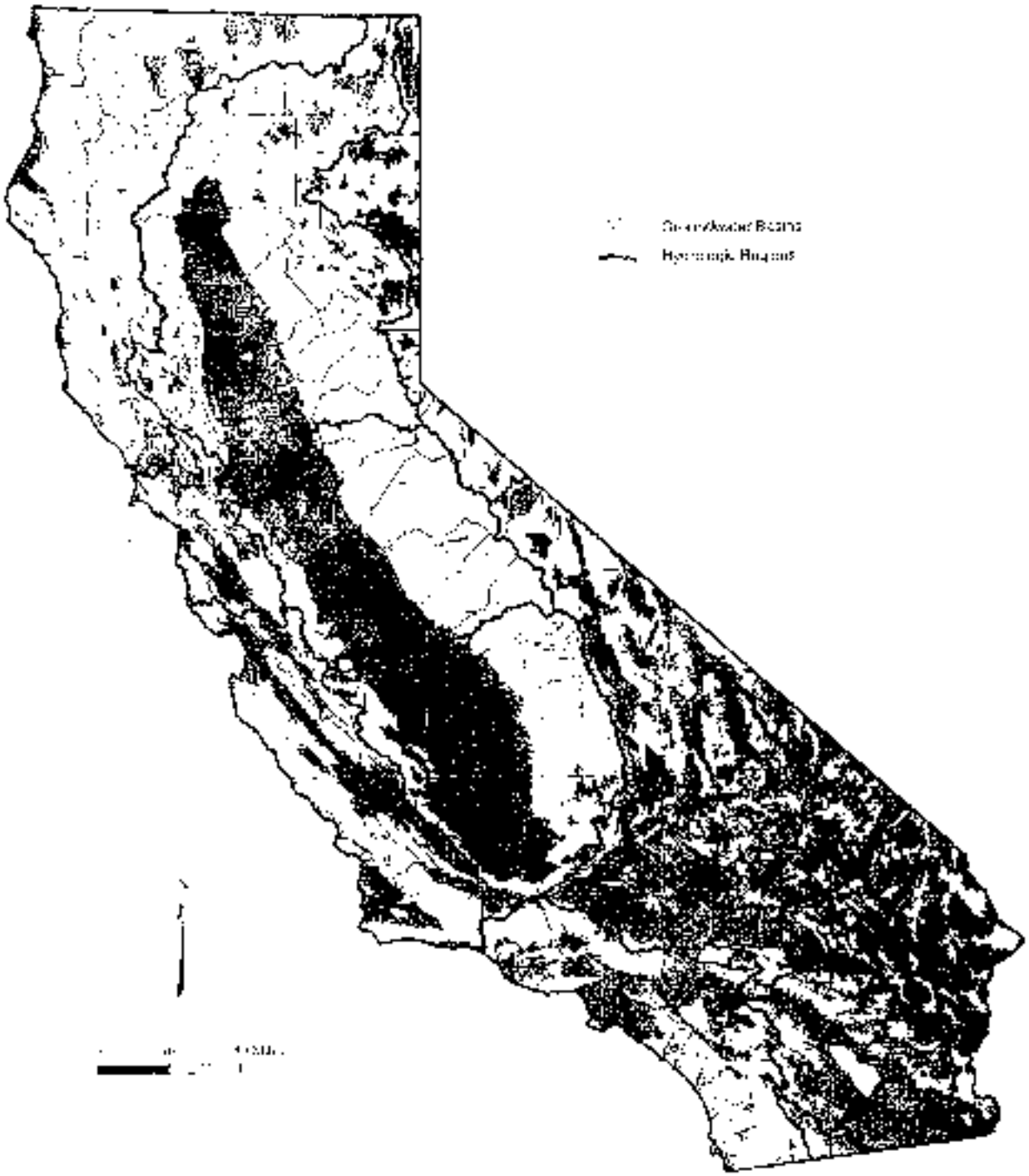

Figure 20 Groundwater basins and subbasins

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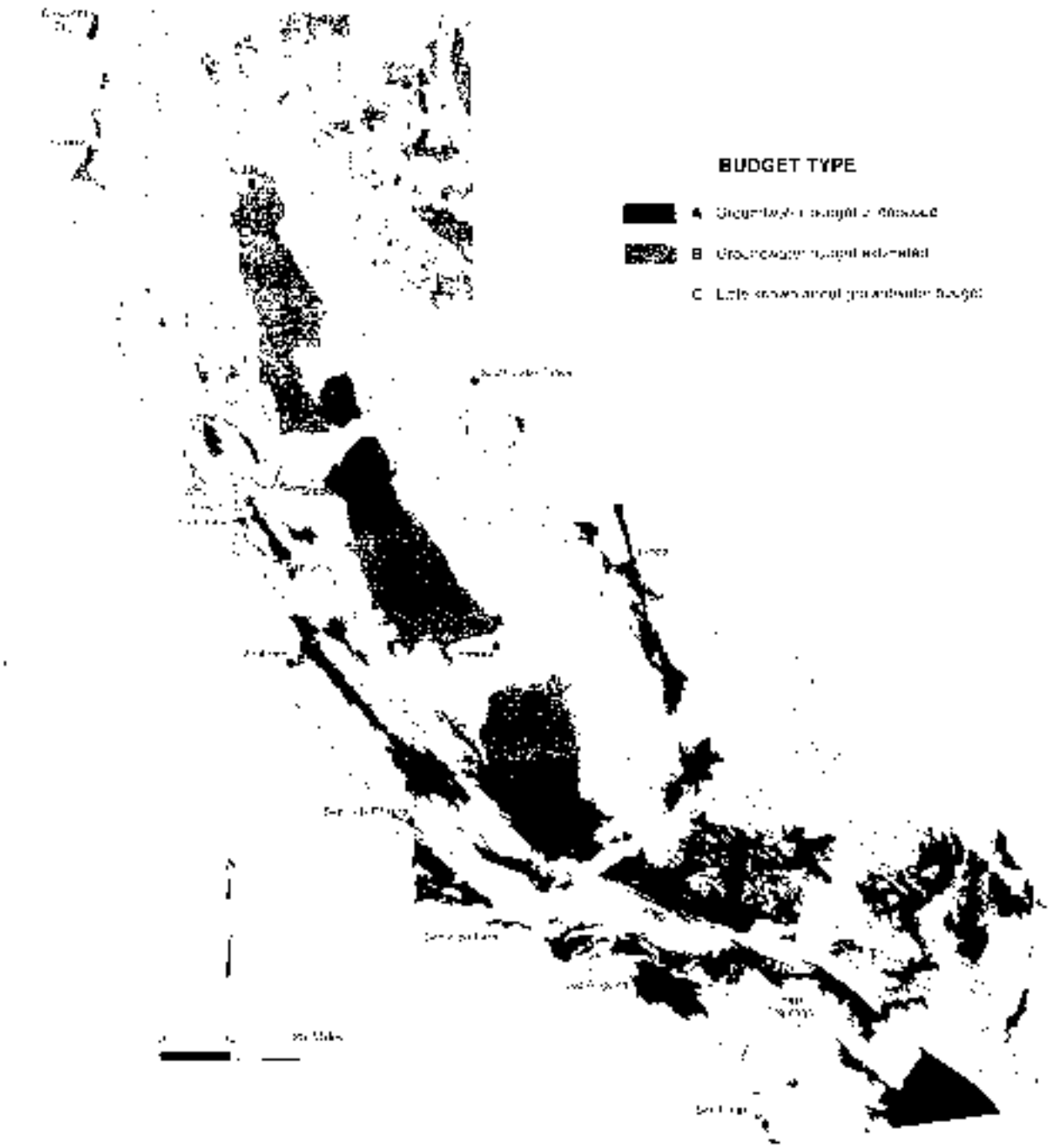

Figure 2. Basin and subbasin groundwater budget types

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Box B Explanation of Groundwater Data Tables

A groundwater data table for each hydrologic region is included at the end of each hydrologic region section in Chapter 7. The tables include the following information:

Basin/Subbasin Number. The basin numbering format is x-xxx.xx. The first number in the sequence assigns the basin to one of the nine Regional Water Quality Control Board boundaries. The second number is the groundwater basin number. Any number following the decimal identifies that the groundwater basin has been further divided into subbasins. Reinterpretation of available hydrogeologic information resulted in the deletion of some basins and subbasins as compiled in Bulletins 118-75 and 118-80. Because of this, there are some gaps in the sequence of basin numbers in this report. The methods used for developing the current groundwater basin maps are discussed in Appendix H. The names and numbers of the basins deleted, along with any comments related to their elimination are included in the appropriate region in Chapter 7. Previously unidentified groundwater basins or subbasins that were delineated during this update are assigned new identification numbers that sequentially follow the last number used in Bulletin 118-80 for groundwater basins or subbasins.

Basin or Subbasin Name. Basin names are based on published and unpublished reports, topographic maps, and local terminology. Names of newly delineated basins or subbasins are based on the principal geographic feature, which in most cases corresponds to the name of a valley. In the case of a subbasin, its formal name should include the name of the basin (for example, Sacramento Valley Groundwater Basin, North American Subbasin). However, both informally and informally, the term subbasin is used interchangeably with basin (for example, North American Basin).

Area. The area for each basin or subbasin is presented in acres rounded to three significant figures (for example, 147,148 acres was rounded to 147,000 acres). The area data box only the upper surface or map view of a basin. The basin underlies the area and may extend beyond the surface expression (discussed in Chapter 3).

Groundwater Budget Type. The type of groundwater budget information available was classified as Type A, B, or C based on the following criteria:

Type A - indicates one of the following: (1) a groundwater budget exists for the basin or enough components from separate studies could be combined to give a general indication of the basin's groundwater budget, (2) a groundwater model exists for the basin that can be used to calculate a groundwater budget, or (3) actual groundwater extraction data exist for the basin.

Type B - indicates that a use-based estimate of groundwater extraction is calculated for the basin. The use-based estimate is determined by calculating the overall use from California Department of Water Resources land use and urban water use surveys. Known surface water supplies are then subtracted from the total demand, leaving the rest of the use to be met by groundwater extraction.

Type C - indicates that there are not enough data to provide either an estimate of the basin's groundwater budget or groundwater extraction from the basin.

Well Yields. Maximum and average well yields in gallons per minute (gpm) are reported for municipal supply and agricultural wells where available. Most of the values reported are from initial tests reported during construction of the well, which may not be an accurate indication of the long-term production capacity of the wells.

Box B continued on next page

AR0069732

Box B Explanation of Groundwater Data Tables (continued)

Types of Monitoring. This includes monitoring of both groundwater levels and quality. "Levels" indicate the number of wells actively monitored without consideration of frequency. Most wells are monitored semi-annually, but many are monitored monthly. "Quality" indicates the number of wells monitored for various constituents; these could range from a grab sample taken for a field specific conductance measurement to a full analysis of organic and inorganic constituents. "Title 22" indicates the number of public water system wells that are actively sampled and monitored under the direction of California Department of Health Services (DHS) Title 22 Program.

Total Dissolved Solids. This category includes range and average values of total dissolved solids (TDS). This data primarily represents data from published reports. In some cases, a range of average TDS values is presented.

Active Monitoring

The summary of active monitoring includes wells that are monitored for groundwater elevation or groundwater quality within the delineated groundwater basins as of 1999. Groundwater elevation data collected by DWR and cooperators are available online at http://wdl.water.ca.gov. Most of the water quality data are for public supply wells and were provided by the California Department of Health Services (DHS). Other groundwater level and water quality monitoring activities were reported by local agencies during this update. The summary indicates that there are nearly 14,000 wells monitored for groundwater levels, 10,700[1] wells monitored under DHS water quality monitoring program, and 4,700 wells monitored for miscellaneous water quality by other agencies.

[1] Some counties include wells in both DHS and local quality; through joint data exchange, DHS has responsibility for more than 10,000 public supply wells.

AR0069733

Box 5: What Happens When an MCL Exceedance Occurs?

All suppliers of domestic water to the public are subject to regulations adopted by the U.S. Environmental Protection Agency under the Safe Drinking Water Act (42 U.S.C. 300f et seq.) as well as by the California Department of Health Services under the California Safe Drinking Water Act (Health and Safety Code §§ 116270-116760).

These regulations include primary drinking water standards that establish maximum contaminant levels (MCLs) for inorganic and organic chemicals and radioactivity. MCLs are based on public protection, technical feasibility and economic factors.

California requires public water systems to sample their drinking water sources, analyze for regulated contaminants, and determine compliance with the MCLs on a regular basis. Sampling frequency depends on the contaminant, type of water source, and previous sampling results. Frequency can range from monthly to once every nine years, or none at all if sampling is waived because the source is not vulnerable to the contaminant.

Primary MCLs are enforceable standards. In California, compliance is usually determined at the wellhead or the surface water intake. To meet water quality standards and comply with regulations, a water system with a contaminant exceeding an MCL must notify the public and remove the source from service or initiate a process and schedule to install treatment for removing the contaminant.

Notification requirements reflect the severity of the regulated health risks. Immediate health concerns prompt immediate notice to consumers. Violations that do not pose a significant health concern may use a less immediate notification process. In addition to consumer notification, a water system is required by statute to notify the local governing body (for example, city council or county board of supervisors) whenever a drinking water well exceeds an MCL, even if the well is taken out of service.

Detections of regulated contaminants (and certain unregulated contaminants) must also be reported to consumers in the water system's annual Consumer Confidence Report.

Groundwater Quality

This summary of water quality relied heavily on data from the DHS Title 22 water quality monitoring program. The assessment consisted of querying the DHS database for active wells that have constituents exceeding the maximum contaminant level (MCL) for drinking water. Summaries of this assessment for each of the State's hydrologic regions (HRs) are discussed in this chapter.

DHS data are the most comprehensive statewide water quality data set available, but this data set should not be used as a sole indicator of the groundwater quality in California. Data from these wells are not necessarily representative of any given basin; it only represents the quality of groundwater where a public water supply is extracted.

AR0069734

The Natural Resources Defense Council (NRDC 2001) issued a report that concludes California's groundwater resources face a serious long-term threat from contamination. Despite heavy reliance on groundwater, no comprehensive statewide assessments of groundwater quality were available. In response to the NRDC report, the State Water Resources Control Board (SWRCB) is planning a comprehensive assessment of the State's groundwater quality. This program is discussed in Chapter 4, in the section titled "Groundwater Quality Monitoring Act of 2001 (AB 599)."

Regional Groundwater Use

The importance of groundwater as a resource varies regionally throughout the State. For planning purposes, DWR divides California into 10 hydrologic regions (HRs), which correspond to the State's major drainage areas. HR boundaries are shown in Figure 22. A review of average water year supplies from the California Water Plan (DWR 1998) shows the importance of groundwater as a local supply for agricultural and municipal use throughout the State and in each of California's 10 HRs (Table 12 and Figure 23).

Table 12 Annual agricultural and municipal water demands met by groundwater

Hydrologic region	Total Demand Volume (TAF)	Demand met by Groundwater (TAF)	Demand met by Groundwater (%)
North Coast	960	265	25
San Francisco Bay	1353	68	5
Central Coast	1263	1045	83
South Coast	5124	1177	23
Sacramento River	8720	2692	31
San Joaquin River	7301	2146	30
Tulare Lake	10536	4348	41
North Lahontan	569	157	28
South Lahontan	480	269	56
Colorado River	4467	357	8

Source: DWR 1998

With more than 80 percent of demand met by groundwater, the Central Coast HR is heavily reliant on groundwater to meet its local needs. The Tulare Lake and South Lahontan HRs meet more than 40 percent of their local demand from groundwater. The South Coast, North Coast, North Lahontan, San Joaquin River, and Sacramento River HRs take between 20 and 40 percent of their supply from groundwater. Groundwater is a relatively minor source of supply in the San Francisco Bay and Colorado River HRs.

Of all the groundwater extracted annually in the state, an estimated 35 percent is produced from the Tulare Lake HR. More than 70 percent of groundwater extraction occurs in the Central Valley (Tulare Lake, San Joaquin River, and Sacramento River HRs combined). Nearly 20 percent is extracted in the highly urbanized South Coast and Central Coast HRs, while less than 10 percent is extracted in the remaining five HRs combined.

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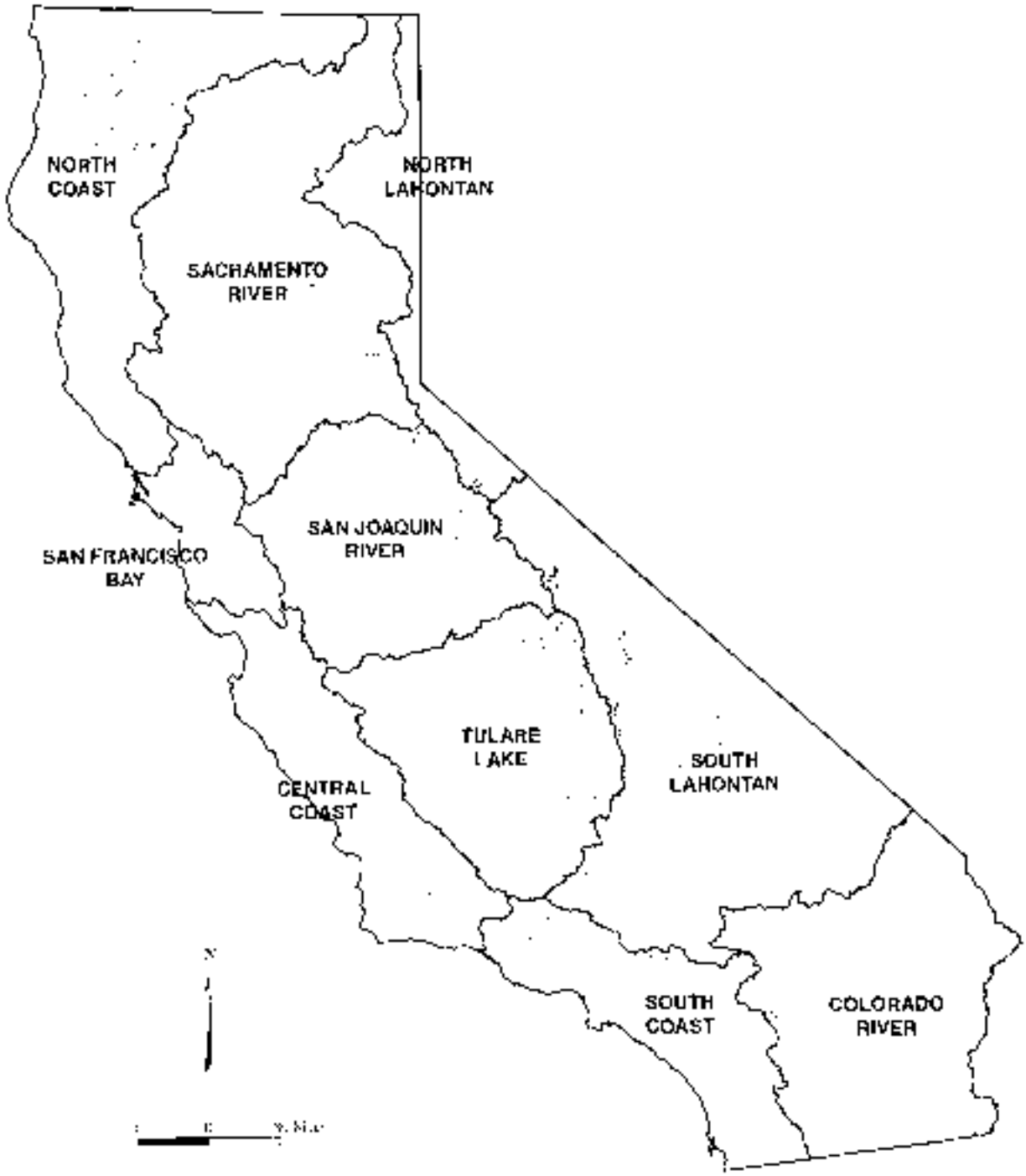

Figure 22 California's 10 hydrologic regions

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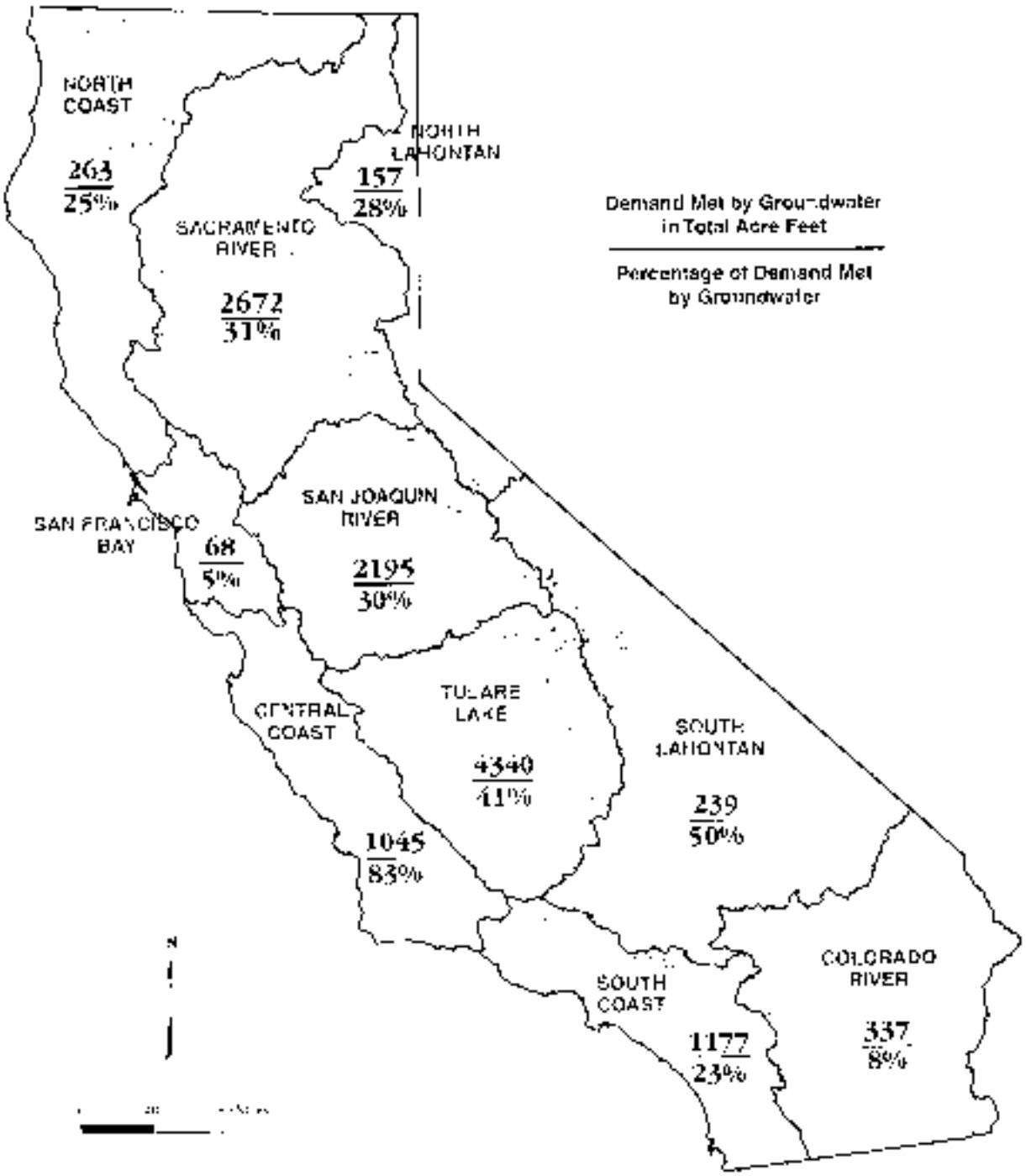

Figure 23 Agricultural and urban demand supplied by groundwater in each hydrologic region

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The remainder of this chapter provides a summary of each of the 10 HRs. A basin location map for each HR is followed by a brief discussion of groundwater occurrence and groundwater conditions. A summary tabulation of groundwater information for each groundwater basin within the HR is provided. Greater detail for the data presented in these tables, including a bibliography, is provided in the individual basin/subbasin descriptions in the supplemental report (see Appendix A). Because the groundwater basin numbers are based on the boundaries of the State's nine Regional Water Quality Control Boards (RWQCB), Figure 24 shows the relationship between the Regional Board boundaries and DWR's HR boundaries.

The groundwater basin tabulations give an overview of available data. Where a basin is divided into subbasins, only the information for the subbasins is provided. The data for each subbasin generally come from different sources, so it is inappropriate to sum the data into a larger basin summary. An explanation of each of the data items presented in the summary table is provided in Box B.

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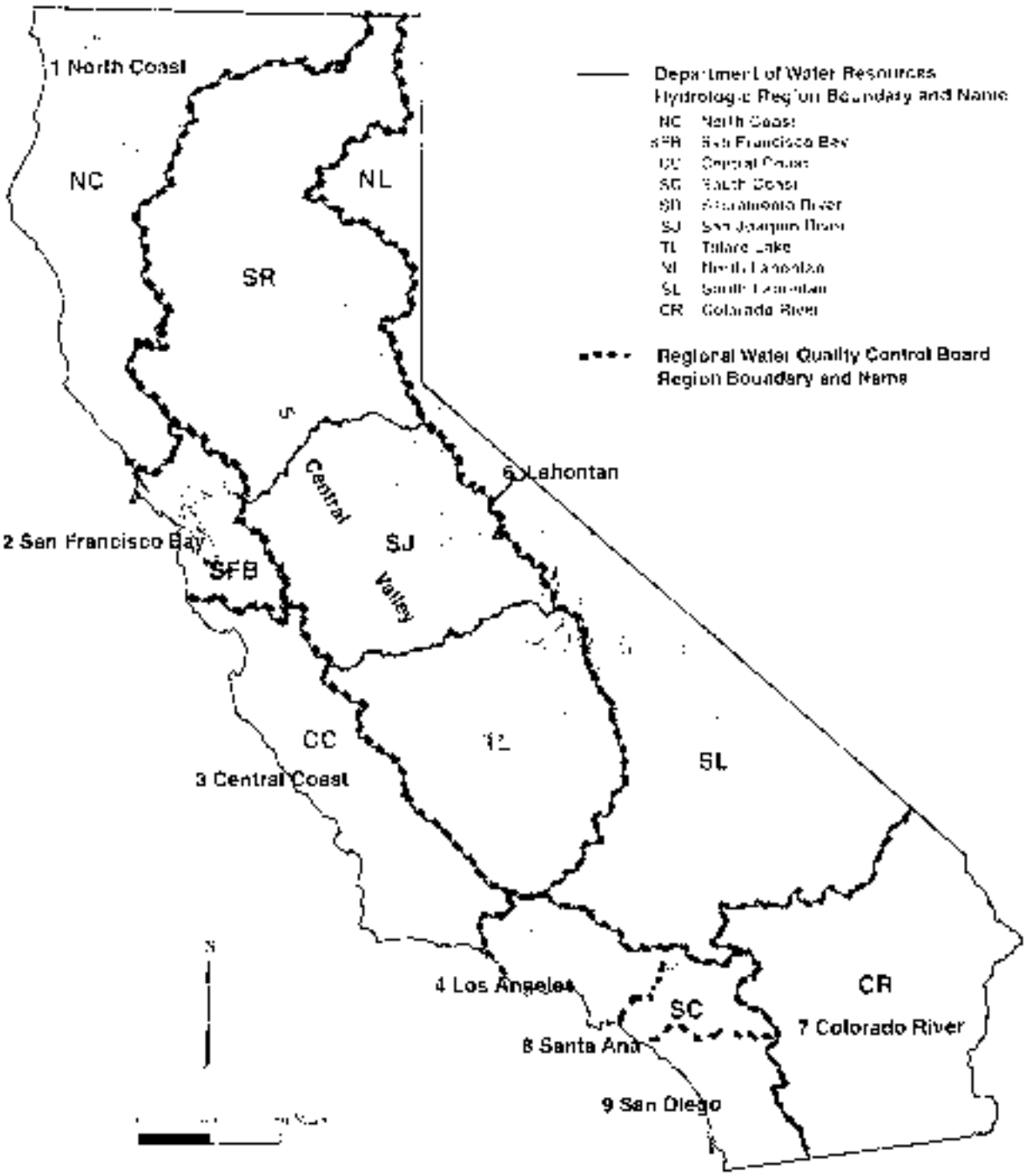

Figure 24. Regional Water Quality Control Board regions and Department of Water Resources hydrologic regions

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North Coast Hydrologic Region

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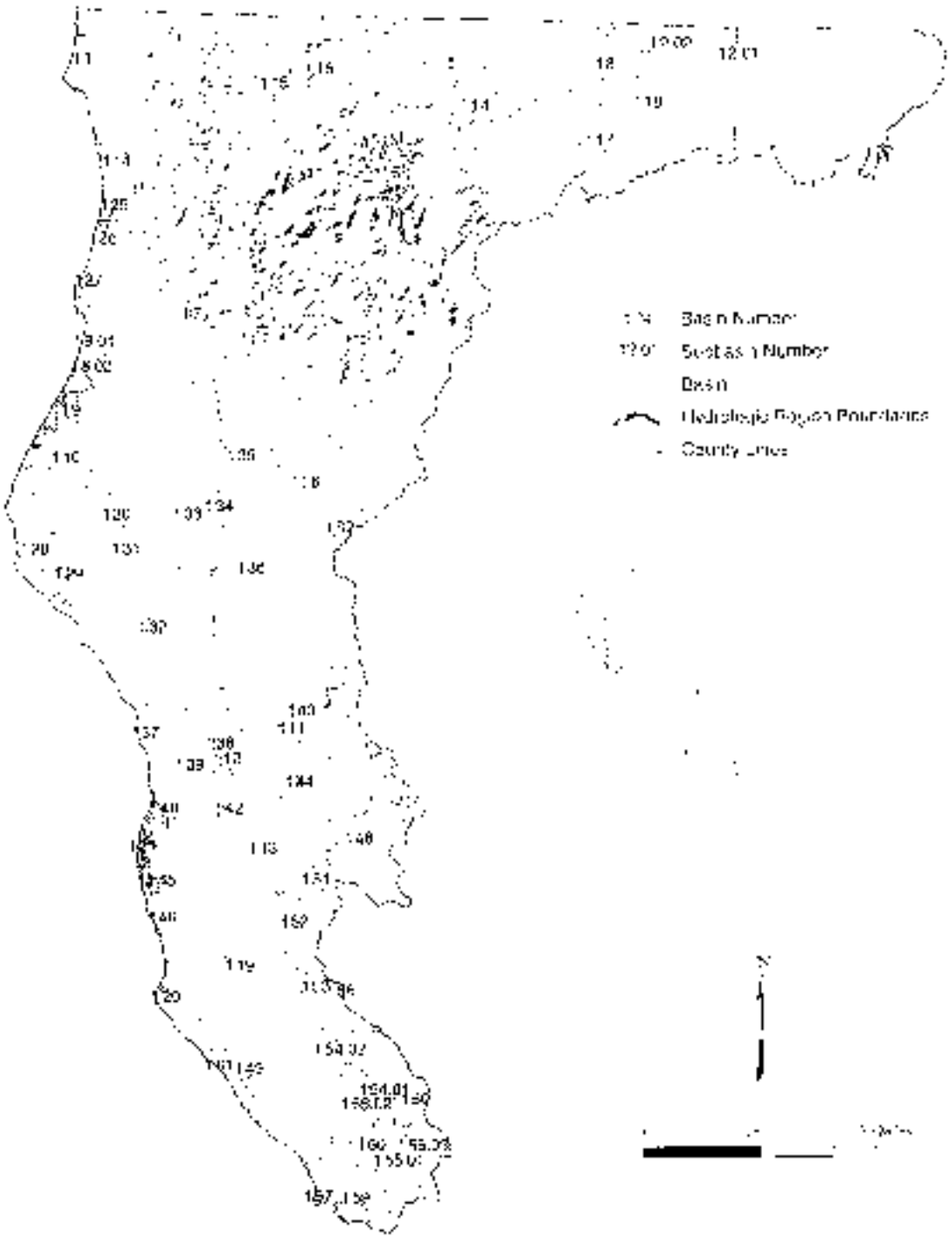

Figure 25 North Coast Hydrologic Region

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Basins and Subbasins of the North Coast Hydrologic Region

Basin/subbasin	Basin name
1-1	Smith River Plain
1-2	Klamath River Valley
1-2.01	Tule Lake
1-2.02	Lower Klamath
1-3	Butte Valley
1-4	Shasta Valley
1-5	Scott River Valley
1-6	Hayfork Valley
1-7	Canyon Valley
1-8	Mad River Valley
1-8.01	Mad River Lowland
1-8.02	Dows Prairie Subarea
1-9	Eureka Plain
1-10	Eel River Valley
1-11	Lovelo Mound Valley
1-12	Laytonville Valley
1-13	Little Lake Valley
1-14	Lower Klamath River Valley
1-15	Happy Camp Town Area
1-16	Sciad Valley
1-17	Bray Town Area
1-18	Red Rock Valley
1-19	Anderson Valley
1-20	Garcia River Valley
1-21	Fort Bragg Terrace Area
1-22	Fairchild Swamp Valley
1-23	Prairie Creek Area
1-24	Redwood Creek Area
1-27	Big Lagoon Area
1-28	Mattole River Valley
1-29	Honeydew Town Area
1-30	Pepperwood Town Area
1-31	Weott Town Area
1-32	Scotia-Rio Dell Town Area
1-33	Loleta Valley
1-34	Bunsmores Town Area
1-35	Ryanwoods Valley
1-36	Bottelenaw Valley
1-37	Cahoonova Creek Valley
1-38	Lower Eel-Van Duzen Valley
1-39	Bridgeport Town Area
1-40	Ten Mile River Valley
1-41	Potter Valley

Basin/subbasin	Basin name
1-42	Sherwood Valley
1-43	Williams Valley
1-44	Arden Valley
1-45	Big River Valley
1-46	Navarro River Valley
1-48	Gravelley Valley
1-49	Annapolis-Oldcrop Rock Formation Highlands
	Highlands
1-50	Knights Valley
1-51	Petrta Valley
1-52	Ukiah Valley
1-53	Sanel Valley
1-54	Alexander Valley
1-54.01	Alexander Area
1-54.02	Cloverdale Area
1-55	Santa Rosa Valley
1-55.01	Santa Rosa Plain
1-55.02	Healdsburg Area
1-55.03	Rincon Valley
1-56	Mel Dowe I Valley
1-57	Bodega Bay Area
1-58	Wilson Grove Formation Highlands
1-60	Lower Russian River Valley
1-61	Fort Ross Terrace Deposits
1-62	Wilson Point Area

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Description of the Region

The North Coast HR covers approximately 12.46 million acres (19,479 square miles) and includes all or portions of Modoc, Siskiyou, Del Norte, Trinity, Humboldt, Mendocino, Lake, and Sonoma counties (Figure 25). Small areas of Shasta, Tehama, Glenn, Colusa, and Marin counties are also within the region. Extending from the Oregon border south to Tomales Bay, the region includes portions of four geomorphic provinces. The northern Coast Range forms the portion of the region extending from the southern boundary north to the Mad River drainage and the fault contact with the metamorphic rocks of the Klamath Mountains, which continue north into Oregon. East of the Klamath terrane along the State border are the volcanic terranes of the Cascades and the Modoc Plateau. In the coastal mountains, most of the basins are along the narrow coastal strip between the Pacific Ocean and the rugged Coast Range and Klamath Mountains and along inland river valleys; alluviated basin areas are very sparse in the steep Klamath Mountains. In the volcanic terrane to the east, most of the basins are in block faulted valleys that once held Pleistocene-age lakes. The North Coast HR corresponds to the boundary of RWQCB 1. Significant geographic features include basin areas such as the Klamath River Basin, the Eureka/Arcata area, Hoopa Valley, Anderson Valley, and the Santa Rosa Plain. Other significant features include Mount Shasta, forming the southern border of Shasta Valley, and the rugged north coastal shoreline. The 1995 population of the entire region was about 606,000, with most being centered along the Pacific Coast and in the inland valleys north of the San Francisco Bay Area.

The northern mountainous portion of the region is rural and sparsely populated, primarily because of the rugged terrain. Most of the area is heavily forested. Some irrigated agriculture occurs in the narrow river valleys, but most occurs in the broader valleys on the Modoc Plateau where pasture, grain, and alfalfa predominate. In the southern portion of the region, closer to urban centers, crops like wine grapes, nursery stock, orchards, and truck crops are common.

A majority of the surface water in the North Coast HR goes to environmental uses because of the "wild and scenic" designation of most of the region's rivers. Average annual precipitation ranges from 100 inches in the Smith River drainage to 29 inches in the Santa Rosa area and about 10 inches in the Klamath drainage; as a result, drought is likely to affect the Klamath Basin more than other portions of the region. Communities that are not served by the area's surface water projects also tend to experience shortages. Surface water development in the region includes the U.S. Bureau of Reclamation (USBR) Klamath Project, Humboldt Bay Municipal Water District's Ruth Lake, and U.S. Army Corps of Engineer's Russian River Project. An important factor concerning water demand in the Klamath Project area is water allocation for endangered fish species in the upper and lower basin. Surface water deliveries for agriculture in 2001, a severe drought year, were only about 20 percent of normal.

Groundwater Development

Groundwater development in the North Coast HR occurs along the coast, near the mouths of some of the region's major rivers, on the adjacent narrow marine terraces, or in the inland river valleys and basins. Reliability of these supplies varies significantly from area to area. There are 63 groundwater basins/subbasins delineated in the region, two of which are shared with Oregon. These basins underlie approximately 1.023 million acres (1,600 square miles).

Along the coast, most groundwater is developed from shallow wells installed in the sand and gravel beds of several of the region's rivers. Under California law, the water produced in these areas is considered surface water underflow. Water from Ranney collectors installed in the Klamath River, Rowdy Creek, the Smith

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River, and the Mad River supply the towns of Klamath, Smith River and Crescent City in Del Norte County and most of the Humboldt Bay area in Humboldt County. Except on the Mad River, which has continuous supply via releases from Ruth Reservoir, these supplies are dependent on adequate precipitation and flows throughout the season. In drought years when streamflows are low, seawater intrusion can occur causing brackish or saline water to enter these systems. This has been a problem in the town of Klamath, which in 1995 had to obtain community water from a private well source. Toward the southern portion of the region, along the Mendocino coast, the Town of Mendocino typifies the problems related to groundwater development in the shallow marine terrace aquifers. Groundwater supply is limited by the aquifer storage capacity, and surveys done in the Town of Mendocino in the mid-1980s indicate that about 10 percent of wells go dry every year and up to 40 percent go dry during drought years.

Groundwater development in the inland coastal valleys north of the divide between the Russian and Eel Rivers is generally of limited extent. Most problems stemming from reliance on groundwater in these areas is a lack of alluvial aquifer storage capacity. Many groundwater wells rely on hydrologic connection to the rivers and streams of the valleys. The City of Rio Dell has experienced water supply problems in community wells and, as a result, recently developed plans to install a Ranney collector near the Eel River. South of the divide, in the Russian River drainage, a significant amount of groundwater development has occurred in the Santa Rosa Plain and surrounding areas. The groundwater supplies augment surface supplies from the Russian River Project.

In the north-central part of the North Coast HR, the major groundwater basins include the Klamath River Valley, Shasta Valley, Scott River Valley, and Butte Valley. The Klamath River Valley is shared with Oregon. Of these groundwater basins, Butte Valley has the most stable water supply conditions. The historical annual agricultural surface water supply has been about 20,000 acre-feet. As farming in the valley expanded from the early 1950s to the early 1990s, bringing nearly all the arable land in the valley into production, groundwater was developed to farm the additional acres. It has been estimated that current, fully developed demands are only about 80 percent of the available groundwater supply. By contrast, water supply issues in the other three basins are contingent upon pending management decisions regarding restoration of fish populations in the Klamath River and the Upper Klamath Basin system. The Endangered Species Act (ESA) fishery issues include lake level requirements for two sucker fish species and in-stream flow requirements for coho salmon and steelhead trout. Since about 1905, the Klamath Project has provided surface water to the agricultural community, which in turn has provided water to the wildlife refuges. Since the early 1990s, it has been recognized that surface water in the Klamath Project is over-allocated, but very little groundwater development had occurred. In 2001, which was a severe drought year, USBR delivered a total of about 25,000 acre-feet of water to agriculture in California, about 20 percent of normal. In the Klamath River Groundwater Basin this translated to a drought disaster, both for agriculture and the wildlife refuges. In addition, there were significant impacts for both coho salmon and sucker fisheries in the Klamath River watershed. As a result of the reduced surface water deliveries, significant groundwater development occurred, and groundwater extraction increased from an estimated 6,000 acre-feet in 1997 to roughly 60,000 acre-feet in 2001. Because of the complexity of the basin's water issues, a long-term Klamath Project Operations plan has not yet been finalized. Since 1995, USBR has issued an annual operation plan based on estimates of available supply. The Scott River Valley and Shasta Valley rely to a significant extent on surface water diversions. In most years, surface water supplies the majority of demand, and groundwater extraction supplements supply as needed depending on wet or dry conditions. Discussions are under way to develop strategies to conjunctively use surface water and groundwater to meet environmental, agricultural, and other demands.

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Groundwater Quality

Groundwater quality characteristics and specific local impairments vary with regional setting within the North Coast HR. In general, seawater intrusion and nitrates in shallow aquifers are problems in the coastal groundwater basins; high total dissolved solids (TDS) content and general alkalinity are problems in the lake sediments of the Modoc Plateau basins; and iron, boron, and manganese can be problems in the inland basins of Mendocino and Sonoma counties.

Water Quality in Public Supply Wells

From 2004 through 2009, 584 public supply water wells were sampled in 32 of the 63 basins and subbasins in the North Coast HR. Analyzed samples indicate that 553 wells, or 95%, met the state primary Maximum Contaminant Levels (MCL) for drinking water. Thirty-one wells, or 5%, sampled have constituents that exceed one or more MCL. Figure 26 shows the percentage of each contaminant group that exceeded MCLs in the 31 wells.

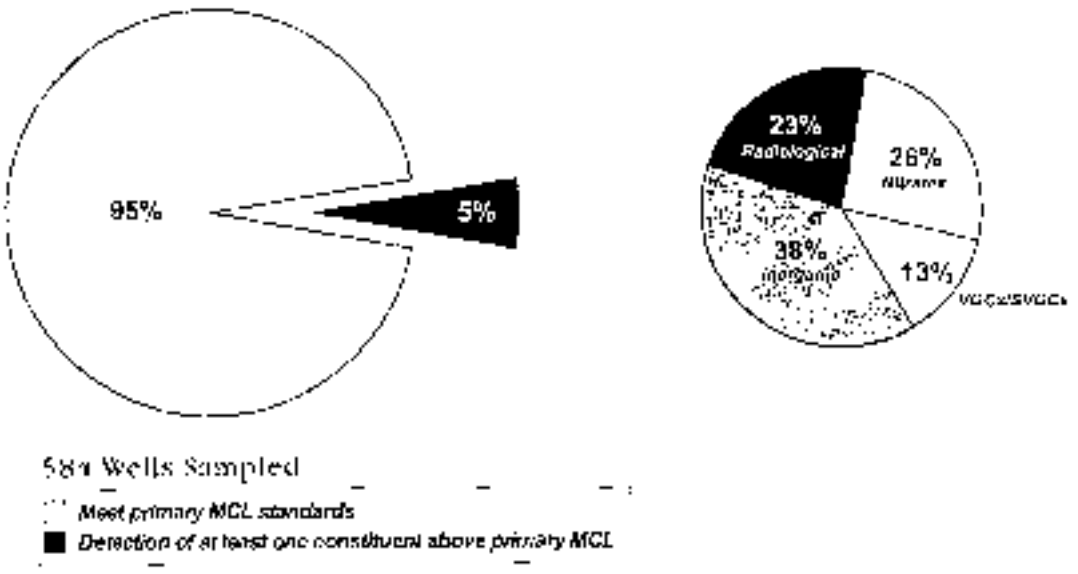

Figure 26 MCL exceedances in public supply wells in the North Coast Hydrologic Region

Table 13 lists the three most frequently occurring individual contaminants in each of the five contaminant groups and shows the number of wells in the HR that exceeded the MCL for these contaminants.

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Table 13 Most frequently occurring contaminants by contaminant group in the North Coast Hydrologic Region

Contaminant group with health significance – Primary exceedance	Contaminant – # of wells Aluminum – 4	Contaminant – # of wells Arsenic – 4	Contaminant – # of wells Fluoride – 4
Inorganics – Secondary	Manganese – 150	Iron – 108	Copper – 2
Radiological	Radium-228 – 3	Combined RA226 + RA228 – 4	Radium-226 – 1
Nitrates	Nitrate (as NO3) – 7	Nitrate (as N) – 1	
VOCs/SVOCs	TCE – 2	2 total exceedances	

TCE = Trichloroethylene
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound

Changes from Bulletin 118-80

Since Bulletin 118-80 was published, RWQCB 2 boundary has been modified. This resulted in several basins being reassigned to RWQCB 1. These are listed in Table 14, along with other modifications to North Coast HR.

Table 14 Modifications since Bulletin 118-80 of groundwater basins in North Coast Hydrologic Region

Basin name	New number	Old number
Wildwood Valley	1-56	2-12
Knights Valley	1-56	2-13
Potter Valley	1-5	2-14
Ukiah Valley	1-52	2-15
Sanel Valley	1-53	2-16
Alexander Valley	1-54	2-17
Santa Rosa Valley	1-55	2-18
Lower Russian River Valley	1-60	2-20
Sonoma Bay Area	1-57	2-21
Modern Pleistocene Recent Volcanic Area	deleted	2-3
Modern Pleistocene Pliocene Volcanic Area	deleted	2-24
Glenelda River Valley	deleted	2-17
Wilson Grove Formation Highlands	1-59	2-25
Petaluma River Tidal Deposits	2-61	
Wilson Point Area	1-62	

AR0069747

Fort Ross Terrace Deposits (1-61) and Wilson Point Area (1-62) have been defined since B118-80 and are included in this update. Mad River Valley Groundwater Basin (1-8) has been subdivided into two subbasins. Sebastopol Merced Formation (2-25) merged into Basin 2-59 and was renamed Wilson Grove Formation Highlands.

There are a couple of deletions of groundwater basins from Bulletin 118-80. The Modoc Plateau Recent Volcanic Area (1-22) and the Modoc Plateau Pleistocene Volcanic Area (1-24) are volcanic aquifers and were not assigned basin numbers in this bulletin. These are considered to be groundwater source areas as discussed in Chapter 6. Cicalala River Valley (1-47) was deleted because the State Water Resources Control Board determined the water being extracted in this area as surface water within a subterranean stream.

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Table 15 North Coast Hydrologic Region groundwater data

Basin Number	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Type A	Type B	Type C	Average	Range
1	SMITH RIVER PLAIN	46,450	B	500	50	3	10	11	164	92 - 400
1-2	KLAMATH RIVER VALLEY									
1-2.01	UPPER KLAMATH EAST BASIN (Lower Klamath)	37,930	B	3,380	1,200	40	8	3	77	40 - 3,220
1-2.02	UPPER KLAMATH EAST BASIN (Upper Klamath)	21,130	B	2,000	1,370	4				
1-3	BUTTE VALLEY	56,200	B	3,000	2,838	28	15	6	110	55 - 1,110
1-4	SHASTA VALLEY	72,640	B	1,200	233	9	14	24		
1-5	SCOTT RIVER VALLEY	61,900	B	3,000	783	6	10	5	208	82 - 1,950
1-6	HAYFORK VALLEY	3,000	B	200			3			
1-7	HOOPA VALLEY	9,940	B	300			4		125	83 - 185
1-8	MAD RIVER VALLEY									
1-8.01	MAD RIVER VALLEY FLOODPLAIN	25,600	B	120	72	3	9	2	184	88 - 2,140
1-8.02	DOWS PRAIRIE SUBBASIN AREA	4,050	B				3			
1-9	CHETCO PLAIN	13,600	B	1,200		3	4	6	172	97 - 694
1-10	EEL RIVER VALLEY	37,500	B	1,200		8	21	26	235	110 - 850
1-11	COVELO ROUND VALLEY	16,400	C	850	193	9	2	26	339	116 - 881
1-12	LAYTONVILLE VALLEY	5,020	A	200		4	3		98	55 - 251
1-13	LITTLE LAKE VALLEY	10,000	A	1,000	43	3	2		162	107 - 1,150
1-14	LOWER KLAMATH RIVER VALLEY	7,010	B							41 - 1,500
1-15	HAPPY CAMP TOWN AREA	2,750	B				2	12		
1-16	SCHOOL VALLEY	2,250	B				4	2		
1-17	BRAY TOWN AREA	1,010	B							
1-18	RED ROCK VALLEY	9,000	B							
1-19	ANDERSON VALLEY	5,200	C	500	30		4			50 - 800
1-20	GARCIA RIVER VALLEY	2,250	C							
1-21	FORT BRAGG TERRACE AREA	28,800	C	70	16		2	31	143	28 - 450
1-22	BENEFICIAL WANE VALLEY	3,250	B							
1-23	PRAIRIE CREEK AREA	27,000	B						106	
1-24	REDWOOD CREEK AREA	7,000	B			1	8	4		110 - 330
1-25	ORICK AREA	11,000	B			1	3	31	134	
1-26	MATTOLE RIVER VALLEY	7,150	B					2		
1-27	HONEYDEW TOWN AREA	2,500	B					1		
1-28	PETROLIA TOWN AREA	6,600	B					1		
1-29	WEOTT TOWN AREA	3,000	B					2		
1-30	GARBERVILLE TOWN AREA	2,000	B					2		
1-31	LAZARIDA VALLEY	900	B							
1-32	ETNA MILLS TOWN AREA	1,300	B							
1-33	IDYLLWILD VALLEY	1,150	B					1		
1-34	BELLEVUE VALLEY	950	B					1		
1-35	COTTONWOOD CREEK VALLEY	280	C						118	118
1-36	LOWER LAYTONVILLE VALLEY	4,150	C							
1-37	BRANSCOMB TOWN AREA	1,150	C						150	60 - 150
1-38	ESTAPOT RIVER VALLEY	1,400	C							
1-39	EEL RIVER VALLEY	5,000	C							

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Table 15 North Coast Hydrologic Region groundwater data (continued)

Basin Subbasin	Basin Name	Area (mi²)	Groundwater Subbasin Type	Well Yield (gpm) Maximum	Well Yield (gpm) Average	Depth to Water (ft) Levels	Depth to Water (ft) Quality	Depth to Water (ft) Depth	TDS (mg/L) Average	TDS (mg/L) Range
1-42	STURGEON VALLEY	1,156	C							
1-43	WILLIAMS VALLEY	1,960	C							
1-44	EDEN VALLEY	140	C						140	140
1-45	ROGERS VALLEY	460	C					2		
1-46	NAVARRO RIVER VALLEY	70	C							
1-48	GRAVELLY VALLEY	1,000	C							
1-49	ANAPHE'S OHLSON RANCH FOR HIGHLANDS	5,050	C	30			0		260	260
1-50	KNIGHTS VALLEY	4,040	C							
1-51	BUTLER VALLEY	8,240	C	100		2	0		340	305
1-52	UKIAH VALLEY									
1-53	SANTA VALLEY	1,950	C	1,250		5	5	5	354	306
1-54	ALEXANDER VALLEY									
1-54.01	ALEXANDER AREA									
1-54.02	CLOVERDALE AREA	4,300	C		300	5		25	330	302
1-55	SANTA ROSA VALLEY									
1-55.01	SANTA ROSA PLAIN	9,000	A	1,500		45		155		
1-55.02	HEALDSBURG AREA	15,000	C	500		5		25	80	500
1-55.03	PENGRA VALLEY	1,600	C			3		25		
1-56	MOSWELL VALLEY	1,500	C	1,200					149	141 - 156
1-57	RUSSIAN BAY AREA	2,400	A	150				5		
1-58	WILSON GROVE FORMATION HIGHLANDS	51,502	C			14		55		
1-60	LOWER RUSSIAN RIVER VALLEY	6,400	C	300				25	170 - 410	
1-61	FORT ROSS TERRACE DEPOSITS	5,400	C	15	25			15	170	230 - 380
1-62	WILSON POINT AREA	500	H							

gpm = gallons per minute
mg/L = milligrams per liter
TDS = total dissolved solids

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San Francisco Bay Hydrologic Region

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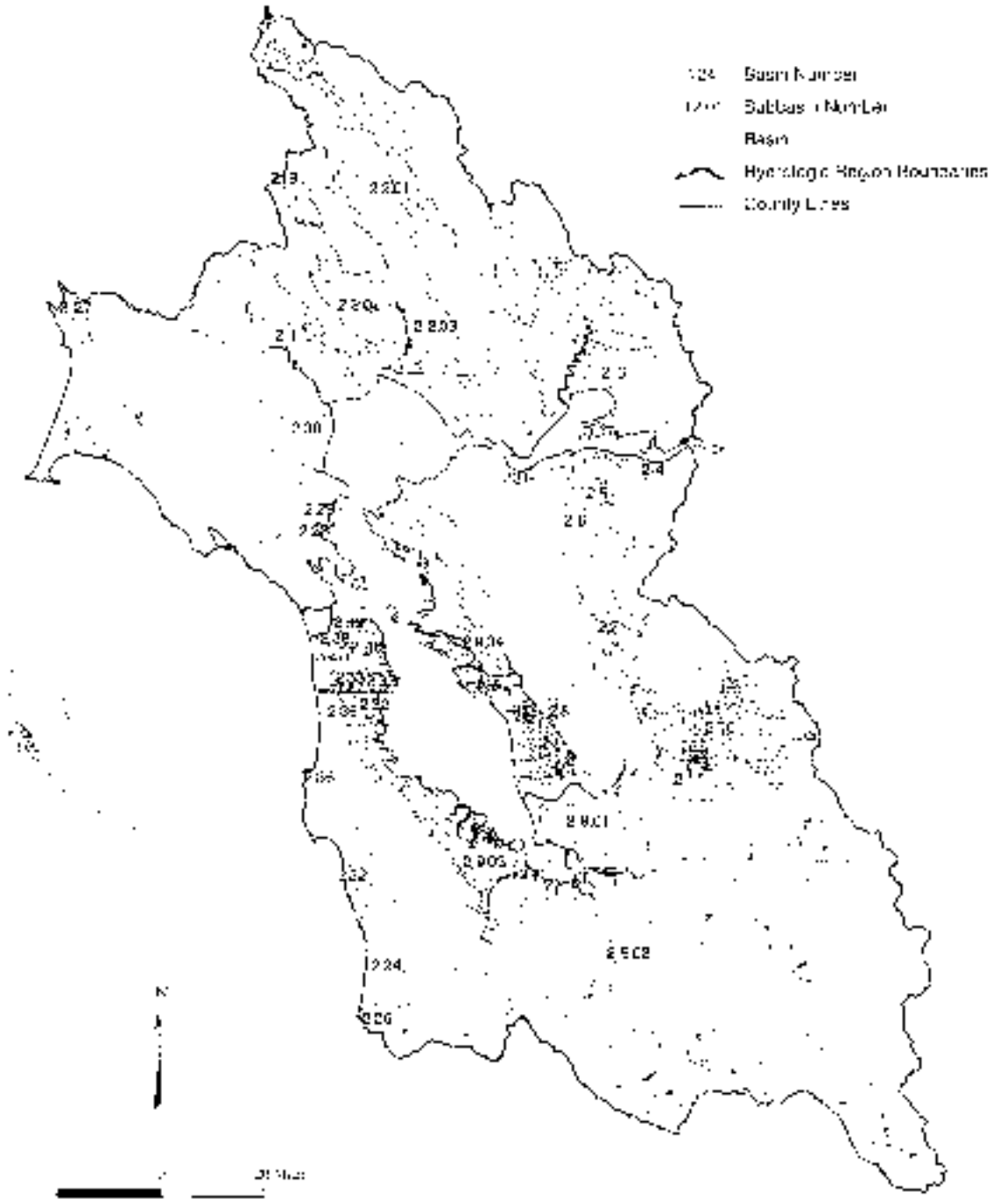

Figure 27 San Francisco Bay Hydrologic Region

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Basins and Subbasins of the San Francisco Bay Hydrologic Region

Basin/subbasin	Basin name
2-1	Petaluma Valley
2-2	Napa-Sonoma Valley
2-2.01	Napa Valley
2-2.02	Sonoma Valley
2-2.03	Napa-Sonoma Lowlands
2-3	Suisun-Fairfield Valley
2-4	Pittsburg Plain
2-5	Clayton Valley
2-6	Ygnacio Valley
2-7	San Ramon Valley
2-8	Castro Valley
2-9	Santa Clara Valley
2-9.01	Niles Cone
2-9.02	Santa Clara
2-9.03	San Mateo Plain
2-9.04	East Bay Plain
2-10	Livermore Valley
2-11	Sunol Valley
2-19	Kenwood Valley
2-22	Half Moon Bay Terrace
2-24	San Gregorio Valley
2-26	Pescadero Valley
2-27	Santa Cruz Area
2-28	Butano Valley
2-29	San Rafael Valley
2-30	Novato Valley
2-31	Arroyo Del Hambre Valley
2-32	Visitacion Valley
2-33	Islais Valley
2-35	Merced Valley
2-36	San Pedro Valley
2-37	South San Francisco
2-38	Colma
2-39	Marin
2-40	Daly Junior Sub - Pedrancini

Description of the Region

The San Francisco Bay HR covers approximately 2.88 million acres (4,500 square miles) and includes all of San Francisco and portions of Marin, Sonoma, Napa, Solano, San Mateo, Santa Clara, Contra Costa, and Alameda counties (Figure 27). The region corresponds to the boundary of RWQCB 2. Significant geographic features include the Santa Clara, Napa, Sonoma, Petaluma, Suisun-Fairfield, and Livermore valleys; the Marin and San Francisco peninsulas; San Francisco, Suisun, and San Pablo bays; and the Santa Cruz Mountains, Diablo Range, Bolinas Ridge, and Coast Mountains of the Coast Range. While being the smallest in size of the 10 HRs, the region has the second largest population in the State at about 5.8 million in 1995 (DWR 1998). Major population centers include the cities of San Francisco, San Jose and Oakland.

Groundwater Development

The region has 28 identified groundwater basins. Two of those, the Napa-Sonoma Valley and Santa Clara Valley groundwater basins, are further divided into three and four subbasins, respectively. The groundwater basins underlie approximately 896,000 acres (1,400 square miles) or about 30 percent of the entire HR.

Despite the tremendous urban development in the region, groundwater use accounts for only about 5 percent (68,000 acre-feet) of the region's estimated average water supply for agricultural and urban uses, and accounts for less than one percent of statewide groundwater uses.

In general, the freshwater-bearing aquifers are relatively thin in the smaller basins and moderately thick in the more heavily utilized basins. The more heavily utilized basins in this region include the Santa Clara Valley, Napa-Sonoma Valley, and Petaluma Valley groundwater basins. In these basins, the municipal and irrigation wells have average depths ranging from about 200 to 500 feet. Well yields in these basins range from less than 50 gallons per minute (gpm) to approximately 3,000 gpm. In the smaller basins, most municipal and irrigation wells have average well depths in the 100- to 200-foot range. Well yields in the smaller and less utilized basins are typically less than 500 gpm.

AR0069753

Land subsidence has been a significant problem in the Santa Clara Valley Groundwater Basin in the past. An extensive annual monitoring program has been set up within the basin to evaluate changes in an effort to maintain land subsidence at less than 0.01 feet per year (SCVWD 2001). Additionally, groundwater recharge projects have been implemented in the Santa Clara Valley to ensure that groundwater will continue to be a viable water supply in the future.

Groundwater Quality

In general, groundwater quality throughout most of the region is suitable for most urban and agricultural uses with only local impairments. The primary constituents of concern are high TDS, nitrate, boron, and organic compounds.

The areas of high TDS (and chloride) concentrations are typically found in the region's groundwater basins that are situated closest to the San Francisco Bay, such as the northern Santa Clara, southern Sonoma, Petaluma, and Napa valleys. Elevated levels of nitrate have been detected in a large percentage of private wells tested within the Coyote Subbasin and Llagas Subbasin of the Gilroy Hollister Valley Groundwater Basin (in the Central Coast HR) located to the south of the Santa Clara Valley (SCVWD 2007). The shallow aquifer zone within the Petaluma Valley also shows persistent nitrate contamination. Groundwater with high TDS, iron, and boron levels is present in the Calistoga area of Napa Valley, and elevated boron levels in other parts of Napa Valley make the water unfit for agricultural uses. Releases of fuel hydrocarbons from leaking underground storage tanks and spills/leaks of organic solvents at industrial sites have caused minor to significant groundwater impacts in many basins throughout the region. Methyl tertiary-butyl ether (MTBE) and chlorinated solvent releases to soil and groundwater continue to be problematic. Environmental oversight for many of these sites is performed either by local city and county enforcement agencies, the RWQCB, the Department of Toxic Substances Control, and/or the U.S. Environmental Protection Agency.

Water Quality in Public Supply Wells

From 1994 through 2006, 485 public supply water wells were sampled in 18 of the 33 basins and subbasins in the San Francisco Bay HR. Analyzed samples indicate that 410 wells, or 85 percent, met the state primary MCLs for drinking water standards. Seventy-five wells, or 15 percent, have constituents that exceed one or more MCL. Figure 28 shows the percentages of each contaminant group that exceeded MCLs in the 75 wells.

Table 16 lists the three most frequently occurring contaminants in each contaminant group and the number of wells in the HR that exceeded the MCL for those contaminants.

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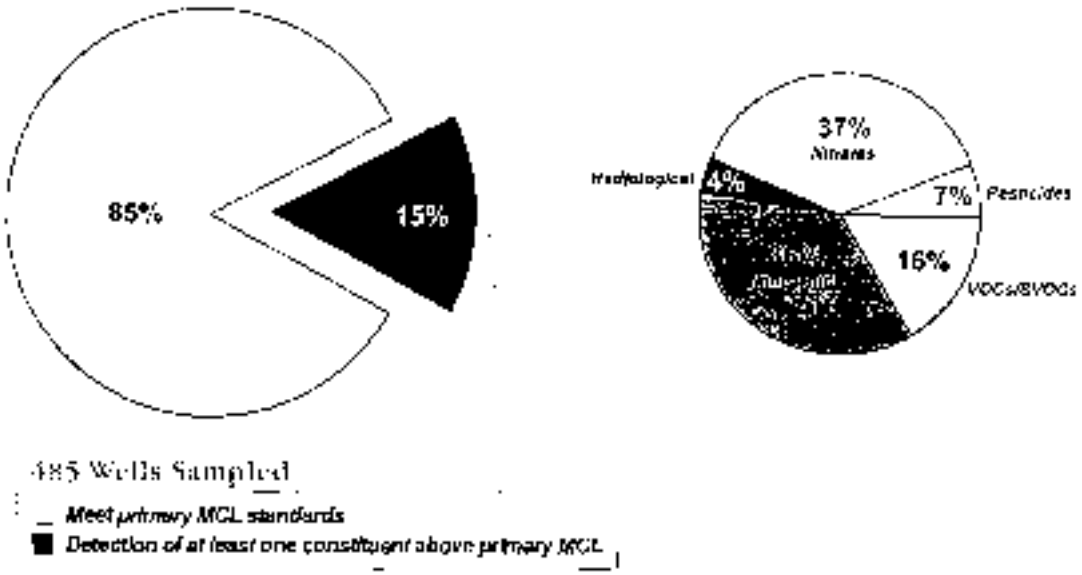

Figure 23 MCL exceedances in public supply wells in the San Francisco Bay Hydrologic Region

Table 16 Most frequently occurring contaminants by contaminant group in the San Francisco Bay Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics	Iron - 37	Manganese - 27	Chloride - 7
Radiological	Gross Alpha - 2	Radium 226 - 1	
Nitrates	Nitrate as NO_3 - 37	Nitrate + Nitrite - 3	Nitrate as N - 2
Pesticides	DCPA - 4	Simazine - 1	
VOCs/SVOCs	PCE - 4	Dichloroethane - 3	TCE - 2 Vinyl Chloride - 2

TCE = Trichloroethylene
PCE = Tetrachloroethylene
VOC = Volatile Organic Compounds
SVOC = Semi-volatile Organic Compounds

AR0069755

Changes from Bulletin 118-80

Since Bulletin 118-80 was published, RWQCB 2 boundary has been modified. This resulted in several basins being reassigned to RWQCB 1. These are listed in Table 17.

Table 17 Modifications since Bulletin 118-80 of groundwater basins in San Francisco Bay Hydrologic Region

Basin name	New number	Old number
Mcdowell Valley	1-56	2-17
Knights Valley	1-58	2-13
Petrta Valley	1-51	2-14
Wilson Valley	1-52	2-15
Sonoi Valley	1-53	2-16
Alexander Valley	1-54	2-17
Santa Rosa Valley	1-55	2-18
Lower Russian River Valley	1-60	2-20
Bodega Bay Area	1-57	2-21

No additional basins were assigned to the San Francisco Bay HR in this revision. However, the Santa Clara Valley Groundwater Basin (2-9) has been subdivided into four subbasins instead of two, and the Napa Sonoma Valley Groundwater Basin is now three subbasins instead of two.

There are several deletions of groundwater basins from Bulletin 118-80. The San Francisco Sand Dune Area (2-34) was deleted when the San Francisco groundwater basins were redefined in a USGS report in the early 1990s. The Napa-Sonoma Volcanic Highlands (2-23) is a volcanic aquifer and was not assigned a basin number in this bulletin. This is considered to be a groundwater source area as discussed in Chapter 6. Bulletin 118-80 identified seven groundwater basins that were stated to differ from 118-75: Sonoma County Basin, Napa County Basin, Santa Clara County Basin, San Mateo Basin, Alameda Bay Plain Basin, Niles Cone Basin, and Livermore Basin. They were created primarily by combining several smaller basins and subbasins within individual counties. This report does not consider these seven as basins. There is no change in numbering because the basins were never assigned a basin number.

AR0069756

Table 18 San Francisco Bay Hydrologic Region groundwater data

Basin Number	Basin Name	Area (sq. mi.)	Groundwater Storage Type	Well Yield (gpm)			Water Chemistry		Use (af/yr)	
				Maximum	Average	Depth	Quality	Title 22	Average	Range
2-1	PETALUMA VALLEY	46,000	C	800		36		24	5,000	50-6,000
2-2	SOUTH SONOMA VALLEY									
2-3	NAPA VALLEY	45,000	A	3,000	1,000	50	Fe	15	55,000	20-100,000
2-4	SONOMA VALLEY	44,000	C	1,150	500	36	Fe	60	9,000	200-20,000
2-5	NAPA-SONOMA LOWLANDS	40,000	C	500	50	0	S	0	1,000	50-1,000
2-6	SUISUN-FAIRFIELD VALLEY	131,000	C	500	200	20	Fe	20	30,000	100-50,000
2-7	PETTEDORO PLAIN	11,000	C							
2-8	CLAYTON VALLEY	12,000	C					48		
2-9	CONCORD VALLEY	15,000	C							
2-10	SAN RAMON VALLEY	7,000	C							
2-11	CASTRO VALLEY	1,800	C							
2-12	SANTA CLARA VALLEY									
2-13	NILES CONE	37,000	A	3,000	2,000	350	Fe	20		
2-14	SANTA CLARA	130,000	C					12	250,000	200-300,000
2-15	SAN MATEO PLAIN	28,000	C					24	45,000	300-450,000
2-16	EAST BAY PLAIN	77,000	A	1,000	UNK	50	Fe	10	90,000	364-120,000
2-17	LIVERMORE VALLEY	61,000	A					30		
2-18	SUISUN VALLEY	15,000	C							
2-19	KENWOOD VALLEY	3,170	C					12		
2-20	HALF MOON BAY TERRACE	9,150	C					9		
2-21	SAN ORTEGA VALLEY	1,030	C							
2-22	PESCADERO VALLEY	4,000	C							
2-23	SAND POINT AREA	1,000	C					6		
2-24	ROSS VALLEY	1,250	C							
2-25	SAN RAFAEL VALLEY	500	C							
2-26	NOVATO VALLEY	78,000	C							
2-27	ARROYO DEL HAMBRE VALLEY	500	C							
2-28	VISITACION VALLEY	800	C							
2-29	OLEMAS VALLEY	1,550	C							
2-30	MERCED VALLEY	6,100	C					10		
2-31	SAN PEDRO VALLEY	850	C							
2-32	SOUTH SAN FRANCISCO	2,150	C							
2-33	TOROS	2,400	C							
2-34	MARINA	220	A							
2-35	DOWNTOWN SAN FRANCISCO	3,000	C							

yield = gallons per minute
depth = feet
UNK = data not available or unknown

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Central Coast Hydrologic Region

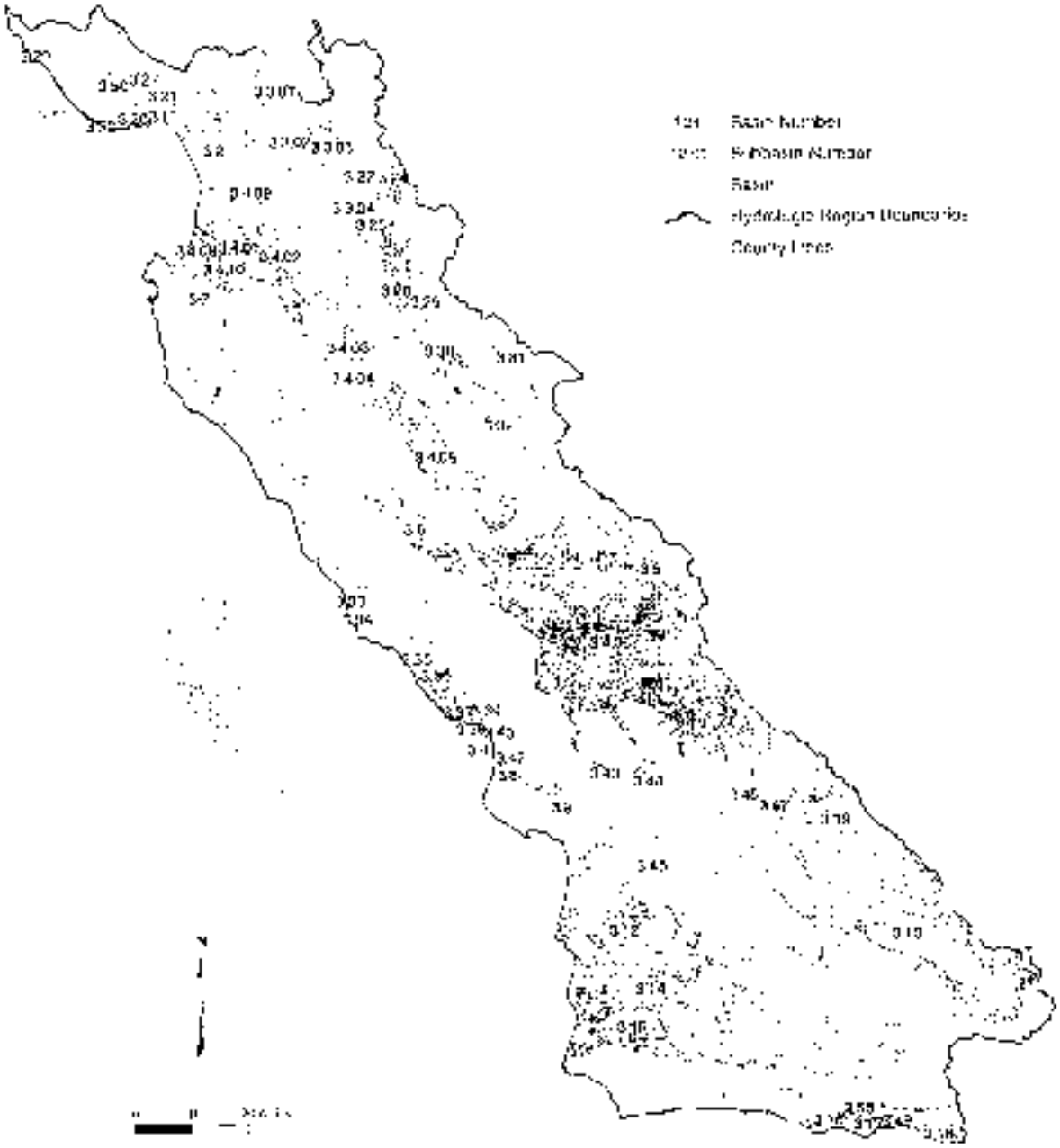

Figure 29 Central Coast Hydrologic Region

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Basins and Subbasins of Central Coast Hydrologic Region

Region/Basin/ subbasin	Basin name
3-1	Scotts Valley
3-2	Pajaro Valley
3-3	Salinas Valley
3-3.01	Llagas Area
3-3.02	Bolsa Area
3-3.03	Hollister Area
3-3.04	San Juan Bautista Area
3-4	Salinas Valley
3-4.01	180-400 Foot Aquifer
3-4.02	East Side Aquifer
3-4.04	Forebay Aquifer
3-4.05	Upper Valley Aquifer
3-4.06	Paso Robles Area
3-4.08	Seca Jo Area
3-4.09	Langley Area
3-4.10	Corral de Tierra Area
3-5	Cholame Valley
3-6	Lockwood Valley
3-7	Carmel Valley
3-8	Los Osos Valley
3-9	San Luis Obispo Valley
3-12	Santa Maria River Valley
3-13	Cuyama Valley
3-14	San Antonio Creek Valley
3-15	Santa Ynez River Valley
3-16	Lompoc
3-17	Santa Barbara
3-18	Carpinteria
3-19	Tularcitos Plain
3-20	Arroyo Nuevo Area
3-21	Santa Cruz Purisima Formation
3-22	Santa Ana Valley
3-23	Upper Santa Ana Valley
3-24	Quien Sabe Valley
3-25	San Luis Valley
3-26	West Santa Cruz Terrace
3-27	Sisquoc Valley
3-28	San Benito River Valley
3-29	Dry Lake Valley
3-30	Winter Water Valley
3-31	Thorndike Valley
3-32	Peach Tree Valley
3-33	San Clemente Valley
3-34	Arroyo de la Cruz Valley

Region/Basin/ subbasin	Basin name
3-35	San Simeon Valley
3-36	Santa Rosa Valley
3-37	Villa Valley
3-38	Cayucos Valley
3-39	Old Valley
3-40	Toro Valley
3-41	Morro Valley
3-42	Chorro Valley
3-43	Los Osos Valley
3-44	Pecho Valley
3-45	Huasna Valley
3-46	Rafael Valley
3-47	Big Spring Area
3-49	Montaño
3-50	Indian Area
3-51	Majors Creek
3-52	Needle Rock Point
3-53	Tembal

AR0069761

Description of the Region

The Central Coast HR covers approximately 7.22 million acres (11,200 square miles) in central California (Figure 29). This HR includes all of Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara counties, most of San Benito County, and parts of San Mateo, Santa Clara, and Ventura counties. Significant geographic features include the Pajaro, Salinas, Carmel, Santa Maria, Santa Ynez, and Cuyama valleys, the coastal plain of Santa Barbara, and the Coast Range. Major drainages in the region include the Salinas, Cuyama, Santa Ynez, Santa Maria, San Antonio, San Lorenzo, San Benito, Pajaro, Nacimiento, Carmel, and Big Sur Rivers.

Population data from the 2000 Census suggest that about 1.4 million people or about 4 percent of the population of the State live in this HR. Major population centers include Santa Barbara, Santa Maria, San Luis Obispo, Gilroy, Hollister, Morgan Hill, Salinas, and Monterey.

The Central Coast HR has 50 delineated groundwater basins. Within this region, the Gilroy-Hollister Valley and Salinas Valley groundwater basins are divided into four and eight subbasins, respectively. Groundwater basins in this HR underlie about 2,290 million acres (3,740 square miles) or about one-third of the HR.

Groundwater Development

Locally, groundwater is an extremely important source of water supply. Within the region, groundwater accounted for 83 percent of the annual supply used for agricultural and urban purposes in 1995. For an average year, groundwater in the region accounts for about 8.4 percent of the statewide groundwater supply and about 1.3 percent of the total state water supply for agricultural and urban needs. In drought years, groundwater in this region is expected to account for about 9.7 percent of the statewide groundwater supply and about 1.9 percent of the total State water supply for agricultural and prison needs (DWR 1998).

Aquifers are varied and range from large extensive alluvial valleys with thick multilayered aquifers and aquifers in small inland valleys and coastal terraces. Several of the larger basins provide a dependable and drought-resistant water supply to coastal cities and farms.

Conjunctive use of surface water and groundwater is a long-standing practice in the region. Several reservoirs including Hernandez, Twitchell, Lake San Antonio, and Lake Nacimiento are operated primarily for the purpose of groundwater recharge. The concept is to maintain streamflow over a longer period than would occur without surface water storage and thus provide for increased recharge of groundwater. Seawater intrusion is a major problem throughout much of the region. In the Salinas Valley Groundwater Basin, seawater intrusion was first documented in the 1930s and has been observed more than 5 miles inland.

Groundwater Quality

Much of the groundwater in the region is characterized by calcium sulfate to calcium sodium bicarbonate sulfate water types because of marine sedimentary rock in the watersheds. Aquifers intruded by seawater are typically characterized by sodium chloride to calcium chloride, and have chloride concentrations greater than 500 mg/L. In several areas, groundwater exceeds the MCL for nitrate.

Water Quality in Public Supply Wells

From 1994 through 2000, 711 public supply water wells were sampled in 38 of the 50 basins and subbasins in the Central Coast HR. Analyzed samples indicate that 587 wells, or 83 percent, met the state primary MCLs for drinking water. One hundred-twenty-four wells, or 17 percent, have constituents that exceed one or more MCL. Figure 30 shows the percentages of each contaminant group that exceeded MCLs in the 124 wells.

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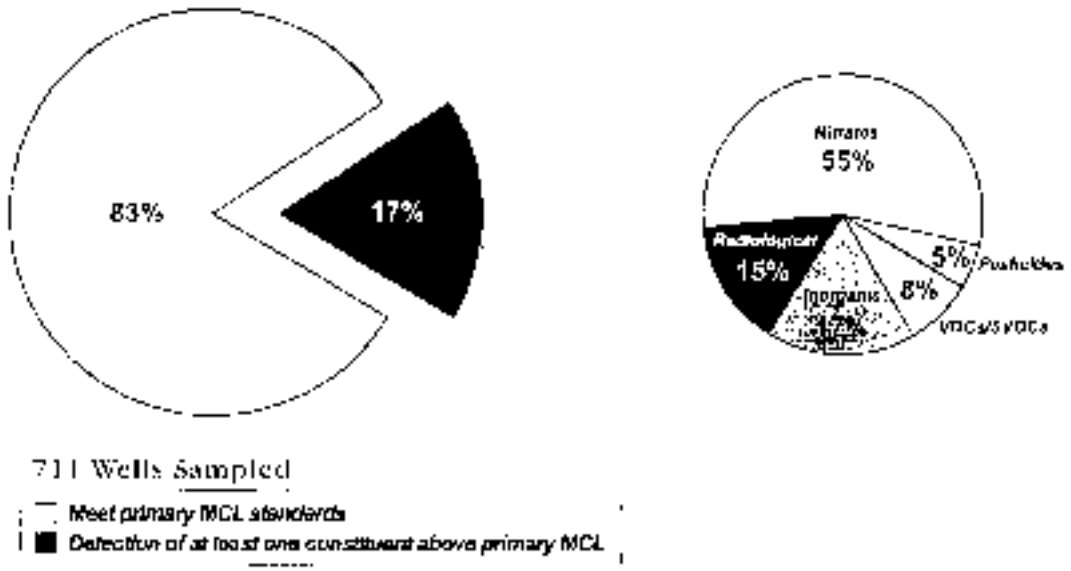

Figure 30 MCL exceedances in public supply wells in the Central Coast Hydrologic Region

Table 19 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for these contaminants.

Table 19 Most frequently occurring contaminants by contaminant group in the Central Coast Hydrologic Region

Contaminant group	Contaminant	# of wells	Contaminant	# of wells	Contaminant	# of
Inorganics – Primary	Arsenic	6	Aluminum	4	Chromium (Total)	4
Inorganics – Secondary	Iron	145	Manganese	135	TDS	11
Radiological	Gross Alpha	15	Radium 226	3	Uranium	3
Nitrates	Nitrate (as NO_3)	59	Nitrate – Nitrite	24		
Pesticides	Heptachlor	4	Di(2-Ethylhexyl)phthalate	2		
VOCs/SVOCs	TCE	3	3 others tied at 2 exceedances			

TCE = Trichloroethylene
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound

AR0069763

Changes from Bulletin 118-80

Four new basins have been defined since Bulletin 118-80. They are Felton Area, Majors Creek, Needle Rock Point, and Foster Groundwater basins. Additionally, new subbasins have been broken out in both the Gilroy-Hollister Valley Groundwater Basin (3-9) and the Salinas Valley Groundwater Basin (3-4) (Table 20)

Table 20 Modifications since Bulletin 118-80 of groundwater basins and subbasins in Central Coast Hydrologic Region

Subbasin name	New number	Old number
Llagas Area	3-3.01	3-3
Bolsa Area	3-3.02	3-3
Hollister Area	3-3.03	3-3
San Juan Bautista Area	3-3.04	3-3
[illegible] Fort Aquifer	3-4.01	3-4
East Side Aquifer	3-4.02	3-4
Upper Forebay Aquifer	3-4.04	3-4
Upper Valley Aquifer	3-4.05	3-4
Pismo Creek Valley Basin	3-12	3-10
Arroyo Grande Creek Basin	3-12	3-11
Cuyama Sand Highlands Basin	3-12 and 3-14	3-18
Felton Area	3-50	
Majors Creek	3-51	
Needle Rock Point	3-52	
Foster	3-53	

Pismo Creek Valley Basin (3-10) and Arroyo Grande Creek Basin (3-11) have been merged into the Santa Maria River Valley Basin (3-12). Cuyama Sand Highlands Basin (3-18) has been merged into the Santa Maria River Valley Basin (3-12) and San Antonio Creek Valley Basin (3-14).

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Table 21 Central Coast Hydrologic Region groundwater data

Basin Number	Basin Name	Area (acres)	Groundwater Storage Type	Well Yield (gpm)		Depth to Water (feet)			Total Depth (feet)	
				Maximum	Average	Spring	Summer	Fall	Average	Range
3-1	SUISUN VALLEY	32,500	C	1,121	600	6	9	10	482	0-1,000
3-2	PAJARO VALLEY	76,800	A	2,000	500	15	15	149	500-650	0-1,500
3-3	CORRALITOS-HOLOHAN VALLEY									
3-3.01	LLAGAS AREA	20,000	C					50		
3-3.02	BOLSA AREA	21,000	A		400	11	11	3		0-1,000
3-3.03	HOLLISTER AREA	32,500	A		400	43	45	24		0-1,000
3-3.04	SAN JUAN VALLEY AREA	74,000	A		100	57	71	41		400-1,000
3-4	SALINAS VALLEY									
3-4.01	180 FOOT AQUIFER	33,200	A			166	176	82	438	200-1,000
3-4.02	EAST SIDE AQUIFER	27,600	A			54	63	63	450	0-1,000
3-4.03	FORT ORD AQUIFER	9,100	A			59	91	72	624	500-1,000
3-4.04	UPPER VALLEY AQUIFER	98,200	A	4,000		86	92	17	445	0-3,000
3-4.05	PASO ROBLES AREA	505,000	A	3,000		57		58	614	0-3,000
3-4.06	SAN ELIJO AREA	25,000	B	3,500	1,000		2	24	401	200-800
3-4.07	LONG VALLEY AREA	19,400	B	1,000	400		1	32		0-1,000
3-4.08	CORRAL DE TIERRA AREA	22,500	C	900	450		1	20		0-1,000
3-5	CHOLAME VALLEY	40,800	C	1,000	1,000	1		9		
3-6	LOCKWOOD VALLEY	98,000	C	1,500	100			9		
3-7	CARRIZO VALLEY	5,100	C	1,000	600	30	23	17	500-600	200-1,000
3-8	TWITCHELL VALLEY	5,000	A	700	300			11	554	0-1,000
3-9	SANTA YSABEL VALLEY	12,000	A	600	200			13	585	0-1,000
3-12	SANTA MARIA RIVER VALLEY	154,000	A	2,500	1,000	280	18	104	598	0-2,000
3-13	CUYAMA VALLEY	147,000	A	4,400	1,100	15	5	5		0-3,000
3-14	SAN ANTONIO CREEK VALLEY	41,800	A		400	50		9	415	0-1,000
3-15	SANTA YNEZ RIVER VALLEY	70,000	A	1,500	750	163	21	78	707	400-700
3-16	GOLETA	5,200	A	600	500	19	1	11	555	0-1,000
3-17	SANTA BARBARA	6,100	A	600	500	35	36	5		0-1,000
3-18	CARPINTERIA	8,120	A	900	800	41	41	4	572	0-1,000
3-19	CARRIZO PLAIN	153,000	C	1,000	500					
3-20	SAN LUIS OBISPO AREA	20,000	C							
3-21	SANTA CRUZ PURISIMA FORMATION	40,000	C	200	50			59	444	400-500
3-22	SANTA ANA VALLEY	9,000	C	700						
3-23	UPPER SANTA ANA VALLEY	1,400	C							
3-24	QUIEN SABE VALLEY	4,700	C	1,200	50					
3-25	TRES PINOS VALLEY	3,900	C	1,225				3		
3-26	WEST SANTA CRUZ TERRACE	3,800	C	500	200			3	681	500-1,000
3-27	SCOTTS VALLEY	900	C	400	100-400	26	2	2	561	100-700
3-28	SAN BENITO RIVER VALLEY	31,200	C	2,000				3		
3-29	DRY LAKE VALLEY	1,400	C							
3-30	BITTER WATER VALLEY	32,200	C							
3-31	HERNANDEZ VALLEY	3,800	C	1,000	50					

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Table 21 Central Coast Hydrologic Region groundwater data (continued)

Basin Subbasin	Basin Name	Area (square miles)	Groundwater Budget Type	Well Yield (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
3-37	PEASTER VALLEY	6,700	C	117	84					
3-38	SAN CASPORO VALLEY	300	C							312-356
3-39	ARROYO DE LA CRUZ VALLEY	750	C							210-288
3-40	SAN SIMEON VALLEY	920	A	1,000	1,000				410	400-2,200
3-41	SANTA ROSA VALLEY	4,650	A	775	400					968-2,833
3-42	VILLA VALLEY	900	C							260-1,621
3-43	CAYUCOS VALLEY	530	C	166	100					415-916
3-44	OSO VALLEY	750	C	335	210					346-1,382
3-45	TORO VALLEY	550	C	450	0					458-702
3-46	MORRO VALLEY	1,300	C	445	300			2	2150	469-1,000
3-47	CHORRO VALLEY	2,300	C	200	200			3	656	60-2,505
3-48	RINCONADA VALLEY	2,150	C	0	0					
3-49	POZO VALLEY	6,440	C	210	160					287-476
3-50	HUASNA VALLEY	4,000	C	0	0					
3-51	RAFAEL VALLEY	2,900	C	0	0					
3-52	BIG SPRING AREA	2,130	C	0	0					
3-53	SANTA MARIA	6,230	A	1,000	750	28	2	4	770	600-1,166
3-54	HILTON AREA	50	C	825	766	6				69-860
3-55	MAJORS CREEK	3.4	C	50	28					
3-56	NIPOMO-MESA	450	C	450	320					
3-57	FOOTHILL	1,130	A					2	525	554-1,128

gpm = gallons per minute
mg/L = milligrams per liter
TDS = Total dissolved solids

AR0069766

South Coast Hydrologic Region

AR0069767

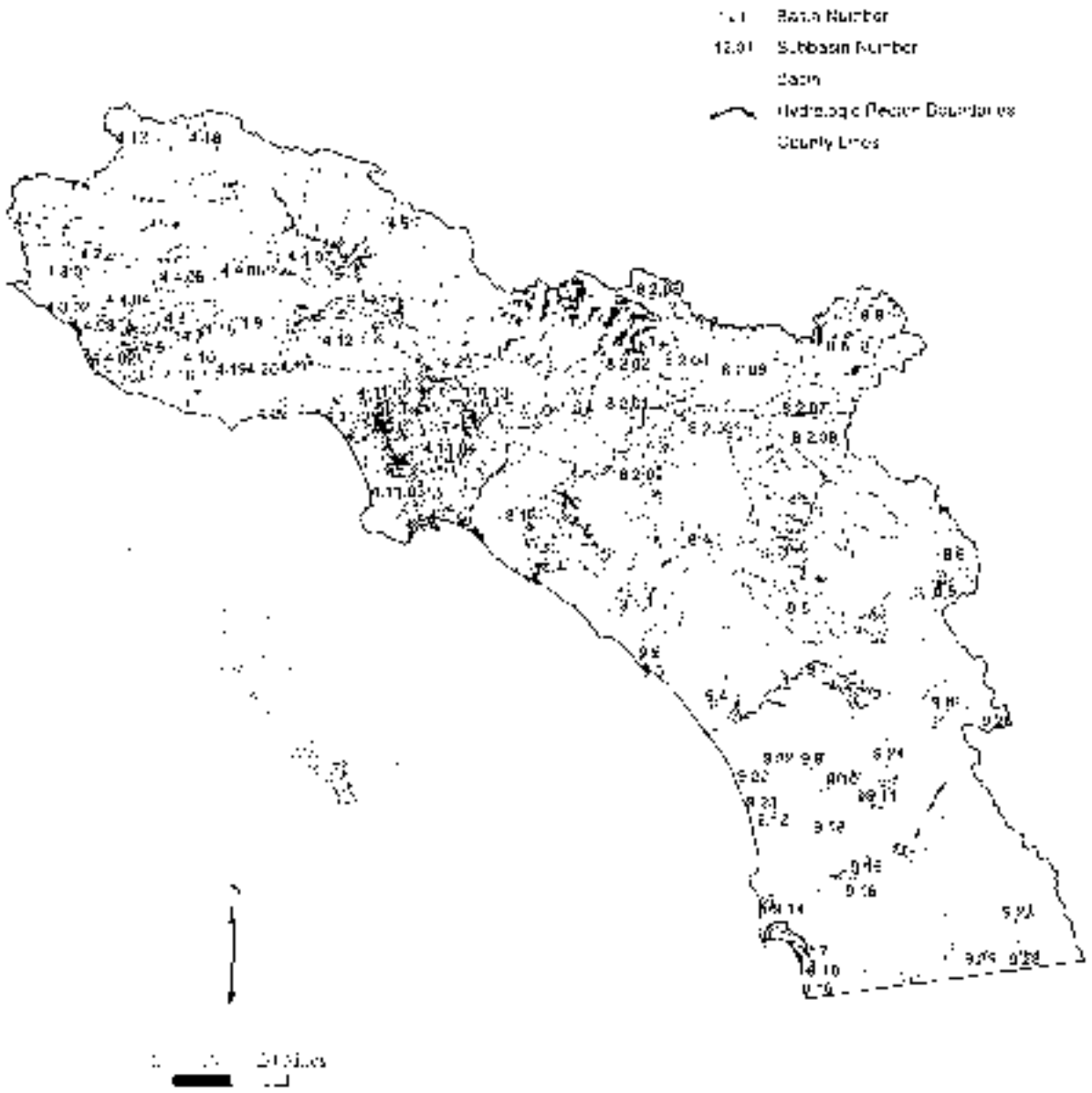

Figure 31 South Coast Hydrologic Region

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Basins and Subbasins of the South Coast Hydrologic Region

Basin/subbasin	Basin name
4-1	Upper Ojai Valley
4-2	Ojai Valley
4-3	Ventura River Valley
4-3.01	Upper Ventura River
4-3.02	Lower Ventura River
4-4	Santa Clara River Valley
4-4.01	Upper
4-4.02	Middle
4-4.03	Santa Paula
4-4.04	Fillmore
4-4.05	Piru
4-4.06	Santa Clara River Valley, East
4-5	Acton Valley
4-6	Pleasant Valley
4-7	Arroyo Santa Rosa Valley
4-8	Las Posas Valley
4-9	Simi Valley
4-10	Conejo Valley
4-11	Coastal Plain of Los Angeles
4-11.01	Santa Monica
4-11.02	Hollywood
4-11.03	West Coast
4-11.04	Central
4-12	San Fernando Valley
4-13	San Gabriel Valley
4-15	Puente-Repetto
4-16	Hidden Valley
4-17	Lockwood Valley
4-18	Antelope Valley
4-19	Thousand Oaks Area
4-20	Russell Valley
4-22	Malibu Valley
4-23	Raymond
8-1	Coastal Plain of Orange County
8-2	Upper Santa Ana Valley
8-2.01	Chino
8-2.02	Cucamonga
8-2.03	Riverside-Arlington
8-2.04	Rialto-Colton
8-2.05	Colton
8-2.06	Bunker Hill
8-2.07	Yucaipa
8-2.08	San Timoteo
8-2.09	Temescal

Basin/subbasin	Basin name
8-4	Elsinore
8-5	San Jacinto
8-6	Hemet Lake Valley
8-7	Big Meadows Valley
8-8	Seven Oaks Valley
8-9	Bear Valley
9-1	San Juan Valley
9-2	San Mateo Valley
9-3	San Onofre Valley
9-4	Santa Margarita Valley
9-5	[illegible] Valley
9-6	Cahuilla Valley
9-7	San Diego Bay Valley
9-8	Warner Valley
9-9	Escondido Valley
9-10	San Pasqual Valley
9-11	Santa Maria Valley
9-12	San Dieguito Creek
9-13	Poway Valley
9-14	Mission Valley
9-15	San Diego River Valley
9-16	El Cajon Valley
9-17	Sweetwater Valley
9-18	Otay Valley
9-19	Tijuana Basin
9-22	Bonsall-Lagoon Valley
9-23	San Luis Rey Valley
9-24	Pamo Valley
9-25	Ramona Town Area
9-27	Cottonwood Valley
9-28	Campo Valley
9-29	Potrero Valley
9-32	San Marcos Area

AR0069769

Description of the Region

The South Coast HR covers approximately 6.78 million acres (10,600 square miles) of the southern California watershed that drains to the Pacific Ocean (Figure 3-1). The HR is bounded on the west by the Pacific Ocean and the watershed divide near the Ventura-Santa Barbara County line. The northern boundary corresponds to the crest of the Transverse Ranges through the San Gabriel and San Bernardino mountains. The eastern boundary lies along the crest of the San Jacinto Mountains and low-lying hills of the Peninsular Range that form a drainage boundary with the Colorado River HR. The southern boundary is the international boundary with the Republic of Mexico. Significant geographic features include the coastal plain, the central Transverse Ranges, the Peninsular Ranges, and the San Fernando, San Gabriel, Santa Ana River, and Santa Clara River valleys.

The South Coast HR includes all of Orange County, most of San Diego and Los Angeles Counties, parts of Riverside, San Bernardino, and Ventura counties, and a small amount of Kern and Santa Barbara Counties. This HR is divided into Los Angeles, Santa Ana and San Diego subregions, RWQCBs 4, 8, and 9 respectively. Groundwater basins are numbered according to these subregions. Basin numbers in the Los Angeles subregion are preceded by a 4, in Santa Ana by an 8, and in San Diego by a 9. The Los Angeles subregion contains the Ventura, Santa Clara, Los Angeles, and San Gabriel River drainages, Santa Ana encompasses the Santa Ana River drainage, and San Diego includes the Santa Maria River, San Luis Rey River, and the San Diego River and other drainage systems.

According to 2000 census data, about 17 million people live within the boundaries of the South Coast HR, approximately 50 percent of the population of California. Because this HR amounts to only about 7 percent of the surface area of the State, this has the highest population density of any HR in California (DWR 1998). Major population centers include the metropolitan areas surrounding Ventura, Los Angeles, San Diego, San Bernardino, and Riverside.

The South Coast HR has 56 delineated groundwater basins. Twenty-one basins are in subregion 4 (Los Angeles), eight basins in subregion 8 (Santa Ana), and 27 basins in subregion 9 (San Diego).

The Los Angeles subregion overlies 21 groundwater basins and encompasses most of Ventura and Los Angeles counties. Within this subregion, the Ventura River Valley, Santa Clara River Valley, and Coastal Plain of Los Angeles basins are divided into subbasins. The basins in the Los Angeles subregion underlie 1,01 million acres (1,580 square miles) or about 40 percent of the total surface area of the subregion.

The Santa Ana subregion overlies eight groundwater basins and encompasses most of Orange County and parts of Los Angeles, San Bernardino, and Riverside counties. The Upper Santa Ana Valley Groundwater Basin is divided into nine subbasins. Groundwater basins underlie 979,000 acres (1,520 square miles) or about 34 percent of the Santa Ana subregion.

The San Diego subregion overlies 27 groundwater basins, encompasses most of San Diego County, and includes parts of Orange and Riverside counties. Groundwater basins underlie about 277,000 acres (433 square miles) or about 12 percent of the surface of the San Diego subregion.

Overall, groundwater basins underlie about 2.27 million acres (3,530 square miles) or about 33 percent of the South Coast HR.

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Groundwater Development

Groundwater has been used in the South Coast HR for well over 100 years. High demand and use of groundwater in Southern California has given rise to many disputes over management and pumping rights, with the resolution of most cases playing a large role in the establishment and clarification of water rights law in California. Raymond Groundwater Basin, located in this HR, was the first adjudicated basin in the state. Of the 16 adjudicated basins in California, 11 are in the South Coast HR. Groundwater provides about 23 percent of water demand in normal years and about 29 percent in drought years (DWR 1998).

Groundwater is found in unconfined alluvial aquifers in most of the basins of the San Diego subregion and the inland basins of the Santa Ana and Los Angeles subregions. In some larger basins, typified by those underlying the coastal plain, groundwater occurs in multiple aquifers separated by aquitards that create confined groundwater conditions. Basins range in depth from tens or hundreds of feet in smaller basins, to thousands of feet in larger basins. The thickness of aquifers varies from tens to hundreds of feet. Well yields vary in this HR depending on aquifer characteristics and well location, size, and use. Some aquifers are capable of yielding thousands of gallons per minute to municipal wells.

Conjunctive Use

Conjunctive use of surface water and groundwater is a long-standing practice in the region. At present, much of the potable water used in Southern California is imported from the Colorado River and from sources in the eastern Sierra and Northern California. Several reservoirs are operated primarily for the purpose of storing surface water for domestic and irrigation use, but groundwater basins are also recharged from the outflow of some reservoirs. The concept is to maintain streamflow over a longer period of time than would occur without regulated flow and thus provide for increased recharge of groundwater basins. Most of the larger basins in this HR are highly managed, with many conjunctive use projects being developed to optimize water supply.

Coastal basins in this HR are prone to intrusion of seawater. Seawater intrusion barriers are maintained along the Los Angeles and Orange County sections of the coastal plain. In Orange County, recycled water is injected into the ground to form a mound of groundwater between the coast and the main groundwater basin. In Los Angeles County, imported and recycled water is injected to maintain a seawater intrusion barrier.

Groundwater Quality

Groundwater in basins of the Los Angeles subregion is mainly calcium sulfate and calcium bicarbonate in character. Nitrate content is elevated in some parts of the subregion. Volatile organic compounds (VOCs) have created groundwater impairments in some of the industrialized portions of the region. The San Gabriel Valley and San Fernando Valley groundwater basins both have multiple sites of contamination from VOCs. The main constituents in the contamination plumes are trichloroethylene (TCE) and tetrachloroethylene (PCE). Some of the locations have been declared federal Superfund sites. Contamination plumes containing high concentrations of TCE and PCE also occur in the Bunker Hill Subbasin of the Upper Santa Ana Valley Groundwater Basin. Some of these plumes are also designated as Superfund sites. Perchlorate is emerging as an important contaminant in several areas in the South Coast HR.

Groundwater in basins of the Santa Ana subregion is primarily calcium and sodium bicarbonate in character. Local impairments from excess nitrate or VOCs have been recognized. Groundwater and surface water in the Chino Subbasin of the Santa Ana River Valley Groundwater Basin have elevated nitrate concentrations, partly derived from a large dairy industry in that area. In Orange County, water from the Santa Ana River provides a large part of the groundwater replenishment. Wetlands maintained along the Santa Ana River near the boundary of the Upper Santa Ana River and Orange County Groundwater Basins provide effective removal of nitrate from surface water, while maintaining critical habitat for endangered species.

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Groundwater in basins of the San Diego subregion has mainly calcium and sodium cations and bicarbonate and sulfate anions. Local impairments by nitrate, sulfate, and TDS are found. Camp Pendleton Marine Base, in the northwestern part of this subregion, is on the EPA National Priorities List for soil and groundwater contamination by many constituents.

Water Quality in Public Supply Wells

From 1998 through 2000, 2,342 public supply water wells were sampled in 47 of the 73 basins and subbasins in the South Coast HR. Analyzed samples indicate that 1,360 wells, or 58 percent, met the state primary MCLs for drinking water. Nine-hundred-eighty-two wells, or 42 percent, have constituents that exceed one or more MCL. Figure 32 shows the percentages of each contaminant group that exceeded MCLs in the 982 wells.

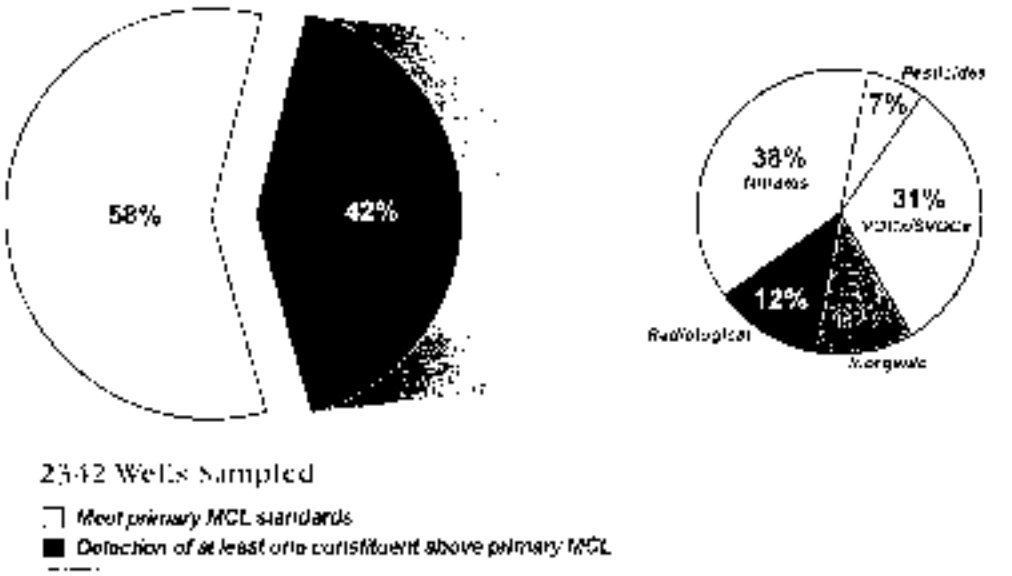

Figure 32 MCL exceedances in public supply wells in the South Coast Hydrologic Region

Table 22 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Changes from Bulletin 118-80

Several modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report (Table 23). The Cajalco Valley (8-31), Jurupa Valley (9-20), Las Pulgas Valley (9-21), Pine Valley (9-26), and Tecate Valley (9-30) Groundwater Basins have been deleted in this report because they have thin deposits of alluvium and well completion reports indicate that groundwater production is from underlying fractured bedrock. The Cuyamaca-Laguna Mountains Area (8-32) is a mountainous area and was not assigned a basin number in this bulletin. This is considered to be groundwater source area as discussed in Chapter 6.

AR0069772

Table 22 Most frequently occurring contaminants by contaminant group in the South Coast Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics - Primary	Fluoride - 56	Thallium - 15	Arsenic - 12
Inorganics - Secondary	Iron - 337	Manganese - 335	TDS - 56
Radiological	Gross Alpha - 204	Uranium - 90	Radium 226 + Radium 228 - 7
Nitrates	Nitrate (as NO3) - 564	Nitrate + Nitrite - 179	Nitrate Nitrogen (NO3-N) - 4
Pesticides	DBCP - 61	Di(2-ethylhexyl)phthalate - 5	Heptachlor - 2 2,3,8 - 2
VOCs/SVOCs	TCE - 196	PCE - 152	1,2-Dichloroethane - 43

DBCP = Dibromochloropropane
EDB = Ethylene Dibromide
VOCs = Volatile Organic Compounds
SVOCs = Semi-volatile Organic Compounds

The Ventura River Valley (4-3), Santa Clara River Valley (4-4), Coastal Plain of Los Angeles (4-11), and Upper Santa Ana Valley (8-2) Groundwater Basins have been divided into subbasins in this report. The extent of the San Jacinto Groundwater Basin (8-5) has been decreased because completion of Diamond Valley Reservoir has inundated the valley. Paloma Valley has been removed because well logs indicate groundwater production is solely from fractured bedrock. The Rayanond Groundwater Basin (4-23) is presented as an individual basin instead of being incorporated into the San Gabriel Valley Groundwater Basin (4-13) because it is bounded by physical barriers and has been managed as a separate and individual groundwater basin for many decades. In Bulletin 118-75, groundwater basins in two different subregions were designated the Upper Santa Ana Valley Groundwater Basin (4-14 and 8-2). To alleviate this confusion, basin 4-14 has been divided, with parts of the basin incorporated into the neighboring San Gabriel Valley Groundwater Basin (4-13) and the Chino subbasin of the Upper Santa Ana Valley Groundwater Basin (8-2.01). The San Marcos Area Groundwater Basin (9-32) in central San Diego County is presented as a new basin in this report.

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Table 23 Modifications since Bulletin 118-80 of groundwater basins and subbasins in South Coast Hydrologic Region

Basin/subbasin name	Number	Old number
Upper Ventura River	4-3.01	4-3
Lower Ventura River	4-3.02	4-3
Oxnard	4-4.02	4-4
Mound	4-4.03	4-4
Santa Paula	4-4.04	4-4
Fillmore	4-4.05	4-4
Piru	4-4.06	4-4
Santa Clara River Valley East	4-4.07	4-4
Santa Monica	4-11.01	4-11
Hollywood	4-11.02	4-11
West Coast	4-11.03	4-11
Central	4-11.04	4-11
Upper Santa Ana Valley	Incorporated into 8-2.01a and 8-13	8-13
Cherry-Hemet Basin Valley	deleted	8-21
Raymond	8-23	8-13
Chino	8-2.01	8-2
Cucamonga	8-2.02	8-2
Riverside-Arlington	8-2.03	8-2
Rialto-Colton	8-2.04	8-2
Chino	8-2.05	8-2
Bunker Hill	8-2.06	8-2
Yucaipa	8-2.07	8-2
San Timoteo	8-2.08	8-2
Temescal	8-2.09	8-2
Cayuga Valley	deleted	8-1
Lytle Basin	8-19	
Bunker Valley	deleted	8-20
Las Posas Valley	deleted	8-21
Bolsa-Mesa Lagoon Valley	8-23	
San Juan Valley	8-24	
Perris Valley	8-25	
Rancho Santa Ana Area	8-26	
Pine Valley	deleted	8-29
Cottonwood Valley	8-27	
Campo Valley	8-28	
Potrero Valley	8-29	
Jacumba Valley	deleted	8-30
San Marcos Area	8-31	Not previously identified

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Table 24 South Coast Hydrologic Region groundwater data

Basin Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Active Monitoring			TDS (mg/L)	
				Max—mum	Average	Levels	Quality	Table 27	Average	Range
4-1	UPPER OJAI VALLEY	7,800	A	700	50	1		1	900	550–1,350
4-2	OJAI VALLEY	8,830	A	1,400	500	24	-	22	940	490–1,140
4-3	VENTURA RIVER VALLEY									
4-3.01	UPPER VENTURA RIVER	7,110	C		600	17		18	800	500–1,250
4-3.02	LOWER VENTURA RIVER	5,560	A		150	-	-	2	-	460–4,000
4-4	SANTA CLARA RIVER VALLEY									
4-4.01	OXNARD	58,000	A	1,000		127	125	69	1,020	160–1,800
4-4.02	MOUND	14,400	A	-	700	11	11	4	1,944	1,440–2,448
4-4.03	SANTA PAULA	2,560	A	-	700	60	36	16	1,490	470–3,610
4-4.04	FILLMORE	20,460	A	2,000	700	53	-	16	1,460	800–2,700
4-4.05	PIRU	8,960	A	-	800	19	-	5	1,800	600–3,100
4-5	SANTA CLARA RIVER VALLEY EAST	60,200	C					12		
4-6	ACTON VALLEY	8,350	A	1,000	150	-		2		
4-7	PLEASANT VALLEY	2,600	A	-	1,000	9	-	12	1,170	930–1,400
4-8	ARROYO SANTA ROSA VALLEY	5,310	A	200	450	6	-	5	660	620–700
4-8	LAS POSAS VALLEY	17,200	A	750				24	1,120	370–2,050
4-9	SIMI VALLEY	12,160	A	-	350	13	-	1		1,589
4-10	CONEJO VALLEY	27,560	A	1,000	160	-	-	5	1,130	550–2,064
4-11	COASTAL PLAIN OF LOS ANGELES									
4-11.01	SANTA MONICA	37,200	C	1,000				12	950	720–1,150
4-11.02	HOLLYWOOD	10,500	A			4	-	1		520
4-11.03	WEST COAST	9,300	A	1,500	-	67	58	33	1,500	-
4-11.04	CENTRAL	177,000	A	11,000	1,250	307	64	294	1,150	200–3,900
4-12	SAN FERNANDO VALLEY	140,000	A	3,250	1,020	1,098	2,085	126	1,250	170–2,150
4-13	SAN GABRIEL VALLEY	91,000	A	1,450	1,000	67	396	259	1,100	490–4,268
4-15	HERRERA BAJADA	4,240	A	1,200	150	1	1	-	-	670–930
4-16	HIDDEN VALLEY	2,150	C	-	-		-	1	1,450	280–2,700
4-17	THOUSAND OAKS VALLEY	21,500	A	350	75	-	-	1	-	-
4-18	LANGLEY VALLEY	2,020	C	-	50				1,350	
4-19	THOUSAND OAKS AREA	5,120	C	-	40	2	-		1,310	1,000–2,300
4-20	RUSSELL VALLEY	2,100	A	-	75	-	-	-	-	-
4-21	MALIBU VALLEY	910	C	1,000	1,000	-		-	-	
4-22	RAYMOND	26,200	A	3,620	1,850	28		9	1,150	138–780
8-1	COASTAL PLAIN OF ORANGE COUNTY	215,000	A	3,500	2,500	521	171	346	1,175	350–6,000
8-2	UPPER SANTA ANA VALLEY									
8-2.01	CHINO	154,000	A	1,500	1,000	12	5	15	880	200–600
8-2.02	CUCAMONGA	9,540	C	1,200	2,115	1	1	21		
8-2.03	RIVERSIDE ARLINGTON	58,600	A	-	-	41	8	45	-	320–750
8-2.04	RIALTO-COLTON	30,190	A	3,000	540	50	5	11	527	
8-2.05	CANON	23,200	C	200	60	-	-	3		
8-2.06	SUNNYSLOPE	30,000	A	2,000	1,247	368	196	264	-	150–550
8-2.07	YUCAIPA	25,600	A	1,800	200	15	2	15	334	-

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Table 24 South Coast Hydrologic Region groundwater data (continued)

Basin Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yield (gpm)		Active Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Total #	Average	Range
8-7.06	SAN TIMOTEO	23,100	A	-	-	67	12	26	-	-
8-7.08	TEMESCAL	23,500	C	-	-	3	2	27	753	470-950
	BLOSSOM	25,700	C	5,410	-	-	1	18	-	-
8-8	SAN JACINTO	165,000	C	-	-	70	15	56	693	165-3,080
8-9	HEMET LAKE VALLEY	16,710	S	820	98	-	-	9	-	-
8-10	HIDDEN MEADOWS VALLEY	14,200	C	1,07	94	-	-	8	-	-
8-11	SEVEN OAKS VALLEY	4,630	S	-	-	-	-	1	-	-
8-12	PERRIS VALLEY	54,600	A	1,000	800	37	27	62	-	-
8-13	SAN JUAN VALLEY	16,700	C	1,001	-	-	-	8	769	450-2,850
8-14	SAN MATEO VALLEY	2,990	A	-	-	-	-	4	586	490-770
8-15	SAN ONOFRE VALLEY	1,540	A	-	-	-	-	2	-	900-1,500
8-16	SANTA MARGARITA VALLEY	6,26	A	1,981	-	4	-	-	-	157-3,010
8-17	TEMECULA VALLEY	87,500	C	1,250	-	140	-	67	476	270-1,000
8-18	COLTON VALLEY	18,700	C	580	-	3	-	1	-	310-690
8-19	SAN LUIS REY VALLEY	57,000	C	2,041	50	-	-	28	1,154	310-3,950
8-20	WARNER VALLEY	52,000	C	1,200	500	-	-	2	-	200
8-21	ESCONDIDO VALLEY	2,890	C	190	50	-	-	1	-	290-5,000
8-22	SAN PASQUAL VALLEY	6,540	C	1,020	600	-	-	2	-	500-1,550
8-23	SANTA YSABEL VALLEY	13,310	A	500	30	-	-	2	1,060	320-1,060
8-24	SAN DIEGUITO CREEK	5,560	A	1,800	200	-	-	-	-	2,200
8-25	POWAY VALLEY	2,470	C	200	150	-	-	1	-	610-1,300
8-26	MISSION VALLEY	2,850	C	-	600	-	-	-	-	-
8-27	SAN DIEGO RIVER VALLEY	9,830	C	2,071	-	-	-	2	-	260-2,870
8-28	EL CAJON VALLEY	7,160	C	910	50	-	-	3 540	-	-
8-29	SWEETWATER VALLEY	5,920	S	1,561	500	-	2	9	1,174	360-5,070
8-30	OTAY VALLEY	6,830	C	1,171	182	-	-	-	-	980-3,080
8-31	TIJUANA BASIN	7,410	A	2,000	500	-	-	-	-	380-3,450
8-32	RATTLESNAKE CANYON VALLEY	741	C	-	-	-	-	-	1,240	770-2,350
8-33	SAN CLEMENTE VALLEY	585	C	1,800	-	-	-	-	-	1,170-3,980
8-34	PAMO VALLEY	1,900	C	-	-	-	-	-	566	270-1,450
8-35	RANCHITA TOWN AREA	3,150	C	125	25	-	-	-	-	380-720
8-36	COTTONWOOD VALLEY	3,850	C	-	-	-	-	1	-	-
8-37	CAMPO VALLEY	3,551	C	-	40	-	-	2	-	800
8-38	POTRERO VALLEY	2,620	C	-	-	-	-	2	-	-
8-39	SAN MARCOS VALLEY	2,130	C	60	-	-	-	-	-	300-700

gpm = gallons per minute
mg/L = milligrams per liter
TDS = total dissolved solids

AR0069776

Sacramento River Hydrologic Region

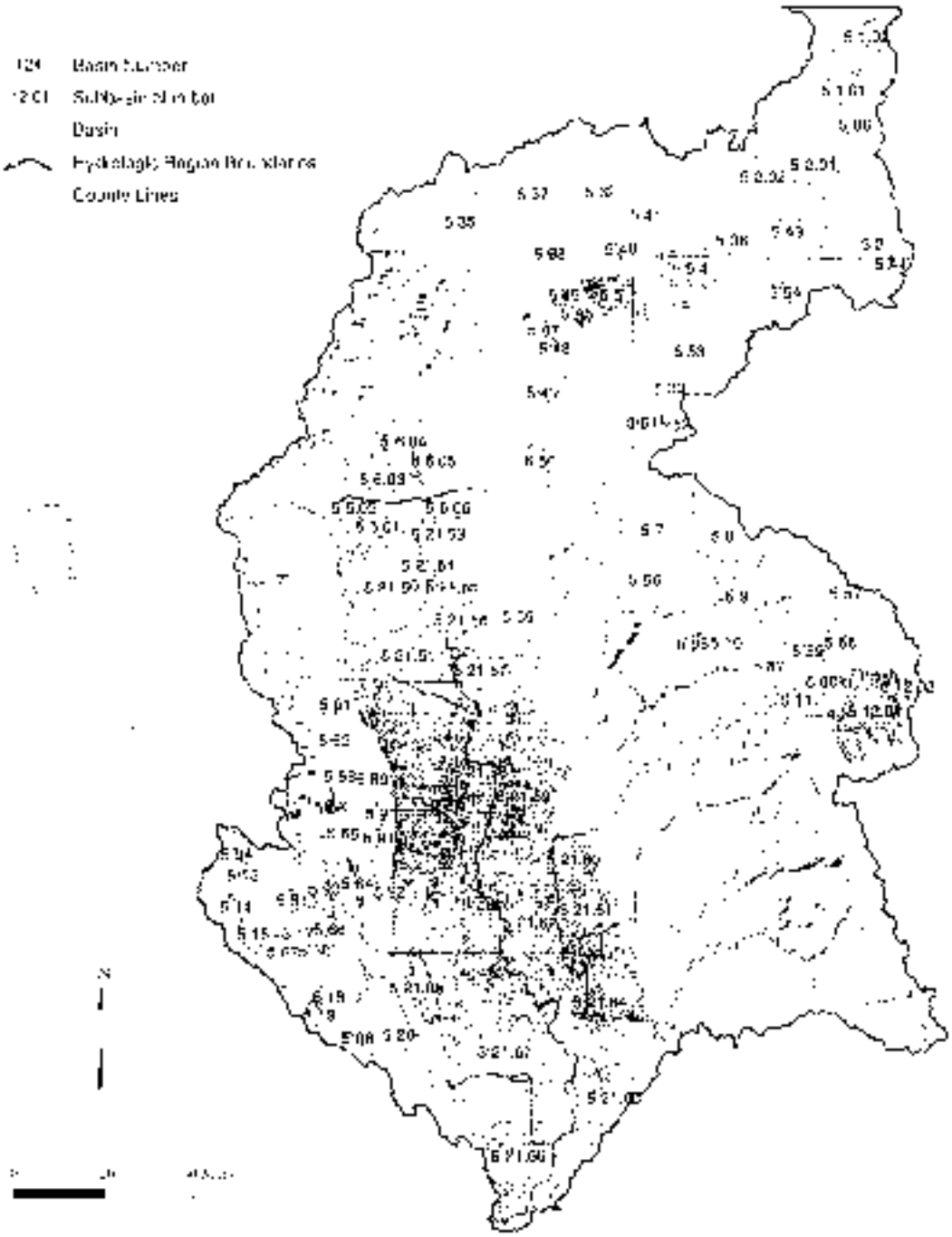

Figure 33 Sacramento River Hydrologic Region

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Basins and Subbasins of the Sacramento River Hydrologic Region

Basin/subbasins	Basin name
5-1	Goose Lake Valley
5-1.01	Lower Goose Lake Valley
5-1.02	Davis Lake Valley
5-2	Alturas Area
5-2.01	North Fork Pit River
5-2.02	Warm Springs Valley
5-3	Jess Valley
5-4	Big Valley
5-5	Dall River Valley
5-6	Redding Area
5-6.01	Anderson
5-6.02	Bonnyview
5-6.04	Cottonwood
5-6.05	Millville
5-6.06	South Battle Creek
5-7	Lake Almanor Valley
5-8	Mountain Meadows Valley
5-9	Indian Valley
5-10	American Valley
5-11	Madesia Valley
5-12	Sierra Valley
5-12.01	Sierra Valley
5-12.02	Chilcoot
5-13	Upper Lake Valley
5-14	Scotts Valley
5-15	Big Valley
5-16	Clear Valley
5-17	Burns Valley
5-18	Coyote Valley
5-19	Collayomi Valley
5-20	Berryessa Valley
5-21	Sacramento Valley
5-21.50	Red Bluff
5-21.51	Corning
5-21.52	Colusa
5-21.53	Dead
5-21.54	Antelope
5-21.55	Dye Creek
5-21.56	Los Molinos
5-21.57	Vina
5-21.58	West Butte
5-21.59	East Butte
5-21.60	North Yuba
5-21.61	South Yuba
5-21.62	Sutter
5-21.64	North American
5-21.65	South American
5-21.66	Solano
5-21.67	Yolo
5-21.68	Capay Valley

Basin/subbasins	Basin name
5-30	Lower Lake Valley
5-31	Long Valley
5-35	Middle Eel Area
5-36	Round Valley
5-37	Upper Eel Area
5-38	Peaslegg Town Area
5-40	Hot Springs Valley
5-41	Egg Lake Valley
5-43	Rock Prairie Valley
5-44	Long Valley
5-45	Cayton Valley
5-46	Lake Britton Area
5-47	Grass Valley
5-48	Hurdy Creek Valley
5-49	Dry Hurdy Creek Valley
5-50	North Fork Butte Creek
5-51	Butte Creek Valley
5-52	Gray Valley
5-53	Dixie Valley
5-54	Ash Valley
5-56	Yellow Creek Valley
5-57	East Chinese Creek Valley
5-58	Chinese Valley
5-59	Grizzly Valley
5-60	Humbug Valley
5-61	Chinese Town Area
5-62	Elk Creek Area
5-63	Stonyford Town Area
5-64	Bear Valley
5-65	Little Indian Valley
5-66	Clear Lake Gas Formation
5-68	Pope Valley
5-69	Lasgo Creek
5-87	Middle Fork Feather River
5-88	Stony Gorge Reservoir
5-89	Squaw Flat
5-90	Funks Creek
5-91	Antelope Creek
5-92	Big Valley
5-93	North Fork Cache Creek
5-94	Middle Creek
5-95	Meadow Valley

AR0069779

Description of the Region

The Sacramento River HR covers approximately 17.4 million acres (27,200 square miles). The region includes all or large portions of Modoc, Siskiyou, Lassen, Shasta, Tehama, Glenn, Plumas, Butte, Colusa, Sutter, Yuba, Sierra, Nevada, Placer, Sacramento, El Dorado, Yolo, Solano, Lake, and Napa counties (Figure 33). Small areas of Alpine and Amador counties are also within the region. Geographically, the region extends south from the Modoc Plateau and Cascade Range at the Oregon border, to the Sacramento-San Joaquin Delta. The Sacramento Valley, which forms the core of the region, is bounded to the east by the crest of the Sierra Nevada and southern Cascades and to the west by the crest of the Coast Range and Klamath Mountains. Other significant features include Mount Shasta and Lassen Peak in the southern Cascades, Sutter Buttes in the south central portion of the valley, and the Sacramento River, which is the longest river system in the State of California with major tributaries the Pit, Feather, Yuba, Bear and American rivers. The region corresponds approximately to the northern half of RWQCB 5. The Sacramento metropolitan area and surrounding communities form the major population center of the region. With the exception of Redding, cities and towns to the north, while steadily increasing in size, are more rural than urban in nature, being based on major agricultural areas. The 1995 population of the entire region was 2.372 million.

The climate in the northern, high desert plateau area of the region is characterized by cold snowy winters with only moderate precipitation and hot dry summers. This area depends on adequate snowpack to provide runoff for summer supply. Annual precipitation ranges from 10 to 20 inches. Other mountainous areas in the northern and eastern portions of the region have cold wet winters with large amounts of snow, which typically provide abundant runoff for summer supplies. Annual precipitation ranges from 40 to more than 80 inches. Summers are generally mild in these areas. The Coast Range and southern Klamath Mountains receive copious amounts of precipitation, but most of the runoff flows to the coast in the North Coastal drainage. Sacramento Valley comprises the remainder of the region. At a much lower elevation than the rest of the region, the valley has mild winters with moderate precipitation. Annual precipitation varies from about 35 inches in Redding to about 18 inches in Sacramento. Summers in the valley are hot and dry.

Most of the mountainous portions of the region are heavily forested and sparsely populated. Three major national forests (Mendocino, Trinity, and Shasta) make up the majority of lands in the Coast Range, southern Klamath Mountains, and the southern Cascades; these forests and the region's rivers and lakes provide abundant recreational opportunities. In the few mountain valleys with arable land, alfalfa, grain and pasture are the predominant crops. In the foothill areas of the region, particularly adjacent to urban centers, suburban to rural housing development is occurring along major highway corridors. This development is leading to urban sprawl and is replacing the former agricultural production on those lands. In the Sacramento Valley, agriculture is the largest industry. Truck, field, orchard, and rice crops are grown on approximately 2.1 million acres. Rice represents about 25 percent of the total irrigated acreage.

The Sacramento River HR is the main water supply for much of California's urban and agricultural areas. Annual runoff in the HR averages about 22.4 maf, which is nearly one-third of the State's total natural runoff. Major water supplies in the region are provided through surface storage reservoirs. The two largest surface water projects in the region are USBR's Shasta Lake (Central Valley Project) on the upper Sacramento River and Lake Oroville (DWR's State Water Project) on the Feather River. In all, there are more than 40 major surface water reservoirs in the region. Municipal, industrial, and agricultural supplies in the region are about 8 maf, with groundwater providing about 2.5 maf of that total. Much of the remainder of the runoff goes to dedicated natural flows, which support various environmental requirements, including in-stream fishery flows and flushing flows in the Delta.

AR0069780

Groundwater Development

Groundwater provides about 31 percent of the water supply for urban and agricultural uses in the region, and has been developed in both the alluvial basins and the hard rock uplands and mountains. There are 88 basin/subbasins delineated in the region. These basins underlie 5,053 million acres (7,900 square miles), about 29 percent of the entire region. The reliability of the groundwater supply varies greatly. The Sacramento Valley is recognized as one of the foremost groundwater basins in the State, and wells developed in the sediments of the valley provide excellent supply to irrigation, municipal, and domestic uses. Many of the mountain valleys of the region also provide significant groundwater supplies to multiple uses.

Geologically, the Sacramento Valley is a large trough filled with sediments having variable permeabilities; as a result, wells developed in areas with coarser aquifer materials will produce larger amounts of water than wells developed in fine aquifer materials. In general, well yields are good and range from one-hundred to several thousand gallons per minute. Because surface water supplies have been so abundant in the valley, groundwater development for agriculture primarily supplemented the surface supply. With the changing environmental laws and requirements, this balance is shifting to a greater reliance on groundwater, and conjunctive use of both supplies is occurring to a greater extent throughout the valley, particularly in dry/critical years. Groundwater provides all or a portion of municipal supply in many valley towns and cities. Redding, Anderson, Cline, Marysville, Sacramento, Olivehurst, Wheatland, Willows, and Williams rely to differing degrees on groundwater. Red Bluff, Corning, Woodland, Davis, and Dixon are completely dependent on groundwater. Domestic use of groundwater varies, but in general, rural unincorporated areas rely completely on groundwater.

In the mountain valleys and basins with arable land, groundwater has been developed to supplement surface water supplies. Most of the rivers and streams of the area have adjudicated water rights that go back to the early 1900s, and diversion of surface water has historically supported agriculture. Droughts and increased competition for supply have led to significant development of groundwater for irrigation. In some basins, the fractured volcanic rock underlying the alluvial fill is the major aquifer for the area. In the rural mountain areas of the region, domestic supplies come almost entirely from groundwater. Although a few mountain communities are supplied in part by surface water, most rely on groundwater. These groundwater supplies are generally quite reliable in areas that have sufficient aquifer storage or where surface water supplies supply throughout the year. In areas that depend on seasonal runoff, water levels can be significantly depleted in drought years and many old, shallow wells can be dewatered. During 2001, an extreme drought year on the Modoc Plateau, many well owners experienced problems with water supply.

Groundwater development in the fractured rocks of the foothills of the southern Cascades and Sierra Nevada is fraught with uncertainty. Groundwater supplies from fractured rock sources are highly variable in terms of water quantity and water quality and are an uncertain source for large-scale residential development. Originally, foothill development relied on water supply from springs and river diversions with flumes and ditches for conveyance that date back to gold mining era operations. Current development is primarily based on individual private wells, and as pressures for larger scale development increase, questions about the reliability of supply need to be addressed. Many existing foothill communities have considerable experience with dry or drought year shortages. In Butte County residents in Cohasset, Forest Ranch, and Magalia have had to rely on water brought up the ridges in tanker trucks. The suggested answer has been the development of regional water supply projects. Unfortunately, the area's development pattern of small, geographically dispersed population centers does not lend itself to the kind of financial base necessary to support such projects.

AR0069781

Groundwater Quality

Groundwater quality in the Sacramento River HR is generally excellent. However, there are areas with local groundwater problems. Natural water quality impairments occur at the north end of the Sacramento Valley in the Redding subbasin, and along the margins of the valley and around the Sutter Buttes, where Cretaceous-age marine sedimentary rocks containing brackish to saline water are near the surface. Water from the older underlying sediments mixes with the fresh water in the younger alluvial aquifer and degrades the quality. Wells constructed in these areas typically have high TDS. Other local natural impairments are moderate levels of hydrogen sulfide in groundwater in the volcanic and geothermal areas in the western portion of the region. In the Sierra foothills, there is potential for encountering uranium and radon bearing rock or sulfide mineral deposits containing heavy metals. Human induced impairments are generally associated with individual septic system development in shallow unconfined portions of aquifers or in fractured hard rock areas where insufficient soil depths are available to properly leach effluent before it reaches the local groundwater supply.

Water Quality in Public Supply Wells

From 1994 through 2000, 1,356 public supply water wells were sampled in 51 of the 88 basins and subbasins in the Sacramento River HR. Samples analyzed indicate that 1,282 wells, or 95 percent, met the state primary MCLs for drinking water. Seventy-four wells, or 5 percent, have constituents that exceed one or more MCL. Figure 34 shows the percentages of each contaminant group that exceeded MCL's in the 74 wells.

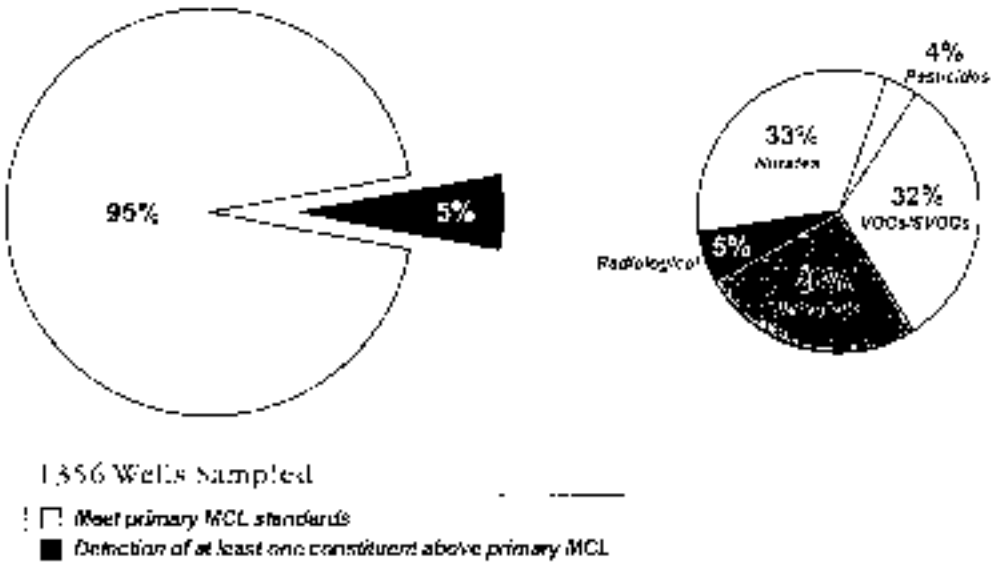

Figure 34 MCL exceedances in public supply wells in the Sacramento River Hydrologic Region

AR0069782

Table 25 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 25 Most frequently occurring contaminants by contaminant group in the Sacramento River Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics - Primary	Cadmium - 4	Chromium (Total) - 3	3 tied at 2
Inorganics - Secondary	Manganese - 221	Iron - 166	Specific Conductance - 3
Radionuclides	Gross Alpha - 4		
Nitrates	Nitrate (as NO_3) - 22	Nitrate + Nitrite - 5	Nitrate Nitrogen (NO_3)-N) - 2
Pesticides	1,2,3-Trichloropropane - 4		
VOCs/SVOCs	PCE - 11	TCE - 7	Benzene - 4

PCE - Tetrachloroethylene
TCE - Trichloroethylene
VOC - Volatile Organic Compounds
SVOC - Semivolatile Organic Compound

Changes from Bulletin 118-80

Some modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report. These are listed in Table 26.

Table 26 Modifications since Bulletin 118-80 of groundwater basins and subbasins in Sacramento River Hydrologic Region

Basin name	New number	Old number
Fandango Valley	5-110	5-39
Homer Swamp Valley	deleted	5-42
Modoc Plateau Recent Volcanic Areas	deleted	5-52
Modoc Plateau Pleistocene Volcanic Areas	deleted	5-53
Mount Shasta Area	deleted	5-51
Sacramento Valley eastside Tuscan Formation/Highlands	deleted	5-55
Clear Lake Pleistocene Volcanics	deleted	5-67

AR0069783

No additional basins were assigned to the Sacramento River HR in this revision. However, four basins have been divided into subbasins. Goose Lake Valley Groundwater Basin (5-1) has been subdivided into two subbasins, Fandango Valley (5-39) was modified to be a subbasin of Goose Lake Valley. Redding Area Groundwater Basin has been subdivided into six subbasins. Sierra Valley Groundwater Basin has been subdivided into two subbasins, and the Sacramento Valley Groundwater Basin has been subdivided into 18 subbasins.

There are several deletions of groundwater basins from Bulletin 118-80. Butcher Swamp Valley Basin (5-42) was deleted due to a thin veneer of alluvium over rock. Modoc Plateau Recent Volcanic Areas (5-32), Modoc Plateau Pleistocene Volcanic Areas (5-33), Mount Shasta Area (5-34), Sacramento Valley Eastside Tuscan Formation Highlands (5-55), and Clear Lake Pleistocene Volcanics (5-69) are no same aquifers and were not assigned basin numbers in this bulletin. These are considered to be groundwater source areas as discussed in Chapter 6.

AR0069784

Table 27 Sacramento River Hydrologic Region groundwater data

River Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
5.1	GOOSE LAKE VALLEY									
5.1-01	LOWER GOOSE LAKE	70,000	B	-	400	0	0	-	761	68 - 53x
5.1-02	DUNCANNON VALLEY	18,200	D	2,000	-	1	1	-	-	-
5.2	ALTURAS AREA								253	180 - 800
5.2-01	SOUTH FORK PIT RIVER	14,000	B	3,000	1,000	0	-	8	-	-
5.2-02	WARM SPRINGS VALLEY	68,000	D	500	313	0	-	0		
5.3	JESS VALLEY	6,700	B		3,000					
5.4	BIG VALLEY	92,000	B	4,000	800	19	9	10	390	151 - 629
5.5	FALL RIVER VALLEY	54,800	B	1,500	266	16	7	5	174	115 - 233
5.6	REDDING AREA									
5.6-01	BOWMAN	86,330	B	2,000	589	9	3	19	-	79 - 247
5.6-02	ROSEWOOD	65,320	D	-	-	4	1	-	-	118 - 274
5.6-03	ANDERSON	98,500	B	1,800	46	7	1	19	341	104 - 556
5.6-04	ENTERPRISE	60,900	B	700	266	12	3	19		168 - 340
5.6-05	VILLAGE	67,900	B	500	254	9	3	4	340	-
5.6-06	SOUTH BATTLE CREEK	32,200	D	-	-	0	1	0	350	-
5.7	LAKE ALMANOR VALLEY	7,150	B			10	1	1	60	52 - 200
5.8	MOUNTAIN MEADOWS VALLEY	8,150	B	-	-	-	-	-	-	-
5.9	INDIAN VALLEY	29,400	B	-	-	-	4	9	-	-
5.10	AMERICAN VALLEY	9,800	D	40	40		1	1	-	-
5.11	MOHAWK VALLEY	19,000	B		500	7	2	15	215	110 - 320
5.12	SIERRA VALLEY									
5.12-01	SIERRA VALLEY	127,000	B	1,500	640	30	15	5	312	110 - 1,020
5.12-02	CHILCOOT	7,550	B			12		8		
5.13	UPPER LANZ VALLEY	7,260	B	900	303	12	1	6	-	-
5.14	SCOTTS VALLEY	7,570	D	1,700	171	3	1	6	88	140 - 179
5.15	BIG VALLEY	24,210	B	1,420	475	43	11	3	219	220 - 650
5.16	HIGH VALLEY	7,460	B	700	12	8	1	1	904	480 - 1,200
5.17	BUTTE VALLEY	5,700	D	-	90	1	1	-	335	280 - 450
5.18	COYOTE VALLEY	6,530	B	800	440	9	1	3	350	175 - 340
5.19	CHEATAM VALLEY	6,500	B	1,000	131	20	4	3	502	150 - 900
5.20	HERSEY VALLEY	1,400	-	-	-	0		0		
5.21	SACRAMENTO VALLEY									
5.21-50	REDDING	206,750	B	1,800	900	50	21	66	307	170 - 480
5.21-51	CORNING	305,640	B	1,500	672	29	7	30	385	140 - 630
5.21-52	COLUSA	578,380	B	5,600	964	24	10	174	514	120 - 1,220
5.21-53	RENO	20,770	2	-	575	0	1	6	-	334 - 960
5.21-54	ANTELOPE	19,210	B	800	575	2	1	23	496	
5.21-55	DYE CREEK	22,730	B	3,400	830	2	1	1	240	150 - 506
5.21-56	LOS MOLINOS	31,720	B	1,000	600	3	2	9	217	
5.21-57	VINA	136,640	B	1,950	1,212	13	5	66	285	98 - 513
5.21-58	WEST BUTTE	58,400	B	4,000	1,431	10	5	16	293	130 - 676

AR0069785

Table 27 Sacramento River Hydrologic Region groundwater data (continued)

Basin Number	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Level	Quality	Use	Average	Range
5-21.59	EAST BUTTE	260,000	H	2,500	1,000	14	4	44	350	100 - 600
5-21.60	NORTH YUBA	100,000	I	3,000		2		3		
5-21.61	SOUTH YUBA	107,000	I	4,000	1,000	20		6		
5-21.62	DOTTAR	210,000	C			62		113		
5-21.64	NORTH AMERICAN	331,000	S		900	121		339	300	150 - 1,000
5-21.65	SOUTH AMERICAN	346,000	I			107		221	221	21 - 561
5-21.66	SOLANO	445,000	C			137	23	330	427	170 - 850
5-21.67	YOLO	320,000	B	4,000	1,000	123	20	45	800	480 - 2,010
5-21.68	CAPAY VALLEY	25,000	I			1		2		
5-26	LOWER CACHE VALLEY	2,500	SI	100	45	3	3	3	568	290 - 1,740
5-27	LONG VALLEY	7,000	B	300	45	2		2		
5-35	SILVERADO AREA	11,000	S		250			1		
5-36	KOUNS VALLEY	5,000	B	1,000	400	3				140 - 490
5-37	TOAD TOWN AREA	3,500	B							
5-38	PONCHA TOWN AREA	2,000	B							
5-40	HOT SPRINGS VALLEY	1,000	B							
5-41	PUTAH CREEK VALLEY	4,500	B		20					
5-42	ROCK PRAIRIE VALLEY	5,000	B							
5-44	LONG VALLEY	1,000	B							
5-45	CLAYTON VALLEY	13,000	B		300					
5-46	LAKE BRITTON AREA	40,000	B					2		
5-47	GOOSE VALLEY	4,500	B							
5-48	HURNEY CREEK VALLEY	3,500	B					3		
5-49	DRY DIGGINS CREEK VALLEY	1,000	B							
5-50	NORTH FORK BATTLE CREEK VALLEY	2,500	B					1		
5-51	BUTTE CREEK VALLEY	3,000	B							
5-52	CLAYS VALLEY	3,500	B							
5-53	DIXIE VALLEY	3,000	B							
5-54	ANTELOPE VALLEY	60,000	B	1,000	1,200					
5-56	YELLOW JACKET VALLEY	2,000	B							
5-57	EAST CHANCE CREEK VALLEY	5,000	B							
5-58	CLOVER VALLEY	5,000	B							
5-59	ORLEANS VALLEY	10,000	B					1		
5-60	SCARBORO VALLEY	9,000	B					8		
5-61	CHROMETOWN AREA	4,000	B							
5-62	PEA CREEK AREA	3,000	B							
5-63	STONYFORD AREA	6,000	B							
5-64	BEAR VALLEY	9,000	B							
5-65	LITTLE INDIAN VALLEY	1,000	B							
5-66	CLEAR LAKE AQUIFORMATION	90,000	B	2,000	500			4		
5-67	POPE VALLEY	7,000	C					1		
5-68	JOSEPH CREEK	4,000	B							

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Table 27 Sacramento River Hydrologic Region groundwater data (continued)

Basin Number	Basin Name	Area (acres)	Groundwater Region Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Level	Quality	Both	Average	Range
5-57	MIDDLE FORK FEATHER RIVER	4,340	M							
5-58	STONY GORGE RESERVOIR	370	S							
5-59	SQUAW VALLEY	320	C							
5-60	FUNKS CREEK	7,160	C							
5-61	ANTELOPE CREEK	1,440	S							
5-62	HUNTOON VALLEY	1,300	M							
5-63	NORTH FORK CACHE CREEK	1,410	C							
5-64	MIDDLE CREEK	900	S							
5-65	MEADOW VALLEY	1,000	C							

gpm = gallons per minute
mg/L = milligrams per liter
TDS = total dissolved solids

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AR0069788

San Joaquin River Hydrologic Region

AR0069789

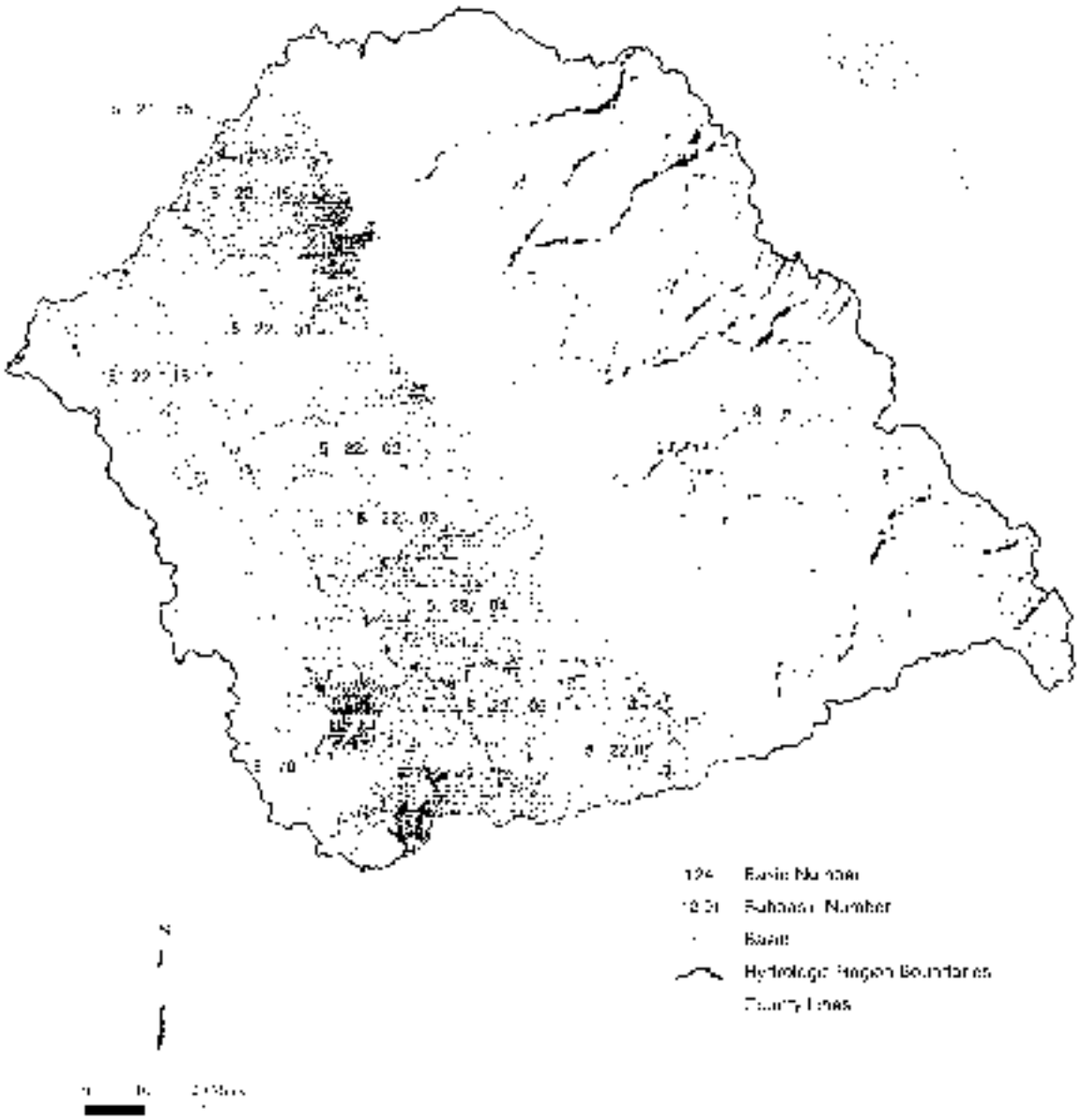

Figure 35 San Joaquin River Hydrologic Region

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Basins and Subbasins of the San Joaquin River Hydrologic Region

Basin/subbasin	Basin name
5-22	San Joaquin Valley
5-22.01	Eastern San Joaquin
5-22.02	Modesto
5-22.03	Turlock
5-22.04	Merced
5-22.05	Chowchilla
5-22.06	Madera
5-22.07	Delta Mendota
5-22.15	Tracy
5-22.16	Tomales
5-69	Yosemite Valley
5-70	Los Banos Creek Valley

Description of the Region

The San Joaquin River HR covers approximately 9.7 million acres (15,200 square miles) and includes all of Calaveras, Tuolumne, Mariposa, Madera, San Joaquin, and Stanislaus counties, most of Merced and Amador counties, and parts of Alpine, Fresno, Alameda, Contra Costa, Sacramento, El Dorado, and San Benito counties (Figure 15). The region corresponds to a portion near the middle of RWQCB 5. Significant geographic features include the northern half of the San Joaquin Valley, the southern part of the Sacramento-San Joaquin Delta, the Sierra Nevada and Diablo Range. The region is home to about 1.6 million people (DWR 1998). Major population centers include Merced, Modesto, and Stockton. The Merced area is entirely dependent on groundwater for its supply, as will be the new University of California at Merced campus.

Groundwater Development

The region contains two entire groundwater basins and part of the San Joaquin Valley Groundwater Basin, which continues south into the Tulare Lake HR. The San Joaquin Valley Groundwater Basin is divided into nine subbasins in this region. The basins underlie 3.73 million acres (5,830 square miles) or about 38 percent of the entire HR area.

The region is heavily groundwater reliant. Within the region groundwater accounts for about 30 percent of the annual supply used for agricultural and urban purposes. Groundwater use in the region accounts for about 18 percent of statewide groundwater use for agricultural and urban needs. Groundwater use in the region accounts for 5 percent of the State's overall supply from all sources for agricultural and urban uses (DWR 1998).

The aquifers are generally quite thick in the San Joaquin Valley subbasins, with groundwater wells commonly extending to depths of up to 800 feet. Aquifers include unconsolidated alluvium and consolidated rocks with unconfined and confined groundwater conditions. Typical well yields in the San Joaquin Valley range from 300 to 2,000 gpm with yields of 5,000 gpm possible. The region's only significant basin located outside of San Joaquin Valley is Yosemite Valley. Yosemite Valley Basin supplies water to Yosemite National Park and has substantial well yields.

AR0069791

Conjunctive Use

Since near the beginning of the region's agricultural development, groundwater has been used conjunctively with surface water to meet water needs. Groundwater was and is used when and where surface water is unable to fully meet demands either in time or area. For several decades, this situation was more of an incidental conjunctive use than a formal one. Historical groundwater use has resulted in some land subsidence in the southwest portion of the region.

Groundwater Quality

In general, groundwater quality throughout the region is suitable for most urban and agricultural uses with only local impairment. The primary constituents of concern are TDS, nitrate, boron, chloride, and organic compounds. The Yosemite Valley Groundwater Basin has exceptionally high quality groundwater.

Areas of high TDS content are primarily along the west side of the San Joaquin Valley and in the trough of the valley. The high TDS content of west-side groundwater is due to recharge of streamflow originating from marine sediments in the Coast Ranges. High TDS content in the trough of the valley is the result of concentration of salts due to evaporation and poor drainage. Nitrates may occur naturally or as a result of disposal of human and animal waste products and fertilizer. Boron and chloride are likely a result of concentration from evaporation near the valley trough. Organic contaminants can be broken into two categories, agricultural and industrial. Agricultural pesticides and herbicides have been detected in groundwater throughout the region, but primarily along the east side of the San Joaquin Valley where soil permeability is higher and depth to groundwater is shallower. The most notable agricultural contaminant is dibromochloropropane (DBCP), a now-banned soil fumigant and known carcinogen once used extensively on grapes and cotton. Industrial organic contaminants include TCE, dichloroethylene (DCE), and other solvents. They are found in groundwater near airports, industrial areas, and landfills.

Water Quality in Public Supply Wells

From 1994 through 2009, 689 public supply water wells were sampled in 30 of the 31 basins and subbasins in the San Joaquin River HR. Samples analyzed indicate that 523 wells, or 76 percent, met the state primary MCLs for drinking water. One-hundred-sixty-six wells, or 24 percent, have constituents that exceed one or more MCL. Figure 26 shows the percentages of each contaminant group that exceeded MCLs in the 166 wells.

Table 28 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Changes from Bulletin 118-80

The subbasins of the San Joaquin Valley, which were delineated as part of the 118-80 update, are given their first numeric designation in this report. Additionally, the Cosumnes Subbasin has been added to the subbasins within the San Joaquin River HR. It is worth noting that the southern portion of the South American Subbasin of the Sacramento Valley Groundwater Basin is also included as part of this HR. The subbasin names and numbers within the region are listed in Table 29.

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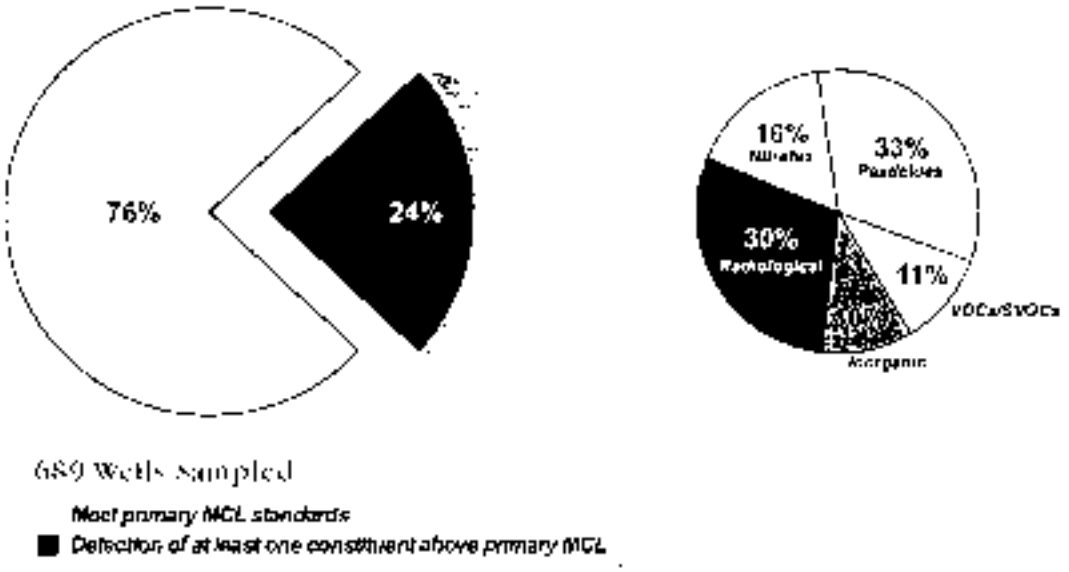

Figure 36 MCL exceedances in public supply wells in the San Joaquin River Hydrologic Region

Table 28 Most frequently occurring contaminants by contaminant group in the San Joaquin River Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics - Primary	Aluminum - 9	Arsenic - 4	4 total Exceedances
Inorganics - Secondary	Manganese - 123	Iron - 102	TDS - 9
Radiological	Uranium - 33	Gross Alpha - 20	Radium 228 - 6
Nitrates	Nitrate as NO_3 - 34	Nitrate + Nitrite - 6	Nitrate Nitrogen (NO3-N) - 3
Pesticides	DBCP - 44	1,2,3-DCP - 11	EDB - 6
VOCs	PCE - 8	Dichloromethane - 3	TCE - 2

DBCP - Dibromochloropropane
TDS - Dissolved Solids
TCE - Trichloroethylene
PCE - Tetrachloroethylene
VOC - Volatile Organic Compound
SVOC - Semivolatile Organic Compound

AR0069793

Table 29 Modifications to Bulletin 118-80 of groundwater basins and subbasins in San Joaquin Hydrologic Region

Subbasin name	New number	Old number
Eastern San Joaquin	5-22.01	5-22
Modesto	5-22.02	5-22
Turlock	5-22.03	5-22
Merced	5-22.04	5-22
Chowchilla	5-22.05	5-22
Madera	5-22.06	5-22
Delta-Mendota	5-22.07	5-22
Tracy	5-22.15	5-22
Cosumnes	5-22.16	5-22

AR0069794

Table 30 San Joaquin River Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater budget type	Well Yield (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Lowest	Quality	Total	Average	Range
5.02	SAN JOAQUIN VALLEY									
5-022.01	EASTERN SAN JOAQUIN	707,000	A	1,500		340	67	340	310	20-1,622
5-022.02	MODESTO	247,000	B	4,500	1000-2000	260	15	209	60-500	300-8,000
5-022.03	TURLOCK	347,000	B	4,500	1000-2000	307	0	165	200-700	90-8500
5-022.04	MERCED	491,000	B	4,450	1000-1500	278	0	142	200-400	200-6500
5-022.05	CHOWCHILLA	159,000	B	4,750	750-2000	295	0	98	200-500	120-6200
5-022.06	MADERA	244,000	B	4,750	750-2000	328	6	127	200-400	90-6400
5-022.07	DELTA-MENDOTA	767,000	B	5,000	1000-2000	816	0	198	720	210-86,000
5-022.11	TRACY	245,000	C	2,100	500-1,000	18	14	186	1,000	210-3,000
5-022.16	COSUMNES	291,000	A	1,000	-	39	13	77	210	140-358
5-023	WESTSIDE VALLEY	2,501	C	1,000	200	8	0	5	56	43-75
5.20	LOS BANOS CREEK VALLEY	2,543	C			8	0	8	-	

gpm = gallons per minute
mg/L = milligrams per liter
TDS = total dissolved solids

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AR0069796

Tulare Lake Hydrologic Region

AR0069797

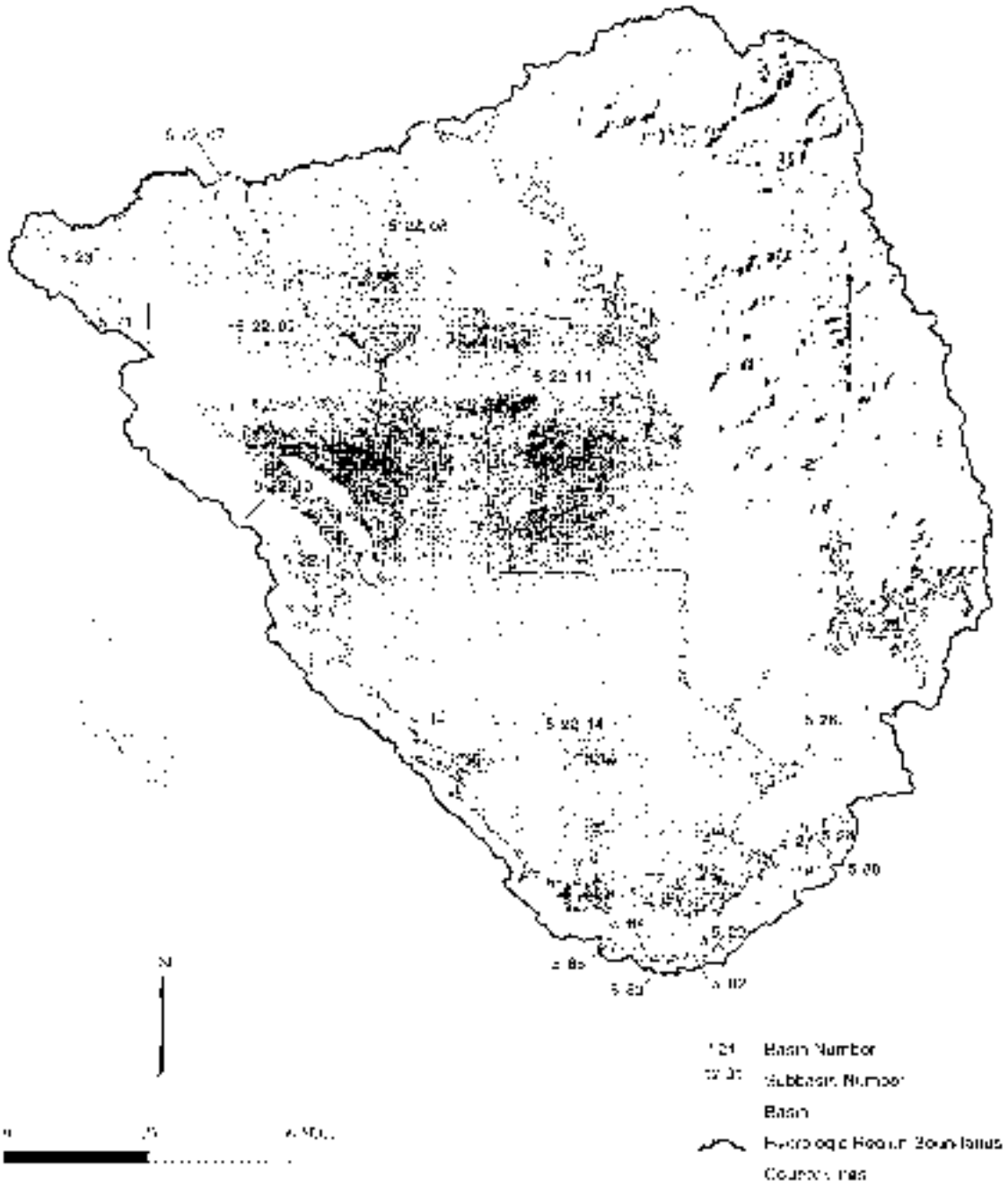

Figure 37 Tulare Lake Hydrologic Region

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Basins and Subbasins of Tulare Lake Hydrologic Region

Basin/Subbasin	Basin name
5-22	San Joaquin Valley
5-22.08	Kings
5-22.09	Westside
5-22.10	Pleasant Valley
5-22.11	Kaweah
5-22.12	Tulare Lake
5-22.13	Tule
5-22.14	Kern County
5-23	Panoche Valley
5-25	Kern River Valley
5-26	Walker Basin Creek Valley
5-27	Cuyama Valley
5-28	Tehachapi Valley West
5-29	Captain Jack Valley
5-31	Antelope Creek Valley
5-80	Brite Valley
5-82	Cuddy Canyon Valley
5-83	Cuddy Basin Area
5-84	Cuddy Valley
5-85	Mil Potrero Area

Description of the Region

The Tulare Lake HR covers approximately 19,0 [illegible] square miles) and includes all of Kings and Tulare counties and most of Fresno and Kern counties (Figure 37). The region corresponds to approximately the southern one-third of RWQCB 5. Significant geographic features include the southern half of the San Joaquin Valley, the Temblor Range to the west, the Tehachapi Mountains to the south, and the southern Sierra Nevada to the east. The region is home to more than 3.7 million people as of 1995 (DWR, 1998). Major population centers include Fresno, Bakersfield, and Visalia. The cities of Fresno and Visalia are entirely dependent on groundwater for their supply, with Fresno being the second largest city in the United States reliant solely on groundwater.

Groundwater Development

The region has 12 distinct groundwater basins and 7 subbasins of the San Joaquin Valley Groundwater Basin, which crosses north into the San Joaquin River HR. These basins underlie approximately 5.35 million acres (8,330 square miles) or 49 percent of the entire HR area.

Groundwater has historically been important to both urban and agricultural uses, accounting for 41 percent of the region's total annual supply and 35 percent of all groundwater use in the State. Groundwater use in the region represents about 10 percent of the State's overall supply for agricultural and urban uses (DWR 1998).

The aquifers are generally quite thick in the San Joaquin Valley subbasins with groundwater wells commonly exceeding 1,000 feet in depth. The maximum thickness of freshwater-bearing deposits (4,000 feet) occurs at the southern end of the San Joaquin Valley. Typical well yields in the San Joaquin Valley range from 300 gpm to 2,000 gpm with yields of 4,000 gpm possible. The smaller basins in the mountains surrounding the San Joaquin Valley have thinner aquifers and generally lower well yields averaging less than 500 gpm.

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The cities of Fresno, Bakersfield, and Visalia have groundwater recharge programs to ensure that groundwater will continue to be a viable water supply in the future. Extensive groundwater recharge programs are also in place in the south valley where water districts have recharged several million acre-feet for future use and transfer through water banking programs.

The extensive use of groundwater in the San Joaquin Valley has historically caused subsidence of the land surface primarily along the west side and south end of the valley.

Groundwater Quality

In general, groundwater quality throughout the region is suitable for most urban and agricultural uses with only local impairments. The primary constituents of concern are high TDS, nitrate, arsenic, and organic compounds.

The areas of high TDS content are primarily along the west side of the San Joaquin Valley and in the trough of the valley. High TDS content of west-side water is due to recharge of stream flow originating from marine sediments in the Coast Range. High TDS content in the trough of the valley is the result of concentration of salts because of evaporation and poor drainage. In the central and west-side portions of the valley, where the Corcoran Clay confining layer exists, water quality is generally better beneath the clay than above it. Nitrates may occur naturally or as a result of disposal of human and animal waste products and fertilizer. Areas of high nitrate concentrations are known to exist near the town of Shafter and other isolated areas in the San Joaquin Valley. High levels of arsenic occur locally and appear to be associated with lakebed areas. Elevated arsenic levels have been reported in the Tulare Lake, Kern Lake and Buena Vista Lake bed areas. Organic contaminants can be broken into two categories, agricultural and industrial. Agricultural pesticides and herbicides have been detected throughout the valley, but primarily along the east side where soil permeability is higher and depth to groundwater is shallower. The most notable agricultural contaminant is DBCP, a now-banned soil fumigant and known carcinogen once used extensively on grapes. Industrial organic contaminants include TCEs, DCEs, and other solvents. They are found in groundwater near airports, industrial areas, and landfills.

Water Quality in Public Supply Wells

From 1994 through 2000, 1,476 public supply water wells were sampled in 11 of the 19 groundwater basins and subbasins in the Tulare Lake HR. Evaluation of analyzed samples shows that 1,019 of the wells, or 71 percent, met the state primary MCLs for drinking water. Four-hundred-twenty-seven wells, or 29 percent, exceeded one or more MCLs. Figure 38 shows the percentages of each contaminant group that exceeded MCLs in the 127 wells.

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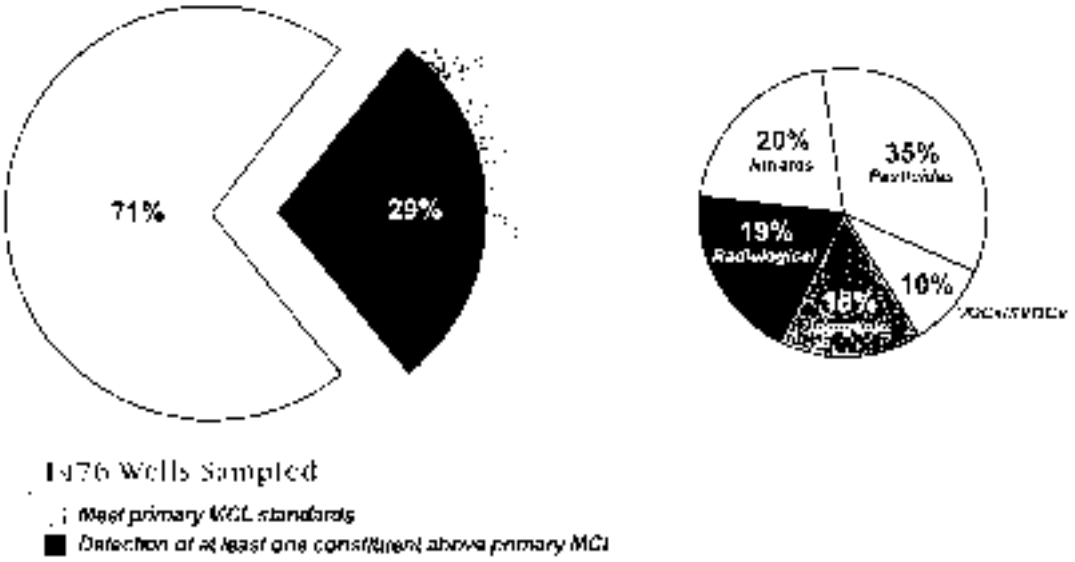

Figure 38 MCL exceedances by contaminant group in public supply wells in the Tulare Lake Hydrologic Region

Table 31 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for these contaminants.

Table 31 Most frequently occurring contaminants by contaminant group in the Tulare Lake Hydrologic Region

Contaminant group	Contaminant – # of wells	Contaminant – # of wells	Contaminant – # of wells
Inorganics – Primary	Fluoride – 33	Arsenic – 26	Aluminum – 12
Inorganics – Secondary	Iron – 155	Manganese – 82	TDS – 9
Radiological	Gross Alpha – 74	Uranium – 34	Radium 228 – 8
Nitrates	Nitrate as NO_3 – 85	Nitrate + Nitrite – 11	Nitrate as N – 2
Pesticides	DBCP – 13	EDB – 24	Di(2-Ethylhexyl)phthalate – 3
VOCs/SVOCs	TCE – 17	PCE – 16	Benzene – 6 MTBE – 6

DBCP = Dibromochloropropane
TDS = Total dissolved solids
TCE = Trichloroethylene
PCE = Tetrachloroethylene
VOC = Volatile organic compound
SVOC = Semivolatile organic compound

AR0069801

Changes from Bulletin 118-80

There are no newly defined basins since Bulletin 118-80. However, the subbasins of the San Joaquin Valley, which were delineated as part of the 118-80 update, are given their first numeric designation in this report (Table 32).

Table 32 Modifications since Bulletin 118-80 of groundwater basins and subbasins in Tulare Lake Hydrologic Region

Subbasin name	New number	Old number
Kings	5-22.08	5-22
Westside	5-22.09	5-22
Pleasant Valley	5-22.10	5-22
Kaweah	5-22.11	5-22
Tulare Lake	5-22.12	5-22
Tule	5-22.13	5-22
Kern County	5-22.14	5-22
Squaw Valley	deleted	5-34
Cedar Grove Area	deleted	5-72
Three Rivers Area	deleted	5-73
Springville Area	deleted	5-74
Templeton Mountain Area	deleted	5-75
Monache Meadow Area	deleted	5-76
Sacate Canyon Valley	deleted	5-77
Rockhouse Meadows Valley	deleted	5-78
Iron Valley	deleted	5-79
Bear Valley	deleted	5-81

Several basins have been deleted from the Bulletin 118-80 report. In Squaw Valley (5-34) all 118 wells are completed in hard rock. Cedar Grove Area (5-72) is a narrow river valley in Kings Canyon National Park with no wells. Three Rivers Area (5-73) has a thin alluvial terrace deposit but 128 of 130 wells are completed in hard rock. Springville Area (5-74) is a thin strip of alluvium adjacent to Tule River and all wells are completed in hard rock. Templeton Mountain Area (5-75), Monache Meadow Area (5-76), and Sacate Canyon Valley (5-77) are all at the crest of mountains with no wells. Rockhouse Meadows Valley (5-78) is in wilderness with no wells. Iron Valley (5-79) and Bear Valley (5-81) both have all wells completed in hard rock.

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Table 33 Tulare Lake Hydrologic Region groundwater data

Basin Subbasin #	Basin Name	Area (acres)	Groundwater Region Type	Well Yield (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Level	Quality	Total	Average	Range
5-22	SAN JOAQUIN VALLEY									
5-22.01	KINGS	926,000	C	3,000	1,000-1,000	500		723	200-700	90-2,000
5-22.02	WESTSIDE	650,000	C	2,000	1,100	900		56	520	220-10,000
5-22.03	PLEASANT VALLEY	736,000	B	3,500	-	151		5	1,500	240-5,000
5-22.04	KAWEAH	340,000	D	2,500	1,000-2,000	593		230	189	75-450
5-22.11	TULARE LAKE	474,000	B	3,000	500-1,000	24		86	2,000-00	200-40,000
5-22.13	TULE	667,000	B	3,000	-	499		150	950	700-31,000
5-22.14	KERN COUNTY	1,050,000	A	4,000	1,000-1,000	2,254	220	476	500-950	150-2,000
5-23	PANOCHE VALLEY	53,100	C	-	-	42	-	-	1,500	990-3,940
5-24	KERN RIVER VALLEY	77,000	C	3,650	650			92	378	253-450
5-25	WALKER BASIN CREEK VALLEY	7,670	C	650				1		
5-26	TUMBLINGS VALLEY	10,000	A	150	90	31		15	542	
5-27	TEHACHAPI VALLEY WEST	14,300	A	1,500	494	45		19	315	250-365
5-28	CANADA LARGA VALLEY	3,600	C	500	255			7	593	570-615
5-31	VAN DUZEN-UPPER VALLEY	15,100	C	-	-			8		
5-30	BUTTE VALLEY	9,170	A	500	50			-	-	
5-47	CUDDY CANYON VALLEY	3,300	C	500	100			3	603	460
5-49	CUDDY-PANOCHA AREA	4,200	C	300	150			5	500	190-815
5-50	CUDDY VALLEY	9,600	A	150	145	3		5	407	321-649
5-51	MILPITERO AREA	7,300	C	2,500	750	3		7	660	572-655

gpm = gallons per minute
mg/L = milligrams per liter
TDS = total dissolved solids

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AR0069804

North Lahontan Hydrologic Region

AR0069805

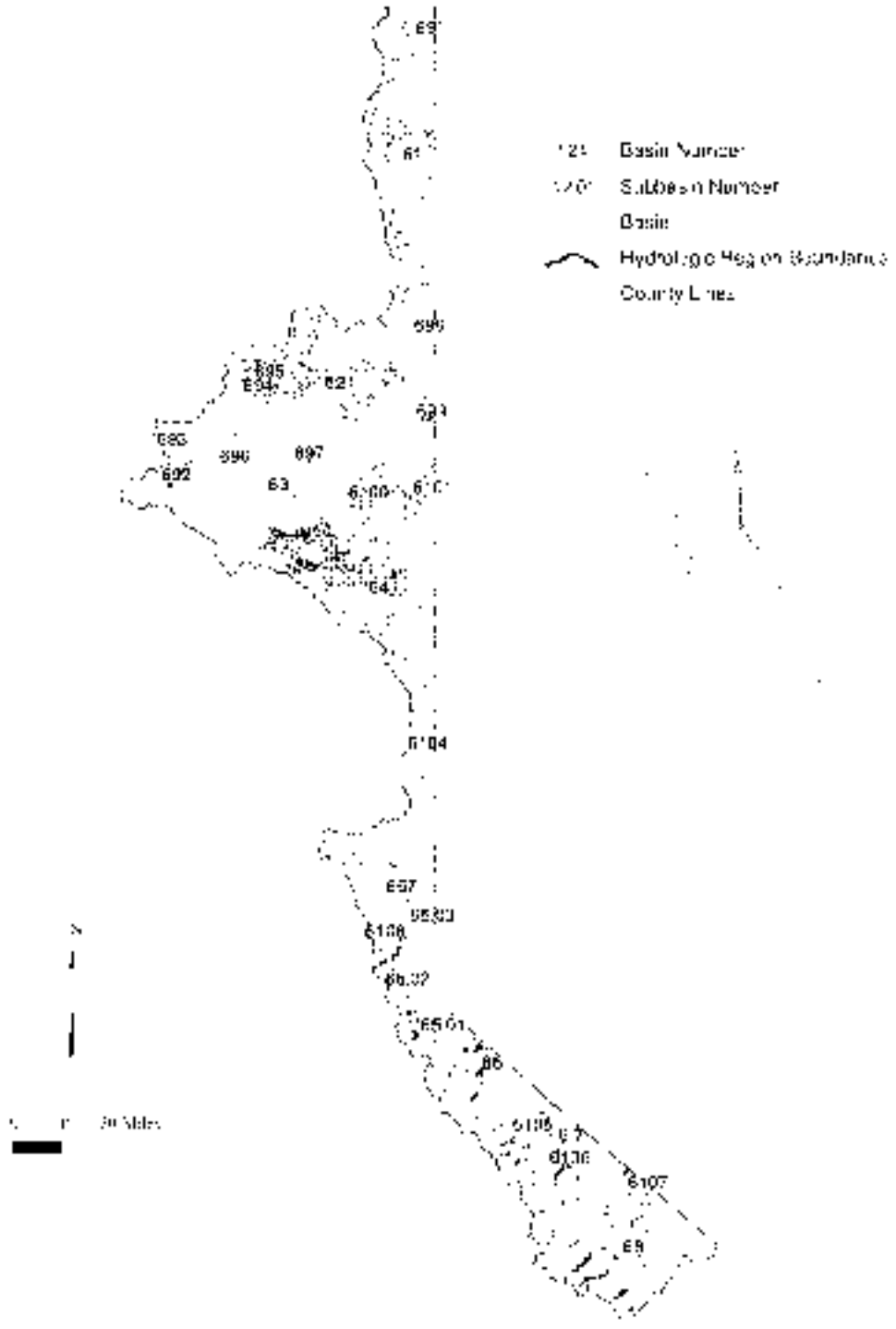

Figure 39 North Lahontan Hydrologic Region

AR0069806

Basins and Subbasins of the North Lahontan Hydrologic Region

Basin/subbasin	Basin name
6-1	Surprise Valley
6-2	Modoc Plateau
6-3	Willow Creek Valley
6-4	Honey Lake Valley
6-5	Tahoe Valley
6-5.01	Tahoe Valley North
6-5.02	Tahoe Valley West
6-5.03	Tahoe Valley South
6-6	Carson Valley
6-7	Antelope Valley
6-8	Bridgeport Valley
6-9.7	Mono-Owens-Rush Valley
6-9.1	Crowley Lake Valley
6-9.2	Hilton Creek Valley
6-9.3	Long Valley
6-9.4	Owens Valley
6-9.5	Grasshopper Valley
6-9.6	Chalfant Valley
6-9.8	Eagle Lake Area
6-9.9	Eagle Lake Valley
6-9.8	Buntingville-Granite
6-9.9	Painters Flat
6-10.0	Secret Valley
6-10	Butte Valley
6-10.4	Long Valley
6-10.5	Standish Valley
6-10.6	Little Antelope Valley
6-10.7	Smoke Creek Flat
6-10.8	Olancha Valley

Description of the Region

The North Lahontan HR covers approximately 3.91 million acres (6,110 square miles) and includes portions of Modoc, Lassen, Sierra, Nevada, Placer, El Dorado, Alpine, Mono, and Tuolumne counties (Figure 39). Reaching south from the Oregon border almost to Mono Lake on the east side of the Sierra, this region encompasses portions of two geomorphic provinces. From Long Valley north, most of the groundwater basins of the region were formed by basin and range block faulting near the western extent of the province. South from Long Valley, most of the basins are in the alpine valleys of the Sierra Nevada or are at the foot of the Sierra along the California-Nevada border where streams and rivers draining the eastern Sierran slopes terminate in desert sinks or lakes. The region corresponds to approximately the northern half of RWQCB 6. Significant geographic features include the Sierra Nevada, the volcanic terrain of the Modoc Plateau, Honey Lake Valley, and Lake Tahoe. The latter two areas are the major population centers in the region. The 1995 population of the entire region was about 84,000 people (DWR, 1998).

The northern portion of the region is rural and sparsely populated. Cattle ranching and associated hay cropping are the predominant land uses in addition to some pasture irrigation. Less than 4 percent of the entire region is irrigated. About 75 percent of the irrigated lands are in Modoc and Lassen counties, and most of the remainder is in Alpine and Mono counties. Much of the southern portion of the region is federally owned and managed as national forest lands where tourism and recreation constitute much of the economic base.

Much of the North Lahontan HR is chronically short of water due to the arid, high desert climate, which predominates in the region. Throughout the northern portion of the region where annual precipitation can be as low as 4 inches, runoff is typically scant and streamflows decrease rapidly during the irrigation season as the snowpack in the higher elevations melts. In the southern portion of the region, annual precipitation ranges from more than 70 inches (mostly snow in the higher elevations of the mountains) to as little as 8 inches in the low elevation valleys. In wet years, surface water can meet much of the agricultural demand, but in dry years, most of the region relies heavily on groundwater to meet water supply needs.

AR0069807

Groundwater Development

There are 24 groundwater basins in the region, one of which is divided into three subbasins. Thirteen of these basins are shared with Nevada and one with Oregon. These basins underlie approximately 1.03 million acres (1,610 square miles) or about 26 percent of the entire region. Although the groundwater basins were delineated based on mapped alluvial fill, much of the groundwater produced in many of them actually comes from underlying fractured rock aquifers. This is particularly true in the volcanic areas of Modoc and Lassen counties where, in many basins, volcanic flows are interstratified with lake sediments and alluvium. Wells constructed in the volcanics commonly produce large amounts of groundwater, whereas wells constructed in fine-grained lake deposits produce less. Because the thickness and lateral extent of the hard rocks outside of the defined basin are generally not known, actual groundwater in storage in these areas is unknown.

Locally, groundwater is an important resource accounting for about 28 percent of the annual supply for agricultural and urban uses. Groundwater use in the region represents less than 1 percent of the State's overall supply for agricultural and urban uses (DWR 1998).

In the northern portion of the region, a sizable quantity of groundwater (nearly 30,000 acre-feet) is extracted annually for agricultural and municipal purposes. Groundwater extracted from the Honey Lake Valley Basin accounts for 41,900 acre-feet of the agricultural supply and 12,000 acre-feet of the municipal supply (based on normalized data from 1990). An additional 5,100 acre-feet is extracted to meet the demands of the Honey Lake Wildlife Area, which provides habitat for several threatened species (Bald Eagle, Sandhill Crane, Bank Swallow, and Peregrine Falcon).

Well yields in the Honey Lake Valley Basin are greatest in alluvial and volcanic deposits. Wells drawing from these deposits may have yields that vary from 10 gpm to more than 2,000 gpm, but drawdown in these cases is generally high. Eight wells in the Honey Lake Wildlife Area have an average yield of between 1,200 and 2,100 gpm. Depths of completed wells in the region range from 20 to 720 feet.

The Honey Lake Valley Basin is very close to exceeding prudent perennial yield, and future development could come at the expense of water for agriculture. A 1987 agreement between DWR, the state of Nevada, and the U.S. Geological Survey resulted in a study of the groundwater flow system in eastern Honey Lake Valley. Upon conclusion of the study in September 1990, a Nevada state engineer ruled that only about 13,000 acre-feet could be safely transferred from the basin.

No major changes in water use are anticipated in the near future in the northern portion of the region. Irrigated agriculture is already constrained by economically available water supplies. A small amount of agricultural expansion is expected but only in areas that can support minor additional groundwater development. Likewise, the modest need for additional municipal and irrigation supplies can be met by minor expansion of present surface systems or by increased use of groundwater.

The principal drainages in the southern portion of the region are the Truckee, Walker and Carson rivers. Water rights in these drainages historically have been heavily contested, and allocations are limited by interstate agreements with Nevada, in-stream environmental requirements, and miscellaneous private rights holders. In the Lake Tahoe Basin, further development is strictly limited because of concerns regarding water quality in the lake. Surface water storage developed in the region's drainages provides urban and agricultural supply to the Reno/Sparks area and to the many smaller communities in the eastern Sierra and at the foot of the mountain slopes. Most communities rely on a combination of surface water and groundwater supply.

AR0069808

In the upper Truckee drainage, the primary groundwater basins underlie the areas around Lake Tahoe and Martis Valley, where the Town of Truckee is located. Both areas use surface water and groundwater for urban and surrounding, rural domestic supplies.

Little is known about the small groundwater basins developed along the foot of the eastern Sierra. Most communities overlying these basins are along the streams and rivers flowing down the mountains, and groundwater is extracted from the underlying alluvium. Groundwater augments surface supplies for agricultural purposes and supports municipal and rural domestic supplies.

Groundwater Quality

In basins in the northern portion of the region, groundwater quality ranges widely from excellent to poor. Wells that obtain their water supply from lake deposits can have high concentrations of boron, arsenic, fluoride, nitrate, and TDS. TDS content generally increases toward the central portions of these basins where concentrations have accumulated over time. The groundwater quality along the margins of most of these basins tends to be of much better quality. There is a potential for future groundwater pollution occurring in urban/suburban areas where single-family septic systems have been installed, especially in hard rock areas. Groundwater quality in the alpine basins is good to excellent. And, as in any area where single-family septic systems have been installed, there is potential for degradation of groundwater quality.

Water Quality in Public Supply Wells

From 1994 through 2000, 169 public supply water wells were sampled in 8 of the 26 basins and subbasins in the North Lahontan HR. Evaluation of the analyzed samples indicates that 147 wells, or 87 percent, met the state primary MCLs for drinking water. Twenty-two wells, or 13 percent, have constituents that exceed one or more MCL. Figure 40 shows the percentages of each contaminant group that exceeded MCLs in the 22 wells.

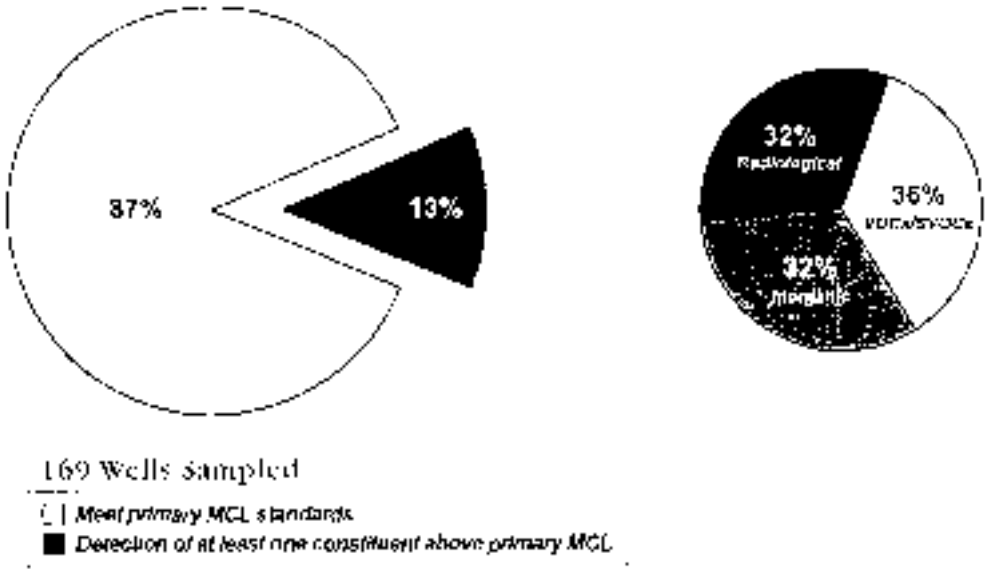

Figure 40 MCL exceedances in public supply wells in the North Lahontan Hydrologic Region

AR0069809

Table 34 lists the three most frequently occurring contaminants in each contaminant group and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 34 Most frequently occurring contaminants by contaminant group in the North Lahontan Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics - Primary	Nitrate - 11	Sulfate - 7	Chloride - 2
Inorganics - Secondary	Iron - 14	Manganese - 10	TDS - 1
Radiologicals	Gross Alpha - 7	Uranium - 5	Radium 226 - 1
VOCs/SVOCs	1,2 Dichloroethane - 8	TCE - 2	MTBE - 1

TCE = trichloroethylene
MTBE = Methyl tert-butyl ether
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound

Changes from Bulletin 118-80

There are no newly defined basins since Bulletin 118-80. The only delineated areas removed from the list of region basins are the Recent and Pleistocene volcanic areas of the Modoc Plateau, previously numbered 6-102 and 6-103, respectively.

AR0069810

Table 35 North Lahontan Hydrologic Region groundwater data

Basin Subregion	Basin Name	Area (acres)	Groundwater Basin Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
6-1	SURPRISE VALLEY	338,000	B	2,000	1,883	10	11	1	374	307 - 1,850
6-2	MADELINE PLAINS	156,800	B		494	1	6	1	410	81 - 1,700
6-3	WILLOW CREEK VALLEY	31,000	B			1	1		401	91 - 1,400
6-4	HONEY LAKE VALLEY	301,150	B	7,500	284	16	24	46	218	98 - 2,200
6-5	LAKE VALLEY									
6-5.01	LAKE VALLEY NORTH	11,900	C	4,000		6		54		79 - 306
6-5.02	LAKE WEST	6,000	C				9	3	152	68 - 1,5
6-5.03	LAKE VALLEY NORTH	2,600	C	900					141	
6-6	CARSON VALLEY	16,700	C							
6-7	ANTELOPE VALLEY	26,100	A					12		
6-8	BRIDGEPORT VALLEY	83,800	C					6		
6-9	MASON VALLEY	25,600	C							
6-10	COWHEAD LAKE VALLEY	6,600	C							
6-11	PINE GROVE VALLEY	9,350	B					1		
6-12	HARVEY VALLEY	4,500	B							
6-13	GRASSHOPPER VALLEY	7,670	B							
6-14	DRY VALLEY	6,200	B							
6-16	EAGLE LAKE AREA		B				2	4		
6-17	HORSE LAKE VALLEY	3,850	B							
6-18	TULELAKE CANYON	6,200	B							
6-19	PAINTERS FLAT	6,400	B							
6-20	SECRET VALLEY	70,950	B			2	2			125 - 1,200
6-21	BULLFLAT	55,130	B							
6-22	LONG VALLEY	46,240	B			11	4		302	27 - 570
6-23	SUNSHARD VALLEY	4,500	C							
6-24	LITTLE ANTELOPE VALLEY	2,500	C							
6-25	SWEETWATER FLAT	4,700	C							
6-26	HUMBOLDT VALLEY	n/a	C	600	330			3		

gpm = gallons per minute
mg/L = milligrams per liter
TDS = total dissolved solids

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AR0069812

South Lahontan Hydrologic Region

AR0069813

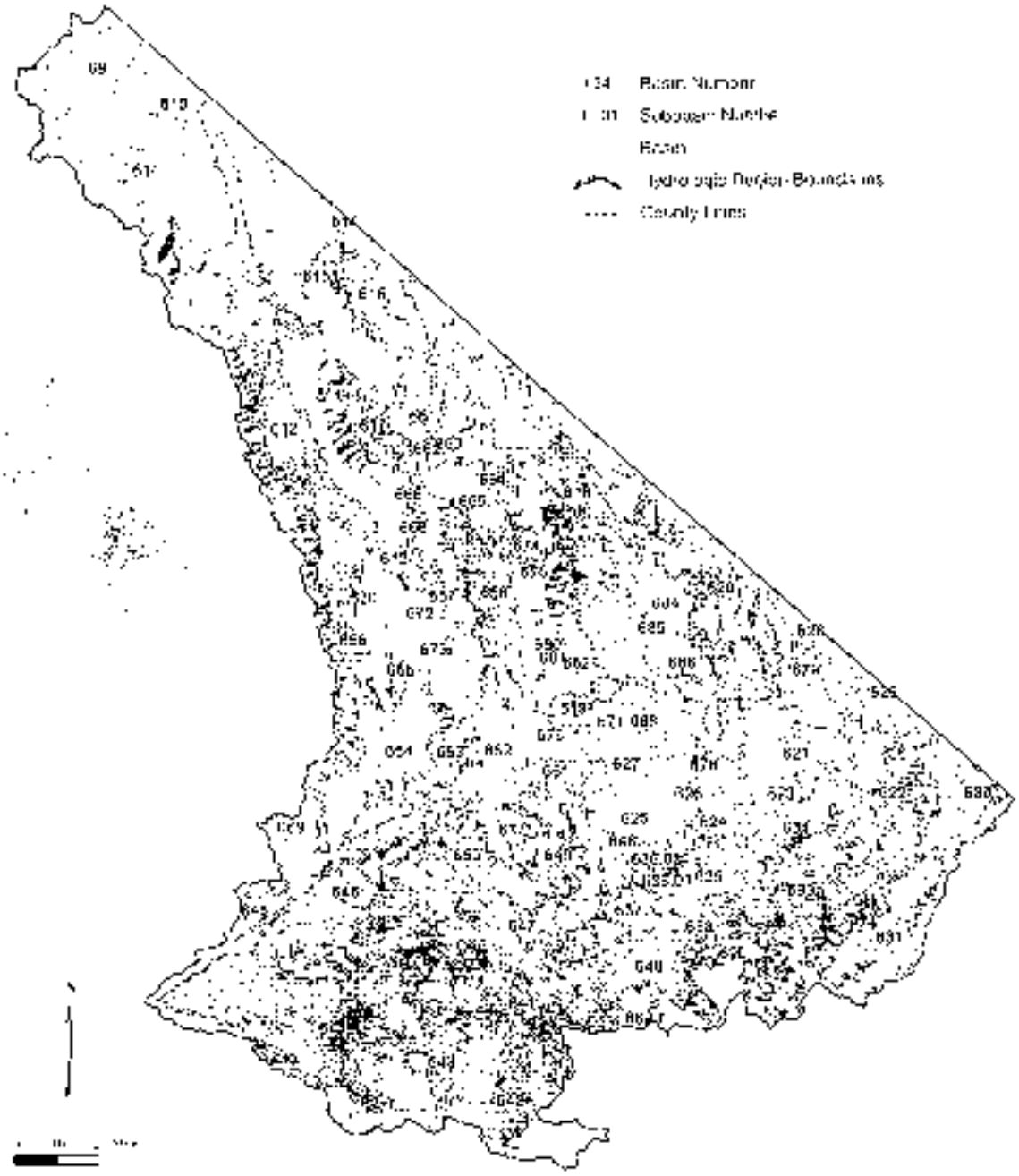

Figure 41 South Lahontan Hydrologic Region

AR0069814

Basins and Subbasins of the South Lahontan Hydrologic Region

Basin/subbasin	Basin name
6-9	Mono Valley
6-10	Adobe Lake Valley
6-11	Long Valley
6-12	Owens Valley
6-13	Black Springs Valley
6-14	Fish Lake Valley
6-15	Deep Springs Valley
6-16	Eureka Valley
6-17	Sylvee Valley
6-18	Death Valley
6-19	Wingate Valley
6-20	Middle Amargosa Valley
6-21	Lower Kingston Valley
6-22	Upper Kingston Valley
6-23	Riggs Valley
6-24	Red Pass Valley
6-25	Bicycle Valley
6-26	Avawatz Valley
6-27	Leach Valley
6-28	Pahrump Valley
6-29	Mesquite Valley
6-30	Ivanpah Valley
6-31	Kelso Valley
6-32	Bicycle Valley
6-33	Soda Lake Valley
6-34	Silver Lake Valley
6-35	Cronise Valley
6-36	Langford Valley
6-36.01	Langford Well Area
6-36.02	Irwin
6-37	Coyote Lake Valley
6-38	Centro Canyon Valley
6-40	Lower Mojave River Valley
6-41	Middle Mojave River Valley
6-42	Upper Mojave River Valley
6-43	Pilot Knob Valley
6-44	Antelope Valley
6-45	Lanfair Valley East
6-46	Fremont Valley
6-47	Harper Valley
6-48	Goldstone Valley
6-49	Superior Valley
6-50	Coolebaugh Valley

Basin/subbasin	Basin name
6-51	Pilot Knob Valley
6-52	Searles Valley
6-53	Salt Wells Valley
6-54	Indian Wells Valley
6-55	Coso Valley
6-56	Rose Valley
6-57	Darwin Valley
6-58	Panamint Valley
6-61	Cuddeback Area
6-62	Rock Creek Valley
6-63	Hidden Valley
6-64	Marble Canyon Area
6-65	Cottonwood Spring Area
6-66	Lee Flat
6-68	Santa Rosa Flat
6-69	Kelso Canyon Valley
6-70	Cactus Flat
6-71	Last Lake Valley
6-72	Coaso Flat
6-73	Wild Horse Mesa Area
6-74	Hamilburg Flats
6-75	Wildrose Canyon
6-76	Brown Mountain Valley
6-77	Tecopa Valley
6-78	Deadman Spring Valley
6-79	Lufkin Valley
6-80	Middle Park Canyon
6-81	Dyne Valley
6-82	Spring Canyon Valley
6-84	Grapevine Valley
6-85	Hazel Valley
6-86	Rhodes Hill Area
6-88	Owl Lake Valley
6-89	Kane Wash Area
6-90	Cady South Area

AR0069815

Description of the Region

The South Lahontan HR covers approximately 21.2 million acres (33,100 square miles) in eastern California. This region includes about 21 percent of the surface area of California and both the highest (Mount Whitney) and lowest (Death Valley) surface elevations of the contiguous United States. The HR is bounded on the west by the crest of the Sierra Nevada and on the north by the watershed divide between Mono Lake and East Walker River drainages; on the east by Nevada and the south by the crest of the San Gabriel and San Bernardino mountains and the divide between watersheds draining south toward the Colorado River and those draining northward. This HR includes the Owens, Mojave, and Amargosa River systems, the Mono Lake drainage system, and many other internally drained basins. Average annual precipitation is about 7.9 inches, and runoff is about 1.3 maf per year (DWR 1994).

The South Lahontan HR includes Inyo County, much of Mono and San Bernardino counties, and parts of Kern and Los Angeles counties (Figure 21). National forests, national and state parks, military bases and other public lands comprise most of the land in this region. The Los Angeles Department of Water and Power is also a major landowner in the northern part of the HR and controls rights to much of the water draining the eastern Sierra Nevada.

According to 2000 census data, the South Lahontan HR is home to about 530,000 people, or 1.6 percent of the state's population. The major population centers are in the southern part of the HR and include Palmdale, Lancaster, Victorville, Apple Valley, and Hesperia.

Groundwater Development

In this report, 79 groundwater basins are delineated in the South Lahontan HR, and the Longford Valley Groundwater Basin (6-36) is divided into two subbasins. The groundwater basins underlie about 11.60 million acres (18,100 square miles) or about 55 percent of the HR.

Most of the groundwater production is concentrated, along with the population, in basins in the southern part of this region. Groundwater provides 41 percent of water supply for agriculture and urban uses (DWR 1998). Much of this HR is public land with very low population density; within these areas there has been little groundwater development and little is known about the basins.

In most smaller basins, groundwater is found in unconfined alluvial aquifers; however, in some of the larger basins, or near dry lakes, aquifers may be separated by aquitards that cause confined groundwater conditions. Depths of the basins range from tens or hundreds of feet in smaller basins to thousands of feet in larger basins. The thickness of aquifers varies from tens to hundreds of feet. Well yields vary in this region depending on aquifer characteristics and well location, size, and use.

Conjunctive use of surface water and groundwater is practiced in the more heavily pumped basins. Some water used in the southern part of the HR is imported from Northern California by the State Water Project. Some of this imported water is used to recharge groundwater in the Mojave River Valley basins (6-40, 6-41, and 6-42). Surface water and groundwater are exported from the South Lahontan HR to the South Coast HR by the Los Angeles Department of Water and Power.

Groundwater Quality

The chemical character of the groundwater varies throughout the region, but most often is calcium or sodium bicarbonate. Near and beneath dry lakes, sodium chloride and sodium sulfate-chloride water is common. In general, groundwater near the edges of valleys contains lower TDS content than water beneath the central part of the valleys or near dry lakes.

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Drinking water standards are most often exceeded for TDS, fluoride, and boron content. The EPA lists 15 sites of contamination in this HR. Of these, three military installations in the Antelope Valley and Mojave River Valley groundwater basins are federal Superfund sites because of VOCs and other hazardous contaminants.

Water Quality in Public Supply Wells

From 1994 through 2000, 605 public supply water wells were sampled in 19 of the 77 basins and subbasins in the South Lahontan HR. Analyzed samples indicate that 506 wells, or 84 percent, met the state primary MCLs for drinking water. Ninety-nine wells, or 16 percent, have constituents that exceed one or more MCL. Figure 42 shows the percentages of each contaminant group that exceeded MCLs in the 99 wells.

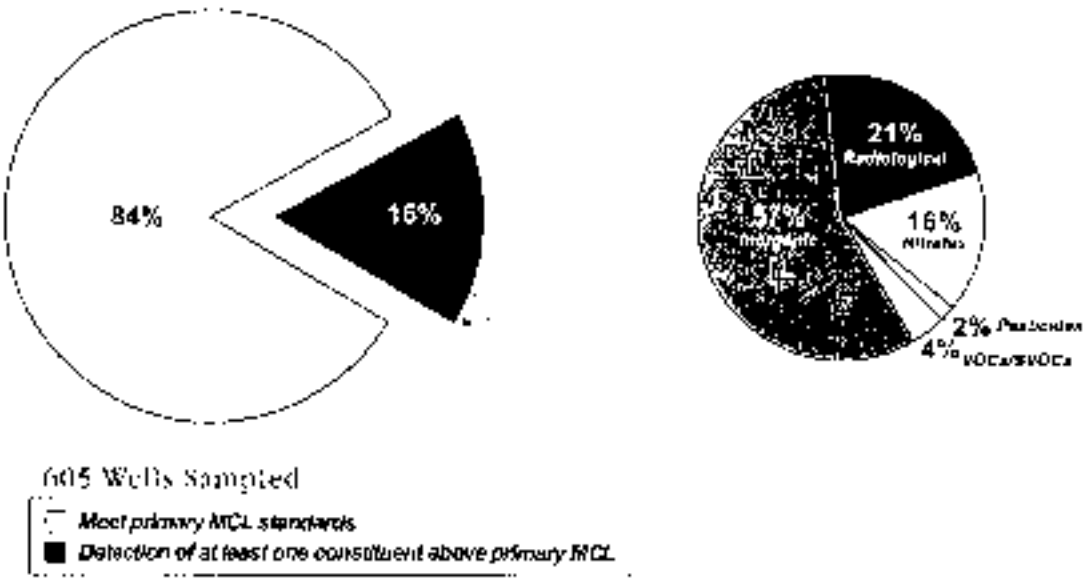

Figure 42 MCL exceedances in public supply wells in the South Lahontan Hydrologic Region

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Table 36 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 36 Most frequently occurring contaminants by contaminant group in the South Lahontan Hydrologic Region

Contaminant group	Contaminant (# of wells)	Contaminant (# of wells)	Contaminant (# of wells)
Inorganics - Primary	Fluoride (6)	Arsenic (19)	Antimony (5)
Inorganics - Secondary	Iron (83)	Manganese (36)	Specific Conductance (5) TDS (5)
Radiological	Gross Alpha (15)	Uranium (7)	Radium 228 (3)
Dissolved Nitrogen	Nitrate (as NO3) (17)	Nitrate + Nitrite (6)	Nitrate (as N) (4)
Pesticides	Di(2-Ethylhexyl)phthalate (2)		
VOCs/SVOCs	MCBF (2)	TCE (2)	Carbon Tetrachloride (2)

TCE = Trichloroethylene
MCBF = Monochlorobenzotrifluoride
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound

Changes from Bulletin 118-80

Several modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report (Table 37). Long Valley Groundwater Basin (6-35) has been divided into two subbasins. Granite Mountain Area (6-59) and Fish Slough Valley (6-60) groundwater basins have been deleted because no information was found concerning wells or groundwater in these basins or because well completion reports indicate that groundwater production is derived from fractured rocks beneath the basins. Furnace Creek Area Groundwater Basin (6-83) has been incorporated into Death Valley Groundwater Basin (6-18), and Butterbread Canyon Valley Groundwater Basin (6-87) has been incorporated into Lost Lake Valley Groundwater Basin (6-71).

Table 37 Modifications since Bulletin 118-80 of groundwater basins and subbasins in South Lahontan Hydrologic Region

Basin/subbasin name	New number	Old number
Long Valley Wells Area	6-35.01	6-35
Swall	6-35.02	6-35
Tipy Valley	Incorporated into 6-40 and 7-14	6-39
Granite Mountain Area	Deleted	6-59
Fish Slough Valley	Deleted	6-60
Furnace Creek Area	Deleted - incorporated into 6-18	6-83
Butterbread Canyon Valley	Deleted - incorporated into 6-71	6-87

AR0069818

Troy Valley Groundwater Basin (6-39) has been split at the Pisgah fault, which is a groundwater barrier, and has been incorporated into Lower Mojave River Valley (6-40) and Lavic Valley (7-14) groundwater basins. This change incorporates part of the South Lahontan HR into a basin in the Colorado River HR[1]. The Middle Mojave River Valley Groundwater Basin (6-41) has changed boundaries along the north (Harper Valley, 6-42) and east sides (Lower Mojave River Valley, 6-40). The new boundaries are along the Camp Rock-Harper Lake fault zone, Waterman fault, and Helendale fault. Groundwater level elevations indicate that these faults are likely strong barriers to groundwater movement.

The boundary between the Upper Mojave River Valley Groundwater Basin (6-42) and the Lucerne Valley Groundwater Basin (7-19) was changed from the regional surface divide to the southern part of the Helendale fault, which is a groundwater barrier. This change incorporates part of the Colorado Desert HR into a basin in the South Lahontan HR[1].

[1] The boundaries of the hydrologic regions are defined by surface drainage patterns. In this case, faults impede groundwater flow causing it to flow beneath the surface drainage divide into the adjacent hydrologic region.
[2] See previous note.

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Table 38 South Lahontan Hydrologic Region groundwater data

Basin No.-Subbasin	Basin Name	Area (acres)	Groundwater Basket Type	Well Yields (gpm)		Types of Measurements			TDS (mg/L)	
				Maximum	Average	Levels	Qual. C.	Title 22	Average	Range
6-09	MOJAVE VALLEY	172,000	A	800	450					206-
6-10	ADELANTO VALLEY	49,800	C							
6-11	LOCKE VALLEY	31,800	A	250	90	20		4		
6-12	OAVINS VALLEY	661,000	A	1,100	1,250	240	7	89		360-49 500
6-13	BLACK SPRINGS VALLEY	9,800	C							
6-14	FISH LAKE VALLEY	48,100	C							
6-15	DEEP SPRINGS VALLEY	45,900	C	70	220					
6-16	EUREKA VALLEY	120,000	C							
6-17	SALINE VALLEY	146,000	C							
6-18	DEATH VALLEY	921,600	C			28		9		
6-19	WILDCAT VALLEY	1,400	C							
6-20	MIDDLE AMARGOSA VALLEY	94,000	B	1,100	1,900			4		
6-21	LOWER KINGSTON VALLEY	28,700	C							
6-22	UPPER KINGSTON VALLEY	120,000	C	25				4		
6-23	ALKALI VALLEY	87,000	C							
6-24	RED PASS VALLEY	46,300	C							
6-25	TIKAPOO VALLEY	56,000	C	710			12	9	618	364-810
6-26	AVAWATZ VALLEY	85,000	C							
6-27	DEATH VALLEY	1,300	C							
6-28	PANAMINT VALLEY	52,100	C	810	450					
6-29	MESQUITE VALLEY	92,800	B	1,800	700					
6-30	IVANPAH VALLEY	199,000	C	600	400			9		
6-31	EMIGRANT VALLEY	171,000	C	550	240					
6-32	BROADWELL VALLEY	92,000	C							
6-33	SODA DRY LAKE VALLEY	85,000	C	2,700	1,100			7		
6-34	SILURIA LAKE VALLEY	15,300	C							
6-35	CRONISE VALLEY	127,000	B	610	350					
6-36	LANGFORD VALLEY									
6-36.01	LANGFORD WELL FIELD	70,000	C	1,700	1,200	11		2	450	440-460
6-36.02	IRWIN	10,600	C	550		40		1	920	696-920
6-37	LUCERNE LAKE VALLEY	88,200	A	710	660	5		4		300-1000
6-38	HAYES CANYON VALLEY	75,100	A	810				4		200 800
6-39	LOWER MOJAVE RIVER VALLEY	289,000	A	2,000	750	20	11	52	370	
6-41	MIDDLE MOJAVE RIVER VALLEY	21,300	A	1,000	1,000	24		14	490	
6-42	UPPER MOJAVE RIVER VALLEY	316,000	A	5,500	1,050	120	32	52	520	120-
6-43	HARPER VALLEY	79,000	A	1,000	250	60	3	2		
6-44	ANTELOPE VALLEY	1,110,000	A	1,500	750	240	30	244	500	2.00 900
6-45	FELICIANO VALLEY EAST	22,000	C	90	50	50		9	550	500-610
6-46	FREMONT VALLEY	1,070,000	C	1,000	600	25		12	960	350 800-1,000
6-47	HARPER VALLEY	410,000	A	3,000	750	11		35		1,00 1,250
6-48	GOLDSTONE VALLEY	28,100	C							
6-50	SUPERIOR VALLEY	120,000	C	350	100					

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Table 38 South Lahontan Hydrologic Region groundwater data (continued)

Basin & Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Observations			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Both	Average	Range
6-50	CHOCOLATE VALLEY	64,000	C	500	300					
6-51	PILOT KNOB VALLEY	29,000	C							
6-52	SEARLES VALLEY	93,000	C	1,000	500					
6-53	SALTWELL SPRINGS VALLEY	39,500	C							
6-54	INDIAN WELLS VALLEY	352,000	A	1,800	815	116	39	61	512	176-1,026
6-55	COSO VALLEY	77,000	C							
6-56	ROSE VALLEY	47,500	C							
6-57	HADLEY VALLEY	44,000	C	150	25					
6-58	PANAMINT VALLEY	254,000	C	25	10					
6-59	CAMEO AREA	6,500	C							
6-60	SAMUELS ROCK VALLEY	47,000	C							
6-61	HIDDEN VALLEY	8,000	C							
6-62	MARBLE CANYON AREA	16,000	C							
6-63	COTTONWOOD SPRING AREA	3,000	C							
6-64	LAKE CAL	29,000	C							
6-65	SANTA ROSA FLAT	500	C							
6-66	KEYSTONE SPRING VALLEY	11,000	C							
6-67	CACTUS FLAT	7,000	C							
6-68	LOST CABIN VALLEY	23,000	C							
6-69	COLES FLAT	2,000	C							
6-70	WILD HORSE MESA AREA	1,000	C							
6-71	HARRISBURG FLATS	24,000	C							
6-72	WILDROSE CANYON	5,000	C							
6-73	BROWNS MOUNTAIN VALLEY	1,000	C							
6-74	GRAPEVINE VALLEY	9,000	C							
6-75	DENNING SPRING VALLEY	2,000	C							
6-76	CALIFORNIA VALLEY	35,000	C							
6-77	MIDDLE PARK CANYON	1,000	C							
6-78	BUTTE VALLEY	8,000	C							
6-79	ANVIL SPRING CANYON VALLEY	4,000	C							
6-80	CRUTCHER VALLEY	59,000	C							
6-81	COLD VALLEY	2,000	C							
6-82	RHODES HILL AREA	15,000	C							
6-83	OWL LAKE VALLEY	23,000	C							
6-84	KANSAS HILL AREA	5,000	C	60						
6-85	CADY MOUNTAIN AREA	2,000	C							

gpm = gallons per minute
mg/L = milligrams per liter
TDS = total dissolved solids

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Colorado River Hydrologic Region

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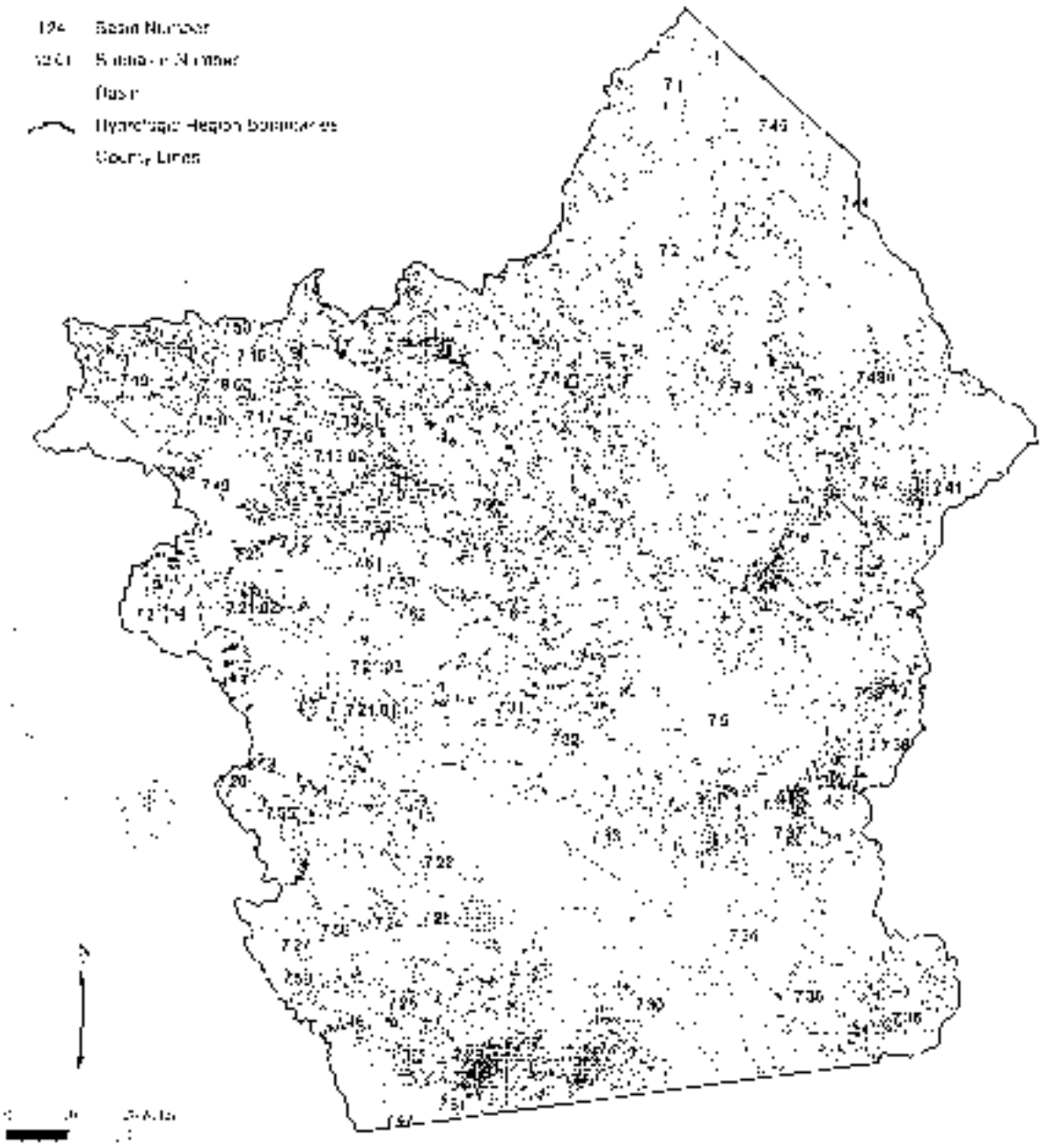

Figure 43 Colorado River Hydrologic Region

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Basins and Subbasins of Colorado River Hydrologic Region

Basin/subbasin		Basin name
7-1		Lee Ferry Valley
7-2		Upper Valley
7-3		Virgin Valley
7-4		Muddy Valley
7-5		Las Vegas Valley
7-6		Pahrump Valley
7-7		Death Valley
7-8		Bristol Valley
7-9		Dale Valley
7-10		Twentynine Palms Valley
7-11		Copper Mountain Valley
7-12		Warren Valley
7-13		Deadman Valley
	7-13.01	Deadman Lake
	7-13.02	Surprise Spring
7-14		Lavic Valley
7-15		Bessemer Valley
7-16		Ames Valley
7-17		Means Valley
7-18		Johnson Valley Area
	7-18.01	Silver Lake
	7-18.02	Upper Johnson Valley
7-19		Lucerne Valley
7-20		Morongo Valley
7-21		Coachella Valley
	7-21.01	Indio
	7-21.02	Mission Creek
	7-21.03	Desert Hot Springs
	7-21.04	San Gorgonio Pass
7-22		West Salton Sea
7-24		Borrego Valley
7-25		Ocotillo-Clark Valley
7-26		Imperial Valley
7-27		San Felipe Valley
7-28		Vallecito-Carrizo Valley
7-29		Coyote Wells Valley
7-30		Imperial Valley
7-31		Ocotillo Valley
7-32		Chocolate Valley
7-33		East Salton Sea
7-34		Arroyo Valley
7-35		Dunaby Valley

Basin/subbasin	Basin name
7-36	Yuma Valley
7-37	Arroyo Seco Valley
7-38	Palo Verde Valley
7-39	Palo Verde Mesa
7-40	Ogilby Slope Point Valley
7-41	Cibola Valley
7-42	Vidal Valley
7-43	Chemehuevi Valley
7-44	Needles Valley
7-45	Piute Valley
7-46	Chemehuevi Valley
7-47	Hayfield Valley
7-48	Helendale Fault Valley
7-49	Paleo Canyon Fault Valley
7-50	Iron Ridge Area
7-51	Last Chance Valley
7-52	Pinto Valley
7-53	Bessie Mountain Area
7-54	Bullion Ridge Fault Valley
7-55	Collins Valley
7-56	Yuqui Well Area
7-57	Mason Valley
7-61	Dale Lake Valley
7-62	Joshua Tree
7-63	Warren Valley FDA

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Description of the Region

The Colorado River HR covers approximately 13 million acres (20,000 square miles) in southeastern California. It is bounded on the east by Nevada and Arizona, the south by the Republic of Mexico, the west by the Laguna, San Jacinto, and San Bernardino mountains, and the north by the New York, Providence, Granite, Old Dad, Bristol, Rodman, and Ord Mountain ranges. An average annual precipitation of 5.5 inches and average annual runoff of only 200,000 acre-feet makes this the most arid HR of California (DWR 1994). Surface runoff drains to many closed basins or to the Colorado River.

This HR includes all of Imperial, most of Riverside, much of San Bernardino, and part of San Diego counties (Figure 43). Many of the alluvial valleys in the region are underlain by groundwater aquifers that are the sole source of water for local communities.

About 533,000 people live within the Colorado River HR (DWR 1998). The largest population centers are Palm Springs, Palm Desert, Indio, Coachella, and El Centro.

Groundwater Development

The earliest groundwater development in California may have been prehistoric water wells dug by the Cahuilla Indians in Coachella Valley of the Colorado River HR. In this report, 64 groundwater basins/subbasins are delineated in this HR. The Deadman Valley, Johnson Valley Area, and Coachella Valley groundwater basins have been divided into subbasins. Groundwater basins underlie about 8,68 million acres or about 26 percent of this HR.

In the Colorado River HR, groundwater provides about 8 percent of the water supply in normal years for agricultural and urban uses (DWR 1998). In most smaller basins, groundwater is found in unconfined alluvial aquifers. In some of the larger basins, particularly near dry lakes, aquifers may be separated by aquitards that create confined groundwater conditions. Depths of basins range from tens or hundreds of feet in smaller basins and along arms of ephemeral rivers to thousands of feet in larger basins. The thickness of aquifers varies from tens to hundreds of feet. Well yields vary in this region depending on aquifer characteristics and well location, size, and use. Some aquifers are capable of yielding thousands of gallons per minute to municipal wells.

Conjunctive use of surface water and groundwater is a long-standing practice in the region. Water is imported from the Colorado River for irrigation in Imperial, Coachella, and Palo Verde Valleys and from groundwater recharge in Coachella Valley. Water imported from Northern California is used to replenish Warren and Joshua Tree groundwater basins. Many agencies have erected systems of barriers to allow more efficient percolation of ephemeral runoff from surrounding mountains. The concept of utilizing groundwater basins in this sparsely populated HR for storing water that would be pumped during drought years is getting much attention.

Groundwater Quality

The chemical character of groundwater in the Colorado River HR is variable. Cation concentration is dominated by sodium with calcium common and magnesium appearing less often. Bicarbonate is usually the dominant anion, although sulfate and chloride waters are also common. In basins with closed drainages, water character often changes from calcium-sodium bicarbonate near the margins to sodium chloride or chloride sulfate beneath a dry lake. It is not uncommon for concentrations of dissolved constituents to rise dramatically toward a dry lake where saturation of mineral salts is reached. An example of this is found at Bristol Valley Groundwater Basin, where the mineral halite (sodium chloride) is formed and then mined by

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evaporation of groundwater in trenches in Bristol (dry) Lake. The TDS content of groundwater is high in many of the basins in this region. High fluoride content is common; sulfate content occasionally exceeds drinking water standards; and high nitrate content is common, especially in agricultural areas.

Two of the primary challenges in the Colorado River HR are overdraft in the Coachella Valley and leaking underground storage tanks. The EPA has not yet placed any contamination sites in this HR on the Superfund National Priorities List; however, one site is under consideration because of high pesticide levels.

Water Quality in Public Supply Wells

From 1994 through 2000, 214 public supply water wells were sampled in 23 of the 64 basins and subbasins in the Colorado River HR. Analyzed samples indicate that 270 wells, or 86 percent, met the state primary MCLs for drinking water standards. Forty-four wells, or 14 percent, have constituents that exceed one or more MCL. Figure 44 shows the percentages of each contaminant group that exceeded MCLs in the 44 wells.

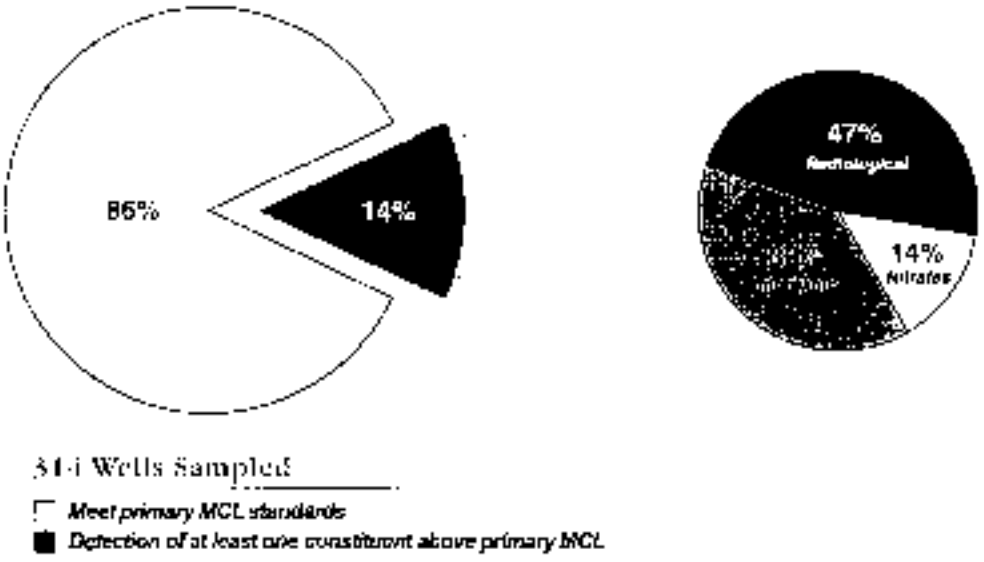

Figure 44 MCL exceedances in public supply wells in the Colorado River Hydrologic Region

Table 39 lists the three most frequently occurring contaminants in each contaminant group and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 39 Most frequently occurring contaminants by contaminant group in the Colorado River Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics - Primary	Fluoride - 17		
Inorganics - Secondary	Iron - 38	Manganese - 35	TDS - 5
Radiological	Radium 228 - 5	Combined RA226 + RA228 - 3	Radium 226 - 1
Nutrients	Nitrate as NO3 - 6	Nitrate + Nitrite - 1	

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Changes from Bulletin 118-80

Several modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report (Table 40). Lucerne Valley East Groundwater Basin (7-60) has been deleted because of lack of information about groundwater in this basin. The Pinyon Wash Area (7-57) and Whale Peak Area (7-58) groundwater basin names have been deleted because they are now incorporated into other larger basins. Similarly, Clark Valley (7-22) and Ocotillo Valley (7-23) groundwater basins are now the combined Ocotillo-Clark Valley Groundwater Basin (7-25). The Deadman Valley (7-13), Johnson Valley Area (7-18), and Coachella Valley (7-21) groundwater basins have been subdivided into subbasins in this report. The western boundary of Lucerne Valley Groundwater Basin (7-19) has been moved eastward from the HR boundary to the Helendale Fault. Groundwater level elevations indicate that this fault is a groundwater barrier and that groundwater flows westward back under the surface divide into the Upper Mojave River Groundwater Basin (6-42). The boundary between Lucerne Valley (7-19) and Johnson Valley Area (7-18) groundwater basins is delineated in this report.

The boundaries of Twentynine Palms Valley (7-10), Copper Mountain Valley (7-11), Warren Valley (7-12), Deadman Lake (7-13), and Ames Valley (7-16) groundwater basins have been redrawn in light of newer groundwater level data. These data indicate that the Pinto Mountain fault is a groundwater barrier. Joshua Tree Groundwater Basin (7-62) is a new basin that has been delineated from parts of Copper Mountain Valley and Twentynine Palms Valley Groundwater Basins because the Pinto Mountain fault is such a strong barrier. Buck Ridge Fault Valley Groundwater Basin (7-64) was presented in Bulletin 118-80 as two unconnected deposits of water-bearing alluvium separated by outcrop of nonwater-bearing rocks. These water-bearing deposits have been designated as separate groundwater basins in this report, with the Buck Ridge Fault Valley Groundwater Basin (7-64) as the northern basin and Vandeventer Flat Groundwater Basin (7-63) presented as the southern basin.

Table 40 Modifications since Bulletin 118-80 of Groundwater Basins in Colorado River Hydrologic Region

Basin name	New number	Old number
Clark Valley	Deleted - combined with 7-25	7-22
Ocotillo-Clark Valley	7-25 (now combined)	7-25
Pinyon Wash Area	Incorporated into 7-56	7-57
Whale Peak Area	Incorporated into 7-28	7-58
Lucerne Valley East	Deleted	7-60
Joshua Tree	7-62 (new)	
Vandeventer Flat	7-63 (new)	

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Table 41 Colorado River Hydrologic Region groundwater data

Basin Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Water Volume (acre-feet)		Years of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
7-1	LANCASTER VALLEY	157,000	C	70	16	-	-	0	547	170-2,250
7-2	ANTELOPE VALLEY	474,000	A	200	100	-	-	0	815	131-2,700
7-3	WARD VALLEY	961,000	A	260	240	-	-	-	-	327-659
7-4	JOSHUA VALLEY	189,000	C	65	-	-	-	-	-	-
7-5	OTHO/VALLA VALLEY	193,000	C	2,980	1,360	13	-	6	-	224
7-6	PINTO VALLEY	183,000	A	1,450	600	-	-	1	-	-
7-7	CADIZ VALLEY	270,080	C	167	66	-	-	-	400	300-3000
7-8	BRISTOL VALLEY	498,000	A	3,000	-	-	-	-	-	300-208,000
7-9	DALE VALLEY	213,000	C	280	225	-	-	2	-	-
7-10	TWENTYNINE PALMS VALLEY	63,480	C	3,080	540	25	-	1	650	-
7-11	COPPER MOUNTAIN VALLEY	80,393	A	3,450	240	-	-	-	-	130-214
7-12	WARREN VALLEY	17,200	A	4,000	350	22	14	19	451	130-250
7-13	DEADMAN VALLEY									
7-13.01	DEADMAN LAKE	80,200	C	3,000	-	25	1	-	-	1,450
7-13.02	SURPRISE SPRING	29,200	C	1,370	650	26	4	4	1,250	141-1,050
7-14	LANIC VALLEY	102,000	C	150	80	-	-	-	-	-
7-15	BESSEMER VALLEY	89,100	C	0	-	-	-	-	-	-
7-16	AMES VALLEY	120,000	C	3,000	-	12	1	17	450	-
7-17	MEANS VALLEY	15,000	C	0	-	1	-	-	-	-
7-18	JOHNSON VALLEY AREA									
7-18.01	BORAX LAKE	74,800	C	-	-	5	-	-	-	900-2,900
7-18.02	UPPER JOHNSON VALLEY	91,800	C						-	3,000
7-19	LUCERNE VALLEY	144,000	A	4,000	-	27	11	21	301	200-5,000
7-20	SUPRISE VALLEY	3,240	C	600	90	-	-	-	-	-
7-21	COACHELLA VALLEY									
7-21.01	INDIO	210,880	A	1,880	350	30	-	201	700	-
7-21.02	MISSION CREEK	49,000	A	1,500	775	5	-	5	2500	-
7-21.03	DESERT HOT SPRINGS	102,000	C	2,700	450	20	-	5	-	600-1,000
7-21.04	SAN GORGONIO PASS	98,200	A	1,000	0	12	5	5	-	104-705
7-22	WEST SALTON SEA	64,000	C	540	450	5	-	-	-	-
7-23	BORREGO VALLEY	51,000	A	2,000	0	0	10	25	-	300-2,440
7-24	COYOTE CLARK VALLEY	23,000	C	3,500	1,150	1	-	2	-	-
7-25	HERWICK IDA VALLEY	4,610	C	700	-	-	-	1	-	509
7-26	SAN FELIPE VALLEY	9,940	C	900	50	-	-	1	-	-
7-27	VALLECITO/CARRIZO VALLEYS	125,000	C	1,500	250	-	-	1	-	-
7-28	COYOTE WELLS VALLEY	24,000	A	-	-	25	6	8	-	-
7-29	IMPERIAL VALLEY	593,000	A	1,000	-	14	-	45	1098	695-1,250
7-30	OCOTILLO/OCOTILLO WELLS	56,300	A	210	105	0	-	1	-	-
7-31	CHOCOLATE VALLEY	130,000	C	0	0	0	-	-	-	-
7-32	EAST SALTON SEA	96,000	C	0	0	1	-	-	-	-
7-33	AMOS VALLEY	30,000	C	100	50	3	-	1	-	-
7-34	ORO GRANDE VALLEY	141,000	C	4,000	50	27	-	2	-	-

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Table 41 Colorado River Hydrologic Region groundwater data (continued)

Basin/Subbasin #	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Level	Quality	Title 22	Average	Range
7.16	YUCCA VALLEY	7,700	C	700	40	59	3	15	-	-
7.17	ARROYO SECO VALLEY	258,000	C			2	0	1	-	-
7.18	PALO VERDE VALLEY	71,600	A			11		10	861	(435-1,050)
7.19	PALO VERDE MESA	236,000	C	1,350	1,000	20	-	15	-	-
7.20	QUECHAN INDIAN VALLEY	15,300	C	75	-	-	-	3	-	-
7.21	CALZONA VALLEY	81,000	C	1,100	200	0	0	0	-	-
7.22	VIDAL VALLEY	115,600	C	1,600	700	-	-	1	-	-
7.23	CHEMEHUEVI VALLEY	71,200	A	0	0	1	0	1	-	-
7.24	NEEDLES VALLEY	88,100	A	1,960	980	31	-	11	-	-
7.25	PIUTE VALLEY	176,000	C	1,000	200	-	-	-	-	-
7.26	CANEBRAKE VALLEY	5,100	C	175	-	-	-	-	-	-
7.27	COLUMBIA VALLEY	3,500	A	1,000	-	-	-	0	-	296 (-,-)
7.28	HELENDALE-FAIRVIEW VALLEY	7,600	C	-	-	-	-	-	-	-
7.29	DEEP CANYON-FAIRVIEW VALLEY	1,100	C	-	-	-	-	-	-	-
7.30	IRON RIDGE AREA	5,200	C	-	-	-	-	-	-	-
7.31	LOST HORSE VALLEY	12,300	C	-	-	-	-	-	-	-
7.32	PLEASANT VALLEY	9,600	C	-	-	-	-	-	-	-
7.33	HEXIE MOUNTAIN AREA	11,200	C	-	-	-	-	-	-	-
7.34	BUCKTHORN-FAIRVIEW VALLEYS	6,900	C	-	-	-	-	-	-	-
7.35	COLLINS VALLEY	7,000	C	1,200	-	-	-	-	-	-
7.36	WAGON WHEEL AREA	15,000	C	0				1		
7.37	HAYFIELD VALLEY	5,550	C	0	0	0	0	1	-	-
7.38	LAVIC VALLEY	5,600	C	0	0	0	0	0	-	-
7.39	JOSHUA TREE	31,900	A	2,200	1,110	25	5	14	186	(27-418)
7.40	VANDENBERG AFB	6,750	C	90	12	-	-	-	-	-

gpm: gallons per minute
mg/L: milligrams per liter
Dry: total flow/col subjs

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Glossary

Glossary

A

acre-foot (af) The volume of water necessary to cover one acre to a depth of one foot, equal to 43,560 cubic feet or 325,851 gallons.

adjudication A case that has been heard and decided by a judge. In the context of an adjudicated groundwater basin, landowners or other parties have turned to the courts to settle disputes over how much groundwater can be extracted by each party to the decision.

alluvial Of or containing to or composed of alluvium.

alluvium A general term for clay, silt, sand, gravel or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, as a cone or fan at the base of a mountain slope.

anthropogenic Of human origin or resulting from human activity.

appropriative right The right to use water that is diverted or extracted by a nonriparian or nonoverlying party for nonriparian or nonoverlying uses. In California, surface water appropriative rights are subject to a statutory permitting process while groundwater appropriation is not.

aquitard A confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores ground water.

aquifer A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs.

aridity A term describing a climate or region in which precipitation is so deficient in quantity or occurs so infrequently that intensive agricultural production is not possible without irrigation.

artesian aquifer A body of rock or sediment containing groundwater that is under greater than hydrostatic pressure; that is, a confined aquifer. When an artesian aquifer is penetrated by a well, the water level will rise above the top of the aquifer.

artesian pressure Hydrostatic pressure of artesian water, often expressed in terms of pounds per square inch or the height, in feet above the land surface, of a column of water that would be supported by the pressure.

artificial recharge The addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells.

available groundwater storage capacity The volume of a groundwater basin that is unsaturated and capable of storing groundwater.

average annual runoff The average value of total annual runoff volume calculated for a selected period of record, at a specified location, such as a dam or stream gage.

average year water demand Demand for water under average hydrologic conditions for a defined level of development.

AR0069836

B

basin management objectives (BMOs) See management objectives

beneficial use One of many ways that water can be used either directly by people or for their overall benefit. The State Water Resources Control Board recognizes 23 types of beneficial use with water quality criteria for those uses established by the Regional Water Quality Control Boards.

borehole geophysics The general field of geophysics developed around the lowering of a variety of probes into a boring or well. Borehole logging provides additional information concerning physical, electrical, acoustic, nuclear and chemical aspects of the soils and rock encountered during drilling.

C

community water system A public water system that serves at least 15 service connections used by year-long residents or regularly serves at least 25 year-long residents (DDS 2000).

confined aquifer An aquifer that is bounded above and below by formations of distinctly lower permeability than that of the aquifer itself. An aquifer containing confined ground water. See artesian aquifer.

conjunctive use The coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resources; that is, the planned and managed operation of a groundwater basin and a surface water storage system, combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply.

contaminant Any substance or property present in the use or reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing, washing, recreation, and cooling. Any solute or cause of change in physical properties that renders water unfit for a given use. (Generally considered synonymous with pollutant).

critical conditions of overdraft A groundwater basin in which continuation of present practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts. The definition was created after an extensive public input process during the development of the Bulletin 118-80 report.

D

deep percolation Percolation of water through the ground and beyond the lower limit of the root zone of plants into groundwater.

desalination A process that converts seawater or brackish water to fresh water or an otherwise more usable condition through removal of dissolved solids.

domestic well A water well used to supply water for the domestic needs of an individual residence or systems of four or fewer service connections.

drinking water system See public water system.

drought condition Hydrologic conditions during a defined period when rainfall and runoff are much less than average.

drought year supply The average annual supply of a water development system during a defined drought period.

AR0069837

E

electrical conductivity (EC) The measure of the ability of water to conduct an electrical current, the magnitude of which depends on the dissolved mineral content of the water.

effective porosity The volume of voids or open spaces in alluvium and rocks that is interconnected and can transmit fluids.

environmental water Water serving environmental purposes, including instream fishery flow needs, wild and scenic river flows, water needs of fresh-water wetlands, and Bay Delta requirements.

evapotranspiration (ET) The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

G

groundwater basin An alluvial aquifer or interlocked series of alluvial aquifers with reasonably well defined boundaries in a lateral direction and having a definable bottom.

groundwater budget A numerical accounting, the *groundwater equation*, of the recharge, discharge and changes in storage of an aquifer, part of an aquifer, or a system of aquifers.

groundwater in storage The quantity of water in the zone of saturation.

groundwater management The planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource.

groundwater management plan A comprehensive written document developed for the purpose of groundwater management and adopted by an agency having appropriate legal or statutory authority.

groundwater mining The process, deliberate or inadvertent, of extracting groundwater from a source at a rate in excess of the replenishment rate such that the groundwater level declines persistently, threatening exhaustion of the supply or at least a decline of pumping levels to uneconomic depths.

groundwater monitoring network A series of monitoring wells at appropriate locations and depths to effectively cover the area of interest. Scale and density of monitoring wells is dependent on the size and complexity of the area of interest, and the objective of monitoring.

groundwater overdraft The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average conditions.

groundwater quality See water quality.

groundwater recharge facility A structure that serves to conduct surface water into the ground for the purpose of replenishing groundwater. The facility may consist of dug or constructed spreading basins, pits, ditches, furrows, streambed modifications, or injection wells.

groundwater recharge The natural or intentional infiltration of surface water into the zone of saturation.

groundwater source area An area where groundwater may be found in economically retrievable quantities outside of normally defined groundwater basins, generally referring to areas of fractured bedrock in foothill and mountainous terrain where groundwater development is based on successful well penetration through interconnecting fracture systems. Well yields are generally lower in fractured bedrock than wells within groundwater basins.

AR0069838

groundwater storage capacity Volume of void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin.

groundwater subbasin A subdivision of a groundwater basin created by dividing the basin using geologic and hydrologic conditions or institutional boundaries.

groundwater table The upper surface of the zone of saturation in an unconfined aquifer.

groundwater Water that occurs beneath the land surface and fills the pore spaces of the alluvium, soil, or rock formation in which it is situated. It excludes soil moisture, which refers to water held by capillary action in the upper unsaturated zones of soil or rock.

H

hazardous waste Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive or has some other property that produces substantial risk to life.

hydraulic barrier A barrier created by injecting fresh water to control seawater intrusion in an aquifer, or created by water injection to control migration of contaminants in an aquifer.

hydraulic conductivity A measure of the capacity for a rock or soil to transmit water; generally has the units of feet/day or cm/sec.

hydrograph A graph that shows some property of groundwater or surface water as a function of time.

hydrologic cycle The circulation of water from the ocean through the atmosphere to the land and ultimately back to the ocean.

hydrologic region A study area consisting of multiple planning subareas. California is divided into 10 hydrologic regions.

hydrostratigraphy A geologic framework consisting of a body of rock having considerable lateral extent and composing a reasonably distinct hydrologic system.

hyporheic zone The region of saturated sediments beneath and beside the active channel and that contains some proportion of surface water that was part of the flow in the surface channel and went back underground and is mixing with groundwater.

I

infiltration The flow of water downward from the land surface into and through the upper soil layers.

infiltration capacity The maximum rate at which infiltration can occur under specific conditions of soil moisture.

in-lieu recharge The practice of providing surplus surface water to historic groundwater users, thereby leaving groundwater in storage for later use.

ISI Integrated Storage Investigations Program, an element of the CALFED Bay Delta Program.

J

joint powers agreement (JPA) An agreement entered into by two or more public agencies that allows them to jointly exercise any power common to the contracting parties. The JPA is defined in Chapter 5 (commencing with Section 6500) of Division 7 of Title 1 of the California Government Code.

L

land subsidence The lowering of the natural land surface due to groundwater (or oil and gas) extraction.

AR0069839

leaky confining layer A low-permeability layer that can transmit water at sufficient rates to furnish some recharge from an adjacent aquifer to a well.

lithologic log A record of the lithology of the soils, sediments and/or rocks encountered in a borehole from the surface to the bottom.

lithology The description of rocks, especially in hand specimen and in outcrop, on the basis of such characteristics as color, mineralogic composition, and grain size.

losing stream A stream or reach of a stream that is losing water by seepage into the ground.

M

management objectives Objectives that set forth the priorities and measurable criteria of local groundwater basin management. For example, one management objective could be to minimize degradation of groundwater quality with a criteria set that groundwater will not be degraded by more than 100 mg/l in terms of TDS.

maximum contaminant level (MCL) The highest drinking water contaminant concentration allowed under federal and State Safe Drinking Water Act regulations.

N

natural recharge Natural replenishment of an aquifer generally from snowmelt and runoff through seepage from the surface.

nonpoint source Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, etc., carried to lakes and streams by surface runoff.

O

operational yield An optimal amount of groundwater that should be withdrawn from an aquifer system or a groundwater basin each year. It is a dynamic quantity that must be determined from a set of alternative groundwater management decisions subject to goals, objectives, and constraints of the management plan.

ordinance A law set forth by a governmental authority.

overdraft See groundwater overdraft.

overlying right Property owners above a common aquifer possess a mutual right to the reasonable and beneficial use of a groundwater resource on land overlying the aquifer from which the water is taken. Overlying rights are correlative (related to each other) and overlying users of a common water source must share the resource on a pro rata basis in times of shortage. A proper overlying use takes precedence over all non-overlying uses.

P

perched groundwater Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater.

perennial yield The maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time (during which water supply conditions approximate average conditions) without developing an overdraft condition.

perforated interval The depth interval where slotted casing or screen is placed in a well to allow entry of water from the aquifer formation.

AR0069840

permeability The capability of soil or other geologic formations to transmit water. See hydraulic conductivity.

pesticide Any of a class of chemicals used for killing insects, weeds or other undesirable entities. Most commonly associated with agricultural activities, but has significant domestic use in California.

point source A specific site from which wastewater or polluted water is discharged into a water body.

pollution (of water) The alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.

porosity The ratio of the voids or open spaces in alluvium and rocks to the total volume of the alluvium or rock mass.

possible contaminating activity (PCA) Human activities that are actual or potential origins of contamination for a drinking water source. PCAs include sources of both microbiological and chemical contaminants that could have an adverse effect upon human health (DHS 2000).

potentiometric surface The surface to which the water in a confined aquifer will rise in a tightly cased well.

prescriptive right rights obtained through the open and notorious adverse use of another's water rights. By definition, adverse use is not use of a surplus, but the use of some surplus water to the direct detriment of the original rights holder.

primary porosity Voids or open spaces that were present when alluvium and rocks were originally deposited or formed.

public supply well A well used as a part of a public water system.

public water system A system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year. (DHS 2000)

pueblo right A water right possessed by a municipality which, as a successor of a Spanish or Mexican pueblo, entitled to the beneficial use of all needed, naturally-occurring surface and groundwater of the original pueblo watershed. Pueblo rights are paramount to all other claims.

R

recharge Water added to an aquifer or the process of adding water to an aquifer. Ground water recharge occurs either naturally as the net gain from precipitation, or artificially as the result of human influence. See artificial recharge.

recharge basin A surface facility constructed to infiltrate surface water into a groundwater basin.

riparian right A right to use surface water, such right derived from the fact that the land in question abuts upon the banks of streams.

runoff The volume of surface flow from an area.

S

safe yield The maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect.

salinity Generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water. See also total dissolved solids.

AR0069841

saline intrusion The movement of salt water into a body of fresh water. It can occur in either surface water or groundwater bodies.

saturated zone The zone in which all interconnected openings are filled with water, usually underlying the unsaturated zone.

seawater intrusion barrier A system designed to retard, cease or repel the advancement of seawater intrusion into potable groundwater supplies along coastal portions of California. The system may be a series of specifically placed injection wells where water is injected to form a hydraulic barrier.

secondary porosity Voids in a rock formed after the rock has been deposited; not formed with the genesis of the rock, but later due to other processes. Fractures in granite and caverns in limestone are examples of secondary openings.

seepage The gradual movement of water into, through or from a porous medium. Also the loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field.

semi-confined aquifer A semi-confined aquifer or leaky confined aquifer is an aquifer that has aquitards either above or below that allow water to leak into or out of the aquifer depending on the direction of the hydraulic gradient.

service area The geographic area served by a water agency.

specific conductance See electrical conductivity.

specific retention The ratio of the volume of water a rock or sediment will retain against the pull of gravity to the total volume of the rock or sediment.

specific yield The ratio of the volume of water a rock or soil will yield by gravity drainage to the total volume of the rock or soil.

spring A location where groundwater flows naturally to the land surface or a surface water body.

stakeholders Any individual or organization that has an interest in water management activities. In the broadest sense, everyone is a stakeholder, because water sustains life. Water resources stakeholders are typically those involved in protecting, supplying, or using water for any purpose, including environmental uses, who have a vested interest in a water-related decision.

stratigraphy The science of rocks. It is concerned with the original succession and age relations of rock strata and their form, distribution, lithologic composition, fossil content, geophysical and geochemical properties—all characters and attributes of rocks as strata—and their interpretation in terms of environment and mode of origin and geologic history.

subsidence See land subsidence.

subterranean stream Subterranean streams flowing through known and definite channels are regulated by California's surface water rights system.

surface supply Water supply obtained from streams, lakes, and reservoirs.

sustainability Of, relating to, or being a method of using a resource so that the resource is not depleted or permanently damaged.

T

total dissolved solids (TDS) A quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter. See also salinity.

AR0069842

toxic Poisonous, relating to or caused by a poison. Toxicity is determined for individual contaminants or for mixtures of contaminants as found in waste discharges.

transmissivity The product of hydraulic conductivity and aquifer thickness; a measure of a volume of water to move through an aquifer. Transmissivity generally has the units of ft²/day or gallons per day/foot. Transmissivity is a measure of the subsurface's ability to transmit groundwater horizontally through its entire saturated thickness and affects the potential yield of wells.

transpiration An essential physiological process in which plant tissues give off water vapor to the atmosphere.

U

unconfined aquifer An aquifer which is not bounded on top by an aquitard. The upper surface of an unconfined aquifer is the water table.

underground stream Body of water flowing as a definite current in a distinct channel below the surface of the ground, usually in an area characterized by joints or fissures. Application of the term to ordinary aquifers is incorrect.

unsaturated zone The zone below the land surface in which pore space contains both water and air.

urban water management plan (UWMP) An UWMP is required for all urban water suppliers having more than 3,000 connections or supplying more than 3,000 acre-feet of water. The plans include discussions on water supply, supply reliability, water use, water conservation, and water shortage contingency and serve to assist urban water suppliers with their long-term water resources planning to ensure adequate water supplies for existing and future demands.

usable storage capacity The quantity of groundwater of acceptable quality that can be economically withdrawn from storage.

V

vadose zone See unsaturated zone.

volatile organic compound (VOC) A manmade organic compound that readily vaporizes in the atmosphere. These compounds are often highly mobile in the groundwater system and are generally associated with industrial activities.

W

water quality Description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

water table See groundwater table.

water year A continuous 12-month period for which hydrologic records are compiled and summarized. Different agencies may use different calendar periods for their water years.

watershed The land area from which water drains into a stream, river, or reservoir.

well completion report A required, confidential report detailing the construction, alteration, abandonment, or destruction of any water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well. The reports were called *Water Well Drillers' Report* prior to 1991 and are often referred to as "driller's logs." The report requirements are described in the California Water Code commencing with Section 13750.

WQCP Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary.

AR0069843

Metric Conversions

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm2)	square inches (in2)	0.00155	645.16
	square meters (m2)	square feet (ft2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km2)	square miles (mi2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters	million gallons (10^6)	0.26417	3.7854
	cubic meters (m3)	cubic feet (ft3)	35.315	0.028317
	cubic meters (m3)	cubic yards (yd3)	1.308	0.76455
	cubic decameters (dam3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m3/s)	cubic feet per second (ft3/s)	35.315	0.028317
	liters per minute (L/min)	gallons per minute (gal/min)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic decameters per day (dam3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	2.989
Specific Capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	(°F-32)/1.8

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Appendices

Appendix A
Obtaining Copies of Supplemental Material

Bulletin 118 Update 2003 includes this report and supplemental material consisting of individual basin descriptions and a GIS-compatible map of each of the delineated groundwater basins in California. The supplemental material will be updated as new information becomes available and can be viewed or downloaded at http://www.waterplan.water.ca.gov/groundwater/118index.htm

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Appendix B
The Right to Use Groundwater in California

California does not have a statewide management program or statutory permitting system for groundwater. Some local agencies have adopted groundwater ordinances under their police powers, or have adopted groundwater management programs under a variety of statutory authorities.

Prior to a discussion of groundwater management, it is helpful to understand some of the laws governing the right to use groundwater in California. When the Water Commission Act of 1913 (Stats. 1913, Ch. 586) became effective in 1914, appropriative surface water rights became subject to a statutory permitting process. This appropriation procedure can be found in Water Code Section 1200 *et seq.* Groundwater classified as underflow of a surface stream, a "subterranean stream flowing through a known and definite channel," was made subject to the State permit system. However, most groundwater in California is presumed to be "percolating water," that is, water in underground basins and groundwater which has escaped from streams. This percolating water is not subject to a permitting process. As a result, most of the body of law governing groundwater use in California today has evolved through a series of court decisions beginning in the early 20th century. Key cases are listed in Table B-1, and some of the most significant are discussed below.

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Table B-1 Significant court cases related to the right to use groundwater in California

Case	Issues addressed
Katz v. Walkinshaw, 141 Cal. 116 (1903)	Established California's Correlative Rights Doctrine. Correlative rights of overlying users, and surplus supply available for appropriation after needs of overlying users.
Peabody v. City of Vallejo, 2 Cal. 2d 351 (1935)	Limited riparian rights under the reasonable and beneficial use requirement of the 1928 constitutional amendment requirement of reasonable and beneficial use.
Pasadena v. Alhambra, 33 Cal. 2d 908 (1949)	First case to apply definition of California's established Doctrine of Mutual Prescription.
Mojave Sand and Gravel Co. v. Antelope Valley Water District, 69 Cal. App. 3d 924 (1977)	Established right to store water in underground basins.
Tehachapi-Cummings County Water District v. Armstrong, 49 Cal. App. 3d 692 (1976)	Modified the Water Prescription Doctrine as articulated in Pasadena v. Alhambra. Overlying owners' water rights must be quantified on the basis of current reasonable and beneficial use of the water. Appropriative rights must be subordinated to overlying rights, including the amount of water available, the extent of overdraft in the basin, and the nature of the water use.
Los Angeles v. San Fernando, 14 Cal. 3d 199 (1975)	Significantly modified Mutual Prescription Doctrine by establishing "safe yield" as the criterion for quantifying rights. Established that the right to store imported water in a basin and recapture water needed to serve the rights of overlying landowners.
Wright v. Goleta Water District, 174 Cal. App. 3d 74 (1985)	The unexercised water rights of overlying owners are protected from appropriators, notice and opportunity must be given to overlying owners before any interference with their rights.
Tri-Desert County Water District v. Blue Skies Country Club,	Reference of overlying rights to adjudication of prescriptive rights by Tri-Desert, 23 Cal. App. 4th 1723 (1994). Overlying rights
Baldwin v. Tehama County, 31 Cal. App. 4th 166 (1994)	City and County regulation of groundwater through police power authority in the Sacramento Valley.
City of Barstow v. Mojave Water Agency,	Held that correlative rights quantified by physical solution. 23 Cal. 4th 1224 (2000), involving adjudicated appropriators, court must consider correlative rights of parties that did not join the stipulation.

This table was modified from Bach, et al. (2002).

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Katz v. Walkinshaw (141 Cal. 116)

In the 1903 decision, *Katz v. Walkinshaw*, the California Supreme Court rejected the English Common Law doctrine of groundwater rights and established the Doctrine of Correlative Rights. Prior to the *Katz* decision, California had followed the doctrine articulated in the 1843 English decision of *Acton v. Blundell* (12 M. & W. 324, 152 Eng. Rep. 1223), which established that landowners enjoyed absolute ownership of groundwater underneath their property. The 1903 decision rejected the English Common Law approach as inapplicable for the "natural conditions" in California, and instead established the Correlative Rights Doctrine and ingrafted to a riparian right. Each overlying landowner was entitled to make reasonable beneficial use of groundwater with a priority equal to all other overlying users. Water in excess of the needs of the overlying owners could be pumped and used on nonoverlying lands on a first-in-time, first-in-right basis under what is known as an appropriative right. An appropriative groundwater right, unlike its surface water counterpart, is not subject to a permitting process. Where overlying owners made full use of available supplies, appropriative rights were extinguished. Where there was insufficient water to meet even the needs of the overlying owners, the court applied the Correlative Rights Doctrine to apportion the available groundwater among the overlying landowners. Figure B-1 depicts the rights to use groundwater established in *Katz v. Walkinshaw*.

City of Pasadena v. City of Alhambra (33 Cal. 2d 908)

The 1949 decision, *Pasadena v. Alhambra*, added significant complexity to the right to use groundwater in California. This decision, involving the adjudication of the Raymond Basin, established the doctrine of mutual prescription. Groundwater levels in the basin had been declining for many years by the time court action was initiated. Most substantial pumpers, both overlying and appropriators, were joined in the action. Previously, appropriators only had a right to water surplus to the needs of overlying users. However, based upon a stipulation by most of the parties, the court in *Pasadena* adopted a program of proportionate reductions. These appropriators had each effectively gained a prescriptive right, similar to that of surface water rights, in which they had taken the water in an open, notorious, and hostile manner for at least five years. Mutual prescription provided groundwater rights to both overlying users and appropriators in depleted groundwater basins by prorating their rights based on the highest continuous amount of pumping during the five years following commencement of the overdraft. All of the users in the Raymond Basin were thus entitled to extract their portion of the court-approved safe yield of the basin.

City of Los Angeles v. City of San Fernando (14 Cal. 3d 199)

In 1975, in *Los Angeles v. San Fernando*, the California Supreme Court significantly limited the Mutual Prescription Doctrine introduced in Pasadena v. Alhambra. This opinion has far-reaching impacts on both the right to use groundwater and the practice of conjunctive use of groundwater and surface water to manage a basin. The case began in 1955, when the City of Los Angeles sued the cities of San Fernando, Glendale, Burbank and other pumpers, asserting a prior right to the San Fernando Valley groundwater basins in the northern part of the City of Los Angeles. The court, relying on Civil Code Section 1007, held that public agencies and public utilities cannot lose their groundwater rights by prescription. This holding effectively ruled out any future "mutual prescription" settlements or judgements involving rights held by public entities.

With respect to the native water supply of the San Fernando Basin, the court found that the City of Los Angeles had prior rights to all of this supply pursuant to its "pueblo right." Pueblo rights are traceable to rights recognized by the Spanish crown and the Mexican government. Under the Spanish/Mexican system, water rights were held in trust by pueblos for the benefit of all of its inhabitants. Under the Treaty of Guadalupe Hidalgo executed by Mexico and the United States in 1848, the municipal successors to Spanish/Mexican pueblos retained their pueblo rights upon the cession of California. In the San Fernando decision, the court confirmed Los Angeles' pueblo right, finding it superior to the rights of all overlying landowners. While a pueblo right is rare, it is an example of the complexity of the rights to use groundwater in California.

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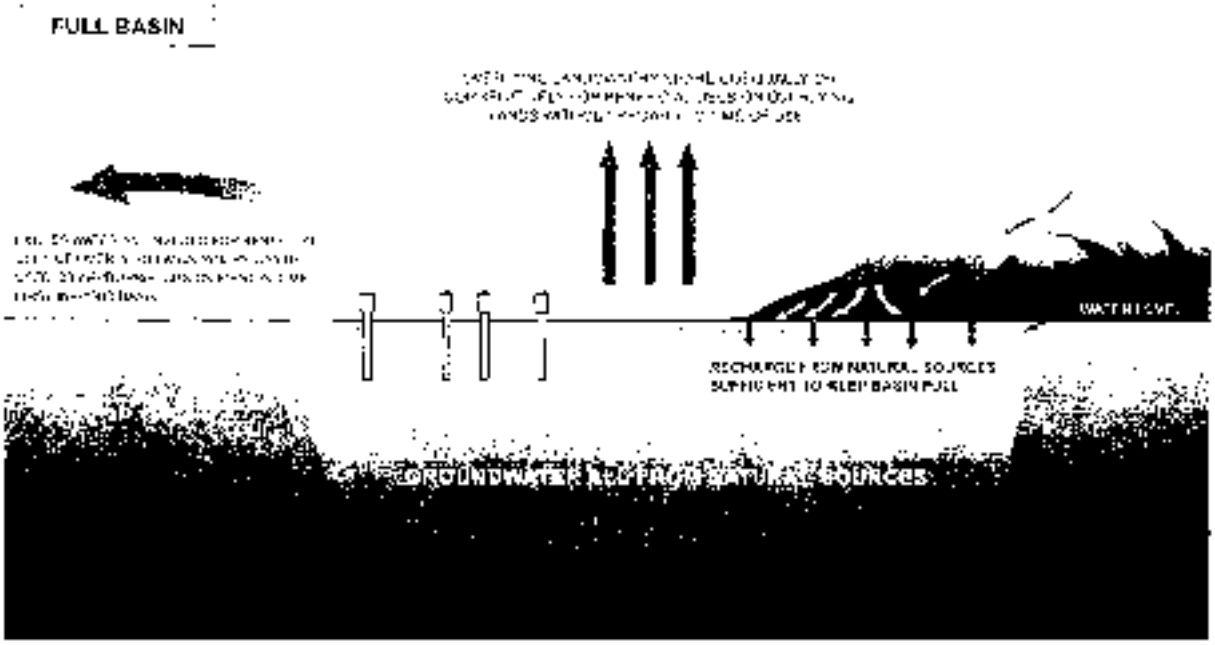

Figure B-1 Rights to groundwater use in full basin established in Katz v. Walkinshaw

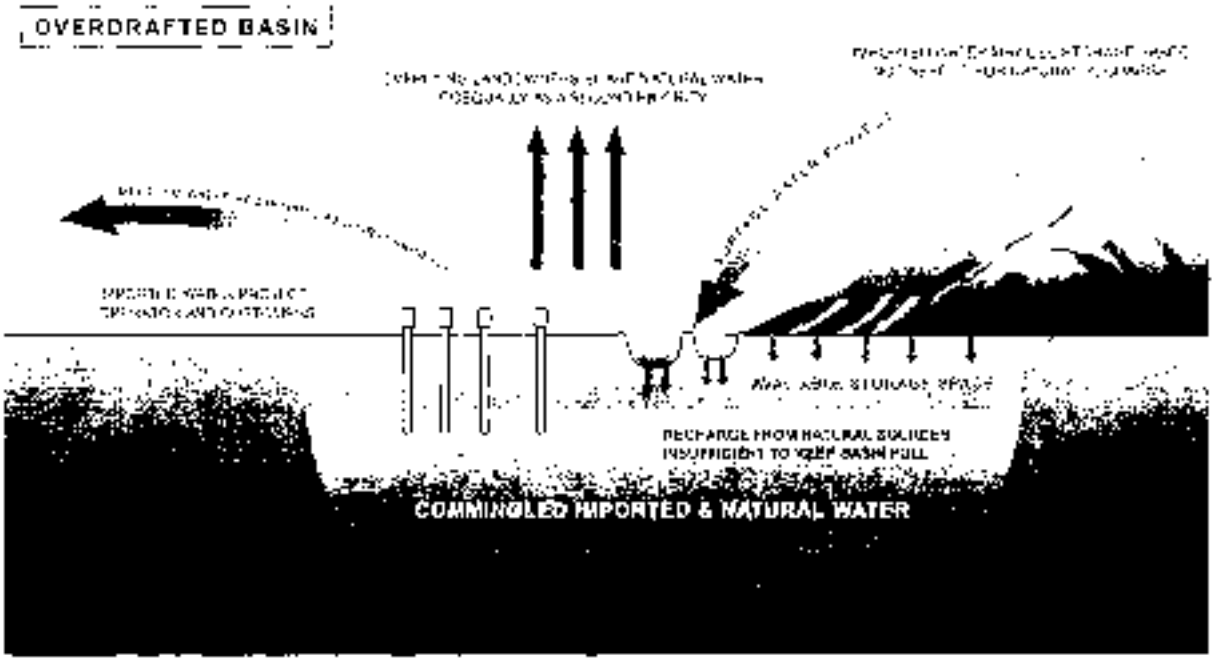

Figure B-2 Rights to groundwater use in overdrafted basin established in Los Angeles v. San Fernando

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For the future of conjunctive use of groundwater basins, the court's holding with respect to the rights to available storage space in the Basin is significant. The court upheld the right of public agencies – namely the cities of San Fernando, Los Angeles, Burbank, and Glendale – to recapture the imported water they added to the Basin. The court held that the rights of the respective public agencies to recover such imported water are of equal priority to the City of Los Angeles' pueblo right, and that all such public agency rights are "prior to the rights dependent on ownership of overlying land or based solely upon appropriation of groundwater from the basin." The court remanded the case, directing the trial court to apportion the safe yield of the Basin accordingly.

The court noted that there did not appear to be any shortage of underground storage space in relation to the demand and, hence, the court did not find it necessary to determine priorities as to the future use of such space. The Judgment issued by the trial court on remand, however, provided: "To the extent of any future spreading or in lieu storage of import water or reclaimed water by Los Angeles, Glendale, Burbank or San Fernando, the party causing said water to be so stored shall have a right to extract an equivalent amount of ground water from the San Fernando Basin." Pursuant to the Judgment, a court-appointed Watermaster now manages the groundwater extraction and storage rights within the SFVARA. Figure 8-2 depicts the rights to use groundwater established in Los Angeles v. San Fernando in an overdrafted basin where water has been stored.

City of Barstow v. Mojave Water Agency (23 Cal. 4th 1224)

In 2000, the California Supreme Court partially overturned the 1995 adjudication of the Mojave River Basin. The trial court had approved a negotiated settlement (or stipulated agreement) that failed to include a well-by-well determination of water rights. The trial court held the negotiated settlement to be binding on all users in the basin, including some pumpers who had not agreed to the settlement. The lower court decision was based on the doctrine of "equitable apportionment," in which the available water is shared based on concepts of equity and fairness. The Court of Appeal had partially reversed the lower court, and held that the trial court did not have the authority to ignore California's traditional water rights doctrine giving overlying users a priority right to beneficial and reasonable use of the groundwater. The Court of Appeal affirmed the trial court's negotiated settlement except as it applied to two of the parties. First, the Court of Appeal reversed the holding against a non-negotiating party since the trial court had ignored that party's existing overlying water rights. Secondly, the Court of Appeal reversed the trial court's judgment as it applied to a company, where the negotiated agreement did not give the company a water allowance equal to its actual water use. The Supreme Court affirmed the Court of Appeal decision, but reversed the judgment applying to the company's water allowance. The Supreme Court also affirmed that the trial court could not apply the doctrine of equitable apportionment when overlying water users had already established a prior water right. The Court stated that, while the trial court could impose a physical solution (such as the negotiated settlement), the court could not simply ignore affected owners' legal water rights. Equitable apportionment, thus, remains a tool for adjudicating basin groundwater rights, but only if all parties stipulate to its use.

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Appendix C
Required and Recommended Components of Local Groundwater Management Plans

Section 10750 et seq. of the Water Code, commonly referred to as Assembly Bill 3030, stipulates certain procedures that must be followed in adopting a groundwater management plan under this section.

Amendments to Section 10750 et seq. added the requirement that new groundwater management plans prepared under Section 10750 et seq. must include component 1 below (SBX7 98 (Stats. 2002, Ch 603)).

In addition, the amendments mandate that if the agency preparing the groundwater management plan intends to apply for funding administered by the California Department of Water Resources (DWR) for groundwater or groundwater quality projects, the agency must prepare and implement a groundwater management plan that includes components 2, 3, 6, 7 and 9 below. DWR recommends that all the components below be included in any groundwater management plan to be adopted and implemented by a local managing entity.

Consideration and development of these components for the specific conditions of the basin to be managed under the plan will help to ensure effective groundwater management. In developing these criteria, DWR recognizes that the goal of a groundwater management plan and the goal of an ordinance to manage groundwater should be the same—assurance of a long-term, sustainable, reliable, good quality groundwater supply. Such efforts can benefit greatly from cooperative management within the basin or region.

None of the suggested data reporting in the components below should be construed as recommending disclosure of information that is confidential under State law.

1. Include documentation that a written statement was provided to the public "describing the manner in which interested parties may participate in developing the groundwater management plan," which may include appointing a technical advisory committee (Water Code § 10753.4 (b)).
2. Include a plan by the managing entity to "involve other agencies that enables the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin." (Water Code § 10753.7 (a)(2)). A local agency includes "any local public agency that provides water service to all or a portion of its service area" (Water Code § 10752 (g)).
3. Provide a map showing the area of the groundwater basin, as defined by DWR Bulletin 118, with the area of the local agency subject to the plan as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a groundwater management plan (Water Code § 10753.7 (a)(3));
4. Establish an advisory committee of stakeholders (interested parties) within the plan area that will help guide the development and implementation of the plan and provide a forum for resolution of controversial issues.
5. Describe the area to be managed under the plan, including:
   a. The physical structure and characteristics of the aquifer system underlying the plan area in the context of the overall basin.,

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b. A summary of the availability of historical data including, but not limited to, the components in Section 7 below.

c. Issues of concern including, but not limited to, issues related to the components in Section 7 below.

d. A general discussion of historical and projected water demands and supplies.

6. Establish management objectives (MOs) for the groundwater basin that is subject to the plan. (Water Code § 10753.7 (a)(1)).

7. Include components relating to the monitoring and management of groundwater levels, groundwater quality, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping. (Water Code § 10753.7 (a)(1)). Consider additional components listed in Water Code § 10753.8 (a) through (f).

8. For each MO, describe how meeting the MO will contribute to a more reliable supply for long-term beneficial uses of groundwater in the plan area, and describe existing or planned management actions to achieve MOs.

9. Adopt monitoring protocols for the components in Section 7 (Water Code § 10753.7 (a)(4)) Monitoring protocols are not defined in the Water Code, but the section is interpreted to mean developing a monitoring program capable of tracking changes in conditions for the purpose of meeting MOs.

10. Describe the monitoring program, including:

a. A map indicating the general locations of any applicable monitoring sites for groundwater levels, groundwater quality, subsidence stations, or stream gages.

b. A summary of monitoring sites indicating the type (groundwater level, groundwater quality, subsidence, stream gage) and frequency of monitoring. For groundwater level and groundwater quality wells, indicate the depth interval(s) or aquifer zone monitored and the type of well (public, irrigation, domestic, industrial, monitoring).

11. Describe any current or planned actions by the local managing entity to coordinate with other land use, zoning, or water management planning agencies or activities. (Water Code § 10753.8 (a), (1))

12. Provide for periodic report(s) summarizing groundwater basin conditions and groundwater management activities. The report(s), prepared annually or at other frequencies as determined by the local management agency, should include:

a. Summary of monitoring results, including a discussion of historical trends.

b. Summary of management actions during the period covered by the report.

c. A discussion, supported by monitoring results, of whether management actions are achieving progress in meeting MOs.

d. Summary of proposed management actions for the future.

e. Summary of any plan component changes, including addition or modification of MOs, during the period covered by the report.

f. Summary of actions taken to coordinate with other water management and land use agencies, and other government agencies.

13. Provide for the periodic re-evaluation of the entire plan by the managing entity.

14. For local agencies not overlying groundwater basins, plans should be prepared including the above listed components and using geologic and hydrologic principles appropriate to those areas (Water Code § 10753.7 (a)(5)).

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Appendix D
Groundwater Management Model Ordinance

In developing this model ordinance, the California Department of Water Resources recognizes that the goal of a groundwater management plan and the goal of an ordinance to manage groundwater should be the same – assurance of a long term, sustainable, reliable, good quality groundwater supply. Such efforts require cooperative management within the region or sub-region.

Chapter X

Groundwater Management Ordinance

Sections:

X.01 Declaration of Findings
X.02 Purpose
X.03 Declaration of Intent
X.04 Definitions
X.05 Groundwater Management Program
X.06 Management Objectives
X.07 Monitoring Program Network
X.08 Monitoring Frequency
X.09 Changes in Monitoring
X.10 Review of Technical Data
X.11 Data Dissemination
X.12 Actions when MO Noncompliance is Reported
X.13 Regional Coordination
X.14 Integrated Resource Management
X.15 Data Relating to Export and Substitution of Groundwater

X.01 Declaration of Findings - The Board finds that:

A. The protection of the groundwater resource for its use within the County is of major concern to the residents of the County for the protection of their health, welfare, and safety.

B. The reliability and sustainability of the groundwater supply for all beneficial uses are of critical importance to the economic, social, and environmental well-being of the County.

C. A lack of effective groundwater management may have significant negative impacts, including, but not limited to:

1. Lower groundwater levels leading to additional expenses for:
   a) Increased energy consumption.
   b) The need to deepen existing wells.
   c) The need to build new wells.
   d) The need to destroy non-functioning wells.
2. Costly damage to public roads, bridges, canals, and other structures caused by land subsidence.
3. Reduction of surface and subsurface flows leading to the potential loss of critical riparian and wetland habitat.
4. Degradation of groundwater quality.

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D. It is essential for management purposes to adopt a monitoring program addressing groundwater levels, groundwater quality, land subsidence, and surface water flow and quality where it directly impacts or is impacted by groundwater.

X.02 Purpose – In support of the findings above, the County has determined that this groundwater management ordinance is necessary to ensure that:

A. Groundwater continues to be a reliable and sustainable resource.
B. The extraction of groundwater does not result in significant adverse economic, environmental or social impacts.
C. Groundwater quality is protected.
D. Excessive land surface subsidence from groundwater extraction is prevented.

X.03 Declaration of Intent

A. The County intends to foster prudent groundwater management practices by establishing a policy that encourages appropriate management of the resource based on recommendations by a committee of stakeholders.
B. The County intends that its groundwater management activities occur as an open and public process that considers input from all stakeholders in the County.
C. The County intends to work cooperatively with interested local agencies to further develop and implement joint groundwater management activities.
D. The County does not intend to regulate, in any manner, the use of groundwater, except as a last resort to protect the groundwater resource.
E. The County intends to act as an enforcing agency should the local resource become threatened.
F. The County does not intend to infringe upon the rights of surface water users in the managed area.
G. The County does not intend to limit other authorized means of managing groundwater within the County.

X.04 Definitions

A. "Aquifer" means a geologic formation that stores groundwater and transmits and yields significant quantities of water to wells and springs. Significant quantity is an amount that that satisfies local needs and may range from thousands of gallons per minute to less than 5 gpm, depending on rock type and intended use.
B. "Board" means the Board of Supervisors of the County.
C. "District" means a district or municipality, located wholly or partially within the boundaries of the County, that is a purveyor of water for agricultural, domestic, or municipal use.
D. "Enforcement Agency" means the Board as the enforcement agency under this chapter.
E. "Groundwater" means all water beneath the surface of the earth below the zone of saturation, but does not include subterranean streams flowing in known and definite channels.
F. "Groundwater Basin" means an aquifer or series of aquifers with a reasonably defined lateral and vertical extent, as defined in Bulletin 118 by Department of Water Resources. "Non-basin areas" are outside defined groundwater basins and contain smaller amounts of groundwater in unconsolidated sediments or fractured hard rock.
G. "Groundwater export" means the conveyance of groundwater outside of the boundaries of the County and outside of the boundaries of any district that is partially within the County.
H. "Groundwater substitution" means the voluntary use of an available groundwater supply instead of surface water for the purposes of using the surface water outside the County and outside the boundaries of any district that is partially within the County.

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L. "Land Subsidence" means the lowering of the ground surface caused by the inelastic consolidation of clay beds in the aquifer system.

I. "Management Objective" (MO) means a condition identified for each subunit to ensure that the groundwater supply is reliable and sustainable. The MOs set acceptable conditions with respect to groundwater levels, groundwater quality, inelastic land surface subsidence, and surface water flows and quality. Compliance with the MOs is tracked by a monitoring program and threshold values that are adopted for each Management Objective.

K. "Recharge" means flow to groundwater storage from precipitation, and infiltration from streams, irrigation, spreading basins, injection wells, and other sources of water.

L. "Reliability" means having an available, predictable, and usable groundwater supply at any given point in time.

M. "Stakeholder" means an individual or an entity, such as a water supplier or a county resident, with a permanent interest in the availability of the groundwater resource.

N. "Subunit" means any subdivision of a groundwater basin or non-basin area in the County created for the purposes of representation of stakeholders and the establishment of local area management objectives.

O. "Sustainable" means the groundwater resource is maintained for use by residents in the basin over a prolonged period of time.

P. "Technical Advisory Committee" means a committee of persons knowledgeable in groundwater management, hydrology, and hydrogeology established for the purpose of providing technical guidance to the Water Advisory Committee.

Q. "Threshold values" mean the limits established by the WAC for groundwater levels, groundwater quality, land surface subsidence, and surface water flow and quality that are not to be exceeded if the MOs are to be met.

R. "Water Advisory Committee" (WAC) means a multiparty advisory body established for the purpose of aiding the Board in providing effective management of the groundwater resources in the County, and representing all of the subunits that are identified.

S. "Water Management Entities" means any local agency, or group of agencies, authorized to manage groundwater.

X.05 Groundwater Management Program

A. The County recognizes that effective groundwater management is key to maintaining a reliable and sustainable resource. For the purposes of establishing an effective groundwater management program, the Board shall appoint a WAC to establish MOs and make recommendations to the Board to ensure that MOs are met.

B. For purposes of establishing a WAC, the groundwater basins and non-basin areas of the County will be divided into subunits based on hydrogeologic principles and institutional boundaries. These subunits shall be established by the Board based on public input to address the groundwater management needs of the County. The WAC shall consist of members that represent each subunit. Upon establishment of the subunits, the Board shall appoint a member to represent each subunit on the WAC.

C. The WAC shall have the following responsibilities to the Board:
   1. Recommend MOs for each groundwater management subunit.
   2. Recommend a groundwater monitoring network for purposes of tracking MOs.
   3. Recommend the frequency of monitoring.
   4. Propose changes in monitoring.
   5. Ensure monitoring data receive technical review.
   6. Ensure that monitoring data are made available to the public.

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7. Recommend actions to resolve noncompliance with MOs.

D. For the purposes of providing technical advice to the WAC in carrying out its responsibilities, a technical advisory committee (TAC) shall be established. The TAC shall consist of local experts or a combination of local expertise and technical consultants from private and public organizations that are nominated by the WAC and approved by the Board. Individuals appointed to the TAC should be highly knowledgeable in groundwater management, hydrology, and hydrogeology. The TAC shall review technical data collected by monitoring programs within the County and advise the WAC.

X.06 Management Objectives

A. To ensure that the County maintains a reliable and sustainable groundwater supply, MOs for groundwater levels, groundwater quality, land subsidence, and surface water flow and quality shall be adopted for each subunit. Threshold values that are not to be exceeded shall be defined for each MO.

B. Compliance with the MOs will be determined by evaluation of data collected from groundwater level, groundwater quality, land subsidence, and surface water flow and quality monitoring networks. Evaluation of these data with respect to threshold values shall be the basis for determining compliance with the MOs.

C. Each WAC member shall recommend MOs for their subunit. The WAC shall develop a comprehensive set of recommendations for all subunits, and the Board shall adopt these MOs for the County. MOs may differ from subunit to subunit, but the established MOs shall be consistent with the overall goal of supply reliability for the County.

D. Groundwater management practices based on the established MOs for one subunit of the County shall not adversely impact adjacent subunits.

X.07 Monitoring Program Network

The WAC shall develop County-wide monitoring programs to collect representative data on groundwater levels, groundwater and surface water quality, land surface subsidence, and stream flow and quality. Each subunit shall propose its own monitoring program, and the WAC shall adopt a comprehensive monitoring program for the County. The data collected, showing current conditions and changes over time as a result of groundwater extraction, shall be evaluated by the WAC in consultation with the TAC. The WAC will recommend policies and actions to ensure that MOs for each subunit are met. The collection and evaluation of the data shall be based on scientifically sound principles, and shall incorporate appropriate quality assurance and quality control protocols.

A. Groundwater levels: The groundwater level monitoring network shall be proposed by the WAC and approved by the Board. The intent of the groundwater level monitoring network is to measure water levels in selected wells that can adequately determine representative conditions in the aquifer system for determination of compliance with the MOs. The network will include selected municipal, domestic, and irrigation wells owned by water districts, private parties, and municipal and industrial water suppliers. Where needed, dedicated monitoring wells may be installed. Participation by well owners will be voluntary.

B. Water Quality: The groundwater quality monitoring network shall be proposed by the WAC and approved by the Board. The intent of the groundwater quality monitoring network is to monitor selected wells that can adequately determine representative groundwater quality conditions in the aquifer system for identification of compliance with the MOs. The network will include selected municipal, domestic, and irrigation wells owned by water districts, private parties, and municipal

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and industrial water suppliers. Where needed, dedicated monitoring wells may be installed. Participation by well owners will be voluntary.

C. Land Subsidence: The land subsidence program and network shall be proposed by the WAC and approved by the Board. The intent of the land subsidence monitoring is to detect land subsidence for determination of compliance with the MOs. The network may include benchmarks that are surveyed for changes in elevation throughout the County, based on the judgment of the WAC of the need for such a program.

D. Surface Water Flow and Quality: The surface water flow and quality network shall be proposed by the WAC and approved by the Board. The intent of this network is to detect changes in surface water flow or surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping for evaluation of compliance with MOs.

X.08 Monitoring Frequency

The recommended frequency of collection of data for each of the parameters listed above shall be determined by the WAC. Initially, each parameter should be measured at the frequencies outlined below, unless the WAC notes upon evaluation of existing data that more frequent monitoring or additional analyses are called for.

A. Groundwater levels should be measured at least three times during the year: one measurement prior to the period of highest groundwater use, one measurement during peak groundwater use, and one measurement following the period of highest groundwater use (approximately the months of _____, _____, and _____).

B. Groundwater quality measurements of electrical conductivity, temperature, and pH should be obtained at least twice annually during the periods of highest and lowest groundwater use (approximately the months of __ and ___). Upon evaluation of the data, the WAC may propose analyses for other constituents.

C. Selected benchmarks in the County land subsidence monitoring network should be surveyed every five years at a minimum. These surveys should be conducted following aquifer recovery and prior to the period of highest groundwater extraction (approximately the month of).

D. Measurement of surface water flow and quality in areas determined to directly affect groundwater levels or quality or that are affected by groundwater pumping shall be obtained at least ___ times per month as long as there are flows in the channel.

X.09 Changes in Monitoring

If evaluation of the groundwater level, groundwater quality, land subsidence, surface water flow, or surface water quality data indicates a need for more or less frequent measurements or analyses, the WAC may propose a change in the monitoring frequency. Similarly, if evaluation of the data indicates that additional monitoring sites are necessary, the WAC may propose an additional or a reduced number of sites for data collection. The Board shall adopt these changes when supported by available evidence.

X.10 Review of Technical Data

A. The TAC shall purpose and the WAC shall adopt standard methods using scientifically sound principles for review and analysis of the collected data. The TAC will meet, as needed and requested by the WAC, to evaluate the technical data and shall report their findings at appropriate meetings of the WAC. The WAC shall meet at least ___ times per month during the period of maximum groundwater use (months of ___ through ____) and quarterly during the off season (months of _____ through ____), or as necessary.

B. During the period of highest groundwater use, the WAC meetings will focus on data review and analysis with respect to compliance with the current MOs. During the period of low

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groundwater use, the WAC meetings will focus on a review of compliance with MOs for the previous period of high groundwater use and consideration of the need for changes to the MOs.

X.11 Data Dissemination

The WAC, in addition to establishing methods for data collection and evaluation, shall establish methods for data storage and dissemination. The WAC shall disseminate the monitoring data and evaluation reports through public presentations and through a County-maintained groundwater Internet site. At a minimum, the WAC shall publicly present findings from the monitoring program to the Board twice annually.

X.12 Actions when MO Noncompliance is Reported

A. Action by Technical Advisory Committee. In the event that the TAC identifies an area that is not in compliance with the MOs, or if noncompliance is reported by any other means, the TAC shall report to the WAC on the regional extent and magnitude of the noncompliance. This information shall also be released to the public no later than _ _ days from the time that noncompliance with MOs was identified. The TAC shall then collect all available pertinent hydrologic data, investigate possible causes for noncompliance with MOs, and recommend actions to the WAC to bring the area into compliance. These recommendations shall be made no later than days after the report of noncompliance is released to the public. The TAC shall first make recommendations that focus on correcting the noncompliance through negotiations with all parties in the affected area.

B. Action by Water Advisory Committee. The WAC shall act as lead negotiator in re-establishing compliance with the MO. If negotiations with parties in the affected area do not result in timely and positive action to re-establish compliance with MOs for the basin, the WAC may recommend a plan to the Board to modify, reduce or terminate groundwater extraction in the affected area or take other necessary actions. Such a plan will be recommended to the Board only after the WAC has thoroughly reviewed the recommendations of the TAC at a public meeting. The modification, reduction, or termination of groundwater extraction in the affected area shall first be applied to wells involved in any export or substitution programs, and then to other wells if necessary. Domestic wells shall not be considered for any modification, reductions, or termination of groundwater extraction.

C. Action by Board of Supervisors. The Board of Supervisors, using its police powers, shall act as the enforcement agency for this ordinance. Any recommendation of the WAC may be appealed to the Board within _ working days.

X.13 Regional Coordination

Management decisions recommended by the WAC and adopted by the Board shall not deleteriously affect groundwater resources in any portions of groundwater basins or non-basin areas that share a common groundwater resource in adjacent counties. To accomplish this goal, the WAC shall meet and coordinate with water management entities outside the County that overlie a common groundwater basin at least twice per year, once prior to the period of highest groundwater use and once following the period of highest groundwater use.

X.14 Integrated Resource Management

A. To ensure integration of planning activities within the County, the WAC shall inform County departments involved with groundwater related activities, including but not limited to Land Use or Zoning, Planning, Public Works, Utilities, and Environmental Health, of all WAC meetings and actions regarding MOs. In turn, these County departments shall take into consideration the

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adopted MOs when approving development or zoning changes or construction projects that may rely on or affect groundwater quantity or quality.

B. To the greatest extent practicable, the WAC should also integrate resource management planning with other agencies within the basin. Resource activities that could benefit from integrated planning with groundwater management include, but are not limited to:
   - Stormwater management planning by other agencies—agricultural, municipal, industrial, local government
   - Watershed management plans
   - Urban water management plans
   - Management and disposal of municipal solid waste and municipal sewage
   - Drinking water source assessment and protection programs
   - Public water system emergency and disaster response plans
   - Surface water and groundwater conjunctive management programs
   - Expansion of surface and groundwater facilities
   - Water efficiency programs
   - Water recycling programs
   - Environmental habitat construction or restoration programs
   - Water quality protection programs
   - Recharge programs
   - Transportation infrastructure planning

X.15 Data Relating to Export and Substitution of Groundwater

A. Districts, persons, or contractors intending to operate a groundwater export or groundwater substitution program shall submit the following data to the WAC ___ working days prior to commencing the program:
   1. A description of the project with the total amount of groundwater to be exchanged or substituted.
   2. The dates over which the project will take place.
   3. A statement of the anticipated impacts of the project relative to adopted MOs.
   4. A discussion of possible contingencies in the event of MO noncompliance.
   5. A map showing the location of the wells to be used by the program.
   6. A summary of any monitoring program proposed.
   7. All required environmental documentation.

B. While the program is in operation, the following information shall be provided to the WAC at least ___ times per month.
   1. All static and pumping groundwater level measurements made in the pumping well during the period of extraction for the export or substitution program.
   2. The amount of groundwater extracted from each well per week.
   3. Static groundwater level measurements in at least ___ of the most proximal wells to the project pumping wells that can be practicably monitored.

C. All costs for providing such information to the WAC shall be borne by the project participants.

Note: Although the terms "County" and "Board" are used throughout the model ordinance for clarity, the model could be used by any local government or agency with appropriate authority or powers.

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Appendix E
SWRCB Beneficial Use Designations[1]

Agricultural Supply (AGR) – Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

Aquaculture (AQUA) – Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Cold Freshwater Habitat (COLD) – Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Estuarine Habitat (EST) – Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

Freshwater Replenishment (FRSH) – Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).

Groundwater Recharge (GWR) – Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Hydropower Generation (POW) – Uses of water for hydropower generation.

Industrial Process Supply (PRO) – Uses of water for industrial activities that depend primarily on water quality.

Industrial Service Supply (IND) – Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well repressurization.

Inland Saline Water Habitat (SAL) – Uses of water that support inland saline water ecosystems including, but not limited to, preservation or enhancement of aquatic saline habitats, vegetation, fish, or wildlife, including invertebrates.

Marine Habitat (MAR) – Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish and fish, or wildlife (e.g., marine mammals, shorebirds).

Migration of Aquatic Organisms (MIGR) – Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

Municipal and Domestic Supply (MUN) – Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

Navigation (NAV) – Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

Noncontact Water Recreation (REC-2) – Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Ocean Commercial and Sport Fishing (COMM) – Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

[1] From SWRCB 2000

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Preservation of Biological Habitats of Special Significance (BIOL) – Uses of water that support designated areas or habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance (ASBS), where the preservation or enhancement of natural resources requires special protection.

Rare, Threatened, or Endangered Species (RARE) – Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under State or federal law as rare, threatened or endangered.

Shellfish Harvesting (SHEL) – Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.

Spawning, Reproduction, and/or Early Development (SPWN) – Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Warm Freshwater Habitat (WARM) – Uses of water that support warmwater ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Water Contact Recreation (REC-1) – Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.

Wildlife Habitat (WILD) – Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

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Appendix F
Federal and State MCLs and Regulation Dates for Drinking Water Contaminants

	U.S. Environmental Protection Agency		California Department of Health Services	
Contaminant	MCL (mg/L)	Date*	MCL (mg/L)	Effective date
Inorganics				
Aluminum	0.05 to 2[b]	1991	[illegible] 0.2[b]	2/25/89 6/89/94
Antimony	0.006	7/92	0.006	6/89/94
Asbestos	0.05 0.01	eff. 6/24/77 20 µm	0.5	??
Asbestos	7 MFL	1991	7 MFL	6/89/94
Barium	1 2	eff. 6/24/77 1991	1	??
Beryllium	0.004	7/92	0.004	6/89/94
Cadmium	0.01 0.005	eff. 6/24/77 1991	0.010 0.005	?? 6/89/94
Chromium	0.05 0.1	eff. 6/24/77 1991	0.05	??
Copper	1.3[a]	6/92	1[a] 1.3[a]	?? 12/11/95
Cyanide	0.2	7/92	0.2 0.15	6/89/94 6/12/91
Fluoride	4 2[c]	1986 1986	2	6/89/94
Lead	0.05[a] 0.015[a]	eff. 6/24/77 6/91	0.05[a] 0.015[a]	?? 2/11/95
Mercury	0.002	eff. 6/24/77	0.002	??
Nickel	Rescinded	1/91	0.1/0.04	
Nitrate	(as NO3)	eff. 6/24/77	(as NO3) 45	??
Nitrate (as N)	10	1991	10	6/89/94
Total Nitrate/Nitrite (as N)	10	1991	10	6/89/94
Selenium	0.05 0.05	eff. 6/24/77 1991	0.01 0.05	?? 6/89/94
Thallium	0.002	7/92	0.002	6/89/94
Radionuclides				
Uranium	20 pCi/L	12/7/00	20 pCi/L	12/8/03
Combined radium-226 & -228	5 pCi/L	eff. 6/24/77	5 pCi/L	??
Gross Alpha particle activity	15 pCi/L	eff. 6/24/77	15 pCi/L	??
Gross Beta particle activity	equal to 4 millirem/yr	eff. 6/24/77	50 pCi/L	??

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Contaminant	U.S. Environmental Protection Agency		California Department of Health Services	
	MCL (mg/L)	Date*	MCL (mg/L)	Effective date
Strontium-90	8 pCi/L	eff. 6/24/77 now covered by Gross Beta	8 pCi/L	77
Tritium	20,000 pCi/L	eff. 6/24/77 now covered by Gross Beta	20,000 pCi/L	77
VOCs				
Benzene	0.005	6/87	0.001	2/25/89
Carbon Tetrachloride	0.005	6/87	0.0005	4/30/89
1,2-Dichlorobenzene	0.6	1/91	0.6	9/30/94
1,4-Dichlorobenzene	0.075	6/87	0.005	4/30/89
1,1-Dichloroethane	--	--	0.005	6/25/90
1,2-Dichloroethane	0.005	6/87	0.0005	4/30/89
cis-1,2-Dichloroethylene	0.07	1/91	0.006	2/25/89
trans-1,2-Dichloroethylene	0.1	1/91	0.01	9/30/94
Dichloromethane	0.005	1/91	0.005	9/30/94
1,3-Dichloropropene	--	--	0.0005	2/25/89
1,2-Dichloropropane	0.005	1/91	0.005	6/30/90
Ethylbenzene	0.7	1/91	0.68 0.7 0.3	2/25/89 9/30/94 eff 12/93
Methyl-tert-butyl Ether (MTBE)	--		0.0013* 0.013	1/7/98 5/17/00
Monochlorobenzene	0.1	1/91	0.03 0.07	2/25/89 9/30/94
Styrene	0.1	1/91	0.1	9/30/94
1,1,2,2-Tetrachloroethane	--		0.001	2/25/89
Tetrachloroethylene	0.005	1/91	0.005	5/89
Toluene	1	1/91	0.15	9/30/94
1,2,4-Trichlorobenzene	0.07	7/92	0.07	9/30/94
1,1,1-Trichloroethane	0.200	6/87	0.200	2/25/89
1,1,2-Trichloroethane	0.005	7/92	0.032 0.005	5/89 9/30/94
Trichloroethylene	0.005	6/87	0.005	2/25/89
Trichlorofluoromethane	--	--	0.15	6/24/90
1,1,2-Trichloro-1,2,2-Trifluoroethane	--	--	1.2	6/24/90
Vinyl chloride	0.002	6/87	0.0005	4/30/89
Xylenes	10	1/91	1.750*	2/25/89

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Contaminant	U.S. Environmental Protection Agency		California Department of Health Services	
	MCL (mg/L)	Date*	MCL (mg/L)	Effective date
SVOC's				
Alachlor	0.002	1991	0.004	9/8/94
Atrazine	0.003	1991	0.003 0.001	4/5/96 6/17/03
Bentazon	--	--	0.018	4/4/89
Benzo(a) Pyrene	0.0002	1992	0.00002	9/8/94
Carbofuran	0.04	1991	0.018	6/24/90
Chlordane	0.002	1991	0.0001	6/24/91
Dalapon	1	1992	0.2	9/8/94
Dibromochloropropane	0.0007	1991	0.0001 0.00002	7/23/89 5/3/91
Di(2-ethylhexyl)adipate	0.4	1992	0.4	9/8/94
Di(2-ethylhexyl)phthalate	0.006	1992	0.004	6/24/91
2,4-D	0.07	eff. 6/24/77 1991	0.1 0.07	77 9/8/94
Dinoseb	0.007	1992	0.007	9/8/94
Diquat	0.02	1992	0.02	9/8/94
Endothall	0.1	1992	0.1	9/8/94
Endrin	0.002 0.002	eff. 6/24/77 1992	0.0002 0.002	77 9/8/94
Ethylene Dibromide	0.00005	1991	0.00005 0.00005	2/25/89 9/8/94
Glyphosate	0.7	1992	0.7	6/24/91
Heptachlor	0.0004	1991	0.00001	6/24/91
Heptachlor Epoxide	0.0002	1991	0.00001	6/24/91
Hexachlorobenzene	0.001	1992	0.001	9/8/94
Hexachlorocyclopentadiene	0.05	1992	0.05	9/8/94
Lindane	0.004 0.0002	eff. 6/24/77 1991	0.004 0.0002	77 9/8/94
Methoxychlor	0.1 0.04	eff. 6/24/77 1991	0.1 0.04 0.03	77 9/8/94 6/12/03
Molinate	--	--	0.02	4/4/89
Oxamyl	0.2	1992	0.2 0.05	9/8/94 5/12/97
Pentachlorophenol	0.001	1991	0.001	9/8/94
Picloram	0.5	1992	0.5	9/8/94
Polychlorinated Biphenyls	0.0005	1991	0.0005	9/8/94
Simazine	0.004	1992	0.010 0.004	4/4/89 9/8/94

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Contaminant	U.S. Environmental Protection Agency MCL (mg/L)	Date[a]	California Department of Health Services MCL (mg/L)	Effective date
Thiobencarb	-	- -	0.07	4/4/89
			0.001[b]	4/4/89
Toxaphene	0.005	eff 6/24/77	0.003	77
	0.003	1991	0.003	9/8/94
2,3,7,8-TCDD (Dioxin)	5x10[-8]	1992	3x10[-8]	9/8/94
2,4,5-TP (Silvex)	0.01	eff 6/24/77	0.01	77
	0.005	1991	0.005	9/8/94
Disinfection Byproducts				
Total trihalomethanes	0.10	11/29/79	0.10	3/14/83
	0.080	eff 11/29/83		
		eff 11/2002		
Total haloacetic acids	0.060	eff 11/2002		
Bromate	0.010	eff 11/2001		
Chlorite	1.0	eff 11/2001		
Treatment Technique				
Acrylamide	TT[c]	1990	TT[c]	9/8/94
Epichlorohydrin	TT[c]	1990	TT[c]	9/8/94

Source: http://www.dhs.ca.gov/ps/ddwem/chemicals/MCL/EPAandDHS.pdf

a "eff" denotes the date the MCL was effective unless data prevented indication when EPA established that it promulgated the MCL.

b Secondary MCL.

c MFL = million fibers per liter with fiber length > 10 microns.

d Regulatory Action Level = treatment technique. If more than 10% of the customer taps sampled exceed the action level, monitoring, corrosion control, source water treatment and public education programs may be required.

e The MCLG = 0 but was converted with the adoption of the regulation to an enforceable standard.

f. MCL is for nitrate + nitrite, 10 mg/L as nitrogen; 1 mg/L for nitrite, 10 mg/L as nitrogen.

g. Effective for surface water systems serving more than 10,000 people; effective 1/2001 for all others.

h. TT = treatment technique, because no MCL was established.

i. Federal and State MCL is 4 mrem/yr. (5/2006)

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Appendix G
Development of Current Groundwater Basin/Subbasin Map

This Bulletin 118 update represents the first time that groundwater basin boundaries have been released as a digital coverage. The basin boundaries for the revised groundwater basin map were primarily defined using geologic contacts and hydrogeologic barriers. Specifically the identification of the groundwater basins was initially based on the presence and areal extent of unconsolidated alluvial sediments identified on 1:250,000 scale, geologic maps published by the California Department of Conservation, Division of Mines and Geology. The identified groundwater basin areas were then further evaluated through review of relevant geologic and hydrogeologic reports and well completion reports, and using the basin definition criteria listed in Table 8. Basin boundaries that are specified in each of the court decisions has been used for the boundaries of adjudicated basins.

Well completion reports for wells present in basin areas that were identified from the geologic map were reviewed to identify the depth to the top of the water table and the top of impermeable bedrock. If there was less than 25 feet of permeable material present or if there was no groundwater present within the permeable material, the area was eliminated from the map. The well completion reports were also reviewed to determine if water supply wells located within the delineated basin areas were extracting groundwater from the permeable materials underlying the area or from the bedrock beneath the permeable material. If the wells only extracted groundwater from the bedrock, the area was eliminated from the map. This resulted in the elimination of some areas identified as basins in previous Bulletin 118 publications. If there were no wells present in basin areas identified from the geologic map and no other information on the geology underlying these areas, the areas were retained in the current version of the map. Additional hydrogeologic information might or might not verify that these areas should be retained as groundwater basins.

Groundwater basins were delineated and separated from each other by the following restrictions on groundwater flow. For more detail on the types of basins and the flow boundaries of those basins, see Table 8.

Impermeable Bedrock. Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline or metamorphic rock.

Constrictions in Permeable Materials. A lower permeability material, even with openings that are filled with more permeable stream channel materials, generally forms a basin boundary for practical purposes. While groundwater may flow through the sediment filled gaps, the flow is restricted to those gaps.

Fault. A fault that crosses permeable materials may form a barrier to groundwater movement if movement along the fault plane has created fine material that impedes groundwater movement or juxtaposed low permeability material adjacent to an aquifer. This is usually indicated by noticeable difference in water levels in wells and/or flow patterns on either side of the fault. Not all faults act as barriers to groundwater flow.

Low Permeability Zone. Areas of clay or other fine-grained material that have significant areal or vertical extent generally form a barrier to groundwater movement within the basin but do not form basin boundaries.

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Groundwater Divide. A groundwater divide is generally considered a barrier to groundwater movement from one basin to another for practical purposes. Groundwater divides have noticeably divergent groundwater flow directions on either side of the divide with the water table sloping away from the divide. The location of the divide may change as water levels in either one of the basins change, making such a "divide" less useful. Such a boundary is often used for subbasins.

Adjudicated Basin Boundaries. The basin boundaries established by court order were used for all adjudicated basins. These court-decided boundaries affect the location of natural boundaries of adjoining basins. Some adjudicated basins are represented as subbasins in this bulletin.

Available reports on the geologic and hydrogeologic conditions in the delineated basin areas were also reviewed to determine if there was information that would further define the boundaries of the basin areas. This review resulted in changes to some of the basin boundaries identified in previous versions of Bulletin 118.

Several of the larger groundwater basins were further subdivided into groundwater subbasins in Bulletin 118-80 and additional large groundwater basins were subdivided during this 2003 revision. The subbasin boundaries were also primarily defined using geologic structures and hydrogeologic divides where possible. If this was not possible, political or institutional boundaries were used.

The hydrogeologic information contained in the basin descriptions that supplement this update of Bulletin 118 includes only the information that was available in California Department of Water Resources (DWR) files through reference searches and through limited contact with local agencies. Local agencies may have conducted more recent studies that have generated additional information about water budgets and aquifer characteristics. Unless the agency notifies DWR or provides a copy of the recent reports to DWR staff that recent information has not been included in the basin descriptions. Therefore, although Senate Bill 610 refers to groundwater basins identified as overdrafted in Bulletin 118, it would be prudent for local water suppliers to evaluate the potential for overdraft of any basin included as a part of a water supply assessment.

Persons interested in collecting groundwater information in accordance with the Water Code as amended by SB 221 and SB 610 may start with the information in Bulletin 118, but should follow up by consulting the references listed for each basin and contacting local water agencies to obtain any new information that is available. Otherwise, evaluation of available groundwater resources as mandated by SB 221 and SB 610 may not be using the most complete and recent information about water budgets and aquifer characteristics.

Groundwater basin and subbasin boundaries shown on the map included with this bulletin are based on evaluation of the best available information. In basins where many studies have been completed and the basin has been operated for a number of years, the basin response is fairly well understood and the boundaries are fairly well defined. Even in these basins, however, there are many unknowns and changes in boundaries may result as more information about the basin is collected and evaluated.

In many other basins where much less is known and understood about the basin, boundaries will probably change as a better understanding of the basin is developed. A procedure for collecting information from all the stakeholders should be developed for use statewide so that agreement on basin boundaries can be achieved.

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Los Angeles Department of Water & Power

2012 POWER INTEGRATED RESOURCE PLAN

December 2012

LADWP's Pine Tree Solar and Wind farms - Tehachapi, CA

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Los Angeles Department of Water & Power

2012 Power Integrated Resource Plan

APPROVED BY:

RONALD O. NICHOLS
GENERAL MANAGER

ARAM BENYAMIN
SENIOR ASSISTANT GENERAL MANAGER
POWER SYSTEM

December 3, 2012

Integrated Resource Planning
Power System Planning & Development

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Los Angeles Department of Water and Power

2012 Power Integrated Resource Plan

December 3, 2012

Recommended by:

Daryl A. Buckley, Director – Power System Transmission and Distribution

Michael A. Coia, Assistant General Manager – Power System Executive Office

John R. Dennis, Power Engineering Manager – Power System Executive Office

Randy S. Howard, Director – Power System Planning and Development

Tyrone G. Jeffery, Manager – Power System Training and Development

John C. Kokoska, Director – Power System Internal Generation

Marvin D. Moon, Director – Power System Engineering

Eric J. Tharp, Director – Power System External Generation

David B. Thrasher, Director – Power System Integrated Support Services

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Preface

This 2012 Integrated Resource Plan (IRP) document revises and builds upon last year's 2011 IRP. Major changes from 2011 include expanded discussion regarding the Power Reliability Program, more detailed information on transmission planning and projects, a new subsection on the impacts of climate change on power system operations, and new case options that analyze higher levels of energy efficiency and solar distributed generation.

The current load forecast used in this IRP is lower than the one used in 2011. Compared to the prior forecast, electricity sales for year 2020 decreased by approximately 5.3 percent mostly due to increasing levels of energy efficiency.

Early coal replacement continues to be a key strategy to reduce greenhouse gas emissions. As with last year's IRP, this 2012 IRP recommends divestiture of the Navajo coal plant by 2015, four years ahead of the scheduled 2019 end date. LADWP will replace the loss of Navajo with energy efficiency, renewable energy, and natural gas generation. LADWP's other coal source – the Intermountain Power Project—is undergoing discussions which could enable a future conversion to lower emitting resources. Because LADWP is one of thirty-six purchasers of IPP energy, any future plans must be agreed to by all project participants. Proposed amendments to the existing contracts are being considered by the purchasers which would require IPP to switch fuel from coal to natural gas no later than July 1, 2025 (two-years before the legal deadline). These amendments require unanimous approval and final purchaser decisions are expected by the end of 2013. Since the results of these discussions are not available for this 2012 IRP, we are hopeful that the plan will be in place for inclusion into next year's IRP process.

This 2012 IRP process included public outreach. Stakeholder meetings were held early in the year to solicit input towards the development of strategic case options. After the case options were analyzed, preliminary results were presented to the public for comment at meetings and through the LADWP website. This 2012 IRP documents the public outreach effort, and addresses the major themes that emerged from that process.

This IRP also includes a general assessment of the revenue requirements and rate effects that support the recommended resource plan through 2032. While this assessment was not as detailed and exhaustive as the financial analysis within the just completed rate case, it does show clearly the general requirements.

The recently concluded rate process confirmed LADWP's revenue requirements, over the next two years, to meet its mandated obligations and responsibilities. As a long-term planning process, the IRP looks at a 20-year horizon to secure adequate supplies of electricity. In that respect, it is our desire that the IRP contribute towards future rate processes by presenting and discussing the programs and projects required to fulfill our City Charter mandate to delivery reliable electric power to the City of Los Angeles.

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1. Introduction and Purpose

This document represents the Los Angeles Department of Water and Power (LADWP) Integrated Resource Plan (IRP) for 2012. The goal of this IRP is to identify a portfolio of generation resources and Power System assets that meets the city's future energy needs at the lowest cost and risk consistent with LADWP's environmental priorities and reliability standards. The IRP is an important planning document for electric utilities, and many states and regulatory agencies require development of an IRP prior to approval of procurement programs or electric rate increases.

This document goes beyond traditional integrated resource planning and incorporates additional Power System planning elements to form a comprehensive Power System plan. It is intended that this Power System plan will drive the priorities, financial planning, and budgeting effort for the Power System.

This IRP considers a 20-year planning horizon to guide LADWP as it executes major new and replacement projects and programs. The overriding purpose is to provide a framework to assure the future energy needs of LADWP customers are met in a manner that balances the following key objectives:

- Superior reliability and supply of electric service
- Competitive electric rates consistent with sound business principles
- Responsible environmental stewardship exceeding all regulatory obligations

In balancing these objectives, LADWP's strategic planning efforts must ensure a high level of system reliability, consider impacts to the local and regional economy, mitigate the volatility in fuel and other cost factors, comply with federal, state, and local regulations, and guarantee fiscal responsibility.

LADWP is the largest municipal utility in the nation, and the third largest utility in California. While numerous recent accomplishments have been made – including achieving 20% of renewable energy sales in 2010 – significant challenges lie ahead. Increasing renewable energy to 33% by 2020, the continued rebuilding of coastal generation units, replacement of coal, infrastructure reliability investments, and ramping up energy efficiency and other demand side programs are all critical and concurrent strategic actions that LADWP will have to carry out over the coming decade.

The 2012 integrated resource planning process developed alternative strategic cases that assess different replacement options for coal-fired generation, as well as different projected levels of energy efficiency and distributed generation. The cases are modeled to determine their respective operational and fiscal impacts, as well as their effects on greenhouse gas emission levels. This document presents the results of this analysis, recommended near-term actions, and a recommended strategy to best meet the future electrical needs of Los Angeles.

AR0069880

LADWP Power System Vision

The transformation that this utility will undergo in the next 20 years will be unprecedented as the use of electricity broadens to new applications and as customer expectations of clean affordable energy continues to take root. Increases in electric vehicle use, expanded electrification of processes to reduce emissions and greenhouse gases, and growing wide-spread use of information technology equipment will require a stable, resilient power grid that delivers affordable power. By adopting energy efficiency, promoting solar rooftop and supporting other clean technologies that mitigate the need to build new fossil-fueled power plants, our customers are embracing the vision of a greener resource portfolio that sustains the environment for future generations.

LADWP and its City Leaders have traditionally taken a leadership position, particularly among public power utilities, to ensure a sustainable, diverse supply of generation and transmission resources to provide electricity to our customers. This utility has also been very progressive in adopting aggressive clean energy goals and programs well before many of today's laws and regulations were in place, and participated in the development of many of the laws and regulations that we see today. In 2000, this utility set out to reduce load growth by 50 percent through the use of renewables, energy efficiency, and distributed generation. Today we have the same electricity consumption as we had in 2000 largely due to these earlier efforts. In 2005, we adopted a renewable target of 20 percent renewable by 2010, and we succeeded to be the largest California utility to achieve 20 percent renewable generation in 2010. Since 1990, we have divested of 2 coal plants and repowered several natural gas in-basin generating stations using cleaner and more efficient new combustion technology, resulting in 21 percent lower greenhouse gas emissions and over 80 percent lower NOx emissions. Reducing ocean water use and reducing the impact on marine life has also been an on-going effort and by next year we will use 42% less ocean water from 1990 levels, with total elimination targeted by 2029.

The world today is not the same as it was 20 years ago, and the world 20 years from now will not be the same as it is today. And while LADWP's mission of providing reliable, affordable electricity in an environmentally responsible manner remains the same, the planning and execution of that mission requires continued diligence to account for, adopt, and even influence, the changing public concerns and priorities related to electricity generation and use.

AR0069881

1.1 Major Changes from Last Year's IRP

Major changes from last year's 2011 IRP include expanded discussion on the Power Reliability Program, more detailed information on transmission planning and projects, a new sub-section on the future impacts of climate change on power generation and operations, and new case options that analyze higher levels of Energy Efficiency (EE) and Distributed Solar Generation (Solar DG).

This 2012 IRP incorporates updates to reflect the latest load forecast, fuel price and projected renewable price forecasts, and other numerous modeling assumptions. Compared to the prior forecast, projected electricity sales in calendar year 2020 decreased by 5.3 percent, mostly due to increased levels of energy efficiency. The new forecast reduces the overall need for renewable energy (assuming 33% RPS) by approximately 461 GWh in 2020 and 745 GWh in 2030.

Long term natural gas price forecasts have been revised downwards from last year with recent prices reaching very low levels over the last year. Compared to last year's 2011 IRP, Opal and SoCal expected gas prices are 16% lower on average in the short term (2011-2020) and 8-9% lower on average in the long term (2021-2030). Coal price forecasts are also lower; with IPP coal at 4% lower for the period 2012-2027, and Navajo coal at 14% lower for the period 2012-2019.

Other changes include lower cost assumptions for solar and geothermal, reflecting price competition for both resources, and updates regarding legislative and regulatory issues. See Section 3 and Appendix N for more details.

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2. Recent Accomplishments

A summary of recent LADWP accomplishments consistent with the objectives of this IRP are presented below in Table ES-1. These accomplishments promote the goals of maintaining high reliability and exercising environmental stewardship, while keeping rates competitive. See Section 1.5 for more details.

Table ES-1. LADWP RECENT ACCOMPLISHED PROJECTS/PROGRAMS

Project/Program	Time Period	Accomplishment
Renewable Portfolio Standard	2003 to 2010	Increased renewable energy percentage from 3% to 20%
Adelanto Solar	2012	10 MW solar project built, put in-service
Energy Efficiency Program	2012	Recommitment goals adopted: 10% by 2020, with target of 15%
Solar Incentive Program	1999 to Present	Provided funding that has enabled the installation of 55 MW of solar to date
Solar Feed-in-Tariff	2012	Pilot program conducted, followed by full scale re-launch for up to 150 MW
Milford II Wind Project	2011	Supply over 100 MW of wind energy
CO_2 Emissions Reduction	1990 to 2010	CO_2 emission 22% lower than 1990 level
Once-through Cooling	1990 to Present	OTC reduced by 17% from 1990 level
Haynes 5&6	2011-12	Repowering project initiated, new turbines installed. In-service scheduled for 2013
Castaic Upgrade	2004 to 2014	Project adds up to 80 MW of renewable capacity
Power Reliability Program	Ongoing	In 2011-12, replaced 1,813 poles, 2,054 transformers, and 51 miles of UG cable
Navajo Generation Station Replacement	Ongoing	Process to divest initiated. RFP for replacement capacity issued.
Southern Transmission System Upgrade	2011	Increased capacity of 480 MW was added to the existing transmission line
Green Power Program	1999 to 2011	Participants receive 104 GWh of renewable energy annually
Electric Vehicles Incentive	2011	Provide a $2000 rebate for home EV charging systems
Demand Response Program	1999 to Present	Signed up 60 MW of load shifting and interruptible load
Alternative Marine Power Program	Through 2012	Signed up 13.8 MW of load to offset diesel motor emissions at the Port of LA

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3. 2012 IRP Development Process

The IRP is prepared by a group of engineers dedicated to LADWP resource planning and preparation of the IRP document. While this group performs the production model and report preparation for the IRP, the bulk of the work is collaborative across the numerous work groups and functional areas of the Power System, including wholesale marketing, grid operations, renewable procurement, environmental and legislative affairs, and financial services.

The following general sequence represents the process to develop this IRP document:

1. Gather stakeholder input
2. Establish clear goals and objectives
3. Identify and approve key assumptions
4. Establish strategic case alternatives
5. Conduct computer modeling of Power System operations
6. Present preliminary findings and gather internal and public comments
7. Recommend and approve a preferred resource case

Stakeholder input was considered in the establishment of the goals and objectives for the IRP analysis. Modeling assumptions and case alternatives were identified and approved by an internal IRP Steering Committee consisting of Power System Division and Section heads. Preliminary results were analyzed and presented to the public for review and input. Final recommendations incorporating public feedback were then forwarded to the General Manager and Board of Water and Power Commissioners.

The IRP development process includes coordination among multiple LADWP organizations responsible for different aspects of Power System operations. Recommended positions at the various stages were presented to LADWP's leadership team, including Division and Section Heads. The approval process for recommendations was based on consensus from the managers of each area of responsibility.

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4. Public Outreach

The 2012 IRP process includes a public outreach effort to provide information and gather public input.

Public outreach began with two stakeholder meetings held in early 2012. LADWP staff met with key major customers and business representatives in February; and in March with key environmental organization representatives. Comments received during these stakeholder meetings were considered in the development of the preliminary cases that were analyzed.

The preliminary results were documented in the 2012 Draft IRP that was made available at www.ladwp.com/lapowerplan on October 5, 2012. The draft IRP was presented at three stakeholder meetings and one public workshop held on October 11, 2012. Comments were accepted through November 5, 2012.

Comments received were synthesized into the following major themes. Each theme is considered of equal importance. The following list is not presented in any order of importance

Eliminate Coal from LADWP's Energy Portfolio

Incorporate More Renewables

Incorporate More Local Solar

Incorporate More Distributed Generation

Incorporate More Energy Efficiency

Reduce Greenhouse Gas Emissions

Look at New Case Scenarios

Financial and Rate Concerns

Maintain Power Reliability

LADWP Should Take a Leadership Role

Public comment and input received was considered prior to finalizing this 2012 IRP.

A summary of the public comments received is included in Section 5 and Appendix O.

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5. Challenges and Critical Issues

LADWP faces a number of concurrent issues and challenges that require careful assessment. Long term strategies must focus on these issues so they can be addressed in the most cost effective manner without compromising reliability compliance and environmental stewardship. The major issues around which the strategies of this IRP are centered include: adequate funding to support programs; ensuring reliability; greenhouse gas emissions reduction; increasing the amounts of renewable generation resources; and addressing once-through cooling.

5.1 Adequate Funding to Support Programs

To support the recommended projects and programs, adequate funding is necessary. Due to the delay of the rate action that was previously anticipated in 2011, many of the programs were scaled down, delayed or deferred. The rate process that concluded on October 5, 2012 is a positive step towards LADWP's fulfillment of its responsibilities and regulatory obligations that are discussed throughout this 2012 IRP.

Properly funded programs will enable LADWP to achieve the following objectives:

- Modernize its coastal generation units to replace aging equipment and to satisfy once-through cooling and local emissions regulatory requirements.
- Implement early coal divestiture and replacement to accelerate the reduction of greenhouse gas emissions and to enhance integration of renewable energy and energy efficiency measures.
- Secure the state-mandated amounts of renewable energy.
- Increase use of local distributed solar generation and combined heat and power to support State goals.
- Through the Power Reliability Program, reduce the number and duration of distribution outages and improve system reliability.
- Implement necessary transmission improvements to maintain reliability and support new resources, including renewables.
- Provide energy efficiency and customer solar programs for participation by our customers through the Customer Opportunities Program.
- Achieve energy efficiency and other demand-side-resource target levels.
- Implement Smart Grid initiatives.
- Comply with FERC-approved reliability and Cyber-security standards.

Securing adequate multi-year funding is crucial to ensure LADWP's ability to stay on track towards meeting its future long term goals and obligations.

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5.2 Ensuring Reliability

Challenges to ensuring continued reliable electric service include the replacement of aging generation facilities, maintaining grid reliability, the integration of intermittent renewable energy resources, and the replacement of poles, power cables, transformers and other elements of the local distribution system.

LADWP's Repowering Program, which began in 1994, is a long term program to upgrade LADWP's in-basin generating units. The program is a sequence of projects that extends to 2029 that will eliminate the use of once through cooling and provide modern units that are more reliable, efficient, and community-friendly than the units they are replacing.

To maintain grid reliability, LADWP's Ten-Year Transmission Assessment Plan has identified a number of necessary improvements that are needed to avoid potential overloads on key segments of the Basin transmission system. These overload conditions, if encountered, could lead to load shedding events (intentional power outages) to minimize the overall impact on the Power System.

The integration of renewable energy into the grid poses major reliability challenges. Because renewable resources like wind and solar produce electricity variably and intermittently (i.e., only when the wind is blowing or when the sun is shining), integration of these resources requires additional supplemental generator units to compensate for significant and often rapid swings in energy production. These swings present operational challenges and must be leveled by controllable generation capable of equally rapid changes of generation in the opposite direction.

Between 2003 and 2005, LADWP experienced a growing number of distribution outages due to, among other things, aging infrastructure (poles, lines, transformers, etc.), deferred maintenance and asset replacement.[1] In response, LADWP established a comprehensive Power Reliability Program (PRP) in 2006 which provided increased funding to address the growing maintenance and replacement backlog. The PRP experienced initial success as the number of outages decreased from 6,323 in 2006 to 4,523 in 2009. Since then, however, funding constraints have prevented any measurable improvement.

5.3 Greenhouse Gas Emissions Reduction

While LADWP has multiple and concurrent GHG emissions reduction strategies, the primary focus is early replacement of coal-fired generation. Because coal-fired energy production emits relatively high levels of CO_2, switching to energy efficiency, renewables and other cleaner fuels will significantly lower the overall emission levels. Early coal replacement facilitates LADWP's compliance with AB 32's upcoming cap and trade program.

During calendar year 2011, 41 percent of the energy delivered to LADWP customers was

[1] To illustrate the age of the distribution system, over 25 percent of the City's 321,780 distribution poles have already exceeded their 60-year life expectancy.

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generated from two coal-fired generating stations: the Intermountain Power Project (IPP), located in Utah, and the Navajo Generating Station (NGS), located in Arizona. The NGS's operating agreement and land lease expires in December 2019 and IPP's Power Purchase Agreement (PPA) contract is in effect until June 2027. Although these stations provide dependable, low cost base load generation to Los Angeles, they emit about twice as much CO_2 as energy generated with natural gas. Accordingly, this 2012 IRP focuses on early coal replacement options as a means to lower LADWP's CO_2 emission levels. Sections 3 and 4 discuss the coal replacement options in detail.

LADWP's CO_2 emissions reduction strategy must comply with state regulations:

- SB 1368, the California Greenhouse Gas Emissions Performance Standard Act, enacted in 2006, prohibits LADWP and other California utilities from entering into long-term financial commitments for base load generation unless it complies with the CO_2 emissions performance standard. The CO_2 emissions level must be equal, or below the emissions performance standard of 1,100 lbs. per MWh that can be achieved by gas-fired combined cycle units. This standard also applies to existing power plants for any long-term investments or contractual extensions, effectively prohibiting LADWP from continued acceptance of coal-fired generation beyond the current contractual expiration dates for NGS (2019) and IPP (2027).
- Assembly Bill (AB) 32, the California Global Warming Solutions Act of 2006, calls for reducing the state's CO_2 emissions to 1990 levels by 2020. The regulations for implementing a greenhouse gas emissions Cap and Trade program under AB 32 were finalized and adopted on October 20, 2011 by the California Air Resources Board (ARB). Enforcement and compliance with the trading program will begin January 1, 2013. LADWP has been granted an administrative allocation of emission allowances that reflects its resource projections through 2020. At this time, it is uncertain if the program will extend beyond 2020.

5.4 Increasing Renewable Resources

LADWP's policy for renewables was initiated in the early 2000's, and has guided the adoption of increasing levels of renewable energy, including the milestone achievement of 20 percent of energy sales in 2010. Major legislation affecting LADWP's renewable policy are SB 1, SB 32, and SB 2 (1X).

Senate Bill 1 (SB 1)

Former Governor Schwarzenegger signed the California Solar Initiative (CSI), outlined in SB 1, on August 21, 2006. The CSI mandated that all California electric utilities, including municipals, implement a solar incentive program by January 1, 2008. The goal of the CSI is 3,000 MW of net-metered solar energy systems over 10 years with expenditures not to exceed $3.35 Billion. Expenditures for local publicly owned electric utilities shall not exceed $784 Million. The LADWP cap amount is $313 Million, based on its serving 39.9% of the municipal load in the state.

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SB 32

SB 32, signed into law on October 11, 2009, requires LADWP to make a tariff available to eligible renewable electric generation facilities within its service territory until LADWP meets its 75 MW share of the statewide target. Through this program, owners or operators of eligible renewable energy systems may sell their energy directly to LADWP. The purchase of SB 32 qualifying energy includes all environmental attributes, capacity rights, and renewable energy credits. This energy is just one of the many renewable energy sources that will apply towards LADWP's 33 percent renewable requirement.

SB 2 (1X)

Following the passage of SB 2 (1X) in 2011, LADWP's renewable energy policy is now largely driven by those requirements of SB 2 (1X).

SB 2 (1X), which was passed in April 2011 and became effective on December 10, 2011, subjects all utilities to procurement of eligible renewable energy resources of 33 percent by 2020, including the following interim targets:

- Maintain at least an average of 20 percent renewables between 2011 and 2013
- Achieve 25 percent renewables by 2016

In December 2011, LADWP amended its Renewable Portfolio Standard Policy and Enforcement Program to comply with the requirements of SB 2 (1X). However, LADWP's policy continues to include some requirements that are not a part of SB 2 (1X) but were in place prior to enactment of the State legislation. These additional requirements include the provision for LADWP to own at least 50 percent of its renewable energy resources, and to give preference to projects located within the City.

As LADWP expands its renewable resource portfolio, it is important that it do so in a cost effective manner to minimize the impact on ratepayers. Some of the considerations in selecting these resources are as follows:

- Cost differences for different renewable technologies
- Cost trends that reflect decreasing prices
- Variable integration costs and operational impacts
- Technologies that deliver more energy during peak hours
- Preference for local projects
- Proximity of projects to transmission
- For PPA resources, tax credits that can be passed along as cost savings
- PPA proposals that provide future ownership opportunities
- Overall diversity of resource mix and geography
- Qualification as "Bucket 1" energy according to CEC RPS regulation and guidelines
- Assessing projects on the basis of value to maximize benefits and minimize risks

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In this 2012 IRP, the overall base renewable portfolio levelized cost is $98/MWh, which represents an $11/MWh decrease from last year. This cost reduction was achieved by selecting a more optimized and diverse portfolio that accounts for changing price trends and market developments. By maintaining flexibility in the selection of cost-effective renewable resources, LADWP is able to secure the best pricing as market conditions evolve.

5.5 Once Through Cooling

Once-through cooling (OTC) is the process of drawing water from a river, lake, or ocean, pumping it through a generating station's cooling system, and discharging it back to the original body of water. OTC is a utility regulatory issue, stemming from the Federal Clean Water Act Section 316(b) and administered locally by the State Water Resources Control Board (SWRCB).

OTC regulations affect LADWP's three coastal generating stations – Scattergood, Haynes, and Harbor. To comply with OTC regulations, generation units at those stations that utilize ocean water for cooling will be repowered with new units that do not use ocean water. The amount of generation capacity affected by OTC is significant – approximately 2,600 MW of LADWP's total in-basin plant capacity of 3415 MW. The total expenditures required are also significant, on the order of $2.2 billion. Because of the size and scope of the effort required, the work to comply with OTC regulation is a long term program, extending to 2029. Figure ES-1 is a timeline of the program target dates. More information regarding OTC is provided in Section 1.6.6.

Figure ES-1. Timeline for OTC compliance.

5.6 Workforce Development

To effectively implement the programs and projects recommended in this IRP, an effective human resources strategy is required. The Power System is challenged to develop a sustainable workforce development plan that addresses the following human resource elements:

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Staffing
Adequate staffing is needed to meet mandated deadlines and regulatory obligations, to execute new and expanded work functions, and to manage the volume of retirements expected over the next 3-5 years.

Proper Skill Sets
New work areas such as renewable energy facility operations, solar distributed generation, and smart grid deployment will require analysis to identify the skills, knowledge and abilities required to perform these functions in a safe, effective and efficient manner.

Training/Professional Development and New Technologies
LADWP supports employee development by providing various computer-based training programs, and offers tuition reimbursement for those who return to school to enroll in work-related courses and advanced degree programs. Across the Power System, different work groups are encouraged to develop training specific to their particular functions and needs. This is especially important as new and emerging technologies become applicable to various work functions. Applied correctly, technology increases employee productivity, enhances safety, and enables new and expanded customer services.

Recruitment
Recruiting the best qualified employees assures an effective workforce capable of meeting the near term and long term challenges identified in this IRP. Continued use of LADWP's website and social media to promote career opportunities will help ensure that the best qualified individuals consider joining the LADWP workforce.

5.7 Other Challenges

Additional challenges that LADWP must address in the coming years include:

- Managing potential natural gas price volatility
- Incorporating higher levels of Distributed Generation (DG) that advance renewable resource and local solar objectives, and support the State's promotion for more DG
- A heightened demand for transmission planning to support new and intermittent resources that has introduced greater complexity
- Cyber security regulations
- The relicensing of the Castaic Pumped Storage facility with the Federal Energy Regulatory Commission
- Accounting for the effects of climate change on power generation, operations, and markets
- Load factor improvement
- Acquisition of replacement resources for coal-fired generation

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6. Strategic Case Alternatives

The 2012 IRP strategic cases incorporate the latest developments in legislation and regulation, and tactical plans developed by the Power System. This 2012 IRP also includes updated assumptions that have influenced the composition of potential resource portfolios that can fulfill LADWP's goals of reliability, competitive rates, and environmental stewardship.

The coal cases analyzed in this 2012 IRP consider different replacement dates for LADWP's two coal resources – the Navajo Generating Station (NGS), and the Intermountain Power Project (IPP). The coal replacement dates for Cases 1, 2 and 3 are similar to the cases analyzed in last year's 2011 IRP. The replacement date of December 2023 for IPP (Case 4) is new for this year.

In addition to the coal cases, this 2012 IRP also analyzes four additional cases to consider higher levels of energy efficiency and solar distributed generation.

The assumptions used in the development of all cases have been updated to reflect recent changes in fuel pricing, renewable project cost estimates and renewable resource mix, and updated energy efficiency goals including 10 percent by 2020.

Section 3 of this IRP provides more information surrounding the development of the cases, including resource adequacy and net-short considerations. Table ES-2 provides a detailed description of each strategic case. For comparison purposes, the recommended case from last year's IRP is included in the table.

More detailed description of the assumptions used in developing these cases can be found in Appendix N.

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Table ES-2. CANDIDATE RESOURCE PORTFOLIOS FOR 2012 IRP

COAL CASES

		GHG or SB1368 Compliance Date		2020	2010 thru 2020	2010 thru 2032	New Renewables Installed Capacity (MW) 2012 - 2020					New Renewables Installed Capacity (MW) 2012-2032				
Case ID	Resource Strategy	Navajo Replacement	IPP Replacement	RPS Target	EE (GWh)	EE (GWh)	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
1 (Base Case)	No Early Coal Divestiture	12/1/2019	6/15/2027	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
2	Navajo Early Replacement	12/31/2015	6/15/2027	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
3	Navajo and IPP Early	12/31/2015	12/31/2020	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
4	Navajo and IPP Early (Alt.)	12/31/2015	12/31/2023	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
2011 Recommended	Navajo Early Replacement	12/31/2015	6/15/2027	33%	1443	2183	243	492	401	325	0	308	492	451	495	162

ENERGY EFFICIENCY AND DISTRIBUTED GENERATION CASES

		2020	2010 thru 2020	2010 thru 2032	New Renewables Installed Capacity (MW) 2012 - 2020					New Renewables Installed Capacity (MW) 2012-2032				
Case ID	Resource Strategy[1]	RPS Target	EE (Net GWh)	EE (Net GWh)	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
5 (Base Case)	Base EE , Base Solar DG	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
6	Advanced EE, Base Solar DG	33%	2300	4000	242	0	887	337	39	283	0	915	496	114
7	Base EE, High Solar DG	33%	2300	3500	242	0	847	485	39	258	0	876	852	95
8	Advanced EE, High Solar DG	33%	2300	4000	242	0	847	485	39	258	0	876	852	0

[1]EE percentages are as follows:

	By 2020	By 2032
Base EE	10%	15.2%
Advanced EE	10%	17.4%

The feasibility of attaining EE levels greater than 10% are uncertain at this time, but will be addressed in the upcoming EE Potential Study to be completed in 2013.

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7. Evaluation of Strategic Case Options

Key results for each model run were tabulated and compared against each other. Each strategy was compared on average incremental dollars per megawatt hour generation cost and the total million metric tons of CO_2 emissions. The selection of the best case for LADWP ratepayers hinges mainly upon the load forecast, price of fuel, and CO_2 emission levels. All cases meet the mandated RPS percentage targets and reliability standards. The analytics performed for this IRP examined the associated costs of each strategic case.

The key modeling results are summarized below:

7.1 CO_2 Emissions Considerations

Current GHG emissions levels are approximately 14.1 MMT which is 21 percent below 1990 levels due to the prior elimination of power from the Mojave and Colstrip coal plants, completed repowering of units at Haynes and Valley generating stations with cleaner gas-fired replacements, and increased renewable generation from 3% in 2003 to 20% of overall sales in 2010. Using Case 1 (Navajo divestiture in 2019, IPP replacement in 2027) as a baseline, early divestiture of Navajo in Cases 2, 3 and 4 results in approximately 7.2 MMT less GHG emissions between 2016 and 2019. For Case 3 (IPP replaced in 2020) there is an additional post-2020 cumulative reduction of 19.5 MMT. For Case 4, the post-2020 reduction is 9.3 MMT. These GHG emission reductions are shown below in Table ES-3 and Figure ES-2.

Table ES-3 GHG EMISSIONS REDUCTION LEVELS IN MMT

Case	Reduction 2016-19	Reduction 2020-27	Total Reduction 2016-27
1	Baseline	Baseline	Baseline
2	7.2	0.0	7.2
3	7.2	19.5	26.7
4	7.2	9.3	16.3

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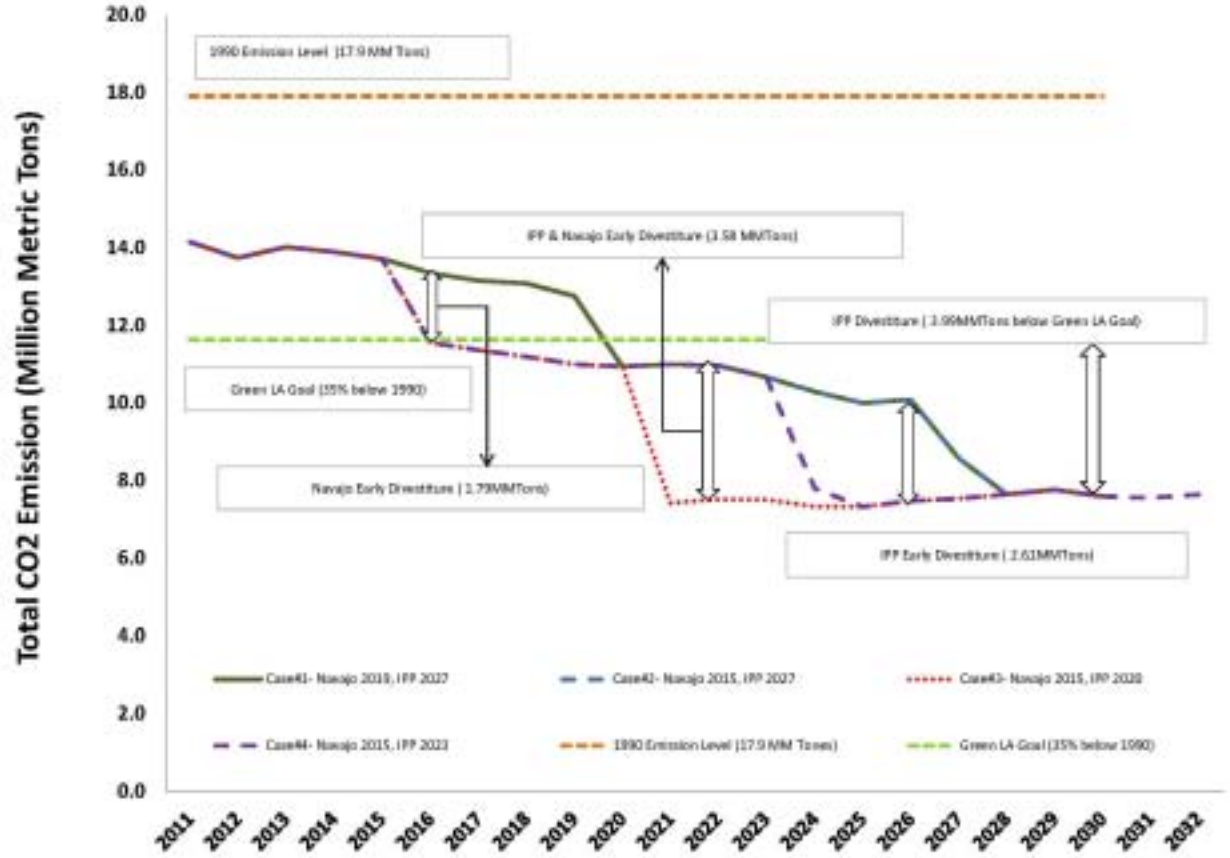

Figure ES-2. GHG emissions comparison by calendar year.

Emissions levels for energy efficiency and solar distributed generation, Cases 5 thru 8, were also evaluated and are shown in Figure ES-3. Advanced levels of EE were found to result in slightly lower emissions of CO_2 as compared to the Base EE cases. Higher levels of Solar DG were found to have little effect on reducing CO_2 emissions since Solar DG would have been replaced with other zero emissions resources. Although these higher levels of EE and distributed generation have a small impact on emissions compared to the base EE, it is important to note that the base level of energy efficiency in itself has a very significant impact on reducing overall CO_2 levels as shown by the "No More EE" curve illustrated in Figure ES-2. If no additional EE were implemented, annual GHG emissions levels would be approximately 2.0 MMT higher by 2032. This is equivalent to removing 385,000 cars from the road. For reference purposes, the CARB emissions allocation for LADWP as part of the AB 32 Cap and Trade program being implemented in 2013 and ending in 2020 is included in Figure ES-3.

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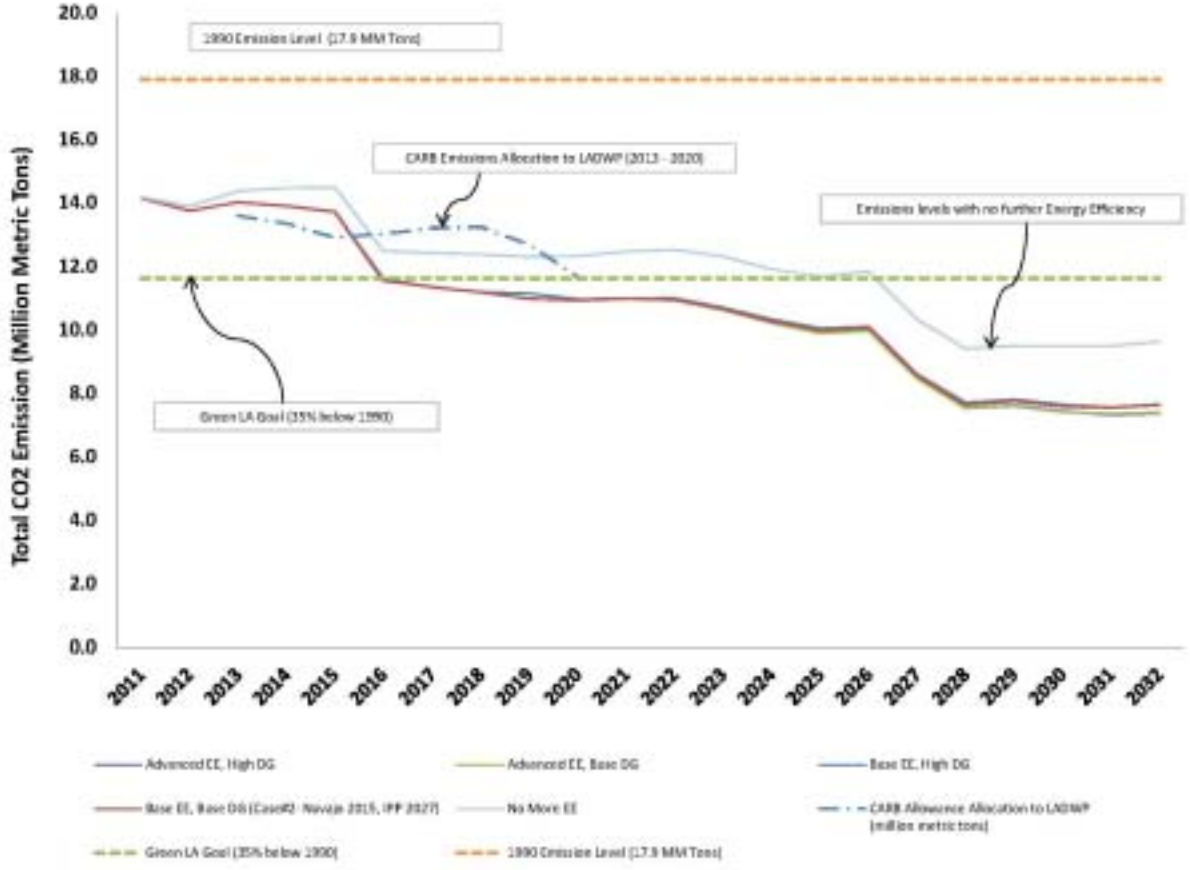

Figure ES-3. GHG emissions comparison for Energy Efficiency and Solar Distributed Generation cases by calendar year.

7.2 Total Power System Cost Comparisons

The total Power System cost for each case includes bulk power costs, depreciation costs related to transmission, distribution, and generation, bond debt-service, and city transfer costs[2]. These costs assume full funding of the Power System programs including the Power Reliability Program and Energy Efficiency programs among others. Total annual Power System costs are shown in Figure ES-4 and reflect short-term spending reductions through 2011-12 fiscal year with subsequent years reflecting a restoration of funding levels to ensure that the longer term IRP recommendations can be implemented. To the extent that energy efficiency costs are lower than the costs of generation it is replacing, its effect is to lower total costs. The costs shown in Figure ES-4 do not attempt to represent a thorough analysis of Power System finances, but they do illustrate the general trend of Power System costs relative to the 4 coal and 4 EE/DG cases analyzed.

[2] The city transfer payment is 8% of the previous year's operating revenue.

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Note:
Unless otherwise stated, forecasted costs in all charts in this IRP are "nominal".

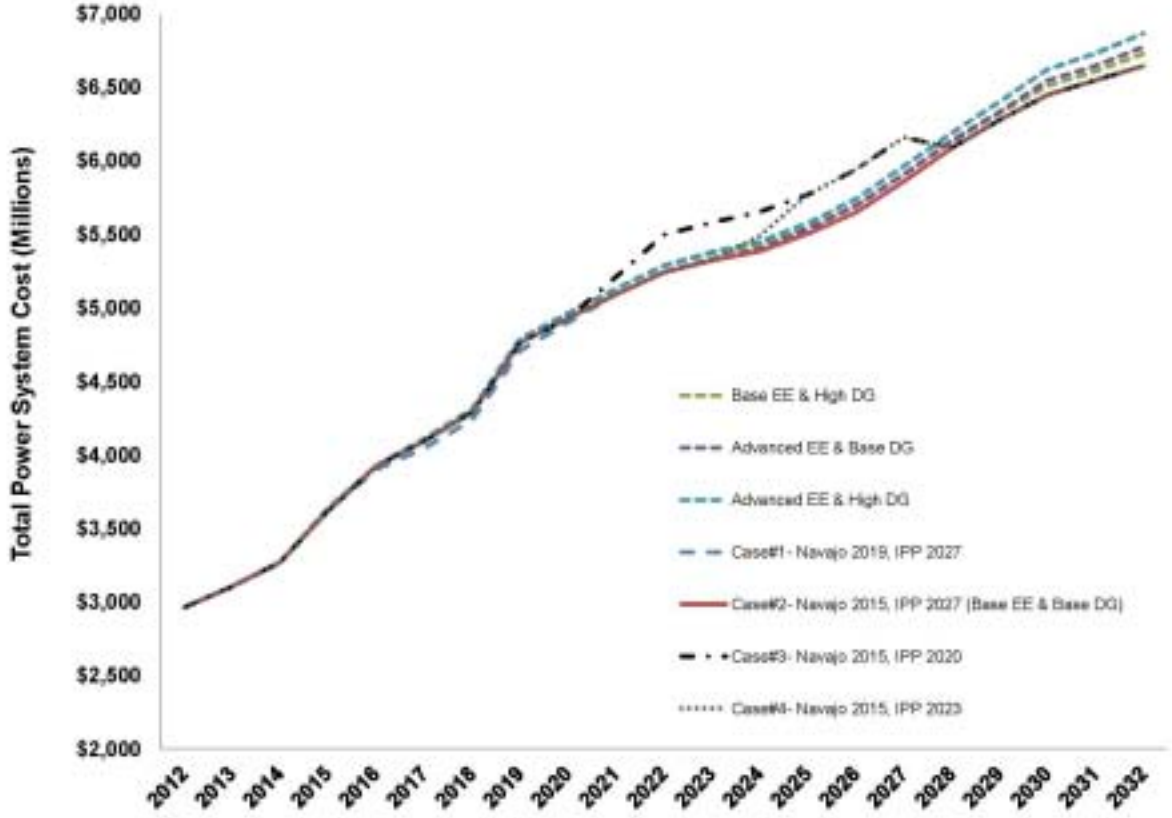

Figure ES-4. Comparison of annual Power System costs over the next 20 fiscal years.

The cost differences between the cases are highlighted in Table ES-4, which presents the incremental costs of the 4 coal cases and the 4 EE/DG cases. For the coal cases, the values listed under the Case 2 column represent the incremental costs between Cases 1 and 2 – i.e., the cost of early divestment of Navajo. The values listed under Case 3 and Case 4 represent the additional incremental costs of early IPP replacement in 2020 and 2023, respectively.

All EE & DG cases assume Navajo divestment in 2015 and IPP replaced in 2027. The values shown for Cases 6, 7, and 8 represent each case's incremental costs when compared to Case 5.

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TABLE ES-4 INCREMENTAL COST COMPARISONS BETWEEN CASES

Coal Case Summary

	Case 1	Case 2	Case 3	Case 4
Case Description	Navajo 2019, IPP 2027	Navajo 2015	IPP 2020	IPP 2023
Total Incremental Revenue $M	$0	$205	$1,790	$980
Average Incremental Revenue ($M/yr)	$0	$51	$275	$280

EE & DG Case Summary

	Case 5 (Baseline) *	Case 6	Case 7	Case 8
Case Description	Base EE & Base DG	Base EE & High DG	Advanced EE & Base DG	Advanced EE & High DG
Total Incremental Revenue $M	$0	$669	$494	$1,247
Average Incremental Revenue ($M/yr)	$0	$32	$24	$59

7.3 Sensitivity Analyses

An analysis of the effects of fuel price volatility was performed for the four coal cases and is shown in Figure ES-5. With the early divestiture of Navajo in 2015 and the IPP coal contract ending in June 2027, increased bulk power costs are expected with the replacement of each of these resources.

Elimination of coal involves the switch to more natural gas generation, which has higher fuel price volatility compared to coal. The resulting decrease in fuel diversity, along with the higher volatility of natural gas, will increase the risk of fuel cost changes in the future and so warrants careful evaluation when comparing the different case scenarios.

It is important to note that bulk power costs shown in Figure ES-5 include fuel, renewable and other purchase power costs in addition to coal replacement costs. After applying high and low fuel prices to these bulk power costs, the replacement of these resources could result in large cost increases should fuel prices remain at higher than expected levels. Conversely, lower than expected fuel prices could have the opposite effect on bulk power costs.

To help manage natural gas fuel price volatility, LADWP employs financial hedges for up to ten years, and physical hedges for up to five years. LADWP is in the process of developing a revised hedging strategy based on the newly approved rate ordinance.

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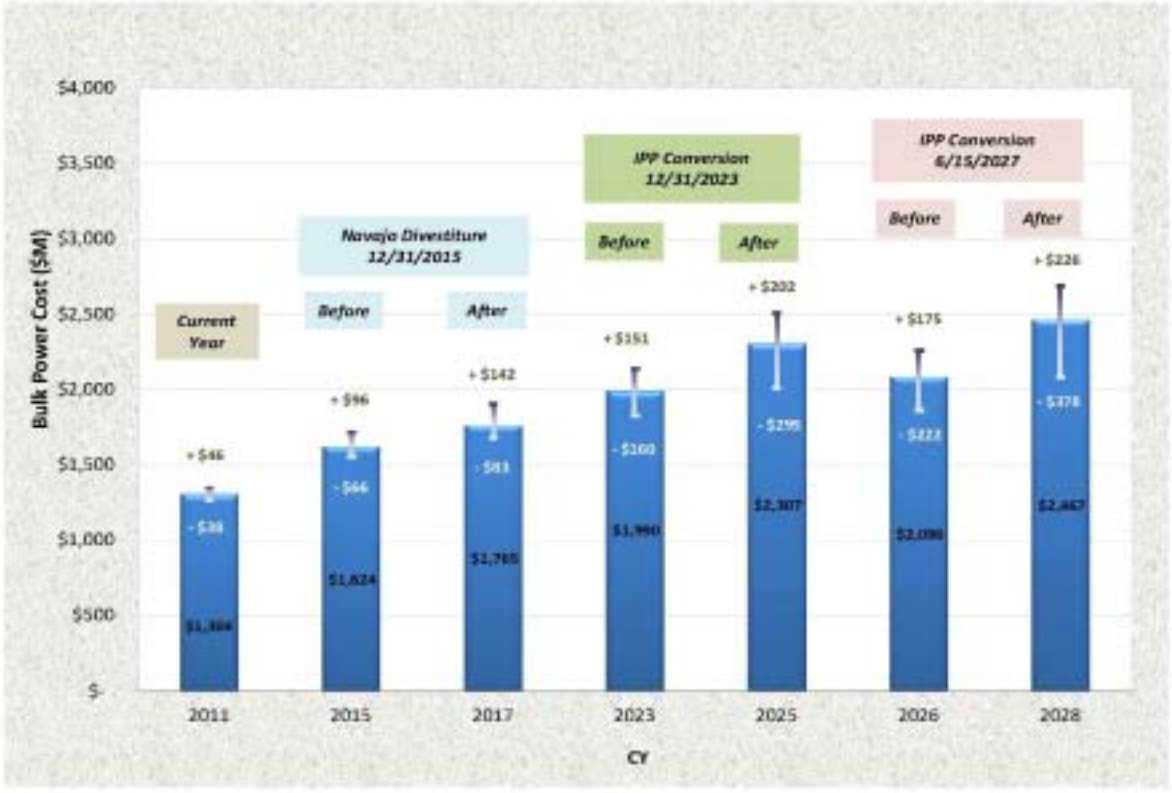

Figure ES-5. Bulk power cost before and after coal replacement with potential cost impacts from high (+$) and low (-$) fuel prices.

Increased risk exposure from high fuel costs may translate into higher customer electric rates. Figure ES-6 shows the potential rates that could be experienced under the 4 coal cases given high, expected, and low fuel ranges for both gas and coal fuel types. Today, overall coal costs represent approximately 65 percent of overall fuel expenditures. Once Navajo coal is replaced in 2015, this percentage will drop to 50 percent of overall fuel expenditures. From 2023 thru 2026, coal expenditures will gradually drop to 30 percent before reaching zero percent in 2027 when IPP coal is replaced, and future fuel price increases will be based solely on natural gas and nuclear.

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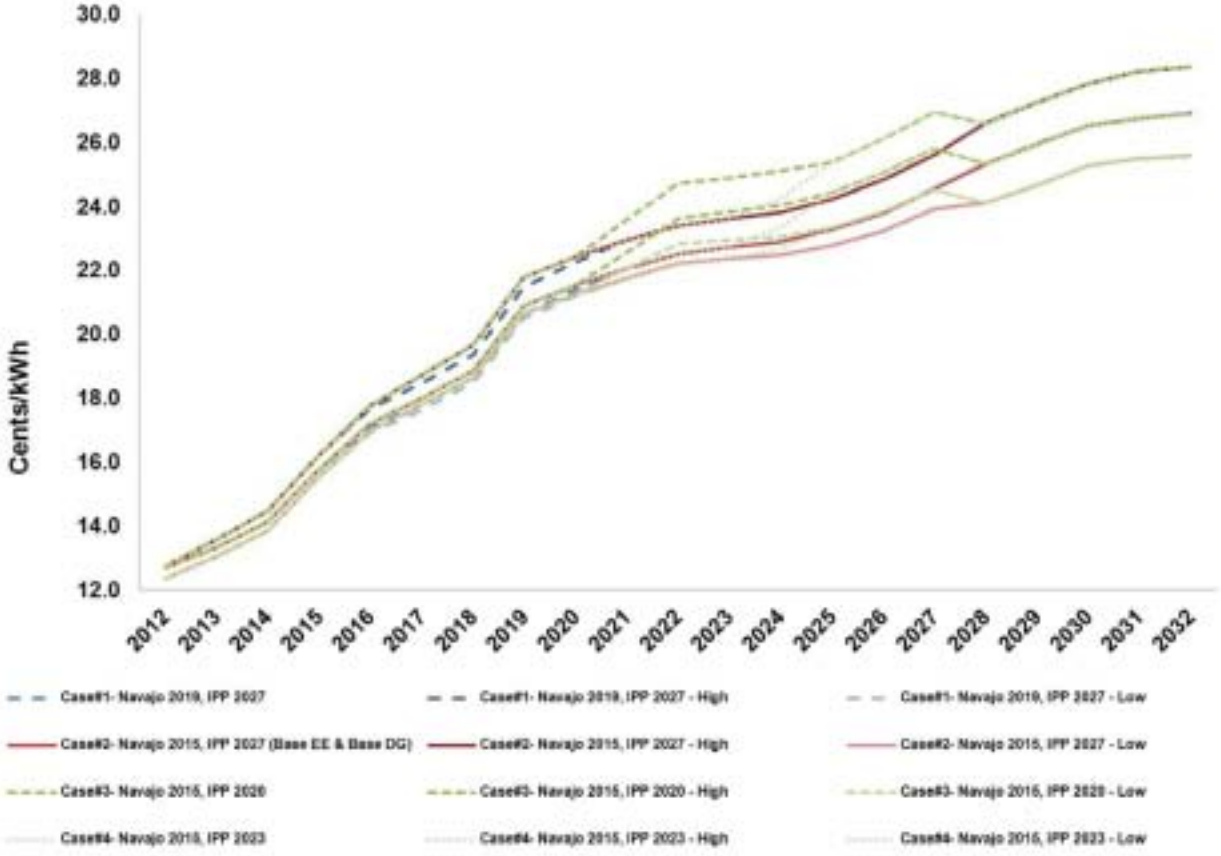

Figure ES-6. Estimated electric rate comparison with fuel price sensitivity over 20 years by fiscal year-ending

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7.4 Rate Contributions Breakdown

Figure ES-7 presents the fiscal year breakdown for Case 5 comprising rate contributions from reliability, energy efficiency, renewable energy, reliability, coal replacement, OTC repowering, other Generation, Transmission and Distribution (GT&D), and fuel costs between 2012 and 2032. These individual contributions represent incremental adders to the rates. For analysis purposes, the Reliability Program has been segmented into the basic program and preferred program. The preferred program contribution shown is incremental to the basic program.

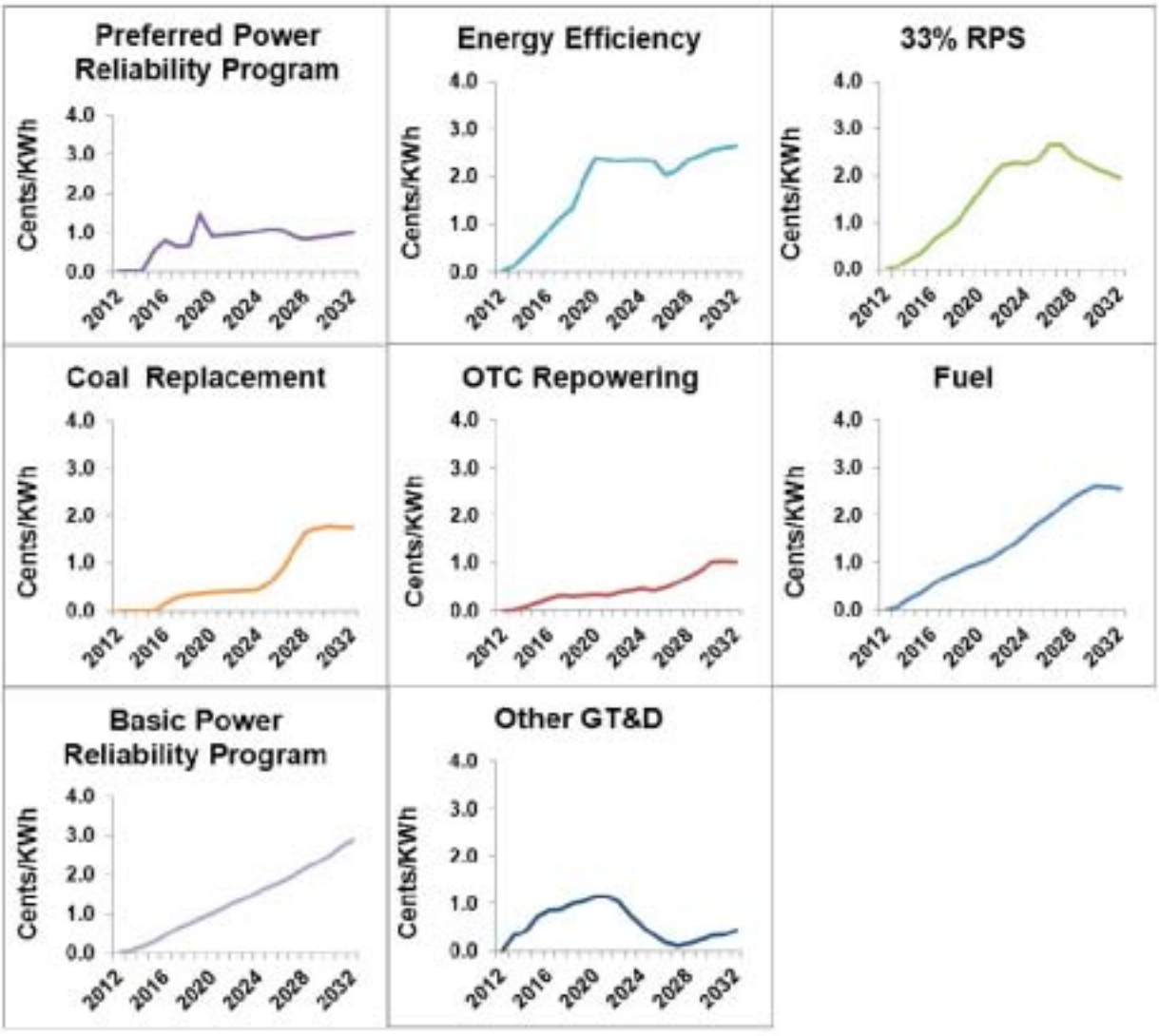

Figure ES-7. Retail electric rate contributions breakdown, based on the 2012-13 budget forecast (Case 5).

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Figure ES-8 shows the total retail rate impact after combining all of the program components. One can draw the conclusion that rising fuel costs and complying with various regulatory requirements are the primary drivers of the growth in rates.

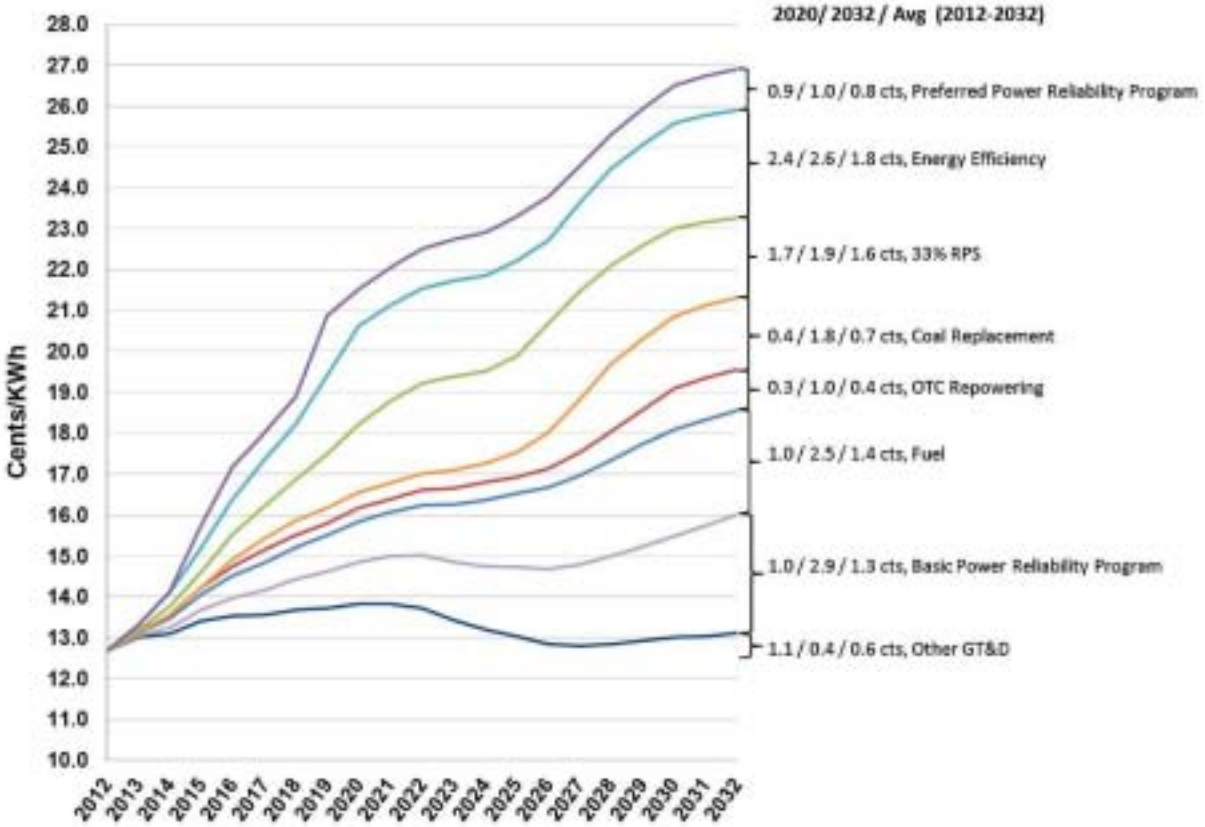

Figure ES-8. Total retail electric rate composite by fiscal year, based on the 2012-13 budget forecast (Case 5).

A few observations from Figures ES-7 and ES-8[3] can be made regarding the RPS and EE programs. Firstly, the influence of the RPS program on rates increases substantially through 2020 after the RPS percentage of sales reaches 33% and the RPS component of rates begins to decline as fuel savings increases over time with escalating fuel prices. In 2027, the RPS component of rates increases as new renewable projects are added to replace expiring PPA agreements and then the RPS component of rates resumes a downward trend due to fuel savings. Secondly, the EE program component of rates increases over time as program incentive payments and net revenue loss attributable to the EE program are recovered. Like RPS, EE has

[3] Figures ES-7 and ES-8 represent forecasted rate increases based on system averages, and do not account for rate structure variations across and within customer classes.

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savings beyond 2020 due to fuel savings. Thirdly, general inflation in fuel costs and GT&D costs represents a significant growth in rates.

Preferred levels of funding for the Power Reliability Program (PRP) include capital and O&M expenditures to replace over age distribution and transmission system components that have exceeded their life expectancy and ensure levels of funding to reduce the backlog of "fix-it" tickets which are temporary repairs that need to be corrected. The spikes in the preferred PRP and EE curve occurs when capital borrowing limits are reached around 2019-20 and cash is needed to fund capital expenses. This quickly subsides as the capacity to borrow resumes shortly thereafter.

The GT&D component of rates rises in the early years because of general inflationary pressure. After 2023 when the IPP debt is fully paid, the GT&D component of rates lowers slightly and goes slightly negative until IPP is replaced with new gas-fired generation and then resumes the familiar inflationary path.

Figures ES-9 and ES-10[*] further illustrate the impact to average residential and commercial/industrial customer monthly bills from these environmental and reliability programs. To show the potential effect of energy efficiency on customer bills, the dashed lines on these figures represents what a total monthly bill would amount to after implementing energy efficiency measures that result in a 14% savings. While LADWP's overall energy efficiency program is evolving and much will depend on the new potential study to be conducted in 2013, these figures illustrate what may reasonably be achievable by customers who have not already implemented significant energy efficiency measures to reduce their electricity consumption.

[*] Figures ES-9 and ES-10 are general representations only and do not account for rate structure variations across and within customer classes such as the effect of tiered rates, minimum charges, time-of-use, etc. The figures provide an indication of the relative contributions of the individual program areas toward a typical monthly bill.

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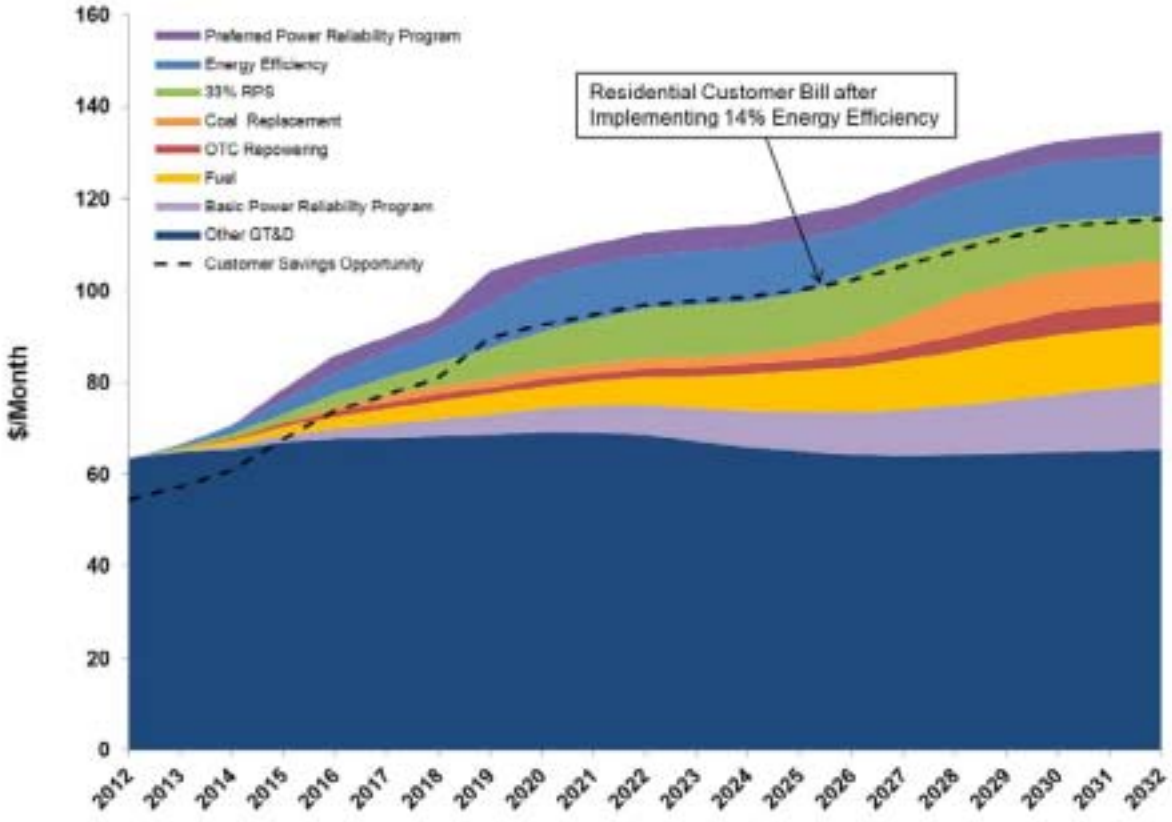

Figure ES-9. Average residential customer bill (500 kWh/month) with environmental and reliability programs by fiscal year based on the 2012-13 budget forecast (Case 5).

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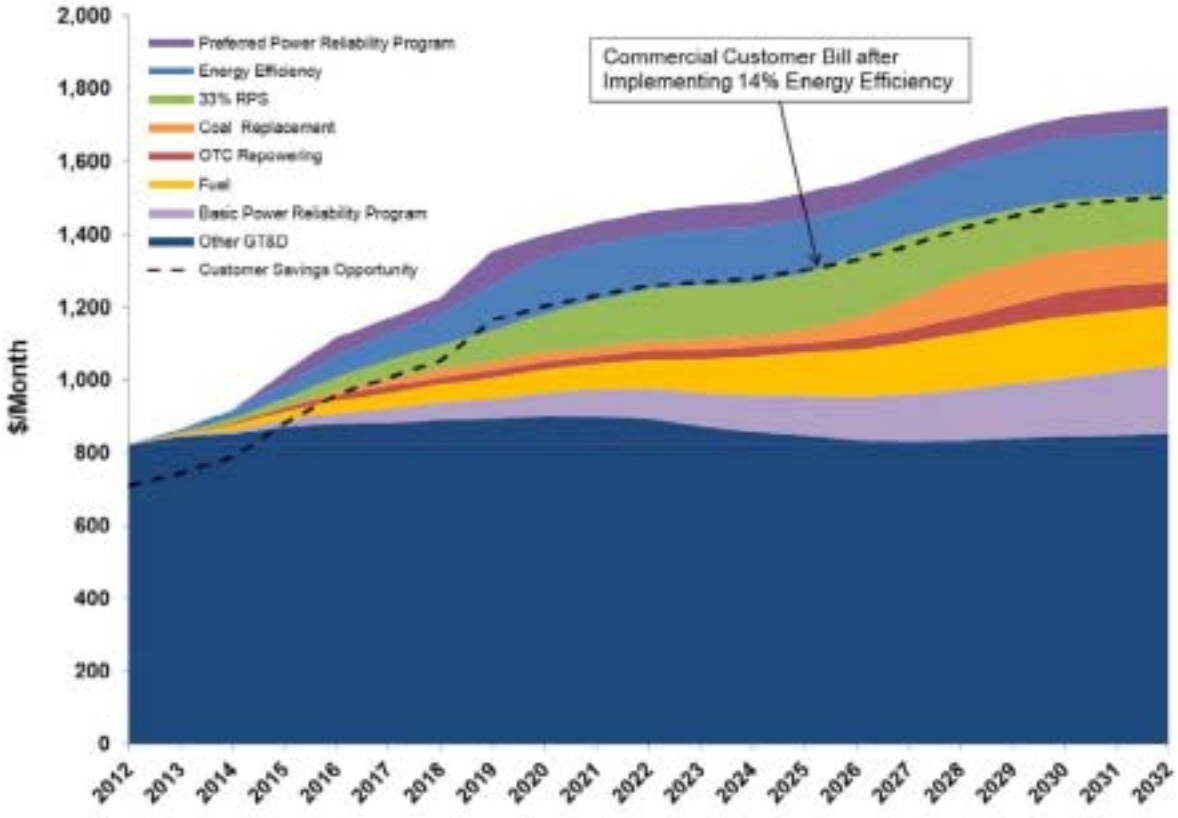

Figure ES-10. Average commercial/industrial customer bill (6,500 kWh/month) with environmental and reliability programs by fiscal year based on the 2012-13 budget forecast (Case 5).

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8. Recommendations

8.1 Strategic Overview

LADWP's recommended strategy set forth in this IRP for meeting its key objectives can be separated into two areas: (1) Regulatory and Reliability Initiatives, and (2) Strategic Initiatives. Regulatory and Reliability Initiatives are required actions to ensure system reliability and compliance with regulatory and legislative mandates. Strategic Initiatives are policy actions to achieve objectives established by the LADWP Board of Water and Power Commissioners and the Los Angeles City Council, and reflect their vision and leadership. These policies include, for example, energy efficiency targets, social and economic development goals, early compliance with SB 1368, and investing in local solar distributed generation.

Regulatory and Reliability Initiatives

- RPS

  LADWP must increase its percentage of renewable energy per recently enacted state law, from the current 20 percent, to 33 percent by the end of 2020. SB 2 (1X) also establishes interim targets to ensure progress towards the 33 percent goal. In addressing this mandate, it is important that LADWP expand its renewable portfolio in the most cost-effective manner as possible. As two subsets of the RPS program, SB 1 requires $313 Million of expenditures towards solar incentives (Customer Net Metered), and SB 32 mandates a Feed in Tariff program of 75 MW (although LADWP by choice will exceed this mandate and provide 150 MW by 2016).

- Power Reliability Program (PRP) and System Infrastructure Investment

  To ensure system reliability, LADWP must re-establish sustained funding to invest in replacing transmission and distribution infrastructure that are contributing to outages. Recent funding shortfalls have resulted in an increase in the frequency and duration of system outages. Section 1.6.3 of this IRP discusses the importance of fully funding the Power Reliability Program (PRP). As discussed in Section 2.4.6, the PRP will also increase the resiliency of the distribution infrastructure to better withstand the higher future wear-and-tear effects that are expected due to climate change.

- Re-powering for Reliability and to Address OTC

  LADWP will continue to re-power older, gas-fired generating units at its coastal generating station for the reasons discussed in Section 2.4.2. The repowering program is a long-term series of projects through 2029 that will increase generation reliability and efficiency, reduce NO_X emissions, and eliminate the need for once-through ocean water cooling.

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- AB 32 – GHG Cap and Trade

  LADWP will participate in the mandated greenhouse cap-and-trade system which is scheduled to start January 1, 2013. LADWP has been granted an administrative allocation of emission allowances that reflects its resource projections through 2020. At this time, it is uncertain if the program will extend beyond 2020 and if so, what LADWP obligations would be.

- Energy Efficiency (EE)

  LADWP will continue to pursue and implement EE programs per AB 2021 standards and as directed by the Board of Water and Power Commissioners, who have adopted a goal of achieving 10 percent EE by 2020, with a target of up to 15% by 2030 pending the results of an upcoming new EE Potential Study. The Base EE cases evaluated in this 2012 IRP have all incorporated 10% EE by year 2020, with higher levels of up to 15% by 2032. Next year's IRP will incorporate the findings and recommendations of the potential study as they are finalized and approved.

- SB 1368 Compliance

  LADWP's two coal fired generation sources, the Navajo Generating Station (NGS), and the Intermountain Power Project (IPP), must be compliant with the mandates established in SB 1368 by 2019 and 2027, respectively. IRP modeling determined that these units will be replaced earlier with a combination of renewable energy, demand response, EE, short term market purchases, and conventional gas-fired generation.

- Energy Storage

  Per AB 2514, LADWP is investigating Energy Storage (ES) technologies and will establish targets for implementation by October 1, 2014. LADWP will look for programs and projects that support its unique electric grid, resource plan, and projects that will facilitate renewable integration, distributed generation and demand response. As these projects are identified and scoped, they will be incorporated into and analyzed in future IRPs. See Section 2.4.5 for more information.

- Castaic FERC Re-licensing Program

  On January 31, 2022, the Federal Energy Regulatory Commission's (FERC) license to operate Castaic Pumped-storage Hydroelectric Plant will expire. The license is a co-license between LADWP and the Department of Water Resources and includes a number of hydro power plants along the California Aqueduct. Both parties have initiated the joint re-licensing process that, on average, requires ten years to complete. Through 2015, LADWP expects to complete preliminary studies, contract negotiations, and prepare a new application strategy. In 2016, LADWP expects to file a notice-of-intent (NOI) and initiate the formal studies and applications.

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- Transmission

  LADWP's Ten-Year Transmission Plan is prepared each year to ensure that LADWP remains compliant with NERC Transmission Planning Standards. The planning process involves complex modeling of the LADWP system, and concludes with findings and recommendations to maintain operational flexibility and avoid potential future overload conditions. LADWP will continue to implement the recommended projects, including construction of a new transmission line between Scattergood Generating Station and Receiving Station K, and upgrades at various other receiving and switching stations.

Strategic Initiatives

- Early Compliance with SB 1368

  Regarding the Navajo Generating Station (NGS), while power imports can legally continue until 2019, LADWP recommends divestiture from NGS four years earlier, in 2015. There are many strategic advantages to early divestiture, including:

  1. Better sales terms and conditions than waiting until the 2019 deadline.
  2. Avoiding the risk of pending federal regulations that could potentially encumber the plant with expensive mitigation requirements.
  3. Better availability and pricing for replacement generation (including existing plants), and lower fuel costs.
  4. Reduced CO_2 emissions, alleviating LADWP from subsequently having to purchase emission credits for native load.
  5. Transmission network for importing additional solar and geothermal resources becomes available.
  6. Low load growth and increased renewable energy place less reliance on the plant for energy.
  7. Provides time to handle contingencies, and to ensure that competition for replacement resources is going to benefit our ratepayers.

  Regarding the Intermountain Power Project (IPP), LADWP recommends modeling and planning to be compliant with SB 1368 by 2027. However, LADWP, the Intermountain Power Agency (IPA), and the other 36 participants are considering the conversion of IPP from coal to natural gas. A new contractual arrangement is in process, which will establish a firm conversion date that will be no later than, and possibly sooner, than 2027. Until a firm conversion date is established and for analysis purposes, Case 4 was developed for this IRP which has IPP coal replacement in 2023. Once a firm date is determined, it will be incorporated into the IRP base case model runs.

  Strategically, it is important for LADWP to remain a participant at IPP to retain geographic diversity in its resource mix, access the regional fuel supply, and retain the project's transmission lines to access renewable energy from the region.

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- Local Solar

  Comments received at prior public workshops indicate local solar development should be a priority in LADWP's renewables procurement strategy. LADWP is recommending a policy action to allow 340 MW of its solar resources be sited locally by 2016, through initiatives including the Solar Incentive Program, feed-in tariffs, and installation of solar on City-owned properties.

- Demand Response

  LADWP should accelerate its evaluation and implementation of Demand Response programs that will initially provide 5 MW of new peak demand capacity beginning in 2013 and gradually build to 200 MW by 2020 and 500 MW by 2026. Ramping the program in this manner will promote the development of in-house expertise, and will also allow time to deploy the supporting information systems necessary to implement these systems successfully.

- Advanced Technologies/Research and Development

  LADWP is looking ahead to technologies that will enhance the reliability of its system including smart grid, energy storage, enhanced information and management systems, automation of system functions, advanced methods of outage management, and weather forecasting. These system enhancements will increase reliability, facilitate the integration of local solar generation and other variable renewable resources into the distribution network, enable smart charging of electric vehicles, and advanced demand-side management technologies. LADWP should continue to pursue grants, cost sharing opportunities, and joint projects that promote the use and deployment of new technologies that meet its strategic goals.

- Provide Sufficient Generation

  Provide sufficient generation, demand response, and limited short term purchases in peak season Q3 to cover operating and replacement reserves in accordance to applicable federal and regional reliability requirements.

- Control of Transmission Assets

  In addition to the regulatory requirement to remain compliant with NERC Transmission Planning Standards, LADWP will maintain its policy of maintaining control of its transmission assets and continue to augment those assets commensurate with load growth, reliability needs, and renewable energy opportunities.

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- Collaborate with Water System

  The LADWP Power System will continue to work with the Water System to develop programs that reduce the usage of electricity and conserve water, as well as optimizing hydroelectric energy production.

- Financial Targets

  To preserve and maintain its credit rating, the following financial targets have been adopted:
  - Maintain debt service coverage at 2.25 times
  - Minimum operating cash target of $300 million
  - Debt-to-capitalization ratio less than 68 percent

8.2 Recommended Strategic Case

Achieving the goals of reliability and environmental stewardship, while maintaining competitive rates, requires that costs be closely managed. Considering these factors, Case 5 with early Navajo coal divestiture in 2015, Base EE and Base DG with additional local solar Feed in Tarrif (FiT) DG becomes the Recommended Case for the 2012 IRP. Whereas Case 5 has 75 MW of local solar FiT by 2016, the new recommendation is to adopt an additional 75 MW for a total of 150 MW by 2016 based on input that was received from the public outreach efforts. The increase in cost for the additional 75 MW of FiT is an average of 0.018 cents/kWh or a 9 cent increase in the typical residential monthly bill (500 kWh/month). Although Case 5 with the added FiT represents additional cost as compared to the 2011 Recommended Case, the additional costs to rate payers appears to be reasonable in light of the benefits of job growth and support of the local economy from adopting higher levels of DG solar. As described in the 2011 IRP, the environmental benefits of reducing GHG emissions by 7.2 MMT are still present with the early Navajo replacement. The cost to implement Navajo divestiture in terms of metric tons of GHG removed is $28/MMT. This represents a reasonable cost in line with the range of expected AB 32 cap and trade allowance prices. Other benefits of early Navajo divestiture include a better sales price than waiting until 2019, and better availability (lower costs) of replacement energy. With Case 5 and the noted addition of FiT and Navajo divestiture in place, LADWP can begin to focus its attention on early replacement of IPP coal generation, prior to 2027, by working with the other power purchasers and the IPP plant owner.

The 2011 IRP included the same recommendation to accelerate divestiture of Navajo and this 2012 IRP further clarifies and supports this prior recommendation. This 2012 IRP recommended case presents a reasonable approach to achieving environmental goals and promoting job growth in the local economy without excessive costs to our ratepayers while limiting potential exposure to possible fuel price volatility to within manageable limits.

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Table ES-5. 2012 IRP RECOMMENDED CASE

	2020	SB 1368 Compliance Date		New Renewables Installed (MW) 2012-2020				New Renewables Installed (MW) 2012-2032				
Case ID	RPS Target	Navajo End Date	IPP End Date	Geo/ Biomass	Non-DG Solar	Dist. Solar	Generic	Geo/ Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
Case 5	33%	12/31/2015	6/15/2027	242	842	382	39	283	54	915	496	114

Figure ES-11 illustrates the changing generation resource percentages for 2010, 2020, and 2030 based on the Recommended Case. Because energy efficiency forecasts are forward-looking, the savings of 1,256 GWh or 5.5 percent of sales that was implemented between 2000 and 2010 are embedded into the load forecast and are not included as part of the generation resource mix shown below.

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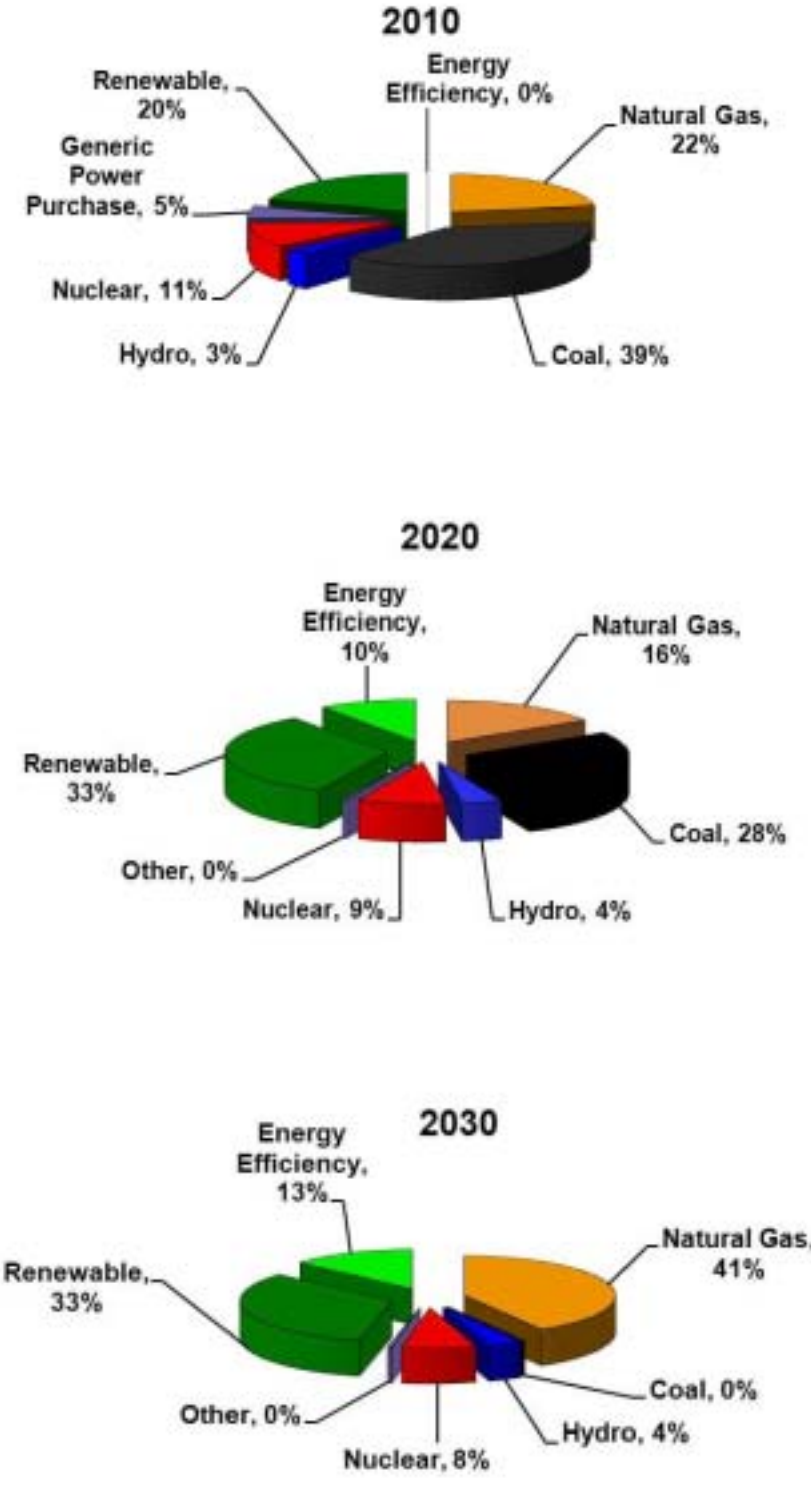

Figure ES-11. Recommended case generation resource percentages for 2010, 2020, and 2030.

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Figure ES-12 shows the breakdown of renewable generation by technology, and Figure ES-13 illustrates the dependable capacity mix for the recommended case.

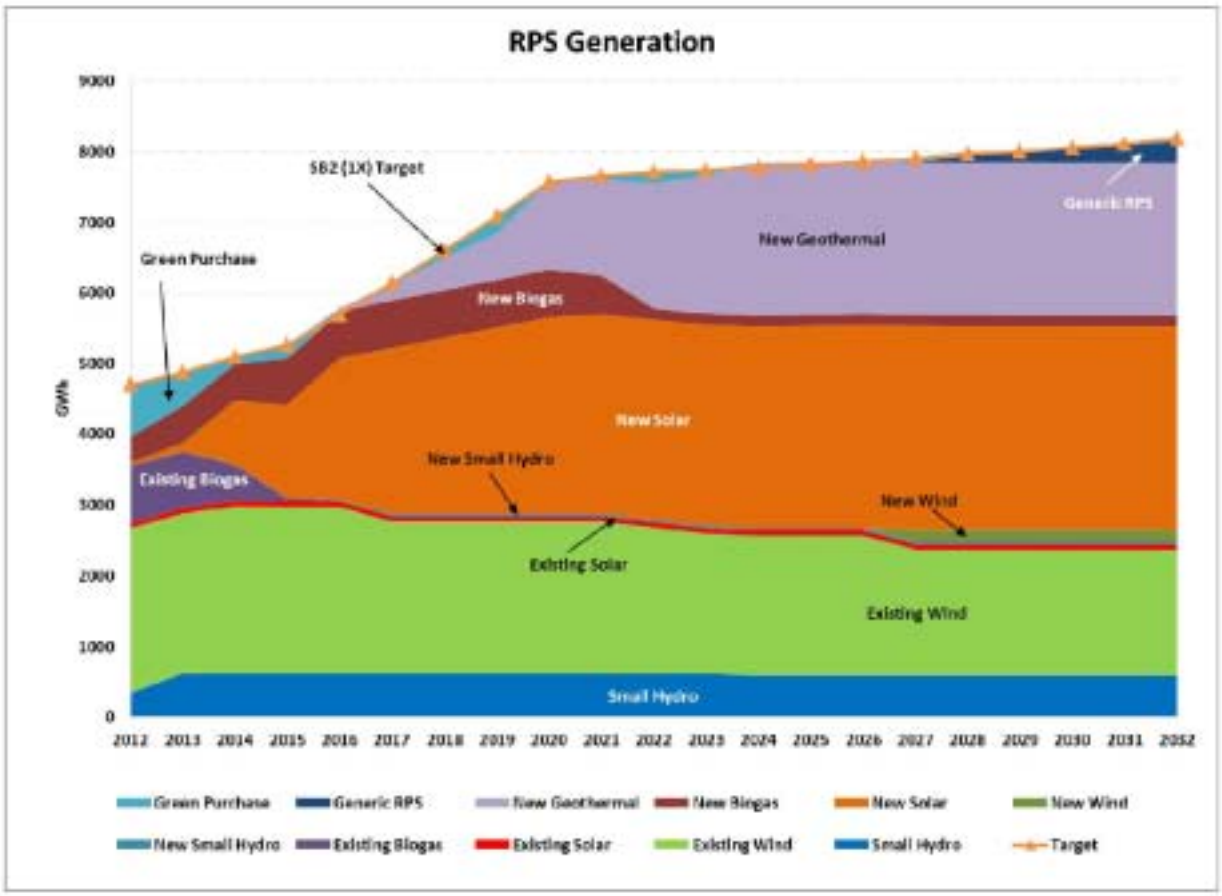

Figure ES-12. Recommended case renewable generation by technology.

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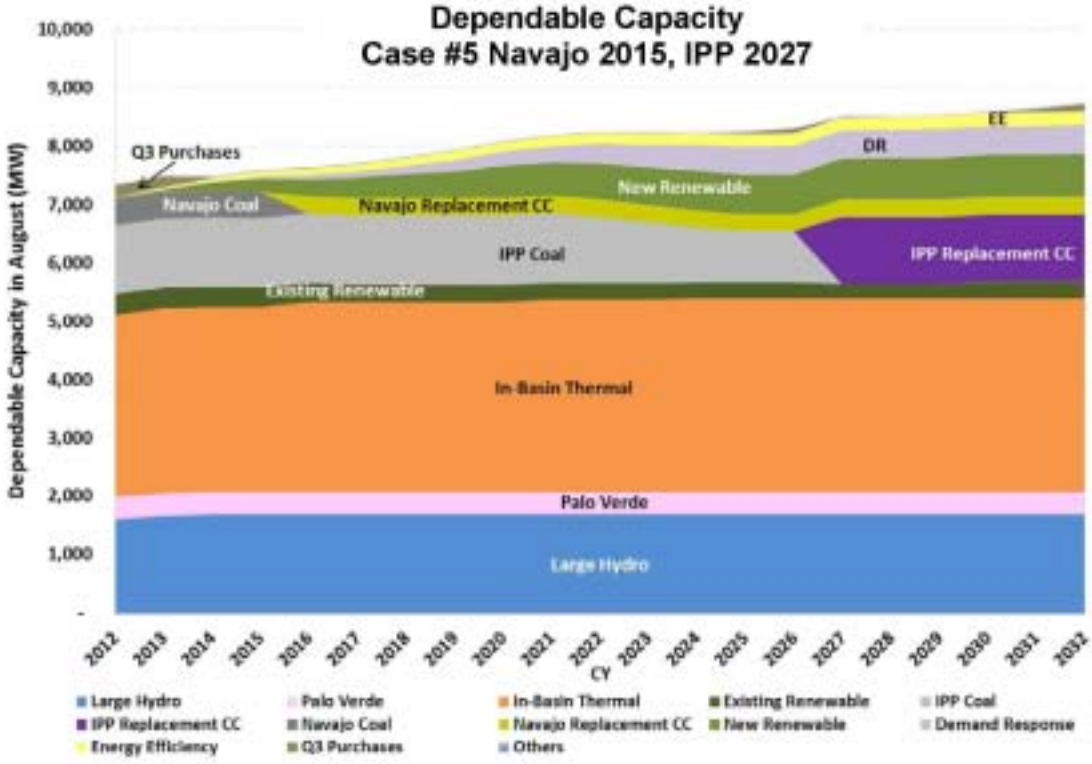

Figure ES-13. Dependable capacity profile, recommended case.

Because the analysis and conclusions are dependent on a number of assumptions, LADWP will constantly refresh its analysis as new IRPs are developed in future years.

8.3 Recommended Near Term Actions

Except for early Navajo divestiture, the actions needed to be taken by LADWP in the next two to four years are very similar no matter what resource strategy is chosen. Based on the strategic requirements presented earlier and projected resource procurement needs, the following actions are recommended to be taken in the near-term:

1. Proceed with re-powering plans for generation units at the Haynes and Scattergood Generating Stations, and pre-development plans for the Harbor Generating Station.
2. Continue to investigate the technical and contractual options for coal-fired generation to be compliant with SB 1368.
3. Divest from the Navajo Coal Plant by 2015.

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4 Continue the implementation of existing energy efficiency efforts, in anticipation of an expanded program pending the results of a new energy efficiency potential study to be conducted in 2013

5 Continue to implement the Power Reliability Program (PRP) to replace aging infrastructure components. Develop electric modeling capability to better define the necessary investments and to prioritize the expenditures

6 Develop/update a sustainable workforce development plan that addresses staffing needs, skill set identification for new and evolving work areas, training/professional development, application of new technologies, and recruitment strategy

7 Implement recommendations contained in the Ten-Year Transmission Assessment Plan

8 Develop a Demand Response Program to initially provide 5 MW of new peak load reduction capability by 2013 which will ramp up incrementally to 200 MW by 2020 and 500 MW by 2026

9 Implement renewable strategies for geothermal, biogas, solar, and wind resources to ensure increasing levels of renewable procurement in accordance with SB 2 (1X). Sign Power Purchase Agreements for an additional 300-400 MW of cost effective renewable energy projects by 2014

10. Complete a comprehensive study of issues associated with integrating increasing amounts of variable energy resources such as wind and solar to reflect possible megawatt limits for the LADWP electric Power System

11 Develop and incorporate strategies to
   a Fully utilize existing transmission assets.
   b Locate renewables as close as practical to the load center to reduce transmission losses.
   c Preserve existing brown field sites to be repurposed for renewable or natural gas generation.
   d Incorporate the concept of O&M cluster zones[5] to maximize operational efficiencies.
   e Assess and develop necessary transmission facilities to deliver electricity generated from new facilities.

12 Develop a renewable energy feed-in tariff program to encourage 150 MW of renewable generation resources to be developed by 2016

13 Encourage the development of an additional 50 MW of customer net-metered solar projects before 2015

14. Develop up to 30 MW of solar capacity on existing properties under public/private partnership projects before 2015

15. Investigate the use of term physical gas supply arrangements, either with contracts for physical supplies or futures contracts to limit LADWP's exposure to volatile gas prices. Evaluate and potentially implement any recommendations in the Fuel Hedging Plan.

16 Investigate and develop energy storage targets by October 1, 2014, per AB 2514

[5] Clustering renewable projects in relative proximity with decrease O&M expenditures due to economies of scales and personnel efficiencies. This would need to be balanced with the need for geographic diversity.

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17 Refine and implement a Smart Grid strategy that can assist in the procurement and development of advanced technologies to support areas such as weather forecasting/ energy scheduling, customer kWh metering, high speed communications and information systems, and energy storage systems. Deployment of these technologies will increase operational efficiency, help reduce system losses, improve outage response times, increase utilization of predictive/proactive maintenance techniques for improved grid reliability, enable better management of the Power System, and lower costs.

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1.0 INTRODUCTION

1.1 Overview of the 2012 Integrated Resource Plan

This document represents the Los Angeles Department of Water and Power (LADWP) Integrated Resource Plan (IRP) for 2012. The goal of this IRP is to identify a portfolio of generation resources and Power System assets that meets the city's future energy needs at the lowest cost and risk consistent with LADWP's environmental priorities and reliability standards. The IRP is an important planning document for electric utilities, and many states and regulatory agencies require development of an IRP prior to approval of procurement programs or electric rate increases.

This document goes beyond traditional integrated resource planning and incorporates additional Power System planning elements to form a comprehensive Power System plan. It is intended that this Power System plan will drive the priorities, financial planning, and budgeting effort for the Power System.

This IRP considers a 20-year planning horizon to guide LADWP as it executes major new and replacement projects and programs. The overriding purpose is to provide a framework to assure the future energy needs of LADWP customers are met in a manner that balances the key objectives of:

- Superior reliability and supply of electric service
- Competitive electric rates consistent with sound business principles
- Responsible environmental stewardship exceeding all regulatory obligations

In balancing these key objectives, LADWP's strategic planning efforts must ensure a high level of system reliability, consider impacts to the local and regional economy, mitigate the volatility in fuel and other cost factors, comply with federal, state, and local regulations, and guarantee fiscal responsibility.

LADWP is the largest municipal utility in the nation, and the third largest utility in California. While numerous recent accomplishments have been made – including achieving 20% of renewable energy sales in 2010 – significant challenges lie ahead. Increasing renewable energy to 33% by 2020, the continued rebuilding of coastal generation units, replacement of coal, infrastructure reliability investments, and ramping up energy efficiency and other demand side programs are all critical and concurrent strategic actions that LADWP will have to carry out over the coming decade.

The 2012 integrated resource planning process developed alternative strategic cases that assess different replacement options for coal-fired generation, as well as different projected levels of energy efficiency and distributed generation. The cases are modeled to determine their respective operational and fiscal impacts, as well as their effects on greenhouse gas emission levels. This document presents the results of this analysis and recommends the appropriate near-term actions and long-term plan to best meet the future electrical needs of Los Angeles.

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LADWP Power System Vision

The transformation that this utility will undergo in the next 20 years will be unprecedented as the use of electricity broadens to new applications and as customer expectations of clean affordable energy continues to take root. Increases in electric vehicle use, expanded electrification of processes to reduce emissions and greenhouse gases, and growing wide-spread use of information technology equipment will require a stable, resilient power grid that delivers affordable power. By adopting energy efficiency, promoting solar rooftop and supporting other clean technologies that mitigate the need to build new fossil-fueled power plants, our customers are embracing the vision of a greener resource portfolio that sustains the environment for future generations.

LADWP and its City Leaders have traditionally taken a leadership position, particularly among public power utilities, to ensure a sustainable, diverse supply of generation and transmission resources to provide electricity to our customers. This utility has also been very progressive in adopting aggressive clean energy goals and programs well before many of today's laws and regulations were in place, and participated in the development of many of the laws and regulations that we see today. In 2000, this utility set out to reduce load growth by 50 percent through the use of renewables, energy efficiency, and distributed generation. Today we have the same electricity consumption as we had in 2000 largely due to these earlier efforts. In 2005, we adopted a renewable target of 20 percent renewable by 2010, and we succeeded to be the largest California utility to achieve 20 percent renewable generation in 2010. Since 1990, we have divested of 2 coal plants and repowered several natural gas in-basin generating stations using cleaner and more efficient new combustion technology, resulting in 21 percent lower greenhouse gas emissions and over 80 percent lower NOx emissions. Reducing ocean water use and reducing the impact on marine life has also been an on-going effort and by next year we will use 42% less ocean water from 1990 levels, with total elimination targeted by 2029.

The world today is not the same as it was 20 years ago, and the world 20 years from now will not be the same as it is today. And while LADWP's mission of providing reliable, affordable electricity in an environmentally responsible manner remains the same, the planning and execution of that mission requires continued diligence to account for, adopt, and even influence, the changing public concerns and priorities related to electricity generation and use.

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1.1.1 Major Changes from Last Year's IRP

Major changes from last year's 2011 IRP include expanded discussion on the Power Reliability Program, more detailed information on transmission planning and projects, a new sub-section on the future impacts of climate change on power generation and operations, and new case options that analyze higher levels of Energy Efficiency (EE) and Distributed Solar Generation (Solar DG).

This 2012 IRP incorporates updates to reflect the latest load forecast, fuel price and projected renewable price forecasts, and other numerous modeling assumptions. Compared to the prior forecast, projected electricity sales in calendar year 2020 decreased by 3.4 percent, mostly due to increased levels of energy efficiency. The new forecast reduces the overall need for renewable energy (assuming 33% RPS) by approximately 461 GWh in 2020 and 745 GWh in 2030.

Long term natural gas price forecasts have been revised downwards from last year with recent prices reaching very low levels over the last year. Compared to last year's 2011 IRP, Opal and SoCal expected gas prices are 16% lower on average in the short term (2011-2020) and 8-9% lower on average in the long term (2021-2030). Coal price forecasts are also lower, with IPP coal at 4% lower for the period 2012-2027, and Navajo coal at 14% lower for the period 2012-2018.

Other changes include lower cost assumptions for solar and geothermal, reflecting price competition for both resources, and updates regarding legislative and regulatory issues. See Section 3 and Appendix N for more details.

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1.2 Organization of the IRP

This document is organized as follows:

- Section 1, "Introduction," presents an overview of the LADWP Power System, and the issues and challenges facing LADWP as it strives to secure a reliable supply of electricity for the next 20 years, at competitive rates, and in an environmentally responsible manner.
- Section 2, "Load Forecast and Resources," provides forecasts of electricity demand, discusses the resources available or needed to meet that demand, and addresses the issues associated with each resource and the Power System in general.
- Section 3, "Strategic Case Development," establishes potential alternatives (Cases) available to LADWP to meet its projected electricity demand, and considers varying levels of energy efficiency and solar distributed generation as well as different options for early replacement of coal fired generation.
- Section 4, "Strategic Case Analysis," addresses the operational modeling and the results used to assess the impact of each alternative on cost, energy rates, and levels of greenhouse gas emissions.
- Section 5, "Recommendations," provides the strategic overview, the recommended case including the revenue requirements to support it, and the near term actions required to keep LADWP on track towards meeting its obligations and responsibilities.

Detailed information is provided in the following Appendices:

Appendix A: Load Forecasting
Appendix B: Energy Efficiency and Demand side Management
Appendix C: Environmental Issues
Appendix D: Renewable Portfolio Standard
Appendix E: Power Reliability Program
Appendix F: Generation Resources
Appendix G: Distributed Generation
Appendix H: Fuel Procurement Issues
Appendix I: Transmission System
Appendix J: Integration of Intermittent Renewable Resources
Appendix K: Energy Storage
Appendix L: Smart Grid
Appendix M: Climate Change Effects on Power Generation
Appendix N: Model Description and Assumptions
Appendix O: Public Outreach
Appendix P: Abbreviations and Acronyms

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1.3 Objectives of the IRP

This 2012 IRP documents the long term planning efforts for LADWP's Power System. It includes a review of the various issues and considerations that LADWP must address moving forward, and summarizes the planning process used to identify future energy resource requirements. The recommended long term plan is presented, as are the actions and initiatives LADWP must undertake over the next several years. The key objectives of LADWP's long term planning efforts are: (1) maintaining a high level of electric service reliability, (2) exercising environmental stewardship, and (3) keeping its energy rates competitive.

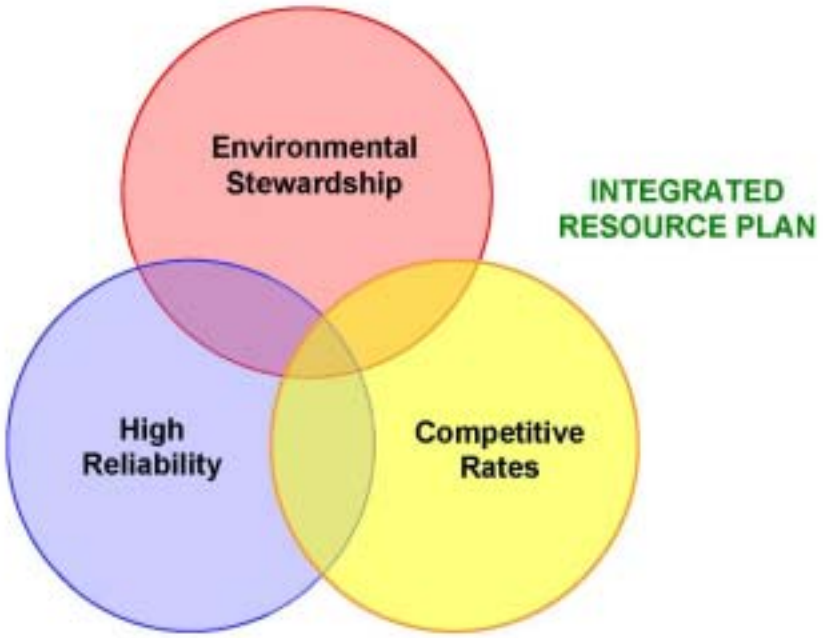

Figure 1-1. Objectives of this IRP.

1.3.1 Reliable Electric Service

Providing reliable electric service to the residents and businesses of Los Angeles has always been a cornerstone of LADWP. Some of the key principles, policies and program areas related to reliability are listed here:

- Reliability Standards

  LADWP continues to be in compliance with all applicable Federal Energy Regulatory Commission (FERC), North American Electric Reliability Corporation (NERC) and Western Electric Coordinating Council (WECC) standards regarding bulk power

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system reliability. With the enactment of the Energy Policy Act of 2005, FERC granted NERC the legal authority to enforce reliability standards with all users, owners and operators of the bulk power system in the United States. WECC, under the delegated authority of NERC, is the regional entity responsible for coordinating and promoting bulk electric system reliability in the Western Interconnection. Both of these electric utility organizations enforce reliability standards on owners, operators and users of the bulk power system.

- CAISO

  The California Independent System Operator (CAISO) was established in 1998 as part of California's electric utility restructuring effort. CAISO was established as a non-profit public benefit corporation charged with operating the majority of California's high-voltage wholesale power grid and providing equal access to the grid for all qualified users. LADWP is not a member of CAISO but was certified by CAISO in 2012 to be a scheduling coordinator which authorizes LADWP to buy and sell energy and ancillary services directly with CAISO.

- Balancing Authority

  LADWP is a registered Balancing Authority with NERC and is responsible for coordinating and balancing the load, generation and delivery of electricity through its system. LADWP will continue to maintain its presence as a Balancing Authority.

- Self-Sufficiency

  LADWP maintains a policy of owning or controlling its transmission and generation resources to serve its native load customers. However, in consideration of economic and environmental factors involved with the coal replacement options (discussed in Section 3 and 4), a limited amount of firm energy is proposed to come from 3rd quarter purchases acquired from the electricity market.

- Coastal Power Plants

  LADWP operates three coastal natural gas-fired power plants that are critical to its operations. These plants were built from the 1940s up to the 1970s. One of these plants was modernized in the 1990s, resulting in increased efficiency and reliability while reducing emissions and maintenance costs. The modernization of the remaining generation units is a long term program targeted for completion in 2029. LADWP must modernize these plants to comply with environmental regulations, improve efficiency, better integrate renewable resources, and provide for transmission import capability. See Section 1.6.6 and Appendix C for more details.

- Power Reliability Program

  In response to an increase in power outages between 2003–2005, LADWP established the Power Reliability Program. The goals of the program include: (1) mitigating problem circuits and stations based on the types of outages specific to a given facility, (2) implementing proactive maintenance and capital improvements to prevent problems before they occur, and (3) establishing replacement cycles for facilities that are in alignment with the equipment's life cycle. See Section 1.6.3 and Appendix E for more details.

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- Smart Grid

  Smart Grid refers to the application of advanced information-based technologies that will improve system operations in a variety of areas. Smart Grid technologies provide information that allows the implementation of real-time, self-monitoring communication networks that are predictive rather than reactive to system disruptions. These technologies will enable LADWP and its customers to make decisions to optimize the use of energy, improve reliability, and reduce the consumption of fossil fuels. See Appendix F for more information.

- Distributed Generation

  Distributed Generation (DG) refers to the installation and operation of small-scale electric generators that are located at or near the electrical load. Cogeneration, solar photovoltaic, and fuel cells are examples of DG applications. As more DG is added within the city of Los Angeles, it is important that these generation sources be managed in a manner that does not reduce grid reliability. More information on DG is provided in Section 2.3.3 and Appendix G.

1.3.2 Competitive Rates Consistent With Sound Business Principles

Historically, LADWP's electric rates have been consistently among the lowest in California. As utilities throughout the industry address renewable energy, greenhouse gas emissions, ocean water cooling and other issues, it can be expected that rates for most, if not all utilities, will rise. By continuing its strategic planning and implementation activities, LADWP hopes to maintain its rates as among the lowest in the region.

Energy rates

Based on a typical monthly residential bill for a customer consuming 500 kWh of electricity, the LADWP has the lowest monthly electric bill compared to five of its neighboring utilities in Southern California. See Figure 1-2 below.

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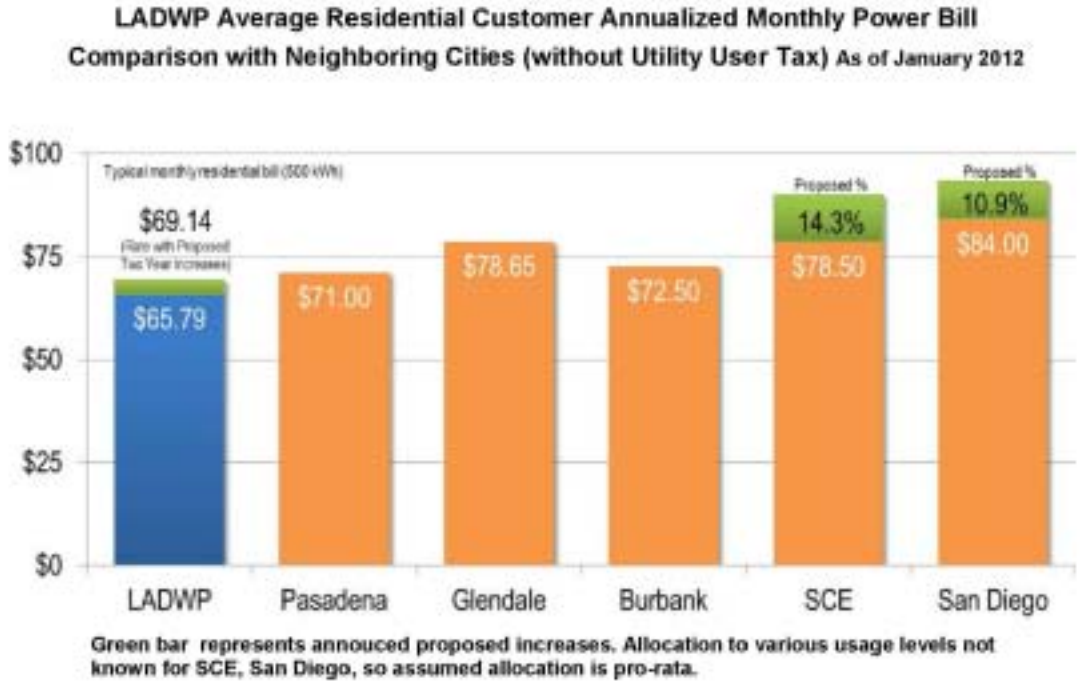

Figure 1-2. LADWP power bill comparison among other electric utilities.

While LADWP provides electricity at competitively low rates, several factors challenge the current rate structure. These factors include the costs to replace aging infrastructure, the potential volatility of natural gas and coal prices, and new regulatory requirements for renewable energy and the reduction of greenhouse gas emissions and use of ocean water for power plant cooling. Transmission capacity upgrades, energy efficiency and demand response programs, and projects to implement coal replacement will also exert upward pressure on energy rates. Because of these and other initiatives, it is expected that future structural rate adjustments and amendments to the Rate Ordinance will be necessary to maintain appropriate debt ratios and bond ratings.

Since LADWP sells substantial amounts of bonds to finance its capital expenditures, maintaining its high credit rating is essential to minimizing financial costs. To maintain its high credit rating, LADWP adheres to the following policies:

- Debt service coverage

  Maintain a debt service coverage ratio of at least 2.25
- Cash on hand

  Maintain a cash balance of $300 Million
- Capitalization ratio

  Maintain a debt-to-capitalization ratio of less than 68%

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These financial parameters are used in the electric rates analysis discussed in Section 5.5.

1.3.3 Environmental Stewardship

LADWP's mission includes a role as an environmentally responsible public agency. Programs and subject areas related to improving the environment include:

- Renewable energy

  LADWP will continue its efforts to increase the use of renewable energy resources in a cost effective manner. LADWP will, at a minimum, comply with local, state and federal mandates for levels of renewable energy as a percentage of electricity sales. Senate Bill (SB) 2 (1X) sets renewable energy targets of 20% for years 2011-2013, 25% by 2016 and 33% by 2020 and thereafter. For more information, see Sections 1.5, 1.6.5, 2.4, 3.4.3, and Appendix D.

- Carbon dioxide (CO_2) emissions

  LADWP will continue its efforts to reduce CO_2 emissions. The potential early replacement of coal-fired generation, a key strategic focal point of this 2012 IRP, is one means of achieving reductions of CO_2 emissions. Additional recommended means of reducing CO_2 emissions include the continuation and expansion of energy efficiency programs and the transition towards increasing amounts of energy generated from renewable resources. For further information, see Section 3.6.4 and Appendix C.

- Once-Through Cooling (OTC)

  LADWP has embarked on a series of repowering projects that are eliminating the use of ocean water for cooling at its coastal generating stations. A series of repowering projects is planned through 2029. As each project is completed, the use of ocean water decreases. Within the 20-year planning horizon of this IRP, these projects will totally eliminate the use of ocean water. More information on OTC can be found in Sections 1.6.6.

- Energy Efficiency

  Energy efficiency programs has been ongoing for more than a decade, and will be serving a more prominent and strategic resource planning role as LADWP looks to the next 20 years and beyond. This IRP considers higher levels of energy efficiency than was previously considered in past IRPs. LADWP is committed to developing comprehensive programs with measurable, verifiable goals as well as implementing robust, cost-effective energy efficiency programs. Further information regarding LADWP's EE Program can be found in Section 2.3.1 and Appendix B.

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- Solar Incentive Program and Feed-in Tariff

  LADWP's Solar Incentive Program (SIP) encourages the installation of solar PV capacity in Los Angeles. This program is a multi-year investment designed to expand solar power in the city to meet the goals of SB 1. This program provides a one-time incentive to customers who install a solar PV system on their property for their consumption. When a customer's SIP solar system produces more energy than they use for the billing cycle, the excess energy is calculated as a credit to be used on the customer's future bill.

  Additionally, LADWP is implementing a separate SB 32 Feed-in Tariff (FiT) program, whereby LADWP contracts to purchase ALL the power generated from an eligible renewable system under a standard power purchase contract. Although this program is open to all eligible renewable generators, most will likely be solar.

  The FiT and SIP programs are exclusive from each other; one renewable system cannot be enrolled in both. However, one property may have two separate renewable systems; one system feeding energy directly to LADWP's grid via a FiT meter and the other system feeding the customer's load via a Net-metering scheme.

  Solar energy will help LADWP achieve its environmental goals of increased energy generated from renewable resources and reduced levels of greenhouse gas emissions.

- Demand Response Program

  This IRP recommends the implementation of a Demand Response (DR) program, which will lessen environmental impacts by deferring the need to build additional generation facilities and infrastructure; as well as reducing energy usage and the associated greenhouse gas emissions. For a full discussion of DR and details regarding LADWP plans, see Section 2.3.2.

"Demand Response" is a mechanism utilities use to manage energy demand, especially during critical peak demand periods. When demand is at its highest (e.g., on a hot August afternoon), almost all of the generation supply is engaged, leaving little reserve available in case a generating unit falters or a transmission line trips. To reduce the risk of system failure that this condition imposes, demand response provides a means to lower the demand. Customers who sign up to participate are provided financial incentives and agree to lower their demand if and when called upon by the utility.

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1.4 LADWP's Power System

LADWP's Power System serves approximately 4.1 million people and is the nation's largest municipal electric utility. LADWP experienced an all-time net energy-for-load peak demand of 6,142 megawatts (MW), which occurred on September 27, 2010, and has an installed net dependable generation capacity greater than 7,125 MW. Its service territory covers the City and many areas of the Owens Valley, with annual sales exceeding 23 million megawatt-hours (MWh). LADWP is the third largest California electric utility in terms of consumption, behind Southern California Edison and Pacific Gas & Electric—see Figure 1-3 below. Projected future demand growth for LADWP is less than one percent per year[1].

"Capacity" is a measure of the capability to produce power or the rate at which energy is transferred. The term is applied to the amount of electric power delivered or required to meet the power demand, and is expressed in Megawatts (MW) or Gigawatts (GW). "Energy" is a measure of the quantity of electricity used in a given time period and is expressed in Megawatt-hours (MWh) or Gigawatt-hours (GWh).

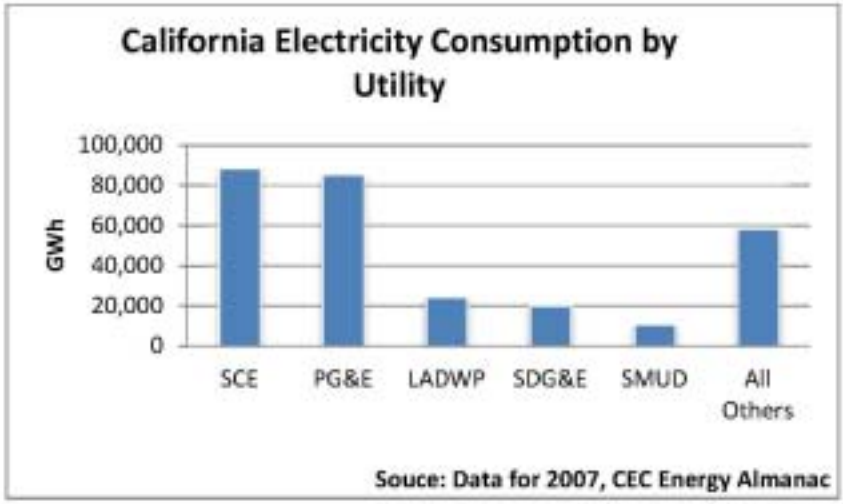

Figure 1-3. Comparison of California utilities by consumption.

LADWP is a "vertically integrated" utility—both owning and operating the majority of its generation, transmission, and distribution systems. LADWP is currently fully resourced to meet peak demand but maintains transmission and wholesale marketing operations to keep production costs low and increase system reliability.

While LADWP customers represent roughly 10 percent of California's electrical load, approximately 25 percent of the state's total transmission capacity is owned by LADWP. LADWP's transmission reach also extends beyond California, enabling the transport of power from a diversified set of generation resources from across the Western United States.

[1] Prior to energy efficiency and distributed generation, which will reduce load growth to an approximate yearly average of 0.3% between 2012 and 2032.

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Additional information on the Power System's generation and transmission assets can be found in Section 2.4 and Appendices F and I.

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1.5 Recent Accomplishments

A summary of recent LADWP accomplishments consistent with the objectives of this IRP are presented below. These accomplishments promote the goals of maintaining high reliability and exercising environmental stewardship, while keeping rates competitive.

- Renewable portfolio standard

  Through the active procurement of renewable resources, LADWP has increased the renewable energy component of its resource mix from 3% in 2003 to 20% in 2010. In 2011, the renewable percentage slightly decreased to 19% due to less wind and small hydro generation.

- Adelanto Solar Power Project

  On July 23, 2012, the Adelanto Solar Power Project was commissioned as LADWP's first utility-scale solar power plant. The 10 MW(AC) project was built by LADWP crews and is owned and operated by LADWP, making it the largest municipally-owned solar project in the nation. The project makes use of existing LADWP land and ties directly to an existing electrical switching station. The project will provide valuable experience and data regarding solar plant operations, the integration of variable renewable resources, and the financial requirements (capital costs, O&M costs, etc.) associated with building and operating a large solar facility. The experience gained from this project will facilitate the construction of future solar projects.

- Energy efficiency

  LADWP continues its commitment to energy efficiency through numerous programs and services to customers, encouraging the adoption of energy saving practices and installation of energy-efficient equipment. Since 2000, LADWP energy efficiency programs have resulted in 1,377 GWh of energy savings, or over 5% of energy sales.

  In 2012, the Board of Water and Power Commissioners adopted a goal of 10% energy efficiency by 2020, with a target of 15% pending the results of a new potential study to be conducted in 2013.

- Solar Incentive Program and Feed-in-Tariff (FiT)

  As of September 1, 2012, LADWP has encouraged the installation of over 36 MW of solar capacity at over 6,200 customer locations through its ratepayer-funded Solar Incentive Program. Separately, a FiT pilot program was conducted, which will enable a full-scale program launch for 150 MW by 2016.

- Emissions reduction

  As of 2011, CO_2 emissions from power generation are 21% lower than 1990 levels. The lower emissions are attributed to discontinued generation from the Colstrip and Mohave generation stations, increased generation from renewable resources, and the ongoing repowering of the in-basin natural gas units.

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Due to the installation of advanced pollution control equipment at all of its in-basin generating stations, NOx emissions from LADWP's local generating plants are at least 98 percent lower than 1998 levels.

- Once through cooling

  As a result of completed repowering projects, LADWP has reduced the use of once-through ocean water cooling by 17% from 1990 levels. The current plan calls for a complete phase-out of ocean water cooling by 2029.

- Haynes 5 & 6

  The September 2011 groundbreaking ceremony signified the start of construction for the replacement of Haynes Units 5 and 6. The original units, which date back to the mid 1960's, will be replaced with efficient modern units that will facilitate the integration of intermittent renewable energy. This project is expected to be in service by May 2013, and is one of many projects that that will eliminate the use of ocean water for cooling by 2029.

- Castaic

  The seven units of the Castaic Hydroelectric Plant are currently being rotated out of service for modernization. This multi-phase process began in 2004 and is expected to continue through 2014. To date, five units have been completed. The associated increase in efficiency is projected to add up to 80 MW of renewable qualifying capacity to Castaic. The increased capacity also results in more reserves available to reliably meet peak system demands.

- Power Reliability Program (PRP)

  The PRP is a comprehensive long-term power reliability program developed by LADWP to replace aging infrastructure and make permanent repairs to generation, transmission, and distribution infrastructure. Through the program, LADWP successfully reduced the number of distribution outages by 28% between 2006 and 2009 by accelerating the replacement of transformers, poles, underground cables, and other equipment. In FY 2011-12, 1,813 poles, 2,054 transformers, and 51 miles of underground cable were replaced. See Section 1.6.3 and Appendix D for more information.

- Green Power Program

  LADWP offers its customers an opportunity to participate in the Green Power Program. "Green Power" is produced from renewable resources such as wind energy, geothermal, or other renewable resources, rather than conventional generating plants. In 2011, 17,700 LADWP customers participated in the program, receiving approximately 74,000 MWh of renewable energy. Since program inception in 1999 to the end of 2013, 872,131 MWh of renewable energy was procured, making it one of the largest voluntary green pricing programs in the nation.

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- Upgraded capacity on the Southern Transmission System (STS)

  In May 2011, the 488-mile Intermountain Power Project DC Line was upgraded from 1920 MW to 2400 MW, allowing the import of additional amounts of renewable energy from Utah. Of the 2400 MW total capacity, LADWP's share is 1128 MW.

- Navajo Generating Station (NGS) retrofitted with low NO_x burners

  In March 2011, NGS completed a three-year project that retrofitted the boilers of all three units with low NO_x burners and separated over fire air systems. This project was successful in reducing NO_x emissions by ~40% which represents an annual NO_x emission reduction of 11,000 tons per year.

- Barren Ridge Switching Station

  The Barren Ridge Switching Station, located 15 miles north of Mohave, was completed in 2009. This substation is a key component of the Barren Ridge Renewable Transmission Project (BRRTP), which will enable LADWP to interconnect approximately 1,400 MW of wind, solar, and other renewable resources that will be available in the next several years from the Mohave Desert and Tehachapi Mountain areas. The Environmental Impact Report for the BRRTP was approved by the Board of Water and Power Commissioners in September 2012. For more information see Section 2.4.4.

- Milford II Wind Project

  In May 2011, LADWP began receiving over 100 MW of new wind energy. Milford II is an expansion of the 200 MW Milford I wind farm project. Together, Milford I and II are providing approximately 2.6% of LADWP's total energy sales.

- Electric Vehicles Incentive for Home Chargers

  To encourage the transition towards electric vehicles, LADWP launched a demonstration program in April 2011 providing a $2,000 rebate for home charging systems. LADWP also worked with other City agencies to streamline the process time for permitting and installation of these systems.

- Initiated Coal Replacement

  Processes to replace coal generation from the IPP and Navajo stations have been initiated and are in progress. At Navajo, LADWP is planning to divest from the project by the end of 2015, which is four years ahead of the date required by SB 1368. At IPP, LADWP is working with the other participants to establish the contractual structure to enable a conversion from coal to natural gas. The date of conversion will likely be established before next year's 2013 IRP.

- Demand Response and Smart Grid

  LADWP is developing and enhancing its Demand Response and Smart Grid programs, which are important components of its future resource plan. To date, 60 MW of load shifting and interruptible load has been secured. Program managers

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and support staff have been established to move these programs forward, and appropriate resources have been budgeted

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1.6 Key Issues and Challenges

LADWP faces a number of concurrent issues and challenges that require careful assessment. Long term strategies must focus on these issues so they can be addressed in the most cost effective manner without compromising reliability, compliance and environmental stewardship. The major issues around which the strategies of this IRP are centered include: ensuring reliability, greenhouse gas emission reduction, increasing the amounts of renewable generation resources, and addressing once-through cooling.

1.6.1 Adequate Multi-year Funding to Support Programs

To support the recommended projects and programs, adequate funding is necessary. Due to the delay of the rate action that was previously anticipated in 2011, many of the programs were scaled down, delayed or deferred. The rate process that concluded on October 5, 2012 is a positive step towards LADWP's fulfillment of its responsibilities and regulatory obligations which are discussed throughout this 2012 IRP.

Properly funded programs will enable LADWP to achieve the following objectives:

- Modernize its coastal generation units to replace aging equipment and to satisfy once-through cooling and local emissions regulatory requirements
- Implement early coal divestiture and replacement to accelerate the reduction of greenhouse gas emissions and to enhance integration of renewable energy and energy efficiency measures
- Secure the state-mandated amounts of renewable energy
- Increase the use of local distributed solar generation and combined heat and power to support State goals
- Through the Power Reliability Program, reduce the number and duration of distribution outages and improve system reliability
- Implement necessary transmission improvements to maintain reliability and support new resources, including renewables.
- Provide energy efficiency and customer solar programs for participation by our customers through the Customer Opportunities Program
- Achieve energy efficiency and other demand-side resource target levels
- Implement Smart Grid initiatives.
- Comply with FERC-approved reliability and Cyber-security standards

Securing adequate multi-year funding is crucial to ensure LADWP's ability to stay on track towards meeting its future long term goals and obligations.

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1.6.2 Ensuring Reliability

Challenges to ensuring continued reliable electric service include the replacement of aging generation facilities, maintaining grid reliability, the integration of intermittent renewable energy resources, and the replacement of poles, power cables, transformers and other elements of the local distribution system (distribution reliability is further discussed in Section 1.6.3 below).

Aging Facilities and Infrastructure

LADWP's generating plants sited within the Los Angeles Basin were primarily built in the late 1950s and early 1960s. While many generating units at these plants have undergone extensive upgrades, others are approaching the end of their service lives. Replacement of these older units (also known as "repowering") began in 1984, and will continue through 2029. The new repowered units will be substantially cleaner, more reliable, community-friendly, and efficient than the units they are replacing. Repowering LADWP's gas-fired units will also assist in integrating intermittent renewable resources into LADWP's energy mix by providing quick response, back-up generation capacity.

Grid Reliability

LADWP's local transmission system cannot be reliably operated without generation from local thermal generating plants. The amount of generation required to provide transmission reliability is termed Reliability Must Run (RMR) generation. Repowering these local units will maintain transmission reliability by maintaining the reliability of RMR generation.

Historically, LADWP's local generation has provided voltage control for the basin transmission system. Over the years, as imports into the basin transmission system have increased, fewer local generators are needed on-line at any given time to supply power, reducing voltage control options for Power System operators. LADWP is countering this with plans to install static capacitors and reactors at strategic locations throughout the city. These installations are increasingly important as more renewables are imported.

LADWP's latest Ten-Year Transmission Assessment Plan has identified a number of infrastructure improvements that are needed to avoid potential overloads on key segments of the Basin transmission system. These overload conditions, if encountered, could lead to load shedding events (intentional power outages) to minimize the overall impact on the Power System.

Integration of Intermittent Renewable Energy

The integration of renewable energy into the grid poses major challenges. Integrating renewables will, paradoxically, require additional gas-fired generation to provide reserves and maintain system reliability. Because renewable resources like wind and solar produce electricity variably and intermittently (i.e., only when the wind is blowing or

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when the sun is shining), integration of these resources requires that controllable generators are online to smooth significant and often rapid changes to energy production. This stabilizing activity is known as "regulation" (see discussion box). A potential solution would use energy storage to regulate delivery of energy and reduce the severity of integration problems. For regulation, LADWP currently uses gas-fired combustion turbines and hydro resources, including pumped water storage. Batteries and compressed air offer alternative storage solutions, but those technologies are still in development and have not yet been proven commercially viable. See Section 2.4.5 for a discussion of LADWP's energy storage development activities.

"Regulation" is necessary because the amount of electricity generated must always match system load, or electricity demand. If load and generation do not match, the power frequency would vary from the target frequency, resulting in problems that can damage motors, appliances and other equipment, and may lead to system collapse and power outages.

LADWP is conducting studies to determine the maximum levels of intermittent energy resources that can be integrated reliably and to identify the investments necessary to maintain power grid reliability with intermittent resources contributing significantly to its energy portfolio.

1.6.3 Power Reliability Program (PRP)

Between 2003 and 2005, LADWP experienced a growing number of distribution outages due to, among other things, aging infrastructure (poles, lines, transformers, etc.), and deferred maintenance and asset replacement. To illustrate, Figure 1-4 shows the number of electrical distribution poles categorized by age. As shown, more than 50 % of the poles are 50 years or older and more than 25% already exceed the average life span of 60 years.

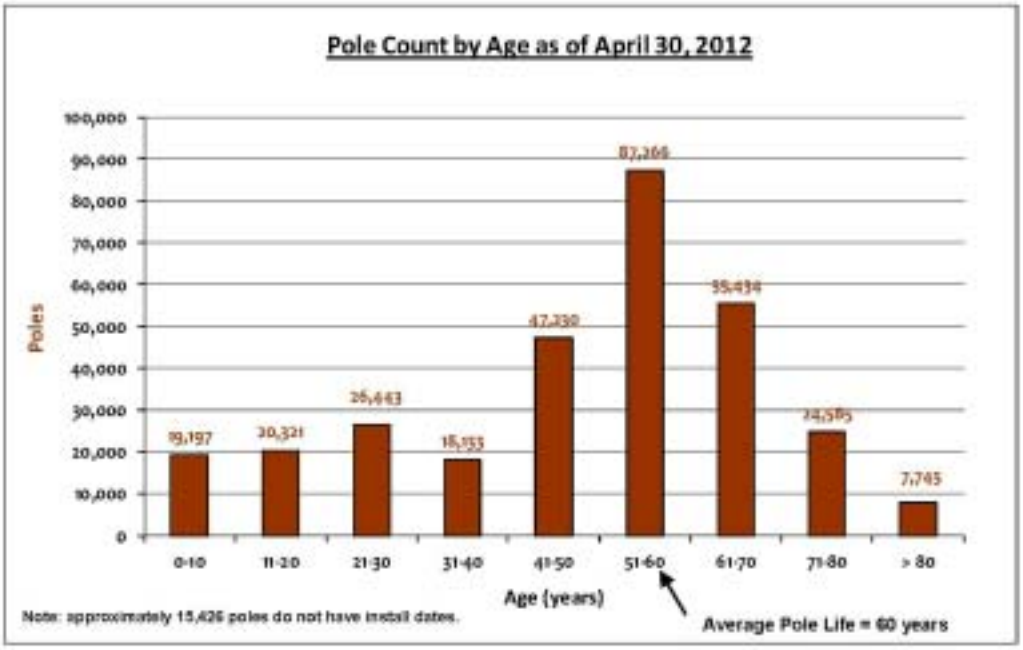

Figure 1-4. Pole count by year range installed.

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Like all other electricity utilities in the US, LADWP uses a number of metrics to measure the performance and reliability of its electric power system. The two primary metrics are called SAIFI and SAIDI.

The System Average Interruption Frequency Index (SAIFI), is the average number of sustained service interruptions per customer during the year. It is the ratio of the annual number of interruptions to the number of customers. In other words, it measures how many times the average customer has been out of service. 1.1 is the recent national average. In 2002, LADWP's SAIFI index was 0.49; in 2011 it was 1.03.

The System Average Interruption Duration Index (SAIDI), is the average duration of interruptions per customer during the year. It is the ratio of the annual duration of interruptions (sustained) to the number of customers. In other words, it measures how long the average customer was without power. 90 minutes is the recent national average. In 2002 LADWP's SAIDI index was 59.29; in 2011 it was 214.44.

The trends for both SAIDI and SAIFI are shown in Figure 1-5.

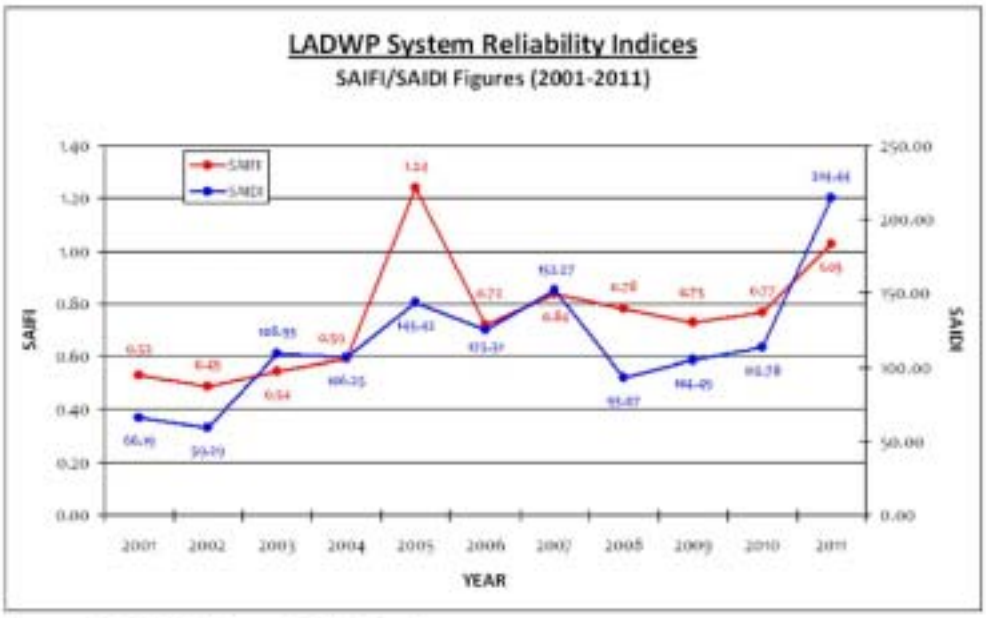

Figure 1-5. LADWP's reliability indices.

In response to the decline in service reliability, LADWP established a comprehensive Power Reliability Program (PRP) in 2006 which provided increased funding to address the growing maintenance backlog. The goals of the program include: (1) mitigating problem circuits and stations based on the types of outages specific to a given facility, (2) implementing proactive maintenance and capital improvements to avert problems before they occur, and (3) establishing replacement cycles for facilities that are in alignment with equipment life cycle.

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PRP funding has been inconsistent since its inception. As shown in Figure 1-6, the initial years of the program resulted in some reliability gains as outages decreased from 6,323 in 2006 to 4,523 in 2009. Funding levels since then, however, have declined and the number of outages has remained above 4,500 per year.

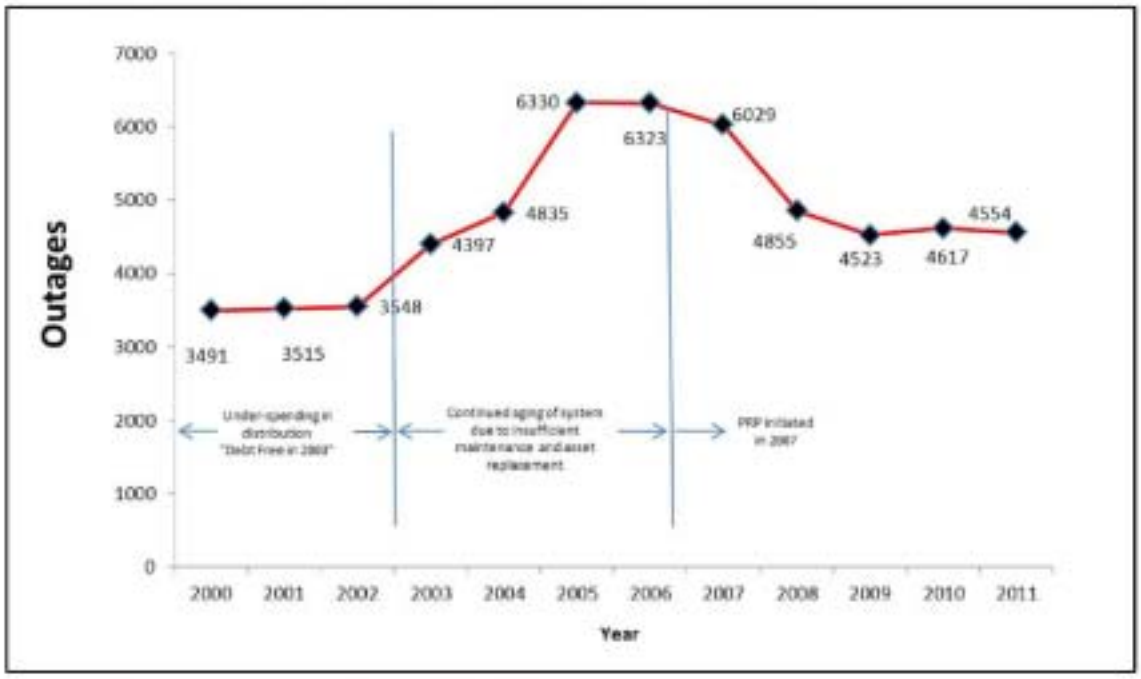

Figure 1-6. Total outages between 2000-2011.

Adequate funding is necessary to get the PRP back on track towards its goal of reducing outage levels. Additional information on LADWP's PRP can be found in Appendix E.

1.6.4 GHG Emissions Reduction

The focus of LADWP's GHG emissions reduction strategy is early replacement of coal-fired generation. Because coal emits relatively high levels of CO_2, switching to energy efficiency, renewables and other fuels will significantly lower overall emission levels. Early coal replacement facilitates LADWP's compliance with AB 32's upcoming cap and trade program.

LADWP's GHG emissions reduction strategy must comply with state and federal regulations:

- SB 1368, the California Greenhouse Gas Emissions Performance Standard Act, enacted in 2006, prohibits LADWP and other California utilities from entering into long-term financial commitments for base load generation unless it complies

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with the GHG emissions performance standard. The GHG emissions level must be equal, or below, that of a gas-fired combined cycle units (i.e., 1,100 lbs per MWh). This standard also applies to existing power plants for any long-term investments or contractual extensions, thus effectively prohibiting LADWP from continued coal-fired generation beyond the current contractual expiration dates for NGS (2019) and IPP (2027).

- Assembly Bill (AB) 32, the California Global Warming Solutions Act of 2006, calls for reducing the state's CO2 emissions to 1990 levels by 2020. The regulations for implementing a greenhouse gas emissions Cap and Trade program under AB 32 were finalized and adopted on October 20, 2011 by the California Air Resources Board (ARB). Enforcement and compliance with the trading program will begin January 1, 2013. LADWP has been granted an administrative allocation of emission allowances that reflects its resource projections through 2020.

LADWP has historically relied upon coal for base load generation. In calendar year 2011, 41 percent of the energy delivered to LADWP customers was generated from NGS and IPP. The NGS's operating agreement and land lease expires in 2019 but has a stipulation for a 25 year extension. IPP's Power Purchase Agreement (PPA) contract is in effect until 2027. These stations have provided dependable, low cost base load generation to Los Angeles. However, as coal-fired electricity emits about twice as much CO_2 as energy generated with natural gas, this 2012 IRP focuses on early coal replacement options as a means to lower LADWP's GHG emission levels. Section 2.4.2.3 presents more detail on LADWP's early replacement plans, and Sections 3 and 4 discuss the alternative coal replacement case options that were modeled and analyzed.

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1.6.5 Increasing Renewable Resources

Initiatives to utilize renewable resources to generate electricity support the goal of reducing GHG emissions and decrease our reliance upon fossil fuels.

- State legislation – SB 2 (1X) – which was passed in April 2011 and became effective December 10, 2011, requires utilities to procure eligible renewable energy resources of 33 percent by 2020, including the following interim targets:
  - Maintain at least an average of 20 percent renewables between 2011 and 2013
  - Achieve 25 percent renewables by 2016
  - Achieve 33 percent renewables by 2020 and maintain this level in all subsequent years

- SB 32, signed into law on October 12, 2009, requires LADWP to make a tariff available to eligible renewable electric generation facilities until LADWP meets its 75 MW share of the statewide target. Through this program, owners or operators of eligible renewable energy systems may sell their energy directly to LADWP. The purchase of energy will include all environmental attributes, capacity rights, and renewable energy credits which will apply towards LADWP's 33 percent renewable requirement.

- Former Governor Schwarzenegger signed the California Solar Initiative (CSI), outlined in SB 1, on August 21, 2006. The CSI mandated that all California electric utilities, including municipals, implement a solar incentive program by January 1, 2008. The goal of the CSI is 3,000 MW of net metered solar energy systems over 10 years with expenditures not to exceed $3.35 Billion. Expenditures for local publicly owned electric utilities shall not exceed $784 Million. The LADWP cap amount is $313 Million, based on its serving 39.9% of the municipal load in the state.

- The LADWP Board of Commissioners has adopted a policy to achieve 20 percent renewables by 2010, and 33 percent by 2020. The Board and City Council have approved projects and long-term power purchase agreements that achieved the 20 percent RPS goal in 2010. The policy has been revised to incorporate SB 2 (1X) requirements, and is included as Reference D-2 of Appendix D.

In addition, SB 2 (1X) sets certain conditions regarding renewable energy contracts entered into on or after June 1, 2010, as shown in Table 1-1.

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Table 1-1. SB 2 (1X) CATEGORY REQUIREMENTS FOR RPS ENERGY CONTRACTS

Portfolio Content Category[1]	RPS % Target		
	Compliance Period 1 (1/1/2011 – 12/31/2013)	Compliance Period 2 (1/1/2014 – 12/31/2016)	Compliance Period 3 (1/1/2017 – 12/31/2020)
1	Minimum 50%	Minimum 65%	Minimum 75%
2	See footnote 2	See footnote 2	See footnote 2
3	Maximum 25%	Maximum 15%	Maximum 10%

[1]Categories are defined as follows:

Category 1 = Energy and RECs from eligible resources that

- Have the first point of interconnection with a CA balancing authority or with distribution facilities used to serve end users within a CA balancing authority area; or
- Are scheduled into a CA balancing authority without substituting electricity from another source. If another source provides real-time ancillary services to maintain an hourly import schedule into CA, only the fraction of the schedule actually generated by the renewable resource will count; or
- Have an agreement to dynamically transfer electricity to a CA balancing authority.

Category 2 = Firmed and shaped energy or RECs from eligible resources providing incremental electricity and scheduled into a CA balancing authority.

Category 3 = Energy or RECs from eligible resources that do not meet the requirements of category 1 or 2, including unbundled RECs.

[2]Remainder % of resources which are neither in Category 1 nor Category 3.

The legislation allows for the California Energy Commission to issue a notice of violation and correction, and to refer all violations to the California Air Resources Board. Failure to achieve the targets may result in significant penalties.

The challenges of adopting more renewable resources such as wind, solar and geothermal, are: (i) obtaining local and environmental rights and permits for renewable projects and the associated transmission lines needed to deliver energy to Los Angeles; (ii) establishing reliable and cost-effective integration of large scale wind and/or solar projects into the LADWP balancing area through the addition of regulation-capable generation; and (iii) developing geothermal sites which are potentially scarce, require large capital costs, impose exploration risks, and have limited transmission line access. In addition, energy from renewable resources is generally more expensive than energy from conventional fossil fuel resources, and must be fully funded through customer rates.

1.6.6 Once-through Cooling

Once-through cooling (OTC) is the process of drawing water from a river, lake, or ocean, pumping it through a generating station's cooling system, and discharging it back to the original body of water. OTC is a utility regulatory issue, stemming from the Federal Clean Water Act Section 316(b) and administered locally by the State Water Resources Control Board (SWRCB). The interpretation of rules and development of guidelines for OTC have been several years in the making. See Appendix C for details.

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OTC regulations affect LADWP's three coastal generating stations – Scattergood, Haynes, and Harbor. To comply with OTC regulations, generation units at those stations that utilize ocean water for cooling will be repowered with new units that do not use ocean water. The amount of generation capacity affected by OTC is significant – approximately 2,600 MW of LADWP's total in-basin plant capacity of 3415 MW. The amount of expenditures required is also significant, on the order of $2.2 billion. Because of the size and scope of the effort required, the work to comply with OTC regulation is a long term program, extending to 2029.

It should be noted here that many of the units being replaced are older units that would have eventually been replaced even without the OTC requirement. However, the OTC mandate requires a significant reduction in the use of ocean water and therefore, OTC is being eliminated and replaced with closed cycle cooling. Satisfying the OTC mandate accelerates the replacement schedule of the affected generation units.

Discussions between LADWP and the SWRCB have resulted in the following timeline for OTC compliance (Figure 1-7).

Figure 1-7. Timeline for OTC compliance.

There are many constraints and considerations that were factored into the development of the OTC compliance timeline. Because the LADWP Power System relies on the in-basin units to provide transmission system reliability, as well as local sources of power generation, it is important to keep all of the units available to meet local capacity requirements. An existing unit that is being replaced cannot be decommissioned (shut down) until the new replacement unit is built, tested, and ready to go on-line. This requires a strict sequencing of the separate repowering projects, as shown on Figure 1-7.

There are many challenges to meeting the target dates. The limited space available within some of the generating station property boundaries presents planning and construction difficulties. Other issues include the long lead times required for environmental

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permitting, engineering design, and equipment procurement. Any unforeseen delay – for example, a delay in acquiring an environmental permit or a delay in delivery of new plant components – will adversely affect the schedule. The timeline shown in Figure 1-7 represents LADWP's best effort to comply with the mandated compliance deadlines while also meeting its reliability responsibilities.

The effects of the repowering program on ocean water use are shown in Figure 1-8. As individual units are replaced with new units that do not use ocean water, OTC levels decrease. The overall goal of the program is the total elimination of OTC by 2029. Additional discussion regarding LADWP's compliance with OTC regulations can be found in Appendix C.

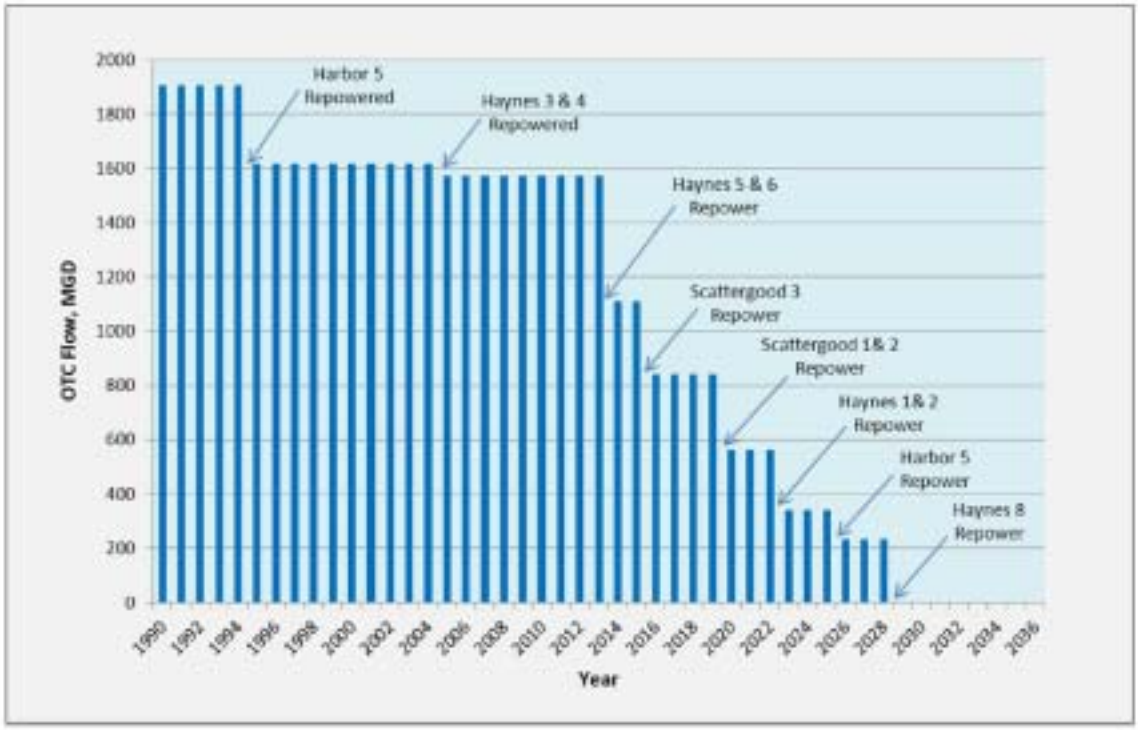

Figure 1-8. LADWP's reduction in once-through cooling from 1990 to 2029.

1.6.7 Workforce Development

To effectively implement the programs and projects recommended in this IRP, an effective human resources strategy is required. The Power System is challenged to develop a sustainable workforce development plan that addresses the following human resources elements:

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Adequate Staffing
Ensure adequate staffing so that LADWP can comply with mandated deadlines and fulfill its regulatory obligations. The Power System employs approximately 4,000 employees in 150 civil service classifications who perform core work related to generation, transmission and distribution of electricity. Workload requirements and competencies are continuously reviewed to determine the composition and number of employees needed. Achieving and maintaining proper staffing levels is complicated by the fact that a significant number of employees are expected to retire in the next 3-5 years.

Proper Skill Sets
New and expanded work areas such as renewable energy facility operations, energy efficiency, solar distributed generation, power reliability and smart grid deployment will require analysis to identify the skills, knowledge, abilities, and staffing levels required to perform these functions in a safe, effective and efficient manner. New job classifications may be required for new or specialty areas.

Training/Professional Development and New Technologies
Developing and promoting the development of both new and existing employees is a key human resource management objective. LADWP supports employee development by providing various computer based training programs, and offers tuition reimbursement for those who return to school to enroll in work-related courses and advanced degree programs. Across the Power System, different work groups are encouraged to develop training specific to their particular functions and needs. This is especially important as new and emerging technologies become applicable to various work functions. Applied correctly, technology increases employee productivity, enhances safety, and enables new and expanded customer services.

Recruitment
Recruiting the best qualified employees assumes an effective workforce capable of meeting the near term and long term challenges identified in the IRP. Working with source institutions such as colleges and vocational schools will expand LADWP's candidate pool, from which the highest qualified individuals can be offered positions. To promote the local economy, strategic recruiting is planned in areas of the City which have historically been untapped as sources for entry-level craft jobs. Continued use of LADWP's website and social media to promote career opportunities will sustain public awareness and help ensure that the best qualified individuals consider joining the LADWP workforce.

1.6.8 Additional Challenges

Additional challenges that LADWP must address include an increased risk from natural gas price volatility, a push towards higher levels of distributed generation, a need for more robust and precise transmission planning, addressing cyber security legislation, hydro-plant re-licensing, the future effects of climate change on power generation and operations, and improving system load factor.

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- Natural Gas Price Volatility

  To the extent that LADWP seeks to reduce its GHG footprint, but cannot meet all its future needs through renewable resources and DE/DSM programs, a greater percentage of generation utilizing natural gas will be forthcoming. To reduce the price risk inherent when relying so much on a single fuel type, LADWP will need to continue to develop and implement strategies to hedge against natural gas price volatility. These strategies are designed to protect LADWP from potential future price fluctuations, and include financial hedging products, ownership of gas reserves to supply a portion of its fuel needs, and other potential products and contractual arrangements.

- Distributed Generation

  The Governor has called for a statewide goal of 12,000 MW of renewable power generation within the local distribution grid. LADWP's portion of that would amount to approximately 1,200 MW. While this IRP investigates higher levels of distributed generation (see Cases 7 and 8 in Section 3 and 4), a number of complicating factors could make this a difficult goal to attain. Having adequate reserves, addressing operational impacts, and loss revenues that would have to be made up elsewhere are some of the factors that need to be considered and analyzed. This issue will require on going attention and assessment beyond this current IRP and should be an item for discussion in subsequent IRPs.

- Transmission Planning

  As resource planning has become more dynamic and complex in response to the growing number of external drivers and influencing factors, so too are the demands on transmission planning to support it. It is important that transmission considerations be connected to resource planning so that alternative options are evaluated in a realistic and effective manner. Importing new renewable energy from distant locations, dealing with intermittent energy, switching away from coal which may free up transmission capacity, the transmission needs for potential new power plants; these and other resource planning considerations all require adequate transmission. As LADWP controls a large amount of transmission in the state, it should leverage those assets to best meet the needs of the City and the ratepayers.

- Cyber Security Legislation & Regulation

  Congress is currently contemplating several Cyber Security Bills, all of which have their unique approach to protect the nation's critical infrastructure against cyber-attacks. The two prominent approaches to cyber security legislation range from Information Sharing to Federal Oversight and the development of new cyber security standards. Public power is working with House and Senate representatives to develop a bill that focuses more on information sharing and which would allow a utility to take voluntary actions as they see best for their organization.

  Along with Cyber security legislation, electric utilities are also concentrating on the development and implementation of NERC cyber security reliability standards.

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NERC is currently working with industry on version 5 of these standards in order to prevent cyber incidents that could lead to misoperation or instability in the bulk electric system

- Castaic FERC Re-licensing Program

On January 31, 2022, the Federal Energy Regulatory Commission's (FERC) license to operate Castaic Pumped-storage Hydroelectric Plant will expire. The license is a co-license between LADWP and the Department of Water Resources (DWR) and includes a number of hydro power plants along the California Aqueduct. Both parties have initiated the joint re-licensing process that, on average, requires ten years to complete. Through 2015, LADWP expects to complete preliminary studies, contract negotiations, and prepare a filing strategy. In 2016, LADWP expects to file a notice-of-intent (NOI) and initiate the formal studies and applications.

- Effects of Climate Change Global Warming

While LADWP is actively working to reduce its GHG emissions and thus lower its contribution to the problem of global warming, it must also look at the consequences of climate change and how it affects power generation and operations. Warmer temperatures, more volatile weather patterns, an increase in the number and duration of heat waves, stressed water availability and rising sea levels are some of the impacts that must be considered to ensure adaptation of the Power System to those future conditions. See Section 2.4.6 and Appendix M.

- Load Factor Improvement

Load factor represents how constant energy usage is over a given day. A 100 percent load factor means that the same amount of power is used throughout the day, so the system is getting full use of its generation, transmission, and distribution resources. A low load factor results in generators being started more often to serve load for a few hours a day, which is not optimum. As an analogy, a car traveling at constant speed will get the best gas mileage and reduced wear and tear than a car in stop-and-go traffic.

From the 1990s through 2005, annual system load factors were trending slowly upward, which is a positive movement. Since 2006, however, system load factors are trending down. Some of this decline is due to the fact that much of the historic energy efficiency effort is directed at lighting, which has higher impact on energy sales when compared to peak demand. Also, most customers are making greater efforts to conserve energy, but during extreme weather events safety and comfort predominate over conservation causing the peak to spike. LADWP will consider programs to shift load from peak hours to off peak hours to reverse this trend and improve system performance.

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1.7 Public Process

The 2012 IRP process includes a public outreach effort to provide information and gather public input.

Public outreach began with two stakeholder meetings held in early 2012. LADWP staff met with key major customers and business representatives in February, and in March with key environmental organization representatives. Comments received during these stakeholder meetings were considered in the development of the preliminary cases that were analyzed.

These preliminary results were documented in the 2012 Draft IRP document and were presented at three additional stakeholder meetings with major account customers, environmental organizations, and neighborhood councils, and discussed at an additional general public workshop held on October 11, 2012. The 2012 Draft IRP was made available for public comment through the LADWP website.

www.ladwp.com/ladpowerplan

Comments were accepted through November 5, 2012. Considering the public comment and input received, a final set of recommendations was made.

A summary of the public comments received is included in Section 5 and Appendix O.

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1.8 2012 IRP Development Process

The IRP is prepared by a group of engineers dedicated to LADWP resource planning and preparation of the IRP. While this group performs the production model and report preparation for the IRP, the bulk of the work is collaborative across the numerous work groups and functional areas of the Power System, including wholesale marketing, grid operations, renewable procurement, environmental and legislative affairs, and financial services.

The IRP is developed in multiple stages, including:

1 Gather stakeholder input

Meetings are held with stakeholder groups to discuss the key strategic planning issues and to gather input. This is done early in the process to ensure those concerns expressed are given due consideration in the establishment of goals and objectives, and in the development of the alternative cases for study and analysis.

2 Establish clear goals and objectives

The overarching goal of LADWP's IRP planning efforts is to produce a long term plan that ensures a future supply of electricity that is reliable, competitively priced, and is secured in a manner consistent with environmental stewardship. Through the planning and development process, specific initiatives, programs and projects (many which are in progress) are identified and assessed. The planning effort is collaborative among cross functional organizations within LADWP. Each initiative, program and project will have its own appropriate set of goals and objectives, which in turn supports the collective goal of reliable, affordable electricity that is sensitive to the environment.

3 Identify and approve key assumptions

The assumptions form the basis for subsequent analyses, and include such factors as load and fuel price forecasts, renewable resource percentage targets, CO_2 allowances and pricing, projected energy efficiency implementations, repowering schedules, etc. Assumptions are prepared and approved by the internal LADWP organizations responsible for the respective subject areas. The assumptions are then presented to LADWP management for comments and acceptance.

4 Establish strategic case alternatives

Each of the strategic cases is developed by IRP staff with input from each of the internal LADWP organizations. The strategic cases are designed to consider alternative future resource portfolios, and reflect real decision points and plans that LADWP will have to implement. The current major decision areas for LADWP is coal replacement, energy efficiency, and distributed generation, therefore, this IRP considers cases which offer alternative options for these three subject areas. Each case is vetted through LADWP management and working meetings are held to agree on final cases to be assessed.

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5 Conduct computer modeling of Power System operations

Simulations of the case alternatives are made using the Planning and Risk (PAR) software. PAR is a widely used hourly production cost model that commits and dispatches resources to minimize the cost of serving electric load. PAR is used by many utilities across the US and the world. The modeling results are vetted for quality. Post model analysis is then conducted to account for non-generation system costs, including transmission and distribution. The final results compare each case in terms of reliability, costs, and CO_2 emissions reduction. The results are reviewed by management for comments and acceptance. If needed, modifications are made to the model input assumptions for new computer runs.

6 Present preliminary Findings and gather public comments

Public meetings are held where the findings of the case analysis are presented. These results are considered preliminary at this point. Following public input, a final analysis of the cases is then conducted. It is possible that one or more of the cases may be modified as a result of public input.

7 Recommend and approve a preferred case

Based on the results of the final analysis, a preferred case is recommended. The preferred case is then presented to management for review and acceptance.

The IRP development process includes coordination among multiple LADWP organizations responsible for different aspects of Power System operations. Recommended positions at the various stages are presented to LADWP's leadership team, including Division and Section Heads. The approval process for recommendations is based on consensus from the managers of each area of responsibility.

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1.9 Summary

LADWP is in the process of transforming its Power System. Approximately 70% of its Power System generation will be replaced within the next 15 years. Numerous challenges are being addressed concurrently, including meeting renewable resource requirements, once-through cooling, natural gas repowering, coal replacement, GHG reduction, energy efficiency, demand response programs and others. Meeting all of these challenges requires considerable amounts of labor and capital resources, which applies upward pressure on LADWP's electric rates.

LADWP is focusing on both near-term and long-term solutions. To achieve the objectives and goals documented in this 2012 IRP, LADWP will continue to implement its existing programs and projects, but will also introduce and expand new initiatives and program areas. The following list shows the major activities that require action over the next 3-5 years (for more information, see the referenced IRP sections).

Major Power System Activities 2012–2017

Programs Already in Progress

- **Haynes 5&6 Repowering** (Sections 1.6.6, 2.4, 3.3, 5.3, Table 5-4, Appendix F)
- **Scattergood Repowering** (same as Haynes 5&6 references)
- **Coal Replacement Planning and Implementation** (Sections 1.6.4, 2.4.2.6, 3.3, 3.5, 4 and 5)
- **Replacing aging distribution infrastructure** (Sections 1.6.7, 1.6.8 and 2.4.2.3, Appendix E)
- **RPS procurement** (Sections 1.6.5, 2.4.3, 3.4, and 5, Appendices D and N)
- **Solar Program Development** (Sections 2.4.3, 3.2.4 and 5, Appendices D, G, and N)
- **Existing EE program elements** (Section 2.3, Appendix B)

New and Expanded Program Areas

- **Demand Response Program** (Sections 2.3.2, 5.3, and 5.6, Table 4-2)
- **New EE program elements** (Section 2.3, Table 1-6, Appendix B)
- **Smart Grid Implementation** (Section 2.4.5, Table 4-6, Appendix L)
- **Transmission Line Improvements** (Sections 2.4.4, Appendix J)
- **Grid Reliability Improvements** (Sections 2.4.4 and 5.1)
- **Haynes 1&2 Repowering** (Sections 1.6.6 and 5.3, Table 4-6)
- **Distributed Generation** (Sections 2.3.3, 3.5, 4.3.3.1, Appendices G and N)

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2.0 LOAD FORECAST AND RESOURCES

2.1 Overview

Through an IRP, utilities forecast the demand for energy and determine how that demand will be met. Meeting forecasted demand is accomplished by the planning and delivery of electric power generating ("supply-side") resources through transmission and distribution systems. Another key element of IRP planning is to determine how to reduce energy demand and increase the efficiency of the utility customer's use of electricity, known as "demand-side resources."

This section of the IRP addresses the following:

- Forecasting of future energy demand
- Demand-side Resources (DSR), including Energy Efficiency and Demand Response
- Distributed Generation
- Supply-side Resources
- Transmission/Distribution, including grid reliability
- Advanced Technologies, including Smart Grid and Energy Storage
- Climate Change Effects on Power Generation
- Reserve requirements

The discussions include the technical, regulatory, and economic factors that affect LADWP's planning and execution of programs and projects.

Data for this analysis comes from publicly available reports from organizations such as the California Energy Commission (CEC), California Public Utilities Commission (CPUC), the North American Electric Reliability Corporation (NERC), the Federal Energy Regulatory Commission (FERC), other industry forecasts, and internal LADWP sources. Also highlighted in this IRP are additional studies that are either underway or will be performed in the near future to provide additional clarity regarding the boundaries and needs of the system.

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2.2 Forecast of Future Energy Needs

This IRP utilizes LADWP's 2012 Load Forecast, dated March 7, 2012, of customer demand for energy over the next 20 years (the complete 2012 Load Forecast is included in Appendix A). Econometric models are used to forecast retail sales and peak demand. Net Energy for Load (NEL) is defined as the production necessary to serve retail sales. NEL, and its allocation across various times of the day, are functions of the retail sales and peak demand forecasts. The retail sales forecast is the sum of seven separate customer class forecasts. The classes are residential, commercial, industrial, plug-in electric vehicle (PEV), intradepartmental, streetlight, and Owens Valley. The drivers in the retail sales models include normalized weather, population, employment, construction activity, and personal consumption. The NEL forecast is derived from the retail sales forecast by applying a normalized loss factor of 11.5 percent. Losses can vary depending on the sources of energy production. NEL load growth becomes a driver of the peak demand forecast. Peak demand is also a function of temperature, heat buildup, and time of year. The NEL forecast is allocated using the Loadfarm algorithm developed by Global Energy. The inputs into the algorithm are NEL, peak demand, minimum demand, and system load shape.

2.2.1 2012 Retail Electrical Sales and Demand Forecast

The effect of the recent recession and slower than normal recovery, combined effective energy efficiency programs depressed electricity sales by approximately 6.4 percent off their fiscal year 2007-08 peak. Economic activity in commercial sectors such as construction, real estate, retail, and leisure are forecasted to recover as the economy expands.

The electricity consumption within LADWP's service territory is forecasted to rise 0.8% over the next five years as energy efficiency and solar rooftop expansion offset growth from economic activity. The growth in annual peak demand over the next twenty years is predicted to be about 0.6 percent – approximately 40 MW per year – with less growth over the next few years due to the current recession. After 2018, some of the growth will not be realized at the meter depending on the adoption of energy efficiency and distributed generation technologies.

The 2012 forecast is LADWP's official Power System forecast. This forecast is used as the basis for LADWP Power System planning activities including, but not limited to, integrated resource planning, transmission and distribution planning, and wholesale marketing. The forecast is a public document that uses only publically available information.

Table 2-1 summarizes the data sources used to develop the forecast and where these data sources have been updated from previously published forecasts.

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Table 2-1: LOAD FORECAST DATA SOURCES

Data Sources	*Updates*
1. Historical Sales through December 2011 are reconciled to the General Accountings Consumption and Earnings Report.	*Historical Sales, Net Energy for Load and weather data is updated through December 2011.*
2. Historical NEL, peak demand and losses through December 2011 are reconciled to energy accounting data.	
3. Historical weather data is provided by the National Weather Service and Los Angeles Pierce College.	*Weather is updated through December 2011.*
4. Historical Los Angeles County employment data is provided by the State of California Economic Development Division using the March 2010 benchmark.	*Employment data is updated through December 2011 using the March 2010 benchmark.*
5. Historical population and forecasts is provided by the State of California Department of Finance.	Population data is updated through January 2012.
6. The long-term Los Angeles County economic forecast is provided by UCLA Anderson Forecast.	
7. The construction activity forecast is provided by McGraw-Hill Construction.	*Building permit data is updated through December 2011.*
8. The plug-in electric vehicle (PEV) forecast is based on the California Electric Vehicle Coalition which has been adopted as the statewide PEV forecast.	
9. The port electrification forecast is provided by the Port of Los Angeles.	
10. The housing forecast is informed by the City of Los Angeles "Housing that Works" plan.	

2.2.2 Five-year Sales Forecast

The Retail Sales Forecast represents sales that will be realized at the meter through Fiscal Year Ending (FYE) 2017. After FYE 2017, some of the forecasted sales will not be realized at the meter due to the incremental impacts of LADWP-sponsored energy efficiency programs.

The historical accumulated energy efficiency and solar savings are from 1999 forward and only include LADWP installed savings. Since July 1, 2008, LADWP installed energy efficiency savings are 715 GWh for which LADWP recovers lost revenue. In the forecast, energy efficiency and solar savings are expected to occur uniformly throughout the year as a simplifying assumption. Installation schedules are difficult to prepare because they rely on the customers allowing the installation to occur.

Retail sales decrease of 0.6 percent in FYE 2014, as shown in Figure 2-1, is attributed to the full ramp up of the lighting efficiency requirements of AB 1109 (approved in 2007 and known as the "Huffman Bill") and accelerated incremental savings rates in

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LADWP's energy efficiency programs. Beginning January 2012, the Huffman Bill significantly raises the efficiency standard of light bulbs. The 0.5 increase in FYE 2015 is due to the projected completion of port electrification projects and a decline in the LADWP incremental energy efficiency savings rate.

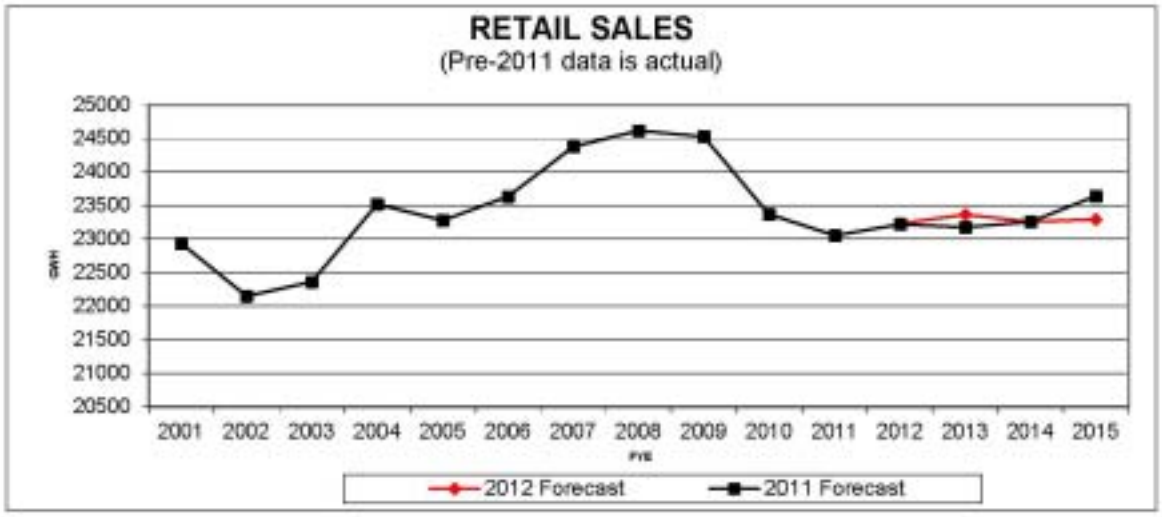

Figure 2-1. Retail sales net of energy efficiency and distributed generation.

Table 2-2 shows projections of short-term retail sales growth:

Table 2-2. SHORT-TERM GROWTH

Fiscal Year	Retail Sales		Additional Load if not for EE & Solar Savings
Ending June 30	(GWH)	Growth Rate (Year-Over-Year)	(GWH)
2010-11	23,053	-1.50%	0
2011-12	23,232	0.8%	255
2012-13	23,364	-0.4%	592
2013-14	23,256	-0.6%	928
2014-15	23,294	0.2%	1302

For IRP modeling and analysis, adjustments are made to the approved load forecast to account for the alternative energy efficiency targets and customer net-metered solar projections. These adjustments are shown in Appendix N.

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2.2.3 Electrification

A result of AB 32 will be to encourage increased electrification as a means to reduce GHG emissions. This has added a degree of uncertainty to the forecast of future electricity needs in terms of both additional resulting load and the speed of implementation of electrification programs.

In the transportation sector, fuel switching from diesel and gasoline to electric power can result in air quality improvements if the sources of electric power are clean. Figure 2-2 shows the forecasted number of plug-in electric vehicles (PEVs) within the LADWP service area over the next 20 years. To support the adoption of electric vehicles, LADWP launched a pilot program in May 2011 that provides 1000 customer rebates of up to $2,000 towards the purchase and installation of electric vehicle home charging systems. Supporting the City's electric vehicle infrastructure, LADWP is also in the process of retrofitting 117 vintage chargers on City property.

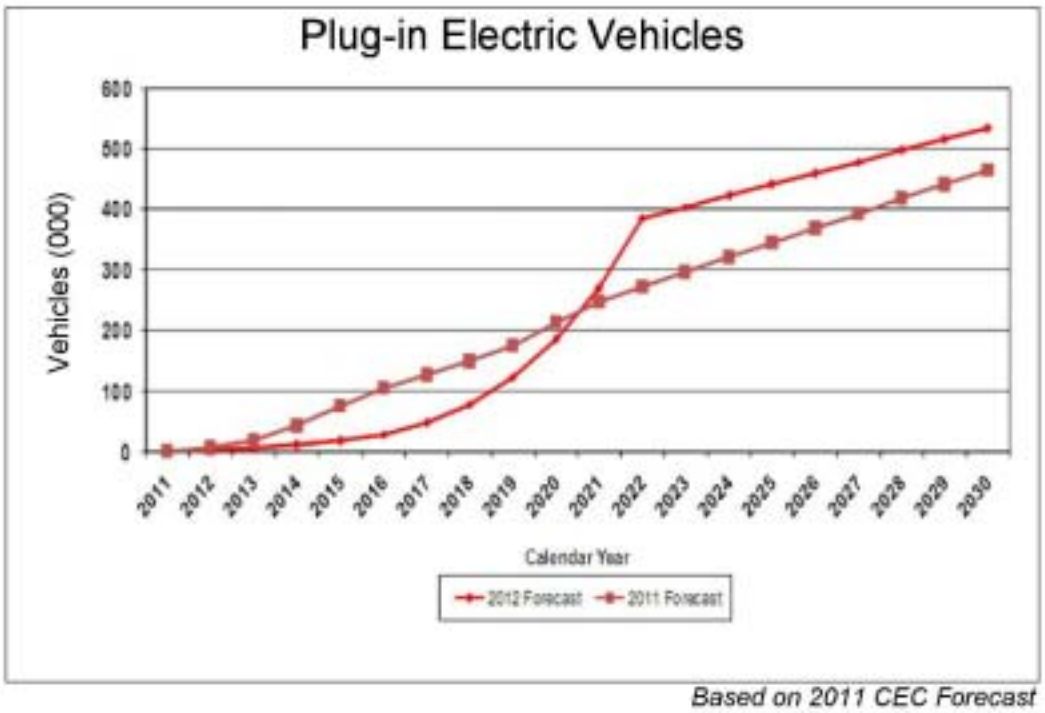

Figure 2-2. Forecasted number of plug-in electric vehicles.

Other agencies in the LA air basin have initiatives underway for "electrification" to replace existing diesel fueled trucks and gasoline powered cars with electric power. In addition, planned expansions to light railway and the metro system would add additional electric load to the system. Another example of transportation sector electrification is the Clean Air Action Plan developed jointly by the Port of Los Angeles and the Port of Long Beach to reduce air pollution from their many mobile sources as well as some fixed

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sources. This includes trucks, locomotives, ships, harbor craft, cranes, and various types of yard equipment. One of the programs, Alternative Marine Power (AMP), allows AMP-equipped container vessels docked in port to "plug-in" to shore-side electrical power instead of running on diesel power while at berth.

Plug-in Electrical Vehicles (PEVs)

Large scale deployment of electric vehicles will significantly affect the way electricity is consumed. It is estimated that by 2015, the United States will have one million EVs in deployment, 10% of which is expected to be in California. The introduction of electric vehicles in Southern California brings a challenging set of planning, regulatory and cost issues. Because EVs require a unique infrastructure, including specialized charging equipment and adequate electric service, it is essential to anticipate and predict the grid impact in Southern California from the EV deployment.

Regulated utilities in California are now responding to regulatory direction to submit plans for large-scale EV initiative with full delineation of costs and benefits. This regulatory initiative is an aggressive step, seeking to promote accelerated adoption of EVs. The EV deployments and the associated utility customer features are proceeding throughout the State of California. Energy needed for PEVs will come partially from the utility electric grid. It is expected that the "fuel shift" from traditional transportation fuels will increase customers' demand for electricity from the electric grid.

PEVs also present an opportunity to influence charging patterns by incentivizing charging during off-peak time periods, resulting in better system load factor. Currently 80% of PEV charging in Los Angeles occurs during off peak hours (per US DOE)

LADWP will use a part of the $120 million Smart Grid demonstration grant award from DOE to demonstrate the integration of electric vehicles into the LADWP-managed electric system. The demonstration will use internal fleet equipment, privately owned EV chargers, and will include electric vehicle fleets from both UCLA and USC. These complementary fleets provide the opportunity to test EVs in both the controlled environment of a corporate fleet and the "real world" usage of individuals. These opportunities will test the integration of EVs into the grid, along with acquisition of EV communications to the grid management.

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2.2.4 Peak Demand Forecast

Growth in annual peak demand over the next ten years is 1.0 percent as shown in Table 2-3.

Table 2-3: FORECASTED GROWTH IN ANNUAL PEAK DEMAND

Fiscal Year End June 30	Base Case Peak Demand (MW)	Growth rate Base Year 2010-11	One-in-Ten Peak Demand (MW)
2011-12	5635[1]		6046
Forecast			
2015-16	5591	0.8%	6028
2020-21	5791	1.0%	6244
2030-31	6381	1.1%	6885
2040-41	6992	1.1%	7546

[1] Weather-normalized. Actual peak was 5907 MW

In 2010, the System set its all-time annual net energy for load peak at 6142 MW on September 27, 2010 on a day that was a one-in-thirty-five year weather event. The weather-adjusted one-in-two peak for 2011 is 5635 MW. Figure 2-3 presents the one-in-ten peak demand forecast, which is used for integrated resource planning. In the 1990s through 2005, annual system load factors were trending slowly upward. Since 2006, system load factors are trending down. Two factors are generally thought to be contributing to this effect. Most customers are making greater efforts to conserve energy but during extreme weather events safety and comfort predominate over conservation causing the peak to spike. Much of the historical and forecasted energy efficiency effort is lighting which has a greater impact on consumption rather than peak which lowers the load factor.

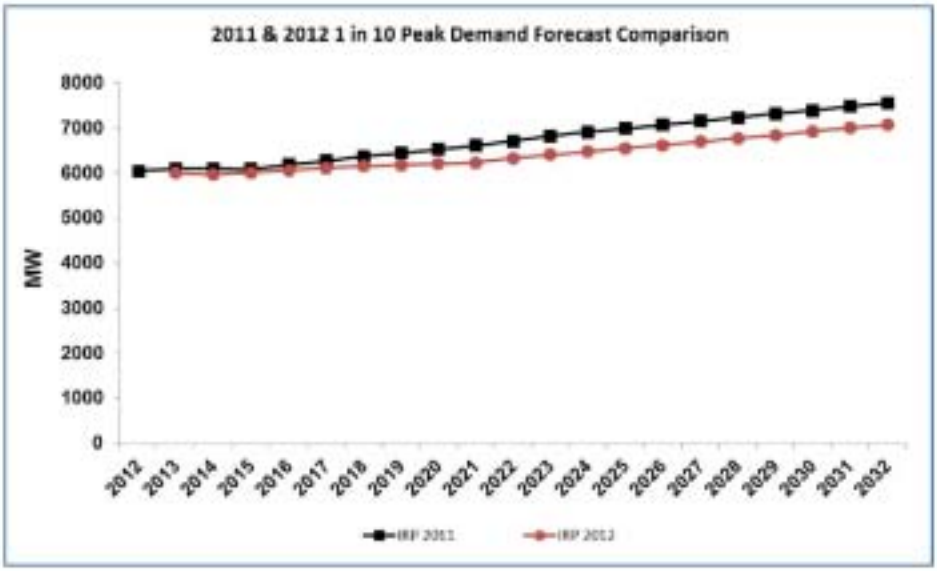

Figure 2-3. One-in-ten peak demand forecast comparison.

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2.3 Demand-Side Resources

Demand Side Resource (DSR) programs, including energy efficiency, have become important elements of IRP planning. Also known as Demand Side Management, DSR programs help to counter or minimize energy demand growth and thereby lessen the need to build more physical generation assets and improve load factor. This section discusses the following DSR initiatives:

- Energy Efficiency (EE)
- Demand Response (DR)
- Distributed Generation (DG)

Key DSR data assembled for this IRP included:

- The energy efficiency forecast, which was based on the Board-approved AB 2021 objectives, the City of Los Angeles Green Plan, and Demand Forecast Energy Efficiency Quantification Project working papers. Historical installation rates were referenced as part of the forecast.
- An estimate of the amount of solar rooftop and other distributed generation.
- An assessment of existing and developing technological improvements in large scale battery systems for energy storage.

2.3.1 Energy Efficiency

Energy Efficiency (EE) is a key strategic element in LADWP's resource planning efforts. EE is an overall cost effective resource in LADWP's supply portfolio and serves an important and multi-faceted role in meeting customer demand. One of the most widely recognized examples of an EE program is the replacement of incandescent lights with compact fluorescent lamp (CFL) bulbs. CFLs consume up to 75% less energy than incandescent bulbs while producing an equivalent amount of illumination and last up to 10 times longer.

Since 2000, LADWP has spent approximately $315.2 million in capital and O&M on its energy efficiency (EE) programs and these programs have reduced consumption by approximately 1,377 GWh. LADWP is committed to implementing comprehensive programs with measurable, verifiable goals as well as implementing robust, cost effective energy efficiency programs.

Under Assembly Bill 2021 (AB 2021), publicly-owned utilities such as LADWP, must identify, develop and implement programs for all potentially achievable, cost-effective EE savings and establish annual targets.

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Furthermore, utilities are required to conduct periodic "Potential" studies to update their forecasts and targets. LADWP's most recent study, carried out in late 2010, is the basis for the EE recommendations contained in last year's 2011 IRP and was used to develop the initial financial plan and proposed rates for fiscal year ending (FYE)[1] 2013 and FYE 2014. LADWP is currently proceeding with the 2013 EE Potential Study, to be completed in 2013.

2.3.1.1 Recommended Target - 10% by 2020

The base plan for energy efficiency programs established in December 2011 puts LADWP on a path to achieve energy savings equivalent to 8.6% of 2010's energy consumption by 2020. This level of savings reflects the findings of the latest energy efficiency potential study and was approved by the LADWP's Board of Commissioners in December 2011. The 2010 reference point is specified by AB 2021, which encourages the state's electric utilities to achieve cumulative savings of 10% of total energy consumption levels by 2020. The Board's adoption of an 8.6% energy savings goal by 2020 was an interim goal. In that adoption, the Board requested LADWP to evaluate options to increase the rate of energy efficiency savings to achieve the targeted goal of 10% by 2020. LADWP determined that a 10% goal by 2020 was indeed achievable, and the Board formally adopted this target on May 24, 2012.

LADWP's baseline EE spending in the initial financial plan for FYE 2013 and 2014 (based on the 8.6% target) is $87M and $99M, respectively. In order to achieve the 10% level of GWh savings, LADWP recommended increasing spending on EE programs. This change would add funding to existing programs, modify existing programs or develop new programs that provide additional GWh savings necessary to put the utility on a projected path to achieve 10% savings by 2020. Other changes included reallocating costs from support functions to programs, capitalizing the vast majority of the programs, and updating assumptions related to other programs. The Board adopted the increased EE budget for 2013-14 at the same time as the 10% savings goal, on May 14, 2012.

On May 24, 2012 the Board also acknowledged plans to conduct a new updated energy efficiency potential study to be completed by June 30, 2013. The new potential study will be used to develop a long-term plan for the scope and estimated costs to achieve 10%, 12.5%, and 15% savings by 2020. The energy efficiency planning scenarios resulting from the new study will be considered for inclusion into future IRPs.

2.3.1.2 Total Additional EE Investment Required to Reach Required 10% GWH Savings

As shown in Figure 2-4 and Table 2-3 below, LADWP recommended an additional $41 million and $40 million in expenditures in FYEs 2013 and 2014 respectively. This level of additional spending is well above LADWP's historic and current levels and produces

[1] FY 2013 refers to 7/1/2013 to 6/30/2014. FY 2014 refers to 7/1/2014 to 6/30/2015. LADWP's fiscal year begins on July 1 and ends on June 30.

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the GWh savings required in the next two fiscal years to put LADWP on a path which, if continued beyond FYE 2014, would reach at least the 10% required by year 2020 per AB 2021. Notably, this level of funding puts LADWP on par with California's Investor Owned Utilities (IOUs) in terms of EE investment on a per-ratepayer basis, giving LADWP the third largest portfolio of EE programs in California. Moving forward with this level of commitment then allows LADWP to prepare plans beyond the next two fiscal years to achieve the 10% energy efficiency savings by 2020, or to consider even further energy efficiency improvements beyond 10% if deemed appropriate.

The yellow line in Figure 2-4 represents the level of energy savings required to pace LADWP towards the 10% reduction target. Expenditures for this level of savings were approved in the recently concluded rate process.

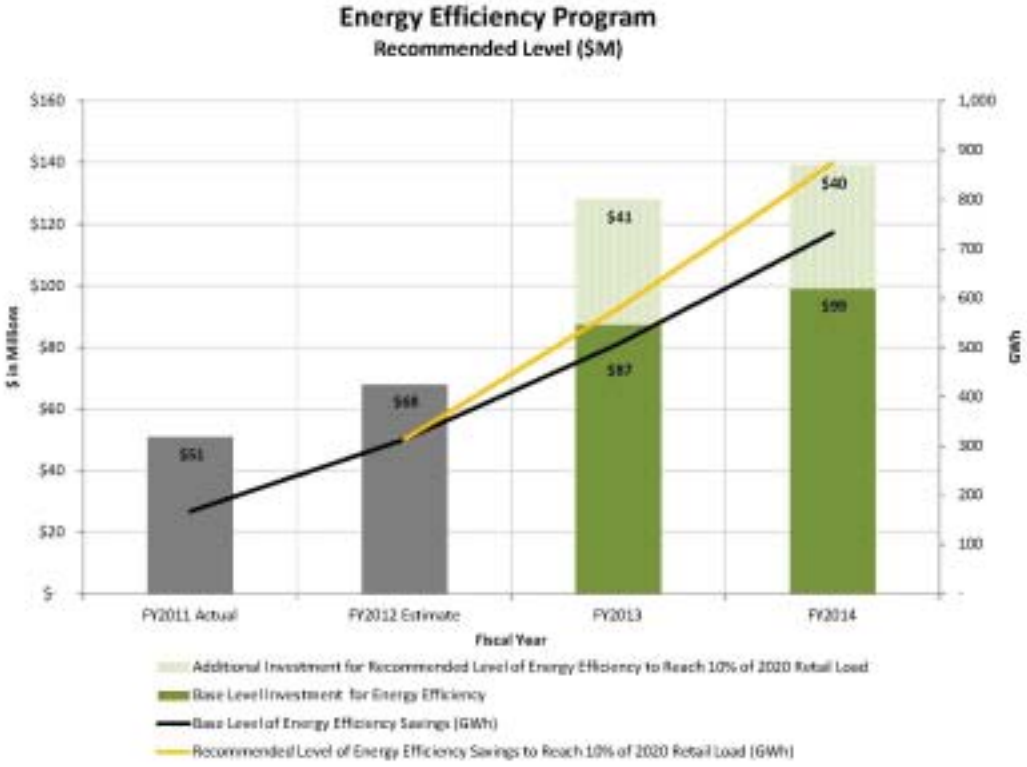

Figure 2-4. Energy efficiency recommended investment and energy savings through FYE 2014.

Table 2-4 below shows proposed spending for the next two years, along with an extended outlook through FYE 2017.

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Table 2-4. TOTAL ENERGY EFFICIENCY EXPENSES AND USAGE SAVINGS

Energy Efficiency Program	Proposed Rate Period Cost ($000s)		Extended Outlook Cost ($000s)			Total Five Years FY 2013 to FY 2017		
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Cost ($000s)	GWh Savings	Cost ($/kWh)
Residential Programs								
Refrigerator Recycling Program	1,033	1,212	1,440	1,683	2,400	7,768	100.0	0.016
Refrigerator Exchange Program	6,200	6,323	14,126	15,451	21,879	63,979	59.9	0.076
Consumer Rebate Program	2,067	3,161	3,260	4,414	5,470	18,372	13.5	0.105
Income Qualified and Multi-Family Program	12,380	12,676	6,540	6,736	6,850	45,186	10.6	0.327
Residential Lighting Program	723	1,054	1,630	2,207	4,102	9,717	71.6	0.026
Residential Home Electronics Program	0	0	543	1,104	1,367	3,014	6.0	0.100
Behavioral Programs	2,067	2,108	2,173	2,207	2,735	11,290	113.5	0.099
Energy Upgrade California	1,033	2,108	1,087	1,104	1,367	6,699	7.0	0.095
AC/Tune-Up	2,067	2,108	2,173	2,207	2,735	11,290	5.2	0.215
Residential Subtotal	**$27,570**	**$30,750**	**$32,973**	**$37,115**	**$48,905**	**$177,313**	**387.4**	**0.118**
Non-Residential Programs								
Commercial Lighting Efficiency Offer	10,333	10,538	7,607	7,725	8,205	44,408	165.9	0.024
Chiller Efficiency Program	2,583	3,161	3,803	3,863	4,786	18,197	23.4	0.039
Refrigeration Program	1,033	1,581	1,630	1,655	2,051	7,951	75.5	0.026
HVAC Program (5 to 20 tons)	2,067	2,181	2,336	2,456	3,138	12,178	15.1	0.054
Custom Performance Plus	10,333	10,906	11,627	12,250	15,725	60,843	92.4	0.041
Custom Performance-Based Efficiency	12,400	14,753	15,213	15,451	19,144	76,961	365.3	0.018
New Construction	1,292	1,844	2,173	2,207	2,735	10,251	82.7	0.008
LAUSD	11,327	11,569	12,047	12,453	12,586	59,982	136.1	0.043
Lighting Direct Install Program	36,163	36,967	37,979	38,924	39,649	189,721	101.7	0.170
Retrocommissioning (RCx)	4,133	4,215	4,347	4,414	4,102	21,212	77.9	0.027
Demand Response Pgm Dev/Program Support	258	738	1,304	2,207	5,470	9,977	0.0	0.00
Non-Residential Subtotal	**91,943**	**98,473**	**100,066**	**103,606**	**117,591**	**511,680**	**1,136.1**	**0.045**
Subtotal General Program Support	7,684	8,512	10,341	11,313	13,250	51,100	N/A	0.00
TOTAL ENERGY EFFICIENCY PROGRAM	$127,197	$137,736	$143,379	$152,034	$179,747	$740,094	1,523.5	0.079

Note: LADWP reserves the right to adjust programs, budgets, and individual program savings target at any time in order to respond to changing business conditions and market needs.

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The spending shown in Table 2-4 results in cumulative savings of 1,523.8 GWh in FYE 2013 through FYE 2017 combined at an average cost per kWh of $0.079

2.3.1.3 Program Descriptions

The different EE program elements are briefly described as follows

Residential Programs

Refrigerator Recycling Program. The program provides free pick-up and recycling of old, inefficient refrigerators along with a cash incentive of $50 for each recycled refrigerator

Refrigerator Exchange Program. Provides new energy-efficient refrigerators to low-income customers in exchange for existing inefficient older models. Program planning includes improved outreach and continued expansion to apartment owners

Consumer Rebate Program (CRP). The CRP is designed to both educate and encourage the LADWP's residential customers to purchase high efficiency refrigerators, air-conditioners, appliances, and other energy-saving products that meet or exceed Energy Star efficiency rating

Home Energy Improvement Program. This program, offers residential customers the opportunity to reduce their energy bills by allowing qualified Department staff to make energy efficiency and water conservation upgrades to their home. For residential customers residing in multi-family dwelling, common area efficiency upgrades will also be addressed. All residential customers may apply, however, first consideration will be given to registered low-income and lifeline customers, and Tier 2 residential customers who demonstrate the greatest economic need

Residential Lighting Program. This program is currently under development

Behavioral Programs. Provides residential end-users with information on their energy use, comparisons with usage by others, goal setting, rewards and additional tactics that encourage efficient energy use. This is a new program not included in the base energy efficiency program.

Energy Upgrade California. This is a collaborative program administered by the California Energy Commission in partnership with public and private utilities, the California Public Utilities Commission and participating counties. The program is funded by grants and contracts from the U.S. Department of Energy, the Energy Commission, and California utility customers. This is a new program not included in the base energy efficiency program.

AC Tune Up. Provides qualifying residential customers with Air Conditioning refrigerant charge adjustments and condenser coil cleaning. Program is currently in development

Non-Residential Programs

Commercial Lighting Efficiency Offer. Provides menu-based rebates for energy efficient lighting technologies, including T8 and T5 lamps with electronic ballasts, high bay linear fluorescent fixtures, induction lamps, LED exit signs, LED channel signs, occupancy sensors, and others.

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Chiller Efficiency Program. Rebates are available for all types of chillers (air-cooled and water-cooled). In addition, water-cooled centrifugal chillers now can be tested at either standard Air-conditioning and Refrigeration Institute (ARI) or non-standard ARI conditions provided the cooling tower meets specific performance criteria. Higher rebate levels are based on the percentage that the chiller's Integrated Part-Load Value performance exceeds California's Current Title 24 requirements for chillers.

Refrigeration Program. The new Refrigeration Efficiency Program encourages best practices and retrofit measures and technologies to reduce energy in fixed store refrigerator cases and cold storage facilities.

HVAC Program (5 to 20 tons). Offers incentives for replacing inefficient package units with high efficiency units. This is a new program not included in the base energy efficiency program.

Custom Performance Plus. An enhanced version of the Custom Performance Program that is in the base level EE plan, targeting industrial process efficiency improvements with minimum energy saving requirement of one GWh. Program is currently in development. This is a new program not included in the base energy efficiency program.

Custom Performance Based Program. This program continues offering savings-based incentives for the installation of energy savings measures, equipment or systems that exceed Title 24 or minimum industry standards, with differing incentive rates established for three categories of efficiency measures (lighting, HVAC, other).

New Construction Program. This program is being redeveloped. Plans are underway to offer incentives for projects exceeding current Title 24 requirements for energy efficiency.

Energy Efficiency Measures for LAUSD. Los Angeles Unified School District (LAUSD) is the largest power customer of the utility. LADWP is presently working with LAUSD to develop a focused energy efficiency program to reduce energy use at LAUSD facilities that are within the City of Los Angeles[1]. LADWP has proposed to LAUSD undertaking specific energy efficiency measures in FYE 2013 while LADWP works with LAUSD to develop a detailed energy usage and energy efficiency potential study of LAUSD facilities that will provide the basis for a multi-year energy efficiency plan that LADWP and LAUSD would collaboratively undertake as part of LADWP's overall energy efficiency investment program. The Energy Efficiency Alternative Plan presented herein provides for an allocation of funding and target energy savings for the next two fiscal years. This plan will be developed in more detail in cooperation with LAUSD.

Small Business Direct Install Program (SBDI): This program will retrofit the existing lighting of qualifying business customers to new, high efficiency lighting systems. The SBDI will initially target the smallest business customers in the A1 rate class, but may be expanded to other customer segments. This program is expected to operate for three years.

Retrocommissioning (RCx) Express. (RCx Express) program is a continuation of the American Recovery and Reinvestment Act (ARRA) grant-funded pilot program for non-residential customers, replacing the ARRA grant funding with Department funding from rate revenue. The pilot program design is based on lessons learned from SCE's Retrocommissioning program. The

[1] Some of the LAUSD facilities are located outside of the boundaries of the City of Los Angeles and are served by Southern California Edison.

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LADWP program offers a cash incentive (rebate) to those who undertake a "tune-up" of their existing building system equipment and bring it back up to its original performance level. The program does not require a Retrocommissioning study, but offers a menu of 13 items that qualify for incentives. Program offerings include incentives for replacement or repair of certain lighting sensors, air conditioning economizers, restoration of fan and pump variable frequency drives, operations set point strategies for supply air, temperature or duct pressure, chilled water and condenser water, operating schedules and boiler lockout.

Other Programs

Other programs in support of residential and industrial energy efficiency programs includes: (1) development of an on-bill financing mechanism for third party financing and LADWP collection of payments for such financing; (2) program outreach and community partnerships; (3) marketing to increase awareness of energy efficiency programs; and (4) measurement and verification of energy efficiency program savings.

2.3.1.4 Effect of EE on Electric Rates and Bills

The key factor that determines EE's effect on electric rates and customer bills is the comparison of its costs to the cost of the generation it is replacing. The following Table 2-5 conceptually illustrates the three possibilities – EE costs are lower, the same, or higher than the costs of the generation resources being replaced.

Table 2-5. EFFECT OF EE ON RATES AND BILLS

Are EE costs lower, the same, or higher than the generation it is displacing?	Effect on Total Cost $ (Which Must Equal Revenue Collected)	Effect on Total Energy Sales kWh	Effect on Rates $/kWh	Effect on "System-wide" Average Bill
Lower	Lower	Lower	see discussion below	Lower
Same	Same	Lower	Higher	Same
Higher	Higher	Lower	Higher	Higher

When EE costs are lower than the generation it is replacing (see Row 1 in Table 2-5), there are overall reductions in both total costs and energy sales. This could result in upward rate pressure since there are less kWhs to spread the costs over. However, the reduction in total costs may be large enough to keep rates flat, and more so in the long term as avoided cost benefits accrue over time. Lower total costs also means less revenue collected from customers; hence the "System-wide" average customer bill is lower, which benefits all customers. Those who implement energy efficiency measures will see further reductions.

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Table 2-5 also illustrates the case where EE costs are higher than the generation it is replacing. If EE is replacing less expensive resources (such as or coal, notwithstanding CO_2 allowance costs), the effect is a higher rate *and* higher "average" bill due to the higher total system costs.

As a practical consideration, there is little choice regarding which generation will be replaced by energy efficiency. While the effect of EE on Power System operations is to lower energy consumption and thus lower the amount of generation to be dispatched on a given day, the methodology for dispatch continues to be based on the economics of the generation available. Thus, the key measure of EE's impact on overall rates and bills is the comparison of its cost to the Power System's avoided cost of generation. As long as the cost of EE is lower than the avoided cost of generation, there is the beneficial effect of lower total costs and lower total revenue required.

The variations in EE costs, based on the different measures available, are identified in the energy efficiency potential study, and are factored into the development of EE program elements. A new potential study is planned for completion in 2013 and will provide updated information to modify the overall EE program.

Further information regarding LADWP's EE program is included in Sections 4 and 5, and Appendix B. A detailed discussion of avoided costs of generation can be found in Section 4.3.3 and Appendix N, Section N.4.

2.3.2 Demand Response

Demand Response (DR) is an important energy management tool that facilitates the reduction in energy use over a given time period in response to a price signal, financial incentive, or other triggering mechanism. The objective of DR is to lower energy usage at critical peak demand periods, in a manner which decreases overall system costs. LADWP's DR programs will be based on incentives to encourage customer participation based on lower rates, rebates, or other financial incentives.

The benefits of demand response are many:

> ***Increased Reliability.*** The ability to strategically lower energy consumption is one way to help overcome supply-demand constraints and reduce the chance of overload and power failure. This is especially important at those few critical peak times each year when demand is at its highest, as well as those times when generation units are off-line, whether due to a forced outage or scheduled maintenance.
>
> ***Lower System Costs.*** DR eliminates or defers the need to build additional power plants and the associated transmission and distribution infrastructure. Additionally, DR may reduce purchased energy costs by reducing the amount of energy that would otherwise be purchased to meet load, especially during the expensive peak demand periods. The overall effect is to save money which helps keeps rates low.

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Less Environmental Impact By eliminating or deferring the need to build additional infrastructure, the associated construction and operational impacts are also eliminated or deferred. Furthermore, the reduction in energy usage results in less operational impacts, including less fuel consumption, less carbon emissions, and less transmission use.

Help Integrate Renewables Under certain circumstances, DR can enable customer loads to respond to fluctuations in generation from wind and solar power.

DR is a relatively new demand-side resource, and LADWP plans to develop an active program over the next several years. As discussed in Section 5, one of the recommendations of this 2012 IRP is to provide funds to develop and implement DR. The analysis of all strategic cases considered in this 2012 IRP (discussed in more detail in Section 4) calls for a small 5 MW DR program beginning in 2013 that will build to 200 MW by 2020 and 500 MW by 2026. This gradual expansion will facilitate the development of in-house expertise that will ensure a sound DR program by the end of this decade, and will also allow time to deploy the supporting IT infrastructure and to implement required IT systems and processes.

A variety of program elements are being considered for LADWP's DR program. The following are some of the offerings that are commonly adopted in the industry. Depending on the circumstances of how energy is used, certain programs will be more suitable to particular customer segments than others. LADWP's initial planning focus is on items 1 and 2 below.

1- Curtailable/Interruptible Commercial/Industrial customers who sign up are on call for curtailment of power, and are provided credit even if an event is not triggered. However, curtailments are firm and mandatory; penalties are assessed for under performance or non-performance.

2- Direct Load Control Customers sign up and agree to be subjected to demand reductions as-needed based on power system needs and constraints. The typical example is a customer's central air conditioning system which may be remotely shut down by the utility during high peak conditions. In exchange, the customer gets an incentive payment or bill credit.

3- Peak Rebate Pricing Customers who participate in the Peak Rebate Pricing are notified in advance in which the retail electric rates are temporarily adjusted up, typically as a response to events or conditions such as extreme high peak load. The customer receives a rebate for reducing or shifting their load during the peak load event, but there is no penalty if the customer does not reduce load during the peak load event.

4- Critical Peak Pricing Similar to the Peak Rebate Pricing, customers who participate are notified in advance of the event and can avoid the higher prices by decreasing their energy use during this time period. The customer incentive to participate is a lower base rate throughout the year.

5- Real Time Pricing Retail rates are varied on an hourly basis or other short-term basis and are typically tied to variations in the commodity market prices for wholesale power supplies. Consumers are provided with access to the changing market prices on a continuous basis, and

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can change their usage patterns accordingly to lower their energy costs. The premise is that customers will reduce usage during the expensive high peak periods.

6- Demand Bidding – Commercial/Industrial customers are given the opportunity to receive a credit for voluntarily reducing load when an event is called. The customer is not penalized if they are unable to meet their reduction target.

7- Aggregation Programs – DR aggregators are third party contractors who work with groups of customers to make combined loads available for reduction or interruption. The aggregator works with LADWP and the combined load is assigned to the appropriate DR program. Customers work directly with the aggregator. Terms, conditions and payment may vary per aggregator.

In designing the overall program, a number of parameters need to be established, such as the specific program elements to offer, and for each program element: customer eligibility, the type and size of incentives, contract duration, event duration, number of events, notification lead times, automation, billing requirements, etc.

This 2012 IRP recommends funding to initiate a formal DR program with the capacity targets as shown in Table 2-6:

Table 2-6. DEMAND RESPONSE TARGET SCHEDULE (NEW MW CAPACITY)

Yr.	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Target	5	10	20	40	75	100	150	200	250	300	350	400	450	500

DR will play a significant long-term role in securing adequate system capacity, especially in the case of early coal replacement. Section 4 discusses the strategic cases in detail. As shown in the case analysis, DR is a strategic component of LADWP's future resource portfolio.

2.3.3 Distributed Generation

Distributed Generation (DG) is the concept of installing and operating small-scale electric generators located at or near the electrical load. These numerous small generators are "distributed" across the service area, as opposed to the traditional configuration of a few large centralized generating stations. DG sources can be utility-owned or customer-owned. A large subset of DG is combined heat and power systems, also known as cogeneration, which are primarily owned and operated by industrial and commercial customers.

Many categories of electrical generation fall under the DG definition, with the key characteristic being that they are located at or near the service load. The most common technologies used today for DG are turbines and internal combustion engines. Solar PV is a newer technology that is forecasted to account for an increasing percentage of DG. Other DG technologies are microturbines and fuel cells. Under a pilot project, LADWP installed a total of four 200-250 kW fuel cell power plants in various locations in Los Angeles. Although the pilot project is now

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complete and inactive, it has provided considerable operational data and experience. LADWP continues to closely monitor fuel cell development. More details regarding DG can be found in Appendix G.

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2.4 Generation Resources and Transmission Assets

The Supply-Side Resources discussed in this section include

- Existing Generation Resources
    - Natural Gas
    - Coal
    - Nuclear
    - Large Hydro
    - Existing Renewable energy resources (small hydro, wind, solar, biogas, and geothermal)
- Spot Purchases

The major issues affecting generation are presented, including the need to repower the in-basin natural gas units and the future disposition of coal-fired generation.

This section concludes with

- Future Renewable Resources
- Transmission and Distribution Facilities-Grid Reliability
- Advanced Technologies and Research and Development
- Climate Change Effects on Power Generation
- Reserve Requirements

The LADWP Power System has a diverse mix of generating resources. Figure 2-8 shows LADWP's Power System capacity and energy breakdown as of December 31, 2011 as well as what the capacity and energy mix was at the end of 2006.[1] The largest change between these two periods is the decrease in coal-fired energy from 47 percent in 2006 to 41 percent in 2011, and the corresponding increase in energy from renewable resources, from 7 percent in 2006 to 19 percent in 2011.

[1] "Capacity" is a measure of the capability to produce power or the rate at which energy is transferred. The term is applied to the amount of electric power delivered or required to meet the power demand, and is expressed in Megawatts (MW) or Gigawatts (GW). "Energy" is a measure of the quantity of electricity used or generated over time period and is expressed in Megawatt-hours (MWh) or Gigawatt-hours (GWh).

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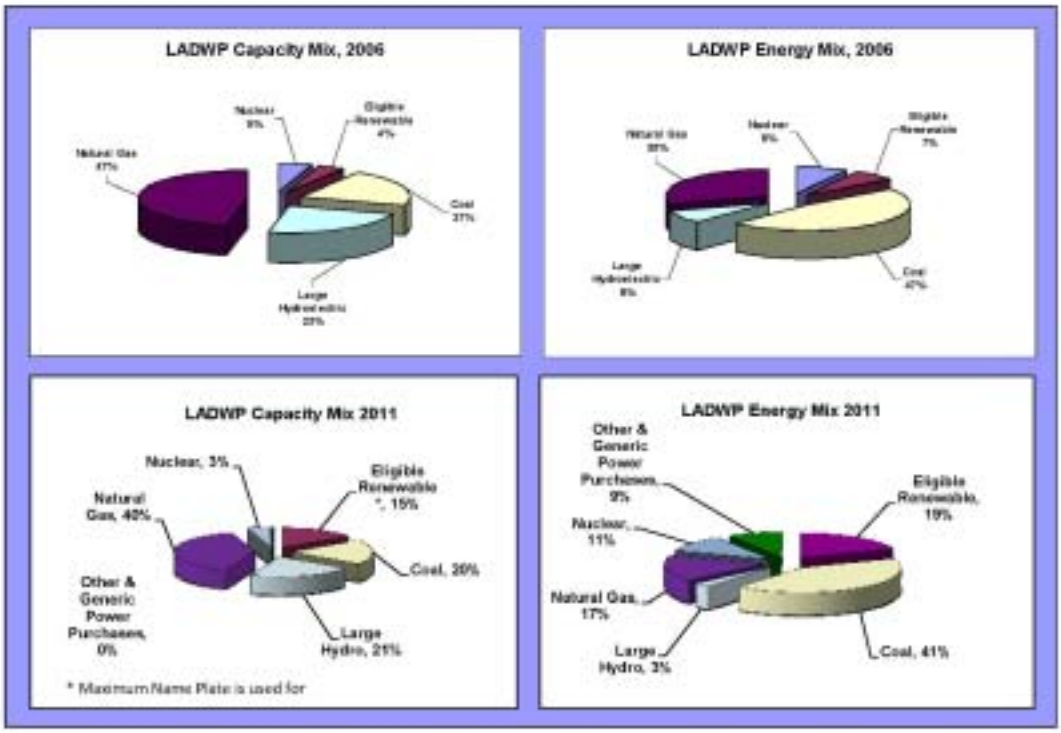

Figure 2-5: LADWP capacity and energy mix for 2006 and 2011.

2.4.1 Generation Resources

LADWP is vertically integrated, both owning and operating the majority of its generation, transmission and distribution systems. Generation resources that are not wholly owned by LADWP are available as entitlement rights resulting from undivided ownership interests in facilities that are jointly-owned with other utilities. Table 2-7 lists existing LADWP generation resources.

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Table 2-7. CAPABILITY OF EXISTING LADWP GENERATING RESOURCES[1] (AS OF APRIL 2012)

Name of Plant	Fuel Source	Unit No.	In Service Date	Age (Years)	Net Maximum Unit Capability (MW) [2]	Net Maximum Plant Capability (MW) [3]	Net Dependable Plant Capability (MW) [4]	Comments
Harbor Generating Station	Natural Gas	1	1995	17	82	466	452	Units 1, 2 and 5 operate as a combined cycle unit. Once-through cooling (OTC)
		2	1995	17	82			
		5	1995	17	85			
		10	2002	10	47.4			
		11	2002	10	47.4			
		12	2002	10	47.4			
		13	2002	10	47.4			
		14	2002	10	47.4			
Haynes Generating Station	Natural Gas	1	1962	50	222	1,555.8	1,525	Units 8, 9 and 10 operate as a combined cycle unit. Unit 7 is used for auxiliary power only. OTC
		2	1963	49	222			
		5	1968	45	292			
		6	1967	45	243			
		7	1970	42	1.6			
		8	2005	7	250			
		9	2005	7	162.5			
		10	2005	7	162.5			
Scattergood Generating Station	Natural Gas	1	1958	54	163	817	798	Includes 16 MW for Hyperion digester gas. OTC
		2	1959	53	164			
		3	1974	38	450			
Valley Generating Station	Natural Gas	5	2001	11	43	578	558	Units 6, 7 and 8 operate as a combined cycle unit
		6	2003	9	159			
		7	2003	9	159			
		8	2003	9	215			
Total Net Capability of Natural Gas Stations						**3,415**	**3,329**	
Intermountain Generating Station	Coal	1	1986	26	900	1175	1175	Reduced by current recall
		2	1987	25	900			
Navajo Generating Station	Coal	1	1974	38	750	477	477	
		2	1974	38	750			
		3	1975	37	750			
Total Net Capability of Coal Stations						**1,652**	**1,652**	
Palo Verde Generating Station	Nuclear	1	1986	27	1,333	387	380	
		2	1986	27	1,336			
		3	1988	25	1,334			
Total Net Capability of Nuclear Stations						**387**	**380**	
Castaic Power Plant	Hydro	Various	1972-1978	34-40	1,635	1,247	1,175	Pumped Storage
Hoover Power Plant	Hydro	Various	1936	76	491	491	468	
Total Net Capability of "Large" Hydro Stations						**1,738**	**1,643**	
Aqueduct System	Hydro	Various	1917-1987	25-95	136.7	83.1	24.2	11 Units total
Owens Valley System	Hydro	Various	1908-1958	54-104	18	12.5	1.2	7 Units total
Owens Gorge System	Hydro	Various	1952-1953	59-60	112.5	112.5	109.5	3 Units total
Owned & Contracted Renewables	Renewable/ DG	Various	2002-2012	2-10	1,141	1,109	330	Note [5]
Total Net Capability of Small Hydro and Renewable / Distributed Generation						**1,317**	**465**	
Total Net Capability of LADWP Resources						**8,509**	**7,469**	
California State Capacity Entitlement						-120	-56	Note [6]
Total Net Capability of LADWP System						**8,389**	**7,413**	Note [7]

Notes:

1. Power source data are based on Power System Engineering Division's January 2012 Generation Ratings and Capabilities Sheet and power purchase agreements for contract sources.
2. All units can attain maximum capability only when the weather and equipment are simultaneously at optimum conditions.
3. Reflects: water flow limits at hydro plants, sum of unit output at in-basin thermal or renewable plants, or LADWP contract entitlement of external thermal plants.
4. Reflects: year- round outputs adjusted for low-generation season. For hydro plants, winter is the low-generation season.
5. Owned or contracted renewable projects in wind, solar, hydro, landfill gas, biomass, and distributed generation in-service as of April 2012.
6. The maximum State (CDWR) Capacity Entitlement from Castaic Power Plant is 120 MW. The average for FY 09-10 was approximately 55 MW. The actual amount varies weekly.
7. Total Net Capability of LADWP System may vary due to unit outages, de-ratings and sales obligations.

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Natural Gas

LADWP is the sole owner and operator of the following four electric generating stations in the Los Angeles Basin (the "In-basin stations"):

- Haynes Generating Station, located in Long Beach
- Harbor Generating Station, located in Wilmington
- Scattergood Generating Station, located in Playa del Rey
- Valley Generating Station, located in the San Fernando Valley

A map of the in-basin generating stations is shown in Figure 2-6.

Figure 2-6. LADWP in-basin generating stations.

Each station consists of multiple generating units, with each unit ranging in size between 43 MW and 450 MW. A summary of each station's capabilities is shown in Table 2-7. Detailed information on each generating station is included in Appendix F.

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While all of these stations utilize natural gas as a fuel source, a special arrangement has been made that enables the Scattergood Generating Station to also use digester gas from the adjacent Hyperion Sewage Treatment Plant. The digester gas currently accounts for 16 MW of Scattergood's generation output. The agreement enabling this arrangement will end by 2015, but will be extended to account for a potential physical plant reconfiguration at the Hyperion Plant Facility.

Securing continued local generation capacity is important for grid reliability. LADWP's local transmission system cannot be reliably operated without generation from local thermal generating plants. The amount of generation required to provide transmission reliability is termed Reliability Must Run (RMR) generation. RMR generation is incorporated into all of the strategic cases considered in this IRP.

The major issues facing the in-basin stations include the need to replace some of the older units that are approaching the end of their service life, compliance with regulations related to ocean water cooling and NOx emissions, and fuel price volatility. Natural gas fuel prices and procurement issues are presented in detail in Appendix H.

Natural gas will continue to be the essential fuel for LADWP's generation due to abundant supply levels. Natural gas will be used to supply base load (as is currently used), and will also provide for the integration of intermittent renewable generation. Natural gas is also a major component of LADWP's coal replacement strategy.

Coal

LADWP's coal generating capacity comes from the Navajo Generating Station (NGS) and the Intermountain Generating Station (IGS). IGS is also referred to as the Intermountain Power Project (IPP). The amount of capacity available to LADWP from these stations is 477 MW from NGS and up to 1,200 from IPP. A summary of each station is included in Table 2-7. Further details and discussion is provided in Appendix F.

Contractual arrangements for power from IPP will expire on June 15, 2027. LADWP and the other participants at IPP are considering plans to convert the facility to natural gas. LADWP is one of thirty-six purchasers of IPP energy, and any future plans must be agreed to by all parties involved. Proposed amendments to the existing contracts are being considered by the purchasers which would require IPP to switch fuel from coal to natural gas no later than July 1, 2025 (two-years before the legal deadline). These amendments require unanimous approval and final purchaser decisions are expected by the end of 2013. Although the results of these discussions will not be available for this 2012 IRP, it is hopeful that the plan will completed in time for inclusion into next year's IRP process.

NGS operates under a co-tenancy agreement that remains effective throughout the initial term of its land lease until December 31, 2019. LADWP has been working with its partners on arrangements that would allow it to divest early from NGS, in 2015. See Section 2-12.3 for more details.

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Nuclear

LADWP has contractual entitlements totaling approximately 387 MW of capacity from the Palo Verde Nuclear Generating Station (PVNGS). PVNGS, located approximately 50 miles west of Phoenix, Arizona, consists of three generating units. Of the 387 MW capacity available to LADWP, approximately 159 MW is available through a power sales agreement with the Southern California Public Power Authority (SCPPA). Further details are provided in Appendix F.

Large Hydro

LADWP's large hydroelectric facilities include the Castaic Pumped-storage Hydroelectric Plant and an entitlement portion of the capacity of Hoover Dam. The Castaic Pumped-storage Hydroelectric Plant, located in Castaic, California, is LADWP's largest source of hydroelectric capacity and consists of seven units. Hoover Dam, located on the Arizona-Nevada border, consists of seventeen units. Details of these plants are provided in Appendix F.

A distinction is made between "large hydro" and "small hydro." According to a provision of SB 2 (1X), small hydro includes a facility which consists of generating units with a nameplate capacity not exceeding 40 MW for each unit that is operated as part of a water supply or conveyance system. LADWP's small hydro units are located along the Los Angeles Aqueduct. These units qualify as renewable resources for electricity generation.

Current Renewable Energy Projects

LADWP's existing renewable resources total over 1,200 MW of capacity, and consist of wind, small hydro, solar, biogas and geothermal resources. More detailed information is presented in Section E.2.5 of Appendix F. A listing of existing renewable projects by resource type is as follows:

- Wind Resources
  - Linden
  - Pebble Springs
  - Pine Tree
  - PPM Wyoming
  - Wilkes Creek
  - Windy Point
  - Mifford I
  - Mifford II
- Small Hydro
  - Aqueduct, Owens Valley and Owens Gorge projects
  - North Hollywood
  - Sepulveda
  - Castaic Efficiency Upgrades

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- Solar
  - LADWP In-Basin
  - Customer Net Metered
  - Adelanto Solar Project

- Biogas/Biomass
  - Bradley
  - Lopez Canyon
  - Toyon
  - Atmos and Shell
  - Hyperion Digester Gas

Additional renewable energy comes from market purchases.

Figure 2-7 presents the profile for LADWP's renewable resources portfolio as of 2011.

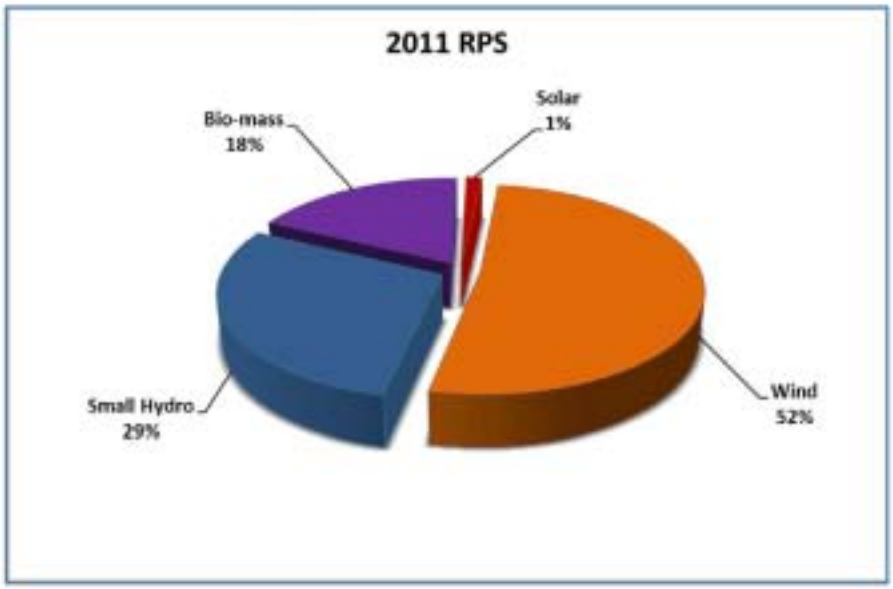

Figure 2-7: 2011 LADWP renewable energy mix.

Spot Purchases

Although LADWP's policy has been to be self-sufficient and capable of generating all of its energy needs from resources it owns or controls, it also participates in energy markets if it is in the City's best economic interest. This happens when energy can be acquired from the wholesale market for a cost which is less than which LADWP can produce such energy. Periodically, capacity and energy is purchased from providers within the Western Electricity Coordinating Council (WECC) jurisdiction under short-term "spot" arrangements to be delivered to the

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LADWP transmission system. These purchases are used by LADWP in conjunction with other resources for economical Power System operation.

The cost and availability of economical energy on the spot market has fluctuated greatly in recent years. While LADWP currently continues to execute economical spot purchase opportunities, it cannot guarantee the future availability of economic energy from either the Pacific Northwest or the Southwest at prices below LADWP's costs for producing power from its own resources.

Spot Sales

LADWP often has a surplus of generating capacity and energy. Consistent with prudent utility practice, LADWP offers this surplus into wholesale electricity markets within the WECC at prices above LADWP's production costs. This way, LADWP's ratepayers benefit both by receiving the lowest cost energy in the Power System and from economic purchases, in addition to economic benefits resulting from wholesale revenue generated from sales.

2.4.2 Major Issues Affecting Existing Generation Resources

Three major issues affecting LADWP's existing generation fleet are: (1) the need to rebuild or "repower" some of its in-basin generating units, (2) compliance with state and local regulations regarding once-through cooling and NO_x emissions, and (3) strategies for replacement of coal-fired energy to accelerate GHG reductions.

2.4.2.1 Repowering Program to Replace Aging Infrastructure

There is a need to modify or replace some of LADWP's older gas-fired generation facilities located at the Haynes and Scattergood generating stations. These units were primarily built in the late 1950s and the early 1960s and are approaching the end of their service lives. LADWP must modernize these plants to maintain system reliability, improve efficiency, and better integrate renewable resources.

- System reliability

  As facilities age, they require more maintenance and become more susceptible to operational limitations and outages. The units to be replaced at Haynes and Scattergood Generating Stations are between 44 and 53 years old, and are among the oldest remaining units in LADWP's generation fleet. LADWP's local basin transmission system was never intended to be reliably operated without generation from these plants. By virtue of their location within the basin transmission system, Haynes and Scattergood generation ensures that loading on basin transmission lines remain within the circuits' ratings, and system voltage remains within acceptable limits. Minimizing outages at these locations is therefore especially important. Variable-energy resources, such as solar or wind power, can augment existing in-basin gas-fired generation, but the variable resources cannot replace the role local gas-fired generation plays in transmission reliability. The amount of generation required to provide

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transmission reliability is termed Reliability Must-Run (RMR) generation. Repowering these local units will maintain transmission reliability by increasing the availability of RMR generation.

- Increased efficiencies

  New units will operate more efficiently, generating more energy and less emissions with the same amount of fuel. Operational costs per energy output will decrease.

- Integrating renewables

  The new units will incorporate new technologies which will enable faster start-up and faster ramping of generation output. This ability to increase or decrease generation on short notice, measured by what is termed "ramp rate," is an important requirement for integrating renewable resources. Wind resources produce power when the wind is blowing. When the wind suddenly begins blowing or stops blowing, the energy being delivered also changes but the customer load (the amount of energy the power system requires) remains substantially the same. Solar photovoltaic resources are subject to even greater output variability as clouds pass overhead and vary the intensity of available sunlight. To compensate for these fluctuations, natural gas "peaker" units (which are included in the new unit configurations) are able to quickly start, stop, and ramp up and down so that the total energy generated continuously matches customer load. Integrating significant amounts of intermittent renewable resources, such as wind and solar photovoltaic, will not be possible without the fast load-following and renewable energy generation following capability that the repowering program will provide.

2.4.2.2 Repowering Program to Comply With Regulatory Requirements

In addition to the reasons stated in Section 2.4.2.1, the repowering program is necessary to comply with State and Federal regulations related to once through cooling as well as local NO_X emission mandates.

- Once through cooling

  Once-through cooling (OTC) is the process where water is drawn from the ocean, is pumped through equipment at a power plant to provide cooling, and then is discharged back to the receiving water source. A cooling process is necessary for nearly every type of conventional electrical generating station and an OTC process utilizing ocean water is a major reason why many electrical generating stations were sited along the coastline. Typically, the water used for cooling is not chemically changed in the cooling process, however, the temperature of the water increases before it is returned to the ocean.

  LADWP operates three coastal generating stations – Scattergood, Harbor, and Haynes – that utilize OTC. The combined net capacity of these stations is 2,839 MW. Further information regarding repowering can be found in Section 1.6.6.

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In order to comply with the statewide OTC policy, LADWP has chosen to eliminate OTC and replace it with closed cycle cooling. Interim requirements are necessary until a facility is deemed fully compliant, including the funding by LADWP of mitigation projects to alleviate impacts, such as habitat restoration with the development of wetlands, in addition, feasibility pilot studies are required for the installation of alternative technologies to reduce impingement and/or entrainment in the interim. These issues are discussed in more detail in Appendix C.

- NOX compliance

  In mid-2000, during the statewide energy crisis, LADWP predicted that NO_x emissions from the in-basin generating units would exceed the available supply of NO_x RECLAIM Trading Credits issued by the South Coast Air Quality Management District (SCAQMD). Although LADWP's NO_x emissions ultimately did not exceed its allocation in 2000, on August 29, 2000 the SCAQMD Hearing Board issued a "Stipulated Order for Abatement" to the LADWP. Under the terms of the Order, LADWP was required to perform a series of repowering projects at its in-basin generating stations. The Stipulated Order was later superseded by a Settlement Agreement to accommodate scheduling and other issues. This agreement was revised in September 2011 and addresses the current repowering projects at the Haynes and Scattergood Generating Stations.

2.4.2.3 Coal-Fired Generation

SB 1368, the California Greenhouse Gas Emissions Performance Standard Act, enacted in 2006, prohibits California utilities from entering into long-term financial commitments for base load generation unless it complies with the GHG emissions performance standard. As this standard also applies to existing power plants for any long-term investments or contractual extensions, it affects LADWP's coal-fired generation resources.

SB 1368 Compliant Coal-Fired Generation

As presented in Section 3, the analysis of future potential resource portfolios includes a set of strategic cases that accelerate compliance with SB 1368 for coal-fired generation. The feasibility of adopting and implementing this will depend on a number of factors, including (1) resolving contractual issues, (2) the cost of alternatives (and LADWP's ability to cover its costs) and (3) other legislative and regulatory factors.

SB 1368 compliant power will reduce the GHG emissions for LADWP, reduce regulatory compliance costs, and spur development of renewable resources in the western United States. SB 1368 established a greenhouse gas emissions performance standard that limits long-term investments in base load generation by the state's utilities to power plants that meet an emissions performance standard, which was jointly established by the California Energy Commission and the California Public Utilities Commission. Subsequently, the Energy Commission designed regulations that establish a standard for base load generation owned by, or under long-term contract to publicly owned utilities, of 1,100 lbs CO_2 per megawatt-hour (MWh).

There are several methods to achieve SB 1368 compliance, for example: replace coal generation

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with energy efficiency, renewable energy, natural gas-fired generation, carbon sequestration, coal gasification, or the application of other potentially emerging technologies. Since coal generation operates as a base load resource for LADWP, any replacement option would also need to provide some base load generation around the clock while reducing GHG emissions.

Intermountain Power Project

The Intermountain Power Project (IPP) is a coal-fired generating station located near Delta, Utah. IPP consists of two generating units with a combined capacity of 1800 MW. LADWP is the operating agent. LADWP is also the largest single purchaser and has a power purchase agreement for 44.617 percent (803 MW) of IPP's total output. LADWP has additional purchase obligations for up to 22.168 percent (399 MW) of additional output. These additional obligations are dependent on the power usage of the Utah and Nevada participants. The power sales contract for IPP expires in 2027.

In addition to the generating units, IPP includes four important transmission lines, a 500-kV DC transmission line from the generating station to Adelanto, California (a distance of 490 miles), two parallel 345-kV AC transmission lines from the generating station to Mona, Utah, 50 miles away, and a single 230-kV AC transmission line from the generating station to the Gonder Switchyard near Ely, Nevada about 144 miles away.

At IPP, LADWP has no ownership rights in the generating station or the transmission lines. Rather, LADWP has a long-term power purchase contract which expires in 2027 and which also includes renewal option rights. With firm "take or pay" obligations, LADWP is contractually committed to the project to 2027. LADWP is one of 36 participants that purchase power. The owner of IPP is the Intermountain Power Agency (IPA), a separate entity and a political subdivision of the State of Utah.

IPP Coal Conversion

For some time, the 36 participants and IPA have been considering the future disposition of the IPP facility. In addition to satisfying SB 1368 requirements, pending and potential federal legislative and regulatory actions regarding CO_2, NO_x, fly ash, etc., have introduced uncertainty to the future operating economics for the facility. Considering these uncertainties, as well as other changes across the coal industry and factors unique to the IPP organizational structure, the IPP parties have investigated alternatives to the continued use of coal as a fuel source.

The feasibility of converting the IPP site from coal to natural gas has been studied, and efforts to convert have been initiated. The method and timing of a conversion requires concurrence from all participants and IPA, and establishing a new contractual structure. Some of the considerations that concern LADWP are:

- LADWP and the other IPP participants are contractually obligated to continued debt payments through 2023. An early exit from IPP prior to the end of the debt payment schedule will incur a financial penalty, not only for LADWP but for all of the 36 project participants.

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- The existing power purchase contract extends to June 15, 2027. These are "take or pay" contracts which LADWP could not walk away from without incurring monetary/legal penalties
- Any penalties incurred by LADWP through the preceding bullet points would be incurred by the LADWP ratepayers
- By remaining with the project, LADWP can continue to use the project's transmission assets to deliver renewable energy from the Utah region
- In addition to the transmission, LADWP can also continue to use the site, the staffing and the other related infrastructure that has been developed over the years at IPP

In response to these and other considerations, a new power purchase contract is being drafted to construct a natural gas replacement facility located at the IPP site. The in-service date for the new facility will likely be sometime between the debt payment completion schedule at the end of 2023 and the end date for the existing power contracts in June 2027. For modeling purposes, until the contract is finalized a date of December 31, 2023 will be used as an assumed early conversion date (see Case 4 in Section 3.5).

As of this writing, the IPP participants are considering the conversion to natural gas. The following steps have been identified to establish the new contractual structure and are in progress:

1. Amend the Utah Interlocal Cooperation Act and Electric Power Facilities Act completed by the Utah legislature in March 2012
2. Amend the IPP Organization Agreement between the 23 Utah municipal members
3. Adopt the Second Amendatory Power Sales Contract between all 36 power purchasers
4. Adopt Renewal Power Sales Contracts
5. Adopt Renewal Excess Power Sales Agreements

Assuming the timely completion of the new agreements, the new conversion date will be incorporated into the 2013 IRP model runs.

Navajo Generating Station

The Navajo Generating Station (NGS) is a coal-fired generation station located near Page, Arizona. It consists of three units with a combined capacity of 2,250 MW. Salt River Project is the Operating Agent. As one of six owners, LADWP has a 21.2 percent ownership share in the station's generation. NGS operates under a co-tenancy agreement which shall remain effective throughout the initial term of the land lease with the Navajo Nation and throughout the lease extension thereafter.

While LADWP is contractually committed to NGS until December 31, 2019, significant progress has been made to exit from the project by 2015. Early divestiture of NGS is in LADWP's best interest for a number of reasons:

1. A better sales price than waiting until the 2019 deadline

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2. Avoids the risk that pending federal regulations could potentially encumber the plant with expensive mitigation requirements.
3. Better availability of replacement generation.
4. Reduced CO_2 emissions, relieving LADWP from having to purchase emission credits within the soon-to-be implemented statewide cap and trade program.
5. Makes room on the transmission network for importing additional solar and geothermal resources.
6. Maximizes the value of the plant to help pay for renewables and energy efficiency.
7. Provides time to handle contingencies, and to ensure that competition is going to benefit our ratepayers.

The coal replacement options considered in this IRP analysis are presented in Section 3 – "Strategic Case Development."

2.4.3 Future Renewables for LADWP

SB 2 (1X)

The increase of renewables, as a percentage of electricity sales, to the regulatory mandated 33% by year 2020 requires the continued diligence of LADWP to pursue renewable projects and power purchase contracts. The development of a solar feed-in tariff and continued encouragement for customer net-metered solar is also necessary to support increased solar capacity. Because the acquisition of additional renewables is mandated by law, all of the strategic cases analyzed in this IRP include portfolios with the required amount of renewable resources. The 2012 recommended Case 5 with 150 MW of FiT includes the following targets for new renewable acquisitions between 2011 and 2020[5]:

New Renewable Installed Capacity (MW) 2012-2020			
Geothermal & Biomass	Non-DG Solar	Distributed Solar	Generic
242	842	382	39

Furthermore, maintaining at least 33% of renewables beyond 2020 requires additional renewables to account for system loading, project turnover, and output degradation as projects age. The 2012 recommended Case 5 with 150 MW of FiT includes the following additional targets for new renewable acquisitions between 2021 and 2030[4]:

New Renewable Installed Capacity (MW) 2021-2030			
Geothermal & Biomass	Wind	Distributed Solar	Generic
41	54	114	75

[5] The DG/EE Cases 5-8 have alternative renewable mixes due to higher levels of Solar DG and EE.

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SB 1 Solar Requirements

Former Governor Schwarzenegger signed the California Solar Initiative (CSI), outlined in Senate Bill 1 (SB 1), on August 21, 2006. The CSI mandates that all California electric utilities, including municipals, implement a solar incentive program by January 1, 2008. The goal of the CSI is 3,000 MW of net-metered solar energy systems over 10 years with expenditures not to exceed $3.35 Billion. Expenditures for local publicly owned electric utilities shall not exceed $784 Million. The LADWP cap amount is $313 Million, based on its serving 39.9% of the municipal load in the state, representing 280 MW of the 1,000 MW goal.

SB 32 – FIT

SB 32, signed into law on October 11, 2009, requires LADWP to make a tariff available to eligible renewable electric generation facilities within its service territory until LADWP meets its 75 MW share of the statewide target. Through this program, owners or operators of eligible renewable energy systems may sell their energy directly to LADWP. The purchase of SB 32 qualifying energy includes all environmental attributes, capacity rights, and renewable energy credits. This energy is just one of the many renewable energy sources that will apply towards LADWP's 33 percent renewable requirement.

Power Purchase Agreement (PPA) Option to Own Clause

As policy, PPAs for renewable energy are required to contain purchase options which LADWP may choose to exercise at different times during the term of the agreement. LADWP's goal is to own (either directly or through joint powers authority) at least 50% of its eligible renewable energy resource portfolio. For more detailed information regarding LADWP's Renewable Portfolio Standard Policy and Enforcement Program, see Reference D-2 in Appendix D.

Further information regarding renewables can be found in Appendices D.1 and N.

2.4.4 Transmission and Distribution Facilities/Grid Reliability

Electricity from LADWP's power generation sources is delivered to customers over an extensive transmission and distribution system. To deliver energy from generating plants to customers, LADWP owns and/or operates approximately 20,000 miles of alternating current (AC) and direct current (DC) transmission and distribution circuits operating at voltages ranging from 120 volts to 500 kilovolts (kV). Major transmission lines connecting to out-of-basin generating resources are shown in Figure 2-8. Appendix I provides more details regarding LADWP's transmission system.

In addition to using its transmission system to deliver electricity from its power generation resources, LADWP arranges for the transmission of energy for others through its Open Access Same Time Information System (OASIS) when surplus transmission capacity is available and saleable. LADWP uses its extensive transmission network to sell its excess energy and capacity

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in the California, Northwest, and Southwest energy markets. Revenues from these excess energy sales are used to reduce costs to ratepayers and for capital improvements.

In critical times, neighboring utilities look to LADWP's surplus energy and transmission resources to bolster their power system and avoid blackouts. For example, while the nearby San Onofre Nuclear Generating Station remains offline without a set return-to-service date, the California Independent System Operator is attempting to secure the delivery of replacement energy from other potentially available generation sources.

Transmission for Renewable Energy

Since renewable resources are often located long distances from the City of Los Angeles and where transmission facilities do not exist, accessing renewable resources will require extensive infrastructure improvements, including the construction of new transmission lines, upgrades to existing long and short transmission lines, and improvements at transmission facilities and stations to increase their transfer capability. Following is a summary of the major projects:

Barren Ridge Renewable Transmission Project

The Barren Ridge Renewable Transmission Project, scheduled to be completed in 2016, will increase the capacity of the existing 230-kV Barren Ridge-Rinaldi transmission segment from 450 MW to approximately 2200 MW. As of May 2012, approximately 3085 MW from a combination of wind and solar projects are being investigated for potential interconnection. This project will also increase the transmission capacity to the Castaic Pump Storage Power Plant, providing enhanced operational flexibility and integration of variable renewable energy.

Important components of the Barren Ridge Renewable Transmission Project are as follows:

- New Haskell Canyon Switching Station
- New double-circuit 230-kV transmission line from the Barren Ridge Switching Station to the new Haskell Canyon Switching Station
- New 230-kV circuit on existing structures from Haskell Canyon to the Castaic Power Plant
- Reconductor the existing 230-kV transmission line from the Barren Ridge Switching Station to the existing Rinaldi Receiving Station, through the Haskell Canyon Switching Station
- Expand the existing Barren Ridge Switching Station

Up-to-date information on this project is available at:

https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-power/a-p-projects

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Pacific Direct Current Intertie (PDCI) Upgrade

LADWP and its PDCI partners are considering increasing the capacity of the PDCI from 3160 MW to as much as 3650 MW. The benefit of such an undertaking would be a higher-capacity corridor for renewable wind and hydro energy from the Pacific Northwest to Los Angeles. LADWP, as the PDCI operator, is currently developing a cost estimate for the project that considers transmission and station upgrades and the increased dispatch and energy costs during construction to cover the reserve margin. Toward that end, preliminary estimates based on a Light Detection and Ranging study in 2011 indicate the transmission component of the project may cost up to $150 million and require as much as six years to construct. Less aggressive options with lower capacity benefits are also being investigated to facilitate an informed decision by the PDCI partners.

LADWP and its southern DC partners have signed a letter of agreement with the Bonneville Power Administration (BPA) to implement an initial 120 MW capacity increase of PDCI, if the cost is reasonable. In any case, BPA has committed to an extensive overhaul of Celilo HVDC Converter Station which requires coordination at the southern end of the HVDC line at Sylmar HVDC Converter Station. The projected completion date for BPA's Celilo upgrade project is January 2016.

The Haskell Canyon-Olive Transmission Line Project

LADWP plans to reconnect the existing Power Plant 115-kV Transmission Lines 1 and 2 to the new Haskell Canyon Switching Station, and then convert the 115-kV towers to a single circuit 230-kV transmission line from the new Haskell Canyon Switching Station to the existing Olive Switching Station. This project will maintain system reliability and increase the transfer capability from the new Haskell Canyon Switching Station to the Los Angeles Basin transmission system.

The Victorville-Los Angeles (Vic-LA) Project

The Vic-LA Project involves making infrastructural and operational improvements to the existing system between the Victorville area and the Los Angeles Basin in three phases which will allow LADWP to add 500-600 MWs of transfer capacity, subject to operational requirements. The Vic-LA Project can be defined in short, mid, and long term actions, as follows.

1. Short term actions
   - Upgrade the terminal equipment at Rinaldi and Toluca Receiving Stations and modify system protection of the line transformers
   - Add a second Victorville 500/230-kV transformer (Bank K1)
   - Upgrade Victorville-Century transmission system
   - Upgrade the terminal equipment at the Century and Velasco Receiving Stations
   - Trip non-firm resources to maintain the post-contingency flow within the existing Vic-LA system operating limit

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Mid-term actions

- Re-conductor the Victorville-Century 287-kV transmission lines to increase the rating
- Upgrade Banks F & G at Century Receiving Station to increase emergency rating

Long-term actions

- Convert the Victorville-Century 287-kV transmission lines to DC, which is described below

Conversion of the Victorville-Century 287-kV Circuit

Conversion of the Victorville-Century 287-kV AC lines is a potential future project that would increase the transfer capacity by converting the lines from AC to DC. The existing Victorville-Century circuit spans about 84 miles between Victorville and South LA. Converting the lines to DC would require a change-out of insulators along the line, and the installation of AC to DC converter equipment at each end. The transmission towers themselves will not require any modification. Preliminary studies indicate a potential 3-fold increase in power transfer capacity as a result of this project.

Regional transmission plans have shown that in order for LADWP and its Western counterparts to meet their renewable energy goals at minimal cost, additional transmission improvements will be needed. While the projects listed in this subsection have a high priority and a high likelihood of construction, they may not be sufficient to meet future needs. LADWP will continue to evaluate transmission needs and opportunities as necessary.

Grid Reliability

LADWP annually performs a Ten-Year Transmission Assessment Plan. In compliance with the North American Electricity Reliability Corporation (NERC) Compliance Enforcement Program, LADWP's 2012 plan identified a number of transmission improvements that are needed to maintain reliability. These projects include:

- Installation of a new Scattergood-Olympic 230-kV Line 1
- Upgrade circuit breakers and disconnects at RS-L
- Install a variable 90 MVAR shunt reactor bank at Scattergood 230 kV and a variable 90-MVAR shunt reactor bank at RS-K 230 kV
- Relocate the 230/115 kV Banks from Olive Switching Station (SS) to Haskell Canyon SS
- Convert the existing twin 115 kV circuits between Haskell Canyon SS and Olive SS with a new double 230 kV circuit along existing right-of-way

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These infrastructure improvements are critical to avoid potential overloads on key segments of the Los Angeles Basin transmission system.

FERC Order 1000 - The California Transmission Planning Group

With the release of Federal Energy Regulatory Commission (FERC) Order 1000 in July 2011, to direct regional and interregional transmission planning and cost allocation, FERC-jurisdictional (investor-owned) electric utilities are now required to reorganize transmission planning functions to collectively achieve state and federal public policy goals. Order 1000 builds upon the directives of FERC Order 890, issued in February 2007, to open regional and local planning to stakeholders to ensure transparency and non-discriminatory access to transmission service.

LADWP has a longstanding history of working with its Western Electricity Coordinating Council counterparts on regional transmission planning to ensure bulk power reliability and to leverage economies of scale; regional transmission plans are reviewed and approved through a formal process. Since the California Transmission Planning Group (CTPG) was formed in 2009, LADWP has been active in that transmission planning forum. CTPG was formed to comply with Order 890 by providing the increased coordination and public participation mandated while ensuring the electric needs and goals of Californians are reliably and efficiently met. In February 2011, the 2010 California Transmission Plan (California Plan) was released http://www.ctpg.us/images/stories/ctpg-plan-development/2011/02-Feb/2011-02-09_final_statewide_transmission_plan.pdf.

The CTPG was not able to reorganize quickly enough to meet Order 1000's deadline for FERC-jurisdictional entities to join a specific type of regional planning group and to file a regional planning methodology with FERC. In order to meet this timeline, CTPG members resorted to membership in additional regional organizations. CTPG members inside the CAISO footprint joined the CAISO Region, while other CTPG utilities joined the WestConnect Region. LADWP joined the WestConnect Region in November 2012. Other CTPG members in the WestConnect Region include the Sacramento Municipal Utility District, the Imperial Irrigation District, and the Western Area Power Administration.

Because of the large geographical extent of the LADWP transmission system, LADWP's planning takes place in various forums for sub-regional, regional, and inter-regional issues. Membership in WestConnect will allow LADWP to engage with the changes to regional planning caused by Order 1000. At the same As CTPG member utilities evaluate their options, they continue to press forward with their current transmission assessment to ensure California's electric power policy goals are reached efficiently and without undue hardship to the consumer or to the electric grid. California's electric power policy goals include:

- Attainment of renewable portfolio standard goals as promulgated by SB 2 (1X), which was passed in April 2011 and became effective December 10, 2011
- Satisfaction of repowering/retirement deadlines of fossil-fueled Once-Through Cooling power plant units as negotiated with the State Water Resources Board to comply with Federal Clean Water Act §326(b)

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As a municipal utility, LADWP is outside FERC jurisdiction, so, in a technical sense, Order 1000 is not a mandate. Consistent with its response to other FERC Orders, however, LADWP is seeking to conform to this order with the same consideration as it would to an industry standard.

LADWP's extensive network of transmission resources is described in Appendix I. Figure 2-8 shows its major out-of-basin generation resources. Noteworthy is the fact that while LADWP customers represent roughly ten percent of California's electrical load, approximately 25 percent of the state's total transmission capacity is owned by LADWP. LADWP also differentiates itself from its counterparts by continuing to operate as a vertically integrated electric utility – owning and operating its generation, transmission, and distribution resources rather than as a parent company with subsidiaries carrying out the various functions that comprise the supply chain.

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Figure 2-8: Major out-of-basin generating stations and major transmission lines.

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2.4.5 Advanced Technologies and Research and Development

LADWP is looking ahead to technologies that will benefit operations and enhance reliability, including smart grid applications and energy storage systems. Many programs, such as demand response and electric vehicles, will rely on deployment of Advance Metering Infrastructure to support their functionality and effectiveness. The implementation of Smart Grid technologies will provide enhanced information systems, automation of system functions, and advanced methods of outage management. Although energy storage technologies (except for Pumped Water Storage) are still being developed and are not currently cost effective for large scale applications, their potential for altering how electricity is generated and consumed is high.

2.4.5.1 Smart Grid

"Smart Grid" is a term used to describe a variety of advanced information-based utility improvements. Smart Grid refers to intelligent data gathering and advanced two-way digital communication capabilities overlaid on electric distribution networks to provide real-time data that enhances the utility's ability to optimize energy use. Smart Grid is a national policy evolving from the Energy Policy Act of 2005, and is a major enabler for many existing and potentially new DSR/EE programs.

Smart Grid technologies can turn every point in the existing network—including every meter, switch and transformer—into a potential information source, able to feed performance data back to the utility instantly. Smart Grid Technologies will provide utilities with the information required to implement real-time, self-monitoring networks that are predictive rather than reactive to instantaneous system disruptions. It can enable the utility and consumer to make decisions to optimize the use of energy, improve reliability, and reduce the consumption of fossil fuels.

A smart grid has the following characteristics:

- *Enables new products, services and markets*
- *Enables active participation by consumers through self-monitoring and more responsible consumption decisions*
- *Auto-selects safest and most efficient forms of storage and generation based on real-time energy needs and concerns*
- *Provides power quality for the digital economy*
- *Optimizes asset utilization and operates efficiently*
- *Anticipates and responds to system disturbances (self-heals)*
- *Operates resiliently against attacks and natural disasters*

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LADWP is implementing nine major Smart Grid initiatives.

1. Renewable Integration to support the adoption and utilization of renewable resources
2. Transmission Automation to better monitor the transmission system to predict instability and take corrective actions before they escalate into major problems
3. Substation Automation to enable remote monitoring and control of substation feeder lines
4. Distribution Automation to optimize operational efficiency.
5. Advanced Metering Infrastructure which will enable a number of demand-side capabilities
6. Demand Response is a tool that will provide reduction of peak loads at critical times to relieve system stress during periods of overload
7. Advance Telecommunications will enable real-time control and observation of deployed automation equipment
8. System and Data Integration will optimize the communications and integration of separate systems and sub-networks
9. Cyber Security to protect the Smart Grid from physical and cyber attacks.

Demonstration Program

In addition to the Smart Grid initiatives, LADWP, through a US Department of Energy grant awarded in 2009 is leading a group of local research institutions in a regional demonstration program. The program includes pilot projects in four interrelated areas – Demand Response, Consumer Behavior, Cyber Security and Electric Vehicle Integration.

More information on this demonstration program and all of LADWP's Smart Grid initiatives can be found in Appendix I.

2.4.5.2 Energy Storage

California Assembly Bill (AB) 2514, which became law on January 1, 2011, requires governing boards of local publicly-owned electric utilities, including LADWP, to identify and procure viable and cost-effective Energy Storage (ES) Systems. The targets must be formally approved by the Board of Water and Power Commissioners by October 1, 2013, and be implemented in two phases – by the end of 2016 and the end of 2021. Accordingly, LADWP has initiated a process to develop an ES plan which will include the appropriate ES targets per AB 2514.

Although LADWP does not currently have a formal ES plan, it has been practicing energy storage since 1973 through its daily operation of the Castaic Pump Storage Power Plant. In developing its formal Energy Storage Plan (ES Plan), LADWP's investigation will include options to leverage and/or augment the ES capabilities of the Castaic facility.

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Some of the key considerations for the ES Plan are as follows:

- LADWP will look for ES programs and projects that will support its unique electric grid, resource plan, and projects that will facilitate renewable integration, distributed generation and demand-side management; and programs that address resource adequacy and reliability issues.

- A review of the current state of ES technologies will be required, including current cost projections.

- Per AB 2514, the ES systems shall be cost-effective.

To support its ES planning efforts, LADWP will consider the following two initiatives as a means to provide valuable technical information:

1. LADWP is participating in a working group with the US DOE for the development of an ES protocol for use in measuring and quantifying the performance of ES system applications. It is anticipated that the protocol will assist LADWP to evaluate the performance of ES and to make more informed decisions as potential applications are consider for implementation.

2. DWP is planning to incorporate into its ES Plan the results from three ES research projects conducted by the Electric Power Research Institute:

    a. Strategic Intelligence and Technology Assessments of Energy Storage and Distributed Generation, Project 94.001 – This project provides analysis and strategic information on ES and distributed energy resource systems. It includes assessments and evaluations of various technologies.

    b. Distributed Energy Storage Options for Power Delivery and End Use, Project 94.002 – This project provides information and guidelines for using distributed ES and distributed generation systems for power delivery and end user applications such as peak management, peak shifting, etc.

    c. Bulk Power Energy Storage Solutions, Project P94.003- This project provides information and guidelines for using bulk ES to shift off-peak energy and integration of variable renewable generation.

A status update of the ES Plan will be provided in next year's 2013 IRP document. Per AB 2514, the ES targets are to be approved no later than October 1, 2014.

For more information, see Appendix K.

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2.4.6 Climate Change Effects on Power Generation

Because the energy sector is an acknowledged contributor to the problem of climate change, much discussion and effort has been directed towards mitigation strategies – mainly in the form of GHG emissions reduction. However, as climate change is increasingly being accepted as a reality, it is important to also consider the energy sector as one that will be subjected to the impacts of global warming. Rising average temperatures, changes in precipitation amounts and patterns, more frequent extreme weather events and a rise in sea level are some of the consequences that may be expected. Understanding how these effects impact power generation and incorporating that knowledge into the planning process facilitates adaptation of the power system to respond in ways that mitigates potential problems and takes advantage of any opportunities.

The influence of climate change on resource planning can be addressed on two levels: (1) how it affects *energy consumption*, and thus how much generation should be planned for and secured, and (2) how it affects *power generation* operations and the siting of new facilities.

Energy Consumption

Mean temperatures in Los Angeles are expected to rise. Additionally, extreme heat conditions, such as heat waves and very high temperatures, may last longer and become more common place.[1] In response to these conditions, electricity consumption will increase, mainly due to increased air conditioning demand. These effects are reflected in LADWP's energy and demand forecast. It is important to ensure that the latest findings and conclusions continue to be incorporated into future load forecasts.

A recent study by the UCLA Department of Atmospheric and Oceanic Sciences[2] focuses on temperature changes in the local region in years 2041-2060. The study concluded that annual average temperatures will increase between 3.7 °F and 4.4 °F across the City of Los Angeles. While the UCLA study looked at temperature changes in the 2041-2060 timeframe (which is beyond the 20-yr planning horizon for the 2012 IRP), the findings corroborate other studies and supports the expectation of higher future temperatures which will increase electricity use. More information on this study can be found in Appendix M.

Power Generation

An increase in frequency and duration of heat waves, and potentially more volatile weather patterns will add stress to the utility infrastructure. Areas may become more prone to flooding, and river flows may increase or decrease depending on location. At the same time, other areas may become more drought stricken, affecting water available for power plant cooling. Thermal efficiencies will decrease as temperatures rise, resulting in more fuel required to generate the same amount of power. New facility siting will have to account for these new environmental and weather-related conditions. Sea level rise, although not a foreseeable problem within the 20-year

[1] Global Climate Change. California Energy Commission. CEC-600-2006-013. page 2.
[2] Hall, et al., 2012. Mid-Century Warming in the Los Angeles Region. Available at: www.escience.LA

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planning horizon of this IRP, will need to be monitored and mitigation measures implemented, if required.

Actions to Address Climate Change

LADWP should continue its efforts towards reducing GHG emissions. These efforts include adopting more renewable resources, repowering its older natural gas generating stations, investing in energy efficiency and demand response programs, and pursuing coal replacement. To prepare for and adapt to climate change, LADWP should ensure that its load forecast continues to properly incorporate expected higher temperatures (and the corresponding higher electricity demand) due to global warming, and that its Power Reliability Program is fully funded to optimize the resiliency of its infrastructure to better withstand the more volatile weather patterns that will be expected.

As the science of climate change continues to evolve, LADWP should stay abreast of the latest findings and conclusions. Subsequent IRPs will monitor developments in climate change and develop/refine recommendations to mitigate any negative impacts as part of the resource planning process.

More detailed information regarding climate change and its effect on power generation can be found in Appendix M.

2.4.7 Reserve Requirements

Two important aspects of electric power system reliability are "resource adequacy" and "security." Resource adequacy refers to the availability of sufficient generation and transmission resources to meet customer's projected energy needs plus reserves for contingencies. Security refers to the ability of the system to remain intact after experiencing sudden disturbances, outages or equipment failures.

LADWP, as part of the electric power grid of the western United States and Canada (and a small section of northern Mexico), is required to meet operational, planning reserve and reliability criteria, and the resource adequacy standards of the WECC and the North American Electric Reliability Corporation (NERC). Based on these standards, the system reserve margin requirements and other criteria which LADWP uses to plan and operate and are defined as follows:

Generation Capacity Requirement – Net Power Demand – System Reserve Requirement
System Reserve Requirement – Operating Reserve – Replacement Reserve
Operating Reserve – Contingency Reserve – Regulation

The "Net Power Demand" is the total electrical power requirement for all of LADWP's customers at any time. The other reserve requirements are defined below, as well as numerically calculated.

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The loss of the largest single contingency of generation or transmission is a key reserve margin determinant for LADWP and defines the Contingency Reserve as well as the Replacement Reserve requirements. Based on current NERC Standards, at least 50 percent of the Contingency Reserves must be Spinning Reserve. The Replacement Reserve requirement is to restore Operating Reserves within 90 minutes of a contingency event. The Regulation Requirement of 75 MW is related to system load variations due to customer load changes. This regulation requirement is anticipated to increase in the future as additional amounts of intermittent renewable generation are added to the generation mix. Given LADWP's current total generation portfolio, the system reserve requirement is approximately 1,100 MW. Therefore, if the system demand is 5,000 MW, LADWP must have a total of 6,100 MW of dependable and dispatchable generating capacity (and the transmission for that capacity) to meet the 5,000 MW demand.

Due to the variable and intermittent nature of some renewable resources, particularly resources such as wind and solar photovoltaic, their generation capacity cannot be fully depended upon to meet peak demand conditions. As LADWP acquires a larger proportion of such resources, studies on the characteristics of these variable and intermittent resources will need to be carried out to determine their effect on reserve and regulation requirements. Refer to Appendix J for additional information on issues associated with integrating intermittent energy resources.

The capacity value of a generating resource is based on its ability to provide dependable and reliable energy and capacity during peak periods when the system requires reliable resources for stable operation. Resources that can provide firm capacity will have a higher capacity value than resources that cannot. For purposes of planning LADWP's reserves adequacy calculations, it is assumed that the dependable capacity of wind would be 10 percent of its nameplate capacity (unless a firming and shaping contract is in place), and the dependable capacity of solar photovoltaic would be 27 percent of its nameplate capacity. Because dependable capacity is an on-going area of study, these percentage values are subject to change. Any changes will be incorporated into future IRPs.

Local Resources for Grid Stability and Contingencies

As a subset of the reserve requirements, LADWP has located a significant amount of generating resources within the Los Angeles (LA) area. The specific amount of capacity that needs to be located in the LA Basin is approximately 3,000 MW, but varies, depending on the combination of which units are operating and how much power is flowing on the transmission system at the time. LADWP's local transmission system cannot be reliably operated without generation from local thermal generating plants. The amount of generation required to provide transmission reliability is termed Reliability Must Run (RMR) generation. RMR generation is incorporated into all of the strategic cases considered in this IRP.

This local requirement is particularly important in the context of deciding how to schedule the repowering of units that use once through cooling. It is for this reason that no unit will be taken out of service before an equivalently-sized, locationally-equivalent replacement unit is constructed, tested and ready to be placed in-service.

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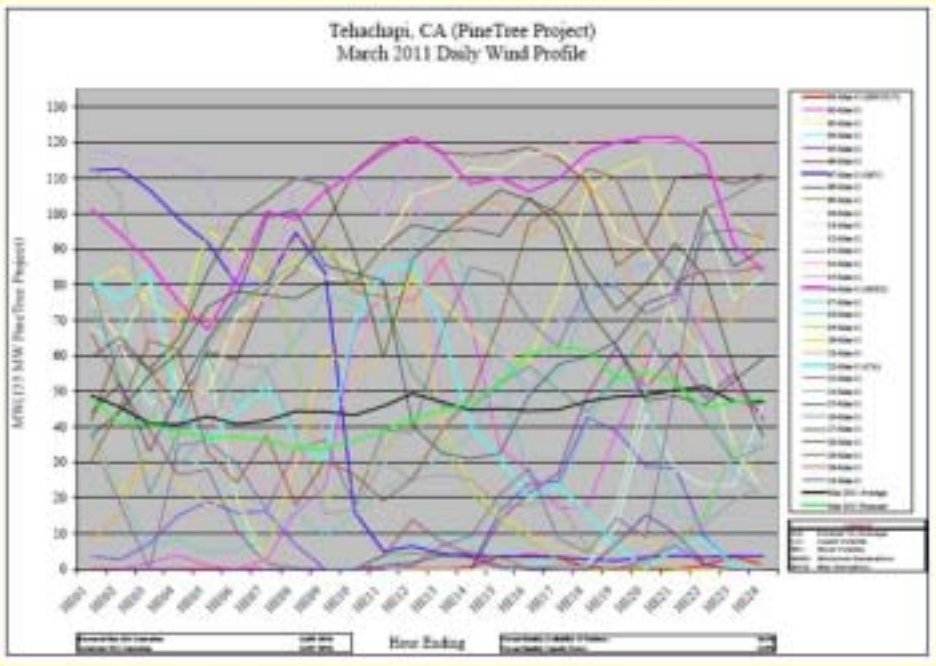
Integration of Intermittent Energy

One of the main responsibilities of power system operators is to maintain the balance between the total aggregate electrical demand of the power system's customers and the amount of energy generated to meet that demand on an instantaneous basis. Conventional electrical generation technologies, such as nuclear, coal, natural gas and large hydro are controllable and dispatchable by the power system operators throughout the day to maintain this instantaneous balance between demand and generation.

With the much higher percentage of renewables coming on line, a variety of modifications will need to be made to the Power System to successfully and reliably integrate these higher penetrations of renewable resources. In preparation, LADWP has conducted preliminary studies on integrating renewable resources, and has also reviewed many renewable resource integration studies published over the last several years.

Individual wind farms tend to have a high variability in the amount of energy produced (see figure below), but multiple wind farms located in diverse geographic areas are thought to reduce the overall variability in the amount of aggregated wind energy production.



Energy generated from Solar PV technology is highly sensitive to cloud cover. These PV systems can experience variations in output of ± 50 percent in 30 to 90 seconds, and ± 70 percent in five to 10 minutes. When a single large sized PV facility experiences these rapid changes in output, the Power System must also be able to react just as quickly with other generation resources to accommodate such rapid changes. The capabilities of a power system's dispatchable resources will limit the size of a single PV facility.

See Appendix J for more details regarding integrating intermittent resources.

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3.0 STRATEGIC CASE DEVELOPMENT

3.1 Overview

IRP planning is an on-going process and as such, the development of the 2012 IRP strategic cases incorporates the latest changes that have occurred in the regulatory landscape and tactical plans developed by the Power System. This 2012 IRP also includes many updated assumptions that have been developed over the past year. These assumptions have influenced the composition of potential resource portfolios that can fulfill LADWP's goals of reliability, competitive rates and environmental stewardship.

The coal cases analyzed in this 2012 IRP consider different replacement dates for LADWP's two coal resources – the Navajo Generating Station (NGS), and the Intermountain Power Project (IPP). The coal replacement dates for Cases 1, 2 and 3 are similar to the cases analyzed in last year's 2011 IRP. The replacement date of December 2023 for IPP (Case 4) is new for this year.

In addition to the coal cases, this 2012 IRP also analyzes four additional cases to consider higher levels of energy efficiency and solar distributed generation.

The 2012-13 fiscal-year financial planning process included many of the assumptions and recommendations that were used in the 2012 IRP. This is a continual process that requires the budget and the IRP model to be guided by the same assumption set although these assumptions change frequently based on market conditions for fuel, energy resource availability and pricing, regulatory environment, load forecasts, and the reliability needs of our system.

Primary regulations and state laws affecting the Power System, including AB 32, SB 1368, SB 1, SB 2 (1X), SB 32, and US EPA 316(b), have become more certain over the last 2 years although many details are still being finalized mainly involving existing renewable projects and their applicability towards meeting in-state or out-of-state qualifications. This 2012 IRP attempts to incorporate the latest interpretation of these major regulations and state laws as we understand them today.

Section 3.2 summarizes the major changes from last year's model assumptions. Section 3.3 discusses the legislative and regulatory mandates that have a bearing on the resource portfolios being considered for this IRP. Section 3.4 describes the development process for the candidate strategic cases, and Section 3.5 presents the final candidate cases that were analyzed. The analyses and comparison of the case results are presented in Section 4.

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3.2 2012 IRP Model Assumptions

At the heart of the IRP analysis effort is the computer-based production cost modeling of the LADWP Power System. To perform this modeling a significant amount of input data is developed. The production model and input assumptions are covered in detail in Section 3.2.2 and Appendix N. This section summarizes the major changes in the assumptions since last year's IRP, followed by a discussion of the general price inputs that were applied to this 2012 IRP.

3.2.1 Major Changes From the 2011 IRP Assumptions

Major assumption changes from last year's IRP are summarized here. Additional detail regarding the assumptions can be found in Appendix N.

Load Forecast

As shown in Table 3-1, the new load forecast is lower than the previous forecast used in the 2011 IRP. Compared to the prior forecast, electricity sales in the calendar year 2020 decreased by 5.3 percent mostly due to increased levels of energy efficiency. The new forecast reduces the overall need for renewable energy (assuming 33% RPS) by approximately 461 GWh in 2020 and 745 GWh in 2030. The complete load forecast is included in Appendix A. Adjustments made to the approved load forecast to account for the latest projections of energy efficiency savings and customer-net-metered solar are shown in Appendix N.

Table 3-1. TOTAL ADJUSTED ELECTRICITY SALES IN GWH

	2020	2030
New Forecast – 2012 IRP	22,958	24,424
Old Forecast – 2011 IRP	24,239	26,665
Difference	-1,281	-2,241

Energy Efficiency

The Energy Efficiency (EE) forecast used in the 2012 IRP includes higher levels of funding for the 2012/13 thru 2019/20 fiscal years to achieve 10 percent EE from 2010 thru 2020. This represents 1,084 GWh of additional EE savings by 2020 as compared to the 2011 IRP. Higher funding levels required to achieve this target were approved through the recent rate action for the 2012/13 and 2013/14 fiscal years. As a comparison, the 2011 IRP forecasted a 6 percent EE achievement during the same period 2010 thru 2020.

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On December 6, 2011, the Board of Water and Power Commissioners approved an advanced EE program with a goal of 8.6 percent of sales by the end of fiscal year 2019-20 and beginning fiscal year 2010-11. Subsequently, on May 24, 2012 the Board of Water and Power Commissioners approved a target of 15 percent energy efficiency subject to the results of an updated energy efficiency potential study to be completed by June 30, 2013. The potential study will be used to develop a long term plan for the scope and estimated costs for additional programs to achieve 10 percent, 12.5 percent, and 15 percent energy efficiency savings by 2020. Inclusion of the 12.5 percent and 15 percent energy efficiency savings by 2020 will be considered for inclusion in future IRP's.

The cumulative EE savings incorporated in the 2012 IRP will reach 2,705 GWh (Net 2,500 GWh) from 2010 thru 2020 and 4,117 GWh (Net 3,800 GWh) from 2010 thru 2032. Using The Total Sales to Ultimate Customers for 2010/11 fiscal year as the baseline and using net EE savings, the 2012 IRP forecasts a 10 percent energy efficiency savings by 2020 and 15 percent energy efficiency savings by 2032. Historical efficiency savings of 1,256 GWh from 2007 to 2010, equivalent to 5.5 percent of customer sales, are already embedded in the load forecast. Figure 3-1 below shows the projected cumulative gross savings from 2001 through 2032.

Federal and State efficiency standards create fewer opportunities to give financial incentives to customers to install products that exceed the higher efficiency standards. This reduces the effectiveness of incentives to realize incremental energy savings targets. To combat this natural decline, additional programs requiring direct installation of energy efficiency measures at customer sites will be required to implement these higher savings. Although savings from Federal and State efficiency standards cannot be counted in the achievements made by the utility, these savings are nevertheless accounted for in the sales load forecast and do contribute to reducing overall sales and load growth.

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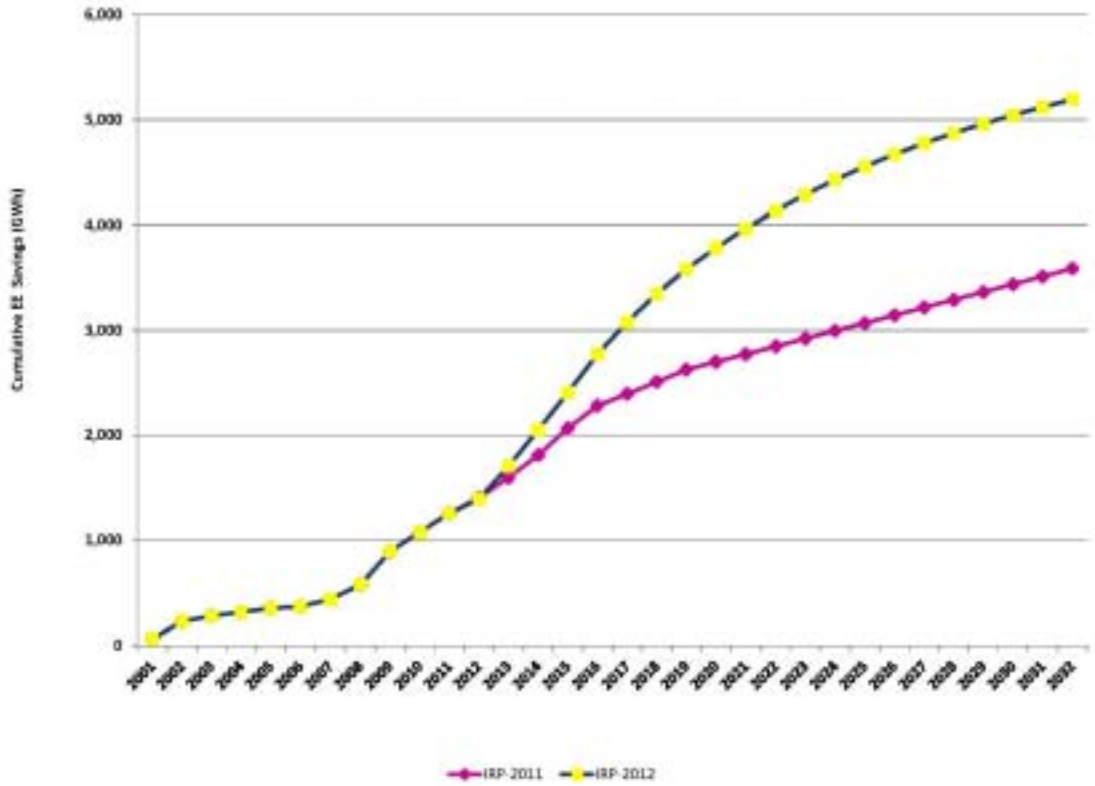

Figure 3-1. Comparison of 2011 and 2012 IRP gross energy efficiency forecasts by fiscal year.

Solar C-N-M and FiT

The solar Customer-Net-Metered (CNM) program (a.k.a. Solar Incentive Program) and Feed-In-Tariff (FiT) programs used in the 2012 IRP are shown in Figure 3-2. CNM solar starts out lower than last year's forecast, but quickly catches up and surpasses it, reflecting the recent program delay followed by a re-commitment of funding. Continued strong interest in the program is expected. FiT is lower in 2012-2014 due to a delay in implementation of the program due to budget constraints, but quickly reaches 150 MW or 210 GWh by 2016, reflecting the plan to accelerate the program to take advantage of tax benefits available through 2016.

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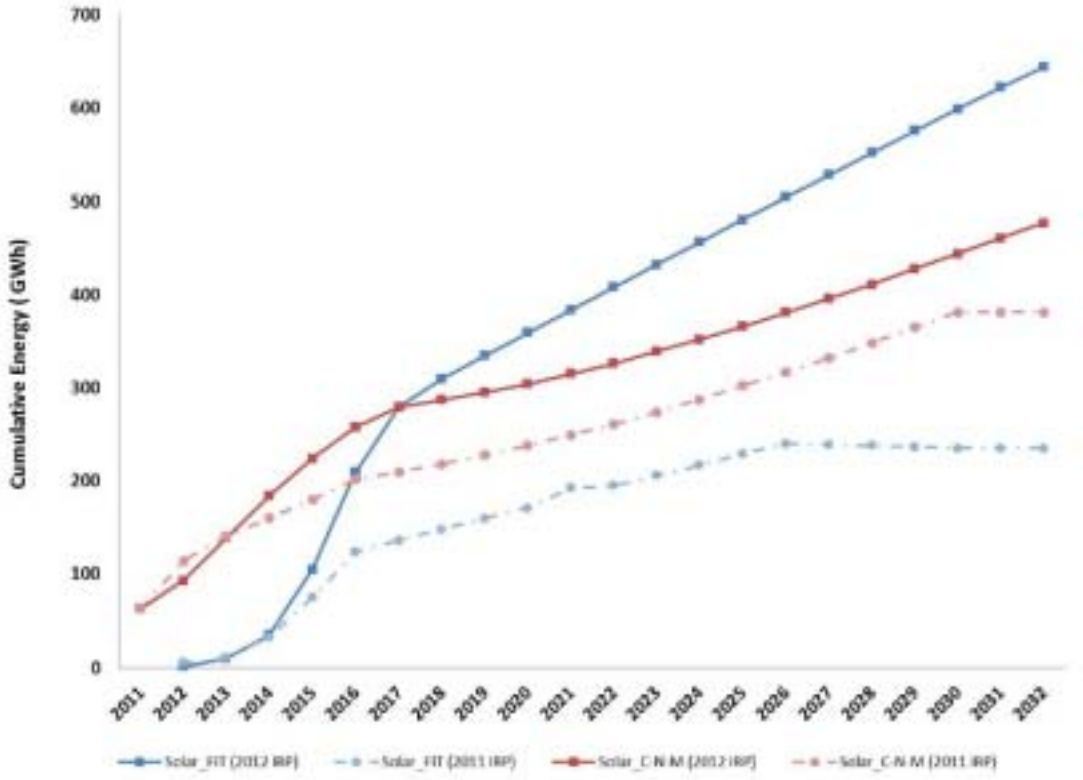

Figure 3-2. Comparison of FiT and CNM (SIP) solar projections, 2012 vs. 2011.

Renewables

Table 3-2 is a comparison of the overall renewable additions planned for the 2012 IRP vs. the 2011 IRP:

Table 3-2. RENEWABLE ADDITIONS, 2011 VS. 2012

		2020	New Renewable Installed Capacity (MW) 2012 – 2020					New Renewable Installed Capacity (MW) 2012 – 2032				
Case ID	Resource Strategy	RPS Target	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic	Geo / Biogas	Wind	Non-DG Solar	Dist. Solar	Generic
All Cases in 2011 IRP	33% RPS SB 2 (1X) Compliant	33%	243	492	401	325	0	308	492	451	466	162
Base Case in 2012 IRP	33% RPS SB 2 (1X) Compliant	33%	242	0	887	337	39	283	54	915	496	114

Compared to last year's IRP, solar now holds a more prominent position in the overall portfolio mainly replacing future planned wind projects as prices for solar PPAs have dropped significantly over the last year while the availability of competitively priced in-state wind projects has decreased. Solar is also well suited to utilize the Navajo and

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Barren Ridge transmission line capacity that will become available in 2016. Increased use of solar will further diversify the renewable resource mix which already contains a strong wind focus.

GHG Costs

Projected GHG cost assumptions resulting from the California Air Resources Board's Cap and Trade Regulation have been lowered. The forecast assumes GHG pricing will start at $15 per metric ton in 2013 and escalate to $30 per metric ton in 2020 with a $3 per metric ton increase for every year in between. In the 2011 IRP, GHG pricing started at $24 per metric ton in 2013 and escalated to $45 per metric ton in 2020.

Gas Prices

Long term natural gas price forecasts have been revised downwards from last year with recent prices reaching very low levels over the last year. However, it is expected that these unusually low prices will eventually reach an equilibrium supply/demand level over the next year as new gas drilling continues to decline and new sources of demand come on-line. Opal and SoCal expected gas prices used in the 2012 IRP were 16 percent lower on average, in the short term (2011-2020), and were 8 and 9 percent lower on average, respectively, in the long term (2021-2030) as compared to the 2011 IRP. The Pinedale gas reserves owned by LADWP continue to provide a low cost source of gas and hedge against future gas volatility and estimates of gas volumes to be produced from Pinedale have not been revised since the 2011 IRP.

Coal Prices

IPP forecasted coal prices are 4 percent lower for the period 2012 thru 2027 as compared to the 2011 IRP. Navajo coal prices are 14 percent lower for the period 2012-2019 as compared to the 2011 IRP.

IPP Payoff

IPP capacity is a function of the capacity recalled by Utah participants under the IPP Excess Power Sales Agreement. Estimates for these excess shares put to LADWP by Utah participants has risen from 222 MW assumed in the 2011 IRP to 318 MW in the 2012 IRP thereby increasing our share of the IPP capacity entitlement. This raised the energy and capacity expected from IPP generation in the 2012 IRP. This trend is believed to be occurring because of the lower gas prices relative to coal.

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3.2.2 General Price Inputs

General price assumptions are presented here for supply side resources, fuel, and GHG allowances. More details are provided in Appendix N.

Supply-side Resources

Table 3-3 presents a summary of the major price assumptions for supply-side resources. Generally lower prices for solar and geothermal have been incorporated into the 2012 IRP modeling as price competition has lowered prices for both resources. Dependable capacity is an on-going area of study and could change in future IRP's as more data becomes available.

Table 3-3. SUMMARY OF SUPPLY-SIDE RESOURCE ASSUMPTIONS

Resource	Levelized Cost[1] ($/MWh)	Capacity Factors	Dependable Capacity
Solar Photovoltaic – PPA	$116	25% - 32%	27%
Solar Photovoltaic - LA Solar – Public/Private Partnership In-Basin	$154	20-23%	27%
Solar Photovoltaic – LA Solar – Public/Private Partnership Owens	$153	25%	27%
Solar Customer-Net-Metered	$130	18%	27%
Solar Feed-In-Tariff	$152	19%	27%
Wind	$105	24% - 37%	10%
Geothermal	$109	91%-95%	90%
New Combined Cycle Gas (310 MW)	$80	59%	100%
New Simple Cycle Gas (50/100 MW)	$225	9%	100%

[1]Net Present Value (annual costs, 2012-2032) / NPV of Energy Produced

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Natural Gas Prices

High, low, and medium natural gas price forecasts were developed to test each portfolio against a range of potential natural gas prices. The medium or expected gas forecast originates from Platts and is the standard used by LADWP for financial and fuel procurement planning. The high and low forecast, shown on Figure 3-3, are fundamental forecasts obtained from Wood Mackenzie that consider a range of future assumptions including economic growth, supply and demand, and environmental regulations.

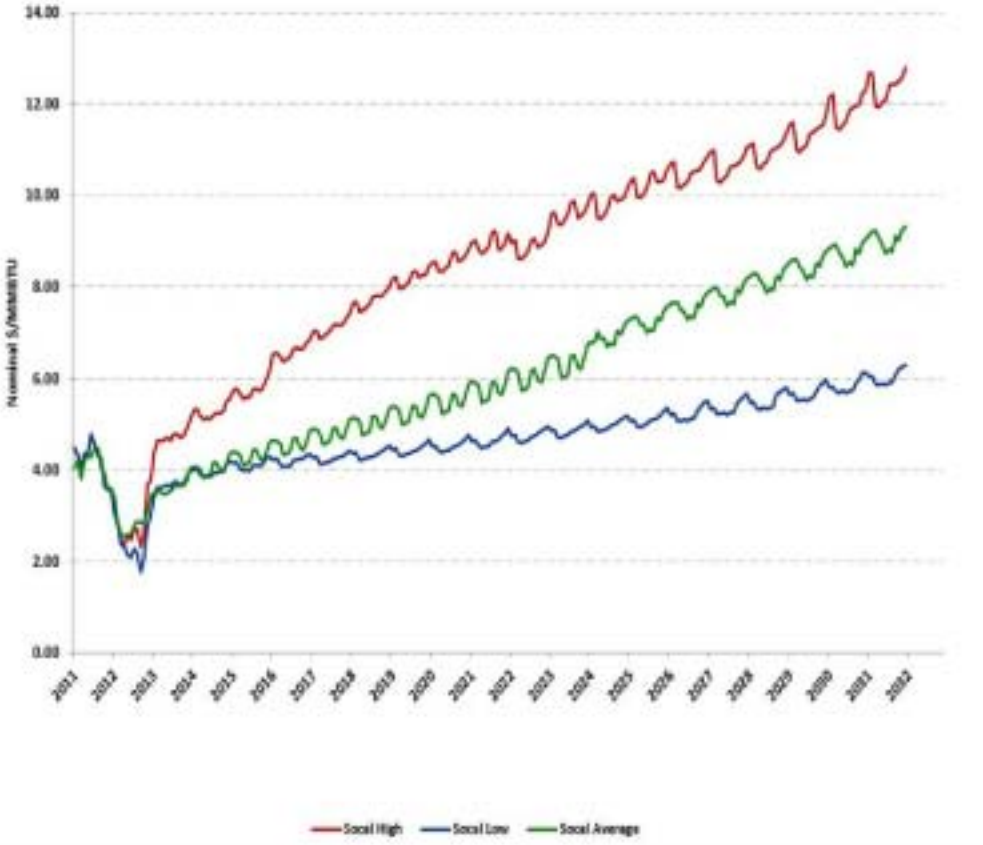

Figure 3-3. Natural gas price forecast (SoCal).

Note: Unless otherwise stated, forecasted costs in all charts in this IRP are "nominal."

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Coal Prices

A +20 percent factor was applied to the expected coal fuel price provided by LADWP's External Generation Division, to determine a high and low range for coal prices. Actual coal fuel prices have intentionally been left out of this IRP to comply with non-disclosure agreements with coal suppliers.

GHG Emissions Allowance Prices

Price scenarios were also developed and tested for GHG allowance prices using staff estimates and price forecasts available from recent brokerage transactions. The forecast assumes GHG pricing will start at $15 per metric ton in 2013 and escalate to $36 per metric ton in 2020 with a $3 per metric ton increase for every year in between. Forecasts of further GHG costs beyond 2020 and sensitivity around GHG allowance prices were not considered for the 2012 IRP. Considering the allocation administratively provided to LADWP and the planned divestiture of Navajo and implementation of further renewables reducing our overall GHG emissions, the overall cost impact of the CARB Cap and Trade Regulations is expected to be relatively neutral when considering the entire 8 year program (it should be noted that the initial years of the Cap and Trade program may require the purchase of allowances).

The likelihood of a future Federal Carbon Tax or a continuation of the CARB Cap and Trade regulations beyond 2020 are speculative at this time and will be addressed in future IRP's as necessary.

Figure 3-4 depicts the GHG allowance prices used to evaluate the portfolios.

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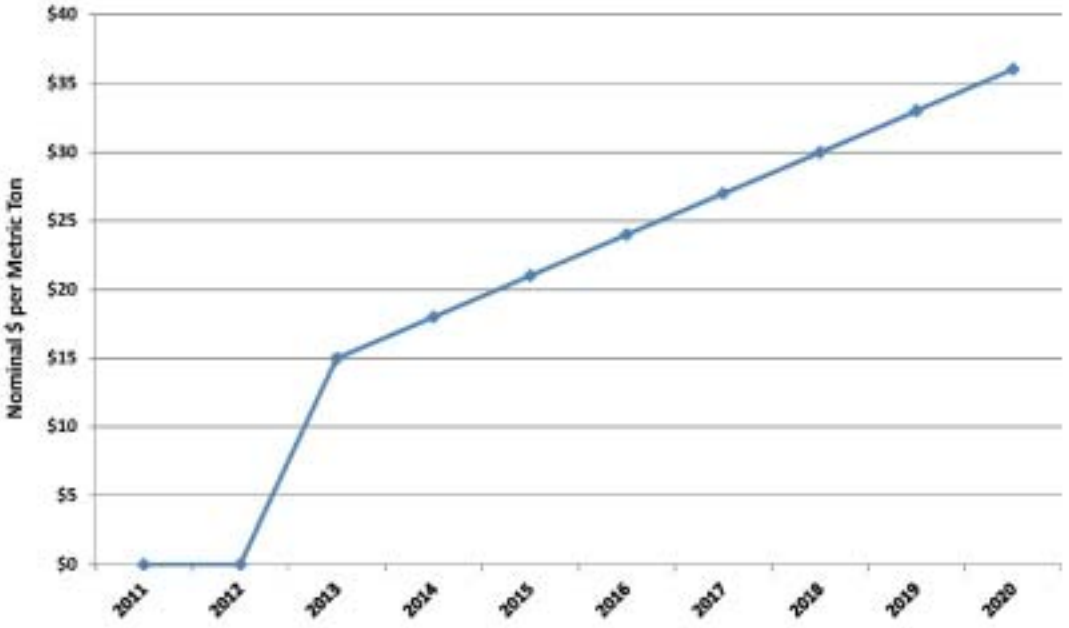

Figure 3-4. Assumed GHG emissions allowance prices.

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3.3 Addressing Legislative and Regulatory Mandates

The 2012 IRP strategic cases must satisfy the requirements of the most-recently implemented environmental and RPS regulations. In many cases, the regulations have predetermined a limited set of resources that can be considered to meet future generation needs. The net effect is to constrain and limit the set of alternatives that can be analyzed.

Coal Replacement/GHG Reduction

SB 1368 requires that imported base load energy from outside California meet a GHG emissions performance standard of 1,100 lbs per MWh. To comply with this requirement, all future base load generation outside the LA Basin will need to come from either highly efficient combined cycle gas turbines (if fossil fueled), or from renewable energy resources. This eliminates the use of coal-fired generation, at least until future coal combustion and sequestration technology improves sufficiently to make this a viable option. As a result, four coal replacement cases have been considered in this 2012 IRP to define the costs and operational impacts that replacement of these facilities will have in meeting future energy and capacity load requirements.

OTC

Once-through cooling regulations effectively prohibits the use of ocean water cooling in all of the coastal power stations, which comprises 3 of the 4 in-basin gas-fired generation facilities, and sets specific deadlines to repower this generation prior to 2029. The limited resources available to repower these in-basin generation units under the accelerated time frame further limits the flexibility of altering repowering schedules based on system operation and capital requirements. Therefore, all strategic cases considered include the same repowering schedule as shown in Figure 3-5 below:

Figure 3-5. Timeline for OTC repowering projects.

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Out-of-State Renewables, Energy Efficiency and Distributed Generation

As discussed at the end of Section 1.6.5, SB 2 (1X) defines categories with predefined percentage limitations on the amount of out-of-state renewable generation and renewable energy credits that can be used to meet renewable portfolio standards. Wind, small hydro, and biogas provide the largest contributions to LADWP's current portfolio as shown in Figure 2-7. Future renewable generation will rely heavily on solar PV and wind resources located within the State to fulfill the in-state percentage requirements of SB 2 (1X). This limits the potential use of renewable resources located outside of California. The strategic cases evaluated in the 2011 IRP established a diversified resource mix for the next 20 years including goals for estimated MW's installed for each renewable technology. The 2012 IRP retains the same diversified renewable mix goals set forth in the 2011 IRP recommended case while including a more solar-focused portfolio.

As shown in Table 3-2, all Coal Replacement cases being considered in the 2012 IRP use the base renewable resource plan. However, the energy efficiency and distributed generation cases described in Table 3-3 include different potential renewable portfolios for the High DG and Advanced EE options to account for the effects these demand resources have on reducing customer sales. Future IRP's will likely address different renewable resource mixes as the CEC further develops specific qualifying criteria for meeting in-state and out-of-state category requirements.

The 2012 IRP Strategic Cases were developed to assist policymakers and ratepayers to make informed decisions regarding the accelerated replacement of Coal resources to promote GHG reduction prior to SB 1368 compliance, advanced levels of energy efficiency to comply with and exceed the 10 percent by 2020 goals set forth by AB 2021 and higher levels of solar distributed generation to help achieve the Governor's statewide goal of 12,000 MW of solar distributed generation by 2020.

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3.4 Candidate Portfolios Development Process

A candidate portfolio is a set of renewable and non-renewable generation resources, demand side resources, regulatory constraints, policy goals, and assumptions that are used to model strategic scenarios. Candidate portfolios are selected to cover a spectrum of possible scenarios, providing decision makers information on which portfolios are likely to be the most desirable. Additionally, each candidate portfolio must ensure resource adequacy – the ability to meet total peak demand.

3.4.1 Public Input

Before developing candidate portfolios, LADWP met with and gathered input from key ratepayer, customer and business representatives, as well as key environmental organization representatives. Comments received from these early discussions were factored into the overall objectives, goals and policy guidelines used in the initial construction of the draft candidate portfolios. Subsequent public review of the preliminary findings provided further input which was considered prior to finalizing a recommendation.

3.4.2 Net Short and Resource Adequacy

The first step in developing the 2012 IRP candidate portfolios was to determine how LADWP can meet and maintain its renewable energy policy goals: 20 percent renewables by 2020 and 33 percent renewables by 2020. The net short – the gap between renewable energy policy goals and current renewable generation – was calculated for each strategic case, and the contribution of its renewable energy component towards resource adequacy was determined. Energy efficiency, demand response, combined-cycle gas generation, and term purchases were then considered to supply the remaining deficiency in resource adequacy. Details regarding net short calculations and resource adequacy are included in Section 4.3.1.1 and Appendix N.

3.4.3 Renewable Resources Selection Process

Over the last ten years, LADWP has issued several requests for proposals for renewable energy and gained a thorough understanding of the nature and availability of the different renewable resource technologies. This knowledge was used in developing the candidate portfolios. Additionally, LADWP largely considered renewable resources within the Western Governors' Association's Western Renewable Energy Zones (WREZ). In the WREZ initiative, Qualified Resource Areas were defined as areas of dense, high-quality renewable energy resources, meeting various resource size, quality, environmental, and technical criteria. LADWP screened all resources to ensure they are located near available LADWP transmission infrastructure, or can be delivered to areas under LADWP's balancing authority.

A valuation process designed to provide a single ranking value to a resource was then applied. This step is intended to identify resources with the combination of lowest cost

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and highest value. The valuation approach is similar to the bid evaluation process many utilities use when procuring renewable resources. Some of the considerations in selecting these resources are as follows:

- Cost differences for different renewable technologies and projects
- Cost trends that reflect decreasing prices
- Variable integration costs and operational impacts
- Technologies that deliver more energy during peak hours
- Preference for local projects
- Proximity of projects to transmission
- For PPA resources, tax credits that can be passed along as cost savings
- PPA proposals that provide future ownership opportunities
- Overall diversity of resource mix and geography
- Satisfying category, or "bucket," requirements according to CEC RPS regulation and guidelines (see Section 1.6.3)

After applying the appropriate constraints, resources were selected and added progressively to its renewable resource mix based on lowest rank cost and transmission availability until the net short was mitigated.

In this 2012 IRP, the overall renewable portfolio levelized cost is $98/MWh, which represents an $13/MWh decrease from last year. This cost reduction was achieved by selecting a more optimized and diverse portfolio that increases the contribution from cost-effective large central solar projects and biogas resources. Although LADWP continues to evaluate and develop wind and geothermal resources, they tend to be very site specific and typically lie a greater distance from existing transmission, or require transmission that must be purchased from other utilities. Another factor considered were solar tax credits which extend beyond those for wind and geothermal. Biogas uses the existing gas delivery infrastructure and existing combined cycle generating units making this a very cost effective and fully dependable resource. By maintaining flexibility in the selection of cost-effective renewable resources, LADWP is able to secure the best pricing for its ratepayers, as market conditions evolve.

3.4.4 Distributed Generation Levels

This year's IRP considers higher levels of Distributed Generation (DG), partly in response to the Governor's State-wide initiative for 12,000 MW of local renewable DG. Due to reliability and operational concerns, the maximum amount of DG considered is limited to 15% of the maximum annual peak load per circuit.* Because this is a relatively new area of study, LADWP is proceeding cautiously until it has a better understanding of the impacts intermittent resources will have on its distribution grid. Potential impacts include cost increases for infrastructure enhancements, the need for curtailment during

* Refer to "Updated Recommendations for Federal Energy Regulatory Commission – Small Generator Interconnection Procedures Scenarios" Prepared by Sheehan and Cleveland, July 2010, and "Model Interconnection Procedures" by the Interstate Renewable Energy Council, 2009 Edition.

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high generation/low load periods, and new procedures to maintain reliability. As more experience is gained along with more industry-wide research in this area, it is possible that future IRPs will consider higher DG levels.

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3.5 2011 IRP Strategic Cases

The 2012 IRP analyses a focused set of strategic cases expanding on the results from the 2011 IRP. A streamlined set of 4 coal replacement cases and 4 energy efficiency and solar distributed generation cases were evaluated for the 2012 IRP. Unlike other areas that are constrained by mandated regulatory requirements (such as renewable resources), the decision to divest from coal earlier than legally required, and accelerate energy efficiency programs or solar distributed generation programs is discretionary and thus appropriate for analysis. The 2012 IRP strategic cases are designed to assist policymakers and ratepayers to make informed decisions regarding these major initiatives particularly with regard to the environmental benefits and resulting resource and financial impacts.

Tables 3-4 and 3-5 provided a detailed description of each of the strategic cases.

It should be noted that the same renewable resource plan applies to Cases 1 thru 5. Cases 6 thru 8 include different renewable resource plans to adjust for increasing amounts of solar distributed generation and reductions in forecasted sales resulting from additional energy efficiency and CCSM solar distributed generation. Table 3-5 summarizes each renewable portfolio. For comparison purposes, the recommended case from the 2011 IRP is also included.

The different cases require distinct resource strategies to replace coal generation capacity and to meet future load growth. These strategies include the construction of new natural gas units, renewable generation, electricity purchases in the 3rd Quarter as needed to fill short term resource adequacy deficiencies, and the implementation of demand response and energy efficiency programs. A detailed breakdown of these strategies is discussed in Sections 4 and 5.

The candidate portfolios were modeled and the case results were compared against each other. The analysis included measurements of power costs, emissions, and fuel usage. High and low scenarios based on fuel prices were also modeled for the coal replacement cases to quantify the risk associated with fuel price volatility. Section 4 discusses the modeling results to facilitate a dialogue with our stakeholders and ratepayers with a goal of selecting the recommended case for the 2012 IRP.

Section 5 discusses in greater detail Case 5 with early Navajo divestiture which is a variation of the recommended case from the 2011 IRP with updates including 50% energy efficiency, enhanced solar focus including increased local distributed solar, and other updated assumptions. This discussion primarily involves the impact on Power System revenue requirements, rates, and customer bills.

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Table 3-4. DESCRIPTION OF STRATEGIC CASES

Case ID	Description
Case 1 (Coal Base Case)	No Early Coal Replacement – This case assumes coal resources will be replaced with combined cycle natural gas and renewable resources upon the expiration of coal contracts with no early compliance with SB 1368. Maintains the 33 percent standard renewables mix recommended to comply with SB 2 (1X) and the 10 percent energy efficiency savings by 2020 to comply with AB 2021.
Case 2	Navajo Early Divestiture Strategy – This case considers early divestment of Navajo on 12/31/2015, or 4 years prior to contract expiration, with IPP replacement at the end of contract expiration in 2027. Maintains the recommended 33 percent standard renewables mix to comply with SB 2 (1X) and the 10 percent energy efficiency savings by 2020 to comply with AB 2021.
Case 3	Navajo and IPP Early Replacement Strategy – This case considers early divestment of Navajo on 12/31/2015, 4 years prior to contract expiration, and early replacement of IPP on 12/31/2020 or 7 years prior to contract expiration. Maintains the recommended 33 percent standard renewables mix to comply with SB 2 (1X) and the 10 percent energy efficiency savings by 2020 to comply with AB 2021.
Case 4	Navajo and IPP Early Replacement Strategy (Alternate) – This case considers early divestment of Navajo on 12/31/2015, 4 years prior to contract expiration, and early replacement of IPP on 12/31/2023 when the IPP debt burden is fully paid 3.5 years prior to contract expiration. Maintains the recommended 33 percent standard renewables mix to comply with SB 2 (1X) and the 10 percent energy efficiency savings by 2020 to comply with AB 2021.
Case 5 (EE and DG Base Case)	Base Energy Efficiency and Base Solar Distributed Generation - Indentical to Case 2 and used as a baseline comparison to Cases 6 thru 8.
Case 6	Advanced Energy Efficiency and Base Solar Distributed Generation - Considers early divestment of Navajo with 10 percent energy efficiency savings by 2020 and an additional 500 GWh of energy efficiency savings between 2020 thru 2032.

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Case 7	Base Energy Efficiency and High Solar Distributed Generation - Considers early divestment of Navajo with 10 percent energy efficiency savings by 2020. Increases solar distributed generation thru the FiT program from 75 MW to 150 MW by 2016 and 150 to 305 MW by 2026 and increases CNM (SIP) solar from 145 to 183 MW by 2020 and 252 to 363 MW by 2032
Case 8	Advanced Energy Efficiency and High Solar Distributed Generation - Considers early divestment of Navajo with 10 percent energy efficiency savings by 2020 and an additional 500 GWh of energy efficiency savings between 2020 thru 2032. Increases solar distributed generation thru the FiT program from 75 MW to 150 MW by 2016 and 150 to 305 MW by 2026 and increases CNM (SIP) solar from 145 to 183 MW by 2020 and 252 to 363 MW by 2032.

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Table 3-5. CANDIDATE RESOURCE PORTFOLIOS FOR 2012 IRP

COAL CASES

		GHG or SB1368 Compliance Date		2020	2010 thru 2020	2010 thru 2032	New Renewables Installed Capacity (MW) 2012 - 2020					New Renewables Installed Capacity (MW) 2012-2032				
Case ID	Resource Strategy	Navajo Replacement	IPP Replacement	RPS Target	EE (GWh)	EE (GWh)	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
1 (Base Case)	No Early Coal Divestiture	12/1/2019	6/15/2027	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
2	Navajo Early Replacement	12/31/2015	6/15/2027	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
3	Navajo and IPP Early	12/31/2015	12/31/2020	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
4	Navajo and IPP Early (Alt.)	12/31/2015	12/31/2023	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
2011 Recommended	Navajo Early Replacement	12/31/2015	6/15/2027	33%	1443	2183	243	492	401	325	0	308	492	451	495	162

ENERGY EFFICIENCY AND DISTRIBUTED GENERATION CASES

		2020	2010 thru 2020	2010 thru 2032	New Renewables Installed Capacity (MW) 2012 - 2020					New Renewables Installed Capacity (MW) 2012-2032				
Case ID	Resource Strategy[1]	RPS Target	EE (Net GWh)	EE (Net GWh)	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic	Geo / Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
5 (Base Case)	Base EE , Base Solar DG	33%	2300	3500	242	0	887	337	39	283	54	915	496	114
6	Advanced EE, Base Solar DG	33%	2300	4000	242	0	887	337	39	283	0	915	496	114
7	Base EE, High Solar DG	33%	2300	3500	242	0	847	485	39	258	0	876	862	95
8	Advanced EE, High Solar DG	33%	2300	4000	242	0	847	485	39	258	0	876	862	0

[1]EE percentages are as follows:

	By 2020	By 2032
Base EE	10%	15.2%
Advanced EE	10%	17.4%

The feasibility of attaining EE levels greater than 10% are uncertain at this time, but will be addressed in the upcoming EE Potential Study to be completed in 2013.

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AR0070021

4.0 STRATEGIC CASE ANALYSIS

4.1 Overview

Section 3 discussed the development process for alternative case options, and presented the resulting 8 cases being considered for study. This Section 4 presents the analysis of the 8 cases, including the modeling methodology and the analysis results.

The analysis was performed on the generating resources using an hourly chronological production cost model. The model simulated the operation and electric loading of the LADWP Power System over a 20-year planning horizon with different portfolios of generating resources. The objective function of the production cost model is to minimize system cost, which is achieved by finding the least cost method to meeting the electric system demand using the specified generating resource portfolios.

The resources defined in the model consist of existing LADWP generating resources, generation currently under differing stages of development, and generic types of future generating resources with locations or projects that are not yet identified. The resource mix of renewable generating resources and thermal generating resources must satisfy: (1) resource adequacy requirements for reliability, (2) specific increasing targets of renewable resources as a percentage of total energy sales, and (3) other goals and objectives such as 10 percent energy efficiency, reliable integration of renewables, etc.

The 2012 IRP continues to evaluate the coal replacement strategies considered in the 2010 and 2011 IRPs with updated cost and assumptions information. Additionally, a new case (Case 4) was also developed with the goal of divesting of Navajo on December 31, 2015 and replacing IPP by the end of 2023. The date of 2023 was selected because this is the earliest practical transition point considering that the capital bonds to build IPP will be paid in full at the end of 2023. Any earlier divestiture would significantly increase ratepayer costs by expending debt payments on a facility that was not providing energy. Every year, LADWP purchases a percentage (~60%) of IPP generation from its owner, Intermountain Power Agency (IPA). LADWP's obligations to make payments with respect to IPP are unconditional "take-or-pay" obligations, obligating LADWP to make such payments as operating expenses of the Power System whether or not the applicable project is operating or operable, or the output thereof is suspended, interfered with, reduced, curtailed, or terminated in whole or in part. Since LADWP is just one of 36 utilities purchasing energy from IPA, any agreement to replace IPP will need the cooperation of all power purchasers involved. This new Case 4 also targeted an early IPP replacement date of 2023 so LADWP can avoid the financial burden of paying for both the replacement CC units and the IPP associated cost from 2024 to 2027. The actual replacement date may vary based on the final agreement with the other power purchasers. However, for evaluation purposes, this is a reasonable transition point to consider.

As a new addition for the 2012 IRP, four new scenarios (Cases 5 – 8) have been developed, focusing on alternative energy efficiency (EE) and solar distributed generation (DG)

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strategies over the next 20 years. These four new EE+DG scenarios include the same coal replacement timeline with Navajo divested in 2015 and IPP replaced in 2027. The detailed discussion on the scenarios and the analyzed results can be found in Sections 3 and 4.3.

All 8 cases were modeled, and the results were tabulated and compared against each other. Each strategy was ranked on average dollars per megawatt hour generation cost and the total million metric tons of CO_2 emissions. All of the strategic cases meet electric system reliability requirements per WECC and NERC standards.

Load forecast, prices of natural gas and coal, GHG emissions levels, capital, and O&M costs are the major cost drivers for bulk power in the cases analyzed. All cases meet the mandated RPS percentage targets and renewable resources are adjusted for each case analyzed depending on energy sales adjustments needed based on varying amounts of distributed solar generation and energy efficiency.

Section 4.2 reviews the modeling considerations for the cases that were presented in Section 3, along with the model assumptions and analysis methodology. Section 4.3 presents the modeling results, including cost comparisons and the rate impact results of the different cases. Section 4.4 presents the strategic case conclusions and the recommended case.

Section 5 includes long and short-term actions that are recommended towards implementation of the recommended case, including an estimate of the revenue requirements and electricity rate schedule needed to support it.

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4.2 Strategic Case Modeling Considerations

The cases analyzed in this 2012 IRP were introduced in Section 3.5 and are briefly discussed here. The timing of coal replacement and the variations in energy efficiency and distributed generation quantities and the resultant changes in resource mix are the key parameters that differentiate the 8 cases evaluated. Table 3-5 summarizes the portfolios for each case.

The following inter-related resource parameters were assumed to occur in the 8 coal and EE/DG potential resource strategies:

- OTC Repowering Schedule per Figure 1-15
- Net Energy efficiency penetration of approximately 3500 GWh by FY 2032 for base EE and 4000 GWh by FY 2032 for advanced EE
- RPS Resource Mix, schedule per Table 3-5
- GHG allowance allocations and prices shown in Appendix N
- Gas and Coal Fuel prices, as discussed in Section 3.2.2.
- IPP capacity and recall schedule shown in Appendix N

Coal strategic cases were also subjected to high and low scenario runs, which were based on high and low values for natural gas and coal prices. High and low fuel scenario runs were not performed for the EE/DG cases evaluated. The high and low scenarios simulated production over the same 20-year horizon, and provided a measure of the level of risk due to potential future fuel price volatility.

4.2.1 Modeling Methodology

4.2.1.1 Planning & Risk (PROSYM)

Simulations were performed using Planning & Risk (PAR), a third-party software program sold and distributed by Ventyx Corporation. PAR is an hourly chronological production cost model that commits and dispatches resources with certain operational constraints applied to the system to minimize the cost of serving electric load. It utilizes the PROSYM unit commitment and dispatch algorithm. PAR is a widely used production cost model used by many utilities across the US and the world to help plan and optimize power systems. Additional information on the model can be found in Appendix N.

4.2.1.2 Model Assumptions

To perform model simulations, a large set of input data is required. The key parameters that influence the analysis results are fuel prices, load forecast (including adjustments for energy efficiency and other demand side management programs), coal replacement strategies, and operational inputs regarding future gas-fired units. Details regarding the model assumptions are provided in Section 3 and Appendix N

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4.2.1.3 Net Short of Renewables

In developing the future renewable portfolio mix, the primary requirement was to meet the SB 2 (1X) goals for RPS percentage (see Section 1.6.5 for details) which includes meeting the RPS portfolio content categories as shown in Table 1-1. Other considerations included costs, resource and geographical diversity, and proximity to existing transmission. The process by which the renewable resource portfolio was constructed is described in Section 3.4.

4.2.1.4 Resource Adequacy

As a prerequisite for any potential future portfolio, all cases considered must satisfy Resource Adequacy (RA) requirements. RA is the ability to supply the aggregate demand and energy requirements of customers at all times, taking into consideration future load growth and planning reserve margins. In calculating RA for a given portfolio, generation resources are assigned a percentage of their nameplate capacity, known as "Net Dependable Capacity" that can be counted towards the RA requirement. The net dependable capacity values vary depending on the type of generation resource. Throughout the energy industry there is an on-going debate on how much variable energy resources can be relied upon during the summer system peak. Table 4-1 lists the net dependable capacities of the different resource technologies assumed for this IRP analysis.

Table 4-1: NET DEPENDABLE CAPACITY ASSUMPTIONS FOR NEW RESOURCES

Plant Technology	Net Dependable Capacity
Natural Gas Combined-Cycle	100%
Natural Gas - Gas Turbine	100%
Wind	10%
Solar PV	27%
Solar Thermal	68%
Geothermal	90%

The specific RA analyses for each of the four coal strategic cases are presented later in Section 4.3.1.1.

4.2.1.5 Model Runs and Scorecards

The evaluation of each strategic case yielded a tremendous amount of information about the LADWP Power System. In order to organize and interpret the modeling results, a scorecard system was developed to rank and check the output results. The scorecard is a very detailed and complex Microsoft Excel based spreadsheet that summarizes all the important inputs and outputs and includes metrics such as total system power costs, plant generation, CO_2 emissions, and fuel costs.

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4.2.1.6 Post Modeling Analysis

While the production cost modeling provides detailed information on estimated bulk power costs, reliability and mandated regulatory program revenue requirements are evaluated through analysis external to the production cost model. The results of this analysis are provided in Section 4.3 to provide a more complete view of the total cost components that make up total Power System costs. This Section also illustrates the revenue requirements to fund these specific programs to maintain a reliable electric system while also complying with regulatory requirements for renewable portfolio standards, local solar, once-through-cooling, and energy efficiency.

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4.3 Modeling Results

The modeling results are presented in terms of LADWP's overall goals of: (1) reliability, (2) environmental stewardship and (3) economic, or cost, considerations.

4.3.1 Reliability Considerations

Resource strategies are not designed to totally avoid the chance of a power outage due to inadequate supply resources. Such a strategy would be very expensive and would mean that some resources would be built with a small chance of ever operating, or would have an unacceptably low capacity factor. Most power outages are distribution based (e.g., a winter storm that knocks down local distribution lines) and not a result of insufficient generation resources. The reliability criterion of "1 day in 10 years" attempts to quantify what is an acceptable amount of loss of load (i.e. a power outage). The generally accepted industry interpretation of the criteria is that a system is considered reliable if there are no more than a total of 24 hours of loss of load in a 10 year period (87,600 hours). This criterion translates to a 0.03 percent chance that load will not be served.

Based on the reliability calculation, no single resource strategy is significantly more or less reliable than another strategy, and all strategies meet this criteria. The economic aspects of each of the resource strategies are only valid if the resource strategy meets the NERC reliability standard of "1 day in 10 years." For this evaluation on reliability, each resource strategy was considered equal in terms of the reliability criteria.

4.3.1.1 Resource Adequacy

The process of ensuring resource adequacy for each strategic case is iterative. Initially, a model run is made for each case without any resource additions. The results indicate the amount of resource surplus or shortfall into the future. Without any resource additions, a deficit is eventually reached as a result of coal replacement, generation unit retirements and the expiration of power purchase contracts on the supply side, as well as load growth adjusted for resources such as EE and Solar DG on the demand side. Figure 4-1 presents the resource shortfalls for the four coal replacement cases prior to any resource additions. For planning purposes, the figures focus on the most critical months of each year – July through October.

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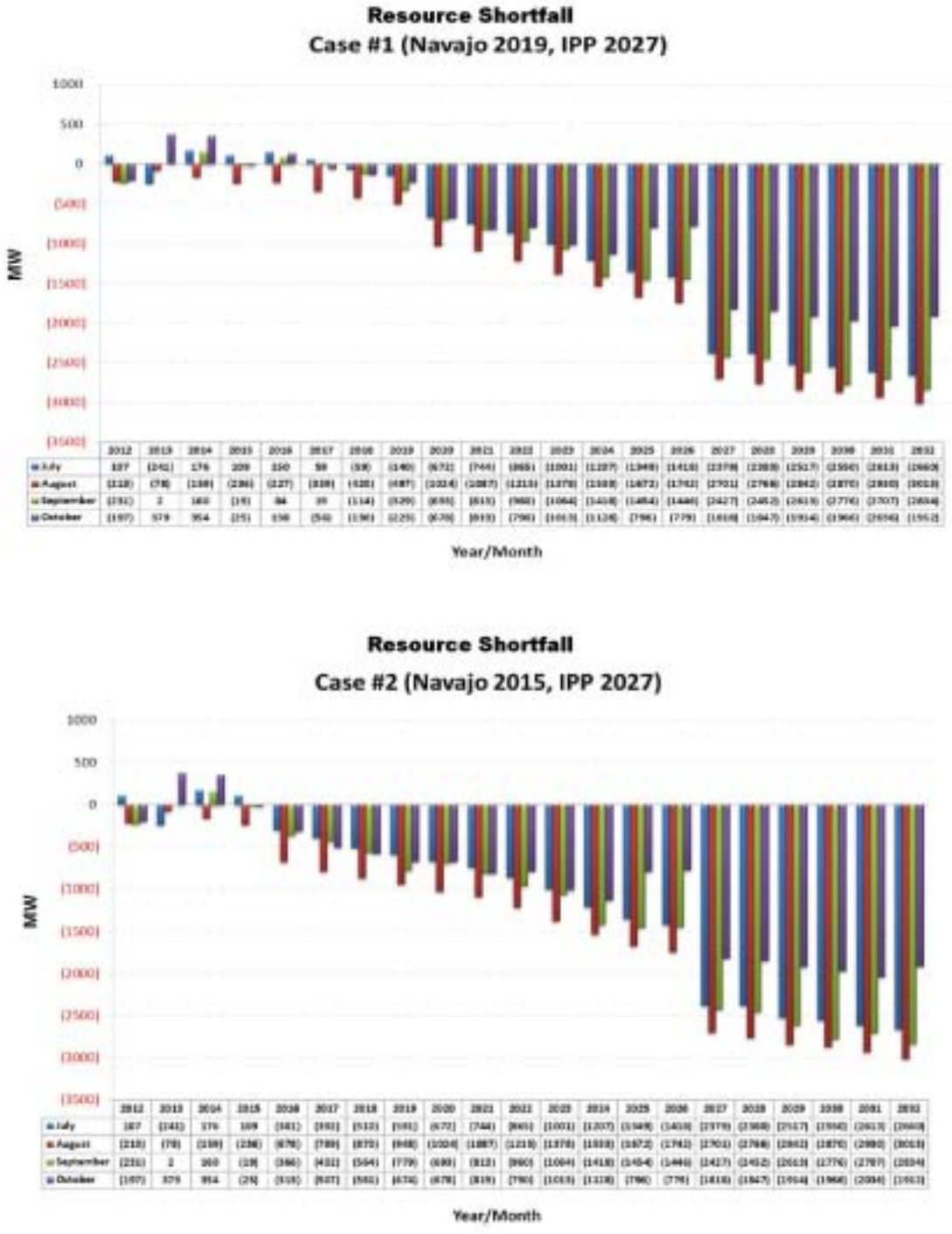

Figure 4-1. Summer months resource adequacy shortage for Cases 1-4, by calendar year ("1 in 10" reliability criteria)

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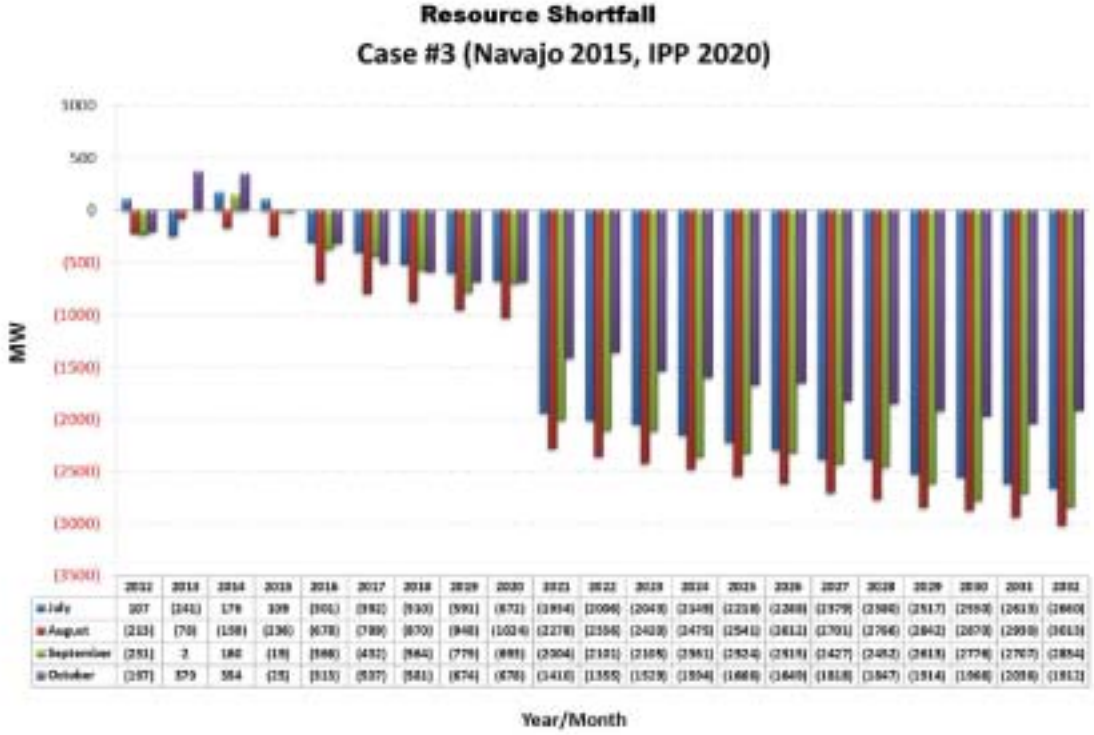

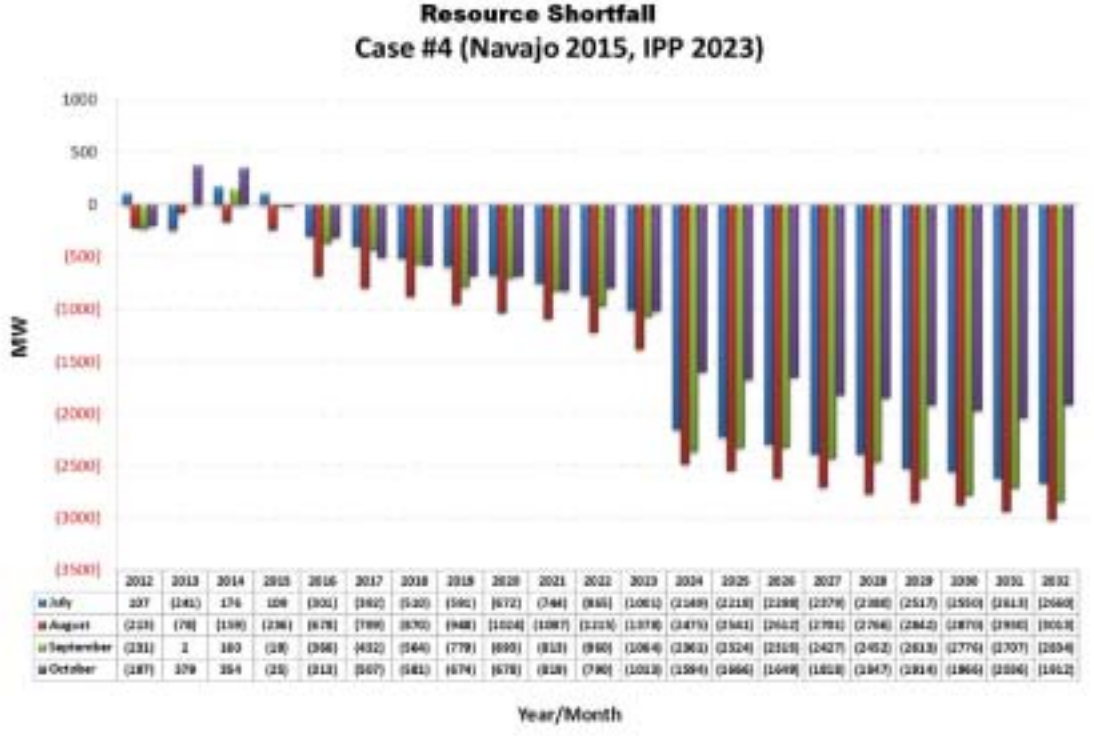

Figure 4-1. (continued)

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Once the deficits have been quantified, the means of satisfying the shortfall is assessed. Some of the considerations that LADWP accounted for in identifying potential solutions include:

- Any additional renewables will increase LADWP's overall renewable resource portfolio and help achieve compliance with SB 2 (1X).
- Energy efficiency, demand response, peak season Q3 term purchases, and replacement gas fired generation were considered to provide the most economical and well diversified blend of resources.
- The additions had to be separate and distinct from the in-basin OTC repowering projects which are already included in the shortfall calculation.
- Large scale generation additions were located out-of-basin to take full advantage of the existing transmission infrastructure and to comply with local environmental regulations.
- Where feasible, the new generation sites should make use of existing transmission and fuel supply infrastructure.
- As with all planning activities, the solution must address reliability, costs, and environmental stewardship.

After careful consideration, LADWP's IRP team consisting of the IRP staff, Power System Management, Environmental Affairs, and the Energy Efficiency Group, developed a resource replacement strategy for each case and briefed the General Manager. The resource solution employs a mix of new renewable generation, energy efficiency, demand response, new gas-fired combined cycle units, and Q3 Term Purchases to replace Navajo and IPP Coal and to supplement load growth adjusted for demand side resources. Table 4-2 shows the breakdown of the replacement resources recommended for the four coal cases. Replacement resources for the 4 EE-DG cases were also developed and are shown in Appendix N.

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Table 4-2. RESOURCES RECOMMENDED FOR RESOURCE ADEQUACY BY CALENDAR YEAR

Case#1 (Navajo 2015, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	119	139	159	179	199	219	239	259	279	299	319	339	359	379	399	419
Demand Response	1	20	20	40	71	100	100	200	200	300	300	400	400	500	500	500	500	500	500	500	500
New Renewable	22	86	87	223	286	347	351	442	542	547	600	625	638	662	666	670	687	691	703	711	731
Navajo Replacement CC	0	0	0	0	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150	1150	1150
Q3 Term Purchase	200	171	0	0	0	0	0	0	0	0	0	0	0	210	70	0	0	0	0	50	121
Total Replacement	244	257	165	342	460	561	575	784	1346	1313	1420	1511	1600	1890	1747	2506	2854	2867	2980	3043	3130

Case #2 (Navajo 2015, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	119	139	159	179	199	219	239	259	279	299	319	339	359	379	399	419
Demand Response	1	20	20	40	71	100	100	200	200	300	300	400	400	500	500	500	500	500	500	500	500
New Renewable	22	86	87	223	286	347	351	442	542	547	600	625	638	662	666	670	687	691	703	711	731
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150	1150	1150
Q3 Term Purchase	200	171	0	0	0	0	0	0	0	0	0	0	0	210	70	0	0	0	0	50	121
Total Replacement	244	257	165	342	760	861	875	1084	1346	1313	1420	1511	1600	1890	1747	2506	2854	2867	2980	3043	3130

Case #3 (Navajo 2015, IPP 2020)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	119	139	159	179	199	219	239	259	279	299	319	339	359	379	399	419
Demand Response	1	20	20	40	71	100	100	200	200	300	300	400	400	500	500	500	500	500	500	500	500
New Renewable	22	86	87	223	286	347	351	442	542	547	600	625	638	662	666	670	687	691	703	711	731
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
Q3 Term Purchase	200	171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	121
Total Replacement	244	257	165	342	760	861	875	1084	1346	2463	2570	2863	2750	2911	2822	2506	2854	2867	2980	3043	3130

Case #4A (Navajo 2015, IPP 2024)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	119	139	159	179	199	219	239	259	279	299	319	339	359	379	399	419
Demand Response	1	20	20	40	71	100	100	200	200	300	300	400	400	500	500	500	500	500	500	500	500
New Renewable	22	86	87	223	286	347	351	442	542	547	600	625	638	662	666	670	687	691	703	711	731
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150	1150	1150	1150	1150	1150
Q3 Term Purchase	200	171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	121
Total Replacement	244	257	165	342	760	861	875	1084	1346	1313	1420	1511	1750	2911	2822	2506	2854	2867	2980	3043	3130

Figure 4-2 shows the net dependable capacity profiles for the 4 coal cases after including the recommended resources to satisfy resource adequacy requirements. In each case, Navajo is replaced with new renewable generation and a 300 MW replacement combined cycle gas-fired unit upon divestiture. Energy efficiency, demand response, and Q3 term purchases supply capacity that primarily contributes to peak load growth. Figure 4-3 presents the generation profiles for the same 4 coal cases.

When IPP energy ceases in 2027 for Cases 1 and 2, 2020 for Case 3, and 2023 for Case 4, that production is replaced entirely with two 575 MW combined cycle natural gas units. The larger combined cycle units will be necessary to reduce Q3 term purchases and to provide energy and capacity for additional load growth. By 2020, most of the renewable portfolio will have already been built to replace Navajo, with continued load growth being offset by renewables, energy efficiency, demand response, Q3 term purchases, and a portion of the two 575 MW combined cycled gas-fired units.

Q3 term purchases are meant to satisfy peak load growth in the summer months where capacity is needed only over a short period of time, typically over a few weeks of the summer months. The planned addition of Q3 term purchases helps to limit the amount of capital intensive resources that would be necessary to supply peak load growth. Continual evaluation

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of future market conditions will be needed to ensure that the market possesses adequate depth and reasonable pricing so that these term purchases can be relied upon to fill system capacity needs.

In Cases 2, 3 and 4 with the Navajo Generating Station (NGS) divested in 2015, the 300 MW combined cycle gas-fired unit and demand response resources are fulfilling two purposes, (1) replacing capacity and energy that would have been provided by NGS and (2) providing dispatchable resources to enable the integration of increasing amounts of intermittent renewable energy as these resources are ramped up from the current 20% RPS to 33% RPS in 2020.

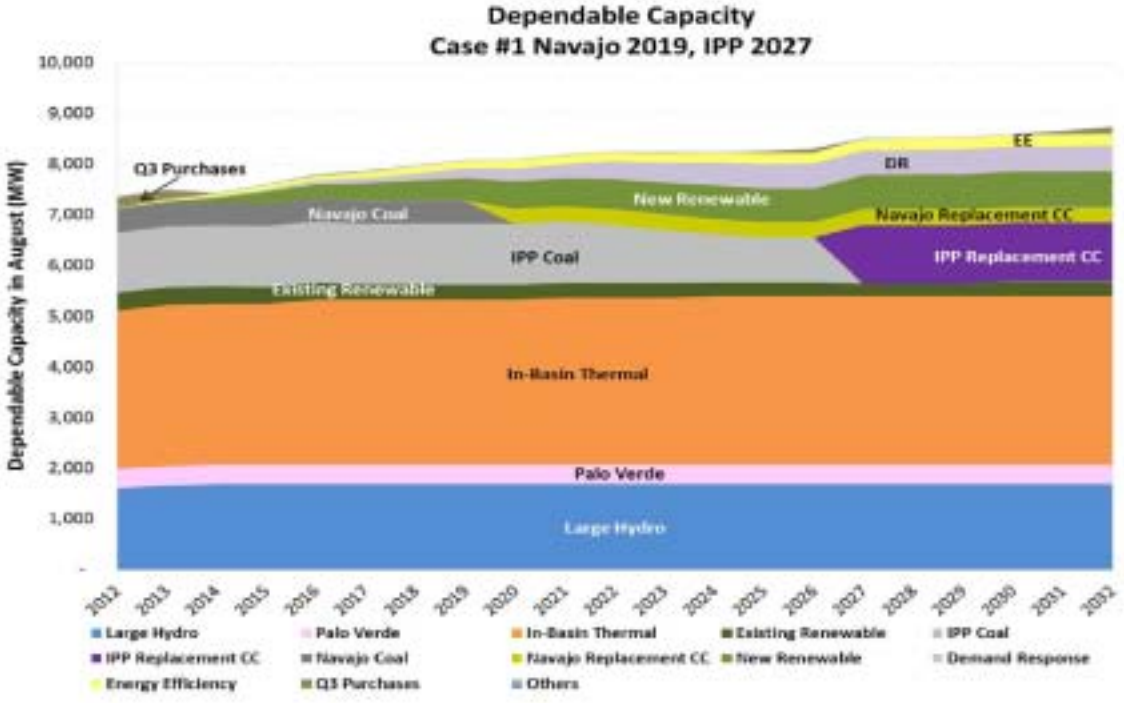

Figure 4-2. Dependable capacity profiles, Cases 1 - 4.

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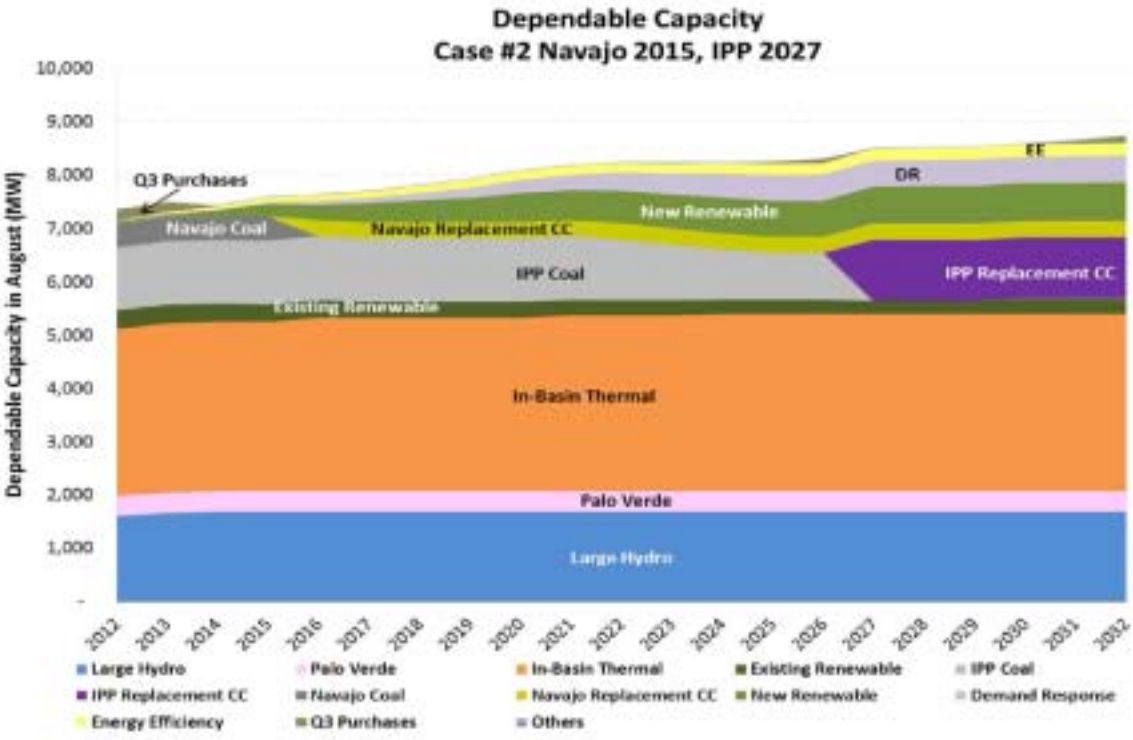

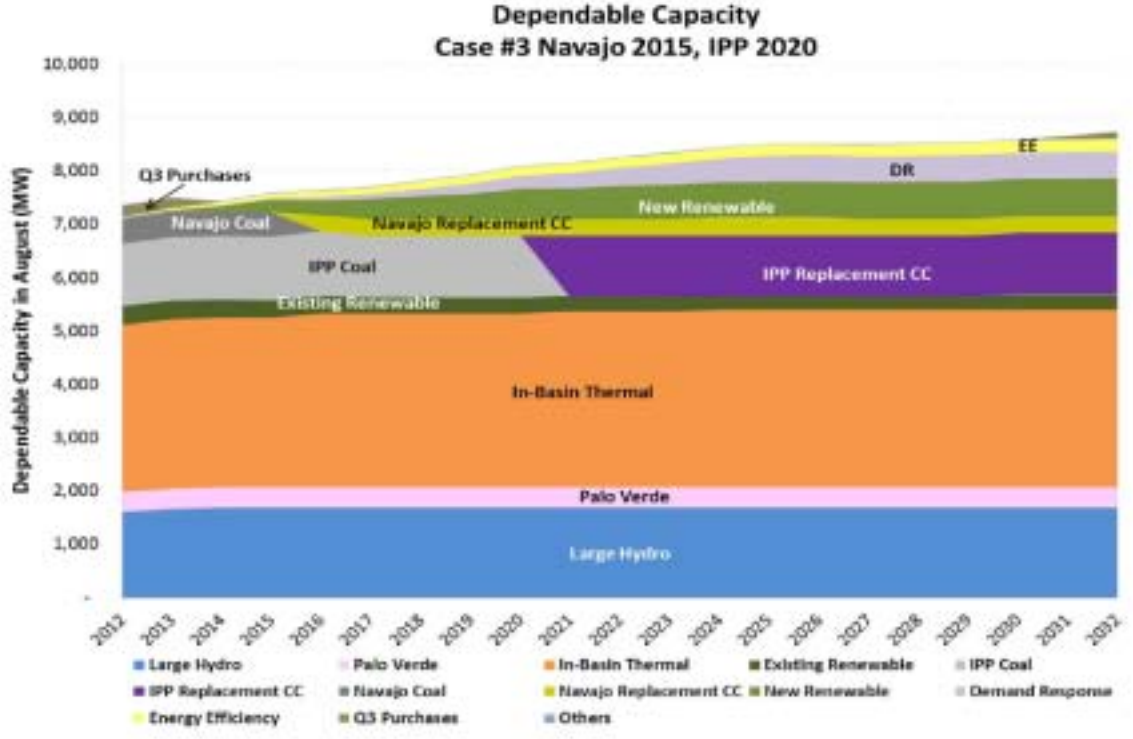

Figure 4-2. (continued)

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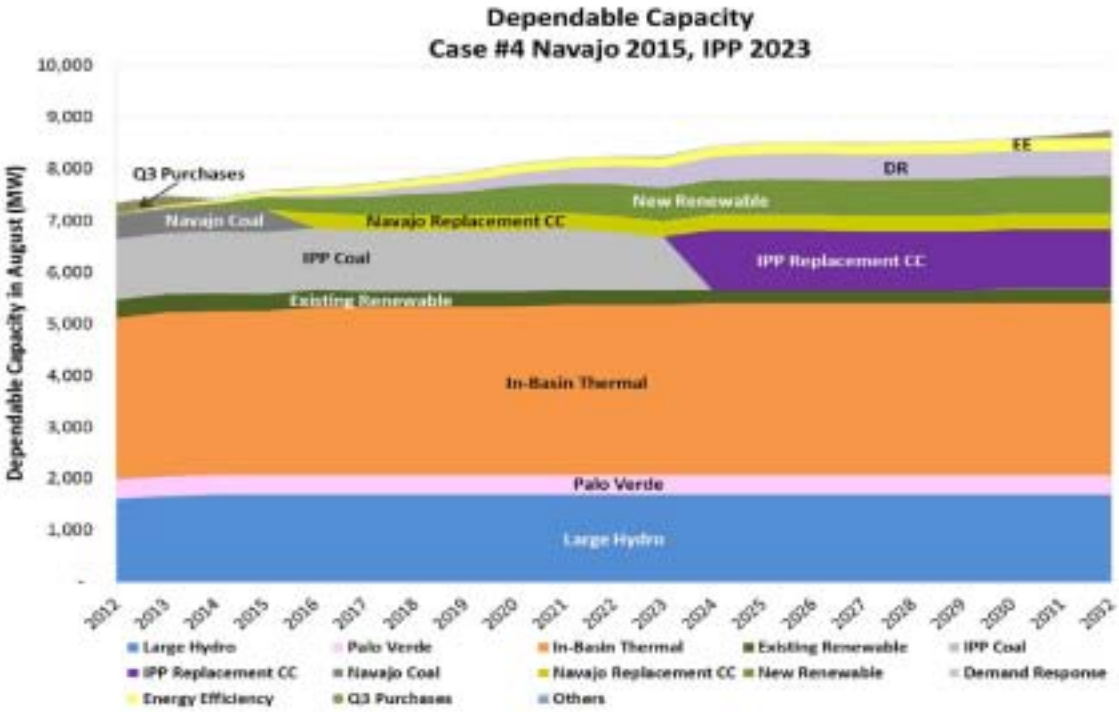

Figure 4-2. (continued)

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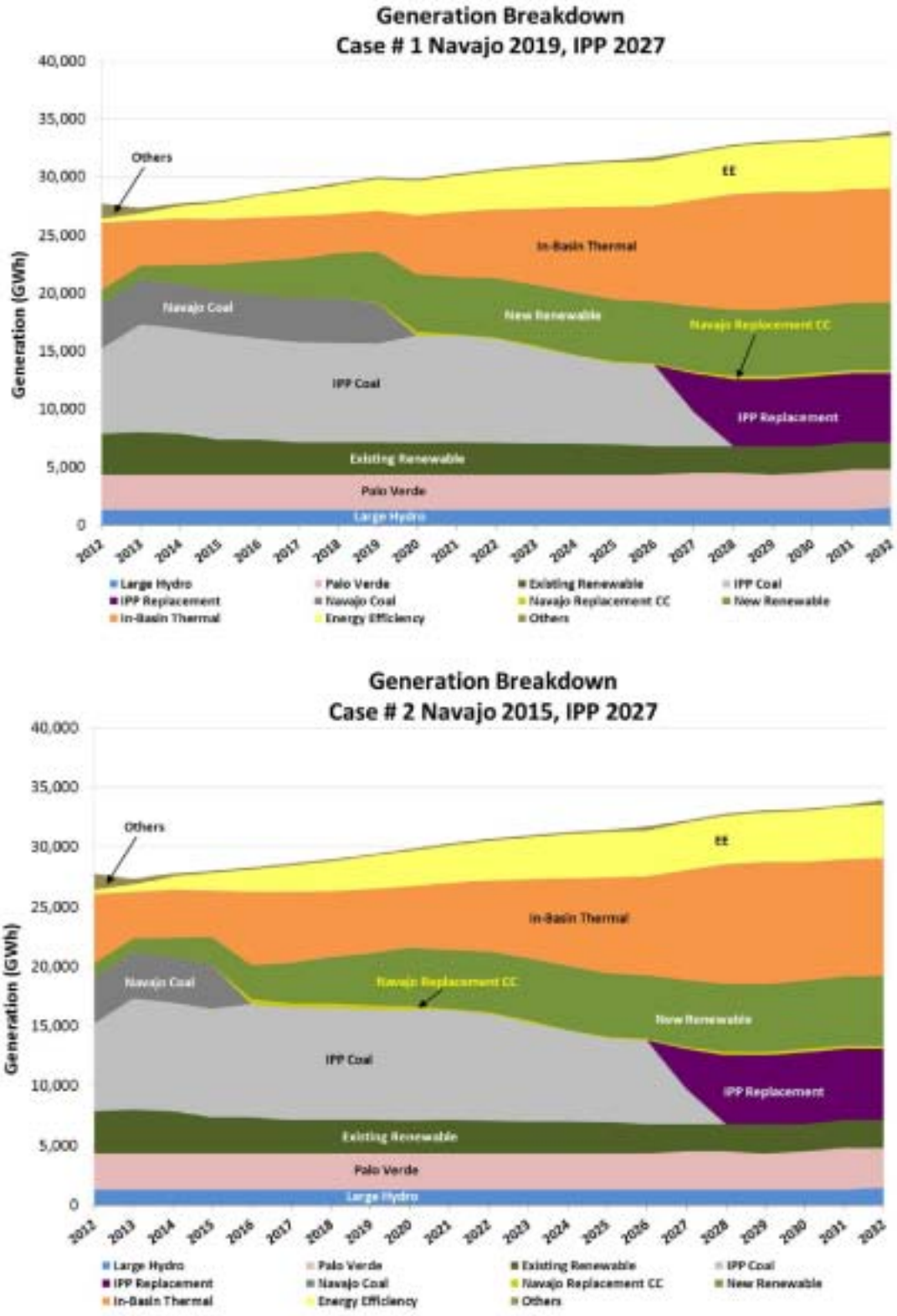

Figure 4-3. Generation mix profiles, Cases 1 - 4.

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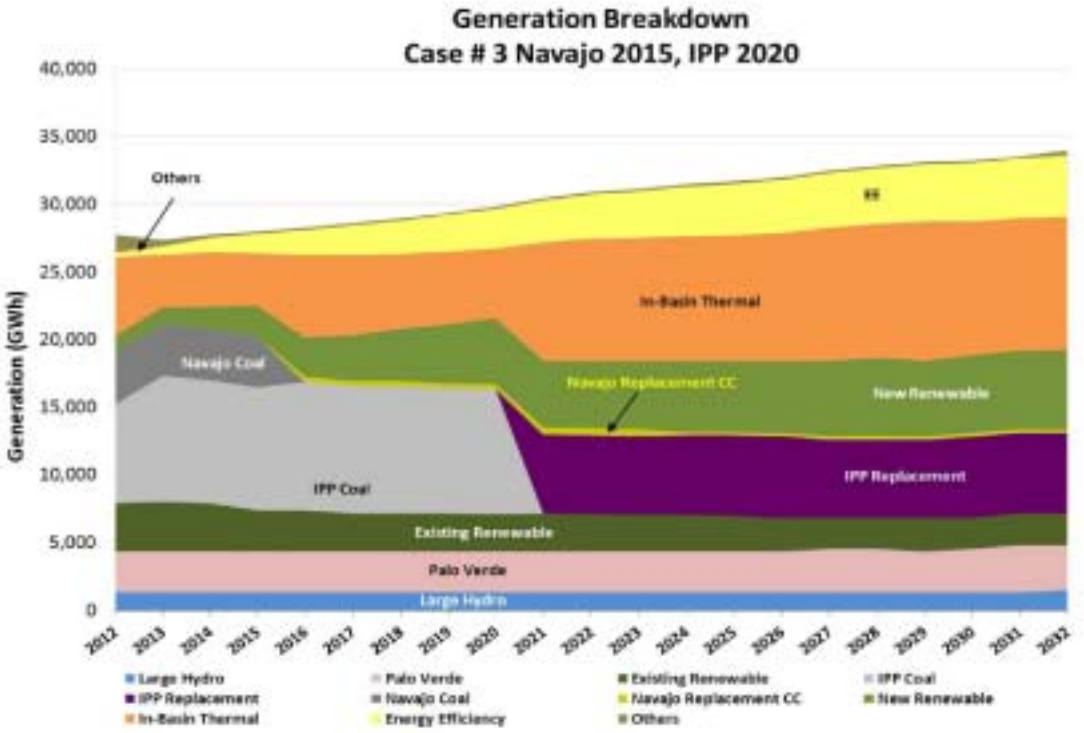

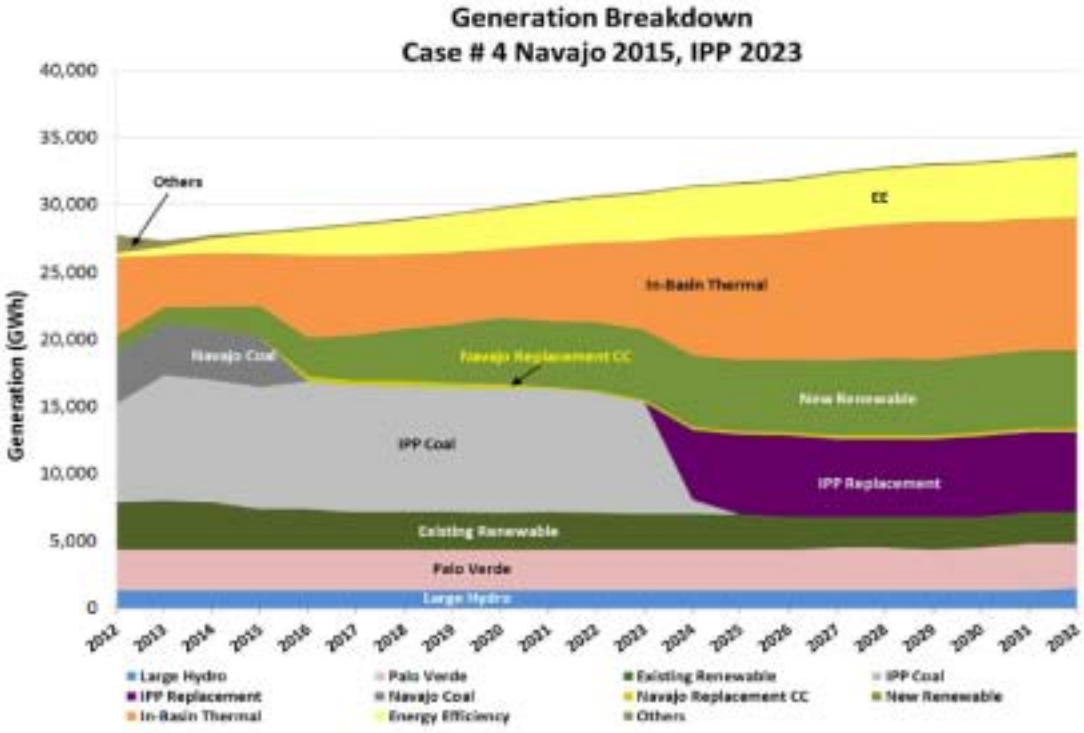

Figure 4-3. (continued)

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4.3.2 GHG Emissions Considerations

The primary objective of coal replacement is to reduce overall GHG emissions. Energy produced from coal emits approximately twice the amount of GHG emissions, when compared to energy produced from natural gas. The reductions of GHG emissions are reflected in the production cost model simulations. Figure 4-4 illustrates a comparison of the resulting GHG emission levels of the four cases. Divestiture of Navajo results in an average 1.81 Million Metric Tons (MMT) reduction in GHG each year while IPP results in an average 2.78 MMT reduction each year. GHG reductions are accelerated in Cases 2, 3 and 4 with the replacement of Navajo and IPP prior to the expiration of existing power contracts with these facilities. Case 1 represents the normal course of emissions reductions with no early replacement. Reduction levels are eventually reached in all cases in 2019 and then again in 2027 when SB 1368 essentially prohibits the importation of energy produced from coal when the existing power contracts expire.

Current total GHG emissions levels are approximately 14.1 MMT which is 21 percent below 1990 levels due to the elimination of Mojave and Colstrip Coal, completed repowering of units at Haynes and Valley generating stations with cleaner gas-fired replacements, and increased renewable generation from 3% in 2003 to 20% in 2010. Using Case 1 (Navajo divestiture in 2019, IPP replacement in 2027) as a baseline, early divestiture of Navajo in Cases 2, 3 and 4 results in approximately 7.2 MMT less GHG emissions between 2016 and 2019. For Case 3 (IPP replaced in 2020) there is an additional post-2020 cumulative reduction of 19.5 MMT. For Case 4, the post-2020 reduction is 9.3 MMT. These GHG emission reductions are shown below in Figure 4-4 and Table 4-3.

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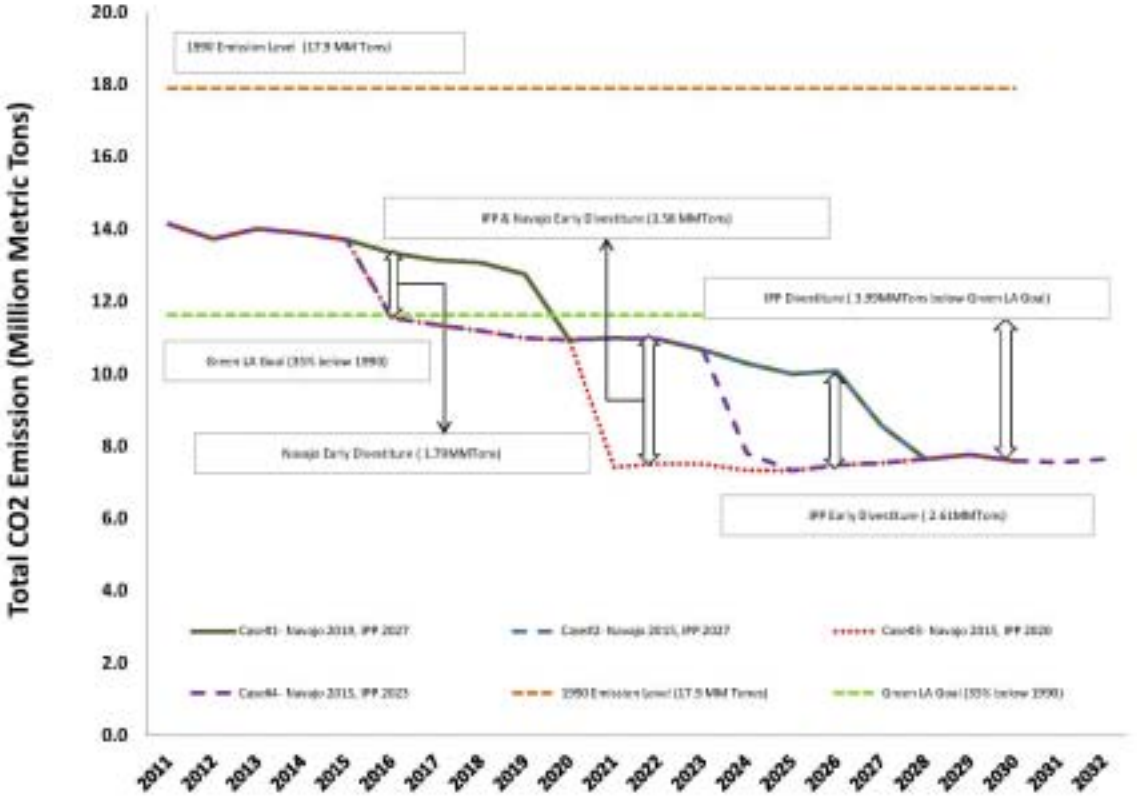

Figure 4-4. GHG emissions comparison by calendar year.

Table 4.3 GHG EMISSIONS REDUCTION LEVELS IN MMT

Case	Reduction 2016-19	Reduction 2020-27	Total Reduction 2016-27
1	Baseline	Baseline	Baseline
2	7.2	0.0	7.2
3	7.2	19.5	26.7
4	7.2	9.3	16.3

Emission levels for the energy efficiency and solar distributed generation, Cases 5 thru 8 were also evaluated as shown in Figure 4-5. Advanced levels of EE were found to result in slightly lower emissions of CO_2 as compared to the Base EE cases. Higher levels of Solar DG were found to have little effect on reducing CO_2 emissions since Solar DG would have been replaced with other zero emissions resources. Although these higher levels of EE and distributed generation have a small impact on emissions compared to the base EE, it is important to note that the base level of energy efficiency in and of itself has a very significant impact on reducing overall CO_2 levels as shown by the "No More EE" curve illustrated in Figure 4-4. If no additional EE were implemented, annual GHG emissions levels would be

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approximately 2.0 MMT higher by 2032. This is equivalent to removing 385,000 cars from the road. For reference purposes, the CARB emissions allocation for LADWP as part of the AB 32 Cap and Trade program being implemented in 2013 and ending in 2020 is shown in Figure 4-5.

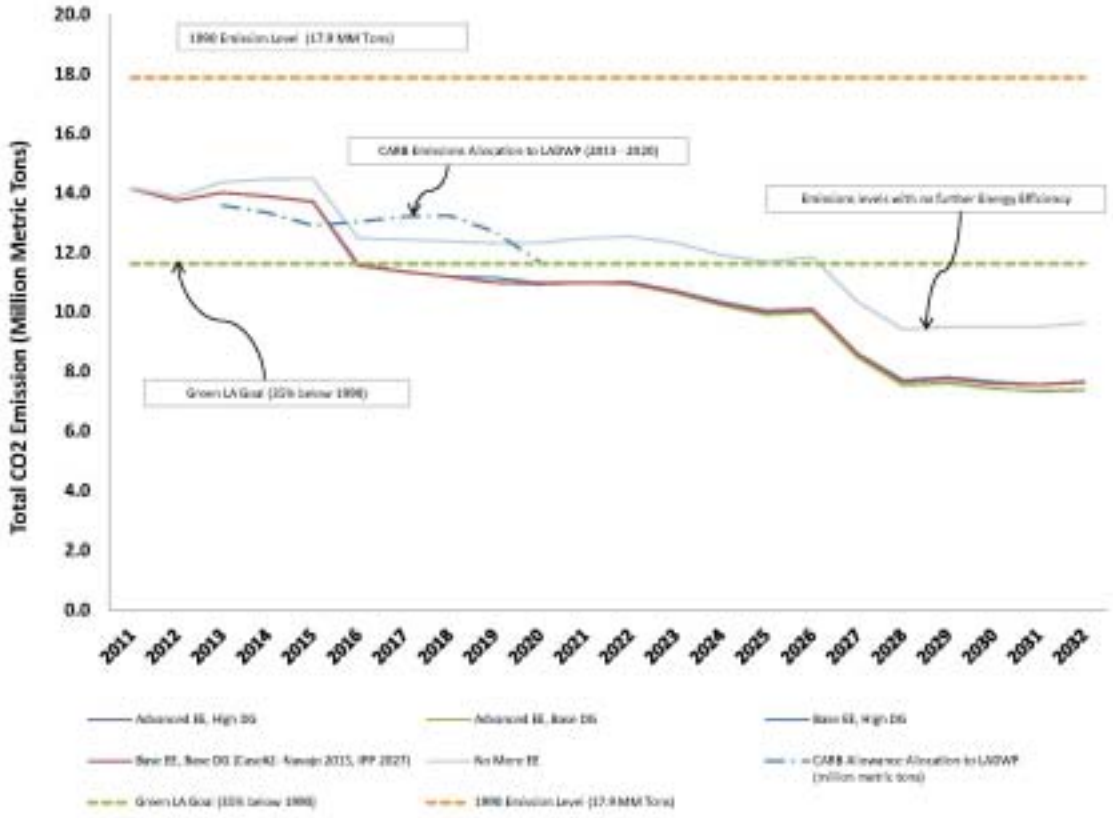

Figure 4-5. GHG emissions comparison for Energy Efficiency and Solar Distributed Generation cases by calendar year.

In addition to GHG, Oxides of Nitrogen (NO_X) were also measured within the production model. Figure 4-6 summarizes NO_X emissions for each of the four cases. With the installation of SCR equipment since 1989, NO_X emissions of in-basin generation has been reduced by 90 percent.

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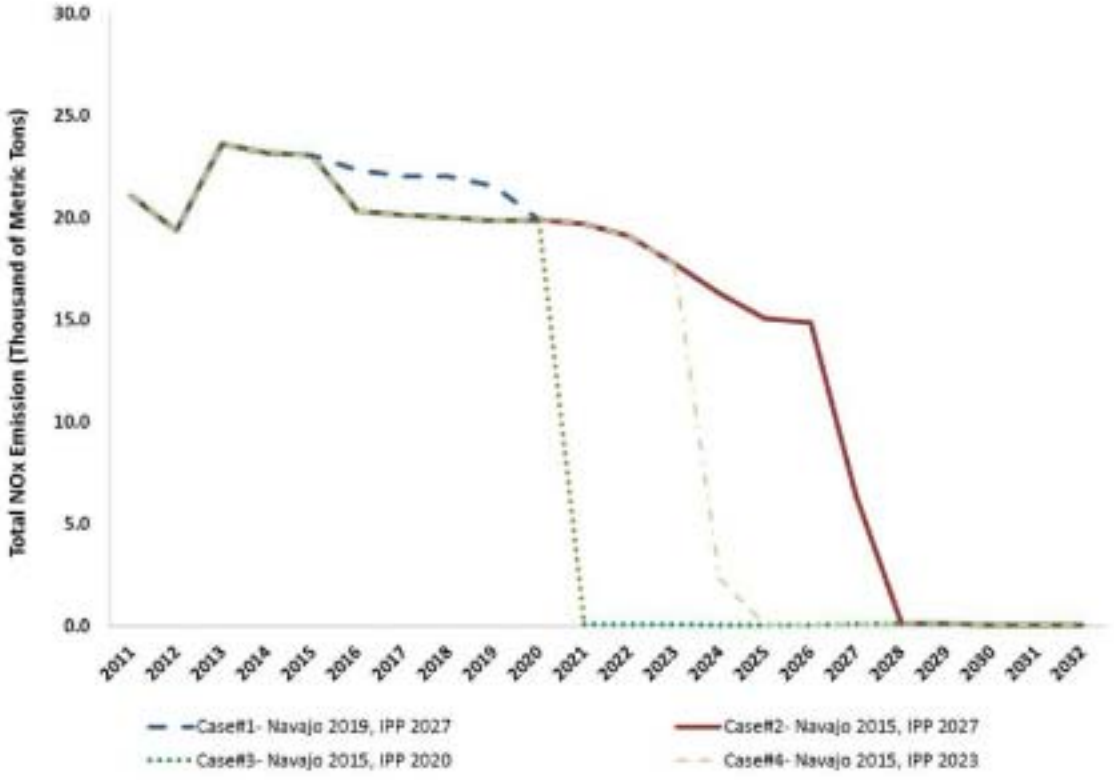

Figure 4-6. NO_X emissions comparison by calendar year

4.3.3 Economic Considerations

The economic considerations for the eight coal and EE/DG cases included a comparison of fuel and variable costs. The coal cases were further subjected to fuel price stress tests to account for potential future price volatility which affects possible ranges of bulk power costs related to coal replacement. Reliability and regulatory revenue requirements are also addressed to quantify the impact of these programs on future total Power System costs.

4.3.3.1 Cost Comparison Between EE and DG Cases 5 thru 8

Two scenarios of Energy Efficiency (EE) were considered including a Base EE case and an Advanced EE case. By using FY 2010-11 Total Sales to Ultimate Customers (23,053 GWh) to calculate the energy savings percentage, the Base EE case forecasts LADWP will achieve 10% of Net EE savings by 2020 and 15% EE savings by 2032. The Advanced EE case forecasts the same EE savings up to and including 2020 as in the Base EE case, but gradually adds another 500 GWh of savings by 2032. The Net EE savings in GWh for the two scenarios along with the projected budget are shown below in Figures 4-7 and 4-8.

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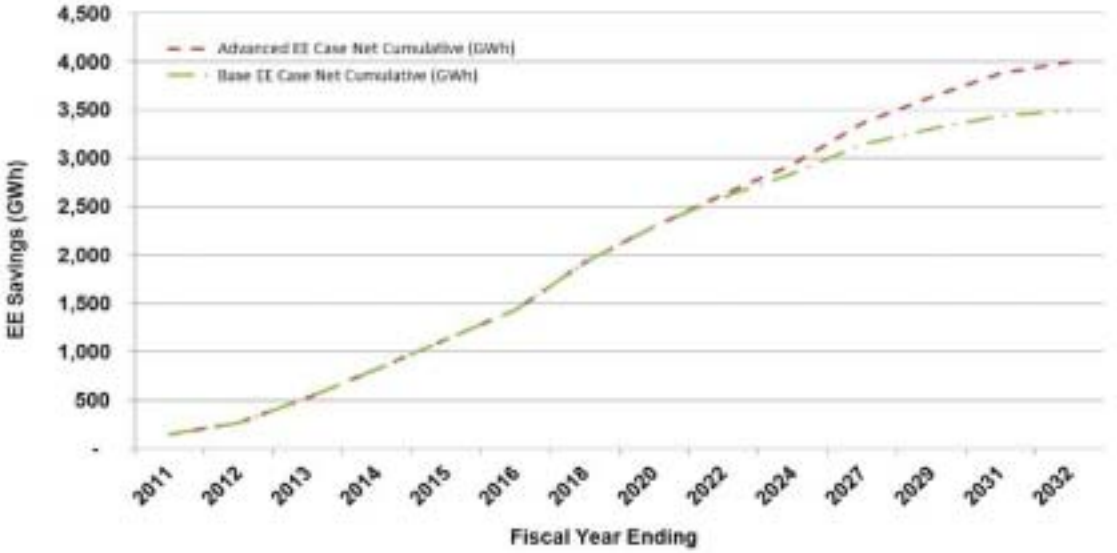

Figure 4-7. Advanced EE and Base EE GWh Comparison

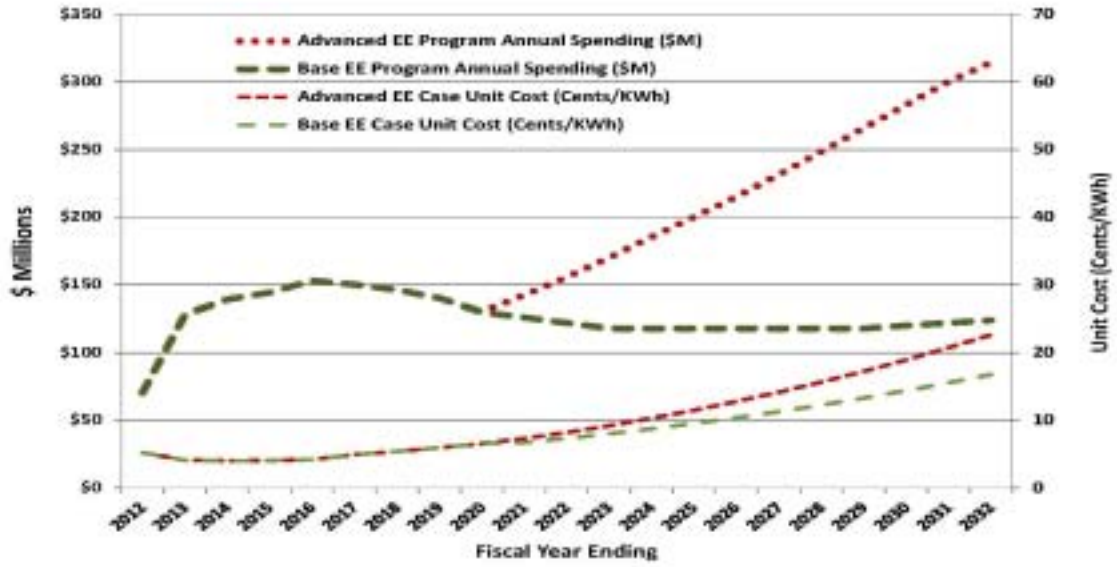

Figure 4-8. Advanced EE and Base EE Program Cost Comparison

Solar Distributed Generation (DG) includes local solar generation that is directly interconnected to the distribution system. Distributed generation comprises solar generation from the Feed in Tariff (FiT), Utility Built Solar (UBS), and customer net metered programs. UBS are solar projects that would be built and operated by LADWP, and may be located in the city or out-of-basin. The detailed Solar DG scenarios in GWh and unit cost are shown in

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Figure 4-9, along with curves for LADWP's Utility Built Solar (UBS) program. The two scenarios for Solar DG consist of one Base DG case and one High DG case.

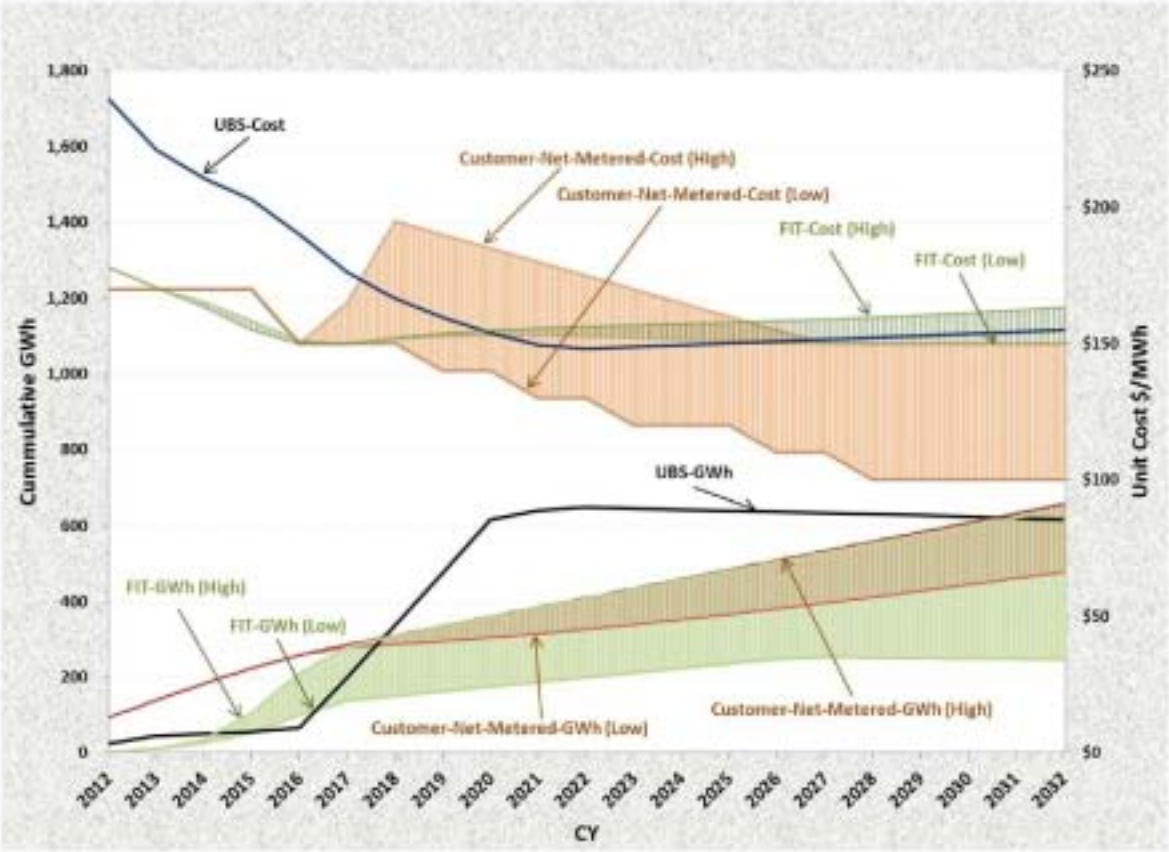

Figure 4-9. High and Base DG solar program cost assumptions and GWh comparison

The Base EE and Base DG energy forecasts are used in all four coal strategic cases evaluated in the 2012 IRP. The Base Case assumes divestment of Navajo Generating Station by December 31, 2015 and Intermountain Generating Station will be replaced by natural gas generation by June 15, 2027. Different combinations of EE and DG cases were analyzed in the production model simulations including: (1) Base EE with Base DG, (2) Base EE with High DG, (3) Advanced EE with Base DG, and (4) Advanced EE with High DG. The detailed analysis was conducted using the PROSYM production cost modeling software .

There are various resource changes associated with different EE and DG combinations due to RPS mandatory and system reliability requirements. For example, when the High DG and Advanced EE case is modeled, the more aggressive EE reduces both customer energy sales and load demand which relaxes the requirements on RPS and peak demand. Also, with higher Solar DG some non-solar-DG renewable resources were reduced or even eliminated to avoid unnecessary expenditures on renewable energies beyond the amount mandated by SB 2 (1X).

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Demand-Side Resources – Total Revenue Requirements

Due to the load reduction nature of energy efficiency and solar customer-net-metered "demand-side" programs, analysis of the revenue requirements of these specific programs must be handled in a different manner than other distributed generation programs such as solar feed-in-tariff and utility built solar. The modeling results were analyzed to determine the net revenue loss due to reduced sales and the program costs which consist mainly of incentive payments paid to customers to subsidize the cost of these demand-side measures. While the program costs are relatively straight forward to evaluate, determining the net revenue loss is a more complex process that requires first determining the costs that the utility avoids by implementing these programs which is simply described as "avoided costs."

Determining Net Revenue loss involves first determining the avoided costs from implementation of demand-side energy savings, including: fuel, variable O&M, emissions, transmission and distribution deferred upgrades, capital investments for new generation, fixed O&M, and energy transport losses. The avoided costs and fixed billing charges from demand and minimum billing charges are then subtracted from the gross revenue loss to determine the net revenue loss as shown in Figures 4-10 through 4-13 below. A full detailed discussion of avoided costs and revenue loss results are included in Appendix N.

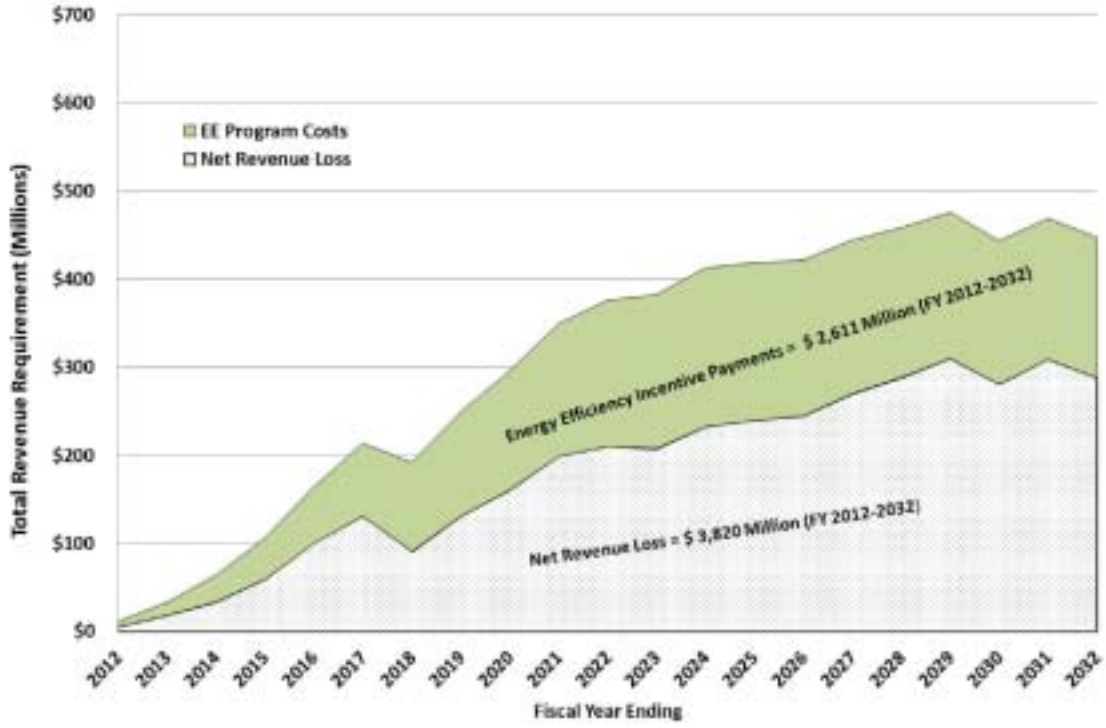

Figure 4-10. Base EE - Total Revenue Requirement

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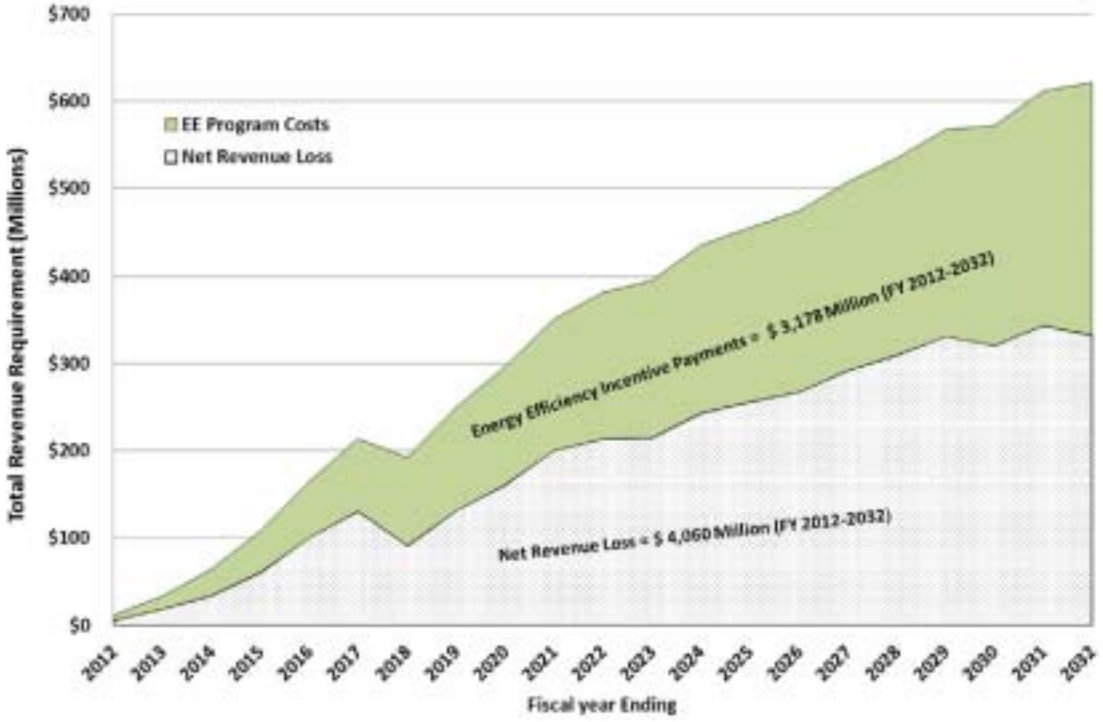

Figure 4-11. Advanced EE - Total Revenue Requirement

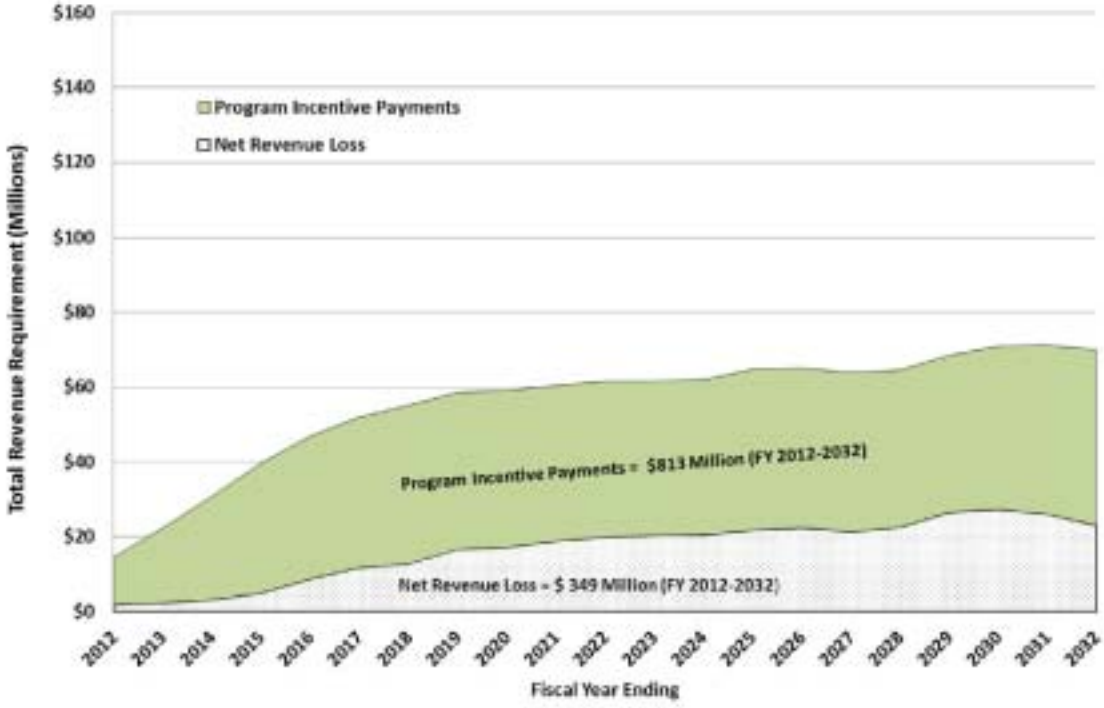

Figure 4-12. Base CNM Solar - Total Revenue Requirement

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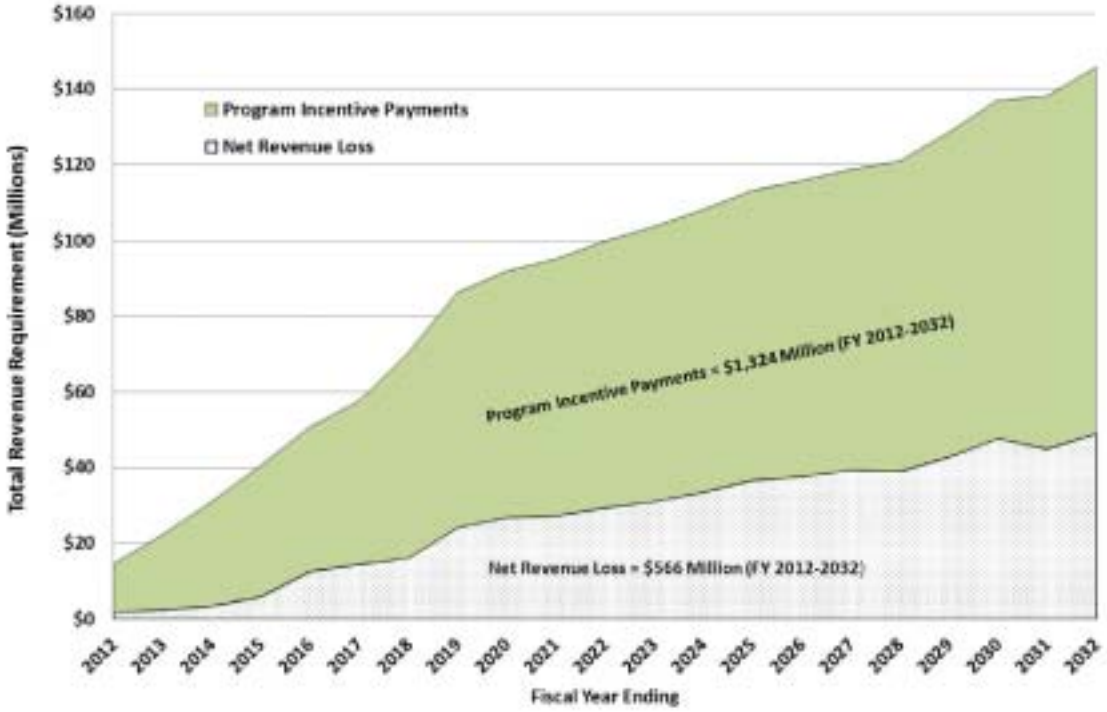

Figure 4-13 High CNM Solar - Total Revenue Requirement

Solar DG resources including Solar Feed-In-Tariff and Utility Built Solar do not result in revenue losses because these programs do not reduce customer sales. Therefore, the energy costs offset by the avoided costs savings of these programs must be calculated separately and then added to the demand-side EE and CNM costs to arrive at the final bulk power costs for the different cases as shown in Figure 4-14 below. FiT and UBS also result in avoided costs similar to EE and CNM with only slight differences. Although the evaluation considered the entire period of 2012 thru 2032, only the years 2020 thru 2032 are shown in Figure 4-14. The reason for this is that all cases have the same EE savings from 2012 thru 2020 and only slightly higher solar DG savings for this time period. Increased levels of EE and solar DG mostly occur in the later period from 2020 thru 2032 in the cases evaluated. Integration costs for solar resources, assumed to be $7/MWh based on recent studies performed by outside consultants, and all other bulk power resource costs were aggregated together to determine the total bulk power costs of the 4 EE/DG cases evaluated. The incremental differences between these 4 EE/DG cases can be seen in Table 4-4 below.

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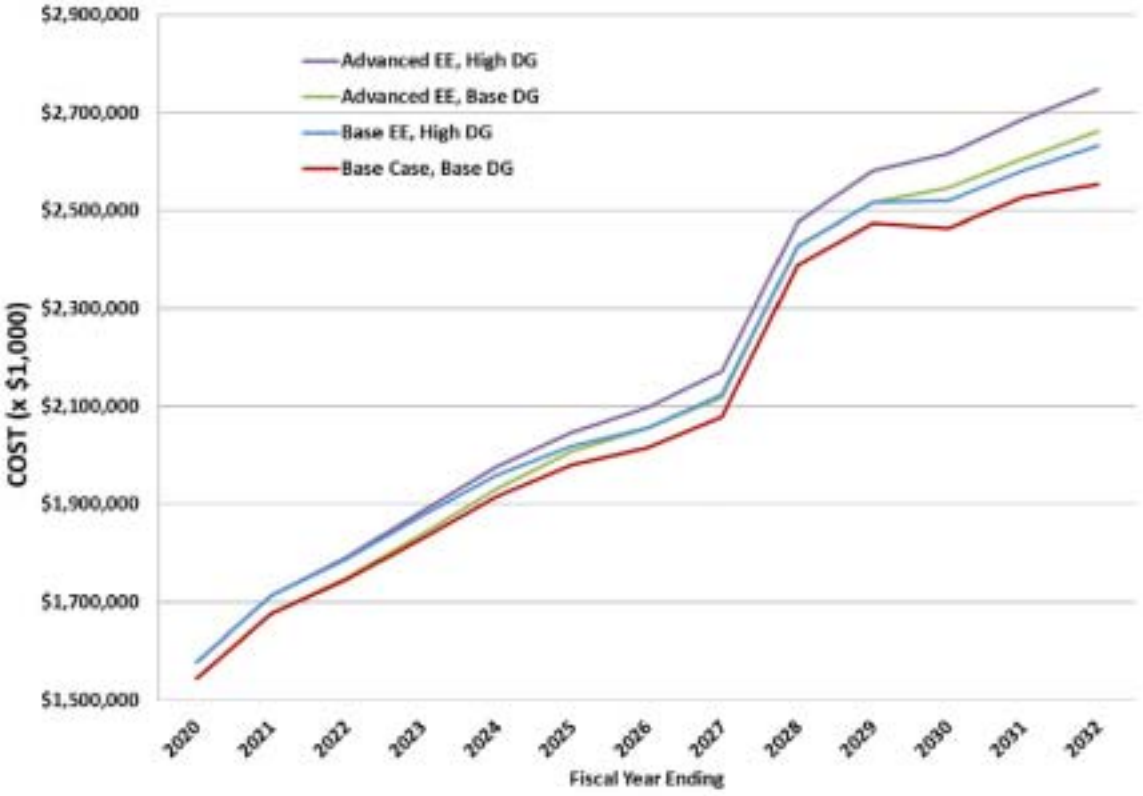

Figure 4-14. Bulk Power Cost Comparison of EE/DG cases (2020 thru 2032)

Table 4-4. Incremental Cost vs. Base EE, Base DG Comparison

	Base EE & Base DG	Base EE & High DG	Advanced EE & Base DG	Advanced EE & High DG
Fuel & Program Costs $M	$0	$428	$254	$766
DG Integration Costs - DG $M	$0	$39	$0	$39
T&D Savings - FIT, UBS $M	$0	($15)	$0	($15)
Net Lost Revenue - EE CNIM $M	$0	$217	$240	$457
Total Incremental Revenue $M	$0	$669	$494	$1,247
Average Incremental Revenue ($M/yr)	$0	$32	$24	$59
Average Incremental Cost (Cents/kWh)	0.00	0.14	0.10	0.26

The results show that both higher levels of EE and DG must be carefully considered in the utilities overall finances as these programs tend to require higher levels of revenue as

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compared to other alternatives. For customers that implement both EE programs and Solar CNM, the opportunity to realize savings in their use of electricity and associated savings can be substantial and should be encouraged. However, from the utility perspective, it is important that cost recovery mechanisms are established to recover reduced revenues that come from Solar CNM and Energy Efficiency to minimize the impact on other programs that require appropriate funding levels to maintain reliability of the electric grid and comply with existing laws and regulations. Careful planning of these resources must also be evaluated periodically as new cost information becomes available (e.g., Energy Efficiency Potential Study) to provide the most economical mix of future resources.

4.3.3.2 Cost Comparison Between Coal Cases 1 thru 4

The total fuel and variable costs for the 4 coal replacement cases are shown in Figure 4-15 below. The natural gas price used in the production model was the 20-yr long-term natural gas price forecast from Platts and is also considered as the expected natural gas price in the stress test study in Section 4.3.3.3.

Figure 4-15. Total fuel and variable cost comparison by fiscal year (Includes renewable project costs).

Replacement of IPP and Navajo results in higher fuel and variable O&M costs, as less expensive coal is replaced with relatively higher cost gas-fired energy. The resulting increase in fuel costs from the Navajo divestiture is due to a blended increase of in-basin and out-of-basin gas fired generation. In reality, resources replacing Navajo consist of a blend of new

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energy efficiency, new renewable energy, and new replacement gas-fired combined cycle units. The gas-fired replacement resources for Navajo can be better seen in Table 4-5. Because all 4 coal cases analyzed have the same renewable portfolio, the cost differences between the cases can only be attributed to increased gas cost; therefore, the costs shown in Table 4-5 do not include any incremental costs associated with new renewable resources.

Table 4-5. Increased incremental capital, fuel, and variable O&M costs related to replacement of Navajo and IPP by fiscal year

Delta -Navajo Early Divestiture Study (Case 2 - Case 1) ($M) [FYE]	2016	2017	2018	2019	2020	Total
Capital & Fixed OM Cost						
300 MW Navajo Replacement Cost	$9 M	$18 M	$18 M	$18 M	$12 M	$74 M
Fuel Cost	$12 M	$28 M	$32 M	$33 M	$17 M	$121 M
VOM Cost	$0 M	$3 M	$2 M	$3 M	$1 M	$9 M
Total Cost Delta	**$22**	**$48**	**$52**	**$53**	**$30**	$205 M

Delta - IPP 2020 Conversion Study (Case 3 - Case 2) ($M) [FYE]	2021	2022	2023	2024	2025	2026	2027	Total
Capital & Fixed OM Cost								
IPP Replacement Cost	$19 M	$38 M	$43 M	$52 M	$61 M	$64 M	$59 M	$337 M
Natural Gas Pipe line Cost *	$4 M	$4 M	$4 M	$4 M	$4 M	$4 M	$4 M	$30 M
SubTotal	$23 M	$43 M	$47 M	$56 M	$65 M	$69 M	$63 M	$368 M
Fuel Cost	$80 M	$177 M	$176 M	$178 M	$167 M	$190 M	$204 M	$1,173 M
VOM Cost	$18 M	$39 M	$39 M	$39 M	$38 M	$39 M	$38 M	$250 M
Total Cost Delta	**$121**	**$259**	**$262**	**$273**	**$270**	**$298**	**$305**	$1,790 M

*Note: * Pipeline installation cost is based on $60 M one-time cost amortized over 25 year period with 5.5% interest.*

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Delta - IPP 2023 Conversion Study (Case 4 - Case 2) ($M) [FYE]	2021	2022	2023	2024	2025	2026	2027	Total
Capital & Fixed OM Cost								
IPP Replacement Cost				$24 M	$61 M	$64 M	$59 M	$208 M
Natural Gas Pipe line Cost *				$4 M	$4 M	$4 M	$4 M	$17 M
SubTotal				$28 M	$65 M	$69 M	$63 M	$225 M
Fuel Cost				$65 M	$167 M	$190 M	$204 M	$627 M
VOM Cost				$13 M	$38 M	$39 M	$36 M	$128 M
Total Cost Delta				$106	$270	$298	$305	$980 M

*Note: * Pipeline installation cost is based on $60 M one-time cost amortized over 25 year period with 5.5% interest.*

4.3.3.3 Fuel Price Stress Test

The importance of stress testing the model results of the 4 coal cases is to determine the range of exposure to economic risk due to fuel price volatility. Historically, natural gas prices have tended to be volatile and unpredictable and LADWP employs hedging techniques to constrain volatility within acceptable ranges. However, diversification of fuel resources is also an effective means to mitigate economic exposure to a single fuel source. For example, renewable energy supplies a necessary hedge against increased fuel price exposure and eliminates the fuel cost for 20 percent of our current fuel supply.

Coal purchased by LADWP over the last 30 years has traditionally been provided primarily through long term coal contracts where future costs are reasonably predictable. Additionally, a small portion of LADWP's coal supply is provided through short term coal purchases subject to market fluctuations. Therefore, natural gas prices become the primary concern when assessing future cost impacts. Replacing Navajo and IPP Generating Stations with gas fired generation would expose our ratepayers to fuel markets which may result in higher or lower fuel costs which are much less predictable.

Realizing the need for accurate fuel price forecasts, LADWP contracted with Wood Mackenzie Research and Consulting to provide natural gas price high and low forecasts to stress test future power production costs as shown in Figure 4-16. Also included in the high and low range forecasts were coal prices received from LADWP's External Generation Group. Based on the expertise and experience of the Coal Supply Group, a $\pm$20 percent factor was applied to the expected coal fuel price to determine a high and low range for coal prices.

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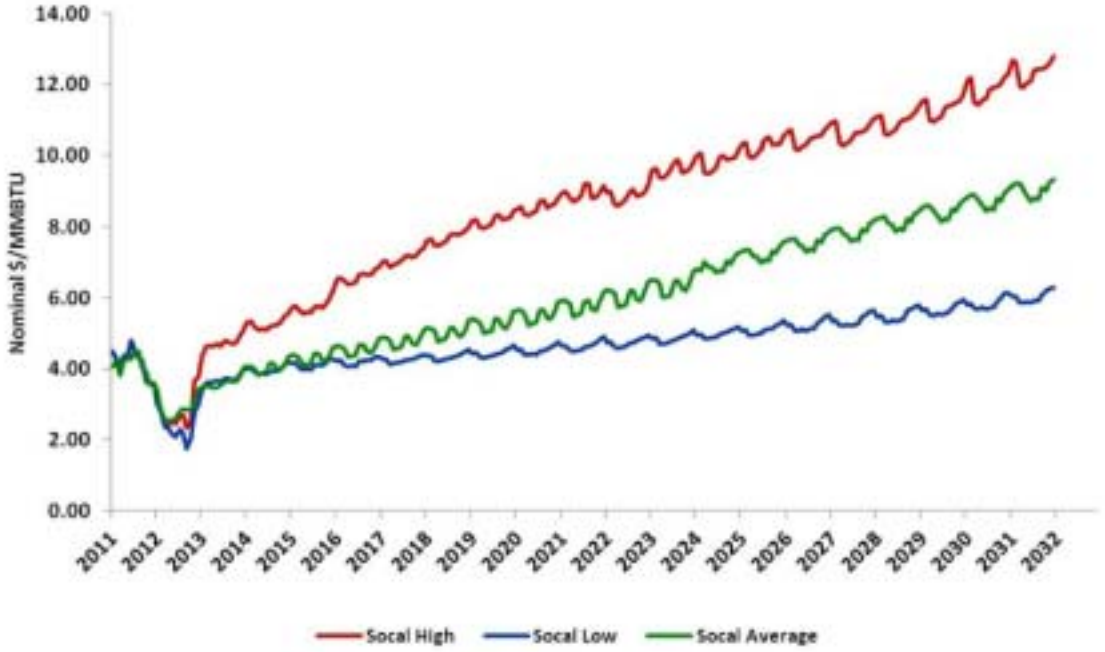

Figure 4-16. High, low, and expected natural gas price forecasts (So Cal Gas).

The natural gas price curves furnished by Wood Mackenzie Research and Consulting show a greater propensity towards higher than expected gas fuel prices, and less risk of experiencing lower than expected prices. This is wholly consistent with past historical gas prices which are shown in Figure 4-17 – the relative shape of the curve is asymmetrical with the forward tail (higher prices) extending further away from the mean of the curve.

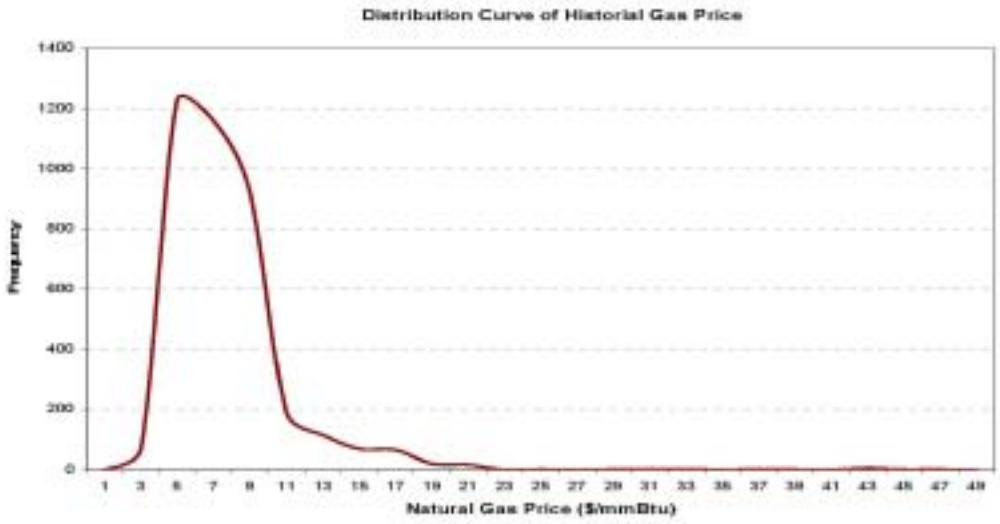

Figure 4-17. Historical distribution of natural gas prices (SoCal, 2005 through 2010).

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The high and low fuel price ranges were then incorporated into the four strategic case model runs. The four charts shown in Figure 4-18 display the results of bulk power costs for each of the 4 coal cases. The wider the range from the high fuel case to the medium fuel case indicates increased exposure to risk from the higher fuel costs.

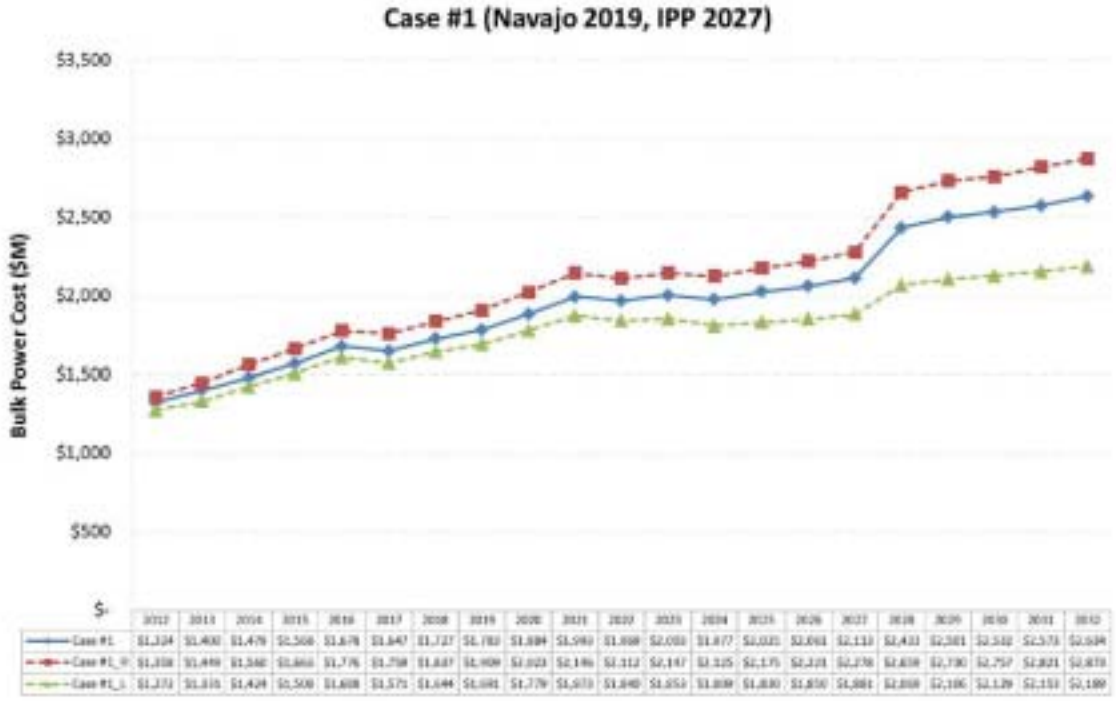

Figure 4-18. Bulk power cost comparison - high, low, and expected fuel prices.

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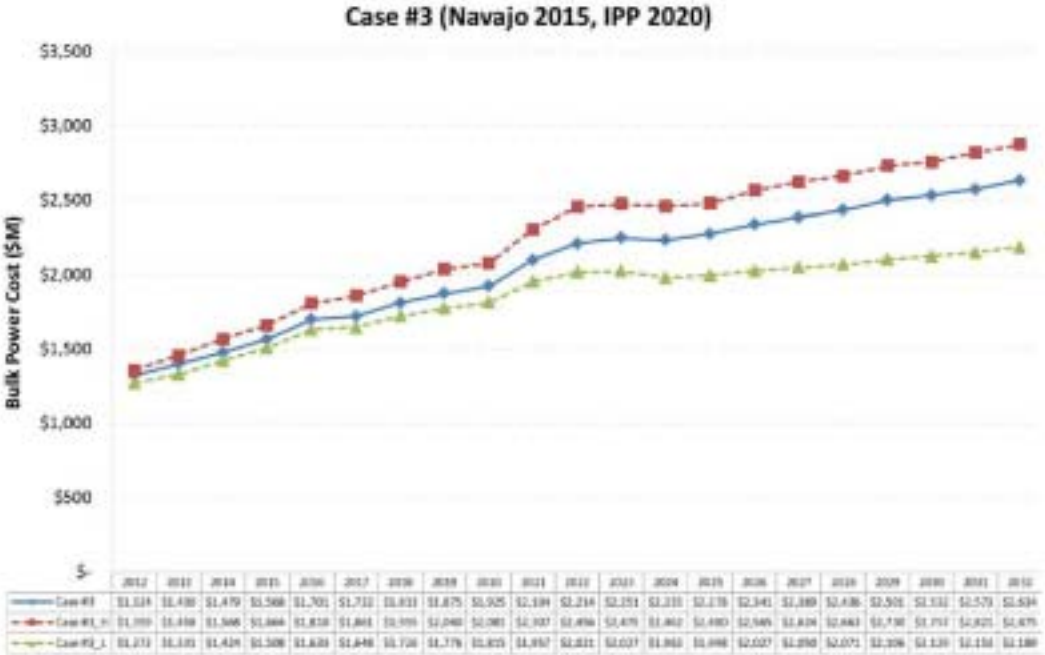

Figure 4-18. (continued)

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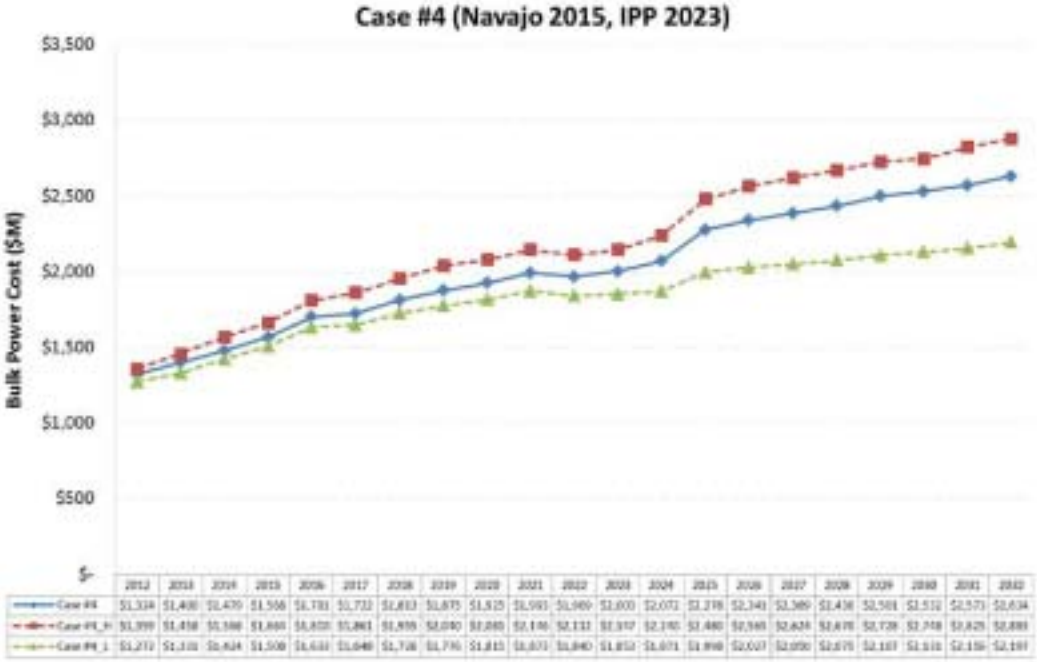

Figure 4-18. (continued)

An analysis of the effects of fuel price volatility was performed for the four coal cases and is shown in Figure 4-18. With the early divestiture of Navajo in 2015 and the IPP coal contract ending in June 2027, increased bulk power costs are expected with the replacement of each of these resources.

Elimination of coal involves the switch to more natural gas generation, which has higher fuel price volatility compared to coal. This higher volatility will increase the risk of fuel cost changes in the future and so warrants careful evaluation when comparing the different case scenarios.

It is important to note that bulk power costs shown in Figure 4-19 include fuel, renewable and other purchase power costs in addition to coal replacement costs. After applying high and low fuel prices to these bulk power costs, the replacement of these resources could result in large cost increases should fuel prices remain at higher than expected levels. Conversely, lower than expected fuel prices could have the opposite effect on bulk power costs

To help manage natural gas fuel price volatility, LADWP employs financial hedges for up to ten years, and physical hedges for up to five years. LADWP is in the process of developing a revised hedging strategy based on the newly approved rate ordinance.

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Figure 4-19. Bulk power cost with high and low fuel costs by calendar year.

By the year 2020 NGS will retire in all four cases, with Case 3 and 4 showing IPP being replaced in 2020 and 2023, respectively, with two 575 MW combined cycle units.

With all coal generation being eliminated the exposure risk of much higher spending on fuel and variable costs will be present.

Increased risk exposure from high fuel costs may translate into higher customer electric rates. Figure 4-20 shows the potential rates that could be experienced under the 4 coal cases given high, expected, and low fuel ranges for both gas and coal fuel types. Today, overall coal costs represent approximately 65 percent of overall fuel expenditures. Once Navajo coal is replaced in 2015, this percentage will drop to 50 percent of overall fuel expenditures. From 2023 thru 2026, coal expenditures will gradually drop to 30 percent before reaching zero percent in 2027 when IPP coal is replaced, and future fuel price increases will be based solely on natural gas and nuclear.

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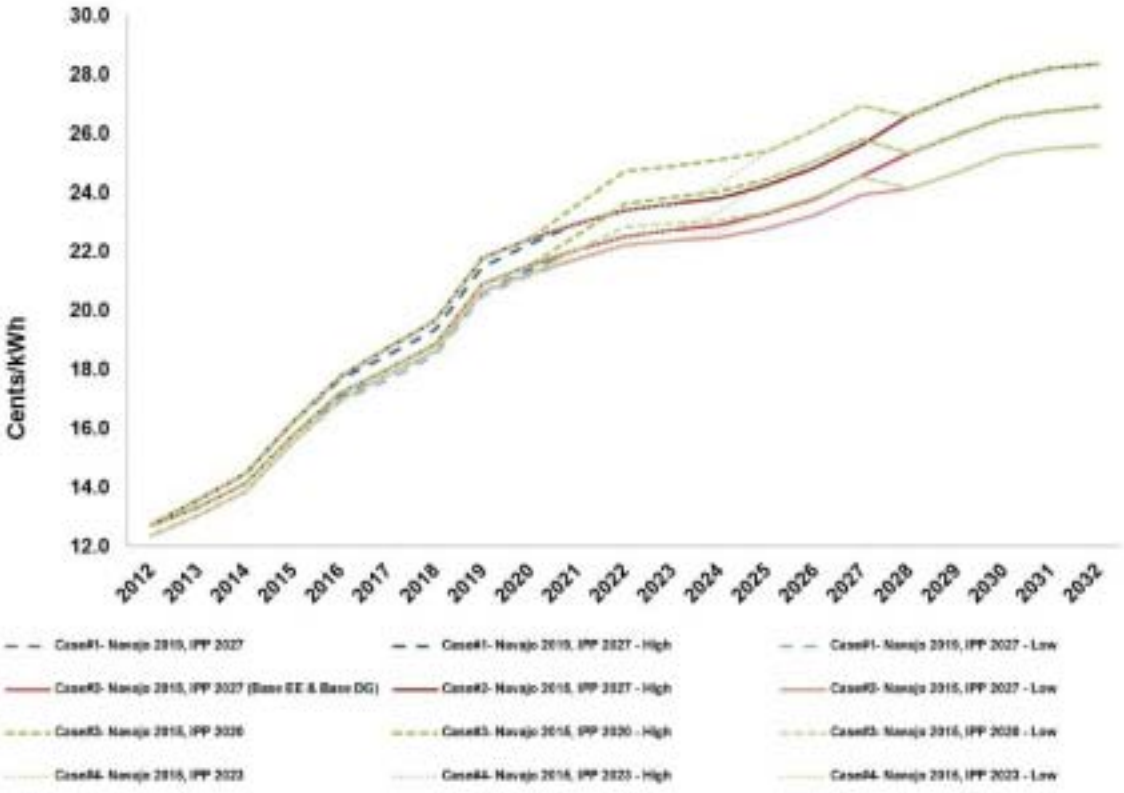

Figure 4-20. Estimated electric rate comparison with fuel price sensitivity over 20 years by fiscal year-ending

4.3.3.4 Reliability and Regulatory Revenue Requirements

Bulk Power costs discussed previously make up less than half of the cost to operate the electric power system. Continued investments in transmission, distribution, and generation resources are required to maintain a reliable electric system. While specific regulatory and reliability programs such as RPS, OTC, and PRP attract the most attention, investments in these programs are a subset of the generation, transmission, and distribution system that comprises the Power System. Besides fuel and inflation costs, these reliability and regulatory programs are the largest factors driving increases in Power System costs.

The revenue requirements of these programs are further illustrated in Figure 4-21 and Table 4-6. Today, these reliability and regulatory programs comprise 28% of all Power System costs and in 2020 these same programs will grow to approximately 42%.

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Table 4-6 shows the breakdown of these reliability and regulatory costs with RPS and PRP programs clearly being the major drivers behind overall increases in Power System costs. The importance of adequately funding of these programs through consistent revenue increases over time is essential to achieving the goals of reliability, environmental stewardship, and maintaining competitive rates.

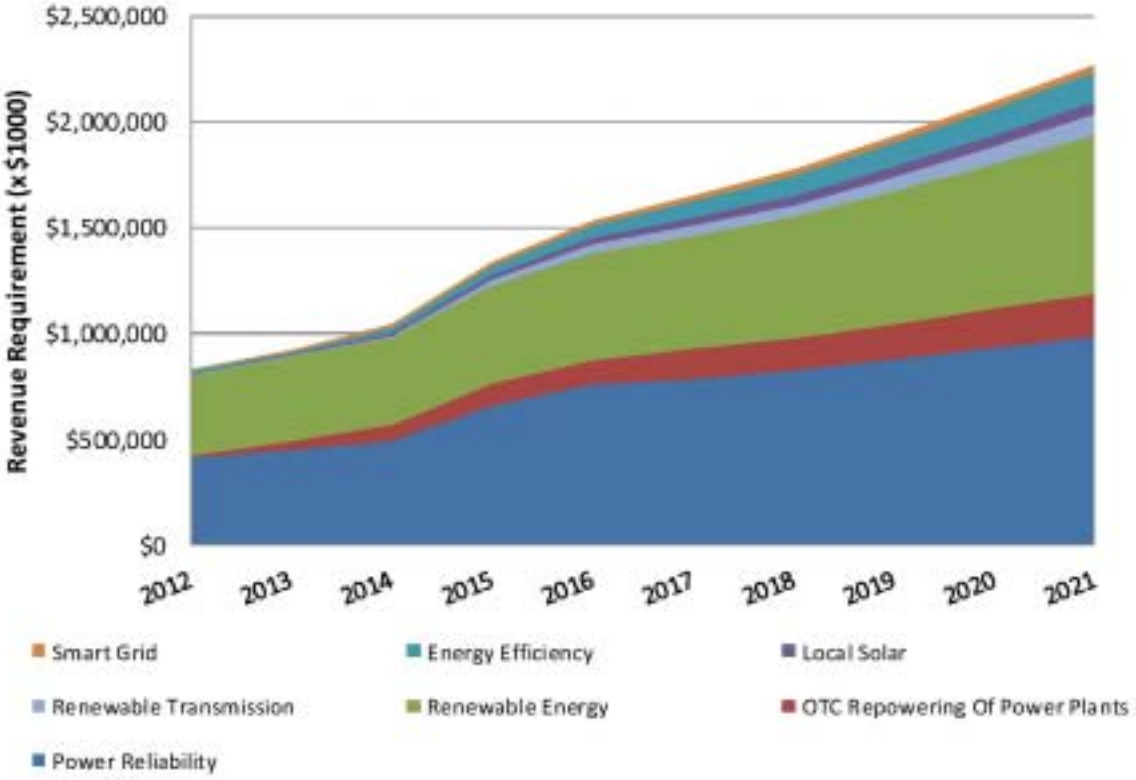

Figure 4-21. Annual revenue requirement for reliability and regulatory program for fiscal year ending 2012 through 2021.

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Table 4-6. Annual revenue requirements of Power System programs, fiscal year ending 2012 through 2021 (x$1000) – Case 2

Power Reliability											
Debt Service (Less Build Grid)											
O&M	$562,542	$596,529	$572,302	$534,033	$512,000	$534,000	$554,000	$561,250	$562,248	$596,551	
Sum Total 2011-2020	$7,195,805										
OTC Repowering Of Power Plants											
Debt Service											
Sum Total 2011-2020	$1,182,154										
Transition from Coal Early (NGS)											
Debt Service											
Fuel & VOM											
Sum Total 2011-2020	$205,468										
Renewable Energy											
Debt Service											
O&M											
Purchased Power (PPAs)											
Sum Total 2011-2020	$6,319,979										
Renewable Transmission											
Debt Service											
Sum Total 2011-2020	$142,731										
Local Solar											
SBI Debt Service											
UDS Debt Service											
LT PPAs											
Sum Total 2011-2020	$313,480										
Energy Efficiency											
Debt Service											
O&M											
Sum Total 2011-2020	$711,747										
Smart Grid											
Debt Service (Operation Support)											
Debt Service (PRP)											
Sum Total 2011-2020	$188,877										
Basic Gen. Trans. Dist											
Sum Total 2011-2020	$25,130,091										
Total Power System Revenue Requirement											
Sum Total 2011-2020	$40,957,000										

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4.3.3.5 Total Power System Cost Comparisons

The total Power System cost for each case includes bulk power costs, depreciation costs related to transmission, distribution, and generation, bond debt-service, and city transfer[9] costs. These costs assume full funding of the Power System programs including the preferred Power Reliability Program and Energy Efficiency programs among others. Total annual Power System costs are shown in Figure 4-22 and reflect short-term spending reductions through 2011-12 fiscal year with subsequent years reflecting a restoration of funding levels to ensure that the longer term IRP recommendations can be realized. To the extent that energy efficiency costs are lower than the costs of generation it is replacing, its effect is to lower total costs. The costs shown in Figure 4-22 do not attempt to represent a thorough analysis of Power System finances. The main goal of this section is to illustrate the general trend of Power System costs relative to the 4 coal and 4 EE/DG cases analyzed.

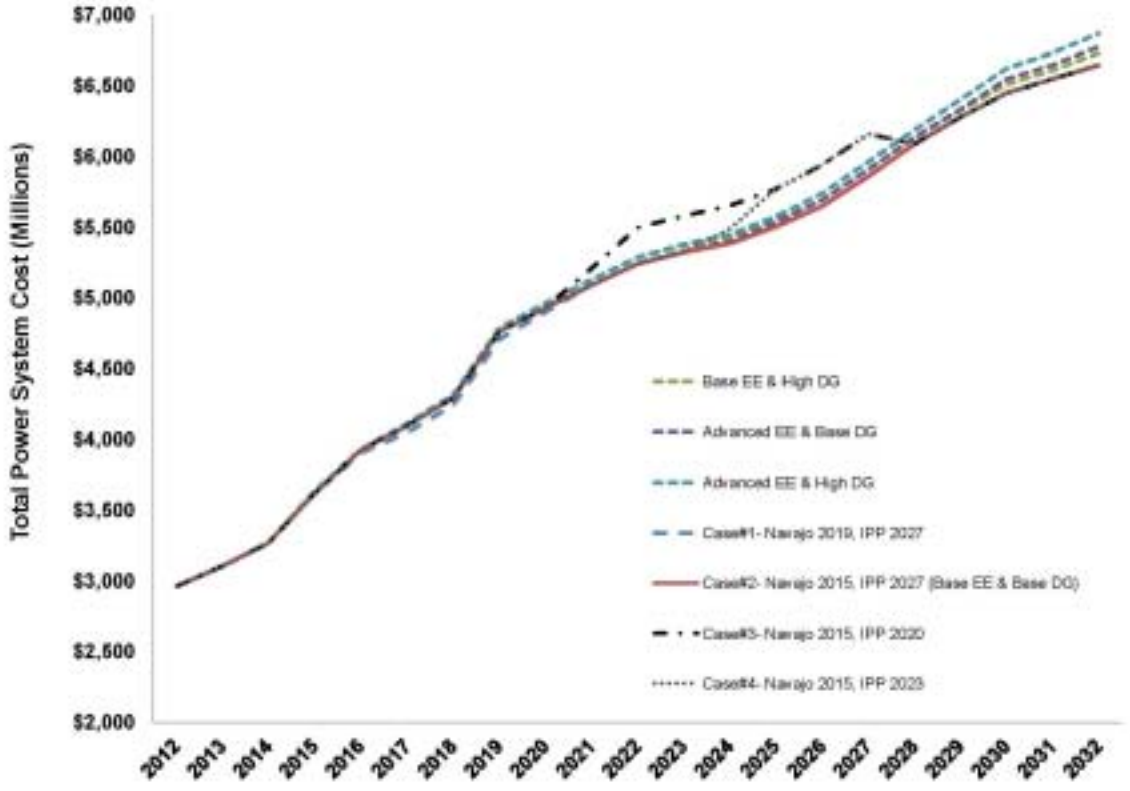

Figure 4-22. Comparison of annual Power System costs over the next 20 fiscal years.

[9] The city transfer payment is 8% of the previous year's operating revenue.

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The cost differences between the cases are highlighted in Table 4-7, which presents the incremental costs of the 4 coal cases and the 4 EE/DG cases. For the coal cases, the values listed under the Case 2 column represent the incremental costs between Cases 1 and 2 – i.e., the cost of early divestment of Navajo. The values listed under Case 3 and Case 4 represent the additional incremental costs of early IPP replacement in 2020 and 2023, respectively.

All EE & DG cases assume Navajo divestment in 2015 and IPP replaced in 2027. The values shown for Cases 6, 7, and 8 represent each case's incremental costs when compared to Case 5.

TABLE 4-7 - INCREMENTAL COST COMPARISONS BETWEEN CASES

Coal Case Summary

	Case 1	Case 2	Case 3	Case 4
Case Description	Navajo 2019, IPP 2027	Navajo 2015	IPP 2020	IPP 2023
Total Incremental Revenue $M	$0	$205	$1,790	$980
Average Incremental Revenue ($M/yr)	$0	$51	$275	$280

EE & DG Case Summary

	Case 5 (Baseline) *	Case 6	Case 7	Case 8
Case Description	Base EE & Base DG	Base EE & High DG	Advanced EE & Base DG	Advanced EE & High DG
Total Incremental Revenue $M	$0	$669	$494	$1,247
Average Incremental Revenue ($M/yr)	$0	$32	$24	$59

Figure 4-23 illustrates the net present value of the total Power System costs for each of the coal strategic cases.

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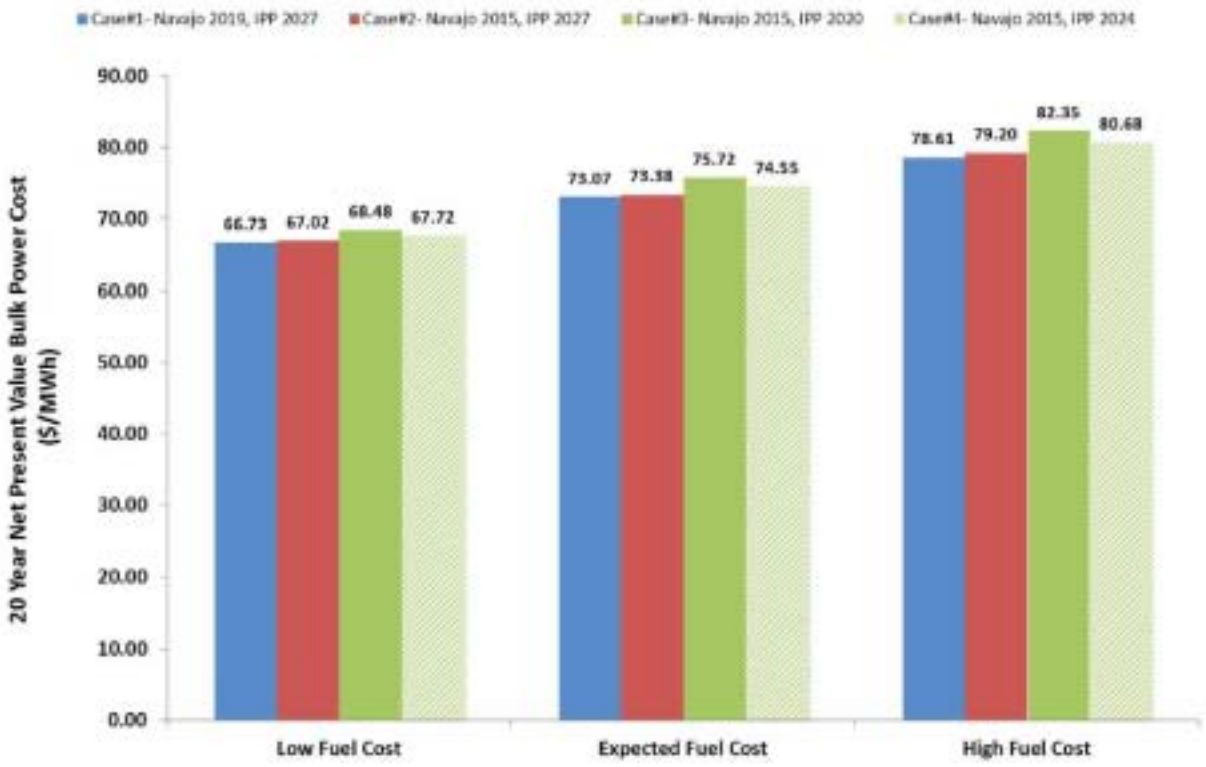

Figure 4-23. Total net present value comparison of Power System costs of 4 coal cases.

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4.4 Strategic Case Conclusions and Recommendations

4.4.1 Reliability

All four cases were designed to satisfy Power System reliability requirements. Based on the loss of load probability and resource adequacy analysis discussed in Section 4.3.1, all four cases are considered equal in terms of meeting reliability. To ensure that reliability is maintained during the replacement of Navajo and IPP, specific replacement strategies should be employed to assure a smooth transition. Further analysis may be required to refine the appropriate blend of renewable, gas-fired, energy efficiency, and demand response resources to replace Navajo and IPP based on reliability considerations.

4.4.2 GHG Emissions Reduction

As expected, the sooner generation from coal is removed from LADWP's portfolio, the greater the reduction of GHG emissions is achieved. Case 2 removes NGS energy four years earlier than in Case 1 and results in 7.2 million metric tons less GHG emissions over the 20-year study period. In addition to early NGS divestiture, Case 3 accelerates the replacement of IPP seven years earlier than Case 2, results in a further reduction of 19.5 million metric tons over the 20-year period whereas Case 4 replaces IPP four years earlier which reduces an additional 9.3 million metric tons of GHG emissions. See Figure 4-4 and Table 4-3.

4.4.3 Economic

While the Base Case appears the least cost assuming moderate GHG emission costs, it fails to make significant progress toward the reduction of GHG emissions goals set forth by LADWP. The choice between coal replacement options of either Case 2, 3 and 4 depends on the level of rate increases ratepayers are willing to support while achieving the 33% required RPS by 2020, repowering of in-basin gas fired generation, funding and implementing local solar, Demand Response and Energy Efficiency programs, and providing additional external generation to supplement the lost generation resulting from coal replacement.

With early divestiture of Navajo, an additional revenue increase of $51 million per year or $205 million over four years would be necessary to achieve GHG reductions of 7.2 million metric tons between years 2016 and 2019. This equates to a cost of $28 to remove 1 metric ton of GHG. However, as previously discussed in Section 4.3.3.3, the early divestiture of Navajo will expose ratepayers to potentially higher natural gas fuel prices that may result in further revenue increases up to $141 million per year if gas prices were to remain at these higher levels.

Considering Case 3 with early replacement of IPP and Navajo, revenue increases of approximately $275 million per year or $1,790 million over 6.5 years would be necessary to achieve additional GHG reductions of 19.5 million metric tons between the years 2021 and 2027 due to the replacement of IPP. This equates to a cost of $92 to remove 1 metric ton of

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GHG. With potentially higher natural gas fuel prices, additional revenue increases could be as high as $214 million per year if gas prices were to remain at these higher levels.

The new Case 4 presents a new scenario with early divestiture of Navajo and replacement of IPP in 2023 with a better financial plan as discussed in the beginning of this section, at the same time yielding significantly reduced GHG emissions. Case 4 will result in an increase of $245 million per year or $980 million over a four year period and would result in a cost of $105 to remove 1 metric ton of GHG.

4.4.4 Recommended Case

Decisions to fund coal replacement strategies, energy efficiency, or distributed generation cannot take place independent of other Power System programs. Maintaining reliability and meeting regulatory requirements are primary considerations before any discretionary coal replacement or EE/DG cases can be considered. However, this IRP presupposes funding of these programs so that the recommended case can be implemented.

Achieving the goals of reliability and environmental stewardship, while maintaining competitive rates, requires that costs be closely managed. Considering these factors, Case 5 with early Navajo coal divestiture in 2015, Base EE and Base DG with additional Local Solar FiT DG becomes the Recommended Case for the 2012 IRP. Whereas Case 5 has 75 MW of local solar FiT by 2016, the new recommendation is to adopt an additional 75 MW for a total of 150 MW by 2016 based on input that was received from the public outreach efforts. The increase in cost for the additional 75 MW of FiT is an average of 0.018 cents/kWh or a 9 cent increase in the typical residential monthly bill (500 kWh/month). Although Case 5 with the added FiT represents additional cost as compared to the 2011 Recommended Case, the additional costs to rate payers appears to be reasonable in light of the benefits of job growth and support of the local economy from adopting higher levels of DG solar. As described in the 2011 IRP, the environmental benefits of reducing GHG emissions by 7.2 MMT are still present with the early Navajo replacement. The cost to implement Navajo divestiture in terms of metric tons of GHG removed is $28/MMT. This represents a reasonable cost in line with the range of expected AB32 cap and trade allowance prices. Other benefits of early Navajo divestiture include a better sales price than waiting until 2019, and better availability (lower costs) of replacement energy. With Case 5 and the noted addition of FiT and Navajo divestiture in place, LADWP can begin to focus its attention on early replacement of IPP coal generation, prior to 2027, by working with the other power purchasers and the IPP plant owner.

The 2011 IRP included the same recommendation to accelerate divestiture of Navajo and this 2012 IRP further clarifies and supports this prior recommendation. This 2012 IRP recommended case presents a reasonable approach to achieving environmental goals and promoting job growth in the local economy without excessive costs to our ratepayers while limiting potential exposure to possible fuel price volatility to within manageable limits.

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5.0 RECOMMENDATIONS

5.1 Strategic Overview

LADWP's recommended strategy set forth in this IRP for meeting its key objectives can be separated into two areas: (1) Regulatory and Reliability Initiatives, and (2) Strategic Initiatives. Regulatory and Reliability Initiatives are required actions to ensure system reliability and compliance with regulatory and legislative mandates. Strategic Initiatives are policy actions to achieve objectives established by the LADWP Board of Water and Power Commissioners and the Los Angeles City Council, and reflect their vision and leadership. These policies include, for example, establishment of LADWP's Energy Efficiency targets, social and economic development goals, early compliance with SB 1368, and investing in infrastructure reliability.

Regulatory and Reliability Initiatives

- RPS

  LADWP must increase its percentage of renewable energy per recently enacted state law, from the current 20 percent, to 33 percent by the end of 2020. SB 2 (1X) also establishes interim targets to ensure progress towards the 33 percent goal. In addressing this mandate, it is important that LADWP expand its renewable portfolio in the most cost-effective manner as possible. As two subsets of the RPS program, SB 1 requires $313 Million of expenditures towards solar incentives (Customer Net Metered), and SB 32 mandates a Feed in Tariff program of 75 MW (although LADWP by choice will exceed this mandate and provide 150 MW by 2016).

- Power Reliability Program (PRP) and System Infrastructure Investment

  LADWP must re-establish sustained funding to invest in replacing transmission and distribution infrastructure that are contributing to outages to ensure system reliability Recent funding shortfalls have resulted in an increase in the frequency and duration of system outages. Section 1.6.3 of this IRP discusses the importance of fully funding the Power Reliability Program (PRP). As discussed in Section 2.4.6, the PRP will also optimize the resiliency of the distribution infrastructure to better withstand the more volatile weather patterns that are expected due to climate change.

- Re-powering for Reliability and to Address OTC

  LADWP will continue to re-power older, gas-fired generating units at its coastal generating station for the reasons discussed in Section 2.4.2. The repowering program is a long-term series of projects through 2029 that will increase generation reliability and efficiency, reduce NO_X emissions, and eliminate the need for once-through ocean water cooling.

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- AB 32 – GHG Cap and Trade

  LADWP will participate in the mandated greenhouse cap-and-trade system which is scheduled to start January 1, 2013. LADWP has been granted an administrative allocation of emission allowances that reflects its resource projections through 2020. At the same, it is uncertain if the program will extend beyond 2020, and if so, what LADWP obligations would be.

- Energy Efficiency (EE)

  LADWP will continue to pursue and implement EE programs per AB 2021 standards and as directed by the Board of Water and Power Commissioners, who have adopted a goal of achieving 10 percent EE by 2020, with a target of up to 15% by 2020 pending the results of an upcoming new EE Potential Study. The Base EE case evaluated in this 2012 IRP includes 10% EE by the year 2020, with higher levels of up to 15% by 2032. Next year's IRP will incorporate the findings and recommendations of the potential study as they are finalized and approved.

- SB 1368 Compliance

  LADWP's two coal-fired generation sources, the Navajo Generating Station and the Intermountain Power Project (IPP), must be compliant with the mandates established in SB 1368 by 2019 and 2027, respectively. IRP modeling determined that these units will be replaced earlier with a combination of renewable energy, demand response, EE, short term market purchases, and conventional gas-fired generation.

- Energy Storage

  Per AB 2514, LADWP is investigating Energy Storage (ES) technologies and will establish targets for implementation by October 1, 2014. LADWP will look for programs and projects that support its unique electric grid, resource plan, and projects that will facilitate renewable integration, distributed generation and demand response. As these projects are identified and scoped, they will be incorporated into and analyzed in future IRPs. See Section 2.4.5 for more information.

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- Castaic FERC Re-licensing Program

  On January 31, 2022, the Federal Energy Regulatory Commission's (FERC) license to operate Castaic Pumped-storage Hydroelectric Plant will expire. The license is a re-license between LADWP and the Department of Water Resources and includes a number of hydro power plants along the California Aqueduct. Both parties have initiated the joint re-licensing process that, on average, requires ten years to complete. Through 2015, LADWP expects to complete preliminary studies, contract negotiations, and prepare a new application strategy. In 2016, LADWP expects to file a notice-of-intent (NOI) and initiate the formal studies and applications.

- Transmission

  LADWP's Ten-Year Transmission Plan is prepared each year to ensure that LADWP remains compliant with NERC Transmission Planning Standards. The planning process involves complex modeling of the LADWP system, and concludes with findings and recommendations to avoid potential future overload conditions. LADWP will continue to implement the recommended projects, including construction of a new transmission line between Scattergood Generating Station and Receiving Station K, and upgrades at various other receiving and switching stations.

Strategic Initiatives

- Early Compliance with SB 1368

  Regarding the Navajo Generating Station (NGS), while power imports can legally continue until 2019, LADWP recommends divestiture from NGS four years earlier, in 2015. There are many strategic advantages to early divestiture, including:

  1. Better sales terms and conditions than waiting until the 2019 deadline.
  2. Avoiding the risk of pending federal regulations that could potentially encumber the plant with expensive mitigation requirements.
  3. Better availability and pricing for replacement generation.
  4. Reduced CO_2 emissions, alleviating LADWP from subsequently having to purchase emission credits within the soon-to-be implemented statewide cap and trade program.
  5. Transmission network for importing additional solar and geothermal resources becomes available.
  6. Low load growth and increased renewable energy place less reliance on the plant for energy.
  7. Provides time to handle contingencies, and to ensure that competition for replacement resources is going to benefit our ratepayers.

AR0070066

Regarding the Intermountain Power Project (IPP), LADWP recommends modeling and planning to be compliant with SB 1368 by 2027. However, LADWP, the Intermountain Power Agency (IPA), and the other 36 participants are considering the conversion of IPP from coal to natural gas. A new contractual arrangement is in process, which will establish a firm conversion date that will be no later than, and possibly sooner, than 2027.

Strategically, it is important for LADWP to remain a participant at IPP to retain geographic diversity in its resource mix, access the regional fuel supply, and retain the project's transmission lines to access renewable energy from the region.

- Demand Response

  LADWP should accelerate its evaluation and implementation of Demand Response programs that will initially provide 5 MW of new peak demand capacity beginning in 2013 and gradually build to 200 MW by 2020 and 500 MW by 2026. Ramping the program in this manner will provide the development of in-house expertise, and will also allow time to deploy the supporting information systems necessary to implement these systems successfully.

- Local Solar

  Comments received at prior public workshops indicate local solar development should be a priority in LADWP's renewables procurement strategy. LADWP is recommending a policy action to allow 340 MW of its solar resources be sited locally by 2036, through initiatives including the Solar Incentive Program, feed-in tariffs, and installation of solar on City-owned properties. Local solar costs an estimated additional $36/MWh over utility-scale solar located outside the Los Angeles Basin, estimated to cost $176/MWh, primarily due to economies of scale and about 30% better solar insolation, even when considering transmission and distribution costs.

- Advanced Reliability Improvements

  LADWP is looking ahead to technologies that will enhance the reliability of its system, including smart grid, energy storage, enhanced information and management systems, automation of system functions, advanced methods of outage management, and weather forecasting. These advanced system enhancements will increase reliability, facilitate the integration of local solar generation and other variable renewable resources into the distribution network, enable smart charging of electric vehicles, and advanced demand-side management technologies. LADWP should continue to pursue grants, cost-sharing opportunities, and joint projects that advance the use and deployment of new technologies that meet its strategic goals.

AR0070067

- Provide Sufficient Generation

  Provide sufficient generation, demand response, and limited short term purchases in peak season Q3 to cover operating and replacement reserves in accordance to applicable federal and regional reliability requirements.

- Control of Transmission Assets

  In addition to the regulatory requirement to remain compliant with NERC Transmission Planning Standards, LADWP will maintain its policy of maintaining control of its transmission assets and continue to augment those assets commensurate with load growth, reliability needs, and renewable energy opportunities.

- Collaborate with Water System

  The LADWP Power System will continue to work with the Water System to develop programs that reduce the usage of electricity and conserve water, as well as optimizing hydroelectric energy production.

- Financial Targets

  To preserve and maintain its credit rating, the following financial targets have been adopted.

  - Maintain debt service coverage at 2.25 times
  - Minimum operating cash target of $300 million
  - Debt-to-capitalization ratio less than 68 percent

AR0070068

5.2 Incorporating Public Input

Through its public outreach efforts in 2012, LADWP received various suggestions from the community including increasing energy efficiency and conservation, eliminating coal from LADWP's resource mix, emphasizing local solar generation, maintaining competitive rates, and addressing infrastructure reliability issues. This input played a key role in shaping the recommendations set forth in this IRP. The major themes that emerged from the public input are listed below. Each theme is considered of equal importance and the themes are not listed in any order of priority.

Major Discussion Themes

Eliminate Coal From LADWP's Energy Portfolio

The majority of comments favored the early removal of coal from LADWP's resource portfolio. Some were concerned that Navajo would continue to operate after LADWP divestiture, and suggested the plant be shut down. Greenhouse gas emissions, along with other pollutants associated with coal energy were noted.

Incorporate More Renewables

Many public comments suggested higher levels of renewables, beyond the mandated 33% by 2020. Some promoted the idea of 50% and even 100% renewables. LADWP's approach regarding this is to proceed cautiously until more is known about the operational and financial implications of higher levels of renewables. The IRP is prepared annually, and it is possible that future IRPs will include cases that incorporate higher levels of renewables.

Incorporate More Local Solar

Many comments promoted the adoption of higher levels of local solar, noting the abundance of sunshine in southern California region. The benefit of providing local jobs was also noted as a supporting argument to increase penetration levels. One comment suggested installing solar on every house and building in Los Angeles. Regarding LADWP's current solar incentive program, multiple comments recommended hiring more inspectors to streamline the process which many see as too slow, especially when compared to other utilities.

Incorporate More Distributed Generation

Since the majority of LADWP's new Distributed Generation (DG) will come from local solar, this theme is somewhat associated with the More Local Solar theme. Most of the comments regarding more DG point to the governor's statewide goal for 12,000 MW, of which LADWP's proportionate share is assumed to be 1,206 MW. Within this 2012 IRP, the highest levels of new DG considered for analysis were 485 MW by 2022, and 852 MW by 2032. LADWP's concern with DG levels is maintaining reliability (see Section 3.4.4). Numerous utility studies have recommended a limit of 15% of the peak load circuit capacity, which for LADWP is approximately 900 MW. As LADWP adopts more DG per its current plan, and as more experience is gained along with more industry-wide research in this area, it is possible that future IRPs will consider higher DG levels.

AR0070069

Incorporate More Energy Efficiency

LADWP's Energy Efficiency (EE) targets, based on year 2030, have increased significantly, from 8.6% approved in December 2011, to 10% approved in May 2012, with a further anticipated increase to 15% pending completion of an updated potential study in 2013. Comments received supported incorporating more EE and Demand Response into LADWP future plans. As presented in this 2012 IRP, EE and DR is a vital component within all long term resource planning options. As the results of the upcoming potential study are developed and finalized, they will be adopted into the IRP planning strategy.

Reduce Greenhouse Gas Emissions

This was an overarching theme of the public comments received. Indirect societal costs, health effects, global warming, and super storm Sandy were cited as reasons for accelerating the timelines to reduce GHGs. In considering the GHG impacts of fuel consumption for electricity generation, many comments pointed to the additional impacts resulting from fuel production (coal mining and gas drilling). Comments pointed out the need for considering energy efficiency, demand response, load shifting, and other technologies such as shunt reactive support to offset future additions of gas-fired capacity.

Look at New Case Scenarios

Many comments suggested a scenario that contained no new gas-generation resources, an eventual portfolio of 100% renewables, and investments in EE, conservation, renewables and demand response. Some felt that multiple sets of potential renewable resource mixes should be considered. LADWP prepares a new IRP annually and will consider new scenarios within subsequent case optimization processes.

Financial and Rate Concerns

Some comments expressed concern that LADWP needs to ensure its financial stability and integrity. Many comments presented concerns with rising electricity rates wanting to ensure that the cost and benefits were clearly presented, and recommended a comparison of costs with other regional and out-of-state utilities. One comment suggested that LADWP keep coal for as long as possible explaining that other forms of energy were not mature and too costly. Conversely, other comments suggested that rate increases were acceptable if EE options are made available to help customers reduce their bills. One comment suggested that LADWP rates are too low and the tiers are too generous – resulting in disincentives for EE and renewables.

Maintain Power Reliability

Some comments expressed concern about the state of the LADWP infrastructure, noting that the reliability program continues to be subject to budgets cuts – unlike mandated areas such as renewables. They point to the 2011 windstorm and 2006 heat storm as evidence that the infrastructure is getting older and more costly to maintain, and suggest that paying more now to address this problem will save money later.

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LADWP's Should Take a Leadership Role

Regarding renewable resources and other green energy matters, many suggested that LADWP, as a municipal utility, should lead by example, consider unconventional business models, and through its governance, garner the political will to do something different.

For further discussion of the themes and the overall public outreach process, see Appendix O.

5.3 Recommended Strategic Case

As discussed in Section 4.4.4, Case 5 with the addition of 150 MW of EE1 by 2016 has emerged as the Recommended Case for this 2012 IRP. The key attributes of Case 5 includes the following:

- At least 18 percent of Los Angeles' electric needs will be met through new customer energy efficiency measures by 2020.
- At least 500 MW of capacity reduction through Demand Response programs by 2026.
- Generate at least 33 percent of its electricity from renewable resources by 2020 and maintain that level through 2032. Although this IRP incorporates one combination set of renewable resources to achieve a 33% RPS, LADWP will not limit itself to only these types and amounts of resources to achieve its goals and needs flexibility in resource development for the best fit for the electrical system.
- Diversify LADWP's RPS through incorporating 114 MWs of generic renewable resources by 2032. These resources could be technologies such as biomass, ocean tidal power or other emerging technologies.
- Diversify LADWP's energy portfolio through a variety of fuels, technologies and power plant sites throughout the western United States to maintain a high level of reliability.
- Implement advanced reliability improvements thru Smart Grid.
- Emphasize local solar by proposing approximately 340 MW of solar capacity to be locally sited in Los Angeles by 2016. This will be accomplished through programs such as the Customer Solar Incentive Program, a feed-in tariff goal of 150 MW by 2016, and Solar on Los Angeles properties under public/private partnership (a.k.a. UBS).

Benefits of early Navajo divestiture include a better sales price than waiting until 2019, and better availability (less costs) of replacement energy. With Case 5 and the noted addition of EE1 and Navajo divestiture in place, LADWP can begin to focus its attention on early replacement of IPP coal generation, prior to 2027, by working with the other power purchasers and the IPP plant owner.

The Recommended Case for 2012 is summarized in Table 5-1.

AR0070071

Table 5-1. 2012 IRP RECOMMENDED CASE

	2020	SB 1368 Compliance Date		New Renewables Installed (MW) 2012-2020				New Renewables Installed (MW) 2012-2032				
Case ID	RPS Target	Navajo End Date	IPP End Date	Geo/ Biomass	Non-DG Solar	Dist. Solar	Generic	Geo/ Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
Case 5	33%	12/31/2015	6/15/2027	242	842	382	39	283	54	915	496	114

Figure 5-1 illustrates the changing generation resource percentages for 2010, 2020, and 2030 based on the Recommended Case. Because energy efficiency forecasts are forward-looking, the savings of 1,256 GWh or 5.5 percent of sales that was implemented between 2000 and 2010 are embedded into the load forecast and are not included as part of the generation resource mix shown below.

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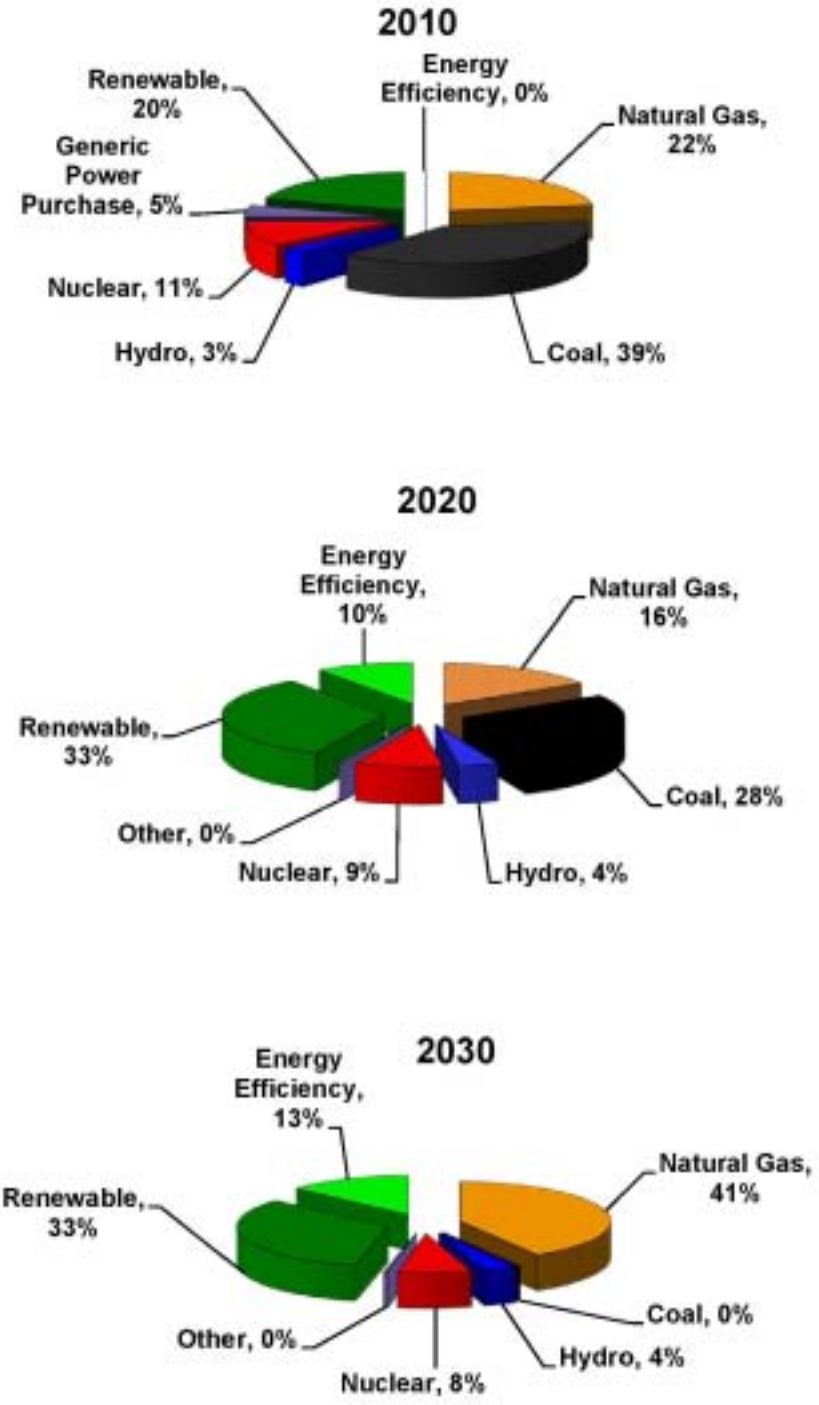

Figure 5-1. Generation resource percentages for 2010, 2020, and 2030.

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Figure 5-2 shows the renewable energy resource mix of the Recommended Case. The major change from the 2011 IRP is expanded levels of new solar over the next 20 years and lower amounts of new wind.

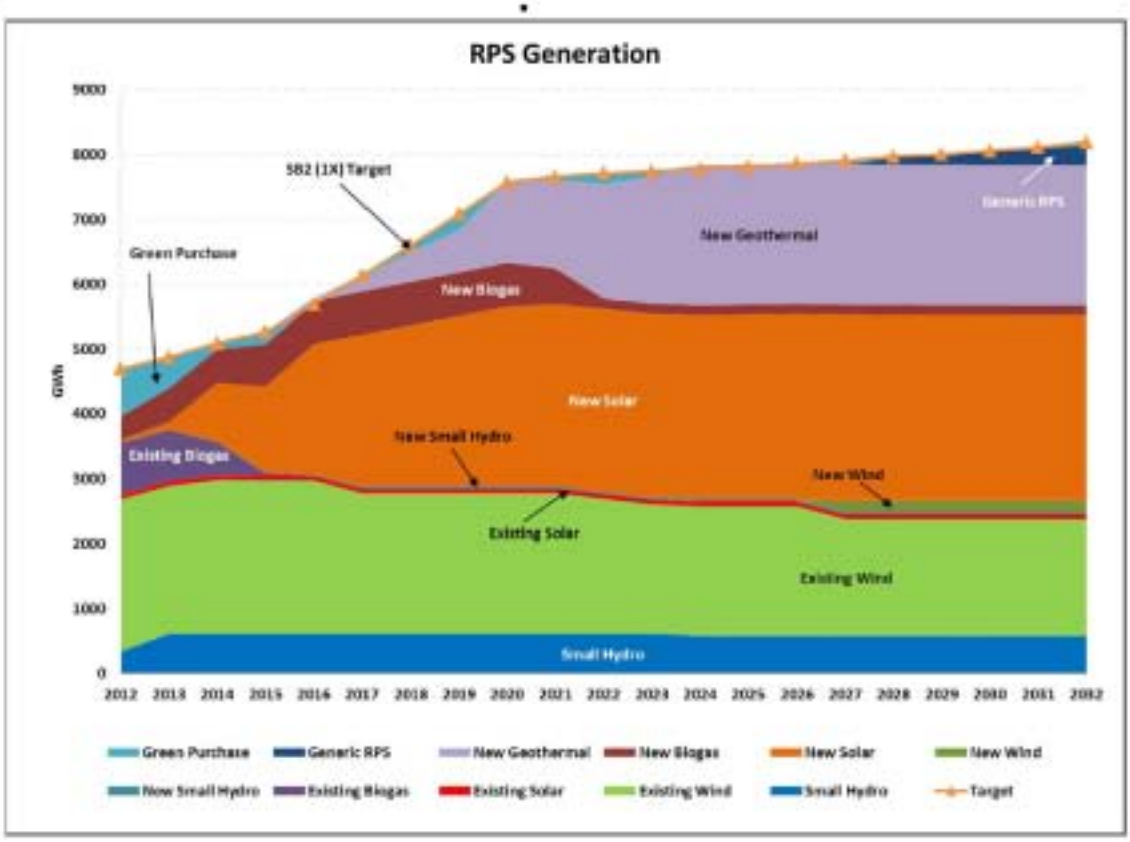

Figure 5-2. Recommended case renewable generation by technology.

The Table 5-2 below illustrates the revenue requirements necessary to supply the recommended resources required to meet future load growth, achieve energy efficiency targets, secure the necessary demand response capabilities, reach and maintain the RPS requirement of 33% by 2020 and thereafter, and ensure that the necessary replacement resources are in-service before divestiture of Navajo in 2015 and replacement of IPP in 2027 can occur.

AR0070074

Table 5-2. Revenue and resources recommended to replace coal and load growth ($ million)

FY	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy & Capacity Cost																					
Energy Efficiency	$ 6	$ 15	$ 30	$ 47	$ 64	$ 83	$ 101	$ 118	$ 135	$ 151	$ 166	$ 181	$ 195	$ 209	$ 223	$ 237	$ 252	$ 266	$ 280	$ 294	$ 309
Demand Response	$-	$ 2	$ 2	$ 2	$ 3	$ 5	$ 7	$ 10	$ 14	$ 15	$ 16	$ 18	$ 20	$ 21	$ 23	$ 24	$ 24	$ 24	$ 24	$ 24	$ 24
New Renewable																					
Solar	$ 8	$ 20	$ 57	$ 125	$ 204	$ 267	$ 294	$ 308	$ 343	$ 357	$ 362	$ 365	$ 369	$ 372	$ 374	$ 376	$ 378	$ 377	$ 379	$ 380	$ 382
Wind	$-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 15	$ 26	$ 26	$ 26	$ 26	$ 26
Geo	$-	$ -	$ -	$ -	$ -	$ 12	$ 30	$ 42	$ 72	$ 128	$ 155	$ 198	$ 229	$ 246	$ 248	$ 252	$ 252	$ 256	$ 258	$ 261	$ 265
Small Hydro	$-	$ -	$ -	$ -	$ -	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2
Generic RPS	$-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5	$ 18	$ 27	$ 34	$ 43
Green Purchase	$ 13	$ 26	$ 14	$ 7	$ 3	$ 1	$ 4	$ 30	$ 8	$ 1	$ 7	$ 9	$ 3	$ -	$ -	$ 2	$ 3	$ 2	$ 3	$ 2	$ 3
New Renewable Subtotal	**$ 21**	**$ 46**	**$ 71**	**$ 132**	**$ 209**	**$ 281**	**$ 330**	**$ 372**	**$ 425**	**$ 488**	**$ 526**	**$ 575**	**$ 602**	**$ 620**	**$ 624**	**$ 647**	**$ 666**	**$ 681**	**$ 695**	**$ 705**	**$ 722**
Q3 Term Purchase	$ 1	$ 8	$ 7	$ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0	$ 3	$ 8	$ -	$ -	$ -	$ -	$ 2
Replacement CC Capital Cost																					
Navajo Replacement CC	$-	$ -	$ -	$ -	$ 1	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18
IPP Replacement CC	$-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 6	$ 133	$ 133	$ 133	$ 133	$ 133
Total	**$ 27**	**$ 62**	**$ 103**	**$ 181**	**$ 278**	**$ 386**	**$ 455**	**$ 519**	**$ 591**	**$ 671**	**$ 725**	**$ 793**	**$ 834**	**$ 867**	**$ 887**	**$ 932**	**$ 1,089**	**$ 1,121**	**$ 1,148**	**$ 1,174**	**$ 1,286**

The Recommended Case will meet the LADWP combined objectives of maintaining a reliable Power System, environmental stewardship, and minimizing ratepayer impacts. The Recommended Case provides a roadmap for the LADWP to achieve its long term planning goals, while providing the required reliability and necessary flexibility to adapt to dynamic economic, environmental, and regulatory conditions. The Recommended Case will put upward pressure on retail rates, but will maintain adequate reliability and avoid fines and penalties that may otherwise result from violations in state and federal laws. The Recommended case also successfully reduces the amount of GHG emissions released into the environment and provides for additional job growth and economic benefits thru the increased use of local solar.

AR0070075

5.4 Revenue Requirements

A brief discussion is in order here regarding budget shortfalls over the past few years. These shortfalls have prevented LADWP from fully funding existing and new programs during that timeframe. The delays surrounding resolution of the Power System budget have the potential of impeding LADWP's ability to meet its long term plans and obligations.

Based on the 2010 IRP, a multi year rate increase was recommended beginning fiscal year 2011-12. The rate increase would have supported elements of the 2010 IRP, all of which remain as the foundation for LADWP's short and long term plans. Because the rate increase was not realized in July 2011, many of the programs that required funding were scaled down, delayed or deferred.

Last year's 2011 IRP was prepared concurrent to the rate process that began in early 2011, and recognized that the process would likely conclude in 2012. As of this writing, the rate ordinance has been completed having received City Council and Mayor approval on October 5, 2012.

Although somewhat outside LADWP's control, future *multi-year* funding plans are desirable to provide consistent and sustainable project and program development. Funding that is based on annual budgets are subject to year to year fluctuations which introduces uncertainty for our customers and the inefficient use of staff and financial resources that are necessary to meet LADWP's objectives and compliance requirements.

Properly funded programs will enable LADWP to achieve the following objectives:

- Modernize its coastal generation units to replace aging equipment and to satisfy once-through cooling regulatory requirements
- Implement early coal divestiture and replacement.
- Secure the state-mandated amounts of renewable energy.
- Through the Power Reliability Program, reduce the number of distribution outages and improve system reliability
- Implement necessary transmission improvements to maintain reliability
- Achieve energy efficiency target levels
- Implement Smart Grid initiatives
- Comply with FERC-approved reliability standards

Securing adequate multi-year funding will help to ensure LADWP's ability to stay on track towards meeting its future long term goals and obligations.

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5.5 Electric Rates

LADWP currently uses an Excel-based financial model that has been developed and used for over a decade. This financial model has been used to develop forward-looking Power System financials for the Board of Water and Power Commissioners' annual budget approval and for rating agency presentation for debt issuances.

The model is modified to analyze fuel expense, purchased power expense, and additional capital and O&M expenses for any new LADWP-owned resource additions as well as off-balance sheet resource additions. The strategic cases are overlaid on existing capital and O&M expenses for the approved FY12-13 budget data, which contains forward-looking budget data up until FY21-22. For years beyond FY22-23, general capital and O&M expenses are escalated at 2.5 percent per annum.

Effective November 11, 2012 LADWP retail revenue shall be funded from the existing Electric Rate Ordinance and the Incremental Electric Rate Ordinance through the following billing factors:

(1) Base Rate
(2) Energy Cost Adjustment (ECA) and Reliability Cost Adjustment (RCA) factors
(3) Incremental adjustments:
- Variable Energy Adjustment (VEAA),
- Capped Renewable Portfolio Standard Energy Adjustment (CRPSEAA),
- Variable Renewable Portfolio standard Energy Adjustment (VRPSEAA),
- Incremental Reliability Cost Adjustment (IRCA), and
- Incremental Base Rates

These factors are described briefly below.

Effective November 11, 2012, the Base Rate under the existing Electric Rate Ordinance shall be capped and remain fixed at their levels as of November 3, 2010. The Base Rate covers a portion of a rate other than the adjustments and is used to cover expenses from debt service arising from capital projects except RPS projects, operational and maintenance expense except RPS related, public benefit spending, property tax, and pro-rated portion of the city transfer.

The ECA under the existing Electric Rate Ordinance is used to cover fuel, purchased power, RPS and energy efficiency-related expenses. Effective November 11, 2012 under the Incremental Electric Rate Ordinance the ECA factor shall be known as the Capped Energy Cost Adjustment and shall not exceed $0.05603/kWh, which was the level applied as of November 3, 2010.

The RCA under the existing Electric Rate Ordinance is used to cover power reliability related expenses. Effective November 11, 2012 under the Incremental Electric Rate Ordinance the RCA factor applied to residential customers shall be known as the Capped Residential Capped Reliability Cost Adjustment and shall not exceed $0.00304/kWh and the RCA factor applied to general service customers shall be known as the General Service Capped Reliability Cost

AR0070077

Adjustment and shall not exceed $0.06 per kW, which were the levels applied as of November 3, 2010.

The Incremental Electric Rate Ordinance provides incremental charges to provide funding of expenditures outlet by the existing ordinance. These incremental charges are in addition to charges paid in corresponding rates of the existing Electric Rate Ordinance. These incremental charges provide more granularity and transparency for LADWP and our customers and include the following:

- Variable Energy Adjustment (VEA): Recovers costs associated with fuel, non-renewable portfolio standard power purchase agreements, economy purchases, legacy ECAF under-collection, and base rate decoupling from energy efficiency impact.
  Capped Renewable Portfolio Standard Energy Adjustment (CRPSEA): Recovers costs associated with renewable portfolio standard O&M, debt service, and energy efficiency programs.
- Variable Renewable Portfolio standard Energy Adjustment (VRPSEA): Recovers costs associated with renewable portfolio standard market purchases and costs above and beyond any O&M and debt service payments.
- Incremental Reliability Cost Adjustment (IRCA): Recover costs associated with O&M, debt service expense of the Power System Reliability Program (PRP), and RCA under-collection.
  Incremental Base Rates: Recovers costs of providing electric utility service that are not recovered by the above adjustment factors and Base Rate. These costs include labor costs, real estate costs, costs to rebuild and operate local power plants, equipment costs, operation and maintenance costs, expenditures for jointly owned plants and other inflation-sensitive costs.

To sustain LADWP's financial strength while mitigating rate impacts to customers, maintain existing "AA-" credit rating or equivalent bond ratings to minimize financing costs, and obtain funding needed for Power System capital programs, the LADWP has adopted the following financial metric targets: (1) maintain debt service coverage of at least 2.25, (2) unrestricted operating cash target of $300 million and (3) capitalization ratio of less than 68.

Debt service coverage is the amount of cash available from operation divided by the debt service amount. The debt service amount contains only LADWP's direct debt. Capitalization ratio is the ratio of the total direct debt divided by the total asset.

To achieve these various financial coverage parameters, the base rate factor will need to be increased as necessary to meet the objectives of this IRP.

5.5.1 Rates Analysis for Cases

The retail electric rates, including estimated CO_2 emission expenses, for all strategies are discussed in this subsection. Factors driving the increases over the twenty-year period include rising fuel price, increased power reliability program spending, replacement of aging basin

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generating units to meet once-through cooling and South Coast Air Quality District emission requirements, replacement of coal generation to lower CO_2 emissions, installation of renewables generation according to legislative mandates and program costs for energy efficiency, demand response, and other programs, and payment for emission allowances due to anticipated CO_2 cap and trade requirements.

The capital cost and the associated O&M expense of any new generation resource is priced at 2012 dollars with 2.5 percent escalation except for certain solar projects, which are priced at levelized 2012 dollars due to anticipated pricing declines.

For each year, the retail rate through either the base rate or the energy cost adjustment factor is raised sufficiently high enough to meet the various financial ratios recommended by financial advisors to maintain LADWP's "AA-" bond rating.

Using Case 5 as an example, which is very similar to the 2011 Recommended Case except for additional energy efficiency of 10% by 2020 and slightly higher amounts of solar DG, customer rates are estimated to increase on average 6 percent to 7 percent per year over the next five years, and 3 percent to 4 percent per year over the next 20 years.

The CO_2 emission allowance price is estimated to range from $15 per Metric Ton in 2013 to $36 per Metric Ton in 2020. The California Air Resources Board established an allocation cap, and emissions exceeding this cap will require purchases of additional allowances or in some cases, emissions below the cap can be used in future compliance periods.

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Assumptions used to model rate impacts can change. In order to reflect the variability in model assumptions, a sensitivity analysis was performed to determine a realistic range of rate impact trajectories. Figure 5-3 shows the retail price impact comparison of the 2012 IRP recommended case bounded by a high and low range fuel price. The high range assumes higher natural gas and coal costs while the low range assumes minimal natural gas and coal costs.

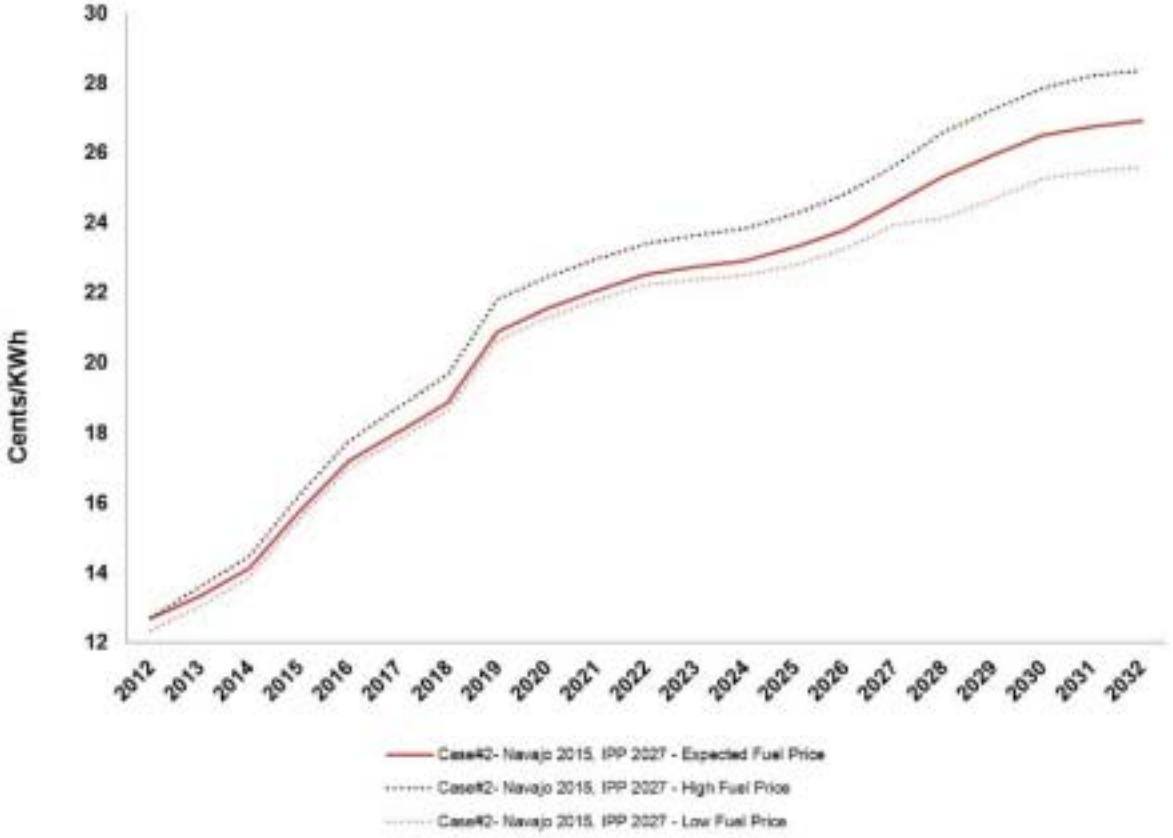

Figure 5-3. Recommended Case - retail price impact bounded by high and low range fuel.

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Figure 5-4 presents the fiscal year breakdown for Case 5 comprising rate contributions from reliability, energy efficiency, renewable energy, coal replacement, OTC repowering, other General Transmission and Distribution (GT&D), and fuel costs between 2012 and 2032. These individual contributions represent incremental adders to the rates. For analysis purposes, the Reliability Program has been segmented into the basic program and preferred program. The preferred program contribution shown is incremental to the basic program.

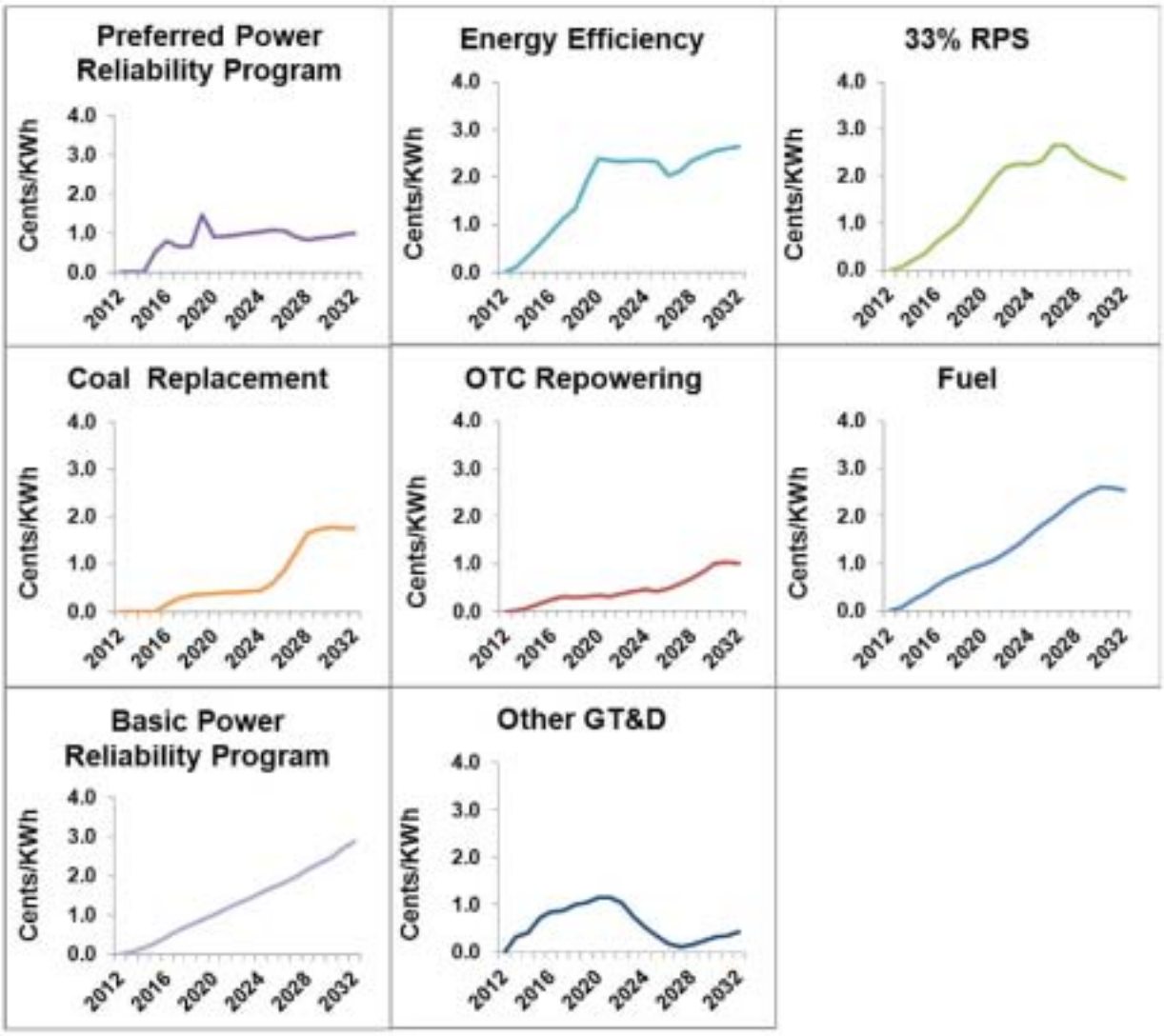

Figure 5-4. Retail electric rate contributions breakdown, based on the 2012-13 budget forecast (Case 5).

Figure 5-5 shows the total retail rate impact after combining all of the program components. One can draw the conclusion that rising fuel costs and complying with various regulatory requirements are the primary drivers of the growth in rates.

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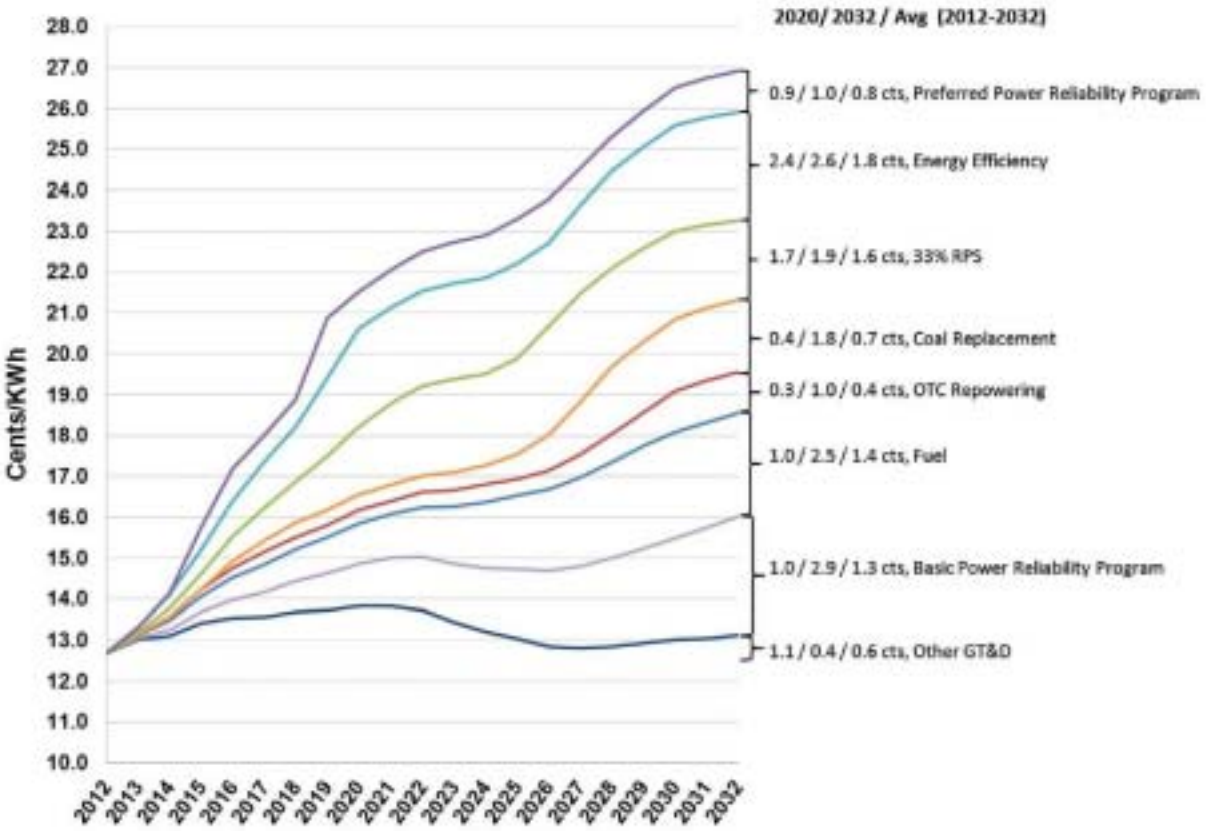

Figure 5-5. Total retail electric rate composite by fiscal year, based on the 2012-13 budget forecast (Case 5).

A few observations from Figures 5-4 and 5-5[10] can be made regarding the RPS and EE programs. Firstly, the influence of the RPS program on rates increases substantially through 2020 after the RPS percentage of sales reaches 33% and the RPS component of rates begins to decline as fuel savings increases over time with escalating fuel prices. In 2027, the RPS component of rates increases as new renewable projects are added to replace expiring PPA agreements and then the RPS component of rates resumes a downward trend due to fuel savings. Secondly, the EE program component of rates increases over time as program incentive payments and net revenue loss attributable to the EE program are recovered. Like RPS, EE has savings beyond 2020 due to fuel savings. Thirdly, general inflation in fuel costs and GT&D costs represents a significant growth in rates.

Preferred levels of funding for the Power Reliability Program (PRP) include capital and O&M expenditures to replace over age distribution and transmission system components that have exceeded their life expectancy, and ensure levels of funding to reduce the backlog of "fix-it"

[10] Figures 5-4 and 5-5 represent forecasted rate increases based on system averages, and do not account for rate structure variations across and within customer classes.

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tickets which are temporary repairs that need to be corrected. The spikes in the preferred PRP and EE curve occurs when capital borrowing limits are reached around 2019-20 and cash is needed to fund capital expenses. This quickly subsides as the capacity to borrow resumes shortly thereafter.

The GT&D component of rates rises in the early years because of general inflationary pressure. After 2023 when the IPP debt is fully paid, the GT&D component of rates lowers slightly and goes slightly negative until IPP is replaced with new gas fired generation and then resumes the familiar inflationary path.

The cost contributions from various environmental and reliability programs towards the retail rates are summarized in Table 5-3.

Table 5-3. Cost contributions from various environmental and reliability programs

Program	Retail Rate Impact at FY2020 (cents/kWh)	Retail Rate Impact at FY2032 (cents/kWh)	Average Retail Rate Impact 2012-2032 (cents/kWh)
33% RPS from 20%	1.7	1.9	1.6
Preferred EE (20% by 2020)	2.4	2.6	1.8
Preferred Power Reliability Program	0.9	1.0	0.8
Basic Power Reliability Program	1.0	2.5	1.4
Coal Replacement	0.4	1.8	0.7
OTC Repowering	0.3	1.6	1.0
Total – Recommended Case	**6.7**	**11.5**	**7.2**

Figures 5-6 and 5-7[1] further illustrate the impact to average residential and commercial-industrial customer monthly bills from these environmental and reliability programs. To show the potential effect of energy efficiency on customer bills, the dashed lines on these figures represents what a total monthly bill would amount to after implementing energy efficiency measures that result in a 14% savings. While LADWP's overall energy efficiency program is evolving and much will depend on the new potential study to be conducted in 2013, these figures illustrate what may reasonably be achievable by customers who have not already implemented significant energy efficiency measures to reduce their electricity consumption.

[1] Figures 5-6 and 5-7 are general representations only, and do not account for rate structure variations across and within customer classes, such as the effect of tiered rates, minimum charges, time-of-use, etc. The figures provide an indication of the relative contributions of the individual programs towards a typical monthly bill.

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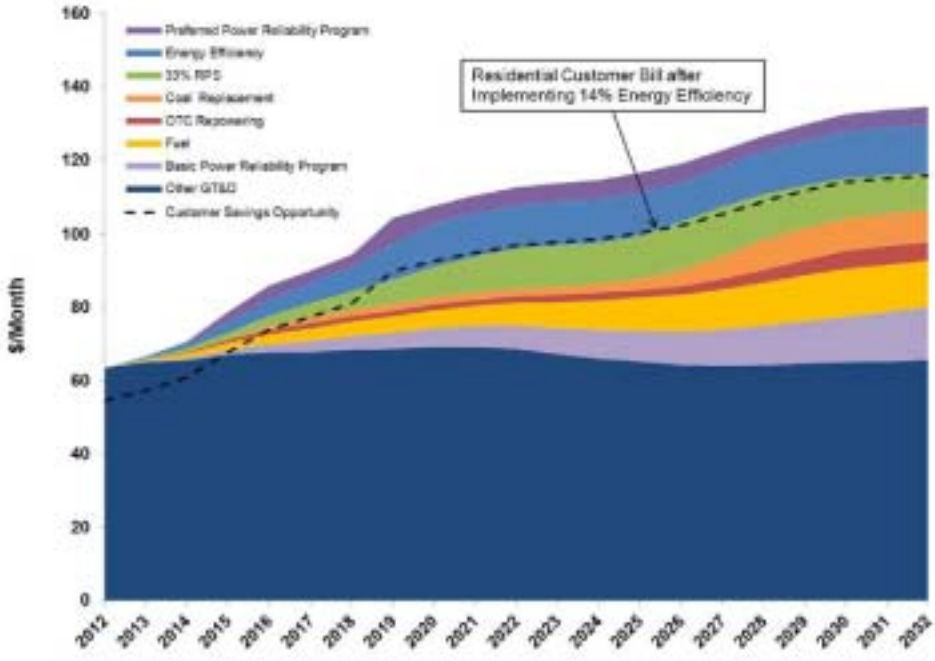

Figure 5-6. Average residential customer bill (500 kWh/month) with environmental and reliability programs by fiscal year based on the 2012-13 budget forecast (Case 5).

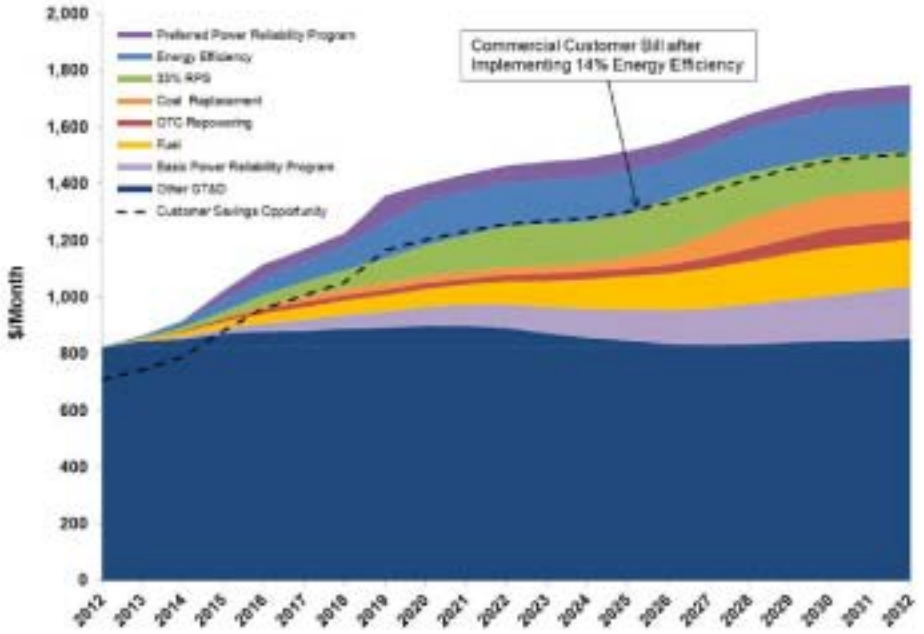

Figure 5-7. Average commercial/industrial customer bill (6,500 kWh/month) with environmental and reliability programs by fiscal year based on the 2012-13 budget forecast (Case 5).

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Aside from the environmental and reliability improvement programs, increased fossil fuel expenses also drive the rate increase, for example: (1) coal that feeds IPP's projected to climb by 76 percent from 2012 to 2027, and (2) natural gas at SoCal border is projected to climb from 2013's $3.62/MMBtu to 2032's $9.31/MMBtu. If these fuel increases do not materialize, then the average rate and cost curves shown in Figures 5-3 thru 5-7 will shift downward, however, the cost of environmental and reliability programs will remain substantially unchanged.

Because the analysis and conclusion are heavily dependent on a number of assumptions, LADWP will continually update its long term plan. As expectations change (e.g., due to technology development, commodity price fluctuations, and policy changes), they will be analyzed and incorporated into subsequent IRPs.

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5.6 Recommended Near-term Actions

Except for early Navajo divestiture, the actions needed to be taken by LADWP in the next two to four years are very similar no matter what resource procurement strategy is chosen. Base on the strategic requirements presented earlier and projected resource procurement needs, the following actions are recommended to be taken in the near-term:

1. Proceed with re-powering plans for generator units at the Haynes and Scattergood Generating Stations, and pre-development plans for the Harbor Generating Station.
2. Continue to investigate the technical and contractual options for coal-fired generation to be compliant with SB 1368.
3. Divest from the Navajo Coal Plant by 2015.
4. Continue the implementation of existing energy efficiency efforts, in anticipation of an expanded program pending the results of a new energy efficiency potential study to be conducted in 2013.
5. Continue to implement the Power Reliability Program (PRP) to replace aging infrastructure components. Develop electric modeling capability to better define the necessary investments and to prioritize the expenditures.
6. Develop/update a sustainable workforce development plan that addresses staffing needs, skill set identification for new and evolving work areas, training/professional development, application of new technologies, and recruitment strategy.
7. Implement recommendations contained in the Ten-Year Transmission Assessment Plan.
8. Develop a Demand Response Program to initially provide 8 MW of new peak load reduction capability by 2013 which will ramp up incrementally to 200 MW by 2020 and 500 MW by 2026.
9. Implement renewable strategies for geothermal, biogas, solar, and wind resources to ensure increasing levels of renewable procurement in accordance with SB 2 (1X). Sign Power Purchase Agreements for an additional 300-400 MW of cost effective renewable energy projects by 2014.
10. Complete a comprehensive study of issues associated with integrating increasing amounts of variable energy resources such as wind and solar to reflect possible megawatt limits for the LADWP electric Power System.
11. Develop and incorporate strategies to:
    a. Fully utilize existing transmission assets.
    b. Locate renewables as close as practical to the load center to reduce transmission losses.
    c. Preserve existing brown field sites to be repurposed for renewable or natural gas generation.
    d. Incorporate the concept of O&M cluster zones[1] to maximize operational efficiencies.
    e. Assess and develop necessary transmission facilities to deliver electricity generated from new facilities.

[1] Clustering renewable projects in relative proximity will decrease O&M expenditures due to economies of scales and personnel efficiencies. This would need to be balanced with the need for geographic diversity.

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12. Develop a renewable energy feed-in tariff program to encourage 150 MW of renewable generation resources to be developed by 2016
13. Encourage the development of an additional 80 MW of customer net-metered solar projects before 2015.
14. Develop up to 30 MW of solar capacity on existing properties under public/private partnership projects before 2015
15. Investigate the use of term physical gas supply arrangements, either with contracts for physical supplies or futures contracts to limit LADWP's exposure to volatile gas prices. Evaluate and potentially implement any recommendations in the Fuel Hedging Plan
16. Investigate and develop energy storage targets by October 1, 2014, per AB 2514
17. Refine and implement a Smart Grid strategy that can assist in the procurement and development of advanced technologies to support areas such as: weather forecasting/ energy scheduling, customer kWh metering, high speed communications and information systems, and energy storage systems. Deployment of these technologies will increase operational efficiency, help reduce system losses, improve outage response times, increase utilization of predictive/proactive maintenance techniques for improved grid reliability, enable better management of the Power System, and lower costs

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5.7 Long-Term Planning Considerations

The analysis and conclusions contained in this IRP are heavily dependent on a number of assumptions, such as the projected fuel and purchase power costs, RPS target goals, renewable generation costs, proposed state and federal mandates, and GHG emissions costs. If these assumptions were to change, LADWP's long-term strategies will need to change accordingly.

Integrated resource planning is an on-going process. LADWP will continue to adapt and refine the IRP as the uncertainties are better understood, and policy direction and requirements are solidified. A new IRP process will be undertaken in 2013.

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Appendix A. Load Forecasting

A.1 Overview

The 2012 Retail Sales and Demand Forecast (2012 Forecast) is a long-run projection of electrical energy sales, production, and peak demands in the City of Los Angeles (City) and Owens Valley. A flowchart of the forecast process is illustrated on Figure A-1. The sections which follow describe the four key components shown on the flow chart: data collection, sales and Net Energy for Load (NEL) forecast, peak demand forecast, and hourly allocation.

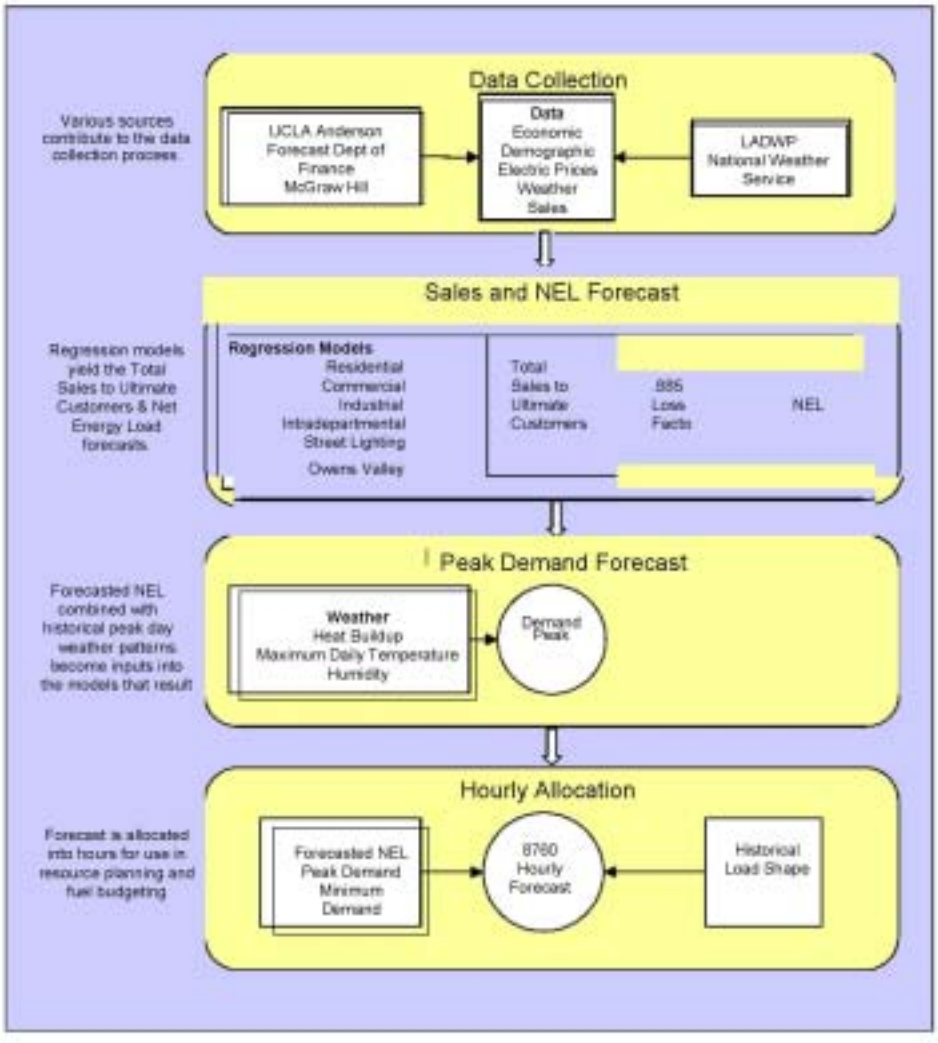

Figure A-1. Overview of the load forecasting process

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A.2 Data Collection

Data collection is the first step in the process. LADWP purchases an economic forecast of Los Angeles County from the Los Angeles Modeling Group of the University of California of Los Angeles (UCLA) Anderson Forecast Project. The Los Angeles County Forecast provides time series data for various demographic and economic statistics beginning with year 1991 and continuing through the forecast horizon. For demographic history and projections, LADWP uses the State of California Department of Finance Demographic Research Unit. To gain further insight into development patterns, LADWP purchases a construction forecast from McGraw-Hill Construction service. The construction forecast gives a five-year view of construction projects detailed by building types. Weather also affects energy sales and demand. Weather data is collected from three key stations – Civic Center, Los Angeles Airport, and Woodland Hills. The other key components in the forecast are from LADWP's own internal data. Historical sales, Net Energy for Load (NEL), billing cycles, electric price, and budget data is incorporated into the forecast. The economic, demographic, weather, and electric price data provide the key inputs to the models that forecast retail electric sales.

A.3 Sales and NEL Forecast

The retail sales forecast is divided into seven separate customer classes; residential, commercial, industrial, plug-in electric vehicle (PEV), intradepartmental, streetlight and Owens Valley. The residential, commercial, industrial, and streetlight classes are commonly used sales classes throughout the electric industry because they represent relatively homogeneous loads. Intradepartmental sales are sales to the Water System and are primarily related to water pumping activities.

The California Energy Commission's PEV forecast has been adapted to the LADWP service area. Further, PEV load is forecast as a separate class, which will facilitate financial modeling due to the expected subsidies and production modeling as PEV load has a unique load shape when compared to the residential class.

Owens Valley sales include all of the above sales classes. The Owens Valley service area is separate and discrete from the Los Angeles service area. Because of limited land available to be developed, Owens Valley sales exhibit very slow growth rates, and total sales are relatively small compared to total LADWP system sales. As such, Owens Valley sales are rolled into a single class and forecast separately.

The forecast model consists of six single equations plus the adapted PEV forecast. For the residential, commercial, and industrial sales classes, the equations are estimated using Generalized Least Squares regression techniques. Historical sales for each customer class are the dependent variables. Sales are regressed against a combination of the demographic, economic, weather, and electric price variables. Binary variables are used to account for extraordinary events like earthquakes, civil disturbances, billing problems, and the California Energy Crisis. The equations fit

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historical data quite accurately, producing coefficients of determination (R-Squared) statistics greater than 80 percent. For the streetlight, intradepartmental, and the Owens Valley sales classes, time trend models are used. The results of the six equations plus the PEV forecast are summed to forecast Total Sales to Ultimate Customers (Sales).

The Retail Sales Forecast represents sales that will be realized at the meter. The NEL forecast is a function of the Sales forecast. The NEL is forecast by adjusting annual forecasted Sales upward by a historic average loss factor and then allocating a portion of the annual energy to each calendar month based on historical proportions. Loss factor has the potential to change on the way that the System is run. Electricity generated in distant places will have a higher loss factor than electricity generated located locally. The change in loss factor is accounted for in the resource planning models.

The 2012 Forecast includes committed energy efficiency and customer self-generation. Committed energy efficiency includes budgeted utility programs and expected energy efficiency gains from the Huffman Bill lighting standards. Expected Huffman Bill energy efficiency savings were developed by Global Energy for the 2010 LADWP Energy Potential study. Since the 2012 Forecast is created early in the planning process, budgeted utility energy efficiency programs are subject to change. Planners using the 2012 Forecast should be aware of the potential changes and make appropriate adjustments. Forecasting self-generation which currently is almost entirely focused on solar rooftops in the LADWP service area follows a process similar to the energy efficiency. Planners working with energy efficiency and self-generation data should be careful to include only the incremental impacts of the programs on retail sales In the Forecast, energy efficiency and self-generation savings are expected to occur uniformly throughout the year as a simplifying assumption.

A.4 Peak Demand Forecast

The next step is to forecast annual peak demand. The drivers for forecasted peak demand are temperature, load growth, and time of the summer. The temperature variable used in the estimation is the weighted-average of three weather stations. The temperature variable incorporates heat buildup effects and humidity. Temperature is then divided into splines using a unique megawatt- response per degree estimate for different levels of temperature. Ordinary Least Square regression techniques are used to model maximum weekday summer daily hourly demand against the temperature splines and the time of the summer. The constant that is estimated from the regression model is assumed to be the weather-insensitive demand at the peak hour. To forecast the peak demand, it is assumed that the peak will occur in August and that the peak day temperature is equal to the forty-year historical mean peak day temperature. Peak demand then is assumed to grow at the same rate as sales.

The forecast process described above produces the trend (or base case) forecast. LADWP also produces alternative peak demand forecasts. LADWP wants to ensure that it can meet native demand with its own resources. System response to weather is uncertain. Temperature and humidity are the primary influences, but other variables such as cloud cover and wind speed can also influence the load. The problem is further

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complicated by the fact that LADWP serves three distinct climate zones including the Los Angeles Basin, the Santa Monica Bay Coast, and the San Fernando Valley. To prepare for these uncertainties, LADWP formulates its alternative cases by examining expected demands at different temperatures. Based on the Central Limit theorem, it is assumed that the normal distribution produces unbiased and efficient estimators of the true distribution of peak day temperatures. The normal distribution is estimated from the 40 year historical sample of peak day temperatures. From the normal distribution, the probability that the peak day temperature will be below a given temperature can be determined. For the one-in-ten case, it is the given temperature where ninety percent of the time the actual peak day temperature is expected to be below it and ten percent of the time the actual temperature will be above it. Similar calculations are performed for the one-in-five and one-in-forty cases. These temperatures are input into the peak demand regression model to provide the alternative peak demand forecasts.

In the Integrated Resource Plan, LADWP uses the One-in-Ten Case Peak Demand forecast rather than the Base Case forecast. LADWP's policy regarding obligation to serve is to be self-sufficient in supplying native load and not rely on external energy markets. The Base Case Peak Demand forecast falls short of this standard since it is expected that fifty percent of the time actual peak demands will exceed the Base Case Peak Demand forecast. The One-in-Ten Case provides LADWP ninety percent confidence that the forecasted peak demand will not be exceeded in any given year.

A.5 Hourly Allocation

The final step of the process is to forecast a monthly peak demand and load for each hour in the year. Monthly peak demands, outside of the August annual peak, are forecast using the load factor formula. The historical average monthly load factor and the forecasted NEL for each month are the known inputs. To forecast load for each hour of the year, the Loadfarm algorithm developed by Global Energy is used. The inputs into Loadfarm are a historical system load shape, monthly forecasted energy, and monthly forecasted peak demand. The system load shape is developed using a ranked-average procedure permuting historical loads so that all peaks occur on the fourth Thursday in August. Table A-1 contains the numerical 2012 Forecast.

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Table A-1. TREND CASE ENERGY SALES AND PEAK DEMAND

	SECTOR SALES					Total Sales to Ultimate Customers	Net Energy for Load	Peak Demand
Fiscal Year	Residential (GWh)	Commercial (GWh)	Industrial (GWh)	Miscellaneous* (GWh)	PHEV (GWh)	(GWh)	(GWh)	(MW)
2000-01	7,542	12,107	2,754	831	0	23,234	26,688	5,255
2001-02	7,762	11,843	2,406	378	0	22,149	24,903	4,809
2002-03	7,358	12,077	2,383	345	0	22,363	25,370	5,185
2003-04	8,061	12,408	2,485	365	0	23,320	26,704	5,410
2004-05	7,907	12,374	2,447	551	0	23,279	26,230	5,418
2005-06	8,041	12,580	2,457	551	0	23,624	26,939	5,667
2006-07	8,496	12,684	2,357	547	0	24,084	27,502	5,710
2007-08	8,540	12,734	2,366	576	0	24,617	27,939	6,047
2008-09	8,578	12,684	2,303	560	0	24,326	27,447	6,006
2009-10	8,300	12,463	2,073	537	0	23,373	26,526	5,709
2010-11	8,003	12,333	2,169	464	0	23,053	26,252	6,140
2011-12	8,454	12,474	1,992	475	1	23,392	26,458	5,907
2012-13	8,407	12,513	1,947	480	4	23,344	26,360	5,606
2013-14	8,284	12,545	1,947	486	8	23,268	26,310	5,577
2014-15	8,270	12,568	1,936	479	12	23,264	26,311	5,604
2015-16	8,257	12,587	1,937	480	22	23,283	26,312	5,591
2016-17	8,230	12,632	1,936	487	34	23,319	26,336	5,660
2017-18	8,266	12,607	1,938	484	51	23,378	26,392	5,597
2018-19	8,361	12,764	939	486	97	23,887	26,765	5,659
2019-20	8,474	12,620	940	488	151	23,973	27,115	5,725
2020-21	8,363	12,122	1,940	490	222	24,333	27,457	5,791
2021-22	8,536	12,312	94	493	328	24,711	27,870	5,861
2022-23	8,716	12,442	947	494	402	24,997	28,165	5,943
2023-24	8,805	12,572	1,942	496	415	25,230	28,527	5,992
2024-25	8,896	12,702	1,942	498	429	25,467	28,795	6,050
2025-26	8,985	12,831	1,943	500	452	25,713	29,070	6,105
2026-27	9,076	12,960	1,942	503	467	25,945	29,287	6,160
2027-28	9,166	14,029	1,944	505	-489	25,155	28,626	6,216
2028-29	9,260	14,017	1,945	506	505	26,231	29,828	6,271
2029-30	9,451	14,244	1,945	507	526	26,673	30,101	6,326
2030-31	9,447	14,460	1,946	509	542	26,015	30,386	6,381
2031-32	9,543	14,603	1,946	511	562	27,188	30,746	6,441
2032-33	9,643	14,765	1,947	513	580	27,448	30,975	6,515
2033-34	9,741	14,907	1,947	515	599	27,710	31,271	6,580
2034-35	9,840	15,048	948	517	617	27,971	31,569	6,615
2035-36	9,940	15,189	1,948	519	635	28,233	31,921	6,679
2036-37	10,039	15,329	1,949	521	654	28,490	32,156	6,753
2037-38	10,139	15,470	1,950	523	674	28,756	32,452	6,798
2038-39	10,240	15,610	1,950	525	692	29,017	32,748	6,858
2039-40	10,341	15,751	90	527	711	29,260	33,114	6,917

* To be updated through December 2011

Annual Percent Change								
1991-2001	1.02%	0.55%	-1.03%	0.50%		0.90%	0.48%	-0.02%
2001-11	0.62%	0.12%	-2.24%	-1.24%		0.05%	0.22%	1.45%
2011-17	0.25%	0.27%	-2.07%	0.65%		0.12%	-0.01%	-1.58%
2011-21	0.55%	0.62%	-1.70%	0.65%		0.54%	0.45%	-0.56%
2011-31	0.75%	0.81%	-0.56%	0.47%		0.78%	0.73%	0.15%
2011-40	0.86%	0.85%	-0.40%	0.44%		0.83%	0.80%	0.41%

Includes Streetlighting, Electric Vehicle and Title-X Departmental
Revised normalized

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CITY OF LOS ANGELES

DEPARTMENT

OF

WATER AND POWER

2012 RETAIL ELECTRIC SALES AND DEMAND FORECAST

Ronald O. Nichols
General Manager

Adam Benyamin
Senior Assistant General Manager
Power System

Philip R. Leiber
Chief Financial Officer

March 7, 2012
Load Forecasting, Room 956
Financial Services Organization

Document reflects previous 6.6% energy efficiency goal by 2020.
Forecast will be updated to incorporate revised goal.

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2012 Retail Electric Sales and Demand Forecast

Overview

The 2012 Retail Electric Sales and Demand Forecast (Forecast) supersedes the 2011 Retail Electric Sales and Demand Forecast as the City of Los Angeles Department of Water and Power's (LADWP) official Power System Forecast. The Forecast is the basis for LADWP Power System planning activities including but not limited to Financial Planning, Integrated Resource Planning (IRP), Transmission and Distribution Planning and Wholesale Marketing.

Because the Forecast is a public document, only publically available information is used in its development. (This practice has become a standard among California electric utilities.) LADWP Planners wishing to use their own proprietary data should adjust the Forecast accordingly. The Load Forecast Group (LFG) is available to help Planners make adjustments and produces an Unmitigated and Gross Forecast to facilitate those adjustments.

Data Sources

1. Historical Sales reconciled to the Consumption and Earnings Report prepared by General Accounting
2. Historical NEL, Peak Demand and Losses reconciled to the PowerMaster database maintained by the Power System Planning & Development Group
3. Historical weather data is provided by the National Weather Service and Los Angeles Pierce College.
4. Historical Los Angeles County employment data is provided by the State of California Economic Development Division using the March 2010 Benchmark.
5. Historical population estimates and projections are provided by the State of California Department of Finance.
6. The long-term Los Angeles County economic forecast with quarterly short-run updates is provided by UCLA Anderson Forecast.
7. The construction activity forecast is provided by McGraw-Hill Construction.
8. The Electric Vehicle forecast is based on the California Energy Commission (CEC) statewide forecast. The California Electric Transportation Coalition of which LADWP is a member prepared the CEC forecast.
9. The port electrification forecast is provided by the Port of Los Angeles.
10. The LADWP program energy efficiency forecast is based on the LADWP Energy Efficiency projected budget through Fiscal year 2016-17 dated February 21, 2012. Historical installation rates are provided by the Energy Efficiency group.
11. The forecasted impacts of the Energy Independence Security Act (EISA) and the Huffman Bill on residential lighting rely on the Energy Efficiency Potential Study prepared in 2010 by Global Energy.
12. Historical and projected solar rooftop installations are the draft 2011 Integrated Resources Planning Assumptions document dated October 14, 2011.
13. Electric Price Forecast is developed by Financial Services organization.
14. Historical data is current through December 2011.

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Five-Year Sales Forecast

The Retail Sales Forecast represents sales that will be realized at the meter through Fiscal Year End 2017. After FYE 2017, some of the forecasted sales will not be realized at the meter due to the incremental impacts of LADWP-sponsored energy efficiency programs. After FYE 2017, LADWP-sponsored energy efficiency programs will be accounted for in the Integrated Resource Plan.

The historical accumulated Energy Efficiency and Solar Saving are from 1999 forward and only include LADWP installed savings. Since July 1, 2008, LADWP-installed Energy Efficiency savings are 715 GWH for which LADWP recovers lost revenue. In the Forecast, energy efficiency and solar savings are expected to occur uniformly throughout the year as a simplifying assumption. Installation schedules are difficult to prepare because they rely on the customers allowing the installation to occur.

Retail sales decrease of 0.6 percent in Fiscal Year 2013-14 is attributed to the full ramp up of the Huffman Bill and accelerated incremental savings rates in LADWP's energy efficiency programs. Beginning January 2012, the Huffman Bill significantly raises the efficiency standard of light bulbs. The 0.5 increase in FYE 2014-15 is due to the projected completion of port electrification projects and a decline in the LADWP incremental energy efficiency savings rate.

Forecasted Energy Efficiency is based LADWP Board approved AB 2021 goal of saving 2161 GWH from FYE 2011 through FYE 2020 and forecasted Huffman bill savings. The targeted goal for rooftop solar installations is 242 MW by 2020.

Short-Run Growth

Fiscal Year	Retail Sales		Accumulated EE & Solar Savings	Gross Sales
Ending June 30	(GWH)	YOY Growth Rate	(GWH)	(GWH)
2010-11	23053		1470	24523
Forecast				
2011-12	23232	0.8%	1725	24957
2012-13	23361	0.6%	2102	25426
2013-14	23256	-0.4%	2428	25684
2014-15	23294	0.2%	2772	26066
2015-16	23253	-0.2%	3113	26366
2016-17	23224	-0.1%	3448	26672

* Actual sales through December 2011

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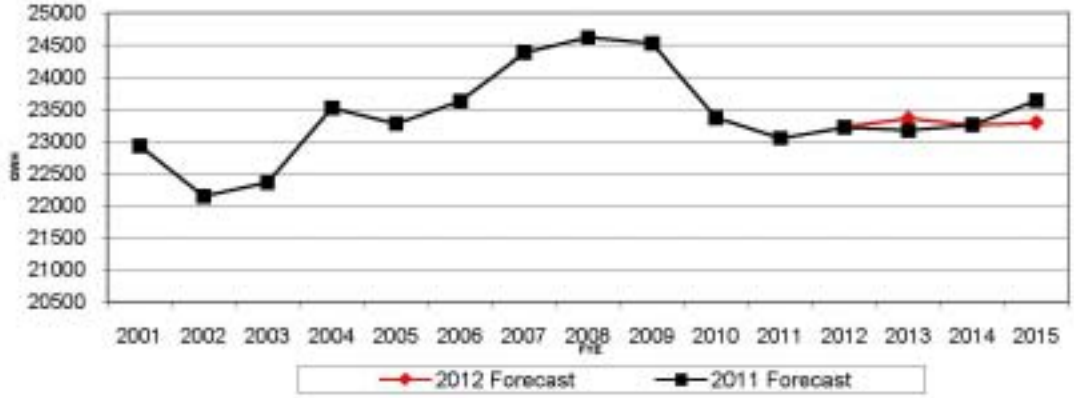
Retail Sales Net of Energy Efficiency and Distributed Generation



Peak Demand Forecast

Growth in annual peak demand over the next ten years is 0.3 percent.

Long-Run Growth

Fiscal Year End June 30	Base Case Peak Demand (MW)	Growth Rate Base Year 2011-12	One-in-Ten Peak Demand (MW)
2011-12	5631[1]		6073
Forecast			
2016-17	5590	-0.1%	6026
2021-22	5881	0.4%	6342
2031-32	6441	0.7%	6885
2040-41	6992	0.7%	7546

[1]Weather-normalized. Actual peak was 5907 MW.

In 2011, the System set its calendar annual peak at 5907 MW on September 7, 2011 on a day that was a 1-in-2.3 weather event. The weather-adjusted one-in-two peak for 2011 is 5631 MW. The following graph of the One-in-Ten peak demand forecast is used for the Integrated Resource Plan (IRP). In the 1990s through 2005, annual System load factors were trending slowly upward. Since 2006, System load factors are trending down. Three factors are generally thought to be contributing to this effect. Most customers are making greater efforts to conserve energy but during extreme weather events safety and comfort predominate over conservation causing the peak to spike. Much of the historical and forecasted energy efficiency effort is lighting which has a greater impact on consumption rather than peak which lowers the load factor. Solar rooftops peak production is between 1200 and 1300 hours and declines to 40 to 50 percent of capacity at 1600 hours when the

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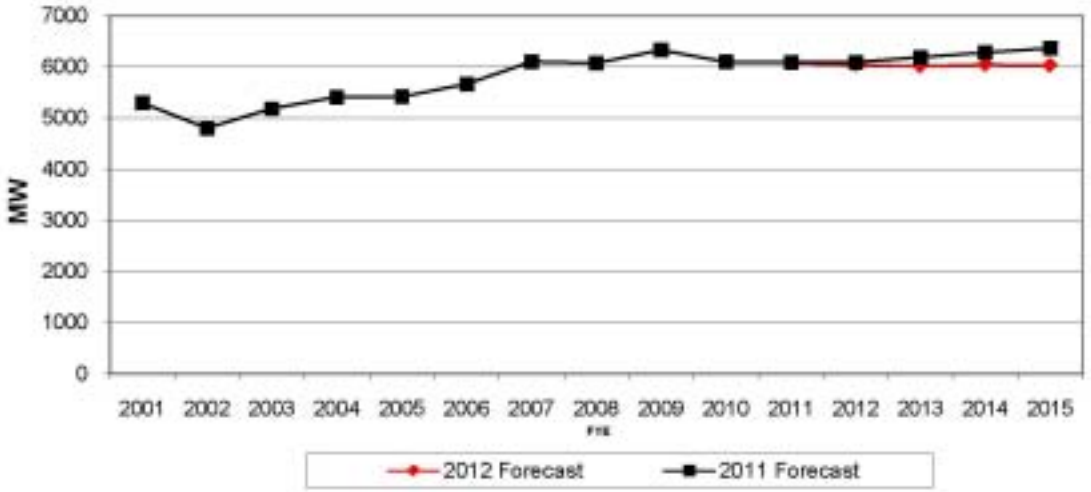
peak occurs. In contrast, the load factor will rise due to significant load growth from the greater use of electric vehicles. The new electric vehicle forecast adopted from the California Electric Transportation Coalition has less impact on the peak than the 2011 Forecast.

One-in-Ten Peak Demand Comparisons



The Peak Demand Forecast is primarily used in the following areas:

1. Integrated Resource Planning
2. Wholesale Energy Marketing
3. Distribution Planning
4. Transmission Planning

In Integrated Resource Planning, LADWP uses the One-in-Ten Case Peak Demand forecast rather than the Base Case forecast. LADWP's policy is to ensure reliability in times of volatility by controlling its own generation capacity. Planning generation resources at the one-in-ten level has proven over the years to be an effective tool in meeting the reliability policy. The one-in-ten case is based on historical peak day weather events and uses a statistical model and the underlying retail sales forecast to forecast an annual peak demand. The peak demand is adjusted for lighting energy efficiency and electric vehicle impacts.

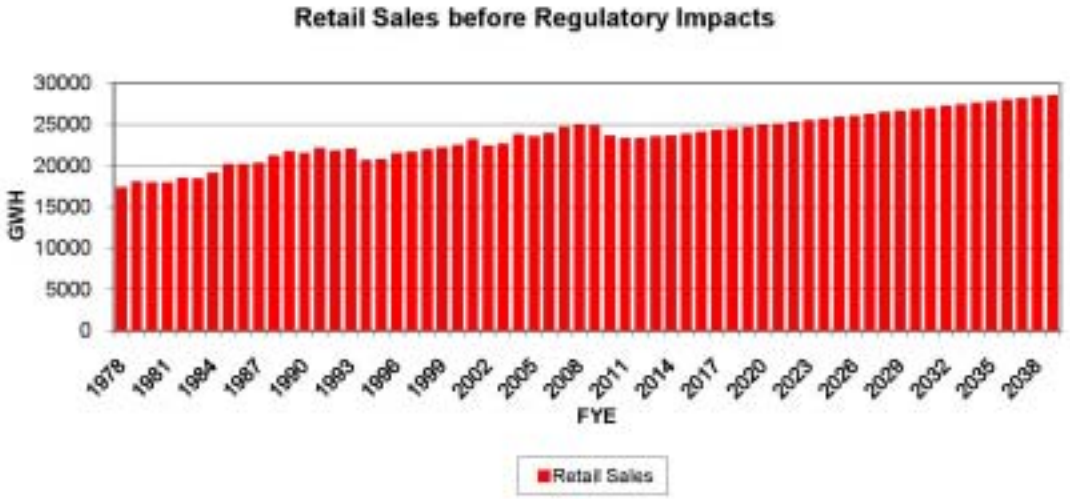
Plausibility

To measure plausibility we compare the current forecast to historical periods. Data is available electronically from 1978 forward. A direct comparison is not appropriate because the forecast period includes programs that reduce all forms of energy consumption due to an aggressive regulatory agenda primary aimed at reducing greenhouse emissions. Instead the unmitigated forecast is compared against history. The unmitigated forecast is the forecast that would occur before the impacts of AB 32 and AB 2021 are considered. It might also be considered a "business-as-usual" case.

AR0070101

The decline in forecasted sales 2008 through 2010 is most directly compared to the decline in sales between 1992 and 1994. The 1992 through 1994 time period was difficult for Los Angeles in many aspects. An economic slump occurred mostly created by the downsizing of the aerospace industry but it also was time of civil unrest and natural disaster. The combination of events caused a major migration of people leaving Los Angeles. Peak-to-Trough sales declined 7 percent in the 1992 through 1994 time period. The following table shows all the peak-to-through declines since 1978. The chart then gives visual evidence of the long-term perspective.

Peak-to-Trough Analysis		
Years	GWH Decline	Percent Decline
2008-2010	1,910	8.3%
1992-1994	1,421	7.0%
2000-2002	572	2.6%
1979-1980	322	1.8%
1981-1982	145	0.8%



Primarily due to the recession that began in December 2007 and ended in June 2009, the historical sales experienced a decline of 8.3 percent in the 2008 through 2010 time period. While the 1992-94 sales decline was specific to Los Angeles and the aerospace industry, in 2008-2010 the decline in Los Angeles mirrored the malaise in the national economy. Going forward, there are conflicting trends in the economic forecast for Los Angeles County going forward. On the positive note, Real Personal Income is increasing. Per capita energy consumption is historically positively correlated with increases in personal income and consumption. The negative trends are population out-migration and fewer jobs in Los Angeles County. Population out-migration means smaller demand for housing infrastructure. Fewer jobs imply that vacant commercial floor space will not be absorbed. Based on economic variables sales will not reach 2008 levels until 2021. The next decade will be much like the 1990s.

Variables in the Forecast

Population The 2010 United States Census reported 3,792,621 residents in the City of Los Angeles. This number was far lower than the previous 4,094,764 estimated by State of California Department of Finance Demographic unit. The State relies on birth-death records and driver license data to estimate population between censuses. The 2000 United States Census reported 3,694,742. The population growth rate was only 0.2 percent per annum in the first decade of the 21st century. This data seems contrary to other data such as new residential accounts for example. New residential accounts increased at a 0.5% rate in the same time period. This Forecast relies less on the population data since it gives us an unexpected result.

SB 375 SB 375 layers statewide guidelines onto local planning decisions. It favors redevelopment, known as brown field development, near transportation centers over new (green field) development. The goal is to reduce vehicle miles traveled thereby reducing emissions. Most development in Los Angeles is brown field development. However, brown field development is more complicated and expensive than green field development so overall development could slow. The City of L.A.'s "Housing that Works" plan fits well into the SB 375 structure. Residential construction activity is forecast to rebound to normal levels within the next three years.

Emission Allowances AB 32 seeks to reduce emissions to 1990 levels using a cap-and-trade scheme. Originally the program was to begin in 2012 but has been delayed. Program is designed to protect utilities and consumers. Climate impacts are unknown.

Electric Vehicles LADWP is making electric vehicles a key strategic initiative. The Forecast uses the 2011 California Energy Commission mid-level forecast for electric load growth. This forecast was developed by the California Plug-in Electric Vehicle Coalition of which LADWP is a member. Demand response strategies are intrinsic to this forecast whereas in the 2011 Forecast Demand Response strategies for electric vehicles were external to the electric vehicle forecast. Alternative forecasts for load growth from electric vehicles vary widely.

Energy Efficiency According to the State of California Strategic Plan, achieving the energy efficiency goals relies on new emerging technologies. The firming of the market availability and the adoption rates for the new technologies is unknown.

Smart Grid It is unknown when LADWP will complete its Smart Grid program. Some believe that developing a Smart Grid system is a necessary precondition towards a successful electric vehicle program. Also Smart Grid is an important component towards achieving energy efficiency goals in the residential sector.

Vacancy Factor in Residential Sector Vacancy rose faster than expected in the recession. Some of the vacancy rate was due to households combining and living in the same structure. Vacancy could rapidly swing lower as the economy begins to expand. The Forecast has vacancy rate returning to five percent which is the long-term average by 2015.

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Vacancy Factor in Commercial Sector - High vacancy factor is expected to remain more persistent in the commercial sector as models for delivery of services especially in retail change. The rise of big box retail stores and the Internet have crowded out the small retail shop owner over the past twenty years. There is a smaller need for a physical presence.

Panama Canal Widening - Panama is widening its canal to accommodate the modern larger container ships. It is expected to be completed by 2014. Eastern seaports are also dredging to allow the larger container ships to dock. Currently the larger container ships dock in Los Angeles and Long Beach and the goods are shipped by rail to the East Coast. A decline in this business would hurt the Los Angeles economy. Wholesale Trade and Transportation represent about ten percent of the employment in Los Angeles County.

AR0070104

2012 RETAIL ENERGY AND DEMAND FORECAST

NET ELECTRICITY SALES BY CUSTOMER CLASS AND SYSTEM PEAK DEMAND WITH REGULATORY IMPACTS

2002-01														
2001-02														
2002-03														
2001-04														
2004-05														
2005-06														
2006-07														
2007-08														
2008-09														
2009-10														
2010-11														
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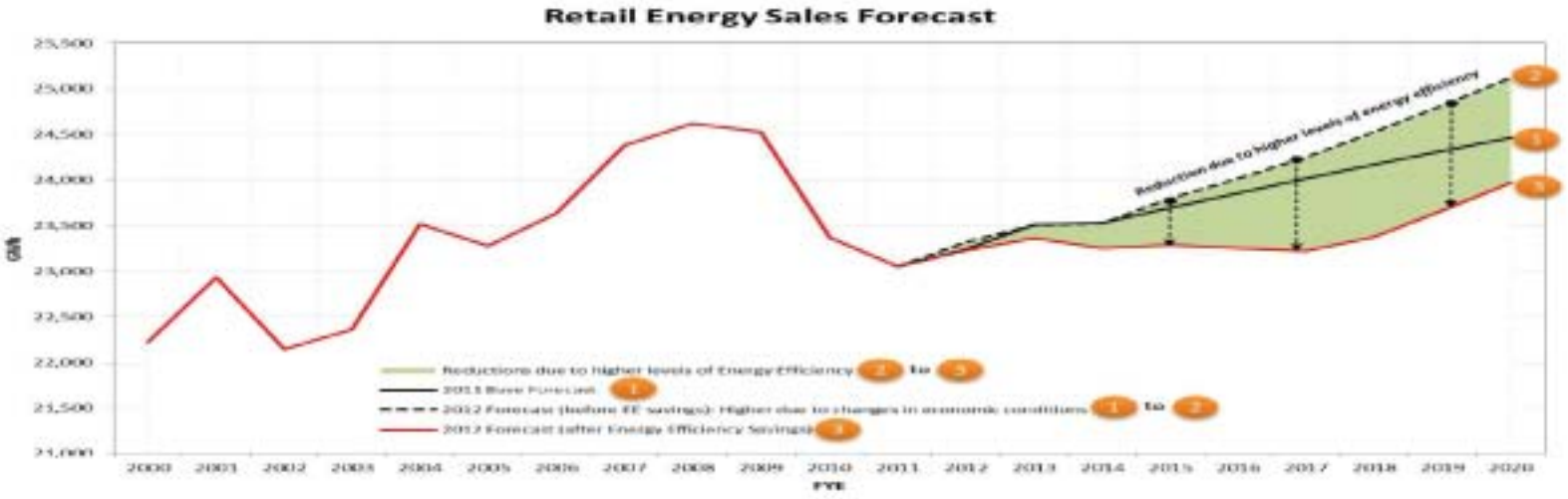
2033-34														
2034-35														
2035-36														
2036-37														
2037-38														
2038-39														
2039-40														
Annual Percent Change														
1997-2001														
2001-11														
2011-17														
2011-21														
2011-31														
2011-40														

Retail Sales

Key Change Factors from 2011 to 2012 forecast:

- ✓ EE included through FYE 2017
- ✓ EE has contributed to the reduction in the retail sales forecast as part of implementing AB 2021. LADWP has targeted an additional 8.6% reduction by 2020.
- ✓ Construction activity remains at low level for extended period. Construction jobs concentrated on rebuilding infrastructure rather than adding housing units or commercial floor space which would have greater impact on electricity sales.



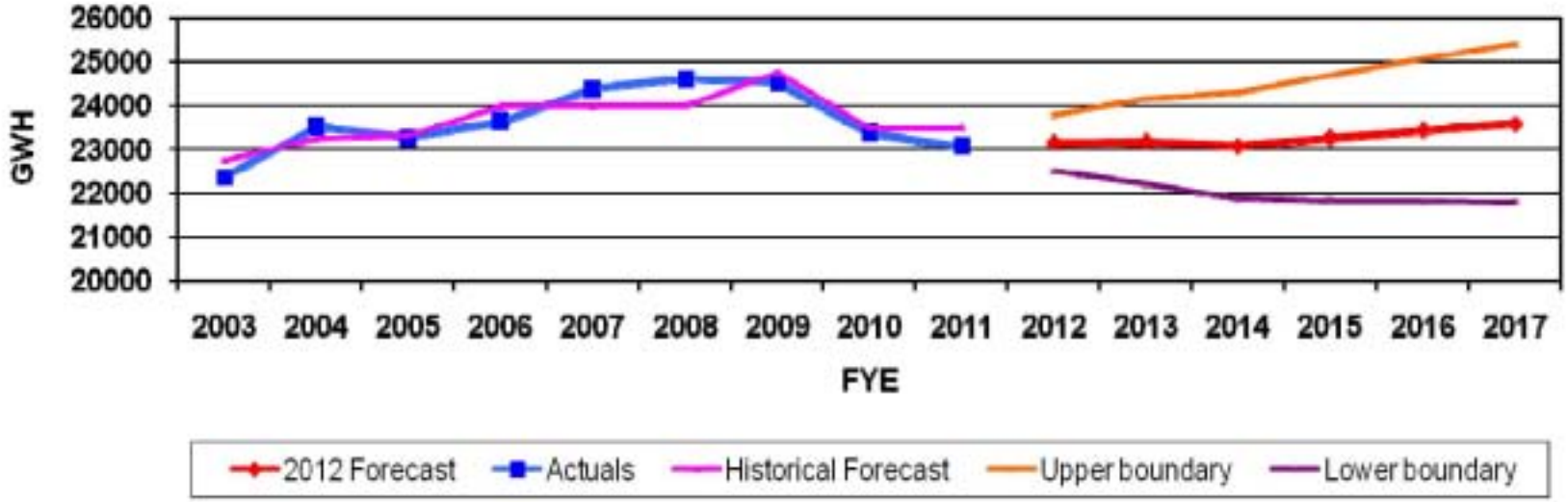
Retail Sales

Accuracy:

✓EE and Solar were not modeled explicitly in Historical Forecasts.

✓Historical accuracy is 0.2% with a 1.6% deviation. However expect larger variation in accuracy due uncertainty of new programs.

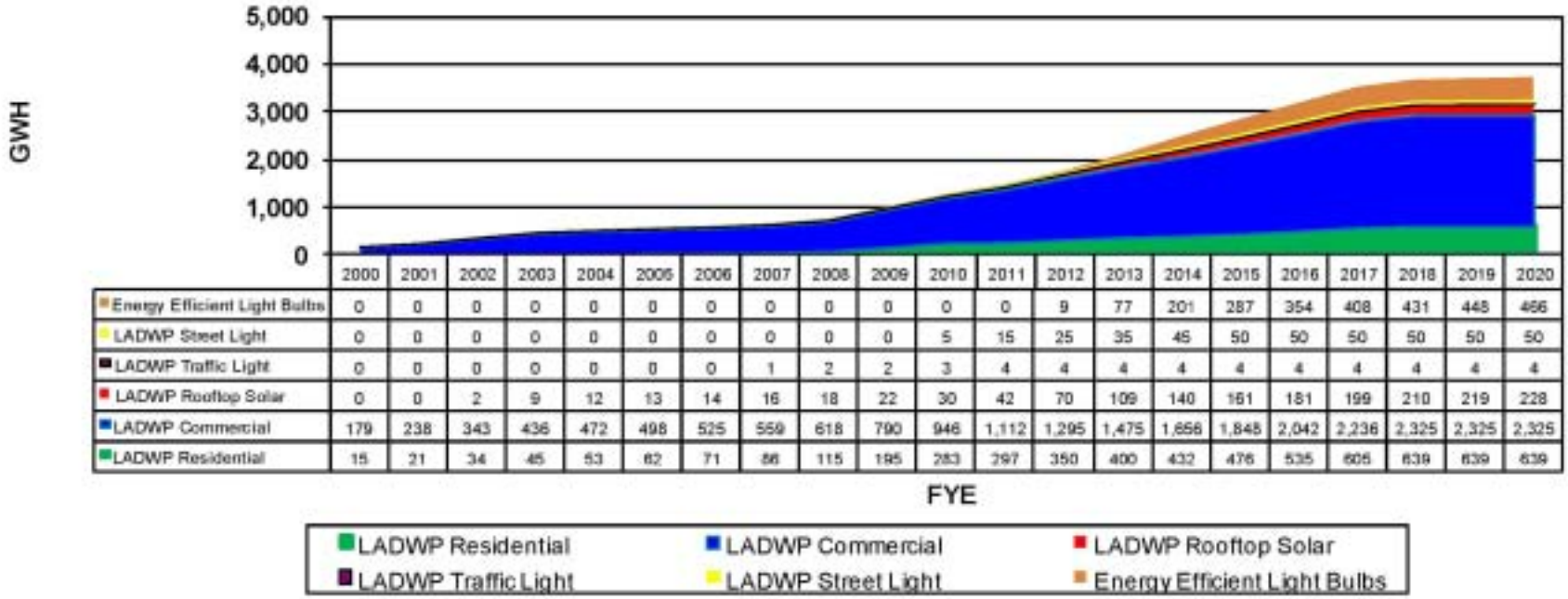
✓Forecast variation is a function of weather, economic forecasts, meeting program goals and model specification.



Energy Efficiency and Solar Rooftops

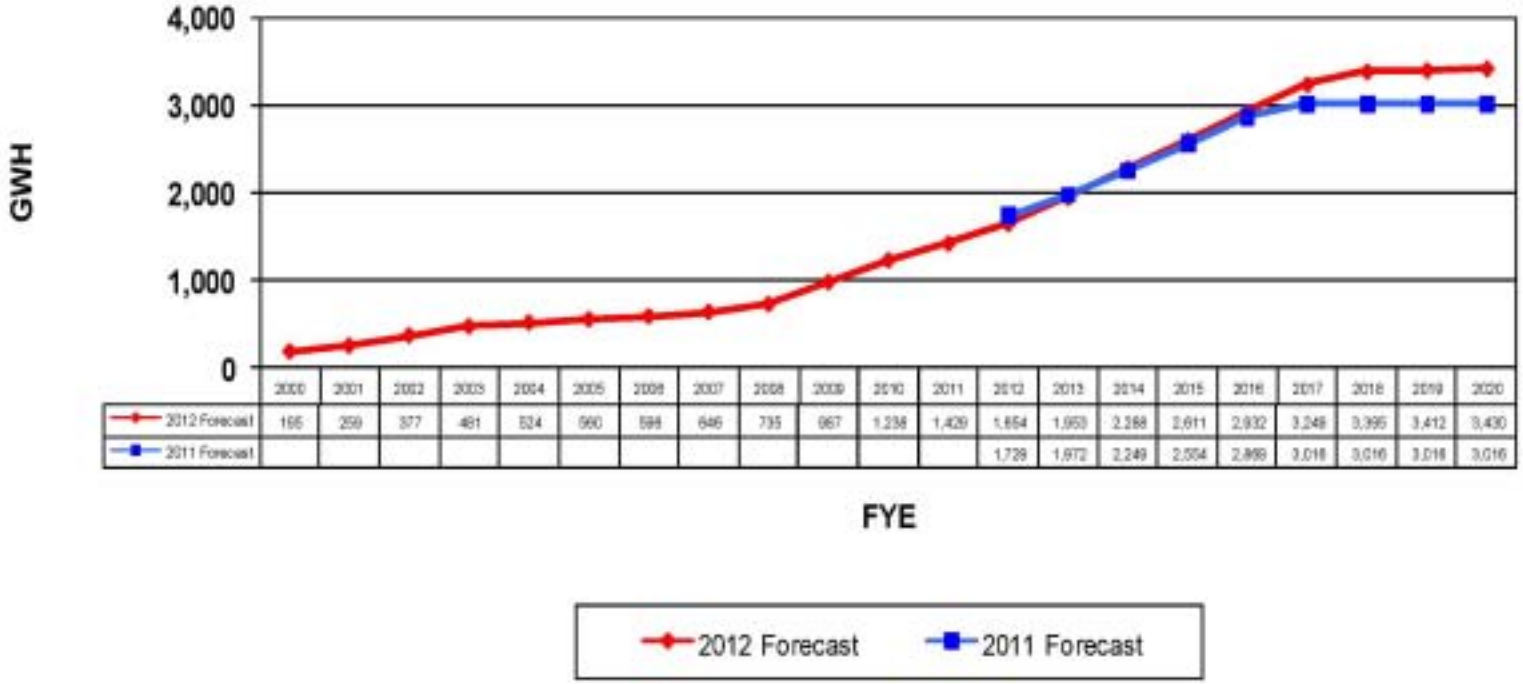
Historical and Forecasted Accumulated Savings

- ✓ EE before 2008 not included in ECAF Lost Revenue calculation.
- ✓ Energy Efficient Light Bulbs savings are the result of a new State appliance standard. (Huffman)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Energy Efficient Light Bulbs	0	0	0	0	0	0	0	0	0	0	0	0	9	77	201	287	354	408	431	445	466
LADWP Street Light	0	0	0	0	0	0	0	0	0	0	5	15	25	35	45	50	50	50	50	50	50
LADWP Traffic Light	0	0	0	0	0	0	0	1	2	2	3	4	4	4	4	4	4	4	4	4	4
LADWP Rooftop Solar	0	0	2	9	12	13	14	16	18	22	30	42	70	109	140	161	181	199	210	219	228
LADWP Commercial	179	238	343	436	472	498	525	559	618	790	946	1,112	1,295	1,475	1,656	1,848	2,042	2,236	2,325	2,325	2,325
LADWP Residential	15	21	34	46	53	62	71	86	115	195	283	297	350	400	432	476	535	605	639	639	639

Energy Efficiency Program Change



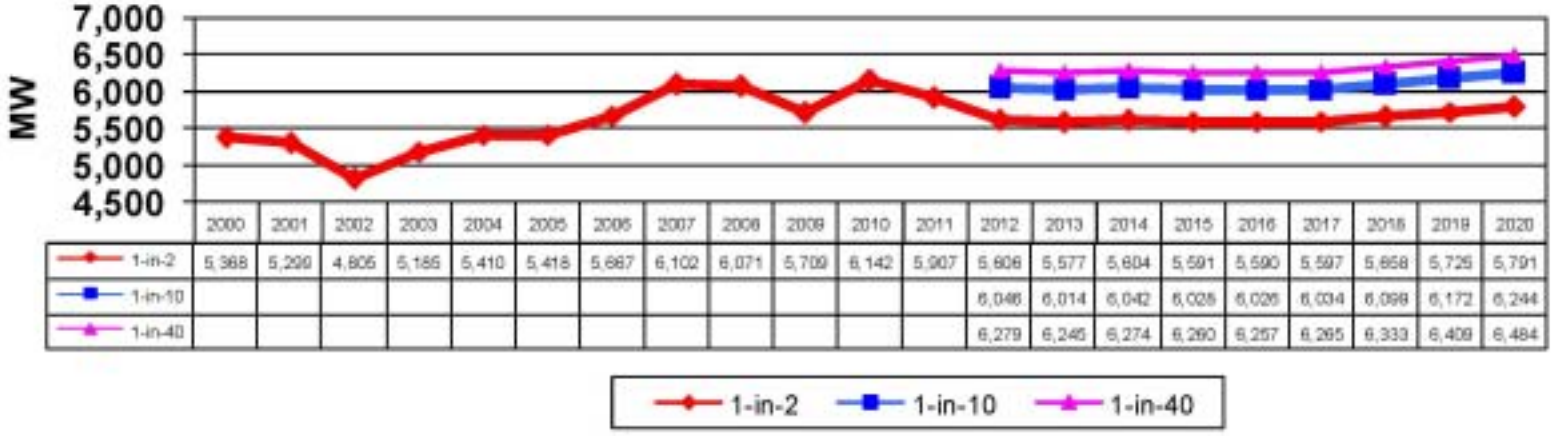
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2012 Forecast	195	259	377	481	524	560	599	646	735	867	1,238	1,429	1,654	1,953	2,288	2,611	2,932	3,248	3,395	3,412	3,430
2011 Forecast													1,729	1,972	2,249	2,554	2,869	3,016	3,016	3,016	3,016

Peak Demand

Cases:

✓The variance around the 1-in-2 forecasted peak has widened based on events since 2006.

✓Based on the climate change finding, it is now expected that the System will approach its potential more frequently so the distance between the 1-in-10 and 1-in-40 forecasts is compressed.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1-in-2	5,368	5,299	4,805	5,155	5,410	5,418	5,667	6,102	6,071	5,709	6,142	5,907	5,606	5,577	5,604	5,591	5,590	5,597	5,658	5,725	5,791
1-in-10													6,046	6,014	6,042	6,028	6,026	6,034	6,098	6,172	6,244
1-in-40													6,279	6,246	6,274	6,260	6,257	6,265	6,333	6,409	6,484

Peak Demand

✓Annual peak demand is dependent on the severity of the heat storms that are encountered during the year.

✓The cases are built on the probability of a weather event occurring in a given year.

NEL (MW) Fiscal Year Annual Peak Demand				
Fiscal Year	Base Case	1 in 5	1 in 10	1 in 40 Hot
2012-13	5,606	5,894	6,046	6,279
2013-14	5,577	5,863	6,014	6,245
2014-15	5,604	5,891	6,042	6,274
2015-16	5,591	5,878	6,028	6,260
2016-17	5,590	5,876	6,026	6,257
2017-18	5,597	5,884	6,034	6,265
2018-19	5,658	5,947	6,099	6,333
2019-00	5,725	6,018	6,172	6,409
2020-21	5,791	6,088	6,244	6,484
2021-22	5,881	6,184	6,342	6,586
2022-23	5,942	6,248	6,409	6,656
2023-24	5,995	6,305	6,467	6,716
2024-25	6,050	6,363	6,526	6,779
2025-26	6,105	6,421	6,586	6,840
2026-27	6,160	6,478	6,645	6,902
2027-28	6,216	6,537	6,705	6,965
2028-29	6,271	6,595	6,765	7,027
2029-30	6,326	6,653	6,824	7,088
2030-31	6,381	6,712	6,885	7,151

1-in-10 Peak Demand

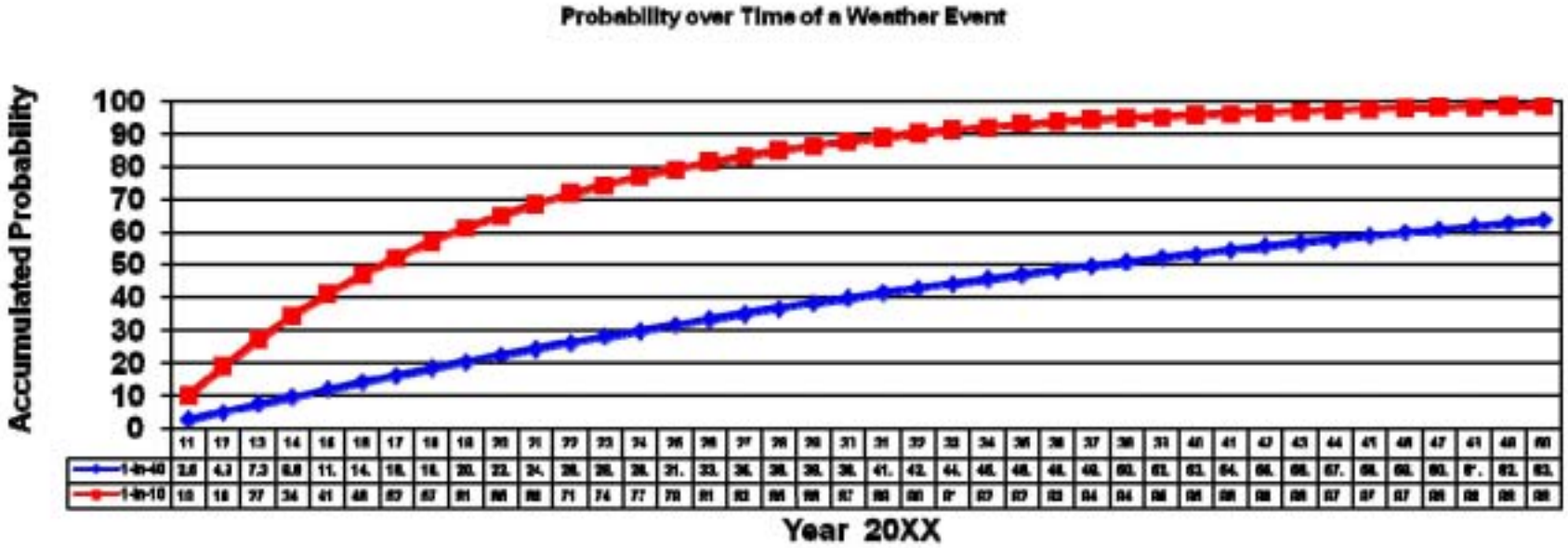
1-in-10 peak used in Integrated Resource Planning process:

- ✓2011 Actual Peak = 5907 MW.
- ✓2011 Weather-Normalized peak = 5631 MW.
- ✓2011 Forecasted Weather-normalized peak = 5589 MW.
- ✓Peaks after 2006 have tended to spike.

1-in-10 Peak Demand

Probability accumulates over time:

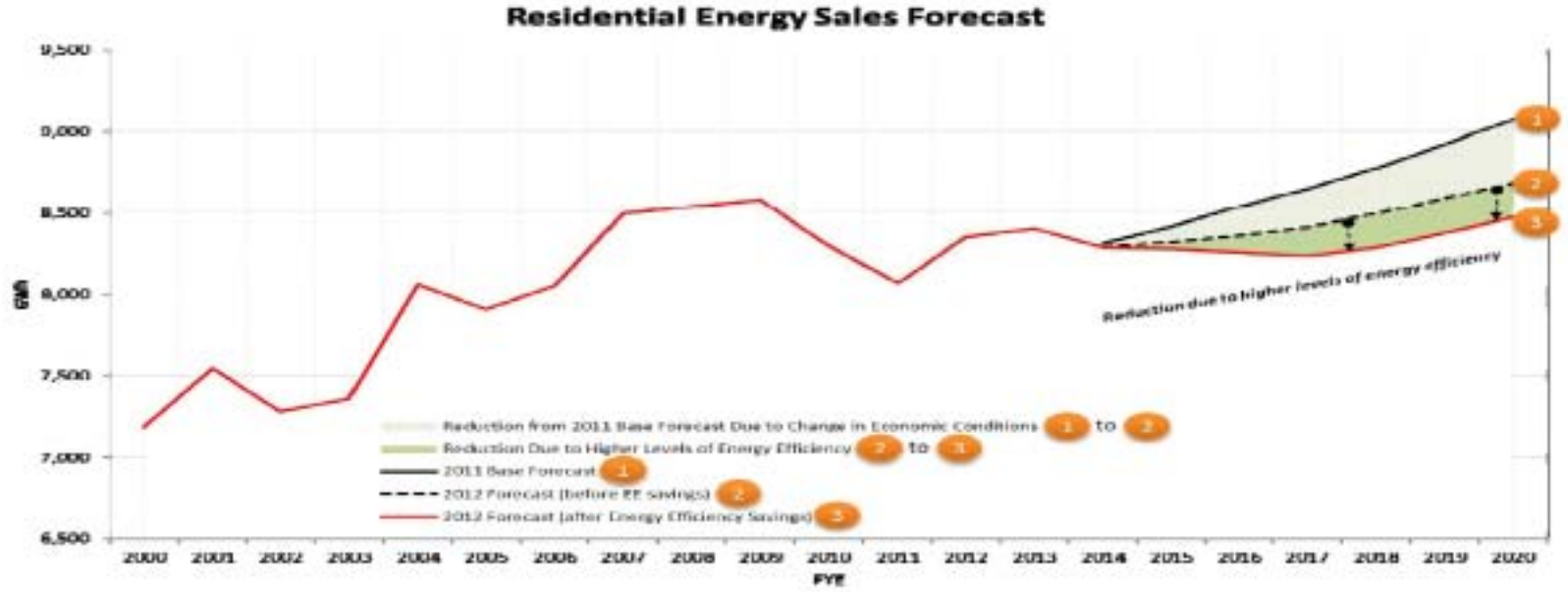
- ✓There is a 65% chance of having a 1-in-10 weather event by 2020.
- ✓There is a 22% chance of having a 1-in-40 weather event by 2020.
- ✓$P_t=1-(1-P_e)^t$



Residential Energy Sales

Components of Change

- ✓ Lowered new-units-built forecast
- ✓ Lower economic forecast

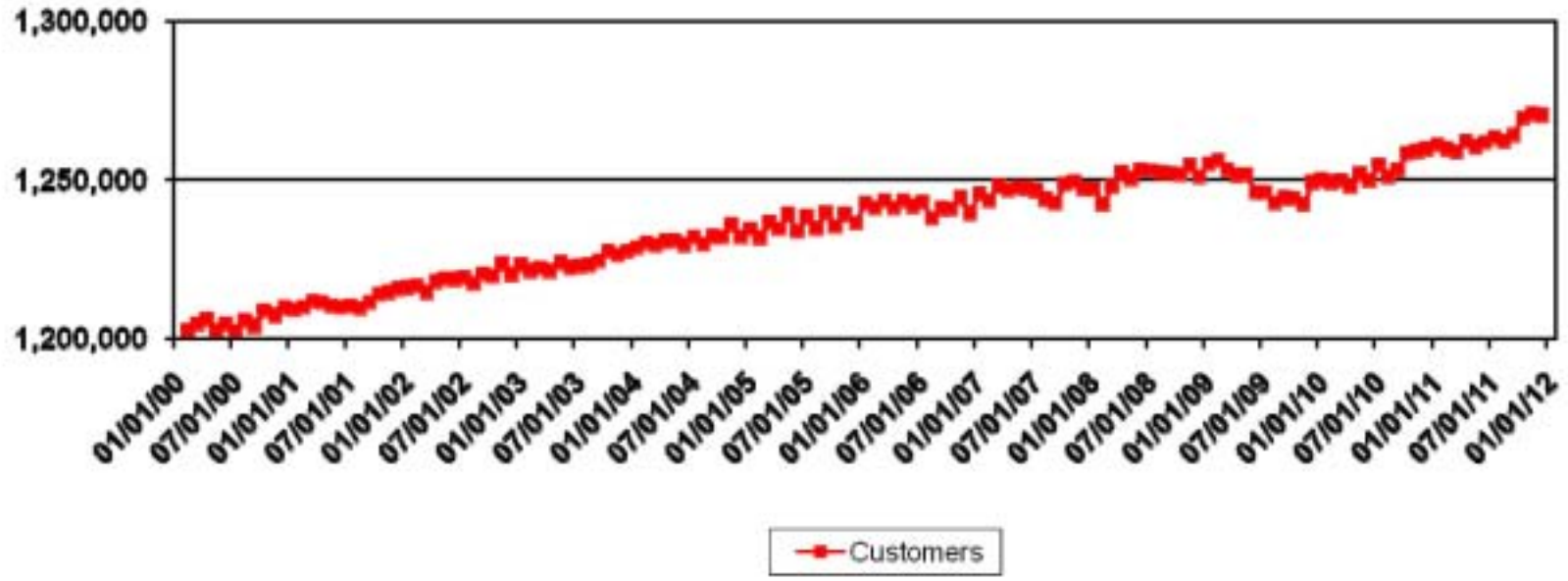


Residential Energy Sales

Number of Residential Customers

Recent Evidence

- ✓ 10,000 active meters added in 2011.
- ✓ Returning to long-term trend quickly.
- ✓ The majority of residential customers are renters and live in multi-family units.
- ✓ The attractiveness of downtown living has increased due to the "Housing that Works" plan.



Residential Energy Sales
Average Sales per Customer

Recent Evidence

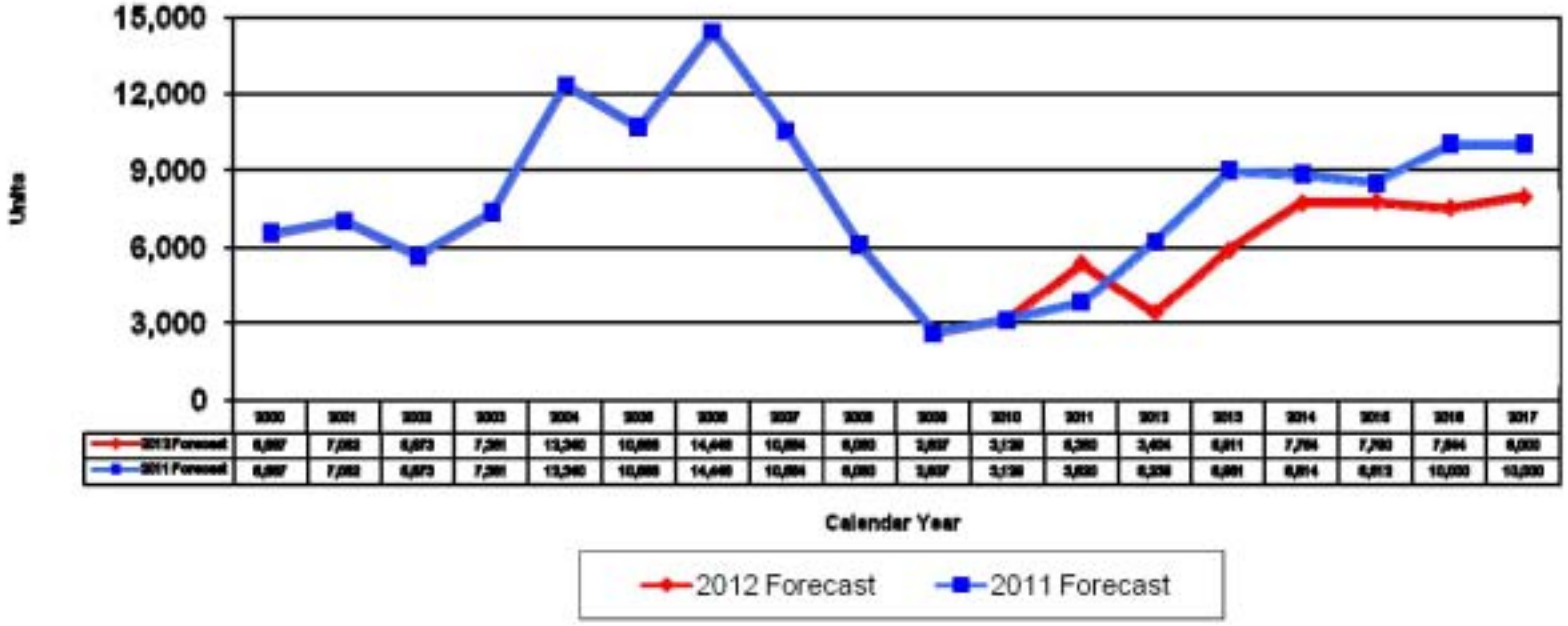
- ✓Sales per residential customer reached an all-time high of 519 KWH per month in December 2008.
- ✓The December 2011 rate is 482 KWH per Month.
- ✓Weather -normalized September 2011 rate is 495 kWh per Month.

Residential Energy Sales

New Residential Building Units

Recent Evidence

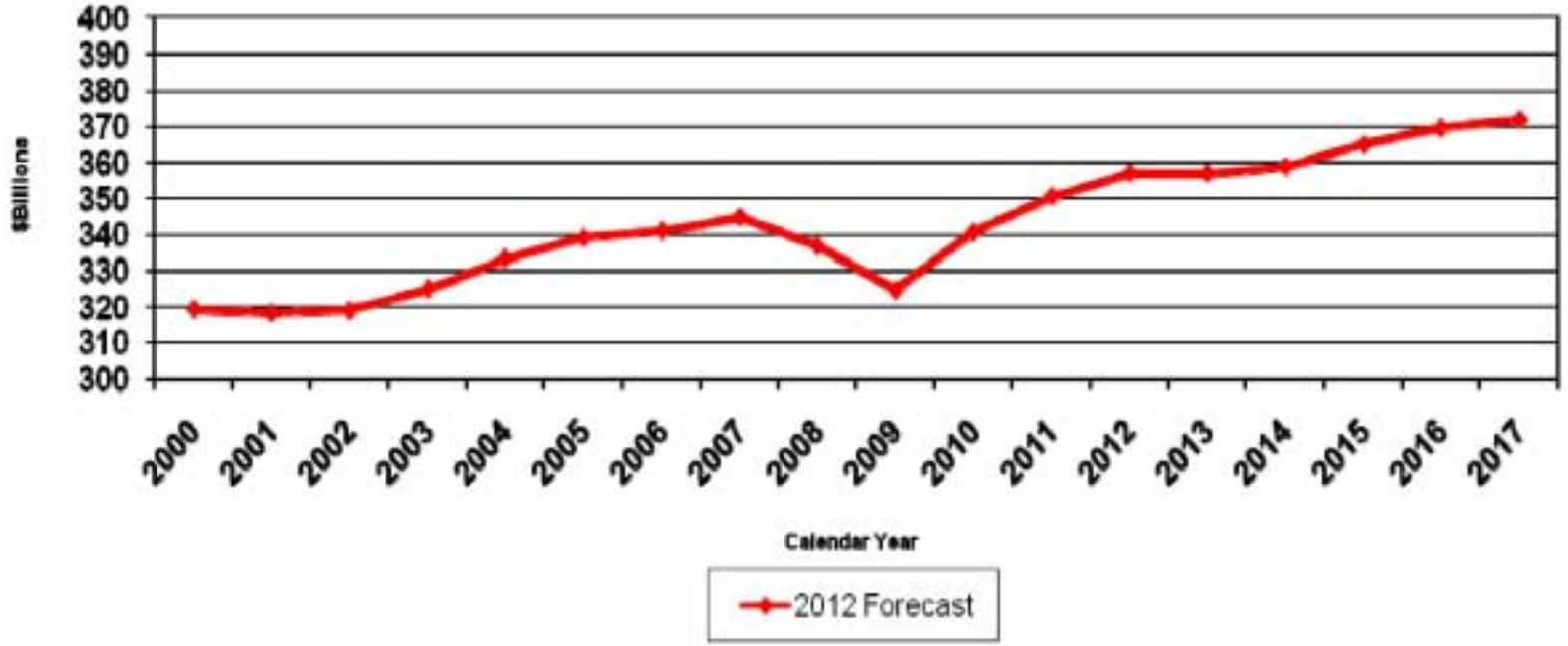
- ✓ New units are 20% Single-Family and 80% Multi-family which lowers future average consumption per household.
- ✓ Recent Housing Starts are at historical lows.



Residential Energy Sales
Recent Economic Impact

Real Personal Consumption

- ✓ Recovery ends and expansion begins in 2012.
- ✓ 1% growth - Below historical mean growth.



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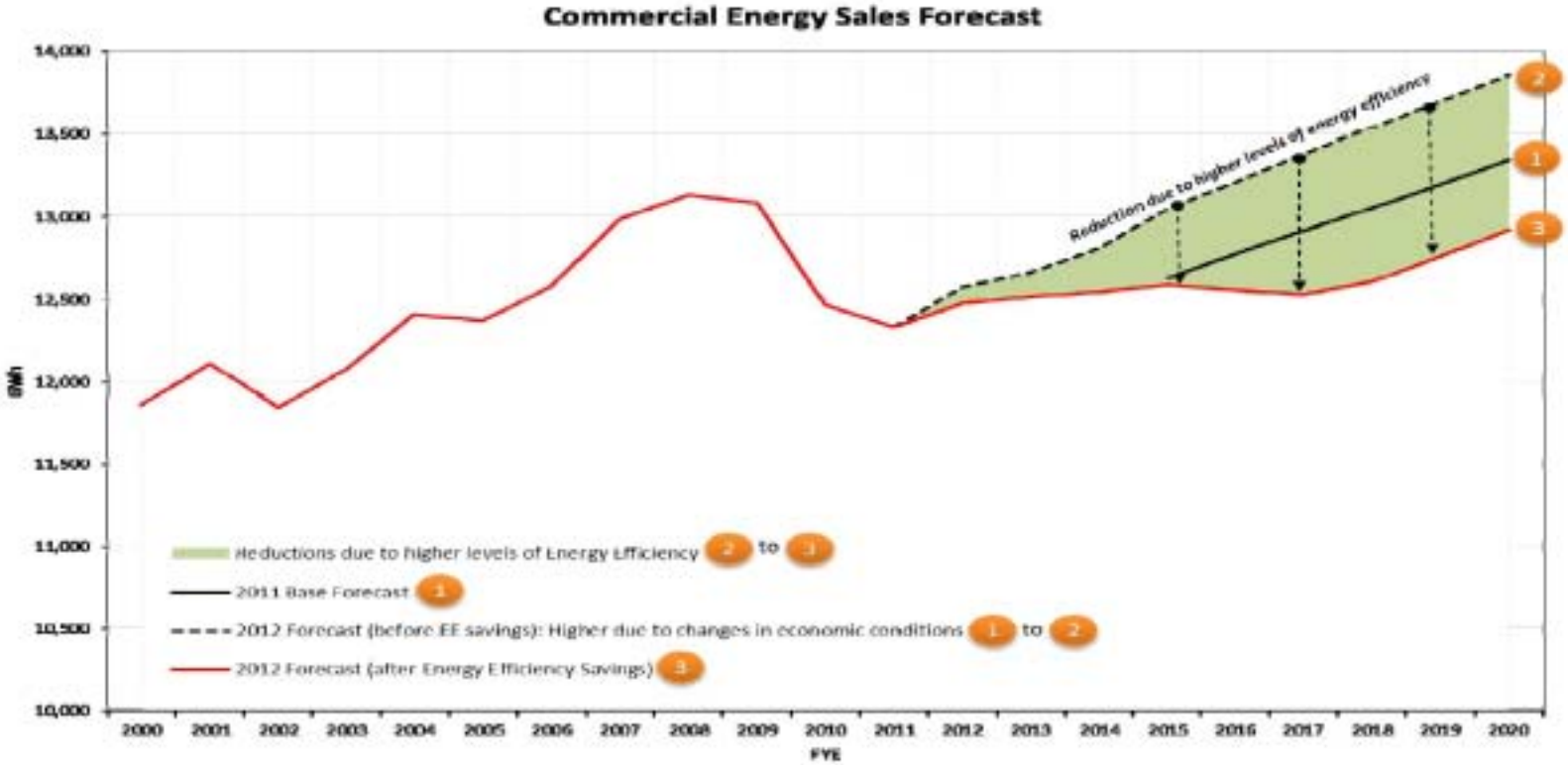
Commercial Energy Sales

Components of Change

- ✓ Service employment forecast slightly higher.
- ✓ Commercial construction activity down but positive absorption.



Commercial Energy Sales

Number of Commercial Customers

Recent Evidence

- ✓ There is a delay in bill collection. There are approximately 750 accounts past due, as result of the AMI implementation. LADWP is working to resolve this issue.

Commercial Energy Sales
Average Sales per Customer

Recent Evidence

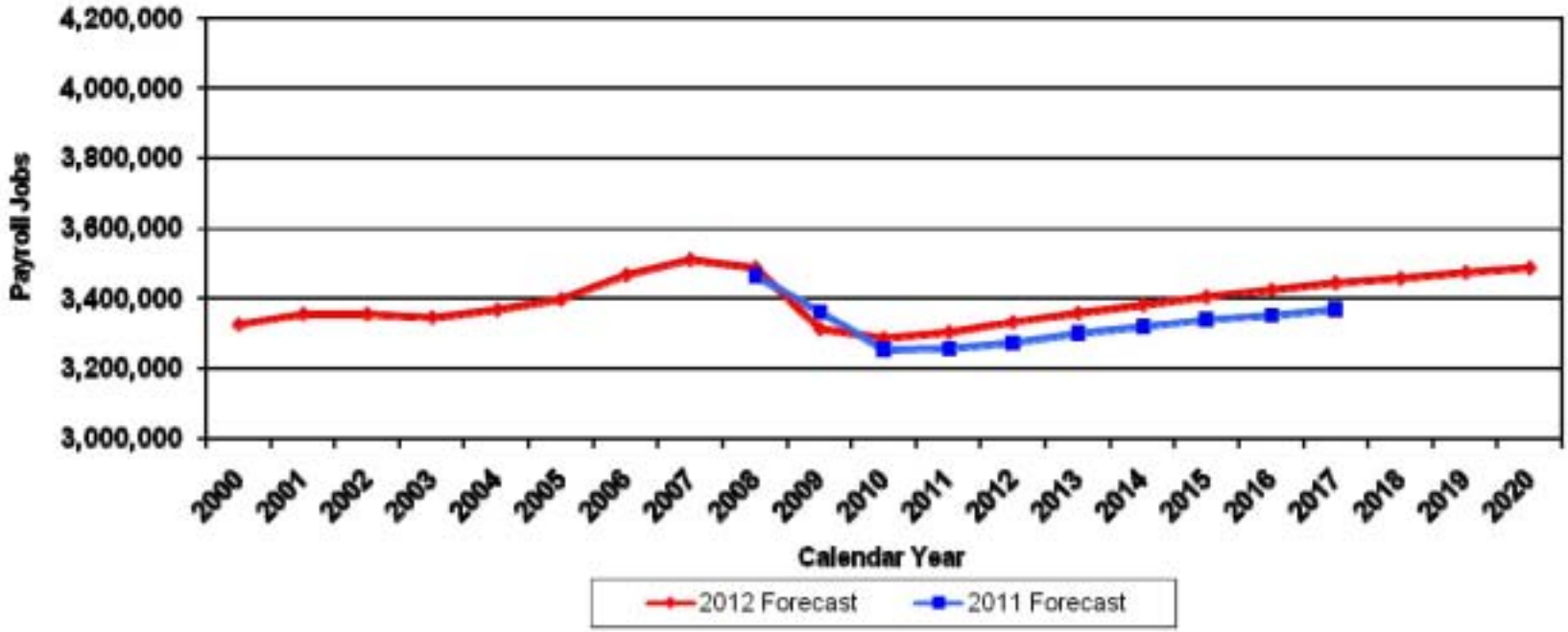
- ✓ Sales per customer per month peaked in July 2008 at 9265 KWH per month.
- ✓ Currently sales per customer per month are 8614 KWH.
- ✓ Weather normal sales per customer per month is 8690 KWH.

Commercial Energy Sales

Local Employment in Service Sector

LA County Commercial Services Employment

- ✓ Changing service delivery models – Internet and Big box retailers are two examples.
- ✓ Employment does not return to former high by 2020.



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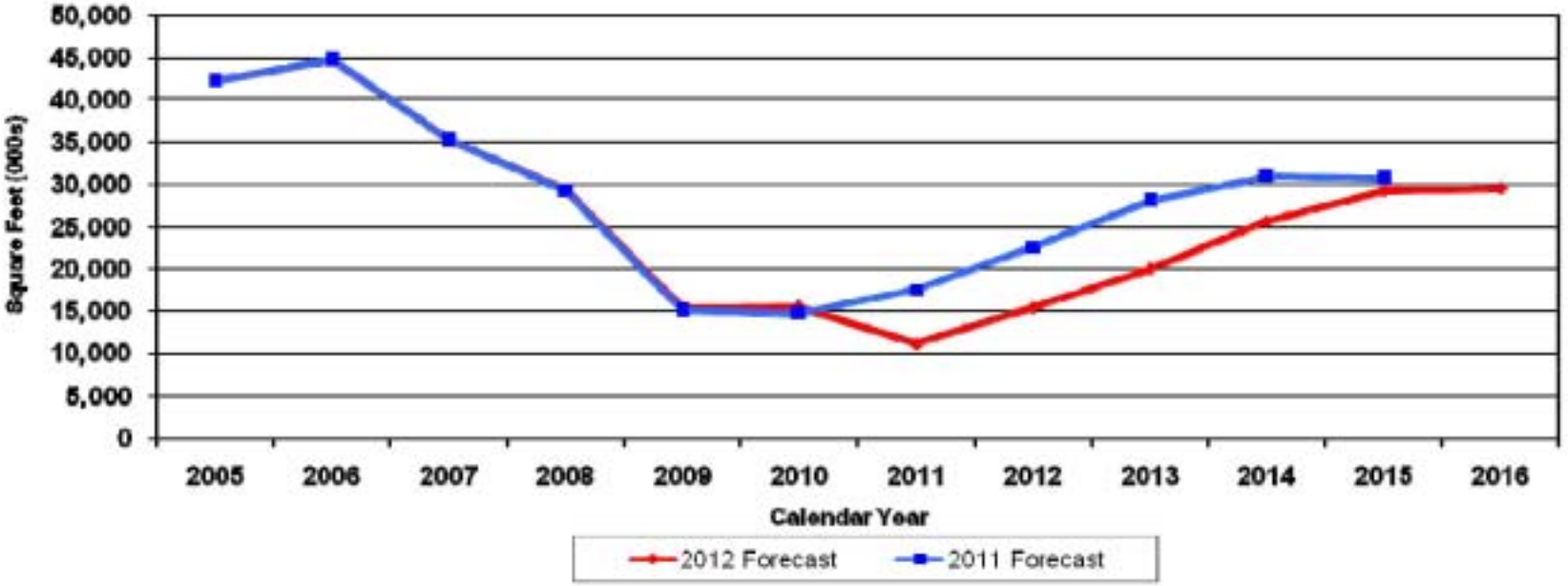
Commercial Energy Sales

McGraw-Hill Construction Forecast

Commercial Floorspace Additions

- ✓ Construction activity at historically low levels.
- ✓ Office vacancy rates in San Fernando Valley at 18 percent.
- ✓ New models for delivering commercial services require smaller physical presence.



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Industrial Energy Sales

Components of Change

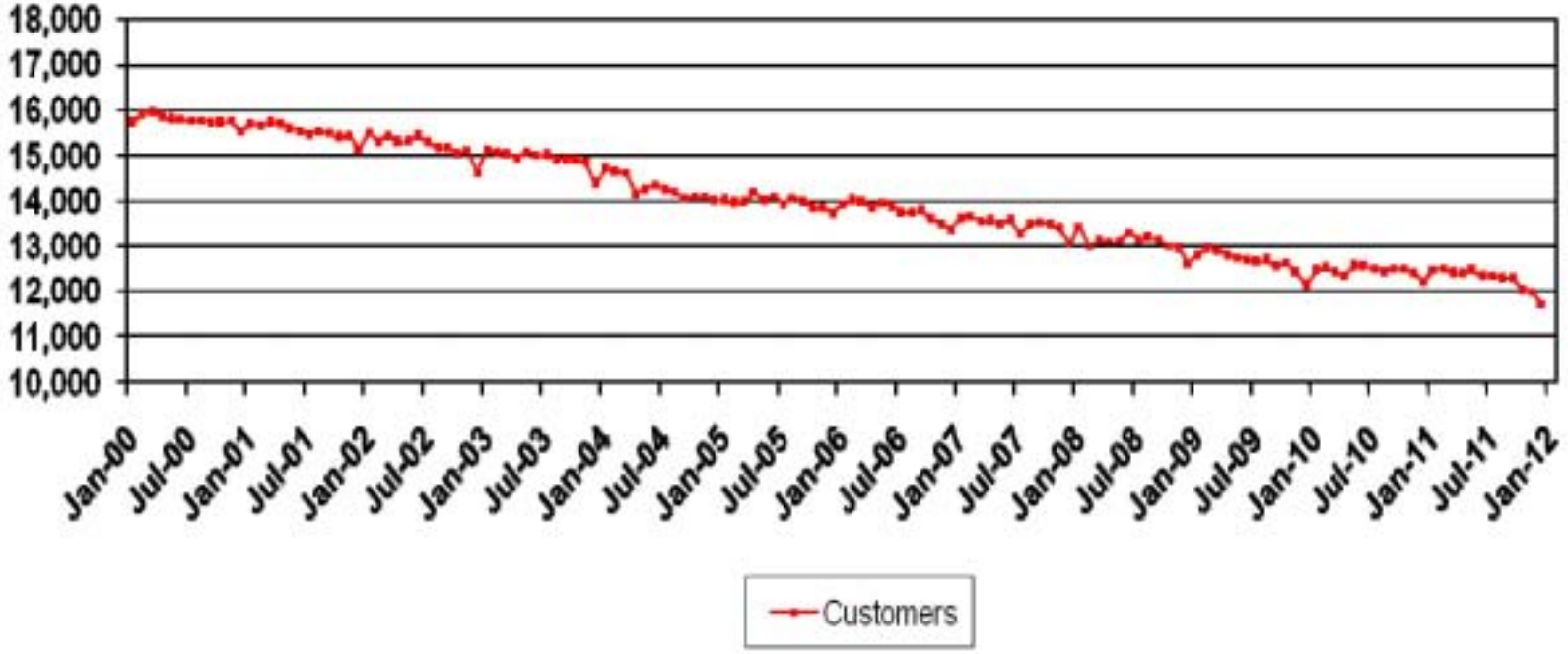
- ✓ Land use issue: Once industrial land is vacated, residential and commercial buildings tend to replace it. 3 to 4 percent vacancy rates in the industrial sector.
- ✓ Manufacturing that is staying tends to be high-value added manufacturing and process industries.
- ✓ Other manufacturing continues to move offshore or to the States with better business climate.
- ✓ No EE or rooftop solar in the Industrial Forecast. All EE and solar assigned to Residential, Commercial and Streetlight sectors.

Industrial Energy Sales

Number of Industrial Customers

Recent Evidence

- ✓The number of Industrial customers is continually and relentlessly declining.
- ✓The decline began in the 1970s.
- ✓The forecast is for the heavy process industries to remain although no new heavy industry will be built. It is the light industry and assembly jobs that are disappearing.

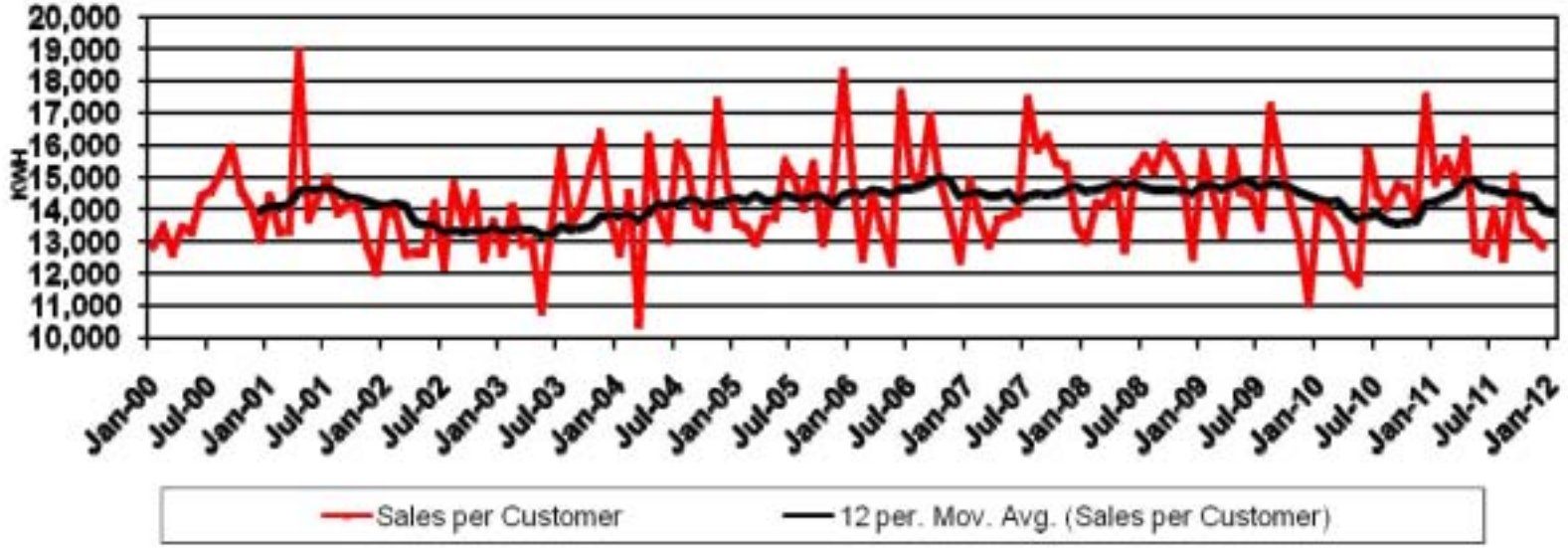


Industrial Energy Sales
Average Sales per Customer

Recent Evidence

✓Sales per customer per month peaked in October 2006 at 15026 KWH per month. High consumption partially attributed to a large self-generation unit being off-line at a refinery.

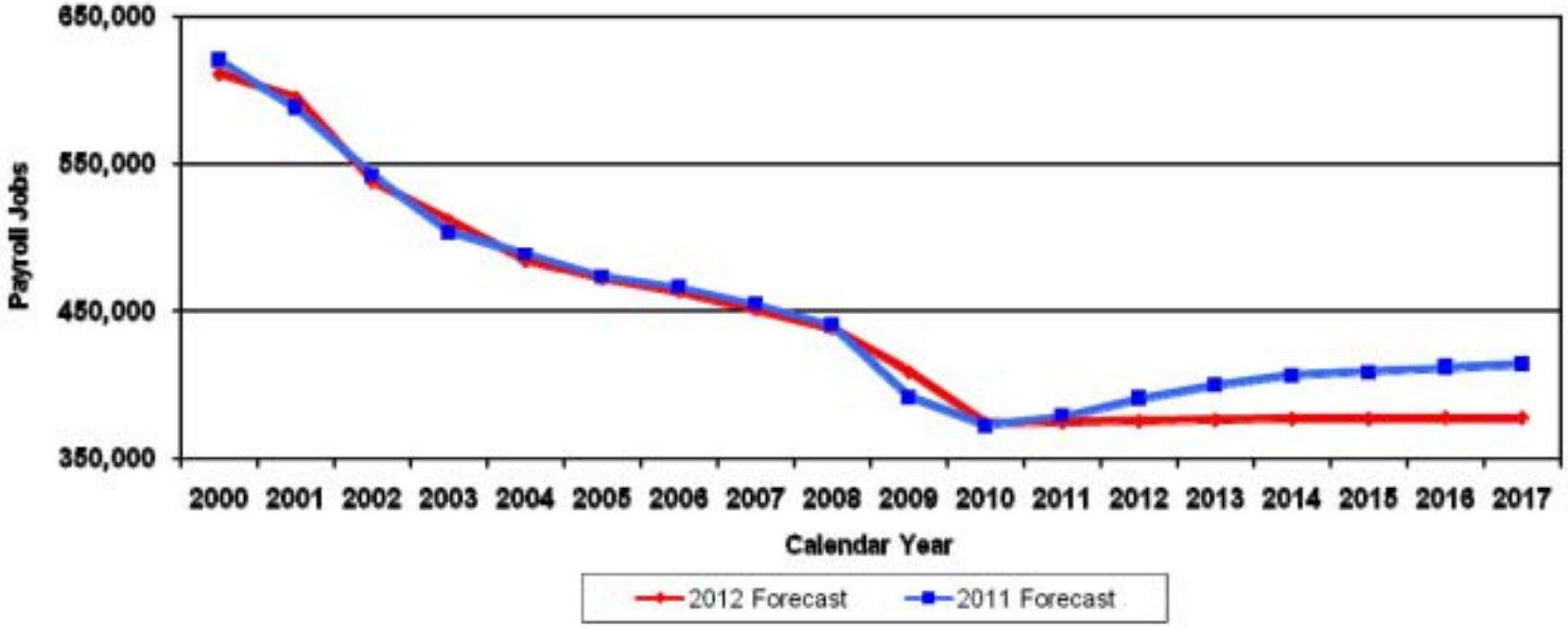
✓Currently sales per customer per month are 14000 KWH.



Industrial Energy Sales
Local Manufacturing Employment

LA County Manufacturing Employment

✓Future employment forecast is flat. If Los Angeles continues to lose manufacturing jobs then there will be a mismatch with the education level of the population and available high paying jobs. It could lead to significant population out-migration.



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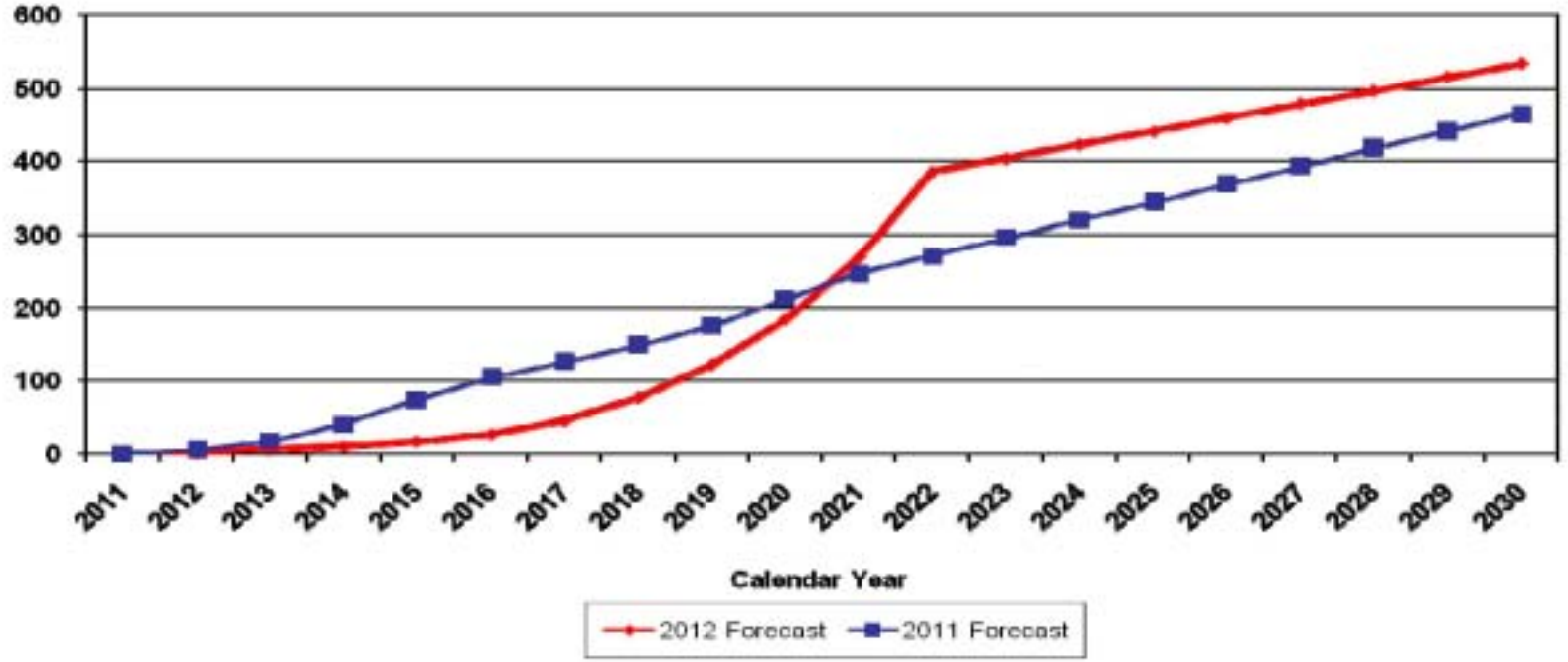
Electric Vehicle Sales

Load Growth

- ✓2012 forecast developed by the Plug-in Electric Vehicle Collaborative.
- ✓Also adopted by California Energy Commission



Plausibility

- Comparing unmitigated 2012 Sales Forecast to historical sales.
  - Unmitigated means forecasting sales based on economics alone before the impacts of environmental programs are considered.
  - Forecasted sales decline from 2008 to 2011 is largest in the past 30 years but smaller in scale.
  - No growth from economic factors in the next ten years. Next decade similar to what occurred in the 1990s before additional regulation.
  - LA is a mature economy.

Peak-to-Through Analysis		
Years	GWH Decline	Percent Decline
2008-2011	1,564	6.4%
1992-1994	1,421	7.0%
2000-2002	572	2.6%
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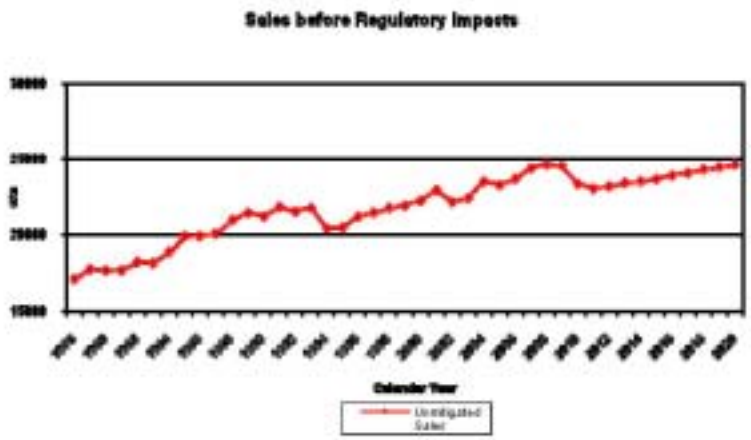
1981-1982	145	0.8%



Appendix B Energy Efficiency

Energy Efficiency (EE) is a key strategic element in LADWP IRP planning efforts. EE is a very cost-effective supply-side resource, and serves an important and multi-faceted role in meeting customer demand. One of the most widely recognized examples of EE is the replacement of incandescent lights with compact fluorescent lamp (CFL) bulbs. CFLs consume up to 75 percent less energy than incandescent bulbs while producing an equivalent amount of illumination, and last up to 10 times longer.

The reduction in energy demand that EE enables, translates into a number of benefits:

- Deferred need to build physical generation assets
- Reduced RPS compliance costs
- Reduced environmental footprint, including lower GHG emissions
- Potential for local job creation opportunities

The following subsections summarize the background of LADWP's EE program, and then review the most recently completed EE potential study that was conducted in 2010 and finalized in February 2011. Based on the study results, a plan is recommended with identified savings and costs targets. For more specific details regarding the 2010 study, see the reference at the end of this appendix.

It should be noted that efforts are in progress to commission a new EE Potential Study that will supersede the 2010 study. In 2012, the Board of Water and Power Commissioners adopted a goal of achieving 10 percent EE by 2020, with a target of up to 15% by 2020 pending the results of the new study. The cases evaluated in this 2012 IRP have all incorporated 10% EE by year 2020, with higher levels of up to 17% by 2032. Next year's IRP will incorporate the findings and recommendations of the new potential study as they are finalized and approved.

B.1 Background

LADWP has active EE programs that have been in place for several years. Since 2000, LADWP has spent approximately $315.2 million on its EE programs, which have reduced consumption by approximately 1,377 GWh. LADWP continues its commitment to developing robust, cost-effective EE programs with measurable and verifiable goals.

LADWP offers numerous EE programs and services for residential, commercial, industrial, governmental, and institutional customers to promote the efficient use of energy through the installation of energy efficient equipment. Examples include:

- The Commercial Lighting Efficiency Offer (CLEO), which provides rebates for a variety of high efficiency lighting measures to retrofit existing buildings. The CLEO program enjoys sustained high rates of participation and has achieved 433 GWh of

AR0070130

energy savings since 2000.

- The Chiller Efficiency Program, which provides incentives for customers to replace old electric chillers with new, high-efficiency units. Chillers provide space conditioning for larger buildings and the program has reduced associated peak electrical demand by more than 52 MW since 2001.
- The Small Business Direct Install (SBDI) Program, which assists eligible small businesses (A1 rate customers) in Los Angeles in becoming more energy efficient through free lighting assessments and free lighting retrofits (up to $2,500 in cost). SBDI began in 2008 and has achieved 149 GWh of energy savings since its inception.
- The Custom Performance Program, which provides performance-based incentives for energy efficiency measures not included on LADWP's menu-based EE programs. Measures supported include controls and control systems, high efficiency motors, and data server virtualization. The Custom Performance Program has achieved 200 GWh of energy savings since 2006.
- The Refrigerator Exchange Program, which delivers new Energy Star refrigerators to eligible residential customers, and picks-up/recycles customers' old, inefficient refrigerators. This program has replaced and recycled more than 53,000 refrigerators since 2007, achieving an energy savings of 49 GWh.

However successful LADWP's EE program has been, for a variety of reasons it did not meet targets that were set back in 2006. A summary the program since 2006 is presented in Table B-1.

Table B-1. LADWP EE PROGRAM PROGRESS-TO-DATE

	FY 06-07	FY 07-08	FY 08-09	FY 09-10	FY 10-11	FY 11-12	Cumulative FY 06-12
LADWP Adopted Targets (2006) - Net GWh	58	275	315	300	280	255	1,483
Actual Energy Savings Achieved - Net GWh	58	118	270	156	154	107	863
Actual % of Adopted Target	100%	43%	86%	52%	55%	42%	58%
Actual Energy Savings - Gross GWh	68	139	318	184	181	126	1016
Approved EE Budget ($million)	28	79	77	93	69	70	416
Revised EE Budget ($million)	n/a	n/a	n/a	>50	50	55	
Actual EE Funds Spent ($million)	14	38	68	44	50	37	251
Actual % of Budget	51%	48%	88%	48%	72%	68%	62%
Effective Cost - $/kWh	$0.018	$0.023	$0.018	$0.020	$0.023	$0.035	$0.291

Some key points regarding Table B-1 are as follows:

- The economic outlook in 2006, which the targets were based on, was more elevated then what actually transpired. As the higher outlook in 2006 failed to materialize, in retrospect the prior EE targets were overly ambitious.
- Since 2006, regulatory requirements have increased (OTC, RPS, GHG, etc.), resulting in additional demands outside of the EE program.

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- Revenue streams required to support EE programs did not materialize. A spending freeze in 2009 and spending cutback in 2010 resulted in underfunding which hindered the attainment of program goals.
- Actual load profiles were less than forecasted, further affecting program performance.

An assessment of LADWP's EE program was undertaken in 2010. The assessment, also known as an Energy Efficiency Potential Study, includes an updated plan for moving forward.

B.2 Energy Efficiency Potential Study

Per Assembly Bill 2021 (AB 2021), publically owned utilities such as LADWP, must identify and develop all potential achievable, cost-effective EE savings and establish annual targets. Furthermore, utilities are required to conduct periodic "Potential" studies to update their forecasts and targets. The most recent study was carried out in late 2010 and is the basis for the EE recommendations contained in this 2011 IRP.

For more in-depth information, see the study referenced at the end of this appendix. This section presents a brief summary of the methodology and findings.

The 2010 Potential Study objectives were as follows:

- To estimate savings possible through utility programs and other interventions (such as the American Recovery and Reinvestment Act)
- Identify energy-efficiency technologies and measures that will produce savings
- Link the energy saving measures with utility programs to achieve savings
- Provide guidance for setting 10-year targets for CEC

The analysis methodology is shown in Figure B-1.

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Figure B-1. 2010 Energy Efficiency Potential Study analysis approach.

Some of the key factors that were considered in the study include:

- Changes in the customer base since the last study
- Building codes
- Adoption of new appliance standards
- Naturally-occuring conservation
- Trends in appliance satuations
- How customers use electricity today
- Technological changes in appliances and equipment

The resulting baseline forecast for the overall customer base is shown in Figure B-2.

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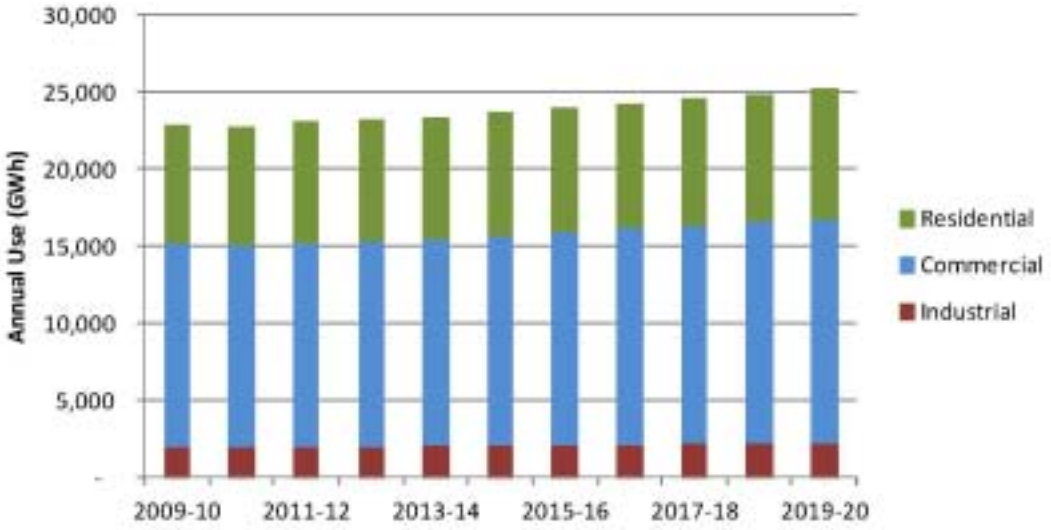

Figure B-2. Baseline forecast results through 2019-20.

Segmented forecasts for the industrial, commercial, and residential sectors are shown in Figures B-3, B-4, and B-5.

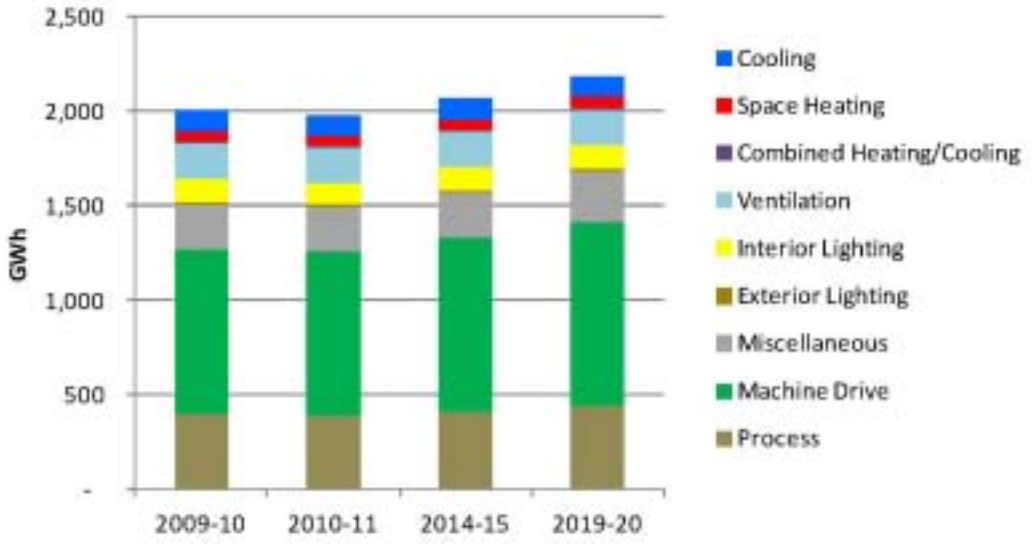

Figure B-3. Industrial sector baseline forecast results.

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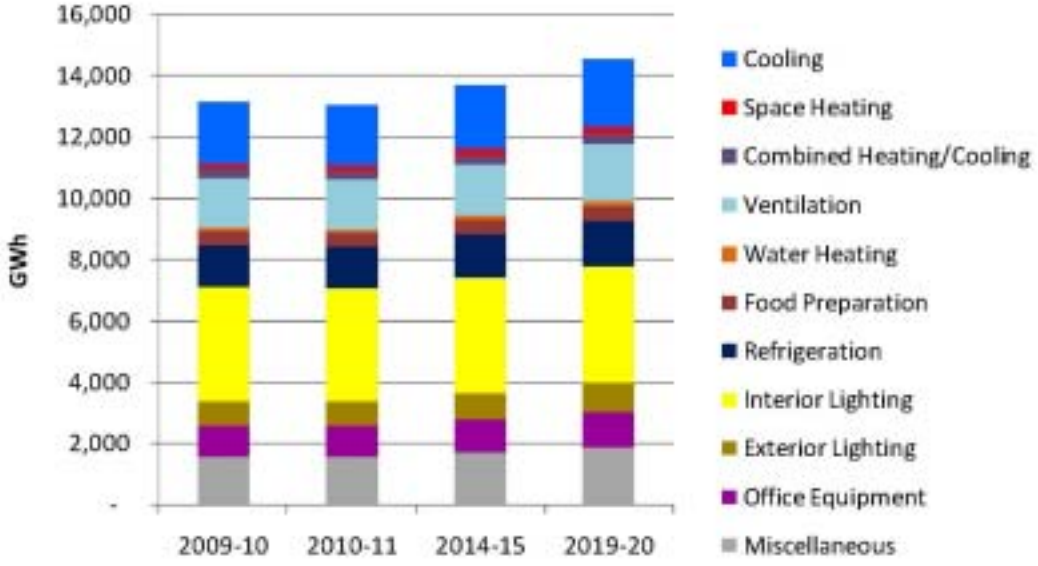

Figure B-4. Commercial sector baseline forecast results.

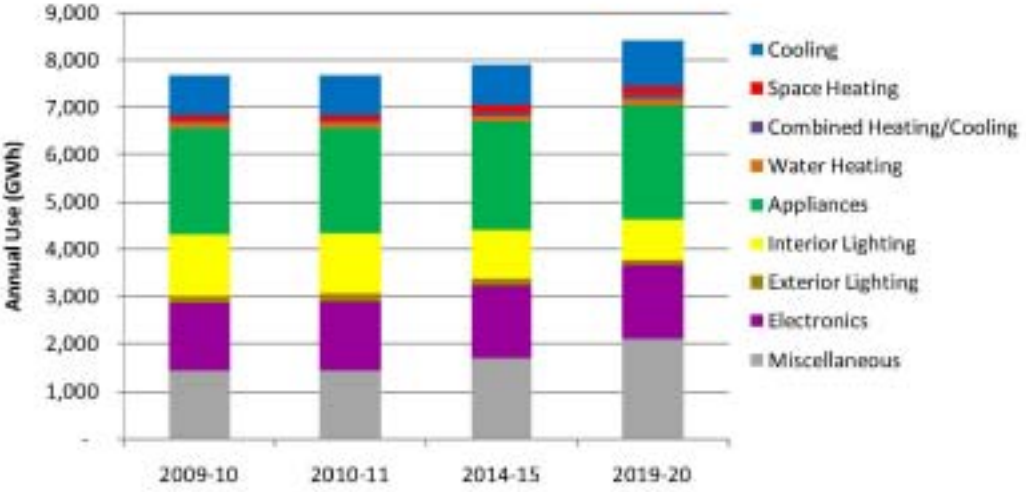

Figure B-5. Residential sector baseline forecast results.

The study evaluated a multitude of measures for potential inclusion into LADWP's EE program, including:

- Existing program elements
- High-efficiency air conditioners (higher efficiency levels, variable refrigerant flow systems)
- High-efficiency lighting (CFLs, LED lamps)
- Upgraded insulation in buildings
- Retrocommissiong and routine maintenance
- Programmable Communicating Thermostats and Energy Management Systems

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B.3 EE Study Results and Plan

To understand the study results the following terms are defined:

2010 Potential Study Definitions

Term	Definition
Technical Potential	Customers are assumed to install most efficient option regardless of costs.
Economic Potential	Customers are assumed to install most efficient cost-effective option.
Maximum Achievable Potential	Sets maximum targets for savings. Assumes "ideal" implementation conditions and customer preferences.
Realistic Achievable Potential	Includes realistic parameters for implementation; incorporates real-world limitations: Advance program potential: Utility pays 100% of incremental cost to upgrade to EE measures. Base program potential: Utility pays 50% of incremental cost.

Key drivers/assumptions influencing EE potential levels are:

- Program budgets are assumed to grow over time
  - Financing impacts
  - Federal grants impact
- Staffing levels and other required resources will increase with program expansion
- Avoided costs will rise with changes to the generations mix

The study found that there is a realistic potential to reduce energy consumption from the baseline forecast by 8.6% by year 2019-20. Figure B-6 shows the cumulative % energy savings through fiscal year 2019-20, and Figure B-7 shows the cumulative absolute savings.

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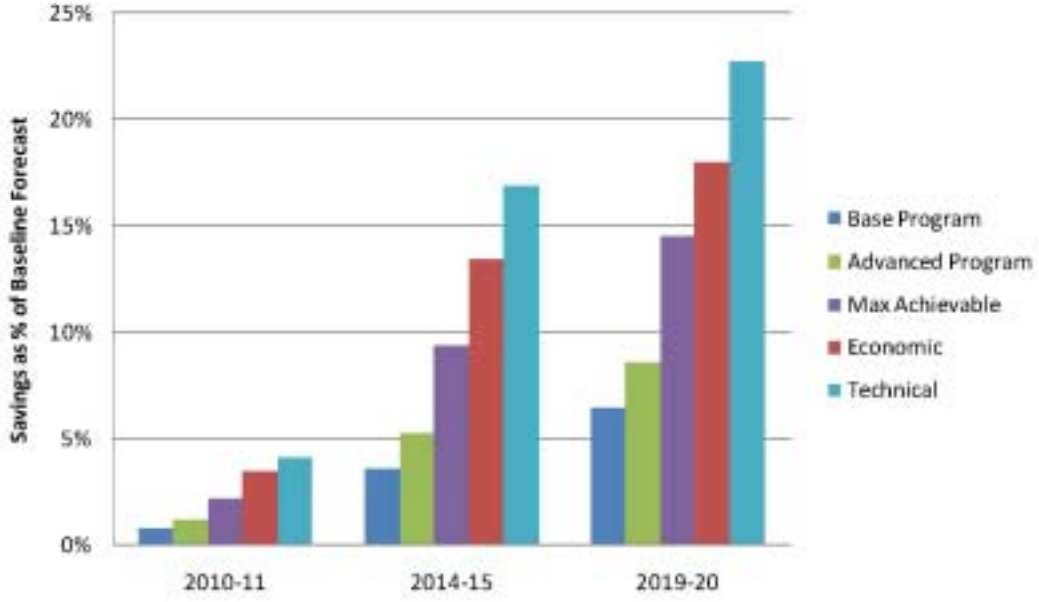

Figure B-6. Cumulative energy savings as a percentage of the baseline forecast.

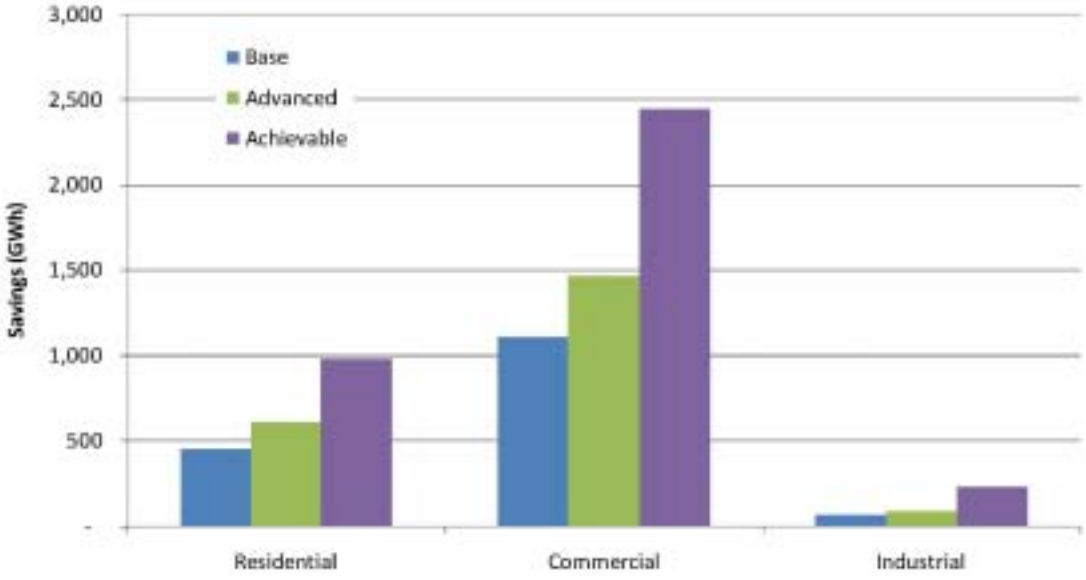

Figure B-7. Cumulative energy savings in GWh.

The Potential Study found that the net present value of avoided energy costs exceeds the NPV of program costs (including incentive payments, administrative costs and customer contributions) in both the Base and Advanced programs. Table B-2 and Figure B-8 illustrate the cost and benefit findings.

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Table B-2. Financial Metrics

	Total Savings (GWh)	Total Cost ($Million)	Total Benefits ($Million)	Net Benefits ($Million)	Benefit/ Cost	Cost of Conserved Energy (cents/kWh)
Base Program	18,719	$1,073	$1,092	$18	1.02	5.73
Advanced Program	25,290	$1,411	$1,483	$72	1.05	5.58
Max Achievable	46,209	$2,139	$2,681	$542	1.25	4.63

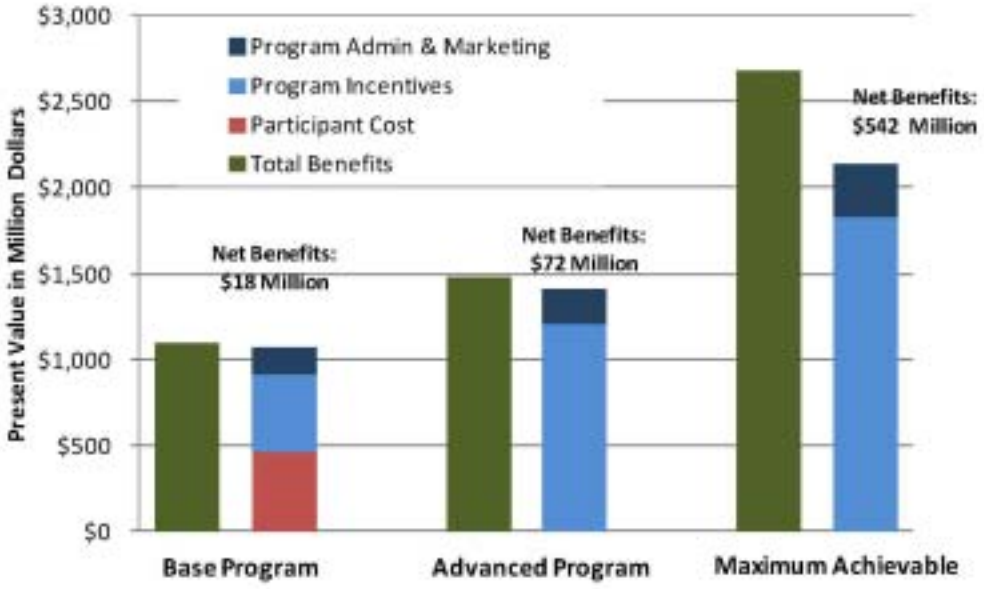

Figure B-8. Cost and benefits for base and advanced programs.

The analysis includes an assessment of the current program portfolio and the development of recommended changes.

Residential Programs

LADWP currently has the following existing residential EE programs:

Consumer Rebate
Refrigerator Turn-In and Recycle
Low Income Refrigerator Exchange
Compact Fluorescent Lamp (CFL) Distribution

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The following recommendations resulted from the 2010 potential study:

1. LADWP should keep its existing programs, with the exception of CFL Distribution which should be replaced with a broader lighting initiative adapted to revised lighting standards.
2. Two new programs should be adopted, (1) Low-income, and (2) Whole House Performance.

A continued effort towards public outreach is also recommended to maintain and broaden public awareness of available EE benefits, and to promote participation.

Figure B-9 illustrates potential residential EE program savings for fiscal year 2019-20.

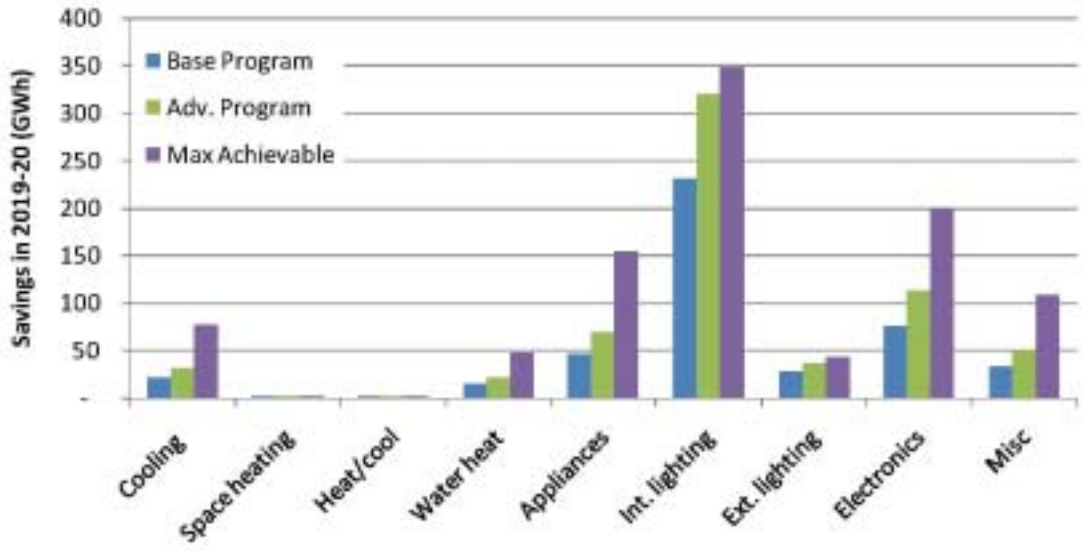

Figure B-9. Potential residential EE program savings in 2019-20.

Commercial and Industrial (C&I)

LADWP currently has the following existing C&I EE programs:

Commercial Lighting Efficiency
Chiller Efficiency
Refrigeration
Customer Performance
Small Business Direct Install
New Construction Incentive
Financing Programs
Energy Audits
Technical Assistance

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The following recommendations resulted from the 2010 potential study:

1. LADWP should keep its existing program elements, but should adapt the lighting program to educate customers on the expanded choices in energy efficiency bulbs available that will comply with new lighting standards.

Figures B-10 and B-11 illustrate potential commercial and industrial savings for year 2019-20.

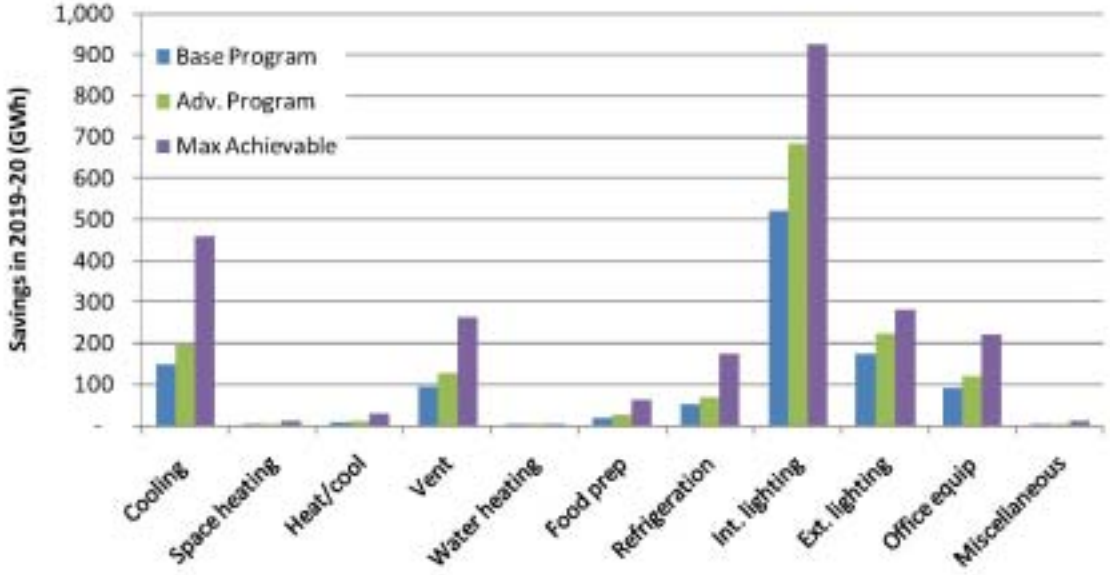

Figure B-10. Projected commercial EE savings in 2019-20.

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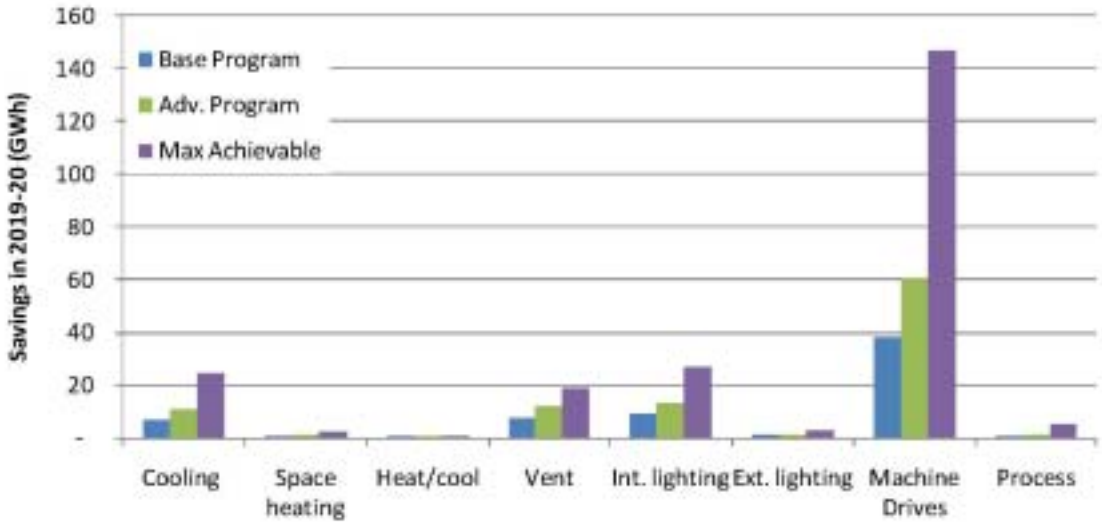

Figure B-11. Projected industrial EE savings in 2019-20.

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B.4 References

1. "LOS ANGELES DEPARTMENT OF WATER AND POWER ENERGY EFFICIENCY AND DEMAND RESPONSE POTENTIAL STUDY VOLUME 1 – ENERGY EFFICIENCY POTENTIAL" prepared by: Global Energy Partners, February 2011.

2. Assembly Bill: "BILL NUMBER: A.B. No. 2021, AUTHOR : Levine, TOPIC : Public utilities: energy efficiency." - "Assembly Bill No. 2021, CHAPTER 734, An act to add Section 25310 to the Public Resources Code, and to amend Section 9615 of the Public Utilities Code, relating to energy efficiency."

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Appendix C Environmental Issues

C.1 Overview

LADWP's mission includes a role as an environmentally responsible public agency. LADWP continues to develop and implement programs to improve the environment, including:

- Increasing the use of renewable energy to meet the needs of LADWP's customers (20 percent by December 31, 2010 and 33 percent by December 2020 through the development of wind, solar, geothermal, and biomass energy sources and acquiring the associated transmission required to transmit such energy to Los Angeles.
- Prioritizing the use of Energy Efficiency (EE), Demand Side Management (DSM), renewable Distributed Generation (DG), and other renewable resources.
- Continuing the modernization of LADWP's in-basin generating stations, including the repowering of four older, less-efficient utility steam boiler units with advanced gas turbine generating units.

This Appendix provides information on a number of environmental issues and policies including oxides of nitrogen (NO_X) emissions, GHGs and climate change, power plant once-through cooling, (OTC), and mercury emissions.

C.2 Emissions of Oxides of Nitrogen (NO_X)

Oxides of nitrogen, or NO_X, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the oxides of nitrogen are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2), is a major precursor for "smog," which can be seen as a reddish-brown layer over many urban areas. Oxides of Nitrogen is also a precursor to the formation of ozone, and the South Coast Air Basin (SCAB), in which Los Angeles is situated, has the one of the highest ozone levels in the United States.

NO_X forms when fuel is burned at high temperatures, as in a combustion process. Figure C-1 shows the primary man-made sources of NO_X as reported by the United States Environmental Protection Agency (U.S. EPA) in 2008. The U.S. EPA first set standards for NO_2 in 1971, setting both a primary standard (to protect health) and a secondary standard (to protect the public welfare) at 0.053 parts per million (53 ppb), averaged annually. The Agency has reviewed the standards twice since that time, but chose not to revise the standards at the conclusion of each review. All areas in the U.S. meet the current (1971) NO_2 standards.

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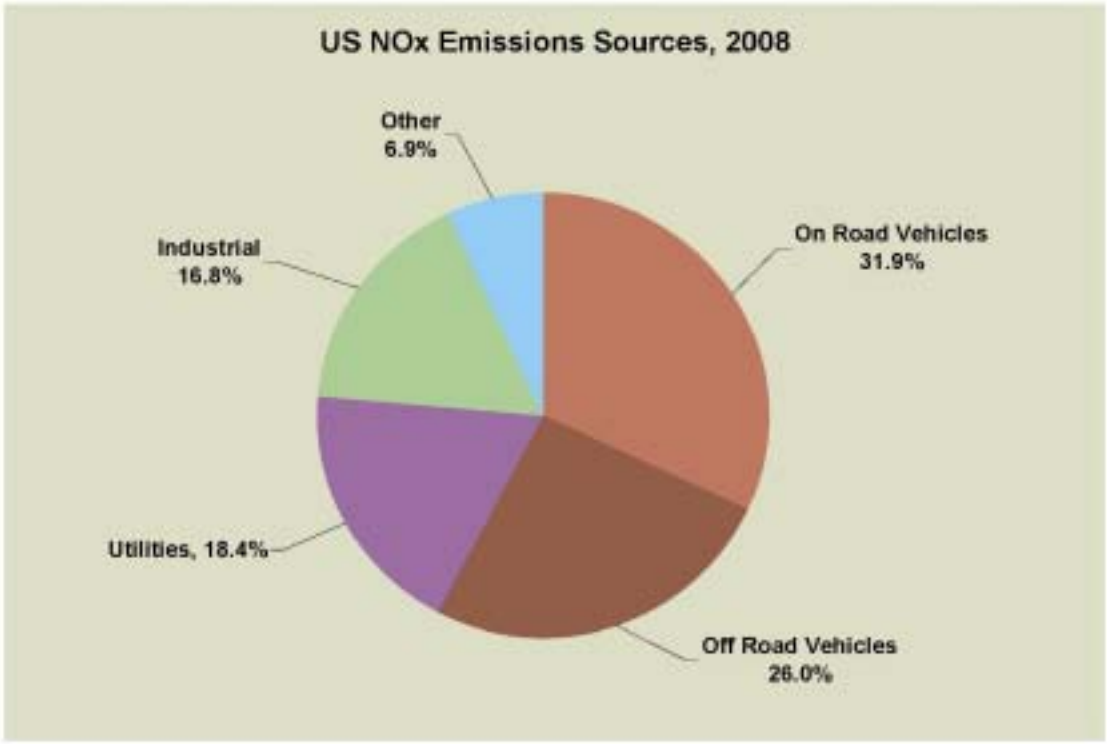

Source: U.S. Environmental Protection Agency

Figure C-1. NO_X emission sources in the U.S.

The SCAB (including Los Angeles, Orange, San Bernardino, and Riverside counties) has some of the worst air quality in the United States due in part to the level of NO_X emissions. The majority of NO_X emissions result from mobile sources such as on-road and off-road vehicles, and not stationary sources such as power plants.

The California Air Resources Board (CARB) estimates in its 2010 Almanac of Emissions and Air Quality that emissions in the SCAB were 742 tons of NO_X per day. This is down from 820 tons per day in 2008 due to additional regulatory requirements for stationary sources, and more efficient cars. CARB projects in their Almanac that SCAB NO_X emissions will continue to decrease from 56 tons per day to 52 tons per day. Figure C-2 shows the estimate 2008 NO_X emission sources.

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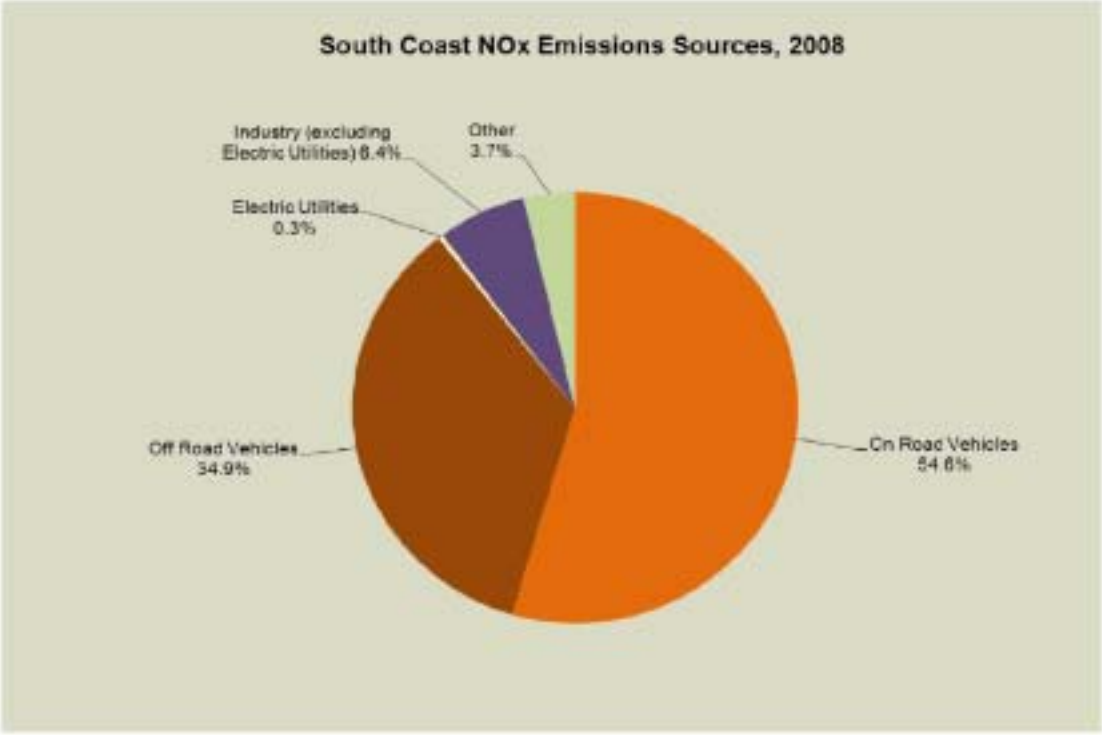

Source: California Air Resources Board

Figure C-2. Local NO_X sources in 2010.

For comparison, the average daily NO_X emissions from LADWP's in-basin generating stations (Harbor, Haynes, Scattergood, and Valley) combined was 0.65 short tons of NO_X per day in 2008, which represents 0.08 percent of the 2008 average daily NO_X emissions in the South Coast Air Basin. The low NO_X emissions from LADWP's in-basin generating stations are due to the use of natural gas at all facilities and the installation of advanced emissions control systems.

Forecasts project that South Coast Air Basin NO_X emissions will continue to decrease over the next decade. Targets for 2015 are 580 tons per day, while the 2020 target is 468 tons per day. The majority of this reduction is expected to come from a reduction in vehicle emissions; total tons emitted from stationary sources during this time period are only projected to decrease from 56 tons per day to 52 tons per day.

A major tool employed by the SCAQMD to reduce NO_X emissions from stationary sources is the RECLAIM (Regional Clean Air Incentives Market) trading program. RECLAIM is a market-driven regulatory program started in 1994 that superseded the SCAQMD's existing NO_X rules for facilities with NO_X emissions exceeding 4 tons per year. These "command and control" rules limited the emission rates of stationary combustion equipment and have been replaced by a facility-wide emissions cap, which gradually declines each year. Facilities receive emission allocations, called RECLAIM Trading Credits (RTCs), in which one credit grants the right to emit one pound of NO_X. Facilities must have sufficient RTCs in their RECLAIM facility accounts to cover their actual emissions. RECLAIM is a market-driven program because the RTCs can

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be bought and sold, which allows for the emissions reductions to be made in the most cost-effective manner.

All of LADWP's in-basin power plants now have advanced pollution control equipment, which reduces NO_X emissions by at least 90 percent. However, the allocation of RTCs to each of LADWP's power plants declines over time, and the entire future allocation of RTCs was reduced about 22.5 percent by the SCAQMD in 2005. Using the resource planning studies and other considerations, the environmental assessment results show that the projections meet LADWP's NO_X goals.

C.3 Greenhouse Gas Emissions and Climate Change

C.3.1 Federal Efforts To Address Climate Change

Federal Climate Change Legislation

Several Congressional bills have been proposed in recent years to regulate GHG emissions under a federal cap-and-trade program, but none have garnered enough support for passage by both the House of Representatives and the Senate. In 2010, focus shifted to the U.S. EPA and the authority it has to regulate GHG emissions under the Clean Air Act (discussed in more details below).

Federal Regulation of Greenhouse Gases Under the Clean Air Act

In the absence of federal legislation, GHG emissions may still be regulated through the U.S. EPA through its authority under the Clean Air Act. In April 2007, the Supreme Court ruled in *Massachusetts v. EPA* that the U.S. EPA must make a determination when it comes to regulating motor vehicle emissions. The Supreme Court ruling gives the U.S. EPA the authority to regulate GHGs under the Clean Air Act for mobile and stationary sources. On December 7, 2009, the U.S. EPA Administrator signed two distinct findings regarding GHGs under section 202(a) of the Clean Air Act:

- Endangerment Finding: The Administrator found that the current and projected concentrations of the six key well-mixed GHGs--carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)--in the atmosphere threaten the public health and welfare of current and future generations.
- Cause or Contribute Finding: The Administrator found that the combined emissions of these well-mixed GHGs from new motor vehicles and new motor vehicle engines contribute to the GHG emissions which threatens public health and welfare.

In December 2009, U.S. EPA published its findings in the *Federal Register*, stating: "The Administrator finds that greenhouse gases in the atmosphere may reasonably be anticipated both to endanger public health and to endanger public welfare." The impacts of climate change that will cause harm to human health and welfare of current and future generations include but are not limited to: increased drought; more heavy downpours and flooding; more frequent and intense heat waves and wildfires; greater sea level rise; more intense storms; and harm to water resources, agriculture, wildlife, and ecosystems.

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EPA Tailoring Rule for Regulating Stationary Sources under the Clean Air Act

The Environmental Protection Agency finalized its "Tailoring Rule," which establishes a phased timetable for implementing Clean Air Act permitting requirements for GHG emissions from large stationary sources. The rule provides that Prevention of Significant Deterioration (PSD) requirements will first apply to GHG emissions effective January 2, 2011. This initial phase will apply to new and modified facilities that would already be required to obtain PSD permits as a result of their non-GHG emissions, and whose construction will result in an increase in GHG emissions of at least 75,000 tons CO_{2e} per year. A second phase of the program will commence on July 1, 2011, and will impose PSD requirements on new facilities that emit at least 100,000 tons CO_{2e} per year, as well as modified facilities whose emissions will increase by at least 75,000 tons CO_{2e} per year. In addition to these PSD requirements, the Tailoring Rule sets comparable emission thresholds and timetables for new and existing facilities to obtain operating permits under Title V of the Clean Air Act. It is anticipated that LADWP's Scattergood generating station will be subject to the new permitting requirements under the EPA's Tailoring Rule.

C.3.2 Western Climate Initiative (WCI)

Originally established by the Western Governor's Association in February 2007, the WCI has been reduced to a collaboration of only California and Quebec to reduce GHG emissions 15 percent below 2005 levels by 2020. The primary mechanism for achieving these reductions will be through a regional cap-and-trade program.

CARB is in the process of developing regulations to link California's market with Quebec.

C.3.3 California Efforts to Address Climate Change

This section presents an overview of the California greenhouse gas emissions inventory and trends from 2000 through 2009. A new edition of California's greenhouse gas emission inventory was released April 6, 2012. It includes emissions estimates for years 2000 to 2009. Figure C-3 depicts the general trend in emissions from 2000 to 2009, and Figure C-4 displays 2009 statewide emissions by economic sector.

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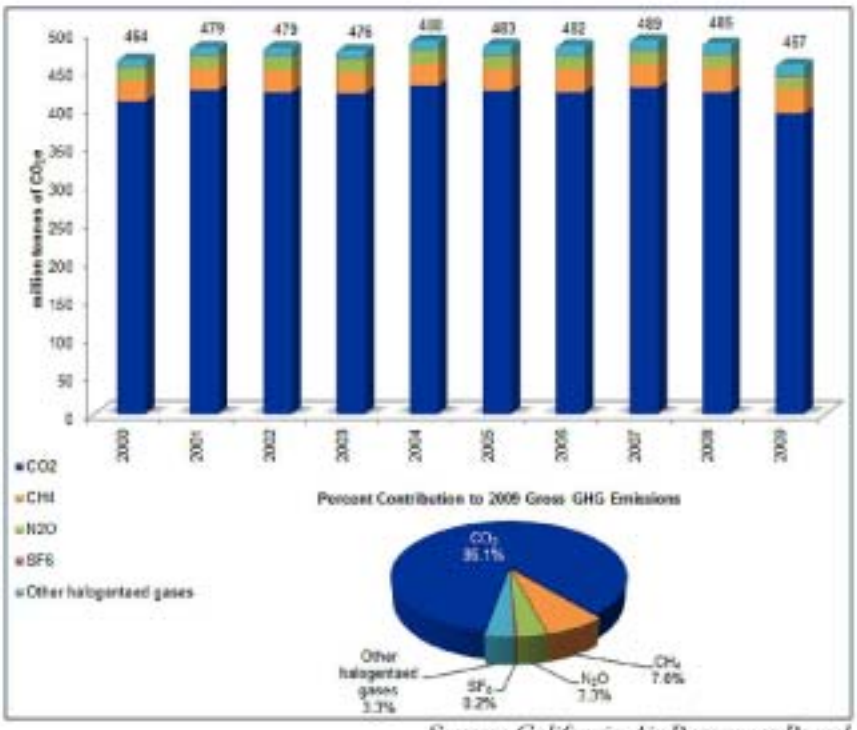
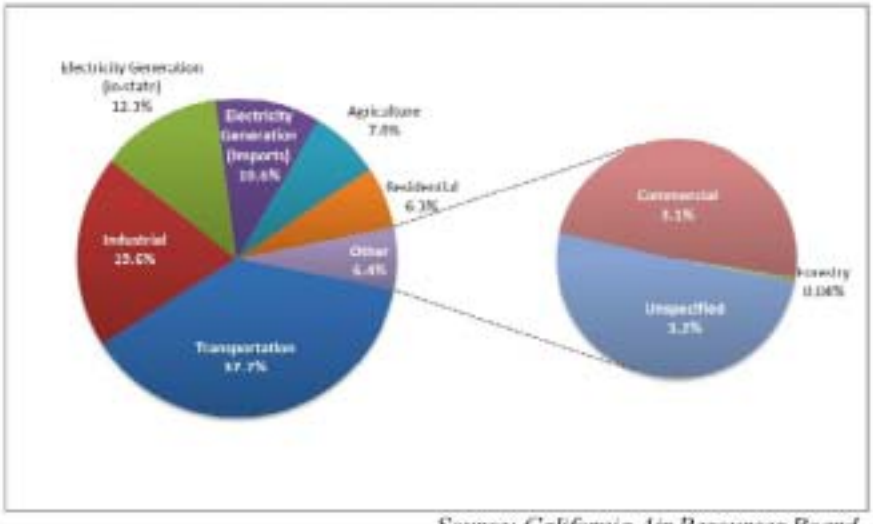


Source: California Air Resources Board

Figure C-3. California GHG emissions, 2000-2009.



Source: California Air Resources Board

Figure C-4. 2009 California GHG emissions by Economic Sector.

As California strives to achieve its benchmark goals under AB 32, the California inventory will become an increasingly valuable tool to keep track of greenhouse gas emissions from each sector. Maintaining and updating greenhouse gas inventory methodologies and data are

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imperative for a successful greenhouse gas reduction program. In 2009, total California GHG emissions were 457 million tons of carbon dioxide equivalent (MMT CO_2e), net emissions were 453 MMT CO_2e, reflecting the influence of sinks (net CO_2 flux from forestry). While total emissions have increased by 8.8 percent from 1990 to 2009, emissions decreased by 8.8 percent from 2008 to 2009 (185 to 457 MMT CO_2e). The total net emissions between 2000 and 2009 decreased from 459 to 453 MMT CO_2e, representing a 1.3 percent decrease from 2000 and a 6.1 percent increase from the 1990 emissions level. The transportation sector accounted for approximately 38 percent of the total emissions, while the industrial sector accounted for approximately 20 percent. Emissions from electricity generation were about 24 percent with almost equal contributions from in-state and imported electricity.

California Governor's Executive Order S-3-05

On the state level, Governor Schwarzenegger signed Executive Order S-3-05 on June 1, 2005 which established the following GHG targets:

- By 2010, reduce emissions to 2000 levels
- By 2020, reduce emissions to 1990 levels
- By 2050, reduce emissions to 80 percent below 1990 levels

California SB 1368: Greenhouse Gas Emissions Performance Standard

SB 1368 was signed into law on September 29, 2006 and requires the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) to establish a GHG emissions performance standard and implement regulations for all long-term financial commitments in baseload generation made by load serving entities (LSEs) including local publicly-owned electric utilities (POUs). The CPUC adopted its regulations for the investor-owned utilities and other LSEs in January, 2007. The CEC adopted similar regulations for POUs in August 2007. Strategies implemented by the CPUC and CEC under SB 1368 are expected to result in a combined GHGs emissions reduction of over 15 million metric tons (MMT CO_2e) by 2020. The GHG emissions performance standard is based on the emissions profile of combined-cycle, natural gas fired generating units. The CPUC's regulations establish an emissions performance standard of 1,100 pounds (0.5 metric tons) of CO_2 per megawatt hour (MWh) of electricity. This standard was established in consultation with the CPUC and the CARB and is the same as the emissions performance standard adopted by the CPUC for the LSEs.

The broad objectives of these regulations are to internalize the significant and under-recognized cost of emissions and to reduce potential financial risk to California consumers for future emission control costs. Specifically, these regulations are intended to prohibit any LSE from entering into or renewing a long-term financial commitment for baseload generation that exceeds the GHG emissions performance standard, currently set at 1,100 pounds per MWh.

These regulations would require POU's, within 30 days of making a long-term financial commitment to a baseload facility, to certify to the CEC that such a commitment complies with these regulations and provide back-up material to support such commitment. The

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regulations then provide for CEC review of these compliance filings and a determination of whether or not the commitment, and the underlying facility as described in the commitment, complies with these regulations. Additionally, the CPUC may open an investigatory proceeding and gather additional information if it believes that covered procurements made by a POU do not comply with these regulations.

At its December 14, 2011 business meeting, the California Energy Commission granted a Petition to "initiate a new rulemaking proceeding to ensure that the current practices of California POUs meet the requirements of SB 1368 and California's Emissions Performance Standards" specifically as it relates to three coal-fired power plants including the San Juan Generating Station, Navajo Generating Station and the Intermountain Power Project. The Commission directed Commission Staff to prepare an order instituting rulemaking that encompassed the various issues raised by the Petitioners and other stakeholders. At its January 12, 2012 business meeting the Commission adopted an order instituting rulemaking (OIR) 12-01-12-7, which initiated a proceeding to discuss, and if warranted implement possible changes to the EPS regulations.

AB 32: The California Global Warming Solutions Act of 2006

In 2006, the California Legislature passed and Governor Schwarzenegger signed Assembly Bill 32, the Global Warming Solutions Act of 2006, which declared that global warming poses a serious threat to the economic well-being, public health, natural resources, and environment of California. It set into law a 2020 GHG emissions reduction goal that would require the reduction of statewide emissions of GHGs[1]. In 2007, the ARB established a 1990 statewide greenhouse gas emissions baseline of 427 MMT of carbon dioxide equivalent (CO_2)[2] and adopted a regulation for mandatory emissions reporting from the most significant sources that contribute to statewide emissions, including all electricity consumed in the state as well as imported electricity. The 2020 target was set at the 1990 baseline level of 427 MMT CO_{2e}.

The AB 32 Scoping Plan

In December 2008, the CARB adopted the AB 32 Scoping Plan, which serves as California's blueprint for reducing greenhouse GHG emissions. Key elements of the AB 32 Scoping Plan's recommendations for reducing California GHG emissions to 1990 levels by 2020 include:

- Expanding and strengthening existing energy efficiency programs as well as building and appliance standards
- Achieving a statewide renewables energy mix of 33 percent.
- Developing a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system
- Expand use of Combined Heat and Power (CHP) by 30,000 GWh statewide

[1] GHGs covered by AB 32 include the following: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

[2] Carbon dioxide equivalent or CO_{2e} means the amount of carbon dioxide by weight that would produce the same global warming impact as a given weight of another greenhouse gas, based on the best available science, including from the Intergovernmental Panel on Climate Change.

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- Establishing targets for transportation-related GHG emissions for regions throughout California and pursuing policies and incentives to achieve those targets
- Adopting and implementing measures pursuant to existing State laws and policies, including California's clean car standards, goods movement measures, and the Low Carbon Fuel Standard
- Creating targeted fees, including a public goods charge on water use, fees on high global warming potential gases, and a fee to fund the administrative costs of the state's long term commitment to AB 32 implementation

All programs developed under AB 32 contribute to the reductions needed to achieve this goal, and will deliver an overall 15% reduction in greenhouse gas emissions compared to the "business-as-usual" scenario in 2020 if nothing was done at all. In 2010, the ARB made revisions to the expected 2020 emission reductions in consideration of the economic recession and the availability of updated information from development of measure-specific regulations. ARB staff re-evaluated the baseline in light of the economic downturn and updated the projected 2020 emissions to 545 MMTCO$_2$e. Two reduction measures (Pavley I and the Renewables Portfolio Standard (12% → 20%)) not previously included in the 2008 Scoping Plan baseline were incorporated into the updated baseline, further reducing the 2020 statewide emissions projection to 507 MMTCO$_2$e. The updated forecast of 507 MMTCO$_2$e is referred to as the AB 32 2020 baseline. Reduction of an estimated 80 MMTCO$_2$e are necessary to reduce statewide emissions to the AB 32 Target of 427 MMTCO$_2$e by 2020.

Executive Order S-21-09

On September 15, 2009, Governor Schwarzenegger signed Executive Order S-21-09, which, among other things, ordered CARB to work with the Commissions to ensure that a regulation adopted under authority of AB 32 to encourage the creation and use of renewable energy sources shall build upon the RPS program developed to reduce GHG emissions in California and shall regulate all California publicly owned utilities, like LADWP. In addition, Executive Order S-21-09 provides that CARB may delegate policy development and implementation to Commissions, that CARB is to consult with the CAISO and other balancing authorities on impacts on reliability, renewable integration requirements and interactions with wholesale power markets in carrying out the provisions of Executive Order S-21-09, and that CARB is to establish the highest priority for those resources with the least environmental costs and impacts on public health that can be developed most quickly and that support reliable, efficient, and cost-effective electricity system operations including resources and facilities located throughout the Western Interconnection.

AB 32 Cap-and-Trade Regulation (Adopted October 20, 2011)

The cap-and-trade program is a key element in California's climate plan. The cap-and-trade program sets a statewide limit on sources responsible for 85 percent of California's greenhouse gas emissions, and establishes a price signal needed to drive long-term investment in cleaner fuels and more efficient use of energy. The program is designed to provide covered entities the flexibility to seek out and implement the lowest-cost options to reduce emissions. The program covers about 350 businesses, representing 600 facilities and it starts in 2013 for electric utilities and large industrial facilities, while distributors of transportation, natural gas and other fuels join in 2015. The ARB expects to link with Quebec in 2013.

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Although the program commenced on January 1, 2012, the enforceable compliance obligation starts with the 2013 GHG emissions. The first auction of California carbon allowances occurred in November 2012.

Combined Heat and Power

Assembly Bill 1613 (Blakeslee, 2007) as amended by AB 2791 (Blakeslee, 2008), created the Waste Heat and Carbon Emissions Reduction Act of 2007, which requires among other things that a local publicly owned electric utility serving retail end-use customers to establish a program that allows retail end-use customers to utilize combined heat and power (CHP) systems that reduce emissions of greenhouse gases by achieving improved efficiencies utilizing heat that would otherwise be wasted in separate energy applications and that provides a market for the purchase of excess electricity generated by a combined heat and power system, at a just and reasonable rate, to be determined by the governing body of the utility. LADWP is in compliance with this requirement as it offers a Standard Energy Credit for distributed generation, including CHP.

As part of the ARB's 2008 Climate Change Scoping Plan, a CHP measure was included that calls for 4,000 MW of new CHP capacity that would result in an estimated reduction of 6.7 million metric tons of annual GHG emission reductions and displace 30,000 GWh of electricity demand by 2020. Governor Brown's Clean Energy Jobs Plan includes a target of 6,500 MW of additional installed CHP capacity over the next 20 years. Faced with the slow development of new CHP in California, the Energy Commission updated its CHP market assessment to update the potential for new CHP and to understand the amount of new CHP that current policy may provide, and the emissions reductions gained from old, retiring CHP and its associated capacity. Understanding the full range of opportunities, motivations, policy successes, and remaining regulatory barriers for CHP across industrial, commercial, and residential sectors will help determine where the opportunities for development of new facilities are the greatest. This information will be used to develop policies and regulations to encourage CHP and support the state's GHG emissions reduction goals.

The California Energy Commission provided an update in February 2012 for a CHP Market Assessment that was originally conducted in 2009. Market penetration estimates of CHP were presented for three market development scenarios — a Base Case reflecting continuation of existing state policies and two additional cases (Medium and High) that show the market impacts of additional CHP policy actions and incentives. The CEC's report suggests that the cumulative statewide market penetration for the base case is 1,888 MW, down from 2,998 MW as originally projected in 2009. The 2012 market scenarios, in general, show lower cumulative market penetration than the 2009 scenarios. The Base Case results show that, under the current policy landscape, CHP will fall short of the ARB Scoping Plan market penetration target. The report suggests that "additional policy measures, represented in the Medium and High Cases, are needed to raise market penetration up to the Scoping Plan target." The updated 2012 assessment suggests that the LADWP service territory's share of new CHP under the base case market penetration scenario is 15 percent overall. The assessment suggested a range for LADWP's new

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CHP capacity (MW) starting with the base case at 224 MW by 2020 increasing to 281 MW by 2030, up to the high case of 557 MW by 2020 increasing up to 698 MW.[3]

C.3.4 LADWP's Efforts To Address Climate Change

Since 1998, LADWP has taken steps to move away from dependence on coal generating resources, including the divestiture of power purchase agreements with Colstrip and Coronado Generating Stations, the shutdown of Mohave Generating Station in December 2005, and the discontinuation of involvement in the development of Unit 3 at Intermountain Generating Station. Table C-1 shows the downward trajectory in LADWP's power generation portfolio CO_2 emissions and CO_2 emissions intensity between 1990 and 2011.

Table C-1. HISTORICAL LADWP POWER GENERATION CO_2 EMISSIONS

Year	Total CO_2 Emissions from Owned & Purchased Generation (metric tons)	Total CO_2 Emissions from Owned & Purchased Generation minus Wholesale Power Sales (metric tons)	Total Owned & Purchased Generation (MWh)	LADWP System CO_2 Intensity Metric (lbs CO_2/MWh)
1990	17,925,410	17,764,874	25,481,532	1,551
2000	18,464,480	16,992,238	28,806,750	1,413
2001	18,086,034	16,663,305	28,032,375	1,422
2002	16,873,841	16,237,832	26,808,569	1,388
2003	17,274,623	16,710,232	27,337,694	1,393
2004	17,609,759	16,604,943	28,138,391	1,380
2005	16,928,681	15,854,278	28,301,700	1,319
2006	16,838,147	15,885,136	29,029,883	1,279
2007	16,461,774	15,523,035	29,141,703	1,245
2008	16,232,608	15,650,115	29,394,809	1,217
2009	14,646,410	13,829,395	28,041,998	1,151
2010	13,771,186	12,844,288	27,490,878	1,104
2011	14,169,324	13,631,178	27,025,925	1,156
Difference between 1990 and 2011	-3,756,086	-4,133,696	1,544,393	-395
% Change from 1990	-21%	-23%	6%	-25%

Notes:
1. Calculated CO_2 emissions for specified sources using fuel data and fuel-specific emission factors from 40 CFR Part 98 Subpart C Table C-1..
2. Calculated CO2 emissions for unspecified power purchases using MWh purchased x default emission factor (1,100 lbs CO_2/MWh).

[3] California Energy Commission, "Consultant Report: Combined Heat and Power: Policy Analysis and 2011-2030 Market Assessment," ICF Consulting, February 2012, Publication No. CEC, 200-2012-002, Appendix D.

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SF6 Emissions

In February 2010, CARB adopted a new regulation to reduce SF6 emissions from gas insulated electrical switchgear as part of the AB 32 program. This new regulation imposes a declining limit on a utility's annual average SF6 emissions rate starting at 10 percent in 2011 and decreasing to 1 percent in 2020, as well as new recordkeeping and reporting requirements.

Over the past decade, LADWP has been proactive in reducing SF6 emissions by implementing its own internal program to reduce emissions through equipment replacement, repair, and process improvements. This voluntary effort to reduce SF6 emissions demonstrates LADWP's commitment to environmental stewardship and puts LADWP in a good position to comply with the new emission limits imposed by the SF6 regulation.

C.4 Power Plant Once-Through Cooling Water Systems

Power plants with "once-through cooling" (OTC) systems draw or take in water from coastal/estuarine water, via intake pipes, to cool turbines used to generate electricity. After the water is used for cooling it is discharged to a nearby water body. OTC systems can impact the marine environment.

LADWP has three coastal generating plants that utilize OTC. The new state wide OTC Policy and upcoming 316 b Federal Rule requires minimizing and/or reducing the impacts on marine life.

In order to reduce these impacts, LADWP has committed to completely eliminate OTC by replacing it with closed cycle cooling to comply with the Statewide OTC policy and upcoming Federal rule.

In addition, LADWP has already implemented the following:

- In the 1970's LADWP installed a velocity cap (a large disk-shaped structure just upstream of the ocean water intake pipe) at its Scattergood Generating Station to control IM. In 2006, LADWP conducted an effectiveness study on its velocity cap and the results showed that it is 96% effective.

- To date, LADWP has reduced the number of power plant units that utilize OTC from 14 to 9, reducing ocean water use from 1904 MGD to 1571 MGD, an overall reduction of ocean water usage by 17%.

- LADWP has spent over $600 million dollars to replace the older generating units with more efficient generating units (known as "repowering") at its Haynes and Harbor Generating Stations. This has resulted in a reduced use of coastal waters.

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To further reduce impacts and completely eliminate OTC, LADWP plans to do the following:

- By 2013, the Haynes 5&6 repowering project will be completed, reducing the number of OTC units to 7. This will decrease ocean water use from 1571 MGD to 1110.2 MGD, an overall reduction of 43% from 1990 ocean water usage levels.

- By 2015, the Scattergood 3 repowering project will be completed, further reducing the number of OTC units to 6 and decreasing ocean water use from 1110.2 MGD to 839.8MGD, an overall reduction of 56% from 1990 ocean water usage levels.

- By 2020, the Scattergood 1&2 repowering project will be completed, further reducing the number of OTC units to 4 and decreasing ocean water use from 839.8 MGD to 563.3MGD, an overall reduction of 70% from 1990 ocean water usage levels.

- By 2024, the Haynes 1&2 repowering project will be completed, further reducing the number of OTC units to 2 and decreasing ocean water use from 563.3 MGD to 338.7 MGD, an overall reduction of 82% from 1990 ocean water usage levels.

- By 2026 the Harbor 5 repowering project will be completed, further reducing the number of OTC units to 1 and decreasing ocean water use from 338.7 MGD to 230 MGD, an overall reduction of 87% from 1990 ocean water usage levels.

- By 2029, the final repowering project, Haynes Unit 8 will be completed, reducing the number of OTC units to 0, resulting in 100% elimination of OTC.

Figure C-5 shows LADWP's reduction in OTC usage from 1990 to 2029.

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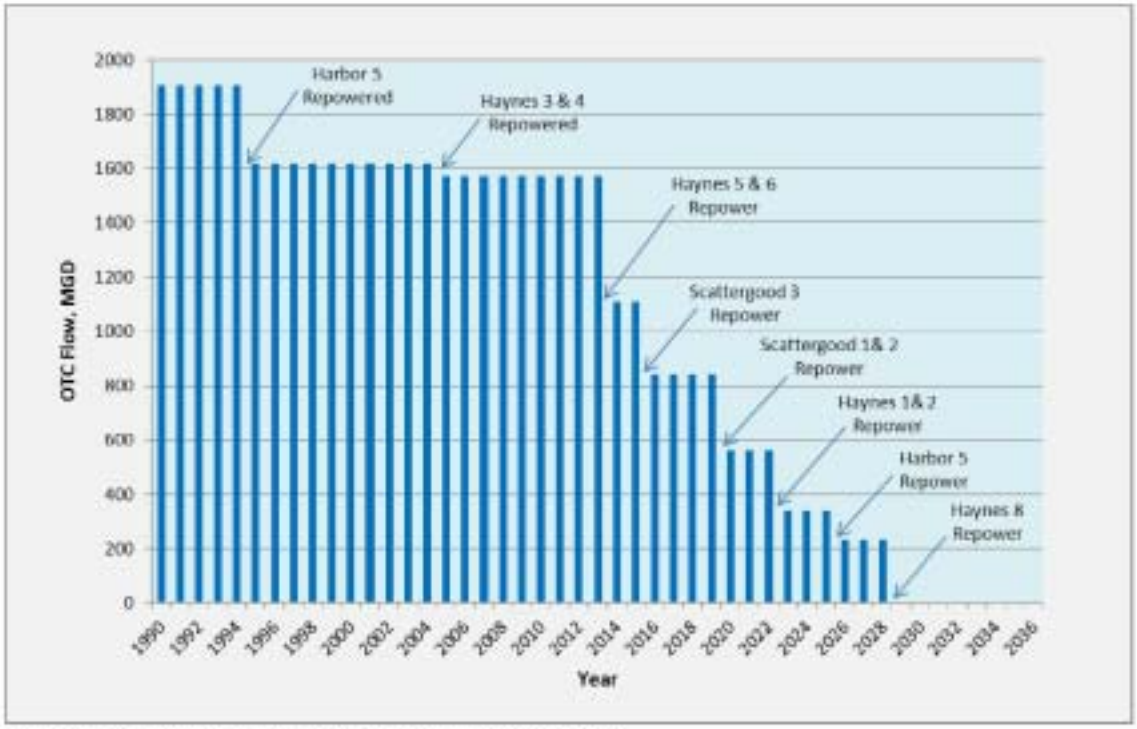

Figure C-5: LADWP OTC reduction from 1990 to 2029.

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C.4.1 USEPA 316(b) Requirements for Cooling Water Intake Structures

EPA's Clean Water Act Section 316(b) Phase II Cooling Water Intake Structure Rule (Rule) released in 2004 was subsequently challenged and ultimately heard in both the Second Circuit Court and in the U.S. Supreme Court. The Second Circuit Court issued its decision on January 25, 2007, and determined that the restoration and cost-benefit elements of the original 2004 Rule were unlawful and that other fundamental components of the 2004 Rule, such as the impact reduction performance standards attainable for certain technologies, were to be remanded for further evaluation and demonstration by U.S. EPA. The U.S. Supreme Court was subsequently asked to weigh in on the ability to use the "wholly disproportionate" cost-benefit test in the application of the 316(b) regulations. On April 1, 2009, the Supreme Court affirmed that a cost-benefit analysis can be used by regulatory agencies. While the various challenges proceeded through the court processes, U.S. EPA gave the states permission to continue with implementation and enforcement of the Clean Water Act 316 (b) requirements using "Best Professional Judgment (BPJ) when reauthorizing facility National Pollutant Discharge Elimination System (NPDES) permits.

During this period, LADWP completed the required Characterization Study to identify baseline biological impacts in order to determine an appropriate impingement mortality (IM) and entrainment (E) reduction method. However, when the Rule was remanded to U.S. EPA to re-study and then re-propose a rule, it essentially remanded the Rule and placed the fulfillment of its associated requirements on hold. At that point, LADWP stopped any further work necessary to comply with the suspended Rule and has been awaiting the outcome of U.S. EPA's effort to re-propose a new rule. The UP EPA publicly noticed the new proposed rule for existing facilities on April 19, 2011 and the comment period ended on August 18, 2011. The US EPA is under a settlement agreement with the Riverkeeper to have a final rule by no later than July 2012. In the meantime, EPA has given the State Permitting Authorities permission to continue with the regulation of Section 316 B with the use of BPJ.

C.4.2 SWRCB 316(b) Requirements for Cooling Water Intake Structures

On June 30, 2009, the SWRCB released its draft Once-Through Cooling Water Policy for public review and comment, with the accompanying Supplemental Environmental Document released on July 14, 2009. Comments were due September 30, 2009. Subsequent policy drafts were issued on November 23, 2009 and March 22, 2010 with corresponding comment periods. The final Policy version was adopted on May 4, 2010 and became effective on October 1, 2010. The adopted Policy has major implications for the coastal power plants making it extremely difficult to continue the use of OTC retrofitted with IM and E impact control technology; making the use of cooling towers the only certain compliance path. The Policy proposes a two-track compliance pathway. Track I requires OTC flows to be reduced commensurate with wet closed cycle cooling (CCC) or a 93 percent flow reduction and essentially requires the installation of cooling towers. If Track I can be demonstrated as "not feasible" a Track II compliance option is available. A Track II compliance pathway requires the biological impacts to be reduced on a unit by unit basis to a level comparable with (i.e., within 10 percent) what would exist with CCC. New consecutive 36-month IM and E baseline studies will be required if a Track II compliance pathway is pursued. Until compliance is achieved, interim measures are required, which include flow reductions when

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there is no unit load and mitigation measures (commencing five years from the effective date of the policy and continuing until the facility is in full compliance). Lastly, to prevent disruption in the state's electrical power supply during implementation of the Policy, a committee of state energy and resource agencies known as the Statewide Advisory Committee on Cooling Water Intake Structures (SACCWIS) will assist the SWRCB in reviewing the required utility implementation plans along with the annual grid reliability studies in order to monitor any grid reliability impacts and schedules.

LADWP's implementation plan was the first plan to be reviewed by the SWRCB and SACCWIS. As a result, the SWRCB prepared and adopted an Amendment to the Policy on July 19, 2011. This Amendment modified LADWP's compliance schedule on a unit-by-unit basis with the following compliance dates ::12/31/2013 for Haynes Units 5&6; 12/31/2015 for Scattergood Unit 3; 12/31/2024 for Scattergood Units 1&2; 12/31/2029 for Haynes Units 1&2 and 8, and Harbor Unit 5. In addition, the Amendment requires LADWP to submit any additional information requested, by January 1, 2012, by the SACCWIS and submit the information responsive to SACCWIS to the SWRCB by December 31, 2012 in order for the SWRCB to evaluate whether further modifications to the dates are necessary. Furthermore, LADWP must commit to complete elimination of OTC and in the interim must prepare a mitigation plan and fund projects to offset impacts until each unit is fully compliant. In addition, LADWP must conduct a study or studies, singularly or jointly with other facilities, to evaluate new technologies or improve existing technologies to reduce impingement and entrainment, submit the results of the study and a proposal to minimize entrainment and impingement to the Chief Deputy Director no later than December 31, 2015, and upon approval of the proposal by the Chief Deputy Director, complete implementation of the proposal no later than December 31, 2020. LADWP is in the process of developing its mitigation plan and commencing the alternative technologies studies. The Haynes Units 5&6 repowering project has broken ground and is in its construction phase in order to meet the 2013 deadline. Also, the conceptual planning and design for the Scattergood Unit 3 project has commenced in order to meet the 2015 deadline.

C.5 Mercury Emissions

Mercury (Hg) emissions are an issue for all coal fired power plants. However, the level of such emissions varies widely based on the type of coal burned and the type of emission controls on the plants.

Coal-burning power plants are the largest human-caused source of Hg emissions to the air in the United States, accounting for over 50 percent of all domestic human-caused Hg emissions (Source: 2005 National Emissions Inventory). The EPA estimates that less than ½ of all Hg deposited within the U.S. comes from U.S. sources.

The IGS in Utah, of which LADWP is the Operating Agent, has one of the lowest mercury emission rates in the country. This is due to the fact that the existing emission control devices, which are designed to reduce sulfur dioxide and particulate matter, have the co-benefit of removing about 96 percent of the mercury from bituminous coal which is burned at IGS.

On March 15, 2005 U.S. EPA promulgated the Clean Air Mercury Rule (CAMR), which established a nationwide cap-and-trade program for mercury emissions. CAMR was designed to

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reduce mercury emissions by 60 percent between 2010 and 2018. Several legal challenges of the CAMR ensued. As a result, the D.C. Circuit vacated U.S. EPA's Clean Air Mercury Rule on February 18, 2008. On May 3, 2011, EPA proposed NESHAPs for coal- and oil-fired EGUs under Clean Air Act (CAA) section 112(d) and proposed revised NSPS for fossil fuel-fired EGUs under CAA section 111(b). The proposed NESHAP would protect air quality and promote public health by reducing emissions of the hazardous air pollutants (HAP) listed in CAA section 112(b). In addition, these proposed amendments to the NSPS are in response to a voluntary remand of a final rule. EPA finalized its rule in December 2011.

C.6 Coal Combustion Residuals

On May 4, 2010, the U.S. Environmental Protection Agency released pre-publication co-proposals to regulate the management of coal ash from coal-fired power plants.

Coal combustion residuals (CCRs), commonly known as coal ash, are byproducts of the combustion of coal at power plants and are typically disposed of in liquid form at large surface impoundments and in solid form at landfills, most often on the properties of power plants. There are almost 900 landfills and surface impoundments nationwide.

Due to the metal constituents of the CCRs, EPA's co-proposals will establish control measures, such as liners and groundwater monitoring, which would be in place at new landfills to protect groundwater and human health. Existing surface impoundments would also require liners, with incentives to close the impoundments and transition to landfills, which store coal ash in dry form.

The proposed regulations may change the way CCRs are handled and stored at Intermountain Power Plant and Navajo generating station. If implemented, the rules would require the phase-out of wet handling systems and surface impoundments of bottom ash and the subsequent permitting and installation of lining under fly ash landfills. The facilities would have to conduct additional groundwater monitoring, and provide closure and post-closure care of the surface impoundments and landfills. For Mohave generating station, the rules, as proposed are expected to have minimal impacts because the facility did not operate any surface impoundment.

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Appendix D Renewable Portfolio Standard

D.1 Overview

LADWP has historically maintained that its major objectives concerning integrated resource planning are; (1) providing reliable service to its customers; (2) remaining committed to environmental leadership; and (3) maintaining a competitive price.

Since its 2007 IRP, LADWP has made great strides towards achieving the 2010 goal of increasing its supply of electricity from "eligible" renewable resources to 20 percent, measured by the amount of electric energy sales to retail customers, and has met the 20 percent goal for calendar year 2010.

On April 12, 2011, the California governor signed into law the Senate Bill 2 (1X) which extends the 20 percent target to 2013, and ramps up the target to 25 percent by December 31, 2016 and 33 percent by December 31, 2020.

On December 6, 2011, the LADWP Board approved the Renewables Portfolio Standard Policy and Enforcement Program and is included in Reference D-1 and D-2.

This 2012 IRP documents how LADWP expects to maintain 20 percent renewable energy and describes the process for LADWP's continuing commitment to increase the renewable energy goal to 25 percent by 2016 and 33 percent by 2020. Additionally, LADWP will continue to encourage voluntary contributions from customers to fund renewable resources above the stated Renewable Portfolio Standard (RPS) goal, as part of its Green Power for a Green LA Program (GREEN).

D.2 Renewable Energy Requests for Proposals (RFPs)

To help meet the renewable energy goals for the GREEN Program and the RPS policy, LADWP has issued four major Request for Proposals (RFP) for renewable energy projects: January 2001, June 2004, January 2007, and March 2009. LADWP performed detailed technical and economic analysis of the proposals on a least-cost, best-fit basis. This approach considered factors such as cost, technical feasibility, project status, transmission issues, and environmental impact.

Separately, the Southern California Public Power Authority (SCPPA), of which LADWP is a member, has issued five RFPs for renewable energy projects.

D.2.1 2001 Renewable RFP

In response to the 2001 RFP, a total of 21 projects were proposed. The 120 megawatts (MW) Pine Tree wind project met LADWP's renewable, economic, technical and least-cost, best fit criteria. The Pine Tree wind project is an eighty turbine wind farm facility located in the

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Tehachapi area, and is owned and operated by LADWP. This project was put in-service in June 2009.

The Pine Tree wind farm was expanded with ten new wind turbines that added 15 MW, for a total of 135 MW. The expansion was completed in 2011.

D.2.2 2004 LADWP Renewable RFP and the 2005 SCPPA Renewable RFP

In June 2004, LADWP issued another RFP with the intent of securing an increased portion of its power requirements from renewable resources. The goal of LADWP's 2004 RFP was to obtain about 1,300 gigawatts hours (GWhs) per year of renewable energy per year to meet the then RPS interim goal of 13 percent by 2010. A total of 57 distinct proposals were received, covering nearly all types of renewables, although wind and geothermal represented the largest share of proposed energy. Most of the proposals were from new California projects, with only a few actually located in Los Angeles. The proposals offered a mix of power purchase and ownership options.

To ensure fairness and consistency during the evaluation process of the 2004 RFP, the evaluation team included two independent entities. The team evaluated proposals through a structured process consisting of two phases. The Phase 1 evaluation included completeness and requirements screening, a technical and commercial evaluation, and an economic assessment. Proposals short-listed were then evaluated in greater detail in the Phase 2 evaluation, which included a comparison of Net Levelized Cost (NLC). The NLC of each proposal equals the levelized busbar cost of energy, in units of $/MWh, less the avoided energy and capacity costs, and adding the levelized transmission costs to cover wheeling, losses, transmission upgrades, etc.

In 2005, the Southern California Public Power Agency (SCPPA), of which LADWP is a participant, also issued an RFP for renewable resources.

Five contracts for renewable energy resulting from the 2004 and 2005 RFPs have been entered into, which provide 1,179 GWhs/yr of renewable energy from landfills, small hydro and wind.

D.2.3 2006 SCPPA and 2007 LADWP Renewable RFPs

In 2006 SCPPA issued an RFP for renewable resources, in which LADWP participated.

In January 2007, LADWP issued another RFP with the intent of obtaining approximately 2,200 GWhs of renewable energy per year to meet the RPS goal of 20 percent by 2010. A total of 59 distinct proposals were received, covering wind, solar thermal, solar photovoltaic (PV), geothermal, and biomass renewable technologies. The proposals offered a mix of power purchase and ownership options.

Three contracts for renewable energy resulting from the 2006 and 2007 RFPs have been entered into, which provide 424 GWhs/yr of renewable energy from wind and small hydro projects. Several other proposals that were received are currently being negotiated.

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D.2.4 2008 SCPPA and 2009 LADWP Renewable RFPs

In 2008 SCPPA issued an RFP for renewable resources, in which LADWP participated.

In March, 2009, LADWP issued a fourth RFP for Renewable Resources. The intent of this RFP was to obtain a sufficient amount of renewable energy per year to achieve the RPS goals, set by the Mayor, of 20 percent by 2010 and 35 percent by December, 31, 2020.

The 2008 RFP process resulted in two contracts, which provide 834 GWhs/yr of renewable energy from wind resources. Several other proposals that were received are currently being negotiated.

D.2.5 2011 SCPPA RFP

In January 2011, the Southern California Public Power Agency (SCPPA) also issued an RFP for renewable resources, in which LADWP participated. LADWP participated in the evaluations of the RFP proposals. LADWP evaluated proposals through a structured process. The evaluation included a completeness and requirements screening, a technical and commercial evaluation, and an evaluation of deliverability of the product. The evaluation also considered the Net Levelized Cost (NLC) for each proposal. The NLC of each proposal is equal to the levelized busbar cost of energy, in units of $/MWh, less the avoided energy and capacity costs, and adding the delivery cost to LADWP's load. Other factors were also considered, including: compliance with pending State renewable portfolio standard legislation, utility scale project experience, capacity, commercial operation date, and labor issues.

In August 2011, SCPPA issued another RFP for renewable resources. The response deadline is November 30, 2012.

D.3 Renewable Project Strategy

LADWP (and SCPPA) has increased its renewable energy through successful project development and completed agreement negotiations with multiple developers and project entities resulting from the above described RFPs. Existing renewable projects that supply LADWP are geographically diverse; wind energy comes from the ridges of the California Tehachapi Mountains, the north-central hills of Oregon, the southern Washington Columbia River Gorge area, the Milford Valley of Utah, and Southwestern Wyoming. Planning for future renewable energy will continue to emphasize geographic diversity, as well as technology diversity.

The variety of renewable energy projects and technologies facilitates the Power System capability to integrate renewable energy reliably. As described in other sections of the IRP, LADWP will maintain its Balancing Authority responsibility by addressing system issues such as reserve sharing, reserve commitments, system voltage support, spinning reserves, existing and future quick response combustion turbine units, etc.

This IRP describes several fundamental principles for the RPS progression from the current 20 percent renewable energy to a potentially higher goal of 33 percent by 2020. Issues and principles affecting the future of the RPS plans are discussed below:

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D.3.1 Issues

- The "Ramp Rate", i.e., the annual rate of progress from 20 percent to 33 percent renewables, will be subject to several factors. The time frame is 10 years, which would equate to a constant ramp of 1.33 percent per year. However, the projected ramp rate is not a straight line, but rather varies from year to year depending on factors both external and internal to the LADWP. These factors include SB 2 (1X) requirements, LADWP fiscal constraints, renewable energy technology improvement over time, renewable energy pricing, LADWP system integration limits, and transmission constraints, both in the LADWP systems and regionally.

- Steady investment in renewable resources is required to maintain a 20 percent RPS between 2010 and 2012 and to ramp to 33 percent between 2013 and 2020. There are several reasons for this path forward: Between 2010 and 2012, the projects maintaining the 20 percent RPS will become fully integrated into the system; reflecting 2010 economic conditions and allowing time for pricing adjustments and efficiencies of certain renewable industries such as solar PV to reach the marketplace. For budgeting and planning purposes, the assumed RPS implementation strategy is 1 percent annual RPS increases from 2013 thru 2015 and 2 percent from 2016 thru 2020. Of course, all of this strategy is dependent on adequate funding.

- Transmission limitations in several regions are constraining development activities. These constraints are being studied at regional, statewide, and Western Electricity Coordinating Council (WECC) levels and potential federal and state legislative actions will affect transmission availability. Further resource decisions are dependent on transmission availability and cost.

- Greenhouse Gas (GHG) and other climate change regulatory and legislative issues are pending. The eventual cap and trade methodology and market mechanisms that are implemented will influence RPS strategic and tactical decisions.

- Within the overall RPS plan, decisions as to specific projects, technologies, operational strategies, and project financial structures, will be made as the marketplace and regulatory environment change.

D.3.2 Principles

Future renewable projects will be strategically obtained with the following principles.

1. Geographic diversity is important to maintain and enhance power system reliability.

2. The use of existing LADWP assets such as transmission lines, land, and existing generation resources should be maximized.

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3. Pursue multi-faceted development with adequate back-up strategies to handle project delays, project failures, reduced generation output, and operation or maintenance impacts.

4. Projects shall be targeted to specifically meet the Power System/Renewables Policy objectives.

5. Flexible RPS goals will be established to address the variable nature of renewable energy while conforming to applicable state and federal requirements

6. Ownership, operation, and maintenance are core objectives to maintain power system reliability and cost stability. The Power System is interested in owning projects that are based on proven technology.

7. Operation and maintenance (O&M) management is a key criterion in clustering renewable projects. Keeping projects in close proximity would reduce O&M costs due to economies of scale and personnel efficiencies.

D.3.3 Balancing Renewable Resources

Several of these principles may be overlapping or even conflicting. For example, clustering of renewable projects would decrease O&M expenditures, but too many projects in an area will not meet the needs for geographic diversity. Also, ownership goals may impact project costs and immediate availability. Obtaining tax credits and/or grants may necessitate the need for developers to own a project for a certain number of years (typically 7-10 years) to capture tax advantages; thereby lowering the ultimate cost to LADWP.

Subject to further studies, given the wind and solar projects coming on-line, limitations on the percentage of intermittent resources may be required. There may be more stringent limitation in certain resource areas, or along certain transmission systems. It is possible that no more than 15-20 percent intermittent energy can be ultimately integrated in the current electric grid. Of the 20 percent renewable energy consumed in 2010, less than $1/5^{th}$ of that amount was of an intermittent type. Most renewable resources are either small hydro or biogas having a predictable energy pattern or wind projects that have their energy output firmed and shaped by outside balancing authorities before delivery to LADWP. The total amount of intermittent energy obtained will not be increased beyond current levels unless studies demonstrate that these resources can be reliably integrated.

Wind, as shown elsewhere in this IRP, is a volatile renewable energy resource. It is recommended that LADWP's wind forecasting tools and meteorological analysis capabilities be enhanced to provide efficient integration of wind energy.

Similar studies will be required for solar projects coming on line in the next few years, and limitations of the percentage of solar will be required. Photovoltaic solar systems can have dramatic voltage changes, resulting from passing cloud cover and/or storms. Large installations of solar PV will likely need to be limited in size within a geographical area, unless it is coupled with solar thermal systems or energy storage systems.

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The renewable energy mix of 2011 is shown on Figure D-1

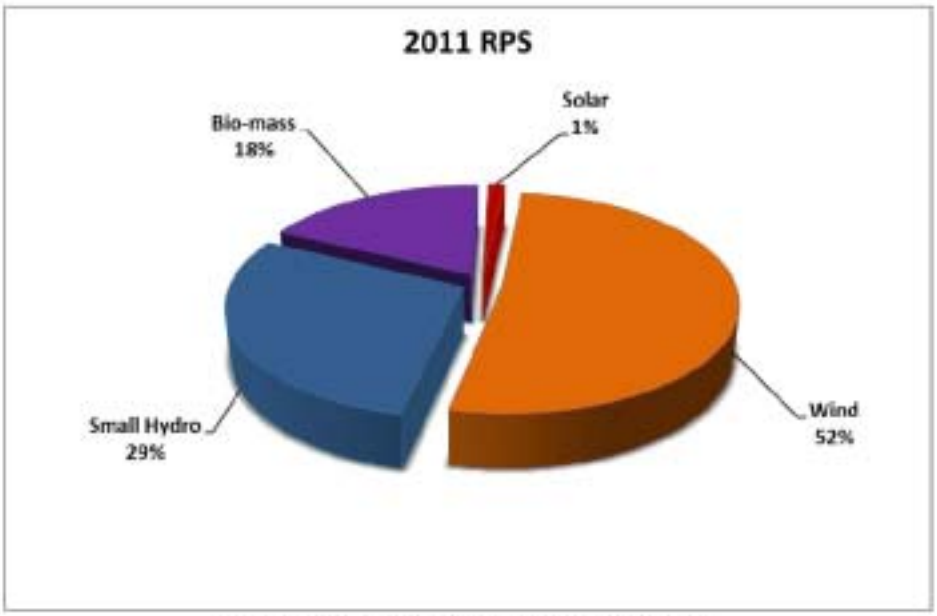

Figure D-1: 2011 Renewable Energy Mix

D.3.4 Impacts of CA Senate Bill SB 2 (1X)

On April 12, 2011, Governor Edmund G. Brown Jr. signed into law the California Renewable Energy Resources Act (herein referred to as "Act" or "SB 2 (1X)"). This Act sets new Renewable Portfolio Standard (RPS) procurement targets, new renewable resource eligibility definitions, and new reporting requirements applicable to Publicly Owned Electric Utilities (POUs). SB 2 (1X) became effective December 10, 2011, 90 days after the end of the special session in which it was enacted.

This bill expresses the intent that the amount of electricity generated from eligible renewable energy resources be increased to an amount that equals at least 20% of the total electricity sold to retail customers in California by December 31, 2013, 25% by December 31, 2016 and 33% by December 31, 2020. In addition, this bill requires POU governing boards to adopt a policy with similar goals imposed on IOUs to enforce the RPS Program on its respective utility.

According to the legislation, POU governing boards were directed to adopt "a program for the enforcement of this article" by January 1, 2012. As such, POU governing boards have discretion to interpret the following provisions:

- Procurement Target Goals
- Reasonable Progress to achieve such goals
- Procurement Requirements
- Rules to apply excess procurement for future compliance periods
- Conditions that allow for delaying timely compliance

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- Cost limitations for procurement expenditures.

Resources obtained in compliance with SB 2 (1X) must meet the following criteria:

Category (aka "Buckets")	Percentage of RPS Target
1. Either: Have a first point of interconnection with a California balancing authority, have a first point of interconnection with distribution facilities used to serve end users within a California balancing authority area, or are scheduled from the eligible renewable energy resource into a California balancing authority without substituting electricity from another source [PUC Section 399.16(b)(1)(A)]. Or, have an agreement to dynamically transfer electricity to a California balancing authority. [PUC Section 399.16(b)(1)(B)]	**Compliance Period 1 (2011-2013):** 50% of RPS minimum from this category. **Compliance Period 2 (2014-2016):** 65% of RPS minimum from this category. **Compliance Period 3 (2017 to 2020):** 75% of RPS minimum from this category. **Post – 2020** 75% of RPS minimum from this category.
2. Firmed and shaped eligible renewable energy resource electricity products providing incremental electricity and scheduled into a California balancing authority. [PUC Section 399.16(b)(2)]	Shall be calculated as the remainder of resources which are not in either Category 1 or Category 3.
3. Eligible renewable energy resource electricity products or any fraction of the electricity generated, including unbundled RECs that do not qualify under Bucket 1 or 2. [PUC Section 399.16(b)(3)]	**Compliance Period 1 (2011-2013):** 25% of RPS maximum from this category. **Compliance Period 2 (2014-2016):** 15% of RPS maximum from this category. **Compliance Period 3 (2017 to 2020):** 10% of RPS maximum from this category. **Post – 2020** 10% of RPS minimum from this category.

The regulations promulgating this legislation by the CEC over POUs were finalized. The Fourth Edition Renewable Energy Program Overall Program Guidebook and the Fifth Edition Renewable Portfolio Standard Eligibility Guidebook were adopted by the CEC on May 9, 2012.

D.3.5 Renewable Energy Credits

The Public Utilities Code Section 399.12 (h) defines a Renewable Energy Credit (REC) as "a certificate of proof, issued through the accounting system established by the California Energy Commission…that one unit of electricity was generated and delivered by an eligible renewable energy resource." RECs include all renewable and environmental attributes, including avoided greenhouse-gas (GHG) attributes, associated with the production of electricity from the eligible renewable energy resource.

The primary method of renewable energy resource procurement will be through the development and acquisition of physical generation assets and energy purchase contracts, in which LADWP

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will acquire the "renewable energy credit" (REC) from the renewable resource "bundled" with the associated energy.

In order for RPS compliance targets to be managed effectively, LADWP may buy, sell, or trade RECs without the associated energy (unbundled). This procurement approach will be limited by the percentage requirements established by PUC Section 399.16(b)(3), and as described in the City of Los Angeles Department of Water and Power Renewable Portfolio Standard Policy and Enforcement Program, as amended on December 2011.

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D.4 Transmission of Renewable Energy

California and many of the western states contain a variety of resources (wind, solar, geothermal, and other "eligible" resources previously defined in the RPS Policy) that can be developed to ultimately generate electricity. However, the current transmission system was not primarily designed with these natural resources in mind.

Even with the substantial existing transmission system owned by LADWP, and the other transmissions systems in California, there is only a limited amount of transmission lines to many of the potential renewable resource locations. In order to gain access to these sources of renewable energy, LADWP is planning on building additional transmission lines and expanding the capabilities of several existing lines, and utilizing transmission lines as part of renewable purchase power agreements. These projects include:

1. Barren Ridge Renewable Transmission Project (BRRTP) - Transmission access and transmission line upgrades are needed to accommodate proposed wind projects in the Tehachapi area and solar thermal projects in the Mojave Desert, which total nearly 1,000 MW. The initial project was the construction of the Barren Ridge substation which supports the 135 MW Pine Tree Wind project. This substation interconnects with LADWP's existing 230 kV Inyo-Rinaldi transmission line (which was built to gain access to the renewable hydro-generated energy from LADWP's aqueduct system in the Owens Valley). The Inyo-Rinaldi transmission capacity needs to be increased in order to accommodate additional renewable energy projects. A full Environmental Impact Report (EIR) process is currently underway on this project.
2. Related to the BRRTP project, the potential Owens Valley Solar projects may require further upgrades to the Inyo-Barren Ridge segment of this transmission line and a generation tie-line into the project area. Depending on ultimate solar build-out in the Owens Valley, additional new transmission may be required.
3. The joint Southern California Edison/Imperial Irrigation District upgrade of Path 42 is critical for delivery of renewable generation from the IID area into the California ISO. Upgrading Path 42 requires improvements to facilities under the control of SCE and the California ISO as well as facilities under IID control. The IID upgrades consist of replacing the 220 kV circuits between the Coachella Valley Substation and the Mirage Substation with bundled circuits, two conductors per circuit. The IID portion of the upgrades would increase the capacity of IID's portion of the path by around 800 MW. The total renewable potential for the California ISO/IID Path 42 upgrades is approximately 1,400 MW.

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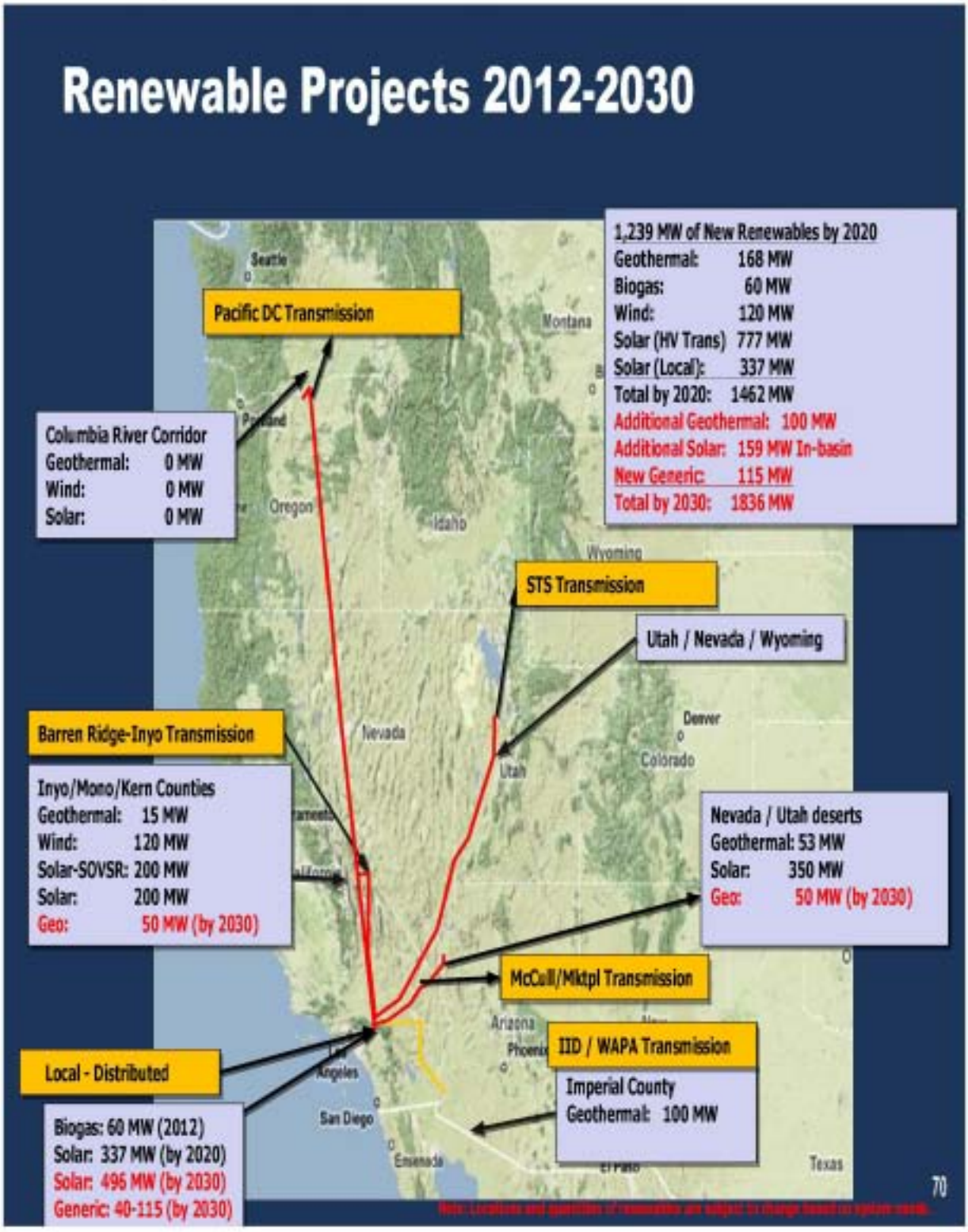

Figure D-2: Renewable Transmission Paths and Potential Resources, 2010 - 2030

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D.5 Funding the RPS

For LADWP to develop a responsible and prudent renewable energy policy, it must balance environmental objectives such as fuel diversity, energy efficiency and clean air against its core responsibility to provide and distribute safe, reliable, and low-cost energy to its customers. That means developing a RPS that ensures LADWP's continued financial integrity and striving to mitigate the financial impact on retail customers.

The financial impact of meeting a 33 percent RPS goal will vary depending on the mix of resource types and associated costs. Generally, renewable energy costs more than traditional energy sources such as natural gas and coal. However, a diversified energy portfolio, including a larger mix of renewables, may also reduce the risk of price spikes due to fuel supply shortages.

Estimated RPS revenue requirements to comply with SB 2 (1X) compliance targets of 25 percent renewable in 2016 and 33 percent in 2020 are shown in Figure D-3. Revenues required for an additional 4000 GWh annually for 2020 and beyond will require increasing annual renewable portfolio costs from 387 million to 848 million over the next 9 years.

During the early years of the RPS program, low cost, small hydro resources and biogas comprised the bulk of the portfolio with relatively higher cost wind energy being recently introduced over the last several years. Going forward, higher cost resources such as solar, geothermal, and wind must be used to comply with RPS standards as other lower cost alternatives have been largely exhausted. As can be seen in Figure D-4, contracts for renewable projects totaling 548 GWh or 12 percent of the renewable energy supply will expire over the next 4 years and will need to be replaced with higher cost renewable resources. Maintaining the current 20 percent RPS will require additional revenue to compensate for these higher cost replacement resources.

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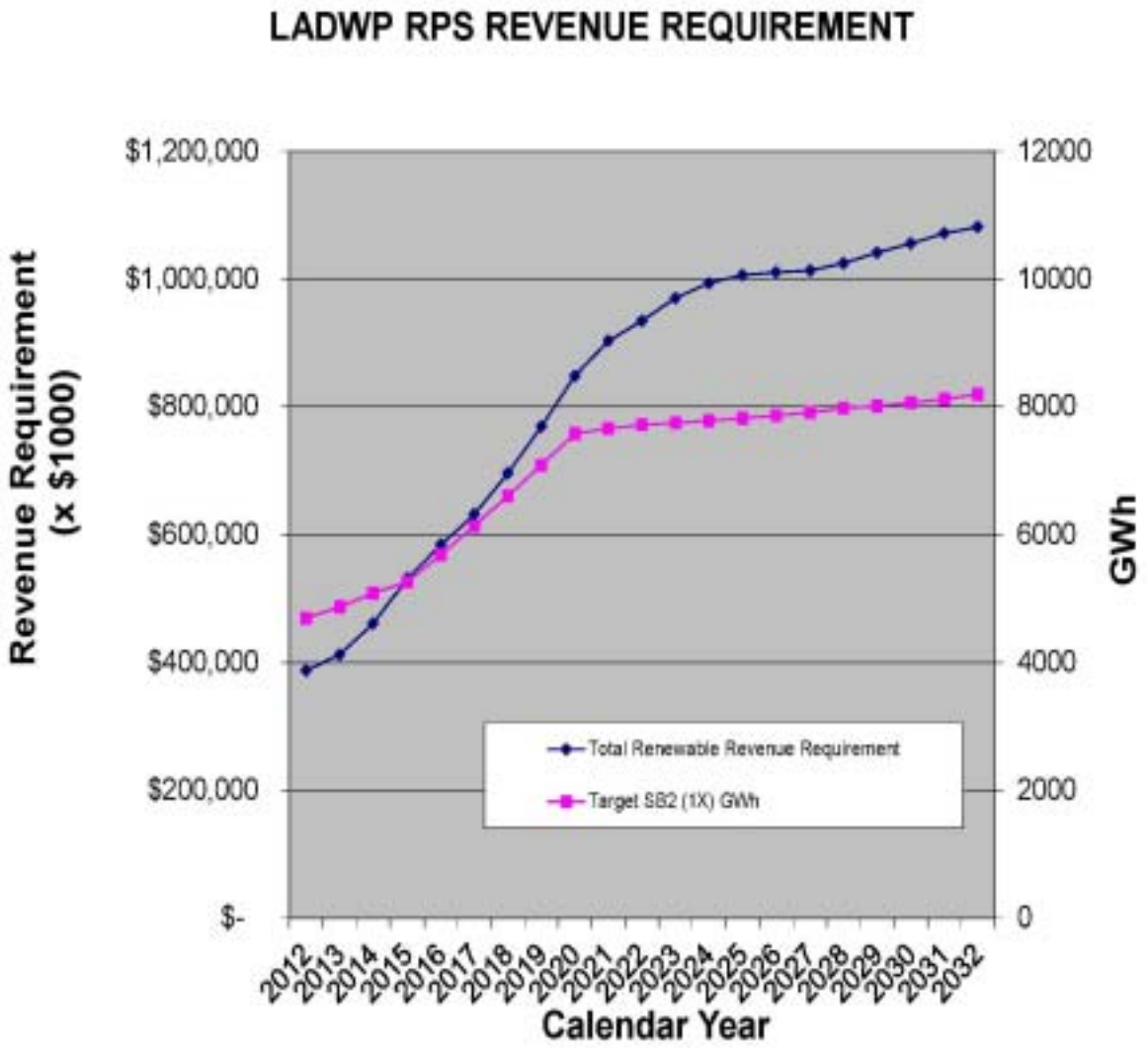

Figure D-3 – LADWP RPS Revenue Requirement 2012-2030.

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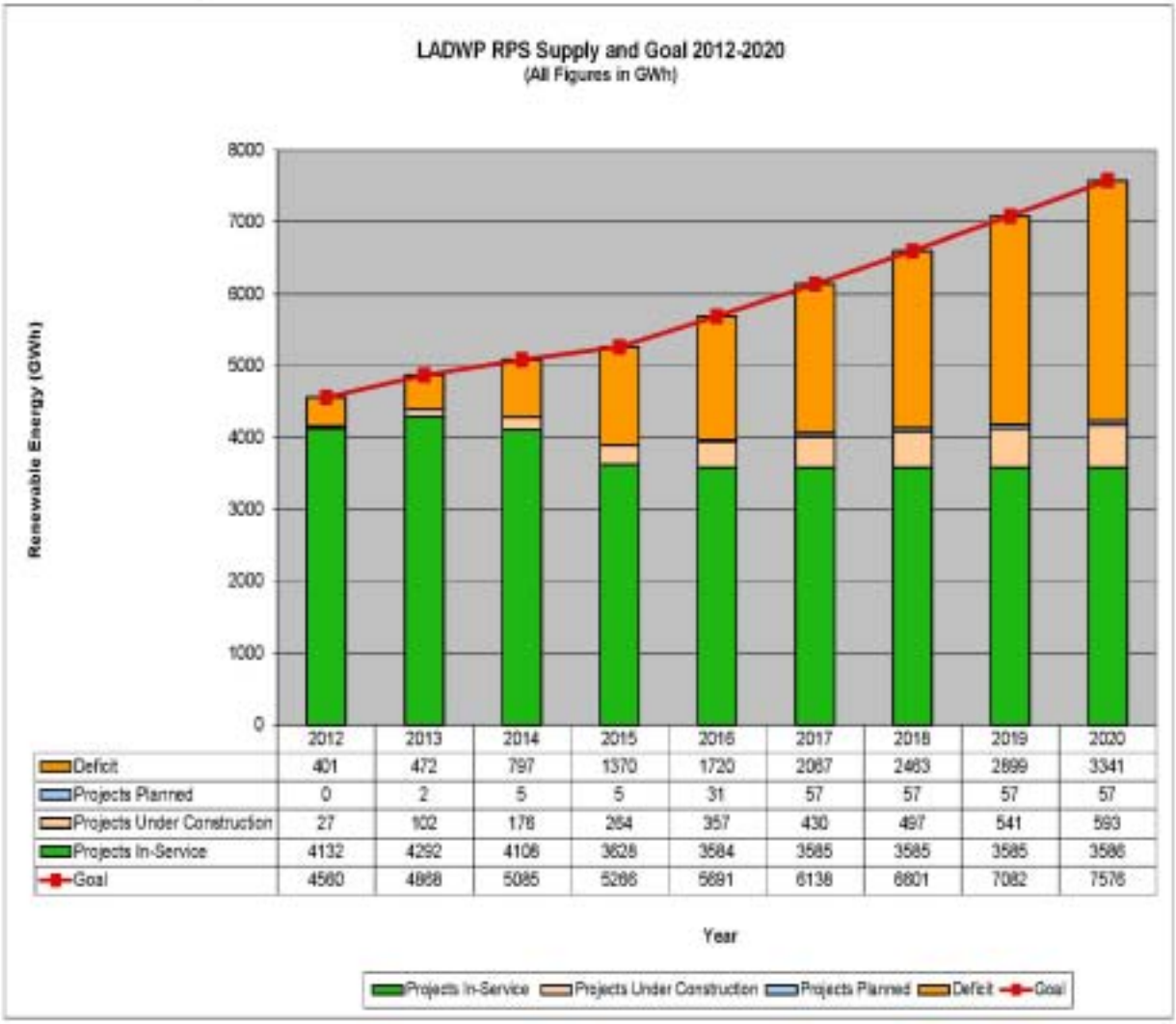

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Deficit	401	472	797	1370	1720	2087	2463	2899	3341
Projects Planned	0	2	5	5	31	57	57	57	57
Projects Under Construction	27	102	178	264	357	430	497	541	593
Projects In-Service	4132	4292	4106	3628	3584	3585	3585	3585	3586
Goal	4560	4868	5085	5266	5691	6138	6801	7082	7576

Figure D-4. LADWP RPS supply and goals for 2011-2020.

D.6 Other LADWP Renewable Projects

LADWP has several additional projects that are in various stages of development. LADWP also has short-listed additional renewable energy projects that have been offered in response to past LADWP's Request for Proposal (RFPs) or SCPPA RFPs. These short-listed projects and other proposals from upcoming RFP's will be used to select future projects, subject to the criteria enumerated within this section.

The eligibility of wind, solar, and geothermal projects to count toward renewable energy targets is well understood. LADWP has also procured biogas and is considering the use of certain types of biomass. Energy generated from this category is RPS-eligible.

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D.6.1 Biogas and Biomethane

Biogas continues to be one of the few renewable energy resources available that provides dispatch and base load characteristics, which effectively makes it a reliable and predictable renewable energy resource. Biogas is also needed to support other renewable resources that have low capacity factor characteristics, such as wind and solar. By capturing biogas for the use of electricity generation rather than flaring it and creating a secondary source of greenhouse gas emissions, utilities are clearly reducing the total amount of greenhouse gases emitted. Furthermore, by injecting biogas into the existing natural gas pipeline system, utilities are effectively offsetting the cost of building additional unnecessary infrastructure to supply biomethane to California.

The current California Energy Commission (CEC) Overall Program Guidebook of May, 2012 defines biogas as "includes digester gas, landfill gas, and any gas derived from an eligible biomass feedstock", and biomethane or pipeline biomethane as "biogas that has been upgraded or otherwise conditioned such that it meets the gas quality standards applicable to the natural gas transportation pipeline system into which the biogas is first accepted for transportation."

Digester gas is typically derived from the anaerobic digestion of agricultural or human or animal waste and biomass is typically defined as any organic material not derived from fossil fuels, including agricultural crops, agricultural wastes and residues, waste pallets, crates, dunnage, manufacturing, construction wood wastes, landscape and right-of-way tree trimmings, mill residues that result from milling lumber, rangeland maintenance residues, biosolids, sludge derived from organic matter, and wood and wood waste from timbering operations. The CEC also considers landfill gas (LFG) - gas produced by the breakdown of organic matter in a landfill - a renewable fuel.

In keeping with capturing the intent of the California legislature to increase use of renewable fuels, the LADWP amended its RPS policy when the CEC issued its third edition of the Guidebook in January 2008. Language from the then CEC Guidebook stated, "RPS-eligible biogas (gas derived from RPS-eligible fuel such as biomass or digester gas) injected into a natural gas transportation pipeline system and delivered into California for use in an RPS-certified multi-fuel facility may result in the generation of RPS-eligible electricity."

The LADWP's gas-fired generating units capable of burning a mixture of biogas/biomethane and conventional natural gas fall under the CEC multi-fuel designation. The CEC Guidebook stated, "…only the renewable portion of generation will count as RPS eligible, and only when the Energy Commission approves a method to measure the renewable portion."

Pursuant to the CEC Guidebook, the LADWP calculates the amount of RPS-eligible electricity produced at its gas-fired generating units by multiplying the total generation of the facility by the ratio of the quantity of biogas used to the quantity of total gas used by the facility. Both the energy generated and the quantity of gas used must be measured on a monthly basis.

The LADWP currently produces RPS-eligible energy derived from biogas/biomass. Digester gas produced at the Hyperion Wastewater Treatment facility is piped to the adjacent Scattergood Generating Station, where it is used to produce RPS-eligible energy. Additionally, the LADWP

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procures biogas/biomass-derived renewable energy via gas-fired microturbines located at several landfills throughout Los Angeles.

The LADWP currently holds contracts with developers to purchase pipeline biomethane. Under these contracts, the LADWP obtains LFG from several landfill sites located outside California. LFG produced by the landfills is scrubbed and filtered to pipeline grade and injected into the interstate natural gas pipeline system for delivery to the LADWP's most efficient gas-fired generating units.

In its latest edition of the RPS Eligibility Guidebook (5th Edition)[1], the CEC has noted that it has suspended the RPS eligibility related to biogas and put certain conditions of suspension and eligibility limitations in place, as described in Resolution No. 12-0328-3[2]. The suspension, which took effect on March 28, 2012, was adopted by the CEC Commissioners to provide the CEC staff with additional time to evaluate issues surrounding the continued eligibility of biomethane as a result of changes in law under SB 2 (1X). The suspension will remain in effect until the Energy Commission takes subsequent action to lift the suspension.

The California Legislature is currently proposing legislation that will revise the current eligibility requirements of biogas for entities who procured this resource prior to the effective date of the suspension. If legislation is executed, the CEC will subsequently modify its RPS Eligibility Guidebook to comply with such new requirements pertaining to the eligibility of Biogas.

D.6.2 Municipal Solid Waste

- The current CEC criteria sets forth several conditions for RPS-eligibility of municipal solid waste (MSW) conversion facilities: The facility uses a two-step process to create energy whereby in the first step (gasification conversion) a non-combustion thermal process that consumes no excess oxygen is used to convert MSW into a clean burning fuel, and then in the second step this clean-burning fuel is used to generate electricity. The facility and conversion technology must meet certain criteria which include the following:
- The technology does not use air or oxygen in the conversion process, except ambient air to maintain temperature control.
- The technology produces no discharges of air contaminants or emissions, including greenhouse gases as defined in Section 42801.1 of the Health and Safety Code.
- The technology produces no discharges to surface or groundwaters of the state.
- The technology produces no hazardous wastes.
- To the maximum extent feasible, the technology removes all recyclable materials and marketable green waste compostable materials from the solid waste stream before the conversion process, and the owner of operator of the facility certifies that those materials

[1] Renewables Portfolio Standard Eligibility, Fifth Edition, California Energy Commission, Efficiency and Renewable Energy Division. Publication Number: CEC-300-2012-002-CMF.
[2] Notice of Correction to Resolution on Suspension of the RPS Eligibility Guideline related to Biomethane, issued April 5, 2012. Available at: http://www.energy.ca.gov/portfolio/notices/2012-04-05_Notice_of_Correction_to_Resolution_on_Suspension_Biomethane_TN-64618.pdf

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will be recycled or composted

The facility certifies that any local agency sending solid waste to the facility diverted at least 30 percent of all solid waste it collects through solid waste reduction, recycling, and composting

The LADWP currently does not procure energy from any MSW combustion or conversion facilities, but may consider projects that meet all CEC criteria.

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D.7 Power Content Label

In 1997, Senate Bill 1305 was approved, which required Energy Service Providers (ESP) to report to their customers information about the resources that are used to generate the energy that they sell. A form, called the Power Content Label, would be used for this purpose, which would also provide a common reporting method to be used by all ESPs.

In addition, the 2002 Senate Bill 1078 established California's Renewable Portfolio Standard (RPS) which included both a requirement for electric utilities to report annually to their customers the resource mix used to serve its customers by fuel type, and to report annually to its customers the expenditures of public goods funds used for public purpose programs. The report should contain the contribution of each type of renewable energy resource with separate categories for those fuels considered eligible renewable energy resources, and the total percentage of eligible renewable resources that are used to serve the customers' energy needs.

LADWP's 2011 Power Content Label is shown in Table D-1. As LADWP has two separate renewable programs, the RPS policy and GREEN, both of these programs are reported on the Power Content Label.

Table D-1: LADWP's 2011 Power Content Label

POWER CONTENT LABEL

Annual Report of Actual Electricity Purchases for LADWP
Calendar Year 2011

ENERGY RESOURCES	LADWP Power ACTUAL MIX	LADWP Green Power ACTUAL MIX	2011 CA POWER MIX** (for comparison)
Eligible Renewable * **	**19%**	**100%**	**14%**
-- Biomass & waste	3%	0%	2%
-- Geothermal	0%	0%	5%
-- Small hydroelectric	6%	0%	2%
-- Solar	0%	0%	0%
-- Wind	10%	100%	5%
Coal	41%	0%	8%
Large Hydroelectric	3%	0%	13%
Natural Gas	17%	0%	37%
Nuclear	11%	0%	16%
Other	0%	0%	0%
Unspecified sources of power*	**9%**	**0%**	**12%**
TOTAL	**100%**	**100%**	**100%**

* "Unspecified sources of power" means electricity from transactions that are not traceable to specific generation sources.

** Percentages are estimated annually by the California Energy Commission based on the electricity sold to California consumers during the previous year.

*** This is in accordance with Los Angeles City Council's action on 10-5-04 for File No. 03-2688 (RPS)

For specific information about this electricity product, contact LADWP at 1-800-DIAL-DWP. For general information about the Power Content Label, contact the California Energy Commission at 1-800-555-7794 or www.energy.ca.gov/consumer.

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Reference D-1 – LADWP Renewables Portfolio Standard Policy and Enforcement Program Amended December 2011 - Board Resolution:

WHEREAS in August 2000, the Board of Water and Power Commissioners (Board) approved a resolution that authorized the Los Angeles Department of Water and Power (LADWP) to adopt an Integrated Resource Plan that established a goal of meeting 50 percent of projected load growth through a combination of Demand-Side-Management, Distributed Generation, and Renewable Resources; and

WHEREAS in 2002, the California Legislature passed Senate Bill 1078 that established the California Renewables Portfolio Standard (RPS), and a goal for all investor-owned utilities to increase their use of renewable resources by at least 1 percent per year, until 20 percent of their retail sales were procured from renewables by 2017; and

WHEREAS publicly-owned utilities like LADWP were exempt from California Senate Bill 1078, however they were encouraged to establish renewable resource goals consistent with the intent of the California Legislature; and

WHEREAS on June 29, 2004, the Los Angeles City Council adopted a LADWP RPS Framework and requested that the Board establish a RPS Policy, including achieving "20 percent renewable energy by 2017" and "incorporating this RPS into all future energy system planning"; and

WHEREAS on October 15, 2004, the Los Angeles City Council adopted a resolution approving the inclusion of existing LADWP hydroelectric generation units greater than 30 megawatts in size, excluding the Hoover hydroelectric plant, as part of the City's RPS list of eligible resources; and

WHEREAS on June 29, 2005, the Los Angeles City Council approved LADWP's Renewables Portfolio Standard Policy, which was designed to increase the amount of energy LADWP generated from renewable power sources to 20 percent of its energy sales to retail customers by 2017, with an interim goal of 13 percent by 2010; and

WHEREAS in December of 2005, the Board recommended that LADWP accelerate the RPS goal to obtain 20 percent renewables by 2010, which recommendation included updating LADWP's Integrated Resource Plan to include this goal, proceeding with the negotiation and contract development for renewable resources proposed and selected in LADWP's 2004 RPS and Southern California Public Power Authority 2005 RPS, supporting the cost of accelerating the RPS, and maintaining the financial integrity of LADWP's Power System during times of natural gas price volatility; and

WHEREAS on April 11, 2007, the Board amended LADWP's RPS Policy by advancing the date of the goal that required 20 percent of energy sales to retail customers be

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generated from renewable resources to December 31, 2010 and by establishing renewable energy procurement ownership targets and

WHEREAS, on May 20, 2008 the Board approved an amended RPS Policy, which included an additional RPS goal that required 35 percent of energy sales to retail customers be generated from renewable resources by December 31, 2020, expanded the list of eligible renewable resources, and provided new energy delivery criteria, and

WHEREAS, the California Renewable Energy Resources Act will become effective on December 10, 2011, and requires the governing board of a local publicly owned electric utility such as LADWP to adopt a program for enforcement, in accordance with Public Utilities Code Section 399.30(e), by January 1, 2012.

NOW THEREFORE BE IT RESOLVED that the Board of Water and Power Commissioners of the City of Los Angeles hereby adopts the Renewables Portfolio Standard Policy and Enforcement Program Amended December 2011, approved as to form and legality by the City Attorney, and on file with the Secretary of the Board.

I HEREBY CERTIFY that the foregoing is a full, true, and correct copy of a resolution adopted by the Board of Water and Power Commissioners of the City of Los Angeles at its meeting held

Secretary

AR0070180

Reference D-2 – LADWP Renewables Portfolio Standard Policy and Enforcement Program Amended December 2011:

City of Los Angeles Department of Water and Power
Renewables Portfolio Standard Policy
and
Enforcement Program
Amended December 2011

1. Purpose:

On April 12, 2011, Governor Jerry Brown signed into law the California Renewable Energy Resources Act (herein referred to as "Act" or "SB 2 (1X)"). This Act sets new Renewable Portfolio Standard (RPS) procurement targets, new renewable resource eligibility definitions, and new reporting requirements applicable to local Publicly Owned Electric Utilities (POUs). It is anticipated that SB 2 (1X) becomes effective on December 10, 2011, ninety days after the end of the special legislative session (1X) in which it was enacted.

This RPS Renewables Portfolio Standard Policy and Enforcement Program (RPS Policy) as amended, represents the continued commitment by the Los Angeles Department of Water and Power (LADWP) to renewable energy resources. It is being adopted in accordance with the newly added Section 399.30 (e) of the Public Utilities Code (PUC), requiring the governing boards of POUs to adopt "a program for enforcement of this article" on or before January 1, 2012.

The SB 2 (1X) also requires the California Energy Commission (CEC) to "adopt regulations specifying procedures for enforcement of this article", which include a public process under which the CEC may issue a notice of violation and correction against a POU for failure to comply. The CEC is further required to refer violations of its regulations to the California Air Resources Board which may impose penalties to enforce the Act consistent with California Assembly Bill 32, (AB32 - California Global Warming Solutions Act of 2006).

It is the intent of LADWP to comply with the provisions of the Act, and with applicable enforcement regulations adopted by the CEC pursuant to the Act. It is also the intent of LADWP to update this RPS Policy, as necessary, after the CEC adopts regulations specifying procedures for enforcement.

The Board of Water and Power Commissioners of the City of Los Angeles (Board) retains its jurisdiction to enforce the RPS Policy in accordance with PUC Section 399.30 (e).

2. Background:

In 2002, California Senate Bill 1078 (SB 1078) added Sections 387, 390.1 and 399.25, and Article 16 (commencing with Section 399.11) to Chapter 2.3 of Part I of Division 1 of the PUC, establishing a 20 percent RPS for California investor-owned electric utilities.

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SB 1078 provided that each governing board of a local POU be responsible for implementing and enforcing a RPS that recognizes the intent of the Legislature to encourage renewable resources and the goal of environmental improvement while taking into consideration the effect of the standard on rates, reliability, and financial resources.

On June 29, 2004, the Los Angeles City Council passed Resolution 03-2064-S1 requesting that the Board adopt an RPS Policy of 20 percent renewable energy by 2017 setting applicable milestones to achieve this goal, and incorporate this RPS into a future Integrated Resource Plan (IRP)

On May 23, 2005, the Board adopted a LADWP RPS Policy that established the goal of increasing the amount of energy LADWP generates from renewable power sources to 20 percent of its energy sales to retail customers by 2017, with an interim goal of 13 percent by 2010. On June 29, 2005, the Los Angeles City Council approved the LADWP RPS Policy

On April 17, 2007, the Board amended the LADWP RPS Policy by accelerating the goal of requiring that 20 percent of energy sales to retail customers be generated from renewable resources by December 31, 2010. In addition, the amended policy established a "Renewable Resource Surcharge" and also established renewable energy procurement ownership targets.

The Board subsequently approved a RPS Policy, as amended April 2008, which included an additional RPS goal of requiring that 35 percent of energy sales to retail customers be generated from renewable resources by December 31, 2020, expanded the list of eligible renewable resources, and provided new energy delivery criteria

In 2010, LADWP achieved its RPS goal of 20 percent

3. RPS Compliance Targets

To promote stable electricity prices, protect public health, improve environmental quality, provide sustainable economic development, create new employment opportunities, reduce reliance on imported fuels, and ensure compliance with applicable state law, the following RPS compliance targets are hereby adopted:

1. For the period of January 1, 2011 to December 31, 2013, LADWP will procure sufficient electricity products from eligible renewable energy resources to achieve an average of 20 percent of retail sales during such period
2. LADWP will increase its procurement of electricity products from eligible renewable energy resources to achieve 25 percent of retail sales by December 31, 2016, based on an average percentage of retail sales calculations for the period of January 1, 2015 to December 31, 2016
3. LADWP will increase its procurement of electricity products from eligible renewable energy resources to achieve 33 percent of retail sales by

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December 31, 2020 based on an average percentage of retail sales calculations for the period of January 1, 2020 to December 31, 2020.

4. For each calendar year after 2020, LADWP will procure sufficient electricity products from eligible renewable energy resources to achieve a minimum 33 percent of retail sales based on an average percentage of retail sales calculations for the period of January 1 to December 31 in each such calendar year.

The LADWP will continue to encourage voluntary contributions from customers to fund renewable energy resources in addition to the stated RPS compliance targets in accordance with its Green Power for a Green L.A. Program or any successor program.

4. Eligible Renewable Energy Resources

Prior to the enactment of SB 2 (1X), the LADWP RPS Policy defined the following technologies as "eligible renewable resources": biodiesel biomass conduit hydroelectric (hydroelectric facilities such as an existing pipe, ditch, flume, siphon, tunnel, canal, or other manmade conduit that is operated to distribute water for a beneficial use); digester gas; fuel cells using renewable fuels; geothermal; hydroelectric incremental generation from efficiency improvements; landfill gas; municipal solid waste; ocean thermal, ocean wave, and tidal current technologies; renewable derived biogas (meeting the heat content and quality requirements to qualify as pipeline grade gas) injected into a natural gas pipeline for use in renewable facility; multi-fuel facilities using renewable fuels (only the generation resulting from renewable fuels will be eligible); small hydro 30 Mega Watts (MW) or less, and the Los Angeles Aqueduct hydro power plants; solar photovoltaic, solar thermal electric, wind, and other renewables that may be defined later."

All renewable energy resources approved by the Board as part of its renewables portfolio in accordance with applicable law and previous versions of this RPS Policy, including without limitation those on Appendix A, will continue to be eligible renewable energy resources. Those renewable energy resources will count in full towards LADWP's RPS targets adopted in section 3 under this updated RPS Policy.

For RPS resources procured after the effective date of SB 2 (1X), "eligible renewable energy resource" means a generation facility that meets eligibility criteria under applicable law, including a "Renewable Electrical Generation Facility" as defined in Section 25741 (a) of the Public Resources Code and "Eligible Renewable Energy Resource" as defined in PUC Sections 399.12 (e) and 399.12.5.

5. Long-Term Resource and Procurement Plan

The LADWP will integrate the RPS Policy into its long-term resource planning process and the RPS Policy will not compromise LADWP's IRP objectives of service reliability, competitive electric rates, and environmental leadership. Future IRPs will incorporate

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and expand upon RPS compliance targets, and further define plans for procuring eligible renewable energy resources by technology type and geographic diversity.

Each year, the Board accepts an annual fiscal year budget including a Fuel and Purchased Power Budget (FPP), which defines the specific expenditures for renewable energy resources. The annual fiscal year budget, including the FPP, will comprise the LADWP Renewable Energy Resources Procurement Plan, as required under SB 2 (1X).

6 Procurement of Eligible Renewable Energy Resources

The LADWP will procure eligible renewable energy resources based on a competitive method and least-cost, best-fit evaluators. Furthermore, preference will be given to projects that are located within the City of Los Angeles or on City-owned property and are to be owned and operated by LADWP to further support LADWP's economic development and system reliability objectives.

Notwithstanding the foregoing, LADWP will also procure eligible renewable energy resources through programs such as a Distributed Generation Feed-In Tariff, Senate Bill 1 (SB1) Customer Net Metered Solar PV, other local renewable energy programs, or similar procurement processes. These transactions will be made in as cost-effective a manner as is feasible in each respective instance, with pricing that reflects applicable legal requirements and market conditions, prevailing policy, and competitive methods. Short-term renewable energy transactions will be needed as well, on a limited basis, to manage LADWP's RPS eligible renewable energy resources portfolio effectively based on prevailing wholesale practices.

Before December 31, 2010, LADWP pursued its 20 percent RPS goal in a manner which resulted in a minimum of 40 percent renewable energy generation ownership that LADWP developed or that LADWP procured through contracts with providers of renewable energy. Further, with respect to the foregoing contracts with providers, such contracts provided for LADWP ownership or an option to own, either directly or indirectly (including through joint powers authorities).

On or after January 1, 2011, a minimum of 75 percent of all new eligible renewable energy resources procured by LADWP will either be owned or procured by the LADWP through an option-to-own, either directly or indirectly (including through joint powers authorities) until at least half of the total amount of eligible renewable energy resources by Megawatt-hour (MWh), is supplied by eligible renewable energy resources owned or optioned either directly or indirectly (including through joint powers authorities) by LADWP.

The first priority for LADWP will be to pursue outright ownership opportunities, and the second priority will be consideration of procuring option-to-own, cost-based renewable energy resources. In comparing outright ownership to "option-to-own," option-to-own projects must show clear economic benefits, such as pass-through of Federal or State

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tax credits or incentives, which could not otherwise be obtained, or the need to evaluate new technology. The option-to-own will be exercisable with the minimum terms necessary to obtain and pass those tax credits and/or incentives to LADWP and/or upon a reasonable amount of time to evaluate the operation of the new technology.

7. Portfolio Content Categories

As required by SB 2 (1X), eligible renewable energy resources procured on or after June 1, 2010, will be in accordance with PUC Sections 399.16 (b) and (c). Section 399.15 (b) defines eligible renewable energy resources in three distinct portfolio content categories, commonly known as "buckets". LADWP will ensure that the procurement of its eligible renewable energy resources on or after June 1, 2010, will meet the specific percentage requirements set out in Section 399.16 (c) for each bucket in each compliance period.

These buckets and percentage requirements are summarized in Table 1 below.

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Table 1 Procurement Content Categories and Percentage Requirements

Category (aka "Buckets")	Percentage of RPS Target
4. Either: Have a first point of interconnection with a California balancing authority, have a first point of interconnection with distribution facilities used to serve end users within a California balancing authority area, or are scheduled from the eligible renewable energy resource into a California balancing authority without substituting electricity from another source [PUC Section 399.16(b)(1)(A)]. Or, have an agreement to dynamically transfer electricity to a California balancing authority. [PUC Section 399.16(b)(1)(B)]	**Compliance Period 1 (2011-2013):** 50% of RPS minimum from this category. **Compliance Period 2 (2014-2016):** 65% of RPS minimum from this category. **Compliance Period 3 (2017 to 2020):** 75% of RPS minimum from this category. **Post 2020:** 75% of RPS minimum from this category.
5. Firmed and shaped eligible renewable energy resource electricity products providing incremental electricity and scheduled into a California balancing authority. [PUC Section 399.16(b)(2)]	Shall be calculated as the remainder of resources which are not in either Category 4 or Category 5
6. Eligible renewable energy resource electricity products, or any fraction of the electricity generated, including unbundled RECs, that do not qualify under Bucket 1 or 2. [PUC Section 399.16(b)(3)]	**Compliance Period 1 (2011-2013):** 25% of RPS maximum from this category. **Compliance Period 2 (2014-2016):** 15% of RPS maximum from this category. **Compliance Period 3 (2017 to 2020):** 10% of RPS maximum from this category. **Post 2020:** 10% of RPS maximum from this category.

The LADWP will define the specific scheduling methods, including firming services, as needed, to maintain transmission system reliability and compliance with these procurement content categories and specified percentage requirements.

Subject to the provisions of PUC Section 399.16 (c), renewable electricity products procured prior to June 1, 2010, are exempt from these portfolio content categories and will continue to count in full toward LADWP's RPS compliance targets.

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8 System Rate Impact.

The LADWP may not make any major financial commitment to procure renewable resources prior to evaluating the rate impact and any potential adverse financial impact on the City transfer

9 Compliance Considerations:

In accordance with this RPS Policy, the Board will review the annual fiscal year budget and Renewable Energy Resources Procurement Plan, and will ensure that reasonable progress is being made towards compliance with the RPS compliance targets.

Reasonable progress may include activities that further the development and procurement of eligible renewable energy resources. Such activities may include, but are not limited to, real estate purchases for future project development, project planning and environmental permitting for either renewable energy projects or transmission in support of renewable energy projects, and other engineering, planning, budgeting, contracting and regulatory compliance activities.

In accordance with PUC Section 399.30 (d) (2), under exceptional circumstances the Board may adopt conditions that allow for delaying timely compliance with the RPS compliance targets, consistent with PUC Section 399.15 (b). Such conditions may include permitting interconnection or environmental delays, transmission constraints, resource availability, or operational limitations

In accordance with PUC Section 399.30 (d) (3), under exceptional circumstances the Board may adopt cost limitations for procurement expenditures consistent with PUC Sections 399.15 (c) and 399.15 (d).

In accordance with PUC Section 399.30 (d) (1), under exceptional circumstances the Board may adopt rules permitting LADWP to apply excess procurement in one compliance period to subsequent compliance periods in the same manner as allowed for retail sellers pursuant to PUC Section 399.13

10. Reporting and Notice Requirements:

The LADWP will provide a monthly RPS Progress Report to the Board of Commissioners. Additionally an annual report will be provided to its customers and the CEC containing all information required to be reported pursuant to SB 2 (1X), SB 1078, SB 107, and related regulations.

Per PUC Section 399.30 (e), the Board will adopt the program for enforcement at a publicly noticed Board meeting offering all interested parties an opportunity to comment. No less than 30 days' notice shall be given to the public of any meeting held for

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purposes of adopting the program. No less than 10 days' notice shall be given to the public before any meeting is held to make a substantive change to the program.

Per PUC Section 399.30 (f), LADWP will post notice whenever the Board will deliberate in public on its Renewable Energy Resources Procurement Plan. LADWP will either notify the CEC of the date, time, and location of the meeting in order to enable the CEC to post the information on its Internet Web site, or provide the CEC with the uniform resource locator (URL) that links to this information. In addition, upon distribution to the Board of information related to LADWP's renewable energy resources procurement status and future plans, for the Board's consideration at a noticed public meeting, LADWP shall make that information available to the public and shall provide the CEC with an electronic copy of the documents for posting on the CEC's Internet Web site, or provide the Uniform Resource Locator (URL) that links to the documents or information regarding other manners of access to the documents.

Per PUC Section 399.30 (g), LADWP shall annually submit to the CEC documentation regarding eligible renewable energy resources procurement contracts that it executed during the prior year.

Per PUC Section 399.30 (l), LADWP shall report, on an annual basis, information on (1) expenditure of public goods funds for eligible renewable energy resources development, (2) the resource mix used to serve its retail customers by energy source, and (3) status in implementing the RPS and progress toward attaining the RPS.

LADWP will continue to provide a Power Content Label Report to its customers as required by SB 1305 (1997) and AB 162 (2009), and an annual report of the total expenditure for eligible renewable energy resources funded by voluntary customer contributions.

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11 Use of Renewable Energy Credits

The primary method of renewable energy resource procurement will be through the development and acquisition of physical generation assets and energy purchase contracts where the "Renewable Energy Credit" (REC) is "bundled" with the associated energy. PUC Section 399.12 (h) provides the REC definition.

In order for RPS compliance targets to be managed effectively, LADWP may buy, sell or trade RECs without the associated energy (unbundled). This procurement approach will be limited by the percentage requirements established by PUC Section 399.16 (b) (3) and as described in section 7 above.

RPS Policy & Enforcement Program
Appendix A – List of LADWP RPS Resources prior to SB 2 (1X)

PPM SW Wyoming – Pleasant Valley Wind	Cottonwood Power Plant
Linden Wind	Division Creek P. P.
PPM Pebble Springs Wind	Big Pine Power Plant
Willow Creek Wind	Pleasant Valley P. P.
Pine Tree Wind Power Project	Upper Gorge P. P.
Milford Wind Phase I	Middle Gorge P. P.
Milford Wind Phase II	Control Gorge P. P.
Windy Point Phase I	North Hollywood Pump Station PP
Powerex - BC Hydro	Castaic Hydro Plant – Efficiency Upgrades
MWD Sepulveda	SB-1 Customer Net Metered Solar PV
Lopez Canyon Landfill	DWP Built Solar
WM Bradley Landfill	Silverlake Library
Penrose Landfill	LA Convention Center Canopy
Toyon Landfill	Sun Valley Library
Valley Generating Station (GS) – Multi-fuel	Lake View Terrace Library
Scattergood GS – Multi-fue	Canoga Park Library
Haynes GS – Multi-fuel	North Central Animal Shelter
Harbor GS – Multi-fuel	Ascot Library
Shell Energy Landfill Gas	Hyde Park Library
Almas Energy Landfill Gas	Ducommun Fitness Center
Hyperion Digester Gas – Scattergood GS	Truesdale Warehouse
LADWP Small Hydro Power Plants (PP)	Van Nuys Truck Shed
San Francisquito Power Plant 1	Distribution Station 3 (Vincent Thomas Bridge)
San Francisquito Power Plant 2	Main Street Yard
San Fernando Power Plant 2	Exposition Park Library
Foothill Power Plant	Granada Hills Yard
Franklin Power Plant	LADWP JFB Parking Lot
Sawtelle Power Plant	LA Convention Center Cherry St Parking Lot
Harwee Power Plant	Council District 6 Field Office

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Appendix E Power Reliability Program

Reliability represents one of the three main objectives of LADWP (see Figure 1-1). However, many people have trouble understanding what reliability is and why it so important.

The reliability discussed in this section refers to the electricity delivery infrastructure, and its job of delivering electricity to its customers in a safe and effective manner.

A good analogy would be one's car – how reliable it is at performing its job depends on how well it is maintained. As the years go by, certain components of a car began to fail (e.g., brakes, battery, water pump, etc.) and need to be replaced. Likewise, certain components of the electrical distribution infrastructure (e.g., poles, cables, transformers, etc.) eventually reach the end of their service lives. Unless they are replaced, they will begin to fail, causing various problems including power outages. As discussed later in this section, the level of outages caused by aging system components has reached an unacceptable level.

Ironically, the more successful a utility is in terms of reliability, the less awareness and attention it is given. For the general public, the historically high level of electric service has engrained an expectation of high reliability, to the extent that it is not given much thought – when a light switch is flipped, we expect the lights to turn on. It is only when the light doesn't turn on (or goes off during a power outage) that much public notice is given to the electricity delivery infrastructure.

The difficulties in managing reliability include the following:

- Because the consequences of deficient reliability are not experienced until electricity delivery is compromised, the need to allocate appropriate capital resources to better maintain system integrity – before problems occur – may not be fully appreciated by those outside the utility.
- External regulatory mandates are demanding a growing share of LADWP's limited financial resources. As rate actions have been delayed over recent years, inadequate revenues have resulted in underfunding for reliability programs.
- Reliability levels that become unacceptable due to deferral of infrastructure upkeep and replacement are more difficult to recover from and in the end are more costly.

History of High Reliability

Reliable electric power has been a cornerstone objective of LADWP since it began offering municipal electricity in 1917. Historically, LADWP's Power System reliability has consistently placed in the top quartile of the electric utility industry. However, as a result of aging electrical distribution infrastructure, reliability levels started to decrease in the early to mid-2000s. There are significant challenges for LADWP to halt the decline and to restore reliability to acceptable levels.

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The City of Los Angeles (City) was founded in 1781 and incorporated in 1850. Since then, Los Angeles has grown to the Nation's second largest City with a population of almost 4 million residents. Most of this growth occurred between 1920 (when there were roughly 580,000 residents) and 1970 (when the City had grown to over 2.8 million residents). This incredible growth of 2.2 million residents – roughly 56 percent of today's population – coincided with the mass electrification of homes and businesses throughout the country. During this time, LADWP installed tremendous amounts of electrical infrastructure to ensure that these growing numbers of new homes and businesses were supplied with reliable electric service. Figure E-1 shows the number of electrical distribution poles categorized by age, and illustrates that the bulk of the installations were made within the timeframe of this growth period.

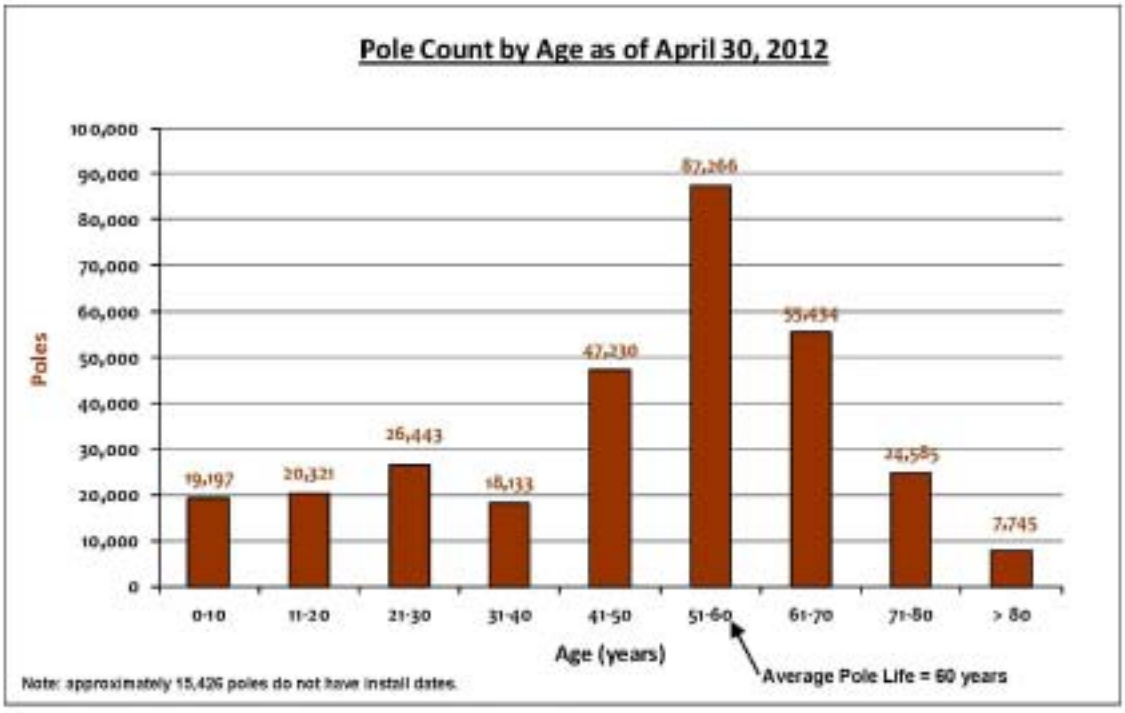

Figure E-1. Pole count by year range installed.

Reliability Levels Decrease

As a testimony to the initial design and installation of this electrical infrastructure, it had reliably served the residents of the City for 40 to 70 years. However, as stated previously, reliability began to deteriorate in the early to mid-2000's. Increasing outage rates, including several high profile outages, have resulted in service reliability concerns.

Table E-1 below summarizes several significant service interruptions since FY 2005-06.

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Table E-1. MAJOR POWER OUTAGES SINCE FY 2005-06

Date of Event	Type	Duration (days)	Outages (sustained)	Customers Affected (sustained)
December 31, 2005 - January 4, 2006	Wind/Rain	3.56	189	79,918
July 21-28, 2006	Heat	6.89	1033	46,981
January 5-8, 2007	Wind	2.92	150	62,725
April 12-16, 2007	Wind / Rain	3.57	218	105,796
August 30 - September 7, 2007	Heat	7.33	858	60,891
September 21-24, 2007	Rain	2.11	86	42,452
January 4-7, 2008	Rain	3.02	129	57,981
January 24-28, 2008	Rain	4.66	119	54,236
November 15-17, 2008	Fire/Wind	2.08	200	133,524
October 13-16, 2009	Rain	2.95	156	93,754
October 27-30, 2009	Wind	2.81	176	87,763
January 18-24, 2010	Wind/Rain	5.84	319	172,883
September 27-30, 2010	Heat	2.92	228	32,010
October 4-7, 2010	Rain	2.83	116	103,112
December 19-23, 2010	Rain	4.96	139	52,786
March 20-22, 2011	Wind/Rain	2.22	196	106,491
November 30 - December 4, 2011	Wind	3.75	419	222,567

The increase in problems appears to be the result of an aging infrastructure and a significant amount of deferred maintenance and deferred reliability-enhancing capital work. Several years of limited funding and reduced staffing levels are underlying contributors to the deferred infrastructure replacement cycle, maintenance, and capital improvements.

Reliability Performance Indicators – SAIFI and SAIDI

Like all other electricity utilities in the US, LADWP uses a number of metrics to measure the performance and reliability of its electric power system. The two primary metrics are called SAIFI and SAIDI.

System Average Interruption Frequency Index (SAIFI): SAIFI is the average number of sustained service interruptions per customer during the year. It is the ratio of the annual number of interruptions to the number of customers. In other words, it measures how many times the

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average customer has been out of service. 1.1 is the recent national average. In 2002, LADWP's SAIFI index was 0.49; in 2011 it was 1.03.

System Average Interruption Duration Index (SAIDI): SAIDI is the average duration of interruptions per customer during the year. It is the ratio of the annual duration of interruptions (sustained) to the number of customers. In other words, it measures how long the average customer was without power. 90 minutes is the recent national average. In 2002 LADWP's SAIDI index was 59.29; in 2011 it was 214.44.

The trends for both SAIDI and SAIFI are shown in Figure E-2.

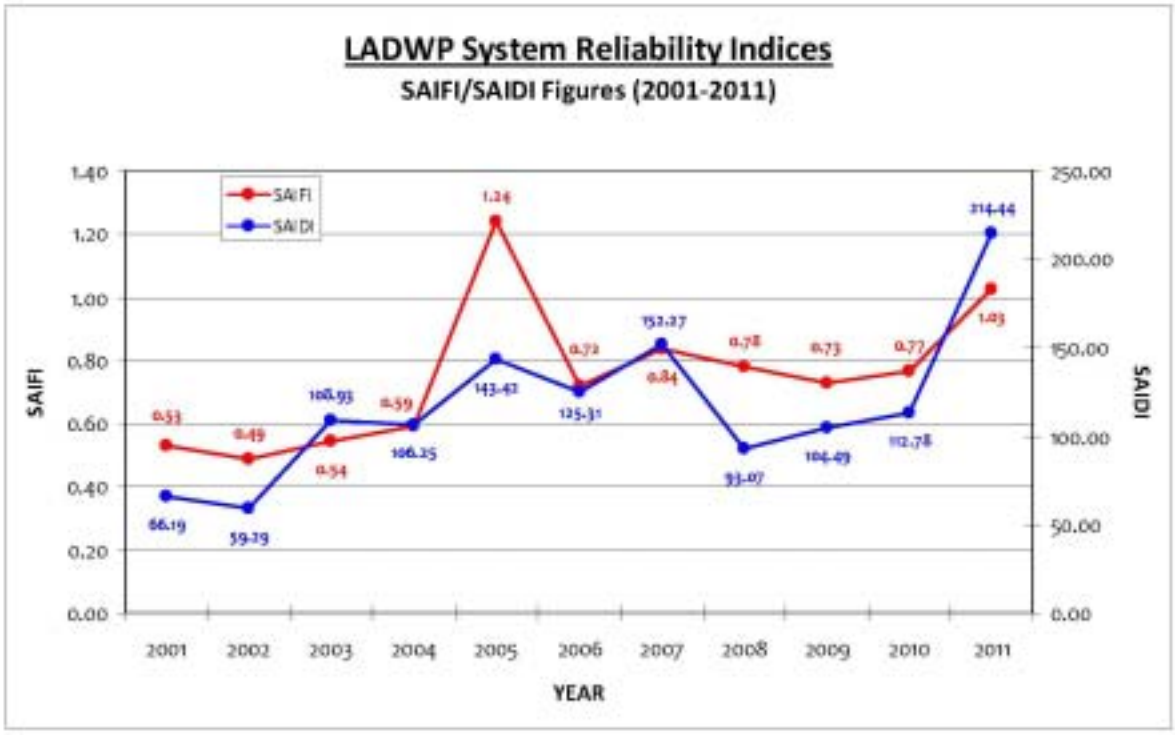

Figure E-2. LADWP's reliability indices.

The PRP is Initiated

As a result of deteriorating service, in 2007 Power System staff and independent industry expert consultants developed recommendations encapsulated in an initiative called the Power Reliability Program (PRP). The PRP is recognition that an infrastructure based industry, such as an electric utility, requires substantial re-investments in the infrastructure to have a viable and reliable system, and that these investments need to be stepped up on a permanent ongoing basis to support reliability in the long term.

The goals of the PRP include:

- Mitigating problem circuits and stations based on the types of outages specific to the facility

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- Implementing proactive maintenance and capital improvements that take into account system load growth and the inspections and routine maintenance that must take place to identify problems before they occur
- Establishing replacement cycles for system components that are in alignment with the equipment's life cycle

The system components that are being replaced include the following (see Figure E-3.):

- Power Poles
- Underground Cable
- Distribution and Substation Transformers
- Substation Circuit Breakers
- Overhead Transmission

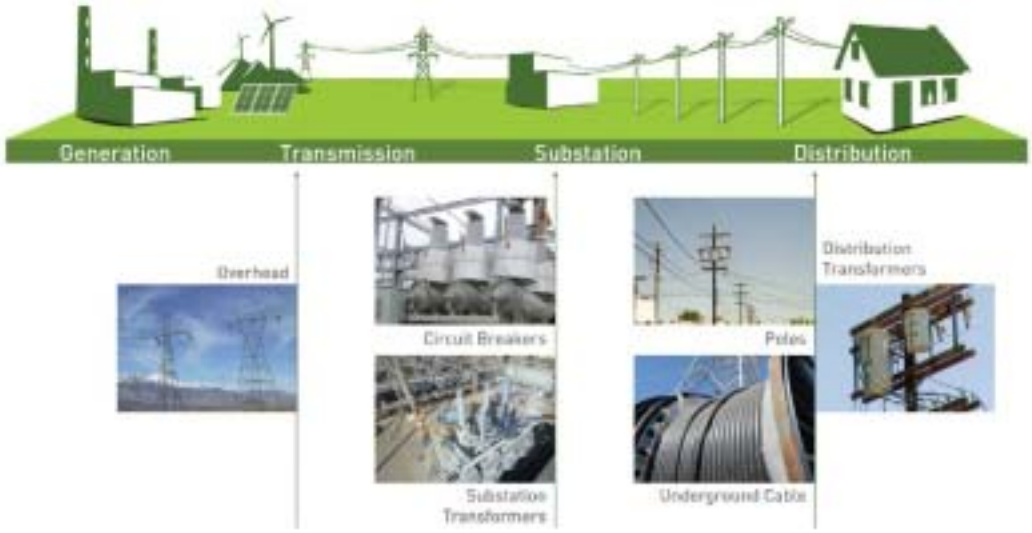

Figure E-3. Power System infrastructure assets for electricity delivery.

Infrastructure Replacement

Through the PRP, LADWP has moved forward with increased infrastructure replacement in key areas to reduce the average age of the critical components of its power system. While improvements have been made to reduce the age of certain equipment, more investment is required.

Increased investment in transformer and underground cable replacement in recent years has reduced outages related to these aspects of the distribution system; however, investment in overhead facilities has continued to lag targeted levels with a corresponding increase in overhead-related outages. Despite recent investments, there is an increasing amount of critical infrastructure components that are operating beyond their useful life.

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Asset Replacement Cycles

LADWP utilizes metrics to track the age, condition and impact on reliability for each major type of asset in its infrastructure. Table E-2 presents proposed and actual replacement cycles for PRP asset elements. Given the number and age of each asset element, a key consideration is to replace these assets at a rate that corresponds to their respective service lives. Replacement cycles that exceed the average service life by a factor of 2 or 3 puts the system at increased risk of service interruption.

Table E-2. REPLACEMENT CYCLES FOR INFRASTRUCTURE ASSETS

		Recommended		Actuals	Projected	Budgeted FY 2012-13	
Asset	Count	Replacement Cycle (years)	Proposed Replacement Rate (units/year)	FY 2010-11	CY 2011-12	Actual Replacement Rate	Replacement Cycle (years)
Poles	321,780	60	5,000	2,481	2,100	1,820	166
Underground Cable (miles)	4,500	75	50	68	52	28	161
Distribution Transformers	126,000	60	2,400	2,606	2,400	2,400	53
Large Substations Transformers	88	45	2	1	1	2	45
Local Substation Transformers	360 (approx.)	50	7	3	7	7	50
Substation Circuit Breakers	4,934	50	100	33	33	0	∞
Overhead Transmission (miles)	3,623	Maintenance & Capital Upgrade	100	0	1	0	∞
Underground Transmission (miles)	124	75	1 ckt./yr. (approx., 2 mi. each)	1	0	0	∞

Pole Replacement Program

Since approximately 70% of LADWP's system is overhead, pole and cross arm replacements are a major driver of reliability. As shown in the Figure E-4, the majority of LADWP's poles currently exceed their useful 60 year life. While the recommended replacement rate is 60 years, over 80,000 poles (26%) are more than 60 years old. Therefore, additional investment in pole replacement is warranted.

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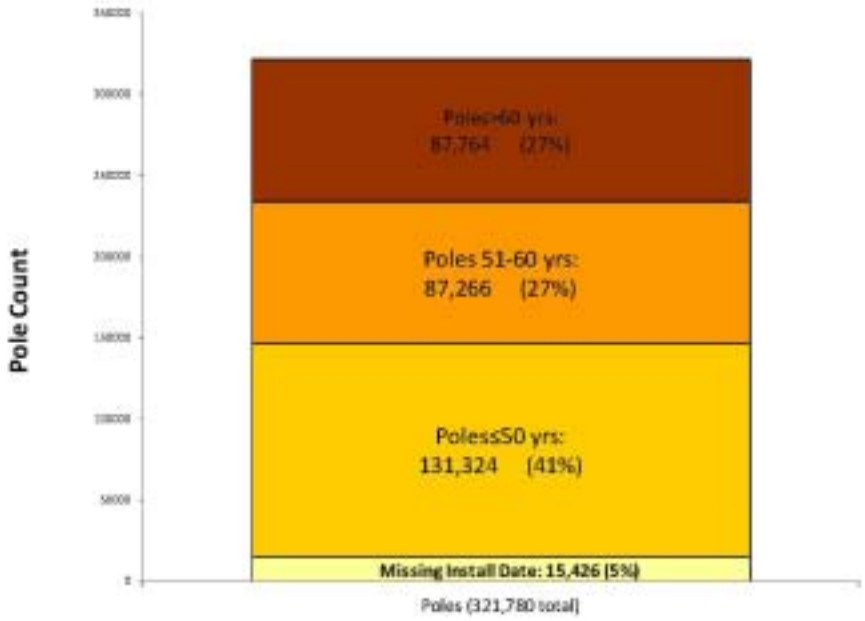

Figure E-4. Pole aging.

A growing number of these poles are in need of expeditious replacement. The following picture illustrates the poor condition of some of LADWP's older poles.

Picture: Pole condition illustrative.

LADWP identifies the poles that are most critically in need of replacement and replaces them as soon as possible. However, LADWP is not replacing poles and cross-arms at a pace that is keeping up with the aging of the system.

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Funding for pole replacement has LADWP on a 166 year replacement cycle which is more than double the ideal 60 year cycle. Figure E-5 below shows the recent pole replacement amounts and target levels to 2017.

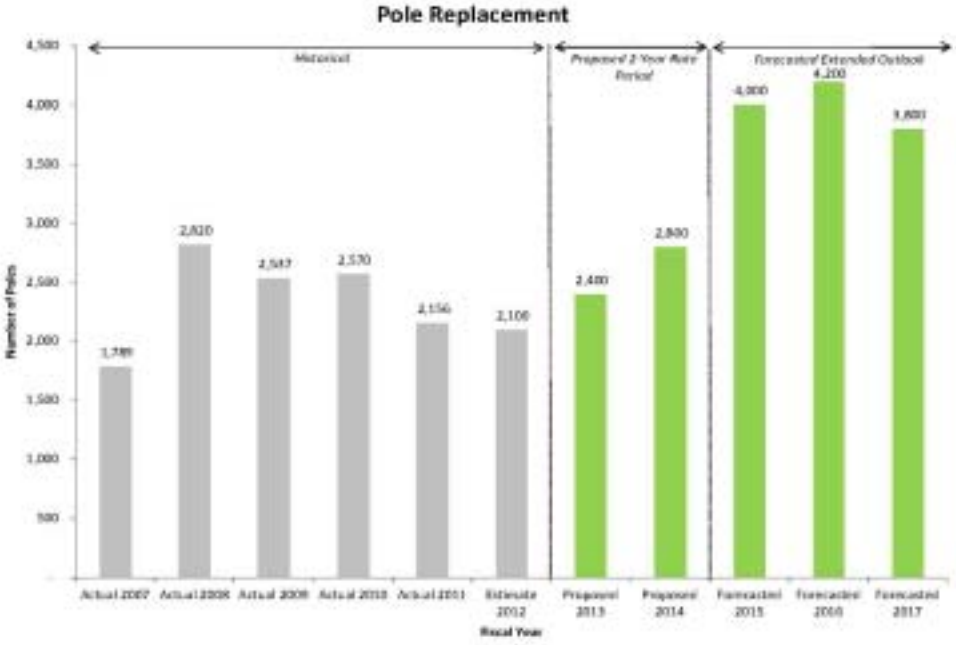

Figure E-5. Historical and forecasted pole replacement (FY 2007 – 2017).

To move towards the ideal life cycle, replacements will need to ramp up to around 5,000 per year over the next several years, pending available funds.

Underground Cable (UG) Replacement Program

LADWP has replaced on average 53 miles per year of UG cable over the past five years. Replacements have targeted cable failures that have caused outages contributing 27% to overall SAIFI. A pilot cable replacement program focused on the 5 worst performing UG circuits and produced a better than 50% reliability improvement; these circuits reflected 66% of common outage causes. LADWP's recent program compare favorably with best practices for utilities with aging underground cable. In an attempt to balance spending and rate levels, the proposed expenditures target replacement of 27 miles of UG cable per year for the next two years. While recent gains should help mitigate any short term decrease in reliability, over time it is likely that reliability could decrease.

Following LADWP's current replacement schedule, cable will be replaced every 159 years compared to a more ideal level of 72 years. In the past five years, the PRP has provided funding for the replacement of cable as shown in Figure E-6. Due to limited funding, the cable replacement program targets were reduced in order to more fully address replacement of other infrastructure assets.

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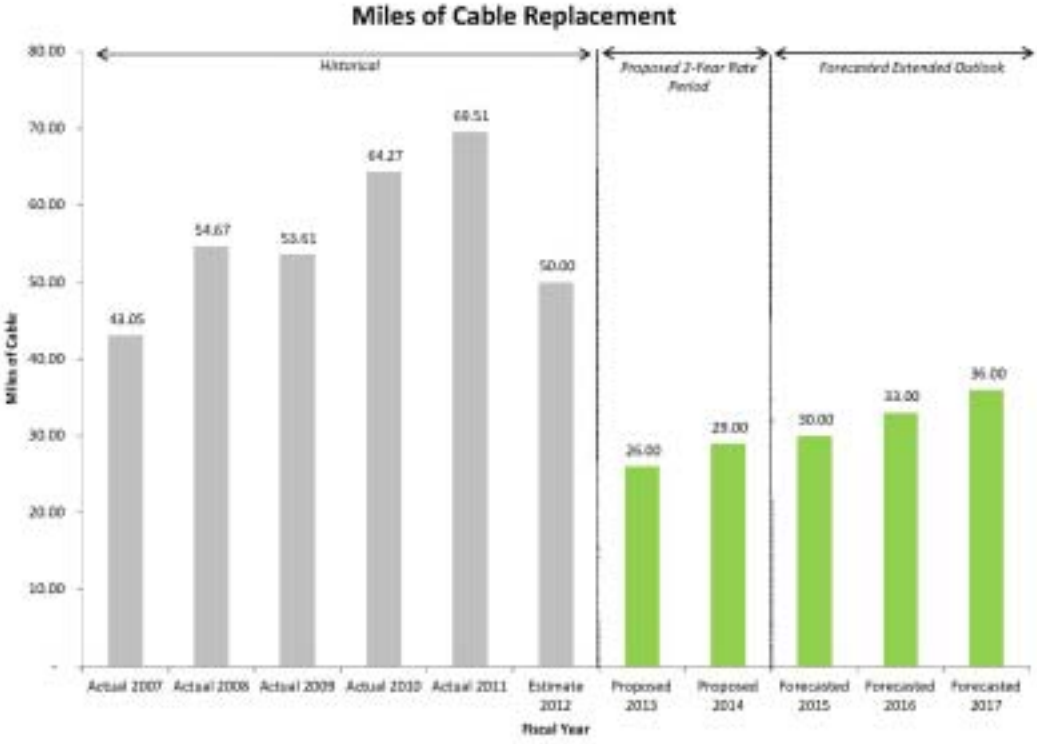

Figure E-6. Historical and forecasted cable replacement (FY 2007-2017).

Notwithstanding this decreased replacement target, cables identified as in critical need of replacement, like the one shown in picture below, are scheduled for replacement as soon as possible.

Picture: Illustrative of Cable Scheduled for Replacement.

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Distribution Transformer Replacement Program

Transformers play a critical role in the delivery of electricity to the city of Los Angeles. Many factors shorten the life of a transformer including: corrosion; moisture; physical damage; electrical surges; heat; loading; and, age. Transformer failures have been trending up in the past four years. With respect to age, overhead transformers have an average age to failure of 35 years; underground transformers at 23 years; and PAD transformers at 27 years. As shown in Figure E-7, the vast majority of LADWP's 957 transformer banks are over 40 years old with a significant number of those over 50 years old.

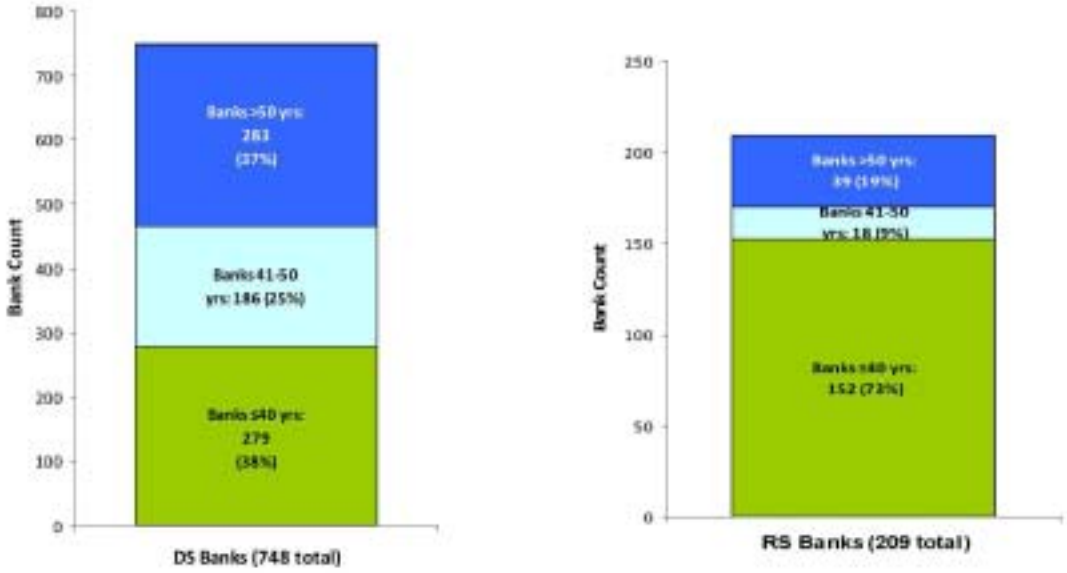

Figure E-7. DS and RS bank aging.

In recent years the PRP has provided funding to replace significant numbers of transformers as shown in Figure E-8.

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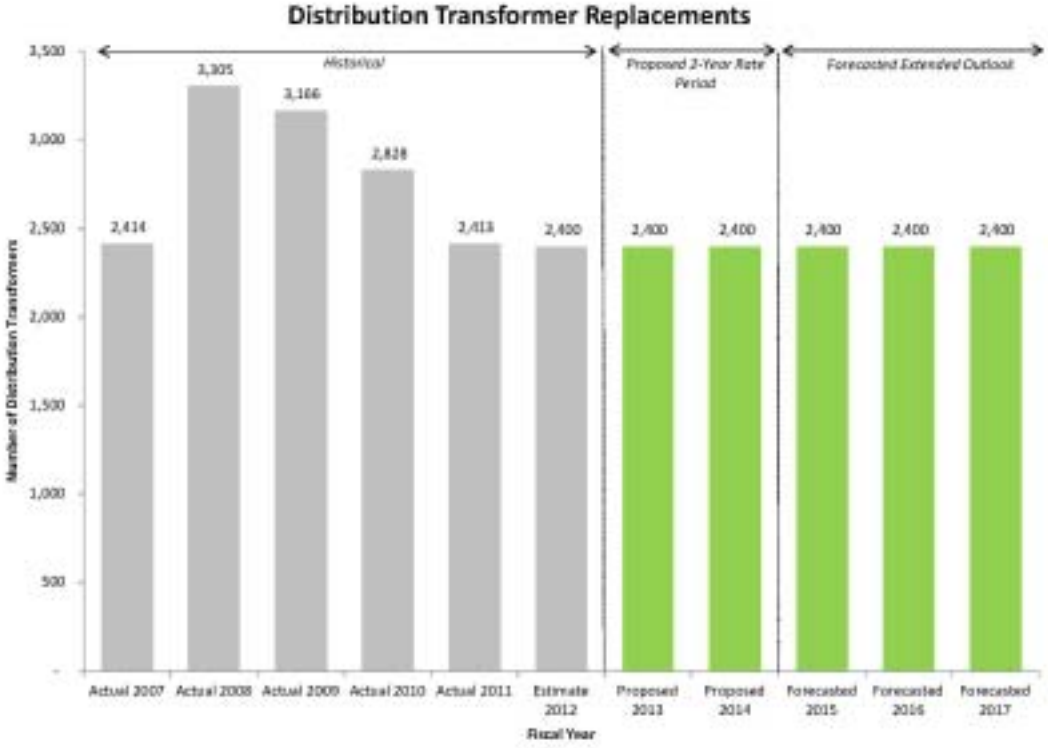

Figure E-8. Historical and forecasted distribution transformer replacements (FY 2007-2017).

Expected transformer replacements are expected to average 2,400 for the next five-years. Existing units may be run until closer to overload status, but new business related installations will continue as in the past. However, the risks of additional failures will be at least partially mitigated by maintaining an appropriate replacement inventory to permit prompt corrective actions.

Work Backlog

Another objective of the PRP is to reduce the backlog of needed work on the distribution system.

LADWP maintains a list of known required distribution system repairs and replacements that have not been completed. The size of this backlog has grown in recent years, as illustrated in Figure E-9. To bring down the nearly 41,000 repair orders in the queue to a desired base or on-going level of 2,000-5,000 would take 3 million work hours to catch up. Proposed funding levels do not provide enough for this catch-up. Based on forecasted PRP investment levels, the repair order backlog is projected to increase to approximately 44,000 tickets in 2017.

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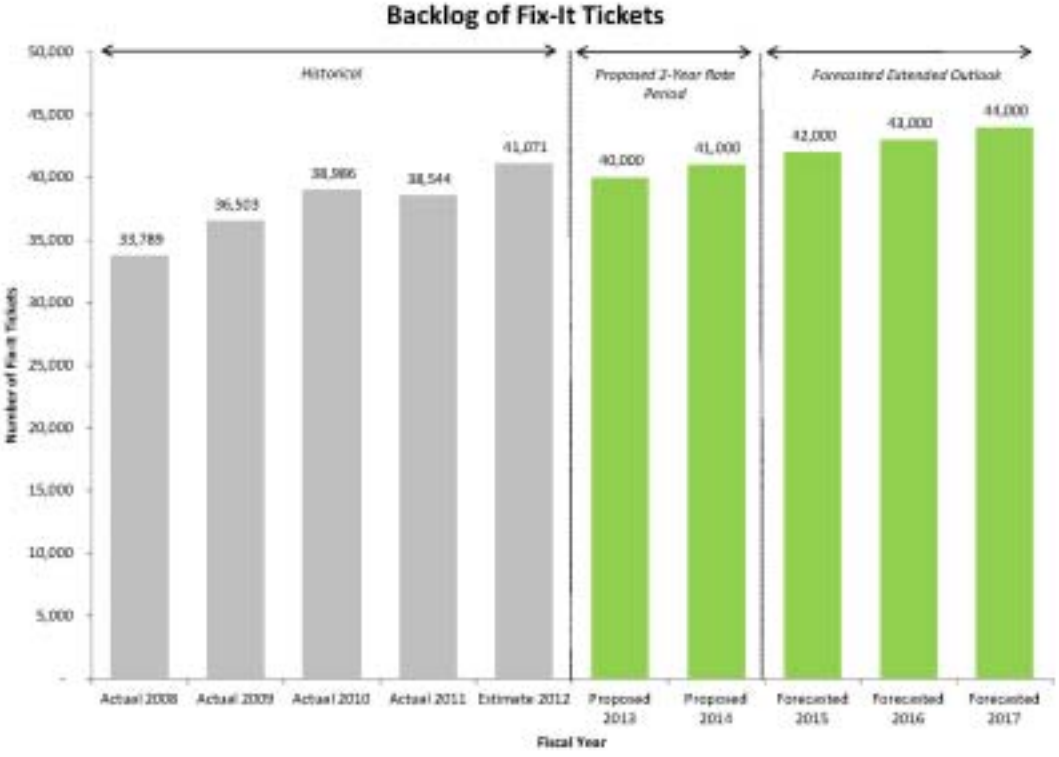

Figure E-9. Historical and forecasted backlog of repair orders (FY 2008 – FY 2017).

Funding Challenges

Funding of the PRP has been inconsistent since its inception. As shown in Figure E-10, the initial years of the program resulted in some reliability gains as outages decreased from 6,323 in 2006 to 4,523 in 2009. Funding levels since then, however, were below levels proposed when the PRP was initially designed in 2007. The numbers of outages are no longer declining. During FYE 2012, funding was cut by over $100 million from the previous year, given the limited resources available without the rate action proposed during 2011.

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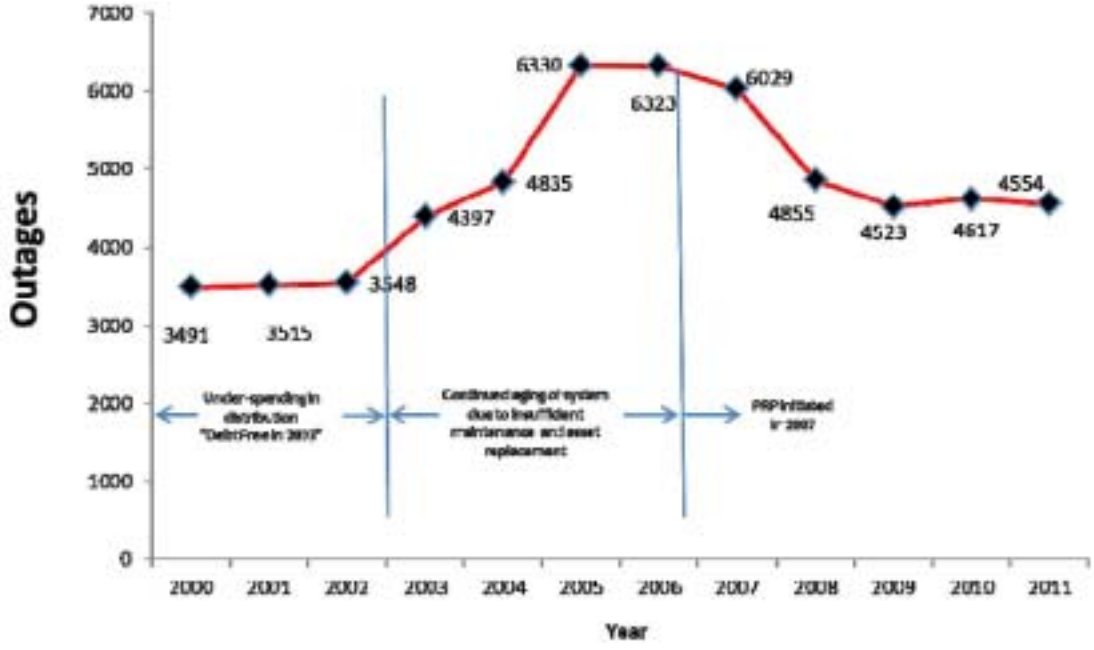

Figure E-10. Total outages between 2000-2011.

Asset Management Process

Reliability improvement in light of aging infrastructure and limited resources has become a critical issue for many utilities including LADWP. Both customers and policy makers are demanding increased service levels at the same time that funding for additional initiatives is limited due to financial constraints and competing priorities. LADWP's investment decisions will balance the following factors:

- Strict Asset Management Principles,
- A Rigorous Reliability Analysis; and
- Staffing and Other Resource Optimization.

LADWP's approach to addressing these challenges will be based on a systematic analytical approach to manage the available resources and expenditures to meet basic service needs in a manner that attempts to maintain overall reliability.

PRP - Summary and Recommendations

Reliability of the electricity delivery infrastructure is a key objective of LADWP. Historically, LADWP had attained adequate levels of reliability relative to the utility industry. However, beginning in the mid 2000's reliability began to decrease, the main cause being aging infrastructure. Deferred maintenance and investment did not keep pace with replacement needs, and the number and duration of outages began to increase. In response, LADWP initiated the Power Reliability Program in 2007 to address infrastructure reliability and lower the replacement

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cycles of infrastructure components to acceptable ranges that account for their expected service lives.

The PRP experienced initial successes, but as funding levels became constrained, outage levels, which had been decreasing, reversed and began to increase. Adequate funding is critical to restoring reliability to levels that LADWP customers expect and deserve. Figure E-11 presents the actual annual expenditures from FY 2008 to FY 2012, along with proposed spending levels through FY 2017. While the "Preferred T&D Reliability Expenditures" shown on the figure is the level of expenditure required to fully fund the PRP, the "Basic T&D Reliability Expenditures" is the projected expenditures to be available for the program.

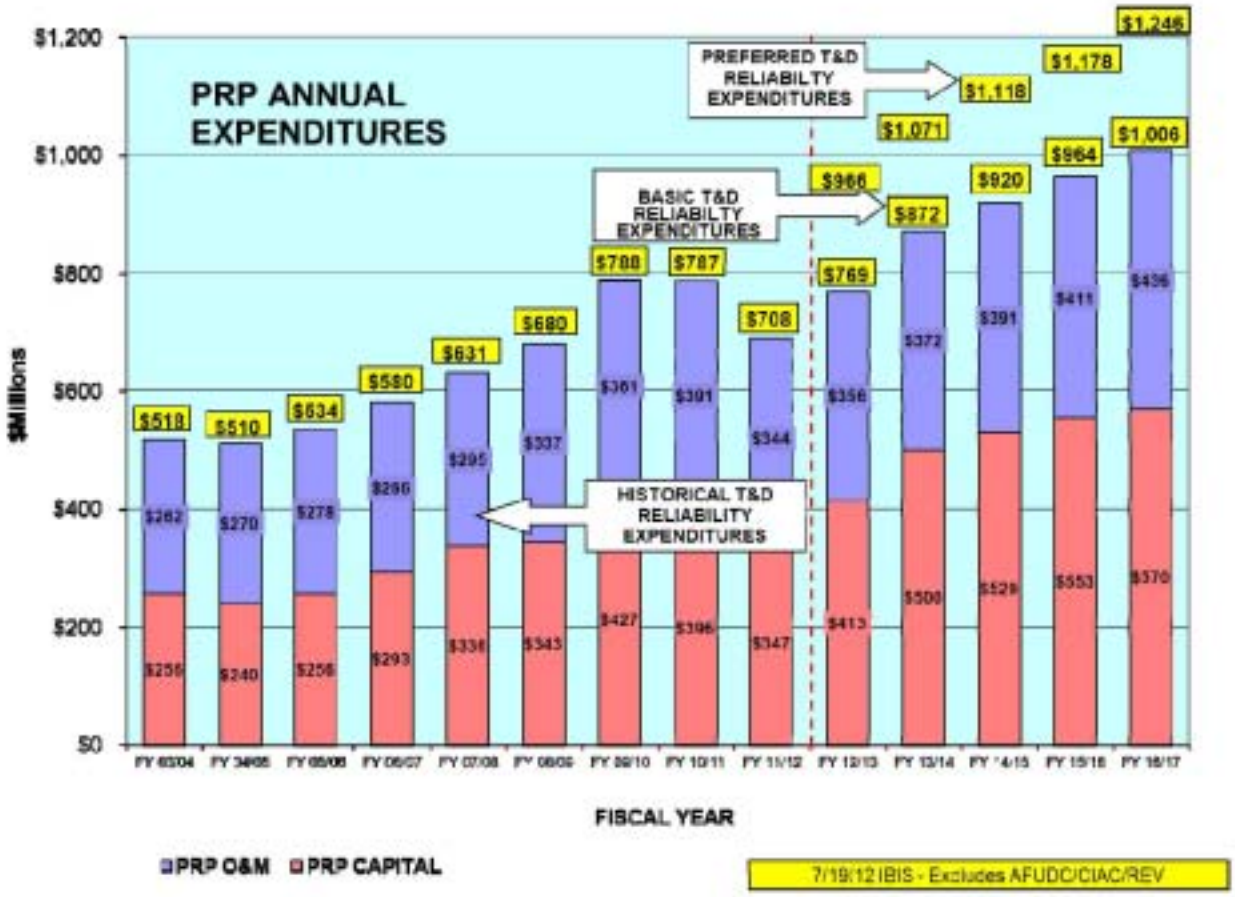

Figure E-11. Historical and proposed replacement targets and funding through FY 2017.

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Appendix F Generation Resources

F.1 Overview

LADWP's generation resources are presented in this Appendix. Resources that are not wholly owned by LADWP are available either as long-term power purchase agreements or as entitlement rights resulting from undivided ownership interests in facilities that are jointly-owned with other utilities. Most of these additional resources are available through LADWP's participation in the Southern California Public Power Authority (SCPPA). Each project participant with respect to jointly-owned units is responsible for providing its share of construction, capital, operating, and maintenance costs.

F.2 Resources

Generation resources for LADWP are comprised of the following five categories:

- In-Basin Thermal Generation
- Coal Fired Thermal Generation
- Nuclear-Fueled Thermal Generation
- Large Hydroelectric Generation
- Renewable Resources and Distributed Generation

F.2.1 In-Basin Thermal Generation

LADWP is the sole owner and operator of four electric generating stations in the Los Angeles Basin (the "Los Angeles Basin Stations"), with a combined net maximum generating capability of 3,415 megawatts (MWs) and a combined net dependable generating capability of 3,329 MWs. Natural gas and digester gas are used as fuel for the Los Angeles Basin Stations. Low-sulfur, low-ash residual distillate is used for emergency back-up fuel for some of the stations.

LADWP's natural gas-fueled generating plant capabilities are shown in Table F-1.

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Table F-1. NATURAL GAS GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Capability (kW)	Net Dependable Capability (kW)
Harbor	1	1995	85,340	82,000	452,000[2]
	2	1995	85,340	82,000	
	5	1995	75,000	65,000	
	10	2002	60,500	47,400	
	11	2002	60,500	47,400	
	12	2002	60,500	47,400	
	13	2002	60,500	47,400	
	14	2002	60,500	47,400	
Haynes	1	1962	230,000	222,000	1,525,000[3]
	2	1963	230,000	222,000	
	5	1966	343,000	292,000	
	6	1967	343,000	243,000	
	7	1970	2,000	1,599	
	8	2005	264,350	250,000	
	9	2005	182,750	162,500	
	10	2005	182,750	162,500	
Scattergood	1	1958	163,200	183,000	796,000
	2	1959	163,200	184,000	
	3	1974	496,800	450,000	
Valley	5	2001	60,500	43,000	556,000[4]
	6	2003	182,750	159,000	
	7	2003	182,750	159,000	
	8	2003	264,350	215,000	
Total				3,414,599	3,329,000

Notes:

1. COD refers to Commercial Operation Date.
2. Harbor Generating Station Net Dependable Plant Capability is 452 MW, reflecting Units 1 and 2 reduced performance during hot-weather conditions.
3. Haynes Generating Station Net Dependable Capability is 1,525 MW reflecting 8, 9, and 10 reduced performances during hot weather conditions; and Unit 7 used for auxiliary power only. Unit 5 Net Maximum Unit Capability was decreased to 292 MW to reflect LP hot-reheat piping derating. Unit 6 Net Dependable Unit Capability is 238 MW reflecting 243 MW transformer derating during hot weather conditions. Unit 4 was decommissioned in November 2003 and Unit 3 was decommissioned in September 2004.
4. Valley Generation Station Net Dependable Capability limited to 556 MW reflecting reduced performance during hot weather conditions.

Haynes Generating Station

The largest of the Los Angeles Basin Stations is the Haynes Generating Station, located in the City of Long Beach, California . The Haynes Station currently consists of eight generating units (Unit 7 is used for auxiliary power only) with a combined net maximum capability of 1,556 MWs and a net dependable capability of 1,525 MWs. This station includes a 575 MW

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combined-cycle generating unit installed in February 2005. The combined-cycle generating unit includes two combustion turbines and a common steam turbine. The combustion turbines can each operate with the steam turbine independently or together in a two on one configuration (and are counted by LADWP as three generating units). LADWP plans to repower unit 5 and 6 with six 100 MW simple-cycle gas turbine units targeted by June 2013.

Valley Generating Station

The Valley Generating Station is located in the San Fernando Valley. The Valley Station began its repowering in 2001 with a simple-cycle, 60.5 MW gas–turbine generator. Repowering was completed in 2004 with the installation of a combined-cycle generating unit consisting of two gas turbines with heat recovery steam generators, which supplies one steam turbine with a combined net maximum capability of 576 MWs. The total net dependable capacity for the Valley Station is 556 MWs.

Harbor Generating Station

The Harbor Generating Station is located in Wilmington, California. The Harbor Station was repowered in 1995 with a combined-cycle generating unit (counted as three units). Five additional peaking combustion turbines were installed in 2002 for a total of eight generating units. These activities resulted in the Harbor Station's net maximum capability of 466 MWs and a net dependable capability of 452 MWs.

Scattergood Generating Station

The Scattergood Station is located in Playa del Rey, California and is comprised of three steam generating units with a net maximum capability of 817 MWs and a net dependable capability of 796 MWs. Units 1 and 2 also burn digester gas from the adjacent Hyperion Wastewater Treatment Plant.

All of these generating stations are certified to burn biogas. This will allow the electricity produced from the biogas to be qualified for the Renewable Portfolio Standard.

F.2.2. Coal-Fired Thermal Generation

LADWP's coal generating capacity comes from the Navajo Generating Station and the Intermountain Generating Station (IGS). IGS is also referred to as the Intermountain Power Project (IPP). Coal generating resources are summarized in Table F-2.

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Table F-2: COAL GENERATING RESOURCE

Plant Name	Unit	COD[1]	Net Max Capability (Total kW)	Net Max Capability (LADWP kW)	Net Dependable Capability (LADWP kW)	LADWP Expiration	LADWP Share
Intermountain	1 2	1986 1987	900,000 900,000	401,553 401,553	401,553 401,553	15Jun2027	44.617%
Intermountain	1 2	1986 1987	900,000 900,000	36,000 36,000	36,000 36,000	15Jun2027	4% (UP&L)
Intermountain	1 2	1986 1987	900,000 900,000	163,512 163,512	149,500 149,500	15Jun2027	18.168% (Recallable)
Total				1,202,130[2]	1,174,106[2]		
Navajo	1 2 3	1974 1974 1975	750,000 750,000 750,000	159,000 159,000 159,000	477,000[3]	31Dec2019	21.2%
Total				1,679,130	1,651,106		

Notes:

1. COD refers to Commercial Operation Date.
2. IPP's Net Capacity available maybe less than 1202 MW due to Excess Power Recall. The LADWP entitlement is 44.617% direct ownership plus a 4% purchase from Utah Power & Light Company, plus 86.281% of up to 21.057% of muni's and co-op's recallable entitlement which can vary (shown is that of summer 2012). The nominal net Maximum Unit Capability and Net Dependable of both Units 1 and 2 is 900 MW.
3. LADWP's contract entitlement is 21.2% of Navajo's total net generation.

Intermountain Power Project (IPP)

General. The IPP consists of: (a) a two-unit coal-fired, steam-electric generating plant located near Delta, Utah, with net rating of 1,800 MWs and a switchyard located near Delta, Utah; (b) a rail car service center located in Springville, Utah; (c) certain water rights and coal supplies; and (d) certain transmission facilities consisting primarily of the Southern Transmission System. Pursuant to a Construction Management and Operating Agreement between the Intermountain Power Authority (IPA) and LADWP, IPA appointed LADWP as project manager and operating agent responsible for, among other things, administering, operating and maintaining IPP.

Power Contracts. Power is provided to LADWP under three separate agreements.

- Pursuant to a Power Sales Contract with IPA (the "IPP Contract") and a Lay-Off Power Purchase Contract with Utah Power & Light Company ("UP&L") and IPA, LADWP is entitled to 44.617 percent of the capacity of the IPP (currently equal to 803 MWs). The IPP Contract terminates in 2027 and may be renewed by LADWP under certain circumstances, subject, in addition, to legal and regulatory mandates.

- Pursuant to a Power Purchase Agreement with UP&L, LADWP purchases capacity and energy equivalent to the capacity and energy made available to UP&L pursuant

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to its 4 percent entitlement in the IPP (currently equal to approximately 72 MWs) until 2027, subject to certain renewal rights, which are dependant upon certain factors including the renewal of the IPP Contract.

- LADWP also has available additional capacity in the IPP through an excess power sales agreement with certain other IPP participants (the "IPP Excess Power Sales Agreement"). Under the IPP Excess Power Sales Agreement, LADWP is entitled to a maximum 18.168 percent of the capacity of IPP (equal to approximately 327 MWs). However, this amount varies as portions of it may be recalled by other participants. Of the maximum possible 327 MW allowed under this Agreement, approximately 209 MW is the summer 2012 entitlement amount.

Fuel Supply: IPA sold its 50 percent undivided interest in the Crandall Canyon Mine in Emery County, Utah and 50 percent undivided interest in the West Ridge Mine in Carbon County, Utah, in 2010. As part of the sale, a continued long term contract for fuel from the West Ridge Mine for IPP was agreed to at about 20 percent of the annual 6,000,000 ton coal requirement. LADWP, in its role as Operating Agent, manages all fuel supply contracts on behalf of IPA, including several long-term coal supply agreements that can provide approximately 60 percent of the coal requirements for the IPP. Spot market and opportunity purchases provide the balance of the fuel requirements for the facility. Additional information regarding IPP's fuel procurement strategy is found in Appendix H.

Over the past several years, the IPP units have had several substantial modifications, including cooling tower additions, high pressure turbine replacements, boiler capacity additions, distributed control system replacement, scrubber outlet modifications and rebuilds, and induced draft fan drive replacement. These modifications have decreased emissions and increased plant efficiency. They have also increased the plant's capacity by 110 MW, resulting in a 68 MW increase in capacity for LADWP.

Navajo Generating Station

The Navajo Generating Station (NGS) is located near the City of Page, Arizona. Salt River Project (SRP) is the operating agent for the Navajo Station. The Navajo Station is a coal-fired electric generating station and consists of three units with a combined net maximum capacity of 2,250 MWs. LADWP's entitlement of the Navajo Generating Station capability is 21.7 percent. On March 23, 1976, LADWP, Arizona Public Service Company (APS), Nevada Power Company (NPC), SRP, Tucson Electric Power Company (TEP) and the U.S. Department of Interior executed the Navajo Project Co-Tenancy Agreement effecting the co-owners' participation, and the operation and maintenance of the Navajo Project for as long as the land lease with the Navajo Nation is in effect until December 31, 2019 and throughout the lease extension thereafter. Negotiations are currently under way between the Navajo Nation and SRP, on behalf of the NGS participant owners, to renew the terms of the lease and all rights of way (ROWs) and grants related to the NGS site, transmission and railroad until December 31, 2044.

The station's SO_2 scrubbers, which were installed in 1999, continue to operate in full compliance with federal regulations for SO_2. The plant-wide compliance number has been under the emission limit of 0.10 pounds per million Btu.

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NGS also completed its Low NO_x burner Separated Overfire Air (SOFA) retrofit project in late March 2011. The Low NO_x-SOFA installation on all three units' boilers has contributed to a successful reduction of NO_x emissions by 40%, representing an annual NO_x emissions reduction of 14,800 tons/year. The NO_x emission is now under the limit of 0.24 pounds per million Btu.

Stringent NO_x emissions control standards currently being considered by the federal government for the pending Regional Haze Best Available Retrofit Technology (BART) ruling may require Navajo Generating Station to install Selective Catalytic Reduction (SCR) systems which carry a capital cost of approximately $550 million (or $137 million for LADWP). Should the new regulations require the installation of baghouses in addition to the SCRs, the combined capital cost of both SCRs and baghouses would amount to $1.13 billion (or $240 million for LADWP). The installation of these SCRs and baghouses could begin as early as 2017 and as late as 2029. On the other hand, if only Non-Selective Catalytic Reduction (NSCR) is required, the capital cost will be $40 million (or $8.5 million for LADWP).

In March 2011, the Environmental Protection Agency (EPA) released another proposed rule called the Utility Maximum Achievable Control Technology (MACT) that sets the national emissions standards for hazardous air pollutants (HAP) for electric generating units (EGUs). This rule calls for compliance of monitoring systems for Hg, particulate matter, and SO_2 (or HCl), hourly data collection, quarterly submission of emissions data, and new work practice standards for dioxins, furans, and other organic HAPs that would require regular "tune ups" of boilers to optimize combustion. These MACT modifications could be as much as $148.5 million (or $31.5 million for LADWP) or less depending on the required compliance systems.

The EPA also proposed federal regulations governing the disposal of coal ash and other coal combustion byproducts (CCBs) under the Resource Conservation and Recovery Act (RCRA). Under this rule, CCBs may be classified as either RCRA Subtitle C hazardous waste or RCRA Subtitle D non-hazardous waste. The regulation of CCBs under RCRA Subtitle C would impose staggering compliance costs on the power industry including NGS. An unfavorable ruling would jeopardize fly ash sales, trigger significant capital improvement to minimize environmental releases of coal ash and other byproducts, involve additional manpower to manage new programs, and require additional monitoring of the ash disposal landfill. Such coal ash disposal initiatives could amount to approximately $10 million (or $2.1 million for LADWP).

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F.2.3. Nuclear-Fueled Thermal Generation

LADWP's nuclear-fueled generating plant capabilities are shown in Table F-3.

Table F-3. NUCLEAR GENERATING RESOURCES

Plant Name	Unit	COD[1]	License Expiration	Net Max Capability (Total kW)	Net Max Capability (LADWP kW)	Net Dependable Capability (LADWP kW)	LADWP Share[2]
LADWP Direct Ownership Interest:							
Palo Verde	1 2 3	1986 1986 1988	2045 2046 2047	1,333,000 1,336,000 1,334,000	75,981 76,152 76,038	74,727 74,898 74,784	5.7%
LADWP Entitlement Interest Through SCPPA:							
Palo Verde	1 2 3	1986 1986 1988	2045 2046 2047	1,333,000 1,336,000 1,334,000	52,787 52,906 52,826	51,916 52,034 51,955	3.96% (SCPPA)
Total					386,690	380,314	

Notes:
1. COD refers to Commercial Operation Date.
2. LADWP's contract entitlement is 9.66 percent of generation comprised of 5.7 percent direct ownership in Palo Verde and another 67 percent power purchase of SCPPA's 5.91 percent ownership of Palo Verde.

Palo Verde Nuclear Generating Station (PVNGS) is located approximately 50 miles west of Phoenix, Arizona. PVNGS consists of three nuclear electric generating units (numbered 1, 2 and 3), with a net design electrical rating of 1,333 MW (Unit 1), 1,336 MW (Unit 2) and 1,334 MW (Unit 3) and a net dependable capacity of 1,311 MW (Unit 1), 1,314 MW (Unit 2) and 1,312 MW (Unit 3). PVNGS's combined net design capacity is 4,003 MW, and its combined net dependable capacity is 3,937 MW. All three units have been operating under 40-year Full-Power Operating Licenses from the Nuclear Regulatory Commission (NRC) expiring in 2025, 2026, and 2027, respectively. In April 2011, the NRC approved Palo Verde's application to extend the units' operating licenses to 20 years beyond the original term, allowing Unit 1 to operate through 2045, Unit 2 through 2046, and Unit 3 through 2047. APS is the operating agent for PVNGS. For the fiscal year ended June 30, 2011, PVNGS provided over 3.1 million megawatt-hours ("MWhs") of energy to the Power System. LADWP has a 5.7 percent direct ownership interest in the PVNGS (approximately 224 MW of dependable capacity). LADWP also has a 67.0 percent generation entitlement interest in the 5.91 percent ownership share of PVNGS that belongs to SCPPA through its "take-or-pay" power contract with SCPPA (totaling approximately 156 MWs of net dependable capacity), a joint powers authority in which LADWP participates, so that LADWP has a total interest of approximately 380 MW of net dependable capacity from PVNGS. Co-owners of PVNGS include APS; the SRP Agricultural Improvement and Power District, a political subdivision of the state of Arizona, and the Salt River Valley Water Users'

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Association, a corporation (together, the "Salt River Project"); Edison; El Paso Electric Company; Public Service Company of New Mexico; SCPPA, and LADWP.

The aftermath of the Fukushima earthquake and tsunami prompted the U.S. nuclear industry to form a task force under the direction of Palo Verde's Chief Nuclear Officer to take immediate actions in ensuring the reliability of all U.S. nuclear plants. Palo Verde itself has established a task force to evaluate the plant's safety and emergency preparedness. An initial assessment of the plant systems, safety policies, and emergency procedures revealed significant differences between Palo Verde and Fukushima. Palo Verde's low-seismic location, robust pressurized water reactor design, redundant safety features, ample effluent water supply, and multiple back-up power sources make a similar catastrophe in Arizona highly improbable. Despite the seemingly substantial advantages, Palo Verde, in conjunction with other nuclear agencies, is continuously working to make sure that the plant is adequately prepared to meet beyond design basis events, respond to extended loss of power supply situations, and mitigate potential fire and flood events. While evaluations are still in progress, among the initial recommendations are plans to accelerate fuel removal from the spent fuel pools and possibly purchase a standby diesel generator as reinforcement to the existing back-up power sources.

F.2.4 Large Hydroelectric Generation

LADWP's large hydroelectric facilities include the Castaic Pumped Storage Power Plant and an entitlement portion of the Hoover Power Plant. LADWP's hydroelectric plant capabilities are shown in Table F-4.

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Table F-4. LARGE HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Capability (LADWP kW)	Net Dependable Capability (LADWP kW)	LADWP Expiration	LADWP Share
Castaic[2]	1 2 3 4 5 6 7	1973 1974 1976 1977 1977 1978 1972	212,500 265,000 265,000 265,000 265,000 265,000 56,000	250,000 265,000 270,000 265,000 265,000 265,000 55,000	1,175,000	Owned Asset	100%
Hoover[3]		1936	2,079,000	491,000	468,000	30Sep2017	25.16%
Total				2,126,000	1,643,000		

Notes:

1. Commercial Operation Date.
2. Castaic Power Plant is re-rated at 1,175 MW. Castaic Power Plant Units 2, 4, 5, 6 modernizations were completed September 2004, June 2006, July 2008, and December 2005 respectively. Unit 3 modernization was completed in June 2009.
3. LADWP's entitlement is 25.16% of the plant's contingent capability of 1,951 MW (or 491 MW). The reduced entitlement is due to lower lake levels resulting from the western drought, which has abated recently. The current Hoover net plant capability as of April 20, 2012 is 1,861 MW. The 15.4229% is LADWP's share of total Hoover generation.

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Castaic Pump Storage Power Plant.

The Castaic Pump Storage Power Plant (the "Castaic Plant") is located near Castaic, California. The Castaic Plant is LADWP's largest source of hydroelectric capacity and consists of seven units with a net dependable capacity of 1,175 MWs. The Castaic Plant provides peaking and reserve capacity for LADWP's load requirements.

Hoover Power Plant.

General. The Hoover Power Plant (the "Hoover Plant") is located on the Arizona-Nevada border approximately 25 miles east of Las Vegas, Nevada and is part of the Hoover Dam facility, which was completed in 1935 and controls the flow of the Colorado River. The Hoover Plant consists of 17 generating units and two service generating units with a total installed capacity of 2,080 MWs. LADWP has a power purchase agreement with the United States Department of Energy Western Area Power Administration ("Western") for 491 MWs of capacity (calculated based on 25.16 percent of 1,951 MWs of total contingent capacity) and energy from the Hoover Plant through September 2017. The facility is owned and operated by the United States Bureau of Reclamation.

Drought Conditions. The long drought conditions and low lake levels have been improved recently, consequently LADWP's capacity entitlement at the Hoover Plant has increased to 468 MWs (calculated based on 25.16 percent of 1,861 MW output capability as of April 20, 2012).

F.2.5 Renewable Resources and Distributed Generation

LADWP's Renewable Resources and Distributed Generation consists of

- Eligible renewable small hydro resources as shown in Tables F-5, F-6 and F-7.
- Renewable and distributed generation resources as shown in Table F-8.

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Table F-5. OWENS VALLEY SMALL HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Unit Capability (LADWP kW)	Net Max Plant Capability (LADWP kW)	Net Dependable Capability (LADWP kW)
Haiwee[3]	1 2	1927 1927	2,800 2,800	3,600 3,600	4,200	0
Cottonwood[3]	1 2	1908 1909	750 750	1,200 1,200	1,900	400
Division Creek	1	1909	600	680	680	400
Big Pine[4]	1	1925	3,200	3,050	3,050	400
Pleasant Valley[5]	1	1958	3,200	2,700	2,700	0
Total					12,530	1,200[2]

Note:

1. Commercial Operation Date.
2. Owens Valley combined Net Dependable Plant Capability is 1.2 MW based on 20-years of historical data. 1.2 MW consists of 0 MW from Haiwee and Pleasant Valley and 0.4 MW each from Cottonwood, Division Creek and Big Pine.
3. Haiwee maximum unit capability is 3.6 MW each when feed is taken from North Haiwee Reservoir. Cottonwood Power Plant Units 1 and 2 were re-wound to higher Net Maximum Unit Capability of 1.2 MW.
4. Big Pine Net Maximum Unit Capability is limited to maximum flow through penstock.
5. Pleasant Valley Power Plant output is limited to Division of Safety of Dams (DOSD) reservoir level restriction.

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Table F-6. OWENS GORGE SMALL HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Unit Capability (kW)	Net Max Plant Capability (kW)	Net Dependable Capability (kW)
Upper Gorge	1	1953	37,500	37,500	37,500	36,500
Middle Gorge	1	1952	37,500	37,500	37,500	36,500
Control Gorge	1	1952	37,500	37,500	37,500	36,500
Total[2]					112,500	109,500

Notes:

1. Commercial Operation Date.
2. Owens Gorge Net Dependable Plant Capability was decreased to 109.5 MW to reflect re-watering flow.

The Owens Gorge and Owens Valley Hydroelectric generating units (the "Owens Gorge and Owens Valley Hydroelectric Generation") are located along the Owens Valley in the Eastern High Sierra. The Owens Gorge and Owens Valley Hydroelectric Generation are a network of hydroelectric plants which use water resources of the Los Angeles Aqueduct and three creeks along the Eastern Sierras. The water flow fluctuates from year to year; as a result, water flow may be reduced from seasonal norms from time to time.

San Francisquito Canyon and at the Los Angeles and Franklin Reservoirs. LADWP also owns and operates 12 units located north of the City along the Los Angeles Aqueduct in San Francisquito Canyon and at the Los Angeles and Franklin Reservoirs. The net aggregate dependable plant capability of these smaller units is 24 MWs under average water conditions. Table F-7 summarizes these 12 units.

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Table F-7. AQUEDUCT SMALL HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Unit Capability (kW)	Net Max Plant Capability (kW)	Net Dependable Capability (kW)
Foothill (PP4)	1	1971	11,000	9,900	9,900	2,900
Franklin (PP5)	1	1921	2,000	2,000	2,000	400
San Francisquito 1 (PP1)	1A 3 4 5A	1983 1917 1923 1987	25,000 9,375 10,000 25,000	27,000 10,000 12,000 27,000	46,500	13,000
San Francisquito 2[2] (PP2)	1 2 3	1919 1919 1912	14,000 14,000 14,000	0 14,000 18,000	18,000	5,700
San Fernando 1 (PP3)	1 2	1922 1922	2,800 2,800	3,200 2,900	6,000	2,100
Sawtelle (PP6)	1	1986	640	650	650	130
Total[3]					83,050	24,230

Note:

1. Commercial Operation Date.
2. San Francisquito Power Plant 2, Unit 1 has been out of service since 1995. The plant's Unit 2 stator heating limits capacity to 8 MW during hot weather condition. The plant's Unit 3 has a new generator with refurbished turbine as of the end of 2006. The contract specification is 18 MW output, but the unit was tested to only 16 MW due to low water flow and restricted downstream capacity. Assumed maximum actual output is 18 MW.
3. Aqueduct combined Net Dependable Plant Capability reflects low water availability during winter.

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Table F-8. RENEWABLE AND DISTRIBUTED GENERATING RESOURCES[1]

Includes only Projects in Service as of April 2012

Plant Name	PPA/Own	COD	Net Max Capability[2] (Installed kW)	Net Max Capability[3] (LADWP kW)	Net Dependable Capability[4] (LADWP kW)	LADWP Share
PPM SW Wyoming	PPA	2006	144,000	82,200	8,220	57%
Willow Creek	PPA	2008	72,000	72,000	36,000	100%
PPM Pebble Springs	PPA	2009	98,700	68,695	34,000	70%
Pine Tree	Own	2009	120,000	120,000	12,000	100%
Milford Wind Phase I	PPA/Own	2009	200,000	185,000	18,500	93%
Windy Point Phase II	PPA/Own	2010	262,200	262,200	73,000	100%
Pine Tree Expansion	Own	2010	15,000	15,000	1,500	100%
Linden	Own	2010	50,000	50,000	25,000	100%
Milford Wind Phase II	PPA/Own	2011	102,000	102,000	10,200	100%
Wind Subtotal				**957,095**	**218,420**	
DWP Built Solar	Own	1999-2012	2,100	2,100	567	100%
Solar CNM (SB1)	Own (REC's only)	1999-2012	54,000	54,000	14,580	100%
Solar Subtotal				**56,100**	**15,147**	
Small Hydro	Own	1908-1987	208,080	208,080	134,930	100%
MWD Sepulveda	PPA	2008	8,540	8,540	8,540	100%
Castaic U3&U5 Upgrade	Own	2008-2009	30,000	30,000	30,000	100%
North Hollywood PS Power Plant	Own	2010	1,000	1,000	1,000	100%
Small Hydro Subtotal				**247,620**	**174,470**	
Hyperion Digester Gas	Own	1995	16,000	16,000	16,000	100%
Lopez Microturbine	Own	2002	1,500	1,500	1,500	100%
WM Bradley	PPA	2006	6,400	6,400	6,400	100%
Shell Energy Landfill Gas	PPA	2009	n/a	n/a	n/a	n/a
Atmos Energy Landfill Gas	PPA	2009	n/a	n/a	n/a	n/a
Toyon Power Plant	PPA	2010	3,600	3,600	3,600	100%
Shell Renewable Biomethane	PPA	2012	n/a	n/a	n/a	n/a
Biomass/Landfill Gas Subtotal				**27,500**	**27,500**	
Customer Cogenerations	PPA	1996-2000	303,000	45,000	45,000	15%
Distributed Generation Subtotal				**45,000**	**45,000**	
Total In Service Renewables & DG				**1,333,315**	**480,537**	

Notes:

[1] Table include LADWP's renewables and distributed generating sources from LADWP-owned and contracted projects. This table is based on data from the April 10, 2012 RPS Master Project List and contract sources.

[2] The full-load continuous rating of a generator unit under specified conditions as designated by the manufacturer.

[3] Maximum Plant Capability reflects water flow limits at hydro plants; or sum of each unit at renewable plants.

[4] Net Dependable Plant Capability reflects the amount of generating capability that can depend on during the peak demand hours of a day. Dependable capacity of a renewable technology plant is estimated by applying a Dependable Capacity Factor (DCF) to the plant nameplate capacity. The conservative factor is used until LADWP gains more actual amount of operating experience with renewable technologies. DCFs currently used are as follow:

- Digester Gas 1.00
- Geothermal 0.90
- Landfill Gas 1.00
- Muncipal Solid Waste Conversion 1.00
- Small Hydroelectric 1.00
- Solar Photovoltaic 0.27
- Wind 0.10 (projects with firming contracts are rated at firming levels)

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Appendix G Distributed Generation

G.1 Overview

Distributed Generation (DG) is a concept of installing and operating small-scale electric generators, typically less than 20 megawatts MW, at or near an electrical load and interconnected to the electric utility distribution system. The most common technologies used today for DG are turbines and internal combustion engines (ICEs). However, new technologies including fuel cells, microturbines, and solar PVs are now being developed. The promise of DG is to provide electricity to customers at a reduced cost and more efficiently than the traditional utility central generating plant with transmission and distribution wire losses. Other benefits that DG could potentially provide, depending on the technology, include reduced emissions, utilization of waste heat, improved power quality and reliability and deferral of transmission or distribution upgrades.

DG can be customer installed or utility installed. The benefits for customer installed DG include waste heat recovery, backup power and power quality. The benefits for utility installed DG include generation, transmission and distribution infrastructure deferral, and reduction of delivery losses.

This Appendix describes DG on the grid, ICE technologies, fuel cells, and PV technologies.

G.2 Distributed Generation on the Grid

The introduction of competition into the electric marketplace has driven the development of new electrical generation technologies. Most technologies being developed for DG applications are more costly than traditional generating resources. However, it is anticipated that, with advances in the technologies and a greater demand for DG, costs will decrease, and more systems will be installed.

As of 2010, LADWP has approximately 161 GWh of combined heat and power and 79 GWh coming from landfill or process gas that is put into the electrical grid. Most of the combined heat and power DG is made up of 20 MW or larger natural gas combustion engines. The amount of customer DG installed in the future will depend on several factors including reliability, cost of the technologies, and natural gas and electricity prices. With stable electricity prices and high natural gas prices, customer generation becomes less attractive. Additionally, as of September 1, 2012, about 6,200 LADWP customers have installed over 56 MW of solar PV energy systems with the help of LADWP's Solar Incentive Program.

LADWP has installed 3 MW of solar PV energy systems on LADWP and City of Los Angeles (City) facilities to generate clean, renewable energy for the LADWP grid. LADWP has also installed various other DG technologies for demonstration purposes to understand the operating issues and benefits associated with various equipment and to promote the development of new clean, efficient technologies.

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Tables G-1 and G-2 provide projections of Cogeneration and PV capacity and energy used in the 2012 IRP. Cogeneration forecast is from 2012 Retail Energy and Demand Forecast.

Table G-1. PROJECTED DISTRIBUTED GENERATION COGEN - CUMULATIVE

Calendar Year		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Customer generated	MW	224	232	238	243	248	252	254	256	258	261	264	267
	GWh	1,116	1,184	1,208	1,227	1,248	1,263	1,271	1,280	1,290	1,301	1,312	1,315

Table G-2. PROJECTED SOLAR PV DISTRIBUTED GENERATION - CUMULATIVE

Calendar Year		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Customer generated	MW	72	108	145	187	241	154	266	279	292	307	321	337
	GWh	94	149	210	276	358	416	437	458	479	502	526	551
Utility generated	MW	3	6	9	12	21	37	54	71	88	101	100	100
	GWh	4	8	13	19	29	52	81	111	141	167	178	177

NOTE: Solar Distributed generation includes the Solar Incentive Program (SIP), Feed in Tariff program (FiT) and Utility Built Solar (UBS)

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G.3 Internal Combustion Engines

ICEs include reciprocating engines and combustion turbines. Improvements have been seen recently in the emissions and efficiencies of reciprocating engines and combustion turbines. Combustion turbines have typically been in the multi-MW size, but recently small-scale combustion turbines, or microturbines, have been developed.

Microturbines are machines ranging in size from 28 kilowatts (kW) to 500 kW, which include a compressor, combustor, turbine, alternator, recouperator, and generator. They have the potential to be located on sites that have space limitations to produce power. The advantages of microturbines are that there are a small number of moving parts, are compact in size, are lightweight, and can utilize waste fuels.

LADWP has installed nearly 2 MW of microturbines, the first of which was located at LADWP's Main Street Center in 1999. Additional microturbines have been installed at LADWP facilities and the Lopez Canyon landfill.

G.4 Fuel Cells

A fuel cell combines hydrogen and oxygen to produce electricity through an electrochemical process. Besides electricity, fuel cells produce water and heat. If the oxygen source is air, then small amounts of NO_X may also be emitted. Fuel cells produce energy at relatively higher efficiencies and emit far fewer air pollutants than combustion technologies. Fuel-cell power plants are now becoming commercially available for use by electric power producers, industrial facilities, and large commercial buildings. Smaller systems for residential, small commercial buildings and transportation applications are expected to be commercially available in the near future. The pricing for these products is expected to become competitive due to several factors:

- A fuel cell is a fairly simple technology with reasonably priced components.
- Significant recent investments in the technology are accelerating the development of fuel cells, and costs are decreasing.
    - Integrating fuel processing and power conditioning equipment can be a significant cost with regard to fuel cells, but reductions are likely as more fuel cells are manufactured and installed.

Under a pilot project, LADWP installed a total of four 200-250 kW fuel cell power plants in various locations in Los Angeles that have provided considerable experience and data. All four fuel cell plants have accomplished the task and the fuel cells have been removed from service.

G.5 Photovoltaics

Solar energy is converted to electricity using two power technologies: PV systems and solar thermal power systems. PV systems convert sunlight directly into electricity. PV systems are

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modular, portable, highly reliable, and have low environmental impact, making them ideal for power applications of all sizes. Several large PV systems capable of powering hundreds of homes are now connected to utility grids throughout the United States. Many utilities are installing these systems on the rooftops of schools and their customers are installing them on the rooftops of their houses. LADWP has recently seen the popularity of local customer owned solar generation skyrocket due to the combination of utility paid incentives and recent federal tax law changes, as well as declining solar equipment costs.

A typical 4 kW alternating current (AC) residential rooftop solar power system produces 6,600 kW-hours per year. Presently, LADWP has installed about 1.3 MW of PV at LADWP facilities and other City facilities. LADWP incentives have supported the installation of over 51 MW on its customers' properties, as of May 1, 2012. In 2006 state legislation SB1 required all utilities to offer incentives to customers to install solar energy systems through 2016. LADWP's solar incentive program has been developed with a goal of encouraging the installation of 280 MW of customer installed solar PV systems by 2016 with a budget of $313 million over 10 years, however because of LADWP's lower electric rates, a higher incentive amount has been offered which will reduce the expected amount of customer installed solar to approximately 165MW. An additional 150MW of distributed solar is expected to be installed through a new feed-in tariff program.

The energy generation characteristics of a typical PV installation are that the output peaks around 1:00 p.m., and that 90 percent of a solar PV system's energy is produced from 10:00 a.m. to 4:00 p.m. during a typical summer day in California. Another point worth noting is that a solar PV system can be designed to coincide more closely to the system load profile by altering the module's orientation. While this will increase the energy produced during the peak load of the utility, it will result in an overall lower amount of energy produced for the day. Cloud cover also affects the energy output of a solar photovoltaic installation. The type of clouds will either raise or lower the output of the PV system. Darker rain clouds will lower PV output, but a light marine layer may actually produce more energy than the nameplate rating of the modules due to light reflecting off of the modules, back to the atmosphere, and then back to the modules. This does not happen often but does cause design issues that must be taken into account.

G.6. Combined Heat and Power (CHP) Program

Combined heat and power (CHP) systems, or also known as thermal cogeneration, simply capture and utilize excess heat generated during the production of electric power. CHP systems offer economic, environmental and reliability-related advantages compared to power generation facilities that produce only electricity. Distributed power generation systems, which are frequently located near thermal loads, are particularly well suited for CHP applications.

Currently CHP installed in the LADWP Power System consists primarily of cogeneration projects of industrial and commercial customers. This totaled to approximately 265 MWs nameplate capacity operating in the LADWP's service area. Some cogeneration projects sell excess energy to the LADWP under interconnection agreements.

Current barriers to the expansion of CHP can be attributed to:

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- Natural gas price volatility in recent years has caused uncertainty in the economic feasibility of CHP projects
- Diminishing industrial customer base in recent years has reduced CHP developable potential
- Reliability and economic issues made small systems infeasible
- Added cost from utility replacement reserve requirements
- Uncertain Green House Gas emissions add costs to CHP electric generation
- Air quality siting restriction for new carbon-based CHP electric generation

LADWP is developing CHP target goals to incorporate CHP generation in its future resource mix. LADWP is currently considering development of the following self-owned CHP projects:

- Terminal Island Renewable Energy Project is a fuel cell plant to produce 4 MW of electricity and process heat using methane gas
- Los Angeles Bureau of Sanitation Alternative Technologies Projects to convert waste to heat

To encourage customer-developed CHP, shift demand from electric grid, and provide accurate price signals to customers, LADWP is currently offering a Standard Energy Credit (SEC) to its customers for excess energy they sell to LADWP. The SEC is based on LADWP marginal generation cost, and is updated and posted monthly. In the future, for renewable CHP, LADWP will provide a renewable premium based on the energy market plus the SEC. For non-renewable CHP, LADWP will continue to purchase CHP excess energy at the SEC.

Current Net Metering Incentives offered to customers require

- Customer must purchase electric services from LADWP to be eligible for interconnection
- Customer submits completed Standard Offer Agreement for interconnection and qualification for the CG Rate
- Customers pay for all costs associated with time-of-use metering, interconnection, and safe grid-parallel operation of the generation facilities
- For cogeneration facilities greater than one megawatt, the customer is required to install remote monitoring equipment for LADWP
- Customer maintains adequate insurance on generating facilities
- Excess power reimbursements are made to the customer at end of billing period at the CG Rate
- The interconnection agreement has a three year term and requires approval by the General Manager initially and for renewal and extension

Inclusion of the CHP goals under the IRP process will help communicate CHP program information and facilitate stakeholder feedback

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Appendix H Fuel Procurement Issues

H.1 Overview

This Appendix presents issues and strategies related to LADWP procurement of both natural gas and coal.

H.2 Natural Gas

LADWP generates about 22 percent of energy from natural gas-fired generation. Or, in other words, almost one-fourth of LADWP's energy generation is exposed to the risks of gas price volatility. This percentage will increase in the future as coal is removed from LADWP's resource portfolio, and with the integration of additional variable energy resources. Figure H-1 below graphically illustrates the daily natural gas spot market price (including delivery charges to LADWP's gas plants) and the large price fluctuations from the year 2002 to 2006.

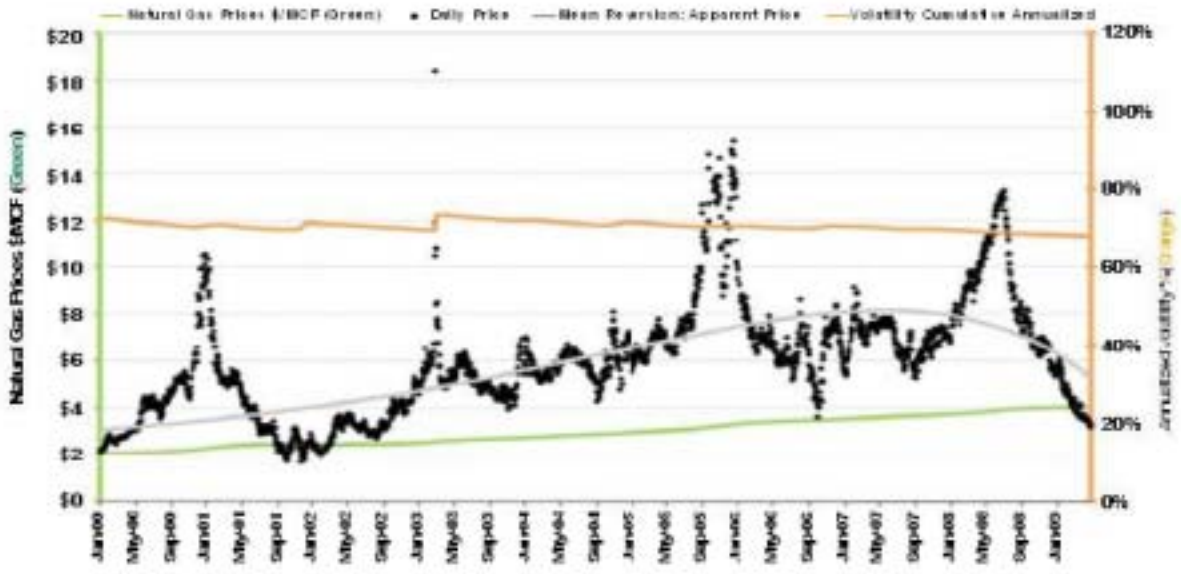

Figure H- 1. Natural gas daily spot prices.

As is shown on Figure H-1, the natural gas market has been very volatile with extreme variations of prices. Since gas currently plays such an important role in LADWP's generation portfolio, it is paramount that the impact of gas price volatility to the resource plan be mitigated.

To minimize LADWP's exposure to natural gas price volatility, LADWP has implemented a variety of actions since the 2000 IRP, which include:

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1. Created a financial risk management program to mitigate natural gas price spikes and a comprehensive gas procurement strategy to support renewable generation and long term financial goals.
2. Established executive controls over energy risk management and natural gas hedging activities by creating an Executive Risk Policy Committee to provide clearance for all major hedging decisions.
3. Established a Fuels and Risk Advisory Working Group to examine forecasting methodologies, term hedging strategies and other items of importance to fuel procurement.
4. LADWP obtained approval from the Los Angeles City Council to delegate its award authority to LADWP's General Manager for approving limited term and price gas procurement contracts. LADWP also approved pro forma NAESB (North American Energy Standards Board) contracts for use in procuring natural gas. Additional authority was obtained for procurement of up to 10-year strips of biogas.
5. LADWP has participated with SCPPA in purchasing an active gas reserve in the Pinedale anticline area of Wyoming. This reserve is currently producing for SCPPA over 50,000 million British thermal units (MMBtu)/day, of which LADWP receives approximately 83 percent of the project.
6. LADWP has also replaced approximately 1,100 megawatts (MW) of electrical generation with combined cycle technology. This technology is much more efficient in generating electricity than the generating units that were replaced, resulting in a 30 percent to 40 percent decreased usage of natural gas to generate the same amount of electricity.
7. As a result of implementing the greater use of renewable energy, LADWP's usage of natural gas and coal will be reduced considerably. A general discussion on natural gas pricing issues is provided in the following subsections.

H.2.1 Natural Gas Pricing Issues

Gas delivered to the burnertip for electric generation in California is comprised of three elements: 1) commodity costs; 2) interstate transportation; and 3) intrastate transportation. Other concerns include regulatory/legal issues, gas price volatility, support for renewables and gas supply issues.

Commodity Costs

Natural gas for electric generation is produced primarily outside California in areas known as basins, such as the Green River Basin near Opal, Wyoming; the San Juan Basin near San Juan, New Mexico; and the Permian Basin in west Texas. Gas produced from individual wells is gathered by small pipeline systems and delivered into a gas plant that processes the raw gas into pipeline quality gas for delivery to markets. Prior to the 1980s, this pipeline gas was sold as a bundled product by various interstate pipelines to distribution companies in the individual states, such as the Southern California Gas Company (SoCal) and the Pacific Gas & Electric Company (PG&E). Eventually interstate gas rates were restructured so that interstate pipelines became

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transport-only businesses with the gas marketing function spun off to the market via unregulated affiliates or independent marketers.

Intensified exploration in non-traditional producing areas of the country, chiefly the so-called shale gas, has produced a surplus of gas, which has pressured prices lower recently and will continue to do so in the foreseeable future. The development of Liquefied Natural Gas (LNG) import terminals in the United States has been delayed by a number of factors, including regulatory requirements, environmental issues, safety concerns, and economic uncertainty. Development of resources known to exist in the United States offshore continental shelf, especially in view of the blowout of a deep underwater well near the coast of Louisiana, continues to experience similar issues. In light of the burgeoning supply of shale gas some LNG import terminals have applied to the FERC to convert to export terminals.

Interstate Transportation

The interstate pipeline companies that formally sold bundled gas along with their transportation services have now focused primarily on the transportation of gas from producing basins to interconnections with the individual state's local distribution companies. The jurisdiction for the regulation of these companies falls under the authority of the Federal Energy Regulatory Commission (FERC). California is currently served by seven interstate pipelines although only four are actually directly connected to supply basins. The other three redistribute gas from other interstates. Volatility in gas prices into California has arisen because of various supply-related issues, variations in liquidity stemming from fewer suppliers in the aftermath of the market adjustment following 2000-2001, financial trading of commodities by funds, and weather-related events throughout the country. Limited price discovery has also added an element of uncertainty in gas transactions. Additional pipeline capacity to California is readily available through expansions of existing pipelines and interruptible capacity. LADWP has firm capacity on the Kern River pipeline approximately equal to its forecasted average gas requirement although there is a certain amount of uncertainty in this forecast depending upon the degree of implementation of renewables.

Intrastate Transportation

SoCal is the sole provider of intrastate gas transportation services in Southern California. These services consist primarily of delivering gas from the interconnections with interstate pipelines near the California border, but also include storage, balancing, wheeling, parking, and loaning of gas. Ever since May 1988, SoCal has been relieved of its obligation to serve the so-called non core customers, those who are able to make their own arrangements for procuring their own gas. All electric generators such as LADWP are deemed non-core or transport-only customers. The rate charged by SoCal for this transportation only service is regulated by the California Public Utilities Commission (CPUC). This rate is the lowest for any customer class (outside of any special negotiated rate) because it provides the minimum service and provides as close to cost-of-service pricing as possible. LADWP's active participation in SoCal's rate cases at the CPUC was instrumental in achieving this distinction.

Additional services relating to the delivery of gas are available from SoCal, but the rates are subject to negotiation and, usually, CPUC approval. Generally speaking, these services are of more value to marketers than to municipal generators, but in any case add to the cost of delivered gas.

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One issue that has emerged from the recent price volatility in Southern California is whether or not SoCal has the ability to accept all the gas that will be filling the expanded interstates over the next few years. The CPUC has addressed this issue in a recent proceeding into the adequacy of SoCal's system to serve the expected load on its system. So far no conclusions can be made but SoCal is confident that they have the problem in hand because of their recent completion of various system upgrades increasing takeaway capacity by approximately 21 percent. SoCal has been able to settle rate allocation issues to allow its intrastate transmission system to accommodate the delivery of LNG Gas supplies into its system. In addition SoCal is planning system upgrades to provide more reliability in the southern part of their system which should increase overall system reliability. SoCal has also announced its intention to improve reliability with a Pipeline Safety Enhancement Program which will, among other things, replace significant portions of older transmission lines.

Regulatory/Legal Issues

Several issues at the CPUC and FERC also impact pricing. SoCal revised its rates on October 2008 to accommodate the delivery of LNG into California, through the implementation of what is known as the Firm Access Rights (FAR) decision, now termed Basic Transportation Service or BTS. Implementation of BTS has affected the role of transportation pricing and the distribution of receipt point allocations for deliveries into the California market. The BTS program has been renewed for another three years. The Department has obtained BTS rights that match with its firm Kern River Interstate capacity. Another issue regarding the SoCal system, is the Wobbe Index. The Wobbe Index relates to the energy content of the natural gas delivered into SoCal's system which affects operating characteristics of gas turbines and emissions levels. The Wobbe Index has risen to prominence due to environmental concerns which may substantially affect SoCal's service to electric generators. The CPUC has already allowed SoCal to set sufficiently high limits on the Wobbe Index for gas coming into its system. This will chiefly benefit LNG sourced gas although there is a challenge being mounted by the South Coast Air Quality Management District (SCAQMD). The SCAQMD has adopted a new rule, Rule 1333, which proposes to monitor the effects of any increase in the Wobbe Index and could be interpreted as an attempt to regulate the distribution of natural gas. It is anticipated that the CPUC will oppose this initiative, and at this point in time, SoCal has filed a lawsuit to set aside Rule 1333.

The FERC has approved new tariff sheets for the Kern River pipeline in which LADWP has a substantial interest. Kern River had applied for a significant rate increase, but lost after a long proceeding at the FERC. The rate case was settled by most of the interested parties and refunds were distributed. The Department is in the process of seeking approval of restated transportation contracts to reflect the newly approved tariffs which will make the Department's contracts consistent with the contracts of all the other Kern River shippers and insure rollover rights when the contracts eventually expire.

Gas Price Volatility

During the winter 2000-2001 gas prices were highly volatile. This was somewhat repeated in milder form briefly in early 2003 and the second half of 2005. For the most part, extreme volatility has subsided with prices remaining at substantially lower levels than in previous years due to the recession. Forward pricing indicates that gas prices will move relatively sideways with a slight bias

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upward, in part due to the competing effects of the economy and increased supplies of shale gas. The industry has endeavored to reduce volatility through a massive effort of injecting gas into storage for winter use, thereby eliminating the perception of a huge overhang of expected gas purchases during the winter heating season. Due to the abundance of shale gas production, storage levels at the end of the injection season have typically reached record levels.

Gas Supply Issues

- New drilling techniques make it possible to extract natural gas from deep shale rock formations. The advances mean the United States has more abundant natural gas resources than previously believed. Gas advocates say it could significantly alter the future U.S. energy market.
- Horizontal drilling ($1.06-$1.34 /thousand cubic feet (Mcf)) vs. vertical drilling ($1.71 Mcf): horizontal wells open up much larger area of the resource-bearing formation.
- Hydraulic Fracturing (or fracking): Injecting a mixture of water and sand at high pressure to create multiple fractures throughout the rock, liberating trapped gas. Environmental issues have become more prominent.
- Combination of the Horizontal drilling and fracking.
- With more drilling experience, U.S natural gas reserves are likely to rise dramatically in the next few years. At current level of demand, U.S. has about 90 years of proven and potential supply.
- Preliminary estimates suggest that shale gas resources around the world could be equivalent to or even greater than current proven natural gas reserves.

H.2.2 Natural Gas Procurement Strategy

LADWP retained the services of PriceWaterhouse Coopers (PwC) in 2003 to assess, validate, and verify LADWP's current gas procurement strategy. Their report assessed the current strategy, suggested changes and enhancements to that strategy, and prepared a preliminary plan and timetable for implementing the changes.

As a result of PwC's review of gas operations, LADWP decided to adopt a program of protecting its gas costs from price volatility through financial hedging. The appropriate authority was sought and received by the City Council to employ financial hedges for up to ten years and physical hedges for up to five years, and to limit spending for this effort to no more than $15 million per year.

In addition, an Executive Risk Policy Committee was formed with senior management as members to provide oversight over the energy risk management activities of LADWP, including natural gas. Several actions have taken place.

First, LADWP's Financial Services Organization (FSO) negotiated individual ISDA (International Swaps and Derivatives Association) agreements with potential counterparties for the swaps to

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hedge gas prices. Fiscal Year 03-04 was the first complete year for using financial hedging to cap gas prices over a portion of forecasted gas requirements.

Second, LADWP obtained approval of two ordinances from the Council authorizing the Board of Water and Power Commissioners to delegate its award authority to the General Manager for approving gas procurement contracts. Subsequently the Board approved two separate pro forma NAESB (North American Energy Standards Board) contracts for use in procuring natural gas for up to one year, and for up to five years in duration. A number of the one-year NAESB agreements are now being used to buy gas. Five year strips of gas for physical risk management purposes were completed in late 2008 using the 5-Year NAESB authority. In addition, in mid 2009 the 5-Yr NAESB was used to obtain strips of biogas which contributes to the LADWP's Renewable Portfolio Standard goal. Additional hedging with natural gas is on hold due to the reduced gas usage and current hedge status limit set by the City Charter.

Third, LADWP participated through SCPPA in a Request for Proposal (RFP) process soliciting proposals for a term supply of natural gas for 30 years for up to an average of 27,500 MMBtu/Day with a discount to index. The agreements were negotiated but the deal was never completed because difficulties with the economy greatly reduced the anticipated discount offered under the prepay.

Fourth, LADWP has participated with the SCPPA in purchasing an active gas reserve in the Pinedale anticline area of Wyoming. Savings from this purchase have totaled approximately $52,000,000 for the six and a half years of ownership. Further production is indicated by virtue of the fact that neighboring production has been approved for drilling on 10-acre spacing, up from the current 20-acre spacing, by the Wyoming Division of Oil, Gas and Conservation. Other production adjacent to the SCPPA properties has already shown promise although development depends upon a number of environmental challenges.

PwC noted that LADWP's previous gas procurement strategy was highly dependent on spot market purchases and lacked the flexibility necessary to appropriately manage the price risk involved in gas buying, trading, and transportation activities. They argued at the time that price risk was a critical issue because gas was playing an increasingly important role in LADWP's future due to increased reliance on natural gas-fired generation. (Note that the 2030 IRP had recommended repowering four natural gas-fired generating stations and adding six gas-fired simple cycle combustion turbines to make up for a sale of a portion of LADWP's interest in the coal-fired Mohave plant, to replace units that were over 40 years old, and to meet anticipated load growth). Additionally, the increased use of renewables, such as wind and solar projects, may require higher levels of reserve margins because of their variable and intermittent nature, with the higher reserve margins being provided by gas-fired generation. Also, gas price volatility and constraints on the SoCal intrastate transportation system required LADWP to place more importance on gas supply management.

Of major significance, the Department has sought a minor change in its hedging authority to allow it to purchase up to 10 year supplies of biogas only. Using this authority the Department was able to purchase a maximum of 10,000 MMBtu/day of landfill gas from Shell Energy North America. This amount accounts for about 2% of the Department's committed goal of achieving 33 % renewables by 2020.

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Implementation Actions

LADWP has adopted strategies to reduce exposure to daily gas price swings, by the use of monthly spot purchases, implementation of index based financial swaps, physical term purchases, and ownership of gas reserves. Monthly spot purchases lock in first of the month indexes and reducing the volumes subject to floating daily prices. The reserve acquisition will reduce overall costs through amortization of the purchase price for the reserve. Additional administrative procedures were put in place to further strengthen deal tracking and audit trails.

An important initiative was put into play to obtain delegated authority from the City Council to allow LADWP management to execute SoCal's Master Service Contracts. This contract allows the LADWP to take advantage of additional services offered by SoCal such as storage, parking, loaning and wheeling. The initiative was completed in early 2008.

Additional Actions To Be Considered

With respect to transportation and storage options, LADWP will need to evaluate its options in view of the aggressive schedule adopted by the Board of Commissioners in meeting its goals for implementation of renewable technologies for generation and elimination of coal-fired generation. The successful completion of both these goals will significantly impact the need for natural gas generation. To this end, LADWP has begun to develop standardized methods for evaluating capacity projects. Factors to consider in evaluating options including:

- Cost of being short gas supply
- The amount of fuel carried in inventory for emergencies
- The type of fuel carried in inventory for emergencies
- Cost of alternatives
- Demand Side Management (DSM)
- Spot power purchases
- Alternative generation costs
- Service interruptions and preparation for emergency fuel supply
- Political and budget impacts
- Cost of being over-contracted for off-peak periods
- Cost of new capacity (initial capital and demand and charges)
- Value of excess capacity sold on short-term basis

These factors are applied to the contracting options that range from meeting baseload requirements to meeting peak requirements.

SoCal is LADWP's only available intrastate transportation supplier by virtue of its authorized franchise. Since SoCal provides 100 percent firm full requirements service, LADWP's transportation need is met. Storage is being developed by others. In the meantime, LADWP may participate in SoCal's auction to acquire an appropriate amount of inventory space, injection rights and withdrawal capacity on a year to year basis. Storage is most effective contiguous to load centers. However, the most geologically effective sites in the greater Los Angeles area have already been developed by SoCal Storage service. Storage is primarily useful for minor load balancing and, to some extent, hedging. Given the robustness of SoCal's distribution system in

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particular, and the interstate transportation system in general, storage is not necessary for emergency backup supply for power generation.

H.2.3 Proposed Actions

LADWP proposes to take the following actions to provide additional flexibility in implementing its natural gas procurement strategy:

- Increase the long-term natural gas hedging price cap. LADWP's authority for purchasing financial swaps for long-term natural gas is currently limited to $10.00 per MMBtu.
- Increase the short-term physical natural gas purchase price cap. LADWP's authority for purchasing short-term natural gas is currently limited to a rolling twelve months at $20.00 per MMBtu.
- Obtain delegated authority to execute SoCal's Master Services Contracts (MSC) along with the attachments for ancillary services as soon as the new MSC is published by SoCal after several regulatory proceedings have been concluded which may affect the form of MSC.
- Increase the term limitation for its short-term power purchases. LADWP's authority for purchasing short-term power is currently limited to a rolling eighteen months from date of execution. And likewise increase to eighteen months the 1-year gas NAESB contracts for short term gas purchases as has been done for electric deals.
- Seek authority to enter into long-term power purchase hedging contracts. LADWP is currently not authorized to enter into such arrangements.

In summary, LADWP has attempted to mitigate the impacts of volatile natural gas supplies and prices by acquiring a natural gas field, utilizing financial hedging contracts, and repowering over 1,000 MW of electrical generation with more efficient combined cycle technology.

H.2.4 Liquefied Natural Gas

LADWP has been carefully monitoring for years the development of LNG throughout the country, and in particular the many projects aimed at California. Generally, LADWP has been supportive of the concept but has not taken an active role in any proposed project. LADWP supports making additional supplies available to the market in California for reliability and cost reasons. This will be especially true as more states implement environmental regulations that will limit the amount of electricity produced from coal resources and shift much of the energy production to natural gas.

Currently there are no active LNG projects in California though several have been planned. Environmental issues and price containment from non-conventional shale gas have made project development a challenge. And in fact the current trend is to build or convert existing import terminals to export terminal due to the expanding production of shale gas nationwide.

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H.3 Coal Procurement Strategy for the Intermountain Generating Station

H.3.1 Intermountain Generating Station

The Intermountain Power Agency (IPA) owns the Intermountain Generating Station (IGS). LADWP receives part of the power from IGS under a power purchase agreement with IPA that currently runs through 2027. LADWP is additionally under contract with IPA to oversee the operations of IGS and is known in that role as the Operating Agent. One of LADWP's duties as the Operating Agent is to arrange for the procurement of coal or coal assets, including any transportation services needed to get the procured coal to IGS. All contracts for coal procurement or coal asset ownership are done under the name of IPA. Management approval for coal procurement or coal asset ownership is given by the Intermountain Power Project Coordinating Committee (IPPCC), which is made up of IGS power purchasers (including LADWP), and the IPA Board of Directors (which does not include LADWP). Future coal procurement and coal asset ownership and related strategic development are therefore, done at the discretion and approval of the IPPCC and IPA Board of Directors on behalf of the power purchasers and owners of IGS.

H.3.2 Coal Supply – A Role for the Operating Agent

In its role as Operating Agent, LADWP administers, on behalf of IPA, a diversified portfolio of coal supply contracts that should by design hedge IGS power purchasers against escalating coal prices. The portfolio contains a combination of long-term, mid-term, and short-term coal supply contracts, which are either market price-based, fixed price-based, or cost of production price-based.

H.3.3 Coal Portfolio

The current coal procurement portfolio mix is as follows:

Long-term fixed pricing (with contracts beyond 2013):	60 percent
Short-term market pricing (spot market purchases):	40 percent

In all, the Operating Agent procures up to six million tons of coal per year for IGS based on current capacity factors. At present, IPA has in place coal contracts which can supply all of the coal needs of IGS through 2013, with a significant portion of the coal needs beginning 2014 also already in place.

Historically, the vast majority of coal procured for IGS has come from Utah sources. The procurement of coal in the near- and far-term will likely be done in a similar manner as described above, with the percentages of the pricing methodologies in the portfolio mix being determined with pricing and security of supply in mind. While Utah coal is expected to remain a key part of the IGS coal supply for the next 20 years, Utah sources of coal are diminishing. Thus, it is prudent for to the Operating Agent (with IPPCC and IPA Board of Directors guidance and approval) to seek out sources from new Utah mines and from other Rocky Mountain States. For

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several years the Operating Agent has procured short-term contract coal from more than a half dozen sources in Colorado and Wyoming. This will have to be done to a greater extent in the future. Since travel time using IPA-owned unit-trains increases while traveling greater distances to the out-of-state sources, the Operating Agent has already made arrangements to lengthen IPA's unit-trains, obtain additional railcar capacity, and expand IPA's railcar operation and maintenance facility.

H.4 Alternative Fuels for Basin Generation

Although there will be ample supplies and delivery capacity for natural gas to power all Basin generation for the foreseeable future, there is some concern that that LADWP will become too dependent on a single fuel. As a consequence, a great deal of thought has been put into identifying potential backup supplies in the event of an emergency.

Among those considered are liquefied natural gas and ultra-low sulfur (CARB) diesel. Both fuels present unique storage, handling, operational, and/or environmental problems. Both are deemed too expensive to implement.

The greatest disaster that could possibly affect the LADWP's ability to generate electrical energy for native load would be a massive earthquake such as the Northridge Earthquake that afflicted Los Angeles in 1994. During that event, due to transmission line problems, the entire power system in Los Angeles was islanded and all available basin generation was put on line. No power was brought in from the Pacific Intertie and minimal power from Palo Verde, Navajo, Mohave or Intermountain power was available. Natural gas demand for power increased by 200,000 MMBtu/Day and was provided by a minority supplier in a timely fashion. This situation persisted for over two weeks until field crews could repair damage to transmission lines. No power plants were damaged as a result of the quake, but some were temporarily taken off line until the situation stabilized. All generation was eventually brought on line within a few hours of the quake. If the quake were much more severe, damage to the power plants' turbines would have necessitated them to be taken off line. The gas delivery system, both SoCal's distribution system as well as the interstate transmission systems, were not harmed by the Northridge quake. Characteristically, gas pipelines are imbedded in sand-filled trenches that allow the pipes to move about when the earth shifts, thereby reducing the possibility of breaking. Major transmission lines bring gas from the East and cross the San Andreas Fault, which move all the time, but rarely cause delivery outages. Thus it would appear that the gas delivery infrastructure is more robust than the power plants that depend on it.

We can conclude from this that although it might seem desirable to maintain some type of backup supply of fuel for in-Basin power plants, the existing natural gas supply system is likely both adequate and reliable enough to withstand a major disruption event.

However as a matter of prudent management of electric operations, the issue of backup fuel supplies or some other accommodation is being actively studied by the Fuels and Risk Advisory Working Group.

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Appendix I Transmission System

I.1 Transmission Resources

LADWP is one of only a handful of electric utilities that own and operate a system with both alternating current (AC) and direct current (DC) transmission lines. The typical utility is exclusively an AC system with a shorter geographical reach than the LADWP network. LADWP employs its DC lines to import bulk power across state lines from markets and plants in Utah/Wyoming, Washington and Oregon. To lower transmission losses, AC/DC conversion equipment is utilized to interconnect its long distance DC lines with the AC system. Table I-1 lists LADWP's transmission resources.

Table I-1. BREAKDOWN OF TRANSMISSION RESOURCES

Voltage Class	AC/DC	Circuit-Miles
Out-of-Basin		
±500kV	DC	1,068
500kV	AC	1,069
345kV	AC	189
287kV	AC	350
230kV	AC	353
Out-of-Basin Circuit-Miles		3,029 (81%)
In-Basin		
230kV	AC	521
138kV	AC	153
115kV	AC	44
In-Basin Circuit-Miles		718 (19%)
Total Circuit-Miles		**3,747 (100%)**

As Table I-1 shows, the majority of LADWP's transmission assets are located outside of the Los Angeles Basin. Originally constructed to supply lower cost electricity to its customers and thereby maintain lower electricity rates, these assets are vitally important to LADWP's attainment of its 33% RPS goal by 2020. Excess transmission capacity is sold on a non-discriminatory basis in a wholesale market under an open-access transmission tariff largely conforming to FERC Order 890.

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A one-line diagram of the key bulk power transmission lines is shown in Figure I-1. The transmission capabilities of the different systems are summarized in Table I-2.

Table I-2. IMPORT CAPABILITY OF TRANSMISSION RESOURCES

Transmission System	Transfer Rating (MW)	LADWP Share (MW)
East-to-LA Basin	4,000	3,566
West-or-River	10,623	3,273
East-of-River	9,256	1,456[1]
Pacific DC Intertie @ NOB	2,990	1,196
Owens Valley Transmission	450	450
Intermountain	2,400	1,428

[1]As of 6/1/2012

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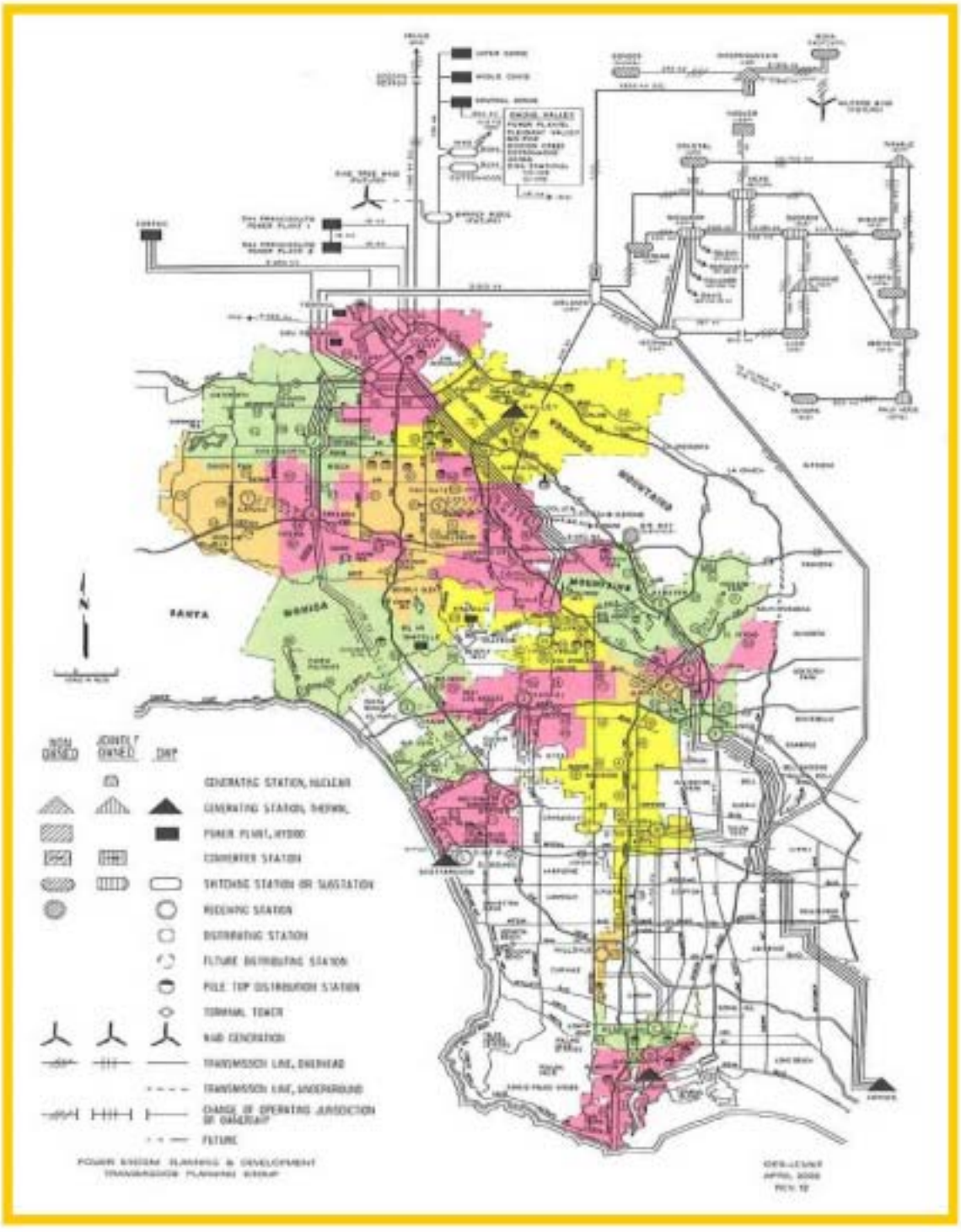

Figure I-1. LADWP Power System diagram.

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I.2 Basin Transmission System

LADWP's basin transmission network is comprised of overhead and underground lines ranging from 115kV to 230kV; 4 switching stations that tie together multiple Transmission System circuits; and 20 receiving stations that serve as gateways to the distribution system and as tie points for basin power plants.

Because LADWP serves a metropolis, system reinforcements, additions, and improvements are often challenging; construction in crowded thoroughfares inconveniences so very many people. Compounding this challenge is the very real need to invest in an aging transmission infrastructure, parts of which date back to 1916. LADWP continues to explore and exercise feasible options to increase the utility of its resources, including dynamically rating critical belt-line segments. Even so, it is clear that long-term investments must be made in the near-term. According to the Ten-Year Transmission Assessment released in November 2010, LADWP's transmission system is capable of handling expected system peak loads for the next four years when supported by approved remedial actions to address vulnerable, critical double contingencies.

Further, the annual Ten-Year Transmission Assessments have consistently identified the need to install Scattergood-Olympic – 230kV Line 1 for many years now. With each passing year, the urgency becomes more apparent so that now even remedial actions have limited benefit. For this reason, LADWP is moving forward with the installation. With construction slated to begin in 2012, the new 15-mile long Scattergood-Olympic 230kV Line 1 in the Westside should be in-service before Summer 2015. Information on this project is available at the following website: http://www.ladwp.com/ladwp/cms/ladwp013744.jsp.

I.3 East-to-LA Basin Transmission System

The East-to-LA Basin System (see Table I-3) transmits power into the Los Angeles Basin from distant resources in Utah and the Desert Southwest. The Adelanto Converter Station receives power from the Intermountain DC corridor. The Victorville Switching Station is similarly joined to the task of receiving power from the West-of-River System.

Table I-3. EAST TO LA BASIN TRANSMISSION SYSTEM

Transmission Line	Voltage Class (kV)	Transfer Limit (MW)	LADWP Ownership (%)	LADWP Scheduling (%)
Victorville-Century Lines 1&2 Victorville-Rinaldi Adelanto-Toluca Adelanto-Rinaldi	287 500 500 500	4,000	100	100

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I.4 West-of-the-River System

LADWP's West-of-River (WOR) system transmits power from the Mead/McCullough/Marketplace area to the Adelanto/Victorville area along WECC's WOR (Path 46). Path 46 facilitates transportation of electricity from the Navajo Generating Station (Page, Arizona) and the Palo Verde Generating Station (Wintersburg, Arizona) to Southern Nevada and to Southern California, respectively. Until the 1580 MW Mohave Generating Station was shut down in 2005, the Mohave-Lugo 500kV and the Mohave-Eldorado 500kV Lines primarily interconnected that station to the WECC power grid. Since 1996, LADWP has been selling available capacity in the wholesale markets via OASIS. The Palo Verde-Devers 500kV Line No. 1, of which LADWP has 368MW of bi-directional transmission service rights, and 368MW of bi-directional transmission service rights between Devers and Sylmar, is common to both the West-of-River System and the East-of-River System. Both systems are also related in that the capacity ratings are seasonally adjusted according to the Southern California Import Transmission (SCIT) Operating Nomogram.

The WOR system is summarized on Table I-4 and shown on Figure I-2.

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Table I-4. WOR TRANSMISSION SYSTEM

	Transmission Line	Voltage Class (kV)	Allocation (MW)	LADWP Entitlement (MW)
North	McCullough-Victorville Lines 1&2 Hoover-Victorville	500 287	2,592	2,592
	Marketplace-Adelanto	500	1,291	313
	Eldorado-Lugo Eldorado-Pisgah Eldorado-Cima-Pisgah Mohave-Lugo Julian Hinds-Mirage	500 230 230 500 230	2,754	0
		North Subtotal	6,637	2,905
South	Palo Verde-Devers	500	1,802	368
	Ramon-Mirage Coachella-Devers	230 230	600	0
	North Gila-Imperial Valley El Centro-Imperial Valley	500 230	1,584	0
		South Subtotal	3,986	368
		WOR Total	10,623	3,273

Figure I-2. LADWP West-of-Colorado transmission resources.

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I.5 East-of-the-River (EOR) System

LADWP's East-of-the River (EOR) system transmits power from the north-central and central areas of Arizona to the McCullough/Marketplace/Mead area along the WECC EOR (Path 49). Path 49 facilitates transportation of electricity from Navajo Generating Station (Page, Arizona) and Palo Verde Generating Station (Wintersburg, Arizona) to Southern Nevada and to Southern California, respectively. The Palo Verde-Devers 500kV Line No. 1, of which LADWP has 368MW of bi-directional transmission service rights, and 368MW of bi-directional transmission service rights between Devers and Sylmar, is common to both the West-of-River System and the East-of-River System. Both systems are also related in that the capacity ratings are seasonally adjusted according to the Southern California Import Transmission (SCIT) Operating Nomogram.

The EOR system is summarized on table I-5 and shown on Figure I-3.

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Table I-5. EOR TRANSMISSION SYSTEM

Transmission Line	Voltage Class (kV)	Allocation (MW)	LADWP Entitlement (MW)
Navajo-Crystal	500	9,256, east to west non-simultaneous	1,456
Moenkopi-Eldorado	500		
Liberty-Peacock-Mead	345		
Palo Verde-Devers	500		
Hassayampa-North Gila	500		
Perkins-Mead	500		

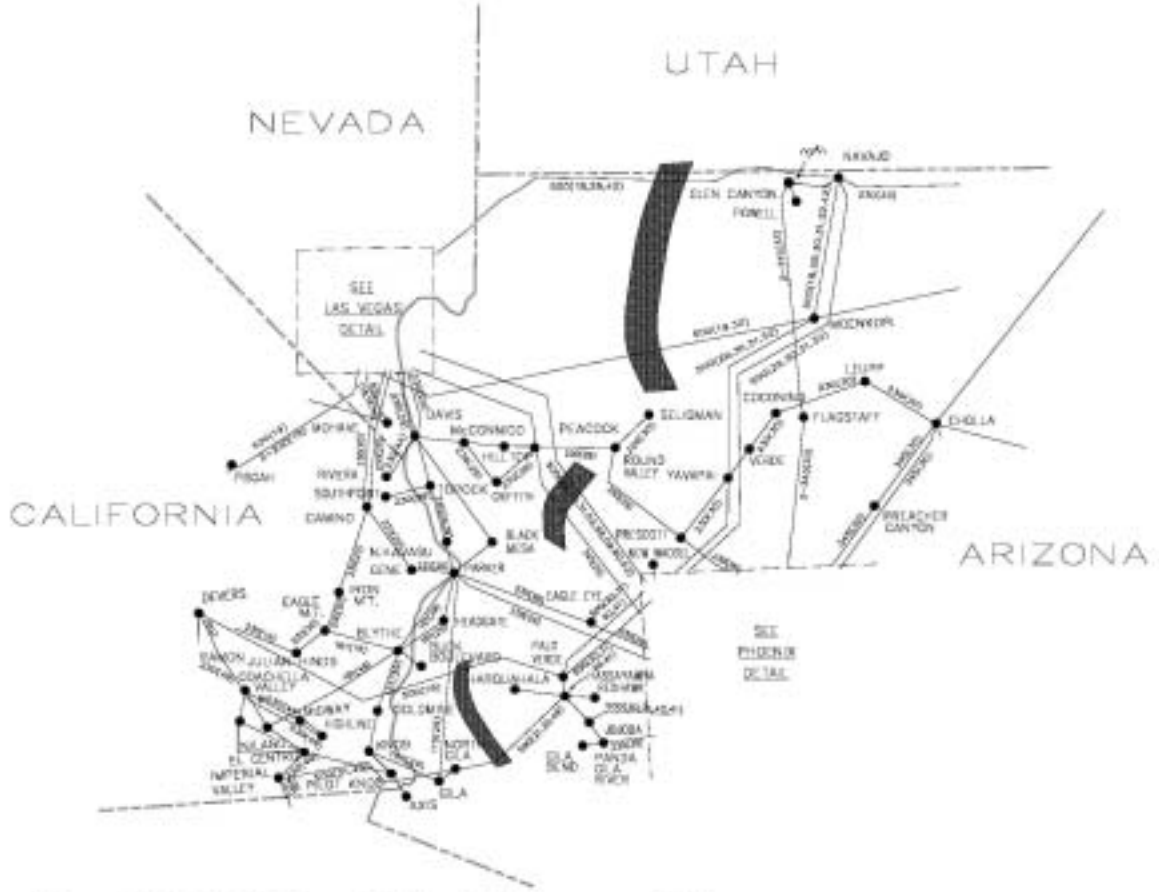

Figure I-3. LADWP East-of-Colorado River transmission resources.

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I.6 Owens Valley Transmission Line

Essentially a segmented single line, the Owens Valley System is becoming increasingly important as a corridor to import renewable resources that support LADWP's RPS goals. Developers have proposed interconnecting renewable resource projects totaling more than 2950MW. These projects have been placed in the interconnection queue but require the construction of LADWP's Barren Ridge Renewable Transmission Project, described in Section 2.4.8 of this IRP.

The Owens Valley transmission system is summarized on Table I-6 and shown on Figure I-4.

Table I-6: Owens Valley Transmission System

Transmission Line	Voltage Class (kV)	Approximated Allocation (MW)	LADWP Expiration	LADWP Entitlement (MW)
Owens Gorge-Inyo Inyo-Cottonwood Cottonwood-Barren Ridge Barren Ridge-Rinaldi	230 230 230 230	450[1]	Owned Asset	450

[1] The normal rating of the line is 459 MVA,

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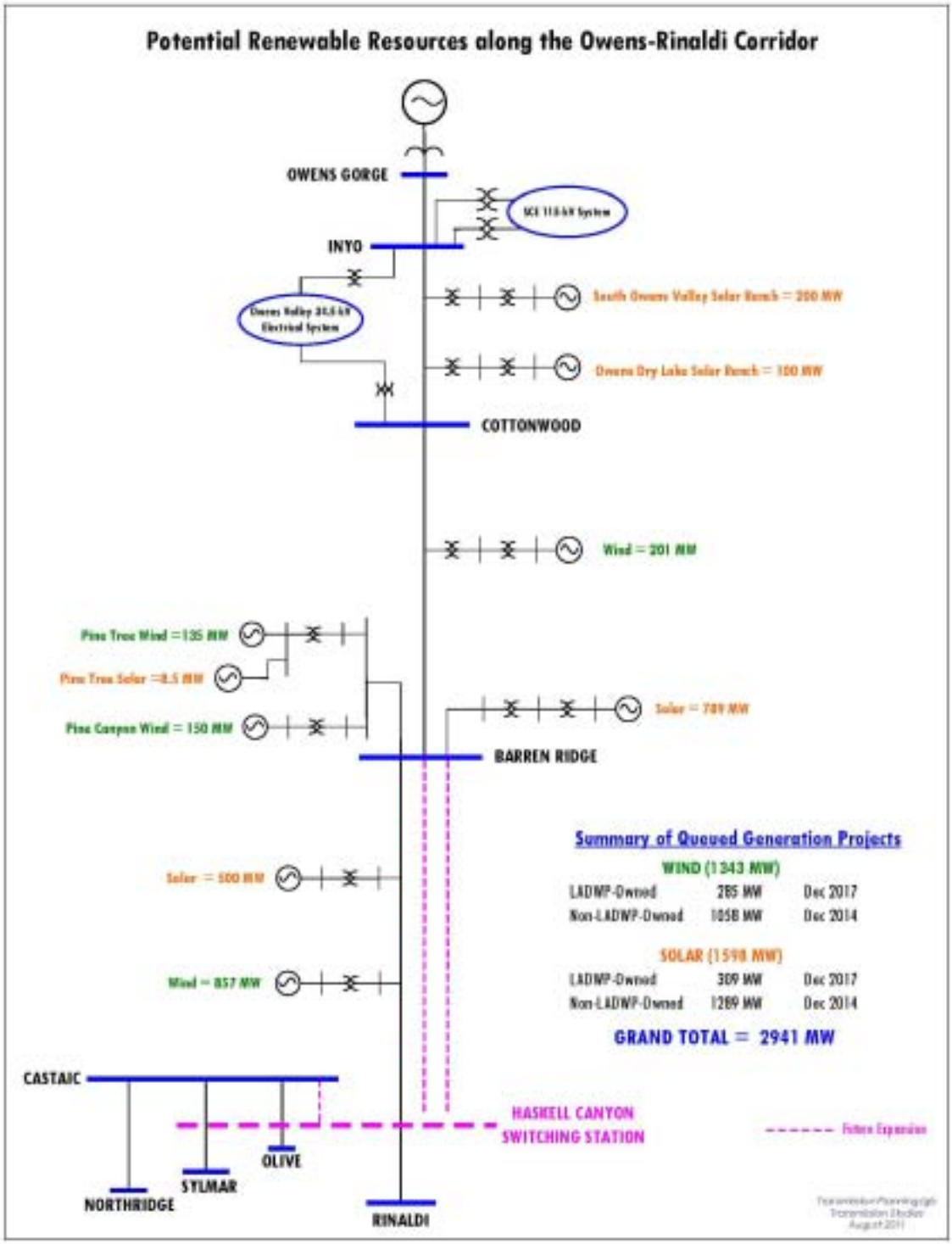

Figure I-4. Owens Valley transmission resources.

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I.7 Intermountain System

The Intermountain System is comprised of three WECC paths operated by LADWP on behalf of the Intermountain Power Authority:

- WECC Path 27, the 488-mile Intermountain Power Project DC Line, was upgraded from 1920MW to 2400MW in May 2011. The increased capacity has been accommodating transmission of wind energy from Utah (see Table I-7 and Figure I-5).
- WECC Path 28, the 50-mile Intermountain-Mona 345kV line ties Pacificorp to LADWP's Balancing Authority Area (see Table I-8 and Figure I-6).
- WECC Path 29, the 144-mile Intermountain-Gonder 230kV line ties NV Energy to LADWP's Balancing Authority Area (see Table I-9 and Figure I-7).

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Table I-7. WECC PATH 27

Transmission Line	Allocation (MW)	LADWP Expiration	LADWP Share (%)	LADWP Scheduling (%)
Intermountain-Adelanto Adelanto-Intermountain	2400 1400	15Jun2027	59.5	59.5

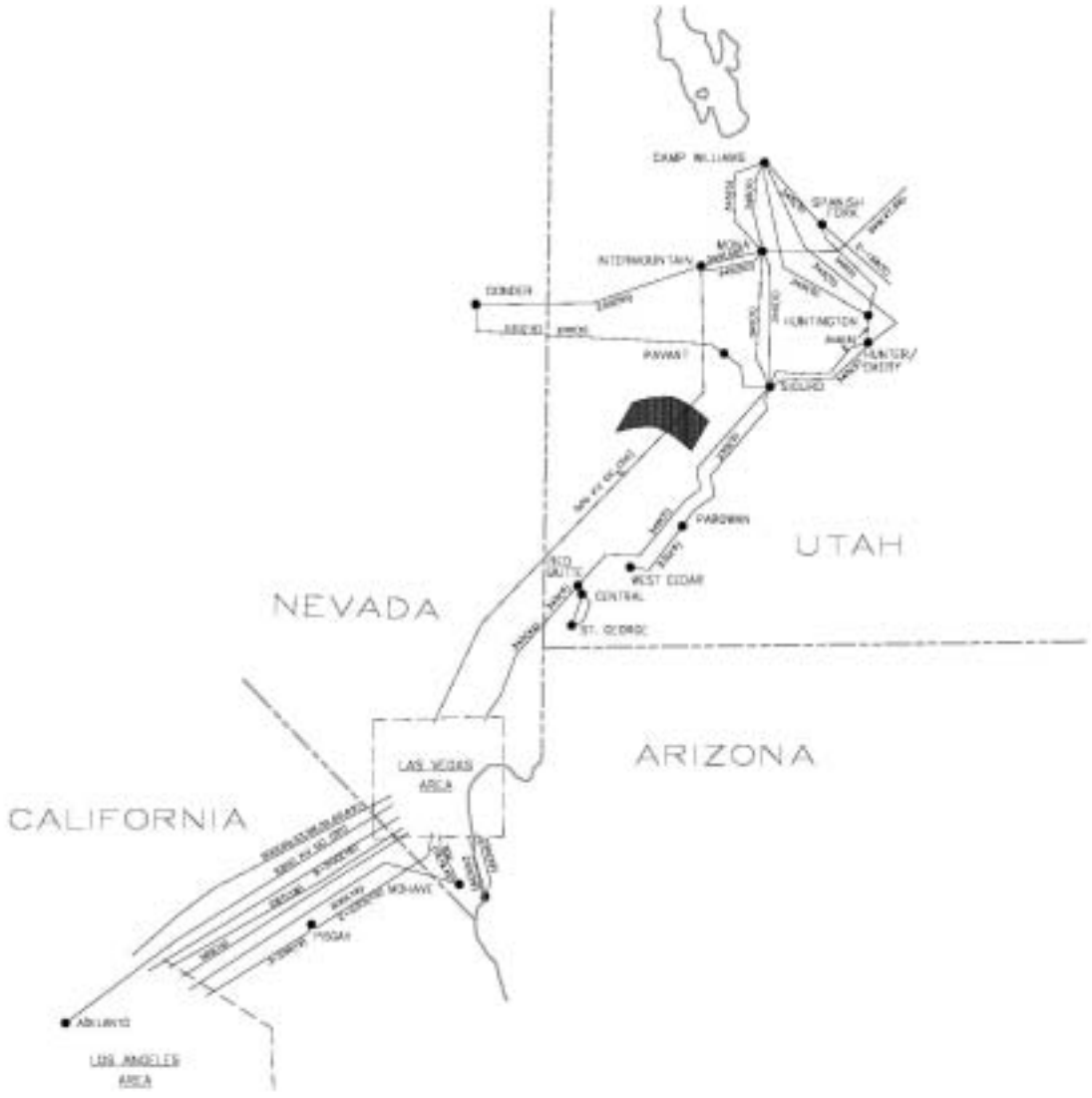

Figure I-5. WECC Path 27.

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Table I-8: WECC PATH 28

Transmission Line	Allocation (MW)	LADWP Expiration	LADWP Share (%)	LADWP Entitlement (MW)
Intermountain-Mona Mona-Intermountain	1200 1400	n/a	0	0

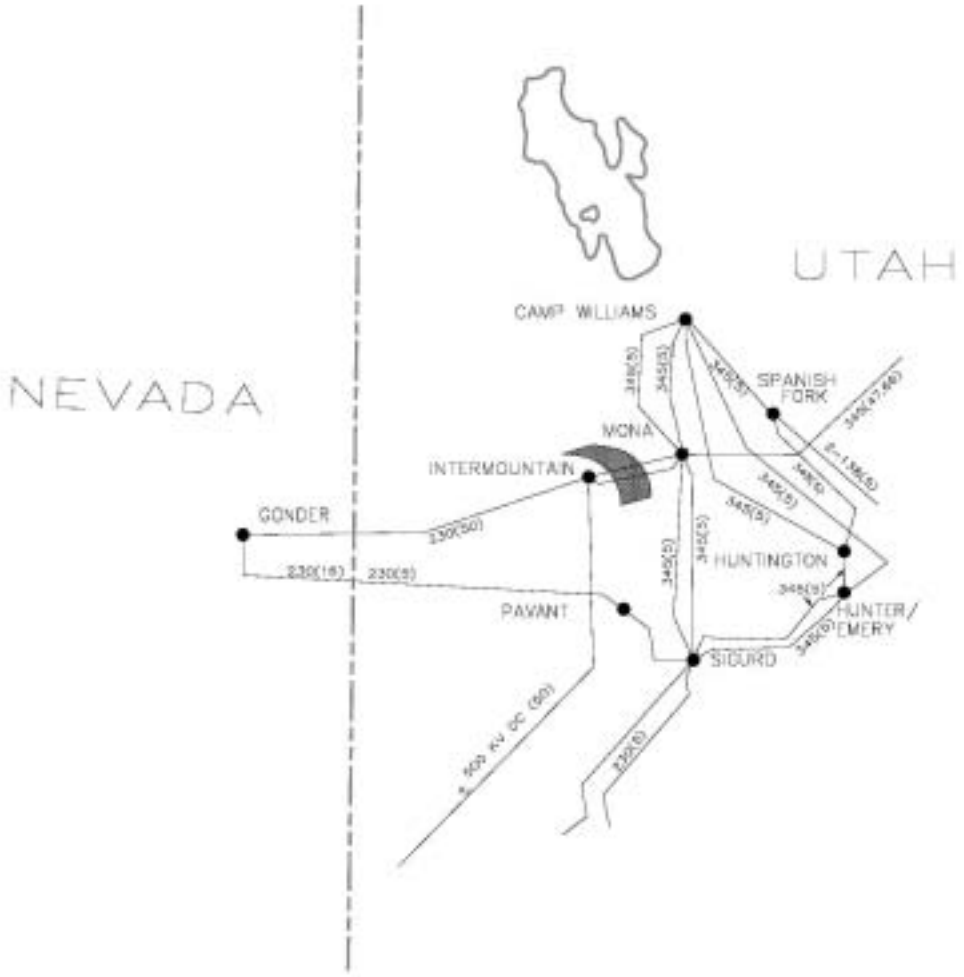

Figure I-6. WECC Path 28.

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Table I-9: WECC PATH 29

Transmission Line	Allocation (MW)	LADWP Expiration	LADWP Share (%)	LADWP Entitlement (MW)
Intermountain-Gonder	200 non-simultaneous bi-directional	n/a	0	0

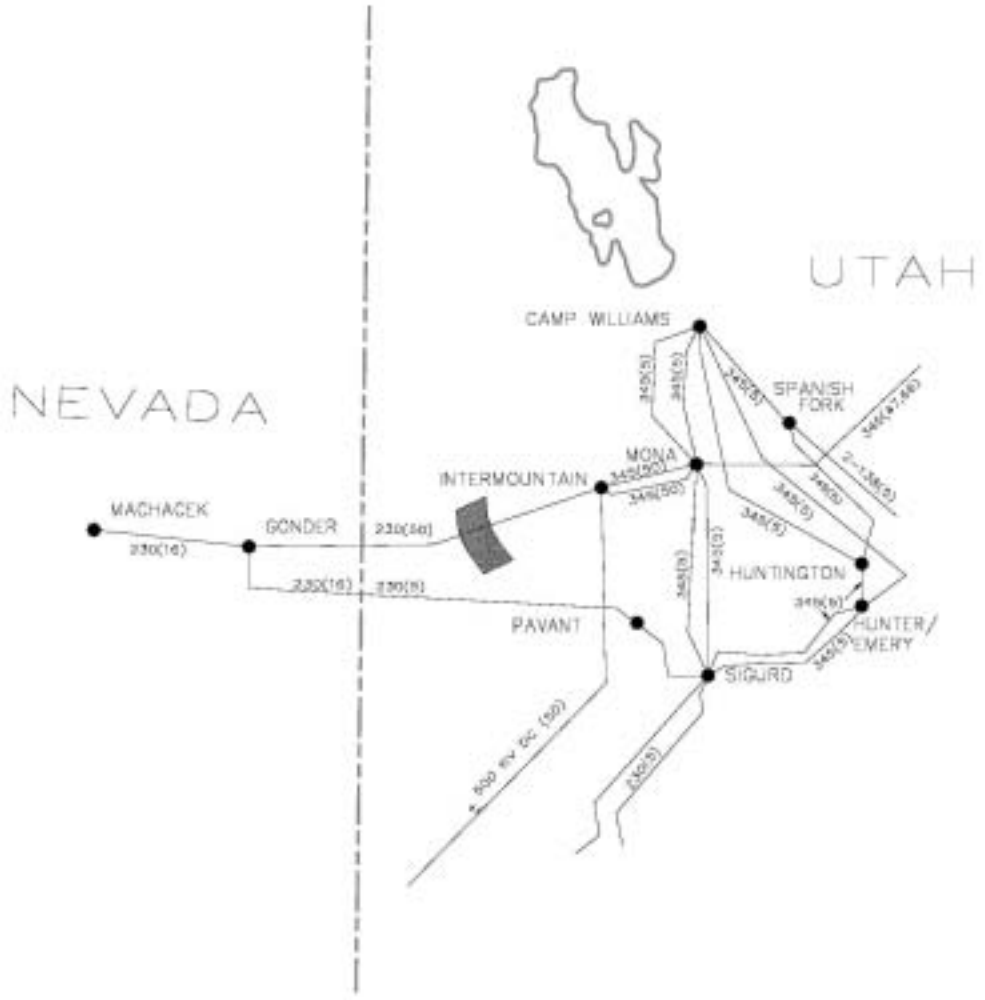

Figure I-7. WECC Path 29.

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I.8 Pacific DC Intertie System

Also known as WECC Path 65, the Pacific DC Intertie is a ±500kV DC line stretching from the Pacific Northwest to the Los Angeles Basin. This corridor provides the means for LADWP to import wind energy and hydroelectricity created from spring runoffs. For the Pacific Northwest, it provides access to low cost generation resources during cold winter months. As described in 2.4.8 of this IRP, research into the various technological options to increase the capacity of the Pacific DC Intertie is being conducted.

Table I-10. WECC PATH 65

Transmission Line	Voltage Class (kV)	Allocation (MW)	LADWP Ownership (%)	LADWP Scheduling (%)
Sylmar-Celilo	+/- 500 kV DC	3100, both directions	40	40

Figure I-8. WECC Path 65.

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I.9 Interconnections with Other Utilities

A number of utilities interconnect with LADWP's transmission system. The tie points are listed in Table I-11.

Table I-11. TRANSMISSION TIE POINTS WITH OTHER UTILITIES

Utility	Regional Transmission Organization	Location	Voltage Class (kV)
Arizona Public Service	--	Marketplace Switching Station	500
Bonneville Power Administration	--	Pacific DC Intertie @ North of Oregon Border	500
City of Anaheim	California ISO	Marketplace Switching Station	500
City of Azusa	California ISO	Marketplace Switching Station	500
City of Banning	California ISO	Marketplace Switching Station	500
City of Burbank	--	Marketplace Switching Station Toluca Receiving Station	500 69
City of Colton	California ISO	Marketplace Switching Station	500
City of Glendale	--	Marketplace Switching Station Airway Receiving Station	500 230
City of Pasadena	California ISO	Marketplace Switching Station St. John Receiving Station (emergency)	500 34.5
Cities of Modesto Redding Santa Clara	California ISO	Marketplace Switching Station	500
City of Riverside	California ISO	Marketplace Switching Station	500
City of Vernon	California ISO	Marketplace Switching Station	500
Intermountain Power Agency	--	Adelanto Switching Station, after 15Jun2027	500
NV Energy	--	McCullough Switching Station Gonder, until 15Jun2027	500 and 230 230
Pacificorp	--	Mona, until 15Jun2027	345
Salt River Project	--	Marketplace Switching Station	500
Southern California Edison	California ISO	Eldorado Substation Victorville-Lugo midpoint Velasco Receiving Station-Laguna Bell (emergency) Sylmar Switching Station Inyo Substation Haiwee (emergency)	500 500 230 220 115 115
Western Area Power Administration	--	Marketplace Switching Station McCullough Switching Station Mead Substation	500 500 and 230 287

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Appendix J Integration of Intermittent Energy From Renewable Resources

J.1 General Integration Principles

One of the main responsibilities of power system operators is to maintain the balance between the total aggregate electrical demand of the system's customers and the amount of energy generated to meet that demand on an instantaneous basis. Conventional electrical generation technologies, such as nuclear, coal, natural gas and large hydro are controlled and dispatched by the power system operators throughout the day to maintain this instantaneous balance between demand and generation.

However, some renewable resources generate energy following the vagaries of nature in a variable and intermittent manner, and the energy from these renewable resources is generally not controlled by power system operators but received dynamically as it is produced. For example, solar resources only produce energy during daylight hours, and wind resources only produce energy when the wind is blowing. Such renewable resources are often referred to as variable and intermittent renewable generation technologies.

It is anticipated that the amounts of energy generated from solar and wind resources will be substantial and increasing over time. The percentage of solar and wind resources compared to the total capability of a utility's power system may also be defined as "percent penetration." Percent penetration can be measured either by a capacity or energy method. Either measurement method is important; since a utility may use this information to determine the maximum amount of intermittent resources that a power system can accommodate without impairing the utility's ability to reliably maintain the required instantaneous balance between demand and generation.

Because power system operators cannot control or dispatch the production of energy from most renewable resources, the remainder of the power system must be controlled and dispatched to accommodate both the changes in renewable energy production and the changes in customer demand. In general, with the addition of increasing amounts of variable and intermittent renewable generation, the conventional controllable generation resources of a power system must become more flexible in their ability to rapidly ramp up or ramp down their output in order to successfully and reliably integrate new renewable generation.

J.2 Findings of System Integration Studies

In the last several years, LADWP has been increasing its efforts to acquire renewable resources. In 2003, 3 percent of energy sold to its customers was generated from renewable energy resources. This increased substantially to 20 percent in 2010, and 33% is mandated in 2020. With the much higher percentage of renewables coming on line, a variety of modifications will need to be made to the Power System to successfully and reliably integrate these higher penetrations of renewable resources. In preparation, LADWP has conducted preliminary studies on integrating renewable resources, and has also reviewed many renewable resource integration studies published over the last several years.

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These studies have yielded some common observations and recommendations regarding the integration of intermittent renewable resources into power system generation portfolios. Some common observations of these studies include the following:

1. Larger power systems with robust transmission systems tend to have a greater ability to integrate intermittent wind and solar resources.
2. Individual wind power plants tend to have a high variability in the amount of energy produced (see Figure J-1, which illustrates the power output from the Pine Tree Wind Farm, rated at 135 MW with 90 wind turbines located over 7,100 acres).
3. Wind energy production impacts a power system's regulation (minute to minute generation variability), load following (hourly variability), and unit commitment decisions (day-ahead flexibility) (see Figure J-2, which illustrates the instantaneous generation for the Pine Tree Wind Farm for a single day).
4. Wind is usually categorized primarily as an energy resource. The dependable capacity value of a wind farm to the power system is much lower than the rated capacity of the wind turbines.
5. There is a financial cost to integrate intermittent wind and solar renewable projects into existing power systems, and this cost increases with increasing amounts of intermittent renewable resources.
6. Wind energy production patterns are not usually aligned with daily load patterns. Wind production tends to be greatest in the evenings when the daily load is near its minimum.

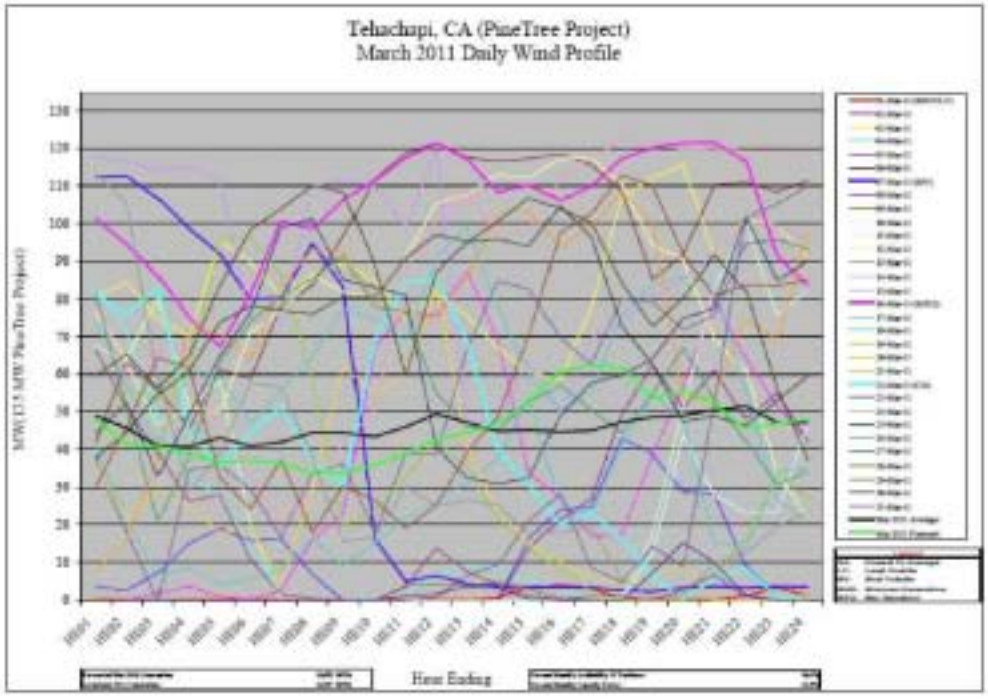

Figure J-1. Wind farm daily wind profiles.

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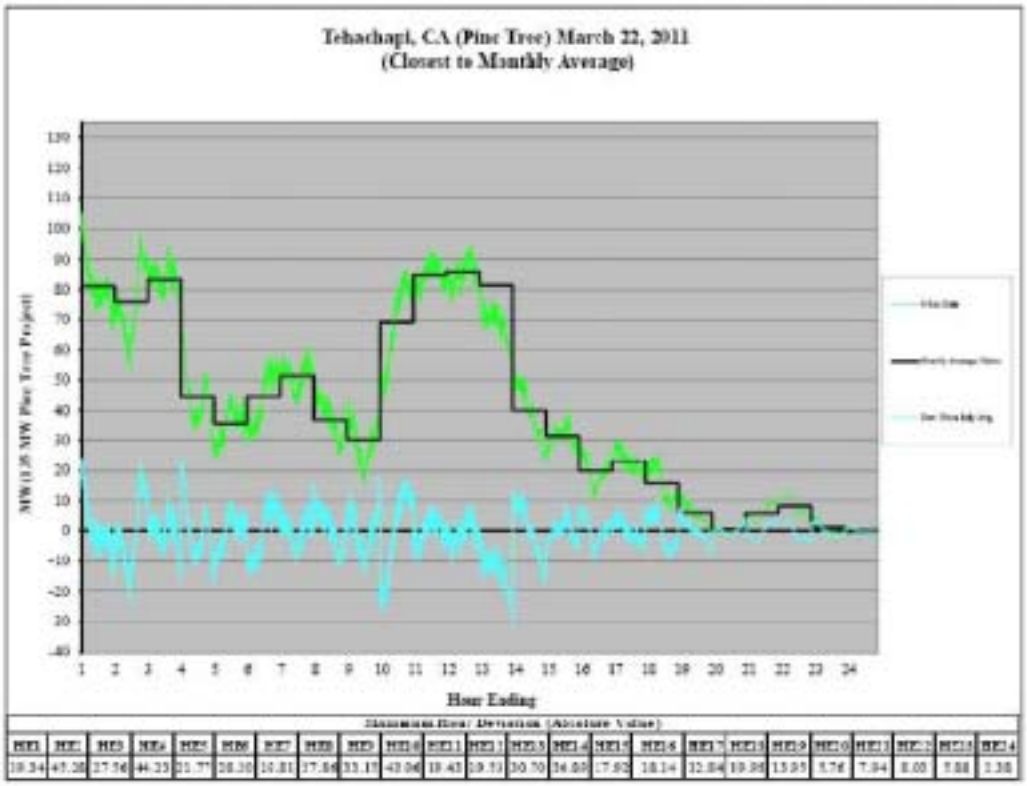

Figure J-2. Wind farm variability measured instantaneously.

7. In many cases high wind energy production during low power system energy demand hours represents the greatest challenge for power system operations.

8. Average daily and monthly wind energy production profiles are not representative of actual hourly production, due to the high variability in hourly energy production (see Figure J-1).

9. Solar energy production patterns are more closely aligned with daily load patterns than with wind energy production patterns, yet also exhibit variable and intermittent characteristics (see Figure J-3, which illustrates instantaneous output from LADWP's 10 MW Solar Photovoltaic facility located at Adelanto, California. Output tends to be smooth (about 40% of the days), or semi-volatile or volatile (about 60% of the days).

10. Energy generated from Solar PV technology is highly sensitive to cloud cover. These PV systems can experience variations in output of + 50 percent in 30 to 90 seconds, and + 70 percent in five to 10 minutes. When a single large sized PV facility experiences these rapid changes in power output, the Power System must also be able to react just as quickly with other generation resources to accommodate such rapid changes. The capabilities of a power system's dispatchable resources will limit the size of a single utility scale solar PV facility.

11. In the current energy market, the energy from renewable resource generation will tend to displace the marginal resource, which is typically natural gas. However, if future financial burdens are applied to carbon fuels such as coal, and coal becomes the marginal resource,

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then coal energy may tend to be displaced by renewable resources.

Figure J-3. Solar photovoltaic power generation days at the 10 MW Adelanto facility.

Some common recommendations from these renewable energy integration studies include the following:

1. Successful integration of intermittent renewable resources requires an investment in transmission and generation resources and cooperative operational agreements between power system operators and energy providers.
2. New generation should be able to operate flexibly, meaning it should be able to start and stop quickly and to cycle on and off many times throughout the year. It should also be able to ramp (change the amount of energy it produces) quickly and operate at low generation levels.
3. State-of-the-art forecasting, particularly for wind resources, needs to be made available to power system operators.
4. Variable generators need to have NERC reliability standard compliant features, including low-voltage ride-through, voltage control, and reactive power control.
5. Wind and solar energy production must be curtailable by power system operators if variable energy production negatively affects power system reliability. The power system operators also must have the ability to set power ramp rates for wind and solar projects if needed to ensure power system reliability.
6. Natural gas fired combustion turbines and pump-storage hydro plants are effective tools for integrating intermittent renewable resources into existing power systems. Other energy storage devices described in Appendix K may also assist in integrating intermittent renewable resources.
7. Customer demand response programs may work well in integrating intermittent renewable resources.

Further studies, planning and system modeling will be needed as additional renewable resources come on-line to maintain power system reliability.

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Appendix K Energy Storage

K.1 Overview

This Appendix provides a review of the general requirements of grid-scale energy storage systems (ESSs) and ESS technologies, followed by a copy of a February 2012 resolution by the Water and Power Board of Commissioners regarding energy storage targets, and a copy of AB 2514.

K.2 Requirements of Grid-Scale Energy Storage Systems

LADWP plans to meet its 33 percent renewable generation goal by acquiring and self-developing eligible renewable resources including wind and solar. Because wind and solar are intermittent resources by nature, integrating them into the power system is a major challenge. One method of integrating these intermittent generating resources will be large-scale ESSs. The LADWP currently has electrical storage capacity of 1175 megawatts (MW) of pumped storage at the Castaic Lake Hydroelectric Pumped Storage Plant. The ESSs used in the system should be cost effective and provide economical benefit to LADWP.

The ESS power and energy requirements vary widely with the particular grid support application (Figure K-1). Power quality applications require ESSs with high power capability and short storage capacity, while grid support systems require high power output and medium storage capability. Grid-connected renewable energy generation requires large-scale energy storage and large power capability.

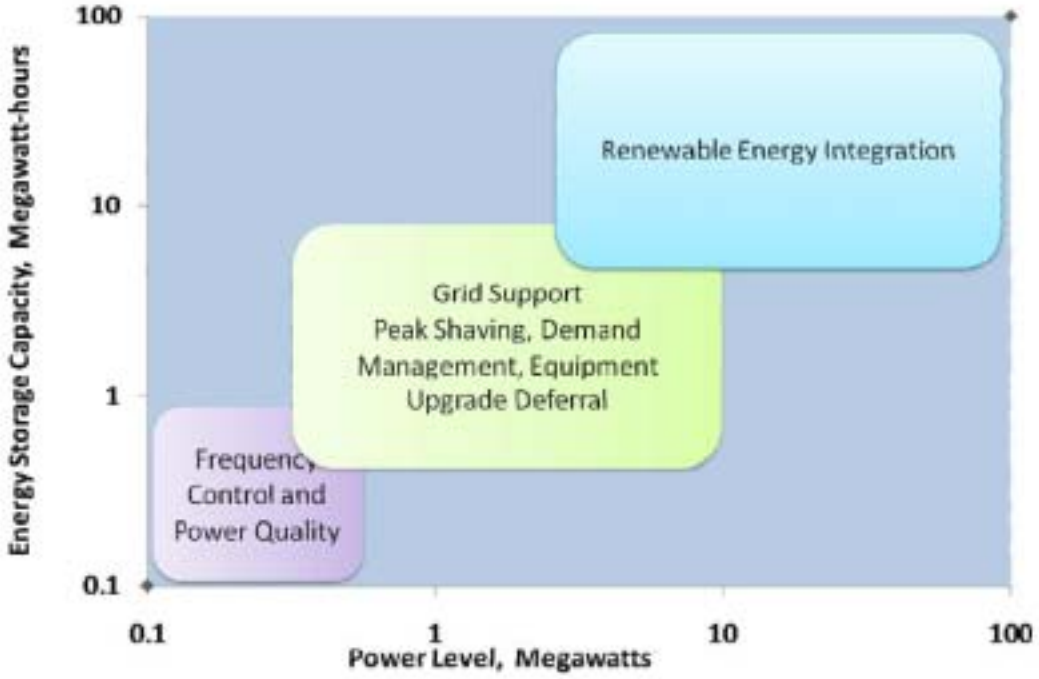

Figure K-1. Requirements of grid-scale ESS.

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Electrical ESSs are critical for the integration of intermittent renewable energy sources, load shifting, and improving the stability and reliability of the electricity grid. Such electrical ESSs must be capable of storing hundreds of megawatt-hours (MWhs) and operating without significant degradation for 15-20 years at a cost comparable to today's power plants.

K.3 Energy Storage System Technologies

LADWP is presently in the process of assessing various advanced electrical energy storage technologies to meet its renewable energy program goals. The technologies that look promising for grid-scale energy storage are rechargeable batteries, compressed-air energy storage (CAES), pumped hydro-storage, flywheels energy storage (FES), and supercapacitors. Table K-1 summarizes the salient characteristics of the various energy storage technology options. Among these options, CAES and pumped hydroelectric systems are the technologies most suited for storing large quantities of electrical energy for long periods of time. Rechargeable batteries can support applications requiring a few minutes to a few hours of energy storage. However, hybrid ESSs consisting of rechargeable batteries and other electrical storage systems are likely to meet a wide range of requirements.

Table K-1. COMPARISON OF VARIOUS ESS TECHNOLOGIES

Electrical Storage Technology	Power	Energy Storage Capacity	Duration of Discharge	Advantages	Challenges / Issues
Lead Acid	< 1 MW	0.1 kWh - 1 MWh	1 - 5 hours	low cost, mature technology	limited cycle life low energy density
Lithium-Ion	< 2 MW	0.1 kWh - 10 MWh	1 - 8 hours	high energy density, high power density	high cost, safety in large systems, life,
Sodium Sulfur	< 40 MW	< 250 MWh	1 - 24 hours	high energy density, modest power density	high temperature operation, cost, safety of large systems, life
Redox Flow	< 5 MW	< 15 MWh	1 - 24 hours	long life, safe, easily scalable, medium cost	low energy density, low power density
Compressed Air	25 MW - 3000 MW	1 GWh	1 - 24 hours	high capacity, low cost	special site requirements
Pumped Hydro	100 MW - 4000 MW	15 GWh	4 - 24 hours	mature, high capacity, low cost	special site requirements
Flywheels	< 1 MW	< 10 MWh	< 1 hour	high power density	low energy density, high cost
Supercapacitors	< 1 MW	< 100 kWh	< 1 minute	high power density, long life, high efficiency	low energy density, high cost
Superconducting Magnetic Storage	< 10 MW	< 1 MWh	< 30 minutes	high power density, high efficiency	high cost

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K.3.1 Rechargeable Batteries

Rechargeable batteries, upon being charged, convert electrical energy into chemical energy within reactant materials. The chemical energy can be returned as electrical energy upon discharge of the batteries. The rechargeable batteries being considered for the grid support applications described in this appendix are Lithium-Ion Batteries, Sodium-Sulfur (NaS) Batteries, and Redox Flow Batteries. The key challenges for these battery systems are summarized in Table K-2.

Lithium-Ion Batteries

The basic chemistry of these batteries is the same as that of the batteries used in cell phones, laptops, and other portable electronic devices. Large batteries can be fabricated using the same chemistry to provide ESSs for the grid. These batteries consist of carbon-based anode materials and lithiated metal oxide (metals such as cobalt, nickel, and manganese) cathode materials along with an organic electrolyte. Other material choices include lithium titanate for the anode and lithium iron phosphate for the cathode. The cells are sealed to prevent exposure of the battery chemistry to moisture and oxygen. These batteries offer specific energy values as high as 200 watt hour per kilogram (Wh/kg) and 400 watt hour per liter (Wh/L). They are three to six times lighter than lead acid batteries for the equivalent capacity and allow for fast charging and discharging. Operational life of about five years has been demonstrated. Further research is currently being done to improve battery-life characteristics for automotive applications. Cost and safety are the key challenges for widespread deployment of these types of batteries. Lithium iron phosphate and lithium titanate are particularly attractive for automotive applications because of their lower cost and higher abuse tolerance, albeit at a moderate reduction in energy density to 100 Wh/kg. AES Energy Storage is current installing a 32 MW lithium-ion storage system to regulate the 100-MW Laurel Mountain Wind Farm in West Virginia. Similarly, A123 Systems and AES have jointly deployed a 2 MW system (see Figure K-2). The current cost for lithium-ion batteries is between $650-$1000/kWh and $400-$2000/kW. Current costs of lithium-ion batteries are coming down because of ongoing developments in the automotive industry and are expected to reach $250/kwh by 2020.

Figure K-2. Lithium-ion batteries.

Sodium-Sulfur Battery

This type of battery was developed prior to lithium ion batteries and uses metallic sodium and elemental sulfur. A sodium-ion conductive ceramic separates both electrodes. Redox and Lithium-Ion batteries can operate at ambient temperatures, but NaS batteries must operate at

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about 450°C and must be maintained at this high temperature by appropriate thermal insulation. Repeated heating and cooling cycles will reduce the life of NaS batteries. Since NaS batteries consist of reactive materials maintained at high-temperatures, engineering measures are required to ensure safe operations. Notwithstanding these challenges, large-scale NaS battery installations have been demonstrated worldwide, with the largest installed unit being 34 MW, 245 MWh for a wind power stabilization application in Northern Japan by NGK Insulators Inc. (see Figure K-3). Thus far in the U.S., about 40 MWs have been deployed for grid support and integration with wind energy systems. General Electric USA has recently announced its intention to develop and manufacture NaS batteries for renewable energy system integration. The projected cost of large-scale NaS batteries is $450/kW and $400/kWh.

Figure K-3. Sodium-sulfur batteries.

Redox Flow Batteries

In a redox flow battery (see Figure K-4), the chemicals produced in the cell stack during electrical charging are pumped out of the cell stack and stored as a solution in tanks. The solutions are then re-circulated through the cell stack when the energy needs to be regenerated. Since large amounts of energy can be stored as solutions in tanks, the redox flow battery concept is particularly suitable for large-scale energy storage applications. The Vanadium Redox Battery (VRB) is one of the best known examples of a redox flow battery that has been scaled up to MWh sizes; systems with the power level of 2 MW and storage capacity of 12 MWh have been demonstrated. Many units based on VRB technology are in operation worldwide. Some of the flow battery systems have been in operation for over 30 years with minimal maintenance. The life cycle emission from these batteries is less than 25 percent of that of lead-acid batteries. The capital cost for these batteries is in the range of $1000/kW and $300/kWh. With a 15-year life span, the amortized cost of this system is comparable to that of lead acid batteries.

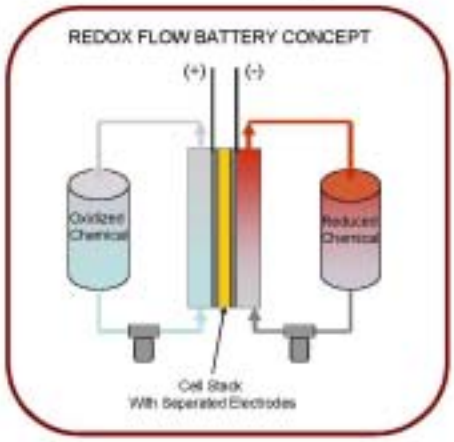

Figure K-4. Redox flow batteries.

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Table K-2: KEY CHALLENGES OF BATTERY SYSTEMS

Vanadium Redox Battery	Lithium Ion Battery	Sodium-Sulfur Battery
High cost of vanadium Negative environmental impact of using large quantities of a biologically active heavy metal such as vanadium Low-efficiency Low to Moderate power density Loss of efficiency by cross diffusion of constituents, Low storage capacity of solutions	Operational safety of large-scale batteries Degradation after 2000 cycles on deep discharge which translates to about 3-4 years of operation. High cost of materials to achieve high-energy density.	High temperature operation of the battery (400°C) adds to cost, maintenance and safety Rapid degradation of sealing elements when subjected to thermal cycling. Degradation of battery over 1000 cycles High cost arising from materials and manufacturing methods.

K.3.2 Compressed Air Energy Storage

CAES systems compress large masses of air during periods of low energy demand (off-peak) and then expand the air in turbogenerators to produce power during periods of peak demand. Heating the compressed air before sending it through the turbogenerator results in a three-fold increase in the power that could otherwise be generated without the heater. Compressed air stores mechanical energy that can be released very rapidly. However, the stored energy density of CAES systems is relatively small compared to liquid fuel (gasoline, diesel). Currently, about 80-85 percent of the mechanical work for compressing the air is lost as waste heat during the compression. New air compressor devices that recover the heat generated will substantially increase the efficiency.

K.3.3 Pumped Hydroelectric Storage

Pumped Hydroelectric Storage (PHS) is one of the most widely used ESS technologies. The PHS system involves pumping water from a lower reservoir to a higher reservoir when electricity is available (generally at night) and then flowing water down through hydroelectric generators to produce electricity when additional power capacity is needed (typically at midday during periods of peak demand). PHS systems require a particular geographical topology where reservoirs can be situated at different elevations and where sufficient water is available. PHS systems constitute 3-4 percent of the current worldwide power generation capacity. The typical size of these PHS systems is around 1000 MW, and the storage capacity can exceed thousands of MWhs based on the size of the reservoirs and the hydroelectric generator assets involved. The round-trip efficiency of these systems usually exceeds 70 percent. Installation costs of these systems tend to be high because of the geographical siting requirements. System cost is estimated to be $4000/kW and $200/kWh.

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K.3.4 Flywheel Energy Storage

FES systems work by using an electric motor to accelerate a rotor (flywheel) to a very high speed, maintaining the energy in the system as rotational energy using very low-friction bearings and engaging an electric generator to convert the rotational energy back to electricity by decelerating the flywheel. FES technology is a good fit for managing relatively limited amounts of electricity for short periods of time and is being considered as a strong contender for frequency control of the grid. Beacon Power Corporation has developed a flywheel system for frequency control of the grid and is currently testing several installations of prototype equipment.

K.3.5 Supercapacitor Energy Storage

Supercapacitor Energy Storage (SES) and Ultracapacitor Energy Storage (UES) systems are targeted to fill the gap between capacitors and batteries. These devices can deliver large amounts of power for short periods of time and can be used to dampen the in-rush current noise caused by the start-up and shut down of large motors and generators in large power system facilities. However, these devices are not likely to be good candidates for large-scale energy storage.

K.3.6 Superconducting Magnetic Energy Storage

Superconducting Magnetic Energy Storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil, which has been cryogenically cooled to a temperature below its superconducting critical temperature. SMES technology is highly efficient, but manufacture of actual commercial equipment has been hard to achieve. This technology appears to be too immature for large scale commercialization.

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K-4 Benefits

Quantifiably advances in ESS technologies, and implementation will result in several benefits as shown on Table K-4.

Table K-4. BENEFITS OF ENERGY STORAGE SYSTEMS

LADWP Approach	Benefits	Metrics
Use Battery Energy Storage to supply energy when the generation dips from the wind or solar generators during peak demand periods or demand increases	Lower electricity cost	Lowering peak demand needed from expensive combustion turbine generators with wind and solar generation
Use Battery Energy Storage to supply energy when the generation dips from the wind or solar generators or during system disturbances	Reduced power interruptions and increase reliability	Fewer and Shorter outages
	Reduced costs from better power quality	Fewer momentary outages
		Fewer severe sags and swells
		Lower harmonic distortion
Use Battery storage energy from green power reduces CO2 Emissions	Reduced damages as a result of lower GHG/carbon emissions	Percentage of green power relative to total power generated.
Increase of battery storage from green power to reduce need for oil or gas		
Reduce reliance on non renewable resources	Greater energy security from reduced oil consumption	Percentage of green energy utilized

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LOS ANGELES DEPARTMENT OF WATER AND POWER (LADWP) BOARD APPROVAL LETTER

TO: BOARD OF WATER AND POWER COMMISSIONERS	DATE: February 2, 2012
ARAM BENYAMIN Senior Assistant General Manager – Power System RONALD O. NICHOLS General Manager	SUBJECT: **LADWP Energy Storage Targets**
	FOR COMMISSION OFFICE USE: RESOLUTION NO. 012 168 FEB 07 2012 COPY RESO TO : 2. SK. A&M - Power Supply 2-17-12
CITY COUNCIL APPROVAL REQUIRED: Yes ☐ No ☒	IF YES, BY WHICH CITY CHARTER SECTION:

PURPOSE

To comply with State Assembly Bill 2514 (AB 2514), which became law on January 1, 2011, the Board of Water and Power Commissioners (Board) must take action by March 1, 2012, to initiate a process to determine appropriate targets, if any, for the LADWP to procure viable and cost-effective energy storage systems.

BACKGROUND

The AB 2514 became law on January 1, 2011. The bill requires the governing board of a local publicly owned electric utility, such as LADWP, to initiate a process by March 1, 2012, to determine appropriate targets, if any, for LADWP to procure viable and cost-effective energy storage systems by certain dates. AB 2514 further requires that if determined to be appropriate, this Board shall adopt procurement targets by October 1, 2014, for LADWP to procure viable and cost-effective energy storage systems to be achieved by a first target date of December 31, 2016, and a second target date of December 31, 2021.

Furthermore, AB 2514 requires the Board to re-evaluate the determinations made regarding the energy storage system procurement not less than once every three years and for LADWP to report to the California Energy Commission regarding the energy storage system procurement targets and policies that may be adopted by the Board, and any modifications made to those targets as a result of the Board's re-evaluations.

The LADWP's 2011 Power System Integrated Resource Plan provides a review of the general requirements of grid-scale energy storage systems and technologies, which may serve as an initial framework to determine appropriate targets, if any, for LADWP to procure viable and cost-effective energy storage systems.

RECOMMENDATION

It is recommended that your Honorable Board adopt the attached Resolution initiating a process to determine appropriate energy storage system targets, if any, consistent with AB 2514.

TA:nsh
e-c/att: Ronald O. Nichols
Richard M. Brown
Aram Benyamin
James B. McDaniel
Lorraine A. Paskett
Philip R. Leiber
Ann M. Santilli
Gary Wong
Randy S. Howard
Oscar A. Alvarez
Than Aung

RESOLUTION NO 012 168

WHEREAS, State Assembly Bill 2514 (AB 2514) became law on January 1, 2011, requiring the governing board of a local publicly owned electric utility, such as the Los Angeles Department of Water and Power (LADWP), to initiate a process by March 1, 2012, to determine appropriate targets, if any, for LADWP to procure viable and cost-effective energy storage systems by certain dates; and

WHEREAS, if determined to be appropriate, the Board of Water and Power Commissioners (Board) shall adopt procurement targets by October 1, 2014, for LADWP to procure viable and cost-effective energy storage systems to be achieved by a first target date of December 31, 2016, and a second target date of December 31, 2021, and

WHEREAS LADWP's 2011 Power Integrated Resource Plan (IRP) provides a review of the general requirements of grid-scale energy storage systems and technologies and includes a proposed energy storage demonstration project, which may serve as an initial framework to determine appropriate targets, if any, for LADWP to procure viable and cost-effective energy storage systems; and

WHEREAS, pursuant to AB 2514, the Board shall re-evaluate the determinations made regarding energy storage system procurement not less than once every three years; and

WHEREAS, LADWP shall report to the California Energy Commission regarding any energy storage system procurement targets and policies that may be adopted by this Board, and any modifications made to those targets as a result of the Board's reevaluations

NOW, THEREFORE, BE IT RESOLVED that the Board of Water and Power Commissioners of the City of Los Angeles hereby initiates a process directing LADWP to determine appropriate targets, if any, for LADWP to procure viable and cost-effective energy storage systems by December 31, 2016, and December 31, 2021 pursuant to AB 2514.

BE IT FURTHER RESOLVED that LADWP shall report back to this Board prior to October 1, 2014, regarding potential procurement targets, if any, for LADWP to procure viable and cost-effective energy storage systems, at which time this Board may determine whether it is appropriate to adopt such targets.

I HEREBY CERTIFY that the foregoing is a full, true, and correct copy of a resolution adopted by the Board of Water and Power Commissioners of the City of Los Angeles at its meeting held FEB 07 2012

FEB 07 2012

Barbara E. Moschos

Secretary

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Assembly Bill No. 2514

CHAPTER 469

An act to amend Section 9620 of, and to add Chapter 7.7 (commencing with Section 2835) to Part 2 of Division 1 of, the Public Utilities Code, relating to energy.

[Approved by Governor September 29, 2010. Filed with Secretary of State September 29, 2010.]

LEGISLATIVE COUNSEL'S DIGEST

AB 2514, Skinner. Energy storage systems.

Under existing law, the Public Utilities Commission (CPUC) has regulatory authority over public utilities, including electrical corporations, as defined. The existing Public Utilities Act requires the CPUC to review and adopt a procurement plan for each electrical corporation in accordance with specified elements, incentive mechanisms, and objectives. The existing California Renewables Portfolio Standard Program (RPS program) requires the CPUC to implement annual procurement targets for the procurement of eligible renewable energy resources, as defined, for all retail sellers, including electrical corporations, community choice aggregators, and electric service providers, but not including local publicly owned electric utilities, to achieve the targets and goals of the program.

The existing Warren-Alquist State Energy Resources Conservation and Development Act establishes the State Energy Resources Conservation and Development Commission (Energy Commission), and requires it to undertake a continuing assessment of trends in the consumption of electricity and other forms of energy and to analyze the social, economic, and environmental consequences of those trends and to collect from electric utilities, gas utilities, and fuel producers and wholesalers and other sources, forecasts of future supplies and consumption of all forms of energy.

Existing law requires the CPUC, in consultation with the Independent System Operator (ISO), to establish resource adequacy requirements for all load-serving entities, as defined, in accordance with specified objectives. The definition of a "load-serving entity" excludes a local publicly owned electric utility. That law further requires each load-serving entity to maintain physical generating capacity adequate to meet its load requirements, including peak demand and planning and operating reserves, deliverable to locations and at times as may be necessary to provide reliable electric service. Other existing law requires that each local publicly owned electric utility serving end-use customers to prudently plan for and procure resources that are adequate to meet its planning reserve margin and peak demand and operating reserves, sufficient to provide reliable electric service to its customers. That law additionally requires the utility, upon request, to provide

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the Energy Commission with any information the Energy Commission determines is necessary to evaluate the progress made by the local publicly owned electric utility in meeting those planning requirements, and requires the Energy Commission to report the progress made by each utility to the Legislature, to be included in the integrated energy policy reports. Under existing law, the governing body of a local publicly owned electric utility is responsible for implementing and enforcing a renewables portfolio standard for the utility that recognizes the intent of the Legislature to encourage renewable resources, while taking into consideration the effect of the standard on rates, reliability, and financial resources and the goal of environmental improvement.

This bill would require the CPUC, by March 1, 2012, to open a proceeding to determine appropriate targets, if any, for each load-serving entity to procure viable and cost-effective energy storage systems and, by October 1, 2013, to adopt an energy storage system procurement target, if determined to be appropriate, to be achieved by each load-serving entity by December 31, 2015, and a 2nd target to be achieved by December 31, 2020. The bill would require the governing board of a local publicly owned electric utility, by March 1, 2012, to open a proceeding to determine appropriate targets, if any, for the utility to procure viable and cost-effective energy storage systems and, by October 1, 2014, to adopt an energy storage system procurement target, if determined to be appropriate, to be achieved by the utility by December 31, 2016, and a 2nd target to be achieved by December 31, 2021. The bill would require each load-serving entity and local publicly owned electric utility to report certain information to the CPUC, for a load-serving entity, or to the Energy Commission, for a local publicly owned electric utility. The bill would make other technical, nonsubstantive revisions to existing law. The bill would exempt from these requirements an electrical corporation that has 60,000 or fewer customers within California and a public utility district that receives all of its electricity pursuant to a preference right adopted and authorized by the United States Congress pursuant to a specified law.

Under existing law, a violation of the Public Utilities Act or any order, decision, rule, direction, demand, or requirement of the CPUC is a crime.

Because certain of the provisions of this bill require action by the CPUC to implement, a violation of these provisions would impose a state-mandated local program by creating a new crime. Because certain of the bill's requirements are applicable to local publicly owned electric utilities, the bill would impose a state-mandated local program.

The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement.

This bill would provide that no reimbursement is required by this act for specified reasons.

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The people of the State of California do enact as follows:

SECTION 1. The Legislature finds and declares all of the following:

(a) Expanding the use of energy storage systems can assist electrical corporations, electric service providers, community choice aggregators, and local publicly owned electric utilities in integrating increased amounts of renewable energy resources into the electrical transmission and distribution grid in a manner that minimizes emissions of greenhouse gases.

(b) Additional energy storage systems can optimize the use of the significant additional amounts of variable, intermittent, and offpeak electrical generation from wind and solar energy that will be entering the California power mix on an accelerated basis.

(c) Expanded use of energy storage systems can reduce costs to ratepayers by avoiding or deferring the need for new fossil fuel-powered peaking powerplants and avoiding or deferring distribution and transmission system upgrades and expansion of the grid.

(d) Expanded use of energy storage systems will reduce the use of electricity generated from fossil fuels to meet peak load requirements on days with high electricity demand and can avoid or reduce the use of electricity generated by high carbon-emitting electrical generating facilities during those high electricity demand periods. This will have substantial cobenefits from reduced emissions of criteria pollutants.

(e) Use of energy storage systems to provide the ancillary services otherwise provided by fossil-fueled generating facilities will reduce emissions of carbon dioxide and criteria pollutants.

(f) There are significant barriers to obtaining the benefits of energy storage systems, including inadequate evaluation of the use of energy storage to integrate renewable energy resources into the transmission and distribution grid through long-term electricity resource planning, lack of recognition of technological and marketplace advancements, and inadequate statutory and regulatory support.

SEC. 2. Chapter 7.7 (commencing with Section 2835) is added to Part 2 of Division 1 of the Public Utilities Code, to read:

Chapter 7.7. Energy Storage Systems

2835. For purposes of this chapter, the following terms have the following meanings:

(a) (1) "Energy storage system" means commercially available technology that is capable of absorbing energy, storing it for a period of time, and thereafter dispatching the energy. An "energy storage system" may have any of the characteristics in paragraph (2), shall accomplish one of the purposes in paragraph (3), and shall meet at least one of the characteristics in paragraph (4).

(2) An "energy storage system" may have any of the following characteristics:

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(A) Be either centralized or distributed.

(B) Be either owned by a load-serving entity or local publicly owned electric utility, a customer of a load-serving entity or local publicly owned electric utility, or a third party, or is jointly owned by two or more of the above.

(3) An "energy storage system" shall be cost effective and either reduce emissions of greenhouse gases, reduce demand for peak electrical generation, defer or substitute for an investment in generation, transmission, or distribution assets, or improve the reliable operation of the electrical transmission or distribution grid.

(4) An "energy storage system" shall do one or more of the following:

(A) Use mechanical, chemical, or thermal processes to store energy that was generated at one time for use at a later time.

(B) Store thermal energy for direct use for heating or cooling at a later time in a manner that avoids the need to use electricity at that later time.

(C) Use mechanical, chemical, or thermal processes to store energy generated from renewable resources for use at a later time.

(D) Use mechanical, chemical, or thermal processes to store energy generated from mechanical processes that would otherwise be wasted for delivery at a later time.

(b) "Load-serving entity" has the same meaning as defined in Section 380.

(c) "New" means, in reference to an energy storage system, a system that is installed and first becomes operational after January 1, 2010.

(d) "Offpeak" means, in reference to electrical demand, a period that is not within a peak demand period.

(e) "Peak demand period" means a period of high daily, weekly, or seasonal demand for electricity. For purposes of this chapter, the peak demand period for a load-serving entity shall be determined, or approved, by the commission and shall be determined, or approved, for a local publicly owned electric utility, by its governing body.

(f) "Procure" and "procurement" means, in reference to the procurement of an energy storage system, to acquire by ownership or by a contractual right to use the energy from, or the capacity of, including ancillary services, an energy storage system owned by a load-serving entity, local publicly owned electric utility, customer, or third party. Nothing in this chapter, and no action by the commission, shall discourage or disadvantage development and ownership of an energy storage system by an electrical corporation.

2836. (a) (1) On or before March 1, 2012, the commission shall open a proceeding to determine appropriate targets, if any, for each load-serving entity to procure viable and cost-effective energy storage systems to be achieved by December 31, 2015, and December 31, 2020. As part of this proceeding, the commission may consider a variety of possible policies to encourage the cost-effective deployment of energy storage systems, including refinement of existing procurement methods to properly value energy storage systems.

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(2) The commission shall adopt the procurement targets, if determined to be appropriate pursuant to paragraph (1), by October 1, 2013.

(3) The commission shall reevaluate the determinations made pursuant to this subdivision not less than once every three years.

(4) Nothing in this section prohibits the commission's evaluation and approval of any application for funding or recovery of costs of any ongoing or new development, trialing, and testing of energy storage projects or technologies outside of the proceeding required by this chapter.

(b) (1) On or before March 1, 2012, the governing board of each local publicly owned electric utility shall initiate a process to determine appropriate targets, if any, for the utility to procure viable and cost-effective energy storage systems to be achieved by December 31, 2016, and December 31, 2021. As part of this proceeding, the governing board may consider a variety of possible policies to encourage the cost-effective deployment of energy storage systems, including refinement of existing procurement methods to properly value energy storage systems.

(2) The governing board shall adopt the procurement targets, if determined to be appropriate pursuant to paragraph (1), by October 1, 2014.

(3) The governing board shall reevaluate the determinations made pursuant to this subdivision not less than once every three years.

(4) A local publicly owned electric utility shall report to the Energy Commission regarding the energy storage system procurement targets and policies adopted by the governing board pursuant to paragraph (2), and report any modifications made to those targets as a result of a reevaluation undertaken pursuant to paragraph (3).

2836.2. In adopting and reevaluating appropriate energy storage system procurement targets and policies pursuant to subdivision (a) of Section 2836, the commission shall do all of the following:

(a) Consider existing operational data and results of testing and trial pilot projects from existing energy storage facilities.

(b) Consider available information from the California Independent System Operator derived from California Independent System Operator testing and evaluation procedures.

(c) Consider the integration of energy storage technologies with other programs, including demand-side management or other means of achieving the purposes identified in Section 2837 that will result in the most efficient use of generation resources and cost-effective energy efficient grid integration and management.

(d) Ensure that the energy storage system procurement targets and policies that are established are technologically viable and cost effective.

2836.4. (a) An energy storage system may be used to meet the resource adequacy requirements established for a load-serving entity pursuant to Section 380 if it meets applicable standards.

(b) An energy storage system may be used to meet the resource adequacy requirements established by a local publicly owned electric utility pursuant to Section 9620 if it meets applicable standards.

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2836.6. All procurement of energy storage systems by a load-serving entity or local publicly owned electric utility shall be cost effective.

2837. Each electrical corporation's renewable energy procurement plan, prepared and approved pursuant to Article 16 (commencing with Section 399.11) of Chapter 2.3 of Part 1, shall require the utility to procure new energy storage systems that are appropriate to allow the electrical corporation to comply with the energy storage system procurement targets and policies adopted pursuant to Section 2836. The plan shall address the acquisition and use of energy storage systems in order to achieve the following purposes:

(a) Integrate intermittent generation from eligible renewable energy resources into the reliable operation of the transmission and distribution grid.

(b) Allow intermittent generation from eligible renewable energy resources to operate at or near full capacity.

(c) Reduce the need for new fossil-fuel powered peaking generation facilities by using stored electricity to meet peak demand.

(d) Reduce purchases of electricity generation sources with higher emissions of greenhouse gases.

(e) Eliminate or reduce transmission and distribution losses, including increased losses during periods of congestion on the grid.

(f) Reduce the demand for electricity during peak periods and achieve permanent load-shifting by using thermal storage to meet air-conditioning needs.

(g) Avoid or delay investments in transmission and distribution system upgrades.

(h) Use energy storage systems to provide the ancillary services otherwise provided by fossil-fueled generating facilities.

2838. (a) (1) By January 1, 2016, each load-serving entity shall submit a report to the commission demonstrating that it has complied with the energy storage system procurement targets and policies adopted by the commission pursuant to subdivision (a) of Section 2836.

(2) By January 1, 2021, each load-serving entity shall submit a report to the commission demonstrating that it has complied with the energy storage system procurement targets and policies adopted by the commission pursuant to subdivision (a) of Section 2836.

(b) The commission shall ensure that a copy of each report required by subdivision (a), with any confidential information redacted, is available on the commission's Internet Web site.

2838.5. Notwithstanding any provision of this chapter, the requirements of this chapter do not apply to either of the following:

(a) An electrical corporation that has 60,000 or fewer customer accounts within California.

(b) A public utility district that receives all of its electricity pursuant to a preference right adopted and authorized by the United States Congress pursuant to Section 4 of the Trinity River Division Act of August 12, 1955 (Public Law 84-386).

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2839. (a) (1) By January 1, 2017, a local publicly owned electric utility shall submit a report to the Energy Commission demonstrating that it has complied with the energy storage system procurement targets and policies adopted by the governing board pursuant to subdivision (b) of Section 2836.

(2) By January 1, 2022, a local publicly owned electric utility shall submit a report to the Energy Commission demonstrating that it has complied with the energy storage system procurement targets and policies adopted by the governing board pursuant to subdivision (b) of Section 2836.

(b) The Energy Commission shall ensure that a copy of each report or plan required by subdivisions (a) and (b), with any confidential information redacted, is available on the Energy Commission's Internet Web site, or on an Internet Web site maintained by the local publicly owned electric utility that can be accessed from the Energy Commission's Internet Web site.

(c) The commission does not have authority or jurisdiction to enforce any of the requirements of this chapter against a local publicly owned electric utility.

SEC. 3. Section 9620 of the Public Utilities Code is amended to read:

9620. (a) Each local publicly owned electric utility serving end-use customers, shall prudently plan for and procure resources that are adequate to meet its planning reserve margin and peak demand and operating reserves, sufficient to provide reliable electric service to its customers. Customer generation located on the customer's site or providing electric service through arrangements authorized by Section 218, shall not be subject to these requirements if the customer generation, or the load it serves, meets one of the following criteria:

(1) It takes standby service from the local publicly owned electric utility on a rate schedule that provides for adequate backup planning and operating reserves for the standby customer class.

(2) It is not physically interconnected to the electric transmission or distribution grid, so that, if the customer generation fails, backup power is not supplied from the electricity grid.

(3) There is physical assurance that the load served by the customer generation will be curtailed concurrently and commensurately with an outage of the customer generation.

(b) Each local publicly owned electric utility serving end-use customers shall, at a minimum, meet the most recent minimum planning reserve and reliability criteria approved by the Board of Trustees of the Western Systems Coordinating Council or the Western Electricity Coordinating Council.

(c) Each local publicly owned electric utility shall prudently plan for and procure energy storage systems that are adequate to meet the requirements of Section 2836.

(d) A local publicly owned electric utility serving end-use customers shall, upon request, provide the Energy Commission with any information the Energy Commission determines is necessary to evaluate the progress made by the local publicly owned electric utility in meeting the requirements of this section.

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(e) The Energy Commission shall report to the Legislature, to be included in each integrated energy policy report prepared pursuant to Section 25302 of the Public Resources Code, regarding the progress made by each local publicly owned electric utility serving end-use customers in meeting the requirements of this section.

SEC. 4. No reimbursement is required by this act pursuant to Section 6 of Article XIII B of the California Constitution because a local agency or school district has the authority to levy service charges, fees, or assessments sufficient to pay for the program or level of service mandated by this act or because costs that may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, eliminates a crime or infraction, or changes the penalty for a crime or infraction, within the meaning of Section 17556 of the Government Code, or changes the definition of a crime within the meaning of Section 6 of Article XIII B of the California Constitution.

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Appendix L Smart Grid

LADWP's Smart Grid Program is described in the following "Smart Grid Deployment Plan" dated October 31, 2011

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Smart Grid

Deployment Plan

Prepared by: Power System Engineering Division
Power System Information and Advanced Technologies (PSIAT) Section

Smart Grid Team

Version 1.0

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1 Introduction

1.1 Purpose of this document

The Los Angeles Department of Water and Power (LADWP) Smart Grid Deployment Plan represents a roadmap to address the anticipated future needs of the people of the City of Los Angeles. By meeting the requirements of both SB 17 and Title XIII, LADWP's Smart Grid Deployment Plan outlines the coordinated and integrated approach in implementing new technologies while maintaining or improving safety and reliability.

1.2 Smart Grid Initiative Background

Smart Grid is a national policy that grew as a response to The Energy Policy Act of 2005, which called for advanced metering. It, however, has been insufficient to achieve the desired goals of energy conservation, migration to renewable energy, and reduction of CO2 emissions from power plants. The federal Energy Independence and Security Act of 2007 called for the implementation of Smart Grid systems as a "Policy of the United States". The new Energy Independence and Security Act of 2007 authorizes $100 M each year from 2008 through 2012 to be divided between five Smart Grid demonstration projects throughout the nation. The Department of Energy is required to report within one year on the status of Smart Grid deployments and identify any regulatory or government obstacles.

Additionally, utility executives and regulators have become increasingly concerned about multiple issues that can only be addressed through an enterprise wide Smart Grid solution. The four main concerns are:

(a) Cost and uncertainty about New Generation and Transmission

(b) Environmental impacts ("Green House" gases emitted from fossil fuel power plants and proposed right-of-ways for transmission lines crossing through pristine forests, deserts and wild life areas to service urban areas) such as those proposed in AB 32, the *California Global Warming Solutions Act, 2006*.

(c) Increasing requirements for the use of Renewable and Distributed Generation (Wind, Solar, Geothermal, Hydro, and Biomass)

(d) Demographics: aging workforce

Regulated utilities in California are now responding to regulatory direction to submit plans for large-scale AMI and Smart Grid initiatives with full delineation of costs and benefits. This regulatory initiative is an aggressive step, seeking to promote customer awareness of peak load periods, and response to peak-sensitive pricing. The Smart

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Grid deployments and the associated utility customer features are proceeding through out the State of California.

1.3 Smart Grid Definition

The Los Angeles Department of Water and Power maintains that the definition of a smart grid is a system which facilitates the integration of advanced technologies in existing networks to improve system performance, power flow control, and reliability. Such a system is characterized by the following:

(a) Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid.

(b) Dynamic optimization of grid operations and resources, with cost-effective full cyber security.

(c) Deployment and integration of cost-effective distributed resources and generation, including renewable resources.

(d) Development and incorporation of cost-effective demand response, demand-side resources, and energy-efficiency resources.

(e) Deployment of cost-effective smart technologies, including real time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices for metering, communications concerning grid operations and status, and distribution automation.

(f) Integration of cost-effective smart appliances and consumer devices.

(g) Deployment and integration of cost-effective advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air-conditioning.

(h) Provide consumers with timely information and control options.

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(i) Develop standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

(j) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

1.4 Stakeholders

1.4.1 Customer

LADWP ratepayers are the Customers and will realize the monetary, social, and environmental benefits of the plan.

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2 LADWP Smart Grid Initiatives

2.1 Smart Grid Objectives

Currently, the Department is involved in two strategic initiatives related to Smart Grid. The first is the Smart Grid Regional Demonstration Project and the second is the Smart Grid Investment Program.

The Smart Grid Regional Demonstration Project began in December of 2009, when LADWP was awarded 60.2 million dollars grant from the Department of Energy for the American Reinvestment and Recovery Act for Smart Grid Demonstrations. As a result of the award, LADWP is managing a consortium of Los Angeles metropolitan area research institutions with established energy and technology transfer programs. Together, the team is carrying out a regionally unique demonstration by using innovative technology test beds located at LADWP's partner university campuses and technology transfer laboratories to prove the viability of the demonstration technology. Additional research is being conducted to explore options for informed, enabled customers based on historical usage and pricing data. This research uses a multi-tiered rate approach to address the diversity of customer demands by exploring time-varying and time-of-use products for the end consumer. The regional demonstration project includes four interrelated project initiatives, which will be incorporated into the long term investment program:

(a) A fully integrated demonstration of Smart Grid operation and technology as applied to Demand Response.

(b) A comprehensive portfolio of research empoying a unique test bed structure to identify historical usage and consumer adoption obstacles essential for succesful adoption of Smart Grid Technologies and improved energy usage patterns.

(c) Demonstration of next generation cyber security technologies using the Regional Project as the driving source of specific system architecture and models.

(d) The integration of electric vehicles into the LADWP managed grid, addressing solutions to overcome both technical and social impediments.

The Smart Grid investment plan is a 10-year project that incorporates 11 strategic initiatives.

2.1.1 Links with the Department's Strategic Objectives

The Smart Grid Implementation Plan continues to align LADWP's efforts to implement the technology with the goal of increasing LADWP's Power System monitoring,

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control and reliability while decreasing operating costs and gaining significant efficiencies.

2.2 LADWP Smart Grid Initiatives in Progress

"Smart Grid" is a term used to describe a variety of advanced information-based utility improvements. Smart Grid is a major enabler for many existing and potentially new Demand Side Resource programs. Smart Grid is a national policy evolving from the Energy Policy Act of 2005. Smart Grid refers to intelligent data gathering and advanced two-way digital communication capabilities overlaid on electric distribution networks to provide real-time data that enhances the utility's ability to optimize energy use. Smart Grid technologies can turn every point in the existing network—including every meter, switch and transformer—into a potential information source, able to feed performance data back to the utility instantly. Smart Grid Technologies will provide utilities with the information required to implement real-time, self-monitoring networks that are predictive rather than reactive to instantaneous system disruptions. It can enable the utility and consumer to make decisions to optimize the use of energy, improve reliability, and reduce the consumption of fossil fuels.

Section 8360 of the Senate Bill 17 defines the policy that governs the way utilities modernize transmission and distribution systems. LADWP's eleven Smart Grid Initiatives are designed to be collectively compliant with SB17. The following is the list of the initiatives:

(a) Renewable Integration

(b) Transmission Automation Initiative

(c) Substation Automation Initiative

(d) Distribution Automation Initiative

(e) AMI Metering Initiative

(f) Demand Response Initiative

(g) Communications Initiative

(h) Cyber Security Initiative

(i) System and Data Integration Initiative

(j) Feed-In Tariff Initiative

(k) Solar Incentives Program

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2.3 Renewable Integration

LADWP has a comprehensive Integrated Resource Plan where new Wind, Solar, and Geothermal Power Plants, as well as Energy Storage, and Electric Vehicles will be incorporated into the power generation mix. Currently, the ECS/Historian Servers have been installed at Pine Tree Generation Station, and there are plans to install more of these servers at each of the power plants. These servers allow for real-time monitoring and control of renewable sources, which will be equipped with automation equipment in order to facilitate peak shaving activities and to better support the adoption and utilization of renewables.

2.4 Transmission Automation Initiative

For years, LADWP has worked in substations to meter the transmission lines and record Phasor Measurement Units (PMU). These measurements are used to determine the health of the Electrical System. LADWP will install PMUS, and upgrade Tie-Line Meters to improve measurement, provide backup metering at Tie Points, collect dynamic reads, and reroute power. The real-time data provided by PMU will be used for predicting instability in the transmission system and undertaking preventive actions.

2.5 Substation Automation Initiative

For the past five years, LADWP has implemented a comprehensive program to install a new Power System Substation Automation System (SAS) from the Energy Control Center to the Substations, transmission, and Generation Stations. Currently, 80 of the approximate 200 substations and generation stations have been updated to the new Substation Automation, and a new SCADA system has been implemented. There are approximately 70 more stations in the inventory that will be implemented over the next two to three years. Approximately 840 feeders now have remotely controlled circuit breakers and remote monitoring of megawatt loading of wire/cables. A significant amount of data is already being processed through the SCADA system and is available to the load dispatchers and other personnel on an as needed basis. At the conclusion of this project, the vast majority of feeders at all substations will be observable and controllable from the Energy Control Center.

2.6 Distribution Automation Initiative

There have been several pilot projects for the Distribution Automation relating to devices outside the substation walls (Current's Broadband over Power Line project, Ricochet Spread Spectrum project, and Telemetric Cellular project). These projects were never rolled out as the industry was still being developed and LADWP's decision was to wait until more robust solutions were available. Additionally, some of the pilot programs were never considered industry standard since it was using obsolete

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technology. The LADWP is currently evaluating fault indicators, remotely controlled switches and automatic cap banks. These devices can be used for dynamic optimization of the distribution system.

2.7 AMI Metering Initiative

LADWP has been progressing over the past few years with the AMI Metering Initiative.

- As of 6/01/11, the LADWP has installed 162,200 AMR meters
  - Residential Meters (F meters) – 85,000 (using RF Technology and one way communication providing billing information for walk or drive by meter reading)
  - Small Commercial Demand Meters (FM meters) – 68,000 (using RF Technology and one way communication providing billing information)
  - Large Commercial Wireless Meters (A meters) – 9,000 (using Cellular Technology and two way communication providing billing information and load profile information)
- AMR meters represent approximately 10.6% of the total meters in the system but over 45% of the power revenue

Wireless meter reading and real-time pricing are available for 9,000 Large Commercial Customers with demand greater than 200kW. The newest AMI meters have the capability of short range connectivity. This feature will be used by the Home Area Network devices that display various real-time energy consumption data to the customers.

2.8 Demand Response Initiative

LADWP has had a Demand Response (DR) rate for years for large industrial users. Currently, there are 30 Megawatts of interruptible load, but very rarely has this been used because LADWP has had a philosophy to cover all its loads. This pilot program is also voluntary in that when a load reduction is required, the customer has the option to not participate and pay for the higher cost of energy. Currently, the LADWP is planning to develop a formal demand response program that will allow the Department to reduce generation cost and distribution system strain during peak consumption periods.

2.9 Communications Initiative

The component that pulls all of the initiatives together is the common communication network. Over the past ten years, thousands of miles of fiber optic cable has been installed in over 72 substations as part of a fiber optic broadband infrastructure. The plan is for all substations to have fiber optic connections within the next two years.

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LADWP evaluates different communication protocols that can be used for the real-time control and observation of deployed automation equipment.

2.10 Cyber Security Initiative

The implementation of Smart Grid will involve a wide deployment of smart remotely controlled network capable devices. These devices can be potential points of cyber attack due to network connectivity. This is why NERC and FERC have developed strict procedures and guidelines that require utilities to treat any critical cyber asset (CCA) with great attention. The breach of CCA can result in critical damage to the power distribution system.

Due to the importance of Cyber Security, the Smart Grid will need to better understand and improve the cyber security, and more importantly, three key items will be developed:

- Grid Resilience: this effort will show how the Smart Grid can operate resiliently against physical and cyber attack.
- Operational Effectiveness: this effort will demonstrate a complete cyber security testing approach for components and installed systems.
- Redefinition of Security Perimeter: this effort will demonstrate new cyber security measures that address the expansion of this perimeter by Smart Grid technologies to the meter in residential and commercial sites.

2.11 System and Data Integration Initiative

Significant progress has been made in the Power System in implementing the best of breed systems (see **Figure 2.11-1** Power System Technology Architecture). These systems are the backbone of the business and information processes in the Power System. Additionally, significant integration between these and the corporate systems is in place.

In particular, OSIsoft's Pi Historian is a fast real time data processing system that has been purchased and installed by LADWP. The next Pi Historian initiative is to use it as a central repository for all of LADWP's real-time data and to allow access to the appropriate users of the data throughout the utility. LADWP has currently installed the Pi Historian in two locations (ECC and JFB) with a tag count of 20,000 data points. There are three pilot Pi Historian applications running at this time: 1) door/gate alarm; 2) Operation logger; and 3) Power System Dashboard real time data. Five user groups (Reliability, Planning, Station Operators, Grid Operations, and Meter) are also currently developing new applications.

In addition, LADWP is working on integrating the Meter Data Management System (MDMS), Outage Management System (OMS), and Customer Information System

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(CIS) with various Web services. These services will be designed to provide accurate and timely information to customers regarding their consumption, billing, any pending outages and restoration statuses. The customers will have the option to adjust their accounts to set up their profile and notification preferences.

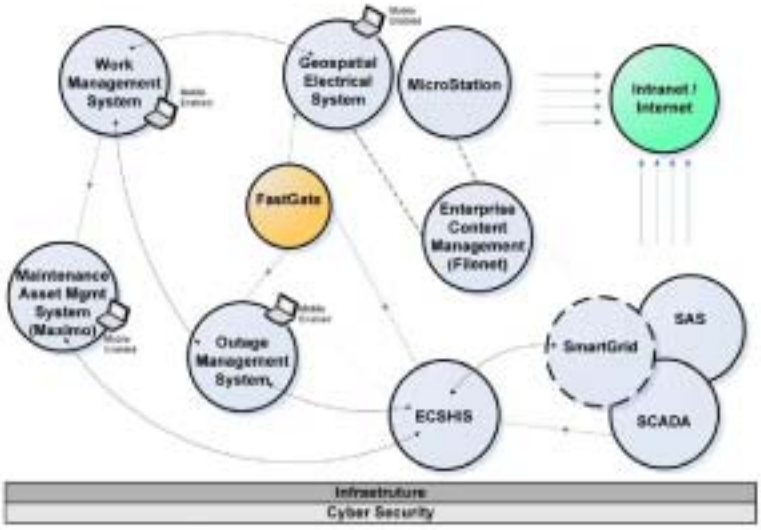

Figure 2.11-1 Power System Technology Architecture

2.12 Feed-In Tariff Initiative (FiT)

FiT seeks to purchase energy from small and medium-scale renewable energy projects (from 30 kilowatts up to one megawatt in AC capacity) within the service territory of LADWP under a long-term Standard Offer Power Purchase Agreements (SOPPA). The SOPPA terms are standard for all participants, can be up to 20 years in duration, and participants will be paid the bid base price of energy plus Time-of-Delivery (TOD) multipliers. FIT is a distributed generation (DG) program designed for the local Los Angeles market, and gives LADWP customers the opportunity to sell energy to LADWP from using their property as the DG site.

2.13 Solar Incentive Program (SIP)

The LADWP Solar Photovoltaic Incentive Program provides financial incentives to LADWP customers who purchase and install their own solar power systems. LADWP currently also provides an additional incentive payment for systems using PV modules manufactured in the City of Los Angeles.

LADWP currently provides a Los Angeles Manufacturing Credit (LAMC) for qualifying photovoltaic equipment manufactured in Los Angeles as approved by the LADWP guidelines. The goal of the LAMC is to promote local economic development through

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manufacturing and job creation within the City of Los Angeles and to reduce costs through increased volume and competition.

3 Proposed Deployment Plan

The overall scope of the Smart Grid Deployment Plan includes the following three overlapping phases:

3.1 Implement a short term plan (one year horizon)

This plan includes the following coordinated activities:

- Create a Smart Grid System Architecture (**Table 3.1-1** *SG Architecture (Phase 1) Schedule* & **Table 3.1-2 SG Architecture (Phase 2) Schedule**)
- Create a Comprehensive Business Plan/Case (**Table 3.1-3 SG Business Plan Schedule**)
- Integration of Various Information Systems
- Participate in Standard Development
- Creation of a Multi Disciplinary matrix team

Table 3.1-1 SG Architecture (Phase 1) Schedule

Table 3.1-2 *SG Architecture (Phase 2) Schedule*

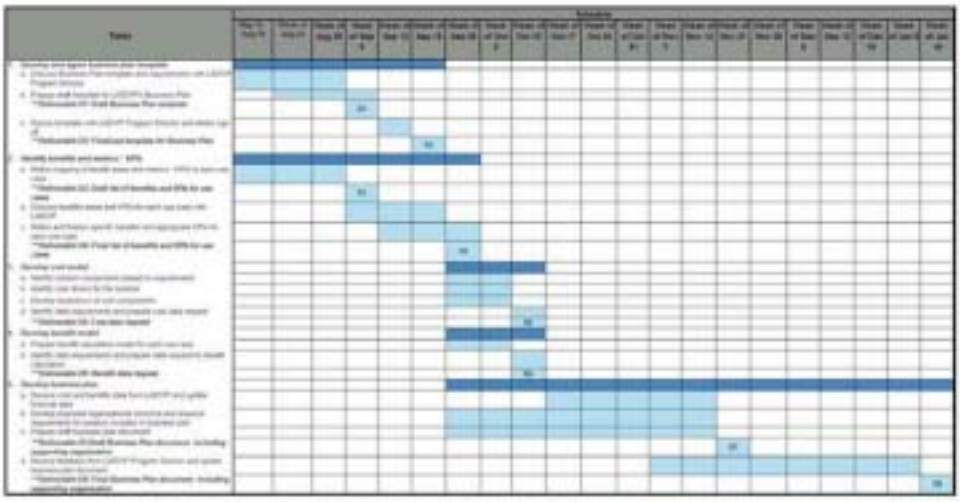

Table 3.1-3 *SG Business Plan Schedule*

3.2 Implement a mid term plan (up to five years horizon)

This plan includes the following coordinated activities:

- Complete and implement LADWP's ARRA Smart Grid Regional Demonstration Project, which focuses on Customer and Behavioral Studies, Cyber Security, Demand Response, and Electric Vehicles.

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Figure 3.2-1 *Smart Grid Regional Demonstration Project Schedule* below shows the implementation schedule of the Smart Grid Regional Demonstration Project.

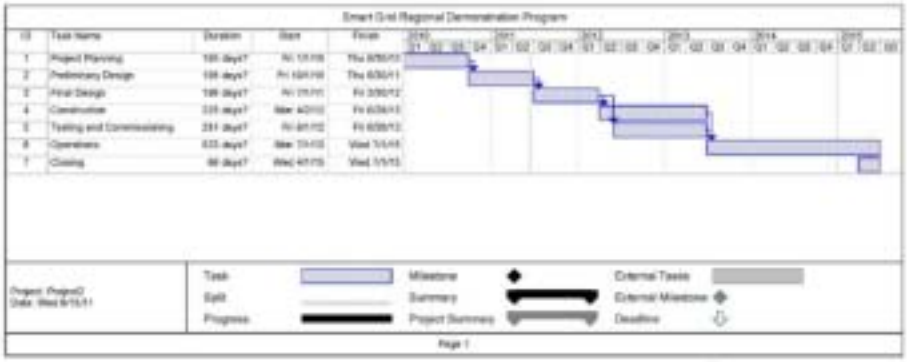

Figure 3.2-1 Smart Grid Regional Demonstration Project Schedule

- Implement the balance of the SAS project to automate all generation, substation, and transmission with the SCADA system. **Table 3.2-1** *Substation Automation Project Installation Progress Schedule* below shows the overall schedule of activities to implement the SAS project.

Stations for Site Acceptance Test (SAT)			
RS-T	Monday, January 25, 2012	Friday, February 12, 2012	3 Weeks
IS-1221	Monday, February 15, 2012	Friday, February 26, 2012	2 Weeks
IS-1263	Monday, March 01, 2012	Friday, March 12, 2012	2 Weeks
RS-N	Monday, March 15, 2012	Friday, April 02, 2012	3 Weeks
DS-24	Monday, April 05, 2012	Friday, April 16, 2012	2 Weeks
RS-C	Monday, April 19, 2012	Friday, May 07, 2012	3 Weeks
DS-135	Monday, May 10, 2012	Friday, May 21, 2012	2 Weeks
RS-E	Monday, May 24, 2012	Friday, June 25, 2012	5 Weeks
DS-81	Monday, June 28, 2012	Friday, July 09, 2012	2 Weeks
DS-30	Monday, July 12, 2012	Friday, July 23, 2012	2 Weeks
RS-M	Monday, July 26, 2012	Friday, August 06, 2012	2 Weeks
DS-36	Monday, August 09, 2012	Friday, August 20, 2012	2 Weeks
DS-76	Monday, August 23, 2012	Friday, September 03, 2012	2 Weeks
RS-U	Monday, September 06, 2012	Friday, September 24, 2012	3 Weeks
DS-21	Monday, September 27, 2012	Friday, October 08, 2012	2 Weeks
RINALDI	Monday, October 11, 2012	Friday, October 29, 2012	3 Weeks
DS-26	Monday, November 01, 2012	Friday, November 12, 2012	2 Weeks
HALLDALE	Monday, November 15, 2012	Friday, December 03, 2012	3 Weeks
DS-143	Monday, December 06, 2012	Friday, December 17, 2012	2 Weeks
DS-15	Monday, December 20, 2012	Friday, December 31, 2012	2 Weeks
RS-J	Monday, January 03, 2013	Friday, January 21, 2013	3 Weeks

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DS-2	Monday, January 24, 2013	Friday, February 04, 2013	2 Weeks
RS-Q	Monday, February 07, 2013	Friday, February 25, 2013	3 Weeks
DS-95	Monday, February 28, 2013	Friday, March 11, 2013	2 Weeks
RS-L	Monday, March 14, 2013	Friday, April 01, 2013	3 Weeks
DS-50	Monday, April 04, 2013	Friday, April 15, 2013	2 Weeks
RS-S	Monday, April 18, 2013	Friday, May 06, 2013	3 Weeks
DS-56	Monday, May 09, 2013	Friday, May 20, 2013	2 Weeks
RS-R	Monday, May 23, 2013	Friday, June 10, 2013	3 Weeks
DS-105	Monday, June 13, 2013	Friday, June 24, 2013	2 Weeks
RS-F	Monday, June 27, 2013	Thursday, June 30, 2013	1 Weeks
RS-Q	Sunday, July 03, 2013	Thursday, July 21, 2013	3 Weeks
IS-3115	Sunday, July 24, 2013	Thursday, July 28, 2013	1 Weeks
IS-3130	Sunday, July 31, 2013	Thursday, August 04, 2013	1 Weeks
IS-1671	Sunday, August 07, 2013	Thursday, August 11, 2013	1 Weeks

Table 3.2-1 Substation Automation Project Installation Progress Schedule

- Implement the balance of the projects at ECC to use all of the features and upgrades of the SAS and other systems with the new technology. **Figure 3.2-2** ***ECC Plans to be Implemented*** below shows the activities and systems to be implemented.

Figure 3.2-2 ECC Plans to be Implemented

- Implement the balance of the projects at ETC to use all of the features and upgrades of the Smart Grid systems with the new technology. **Figure 3.2-3** ***ETC Plan and Enhancements*** below shows the various activities to be implemented.

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Figure 3.2-3 ETC Plan and Enhancements

- Implement a new CIS and Supply Chain System

The effort must be made to implement a new CIS, and a new Supply Chain Corporate System. These systems will be able to manage the new information and transaction of a Smart Grid system.

Other activities to be implemented during this phase are as follows:

- Implement the balance of the electric model with the GIS system and engineering design tools
- Create and advertise Multiple RFPs as needed to start the implementation of the Smart Grid components
- Create Multiple contracts as needed to bring the vendors on-board

3.3 Implement the full Smart Grid Features (up to 10 years)

Implement all the remaining features indicated in this plan in various phases based on the requirements and needs identified, and with the dynamics of the utility and technology environment. The phases of this significant program could include two large pilot periods where various telecommunication technologies will be tested while Smart Grid technology will be utilized to cover overhead, underground, single family residences, multi-family residences, and medium and large customers in a couple of neighborhoods. The final phase would be the full city wide implementation assuming the data and results from the pilot programs are satisfactory.

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The full functionality of the Smart Grid could include all of the following aspects:

(a) Outage Notifications

(b) Transformer Monitoring

(c) Capacitor Controls

(d) Line Switch Controls

(e) Automatic Meter Reading

(f) Load Control of residential and commercial devices (DSM Program)

(g) Video Surveillance via Smart Grid

(h) Fault Management

(i) Transformer Deterioration

(j) Transformer Overloading

(k) Current Monitoring

(l) Cable Management

(m) Surge Protection

(n) Lighting Controls

(o) Weather

(p) Municipal Applications

(q) Other applications as they become available.

Other features could include:

- Installation of Smart Grid equipment in the City of Los Angeles Facilities
- Installation of Smart Grid equipment and potentially replacement all of the water meters
- Access to broadband capabilities (Internet access, VoIP, video) for City of Los Angeles Municipality
- Access to City of Los Angeles Municipal information via broadband connections

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- Set up an internal LADWP organization to maintain and operate the Smart Grid equipment
- Maintain, install, and operate the Smart Grid equipment through the following organization and service components:

  1. Services
  2. Customer response center
  3. Network Operation Center (NOC)

3.4 Related Projects

The following projects are related to the Smart Grid as follows:

1. Substation Automation System: Extension and upgrade of the remaining Switching, Receiving, and Distribution Systems
2. Telecommunications system: Extension and upgrade of the telecommunications to support the Power System operations through the implementation of a fiber optic broadband network.
3. Subtransmission and distribution switches: Automation of subtransmission and distribution switches, implementing line monitoring, line switch control, and 4.8 kV line capacitor bank control.
4. Fault and outage detectors: Installation of remotely monitored fault and outage detectors which would provide a means to locate faults and outages on selected 4.8 kV distribution lines.
5. Operating orders, procedures, and processes: Re-engineering of operating orders and processes as required for monitoring and controlling changes of the Power System.

3.5 Constraints

The following are potential constraints:

- Budget/Cost
- Regulatory environment which may limit Smart Grid installations
- Internal Resources
- Political environment (City/State/Federal)

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3.6 Urgency

The timing of LADWP's Smart Grid Deployment coincides with the initiatives by other major U.S. utilities. Additionally, the Department of Energy is encouraging utilities to invest in Smart Grid by offering grants and the regulatory environment seems to support Smart Grid as an alternative to the existing utility practice.

3.7 Procurement Process

The Smart Grid Plan will utilize the procurement process as follows:

(a) Determination of requirements

(b) Preparation of RFP(s)

(c) Vendor(s) Selection

(d) Preparation of Agreements

(e) Initial Implementation – Phase 1

(f) Phase 1 Evaluation

(g) Multi-phase implementation over the next 10 years.

4 Critical Milestones

4.1 Schedules and Critical Milestones

The Smart Grid Plan assumes a 1-year, 5-year, and 10-year implementation.

4.1.1

4.1.2 Critical Milestones

Table 4.1.2-1 Critical Milestones illustrates the critical milestones:

Milestone or Event	Significance
Smart Grid Business/Project Plan and Architecture Presentation	Get concurrence from Management
Setup of Smart Grid Project Committee	Establish Project Committee
Preparation of Smart Grid Project Requirements	Establish project requirements
Advertise Request for Proposals	Request for Proposals
Vendors Selection	Selection of qualified bidder
Board Approval	Contract approval by LADWP Board of Commissioners

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City Council Approval	Contract approval by City of Los Angeles
Contracts Award	Execution of contract award
Implementation Phase 1	Implement Smart Grid Phase 1 (Pilot Programs)
Evaluation of Phase 1	To continue Full Implementation
Begin full deployment	Implement city wide

Table 4.1.2-1 Critical Milestones

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5 Budget

Smart Grid equipment costs are expected to continue to drop due to technology advances and significant market changes, **Table 4.1-1** Budget Estimates for various Systems given below is our best estimate for various alternatives at this point. As RFPs are produced and responses are received, we will have a better idea as to the cost of these types of systems and process.

	Single Unit				Total			
	P2P	Single Unit RF	RF Mesh	BPL/PLC	P2P	RF	RF Mesh	BPL/PLC
AMI (w/o communications)								
Residential	200.00	160.00	200.00	220.00	248,992,000.00	199,193,600.00	251,992,000.00	273,991,200.00
Commercial	317.50	347.50	387.50	337.50	57,029,032.50	62,417,602.50	69,602,362.50	60,621,412.50
Industrial	367.50	367.50	367.50	376.50	17,050,897.50	17,050,897.50	48,485,525.50	17,468,470.50
					323,071,930.00	**278,662,100.00**	**400,079,888.00**	**351,981,083.00**
DA 4.8 kv (w/o communications)								
switches	950.00	-	950.00	1,150.00	12,831,850.00	-	12,831,850.00	15,533,050.00
capacitors	950.00	-	950.00	1,150.00	2,998,200.00	-	2,998,200.00	3,629,400.00
transformers	950.00	-	950.00	1,150.00	96,210,050.00	-	96,210,050.00	116,470,850.00
DA 35.5 kv (w/o communications)								
switches	1,700.00	-	1,700.00	-	8,746,500.00	-	8,746,500.00	-
capacitors	950.00	-	950.00	-	-	-	-	-
					120,791,400.00	-	**120,791,400.00**	**135,633,300.00**
DR (w/o communications)								
Residential	77.00	-	77.00	77.00	95,861,920.00	-	95,861,920.00	95,861,920.00
Commercial	77.00	-	77.00	77.00	13,830,663.00	-	13,830,663.00	13,830,663.00
					109,692,583.00	-	**109,692,583.00**	**109,692,583.00**
Communications					**7,671,847.47**	**10,407,798.40**	**10,407,798.40**	**49,624,933.00**

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SAS					60,000,000.00	60,000,000.00	60,000,000.00	60,000,000.00
Applications					110,000,000.00	110,000,000.00	110,000,000.00	110,000,000.00
				TOTAL	731,227,760.47	459,069,890.40	746,537,041.40	818,831,566.00

Table 4.1-1 Budget Estimates for various Systems

The pie chart below (**Figure 4.1-1** P2P Cost Graph) depicts the P2P estimated cost in the nine different categories of the smart Grid.

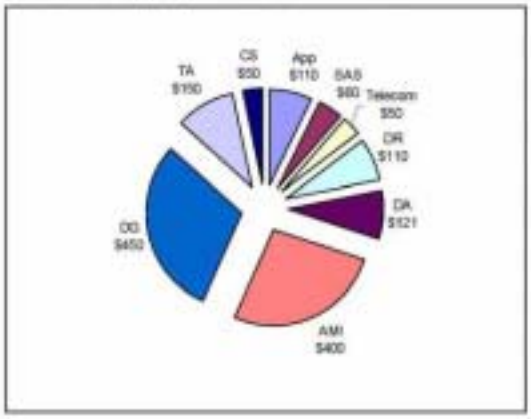

Figure 4.1-1 P2P Cost Graph

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6 Impacts

6.1 Internal

The Smart Grid equipment will impact several areas within LADWP. **Table 6.1-1** Potential Impacts within LADWP shows some potential impacts on these organizations:

Area within LADWP	Nature of impact
Meter Reading	Automated method reading of electric meters
Control System Operations	may gain capability to control devices at all levels
Customer Service	Establish direct communications with customer
Electric Trouble Dispatch	Will process trouble calls using Smart Grid information
Engineering Design	Power network design process (OH/UG)
Distribution Line Crews	Maintain and operate new Smart Grid equipment
ITS	Provides support of Smart Grid network equipment
Water Meters	Automated method of reading water meters

Table 6.1-1 Potential Impacts within LADWP

Area within the department	Nature of impact
Energy Control Center	Will use SAS for real-time data instead of current RTU
Electric Trouble Center	Will use real-time data
Plant Control System Operations	Will use real-time data access and archived data
Substation Operations	Selected station status information will be available
Substation Maintenance	Will access intelligent relay settings and logs without having to connect directly to the devices
ITS	Provides support of ECS WAN network.
Power Systems Operation and Maintenance	Provides support of SAS application software and hardware
Engineering	Will use archived data

Table 6.1-2 Potential Impacts within department

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6.2 External

Table 6.2-1 Potential Impacts external to LADWP shows some potential impacts on organizations that are external to LADWP:

Area external to LADWP	Nature of impact
City of Los Angeles	Gain fiber optic broadband infrastructure
Broadband Companies	May perceive competition from LADWP and receive services.
Gas Utility	Opportunities to collaborate with LADWP
State of California (CPUC)	May encourage Smart Grid installation at Los Angeles

Table 6.2-1 Potential Impacts external to LADWP

7 Smart Grid Business Plan & Evaluation Strategy

A Smart Grid business plan will be developed in conjunction with the roadmap and architecture development activities which will include cost-benefit analysis of projects for implementation of the functionality identified in the Smart Grid architecture and roadmap. The business plan documentation will outline the project description; costs associated with the implementation; and expected benefits. The financial analysis will be based on estimated benefits and costs information and will be updated throughout the course of the implementation of the projects as the actual cost data become available. The business plan development process will include an assessment to identify the benefit areas and develop an estimate of actual quantifiable benefits expected from investment into particular Smart Grid area. The benefits resulting from LADWP's Smart Grid investments could be in various areas including but not limited to better customer service, reduced operational costs, higher operational efficiency, and achievement of environmental goals. The benefit estimation will be developed using LADWP KPIs and other relevant metrics. The business plan will also include a cost model to estimate the implementation costs of each project. The cost estimates will be based on assumptions of the technology and implementation choices, and will be updated during implementation of the projects with actual costs and implementation plans.

8 Smart Grid Safety

Smart Grid Deployment Plan requires specific installation, maintenance, and operation procedures, which LADWP personnel will need training on. Additionally, the Smart Grid equipment will require compliance and resolution of issues relating to the following state regulations:

(a) California Public Utilities Commission - General Order 128 – Construction of underground electric supply and communication systems.

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(b) California Public Utilities Commission - General Order 95 – Overhead electric line construction.

(c) California Public Utilities Commission - General Order 165 – Inspection Cycles for electric distribution facilities

(d) The Smart Grid vendors and utilities are currently handling all of these issues with success.

9 Smart Grid Operational issues

LADWP intends to own and operate the Smart Grid equipment. The ownership entails the support and ability to operate the Smart Grid network by LADWP personnel.

The following are potential operational issues:

- 24/7 operational support of the Smart Grid equipment
- Training of Crews for the operation and maintenance of the Smart Grid equipment
- 24/7 operational support of the telecommunications and fiber optic broadband infrastructure access

10 Smart Grid Performance Measurement

The critical success factors essential for plan success are as shown in **Table 10-1** Critical Success Factors:

Critical Success Factors	Measurement method
Plan Buy-in from LADWP Board	LADWP Board Approval
Plan Buy-in from City	City Council approval
Appropriate plan budget	Budget approval
Smart Grid Technical Feasibility	Market proven Smart Grid technology
Secure staffing resources	Appropriate resource leveling based on project scope
Regulatory Support for Smart Grid	City, State legislative approvals for Smart Grid implementation

Table 10-1 Critical Success Factors

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11 Smart Grid Product Benefits Realization

The benefits will be measured as shown in **Table 11-1** Benefits:

Potential Benefits	Measurement method
Municipal fiber optic broadband Capability	No. of City of Los Angeles Broadband users
Smart Grid enabled Automated meter reading	No. of automated meter reads
Customer Energy Management Programs	No. of devices under Direct load control
Improved reliability	No. of Utility applications in service
Additional Revenue Sources	Capitalize on revenue generating opportunities

Table 11-1 Benefits

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12 Conclusion

The Los Angeles Department of Water and Power is dedicated to integrating new technologies to improve system performance, power flow control, safety and reliability. By maintaining a high level of commitment and service for the City of Los Angeles, LADWP is taking the necessary steps to:

(a) Coordinate efforts across multiple stakeholders

(b) Integrate new technologies to supplement the power system

(c) Deliver safe, secure, and efficient electrical service well into Los Angeles's future

LADWP's overall strategic plan is inclusive of the Smart Grid Deployment plan. LADWP's focus is the City of Los Angeles, customer enhancement, utility services, and operations. LADWP looks forward to further collaborate with policymakers, customers, and stakeholders as the process of Smart Grid implementation unfolds.

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Appendix M - Climate Change Effects on Power Generation

The association of power generation and climate change usually centers on the industry's contribution towards atmospheric Greenhouse Gas (GHG) emissions and its efforts to reduce such emissions. Throughout this IRP is discussion of various LADWP programs and projects whose key objective is to lower GHG emissions. However, an important factor to also consider in resource planning is how climate change *affects* electricity demand, or consumption, and how it impacts the process of generating electricity. Rising average temperatures, changes in precipitation amounts and patterns, more frequent extreme weather events and a rise in sea level are some of the effects that may be expected from global warming. Understanding how these effects impact power generation and incorporating that knowledge into the planning process facilitates adaptation of the power system to respond in a way that mitigates potential problems and takes advantage of any opportunities.

The effects of climate change on resource planning can be addressed on two levels: (1) how it affects *energy consumption*, and thus how much generation should be planned for and secured, and (2) how it affects *power generation* operations and the siting of new facilities.

Energy Consumption

The effects of rising temperatures on energy consumption will vary by region and season. In traditionally cooler regions, net energy use may actually decrease due to less heating requirements. In warmer regions, an increase in cooling demand will mean an increase in energy usage, specifically electricity. Within LADWP's service territory, a net increase in electricity for cooling can be expected. Along with increased temperatures, there is also an increased potential for extreme weather events, such as heat storms of longer duration. Preliminary findings are as follows:

Global Warming Impacts Affecting Energy Consumption

1. Mean temperatures will continue to rise in Los Angeles increasing Cooling Degree Days and decreasing Heating Degree Days.[1]
2. Extreme heat conditions, such as heat waves and very high temperatures, may last longer and become more common place.[2]
3. Air conditioning saturation will increase with the rise of mean temperatures.[3]

[1] Climate Scenarios for California, California Energy Commission, CEC-500-2005-203-SF

[2] Global Climate Change, California Energy Commission, CEC-600-2005-007, page 2

[3] Air conditioning market saturation and long-term response of residential cooling energy demand to climate change, D.J. Sailor, Energy 28 (2003) pages 941-951

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These effects have been incorporated into LADWP's load forecast. Due to the ongoing nature of climate change studies and advancements, it is important that LADWP stay abreast of current findings and conclusions, and incorporate such findings as appropriate.

A recent study by the UCLA Department of Atmospheric and Oceanic Sciences[4] focuses on temperature changes in the Los Angeles region in years 2041-2060. A key attribute of the study is its high resolution perspective for the Los Angeles region, including unique predictions for individual areas such as San Pedro, Woodland Hill, San Fernando and Downtown LA. Due to the region's varied topology, some areas are expected to experience more warming than others.

The UCLA study results for the City of Los Angeles show annual average temperature increases of between 3.7 and 4.3 °F (an average increase of 4.0 °F), depending on location within the city.[5] The number of days per year in which temperatures will surpass 95 °F are shown to increase – at worst by a factor of 4.0, but again depending on location as shown in Table M-1 below:

Table M-1 – NUMBER OF DAYS WITH TEMPERATURES ABOVE 95 °F

	Number of Days Baseline	Number of Days, Study Results, Mean	Increase Factor over Baseline
Downtown	1.4	4.6	3.3
San Pedro	0.6	1.4	1.4
Venice	0.1	0.1	1.0
Sylmar	6.8	25.5	3.8
San Fernando	7.9	26.3	3.3
Woodland Hills	4.2	16.7	4.0
El Sereno	2.3	6.8	3.0
Eagle Rock	2.0	6.0	3.0
Porter Ranch	8.0	30.1	3.8

While the UCLA study looks at temperature changes in the 2041-2060 timeframe (which is beyond the 20-yr planning horizon for the 2012 IRP), the findings corroborate other studies and supports the expectation of higher future temperatures which will increase electricity use. As this study is specific to the Los Angeles region, it provides detailed information which local government, utilities (including LADWP), hospitals and other institutions can use to help prepare for the future.

[4] Hall, et al., 2012: Mid-Century Warming in the Los Angeles Region. Available at: www.c-change.LA
[5] The study includes two GHG emission scenarios – a business-as-usual scenario and an aggressive emissions mitigation scenario. The data noted here is from the business-as-usual scenario.

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Power Generation

The impacts of climate change on power generation go beyond the need to meet increased loads and higher peak demands. The potential expressions of global warming that are the major areas of concern for power generation are extreme weather events, water availability, and rising sea levels. Consequences include decreased thermal efficiencies and siting impacts for new facilities.

Extreme Weather

From a national perspective, an increase in "extreme weather conditions" usually refers to an increase in the number, intensity and duration of hurricanes, such as on the East Coast and Gulf of Mexico, tornadoes in the Mid-West, floods, droughts, etc. These extreme events have the power to disrupt and damage power generating facilities. Fortunately, such events affecting LADWP generation sources have been relatively less frequent. However, extreme weather conditions in other areas of the country can impact LADWP by disrupting fuel supply production and transportation.

Locally, an increase in frequency of weather anomalies can be a cause for concern. In July 2006, a prolonged heat wave resulted in major service disruptions. And in November 2011, a severe wind storm resulted in extensive damage and power outages across the region, affecting over 220,000 LADWP customers. Such events stretch available resources and expose vulnerabilities in the electric delivery system. To the extent climate change contributes to an increase in such events, more human and capital resources must be provided to increase the resiliency of the electricity infrastructure to better withstand these extreme conditions; and, when outages do occur, to restore interrupted service in an expeditious manner that adequately addresses public health and safety needs.

Water Availability

Changes in weather patterns due to climate change will likely result in increased variations of water availability, with some regions experiencing more drought conditions and other areas becoming more subject to flooding. This affects power generation in a number of different ways. A decline in water levels behind hydro dams will decrease generation capacity which would have to be made up elsewhere. Changes in stream and river flows will affect the output of run-of-the river hydro facilities, which may be positive or negative. Flooding conditions could threaten the operation of generating stations, including renewable wind and solar facilities. In drought stricken areas, a scarcity of cooling water availability will increase the demand and price for water. Increased competition for water can be expected from other water consumers, including the agriculture, mining, industrial, residential and commercial sectors within the affected region.

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For California, the research to date indicates a potential of reduced snowpack in the Sierras, which would decrease hydro-electric output. An increased likelihood of drought conditions in the U.S. Southwest would also impact hydro generation in addition to constraining sources for cooling water. Developments such as these will have negative implications for LADWP's hydro-electric and thermal generation operations.

Sea Level Rise

Sea Level Rise (SLR) is another area of ongoing study. While projections vary, the October 2010 State of California Sea-Level Rise Interim Guidance Document uses a baseline that estimates a 5-8 inch rise by year 2030. Within the 20-year planning horizon of this IRP, SLR in this range will not present a problem to LADWP's coastal generating facilities. Longer-term effects, such as what may be projected for the end of the century, would be addressed over time. Because the more pronounced effects of SLR are not anticipated to occur until 60+ years into the future, strategies to mitigate possible negative impacts can be developed and implemented in a deliberate and methodical manner. For example, generating stations are expected to be replaced every 50-55 years, and if warranted due to extreme SLR, consideration can be given to relocate inland as part of the replacement process.

Decreased Thermal Efficiency and Output

An increase in temperature due to global warming will impact the thermodynamic efficiency for power plant generating equipment. An increase in ambient temperature decreases efficiency, resulting in less output per unit of fuel. On average, an increase of 5 °F decreases efficiency by approximately 0.4 to 0.8 percent. Higher temperatures would also decrease the amount of energy capable of being generated. A 5 °F increase reduces available output by about 1.0 to 2.0 percent.[1]

New Facility Siting

The potential impacts of water availability and extreme weather events could impact the siting of new energy generation and transmission infrastructure. This would be more pronounced in areas where water availability is expected to decrease, such as the US Southwest. This doesn't necessarily preclude potential sites as candidate locations, but it may necessitate higher construction and operation costs, and incorporation of engineering designs and processes that are more weather-hardened and use less water.

Actions to Address Climate Change

Reducing GHG emissions to minimize its impact on climate change/global warming is a key LADWP strategic objective. As discussed in other parts of this IRP, LADWP is

[1] The ranges shown reflect differences across different generation methods (e.g., combined cycle vs. combustion turbine). Values shown are approximations. Relative humidity is also an influencing factor.

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modifying its resource mix to adopt more renewable resources such as wind and solar, which do not emit GHG emissions. Replacing older inefficient gas-fired units at its in-basin generating stations will reduce the amount of fuel needed to generate electricity, which also decreases emissions. Ensuring the adoption of energy efficiency programs will offset the amount of emissions in direct proportion to the resulting energy savings – every unit of electricity saved also eliminates the corresponding amount of GHG that would otherwise be emitted. And, to further reduce GHG emissions LADWP is actively working to divest itself from its two coal power plants – the Navajo Generating Station and the Intermountain Power Project – although contractual, legal and financial issues present challenges that need to be worked out.

To prepare for and adapt to climate change, LADWP incorporates into its load forecast increases in electricity demand resulting from expected higher future temperatures. Implementation of LADWP's Power Reliability Program will increase the resiliency of its electricity delivery infrastructure, better preparing it to withstand the more frequent and prolong weather events (heat waves) that will be expected. Other considerations include a heightened awareness and accounting of potential effects on water availability, new facility siting, thermal efficiencies, and sea level rise. Although this IRP document addresses only the power side of LADWP, it is worth noting here that water conservation will play a large role in both reducing GHG emissions and as a means of adapting to the effects of climate change.

Conclusion

Global warming is a major environmental concern that warrants continuous attention. LADWP's efforts to reduce GHG emissions should continue, as should planning activities to prepare for and adapt to the future consequences of climate change. As a responsible municipal utility, LADWP should base its recommendations and actions on sound scientific studies and principles, and in concurrence with City policy.

As the science of climate change continues to evolve, LADWP should stay abreast of the latest findings and conclusions. Subsequent IRPs will monitor developments in climate change and develop/refine recommendations to mitigate any negative impacts as part of the resource planning process.

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Appendix N Model Description and Assumptions

N.1 Overview

The study horizon for the model analysis is the 20 year period 2012 through 2032. In performing this modeling, it is necessary to assume certain actions are taken in each of the next 20 years. However, it must be understood that the Integrated Resource Plan (IRP) is an ongoing process. A new IRP is developed every two years. Between each 2-year interval, the most recent IRP is modified if appropriate. The key results from this IRP analysis is the action plan that will be put in place for the next 1 to 5 years. These near-term actions are important recommendations that will enable and support the goals and objectives of the long term plan.

This Appendix presents the Model Analysis and is organized as follows:

- Section N.2, Model Description, provides a description of the model selected by LADWP to simulate the operation of its power system under different futures and with different resource portfolios.
- Section N.3, Resource Selection Process/Gap Analysis, describes the method used to assess the amount of future renewables and other replacement resources required to satisfy resource adequacy requirements including a description of the valuation process used in selecting the future renewable resource portfolio.
- Section N.4, Avoided Costs and Net Revenue Losses, describes the analysis and results to determine the net revenue loss used in the evaluation of the energy efficiency and distributed generation case comparisons (Cases 5 thru 8) found in Section 4.3.3.1.
- Section N.5, Model Inputs and Assumptions, presents the major input parameters that were used in the production cost model runs.

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N.2 Model Description

LADWP has chosen a widely used and industry accepted hourly chronological unit commitment and dispatch model to simulate the operation of the LADWP power system under different futures and with different resource portfolios. The model is the Planning & Risk model (PaR) licensed from Ventyx (an Atlanta based software firm). It uses the PROSYM unit commitment and dispatch algorithm.

PROSYM is designed for performing planning and operational studies, and as a result of its chronological structure, accommodates detailed hour-by-hour investigation of the operations of electric utilities. Because of its ability to handle detailed information in a chronological fashion, planning studies performed with PROSYM closely reflect actual operations. PROSYM considers a complex set of operating constraints to simulate the least-cost operation of the utility. This simulation, respecting chronological, operational, and other constraints, is the essence of the model.

This model looks at the LADWP load for each hour and then dispatches LADWP generation supplies on an economic basis (lowest variable cost units first) until the load is met. The model output reflects all the variable costs incurred in meeting the load for each study performed. The fixed costs for the resources are added to the modeled variable costs to develop the total power cost incurred in meeting the load.

The model is also capable of representing certain transmission constraints on a utility system. LADWP load is generally confined to the geographic area of Los Angeles. An IRP would not generally be a replacement for transmission planning activities needed in the service area. However, LADWP does have generation outside of Los Angeles and has transmission rights to other areas of the Western Interconnect. To better represent the constraints and opportunities related to these remote facilities, the modeling topology depicted on Figure N-1 was developed for this IRP.

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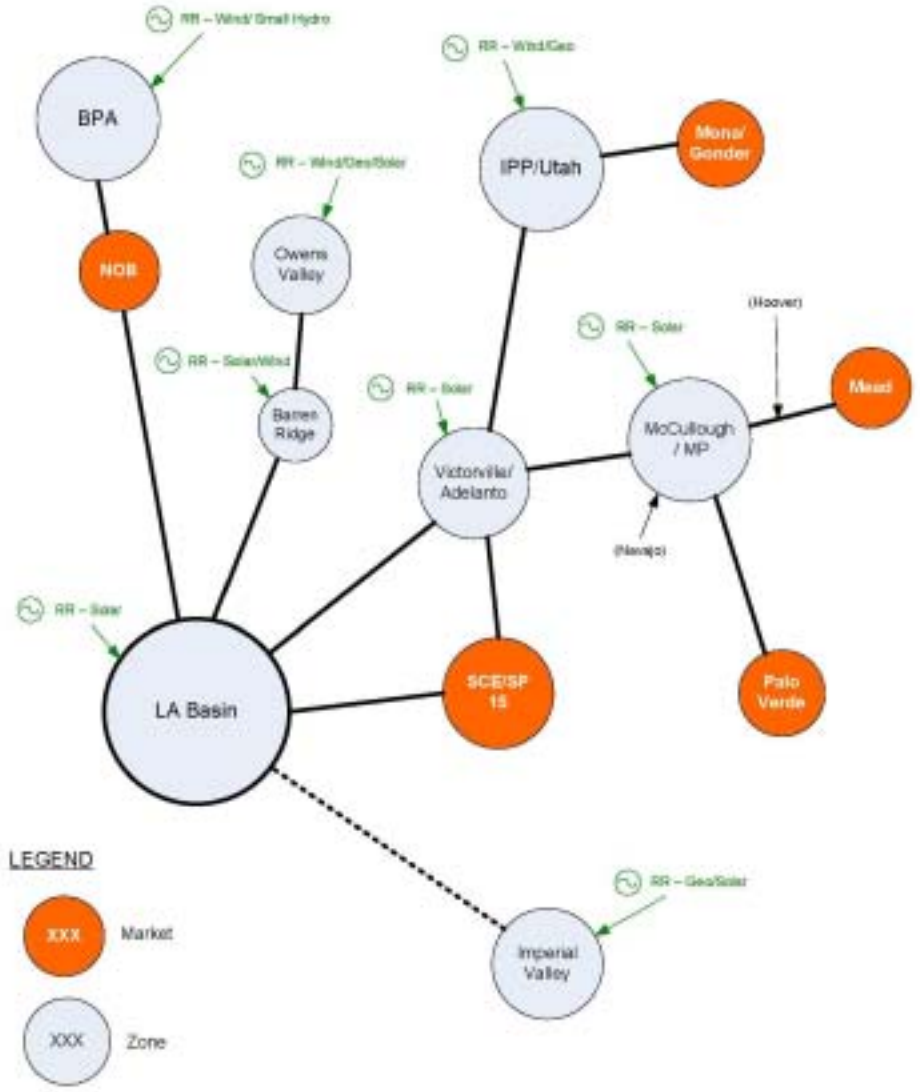

Fig N-1: LADWP Modeling Topology.

On a day-to-day basis, LADWP will buy power in spot markets if such a purchase can be done both without causing a reliability problem and if the price of the spot market power is less than the operating cost of its own power plants. Similarly, on a day-to-day basis, LADWP will sell power in spot markets if the price of power in the spot market is greater than the cost of operating an LADWP resource and the power is not needed to meet LADWP load. In an IRP analysis, it may or may not be desirable to attempt to reflect spot market activity. For this IRP, short term and long term market purchases and sales were included in the overall energy mix. For resource adequacy, some limited Q3 purchases were included to supply short term capacity deficits in future years resulting from coal divestment and load growth.

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N.3 Resources Selection Process/Gap Analysis

The gap analysis in this IRP evaluated both a Resource Adequacy (RA) need as well as a need to meet certain goals for renewables as a percentage of billed energy (renewable need). The RA need compares available generation supplies to the load that needs to be served. For LADWP, this comparison was based on the annual peak load plus a planning reserve margin. In addition to a system wide demonstration of RA, a certain amount of generation needs to be located in the Los Angeles service territory to assure local reliability. Sections 2.4.7, 3.4.2, 4.2.1.4 and 4.3.1 of this report discuss the LADWP approach to RA.

N.3.1 Resources recommended for Resource Adequacy

The displaced energy from early coal replacement is generally replaced with a combination of renewable energy and new gas-fired combined cycle generation. Energy efficiency, demand response, and short term 3rd quarter market purchases are used to primarily satisfy load growth. Table N-1 summarizes the different replacement resources for the different cases that were evaluated.

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Table N-1. Resources recommended for resource adequacy by calendar year

Case#1 (Navajo 2019, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	155	166	175	184	192	199	206	212	217	222	227	231	236
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	22	36	87	223	286	347	393	440	540	547	600	629	658	662	666	673	687	695	703	711	719
Navajo Replacement CC	0	0	0	0	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1250	1150	1250	1150	1250	1150
Q3 Term Purchase	200	175	0	0	0	0	0	0	0	0	0	0	0	25	75	0	0	0	0	50	125
Total Replacement	244	257	165	342	460	563	675	784	1245	1313	1425	1513	1600	1686	1747	2835	2854	2867	2880	2943	3830

Case #2 (Navajo 2015, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	155	166	175	184	192	199	206	212	217	222	227	231	236
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	22	36	87	223	286	347	393	440	540	547	600	629	658	662	666	673	687	695	703	711	719
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1250	1150	1250	1150	1250	1150
Q3 Term Purchase	200	175	0	0	0	0	0	0	0	0	0	0	0	25	75	0	0	0	0	50	125
Total Replacement	244	257	165	342	760	863	975	1084	1245	1313	1425	1513	1600	1686	1747	2835	2854	2867	2880	2943	3830

Case #3 (Navajo 2015, IPP 2020)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	155	166	175	184	192	199	206	212	217	222	227	231	236
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	22	36	87	223	286	347	393	440	540	547	600	629	658	662	666	673	687	695	703	711	719
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	1250	1150	1150	1150	1350	1150	1250	1150	1250	1150	1250	1150
Q3 Term Purchase	200	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	125
Total Replacement	244	257	165	342	760	863	975	1084	1245	2463	2675	2963	2750	2811	2822	2835	2854	2867	2880	2943	3830

Case #4 (Navajo 2015, IPP 2023)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	155	166	175	184	192	199	206	212	217	222	227	231	236
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	22	36	87	223	286	347	393	440	540	547	600	629	658	662	666	673	687	695	703	711	719
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1250	1150	1250	1150	1250	1150
Q3 Term Purchase	200	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	125
Total Replacement	244	257	165	342	760	863	975	1084	1245	1312	1425	1513	2750	2811	2822	2835	2854	2867	2880	2943	3830

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Case#5 Base EE & Base DG (Navajo 2019, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	155	166	175	184	192	199	206	212	217	222	227	231	236
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	22	36	141	223	286	347	393	440	540	547	600	629	658	662	666	673	687	695	703	711	719
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,150	1,150	1,150	1,150	1,150	1,150
Q3 Term Purchase	200	175	0	0	0	0	0	0	0	0	0	0	0	25	75	0	0	0	0	50	125
Total Replacement	244	257	219	342	760	863	975	9084	1245	1313	1425	1513	1600	1686	1747	2838	2854	2867	2880	2943	3038

Case #6 Advanced EE & Base DG (Navajo 2015, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	156	167	178	189	199	210	219	229	238	247	256	264	273
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	25	35	141	223	286	347	393	440	528	547	600	629	658	662	666	668	682	690	698	706	714
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,150	1,150	1,150	1,150	1,150	1,150
Q3 Term Purchase	200	150	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	25	75
Total Replacement	247	232	219	342	760	863	974	9084	1245	1314	1428	1516	1607	1671	1760	2847	2870	2887	2904	2945	3011

Case #7 Base EE & High DG (Navajo 2015, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	155	166	175	184	192	199	206	212	217	222	227	231	236
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	25	35	143	225	295	362	423	518	569	580	658	670	678	686	694	701	720	734	742	755	769
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,150	1,150	1,150	1,150	1,150	1,150
Q3 Term Purchase	200	150	0	0	0	0	0	0	0	0	0	0	0	25	100	0	0	0	0	0	0
Total Replacement	247	232	221	344	769	878	995	1162	1274	1348	1463	1554	1620	1710	1789	2863	2888	2906	2918	2936	2964

Case #8 Advanced EE & High DG (Navajo 2015, IPP 2027)

Capacity (MW)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Energy Efficiency	17	37	58	79	99	116	131	144	156	167	178	189	199	210	219	229	238	247	256	264	273
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500	500	500	500
New Renewable	25	35	143	225	295	362	423	518	569	580	658	670	678	686	694	701	709	717	724	732	740
Navajo Replacement CC	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,150	1,150	1,150	1,150	1,150	1,150
Q3 Term Purchase	200	150	0	0	0	0	0	0	0	0	0	0	0	25	75	0	0	0	0	0	25
Total Replacement	247	232	221	344	769	878	995	1162	1274	1347	1463	1559	1628	1721	1788	2880	2897	2914	2930	2947	2988

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N.3.2 Amount of Renewables Needed

To determine the amount of renewable energy necessary to meet future targets, forecasts were made for the future power demand and the amount of existing renewable capacity available to meet these requirements. The difference between the projected amount required and the amount currently being utilized is the net short that will need to be acquired to meet RPS guidelines. A description of the methodology undertaken to define the future renewable needs is outlined below.

LADWP Renewable Net Short

The net short is the generation target to be met with resources identified in this project. The calculation for the net short was performed using the following equation:

Net Short(GWh) = (Forecasted Energy Sales) x (Annual Renewable Percent Goal) – (Operating Renewable Resources – Under Construction and Pre-construction Renewable Resources - Renewable Energy Purchases)

SB 2 (1X) has established the level of renewables required by 2020 and beyond, and also sets interim targets between now and 2020. These levels and targets represent the *Annual Renewable Percent Goal* parameter in the equation. By incorporating forecasted sales, existing renewable projects, and current and forecasted renewable energy purchases, the net short can be calculated.

N.3.3 Renewable Resources Selection Process

Over the last ten years, LADWP has issued several requests for proposals for renewable energy and gained a thorough understanding of the nature and availability of the different renewable resource technologies. This knowledge was used in developing the renewable portfolio. Additionally, LADWP largely considered renewable resources within the Western Governors' Association's Western Renewable Energy Zones (WREZ). In the WREZ initiative, Qualified Resource Areas were defined as areas of dense, high-quality renewable energy resources, meeting various resource size, quality, environmental, and technical criteria. LADWP screened all resources to ensure they are located near available LADWP transmission infrastructure. Assumptions were made for the cost and performance of each technology used to convert the renewable resources to electricity. These assumptions were used in calculating the levelized cost of electricity.

A valuation process designed to provide a single ranking value to a resource was then applied. The valuation process is a method to rank the total value of separate renewable resource projects, and accounts for such parameters as transmission costs, integration costs, supply curves, load shapes, the capacity benefit provided by the resource, capital and O&M costs, financial factors and other measures This step is intended to identify resources with the combination of lowest cost and highest value. The valuation approach is similar to the bid evaluation process many utilities use when procuring renewable resources.

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After applying the appropriate constraints, resources were selected and added progressively to the renewable resource mix based on lowest rank cost and transmission availability until the net short was mitigated. To assess and rank projects consistently, a method must be developed to measure the economics of all resources on a consistent basis. Renewable technologies all have different characteristics, with different cost requirements and energy delivery patterns. Resource valuation is a way to measure different renewable resources on a comparable basis.

N.3.4 Renewable Generation Cost

The cost of generation is calculated as a levelized cost of energy ("LCOE") at the point at which the project will interconnect to the existing transmission system. The LCOE for a project is the total life-cycle cost of generating electricity at the facility normalized by the total generation from the facility and is calculated in terms of dollars per megawatt hour ($/MWh). LCOE provides a consistent basis for comparing the economics of disparate projects across all technologies and ownership.

For each project or resource class, a pro forma financial analysis was conducted to determine the life-cycle cost. This pro forma model uses input assumptions for key project variables to determine expected revenues, costs, and year-by-year after-tax cash flow over the project life. The pro forma model used is consistent with the model used in CEC's Cost of Generation model, as well as those used in WREZ and California's Renewable Energy Transmission Initiative. It is also very similar to the model used by the CPUC to calculate the Market Price Referent (MPR), with the necessary modifications to make the calculations appropriate for renewable resources, including the modeling of tax incentives, accelerated depreciation, and other incentives.

The analysis included appropriate assumptions for each project. Some assumptions were tailored to be technology specific, such as financing terms and appropriate tax incentives. Other assumptions such as capacity factor and capital cost depended on geography and the available natural resource. Specific costs included in the generation costs were:

- Capital costs
- Generation interconnection costs ("gen-tie")
- Fixed operation and maintenance
- Variable operation and maintenance
- Heat rate (if applicable)
- Fuel costs (if applicable)
- Incentives
- Net plant output
- Capacity factor
- Economic life

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N.3.5 Renewable Generation Cost

The integration cost of a project is the indirect operational cost to the transmission system to accommodate the generation from the project into the grid. The addition of substantial amounts of intermittent and as-available renewable resources could result in substantial generation swings on the transmission system, and the grid operator must accommodate these swings by ensuring there is sufficient regulation service, modifications to current daily ramps, additional reserve capacity, and voltage support. Additional integration costs will include wear-and-tear on resources if they are required to repeatedly cycle to adjust for the intermittent resource output.

N.3.6 Renewable Resource Capacity Value

The capacity value of a generating resource is based on its ability to provide dependable and reliable capacity during peak periods when the system requires reliable resources for stable operation. Resources that can provide firm dependable capacity will have a higher capacity value than resources that cannot. In the WREZ model, the ability of a renewable resource to generate power during the top 10 percent of the model's yearly load was used as the capacity credit. LADWP uses a more conservative approach by considering the dependable capacity which varies depending on the resource type and is a fraction of the total available capacity as shown in Table 3-4.

The baseline value of capacity is the cost of the next most likely addition of low-cost capacity, defined as the fixed carrying costs of a simple cycle gas turbine generator. This includes the capital costs, fixed operations and maintenance costs, and other fixed charges associated with the gas turbine generator capacity, expressed as a dollar per kilowatt per year ($/kW-year). The fixed carrying cost assumed in the model is $100/kW-yr. The baseline capacity value does not include variable costs, such as fuel purchases. For new projects, the capacity factor is derived from the projected generation profile for the resource. The formula for calculating capacity value ($/kW-yr) is:

$$\textit{Capacity Value (\$/MWh)} = \textit{(Dependable Capacity Factor) x (Baseline Capacity Value) / (Project Capacity Factor * 8760/1000)}$$

N.3.7 Renewable Resource Energy Value

The energy value of a resource assesses the value of its hourly output to the energy markets. Resources that produce more power during high-price, peak demand periods will have a higher energy value than resources that provide power primarily during low demand periods.

The formula for calculation of energy value is:

$$\textit{Energy Value (\$/MWh)} = \Sigma\,[\textit{(Energy Value in Time Period) x (Energy Output in Time Period)}] \,/\, \textit{Total Energy Output}$$

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N.3.8 Renewable Energy Portfolio

Utilizing the methodology described in the previous subsections, a best-value portfolio of renewable resources was developed. This base portfolio was used in all 4 coal cases considered in this IRP and the Base EE, Base DG case which is identical to Coal Case #2. Figures N-2 and N-3 show the renewable capacity and energy production schedules for the base portfolio. To accommodate advanced levels of EE and higher levels of Solar DG for the 3 additional EE/DG Cases evaluated (6 thru 8), certain renewable projects were delayed or eliminated to accommodate the advanced levels of EE and higher levels of DG to maintain consistency with the procurement targets established by SB 2 (1X).

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RPS Capacity (MW)

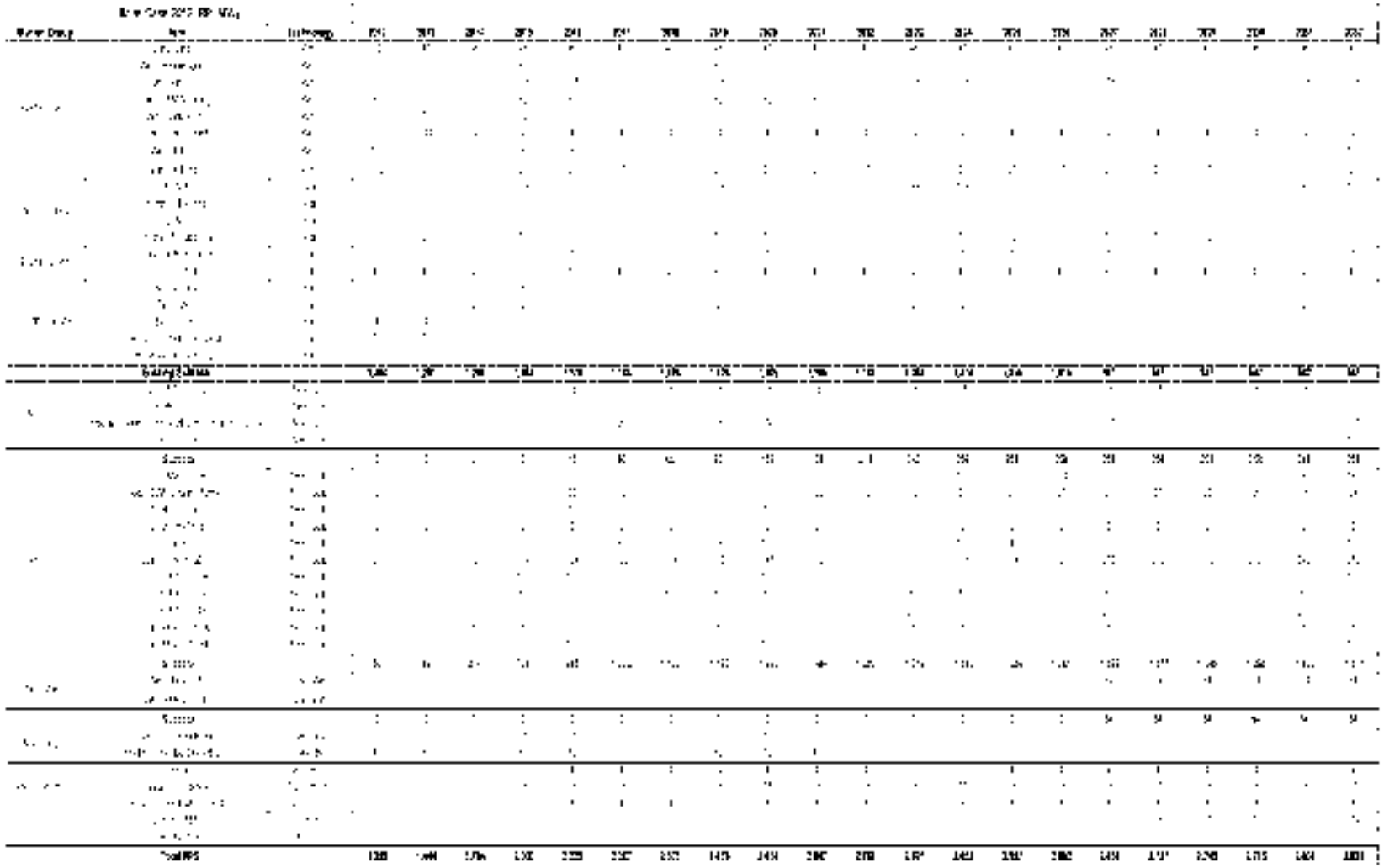

Figure N-2. Renewable resource capacity in MW for all Coal cases and the Base EE Base DG case.

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RPS Energy (GWh)

Base Case 2012 IRP (GWh)																						
Status Group	Item	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Existing Wind	Wind_Linden	140	136	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131
	Wind_RobbleSprings	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169						
	Wind_PineTree	322	326	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362
	Wind_PRMWyoming	267	197	171	171	171	171	171	171	171	171	86										
	Wind_WillowCrk	185	185	197	197	197																
	Wind_WindyPoint	680	645	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641
	Wind_Milford	412	404	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434
	Wind_Milford2	289	208	212	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206
Existing Small Hydro	AQ&OV&OG	300	569	569	569	569	569	569	569	569	569	569	569	569	569	569	569	569	569	569	569	569
	North Hollywood	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Sepulveda	30	34	33	33	33	33	33	33	33	33	33	33									
	Castaic3&5 Upgrade	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Existing Solar	Solar_DWP_Basin_E	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Solar_C-N-M	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Existing Biogas	Bio_Bradley	43	44	44	44																	
	Bio_Lopez	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Bio_Toyon	6	7																			
	Altres & Shell Gas Coast	628	610	343																		
	Hyperion Digester Gas	130	131	131																		
	Existing Subtotal	3,589	3,751	3,568	3,668	3,644	2,947	2,947	2,947	2,947	2,947	2,781	2,676	2,643	2,643	2,643	2,451	2,451	2,451	2,451	2,451	2,451
New Geo	Geo PPA 2015 O					42	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125
	Geo PPA 2017 T									330	441	441	441	441	441	441	441	441	441	441	441	441
	Imperial County Joint Geothermal Project -1,2,3,4						100	333	533	800	800	800	800	800	800	800	800	800	800	800	800	800
	Generic_Geo											400	600	800	800	800	800	800	800	800	800	800
	Subtotal					42	225	458	658	1,255	1,366	1,765	1,966	2,166	2,166	2,166	2,166	2,166	2,166	2,166	2,166	2,166
New Solar	Solar_DWP_Owens						110	220	330	440	439	436	433	431	429	427	425	423	421	418	414	412
	Solar_DWP_Basin_Planned	16	6	11	17	27	58	78	109	139	165	178	175	174	174	173	172	171	170	169	168	167
	Adelanto Solar	11	20	20	20	20	28	28	19	19	19	19	19	19	19	19	19	18	18	18	18	18
	Solar_PineTree	4	17	17	17	17	17	17	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	Solar_RT	1	10	26	62	100	137	150	163	176	187	200	212	224	236	248	253	252	251	249	248	246
	Solar_C-N-M (SB1)	23	69	113	154	198	208	216	225	234	245	256	268	282	296	311	325	341	358	374	391	407
	Solar PPA 2015 B				178	337	335	332	329	327	324	321	319	316	314	311	309	308	304	301	299	297
	Solar PPA 2015 R				73	145	144	143	141	140	139	138	137	136	135	134	133	132	130	129	128	127
	Solar PPA 2014 K			518	561	556	552	547	543	539	534	530	526	522	517	513	509	505	501	497	493	489
	Solar PPA 2015 Obl			158	263	327	325	322	320	317	314	312	309	307	305	302	300	297	295	293	290	288
	Solar PPA 2015 Pbl					256	441	438	435	432	429	426	423	420	417	414	411	408	405	402	400	397
	Subtotal	41	122	864	1,326	2,014	2,338	2,495	2,636	2,777	2,811	2,830	2,837	2,848	2,858	2,867	2,873	2,875	2,868	2,858	2,856	2,854
New Wind	Wind_PineCTN																175	175	175	175	175	175
	Wind PPA 2012 bl																					
	Subtotal PPA's																					
	Subtotal																175	175	175	175	175	175
New Bio Gas	Hyperion Gas Extension				131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131
	Shell Renewable Biomethane	361	520	526	526	526	520	520	520	520	480											
New Small Hydro	WSHydro					11	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
	Castaic U1 update		2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Aqueduct PP Improvement					15	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
	Generic_RPS																	100	150	200	250	300
	GreenPurchase	118	458	73	119		1	84	258		22	145	83				32	3				26
	Total RPS	4,679	4,883	5,070	5,349	5,782	6,118	6,501	7,098	7,597	7,634	7,690	7,719	7,843	7,863	7,954	7,883	7,952	7,908	8,047	8,096	8,170

Figure N-3. Renewable energy production in GWh for all Coal cases and Base EE, Base DG case.

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N.4 Avoided Costs and Net Revenue Losses – Energy Efficiency and Distributed Generation Case Comparisons (Cases 5 thru 8)

Due to the load reduction nature of energy efficiency and solar customer-net-metered (CNM) programs, generally referred to as "demand side programs" or "customer opportunity programs", customer sales are reduced leaving the utility with a potential loss of revenue if the cost savings experienced by the utility from these programs does not fully offset the lost sales revenue. The cost savings experienced by the utility from demand side programs are typically referred to as "avoided costs". The difference between the lost sales revenue and the avoided costs is referred to as the "net revenue loss". Modeling of net revenue loss addresses ratepayer concerns that the impact to customer bills and rates due to changes in utility revenues and operating costs be fully considered when comparing the cost of these demand side programs to other resource alternatives. Avoided costs described herein include only those costs that can be avoided by LADWP thru implementing demand side programs and does not consider avoided costs experienced by the customer participating in these programs nor does it consider the wider societal cost benefits of these programs.

Avoided costs are sometimes difficult to quantify since it is not always fully understood what the effect these demand side programs will have on reducing utility costs. There exists a wide range of opinions on the types of avoided costs that should be considered and how those costs are calculated. The larger avoided cost savings components of fuel, emissions, capacity savings, and reduced transfers of surplus revenue (city transfers), are fairly well understood and estimating these cost savings can be effectively performed using production cost modeling software. The production cost model program PROSYM was employed in this analysis and is further described in Section M.2. Less well understood are the system wide savings associated with deferred transmission and distribution upgrades. Distribution savings in the form of deferred upgrades to the distribution system will require further study and were not included in this analysis. Cost savings associated with deferred transmission upgrades were included and are based on upgrades that have recently occurred. Emissions cost savings from CARB's Cap and Trade program were included in this analysis where costs exceeded the emissions allocation to LADWP. Additional work to identify and further quantify avoided costs will be addressed in future IRP's.

Calculations of avoided costs and net revenue losses can vary among utilities because each utility has different cost structures and rate recovery mechanisms. Current methodologies used to calculate avoided costs for an investor-owned utility such as the Ratepayer Impact Measure (RIM) Test may not necessarily apply for vertically-integrated utilities such as LADWP that have direct control over generation, transmission, and distribution resources. It is still unclear whether this same test can be used to evaluate avoided costs for LADWP. Future IRP's will examine the appropriateness of this model for use in evaluating future avoided costs.

Demand side programs such as energy efficiency and solar CNM programs primarily reduce the fuel and variable operating and maintenance costs of marginal gas-fired generation. These programs can also offset lower cost resources such as coal or hydro depending on the size of the demand side resource and the hours over which the energy savings occur. Besides fuel savings, the utility will also experience other fixed and variable cost savings associated with generating, transmitting, and distributing electricity, and lowered compliance obligations of renewables

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which are typically based on a percentage of overall customer sales, and city transfers which are based on a percentage of the Power System's gross revenues. As fuel prices rise, these avoided costs will increase so loss of net revenue experienced by the utility will be reduced. Because fuel market price forecasts can vary considerably from year to year, it is important that avoided costs be reexamined periodically.

N.4.1 Analysis of Avoided Costs and Net Revenue Loss - Base EE and Advanced EE

While implementation of the EE program dramatically reduces customer sales, it is important to capture the effects of this loss in revenue. A portion of this loss in revenue can be recovered from demand charges from commercial customers which is a significant portion of a commercial or industrial customer's bill. Residential minimum bill charges were not considered since EE programs would typically offset electrical usage above minimum thresholds. There are also avoided costs of supplying additional generation resources to meet load growth because the EE program reduces system load and to a smaller extent, peak demand as well. Net Revenue Loss is the remaining loss after deducting fixed demand charges from commercial and industrial customers and savings associated with avoided costs. Table N-2 lists all the avoided costs associated with EE programs considered including a brief explanation of each component of the total avoided cost.

Table N-2: EE Program Avoided Costs Considered

List of Avoided Cost	Reasons
Avoided Energy- Fuel, Renewable	**Fuel:** EE reduces customer load, which results in less generation primarily from gas units so there will be less fuel and variable O&M cost.
	Renewable: EE reduces customer sales, and at the same time RPS % is calculated based on the customer sale. Lower customer sales results in less renewable energy procurement to meet the mandated RPS percentage.
Avoided Emissions	Lower generation levels will result in lower greenhouse gas emissions. Per AB32, utilities will be charged for the CO2 emission amount beyond their allocation of allowances.
Avoided City Transfer	EE reduces customer sales which reduces total revenue thereby lowering the transfer to the City which is currently 8 percent of total revenue.
Avoided Transmission & Distribution	With reduced peak load from EE, less MW's will be needed during peak hours so some transmission and distribution upgrades can be deferred.
Avoided Capacity	With reduced peak demand due to EE, fewer peaker units will be built to meet system reserve requirements resulting in deferred capital spending.
Avoided O&M	With lower peak demand and fewer peaker units being built, there will be a savings of fixed O&M costs.
Avoided Losses	EE reduces customer sales thereby lowering the amount of energy we will need to generate to cover distribution and transmission losses.

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Figure N-4 shows the avoided costs, fixed billing charges recovered and net revenue loss for the Base EE case. The gross revenue loss shown is $12,227 Million from FY 2012 to FY 2032 and is determined by using the forecasted average customer electricity rate in $/kWh multiplied by the EE energy savings in kWh. The total avoided cost is $6,187 Million over the next 20 years, and the recovered fixed billing charges is $2,220 Million. The small dotted area at the top of Figure N-4 shows the final net revenue loss due to the implementation of Base EE program. An observation from our study was that the net revenue loss was found to be more significant as EE GWh achievement increases.

As mentioned in the previous section, EE program reduces customer sales which means less renewable energy will be needed to meet RPS targets. With the Base EE case, the forecasted customer sales will stay below FY 2010-11 levels over the next 10 years with minimal growth thereafter. This lowered growth rate expected with the Base EE reduces the need to build ~ 800 GWh of renewable energy beginning in 2018 and will save approximately $110 Million assuming the renewable energy that is offset comes from a combination of geothermal and wind. These savings also apply to years beyond 2018 as well. This explains the large increase in avoided energy starting in 2018 (avoided fuel and renewable costs shown in the blue area in Figure N-4).

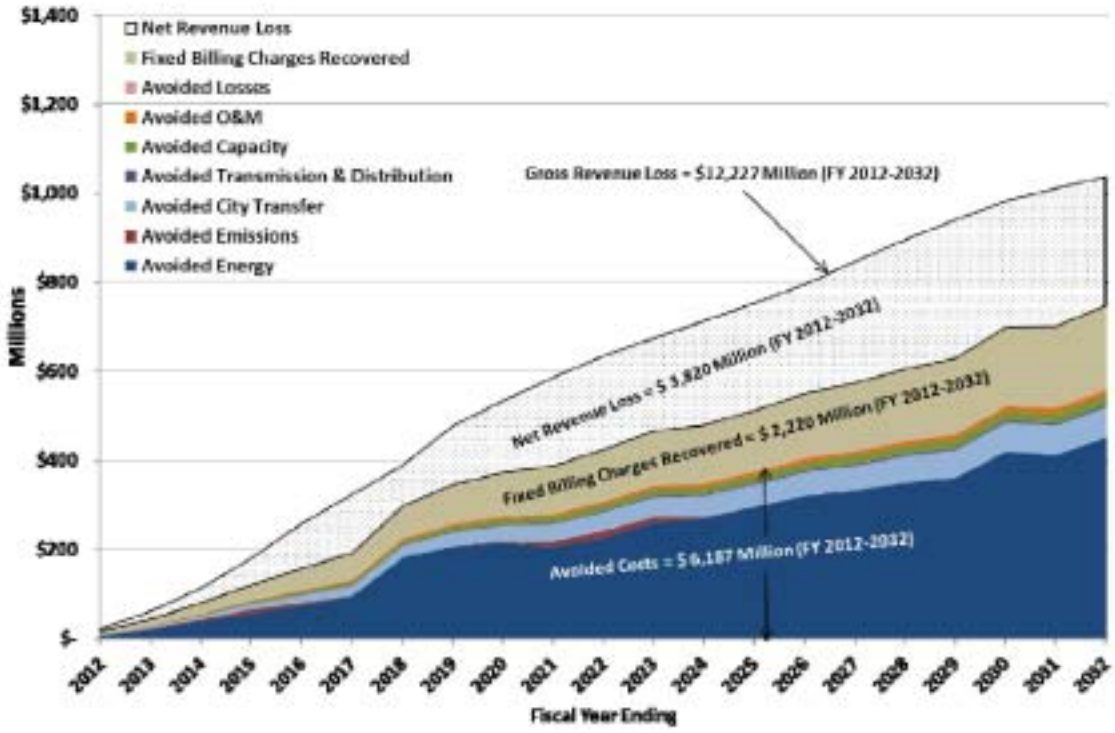

Figure N-4: Base EE Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss

The associated rates breakdown associated with Figure N-4 is shown in Figure N-5.

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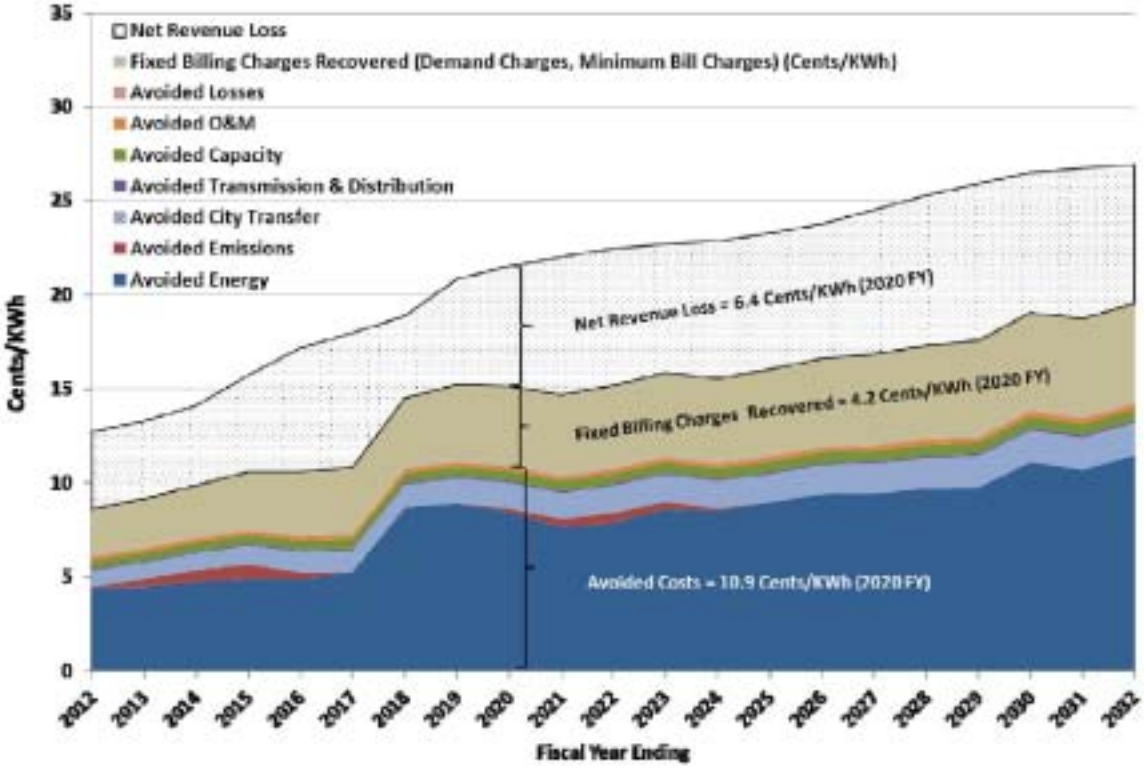

Figure N-5: Base EE Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss (in Cents/kWh)

For the Advanced EE case discussed in previous section, similar figures are shown below. The total Net Revenue Loss for this Advanced EE case is $4.06 Billion, which is $240 Million higher than the Base EE case because of the higher level of energy savings (500 GWh) in the last decade. Similar to the Base EE case, the rapid increase of Avoided Energy cost in 2018 as shown in Figure N-6 is also due to the considerable savings in procuring additional renewables resulting from the lowered sales.

The associated rates breakdown associated with Figure N-6 is shown in Figure N-7.

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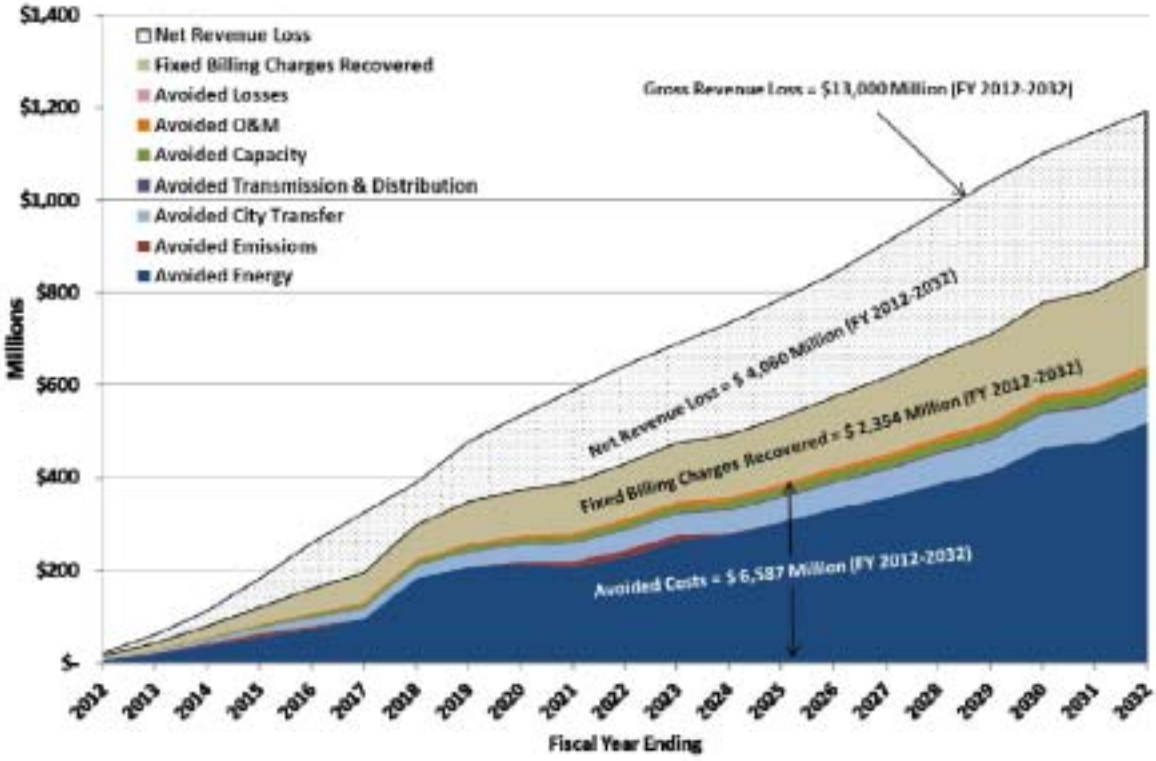

Figure N-6: Advanced EE Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss

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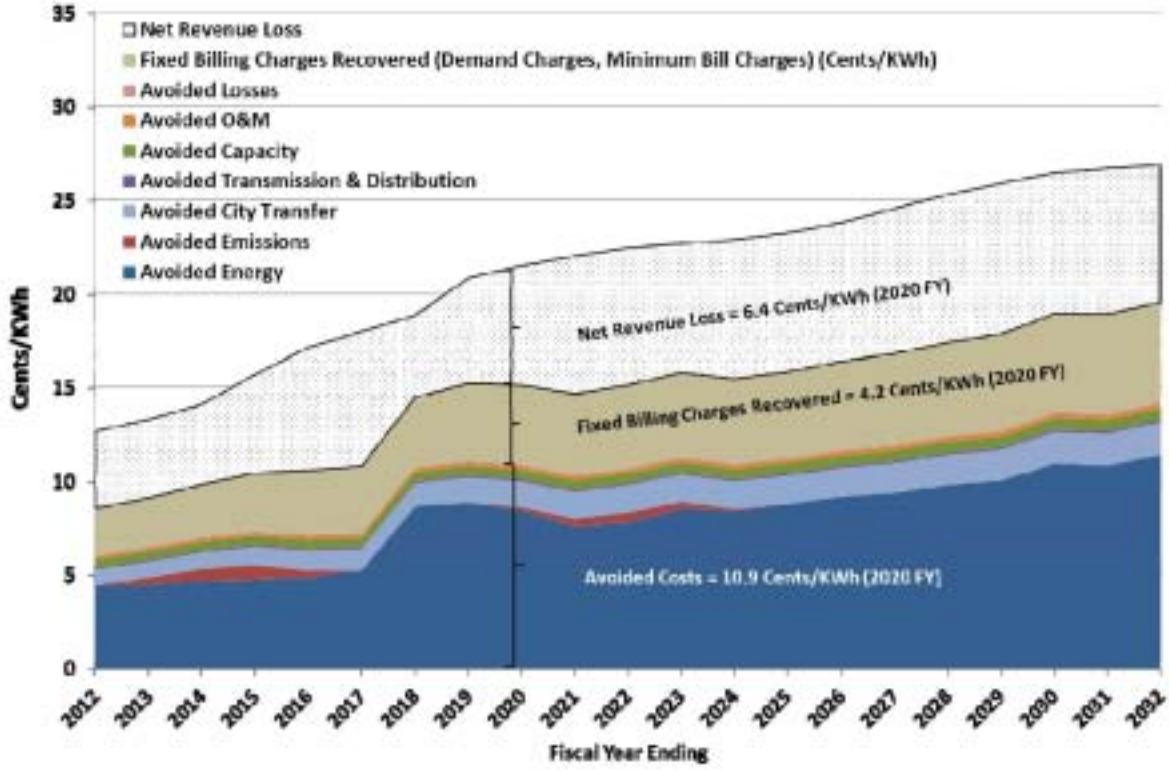

Figure N-7: Advanced EE Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss (in Cents/kWh)

N.4.2 Analysis of Avoided Costs and Net Revenue Loss – Base and High Solar CNM

Two Solar DG Cases were evaluated which comprise several internal programs including Customer Net Metered (CNM) Solar (a.k.a. Solar Incentive Program), Feed In Tariff (FIT), and Utility Built Solar on City Properties. The analysis presented below is intended to represent the avoided costs and net revenue loss for the Solar CNM program only. However, in the final comparison of distributed generation and energy efficiency cases discussed in Section 4.3.3.1, many of the same avoided costs were considered with the exception that avoided renewable, avoided capacity, and avoided O&M only apply to Solar CNM due to the unique feature that demand side resources possess which is reducing peak load and reduced customer sales.

Similar to the EE programs described previously, revenue loss offset by the avoided costs described in Table N-3 and fixed billing charges recovered from minimum bill charges for residential customers must be considered in the evaluation of costs for the Solar CNM program. A smaller portion of this loss in revenue can be offset with fixed bill charges as compared to EE programs primarily because demand charges for commercial customers cannot easily be reduced using solar resources that require the utility to fully back up the customer when solar production plummets during cloudy days.

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Table N-3: Solar CNM Program Avoided Costs

List of Avoided Cost	Reasons
Avoided Fuel	Solar DG or Customer-Net-Metered solar reduces customer load, over time, as it displaces energy generated by plants from gas utility. Solar generation profile is similar to the system load profile and will displace more expensive peaker generation resulting in lower regional system O&M costs
Avoided Renewable	Solar CNM programs reduce customer sales which reduces the amount of renewable energy expenditures to meet the mandated RPS %
Avoided Emissions	Lower generator costs will result in lower greenhouse gas emissions. For AB32 utilities will be charged for the CO2 emissions it emits and their allowances
Avoided City Transfer	Solar CNM reduces customer sales which reduces the amount of revenue collected for transfer to the City which is tied to % percentage of gross revenue
Avoided Transmission & Distribution	With lower peak load from the less MWs will be needed for the peak hours so some transmission and distribution upgrades can be deferred
Avoided Capacity	With lower peak demand due to Solar DG fewer peaker units will be built to meet system reserve requirements resulting in deferred capital spending
Avoided O&M	With lower peak demand and fewer peaker units being built there will be savings of Fixed O&M costs
Avoided Losses	Distribution losses are the losses incurred during the transfer of energy as it travels to penetrate homes that are far away and transformers down

Among Solar DG programs, the Solar CNM program impacts system costs in a similar manner as energy efficiency so the same methodology was employed. Figure N-8 shows avoided costs, recovered fixed billing charges, and net revenue loss for the Base Solar CNM case. Over the next 20 years for the Base Solar CNM, the gross revenue loss will be $1,484 Million, the total avoided cost is $878 Million, and the fixed billing charges are $257 Million. The small dotted area at the top of Figure N-8 shows the final net revenue loss as $349 Million due to the implementation of Base Solar CNM program. Like EE programs, the net revenue loss of Base Solar CNM increases as Solar CNM generation increases, however, the avoided cost is more evenly distributed throughout time since Solar CNM is a smaller program and reductions in RPS generation are less significant. The rate breakdown associated with Figure N-8 for the Base Solar CNM case is shown in Figure N-9 below.

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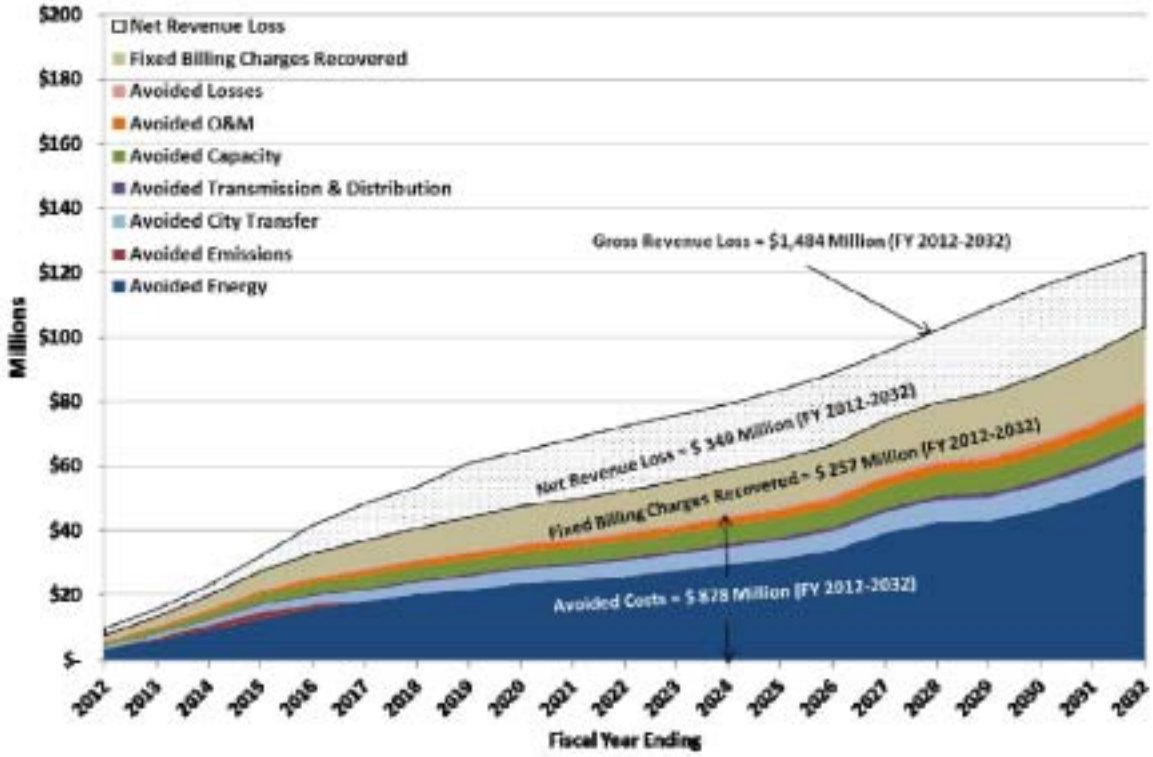

Figure N-8: Base Solar CNM Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss

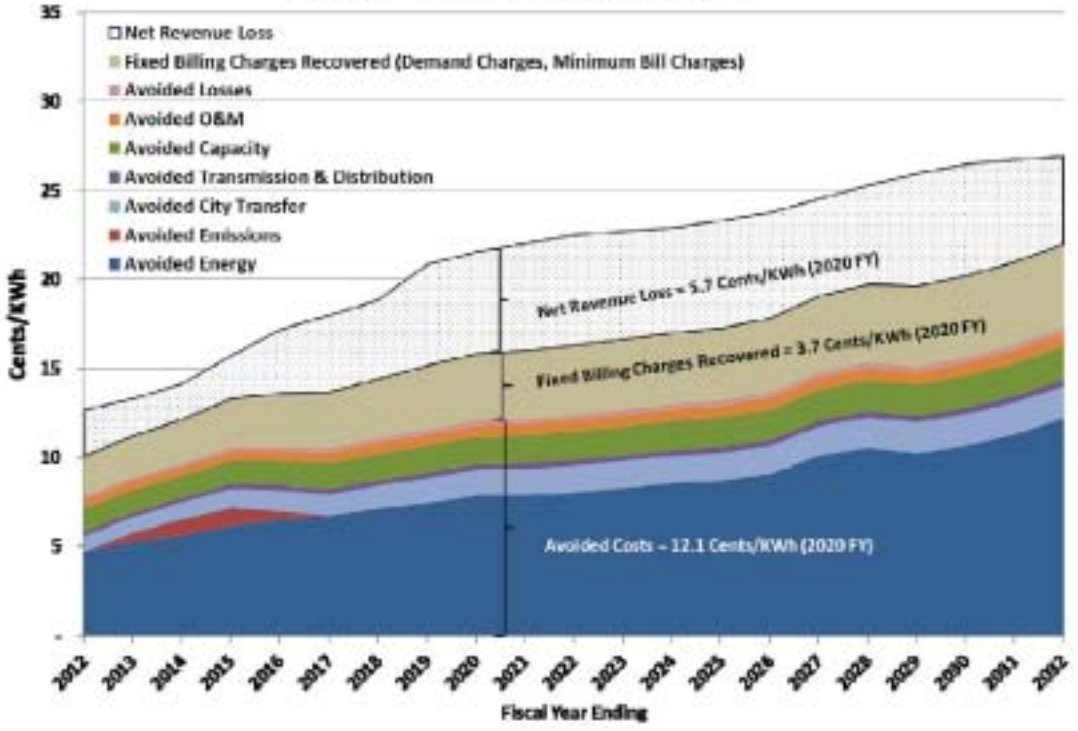

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Figure N-9: Base Solar CNM Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss (in Cents/kWh)

For High Solar CNM, similar figures are shown below in Figures N-10 and N-11. The total net revenue loss for the High Solar CNM is $566 Million, which is $217 Million more than the Base Solar CNM. The Solar CNM program results in net revenue losses so more Solar CNM generation with result in a greater loss of revenue.

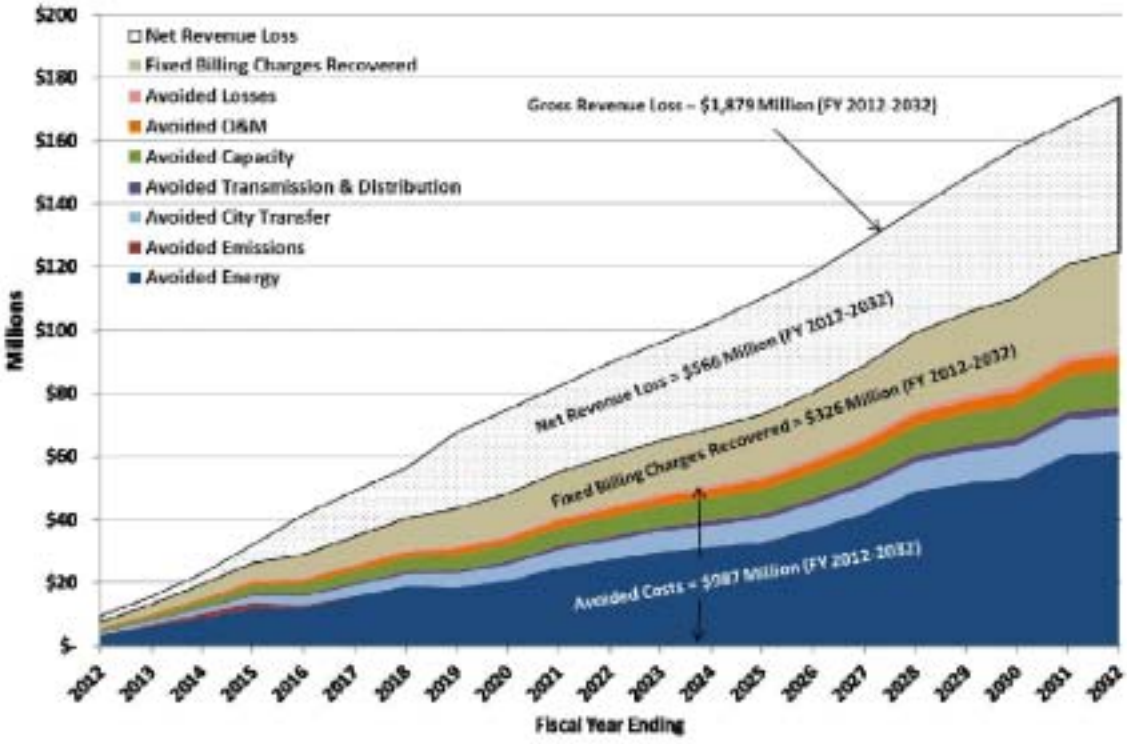

Figure N-10: High Solar CNM Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss

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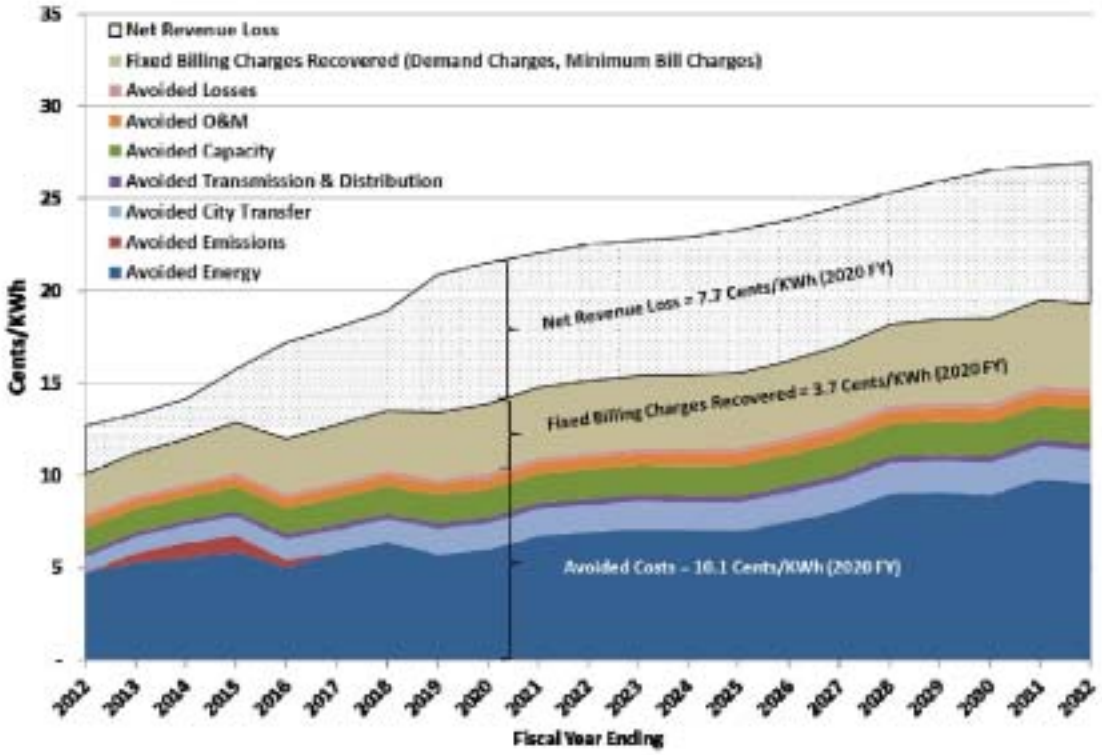

Figure N-11: High Solar CNM Program annual Avoided Cost savings, Fixed Billing Charges Recovered and Net Revenue Loss (in Cents/kWh)

N.7 Model Input and Assumptions

The following pages present the major input parameters and assumptions that were incorporated into the production cost model for this 2012 IRP.

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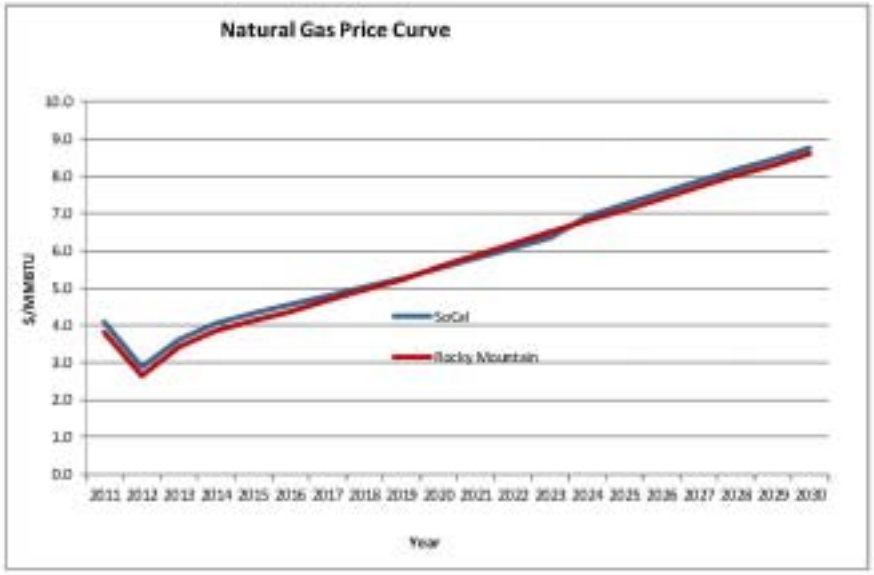
Load Forecast

	2012 Forecast						2012 IRP					
Year	Net Energy for Load (A)	Energy Efficiency (B)	Solar Rooftop Program (C)	Forecasted Sales (D)	% Annual Sales Change before EE	% Annual Sales Change after EE	Net Energy for Load for model run (E)	Solar Rooftop Program (F)	Energy Efficiency (G)	IRP Calculated Sales (H)	% Annual Sales Change before EE	% Annual Sales Change after EE
2012	26,405	-259	-50	22,426	2.67%	1.55%	26,405	-42	-220	22,482	2.75%	1.6%
2013	26,335	-464	-107	22,780	2.21%	-0.02%	27,002	-77	-555	23,344	0.70%	-0.5%
2014	26,311	-693	-161	23,069	1.30%	0.24%	27,264	-102	-822	23,237	0.37%	0.5%
2015	26,317	-936	-171	23,276	0.87%	-0.36%	27,562	-124	-1159	23,147	1.00%	-0.4%
2016	26,274	-1,196	-191	23,237	0.61%	0.17%	27,647	-148	-1509	23,015	0.92%	0.5%
2017	26,314	-1,455	-206	23,366	1.58%	0.17%	28,136	-185	-1856	23,626	1.07%	-0.4%
2018	26,549	-1,451	-214	23,526	1.13%	1.12%	28,430	-174	-2189	23,890	0.94%	0.4%
2019	26,810	-1,451	-223	23,823	1.19%	1.26%	28,802	-185	-2481	23,947	0.21%	0.1%
2020	27,063	-1,451	-233	24,128	1.21%	1.28%	29,166	-196	-2765	23,904	1.30%	0.3%
2021	27,300	-1,451	-244	24,547	1.64%	1.74%	29,569	-208	-3062	23,541	1.31%	0.0%
2022	27,539	-1,451	-256	24,879	1.29%	1.25%	29,967	-221	-3100	23,232	1.27%	0.6%
2023	27,808	-1,451	-268	25,111	0.88%	0.83%	30,341	-235	-3227	23,386	1.10%	0.7%
2024	28,038	-1,451	-281	25,254	0.51%	0.57%	30,690	-251	-3342	23,517	0.99%	0.5%
2025	28,275	-1,451	-296	25,527	0.85%	0.84%	30,946	-267	-3448	23,618	0.77%	0.4%
2026	28,447	-1,451	-311	25,685	0.90%	0.66%	31,137	-283	-3541	23,761	0.98%	0.6%
2027	28,488	-1,451	-326	25,674	0.88%	0.83%	31,402	-300	-3632	23,844	0.90%	0.6%
2028	28,727	-1,451	-341	25,918	0.89%	0.94%	31,750	-318	-3712	24,102	0.98%	0.7%
2029	28,966	-1,451	-357	26,158	0.85%	0.90%	32,006	-337	-3786	24,236	0.70%	0.6%
2030	29,243	-1,451	-372	26,756	0.86%	0.91%	32,302	-356	-3857	24,408	0.96%	0.7%

Notes
1. Net Energy for Load model run (E) = Net Energy for Load (A) + Energy Efficiency (B) 0.665 + Solar Rooftop (C) 0.665
2. Energy Efficiency in 2012 IRP = Difference from Energy Efficiency in Forecasted IRP Years EE as Average Percentage
3. IRP Calculated Sales (H) = [E – (F 0.885) – (G 0.885) + 37] 0.955

Natura Gas Prices

Gas Price used in IRP 2012		
Year	SoCal	Rocky Mountain
2011	4.1	3.8
2012	2.9	2.7
2013	3.6	3.4
2014	4.0	3.8
2015	4.3	4.1
2016	4.6	4.4
2017	4.8	4.7
2018	5.0	5.0
2019	5.3	5.2
2020	5.5	5.6
2021	5.8	5.9
2022	6.1	6.2
2023	6.3	6.5
2024	6.9	6.8
2025	7.3	7.1
2026	7.6	7.4
2027	7.9	7.7
2028	8.2	8.0
2029	8.5	8.3
2030	8.7	8.6



Natural Gas Prices and Volume for Pinedale Reserves

Pinedale Gas Price	
Date	$/MMBTU
7/1/2011	3.45
7/1/2012	4.00
7/1/2013	4.17
7/1/2014	4.20
7/1/2015	4.24
7/1/2016	4.28
7/1/2017	4.32
7/1/2018	4.36
7/1/2019	4.40
7/1/2020	4.44
7/1/2021	4.48
7/1/2022	4.48
7/1/2023	4.48
7/1/2024	4.48
7/1/2025	4.48
7/1/2026	4.48
7/1/2027	4.48
7/1/2028	4.48
7/1/2029	4.48

Pinedale Gas Volume	
Date	GBTU/Day
7/1/2011	30.65
7/1/2012	32.25
7/1/2013	23.54
7/1/2014	19.68
7/1/2015	18.27
7/1/2016	15.97
7/1/2017	14.49
7/1/2018	13.22
7/1/2019	12.34
7/1/2020	11.47
7/1/2021	10.66
7/1/2022	10.66
7/1/2023	10.66
7/1/2024	10.66
7/1/2025	10.66
7/1/2026	10.66
7/1/2027	10.66
7/1/2028	10.66
7/1/2029	10.66

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LADWP Existing Generation Resources

LADWP Generator Ratings and Capabilities of Power Sources (as of April 2012)[1]							
NAME OF PLANT	UNIT NO.	DATE FIRST CARRIED SYSTEM LOAD	GENERATOR NAMEPLATE[2] (kVA)	GENERATOR NAMEPLATE[2] (kW)	NET MAXIMUM UNIT CAPABILITY[3] (kW)	NET Maximum PLANT CAPABILITY[4] (kW)	NET DEPENDABLE PLANT CAPABILITY[5] (kW)
	1A	12/19/1983	25,000	23,800	27,000		
San Fernandito	3	4/18/1917	11,719	8,375	10,000		
Power Plant 1	4	5/21/1923	12,500	10,000	12,000		
(PP1)	5A	4/9/1967	25,000	25,000	27,000	49,000	13,000
San Fernandito	1	7/9/1919	17,500	14,000	0		
Power Plant 2	2	8/7/1919	17,500	14,000	14,000		
(PP2)	3	8/29/1932	17,500	14,000	19,000	19,000	5,700
San Fernando	1	10/23/1922	3,500	2,800	3,200		
Power Plant (PP3)	2	10/23/1922	3,500	2,800	2,800	6,000	2,100
Foothill Power Plant (PP4)	1	12/8/1971	11,000	11,000	8,900	8,900	2,000
Franklin Power Plant (PP5)	1	8/3/1921	2,500	2,000	2,000	2,000	400
Sawtelle Power Plant (PP6)	1	8/5/1988	711	640	650	650	130
Aqueduct Hydro Subtotal					**126,850**	**83,550**	**24,230**
Haiwee Power Plant	1	7/18/1927	3,500	2,800	3,800		
	2	7/18/1927	3,500	2,800	3,900	4,200	0
Cottonwood	1	11/13/1908	937	750	1,200		
Power Plant	2	10/13/1909	937	750	1,200	1,900	400
Division Creek P. P.	1	3/23/1908	750	600	650	650	400
Big Pine Power Plant	1	7/29/1925	4,000	3,200	3,850	3,850	400
Pleasant Valley P. P.	1	2/5/1958	4,000	3,200	2,700	2,700	0
Owens Valley Hydro Subtotal					**16,830**	**12,550**	**1,200**
Upper Gorge P. P.	1	8/19/1953	37,500	37,500	37,500	37,500	36,500
Middle Gorge P. P.	1	5/11/1952	37,500	37,500	37,500	37,500	36,500
Control Gorge P. P.	1	4/1/1952	37,500	37,500	37,500	37,500	36,500
Owens Gorge Hydro Subtotal					**112,500**	**112,500**	**108,500**
	1	7/1/1973	250,000	212,500	265,000		
	2	7/9/1974	257,500	265,000	265,000		
	3	7/13/1976	257,500	265,000	270,000		
Castaic Power Plant	4	6/18/1977	257,500	265,000	265,000		
	5	12/18/1977	257,500	265,000	265,000		
	6	6/1/1978	257,500	265,000	265,000		
	7	1/27/1972	70,000	68,000	68,000	1,247,000	1,175,000
Castaic Hydro Subtotal					**1,635,000**	**1,247,000**	**1,175,000**
Hoover Power Plant (Capacity and energy purchase from WAPA through Sep					**491,000**	**491,000**	**466,000**
TOTAL HYDRO (Based on average hydro conditions)					**2,381,180**	**1,946,090**	**1,777,930**
	1	1/31/1965	100,400	85,340	82,000	82,000	78,500
	2	1/31/1966	100,400	85,340	82,000	82,000	78,500
	5	1/31/1965	93,750	75,000	65,000	65,000	62,000
Harbor Generating	10	1/4/2002	71,176	60,500	47,400	47,400	47,400
Station	11	1/4/2002	71,176	60,500	47,400	47,400	47,400
	12	1/4/2002	71,176	60,500	47,400	47,400	47,400
	13	1/4/2002	71,176	60,500	47,400	47,400	47,400
	14	1/4/2002	71,176	60,500	47,400	47,400	47,400
Harbor Generating Station Subtotal					**666,800**	**666,800**	**653,800**
	5	8/17/2001	71,176	60,500	43,000	43,000	43,000
Valley Generating	6	8/4/2003	215,000	182,750	159,000	159,000	156,000
Station	7	8/8/2003	215,000	182,750	159,000	159,000	156,000
	8	11/13/2003	311,000	264,350	215,000	215,000	201,000
Valley Generating Station Subtotal					**576,000**	**576,000**	**556,000**
Scattergood	1	12/1/1958	192,000	163,200	163,000	163,000	174,000
Generating Station	2	7/1/1959	192,000	163,200	164,000	164,000	177,000
	3	10/8/1974	562,000	486,800	490,000	490,000	445,000
Scattergood Generating Station Subtotal					**817,000**	**817,000**	**796,000**

	1	8/2/1962	270,000	220,000	222,000	222,000	222,000
	2	4/7/1963	270,000	220,000	222,000	222,000	222,000
	3	7/14/1964	270,000	220,000	0	0	0
	4	3/9/1965	270,000	220,000	0	0	0
Haynes Generating	5	6/13/1966	381,000	343,000	392,000	392,000	392,000
Station	6	3/18/1967	381,000	343,000	343,000	343,000	238,000
	7	9/1/1970	2,900	2,900	1,666	1,666	0
	8	1/25/2005	311,000	264,350	260,000	260,000	238,000
	9	1/25/2005	215,000	182,750	162,500	162,500	158,000
	10	1/25/2005	215,000	182,750	162,500	162,500	158,000
Haynes Generating Station Subtotal					**1,565,666**	**1,555,666**	**1,535,000**
Total Basin Thermal					**3,444,589**	**3,434,589**	**3,329,000**
Mohave Generating	1	4/1/1971	669,000	615,000	0	0	0
Station	2	10/1/1971	669,000	615,000	0	0	0
Mohave Generating Station Subtotal					**0**	**0**	**0**
Navajo Generating	1	2/1/1974	882,400	803,000	750,000	159,000	159,000
Station	2	12/31/1974	882,400	803,000	750,000	159,000	159,000
	3	11/29/1975	882,400	803,000	750,000	159,000	159,000
Navajo Generating Station Subtotal					**2,250,000**	**477,000**	**477,000**
Intermountain	1	6/8/1986	891,000	820,000	900,000	587,290	587,290
Generating Station	2	4/30/1987	891,000	820,000	900,000	587,290	587,290
Intermountain Generating Station Subtotal					**1,800,000**	**1,174,580**	**1,174,580**
Palo Verde Nuclear	1	1/30/1986	1,550,000	1,403,000	1,333,000	128,768	128,640
Generating Station	2	9/19/1986	1,550,000	1,403,000	1,336,000	129,056	128,935
	3	1/19/1988	1,550,000	1,403,000	1,334,000	128,864	128,739
Palo Verde Generating Station Subtotal					**4,003,000**	**386,688**	**386,314**
Total External Thermal (Coal and nuclear fuels)					**8,053,000**	**2,038,370**	**2,037,894**
TOTAL THERMAL					**11,497,589**	**5,472,959**	**5,366,894**
NET MAXIMUM AND NET DEPENDABLE SYSTEM CAPABILITY w/o CSW						**7,396,548**	**7,138,824**
Transfer	Statelv Capacity Entitlement					**-126,000**	**-66,000**
NET MAXIMUM AND NET DEPENDABLE SYSTEM CAPABILITY						**7,270,548**	**7,072,824**
Renewables/Distributed Generation as of April 30, 2012 [6]						**1,109,200**	**339,580**
NET MAXIMUM AND NET DEPENDABLE SYSTEM CAPABILITY w/ RE/DG						**8,380,164**	**7,412,434**

Notes:
[1] This table is based on data from Power System Engineering Division January 1, 2012 Generation Rating and Capabilities of Power Sources sheet. This table also include data for the renewables and distributed generating resources owned and contracted by LADWP. The data are from the April 10, 2012 RPS Master Project List and project contracts.
[2] Name plate capability is the full load continuous rating of a generating unit under specified conditions as designated by the manufacturer.
[3] Unit net attained Maximum Capability when the weather and equipment are simultaneously at optimal conditions.
[4] Maximum Plant Capability reflects water flow limits at hydro plants, or sum of each unit at in-basin thermal plants, or entitlements from external thermal plants.
[5] Net Dependable Plant Capability reflects year-round outputs adjusted for low generation season. For hydro plants, winter is the low generation season. Thermal plants experience reduced performance during hot weather conditions.
[6] Dependable capacity of renewable technology plants are estimated by applying a Dependable Capacity Factor (DCF) to the plant name plate capacity. The conservative factor is used until LADWP gains more actual amount of operating experience with renewable technologies. DCFs currently used are as follow:
Digester Gas 1.00
Geothermal 0.95
Landfill Gas 1.00
Municipal Solid Waste Conversion 1.00
Small Hydroelectric 1.0
Solar Photovoltaic 0.27
Solar Thermal 0.27
Wind 0.10 (projects with firming contracts are rated at firming levels)

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IPP Capacity for LADWP

IPP Capacity (MW)								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2011	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2012	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2013	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2014	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2015	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2016	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2017	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2018	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2019	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2020	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2021	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2022	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2023	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2024	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2026	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2027	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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IPP Debt Service and O&M, and Generation Expenses

FY	IPA Generation Debt Service									IPA Generation O&M	IPA Generation DS & O&M	DWP's Share of IPA Generation Expenses
[illegible]									[illegible]	[illegible]	[illegible]	[illegible]
[illegible]									[illegible]	[illegible]	[illegible]	[illegible]
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Demand Response Schedule

Fiscal Year	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MW	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Annual Budget ($000)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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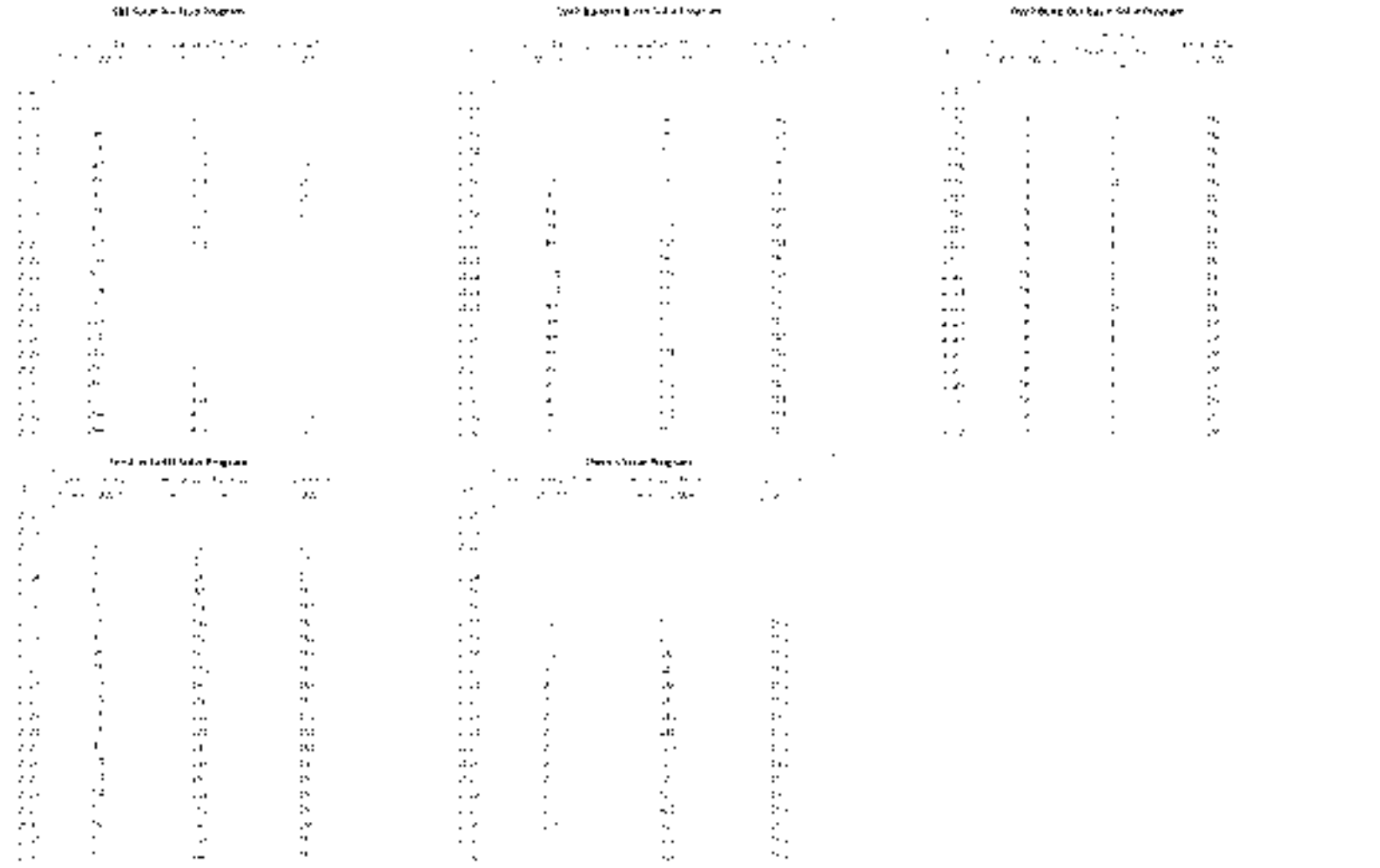
LADWP Solar Program



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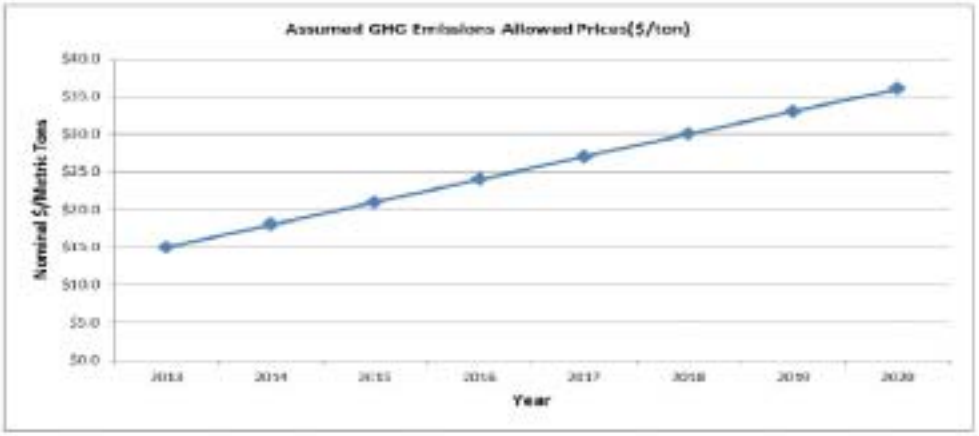
CO_2 Allocations and Costs Assumptions

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electrical Sector Total	95.8427	94.0851	92.2268	90.3725	88.5139	86.7576	84.9813	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427
DWP Factor	0.14165509	0.14169262	0.14086639	0.14434701	0.14814139	0.15381656	0.14963257	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137
DWP Allocation (MMT)	13.584	13.330	12.920	13.040	13.216	13.208	12.704	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680
Cost Assumption ($/ton)	$15.0	$18.0	$21.0	$24.0	$27.0	$30.0	$33.0	$36.0	$39.0	$42.0	$45.0	$48.0	$51.0	$54.0	$57.0	$60.0	$63.0	$66.0



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Appendix O Public Outreach

This Appendix O describes the public outreach that was carried out as part of the 2012 IRP process to involve the public in the development of this LADWP 2012 IRP. The appendix is arranged into four sections:

1. Outreach Overview: Describes the purpose of the public outreach effort, and outlines the outreach process and its relationship to this IRP.
2. Community Outreach Program: Provides an overview of all aspects of the outreach, including stakeholder meetings, website, and public workshops.
3. Comments and Discussion Themes: Presents a summary of the public comments inputted during the community outreach program; and discussion of themes synthesized from the public input.
4. Exhibits: Include the notes from the stakeholder meetings and public workshops, comment forms submitted at the public meetings and online, and other comments that were submitted through the website, e-mail, and US mail.

O.1 Outreach Overview

The 2012 IRP process included a public outreach effort to provide information, increase awareness, and gather public input on LADWP's long-term power resource plan. Public outreach consisted of a series of stakeholder meetings, a public workshop, and a dedicated website (www.ladwp.com/lapowerplan). Comments were gathered at the stakeholder meetings and public workshop, and were also provided through an online comment form, direct e-mail, and the US mail.

The public outreach began with two stakeholder meetings held in early 2012. Comments received at these meetings were considered in the development of the preliminary planning cases which were subsequently modeled and were analyzed.

The preliminary results were documented in the 2012 Draft IRP that was made available on the website on October 5, 2012. The draft IRP was presented at three stakeholder meetings and one public workshop held on October 11, 2012. Comments were accepted through November 5, 2012.

The many public comments and input received were synthesized into a set of discussion themes that reflect the major ideas provided by the public. The themes were reviewed and considered in developing the final recommended plan that is incorporated in this final 2012 IRP document.

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O.2 Community Outreach Program

LADWP developed a multipronged outreach approach to allow community members and stakeholders different opportunities to provide input on the 2012 IRP. Community involvement opportunities were provided through a website, stakeholder meetings, and a general public workshop. Comments were accepted at the meetings and workshops, through the website, and via direct e-mail and the US mail. Input collected through each of these means is considered of equal importance when considered by LADWP staff.

- **Pre-Draft Stakeholder Meetings**. LADWP conducted meetings targeting specific stakeholders in early 2012, including business and industry representatives on February 8, and environmental groups on March 1. The purpose of these meetings was to discuss and collect public inputs for consideration in the development of the 2012 Draft IRP. Input collected at these meetings is included in the discussion themes found in the next section of this appendix. Discussion notes can also be found in Exhibit A.

- **Draft IRP Stakeholder Meetings and Public Workshop**. LADWP conducted three meetings targeting specific stakeholders in the fall of 2012, including environmental groups on September 21, commercial/business customer representatives on October 4, and Neighborhood Council members on October 23. A general public workshop was also held, on October 11. The purpose of the workshop and meetings was to present the 2012 Draft IRP and collect public input for consideration prior to preparing the 2012 Final IRP. Input collected at these meetings is included in the discussion themes found in the next section of this document. Discussion notes can also be found in Exhibit B.

- **Website and Online Forms**. A project website (www.ladwp.com/lapowerplan) was utilized for the 2012 IRP. The website included an announcement of the public workshop, and a section that allowed the public to submit comments and questions about the plan online. The website provided access to a complete version of the 2012 Draft IRP and associated technical appendices, as well as a stand-alone version of the Executive Summary. Comments submitted through the website can be found in Exhibit C. Comments submitted through other methods (e-mail or U.S. mail) can be found in Exhibit D.

O.3 Discussion Themes

The public workshops, stakeholder meetings, online survey, and comment forms yielded a significant amount of information from LADWP customers related to the 2012 IRP. This information has been synthesized into a set of discussion themes that reflect the major ideas provided by participants during the community outreach program:

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The discussion themes listed below are not representative of the city at-large, and only encompass input from participants in the public workshops, attendees at the stakeholder meetings and public workshop, and members of the public who completed the online comment form, or submitted comments through e-mail or the US mail. All the ideas that were prioritized during the public workshops are included within the discussion themes, however, each theme is considered to be of equal importance, and the themes are not listed in any order of priority.

Theme: Eliminate Coal from LADWP's Energy Portfolio

Discussion

The majority of comments favored the early removal of coal from LADWP's resource portfolio. Some were concerned that Navajo would continue to operate after LADWP divestiture, and suggested the plant be shut down. Greenhouse gas emissions, along with other pollutants associated with coal energy were noted.

Related LADWP Actions:

- LADWP is proceeding with plans to replace Navajo Generating Station by 2015 – four years ahead of the SB 1368 requirement.
- The Intermountain Power Project is modeled in this IRP through 2027, but LADWP is working with the project participants to convert the IPP facility from coal to natural gas, and is hopeful that a firm conversion date can be established in time for next year's IRP analysis.

Theme: Incorporate More Renewables

Discussion

Many public comments suggested higher levels of renewables, beyond the mandated 33% by 2020. Some promoted the idea of 50% and even 100% renewables. LADWP's approach regarding this is to proceed cautiously until more is known about the operational and financial implications of higher levels. The IRP is prepared annually, and it is possible that future IRPs will include cases that incorporate higher levels of renewables.

Related LADWP Actions:

- LADWP will increase its levels of renewable resource generation in accordance with SB 2 (1X).
- LADWP will complete a study to consider issues associated with integrating increasing amounts of variable energy resources such as wind and solar, to reflect possible megawatt limits for the LADWP electric power system.

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Theme: Incorporate More Local Solar

Discussion

Incorporate More Local Solar

Many comments promoted the adoption of higher levels of local solar, noting the abundance of sunshine in the southern California region. The benefit of providing local jobs was also noted as a supporting argument to increase penetration levels. One comment suggested investing to install solar on every house and building in Los Angeles. Regarding LADWP's current customer incentive program, multiple comments recommended hiring more inspectors to streamline the process which many see as too slow, especially when compared to other utilities.

Related IRP Recommendations

- Develop a renewable energy feed-in tariff program to encourage 150 MW of renewable generation resources to be developed by July 2013.
- Encourage the development of an additional 50 MW of customer net-metered solar projects before 2015.
- Develop up to 30 MW of solar capacity on existing properties under public/private partnership projects before 2015.

Theme: Incorporate More Distributed Generation

Discussion

Since the majority of LADWP's new Distributed Generation (DG) will come from local solar, this theme is somewhat associated with the More Local Solar theme. Most of the comments regarding more DG point to the governor's statewide goal for 12,000 MW, of which LADWP's proportionate share is assumed to be 1,200 MW. Within this 2012 IRP, the highest levels of new DG are 485 MW by 2020, and 852 MW by 2032. LADWP's concern with DG levels is maintaining reliability (see Section 3.4.4). Numerous utility studies have recommended a limit of 15% of the peak load circuit capacity – for LADWP this is approximately 980 MW. As LADWP adopts more DG per its current plan, and as more experience is gained along with more industry-wide research in this area, it is possible that future IRPs will consider higher DG levels.

Related LADWP Actions.

LADWP will continue its study of issues associated with integrating increasing amounts of variable energy resources to assess possible megawatt limits for the LADWP electric power system.

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- LADWP will further develop its Smart Grid plans, which will facilitate the adoption of increasing levels of distributed generation.

  LADWP will investigate applications for energy storage, including those that may enable higher levels of local distributed generation.

Theme: Incorporate More Energy Efficiency and Demand Response

Discussion

LADWP's Energy Efficiency (EE) targets, based on year 2020, have increased significantly, from 8.6% approved in December 2011, to 10% approved in May 2012, with a further anticipated increase to 15%, pending completion of an updated potential study in 2013. Comments received supported more EE and Demand Response (DR) incorporated into LADWP future plans. As presented in this 2012 IRP, EE and DR are vital components within all long-term resource planning options. As the results of the upcoming potential study are developed and finalized, they will be adopted into the IRP planning strategy.

Related LADWP Actions:

In May 2012, the Board of Water and Power Commissioners approved a revised target of 15% of energy efficiency by 2023, subject to an updated potential study.

Implement 206 MW of demand response by 2020 and 500 MW of demand response by 2026.

Theme: Reduce Greenhouse Gas Emissions

Discussion

This was an overarching theme of the public comments received. Indirect societal costs, health effects, global warming and super storm Sandy were cited as reasons for accelerating the timelines to reduce GHGs. Rooftop gardens were promoted as a means to absorb CO_2. In considering the GHG impacts of fuel consumption for electricity generation, many comments pointed to the additional impacts resulting from fuel production (coal mining and gas drilling). Comments pointed out the need for considering energy efficiency, demand response, load shifting, and other technologies such as shunt reactive support to offset future additions of gas-fired capacity.

Related LADWP Actions:

- LADWP is pursuing coal replacement (see above Theme).

  LADWP is repowering its coastal generation with more efficient units.

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- LADWP is adopting higher levels of renewables and energy efficiency, demand response, and other load shifting strategies

  Provide financial incentives to encourage customers to shift their load away from peak hours to reduce need for on-line generation and capacity additions

- Continue to investigate upgrades to the transmission and distribution system to provide voltage support and power import capabilities to minimize on-line generation

- Consider quick start generators when repowering to reduce the need for on-line generation

Theme: Look at New Case Scenarios

Discussion

Many comments suggested a scenario that contained no new gas-generation resources, an eventual portfolio of 100% renewables, and investments in EE, conservation, renewables and Demand Response. Some felt that multiple sets of potential renewable resource mixes should be considered.

Related LADWP actions

- LADWP prepares a new IRP annually and will consider new scenarios within subsequent case option development processes

Theme: Financial and Rate Concerns

Discussion

Some comments expressed concern that LADWP needs to ensure its financial stability and integrity. Many comments presented concerns with rising electricity rates and wanted to ensure that the cost and benefits were clearly presented; and recommended a comparison with other regional and out-of-state utilities. One comment suggested that LADWP keep coal for as long as possible, and that other forms of energy are not mature and are too costly. Conversely, other comments suggested that rate increases were acceptable if EE options are made available to help reduce customer bills. One comment suggested that LADWP rates are too low and the tiers are too generous – resulting in disincentives for EE and renewables.

Related LADWP actions

LADWP will continue to work with our stakeholders including the Office of the Ratepayer Advocate (ORA) to ensure that the financial requirements of meeting its mandated obligations and discretionary goals are clearly delineated and understood.

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- Provide EE and CSM solar incentives to help customers reduce the impact that rates have on their bills

  Encourage demand response incentives and time-of-use rates to encourage shifting of load away from peak hours and reduce customer bills.

Theme: Maintain Power Reliability

Discussion

Some comments expressed concern about the state of the LADWP infrastructure, noting that the reliability program continues to be subject to budgets cuts - unlike mandated areas such as renewables. They point to the 2011 wind storm and 2006 heat storm as evidence that the infrastructure is getting older and more costly to maintain, and suggest that paying more now to address this problem will save money later.

Related LADWP actions

Continue to prioritize those infrastructure elements that are in urgent need of repair/replacement, and try to extend reliable operations with the (less than fully funded) budget provided. See Section 1.6.3 and Appendix E for more information.

LADWP will continue to work with our stakeholders and the Office of the Ratepayer Advocate (ORA) to ensure that the financial requirements of meeting its mandated obligations and discretionary goals are clearly delineated, and understood.

Theme: LADWP Should Take a Leadership Role

Discussion

Regarding renewable resources and other green energy matters, many suggested that LADWP, as a municipal utility, should lead by example, consider unconventional business models, and through its governance garner the political will to do something different.

Related LADWP actions

LADWP's first and foremost responsibility is to its ratepayers, and will continue to pursue its balanced strategy of reliability, competitive rates, and environmental stewardship. To the extent that new ideas or unconventional approaches to long term planning could potentially benefit the ratepayers, they should and will be considered.

LADWP will continue to provide transparency in its resource planning activities to encourage input from all stakeholders.

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- Advocate for consistency and clarity in regulations that affect our ratepayers while meeting environmental objectives.

O.4 Exhibits

- **A – Stakeholder Meeting Notes and Survey/Comment Forms**
- **B – Public Workshop Notes and Survey/Comment Forms**
- **C – Website Online Survey/Comment Forms**
- **D – Other Survey/Comment Inputs**

To view these exhibits, please visit www.ladwp.com/laipowerplan

Appendix P Abbreviations and Acronyms

P.1 Overview

This appendix presents acronyms for agencies and other entities, facilities and locations, electric industry terms, miscellany, and units of measure.

P.2 Agencies and Other Entities

APS	Arizona Public Service Company
BPA	Bonnerville Power Administration
BOS	Bureau of Sanitation
CAISO	California Independent System Operator
CARB	California Air Resources Board
CEC	California Energy Commission
City	City of Los Angeles
CPUC	California Public Utilities Commission
DOD	U.S. Department of Defense
DOE	U. S. Department of Energy
EPA	U. S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
FSO	LADWP Financial Services Organization
IID	Imperial Irrigation District
IOU	California investor owned utilities
IPA	Intermountain Power Agency
IPCC	Intergovernmental Panel on Climate Change
IPPCC	Intermountain Power Project Coordinating Committee
ISDA	International Swaps and Derivatives Association
JPL	NASA Jet Propulsion Laboratory
LADWP	Los Angeles Department of Water and Power
NAESB	North American Energy Standards Board
NASA	National Aeronautic Space Administration
NERC	North American Electric Reliability Corporation
NPC	Nevada Power Company
NREL	National Renewable Energy Laboratory
PG&E	Pacific Gas and Electric Company
PwC	PriceWaterhouse Coopers
RTO	Regional Transmission Organization
RWQCB	Regional Water Quality Control Board
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SCPPA	Southern California Public Power Agency
SoCal	Southern California Gas Company
SRP	Salt River Project
SWRCB	State Water Resources Control Board

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TEC	Tucson Electric Company
UCLA	University of California at Los Angeles
UCSD	University of California at San Diego
USC	University of Southern California
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council

P.3 Facilities and Locations

BPA	Bonnerville Power Administration
BBRTP	Barren Ridge Renewable Transmission Project
BRSS	Barren Ridge Switching Station
COB	California-Oregon Border
COI	California-Oregon Intertie
EOR	East-of-the-River
HSS	Haskell Switching Station
IGS	Intermountain Generating Station
IPP	Intermountain Power Project
NOB	Nevada-Oregon Border
NTS	Northern Transmission System
PACI	Pacific AC Intertie
PDCI	Pacific High Voltage Direct Current Intertie
PTWPP	Pine Tree Wind Power Project
PVD2	Palo Verde-Devers Line No. 2
PVNGS	Palo Verde Nuclear Generating Station
SHARE	Scattergood-Hyperion Alternative Renewable Energy Project
SRP	Salt River Project
STS	Southern Transmission System
UGPP	Upper Gorge Power Plant
US	United States
WREZ	Western Renewable Energy Zone
WOR	West-of-the-River
WSPP	Western Systems Power Pool

P.4 Electric Industry Terms

A/C	air conditioning
AC	Alternating Current
AEDP	Advanced ESS Demonstration Project
AMI	Advanced Metering Infrastructure
AQMP	Air Quality Management Plan
BACT	Best Available Control Technology
BIGCC	Biomass Integrated Gasification Combined Cycle
BPJ	Best Professional Judgment
CAES	compressed air energy storage
CAMR	Clean Air Mercury Rule

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CAP	Climate Action Plan
CCC	closed cycle cooling
CH_4	methane
CHP	combined heat and power
CLEO	Commercial Lighting Efficiency Offer
CLFR	compact linear fresnel reflector
CNG	compressed natural gas
CNM	Customer Net Metered
CO_2	carbon dioxide
CSI	California Solar Initiative
CSP	concentrating solar thermal power plants
CY	calendar year
DC	Direct Current
DC&M	Distribution Construction and Maintenance
DG	distributed generation
DNI	direct normal insolation
DR	Demand Response
DSM	Demand Side Management
E&L	Environment and Lands
ECAF	Energy Cost Adjustment Factor
EDS	Energy Dissipation Station
EE	Energy Efficiency
EHV	Extra-High Voltage
ESPs	energy service providers
ESS	energy storage system
ETD	Electric Trouble Dispatch
FAR	Firm Access Rights
FES	flywheel energy storage
FIT	Feed-in Tariff
GHG	greenhouse gas
GHGs	greenhouse gases
GREEN	Green Power for Green LA Program
GT&D	Generation, Transmission and Distribution
GWP	global warming potential
HHV	higher heating value
HRSG	heat recovery steam generator
HVAC	heating, ventilating, and air conditioning
ICEs	internal combustion engines
IGCC	integrated gasification combined cycle
IM	impingement mortality
LCOE	levelized cost of energy
LF	Load Factor
LFG	landfill gas
LNG	liquefied natural gas
LPG	propane
LSE	loadserving entities

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NaS	sodium-sulfur
NEL	Net Energy for Load
N_2O	nitrous oxide
NO_2	nitrogen dioxide
NOx	oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NPHR	net plant heat rate
O&M	operations and maintenance
OASIS	open-access same-time information systems
OATTS	open-access transmission tariffs
OTC	once-through cooling
PFCs	perfluorocarbons
PHEV	plug-in hybrid electric vehicle
PHS	pumped-hydro storage
PMU	power measurement units
POUs	publicly-owned electric utilities
PTC	production tax credit
PV	photovoltaic
QRAs	Qualified Resource Areas
RASS	Residential Appliance Saturation Survey
RECLAIM	Regional Clean Air Incentive Market
RETI	Renewable Energy Transmission Initiative
RPS	Renewable Portfolio Standard
RS	receiving station
RTCs	RECLAIM Trading Credits
Rule	Cooling Water Intake Structure Rule
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAS	Substation Automation System
SCADA	supervisory control and data acquisition
SEC	Standard Energy Credit
SES	super capacitor energy storage
SF_6	sulfur hexafluoride
SIP	Solar Incentive Program
SMES	Superconducting Magnetic Energy Storage
SNCR	selective non-catalytic reduction
SOx	sulfur oxide
T&T	transmission and delivery
UBS	Utility-built Solar
UES	ultra capacitor energy storage
VRB	Vanadium Redox Battery
WEC	Wave Energy Converter
XRT	experimental demand response contract
ZTA	Zone Identification and Technical Analysis
ZNE	Zero Net Energy

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P.5 Miscellany

A	Category of Flow Meter
AB	Assembly Bill
AMR	Automatic Meter reading
CFL	compact fluorescent light
CI	commercial/industrial
CIS	Customer Information System
CS	Customer Service
CSA	Candidate Study Aras
ECC	Energy Control Center
EIR	Environmental Impact Report
F	Category of flow meter
FM	Category of flow meter
GDP	gross domestic product
JFB	John Ferraro Building
LED	light-emitting diode
MFR	multi-family residence
NLC	net levelized cost
OH	overhead
QRAs	Qualified Resource Areas
RF	Radio Frequency
RFP	Request for Proposal
SB	Senate Bill
SBDI	Small Business Direct Install
SFR	single family residence
UG	Underground

P.6 Units of Measure

BTU	British thermal unit
GWh	gigawatt-hour
kV	kilovolt
kW	kilowatts
MMBtu	Million British thermal units
MMT	million metric tons
$MMTCO_2E$	million metric ton CO2 equivalent
MVA	mega volt amperes
MW	megawatt
MWhs	megawatt hours
TWh	terawatt hour

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The EDR-City Directory
Abstract

Capitol Tower Building
1760 Vine Street
Hollywood, CA 90028

Inquiry Number: 1480337.6

Wednesday, August 22, 2018

The Standard in Environmental Risk Management Information

440 Wheelers Farms Road
Milford, Connecticut 06461

Nationwide Customer Service

Telephone 1-800-352-0050
Fax 1-800-231-6802
Internet www.edrnet.com

EDR City Directory Abstract

Environmental Data Resources, Inc's (EDR) City Directory Abstract is a component report designed to assist environmental professionals in evaluating potential liability on a target property resulting from past activities. EDR's City Directory Abstract includes a review and abstract of available city directory data for certain locations. The following is the name of the contiguous developed area for your address.

Thank you for your business.
Please contact EDR at 1-800-352-0050
with any questions or comments.

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SUMMARY

- *City Directories*

Sources consulted, including city cross reference and telephone directories, were reviewed at approximately five year intervals starting approximately 1920 through 2015. Where years were not necessarily available, a summary of findings for adjacent years is provided in the text of this report.

This report compiles information by geocoding the subject properties (that is, placing the addresses on a grid) for each subject property and evaluating historical records containing addresses within 1/8 mile of the subject property. There is no warranty or guarantee that all potential environmental concerns for the subject properties will be identified in this report. No warranty or guarantee is expressly made regarding the accuracy of any information contained in the enclosed databases or concerning those properties that may not be addressed in this report.

Date EDR Searched Historical Sources: August 23, 2016

Banjas/Property:
1750 Ivar Street
Hollywood, CA 90028

Year	Type	Source
1922	Address Not Listed in Research Source	Los Angeles Directory Co
1927	Address Not Listed in Research Source	Los Angeles Directory Co
1933	Address Not Listed in Research Source	Los Angeles Directory Co
1938	Address Not Listed in Research Source	Los Angeles Directory Co
1943	Address Not Listed in Research Source	Los Angeles Directory Co
1949	Address Not Listed in Research Source	Los Angeles Directory Co
1952	Address Not Listed in Research Source	Los Angeles Directory Co
1954	Hollywood Hollywood Hollywood & Vicinity (Polk)	Los Angeles Directory Co
1959	Address Not Listed in Research Source	Los Angeles Directory Co
1967	Address Not Listed in Research Source	Los Angeles Directory Company (Polk Directory)
1972	Address Not Listed in Research Source	Los Angeles Directory Co
1976	Address Not Listed in Research Source	Los Angeles Directory Co
1980	Address Not Listed in Research Source	Los Angeles Directory Co
1985	Address Not Listed in Research Source	Los Angeles Directory Co

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Year	Uses	Source
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Company Publishers
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	R. L. Polk & Co
[illegible]	Address Not Listed in Research Source	R. L. Polk & Co
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	Pacific Directory [illegible]
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	Pacific Telephone
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co Publishers
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co
[illegible]	Address Not Listed in Research Source	R. L. Polk & Co
[illegible]	Address Not Listed in Research Source	R. L. Polk & Co
[illegible]	Address Not Listed in Research Source	Pacific Telephone
[illegible]	Address Not Listed in Research Source	Pacific Telephone

Year	Uses	Source
[illegible]	[illegible]	Pacific Telephone
	[illegible]	
	BATES [illegible]	
	[illegible]	
	CAMPBELL [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	GUILD [illegible] ADVERTISING [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
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	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible] STUDIOS [illegible]	

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Year	Data	Source
1960	Address Not Listed in Research Source	Pacific Telephone
1961	Address Not Listed in Research Source	[illegible]
1962	[illegible]	Pacific Telephone
	AMERICAN MUSIC [illegible] (75%)	
	[illegible]	
	COMMUNITY RECORDS [illegible]	
1963	Address Not Listed in Research Source	Pacific Telephone
1964	Address Not Listed in Research Source	Pacific Telephone
1965	Address Not Listed in Research Source	[illegible]
1966	Address Not Listed in Research Source	Pacific Telephone
1967	[illegible]	R.L. Polk & Co
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	TOWER RECORDS [illegible]	
1968	Address Not Listed in Research Source	Pacific Telephone
1970	VINE ST	R.L. POLK & CO
	CAPITOL PHONOGRAPHIC (75%)	
	CAPITOL RECORDS INC (75%)	
	CAPITOL RECORDS INC [illegible]	
	TOWER RECORDS [illegible]	
	[illegible]	R.L. POLK & CO
	ANGEL RECORDS [illegible]	
	APPLE RECORDS INC (75%)	
	CAPITOL INDUSTRIES INC EXECUTIVE OFFICE (75%)	
	CAPITOL RECORDS DISTRIBUTING CORP [illegible] (75%)	
	CAPITOL RECORDS INC (75%)	

4240[illegible]

Year	Data	Source
1970	[illegible]	
	TOWER RECORDS [illegible]	
	VINE ST	R.L. POLK & CO
	ANGEL RECORDS [illegible]	
	APPLE RECORDS INC (75%)	
	CAPITOL INDUSTRIES INC EXECUTIVE OFFICE (75%)	
	CAPITOL RECORDS [illegible]	
	CAPITOL RECORDS DISTRIBUTING CORP (75%)	
	CAPITOL RECORDS INC [illegible]	
	CAPITOL RECORDS INC (75%)	
	TOWER RECORDS [illegible]	
	[illegible]	R.L. POLK & CO
	ANGEL RECORDS [illegible]	
	TOWER RECORDS (75%)	
	VINE ST	R.L. POLK & CO
	ANGEL RECORDS (75%)	
	APPLE RECORDS INC (75%)	
	CAPITOL INDUSTRIES INC EXECUTIVE OFFICE (75%)	
	CAPITOL PHONOGRAPHIC (75%)	
	CAPITOL RECORDS DISTRIBUTING CORP (75%)	
	CAPITOL RECORDS INC (75%)	
	CAPITOL RECORDS [illegible]	
1971	VINE ST	[illegible]
	ANGEL RECORDS (75%)	
	APPLE RECORDS INC (75%)	
	[illegible] MUSIC [illegible]	
	CAPITOL INDUSTRIES INC EXECUTIVE OFFICE (75%)	
	CAPITOL PHONOGRAPHIC (75%)	
	CAPITOL RECORDS DISTRIBUTING CORP (75%)	
	CAPITOL RECORDS INC (75%)	
	CAPITOL RECORDS [illegible]	
	ELECTRIC & MUSICAL INDUSTRIES [illegible] (75%)	
	[illegible]	
	GENERAL EXECUTIVE OFFICE (75%)	
	GENERAL EXECUTIVE OFFICE (75%)	
	GENL EXECUTIVE OFC (75%)	

[illegible]

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Year	Name	Source
1977	[illegible]	
	[illegible] (1750)	
	GLENWOOD MUSIC (1750)	
	[illegible]	
	RECORDING STUDIOS (1750)	
	TOWER RECORDS (1750)	
	VANGUARD SONGS (1750)	
197[illegible]	[illegible]	[illegible]
1978	[illegible]	Pacific Telephone
	ANGEL RECORDS (1750)	
	[illegible]	
	CAPITOL PHONOGRAPHS (1750)	
	[illegible]	
	[illegible]	
	GLENWOOD MUSIC (1750)	
	RECORDING STUDIOS (1750)	
	[illegible]	Pacific Telephone
	ANGEL RECORDS (1750)	
	APPLE RECORDS INC (1750)	
	CAPITOL INDUSTRIES [illegible] (1750)	
	CAPITOL RECORDS [illegible] (1750)	
	CAPITOL RECORDS INC (1750)	
	CAPITOL RECORDS INC (1750)	
	CAPITOL RECORDS [illegible]	
	GLENWOOD MUSIC (1750)	
	APPLE RECORDS INC (1750)	
	CAPITOL PHONOGRAPHS (1750)	
	CAPITOL RECORDS INC (1750)	
	GLENWOOD MUSIC (1750)	
	[illegible]	Pacific Telephone
	ANGEL RECORDS (1750)	
	CAPITOL INDUSTRIES INC (1750)	
	CAPITOL RECORDS INC (1750)	
	CAPITOL RECORDS INC (1750)	
	GLENWOOD MUSIC (1750)	

Year	Name	Source
1979	[illegible]	[illegible]
	ANGEL RECORDS (1750)	
	AUDIO DEVICES INTERNATIONAL (1750)	
	APPLE RECORDS INC (1750)	
	BEECHWOOD MUSIC (1750)	
	CAPITOL INDUSTRIES [illegible] (1750)	
	CAPITOL RECORDS INC (1750)	
	CAPITOL RECORDS INC (1750)	
	CAPITOL [illegible] (1750)	
	CAPITOL PRODUCTIONS [illegible] (1750)	
	CAPITOL SPECIAL MARKETS (1750)	
	EXECUTIVE OFFICES (1750)	
	[illegible] (1750)	
	GLENWOOD MUSIC (1750)	
	[illegible]	
	[illegible] (1750)	
	[illegible] (1750)	
	RECORDING STUDIOS (1750)	
	[illegible] (1750)	
	VANGUARD SONGS (1750)	
1980	[illegible]	Pacific Telephone
	ANGEL RECORDS (1750)	
	APPLE RECORDS INC (1750)	
	ANGEL RECORDS [illegible] LOS ANGELES (1750)	
	[illegible] (1750)	
	CAPITOL INDUSTRIES INC EXECUTIVE OFFICE [illegible] LOS ANGELES (1750)	
	CAPITOL [illegible] LOS ANGELES (1750)	
	CAPITOL RECORDS INC [illegible] LOS ANGELES (1750)	
	CAPITOL [illegible] LOS ANGELES (1750)	
	[illegible]	Pacific Telephone
	ANGEL RECORDS (1750)	
	CAPITOL INDUSTRIES INC (1750)	
	CAPITOL RECORDS INC (1750)	
	CAPITOL RECORDS INC (1750)	
1981	[illegible]	Pacific Telephone

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Year	Make	Service
1971	[illegible]	
	ANGEL RECORDS (1967)	
	APPLE RECORDS INC OFFICE (1968)	
	CAPITOL [illegible]	
	CAPITOL PRODUCTIONS LABEL (1969)	
	CAPITOL RECORDS INC (1970)	
	CAPITOL STUDIOS [illegible]	
1969	[illegible]	Pacific Bell
	ANGEL RECORDS (1967)	
	CAPITOL [illegible]	
	[illegible]	
	[illegible]	
	FLOORING STUDIOS (1969)	
	[illegible]	Pacific Bell
	ANGEL RECORDS (1967)	
	[illegible]	
	CAPITOL INDUSTRIES INC D BELL RECORDS (1969)	
	CAPITOL RECORDS INC (1970)	
	CAPITOL RECORDS INC (1970)	
	CAPITOL RECORDS INC (1970)	
	[illegible]	[illegible]
	ANGEL RECORDS (1967)	
	CAPITOL RECORDS (1967)	
	CAPITOL RECORDS INC (1970)	
	[illegible]	
1969	[illegible]	Abbey Road
	ANGEL RECORDS (1967)	
	CAPITOL RECORDS PRODUCTIONS (1970)	
	CAPITOL RECORDS [illegible] OFFICE (1970)	
	CAPITOL RECORDS (1967)	
	CAPITOL RECORDS INC (1970)	
	CAPITOL STUDIOS HOLLYWOOD (1969)	
	RECORDING STUDIOS (1969)	
1969	Pacific Bell Logo Building Studio	Pacific Bell

Year	Make	Service
1971	[illegible]	Abbey Road
	ANGEL RECORDS (1967)	
	CAPITOL RECORDS (1970)	
	[illegible]	
	CAPITOL RECORDS (1970)	
	GRAPHICS STUDIOS (1970)	
	RECORDING STUDIOS (1970)	
	[illegible]	Pacific Bell
	[illegible]	
1969	[illegible]	Pacific Bell Telephone
	ANGEL RECORDS (1967)	
	CAPITOL RECORDS (1970)	
	[illegible]	
	CAPITOL RECORDS [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	Pacific Bell Telephone
	[illegible]	
	[illegible]	Pacific Bell Telephone
	ANGEL RECORDS [illegible]	
	CAPITOL RECORDS [illegible]	
	CAPITOL RECORDS (1970)	
	[illegible]	
	CAPITOL RECORDS [illegible]	
	CAPITOL RECORDS [illegible]	
	[illegible]	
	CAPITOL RECORDS (1970)	
	[illegible]	
	[illegible]	
1969	Pacific Bell Telephone Company	CTC

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Year	Issue	Source
1994	[illegible]	[illegible]
2001	[illegible]	Rancho Santa Margarita
	[illegible]	
	[illegible]	
	[illegible]	
2011	Address Verification Response Source	[illegible] Company, Inc.
2012	Address Verification Response Source	[illegible] Company
2014	Address Verification Response Source	[illegible] Company

Adjoining Properties

SURROUNDING

[illegible]
[illegible]

Year	Item	Source
1937	[illegible]	Los Angeles County, Ca
1938	Address Verification Response Source	Los Angeles County, Ca
1939	[illegible]	Los Angeles County, Ca
1940	[illegible]	Los Angeles County, Ca

Year	Issue	Source
1941	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
1946	Address Verification Response Source	Los Angeles County, Ca
1947	[illegible]	Los Angeles County, Ca
1948	Address Verification Response Source	Kapnistakis, Douglas, Petrovich
1949	[illegible]	Los Angeles County, Ca
1950	[illegible]	Los Angeles County, Ca
	[illegible]	
	[illegible]	
	[illegible]	

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Year	Listing	Source
1920	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
1930	[illegible]	Los Angeles Directory Co.
1931	[illegible]	Los Angeles Directory Co.
1932	[illegible]	Los Angeles Directory Co.
1933	[illegible]	Los Angeles Directory Co.
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	

Year	Listing	Source
1929	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
1930	[illegible]	Los Angeles Directory Co.
1931	[illegible]	Los Angeles Directory Co.
1932	[illegible]	Los Angeles Directory Co.
1933	[illegible]	Los Angeles Directory Co.
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	

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Year	Date	Source
1912	[illegible]	Los Angeles Times (Los Angeles, CA)
1912	[illegible]	Los Angeles Evening Post-Record
1913	[illegible]	Los Angeles Times (Los Angeles, CA)
1913	[illegible]	Los Angeles Times (Los Angeles, CA)

Year	Date	Source
1913	[illegible]	Los Angeles Evening Post-Record

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Year	Item	Source
[illegible]	[illegible]	[illegible]

Year	Item	Source
[illegible]	[illegible]	[illegible]

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Year	Item	Source
[illegible]	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
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[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

Year	Item	Source
[illegible]	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
1951	[illegible]	Los Angeles Directory Co Publishers
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
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	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	

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Year	Name	Source
[illegible] (continued)		
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
[illegible]	Address Not Listed in Research Source	Los Angeles Directory Co.
[illegible]	Address Not Listed in Research Source	R.L. Polk & Co.
[illegible]	Address Not Listed in Research Source	R.L. Polk & Co.
[illegible]	[illegible]	Pacific Telephone
	[illegible]	
	[illegible]	
[illegible]	Address Not Listed in Research Source	Pacific Telephone
[illegible]	[illegible]	Pacific Telephone
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	

Year	Name	Source
[illegible] (continued)		
	[illegible]	
	NEW DEAL INVESTMENTS LTD (1770)	
[illegible]	Address Not Listed in Research Source	Pacific Telephone
[illegible]	Address Not Listed in Research Source	[illegible]
[illegible]	[illegible]	Pacific Telephone
	[illegible]	
	DUPARS RESTAURANTS & BAKERIES (1748)	
	[illegible]	
	[illegible]	Pacific Telephone
	[illegible]	
	[illegible]	Pacific Telephone
	[illegible]	
	[illegible]	
	HOLLYWOOD [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
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	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	DUPARS RESTAURANTS & BAKERIES (1748)	
	HOLLYWOOD [illegible]	
	[illegible] AUTO PARTS [illegible]	
	[illegible]	

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Source

Source

AR0070367

Year Client Source

Year Client Source

AR0070368

Year	Name	Source
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	ELDORADO RECORDING STUDIO [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible] PRODUCTIONS [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible] MUSIC PUBLISHERS [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
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	[illegible]	

Year	Name	Source
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	BOOTH LOUIS [illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	DUCHESS MUSIC CORP [illegible]	
	[illegible]	
	EXOTICA AGENCY [illegible]	
	[illegible]	
	GOOD HOUSEKEEPING MAGAZINE [illegible]	
	[illegible]	
	[illegible]	
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	[illegible]	
	[illegible]	
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	[illegible]	
	[illegible]	

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Year	Title	Source
[illegible]		
	REFLECTION RECORDS (???)	
	[illegible]	
	SCOTTSDALE, (???)	
	[illegible]	
	SOUND ENTERPRISES (???)	
	[illegible]	
	[illegible]	
	VERVE RECORDS (???)	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	
1975	[illegible]	[illegible]
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2023	[illegible]	Forrest B Company

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Year	Name	Source
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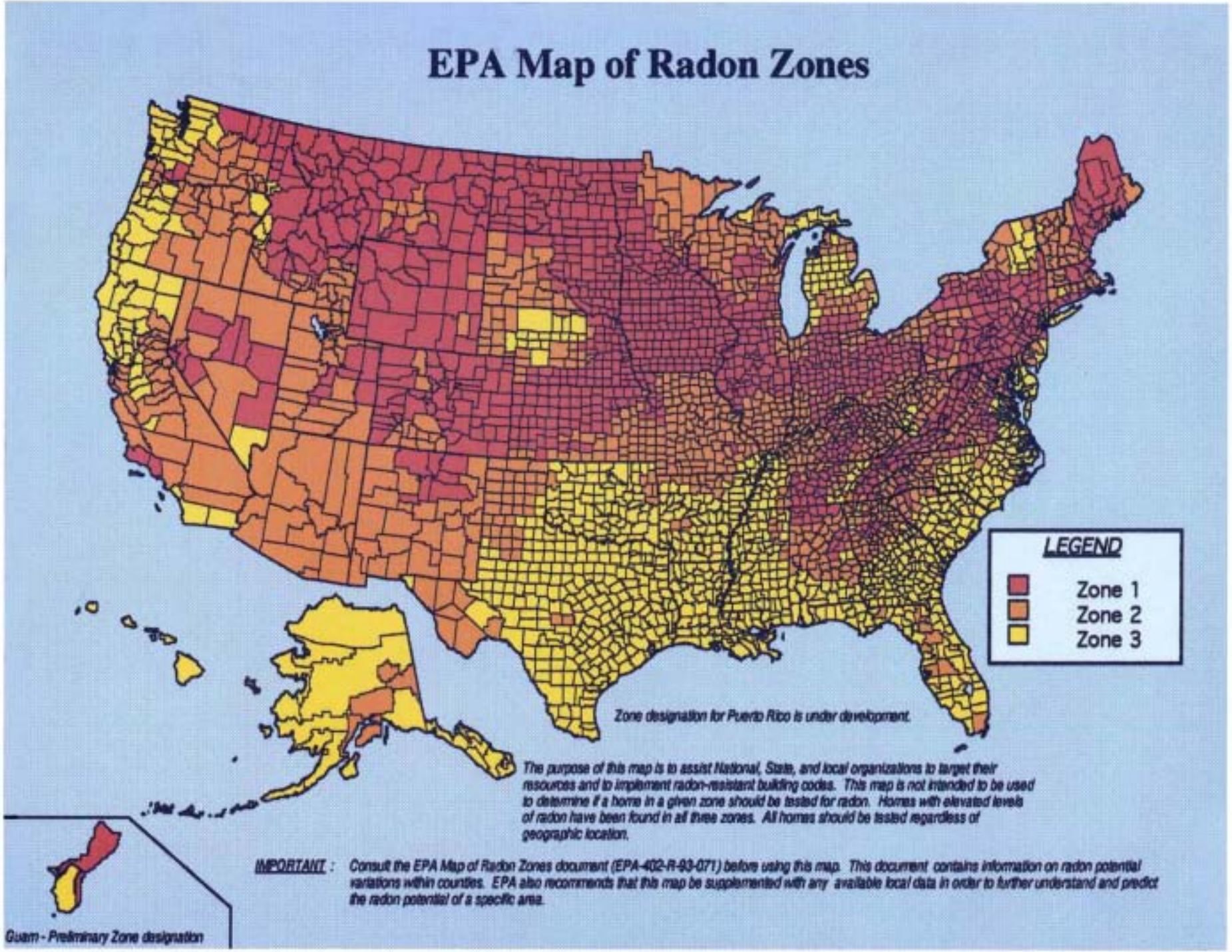
EPA Map of Radon Zones



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ESTIMATING 2003

BUILDING-RELATED

CONSTRUCTION AND DEMOLITION MATERIALS AMOUNTS

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1 Introduction

Construction and demolition (C&D) materials are generated when new structures are built and when existing structures are renovated or demolished (including deconstruction activities). Structures include all residential and nonresidential buildings, as well as public works projects, such as streets and highways, bridges, utility plants, piers, and dams. While definitions of what constitutes C&D materials vary from state to state, C&D materials measured by various parties can include land clearing debris, the vegetation that is removed when a new site is developed. Typical components of C&D materials are shown in Table 1-1.

Table 1-1. Typical components of C&D Materials

Material Components	Content Examples
Wood	Framing and framing lumber, stumps, trees, engineered wood
Drywall	Sheetrock (wallboard)
Metals	Pipes, rebar, flashing, wiring, framing
Plastics	Vinyl siding, doors, windows, flooring, pipes, packaging
Roofing	Asphalt, wood, slate, and tile shingles, roofing felt
Masonry	Cinder blocks, brick, masonry cement
Glass	Windows, mirrors, lights
Miscellaneous	Carpeting, fixtures, insulation, ceramic tile
Cardboard	From newly installed items such as appliances and tile
Concrete	Foundations, driveways, sidewalks, floors, road surfaces (all concrete containing portland cement)
Asphalt pavement	Sidewalks and road structures made with asphalt binder

The U.S. Environmental Protection Agency (EPA) has targeted C&D materials for reduction, reuse, and recovery as part of its Resource Conservation Challenge (RCC).[1] The RCC is a national effort to conserve natural resources and energy by managing materials more efficiently. The goals of the RCC are to prevent pollution and promote reuse and recycling, reduce priority and toxic chemicals in products and waste, and conserve energy and materials. The RCC has identified four national focus areas.

- Municipal solid waste recycling
- Industrial materials recycling, specifically:
  - C&D materials reduction, reuse, and recycling
  - Coal combustion products
  - Foundry sands
- Green Initiatives: Green Building and Electronics
- Priority and toxic chemical reductions[1]

With respect to C&D materials, EPA has undertaken the following activities in an effort to increase the amount of C&D materials reduced, reused, or recycled:

- Conduct outreach and education with industry and public-sector partners, and
- Recognize those with successful reuse or recycling programs, and
- Participate in green efforts, such as green building programs and green highway programs.

[1] More information about the RCC can be found at www.epa.gov/rcc.

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Furthermore, the recently-issued Executive Order 13423 requires all federal construction, renovation, and demolition projects to achieve a 50% recycling rate where markets or on-site recycling opportunities exist. EPA is committed to helping achieve that recycling rate. One of the important tasks for EPA under the RCC is to track the progress of C&D materials recovery by estimating the amount that is generated and recovered.

The purpose of this study is to determine the amount of building-related C&D materials generated and recovered in the U.S. during 2003, updating the findings of the 1998 EPA report *Characterization of Building-Related Construction and Demolition Debris in the United States* (EPA 530-R-98-010). Limited information is available on the amount of C&D materials generated and managed in the U.S. The methodology used in this report to estimate the amount of building-related C&D materials generated and recovered in the U.S. during 2003 is based on national statistical data and typical waste generation during building construction, renovation, demolition, or maintenance activities. The recovery estimate relies on 2003 data reported by state environmental agencies.

Finally, we would note that accurate measurements of C&D generation and recovery are critical in order to measure progress toward achieving increased C&D materials reuse and recycling. However, efforts to improve C&D measurement are currently hampered by a general lack of data. Thus, it should be recognized that the C&D materials estimates presented to date, including those in this report, have some level of uncertainty, and the results should be viewed in that light. Nevertheless, we believe that the estimates contained in this report reflect and are based on the best data that are currently available.

1.1 THE CONSTRUCTION INDUSTRY

1.1.1 Size of the Construction Industry

The amount of C&D materials that are generated and subsequently managed in the U.S. is dependent on the amount of activity that takes place in the entire construction, demolition, renovation, and maintenance industry. Construction is a vital sector of the economy, directly or indirectly, providing jobs and income to a large population in the U.S. Americans look to the construction industry to meet the demands of a growing population and economy. As such, federal agencies, such as the U.S. Census Bureau (USCB), regularly track the construction industry as an indicator of the economy. The construction industry is very large, yet dominated by very small businesses. For example, according to USCB data, there were 710,000 construction establishments in 2002 with 7.2 million employees, with an average employment of ten employees per establishment. In 2002, 90 percent of construction establishments had fewer than 20 employees, while only one percent of construction establishments had 100 employees or more (2005a).

The USCB uses construction spending, new home sales, and housing starts as one set of indicators of the health of the U.S. economy. The construction industry boomed during the late 1990s and into the early 2000s. Figure 1-1 shows the amount of growth in spending during that time. EPA published an estimate (in 1998) of the amount of building-related C&D materials generated in the U.S. during 1996. The estimate presented in the current report is for the amount of building-related C&D materials generated in the U.S. during 2003. Between these years, the amount of money spent on construction (for *all* structures, including buildings, roads, bridges,

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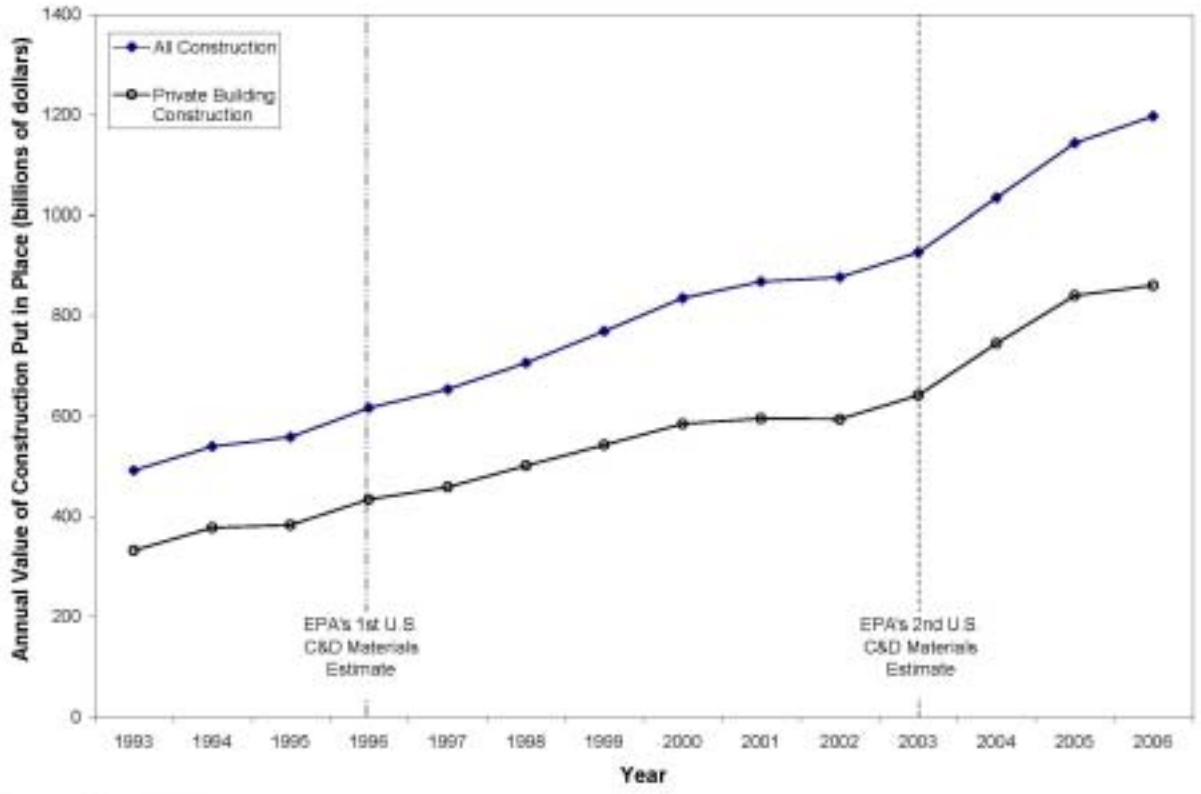
etc.) in the U.S. increased by approximately 50%, from an estimated $620 billion in 1996 to an estimated $930 billion in 2003. These costs do not have a direct relationship with materials consumption as they may include inflation, profit, and other costs. They can be used as an indicator of construction activity, however. The USCB does not break down these amounts by structure type (building vs. non-building), but does break the amounts down by use category. Those categories (as described by the USCB) that were assumed to primarily consist of building construction were aggregated for this report[2]. The USCB, however, did not break down public construction by use category until 2002, thus only private building construction spending is shown in Figure 1-1. Between 1996 and 2003, private building construction spending increased 32%. During that same time, the population of the U.S. only increased 8%.

Figure 1-1. U.S. construction spending.



Source: USCB, 2008

1.1.2 Efforts by the Construction Industry to Increase C&D Materials Recovery

The construction industry is taking large strides to lessen its impact on the environment. In furtherance of these efforts, the Associated General Contractors of America (AGC;

[2] Based on their descriptions, the USCB categories that were assumed to consist mostly of building construction and used to estimate building construction spending for Figure 1-1 were Residential, Lodging, Office, Commercial, Health Care, Educational, Religious, Public Safety, and Manufacturing. Categories that were assumed to contain mostly non-building construction were Amusement and Recreation, Transportation, Communication, Power, Sewage and Waste Disposal, and Water Supply.

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http://www.agc.org) created an Environmental Agenda in 2006, which lists seven goals. Four of these goals relate most to materials management, which are:

1. Encourage environmental stewardship through education, awareness and outreach.
2. Recognize environmentally responsible construction practices.
3. Identify opportunities to reduce the impact that construction practices have on the environment, including
    - Facilitating members' efforts to recycle or reduce construction and demolition debris.
    - Identifying and maximizing the contractor's role in "green" construction.
4. Identify ways to measure and report environmental trends and performance indicators of such trends.

Other efforts undertaken by the construction industry include the following:

- The Building Materials Reuse Association (BMRA; http://www.buildingreuse.org) facilitates building deconstruction and the reuse and recycling of recovered building materials. They produce information on deconstruction techniques and information on how to make a successful deconstruction or reuse business. They convene annually to transfer this knowledge among contractors, government representatives, and researchers.

- The Construction Materials Recycling Association (CMRA; http://www.cdrecycling.org) aids their members in the appropriate methods for processing material to ensure environmental protectiveness, as well as producing a high-value product. They have developed websites to reach out to any recyclers, users of recycled materials, and regulators in order to provide a better understanding of C&D materials recycling. They have developed websites that contain research and practical information for the recycling of concrete (http://concreterecycling.org), drywall (http://drywallrecycling.org), and asphalt shingles (http://shinglerecycling.org).

- The National Association of Home Builders (NAHB; http://www.nahb.org) issued Green Home Building Guidelines that contractors can follow to make their homes more "green," including reducing, reusing, and recycling construction waste. They also put on an annual Green Building Conference that brings together contractors and researchers to discuss new "green" construction techniques. The NAHB Research Center also pursued research in the area of C&D materials recycling, such as using the material on-site.

- The National Demolition Association (NDA; http://www.demolitionassociation.com) actively promotes recycling and reuse of the materials generated during a demolition. They released a report titled, "Demolition Industry Promotes C&D Recycling," in which they describe ways that the industry and government can work together to overcome recycling barriers. The "members of the National Demolition Association are committed to increasing the recycling and reuse of the material generated" on their jobsites. They state that "recycling is good for the environment, good for the nation's economy, a positive use of valuable commodity, and good for the country."

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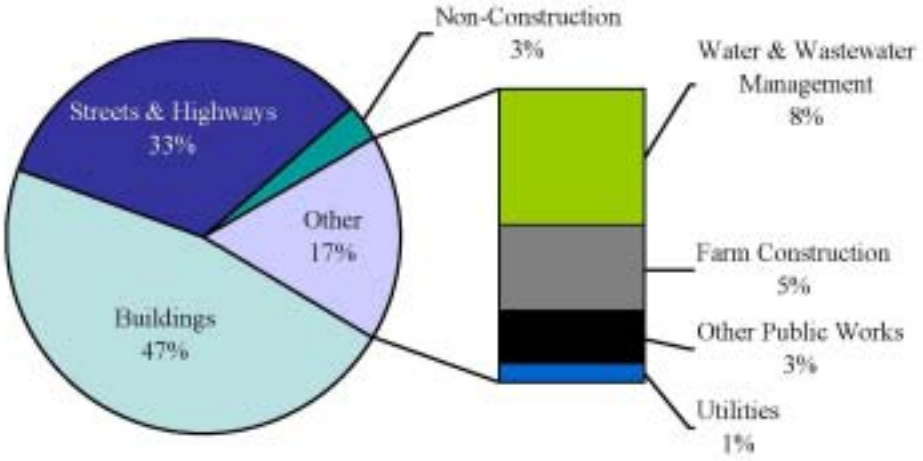
1.2 ESTIMATING BUILDING-RELATED C&D MATERIALS GENERATION AMOUNTS

There are a variety of sources of C&D materials and a variety of reasons to estimate the amount that is generated from each. C&D materials can be generated as part of normal daily life, or as part of the debris stream resulting from natural disasters. This report estimates the amount of materials generated from *building* projects that occur as a result of normal daily life, not debris resulting from disasters. C&D materials resulting from rebuilding efforts after a disaster are included in this estimate, however. In 2008, EPA published *Planning for Natural Disaster Debris,*[3] which discusses tools for forecasting disaster debris generation amounts.

One of the most common reasons to estimate the amount of C&D materials generated or recovered is to target materials for materials recovery programs. Diverting C&D materials from landfills is important because it saves natural resources, decreases greenhouse gas emissions, reduces the need for landfill space, and saves money.

Concrete is one of the most common materials used in construction. Portland cement is a key ingredient in concrete (or, more specifically, portland cement concrete). As shown in Figure 1-2, The Portland Cement Association estimated that buildings consumed only 47% of cement produced in 2003. Thus, estimating the amount of building-related C&D materials is only looking at a portion of the C&D materials stream.

Figure 1-2. Estimated consumption of portland cement in 2003.



Source: Portland Cement Association, 2006

[3] *Planning for Natural Disaster Debris* (EPA530-K-08-001) can be downloaded at http://www.epa.gov/epawaste/conserve/imr/cdm/debris.htm.

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There are three primary aspects of a building's life cycle that impact the C&D materials stream: construction, renovation, and demolition/deconstruction. Initial construction requires the most materials to be purchased, but produces the smallest amount of waste. Per building, a demolition will generate the largest amount of waste of the three activities as all materials are typically removed and enter the waste stream. Renovations (including remodeling, replacements, and additions) are a combination of both construction and demolition, removing old materials and adding new materials.

The methodology used in this report for estimating the amount of building-related C&D materials generated used national statistical data and typical waste generation data from construction, renovation, and demolition sites. National statistical data on the amount of building construction, renovation, and demolition activity were obtained from the USCB and other national sources. Some statistical data on construction are no longer collected, where this is the case, the data used in this report were projected from older data. Typical waste generation data from construction, renovation, and demolition sites was determined as an average of waste sampling studies performed at specific job sites as reported in the literature.[5] Due to the variability of construction styles, materials, and sizes, it is unknown if the waste sampling data available are representative of the entire construction industry across the U.S. Additional waste characterization studies performed at individual job sites from around the U.S. would increase confidence in these estimates.

1.3 ESTIMATING THE RECOVERED AMOUNT OF BUILDING-RELATED C&D MATERIALS

There are four stages involved in the C&D materials management process: generating the material at a job site, transporting the material to the landfill/processor-user of recycled materials (if not used on site), processing/incinerating/disposing of the material at a recycling facility/incinerator/landfill, and, in the case of recycling, using the recycled materials. Definitions of these terms as used in this document are shown in Figure 1-3. Gauging the amount of materials that flow through any stage can be performed by surveying those that are involved in the process. Surveys can be complicated and burdensome to conduct, depending on the sample size and the response rate. As a result, few entities collect this kind of information.

Recovery of building-related C&D materials for recycling, beneficial use, reuse, or waste-to-energy in 2003 was estimated using data reported by state environmental agencies. Few states report the amount of C&D materials recovered, disposed, and/or generated, however. EPA continues to investigate additional sources of C&D materials data. Additional data on construction materials recovery would increase the confidence in this estimate.

[5] Land clearing materials were excluded from the C&D estimates in this report since the site materials composition studies used to estimate the amount of materials generated at a typical job site did not include land clearing materials.

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Figure 1-3. C&D Materials Management Definitions

For purposes of this report, the following is a working set of definitions:

C&D materials are debris and other secondary construction or building materials during construction, renovation, and demolition activities.

Disposal means placing materials in a landfill.

Energy recovery refers to combustion of waste materials to provide energy.

Generation refers to activities during construction, renovation, or demolition that produces debris and other unused materials.

Recycling includes processing a used material, generally through size reduction, to make it usable as an ingredient in a new product. Sorting may be a necessary step for recycling if materials are delivered to a recycler in a mixed load.

Reuse is utilizing a used product or material in a manner that generally retains its original form and identity with minor refurbishments. Examples include fixtures, lumber, and doors that are refurbished for use.

Recovery refers to the reuse and recycling of materials, as well as utilizing materials for energy recovery.

Source reduction refers to activities that prevent C&D materials from being generated.

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2 Amount of Building-Related C&D Materials Generated

Building-related C&D materials can be divided into six categories: residential construction, residential demolition, residential renovation, nonresidential construction, nonresidential demolition, and nonresidential renovation. These categories were selected based on the relationship between available statistical data and waste sampling data. The following sections describe the data used and the methods for estimating the amount of building-related C&D materials generated, on a weight basis. Tables A-1 through A-5 in Appendix A are worksheets that provide details of the calculations used to arrive at generation for each component of the C&D materials stream.

2.1 METHODOLOGY AND RESULTS

The methodology used for this study combines national statistical data on industry activity with point source waste assessment data (i.e., waste sampling at construction, renovation, and demolition sites) to estimate the amount of C&D materials produced nationally. In general, the amount of waste (tons[1]) generated is the product of the level of activity (usually area, square feet, ft^2) and the typical amount of waste generated for that activity (usually weight per unit area, pounds per square feet, lb/ft^2). Total waste amounts are generally described in terms of weight rather than volume. This is because the volume of waste materials can change through compaction or other processing. The weight, however, generally remains constant.

2.1.1 Residential Construction

The amount of waste (tons) generated from the construction of new single and multi-family homes can be determined by multiplying the total area (ft^2) of new residential construction by the typical amount of waste generated per unit area (lb/ft^2), as shown in the equation below. The total area of new residential construction can be determined by dividing the total amount spent (U.S. dollars, $) on new residential construction by the average cost of new construction (as defined by the USCB) per unit area ($/ft^2).

Total U.S. Residential Construction Waste (tons/year) =	Total Residential Construction Put-in-Place Value ($/year) / Average Cost Per Area of Residential Construction ($/ft^2)	× Average Waste Generated Per Area for Residential Construction (lb/ft^2) / 2000 lbs/ton

Waste sampling data for new residential construction were identified for 95 projects from eight sources. The results from these studies are presented in Table 2-1. Generation rates ranged from 2.41 to 11.3 lb/ft^2. The variation in types of houses, the specific practices of the builders, and the lack of uniform standards for the collection and storage of the sampled materials may explain the differences in the estimates. In addition, these estimates, which are in some places based on 1990s data, may change with time reflecting changes in material usage and practices. Results from each source were used to develop a weighted average estimate of the overall residential construction waste generation rate of 4.39 lb/ft^2. While this category contains the largest number of job site C&D materials surveys, it is important to note that it may still not be representative of

[1] The use of "tons" throughout this document refers to U.S. short tons.

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all residential construction styles across the nation. House sizes, materials, and foundation types vary regionally and can affect the amount of waste produced during construction.

Table 2-1. Summary of Residential Construction Job Site C&D Materials Surveys.

Date	Research Group [1]	Type of data	Location	No. of Units	Building Size (sq ft)	Total Waste (Pounds)	Disposition rate (lb/sq ft)	Average Generation (lb/sq ft)
1997	NAHB	Site-specific	Portland, OR	1	3,400	13,940	4.10	
1997	NAHB	Site-specific	Grand Rapids, MI	1	2,400	12,192	5.08	
1997	NAHB	Site-specific	Tucson, AZ	1	2,200	16,280	7.40	
1997	NAHB	Site-specific	Las Vegas/Clark Cty, NV	1	2,450	9,457	3.86	
		Subtotal			10,250	45,912		4.48
1998	NAHB	Site-specific	Portland, OR	1	3,600	13,860	3.85	
1998	NAHB	Site-specific	Portland, OR	1	1,250	8,000	6.40	
1998	NAHB	Site-specific	Portland, OR	1	1,250	10,500	8.40	
		Subtotal			6,100	32,360		6.13
1999	NAHB2002	Site-specific	Portland, OR	37	2,400	17,760	3.71	3.71
1999-07	Woodfor 2 - 1x	Site-specific	North Carolina	1	3,250	19,500	6.00	
1999-07	Woodfor 2	Site-specific	North Carolina	1	3,250	36,722	11.30	
1999-07	Woodfor 2	Site-specific	North Carolina	1	3,250	25,350	7.80	
1999-07	Woodfor 2	Site-specific	North Carolina	1	3,250	28,860	8.88	
1999-07	Woodfor 2	Site-specific	North Carolina	1	3,250	25,122	7.73	
					16,250	135,554		8.20
1999	Wellington Complex 1a	Site-specific	Shelby Co., IL	1	2,400	17,856	7.44	7.44
	Global Innovator	Site-specific	Richland Ms, WA	1	1,850	4,450	2.41	2.41
1998	University of Florida	Site-specific	Alachua County	5	1,750	8,925	5.10	5.10
1999	NAHB	Multi-family	Oklahoma, MD	66	941,000	20,702,000	4.75	
1999	Wellington Complex 1b	Multi-family	Shelby Co., IL	6	7,800	11,856	1.52	
					948,800	20,713,856		1.00
Total				93	1,033,450	21,131,511		4.50

AMOUNT GENERATED: 2003

Number of New Privately-Owned Housing Units Started in 2003 [2]	1,847,900 units
Average Size of Constructed Unit [3]	2,349 sq. ft.
Total Square Feet Constructed	4,341,000,000 sq. ft.
Average C&D Waste Generation Rate Based on Total Square Feet	4.86 pounds per sq. ft.
Total Estimated Generation of Residential Construction Debris	**10 million tons**

[1] NAHB = National Association of Home Builders; NAHB Research Center, Inc., Upper Marlboro, MD; Woodfor 2 = specific to City, NC; University of Florida Center for Construction and the Environment; Gainesville, FL; Global Innovator = Global Green USA; Wellington Complex = Habitat for Humanity International, Inc., Lakewood, CO.

[2] Total number of privately-owned housing units started in 2003 (1,847,900) from U.S. Census Bureau, Housing Starts, Table 5, "Privately-Owned Housing Units Started by Purpose of Construction and Type of Structure: 2003 and Earlier Years," http://www.census.gov/const/www/newresconstindex.html.

[3] Weighted average of single-family detached and multi-family housing units started in 2003 (2,349 sq. ft.) from U.S. Census Bureau, Housing Starts, Table 5, "Privately-Owned Housing Units Started by Purpose of Construction and Type of Structure: 2003 and Earlier Years," http://www.census.gov/const/www/newresconstindex.html.

The USCB collected national statistical data on the amount of residential construction activity in the U.S. during 2003, including the number of construction permits and the total square feet of new construction. According to the USCB's "Current Construction Reports (C-30)," in 2003 the

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value of new residential construction put-in-place" totaled $353 billion. Average construction cost per area ($76.80/ft^2) was found by dividing the total value, in areas where permits are required, ($282 billion) by the total area of floor space (3,627 million ft^2), both obtained from the U.S. 2004 Statistical Abstract, which reports 2003 data. The quotient of this factor and the total value of construction produce a total of 4,592 million ft^2 of new residential construction in 2003. The product of the total area and the average waste generated per unit area, 4.39 lb/ft^2, results in the total estimated C&D generation amount for residential construction of 10 million tons in 2003.

2.1.2 Nonresidential Construction

The methodology for estimating the total amount of C&D generation for nonresidential construction materials is similar to that for residential construction materials, although the design of nonresidential buildings is more varied than residential buildings. Nonresidential buildings include lodging, office, commercial, health care, educational, religious, public safety, and manufacturing facilities. There are fewer material assessments for nonresidential buildings, making the average generation rates for C&D materials more uncertain. Table 2-2 shows the results of 12 nonresidential job site waste surveys. The buildings in these surveys include a retail store, restaurant, institutional building, seven office buildings, and two public facilities. Ranging from 1.61 to 8.59 lb/ft^2, the weighted average material generation rate from these studies is 4.34 lb/ft^2.

The 2003 value of new nonresidential building construction put-in-place, as reported in the *Current Construction Reports*, is almost $257 billion. Average construction costs in 2003 were $111/ft^2, resulting in an estimated 2,318 million ft^2 of new construction. The product of the total area (in ft^2) of new construction and the average waste generation rate, 4.34 lb/ft^2, results in a C&D materials generation estimate of **5.01 million tons** for nonresidential construction in 2003. Appendix Table A-2 contains a detailed methodology.

2.1.3 Residential Demolition

When buildings are demolished, large quantities of materials are generated. The entire weight of a building, including the concrete foundations, driveways, patios, etc., may be generated as C&D materials when a building is demolished. On a per building basis, demolition waste quantities are often 20 to 30 times as much as C&D materials generated during construction.

Table 2-2. Summary of Nonresidential Construction Job Site Surveys of C&D Materials.

[a] According to the USCB (2008), "The 'value of construction put-in-place' is a measure of the value of construction installed or erected at the site during a given period. For an individual project, this includes cost of materials installed or erected, cost of labor (both by contractors and force account) and a proportionate share of the cost of construction equipment rental, contractor's profit, cost of architectural and engineering work, miscellaneous overhead and office costs chargeable to the project on the owner's books, interest and taxes paid during construction (except for state and locally owned projects). The total value-in-place for a given period is the sum of the value of work done on all projects underway during this period, regardless of when work on each individual project was started or when payment was made to the contractors. For some categories, published estimates represent payments made during a period rather than the value of work actually done during that period. For other categories, estimates are derived by distributing the total construction cost of the project by means of historic construction progress patterns."

[b] As noted in Text, the categories used for nonresidential building construction from the Current Construction Reports were lodging, office, commercial, health care, educational, religious, public safety, and manufacturing.

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Date	Research Group	Type of Data	Location	Building Size Sq ft	Total C&D Debris Pounds	Generation rate Lb/sq ft
1995 c	[illegible]	Retail Store	Seattle, WA	97,000	115,000	1.19
1995 c	NAHB	Corporate Office Center	Portland, OR	11,859	17,000	1.21
1995	NAHB	Restaurant	Portland, OR	5,000	11,000	2.19
1995	NAHB	Office, commercial, mid-rise	Portland, OR	7,452	20,000	1.61
1995-1999	EPA	Office, commercial	New Haven, CT	1,000,000	2,500,000	2.11
1997	Seattle Construction	Office, commercial	Seattle, WA	297,000	1,041,750	3.84
2001-2002	Waste to Wisdom, Inc.	Commercial, Industrial	Madison, WI	425,000	1,500,000	3.76
2001-2003	Waste to Wisdom, Inc.	Office	Madison, WI	75,000	175,000	3.21
2002	Waste to Wisdom, Inc.	Office	Madison, WI	82,000	150,000	1.46
2001-2003	Waste to Wisdom, Inc.	Natural Center	Madison, WI	54,000	200,000	3.70
2003-2004	Waste to Wisdom, Inc.	Urban Technology Center	Madison, WI	27,000	130,000	4.81
		Totals		2,491,427	10,935,,20	
		Average				4.54

EXTRAPOLATION

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Value of new private residential construction put in place	$225,591 million dollars
Average cost per square foot	$111.00 per square foot
Total square feet of new residential construction	2,032 million square feet
Average C&D debris generation rate	4.54 pounds per square foot
Total Estimated Generation of Nonresidential Construction Debris	**9.01 million tons**

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[1] Demolition of buildings

[2] "Expenditures for Construction of Private Residential Structures by Type of Structure," "Value of Private Nonresidential Construction Put in Place by Type of Construction," and "Price Indexes for New Single-Family Houses Sold Including Lot Values"

[3] Appendix Table A-2

The quantity of demolition material can be estimated by multiplying the number of residential demolitions per year by the average demolished area. This total is then multiplied by the typical waste generated per square foot, determined from an average of job site characterizations of C&D materials. The number of demolitions per year is estimated from "Components of Inventory Change (CINCH)" data (HUD 2007). This information is reported in two year intervals; therefore, the number of single family and multifamily units lost to demolition[1] for the period 2003-2005[2] was divided in half to determine the residential units demolished per year. This number was then added to the number of single family and multifamily units that are lost due to damage or are condemned (again divided in half) and then multiplied by 50%. The 50% estimate represents the number of units that have been condemned or lost to damage that will actually be demolished that year. While no data exist to support this estimate, experts at the U.S. Department of Housing and Urban Development found this to be an acceptable approximation. The units destroyed through intentional demolitions or disasters, such as fires or weather-related incidents between 2003 and 2005 averaged 270,000 per year.

[1] The units that are lost to damage or are condemned do not reenter the housing stock unless they are repaired. These units are not accounted for in "units lost to demolition."

[2] While the years span is 2003 to 2005, the data represents the change in the amount of housing stock available in 2003 to the amount of housing stock at the same time in 2005 (a two-year span).

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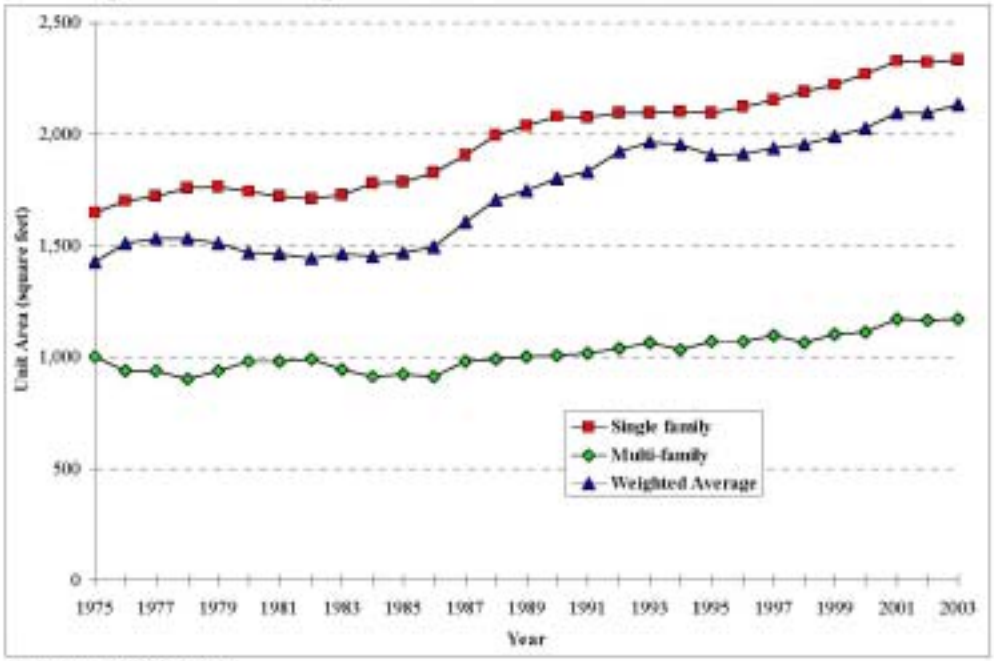
Houses of all ages and sizes are demolished, but on average, older houses are demolished more frequently and are smaller than new houses. New single-family housing units and multi-family housing units (including apartments and condominiums) built in 2003 had average areas of 2,330 ft^2 and 1,170 ft^2, respectively. Figure 2-1 shows how average new house sizes have increased over the last 28 years. Multi-family houses have remained nearly the same, while new single-family houses grew from 1,600 ft^2 to 2,330 ft^2 in 1975. Although homes demolished in 2003 may have been built before 1975, it was assumed that this area was representative of most demolished homes. Thus, the average single-family and multi-family houses are assumed to be that of 1975 (1,600 ft^2 and 1,000 ft^2), respectively, when demolished.

Figure 2-1. Average Unit Size of New Residential Construction



Source: USCB 2005b

Table 2-3 shows four single-family house demolition assessments and one multi-family deconstruction assessment.[10] The weight of houses when demolished depends critically on whether the houses have concrete foundations and basement walls. The use of masonry in exterior cladding also affects the house weight significantly. None of the single-family houses in Table 2-3 had full basements. Therefore, adjustments were made to the sampling data to develop an estimate of residential demolition materials, which reflects the likely impact of some of the demolished houses having basements. These adjustments are more fully shown in Table A-3 in Appendix A.

Table 2-3. Summary of Residential Demolition Job Site Waste Surveys

[10] Deconstruction refers to the systematic dismantling of a building in an attempt to recover as much material as possible. Demolition refers to the removal of the building through mechanical means in an attempt to remove the building as quickly and inexpensively as possible. While both methods may recover materials, the main goal of deconstruction is to recover as much material as possible. Thus, while the different methods may lead to different recovery rates, they will both have the same generation amounts and can be used for comparison in the generation estimate presented here.

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Date	Research Group (1)	Type of data	Location	Building Size Square feet	C&D Debris Pounds	Generation rate lb/sq ft
1992	NAHB	SF Demolitions (2)	Portland, OR	1,258	160,460	87
1992	NAHB	SF Demolitions (3)	Portland, OR	1,274	139,081	81
1992	NAHB	SF Demolitions (4)	Portland, OR	1,761	321,061	111
1995	University of Florida	SF Demolitions (5)	Gainesville, FL	1,475	1,965	87
	Total single-family weighted-average demolitions			1,756	327,965	93
1997	NAHB	SF Demolitions (6)	Maryland	2,000	254,400	127

(1) NAHB=Portland, University of Florida=Center for Construction and Environment, NAHB=National Association of Home Builders

(2) 1992 is lowest weighted-average

(3) Concrete rubble not included

(4) Small house with no basement

(5) Average of seven single-family wood-framed houses

The USCB provides data on the types of foundations in existing houses in the *Statistical Abstract of the United States: 2004*. Forty-three percent of single-family houses have basements, 29% are on concrete slabs, and all other single-family homes have crawl spaces. The amount of concrete can range from zero for houses without basements, garages, or driveways to more than 150 lb/ft^2 for those homes with all of these structures (calculation described in Table A-3 in Appendix A). Based on these estimates, the total amount of residential demolition materials generated in 2003 was estimated to be **19 million tons**.

2.1.4 Nonresidential Demolition

The initial estimate of nonresidential demolition materials generation, for 1996, used the number of demolitions per year, the average size (ft^2) of buildings being demolished, and the typical materials generated per unit area. Prior to 1998, the number of demolition permits could serve as a source for estimating the number of demolitions per year. The Census Bureau, the source for demolition permits, discontinued demolition permit data collection after 1998 and an alternative methodology was developed for this study. For the 2003 estimate, the 1996 estimate of total area was extrapolated to 2002 using the value of demolition work published in the Economic Census by the USCB. Since the Economic Census is only published every five years and similar economic data were not available to predict an estimate for 2003, the nonresidential demolition materials estimate was held constant for 2003. This total area (ft^2) was then multiplied by the typical materials generation per unit area (lb/ft^2) taken from an average of several job site waste surveys.

The typical materials generation per unit area (lb/ft^2) was developed from material assessments. Table 2-4 shows the results of waste assessments at 27 nonresidential buildings. The assessments conducted after 1996 were added to the assessments used in the 1996 estimate. These additional assessments increased the generation factor from 155 lb/ft^2 to 158 lb/ft^2. It should be noted, however, that the lack of material assessments increases the uncertainty of this average generation rate of C&D materials. As shown in Table 2-4, the generation rates produced at these

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sites vary widely from 36 to 358 pounds per square foot. As one might expect, nonresidential buildings vary greatly in size and materials used. Additional waste assessments would reduce the uncertainty of the estimated generation amount of nonresidential demolition debris.

Table 2-4. Summary of Nonresidential Demolition Job Site Surveys of C&D Materials.

Date	Research Organization	Type of Building	Location	Building Size (Sq. ft.)	Total Waste (Tons)	Generation Rate (lbs/sq ft)
1991	[illegible]	Department	[illegible]	[illegible]	[illegible]	[illegible]
1993-1995	[illegible]	Warehouse	[illegible]	[illegible]	[illegible]	[illegible]
1993	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1995	Washington State	[illegible]	Washington State	[illegible]	[illegible]	[illegible]
1995-1996	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1997	EPA	Commercial Buildings	Subject Site	178,750	[illegible]	[illegible]
1997	WSDOT	Warehouse	Seattle, WA	[illegible]	[illegible]	[illegible]
1998	University of Florida	Concrete/Masonry	Alachua County, FL	[illegible]	[illegible]	[illegible]
2001	Ted Campbell	Steel Building	Port Campbell, VA	[illegible]	[illegible]	[illegible]
		Totals		2,958,150	232,039	158

COMPARISON

[illegible]	[illegible]

EXTRAPOLATION

[illegible]	[illegible]		
	Published [illegible]	[illegible]	[illegible]
1997	[illegible]	[illegible]	[illegible]
1997	[illegible]	[illegible]	[illegible]
2002	[illegible]	[illegible]	[illegible]

Total nonresidential demolition debris 2002 (1996 estimate factored for growth)[4]	84,312,000 tons per year
Total nonresidential demolition debris 2002 [5]	84,312,000 tons per year

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

The 1996 estimate of nonresidential demolitions was used as the basis for the 2002 estimates. The first step was to apply the new generation factor to the original 1996 data. The number of demolition projects estimated in 1996 (43,795 projects) is multiplied by the average building floor area (13,500 ft²) and the new generation factor of 158 lb/ft².[1] The adjusted 1996 baseline

[1] 1996 Statistical Abstract, Table 1206 from U.S. Energy Information Administration "Commercial Building Characteristics 1992"

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shown in Table 2-4, is 46 million tons (an increase of approximately one million tons over the original published estimate).

The second step takes the net value of construction work in the category for wrecking and demolition contractors for 1997 and 2002 from the Economic Census. After adjusting for inflation, the growth rate was calculated from 1997 to 2002. This assumes that economic growth (measured by net value) in the wrecking & demolition industry is directly related to demolition materials generation. The growth rate of 1.4 in net value of construction work for wrecking and demolition contractors from 1997 to 2002 predicts nonresidential demolition materials to be 65 million tons in 2002 (Table 3-4). Since no data source exists for 2003, it is assumed that 65 **million** tons of nonresidential demolition materials were generated in 2003.

2.1.5 Residential Renovation

Renovation includes improvements and repairs to existing buildings, including driveways. Renovation materials consist of both construction and demolition materials as old materials are removed and new materials are added. The renovation waste stream can be fairly homogeneous such as when driveways or asphalt roofs are replaced, or heterogeneous such as when buildings are modified or enlarged.

Because of the wide variation in renovation projects, waste assessments should be separated by renovation type to determine generation per square foot. Table 2-5 shows the results of five waste assessments that have been made at residential sites, illustrating a wide variation in generation rates on a square foot basis. Renovating kitchens, bathrooms, and entire houses typically generates more waste per square foot than new construction, largely because of the demolition that accompanies remodeling. However, some renovation activities, like roof replacement, produce relatively low amounts of material on a square foot basis.

Table 2-5. Summary of Residential Renovation Job Site Surveys of C&D materials

Date	Research Group (1)	Type of data	Location	Size of Project Sq ft	C&D Debris Pounds	Generation rate lb/sq ft	Average generation lb/sq ft
1997	NAHB	SF Remodel/Kitchen/Bath	Maryland	500	10,733	[illegible]	
1997	NAHB	SF Remodel/Bathroom	Chapel Hill, NC	40	2,883	72.10	
		Total		2040	13,616		22.66
1998	NAHB	Kitchen remodel	Portland, OR	150	7,941	52.94	
1998/99	NAHB	House remodel	Portland, OR	1,330	26,501	19.9	
		Total		1,480	34,442		24.05
1997	NAHB	SF Remodel/New roofs	Maryland	1,210	4,018	3.3	3.31

(1) NAHB: National Association of Home Builders; NIST: Portland

Renovation materials generation were estimated for this analysis by determining the number of major home improvements (from the U.S. Census Statistical Abstract and home improvement studies), and then estimating the amount of material produced by each type of improvement. Since minor improvement projects cannot be included in a study of this type, a succession of the major projects a residence can go through can be useful for making first estimates.

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Appendix A Tables A-6, A-7, A-8, and A-9 show some of the assumptions made and the results of estimating the amount of material produced when driveways are replaced, when asphalt and wood roofs from residences having one to four units per structure are replaced, and when residential heating and cooling equipment is replaced. Based on the assumptions, driveway replacement generated 28 million tons of concrete. Asphalt roof replacement produced 7 million tons of largely asphalt shingle waste and wood roof replacement produced 2 million tons of largely wood waste. The replacement of heating, ventilating, and air conditioning (HVAC) equipment produced 2.1 million tons of materials. Remodeling kitchens, bathrooms, and other home interiors generated approximately 0.7 million tons. On this basis, the total residential renovation generation from the improvement or replacement projects itemized above, was estimated to be **37.8 million tons** in 2003.

2.1.6 Nonresidential Renovation

No information was found on the total amount of money spent on nonresidential renovation in 2003. The USCB last estimated that the total dollars spent for nonresidential renovation projects in 1992 was $155 billion. This report assumed the ratio of residential to nonresidential dollars is the same in 2003 as in 1992. Therefore, the total amount of money spent on nonresidential renovation was calculated using the amount spent on residential renovation and the ratio of residential to nonresidential renovation in 1992.

Very few material assessments are available for nonresidential renovation. Additionally, the materials assessments available do not have any consistency. Therefore, a methodology similar to the one used for residential renovation cannot be used to estimate the materials generated during nonresidential renovations. In the absence of adequate materials assessment data, total dollars spent on nonresidential and residential renovation were compared. It was assumed that the amount of materials generated is proportional to the dollars spent in these two sectors. (See Table A-5 for more details of this analysis.)

Based on the assumption that materials generation per dollar is equal to the residential rate, total nonresidential renovation materials generated was estimated to be **29 million tons** in 2003. Table 2-6 shows nine assessments that have been made at nonresidential renovation sites; these data show a wide variation in generation rates on a square foot basis. Since this estimate is based on relatively old data and few material assessments, this estimate of nonresidential renovation generation amounts has a high level of uncertainty.

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Table 2-6. Summary of Nonresidential Renovation Job Site Surveys of C&D Materials.

Date	Research Group (1)	Typical data	Location	Building Size	C&D Debris	Generation Rate
				Sq ft	Pounds	Pounds/sq ft
	Natural Resources Canada	Office Renovation	Ottawa, Ontario	[illegible]	28,000	3.81
	MRSA Portland	Office Renovation	Portland, OR	6,000	18,000	3.00
1997	Nelson Construction	Office Renovation	Seattle, WA	72,000	2,051,520	28.49
1998	Nelson Construction	Office Renovation	Seattle, WA	180,000	1,728,000	9.60
1999-2000	EPA	Office Renovation	San Jose, CA	75,000	75,000	1.00
1998	EPA	Office Renovation	Austin, TX	15,511	110,000	7.10
		Total Office Renovation		355,511	1,982,180	5.58
1997	Nelson Construction	Hospital Renovation	Seattle, WA	210,000	105,000	0.50
	MRSA	Hospital Renovation	Portland, OR	10,369	30,000	2.89
1999	MRSA	Department Store	Portland, OR	198,000	1,980,000	10.00
		Total Other Renovation		418,369	2,115,000	5.06

1 Nelson Construction = Redmond, Washington; MRSA = Portland, OR; EPA Waste Reduction Record Series

2.2 AMOUNT OF BUILDING-RELATED C&D MATERIALS GENERATED IN 2003

Table 2-7 summarizes the estimates for C&D materials generation from the construction, demolition, and renovation of residential and nonresidential buildings in the United States in 2003. The estimated total is almost 170 million tons, with 39% coming from residential and 61% from nonresidential sources. Figure 2-2 provides a breakdown, in percent of total, of the six building sectors that generate C&D materials. The largest sector is nonresidential demolition at 39%. Residential and nonresidential renovation materials make up 22% and 39%, respectively, followed by residential demolition at 11%. New construction represents 9% of total C&D materials, with residential construction at 6% and nonresidential construction at 3%.

Table 2-7. Estimated Amount of Building-Related C&D Materials Generated in the U.S. During 2003.

Source	Residential		Nonresidential		Totals	
	Million Tons	Percent	Million Tons	Percent	Million Tons	Percent
Construction	10	6%	5	3%	15	9%
Renovation	38	22%	68	39%	106	62%
Demolition	19	11%	30	18%	49	29%
Totals	67	39%	103	61%	170	100%
Percent	39%		61%		100%	

*C&D Debris generated on site (Table 2-5) or from NAICS calculated from generation Quantities that equal 0 tons or estimated to be zero

Note: Data are not added to the appropriate significant digits. Totals may not add due to rounding.

Figure 2-2. Contribution to the C&D Materials Stream by Each Building Sector

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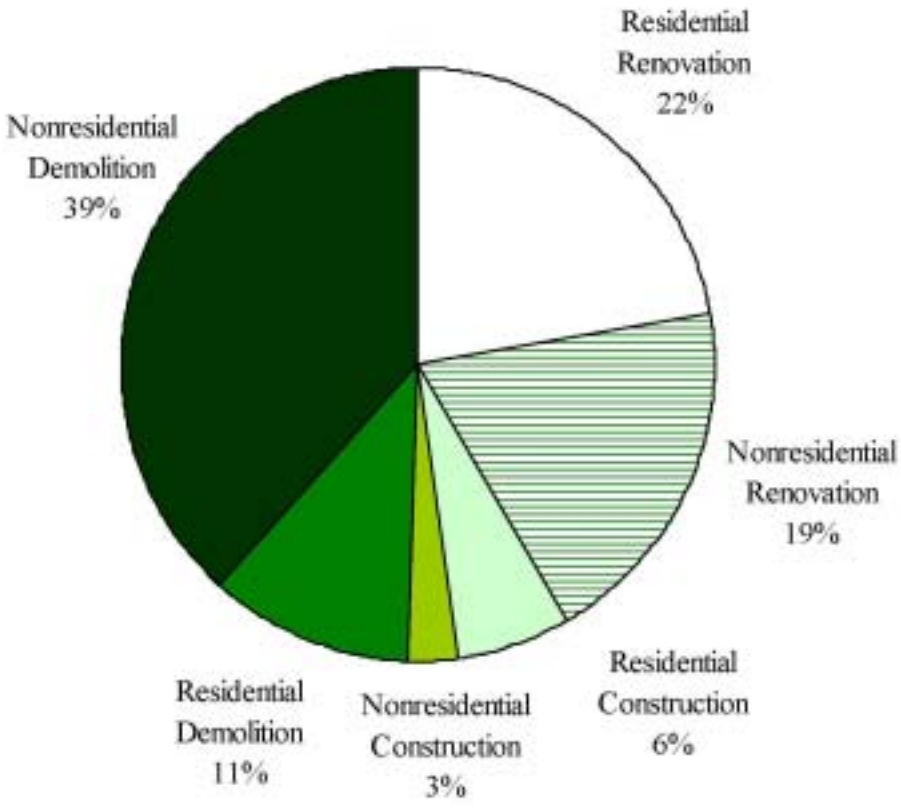

The 2003 estimate of 170 million tons is equal to 3.2 pounds of building-related C&D materials generated per capita per day (pcd). In 1996, this per capita rate was estimated to be 2.8 pcd. When comparing the 2003 C&D materials generation rate of 3.2 pcd to the municipal solid waste (MSW) generation rate of 4.45 pcd (EPA 2005), it is noteworthy that amount of C&D materials generated per person is less than the amount of MSW generated per person. While not every person generates C&D materials personally, population growth increases the need for buildings and infrastructure to support that growth.

The amount of C&D materials generated varies considerably from one community to another. This variation is created, in part, by the difference in construction styles, historical and current growth of the community, and local economics. In fast growing areas, the C&D waste stream from buildings consists primarily of construction materials, with much smaller quantities of demolition materials. Demolition materials are produced when older buildings are demolished to make way for the new developments. By contrast, in many urban areas demolition materials dominate the C&D stream. As definitions of "C&D materials," "generation," "recycling," "disposal," and "recovery facility" (or other similar terms) vary among states, adjustments may be required when comparing the results of this report with data reported by specific state agencies to ensure the same materials and sources are included in the comparison[12]. Similar

[12] A first example of differing definitions among states involves the definition of "generation." State A may report a "generated" amount as a sum of the amount disposed and recovered at C&D materials facilities within the state borders, regardless of what state in which the C&D materials were generated. On the contrary, State B determines

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adjustments may also be required when comparing data from any two states. The components that make up C&D materials also vary a great deal depending on the type of construction and the methods used by the construction industry.

the amounts of C&D materials imported to and exported from their state and accounts for additions/subtractions as appropriate in their amount "generated." A second example involves the types of facilities that the state collects from. State C does not require facilities that process only concrete or asphalt pavement to report annual amounts that they receive. On the contrary, State D does require these facilities to report their amounts to the state and their amounts are included in the overall State D C&D materials recovery amounts. A third example involves incentives for using different definitions. State E levies a fee associated with various types of waste. If C&D materials have a lower fee than other materials, generators are incentivized to classify their waste as C&D materials rather than another waste, even though it might not fall within the classical definition that may be used outside of State E. These three examples are just some of the reasons why definitions play such an important role in measuring C&D materials amounts.

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3 Building-Related C&D Materials Management

EPA's 1989 Agenda for Action endorsed an Integrated Waste Management Strategy to address the growing amount of municipal solid waste, including C&D materials generated. This strategy refers to "the complementary use of a variety of waste management practices to safely and effectively handle the municipal solid waste stream with the least adverse impact on human health and the environment." The components of the Strategy are: source reduction (or waste prevention), recycling, including off-site (or community) composting, combustion with energy recovery, disposal through landfilling and combustion without energy recovery. Components of C&D materials can be and are managed in each of these ways. Different measurement methodologies were used for each type of management method. Because many C&D processing facilities send materials to be beneficially used in a variety of markets, the term "recovery" is used here to represent the reuse, recycling, and combustion with energy recovery of C&D materials.

3.1 SOURCE REDUCTION

Currently, there are no known estimates of sources reduced on-site through improved methods and materials. Efforts including purchasing optimization during construction to avoid surplus materials and reusing existing shell and structure during renovation can reduce the amount of materials that need to be removed from the site and managed. The amount of used materials avoided through these efforts had not been documented, but any efforts to document these trends may be considered for use in future C&D materials estimations.

3.2 MATERIALS RECOVERY

C&D materials recovery includes efforts to reuse, recycle, or otherwise beneficially use C&D materials in various applications, including use in energy recovery applications. There are many drivers for C&D materials recovery. Historically, economics has been the primary driver for recovery. In locations where disposal fees were high, recovery became an economically preferable option. Materials that have traditionally retained a high value when recovered, such as metals, were recovered even in areas that had low disposal fees. These economic drivers remain in place today, but an additional factor is affecting the economics of recycling today that did not exist in the past: green building programs. Specifically, green building rating systems typically give credits for the reuse or recycling of C&D materials. Since the creation of the U.S. Green Building Council in 1993 and the spike of green buildings in 2000, demand for reuse or recycling opportunities has increased in areas where such opportunities had not existed. More information on green building can be found at www.epa.gov/greenbuilding.

3.2.1 Barriers to C&D Materials Recovery

Barriers to materials recovery still exist, however. Many buildings and building materials are not designed to be reused or recycled. EPA's Lifecycle Building Challenge is a design competition that challenges professionals and students to design building materials and assemblies for reuse and recycling. More formation can be found at www.lifecyclebuilding.org. If C&D materials will be generated at construction sites, C&D materials management should be included in the construction plan. Successful planning teams include the owner of the building,

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the architect, and the contractor. Success stories of C&D recovery can be found at www.epa.gov/cdmaterials.

There are other barriers that exist to C&D materials recovery. In some locations, recovery facilities do not exist. Even where facilities do exist, markets have not been found for some materials for a variety of reasons. There could be a lack of demand for a material, an unwillingness to use recycled materials in place of virgin resources, or a regulatory prevention of its use. Many markets view recycled materials as inferior simply because they are viewed as wastes, yet they often have the same chemical or physical properties as comparable virgin materials, and provide comparable performance; in some cases, they provide superior performance than do virgin materials at a lower cost. EPA aims to expand recognition of the value of C&D materials so that they are more widely viewed as locally available resources, rather than un-usable discards.

Potentially harmful materials, such as asbestos, lead-based paint (LBP), and polychlorinated biphenyls (PCBs), have historically been used in the construction and maintenance of many buildings. These materials can greatly affect the recyclability of some materials, especially those derived from older buildings. In some instances, concerns about the possibility of these materials entering the recycling stream have prevented entire segments of the C&D materials stream from being recycled. The specific percentage of C&D materials that contain asbestos, lead, or PCBs is unknown. As a result, it is very difficult to determine the impact the presence of these compounds in C&D materials has on C&D materials recovery. Some data are available on the use and prevalence of these harmful materials in buildings. It was recently reported that, as of 2000, 38 million homes in the U.S. still contained LBP somewhere in the building, either on interior or exterior surfaces (Clickner et al. 2001). According to the United States Geological Survey (USGS), asbestos use in all applications (including construction) declined from approximately 7,600 tons in 2002 to approximately 5,100 tons in 2003. In fact, the consumption of asbestos in 2003 represented less than 0.6% than that of the consumption in 1973, the peak year for U.S. asbestos consumption. According to the USGS, the current primary use of asbestos in construction is in some roof coatings, not in asphalt shingles (2003). In fact, recent testing of old asphalt shingles from re-roofing activities collected at recycling centers indicates that the presence of asbestos is relatively rare and should continue to be come even more rare as these shingles are removed an replaced with non-asbestos-containing shingles (CMRA 2007). Unfortunately, asbestos testing costs and time delays can be a disincentive to recycling and, as a result, recycling rates for asphalt shingles continue to be low. LBP was banned in 1978, some uses of asbestos in buildings were banned by 1978, and PCBs were banned in 1979.

3.2.2 Quantifying Recovery of C&D Materials

There are a number of organizations that are working to overcome the barriers to C&D materials recovery. EPA works with other governmental and industry partners in funding new research, promoting safe uses for C&D materials, and in conducting education and outreach. For example, through the WasteWise partnership program, the EPA rewards those who have created successful recycling programs. For more information about WasteWise, please see www.epa.gov/wastewise. To learn more about what the EPA is doing to increase C&D materials recovery, please see www.epa.gov/cdmaterials.

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There are various sources of C&D materials recovery data that capture different parts of the recovery stream, including surveys of contractors, surveys of recyclers, and estimates made by state environmental agencies. These sources are discussed in detail in Appendix B. While the surveys of contractors could be used for this estimate, EPA was not able to find a recent survey of recycling in the residential building sector. Additionally, those surveys of demolition and non-residential contractors may not represent actual recovery as the recycling facilities may actually dispose of a portion of the materials that they receive. While a survey of recyclers was performed, the surveyors were unable to distinguish the amount of materials derived from buildings from other materials that were present in the recycling stream. Thus, these estimates for C&D recovery cannot be compared with the amount of C&D materials generated, which only represents building materials.

Data collected by state environmental agencies on the amount generated, disposed, and recovered, on the other hand, are viewed as the most accurate source of information. Unfortunately, only eight states collect recovery and disposal or generation amounts that could be used to estimate a recovery rate (see Table 3-1). These states represent approximately 21% of the U.S. population. Thus, the weighted recovery rate estimated using the eight states' data may not be fully representative of the entire country. Additionally, state definitions of what constitutes C&D materials and recycling vary. For example, some states count C&D materials that are used as alternative daily cover in landfills and for energy recovery[13] to be counted as recycling, while others do not. In the chart below, EPA has labeled the category measured as "recovery" instead of "recycling" in order to include materials that are recovered for other uses that do not fall under the definition of "recycling."

The weighted average recovery rate for the eight states for 2003 was 48%. While this number may not be fully representative of the entire country, it does provide an indicator of C&D materials recovery in the U.S. However, it is, at best, an approximation. For instance, it is known that the recovery numbers provided by some states likely include some concrete, asphalt pavement, and metals from non-building sources, while other states do not include those materials. Additionally, recovery efforts after disasters could be included in the reported numbers.[14] Thus, the recovery estimate of 48% for buildings may be high. On the other hand, the reported numbers for other states may not capture the entire amount of building-related C&D materials that are recovered in that state, either because the C&D materials were exported or because only certain types of C&D materials recycling facilities are required to report. As with comparing generation estimates, definitions of "recycling" and "C&D materials" can vary widely from state to state (see footnote on page 19). The EPA intends to continue working with state environmental agencies and other partners to develop better national recovery estimates for the future.

Unfortunately, looking overall at state data does not provide a breakdown of the recovery amounts for specific materials within the C&D recycling stream, so it is not possible to determine which sectors or which materials have the largest influence on the recovery rate.

[13] On the question of energy recovery, a major market for C&D wood is its use as "boiler fuel." Most recyclers include amounts of wood sold for boiler fuel in their reporting for recycling.

[14] For example, over seven million cubic yards (approximately 2 million tons) of vegetative debris was generated in the three most affected counties of Mississippi after Hurricane Katrina during 2005 and 2006. Such amounts can have large impacts on data reported as "recycled" and "disposed."

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Additionally, it is not possible to estimate a material composition. If, through continued work with state environmental agencies and industry, such estimates are able to be derived, they may be included in future C&D materials estimations.

Table 3-1. Amount of C&D materials disposed and recovered by reporting state.

State	Amount of C&D Materials, 2003 (tons)		2003 Recovery Rate
	Disposed	Recovered	
Florida[27]	5,577,269	1,998,256	
Maryland	1,913,774	2,270,100	
Massachusetts	7,200,000	3,600,000	
New Jersey[28]	1,519,783	5,582,346	
North Carolina	1,814,401	210,002	
Utah	1,054,296	16,161	
Virginia	3,165,948	93,151	
Washington	1,780,356	2,610,900	
Total	**17,575,425**	**16,012,846**	**48%**

3.3 LANDFILL DISPOSAL

Based upon the recovery estimate above, 52% of the building-related C&D materials were discarded in 2003. Much of this material goes to specifically designated C&D landfills. However, C&D landfills are regulated by state and local governments, and the federal government does not collect disposal data for these landfills. Using a survey of states, Kaufman et al. (2004) reported the number of landfills to be over 1,900 in 2002. This number decreased to over 1,500 in 2004 (Simmons et al. 2006). The reasons for this decrease vary from state to state.

Similar to the recovery estimate, it is not possible to determine which sectors or materials have the largest influence on the national disposal rate. Some state and local environmental agencies have investigated the composition of the waste disposed in landfills within their state.[29] These reports should be consulted when examining regional C&D materials disposal.

C&D materials may also be disposed of in MSW landfills. The amount of C&D materials commingled with MSW and disposed of in MSW landfills or combusted in incinerators without energy recovery is not known, but could be significant. In some areas, disposal in MSW landfills is the most common management method for C&D materials. A portion of residential

[a] Disposed amount calculated as the amount "recycled" subtracted from the amount collected. [b] Source: FDEP 2005.

[c] Includes asphalt & concrete recycled. Source: MDE 2004.

[d] Includes tons reported as Disposed and Recycled; does not include tons reported as Other/Diverted. Source: MDEP 2006.

[e] Includes tons reported as Recycled of "Other Bricks & Concrete/Stone," "Asphalt, Concrete & Masonry," and "Wood Waste." Source: NJDEP 2005. [f] Disposal calculated as (Type 13C waste + 0.25 x Type 13 waste). Source: Rinaldi, S., NJDEP, Personal Communication, 2009.

[g] Source: NCDENR 2006.

[h] Source: UDEQ 2008.

[i] Recovered represents those materials reported as "Recycled," "Composted," and "Other." Source: VDEQ 2004.

[j] Source: WDEQ 2008.

[k] Examples of C&D materials composition studies performed by state or local environmental agencies include (but are not limited to): CIWMB 2000; Rendant et al. 2003; OCDSWM 2006; VDEQ 2002; and Iowa DNR 2009.

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renovation materials is also discarded by homeowners into the household trash and disposed of in MSW landfills or combusted in incinerators. Some C&D materials, typically those considered to be "inert," are used as fill in old quarries and other pits. Some states do not require permits for this use of C&D materials and, therefore, little is known about the total amount of materials used in this manner.

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4 Conclusions

A methodology utilizing national statistical data on the amount of construction, renovation, and demolition activity in the U.S. and average amounts of waste generated at job sites was used to estimate that approximately 170 million tons of building-related C&D materials were generated in the U.S. during 2003. This is a 25% increase in generation from the 1996 estimate of 136 million tons. During the same time period, total construction spending increased 50% (USCB, 2007), however it was estimated that building construction increased only 32%. Construction spending increases can also reflect inflation, profit, and other factors that do not necessarily correlate to increased materials use.

Of the amount generated, approximately 48% was estimated to be recovered, based on state reported disposal and recovery data. This recovery rate may be an overestimate due to the inclusion of materials that are from non-building sources. This recovery estimate is a 23% increase from the 1996 estimate. Comparison of these estimates should be viewed with caution because data limitations created the need for different methodologies in 1996 and 2003.

The amount of available information varies from year to year as few entities collect consistent national data regarding C&D materials. Thus, various sources of data must be relied on to make national estimates of C&D generation and recovery. Decreasing available landfill space and interest in green building will all have a positive impact on the rates of recovery of C&D materials, until recently, the rise in commodity prices had a similar impact. EPA will continue to work in partnership with state environmental agencies, AGC, BNRA, CMRA, NAHB, and NDA to actively promote recovery and recycling of C&D materials.

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APPENDIX A

BUILDING-RELATED C&D MATERIALS GENERATION AMOUNT CALCULATIONS

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Table A-1. Residential Construction Materials Worksheet

Method Used:

(1) Start with total dollars of new construction from Census Bureau Current Construction Reports (C-30)

(2) Calculate sq ft of new construction from total dollars and $/sq ft construction cost

(3) From empirical waste assessment, estimate lb/sq ft of new construction

(4) Calculate tons generation

Calculation	2003
(1) C-30, Residential Construction	$352,252,000,000
Total dollar private new residential and public housing & nodev. depreciation	
(2) Table 925 of 2001 Statistical Abstract of the United States (Note: whole industry not included)	
Residential Construction	$282,070,000,000
Residential sq ft of new construction	3,072,000,000 sq ft
Cost of new construction	
($/residential construction sq ft Residential new construction	$ 91.80 per sq ft
2+3 Total sq ft of new construction = $352,252,000,000 / $91.80	3,837,000,000 sq ft
(3) See sampling waste assessment results Table 2-	
Average Generation	4.39 lb/sq ft
(4) Total estimated amount of residential construction materials generated in 2003	**16,100,000,000 tons**

Note: Data are rounded to the appropriate significant digit. Data may not add due to rounding shown.

Table A-2. Nonresidential Construction Materials Worksheet

Method Used:

(1) Start with total dollars of new construction from Census Bureau Current Construction Reports (C-30)

(2) Calculate sq ft of new construction from total dollars and $/sq ft construction cost

(3) From empirical waste assessment, estimate lb/sq ft of new construction.

(4) Calculate tons generation

Calculation	2003
(1) C-30, Nonresidential Construction*	$256,501,000,000
Total dollar value of new construction, additions, and alterations to buildings for industrial, commercial, educational, religious, public safety, and miscellaneous categories	
(2) Table 925 of 2001 Statistical Abstract of the United States (Note: whole industry not included)	
Nonresidential Construction	$153,501,000,000
Nonresidential sq ft of new construction	1,368,000,000 sq ft
Cost of new construction	
($/Nonresidential Construction sq ft Nonresidential new construction	$112.21 per sq ft
2+3 Total sq ft of new construction = 256,501,000,000 / 112.21	2,286,000,000 sq ft
(3) See sampling waste assessment results Table 4	
Average Generation	4.34 lb/sq ft
(4) Total estimated amount of nonresidential construction materials in 2003 =	**5,000,000,000 tons**

*Data downloaded from the Census Bureau website on July 2005

Note: Data are rounded to the appropriate significant digit. Data may not add due to rounding shown.

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Table A-3. Residential Demolition Materials Worksheet

Model Used

(1) How many demolitions per year?

(2) What is the average size (square feet) of the demolished buildings?

(3) How many pounds per square foot are generated?

(4) What is the total generation?

Calculation

(1) Assume 2,000,000 residential demolitions per year [1]

(2) What is the average size (square feet) of the demolished buildings?

Single-family homes: 1,500 sq ft [2]

Multi-family homes: 1,000 sq ft [3]

(3) How many pounds per square foot are generated?

Single-family homes: 155 lbs/sq ft [4]

Multi-family homes: 155 lbs/sq ft [4]

(4) What is the total generation?

Single-family homes	310,000,000,000 lbs
Multi-family homes	155,000,000,000 lbs
Total	465,000,000,000 lbs

[1] Assumption. Based on 2015 housing stock, there are approximately 120 million housing units in the United States. Assuming an average lifespan of 60 years, approximately 2 million units are demolished each year.

[2] Assumption. Single-family homes are assumed to be 1,500 square feet on average, based on data from the U.S. Census Bureau's American Housing Survey.

[3] Assumption. Multi-family homes are assumed to be 1,000 square feet on average, based on data from the U.S. Census Bureau's American Housing Survey.

[4] Assumption. Based on the assumption that 50% of the demolished buildings are made of concrete and 50% are made of wood, with an average density of 155 lbs/sq ft for concrete and 50 lbs/sq ft for wood.

Note: Data not available for the specific year requested. Data may not be available for all states.

Single-family homes	100%	155	310,000,000	48,050,000,000
Multi-family homes	100%	155	155,000,000	24,025,000,000
Total			465,000,000	72,075,000,000

Total estimated amount of residential demolition materials generated in 2015: 72,075,000,000 tons

Table A-4. Residential Renovation Materials Worksheet

Method Used:

1) Estimate the amount of renovation debris (roofs, driveways, HVAC, kitchens, etc.) and the amount associated from each
2) Calculate total generation

Calculation:

1) Estimates for remodeling:

	Million Sq. Ft.	Demolished	Tons
Kitchen remodel	1.2	0.75	1,800,000
Kitchen, complete	0.38	1.5	2,660,000
Bath remodel	1.60	0.25	800,000
Bath complete	0.70	1.00	700,000
Additions	1.50	0.75	1,800,000

2) Replacements (new construction, following Appendix Tables A-5, A-7, A-8, & A-9):

Roofing (square feet of roofing)	20,000,000 (tear-off)
Asphalt roofs	7,000,000
Wood roofs	2,000,000
Siding & A/C replacement	2,500,000
Kitchen remodeling	3,000,000
Bathroom remodeling	1,000,000
Additions	1,500,000

Total estimated amount of residential renovation materials in 2005: 37,806,000 tons

a) *The Changing Structure of the Remodeling Industry*, Joint Center for Housing Studies of Harvard University

b) Year 1998

Note: Data are rounded to the appropriate significant digit. Data may not add to totals shown.

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Table A-5. Nonresidential Renovation Materials Worksheet

Method Used

Estimate total nonresidential and residential improvement expenditures and assume that the amount of waste generated is proportional to dollars spent in these two sectors

- (1) Determine total expenditures of nonresidential construction projects from historical Census data*
- (2) Multiply quantity of residential renovation debris (Table A-4) by the ratio of nonresidential to residential improvement expenditures

Calculation

(1) Total estimated expenditures for nonresidential improvements in 2003**	155,386
This compares to 2003 residential improvement expenditures of	176,899
Total 2003 improvement expenditures	332,285

(2) Estimated generation of nonresidential renovation materials in the 2003

155,386 / 332,285 x 37,816,400 = 17,680,000 tons

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* Obtain historical numbers by averaging the ratio of nonresidential dollars spent for the years 2003 and 1992. See the Methodology used for 1998 - 2003. No data available on nonresidential renovation debris generated in 2003.

** Assume same ratio of expenditures in 1992 ($100,400 nonresidential and $134,500 residential) which translates the current dollars spent of nonresidential renovation debris

(100,400/134,500 x 176,899 = 155,386)

Note: Data are rounded to the appropriate significant digits. Data may not add to totals shown.

Table A-6. Estimated Weight of Residential Concrete Driveways Replaced in the U.S. 2003

Total Housing units under 5 units Structure 2003 housing units Median age of housing = 32 years				82,003,000
Assume 2 driveways of concrete per unit	8	x	15	x 0.333
Estimated Net new driveways volumes (ft)	100			
Estimated percent of driveways replaced each year	2%			
Est. percent of houses with concrete driveways	60%			
Replacements (units/ units times 2 replaced)				2,000,000
total concrete removed (ft)				20,000,000
Density of concrete (lbs/cf)	150			
Total tons of concrete in 2003				**20,000,000**

(1) 2003 Statistical Abstract of the United States

Note: Data are rounded to the appropriate significant digits. Data may not add to totals shown.

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Table A-7. Estimated Weight of Residential Asphalt Roofs Replaced in the U.S., 2003

Total Housing units with 1-5 units/structure, 2003 housing unit. Median age of housing = 32 years (1)		93,043,000
Assume average roof area (sq ft)	1,400	
Assume weight of asphalt roof (lbs/100 sq ft)	240	
Average wt of asphalt roof (lbs/roof)	3,400	
Estimated percent of homes with asphalt roofs (2)	67%	
Estimated percent of roofs replaced each year (2)	7%	
Replacements/yr (total no. times percent replaced)		4,000,000
Total tons of asphalt roofing removed in 2003		7,000,000

(1) 2001 Statistical Abstract of the United States
(2) NAHB Research Center: Waste Management Update 2, October 1996
Note: Data are rounded to the appropriate significant digits. Data may not add to totals shown.

Table A-8. Estimated Weight of Residential Wood Roofs Replaced in the U.S., 2003

Total Housing units with 1-5 units/structure, 2003 housing units. Median age of home = 32 years (1)		93,043,000
Assume average roof area (sq ft)	1,400	
Assume weight of wood roof (lbs/100 sq ft)	200	
Calculated weight of wood roof (lbs/roof)	3,000	
Estimated percent of homes with wood roofs	25%	
Estimated percent of roofs replaced each year	3%	
Replacements/yr (total times percent replaced)		2,000,000
Total tons of wood roofing removed in 2003		3,000,000

(1) 2001 Statistical Abstract of the United States
Note: Data are rounded to the appropriate significant digits. Data may not add to totals shown.

Table A-9. Estimated Weight of Residential HVAC Equipment Replaced in the U.S., 2003

Total Housing units, 2003 [illegible]
Median age of housing = 32 years (1)

	Estimated lb/unit	Number in use (1)	Est. % replaced each year	Total TPY
Warm air furnaces	300	75,420,000	5	[illegible]
Electric heat pumps	400	15,270,000	5	[illegible]
Steam or hot water systems	1,000	16,120,000	5	[illegible]
Floor, wall or pipeless furnaces	200	6,720,000	5	[illegible]
Built-in electric units	200	5,380,000	5	[illegible]
Room heaters	200	5,210,000	5	[illegible]
Stoves	200	1,850,000	5	[illegible]
Fireplaces	300	250,000	5	[illegible]
Central air	400	72,650,000	5	[illegible]
Total Replacement Products in the U.S. (2003)				**2,000,000**

(1) 2001 Statistical Abstract of the United States
Note: Data are rounded to the appropriate significant digits. Data may not add to totals shown.

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APPENDIX B

SOURCES OF C&D MATERIALS RECOVERY DATA

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Sources of C&D Materials Recovery Data

Many sources compile information on C&D materials recovery, either for reuse, recycling, beneficial use, or energy. Industry associations are interested in the amount of materials that their members recover. Some federal agencies collect data on C&D materials recovery in studies that they perform. Since C&D materials are regulated at the state and local level, some state agencies track the amount that is disposed and/or the amount that is recycled in their state.

Surveys of C&D Materials Processors/Recyclers and Reuse Stores

Construction Materials Recycling Association (CMRA). The CMRA represents companies that process materials for recycling, beneficial use, or energy recovery markets. They surveyed their members in 2004 to determine the number of operating facilities and the amount of material that they are processing. Since not all C&D materials recyclers are members of the CMRA, they projected the member survey results onto the non-members. Sources of materials include all C&D generators, including building, road, and other structure sites.

The number of recycling facilities for C&D materials has been growing rapidly in the last few years. The CMRA estimated there were at least 2,800 operating C&D recycling facilities in 2004. That estimate included approximately 2,400 concrete and asphalt pavement crushing facilities, 250 mechanized mixed-waste C&D facilities, and 150 wood waste processors.

CMRA estimated that approximately 197 million tons of C&D materials were recovered in 2004, including 28 million tons at mixed[1] C&D materials processing facilities, 155 million tons at concrete and asphalt crushing facilities, and 14 million tons at wood waste processing facilities. These amounts do not include asphalt pavement recycled on-place or at hot-mix asphalt plants. These amounts, however, include materials from many sources beyond typical building construction, renovation, or demolition sites, such as concrete from transportation and utility projects, wood waste from land clearing, and wood waste in the form of pallets and wood spools. It also does not include any materials that were reused or recycled at the job site, without first processing the material at a recycling facility.

It can be assumed that most of the materials that mixed C&D materials processing facilities receive are from buildings. Some of the materials from buildings, however, go to concrete asphalt pavement facilities and wood waste processing facilities, but the majority does not. Thus, if this amount (28 million tons) is compared to the amount of C&D materials estimated as generated (164 million tons), the recycling rate would be 16%. This is much lower than the estimated 48% calculated using reported state data. This quick calculation demonstrates the uncertainty inherit in the estimates generated for this report.

Building Materials Reuse Association (BMRA). The BMRA is a non-profit educational organization whose mission is to facilitate building deconstruction and the reuse/recycling of recovered building materials. Members include owners of C&D materials reuse stores, deconstruction contractors, and manufacturers of reclaimed wood products. In 2006, the BMRA surveyed their members to determine the amount of C&D materials reused in the U.S. and

[1] Mixed C&D processing facilities are those that accept heterogeneous loads of C&D materials and do not require C&D materials loads to be segregated by material.

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received a 17% response rate to the survey. If the results of this survey were projected to their entire membership, it can be estimated that approximately 200,000 tons of C&D materials are reused in the U.S. every year.

Surveys of Contractors

National Demolition Association (NDA). The NDA is a non-profit trade organization representing more than 1,000 U.S. and Canadian companies which offer standard demolition services, as well as a full range of demolition-related services and products. Its educational efforts help members stay abreast of regulatory and safety matters. The NDA also keeps regulators informed about issues facing their industry. In addition, the NDA is dedicated to increasing public awareness of the industry, as well as providing members with information on the latest technical advances in equipment and services. In 2005, the NDA surveyed their membership to gather data on the quantity of demolition materials recovered for recycling. They learned that demolition contractors recycle concrete, masonry, wood metals, and asphalt pavement.

Associated General Contractors (AGC) of America. The AGC is a national construction trade association representing all facets of commercial construction for both public and private entities. The AGC has approximately 32,000 member companies representing general contractors, specialty contractors, service providers, and suppliers. In 2004, the AGC sent an email survey to their members regarding C&D materials and received 328 responses. Of these responses, 58% reported that they recycle C&D materials, mostly asphalt pavement, concrete, steel, and wood.

Data Collected by State Agencies

A search of reuse, recycling, or diversion data collected by states was performed. Eight states collected data on C&D materials recycling for 2003. Although this information is labeled as tons "recycled," these numbers could also include C&D wood used as boiler fuel or other C&D materials that were not, by some definitions, "recycled." These data show that there is significant recovery of C&D materials for recycling in some locations. However, it is not known if these areas are fully representative of the United States as a whole.

Data Collected by Federal Agencies

U.S. Department of Agriculture (USDA). Deconstruction is the process of selective dismantling or removal of materials from buildings before or instead of demolition. A common practice in the United States is to remove materials of value from buildings prior to and during demolition for recycling or reuse. Reuse examples include electrical and plumbing fixtures that are reused; steel, copper, and lumber that are reused or recycled; wood flooring that is remilled; and doors and windows that are refinished for use in new construction. The USDA Forest Service has compiled a directory of companies that are involved in the deconstruction and reuse of materials from wood-framed buildings (USDA 2004). According to this directory, there are 420 companies involved in deconstructing buildings or selling reusable materials.

The USDA has also collected information on the amount of wood waste that is generated and recovered (McKeever 2004, McKeever and Falk 2004). They have estimated that approximately

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39 million tons of C&D wood waste was generated in 2002. This represents approximately 24% of the total C&D estimate of 164 million tons reported in this study, which is consistent with past estimates that show that wood represents approximately 20-30% of building-related C&D materials (Sandler, 2003).

U.S. Geologic Survey (USGS). The USGS has been keeping track of the amount of minerals that the U.S. extracts, imports, and exports since the late 19th century. They publish the Minerals Yearbook annually, which reports the results of minerals and metals producer surveys. When surveying crushed stone, sand, and gravel producers, they have discovered that some of these producers have started recycling concrete to supplement their business. While it is assumed that these producers recycle a small portion of the total amount of concrete recycled in the U.S., these data demonstrate the increasing acceptance of and demand for recycled concrete aggregate.

U.S. Department of Energy (USDOE). The USDOE reports the amount of energy that is produced from various sources, including wood waste. It is unknown, however, the proportion of the wood waste used for energy that originated from C&D sources. Other sources of wood waste include paper production plants, saw mill, plants, retail stores, and other sources.

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Construction & Demolition Materials Recycling – Measuring Success

Melinda L. Tomaino
The Associated General Contractors of America
Resource Conservation Challenge Workshop
Thursday, February 22, 2007

About AGC of America

- National trade association, est. 1918
- 98 chapters
- Approx. 32,000 member companies
  - 7,000 general contractors
  - 11,000 specialty contractors
  - 13,000 service providers and suppliers

About AGC Members

- Majority are small businesses
- Multiple types of construction
- Varied project delivery methods

AGC Environmental Services

- Compliance tools, educational programs, publications
- Storm water, wetlands (Section 404 permits), TMDL, air quality, diesel retrofit, endangered species, hazardous and non-hazardous waste, EMS, green construction, C&D debris recycling

AGC/EPA Joint Efforts

- Network Partner, EPA National Environmental Performance Track Program
- Partner, EPA Sector Strategies Program
- OECA – Compliance tools
- OAR – Reports, workgroups and collaboratives
- OSWER – _____

2004 C&D Debris Survey

- Gather data
  - Establish a baseline
- Understand the barriers
  - Facilitate recycling

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2004 C&D Debris Survey

- Survey e-mail sent May 28, 2204 and closed June 26, 2004
- 811 members went to the online survey page from e-mail
- 328 completed the survey

Survey Results

- Size of company
  - 123 small businesses
  - 82 medium-sized businesses
  - 123 large businesses
- Does company recycle
  - 191 do recycle
  - 137 do not

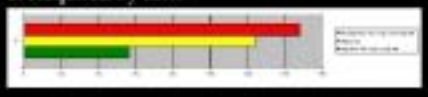
Survey Results

- What affects decision to recycle (or not to recycle)
  - a. Money.

Survey Results

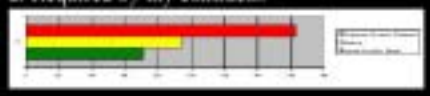
- b. Public image.

- c. Required by law.

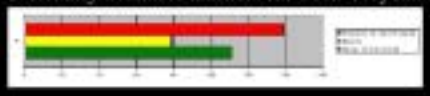


Survey Results

- d. Required by my contracts.

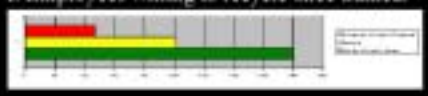


- e. Readily available markets for C&D recyclables.



Survey Results

- f. Employees willing to recycle once trained.



- g. Subcontractors willing to recycle once trained.

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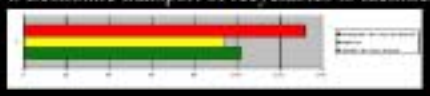
Survey Results

- h. Flexible disposal practices.

- i. Economic transport of recyclables to facilities.



Building Your Quality of Life

Survey Results

- Project-specific information and estimates
  - Respondents by project type—
    - 186 building, 59 highway, 29 demolition, 20 utility, 26 unspecified
  - Projects in 43 states
  - Projects varied in value ($1500 to $4 billion)
  - Focused on asphalt, concrete, steel, and wood

Building Your Quality of Life

Survey Results

- 68.0 percent of asphalt debris was recycled of the average 15,664 tons generated per site (91-93 recorded responses)
- 88.7 percent of concrete debris was recycled of the average 15,126 tons generated per site (148-151 recorded responses)
- 13.6 percent of wood debris was recycled of the average 1,708 tons generated per site (121-125 recorded responses)
- 87.3 percent of steel debris was recycled of the average 1,939 tons generated per site (123-128 recorded responses)

Building Your Quality of Life

AGC Conclusions

- Survey results suggest contractors are willing to recycling, where feasible.
- Survey results and other communications with contractors show an absence of cultural barriers to recycling.
- Choices to recycle depend on local issues, such as availability of recycling facilities and a market for recycled materials.

Building Your Quality of Life

Next Steps

- AGC's Environmental Agenda —
  - Objective 4: Facilitate members' efforts to recycle or reuse C&D debris
    - Develop resources for members
    - Investigate barriers to recycling

Building Your Quality of Life

Contact Information

- Melinda L. Tomaino, LEED AP
  Associate Director, Environmental Services
  AGC of America
  2300 Wilson Blvd, Suite 400
  Arlington, VA 22201
  (703) 837-5415
  tomainom@agc.org

Building Your Quality of Life

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Trends in Building Deconstruction and Materials Reuse
Brad Guy 11/06/06

Introduction

This article is intended to provide an update on some of the trends in the deconstruction and reuse industry. One major aspect of the building materials reuse industry in North America is the HFH ReStore network. ReStores are retail outlets for donated and reclaimed building materials facilities operated by HFH affiliates as a fundraising mechanism for their home-building programs. The Habitat for Humanity (HFH) ReStore network is growing by leaps and bounds. As an example, in Canada in 2000 there were 16 ReStores with gross sales of $3.1 million. In 2005, there were 41 Canadian ReStores with gross sales of $14.5 million. This is a growth of 156% in the number of stores, and a growth of 368% in revenues in just 5 years (HFH Partnernet, 2006). The numbers for the US are similar. According to a study by Penn State University, the average ReStore age is 5 years, with the oldest is 18 years old. More than half of the ReStores have operated for less than 5 years (57.8%), while 28.8% have operated for more than 5 but less than 10 years, and 13.6% have operated for more than 10 years (Judd and Echols, 2005).

Survey

In a recent survey of deconstruction and reuse organizations, an attempt was made to ascertain the materials flows and economics of deconstruction and reuse in the US. An email survey was sent to 450 organizations identified in three categories, deconstruction services, reused materials retail sales and value added products manufacturing with reclaimed wood. A total of 76 responses was received or about a 17% response rate.

Of these 76 respondents, 41 were reuse stores only, and 28 combined both deconstruction services with retail reuse sales. Of the firms that were reuse stores only, 59% reported conducting some form of active salvage operations, with the remaining 41% relying solely on donations. The remaining 7 respondents focused on wood reuse only, through remanufacturing.

Employment

Firms combining deconstruction with a reuse store employ on average more full-time employees (FTE) per organization than those with a reuse store only, 5.8 to 4.6 FTE per firm respectively. It should be noted that many non-profit reuse stores especially the HFH ReStores may also have labor provided by volunteers that is not accounted for by a measure of FTE, while comprising a significant component of the total labor utilized by the organization. The large majority of organizations employed a small number of persons, with 12% of combined deconstruction and reuse firms reporting 16 or more employees. Firms that conduct reclaimed wood value-adding products manufacturing reported an average of 15 employees per firm. Clearly, the value-added aspect of the both front-end deconstruction and back-end remanufacturing provides much greater potential for employment than direct retail resale by itself.

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Table 1. Firms with Deconstruction and Reused Materials Sales
1-5 employees - 69% of firms
6-10 employees - 14% of firms
11-15 employees - 5% of firms
16-20 employees - 10% of firms
More than 20 employees - 2% of firms

Revenues
Firms combining deconstruction and a reuse store reported greater average annual revenues per organization than organizations with a reuse store only. $430,796 to $383,849 per firm, respectively. The difference is about 12% average higher annual revenues per firm. Anecdotally, while there is some investment required for deconstruction and salvage services, a much greater investment is required for the facilities and equipment of a reuse store, such as the warehouse space, racking for materials, fork-lift, a truck for pick-ups, etc. Adding deconstruction to a reuse facility operation can add net revenue potential evidenced by higher average revenues for the combined firms. The investment is minimal in terms of equipment compared to demolition, but similar to demolition in terms of potential increased insurance requirements. Adding a reuse facility to an existing demolition or deconstruction firm is a greater investment than the deconstruction operational requirements alone. There is more capital investment in land, building(s), and equipment.

Not surprisingly, the firms engaged in reclaimed lumber value-adding reported average annual revenues of $2,089,286 per firm. With an average 3 times more employees, these firms also have 3-4 times greater annual revenues than the organizations engaged in the recovery of the materials and direct reused materials sales. Anecdotally, there is trend towards reuse firms adding a value-added component to their operations. Also anecdotally, there are considerable difficulties to the endeavor especially when the value-added product sales are located at the reuse facility. In many cases the markets are very different for a value-added higher cost remanufactured product and the reused building materials store's established clientele which are used to purchasing low-cost products.

Materials Flow
The average amount of materials reported handled annually by firms engaged in both deconstruction and retail reuse sales was 1,011,286 LBS per firm compared to 583,476 LBS per firms only engaged in reuse retail sales. The firms engaged in wood value-adding reported about 1,132,500 LBS of wood materials handled on average per firm per year. Most reuse retail sales firms that responded did not know the amount of materials they handled per year in mass. About 69% of the firms conducting only reuse sales reported not knowing the materials they handled other than by revenues. About 63% of the firms conducting both deconstruction and reuse sales reported not knowing the total amount of materials they handled by mass. Firms that remanufacture wood products all reported a board feet metric of the wood materials they processed. There seems to be a small correlation between the amount of materials handled and number of employees and the attention paid to tracking the materials handled.

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While many non-profit reuse firms may rely more on volunteer labor and function with lower revenues, making it difficult to justify and implement quantity-based inventory systems, they might also be motivated to track materials flow in regards to environmental metrics for the purposes of donor reporting and demonstrating goals such as waste diversion.

Revenues per Employee and Mass of Materials

The average revenues per employee reported by firms engaged in combined deconstruction and reuse retail sales was $73,900 compared to $96,516 per firm for organizations engaged in reuse retail sales only. It is not clear if this relates to wage differences between deconstruction employees and retail store employees in general or other factors. An anecdotal factor, as mentioned above, is that there is less capital overhead involved in just a reuse retail operation by itself compared to a combined deconstruction and reuse retail sales operation.

Keeping this capital investment lower for reuse firms would certainly increase revenues per employee, but it can be noted that the combined deconstruction and reuse retails sales firms employ on average more persons per firm, move more materials by mass per firm (of which more will be commodity materials such as lumber and brick which are lower value per pound than many other building components such as doors, windows, cabinets and fixtures that are the predominant products in building materials reuse retail stores). Perhaps a trend towards larger facilities and more combined deconstruction and reuse firms will follow in the next few years. At this time we do not have sufficient information over time to make this claim.

The revenue per mass of material handled was also calculated from the firms that reported quantities handled per year. For firms engaged in both deconstruction and reuse retail sales the average revenue per mass of materials was $1.39 / LB of materials handled. For firms engaged in reuse retail sales only it was $0.91 / LB and for firms engaged in reclaimed wood value-adding it was $3.10 / LB of wood materials. Clearly there is a correlation between the amount of materials handled and the revenues generated on average and a 3-times greater economic return per LB by the firms engaged in reclaimed wood value-adding. The last significant factor gleaned from this survey is the growth in sales by the three types of firms that were categorized. As noted in Table 2, annual sales revenue growth by firms with combined deconstruction and reuse sales on average was 56%. As noted in Tables 4, annual sales revenue growth by firms with reuse retail sales only on average was 32%. As noted in Tables 5, annual sales revenue growth by firms with reclaimed wood remanufacturing on average was 28%.

Table 2. Combined Deconstruction and Reuse Sales Firms

	FTE	Revenues annual	Revenues/FTE	#s annually	Revenues/LB	% growth
Average	5.8	$430,796	$73,900	1,011,286	$1.39	56

Table 3. Deconstruction Component of Deconstruction and Reuse Sales Organizations

	Annual projects	Contract / project
Average	28	$12,655

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Table 4. Retail Sales Reuse-Only Firms

	FTE	Revenues annual	Revenues/FTE	#s annually	Revenues/LB	% growth
Average	4.6	$383,849	$96,516	583,376	$0.91	32

Table 5. Reclaimed Wood Remanufacturing Firms

	FTE	Revenues annual	Revenues/FTE	#s annually	Revenues/LB	% growth
Average	15	$2,089,286	$132,604	1,132,500	$3.10	28

Reclaimed Materials Being Recovered and Sold

The last aspect of this review of the deconstruction and reuse industry was a focus group review of the most "popular" reclaimed materials. The focus group participants all engaged in recovery and reuse operations. An extensive list of 39 the most common reused materials categories was provided to each participant. They were asked to rank each product based on three criteria. The criteria were: highest resale value; ease of removal from an existing building; and ease of inventory. These rankings were combined, scored and averaged to produce an overall score for the materials deemed most easily recoverable, inventoried and sold. According to this focus group of six successful deconstruction and reuse store operations, the reclaimed products with highest value for resale were grouped into four tiers.

The top tier of reclaimed products based on value includes:

- Architectural elements
- Windows - decorative
- Cabinets - complete sets
- Lumber - wood finish flooring

The second tier of products based on value includes:

- Doors – interior and exterior
- Hardware – including door and plumbing fixtures
- Windows – double-glazed

The third tier of products based on value includes:

- Light fixtures
- Appliances – no more than 5 years old
- Lumber – 1 x sheathing materials

The fourth tier of products based on value includes:

- Brick and stone
- Lumber – floor joists and sub-flooring
- Electrical – hardware and fixtures

From the perspective of the ease of removal only, the products deemed easiest to remove by this group of experts include:

Easiest to remove for salvage:

- Doors – exterior and interior with associated hardware
- Fixtures – ceiling fans, lights, faucets, sinks, mirrors

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The second tier of easy-to-remove components includes:

- Cabinets – tops and complete sets
- Electrical – hardware and fixtures
- Exterior – pavers
- Windows – decorative

The third tier of easiest-to-remove components includes:

- Architectural elements
- Windows – double-glazed

Most Desirable Overall (value, removal, inventory) Best to Less Desirable

1. Doors
2. Mantels
3. Architectural elements
4. Faucet - complete set
5. Cabinets - with doors and drawers
6. Windows - double-glazed

Least Desirable Overall (value, removal, inventory) Worst to More Desirable

1. Brick - three-hole
2. Lumber - porch roof framing
3. Lumber – exterior wall framing
4. Slate roofing
5. Lumber - non-load-bearing wall framing
6. Stone - building

Caveats:

Given that a non-profit reuse sales facility is much more amenable to volunteer labor than deconstruction activities, the reuse sales only organizations potentially make greater use of volunteer labor which is not accounted for in the FTE accounting. Adding in the volunteer labor used by non-profit organizations would produce a lower revenues / employee + volunteer number for both types but potentially more so for the organizations that conduct reuse sales only, widening this disparity.

Of important note is that the pre-ponderance of the deconstruction / salvage and reuse retail sales organizations that reported were non-profits versus for-profits, 87% to 13%, respectively. It should be noted that as non profit organizations their IRS reporting is legally required to be made available to the public, whereas this is not so for for-profit organizations. All of the wood remanufacturing firms that reported were for-profits. The proportion of non-profit to for-profit firms reporting is much greater than past surveys suggest is the proportion of non-profit to for-profit in the industry as whole, so this would clearly distort this information towards the non-profit Firm model.

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How Much C&D Is Recycled?

William Turley
Executive Director

CMRA
Construction Materials Recycling Association

Estimate of 2004 CMRA Members

Classification	Est. Number of CMRA Members	Est. of C&D Marketplace Activity in Classification
Processors / Recyclers	100	71 %
Equipment Vendors	13	9 %
Non-Profits / Public Sector	15	11 %
Other, incl. C&D Consultants	12	9 %
Total	**140**	**100 %**

Survey Responses

- **All 140 CMRA Members were sent the CMRA Survey instrument, plus over 950 other industry-related companies**
- **39 CMRA Members returned the Survey**
- **28% level of CMRA member participation in providing some response to Survey**
- **Of CMRA Members that are Processors / Recyclers, 29 of an estimated 100 returned the Survey representing 29 %**

Summary Returned Surveys

- Companies with Processing Plants:29
  - Mixed C&D Recyclers: 14
  - Wood waste Processors: 3
  - Concrete/Asphalt Recyclers: 12
- Members w/o Processing Plants: 10

Summary of Mixed C&D Surveys

- Companies Reporting CY 2004 Activity:
  - Mixed C&D Companies: 14
  - Total No. of Mixed Plants Included in the Survey Data: 16
- Range of Annual Capacity
  - Plants < 20,000 TPY: 4 (Small)
  - Plants > 20,000 TPY: 12 (Med.-Large)

Throughput of Mixed C&D Plants

- Tons Processed (All): 1,768,000 TPY
- Size Range: 7,000 – 485,000 TPY
- Annual Throughput Reported:
  - Avg. Throughput (All): 110,500 TPY
- Materials Recycled:
  - Avg. Recycled Quantity (All): 78,000 TPY
  - Avg. Percent: 71% (Includes ADC)

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Throughput of M-L Mixed C&D Plants

- Tons Processed (M-L): 144,000 TPY
- Materials Recycled (M-L): 102,000
  - Avg. Percent: 71% (Includes ADC)

Throughput of Small Mixed C&D Plants

- Tons Processed (S): 9,800 TPY
- Materials Recycled (M-L): 8,600
  - Avg. Percent: 88% (Includes ADC)

Summary of Materials Recycled From Mixed C&D Processing Plants

Material	Total Amount Recycled, TPY	% of total TPY
Concrete/Asphalt	433,000	24.7
Wood	340,000	19.5
Gypsum	15,000	0.8
Metals	78,000	4.5
Asphalt Shingles	18,000	1.0
Alt. Daily Cover (ADC)	300,000	17.1
All Other Materials	65,000	3.7
Residue/Discards	512,000	29.0
Total	**1,760,000**	100

Summary of Recycling Surveys Concrete/Inerts-based Plants

- Companies Reporting CY 2004 Activity:
  - Concrete/Inerts Recyclers: 12
  - Total No. of Plants Included in the Survey Data: 36
- Range of Annual Capacity
  - Plants < 50,000 TPY: 2 (Small)
  - Plants > 50,000 TPY: 34 (Med.-Large)

Throughput of Concrete/Inerts Plants

- Tons Processed (All): 5,415,000 TPY
- Size Range: 20,000 – 250,000 TPY
- Annual Throughput Reported:
  - Avg. Throughput (All): 150,000 TPY
- Materials Recycled:
  - Avg. Recycled Quantity (All):149,000 TPY
  - Avg. Percent: 99%

Materials Reported as Recycled From Concrete/Inerts Processing Plants

Material	Total Amount Recycled, TPY	Amount % Basis
Concrete/Asphalt	5,394,000	99.6%
Metals	18,000	0.35%
Asphalt Shingles	>1,000	0.02%
Residue/Discards	< 1,000	0.02%
Total	**5,415,000**	100

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Recycling Surveys Waste Wood Processing Plants

- Companies Reporting CY 2004 Activity:
  - Waste Wood Recyclers: 3
  - Total No. of Plants Included in the Survey Data: 4
- Range of Annual Capacity
  - Plants @ 1,000 TPY: 1 (Small)
  - Plants > 5,000 TPY: 3 (Med.-Large)

Throughput of Waste Wood Plants Returning the Survey

- Tons Processed (All): 148,000 TPY
- Size Range: 1,000 – 70,000
- Annual Throughput Reported:
  - Avg. Throughput (4-plants): 37,000 TPY
- Materials Recycled:
  - Avg. Recycled Quantity (All):36,500 TPY
  - Avg. Percent: 99.5%

Materials Reported as Recycled From Waste Wood Processing Plants

Material	Total Amount Recycled, TPY	Amount % Basis
Wood, Mulch, etc.	147,000	>99
All Other Marketed	1,000	<1
Total	**148,000**	100

Preliminary Estimate of C&D Using 1997 C&D Processing Plant Data

Facility Type	Est. No. of Plants in 1997	CMRA Survey Avg. Input, TPY	Est. of Annual C&D Waste Processed, Tons
Mixed C&D	224	110,500	25,000,000
Concrete Crushing, (Incl. Asphalt ,Brick and Block)	479	125,000 (adjusted for mobile and fixed)	60,000,000
Wood Waste Processing	360	30,000	11,000,000
Total	1,063	-	96,400,000

Estimate of Today's C&D Processed Using CMRA 2004 C&D Processing Plant Data

Facility Type	Est. No. of Plants in 2004	CMRA Survey Avg. Input, TPY	Est. of Annual C&D Waste Processed
Mixed C&D	250	110,500	28,000,000
Concrete Crushing, (Incl. Asphalt, Brick and Block)	1,300 units (700 Portable + 800 Fixed Units)	50,000 tpy (portable) + 150,000 tpy (fixed)	135,000,000
Wood Waste Processing	490	30,000	14,000,000
Total	2,200	-	197,000,000

Comment on 2004 Inerts Crushing Data…re: Asphalt Pavement

- Est. Baseline: 155 million Tons
- "Rough" Est. of Concrete vs. Asphalt:
  - Concrete 85-90% of total
  - Asphalt 10-15% of total
- Rough Estimate of Throughput:
  - Crushed Concrete: 130-140 million TPY
  - Crushed Asphalt: 15-25 million TPY
- Note: the above asphalt numbers do not include the highway millings and contractor's specific full –depth removal project work of which the "total" for these activities is estimated by the National Asphalt Pavement Association's (NAPA) to be an estimated 90 million TPY by their industry association, with greater than 80% or 72 TPY recycled.

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But Is There Even More?

- 2500 Crushers x 70%= 1750
- 100 tons per hour
- 1600 hours per year
- Grand Total: 280,000,000 tons per year
- And that is only recycled, not generated

Thank You

CMRA
Construction Materials Recycling Association

William Turley
630/585-7530
turley@cdrecycling.org
www.cdrecycling.org

Status of NDA Demolition Debris Generation & Recycling Survey Evaluation

Presentation to:

National Demolition Association

Presentation by:

Robert H. Brickner, Sr. Vice President

Gershman, Brickner & Bratton, Inc.

8550 Arlington Boulevard, Suite 203, Fairfax, VA 22031
1-508-573-5001 / Fax: 703.698.1306
www.gbbinc.com

September 24, 2005

1

Status of Survey Responses

- 555 NDA Members were sent the Survey
- 105 NDA Members in the USA returned their Survey (2 more from Canada)
- Almost 20% Level of Participation

2

Summary of Returned Surveys

- Re: inquiries about Company's decisions to Recycle
  - 100% of Surveys responded to at least part of the questions
  - Questions response & the GBB Rating:

Strongly Agree	= 1
Agree	= 2
Neutral	= 3
Disagree	= 4
Strongly Disagree	= 5

3

Company's Decision to Recycle

Average Rating of Survey Responses

What effects your Company Decisions	Avg. Rating
5a. Recycling Saves Money	1.8
5b. Recycling Improves Demo Company Image	1.8
5c. Recycling is Required by Law	3.0
5d. Recycling is Required by Contracts	3.2
5e. Readily available markets for C&D recyclables	2.9
5f. Employees willing to recycle C&D wastes once trained	2.2
5g. Subcontractors willing to recycle C&D once trained	2.6
5h. Established waste disposal practices can change w/o major difficulty to include C&D recycling	2.8
5i. C&D recyclables can be economically transported to recycling facilities	2.6

4

Methodology of GBB Allocation of Survey Data

- Example: Demo Generation Reported – 100 Tons per Year (TPY)
- Split of Work in CA – 90% = 90 Tons
- Split of Work in NM – 10% = 10 Tons

5

Summary of Members Survey Data

(Demo Generated in States > 400,000 TPY)

State (No. of Surveys)	Demo Generated (TPY)	% of Total, by State
CA (19)	4,578,251	29.0%
FL (7)	2,452,572	15.5%
TX (5)	1,506,304	9.5%
NJ (6)	1,340,453	8.5%
MN (5)	739,433	4.7%
OH (5)	561,994	3.6%
IL (6)	549,090	3.5%
WA (4)	477,668	3.2%
Other 42 States	3,550,194	22.5%
Total	**15,786,627**	100%

6

Aggregation of Recycling Data

(Survey's of States > 400,000 TPY reported)

State	Demo Recycled TPY	% Recycled in the State
CA(19)	4,110,000	90%
FL(7)	2,213,000	90%
NJ(6)	965,000	72%
TX(5)	745,000	49%
MN(5)	567,000	77%
WA(4)	497,000	88%
IL(8)	407,000	74%
Other 43 States	2,148,000	19%
Total	**11,590,000**	73% (Nationwide)

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Summary of Materials Recycled

Material	Total Amount Recycled, TPY	% Recycled of total TPY
Concrete	6,845,000	61.2
Wood	350,000	3.1
Brick/Block	510,000	4.5
Metals	940,000	8.4
Sheetrock	45,000	<0.5
Asphalt Pavement	2,675,000	23.9
Other Materials	125,000	1.1
Mixed Stream	100,000	<1
Total	**11,590,000**	

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Identified Project Sources

(Percent of the Waste Material)

Structural/Buildings... 80.0%
Bridges..... 1.5%
Other..... 18.5%

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Review of Demo Waste Generated

(by Gross Sales of Company)

Sales (No. Surveys)	Avg. TPY Generated
< $2 million (36)	48,083
>$2mil <$5 mil (28)	96,203
>$5mil <$10 mil (25)	254,401
> $10 million (16)	634,412

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Est. of Current NDA Members

(%, by Gross Sales Volume)

Annual Sales	Est. % of Membership	Est. Number of NDA Members
< $2 million	40	222
>$2mil <$5mil	25	139
>$5mil <$10mil	25	139
>$10 million	10	55
Total	**100**	**555**

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Est. of Annual NDA Member Demolition Waste Handled, Tons

Est. Number of NDA Members, by Sales Range	Avg. Tons Generated, by Sales Range	Est. of TOTAL Demolition Waste, by Sales Range
222 (< $2 million)	48,083	10.7 million
139 (>$2mil <$5mil)	89,077	12.4 million
139 (>$5mil <$10mil)	200,843	27.9 million
55 (>$10 million)	634,412	34.9 million
Total		**85.9 million**

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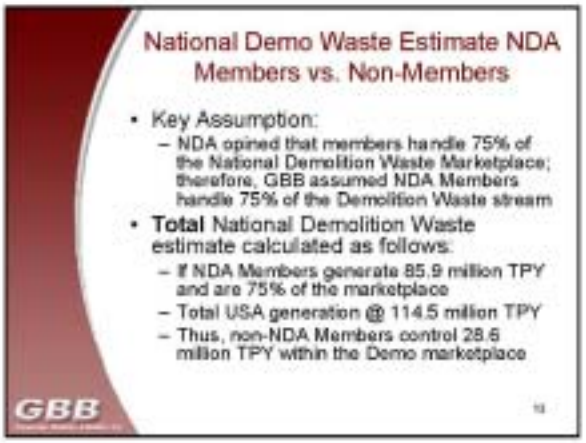
National Demo Waste Estimate NDA Members vs. Non-Members
• Key Assumption:
– NDA opined that members handle 75% of the National Demolition Waste Marketplace; therefore, GBB assumed NDA Members handle 75% of the Demolition Waste stream
• **Total** National Demolition Waste estimate calculated as follows:
– If NDA Members generate 85.9 million TPY and are 75% of the marketplace
– Total USA generation @ 114.5 million TPY
– Thus, non-NDA Members control 28.6 million TPY within the Demo marketplace
GBB

United States
Environmental Protection
Agency
Office of Resource Conservation and Recovery
EPA530-R-09-002
www.epa.gov/epawaste
March 2009

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NOISE FROM CONSTRUCTION EQUIPMENT AND OPERATIONS, BUILDING EQUIPMENT, AND HOME APPLIANCES

DECEMBER 31, 1971

U.S. Environmental Protection Agency
Washington, D.C. 20460

AR0070437

NOISE FROM CONSTRUCTION EQUIPMENT AND OPERATIONS, BUILDING EQUIPMENT, AND HOME APPLIANCES

DECEMBER 31, 1971

Prepared by

BOLT, BERANEK AND NEWMAN
under
CONTRACT 68-04-0047

for the

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

This report has been approved for general availability. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of EPA. This report does not constitute a standard, specification, or regulation.

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1. INTRODUCTION

As a society evolves technologically, the sources of noise grow in number and kind. Noise levels increase and the effects of noise on society become increasingly severe. Concomitantly, society continually requires more machinery, operating at higher speeds with greater power output. Aircraft, for example, have continued to grow in number and noise level, creating almost intolerable conditions for populations living, working, and playing in the vicinity of airports. Trucks and construction equipment require increasingly powerful engines to enable a single operator to move more goods, materials, or earth faster and more economically. The thunder of these engines not only degrades the quality of life in our communities but also causes the operators to incur substantial levels of permanent hearing loss. A profusion of appliances that provide the energy needed to do everything from brushing our teeth and cooling our houses, to washing our dishes, disposing of our garbage, and cutting our grass often generate noise levels that interfere with conversation and disturb neighbors. Even the wilderness, once a refuge from hectic urban life, is now disturbed by the noise of trail bikes, all-terrain vehicles, and snowmobiles.

Given that noise is a serious environmental problem, some appropriate questions one might ask in seeking a comprehensive noise-control objective are: Precisely what are the sources of noise pollution? How many people are exposed to these sources and how are they affected? What can be done to control the noise output of offending sources? This report attempts to answer these questions for the specific categories of construction, home appliances, and building equipment.

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1.1 Source Characterization

The two principal objectives in characterizing sources are (1) evaluating noise levels in quantitative terms that may be used to determine the impact on people and (2) obtaining the information needed to assess the noise reduction that can be achieved. Relating measurable aspects of sound to human response is difficult at best. Such impact criteria as speech interference, sleep interruption, and annoyance depend not only on the physical nature of sound such as level, spectral content, and degree of fluctuation but also on the nonphysical aspects of noise such as the information content or implications of the sound. A rattling piece of equipment is often annoying not because of the noise level but primarily because it indicates a malfunction requiring attention.

Several attempts have been made to include various aspects of noise in a single number related to annoyance. Most of these methods try to account for the unequal sensitivity of the human hearing mechanisms to different frequencies and some try to account for fluctuations of level with time. A single number which accounts rather well for the human ear's relative insensitivity to low and very high frequency sound is the A-weighted scale. This weighting has been found to correlate about as well with annoyance as other indices [1]; it is quite widely accepted and can be read on a meter. In this report, we use A-weighting [dB(A)] to characterize noise insofar as impact evaluations are concerned.

Noise spectra are of far more use than single number ratings for assessing the contribution from various components to total noise levels. Pure tones associated with integer multiples of speeds of rotating machinery often appear as identifiable spectral peaks. Exhaust noise from an internal combustion engine

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typically contributes the dominant low-frequency component, whereas engine structural radiation and turbocharger whine usually generate the high-frequency levels. Hence, where possible, we provide noise spectra in octave or one-third octave bands.

Once sources have been characterized, we evaluate the abatement potential associated with each. Our evaluation is based on a somewhat broad analysis of the component contributions and to a great extent on judgment developed from experience with similar sources. For example, prior work with internal combustion engines enables us to estimate the benefit achievable from state-of-the-art mufflers or engine enclosures. We estimate our predictions of achievable abatement potential to be within ±5 dB. A more accurate prediction of noise reduction would require detailed diagnosis of contributions from each source component and implementation of experimental noise-control treatment.

Because of the large number of sources evaluated (see Sec. 2), we place much detailed information (e.g., a number of noise spectra for sources whose impact is small) in Appendix A. Included in Appendix B is the background to the development of impact criteria and in Appendix D a discussion of existing standards.

1.2 Impact Evaluation

We evaluate the impact of noise on people, using two principal measures: intensity and extent. Clearly, it is important to know the levels to which a person may be exposed and the effects of this exposure. Thus, once the sources have been characterized and the relation of a listener to the source has been postulated, we estimate the physiological, psychological, and sociological effects of the noise. For example, permanent hearing damage is likely to occur for a significant percentage of the population

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exposed to levels of 90 dB(A) for eight hours a day over an extended period of time. If the exposure time is short (e.g., 15 minutes a day), the noise may or may not contribute to hearing damage, but during exposure one cannot conduct an intelligible conversation. Exposure during evening hours to levels of noise that exceed approximately 70 dB(A) will usually lengthen the time one requires to go to sleep or will awaken someone who is already asleep - especially if the noise is intermittent and the background level is low.

The extent of noise impact is as important as the intensity in assessing the magnitude of noise pollution since this measure gives some perspective to the contribution from various sources. A truly comprehensive assessment would involve a detailed social survey with extensive noise measurements and statistically significant samples from every stratum of society. Such a program would no doubt cost millions of dollars and several calendar years. Clearly, this approach is not feasible in the three-month time period available for this study, nor would it represent an entirely justifiable allocation of resources. The goal of determining the impact of noise can be viewed only as an intermediate step to solving the actual problem: reducing the noise exposure of our population. Hence, an order-of-magnitude assessment of impact is probably an adequate guide to the development of a noise-abatement program. What matters, for example, is that approximately six million workers on night shifts and children under four cannot sleep because of construction noise. One's approach to construction-noise abatement would probably not be different if the figure were two million or ten million. We therefore provide this impact evaluation, not by social survey, but by estimating (1) the noise levels to which people are exposed, (2) the effects of noise on these people, and (3) the number of people

exposed. These estimates are based on measured values of equipment noise, data on human response to noise, statistics of equipment utilization, and statistics of population distributions. The impact of construction, appliances, and building equipment is discussed in Sec. 3.

1.3 Industry Assessment

To bring about control of environmental noise, the EPA must have information not only about the technology of abatement but also about the nature of the industry it may be called upon to influence. An understanding of the pressures for and against noise control is helpful in assessing the extent to which an industry is likely to institute noise control measures on its own and how the industry will be affected if it is compelled to produce quieter products. For example, the principal impact of construction noise, other than hearing-damage risk to operators (who have been unexpectedly vocal about their plight), is on the community rather than the purchaser. The community has been able to exert very little influence on the purchaser or the manufacturer, the result being that very little has been accomplished in quieting construction equipment. For example, diesel-powered equipment is sometimes advertised and sold without even mufflers. A small number of companies, however, have begun to produce quiet equipment; they attribute their recent success in the marketplace to certain local noise legislation and to the threat of such regulations spreading to other communities.

An example of the efforts that noise regulations may have on business comes from the home appliance industry. An air-conditioner manufacturer has indicated that certain marketplace pressures inhibit him from implementing additional noise control in bottom-of-the-line items. He argues that more noise control

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would increase the price of an item, thereby harming his competitive position. If all manufacturers were required to make their products quieter (and therefore more costly), one could argue that a segment of the population at lower income levels could no longer afford air-conditioners and would be deprived of that comfort.

By interviewing manufacturers of construction equipment, home appliances, and building equipment, we obtained their views of the relevance of noise control to their business. We found a substantial difference between the attitudes of people who manufacture construction equipment and those who manufacture appliances. The former, who find practically no marketplace demand for quiet equipment, are faced with the prospect of a mélange of state and city ordinances; they almost welcome "reasonable" federal standards. The latter find an increasing marketplace demand for quiet appliances and prefer not to see the implementation of federal standards or labeling requirements. Chapter 4 of this report contains an analysis of the pressures on industry to reduce (or not to reduce) noise levels, its response to these pressures, its present achievements, and its potential.

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2. SOURCE CHARACTERIZATION

2.1 Construction Equipment and Operation

Construction has become a major noise problem in many cities and towns. The trend toward urban renewal and more high-rise structures has created an almost perpetual din on city streets. Equipment associated with construction projects is more numerous, and the time span for construction at a given site has lengthened. Residents very near a construction site may well plan on two years of intolerable noise levels as a high-rise structure is being built.

In this section, we consider the construction noise problem as it relates to residential and nonresidential buildings, city streets, and public works, because these kinds of project usually take place in areas where the number of people likely to be exposed is very high. Heavy construction, such as highways and civil works, has been omitted from our study because the vast bulk of this activity occurs in thinly populated areas where the noise affects very few people. We view construction as a process that can be categorized according to type and that consists of separate and distinct phases.

2.1.1 The construction process

The basic unit of construction activity is the construction site, which exists in both space and time. The temporal dimension consists of various sequential phases which change the character of the site's noise output as work progresses. These phases are discussed further below. In the case of building construction, the spatial character of the site is self-evident; in the case of sewers and roads, the extent of a site is taken, for reasons explained in Sec. 3.2, to be one standard city block or

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about 1/8 of a mile. (That is, if a city reports 40 miles of sewer construction, we consider that project as consisting of 320 separate sites.)

Construction sites are typically classified in the fifteen categories in which construction data is reported by the U.S. Bureau of Census and various state and municipal bodies. The categories are:

- Residential buildings:
  - one- to four-family
  - Five-family and larger
- Nonresidential buildings:
  - Office, bank, professional
  - Hotel, motel, etc.
  - Hospitals and other institutions
  - Schools
  - Public works buildings
  - Industrial
  - Parking garages
  - Religious
  - Recreational
  - Store, mercantile
  - Service, repair station
- Municipal streets
- Public works (e.g., sewers, water mains).

For purposes of allocating construction effort among the different types of sites, it is possible to group the nonresidential sites into four larger categories which are differentiated by the cost of the average building in each category, as well as by the distribution of effort among the various construction

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phases. These four groups, in order of decreasing average cost per building, are:

- Office buildings, hospitals, hotels
- Schools, public works buildings
- Industrial buildings, parking garages
- Stores, service stations, recreational buildings, and religious buildings.

Construction is carried out in several reasonably discrete steps, each of which has its own mix of equipment and consequently its own noise characteristics. The phases (some of which can be subdivided) are:

- *Building Construction*
  1. a. Clearing
     b. Demolition
     c. Site preparation
  2. Excavation
  3. Placing foundations
  4. a. Frame erection
     b. Floors and roof
     c. Skin and windows
  5. a. Finishing
     b. Cleanup
- *City Streets*
  1. Clearing
  2. Removing old roadbed
  3. Reconditioning old roadbed
  4. Laying new subbase, paving
  5. Finishing and cleanup

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- *Public Works*
  1. Clearing
  2. Excavation
  3. Compacting trench floor
  4. Pipe installation, filling trench
  5. Finishing and cleanup.

Defining the construction phases as above allows us to account for the variation in site noise output with time. By inventorying the equipment which is to be found at each site in each phase, we can derive a representative source level for each phase by the process described below.

2.1.2 Equipment noise characteristics

Despite the variety in type and size of construction equipment, similarities in the dominant noise sources and in patterns of operation permit one to assign all equipment to a very limited number of categories. These categories are described below and are indicated in Fig. 1, together with corresponding noise level data. Corresponding spectra and the sources of this data are given in Appendix A.

Equipment Powered by Internal Combustion Engines

The most prevalent noise source in construction equipment is the prime mover, i.e., the internal combustion engine (usually of the diesel type) used to provide motive and/or operating power. Engine-powered equipment may be categorized according to its mobility and operating characteristics, as (1) earthmoving equipment (highly mobile), (2) handling equipment (partly mobile), and (3) stationary equipment.

Earthmoving equipment includes excavating machinery (backhoes, bulldozers, shovels, front loaders, etc.) and highway

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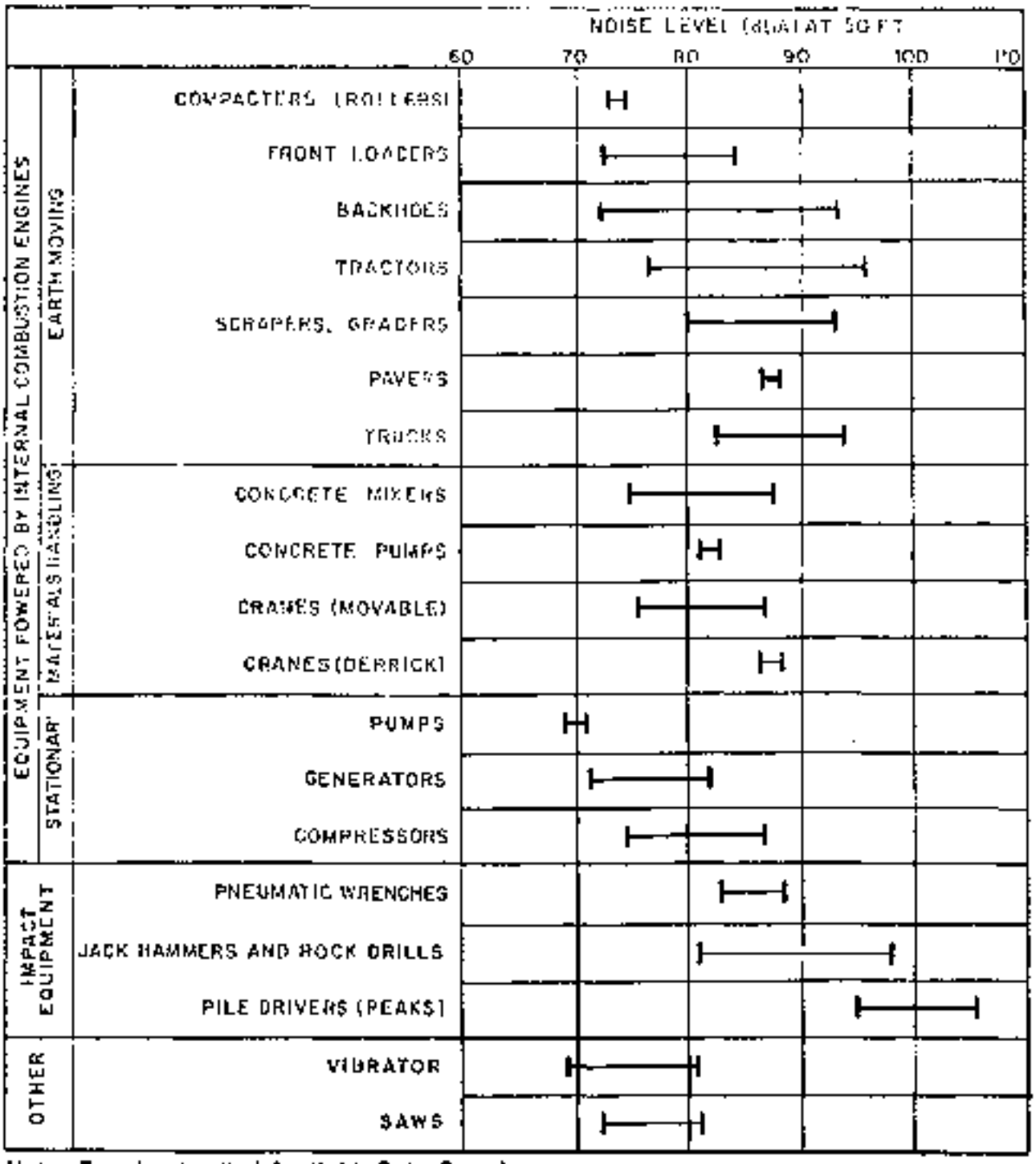

Note: Based on Limited Available Data Samples

FIG. 1. CONSTRUCTION EQUIPMENT NOISE RANGES.

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building equipment (compactors, scrapers, graders, pavers, etc.). Internal combustion engines are used for propulsion (either on wheels or tracks) and for powering working mechanisms (buckets, arms, trenchers, etc.). Engine power varies from about 50 hp to over 600 hp. Engine noise typically predominates, with exhaust noise usually being most significant and with inlet noise and structural noise being of secondary importance. Other sources of noise in this equipment include the mechanical and hydraulic transmission and actuation systems, and cooling fans (often very significant). Typical operating cycles may involve one or two minutes of full-power operation, followed by three or four minutes at lower power.

Noise levels at 50 ft from earthmoving equipment range from about 73 to 96 dB(A). The greatest and most direct potential for noise abatement here lies in quieting the engine by use of improved mufflers.

Engine-powered materials-handling equipment such as cranes, derricks, concrete mixers, and concrete pumps, is used in a more-or-less fixed location; mobility of this equipment over the ground is not part of its major work cycle. Although noise from the working process (such as the clanking of aggregate in the concrete mixing bin) often is the most "identifiable" noise component, the dominant source of noise generally is the prime mover. Noise levels at 50 ft range from about 75 to 90 dB(A). The greatest potential abatement for noise again lies in engine quieting, with treatment of power transmission and working mechanisms being of secondary importance.

Stationary equipment, such as pumps, electric power generators and air compressors, generally runs continuously at relatively constant power and speed. Noise levels at 50 ft range

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from about 70 to 80 dB(A), with pumps typically at the low end of this range. Stationary equipment, because of its fixed location and constant speed and/or load operation, may be quieted more easily than mobile equipment; engine mufflers can be more effective, and use of enclosures becomes feasible. [In fact, noise from some air compressors, has already been reduced by about 10 dB(A) by use of appropriate enclosures.]

The greatest near-term abatement potential for all current equipment powered by internal combustion engines lies in the use of better exhaust mufflers, intake silencers, and engine enclosures (in conjunction with appropriate cooling system and fan design). Reductions of 5 to 10 dB(A) appear to be achievable, usually without great difficulty. Practical long-term abatement [of about 15 to 20 dB(A)] can probably be achieved by basic engine design changes. Of course, replacement of the internal combustion engine by a quieter prime mover, such as a gas turbine or electric motor, would eliminate the reciprocating-engine noise source altogether.

Impact Equipment and Tools

Conventional pile drivers are either steam-powered or diesel-powered; in both types, the impact of the hammer dropping onto the pile is the dominant noise component. With steam drivers, noise is also generated by the power supply (a boiler) and the release of steam at the head; with diesel drivers, noise is also generated by the combustion explosion that actuates the hammer. Noise levels are difficult to measure or standardize, because they are affected by pile type and length, but peak levels tend to be about 100 dB(A) (or higher) at 50 ft.

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Impact-noise is absent in the so-called "sonic" (or vibratory) pile drivers. These do not use a drop hammer, but vibrate the pile at resonance. The noise associated with pile vibrations typically occurs around 150 Hz and is barely audible. The power source, which generally consists of two gasoline engines, is the primary noise source.

Abatement can be accomplished best by substituting use of a sonic pile driver for an impact machine where possible. (Unfortunately, sonic pile drivers are useful only for some soils.) Impact noise reduction at the source generally is very difficult. Substitution of nonimpact tools offers the best practical abatement potential; otherwise, reductions of perhaps 5 dB(A) may be obtained by use of enclosures.

Most impact tools, such as jack hammers, pavement breakers, and rock drills are pneumatically powered, but there are also hydraulic and electric models. The dominant sources of noise in pneumatic tools are the high-pressure exhaust and the impact of the tool bit against the work. Noise levels at 50 ft typically range from 80 to 97 dB(A).

An exhaust muffler on the compressed air exhaust can lower noise levels from the exhaust by up to about 10 dB(A). Pneumatic exhaust noise, of course, is absent in hydraulic or electric impact tools. Reduction of the impact noise from within a tool can be accomplished by means of an external jacket, which can contribute perhaps a 5 dB(A) reduction. Reduction of the noise due to impact between the tool and material being worked upon generally is difficult and requires acoustic barriers enclosing the work area and its immediate vicinity. Depending on the impacted structures, such barriers may reduce noise by 3 to 10 dB(A).

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Small hand-held pneumatic tools, such as pneumatic wrenches, generate noise of levels between 84 and 88 dB(A) at 50 ft. The exhaust and the impact are the dominant noise sources. Because of the obvious weight and size limitations to which hand tools are subject, only small and light mufflers can be used with them, limiting the achievable noise reduction to 5 dB(A) at best. The best practical means for reducing the noise from impact tools consists of using other types of tools to accomplish the same functions.

2.1.3 Site noise characteristics

To characterize the noisiness — i.e., the average noise annoyance potential — of the various types of construction sites during each phase of construction, a Noise Pollution Level (NPL) was calculated for each type of site and each construction phase. The NPL used here was taken as the same measure that was used for similar evaluation of traffic noise [2]. The NPL (in dB) is defined as the sum of the A-weighted average sound pressure level and 2.56 times the standard deviation of the A-weighted sound pressure level*; thus, NPL accounts for the effect of steady noise, plus the annoyance due to fluctuations.

Although a thorough study relating NPL to subjective descriptors of annoyance (e.g., acceptable, unacceptable) has not been accomplished, a provisional interpretation of NPL in such terms can be suggested. On the basis of an evaluation of domestic and

*A-weighting refers to a standard weighting of the various frequency components, approximating the behavior of human hearing. The average sound pressure level is computed on the basis of the time-average root-mean-square sound pressure, whereas the standard deviation is calculated from the time-variation of the dB(A) values.

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Foreign social surveys and psycho-acoustic studies, the Department of Housing and Urban Development has adopted a set of "guideline criteria" [3] for outdoor noise levels in residential areas as shown in Fig. 2 [4]. According to this chart, the community noise situation is evaluated by comparing a measured distribution of A-weighted levels with the criteria curves. The situation is categorized by the region of least desirability penetrated by the actual noise distribution. Since this criterian is based on level distributions, the boundaries between regions of acceptability may be defined in terms of the NPL. Thus, the following descriptors of NPL values may be used in interpreting the site noise NPL levels used in the remainder of this report.

Clearly Acceptable: The noise exposure is such that both the indoor and outdoor environments are pleasant.	NPL less than 62 dB
Normally Acceptable: The noise exposure is great enough to be of some concern but common building constructions will make the indoor environment acceptable, even for sleeping quarters, and the outdoor environment will be reasonably pleasant for recreation and play.	NPL between 62 and 74 dB
Normally Unacceptable: The noise exposure is significantly more severe so that unusual and costly building constructions are necessary to ensure some tranquility indoors, and barriers must be erected between the site and prominent noise sources to make the outdoor environment tolerable.	NPL between 74 and 88 dB
Clearly Unacceptable: The noise exposure at the site is so severe that the construction costs to make the indoor environment acceptable would be prohibitive and the outdoor environment would still be intolerable.	NPL greater than 88 dB

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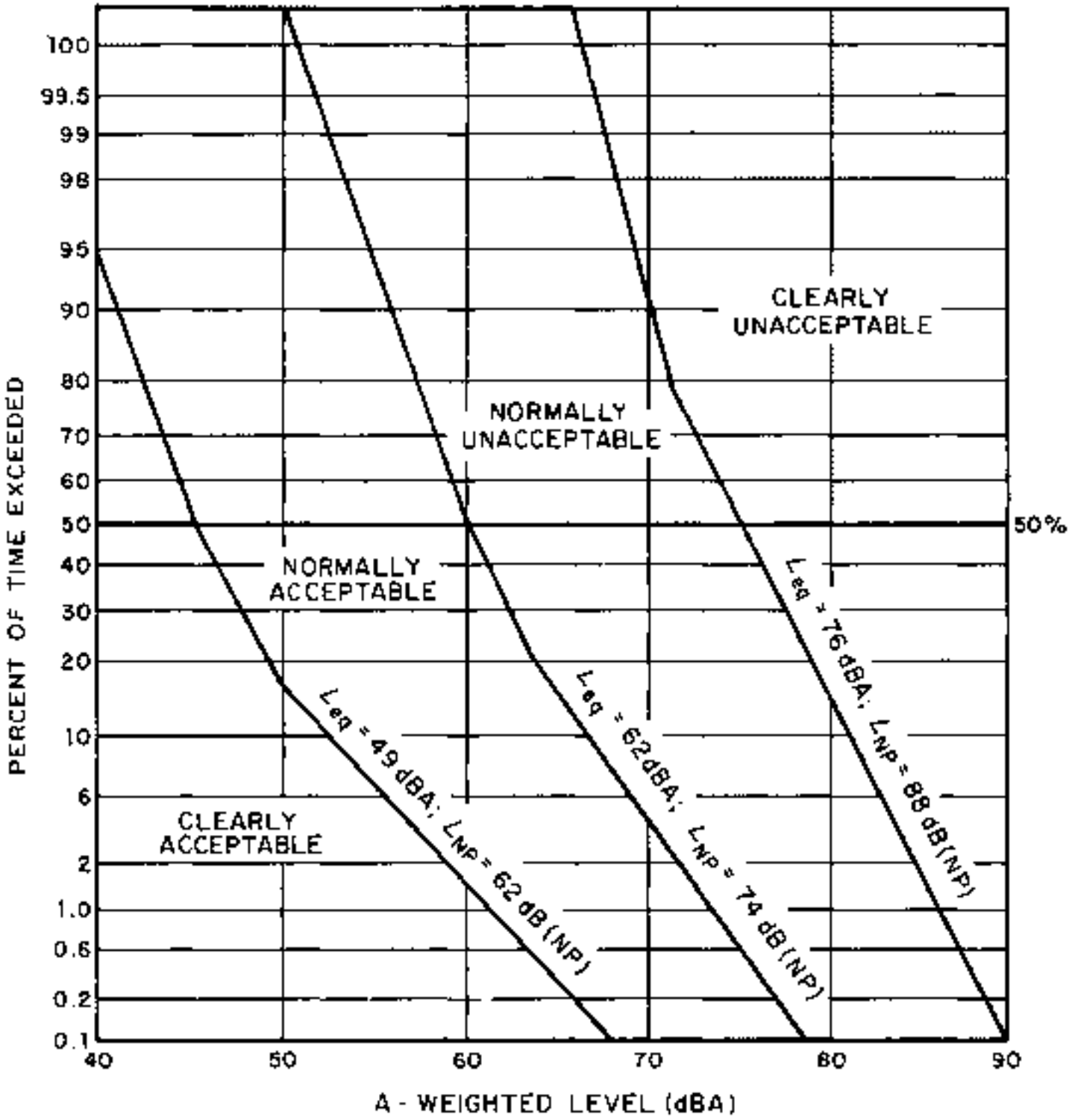

FIG. 2 PROVISIONAL CRITERIA RELATING NPL TO COMMUNITY NOISE ACCEPTABILITY

We must emphasize that these criteria have not been officially or unofficially adopted by HUD or any other government agency. They are presented here solely to enable the reader to interpret NPL values computed in this report.

The aforementioned averages of noise annoyance potential were calculated on the basis of information obtained on (1) the number of each item of equipment typically present at a site (in a given phase), (2) the length of the duty cycles of this equipment, and (3) the average noise levels during operation. For purposes of site characterization, the noisiest piece of equipment was assumed to be located at 50 ft from an observer, and all other equipment was assumed to be located at 200 ft from the observer; ambient noise, of levels depending on the surroundings of the site, was taken to be present in addition to the equipment noise. (Note that pile driver noise was not included in the NPL calculations, because its repetitive impact character makes its intrusion characteristics different from the more continuous noises for which the NPL concept was developed.) Clearly, this construction noise model is not entirely realistic; however, it may be expected to fulfill its intended purposes — that of yielding at least a relative measure of the noise annoyance associated with each type of site and phase for the most adverse conditions likely to be associated with each phase.

Table 1 shows NPLs calculated for each of five phases for each of four types of construction. For residential housing and public works construction, two NPL values are given in the table; one pertains to a noisy [70 dB(A)] background characteristic of urban conditions, the other to relatively quiet [50 dB(A)] ambient conditions found in suburban environments. As one may expect, the values indicated in the table reflect the fact that a given intruding noise is more annoying if it occurs in a quieter environment.

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TABLE I-a. TYPICAL RANGES OF NOISE LEVELS AT CONSTRUCTION SITES WITH A 50 dB(A) AMBIENT TYPICAL OF SUBURBAN RESIDENTIAL AREAS

	Domestic Housing		Office Building, Hotel, Hospital School, Public Works		Industrial Parking Garage, Religious, Amusement & Recreations, Store, Service Station		Public Works Roads & Highways, Sewers, and Trenches		
	I	II	I	II	I	II	I	II	
Ground Clearing	83	83	84	84	84	83	84	84	Energy Average dB(A)
	8	15	7	16	9	16	9	8	Standard Deviation
	103	122	101	123	106	124	103	104	NPL
Excavation	88	75	89	79	89	71	88	78	Energy Average dB(A)
	8	14	6	2	5	2	7	3	Standard Deviation
	109	111	105	85	105	77	106	86	NPL
Foundations	81	81	78	78	77	77	88	88	Energy Average dB(A)
	10	17	3	3	4	5	8	8	Standard Deviation
	107	124	84	86	87	90	106	108	NPL
Erection	81	65	87	75	84	72	79	75	Energy Average dB(A)
	10	9	6	2	9	7	9	11	Standard Deviation
	107	87	99	79	107	91	103	108	NPL
Finishing	88	72	89	75	89	74	84	84	Energy Average dB(A)
	7	12	7	8	7	10	7	5	Standard Deviation
	105	104	107	97	105	100	101	104	NPL

I – All pertinent equipment present at site.

II – Minimum required equipment present at site.

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TABLE 1-b. TYPICAL RANGES OF NOISE LEVELS AT CONSTRUCTION SITES WITH A 70 dB(A) AMBIENT TYPICAL OF URBAN AREAS

	Domestic Housing		Office Building, Hotel, Hospital School, Public Works		Industrial, Parking Garage, Religious, Amusement & Recreations, Store, Service Station		Public Works Roads & Highways, Sewers, and Trenches		
	I	II	I	II	I	II	I	II	
Ground Clearing	84	83	84	84	84	87	84	84	Energy Average dB(A)
	6	8	6	8	6	8	6	7	Standard Deviation
	100	103	99	103	101	103	100	101	NPL
Excavation	88	76	89	79	89	74	89	79	Energy Average dB(A)
	7	5	6	2	7	1	6	2	Standard Deviation
	106	88	104	85	106	77	105	85	NPL
Foundations	81	81	78	78	78	78	88	88	Energy Average dB(A)
	7	7	3	2	3	3	8	8	Standard Deviation
	99	100	85	86	85	85	108	108	NPL
Erection	82	71	85	76	85	74	79	79	Energy Average dB(A)
	6	1	5	1	7	2	4	4	Standard Deviation
	97	75	97	79	103	80	88	88	NPL
Finishing	88	74	89	76	89	75	84	84	Energy Average dB(A)
	7	4	6	4	6	3	6	6	Standard Deviation
	106	84	104	86	104	84	100	100	NPL

I – All pertinent equipment present at site.

II – Minimum required equipment present at site.

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The NPL values shown in Table I obviously depend on the previously described model of site noise. For this model, the average sound pressure level depends strongly on the one or two noisiest pieces of equipment, whereas the standard deviation depends largely on the numbers and duty cycles of the less noisy equipment and on the ambient noise level.

As evident from Table I, in building construction, the initial ground clearing and excavation phases tend to be the noisiest, the subsequent foundation and erection phases tend to be somewhat less noisy, and the final finishing phase again tends to be relatively noisy. In public works construction, on the other hand, NPLs are more nearly the same for all phases, except that the erection phase tends to be less noisy.

Table II lists the two noisiest types of equipment for each site type and phase, together with the average A-weighted noise levels (at 50 ft) for this equipment. Inspection of this table indicates that rock drills, which typically are the noisiest equipment, are prevalent in the excavation and finishing phases; trucks, on the other hand, are somewhat less noisy than rock drills or similar equipment but are present in nearly all phases.

Effect of Equipment Quieting

To assess the effect of some quieting strategies on the previously described site noise model, we recalculated the NPL for three "strategies" for each type of site and each phase:

Strategy 1:

- Only the noisiest piece of equipment being quieted by 10 dB(A), with this equipment remaining at the previously specified 50 ft distance from the observer.

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TABLE II. NOISIEST EQUIPMENT TYPES OPERATING AT CONSTRUCTION SITES*

Construction Phase	Construction Type: Domestic Housing	Office Bldgs.	Industrial	Public Works
Ground Clearing	Truck (91)	Truck (91)	Truck (91)	Truck (91)
	Bulldozer (88)	Bulldozer (88)	Bulldozer (88)	Bulldozer (88)
Excavation	Rock Drill (98)	Rock Drill (98)	Rock Drill (98)	Rock Drill (98)
	Truck (91)	Truck (91)	Truck (91)	Truck (91)
Foundations	Concrete Mixer (85)	Jack Hammer (88)	Jack Hammer (88)	Truck (91)
	Pneumatic Tools (85)	Concrete Mixer (85)	Concrete Mixer (85)	Scraper (88)
Erection	Concrete Mixer (85)	Derrick Crane (88)	Derrick Crane (88)	Paver (89)
	Pneumatic Tools (85)	Jack Hammer (88)	Jack Hammer (88)	Bulldozer (88)
Finishing	Rock Drill (98)	Rock Drill (98)	Rock Drill (98)	Truck (91)
	Truck (91)	Truck (91)	Truck (91)	Paver (89)

*Numbers in parentheses represent typical dB(A) levels at 50 ft. See Table I for definition of construction types.

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Strategy 2:

- Only the noisiest piece of equipment being quieted by 10 dB(A), with this equipment moved to 200 ft and with the next noisiest equipment (unquieted) moved to 50 ft from the observer position

Strategy A:

- All items of equipment quieted by 10 dB(A).

The results of these calculations are shown in Table III, together with the NPL values previously obtained without any quieting (Strategy 0). It appears that quieting only the noisiest piece of equipment generally reduces the site NPL relatively little, if other types of equipment can also operate near the observer (compare Strategies 0 and 2). On the other hand, quieting the noisiest equipment and letting no others operate near the observer may result in significant reductions (compare Strategies 0 and 1). Of course, quieting all equipment (Strategy A) results in the lowest NPL values; however, these values are often only slightly lower than those obtained by quieting only the noisiest item (Strategy 1).

The site noise model used here initially assumes the noisiest equipment to be located nearest the observer. It can happen that quieting the noisiest equipment, moving it away from the observer, and moving the second noisiest equipment near the observer (Strategy 2) results in an *increase* in the NPL, if the second noisiest equipment is used more frequently than the noisiest. This peculiarity of the noise model, where equipment quieting seemingly increases the noise, is evident at several places in Table III.

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TABLE III. NOISE POLLUTION LEVELS IN dB(A) OF CONSTRUCTION SITES, VARIOUS EQUIPMENT QUIETING STRATEGIES*

		Domestic Housing								Office Building				Industrial				Public Works							
	Ambient	Urban				Rural				Urban				Urban				Urban				Rural			
	Quieting Strategy**	0	1	2	A	0	1	2	A	0	1	2	A	0	1	2	A	0	1	2	A	0	1	2	A
Construction Phase	Ground Clearing	100	88	96	85	103	91	101	94	99	86	96	85	101	87	97	86	100	84	97	85	103	87	91	91
	Excavation	106	93	109	92	109	93	111	100	104	91	105	91	106	92	104	91	104	91	98	91	106	92	95	94
	Foundation	89	81	81	80	107	86	83	96	80	80	94	76	85	82	98	76	108	87	90	90	108	89	95	89
	Erection	97	82	86	81	107	105	102	93	97	84	85	85	103	88	84	86	88	82	86	77	103	88	90	94
	Finishing	106	93	99	90	106	93	99	95	104	91	98	90	104	91	97	89	100	89	94	85	101	88	95	90

* See text for site noise model; see Table I for construction type and ambient noise definitions.

** 0 — No quieting

1 — Noisiest equipment, at 50 ft from observer, quieted by 10 dB(A).

2 — Noisiest equipment quieted by 10 dB(A) and moved to 200 ft from observer; second-noisiest equipment (not quieted) moved to 50 ft from observer.

A — All equipment quieted by 10 dB(A).

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Other Means for Site Noise Control

The NPL generated by a construction site also may be reduced by means other than quieting the equipment:

- Replacement of individual operations and techniques by less noisy ones — e.g., using welding instead of riveting, mixing concrete offsite instead of onsite, and employing prefabricated structures instead of assembling them on site.
- Selecting the quietest of alternate items of equipment — e.g., electric instead of diesel-powered equipment, hydraulic tools instead of pneumatic impact tools.
- Scheduling of equipment operations to keep average levels low, to have noisiest operations coincide with times of highest ambient levels, and to keep noise levels relatively uniform in time; also, turning off idling equipment.
- Keeping noisy equipment as far as possible from site boundaries.
- Providing enclosures for stationary items of equipment and barriers around particularly noisy areas on the site or around the entire site.

Equipment Noise Reduction Potential

Table IV lists the present average noise levels in dB(A) for the various types of construction equipment discussed previously; also listed are the noise levels expected to be achievable in a relatively short time, with limited cost and performance penalties. In addition, the table shows the most significant noise sources for each type of equipment and assigns a numerical "usage" factor to each item, on the basis of which one can assess the significance of quieting of the various individual items. From

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TABLE IV. IMMEDIATE ABATEMENT POTENTIAL OF CONSTRUCTION EQUIPMENT

Equipment	Noise Level in dB(A) at 50 ft		Important Noise Sources[2]	Usage[3]
	Present	With Feasible Noise Control[1]		
Earthmoving				
front loader	79	75	E C F I H	.4
backhoes	85	75	E C F I H	.16
dozers	80	75	E C F I H	.4
tractors	80	75	E C F I W	.4
scrapers	88	80	E C F I W	.4
graders	85	75	E C F I W	.08
truck	91	75	E C F I T	.4
paver	89	80	E D F I	.1
Materials Handling				
concrete mixer	85	75	E C F W T	.4
concrete pump	82	75	E C H	.4
crane	83	75	E C F I T	.16
derrick	88	75	E C F I T	.16
Stationary				
pumps	76	75	E C	1.0
generators	78	75	E C	1.0
compressors	81	75	E C H I	1.0
Impact				
pile drivers	101	95	W P E	.04
jack ha mers	88	75	P W E C	.1
rock drills	98	80	W E P	.04
pneumatic tools	86	80	P W E C	.16
Other				
saws	78	75	W	.04
vibrator	76	75	W E C	.4

Notes:

1. Estimated levels obtainable by selecting quieter procedures or machines and implementing noise control features requiring no major redesign or extreme cost.
2. In order of importance:
   - T Power Transmission System, Gearing
   - C Engine Casing
   - E Engine Exhaust
   - P Pneumatic Exhaust
   - F Cooling Fan
   - W Tool-Work Interaction
   - H Hydraulics
   - I Engine Intake
3. Percentage of time equipment is operating at noisiest mode in most used phase on site.

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this table, one may determine that control of engine noise, and particularly of engine exhaust noise, will affect many items of equipment with high usage factors and thus should be given high priority.

Table V presents a brief listing of the noise control techniques applicable to the sources indicated in Table IV, together with an estimate of the noise reductions that may readily be achieved by means of these techniques.

2.2 Home Appliances

The use of convenient and sometimes necessary appliances constitutes a growing noise problem within the home. Almost without exception, appliances could be significantly quieter. However, manufacturers offer three primary arguments for opposing quieter redesign; they believe

- that the public associates the noise generated by a device with its power;
- that quieter appliances would be marketed at a price disadvantage and since the public has not objected to noise, that the public, in general, is satisfied;
- that since appliances are generally controlled by the operator, the option, as with air conditioners, "to have quiet or to be cool" is "option enough".

Yet, in keeping with the public's growing awareness of noise, many appliances are advertised as being "noiseless", "quiet", "vibration-free".

Although many manufacturers have made detailed acoustic measurements of the noise output of their appliances, very little data has been reported in the open literature. Some of the

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TABLE V. NOISE CONTROL FOR CONSTRUCTION EQUIPMENT

Source	Control Techniques	Probable Noise Reduction in dB(A)*
Engine		
exhaust	improved muffler	10
casing	improved design of block	2
	enclosure	10
fan (cooling)	redesign	5
	silencers, ducts and mufflers	5
intake	silencers	5
Transmission	redesign, new materials	7
	enclosure	7
Hydraulics	redesign, new materials	7
	enclosure	10
Exhaust		
(pneumatic)	muffler	5-10
Tool-Work		
interaction	enclosure	7-20
	change in principle	10-30

*Note that noise reductions are not additive. Incremental reductions can be realized only by simultaneous quieting of all sources of equal strength.

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literature (especially "nonacoustic" reporting) presents insufficient information to enable utilization of the reported measurements in this study. For example, in one report [8], the noise levels are described as being "recorded at operator's or housewife's normal ear distance"; for those appliances not requiring continual operation, the distance from the exposed person to the appliance is not specified. In other examples drawn from newspapers, trade journals, and magazines measurements are not qualified as to distance from the source, type of instrumentation, and weighting network (if any) that was used. In the following sections, only the literature found to be well-documented and considered accurate will be used in appropriate discussions.

2.2.1 Measurements

Because of the scarcity of reliable data, we measured the noise from thirty types of home appliances and eleven types of home shop tools. Sound levels were measured in dB(A) at a distance of 3 ft from the appliance and a height of 5 ft; this measurement position approximates the location of the operator's ear for those appliances requiring an operator. For those appliances not requiring an operator, this position represents noise levels in the vicinity of the appliance. Noise levels in the reverberant field of the room in which the appliance is being operated may be on the order of 2 to 3 dB(A) less than the measurement at 3 ft.

Noise levels in adjacent rooms with the interconnecting door open may be as much as 10 dB(A) less than the levels at 3 ft or as much as several dB(A) greater than the 3 ft levels, depending upon the details of the installation. For the appliances that are used near the ear (e.g., an electric-shaver), the noise level at the ear may be as much as 10 dB(A) greater than the 3 ft mea-

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[illegible]. Figure 3 summarizes the noise measurements made by [illegible] and some of those reported in the literature. Each point represents a single measurement. Several measurements are given for a single appliance that operates in different modes. The solid circles represent noise levels generated by American manufacturers; foreign brands are represented by the squares. Problems arise in evaluating this data because the appliances were manufactured in different years by different companies, were sold with the [illegible] offered by the manufacturers, and may be [illegible] different features. For example, a recently built refrigerator may be frost-free and may have special devices such as [illegible] heaters; therefore it may generate more noise than earlier refrigerators. Figure 4 presents octave band spectra for refrigerators that were manufactured through 1968 [6] and in 1965, 1967, and 1970 [7]. Noise generated by this sample of refrigerators demonstrates the problem of data comparison: the unit that was old in 1968 was the noisiest, while the 1970 unit was second quietest. The quietest refrigerator is the 1965 model. However, there is considerable difference between the physical size of the units, and the newer models incorporate such features automatic defrost, ice-cube maker, water dispenser, and humidified compartment.

2.2.2 Noise abatement potential

The thirty appliances and eleven shop tools surveyed exhibited no apparent acoustical problems that could not be abated through the diligent application of noise control technology. Achieving a cost-effective solution that can be incorporated into the design of an appliance is more difficult but still possible. Standard noise control techniques are readily available; wrapping, damping, flexible connections, vibration isolation, better

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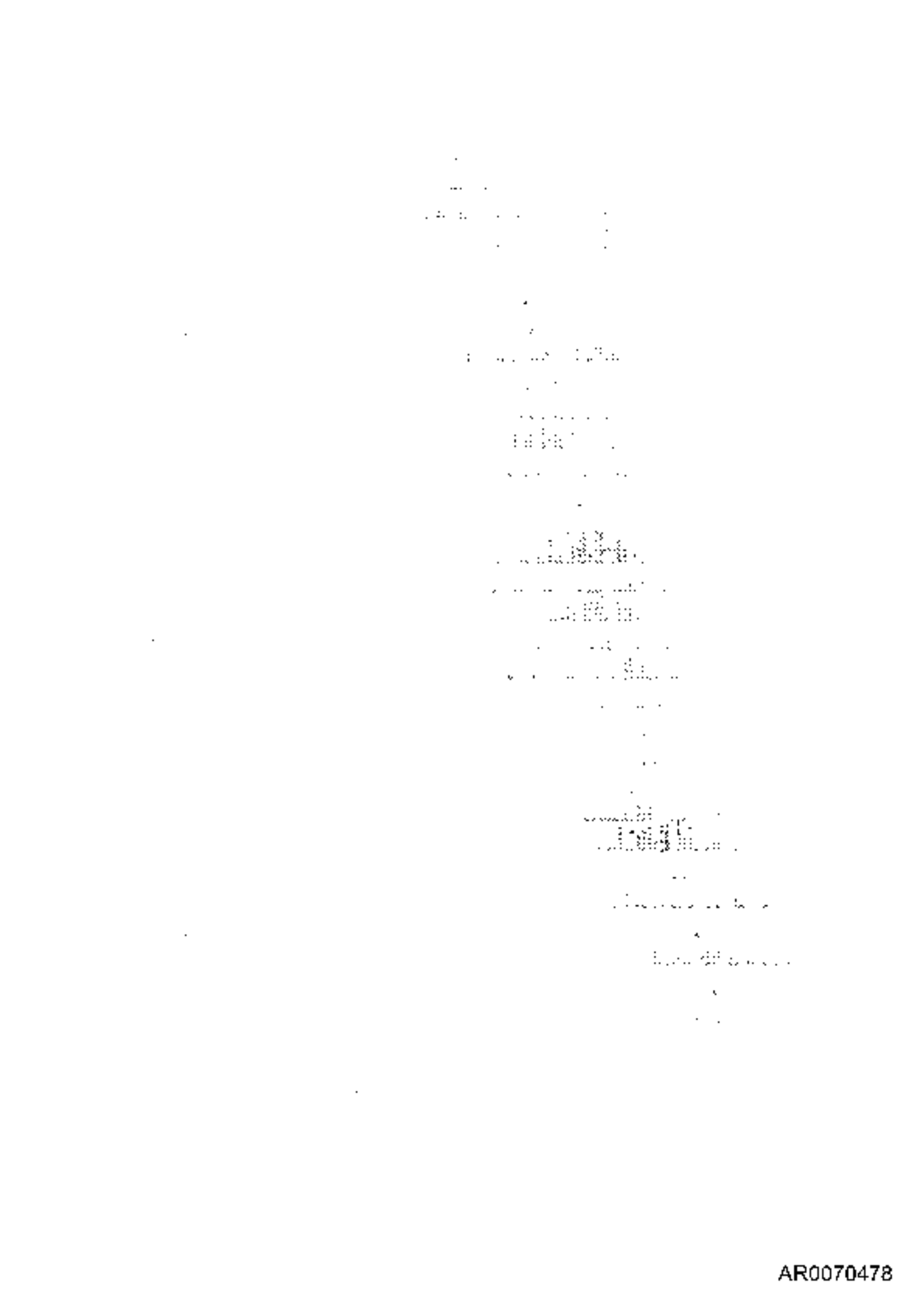

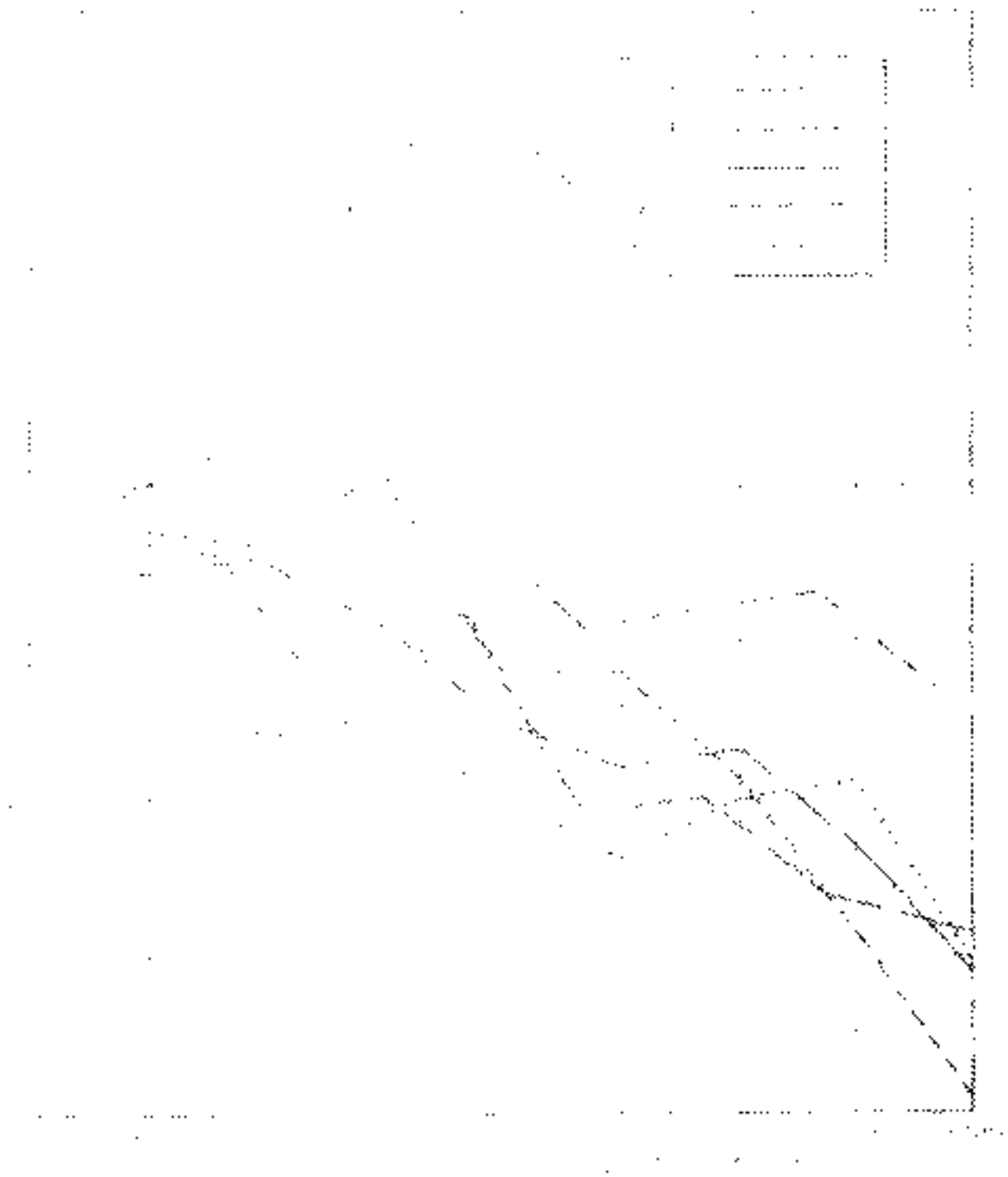

balance, and smoother mechanical connections. Since many appliances have similar mechanisms, noise control techniques used on one appliance can often be applied to another.

After reviewing the operating characteristics and mechanical properties of appliances, we ranked the noise sources in order of their contribution to the total noise generated by an appliance (see Table VI). Definitive measurements are not available to enable a quantitative breakdown of the contribution of individual components. However, in general, motors, fans, knives (or other cutting blades), and air flow are the most frequent sources of noise. Noise radiated from the casing or panels of the appliances and noise radiated from walls, floors, cabinets, sinks (set into vibration by solid structural connections) are also of major importance.

We review here in some detail the noise generating mechanisms of several appliances that have high enough noise levels and exposure time to be considered annoying. Included in this review are air conditioners, dishwashers, food waste disposers, vacuum cleaners, and toilets. Other appliances are discussed in Appendix A.

Room Air Conditioners

Figure 5 is a schematic view of a typical room air conditioner. Basically, warm air in the room or from outside is drawn through a dust filter, blown across cold evaporator coils and distributed back into the room. Fluid in the evaporator, heated by this action, flows to the condenser coils. Outside air is blown across these coils by the propeller fan. The fluid is then compressed and flows back to the evaporator.

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TABLE VI. SOURCES OF APPLIANCE NOISE

Appliance	Source	Air Flow	Combustion Roar	Compressor	Fan	Gears	Knives (Cutting Blades)	Motors	Panels	Pump	Structureborne	Water Noise
Can Opener, electric						1		1	2			
Clothes Dryer			1					1	2			
Clothes Washer								2	2	2		1
Coffee Mill												
Dehumidifier		1		1	1			1	2			
Dishwasher					3			3	2	2	2	1
Dryer and Trimmer							1	2				
Fan		1			1			2				
Food Blender							1	1	2			
Food Mixer							1	1	2			
Food Waste Disposer							1	2			2	1
Freezer				1	1			1	2			
Hair Clipper						2		1				
Hair Dryer		1			1			2				
Heater, electric		1			1			1	2			
Hedge Clippers						2		1				
Hope Shop Tools					1	1		1	1		2	
Humidifier		1			1			1				

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TABLE VI (continued)

Appliance	Source	Air Flow	Combustion Roar	Compressor	Fan	Gears	Knives (Cutting Blades)	Motors	Panels	Pump	Structureborne	Water Noise
Knife, electric						1		1				
Knife Sharpener								1				
Lawn Mower						1		1	1			
Oral Lavage								1		1		
Refrigerator				1	1			1				
Room Air-Conditioner		1		2	2			2	3		1	
Sewing Machine								1				
Shaver, electric						1		1				
Toilet											2	2
Toothbrush, electric						1	1					
Vacuum Cleaner		1			1			1	2			
Water Faucet											2	1

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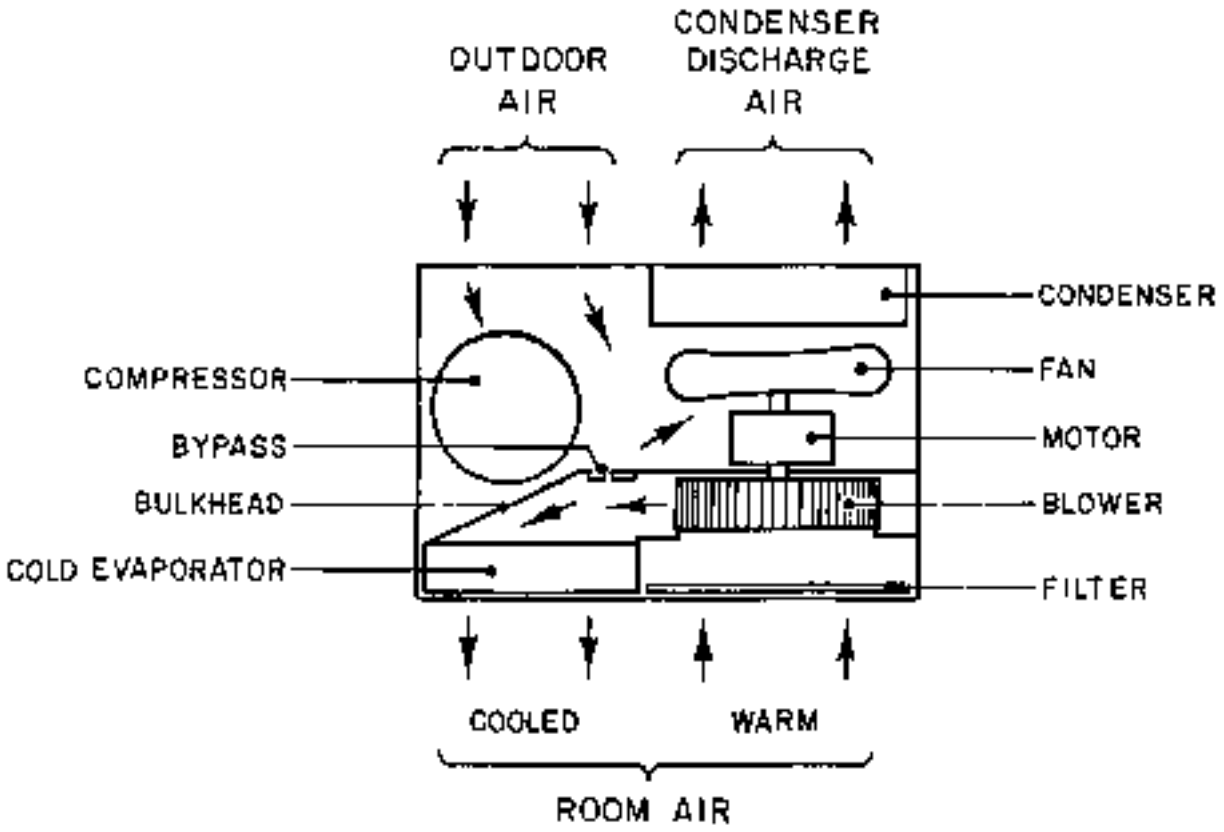

FIG. 5. SCHEMATIC VIEW OF A TYPICAL ROOM AIR CONDITIONER.

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The major sources of noise in this process are the motor, the blower (evaporator fan), the propeller fan (condenser fan), the compressor, and the air flow across the evaporator coils. In addition, panels of the housing radiate noise, as does the structure upon which the air conditioning unit is mounted. The character of this noise is complex, consisting of pure tones, pulsating sounds, intermittent clicks, buzzes and rattles, all superimposed on broadband noise [8]. The tonal components and broadband noise represent the primary noises that require noise control treatment; for the most part, buzzes and rattles (often caused by loose parts), intermittent clicks (caused by spring activated thermostat controls and relays), and pulsating noises (generated by the capillary tube and evaporator valves) have been controlled in current models so that they do not dominate the total noise level.

Pure tones may be generated by (1) the motor at multiples of the rotation speed, (2) the compressor at multiples of the pumping fundamental frequency (the speed in revolutions per second times the number of pumping cycles per revolution), and (3) the propeller fan at blade-passage frequency (the speed in revolutions per second times the number of blades). Whether or not these pure tones appear in the spectrum heard indoors depends upon the structural connections between the components and the enclosure panels as well as on connections to supporting structures. In Fig. 6, noise levels measured on a particular unit with the fan on high speed, with and without the compressor, illustrate this concept; the increase in the one-third octave band centered at 63 Hz is due to a lack of sufficient vibration isolation of the compressor from its case and/or insufficient isolation of the casing from the wall supporting it.

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Broadband noise is generated by the blower, the flow of air through the evaporator coils, and the deflection of the air into the room. Often the blower can operate at several speeds; the slower the speed, the lower the noise level from both the blower and the air flow (see Fig. 7).

Noise control means that can be applied to motor and compressor noise include better vibration isolation of the motor and fans from the housing through use of rubber or neoprene mounts. Compressors, usually hermetically-sealed, can be mounted on springs internally, and on rubber or neoprene pads externally. A more thorough isolation of the motor, fans, and compressor from the casing and of the complete unit from its support could result in a noise reduction of about 5 dB in the low-frequency region controlled by tonal sounds from these components.

The broadband noise generated by the centrifugal blower and the air flow can be reduced by

- reducing the air velocity by using the low-speed fan (if maximum cool is not required);
- reducing the air velocity by increasing the area of the evaporator coils (perhaps increasing the total size of the unit);
- incorporating sound absorbing material, such as open-cell polyurethane foam, between the evaporator coils and the deflection grids and in the duct passage between the blower and the evaporator coils and the blower and the dust filter; and
- tightening the gasketing system to eliminate rattles.

Broadband noise can be reduced by 10 to 15 dB through effective use of these techniques. Coupled with more effective isolation

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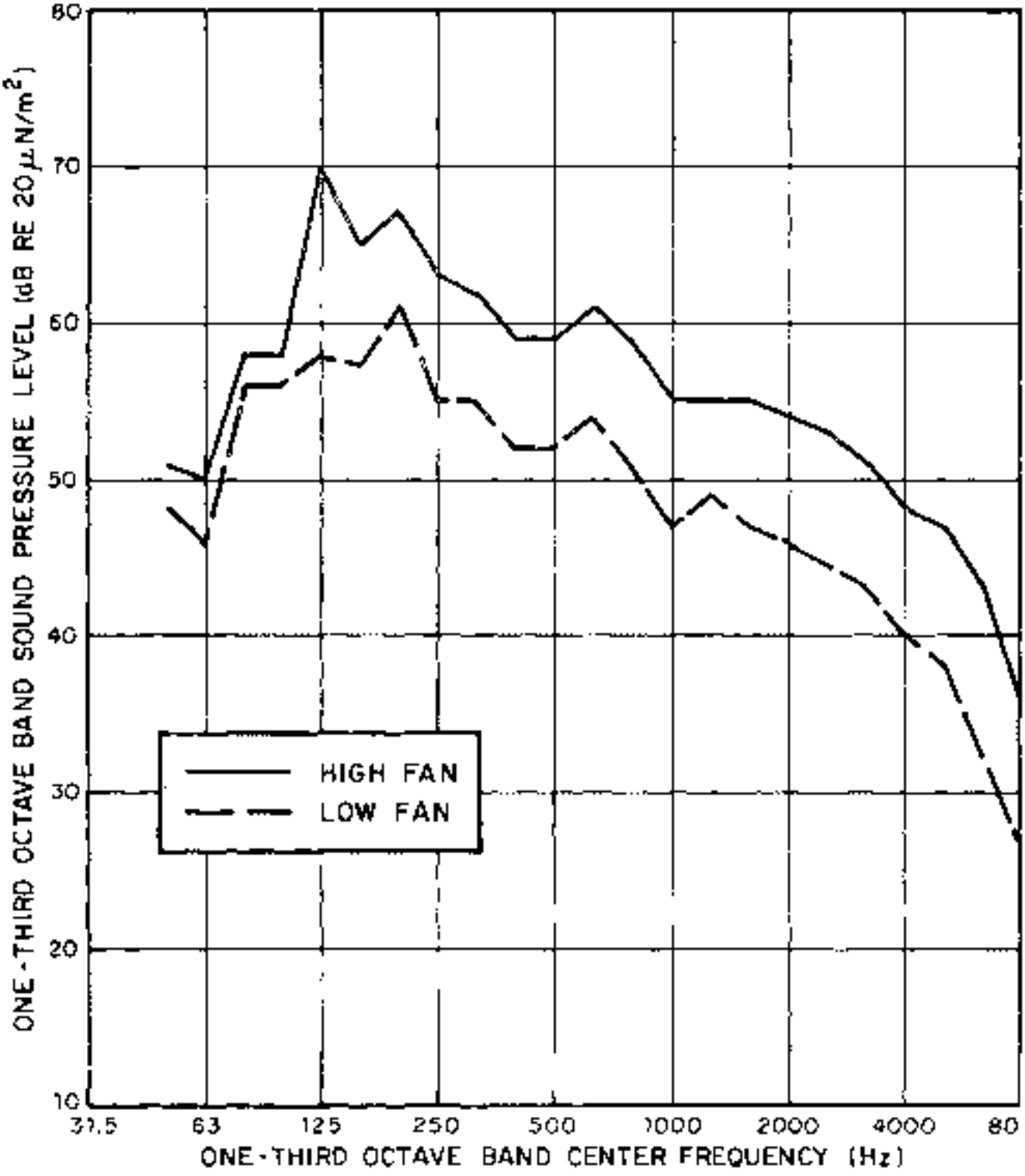

FIG. 7. SOUND PRESSURE LEVELS FROM AIR CONDITIONER AT FAN SETTINGS (MEASURED AT 3 ft)

of the compressor, motor, and [illegible], a total noise reduction of 10 to 15 dB(A) is not unreasonable. Perhaps an appropriate design goal for room cool operation is 45 dB(A) at 3 ft.

Dishwashers

A dishwasher is essentially a tub equipped with a water spray system that is driven by a motor-pump assembly. Heating coils and a blower are provided to assist in the drying operation. A complete wash may consist of as many as thirteen cycles: rinse, fill, wash, drain, fill, rinse, drain, fill, rinse drain, fill, rinse, drain. Figure 8 plots the noise level in dB(A) as a function of operation (e.g., In this example, the wash and rinse cycles are noisier than the drain and fill cycles by about 8 dB(A). Figure 9 presents octave band measurements made during the wash cycle on five different dishwashers. The data varies 5 to 20 dB between the quietest and noisiest dishwasher measured in 1971, depending on the frequency band of interest, representing about 10 dB(A) difference between the quietest and the noisiest. Although the data sample is small, this figure also illustrates, that some newer dishwashers are noisier than older ones.

The noise generating mechanisms in a dishwasher include the impingement of water against the sides and top of the tub, the motor, the pump, the excitation of panel casings, structural connections to water supply, water drain and cabinet, and the blower.

Broadband "water noise" is most important in the frequency range above 300 to 400 Hz; motor-induced noise, often pure tones at the motor rotation frequency and harmonics thereof, dominate the lower frequencies. The kick panel below the loading door on a dishwasher installed in a typical kitchen-cabinet also transmits noise from the motor enclosure into the room.

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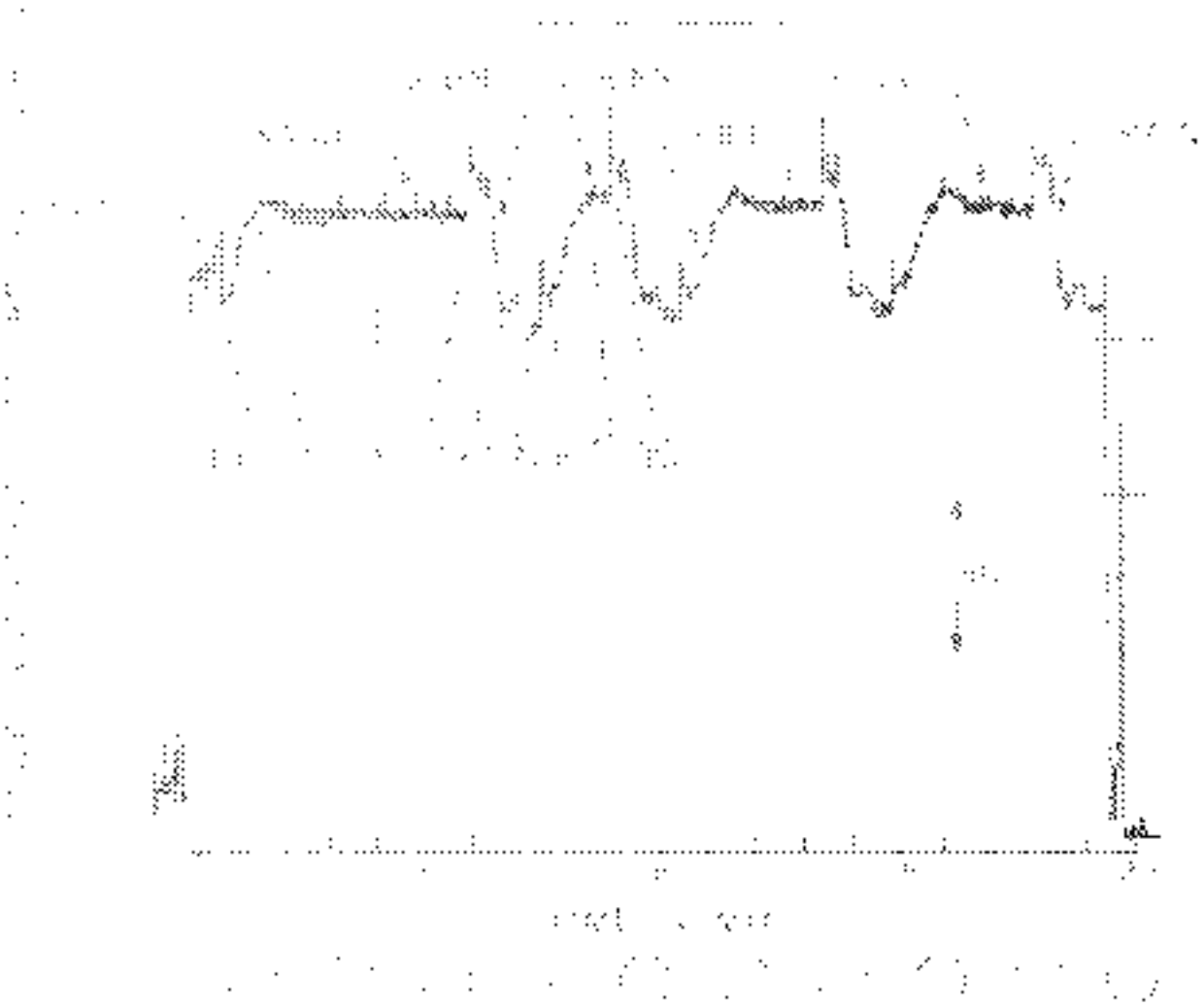

Through the use of experimental splash curtains, which prevent impingement of the water spray on the tub walls, water noise has been reduced by 6 to 8 dB(A) [11]. The motor-pump assembly is often isolated from the tub by rubber mounts; however, the effectiveness of these mounts can be reduced in the installation process by an insufficient clearance between the motor and the floor.

Often, the sides and top of a dishwasher are brought into contact with the cabinet. A clearance of 1/2 in. all around the machines, with neoprene isolation pads insuring the clearance, will reduce the noise radiated by the cabinet as well as the noise transmitted to other parts of the house. The use of rubber hoses for supply and drainage are an improvement over the copper tubing often provided. The incorporation of acoustic material in the motor-pump enclosure and a kick panel that is sealed (no air leaks) would also reduce the noise. It is anticipated that - if

- water noise were reduced (e.g., by installing splash curtains);
- effective vibration isolation of the motor-pump from the tub were ensured;
- effective vibration isolation of the dishwasher housing from the floor, cabinet walls and top were ensured;
- rubber hoses were used;
- acoustical absorption material were installed in the motor enclosure; and
- the kick panel were sealed air-tight -

the noise levels of a typical dishwasher could be reduced by some 10 to 15 dB(A), from a level in the mid sixties to one in the low

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fixtures. Because of its intermittent operation, a goal of 45 to 50 dB(A) at 3 ft is probably acceptable.

Food Waste Disposers

Continuous-feed and batch-feed disposers are chambers in which food waste is ground by a motor-driven wheel with cutting edges. Figure 10 presents one-third octave band sound pressure level data for four different disposers. Although the details of the spectra differ, each has a major peak at 125 Hz and several minor peaks at higher frequencies, all superimposed on broadband noise. The peak at 125 Hz is primarily motor noise. The minor peaks can be attributed to the blade-passage frequency of the grind wheel, multiples thereof, and resonances in the sink. The broadband noise is generated by the sloshing of water and waste against the housing of the chamber.

Noise is transmitted up through the mouth of the disposer. Batch-feed disposers, which require the sink cover to be in place before operation, have the potential for being quieter. Continuous-feed units sometimes have partial rubber closures at the mouth of the unit (primarily to prevent food waste from being expelled); for these closures to be effective in controlling noise, they must overlap to shut off the entire opening.

Basic noise control treatments that have been moderately successful include vibration isolation of the disposer from the sink and the enclosure of the chamber and motor with a double wall construction. It is estimated that the noise levels generated by disposers could be reduced by about 10 dB(A) with the following treatments:

- effective vibration isolation of the disposer from the sink;
- damping of the sink;

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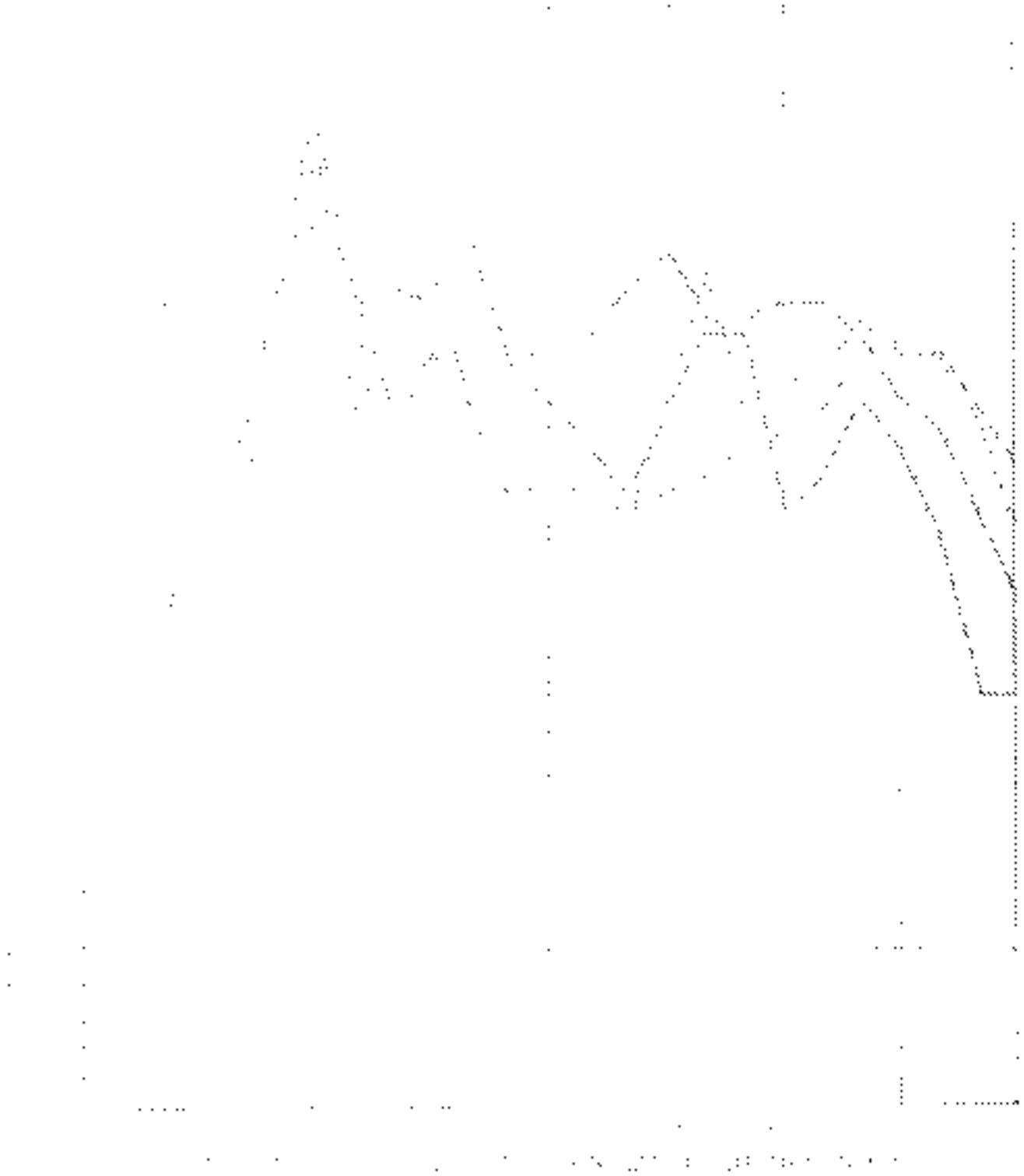

- flexible connections between the disposer and the drain pipe, which will also reduce the noise transmitted to other rooms and/or apartments;
- flexible electrical connection;
- enclosure of both the grinding chamber and motor, with appropriate ventilation; and
- effective closure of the mouth of the disposer.

Vacuum Cleaners

Canister vacuum cleaners consist of a tank (either horizontal or vertical) that provides suction, a connecting hose, and appropriate nozzles. Some recently manufactured canister units also have powered rotating brush attachments for cleaning carpets. Figure 11 presents sound pressure levels measured in one-third octave frequency bands for four canister units. As with other appliances, the peak at 125 Hz is motor-induced noise. The peaks in the 800 to 1600 Hz range are probably caused by the blade-passage frequency of the blower and/or resonances of the unit structure. Through the use of better blower design, more thorough vibration isolation of the motor and blower(s) from the structure, and damping and sealing of the canister structure, the noise generated by canister units could be reduced by 10 dB(A).

In addition to a motor-blower assembly, upright vacuum cleaners have a mechanism (either vibrating agitators or rolling brushes) that beats the carpet to bring dirt to the surface where it is sucked away. Figure 12 presents one-third octave band sound pressure level data for two upright vacuum cleaners -- a large unit with a beating mechanism and a small one without a beater. For the larger unit, the low frequency noise is again

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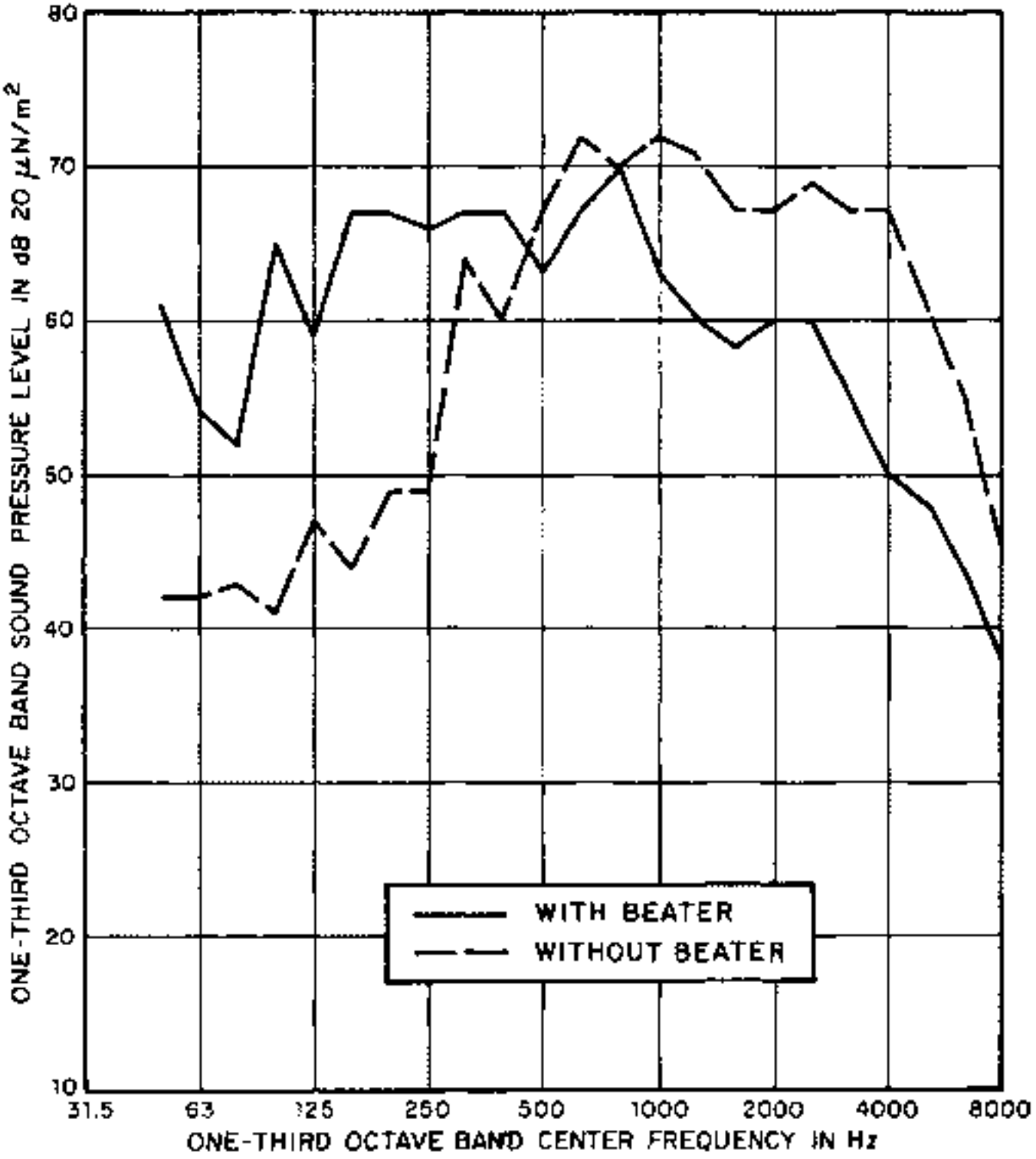

FIG. 12. SOUND PRESSURE LEVELS OF TWO UPRIGHT VACUUM CLEANERS (MEASURED AT 3 FT)

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motor-induced. The peaks in the higher frequency range are caused by fan(s) and/or structural radiation. The difference between the two units in the low-frequency bands is due to the difference in capacity as well as to the lack of a heater on one model. Noise control for upright cleaners will be more difficult to achieve than for the canister units because of the location of the heater and the limitations on size. It is anticipated that a 5 dB(A) noise reduction could be achieved on the typical unit.

Water closets

Water closets are either of the tank type or the valve type and are either floor-mounted or wall-mounted. Figure 13 illustrates the time history of the sound pressure level in the 250 Hz octave band for operation of a tank water closet [12]. Time Period A represents the valve opening and releasing water in the tank to flow into the bowl through an opening in the base of the bowl. The water produces a swirling action in the lower half of the bowl (Time Period B). The valve closes (Time Period C) and the tank and bowl are refilled (Time Period D).

Figure 14 illustrates the time history of the sound pressure level in the 250 Hz octave band for a flush valve water closet [7A]. The valve opens (A); air and then water are forced out of the pipe supply (B); the valve closes (C) and the bowl is refilled (D). A comparison of these two figures suggests that flush valve water closets generate somewhat higher initial noise levels during an operating cycle but that the noise does not persist as long as with tank water closets. Since the character of the sounds is different, it is not clear at this time which would be more desirable.

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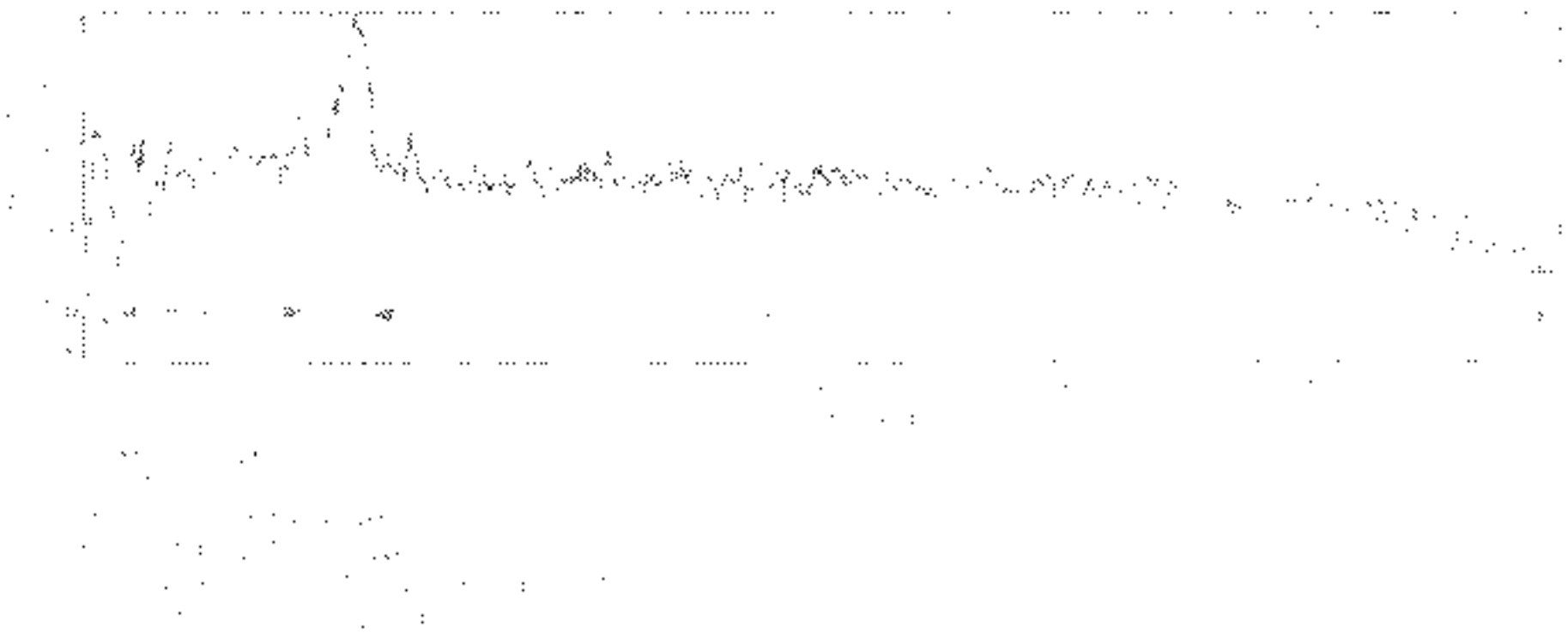

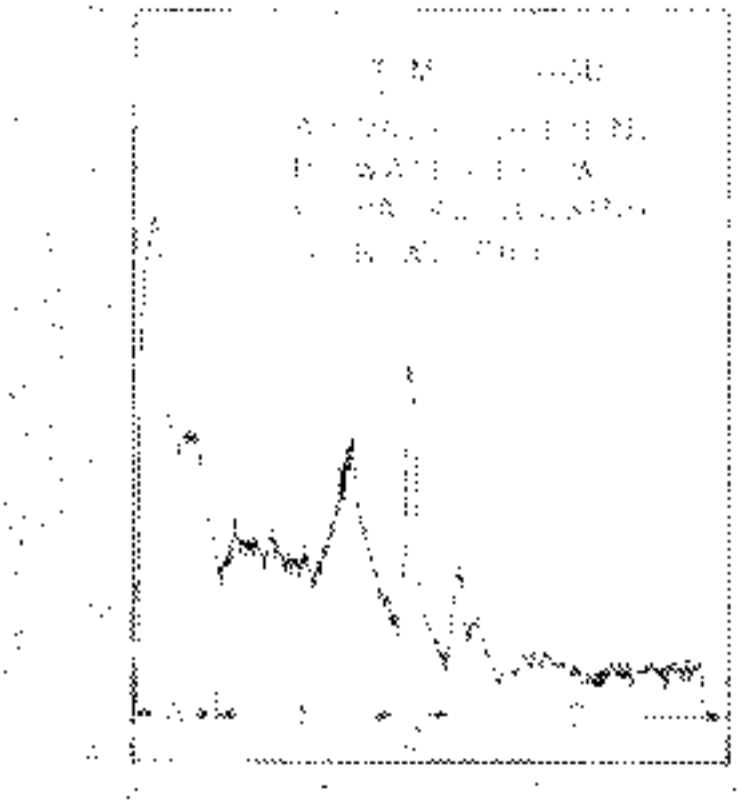

Figure 15 presents peak octave band data for a sampling of tank water closets and Fig. 16 for flush valve water closets. A comparison of these two figures shows that it is possible to have relatively noisy or quiet operation with either type of water closet provided. For tank water closets, water flow control and inlet water pressure are both important variables in the noise generated [12]. For flush valve closets, bowl design was found to be of major importance, with valve type (exposed flush vs recessed flush) and mounting (floor vs wall) of lesser importance. Resilient mounting of water closets and piping was found to be more important for some fixtures than for others - e.g., a range of several dB(A) to 15 dB(A) for valve-operated water closets.

2.3 Building Equipment

The proper operation of large buildings requires a number of different types of electrical and mechanical equipment. In this section, we review the noise levels generated by electrical and mechanical equipment, present noise levels for a typical multi-story building, and discuss the possibilities of noise control through architectural modification. Detailed descriptions of additional building equipment types are given in Appendix A.

2.3.1 Types of equipment

The majority of electrical and mechanical equipment in buildings is used to supply the building occupants with a suitable quantity of air at a comfortable temperature and moisture content. In addition, pumping and piping systems are used for water and fluid circulation, elevators and escalators are used for movement of personnel, and various conveyence systems are used for moving material.

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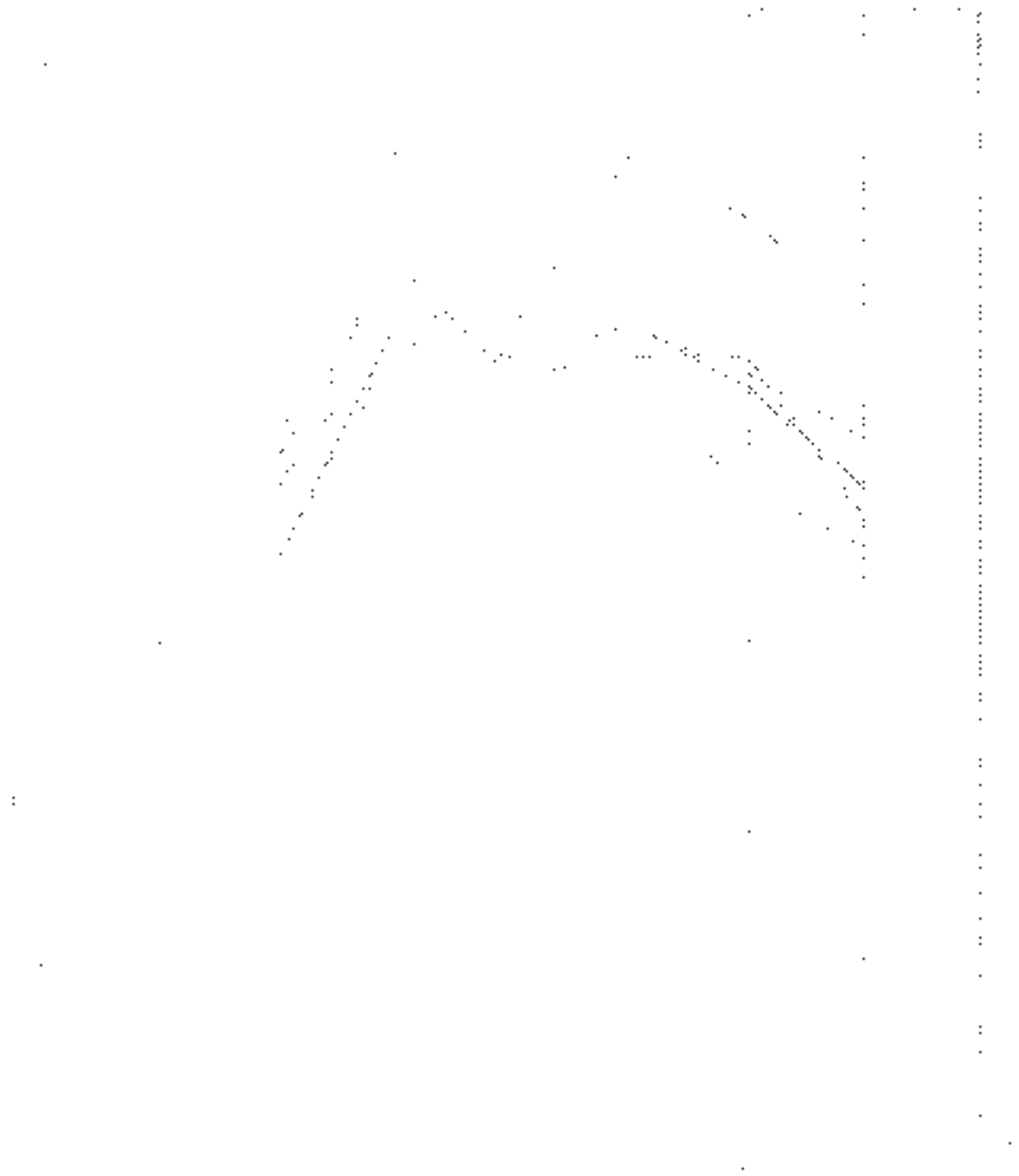

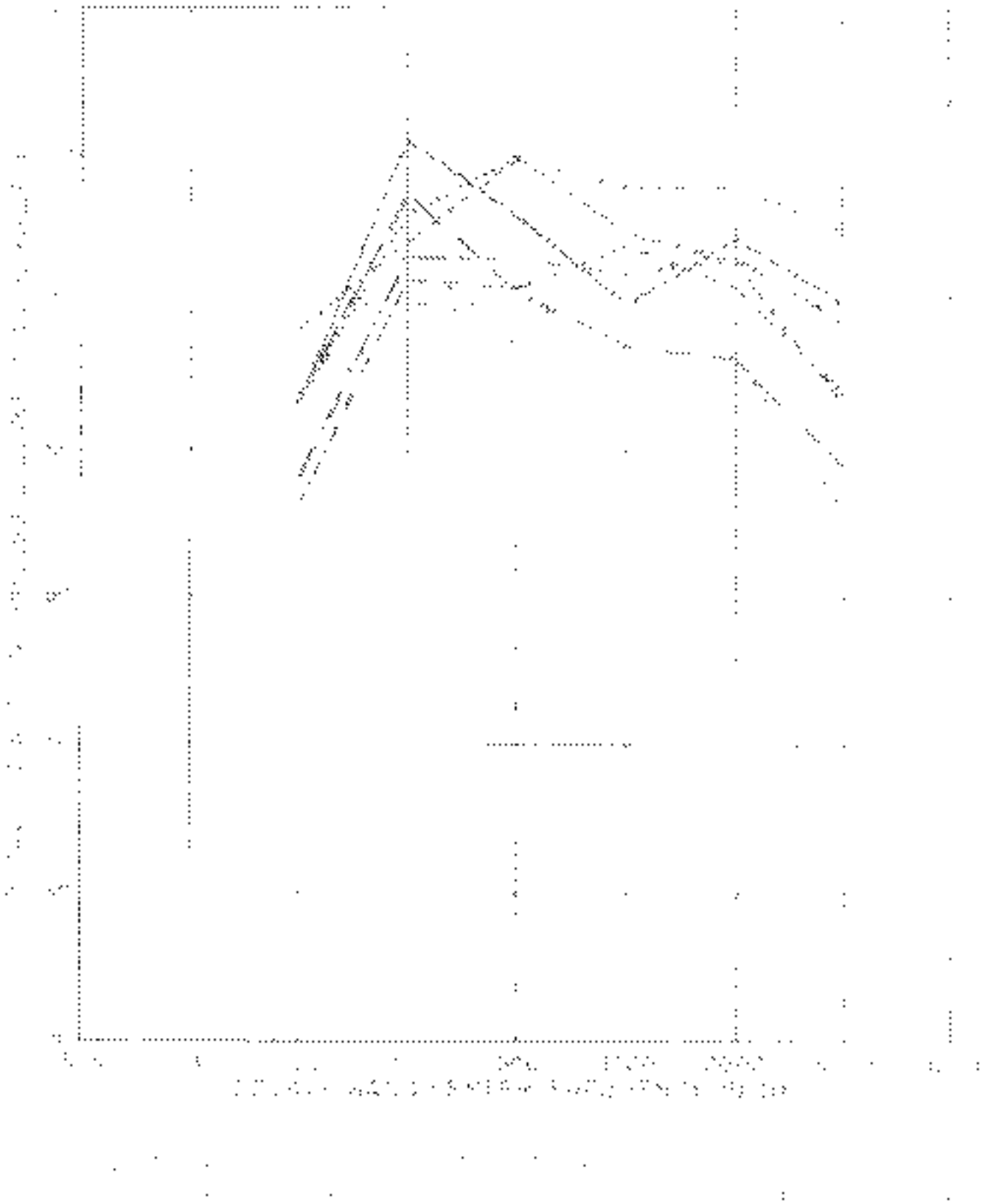

Figure 17 presents the typical range of sound levels in dB(A) at 3 ft for building equipment. Much of this equipment is hidden in mechanical equipment rooms, above ceilings, in walls, or behind cabinet type exterior enclosures. Table VII, which summarizes the exposure of occupants to the noise generated by building equipment, shows that occupants are *directly* exposed to the noise of only about eight different types of equipment. The noise generated by these units is thus of special interest since there are no intervening walls to provide attenuation. The noise generated by building equipment hidden from view can be sufficiently attenuated through the proper use of current architectural techniques. In practice, such techniques are not always implemented.

2.3.2 Noise levels within a typical multistory building

Although details of the frequency spectrum are of considerable importance in selecting noise control treatments, the model presented in this section is keyed, for simplification, to dB(A); it is not intended that this method be used for actual situations. Figure 18 presents a cross-section of a multistory building, locating a typical occupant with respect to building equipment. Figure 19 summarizes the noise exposure in dB(A) of an occupant to individual sources. The higher level in each case is representative of the sound level near the source — e.g., at 3 ft. The lower level is representative of the level to which the contribution from a particular source is reduced through proper implementation of noise control techniques. The treatments include:

E — enclosure of noise source

D — ductwork lined with acoustically absorbing material

W — wall

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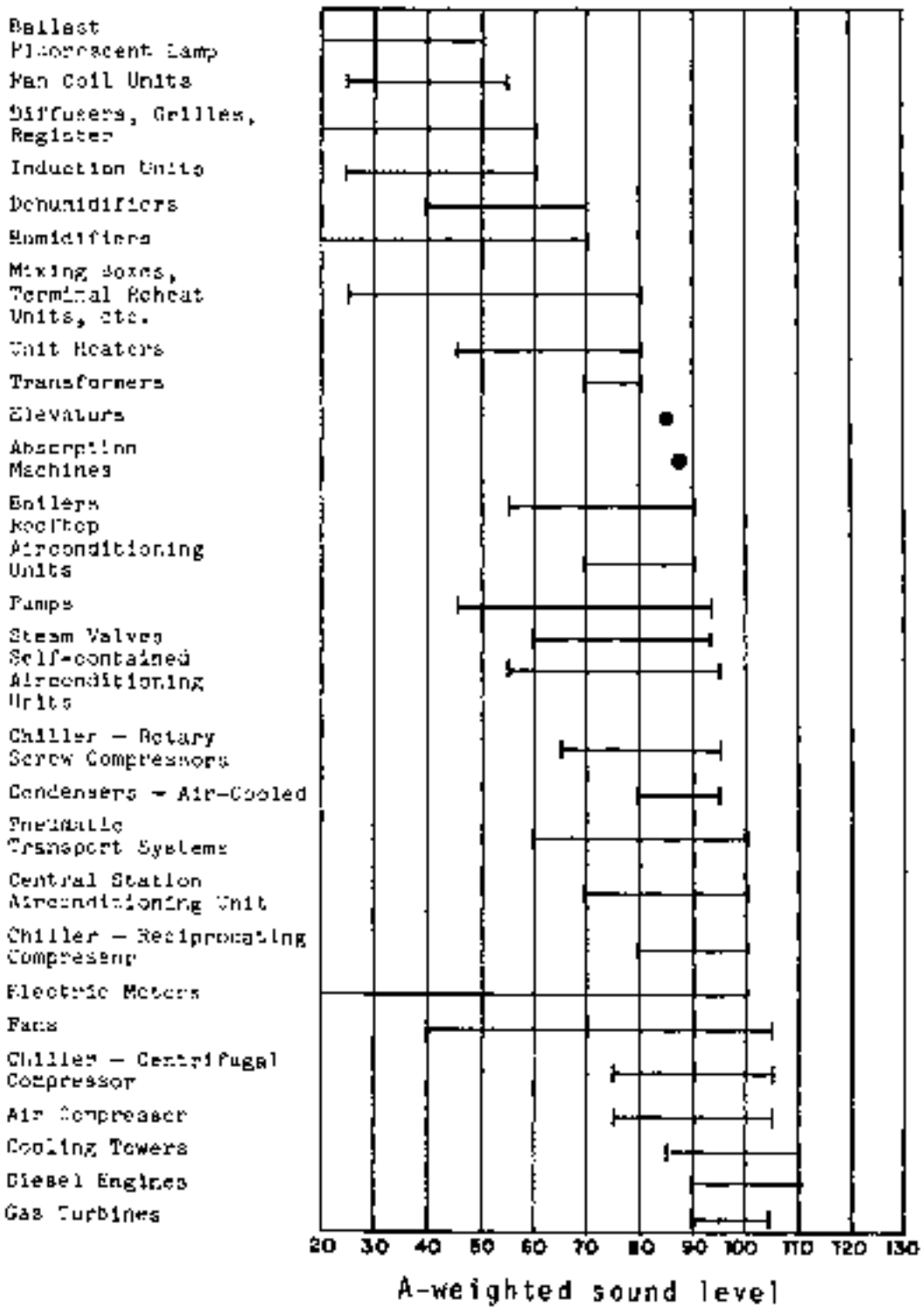

FIG. 17. RANGE OF SOUND LEVELS IN dB(A) TYPICAL FOR BUILDING EQUIPMENT AT 3 FT.

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TABLE VII. EXPOSURE OF BUILDING OCCUPANTS TO THE NOISE OF BUILDING EQUIPMENT

Building Equipment	Location	Type of Exposure		
		Direct	Indirect	
			Through Mechanical Distribution System	Through Walls, Floors, etc.
Air Conditioning				
	MER*		x	x
	Roof. Unit		x	x
	Wind. Unit	x		
Absorption Machines	MER			x
Air Compressor	MER			x
Ballasts	Room	x		
Boilers	MER			x
Boiler Feed System	MER			x
Chillers	MER			x
Condensers	Rooftop			x
Cooling Towers	Rooftop			x
Dehumidifiers	MER		x	x
Diesel Eng.	MER			x
Diffusers	Room	x		
Electric Motors	MER			x
Elevators	Varies	x	x	x
Escalators	Varies	x	x	x
Fans	MER		x	x
	Room	x		
Furnaces	MER			x
Gas Turbines	MER			x
Heat Pumps	MER			x
Humidifiers	MER		x	x
Mixing Boxes and Air Control Units	Varies	x	x	
Pneumatic Transporter System	Varies		x	x
Pumps	MER			x
Steam Valves	MER			x
Transformers	MER			x
Unit Vent and Unit Heat	Room	x		

*Mechanical Equipment Room

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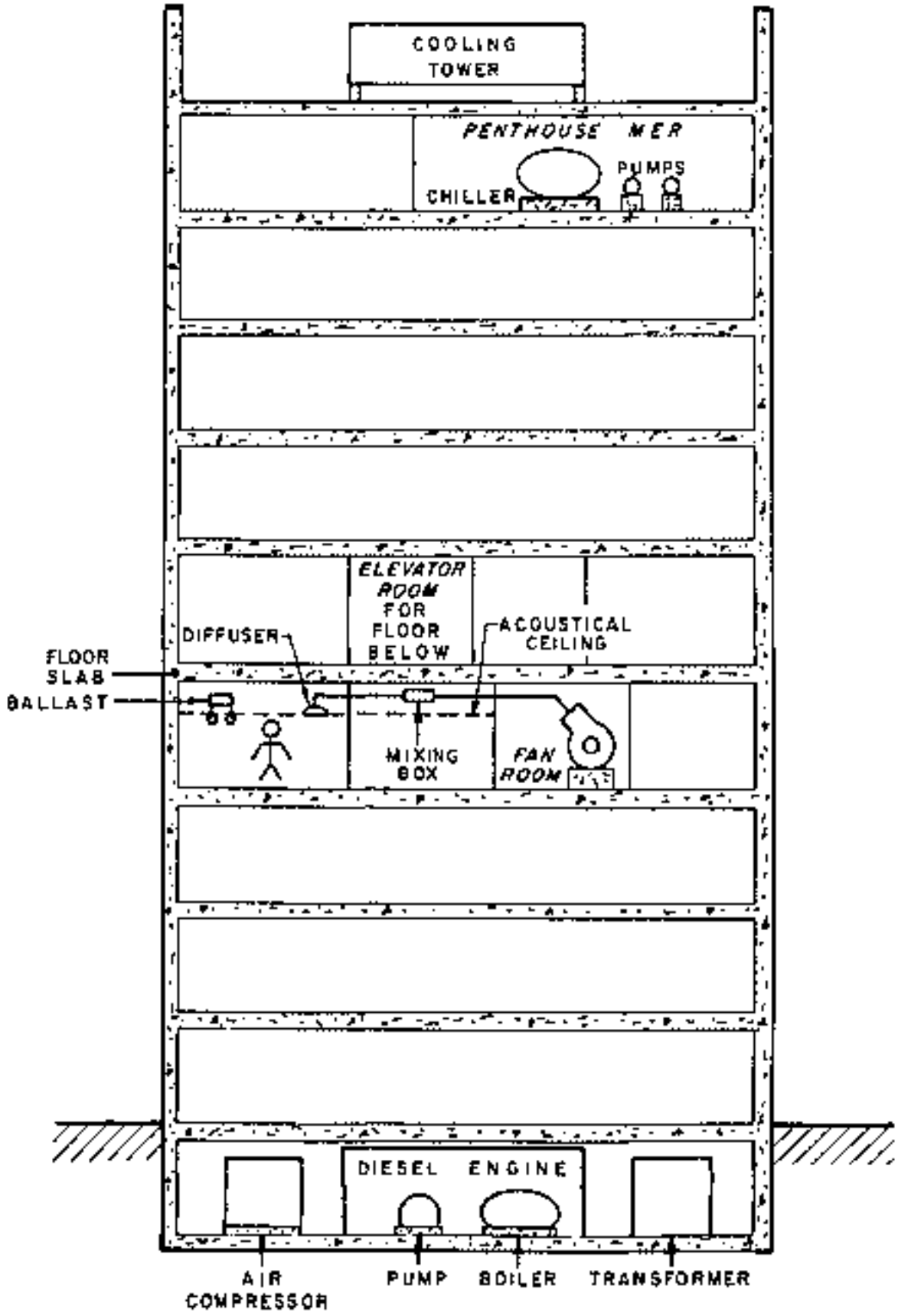

FIG. 18. CROSS-SECTION OF A TYPICAL MULTISTORY BUILDING SHOWING BUILDING EQUIPMENT.

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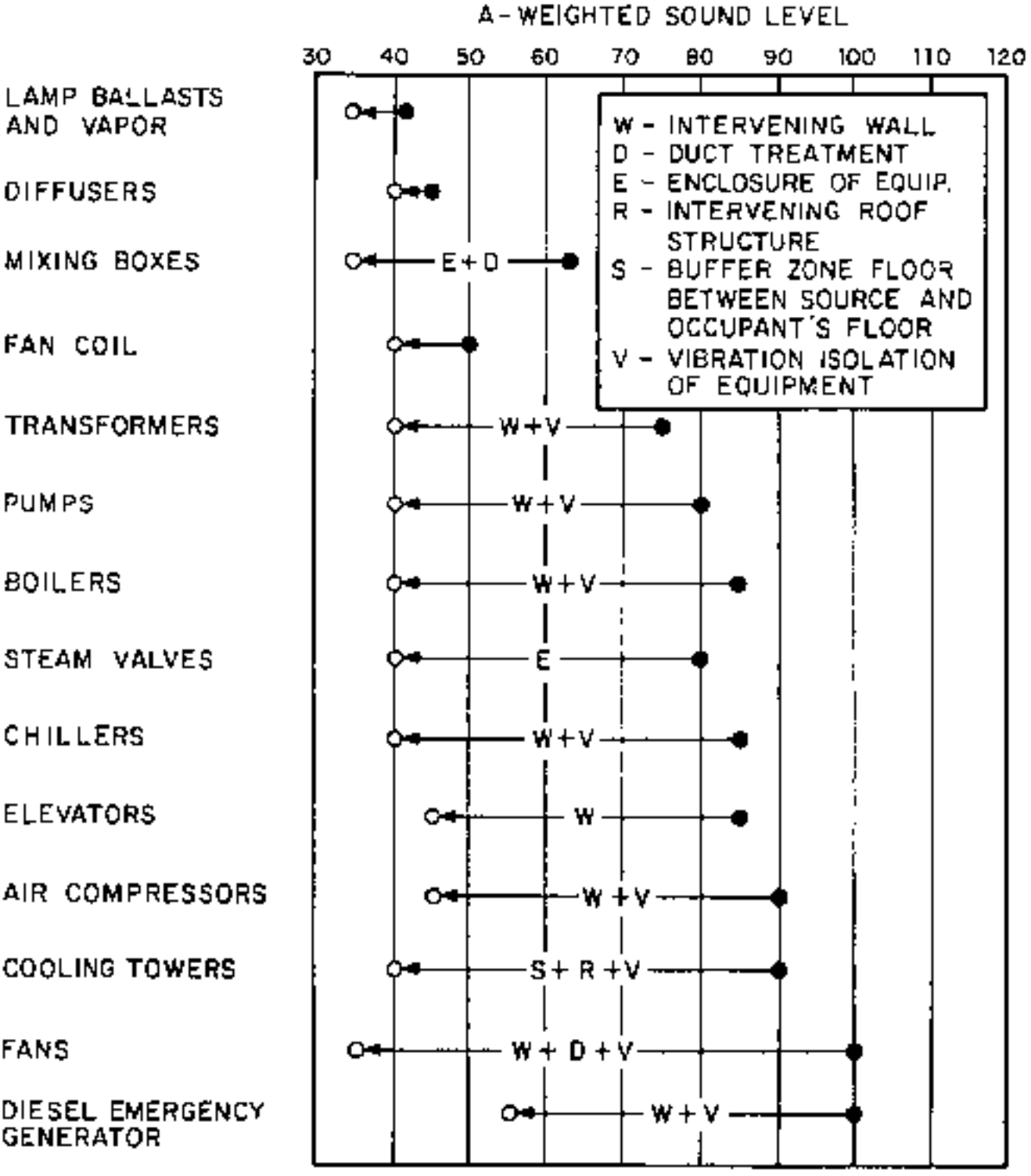

FIG. 19. RANGE OF BUILDING EQUIPMENT NOISE LEVELS TO WHICH PEOPLE ARE EXPOSED.

R -- roof slab

S -- intervening story -- e.g., the penthouse mechanical equipment floor

V - vibration isolation.

Goals for acceptable noise levels vary with the activities to be held in a space. If one is interested in increasing the speech privacy within an office, then a higher noise level of an appropriate spectral shape would be appropriate. On the other hand, if one is performing certain types of tests or listening to critical sounds, a quieter environment is required. Through the use of current technology, it is possible to achieve virtually any noise goal, if the owner of the building is willing to bear the cost and space requirements of the treatment. Of course, by specifying quiet equipment, the owner may minimize these requirements.

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3. IMPACT

3.1 Noise Level Criteria for Impact Evaluation

In this report, the impact of noise exposure upon people is evaluated primarily in terms of three direct effects and secondarily in terms of a number of indirect consequences. The three major effects are speech interference, sleep interference, and annoyance. Two rationales for emphasizing these effects in particular. First, they are among the most salient and tangible consequences of noise exposure and thus can be most readily interpreted in societal terms. Evidence that they are widely understood by the public may be found in their frequent mention in noise complaints. Secondly, research on these three effects has been more extensive than on other noise effects; therefore, sharper predictions can be made with greater confidence.

Although the three primary effects are used to summarize the major impact of noise exposure, the indirect consequences of exposure also demand consideration. These effects include physiological stress, annoyance, startle, and task interference. They are termed "indirect" in that they are not produced exclusively by noise, nor are they simple functions of the physical magnitude of noise exposure. Further, relatively little systematic information about these effects is available; thus, specification of precise levels of noise exposure leading to particular levels of effect is a somewhat speculative matter. However, one may not assume that these secondary consequences are unimportant merely because they are difficult to quantify.

The following table presents the physical levels at which it is felt that each of the above-mentioned effects of noise exposure achieves (1) a moderate level of effect and (2) an appreciable level of effect. The decisions leading to these specifications are discussed below.

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TABLE VIII. ESTIMATES OF MAGNITUDES OF NOISE EFFECTS
[IN dB(A)]

Effect	Moderate Level	Appreciable Level
Hearing Damage Risk	70	90
Speech Interference	45	60
Sleep Interference	40	70
Physiological Stress	*	90
Startle	*	110
Annoyance	40	60
Task Interference	55	75

3.1.1. Hearing-damage risk

The hearing-damage risk levels specified in Table VIII were selected on the basis of eight hours of daily exposure. Exposure durations of this order are chosen as representative of the amount of time usually spent in home and work environments. Since hearing-damage risk is cumulative over long periods of time [73], the recommendations are intended to account for prolonged noise exposure over a period of years.

The estimate of the level at which hearing-damage risk commences was determined on a rather stringent basis. The Walsh-Healey Public Contracts Act, as amended to include noise limits for hearing conservation, is based on a CHABA report [74], which permits permanent threshold shifts up to 10 dB at frequencies

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*Effects at low levels are at best weak functions of the physical intensity of noise. They are determined far more strongly by factors such as the meaning associated with the acoustic signal, attitudes toward the source, rise time of the signal, unexpectedness of the signal, and so forth. It therefore makes little sense to specify discrete levels in these cases.

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over 1000 Hz; up to 15 dB at 2000 Hz, and up to 20 dB at frequencies above 3000 Hz. Hearing losses of these magnitudes are considered inconsequential in the sense that they are ineligible for compensation under the terms of the [illegible] legislation. Even these surprisingly low limits are based on the questionable assumption of a sixteen-hour daily recovery period of little or no noise exposure [17]. Further, the OSHA regs. [74] is intended to afford this partial protection to only half of the population exposed to noise. Clearly, these criteria are neither applicable to individual circumstances nor capable of protecting many people from sizeable hearing losses.

Kryter's published redefinition of the hearing-damage risk criterion [75] maintains that no permanent threshold shift whatever is tolerable at 2 frequencies below 2000 Hz and that no more than a 10 dB shift is tolerable at other frequencies. Kryter also applies the protection afforded by his definition to 75% of the population rather than 50%. He states that the 'threshold' of hearing-damage risk for eight hours of daily exposure is 67 dB(A). Glorig et al [13] operating under similar assumptions specify 75 dB(A) as the level at which hearing-damage risk commences. Miller [16] believes that a level of 70 dB(A) represents a level of noise exposure above which hearing-damage risk becomes nonnegligible. In Miller's terminology, habitual exposure to levels between 70 and 90 dB(A) represents yellow (i.e., cautionary) risk of hearing damage; exposure to levels between 90 and 90 dB(A) entails "orange" risk; while exposure to levels in excess of 90 dB(A involves "red" (serious) risk.

The estimate of Table VIII for the onset of hearing-damage risk agrees with Miller's estimate. The estimate of the level at which appreciable risk of hearing damage occurs agrees both

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with Miller's estimate and the provisions of the Walsh-Healey Act. The latter criteria, based on a report of the NAS-NRC Committee on Hearing, Bioacoustics, and Biomechanics [14], indicates that eight hours of daily exposure to levels in excess of 90 dB(A) constitutes a serious risk of hearing damage to one-half of the population.

3.1.2 Speech interference

The levels specified in Table VIII for speech interference are the most straightforward and readily defensible of all of the estimates. A criterion for adequate verbal communication in the home was taken to be comprehension of 98% of all sentences or an equivalent rate of comprehension of 85% of the words of a standard phonetically balanced (PB) list. In terms of nominal vocal effort [approximately 65 dB(A) at a distance of one meter], such a level of speech intelligibility would be sustained at a speaker-listener distance of approximately five meters in a noise background of 45 dB(A) [17]. Five meters was taken to be the maximal distance at which conversation in normal levels might reasonably be expected to be held in a quiet outdoor (nonreverberant) environment.* The level of appreciable effect specified in Table VIII was derived by assuming that noise-induced speech interference would be intolerable if conversation at nominal levels of vocal effort were precluded at speaker-listener distances greater than one meter. Such conditions prevail in noise environments in excess of 60 dB(A) [17].

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*Greater speaker-listener distances would be possible indoors at the same levels of vocal effort and speech intelligibility, because sound pressure levels diminish more slowly than predicted by the inverse square law.

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It should be pointed out that selection of the above criterion represents a belief that the 70% comprehension of PB words suggested by Webster [17] and Bormanx [18] does not provide for a reasonable standard of communication in the home. Webster's criterion was established for "barely adequate communication" and is inappropriately applied to the home environment. The levels recommended in this report are thus 5 dB lower than Webster's.

3.1.3 Sleep interference

Two principal ways in which noise exposure can interfere with sleep are to delay the onset of sleep and to shift sleep "stages". Scores of studies are available on the sleep-delaying and stage-shift effects of noise exposure. Although there is frequently broad agreement among studies, detailed agreement is lacking. Discrepancies among outcomes of similar studies are attributable to incomparable control conditions, differences in experimental design, and the host of individual differences which beset sleep research.

For example, it is universally observed that the initial time required for subjects to fall asleep increases monotonically with exposure to increasing noise levels. Unfortunately, different studies produce estimates of the sleep-delaying effects of noise that are more than 35 dB apart. Thus, two studies report delays in onset of sleep from 20 to 90 minutes [19,20], corresponding to exposure to continuous noise at levels of 35 dB(A) and 50 dB(A), respectively. Other studies, [21–23] however, report that subjects can fall asleep in as little as twelve minutes despite exposure to noise levels of 70 dB(A).

Further, prolonged exposure to high noise levels can produce tinnitus (ringing in the ears), which has been claimed to delay

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the onset of sleep [24]. In other words, aftereffects of noise, even in the absence of *any* noise exposure at bedtime, can impede sleep. It is also claimed in the literature that levels as low as 35 dB(A) can either induce a shift from a "deeper" to a "lighter" level of sleep or awaken certain people [26]. Pronounced differences in sensitivity to noise during sleep have been observed as a function of age as well.

An absolute criterion for noise exposure levels in sleeping quarters is obviously unjustifiable on the basis of extant research. A conservative criterion for noise exposure (from the point of view of minimizing sleep interference) might be based on the lowest levels at which sleep interference have been reported. According to the Wilson Report [26], levels of 40 dB(A) have been known to awaken approximately 25% of the sleeping population, while levels of 45 dB(A) appear to keep about 20% of the population from falling asleep immediately. These considerations have led to the adoption of 40 dB(A) as a criterion level for the onset of sleep interference effects. According to the Wilson Report data, a little more than half of the population may be awakened by noise exposure to levels of 70 dB(A), while a little less than half of the population will find some difficulty in falling asleep when exposed to such levels. These data led to adoption of 70 dB(A) as the level at which sleep interference effects become considerable.

3.1.4 Physiological stress

The amount of stress produced by low-level acoustic signals is primarily determined by their meaning. A footfall in one's bedroom at night, or a growling animal, or one's boss's voice can excite stress mechanisms by virtue of their implications rather

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than their physical attributes. Since it is the learned and instinctive associations to sounds which are largely responsible for their ability to create stress, no level of minimal effect has been specified.

At high noise levels a somewhat stronger case may be made for specification of a criterion. Studies of physiological correlates of noise-related stress in animals suggest that noise levels in the vicinity of 90 dB(A) produce strong effects [57]. Pupillary dilation, increased pulse pressure and heart rate, and pulse volume changes have been observed in humans exposed to noise levels of approximately 70 dB(A) [58]. There can be little argument that at even higher levels noise stimulation induces stress in and of itself, rather than as an exclusive function of its meaning. Extremely intense noise fields can cause auditory and bodily pain. Such intense fields commonly are associated with strong vibrational components, which can also be harmful.

3.1.5 Startle

The arguments above about the relative roles of meaning and levels of acoustic signals in determining stress also apply to startle. For the same reasons, therefore, no minimal level of effect can be specified.

A major obstacle to establishing a firm criterion for the startling effects of high level noise is the phenomenon of habituation. In general, humans display a marked decrease in sensitivity to repeated exposure to startling sounds. Expectedness, regularity, familiarity, arousal level, and numerous other factors strongly mediate startle effects. Even at high absolute noise levels, startle is as much affected by signal-to-noise ratio considerations as it is by the level of the startling signal.

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Thus, an exploding paper bag would almost certainly produce more startle in a library than in a boiler factory.

The level recommended in Table VIII is therefore chosen to represent a noise level sufficiently rarely heard and of a signal-to-noise ratio sufficiently great to make a significant startle reaction highly probable.

3.1.6 Annoyance

The levels recommended in Table VIII for gauging annoyance effects are intended to reflect the lowest level at which any of the other tabled effects can occur. In other words, one is expected to be annoyed by a noise sufficiently intense to produce sleep interruption, speech interference, etc.

It is, of course, also true that long-term exposure to very low level noises can be annoying. A dripping faucet or a chalk squeak can be exceptionally irritating. Once again, however, it is the meaning of the acoustic signal rather than its level *per se* which plays a major role in determining the magnitude of annoyance. Also, the spectral composition and temporal density of noise heavily influences its annoyance value. Unfortunately, temporal and spectral factors cannot be adequately expressed in dB(A).

3.1.7 Task interference

The literature on the effects of noise on human performance contains numerous conflicting and inconclusive reports. By and large, high-intensity, aperiodic, intermittent noise is reported to impede efficient work to a greater extent than low-intensity, steady-state noise [29]. Nonetheless, numerous studies find no effects of noise on performance, while a few studies find

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occasional improvements in performance attributable to noise exposure [30]. Of course, improvements in performance when an environment is changed (presumably worsened) are often due to changes in the level of attention perceived by the subject and their attendant reaction. The nature of the task at hand and the duration of noise exposure also influence the extent of task interference.

It is our feeling that the most sensitive and complex tasks (of the nature of brain surgery, diamond cutting, etc.) might be sensitive to interference from noise at levels as low as 65 dB(A). Although most published studies which report task interference give levels in the vicinity of 90 to 110 dB(A), it is felt that certain tasks might prove susceptible to appreciable interference at approximately 75 dB(A).

3.2 Construction Noise

3.2.1 Extent of exposure

Our determination of the impact of construction noise on the American public is based on information obtained about the number of people exposed to such noise and the extent of their exposure. This information was gathered in four steps:

- We determined the number of construction sites of various types in various geographical regions.
- We determined the density of people in the geographical regions (two classes of people were considered: stationary population such as workers and residents and transient population such as drivers and pedestrians).
- We postulated a model of sound propagation around a typical construction site.

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- We combined the information obtained in the first three steps with the site source level data presented in Sec. 2.1 to determine the number of people exposed to given levels of noise.

For the purpose of gathering and analyzing population and construction site statistics, we divided the U.S. into five regions. These regions are based on those defined by the U.S. Bureaus of the Budget [31] and of the Census [32]. A key to understanding the rationale used for establishing these regions is the concept of Standard Metropolitan Statistical Area (SMSA). An SMSA is a group of contiguous counties which contains at least one central city of 50,000 inhabitants or more, or "twin cities" with a combined population of 50,000 or more. There are 233 SMSAs containing 65% of the nation's population and about 10% of the land area. The population density in the nonmetropolitan areas is too low to create much construction noise exposure or to allow meaningful computation of the exposure that does exist. This study, therefore, restricts itself to construction occurring within the SMSAs (see Table IX).

Classification of Construction Sites

As explained in Sec. 2.1, four major categories of construction were studied:

- Residential buildings
- Nonresidential buildings
- Municipal roads
- Public works

Certain heavy construction and large civil works, such as dams and bridges, were omitted because this type of construction

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TABLE IX. METROPOLITAN REGIONS CONSIDERED IN CONSTRUCTION NOISE EXPOSURE ESTIMATE: STATISTICS AS OF 1970*

	Population (thousands)	Area (sq. mi.)	Population Density (people per sq. mi.)
Large High-Density Central Cities** (12)	22,299	1,462	15,160
Large Low-Density Central Cities (14)	10,539	2,382	4,410
All Other SMSA Central Cities (196)	15,990	6,981	3,710
Urban Fringe	49,080	14,797	3,320
Non-Urban Outside Urban Areas	92,349	739,276	125

*Population figures are extrapolated to 1970 from 1960 Census figures according to recent growth rates.

**Large cities are those whose metropolitan area population exceeded 1,000,000 in 1960.

High-Density: Baltimore, Boston, Buffalo, Chicago, Cleveland, Detroit, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis, Washington.

Low-Density: Atlanta, Cincinnati, Dallas, Denver, Houston, Kansas City, Los Angeles, Milwaukee, Minneapolis-St. Paul, Miami-Ft. Lauderdale, New Orleans, St. Petersburg-Tampa, San Diego, Seattle-Tacoma.

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rarely takes place in heavily populated areas. The residential and nonresidential building categories were further subdivided into specific types of buildings to account for variations in the duration of construction and the mix of machinery at different kinds of sites.

The Number of Construction Sites

Data on the annual number of building sites on which construction was begun in 1969 was collected from the U.S. Postal and Defense Services Administration [33] and from unpublished compilations made by the Bureau of the Census. Data for large central cities and for the nation as a whole were directly available; sites were ascribed to "other central cities", "urban fringe", and "nonurbanized metropolitan area" on the basis of population distribution. The number of residential and nonresidential building sites in the five metropolitan-area regions is shown in the first two columns of Table X, as well as the average cost of construction for each case. A more detailed breakdown by type of building is given in Appendix B.

Data on total municipal road construction [34] was apportioned among the various metropolitan regions by assuming a constant ratio of miles of road constructed to miles of road in place. The number of miles of such work performed in 1969 is shown in the third column of Table X.

Unlike the case with buildings and roads, data on construction and maintenance of public works such as sewers and water mains is not collected on a national basis. The extent of this construction, therefore, has been estimated first by determining the ratio of sewer construction to street construction for several cities in the Boston area and then by using this ratio to

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TABLE X. ANNUAL CONSTRUCTION ACTIVITY — 1970*

Metropolitan Regions	Residential Buildings (no. of sites)	Nonresidential Buildings (no. of sites)	Municipal Streets (miles)	Public Works (miles)
Large high-density central cities	8,708	1,952	273	398
Large low-density central cities	21,578	4,303	2,150	3,140
Other central cities	102,559	12,321	6,000	8,700
Urban fringe	262,800	30,915	11,800	16,865
Met. area outside urban fringe	118,779	13,758	21,700	31,550
Total	514,424	62,549	41,923	60,653

* All figures are in thousands.

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estimate the miles of sewer construction nationwide for 1970. These figures are contained in the fourth column of Table X. A more detailed description of this computation is contained in Appendix B.

Construction Phases

Construction of buildings and other works is carried out in discrete stages, each of which has its own characteristic mix of equipment. Because of the items of equipment on a site change as construction progresses, the noise output from the site also changes with time. As explained in Sec. 2.1, we have characterized the noise output from each site according to construction phase:

- Clearing and demolition
- Excavation
- Placement of foundations
- Erection of frame, floors, roof, and skin
- Finishing and cleanup.

These phase descriptions are used for road and sewer construction, even though the actual operations are different from those for buildings, so as to allow a consistent analysis of the various types of sites. (See Sec. 2.1 for a more complete description.) A list of the equipment commonly found in each phase is given in Table A-1.

Number of Individuals Exposed

We obtained the number of people exposed to various levels of noise from construction sites by combining information on

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population density, the number of sites active per year, and the sound propagation model described below.

We revised the population figures in Table IX, which represent the residential distribution of the U.S. population, to reflect the net transfer [25] of people from suburbs to central city during the average working day, the period when most construction noise is produced. These revised density figures are given in Table XI in terms of people per square mile and people per one-eighth mile of street (assuming the entire metropolitan area to be divided into city blocks one-eighth of a mile long).

TABLE XI. GEOGRAPHICAL DISTRIBUTION OF WORKING-DAY POPULATIONS

	People per square mile	People per 1/8 mile of street (approximate)
Large high-density central cities	16,650	130
Large low-density central cities	4,860	40
All other central cities	4,070	32
Urban fringe	3,100	24
Met. area outside urban fringe	114	--

Note that the number of people per city block in the metropolitan area outside the urban fringe is negligible and therefore is disregarded in the following discussions.

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In addition to the working-day population density estimate given in Table XI, we must also account for the number of passers-by who are exposed to construction noise. Since there are no data on typical driver and pedestrian distributions, a definitive estimate of this type of exposure is not possible. We have, however, made an order-of-magnitude estimate on the basis of some survey work performed by the Boston Traffic Department (1970). Although incomplete, these surveys report seemingly reasonable numbers, which are therefore offered in Table XII as preliminary estimates.

TABLE XII. NUMBER OF PEOPLE PER DAY PASSING A CONSTRUCTION SITE

	Drivers and Passengers	Pedestrians
Large high-density central cities	3000	1000
Large low-density central cities	3000	1000
Other central cities	1500	500
Urban fringe	500	100

Table XIII presents the total number of building construction sites active in 1970 (see Table X) for all metropolitan regions. In the case of roads and sewers, the definition of a "construction site" is somewhat obscure, since such projects extend linearly for some distance with construction usually occurring one section at a time. The area of influence of construction on one section is about one-eighth of a mile. We therefore consider each eighth-mile of street and sewer construction as an independent site.

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TABLE XIII. LEVEL OF ANNUAL CONSTRUCTION ACTIVITY

Type of Site	Number of Sites (National Total)
Residential Building	514,424
Nonresidential	62,549
Municipal Streets	336,000
Public Works	485,000

The level of exposure to noise from a construction site depends on one's distance from the site and the nature of his immediate environment. In city streets, it has been found experimentally that sound intensity decreases as the inverse square of the distance from the source [36]. In logarithmic units, this amounts to a 6 dB reduction per distance doubled. This model has been adopted for open-air propagation, which is significant in the case of pedestrians. In addition, a factor of 20 dB(A) attenuation has been included for people who are inside buildings with closed windows and 15 dB(A) for people inside cars with closed windows [37]. Construction noise is assumed to propagate along the street adjacent to the site, but to be heavily attenuated in the direction transverse to the street; in effect, only the people along the street adjacent to the site are affected by the noise. A further assumption is that the sound is reduced 10 dB(A) when one crosses a street intersection [36].

Using these parameters, we illustrate in Fig. 20 a representative geometry for a building construction site and contours of attenuation for observers. Details of the computations involved in constructing this diagram are given in Appendix B. Assuming a uniform distribution of observers along the sides of

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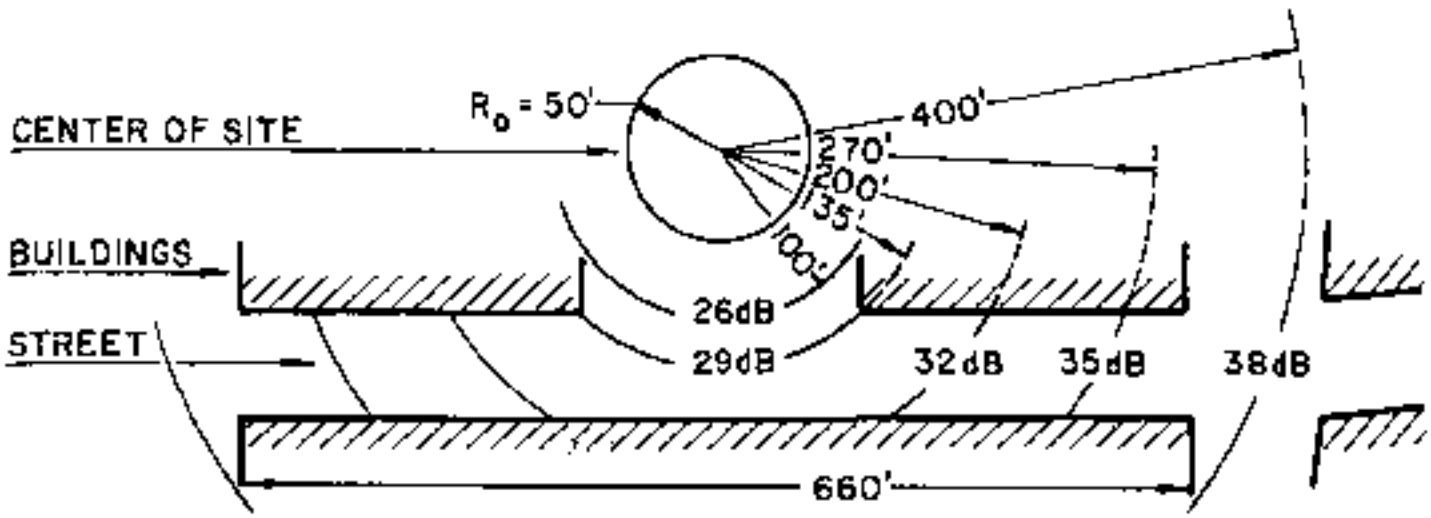

FIG. 20. CONSTRUCTION SITE GEOMETRY AND ATTENUATION CONTOURS FOR A STATIONARY POPULATION WITHIN BUILDINGS. (SEE APPENDIX 9 FOR METHOD OF COMPUTATION.)

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the street, we can determine the fraction of people within each set of attenuation contours. These proportions, which are shown in Table XIV below, apply only to observers in buildings with closed windows adjacent to the street on which building construction is taking place; drivers and pedestrians move relative to the site, crossing contours as they go.

TABLE XIV. DISTRIBUTION OF STATIONARY OBSERVERS RELATIVE TO ATTENUATION CONTOURS

Attenuation Interval	Percent of Observers
26 – 29 dB	15%
29 – 32 dB	35%
32 – 35 dB	32%
35 – 40 dB	18%

All observers more than 40 dB away from the site have been disregarded, as they are assumed to be unaffected by the noise. The actual number of people within each pair of attenuation contours can be obtained by multiplying the percentages in Table XIV by the number of people per 1/8 mile of city street for the appropriate metropolitan area (as given in Table XI).

In the case of street and sewer construction, operation is typically distributed along the length of the street and cannot be modeled as a point source. Accordingly, all the people in the eighth-mile of city street adjoining the site are assumed to be exposed to the same noise level. This level is taken to be the source level of the site diminished 20 dB to account for attenuation within buildings with closed windows.

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The noise exposure of pedestrians and drivers cannot be computed by the above model, since, as noted above, their distance from the site varies with time. In these cases, we consider the peak exposure experienced by the transient observer. For pedestrians, this exposure is 6 dB less than the site source level referenced to 50 ft; for drivers, it is 20 dB less.

Noise Exposure Estimates

The above figures on observer densities, number of sites, and attenuation have been combined with the data on average and peak site source levels presented in Sec. 2.1 to determine the number of people exposed to particular levels of noise. Table XV shows the national noise exposure of the stationary population due to residential building, nonresidential building, municipal street, and public works construction. The noise levels are broken down into the five phases of construction described above.

To compute exposure of drivers and pedestrians, one multiplies the number of people per day passing each site by the number of sites. This gives the number of passersby exposed per day of site operation. Multiplying this number by the average number of days each site is operated gives the total annual number of instances in which an individual passes a construction site and is thus exposed to noise. For this computation, we use the number of sites from Table X and the number of passersby from Table XII. The duration of construction on the average site is not available from survey data but the following figures are considered typical:

- Residential buildings (single-family only) — 27 days
- Nonresidential buildings and multifamily dwellings — 170 days
- Streets and Public Works — 7 days.

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TABLE XV. AVERAGE AND PEAK EXPOSURE LEVELS TO CONSTRUCTION NOISE

Number of People	Average Levels, Construction Phase					Peak Levels, Construction Phase				
	I	II	III	IV	V	I	II	III	IV	V
				RESIDENTIAL BUILDING CONSTRUCTION						
1,725,000	56.5	64.5	54.5	47.5	54.5	63.5	70.5	57.5	57.5	70.5
4,625,000	53.5	61.5	51.5	44.5	51.5	60.5	67.5	54.5	54.5	67.5
3,680,000	51.5	48.5	48.5	41.5	48.5	57.5	64.5	51.5	51.5	64.5
2,070,000	47.5	45.5	45.5	38.5	45.5	54.5	61.5	48.5	48.5	61.5
11,500,000										
				NONRESIDENTIAL BUILDING CONSTRUCTION						
575,000	56.0	64.0	54.0	47.0	54.0	63.0	70.0	57.0	57.0	70.0
325,000	53.0	61.0	51.0	44.0	51.0	60.0	67.0	54.0	54.0	67.0
460,000	50.0	58.0	48.0	41.0	48.0	57.0	64.0	51.0	51.0	64.0
370,000	47.0	45.0	45.0	38.0	45.0	54.0	61.0	48.0	48.0	61.0
1,730,000										
				MUNICIPAL STREET AND PUBLIC WORKS CONSTRUCTION						
14,500,000*	63.0	65.0	60.0	56.0	64.0	71.0	78.0	71.0	69.0	71.0
				FEDERAL AND STATE HIGHWAY CONSTRUCTION						
7,000,000*	63.0	65.0	60.0	56.0	64.0	71.0	78.0	71.0	69.0	71.0

*Assuming homogeneous exposure of all people indoors with windows shut.

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The estimated number of occasions per year in which a driver or pedestrian passes a site is shown in Table XVI below. These figures do *not* represent the number of people who pass construction sites, since one person may pass many sites, or one site many times. If one divides the grand total of Table XVI, 24.7 billion passings, by the total national metropolitan population of 137 million, it is seen that the average inhabitant of metropolitan areas passes a construction site approximately 180 times per year.

3.2.2. Impact assessment

Determining the impact of construction noise on people is a multistage process. The procedures by which estimates of levels and durations of noise exposures were derived are discussed in the preceding section (3.2.1). Development of the criteria by which the severity of noise effects are judged is discussed in Sec. 3.1. In this section, we explicitly combine the exposure data with the criteria; Appendix B contains a number of important comments on the inferences which may be prudently drawn from the findings reported here.

Table XV of Sec. 3.2.1 and Table XVII of this section provide an overview of the exposure data as they pertain to impact assessment. The tables contain information about the number of people who receive primary and secondary exposure to construction site noise and the levels of noise to which they are exposed *in their listening environments*. Estimates of the duration of noise exposures are also presented in the tables. The following discussion is organized according to strength of impact.

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TABLE XVI. ESTIMATED ANNUAL PASSINGS OF CONSTRUCTION SITES — ALL METROPOLITAN REGIONS* (MILLIONS OF OCCURRENCES)

	Residential Buildings	Nonresidential Buildings	Municipal Streets and Public Works	Total
Drivers and Passengers	8,300	5,160	1,980	18,440
Pedestrians	2,760	2,700	882	6,342
			Grand Total	24,782

*A "passing" is defined as one person passing one site by car or foot.

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Speech Interference

Perhaps the single most obvious effect of exposure to construction site noise is speech interference. Even cursory examination of Table XV reveals that in almost all phases of construction, noise levels associated with construction activity are capable of degrading speech communication. In many instances — specifically, those in which construction noise produces levels approaching or exceeding 80 dB(A) in the listening environment — degradation of speech communication is severe. When one considers that the "average" levels of Table XVII are energy averages, it is clear that peak levels of construction noise, although infrequent, can preclude speech communication completely.

It is apparent from Table XVII that for those people who live or work in the vicinity of construction sites (i.e., those who receive primary exposure to construction noise), the duration of speech interference effects can be considerable. It seems safe to state that approximately 34 million people suffer a total of several hundred hours of speech interference yearly as a result of exposure to construction site noise in the United States. Approximately 20 million of those people must communicate in noise environments which seriously degrade speech intelligibility and/or demand significantly increased vocal effort.

In contrast to those who must endure such speech interference on a relatively long term basis, there are many more people who suffer the same effects on a briefer time scale. These people are the passersby who are exposed to construction site noise for a matter of minutes daily. Although the actual number of different individuals who pass by construction sites on foot or in vehicles is difficult to estimate, there are probably on the order of 25 billion such brief encounters yearly. The prin-

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TABLE XVII. ORDER OF MAGNITUDE ESTIMATES OF YEARLY DURATION OF CONSTRUCTION NOISE EXPOSURE

Source	Number of People	Hours of Exposure by Construction Phase				
		I	II	III	IV	V
Primary (Stationary) Exposure to Domestic Construction Noise	11,500,000	24	24	40	80	40
Primary (Stationary) Exposure to All Other Building Construction	1,500,000	80	320	320	480	160
Primary (Stationary) Exposure to All Other Construction in SMSA Areas	14,500,000	8	8	16	16	8
Municipal Public Works		12	12	24	24	12
Federal and State Highway	7,000,000	250	250	500	500	250
Subtotal						
Secondary (Passerby) Exposure of Pedestrians to Construction in All SMSA Areas	6,348,000,000*	Five minutes' exposure to levels approximately 30 dB higher than those of Table XV				
Secondary (Passerby) Exposure of Drivers and Passengers to All Construction in SMSA Areas	18,440,000,000*	Thirty seconds' exposure to levels approximately 15 dB higher than those of Table XV				
Subtotal						

*These figures represent the number of annual occurrences of exposure, defined as the product of the number of people exposed and the frequency of their exposure.

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cipal effect of such transient exposure to construction noise is probably interruption of conversation.

Applying state-of-the-art noise reduction techniques to the major sources of construction noise could provide a meaningful reduction of both the severity of speech interference and the number of people exposed to speech interference effects. Quieting all construction equipment by 10 dB(A) would lower peak construction noise levels by an equivalent amount and average levels by a somewhat lesser amount (due to overlapping temporal patterns of use). Nonetheless, speech interference effects increase sharply in the range between 60 and 80 dB(A), so that a noise reduction of about 10 dB(A) would be highly beneficial. Interestingly enough, the advantages of reducing construction noise an additional 10 dB(A) might not be as great. Although 70 dB(A) reduction of construction noise would clearly result in even less speech interference than would a 10 dB(A) reduction, at the resulting levels construction noise might well be submerged in background noise a good part of the time. Additional reductions [beyond the first 10 dB(A)] might be necessary for the benefit of those who operate the equipment, however.

Sleep Interference

To the extent that construction activity and sleep do not commonly occur during the same hours, construction noise does not interfere with sleep. However, daytime sleeping needs of the very young, the aged, and people working irregular or night hours, and emergency and other nighttime construction work must be taken into account. The total number of adults so affected by construction is estimated to be about 3 million. Judging from the ratio of people exposed to construction noise to the total population of the country, approximately 1/7 of the children four years of

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age or younger, or about 7.3 million, might also be exposed to sleep interference from construction noise.

The 5.5 million people attempting to sleep during exposure to construction noise are likely to encounter substantial interference. Even at relatively great distances from construction sites, levels in the vicinity of 50 dB(A) are encountered. Such levels are capable of significantly lengthening the time required to fall asleep and of awakening roughly 40% of sleeping persons.

Nonetheless, the usefulness of reducing average construction noise levels by 10 dB(A) (possible through state-of-the-art noise reduction procedures) appears marginal. The number of people whose sleep is disturbed by construction noise is relatively small, and the shallow slope of the function relating the number of people awakened to noise levels argues that construction noise would have to be reduced by much more than 10 dB(A) to effect a significant reduction of sleep interference.

Hearing-Damage Risk

The risk of hearing damage from construction noise for those not directly concerned with construction activity does not seem very great. In most cases the distance between the construction site and people exposed to its noise and the transmission loss of the buildings or vehicles are sufficiently great to minimize the probability of hearing damage. It is possible that peak noise levels from construction sites might present some risk to those who are frequently in close proximity to the site. The greater number of such people (presumably pedestrians), however, are subject only to short exposure durations.

If state-of-the-art noise reduction techniques were applied to the major sources of construction noise, exposure levels would

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probably be sufficiently reduced to render hearing damage a remote risk. In short, construction noise does not pose a major hearing-damage risk for the public.

Other Indirect Effects

Without doubt, a major consequence of exposure to construction noise for many people is annoyance. Both those who are exposed to construction noise on a regular, long-term basis as well as those who are exposed to it on a transient basis are annoyed by their exposure. Annoyance is particularly great if the noise intrusion from the construction site is perceived as unnecessary or inappropriate. People who must endure weeks or months of construction noise exposure may exhibit some form of habituation to the noise, but despite the commonly expressed attitude toward noise of "you get used to it", it is doubtful that construction noise ever loses all of its annoyance value.

In relative terms, annoyance from construction noise probably represents less of a problem than annoyance produced by aircraft or traffic noise. Nonetheless, both individual complaint behavior and community action could conceivably result from the annoyance of exposure to construction noise.

One measure formulated to provide some degree of quantification for annoyance due to noise exposure is the Noise Pollution Level [8]. Table I contains NPL's encountered in the immediate vicinity of construction sites. Unfortunately, interpretation of NPL's is not a straightforward procedure. Relative interpretations of two or more noise situations are readily enough made through use of the NPL index. Few grounds exist, however, for absolute interpretations. It has been suggested that long-term exposure to noise levels characterized by an NPL value of 72

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(computed from A-level measurements) is "acceptable" [2]. By this criterion, noise levels in the immediate vicinity of construction sites are clearly "unacceptable" on a long-term basis. However, the bulk of exposure to construction noise of such high levels is of a transitory nature. Residents or transients exposed to construction noise would be exposed to levels about 30 dB lower. Although it would be tempting to assert that such exposure (to NPL's in the range of 60–70) would be marginally acceptable, only meager evidence could be marshalled to support such a claim.

It is distinctly possible for exposure to construction noise to result in task interference. It seems plausible that among the approximately 20 million people exposed on a long-term basis to the highest levels of construction noise (Table XV), some might be engaged in exacting manual or mental work which could be sensitive to interference. Such tasks might include medical operations, library use, scholarly activities, and the like. Unfortunately, one cannot quantify the amount of task interference produced by construction noise by applying the usual procedures of estimation and assumption.

Similar comments apply to the potential startle and physiological stress produced by exposure to construction noise. Although startle does not seem to be a very common consequence of exposure to construction noise, it is nevertheless possible for startle to result from unexpectedly or intermittently high-level noise. The size of the standard deviations of distributions of construction noise levels discussed in Sec. 3.2.1 makes the occurrence of unusually high noise levels reasonably probable events.

As for the stressful consequences of exposure to construction noise, we can offer only informed conjecture. Noise-induced

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physiological stress is known to be cumulative, and exposure to construction noise is only one determinant. Perhaps some of the people who are faced with exposure to construction noise at work every day for months must also face noisy home environments. For such people, exposure to construction noise could constitute a major source of stress.

Tables XVIII and XIX summarize the impact of construction noise on people. A composite quantity intended to reflect both the extent and duration of exposure to specific noise sources was developed to permit concise summation. The quantity is defined as the product of the estimated number of people exposed to noise from a particular source and the estimated duration of individual exposure to the same source. The statistic expressing the quantity is called (for lack of a better term) the "person-hour".

Extreme caution must be used in interpreting figures expressed in terms of person-hours. First, figures so expressed are intended only as order-of-magnitude estimates rather than as precise quantities. Second, inferences about the equivalence of number of people and duration of exposure in assessing psychological or physiological impact are completely unjustified. No compensatory model of number of people exposed and exposure duration is intended. Third, comparison of person-hour figures for exposure to noise from one source with person-hour figures for exposure to noise of another source is without theoretical foundation. Thus, comparisons of impact among different sources expressed in common terms of person-hours should be performed in a fashion similar to "addition" of apples and oranges. In other words, inferences about severity of impact may be drawn only withint person-hour estimates of similar origin.

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TABLE XVIII. ORDER-OF-MAGNITUDE ESTIMATES OF CONSTRUCTION NOISE EXPOSURE IN MILLIONS OF PERSON-HOURS PER WEEK

Source	Millions of Person-Hours Per Week
Primary (Stationary) Exposure to Domestic Construction Noise	42
Primary (Stationary) Exposure to All Other Building Construction	39
Primary (Stationary) Exposure to All Other Construction in SMSA Areas	18
Subtotal	101
Secondary (Passerby) Exposure to Pedestrians to All Construction in SMSA Areas	10
Secondary (Passerby) Exposure of Drivers and Passengers to All Construction in SMSA Areas	0.3

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TABLE XIX. ORDER-OF-MAGNITUDE ESTIMATES OF IMPACT OF PRIMARY AND SECONDARY EXPOSURE TO CONSTRUCTION NOISE EXPRESSED IN MILLIONS OF PERSON-HOURS PER WEEK

Noise Source	Speech Interference*		Sleep Interference*		Hearing Damage Risk	
	Moderate (45–60)	Severe (>60)	Slight (35–50)	Moderate (50–70)	Slight (70–80)	Moderate (80–90)
Primary (Stationary) Exposure to Domestic Construction Noise	44			2	0	
Primary (Stationary) Exposure to All Other Building Construction	38			2	0	
Primary (Stationary) Exposure to All Other Construction in SMSA Areas	14			1	0	
Secondary (Passerby) Exposure of Pedestrians to Construction in All SMSA Areas		10	0			10
Secondary (Passerby) Exposure of Drivers and Passengers to all Construction in SMSA Areas		0.3	0			0.3

*Entries in these columns may not be interpreted directly as person-hours of direct speech or sleep interference (see text).

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With these restrictions firmly in mind, the reader is referred to Tables XVIII and XIX for a concise summary of the impact of construction noise on people. Table XVIII expresses the impact of construction noise in terms of millions of person-hours per week. (It may be useful to bear in mind that a week in the United States contains approximately 35 billion person-hours.) Table XIX relates the impact of construction noise directly to the principal criteria of Sec. 3.1 in terms of person-hours per week. Entries for speech interference and sleep interference effects reflect the number of person-hours of potential impact, which may be interpreted as upper bounds.

3.3 Appliances

3.3.1 Extent of exposure

This section is concerned primarily with power tools and household appliances whose volume cannot be controlled by the user. Therefore, volume-controllable equipment such as televisions, radios, and stereos are not included, nor are gasoline-engine powered outdoor equipment and audible signaling mechanisms (bells, alarms, etc.). It should be noted, however, that non-controllable noise-producing devices often raise the background level of noise to such a degree that volume-controllable sound has to be increased in level to be heard and, hence, is more apt to affect neighbors. An estimate of the number of noncontrollable noise-producing devices being used in the United States in 1971 is given in Table XX.

To determine the extent of exposure to home appliance and tool noise, we gathered three kinds of data: The distribution of appliances and tools over family units, the time that the devices are typically in use, and the exposure of people who are

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TABLE XX. NONCONTROLLABLE HOUSEHOLD NOISE SOURCES (1971) [31]

	Number (thousands)	Percent of Homes
Wired Refrigeration	69,400	100
Complete Plumbing	68,000	98
Major Appliances		
Refrigerator	63,600	95.8
Clothes Washer	57,000	91.0
Vacuum Cleaner	61,900	89.2
Clothes Dryer	41,300	59.5
Freezer	35,700	51.5
Air Conditioner	19,000	27.4
Dishwasher	11,700	16.9
Food Disposer	11,100	16.0
Trash Disposal	(Unavailable in 1970)	
Other Appliances		
Food Mixer	43,200	62.2
Can Opener	47,100	67.8
Sewing Machine	31,300	45.0
Food Blender	24,900	35.9
Electric Shaver	23,400	33.7
Sibling Knife	19,000	27.4
Floor Polisher	10,900	15.7
Power Tools		
Saw, drill, etc.	42,900	70.0
Outdoor Equipment		
Electric Mower	2,900*	4.2
Edger	1,300	1.9
Trimmer	1,000	1.4
Building Equipment (Residential)		
Fan	53,400	80.9
Humidifier	4,600	6.6
Dehumidifier	4,200	6.1

*There are approximately 3 million powered mowers in use.

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in the home. In collecting this information, we found that the variables, particularly with respect to personal behavior, covered a very large range. We therefore created a simplified model to cover the range of household values.

Data were obtained from a variety of sources. Statistical information was collected from government sources, such as the Bureau of the Census. Of particular help was information provided by Cornell University's College of Human Ecology on domestic living patterns. Industry information was obtained from various trade and business publications. Individual company materials were used in instances where the material was applicable to the whole industry and was available to the public. Various simulations representing consumer and home economists were conducted. We also conducted our own survey of appliance use in 40 households.

Appliances, Tools, and Building Equipment

The dimensions used by industry to analyze household appliance purchase and use patterns usually include home ownership, age of the head of the family, size of family, and family income. Since these dimensions are interrelated, we chose only one — family income level — for our analysis. We treat the time that appliances are used as a function of the age of the homemaker and of the number of school and pre-school children in the family. Figure 21 shows the trend toward greater use of home appliances and power tools. Figure 22 gives the distribution of some common appliances as a function of income level.

Noise-producing devices used in and around the home are usually classified as

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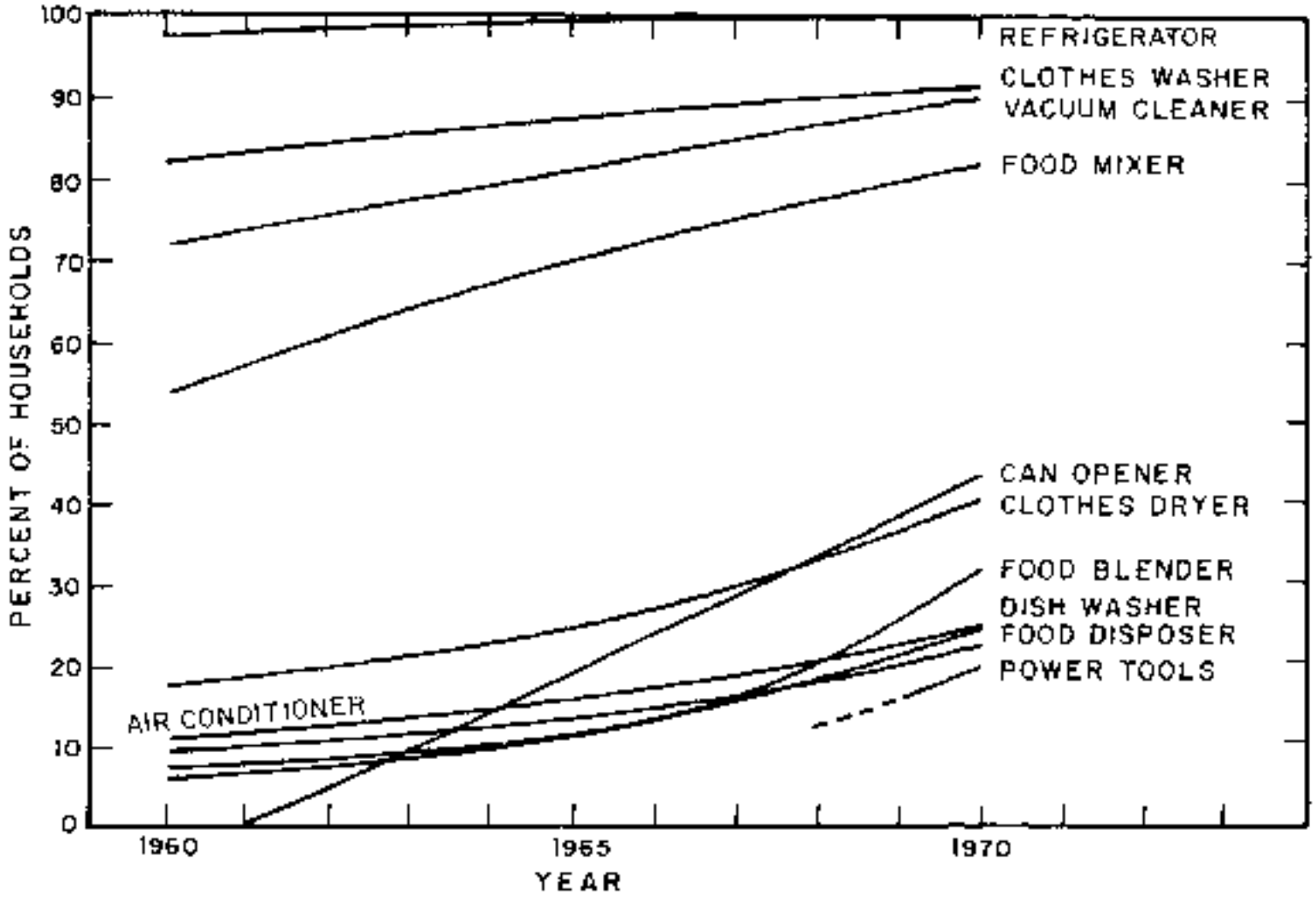

FIG. 21. PERCENT OF HOUSEHOLDS WITH SELECTED NOISE-PRODUCING APPLIANCES AND TOOLS.

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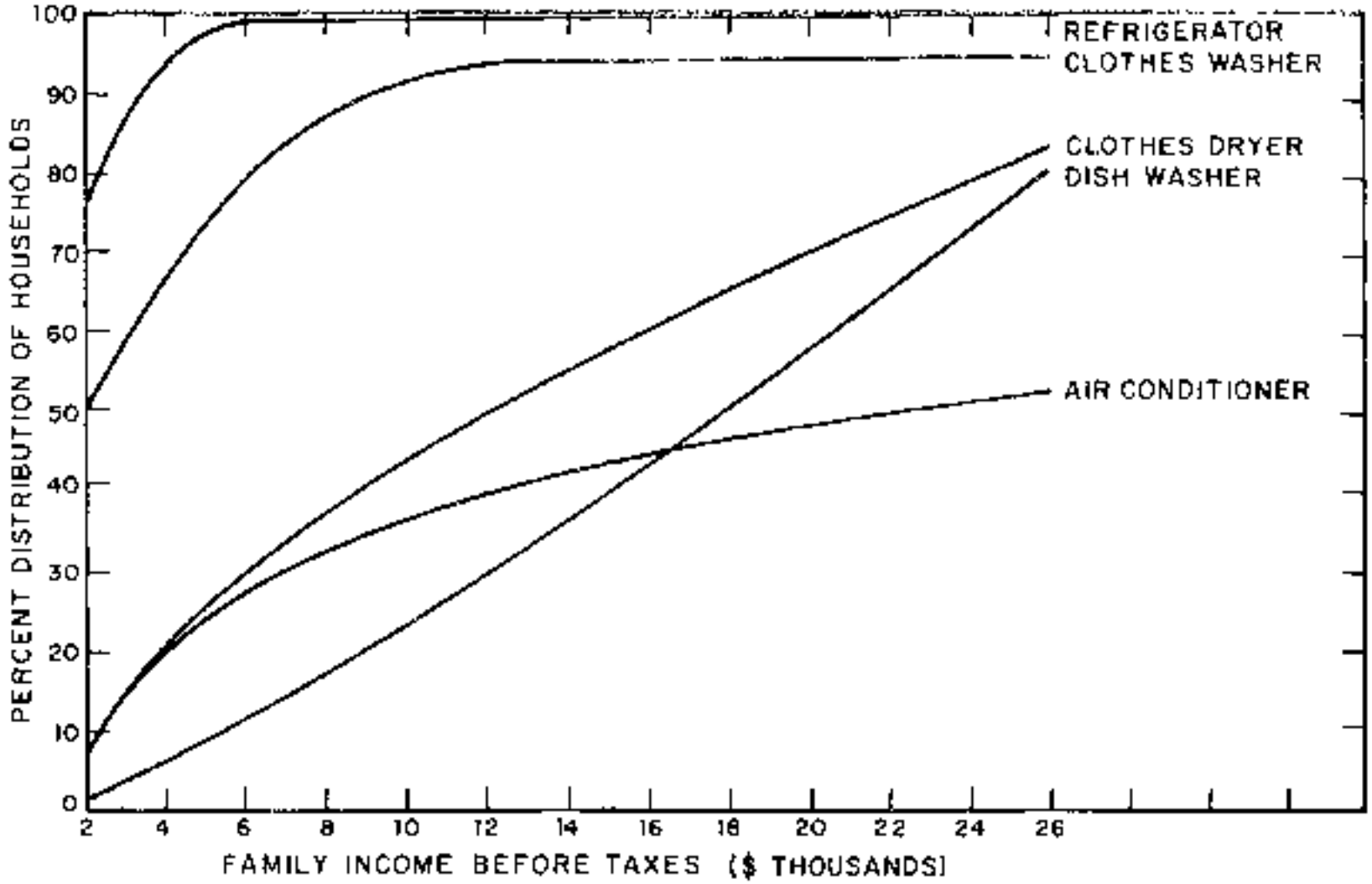

FIG. 28. ESTIMATED PLACEMENT DISTRIBUTION OF MAJOR APPLIANCES BY INCOME LEVEL.

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- Major Appliances (including clothes washers, clothes dryers, refrigerators and freezers, air conditioners, dishwashers, vacuum cleaners, disposers, dehumidifiers, and compactors)
- Other Household Appliances
- Power Tools
- Outdoor Equipment
- Building Equipment

Other convenient classifications are based on time mode of operation (continuous or intermittent) and method of operation (manual or automatic).

Analysis of the noise-producing building equipment used in homes is complicated by interaction of the equipment with the structure of the house, by do-it-yourself modifications of equipment, and by differences in the adequacy of equipment maintenance. Size of housing is also a factor in noise level. Smaller housing units are apt to be noisier because of reverberant buildup of sound levels. Larger housing units on the other hand, frequently reflecting a higher standard of living, tend to have more appliances and more frequent exposure but lower noise levels for any particular appliance owing to the larger space and to the room separation from the various sources. Multiple-family housing units are subject to higher levels of noise from the building equipment.

In heating systems either the heating source or distribution system or both are common sources of noise; however, the number of factors involved is too great to allow a precise analysis of the extent of heating noise. Electric heating, which is essentially noiseless, is currently being used by 4.4 million customers.

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(It should be noted, however, that electric heating customers are likely to be high users of electric appliances. Furthermore, humidity control, ventilating, and/or air cleaning, which are often used in conjunction with electric heating, require air circulation; therefore, fan noise is present where these additional functions are performed.) The more common heating systems generate burner noise, fan/duct noise (in hot-air systems), and pipe, valve, and pump noise (in hot water and steam systems).

Twenty-one percent of all households have one or more room air conditioners. Location of these air conditioners is distributed approximately [36]:

Living Room	35%	Kitchen	7%
Master Bedroom	27%	Playroom	4%
Other Bedroom	5%	Other	22%

All dehumidifiers and many humidifiers are substantial noise sources. Frequently, dehumidifiers are located in the basement and therefore direct exposure to the noise is small. Dehumidifiers are used in 6.7% of homes; humidifiers in 7.0% [30].

Living patterns, equipment installations, etc. are variables that make it difficult to estimate the extent of plumbing noise. The typical range of toilet flushes is 10 to 50 per day. Complete plumbing (hot and cold water, bath or shower, toilet) is found in 82% of all rental units and in 93% of all owner-occupied units in the United States.

The number of fans being used in this country far exceeds the total number of households. Many fans are part of other appliances, but many are used for immediate air circulation (i.e., cooling fans, kitchen fans, etc.).

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Use of Domestic Appliances and Tools

The extent to which appliances are used is an important factor in assessing the total noise exposure. Statistical information is scarce, but we have found the following sources useful:

- BBN survey (in-depth study of noise levels and appliance use in 20 homes).
- New York State College of Human Ecology, Cornell University (both published and unpublished data gathered as part of a 1296-household survey of Syracuse, New York).
- Department of Agriculture information based on studies of home activities (a long-term interest, which is now being continued under the Agriculture Research Service Division of the Department of Agriculture).
- Potomac Electric Power Company (an informal survey conducted by their Home Services Department).
- Manufacturer's industry information.

Although many factors affect the range of appliance use, there is a tendency for people in the family-raising years to have increased incomes, own their homes, and possess more appliances. The time a homemaker spends in household activities is a strong function of age, number of children, and the presence of pre-school children, as shown in Table XXI. Table XXII presents the information on which we base our estimate of typical use of appliances; Table XXIII gives our estimate of appliance use in two typical households; appliance operating times are estimated from Table XXII. Using the values of appliance use (total minutes per week) and of average noise levels given in Table XXIII, we present in Fig. 23 a schematic illustration of the noise levels of the two typical households.

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TABLE XXI. AVERAGE HOURS PER DAY SPENT ON HOUSEHOLD WORK BY 1296 HOMEMAKERS, ACCORDING TO NUMBER OF CHILDREN AND AGE OF YOUNGEST CHILD, SYRACUSE, NEW YORK AREA, 1967–68 [*sp*]

	Hours
All homemakers	7.3
Number of children	
0	4.8
1	6.8
2	7.8
3	7.7
4	8.2
5 or 6	8.5
7 to 9	9.2
Age of youngest child	
Under 1 year	9.3
1 year	8.3
2 to 5 years	7.7
6 to 11 years	7.1
12 to 17 years	6.8

Level of Exposure

We have selected two criteria to show different measures of exposure. A *potential exposure* represents the number of people likely to be exposed to an appliance and depends solely on an average distribution of the population and the percentage of households that possess the particular appliance. A *primary exposure* is estimated by the normal mode of operation, the location

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TABLE XXII. APPLIANCE USAGE SOURCE DATA (TIMES PER DAY UNLESS INDICATED)

Appliance	Cornell University Data, 1296 Homes* (N.Y. State College of Human Ecology)									Potomac Electric Co., Home Services Dept. (informal estimate for home with 2–3 children)	SSN estimate of use for family with 3 children
	Percent of homes with appliance	Percent used various day (of 1296)	Number of days in one week which appliance was used. 0	1	2	3	4	5	6	7		
Clothes washer†		62	135	134	167	197	163	163	178	159	2	1.5
Clothes dryer		43										
Dishwasher	30		931	4	5	13	33	25	14	272	2	1.5
Food disposer	24	22	1002	1	5	2	5	3	10	268	6-7	5
Vacuum cleaner	97	66	111	211	275	269	164	75	80	110	3/wk	3/wk
Room air conditioner	17											
Trash disposer												
Food mixer }	98	28	277	226	286	207	153	80	28	39	1–2/wk	2/wk
Food blender }											3/wk	3/wk
Can opener											2	2
Sewing machine												1/wk
Slicing knife												1/wk
Floor polisher	48	3	1161	107	17	6	1	0	0	4		2/mo
Electric shaver												1
Power tools (saw, etc.)												2/mo
Mower	72											1/wk

†No. of Loads		0	1	2	3	4	5	6	7	8	Ave.
on One Day	Homes	502	210	263	159	82	41	18	6	5	1.50

*Sample selected to give equal numbers of homes with different number of children; therefore, sample shows homes with more persons than national average.

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TABLE XXIII. USE OF NONCONTROLLABLE NOISE-PRODUCING APPLIANCES AND TOOLS IN TYPICAL HOUSEHOLDS

	Average dB(A)[3]	Household No. 1* Times Used Per Week[2]	Minutes Per Use[1]	Total Minutes Per Week	Household No. 2† Times Used Per Week	Minutes Per Use	Total Minutes Per Week
Major Appliances							
Clothes washer	84	10.5	30	315	7	30	210
Vacuum cleaner	70	3	30	90	2	30	60
Clothes dryer	57	7	30	210			
Room air conditioner	53	(Full-time - seasonal)					
Dishwasher	65	10.5	45	472			
Food disposer	70	6	0.2	1			
Household Appliances							
Food mixer	69	2	5	10	1	5	15
Can opener	69	14	0.2	3			
Sewing machine	70	1	15	15	0.5	15	15
Food blender	76	1	3	3			
Electric shaver	64	7	2	14			
Sliding knife	71	1	1	1			
Floor polisher		1	10	10			
Trash disposer		14	1	14			
Power Tools							
Saw, drill, etc.	83	0.5	20	10			
Mower		1	30	30			
Edger	81	0.75	5	4			
Trimmer	81	0.25	15	4			

*2 Adults, 3 children (1 pre-school age), family income $16,000.
†2 Adults, family income $8,000.
[1]Measurements taken 3 ft. from source during BBN household survey.
[2]Based on data from BBN survey, Cornell Univ. survey of Syracuse, N.Y., and Potomac Electric Power Company information.
[3]Based on average cycle times of current model appliances.

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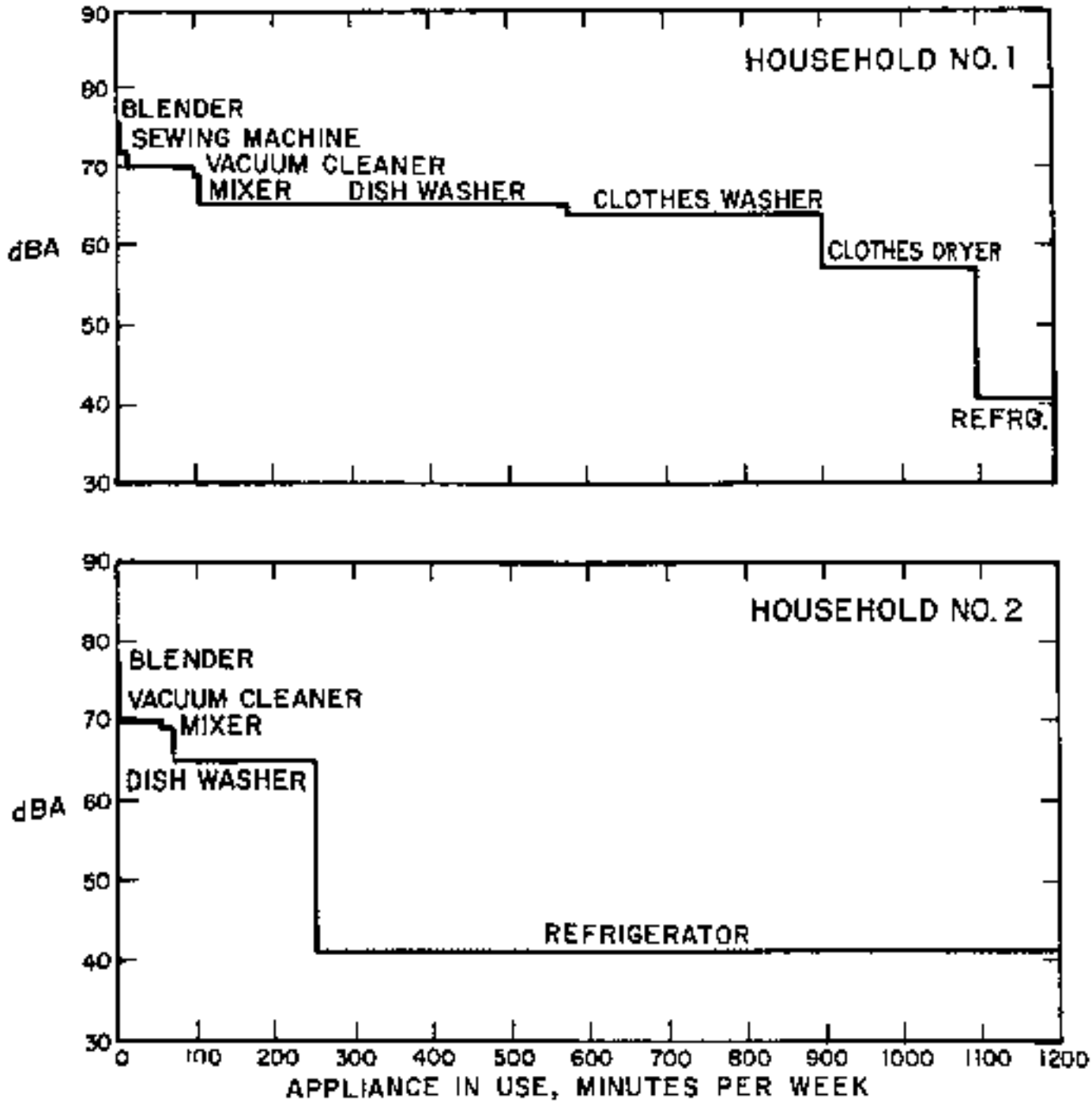

FIG. 23. NOISE PROFILES FROM APPLIANCE FOR TYPICAL HOUSEHOLDS PER WEEK (AT 3 ft)
No. 1: AVERAGE-INCOME FAMILY WITH CHILDREN
No. 2: LOWER-THAN-AVERAGE-INCOME FAMILY WITHOUT CHILDREN

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of the appliance, and the number of operators and observers likely to be exposed to noise when the appliance is operating. Table XXIV gives these two kinds of exposure for each appliance; Table XXV relates exposure to room level.

3.3.2 Impact assessment

The estimates of the extensiveness of distribution, duration of exposure, and noise levels of a variety of building equipment and home appliances are discussed here with a view toward assessing the impact of noise from these sources on people in the home environment. To approximate the environment in which noises are heard, we had to adjust the noise levels from the standardized values used in previous sections (i.e., levels recorded at a measurement position 3 ft from the source). Thus, 10 dB was added to the noise levels of hand-held appliances, such as electric shavers, to obtain a fair representation of noise levels at the user's ear. Similarly, 2 dB was subtracted from levels for exposure to noise in a highly reverberant field, such as a kitchen or bathroom; 3 dB from standardized measurements to account for noise exposure in less reverberant spaces, such as carpeted (living room) or open areas; 10 dB from the standard values to compensate for exposure in adjacent rooms connected by open doors; and 20 dB to represent the transmission loss of a typical frame house to noise from external sources (such as powered yard tools). Levels for about thirty typical home appliance and building noise sources adjusted in this manner appear in Table XXVI.

Table XXVII classifies the noise sources discussed in the previous section of this report into four categories: (1) Quiet Major Equipment and Appliances, characterized by operating levels lower than 60 dB(A); (2) Quiet Equipment and Small Appliances,

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TABLE XXIV. NUMBER OF INDIVIDUALS EXPOSED TO INDICATED APPLIANCES (MILLIONS — 1970) [38]

	Potential Exposure	Primary Exposure
Major Appliances		
Refrigerator	199	72
Clothes washer	183	66
Vacuum cleaner	181	66
Clothes dryer	80	29
Freezer	63	23
Air conditioner	60	21
Dishwasher	47	17
Food disposer	46	17
Trash disposer	-	-
Household Appliances		
Food mixer	163	59
Can opener	86	31
Sewing machine	100	36
Food blender	63	23
Electric shaver	80	25
Sliding knife	80	80
Floor polisher	32	10
Power Tools		
Saw, drill, etc.	40	13
Outdoor Equipment		
Electric Mower	6	2
Edger	3	1
Trimmer	12	4
Building Equipment (residential)		
Fan	160	90
Humidifier	15	5
Dehumidifier	13	1

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TABLE XXV. ESTIMATED NUMBER OF INDIVIDUALS EXPOSED TO DOMESTIC APPLIANCE NOISE (MILLIONS – 1965)*

Family Income ($ thousands)	Typical Appliance Possession	Total House-holds	Potential Secondary Exposure	Potential Primary Exposure: "Home-makers"	Potential Primary Exposure: Children Under 6 yrs.	Potential Primary Exposure: Night Workers	Total Persons Primary Exposed
Under 5	Mostly only essential	12.6	41	12.6	2.9	0.6	9.3
5 – 10	Wide variety of appliances	21.2	71	21.2	6.0	1.0	18.8
10 – 15		16.8	55	16.8	5.0	0.8	14.4
15 and over	Often most appliances	12.0	39	12.0	3.8	0.5	10.5
Total		62.8	200	62.8	17.7	3.0	53.0

*Calculated from average distributions and income information in Ref. 36.

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TABLE XXVI. SOUND PRESSURE LEVELS OF HOME APPLIANCES AND BUILDING EQUIPMENT ADJUSTED FOR LOCATION OF EXPOSURE [IN dB(A)]

Noise Source	Level of Operator Exposure	Level of Exposure to People in Other Rooms
Group I: Quiet Major Equipment and Appliances		
Refrigerator	40	32
Freezer	41	33
Electric Heater	44	37
Humidifier	50	43
Floor Fan	51	[illegible]
Dehumidifier	52	45
Window Fan	54	47
Clothes Dryer	55	48
Air Conditioner	56	48
Group II: Quiet Equipment and Small Appliances		
Hair Clipper	60	40
Clothes Washer	60	52
Stove Hood Exhaust Fan	61	53
Electric Toothbrush	62	42
Water Closet	62	54
Dishwasher	64	56
Electric Can Opener	64	56
Food Mixer	65	57
Hair Dryer	66	51
Faucet	66	51
Vacuum Cleaner	67	60
Electric Knife	68	60
Group III: Noisy Small Appliances		
Electric Knife Sharpener	70	62
Sewing Machine	70	62
Oral Lavage	72	62
Food Blender	73	65
Electric Shaver	75	52
Electric Lawn Mower	75	55
Food Disposal (Grinder)	76	68
Group IV: Noisy Electric Tools		
Electric Edger and Trimmer	81	61
Hedge Clippers	84	64
Home Shop Tools	85	75

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TABLE XXVII. ORDER-OF-MAGNITUDE ESTIMATES OF THE EXTENT AND DURATION OF EXPOSURE TO BUILDING EQUIPMENT AND HOME APPLIANCES

NOISE SOURCE	PRIMARY EXPOSURE*	DURATION†	SECONDARY EXPOSURE*	DURATION†
Group I: Quiet Major Equipment and Appliances				
Refrigerator	70	[illegible]	[illegible]	[illegible]
Fans	90	10	[illegible]	[illegible]
Air Conditioner	[illegible]	[illegible]	[illegible]	[illegible]
Humidifier	[illegible]	[illegible]	[illegible]	[illegible]
Clothes Dryer	[illegible]	[illegible]	[illegible]	[illegible]
Freezer	[illegible]	[illegible]	[illegible]	[illegible]
Group II: Quiet Equipment and Small Appliances				
Plumbing (Faucets, Toilets)	[illegible]	[illegible]	[illegible]	[illegible]
Vacuum Cleaner	[illegible]	[illegible]	[illegible]	[illegible]
Dishwasher	[illegible]	[illegible]	[illegible]	[illegible]
Clothes Washer	[illegible]	[illegible]	[illegible]	[illegible]
Electric Food Mixer	[illegible]	[illegible]	[illegible]	[illegible]
Electric Can Opener	[illegible]	[illegible]	[illegible]	[illegible]
Electric Knife	[illegible]	[illegible]	[illegible]	[illegible]
Group III: Noisy Small Appliances				
Sewing Machine	36	0.75	[illegible]	0.15
Electric Shaver	29	0.25	[illegible]	[illegible]
Food Blender	23	0.02	[illegible]	[illegible]
Food Disposer	17	0.10	[illegible]	[illegible]
Electric Lawn Mower	2.0	0.50	[illegible]	[illegible]
Group IV: Noisy Electric Tools				
Home Shop Tools	13	0.10	40	0.10
Electric Yard Care Tools	5	0.10	10	0.10

*In millions of persons

†In hours per week

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characterized by noise levels between 60 and 70 dB(A); (3) Noisy Small Appliances, characterized by noise levels between 70 and 80 dB(A); and (4) Noisy Electric Tools, characterized by noise levels in excess of 80 dB(A).

Group I: Quiet Major Equipment and Appliances

Group I contains the noise sources to which people are exposed for the greatest lengths of time in the home environment. Most building climate-control equipment, food-refrigeration appliances, and clothes dryers fall into this category. In view of the widespread distribution of equipment in Group I, it is indeed fortunate that this equipment is among the least noisy in the home.

In general, due to the low levels of noise produced by equipment and appliances in Group I, effects of exposure are either negligible or mild. Noise sources in Group I present no appreciable risk of hearing damage under conventional operating conditions. Under certain conditions, however, these noise sources can affect sleep. Of the noisier sources in Group I, only fans and air conditioners are likely to be present in sleeping quarters at night. These devices are characterized by nearly steady-state spectra because of their continuous operation. Differences in levels among operating cycles are small, so that peak noise levels are usually within a few dB of average levels. As such, these devices may delay the onset of sleep, but are unlikely to awaken many people. They may, in fact, facilitate sleep for those directly exposed to their noise, since they function as sources of masking noise which can suppress interference from other sources.

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The major effect of exposure to noise from Group I equipment is speech interference. Conversations in the immediate vicinity of the noisier sources of Group I would have to be conducted in somewhat higher than normal levels, or at slightly shorter than normal speaking distances.

The annoyance value of exposure to noise from Group I appliances is also minimal. The steady-state nature of their amplitude and frequency spectra are highly conducive to rapid habituation. Only rarely does one become sufficiently aware of refrigerator noise, for example, to become annoyed by it. Indeed, it is the noise sources of Group I which define the background noise environment of many homes.

Exposure to Group I noise sources has little or no bearing on startle and stress. Very few people are startled by the noise of their air conditioners or feel menaced by the implications of their refrigerator's whirring.

Considering the mild nature of most of the effects of exposure to noise from Group I sources, noise reduction is not an urgent need. Many appliances in Group I already operate at or near the level of background noise in the home, so that submerging them further into the background noise environment would serve little purpose. Those few noise sources in Group I which do produce noise levels appreciably above background levels could probably profit greatly from approximately 10 dB(A) of quieting. Such noise reduction, well within the capabilities of existing technology, would alleviate the undesirable effects of noise exposure from this group of appliances.

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Group II: Quiet Equipment and Small Appliances

Most of the noise sources of Group II are found in many American homes, although not all of the sources are as common as the major equipment and appliances of Group I. Noise levels in Group II are sufficiently elevated to render certain appreciable effects, particularly speech interference and annoyance. Fortunately, the typical pattern of exposure is an infrequent, brief encounter.

Of the three major effects by which noise impact is gauged in this report, noise sources in Group II produce only speech interference in significant measure. Hearing-damage risk is negligible, both for operators and for others who may experience secondary exposure. Since most of the appliances in this group require an operator, sleep interference is not a serious consequence of primary exposure. Secondary exposure probably affects daytime sleeping to some slight extent. Secondary exposure to plumbing noise in multi-unit residences could conceivably awaken as many as 35% of sleepers, although habituation probably reduces the percentage dramatically.

Operators of the appliances in Group II would find speech communication during operation quite difficult; conversations would have to be conducted with significantly greater than normal vocal effort or at very short ranges, and the intelligibility of fixed level speech (such as radio or television) would become marginal. The obvious mitigating circumstances, however, is the brevity of noise exposure typical of this group of appliances. In practical terms, the most likely consequence of exposure to this sort of short duration appliance noise is a temporary interruption of conversation.

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Annoyance is the most significant of the indirect consequences of exposure to noise from Group II appliances. While the operator may be summarily annoyed by the brief speech interference effects, people experiencing secondary exposure may be equally, if not more, annoyed. The annoyance of these people (such as neighbors in multi-unit residences or other family members in different rooms) is conditioned in part by the intrusive nature of the exposure and in part by feelings of lack of control of the noise source. Feelings of helplessness, exasperation, or frustration are themselves unpleasant and can produce further annoyance. Should secondary exposure become unduly or unreasonably common, physiological stress from emotional arousal might develop.

Primary exposure to the noise of these appliances is not likely to result in much task interference. This is true simply because it is the undemanding and highly practiced task at hand that is generating the noise. Exposure to appliance noise for people other than the operator could interfere with certain highly sensitive tasks. Generally, however, considering the usual brevity of exposure, such task interference would be the exception rather than the rule.

A 10 dB(A) reduction of noise levels produced by appliances of Group II would be a useful and worthwhile endeavor. Many of the effects of secondary exposure would become negligible, while the speech interference effects for the operator would be considerably reduced. It is clear from Table XXVII that the single most common source of noise exposure in the home is plumbing. Better design of plumbing fixtures would have a gradual but significant effect in making multifamily residences less noisy. Sales resistance to less noisy products (including the much-discussed "quiet vacuum cleaner") may be expected to diminish as the public becomes more noise conscious.

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Group III: Noisy Small Appliances

The distribution and exposure patterns of noise sources in Group III continue the trend observed in Group II. Group III appliances are found in fewer homes than the appliances of the preceding group. Exposure to their noise is for equally brief periods at long intervals. Both of these factors tend to moderate the impact of the relatively high-level noise developed by these appliances.

Hearing-damage risk can no longer be dismissed as of minor importance for this group of noise sources. While it is true that average exposure is measured in fractions of hours per week, it is very likely that certain elements of the population are exposed to one or another of Group III source for prolonged periods of time. Some seamstresses, for example, could easily be exposed to several hours of sewing machine noise daily. Yard care specialists might be exposed to equivalent amounts of lawn mower noise. Although even these exposure durations would not constitute an imminent hazard to hearing (in the sense that they would be unlikely to lead to sizeable permanent threshold shifts for many years), they would nevertheless hasten eventual hearing damage in the context of cumulative exposure from many sources. In Miller's [16] terminology, noise sources in Group III would be rated "yellow" (cautionary) with respect to hearing-damage risk.

Speech interference is severe. Operators receiving primary exposure to noise sources of Group III would not attempt conversation during the brief periods in which the appliances are used, although communication by shouting would still be possible. Secondary exposure to the noise of Group III sources would also interfere somewhat with verbal communication. The principal

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form of interference, however, would be degradation of speech intelligibility rather than more severe disruptions of conversation.

Since appliances of Group III require operators, sleep interference effects of primary exposure to their noise are negligible. Sleep interference effects of secondary exposure to this set of appliance noises also tend to be low, both because the noise exposure often occurs during hours during which sleep is uncommon and because the very brief periods of exposure occur only infrequently. Of course, the tendency for more mothers to be employed outside the home during the day constrains their use of appliances to evening hours, when the attendant noise levels may interfere with family social activities and the sleep of young children.

Annoyance is once again the chief indirect effect of exposure to noise from Group III sources. The operator himself may find the noise signature of the appliance unpleasant, particularly if it contains pure tone components or a highly variable temporal distribution of levels. Secondary exposure to these noises is also likely to be annoying, particularly if the people exposed to the noise feel that they are deriving none of the benefits of the appliance's use.

Task interference, startle, and stress reactions are all plausible consequences of exposure to this sort of noise. As usual, however, difficulties in assessing the unexpectedness of the intruding signal or the nature of background activity make precise prediction of the magnitude of these effects impractical.

Reduction of noise produced by appliances of Group III could substantially reduce the levels of hearing-damage risk and speech interference. The operator's annoyance with the noise signature of an appliance could also be affected by noise reduc-

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tion, but special attention would have to be paid to the spectral characteristics of the appliance. All of the effects of secondary exposure to noise from this appliance group would be significantly lessened by a 10 dB(A) reduction of noise output levels.

Group IV: Noisy Electric Tools

Group IV contains the appliances which produce the highest levels of noise exposure in the home environment. Considering the potentially serious effects of exposure to such levels, it is fortunate that the distribution of sources is quite restricted. As may be seen from Table XXVII, only about 250,000 electric yard care tools have been sold, and only about 12 million electric shop tools are in use. Further, the use of such tools is probably concentrated in nonurban areas where secondary exposure effects are not as widespread as they might be in multi-unit residences.

Hearing-damage risk can be great if exposure to the noise levels of Group IV sources is habitual or prolonged. Hobbyists who engage in regular use of power tools are likely to receive considerably more than the average six minutes per week exposure noted in Table XXVII. Many such tools (saws, drills, routers, etc.) are operated within a few feet of the user's ear, making hearing-damage risk even more probable. In Miller's (1971) terminology, such tools can produce "orange" or even "red" hearing damage risk if exposure is prolonged. It is doubtful that any major risk of hearing damage is encountered in secondary exposure, owing to the much lower levels experienced.

Speech interference effects of exposure to noise of Group IV sources can be of sufficient magnitude to preclude verbal communication in any form other than shouting directly into the

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[illegible] be loud enough to require conversation to be conducted at high levels of vocal effort or at very short distances. As was pointed out earlier, however, relatively few people are affected by such secondary exposure, and those who are affected are exposed for only brief intervals.

Sleep interference effects of exposure to Group IV noises could be quite serious were the hours of use of Group IV appliances to coincide with hours of uninterrupted sleep. Primary exposure, of course, is not a problem here, but even secondary exposure can reach levels in the vicinity of 60 to 70 dB(A). Data from the Wilson report [58] may be interpreted as predicting that such levels will awaken one-half of all sleepers and about one-third of all people would find it difficult to fall asleep. Use of electric yard care tools at night is unlikely, but home shop tools are often used at night.

To the extent that noise exposure to such high levels is perceived as avoidable or unnecessary, annoyance effects are probably quite pronounced. A neighbor's noise, particularly at such high levels, is rarely welcome. The high noise levels produced by these tools may also interfere with the very tasks the operators are attempting to accomplish. If noise levels are sufficiently high to mask warning signals or other unexpected acoustic signs of danger, the safety of the operator and his efficiency may be compromised. Stress produced through prolonged exposure to noise levels characteristic of Group IV tools may be appreciable, particularly if exposure is involuntary.

Considering the seriousness of the effects of exposure to noise of appliances in Group IV, application of noise reduction techniques is urgently needed. Reduction of noise levels by as

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little as 10 dB(A) would have immediate benefits in reducing the hearing-damage risk to the operator and reduction of the speech interference and annoyance-related effects for those receiving secondary exposure.

Summary of Effects of Appliance Noise on People

Tables XXVI and XXVII summarize the impact of appliance noise on people in concise terms. Table XXVII contains an account of the extent and duration of noise exposure from all four appliance groups in terms of millions of person-hours per week. The reader is reminded of the cautions expressed in the summary of Sec. 3.2.1 for the interpretations of figures expressed in person-hours. Table XXVIII relates person-hours of exposure directly to the major criteria of Sec. 3.1.

3.4 Projections of Construction and Appliance Noise to the Year 2000

Projecting conditions to the year 2000 involves a number of uncertainties. One of these is the exponential rate at which technology is evolving and affecting society. As pointed out by Sir Arthur Clark*, life in the year 2001 will be as different from the present as the present is from 1890. Who – in 1890 – could have realized the impact that electricity and the automobile would have both on life style and on the environment? Technological innovation, however, is not the only factor to be considered. One simply cannot account for future changes in social attitudes. Although a few far-sighted technologists may have predicted in 1940 the capability to transport passengers at

*Lecture to the Arlington Library Association, Arlington, Mass. (Sept. 1970).

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TABLE XXVIII. ORDER-OF-MAGNITUDE ESTIMATES OF EXPOSURE TO HOME APPLIANCE AND BUILDING EQUIPMENT NOISE EXPRESSED IN MILLIONS OF PERSON-HOURS PER WEEK

Noise Source	Speech Interference*		Sleep Interference*		Hearing Damage Risk	
	Moderate (45–60)	Severe (>60)	Slight (35–50)	Moderate (50–70)	Slight (70–80)	Moderate (80–90)
Group I: Quiet Major Equipment and Appliances						
Fans	[illegible]		[illegible]		[illegible]	
Air Conditioner	[illegible]		[illegible]		[illegible]	
Clothes Dryer	[illegible]		[illegible]		[illegible]	
Humidifier	[illegible]		[illegible]		[illegible]	
Freezer	[illegible]		[illegible]		[illegible]	
Refrigerator	[illegible]		[illegible]		[illegible]	
Group II: Quiet Equipment and Small Appliances						
Plumbing (Faucets, Toilets)		[illegible]	[illegible]		[illegible]	
Dishwasher		[illegible]	[illegible]		[illegible]	
Vacuum Cleaner		[illegible]	[illegible]		[illegible]	
Electric Food Mixer		[illegible]	[illegible]		[illegible]	
Clothes Washer		[illegible]	[illegible]		[illegible]	
Electric Can Opener		[illegible]	[illegible]		[illegible]	
Electric Knife		[illegible]	[illegible]		[illegible]	
Group III: Noisy Small Appliances						
Shaving Machine		[illegible]		[illegible]	[illegible]	
Electric Shaver		[illegible]		[illegible]	[illegible]	
Food Blender		[illegible]		[illegible]	[illegible]	
Electric Lawn Mower		[illegible]		[illegible]	[illegible]	
Food Disposer		[illegible]		[illegible]	[illegible]	
Group IV: Noisy Electric Tools						
Home Shop Tools		[illegible]		[illegible]		[illegible]
Electric Yard Care Tools		[illegible]		[illegible]		[illegible]

*These figures are not directly interpretable in terms of permanent loss of hearing or speech interference (see text).

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supersonic speeds, it is doubtful that they could have predicted that such a technologically feasible system would be abandoned largely because it was expected to make too much noise.

Although any long-term predictions are fraught with such difficulties, one can still make educated guesses with a reasonable level of confidence. Rather than merely extrapolate existing conditions to the indefinite future, we try to be somewhat quantitative by projecting the impact of construction and appliance noise on the basis of existing forecasts of population, family size, gross national product, and trends toward urbanization. Construction activities will continue to follow such growth patterns, although the character of construction may change significantly with greater use of prefabricated materials and the introduction of new kinds of equipment. Similarly, ownership of appliances has been found to be a function of family income level, and we use their relationship to project the growth of appliance use in the generally more affluent households predicted for the year 2000. Also, rather than trying to account for conflicting trends and changing attitudes, we project the extent of exposure with the assumption of no change in noise level for a given equipment or appliance type and consider only major trends that can be easily identified.

We use the following data, taken from the U.S. Census Bureau, for projecting the increase in exposure to construction and appliance noise:

	1970	2000	Ratio
GNP (billions of 1958 dollars)	720	2240	3.2
Total Population (millions)	200	293	1.45
Total Number of Households (millions)	63	104	1.65
People per Household	3.17	2.8	0.9

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3.4.1 Construction activity

Given the predicted increase in population and in financial resources, one can expect fairly extensive building activity. However, the urban areas have limited space available for new building; thus, the trend is for areas outside those now identified as central cities to become urbanized. Figure 24 illustrates this trend for single-family, multi-family, and nonresidential construction activities. With available land becoming more and more scarce within the central city, the building of single-family and multi-family dwellings will continue to decrease sharply. In 2000, we can expect to find approximately one-third the number of residential construction sites as were active in 1970. Nonresidential building is expected to increase. In areas outside the central cities, both residential and nonresidential construction should increase significantly. Nonresidential building activity is expected to increase by over 50% as the present suburbs become urbanized. With this general trend in mind, we use the data given above to project the expected increase in exposure to noise from construction activities.

Nonresidential

We assume that the level of nonresidential construction activity in any given year is proportional to the real Gross National Product (GNP) for that year. To find the nonresidential construction activity for any particular year, the ratio of the GNP for that year to the 1970 GNP is multiplied by the number of nonresidential sites built in 1970 (Table X). The resulting total construction figures are apportioned between "central cities" and "other metropolitan areas" in the same proportions as occurred in 1970. Despite the expected decrease in total con-

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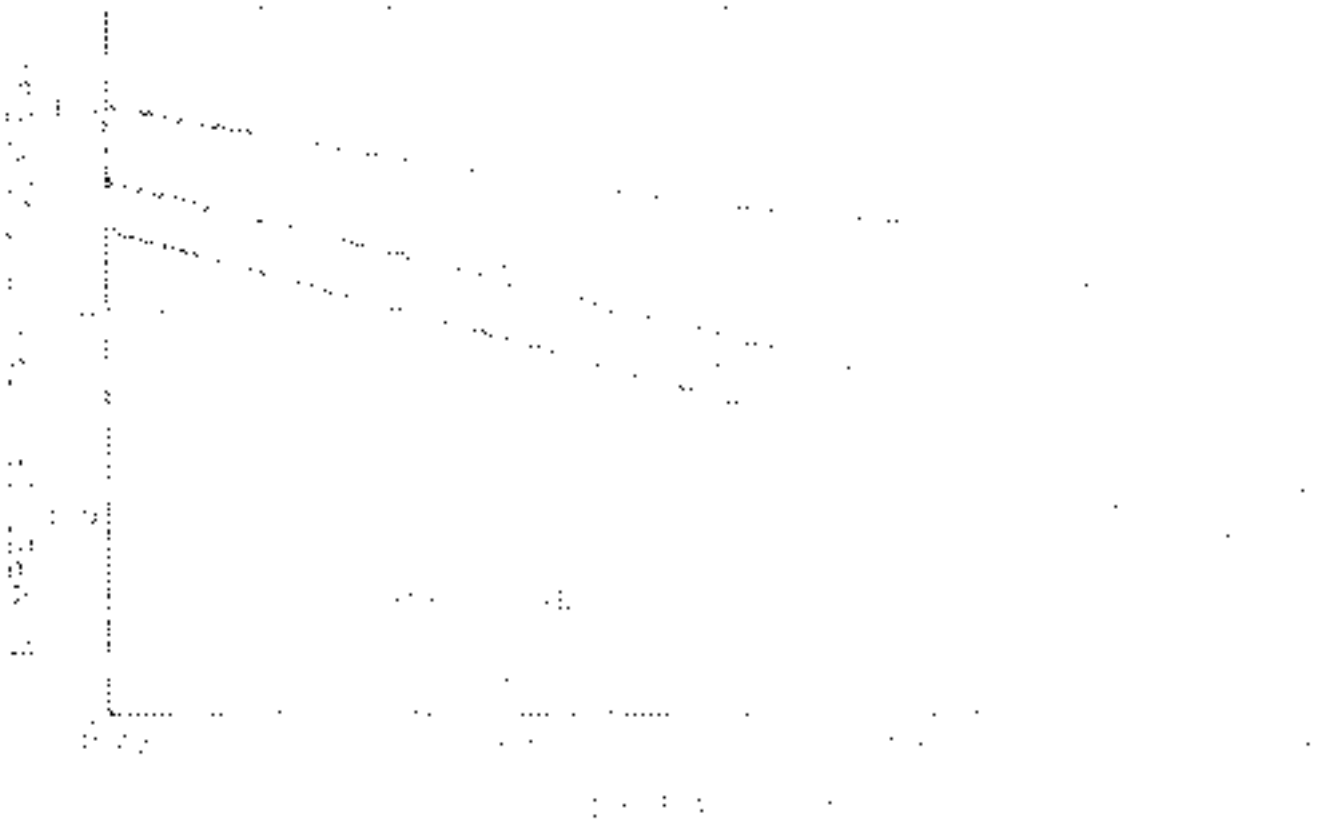

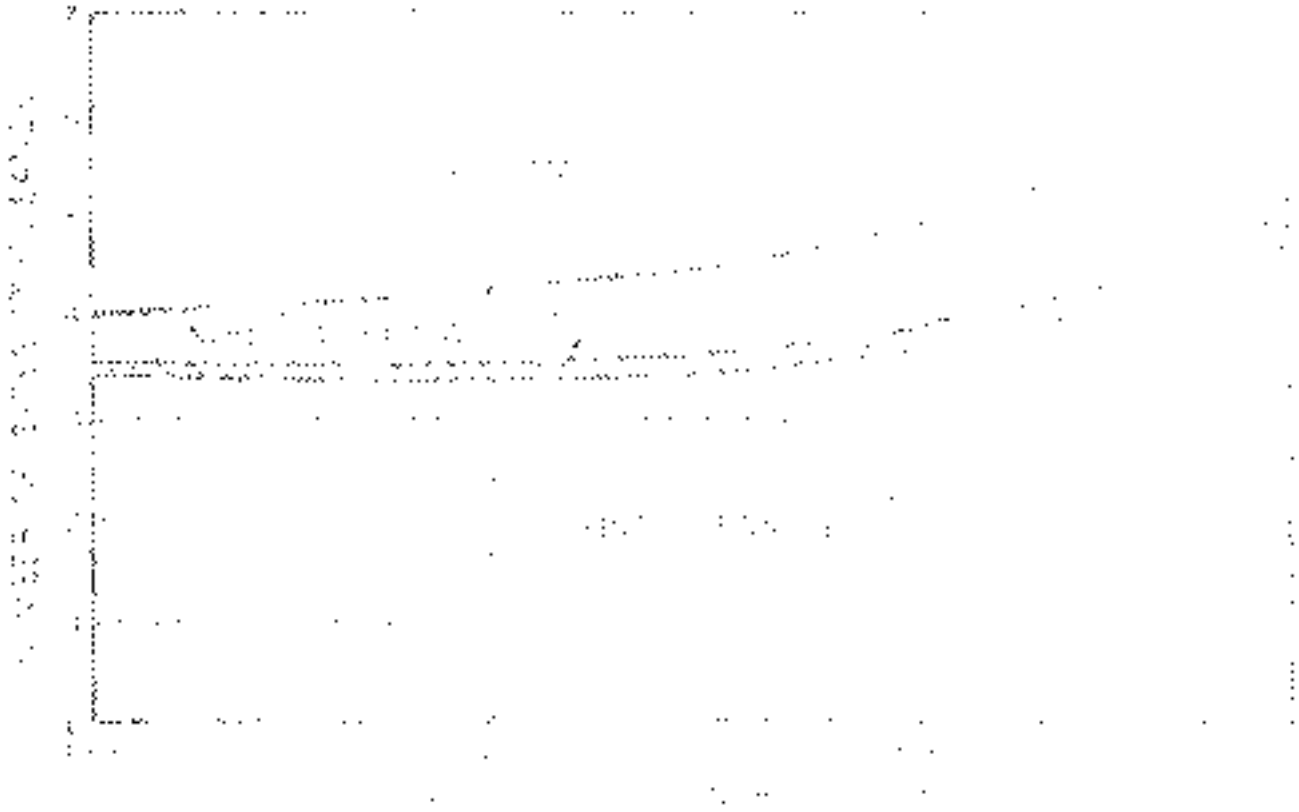

struction site within the central city, nonresidential sites are expected to increase.

Residential

We assume that the population and population density of central cities will remain at their present levels until the year 2000, and that most residential construction in central cities will be for the purpose of replacing decayed units rather than for housing new population. The number of construction sites will decrease due to the established trend toward an increasing population of multi-family dwellings over single-family dwellings. (Two- to four-family houses, which represent a negligible fraction of total construction, are here included in the total for single-family housing.)

For metropolitan areas other than suburbs, the number of units constructed in any one year is assumed to be proportional to the population increase in the previous ten years. To estimate this increase, we project the total metropolitan population by multiplying the projected total national population by the estimated proportion of the population living in metropolitan areas. All the increase in metropolitan areas population for a particular year is ascribed to noncentral city areas.

Roads

A simple but plausible indication of road construction activity, is the population level. Clearly additional people will require additional roads, the capability of rapid transit being small at present. However, the urban areas have limited space for new roads, and urban residents are expressing increasing opposition to new road construction on grounds of aesthetics,

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pollution, and the community dismemberment concomitant with the installation of limited access highways. Thus, it would seem unlikely that road construction will rise as fast as other measures such as the GNP. We therefore project the future level by multiplying the present level of activity by the ratio of the projected population divided by the current population.

The number of people affected by construction sites is computed in the manner described in Sec. 3.2.1. Population densities for all metropolitan areas are assumed to be constant with time – 4500 people/sq mi for central cities and 2400 people/sq mi for other metropolitan areas. At any one site, people are apportioned to specific transmission loss intervals according to the method shown in Fig. 20. The resulting exposure to construction noise is given in Fig. 25 in person-hours. In this figure, multifamily residential construction has been included with nonresidential construction, since these types of building activities are quite similar. Note that the number of people exposed to noise from single-family dwelling construction declines steadily with time. This trend is more than compensated for by the rapid increase in nonresidential and multi-family sites – for which the duration of construction is typically six times greater than the duration for single-family houses. Thus, the number of person-hours of exposure is expected to increase by about 50% in the next 30 years.

3.4.2 Appliance use

We assume that the probability of future appliance ownership as a function of income level will remain the same and that appliance costs will remain approximately the same in current dollars. With these assumptions in mind, we base our approximation of appliance use on projected population, family income,

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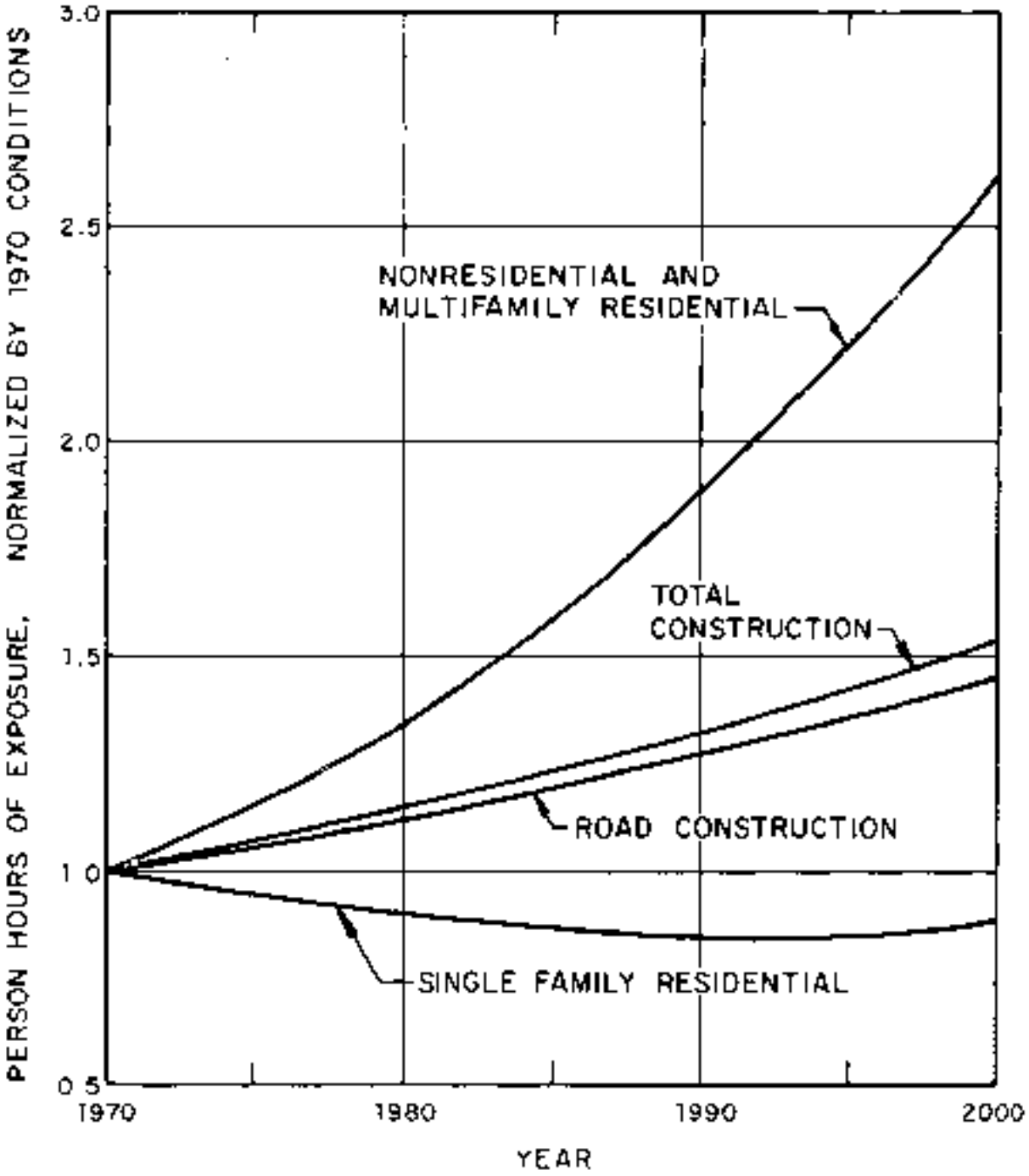

FIG. 25. PROJECTED CHANGE IN EXPOSURE TO CONSTRUCTION NOISE, ASSUMING NO CHANGE IN NOISE LEVELS.

and income distribution. This estimation is likely conservative as some appliances are continuing to increase their acceptance in all income levels, although their growth of acceptance is low at the higher income levels where some appliances have nearly saturated the market. For those appliances for which insufficient information is available on appliance possession at the various income levels to make the projection described above, we estimate future possession from current marketing information on percentage of replacement sales and on market penetration.

In projecting future impact, we estimate that the appliance usage will remain approximately at current levels. Supporting this assumption is the little deviation shown in average time spent by homemakers over the last forty years.

Figure 26 illustrates the increase in exposure to appliance noise by plotting hearing-damage risk and speech and sleep interference in person-hours of exposure. As explained in Sec. 3.1, these three effects are among the most salient and tangible consequencies of noise exposure and thus can be most readily interpreted in nontechnical terms. As can be seen on Fig. 26, we project that number of person hours during which people will be exposed to the risk of hearing damage will more than double in the next thirty years, as will the number of person-hours during which normal conversation will be difficult and people will be either awakened or prevented from falling asleep.

As explained previously, we have not taken into account certain trends, discussed in Sec. 4, which are having some effect on the noise levels produced by construction equipment and appliances. However, one should note, when reviewing these projections, that industries are becoming sensitive to a growing concern about noise pollution among the general population. For

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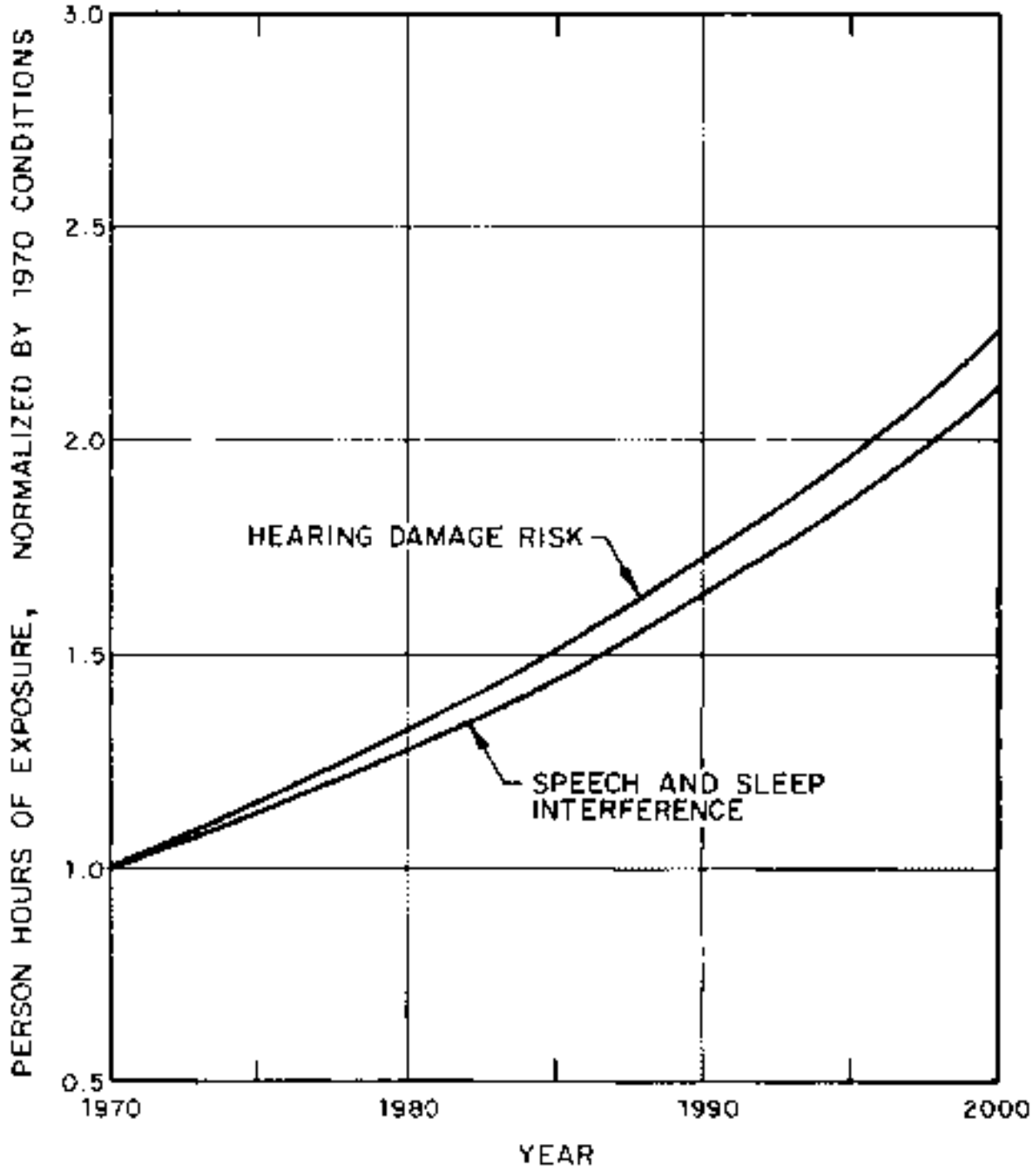

FIG. 26. PROJECTED CHANGE IN EXPOSURE TO APPLIANCE NOISE, ASSUMING NO CHANGE IN NOISE LEVELS.

example, construction equipment has become noisier as it has become more powerful; yet, one manufacturer has developed and is marketing a quiet air compressor. Conversely, refrigerators and air conditioners have become noisier as manufacturers have strived to meet market-place demands for extra features and smaller size. Thus, rather than try to account for an infinite number of variables, we have assumed no change in noise levels for both construction equipment and appliances. We feel that this method has resulted in reasonable near-term projections, if no noise control action is taken.

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4. INDUSTRY EFFORTS

4.1 Introduction

Efforts by industry to quiet products are usually motivated by two factors: market place demand and government regulation. The consumer can exert pressure on industry by electing to buy or not to buy or by selecting a competitive brand that produces less annoying noise levels. This kind of "consumer regulation" can be very effective - particularly with regard to appliances — in that manufacturers are quick to respond to consumer tastes. However, consumer pressure can also subvert efforts a manufacturer may wish to make; for example, housewives often associate the noise produced by a vacuum cleaner with its ability to clean — the noisier the machine, the more satisfied a homemaker may be with its performance. In any event, the purchaser can apply direct pressure to the industry.

Public pressure, on the other hand, is usually very ineffective. The only recourse for people who do not own the noise sources to which they are exposed is to register a complaint. Such complaints have no effect whatsoever unless enough exposed people organize and concentrate their efforts on a particular source. This kind of community response may eventually result in government regulation.

Our analysis of industry efforts to quiet construction equipment, appliances, and building equipment was organized as follows:

- We constructed a matrix of common products and significant manufacturers.

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- We rank-ordered products as to approximate magnitude of noise impact or need for quieting.
- We rank-ordered manufacturers as to their importance in the product area.
- We examined the resulting manufacturer/product "intersections" with a view toward organizing a number of interviews that would cover important products and leading firms and still be within the time and effort constraints of the study.
- We developed an extensive interview format both to guide the interview and to provide a standardized method of reporting. (Full use of this format was not possible within the constraints of this study; it could be useful, however, in the event that industry efforts are to be examined in more detail.)
- Under guidance of the format developed, we collected subjective data and objective observations; this information forms the basis for representative generalizations cited in this report.

As expected, the industry is concerned about releasing data which might disclose proprietary ideas or expose a competitively sensitive area of operations. Accordingly, identity of sources is carefully safeguarded herein. This need for corporate security has limited our collection of statistically meaningful data; the trends observed, however, are clear and, in themselves, undoubtedly represent the noise control environment in industry.

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4.2 Construction Industry Efforts

We view the construction industry as consisting of two major sectors: equipment manufacturing and equipment operation (i.e., building construction). The functions of these two sectors of the industry are so different as to warrant separate discussion.

4.2.1 Equipment operation

Section 3.2 describes this sector of the construction industry in detail, identifying types and phases of site activity and describing the areas in which noise abatement can be achieved.

The industry has, in fact, done almost nothing to quiet site operations. Its attitude may be attributed in part to the fact that quiet equipment has not yet been made available on a cost-effective basis; however, a limited capability does exist for quieting a site by relocating or rescheduling equipment. This sector has not exercised its influence as a "consumer" to bring pressure to bear on the equipment manufacturers, nor has it responded to public complaints. Hence, regulatory measures may be the only solution to the problem of construction site noise, and such regulations are imminent.

4.2.2 Equipment manufacturers

There are approximately 2000 manufacturers* of construction equipment in the U.S. In total, these companies offer about 200 different products. For the purposes of assessing the state of noise control in this sector of the construction industry, we

*Defined by counting separately certain divisions of larger firms which have a highly identifiable product line.

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categorized 48 general types of products that are potentially significant noise sources. We group these product types into three orders of classification: (1) class of noise problem anticipated, (2) relation of equipment to function at the site, and (3) specific equipment names.

I. Engines and power trains

A. Excavating equipment

1. backhoes
2. clamshells
3. dozers
4. draglines
5. loaders
6. rippers
7. (power) shovels

B. Highway equipment

1. compacters
2. graders
3. pavers
4. pipe layers
5. pulverizer/mixers
6. rollers
7. rotary borers and drills
8. scrapers
9. street sweepers
10. trenchers and backfillers

C. Equipment to handle finished materials

1. cranes
2. fork (and similar) lifts
3. travel lifts

D. Mobile units

1. tractors, crawler
2. tractors, wheel
3. trucks

E. Power supplies

1. compressors
2. electric-power generators

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II. Interaction between equipment and materials (may include engines and power tools)

A. Equipment to handle bulk materials

1. bins (and hoppers)
2. concrete mixers
3. conveyors

B. Large impact tools

1. drop hammers
2. pile drivers

C. Medium impact tools

1. jack hammers
2. rock (vibrating) drills

D. Small impact tools (power)

1. impact hammers
2. impact wrenches
3. riveters
4. stud drivers

E. Rotary tools

1. bench drills
2. grinders
3. hand drills
4. hand saws
5. table saws

III. Miscellaneous (may include sources characteristic of I and II above)

A. Pumps

1. concrete pumps
2. stripping pumps
3. well-point pumps

B. Other

1. burners and heaters
2. sand blasters
3. screeds
4. concrete vibrators

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Two assumptions underlie the terminology selected: (1) equipment in transit under its own power is a truck or tractor, even though when working it may be a dozer or a crane, and (2) classification by function at the site is arbitrary since many types of equipment have several uses.

Manufacturers of construction equipment can be classified according to size/type of equipment produced as

- large companies producing large volumes of essentially similar, large items of machinery;
- medium-size companies producing "customized" production runs of more limited numbers, usually of smaller machinery; and
- manufacturers of power hand tools and pneumatic equipment.

Our interview program was organized to cover the two major acoustic source types (prime-movers and power trains) and the forty-eight types of products and three classes of companies identified above. We concentrated our efforts on significant leaders in the industry and companies producing a wide variety of products that have high levels of noise output:

- Of the ten manufacturers intensively interviewed, about eighty product analyses resulted.
- Eight of the firms produced equipment in which the prime-mover or power train is a significant source of noise; two companies produced only power hand tools.

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- Three companies were high-production manufacturers; seven manufactured customized equipment.
- Three-quarters of all the products where subjected to specific analysis, covering all significant noise sources except impact tools and pumps.
- The ten firms represent a significant part of the industry: Of the two thousand firms nominally in the industry, about twenty comprise the industry "core". Eight of the ten interviewed are part of this core.

Our overview of the equipment manufacturing industry showed that:

1. Large companies closely resemble the Detroit assembly-line manufacturing concept. They tend to have large engineering staffs and are quite advanced in their efforts toward developing quieter products. They are aware of the competitive advantage of quieting equipment but are also sensitive to price competition from smaller companies and foreign manufacturers.

2. Medium-size companies producing "customized" items tend to feel more keenly the competitive pressures of the market place. Competition comes not only from domestic and foreign companies but also from other types of equipment that can perform the same operation. Engineering staffs tend to be small and product-oriented, interested only in improvements that incorporate new technology (e.g., hydraulic vs mechanical drive). Little effort has been made toward quieting products, with pressures of current and planned noise control legislation being passed on to their suppliers. They generally have no plans or see no need for developing greater noise control technology.

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3. Manufacturers of hand power tools and pneumatic equipment fall into two categories: large multiproduct companies which tend to mount considerable R&D efforts and smaller companies which are not so innovative but which do follow trends developed by the larger companies. Noise control has been pursued rather vigorously by these larger companies as part of their product improvement programs, but effective quieting of hand tools is difficult because of such practical constraints as size and weight.

Our in-depth interviews revealed that in the past the industry's concern with noise problems has been directed primarily to protection of the equipment operator. The impetus for this concern came largely from noise codes imposed by foreign countries, where some U.S. equipment has had to be "reworked" by foreign distributors. Three of the eight "large equipment" companies interviewed had previously quieted equipment to enter European markets. Switzerland and Belgium, for example, specify permissible noise levels for such machinery; in addition, foreign manufacturers make quieter machines and set a competitive pace in foreign markets. American manufacturers seem to have met this competition by custom-designing equipment for export. There is an implication here, of course, that many American machines marketed abroad have been quieter than counterparts that were marketed domestically; however, this implication has not been verified by this study.

Half the companies interviewed are currently undertaking programs to quiet their products for the domestic market for the first time. Many of the present programs have been started this past year and are aimed primarily at protecting operators, so as to conform to impending legislation/regulation regarding occupational health and safety. Only one of the companies indicated

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that purchasers complain about protection for operators on their own initiative, and only one case emerged where a union had lodged a formal complaint. Six of the eight companies described pressures on behalf of operators that originated with existing or proposed governmental action.

Many manufacturers feel that the efforts they are now making on behalf of equipment operators will pay off in meeting future noise limits designed to protect the public. Perhaps, one of the most promising future approaches has been taken by one of the manufacturers of large equipment, who has charged design teams with the responsibility of integrating noise control into the overall design of his next generation of products and has set up review boards to evaluate new designs from all standpoints, including noise.

Four of the eight companies specifically mentioned the recently enacted Chicago noise ordinance as contributing to their specific future objectives. The industry generally anticipates EPA-administered federal control; the visits of our interviewers reinforced this feeling. Two companies believe that pressures for quieting will increase with time - apparently as a result of an increasing public awareness of noise as an environmental pollutant.

Although the industry has become increasingly aware of the pressures for noise control and has already made some efforts in this area, manufacturers must cope with economic pressures that argue against noise abatement. Some companies feel that the intensity of competition sets the limits on what price the market will bear. One of the industry's leaders was concerned that purchasers will continue using old equipment if prices rise significantly. Other industry leaders point out that foreign-made machines (some of them already quieted) will enter

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the American market if prices rise appreciably. One company predicted that a small rise in the price of truck-mounted concrete mixers would lead to the introduction of alternative methods for handling concrete delivery and production.

Companies who feel that the demand for their products is great enough plan to pass quieting costs onto the consumer, although such threats as foreign competition and alternative methods put limits on this process. The question here is how fast the industry dares to move. One limit on rapid movement is price competition. One company may be able to beat its competitors to the market with a quiet machine, but it does not dare raise prices substantially in the face of competition. Different companies approach this problem differently. Most express the intention to meet or exceed the competition, but they feel that any great competitive advantage they gain through an all-out effort to quiet their products would be short-lived. One company sees its competition as being extremely severe, and fears that it may not be prepared for the next round of quieting, while another company has actively launched a program designed to produce quieter machines than its competitors at lower costs than the competitor will incur.

This company and some others expressed the concern that often accompanies any industry leadership; i.e., a company may invest large sums in quieting which will thus increase the cost of products, while another company that refuses to quiet products keeps it prices low and may successfully challenge noise regulation in the courts.

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While all companies regard cost as an immediate — and perhaps as the ultimate — constraint, two other constraints become paramount if and as costs diminish: time and technology. Three companies, each in a different fashion, represented that costs can be traded for development time; i.e., more time for development would reduce the cost of competition, allowing quieting techniques to be integrated into planned engineering efforts and to be an integral part of the seasonal progression of models. The very company that is setting out to achieve the most quieting for the least cost is the one that feels that technology will eventually supercede cost as the principal factor that limits quieter equipment.

At another firm, the technical limitations are spelled out in terms of: (1) loss of equipment power through increased muffling; (2) increase in the difficulties and cost of maintenance; (3) fire hazards through using insulating materials that can become oil-soaked; (4) unsafe operation by suppressing or distorting the noise "signals" upon which operators depend for safety; and (5) ineffective operation, by disturbing these same "signals", thus hindering the ability of the operator to tell how effectively he is operating.

The industry also voiced concern over the feasibility of noise abatement where equipment and materials being worked interact to become prominent sources of noise; e.g., concrete mixers (where the structure may be the noise radiator); jack hammers (where the tool and its driving media may be the offender); riveters (where the structure of the building may be the primary source); and pile drivers (where both the structure and the media may be significant sources). This "interaction" type noise source may be very difficult to quiet.

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However, no firm interviewed condemned noise limits out-of-hand, nor did they deny their inevitability. Six of the eight companies expressed the opinion that unless they quieted their products, their markets would disappear. Feelings varied from acceptance of inevitable reality to enthusiastic approval of the trend.

During the course of this study, members of the BBN team were actively engaged in the regulatory efforts of three cities and one state — Boston, Chicago, San Francisco, and Illinois. This work provided an insight into the mechanism of regulatory control from outside the construction industry. In addition, discussions were held with the Construction Industry Manufacturer's Association (CIMA) to obtain information about controls within the industry.

There are potentially four levels of regulatory bodies outside the industry: federal, state, city/town, and specialized local departments (city departments of health, air pollution control, zoning/building, etc.). The regulatory power exercised by these bodies is generally graduated into four steps: general standards (setting goals), enabling powers (granting power to a lower body), specific regulations (against which are judged infractions), and procedures (for measuring performance).

The target of the regulatory powers is either basic equipment performance (i.e., noise of new equipment as sold by manufacturer) or equipment operation (e.g., total noise emitted from a site). Regulations are usually aimed toward protecting (1) health (as in the hearing-protection section of the Federal Public Contracts Act) and (2) environmental quality (as in the construction site operating limits proposed for the city of Boston).

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No fixed pattern has yet emerged which interrelates the regulatory bodies, nature of powers, targets, or degree of protection. Current activity at all levels, however, has alerted the industry that controls are imminent. One significant set of controls already in existence limits the noise from new construction equipment sold in Chicago; dual controls are being proposed in Boston, to limit site operation noise and to restrict noise from new equipment. Enabling legislation exists (as in the General Laws of the General Court of Massachusetts), and enabling powers have been passed on through city ordinance (again as in Boston). Even though the Federal Public Contracts Act does not apply to local construction, its philosophy is impressed on the industry, and its effect is increasingly noted in the carryover of standards into new federal occupational health and safety legislation.

In summary, the regulatory bodies outside the construction industry have begun to exercise some influence in the area of noise abatement.

CIMA and the national standards-setting bodies of ASTM/SAE are both actively addressing the problems of measuring equipment noise and recommending quieting standards. The equipment manufacturing industry would like to coordinate its activities with those of its closely related standards-setting bodies (see Appendix B for discussion of a paper prepared by CIMA). Self-regulation via industry-initiated standards is presumably somewhat hindered by federal anti-trust provisions.

As yet, no broad controls have been established. It is assumed that the example set by the City of Chicago equipment noise ordinance will stimulate other similar action, eventually resulting in a proliferation of standards put forth at the local

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level. As an alternative, the industry would welcome one comprehensive overriding standard. However, some anxiety was expressed as to the reasonableness of future legislation, specifically that sufficient time would not be allowed to conform to such a standard. Typical new product lead-times are on the order of five years. Industry believes it could meet noise goals without excessive cost to the consumer, if given enough time.

In general, it appears that industry is aware that it will be forced to comply with ever-tightening noise standards. While this fact seems to worry everyone to some extent, most manufacturers are confident that they will meet the limits set by current and anticipated legislation/regulations/standards. In fact, all but one of the companies interviewed stated their noise control goals in terms of such limits, frequently specifying either the levels stated in the Walsh-Healey Public Contracts Act for operators or those set forth by the Chicago ordinance for public exposure.

Early abatement efforts made by the manufacturers have been highly successful; thus, the industry is somewhat optimistic about its ability to cope with pressures for noise control. However, it is important to note that the industry has begun with the most obvious and the easiest tasks it must accomplish. Future tasks are apt to be far more difficult and costly; therefore, future struggles to comply with more stringent standards could possibly influence company attitudes, making them less receptive to regulation.

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4.3 Building Equipment and Appliance Industry Efforts

Throughout this study we have viewed the home appliance industry as consisting of two major sectors: owner-controlled appliances and major building equipment (such as heating and plumbing systems in multifamily dwellings). We continue this division, since (even though certain large companies produce both types of equipment) the nature of the marketing and of the pressures for noise control are quite different.

4.3.1 Building equipment

The quieting of building equipment involves the contributions and decisions of an interdependent chain that consists of owner, regulatory body, architect, engineer (both mechanical and structural), equipment, and manufacturer. For purposes of analyzing industry programs, three sectors of this network are significant: (1) the equipment manufacturing sector; (2) the design sector, and (3) the control sector.

Overall, quieting of the equipment in a building thus becomes a compromise between the elements of the chain on matters of design, budget and technical performance.

Manufacturing Sector

Manufacturers of building environmental control and services equipment are currently aware of the significance of quieting their products; they realize that they have a role to play in quieting at the source. The manufacturer does not have complete control over the quieting of the finished system; here, he is dependent on the architect and the mechanical/structural engineers as to location, local architectural treatment, and surrounding structural design.

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Given this ambiguity, manufacturers in the past have been uncertain as to what to quiet, how much to quiet, and even how to measure progress in quieting. In a recent review of a wide variety of currently available equipment from a variety of manufacturers, several types of equipment showed spreads as large as 10 dB within the type. However, no line of equipment from a single manufacturer was characteristically noisy or quiet.

Currently, manufacturers are trying to solve problems of rating their equipment. This effort is being channeled largely through the trade associations and the technical societies. The fundamental aim of this effort is to furnish the architect and engineer with ratings that they can utilize in designing their equipment layouts and in specifying their equipment.

In the compressor industry this step has been substantially achieved. The result is that competitive criteria have become clearer and that the major technical barrier to quieting is common to the industry as a whole. (It is the blade-rate scream from the impeller.) It is apparent that if a manufacturer could make a technical breakthrough in this area, he would achieve a strong competitive advantage. There is some question, however, as to whether any single manufacturer can afford the development costs that such a breakthrough would entail.

When rating methods have been developed and when, as a result, the technical problems become better defined, manufacturers of building equipment will face three basic alternatives in reducing the noise from their products that reaches the building's occupant: (1) redesign of the equipment, (2) enclosure of the noise source by the manufacturer and (3) passing the problem along to the building designer.

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Design Sector

The mechanical engineer is starting to add acoustic performance of equipment to the list of building specifications. These specifications are passed back to equipment manufacturers.

The mechanical and structural engineer interface with the equipment manufacturer in the area of containment of noise vs quieting at the source. Trade-off between the two approaches must be considered on both sides. Enclosures, if chosen often become a manufacturer's problem because of the need to bring proper controls and services through the enclosure.

The same two factors face each other regarding size of equipment. The design sector wants compact equipment in order to increase usable space as well as to be able to move through doors, while the manufacturer tends toward larger equipment to favor quieting.

The architect meets the manufacturer at another interface that concerns equipment location, local architectural treatment and selection of structural system. Acoustically remote spaces are often not possible to be allotted to house equipment in view of the high cost of building space and the attendant desire to maximize revenue-bearing space. Architectural taste for openness in design and novel structural systems can often make the isolation of equipment spaces more expensive.

The designer faces a unique combination of equipment for every structure he designs. These combinations create unique problems of design. They also create unique patterns of emission. Thus in one building, the designer may be able to afford a fairly noisy piece of equipment because it will operate by itself or because it will operate in relative isolation. In another

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building he may require a very quiet piece of equipment to perform the same function because it may be operating among the other noisy machinery or in a location that makes the building users vulnerable.

Control Sector

Controls regarding building equipment acoustic performance emanate from four sources: (1) trade associations within the building equipment industry; (2) specialized technical societies also within that industry; (3) generalized professional technical societies (such as ASME, IEEE, etc.) serving all U.S. equipment industries; and (4) regulatory bodies (Federal, state and local).

The role of the trade associations is to set standards for rating the performance of equipment and to evolve guidelines for proper application of the equipment. Among the most active in dealing with noise control are:

- Air Conditioning and Refrigeration Institute
- Air Moving and Conditioning Association
- Air Diffusion Council
- Compressed Air and Gas Institute
- American Gear Manufacturers Association
- National Fluid Power Association
- Hydraulic Institute
- National Electrical Manufacturers Association

In contrast, the technical societies both within the building equipment industry and outside, serving all industries, are dedicated to developing measurement procedures and standardizing the

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techniques for making measurements and reporting results. Most active in the measurement area are:

- American Society of Heating and Refrigerating and Air Conditioning Engineers
- Institute of Electrical and Electronics Engineers
- American Society of Mechanical Engineers
- American National Standards Institute
- American Society for Testing Materials

Government agencies exercise control in three ways: (1) as regulatory agencies concerned with occupational health; (2) again as regulatory bodies concerned with community noise; and (3) as significant purchasers of equipment for use in public buildings or publically financed projects. The occupational health and noise control aspects of the Walsh-Healey Public Contracts Act has served as a pace-setter for establishing targets for the building equipment industry, although the federal act itself generally has little direct applicability to most of equipment currently sold.

As state and local governments extend their protection against occupational health hazards, they are tending to adopt the Walsh-Healey criteria. These enactments tend to put pressure on manufacturers and designers alike. The most active current issue arises from the establishment of a stringent specification (80 dB(A) at three feet) by the General Services Administration for machine noise in federal buildings.

Manufacturers are having difficulty meeting the G.S.A. standards through quieting at source, but G.S.A. replies that containment will solve the problem. In one instance, however,

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a substantial federal building project has not been able to attract qualified equipment bidders. Minimum property standards for FHA-assisted dwelling units have been in effect for a number of years. Some latitude regarding enforcement appears to be permitted to the directors of regional offices.

In total, the criteria for acoustic performance of building equipment are still in a state of evolution. More detailed discussion of standards is contained elsewhere in this report. Measurement procedures are still under development, and the current acoustic performance of standard equipment is still not fully understood within the various sectors of the industry. A system for rating equipment by category is seriously needed to give the control sector, designer and manufacturer a common language. The divergence of the city codes that do exist (15 dB spread) needs to be eliminated to reduce customizing requirements on the equipment manufacturers.

Summary of Pressures For/Against Quieting

a. For

- Quieting deemed a "necessity", no longer a "luxury"; tenants now in second or third generation of air conditioned buildings, and attitude toward quiet has matured to this point of view.
- Architectural desire for openness of design, new lightweight structural systems and economy of nonrevenue bearing space places premium on quieting of source.
- Mechanical engineers increasingly aware of need for quieting, hence now specifying acoustical performance.
- Occupational health and safety pressures spreading, following example set by Walsh-Healey Act.

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- Codes at city level to enhance community quiet.
- Quieting generally becoming cost-beneficial in eyes of building owners.

b. Against

- Technical barriers make next step too expensive for single manufacturer to attempt by himself.
- Lightweight and small equipment desired to fit into small allocated spaces and remain tolerant of light foundations.
- Specific quieting goals are not clearly set, and codes and regulations are confusing and contradictory.

c. Trade-off Must be Examined

- Containment via enclosure vs quieting source — which is more cost effective?

4.3.2 Home appliances

There are approximately 70 to 80 important manufacturers* of home appliances in the U.S. These companies offer 30 to 40 different products that are potentially significant noise sources. For the purposes of assessing the state of noise control within this industry, we rank-ordered specific appliances according to their relative importance with regard to noise abatement in and around the home.

- air conditioners,
- dishwashers,
- water closets,

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*Defined by observing company names and appliance categories in various well-established consumer journals.

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- other major appliances (clothes washers, dryers, refrigerators), and
- appliances whose noise output is interpreted as a measure of its efficiency (vacuum cleaners, blenders).

The industry is characterized by four major company/product mix categories:

- large, multidivisional companies producing a broad range of products;
- medium-size companies formerly specializing in a well-known product but now branching out to take advantage of a good name in the consumer market;
- small and medium-size firms who maintain a certain leadership character through continued specialization; and
- companies manufacturing "private label" appliances to be sold by others, usually by large retailers who contract for and control the product policies of a large volume of home appliances.

Our interview program was organized to cover leading manufacturers of a range of equipment as well as retailers and industry associations. We interviewed eleven manufacturers (or manufacturing divisions of large companies), two major retailers, and two industry associations. Twenty-nine products and ninety-six product/manufacturers were covered by this survey.

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Our overview of the industry's attitude toward noise control shows it to be so direct a function of market place pressure that noise control technology often exceeds application. Appliance manufacturers tend to maintain sophisticated R&D and product engineering staffs that are capable of delivering more noise reduction than market strategy can justify. In fact, some companies have tried — unsuccessfully — to market quiet products, such as air conditioners, vacuum cleaners, blenders, and hair dryers; others have developed a number of quiet prototypes that were not put into production.

Consumer research shows low noise levels are not highly valued by most customers. Several companies keep systematic track of customer correspondence, while the industry itself maintains a Major Appliance Consumer Action Panel (MACAP) that acts as a clearinghouse for complaints. These records, all of which concern major appliances, show relatively little complaint about noise. For example, only 9% of the letters to MACAP in the first eight months of 1971 were about noise.

The objectives for quieting household appliances seem to vary with the market pressures on particular products. With this observation in mind, we organize our discussion of noise control efforts around the "problem" appliances identified above.

Air Conditioners

There is probably more market pressure to quiet air conditioners than to quiet any other household appliance. Since air conditioners emit noise both indoors and out, they frequently affect not only the purchaser and his family, but also neighbors and passersby. Both kinds of emissions generate pressures for

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noise reduction. Pressure from neighbors takes the form of local noise ordinances that specify maximum sound-emission levels at a property line; this pressure is passed on to the manufacturer, as one company pointed out, by dealers or marketing men who are aware of the ordinances.

Dollar sales of room air conditioners grew almost eight-fold in the decade of the 1960's; during that time, indoor quiet emerged as a competitive dimension. Several manufacturers are currently engaged in competitive advertising campaigns to sell the quietness of their room air conditioners and are giving their products brand or model names that imply the quietness. Two large appliance manufacturers independently volunteered the opinion that quiet is becoming more important to purchasers every year. One of these indicated that the fact that air conditioning allows one to close the house against outside noise may soon become a sales argument in air conditioner merchandising. However, one leader in the current "quiet" race indicated that their top-line model is not selling well.

Most quieting effort for air conditioners takes place in modest engineering laboratories that are attached to the local production facilities. One such laboratory reports spending three man-years per year on air conditioner noise control; one man-year per year was a more frequently mentioned level of effort. While the product policy people generally reported that they were making maximal use of available quieting technology, the study project acousticians who initiated the interviews felt that current state-of-the-art technology was not being universally applied.

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Two estimates we received indicate that quieting room air conditioners adds 10 to 15% to their price. There may also be an inherent trade-off between quietness and efficiency (since one way to reduce air noise is to decrease air velocity). Sometimes, quieting results in increasing the air conditioner's physical dimensions, thus detracting from appearance as well as from convenience and ease of installation. There may also be a trend toward model lines differentiated by noise output — i.e., an expensive quiet air conditioner and a cheaper noisier model. One manager pointed out that there are anti-trust constraints against organizing industry consensus on noise levels.

Dishwashers and Food Disposers

The mechanical differences between dishwashers and disposers do not alter the fact that noise control pressures are similar and that the manufacturers' approach to quieting is similar. Thus our survey indicates that these two appliances logically group together.

Quiet is a saleable characteristic of dishwashers and disposers, although the pressures for quieting are not so great as for air conditioners. While we are aware of no advertising campaigns built exclusively on quiet, it is advertised with the same prominence given to power and reliability.

Noise levels from dishwashers and disposers are not currently under public regulation, hence the incentive for quiet comes almost exclusively from the purchaser. This gives rise to marked differences between models; if one wishes, one can buy an inexpensive, noisy dishwasher or disposer. Reports from the industry indicate that landlords frequently do just that.

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Noise emissions from these two appliances are not so completely under the control of manufacturers as in the case of other appliances; the manner of installation greatly influences structureborne and plumbing-borne noises.

Dishwashers, however, present a promising example of industry's response to the purchaser's desire for lower noise levels. In a 1970 survey by the United States Steel Co., 43% of dishwasher owners had no complaints about their appliance, but of those who did, more complained about noise than about any other aspect of its operation. Both survey data and marketing "lore" indicate that the purchaser who has previously used these appliances puts a higher value on quietness than does the new user.

The costs of quieting were estimated by one dishwasher manufacturer to be 10% and by another to add $1 to $2 to manufacturing costs. A disposer manufacturer felt that quieting would add 12% to a product cost, whereas a retailer of disposers estimated 16%. Quieting these machines might deny their availability to those least able to pay.

In the case of dishwashers, one manufacturer indicated the possibility of trade-offs between noise and maintenance costs, and reliability. Another indicated a trade-off between water velocity and quiet but expressed the opinion that there are no serious technical restraints to quieting dishwashers.

In the case of disposers, industry claims inherent problems with water and grinding noise (especially with the noise of grinding bones). Some noise is considered necessary to the user's safety, so he will know when the disposer is operating and when it has finished grinding.

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So far, a number of sophisticated techniques have been applied to dishwashers: isolation, damping, and parts re-design. Manufacturers of both dishwashers and disposers have tried to improve the quality of installation by providing carefully drawn instructions and flexible fittings. One company has reduced noise on its top-line dishwasher from 82 to 75 dB(A) (at an unspecified distance) since 1967 and plans a further reduction in the next few years. Another manufacturer expressed only the desire to keep abreast of the competition; this company tests each machine for noise, rejecting something under 1%.

None of the manufacturers interviewed intends to give up his noisier "economy" lines; goals did not seem to be appreciably influenced by the prospects of noise regulation.

The companies interviewed claimed to have adequate acoustic test facilities, although the efforts devoted to testing and to development varied widely in quantity and quality.

Water Closets

If evidence from mail order catalogues is reliable, quietness in water closets is a marketable attribute. Two top-line, "low profile" models prominently feature quiet in their advertising. One manufacturer indicated in an interview that placement of the height of the tank involves a trade-off between quiet and efficiency, and indicated that quiet designs may be less reliable, less efficient, and more expensive. Like dishwashers and food-waste disposers, economy-models are noisier than more expensive ones.

Currently, one company is trying to eliminate a water hiss that occurs when the tank is full.

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Other Major Appliances

Quieter clothes washers, clothes dryers, and refrigerators tend to be by-products of engineering originally undertaken with other objectives in mind. The classic case is a washing machine model that was incidentally quieted when two gears were removed from the power train to save cost. In the context of product improvement, noise is generally treated as a secondary design goal, although manufacturers are concerned that engineering changes may produce noisier products. For example, refrigerators are becoming larger *and* noisier as manufacturers seek to meet the demand for special options such as ice makers; a spinner-type washing machine produced higher noise levels when spinner speed was increased to 2000 rpm.

Two of four manufacturers interviewed make quiet models of washing machines that sell at a $10 to $20 premium; sales for both lines are disappointing. None of the other models of these companies is marketed on the basis of quiet nor do the mail-order catalogues feature quiet. The single exception is a spinner-type washer in which "quiet operation" appears in the small-type description. There is, then, relatively little evidence of pressure for quieting appliances of this type.

Yet, despite the weakness of market pressures, considerable quieting effort has gone into the design of these appliances, especially washing machines. One manufacturer mentioned six different quieting projects that have recently been completed or are underway. A refrigerator manufacturer mentioned an effort to avoid strange or unidentifiable noise. No specific efforts to quiet dryers were uncovered.

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Vacuum Cleaners

The manufacturers of vacuum cleaners believe that the market pressures are for noisy machines. The three manufacturers and one large retailer interviewed are all convinced that customers use noise as the basis for judging a machine's power. For example, after concentrated technical effort, a manufacturer had significantly reduced the noise from a canister model without reducing its cleaning capability. Housewives who participated in a marketing trial wanted to know "if the machines were really cleaning".

Neither of the large "private label" retailers we consulted mention quiet as a design goal. In fact, in advertising a nap adjuster, one company writes "... just slide the bar across until you hear the right cleaning purr". One company that carefully analyzes its correspondence from customers finds virtually no noise complaints about vacuum cleaners or any of its other portable appliances.

A reasonable level of engineering effort has produced feasible solutions to vacuum cleaner noise problems; according to all interviewed, however, these solutions are not being applied to products that are sold, because vacuum cleaner manufacturers and retailers do not sense a demand for quieter products. In fact, the sale of upright cleaners, whose beaters make them noisier, is growing at the expense of the sale of canister models. Apparently, the beater action of upright cleaners can better handle the new deep-pile weaves that make modern carpets harder to clean. There are technological limits to the quieting of upright vacuum cleaners, because of the interaction between the beater and the carpet, but the noise levels of production models seems to be determined by customer usage demand rather than by technological limitations.

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The company that developed the quiet canister cleaner employs a physicist who works full-time on noise-control studies. The company calls in noise consultants about four times a year and samples its customers at six-month and two-year intervals. They have given considerable attention to the problem of heater noise and estimate that solutions that would not reduce a machine's efficiency would add 50% to its price.

Another large company made a study ten years ago (at a cost of about $30,000) in which they developed ways of reducing vacuum cleaner noise in middle and high frequencies by about 10 dB(A). They have just contracted for a study of their competitors' canister machines and of the effect of using alternate motors in their own machines. Although they have available technical staff and laboratory facilities in-house, they have never applied the results of their studies to the products they market because of customer attitude toward noise.

Small Appliances

During the interviews incidental information was gathered from five different companies concerning eleven small appliances: blenders, can openers, coffee mills, electric knives, fans, hair dryers, ice crushers, knife sharpeners, mixers, oral lavages, and electric tooth brushes. Manufacturers feel that there is public pressure for these appliances to sound as though they are "really doing their jobs". One manufacturer offered the generalization that, in the small appliance field, the quality of the sound is more important than the quantity. An appliance must sound "right". Some must sound powerful, some reliable, and none as though they are malfunctioning or undergoing excessive wear. This manufacturer expressed the belief that an accurate interpretation of the customers' desires in these areas is a condition for remaining in business.

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This market pressure leads to diverse noise-control objectives, both among companies and between product lines produced by a single company. Customer complaints were reported about the noise from fans and hair dryers, and one marketing executive was quoted as believing that quiet is a salesable aspect of mixers. One company which does not manufacture the ice crushers that is sold under its label put a fairly high value on quietness in selecting the model it sells. Yet, none of these small appliances was described as quiet in either of the two mail-order catalogues that we examined. Blenders and electric can openers were specifically described by the managers interviewed as being appropriately noisy. A company which we did not interview was cited as having quieted a blender; in so doing, they slowed it down so that it became less efficient. At least one laboratory is seeking entirely new ways of comminuting foods that could be both quieter and cheaper than blenders. Another is designing a screw-type crushing tool that will substitute a growling sound for the raucous sound of the chipper that current ice crushers employ.

There is also a search for fan blade configurations that will eliminate certain predominant frequencies and produce a more pleasing sound. In addition to room fans, this experimentation includes hair dryers, where quieter designs for air passages are also being sought.

Rubber feet have been added to electric coffee mills to reduce vibration noise, but shielding is not being used because of its adverse effects on costs, size, and aesthetic design. Plastic beaters for mixers promise to reduce both noise and costs.

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Many of these appliances are powered by universal-type motors, which are inexpensive, powerful for their size, but noisy. The size-power ratio considered important in such appliances as hand mixers, electric knives, can openers, and motor-in-the-bonnet hair dryers. Conventional hair dryers also embody a trade-off between speed and quiet; one hair dryer model that was marketed as "quiet" took 30 to 75 minutes longer to dry hair than faster, noisier models.

Speed or the potential power that speed permits was cited as important to electric knives, can openers, and blenders. In the case of blenders, one engineer argued that, if they were slowed down, the intensity of the noise would simply be traded for noise duration with no lessening of resulting impact. There is also reported to be a trade-off for electric tooth brushes between noise and cleansing effectiveness.

Cases of limitations on quieting were pointed out for knife sharpeners where there is grinder-blade interaction, as well as for blenders where rotating knives are essential and a glass casing is necessary if the housewife is to monitor the process visually. In the case of blenders, there is hesitation to experiment with consumer preferences since the already intense domestic competition is being raised by the entrance of Japanese products into the market.

Small appliance manufacturers make frequent use of subjective noise judgements in their developmental work. Their product laboratories tend to be less sophisticated than those for major appliances, although many have access to central acoustical laboratories of great sophistication. One small appliance manufacturer tests new products in his employees' homes. If employees object to the noise the new model makes

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they are asked if they would be willing to pay for a quieter product. The general result of this approach is to make this manufacturer pessimistic about the economic pay-off from quieter products.

Although specific noise goals are hard to identify in the appliance industry and although some manufacturers seem discouraged with the return on their efforts to date, all those interviewed plan to persist in quieting efforts. Technological limits have not yet been reached. One manufacturer believes that the earlier competition which emphasized compactness has now been replaced with an emphasis on quiet. Accordingly, industry generally plans to hold the size of future models constant and to concentrate on producing quieter models, while presumably keeping prices within competitive limits.

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5. CONCLUSIONS AND RECOMMENDATIONS

This report has presented a broad range of facets concerning the noise characteristics of construction, appliances, and building equipment, the influence of this noise on our lives, and the nature of the industries producing and using this machinery. In this section, we summarize our findings and recommend what we believe to be a balanced noise abatement program that may be pursued by EPA.

5.1 Conclusions

One of the most striking factors to emerge from this study is the monumental complexity of the physical, social, and industrial system that we have attempted to understand. There is a wide spectrum of noise-producing machinery types utilized for many different purposes in a nearly endless number of situations. This heterogeneity makes a characterization of even the average properties of the sources and transmission paths difficult at best. Of course, nobody is exposed to average conditions but rather to some part of a multi-variable distribution of circumstances, making some notion of the range of source/path/receiver situation desirable. Furthermore, human response to noise varies widely among individuals and depends not only on the readily measurable aspects of sound such as level and spectrum, but also on such factors as attitudes, predispositions, the information content of the sound, and concurrent nonauditory stimuli. The industrial situation is equally complex, the judgement of industrial leaders and their concommitant directives being influenced by marketplace and legislative demands, as well as by their own personal attitudes. In presenting what we feel are the salient features of this complex system, we claim to have observed no more than the top of the iceberg — and even that at some distance.

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5.1.1 Sources

Despite the tremendous range of equipment, the noise-producing mechanisms are often similar and may be identified as part of a much smaller class. The principal source of noise in many types of construction equipment, for example, is the diesel engine. Exhaust noise is most readily identifiable with structural sound radiation and inlet noise is also of importance. Additionally, the hydraulics, fans, and transmissions of construction equipment generate loud and identifiable noise levels. Such heavy equipment often creates levels in excess of 90 dB(A) at 50 ft. Drilling and cutting machinery are also extremely noisy as are impact tools such as riveters, pavement breakers, certain powered wrenches, and most pile drivers. Noise from jack hammers and rock drills often lies between 80 and 100 dB(A) at 50 ft; pile driver noise can exceed 100 dB(A). Almost invariably, construction equipment, regardless of its size, is noisy.

In evaluating the control technology of construction noise, one finds that approximately 10 dB(A) of noise reduction are generally achievable using state-of-the-art techniques; 20 dB(A) could no doubt be achieved with a certain level of technology development. Of course, these are average values. For some equipment, such as that sold without exhaust mufflers, greater noise reduction would probably be easily achieved; for others, such as riveters, considerable effort would be required to meet these objectives.

The noise levels of home appliances span a much broader range than those of construction equipment. Certain appliances such as food freezers or refrigerators are rather quiet at 30 to 40 dB(A), measured at 3 ft; other items such as food blenders can be as noisy as 80 to 90 dB(A) depending on the type, speed,

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and food being processed. Garbage disposers may even exceed 90 dB(A). By and large, the noisiest classes of home equipment are powered garden and shop tools. Noise from electric lawn mowers, hedge trimmers, and grass edgers all measured between 80 and 90 dB(A). Some shop tools generated nearly 100 dB(A).

Noise from appliances is attributable to electric motors and cooling fans, plus the components being driven by the motors. For refrigeration equipment, these components are compressors and blowers; for food-waste disposers, they are grinders; for shop tools they are typically cutting or grinding elements, often connected to the motor by noise-producing gears. As with construction equipment, noise reduction levels of 10 dB(A) are generally achievable with state-of-the-art techniques; 20 dB(A) often requires either extensive application of existing techniques or the development of new technology to obtain the same results at less cost.

Building equipment probably has as large a range of noise-making devices and noise levels as construction and appliances combined. Diesel engines, gas turbines, and large electric generators or motors are all utilized, especially in so-called "total energy systems" which supply both electric power and temperature control for buildings. Refrigeration and heating equipment, blowers, diffusers, and fluorescent light transformers all generate noise. Fortunately, the noisiest sources of building equipment are usually remotely located, typically in mechanical equipment rooms. Isolating people from this noise is mainly done through architectural treatment.

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5.1.2 Impact

To have tried to measure the impact of noise on people in terms of the levels to which they are exposed, the duration, and the number of people. In a one year period approximately 30 million Americans will find themselves living or working near a construction site. The noise from this site will be sufficiently high to interfere with their conversation most of the day. Three million workers with eight children and 7.5 million children under five who may require naps live near these sites. Many will either find it more difficult to fall asleep or be awakened during their sleep because of construction noise. On the average, a metropolitan-area resident or worker passes a construction site every other day. Pedestrians can be exposed to noise levels in excess of 90 dB(A). Automobile drivers and passengers will often close their windows, thereby reducing the exposure to approximately 80 dB(A). Although many operators of heavy construction equipment are losing their hearing because of noise [99], hearing damage to persons in the environs of construction sites does not appear to be a substantial problem. Most people residing or working in buildings neighboring construction sites are exposed to less than 70 dB(A) most of the time. Some pedestrians are exposed to levels that could contribute to hearing loss particularly if these people are exposed to high noise levels during other times of the day.

One of the most significant aspects of construction noise is that, in any year, 15% of the population are exposed roughly eight hours a day, five days a week for many weeks or months. They have no control over the noise nor do they have much respite from it. The argument that construction is temporary has little appeal to people living near a several year project or one series of projects after another lowers all around them - after all, they argue, life itself is temporary.

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Appliances have an impact on people in a rather different way. Most appliances affect only the people using them and only for a relatively brief time while they are in operation. For example, a food blender may generate 80 dB(A), but only for 30 seconds, at the end of which the user has a desired product. This leads to quite different attitudes toward appliances *vis a vis* construction equipment as bothersome noise sources. Of course, not all appliances affect only the user and his family. Appliances which affect neighbors are typically those which are built in to the home structure or plumbing and those which are used outside. Thus, food-waste disposers, dishwashers, water valves, and toilets are found to annoy and sometimes interfere with the sleep of people in multifamily dwellings. Powered garden tools such as lawn mowers, hedge clippers, and edge trimmers as well as power tools used outdoors (e.g., circular saws, drills, sanders) also generate sufficiently high noise levels to awaken or annoy neighbors.

One of the most striking aspect of appliances is their number. Roughly one billion appliances now are used in homes throughout the U.S. Virtually everyone owns at least some; e.g., 99.8% of homes are equipped with a refrigerator, over 90% have vacuum cleaners. By and large, people in the upper socio-economic stratum have more appliances. However, the generally increasing affluence of the nation coupled with the relatively constant price of appliances over the past 15 years (despite the inflationary growth of most other consumer items) has stimulated the profusion of appliances into homes at every economic level. This large number of appliances and their year-round use (with certain obvious exceptions) has made the exposure to appliance noise very large indeed. In fact, appliances account for more person-hours of speech interference, sleep interruption, and hearing damage than construction.

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However, the impact in terms of annoyance is probably not so great, owing in large part to the controllability of many appliance operation times. For example, one does not have to run the dishwasher while listening to T.V., but it is difficult to ask the pile driver operator outside to cease work until a program of interest is over.

5.1.3 Industry programs

Industry activities in product quieting can best be understood by first considering the pressures they perceive. Demand for quiet appliances reaches manufacturers directly from the purchasers in the marketplace. The people who are exposed to noise, for the most part, are also those who purchase the appliance, or at least influence its selection. Demand for quiet construction equipment is also made by people living or working near construction sites. They generally have no economic influence on the building contractor or equipment manufacturer. Hence, their demands have largely gone unheeded and have been redirected through legislative bodies. A few successes in this arena have begun to create a marketplace demand for quiet equipment by contractors who "see the handwriting on the wall" and are willing to pay something of a premium for equipment that will not be illegal to operate in a few years when anticipated wider-ranging legislative controls are enacted.

The response to pressure for quiet has varied within and across the appliance and construction industries. Some appliance manufacturers have made a credible effort to develop capabilities to deal with noise-control problems and to design appropriate noise-control measures into their products. This has been especially true in the major appliance industry where air conditioners

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and, more recently, dish-washers and food-waste disposers are being treated. As one might expect, the objective of disposer treatment is to reduce noise within the kitchen containing the unit. We know of no disposer designed to reduce transmission of noise through plumbing and into adjacent apartments. The disposers that incorporate airborne sound suppression are top-of-the-line items designed for use by the purchaser. Bottom-of-the-line disposers often have no noise treatment whatsoever and are usually installed in multifamily dwellings. Generally speaking, when noise control is introduced in appliances, it is in top-of-the-line items. There, it serves partly as an added luxury and partly as a test of market acceptability. If successful, it will often be introduced in other line items; if unsuccessful (for whatever reason) the notion will often develop and persist that consumers simply do not care about noise.

The construction equipment industry also shows a spectrum of levels of response to pressure for product quieting. A very few companies have foreseen the demand for quiet equipment and have begun a line of products that are significantly quieter than competitive models. Some companies have conducted experimental noise control projects, often with only a modicum of success. Several companies appear to have given noise-control very little effort (e.g., some heavy construction equipment does not even use exhaust mufflers for diesel engines). On the whole, noise has only begun to become a serious factor in the construction industry, which lacks much of the expertise required to deal successfully with it.

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5.2 Recommendations

Most of the work presented in this report is of the nature of background material that must be applied to the problem of noise reduction to be of real value. Our recommendations therefore relate to the application of this information and the steps that we feel ought to proceed from it.

There appear to be two primary means by which the EPA can influence industry to bring about noise control. The first is to regulate the maximum allowable noise levels that can be produced by new equipment. The second is by instituting a mechanism for disseminating information to the consumer: namely, requiring the labeling of noisy products. In situations where the party exposed to noise is not the purchaser of the noisy equipment and is not in a position to influence the noise level or operation of the equipment, it appears that noise standards must be generated and applied to bring about noise reduction. This is largely the case in the construction industry, where the principal recourse to construction noise control by the community has been through local legislation. On the other hand, when the purchaser is, for all practical purposes, the only party affected by a noisy source and that source is not likely to contribute seriously to hearing damage, then standards appear to constrain unnecessarily one's freedom of choice. Rather it would seem appropriate to ensure that the purchaser is informed of the levels to which he will be exposed, but that he be allowed the freedom to weigh noise against other factors (e.g., price, size, durability) in reaching a decision among alternative products.

Setting standards and labeling requirements is no mean task. There are technical issues that must be resolved involving the conditions under which noise is to be measured. For example,

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the type of sink in which a garbage disposer is installed and the character of food waste being disposed of, must be carefully specified to obtain meaningful and uniform results. Somewhat more difficult is the task of determining the maximum allowable levels for different kinds of equipment. In a sense, these levels invariably represent a compromise between desired values and values that are economically acceptable. This concept may be illustrated qualitatively by Fig. 27 in which we plot cost vs noise reduction. Cost is used to include capital, operation, and maintenance expenditures owing to the application of noise control treatment and whatever performance degradation might occur because of such treatment. Automobile mufflers are a good example; they increase the price of an automobile, often require replacement during the life of an automobile, and slightly degrade engine performance. Results achievable by application of state-of-the-art noise-control techniques are represented by an exponentially increasing curve. The first few dB of noise reduction are typically achieved at low cost; costs gain substantially as greater levels of quieting are sought. Also shown in the Fig. 27 is a cost vs noise reduction curve that might be achievable subsequent to noise-control research and development. In fact, it can probably be said that the sole objective of R&D should be to lower the state-of-the-art curve. The third curve in Fig. 27 shows a relation between cost and noise reduction deemed acceptable by the decision-makers. The curve is concave downward illustrating the notion that as a machine is made quieter, each increment of noise reduction is worth less and less. The intersection of the state-of-the-art curve with the acceptable cost vs noise reduction curve determines the noise reduction one is willing to specify. If this level of reduction is inadequate,

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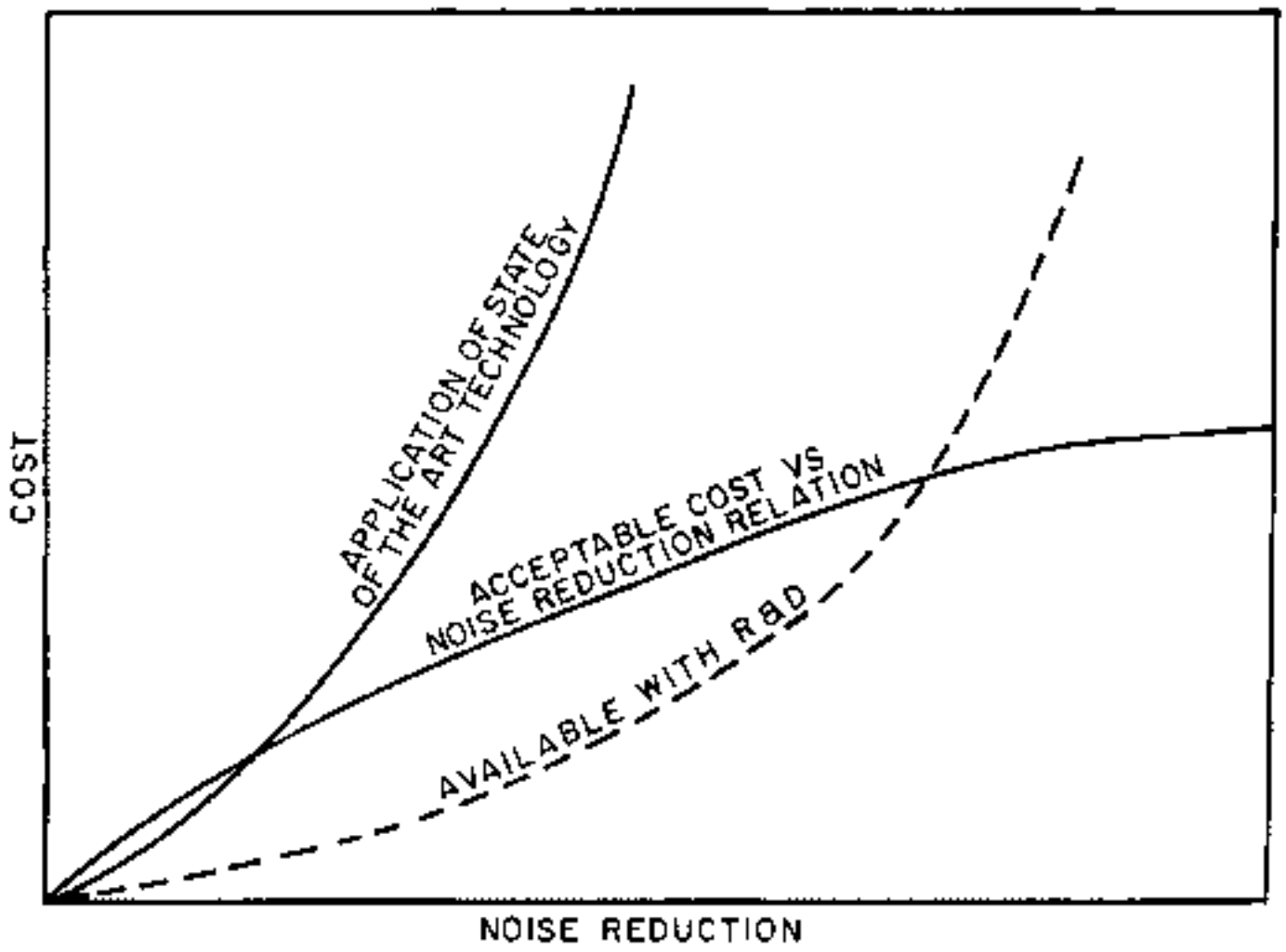

FIG. 27. COST OF NOISE CONTROL VS NOISE REDUCTION

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it is necessary to conduct R&D to achieve a lower state-of-the-art curve and increase the level of noise reduction that can be justified economically.

Each party has its own view of the level of the acceptable cost vs noise reduction curve. For equipment manufacturers who find little marketplace demand for quiet products, the curve is low. People living or working near noisy equipment would naturally draw the curve at a higher level, especially if they did not have to bear a significant part of the cost for quieting the machinery. One of the problems that EPA will have to face is to develop an acceptability curve that is, in some sense, fair to all parties. Although it is difficult, if not impossible, to develop such curves quantitatively, it will be necessary for a decision maker to be aware of the pertinent relations between cost and noise reduction and to account for them in selecting the levels to be achieved. To assist in this process, we recommend here studies of the technology and economics of noise abatement, the economic impact of noise control, the type of improved noise criteria that ought to be developed, and social-indicator studies to measure the attitudes of the public to noise and noise control. First, let us consider which equipment ought to be regulated by standards and which by labeling.

5.2.1 Standards and labeling

We recommend that noise sources having a significant impact on parties who derive little direct benefit from the source ought to be controlled by the establishment of maximum allowable noise levels. This would include most construction equipment, construction sites, and certain types of appliances. Among the items of construction equipment requiring standards are all machinery powered by internal combustion engines as well as tools

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utilizing impact or cutting mechanisms, such as drills, pavement breakers, and saws. Construction site noise levels ought to be regulated to ensure that the contractor deploy and utilize his machinery in a way that minimizes community noise exposure. Typical appliances requiring regulation are electric garden tools (e.g., lawn mowers, hedge clippers, edge trimmers), food-waste disposers, dishwashers, air conditioners, and shop tools. Because the noise of hazardous tools also serves to inform the user of their operation, minimum as well as maximum levels out to be set.

For standards to be applied in a way that may reasonably be met by industry and yet are sufficient to have an impact, we recommend the establishment of a three-phase program. A decreasing sequence of levels would be established and would go into effect approximately, one, four, and seven years subsequent to the time at which the levels are publicly announced.

One Year

The purpose of the first phase is to ensure that highly effective off-the-shelf noise control equipment is utilized on all new machinery. Thus, all machinery powered by internal combustion engines would be required to be equipped with high-quality mufflers, for example. (This contrasts with the current situation in which some construction equipment is advertised and sold without any muffling whatsoever.) One year appears adequate for manufacturers to order, receive, and install such equipment.

Four Years

The second phase would become effective approximately four years after announcement of levels. These levels would be selected to ensure that state-of-the-art noise control techniques are

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incorporated in equipment. To achieve these levels, the manufacturer might have to use sound-absorptive engine enclosures, for example. Appliances might have to incorporate vibration isolators for all motors and pumps. Since the type of treatment envisioned here requires minor changes to equipment, four years appears adequate for manufacturers to design noise treatment and retool selected items of their production lines.

Seven Years

The levels to become effective after a period of seven years should largely represent state-of-the-art advances and should have a significant impact on the level generated by the noise source. Twenty dB(A) of noise reduction for the most offensive construction equipment and appliances would seem reasonable. Seven years allows sufficient time for the research and development needed for state-of-the-art advances and the incorporation of the fruits of this work in production items.

We also recommend labeling of appliances generating significant noise levels affecting primarily the user. Included in a list of items to be labeled are all items controlled by standards, as well as shop tools, vacuum cleaners, food blenders, fans, and hair dryers. Our rationale for labeling rather than standard setting is that a person should be informed of the noise to which he will expose himself and then be free to consider noise as but one of a number of factors accounting for his selection of a particular brand. Noise-control standards would no doubt raise appliance prices, unnecessarily restricting the consumer's range of choice.

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5.2.2 Technology evaluation, demonstration, and development

We recommend the expenditure of appropriate levels of effort to evaluate, demonstrate, and develop technology in support of the establishment of standards. These studies are as follows:

Labeling

To make labeling meaningful, a consistent set of test procedures should be developed for each type of appliance or item of building equipment. This is especially important for appliances whose noise characteristics depend heavily on the installation. Prominent among these are food-waste disposers, dishwashers, plumbing fixtures, and vacuum cleaners (which may rest on a rug or a hard floor).

Standards — Phase I

The first recommended phase of standard setting establishes noise levels that can be met if highly effective off-the-shelf noise control devices are used on all equipment. Prior to the establishment of such standards, a program to measure the noise generated by selected machinery samples targeted for incorporation of such devices would seem appropriate.

Standards — Phase II

The second phase of standards would specify levels requiring the application of noise-control treatment. We recommend that EPA conduct noise-control demonstration projects on selected items for three reasons. First, achievable levels of noise reduction can be accurately evaluated, and accordingly specified, only by means of such programs. Without actually implementing noise-reduction techniques there would probably be an unacceptable

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level of uncertainty associated with predictions. Furthermore, practical implementation problems are often not uncovered until treatment is actually put into practice. Second, such demonstration of results achievable by means of state-of-the-art noise treatment would put to rest any objections raised by the affected industry concerning the technological feasibility of achieving specified levels. Finally, the technical information generated by a demonstration program would be valuable across the affected industry, especially to small companies who often lack the requisite technical capability in noise control.

Standards — Phase III

The third recommended phase of standards is designed to have a significant impact on noise levels and will probably be achievable only through state-of-the-art advances in noise-control technology. To ensure that the state-of-the-art is appropriately advanced in sufficient time for implementation in new machinery we recommend the immediate commencement of R&D programs dealing with the following important aspects of construction and appliance noise (in approximate order of priority):

- diesel engines
- mufflers
- hydraulic systems
- cooling systems
- impact and cutting tools
- other power plants:
  - gas turbines (for nonaircraft use)
  - electric motors

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- Transmissions (gears)
- Water valves

5.3 Economic Impact Studies

Determining the optimum balance between public's desire for quiet and the distributed costs required to achieve it by means of rigorous systems analysis effort would require a large-scale simulation of the economics of the construction industry and its place in the U.S. economy. Such a study is not feasible if usable results are required in a short time or if expenditure of funds is limited. It is possible, however, to make some choices as to what to quiet and how to quiet it, by doing some fairly unsophisticated investigation of how the quieting costs get distributed through the industry and the economy. We recommend treatment of:

- The impact of noise on various segments of the population. (This has largely been performed under the existing EPA contract and needs but a little expansion.)
- Estimated costs of quieting selected pieces of equipment as a function of degree of quieting. (This would be an order-of-magnitude estimate. Data can be obtained from price information on existing mufflers, heavy casings, absorptive materials, etc., as well as a study of price differentials between existing quieted and unquieted machinery — not just construction equipment. Costs of nonhardware guiding techniques, such as scheduling site operations to avoid using many prices of equipment at once, would be estimated by constructing typical scenarios and consulting with industry representatives to determine increases in construction cost increases (or decreases). Allowance should be made for uses

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in which a change in equipment design or operation results in greater productivity, reliability, etc. The effect of such an occurrence could be a net *negative* quieting cost.)

- The distribution of increased equipment cost among producers, purchasers and the purchaser's customers. (Part of the cost will be absorbed by each, depending on the demand elasticity of the commodity. This information exists in published studies of the economics of the construction industry.)
- Allocation of increased equipment costs/rentals among various types of construction. (The resulting increase in construction costs are a strong function of what is being built. Equipment rental typically makes up 20% of the cost of civil works constructions, 10% of the cost of highways, but only 2% in the case of buildings.)

The above data would be used to compute the economic effect of quieting equipment on the public. The outputs would be:

- The expected increase in costs and rentals of housing, offices, industrial space, etc., as a function of the degree and method of site quieting. Also of interest is the degree of intersection of the sets of: (1) surrounding inhabitants, who get the benefits of quiet sites, and (2) building users, who pay the cost, or part of it.
- Expected increase in state, municipal, and federal taxes as a result of increased cost of public works construction, etc.

The net result of the study would be recommendations for an orderly construction quieting program based on the information developed above. The criteria by which specific techniques or regulations would be judged are:

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- Cost-effectiveness (the degree of quieting achieved per dollar expended).
- Cost-benefits (the reduction in community noise exposure as a function of quieting cost).
- Equitability (the degree to which the beneficiaries of a quieting program bear the expense of that program).

5.4 A Program of Public Support Development

Our contact with managers of construction equipment and home appliance manufacturing companies has convinced us that their perspective on and attitudes toward noise control programs will strongly influence the efforts they make to quiet their products. This is even more true of the values they hold regarding the legitimacy and worth of quiet environments. Indeed, we regard the public support of noise abatement efforts as a crucial variable in the success of these efforts.

We would, therefore, recommend a continuous program to diagnose and develop public support for noise abatement. Such a program would embrace five activities:

Exploration of Programs in Other Areas

We visualize this as an inquiry both into the theory of public opinion, attitude change, and shifts in basic values and into the actual techniques of public support development that have been employed in other contexts.

A Continuous Inventory of Opinion-Leader Attitudes

This would be a program of interviews with opinion leaders who are dealing with noise abatement. It would include leaders

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in government, business, relevant professions, and consumer- and ecology-advocate groups.

A Continuous Inventory of Public Awareness, Attitudes, and Values

These should be measured on a well-designed material sample on a continuous basis so that trends over time could be assessed concerning public knowledge, attitudes, and values.

Program Development

A program, based on information obtained from the three activities above, should be developed (1) to optimize the kind and degree of regulation which can be supported by the public opinion that exists, (2) to prescribe a public information program that will improve the quality of public opinion, and (3) to identify profitable areas for demonstration programs.

The Development and Administration of Pilot Programs of Noise Abatement

These pilot programs should test the relation of regulation to various levels of public support in the same sense that pilot programs that test innovative technological prototypes are developed.

We should like to say a word regarding the usefulness and feasibility of the continuous inventories of leader opinion and public opinion — activities 2 and 3 above.

Field research in the behavioral sciences has now reached the point that useful social indicators can often be developed if their development is undertaken on a pragmatic basis. We do

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not visualize that these survey activities will be conducted at the level of public opinion polls. Again, the behavioral sciences have matured to the point that much more useful kinds of information can be gathered. We know from previous noise surveys that local economic status and attitudes toward noise makers influence noise annoyance and noise complaints. A recent study of noise variance noise that we have conducted indicates that the necessity of the noise, and the degree to which one perceives the noise as an intrusion, influences the level of annoyance. The survey efforts envisaged would map factors that would assist in the formulation of noise criteria. Are people willing to put up with "tolerable" levels of noise or do they now demand reduction to "comfortable" levels? Of greatest importance may be attitudes toward the regulating process itself. By now it is well-established in social psychology that basic orientations towards the exercise of influence alter behavior. With respect to the product manufacturer who promises to become an object of regulation, theory would predict that one's enforcement problems would be quite different if the manufacturers complied to regulation because of fear, because compliance was expected by his reference groups, or because his own values indicated compliance. These psychological orientations can be measured through interviews.

5.5 Social Impact

The following recommendations are made to evaluate the impact of noise not only from the sources under consideration in the current report but also from other sources.

1. The most fundamental action that can be taken to further the assessment of noise impact is to initiate research leading

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to development of an absolute scale of annoyance for all noise exposure. The first stage of such a research program would obviously be a planning effort to structure the task and prepare detailed plans for its execution.

The need for such research is immediate. Existing methods for estimating annoyance are relative rather than absolute, limited in scope and application, not widely accepted, and of dubious utility. The intended research would entail simultaneous measurement of both complaint behavior and the offending acoustic signals producing complaints, *at the time of annoyance*. A continuous survey of residential noise annoyance over a considerable period of time is needed, as are surveys of noise annoyance in other environments. Until a well-founded research program of this sort is undertaken, one must continue to rely upon personal experience or the distortions of the popular press for estimates of the true magnitude of the annoyance problem.

2. Since speech interference proved to be such a widespread consequence of exposure to the noise sources considered in this report, research should be conducted to determine how accurately speech interference predictions made on the basis of laboratory data may be extended to real-life situations. Almost all current knowledge of speech interference effects has been produced by studies employing steady-state noise as the interfering signal. No research has been conducted on potentially crucial effects of temporal parameters of noise distributions (including frequency, duration, and periodicity of interference) on verbal communication. Further, little if anything is known of the annoyance value of speech interference. Trade-offs governing the relative annoyance of frequent but short interruptions vs infrequent but long interruptions of verbal communication have not been investigated. It therefore remains impossible to predict whether people would

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suffer more speech interference from one type of appliance than another; whether redesign of machinery for longer duration but lower level noise output would be helpful; whether scheduling changes in the operation of construction machinery would reduce speech interference; and so forth.

3. Noise education programs should be designed to provide the public with the information needed to make decisions about the desirability of noise exposure. A noise-conscious public can exercise a modicum of control over its noise exposure through its purchasing power and its demands for noise control legislation. Consideration should be given to preparation of public information pamphlets, recordings, or other means of increasing public awareness of noise exposure.

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APPENDIX A — DETAILED SOURCE CHARACTERIZATION

A.1 Construction Equipment

Of the considerable body of data on the noise of construction equipment, most pertains to the operator position; the available data on noise radiated by this equipment to its surroundings is very limited. The data presented in Fig. 1 (main text) and in this appendix were obtained from

- The open literature [3-4].
- Reports, including those submitted by various manufacturers at the EPA hearings on construction equipment held in Atlanta, Georgia, July 6 and 9, 1971.
- Field measurements conducted for this project at a number of construction sites in the vicinity of Boston.*

A.1.1 Noise spectra

Much of the equipment used at construction sites is powered by diesel engines, which generally constitute the predominant noise sources. Figure A.1 shows the envelope of the 1/3-octave band spectra of noise from 23 different items of diesel-powered construction equipment, rated from 45 to 770 hp and operating at between 1100 and 2700 rpm, at a variety of conditions (i.e., with various degrees of loading, ranging from none to heavy). These spectra were obtained at various locations around the equipment items, which also varied in the degree of exhaust muffling present.

*These measurements were made with a 1-in. Bruel and Kjaer type 4131 condenser microphone, coupled to a Bruel and Kjaer type 2203 sound level meter. The signals were recorded on a Kudelski Nagra type III tape recorder, and later analyzed in the laboratory by means of a General Radio Corp. "Real-Time Analyzer". Calibration was accomplished with the aid of a Bruel and Kjaer type 4220 piston phone.

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Figures A.5, A.6, and A.7 show the noise spectra from some typical engine-powered items of equipment. The low-frequency peaks typically correspond to the firing frequency (the number of power strokes per unit time — which depends on the engine rpm, number of cylinders, and on the number of power strokes per revolution) and its harmonics. Figure A.2 illustrates the noise made by the tracked bulldozer under various working conditions. These spectra reflect not only the diesel noise but also the noise made by the tracks, rollers, and sprocket of metal on metal and soil.

The other equipment items listed above also operate over the similar kinds of diesel engines. In addition, equipment, however, should include here a wide range of low to higher power applications, with spark-ignition engines relegated to the lower power equipment. Spectra corresponding to two types of gasoline-engine powered equipment are shown in Fig. A.5.

Noise spectra for two air compressors - one diesel, one gasoline-engine powered - incorporating no special noise control provisions are shown in Fig. A.6. Figure A.6 shows the noise spectra associated with several pumps and generators; Fig. A.6 shows noise levels produced by a vibrator acting on a plywood framework and by various drum cutting work. Noise spectra produced by various pneumatic tools are shown in Fig. A.7.

The noise from conventional pile drivers is characterized by intense peaks associated with the impacts of the hammer against the pile. The peak levels associated with these spectra are indicated in Fig. A.8 for two conventional pile drivers, together with the noise levels produced by a sonic (vibratory, nonimpact) pile driver.

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A.1.2 Average construction site noise pollution levels

Based on an analysis of the activities that occur during each phase of construction at the various types of sites, a listing of the equipment active during each phase was developed. This listing, together with an estimate of the fractional number of sites that involve each equipment item, appears in Table A-1.

For site noise analysis, this large table was simplified by averaging equipment usage over similar sites and by grouping together equipment items with similar noise characteristics. For the calculations, equipment with noise characteristics that were not known directly was replaced by equipment expected to have similar (known) noise characteristics (e.g., back fillers and trenchers were replaced by backhoes and loaders). Equipment known to be extremely quiet (e.g., electric cranes, electric fork lifts) was totally omitted from the calculations.

Since a given item of equipment is present at only a fraction of all sites and only during part of each phase, and since it only operates part of the time that it is present, a usage factor was assigned to each equipment item. This factor was calculated as the product of three factors: (1) the fractional number of sites at which the equipment is used (based on Table A-1), (2) the estimated fraction of the phase duration during which the equipment is on site and (3) the duty cycle, i.e., the fractional time that this equipment is operating while on site [5]. The resulting usage factors are summarized in Table A-2.

In order to calculate the site NPL, defined as the sum of the energy-average SPL in dB(A) and 2.56 times the Standard Deviation of A-scale SPL [6], one needs to know not only the average sound

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TABLE A-2a. USAGE FACTORS OF EQUIPMENT
IN DOMESTIC HOUSING CONSTRUCTION*

Equipment†		Construction Phase				
		Clearing	Excavation	Foundation	Erection	Finishing
Air Compressor	[81]		.1			.25
Backhoe	[85]	.02	.04			.02
Concrete Mixer	[85]			.4	.08	.16
Concrete Pump	[82]					
Concrete Vibrator	[76]					
Crane, Derrick	[98]					
Crane, Mobile	[83]				.1	.04
Dozer	[80]	.04	.08			.04
Generator	[78]	.4				
Grader	[85]	.05				.02
Jack Hammer	[88]					.025
Loader	[79]	.04	.08			.04
Paver	[89]					.025
Pile Driver	[101]					
Pneumatic Tool	[85]			.04	.1	.04
Pump	[76]		.4	.7		
Rock Drill	[98]		.01			.005
Roller	[74]					.04
Saw	[78]			.04(2)	.1(2)	.04(2)
Scraper	[88]	.05				.01
Shovel	[82]		.02			
Truck	[91]	.16	.4			.16

* Numbers in parentheses represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

† Numbers in brackets [ ] represent average noise levels [db(A)] at 50 ft.

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TABLE A-2b. USAGE FACTORS OF EQUIPMENT
IN NONRESIDENTIAL CONSTRUCTION*

Equipment†		Construction Phase				
		Clearing	Excavation	Foundation	Erection	Finishing
Air Compressor	[81]		1.0(2)	1.0(2)	1.0(2)	.4(2)
Backhoe	[85]	.04	.16			.04
Concrete Mixer	[85]			.4	.4	.16
Concrete Pump	[82]			.4	.08	.08
Concrete Vibrator	[76]			.4	.1	.04
Crane, Derrick	[88]				.16	.04
Crane, Mobile	[83]				.16(2)	.04(2)
Dozer	[80]	.16	.4			.16
Generator	[78]	.4(2)	1.0(2)			
Grader	[85]	.08				.08
Jack Hammer	[88]		.1	.04	.04	.04
Loader	[79]	.16	.4			.16
Paver	[89]					.1
Pile Driver	[101]			.04		
Pneumatic Tool	[85]			.04	.16(2)	.04(2)
Pump	[76]		1.0(2)	1.0(2)	.4	
Rock Drill	[98]		.04			.005
Roller	[74]					
Saw	[78]			.04(3)	1.0(3)	
Scraper	[88]	.55				
Shovel	[82]		.4			
Truck	[91]	.16(2)	.4			.16

* Numbers in parentheses represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

† Numbers in brackets [ ] represent average noise levels [db(A)] at 50 ft.

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TABLE A-2c. USAGE FACTORS OF EQUIPMENT
IN INDUSTRIAL CONSTRUCTION*

Equipment†		Construction Phase				
		Clearing	Excavation	Foundation	Erection	Finishing
Air Compressor	[81]		1.0	.4	.4	.1
Backhoe	[85]	.04	.16			.04
Concrete Mixer	[85]			.4	.16	.16
Concrete Pump	[82]			.4		.06
Concrete Vibrator	[76]					
Crane, Derrick	[88]				.04	.02
Crane, Mobile	[83]				.08	.04
Dozer	[80]	.04	.16			.04
Generator	[78]	.4	.4			
Grader	[85]	.08				.08
Jack Hammer	[88]		.1	.04	.04	.04
Loader	[73]	.16	.16			.04
Paver	[89]					.12
Pile Driver	[101]			.04		
Pneumatic Tool	[85]			.04	.1(3)	.04(2)
Pump	[76]		.4	1.0(2)	.4	
Rock Drill	[98]		.04			.06
Roller	[74]					--
Saw	[78]			.04(2)	.1(2)	
Scraper	[88]	.14				.08
Shovel	[82]		.2			.06
Truck	[91]	.16(2)	.16(2)			.16

* Numbers in parentheses represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

† Numbers in brackets [ ] represent average noise levels [db(A)] at 50 ft.

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TABLE A-7d. USAGE FACTORS OF EQUIPMENT IN PUBLIC WORKS CONSTRUCTION*

Equipment†		Construction Phase				
		Clearing	Excavation	Foundation	Erection	Finishing
Air Compressor	[81]		1.0(2)	.4	.4	.4(2)
Backhoe	[85]	.04	.4			.16
Concrete Mixer	[85]			.16(2)	.4(2)	.16(2)
Concrete Pump	[82]					
Concrete Vibrator	[76]					
Crane, Derrick	[88]		0.1	.04	.04	
Crane, Mobile	[83]				.16	
Dozer	[80]	.04	.4			.16
Generator	[78]	1.0(2)	.4(2)	.4(2)	.4	.4(2)
Grader	[85]	.08			.2	.08
Jack Hammer	[88]				.04	.1(2)
Loader	[79]	.04	.4			.16
Paver	[89]					
Pile Driver	[101]					
Pneumatic Tool	[85]			.04(2)	.1	.04
Pump	[76]		.4(2)	1.0(2)	.4(2)	
Rock Drill	[98]		.04			
Roller	[74]			.01		
Saw	[78]			.04(2)		
Scraper	[88]	.08		.2	.08	.08
Shovel	[82]	.04	.4	.04		.04
Truck	[91]	.16(2)	.16	.4(2)		.16(2)

* Numbers in parentheses represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

† Numbers in brackets [ ] represent average noise levels [db(A)] at 50 ft.

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pressure, but also enough about its time-variation so that one can determine its standard deviation. In addition, the background noise levels enter in the evaluation of both of these quantities. Accordingly, representative background noise levels were selected as 50 dB(A) for residential, suburban, and rural sites and 70 dB(A) for commercial and industrial (urban) sites, on the basis of data for various U.S. and foreign locations [7].

Representative time-variations of noise were generated by dividing each construction phase into 50 equal time intervals. The start (or "turn-on") times for each individual item listed in Table A-2 were determined at random (by means of a computer random number generator), and the fractional "on-time" duration for each item was taken as its usage factor (Table A-2). From the noise level for each item of equipment, the total noise level in each time interval was then calculated, and from this ensemble of values the desired average and standard deviations were evaluated. For test purposes, the calculations for several sites/phases were repeated several times, with different randomly selected start times; the resulting NPL values were always found to lie within a 3 dB(A) interval. Although such repetitive calculations were not carried out for all sites/phases, the reported site NPL values may be considered as valid within ±2 dB(A).

A.2 Appliances

In the following sections, brief discussions are presented of appliances not covered in the body of the report. We measured the noise levels of many of these appliances; these measurements are presented here as 1/3-octave band sound pressure data.

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A.2.1 Can opener, electric

Noise of electric can openers is generated by the reducing gears, the electric motor, and the grating of the clamp against the moving lip of the can. Additional noise is radiated from the rivets or metal panels of the unit. Can openers are usually supported on small rubber feet which partially isolate the vibration from the work surface; however, wall mounting of the opener can short-circuit this isolation. The A-weighted sound level at a distance of 3 ft was measured for seven electric can openers; the mean level was 66 dB(A).

Figure A.9 shows 1/3-octave band plots of the sound pressure levels measured at a distance of 3 ft for two different can openers. The peaks at 53 and 125 Hz are probably motor-induced while the higher frequency peaks are probably related to the number of teeth in the reducing gears.

A.2.2 Clothes dryer

Clothes dryers are relatively quiet appliances which consist of a rotating drum within a metal enclosure; heat is supplied by either electric coils or a gas flame. The constant noise of the motor and the rumble of the drum, plus the combustion roar in a gas dryer, are punctuated by the noise of buttons or zippers impacting with the metal chamber. A range of sound levels from 51 dB(A) to 66 dB(A), with a mean level of 58 dB(A), was measured at a distance of 3 ft for eleven gas and electric dryers. Figure A.10 shows 1/3-octave band sound pressure level data for five different dryers.

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A.2.3 Clothes washer

The noise generating components of clothes washers include:

- water noise during the filling, agitation, and spinning cycles
- unbalanced loads, which cause excessive vibration to be transmitted into piping and floor
- motor
- pump

Figure A.11 presents the noise levels for the wash cycle of five different machines; Fig. A.12 shows noise levels for the spin cycle of four of these five machines. The peaks in the low-frequency bands probably represent motor-induced noise while those in the mid-frequency bands may be related to spinning of the tub.

A.2.4 Coffee mill

A coffee mill consists of a grinding mechanism that is driven by a motor to produce fine to coarse ground coffee. Motor-induced noise is radiated from the casing and the coffee bean enclosure. Rubber feet are provided for vibration isolation. Measurements were made at a 3 ft distance on two coffee mills: the two sound levels were 75 dB(A) and 78 dB(A).

A.2.5 Dehumidifier

In a home humidifier, a small fan draws air across condensing coils, collecting the moisture in a removable pan. Noise measurements were made of four dehumidifiers; the noise varied from 52 dB(A) to 62 dB(A).

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Figure A.13 present 1/3-octave band data for the quietest of these units. The broad peak in the vicinity of 120 Hz is motor induced; mid-frequency noise is dominated by the fan. Although compressors may be vibration isolated, the casing of a unit is likely an important radiator.

A.2.6 Edger and trimmer

An edger and trimmer consists of a high-speed motor directly driving a two-bladed knife. This lawn tool is used to trim the grass along walkways and the brush along garden paths.

Figure A.14 presents 1/3-octave band data on one unit; the sound level was 81 dB(A). The peaks in the frequency spectrum seem to be the 1st, 2nd, 3rd, 6th, and 20th harmonics of 400 Hz. It is anticipated that narrower band analysis would reveal more tonal components that are related to the blade passage of the cutting edge.

A.2.7 Fan

There are three general categories of fans found in the home: window fans, floor fans, and stove hood and bathroom exhaust fans.

- Window fans are usually standardized to a 14-in. or 22-in. size (12-in. and 20-in. diameter blades respectively). Features on deluxe models include thermostatic control and reversible direction of air flow. Twelve noise measurements of window fans ranged from 47 dB(A) to 66 dB(A); the mean was 57 dB(A). Low-speed to high-speed mean values showed a spread of 17 dB(A).

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Figure A.15 presents 1/3-octave band noise measurements for three window fans for both low and high speed. The tonal components are likely related to the blade passage frequency of the fan, the motor, the blade tip velocity, and the blade design.

- Floor fans or table fans usually consist of a base, a small electric motor, and a blade with protective cage. They often rotate back and forth to spread air movement around an arc of 90° or so and are usually designed to run at various operating speeds. Twenty-two measurements at a 3 ft distance yielded a range of sound levels from 38 dB(A) to 67 dB(A); the mean level was 54 dB(A).

Figure A.16 presents 1/3-octave band data for three floor fans for both low and high speed. The noise sources are very similar to those of window fans.

- Stove hood exhaust fans and bathroom exhausts are typically small axial flow fans mounted directly above the stove to exhaust cooking odors or in the bathroom ceiling to exhaust hot air. The mean dB(A) level of ten measurements at a 3 ft distance was 53 dB(A).

Figure A.17 presents narrowband data for four speeds for one particular stove hood exhaust fan. Again, the tones are related to motor noise and blade passage fan noise. Through the use of appropriate lining it should be possible to reduce the noise of stove hood exhaust fans and bathroom exhaust fans by up to 15 dB(A).

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A.2.8 Food blender

The electrical motor control system on food blenders is designed to drive the cutting blades (located at the bottom of a removable container) at a wide range of speeds in order to perform various food blending tasks. Speed control may be achieved by using a variable-speed motor or solid state electronic networks. The primary sources of noise are the motor, the whirling of the blades causing radiated noise, structureborne noise, and agitating noise of the fluid. From measurements of the noise generated by foreign and domestic food blenders, the sound level ranged from 82 to 88 dB(A) with a mean level of 75 dB(A). The container was half full of water during most of these measurements. Figure A.18 presents a series of narrowband measurements representing the noise levels generated by one food blender running at each of nine different speeds. The peaks in the spectrum shift upward in frequency with increased speed, suggesting a dependence on the blade passage frequency of the cutting edges. Figure A.19 shows the variation in noise level for a maximum speed setting for five food blenders of different manufacture.

A.2.9 Food mixer

Food mixers are available in both portable and table model styles. Portable mixers are lightweight versions of table models - they have no base but consist of the same basic mechanisms: a set of beaters and a variable-speed motor or a single-speed motor with reduction gears. Twenty-five sound level measurements were made at a 3 ft distance on domestic and foreign, portable and table model food mixers. The mixer was operated in a bowl half-full of water for most of the measurements. The sound level ranged from 49 dB(A) to 79 dB(A) with a mean level of 67 dB(A). Figure A.20 shows narrowband analysis of mixer noise at low speed and at high speed.

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A.2.10 Freezer

The mechanical components of a freezer are a compressor, evaporative coils, condensing coils, and one or two fans, as in a refrigerator. Small freezers have the condensing coils spread over the back of the machine. On larger units, with their requirement for forced cooling, the condenser coils are grouped at the bottom and cooled by a fan that also cools the compressor. With the compressor in operation, the sound levels generated by three home freezers were measured; the mean level was 51 dB(A) with a range of 39 to 59 dB(A) at a 3-ft distance. Figure A.21 shows narrowband data for two of the three freezers. The primary noise generators are the motor, fans, and compressor, with some radiation from the casing.

A.2.11 Hair clipper

A measurement of the noise generated by a hair clipper was made at a distance of 3 ft; the sound level was 59 dB(A). The noise is generated by the motor and gears which enable the clipping blades to vibrate.

A.2.12 Hair dryer

Different models of hair dryers all share the design objective of forcing warmed air over wet hair. Table models have a hard-shelled enclosure like that of a professional hairdressers machine. Portable dryers have plastic bonnets connected to the fan and heater by a flexible hose. Noise is generated by the fan, motor and air flow. A faster drying rate is achieved by greater air flow and higher temperatures; this, however, means increased noise from the fan. The latest development of a totally portable unit – with motor and blower attached directly to the bonnet – is the noisiest arrangement because it puts the noise source directly by the ear of the user. Six hair

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dryers were measured at a 3-ft distance; the mean level was 61 dB(A). Figure A.22 shows 1/3-octave band sound pressure levels measured at a distance of 3 ft from three units. The low-frequency tonal components are probably motor related, while the high-frequency peaks may relate to the blade passage of the blower.

A.2.13 Heater, electric

Electric heaters used to heat a single room typically have small single-speed fans that blow air past electric coils into the room. The noise generated by these heaters is due to the electric motors, the fans, air flow, and, often, rattling metallic parts. A noise level of 47 dB(A) was measured at 3 ft from an electric heater.

A.2.14 Hedge clippers

The noise of hedge clippers, in which an electric motor runs one or two cutter bars, is mainly generated by the motor and reciprocating gear action. On some models, one bar moves back and forth against a stationary bar; on other models, two cutters reciprocate. Since the latter is a more balanced action, vibration to the user is reduced. We measured a noise level of 84 dB(A) at 3 ft from one unit.

A.2.15 Home shop tools

Electrically-powered shop tools such as drills, saws, sanders, grinders, lathes, and routers have similar noise generating mechanisms. In general, portable shop tools, due to their requirement to be lightweight and high-powered, require forced cooling of the motor and use high-speed universal motors which are often noisy

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even when running free. Table model shop tools generally use induction motors which are relatively low speed and quiet when running free.

The portable straight-line or vibration sander is relatively quiet when running free [63 dB(A) at 3 ft] because it has a lower power requirement than most power tools and requires no forced cooling. Figure A.23 shows narrowband data for two operations of a belt sander: running free [82 dB(A)] and sanding wood [86 dB(A)]. The primary noise is the vibrating action of the sander foot.

In drills the gears add to the noise – the more sets of gears required, the noisier the operation. The noise generated by four 1/4-in. drills with a single set of gears measured 76 to 80 dB(A), the noise of two 3/8-in. drills with two sets of gears measured 83 dB(A), and the noise of two 1/2-in. drills with three sets of gears measured 84 and 87 dB(A). Figure A.24 presents noise levels measured near a 1/4-in., a 3/8-in., and a 1/2-in. drill; the peaks in the spectrum are probably related to the speed and the teeth ratios of the gears. Figure A.25 presents narrowband data on two different drill presses, one working metal, the other wood.

Noise levels generated by three different grinders working metal [87 to 97 dB(A)] are shown in Fig. A.26. In Fig. A.27 the noise levels generated by a router running free [81 dB(A)] are compared with the levels when it is working wood [88 dB(A)]. Noise levels of a small metal lathe are shown in Fig. A.28 for a running free condition and for cutting metal. Figure A.29 shows the narrowband data for a sabre saw running free and cutting wood.

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Noise levels associated with the cutting of wood by a jig saw, a radial saw, a table saw, and a band saw are shown in Fig. A.30. The tone at 3150 Hz for the table saw may correspond to the frequency of teeth passing a given point [8].

Tools such as a table grinder, lathe, table jig saw, and table band saw generate noise levels in the mid-sixty to mid-seventy dB(A) range at a 3-ft distance while running free. The larger portable tools especially drills and grinders, generate noise levels of 80 to over 90 dB(A) running free.

A.2.16 Humidifier

Room size humidifiers are relatively simple mechanical devices in which a fan forces air through a wetted pad. Humidifiers exemplify the recurring noise problem from air circulation caused by fan, motor, and air movement noise. Figure A.31 shows narrowband data - 41, 51, and 65 dB(A) - for three settings of one humidifier. The higher levels are associated with higher fan speeds and thereby increased flow noise.

A.2.17 Knife, electric

For easy handling in the home, electric knives are designed to be small and lightweight. Therefore, the electric motor and gears for reciprocating blade action are encased in lightweight plastic. While the noise of an electric knife [with a range of 65 to 75 dB(A) and a mean level of 70 dB(A) at 3 ft] can be annoying, it also acts as a signal that the knife is in operation. Figure A.32 shows narrowband data for two of the three samples.

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A.2.18 Knife sharpener

Electric knife sharpeners are often attached to electric can openers as well as being seperate appliances. The rotation of sharpening stones alone is very quiet since just the motor and shaft rotate; however, the interaction between the stone and the knife during the sharpening process makes an unavoidable grating noise. A single measurement was made at a 3-ft distance; while the noise levels vary depending on the pressure of the knife against the stone, 72 db(A) is representative of a typical sharpening operation.

A.2.19 Lawn mower, electric

The gears and the A.C. or battery powered engine of the rotary type electric lawn mower are the main sources of noise. The rattling of the engine housing and other metal parts plus the whirling sound of the blade are also identifiable. Although an electric lawn mower is often quieter than a gasoline-powered lawn mower, the two electric ones that were measured registered 81 and 89 dB(A) at a 3-ft distance. The larger the lawn mower, the more powerful an engine is needed to rotate the blade, and thus the noisier the device. Certain possibilities appear feasible for quieting the electric lawn mower such as changes in blade design and speed to reduce vortex noise, tighter construction of the tool, and sound damping for the motor housing and blade covering.

A.2.20 Oral lavage

An oral lavage is a device that uses the squirting force of water to cleanse the mouth. The motor drives a reciprocating pump, connected to a water supply, which forces a tiny stream of water out the end of a tube. Two measurements gave values of 70 and 72 dB(A).

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A.2.21 Refrigerator

The majority of the refrigerators sold today are automatically defrosting. Cooling coils are located outside the freezer storage area and cold air is circulated through the freezer unit by a fan. The automatic defrost mechanism periodically melts the ice which forms on the coils. The trend in recent years has been to larger refrigerators with features such as automatic ice cube tray filling, ice cube making, and defrosting. Refrigerators with such features require more power and thus larger compressors with resulting higher noise levels. Better sound isolation around the machinery compartment, sound absorbing material in the machinery compartment, and resilient mounting of the motor and compressor have prevented the noise of the newer machines from greatly increasing. Twelve refrigerators were measured at a distance of 3 ft from the front. The levels ranged from 35 dB(A) to 52 dB(A) with a mean level of 42 dB(A). Figure A.33 presents narrowband data for two refrigerators.

A.2.22 Sewing machine

Sewing machines from the simplest to the most sophisticated and complex ones all have variable-speed electric motors, necessary gear and drive mechanisms, and auxiliary accessories. There is a wide range of controls available such as stitch tension, variable stitch length and width, zig-zag stitching, forward-reverse action, needle orientation, etc. The more versatile sewing machines have insertable cams which can be changed for different stitching patterns. Measurements on two sewing machines in operation gave values of 70 dB(A) and 74 dB(A) measured 3 ft from the machine. Figure A.34 shows narrowband data for these two machines.

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possible noise control measures are to reduce noise from the motor, linkages, gears, and clutch by use of different materials and more effective enclosures. Resilient mounting of vibrating parts to reduce structureborne vibration noise is presently used.

A.2.23 Shaver, electric

Electric shavers are run by a compact but powerful electric motor, powered from house current or a rechargeable battery. While shaving mechanisms may vary — using either rotary blades or oscillatory cutting action — the noise is generated by the motor and gears. The mean sound level for men's and women's shavers was 60 dB(A) at a 3 ft distance; the range was 47 to 69 dB(A). Figure A.35 shows narrowband data for four men's shavers and Fig. A.36 presents data for two women's shavers.

A.2.24 Toothbrush, electric

A small, lightweight high-speed motor run by either A.C. power or rechargeable batteries drives the detachable toothbrush. The less expensive models allow rotation in only one plane perpendicular to the axis of the toothbrush. With additional gearing, the more expensive models simultaneously rotate and move laterally to provide better cleaning action.

The main noise sources of an electric toothbrush are the motor and the gears. Typically, the devices with more gears are noisier. The mean sound level of three different electric toothbrushes at a 3 ft distance in bathrooms was 52 dB(A) with a range of 48 to 55 dB(A). At the user distance of about 3 in. from the device, the sound level is about 10 dB(A) higher. Figure A.37 shows narrowband data for an electric toothbrush.

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Due to the overriding requirements for small size and light weight, noise control techniques such as improving the sound transmission loss of the casing or adding sound absorptive material are impractical. The most promising noise reduction possibilities will likely come from the development of quieter gear operations through the use of different materials or through designing the gears with closer tolerances or a different configuration.

A.2.25 Water faucets

Noise from water faucets includes water hammer, turbulence and cavitation noise. For particular values of pressure drop, a valve can be designed to minimize cavitation and its resulting noise; however, no valve configuration has been developed to minimize the noise for the full range of pressures that a valve experiences. The measured sound level at a distance of 3 ft for two water faucets was 61 dB(A). If die-casted brass fittings could replace sand-casted ones, there would be a smoother interior finish which would result in less turbulent flow and quieter operation.

A.3 Typical Equipment in Buildings

Many different types of electrical and mechanical equipment are required for the proper operation of modern large buildings. Much of this equipment is hidden in equipment rooms, behind ceilings, in walls, or behind cabinet type exterior enclosures, but the total cost and volume associated with such equipment represents a significant part of the cost and utility of a successful building. The majority of the equipment (including most of the basic heating and cooling system components) is for supplying the building occupants with a suitable amount of air at a comfortable temperature and moisture content. In addition, pumping and piping systems are

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used for water and fluid circulation, elevators and escalators are used for movement of persons, and various conveyance systems are used for movement of material. In this section, the use and function of building equipment are briefly described. Where available, typical noise levels are presented for the equipment. For detailed information and procedures, the reader is referred to Refs. 9, 10, 11, and 18 at the end of this Appendix.

A.3.1 Prime movers

The function of prime movers is to transform energy — in the form of electric power or combustible fuel — into rotational movement for use in driving other equipment.

Electric Motors are the most widely used of the prime mover devices. They range in capacity from fractional hp up to several thousand hp; most motors fall in the speed range of about 450-3600 rpm. Motor noise is generated by aerodynamic, mechanical, and electrical forces. Aerodynamic noise, often the most prominent noise source, is generated by air turbulence due to movement of the blades of the cooling fan and the slots in the rotor. Recent designs have used higher cooling air velocities, thereby increasing the noise level.

Mechanical noise is due to bearings and shaft unbalance. Although mechanical noise can be identified in rotating machinery, low-frequency vibration rather than noise *per se* is the usual problem. Bearing noise is due to the sliding contact of sleeve bearings and the rolling contact of ball and roller bearings. When new, precision ball bearings are often quieter than sleeve bearings; however, after much use, they are much noisier. In new equipment, unbalance forces are usually small. Wear or build-up of dirt on the rotating component often increases the unbalance in a motor,

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resulting in the generation of vibration at the rotational frequency and its integral multiples; e.g., since the shaft of a 3600 rpm motor turns at 3600 rpm $= 60 \frac{\text{rev}}{\text{min}} = 60 \frac{\text{rev}}{\text{sec}}$, energy will be concentrated at 60, 120, 180 Hz, etc. with the 60-Hz component being the strongest.

Electrical noise is generated by magnetostriction — where a component (iron laminations) contracts and expands in response to an alternating magnetic field. Such effects are particularly noticeable when D.C. or variable-speed motors are supplied rectified A.C. current. The wave-form of the rectified current contains high-frequency components that generate noise in the more audible frequency ranges. The primary excitation frequency for magnetostriction is twice the main power frequency, e.g., in the USA, 2×60 Hz or 120 Hz.

In the past, motor noise was generally less than the noise produced by the driven component. However, motors designed for high-temperature rises or powered by rectified current may now be the controlling noise sources. Even in the case of relatively quiet motors, motor noise often becomes predominant when the driven component is quieted. Figure A.38 presents a range of noise levels typical of a 3 ft measurement position for the many different sizes of motors used in buildings.

Diesel and Natural or LP (Liquified Propane) Gas Internal Combustion Engines are sometimes used when special conditions make them economically feasible. They are often used in emergency power systems, in total energy systems, and for driving large machines such as chillers. Noise generated by internal combustion engines consists of contributions from the intake and the exhaust and radiation from the casing. Although improperly muffled exhaust may be a source of community concern, the intake and radiation from

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the casing are typically greater problems for buildings and considerable detail must be given to controlling the noise. Figure A.39 shows a range of noise levels measured at 3 ft from internal combustion engines found in buildings.

Gas Turbines are used almost exclusively in emergency power and "total energy" systems. A total energy system makes use of the fact that only about 20-30% of the heat energy of most fuels can be turned into mechanical power; the rest is rejected in the form of heat to cooling water and exhaust gases. A total energy system salvages some of the energy which is usually lost and uses it to heat water, etc. The advantages of turbines over equivalent internal combustion engines are their light weight, smaller size, and lower vibration, which can be governing factors for upper story installations. Figure A.40 presents noise levels representative of the noise generated by gas turbines.

Steam Turbines are sometimes used as high horsepower (over 50 hp) prime movers when high-pressure steam is available as a public utility service. Figure A.41 shows the range of noise levels typically found near steam turbines.

Transformers, although their function differs from that of the prime movers listed above, supply primary electrical input power; their output is an altered form of electrical power (higher amperage and lower voltage) rather than motion. The use of transformers permits large amounts of electrical energy to be supplied to a building with relatively small supply cables. Noise generated by transformers is due primarily to the magnetostrictive effect in the transformer cores. Thus, the noise consists of a harmonic series of component tones with a fundamental frequency equal to

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twice the main power frequency. The range of noise levels generated by transformers typically housed in buildings is presented in Fig. A.4.

Generators or Motors are used to produce local electricity in emergencies when electrical power is unavailable from outside sources, to produce direct current electricity, or to convert power from one frequency to another. The noise generating characteristics and noise levels of generators are similar to those of electrical motors.

A.3.2 Fluid handling units

Pumps may be the common centrifugal type that uses an electric motor drive, or the diaphragm or piston or gear-rotor types that are positive displacement units. Many of the pumps in a building are part of the overall air-conditioning system. They convey water to and from cooling towers, chillers, boilers, and coil banks in airconditioners, humidifiers, unit heaters, unit ventilators, and induction units. Pumps may also be used to supply fuel oil to boilers, domestic water to upper floors, emergency fire-fighting water, hot water for various uses such as convectors, ice melting, radiant heating, etc., and for sewerage ejection from low levels.

Noise problems due to pumps are usually caused by mechanical forces and turbulence. Noise is radiated by the casing of the pump and associated piping. In order to prevent the tonal components at the impeller passage frequency (the impeller speed in revolutions per second multiplied by the number of impellers) from being detectable at remote locations, a vibration break of flexible connections in the piping is sometimes provided. However, sound

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energy in the fluid may flank this flexible connection so that the pipe walls are excited downstream of the pipe break. Figure A.43 shows a range of noise levels typical of many pumps used in buildings.

Steam valves may be used either to control volume flow or to reduce the pressure from the main supply system. A steam valve, like any valve, is noisiest when there is a large pressure differential between the upstream and downstream of the valve. A typical spectrum for steam valve noise is presented in Fig. A.44.

A.3.3 Air handling

Fans are the driving mechanism for moving air about a building. Propeller-type fans may be used to distribute large quantities of air at little pressure drop across the fan; centrifugal and axial-flow type fans may build up relatively large static pressures in an air handling system and thus are used mostly in ducted ventilation systems in large buildings. In a ducted system, the air will tend to flow toward regions of lesser static pressure, eventually to be released at ambient pressure in the building proper.

Fan noise is generated by mechanical and aerodynamic sources. Bearings and unbalanced shafts are the primary mechanical sources; with proper construction and maintenance, fan noise from these sources can be minimized. Aerodynamic noise may be divided into components due to rotation and due to vortex shedding. Since an impluse is imparted to the air each time a fan blade passes a given point, the rotational component consists of a series of tones at multiples of the blade passage frequency (rotational speed in revolutions per second times the number of blades). The vortex

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component is primarily the result of the shedding of vortices from the fan blades; it is an example of broadband random noise. Depending upon the type, size, and geometry of a particular fan, the total noise generated will have varying contributions from vortex and rotational noise.

The horsepower, volume flow, and static pressure, and thus the mechanical efficiency, are important indicators of the noise that will be generated by a particular type of fan. Figure A.45 shows estimated levels for a range of fans utilized in buildings. The noise problems that do occur are usually due to either a failure by the mechanical or acoustical system designer to consider an important source or path, or a failure of the builder to incorporate properly the designed noise control features in the building.

Air Control Units and Mixing Boxes comprise a family of supply air control and treatment devices that provide air at the proper volume, pressure, and temperature to a room. These devices include: constant volume control (CVCs), terminal reheat units (TRs), variable volume controls (VVCs), and dual duct mixing boxes. Their function, in many instances, is analogous to steam valves — they take air which has passed through a small duct at high velocity and pressure and reduce its pressure and control its volume flow. A constant volume control takes in air at varying pressure (caused by changing demands elsewhere in the system) and discharges a constant volume of air at a constant pressure. A terminal reheat unit adds the capability of heating the air by passing it over an electric or hot water coil before it is discharged. A variable volume control meters out an amount of heating or cooling air as demanded by a local thermostat and reduces the static pressure of the air to obtain the desired volume. Each of these units is usually located toward the end of supply ducts

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near the space it serves. Noise generated by air control units and mixing boxes is a function of the pressure drop across the device and the volume of air flow. Figure A.46 presents a range of noise levels typical of a 3 ft distance from these units.

Diffusers, Grilles, Registers, and Louvers. After a supply of air at the correct pressure, temperature, and volume has been provided to the vicinity of a room, it must be introduced and distributed into the room without causing drafts. Portions of the air should be directed toward windows and other exterior surfaces that are too cold in the winter and too hot in the summer, while all the air should be distributed so as to provide ventilation to all parts of the space. This is done with various diffusing or direction-controlling devices, usually fabricated from sheet metal, consisting of fins, blades, vanes, etc., that are located at the end of the duct. Perforated grilles, registers, or other similar devices are used to receive the air to be returned to the distribution system. The noise generated by terminal devices, such as diffusers, is dependent on the pressure drop across the device, the volume of air flow, the cross-sectional area, and the spacing between vanes. Figure A.47 illustrates the range of noise levels possible with various diffusers, grilles, etc.

Air Compressors are the source of high-pressure air which is used by many large buildings as an energy source for pneumatic control devices throughout the ventilation system. Such controllers include fresh air intake dampers, zone control dampers, induction units, unit ventilators, mixing valves in mixing boxes, and control valves in CVC and VVC units. The high-pressure air provided by the compressor must be piped throughout the building, first to thermostats and then to the pneumatic operators. Buildings which

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have laboratory or workshop facilities usually supply compressed air to those spaces. Air compressors are most often of the piston type and, depending upon the size of the unit, the reciprocating action of this type of compressor may make satisfactory vibration isolation difficult. Figure A.48 is an example of noise levels generated by reciprocating compressors.

A.3.4 Airconditioners

The usual functions of an airconditioner are to filter particulate matter and odors from the air, to regulate air temperature and humidity, and to propel the conditioned air to its destination. The fan in the airconditioner serves two purposes: 1) to move the air through the filters and heating and cooling coils, and 2) to provide enough static pressure to push the air throughout the duct system to the desired spaces. The heating and cooling coils are liquid-to-air heat exchangers, receiving warm or cold water or refrigerant from other machines and transferring warmth to or from the air carried past them.

Central Station. Strictly speaking, "central station" refers to the entire collection of equipment that has a part in conditioning the air that is ultimately distributed to the building. In its more limited use here, "central station" refers to the fan plenum equipment of the airconditioner. The equipment includes controllers and filters on the inlet side and heating and cooling coils, and temperature controllers and, possibly, zone controllers on the discharge side. The cooling coils act as dehumidifiers in that warm, moisture-laden air condenses on them. Occasionally, a humidifier is incorporated to add humidity for special needs. Central station units are most common in large multistory buildings. The size of a particular unit will depend upon the service that it is supplying. Noise levels for units typically found in buildings are presented in Fig. A.49.

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Unitary Rooftop Units are usually found on one- or two-story buildings. They perform the same function as the larger central station units but do not rely on other machines to provice hot or cold fluid to their heating and cooling coils; in other words, these units include their own compressors, condensers, etc. In a large one-story building or building complex, this can represent a savings on the heating and cooling water piping which would be needed if the units were dependent on other machines. Figure A.50 presents noise levels measured near both small (the lower curve) and large units.

Unitary Split System Units are usually found in small buildings. They are almost identical in function to rooftop units, but they are located on occupied floors in the building. Thus, a remote heat exchanger (either a condenser or cooling tower) must be provided to reject waste heat when the units are cooling. The refrigerant compressor may be located remote from the unit together with the condenser.

Fan Coil Units are rather like miniature central station air-conditioners in that they draw in fresh air and rely on outside sources for hot water, cold water, or steam for their heating and cooling coils. They are small units, usually enclosed within a cabinet and placed under or near windows. Some units, rather than relying on hot water, use electric heating coils. Typical noise levels for fan coil units are presented in Fig. A.51.

Induction Units are similar in appearance and location to fan coil units but receive air from a central station unit at a rather high pressure, 1 to 4-in. static pressure, as compared to less than 1-in. operating static pressure for unit ventilators. This

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air is used to induce circulation of the room air. Such units are also provided with heating and cooling coils to temper the air which they receive from the central supply. A range of noise levels for typical induction units are shown in Fig. A-52.

Humidifiers, Dehumidifiers, Heaters and Furnaces, although grouped under the heading of air conditioners, have only one function: to increase or decrease humidity, or to heat.

- *Humidifiers* are of two general types: 1) those that add steam to the air, and 2) those that blow the air through or over moist surfaces to add water to the air. Both types can be built into ductwork or can stand alone to serve a particular space. The steam type consists of a steam nozzle, a control valve, and possibly a fan. The moist surface type consists of a fan (if not located in ductwork), a water pump, and a moving porous belt or disk which passes through the water and then through the moving air.

- *Dehumidifiers*, if required, may be located in the ductwork where air flow is provided by the system fan. The primary element is a cooling coil which condenses moisture out of the passing air. In such an installation, a heating coil may be provided to temper the excessively cooled air that leaves the cooling coil. A self-contained unit will include a fan but usually not a heating coil.

Unit Heaters consist of a remote fan and heating coil, which may be either electric or mechanical, and receive hot water or steam from an external source. Such units are often used in little-occupied spaces such as mechanical equipment rooms, storage spaces, garages, stairways, etc.

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- *Warm Air Furnaces* burn gaseous or oil fuel and use an integral air-to-air heat exchanger to heat the air. They usually have two built-in-fans, one to circulate the air, the other to provide air for combustion. They are often used in small buildings which do not have access to large quantities of hot water or steam.

A.3.5 Boilers

For supplying warm air to a building, most air conditioning systems use hot water or steam supplied by a boiler that may be located either nearby or remote from the building. (In total energy systems, waste heat from the engines may be captured to heat water in place of or in addition to a boiler.) Boilers heat water or generate steam by burning a fuel and passing the water through or around the fire in a gas-to-liquid heat exchanger. There are two principal types of boilers: water tube and fire tube. In the water tube boiler the tubes are filled with water and pass through the fire. In the fire tube boiler, the boiler is filled with water and combustion takes place in tubes that pass through the water. Steam boilers are usually of the water tube type, while hot water boilers may be either type. Figure A-53 shows a range of noise levels typical of boiler operations; fire tube boilers are represented by the upper part of this range and water tube boilers by the lower parts. Gas-fired burners in boilers are much quieter than oil-fired burners.

A.3.6 Refrigeration machines or chillers

Refrigeration machines or chillers use various methods to remove heat from water supplied to cooling coils (the "chilled water") and transfer that heat to other water for eventual rejection.

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Absorption/Cycle Machines use heat energy and a salt solution to transfer heat from the chilled water system to the reject heat system. The machine is composed of tanks, condensers, evaporators, heat exchangers, pumps, and controls. On a per ton capacity basis, they are larger than vapor compression cycle machines. Figure A-54 presents value levels typical of these machines for estimating use.

Vapor Compression Cycle Machines, which are commonly called chillers, use a compressor to compress the refrigerant; the resulting hot compressed gas passes through a condenser where it is cooled and changed to a liquid. The refrigerant is then allowed to expand, further cooling it. The "chilled water" is then passed through a heat exchanger with the cooled gas and is cooled. The resulting heated refrigerant is again compressed and the cycle repeated. Chillers use various types of compressors: the positive displacement (piston and rotary screw) and the centrifugal types; value levels representative of these types are presented in Figs. A-55, A-56, and A-57 respectively.

Small Hermetic Refrigerant Compressors are used in small airconditioners in conjunction with integral or remote air-cooled condensers. These units function exactly the same as the compressors in vapor compression cycle machines except that the refrigerant is cooled in an air-cooled condenser rather than by a reject-heat water-circuit condenser.

A.3.7 Heat rejectors

In most refrigeration machines, rejected heat is transferred to water, which may be used once, e.g., river water, or repeatedly, in which case it must be cooled for re-use. Cooling towers, spray ponds, and air-cooled condensers are used to cool the water.

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Cooling Towers receive large volumes of warm (typically 85° to 75°F) water and cool it a few degrees. In the process, the incoming warm water is sprayed onto the cooling tower "fill," a stack of wood, plastic planks or sheets, or ceramic blocks which have a large surface area. Typically, a fan is used to force air through the fill, cooling the water by evaporation. The air is expelled in a saturated or near-saturated condition and is usually a few degrees warmer. Noise is generated by the fan and by the water falling into the basin. Centrifugal cooling towers (using centrifugal fans) are quieter than propeller-fan towers. Figure A-58 presents a range of noise levels typical for both centrifugal and propeller towers.

Condensers of the liquid-cooled type are used in all large refrigeration machines; smaller machines use directly air-cooled condensers. In a condenser, the entering gaseous refrigerant is cooled as it passes through the gas-to-air exchanger, where the gas condenses to its liquid form, and the resulting liquid is returned to the refrigeration machine. A fan is frequently used to force air flow through the heat exchanger. Figure A-59 presents a range of noise levels representative of air-cooled condenser noise.

A.3.8 Conveyance systems

In multistory buildings, it is necessary to transport large numbers of people quickly. It is also desirable to transport heavy objects from one floor to another, and in hotels, hospitals, and apartments, to transport trash and soiled laundry to their respective collection areas from many locations in the buildings. Elevators, escalators, and pneumatic transport systems are examples of the conveyance systems used in buildings.

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Elevators consist of three major components: the cab, hoist cables and counterweights, and the hoist motors or hydraulic ram piston. The weight of the cab is partially balanced by the counterweights which are located at the cab is rear. The hoist motors are DC-powered, which is best suited to the frequent starting, acceleration, and stopping operations of elevators. Supply current is controlled by accompanying motor-generator sets (using Ward-Leonard motor drive) or large rectifiers. The hoist motors are located directly over the elevator shaft, usually on the roof of a building, or at various upper floor levels. Hydraulic power is sometimes used for distances of under 60 ft. A hydraulic ram provides the raising force. Figure A-60 presents noise levels typically found in elevator machinery rooms.

Escalators are composed of two major components: the stairs with treads and the drive motors. The motors are usually located beneath the lowest flight, the upper flights being driven by those below.

Pneumatic Transport Systems use low-pressure differentials exerted over large or small areas to move comparable sized loads. The chief components are a high-pressure fan, a duct system, loading and unloading stations, and control devices. In a typical system, the fan is run at an idle speed (say 1/2 full speed which requires only 1/8 of the full-speed hp) until the loading station signals for full-speed operation. The load is then conveyed through the duct system to the desired unloading station. At the unloading station, the passage of the load signals the blower which then drops to idle speed.

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A.3.9 Ballasts

Fluorescent and mercury and light requires higher voltage power than the normal 120 line current. Ballasts are essentially small transformers which alter the voltage to suit this need. Ballasts are usually mounted right to light sheet metal panels in order to provide the required cooling area. These panels often serve as very effective radiators of sound; thus, the noise levels may vary considerably. Figure A-61 presents measured data for one installation. Noise levels in other installations with different ballasts and fixtures may be as much as 10 dB quieter or noisier than the curve presented.

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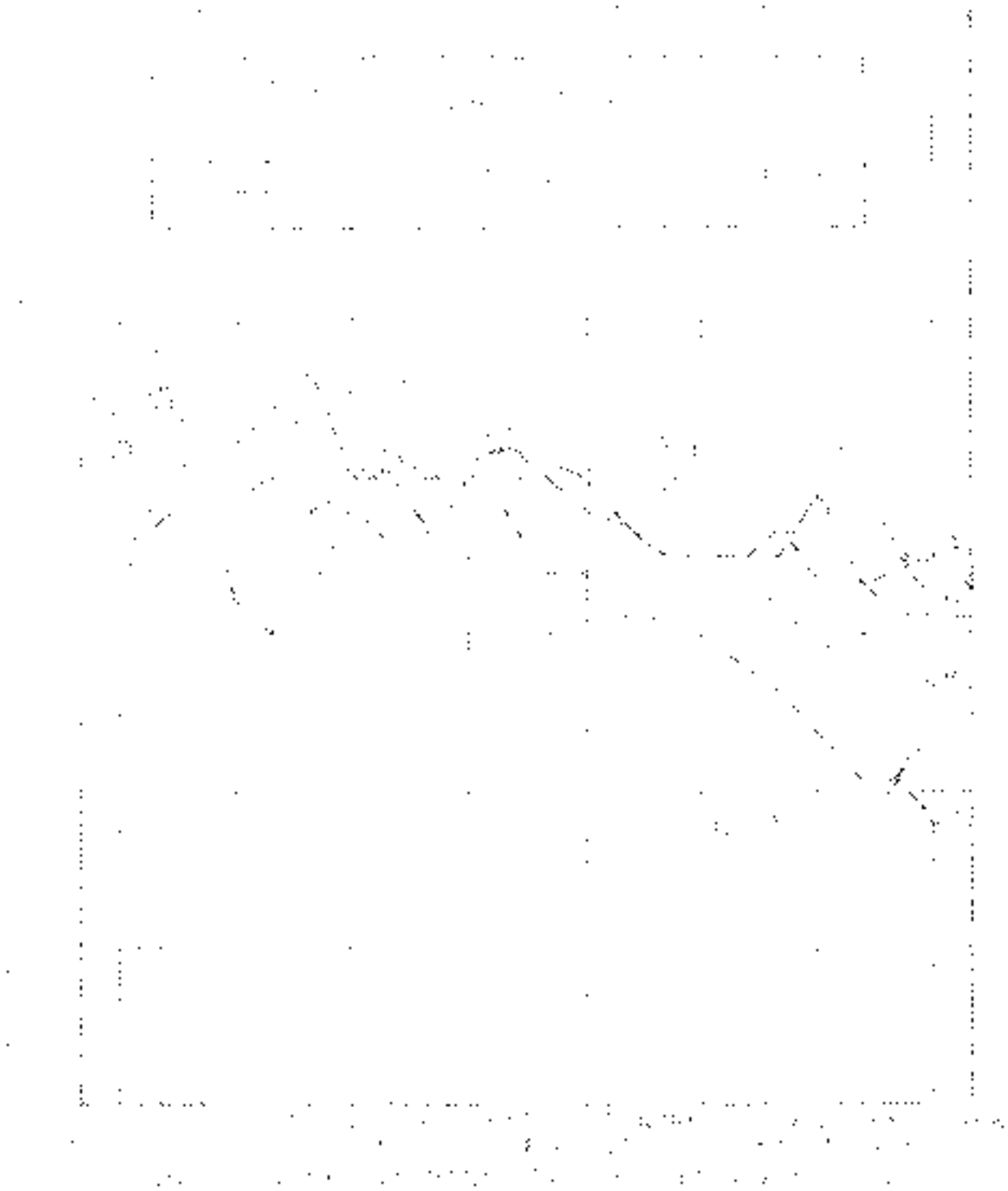

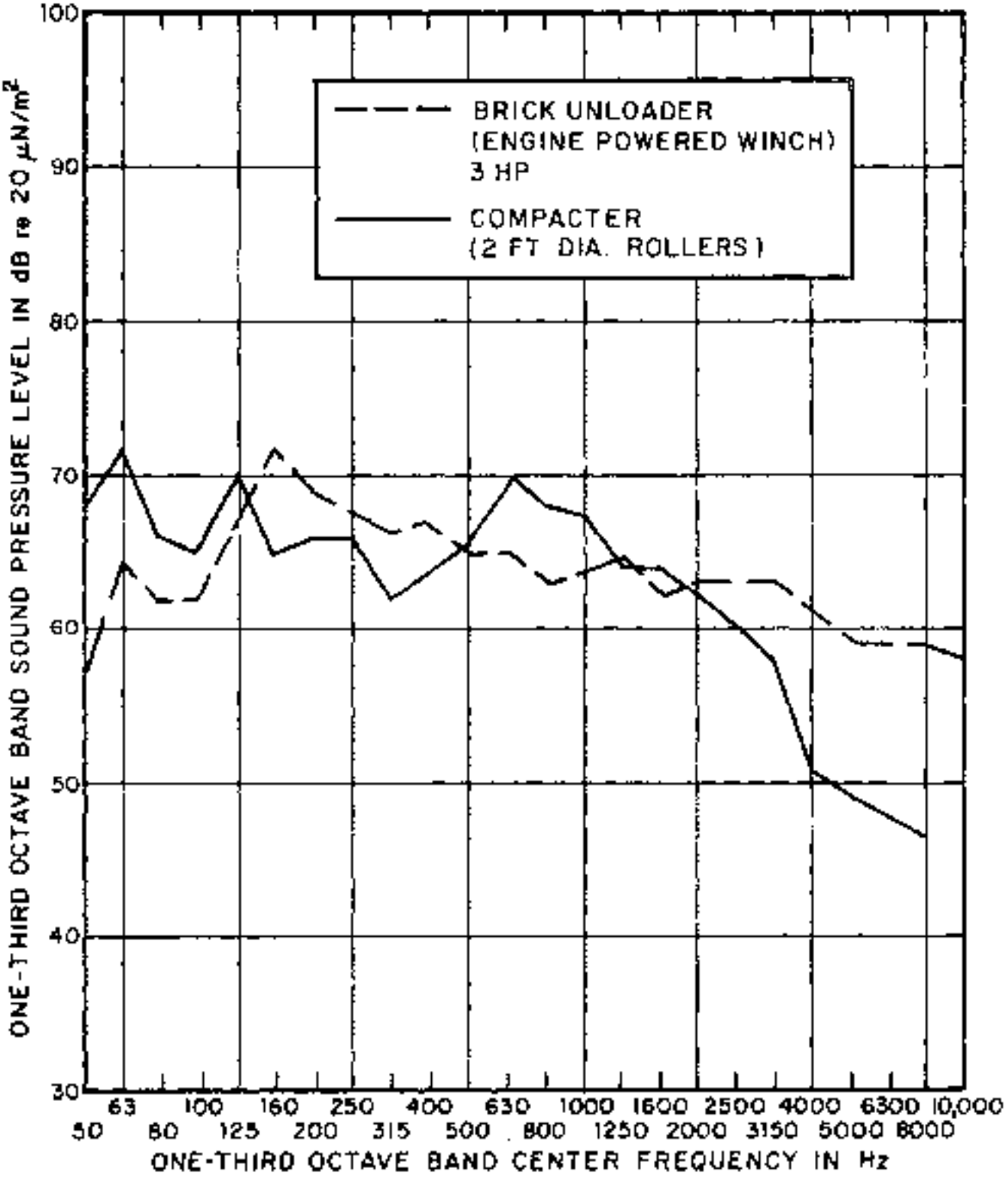

FIG. A.3 SOUND PRESSURE LEVELS FROM TWO GASOLINE-ENGINE POWERED JEEPS OR CONSTRUCTION EQUIPMENT (MEASURED AT 50 FT)

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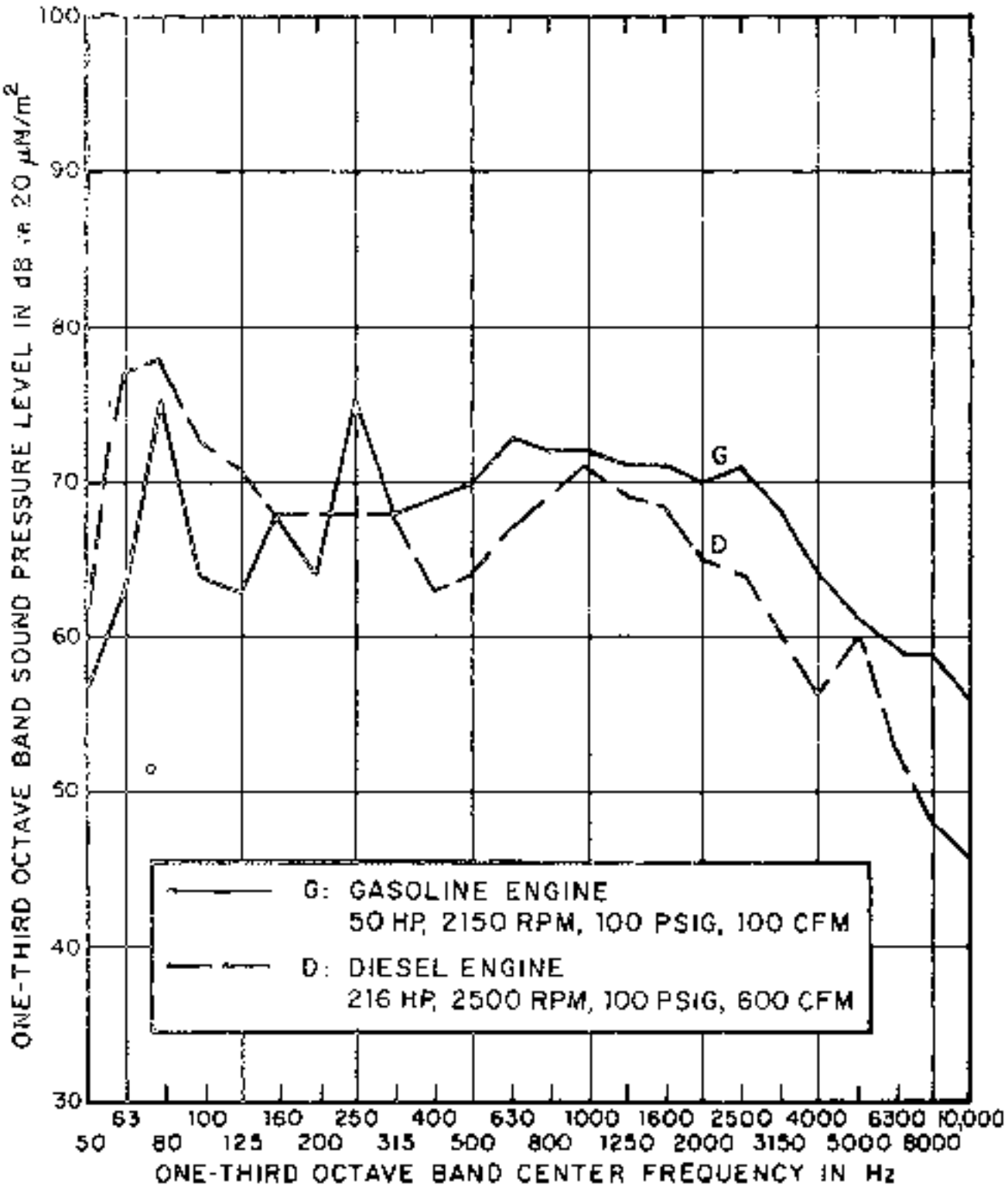

FIG. A.4 SOUND PRESSURE LEVELS FROM TWO AIR COMPRESSORS (MEASURED AT 50 FT)

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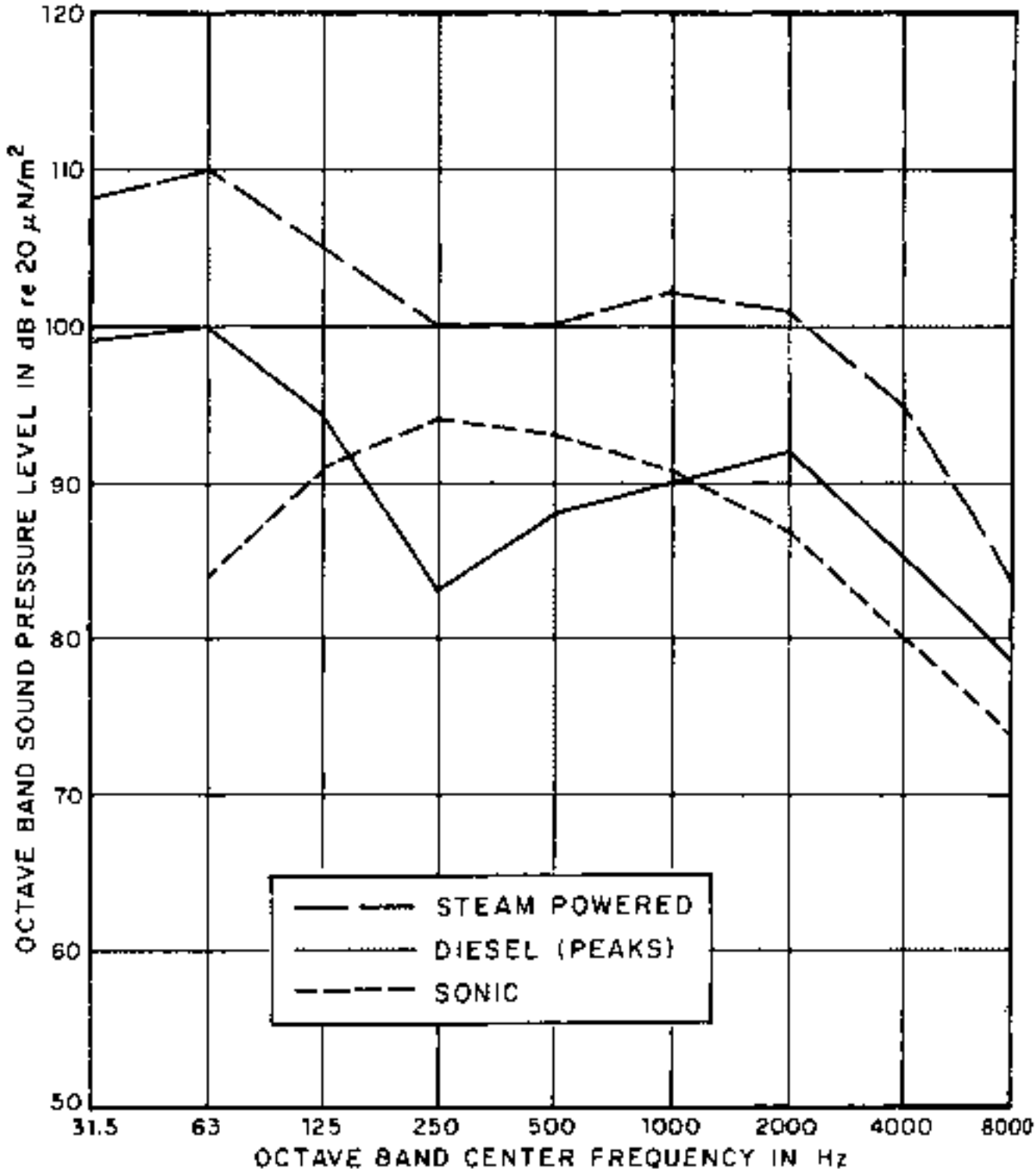

FIG. A.6 PEAK SOUND PRESSURE LEVELS FROM FIELD DRIVERS, DRIVING 14-IN. DIAMETER PIPE PILES (MEASURED AT 50 FT)

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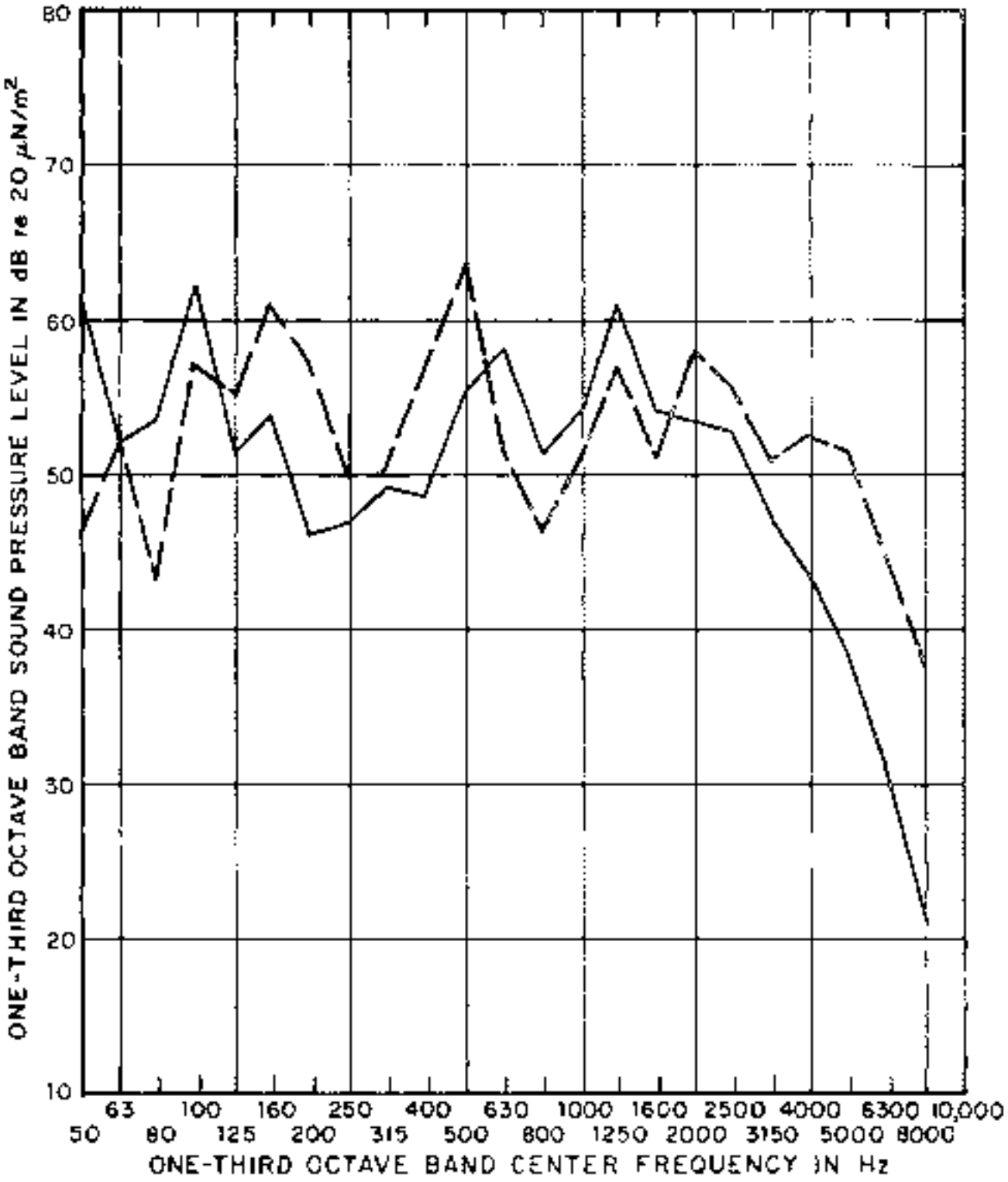

FIG. A.9 SOUND PRESSURE LEVELS FROM TWO CAN OPENERS (MEASURED AT 3 FT)

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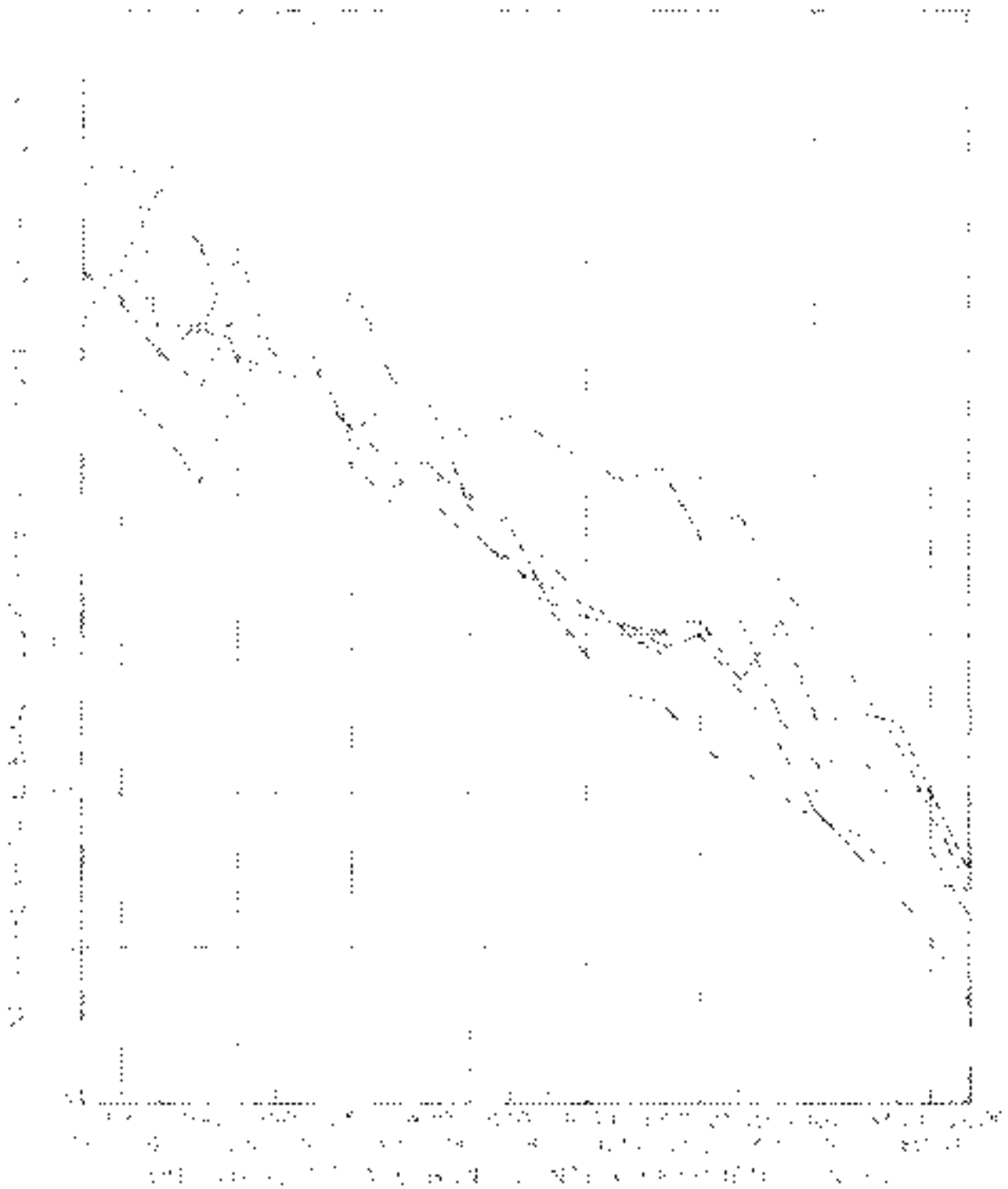

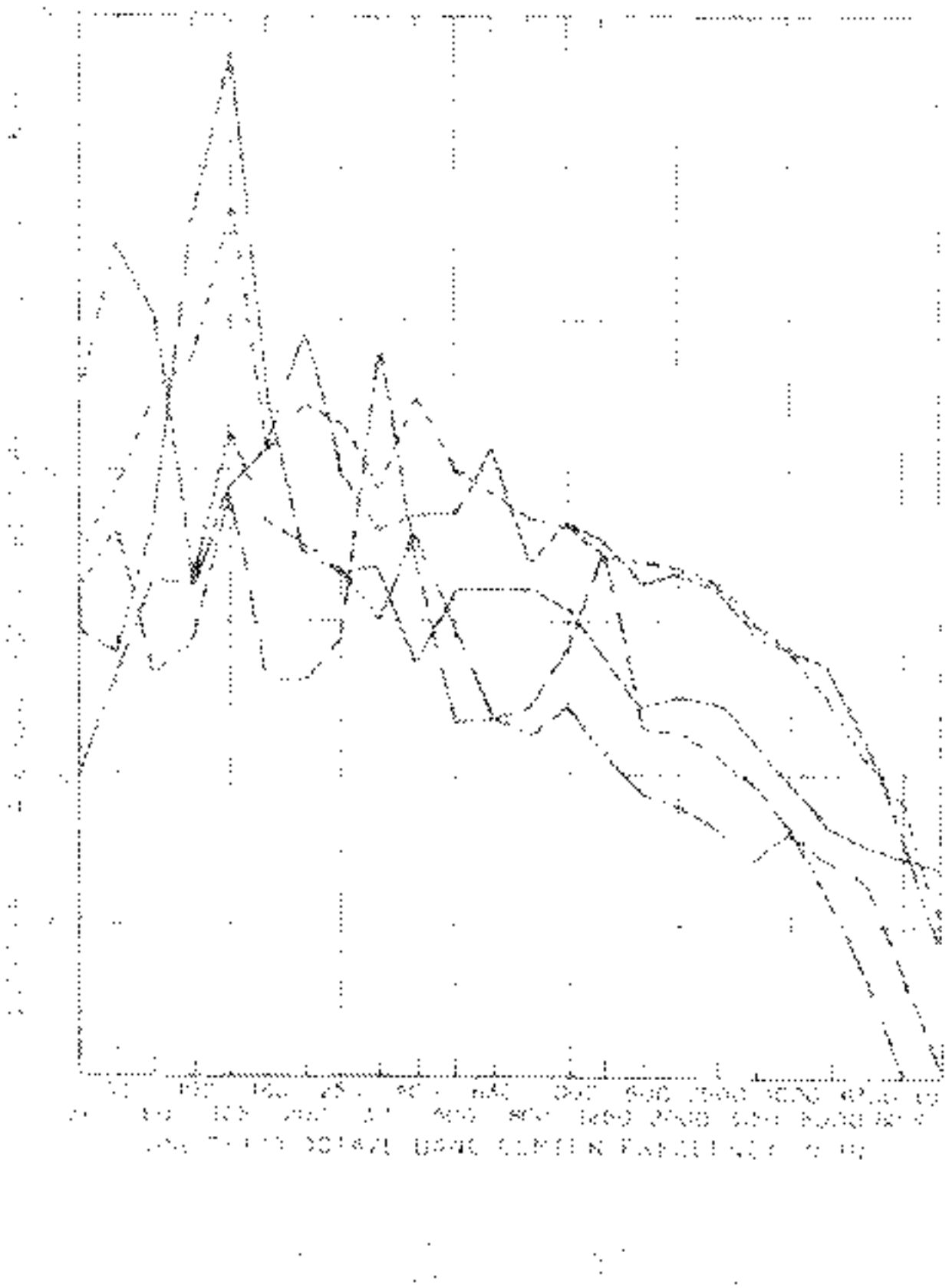

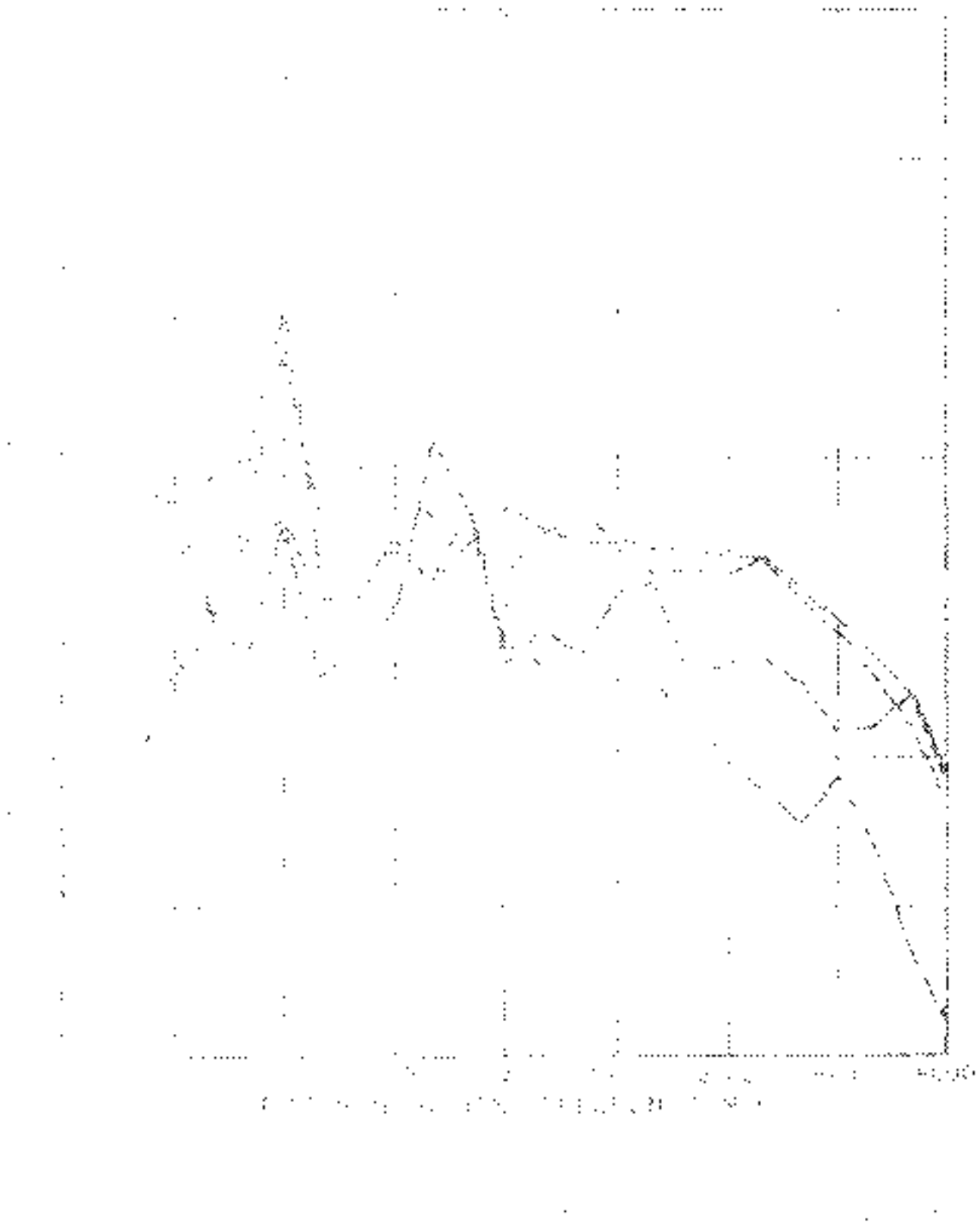

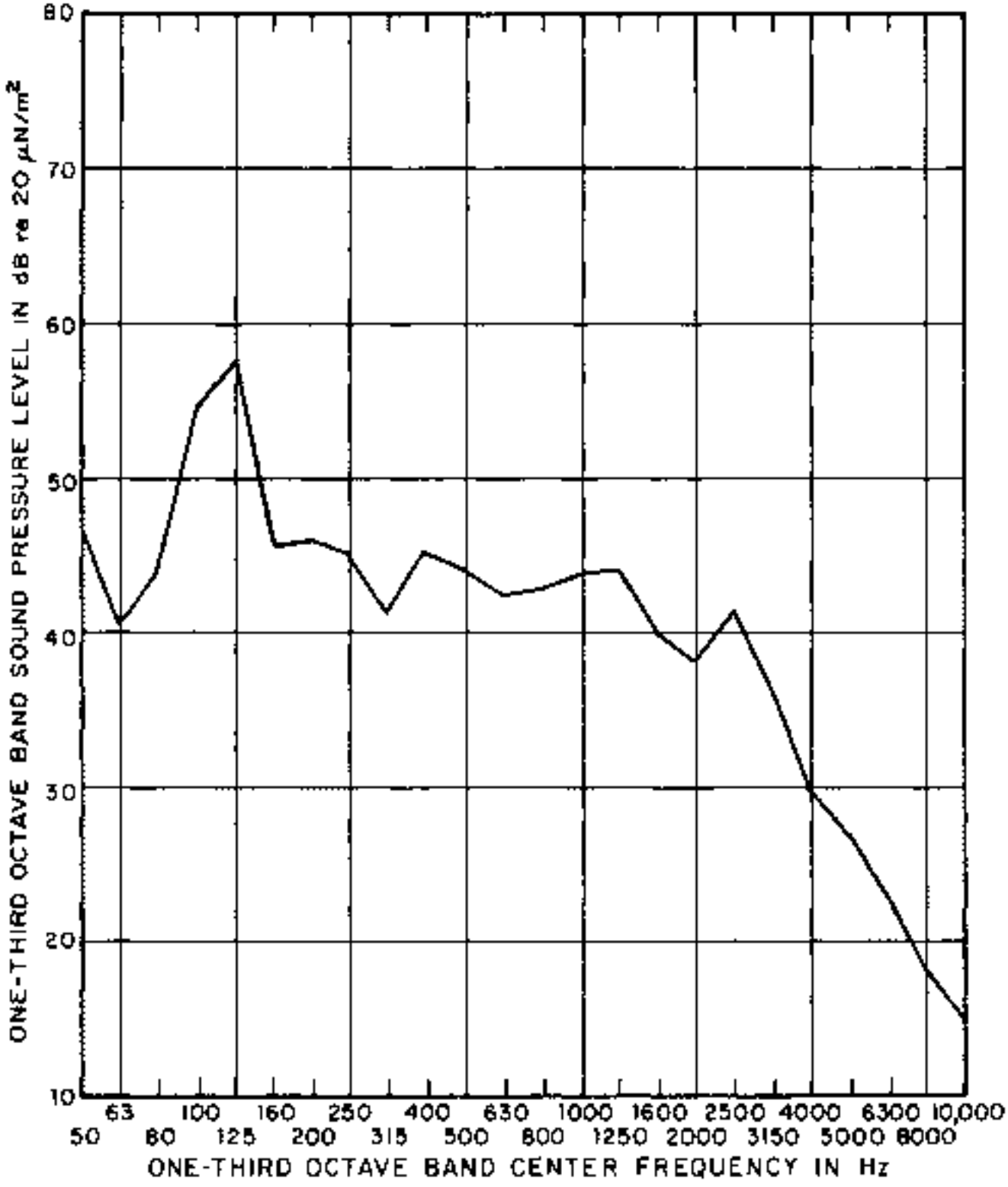

FIG. A.13 SOUND PRESSURE LEVELS FROM A DEHUMIDIFIER (MEASURED AT 3 FT)

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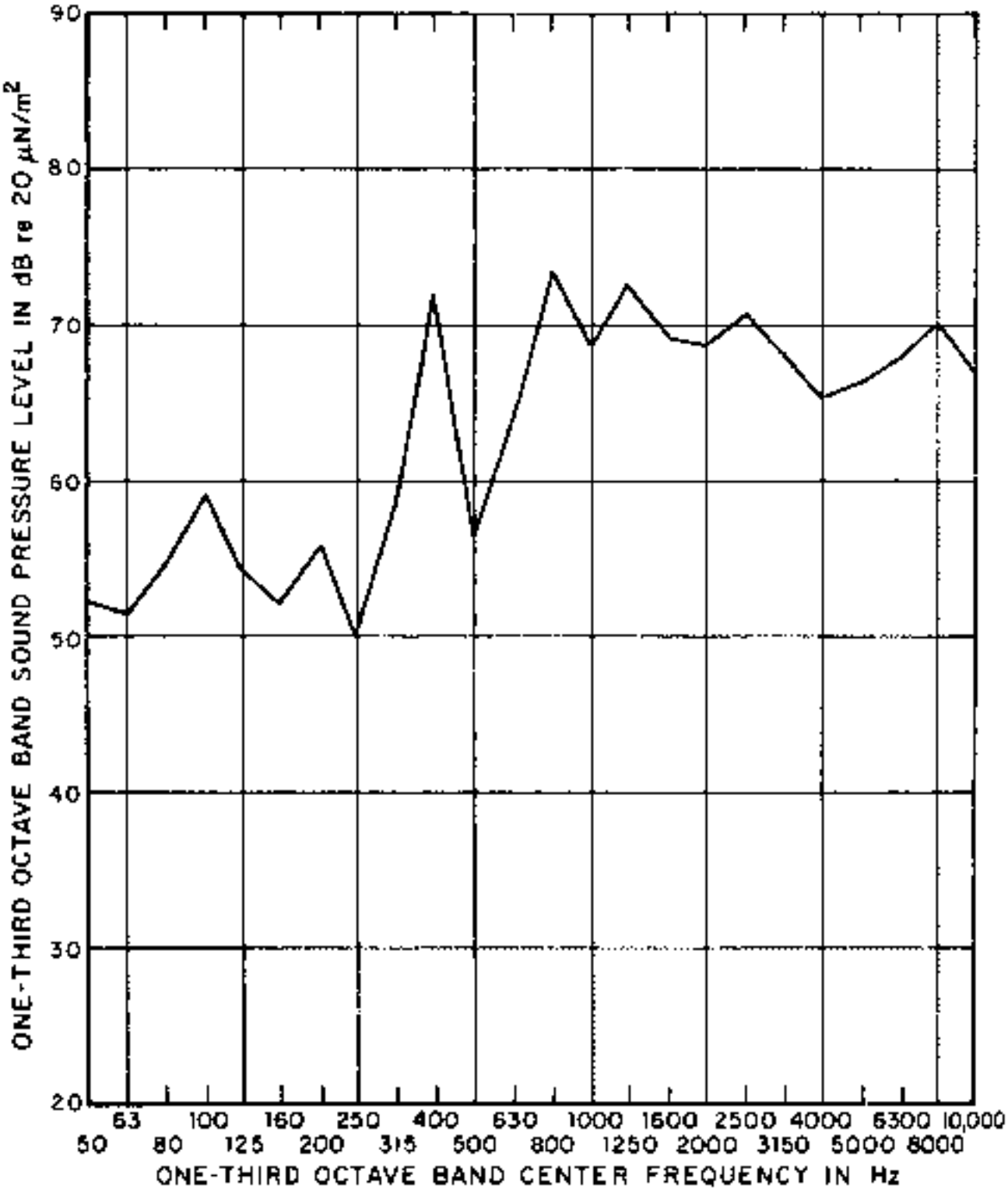

FIG. A.14 SOUND PRESSURE LEVELS FROM AN EDGER AND TRIMMER (MEASURED AT 3 FT)

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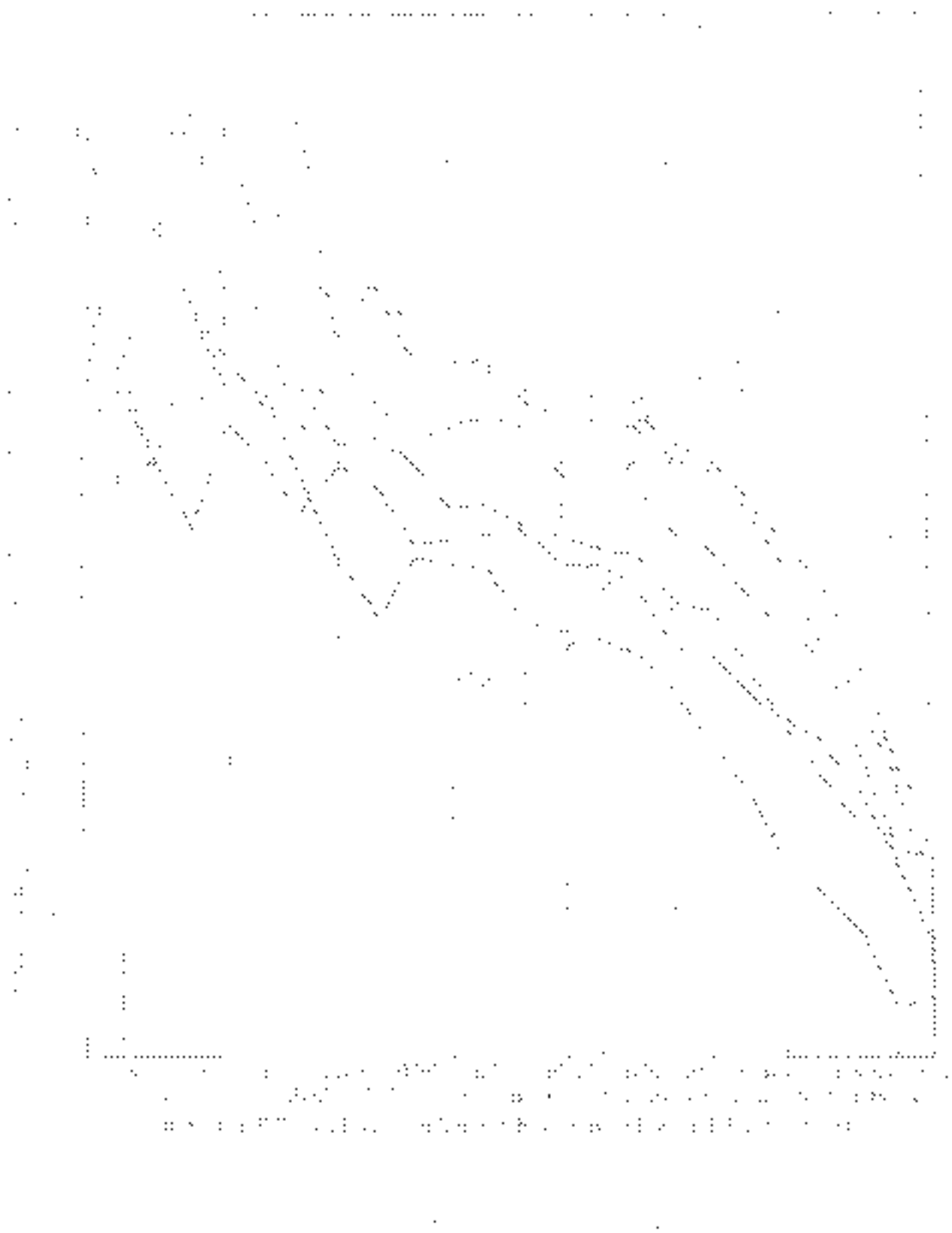

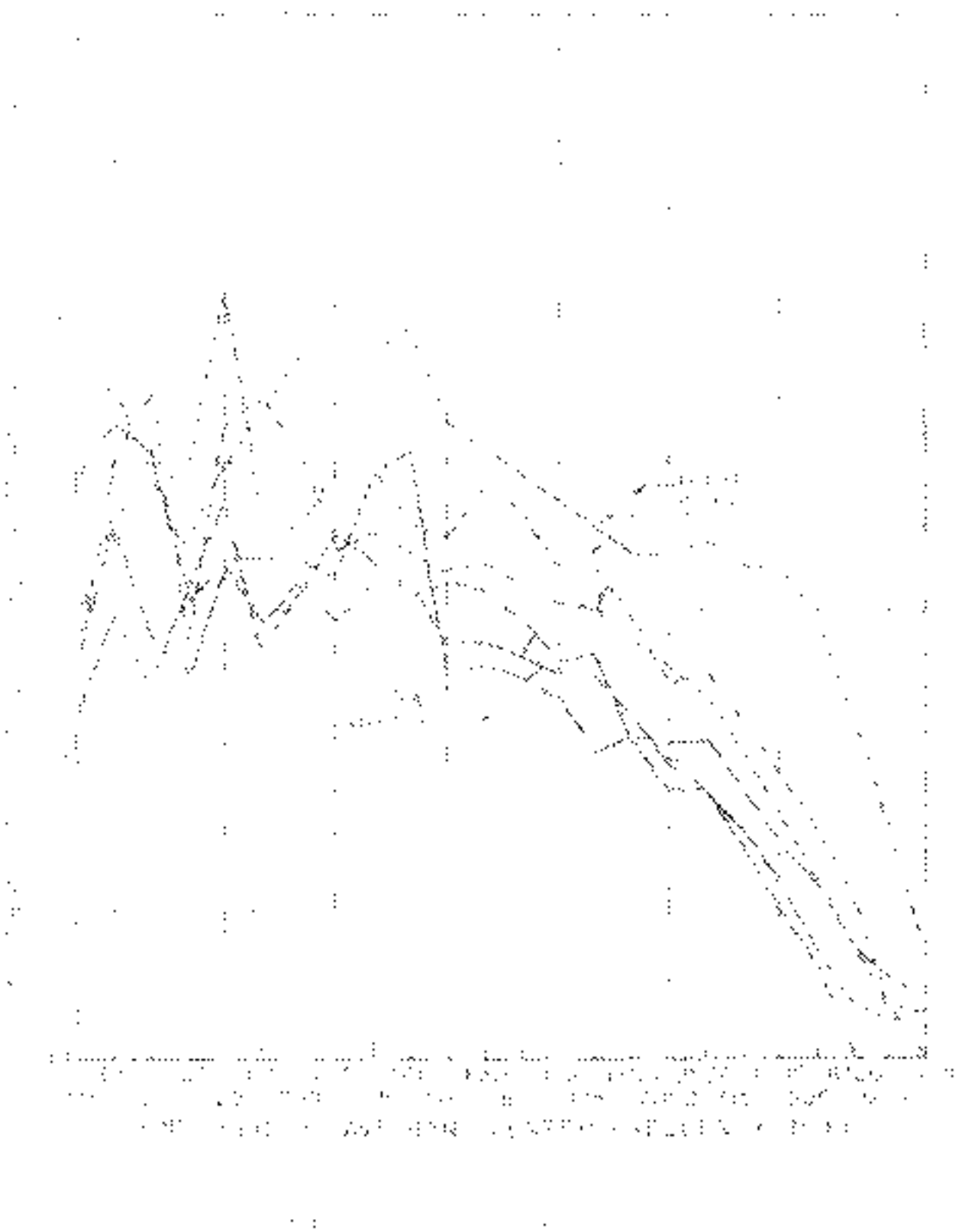

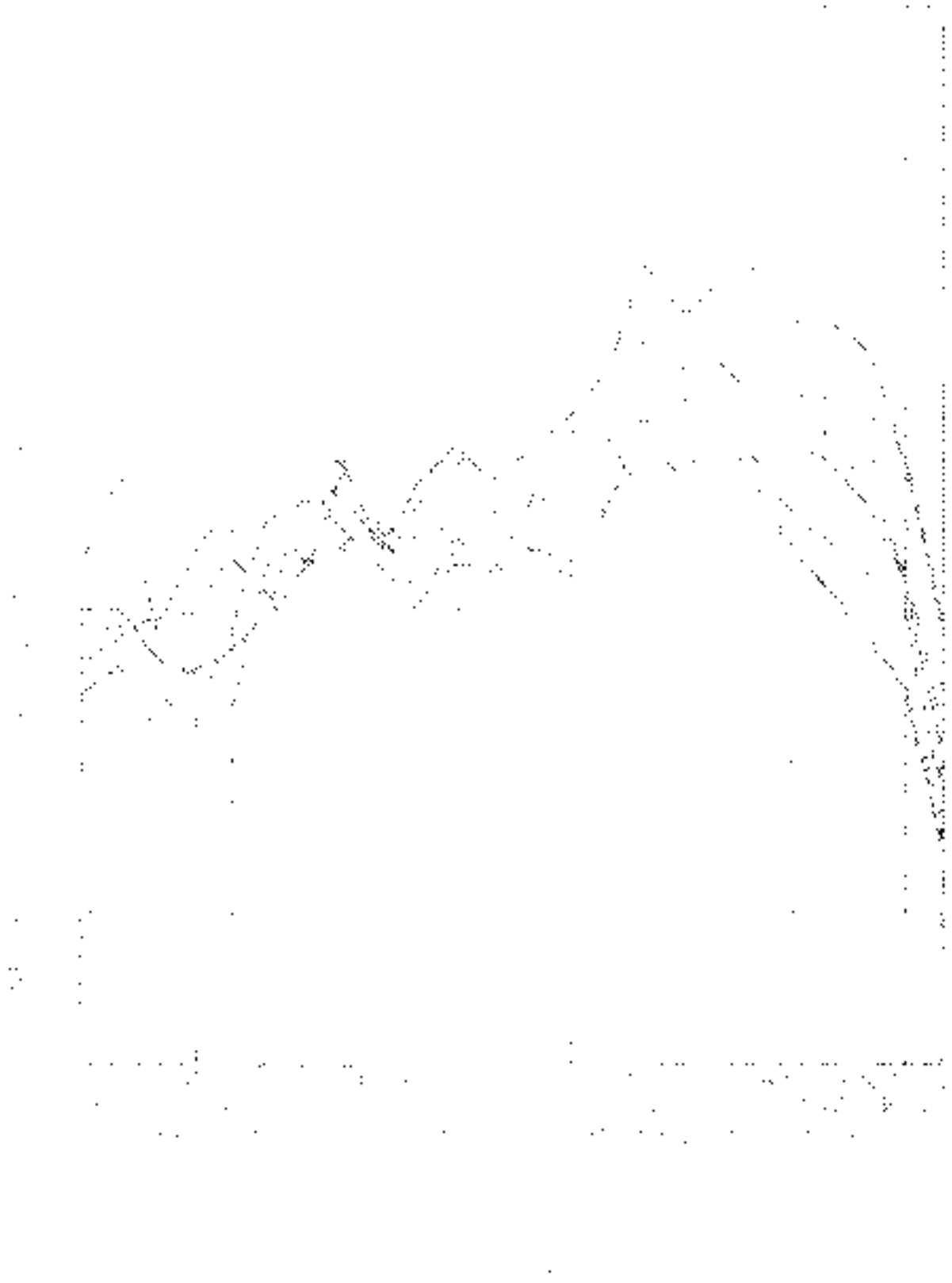

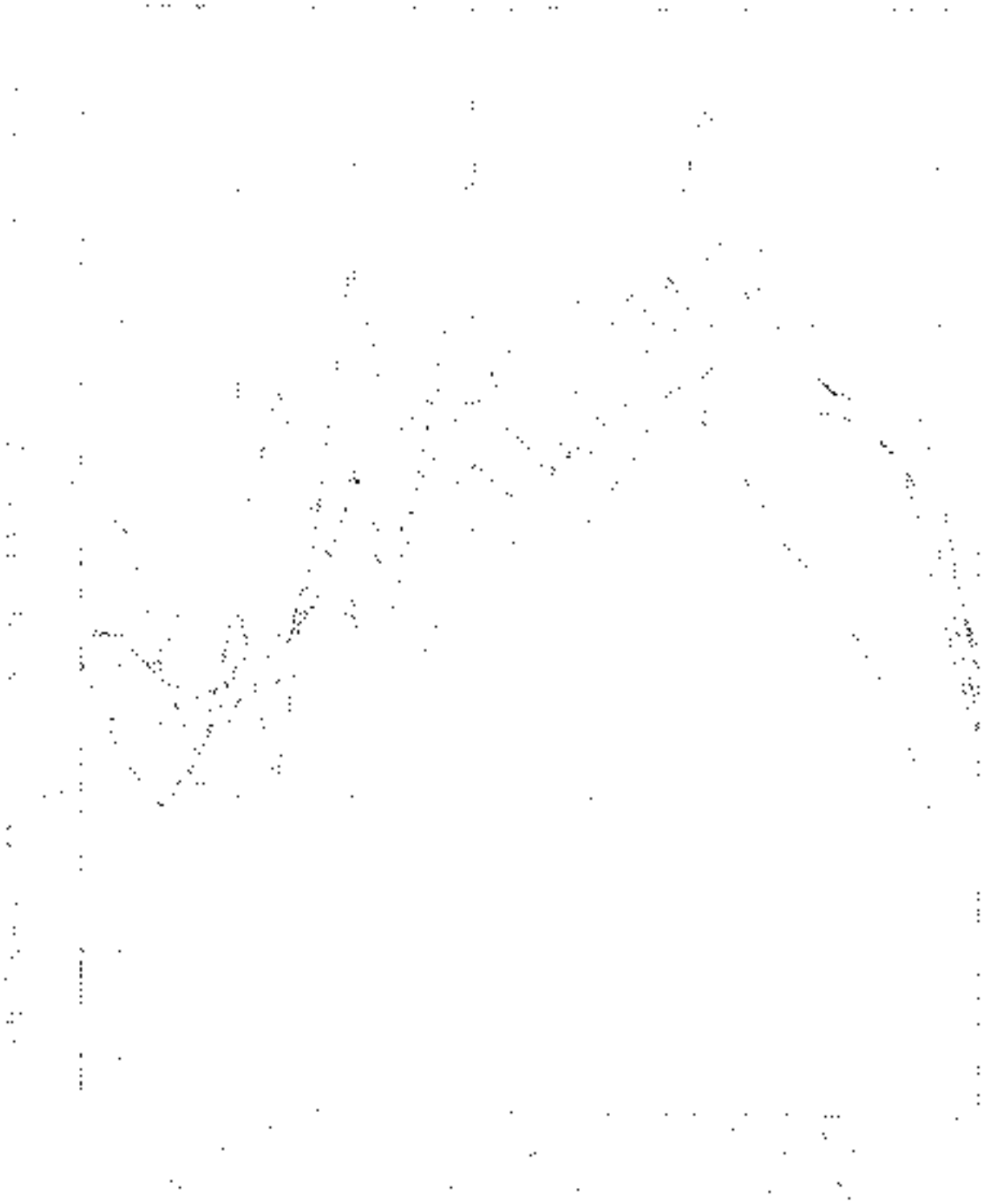

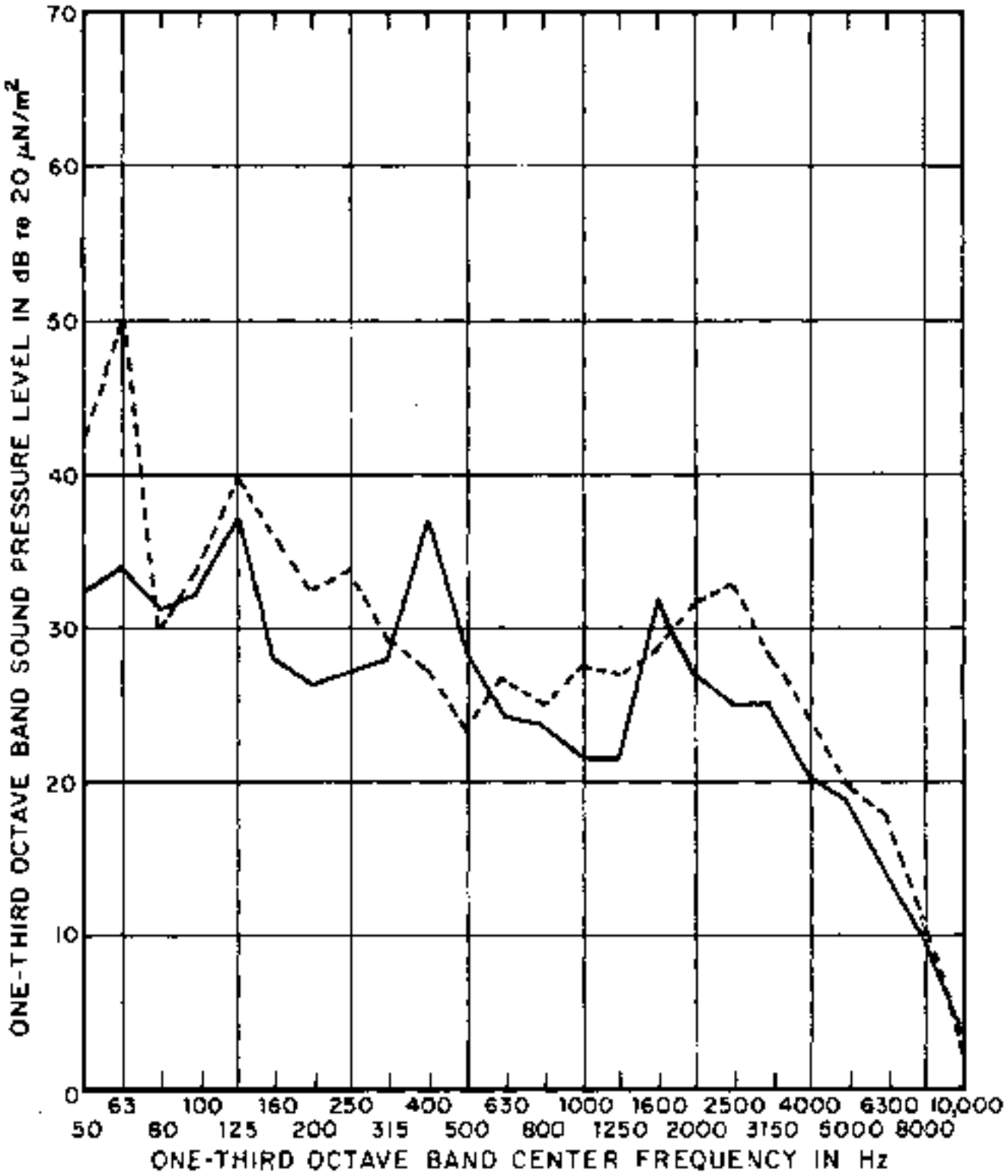

FIG. A.21 SOUND PRESSURE LEVELS FROM TWO -REEVERS (MEASURED AT 3 FT)

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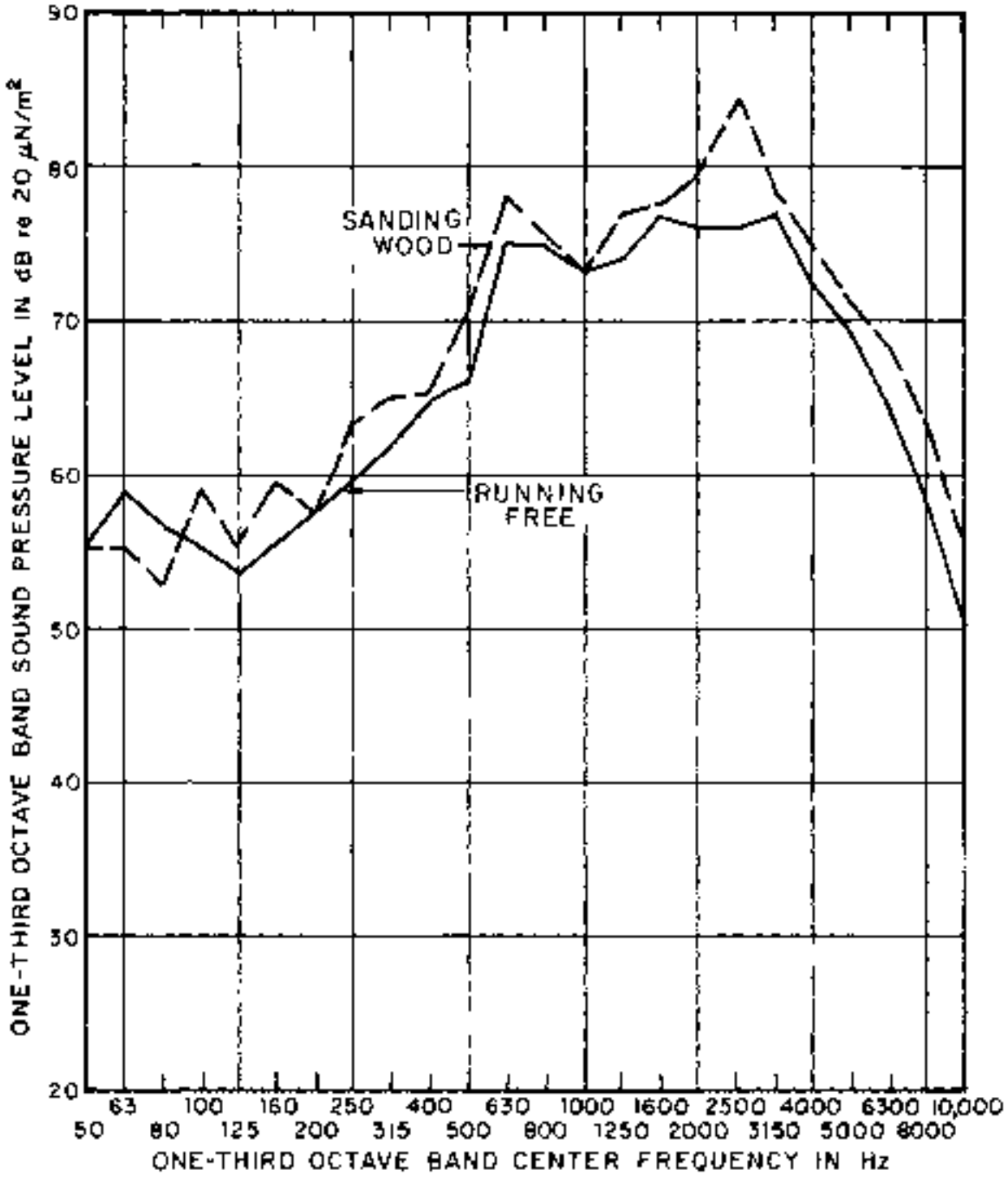

FIG. A.23 SOUND PRESSURE LEVELS FOR A BELT SANDER RUNNING FREE AND SANDING WOOD (MEASURED AT 3 FT)

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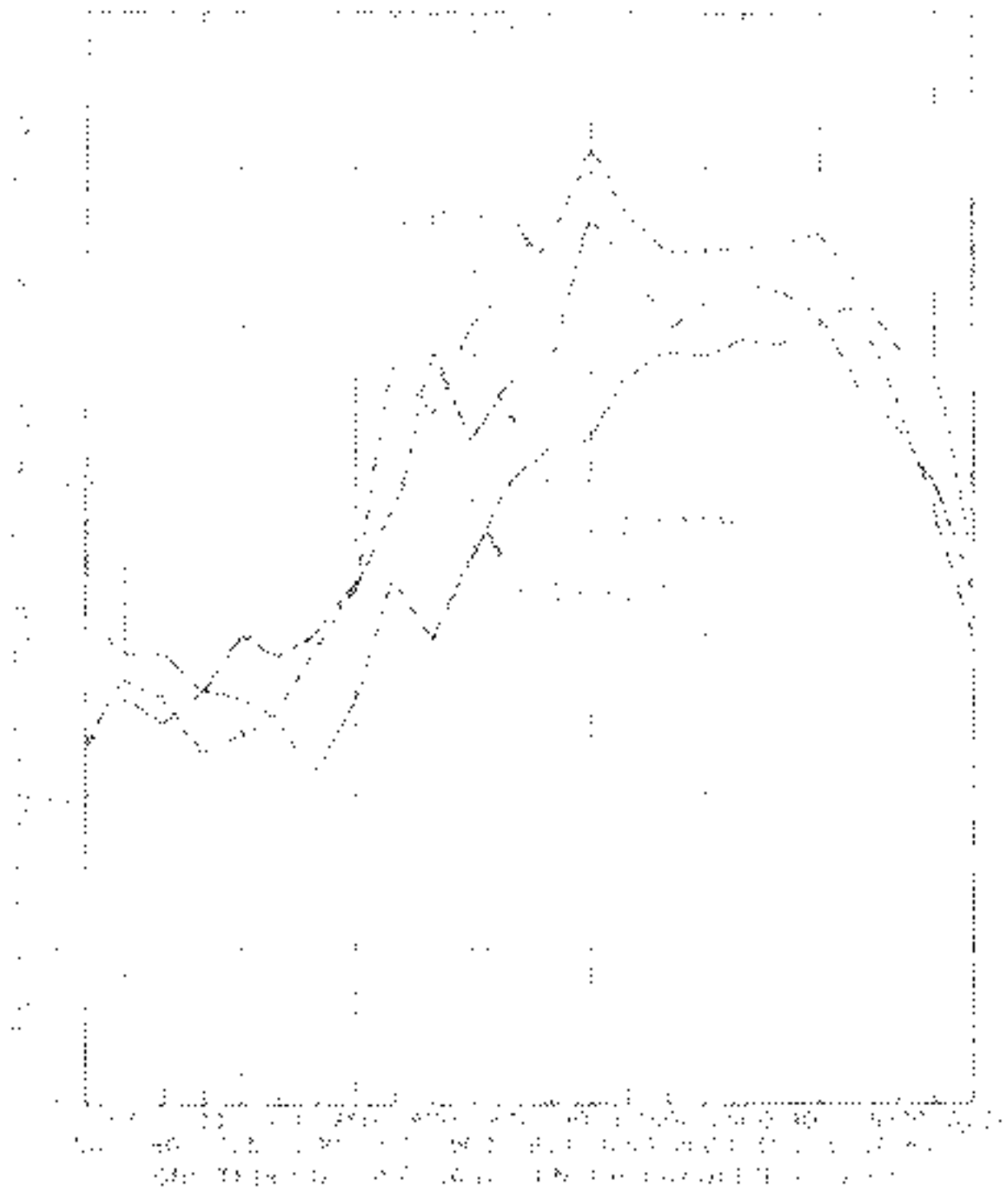

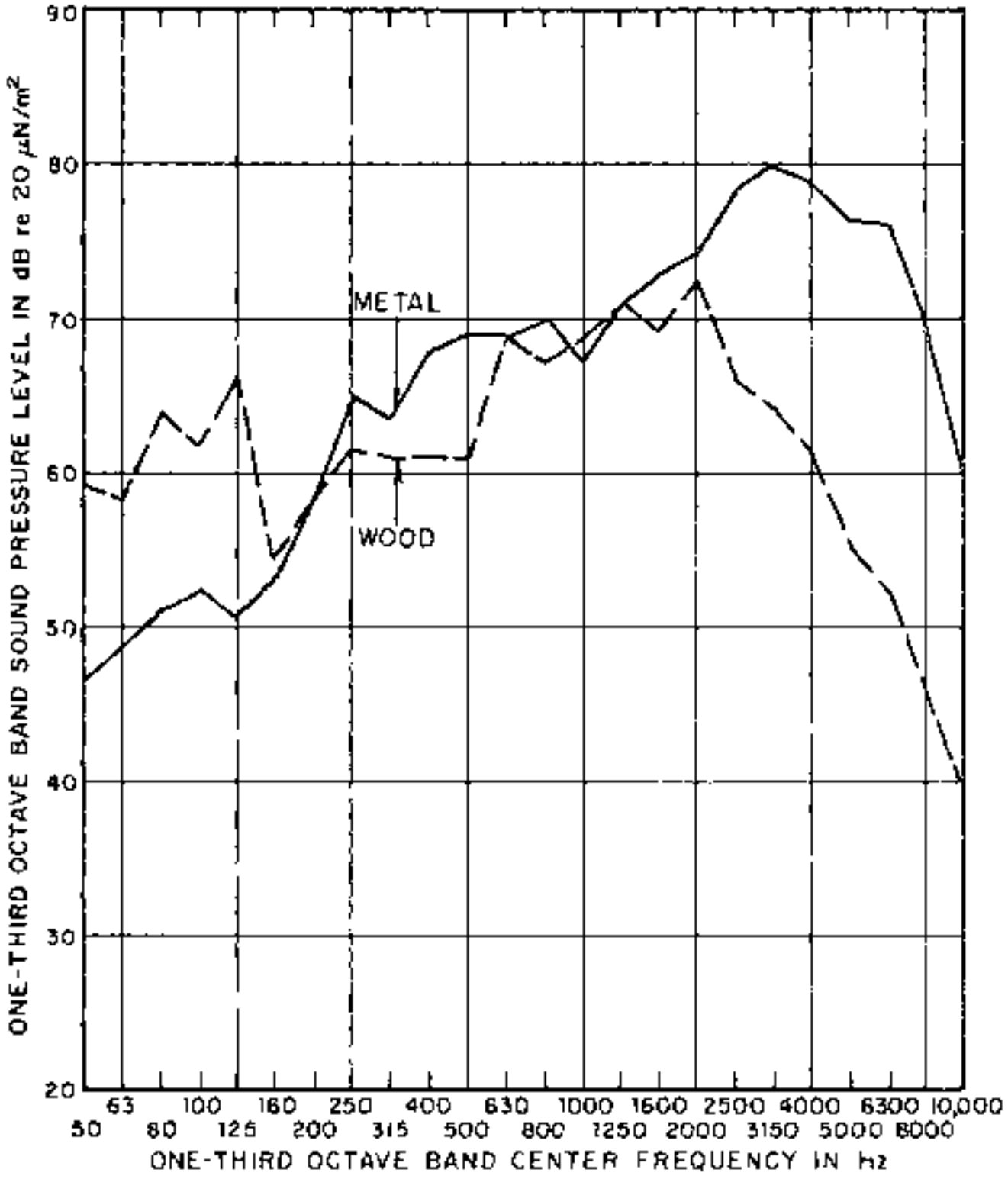

FIG. A.25 SOUND PRESSURE LEVELS FROM TWO DRILL PRESSES DRILLING THROUGH WOOD AND METAL (MEASURED AT 3 FT)

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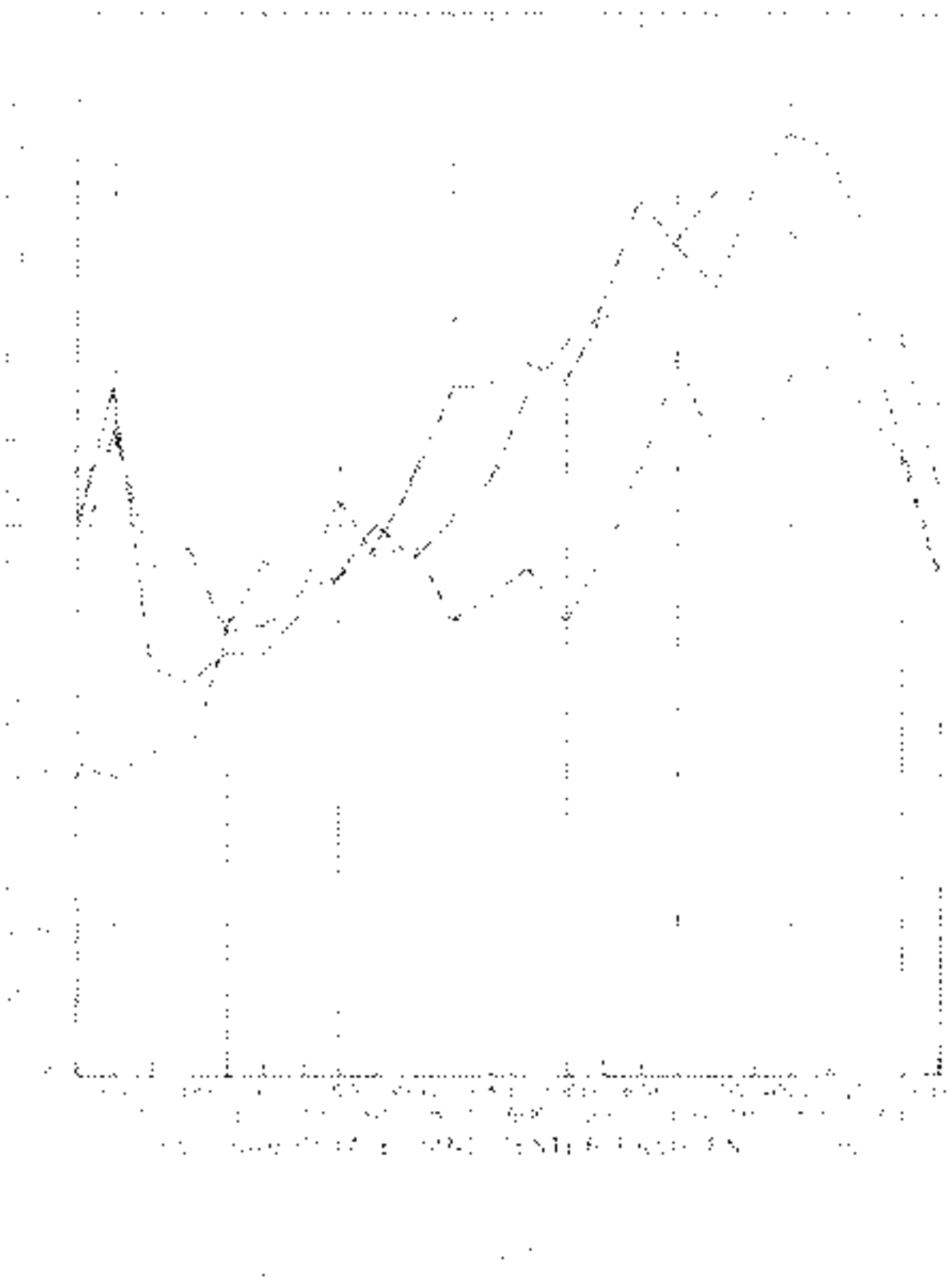

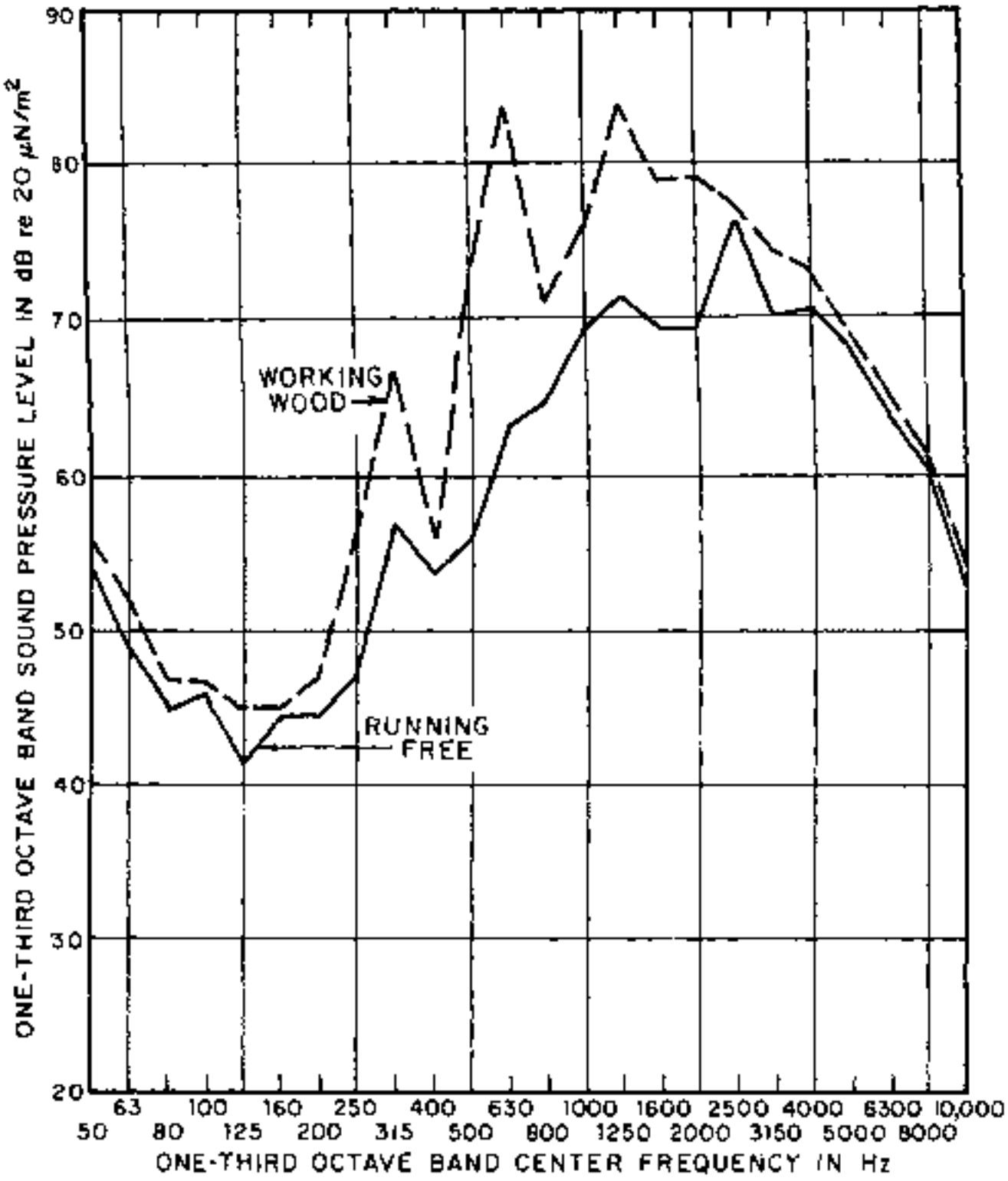

FIG. A.27 SOUND PRESSURE LEVELS FROM A ROUTER RUNNING FREE AND WORKING WOOD (MEASURED AT 3 FT)

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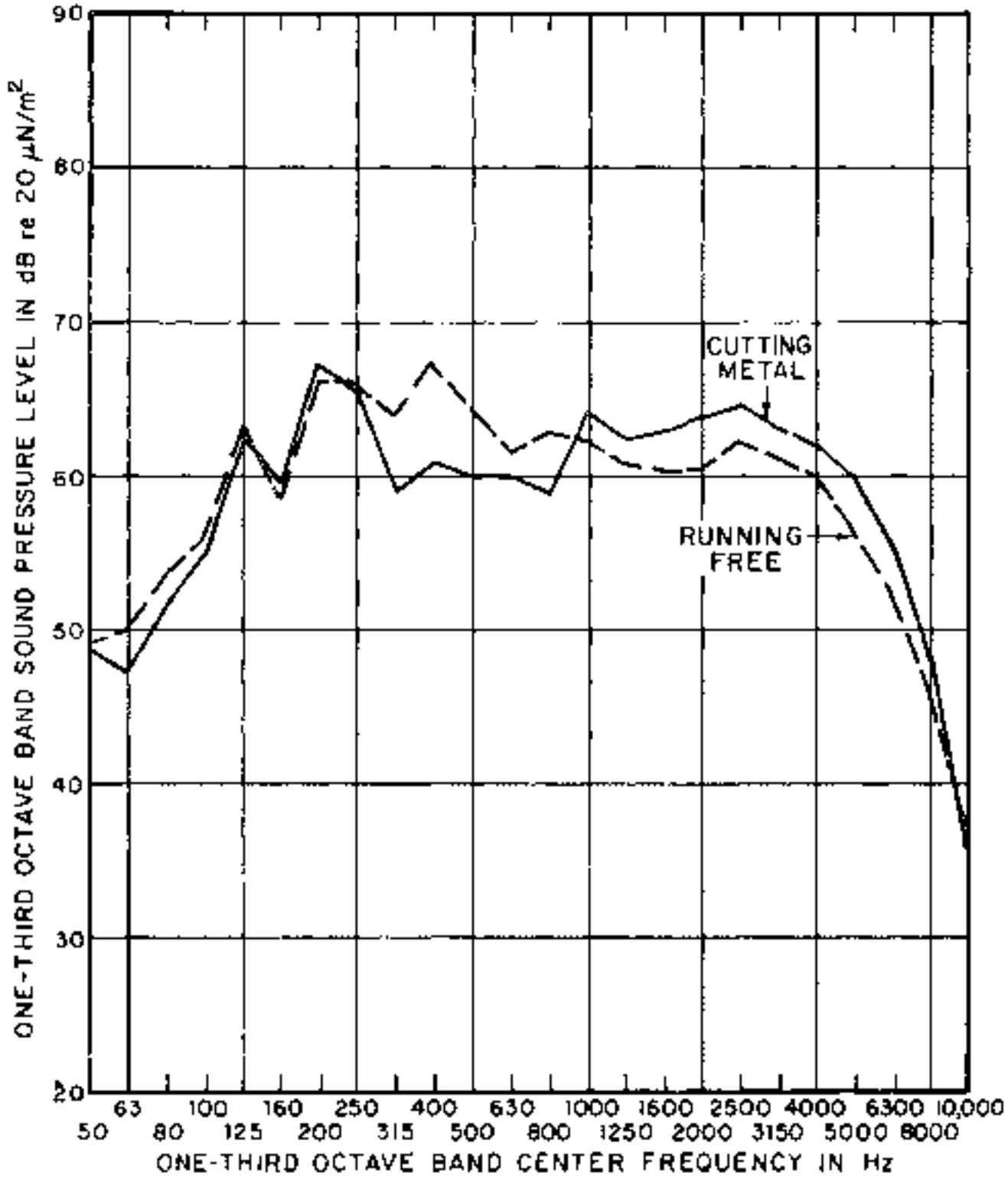

FIG. A.28 SOUND PRESSURE LEVELS FROM A SMALL METAL LATHE RUNNING FREE AND CUTTING (MEASURED AT 3 FT)

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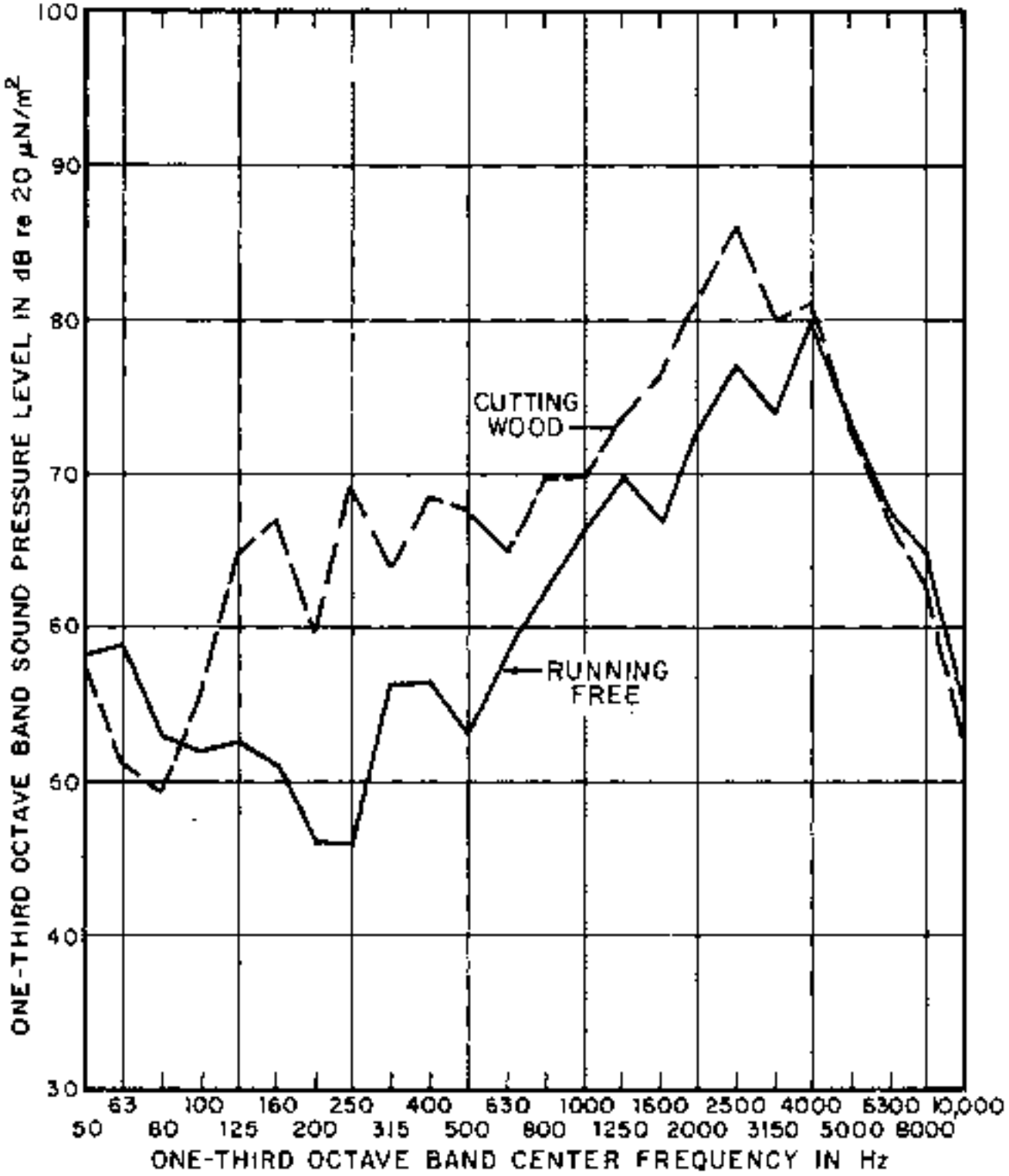

FIG. A.29 SOUND PRESSURE LEVELS FROM A SABRE SAW RUNNING FREE AND CUTTING WOOD (MEASURED AT 3 FT)

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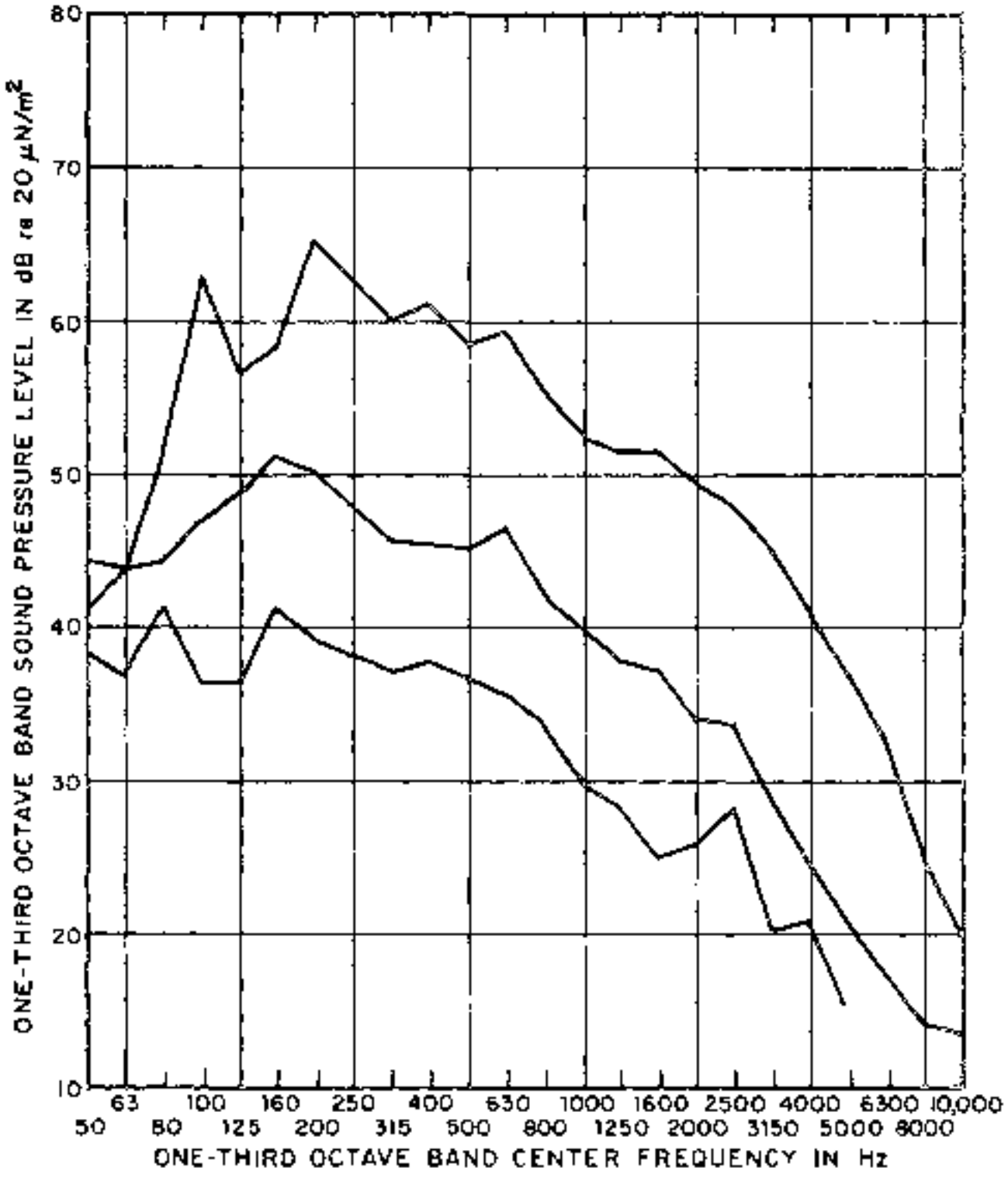

FIG. A.3T SOUND PRESSURE LEVELS FROM A ROOM DEHUMIDIFIER FOR THREE SETTINGS (MEASURED AT 3 FT)

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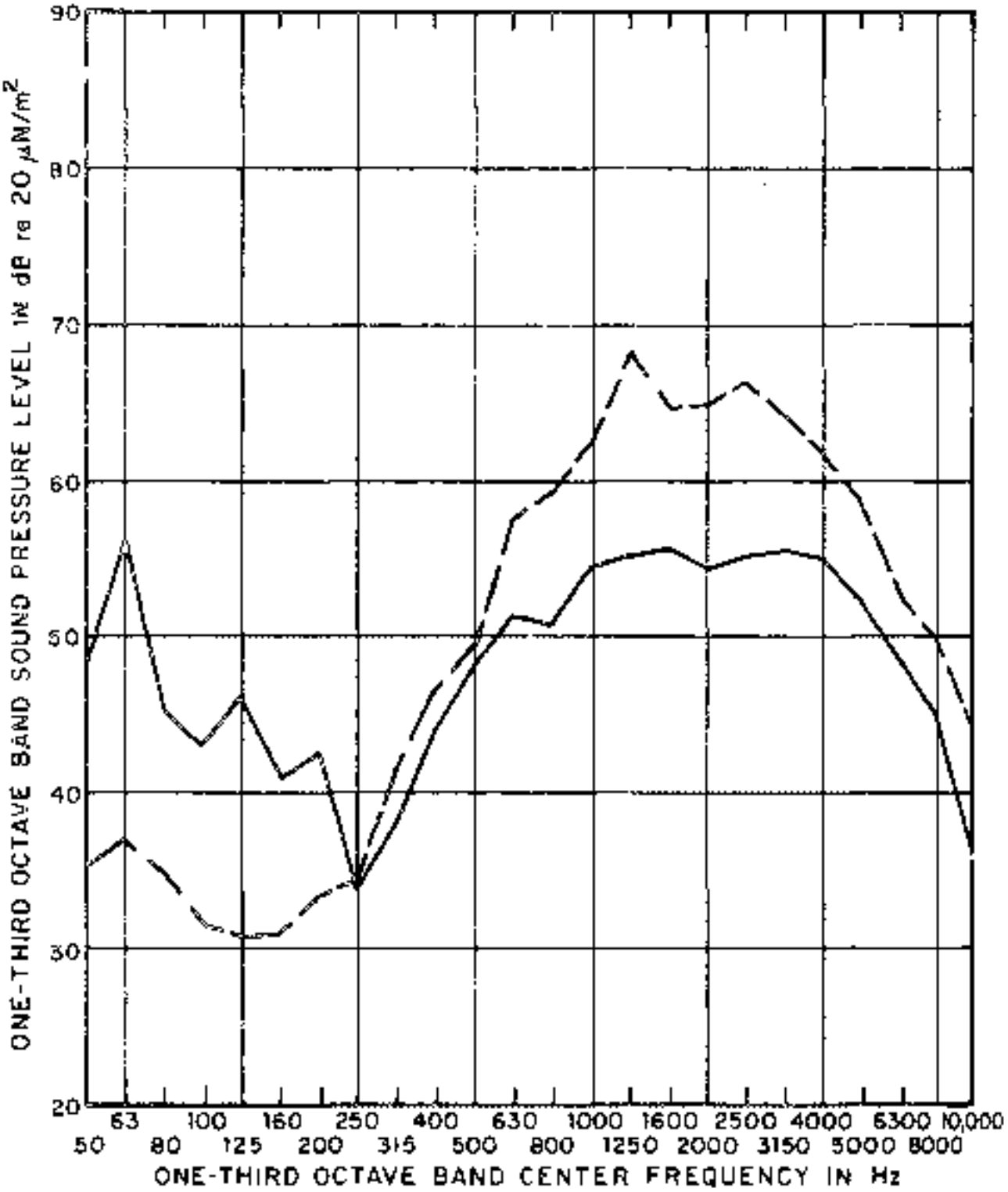

FIG. A.32 SOUND PRESSURE LEVELS FROM TWO ELECTRIC KNIVES (MEASURED AT 3 FT)

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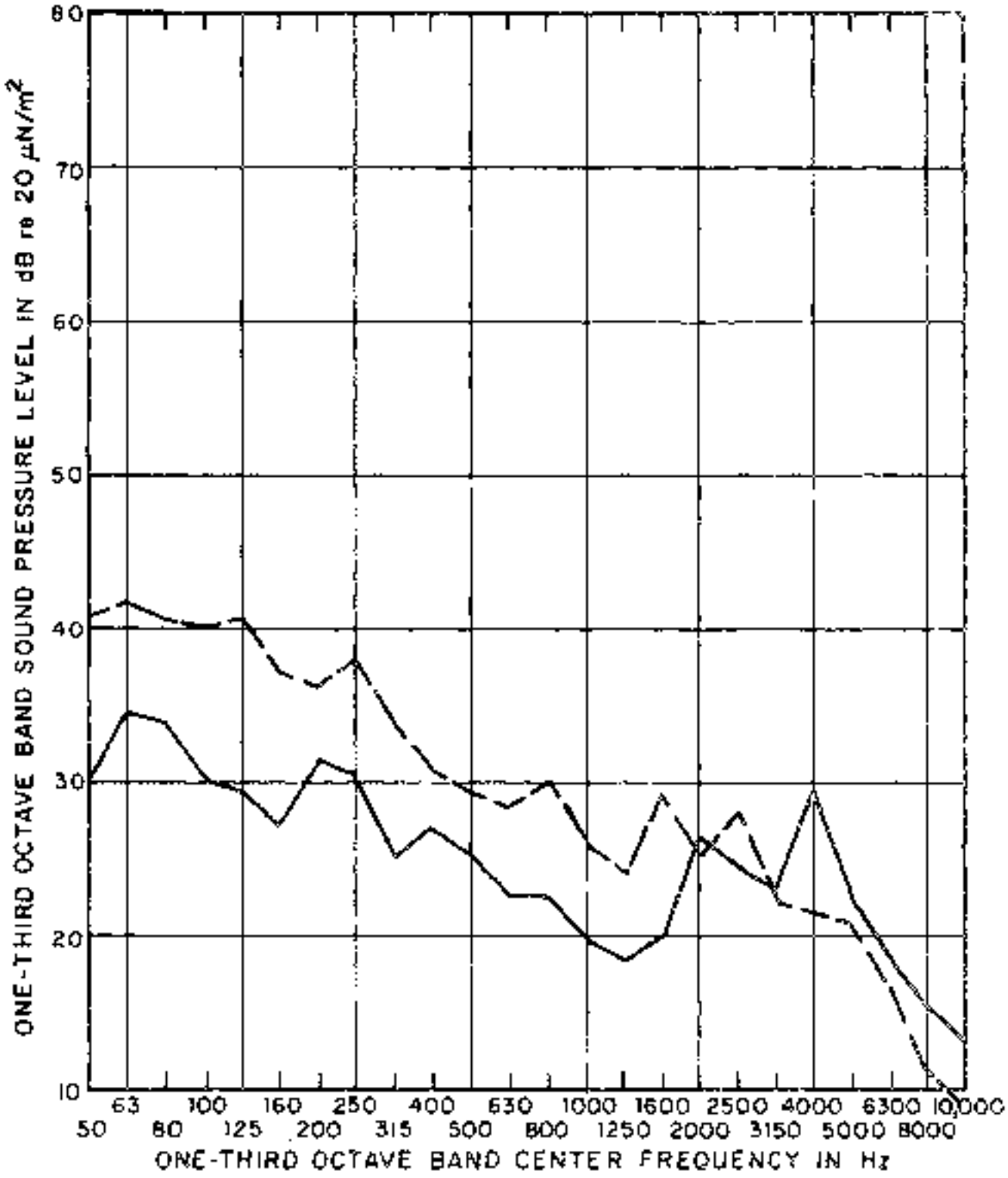


FIG. A.33 SOUND PRESSURE LEVELS FROM TWO REFRIGERATORS (MEASURED AT 3 FT)

AR0070706

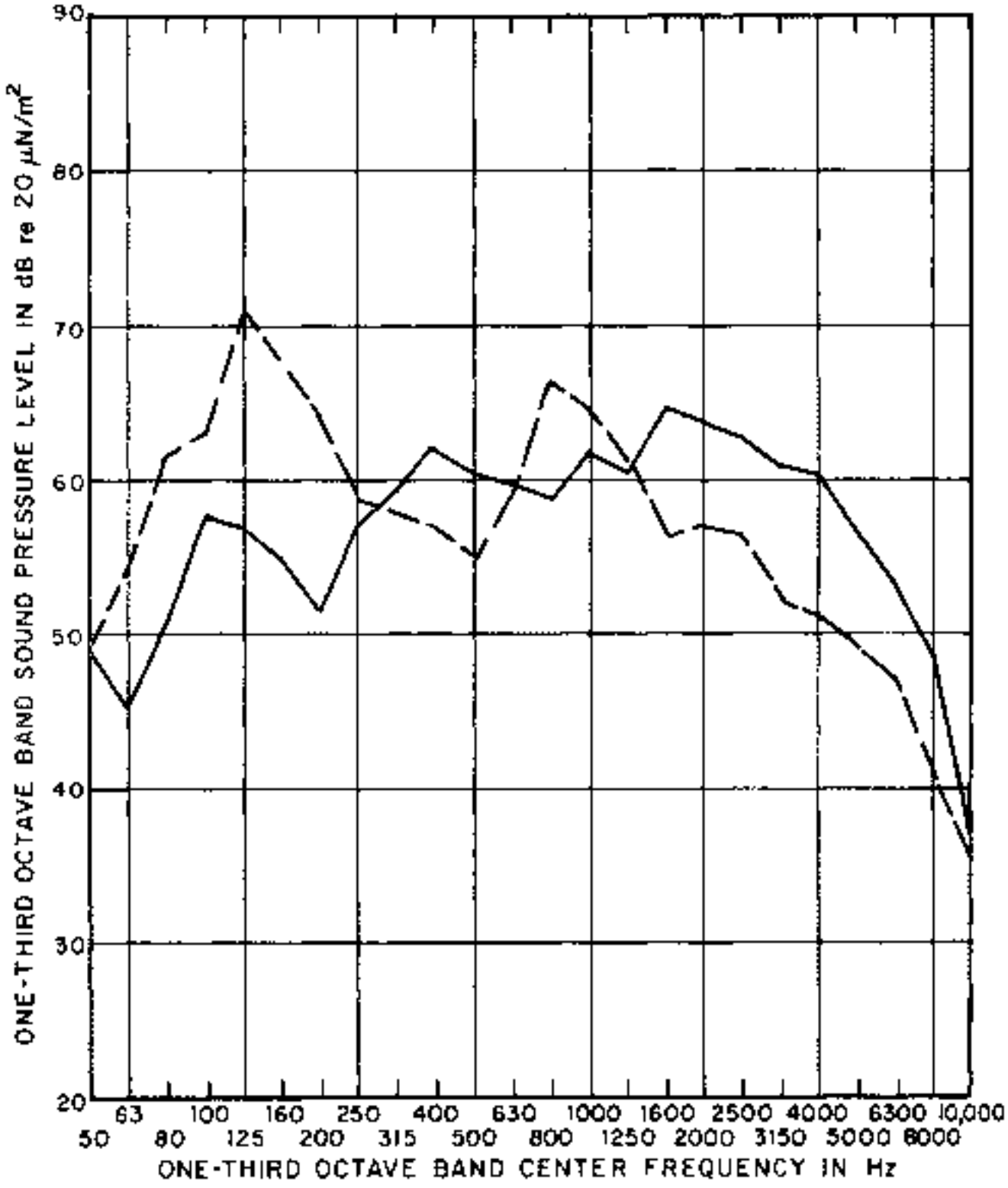
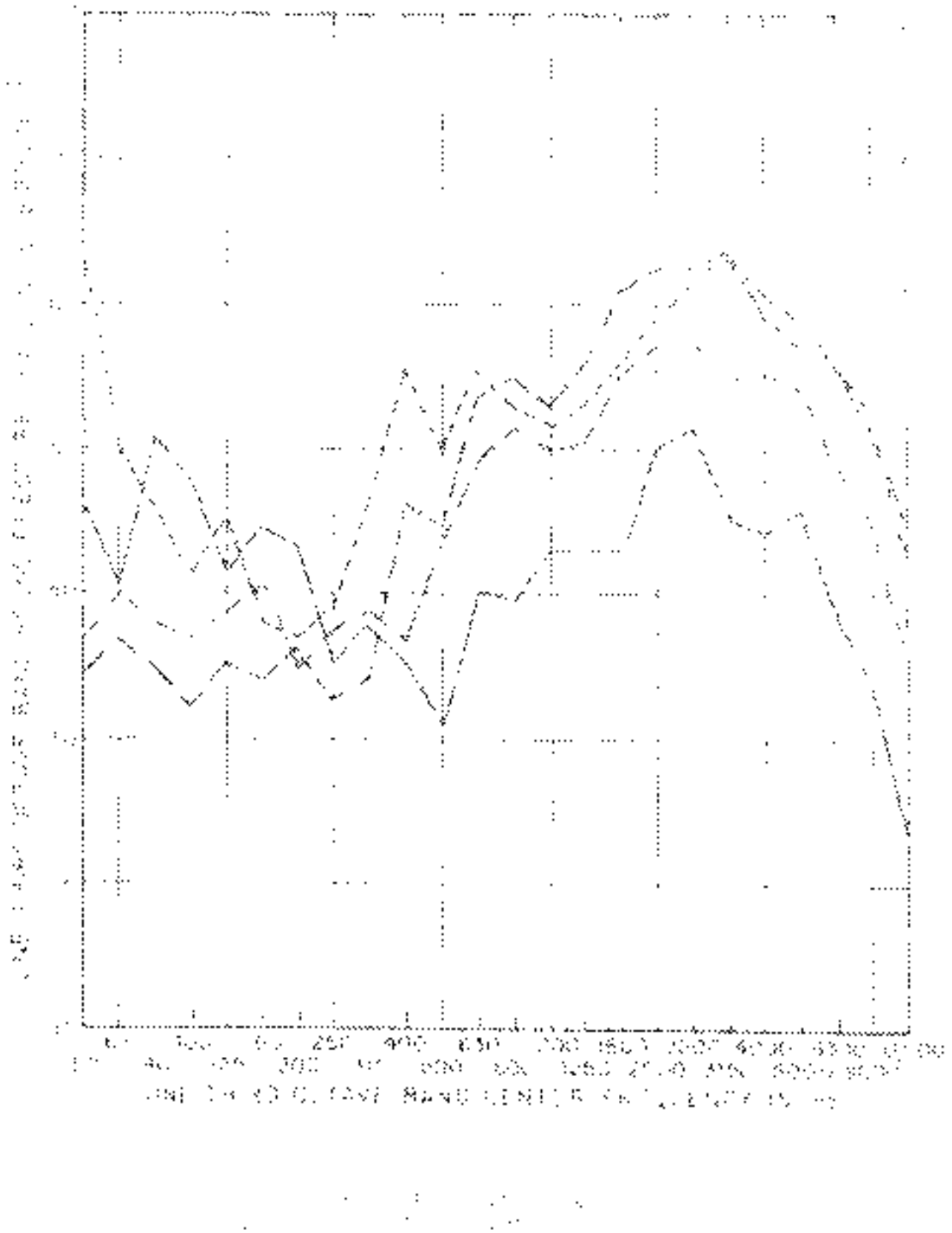


FIG. A.34 SOUND PRESSURE LEVELS FROM TWO SEWING MACHINES (MEASURED AT 3 FT)

AR0070707



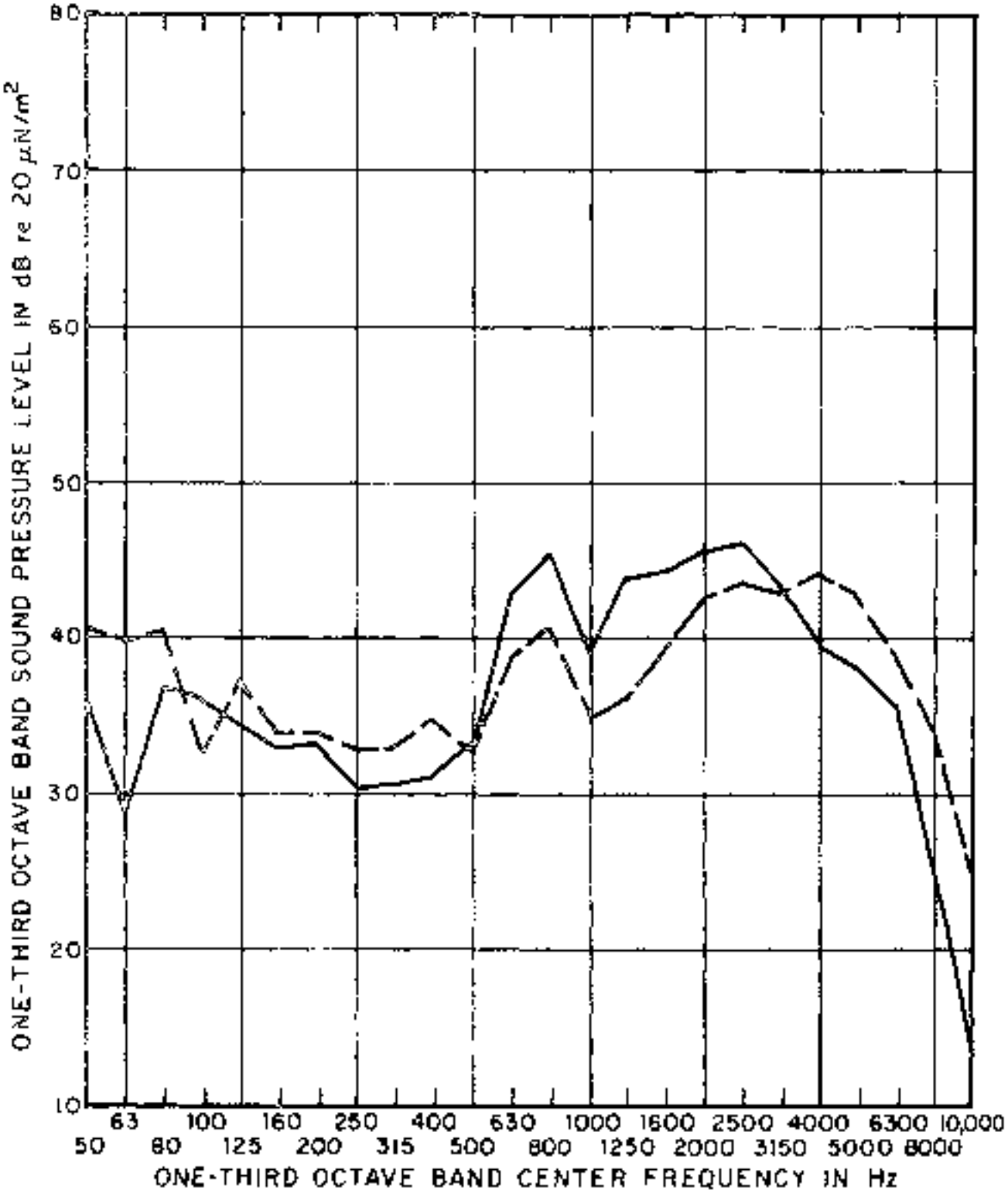


FIG. A.36 SOUND PRESSURE LEVELS FROM TWO WOMEN'S ELECTRIC SHAVERS (MEASURED AT 3 FT)

AR0070709

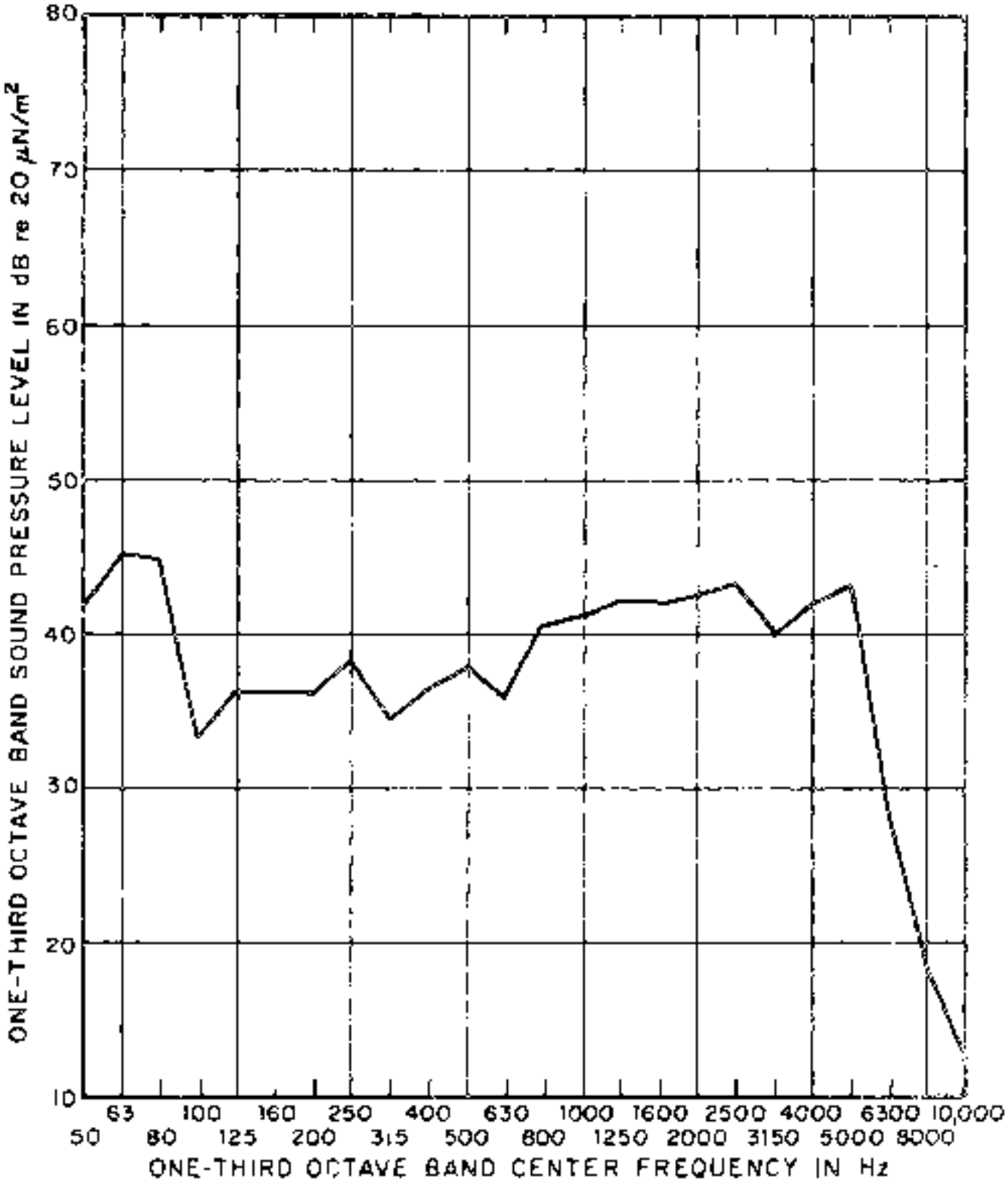


FIG. A.37 SOUND PRESSURE LEVELS FROM AN ELECTRIC TOOTHBRUSH (MEASURED AT 3 FT)

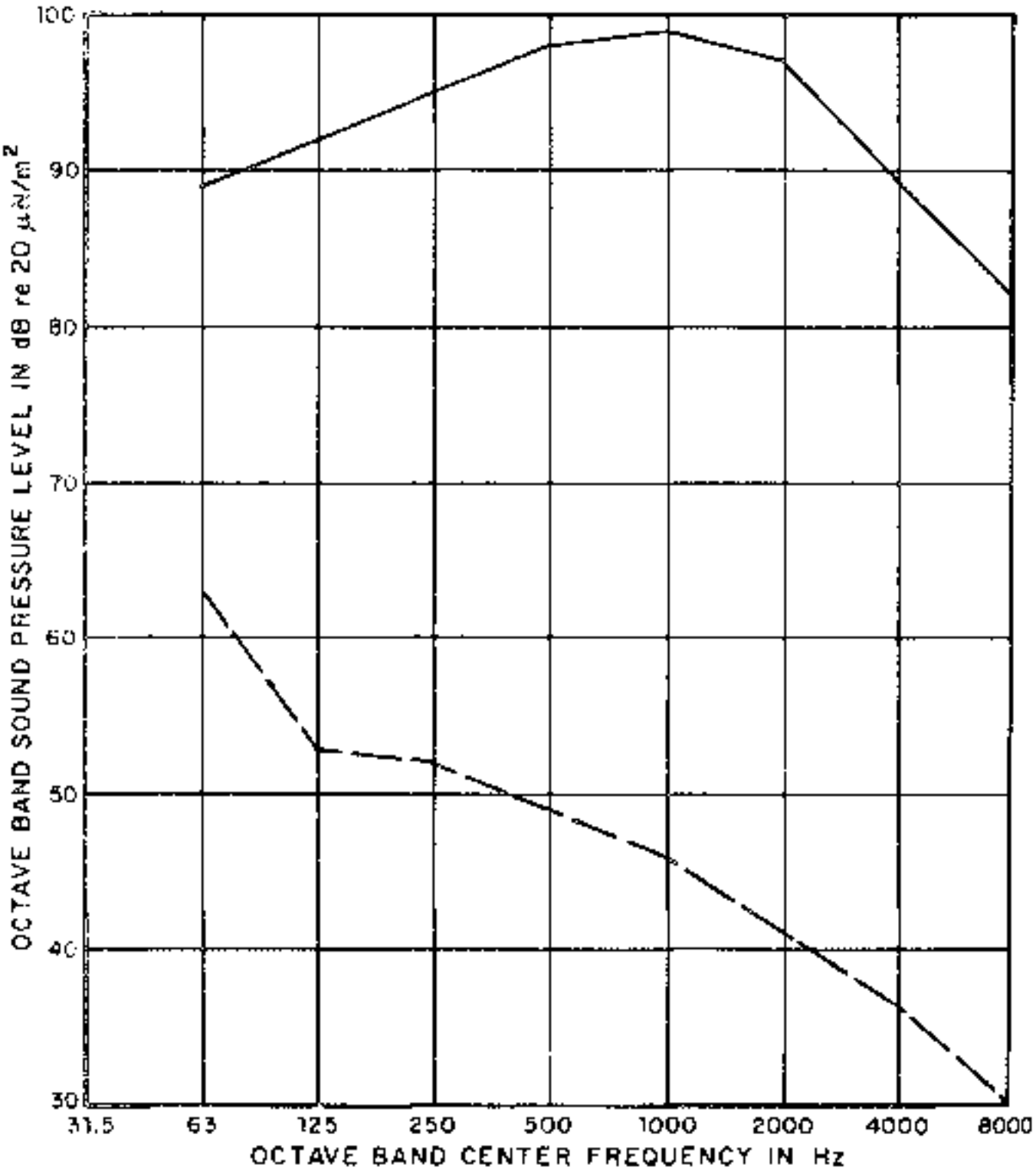


FIG. A.38 RANGE OF SOUND PRESSURE LEVELS FROM DIFFERENT SIZES OF MOTORS (MEASURED AT 3 FT)

AR0070711

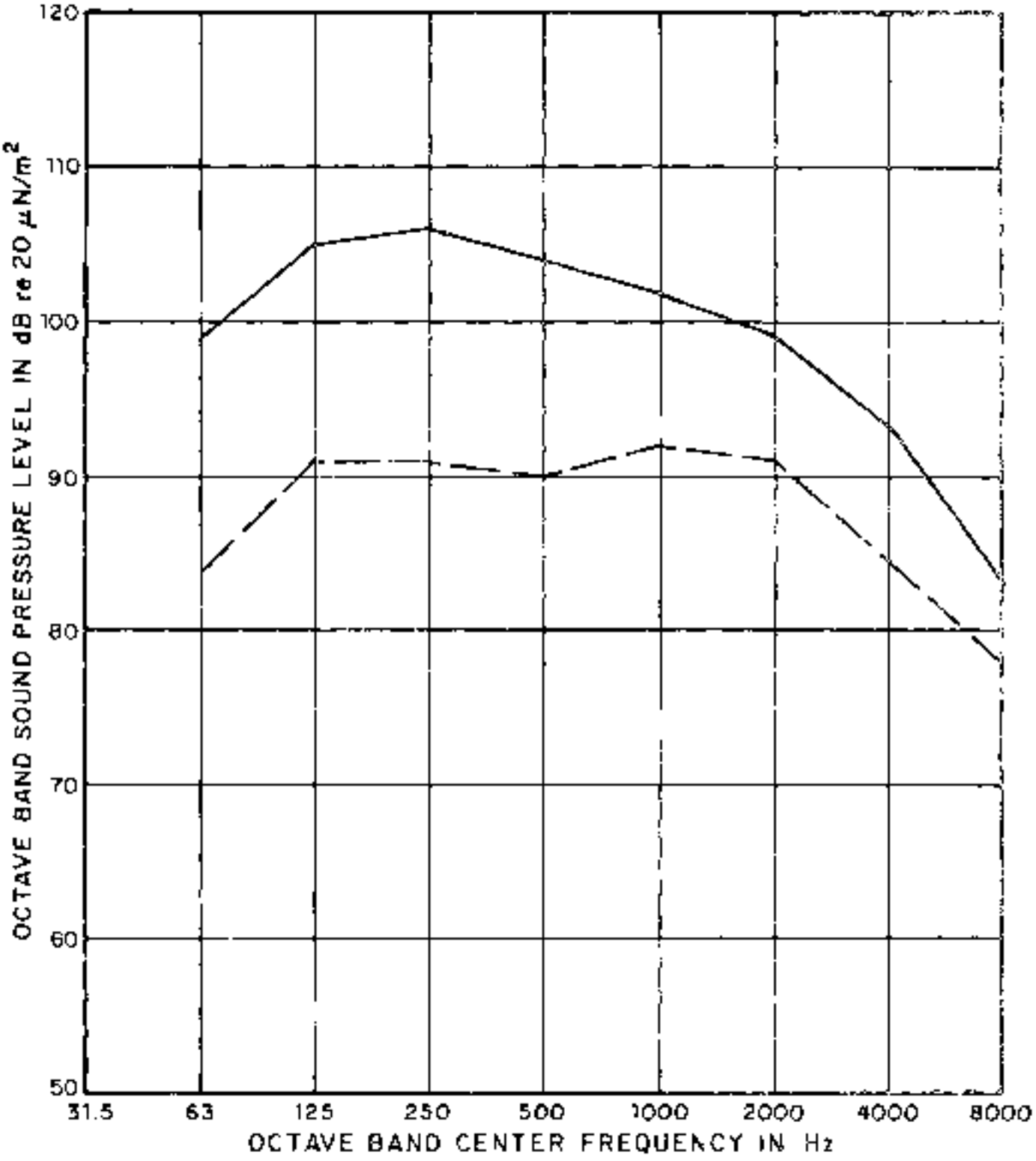


FIG. A.39 RANGE OF SOUND PRESSURE LEVELS FROM INTERNAL COMBUSTION ENGINES (MEASURED AT 3 FT)

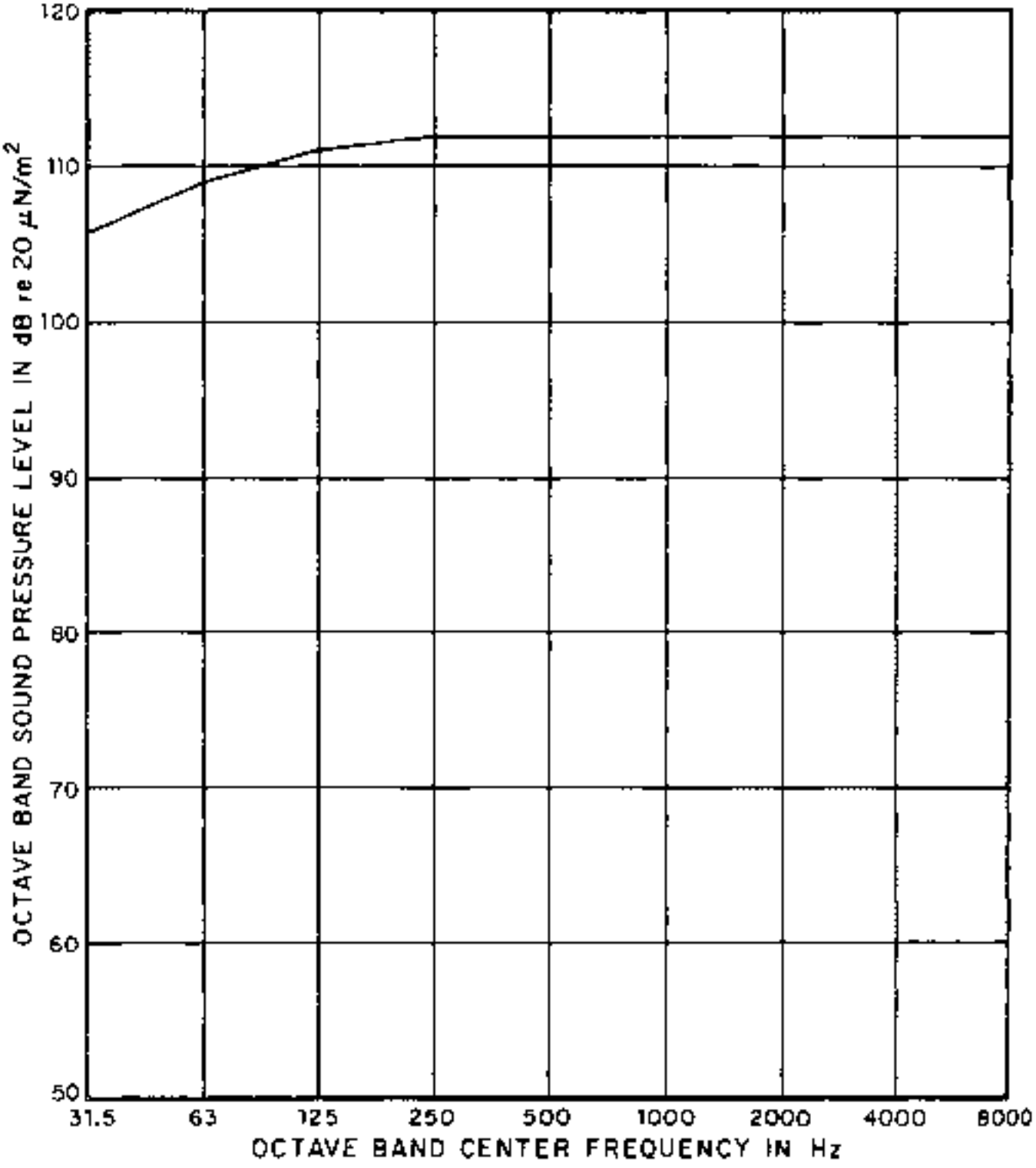


FIG. A-40 TYPICAL SOUND PRESSURE LEVELS FROM GAS TURBINES (MEASURED AT 3 FT)

AR0070713

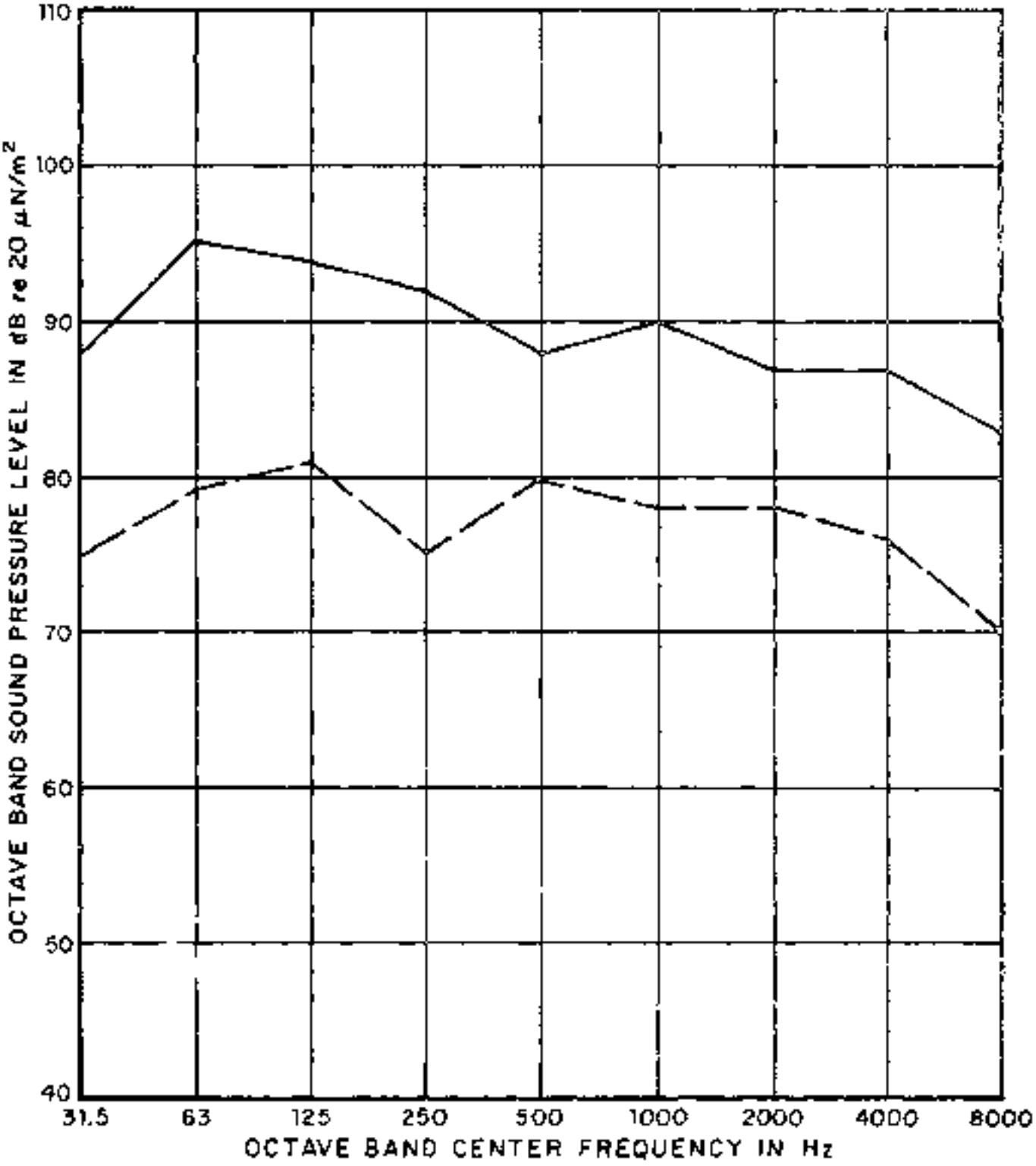


FIG. A.41 RANGE OF SOUND PRESSURE LEVELS FROM STEAM TURBINES (MEASURED AT 3 FT)

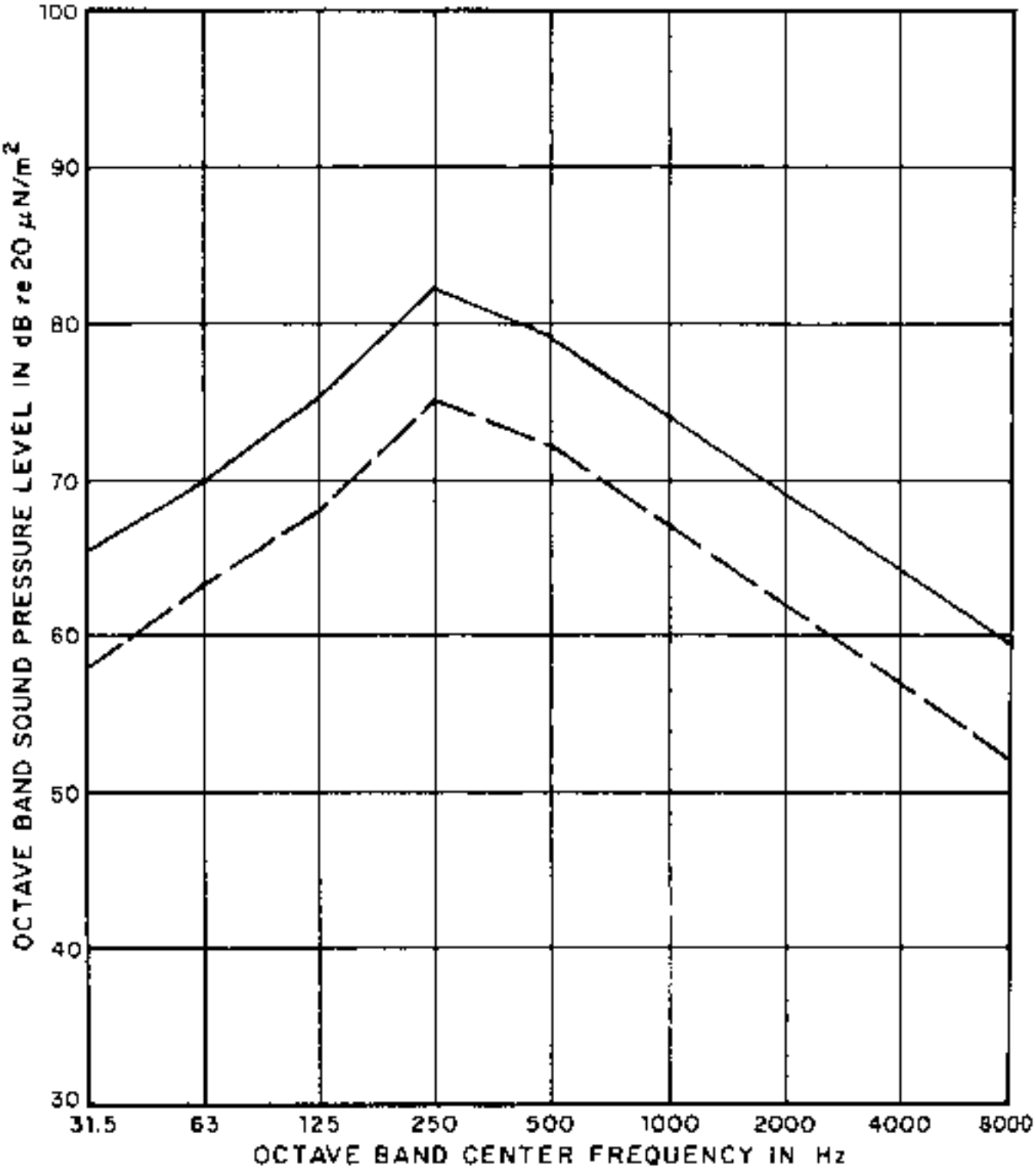


FIG. A.42 RANGE OF SOUND PRESSURE LEVELS FROM TRANSFORMERS (MEASURED AT 3 FT)

AR0070715

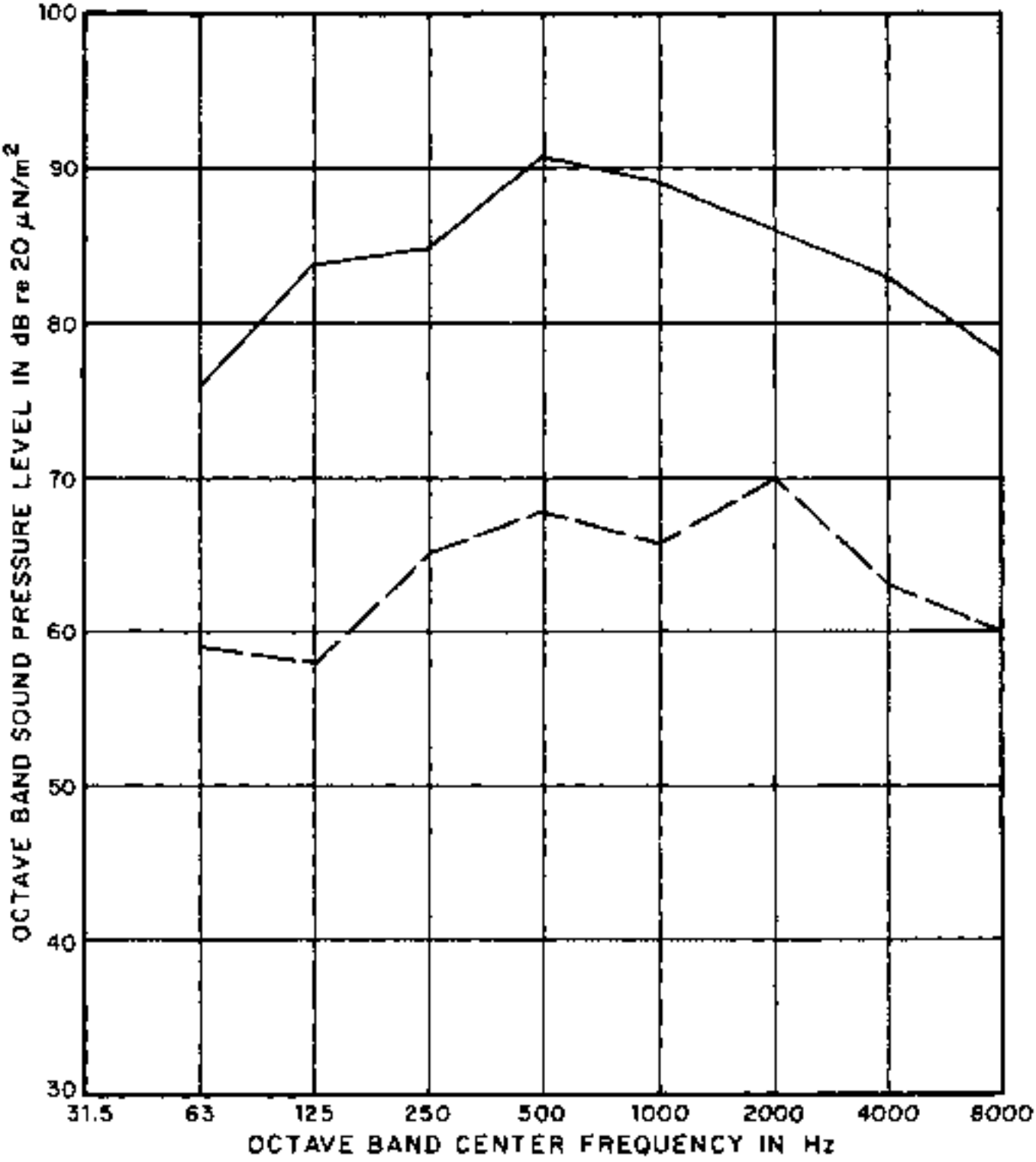


FIG. A.43 RANGE OF SOUND PRESSURE LEVELS FROM PUMPS (MEASURED AT 3 FT)

AR0070716

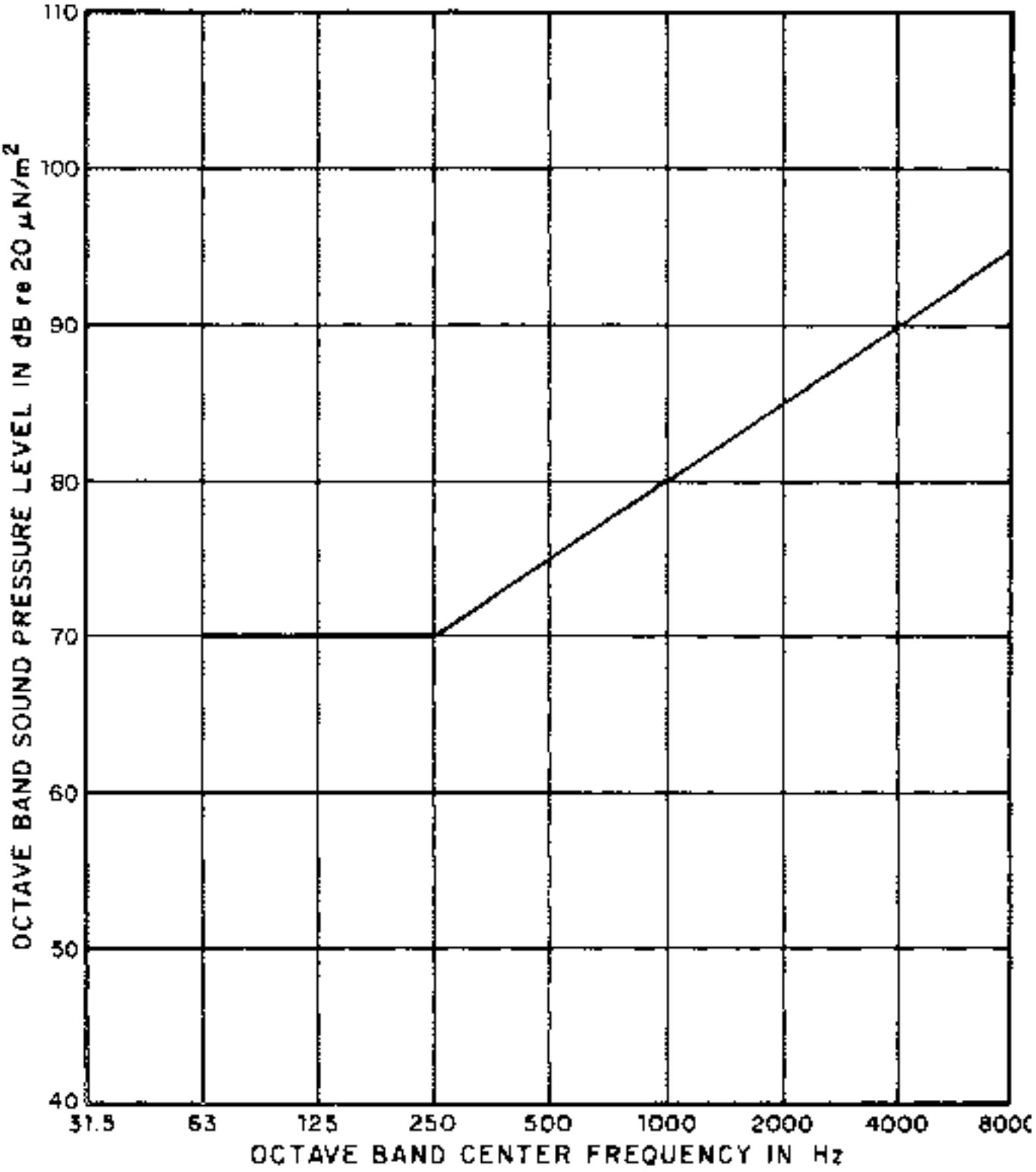


FIG. A.44 TYPICAL SOUND PRESSURE LEVEL FROM STEAM VALVE (MEASURED AT 3 FT)

AR0070717

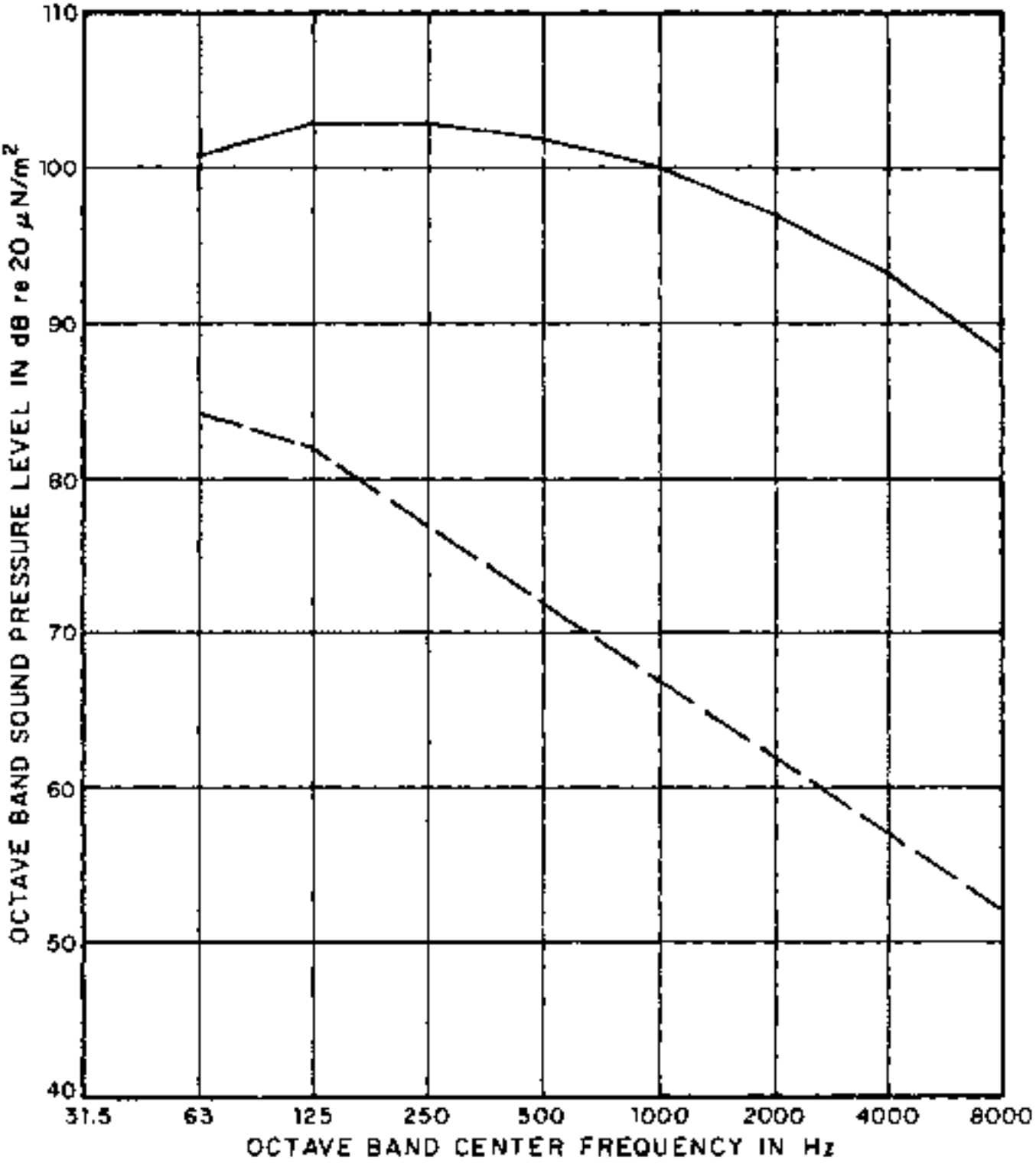


FIG. A.45 RANGE OF SOUND PRESSURE LEVELS FROM FANS (MEASURED AT 3 FT)

AR0070718

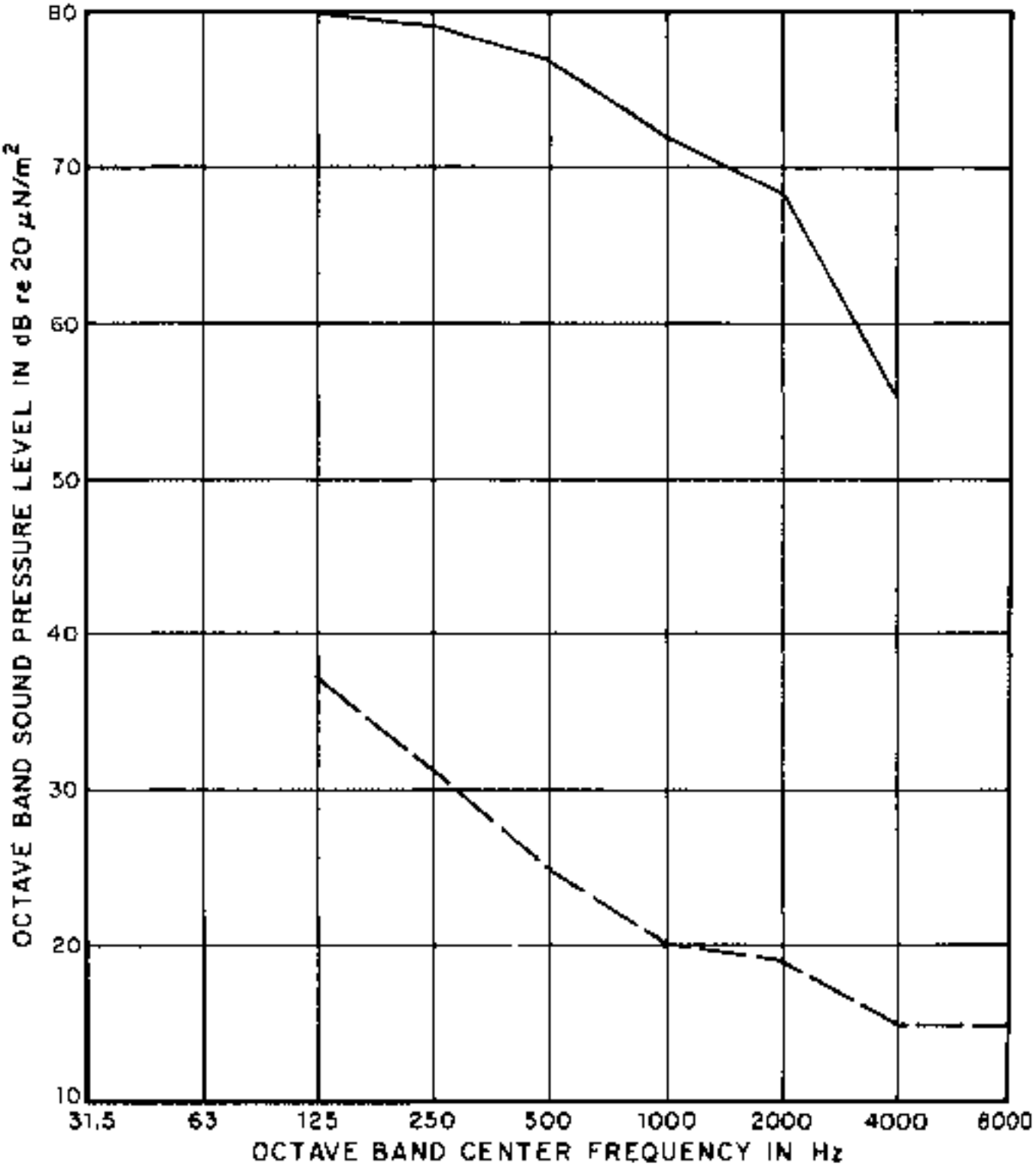


FIG. A.46 RANGE OF SOUND PRESSURE LEVELS FROM AIR CONTROL UNITS AND MIXING BOXES (MEASURED AT 3 FT)

AR0070719

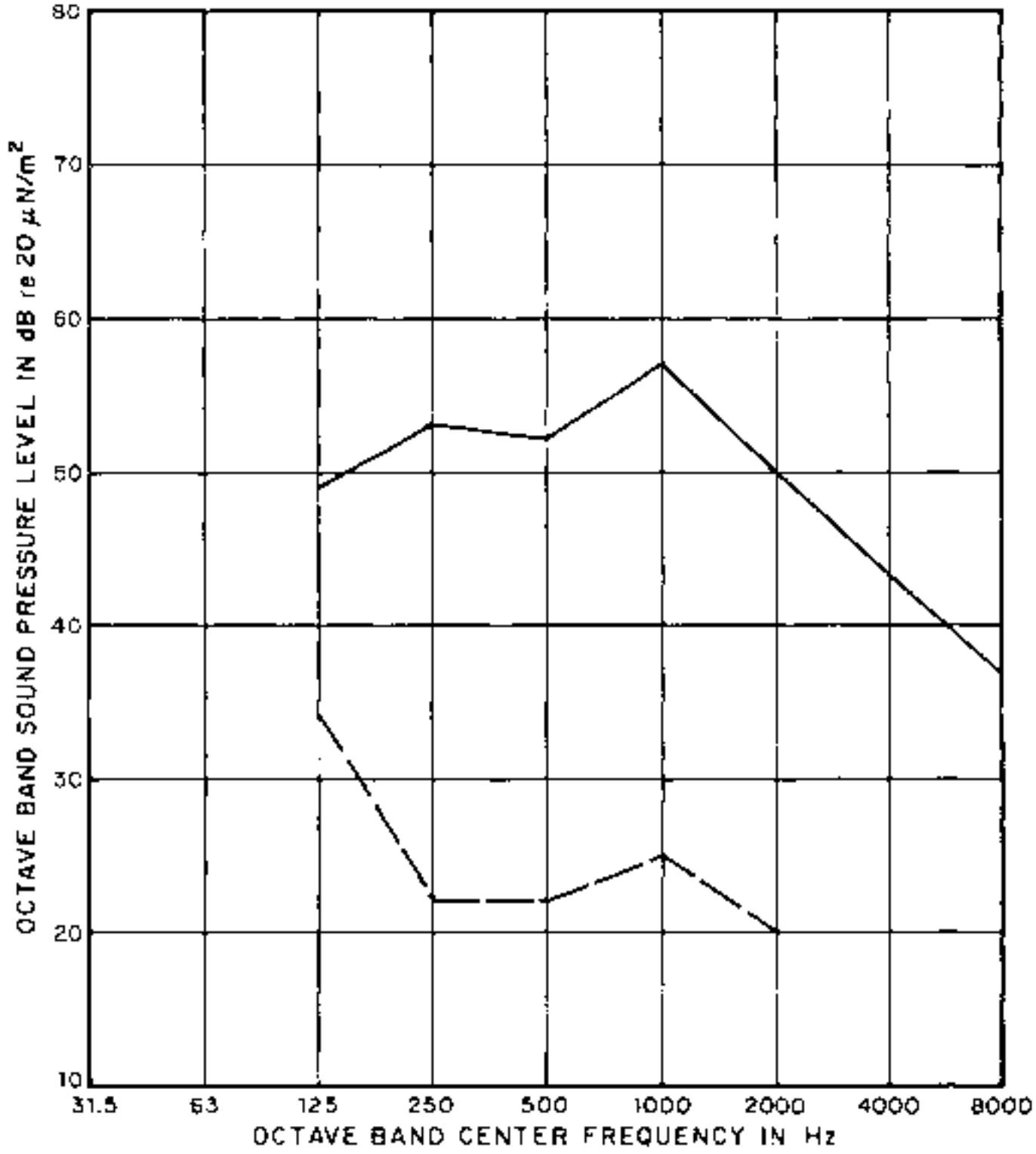


FIG. A.47 RANGE OF SOUND PRESSURE LEVELS FROM DIFFUSERS, GRILLS, REGISTERS, AND LOUVERS (MEASURED AT 3 FT)

AR0070720

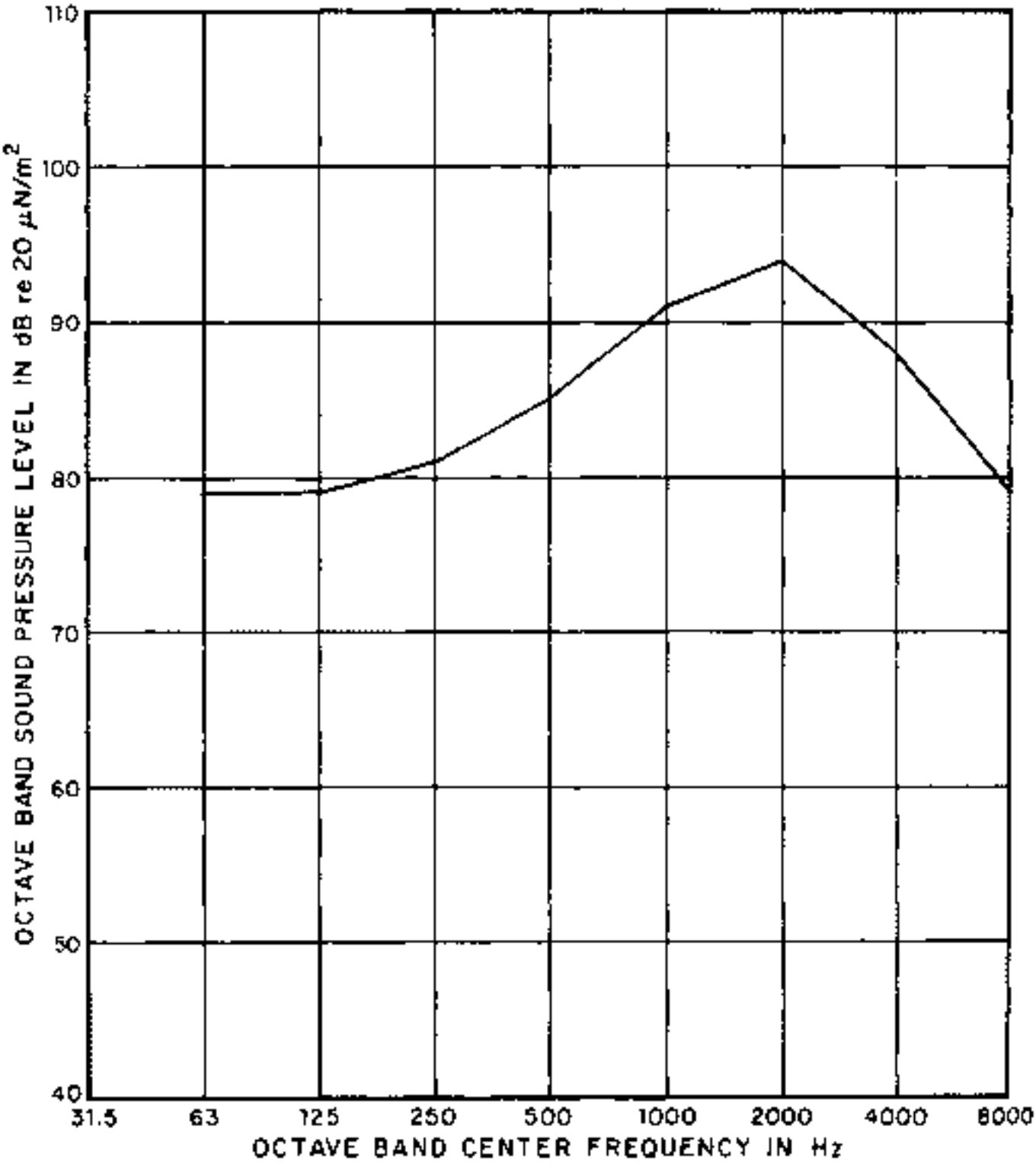


FIG. A.48 TYPICAL SOUND PRESSURE LEVELS FROM RECIPROCATING AIR COMPRESSORS (MEASURED AT 3 FT)

AR0070721

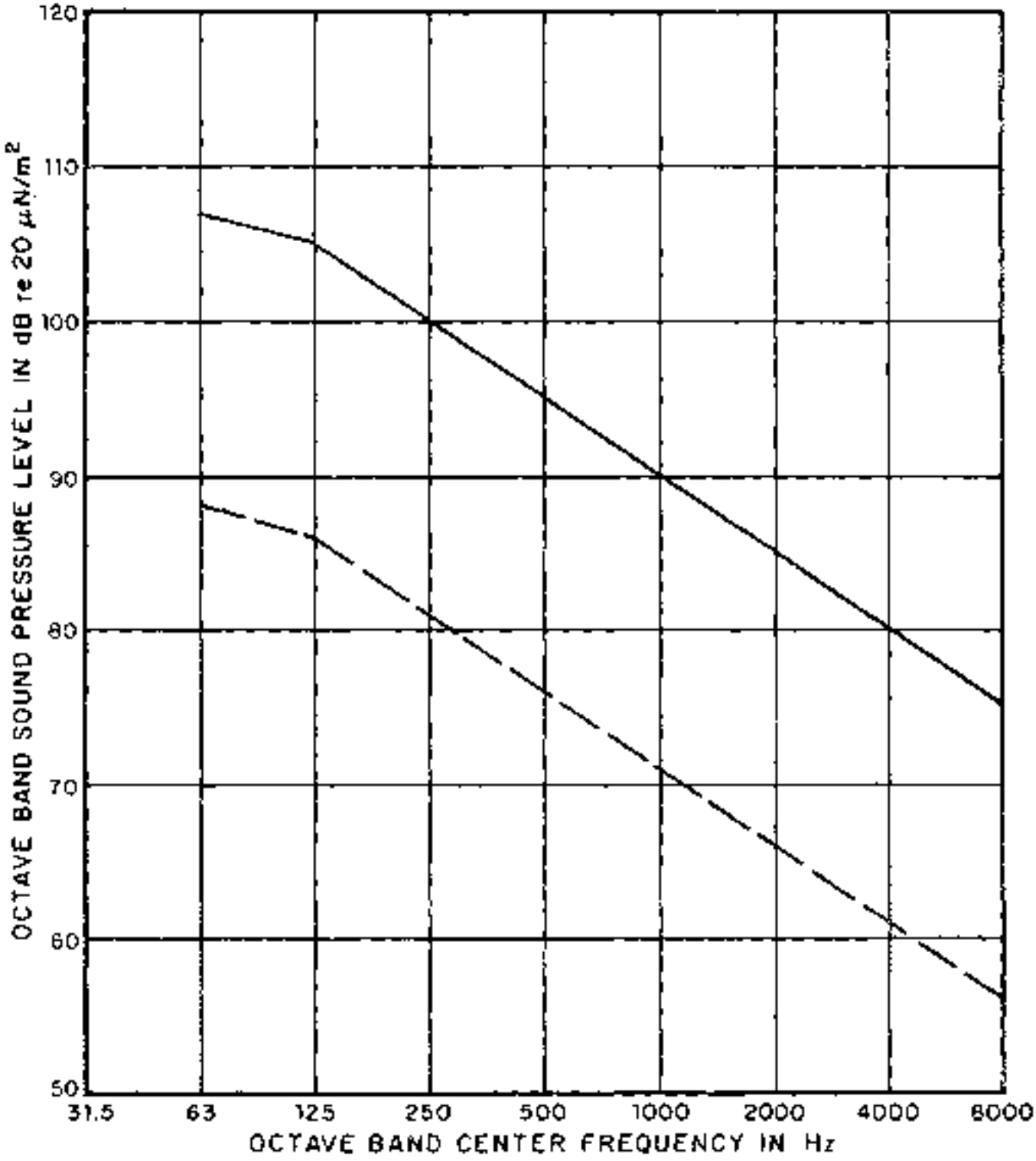


FIGURE A-49 RANGE OF SOUND PRESSURE LEVELS FOR CENTRAL STATION AIR-CONDITIONING UNITS (MEASURED AT 3 FT)

AR0070722

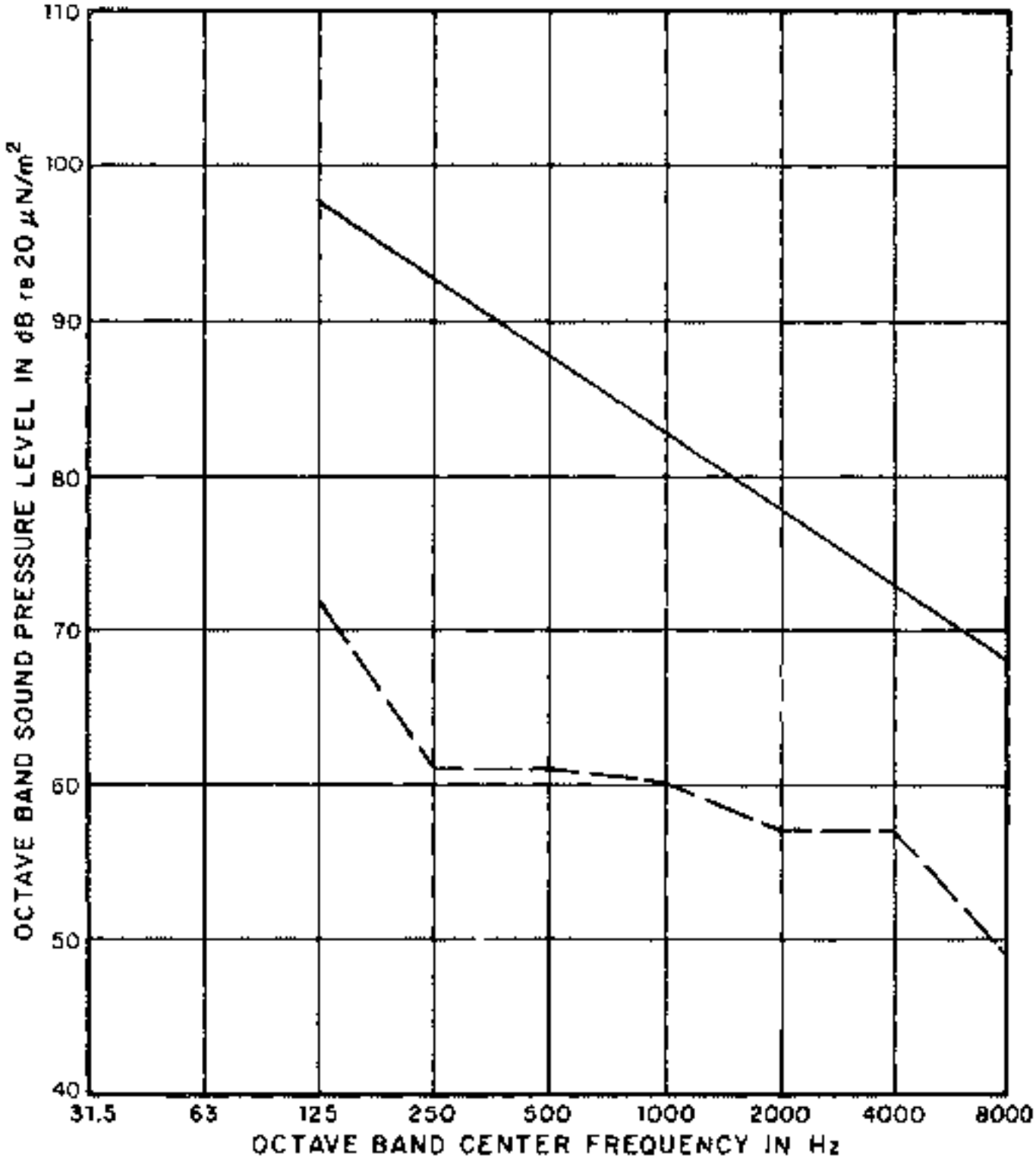


FIG. A.50 SOUND PRESSURE LEVELS FROM UNITARY ROOFTOP AIRCONDITIONING UNITS (MEASURED AT 3 FT)

AR0070723

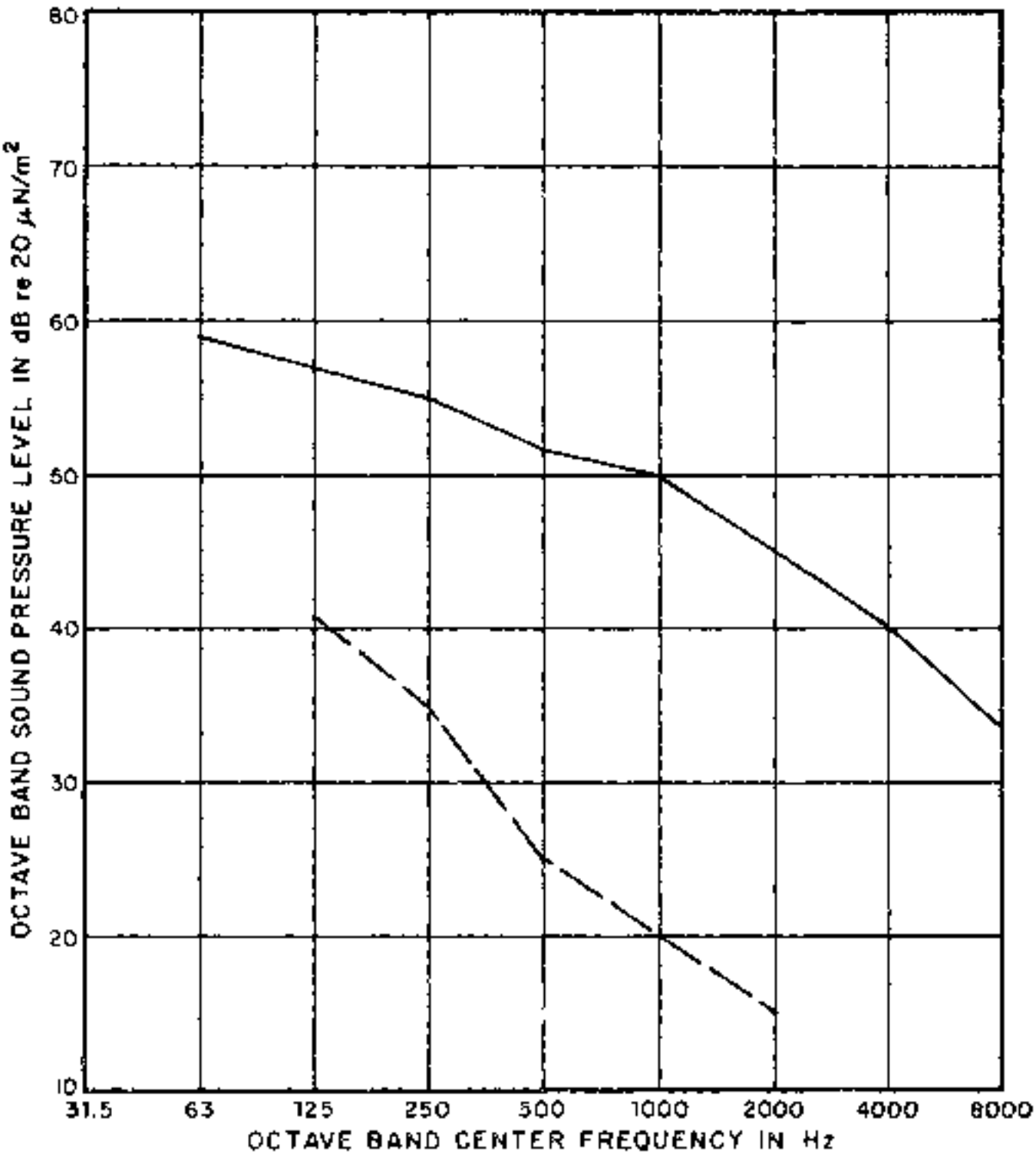


FIG. 5.5C RANGE OF SOUND PRESSURE LEVELS FOR FAN COIL UNITS (MEASURED AT 3 FT.)

AR0070724

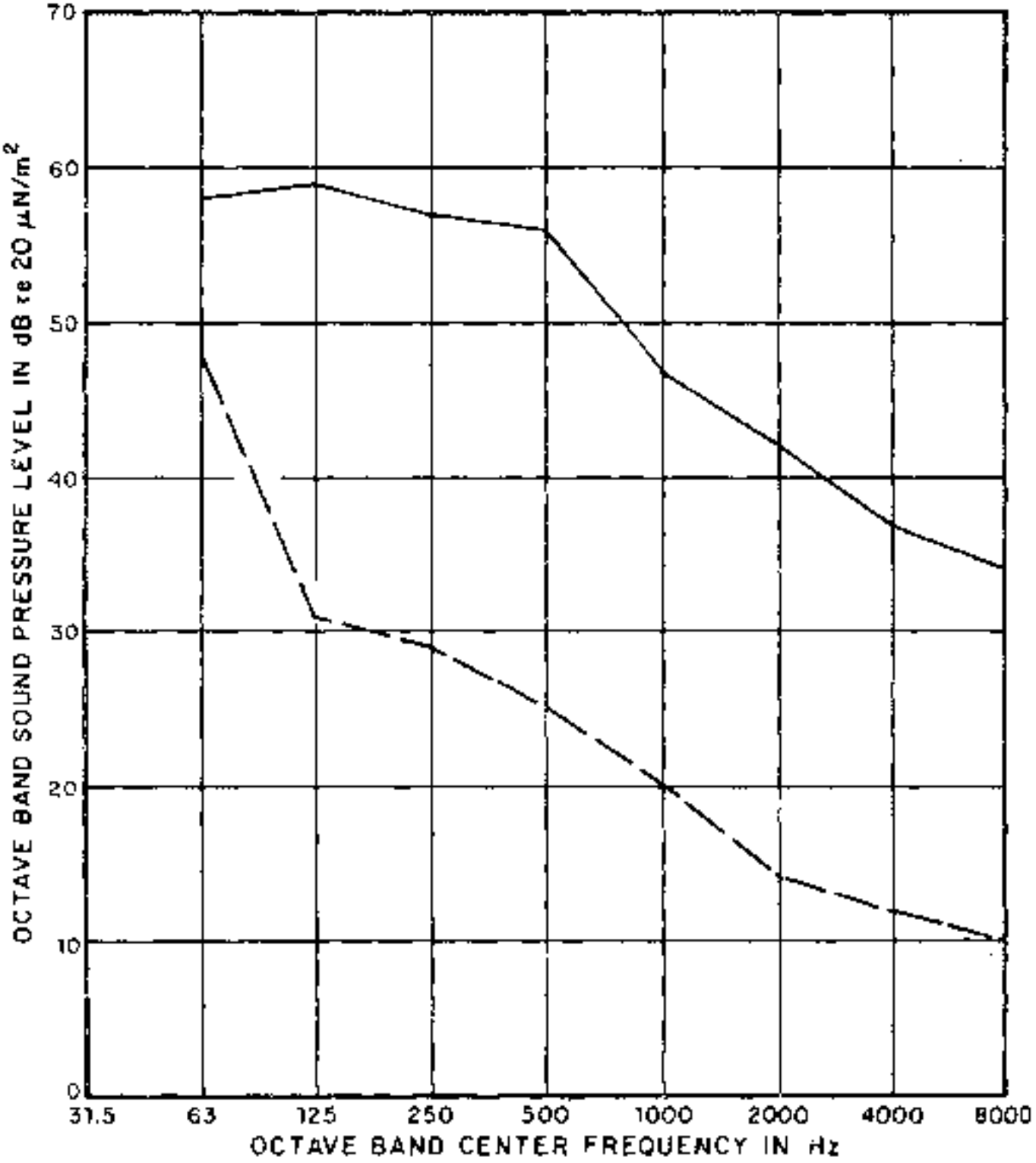


FIG. A.52 RANGE OF SOUND PRESSURE LEVELS FROM INDUCTION UNITS (MEASURED AT 3 FT)

AR0070725

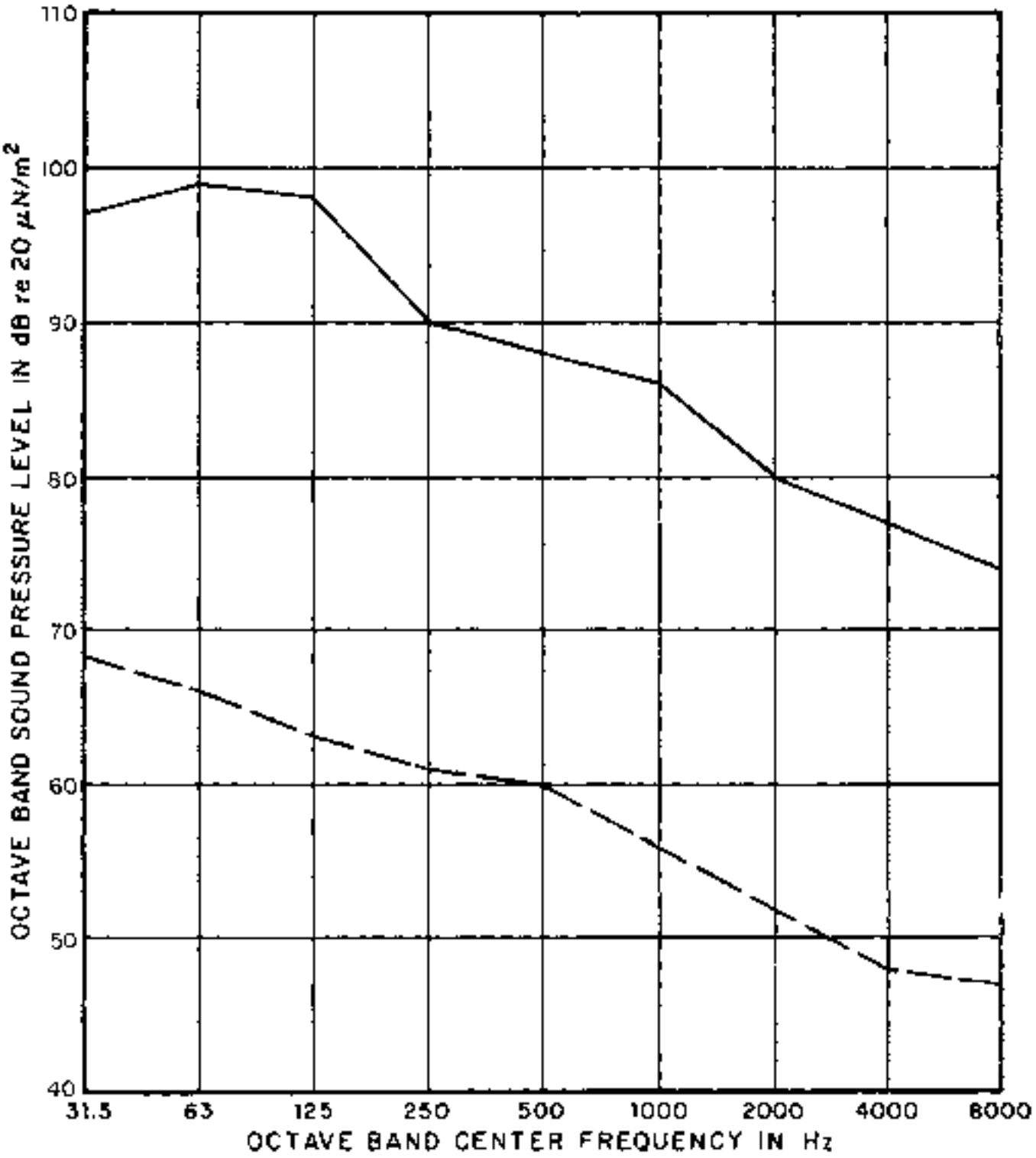


FIG. A.53 RANGE OF SOUND PRESSURE LEVELS FROM BOILERS (MEASURED AT 3 FT)

AR0070726

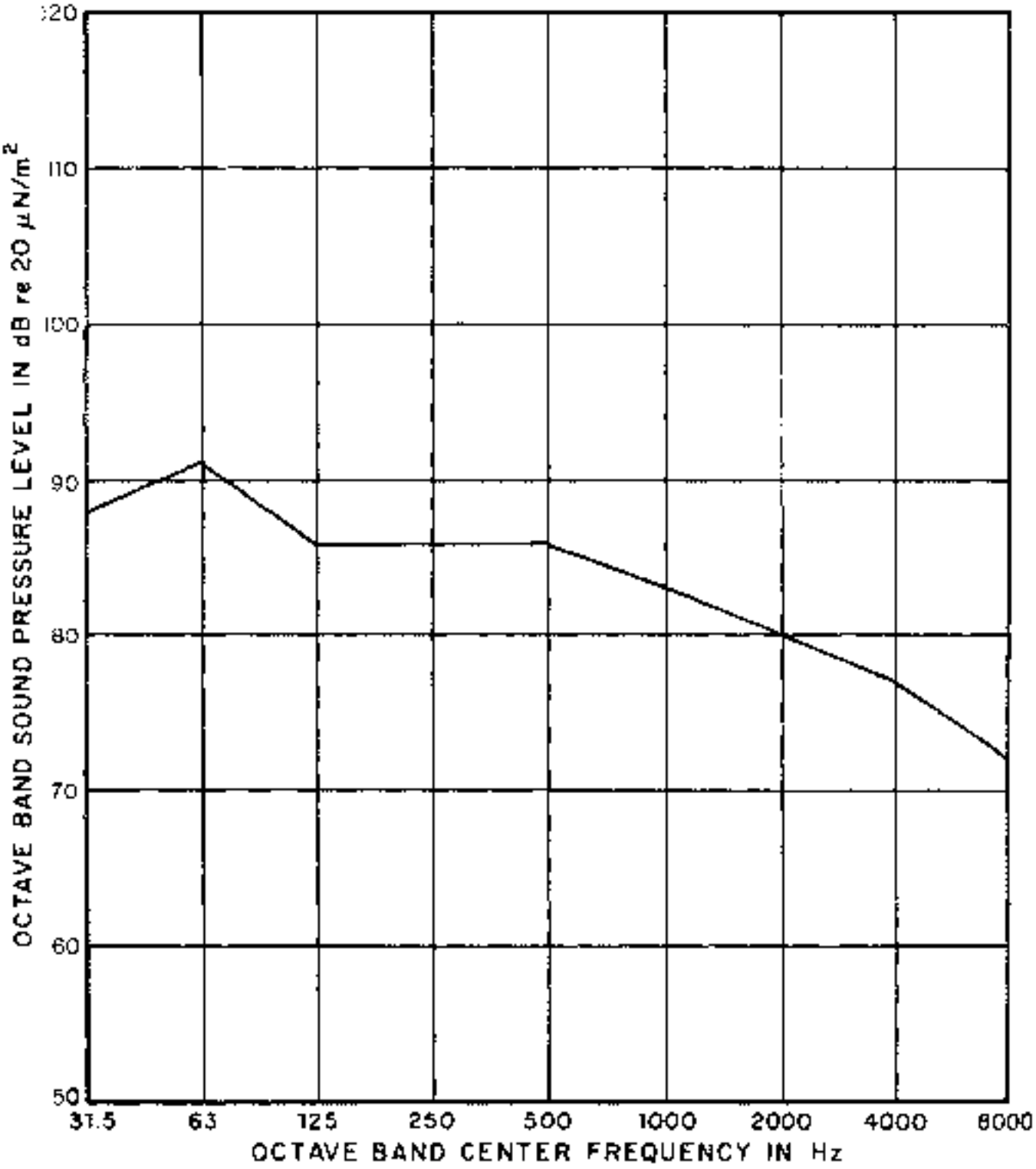


FIG. A.54 TYPICAL SOUND PRESSURE LEVELS FROM ABSORPTION/CYCLE REFRIGERATION MACHINES (MEASURED AT 3 FT)

AR0070727

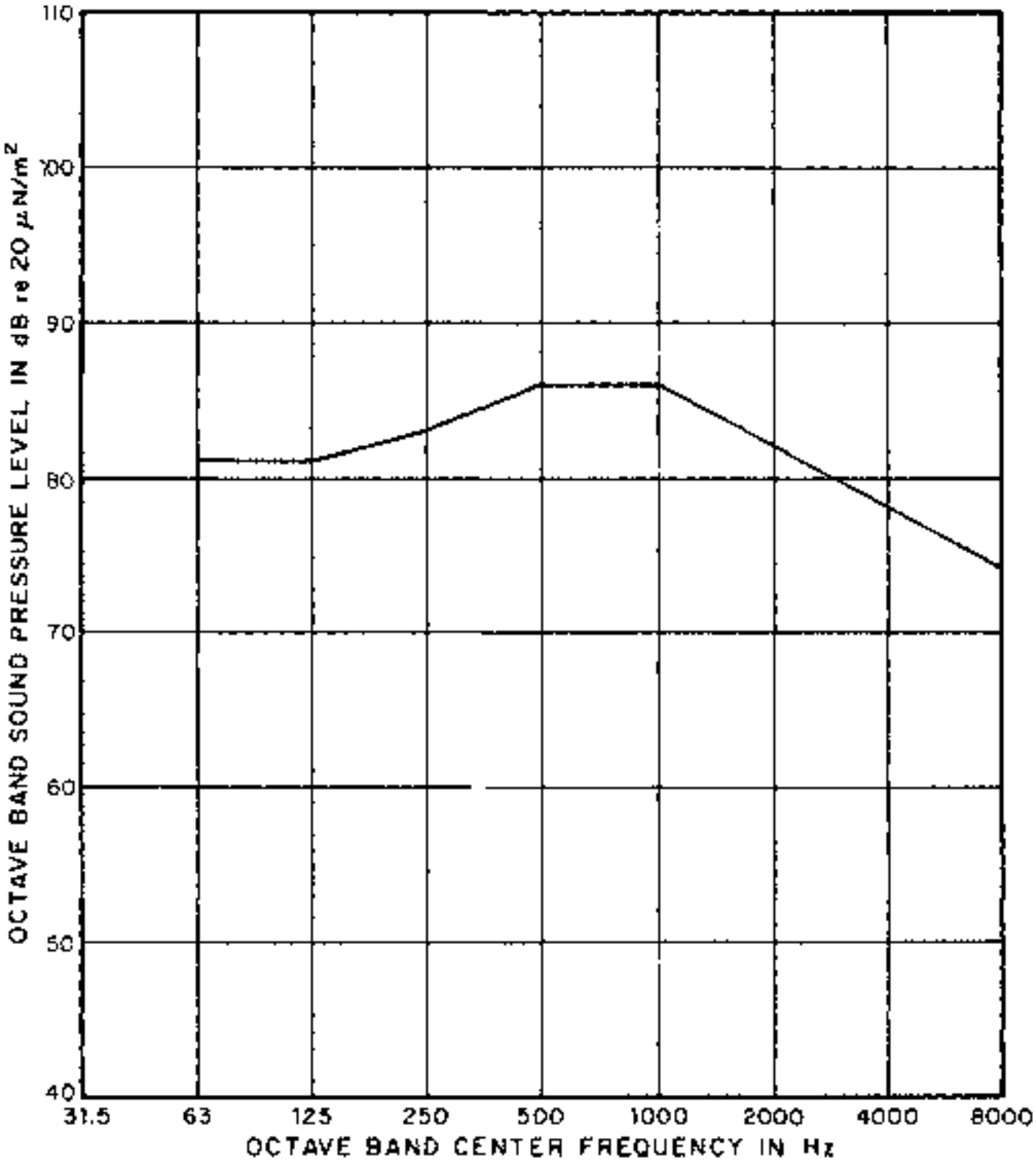


FIG. A.55 TYPICAL SOUND PRESSURE LEVELS FROM CHILLER WITH RECIPROCATING COMPRESSOR (MEASURED AT 3 FT)

AR0070728

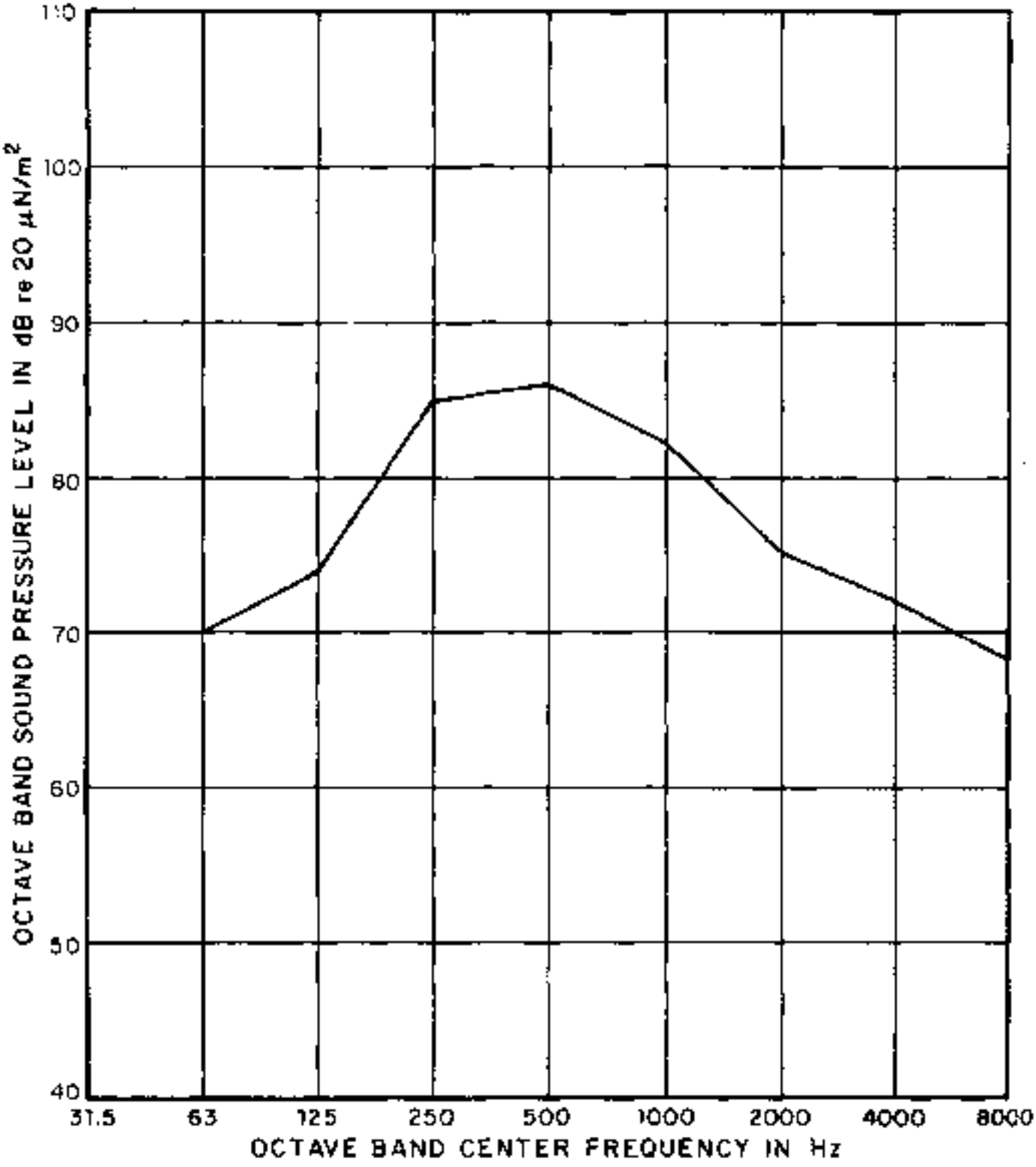


FIG. A.56 TYPICAL SOUND PRESSURE LEVELS FROM CHILLER WITH ROTARY-SCREW COMPRESSOR (MEASURED AT 3 FT)

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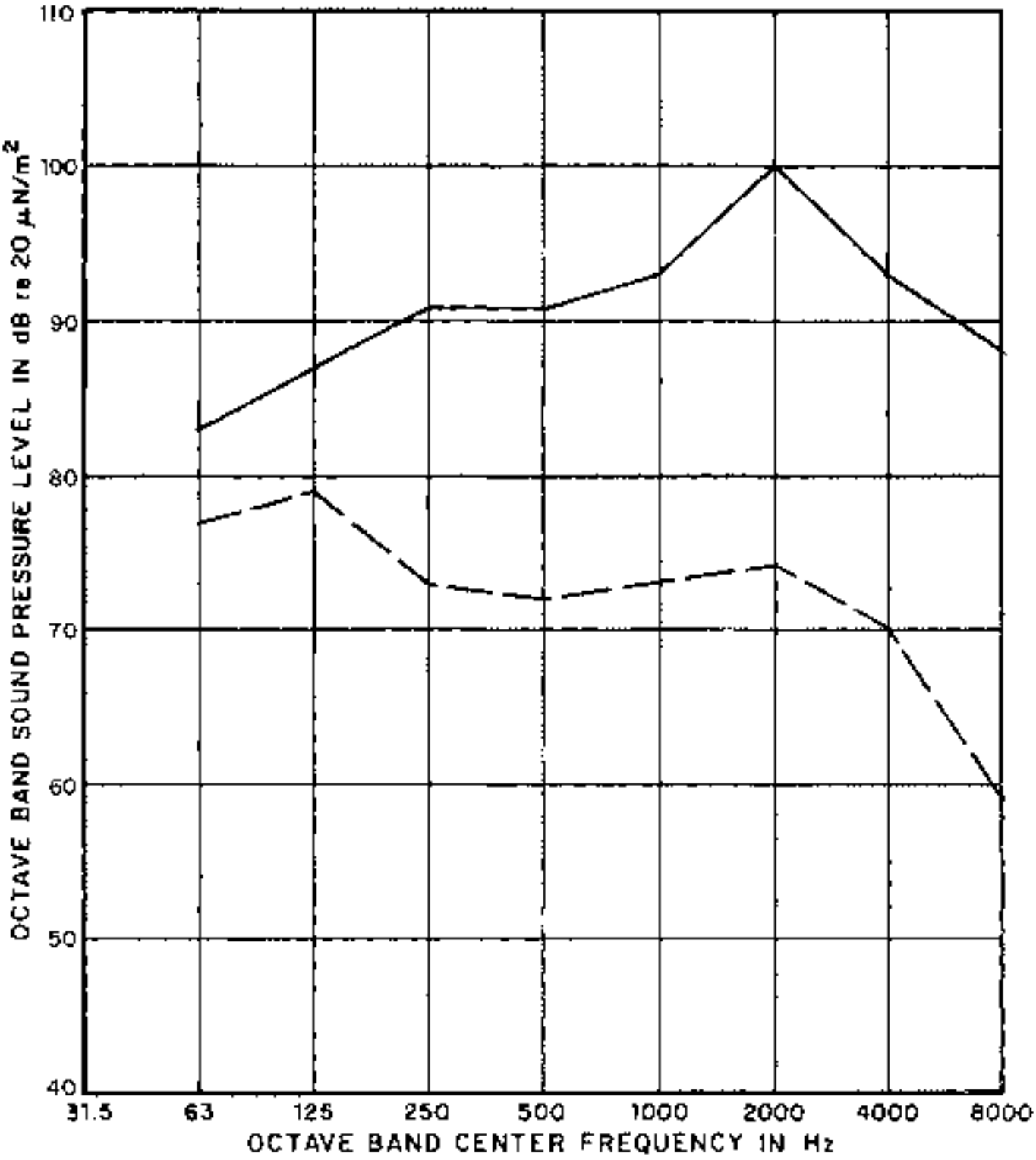

FIG. A.47 RANGE OF SOUND PRESSURE LEVELS FROM CHILLER WITH CENTRIFUGAL COMPRESSOR (MEASURED AT 3 FT)

AR0070730

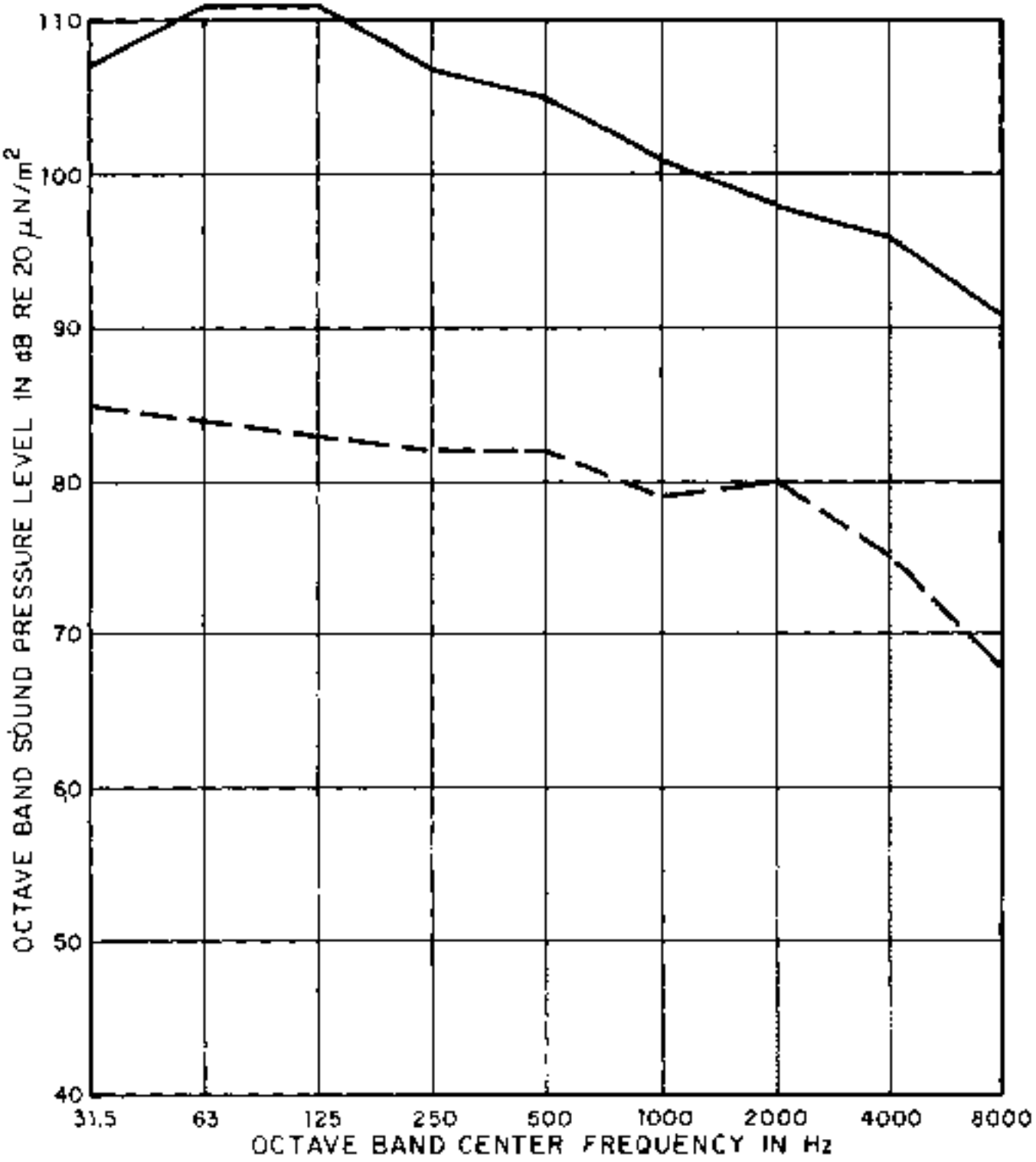

FIG. A.58 RANGE OF SOUND PRESSURE LEVELS FROM COOLING TOWERS (MEASURED AT 3 FT)

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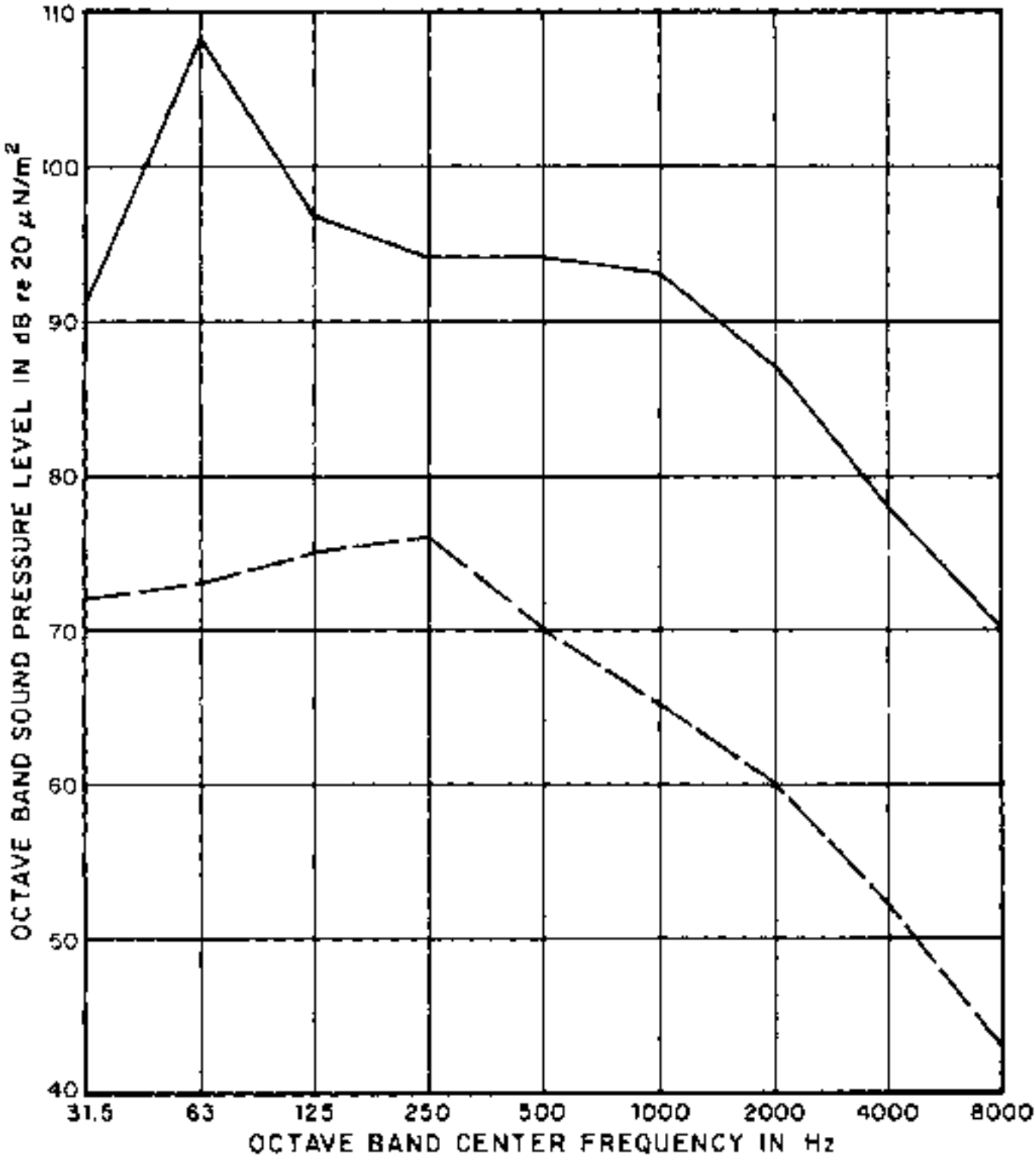

FIG. A.59 RANGE OF SOUND PRESSURE LEVELS FROM AIR-COOLED CONDENSERS (MEASURED AT 3 FT)

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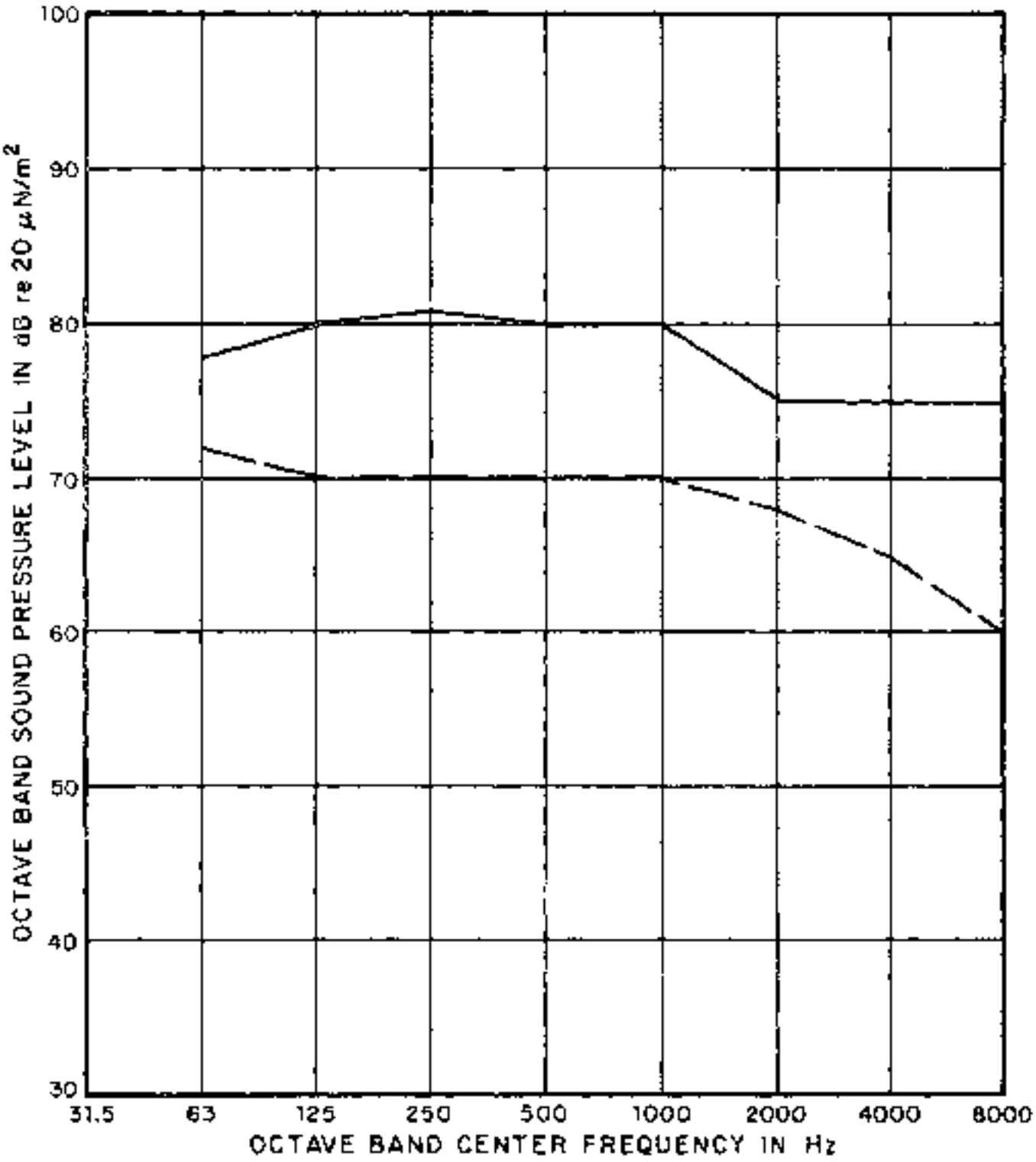

FIG. A.60 RANGE OF SOUND PRESSURE LEVELS FROM ELEVATOR ROOM (MEASURED AT 3 FT)

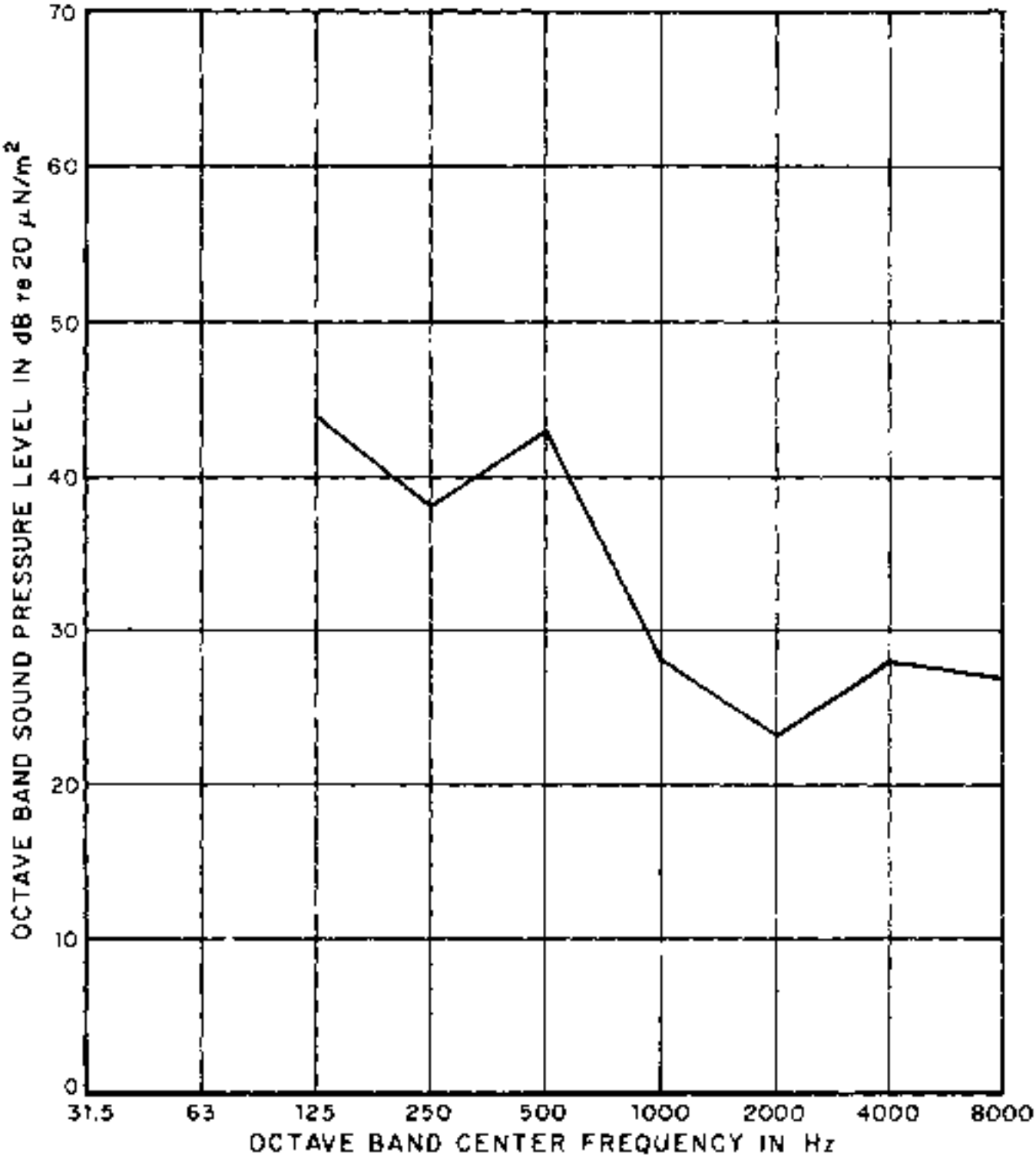

FIG. A.61 SOUND PRESSURE LEVELS FROM BALLASTS (MEASURED AT 3 FT)

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APPENDIX B - IMPACT CONSIDERATIONS

B.1 Interpretation of Impact Estimates

Sections 3.2.2 and 3.3.2 of this report have provided detailed breakdowns of the impact on people of exposure to a variety of noise sources. This section of the report is intended to permit the reader to gain an appreciation for the significance of these estimates. It therefore consists primarily of caveats.

First, it must be stressed that both the physical levels of the noise sources and the levels at which effects on people are specified are, at best, imperfect estimates. Every attempt has been made to obtain unbiased and statistically sufficient estimates. Nonetheless, the actual levels mentioned in the text cannot be regarded as exact. Variability is inherent not only in the measurement process, but also in the noise sources, the propagation paths by which their sounds are transmitted to people, and of course in the responses of people. Thus, individual instances of extreme sensitivity to noise effects are to be expected, as are cases of excessively noisy and quiet sources. In some situations the total amount of variability may be so great as to transform assessment of noise impact, *a priori*, into an imponderable issue. It is important to acknowledge that the impact estimation of Sections 3.2.2 and 3.3.2 can pertain only to the general, rather than the specific, instance.

It must also be understood that research on the effects of noise on people has been conducted for the most part under controlled and simplified conditions. The application of knowledge gained from such experimentation to heterogeneous populations living in complex environments necessarily entails

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a fair amount of interpretation and approximation. Disagreement among experts on matters of detail is probably unavoidable.

Yet another important consideration to bear in mind when reading the sections on the impact of home appliance, building equipment, and construction noise on people is that these noises comprise only a fraction of most people's daily noise exposure. Since many noise effects are cumulative in nature, discussion of the impact of exposure to restricted classes of noise is both artificial and potentially misleading. It is not safe to assume, for example, that hearing damage is not a substantial risk to the public at large merely because the risk from construction noise exposure is negligible.

In short, it has been necessary to make a large number of assumptions in preparing most sections of this report. Assumptions are the coin with which conclusions are purchased. The reader must understand the assumptions before he can decide for himself whether the conclusions are worth the price.

The final caution is perhaps the most basic. Stated simply, it is that no attempt has been made in this report to address the crucial issues of societal desirability and costs of noise impacts. Such issues were purposely avoided as inappropriate and far beyond the scope of the current report. Value judgments about how much noise exposure is tolerable must inevitably be made, however, if this report is to be fully useful. Administrative or legislative bodies must eventually decide how much hearing loss workers must suffer to maintain industrial productivity; how much annoyance, stress, and task interference the public must endure; how much sleep interference is too much; and so forth. The authors hope that this report will provide the data and conclusions essential for intelligent actions on these issues.

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B.2 Discussion of Construction Data

Table B-1 tabulates nonresidential building construction in 1970 by the nature of metropolitan region in which eleven major categories of buildings were constructed. Construction effort in each building category is characterized both by the number of sites and the total construction cost in each region. The average cost of each type of building in each region is also presented in Table B-1. The cost estimates are necessary for accurate estimation of the number of machine-hours of equipment operation at each site. The wide variability of building costs deserves special note. Office buildings in large, high-density central cities cost an average of $1.6 million while the same type of building costs an average of only $.47 million in low-density central cities.

The sources of the data in Table B-1 include the following:

- Columns 1 and 2: Unpublished tabulation by U.S. Bureau of the Census of all nonresidential building permits for 1970,
- Columns 3, 4, 5 and 6: Estimates based on population ratios, construction level ratios (where known), and assumptions about probable unit costs; and
- Column 7: *Construction Review*, except for lines 2, 5, and 7, which were estimated on the basis of known ratios of large city to national construction ratios.

Two categories of nonresidential building are recognized by the Bureau of the Census but are not discussed in this report. One is "residential garages and carports", of which 150,585 were authorized in 1970, at an average cost of $1600. Carport construction was judged to contribute negligibly to construction noise problems. The second category of buildings recognized by

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TABLE B-1. GEOGRAPHIC DISTRIBUTION OF MAJOR NONRESIDENTIAL CONSTRUCTION BY TYPE OF BUILDING (1970)

Type of Building	Large High-Density Central Cities Bldg.	Cost	Avg. Cost	Large Low-Density Central Cities Bldg.	Cost	Avg. Cost	Other Central Cities (Est.) Bldg.	Cost
Office, Bank, Professional	835	$438M	$1963K	815	$559M	$ 685K	1998	$378M
Hotel, Motel, etc.	27	108	4015	56	76	1335	137	127
Hospitals and Institutions	123	326	2647	120	103	861	294	233
Schools	67	72	1095	149	40	267	366	100
Public Works Bldg.	58	48	822	107	64	601	262	75
Industrial	362	92	253	800	93	116	1961	306
Parking Garage	82	33	398	114	49	429	279	48
Religious	81	22	255	169	24	140	392	48
Recreational	43	17	402	380	25	65	932	65
Store, Mercantile Bldg.	533	94	159	1649	205	124	4046	362
Service, Repair Station	341	12	44	553	13	23	1355	41

Type of Building	Urban Fringe (Est.) Bldg.	Cost	Nonurbanized Metropolitan Area (Est.) Bldg.	Cost	Outside Metropolitan Area (Est.) Bldg.	Cost	National Total Bldg.	Cost
Office, Bank, Professional	3168	$600M	1424	$270M	2260	$456M	9900	$2701M
Hotel, Motel, etc.	344	320	154	143	207	157	929	931
Hospitals and Institutions	1590	468	265	210	411	272	1803	1611
Schools	687	197	309	88	465	102	2043	606
Public Works Bldg.	689	195	310	88	421	95	1847	566
Industrial	6370	989	2867	446	3706	391	16336	2310
Parking Garage	841	146	379	66	500	72	2195	414
Religious	1820	185	823	83	970	71	4252	423
Recreational	1395	99	628	44	998	51	4376	301
Store, Mercantile Bldg.	11425	598	5148	449	7258	424	29058	2512
Service, Repair Station	3220	97	1451	43	2050	42	8970	247

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TABLE 3-2. GEOGRAPHIC DISTRIBUTION OF RESIDENTIAL BUILDING CONSTRUCTION BY TYPE OF BUILDING (1970)

Type of Building	Large High-Density Central Cities* Bldg.	Total Const. Cost	Avg. Const. Cost	Large Low-Density Central Cities Bldg.	Total Const. Cost	Avg. Const. Cost
Single-Unit	57+2	$ 56[illegible]	$ 15.1K	17213	$ 330[illegible]	$ [illegible].2K
Two-Unit	2044	-6	22.7	1076	32	29.6
Three- and Four-Unit	177	9	51.2	277	13	46.2
Five-Unit and Larger	745	532	716.0	3012	802	266.0

Type of Building	Other Central Cities Bldg.	Total Const. Cost	Avg. Const. Cost	Urban Fringe (Est.) Bldg.	Total Const. Cost	Avg. Const. Cost
Single-Unit	85775	$14781	$ 17.2K	241830	$4820[illegible]	$ 19.9K
Two-Unit	4776	92	19.3	6190	140	22.6
Three- and Four-Unit	3266	109	33.4	3542	127	35.8
Five-Unit and Larger	9496	1883	190.0	11470	2123	185.2

Type of Building	Nonurbanized Metropolitan Area (Est.) Bldg.	Total Const. Cost	Avg. Const. Cost	Outside Metropolitan Area Bldg.	Total Const. Cost	Avg. Const. Cost
Single-Unit	109018	$2171M	$ 19.9K	165218	$2720M	$ 16.4K
Two-Unit	2800	63	22.6	5455	109	20.0
Three- and Four-Unit	1593	57	35.8	2720	90	33.1
Five-Unit and Larger	5166	957	185.2	33.21	612	184.7

Type of Building	National Total Bldg.	Total Const. Cost
Single-Unit	624767	$11605
Two-Unit	22231	482
Three- and Four-Unit	11595	404
Five-Unit and Larger	32465	6109

*See Sec. 3.2.1.2, Table 1X, for definitions of large high-density and large low-density central cities.

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to "other" but not discussed in the current report is "all other nonresidential buildings", of which 296,814 were authorized at an average cost of $7,700. The latter category of construction was considered too heterogeneous in nature to permit reasonable estimation of the nature of construction noise at a "typical" site.

Table B-2 presents data on the construction effort involved in erecting residential buildings as a function of the type of metropolitan region in which the construction occurs. The data in Table B-2 were obtained from unpublished Bureau of the Census tabulations and from the Census publication *Construction Reports: Housing Authorized by Building Permits and Public Contracts, 1970*

B.3 Estimating the Extent of Public Works Construction Noise

The public is exposed to construction noise not only from operations of erecting buildings of various sorts, but also from operations arising from public works construction. Such operations include road, highway, street, and sidewalk construction and maintenance, as well as sewerage, water works, and utilities installation and maintenance. The noise created by these construction activities is frequently prolonged and intense. Even small repair jobs on water works create considerable noise as sections of pavement are ripped up to gain access to buried pipes.

Estimation of the amount of noise created by such activities required that a number of assumptions be made about the distribution of construction noise from public works sites. The most important assumption was that federal and state public works activity could be neglected for the purposes of this study since it occurs primarily in rural regions of low population density. Attention was therefore concentrated on municipal public works activities within SMSAs.

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Although summary reports contain ample information on federal and state public works activities, comparable municipal data are available only for individual municipalities. We have been able to obtain fairly complete data on municipal public works construction and maintenance for two large, high-density cities: the central city, Boston, Massachusetts, and the adjacent city of Cambridge. We have used this information, together with the figure of 42,000 miles for municipal street construction throughout the country in 1969, published by the Federal Highway Administration, to estimate total sewerage and water works activity (in terms of miles of pipe and mains laid) for the country.

In carrying out these calculations, we assumed average values of 1.0 miles each of water and of sewer main per mile of new street. We further assumed that on the average, water and sewer main additions per year would be 2% and 1.5% of existing footage, respectively, as opposed to 7.5% for the annual increase in length of municipal street systems. This gave estimated country-wide values of some 11,000 miles of water mains and 8,000 miles of sewage mains. These estimates are considered reasonable in that they are about half as great as would be obtained if the respective annual U.S. expenditure for water works and sewer construction were allocated solely to the installation of mains. Moreover, some mains would be installed concurrently with street construction and, as a consequence, not constitute separate sources of noise pollution.

Inherent in our approach to the estimation of exposure of the population to municipal construction noise is the assumption that the locus of both municipal construction and of population exposed is the street system of a municipality. We have therefore focused on the numbers of inhabitants distributed in permanent residence along the streets of a municipality as an index of the impact of

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...ress-associated municipal construction noise. In order to facilitate the use of this approach, we developed a correlation (see Fig. B-1) between population density and the quantities, miles of street per square mile and inhabitants per mile of street for several dozen cities, towns and counties in Massachusetts and Tennessee for which we had data available.

Using the above correlation, together with the amounts of municipal public works construction estimated earlier, we arrived at the figures for these presented in Table B-3. The indicated exposures of residents along streets where municipal public works construction is taking place are 10 million and 4.4 million individuals, for street and water works and sewer construction, respectively, making a total of 14.4 million individuals exposed to public works construction noise.

B.4 Propagation Loss Model For Building Construction Sites in Metropolitan Areas

Two classes of people are exposed to construction noise: the stationary population which inhabits the region around the construction site (workers and residents) and the transient population which passes by the site (drivers, passengers, and pedestrians.) Two models were constructed to estimate the extent to which site noise is attenuated for each class of observers.

Stationary Population

The entire stationary population around a construction site was assumed to be indoors with closed windows. Acoustic propagation loss was modeled by postulating a representative site geometry and applying the formula

$$N = 20 \log \frac{R}{R_0} + 20 \text{ dB}$$

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TABLE B-3. ANNUAL EXPOSURE OF PERSONS IN METROPOLITAN AREAS TO MUNICIPAL CONSTRUCTION NOISE

LENGTH OF MUNICIPAL CONSTRUCTION (MILES)

Activity	Large, High-Density Central Cities	Large, Low-Density Central Cities	All Other Central Cities	Urban Fringes	Met. Areas Outside Urban Fringes	Total
Street, Highway	273	2,150	6,300	11,300	21,700	[illegible]
Sewerage & Water	125	990	2,700	5,065	9,850	18,730
	398	3,140	9,700	16,365	31,550	60,653
Population Density (people/sq. mi.)	15,160	4,410	3,720	3,380	195	
Area (sq. mi.)	1,468	2,389	6,381	14,757	179,276	
Street Distribution (miles of street/ sq. mi.)	21	10.2	9.5	8.9	1.45	
Linear Distribution of Population (people/mile of street)	720	430	390	380	93	

PERSONS EXPOSED TO MUNICIPAL CONSTRUCTION NOISE ($X10^{-3}$)

Activity	Large High-Density Central Cities	Large, Low-Density Central Cities	All Other Central Cities	Urban Fringes	Met. Areas Outside Urban Fringes	Total
Street, Highway	196	925	2,340	4,479	[illegible]	[illegible]
Sewerage & Water	90	425	1,050	1,920	[illegible]	[illegible]
	286	1,350	3,390	6,399	[illegible]	14,350

1/ About 14.3 million people exposed to municipal construction noise.

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where H = total propagation loss

R = range from source to observer

R_0 = reference range at which site source level was measured (50 ft).

Twenty dB was added to account for the loss through building walls with closed windows. The resulting transmission loss contours are shown in Figure 19 of the main text.

Transient Population

People passing by a construction site continuously vary their distance from the site. A model such as the above is not directly applicable. The peak noise level to which passersby are exposed, however, can be computed from the propagation loss at the passerby's closest point of approach (CPA) to the site. This propagation loss is computed from the formula

$$H = 20 \log \frac{R_1}{R_0} + H'$$

where H = total propagation loss

R_1 = range at CPA

R_0 = reference range at which site source level was measured (50 ft)

H' = is a term included to account for baffling or obstructions between source and observer

In the case of pedestrians, we assume that R_1 = 100 feet and H' is zero. H is therefore 6 dB. For drivers, we have assumed R_1 = 100 feet and H' = 15 dB to account for attenuation caused by the transmission loss of an automobile. For this case, H = 21 dB, which was rounded to 20 dB to emphasize that the figure is only an estimate.

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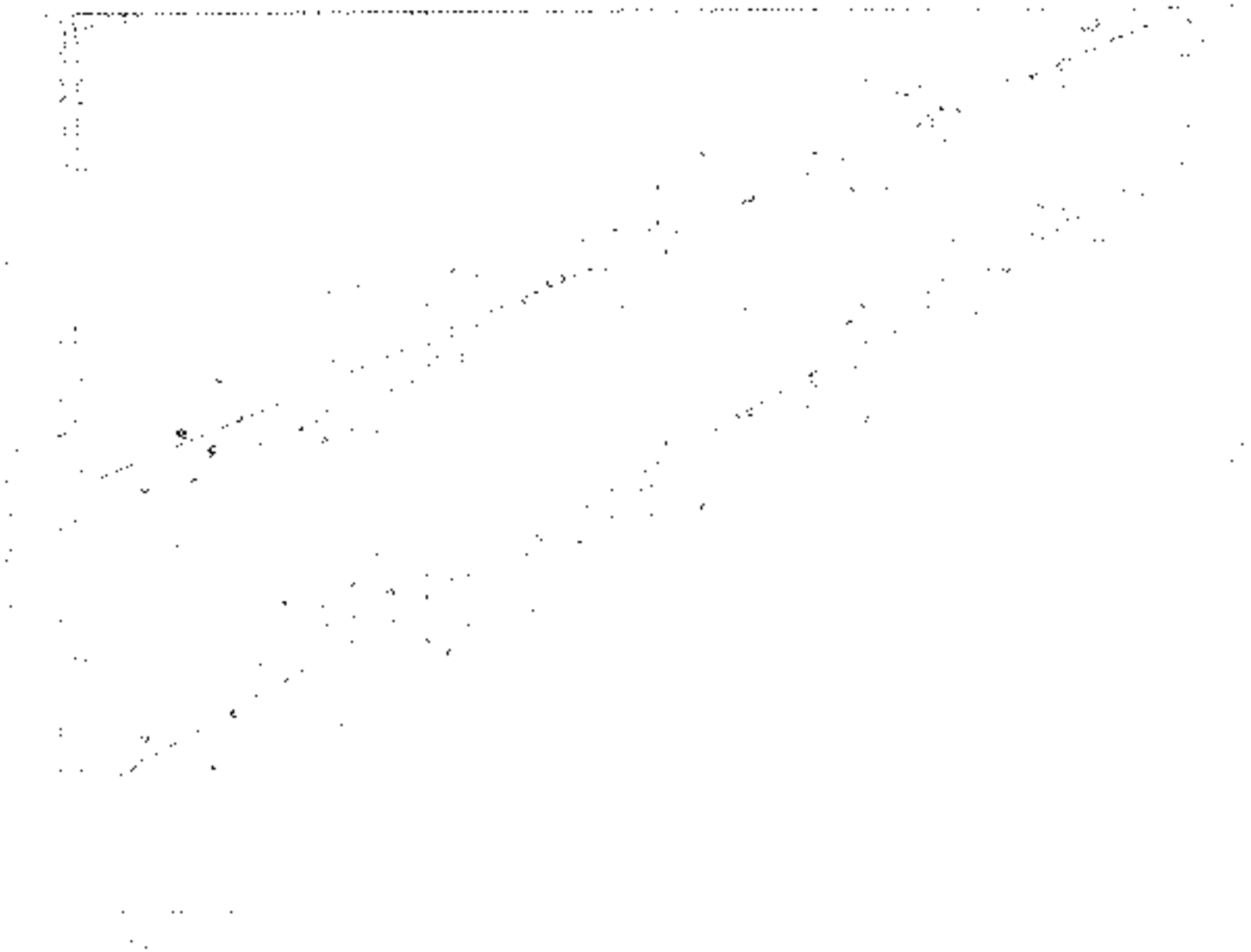

APPENDIX C — SOUND LEVEL CONSIDERATIONS BY AMERICAN CONSTRUCTION MACHINERY MANUFACTURERS

by

H.T. Larmore
Deputy Director for Technical & Safety Services
Construction Industry Manufacturers Association
Milwaukee, Wisconsin

Presented at
The American Industrial Hygiene Association Conference
Toronto, Ontario
May 24, 1971

This presentation will attempt to place the problem of noise into its proper perspective relative to construction and construction machines — both as a potential cause of hearing loss for workers and as an air pollutant for the nearby community at construction sites.

NOISE — THE PROBLEM STATED

Unwanted sound — is not new to the construction industry. Construction sites are noisy. Likewise, it is not new to heavy machines used in the construction of buildings, highways, sewer and water systems, airports and the like. Indeed, it has been a criterion by which some machines have been operated. A skilled operator often relies upon the sound of his equipment for proper operation. Also, noise is often associated with power in the purchase of machines.

These philosophical concepts and the public demand for lower construction costs do not excuse construction machinery from being noisy, but they have contributed to the major emphasis by manufacturers over the past decade to design for greater productivity

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motivation to build quieter machines. The transitory and temporary nature of construction has also allowed a lack of concern for noise. While any particular contract is underway, the workers and neighbors might well be annoyed by the noise. But relief comes when the job is completed and the big machines move on. Next job site - there are new workers; new neighbors.

During the past few decades, the public demand has been for more production with less labor and less cost. This prompted the development of today's remarkable machines with more power, automation and speed than ever before. But machine "improvements" to affect this demand generally tended to increase noise levels. Larger engines produced more noise both internally and from the exhaust. More automation was accomplished through more use of hydraulic power which also is a noise generator. Larger engines and more hydraulic power increased the heat which must be dissipated through larger quantities of air being driven by noisier fans through larger radiators. Increased speed means increased vibration frequencies which tend to concentrate in the audible hearing range.

THE CONCERN FOR NOISE

The concern for noise, only recently voiced by the public and expressed now in actual or proposed legislation at all levels of government would seem to have created a major shift from the "productive Sixties" to the "silent Seventies". Fortunately, our industry is geared to respond to our customer requirements and, hopefully, to recognize changing requirements soon enough to accommodate the necessary lead times for research and development, testing, tooling, manufacturing and distribution. Noise abatement, although recognized by manufacturers of construction

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machines as a legitimate environmental concern, has been and still is difficult to define in precise engineering and machine requirements — how much — how fast — what costs and trade-offs are acceptable — cost/effectiveness ratios — all tend to remain fuzzy with even man/noise effects far from being accurately determined.

The manufacturers of construction machines, without waiting for all the answers, recognized in the late sixties the need for the basic tools for all change and/or regulation — Measurement Standards. Without such tools, base lines cannot be established or progress measured.

Through the Construction Industry Manufacturers Association (CIMA) — the necessary machinery and policies were established some four years ago to recognize needs for Performance or Safety Standards and to promote development of such Standards by nationally recognized technical and Standards writing bodies. Among these were the basic noise measurement Standards as voluntary guidelines for both industry and government authors. These were accepted for development by the Society of Automotive Engineers (SAE). They include for construction machines:

1. Noise measurement at operator station
2. Noise measurement at 50 foot radius
3. Construction job site noise measurement
4. Cumulative operator noise exposure measurement along with standardized reporting methods

Substantial progress has been made by SAE with completion and publication of some of these Standards expected in the near future.

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The measurement of noise levels either at the operator's station or at a distance from the machine is no simple matter. A machine can be subjected to many operational variables. Engine at rated speed, acceleration, full power drawbar load, power take-off load, hydraulic load, idling engine, idling transmission, transport, addition of a cab, roll-over protective structures, windows open — these are some of the variables which affect noise levels. For that reason, a uniform procedure for noise measurement is most important.

There are currently under consideration at least four Federal Bills and twenty State legislative Bills which can regulate noise on construction machinery. Consequently, there is a real need for uniformity not only in measurement methods but in noise limit levels. It can be appreciated that legislators are concerned with protecting operators and others from hearing damage and the nuisance of excessive noise. However, a mass of legislation and regulations which are nonuniform are more of a liability than an asset in reducing noise levels on construction machines. Nonuniformity with little or no lead time for making the changes is leading to stop-gap measures which have unpredictable durability and effectiveness, and which perhaps introduce unwanted trade-offs and compromises through overheating, fire hazards, maintenance interference and reduced output.

WHAT ARE MANUFACTURERS DOING ABOUT NOISE?

So - what are construction machinery manufacturers doing individually and as an industry?

Individually they are:

1. Evaluating the many noise sources peculiar to each machine.

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2. Developing operator enclosures for current products.

3. Developing procedures for customizing current products off the production lines.

4. Developing quieter components and systems for quieter machines in the future.

Through CIDA they are:

1. Seeking new and updated SAE Standards and Recommended Practices for operator and exterior noise levels.

2. Organizing a cooperative effort among governments, noise specialists, contractors and machinery manufacturers to accumulate the great masses of actual on-the-job noise data required by industrial hygienists in their evaluation of the man/noise effects in the construction environment.

3. Creating information on construction machine noise for use by regulatory bodies, consumers, and information media.

4. Investigating a means to express machinery noise sources in a uniform, usable and reliable manner.

THE COMPLEX ANSWERS

These individual and collective efforts are not simple nor do results come easily or cheaply. As a beginning, component noise sources are rapidly being isolated and evaluated. Oversimplification of the problem frequently leads many to believe that engine exhaust noises are the culprit and that larger mufflers would turn the trick. To be sure, this is part of the problem. However, noise reduction of the exhaust permits other machine

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noises to become dominant. Larger mufflers also create a visibility problem since they usually end up directly in front of or behind the operator.

There are several other noise sources which are the same order of magnitude as exhaust noises, depending on the machine and its configuration.

These are:

1. Internal engine noises exclusive of the combustion itself.
2. Engine air inlet
3. Transmission and other gear noises.
4. Hydraulic system noises including the pump, tubes, valves, cylinders and hydraulic motors.
5. Air noise from the fan and radiator.
6. Various moving mechanical elements such as crawler tracks, or scraper elevators.

It is very likely that on a large machine today, each of these noises is individually in excess of 90 dB(A) (decibels on "A" rating scale). In the case of two equal noise source levels, the sum is about 3 dBA higher than either source alone. For four equal noise sources, the sum is about 6 dBA higher. And this in reverse acts much the same way. Suppose the total noise of a machine is 100 dBA composed of four equal noise sources. Let's say the exhaust, engine noises, gear and hydraulic noises and fan noises are these four. If by some magic the exhaust and internal engine noises could be reduced to zero, the machine would still have a noise level of 97 dBA. So, this is the

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challenge to the engineers who are studying each noise source and striving for noise reduction of each component.

QUIETING CURRENT PRODUCTS

For quieting current production machines, some manufacturers are starting to use off-line, extra cost customizing. This may consist of one or more of the following: An isolation mounted cab; larger muffler; sound deadening material around noisy components; and vibration isolation of noise components. These methods are expensive and can have only minimal effect on the total problem. Also, the sound absorbing insulation causes some components to run hotter and can possibly absorb spilled petroleum products. This can be a fire hazard. One would not normally expect to replace such insulation during a machine's expected useful lifetime but durability of such materials and installation techniques are not broadly known.

FUTURE MACHINE QUIETNESS

For future machines, larger capacity cooling fans with non-resonant frequencies are being developed. These would utilize larger volumes of air at lower velocities, new radiator fin designs and more efficient shrouds.

Some gears must be changed from one form to another and perhaps made with more precision. Much noise is generated from variable gear loadings and from gear idling. Gears are designed to transmit a given power level at a required speed. Variations of these will set up vibrations which cause noise. Here again, isolation and insulation seem like possible temporary solutions but heat and flexibility can lead to premature failure and other new problems.

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Hydraulic pumps, transmission lines, valves, cylinders and motors are all noise generators. Oil flowing in a smooth, uniform path should be one of the quietest methods of generating, transmitting and utilizing energy. However, each component has complicated restrictions which induce vibration. If all of the hydraulically performed functions were uniform and continuous, the noise would be minimal. But ease and flexibility of control are reasons for the many applications. Noise reduction programs for hydraulics are underway, but they will take time for development, testing and adopting.

Mechanical components such as the tracks of crawler tractors are noisy but fortunately are of lower frequencies. These types of mechanisms are just not readily quieted and do not lend themselves to encapsulation treatment. The long range, practical solution for all these problems may well dictate future machines of entirely new configurations.

NOISE STANDARDS AND REGULATIONS

Because of the many noise sources which add up to a single composite noise at an individual's ear, a unique but uniform measurement is necessary. For this purpose the SAE Standards are a very practical solution. The development of these Standards requires inputs from a broad spectrum of individuals with various areas of interest. One company cannot develop such Standards nor can just the machine manufacturers' industry. But, through CIMA, the industry is promoting and lending its support to the development of meaningful noise Standards by independent Standards writing bodies which include experts from manufacturers, government, public, users and labor.

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As previously stated, these are noise measurement and reporting Standards being developed by engineers and other highly knowledgeable people in the construction field. Obviously, their efforts must be teamed with practical and effective noise limit Standards developed by the experts in the field of Industrial Hygiene. Such limits should be in keeping with the peculiar type of exposure found in the construction environment. Only when these two tasks are completed can effective and practical noise control programs and regulations be designed and implemented.

For Community Noise Control we visualize total construction job site limits geared to the particular needs of the surrounding community. This would create a natural demand for quieter machines yet still allow contractors and users to utilize their well demonstrated versatility and ingenuity to get the job done in compliance with realistic job site noise limits even with existing machines by using new job layout and operational techniques.

For control of hearing damage risk we would urge that the current Walsh-Healey noise exposure tables might be modified for construction workers to more accurately reflect their unique exposure to intermittent, variable intensity noise and the large seasonable fluctuations in noise dosages. These factors are covered in some detail in a CIMA sponsored study published by SAE, December 1969, as Technical Report — SAE Research Project R-4 and titled "A Study of Noise Induced Hearing Damage Risk, for Operators of Farm and Construction Equipment". This report is available from the Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York.

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In summary, we have attempted to briefly review the background of construction machinery and the relatively recent public concern for noise.

We have outlined the complex and sophisticated industry problems involved and our concern that the public may be moving from apathy to overkill in one easy lesson.

We have indicated an industry recognition of the responsibility to help shape noise abatement legislation and regulation into reasonable and responsible instruments; also, our past and continuing active participation, through CIMA, to effectively utilize our industry expertise in major and necessary Standards activities.

We spoke of the industry efforts, both from individual manufacturers and collectively through CIMA to create quieter machines except as a stop gap, high cost measure.

We outlined the need for new noise limit criteria designed in consideration of the unique types of noise exposure and dosage for construction workers.

It is obvious that construction machine designers and industrial hygienists in both the government and private sectors are operating at the threshold of the art relative to noise. We believe there is real and urgent need for a combining of these two groups into a teamwork effort. Through such a combined grouping of expertise can come the tools and procedures to effectively reach our common noise abatement objectives — and to do so with full consideration of the total needs of our society and at costs and compromises satisfactory to the public.

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APPENDIX D — NOISE CONTROL: REGULATION AND STANDARDS

D.1 Introduction

Control of the noise produced by construction activity, building equipment, and home appliances cannot be expected to proceed in an orderly fashion without supporting guidance in the form of noise criteria, noise standards, and noise limits. This section of the report presents information on the status of currently available guidance for noise control. Trends in development of criteria, standards, and limits are discussed. Where possible, future requirements for noise control guidance are anticipated.

A fundamental distinction must be made among the three basic forms of guidance necessary for systematic noise control. Noise criteria are defined as statements of the effects produced by various levels of noise exposure. Criteria are based on the effects of noise on people, as discussed in Section 3.1 of this report. Noise standards describe the properties of noise environments that are considered desirable. Standards are usually presented as long-term goals that a regulatory program may be designed to attain. Noise limits are in effect regulatory documents intended to limit public exposure to individual noise sources. The limits entail not only a knowledge of the existing noise environment, but also technological and economic constraints on noise abatement. It is intended by writers of noise limits that the noise environment should approach the goals of noise standards in a systematic fashion.

The next section will discuss the elements involved in the development and support of regulatory noise limits for construction equipment; the third section of this appendix will discuss those elements appropriate to building equipment and appliances.

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D.2 Construction Equipment

The body of this report has included discussion of criteria in the estimation and evaluation of the impact of construction equipment noise. The criteria appropriate to construction equipment noise are not unique to such noise sources, of course. The selection of standards for noise exposure must take into account the characteristics of the combined impact of the many noise sources that pollute our environment, and most importantly, must be keyed to the business and recreational activities and situations in society that are to be protected from noise. Thus, the development of a set of standards for the protection of human activity from noise pollution is beyond the scope of the present project and report; indeed, the ultimate selection will be based on further legislation incorporating decisions of national policy. It is our intention here to describe the relationship between the various elements in an environmental regulatory scheme, and to identify their present state of development by scientific and engineering groups, and by State and local governments.

The third of these elements is the noise limit itself, which provides quantitative restriction of noise emissions through incorporation in legally enforceable rules, regulations, and laws. Quantitative limits must be directed at an identifiable legal entity (such as manufacturer, vendor or user), and must be accompanied by specific test and measurement procedures. Although no nationwide noise regulations for construction or other powered outdoor equipment now exist, several states are considering such noise limits, and a number of larger cities have recently enacted or proposed limits for construction equipment.

The next section of this Appendix will review the recent regulatory activities at the State and local levels that apply. Since procedures for construction equipment noise measurement are so important to the successful implementation of source limitations, the last section will discuss these in more detail.

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State and Local Regulations

In the last two years, considerable activity has taken place at the State and local level with regard to reducing the noise of outdoor construction, maintenance, and repair activities.

Both the State of Illinois and the State of Hawaii enacted statutes in 1970 which grant broad regulatory powers over noise to specific state agencies. At this time neither the Illinois Pollution Control Board nor the Hawaii Dept. of Health have adopted any rules or regulations to control construction noise. The Illinois Institute for Environmental Quality has initiated a study of noise sources (including construction and other outdoor powered equipment) that could be covered by State regulations, and proposed limits for such equipment are being studied.

In the State of California, a report to the 1971 Legislature on the Subject of Noise was prepared by the State Dept. of Public Health. This report includes in its recommendations the establishment of noise emission standards for all noise-producing objects now in use as well as to be admitted in the future to California. The construction noise sources identified in the report include all diesel-engine powered equipment, such as generators, compressors, off-highway trucks, bulldozers, loaders, scrapers, power shovels and other excavating equipment, as well as piledrivers, riveting machines, jack hammers, elevators, cement mixers, hammers, power saws, drills, and nailers. Other State legislatures have or will consider a variety of proposed construction noise bills; a bill submitted to the New York State Legislature in 1968 would have limited construction noise as measured at the nearest multiple dwelling.

Because construction-equipment noise is especially severe in urban areas, limits have been proposed or adopted in several larger cities. New York City has proposed coverage of construction sites by permit, and limits for air-compressor and paving-breaker

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equipment in a new noise code; public hearings are scheduled to begin in the City Council Committee on Environmental Protection on 9 September 1971. The City of Boston Air Pollution Control Commission has recently completed a study of community noise and, as part of its plan for noise control, will begin hearings 27 September 1971 on proposed regulations which include limitations on noise of both construction/outdoor powered equipment and on the operation of a construction site. The latter limits, in brief, apply at any nearby area open to the public except public ways, or at a 1000-ft radius from the site, whichever is nearer.

The City of Chicago adopted a comprehensive noise ordinance, effective 1 July 1971. Section 17-4.5 provides that "No person shall sell or lease,...any powered equipment or powered hand tool that produces a maximum noise level exceeding the following noise limits at a distance of 50 ft, under test procedures established by...this chapter." and there follows a table of limits in dB(A) for four categories of equipment. Two categories "Construction and Industrial Machinery" (#1) and "Commercial Service Machinery" (#3) cover the bulk of construction equipment.

"Construction and Industrial Machinery" includes powered outdoor equipment, mobile or stationary, associated with construction sites or industrial operations. Such equipment includes crawler-tractors, dozers, rotary drills, and augers, loaders, power shovels, cranes, derricks, motor graders, paving machines, off-highway trucks, ditchers, trenchers, compactors, scrapers, wagons, compressors, pavement breakers, pneumatic-powered equipment, etc. Specifically excluded are pile drivers.

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"Commercial Service Machinery" includes powered equipment of 20 hp or less intended for infrequent service in residential areas, typically requiring commercial or skilled operators. Such equipment includes chain saws, light pavement breakers, log chippers, powered hand tools, etc.

The limits that apply to these categories are keyed to the date of manufacture of the equipment and provide a timetable for noise reduction as follows:

Manufactured after	Construction and Industrial Machinery	Commercial Service Machinery
1 Jan. 1972	94 dB(A)	88 dB(A)
1 Jan. 1973	90 dB(A)	84 dB(A)
1 Jan. 1975	86 dB(A)	--
1 Jan. 1978	--	--
1 Jan. 1980	80 dB(A)	80 dB(A)

The application of the limits to equipment for lease is most appropriate in the case of construction machinery; such equipment is usually leased rather than sold. Since the limits only apply to equipment manufactured after 1 January 1972, it is too early to look for compiled results, but several contractors in the Chicago area are now asking for "quieted" equipment that will meet these limits, and intend to use such equipment, insofar as possible, to reduce or eliminate community noise complaints. This provides very desirable pressure in the market place for such "quiet" equipment, encouraging manufacturers to offer noise control packages on their construction equipment before the required date.

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Measurement Procedures

Since quantitative limits must be applied to the noise source, most test codes and recommended practices for measurement apply to the operation of an individual item of construction equipment. The following noise measurement procedures are of this form:

SAE Standard J88a Sound Levels for Engine Powered Equipment*

Scope: For engine powered equipment including mobile construction and industrial machinery, but not covering machinery designed for operation on highways, or within factories and building areas.

Test Type: Outdoor free-field measurement on level ground. Measurement distance 50 ft. Equipment operation at speed and load producing maximum sound level.

Data: A-weighted sound level.

City of Chicago Environmental Control Ordinance, Article IV†*
Test Procedures for Noise Emitted by Engine-Powered Equipment and Powered Hand Tools

Scope: For engine-powered equipment, including construction and industrial machinery (not including pile drivers) agricultural tractors and equipment, powered commercial equipment of 20 hp or less, and powered equipment for use in residential areas.

*Society of Automotive Engineers, Inc., NYC, N.Y. 10001

†Sec. 17-4.26 and corresponding section of DEC Code of Recommended Practice. Chicago Department of Environmental Control, Chicago, Ill. 60610.

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Test Type: Outdoor free-field measurement on level surface. Measurement distance 50 ft. Both stationary test and acceleration test (for rubber-tired mobile equipment) at load and speed producing maximum sound level. Pneumatic equipment operated as specified in CAGI-PNEUROP Test Code.

Data: A-weighted sound level.

ANSI S1.13/193 (Proposed) Test-Site Measurement of Noise Emitted by Engine Powered Equipment*

Scope: For determining maximum noise emitted by construction and industrial machinery, transportation and recreation vehicles, and other engine-powered equipment.

Test Type: Outdoor free-field or reflecting ground. Measurement distance 15 meters (50 ft). Moving and stationary tests for construction equipment (Sec. 4.4).

Data: A-weighted sound level

CAGI-PNEUROP† Test Code for the Measurement of Sound from Pneumatic Equipment

Scope: Applies to compressors, percussive and nonpercussive pneumatic equipment. Specifies procedures and operating conditions, not always including process noise.

*American National Standards Institute, NYC, N.Y. 10018
†Compressed Air and Gas Institute, NYC, N.Y. 10017

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Test Type: Indoor or outdoor, measurements in direct field at five positions at 1 meter from equipment. Secondary measurement at 7 meters distance. Non-percussive tools measured running free and with "quiet" work process.

Data: A-weighted and Octave-band sound pressure levels for each measurement point.

The procedures adopted by the City of Chicago are based on the SAE J352 standard and the revisions now under consideration by the SAE Agricultural and Construction Machinery Sound Level Subcommittee. Substantially the same measurement procedures have been proposed by the City of Boston Air Pollution Control Commission in their *Test Procedure for Measurement of Noise from Powered Devices*.

While SAE J952a contained specific noise limits, these are being separated in a later revision now under consideration, and the test procedure will appear separately. This procedure recommends an additional 2 dB tolerance for such noise measurements; this provision has been deliberately omitted in both the Chicago and Boston test procedures, and left to administrative decision. This is more appropriate, and not unlike the enforcement measurement procedures for vehicular speed limits.

Another approach to construction equipment noise measurement is to apply the measurement to the combined operators of all construction equipment at a single test site. At the request of CIMA (Construction Industry Manufacturers' Association) the SAE is developing such a test procedure.

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SAE Recommended Practice (Proposed) Construction Site Sound Level Measurements

Scope: For sites where construction machinery is operated. Measures noise radiated off-site.

Test Type: Field measurement of radiated sound levels at four nearest inhabited locations to any centerpoint of construction activity. If no inhabited locations closer than 1000 ft to a centerpoint, measurements made at 4 locations spaced 90° on 1000 ft radius circle.

Data: A-weighted sound levels at each measurement point define "Construction Site Operational Sound Levels". Provision for a record of "Construction Site Baseline Sound Levels" allows limits to be expressed as change in ambient as well as absolute terms.

The combined-operations measurement procedure is presently being proposed for use by the City of Boston, and the City of Chicago plans a test of the latest SAE draft procedure as part of a feasibility study of noise limitations on construction sites. The Federal Highway Administration is considering this procedure as a basis for regulation of noise from Federal-aid highway construction.

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D.3 Noise Standards for Indoor and Outdoor Equipment for Home and Office Use

The impetus for development of standards for measuring and rating the noise produced by many types of equipment has come from the manufacturers of noise sources. For example, the manufacturers of air conditioning and ventilation appliances are by far the most conscious of the impact of their equipment on the noise environment of the home and office. Within the past decade at least ten different "standard" procedures have been formulated for measuring and rating the noise of various types of air conditioning and ventilating equipment. The automotive and airframe industries have been similarly conscious of the noise impact of their equipment and sophisticated noise standards exist for these sources. By contrast, only one standard has appeared to deal with the noise of rotating electrical machinery; one to deal with gas turbines; one for gear noise; one standard of a general nature, produced by official American National Standards Institute (ANSI), intended to guide noise measurement of practically any piece of machinery; and a draft procedure is under consideration by ANSI to rate the noise of all engine-powered equipment.

Such standards are of two types. Measurement standards specify the manner in which meaningful and reliable acoustical data may be obtained. Rating standards apply these acoustical data to produce ratings, usually single-numbered, that are supposed to correlate with subjective response to equipment noise, thus permitting at least rank-ordering of equipment noise on a justifiable basis.

Both sorts of standards are necessary and form the basis for yet a third class of standards (applications standards) that are used by architects, consultants, building codes, noise

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ordinances and similar organizations. Factors which are considered in developing application standards include the economic, social, and political. Applications standards represent an equilibrium between the costs of reducing noise exposure and the feasible noise reduction made possible by acoustic technology.

The following summaries indicate the general nature of existing U.S. noise measurement and rating standards for domestic and office equipment.

ASHRAE 36-62 Measurement of Sound Power Radiated from Heating, Refrigerating and Air-Conditioning Equipment*

Scope: For unitary, unducted equipment, large or small, for indoor or outdoor use.

Test Type: Reverberation room, substitution method.

Data: Total radiated sound power level in octave or 1/3-octave bands.

ASHRAE 36A-63 Method of Determining Sound Power Levels of Room Air Conditioners and Other Ductless, Through-the-Wall Equipment*

Scope: For room air conditioners, window or attic fans, and other ductless wall- or ceiling-mounted equipment that radiate sound directly both to the conditioned space and the outdoors.

Test Type: Reverberation room, substitution method (2 rooms needed).

Data: Total sound power level radiated to indoors and outdoors, separately, in 1/3-octave bands.

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* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017.

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ASHRAE 36B-63 Method of Testing for Rating the Acoustic Performance of Air Control and Terminal Devices and Similar Equipment

Scope: For air control and terminal devices normally mounted in or connected to duct systems.

Test Type: Reverberation room, substitution method.

Data: Total sound power level radiated into the room served by the device, in octave bands.

AMCA 300-67 Test Code for Sound Rating Air Moving Devices*

Scope: For central station air conditioning and heating and ventilating units, for centrifugal fans, axial and propeller fans, power roof and wall ventilators, steam and hot water unit heaters (but not unit ventilators, room fan-coil units, room air induction units and air cooled refrigerant condensers).

Test Type: Reverberation room, substitution method, based on ASHRAE 36-62.

Data: Total radiated sound power level, in octave bands (including the sound radiated into the ducts, for ducted equipment).

AMCA 301-65 Method of Publishing Sound Ratings for Air Moving Devices*

Ratings for Centrifugal Fans, Axial and Propeller Fans, Power Roof and Wall Ventilators, Steam and Hot Water Unit Heaters; not yet suitable for central station A/C or H/V units.

Ratings: based on octave-band sound power levels, per AMCA 300-67:

For ducted devices, the eight octave-band sound power levels;

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*Air Moving and Conditioning Association, 205 West Touhy Ave., Park Ridge, Ill. 60068

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For unducted devices, the loudness in sones at a reference distence of 5 ft, as calculated from the sound power level data.

AMCA 302 "Application of Sone Loudness Ratings for Nonducted Air-Moving Devices"

Reference material covering applications of the loudness rating in sones (examplea, combinations of sources, prediction of sound loudness indoors and outdoors, variation with fan speed.

AMCA 303 "Application of Sound Power Level Ratings for Ducted Air Moving Devices"

Reference material covering significance and accuracy of sound power level ratings, particularly their relation to sound as heard.

*ANSI*S1.2 - 1962 "American Standard Method for the Physical Measurement of Sound"*

Scope: For all devices, machines or apparatus. Several test procedures are described:

Test Type: Free-field; free-field above reflecting plane; semi-reverberant field; or reverberation room. The semi-reverberant field procedure is similar to that of ASHRAE 36-62.

Data: Sound pressure levels at specific locations, or total sound power levels in octave bands (1/2-octave or 1/3-octave analysis optional); and directivity of the source.

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* American National Standards Institute, 10 East 40th Street, New York, N.Y. 10016

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IEEE #85 "Airborne Noise Measurements on Rotating Electric Machinery"*

Scope: For rotating electrical machinery of all sizes
Several test procedures are described:

Test Type: Free field; free field above reflecting plane; semi-reverberant field; or reverberation room. (Similar to ANSI S1.2-1962, but more detailed.)

Data: Sound levels or sound pressure levels in frequency bands (octave, 1/3-octave, or "narrow") at specified locations or total sound power level, overall or analyzed into frequency bands, and directivity of source.

ANSI S1.19/193 "Test-Site Measurement of Noise Emitted by Engine-Powered Equipment" (Draft only.)

Scope: For residential equipment (Section 4.5) [Other sections deal with automobiles, motorcycles, construction and industrial machinery and recreational equipment]

Test Type: Sound levels measured on flat test site with hard ground surface, free of large reflecting obstacles within 30 meters of equipment under test.

Data: A-weighted sound level measured at a point 50 ft from center of equipment and 4 ft above ground, for noisiest direction and noisiest operating conditions.

ARI+ 443-66 "Standard for Sound Rating of Room Fan-Coil Air-Conditioners"

Scope: For room fan-coil air conditioners.

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* Institute of Electrical and Electronic Engineers, 345 East 47th Street, New York, N.Y. 10017

+ Air-Conditioning and Refrigeration Instutute, 1815 North Fort Meyer Drive, Arlington, Virginia 22209

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Test Type: Reverberation room, substitution method, in accordance with ASHRAE 36-62

Data: Octave-band sound power levels, computed from 1/3-octave band data corrected for presence of pure tones.

ARI 270-67 Standard for Sound Rating of Outdoor Unitary Equipment

Scope: Outdoor sections of factory-made equipment, such as unitary air-conditioners or heat pumps.

Test Type: Reverberation room, substitution method, in accordance with ASHRAE 36-62 or ASHRAE 36A-63.

Data: Sound power levels in 1/3-octave bands.

Rating: Single-number rating based on the 1/3-octave band sound power levels (corrected for the presence of pure tones), by a calculation like the ANSI Standard S3.4, "Computation of Loudness of Noise".

ARI 275-68 Standard for Application of Sound Rated Outdoor Unitary Equipment

Reference material (related to ARI 270-67) establishing a method for predicting annoyance due to operation of outdoor unitary equipment, and providing recommendations for application of such equipment.

Calculation of annoyance level (ANL), taking into account distance, reflections, location of equipment, shielding by barriers, location of observer, multiple units, etc.

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AHAM Room Air-Conditioner Sound Rating*

Scope: Room air conditioners

Test Type: Reverberation room, substitution method, in accordance with ASHRAE 36A-63

Data: Single number (or letter) ratings based on the 1/3-octave band sound power levels (corrected for the presence of pure tones), by a calculation like the ANSI Standard S3.4 "Computation of Loudness of Noise"; the calculations are different for the indoor side and the outdoor side of the unit, such that the two sound ratings would be the same if the sound power levels radiated indoors were all 15 dB less than the levels in corresponding frequency bands radiated to the outdoors. The outdoor calcuation is the same as that of ARI 270-67. The indoor sound rating (a number) is converted to a letter rating (11=A, 12=B, 13=C, etc.) for publication purposes.

HVI+#1966-1 Sound Test Procedure

Scope: For home ventilating equipment.

Test Type: Reverberation room, substitution method, similar to ASHRAE 36-62

Data: Octave band sound power levels, calculated from 1/3-octave band sound pressure levels, are used to compute octave-band free-field sound pressure levels at a reference 5-foot distance.

Rating: The nominal free-field octave-band SPL's at 5 foot are used to calculate loudness in sones, a single number,

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* Association of Home Appliance Manufacturers, 20 North Wacker Drive, Chicago, Illinois 60606

\+ Home Ventilating Institute

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according to ANSI S3.4 - 1968, "Computation of Loudness of Noise."

ADC Test Code 1062.R1 Equipment Test Code*

Scope: For air distribution and control devices (high pressure units).

Test Type: Reverberation room, substitution method, in accordance with ASHRAE 36B-63 (except that the ASHRAE test for attenuation of terminal devices is not used).

Data: Total sound power level radiated into room, in octave bands.

* * * *

In addition to these standards for measuring and rating noise from various kinds of ventilation equipment, both the Home Ventilating Institute and the Air Conditioning and Refrigeration Institute have published directories of equipment, giving noise ratings for each model tested (a large proportion of the manufactured models); and both the Air Conditioning and Refrigeration Institute and the Association of Home Appliance Manufacturers offer guidance for the writers of noise ordinances dealing with their equipment types, to indicate achievable goals and the necessary wording in terms of existing standards, to make the model ordinances enforceable.

At the present time, the existence of several different measurement and rating standards in the ventilating/air-conditioning field is something of an embarrassment, since they are not

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* Air Diffusion Council, 435 North Michigan Ave., Chicago, Ill. 60611

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mutually consistent nor even compatible, but are competing for general acceptance. In an attempt to deal with this situation, an ad hoc working group of ANSI is currently trying to draft a standard for both measurement and rating of equipment noise that exhibits the best features of the already existing standards and that, it is hoped, will be found acceptable by the various organizations that have pioneered in the standardization effort in the United States. It is still too early to predict whether this action will be successful.

In spite of the slightly chaotic present situation, it is clear that a great deal of careful thinking has been done about how to measure equipment noise in the United States; indeed, in this area the U. S. is somewhat in advance of the European practice.

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IPCC
Phone: +41-22-730-8208/84/54
Email: IPCC-Sec@wmo.int

IPCC Fourth Assessment Report: Climate Change 2007

Climate Change 2007: Working Group I: The Physical Science Basis

2.10.2 Direct Global Warming Potentials

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All GWPs depend on the AGWP for CO_2 (the denominator in the definition of the GWP). The AGWP of CO_2 again depends on the radiative efficiency for a small perturbation of CO_2 from the current level of about 380 ppm. The radiative efficiency per kilogram of CO_2 has been calculated using the same expression as for the CO_2 RF in Section 2.3.1, with an updated background CO_2 mixing ratio of 378 ppm. For a small perturbation from 378 ppm, the RF is 0.01413 W m^{-2} ppm^{-1} (8.7% lower than the TAR value). The CO_2 response function (see Table 2.14) is based on an updated version of the Bern carbon cycle model (Bern2.5CC; Joos et al. 2001), using a background CO_2 concentration of 378 ppm. The increased background concentration of CO_2 means that the airborne fraction of emitted CO_2 (Section 7.3) is enhanced, contributing to an increase in the AGWP for CO_2. The AGWP values for CO_2 for 20, 100, and 500 year time horizons are 2.47×10^{-14}, 8.69×10^{-14}, and 28.6×10^{-14} W m^{-2} yr (kg CO_2)$^{-1}$, respectively. The uncertainty in the AGWP for CO_2 is estimated to be ±15%, with equal contributions from the CO_2 response function and the RF calculation.

Updated radiative efficiencies for well-mixed greenhouse gases are given in Table 2.14. Since the TAR, radiative efficiencies have been reviewed by Mantzka et al. (2003) and Velders et al. (2005). Gohar et al. (2004) and Forster et al. (2005) investigated HFC compounds, with up to 40% differences from earlier published results. Based on a variety of radiative transfer codes, they found that uncertainties could be reduced to around 12% with well-constrained experiments. The HFCs studied were HFC-23, HFC-32, HFC-134a and HFC-227ea. Hurley et al. (2005) studied the infrared spectrum and RF of perfluoromethane (CF_4) and derived a 30% higher GWP value than given in the TAR. The RF calculations for the GWPs for CH_4, N_2O and halogen-containing well-mixed greenhouse gases employ the simplified formulas given in Ramaswamy et al. (2001; see Table 6.2 of the TAR). Table 2.14 gives GWP values for time horizons of 20, 100 and 500 years. The species in Table 2.14 are those for which either significant concentrations or large trends in concentrations have been observed or a clear potential for future emissions has been identified. The uncertainties of these direct GWPs are taken to be ±35% for the 5 to 95% (90%) confidence range.

Table 2.14. Lifetimes, radiative efficiencies and direct (except for CH_4) GWPs relative to CO_2. For ozone-depleting substances and their replacements, data are taken from IPCC/TEAP (2005) unless otherwise indicated.

Errata

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m^{-2} ppbv^{-1})	Global Warming Potential for Given Time Horizon			
				SAR[a] (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b] 1.4×10^{-5}	1	1	1	1
Methane[f]	CH_4	12[c]	3.7×10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03×10^{-3}	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl_3F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl_2F_2	100	0.32	8,100	11,000	10,900	5,200
CFC-13	$CClF_3$	640	0.25		10,800	14,400	16,400
CFC-113	CCl_2FCClF_2	85	0.3	4,800	6,540	6,130	2,700
CFC-114	$CClF_2CClF_2$	300	0.31		8,040	10,000	8,730
CFC-115	$CClF_2CF_3$	1,700	0.18		5,310	7,370	8,990
Halon-1301	$CBrF_3$	65	0.32	5,400	6,480	7,140	2,760
Halon-1211	$CBrClF_2$	16	0.3		4,750	1,890	575
Halon-2402	$CBrF_2CBrF_2$	20	0.33		3,680	1,640	503
Carbon tetrachloride	CCl_4	26	0.13	1,400	2,700	1,400	435
Methyl bromide	CH_3Br	0.7	0.01		17	5	1
Methyl chloroform	CH_3CCl_3	5	0.06		505	146	45
HCFC-22	$CHClF_2$	12	0.2	1,500	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	1.3	0.14	90	273	77	24
HCFC-124	$CHClFCF_3$	5.8	0.22	470	2,070	609	185
HCFC-141b	CH_3CCl_2F	9.3	0.14		2,250	725	220
HCFC-142b	CH_3CClF_2	17.9	0.2	1,900	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.2		429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	5.8	0.32		2,030	595	181
Hydrofluorocarbons							
HFC-23	CHF_3	270	0.19	11,700	12,000	14,800	12,200
HFC-32	CH_2F_2	4.9	0.11	650	2,330	675	205
HFC-125	CHF_2CF_3	29	0.23	2,800	6,350	3,500	1,100

HFC-134a	CH_2FCF_3	14	0.16	1,300	3,830	1,430	435
HFC-143a	CH_3CF_3	52	0.13	3,800	5,890	4,470	1,590
HFC-152a	CH_3CHF_2	1.4	0.09	140	437	124	38
HFC-227ea	CF_3CHFCF_3	34.2	0.26	2,900	5,310	3,220	1,040
HFC-236fa	$CF_3CH_2CF_3$	240	0.28	6,300	8,100	9,810	7,660
HFC-245fa	$CHF_2CH_2CF_3$	7.6	0.28		3,380	1030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.6	0.21		2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15.9	0.4	1,300	4,140	1,640	500
Perfluorinated compounds							
Sulphur hexafluoride	SF_6	3,200	0.52	23,900	16,300	22,800	32,600
Nitrogen trifluoride	NF_3	740	0.21		12,300	17,200	20,700
PFC-14	CF_4	50,000	0.10	6,500	5,210	7,390	11,200
PFC-116	C_2F_6	10,000	0.26	9,200	8,630	12,200	18,200

Table 2.14 (continued)

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	RadiativeEfficiency (W m−2 ppb−1)	Global Warming Potential for Given Time Horizon SAR‡ (100-yr)	20-yr	100-yr	500-yr
Perfluorinated compounds (continued)							
PFC-218		2,600	0.28	7,000	6,310	8,830	12,500
PFC-318		3,200	0.32	8,700	7,310	10,300	14,700
PFC-3-1-10		2,600	0.33	7,000	6,330	8,860	12,500
PFC-4-1-12		4,100	0.41		6,510	9,160	13,300
PFC-5-1-14		3,200	0.49	7,400	6,600	9,300	13,300
PFC-9-1-18		>1,000d	0.56		>5,500	>7,500	>8,500
trifluoromethyl sulphur pentafluoride		800	0.57		13,200	17,700	21,200
Fluorinated ethers							
HFE-125		136	0.44		13,800	14,900	8,490
HFE-134		26	0.45		12,200	6,320	1,960
HFE-143a		4.3	0.27		2,630	756	230
HCFE-235da2		2.6	0.38		1,230	350	106
HFE-245cb2		5.1	0.32		2,440	708	215
HFE-245fa2		4.9	0.31		2,280	659	200
HFE-254cb2		2.6	0.28		1,260	359	109
HFE-347mcc3		5.2	0.34		1,980	575	175
HFE-347pcf2		7.1	0.25		1,900	580	175
HFE-356pcc3		0.93	0.93		386	110	33
HFE-449sl (HFE-7100)		3.8	0.31		1,040	297	90
HFE-569sf2 (HFE-7200)		0.77	0.3		207	59	18
HFE-43-10pccc124 (H-Galden 1040x)		6.3	1.37		6,320	1,870	569
HFE-236ca12 (HG-10)		12.1	0.66		8,000	2,800	860
HFE-338pcc13 (HG-01)		6.2	0.67		5,100	1,500	460
Perfluoropolyethers							
PFPMIE		800	0.65		7,620	10,300	12,400
Hydrocarbons and other compounds – Direct Effects							
Dimethylether		0.015	0.02		1	1	<<1
Methylene chloride		0.38	0.03		31	9.7	2.7
Methyl chloride		1.0	0.01		45	13	4

Notes:

[a] The CO_2 response function used in this report is based on the revised version of the Bern Carbon cycle model used in Chapter 10 of this report (Bern2.5CC; Joos et al. 2001) using a background CO_2 concentration value of 378 ppm. The decay of a pulse of CO_2 with time t is given by

$$a_0 + \sum_{i=1}^{3} a_i \cdot e^{-t/\tau_i}$$

Where $a_0 = 0.217$, $a_1 = 0.259$, $a_2 = 0.338$, $a_3 = 0.186$, $\tau_1 = 172.9$ years, $\tau_2 = 18.51$ years, and $\tau_3 = 1.186$ years.

[b] The radiative efficiency of CO_2 is calculated using the IPCC (1990) simplified expression as revised in the TAR, with an updated background concentration value of 378 ppm and a perturbation of +1 ppm (see Section 2.10.2).

[c] The perturbation lifetime for methane is 12 years as in the TAR (see also Section 7.4). The GWP for methane includes indirect effects from enhancements of ozone and stratospheric water vapour (see Section 2.10.3.1).

[d] Shine et al. (2005c), updated by the revised AGWP for CO_2. The assumed lifetime of 1,000 years is a lower limit.

[e] Hurley et al. (2005)

[f] Robson et al. (2006)

[g] Young et al. (2005)

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LOS ANGELES DEPARTMENT OF BUILDING AND SAFETY

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DOCUMENT NO.	DOCUMENT TITLE	CONVERTED to Info Bulletin
MGD 110	Structural Observation	P/BC 2002-024
MGD 111	Approval of New and Used Electrical Equipment and Components	P/EC 2002-001
MGD 112	Procedures for Recognized Testing Agencies Performing Field Services	P/EC 2002-002

PREVIOUSLY ISSUED INFORMATION BULLETINS

DOCUMENT NO.	DOCUMENT TITLE	CONVERTED to Info Bulletin
I.B. DA-1	Disabaled Access Details for Commercial Buildings & Facilities	P/BC 2002-084 thru -091
I.B. DA-2	Unreasonable Harship Determination for Commercial Alteration Projects	P/BC 2002-076
I.B. 1a	Christmas Tree Sales / Pumpkin Sales	P/BC 2002-008
I.B. #2	Requirements to Change the Use of a Building to a Food Establishment	P/GI 2002-003
I.B. #3	General Engineering Contractors and Demolitions	P/GI 2002-015
I.B. #3	Section 311.2.2.1 Group S-3 with A-3, B, M, R-1 or R-2 Occupancy	P/BC 2002-012
I.B. #4	Regulations Applicable When a Building Permit is Issued to Alter, Repair or Add to an Existing Building or the Building is Sold.	P/GI 2002-002
I.B. #4	Importance of Lumber Species and Grade in Wood Shear Walls	P/BC 2002-010
I.B. #6	Notice to Contractors Insurance and License Requrements	P/GI 2002-001
I.B. EL-1	Qualification Criteria for Electrical 1) Counter Plan Check 2) Regular Plan Check	P/GI 2002-012
I.B. ME-1	Qualification Criteria for Mechanical 1) Counter Plan Check 2) Regular Plan Check	P/GI 2002-013
I.B. EXP-1	Express Permits (No Plan Check Required)	P/GI 2002-003
I.B. MISC-1	Adaptive Reuse Provisions	P/BC 2002-009
I.B. MISC-5	Roofing Requirements for Wood Shakes and Shingles	P/BC 2002-013
I.B. ST-1	Qualification Criteria for Building 1) Counter Plan Check 2) Appointment Plan Check 3) Regular Plan Check	P/BC 2002-011
I.B. ST-2	Document Submittal Requirements for a New Single-Family Dwelling	P/GI 2002-010
I.B. ST-3	Document Submittal Requirements for a New Multi-Family Dwelling	P/GI 2002-007

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PREVIOUSLY ISSUED INFORMATION BULLETINS

DOCUMENT NO.	DOCUMENT TITLE	CONVERTED to Info Bulletin
I.B. ST-4	Document Submittal Requirements for an Alteration or Addition to an Existing Single-Family Dwelling or Multi-Family Dwelling	P/GI 2002-009
I.B. ST-6	Document Submittal requirements for Tenant Improvement, Addition, or Alteration to an Existing Commercial/Industrial Building	P/GI 2002-006
I.B. ST-7	Document Submittal Requirements fo a Food Establishment	P/GI 2002-005
I.B. ST-9	Definition of a "B" Contractor (deleted by Dev. Svc. Bur. 5-1-01)	~~P/GI 2002-014~~
I.B. ST-10	Attached Carport & Patio Cover (conversion is under work)	P/BC 2002-005
I.B. ST-11	Detached Carport	P/BC 2002-006
I.B. ST-12	Interim Alternate Method for Distribution of Lateral Forces in Wood Frame Buildings Assuming Flexible Diagrams	P/BC 2002-003
I.B. ST-14	Cutting, Notching, and Boring of Wood Framing Members	P/BC 2002-007
I.B. GR-1	Footings on or Adjacent to Slopes	P/BC 2002-001
I.B. GR-2	Retaining or Slough Wall < 4'-0" High	P/BC 2002-002
I.B. ZO-1	Parking Lot Design	P/ZC 2002-001
I.B. ZO-2	Heights of Fences in Residential Zones	P/ZC 2002-002
I.B. ZO-4	Allowable Yard Projection and Height Requirements for Decks	P/ZC 2002-004
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I.B. Plumb.	Notice to Property Owners Seismic Gas Shut-Off Valve Requirements	P/PC 2002-001
I.B. Plumb.	How to Brace Your Water Heater	P/PC 2002-003
I.B. 99005	Elevator Drains	P/PC 2002-004

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PREVIOUSLY ISSUED INFORMATION BULLETINS

DOCUMENT NO.	DOCUMENT TITLE	CONVERTED to Info Bulletin
I.B. SP-2	Reconstruction and Replacement of Earthquake Damaged Masonry Chimneys	P/BC 2002-070

CITY OF LOS ANGELES
DEPARTMENT OF WATER AND POWER

DRAFT 2010 URBAN WATER MANAGEMENT PLAN

JANUARY 14, 2011

The Draft 2010 UWMP is available for review at www.ladwp.com.

Written comments are due by March 15, 2011 to:
LADWP – Water System
111 N. Hope St, Room 1460
Los Angeles, CA 90012
Attn: Simon Hsu
or
simon.hsu@ladwp.com

** The report is not in the final format.

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Executive Summary

Executive summary will be included following public review.

Presentation at February 2011 public workshops provides an overview of the Urban Water Management Plan findings.

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DRAFT Chapter One
Introduction

1.0 Overview

The availability of water has significantly contributed towards the tremendous growth and development of the City of Los Angeles (City). Since 1902, when the City's population was approximately 102,000, the Los Angeles Department of Water and Power (LADWP) has supported the City's transformation into the nation's second largest city with over 4 million residents, encompassing a 464 square mile area, and comprising the world's sixteenth largest economy. The largest municipal utility in the nation, LADWP was established in 1902 to deliver safe and reliable water and electricity supplies at an affordable price to the residents and businesses of Los Angeles.

With increasing demands for additional water supplies, LADWP along with all other water agencies in Southern California, are faced with the challenge of providing a reliable water supply for a growing population. LADWP will meet the City's water needs through the following actions:

- Pursue cost-effective water conservation, stormwater capture and recycling projects to increase supply reliability.
- Ensure continued reliability of the City's supplemental water supplies from the Metropolitan Water District of Southern California (MWD) through active representation of City interests on the MWD Board
- Protect existing groundwater supplies from contamination and provide treatment to optimize their use
- Maintain the operational integrity of the Los Angeles Aqueduct and in-City water distribution systems
- Meet or exceed all Federal and State standards for drinking water quality

1.1 Purpose

The LADWP 2010 Urban Water Management Plan (UWMP) serves two purposes: (1) achieving compliance with requirements of California's Urban Water Management Planning Act (Act); and (2) serving as a master plan for water supply and resources management consistent with the City's goals and policy objectives.

1.1.1 UWMP Requirements and Checklist

This 2010 Urban Water Management Plan (UWMP) complies with Sections 10610 and 10657 of the California Water Code, Urban Water Management Planning Act (Act), and details how LADWP plans to meet all of the City's customer water needs. The Act became effective on January 1, 1984 and requires that every urban water supplier that provides municipal and industrial water to more than 3,000 customers (or supplies more than 3,000 acre-feet per year) prepare and adopt an Urban Water Management Plan, in accordance with prescribed requirements, every five years. Appendix A contains the Act.

The Act was originally developed due to concerns for potential water supply shortages throughout the State. Therefore, it required information that focused primarily on water supply reliability and water use efficiency measures. Since its original passage in 1983, there have been several amendments added, the most recent adopted in 2009. Some of the recent amendments include: providing assessment of present and proposed future demands to achieve per capita water use reductions by 20 percent by 2020, projecting water use for low-income single family and multi-family residential housing, and the addition of "indirect potable reuse" to the list of recycled water uses. A copy of the 2010 UWMP Act requirements is

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provided in Appendix B. A checklist of the Urban Water Management Plan cross-referencing Act requirements to applicable pages in this UWMP is provided in Appendix C.

With the passage of Senate Bills 610 and 221 in 2001, Urban Water Management Plans took on even more importance. SB 610 and 221 require that counties and cities consider the availability of adequate water supplies for certain new large developments. These statutes require written verification of sufficient water supply to serve these new developments, and Urban Water Management Plans are identified as key source documents for this verification. Based on this statute the LADWP prepares individual Water Supply Assessments for these new large developments.

LADWP's 2010 Urban Water Management Plan is not only designed to meet the current requirements of the Act, but also serves as the City's master plan for water supply and resource management. The UWMP is not only intended for officials in Sacramento, but also helps guide policy makers in the City and the Metropolitan Water District of Southern California (MWD), as well as providing information to the citizens of Los Angeles. The UWMP provides the basic policy principles that guide LADWP's decision-making process to secure a sustainable water supply for Los Angeles.

1.1.2 Water Supply Action Plan

LADWP has a long history of working to ensure that its customers have enough water. These efforts go back to the early 20th century with the building of the Los Angeles Aqueduct. Investments in water rights, aqueducts, reservoirs, conservation and more recently recycled water and stormwater capture have allowed Angelinos to enjoy a water supply that they can rely on. Sound planning and timely investments in water have played a critical role in meeting the water needs of the City despite the fact that Southern California is a semi-arid region

In May of 2008, LADWP's Water Supply Action Plan (Plan), "Securing L.A.'s Water Supply", was released to address a number of critical water supply reliability issues. These water supply issues included: (1) the lowest snowpack on record in the Eastern Sierras in 2007, where Los Angeles historically received the greatest share of its water supply; (2) the driest year on record in 2007 for the Los Angeles basin; (3) anticipated regional water allocations by MWD in response to reductions in imported water available from the San Francisco Bay Delta due to drought and regulatory restrictions; (4) local groundwater contamination in the San Fernando basin, restricting the ability to fully utilize this local resource; (5) Los Angeles Aqueduct delivery reductions due to environmental mitigation and enhancements in the Owen's Valley and Mono Lake Basins, representing nearly one-half of historic water supplies from the Eastern Sierra watershed; and (6) uncertain climate change impacts which threaten traditional water supply sources.

The convergence of these critical issues has far-reaching implications for the City of Los Angeles' water supply that requires long-range planning to sustain a reliable supply of water to meet current and future demand. The Plan was a blueprint for creating sustainable water resources to serve the future needs of the City, and outlined responsible water management and long-term planning. By 2028, the Plan envisioned a six-fold increase in recycled water supplies to a total of 50,000 AFY. Similarly, by 2030, an increase of 50,000 AFY was planned for conservation. As described in the Plan, this aggressive approach included: investments in state-of-the-art technology; a combination of rebates and incentives; efficient clothes washers, and urinals; and long-term measures such as expansion of water recycling and remediating contaminated groundwater supplies. A multi-faceted approach to developing a locally sustainable water supply was developed incorporating the following key short-term and long-term strategies:

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Short-Term Conservation Strategies

- Enforcing prohibited uses of water
- Expanding prohibited uses of water
- Extending outreach efforts
- Encouraging regional conservation measures

Long-Term Strategies

- Increasing water conservation through reduction of outdoor water use and new technology
- Maximizing water recycling
- Enhancing stormwater capture
- Accelerating groundwater basin clean-up
- Expanding groundwater storage
- Green Building Initiatives (added subsequent to the release of the Plan)

As an integral part of the UWMP, the Water Supply Action Plan is incorporated into the associated chapters of the UWMP. The UWMP outlines how the strategies contained in the Water Supply Action Plan will be implemented and how these strategies will increase the reliability of LADWP's water supplies through 2035.

1.2 Service Area

In order to properly plan for water supply, it is important to understand the factors that influence water demands over time. These factors include land use, demographics, and climate.

1.2.1 Land Use

The City of Los Angeles is comprised of approximately 302,165 acres. Residential development constitutes over 51percent of the total land use within the City. Within the residential land use category, single-family residential is the largest at approximately 121,500 acres or 40 percent of the total land use within the City. Multi-family residential is approximately 34,000 acres or 11 percent of the total land use within the City. Open space/parks is the second largest land use within the City occupying approximately 13 percent of the total land use. Commercial and manufacturing land uses combined account for approximately 18 percent of total. Commercial land uses are inclusive of public facilities, such as libraries, public schools, and other government facilities. Exhibit 1A provides a breakdown of the land uses within the City of Los Angeles. The "Other" category includes specific plans, transportation, freeways, rights of way, and other miscellaneous uses that are not zoned.

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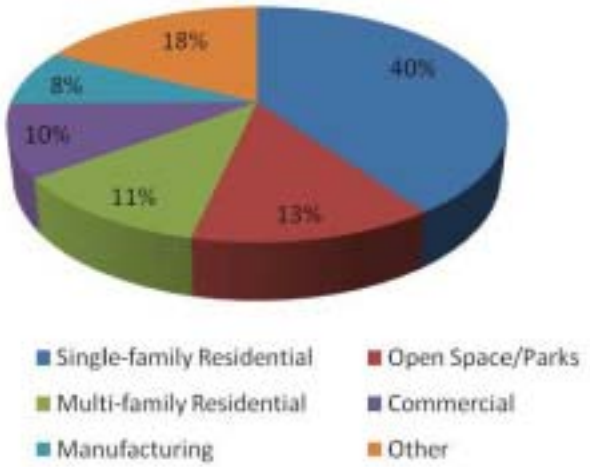
Exhibit 1A
City of Los Angeles Land Uses



Land Use Type	Acres
Single-family Residential	121,470
Open Space/Parks	40,263
Multi-family Residential	34,189
Commercial	30,083
Manufacturing	23,353
Other	52,806
Total	302,165

Source: Data aggregated from City of Los Angeles, Department of City Planning, November, 2009

1.2.2 Demographics

With over 4 million people residing in the LADWP service area, it is slightly larger than the legal boundary of the City of Los Angeles. LADWP provides water service to portions of West Hollywood, Culver City, Universal City, and small parts of the County of Los Angeles.

The population within LADWP's service area increased from 2.97 million in 1980 to 4.1 million in 2009, representing an average annual growth rate of 1.3 percent. The total number of housing units increased from 1.10 million in 1980 to 1.38 million in 2009, representing an average annual growth rate of 0.9 percent. During this time, average household size increased from 2.7 persons in 1980 to 2.9 persons in 2009. Employment grew by about 1.0 percent annually from 1980 to 1990, but declined from 1990 to 2000 as a result of an economic recession that started in 1991. Another decline began in 2008 reflecting the recent economic recession. Overall, employment increased by about 0.3 percent annually from 1990 to 2009. Exhibit 1B summarizes the historical demographics for the LADWP service area.

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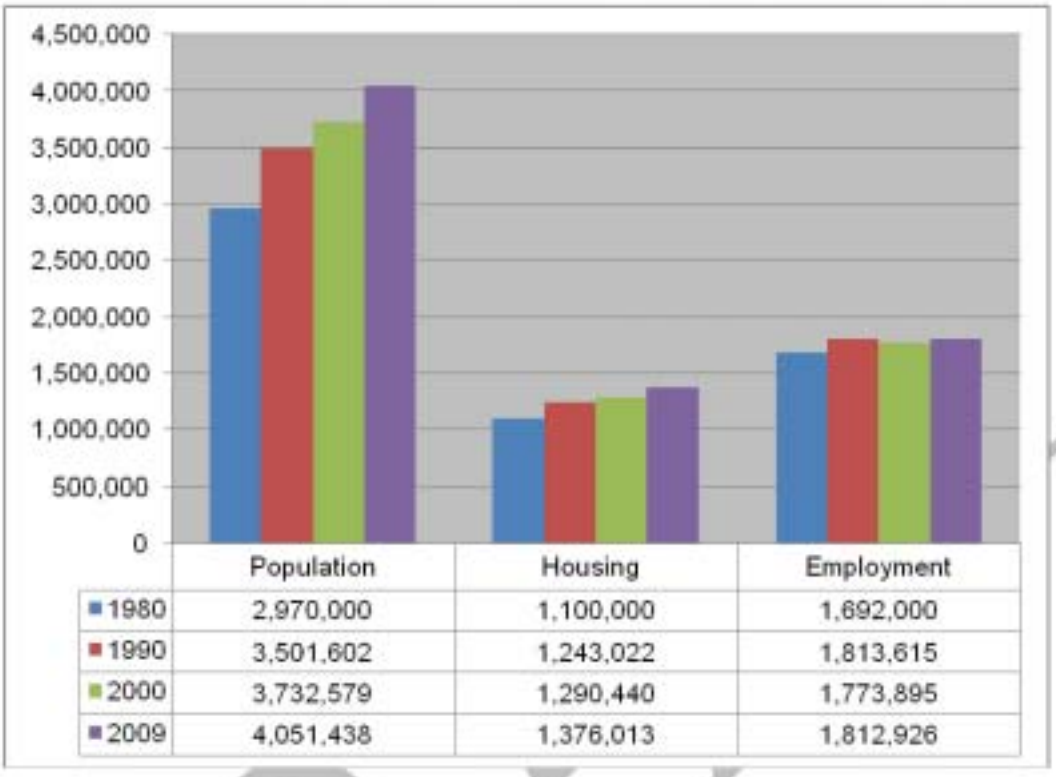
Exhibit 1B
Historical Demographics for LADWP Service Area



	Population	Housing	Employment
1980	2,970,000	1,100,000	1,692,000
1990	3,501,602	1,243,022	1,813,615
2000	3,732,579	1,290,440	1,773,895
2009	4,051,438	1,376,013	1,812,926

Demographic projections were obtained for the LADWP service area from the MWD utilizing a land-use based planning tool that allocates projected demographic data from the Southern California Association of Governments (SCAG) into water service areas for their member agencies. MWD's demographic projections use data reported in SCAG's 2008 Regional Transportation Plan (RTP). Exhibit 1C summarizes these demographic projections for the LADWP service area.

LADWP's service area population is expected to continue to grow over the next 25 years at a rate of 0.4 percent annually. While this is substantially less than the historical 1.3 percent annual growth rate from 1980 to 2009, it will still lead to approximately 367,300 new residents over the next 25 years. According to SCAG's 2008 RTP, housing is expected to grow faster than population over the next 25 years at 0.7 percent annual growth versus 0.4 percent annual growth for population, and it is anticipated that household size will continue to decline over the projection period.

The 2008 RTP projects that by 2035 the average household size will decrease to 2.65 persons per household. Throughout the projection period, multi-family housing units are expected to increase at slightly less than twice the rate of single-family housing units (0.93 percent annual growth vs. 0.47 percent annual growth).

Employment is expected to increase by 0.4 percent annually throughout the projection period. This growth is primarily driven by the current and long-term opportunities available from the economic base within the five-county metropolitan region of Southern California. The economic base is wide-ranging and includes services, wholesale and retail trade, manufacturing, government, financial service industries, transportation, utilities, construction, education, and tourism. Over the 25 year

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forecast period, industrial growth is expected to decline and experience a subtle annual negative growth of -0.4 percent, while commercial employment is expected to increase by about 0.5 percent annually.

Exhibit 1C
Demographic Projections for LADWP Service Area

Demographic	2010	2015	2020	2025	2030	2035
Population	4,100,260	4,172,760	4,250,861	4,326,012	4,398,408	4,467,560
Housing						
Single-Family	627,395	646,067	665,261	678,956	691,703	701,101
Multi-Family	764,402	804,013	846,257	880,580	914,125	942,846
Total Housing	1,391,797	1,450,080	1,511,518	1,559,536	1,605,828	1,643,947
Persons per Household	2.88	2.81	2.75	2.71	2.67	2.65
Employment						
Commercial	1,674,032	1,724,106	1,754,998	1,790,798	1,828,765	1,865,156
Industrial	163,382	157,652	155,012	152,426	150,009	147,508
Total Employment	1,837,415	1,881,758	1,910,010	1,943,224	1,978,773	2,012,664

Source: SCAG Regional Transportation Plan (2008), modified using MWD's land use planning to represent LADWP's service area.

The SCAG demographic projections for population, households, and employment included in their 2008 RTP, and presented in LADWP's 2010 UWMP, vary from what was presented in LADWP's 2005 UWMP. The demographic projections in the 2005 UWMP were based on SCAG's 2004 RTP. The current 2008 projections incorporate the latest population, households, and employment data from multiple local, state and federal agencies. Projected 2008 RTP data reflect adjustments in future population growth related to declining fertility, mortality, labor force participation, and household headship rates; leveling in net migration; fluctuating net domestic migration in response to economic cycles; and an employment shift from the manufacturing sector to the service sector. The SCAG 2008 RTP was adopted in May 2008 prior to the recent recession beginning in 2008. Additionally, MWD has further adjusted the service area boundaries based on LADWP input. Exhibit 1D shows the differences between the SCAG demographic projections for the RTP in 2004 and 2008.

For the forecast year 2030 population was projected to be 4.30 million under the SCAG 2004 RTP and 4.40 million under the 2008 RTP, a difference of about 100,000. Housing was projected to be 1.60 million in 2030 under SCAG 2004 RTP and slightly more under the SCAG 2008 RTP at 1.61 million. Employment was forecast to be less in 2030 under the newest RTP. It is projected to be 2.20 million under the SCAG 2004 RTP versus 1.98 million with the 2008 RTP. It is important to recognize that projected total employment under both the 2004 RTP and 2008 RTP continue to increase from 2010 to 2035. The 2008 RTP simply projects a lower *rate* of increase than does the 2004 RTP. Conversely, the *rate* at which the population increases is expected to be higher with the 2008 RTP as compared with the 2004 RTP.

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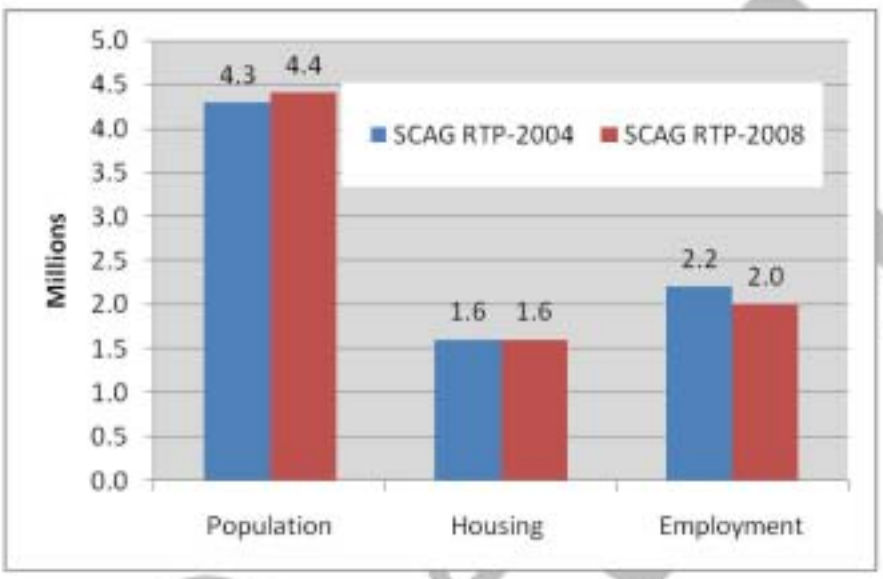
Exhibit 1D
Comparison of SCAG Demographic Projections for LADWP Service Area Between 2004 and 2008 RTP Forecasts for Year 2030



1.2.3 Climate

Weather in Los Angeles is considered mild, which is a major attribute that attracts businesses, residents, and tourists to the City. The City experiences a sizable and popular portion of sunshine throughout the year. Because of its relative dryness, Los Angeles' climate has been characterized as Mediterranean. Exhibit 1E provides a summary of average monthly rainfall, maximum temperatures, and evapotranspiration readings.

The City's average monthly maximum temperature is 76 degrees Fahrenheit based on the period of 1990-2010. This is based on data from the Los Angeles Downtown weather station. The standard annual average evapotranspiration rate (ETo) for the Los Angeles area is 50.29 inches per year. ETo measures the loss of water to the atmosphere by evaporation from soil and plant surfaces and transpiration from plants. ETo serves as an indicator of how much water plants need for healthy growth. Total precipitation averages 14.8 inches per year, with over 90 percent of the total amount typically falling during the period of November through April.

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Exhibit 1E
Average Climate Data for Los Angeles

Average Climate Data for Los Angeles 1990-2008

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum Temperature (°F)[1]	91	95	97	102	101	112	101	104	104	107	99	88	112
Average Maximum Temperature (°F)[1]	82	83	85	89	89	90	93	94	97	94	87	81	89
Average Precipitation (inches)[1]	3.73	4.30	2.48	0.74	0.37	0.08	0.01	0.00	0.08	0.60	0.77	2.11	15.26
Average Eto (inches)[2,3]	1.98	2.26	3.66	4.96	5.46	6.08	6.46	6.31	4.87	3.63	2.56	2.03	50.29

1. 1990-2008, Los Angeles Downtown
USC Weather Station ID 5115
2. Average of Hollywood Hills (Station Id. 73), Glendale (Station Id. 133), and Long Beach (Station Id. 174)
3. www.cimis.water.ca.gov/cimis/welcome.jsp

1.2.4 Water Demand and Supply Overview

Primary sources of water for the LADWP service area are the Los Angeles Aqueducts (LAA), local groundwater, and imported supplemental water purchased from MWD. An additional fourth source, recycled water, is increasingly becoming a larger source in the overall supply portfolio. Two of the supply sources, LAA and water purchased from MWD, are classified as imported as they are obtained from outside LADWP's service area. Groundwater is local and is obtained within the service area. Historical supply sources are increasingly under multiple constraints including potential impacts of climate change, groundwater contamination, and reallocation of water for environmental concerns. To mitigate these impacts on supply sources, LADWP is modifying its water supply portfolio through conservation, water recycling, and stormwater capture.

The primary water supply sources are vital to maintaining LADWP's water system reliability. Pressure on one resource, such as little snowfall in the eastern Sierra Nevada Mountains, will result in an increased reliance on another resource, such as MWD. Supplies available from each source are determined using various computer models in an attempt to balance total projected supplies with projected demands. Exhibit 1F illustrates historical water supplies from 1980 to 2010. As a result of supply shortages, overall demands decreased by over 124,000 AFY in 2009-10 as compared to 2006-07. In 2009-10, approximately 36 percent of the water supply was from the LAA, 14 percent from local groundwater, 48 percent from MWD, and 1 percent from recycled water. From 2005-06 to 2009-10, the five–year average of the water supply portfolio was divided into the following percentages: 36 percent LAA, 11 percent local groundwater, 52 percent MWD, and less than 1 percent recycled water. The imported water (LAA water plus MWD water) supplied on average approximately 88 percent of demands.

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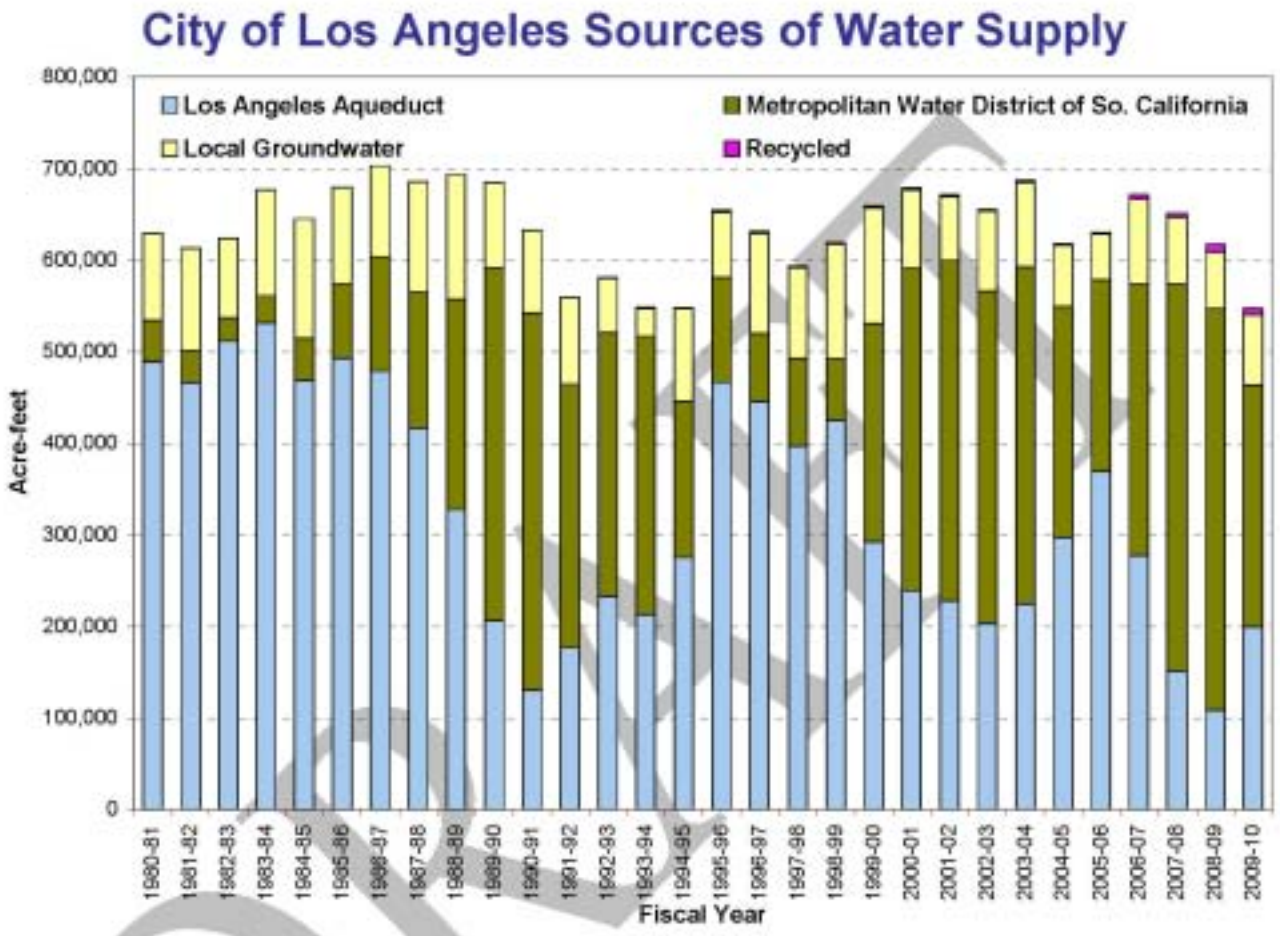
Exhibit 1F
LADWP Historical Water Supply Sources 1980-2010



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Chapter Two
Water Demand

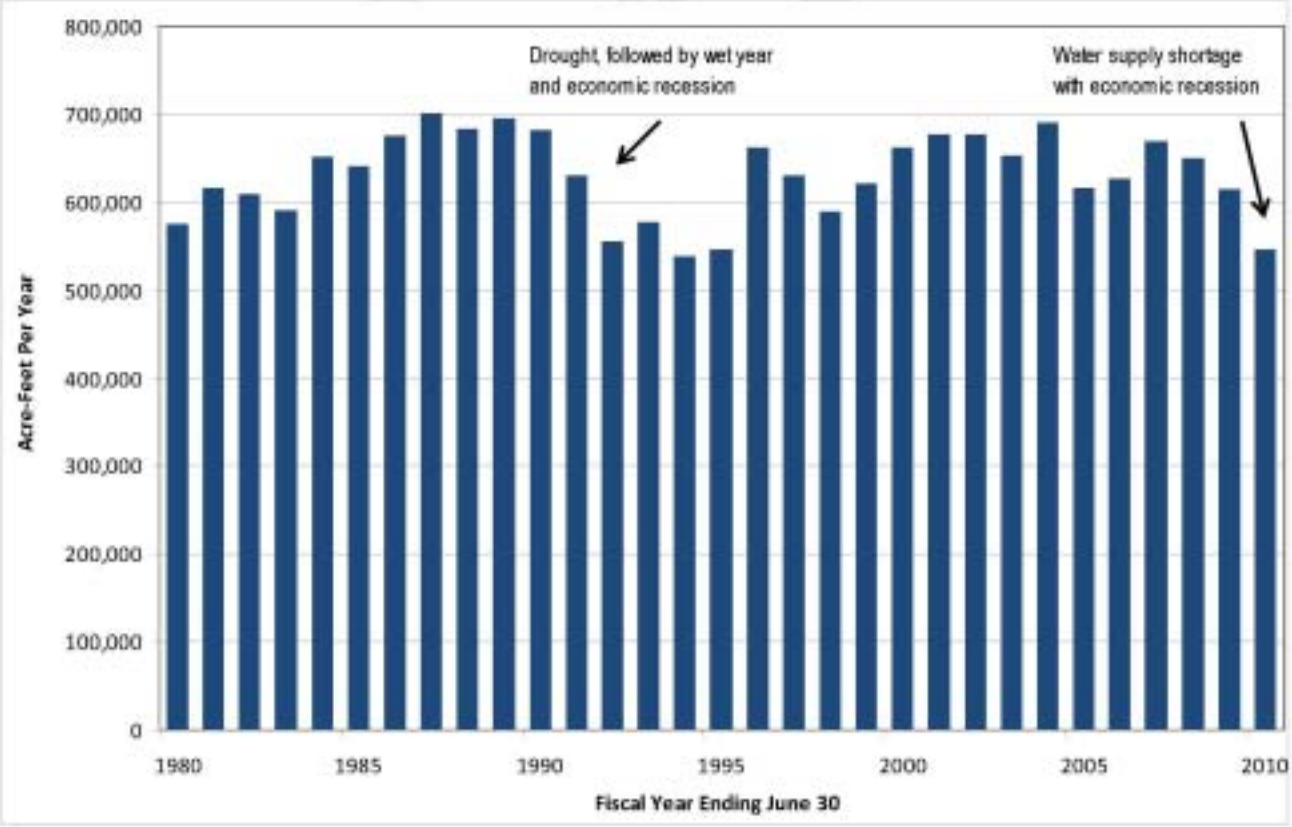
2.0 Overview

In order to properly plan for water supply, it is important to understand water demands and the factors that influence demands over time. LADWP maintains historical water use data separated into the following categories: single-family residential, multifamily residential, commercial, industrial, government, and non-revenue water. This categorization of demands allows better evaluation of trends in water use over time and more precise targeting of water conservation measures.

2.1 Historical Water Use

Exhibit 2A presents the historical water demand for LADWP. As seen in this exhibit, total water demand varies from year to year and is influenced by a number of factors such as population growth, weather, water conservation, drought, and economic activity. In 1991 mandatory conservation imposed on LADWP's customers in response to a six year drought resulted in water use dropping by 8 percent. An economic recession and wet weather in 1992 caused water use to continue to decrease another 12 percent. In 2009 a 3-year water supply shortage coinciding with an economic recession required LADWP to impose mandatory conservation. In 2010 mandatory conservation continued and the economic recession became more severe. This resulted in 2009-10 water use decreasing by 19 percent from 2006-07 levels.

Exhibit 2A
Historical Total Water Demand in LADWP's Service Area



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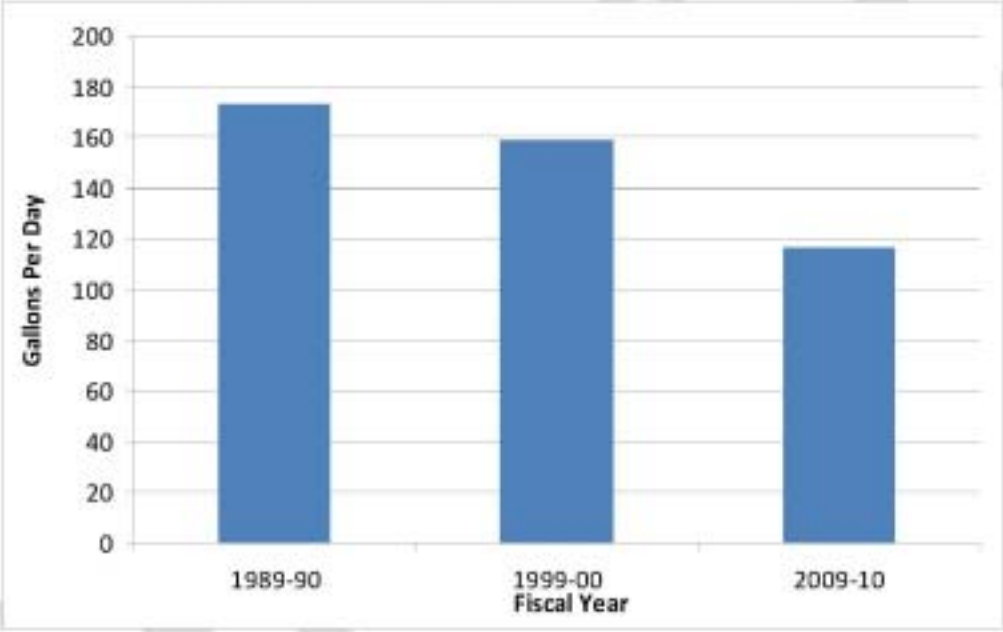
Prior to 1990, population growth in Los Angeles was a good indicator of total demands. From 1980 to 1990, population in the City grew at 1.7 percent annually. Water demands during this same ten year period also grew at 1.7 percent annually. However, after 1991, LADWP began implementing water conservation measures which prevented water demands from returning to pre-1990 levels. Average water demands in the last five years from 2004-05 to 2009-10 are about the same as they were in 1980-81 despite the fact that over 1.1 million additional people now live in Los Angeles. This is evidenced by examining per person (or per capita) water use since 1980 (see Exhibit 2B). In 1989-90, per capita water use was 173 gallons per day (gpd). By 1999-00, per capita water use fell to 159 gpd (or a 10 percent reduction from 1990). In 2009-10, per capita water use is estimated to be 117 gpd – but it is important to note that mandatory conservation and a severe economic recession were occurring at this time.

Exhibit 2B
Historical Per Capita Water Use in LADWP's Service Area



Water Use by Sector

Exhibit 2C shows the breakdown in average total water use between LADWP's major billing categories and non-revenue water in five-year interval for the past 25 years. Non-revenue water, which is the difference between total water use and billed water use, includes water for fire fighting, reservoir evaporation, mainline flushing, system losses, and theft. Single-family residential water use comprises the largest category of demand in LADWP's service area, representing about 36 percent of the total. Multifamily residential water use is the next largest category of demand, representing about 29 percent of the total. Industrial use is the smallest category, representing only 4 percent of the total demand. Although total water use has varied substantially from year to year, the breakdown between the major billing categories of use has not.

Non-revenue water has significantly decreased in recent years. Historically, non-revenue water has averaged 7 percent of total water demand. Since 2005, non-revenue water levels have averaged 5 percent. This may be attributed to a number of steps that LADWP has taken to improve its water system. In 2001, LADWP began replacing its large and intermediate meters. Work was focused on improving accuracy of the meters as well as their strategic placement. In fiscal year 2007-08, an

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accelerated mainline replacement program was launched to repair and replace deteriorating pipelines. In addition, work to replace smaller customer meters was finally completed in fiscal year 2009-10 which also contributes to water loss control. Furthermore, LADWP's ongoing program to remove or cover large open-air reservoirs reduces water loss due to evaporation and infiltration.

Exhibit 2C
Breakdown in Historical Water Demand for LADWP's Service Area

Fiscal Year Ending	Single-Family		Multifamily		Commercial		Industrial		Government		Non-Revenue		Total
	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%	AF
1986-90 Avg	238,248	35%	197,312	29%	123,324	18%	30,502	4%	43,378	6%	52,830	8%	685,594
1991-95 Avg	197,322	35%	177,104	31%	110,724	19%	21,313	4%	38,600	7%	24,100	4%	569,164
1996-00 Avg	222,748	35%	191,819	30%	111,051	18%	23,560	4%	39,830	6%	43,617	7%	632,626
2001-05 Avg	239,754	36%	190,646	29%	109,685	17%	21,931	3%	41,888	6%	58,299	9%	662,203
2005-10 Avg	236,154	38%	180,279	29%	106,955	17%	23,201	4%	42,940	7%	31,929	5%	621,458
25-yr Avg	226,845	36%	187,432	29%	112,348	18%	24,101	4%	41,327	6%	42,155	7%	634,209

Indoor and Outdoor Water Use

In order to assess the potential for water use efficiency and target conservation programs, it is important to characterize water use in terms of indoor and outdoor demands. As with most water utilities, LADWP does not have separate irrigation meters for most of its customers. Only a small fraction of LADWP's customers, mostly parks and golf course, have designated irrigation meters. Therefore, measuring indoor vs. outdoor water demands involves the use of other data and assumptions.

There are two methods that LADWP uses to estimate total outdoor water use: (1) estimation of supplemental water needed for landscape irrigation in accordance with the California Model Water Efficient Landscape Ordinance; and (2) comparing wastewater flows to total water consumption. The first method uses the following formula to estimate the water needed to supplement outdoor landscape irrigation beyond the effect of natural precipitation:

$$LW = (Eto - Eppt) \times 0.62 \times A \times ETAF$$

Where:
LW = Estimated total supplemental water needed for landscape irrigation;
Eto = Reference evapotranspiration for the City of Los Angeles;
Eppt = Effective precipitation (25% of monthly precipitation);
0.62 = Conversion factor to gallons;
A = Total greenscape area; and
ETAF = Et adjustment factor

In 2007, an infrared analysis of the City was conducted as part of the City's Million Trees Program to determine tree canopy and landscape coverage. The infrared analysis methodology used two types of remotely sensed data, infrared imagery and aerial imagery, to determine the total greenscape areas within the City. Results of this effort indicated there is approximately 83,699 acres of greenscape area in Los Angeles. The ETAF (or Et adjustment factor) of 0.8 for the City was derived from types of plants to be irrigated and an assumed irrigation efficiency. It is consistent with the ETAF for non-rehabilitated landscapes as defined in the California Model Water Efficient Landscape Ordinance. The 2004-2007 average total water demand was selected as the basis for calculating outdoor water use percentage. This period was considered to be about average in terms of weather for Los Angeles and had no water restriction implemented by the City. Using the formula described previously, the supplemental water for outdoor landscaping in the City was estimated to be 249,000 AFY. During

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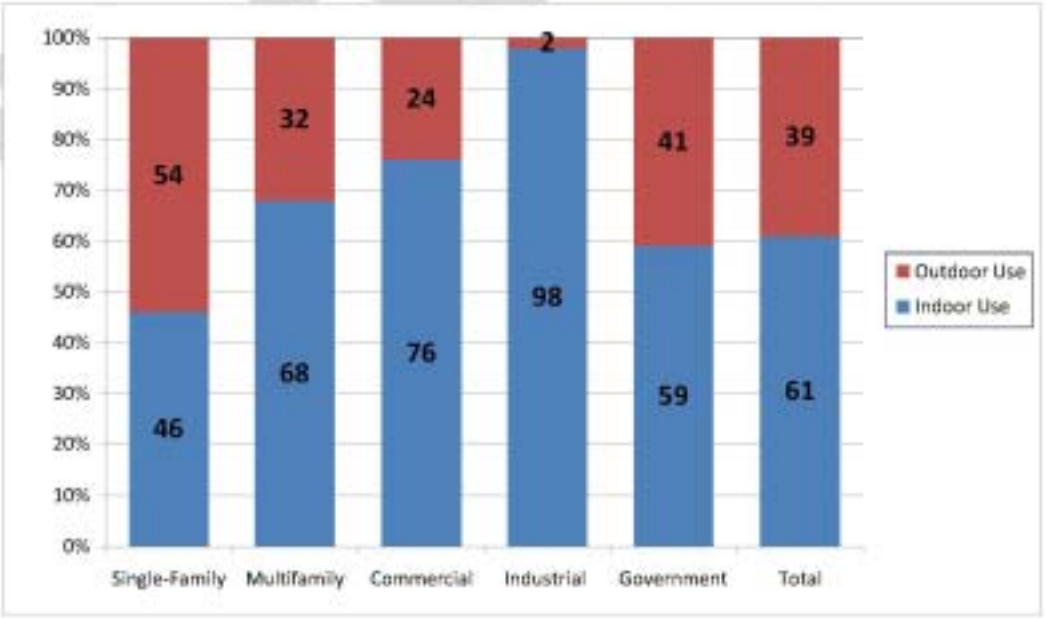
this same period, total water demand averaged 647,000 AFY. Therefore, the City's total outdoor water use represents approximately 39 percent of the total demand.

Comparing wastewater flows to total water consumption is another useful method to assess overall outdoor water use. Since wastewater flow represents indoor water use that flows into the sanitary sewer system, the difference between total water consumption and wastewater flows represents outdoor water use. However, groundwater infiltration and wet weather runoff may enter sanitary sewer systems through cracks and/or leaks in the sanitary sewer pipes or manholes and results in overestimation of the indoor water use. To reduce their impact, only summer months were used to estimate average monthly wastewater attributable to indoor water use. In Los Angeles, the summer months typically have little or no measurable rainfall. Using the same pre-water restriction period of 2004-2007 selected in the first method, the average monthly wastewater flow (only the months of June through September) yields approximately 365 million gallons per day (MGD) or 403,000 AFY of estimated indoor water use. Subtracting this estimated indoor water use from the total water consumption of 647,000 AFY results in an estimated total outdoor demand of 244,000 AFY or 38 percent, which is similar to the 39 percent obtained with the landscape irrigation method. Therefore, two entirely different methods produced very similar results in estimating the total outdoor water use for the City.

To obtain an estimate of indoor vs. outdoor water use for each major billing category, a minimum-month method was used. Monthly water use for single-family, multifamily, commercial, industrial and government was obtained for 2004-2007. The water use in the minimum month, usually one of the cool/wet winter months, is assumed to be mostly indoor use. The difference between any month and the minimum month is all attributed to outdoor water use. But based on the two prior methods, a certain amount of outdoor water use occurs even in the minimum month for some customers. Estimates of the outdoor water use that occurs in the minimum month were developed for each major billing category. Then the outdoor use of each major billing category was summed up to compare with the total outdoor water use obtained from the previous two methods. Exhibit 2D presents the estimated indoor and outdoor water use for the City using all three methods.

Exhibit 2D
Indoor vs. Outdoor Water Use in LADWP's Service Area



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2.2 Quantification of Historical Water Conservation

LADWP has invested hundreds of millions of dollars in water conservation since 1990. These conservation investments include various active programs such as high efficiency toilet rebates, commercial/industrial water audits, education and public outreach and much more. During periods of water shortage, public education and outreach is especially important and has contributed to significant reductions in water use. In an effort to quantify its water conservation efforts, LADWP developed a statistical Conservation Model that correlates total monthly water use in the City with population, weather, the presence of mandatory water conservation, and economic recessions. The model can be used to predict what the water demand would be under actual weather conditions, population growth and economy; but without active or drought water conservation in place. This modeled water consumption without conservation is then compared to actual water consumption—with the difference being attributed to water conservation. In order to assess the model's accuracy, the model is used to "back cast" the period 1980 to 1990 when conservation was not implemented. In this case, the modeled water consumption should be very close to the actual water consumption. After 1990, it is expected that the modeled water consumption will be greater than actual water consumption as LADWP has implemented increasing levels of water conservation measures. Exhibit 2E presents modeled and actual monthly water consumption from 1980 to 2009. As seen, the Conservation Model is performing as expected. The modeled water consumption (red line) is nearly identical to the actual water consumption (blue line) up until 1990. After 1990, the modeled water consumption is greater than actual water consumption.

Exhibit 2E
Modeled vs. Actual Monthly Water Consumption for LADWP

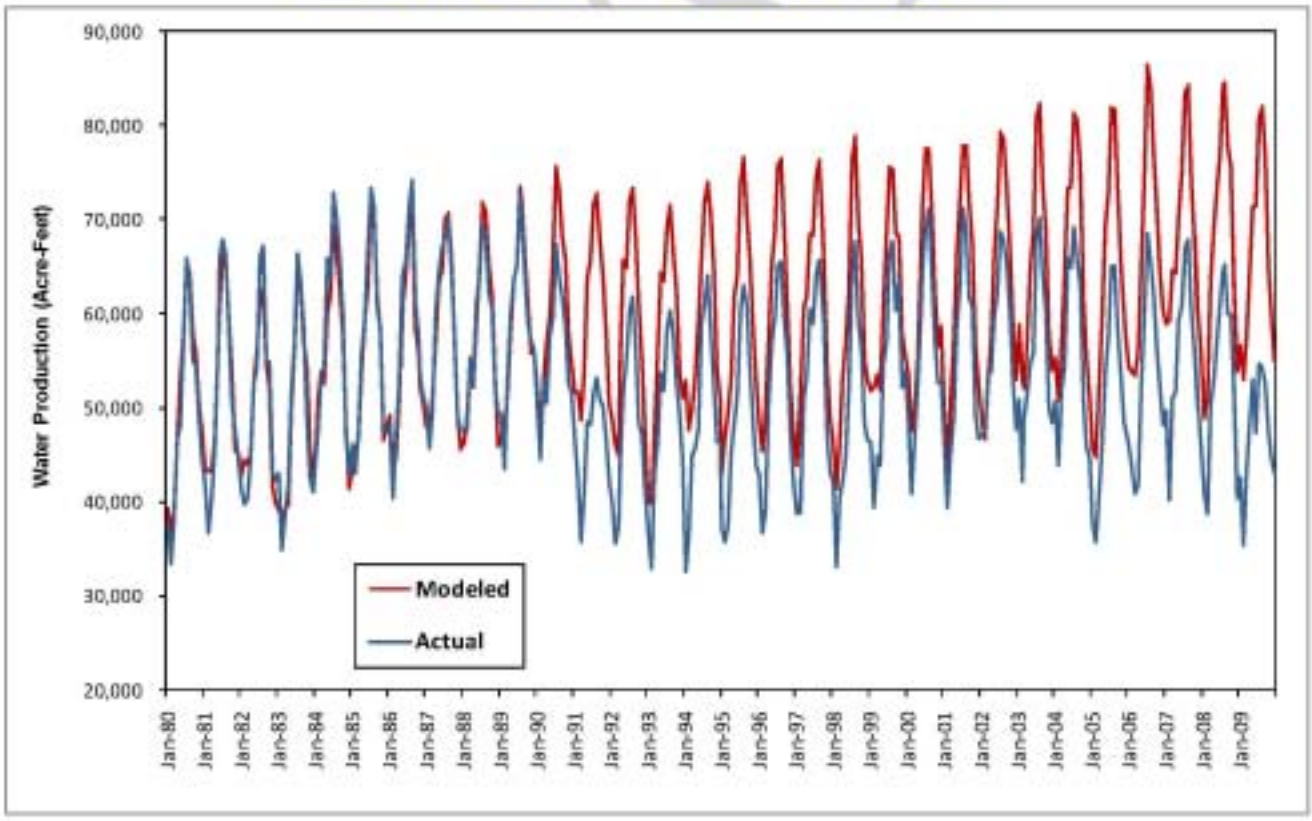

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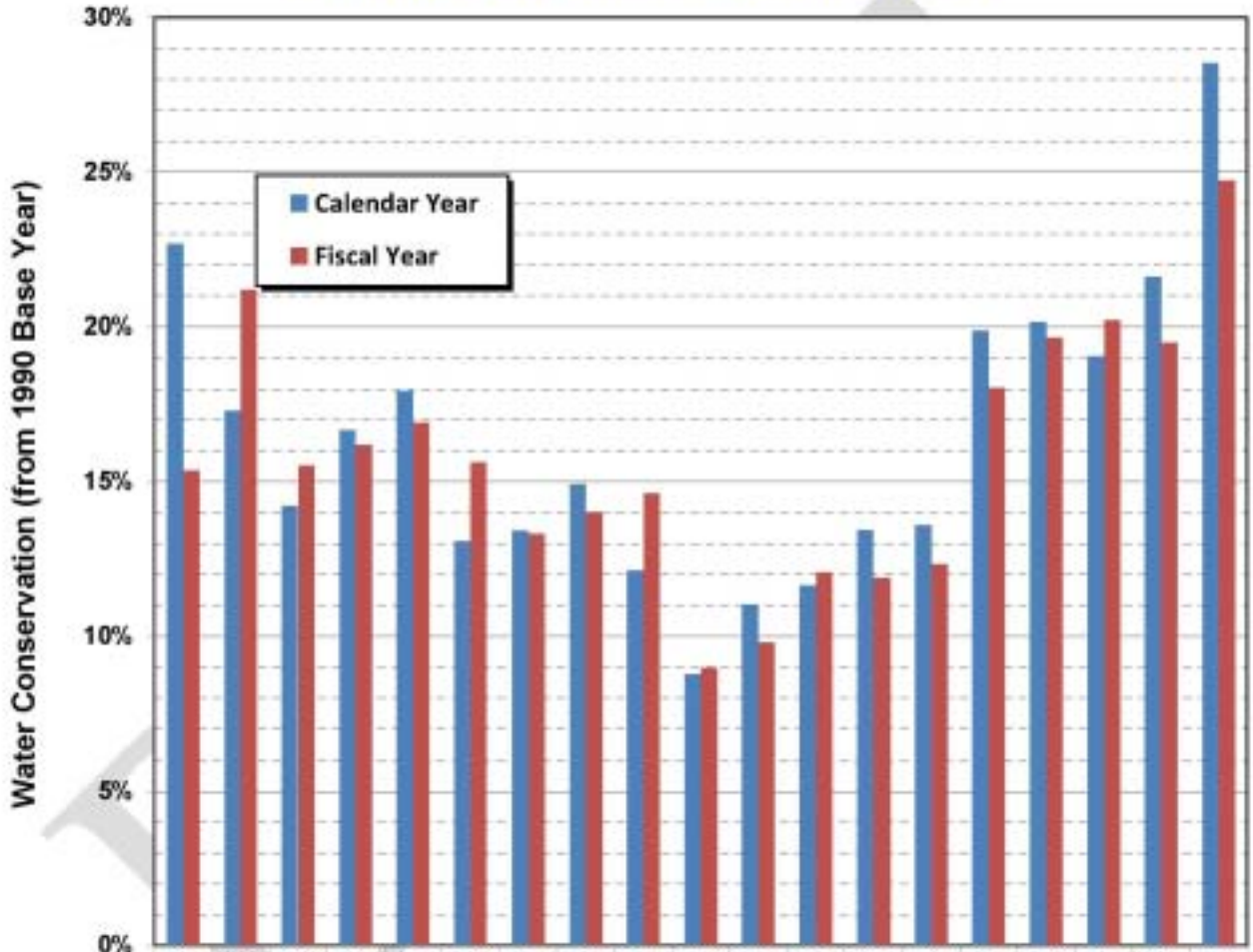
Exhibit 2F summarizes the annual estimated water conservation using the Conservation Model. During periods of water shortage, even when mandatory water conservation is not in place, there is more conservation occurring due to extensive public education and outreach. Water conservation in 2009 represents the highest levels of conservation so far, which reflects a combination of active conservation programs, heightened public education and outreach, and mandatory conservation measures.

Exhibit 2F
Estimates of Total Water Conservation in LADWP's Service Area



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Calendar Year	23%	17%	14%	17%	18%	13%	13%	15%	12%	9%	11%	12%	13%	14%	20%	20%	19%	22%	29%
Fiscal Year	15%	21%	16%	16%	17%	16%	13%	14%	15%	9%	10%	12%	12%	12%	18%	20%	20%	20%	25%

2.3 Water Demand Forecast

Demand Forecast Methodology

LADWP has developed a water demand forecast for each of its major categories of demand. This allows the City to better understand trends in water use and target conservation programs. The methodology used for the demand forecast is called a modified unit use approach. The following steps are used in this approach:

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Step 1: Estimate baseline per unit water use – take each billed category of water demand (e.g., single-family, industrial, etc.) for a base (or starting) period and divide by associated demographic driver (e.g., number of single-family homes or number of industrial employees). This yields for instance, a baseline of 359 gallons used each day in a single-family residence.

Step 2: Modify the estimated baseline per unit water use to account for future changes in the following socioeconomic variables: price of water, personal income, family size, economy, drought conservation effect, and passive water conservation (which accounts for efficiencies in water use from state and local plumbing codes and ordinances).

Step 3: Multiply modified per unit water use for each category in Step 2 by the associated projected demographic drivers (see Exhibit 2G) in order to obtain projected water demands by billed category that does not include active water conservation (which is defined as conservation that LADWP incentives through rebates and programs).

Exhibit 2G
Projected Demographic Drivers
(Based on MWD allocated 2008 SCAG forecast data with corrected service area boundary, 5-17-2010)

Fiscal Year Ending	Single-Family (# Homes)	Multi-Family (# Homes)	Commercial/ Government (# Employees)	Industrial (# Employees)	Landscaping (# of MF Homes)	NRW* (%)
2010	627,395	764,402	1,674,032	163,382	764,402	6.9%
2015	646,067	804,013	1,724,106	157,652	804,013	6.9%
2020	665,261	846,257	1,754,998	155,012	846,257	6.9%
2025	678,956	880,580	1,790,798	152,426	880,580	6.9%
2030	691,703	914,125	1,828,765	150,009	914,125	6.9%
2035	701,101	942,846	1,865,156	147,508	942,846	6.9%

* Calculated from difference between historical production and billing data

Step 4: Estimate non-revenue water (the difference between total water consumption and billed water use) by applying a non-revenue water use factor, and add non-revenue water to the billed category water demands in Step 3 in order to get a forecast of total water consumption without active water conservation.

Step 5: Subtract future projections of active water conservation from the total water consumption in Step 4 in order to determine the water demand forecast that is fully inclusive of both passive and active water conservation.

Applying the Methodology

In Step 1 of this method, historical water demands for single-family, multifamily, commercial/government, and industrial were averaged from 2005 to 2008 to determine the baseline. This period was used because on average, it represented normal weather conditions, and it was before mandatory water use restrictions that occurred in 2009 and 2010. For each of these categories, the water demand was divided by a demographic driver that could be projected into the future. The result of this calculation is a water demand expressed as a unit use water rate. Exhibit 2H presents this unit use calculation for the baseline.

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Exhibit 2H
Baseline Unit Use Water Rates (2005-2008)

Demand Category	Average Water Demand (AFY)	Average Demographic Driver *	Average Unit Use Rate (gallons/day/driver)
Single-Family	244,407	607,301 (homes)	359
Multifamily	184,428	734,461 (homes)	224
Commercial/Gov	153,199	1,631,896 (employees)	84
Industrial	23,613	160,328 (employees)	132

* Source: California Department of Finance and Employment Development Department

Step 2 in the methodology involves modifying these baseline unit use rates to account for changes in the following socioeconomic variables: price of water, personal income, family size, economy, drought conservation effect and passive water conservation. MWD has developed an econometric water demand model as part of its 2010 Integrated Water Resources Plan that is able to account for the impact that personal income, family size and price of water have on water demands. For each of these factors, a statistical coefficient or elasticity was estimated from MWD's Econometric Water Demand. The elasticity is generally interpreted as a percent change in water use resulting from a percent change in the socioeconomic variable. For example, a price elasticity of -0.131 would imply that a 10 percent increase in the real price of water would result in a 1.24 percent decrease in water demand (e.g. $1.24\% = 1-(1+10\%)^{-0.131}$). The following elasticities used in MWD's econometric water demand model were also used for LADWP's water demand forecast:

	Price of Water	Income	Family Size
Single-Family	-0.131	+0.270	+0.550
Multifamily	-0.109	+0.310	+0.450
Commercial/Government	-0.107		
Industrial	-0.107		

Source: MWD 2010 Integrated Water Resources Plan Update Appendix A.1 Demand Forecast

The price elasticities reflect a reduction of approximately 1/3 from those tabulated in MWD's 2010 IRP. However, MWD's 2010 IRP Appendix A.1 states that consumers respond to price increase by installing water-conserving fixtures and appliances. As more water efficient fixtures are installed, the impact of changing water-using behavior through rates is reduced. This is known as "demand hardening". Reducing the price elasticity is to avoid double-counting conservation savings and to account for demand hardening.

Exhibit 2I presents the modified per unit water use over time that incorporates future real increases in the price of water, personal income, and projected changes in family size. Also incorporated are the residual drought conservation effect from the significant public education and mandatory water restrictions that occurred during the drought period of 2009 through 2010, and the effect of passive conservation due to mandated efficiencies from plumbing codes and ordinances.

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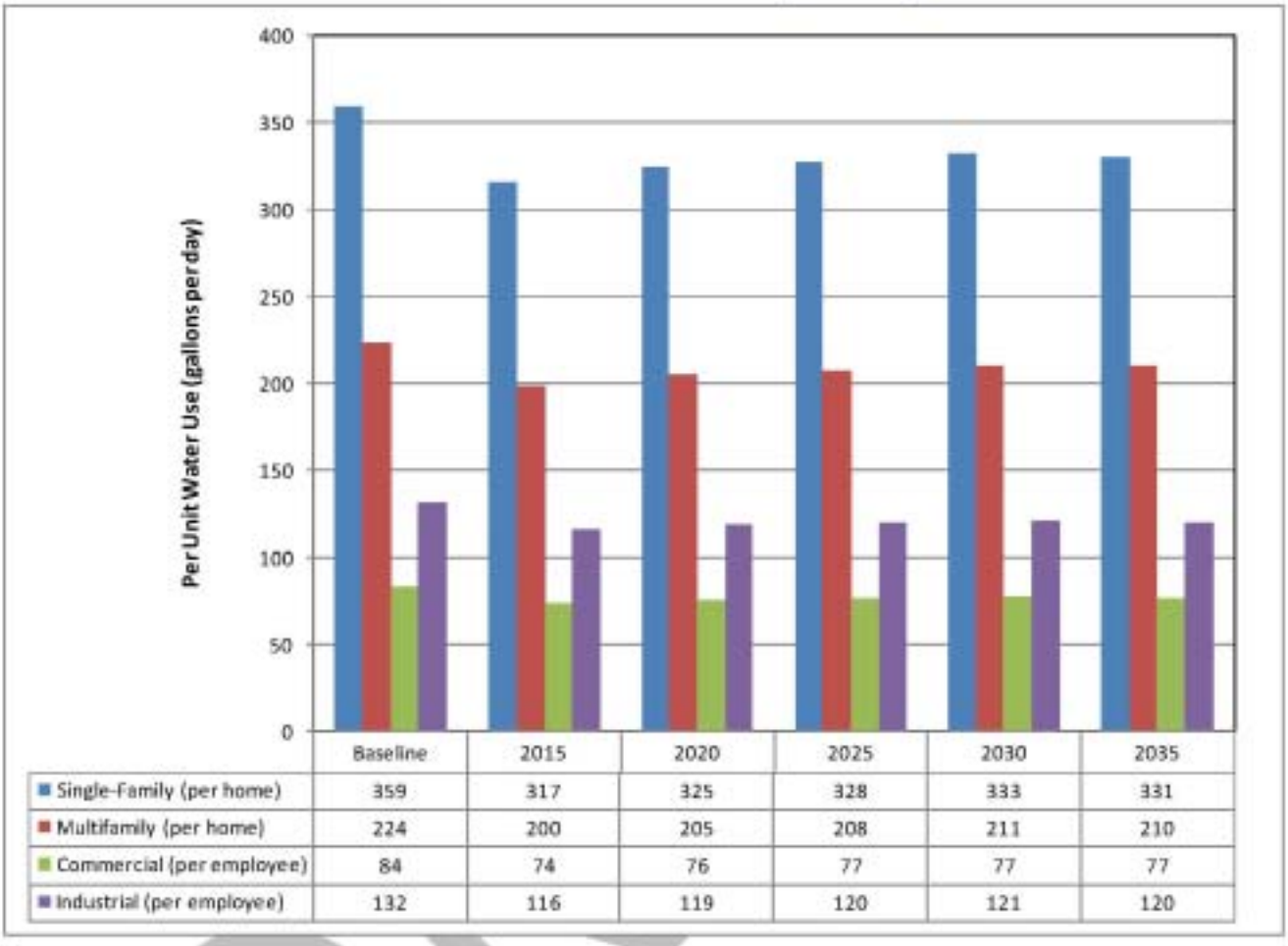
Exhibit 2I
Baseline Unit Use Water Rates (2005-2008)



	Baseline	2015	2020	2025	2030	2035
Single-Family (per home)	359	317	325	328	333	331
Multifamily (per home)	224	200	205	208	211	210
Commercial (per employee)	84	74	76	77	77	77
Industrial (per employee)	132	116	119	120	121	120

Water Demand Forecast Results

Steps 3, 4, and 5 involve applying the modified per unit water use factors shown in Exhibit 2J to the projected demographics for LADWP (see Chapter 1), then adding non-revenue water, and subtracting projected active water conservation (that is summarized in Chapter 3). The result of these steps is the water demand forecast for each of the major categories of demand.

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Exhibit 2J
Water Demand Forecast and Conservation Savings Under Average Weather

Demand Forecast with Passive Water Conservation	2010	2015	2020	2025	2030	2035
Single-Family	208,099	229,115	241,977	249,528	257,693	259,904
Multifamily	158,238	179,653	194,724	205,136	216,054	221,912
Commercial/Gov	129,708	143,081	149,597	153,791	158,628	160,049
Industrial	19,861	20,524	20,726	20,532	20,408	19,852
Non-Revenue	38,236	42,421	44,989	46,617	48,380	49,042
Total	554,140	614,794	652,013	675,604	701,164	710,760
Demand Forecast with Passive & Active Water Conservation	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Single-Family	206,154	225,699	236,094	241,180	246,879	247,655
Multifamily	157,749	178,782	193,220	202,999	213,284	218,762
Commercial/Gov	125,094	135,112	133,597	129,761	126,567	120,420
Industrial	18,729	18,600	16,852	14,708	12,634	10,513
Non-Revenue	37,630	41,370	42,969	43,627	44,421	44,272
Total	545,355	599,563	622,733	632,275	643,786	641,622
Active Water Conservation Savings	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Single-Family	1,944	3,416	5,882	8,349	10,815	12,249
Multifamily	489	871	1,504	2,137	2,770	3,150
Commercial/Gov	4,614	7,969	16,000	24,030	32,061	39,629
Industrial	1,132	1,924	3,874	5,824	7,774	9,339
Non-Revenue	606	1,051	2,020	2,990	3,959	4,771
Total	8,785	15,231	29,280	43,329	57,379	69,138

Water Demand Forecast with Average Weather Variability

Using the weather coefficients from the statistical water conservation model (see Exhibit 2E), annual weather adjustment factors can be derived to determine the range in forecasted water demands due to historical weather variability. This is accomplished by projecting water demands assuming long-term normal weather, and then comparing this normal-weather demand to actual demands. After adjusting for economy and drought conditions, projected water demands can vary by approximately ± 5 percent in any given year due to average historical weather variability. Meaning that water demands under cool/wet weather conditions could be as much as 5 percent lower than normal demands on average; while water demands under hot/dry weather conditions can be as much as 5 percent higher than normal demands on average. Exhibit 2K presents LADWP's historical and forecasted total water demands with both passive and active conservation, under the full range of historical weather variability.

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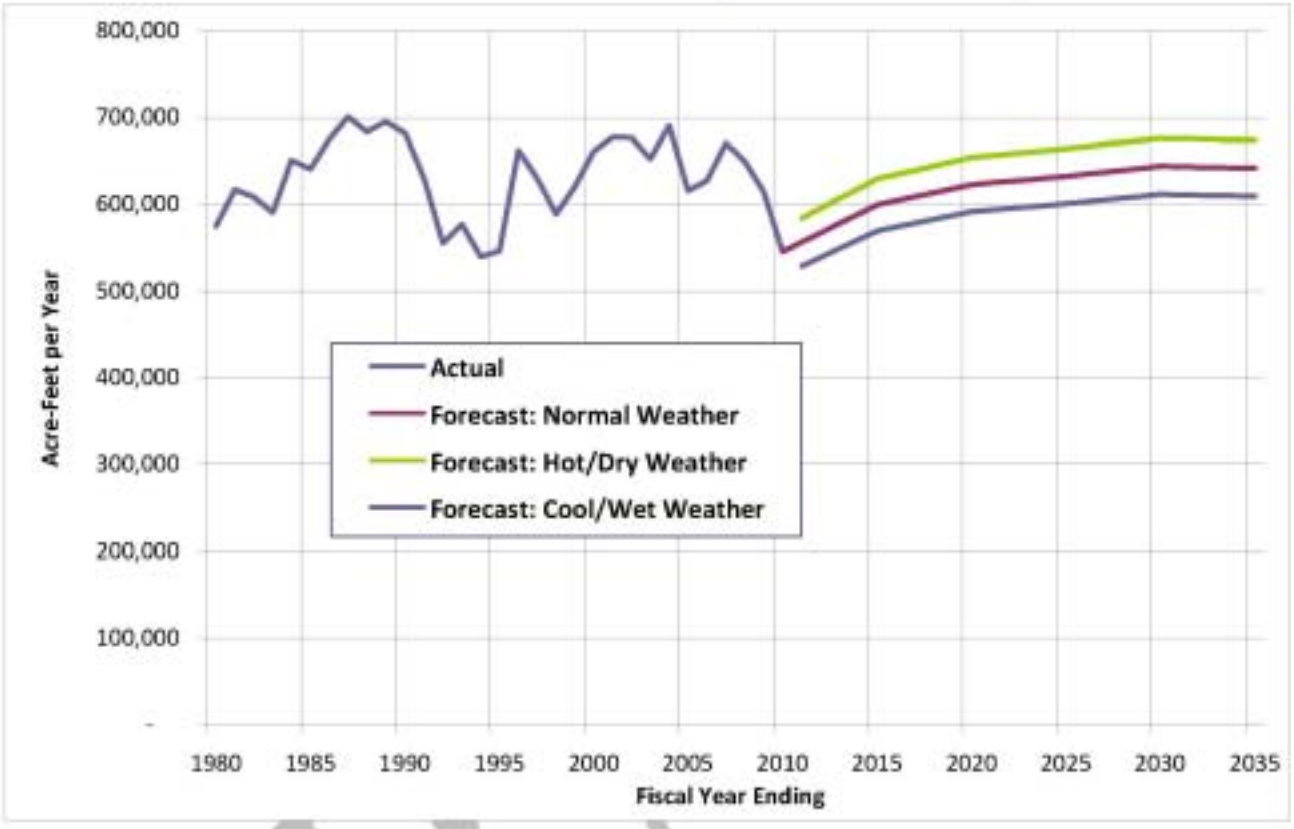
Exhibit 2K
Water Demand Forecast with Average Weather Variability



Low-Income Water Demand Projections

The requirements for the 2010 UWMP call for projections of water demands for low-income customers. For rate relief purposes, LADWP maintains records of low-income water customers. For the fiscal year 2009 - 2010, approximately 6.6 percent of the total number of single-family homes in the City was classified as low-income. On average, these customers used about 20 percent less water per household than overall single-family customers. To forecast low-income single-family water demand, the 6.6 percent ratio of low-income to total single-family homes was applied to the total projection of single-family homes for a projection of low-income single-family homes. The system wide per unit water use for single-family homes was reduced by 20 percent and multiplied by the projection of low-income single-family homes.

Because the water services of LADWP's multifamily residential customers are mostly not individually metered—meaning a multifamily water account can represent 2 or even 100 homes—a different approach was used. LADWP's power system does individually meter multifamily homes and also classifies homes as low-income for rate relief purposes. Therefore, the ratio of current low-income to total multifamily homes in the City was applied to the total projection of multifamily homes in order to get a projection of low-income multifamily homes. For the fiscal year 2009 – 2010, approximately 16.3 percent of the total number of multifamily homes in the City was classified as low-income. Assuming that low-income multifamily homes also use 20 percent less water than overall multifamily homes, an adjusted per unit water use for multifamily homes was multiplied by the projection of low-income multifamily homes. Exhibit 2L presents the water demand forecast for low-income residential water customers.

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Exhibit 2L
Water Demand Forecast for Low-Income Residential Customers

Low-Income Single-Family Customers	2015	2020	2025	2030	2035
Number of Homes	42,640	43,907	44,811	45,652	46,273
Household Water Use (Gallons/Day)*	250	253	254	255	252
Demand Forecast (Acre-Feet/Year)	11,917	12,466	12,734	13,035	13,076
Low-Income Multifamily Customers	**2015**	**2020**	**2025**	**2030**	**2035**
Number of Homes	131,054	137,940	143,535	149,002	153,684
Household Water Use (Gallons/Day)*	159	163	165	167	166
Demand Forecast (Acre-Feet/Year)	23,313	25,196	26,471	27,812	28,527
Total Low-Income Residential Customers	**2015**	**2020**	**2025**	**2030**	**2035**
Demand Forecast (Acre-Feet/Year)	35,230	37,662	39,205	40,847	41,603

* Assumes same percent conservation as system for single-family and multifamily homes.

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DRAFT Chapter Three
Water Conservation

3.0 Overview

Multiple factors are increasingly restricting LADWP's traditional water supply sources. The City of Los Angeles has long recognized water conservation as one of multiple methodologies to reduce demands and improve overall water supply reliability. In May of 2008, LADWP's Water Supply Action Plan (Plan), "Securing L.A.'s Water Supply", was released in response to factors impacting LADWP's major water supply sources beginning in 2007. This plan calls for reducing potable water demands by an additional 50,000 AFY by 2030 through conservation, with multiple conservation strategies to increase the sustainability of LADWP's water supply.

Los Angeles has historically taken a leadership role in managing its demand for water. Los Angeles consistently ranks among the lowest in per person water consumption when compared to California's largest cities. This significant accomplishment has resulted from the City's sustained implementation of effective water conservation programs since the 1980s.

One of LADWP's most effective conservation tools is its customers. During past droughts and water shortages, residents and businesses have aggressively implemented conservation to achieve demand reductions. During FY 09/10, water use was below 1979 water use levels thanks to extraordinary conservation efforts by LADWP customers. Specifically, water use in FY 09/10 was almost 20% lower than water use in FY 06/07 with single-family residential water use 25% lower, multi-family water use 11% lower, commercial water use 16% lower, industrial water use 15% lower, and governmental water use 33% lower.

LADWP has continually invested in water conservation programs and measures targeting cost-effective reductions in water use. Looking forward, LADWP plans to continue to make investments in conservation programs and expand its focus on landscape water use efficiency and conservation opportunities in the commercial/industrial/institutional (CII) customer sectors. LADWP's conservation planning process includes working with other City departments to ensure that mutual needs are addressed and goals are achieved (e.g., landscape water use efficiency and dry weather runoff reduction).

The civic culture of water conservation in Los Angeles began with the installation of water meters on all services in the early 1900's. At that time, this foundational conservation measure resulted in a 30 percent reduction in water use. Throughout the recurrence of periodic water shortages, LADWP customers have demonstrated the necessary concern and responsiveness. When faced with significant supply shortages, City residents have responded with unprecedented reductions in their water use. Los Angeles was one of the cities in southern California to invoke mandatory water rationing during the 1976 through 1977 drought. While severe, the two-year drought resulted in only a temporary reduction in water use, as a subsequent series of wet years erased memories of the water shortage experienced during the brief drought period. However, it was the drought that followed the 1978 through 1986 wet cycle that would prove to be the turning point in Los Angeles' water use awareness.

The drought of 1987-1992 left a permanent imprint on Los Angeles water customers. In response to this drought, LADWP expanded a voluntary water conservation program in 1990. Prompted by an extensive public awareness program and education campaign, LADWP customers responded not only with water saving practices but also by installing conservation measures in their homes and businesses. Devices such as low-flow showerheads and ultra-low-flush (ULF) toilets replaced existing non-water saving devices. These hardware changes, coupled with more responsible use habits, have significantly reduced the amount of imported water that the City would have to otherwise buy as the City's population and commerce has

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continued to grow. In response to the current water shortage conditions the City has reinitiated its extensive public awareness campaigns in addition to campaigns launched by MWD to encourage water saving practices and installation of conservation devices in homes and businesses.

With the recent water supply shortage and reduced deliveries of imported water from MWD, residential customers have repeated conservation levels exceeding 20 percent in the period between 2007 and 2010 as a result of mandatory conservation. During the current water supply shortage, the City has updated its Emergency Water Conservation Plan Ordinance with enforceable water waste provisions and implemented mandatory outdoor watering restrictions. In addition, the City has implemented water shortage year rates reducing Tier 1 water allotments for customers by 15%. Since July 2007, 63 billion gallons of water were saved through conservation. As a direct result of conservation, imported water purchases from MWD are 23% below baseline allocations for fiscal year 2009/2010. In response to recently enacted State laws, LADWP has developed new water conservation goals which aim to reach approximately 64,000 AFY in hardware conservation savings by 2035.

Conservation has had a tremendous impact on Los Angeles' water use patterns and has become a permanent element of LADWP's water management philosophy. Water usage in the City in 2010 was less than it was in 1979 despite an increase in population of over 1,000,000 people (see Exhibit 3A). Exhibit 3B shows historical conservation savings from fiscal year 1990/1991 through 2009/2010 based on installation of distributed conservation devices and rebates/incentives claimed as well as conservation achieved through customers' behavior and lifestyle changes to use water more responsibly. Cumulative yearly savings for the period total 223,593 AFY.

Exhibit 3A
Historical City of Los Angeles Water Use

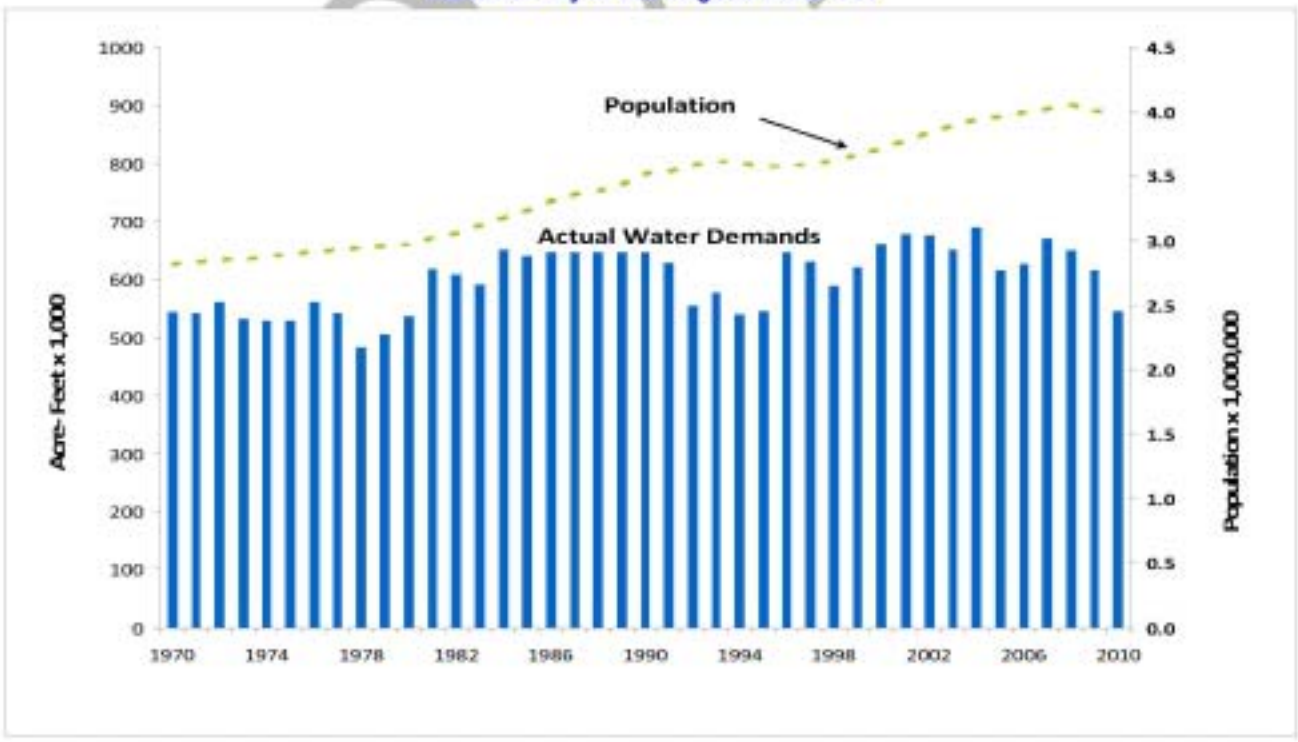

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Exhibit 3B
Historical City of Los Angeles Conservation

Fiscal Year	Additional Yearly Hardware Installed Savings (AF)	Cumulative Yearly Hardware Savings (AF)	Annual Non-Hardware Savings (AF) [1]	Annual Total Savings (AF)
Prior to 1990/1991	30,260	30,260	-	-
1990/1991	3,908	34,168	78,098	112,267
1991/1992	7,456	41,624	108,555	150,179
1992/1993	4,583	46,207	60,210	106,417
1993/1994	4,210	50,417	63,344	113,761
1994/1995	4,761	55,178	63,780	118,958
1995/1996	4,116	59,294	54,871	114,164
1996/1997	3,283	62,576	35,036	97,612
1997/1998	2,650	65,227	31,737	96,964
1998/1999	2,721	67,948	39,666	107,614
1999/2000	3,038	70,986	-4,406	66,580
2000/2001	3,565	74,552	-2,038	72,513
2001/2002	2,263	76,814	16,688	93,502
2002/2003	2,507	79,321	10,405	89,726
2003/2004	3,047	82,368	14,999	97,366
2004/2005	3,124	85,492	48,932	134,423
2005/2006	3,030	88,522	63,664	152,186
2006/2007	2,197	90,719	77,982	168,701
2007/2008	782	91,501	65,587	157,088
2008/2009	3,127	94,628	106,307	200,935
2009/2010	4,269	98,897	124,696	223,593

1. Negative non-hardware savings are due to overestimation in hardware savings due to years with extreme wet weather conditions.

Conservation benefits the City by improving water supply reliability and reducing embedded energy use for water treatment and pumping. Conserving customers see a tangible benefit as well through monetary savings on their water bill. Another ancillary benefit of conserving water is that the need for costly sewer facility expansions is deferred by reducing wastewater discharge into the sewer collection and treatment systems, thus increasing the lifespan of current sewer infrastructure. Water conservation also has the added benefits of reducing greenhouse gas emissions and energy use associated with delivering water supplies to and within the LADWP service area. In the end, the primary beneficiaries of conservation are the water customers and the environment from where the sources of supply originates. Furthermore, increased conservation will result in decreased dry weather runoff which will decrease the amount of pollutants flowing into the rivers and oceans.

Los Angeles has been implementing permanent conservation since the 1980's. In 1988, the City adopted a plumbing retrofit ordinance to mandate the installation of conservation devices in all properties and to require water-efficient landscaping in new construction. The ordinance was amended in 1998, requiring the installation of ULF toilets and water saving showerheads in single-family and multi-family residences prior to resale. A new ordinance adopted in 2009, the Water Efficiency Requirements ordinance, establishes water efficiency requirements for new developments and renovations of existing buildings by requiring

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installation of high efficiency plumbing fixtures in all residential and commercial buildings. LADWP's past water conservation programs have assisted customers affected by the ordinances by offering free ULF toilets and showerheads, free installation of ULF toilets, showerheads and faucet aerators, as well as rebates for ULF toilets purchased and installed. Current water conservation programs co-sponsored by MWD through the SoCal Water$mart Program for residential customers and the Save Water Save a Buck Program for CII customers continue to assist customers in complying with ordinances and reducing overall water demands.

3.1 Water Conservation Goals

Water conservation reduces demand that typically rises over time with growth in population and commerce. By mitigating those increases in demand, water supply reliability is improved while costs are reduced. In the early 1990s, City residents responded with conservation levels exceeding 20 percent due to increasingly drier conditions and mandatory conservation. As normal water supply conditions returned and with continuation of LADWP's conservation program, conservation levels stabilized at approximately 15 percent. With the recent drought and reduced deliveries of imported water from MWD, residential customers have repeated conservation levels exceeding 20 percent in the period between 2007 and 2010 as a result of mandatory conservation. Since July 2007, 63 billion gallons of water were saved through conservation. As a direct result of conservation, imported water purchases from MWD are 23% below baseline allocations for fiscal year 2009/2010. In response to the goals provided in the Plan and recently enacted State laws, LADWP has developed water conservation goals.

3.1.1 Water Supply Action Plan Conservation Goal

To continue increased conservation levels once mandatory outdoor watering restrictions are lifted, LADWP has set a water conservation goal in the Water Supply Action Plan of reducing potable water demands by an additional 50,000 AFY by 2030. This conservation level will further lessen the City's reliance on imported water while providing a drought-proof resource that is not subject to weather conditions. This aggressive approach includes multiple strategies: investments in state-of-the-art technology; a combination of rebates and incentives promoting installation of weather-based irrigation controllers (WBICs), efficient clothes washers and urinals; expansion and enforcement of prohibited water use; reductions in outdoor water use; extending education and outreach efforts; and encouraging regional conservation.

LADWP's commitment to conservation is a proven multi-faceted approach that includes tiered water pricing, education and awareness, financial incentives for the installation of a variety of conservation measures, free water saving showerheads, Technical Assistance Program (TAP) incentives for business and industry, and large landscape irrigation efficiency programs. Conservation is a key component of LADWP's water resource planning efforts and will continue to be implemented over the long term.

3.1.2 Water Conservation Act of 2009

The Water Conservation Act of 2009, Senate Billx7-7, requires water agencies to reduce per capita water use by 20% by 2020 (20x2020). This includes increasing recycled water use to offset potable water use. Water suppliers are required to set a water use target for 2020 and an interim target for 2015 using one of four methods. The 2020 urban water use target may be updated in a supplier's 2015 UWMP. Failure to meet adopted targets will result in the ineligibility of a water supplier to receive water grants or loans administered by the State unless one of two exceptions is met. Exception one states a water supplier may be eligible if they have submitted a schedule, financing plan, and budget to DWR for approval to achieve the per capita water use reductions. Exception two states a water supplier may be eligible if an entire water service area qualifies as a disadvantaged community.

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Four methodologies are stipulated for calculating the water use target. Three of the methods are listed in Water Code § 10608.20(a)(1). The fourth method was developed by DWR. The four methodologies are:

- Method 1 - Eighty percent of the water supplier's baseline per capita water use
- Method 2 – Per capita daily water use estimated using the sum of performance standards applied to indoor residential use; landscape area water use, and commercial, industrial, and institutional uses
- Method 3 – Ninety-five percent of the applicable state hydrologic region target as stated in the state's *draft 20x2020 Water Conservation Plan.*
- Method 4 – Description to be added at end of 2010 once developed by DWR

In 2015, urban retail water suppliers will be required to report interim compliance followed by actual compliance in 2020. Interim compliance is halfway between the baseline water use and 2020 target. Baseline, target, and compliance-year water use estimates are required to be reported in gallons per capita per day (gpcd).

For consistent application of the Act, DWR produced *Methodologies for Calculating Baseline and Compliance Urban Water Per Capita Use* in October 2010. Following requirements provided in the document, LADWP has calculated baseline per capita water use, an urban use target for 2020, and an interim water use target for 2015. Reporting compliance daily per capita water use is not required until the 2015 UWMP cycle as it compares the interim target to actual water use in 2015. Exhibit 3C presents results of the calculations. Calculations and technical bases for the calculations are presented in Appendix X.

Baseline per capita water use is 154 gpcd using a ten-year average ending between December 31, 2004 and December 31, 2009 and 146 gpcd using a five-year average ending between December 31, 2007 and December 31, 2009.

LADWP has adopted Method 3 to set its 2015 interim and 2020 water use targets. Method 3 requires setting the 2020 water use target to 95% of the applicable State hydrologic region target as provided in the *State's Draft 20x2020 Water Conservation Plan.* LADWP is within State hydrologic region 4, the South Coast region. LADWP was required to further adjust the calculated 2020 target to achieve a minimum reduction in water use. The gpcd at 95% of the hydrologic region was 142 gpcd and using 95% of the five-year average base daily per capita water use was equal to 138 gpcd. Therefore, LADWP was required to set the 2020 target at the smaller of the two resultant values. LADWP's interim 2015 target is 146 gpcd and the 2020 target is 138 gpcd.

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Exhibit 3C
20x2020 Base and Target Data

20x2020 Required Data	Gallons Per Capita Per Day (GPCD)
Base Per Capita Daily Water Use	
10-Year Average[1]	154
5-Year Average[2]	146
2020 Target Using Method 3[3]	
95% of Hydrologic Region Target (149 gpcd)	142
95% OF Base Daily Capita Water Use 5-Year Average (146 gpcd)	138
Actual 2020 Target	**138**
2015 Interim Target	146

1. Ten-year average based on calendar year ending between 12/31/04 and 12/31/10.

2. Five-year average based on calendar year ending between 12/31/07 and 12/31/10.

3. Methodology requires smaller of two results to be actual water use target to satisfy minimum water use target.

3.2 Existing Programs, Practices, and Technology to Achieve Water Conservation

LADWP has developed aggressive water conservation programs to address recently enacted State laws and to meet its goal of achieving an additional 50,000 AFY conservation by 2030. LADWP uses multiple programs, practices, and technologies in conjunction with enactment of ordinances to achieve its current water conservation levels throughout its service area and customer classes.

3.2.1 State Laws and City Ordinances

State Laws

In addition to the Water Conservation Act of 2009 multiple legislative bills have been enacted in the past few years requiring water agencies to enact measures to increase water conservation, establishing new plumbing standards, and linking grants and loans to implementation of best management practices (BMPs).

The Water Conservation in Landscaping Act of 2006, Assembly Bill 1881, reduces outdoor water waste through improvements in irrigation efficiency and selection of plants requiring less water. The Act required an update to the existing Model Water Efficient Landscape Ordinance and adoption by location agencies or an equivalent ordinance no later than January 1, 2010. If any agency failed to adopt the ordinance or its equivalent then the ordinance was automatically adopted by statute. The ordinance requires development of water budgets for landscaping, reduces erosion and irrigation related runoff, utilization of recycled water if available, irrigation audits, requirements for landscape and irrigation design, and scheduling of irrigation based on localized climate for new construction and redevelopment projects.

In 2009, Assembly Bill 1465, Urban Water Management Planning, was approved to include language in the UWMP Act that deem water suppliers that are members of the California Urban Water Conservation Council (CUWCC) and comply with the "Memorandum of Understanding Regarding Urban Water Conservation in California," dated December 10, 2008, as it may be

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amended, to be in compliance with the requirement to describe the supplier's water demand management measures in its urban water management plan. A more detailed discussion of the CUWCC and BMP compliance is provided in Section 3.2.3.

Assembly Bill 1420 links state funding for water management by urban water suppliers to implementation of water conservation measures. Urban water suppliers are required to be in compliance with the CUWCC MOU to be eligible for water management grants or loans. Senate Bill X7-7 further clarifies the grant funding conditions required by AB 1420 are repealed on July 1, 2016 and replaced with eligibility determined by compliance with 20x2020 targets.

In the recent years there has been a lot of regulations approved increasing the water use efficiency requirements of plumbing devices, specifically, Assembly Bill 715 (2007), Senate Bill 407 (2009), and the CALGreen Building Standards. AB 716 requires that all toilet and urinal fixtures sold through retail or installed in existing and new residential and commercial building meet the high efficiency standards by January 1, 2014. SB 407 does not address the sale of plumbing fixtures but adds a requirement that beginning in January 1, 2017 all residential and commercial property sales must disclose all non-efficient plumbing fixtures. CALGreen has an effective date of January 1, 2011 and requires use of water efficient plumbing fixtures for all new construction and renovations of residential and commercial properties.

City Ordinances

Los Angeles has utilized ordinances as a tool to reduce water waste since 1988, beginning with the adoption of its first version of a plumbing retrofit ordinance. The ordinance mandated installation of conservation devices in all existing residential and commercial properties and installation of water-efficient landscaping in all new construction. Toilets were required to use less than 3.5 gallons per flush (gpf), urinals less than 1.5 gpf, and showerheads less than 2.5 gallons per minute (gpm). Customers with three acres or more of turf were required to reduce water consumption by 10 percent from 1986 levels or face a 100 percent surcharge on their water bills.

In 1998 the ordinance was amended, requiring the installation of ULF toilets and water saving showerheads in single-family and multi-family residences prior to the close of escrow. This progressive requirement is implemented with the help of local real estate professionals. LADWP has explored the expansion of the City's Retrofit on Resale Ordinance to include nonresidential properties

Los Angeles further increased its water efficiency mandates in 2009 with adoption of the Water Efficiency Requirements ordinance. This ordinance establishes water efficiency requirements for new developments and renovations of existing buildings by requiring installation of high efficiency plumbing fixtures in all residential and commercial buildings. Exhibit 3D summarizes the minimum requirements for new construction and replacement of fixtures in existing buildings.

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Exhibit 3D
Water Efficiency Requirements Ordinance Summary

Device	Requirement
High Efficiency Toilets	1.28 gallons per flush
Urinals	0.125 gallons per flush
Faucets	
Indoor Faucets (Maximum)	2.2 gallons per minute
Private Lavatory Faucets	1.5 gallons per minute
Public Use Lavatory Faucets[1]	0.5 gallons per minute
Showerheads	2 gallons per minute
Dishwashers	
Commercial Dishwashers	varies by type between 0.62 and 1.16 maximum gallons per rack
Domestic Dishwashers	5.8 gallons per cycle
Cooling Towers	5.5 cycles of concentration
Single-Pass Cooling Systems	Prohibited[2]

1. Metering faucets shall not deliver more than 0.25 gallons per cycle.

2. Single pass cooling systems are prohibited unless installed for health and safety purposes that cannot otherwise safely operate.

In an effort to lead by example, LADWP has been retrofitting all its facilities with high efficiency plumbing fixtures since before the effective dates of the ordinance. As of early June 2010, LADWP is 57 percent complete in upgrading its 600 buildings to high efficiency faucets, toilets, urinals, showers, flexible hose connectors, angle valves, as well as correcting leaks and removing existing water damage.

In May 1996, the City's Landscape Ordinance (No. 170,978) became effective with an overarching goal to improve the efficient use of outdoor water. This ordinance was recently amended in 2009 to comply with the previously discussed Water Conservation in Landscaping Act of 2006 and the Model Water Efficient Landscape Ordinance.

LADWP first adopted an Emergency Water Conservation Plan ordinance in the early 1990's in response to drought conditions. Subsequently in the current water shortage LADWP has adopted two amendments expanding prohibited uses, increasing penalties for violating the ordinance, and modifying water conservation requirements. Five phases of water conservation are incorporated into the plan with prohibitions and water conservation measures steadily increasing by phase. Regardless of water supply availability, at a minimum Phase I conservation requirements are in effect unless a more stringent phase is in effect. In response to the ongoing drought conditions, LADWP implemented Phase III restrictions on June 1, 2009, allowing outdoor irrigation only two days per week. Upon the recent ordinance amendment, Phase II implementation began on August 25, 2010 which allows outdoor watering three days per week. Exhibit 3E summarizes the five phases as defined in the latest amendment approved in August 2010.

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Exhibit 3E
Emergency Water Conservation Plan Ordinance Restrictions by Phase

Phase	Restrictions
I	No use of a water hose to wash paved surfaces
	No use of water to clean, fill, or maintain levels in decorative fountains, ponds, lakes or similar structures used for aesthetic purposes unless a recirculating system is used
	No drinking water shall be served unless expressly requested in restaurants, hotels, cafes, cafeterias, or other public places where food is sold, served, or offered for sale
	No leaks from any pipes or fixtures on a customer's premises; failure or refusal to fix leak in a timely manner shall subject the customer penalties for a prohibited use of water
	No washing vehicles with a hose if the hose does not have a self-closing water shut-off device attached or the hose is allowed to run continuously while washing a vehicle
	No irrigation during rain
	No irrigation between 9am and 4pm, except for public and private golf courses and professional sports fields to maintain play areas and event schedules. System testing and repair is allowed if signage is displayed.
	All irrigation of landscape with potable water using spray head and bubblers shall be limited to no more than ten minutes per water day per station. All irrigation of landscape with potable water using standard rotors and multi-stream rotary heads shall be limited to no more than 15 minutes per cycle and up to 2 cycles per water day per station. Exempt from these restrictions are irrigation systems using very low-flow drip-type irrigation when no emitter produces more than 4 gallons of water per hour and micro-sprinklers using less than 14 gallons per hour. This restriction does not apply to Schedule F water customers or water service that has been granted the General Provision M rate adjustment under the City's Water Rate Ordinance, subject to the customer having complied with best management practices for irrigation approved by LADWP.
	No watering or irrigation of any lawn, landscape, or other vegetated area shall occur in a manner that causes or allows excess or continuous water flow or runoff onto an adjoining sidewalk, driveway, street, gutter, or ditch
	No installation of single-pass cooling systems shall be permitted in buildings requesting new water service.
	No installation of non-recirculating systems shall be permitted in new conveyor car wash and new commercial laundry systems.
	Operators of hotels and motels shall provide guests with the option of choosing not to have towels and linens laundered daily.
	No large landscape areas shall have irrigation systems without rain sensors that shut off the irrigation systems.
II	All prohibited uses in Phase 1 shall apply, except as provided.
	No landscape irrigation shall be permitted on any day other than Monday, Wednesday, or Friday for odd-numbered street address and Tuesday, Thursday, or Sunday for even-numbered street addresses. If a street address ends in 1/2 or any fraction it shall conform to the permitted uses for the last whole number in the address. For non-conserving nozzles (spray head sprinklers and bubblers) watering times shall be limited to no more than 8 minutes per watering day per station for a total of 24 minutes per week. For conserving nozzles (standard rotors and multi-stream rotary heads watering times shall be limited to no more than 15 minutes per cycle and up to two cycles per watering day per station for a total of 90 minutes per week.
	Irrigation of sports fields may deviate from non-watering days to maintain play areas and accommodate event schedules with written notice from LADWP. However, a customer must reduce overall monthly water use by LADWP's Board of Water and Power Commissioners adopted degree of shortage plus an additional 5% from the customer baseline water usage within 30 days.

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	If written notice is received from LADWP, large landscape areas may deviate from the non-watering days if the following requirements are met: 1) approved weather-based irrigation controllers registered with LADWP 2) Must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus and additional 5% from the customer baseline within 30 days 3) Must use recycled water if available
	These restrictions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase II, except between the hours of 9am and 4pm.
III	All prohibited uses in Phases I and II shall apply, except as provided.
	No landscape irrigation shall be permitted on any day other than Monday for odd-numbered street address and Tuesday for even-numbered street addresses. If a street address ends in 1/2 or any fraction it shall conform to the permitted use for the last whole number in the address.
	No washing of vehicles allowed except at commercial car washes.
	No filling of residential swimming pools and spas with potable water.
	Irrigation of sports fields may deviate from non-watering days and be granted one additional watering days for a total of two watering days with written notice from LADWP. However, a customer reduce overall monthly water use by LADWP's Board of Water and Power Commissioners adopted degree of shortage plus an additional 10% from the customer baseline water usage within 30 days.
	If written notice is received from LADWP, large landscape areas may deviate from the non-watering days and be granted one extra day of watering for a total of 2 watering days if the following requirements are met: 1) approved weather-based irrigation controllers registered with LADWP 2) Must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus and additional 10% from the customer baseline within 30 days 3) Must use recycled water if available
	These restrictions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase III, except between the hours of 9am and 4pm.
IV	All prohibited uses in Phases I, II, and III shall apply, except as provided.
	No landscape irrigation is allowed.
V	All prohibited uses in Phases I, II, III, and IV shall apply, except as provided.
	The LADWP Board of Water and Power Commissioners is authorized to implement additional water prohibitions based on the water supply situation.

Specific procedures for determining the initiation of a phase and termination of a phase are provided in the Emergency Water Conservation Plan Ordinance. Phases are initiated through recommendations provided by LADWP to the Mayor and City Council (Council).

3.2.2 Conservation Pricing

In 1993, Los Angeles restructured its water rates to provide customers with a clear financial signal to use water more efficiently. It was the first time in LADWP's history that an ascending tiered rate structure was used. This conservation-based rate structure remains in use and applies a lower first tier rate for water used within a specified allotment, and a higher second tier rate for every billing unit (748 gallons) that exceeds the first tier allotment. A unique feature of the rate structure is that the first tier allotment considers factors that influence individual residential customer's water use patterns (i.e. lot size, climate zone, and family size).

The goals of LADWP's two-tiered water rate structure are to:

- Use price as a signal to encourage the efficient use of water

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- Provide basic water needs at an affordable price
- Provide equity among customers
- Use price to stabilize water use during a shortage
- Generate adequate revenue for maintaining and upgrading the water system

In a period where increasing demands and reductions in water supply are becoming more commonplace, a rate structure that provides appropriate signals to encourage efficient water use has become a necessity for many areas, including Los Angeles.

The substantial investments required for water quality improvements, security, and supply development have significantly raised the cost of delivering water. As rates increase, water agencies have noticed a change in use patterns. Because there is a known correlation between price and use, agencies use rates to encourage conservation activities and to postpone the need to construct new facilities or purchase even larger quantities of imported water.

LADWP's tiered rate structure, first implemented in 1993 with assistance from a broad-based group of stakeholders, applies a lower tier block rate for responsible water use within a specified amount of water, and a much higher rate for every billing unit above this block. The higher block rate reflects the "marginal cost," or the projected cost for additional water that would be required to meet these needs.

To further emphasize the conservation message, water charges are based solely on water used. This eliminates the inclusion of fixed charges. There are automatic adjustments triggered when a water shortage exists. In June 2009 shortage year rates went into effect reducing first tier allotments for all customers by 15%. These adjustments are based on the actual water use patterns that occurred during the 1991 period of mandatory water rationing. The purpose of these adjustments is to use price to encourage additional conservation and to provide LADWP with the revenue necessary to operate the system efficiently during a shortage.

3.2.3 CUWCC Best Management Practices

The CUWCC is the voice of urban water conservation in California, and LADWP has been active in the CUWCC since its inception in 1991. Instrumental in the development of the MOU, LADWP was also one of the original signatories. The MOU identifies BMPs as proven conservation measures as determined by the CUWCC. The most recent amendment to the MOU was adopted on June 9, 2010 updating compliance alternatives with the adopted BMPs. A water agency can now comply with the MOU through one of three methodologies: BMP compliance, accomplishing water conservation through a set of measures equal or greater than the water savings provided by the BMPs (Flex Track Menu), or accomplishing water conservation goals as measured in gpcd. All Group One (water suppliers) signatories to the MOU are committed to implement the BMPs.

Over the last 19 years, LADWP has played a significant role in the governance and policy making at the CUWCC, holding a seat on the Board of Directors, Strategic Planning Committee, By-Laws Committee, Research and Evaluation Committee, CII Committee, co-chair of the Membership Committee, and chair of the Group 1 Representation Selection Committee. LADWP also has been actively involved in all of the revisions that the MOU has undergone to date.

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One of the obligations as a signatory to the MOU is to submit a Best Management Practices Retail Water Agency Report to the CUWCC. Previously submitted annually, this report is now submitted biennially and details progress in implementing the foundational and programmatic BMPs as currently specified in the MOU. LADWP actively implements the BMPs and the CUWCC BMP reports are available for review through the internet by accessing CUWCC's website at www.cuwcc.org.

In the early 1990s, the State Water Resources Control Board identified urban water conservation as a major means for resolving problems in the Bay-Delta. Large water agencies, including LADWP, actively participated in work groups to develop conservation strategies. The result of this effort is in the aforementioned MOU.

The MOU commits signatory water suppliers to develop comprehensive conservation programs using sound economic criteria and to consider water conservation on an equal footing with other water management options. The MOU established the CUWCC to monitor implementation of the BMPs and to maintain the list of BMPs.

A BMP is defined as:

(a) An established and generally accepted practice among water suppliers resulting in more efficient use or conservation of water.

(b) A practice for which sufficient data are available from existing water conservation projects to indicate that significant conservation or conservation-related benefits can be achieved; that the practice is technically and economically reasonable and not environmentally or socially unacceptable; and that the practice is not otherwise unreasonable for most water suppliers to carry out.

LADWP implements all of the BMP requirements in the MOU except for wholesale agency assistance programs, which applies only to wholesale water agencies. Foundational BMPs are considered as essential BMPs for any water utility and are ongoing practices not subject to time limitations. Programmatic BMPs are minimal activities required to be completed by each utility within the timeframe of the implementation schedules provide in the MOU. A listing of the BMPs is shown in Exhibit 3F.

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Exhibit 3F
CUWCC BMPs and Implementation Status

Category	Sub-category	Practices	Status
		Foundational	
Utility Operations	Operations Practices	Maintain the position of a trained conservation coordinator	Implemented
		Prevent water waste – enact, enforce or support legislation, regulations, and ordinances	Implemented
		Wholesale agency assistance programs	Not applicable
	Water Loss Control	Conduct Standard Water Audit and Water Balance	Implemented
		Measure performance using AWWA software	Implemented
		Locate and Repair all leaks and breaks	Implemented
	Metering with Commodity Rates	100% of existing unmetered accounts to be metered and billed by volume of use	Implemented
	Conservation Pricing	Maintain a water conserving retail rate structure	Implemented
Education	Public Information Programs	Maintain active public information program to promote and educate customers about water conservation	Implemented
	School Education Programs	Maintain active program to educate students about water conservation and efficient water use	Implemented
		Programmatic	
Residential		Residential Assistance – provide leak detection assistance	Implemented
		Landscape Water Surveys for single family residential accounts	Implemented
		High efficiency clothes washer incentive program	Implemented
		WaterSense Specification (WSS) for toilets	Implemented
Commercial/ Industrial/ Institutional (CII)		Implement unique conservation programs to meet annual water savings goals for CII customers	Implemented
Landscape		Implement Large Landscape custom programs	Implemented
		Offer technical assistance and surveys upon request	Implemented
		Implement and maintain incentive program(s) for irrigation equipment retrofits	Implemented

3.2.3 LADWP Conservation Programs

LADWP develops cost effective programs to achieve multiple goals of cost-effective demand reduction, customer service, environmental responsibility, and compliance with CUWCC BMPs. Conservation potential is considered in determining program approach and duration. Some types of conservation programs result in savings that are more easily measured than others. LADWP's programs include traditional demand-side management measures, as well as infrastructure improvement programs that contribute to water waste reductions. Demand-side management programs, like the rebate programs for water-saving toilets and high-efficiency washing machines, produce results that are measurable. Public information, education, and other general conservation awareness programs are intended to alter customers' behavioral patterns on water use and thus, are more difficult to quantify. It is such behavioral change in water use, however, that the City can point to as the primary reason for significant reduction in water consumption during drought periods. Combined with LADWP's conservation pricing

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structure discussed in Section 3.2.2, these programs increase system reliability and efficiency and will provide a secondary benefit of reducing runoff.

Specific conservation programs (past and present) associated with these categories are broken down in Exhibit 3G, and are fully discussed below. Appendix XX contains the latest biennial reports provided to the CUWCC.

Exhibit 3G
Current and Past Conservation Programs

CUWCC Category	Conservation Measures	pre 1985	Year in Service
	Awareness/Support		
	Pricing		
Utility Operations - Pricing and Operations	Tiered Rate Structure		2009
Utility Operations - Metering	Full Metering and Volumetric Pricing	x	
Utility Operations - Pricing	Sewer Charge using Volumetric Pricing	x	
Education - Public Information Programs	**Public Information**		
	Drought Response Outreach		2008
	Hotel & Restaurant Water Conservation Campaign		2008
	ULFT Customer Satisfaction Survey		1992
	Advertising	x	
	Bill Inserts	x	
	Brochures	x	
	Community Involvement Program	x	
	Exhibits	x	
	Hotline	x	
	Speakers Bureau	x	
	School Education		
	LAUSD MOU		2008
	High School in concert with the Environment - Student Home Water/Energy Survey		1994
	Lower Elementary	x	
	Upper Elementary	x	
	Junior High	x	
	Residential		
Residential	Residential Drought Resistant Landscape Incentive Program		2009
Residential	High Efficiency Clothes Washer Incentive Program		1998
Residential	Better Idea/Neighborhood Bill Reduction Service Program --Showerhead installation		1993
Residential	Community-Based Organization Toilet Distribution Centers, Direct Install		1992
Residential	High Efficiency Toilet Rebate		1990
Residential	Home Water Surveys		1990
Residential	Retrofit Kits Distribution		1988

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Commercial/Industrial/Government			
Commercial/Industrial/Institutional	Commercial/Industrial Drought Resistant Landscape Incentive Program		2009
Commercial/Industrial/Institutional	Water Efficiency Requirements Ordinance		2009
Commercial/Industrial/Institutional	General Services Dept. MOU to Retrofit Plumbing		2009
Commercial/Industrial/Institutional	Public Agency Plumbing Audit and Training Program		2009
Education - Public Information Programs	Targeted Literature Mailing		1993
Commercial/Industrial/Institutional	Commercial/Industrial Conservation Guidebook		1992
Commercial/Industrial/Institutional	Cooling Tower Manual and Workshops		1992
Commercial/Industrial/Institutional	Commercial Rebate Program		1991
Commercial/Industrial/Institutional	Interior Water Use Audits		1991
Commercial/Industrial/Institutional	Technical Assistance Program (TAP)		1991
Landscape; Commercial/Industrial/Institutional	Typical Audits		1991
Landscape			
Landscape	Recreation and Parks MOU		2007
Landscape	Large Turf Irrigation Controller Pilot Program		2000
Landscape	Protector del Agua – English and Spanish Language Workshops		1995
Landscape	Improving Irrigation Performance Manual & Workshop		1993
Landscape	Large Turf Audits and Audit Training		1993
Education - Public Information Programs	Lawn Water Guide Direct Mailing (as requested)		1989
Education - Public Information Programs	Demonstration Gardens		1988
Landscape	Ten Percent Large Turf Water Reduction Program		1988
System Maintenance Measures			
Utility Operations - Water Loss Control	Fire Hydrant Shutoffs		1991
Utility Operations - Water Loss Control	Meter Replacement Program		1988
Utility Operations - Water Loss Control	Cement Mortar Lining of Pipelines	x	
Utility Operations - Water Loss Control	Corrosion/Cathodic Protection	x	
Utility Operations - Water Loss Control	Infrastructure Program	x	

Awareness/Support Measures

Awareness/support measures can be active or passive. Active components include full metering of water use, assessment of volumetric sewer charges, and a conservation rate structure. Passive components typically include providing educational materials for schools, community and customer presentations, maintaining a conservation hotline, and a wide range of information distributed through customer bills, advertising in public venues, LADWP's website, and direct mail. Passive awareness/support measures provide the foundation for the conservation movement to build upon by raising water use awareness, water conservation program visibility, and encouraging community involvement.

In 2008, LADWP entered into an MOU with the Los Angeles Unified School District to further improve our water conservation outreach program. In fiscal year 2009/2010 LADWP budgeted approximately $500,000 in funding for educational programs within area schools. Programs included:

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- Los Angeles Times in Education – provided newspapers to 50,000 students in grades 4-12 and lesson packages for teachers on supply sources and conservation
- "Thirsty City" Live Performances – Play presented to more than 4,300 students introducing students to water supply sources, water supply challenges, and conservation
- Renewable Energy and Conservation Curriculum – 660 teachers were trained in an extensive model conservation program reaching approximately 50,000 6th grade students
- Renewable Energy and Conservation Center – Funding was provided for a science teacher position to set up and establish a Renewable Energy and Conservation Center with students to be bused to center for hands-on lessons focusing on conservation and renewable energy
- Outdoor Education Multi-Day Environmental Experiences – Approximately 700 students in 20 classes in grades 4-12 attended two or three days of outdoor education experiences focusing on environmental measures, including lessons on energy and water
- Eastern Sierra Institute – Training of 25 teachers over three days about the environment and geology of the Eastern Sierra
- Teacher Fellowships – Ten math and science teachers from middle and high schools served in fellowships at LADWP for six weeks during the fall and summer of 2008 working in multiple offices with the intent of developing classroom lessons based on the experiences.
- Infrastructure Academy – 40 students from the Infrastructure Academy completed water conservation audits at 120 schools, including fixture counts, analysis of toilet makes and models, and analysis of irrigation controllers and field conditions

Included within the short-term strategies of the City of Los Angeles' Water Supply Action Plan is a strategy to increase water conservation in the City through an aggressive $2.3 million conservation education campaign. LADWP Public Affairs Office implemented a media campaign that included radio, TV, and newspaper advertisements, billboards, outreach to Neighborhood Councils; and marketing of City rebates for water-efficiency.

Another aspect of awareness/support is that of advocacy. LADWP has been instrumental in the development of more stringent standards for toilets (e.g. Supplementary Purchase Specification for ULF toilets) that are in use within the City as well as by other water agencies in California and other areas. LADWP also assisted in the adoption of higher residential clothes washer efficiency standards by the California Energy Commission. Recognizing the importance of this activity, LADWP actively participates in advocating local and statewide conservation research and planning.

Residential Category

Multiple residential conservation programs were first developed and launched by LADWP during the drought of 1987 through 1992. In 1990, the ULF Toilet Rebate Program was initiated, followed two years later by the ULF Toilet Distribution Program. In 2003, a well-received free installation service component was added to the ULF Toilet Distribution Program that included

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free water-saving showerheads, faucet aerators and replacement toilet flapper valves. Today distribution of free faucet aerators and showerheads continues for all single-family, multi-family, and commercial customers.

In 2008 MWD initiated the region-wide SoCal Water$mart Program for residential water conservation replacing previous LADWP rebate programs and rebate programs offered by individual water service providers throughout the MWD service area. This program sponsored by MWD sets uniform rebate requirements across the MWD service area and provides a clearinghouse for processing rebates for all MWD member agency customers. Local agencies have the option of supplementing baseline rebate amounts to their customers through the program. LADWP has increased baseline rebates for several of the qualifying products. Eligible customers include residential customers residing in single-family and multi-family homes, even if multi-family residents do not receive a water bill.

Although the SoCal Water$mart Program has discontinued rebates for high efficiency toilets (HET), LADWP continues to provide local funding for rebates for its customers of $100 per HET which has proven to be highly successful with over 1900 units installed in fiscal year 09/10 which equates to over 80 AFY savings.

Prior to the SoCal Water$mart Program, LADWP was assisted by community-based organizations (CBOs) to reach the milestone of more than 1.27 million toilets installed through December 31, 2006. CBOs were integral to LADWP's success, reaching into the communities they serve to convey the conservation message and directly undertake conservation activities. Benefits of this approach accrued to community participants through reduced water bills, to the CBOs through employment opportunities and revenues earned, and to the City through significant water savings achieved. Prior to its discontinuation, the program was funded at more than $7 million annually. The toilets replaced through the program continue to produce estimated water savings of more than 20,600 AFY today.

LADWP initiated a High Efficiency Washer Rebate Program in 1998 promoting the purchase and installation of high efficiency washing machines saving both water and energy. As of January 2009, rebates have been paid for more than 66,100 machines purchased and installed throughout the City. The program's minimum efficiency requirements for rebate eligibility were increased in January 1, 2004, resulting in the promotion of higher efficiency models. Initial co-funding of the program was provided by the City's Department of Public Works Bureau of Sanitation, and by the Southern California Gas Company.

In February of 2009 the High Efficiency Washer Rebate Program transferred from LADWP to the SoCal Water$mart Program with co-funding provided by MWD. Since the inception of the SoCal Water$mart Program and through June 2010, over 11,800 rebates for washing machines were issued to LADWP customers with a total annual savings of 368 AFY. Generally rebates are $300 per washing machine with a water factor (a measure of efficiency) of 4.0 or less. As of April 22, 2010 an additional $100 rebate was available for a limited time through the California Cash for Appliances program for a total rebate of $400 per washing machine.

A sprinklerhead rotating nozzle retrofit rebate of $8 per nozzle is available through the SoCal Water$mart Program for a minimum of 25 nozzles. Replacing standard sprinkler heads with rotating nozzles can use up to 20% less water. Rotating nozzles are able to distribute water in a water-efficient manner more uniformly across a landscape than standard sprinklers. Spray from rotating nozzles is less likely to result in misting conditions, misdirection from winds, and reduces runoff onto pervious surfaces thus reducing dry-weather runoff. Between March 2009 and June 2010 2,878 rotating nozzle rebates were issued to LADWP customers saving approximately 12.7 AFY.

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Rebates for installation of weather-based irrigation controllers are also available through the SoCal Water $mart Program. Rebates amounts are $200 per controller for landscape areas of less than one acre and $25 per station for landscape areas greater than one acre. Weather-based irrigation controllers provide customized irrigation schedules based on local site conditions and in response to weather changes. These smart controllers receive weather updates to automatically adjust the schedule and amount of water applied. Between March 2009 and June 2010 81 LADWP customers received rebates for installation of the controllers saving approximately 6.2 AFY.

Initially a synthetic turf rebate program was offered through the SoCal Water$mart Program, but has been discontinued as of June 1, 2010. The program provided rebates of $1.00 per square foot. Approximately 316,547 square feet of synthetic turf was installed by LADWP customers between February 2009 and June 2010 saving approximately 44.3 AFY.

LADWP through the SoCal Water$mart program is offering turf removal rebates of $1 per square foot up to $2,000 per residence. Not all MWD member agencies are participating in the turf removal program and participating agencies have additional requirements beyond MWD's requirements. Areas targeted for turf removal must currently be turf irrigated with potable water for a minimum of one year. All replacement materials must be permeable and either hand watered or irrigated with drip irrigation. A minimum of 250 square feet must be converted to be eligible for a rebate. No invasive plants are permitted and all exposed soil must be covered with mulch. Synthetic turf is an acceptable replacement if it is not used in right of ways or parkways. Applicants are required to maintain the converted area for ten years. The program commenced in December 2009, and as of fiscal year 09/10, over 280,000 square feet of turf area has been converted saving over 39 AFY. In conjunction with the turf removal program, LADWP is conducting a drip system pilot program and is offering free residential drip starter kits.

Water-saving showerheads and faucet aerators remain available to LADWP customers, free of charge, upon request. Approximately 12,124 showerheads and 14,792 faucet aerators were distributed between July 2007 and June 2010 saving approximately 241 AFY. During past droughts, more than 1.5 million water conservation retrofit kits were distributed throughout Los Angeles; the kits included one-gallon toilet displacement bags, low-flow showerheads, and toilet leak detection tablets.

As part of past programs promoting residential water conservation measures, students conducted home water surveys through a resource efficiency education program implemented by LADWP in Los Angeles area high schools. Additionally, local community based organizations visited many Los Angeles residences throughout the year, assessing water conservation opportunities in the home and installing applicable measures to immediately capture water savings.

Another element of LADWP's past efforts was a toilet flapper valve replacement pilot program. Although long-term water savings from ULF toilets are predicated on timely replacement of leaking toilet flapper valves with appropriate replacement units, findings from the pilot program indicate a small incidence of leaking flapper valves in toilets rebated or distributed by LADWP. However, toilet leak testing and flapper valve replacement was added to the past ULF Toilet Distribution Program's installation service component for toilets not replaced through the program.

Commercial/Industrial/Institutional Category

This category represents some of the largest volume water users in LADWP's customer base, and represents a great deal of conservation potential. LADWP, in partnership with MWD, developed and has implemented a commercial rebate program, Save Water Save a Buck Program, designed specifically for customers in the CII sector and multi-family residences with five

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or more units represented by a homeowners association. In the CII sector, the program provides rebates for water saving plumbing fixtures, food service equipment, and landscaping equipment. Within the multi-family sector the program provides rebates for high efficiency washers, high efficiency toilets, and landscape equipment. In addition, packaged water use efficiency solutions are being developed for specific business sectors. Efforts are also underway to better promote the financial incentives available that make water conservation retrofits more cost effective for business and industry. LADWP takes full advantage of regional programs offered through MWD for the CII sector and for many product rebates, provides supplemental funding to boost the base rebate provided by MWD.

The Save Water Save a Buck Program was launched in 2001 to provide menu-based rebates for water conserving measures applicable to many types of CII facilities. Categories of products eligible for rebates, rebate amounts, number of rebates for the LADWP service area, and estimated savings are provided in Exhibit 3H for the period July 2007 through June 2010. During the period, an estimated annual savings of 6,585 AFY, inclusive of LADWP inhouse programs and the Technical Assistance Program (TAP). The program design provides for ease of participation and has been well-received by LADWP customers. The program has been so successful that the SoCal Water$mart Program for residential customers was modeled after it.

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Exhibit 3H
CII Conservation Programs and Savings July 2007 through June 2010

Device Type	Rebate Amount Retrofit	Devices Installed	Estimated Annual Savings (AFY)
Save Water Save a Buck Program			
Current Programs			
High Efficiency Toilets (1.28 gpf or less)	$150 each ($50 new construction)	58,432	2,408.6
Zero and Ultra Low Water Urinals	$500 each ($250 new construction)	6,063	630.9
Cooling Tower pH Conductivity Controller	$3000 each	41	79.7
Cooling Tower Conductivity Controller	$625 each	57	36.7
Air Cooled Ice Machine	$300 each	0	0.0
Connectionless Food Steamer	$600 compartment	23	5.8
Dry Vacuum Pump (maximum 2.0 horsepower)	$125 per 0.5 horsepower	8	0.7
Water Broom	$150 each	73	11.2
Weather Based Irrigation Controller	$50 per station	391	127.1
Central Computer Irrigation Controller	$50 per station	0	0.0
Rotating Nozzles for Pop-up Spray Heads (25 minimum)	$8 each	22,534	99.1
High Efficiency Spray Nozzles for Large Rotary Sprinklers	$13 per head	8,558	308.1
Past Programs			
High Efficiency Coin Clothes Washer	-	1,738	186.8
Pre-Rinse Sprayhead	-	5	0.8
Steam Sterilizer Retrofit	-	6	7.8
X-Ray Processor Recirculation System	-	1	3.2
Synthetic Turf (square feet)[1]	-	15,177	2.1
Subtotal Save a Buck Program	-		**3,908.7**
LADWP Inhouse Programs			
Commercial Showerheads	-	5,180	85.3
Commercial Faucet Aerators	-	20,844	96.5
Water Brooms	-	262	40.2
CII Landscape Program Turf Removal[2]	-	1,251,043	95.6
Technical Assistance Program[3]	-	-	2358.4
Subtotal LADPW Inhouse	-		**2676.0**
Total CII	-		**6584.8**

1. Synthetic Turf rebates as of June 1, 2010 are available through LADWPs Technical Assistance Program.

2. Rebate amount varies and is determined during pre-approval process.

3. Rebates for Technical Assistance Program are $1.75 per 1,000 gallons saved over a two year period with a cap not to exceed the actual cost of the project. Devices installed vary per project.

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LADWP created the Technical Assistance Program (TAP) in 1992 to provide custom-type incentives for retrofitting water-intensive equipment. Different from the Save Water Save a Buck Program, the TAP encourages site-specific projects and TAP incentives are based on a given project's water savings. Financial incentives up to $250,000 are available for products demonstrating water savings. Incentives are calculated at the rate of $1.75 per 1,000 gallons saved over a two-year period with a cap not to exceed the actual cost of the installed product. Projects must save a minimum of 150,000 gallons over a two-year period and operate for a minimum of five years. Eligible customers are CII or multi-family residential customers. Past TAP projects include cooling tower controller upgrades and x-ray processor recirculation systems. The estimated unit cost for TAP overall is about $228 per acre-foot saved with an annual savings of 2,358.4 AFY based on projects installed between July 2007 and programs until June 2010.

Similar to the residential turf removal program, LADWP has a turf removal program for commercial properties. This program started in September 2009 and the rebate is $1.00 per square foot of turf with the total project rebate amount as defined in the pre-approval letter provided by LADWP. Areas targeted for conversion must have live healthy turf irrigated with potable water (recycled water is ineligible) via automatic sprinkler valves when a project approval letter is provided by LADWP. Converted areas must contain enough plants to create at least 30% landscape coverage at maturity. Converted areas may not contain turf or synthetic turf (synthetic turf rebates are available through the TAP). All replacement materials must be permeable and plants must be drought tolerant or California native plants. A minimum of 250 square feet must be converted to be eligible for a rebate. No invasive plants are permitted and all exposed soil must be covered with three inches of mulch. If an irrigation system is used it must be a low flow drip or bubbler system. Applicants are required to maintain the converted area for 15 years.

Water-saving showerheads and faucet aerators are available to LADWP commercial customers, free of charge, upon request. Bathroom faucet aerators are provided in 1.5, 1.0, or 0.5 gallons per minute (gpm), kitchen faucet aerators are provided in 1.5 gpm, and showerheads are provided in 2.0 gpm. Approximately 5,180 showerheads and 20,844 faucet aerators were distributed between July 2007 and June 2010 saving approximately 181.8 AFY combined. LADWP additionally offers an inhouse water broom program in addition to the rebates offered through the Save Water Save a Buck Program.

Landscape Category

Recognizing that a substantial amount of water is used outdoors for irrigation, LADWP continues to invest in landscape irrigation efficiency programs and projects. In addition to the previously discussed landscape ordinances (Section 3.21.), LADWP has sponsored free training courses specifically targeting the City's large turf customers to help these customers comply with the landscape ordinance. To further assist this group, LADWP developed a guidebook, "Improving Irrigation Performance" to demonstrate ways for enhancing existing irrigation systems.

LADWP has also sponsored conservation and garden expos to highlight various aspects of efficient outdoor water use and planting practices, and emphasizing native, drought-tolerant plants. Funding was provided for three demonstration gardens to showcase the use of drought-tolerant plants and flowers, including the landmark Lummis Home in Highland Park. Lawn watering guides were mailed to all single-family and duplex residences. Planting guides for native and drought-tolerant plants are also available upon request. Additionally, to demonstrate the beauty and appeal of a water-conserving landscape, LADWP's John Ferraro Building facility (below) has a drought-tolerant garden that is open to visitors year-round.

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In addition to the Residential and Commercial Landscape Incentive Programs for turf removal, other types of landscape irrigation improvement projects are also funded through the TAP, with incentives calculated on the basis of a project's water savings. LADWP staff includes certified landscape auditors, and large landscape audits are available upon request.

LADWP is also investigating new programs using data obtained through pilot program efforts. A pilot program was conducted to determine the effectiveness of weather based irrigation controllers in large landscape applications. On the basis of the pilot program results showing water savings, financial incentives are available to LADWP customers for the purchase and installation of weather based irrigation controllers through the SoCal Water$mart and Save Water Save a Buck Programs. Additional efforts are being undertaken to make available a landscape irrigation education program for homeowner associations and other large landscape customers. This program would focus on common green areas in multi-unit complexes to improve irrigation efficiency, including irrigation system maintenance and repair, and plant selection.

LADWP has been implementing an internal program to retrofit outdoor landscaping at department-owned facilities to California-friendly and native plantings with efficient irrigation systems. Additionally, a joint effort between the Department of Recreation and Parks and LADWP is targeting public parks through the City Park Irrigation Efficiency Program. City parks with inefficient irrigation systems, leaks, and runoff problems are identified and upgraded with water efficient distribution systems and sprinkler heads, installation of smart irrigation controllers, and planting of California-friendly landscaping. Since the program began in 2007, seven parks have been completed and 4 new weather stations have been installed. An additional benefit of this program is the educational, trade training, and employment opportunity given to the youth of Los Angeles.

There is also potential for the use of non-potable water for irrigation, which can help extend the utility of the City's traditional water supplies. Through increased stormwater capture, groundwater recharge with captured storm and irrigation runoff, and recycled water, imported surface water and local groundwater used for landscape irrigation can be conserved. The potential to use such non-potable water supplies is further discussed in the Recycled Water and Watershed Management chapters (Chapters 4 and 7 respectively).

New Low Impact Development (LID) projects implemented within the City and innovative work by non-profit organizations demonstrate pioneering ways to conserve water for landscapes. As discussed in Chapter 7, LADWP's Watershed Management Group is proactively developing programs in conjunction with other departments to highlight water conservation through LID and implementing stormwater Best Management Practices (BMPs). A local non-profit, TreePeople, has partnered with various City departments, including LADWP on a number of stormwater capture projects.

For over a decade, TreePeople has demonstrated that rainwater is a viable local water resource. The Open Charter Elementary School Stormwater Project is one of several sustainable stormwater management systems that TreePeople installed in Los Angeles. Other examples include: the Center for Community Forestry which harvests rainwater from its entire hardscape into a 216,000 gallon underground cistern for landscape irrigation use; a retrofitted single family residential home in South Los Angeles that captures a 100 year storm event on site; a 7,600 square foot subsurface stormwater infiltration gallery on the Broadous Elementary School campus in Pacoima. Most recently, TreePeople partnered with the Los Angeles and San Gabriel Rivers Watershed Council, LADWP, and other state and federal agencies to retrofit an entire residential block on Elmer Avenue in Sun Valley. This project now intercepts stormwater from 40 acres upstream and infiltrates it back to the aquifer while also demonstrating effective distributed stormwater BMPs on residential homes.

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In partnership with the Los Angeles County Department of Public Works, TreePeople was instrumental in developing the Sun Valley Watershed Management Plan: an alternative stormwater management plan that prioritizes green infrastructure and multi-benefit stormwater capture projects instead of stormdrains. Many projects have been completed, and more are scheduled for construction. These activities create the foundation that will lead to further landscape water conservation and stormwater capture to enhance the City's limited water supplies.

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CASE STUDY:
Los Angeles River Revitalization and the North Atwater Park Project

Background

The Los Angeles (LA) River flows 51 miles through some of the most diverse communities in Southern California—its first 32 miles are within the City of LA. The River has a year-round low flow due to contributions from upstream wastewater treatment plants, urban runoff, groundwater inflow, and natural springs, but can become a torrent of racing flows during the rainy season. The River is almost entirely concrete-lined except for a few reaches. Although the design of the River has served its flood control purpose, the River holds far greater potential to serve as a focal point for environmental restoration, economic growth, community revitalization, and recreation.

Realizing that the River should stand as a symbol of pride for the City of LA and its residents and that it should be a landmark for the public to enjoy and admire, the LA City Council established the Ad Hoc Committee on the River in 2002 and adopted the LA River Revitalization Master Plan (LARRMP) in 2007 (www.lariver.org). Led by the City's Bureau of Engineering and funded by the LA Department of Water and Power, the LARRMP was created through a collaboration of elected officials, city departments and agencies, residents, multi-disciplinary experts, and a wide variety of private and non-profit environmental and recreational groups as the 25-to-50 year blueprint for transforming the City of LA's stretch of the River into an extensive network of parks, walkways, bike paths, and diverse land uses that will ensure the growth and sustainability of healthy communities.

Key Features

In October 2010, the City celebrated the groundbreaking of the North Atwater Park Expansion and Creek Restoration project as the first project to emerge from the LARRMP, which is expected to be open to the public by December 2011. The project was undertaken in connection with the settlement of two Clean Water Act enforcement action, Santa Monica Baykeeper v. City of Los Angeles and United States, and State of California ex. Rel. California Regional Water Quality Control Board, Los Angeles Region v. City of Los Angeles and also funded in part by Proposition 50 through the California Resources Agency to improve River Parkways and the Integrated Resources Water Management. The project will use both structural and natural solutions to restore a degraded creek that is a tributary of the River while also expanding River-adjacent parkland with multiple recreational, wildlife habitat, and water quality benefits. The project will add nearly 3 acres to an existing 5-acre City park, connecting it to the River, where visitors will enjoy watching a wide variety of bird species that presently live in that soft-bottomed stretch of the River, framed by stunning views of Griffith Park in the distance. Some of the project's highlights include:

Outdoor Classroom

The project will encourage young children to explore nature via an educational gathering space near the LA River. This "outdoor classroom" will feature a nature-based art area for independent and guided activities—designed particularly for local students to learn about nature, native plants, and the opportunities and challenges associated with revitalizing the LA River.

Native Demonstration Garden

The park's central focus will be a demonstration garden, which will contain a variety of native plants that are used throughout the park, with interpretive displays to educate visitors about the plant species' characteristics, care, and relationship to water conservation. The park will only include native plants because they are considered "drought-tolerant" given their abilities to thrive in Southern California's climate, requiring much less water than other plants. The park's landscape design aims to set an example in the use of such plants, but also to educate the public on the merits of embracing native vegetation as an important component of solving the region's water crisis.

Creek Restoration

North Atwater Creek currently conveys polluted runoff to the River from an upstream stormdrain system that receives flow from a 40-acre urban area. The Creek will be restored and landscaped with native plants to prevent erosion and to naturally filter stormwater before it is discharged to the River, featuring a 1000-foot-long meandering streambed sustained by intermittent street runoff flows. Water quality improvements will include installation of a device at the entrance of the creek to intercept and capture trash and bacteria and special treatment of flows from adjacent equestrian facilities.

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Accommodating Visitors

While the park's landscape design capitalizes on the opportunity to educate visitors about the many connections between urban life, nature, and water, its structural features do also. For example, the parking lot will be transformed by installing a gravel bioswale along the borders and replacing existing parking spaces with permeable surfaces. These changes will not only address surface water contamination, but also allow stormwater to infiltrate so that it will assist with groundwater augmentation.

Summary

The North Atwater Park project will utilize innovative Low Impact Development (LID) and Best Management Practice (BMP) technologies to simultaneously achieve a variety of benefits, including responsible water conservation, improved water quality, expanded wildlife habitat connectivity, co-located multi-generational recreation, and public education.

The park's goals recognize that, while it is important to transform the existing park into a beautiful, scenic landmark and natural resource, it is equally important to educate the public about the huge potential such achievements have in encouraging wiser water use practices. Fundamentally, the park is about water—respecting LA's water supply and celebrating the River—by simultaneously improving the survivability of our wildlife and human habitat. North Atwater Park is an example of what can happen when public agencies and residents tackle complicated problems with creative planning and successful collaboration.

"The LA River cause is reaching more and more people every day. We are incredibly encouraged by the USEPA's July 2010 decision regarding the River's federal protection status and particularly because of the context in which it was announced—President Obama's America's Great Outdoors initiative is exactly the kind of support we need now and the visit of so many distinguished Administration officials to the River reinforces the belief that the River is important to millions of people here and across the country."

Carol Armstrong, Ph.D., Environmental Supervisor, Project Manager, LA River Project Office

"The City's commitment to LA River revitalization has only gained in momentum over the years and we have now reached an important crossroads for answering the big questions—such as how to capture and reuse storm flows, how to expand our recycled water uses, how to ensure we have enough water to maintain critical wildlife habitat, and how much flood capacity can we add? The River is central to each and every one of the answers."

Larry Hsu, P.E., Senior Civil Engineer, Project Manager, LA River Project Office

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System Maintenance Category

Maintaining system infrastructure reduces water waste and allows for greater water accountability. Infrastructure maintenance is a high priority for LADWP. On-going programs such as pipeline replacement, pipeline corrosion control, and meter replacement preserve the operational integrity of City water facilities, and aims to reduce unaccounted water losses.

In recent years, the LADWP has ramped up its pipeline replacement program from 70,000 LF annually to 130,000 LF annually. LADWP has also made significant progress in replacing and/or retrofitting water meters through its meter replacement program that started in 1988. As a result of extended flow or usage, the moving parts in a water meter can wear down and begin to under-register the actual water consumption. The meter replacement program has been valuable in ensuring the accuracy of the approximately 700,000 meters within the City. Recently, all of the large-sized meters (3-in and larger) in the system were replaced as part of a Large Meter Replacement Program, and the LADWP is also replacing 35,000 small meters annually.

3.3 Future Programs, Practices, and Technology to Achieve Water Conservation

LADWP, on its own, and in cooperation with other agencies continues to investigate future programs, practices, and technology to improve water conservation.

3.3.1 Graywater

As defined by State regulations, graywater is untreated household wastewater which has not come into contact with toilet waste or unhealthy bodily wastes. It includes water sources from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs. It specifically excludes water from kitchen sinks and dishwashers. Graywater is a drought-proof source of supply for subsurface landscape irrigation. Graywater regulations do not allow for its application using spray irrigation. Graywater is also not allowed to pond or runoff, discharge to or reach a storm drain system or surface water body, and is not permitted for irrigation of root crops or edible food crops that are directly in contact with the surrounding soil.

The Graywater Systems for Single Family Residences Act of 1992 legally incorporated the use of graywater as part of the California Plumbing Code. In September 1994, the City approved an ordinance that permitted the installation of graywater systems in residential homes. However, installing graywater systems under the Act was costly in terms of both installation and maintenance. To address the current water shortage and reduce water demands, emergency graywater regulations added Chapter 16A (Part I) "Nonpotable Water Reuse Systems" to the 2007 California Plumbing Code. These regulations were approved by California Building Standards Commission in 2009 and became effective on August 4, 2009. Further revisions were made to the regulations and the regulations became permanent on January 12, 2010 with an effective date of January 20, 2010. These new code changes allow the use of certain types of untreated graywater systems as long as specific health requirements are met as defined by the authority having jurisdiction. The ordinance can be acquired from the City of Los Angeles Department of Building and Safety (LADBS) website at the following link.

http://ladbs.org/LADBSWeb/LADBS_Forms/InformationBulletins/IB-P-PC2008-012Graywater.pdf

Graywater systems in residential buildings are regulated by LADBS. LADBS requires a plumbing permit prior to construction, reconstruction, installation, relocation, or alteration of any graywater systems, treated or untreated. As of fiscal year 2009-10,

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LADWP does not offer any rebates or incentives for graywater systems, but continues to assess the potential for this water conservation technology.

Untreated Graywater Systems

Untreated graywater systems are systems where graywater is collected from non-toilet and non-kitchen sources and is utilized without treatment, for uses such as landscape irrigation. According to a 1999 study prepared by the Soap and Detergent Association, the average untreated graywater system in the US uses 6.3 gallons per day. In a 2010 White Paper prepared by Bahman Sheikh, for the WateReuse Association, Water Environment Federation, and American Water Works Association the potential for graywater generation in 2030, adjusted for conservation devices, is estimated at approximately 75.5 gallons per household per day. Potentially 50 percent of indoor potable water use could be re-used as graywater. Multiple manufacturers have developed untreated graywater systems and many households have installed such systems. However, these systems are not typically monitored, thus health and safety risks associated with the products have not been determined.

Under the recently approved revisions to the graywater system regulation, LADBS does not require a permit for untreated graywater systems supplied by only a clothes washer in a one or two-family dwelling as long as the system does not require modification of existing plumbing. Multiple requirements must be met for a system to be exempt from a permit including, but not limited to:

- Discharge shall be released not less than two inches below the surface of rock, mulch, or soil;
- Designs shall incorporate a means to allow the user to divert flow to the disposal area or the building sewer;
- Design of the system shall not allow contact with humans or pets;
- Water from diapers or other similarly soiled or infectious garments shall be diverted to the building sewer;
- Hazardous chemicals from washing activities, such as soiled rags, shall be diverted to the building sewer;
- An operation and maintenance manual shall be provided and remain with the building.

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CASE STUDY:
Single-Family Home Graywater System

As a community environmental leader, Janie Thompson is taking extraordinary steps in efficient use of water and conservation. With the help of her husband, her household has become an excellent example of a rainwater capture residence, catching rain in 18 separate rain barrels with 60 gallons each. To save even more water, the couple is installing an impressive graywater network, distributing water to the furthest extent of their large 14,850 square foot property.

"In June 2009, when the Mayor announced the ordinance limiting watering to two days per week, we freaked out, and originally thought most of our landscaping would die. With all of our conservation, rainwater capture, and use of graywater, our usage has dropped from 117 hcf to around 54 hcf per month in the summer months. We couldn't be happier. It just goes to show you how much most people in the City over water." – Janie Thompson

Their existing graywater system currently uses the drainage pump from the clothes washer to pump water slightly up grade to tree and flower areas of the backyard. Upon exiting the washer, a 3-way valve reserves the option to divert washer effluent to the sewer system. The graywater piping travels beneath their raised foundation home, into the subsoil, and onto the areas it serves. Once construction is complete, all piping (left) will be buried with existing soil or mulch.

When the stream is pumped to the highest point of the yard, it is sent to numerous subsoil infiltration chambers, through a distribution system of 1" HDPE (High-density polyethylene) pipe. The infiltration chambers are made from 1 gallon paint buckets turned upside down with holes cut in the bottoms (below). The chambers allow for unobstructed exit flow and appropriate soil surface area for infiltration. In addition, they provide a significant volume for water storage during the surge of a pumped load of laundry. Plant roots are attracted toward these water outlets, essentially feeding on nutrients and organics in the graywater. The tops of the chambers are cutout for frequent access, and covered with mulch or stepping stone. The pipe exits can be checked as necessary to ensure free flow.

The next steps in the construction are connection of the bathtub and bathroom sinks. Effluent from these water sources will enter a surge tank and float switch assembly. A graywater dedicated pump will then automatically push water to existing and newly installed infiltration chambers throughout the yard.

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Graywater used from these indoor sources will provide two main benefits. It will displace water used for irrigation and prevent additional water from entering the sewer. This decreases the load on the City sewer system lowering the overall cost of treatment for the Bureau of Sanitation.

The water savings are approximated in the following table. Please note that the clothes washer is a high efficiency front loading model. Showers are estimated at 10 minutes long with a head using 2.5 gallons per min.

Yearly Water Savings				
Washer	14 gal/use	10 uses/wk	140 gal/wk	7,280 gal/yr
Bathtub	40 gal/person/day	3 people	840 gal/wk	43,680 gal/yr
Bath Sink	2 gal/person/day	3 people	42 gal/wk	2,184 gal/yr
			Total	53,144 gal/yr

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Treated Graywater Systems

Treated graywater systems treat water collected from non-kitchen and non-toilet sources for nonpotable reuse indoors and outdoors. Treated graywater systems for indoor use of graywater are not currently permitted by LADBS as there are no water quality standards nor mean to certify onsite treatment systems. Testing agencies are working to address safety concerns while manufacturers are working to improve the technology gap in the systems. Both manufacturers and testing agencies are working together to address gaps in standards to allow the future use of treated graywater for outdoor surface irrigation and for indoor uses in toilets and urinals.

The National Center for Disease Control and Prevention in conjunction with North Carolina State University is developing a program to examine the public health values and impacts associated with decentralized water reuse at eight project sites across the country. Under this program wastewater from homes would be treated to Title 22 standards as required by local health regulators. One of the proposed sites is located in Los Angeles County.

On the international level, treated graywater systems are used in both Europe and Australia. However, treated graywater systems in the United States are not common. A lack of accepted standards for graywater systems imposes a financial risk to companies manufacturing graywater systems. The International Association of Plumbing and Mechanical Officials (IAMPO) and NSF International are the two testing agencies working to develop standards for uniform treated graywater systems applicability in the US. LADWP is closely following the development of the NSF Standard 350 and IAPMO standards to ensure that once a set of standards have been approved by model codes and adopted by the Building Standards Commission, the citizens of Los Angeles can safely install treated graywater systems to maximize water reuse without any health and safety risks.

3.3.2 Demand Hardening

Although LADWP regularly assesses new water conservation opportunities, conservation programs may, at some point in time, diminish a customer's ability to further conserve water, in particular during short-term water supply shortages caused by droughts or other emergencies. This phenomenon is known as "demand hardening." The California Urban Water Agencies defines demand hardening as, "the diminished ability or willingness of a customer to reduce demand during a supply shortage as the result of having implemented long-term conservation measures." Long term conservation measures can include hardware conservation measures, such as the installation of high efficiency toilets and behavioral conservation, such as watering during specified periods of the day.

Demand hardening occurs when options available for reducing water use are limited as the customer base is saturated with hardware conversions causing efficient water usage patterns to prevail. During "dry" years, utility customers who have actively participated in water conservation programs can be disproportionately impacted by water reductions as there is a limited ability for further conservation. The impact of demand hardening would be most prevalent during water supply shortages where customers have already been implementing long-term water conservation measures. Proponents of demand hardening believe that implementation and saturation of new hardware-based conservation devices would generally not occur rapidly enough during a water supply shortage, such as a drought, to reduce short-term water use.

However, it can be argued that hardware-based conservation devices will continue to be developed, piloted and implemented, such as the previously discussed weather based irrigation controllers, thus improving the ability to further conserve in the future. During droughts, consumers will respond to the call for more conservation by behaviorally adjusting their water use

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through methods such as not leaving water running and taking shorter showers. Additionally, full saturation of current conservation devices has not occurred. For these reasons, others believe demand hardening is irrelevant and there is a continued need for aggressive conservation programs.

Full implementation of current conservation measures, including reducing leaks, has the potential to reduce per capita water demands even further. Past water conservation efforts have reduced water use within LADWP's service area even though the population has continued to expand as illustrated in Exhibit 3A. It is expected that future water conservation efforts will continue this trend as increased saturation of water saving hardware devices occurs and new hardware devices are developed.

Though not easily quantifiable, saturation of current water saving hardware devices and installation of future water saving hardware devices combined with potential demand hardening have the ability to impact demand forecasts. As a worst case scenario, demand hardening and its effects are considered in LADWP's water demand forecasts to ensure that the appropriate supply of water is planned for. However, LADWP will continue to maintain its aggressive water conservation program discussed within this section. In the future, LADWP's water demand forecasts will continue to be examined and adjusted accordingly to compensate for additional implementation of long-term water conservation measures as saturation increases and new technology results in new hardware devices.

3.3.3 Projected Water Conservation Savings

To assist in planning future water demands, meeting the Water Supply Action Plan goal, and complying with 20x2020 requirements, LADWP has taken numerous steps to project future water conservation savings by major customer classification for indoor and outdoor use.

Indoor and outdoor active conservation through 2035 has been estimated by major billing sectors as provided in Exhibit 3I. Values presented are cumulative year to year. The bulk of conservation is expected to occur in the indoor portion of the commercial/government sector followed by the industrial sector. Past conservation programs have heavily focused on residential conservation reflecting the smaller residential conservation projections. Residential conservation initially provided the greatest volume saved for the cost. Water use in the CII sector is varied and relatively more expensive to achieve than in the residential sector.

Exhibit 3I
Active Conservation Projections by Sector

Sector	Acre-feet per Fiscal Year				
	2014/2015	2019/2020	2024/2025	2029/2030	2034/2035
Single-Family Residential	3,416	5,882	8,349	10,815	12,249
Multi-Family Residential	871	1,504	2,137	2,770	3,150
Commercial/Government	7,969	16,000	24,030	32,061	39,629
Industrial	1,924	3,847	5,824	7,774	9,339
Total Active Conservation Projections	14,180	27,260	40,340	53,420	64,368

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To determine potential conservation savings for indoor water use in the CII sector, LADWP conducted a high-level study to first estimate CII water use for each subsector (e.g. hospitals, refineries, schools, business parks, restaurants, etc.) and indoor end-use (e.g., toilets, showers, kitchen, laundry, food processing, cooling/heating, etc.), and second determine the potential for indoor water savings for each subsector and end-use. This study involved a sample of water use for approximately 150 of LADWP's largest CII customers to estimate total sector water use, along with employment data from Dunn & Bradstreet. Additional data sources listed below were used to determine indoor end-use estimates for each subsector, as well as the potential for water savings. :

- *BMP 9: A Handbook for Implementing Commercial Industrial & Institutional Conservation Programs.* (2001). California Urban Water Conservation Council.
- *Commercial and Institutional End Uses of Water.* (2000). American Water Works Association Research Foundation.
- *Waste Not, Want Not: The Potential for Urban Water Conservation in California.* (2003). Pacific Institute.
- *Water Efficiency in the Commercial and Institutional Sector: Considerations for a WaterSense Program.* (2009). U.S. Environmental Protection Agency.
- *Watersmart Guidebook---A Water-Use Efficiency Plan-Review Guide for New Businesses.* (2008). East Bay Municipal Utility District.
- *Santa Clara Valley Water District Commercial Institutional Industrial Water Use & Conservation Baseline Study.* (2008). CDM.
- *Water and Energy Efficiency Program for Commercial, Industrial, and Institutional Customer Classes in Southern California.* (2009). U.S. Bureau of Reclamation.
- *Water Use Efficiency Comprehensive Evaluation.* (2006). CALFED Bay-Delta Program.

The study concluded that by targeting just the top 100 or so largest CII users, approximately 4,600 AFY of water could be saved (representing about 3 percent of total CII water use). The study also found that the subsectors that use the most water in the city are: health care (18%), education (14%), food services/drinking places (9%), accommodation (5%), fabricated metal product manufacturing (5%), textile mills (5%), amusement (4%), and food manufacturing (4%). The study also concluded that the potential for indoor water conservation was approximately 23,000 AFY or 15 percent of total CII water use. Exhibit 3J presents the breakdown of this potential indoor water conservation for subsectors and end-uses.

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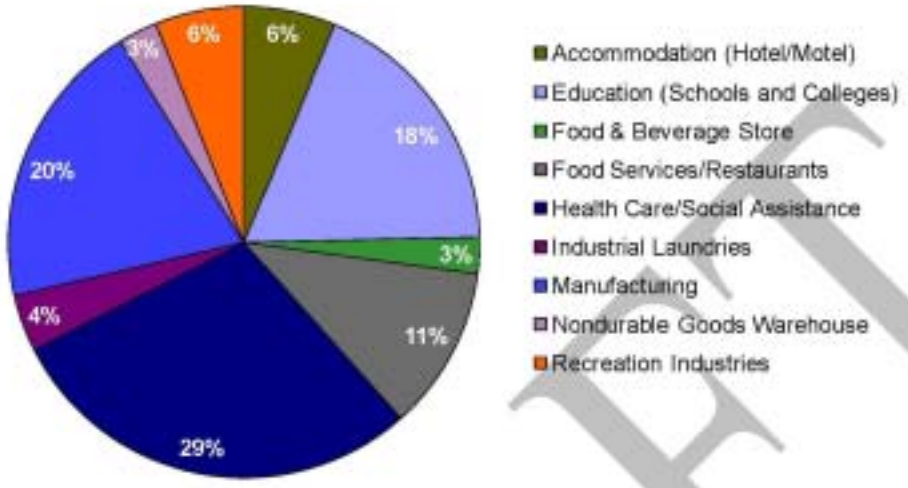
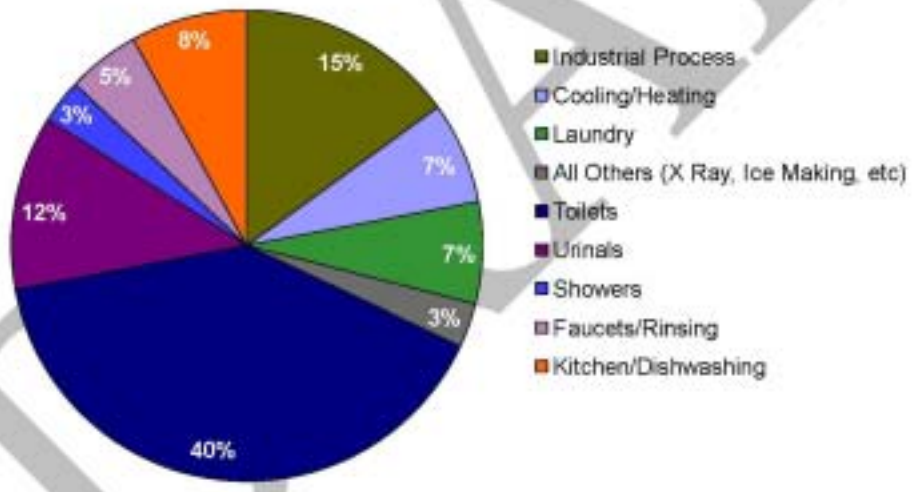
Exhibit 3J
Breakdown of Estimated CII Indoor Water Conservation Potential of 23,000 AF

Percent Water Saved per Subsector



Percent Water Saved per End-Use



Outdoor water use as a percentage of water use was approximated using three methodologies to determine the potential for outdoor water conservation savings. The methodologies and percent outdoor water use determined for each methodology are:

- Minimum-Maximum Methodology (outdoor water use is approximately 39.98%) – based on the premise that during wet months outdoor water use is minimal and during dry months outdoor water use is at its peak

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- Wastewater Treatment Plant Influent Methodology (outdoor water use is approximately 38.32%) – based on determining the average monthly influent flows to the City's four wastewater treatment plants during the dry-weather months of June through September and adjusting for contract agency flows and dry-weather stormwater diversions

- Infrared Analysis Methodology (outdoor water use is 39.67%) – based on an infrared analysis of the City to determine tree canopy and landscape coverages for use in estimating applicable water use requirements for greenscapes based on rainfall data, plant factors, evapotranspiration rates, and irrigation efficiencies

The resultant range between the low and high outdoor water use percentage is approximately 1.35%. This narrow range resulting from the three methodologies confirms the methodologies are fairly accurate.

Greenscape areas related to commercial and residential land uses are the most likely areas to be targeted for outdoor water conservation. Rehabilitation of these areas to meet or exceed the evapotranspiration adjustment factor (ETAF) of 0.7 as required in the Model Water Efficient Landscape Ordinance would result in significant savings ranging from 21,774 to 165,870 AFY. Currently, these savings are not represented in the projected active conservation in Exhibit 3I. Exhibit 3K illustrates the potential savings under three scenarios by customer sectors. Scenario 1 represents an improvement in average irrigation efficiencies and/or installation of less water intensive vegetation to achieve and ETAF of 0.7. Scenario 2 represents an improvement in average irrigation efficiencies and/or replacement of high water use vegetation with less water intensive vegetation in the moderate to low water use range to achieve an ETAF of 0.49. Scenario 3 represents an improvement in average irrigation system efficiency and replacement of all vegetation with very low water use vegetation almost entirely dependent upon effective precipitation to achieve an ETAF of 0.07. This would require incentive programs, such as cash for grass programs. Other large greenscape area, including parks, cemeteries and golf courses, were not considered in the analysis as they would more than likely be preserved as turf or tree canopy areas to retain quality of life benefits. These areas are likely to be targets for recycled water use.

Exhibit 3K
Potential Outdoor Water Use Savings by Sector

Customer Sector	Scenario 1	Scenario 2	Scenario3
	(AFY)		
Single-Family Residential	13,246	42,464	100,901
Multi-family	5,956	19,095	45,371
Commercial	2,573	8,247	19,597
Total	**21,774**	**69,806**	**165,870**

3.4 Cost & Funding

The average cost of conservation rebates, incentives, and hardware installation programs ranges from approximately $325/AF to $400/AF based on current LADWP conservation programs. More than $200 million has been invested in water conservation since 1991. Conservation is the cornerstone of LADWP's water demand management activities and ongoing investments will be made in viable programs, subject to funding availability and LADWP's ability to implement such programs. Outside sources of funding are sought to complement the City's resources. A stronger commitment is also being made to acquire outside grant funding for City conservation projects.

Currently, the funding sources for conservation are:

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- ***Water Rates*** – Water conservation programs are primarily funded through water rates.

- ***MWD Conservation Credits Program*** - MWD offers both commercial and residential rebates to member agency customers that install specified conservation devices. The rebates equate to $195 per AF of water saved, or half the project cost. In addition, MWD reimburses the LADWP for pre-approved projects when completed. In 2009 MWD reimbursed the Department $139,000 for a water broom distribution program. LADWP also expects to be reimbursed in 2011 through the MWD Member Agency Administered funding program for $968,000. The monies are reimbursement for 22.2 acres of turf reduction projects through the Department's Commercial/Industrial Drought Resistant Landscape Incentive Program.

- ***Outside Agency Co-Funding*** - Other agencies realizing benefits from conservation programs are solicited for co-funding of program costs.

- ***Grant Funding*** - LADWP has successfully received grant funding from the State under Proposition 13. A grant for $615,000 supplemented the rebate funding available for commercial ULF toilets and high efficiency clothes washers. LADWP expects to receive a final payment totaling $128,299 for the Commercial High Efficiency Clothes Washer and Ultra Low Flow Toilet Consolidated Water Use Efficiency grant. LADWP has already received $164,691 in support of 1,498 commercial high efficiency washer rebates. LADWP was awarded three grants in 2005 under Proposition 50, which are summarized below:
  - The Cooling Tower Conductivity Controller Replacement Program: Grant to improve the water efficiency of 100 cooling towers in the city of Los Angeles. Total grant amount up to $350,000. Expect completion in 2012.
  - The Los Angeles City Park Irrigation Efficiency Program: Grant to improve the irrigation efficiency at 15 City of Los Angeles municipal parks by installing Weather Based Irrigation Controllers and by upgrading irrigation piping and rotors. Total grant amount up to $362,000. Expect completion in 2011.
  - The Large Landscape "Smart Irrigation" Program: Grant to replace existing manually-adjusted irrigation controllers with "smart irrigation" Weather Based Irrigation Controllers at 75 large landscape customer sites. Total grant amount $131,000. Expect completion in 2011.

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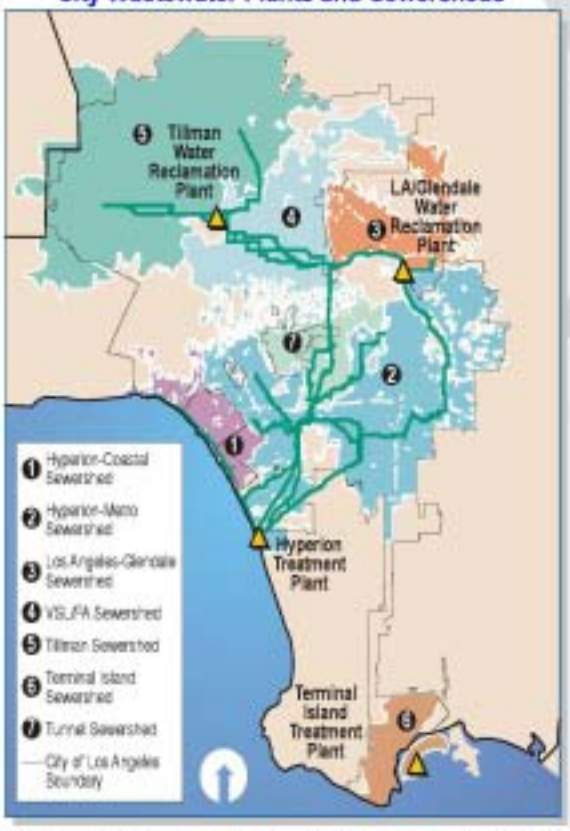
Recycled Water

LADWP is committed to significant expansion of recycled water in the City's water supply portfolio. Realizing multiple factors are decreasing the reliability of imported water supplies, LADWP released the City of Los Angeles Water Supply Action Plan (Plan), "Securing L.A.'s Water Supply" in May of 2008. The Plan established the goal of using 50,000 AFY of recycled water to offset demands on potable supplies. In order to meet this goal, LADWP, in conjunction with the Department of Public Works Bureau of Sanitation (BOS), are working together to develop a Recycled Water Master Plan (RWMP). Opportunities to expand the water recycling program are being studied through development of the RWMP. These include expanding the recycled water distribution system for Non-Potable Reuse (NPR) such as for irrigation and industrial use, along with replenishment of groundwater basins with highly purified recycled water. Beyond 50,000 AFY, LADWP expects to increase recycled water use by approximately 1,500 AFY annually, bringing the total to 59,000 AFY by 2035.

LADWP's water recycling program is dependent on the City's wastewater treatment infrastructure. Wastewater in the City of Los Angeles is collected and transported through some 6,500 miles of major interceptors and mainline sewers, more than 11,000 miles of house-sewer connections, 46 pumping plants, and four treatment plants. BOS is responsible for the planning and operation of the wastewater program. The City's wastewater system serves 515 square miles, of which 420 square miles are within the City. In addition to the City, service is provided to 29 non-City agencies through contract services. Exhibit 4A shows the City's four wastewater treatment plants and seven sewersheds that feed those plants.

Exhibit 4A
City Wastewater Plants and Sewersheds



A portion of the treated effluent from the wastewater plants is utilized by LADWP to meet recycled water demands.

As early as 1960, the City recognized the potential for water recycling and invested in infrastructure that processed water to tertiary quality, a high treatment standard for wastewater. This resulted in the building of tertiary wastewater treatment plants upstream instead of enlarging the two existing terminus treatment plants. These system enhancements brought about the City's expanded recycled water projects, which now supplement local and imported water supplies. The original policy allowing the use of recycled water was adopted by the State Legislature in 1969.

In 1979, LADWP began delivering recycled water to the Department of Recreation and Parks for irrigation of areas in Griffith Park. This service was later expanded to include Griffith Park's golf courses. In 1984, freeway landscaping adjacent to the park was also irrigated with recycled water. In addition, the Japanese Garden, Balboa Lake and Wildlife Lake in the Sepulveda Basin now utilize recycled water for environmentally beneficial reuse purposes. The Greenbelt Project, which carries recycled

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water from the Los Angeles-Glendale Water Reclamation Plant to Forest Lawn Memorial Park, Mount Sinai Memorial Park, Lakeside Golf Club of Hollywood and Universal Studios, began operating in 1992, and represents LADWP's first attempt at water recycling. LADWP continues to successfully implement the use of recycled water for various purposes. In 2009 phase 1 of the Playa Vista development began receiving recycled water. Playa Vista is the first planned development in the City that uses recycled water for all landscape needs. Future recycled water projects will continue to build on the success of these prior projects so that recycled water becomes a more prominent component of the City's water supply portfolio.

The City's water recycling projects seek to displace the use of potable water with recycled water for non-potable uses where infrastructure is available. In compliance with Chapters 7.0 and 7.5 of the California Water Code, the quality of LADWP's Recycled water meets all of the following conditions:

- The source of recycled water is of adequate quality for those uses;
- The recycled water may be furnished for these uses at a reasonable cost to the user;
- The use of recycled water from the proposed source will not be detrimental to public health; and
- The use of recycled water will not adversely affect downstream water rights or degrade water quality.

In addition, the California Water Code requires public agencies, such as the LADWP, to serve recycled water for non-potable uses if suitable recycled water is available.

LADWP is expanding irrigation, industrial/commercial, and studying groundwater replenishment uses of recycled water. Demand for recycled water is driven by customer acceptance of recycled water as a viable alternative to traditional potable supplies. Outreach efforts designed to educate the public on the viability of recycled water and its potential uses are an essential part of the process as the City's recycled water program expands.

4.1 Regulatory Requirements

Recycled water use is governed by regulations at the State and local levels. These regulations are based on multiple factors including the type of use and water quality. LADWP currently uses recycled water for non-potable reuse and is pursuing in-direct potable reuse through groundwater replenishment (GWR) using advanced treated recycled water. Requirements for these two categories of recycled water use are different. This section provides a summary of the complex recycled water regulations, a more in-depth description of these regulations will be included as part of the RWMP.

4.1.1 Non-Potable Reuse Regulations

Non-potable water reuse (NPR) regulations in the City of Los Angeles are governed by the California Department of Public Health (CDPH), State Water Resources Control Board (SWRCB), Los Angeles Regional Water Quality Control Board (LARWQCB) and the Los Angeles County Department of Public Health (LACDPH).

California Department of Public Health

Criteria and guidelines for the production and use of recycled water were established by the CDPH in the California Code of Regulations, Title 22, Division 4, and Chapter 3 (Title 22). Title 22, also known as Water Recycling Criteria, establishes required wastewater treatment levels and recycled water quality levels dependent upon the end use of the recycled water. Title 22 additionally establishes recycled water reliability criteria to protect public health.

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Title 22 specifies recycled water use restrictions based on the potential degree of public exposure to the water and the distance of drinking water wells and edible crops from the area of intended use. Recycled water use applicability also depends on the different levels of treatment. A higher quality water will have a wider variety of applicable uses than a lower quality water. At a minimum, secondary treatment of wastewater is required for recycled water use. In the City of LA, however, all recycled water used is treated, at a minimum, to tertiary levels with additional disinfection. Wastewater treatment levels are discussed in detail in subsection 4.2 of this chapter. Title 22 allows for other treatment methods, subject to CDPH approval. The reliability of the treatment process and the quality of the product water must meet the Title 22 requirements specified for each allowable treatment level. Exhibit 4B provides a summary of the currently approved recycled water uses.

Exhibit 4B
Allowable Title 22 Recycled Water Uses

Irrigation Uses
Food crops where recycled water contacts the edible portion of the crop, including all root crops
Parks and playgrounds
School yards
Residential landscaping
Unrestricted access golf courses
Any other irrigation uses not prohibited by other provisions of the California Code of Regulations
Food crops, surface irrigated, above ground edible portion, and not contacted by recycled water
Cemeteries
Freeway landscaping
Restricted access golf course
Ornamental nursery stock and sod farms with unrestricted public access
Pasture for milk animals for human consumption
Non edible vegetation with access control to prevent use as park, playground or school yard
Orchards with no contact between edible portion and recycled water
Vineyards with no contact between edible portion and recycled water
Non food bearing trees, including Christmas trees not irrigated less than 14 days before harvest
Fodder and fiber crops and pasture for animals not producing milk for human consumption
Seed crops not eaten by humans
Food crops undergoing commercial pathogen destroying processing before consumption by humans
Supply for impoundment
Non restricted recreational impoundments, with supplemental monitoring for pathogenic organisms
Restricted recreational impoundments and publicly accessible fish hatcheries
Supply for Impoundment Uses
Non restricted recreational impoundments, with supplemental monitoring for pathogenic organisms
Restricted recreational impoundments and publicly accessible fish hatcheries
Landscape impoundments without decorative fountains
Supply for cooling or air conditioning
Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist
Industrial or commercial cooling or air conditioning not involving cooling tower, evaporative

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condenser, or spraying that creates a mist
Other Uses
Dual plumbing systems (flushing toilets and urinals)
Priming drain traps
Industrial process water that may contact workers
Structural fire fighting
Decorative fountains
Commercial laundries
Consolidation of backfill material around potable water pipelines
Artificial snow making for commercial outdoor uses
Commercial car washes, not heating the water, excluding the general public from washing process
Industrial process water that will not come into contact with workers
Industrial boiler feed
Nonstructural fire fighting
Backfill consolidation around non potable piping
Soil compaction
Mixing concrete
Dust control on road and streets
Cleaning roads, sidewalks and outdoor work areas
Flushing sanitary sewer
Groundwater recharge

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Non-Potable Reuse Regulatory and Policy Assessment TM, September 8, 2009

Areas where recycled water is used occurs within defined boundaries. Title 22 stipulates use area requirements to protect public health. Use area regulations include requirements addressing recycled water application methods and runoff near domestic water supply wells, drinking fountains, and residential areas. Other requirements include posting signs notifying the public where recycled water is being used, utilization of quick couplers instead of hose bibs, and the prohibition against connecting recycled water systems with potable water systems. Dual plumbed recycled water systems in buildings are also addressed; these systems must meet additional reporting and testing requirements.

To protect public health, Title 22 requires reliability mechanisms. During the design phase, a Title 22 Engineering Report is required to be submitted to CDPH and the local Regional Water Quality Control Board (RWQCB) for approval. Contents of the report include a description of the system and an explanation regarding how the system will comply with Title 22 requirements. Redundancy in treatment units or other means to treat, store, or dispose of recycled water are required in case the treatment unit is not operating within specified parameters. Alarms for operators are required to indicate treatment plant process failures or power failures. In case of power failures, either back-up power, automatically activated short-term or long-term recycled water storage, or a means of disposal is required. Furthermore, system performance must be monitored by water quality sampling and analyses.

As mentioned previously, cross-connections between the potable and recycled water systems are not permitted. The California Code of Regulations, Title 17, Division 1, Chapter 5, Group 4 prevents cross-connections between potable water supply systems and recycled water supply systems. Title 17 specifies that water suppliers must implement cross-connection control programs and backflow prevention systems.

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In addition to Title 22 and Title 17 requirements, CDPH has additional regulations and guidance established in the following documents:

- Guidelines for the Preparation of an Engineering Report for the Production, Distribution, and Use of Recycled Water (2001)
- Treatment Technology Report for Recycled Water (2007)
- Guidance Memo No. 2003-02: Guidance for the Separation of Water Mains and Non-Potable Pipelines (2003)

State Water Resources Control Board and Los Angeles Regional Water Quality Control Board

In May 2009, the SWRCB adopted "Recycled Water Policy" developing uniform standards across all Regional Water Quality Control Boards for interpreting the "Anti-Degradation Policy". When planning and implementing recycled water projects the following must be taken into consideration:

- Mandate for recycled water use – encourages recycled water use and establishes targets to increase use
- Salt/nutrient management plans – requires submittal of salt/nutrient management plans by 2014
- Landscape irrigation projects' control of incidental runoff and streamlined permitting – addresses controlling incidental runoff and streamlining permit processes for recycled water use in landscape areas
- Groundwater recharge – establishes requirements for groundwater recharge projects
- Anti-degradation – establishes that salt and nutrient management plans can address groundwater quality impacts
- Chemicals of emerging concern – establishes a blue-ribbon advisory panel to develop a report on chemicals of emerging concern and update the report every five years.

Water Recycling Requirements (WRR) for each of the City's applicable wastewater treatment plants engaged in water recycling are issued by the LARWQCB. These requirements specify end-users of recycled water and enforce treatment and use area requirements.

In July 2009, the SWRCB adopted a general landscape irrigation permit, "General Waste Discharge Requirements for Landscape Irrigation Uses of Municipal Recycled Water" (General Permit). The General Permit streamlines the regulatory approval for landscape irrigation using recycled water. Agencies with existing WRRs, such as the City, are not required to apply for the General Landscape Irrigation Permit.

Earlier in April 2009, the LARWQCB adopted a general region-wide permit, "General Waste Discharge and Water Recycling Requirements for Non-Irrigation Uses over the Groundwater Basins Underlying the Coastal Watersheds of Los Angeles and Ventura Counties" for non-irrigation uses of recycled water. Similar to the General Permit, this permit streamlines the permitting process and specifies the application process for qualifying projects.

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Los Angeles County Department of Public Health

Title 22 and Title 17 water use regulations are enforced by the LACDPH, Environmental Health Division. LACDPH has published "A Guide to Safe Recycled Water Use, Pipeline Construction and Installation" requiring compliance with Title 22, CDPH, and LARWQCB requirements. After CDPH has approved the plans and specifications and the City has an agreement to serve the customer, LACDPH reviews and approves all plans and specifications prior to construction. After construction LACDPH inspects the systems and conducts cross-connection, pressure, and back-flow prevention device tests. Recycled water use must occur in compliance with the Los Angeles County Recycled Water Advisory Committee's "Recycled Water Urban Irrigation User's Manual". Each site must also have a site supervisor responsible for recycled water use.

City of Los Angeles

Recycled water responsibilities of the City of Los Angeles include complying with all LARWQCB permits for the wastewater treatment plants and production of recycled water, approving recycled water use sites, conducting post-construction inspections, and periodically inspecting use areas and site supervisor records.

LADWP customers are permitted to use recycled water when service is available and per LADWP Ordinance No. 170435 (subsequently amended by Ordinance No. 178902 in 2008). Users are responsible for operations and maintenance of their recycled water systems up to the connection point with LADWP. Users are required to use recycled water in accordance with Titles 22 and 17 and the "Recycled Water Urban Irrigation User's Manual". If a customer is violating these requirements, LADWP may stop providing recycled water to the customer.

4.1.2 Groundwater Replenishment Regulatory Requirements

The regulations governing recharge of groundwater or groundwater replenishment (GWR) with recycled water are established by the CDPH and LARWQCB. Additional approval is required by the SWRCB and California Department of Fish and Game (DFG) if flows will be diverted from surface waters, such as in Los Angeles where recycled water is currently discharged by two treatment plants into the Los Angeles River. The City's GWR project as described in section 4.4.3 will be subject to these regulations.

For groundwater replenishment, LADWP will implement advanced treatment that includes reverse osmosis, microfiltration, and advanced oxidation. This level of treatment will address water quality concerns for the health of the basin along with emerging contaminants of concern.

California Department of Public Health

Regulatory oversight of groundwater recharge projects is provided by the CDPH. CDPH regulates groundwater recharge projects under Title 22 requiring the CDPH to make recommendations on a case by case basis after a public hearing. Requirements for recharge are not provided in Title 22. Draft Groundwater Recharge Reuse Criteria, released in August 2008, are used by the CDPH to evaluate projects for approval or denial. The draft regulations are designed to protect public health through the establishment of stringent requirements by:

- Requiring recycled water to meet maximum contaminant levels (MCLs) established for drinking water;
- Establishing the volume of recycled water used based on Total Organic Carbon (TOC), dilution, and treatment levels;
- Requiring retention of groundwater for six months before reaching a well used for drinking water with validation by a tracer study;

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- Monitoring on a quarterly basis for specified pollutants and chemicals and yearly monitoring of constituents indicating the presence of wastewater in produced recycled water and in downgradient monitoring wells;
- Implementing a source control program; and
- Establishing additional requirements for projects with recycled water contributions greater than 50%, including a review by an Independent Advisory Panel.

Similar to non-potable reuse, project proponents must submit a Title 22 Engineering Report to the CDPH and LARWQCB for review. After completion of the report, the CDPH holds a public hearing followed by issuance of Findings of Fact and Conditions for submission to the LARWQCB.

Los Angeles Regional Water Quality Control Board

Prior to the issuance of a permit, the LARWQCB reviews CDPH's Findings of Fact and Conditions and considers provisions in the adopted Los Angeles Basin Plan (Basin Plan) for the LARWQCB region, applicable State policies (including the SWRCB Recycled Water Policy), and applicable federal regulations if recycled water is discharged to water of the US. The Basin Plan establishes water quality objectives for surface water and groundwater to protect beneficial uses. The LARWQCB then holds a public hearing to consider the permit. Ultimately, if approved, the LARWQCB issues permits in the form of water reclamation requirements and waste discharge requirements.

4.2 Wastewater Treatment Plants

There are four wastewater treatment plants owned and operated by the BOS. City wastewater treatment consists of a series of processes that, at a minimum, remove solids to a level sufficient to meet regulatory water quality standards. During the preliminary, primary, secondary, and tertiary treatment processes, progressively finer solid particles are removed. Preliminary treatment removes grit and large size particles through grit removal basins and screening. Primary treatment relies on sedimentation to remove smaller solids. With most of the grit, large sized particles, and solids already removed, secondary treatment converts organic matter into harmless by-products and removes more solids through biological treatment and further sedimentation. At the end of secondary treatment, most solids will have been removed from the water. Tertiary treatment follows secondary treatment to eliminate the remaining impurities through filtration and chemical disinfection. At this stage, sodium hypochlorite (the chemical contained in household bleach) provides disinfection. All recycled water used within the City is given, at a minimum, tertiary treatment and disinfection. In the Harbor, recycled water is also given advanced treatment with microfiltration/reverse osmosis (MF/RO). MF/RO is a two-stage process using high-pressure membrane filters to remove microscopic impurities from the source water. Exhibit 4C summarizes the treatment levels, capacity, and average flows at the four plants.

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Exhibit 4C
Wastewater Treatment Plants Summary

WastewaterTreatment Plants	Treatment Level	Capacity (mgd)	Average Flows (mgd)[1]
Donald C. Tillman Water Reclamation Plant	Tertiary to Title 22 standards with Nitrification/Denitrification	80	53
Los Angeles - Glendale Water Reclamation Plant	Tertiary to Title 22 standards with Nitrification/Denitrification	20	17
Terminal Island Water Reclamation Plant	Tertiary; Advanced treatment (MF/RO) of 5 mgd	30	15
Hyperion Treatment Plant	Full secondary[2]	450	320

1. Average dry weather flows 2008, except for DCT January 2005 through December 2008.

2. 31 mgd of full secondary treated water delivered to West Basin Water Reclamation Plant operated by West Basin Municipal Water District. Water treated to Title 22 standards for recycled water use.

Sources: City of Los Angeles Recycled Water Master Plan Technical Memorandum, DCT Data Summary, January 29, 2010

City of Los Angeles Recycled Water Master Plan Technical Memorandum, Wastewater Treatment, November 2, 2009

4.2.1 Donald C. Tillman Water Reclamation Plant

In service since 1985, the Donald C. Tillman Water Reclamation Plant (DCT) has an average dry-weather flow capacity of 80 million gallons per day (mgd) and currently treats about 53 mgd. During wet weather, treatment capacity is limited to 40 mgd to prevent downstream infiltration surcharges on the sewer system while utilizing the remaining capacity for limited wet weather storage. Currently, the Bureau of Engineering (BOE) is designing wet-weather storage basins to allow year around operation at 80 mgd. The current level of treatment is Title 22 (tertiary) with nitrogen removal (nitrification/denitrification (NdN). Currently, this plant is providing recycled water to the Japanese Garden, Wildlife Lake, Lake Balboa, treatment plant reuse, irrigation, and industrial uses. Irrigation uses in the adjacent areas include golf courses, parks, and a sports complex. Industrial uses include the Valley Generating Station. The remaining tertiary-treated water is discharged into the Los Angeles River. The city intends on implementing a groundwater replenishment project supplied with tertiary treated Title 22 recycled water from DCT that is purified through advanced treatment to recharge the San Fernando Groundwater Basin. The project will initially recharge 15,000 AFY with the eventual goal of achieving 30,000 AFY.

4.2.2 Los Angeles-Glendale Water Reclamation Plant

The Los Angeles-Glendale Water Reclamation Plant (LAG) is a joint project of the City of Los Angeles and City of Glendale. LAG began treating wastewater in 1976. Originally the plant was designed without considering nutrient removal. Its average dry-weather flow design capacity is 20 mgd and it currently treats about 17.7 mgd. Each city is entitled to 50 percent of the plant's capacity. The City of Pasadena purchased rights to 60 percent of Glendale's capacity but has not yet exercised these rights. The current level of treatment is Title 22 (tertiary) with nitrogen removal (NdN). Recycled water from the LAG provides landscape irrigation to Griffith Park and the Los Angeles Greenbelt Project, including Forest Lawn Memorial Park, Mount Sinai Memorial Park, Universal Studios, and the Lakeside Golf Course. The City of Glendale retains the right to half of the recycled water produced at the plant and serves a number of customers in their service area. As with the DCT, the remaining tertiary-treated water from LAG is discharged into the Los Angeles River.

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4.2.3 Terminal Island Water Reclamation Plant

Originally built in 1935, the Terminal Island Water Reclamation Plant (TIWRP) has been providing secondary treatment since the 1970s. Tertiary treatment systems were added in 1996. The current average dry-weather flow capacity is 30 mgd with average flows of about 15 mgd. Recent completion of the Advanced Wastewater Treatment Facility added MF/RO treatment to a portion of the wastewater effluent producing approximately 3.0 mgd of recycled water. Recycled water is supplied to the Dominguez Gap Seawater Intrusion Barrier to reduce seawater intrusion into drinking water aquifers and to LADWP's Harbor Generating Station for landscape irrigation. Effluent in excess of the MF/RO component is discharged to the Los Angeles Harbor. Future recycled water use is expected to increase to more fully supply the Dominguez Gap Seawater Intrusion Barrier along with other potential customers in the Harbor Area.

4.2.4 Hyperion Treatment Plant

Operating since 1894, the Hyperion Treatment Plant (HTP) is the oldest and largest of the City's wastewater treatment plants. Its $1.2 billion construction upgrade, completed in 1999, allows for full secondary treatment. The current average dry-weather flow capacity of HTP is 450 mgd during dry weather, with an average wastewater flow of 342 mgd. A majority of the treated water is discharged through a 5-mile outfall into the Santa Monica Bay, and the rest, approximately 31 mgd, is delivered to the West Basin Water Reclamation Plant to meet recycled demands in the West Basin Municipal Water District (WBMWD) service area and parts of the City of Los Angeles. As of 2008, approximately 37,000 AFY of water from HTP Plant is sold to West Basin for additional treatment. A portion of this water is sold back to LADWP for the Westside Water Recycling Project, and the rest is then used to meet recycled water demands in West Basin's service area. Users of the Westside Water Recycling Project include Loyola Marymount University and Playa Vista.

4.2.5 Projected Wastewater Volume

Average dry-weather wastewater influent projections for the City's wastewater treatment plants are expected to increase by approximately 20 percent over the next 25 years. Projections include 29 agencies outside of the City with contracts for wastewater treatment. Wastewater effluent that is not recycled is discharged to either the Los Angeles River to the Pacific Ocean or outfalls leading directly to the Pacific Ocean. Wastewater treatment projections for average dry-weather flows to 2035 and disposal methods are provided in Exhibit 4D.

Exhibit 4D
Wastewater Treatment Plant Average Dry-Weather Flows, Reuse and Dischargel Method

Wastewater Treatment Plants	Reuse and Discharge Method	Average Dry-Weather Flow Projections (AFY)					
		2010	2015	2020	2025	2030	2035
Donald C. Tillman Water Reclamation Plant	Recycling and Pacific Ocean via Los Angeles River	82,779	84,347	85,915	87,483	90,283	93,084
Los Angeles - Glendale Water Reclamation Plant	Recycling and Ocean via Los Angeles River	23,299	25,427	27,331	29,460	31,588	33,716
Terminal Island Water Reclamation Plant	Recycling and Outfall to Ocean	18,258	18,594	18,818	19,154	19,715	20,163
Hyperion Treatment Plant	Conveyance to WBMWD for Recycling and Ocean outfall	333,690	339,739	345,788	362,814	366,063	400,899

Sources: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Wastewater Flow Projection, September 30, 2009

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4.3 Existing Recycled Water Deliveries

The City has several recycled water projects currently providing recycled water for landscape irrigation, industrial, and commercial uses spread throughout four service areas:

- Harbor – located in the southern portion of the City and currently served from the water reclamation plant at the TIWRP
- Central City (Metro) – located in the central/eastern portion of the City and is served by LAG
- San Fernando Valley – located in the northern portion of the City and is served by DCT
- Westside – location in the central/western portion of the City and is served by HTP through the WBMWD West Basin Water Reclamation Plant

Locations of the service areas are depicted in Exhibit 4E. Recycled water service areas coincide with potable water service areas. Recycled water deliveries for 2009 were 35,939 AFY, inclusive of municipal and industrial, environmental, and in-plant reuse. Estimated annual demands for online projects were 38,614 AFY.

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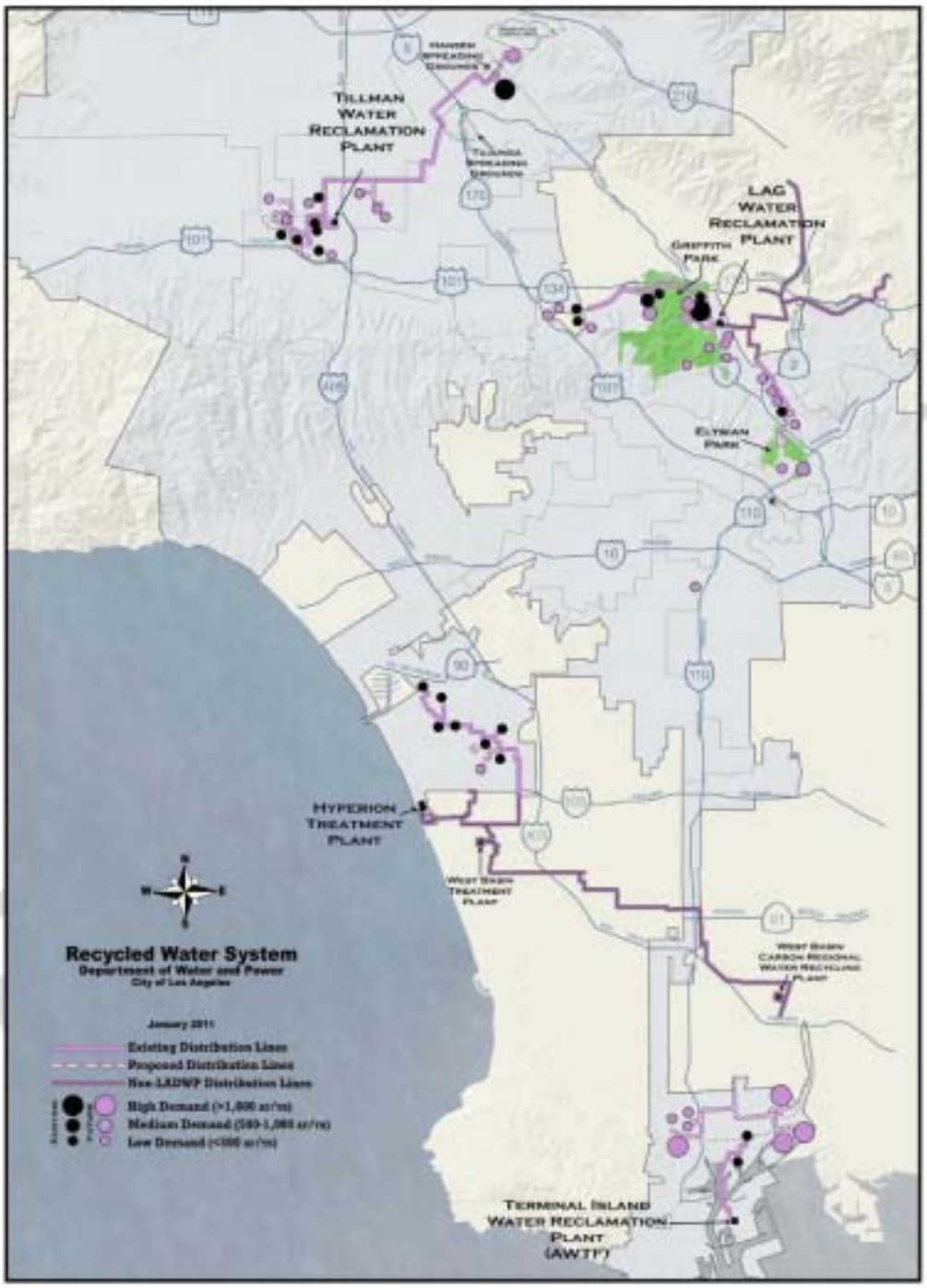
Exhibit 4E
Recycled Water System



4.3.1 Harbor Area

Recycled water in the Los Angeles Harbor area is currently produced at the Advanced Water Treatment Plant (AWTP) located at the TIWRP. The AWTP was online in 2002 with first deliveries to customers commencing in 2006. This project was

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developed jointly by LADWP, BOS, and BOE. Operations and maintenance is provided by BOS with funding from LADWP. Recycled water, treated using microfiltration and reverse osmosis, is currently used for landscape irrigation and groundwater injection with current demands of approximately 3,050 AFY. Treatment capacity of the AWTP is approximately 5,600 AFY. Excess recycled water is discharged into the Los Angeles Harbor. Exhibit 4F summarizes typical annual demands in the Harbor area. Currently two customers are served; LADWP's Harbor Generating Station and the Water Replenishment District (WRD).

Exhibit 4F
Harbor Recycling

Program	Existing Annual Demand (AFY)
Irrigation	
Harbor Generating Station	50
Subtotal Irrigation	50
Groundwater Barrier	
Dominguez Gap Barrier (Water Replenishment District)	3,000
Subtotal Groundwater Barrier	3,000
Total Harbor Water Recycling Project	**3,050**

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Harbor Generating Station

The Harbor Generating Station's demands that could potentially be met with recycled water are approximately 50 AFY including industrial cooling and landscape irrigation. Initially, recycled water was intended for use in the station's cooling tower and boiler make-up feed system components, however, recycled water is not used for these purposes currently as a result of concerns about potential incompatibility between recycled water and these systems. Connections have been installed for recycled water use in these systems and future use will be further investigated as part of the Recycled Water Master Plan.

Water Replenishment District

The WRD's recycled water demands are approximately 3,000 AFY for groundwater injection in the Dominguez Gap Seawater Intrusion Barrier. A blend of 50 percent recycled water and 50 percent imported water is injected into the barrier. The Dominguez Gap Barrier protects the West Coast Groundwater Basin from seawater intrusion.

LADWP is currently expanding recycled water infrastructure in the Harbor area that will increase recycled water usage at least 9,300 AFY by 2014/2015.

4.3.2 Metro Area

The Metro Recycled Water System has supplied the Metro Service Area with recycled water produced at LAG to irrigation customers since 1979. LAG provides recycled water treated to a tertiary level meeting Title 22 standards with Nitrogen removal to customers in the eastern San Fernando Valley. As previously stated, recycled water produced at LAG is equally split between the cities of Los Angeles and Glendale. Current recycled water demands for the Metro Service Area are 1,933

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AFY. Unused recycled water is discharged to the Los Angeles River. Exhibit 4G summarizes current demands for Metro Recycled Water System. Currently 11 customers are served by the Metro Recycled Water System.

Exhibit 4G
Metro Recycling

Program	Existing Annual Demand (AFY)
Irrigation	
Greenbelt Project	1120
Griffith Park	720
Taylor Yard Project	93
Total Irrigation	1,933

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Griffith Park Project

Started in 1979, the Griffith Park project was the City's first recycled water project. Recycled water is used to irrigate two golf courses, parkland, The Los Angeles Zoo Parking Lot, and a seven-mile stretch along the Golden State Freeway (Interstate 5) adjoining the park. Current demands in the Griffith Park Project's service area are 1,120 AFY.

Greenbelt Project

Dedicated in 1992, the Los Angeles Greenbelt Project was the City's first commercial recycling project. Recycled water is used for landscape irrigation at Forest Lawn Memorial Park-Hollywood Hills, Mount Sinai Memorial Park, Lakeside Golf Course and Universal Studios. Current demands in the Greenbelt Project's service area are 720 AFY.

Taylor Yard Project

Rio de LA State Park was connected as the first Taylor Yard project in July 2009. Recycled water is used for landscape irrigation on the park. Current demands in the Taylor Yard Project's service area are 93 AFY.

4.3.3 San Fernando Valley Area

The Valley Recycled Water System receives water from DCT to satisfy irrigation, environmental, and industrial demands. Recycled water is treated to a tertiary level meeting Title 22 standards with Nitrogen removal. Water for in-plant uses at DCT and for environmental uses is dechlorinated. Current estimated recycled water demands for the San Fernando Valley Area are 33,594 AFY. Recycled water produced in excess of demand is discharged to the Los Angeles River providing added environmental benefits. Exhibit 4H summarizes current demands for the Valley Recycled Water System. The East Valley trunkline, a 54 inch diameter pipeline, was previously constructed as the initial backbone of the Valley Recycled Water System's distribution system to deliver water throughout the San Fernando Valley for irrigation, commercial, and industrial use. Eleven customers are currently served by the Valley Recycled Water System, excluding DCT reuse and environmental use.

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Exhibit 4H
Valley Recycling

Program	Existing Annual Demand (AFY)
Irrigation	
Sepulveda Basin Project	*1570*
Van Nuys Area Project	14
Subtotal Irrigation	1,584
Industrial	
Hansen Area Project	
Valley Generating Station	2,100
DCT Reuse[1]	2,920
Subtotal Industrial	5,020
Environmental Use[2]	
Japanese Garden	4,590
Wildlife Lake	7,700
Balboa Lake	14,700
Subtotal Environmental Use	26,990
Total Valley Recycled Water System	**33,594**

1. Based on 2006-2008 actual use, use varies year to year.

2. Does not include environmental benefits provided to Los Angeles River.

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Sepulveda Basin Project

LADWP began serving recycled water to portions of the Sepulveda Basin area in 2007. The latest project was added in 2010. Current recycled water customers in the Sepulveda Basin recreation area include Woodley Golf Course, Balboa Golf Course, Encino Golf Course, Anthony C. Beilenson Park, Van Nuys Golf Course and the Balboa Sports Complex. Current demands in the recreation area are 1,570 AFY.

Van Nuys Area Project

The Van Nuys Area project currently provides recycled water for irrigation purposes to St. Elisabeth's Church, the First Foursquare Church of Van Nuys, Van Nuys High School, and LADWP's Power Distribution Station 81. Current Van Nuys Area Project demands are 14 AFY.

Hansen Area Project

The Hansen Area project currently provides recycled water for industrial purposes to the Valley Generating Station. Recycled water service began in 2008 and demands are approximately 2,100 AFY. Recycled water is used in a cooling tower for one of the generation units at the power generating facility.

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Donald C. Tillman Water Reclamation Plant Reuse

Recycled water is used at DCT for in-plant purposes. Demands vary from year to year based on needs. Between 2006 and 2008 2,920 AFY were used on average.

Environmental Use

Recycled water from DCT has provided environmental benefits since 1984 commencing with deliveries to the Japanese Garden followed by Balboa Lake in 1990 and Wildlife Lake in 1991. Approximate demands are 26,990 AFY. Overflows from these facilities are discharged to the Los Angeles River providing additional environmental benefits in conjunction with unused recycled water discharges to the river.

Japanese Garden

The 6.5 acre Japanese Garden is located at the Sepulveda Dam Recreation Area. The Garden receives more than 10,000 visitors per year. DCT provides about 4,590 AFY of recycled water for the lake and landscaping at the Japanese Garden.

Wildlife Lake

Located in the Sepulveda Basin, the Wildlife Lake uses about 7,700 AFY of recycled water from DCT for wildlife habitat management.

Lake Balboa

Lake Balboa is the centerpiece of the Sepulveda Dam Recreation Area and is a popular recreational facility located in Anthony C. Beilenson Park. About 14,700 AF per year of recycled water is provided for this lake from DCT.

4.3.4 Westside Area

Recycled water supplied to the Westside Recycled Water System is provided by WBMWD via the Edward C. Little Water Recycling Plant (WBWRP), located in the City of El Segundo, for irrigation and commercial (toilet flushing) demands. The WBWRP further treats secondary-treated effluent received from HTP to a tertiary level meeting Title 22 standards. Under an agreement between WBMWD and the City, WBMWD purchases secondary-treated effluent from HTP and LADWP has a right to purchase up to 25,000 AFY of recycled water following tertiary treatment at the WBWRP. Approximately 37,300 AFY of secondary-treated effluent was purchased from HTP in 2008 and LADWP purchased 380 AF of recycled water to serve the Westside of Los Angeles. The WBWRP can treat up to 40 mgd. Recycled water not purchased by LADWP is sold to users within WBMWD's service area.

Deliveries of recycled water from the Westside Recycled Water System first began in 1996. To increase the use of recycled water on the Westside, LADWP has constructed more than five miles of distribution trunk lines to serve the Westchester, Los Angeles International Airport, and Playa Vista development areas. Current estimated recycled water demands for the Westside Area are 676 AFY as shown in Exhibit 4I. Currently 106 customers are served by the system.

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Exhibit 4I
Westside Recycled Water System Estimated Existing Annual Demand

Program	Estimated Annual Demand (AFY)
Irrigation	
Playa Vista Phase 1 (95 customers)	205
Coldwell Banker	2
Cal Trans at Playa Vista	5
Los Angeles International Airport	158
Westchester Golf Course	62
Loyola Marymount University	64
Westchester Park	43
Scattergood Generating Station	31
Carl Nelson Youth Park	16
The Parking Spot	1
Street Medians	4
Hyperion Treatment Plant[1]	85
Subtotal Irrigation	676
Total Valley Recycled Water System	**676**

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Playa Vista, Phase 1

Playa Vista is the first planned development in the City to use recycled water for irrigation of all of its landscaping including residential outdoor use. This project began receiving recycled water in 2009 as part of Phase 1. Phase 2 is considered as a "Near-Term" project (or "Tier 1" use), which are projects to be implemented by the year 2015. Outdoor recycled water is required under the development's mitigation requirements established during the environmental review process. Recycled water is additionally used for toilet flushing in commercial buildings. Annual demands are approximately 200 AFY for Phase 1.

Los Angeles International Airport

Los Angeles International Airport began using recycled water in 1996 for landscape irrigation purposes along its boundaries. Current demands for the airport are 158 AFY.

Westchester Golf Course

Westchester Golf Course began using recycled water in 2009 for irrigation. Current demands for the airport are 62 AFY.

Loyola Marymount University

Loyola Marymount University has been connected to the Westside system since 1996. Recycled water is used to irrigate a portion of the campus landscaping area. Average annual demands are approximately 65 AFY. In 2006, Loyola Marymount

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University installed an on-site disinfection system using hydrogen peroxide to address odor problems related to stagnant water in an oversized pipeline servicing the university.

Westchester Park and Carl Nelsen Youth Park

Westchester and Carl Nelsen Youth Parks both use recycled water for irrigation purposes. Both parks were connected to the system in 1996. Westchester Park demands are approximately 43 AFY and Carl Nelsen Youth Park demands are 16 AFY.

Scattergood Generating Station

Scattergood Generating Station operated by LADWP and located in El Segundo receives recycled water to meet irrigation demands. Average annual demand is approximately 31 AFY. The pipeline servicing the facility is oversized to potentially provide cooling water in the future.

Street Medians and The Parking Spot

Street medians on Manchester Avenue and The Parking Spot were connected to the recycled water system in 2008 and 2003, respectively. Recycled water is served to both facilities to meet irrigation demands. The Parking Spot is a commercially operated parking facility near Los Angeles International Airport. Demands for The Parking Spot are approximately 1 AFY and demands for the street medians are approximately 5 AFY.

Hyperion Treatment Plant

HTP uses recycled water for both landscaping and toilet flushing within the administration building. HTP was connected to the system in 1996. About 65 AFY of recycled water are provided to HTP per year. HTP also provides additional treatment for recycled water use onsite similar to Loyola Marymount University to address odor problems associated with stagnant water in an oversized supply pipe. The pipeline to HTP was oversized to accommodate expanded deliveries to the Scattergood Generating Station in the future. HTP uses filters and disinfection to treat the water prior to its use onsite.

4.3.5 Comparison of 2010 Projections Versus Actual Use

LADWP has made substantial progress in increasing recycled water use in the interim period between completion of the 2005 and 2010 UWMPs. Municipal and industrial recycled water use between 2005 and 2010 increased from 4,870 AFY to 10,651 AFY. The 2005 UWMP projected municipal and industrial recycled water use in 2010 would be approximately 19,870 AFY, however actual use was lower than estimated as shown in Exhibit 4J. Environmental water use of recycled water fluctuates slightly year to year based on lake levels, but is typically 26,990 AFY. For 2010 actual use was 25,129 AFY, or approximately 7 percent less than estimated. Overall total recycled water use in 2010 was approximately 23 percent less than projected.

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Exhibit 4J
2005 UWMP Recycled Water Projections for 2010 versus Actual Use

Program	2005 Projection for 2010 (AFY)	09/10 Actual Use (AFY)
Municipal & Industrial Purposes[1]	19,870	6,864
Environmental Use[2]	26,990	25,008
Total	**46,860**	**31,872**

1. These recycled water supplies offset the demand for imported water within LADWP's service area and include DCT reuse of 2,920 AFY, but do not include deliveries to WBMWD of 34,000 AFY. DCT reuse was not included in 2005 UWMP projections for 2010.

2. Water is ultimately discharged into the Los Angeles River, providing additional environmental benefit. 2005 UWMP projections for 2010 is based on average demands.
Sources: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009; 2005 Urban Water Management Plan for the Los Angeles Department of Water Power, and LADWP Water Recycling Staff

Although LADWP did not meet the 2010 recycled water projection, significant progress has been made including the completion of multiple projects since 2005 as described in Section 4.3.1 through 4.3.4. Additional projects that are proposed for construction in the near future are described in Section 4.4, Recycled Water Master Planning Documents. Additionally, LADWP in conjunction with the BOS is currently developing the City's Recycled Water Master Plan (RWMP) to guide future optimization of this supply source with the goal of increasing municipal and industrial use of recycled water to 50,000 AFY, inclusive of indirect potable reuse.

4.4 Recycled Water Master Planning Documents

LADWP in partnership with BOS is developing the RWMP Documents to replace 50,000 AFY of potable water supplies with recycled water by 2029 and to plan for long-term recycled water use. As previously discussed, the City of Los Angeles' Water Supply Plan, "Securing LA's Water Supply", the City has established a goal of 50,000 AFY with recycled water to reduce the need for potable water and diversify LADWP's available water supply options. Exhibit 4K summarizes LADWP's timeline to achieve the goal of recycling 50,000 AFY by fiscal year (FY) 2029. This goal can be achieved sooner if additional funds are made available such as state and federal grants. The RWMP efforts were initiated in 2009 and are forecast for completion by the middle of 2011. To meet near-term challenges and plan for long-term recycled water the following major tasks were outlined for inclusion in the RWMP Documents:

- Groundwater Replenishment Report;
- Non-Potable Reuse Report;
- Groundwater Replenishment Treatment Pilot Study;
- Max Reuse Concept Report;
- Satellite Feasibility Concept Report;
- Existing System Reliability Concept Report; and

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Within these tasks the RWMP Documents will determine where the existing recycled water system (purple-pipe network) should be expanded to satisfy needs of new customers. A cost benefit analysis will be conducted to identify potential customers considering location and projected use. A review of the wastewater treatment plants will be performed to determine which plants can supply the recycled water and the treatment technologies required. The RWMP Documents will also review available options for maximizing reuse through a combination of alternatives including expansion of non-potable uses, groundwater replenishment with advanced treated recycled water, and/or injection of recycled water as a seawater intrusion barrier. A set of alternatives will then be developed and analyzed for both the near-term and long-term goals. Alternatives will be evaluated as part of an integrated analysis.

The RWMP Documents will include Near-Term recycled water projects (projects to be implemented through 2015 to achieve 20,000 AFY of recycled water use), expansion of the non-potable distribution system beyond 20,000 AFY, and groundwater replenishment with advanced treated recycled water options. When combined with existing reuse, these options are expected to result in 50,000 AFY of reuse by FY 2029, exclusive of environmental reuse, DCT in plant reuse, and sales to WBMWD. Exhibit 4K provides a timeline for projects featured in the RWMP Documents.

Exhibit 4K
Recycled Water Master Planning Documents Implementation Timeline

Timeline	Reuse Volume[1] (AFY)	Description
Existing as of Fiscal Year 2009/2010	6,700	Existing demands already being served
Recycled Water Use by 2015	20,000	Near-Term projects already identified for implementation by 2015
Groundwater Recharge by 2021	15,000	New groundwater replenishment opportunities as identified as part of the Groundwater Master Plan task
Non-Potable Reuse Recycled Water by 2029	Up to 15,000	New projects identified between 2015 and FY 2029 to serve existing potable customers as part of the non-potable reuse master plan

1. Volume to offset municipal and industrial potable water demands. Does not include environmental use, DCT plant reuse, and sales to WBMWD.

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Recycled water projections in five year increments beginning in 2015 through 2035 are presented in Exhibit 4L. Total recycled water production is estimated to increase by 42,000 AFY over the projection period or 84 percent. Environmental reuse and seawater intrusion barrier water are expected to remain constant at 26,990 AFY and 3,000 AFY, respectively. Municipal and industrial use, inclusive of DCT reuse, is expected to increase by 27,000 AFY or approximately 136 percent. Indirect potable reuse (groundwater recharge) with advanced treated recycled water is forecast to provide 15,000 AFY of groundwater recharge beginning in 2021. Recycled water use up to 2025 is inclusive of the near-term options under development in the RWMP. Projections for 2030 and 2035 assume that long-term options being developed as part of the RWMP will increase recycled water use by approximately 1,500 AFY annually beyond FY 2029. Once the alternatives for the RWMP are finalized, the allocation of recycled water use by the municipal, industrial, and groundwater recharge categories may change to achieve the RWMP's recycled water goal of 50,000 AFY.

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Exhibit 4L
Recycled Water Use Projections

Category	Projected Use (AFY)[1]				
	2015	2020	2025	2030	2035
Municipal and Industrial	20,000	20,400	27,000	29,000	29,000
Indirect Potable Reuse (Groundwater Recharge)	0	0	15,000	22,500	30,000
Subtotal[2]	**20,000**	**20,400**	**42,000**	**51,500**	**59,000**
Environmental[3]	26,990	26,990	26,990	26,990	26,990
Seawater Intrusion Barrier (Dominguez Gap Barrier)	3,000	3,000	3,000	3,000	3,000
Total	**49,990**	**50,390**	**71,990**	**81,490**	**88,990**

1. Projected use by category is subject to change per completion of Recycled Water Master Plan, but overall total will not change. Does not include deliveries of 34,000 AFY of secondary treated water to WBMWD for further treatment to recycled water standards.

2. To offset potable use and included in supply reliability tables in Chapter 11.

3. Environmental use includes Wildlife Lake, Balboa Lake, and the Japanese Gardens. Additional environmental benefits associated with recycled water discharges to the Los Angeles River are not included.

Estimates of projected use and implementation timelines in the tables above as well as the annual demands and service dates for individual customers in the following sections may be affected by varying usage patterns of potential customers, timelines to reach agreements, as well as potential financial constraints and changing regulatory requirements.

4.4.1 Near-Term Projects through 2015

"Near-Term" projects are classified in the RWMP Documents as projects that will result in recycled water service between July 1, 2009 and 2015 to achieve 20,000 AFY of recycled water use to displace potable water. All Near-Term projects are either in the planning, design, or construction stage. Near-Term target customers have already been identified as potential recycled water users with a total demand of 15,021 AFY. Implementation of Near-Term projects will result in the connection of approximately 40 additional recycled water customers adding to the existing 130 customers. Full implementation of Near-Term projects with existing projects will result in annual recycled water demand of 20,000 AFY, exclusive of both environmental use and DCT in-plant use (26,990 and 2,920 AFY, respectively). Near-Term reuse is the largest in the commercial/industrial sector followed by the irrigation sector.

Harbor Area

Two projects are planned to meet Near-Term demands in the Harbor area, the Harbor Refineries Water Recycling Project (HRWRP) and the Port of LA Harry Bridges Development, for an estimated total demand of 9,461 AFY. Uses include industrial, irrigation, and toilet flushing in commercial facilities. Most of the recycled water, approximately 9,520 AFY, will be used for industrial purposes, including cooling towers and boiler make-up water at oil refineries. Exhibit 4M summarizes Near-Term demands for the Harbor area.

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Exhibit 4M
Harbor Area Near-Term Estimated Demands

Type	Estimated Annual Demand (AFY)	Estimated Service Date
Harbor Irrigation	300	2014
Port of LA Irrigation/Commercial/Industrial	220	2015
Harbor Commercial/Industrial	9,000	2014-2015
Total Harbor Area Near-Term Demands	**9,520**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Meeting demands in the Harbor Area will require construction of additional infrastructure. Approximately 12 miles of 8 to 30-inch diameter pipeline and a 1 million gallon storage tank are proposed. All infrastructure to serve the Port of LA Harry Bridges Development will be constructed by the Los Angeles Harbor Department.

Through an agreement with WBMWD, LADWP intends on acquiring nitrified Title 22 water from the WBMWD Juanita Millender-McDonald Water Treatment Plant (JMMWTP) to supply recycled water to these customers.

Metro Area

Nine water recycling projects and connection of three miscellaneous customers are planned in the Metro Area with annual demands of approximately 1,813 AFY. Almost all recycled water customers propose to use recycled water for irrigation. Commercial uses of recycled water include street sweeping, vehicle washing, train washing, and laundry. LAG will continue to meet all recycled water demands in the Metro area. Exhibit 4N summarizes Near-Term demands for the Metro area.

Exhibit 4N
Metro Area Near-Term Estimated Demands

Type	Estimated Annual Demand (AFY)	Estimated Service Date
Irrigation	1,713	2010-2015
Commercial/Industrial	100	2011-2013
Total Metro Area Near-Term Demands	**1,813**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Multiple facilities are required in the Metro area to meet near-term demands. Approximately five pump stations ranging in size from 600 to 1,800 gallons per minute are planned for construction. Three water tanks with a combined capacity 4.75 million gallons, including the conversion of an abandoned potable water tank in Griffith Park into non-potable water storage tank, are necessary to meet demands. Pipeline construction will consist of 10 additional miles of pipeline ranging from 8 to 30-inch diameters, including conversion of an existing 16-inch pipeline to a 30-inch pipeline beneath Forest Lawn Road.

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Valley Area

In the Valley area DCT will provide the potential Near-Term annual demands approximating 769 AFY. Almost all Near-Term use, except for 75 AFY, will be for irrigation purposes. These users are all located within close proximity to the existing recycled water system. Exhibit 4O summarizes the potential Near-Term demands for the Valley area.

Exhibit 4O
Valley Area Near-Term Estimated Demands

Type	Estimated Annual Demand (AFY)	Estimated Service Date
Irrigation	769	2010-2013
Commercial/Industrial	75	2010-2013
Total Metro Area Near-Term Demands	**844**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling staff

Only minor facilities will be required to connect near-term users to the existing system. Over 2 miles of pipeline ranging from 16 to 20-inch in diameter are proposed. Additionally, 1 storage tank between 1 to 1.5 million gallons and a pump station of an undetermined volume will be required to meet demands.

Westside Area

LADWP will continue to acquire recycled water from WBMWD to serve Near-Term demands of approximately 350 AFY in the Westside area. Near-Term demands include increasing use at Playa Vista and LAX and adding five new customers. Approximately two-thirds of the water will be for irrigation purposes and one-third for commercial/industrial uses in cooling towers located at LAX. Exhibit 4P summarizes Near-Term demands for the Westside Area.

Exhibit 4P
Westside Area Near-Term Estimated Demands

Project	Estimated Annual Demand (AFY)	Estimated Service Date
Irrigation		
Playa Vista Phase 2	100	2015
Westchester High School	10	2012
Subtotal Irrigation	100	
Commercial/Industrial		
LAX Cooling Towers	240	2015
Subtotal Commercial/Industrial	240	
Total Metro Area Near-Term Demands	**350**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

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Serving Near-Term demands will require limited expansion of the existing recycled water system in the area as additional users will connect to the existing system. Connection of the cooling towers at LAX will require construction of an additional 0.7 miles of 12-inch diameter pipeline.

4.4.2 Non-Potable Reuse (NPR) Projects to be completed between 2015 - 2029

NPR projects to be completed between 2015 – 2029 are being identified through the development of the RWMP. These projects will make up the balance of recycled water demand up to 15,650 AFY to achieve the overall city goal of 50,000 AFY of recycled water displacing potable water uses.

As presented in Exhibit 4Q, the project options will have a total demand of approximately 23,100 AFY, inclusive of demands greater than 5 AFY, which is larger than the goal of up to 15,650 AFY and larger than the initial targeted customer demand of 14,390 AFY. Ultimately, an implementation plan will be developed for the recommended project options with a goal of beginning operations for all projects included in the implementation plan by FY 2029.

Exhibit 4Q
Project Option Demands by Service Area

Service Area	Total Demand[1] (AFY)
Harbor	3,300
Metro	6,100
Valley	10,100
Westside	3,600
Total	**23,100**

1. Includes customers with non-potable demand estimates greater than 5 AFY.

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Tier 2 Non-Potable Reuse Project Options, February 26, 2010

Project Selection

An initial step for evaluating these projects involves identification of potential potable customers that can utilize recycled water. These customers need to have sufficient demand and a viable use for recycled water. A preliminary list of potential of customers and associated demands was completed, identifying targeted customer demands of 14,390 AFY. Irrigation-only demands were focused on first as it is generally easier to convert irrigation-only customers to recycled water use than commercial or industrial users. As described below, during development of the project options potential additional recycled water customers were identified based on their non-potable water demands and distance from recycled water sources.

Next, recycled water project options were developed to meet the goal of maximizing recycled water use, while promoting cost efficiency as well as implement ability and adaptability. Two primary steps were utilized to develop recycled water project options:

- Identification of project segments to serve each customer with non-potable demands in excess of 50 AFY
- Identification of project options combining project segments that are linked and have similar unit costs

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The first step in the development of project options was to define general project areas based on customers with non-potable demands in excess of 50 AFY. In the project areas, transmission pipeline alignments (backbone alignments) and laterals were defined to connect customers with demands greater than 50 AFY to existing recycled water infrastructure. Alignments were then redefined to connect demand clusters of less than 50 AFY, but large enough for consideration as a large demand. Finally, distribution pipeline (laterals) alignments were determined to connect customers with demands less than 50 AFY to backbone alignments.

Initial projects options and unit costs are being identified in the current phase of the RWMP. Refinement of these options will occur prior to development of the integrated alternatives for near-term recycled water use. Options for non-potable reuse transmission (purple) pipelines are considered in conjunction with options developed for groundwater replenishment (see section 4.4.3), maximizing reuse, and satellite plants to develop integrated alternatives. Additional information on recycled water unit cost is presented in section 4.4.5 – RWMP Cost and Funding.

Recycled Water Supply Sources

Recycled water availability varies by service area. Additional supplies may be required to meet longer term demands between 2015 – 2029 that may require a combination of expanding existing facilities, service connections to neighboring agencies outside the City, new facilities, and satellite treatment facilities. Satellite treatment facilities are being investigated in the Metro, Valley, and Westside service areas. The RWMP is investigating options to ensure adequate supplies are available for each service area. As part of the RWMP, LADWP met with neighboring agencies in 2009 to explore potential opportunities for regional development of recycled water reuse facilities. These agencies are listed in Exhibit 4T, in section 4.4.6, Stakeholder Process and Agency Coordination.

4.4.3 Groundwater Replenishment

As part of the RWMP, LADWP is pursuing a Groundwater Replenishment Project (GWR), also known as indirect potable reuse, using highly purified advanced treated recycled water from DCT for spreading in existing spreading basins in the San Fernando Valley area. A minimum goal of 15,000 AFY by 2021 has been set for recharging the San Fernando Basin, a major potable water supply for LADWP. The city anticipates having the ability to eventually deliver greater amounts of up to 30,000 AFY to the GWR. The RWMP includes a groundwater recharge plan providing a capital improvement program and outlines regulatory approval steps required to complete the "Phase 1". Additionally, the RWMP outlines various operational and infrastructure improvements required to meet the goal. When complete the RWMP will contain a recommended GWR alternative. Regulatory requirements for groundwater recharge are discussed in sub-section 4.1.2, Groundwater Recharge Regulatory Requirements.

Currently, LADWP uses multiple spreading grounds located in the eastern portion of the San Fernando Basin to recharge the underlying San Fernando Basin with stormwater and imported water. A detailed discussion of the San Fernando Basin and existing recharge operations is provided in Chapter 6, Local Groundwater. This project would recharge a minimum of 15,000 AFY of advanced treated water in the existing Hansen Spreading Grounds and possibly Pacoima Spreading Basins by allowing the water to percolate into the aquifer. It is expected that native stormwater recharge would continue to occur at the spreading grounds in conjunction with the project.

Infrastructure improvements are required to implement the groundwater replenishment program including an advanced water treatment facility and pipelines to convey the product water to the spreading basins.

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An advanced water treatment facility is necessary to further treat tertiary effluent from DCT to produce highly purified recycled water for recharge. Goals for the advanced water treatment plant include as described in the RWMP are:

- Minimum capacity of 15,000 AFY; with the potential to expand to 30,000 AFY
- Initially in service by 2021;
- Utilization of proven technologies that have demonstrated effective removal of regulated chemicals, constituents of emerging concern, and microorganisms; additional removal of constituents of wastewater origin of interest to CDPH, including pharmaceuticals, personal care products, and endocrine disrupting compounds; and
- Product water shall comply with requirements from the CDPH, RWQCB, and SWRCB and be suitable for indirect potable reuse.

To develop and implement the project within the short-time frame, the advanced wastewater treatment plant will be based on the recently permitted Orange County Water District Groundwater Replenishment System Project. This system provides product water for indirect potable reuse by recharging a groundwater basin used for potable water and preventing seawater intrusion. Proposed technologies include microfiltration or ultrafiltration, reverse osmosis, advanced oxidation using ultraviolet light with hydrogen peroxide, and post-treatment for product water stabilization.

As a by-product of advanced water treatment brine is created. Multiple brine disposal alternatives are presented in the RWMP and a final alternative will be selected upon completion of the plan.

Pipelines to convey water to the Hansen spreading grounds are already in place and were constructed as a part of the previous recycled water initiatives for the East Valley Water Recycling Project. However, if the Tujunga spreading basin will also receive water for spreading then additional pipeline infrastructure will be required.

LADWP is working closely with BOS and regulatory agencies to expedite completion of the project by 2021. Current ongoing tasks include completion of the RWMP, public outreach, pilot testing of processes, and formation of an independent advisory panel. Environmental documentation is expected to be initiated in 2011 and completed in 2013.

Independent Advisory Panel

GWR projects typically have the involvement of an independent third party with scientific and technical expertise to provide expert peer review of key aspects of the project, which can ensure the technical viability of the GWR and facilitate the regulatory process. To accomplish this, LADWP awarded a contract with National Water Research Institute (NWRI) to form an Independent Advisory Panel (IAP) to provide expert peer review of the technical, scientific, regulatory, and policy aspects of the proposed groundwater replenishment project, pilot project testing, and other potential groundwater replenishment projects to maximize reuse as part of the LADWP Recycled Master Planning Documents. The IAP process will provide a consistent, thorough, and transparent review of any proposed GWR projects and pilot testing during their critical formation phase, as well as during the long- term implementation phase.

NWRI has vast experience in the organization and administration of the IAP processes for other agencies such as the Orange County Water District Groundwater Replenishment System Project. NWRI will assist the IAP process by assembling the IAP

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members, developing a detailed scope and approach for the IAP's review, coordinating and facilitating meetings, and preparing IAP reports.

Some of the immediate activities that have been identified for the IAP to address during the initial participation include, but are not limited to review of the following:

- General approach for Recycled Water Master Planning
- Hydrogeology (in-basin groundwater blending)
- Treatment (barriers to replace the fifty-percent blend criteria)
- Reliability features of the Advanced Water Treatment Facility
- Source Control Evaluation for groundwater replenishment
- Draft Engineering Report for groundwater replenishment
- Response to technical concerns raised by regulators and the public

The "Independent Advisory Panel for the City of Los Angeles Groundwater Replenishment Project" consists of 13 members with scientific and/or professional expertise in issues related to the implementation of groundwater replenishment projects. Members with different areas of expertise are based on the requirements of the California Department of Public Health Draft Groundwater Recharge Reuse Regulations dated August 2008, as well as the composition of panels used by the Orange County District and the City of San Diego for the implementation of similar groundwater replenishment projects.

NWRI convened the Independent Advisory Panel for the first time in October 2010 to receive introductory information about the recycled water program and groundwater replenishment project. The Panel is expected to be involved throughout the planning, permitting, design, environmental documentation, and implementation of the groundwater replenishment project.

4.4.4 Efforts Beyond 50,000 AFY

As part of the RWMP, LADWP is developing long-term alternatives to maximize recycled water use beyond 50,000 AFY. After 2029 and through 2035 LADWP expects to increase recycled water use by approximately 1,500 AFY anually. To maximize recycled water use LADWP is investigating the following options in its RWMP:

- Recycled water satellite treatment facilities;
- Expansion of recycled water systems;
- Increasing treatment levels at HTP to tertiary and advanced treatment;;
- Reviewing opportunities for partnerships with agencies within the City and outside the City
- Treatment plant upgrades at DCT and LAG; and
- Methods to increase reliability of the system.

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Additionally, the RWMP will identify how the city can maximize recycled water usage unto the future beyond the 50,000 AFY goal. The long-term recycled water alternatives analysis as part of the RWMP has not been completed. However, LADWP forecasts that in 2035 municipal and industrial recycled water demands along with groundwater replenishment will be approximately 59,000 AFY. In addition to this, 26,990 AFY will also be used for environmental beneficial reuse.

4.4.5 RWMP Cost and Funding

The capital cost of expanding the recycled water system to achieve the initial goal of 50,000 AFY to displace the need of potable water was initially estimated to cost approximately $1 billion. Exhibit 4R summarizes the initial estimated capital costs for the RWMP. However, these estimates are being refined as part of the RWMP that are expected to be updated by early 2011.

Exhibit 4R
RWMP Estimated Capital Costs

Phase	Capital Cost[1] ($ million 2008)
Near-Term projects through 2015	$ 265
Long-Term projects through 2029	$ 435
Groundwater Recharge Project	$ 300
Total RWMP Capital Cost	**$ 1,000**

1. Capital costs will be updated and refined as part of the RWMP.

Unit Cost

Non-Potable Reuse (NPR) and Groundwater Replenishment (GWR) projects are diverse, and result in a wide range of costs to implement and sustain. NPR projects present numerous challenges including distance from treatment plant and the associated transmission pipeline construction costs. This factor is weighed against customer size as well as the adaptability to a particular commercial site or process. For GWR projects, nearby spreading grounds must be acquired, along with the construction of a conveyance pipeline. Initial findings of the RWMP have determined the approximate range of unit cost for recycling to be from $600 - $1,500 / AF. This approximation includes capital, operation and maintenance costs.

Funding

Capital costs for RWMP projects will be covered by the sources identified below, as well as other sources as they become available.

- Water Rates – LADWP water rates are the primary funding source for the recycled water program.
- Federal Funding – LADWP will pursue federal funding as it becomes available. In the past LADWP has received funding for recycled water projects from the Federal Water Project Authorization and Adjustment Act of 1992, Public Law 102-575 (HR429), and the United States Bureau of Reclamation Title XVI Program.
- State Funding – LADWP will pursue state funding as it becomes available, through the SWRCB and DWR for recycled water projects. Propositions 13 and 50 had funds specifically marked for recycled water projects. Funding is available through Proposition 84, Integrated Regional Water Management, for implementation projects, including recycled water projects. Low-interest loans are available through the SWRCB for eligible projects.

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- MWD Local Resources Program Incentive – The Local Resources Program provides funding for water recycling and groundwater recovery projects that prevent a new demand on MWD or displace an existing demand on MWD. Financial incentives up to $250 per acre-foot are available dependent upon MWD water rates and projects costs. Funding is not received until production occurs and terminates upon the expiration of the funding agreement for the project.

4.4.6 Stakeholder Process and Agency Coordination

Stakeholder outreach and coordination with agencies plays a key role in LADWP's recycled water program and the RWMP.

Stakeholder Process

To encourage input as recycled water strategies are developed over the next few years in conjunction with the RWMP, LADWP has initiated an extensive stakeholder process. LADWP has developed two formats for participation of stakeholders, a more intensive Recycled Water Advisory Group (RWAG) and a less intensive Recycled Water Forum.

Over 200 stakeholders were invited to participate in the RWAG representing broad interests across the City, including community groups, environmental groups, neighborhood councils, homeowners' associations, and others. Approximately 60 stakeholders are participating in the process. The RWAG first met in 2009 and will continue to have approximately 5 workshops per year over the next 3 to 4 years. Through the RWAG, stakeholders are provided the opportunity to represent their respective organizations and share input with LADWP and BOS and convey they knowledge gained to their organizations. Two main roles of the RWAG are:

1) Allow stakeholders to provide input on recycled water options from technical, environmental, financial, and social viewpoints

2) Consider key project issues and discuss implementation challenges and acceptability.

Less intensive stakeholder participation opportunities are available through the Recycled Water Forums. The Recycled Water Forums will provide stakeholders the opportunity to hear briefings on recycled water efforts through several weekend or evening meeting throughout the year held within local communities. Stakeholders will have the opportunity ask questions and provide comments and suggestions.

Agency Coordination

To maximize recycled water use and move forward with RWMP efforts, LADWP closely coordinated with agencies at the local and state levels. Coordination is necessary to ensure adequate funding, identification of end-users, adequate availability of supplies, permitting and regulatory approvals, and regional cooperation. If federal funding opportunities become available, LADWP will also coordinate with the applicable federal agencies. Exhibit 4S provides a summary list of agencies LADWP is currently coordinating with to maximize recycled water use. LADWP also coordinates recycled water end use with potential customers by assisting with facility retrofits, providing financial incentives, and public education.

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Exhibit 4S
Recycled Water Agency Coordination

Burbank Water and Power[1]	Los Angeles County Department of Public Works[1]
Central Basin Municipal Water District[1]	Metropolitan Water District of Southern California[1]
Glendale Water and Power[1]	Pasadena Water and Power[1]
Los Angeles County Sanitation Districts[1]	Water Replenishment District of Southern California[1]
Long Beach Water Department[1]	West Basin Municipal Water District[1]
Las Virgenes Municipal Water District[1]	Los Angeles Regional Water Quality Control Board
State Water Resources Control Board	Los Angeles County Department of Public Health
City of Los Angeles Department of Public Works, Bureau of Sanitation, Watershed Protection Division	City of Los Angeles Department of Public Works, Bureau of Sanitation
California Department of Public Health	

1. Met with agencies individually to discuss potential regional recycled water use.

4.4.7 Recycled Water Quality

All recycled water provided by LADWP meets at minimum Title 22 standards. Title 22, Chapter 4, of the California Code of Regulations establishes water quality standards and treatment reliability criteria for water recycling to ensure public safety as discussed in Section 4.1. Title 22 standards are achieved with tertiary treatment and disinfection.

Advanced wastewater treatment is currently provided at the TIWRP by the AWTP. Advanced treatment, which includes microfiltration and reverse osmosis, removes many of the impurities remaining after tertiary treatment and disinfection. Water treated with advanced treatment techniques has the potential to be used for seawater barriers and groundwater recharge. As part of the RWMP, advanced treatment is proposed for DCT to provide indirect potable reuse through groundwater recharge. Exhibit 4C, located in Section 4.2, summarizes the level of treatment provided by each of the City's wastewater treatment plants.

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Chapter Five
Los Angeles Aqueduct System

5.0 Overview

Water has been an integral part of the City's history. The City's population and economy was initially supported through a combination of local surface flows primarily from the Los Angeles River, and groundwater pumping primarily from the San Fernando Basin. When it became apparent that much of the local groundwater supply and local surface flows were fully utilized, the citizens of Los Angeles under the leadership of William Mulholland, then Chief Engineer of the Los Angeles Water Bureau, approved by a 10 to 1 margin a $23 million bond measure to construct the First Los Angeles Aqueduct in 1913. This investment was equal to 12 percent of the entire City's assessed valuation at that time. Then in 1940, an additional $40 million was spent to extend the first aqueduct 40 miles north from the Owens River to streams that were tributaries to Mono Lake, see Exhibit 5A.

Finally, to meet the additional water needs of its population, the City decided to construct the second barrel of the Los Angeles Aqueduct in 1963, later to become known as the Second Los Angeles Aqueduct. Construction of the Second Los Angeles Aqueduct was completed in 1970. The second aqueduct increased the City's capacity to deliver water from the Mono Basin and the Owens Valley to Los Angeles from 485 cubic feet per second (cfs) to 775 cfs.

The value of the City's historical investment in the Los Angeles Aqueduct System is substantial. For nearly a century, the City has benefited from the delivery of high-quality, cost-effective water supplies from the eastern Sierra Nevada.

Over time, environmental considerations have required that the City reallocate approximately one-half of the Los Angeles Aqueduct (LAA) water supply to environmental enhancement projects. As a result, the City has used approximately 205,800 AF of water supplies for environmental enhancement in the Owens Valley and Mono Basin regions in 2010, which is in addition to the almost 107,300 acre-ft per year (AFY) supplied for agricultural, stockwater, and Native American Reservations. Limiting water deliveries to the City from the LAA has directly led to increased dependence on imported water supply from the Metropolitan Water District of Southern California (MWD). LADWP purchase of supplemental water from MWD in 2008-09 is at an all time high.

As indicated in Exhibit 5B, LAA deliveries comprise 39 percent of the total runoff in the Eastern Sierra in an average year. The vast majority of water collected in the Eastern Sierra stays in the Mono Basin, Owens River, and Owens Valley for ecosystem and other uses.

Exhibit 5A
Los Angeles Aqueduct System

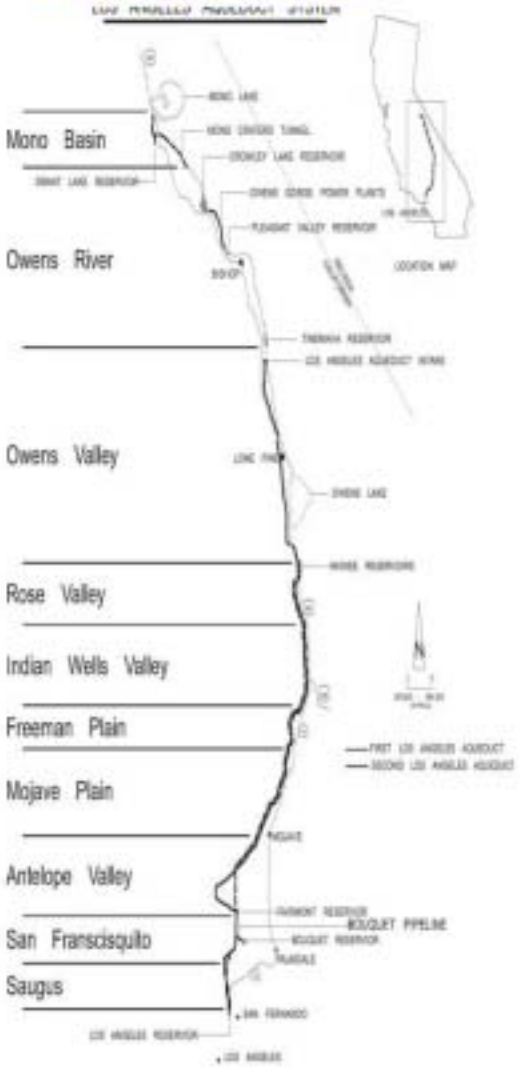

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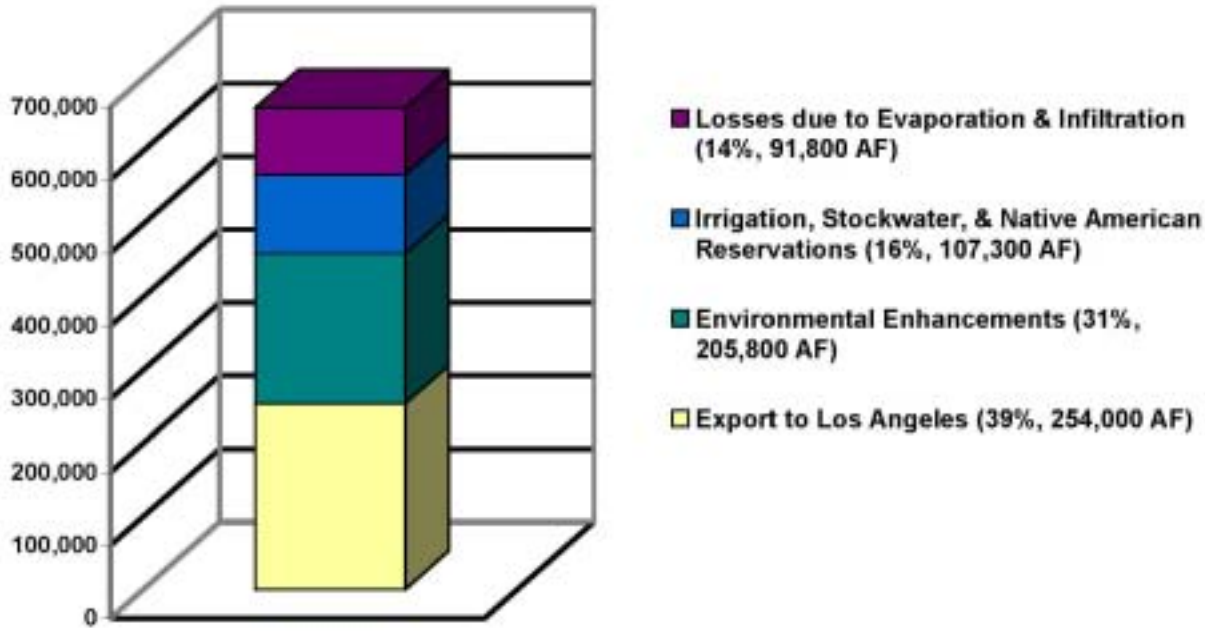
Exhibit 5B
Mono Basin and Owens Valley Water Use Allocations



5.1 Historical Deliveries

Annual LAA deliveries are dependent on snowfall in the eastern Sierra Nevada. Years with abundant snowpack result in larger quantities of water deliveries from the LAA, and typically lower supplemental water purchases from MWD. Unfortunately, a given year's snowpack cannot be predicted with certainty, and thus, deliveries from the LAA system are subject to significant hydrologic variability.

The impact to LAA water supplies due to varying hydrology in the Mono Basin and Owens Valley is amplified by the requirements to release water for environmental restoration efforts in the eastern Sierra Nevada. Since 1989, when City water exports were significantly reduced to restore the Mono Basin's ecosystem, LAA deliveries from the Mono Basin and Owens Valley have ranged from 108,503 AF in 2008-09 to 466,584 AF in 1995-96. Average LAA deliveries since 1989-90 have been approximately 264,799 AF, about 42 percent of the City's total water needs.

The cyclical nature of hydrology is exhibited best by Los Angeles Aqueduct (LAA) deliveries over the last ten years. This general period was characterized by a series of wet years, followed by a series of dry years. From 2000-01 through 2009-10, LAA deliveries supplied an average of 36 percent of the City's water needs. The reliability impact of hydrologic cycles on LAA supplies is evident through historical deliveries. A broader look at how deliveries from the LAA have fluctuated from year to year is shown in Exhibit 5C.

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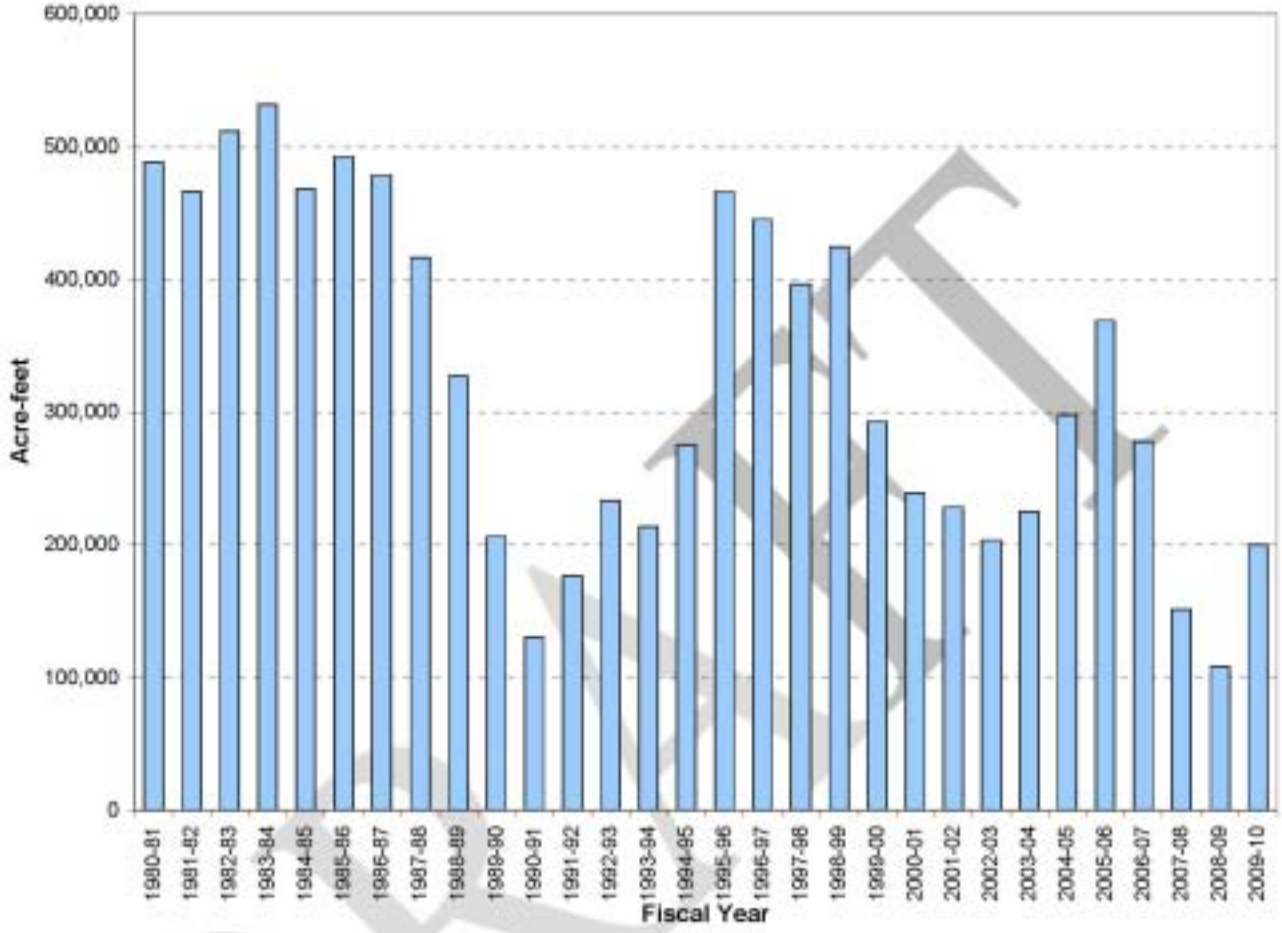
Exhibit 5C
Historical Los Angeles Aqueduct Deliveries



A long term perspective of the general cycle of wet and dry years for the Owens Valley is evident in Exhibit 5D, particularly since the late 1960s. As illustrated, reliance solely on one water supply source is not practical. Therefore, the City relies on the LAA in combination with the Colorado River Aqueduct and the State Water Project as the City's primary imported water sources. These imported sources combined with local groundwater, recycled water, and conservation make up the City's total water supply portfolio. This portfolio of water resources is fundamental to LADWP's ability to deliver a reliable water supply to meet the needs of over 4 million residents of Los Angeles.

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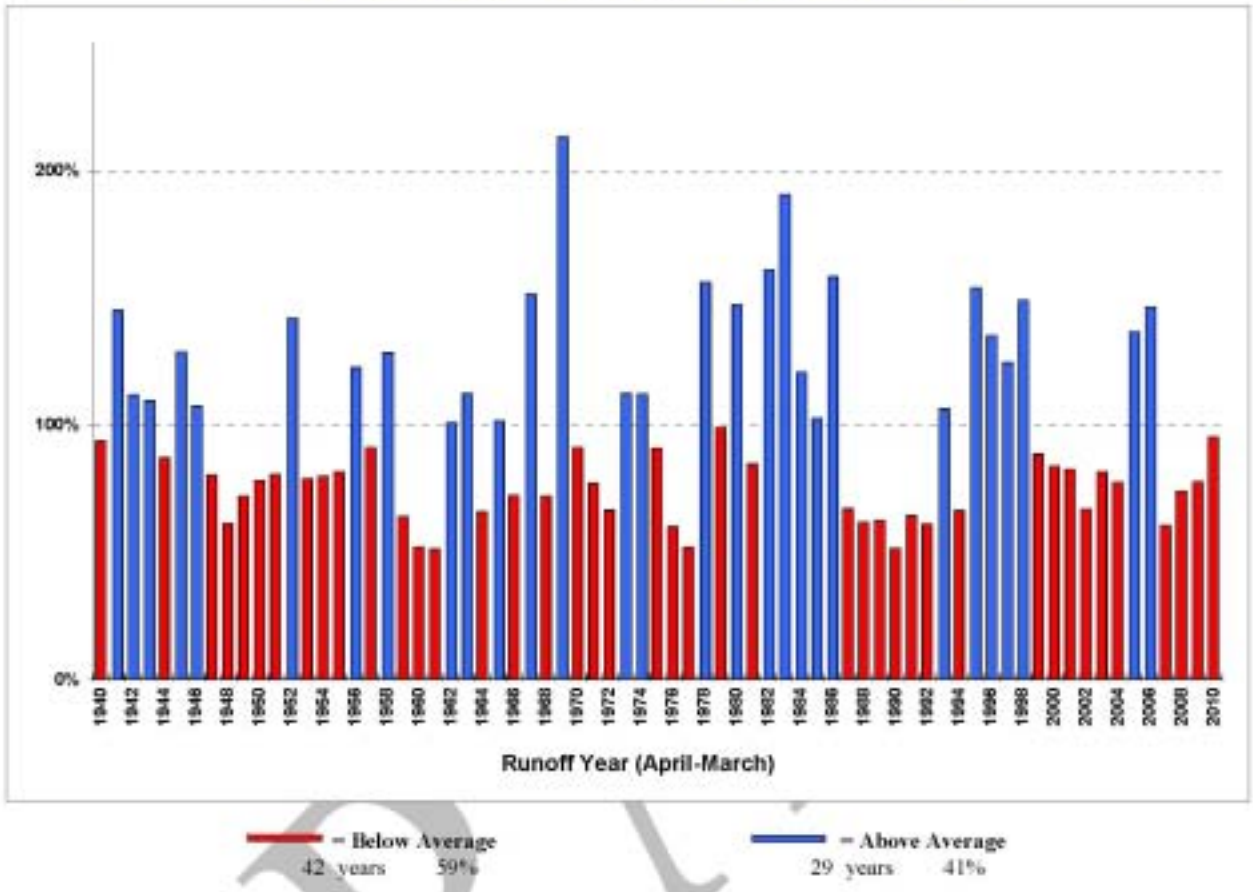
Exhibit 5D
Eastern Sierra Nevada Runoff Owens Valley – Percent of Normal



5.2 Mono Basin and Owens Valley Supplies

Surface runoff from snowmelt in the eastern Sierra Nevada Mountains is the primary source of supply for the LAA. The LAA extends approximately 340 miles from the Mono Basin to Los Angeles. Water is conveyed the entire distance by gravity alone. LADWP regulates system output through storage control at seven reservoirs, beginning with Grant Lake Reservoir to the north and ending with Bouquet Reservoir to the south. The total combined reservoir storage capacity of the system is 300,560 AF. Hydroelectric power is also generated from 12 power plants along the LAA. Combined maximum capability of the power generation facilities is 205 mega-watts. Water-gathering activities for the LAA have a junior priority to meeting the Owens Valley and Mono Basin water obligations for environmental, domestic, agricultural, and recreational water needs.

The LAA is fed by runoff from the eastern slope of the Sierra Nevada. Runoff from the eastern slope reaches its maximum in the late spring and summer, after most of the year's precipitation has already occurred. The snowpack in the eastern Sierra Nevada provides natural storage for the LAA system. This snowpack storage is necessary in light of the minimal primarily regulatory storage capacity along the LAA system.

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Water Rights

The City's export of water from the eastern Sierra Nevada is based on 166 Pre-1914 and 16 Post-1914 water right diversion licenses on various streams in the Mono Basin and Owens Valley. The majority of the City's water rights were filed prior to 1914 with the Counties of Mono and Inyo Recorder's Office. All Post-1914 licenses were granted by the State Water Resources Control Board. The most significant basis for export of surface water from the Eastern Sierra Nevada is an appropriation claim in 1905 to divert up to 50,000 miner's inches (1,250 cubic feet per second) from the Owens River at a location approximately 15 miles north of the town of Independence into the LAA for transport to Los Angeles. The City has since filed Supplemental Statements of Water Diversion and Use forms with the State Water Resources Control Board (SWRCB) for all LADWP diversions and licenses.

The City's water right licenses in the Mono Basin were amended by the SWRCB in 1994 through the Mono Lake Basin Water Right Decision 1631. Currently, water export from the Mono Basin is limited to 16,000 AF per year based on a court order to raise the target elevation of Mono Lake and restore four streams that flow to Mono Lake.

The primary groundwater right through which Los Angeles has developed groundwater resources in the Owens Valley is based on ownership of a majority of the land (approximately 314,000 acres) and associated water rights in the Owens Valley. Management of the groundwater supply in the Owens Valley is according to a 1991 agreement between Inyo County and LADWP. The goal of this agreement is to avoid defined decreases and changes in vegetation, and to cause no significant effect on the environment which cannot be acceptably mitigated, while providing a reliable supply of water for export to Los Angeles and for use in Inyo County.

5.3 Environmental Issues and Mitigation

Over time an increasingly larger portion of the LAA water supply has been reallocated to the environment. As a result, the City's current supply for environmental enhancement in the Owens Valley and Mono Basin is approximately 205,800 AF per year. To accommodate LAA delivery reductions due to these environmental enhancements, LADWP has funded conservation and water recycling programs to improve water use efficiency within the City. Exhibit 5E illustrates the breakdown of LAA water supply commitments by category for Environmental Enhancement and Mitigation Projects have been implemented as part of the City's commitment to meet the environmental water needs of the Owens Valley. Among these environmental projects, LADWP is diverting 10,700 AF of water from the LAA for Owens Valley Enhancement and Mitigation Projects, 10,400 AF for Recreation and Wildlife Projects, and 15,700 AF for the Lower Owens River Project. These annual environmental project diversions are in addition to water that provides environmental benefits in the Mono Basin and Owens Lake.

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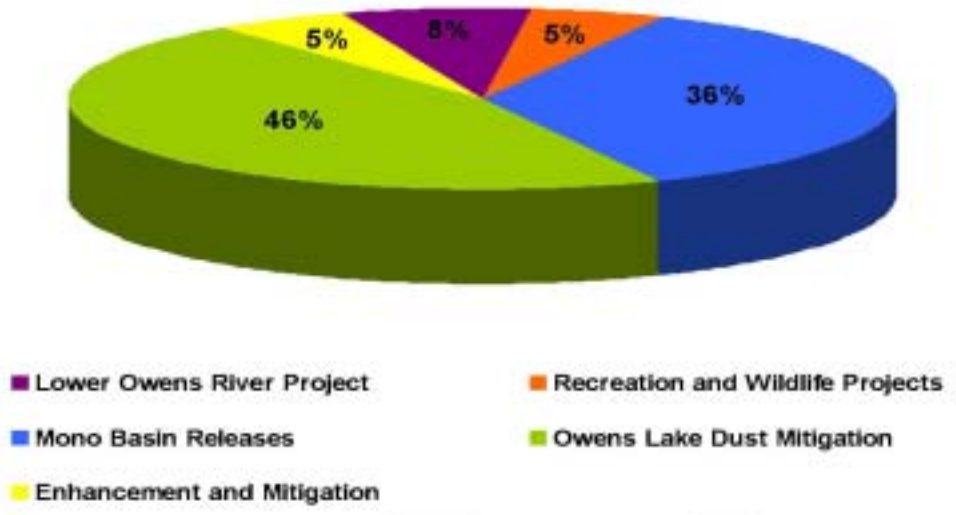
Exhibit 5E
Mono Basin and Owens River Environmental Enhancement Commitments



Environmental Enhancement Commitments	AFY
Lower Owens River Project	15,700
Recreation and Wildlife Projects	10,400
Mono Basin Releases	74,000
Owens Lake Dust Mitigation	95,000
Enhancement and Mitigation	10,700
Total	205,800

Mono Basin

Currently, Mono Basin exports will remain at no more than 16,000 AF per year until Mono Lake reaches its target elevation of 6,391 feet above mean sea level. Exhibit 5F provides the maximum export levels from the Mono Basin under specified conditions as defined in the State Water Resources Control Board Decision D1631 that was issued on September 28, 1994. Since the long-term average of Mono Basin exports before 1994 was approximately 90,000 AFY, the net reduction in water exports in the Mono Basin is estimated at 74,000 AFY of water mainly from Grant Lake Reservoir, Lee Vining Creek, Walker Creek, Parker Creek, and Rush Creek. As of January 2010, Mono Lake is at elevation 6,381 feet. Extensive restoration and monitoring programs in the Mono Basin have improved the streams, riparian, fishery, and waterfowl habitats. With reduced diversions from the basin, Mono Lake's elevation has risen, but has also been fluctuating due to lack of runoff as illustrated during the period of 2000 to 2005 on Exhibit 5F.

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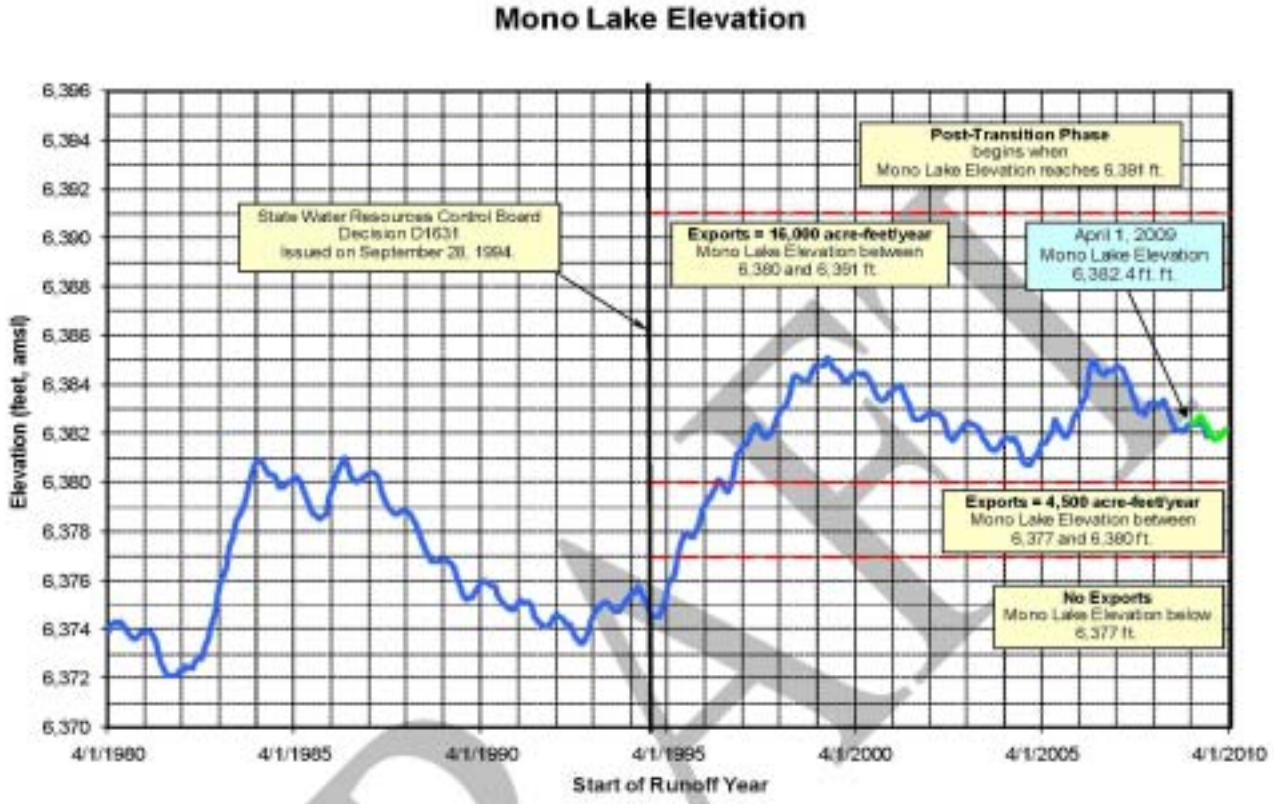
Exhibit 5F
Historical Mono Lake Elevations



To effectively maintain continuous base and peak water flows to the ecosystem restoration area of Lower Rush Creek in the Mono Basin, LADWP completed construction of the Mono Gate One diversion facility upgrade in November 2009. Exhibit 5G summarizes the base and peak flow requirements for Lower Rush Creek. Base and peak flow requirements vary in relation to seven hydrologic conditions ranging from dry to extreme wet as identified by forecasted runoff for Mono Basin. Mono Gate One was originally constructed to release excess water from the aqueduct system during high flows by diverting water into Lower Rush Creek with a system of diversion boards. However, it had no monitoring or flow control capabilities and was not designed for precise flow metering or full-time diversion. Construction completed in the fall of 2009, the new Mono Gate has enabled LADWP to greatly improve measuring and flow capabilities, satisfying one of the operational requirements of the SWRCB.

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Exhibit 5G
Lower Rush Creek Base and Peak Flow Requirements

Hydrologic Condition	Base Flow (cfs)							Peak Flows (cfs)
	Apr	May - Jul	Aug - Sep	Apr - Sep	Oct- Mar	May - Aug	Sep - Mar	
Dry (runoff ≤ 83,665 AF)	N/A	N/A	N/A	31	36	N/A	N/A	None
Dry-Normal I (runoff 83,665 - 91,590 AF)	N/A	N/A	N/A	47	44	N/A	N/A	200 for 7 days
Dry-Normal II (runoff 91,590 - 100,750 AF)	N/A	N/A	N/A	47	44	N/A	N/A	250 for 5 days
Normal (runoff 100,750 - 130,670 AF)	N/A	N/A	N/A	47	44	N/A	N/A	380 for 5 days follows 300 for 7 days
Wet-Normal (130,750 - 166,700 AF)	N/A	N/A	N/A	47	44	N/A	N/A	400 for 5 days followed by 350 for 10 days
Wet (166,700 - 195,400 AF)	N/A	N/A	N/A	68	52	N/A	N/A	450 for 5 days followed by 400 for 10 days
Extreme Wet (runoff > 195,400 AF)	N/A	N/A	N/A	68	52	N/A	N/A	500 for 5 days followed 400 for 10 days

Source: Mono Basin Operations, Guidelines A-G

Lower Owens River Project

Beginning December 2006, the Lower Owens River Project, depicted in Exhibit 5H, releases water from the LAA to create a warm water fishery along a 62-mile section of the Owens River. Water is released near the LAA intake facility and a pump back station is located downstream to return flows to the LAA or to Owens Dry Lake for dust control measures. In accordance with the Memorandum of Understanding between LADWP and Inyo County and the approved Environmental Impact Report, annual monitoring reports are to be prepared to measure project success. The first Lower Owens River Project Annual Monitoring Report was prepared in 2008.

The MOU prescribes requirements for project flows. Both base flows and seasonal habitat peak flows are required by the project. A flow schedule is provided in Exhibit 5I. Seasonal habitat peak flows vary between 40 cfs (zero additional flows beyond the base flow requirements) to 200 cfs. For below average runoff years, seasonal habitat flows may be incrementally lowered from the average runoff year requirements of 200 cfs to 40 cfs (base flow) in proportion to the forecasted runoff flows in the watershed. Base flows are constant at 40 cfs regardless of forecasted runoff flows. It is estimated that the long-term use and transit losses from the project will be approximately 15,700 AFY.

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Exhibit 5H
Lower Owens River Project Area

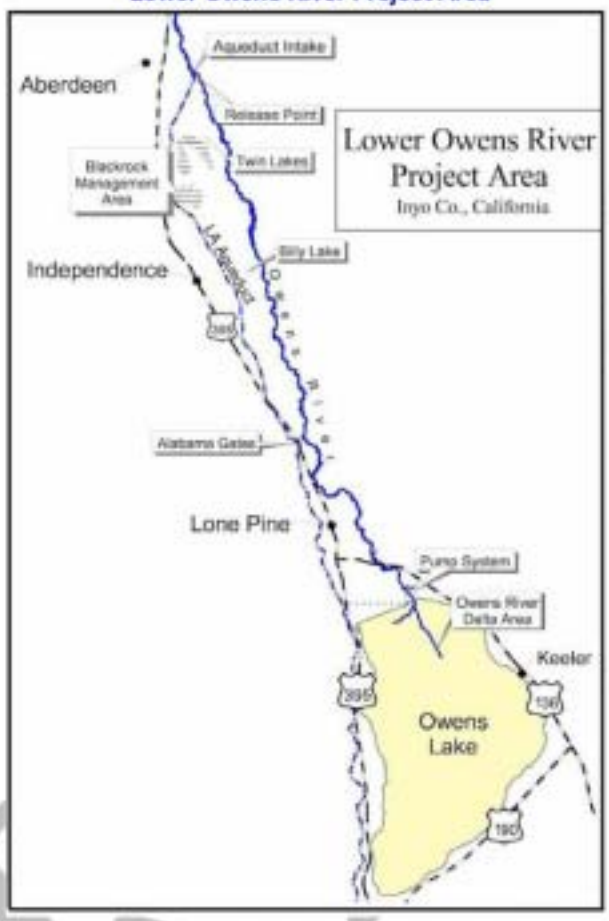

Exhibit 5I
Lower Owens River Base and Peak Seasonal Habitat Flow Requirements

Hydrologic Condition Forecasted[1] (Percent of Average Runoff)	Base Flow (cfs)	Peak Seasonal Habitat Flow (cfs)
50 percent or less	40	Base flow only
70 percent	40	100
100 percent or greater	40	200

1. Runoff forecast determined by LADWP's Runoff Forecast Model for Owens River Basin based on April 1st snow survey.

2. Peak season habitat flows are proportionately ramped up from 40 cfs to 200 cfs based on the percent of average runoff forecasted greater than 50 percent and less than 100 percent.

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5.4 Owens Lake Dust Mitigation

Historically, the Owens River was the main source of water for Owens Lake. Diversion of water from the river, first by farmers in the Owens Valley and then by the City, resulted in the lake being reduced to a small brine pool. The exposed lakebed became a major source of windblown dust resulting in the United States Environmental Protection Agency (EPA) classifying the southern Owens Valley as a serious non-attainment area for particulates (dust) also known as PM_{10} emissions in 1991.

As a result of PM_{10} emissions exceeding regulations, the EPA required California to prepare a State Implementation Plan (SIP) to bring the region into compliance with Federal air quality standards by 2006. In July 1998, LADWP entered into a Memorandum of Agreement with the EPA that: 1) delineated the dust producing areas on the lakebed that needed to be controlled; 2) specified what measures must be used to control the dust; and 3) outlined a timetable for implementation of the control measures. The Memorandum of Agreement was incorporated into a formal air quality control SIP by the Great Basin Unified Air Pollution Control District (District). The plan was approved by the EPA in October 1999.

LADWP's water use for Owens Lake Dust Mitigation has been gradually increased over the years. Exhibit 5J summarizes yearly water use for the Owens Lake Dust Control Project. The 2005 UWMP estimated that up 55,000 AFY of water would be all that was required for the Project. Currently, up to 95,000 AF per year of water is expected to be diverted from the Aqueduct for dust mitigation at the Owens Lake.

Exhibit 5J
Yearly Water Use on Owens Lake (Fiscal Year)

Fiscal Year	Total AF
2002/2003	23,937
2003/2004	31,362
2004/2005	29,494
2005/2006	29,413
2006/2007	54,849
2007/2008	67,262
2008/2009	59,187
2009/2010	75,428
2010/2011	95,000

* Fiscal year 2010/2011 is projected

Since 2001, LADWP has diverted water from the LAA for the Owens Lake Dust Control Project. A combination of shallow flooding, managed vegetation, and a small amount of gravel are used at various lakebed locations as Best Available Control Measures (BACM) for dust control mitigation on almost 40 square miles. Exhibit 5K provides a description of the best accepted control methods. LADWP has completed 9.2 square miles of shallow flooding, 0.5 square miles of modified shallow flooding, and 0.4 square miles of sand fence as part of the Phase 7 project in accordance with the 2008 SIP. However, LADWP had proposed 3.1 square miles of a new waterless dust control measure called Moat and Row which was disallowed by the California State Lands Commission in April 2010. LADWP is working with the District to develop an alternative solution for the areas originally proposed for Moat and Row. LADWP has been ordered to complete an additional 2 square miles of dust control known as the Phase 8 project. LADWP is seeking a lease from the California State Lands Commission to construct Gravel BACM for Phase 8 as it does not require water for operation.

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Exhibit 5K
Dust Control Mitigation Measures

Dust Control Measures		Description
Shallow Flooding	Sheet Flooding	Releases water from arrays of low-flow water outlets spaced at intervals of between 60 and 100 feet along pipelines laid along lake bed contours. Pipelines are spaced between 500 and 800 feet apart. This arrayed configuration of water delivery creates large, very shallow sheets of braided water channels. Water depths in sheet flooded areas are typically at most a few inches deep. The lower edge of sheet flooded areas has containment berms to capture and pond excess flows. The water slowly flows across the typically very flat lake bed surfaces downhill to tail-water ponds where pumps recirculate the water back to the outlets. To maximize project water use efficiency, flows to sheet flow areas are regulated at the outlets so that only sufficient water is released to keep the soil wet. Any water that does reach the lower end of the control area is collected and recirculated back through the water delivery system.
	Shallow Flooding (Pond Flooding)	Water containment berms that allow ponds to be formed that submerge the emissive lake bed areas. These ponds are up to four feet deep. The containment berms are typically rock-faced to protect them from delivery to the pond area until the pond reaches a size and depth sufficient to submerge the required amount of emissive water. Water delivery then ceases until evaporation reduces the pond size to a set minimum.
Managed Vegetation		Control measure consists of creating a farm-like environment from barren playa. The saline soil must first be reclaimed with the application of relatively fresh water and then planted with salt-tolerant plants that are native to the Owens Lake basin. Thereafter, soil fertility and moisture inputs must be managed to encourage rapid plant development and maintenance. Existing Managed Vegetation areas are irrigated with buried drip irrigation tubing and a complex network of buried drains to capture excess water for reuse on the Managed Vegetation area or in Shallow Flooding areas. Managed Vegetation is sustainable at Owens Lake only if salt from the naturally occurring shallow groundwater is prevented from rising back into the rooting zone.
Gravel Blanket		A four-inch layer of coarse gravel laid on the surface of the Owens Lake playa will prevent emissions by preventing the formation of efflorescent evaporate salt crusts, because the large pore spaces between the gravel particles disrupt the capillary movement of saline water to the surface where it can evaporate and deposit salts. The gravel also creates a surface that has a high threshold wind velocity so that direct movement of the large gravel particles is prevented and the finer particles of the underlying lake bed soils are protected. Gravel Blankets are effective on essentially any type of soil surface.

As part of an Interim Management Plan, LADWP and Inyo County have agreed to conduct a joint study to explore the feasibility of extracting and utilizing groundwater beneath Owens Lake to supplement the water supply necessary for dust mitigation activities. This feasibility study is scheduled for completion by November 2011. If groundwater pumping is considered feasible and acceptable, LADWP will first need to obtain required approval from Great Basin Unified Air Pollution Control District, California State Lands Commission, California Department of Fish and Game, and Inyo County.

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5.5 Water Quality

As land owners of much of the Mono Basin and Owens River watersheds, LADWP has placed strict limits on the extent of development impacting the City-owned watersheds. Snowmelt from the eastern Sierra Nevada contains low total organic carbon (TOC), bromide concentrations, and other constituents that can form disinfectant byproducts during the water treatment process. LADWP conducts routine monitoring of all of its water supplies for over 170 constituents and contaminants. Ninety-eight of the constituents and contaminants have enforceable standards.

The LAA supply is the main source of arsenic in LADWP's water supply. Arsenic is collected as the Owens River makes its way down through volcanic formations in the vicinity of Hot Creek in Long Valley. Geothermal springs in these areas have arsenic concentrations of around 200 parts per billion (ppb). Concentrations are dramatically reduced as water in the area mixes with snow melt and other pristine water sources. Historic untreated LAA water arsenic concentrations have ranged from 10 to 74 ppb. During the latest 3-year routine compliance monitoring cycle from 2007 to 2009, the highest arsenic concentration after treatment was 8.1 ppb, while the average arsenic concentration within LADWP's water distribution system was 3.3 ppb, well below the current Federal and State drinking water standard of 50 ppb. In light of potential, more stringent arsenic regulations, LADWP is taking a proactive approach in addressing this issue by investing enhanced coagulation treatment.

LADWP completed an evaluation and preliminary design report for enhanced coagulation at the Los Angeles Aqueduct Filtration Plant in December 2006 as a means of addressing future water quality regulations faced by LADWP, including arsenic. An enhanced coagulation facility using the process as outlined in the report is planned as part of the treatment process at the Los Angeles Aqueduct Filtration Plant by 2021.

To comply with the Stage 2 Disinfectants and Disinfection Byproducts Rule, another water quality improvement effort being implemented is the conversion from chlorine to chloramine residual disinfectant. This transition, which is expected to be completed by April 2014, will allow LADWP to maintain the same high level of disinfection in its water supply while freeing itself from other potential disinfection issues associated with the use of chlorine. The use of chloramines will provide additional operational flexibility by allowing the blending of purchased MWD water (which is chloraminated) into the LADWP distribution system without the problems associated with creating a chlorine/chloramines interface when blending the two supplies.

5.6 Projected Deliveries

Near-term water deliveries are forecasted for the LAA using two models, the Runoff Forecast Model and the Los Angeles Aqueduct Simulation Model (LAASM). These two models used jointly and accurately predict the amount of water available from this the LAA.

The Runoff Forecast Model is used to predict total Owens Valley and Mono Basin stream runoff. The model's estimating equations were developed using historic rainfall and snowfall, as well as streamflow data of each year. Model input consists of 6 months of antecedent rainfall and streamflow data, as well as the final snowpack levels on April 1st. The model's output is the forecasted runoff for the Owens Valley and Mono Basin during the twelve month period following April 1st, assuming that median rainfall occurs during those twelve months.

Runoff flows from the Owens Valley to the City of Los Angeles are modeled by the LAASM. LAASM uses the output of the Forecast Model as input, along with estimates of various uses within the Owens Valley. LAASM uses historically derived

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estimating equations to forecast various losses, including evaporation and infiltration, as well as other inflows such as unmetered springs. The final output from LAASM is the volume of LAA water projected to be delivered to the City of Los Angeles.

Taking the foreseeable factors discussed earlier in this chapter into consideration, the average annual long-term LAA delivery over the next 25 years is expected to be approximately 254,000 AFY and gradually decline to 244,000 AFY due to climate change impact. Deliveries for a series of dry years, using 1988/89 through 1992/93 hydrology, are expected to range from approximately 48,520 AFY to 105,770 AFY. A single dry year minimum of 48,520 AFY is expected with a repeat of the 1990/91 hydrology. Detailed LAA projected deliveries by year are provided in Chapter 11, Water Service Reliability Assessment.

5.7 LAA Delivery Cost

The costs associated with LAA water supply are primarily operation and maintenance costs. Therefore, the unit cost of exporting water from LAA to the City varies mainly with the quantity of water delivered and is highly dependent on hydrological conditions. During dry years, the amount of water delivered to the City decreases, which results in an increase to the unit cost. Over the years, eastern Sierra Nevada environmental enhancement projects also contributed to the overall LAA delivery cost, with increasing expenditures when the Owens Lake Dust Mitigation and Lower Owens River Project were initiated. Exhibit 5L summarizes the historical unit cost of treated water from LAA. The peaks occurred when LAA deliveries significantly decreased during fiscal years 1990-91, 2002-03, and 2008-09 with the LAA deliveries of 130,300 AF at $499/AF; 203,400 AF at $419/AF; and 108,500 AF at $1,003/AF respectively.

Exhibit 5L
Historical Cost of LAA Treated Water

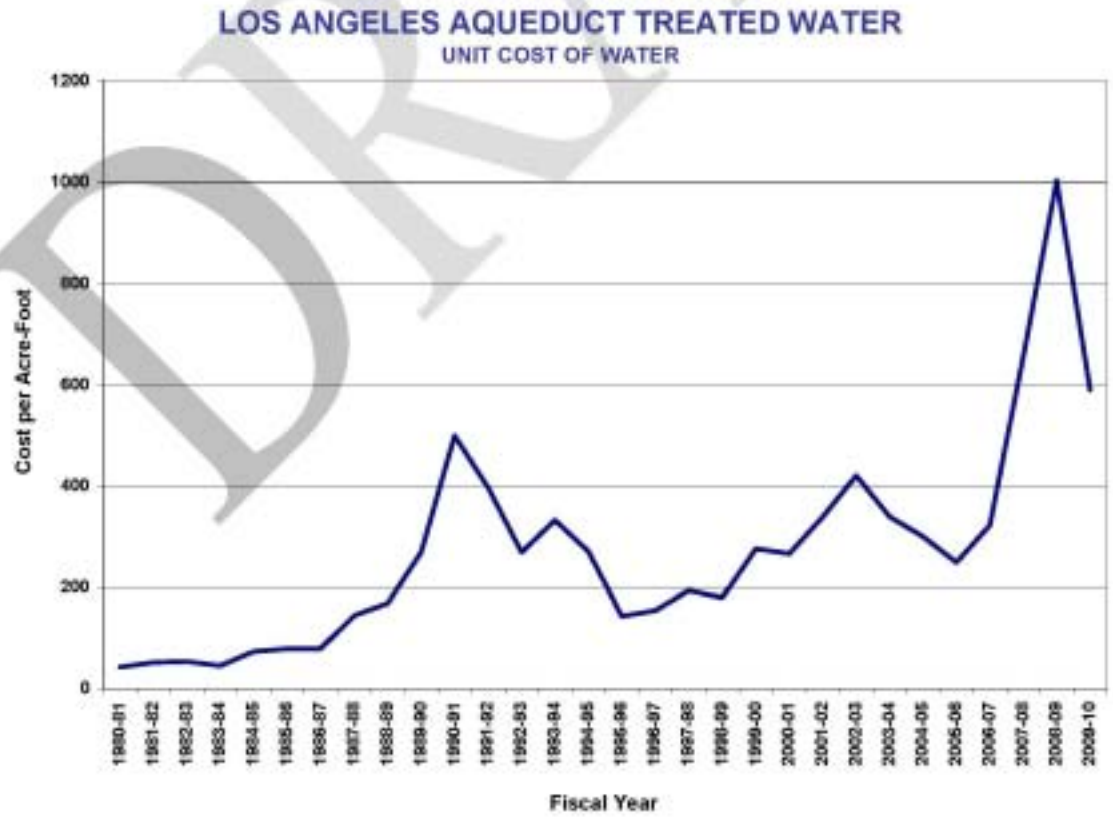

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Exhibit 5M shows the unit cost of LAA treated water from 2005/06 to 2009/10. The 5-year average was $563/AF. The sharp increase in 2008/09 was due to LAA delivery being the lowest on records.

Exhibit 5M
Annual Unit Cost

Fiscal Year	2005-06	2006-07	2007-08	2008-09	2009-10
Unit Cost	$248	$321	$654	$1,003	$589

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Local Groundwater

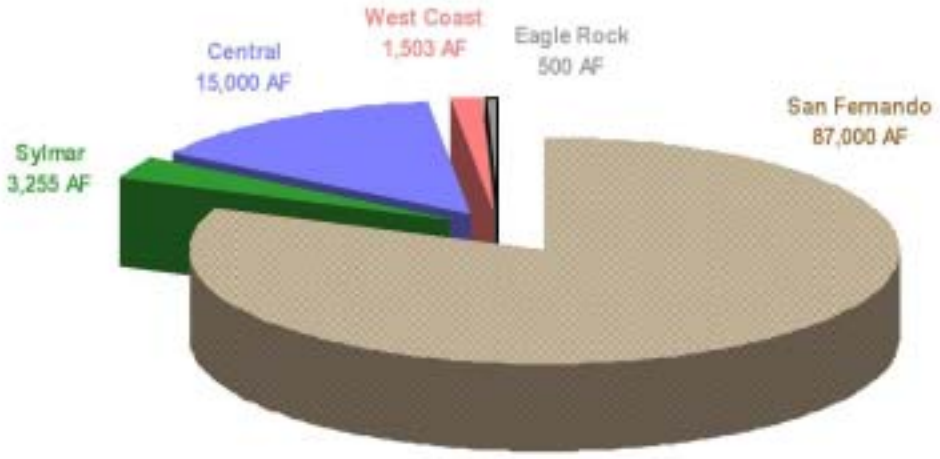
6.0 Overview

A key resource that the City has relied upon as the major component of its local supply portfolio is local groundwater. Over the last ten years local groundwater has provided approximately 12 percent of the total water supply for Los Angeles, and historically has provided nearly 30 percent of the City's total supply during droughts when imported supplies become unreliable. In recent years, contamination issues have impacted LADWP's ability to fully utilize its local groundwater entitlements. Additionally, reduction of natural infiltration due to expanding urban hardscape and channelization of stormwater runoff has resulted in declining groundwater elevations. In response to contamination issues and declining groundwater levels, LADWP is working clean-up of the San Fernando Groundwater Basin, and is making investments to recharge local groundwater basins through stormwater recharge projects, while at the same time replacing or rehabilitating old or deteriorating facilities.

6.1 Groundwater Rights

The City owns water rights in the San Fernando, Sylmar, Eagle Rock, Central, and West Coast Basins. Combined, these water rights total approximately 107,408 AFY. Water rights in the Upper Los Angeles River Area (ULARA), which comprises of the San Fernando, Sylmar, and Eagle Rock basins, total approximately 90,905 AFY which translates into approximately 87,000 AFY in the San Fernando Basin (SFB), 500 AFY in the Eagle Rock Basin, and 3,405 AFY in the Sylmar Basin. Water rights in the Central and West Coast Basin are 15,000 AFY and 1,503 AFY, respectively. However, LADWP does not exercise its pumping rights in Eagle Rock Basin and West Coast Basin at this time. Exhibit 6A summarizes the City's annual local groundwater entitlements by basin. Superior Court Judgments for the San Fernando, Sylmar, Eagle Rock, Central, and West Coast groundwater basins are attached in Appendices X, X, and X, respectively.

Exhibit 6A
Annual Local Groundwater Entitlement



Total: 107,258 AF per year

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The ULARA Groundwater Basin Adjudication

The City's entitlements in the San Fernando, Sylmar, and Eagle Rock Basins were established in a Judgment by the Superior Court of the State of California for the County of Los Angeles in Case No. 650079, *The City of Los Angeles, Plaintiff, vs. Cities of San Fernando, et. al., Defendants*, dated January 26, 1979 (San Fernando Judgment) and the 1984 Sylmar Basin Stipulation (1984 Stipulation). Appendix X contains the Judgment and 1984 Stipulation. The Judgment was based on maintaining a safe yield operation for the basin, whereby groundwater extractions over the long-term will be maintained in a manner that does not create an overdraft condition in the basin. The City has no entitlement in the Verdugo Basin but may have the right to recapture a portion of its import return waters upon application to the Watermaster and issuance of an order after a hearing by the Court. The Judgment and 1984 Stipulation limit groundwater extraction from all four groundwater basins and establish a court-appointed Watermaster and an Administrative Committee made up of a representative from each of the five water supply agencies overlying the ULARA Basins. The five public agencies are the City of Los Angeles, the City of Glendale, the City of San Fernando, the City of Burbank, and the Crescenta Valley County Water District.

The Watermaster assists the Court in administering and enforcing the provisions of the 1979 Judgment and 1984 Stipulation. Among other duties, the Watermaster monitors groundwater levels, recharge operations, recycled water use, extractions, water imports and exports, and reports all significant water-related events in the Basin to the Court and to the parties to the Judgments. The activities of the Watermaster are key components for the effective management of the groundwater resources in the ULARA Basins. Key tasks of the Watermaster for the SFB include:

- Monitoring of radiological and synthetic organic compounds (SOCs) every three years;
- To continue to work with key regulators, such as the Los Angeles Regional Water Quality Control Board (LARWQCB), California Department of Public Health (CDPH), California Department of Toxic Substance Control (CDTSC), and the United States Environmental Protection Agency (USEPA), to expedite clean-up of groundwater at or near known contamination sites
- To continue to support the ongoing activities of the City of Los Angeles and others to recharge the groundwater basin at existing spreading basins on the east side of the San Fernando Valley;
- To help determine the technical feasibility of using advanced treated recycled water to recharge the groundwater basin;
- To continue to work with the Los Angeles Department of Public Works, Bureau of Sanitation, Watershed Protection Division, to enhance groundwater recharge of local basins via the Standard Urban Stormwater Mitigation Plans (SUSMP) procedures for stormwater infiltration at new development and redevelopment project sites; and
- To work with local purveyors in an effort to increase the quantity and quality of the groundwater database for the entire ULARA basin.

Historical Groundwater Production

On average over the past five years, about 83 percent (58,575 AFY) of the City's local groundwater supply was extracted from ULARA groundwater basins, while the Central Basin provided 17 percent (12,512 AFY). Exhibit 6B summarizes the City's local groundwater production by basin over the last five years.

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Exhibit 6B
Local Groundwater Basin Supply
Fiscal Year (July through June in AF)

Groundwater Basin	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	Average	Percentage
San Fernando	35,486	75,640	57,060	49,106	62,218	55,902	79%
Sylmar	1,844	3,901	4,046	576	2,998	2,673	4%
Central	13,290	13,358	12,207	11,937	11,766	12,512	17%
Total	50,620	92,899	73,313	61,619	76,982	71,087	100%

Historically, LADWP operates groundwater production by utilizing conjunctive use of surface water and groundwater to optimize the supply and demand balance. Through conjunctive use, the timing of groundwater extractions can be used to meet varying demands. Furthermore, in the past, LADWP prevented against groundwater overdraft during multiple dry years through strategic pumping. When successive dry years occur, LADWP pumped at greater than average rates for the first few years of the drought, and then pumped at lower rates in subsequent years.

However, since 2007, groundwater contamination issues in the SFB have greatly limited LADWP's ability to pump its full groundwater entitlement. As a result, LADWP has been pumping the maximum amount capable that is not impacted by contamination sources, and therefore, has not been able to utilize its conjunctive use strategies for its groundwater operation. When the clean-up of the SFB is complete, LADWP will be able to return to these strategies to ensure reliability and protect from groundwater overdraft.

6.1 San Fernando Basin

The primary source of local groundwater for the City is the SFB providing over 79 percent of the City's groundwater supply ranging from 35,486 AF to 75,640 AF during the period Fiscal Year 2005-2006 to Fiscal Year 2009-2010. The SFB is the largest of the four ULARA basins. It consists of 112,000 acres and comprises 91.2 percent of the total valley in ULARA. It is bounded on the east by the Verdugo Mountains; on the north by the Little Tujunga Syncline and the San Gabriel and Santa Susana Mountains; on west by the Simi Hills; and on the south by the Santa Monica Mountains. A map of the basin is shown in Exhibit 6C. (ULARA Watermaster Service Report, Water Year 2008-2009)

LADWP has ten major wellfields within the SFB containing 115 wells: the Crystal Springs, Headworks, Tujunga, Rinaldi-Toluca, North Hollywood, Erwin, Verdugo, Whitnall, Pollock, and North Hollywood Operable Unit Wellfields. Of the ten major wellfields, LADWP is currently not pumping at Headworks. These wells were generally installed over a period spanning from 1924 to 1991, with the most recent installations being the Rinaldi-Toluca Wellfield in 1988 and the Tujunga Wellfield in 1991. Collectively these ten wellfields have the ability to pump and serve approximately 547 cubic feet per second (cfs) of water, of which the recent Rinaldi-Toluca and Tujunga wells comprise about 38 percent or 210 cfs.

Groundwater Rights

In accordance with the 1979 San Fernando Judgment, the City has the right to all native water within the SFB, based on its Pueblo Rights, and the right to imported water that is delivered and returned to the SFB by the City. With the native safe yield being fixed at 43,660 AFY and the return of imported water averaging approximately 43,000 AFY, the combined total equates to an average SFB entitlement for the City of approximately 87,000 AFY. The return of imported water right for LADWP is based on 20.8 percent of all water delivered within the San Fernando Basin including recycled water. The Judgment provides for storage of water within the basin when the amount pumped is less than the annual entitlement, and a portion of these stored water credits can be pumped in future years to supplement the City's water supply. The direct

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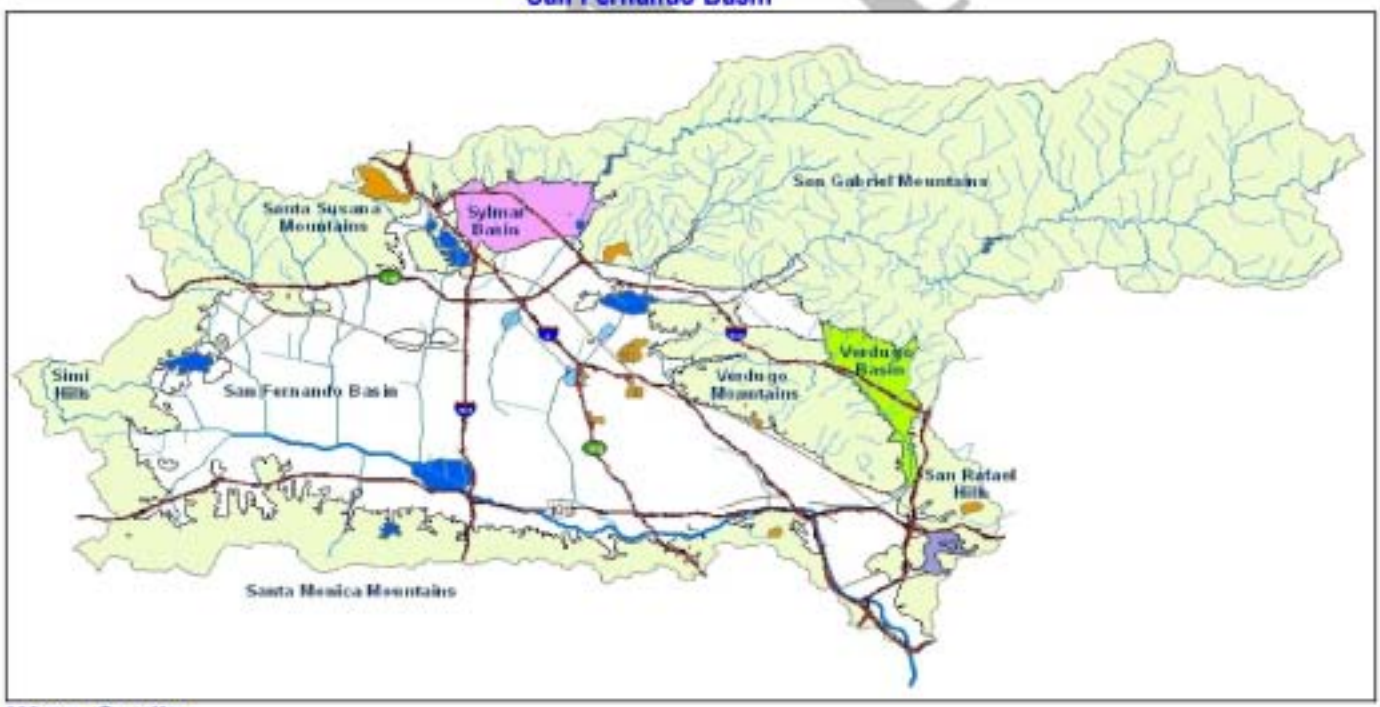
spreading of both imported or recycled water receives 100 percent stored water credit. Increased groundwater pumping due to stormwater capture activities will require an amendment to the Judgment to increase LADWP's groundwater pumping rights based on a demonstrated increase in groundwater levels.

In September 2007, the Cities of Los Angeles, Glendale and Burbank entered into a ten-year Interim Agreement for the Preservation of the San Fernando Basin Water Supply (Interim Agreement). The Interim Agreement is intended to address the overall long-term decrease in stored groundwater within the basin. The Interim Agreement restricts withdrawal of stored water credits and incorporates basin losses into groundwater basin accounting.

Under the Interim Agreement, stored water credits will be reduced for each party by 1 percent annually to account for outflow from the basin. Additionally as described in the Interim Agreement, a proportion of stored water credits available for use during a water year will be calculated for each year, and proportion not available for use during a given year will be reserved for later use. As of October 1, 2009, the City had a stored water credit of nearly 406,313 AF in the SFB, however LADWP's Available Credit or maximum allowable withdrawal of stored water credits for the year beginning October 1 was 108,574 AF. LADWP's Reserve Credits total was 321,316 AF. Reserve Credits (stored water credits minus available stored water credits) will not be available until groundwater levels in the basin recover to a level that will allow for their safe withdrawal. Total Reserve Credits held by all parties in the basin were 376,433 AF as of October 1, 2009.

Exhibit 6C
San Fernando Basin



Water Quality

During well testing in the SFB, trace levels of the contaminants trichloroethylene (TCE), perchloroethylene (PCE), and other volatile organic compounds (VOCs) were detected in the past. The presence of these contaminants is due to improper chemical disposal practices historically conducted by numerous companies in the San Fernando Valley utilizing such materials. Additionally, in the 1990s, detectable amounts of hexavalent chromium and perchlorate were found in various

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wells within the SFB. Since the 1990s, SFB wells have also shown a trend of increasing nitrate levels. The source of nitrates is the result of decades of agricultural activity in the San Fernando Valley.

While LADWP is permitted to withdraw its allotted entitlement of 87,000 AFY from the SFB including a portion of its additional stored water, 2007 was the first year LADWP was unable to pump its allotted entitlement due to contamination impacts. LADWP has 115 wells in the SFB of which 54 wells have been inactivated due to contamination. These inactive wells represent a lost pumping capacity of approximately 221 cfs or 40 percent of LADWP's pumping capacity. Of the remaining 61 active wells, with a combined pumping capacity of approximately 326 cfs, 44 have recorded concentrations for various contaminants above the Maximum Contaminant Level (MCL). Most notable among these contaminants of concern are the VOCs (especially TCE, PCE, and carbon tetrachloride), nitrates, and perchlorate. The remaining 17 wells have recorded marginal levels of contamination, mostly due to VOCs. Hexavalent chromium threatens to be a significant future risk to LADWP's wells. Lastly, LADWP's two largest wellfields, Tujunga and Rinaldi-Toluca, which were the most recently-installed wells in an area believed to be outside the known contamination areas, are being significantly impacted by unknown contamination sources.

LADWP has developed programs to accelerate clean-up of the San Fernando Basin which includes a comprehensive Groundwater System Improvement Study, installing monitoring wells, interim wellhead treatment, and working with regulatory agencies and government officials to hold individuals responsible for the contamination responsible to help clean-up efforts.

Agency Cooperation of SFB Remediation

LADWP actively coordinates with the California Department of Public Health (CDPH), Los Angeles Regional Water Quality Control Board (LARWQCB), California Department of Toxic Substance Control (CDTSC), and the United States Environmental Protection Agency (USEPA) to pursue protective and remedial measures for the SFB. The CDPH, LARWQCB, and CDTSC are the three regulatory agencies with enforcement responsibilities within the SFB. The LARRWQCB and the CDTSC issue enforcement directives for pollutant sites and guide the development of cleanup workplans and the cleanup of polluted groundwater sites. The CDPH oversees the quality of potable water from groundwater sources.

In 1987, LADWP entered into a Cooperative Agreement with the USEPA to conduct the "Remedial Investigation of Groundwater Contamination in the San Fernando Valley." Under this agreement, LADWP has received more than $23 million in Federal grants from the USEPA's Superfund Program to carry out: (1) construction, operation, and maintenance of the North Hollywood Operable Unit, which consists of a groundwater treatment facility and a system of eight production wells (construction completed in 1989); and (2) completion of the Remedial Investigation (RI) to characterize the SFB and the nature and extent of its groundwater contamination. The RI included: (a) the installation in 1992 of 88 shallow and clustered monitoring wells that were developed to monitor contamination plumes of TCE, PCE, and nitrates in the SFB; (b) the development of a groundwater flow model (Flow Model) and the preparation of the RI report that was completed for the USEPA in 1992; and (c) on-going monitoring for TCE, PCE, nitrates, and emerging contaminants.

The Flow Model is a three-dimensional computer simulated model of the SFB based on the MODFLOW model program code that was developed by the United States Geological Survey. It consists of four layers that represent the various depth zones of the SFB. Geologic and hydrogeologic data for the basin, which was generated through field investigation, was analyzed to develop the physical site characterization of the basin for the MODFLOW Flow Model. The Flow Model produced simulated groundwater levels, gradients, and their fluctuations as a function of time. Based on field monitoring and

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Flow Model simulations, groundwater production strategies are reviewed and adjusted monthly to balance the City's water supply need with SFB management.

San Fernando Basin Contamination Clean-Up Programs

In coordination with other agencies, LADWP has completed or is planning various projects to maintain its rights to use the SFB as a reliable local water supply for the City. The following are some of LADWP's completed, current, and planned projects for the SFB. Recharge projects are discussed separately in Chapter 7, Watershed Management.

Groundwater System Improvement Study

LADWP is working on a 6-year, $19.0-million Groundwater System Improvement Study (GSIS) in the SFB that will provide vital information to assist in developing both short- and long-term projects to maximize the use of the SFB. The $11.5-million GSIS professional service contract was awarded to Brown and Caldwell in February 2009.

The GSIS will aim to cover the following main objectives:

- Provide an independent study to identify, characterize, and evaluate emerging water quality constituents for the San Fernando Basin.
- Provide an independent expert evaluation of LADWP's existing groundwater facilities and its current operational strategies to address current issues on water quality regulations and groundwater treatments. Provide expert advice on the need of refurbishing existing groundwater wells.
- Research and evaluate the need for the installation of new monitoring wells in the SFB to characterize the basin for the constituents of concern.
- Develop a research monitoring program to characterize the nature and extent of the various constituents of concern that may pose a risk to LADWP maximizing the utility of the SFB.
- Provide independent expert recommendations on economically feasible short and long-term capital improvement projects to address all regulatory agency requirements.

Through the GSIS, the LADWP has begun developing a conceptual layout for Groundwater Treatment Facilities in the SFB that will include treatment facilities in the vicinity of LADWP's North Hollywood, Rinaldi-Toluca, and Tujunga Well Fields. It is anticipated that construction of the Groundwater Treatment Facilities could begin as early as July 2015. Construction of the Groundwater Treatment Facilities will greatly reduce LADWP's reliance on costly and scarce imported water supplies and will compliment LADWP's strategies for securing the City of Los Angeles' future water supply through sustainable means. The Groundwater Treatment Facilities will also enable LADWP to benefit from its activities to enhance local supplies through groundwater recharge and stormwater projects. An integral part of LADWP's Groundwater Treatment Facilities will be to work closely with the USEPA and the Cities of Burbank and Glendale to ensure that the facilities operations do not adversely affect the on-going cleanup activities being conducted by the aforementioned agencies. Towards this end, LADWP plans to enter into a Groundwater Management Plan with the USEPA.

As of November 2010, the work progress has included a technical review of USEPA's Focused Feasibility Study for the North Hollywood Operable Unit, preparation of conceptual layouts and renderings for the proposed Groundwater Treatment Facilities in the vicinity of the North Hollywood, Rinaldi-Toluca and Tujunga Well Fields, providing assistance in the planning

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aspects for the installation of approximately 40 new monitoring wells in the San Fernando Basin, and providing an independent study to identify, characterize and evaluate emerging water constituents.

Tujunga Wellfield Joint Project. LADWP and MWD have developed a joint project utilizing simple liquid-phase granular activated carbon (GAC) to recover the use of two of the City's contaminated groundwater production wells in the Tujunga Wellfield. The total estimated cost of this project was approximately $7.0 million and was completed in November 2009. LADWP received the permit from the Department of Public Health in May 2010 and started to discharge into the distribution system on May 18, 2010.

Tujunga Wellfield Contamination. The Initial Discovery of the source of contamination at the Tujunga Wellfield by the USEPA and CDTSC is ongoing. Phase I is completed and has not conclusively identified the source of the contamination. The next phase will involve drilling 4-7 deep monitoring wells immediately up gradient of the wellfield to determine the direction of the contamination plumes. The well drilling is expected to be completed late 2011. LADWP is intending to construct up to 22 additional monitoring wells near other wellfields south of the Tujunga Wellfield. Water quality data from the new monitoring wells will assist with further characterizing the groundwater contamination in the SFB. Drilling of these additional wells is expected to begin in Fall 2011 and continue until Winter 2012.

North Hollywood Operable Unit. In 1989, the North Hollywood Operable Unit (NHOU) was placed into service with a capacity of 2,000 gallons per minute (GPM), or 3,230 AF per year. This facility has one aeration tower with vapor-phase granular activated carbon (GAC) air emissions control system. This technology uses air to remove the VOCs from the groundwater and uses the vapor-phase GAC to remove the VOCs from the air stream before it exits into the atmosphere. The fifteen year consent decree expired on December 31, 2004, however, the VOC plume has not been completely remediated. In Water Year 2008-2009, 1,038 AF of VOC contaminated groundwater was treated.

The USEPA is expected to start construction of the NHOU Second Remedy possibly as soon as 2014 to improve containment of contamination from two sites, the Honeywell and Lockheed sites. The primary plume contains high concentrations of VOCs, chromium, and other contaminants of concern. The USEPA issued the Record of Decision (ROD) in December of 2009. The first technical meeting with the potentially responsible party was held in July 2010. A consent decree is expected in early 2011. The ROD recommends more than doubling the capacity plus adding liquid phase GAC (a secondary treatment), construction of 37 monitoring wells, three new extraction wells, deepen existing abandoned well #1, rehabilitation of existing wells, and treatment of chromium and 1-4 Dioxane. As of 2010, Honeywell is continuing its removal of chromium plume at the source of contamination.

Chromium Treatment Research. A cost-effective treatment technology to remove low levels of hexavalent chromium from water does not exist for large scale applications. In 2001, LADWP, along with the Cities of Burbank, Glendale, and San Fernando, and the National Water Research Institute, entered into a research partnership with the American Water Works Association Research Foundation to identify and bench-test new technologies that can remove hexavalent chromium to extremely low levels. This research is being conducted in anticipation of a new standard for hexavalent chromium.

Pollock Wells Treatment Plant. In 1999, the Pollock Wells Treatment Plant was constructed and placed in service. This project was funded by LADWP, and it includes a groundwater treatment facility with four liquid-phase GAC units. Over 3,000 gallons per minute (4,840 AF per year) of groundwater is treated by direct adsorption with GAC to remove VOCs before delivery to customers.

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Remedial Investigation. In 1992, the Remedial Investigation to characterize the nature and extent of groundwater contamination in the SFB was completed for the USEPA. The Remedial Investigation activity included the construction of 88 shallow and clustered monitoring wells, which were developed to monitor contamination plumes of TCE, PCE, and nitrates in the SFB. These monitoring wells are also being used to monitor for emerging chemicals. Updated information and reports can be found on USEPA Region 9 Superfund web page.

Biological Treatment Pilot Test . LADWP will be studying the effectiveness of biological treatment on removal of VOCs contaminants from the Tujunga Wellfield groundwater. Biological treatment is a proven technology for removal of perchlorate and nitrate contaminants from groundwater which are also present in the Tujunga Wellfield groundwater. If biological treatment can also effectively remove VOCs from the groundwater, LADWP can significantly reduce the capital as well as future operations and maintenance costs associated with cleanup and removal of contaminants from the Tujunga Wellfield groundwater.

Pilot Test of Advance and Emerging Groundwater Treatment Technologies. LADWP is investigating the utilization of other advance and/or emerging groundwater treatment technologies for removal of VOCs and perchlorate for possible pilot study(ies) at the Rinaldi-Toluca Wellfield within the next few years.

6.2 Sylmar and Eagle Rock Basins

The Sylmar Basin has provided slightly over 4 percent of the City's local groundwater ranging from 576 AF to 4,046 AF from Fiscal Year 2005-2006 through Fiscal Year 2009-2010. The Sylmar Basin, in the northern part of ULARA, consists of 5,600 acres and comprises 4.6 percent of the valley in ULARA. It is bounded on the north and east by the San Gabriel Mountains; on the west by a topographic divide in the valley fill between the Mission Hills and the San Gabriel Mountains; and on the south by the Little Tujunga syncline, which separates it from the SFB. (ULARA Watermaster Service Report, Water Year 2008-2009) LADWP originally had a total of 3 production wells installed in the Sylmar Basin between 1961-1977. One of these wells was removed from service and is no longer utilized. The remaining wells have the capacity to pump 5 cfs.

The Eagle Rock Basin is the smallest of the four basins. It is located in the extreme southeast corner of ULARA. It consists of 800 acres and comprises 0.6 percent of the total valley. LADWP is not pumping in the Eagle Rock Basin currently. The safe yield of Eagle Rock Basin is derived from imported water delivered by LADWP. There is no measurable native safe yield. LADWP has the right to extract the entire safe yield of the basin. Currently, the groundwater is being pumped by a private party and LADWP is reimbursed for such pumping in accordance with the San Fernando Basin Judgment.

Groundwater Rights

In 1996 upon the recommendation of the Watermaster, the ULARA Administrative Committee approved a temporary safe yield increase for the Sylmar Basin thus temporarily increasing LADWP's rights from 3,105 AFY to 3,255 AFY for a ten-year period. Per the 1984 Stipulation, the safe yield minus private party overlying rights are to be equally split between LADWP and the City of San Fernando. In 2006, a subsequent evaluation of the safe yield was conducted and completed in accordance with Section 8.2.10 of the 1984 Stipulation. Upon recommendation of the parties, the Court approved a new stipulation further increasing the temporary safe yield of the basin and resulting in a temporary increase in LADWP's rights to 3,405 AFY subject to multiple conditions. Conditions imposed on LADWP and the City of San Fernando include installing groundwater monitoring wells to assist in determining basin outflows. This new stipulation became effective on October 1, 2006 and is set to expire on October 1, 2016. As required by the 2006 Stipulation, the safe yield will be re-evaluated by October 1, 2011 and may result in a recommendation for additional changes to the safe yield of the Sylmar Basin.

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Stored water credits accumulated in the basin are determined by adding the previous years stored water credit and the extraction right for the previous year together and then subtracting the actual extractions for the previous year. As of October 1, 2009, LADWP has accrued 9,423 AF of stored water credits in the Sylmar Basin. In 2006, the Watermaster recommended LADWP begin pumping these rights due to the large amount of stored water credits. LADWP has proposed the Mission Wells Improvement Project to initiate pumping the credits and to replace the existing wells that have significantly deteriorated. As proposed, the project consists of constructing a water tank, three wells, and other operational facilities at the Mission Wellfield. Phase 1 was completed in February 2009 and involved replacement of the water tank that was beyond its useful life. Phase 2 is in the planning stages and consists of three new wells with operational facilities and is forecast for completion in August 2014. These new facilities will allow LADWP to pump its current entitlement of 3,405 AFY on an annual basis and draw from its existing stored water credits.

Water Quality

Groundwater quality issues have occurred in the Sylmar Basin related to TCE contamination at one of the two production wells. The effluent from the wellfield is managed in such a way that the groundwater quality meets or surpasses water quality standards. Primary limitations on pumping are related to the deterioration of pumping facilities and not contamination. However, the Mission Wells Improvement Project as previously discussed, will replace the deteriorated wells and increase production capacity to allow LADWP to pump its annual water rights.

6.3 Central Basin

From Fiscal Year 2005-2006 through Fiscal Year 2009-2010 the Central Basin has provided on average approximately 17 percent of LADWP's local groundwater supply ranging from 11,766 AF to 13,358 AF through wells in two major production fields. The Central Basin Watermaster Service area overlies about 227 square miles of the Central Basin in the southeastern part of the Los Angeles Coastal Plain in Los Angeles County. The Watermaster Service Area is bounded by the Newport-Inglewood Uplift on the southwest, the Los Angeles-Orange County line on the southeast, and an irregular line that approximately follows Stocker Street, Martin Luther King Boulevard, Alameda Street, Olympic Boulevard, the boundary between the City of Los Angeles and unincorporated East Los Angeles, and the foot of the Merced and Puente Hills on the north. Twenty-three incorporated cities and several unincorporated areas are within the Central Basin Watermaster Service Area. Groundwater within the basin provides a large portion of the water supply needed by overlying residents and industries. In Fiscal Year 2008-2009 there were 140 parties with rights to water within the Central Basin (Central Basin Watermaster Service Report, Fiscal Year 2009-2010).

Two LADWP facilities provide groundwater supplies in the Central Basin, the Manhattan Wells and the 99th Street Wells. The active Manhattan Wells were installed between 1928-1974 and have a production capacity of 16.9 cfs. Wells at the 99 th Street location were installed between 1974-2002 and have a production capacity of 7.4 cfs. While the 99th Street Wells are newer and have relatively little mechanical or other problems, the Manhattan Wells are much older and have experienced maintenance problems and are approaching the end of their useful life. To restore the City's pumping capacity, LADWP is working on plans to install two new production wells, replace two deteriorated wells, and improve other related facilities at the Manhattan site.

Groundwater Rights

More than 50 years ago, groundwater overdraft and declining water levels in the Central Basin threatened the area's groundwater supply and caused seawater intrusion in the southern part of the Basin. However, timely legal action and adjudication of the water rights halted the overdraft and prevented further damage to the Basin. Today, groundwater use in the Basin is restricted to the allowed pumping allocations by a 1966 Superior Court Judgment and is monitored by a court-

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appointed Watermaster, the Department of Water Resources (DWR). Annually, the Watermaster prepares a Watermaster Service Report indicating groundwater extractions, replenishment operations, imported water use, recycled water use, finances of Watermaster services, administration of the water exchange pool, and significant water-related events in the Basin.

The City's entitlement in the Central Basin of 15,000 AFY was established in a judgment by the Superior Court of the State of California for the County of Los Angeles through the Central Basin Judgment (Case No. 786,656 –second amended judgment). In addition to its annual entitlement, the Central Basin Judgment allows for carryover of unused water rights up to a maximum total cumulative amount of 20 percent of the purveyor's pumping allocation and also allows for over extraction of an additional 20 percent under emergency situations that would be debited against the purveyor's following year entitlement. The City uses its carryover storage right for operational flexibility and conjunctive use. LADWP has allowable carryover storage of 3,000 AF into Fiscal Year 2010-2011.

The Central Basin Judgment does not permit storing water in the basin for later extraction. Through the assistance of a facilitator, multiple parties with groundwater rights within the Central Basin have developed draft framework to allow conjunctive use groundwater storage in the basin and have filed to request amendment of the Judgment to allow groundwater storage.

Water Quality

Although the Manhattan and 99th Street Well fields in the Central Basin are located only approximately 4 miles apart, there is a large difference in water quality between the facilities. One of the Manhattan Wells currently exceeds the MCL of 5 ppb for TCE. The effluent from the wellfield is managed in such a way that the groundwater quality meets or surpasses water quality standards.

Water from 99th Street Wellfield complies with the National Primary Drinking Water Regulations, but requires treatment to comply with the National Secondary Drinking Water Regulations for manganese and iron. These contaminants are not considered to present a risk to human health, but at existing concentrations the contaminants may present taste, color, and odor problems. Corrosion control treatment using zinc orthophosphate as a sequestering agent and sodium hypochlorite to oxidize manganese has been in place at the wellfield for twenty years. Hydrogen sulfide is also present but not an imminent threat to the reliability of this well supply when chlorinated. In 2002, two new wells were drilled and placed into operation. During the first several months of operation of the new wells, numerous color complaints were received from customers. Adjustments in the treatment process were made which improved water quality.

6.4 West Coast Basin

LADWP has not been able to pump its water entitlement from the West Coast Basin since 1980 due to localized groundwater contamination issues and deterioration of the wells at the Lomita Wellfield. The West Coast Basin underlies 160 square miles in the southwestern part of the Los Angeles Coastal Plain in Los Angeles County. The Basin is bounded on the west by Santa Monica Bay, on the north by Ballona Escarpment, on the east by the Newport-Inglewood Uplift, and on the south by San Pedro Bay and the Palos Verdes Hills. Twenty incorporated cities and several unincorporated areas overlie the Basin (West Coast Basin Watermaster Service Report, Fiscal Year 2009-2010).

Groundwater Rights

In 1945, when intrusion of sea water caused by declining water levels threatened the quality of the groundwater supply, legal action was taken to halt the overdraft and prevent further damage to the West Coast Basin. In 1955, the Superior Court of

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Los Angeles County appointed the DWR as the Watermaster to administer an Interim Agreement, and in 1961, the Court retained the DWR as the Watermaster of the Final West Coast Basin Judgment (Case No. 506,806 –amended judgment). Similar to the Central Coast Basin, an annual Watermaster Service Report is prepared. The West Coast Basin Judgment provided the City with a right to 1,503 AFY of groundwater.

Water Quality

Groundwater quality problems in the West Coast Basin were previously related to high levels of total dissolved solids and chlorides. LADWP abandoned operations in the basin in September of 1980 with closure of the Lomita Well Field, and intends to study the feasibility and cost of restoring groundwater pumping.

6.5 Water Quality Goals and Management

The groundwater management efforts that LADWP has undertaken have resulted in all groundwater delivered to customers meeting or exceeding all water quality regulations. As part of its regulatory compliance efforts, LADWP works with the California Department of Public Health (CDPH) to perform water quality testing on production and monitoring wells.

Groundwater Monitoring

LADWP conducts nearly 250,000 field and laboratory tests on more than 25,000 samples collected throughout the year for hundreds of different chemicals such as arsenic, chromium, lead, and disinfection by-products to ensure that they are will within the safe levels before we serve the water to our customers

Every well that is pumped to supply water to the City is actively monitored by LADWP as required by CDPH. LADWP's groundwater monitoring program is comprised of several distinct components, including monitoring of metals, coliform bacteria, inorganics, volatile organic compounds (VOCs) and unregulated compounds such as vanadium, boron, and perchlorate. The frequency and level of monitoring (i.e., annually, quarterly, or monthly), depending on the level of contamination found in each well.

Monitoring for all contaminants is performed at entry points into the distribution system in close proximity to where the water is being pumped from the wells. If water quality problems are detected, the well source is immediately isolated and retested.

Operating Goals

LADWP has established operating goals for TCE, PCE, nitrates, perchlorate, and total chromium that are more stringent than the maximum contaminant levels (MCLs) permitted by Federal or State regulations. These stricter operational goals provide an additional safety margin from these contaminants for City customers. Exhibit 6D summarizes these water quality goals and compares them with the State-regulated requirements, which are generally more stringent than Federal requirements.

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Exhibit 6D
Operating Limits of Regulated Compounds

Compound	State of California Limit	LADWP Operational Goals	LADWP Added Safety Margin
Trichloroethylene (TCE)	5 ppb	3 ppb	40%
Perchloroethylene (PCE)	5 ppb	3 ppb	40%
Nitrate (N03)	45 ppm	30 ppm	33%
Perchlorate (ClO4)	6 ppb	4 ppb	33%
Total Chromium	50 ppb	30 ppb	40%

TCE and PCE compounds are commonly used in industries requiring metal degreasing. PCE is also used in dry cleaning and automotive repair industries.

Nitrate is a concern because of its acute effect of impeding the uptake of oxygen to the blood. Infants (who are in the earliest stages of development) are most sensitive to the effects of nitrates. The current standard for nitrate is 45 parts per million (ppm). A single exceedence of the nitrate standard is classified as an acute violation requiring immediate public notification. Treatment for nitrates may eventually become necessary for affected City groundwater supplies.

In October 2007, a MCL was adopted for perchlorate of 6 ppb. Perchlorate is an inorganic compound that is most commonly used in the manufacture of rocket fuels, munitions, and fireworks. In addition to its detection in groundwater, the compound has also been detected in Colorado River Aqueduct water.

Managing Emerging Contaminants of Concern

LADWP addresses emerging contaminants on many levels: 1) by encouraging the development of standardized testing to enable early detection, and supporting the regulatory framework by providing early occurrence data, 2) by advocating good science and a balanced approach to risk assessment, 3) by seeking to gain a risk perspective with other existing contaminants to manage the emerging contaminants in the absence of regulations, 4) by supporting early interpretation of emerging contaminants in collaboration with research and regulatory agencies, and 5) by supporting the research to develop cost-effective treatment for the removal and management of these emerging contaminants.

An example of how LADWP addresses an emerging contaminant is chromium VI (otherwise known as hexavalent chromium). Hexavalent chromium does not have an enforceable drinking water standard at this time. However, hexavalent chromium is included in the State total chromium standard of 50 ppb. CDPH is expected to establish drinking water standards for the compound in the near future. Chromium is a heavy metal that has been used in industry for various purposes including electroplating, leather tanning, and textile manufacturing, as well as controlling biofilm formation in cooling towers. LADWP began low level monitoring of hexavalent chromium long before monitoring was required by regulators. LADWP supported new health-effects research needed to support risk assessment, and advocated a balanced approach to risk management. LADWP funded research to develop new treatment technologies to reduce hexavalent chromium detection levels.

Most recent among emerging contaminants are pharmaceutically active compounds and personal care products that are finding their way into rivers, lakes, and waterways from urbanized areas. There are concerns about the occurrence and effects of endocrine disrupters, hormone-shifting compounds, and pharmaceuticals. Technology now allows the detection of compounds down to the parts per trillion levels, thus some of these compounds are now being detected. The risk

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assessment field is finding it difficult to keep pace with advances in analytical technology. The question of these contaminants posing a health risk at low levels needs more investigation. LADWP will continue to proactively address emerging contaminants through early monitoring and utilization of a balanced approach to risk management.

LADWP will be incorporating appropriate treatment processes into future groundwater treatment facilities. LADWP has and will continue to solicit input from stakeholders to properly plan and develop processes for removal and treatment of emerging contaminants. LADWP's Recycled Water Advisory Group (RWAG) is an example of ongoing efforts to solicit input.

6.6 Groundwater Pumping Cost

The costs associated with groundwater pumping are primarily operation and maintenance costs. Therefore, the unit cost of groundwater pumping varies mainly with the quantity of water delivered. Exhibit 6F summarizes the historical unit cost of groundwater pumping.

Exhibit 6F
Historical Cost of Groundwater Pumping

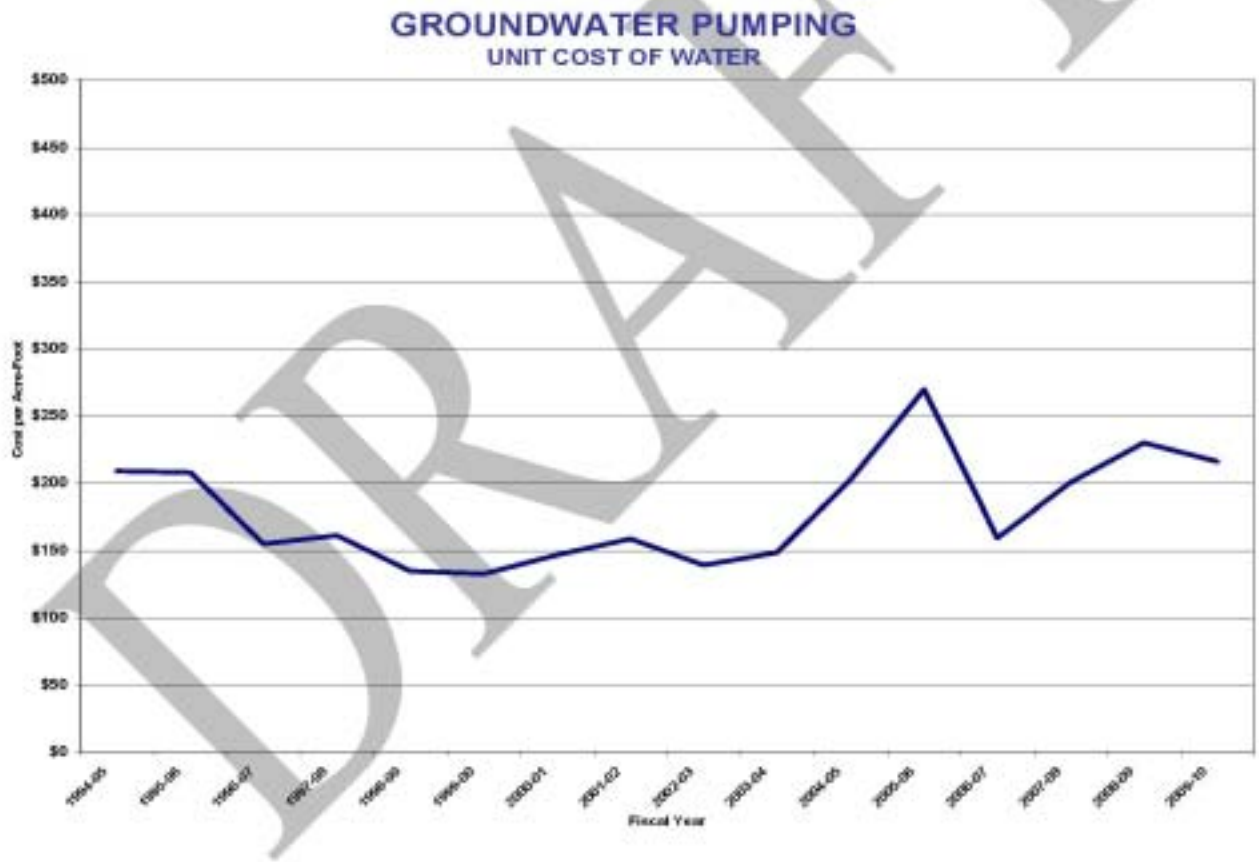

Exhibit 6G shows the unit cost of groundwater pumping from fiscal year 2005/06 to 2009/10. The 5-year average was $215/AF.

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Exhibit 6G
Annual Unit Cost

Fiscal Year	2005-06	2006-07	2007-08	2008-09	2009-10
Unit Cost	$270	$160	$200	$230	$216

6.7 Groundwater Production Projections

Historically, with conjunctive use management of groundwater, storing imported water in the groundwater basins during wet and normal years, groundwater production can actually be increased during dry years. LADWP operated its groundwater resources in this manner. On average, LADWP pumped its adjudicated right of approximately 107,000 AFY, but in dry years LADWP could pump larger quantities of groundwater. For the purposes of an average, single-dry, and multi-dry year drought analysis, after the implementation of the purification complex for SFB and completing the construction of new wells in Sylmar and Central Basins, 110,405 AFY is assumed to be the City's local groundwater production in 2035. After completion of the purification complex for the SFB, if successive dry years occur, LADWP would likely pump at greater-than-average levels for the first few dry years, then start pumping at lower levels in order to prevent groundwater overdraft. LADWP would then replenish the groundwater in wet or normal years following the successive dry period. Exhibit 6E provides groundwater pumping projections by basin between 2010 and 2035 for average, single-dry, and multi-year dry weather conditions in five-year increments.

Exhibit 6E
Groundwater Production 2010 to 2035 for Average, Single-Dry, and Multi-Year Dry Weather Conditions
By Fiscal Year

Basin	FY 2009-10	FY 2014-15	FY 2019-20	FY 2024-25	FY 2029-30	FY 2034-35
	AFY					
San Fernando	62,218	21,000	76,800	92,000	92,000	92,000
Sylmar	2,998	4,500	4,500	4,500	4,500	3,405
Central	11,766	15,000	15,000	15,000	15,000	15,000
Total	76,982	40,500	96,300	111,500	111,500	110,405

- 2015 San Fernando pumping levels are decreased due to anticipated well contamination from plume migration.
- Assumes existing annual rights to 87,000 AFY in SFB will remain unchanged. The Purification Complex is expected to be in operation in 2018-19. Storage credit of 5,000 afy will be used to maximize the pumping thereafter.
- Sylmar Basin production temporarily increases to 4,500 AFY to avoid the expiration of stored water credits then return back to the entitlement of 3,405 AFY in 2030-31.

Not included in the figures above is increased groundwater pumping due to groundwater replenishment of advanced treated wastewater, as well as enhanced stormwater recharge. This Urban Water Management Plan projects increased groundwater pumping through groundwater replenishment of advanced treated wastewater of 15,000 AFY, and increased groundwater pumping through enhanced storm water recharge of and additional 15,000 AFY, both by 2035.

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Watershed Management

7.0 Overview

This Urban Water Management Plan projects stormwater capture providing increased groundwater pumping rights in the San Fernando Basin of 15,000 AFY, and 10,000 AFY of additional water conservation from capture and reuse solutions such as rain barrels and cisterns, for a total of 25,000 AFY by fiscal year ending 2035. The Stormwater Capture Master Plan (refer to Section 7.3 below) will comprehensively evaluate stormwater capture potential within the City.

Stormwater runoff from urban areas is an underutilized resource. Within the City of Los Angeles, the majority of stormwater runoff is directed to storm drains and ultimately channeled into the ocean. Unused stormwater reaching the ocean also carries with it many pollutants that are harmful to marine life. In addition, local groundwater aquifers that should be replenished by stormwater are receiving less recharge than in the past due to increased urbanization. Urbanization has increased the City's hardscape, which has resulted in less infiltration of stormwater and a decline in groundwater elevations.

In addition, development has encroached onto the floodplains requiring the channelization of large waterways that once recharged the groundwater aquifers with large volumes of stormwater runoff. When the floodplains were undergoing rapid development, LADWP and the Los Angeles County Flood Control District (LACFCD) reserved several parcels of land for use as spreading facilities, which are adjacent to some of the largest tributaries of the Los Angeles River, and the Pacoima and Tujunga Washes.

During average and below average years, these spreading facilities are very effective at capturing a large part of the stormwater flowing down the tributaries. However they are incapable of capturing a significant portion of the flows during wet and extremely wet years. Weather patterns in Los Angeles historically are highly varied between very wet years and very dry years. Some climate studies predict that these patterns may become more extreme.

Furthermore, a significant portion of the watershed is not located adjacent to large tributaries and therefore, cannot be served by existing spreading facilities. These areas are the urbanized low-lying flatlands that also produce stormwater, therefore a strategy to create and implement distributed stormwater infiltration solutions is needed. These distributed solutions include widespread, smaller projects at the neighborhood scale and landscape changes at the individual parcel scale.

With the increased attention being placed on stormwater capture, other challenging conditions beyond imperviousness and climate patterns have been identified. These include antiquated spreading facilities, landfills adjacent to spreading, floodplain encroachment, substructures, and other man-made conditions that limit the ability to capture stormwater for later use. Some conditions such as the antiquated delivery systems at the spreading facilities can easily be retrofitted with new gates and telemetry. Whereas other conditions such as the presence of large sanitary landfills adjacent to recharge facilities, are more difficult to rectify.

In January 2008, LADWP created the Watershed Management Group which is responsible for developing and managing the water system's involvement in emerging issues associated with local and regional stormwater capture. The Watershed Management Group coordinates activities with other agencies, departments, stakeholders and community groups for the purpose of planning and developing projects and initiatives to improve stormwater management within the City. The Group's primary goal is to increase stormwater capture by enhancing existing centralized stormwater capture facilities and promoting

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distributed stormwater infiltration systems to achieve the City's long-term strategy of enhancing local stormwater capture. While working to increase stormwater capture for improving long-term groundwater reliability, other watershed benefits can be achieved including increased water conservation, improved water quality, open space enhancements, and flood control.

Additionally, the City is investigating recharge of the San Fernando Basin (SFB) with advanced treated recycled water. A more in-depth discussion of efforts to maximize groundwater recharge with advanced treated recycled water is provided in Chapter 4, Recycled Water.

7.1 Importance of Watershed Management to Groundwater Supplies

Managing native stormwater is a necessary step towards maintaining groundwater elevations in the underlying groundwater basin. Urbanization and its associated increase in impervious surfaces has altered the ability of groundwater basins to naturally replenish pumped groundwater. Stormwater systems in the City were designed primarily for flood control to convey stormwater runoff to the Pacific Ocean as quickly as possible, therefore minimizing the potential for flooding or damage to structures while maximizing land available for development. Within LADWP's service area, the SFB is the most amenable to regional stormwater capture and recharge through spreading basins because of its predominantly sandy soils. However, stormwater once percolated into the groundwater in the underlying SFB is being channeled across impervious surfaces then through concrete-lined canals or conduits to areas outside of the San Fernando Valley.

The essential task of watershed management is to retain as much stormwater runoff as possible for groundwater recharge. Groundwater recharge is the process of increasing an aquifer's water content through percolation of surface water. This occurs in the SFB primarily with captured stormwater, and imported water. Groundwater recharge is essential to maintain groundwater supplies, address the overall long-term decrease in stored groundwater within the SFB, and ensure the long-term water supply reliability of the basin. Furthermore, increasing groundwater recharge and improving the groundwater levels of the SFB could potentially lead to larger pumping rights for LADWP in the future.

During storm events, large portions of stormwater are captured with existing facilities for spreading purposes. LADWP coordinates these activities with the Los Angeles County Department of Public Works Flood Control District (LACFCD) to effectively recharge the SFB through the spreading of native stormwater. Flood control facilities are the primary means to divert native runoff into the spreading ground facilities listed and mapped on Exhibits 7A and 7B. LACFCD oversees operations at the Branford, Hansen, Lopez, and Pacoima Spreading Grounds. The Tujunga Spreading Grounds are operated by LACFCD in partnership with LADWP. LADWP has the ability to spread imported supplies at the Tujunga Spreading Grounds and the Pacoima Spreading Grounds for storage in the SFB, but LADWP has not utilized imported water for groundwater recharge since 1998.

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Exhibit 7A
SFB Spreading Grounds Operations Data

		Annual Spreading (AF)	
Facility	Location	Average[1]	Historic High
Branford	Mission Hills, CA	549	2,142
Hansen	Sun Valley, CA	13,834	35,192
Lopez	Lake View Terrace, CA	527	1,735
Pacoima	Pacoima, CA	6,453	22,972
Tujunga	Sun Valley, CA	4,419	21,115
	Total	25,782	83,156

1. Historic average through water year ending September 2009.

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Exhibit 7B
Spreading Ground Facility Locations

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7.2 Additional Benefits of Watershed Management

Watershed management provides additional important benefits to the City of Los Angeles, including surface water quality improvements, water conservation, open space enhancements, and flood control.

Water quality improvements are necessary because stormwater runoff is a conveyance mechanism that transports pollutants from the watershed into waterways and ultimately the Pacific Ocean. Pollutants include, but are not limited to, bacteria, oils, grease, trash, and heavy metals. The City must also comply with adopted Total Maximum Daily Loads (TMDLs) for pollutants. TMDLs set maximum limits for a specific pollutant that can be discharged to a water body without causing the water body to become impaired or limiting certain uses, such as water body contact during recreation. In 2008, the Los Angeles Board of Public Works adopted the Water Quality Compliance Master Plan for Urban Runoff (WQCMPUR). This 20-year plan provides a strategy for cleaning stormwater and runoff to protect the City's waterways and the Pacific Ocean. Capturing stormwater runoff for groundwater recharge removes a portion of the pollutant conveyance mechanism reducing downstream pollution thereby assisting the City with water quality compliance and improving the overall health of its waterways.

Water conservation is achieved by enhancing the capture and management of localized runoff for local uses. Centralized and distributed mechanisms that provide for water conservation include spreading grounds, rain barrels, and residential cisterns.

Open space enhancement is an added benefit of groundwater recharge projects, which typically provide additional open space areas that may include passive and/or active recreation, educational opportunities, and habitat restoration. Most projects involve increasing vegetation and recreational amenities to create opportunities for wildlife habitat and a recreational/educational resource for the local community. Additionally, open space enhancements assist the City in improving the overall quality of life for residents.

Flood control benefits are achieved when additional storage capacity is added to the storm drain system. Groundwater recharge projects reduce potential flooding by diverting a portion of storm flows into recharge areas, thereby increasing the overall capacity of the storm drain system.

7.3 Stormwater Capture Master Plan

The Stormwater Capture Master Plan (Master Plan) will investigate potential strategies for advancement of stormwater and watershed management in the City. The Master Plan will be used to guide decision makers in the City when making decisions affecting how the City will develop both centralized and distributed stormwater capture goals. The Master Plan will include evaluation of existing stormwater capture facilities and projects, quantify the maximum stormwater capture potential, develop feasible stormwater capture alternatives (i.e., projects, programs, potential policies, etc.), and provide potential strategies to increase stormwater capture. The Master Plan will also evaluate the multi-beneficial aspects of increasing stormwater capture, including potential open space alternatives, improved downstream water quality, and peak flow attenuation in downstream channels, creeks, and streams such as the Los Angeles River.

The Master Plan will recommend stormwater capture projects, programs, policies, and incentives for the City of Los Angeles.

Benefits of the Master Plan include:

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- Investigate stormwater capture models such as the Groundwater Augmentation Model and the Watershed Management Modeling System to identify maximum potential groundwater recharge
- Increased water conservation
- Improved water quality
- Reduced peak flow in the Los Angeles River

Project partners and supporters include:

- City of Los Angeles Department of Water and Power
- City of Los Angeles Department of Public Works
- County of Los Angeles Department of Public Works
- TreePeople, Inc.

7.4 Tree People – Memorandum of Agreement

The Memorandum of Agreement (MOA) with TreePeople has been forged to facilitate a high-level of collaboration between LADWP and TreePeople with the aim of fostering a more sustainable Los Angeles. The partnership it outlines leverages TreePeople's experience in public education and agency integration to further the long-term sustainability objectives of LADWP. Specifically, LADWP and TreePeople are working together to research opportunities within LADWP's facilities and operations for widespread groundwater recharge. This research includes an educational component wherein LADWP and TreePeople learn about each other's initiatives and core business. Ultimately, this exchange of ideas will help the two partners develop concepts for projects that will increase stormwater capture for groundwater recharge.

LADWP was an early sponsor for the TreePeople Trans-agency Resources for Environmental and Economic Sustainability (T.R.E.E.S.) Project, during which time TreePeople developed best management practices for capturing, cleaning and using stormwater; published the handbook Second Nature; created a computerized cost-benefit model; and facilitated a number of design workshops for public agencies. TreePeople has also been integral to the construction and management of three demonstration sites -- a single-family home (Hall House) retrofitted to capture all the rainwater onsite, and two elementary schools (Broadous and Open Charter) that feature strategic landscaping and a cistern or underground infiltrators. LADWP has supported public tours and educational materials for Hall House, and is a key partner in the school projects which were partially funded through the Cool Schools and Sustainable Schools programs.

The overlap between the objectives of LADWP and those of TreePeople is notable in the Tujunga Wash and Sun Valley watersheds, where both have been especially active. Stakeholder processes where the two have worked successfully to further mutual goals including the City's Integrated Resources Plan, the Integrated Regional Water Management Plan, and objectives of the California Urban Water Conservation Council.

7.5 Centralized Stormwater Capture Projects

Existing stormwater capture facilities are inadequate for capturing runoff during very wet years. Weather patterns vary dramaticly in Los Angeles with very wet years and very dry years. Therefore, new projects are necessary to expand the

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capability to capture a larger portion of stormwater flows during wet years. LADWP is working proactively in close partnership with LACFCD on multiple stormwater projects, as listed in Exhibit 7C. These projects will increase centralized stormwater recharge capacity by approximately 26,000 AFY in the SFB, raising groundwater levels and ensuring the future water supply reliability of the SFB. These projects are designed to maximize groundwater recharge into the basin by increasing the total average recharge to approximately 51,700 AFY.

Multiple opportunities exist to develop new recharge projects and improve existing recharge projects in the SFB. LADWP, in collaboration with LACFCD has supported and contributed resources toward the design, construction, and implementation of a variety of projects to increase groundwater recharge of the SFB. Additionally, multiple agreements between LADWP and LACFCD have been approved to facilitate preparing recharge studies, design work, and construction of projects in the SFB for groundwater recharge, flood protection, and other benefits.

Exhibit 7C
Planned LADWP Centralized Stormwater Capture Projects and Expected Annual Recharge

Project	Current Annual Recharge (AFY)	Increased Annual Capture/ Recharge (AFY)	Expected Annual Recharge (AFY)	Estimated Project Completion	Total Project Cost (millions)	LADWP Share (millions)
Sheldon-Arleta Gas Collection System	-	4,000 [1]	-	Complete Nov 2009	$8.2	$6.3
Big Tujunga Dam Rehabilitation [3]	-	4,500	-	Sep 2011	$105.7	$9.0
Hansen Spreading Grounds Upgrade	13,834	1,200	17,284 [2]	Dec 2011	$9.3	$4.8
Tujunga Spreading Grounds Upgrade	4,419	8,000	18,669 [4]	2015	$24.0	$24.0
Pacoima Spreading Grounds Upgrade	6,453	2,000	8,453	2015	$32.0	$16.0
Lopez Spreading Grounds Upgrade	527	750	1,277	2016	$8.0	$4.0
Strathern Wetlands Park	-	900	900 [5]	2016	$46.0	$4.0
Hansen Dam Water Conservation	-	3,400	3,400	2017	$5.0	$2.5
Valley Generating Station Stormwater Capture	-	700	700	2018	$9.7	$9.7
Branford Spreading Basin Upgrade	549	500	1,049	2018	$4.0	$2.0
Total Estimated Yield	**25,782**	**25,950**	**51,732**		**$251.9**	**$82.3**
Total Expenditure-to-date						$18.6
Total Expenditure Remaining						$63.7

1. This will allow increased collection of 4,000 AFY at Tujunga Spreading Grounds.
2. Includes 1/2 benefits from Big Tujunga Dam Rehabilitation Project.
3. No recharge occurs at the facility. All additional capture has been divided between Hansen & Tujunga Spreading Grounds.
4. Including benefits from Sheldon-Arleta Project and 1/2 benefits from Big Tujunga Dam Rehabilitation Project.
5. To be recharged at Sun Valley Park.

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Sheldon-Arleta Methane Gas Collection Project. In 1998, a Task Force comprised of representatives from LADWP, other City Departments (Bureau of Sanitation (BOS), Bureau of Engineering, and Environmental Affairs) and the Upper Los Angeles River Area Watermaster was formed to review the issues surrounding the recharge of groundwater through spreading at the Tujunga Spreading Grounds. The objective of this Task Force was to maximize water spreading at the Tujunga Spreading Grounds without causing off-site landfill gas migration. An outcome of the Task Force was the Sheldon-Arleta Methane Gas Collection Project. The project is designed to restore the original Tujunga Spreading Grounds capacity of 250 cubic feet per second (cfs) with the potential for future enhancement by bringing the Tujunga Spreading Basins closest to the Sheldon-Arleta landfill back online. The Tujunga Spreading Grounds are located adjacent to the closed Sheldon-Arleta Landfill. During spreading operations, water displaces air from the ground potentially increasing migration of methane gas generated by the landfill. In the past, elevated levels of methane gas have been detected in the surrounding communities. Therefore, restrictions were enacted curtailing spreading operations to 20 percent of their original capacity. This project is a joint effort between LADWP and BOS to replace the methane gas collection system within the landfill and thereby contain methane gas onsite. The project is being implemented by LADWP through LABOS's Proposition "O" Clean Water Bond program. Proposition "O" funded approximately $3 million of the $9 million cost. Construction began in 2007 and was completed in November 2009.

Big Tujunga Dam – San Fernando Groundwater Enhancement Project. LADWP and LACFCD approved Cooperative Agreement No. 47717 on September 18, 2007 for the Big Tujunga Dam –San Fernando Groundwater Enhancement Project. This Project will increase stormwater capture and provide other benefits including improvements in flood prevention and environmental enhancement through seismically retrofitting the dam and spillway. Annual stormwater capture will increase by 4,500 AFY for a total capture amount of 6,000 AFY. The project is integrated with the following projects in this section: Hansen Spreading Grounds Enhancement Project, Tujunga Spreading Grounds Enhancement Project, and the Sheldon-Arleta Methane Gas Collection Project. Both the Integrated Regional Watershed Management Plan for the Upper Los Angeles River Watershed and the Tujunga/Pacoima Watershed Plan are being incorporated into the Project. LADWP is contributing $9 million of the $105 million project cost. Construction of the Project is in progress with an anticipated completion date by September 2011.

Hansen Spreading Grounds Enhancement Project. The Hansen Spreading Grounds is a 120 acre parcel located adjacent to the Tujunga Wash Channel downstream from the Hansen Dam. Under Cooperative Agreement No. 47739, the Los Angeles County Flood Control District (LACFCD) and LADWP propose to modernize the facility to increase intake and storage capacity thereby improving groundwater recharge, flood protection and water quality while providing recreational benefits and native habitat improvements. To accomplish the goals of the project, a phased approach is being proposed. Phase 1A will deepen and reconfigure the existing basins; Phase 1B will improve the intake capacity by replacing a radial gate with a new rubber dam and telemetry system; and Phase 2 will develop other compatible uses such as recreational trails and native habitat for the community. Estimated recharge is 17,284 AFY, and estimated cost of this project is $10 million of which LADWP will fund $5 million. The reconstruction of the spreading grounds was completed in December 2009 and the intake structure will be completed in December 2011.

Tujunga Spreading Grounds Enhancement Project. The Tujunga Spreading Grounds Enhancement Project is designed to increase average annual stormwater capture by 8,000 AFY through relocating and automating the current intake structure on the Tujunga Wash, installation of an automated intake structure on the Pacoima Wash, and reconfiguration of the Tujunga Spreading Basins. Other multiple benefits include habitat improvements, passive recreation, educational opportunities, flood protection, and water quality improvements. Owned by LADWP, the Tujunga Spreading Grounds are

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operated by LACFCD in conjunction with other facilities along the Tujunga and Pacoima Wash Channels. Construction is expected to begin in 2012.

Valley Generating Station Stormwater Capture Project. LADWP is leading efforts to capture and infiltrate stormwater from the Valley Generating Station, from adjacent streets, and from the Tujunga Wash Channel. Phase 1 will capture and infiltrate all stormwater from the Valley Generating Station. Phase 2 will divert water from the Tujunga Wash Channel for infiltration at the abandoned gravel pit at the generating station. Total stormwater capture is estimated at 700 AFY. Project designs are expected to be completed at the end of 2011.

Pacoima Spreading Grounds Enhancement Project. LADWP in conjunction with LACFCD is proposing to upgrade the Pacoima Spreading Grounds by improving the intake and stormwater storage capacity. Annual average stormwater capture is expected to increase by approximately 2,000 AFY with completion of the project. Other project benefits include flood protection, water quality improvements, and passive recreation. The final concept report and design has an expected completion date by the end of 2012.

Lopez Spreading Grounds Enhancement Project. The Lopez Spreading Grounds Enhancement Project involves deepening the existing Lopez Spreading Grounds and improving the intake and delivery system. LACFCD is the lead agency for the project. Additional groundwater recharge to the SFB of approximately 750 AFY is expected from the project. Project designs are anticipated to begin in 2013.

Strathern Wetlands Park Project. The Strathern Wetlands Park Project involves the conversion of a 45-acre gravel pit into a multipurpose facility for flood protection, stormwater retention, treatment, groundwater recharge, habitat restoration, and recreation. Estimated stormwater capture is approximately 900 AFY. Proposition "O" funding of $17.8 million has been approved for acquisition of the site. LACFCD purchased the land and project planning is underway. Designs are expected in 2012, and construction is expected to occur in two phases from 2013 to 2016.

Hansen Dam Water Conservation Project. In 2000 the Army Corps of Engineers (ACOE) completed a feasibility study to examine operational changes and facility improvements at the Hansen Dam as part of a cost-shared study with LACFCD. Four scenarios are recommended with additional stormwater capture amounts of up to 3,400 AFY depending on the selected scenario. Designs for the project are anticipated in 2013.

Pacoima Dam Reservoir Sediment Removal Project. The Pacoima Dam Reservoir Sediment Removal Project involves removing sediment from behind Pacoima Dam to increase storage volume. The sediment build-up behind the Dam has decreased the capacity to about 3,300 acre-feet. In the fall of 2009 approximately 80 percent of the Pacoima Dam watershed was burned. This damage will likely increase sediment flow into the reservoir above the estimates provided based on 2005 topography. The Project will involve excavating 5 million cubic yards of sediment and increasing the storage volume by 3,000 acre-feet. Increased storage would decrease the number of reservoir spill events and increase the available recharge flow for the Pacoima and Lopez Spreading Grounds. The excavation will extend over 7,000 feet upstream of the existing dam. The project will produce an additional annual water recharge benefit of 670 AFY.

Branford Spreading Basin Upgrade. The Branford Spreading Basin Project will remove fine silts from the basin and install new pumps to drain the basin. These pumps could be used to drain the existing facility into the Tujunga Spreading Grounds. The expected additional recharge for this project is approximately 500 AFY.

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7.6 Distributed Stormwater Capture

Throughout the City of Los Angeles there are opportunities to capture localized dry and wet weather runoff for local reuse. However, Los Angeles' storm drain systems have historically been designed to protect life and property from flood impacts by quickly redirecting rainfall and runoff from impervious surfaces into the City's storm drain system and ultimately the Pacific Ocean without regard to water quality impacts. The September 2, 2002 Municipal Stormwater National Pollutant Discharge Elimination System Permit (NPDES Permit No. CAS004001) for the Los Angeles region requires all new development or redevelopment projects to develop and comply with a Standard Urban Stormwater Mitigation Plan (SUSMP) to reduce runoff leaving the project site and to improve the project's water quality impacts.

Recently the City has taken initial steps towards promoting distributed capture and infiltration of runoff through development of a suite of distributed runoff demonstration projects. Distributed stormwater capture (also known as decentralized stormwater capture) is defined as any groundwater recharge system less then 500 af or any direct stormwater capture system capturing less then 10 af. In addition, the City is developing a Low Impact Development (LID) ordinance requiring retention of stormwater onsite for new and redevelopment projects which extends beyond SUSMP regulations. The Watershed Management Group is working with the Los Angeles and San Gabriel Rivers Watershed Council (LASGRWC), TreePeople, Los Angeles Department of Public Works Bureau of Sanitation (BOS), Department of Building and Safety (DBS), Los Angeles County Department of Public Works (LACDPW), The River Project and others to evaluate and study the impacts of localized stormwater capture and source control within the City.

LADWP is providing various resources for projects that would enhance the City's ability to capture additional dry and wet weather runoff for beneficial use. Both dry and wet weather runoff can be beneficially used. Dry weather runoff occurs in the absence of rainfall while wet weather runoff occurs as a direct result of rainfall. Dry weather runoff is typically related to inefficient irrigation systems, overwatering, and other wasteful outdoor water use practices. Wet weather runoff represents a significantly larger volume of water than dry weather runoff. Exhibit 7D summarizes the potential water yield and average unit cost of the different resources available to increase localized capture and infiltration of runoff.

7.6.1 Watershed Council – Water Augmentation Study

The Los Angeles Basin Water Augmentation Study (WAS) is a long-term research project, initiated in 2000, created to determine the benefits of implementing a broad-based approach to stormwater infiltration within the Los Angeles Region. The study was led by the Los Angeles & San Gabriel Rivers Watershed Council in partnership with local, state, and federal agencies and organizations, with major support from the federal Bureau of Reclamation. LADWP assisted in the funding and creation of the study report as part of the Technical Advisory Committee.

While centralized strategies such as spreading basins and dams are reliable and effective methods to capture stormwater, increased urbanization, high land costs, and scarcity of imported water for recharge signal the need to pursue additional stormwater capture methods. Furthermore, centralized stormwater infiltration is unable to capture the entire watershed which leaves a large quantity of additional stormwater to be tapped into. The WAS research has concluded that decentralized strategies (distributed stormwater capture such as rainbarrels & cisterns) would provide a local and reliable supply of water that would not negatively impact groundwater quality. Distributed stormwater capture and infiltration systems techniques provide a viable means of augmenting groundwater recharge and reducing the overall cost of treating urban runoff. Based on the findings of this study, the WAS partnership moved forward on a demonstration project in a 24-single family residential home neighborhood in northeast San Fernando Valley to validate study findings.

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CASE STUDY:
Elmer Avenue Neighborhood Retrofit Project

The Background

Initiated in 2000, the Los Angeles Basin Water Augmentation Study (WAS) is a long-term research project led by the Los Angeles & San Gabriel Rivers Watershed Council in partnership with eight local, state, and federal agencies of which LADWP is an active partner. The study is evaluating the practical potential to improve surface water quality and increase local groundwater supplies through infiltration of urban stormwater runoff.

Based on positive findings of the study, the WAS partnership moved forward with a demonstration project to display an integrated and comprehensive approach to water management by retrofitting a neighborhood with strategies to address water conservation, pollution reduction and treatment, flooding, and habitat restoration. The Elmer Avenue Neighborhood Retrofit Project was chosen after an extensive selection process that evaluated neighborhoods based on more than 80 criteria.

The Project

The Elmer Avenue Neighborhood Retrofit Project commenced in July 2009 and was completed in June 2010 and cost approximately $2.5 million. Elmer Avenue receives stormwater runoff from approximately 40 acres of upstream residential area causing flooding in most storms. To address these 40 acres, the project encompasses improvements to both the public right-of-way as well as the private residences. As such, the project required active interaction and cooperation between the WAS partnership and the residents to work together and come up with a solution for the neighborhood.

Public Right-of-Way Improvements:

Infiltration Gallery-

A large infiltration gallery was installed underneath the street right-of-way which is estimated to infiltrate 16 acre-feet annually. The gallery is a sub-surface groundwater collection system, shallow in depth, constructed with perforated pipes where runoff water flows into and then is allowed to infiltrate into the ground to recharge the local groundwater basin.

Bioswale-

The newly installed sidewalks include bio-swales in the parkways to capture and treat stormwater runoff from the local sub-watershed mostly from residential landuse. The bioswales are open shallow channels with gently sloped sides and bottoms filled with vegetation and rip rap where stormwater runoff is collected. Bioswales help reduce the flow velocity and treat stormwater runoff through filtering by the vegetation in the channel, through the subsoil matrix, and/or into the underlying soils. In addition, bioswales trap particulate pollutants (suspended solids and trace metals), promote infiltration and serve as part of the whole stormwater drainage system installed for this project.

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Private Residence Improvements:

Numerous improvements were offered to residents who chose to participate to help reduce runoff as well as exercise better outdoor water conservation such as porous pavers, rain gardens, rain barrels, and drought-tolerant and native landscaping.

The Benefits

The finished project incorporates a mixture of strategies to produce multiple levels of benefits (to the neighborhood but also to the local, regional, and national community whom can take this work as an encouraging model):

- Capture stormwater and dry-weather runoff to prevent flooding and decrease pollution of local rivers and oceans
- Reduce impermeable surfaces and increase groundwater recharge
- Improve neighborhood aesthetics through increased green space and public right-of-way improvements
- Increase community awareness of watershed issues
- Encourage community awareness to being more water and environmentally responsible.

As a result of the success and positive feedback from citizens for the Elmer Avenue Neighborhood Retrofit Project, a second phase is currently underway to Elmer Avenue to retrofit its alleyway. These small projects aim to spark large change by showing citizens and other communities that they too can make changes and improve their neighborhoods to be more water and environmentally friendly.

"By turning our yards into rain gardens and our streets into water recharge facilities, we can ensure clean water for the future. In contrast to a typical urban street, Elmer Avenue now reduces flooding and water pollution, improves water quality, replenishes groundwater supplies, and increases native habitat."

Nancy Steele, Executive Director
Los Angeles and San Gabriel Rivers Watershed Council

"This project is a prime example of how homeowners and the city can work together on a project that demonstrates smart watershed management through stormwater capture and water conservation measures that are beautiful and effective"

Edward Belden, Water Programs Manager
Los Angeles and San Gabriel Rivers Watershed Council

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7.6.2 Integrated Water Resources Plan Analysis

As part of the City of Los Angeles Integrated Water Resources Plan (IRP), further described in Chapter 10, the City investigated the beneficial reuse of urban runoff for both dry and wet weather conditions.

7.6.2.1 Dry Weather Runoff Options

The beneficial use option for dry weather runoff consists of runoff capture, treatment, and reuse. For dry weather flow, most of the runoff could potentially be diverted directly for beneficial use, particularly during the summer months when demands for non-potable water are high (due to the higher irrigation demands in the summertime). The level of treatment of the runoff before being beneficially used would be determined by the ultimate use of the water.

A computer modeling analysis was performed during development of the IRP based on the recycled water demands in Los Angeles and the available dry weather runoff. Based on the data, the model determined which of the recycled water demands could be realistically met through treated runoff. The dry weather runoff available for reuse throughout the City is estimated at 97 mgd (approximately 26,000 million gallons per year). Exhibit 7E identifies the amount of this runoff that could, after treatment, be used to meet the recycled water demands.

Exhibit 7E

Potential Non-Potable Water Demands Met with Dry Weather Treated Runoff

Service Area	Total Demand Served	
	(AF per year)	(million gallon per year)
Aliso Wash	1,400	460
Canoga	3,250	1,050
Reseda	2,900	950
Tujunga / Burbank	9,050	2,950
LA River Reach 3	1,100	360
Dominguez Channel	8,500	2,770
Compton Creek	1,450	470
Ballona	10,850	3,530
Verdugo Wash	100	30
LA River/Arroyo	9,600	3,130
Total	48,200	15,700

Source: City of Los Angeles Integrated Resources Plan, Facilities Plan, Volume 3: Runoff Management

7.6.2.2 Wet Weather Runoff Options

Rain Barrels

Rain barrels are distributed stormwater capture devices used to store rainwater collected from roofs via roof rain gutter systems. Harvested water can be used for outdoor irrigation at a later time. Rain barrels vary in size with a typical rain barrel holding approximately 55 gallons that can be readily installed under any residential roof gutter downspout. Installation of rain barrels at residences throughout Los Angeles, assuming 400,000 residences, could potentially capture 6,400 AFY assuming an annual average rainfall of 17.8 inches, one 55-gallon rain barrel installed per residence, and an average roof area of 500

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square feet. If overflow infiltration is provided, and/or greater roof area is utilized, annual rainfall volume captured can be significantly greater.

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Case Study:
Ballona Creek Watershed Rainwater Harvesting Pilot Program

Funded by the Safe Neighborhood Parks, Clean Water, Clean air and Coastal Protection Bond Act of 2000 (Prop 12) through the Santa Monica Bay Restoration Commission and the California Coastal Conservancy, the City of Los Angeles, Department of Public Works, Bureau of Sanitation, Watershed Protection Division (Stormwater Program) began the City's first free Rainwater Harvesting pilot program in July 2009. The goal of this program is to engage as many property owners as possible, and limiting the installation to one downspout per property allows the City to reach the maximum number of residences.

Liz Herron, Land Use Chair of Mt. Washington Association, supports rainwater harvesting systems: "Rain barrel systems serve environmental purposes by allowing homeowners to collect the rainwater for personal irrigational purposes. It also reduces the amount of rainwater entering into the streets and ocean. These residential systems are successful programs that save water and prevent pollution."

Designed to conserve potable water and reduce the amount of polluted rainwater that runs untreated into the ocean, the $1-million pilot plan has enough funds to install 490 residential rain barrels, disconnect 100 barrels implemented with consultation on rain gardens, and provide one custom-made commercial planter box for each of ten businesses. It is estimated to save 584,100 gallons of water each year. The City estimates there are roughly 18 rain events in LA each year filling each barrel at least once each time.

In a typical year, about 9,600 gallons of water is generated on an average 1,000-square foot residential LA roof top. If each of the 400,000 residential parcels in LA were to install a single rain barrel, the City estimates that about 400 million gallons of water would be saved, which would reduce the demand for water. An evaluation of the program is scheduled for completion in Spring 2011.

The 55-gallon capacity rain barrel was chosen because the weight of 200 pounds is relatively manageable. The rain barrels are also made from food-grade plastic, repurposed from containers in case the harvested rainwater is used to grow food. They are equipped with mesh netting to keep out debris and mosquitoes and connected to the downspouts by a trained rain barrel installation specialist.

Planter boxes that businesses are eligible for will be custom-made to fit the layout and dimensions of the property. The City will be working with the business to make sure they are content with the presentation of the planter box.

The program addresses the City's broad problems of water scarcity and stormwater pollution. Currently outdoor water usage accounts for 1/3 of the average family's overall water consumption. The Rainwater Harvesting program helps to meet the City's water conservation goals by reducing the amount of potable water used for irrigation and other outdoor purposes.

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Cisterns

Cisterns are larger than rain barrels and can range from 100 to 10,000 or more gallons. They store diverted runoff from roof areas and other impervious surfaces. This stored runoff can provide a source of untreated water for gardens and compost, free of most sediment and dissolved salts. Because residential irrigation can account for up to 40 percent of domestic water consumption, water conservation measures such as cisterns can be utilized to reduce demands, especially during hot summer months.

An analysis of the effect of installing cisterns in all single family and multi-family residences in the City was conducted as part of the IRP, which was based on projected household demands, irrigation needs, and historical rainfall data. The results showed that during a storm event of 0.45 inches, the result of installing 1,000-gallon cisterns at all single-family and multi-family residences in the City would be a maximum capture of approximately 440 million gallons. This provides a substantial amount of water conservation and reduction in potable water demands within the City.

The primary beneficial use of dry and wet weather runoff is to meet irrigation demands. These demands are typically non-existent during rain events and low throughout the rainy season. Therefore, the wet weather runoff would need to be stored until the demand exists. This can be done through a regional and/or a localized approach. A regional approach to seasonal storage could include the use of out-of-service reservoirs for seasonal storage. A localized approach would be to construct distributed underground storage facilities, located in open spaces, parks, schools, etc. throughout the City.

Exhibit 7F demonstrates a modular storage media that holds the runoff in a honeycomb-like box under the ground. The storage media has approximately 95 percent voids, so almost all of the storage volume would be filled with water. The maximum depth is 8 feet, which translates to approximately 2.44 million gallons per acre of water storage potential. The containers can also be constructed to be impermeable to prohibit infiltration.

Exhibit 7F
Construction of Underground Cistern for Stormwater Capture

(Photo courtesy of TreePeople)

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According to studies conducted during the development of the IRP, the City currently has an estimated open space area of 6,000 acres, which includes parks, open space, and vacant lots. School sites are also a potential option for installing modular storage media under playgrounds and athletic fields. The total school area in the City is approximately 6,000 acres. Assuming that only 25 percent of this area has no buildings or other structures, this equals approximately 1,500 acres of potentially suitable land. Additionally, there are approximately 900 abandoned or no longer maintained alleys of various unknown dimensions that could potentially be converted to underground storage facilities. Exhibit 7G summarizes the approximate underground storage potential throughout the City.

Exhibit 7G

Underground Storage Potential throughout the City

Land Use	Acres (acres)	Potential Storage Volume[1] (million gallons)
Open space	6,000	15,000
Schools (assume only ~ 25 percent suitable land)	1,500	4,000
Alleys	900 count	Unknown
Total	7,500	19,000

Note: 1. Maximum storage potential shown assumes 4.22 million gallons of storage per acre of land. Actual usable volume may be less.
Source: City of Los Angeles Integrated Resources Plan, Facilities Plan, Volume 3: Runoff Management

The City has the potential to store a considerable volume of wet weather runoff in order to meet the potential future surface water quality regulations if the underground storage options were utilized. This stored water could then be drawn down and beneficially used during the dry weather months.

Rain Gardens

Rain Gardens are another simple form of relatively small scale rainwater harvesting. As gardens or depressions, usually constructed sub-grade, they act as small retention/percolations basins for rainwater collection. Not only do they provide for an attractive landscape, but they are effective in treating and infiltrating stormwater for local groundwater recharge.

While extremely functional, these are basically regular gardens and can be designed to fit well into the surrounding landscape. Many cities and states across the country have extensive rain garden programs, and years of research have gone into their design and performance. Acting as a bio-retention systems, rain gardens treat runoff naturally as it seeps underground. In the case of lowered percolation rates or in hillside developments, rain gardens are typically installed with impermeable liners and supplied with under drains.

Unit cost of rain gardens are similar to that of rain barrels, as the mechanism for collecting water is the same. Cost is dependent upon the form and extent of construction and on the type and quantity landscape used, as well as the associated maintenance. Installation of rain gardens at residences throughout Los Angeles, assuming 400,000 residences, could potentially capture 6,400 AFY assuming an annual average rainfall of 17.8 inches, and an average roof area of 500 square feet. Under these conditions, assuming a 10-15 year lifespan, the cost of rain gardens varies from $308-$5,000 / AF.

Neighborhood Recharge

Neighborhood recharge involves installing recharge facilities in portions of vacant urban lots, abandoned alleys, and City parklands, where the soil is highly permeable. This option involves installing underground storage (such as a honeycomb

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shaped device shown in Exhibit 7F, but without the lining to allow infiltration). This would allow the runoff to be stored underground, while still maintaining a safe area above ground for human activity. The runoff would be pumped or would flow by gravity to the site where it would be collected temporarily until it is able to infiltrate.

The amount of runoff that could be managed by neighborhood recharge was determined as part of the IRP by assuming that only the east San Fernando Valley area has predominantly permeable soils appropriate for infiltration (though there may be other areas within the City that could be usable for recharge with smaller-scale projects). Based on an analysis of the City's Geographical Information System, the maximum total area available for neighborhood recharge facilities is approximately 831 acres, which includes vacant urban lots, abandoned alleys, and 25 percent of City parklands. Assuming an infiltration rate of 2 feet per day, the maximum runoff that could potentially be managed by recharge facilities would be 550 million gallons per day (mgd).

7.6.3 Distributed Stormwater Capture Projects

As an outgrowth of the IRP, neighborhood recharge concept efforts are moving from the conceptual stage visualized in the IRP to actual identified projects in the City which infiltrate wet weather runoff as close as possible to the point of origin. A few of the identified projects are highlighted here.

Whitnall Highway Power Line Easement Stormwater Capture Project. This project involves the capture, treatment, and infiltration of stormwater from streets in the eastern San Fernando Valley using LADWP's Whitnall Power Line Easement in the lower Sun Valley Watershed. Average annual recharge is estimated at 110 AFY. Additional uses of the project site may include open space and recreational enhancements. Designs are anticipated for completion by the end of 2011.

Elmer Avenue Neighborhood Retrofit Project. In December of 2008, the City of Los Angeles partnered with TreePeople and the LASGRWC to retrofit an existing neighborhood in the Sun Valley portion of Los Angeles that is prone to flooding during wet weather events. A combination of Best Management Practices (BMPs); including vegetated swales, infiltration trenches, rain gardens, rain barrels, native and drought tolerant landscaping, roof gutters, street tree plantings, and aligning driveways to drain to vegetated swales are incorporated into this project. This project was designed to capture and infiltrate the equivalent of a 2-year storm, increasing groundwater recharge. Project funding was provided by the US Bureau of Reclamation, DWR, LACDPW, MWD, Water Replenishment District of Southern California and LADWP. Construction was completed in June 2010.

Woodman Avenue Median Retrofit Demonstration Project. LADWP in partnership with the BOS Watershed Protection Division and The River Project, a non-profit organization, are developing the Woodman Avenue Median Retrofit Demonstration Project to capture, treat, and infiltrate stormwater runoff along a portion of Woodman Avenue. The Project will replace the existing median with pre-treatment devices, a vegetated swale, and an underground retention system. Project benefits include reductions in localized flooding, open space enhancements, groundwater recharge, and native habitat enhancement. The CalFed Watershed Program awarded the project a $1.6 million grant. Construction is expected to be completed by the end of 2012.

North Hollywood Alley Retrofit BMP Demonstration Project. The Project's goal is to demonstrate the ability to infiltrate stormwater near the point of origin while increasing groundwater recharge, reducing flooding, and improving water quality. Four segments of alleyways in the San Fernando Valley are proposed to be retrofitted with pervious surfaces and diversion of flows from intersecting streets into these alleyways. Construction is anticipated to begin in early 2011.

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Laurel Canyon Parkway Infiltration Swale Project. Construction of the Laurel Canyon Parkway Infiltration Swale Project will involve construction of an infiltration trench and parkway swale between the street curb and sidewalk near LADWP's Tujunga Spreading Grounds in the San Fernando Valley. Stormwater will be collected and infiltrated into the groundwater from the local residential neighborhood. Construction of the project is anticipated to occur in late 2011.

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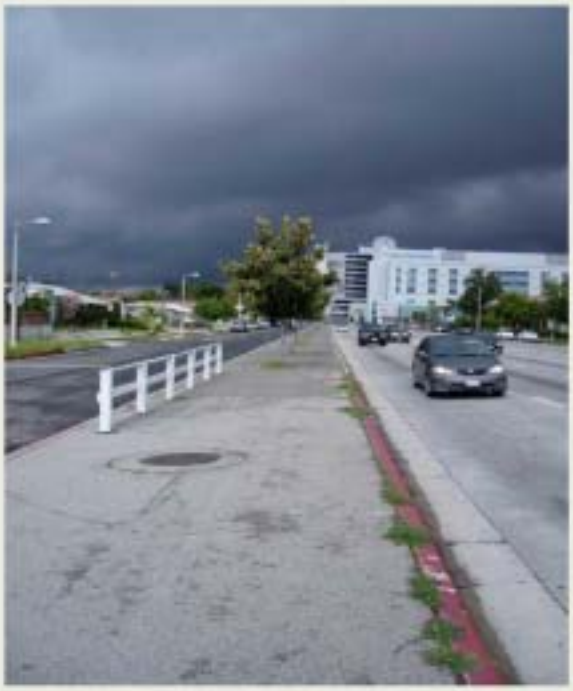
CASE STUDY:
Woodman Avenue Multi-Beneficial Storm Water Capture Project

Originally proposed by the local Panorama City Neighborhood Council for the Tujunga-Pacoima Watershed Plan, the Woodman Avenue project represents an innovative example of stormwater capture, which includes extensive benefits for the environment, the City's groundwater basin, and the surrounding community. The Woodman Avenue median is located along the west side of Woodman Avenue from Lanark Street to Saticoy Street.



The Project's construction will be relatively simple but effective. The Project will capture surface runoff from approximately 130 acres that currently flows along street gutters to storm drains, through the Tujunga Wash and ultimately down the Los Angeles River and into the Pacific Ocean. Instead flows will now be directed through pre-treatment devices into a vegetated swale and an underground retention system for groundwater basin infiltration. The vegetated swale and underground retention/infiltration system will replace an existing 16-foot wide, 3,500-foot long concrete median. After construction of the project, participants will conduct active monitoring of water flows, water quality, and vegetation for approximately three years. This data should provide valuable information to facilitate the development of future projects, and optimize system processes.

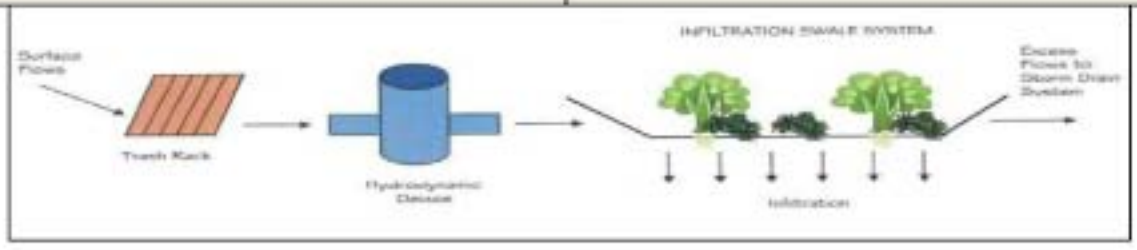
The direct water resource related benefits from this project are three fold. First, the additional water captured will recharge the San Fernando Groundwater Basin with approximately 80 AF per year. This replenishes the City's local groundwater supply, and helps protect pumping rights for City, which ultimately guarantees a more reliable water supply. Secondly, diverted flow alleviates local flooding, particularly during sizable rain events. Finally, the infiltration prevents contaminant carrying runoff and debris from entering local waterways and ultimately coastal areas.

Also recognized are the Community benefits associated with this project. These include creation of open space enhancements such as improved aesthetics and pedestrian access near schools, a walking path, benches, and native vegetation. The River Project will be running an active education program with the local community, including workshops with nearby business owners/residents and the introduction of a curriculum for students at the local elementary school. The organization's goal is to get the students involved in monitoring and maintenance of the project as part of their service learning requirements. Establishing knowledge of sustainable water supplies with the City's youth is an investment in constituent water use practices for generations to come.

Project participants include the Panorama City Neighborhood Council, Council District 6, the Los Angeles Bureau of Sanitation, the Los Angeles Bureau of Street Services, the State of California Water Resources Control Board (SCWRCB), The River Project, and LADWP. This cooperative partnership is anticipating the project's construction to be completion around the end of 2012.

State funding used for the project is provided through Proposition 50. SCWRCB has dedicated $1.6 million through the CALFED Watershed Grant Program, which covers roughly half of the overall project cost.

Melanie Winter from The River Project speaks positively of this stormwater capture project: "The community's involvement in the watershed planning process helped them identify a prime opportunity site that maximizes all the potential benefits. It helps reduce our dependence on imported supplies, addresses peak flows, improves water quality, and re-establishes habitat. It's gratifying to receive State funding to work in a well-rounded partnership to implement this integrated watershed project conceived at the grassroots level."



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7.6.4 Low Impact Development and Best Management Practices

LADWP, in conjunction with other City Departments, is developing programs to highlight water conservation through Low Impact Development (LID) and installation of BMPs. Low Impact Development (LID) is a stormwater management strategy that has been adopted by many localities across the country for the past several years. It is a stormwater management approach that is designed to reduce runoff of water and pollutants from the site(s) at which they are generated.

The past few decades of stormwater management have resulted in the current convention of control-and-treatment strategies. They are largely engineered, end-of-pipe practices that have been focused on controlling peak flow rate and suspended solids concentrations. Conventional practices, however, fail to address the widespread and cumulative hydrologic modifications within the watershed that increase stormwater volumes and runoff rates and cause excessive erosion and stream channel degradation.

In general, implementing integrated LID practices into new development and retrofit of existing facilities can result in enhanced environmental performance while at the same time reducing development costs when compared to traditional stormwater management approaches.

According to the USEPA, infrastructure costs associated with LID practices as compared to traditional stormwater treatment practices result in significant cost savings ranging between 15 percent and 80 percent less than traditional practices. BMPs consist of practices designed to infiltrate runoff for groundwater recharge, reduce runoff volume, and capture rainwater for reuse. Programs under development include pilot projects, retrofitting of existing facilities, new development standards, and assistance in ordinance development.

Retrofit of LADWP Facilities to Meet LID Standards

LADWP is assessing its existing facilities for potential retrofits using LID BMPs. LID BMPs under consideration include pervious pavement, stormwater capture, curb cuts, bioretention cells, and amended soils. Expected benefits include:

- Increased groundwater recharge;
- Decreased outdoor water use;
- Increased compliance with stormwater regulations;
- Improved environmental conditions for employees and the public;
- Improved public image;
- Increased awareness of LID and provide examples for residents; and
- Compliance with Model Water Efficient Landscape Ordinance.

New LADWP Facility Development Using LID Standards

LADWP's Watershed Management Group is developing a framework for implementation of LIDs and BMPs during the new facility development process. Within the framework, LID and BMPs are taken into consideration during the planning, design, implementation, and maintenance processes associated with new LADWP facilities. Benefits include:

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- Reductions in costs associated with stormwater infrastructure and landscape maintenance;
- Reduced costs for grading by using natural drainage;
- Reduced sidewalk costs by using narrower sidewalks;
- Increased groundwater recharge;
- Reduced runoff volume and pollutant loading;
- Reductions in long-term maintenance and operation costs by using drought tolerant landscaping;
- Reduction in life cycle costs of replacing or rehabilitating pipe and below ground infrastructure.

Assistance in Ordinance Development

LADWP is represented on the City of Los Angeles Landscape & Stream Protection Ordinances Joint Meeting Committee through the Watershed Management Group. Other committee members include the Department of Parks and Recreation, the Department of Public Works, the Department of Environmental Affairs, the Department of City Planning, and the Department of Building and Safety. The committee is tasked with developing ordinances for city-wide implementation that in combination reduce water use and improve groundwater recharge among other multiple benefits. Ordinances under review include the:

- Green Building Ordinance using the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System;
- LID Ordinance to incorporate improvements in stormwater management at the point of origin;
- Stream Protection Ordinance to incorporate methodologies for improving surface and groundwater quality;
- Hillside Ordinance revisions to include modifications in policies regarding front yards, side yards, height, fire protection, street access, lot coverage, off-street parking requirements, and exceptions in relation to the ordinances above.

7.6.5 Future Distributed Stormwater Programs

LADWP continues to investigate the potential for implementation of future distributed stormwater programs. Through its Watershed Management Group, LADWP will continue to develop partnerships and programs to improve utilization of stormwater runoff for outdoor water use and groundwater recharge. Potential programs that could be considered in the future include rain barrel/cistern rebates and retrofit incentives for installation of LID BMPs.

7.7 Integrated Regional Water Management Plan (IRWMP) Program

LADWP is a participating agency for the IRWMP which encompasses 92 cities in the Greater Los Angeles County Region. The IRWMP aims to address the water quality, resource, and supply issues of the region. A final plan was adopted on December 16, 2006.

Highlights of the plan that pertain to Watershed issues include:

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- Short and long term objectives to comply with water quality regulations (including TMDLs) by improving the quality of urban runoff, stormwater, and wastewater
- Optimize local water resources to reduce the Region's reliance on imported water
- Long term priority to protect groundwater supplies through stormwater recharge
- Target goal to reduce and reuse 150,000 AFY (40%) of dry weather urban runoff and capture and treat an additional 170,000 AFY (50%) for a total target of 90%
- Target goal to reduce and reuse 220,000 AFY (40%) of stormwater runoff from developed areas and capture and treat an additional 270,000 AFY (50%) for a total of 90%

For more detailed information on the IRWMP, please refer to Chapter 10.

7.8 Cost Analysis

Exhibit 7H compares side by side the various watershed management opportunities LADWP is pursuing and/or investigating to add to its water portfolio.

Exhibit 7H

Water Source	Water Yield (AFY)	Average Unit Cost ($/AF)
Centralized Stormwater Capture[1]	25,950	$60 - $200
Distributed Stormwater Capture		
Urban Runoff Plants[2]	5,000	$4,044
Rain Barrels[3]	6,400	$701 - $1,875
Cisterns[4]	8,000	$2,426
Rain Gardens[5]	6,400	$308 - $5,000
Neighborhood Recharge[6]	12,000	$3,351

Notes:

1. Water Yield and cost is based on LADWP's current planned centralized stormwater capture projects. Additional centralized stormwater capture potential will be identified once the Stormwater Master Plan is complete. Cost assumes 50 year project life.

2. Source: City of Los Angeles Integrated Resources Plan (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSA.

3. Source: Tree People. Assumes 10 - 15 year life, 55 gallon barrels, 1 barrel per residence, 17.8 in annual rainfall, $200-$300 per barrel installed, average used roof area 500 square feet, and 400,000 residences for yield (AFY); 2010 dollars

4. Source: City of Los Angeles Integrated Resources Plan (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSA; capturing and reusing stormwater on-site for schools and government only.

5. Source: Tree People. Assumes 10 - 15 year life, 17.8 in annual rainfall, $3.30 - $25.66 / ft² for rain garden construction, average used roof area 500 square feet, and 400,000 residences for yield (AFY); 2010 dollars

6. Source: City of Los Angeles Integrated Resources Plan (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSMSA.

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It is important to note that the centralized stormwater capture values are based on the planned projects listed in Section 7.5. LADWP is currently compiling a Stormwater Master Plan (see Section 7.3) which will investigate the maximum potential for stormwater capture within the City (for both centralized and distributed capture). Nevertheless, even with this fraction of the potential, it is clear that centralized stormwater capture is a very cost effective, plentiful water supply asset to be pursued. Recognizing its great potential, LADWP will proceed with its efforts on the centralized stormwater capture projects listed in Section 7.5, and closely monitor findings of the Stormwater Master Plan to determine future potential centralized stormwater capture projects.

Distributed stormwater capture values are based on the maximum potential achievable by the City. While the cost listed is high, distributed stormwater capture options are highly variable based on a variety of factors such as the magnitude of the overall program, project locations, etc. Furthermore, distributed stormwater capture projects yield additional benefits to the public outside of water supply generation such as community beautification, public right of way improvements, as well as private residence safety and aesthetic improvements. LADWP will continue to investigate these options to evaluate the best approach to establish a cost effective program that will help add to LADWP's water portfolio.

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Chapter Eight
Metropolitan Water District Supplies

8.0 Overview

As a member agency, the City of Los Angeles purchases water from the Metropolitan Water District of Southern California (MWD) to supplement its supplies from local groundwater, LAA deliveries, and recycled water. LADWP has historically purchased MWD water to make up the deficit between demand and other City supplies. As a percentage of the City's total water supply, MWD water varies from 4 percent in 1983-84 to 71 percent in 2008-09 with the 5-year average of 52 percent between 2005-06 and 2009-10. Exhibit 1F in Chapter 1 illustrates the City's reliance on MWD water during dry years and increasingly in recent years when LAA supply is being cut back for environmental enhancement projects. Although the City plans to reduce its reliance on imported water including LAA and MWD supplies, it has made significant investments in MWD and will continue to rely on the wholesaler to meet its current and future supplemental water needs.

MWD is the largest water wholesaler for domestic and municipal uses in California providing nearly 19 million people with on average 1.7 billion gallons of water per day to a service area of approximately 5,200 square miles. MWD was formed by the MWD Act, and exist pursuant to this statute which was adopted by the California legislature in 1927. MWD's adopted purpose is to develop, store, and distribute water to southern California residents. Additionally, the MWD Act allows MWD to sell additional water when it is available for other beneficial uses. In 1928 MWD was incorporated as a public agency following a vote by residents in 13 cities in southern California. Operating solely as a wholesaler, MWD owns and operates the Colorado River Aqueduct (CRA), is a contractor for water from the California State Water Project (SWP), manages and owns in-basin surface storage facilities, stores groundwater within the basin via contracts, engages in groundwater storage outside the basin, and conducts water transfers to provide additional supplies for its member agencies. Today MWD has 26 member agencies consisting of 11 water districts, one county water authority, and 14 cities, including the City of Los Angeles.

This Urban Water Management Plan projects LADWP's reliance on MWD water supplies will be reduced by half; from the five-year average of 52 percent of total demand between 2005-06 and 2009-10, to 24 percent by 2034-35 under average weather conditions.

8.0.1 History

Initially formed to import water into the southern California region from, MWD's first project was to build the CRA to import water from the Colorado River. The City of Los Angeles originally provided the capital dollars to initiate and complete land surveys of all proposed alignments for the project. Construction was financed through $220 million in bond sales during the Great Depression. Ten years after initiating construction Colorado River water reached southern California in 1941. To meet further water demands in the southern California region, MWD contracted with the SWP in 1960 to deliver almost half of the SWP's water from the San Francisco Bay-Delta region via the California Aqueduct into southern California. After completion of the California Aqueduct, deliveries of SWP water were first received in 1972.

8.0.2 Governance

MWD is governed by a Board of Directors composed of 37 individuals with a minimum of one representative from each of MWD's 26 member agencies. The allocation of the directors and voting rights are determined by each agency's assessed valuation. The city of Los Angeles has four Directors on MWD's Board and controls 19.44 percent of the vote. MWD's Administrative Code defines various tasks which the Board has delegated to MWD staff. A General Manager oversees MWD

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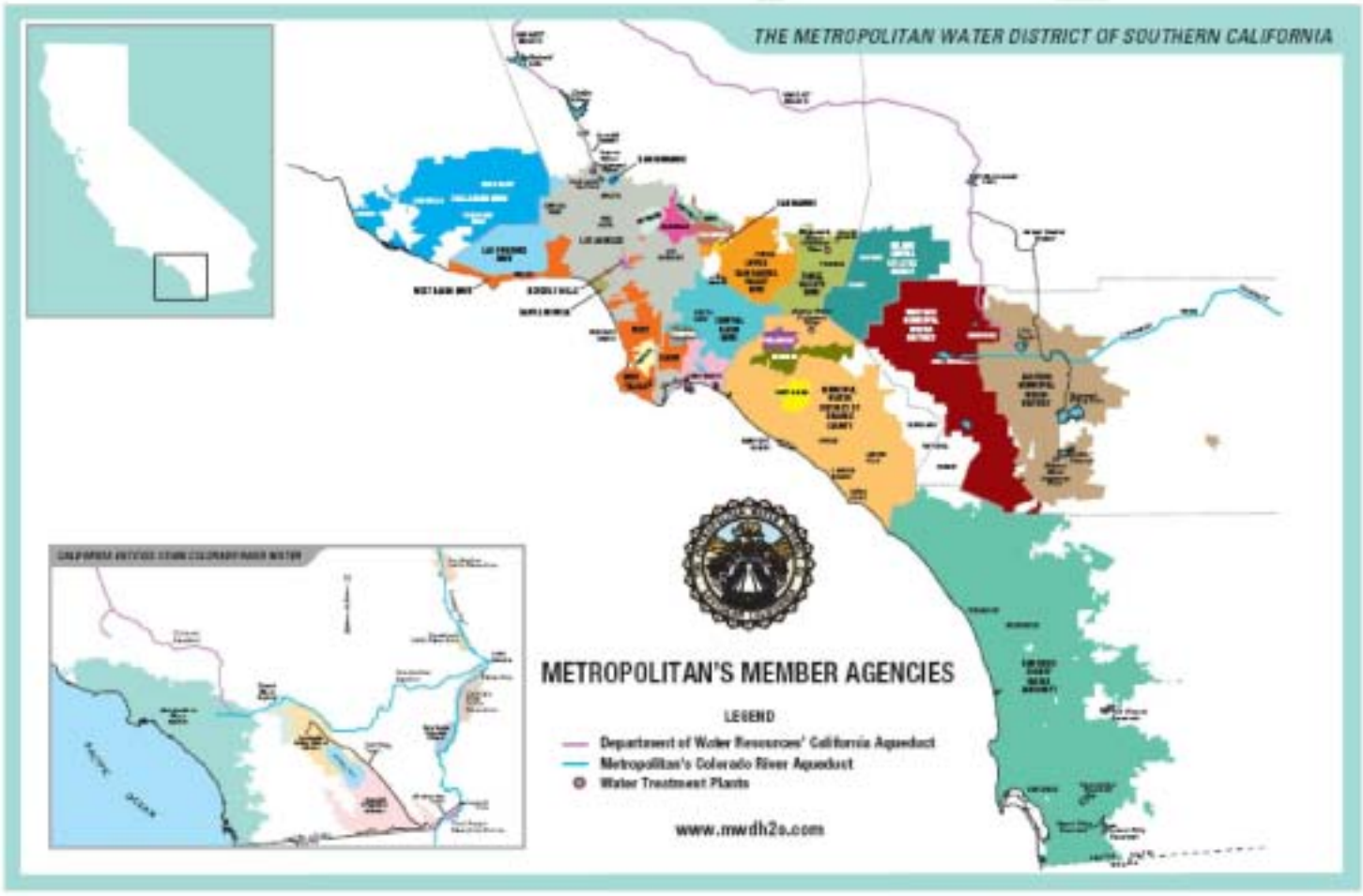
staff. The General Manager, General Auditor, General Counsel, and Ethics Officer serve under direction and authority given directly by the Board.

8.0.3 Service Area

Originally serving an area of 675 square miles in 1928, MWD's service area has grown to approximately 5,200 square miles serving 19 million people via its 26 member agencies. MWD's service area covers portions of Los Angeles, Ventura, Orange, Riverside, San Bernardino, and San Diego counties as depicted in Exhibit 8A. MWD member agencies serve 152 cities and 89 unincorporated areas. Member agencies provide wholesale, retail, or a combination of wholesale/retail water sales in their individual service territories.

Exhibit 8A
MWD Service Area



8.0.4 Major Infrastructure

MWD delivers approximately 6,000 AF per day of treated and untreated water to its member agencies through its vast infrastructure network. Major facilities include the CRA, pumping plants, pipelines, treatment plants, reservoirs, and

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hydroelectric recovery power plants. A summary of the major facilities and capacities are provided in Exhibit 8B and Exhibit 8C illustrates the geographic locations of the facilities.

Exhibit 8B
Major MWD Facilities Summary

Facility	Units	Capacity
Colorado River Aqueduct		
Aqueduct	242 miles	1.3 million AFY
Pumping Plants	5 plants	1,617 feet of total lift
Pipelines	819 miles	
Water Treatment Plants		
Joseph Jensen		750 mgd
Robert A. Skinner		630 mgd
F.E. Weymouth		520 mgd
Robert B. Diemer		520 mgd
Henry J. Mills		220 mgd
Total Treatment Capacity		2,640 mgd
Reservoirs		
Diamond Valley Lake		810,000 AF
Lake Matthews		182,000 AF
Lake Skinner		44,000 AF
Copper Basin		24,200 AF
Gene Wash		6,300 AF
Live Oak		2,500 AF
Garvey		1,600 AF
Palos Verdes		1,100 AF
Orange County		212 AF
Total Reservoir Capacity		1,071,912 AF
Hydroelectric Recovery Plants	16 plants	122 megawatts

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Exhibit 8C
Major MWD Facilities

8.1 Supply Sources

Colorado River supplies, State Water Project supplies, In-Basin Storage, Outside-Basin Storage, and Water Transfers together comprise MWD's total system water supply sources. These sources provide supplemental water to meet the demands in Venture, Los Angeles, Riverside, Orange, San Bernardino and San Diego Counties.

8.1.1 Colorado River

The Colorado River forms California's border with Arizona to the east. The drainage area in California that contributes water to the Colorado River is relatively small and has an arid climate. Accordingly, California has no major tributaries contributing water to the Colorado River.

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The Colorado River Board of California (CRB) is the California state agency given authority to protect the interests and rights of the state and its citizens in matters pertaining to the Colorado River. The Board is comprised of 10 gubernatorial appointees representing the LADWP, MWD, San Diego County Water Authority, Palo Verde Irrigation District, Coachella Valley Water District, Imperial Irrigation District, Department of Water Resources, Department of Fish and Game, and two public members.

8.1.1.1 The Law of the River

The Secretary of the Interior (Secretary) is vested with the responsibility to manage the mainstream waters of the Colorado River pursuant to applicable federal law. This responsibility is carried out consistent with a body of documents referred to as the Law of the River. Water rights to Colorado River water are governed by a complex collection of federal laws, state laws, a treaty with Mexico, other agreements with Mexico, Supreme Court decrees, contracts with the Secretary, interstate compacts, state, and administrative actions at the federal and state levels. Collectively, these documents and associated interpretations are commonly referred to as the "Law of the River" and govern water rights and operations on the Colorado River.

Particularly notable among these documents are:

1) the Colorado River Compact of 1922, which apportioned beneficial consumptive use of water between the Colorado River Upper Basin and Lower Basin; and defined the term "States of the Lower Division" to mean the States of Arizona, California, and Nevada. Serving as the basis of the "Law of the River" the Compact apportioned water to each basin in anticipation of a dam on the Colorado River. The Upper Basin is the portion of the Basin upstream of Lee Ferry, Arizona, while the Lower Basin is downstream of this point. Each basin was apportioned 7.5 million MAF annually and the Lower Basin received the option to an additional 1 MAF annually based on excess flows. California is within the Lower Basin along with Arizona and Nevada;

2) the Boulder Canyon Project Act of 1928 was enacted by Congress to authorize construction of Hoover Dam and the All-American Canal, the Act required that water users in the Lower Basin have a contract with the Secretary, and established the responsibilities of the Secretary to direct, manage, and coordinate the operation of Colorado River dams and related works in the Lower Basin. The Act stipulated conditions, one of which required California to limit Colorado River water use to 4.4 MAF annually plus one-half of the excess water unapportioned by the Colorado River Compact. To satisfy the condition, the California Legislature enacted the Limitation Act in 1929 limiting its use of Colorado River water to the basic apportionment of 4.4 MAF;

3) the California Seven Party Agreement of 1931 was developed in response to the Limitation Act and through regulations adopted by the Secretary, established the relative priorities of rights among major users of Colorado River water in California. The Seven Party Agreement apportioned California's share of Colorado River water to California contractors. Within the agreement priorities were established for each of the four agencies holding contracts for Colorado River Water with the U.S. Bureau of Reclamation. These priorities are shown in Exhibit D. Seven priorities were established with the first four priorities satisfying California's allocation of 4.4 MAF annually and the fifth and sixth priorities relating to California's share of excess Colorado River flows. MWD holds the fourth and fifth priorities. The fourth priority allocates 550 thousand acre-feet (TAF) of California's apportionment to MWD and the fifth priority allocates 662 TAF of California's share of excess flows to MWD.

4) the 1944 Treaty (and subsequent minutes of the International Boundary and Water Commission) related to the quantity and quality of Colorado River water delivered to Mexico. The Treaty guaranteed an annual quantity of 1.5 MAF to be delivered in accordance with the provisions of the Treaty.

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5) the 1963 United States Supreme Court Decision in *Arizona v. California* which confirmed the Lower Basin mainstream apportionments of:

2.8 million acre-feet per year (AFY) for use in Arizona,
4.4 million AFY for use in California, and
0.3 million AFY for use in Nevada;

provided water for Indian reservations and other federal reservations in Arizona, California, and Nevada; and confirmed the significant role of the Secretary in managing the mainstream Colorado River within the Lower Basin;

6) the 1964 United States Supreme Court Decree (Decree) in *Arizona v. California* which implemented the Supreme Court's 1963 decision; allocated 50 percent of the surplus water available for use in California; and allowed the Secretary to release water apportioned to but unused in one state for use in the other two states; the Decree was supplemented over time after its adoption and the Supreme Court entered a Consolidated Decree in 2006 which incorporates all applicable provisions of the earlier-issued Decrees; and

7) the Colorado River Basin Project Act of 1968, which authorized construction of a number of water development projects including the Central Arizona Project (CAP), provided existing California, Arizona, and Nevada water contractors a priority over the CAP and other users of the same character in Arizona and Nevada whenever less than 7.5 million afy is available, and required the Secretary to develop the Long Range Operating Criteria and issue an Annual Operating Plan for mainstream reservoirs.

Exhibit 8D

Listing of Priorities - Seven Party Agreement		
Priority Number	**Agency and Description of Service Area**	**Beneficial Consumptive Use (Acre-feet/year)**
1	Palo Verde Irrigation District - 104,500 acres	
2	Yuma Project, California Portion, not exceeding 25,000 acres	
3(a)	Imperial Irrigation District	
3(b)	Palo Verde Irrigation District - 16,000 acres	3,850,000
4	Metropolitan Water District, City of Los Angeles and/or others on the coastal plain	550,000
5	Metropolitan Water District, City of Los Angeles and/or others on the coastal plain	662,000
6(a)	Imperial Irrigation District	
6(b)	Palo Verde Irrigation District - 16,000 acres of adjoining mesa	300,000
	Total	**5,362,000**

8.1.1.2 Colorado Supply Reliability

Reliability of CRA water for MWD has decreased overtime as a consequence of multiple events. Historically California had used up to 5.4 million afy as Arizona and Nevada were not using their normal apportionments of Colorado River water and surplus water was made available by the Secretary. The 1964 Decree and the 2006 Consolidated Decree of the US Supreme

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Court in *Arizona v. California* confirmed California's allocation was limited to 4.4 MAF annually. As a result MWD can now only rely on its fourth priority allocation of 550 TAF annually. Prior to this, MWD was able to satisfy its fifth priority allocation with Nevada and Arizona's unused water. However, in 1985 Arizona began increasing deliveries to its Central Arizona Project reducing the availability of unused apportionment to fill MWD's fifth priority.

Because of dry years on the Colorado River system and Arizona and Nevada using their full apportionment, the U.S. Secretary of Interior asserted that California must come up with a plan to live within its 4.4 MAF apportionment. Therefore, users from California have developed California's Colorado River Water Use Plan (California Plan). The users included: MWD, Palo Verde Irrigation District (PVID), Imperial Irrigation District (IID), and Coachella Valley Water District (CVWD). This plan identifies actions that California will take to operate within its 4.4 million acre-foot entitlement.

California currently consumes its normal apportionment of 4.4 million AFY, Exhibit 8E and Exhibit 8F illustrate the order of priority, is as follows:

1. PVID - gross area of 104,500 acres of land in the Palo Verde Valley.
2. Yuma Project-Reservation Division - not exceeding a gross area of 25,000 acres in California.

3(a). IID - lands in the Imperial Valley served by the All-American Canal. Export out of basin, primarily agricultural usage. Also, second 63,000 AF in priority 6(a) and balance of any remaining priority 6(a) and 7 water available.

3(b). CVWD - lands in the Coachella Valley served by the Coachella Branch of the All-American Canal. Export out of basin, agricultural usage. Also third 119,000 AF in priority 6(a) and balance of any remaining priority 6(a) and 7 water available.

3(c). PVID - 16,000 acres of land on the Lower Palo Verde Mesa, also priority 6(b).

4. MWD – 550,000 af, also 662,000 af in priority 5, and first 38,000 af in 6(a)

Exhibit 8E
Historical Total Colorado River Basin Storage

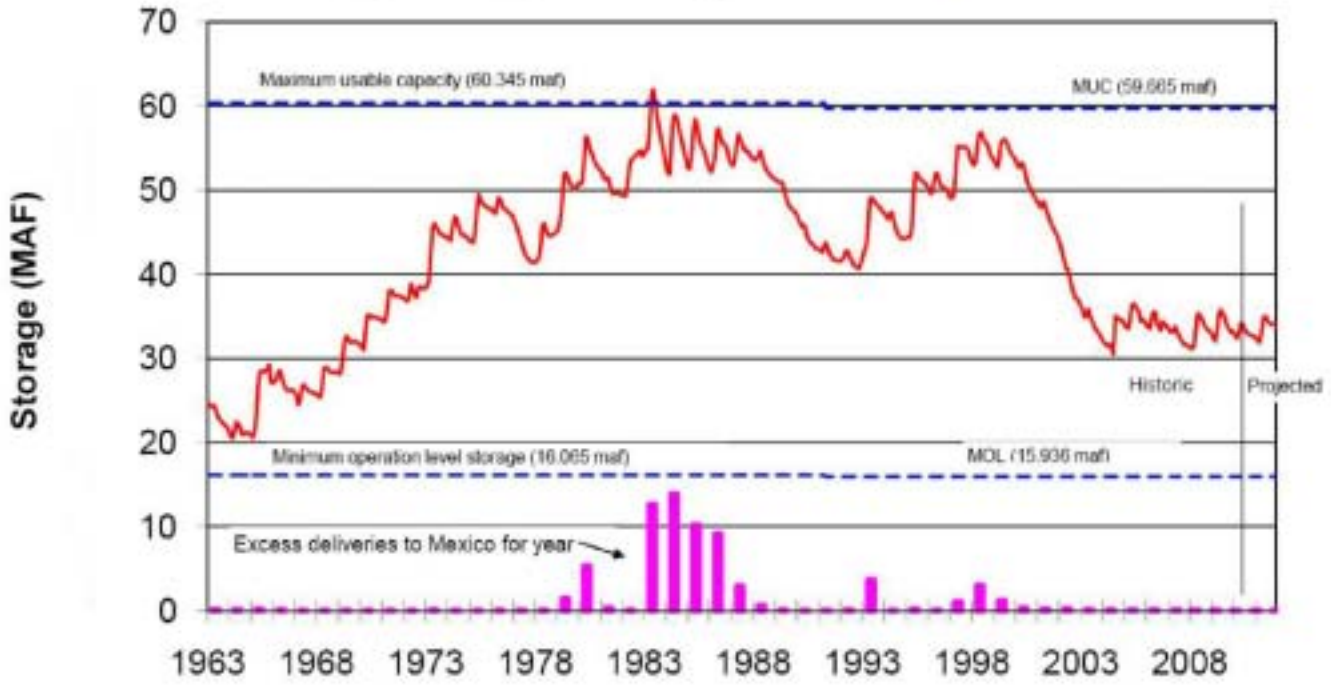

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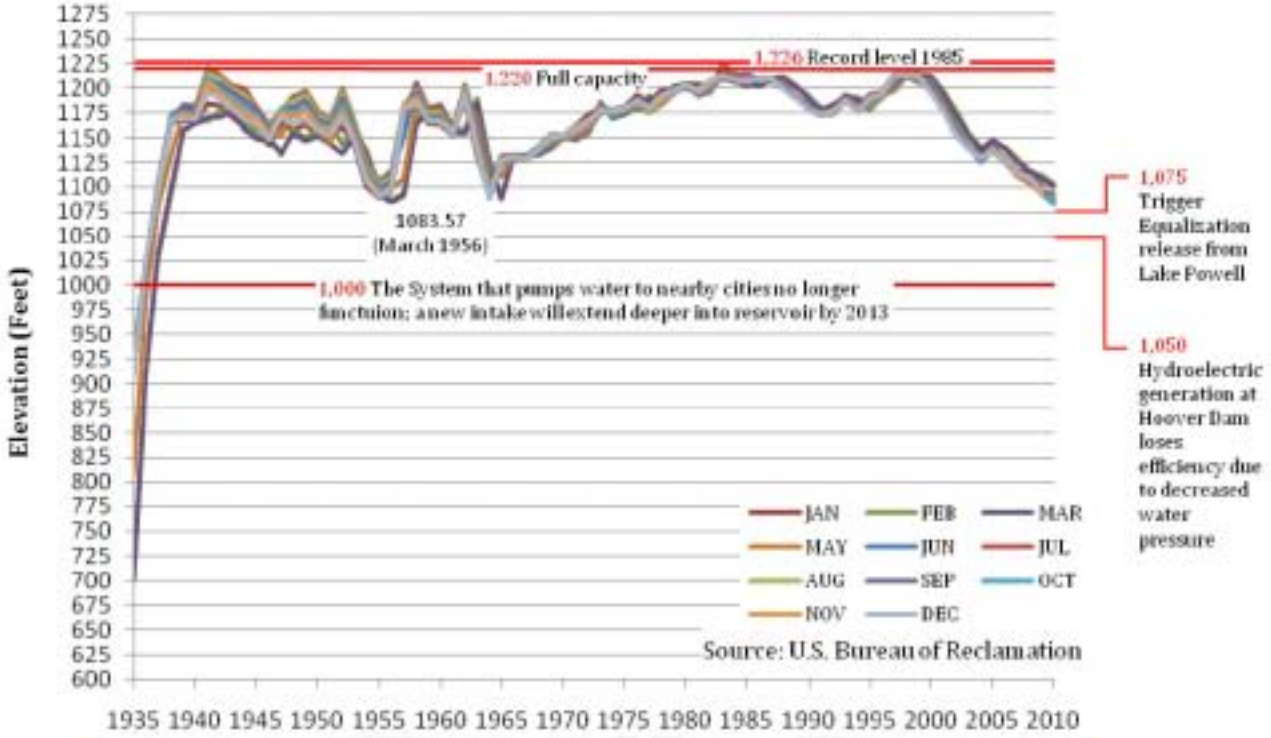
Exhibit 8F
Historical Lake Mead Elevation



The bathtub ring at Lake Mead, August 2010, lake elevation 1,087 feet.

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A component of the California Plan was completion of the Quantification Settlement Agreement (QSA) in 2003, which established baseline water use for each California party with Colorado River water rights. Key to the agreement is the quantification of IID at 3.1 MAF, and CVWD at 330 TAF. Completion of the QSA facilitates the transfer of water from agricultural agencies to urban water suppliers by allowing water conserved on farm land to be made available for urban use. As a result of litigation, the QSA and eleven other agreements were ruled as invalid on February 11, 2010. MWD in conjunction with, CVWD and the SDCWA, have appealed the court's decision. Ultimately, the total impact of the court's decisions on MWD's Colorado River supplies cannot be determined at this time pending the outcome of the appeal. However, MWD's existing conservation, land fallowing, and transfer programs for Colorado River supplies are independent of the QSA and will not be impacted by the QSA lawsuit.

Along with MWD's apportionment, MWD has developed a number of water supply programs to improve reliability of Colorado River supplies, such as agricultural water transfers and storage programs, and has multiple programs under development as listed in Exhibit 8F. Developed programs in conjunction with MWD's apportionment will provide MWD with approximately 1.14 MAF in 2035 under an average year (1922 – 2004 hydrology). Proposed programs under development could add another 182 TAF per year. Non-MWD supplies conveyed through the CRA are forecast at 296 TAF for a total CRA supply capability of 1.61 MAF. However, the CRA has a supply capacity constraint of 1.25 MAF. After subtracting MWD's conveyance obligation of non-MWD supplies, MWD's supplies for 2035 under average year, single-dry year (1977 hydrology), and multi-dry year (1990 – 1992 hydrology) scenarios are all forecast at 954 TAF. Exhibit 8G summarizes the CRA supply forecast for 2035 under an average year.

Exhibit 8G
MWD's CRA Forecast Supplies in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF)/ Year
Current	
Basic Apportionment - Priority 4	550
Imperial Irrigation District/MWD Conservation Program	85
Priority 5 Apportionment (Surplus)	13
Palo Verde Irrigation District Land Management Crop Rotation and Water Supply Program	133
Lower Colorado Water Supply Project	5
Lake Mead Storage Program	400
Quechan Settlement Agreement Supply	7
Forbearance for Present Perfected Rights	-47
Coachella Valley Water District State Water Project/QSA Transfer Obligation	-35
Desert Water Agency and Coachella Valley Water District SWP Table A Obligation	-155
Desert Water Agency and Coachella Valley Water District SWP Table A Transfer Callback	82
Desert Water Agency and Coachella Valley Water District Advance Delivery Account	73
Drop 2 Reservoir Funding	25
Southern Nevada Water Authority Agreement	0
Subtotal of Current Programs	**1,136**
Programs Under Development	

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Additional Palo Verde Irrigation District Transfers	62
Arizona Programs - Central Arizona Project	50
California Indians/Other Agriculture	10
ICS Exchange	25
Agreements with Coachella Valley Water District	35
Hayfield Groundwater Extraction Project	0
Subtotal of Proposed Programs	**182**
Additional Non-MWD CRA Supplies	
San Diego County Water Authority/ Imperial Irrigation District Transfer	200
Coachella and All-American Canal Lining	
To San Diego County Water Authority	80
To San Luis Rey Settlement Parties[1]	16
Subtotal of Non-MWD CRA Supplies	**296**
Maximum CRA Supply Capability[2]	**1,614**
Minus Supply CRA Capacity Constraint of 1.25 MAF Annually	**-364**
Maximum Forecast CRA Deliveries	**1,250**
Minus Non-MWD Supplies[3]	**-296**
Maximum MWD Supply Capability[4]	**954**

1. Subject to satisfaction of conditions specified in agreement among MWD, the US, and the San Luis Rey Settlement Parties
2. Total amount of supplies available without taking into consideration of CRA capacity constraint of 1.25 MAF annually.
3. Exchange obligation for San Diego County Water Authority - Imperial Irrigation District transfer and the Coachella and All-American Canal Lining Projects
4. The amount of CRA water available to MWD after meeting exchange obligations.

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.1.3 Water Quality Issues

Water quality issues for Colorado River supplies encompass high salinity levels, perchlorate, nutrients, uranium, chromium VI, N-nitrosodimethlamine (NDMA), and pharmaceuticals and personal care products (PPCPs). High salinity levels present the most significant issue and the only foreseeable water quality constraint for the Colorado River supply. MWD expects its source control programs for the CRA to adequately address the other water quality issues. MWD has also bolstered its water security measures across all of its operations since 2001, including an increase in water quality tests. Details of MWD's water quality initiatives are available in MWD's 2010 Regional Urban Water Management Plan (RUWMP).

Salinity

Water obtained from the Colorado River has the highest salinity levels of all MWD supply sources averaging 630 mg/L since 1976. Salts are eroded from saline sediments deposited in prehistoric marine environments in the Basin, dissolved by precipitation, and conveyed into the Basin's water courses.

Salinity issues have been recognized in the Basin for over 30 years. The seven basin states formed the Colorado River Basin Salinity Control Forum (Forum) to mutually cooperate on salinity issues in the Basin. The Forum recommended the U.S. Environmental Protection Agency (USEPA) to act upon the Forum's proposal and in response the USEPA approved water quality standards and established numeric criteria for controlling salinity increases. Each Basin State adopted the water quality

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standards, which are designed to limit the flow-weighted average annual salinity level to 1972 levels or below. An outgrowth of the Forum was the Colorado River Basin Control Program. At the core of the program is the reduction in salts entering the river system by intercepting and controlling non-point sources, wastewater, and saline hot springs. Salinity reduction projects have reduced salinity concentration of Colorado River water by over 100mg/L approximating $264 million per year, in 2005 dollars, in avoided damages.

MWD adopted a Salinity Management Policy in 1999 with the goal of achieving salinity concentrations of less than 500 mg/L at delivery. To reduce salinity levels, Colorado River supplies are blended with SWP water supplies to achieve the salinity target in seven out of ten years. In the other three years the target is not possible to achieve as a result of hydrologic conditions that increase salinity on the Colorado River and less SWP water is available for blending. Additionally, to maximize the use of recycled water in agriculture, MWD is trying to obtain lower salinity imported water during the spring/summer months to reduce salinity levels in recycled water.

Perchlorate

In 1997 perchlorate was first detected in the Colorado River attributed to an industrial site upstream of the Las Vegas Wash in Nevada, ultimately draining to the river. Subsequently, an additional groundwater plume was found to be migrating from an additional industrial site, but had not reached the Las Vegas Wash. Since the initial discovery of contamination, remediation efforts have significantly reduced perchlorate loading from the Las Vegas Wash. At Lake Havasu, downstream of the convergence of the Las Vegas Wash and Colorado River, perchlorate levels have decreased from 9 µg/L at their peak in 1998 to less than 6 µg/L in October 2002. Since June 2006 typical levels have been less than 2 µg/L.

Nutrients

Excessive nutrient levels in water can stimulate algal and aquatic weed growth leading to taste and odor concerns. Nutrients include both phosphorous and nitrogen compounds. Other impacts of algal and aquatic weed growth include reductions in operating efficiencies and potentially provide an additional food source for invasive aquatic species, such as quagga and zebra mussels.

Naturally, the Colorado River system has relatively low concentrations of phosphorous. Additional loading to the system as upstream urbanization increases has the ability to increase phosphorous concentrations and impact MWD's ability to blend low nutrient concentration CRA water with high nutrient concentration SWP water. MWD continues to work with agencies located along the lower Colorado River to improve their wastewater management to reduce phosphorous loading.

Uranium

Near Moab, Utah a 16-million ton pile of uranium tailings located approximately 750 feet from the Colorado River is a potential source of uranium loading to the river. In 1999, the US Department of Energy began remediating the site by removing tailings and treating contaminated groundwater. Complete removal of the pile is expected by 2025 or 2019 if additional funding is secured. MWD is tracking clean-up progress and continues to support rapid clean-up of the site.

To address recent uranium mining claims in the vicinity of the Colorado River and the Grand Canyon Area, MWD has sent letters to the Secretary of Interior to highlight MWD's concern of source water protection and recommended close federal oversight. In 1999, the Department of Interior placed a two-year hold on mining claims for 1 million acres adjacent to the Grand Canyon area to conduct additional analyses and H.R. 644, Grand Canyon Watersheds Protection Act, was introduced in 2009. H.R. 644, if approved, would prohibit new mining activities around the Grand Canyon area.

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Chromium VI

Chromium VI has been detected in a groundwater aquifer in the vicinity of the Colorado River near Topock, Arizona. The source of the contamination is a natural gas compression site operated by Pacific Gas and Electric (PG&E) that previously used chromium VI in its operations. Currently, PG&E is engaged in interim clean-up operations to protect the Colorado River. A final treatment alternative is anticipated to be released in 2010. Monitoring upstream and downstream of the site range from non-detect (0.03 µg/L) to 0.06 µg/L which are considered within the background range for the river. MWD is actively involved in the corrective action process through its participation in stakeholder workgroups and partnerships with State and federal regulators, Indian tribes, and other stakeholders.

NDMA and Pharmaceuticals and Personal Care Products

N-nitrosodimenthylamine is a by-product formed by secondary disinfection of some natural waters with chloramines. MWD is involved with projects to understand the potential sources of NDMA precursors in its source watersheds and to develop treatment strategies to minimize NDMA formation at its water treatment facilities. In 2007, MWD initiated monitoring efforts to measure Pharmaceuticals and Personal Care Projects (PPCPs) in its source supplies. PPCPs have been detected at very low levels (low ng/L level; parts per trillion) consistent with monitoring results from other utilities. MWD is involved with programs to improve analytical testing methods, characterize PPCP in drinking water sources in California, and effects of PPCPs on groundwater recharge and recycled water use.

8.1.2 State Water Project

MWD began receiving water from the State Water Project (SWP) in 1972. MWD is the largest of 29 contractors for water from the SWP, holding a contract for 1.912 MAF per year, or 46 percent of the total contracted amount, of the 4.173 MAF ultimate delivery capacity of the project. Variable hydrology, environmental issues, and regulatory restrictions in the San Francisco Bay/Sacramento-San Joaquin River Delta (Bay-Delta) have historically reduced the quantity of water that the SWP delivers to MWD.

8.1.2.1 Major State Water Project Facilities

The SWP is owned by the State of California and operated by the Department of Water Resources (DWR) delivering water to two-thirds of the population of California and 750,000 acres of farmland. Major facilities in the SWP system consist of 701 miles of aqueduct, 34 storage facilities totaling 5.8 MAF of storage, five hydro-electric power plants, four pumping-generating plants, 17 pumping plants, and three pump stations. Exhibit 8H illustrates the location of major SWP facilities. SWP facilities originate in Northern California at Lake Oroville on the Feather River. Water released from Lake Oroville flows into the Feather River, goes downstream to its confluence with the Sacramento River, and then travels into the Bay-Delta. Water is pumped from the Bay-Delta region to contractors in areas north and south of the San Francisco Bay and south of the Bay-Delta. SWP deliveries consist solely of untreated water. In addition to delivering water to its contractors, the SWP is operated to improve water quality in the Delta region, control flood waters, and provide recreation, power generation, and environmental enhancement.

MWD receives SWP water at three locations, Castaic Lake in Los Angeles County, Devil Canyon Afterbay in San Bernardino County, and Box Spring Turnout at Lake Perris in Riverside County. In addition, MWD has flexible storage rights of 65 TAF at Lake Perris at the terminus of the East Branch of the SWP and 153.95 TAF at Castaic Lake at the terminus of the West Branch.

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8.1.2.2 Contract Allocations

Contract allocations, also known as entitlements, for SWP contractors are provided by DWR in a table commonly referred to as Table A. Allocations are based on the original projected SWP maximum yield of 4.173 MAF. Table A is a tool used by DWR to allocate fixed and variable SWP costs and yearly water entitlements to the contractors. Table A contract amounts do not reflect actual deliveries a contractor should expect to receive. MWD has a Table A contract amount of 1.912 MAF. MWD's full Table A contract amount was made available to MWD for the first time in 2006.

Table A Maximum Annual SWP Amounts (acre-feet)

Contractor	Maximum SWP Table A
North Bay	
Napa County Flood Control and Water Conservation District	29,025
Solano County Water Agency	47,756
Subtotal	**76,781**
South Bay	
Alameda County Flood Control and Water Conservation District, Zone 7	80,619
Alameda County Water District	42,000
Santa Clara Valley Water District	100,000
Subtotal	**222,619**
San Joaquin Valley	
Oak Flat Water District	5,700
Kings County	9,305
Dudley Ridge Water District	57,343
Empire West Side Irrigation District	3,000
Kern County Water Agency	998,730
Tulare Lake Basin Water Storage District	95,922
Subtotal	**1,170,000**
Central Coastal	
San Luis Obispo County Flood Control and Water Conservation District	25,000
Santa Barbara County Flood Control and Water Conservation District	45,486
Subtotal	**70,486**
Southern California	
Antelope Valley-East Kern Water Agency	141,400
Castaic Lake Water Agency	95,200
Coachella Valley Water District	121,100
Crestline-Lake Arrowhead Water Agency	5,800
Desert Water Agency	50,000
Littlerock Creek Irrigation District	2,300

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Mojave Water Agency	75,800
Metropolitan Water District of Southern California	1,911,500
Palmdale Water District	21,300
San Bernardino Valley MWD	102,600
San Gabriel Valley MWD	28,800
San Gorgonio Pass Water Agency	17,300
Ventura County Flood Control District	20,000
Subtotal	**2,593,100**
Delta Delivery Total	**4,132,986**

Feather River

Butte County	27,500
Plumas County Flood Control and Water Conservation District	2,700
Yuba City	9,600
Subtotal	**39,800**
Total	**4,172,786**

DWR annually approves the amount of contract allocations SWP contractors will receive. The contract allocation amount received by contractors varies based on contractor demands and projected available water supplies. Variables impacting projected water supplies include snowpack in the Sierra Nevada, capacity available in reservoirs, operational constraints, and demands of other water users. Operational constraints include pumping restrictions related to fish species listed as either threatened or endangered under the federal or state Endangered Species Acts. Contractors' requests for portions of their entitlements cannot always be met. In some year there are shortages and in other years surpluses. In 2008 and 2009 SWP contractors received only 35 percent and 40 percent, respectively, of their SWP contract allocations. In 1991 and 1992 MWD received 391 TAF and 710 TAF, respectively, less than their requests.

DWR bi-annually prepares the State Water Project Delivery Reliability Report to provide contractors with current and projected water supply availability for SWP. The 2009 draft released in January 2010 indicates expected deliveries for multiple-dry year periods will vary from 32 to 38 percent of maximum Table A amounts and for multiple-year wet periods 72 to 94 percent of maximum Table A amounts. Overall the report shows increased reductions in water deliveries on average when compared to the previous 2007 report. Factors impacting deliveries include environmental constraints and hydrologic changes as a result of climate change.

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Exhibit 8H
State Water Project Major Facilities

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In addition to MWD's Table A amount, MWD has long term agreements in place to obtain additional SWP supplies through four other programs:

- Article 21
- Turnback Pool
- Yuba River Accord
- San Luis Carryover Storage
- Desert Water Agency and Coachella Valley Water District Table A Transfer.

Article 21 is in reference to a provision in the SWP contract with DWR that allows SWP contractors, such as MWD, to take additional water deliveries in addition to Table A amounts. Article 21 water is only available under certain conditions as outlined in Article 21. SWP Article 21 of the contracts permits delivery of water excess to delivery of SWP Table A and some other water types to those contractors requesting it. SWP Article 21 water is apportioned to those contractors requesting it in the same proportion as their SWP Table A.

Turnback Pool (Pool) water allows a contractor that has been allocated Table A annual entitlement that the contractor will not use to sell that water to other SWP Contractors through the Pool. If there are more request from contractors to purchase water from the Pool than the amount in the Pool, the water in the Pool is allocated among those contractors requesting water in proportion to their Table A entitlements. If requests to purchase water from the Pool total less than the amount of water in the Pool, the sale of water is allocated to the selling contractors in proportion to their respective amounts of water in the Pool.

In 2007, MWD and DWR signed an agreement allowing MWD to participate in the Yuba Dry Year Water Purchase Program. Under this program, transfers are available from the Yuba County Water Agency during dry years up to 2025. MWD completed purchases of 26.4 TAF and 42.9 TAF in 2008 and 2009, respectively.

As part of the Monterey Amendment, which modified the contractors' long term contracts with DWR, the use of carryover storage by contractors was permitted in the San Luis Reservoir for use during dry years. Carryover storage is curtailed if it impedes with the storage of SWP water for project needs.

MWD entered into a transfer agreement with the Desert Water Agency (DWA) and Coachella Valley Water District (CVWD) for their Table A contract amounts in exchange for an equal amount of water from the CRA. Both DWA and CVWD are SWP contractors, but have no physical connections to obtain SWP water. MWD is able to transfer CRA water to both agencies as a result of their locations adjacent to CRA facilities. DWA and CVWD have a combined Table A amount of 1.912 MAF per year. MWD additionally can provide DWA and CVWD with deliveries of MWD's other SWP water supplies and non-SWP supplies utilizing SWP facilities, thus allowing MWD additional flexibility in managing its water supply portfolio.

MWD also engages in short-term transfer agreements using SWP facilities to bolster supplies as opportunities become available as discussed in the Groundwater Storage and Transfers sub-section. Historically, MWD has obtained transfers through the Governor's Water Bank, Dry-Year Purchase Programs, and the State Water Contractors Water Transfer Program.

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MWD expects to receive 2.046 MAF through its SWP supplies in 2035 under average conditions (1922 – 2004 hydrology). Exhibit 8I summarizes MWD's SWP supplies by program. Current programs are expected to result in 1.441 MAF and programs under development are expected to add an additional 605 TAF. Under multi-year dry conditions (1990 -1992 hydrology), MWD expects to receive only 956 TAF and 1,003 TAF under a single-dry year (1977 hydrology).

Exhibit 8I
MWD Forecast Supplies of SWP Water in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF)
Current	
MWD Table A	1,026
Desert Water Agency and Coachella Valley Water District SWP Table A Transfer	155
San Luis Carryover Storage[1]	208
Article 21 Supplies	52
Yuba River Accord Purchase	0
Subtotal of Current Programs[2]	**1,441**
Programs Under Development	
Delta Conveyance Improvements	605
Integrated Resources Plan SWP Target[3]	0
Subtotal of Proposed Programs[2]	**605**
Maximum SWP Supply Capability[2]	**2,046**

1. Includes carryover water from Desert Water Agency and Coachella Valley Water District.
2. Does not include transfers and water banking associated with SWP.
3. Remaining supply needed to meet Integrated Resources Plan target.

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.2.3 Water Quality Issues

Water quality issues for SWP supplies include total organic carbon (TOC), bromide, arsenic, nutrients, NDMA, and pharmaceuticals and personal care products (PPCPs). TOC and bromide in SWP water present the greatest water quality issues and have restricted MWD's ability to use SWP water at various times as the contaminants form disinfection byproducts during water treatment processes. MWD has initiated a process to upgrade its treatment processes to ozone disinfection to reduce formation of disinfection byproducts and lift potential restrictions on SWP water usage. MWD requires low salinity levels of SWP water to meet blending requirements for CRA water, therefore any increase in salinity levels in SWP supplies is a concern to MWD.

MWD supported DWR in the establishment of a policy regarding water quality of non-SWP water transported through the SWP system and in the expansion of Municipal Water Quality Investigations Programs to include additional monitoring and advanced warnings to Contractors that may impact water treatment processes.

MWD is utilizing its water supply portfolio options to conduct water quality exchanges to reduce total organic compounds and bromide MWD has stored SWP water during periods of high water quality in groundwater storage basins for later use when

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SWP is at a lower water quality. These storage programs were initially designed to provide water during dry SWP conditions, but a few of these programs are now operated for dual-purposes.

TOC and bromide in high concentrations lead to the formation of disinfection byproducts when source water is treated with disinfectants, such as chlorine. Agricultural drainage to the Delta and seawater comingling with Delta supplies increases these contaminants. The Bay Delta Conservation Plan (BDCP) has outlined multiple options to improve the water supply reliability and habitat protection, which is being prepared through a collaboration of state, federal, and local water agencies, state and federal fish agencies, environmental organizations, and other interested parties. The overall goal of BDCP is identifying water flow and habitat restoration actions to both improve water supply reliability and recover endangered and sensitive species and their habitats in California's Sacramento-San Joaquin River Delta. MWD is in the process of computing upgrades to its water treatment plants to use ozone as the primary disinfectant. Ozone disinfection is very effective treatment for control of bromate formation and will allow MWD to treat higher quantities of SWP supplies without blending those supplies with CRA water.

Arsenic

SWP supplies not banked in MWD's SWP groundwater storage programs naturally contain low levels of arsenic ranging from non-detect to 4.0 µg/L and do not require additional treatment for arsenic removal. SWP supplies banked in at least one of these groundwater storage programs contain arsenic levels close to or at the regulatory threshold of 10 µg/L requiring additional treatment for arsenic removal. Historically, MWD has at times restricted flows from one groundwater storage program as a result of arsenic levels. One groundwater storage partner has initiated a pilot arsenic removal program, albeit raising the cost of the groundwater storage program. Arsenic can also be removed at water treatment plants by increasing coagulant doses. To handle arsenic removed during water treatment processes, MWD has had to invest in solids handling facilities.

Nutrients

Nutrient levels in SWP water are significantly higher than in Colorado River water. Both phosphorous and nitrogen compounds are a concern in SWP water, but similar to CRA supplies phosphorous is the limiting nutrient. Nutrient sources in SWP water include wastewater discharges, agricultural drainage, and sediments from nutrient rich soils in the Delta. MWD reservoirs have been temporarily by-passed at times as a result of taste and odor events related to nutrients leading to short-term supply impacts.

MWD is working with other water agencies also receiving SWP water from the Delta region to reduce the impact of nutrient loading from wastewater plants discharging to the Delta. To assist in managing its operations, MWD has implemented an algae monitoring and management program designed to provide warnings in advance of algae and taste and odor issues at its reservoirs allowing adjustments in other system operations.

NDMA and Pharmaceuticals and Personal Care Products

Similar to all of its water supply sources, NDMA and PPCPs are constituents of emerging concern. As described above for Colorado River supplies, MWD is involved with efforts to address both NDMA and PPCPs.

Salinity

Over the long term salinity concentrations in SWP water are significantly lower than in CRA water, but the timing of supply availability and TDS concentrations can vary in response to hydrologic conditions. Additionally, salinity concentrations vary in

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the short term in response to seasonal and tidal flow patterns. MWD requires lower salinity SWP water to blend with CRA water to meet salinity requirements for its member agencies. MWD's blended salinity objective is 500 mg/L.

Environmental constraints also impact MWD's ability to meet its salinity objective. Since 2007 pumping operations in the Bay-Delta have been limited to prevent environmental harm (as discussed in the Delta Issues subsection below). MWD must rely on higher salinity CRA water resulting in an exceedance in MWD's salinity objective at times.

SWP salinity concentrations as specified in the SWP Water Service Contract have not been met. Article 19 of SWP Water Service Contract specifies ten-year average salinity concentrations of 220 mg/L and a monthly maximum of 440 mg/L. MWD is working with DWR and other agencies to reduce salinity in SWP Delta supplies through multiple programs. These programs include modifying agricultural drainages and completing basin plans on the San Joaquin River, modifying levees around flooded islands in the Delta, and installing gates to reduce transportation of salts from seawater.

8.1.2.4 Bay-Delta Issues

The San Francisco Bay-Delta is a major waterway at the confluence of the Sacramento and San Joaquin rivers serving multiple and at times conflicting purposes exacerbated during dry years when water to meet the needs of both people and the environment is in short supply. Approximately two-thirds of Californians receive at least a portion of their water from the Bay-Delta. Almost all water delivered via the SWP to southern California must pass through the Bay-Delta. Runoff from more than 40 percent of the State is also conveyed through the Bay-Delta forming the eastern edge of the San Francisco bay's estuary. A large portion of the Bay-Delta region lies below sea level and is protected by more than 1,100 miles of levees to prevent flooding. Deterioration of the Bay-Delta ecosystem coupled with infrastructure concerns, hydrologic variability, climate change, litigation, regulatory restrictions, and previously discussed water quality issues have resulted in supply reliability challenges for SWP contractors who depend upon the Bay-Delta for water supplies.

Environmental

As an estuarine environment, the Bay-Delta provides habitat for migratory and resident fish and birds, including those placed on the threatened or endangered species list under the federal or California Endangered Species Act (ESA). Five fish species residing in the Bay-Delta were listed as endangered under the ESA, and one additional species was listed as threatened in 2009 under the California ESA. As a result of a combination of lawsuits regarding the ESA listed species and biological opinions and incidental take permits (permits for inadvertently harming ESA listed species) from the U.S. Fish and Wildlife Service and National Marine Fisheries Service, SWP exports and pumping operations in the Bay-Delta have been significantly curtailed. However, DWR prepared a Water Allocation Analysis in 2010 indicating that MWD could receive 150 to 200 TAF less water than forecast for 2010 under average hydrologic conditions. Ongoing litigation, additional species listing, and regulations could further curtail pumping operations and have an additional adverse impact on MWD's supplies and reserves. MWD has filed a lawsuit in conjunction with other SWP contractors challenging one of the biological opinions. As discussed below under the Delta Plan, the Delta Vision process is designed to develop long term solutions to these issues.

Infrastructure

Bay-Delta channels are constrained by a levee system to protect below sea level islands in the Bay-Delta from flooding. Land in the Bay-Delta subsides mainly from ongoing oxidation of aerated peat soils. Some islands are presently twenty feet or more below sea level. Land subsidence is expected to continue increasing the risk of levee failure and island flooding. Many of the levees are old and do not meet modern engineering standards. A catastrophic earthquake could cause widespread levee failure shutting down SWP operations for an extended period of time. Following a levee failure he flow of water onto an island

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can pull saline water fro the San Francisco Bay into the central Delta area and if coupled with pumping in the south Delta draw saline water into the south Delta area. Therefore, pumping in the south Delta may need to be stopped or slowed down for an extended period, and additional flows may need to be released from Lake Oroville to flush saline water out of the Delta. Any salinity introduced into Delta may also impact Delta water quality for an extended period of time.

Recognizing the need for protecting these vulnerable Delta levees, the Bay-Delta Levees Program was formed to coordinate improvements to and maintenance of the Delta levees. Over the next few years the DWR and other agencies will conduct a Comprehensive Program Evaluation. This Program will supplement existing risk studies, develop a strategic plan, recommend priorities, and provide estimates for the Bay-Delta Levees Program.

8.1.2.5 Delta Plan

Former California Governor Arnold Schwarzenegger established the Delta Vision Process in 2006 to address ongoing Bay-Delta conflicts through long-term solutions. The independent Blue Ribbon Task Force completed their vision for sustainable management of the Bay-Delta in 2008. After delivery of the Delta Vision recommendations and goals, the State Legislature initiated the process to conduct information hearings and draft legislation. Ultimately, the Governor called the Seventh Extraordinary Session to address the Delta and water issues in the State. Resulting legislation included the approval of SB 1 X7 addressing Delta policy reforms and governance of the Delta.

A key concept of SB 1 X7 is the formation of a Delta Stewardship Council (Council). The Council is an independent State agency tasked to equally further the goals of Delta restoration and water supply reliability. One of the Council's first major tasks is to develop, adopt, and begin implementation of a Delta Plan by January 1, 2012. Key requirements of the plan as summarized in the MWD RUWMP are:

- Further the coequal goals of ecosystem restoration and water supply reliability;
- Attempt to reduce risks to people, property, and State interests;
- Promote Statewide water conservation, water use efficiency, and sustainable use of water to achieve the coequal goals;
- Improvements to water conveyance/storage and operations of such facilities to achieve the coequal goals;
- Consider including the Bay Delta Conservation Plan (BDCP) into the Delta Plan and allow the BDCP to be eligible for State funding if specific conditions are met.

The BDCP is a joint effort of State and federal fish agencies; State, federal, and local water agencies; environmental organizations; and other parties with the goal of providing for both improvements in water reliability through securing long-term permits to operate the SWP and species/habitat protection in the Delta. MWD is a member of the Steering Committee. An outcome of the plan will be the identification of water flow and habitat restoration actions that assist in recovery of ESA listed and sensitive species and their associated habitats in the Bay-Delta. A range of options to accomplish the outcome will be carried forward to the environmental review phase.

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8.1.3 In-Basin Storage

In basin-storage facilities play a key role in maintaining MWD's reliability during droughts or other imported water curtailments and emergency outages. In-basin storage facilities consist of surface reservoirs and contracted groundwater basin storage. Conjunctive use of surface reservoirs and groundwater basins was first initiated by MWD in the 1950's. Long term storage goals for in-basin storage facilities were established in MWD's Water Surplus and Drought Management Plan (WSDM). The WSDM plan allows storage for hydrology variances, water quality, and SWP and CRA issues.

MWD has established emergency in-basin storage requirements based on a major earthquake that could potentially cutoff all supplies for six months from the all aqueducts serving the region, the CRA, both SWP branches, and LADWP's LAA. Under this scenario, MWD would maintain deliveries by suspending interruptible deliveries, implementing mandatory water use reductions of 25 percent of normal-year demands, water would be made available from surface reservoir and groundwater supplies stored as part of MWD's interruptible supply program, and full local groundwater production would occur. MWD's emergency storage requirement is a function of projected demands and varies with time.

8.1.3.1 Surface Reservoirs

MWD owns and operates seven in-basin surface storage reservoirs. Four of the reservoirs, Live Oak, Garvey, Palos Verdes, and Orange County, are used for regulatory purposes and do not provide drought or emergency storage. Additionally, MWD owns and operates two reservoirs, Copper Basin and Gene Wash, along the CRA outside of the basin for system regulation purposes. Outside its basin, MWD has 1.45 MAF storage rights in Lake Mead on the Colorado River pursuant to its intentionally created surplus agreement with the U.S. Bureau of Reclamation. MWD also has storage rights in DWR's SWP terminal reservoirs, Lake Perris and Castaic Lake, as previously discussed. The total capacity of all in-basin surface reservoirs, inclusive of the rights in the terminal reservoirs, is 1.26 MAF, as listed in Exhibit 8J.

Exhibit 8J
Major MWD Facilities Summary

Reservoir	Capacity (AF)
Dry Year/Emergency/Seasonal Storage Purposes	
Diamond Valley Lake	810,000
Lake Matthews	182,000
Lake Skinner	44,000
Lake Perris (Storage Rights)[1]	65,000
Castaic Lake (Storage Rights)[1]	153,940
Subtotal	1,254,940
Regulatory Purposes	
Live Oak	2,500
Garvey	1,600
Palos Verdes	1,100
Orange County	212
Subtotal	5,412
Total Reservoir Capacity	**1,260,352**

1. MWD holds storage rights for flexible use in DWR terminal storage facilities, Lake Perris and Castaic Lake. In addition, MWD has emergency storage of 334 TAF in DWR's reservoirs.

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MWD operates its three main storage reservoirs, Diamond Valley Lake, Lake Skinner and Lake Matthews, for dry-year, emergency, and seasonal storage. MWD has identified a dry-year storage capacity goal of 620 TAF by 2020. To date this goal has been met and will be sustained with storage at Diamond Valley Lake and the two terminal reservoirs. Under an average year scenario for 2035 (1922-1994 hydrology), 576 TAF per year of in-basin surface storage is projected to be available, exclusive of emergency supplies, as summarized in Exhibit 8K.

Exhibit 8K
MWD Forecast Supplies of In-Basin Surface Storage Supplies in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF)/Year
In-Basin Surface Storage (Diamond Valley Lake, Lake Skinner, Lake Matthews)	444
Lake Perris and Castaic Lake MWD Storage Rights	132
Maximum MWD Supply Capability	**576**

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

MWD reserves a portion of its in-basin surface reservoir storage capacity for emergencies. MWD's emergency surface reservoir storage portfolio is split between storage in its three main reservoirs and DWR reservoirs. MWD's emergency storage capacity, based on demands for 2030, is forecast to be approximately 610 TAF. Approximately 276 TAF is projected to be stored in MWD's facilities and the balance of 334 TAF in DWR's facilities. The balance of available storage capacity, 975 TAF, is for dry-year and seasonal storage.

Any additional reservoir capacity is used for seasonal storage and system operations. Seasonal storage is required to meet peak demands. MWD incorporates reserves of 5 percent into reservoir operations to account for imported water transmission infrastructure maintenance that would restrict or temporarily halt imported water flows.

8.1.3.2 Contracted Groundwater Basin Storage

To improve reliability MWD engages in contracted groundwater basin storage within the basin area. By 2020 MWD aims to develop an annual dry supply of 300 TAF. To meet this goal MWD has worked with local water agencies to increase groundwater storage. Groundwater storage occurs using the following methods:

- Direct delivery – Water is delivered directly by MWD to local groundwater storage facilities including through the use of injection wells and spreading basins.
- In-lieu delivery – Water is delivered directly to a member agency's distribution system and the member agency uses the delivered water and forgoes pumping allowing water to remain in storage.

MWD engages in three main types of contracted storage programs, replenishment, cyclical, and conjunctive use. These programs are designed to deliver water to agencies prior to the actual need for the demands allowing MWD to store supplies for use in dry years. Since 2007 MWD has used these programs to address SWP shortages. MWD provides financial incentives and funding to assist agencies to assist with developing contracted storage programs.

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Replenishment programs provide water to agencies at a discounted cost and can be withdrawn by the recipient after one year. Cyclic storage contracts allow surplus imported water to be delivered for recharge in advance of the actual water purchase. The delivered water is in excess of an agency's planned and budgeted deliveries. The agency purchases the water at a later time when they have a need for groundwater replenishment deliveries.

Conjunctive use contracts allow MWD to request an agency to withdraw previously stored MWD water from storage during dry periods or emergencies. Agencies must pay MWD the current water rate when they are requested to withdraw water from storage. Water withdrawn from storage allows MWD to temporarily curtail delivers by an equal amount. MWD currently has ten conjunctive use programs with a combined storage capacity of 421.9 TAF and a dry-year yield of 117.3 TAF per year as summarized in Exhibit 8L.

Exhibit 8L
In-Basin Conjunctive Use Programs

Program	Storage Capacity (Thousands of AF)	Dry-Year Yield (Thousands of AF/Year)	Balance 12/31/09 (Thousands of AF)
Los Angeles County			
Long Beach Conjunctive Use Project	13	4.3	**6.4**
Foothill Area GW Storage Project	9	3.0	**0.6**
Long Beach Conjunctive Use Project: Expansion in Lakewood	4	1.2	1.8
City of Compton Conjunctive Use Program	2	0.8	0.0
Upper Claremont Heights Conjunctive Use	3	1.0	0.0
Orange County			
Orange County GW Conjunctive Use Program	66	22.0	8.6
San Bernardino County			
Chino Basin Programs	100	33.0	23.0
Live Oak Basin Conjunctive Use Project	3	1.0	0.7
Riverside County			
Elsinore Groundwater Storage Program	12	4.0	0.0
Ventura County			
North Las Posas Groundwater Storage Program	210	47.0	43.5
Total	421.9	117.3	84.6

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

MWD prepared a Groundwater Assessment Study in 2007 in conjunction with local agencies and groundwater basin managers. As indicated in the report there is substantial groundwater storage available in the basin, but there are multiple challenges that must be met to utilize the identified storage. Challenges include infrastructure limitations, contamination, legal issues, and funding.

To further increase the availability of in-basin groundwater storage, MWD has identified nine potential storage programs in the basin and an additional two programs are under development. The Raymond Basin Conjunctive Use Program and the LADWP Groundwater Recovery Project are expected to add an additional 34 TAF per year in 2035 under an average year (1922 – 2004 hydrology).

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In 2009 a reconnaissance-level analysis was prepared for analyzing the potential for using recycled water as a supply source for a conjunctive use program. The study concluded up to 100 TAF of groundwater storage and production could be potentially developed in four major groundwater basins using Los Angeles County Department of Sanitation supplies. MWD initiated a formal study in 2010 to further study. This concept along with the potential to use City of Los Angeles recycled water supplies from the Hyperion Waste Water Treatment Plant as an additional source.

Exhibit 8M provides a summary of forecast groundwater storage supplies available in 2035 under an average year (1922 - 2004 hydrology). Approximately 289 TAF per year are forecast to be available.

Exhibit 8M
MWD Forecast Supplies of In-Basin Groundwater Storage in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF/Year)
Current	
Conjunctive Use	115
Cyclic Storage	139
LADWP Tujunga Well Field Groundwater Recovery Project	12
Subtotal of Current Programs	266
Programs Under Development	
Raymond Basin Conjunctive Use	22
Subtotal of Programs Under Development	34
Maximum MWD Supply Capability	**288**

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.4 Groundwater Storage and Water Transfers

MWD engages in groundwater storage outside of the basin and water transfers to increase the reliability of SWP dry-year supplies. Groundwater storage and water transfers were initiated by MWD in response to concerns that MWD's supply reliability objectives could not be met by the SWP. Groundwater storage and transfer programs were developed to allow MWD to reach its SWP reliability goal. All groundwater storage and water transfer programs designed to bolster SWP reliability are located within the vicinity of the SWP or Central Valley Project (CVP) facilities to facilitate the ultimate deliver of water to MWD. Groundwater storage programs involve agreements allowing MWD to store its SWP contract Table A water in excess of MWD demands and to purchase water for storage. MWD calls for delivery of the stored water during dry years. Transfers involve purchases by MWD from willing sellers during dry years when necessary.

Exhibit 8N summarizes MWD's out of basin groundwater storage and transfer programs supplies in 2035, under an average year (1922 – 2004 hydrology). Current programs are expected to deliver 293 TAF in 2035. Five programs under development are forecasted to deliver an additional 110 TAF for a total of 403 TAF in 2035.

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Exhibit 8N
MWD Forecast Supplies of Groundwater Storage and Transfers in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF/Year)
Current	
San Bernardino Valley MWD Minimum Purchase	20
San Bernardino Valley MWD Option Purchase	29
Central Valley Storage and Transfers	
Semitropic Water Banking and Exchange Program	69
Arvin-Edison Water Management Program	75
San Bernardino Valley MWD Program	50
Kern Delta Water Management Program	50
Subtotal of Current Programs	**293**
Programs Under Development	
Mojave Groundwater Storage Program	43
North of Delta/In-Delta Transfers	33
San Bernardino Valley MWD Central Feeder	5
Shasta Return	18
Semitropic Agricultural Water Reuse	11
Subtotal of Proposed Programs	**110**
Maximum Supply Capability	**403**

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.4.1 Groundwater Storage

MWD has four Central Valley groundwater storage programs with a fifth program under development as described below.

The Semitropic Water Banking and Exchange Program is a partnership formed in 1994 between Semitropic Water Storage District (SWSD) MWD, and five other banking partners. The bank has a total storage capacity of 650 TAF, of which MWD has 350 TAF of storage volume. During years of excess SWP deliveries, beyond MWD's demands, a portion of MWD's SWP entitlement water is stored for withdrawal during dry years. Deliveries for storage are transferred via SWP facilities for direct use by agricultural users that in turn forgo pumping an equal volume of water. In dry years water is pumped from storage to SWP facilities for delivery to MWD or entitlements are exchanged. MWD's average annual supply capability for a dry year (1977 hydrology) is 125 TAF and for multiple dry years (1990 – 1992 hydrology) 107 TAF. By the end of 2009, MWD had 45 TAF in storage.

Since 1997 MWD has had an agreement with Arvin-Edison Water Storage District to use 350 TAF of storage in their groundwater basins. The agreement was amended in 2008 to include the South Canal Improvement project to deliver higher quality water to MWD. During wet years MWD delivers SWP water in excess of its demands for storage and receives return water in dry years in a similar manner as the Semitropic program, except a combination of SWP and CVP facilities are used to

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transfer the water and water can be stored by a combination of direct spreading or in lieu use by agricultural users. MWD's average supply capability is 75 TAF for either a single dry year (1977 hydrology) or multiple dry years (1990 – 1992 hydrology). In 2009 MWF had 95 TAF in storage.

The San Bernardino Municipal Water District Program allows for the purchase and storage of SWP water on behalf of MWD. MWD has a minimum purchase agreement with San Bernardino Municipal Water District (SBMWD) of 20 TAF per year of SBMWD's SWP Table A amount. Additionally, MWD has the option to purchase SBMWD's additional SWP allocation when available and the first right-of-refusal to purchase additional SWP supplies available to SBMWD beyond the minimum and option agreements. If MWD does not require the minimum purchase amount for operations, MWD can store up to 50 AF for future use in dry years within SBMWD's groundwater basins. Water is delivered to MWD via SWP facilities and groundwater pumping conveyed through local connections to MWD's service area. MWD's average annual supply capability for a dry year (1977 hydrology) is 70 TAF and for multiple dry years (1990 – 1992 hydrology) 37 TAF. By the end of 2009, MWD had no water in storage and deliveries have been suspended upon a mutual agreement between MWD and SBMWD.

MWD entered into an agreement with the Kern Delta Water District (Kern-Delta) for the Kern-Delta Water Management Plan in 2001 to allow up to 250 TAF of groundwater storage. During wet years MWD delivers SWP water in excess of its demands for storage and receives return water in a similar manner as the Semitropic program, except the water can be stored by direct recharge or in lieu use by agricultural users. Per terms of the agreement MWD can potentially store beyond 250 TAF. In dry years water is pumped from storage to SWP facilities for delivery to MWD or entitlements are exchanged. When the project is completed 50 TAF per year of dry year supply can be withdrawn. At the close of 2009 MWD had 10 TAF in storage and expects to fully withdraw the amount in 2010.

The Mojave Groundwater Storage Program is currently a demonstration project between MWD and Mojave Water Agency. Similar to the other groundwater storage programs, MWD's excess SWP water will be stored during wet years for withdrawal during dry years. When fully operational, the program is expected to have a dry year yield of 35 TAF.

8.1.4.2 Transfers

MWD utilizes Central Valley water transfers to obtain additional supplies originally destined for agricultural users on an as needed basis. Past transfer agreements have used both spot markets and option contracts. Spot markets occur when there are willing sellers and buyers. Option contracts lock-in MWD's ability to have the option to purchase supplies if needed. Additionally, MWD has multiple long-term transfer programs under development. MWD's ability to conduct transfers and the amount of water to be transferred using SWP facilities are a function of hydrologic conditions, market conditions, and pumping restrictions in the Bay-Delta region. Transfers may require the use of the Bay-Delta for conveyance dependent upon the origin of the water. Historic transfers, as listed in Exhibit 8O, indicate MWD is capable of negotiating contracts with agricultural districts and the State's Drought Water Bank to obtain transfers. MWD also has demonstrated it can work with DWR and the U.S. Bureau of Reclamation (USBR). Cooperation of both agencies is required as transfers use a combination of DWR's SWP and USBR's CVP facilities. Transfers from north of the Delta result in the loss of 20 percent of the water during conveyance while transfers via the California Aqueduct to MWD's service area result in the loss of 3 percent water during conveyance. During dry years and when pumping capacity in the Bay-Delta is available, MWD expects to be able to transfer 125 TAF through SWP facilities.

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Exhibit 8O
MWD Historic Central Valley Water Transfers

Program	Purchases by MWD[1] (AF/Year)
1991 Governor's Water Bank	215,000
1992 Governor's Water Bank	10,000
1994 Governor's Water Bank	100
2001 Dry Year Purchase Program	80,000
2003 MWD Transfer Program	126,230
2005 State Water Contractors Water Transfer Program[2]	0
2008 State Water Contractors Water Transfer Program	26,621
2009 Governor's Water Bank	36,900

1. Transfers requiring use of Bay-Delta result in a water loss of 20 percent. Transfers requiring the California Aqueduct for delivery to MWD's service area result in a 3 percent water loss.

2. 127,275 in options were secured, but not needed.

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.2 MWD Supply Reliability and Projected LADWP Purchases

MWD's 2010 Integrated Water Resources Plan (IRP) Update serves as the foundation for supply forecasts discussed in the RUMWP and continues to ensure system reliability for its member agencies. The 2010 IRP update concluded that the resource targets identified in previous updates, taking into consideration changed conditions identified since that time, will continue to provide for 100 percent reliability through 2030. MWD's subsequent evaluation to extend the resource targets by an additional five years through their 2010 draft RUWMP also concluded the same full reliability during average (1922 – 2004 hydrology), single dry (1977 hydrology), and multiple dry years (1990 - 1992 hydrology). For each of the scenarios there is a surplus in every forecast year. Exhibit 8P summarizes MWD's reliability in five year increments extending to 2035.

The City purchases MWD water to make up the deficit between demand and other City supplies. Whether LADWP can provide reliable water services to the residents of Los Angeles is highly dependent on MWD's assurance on supply reliability. However, the recent water supply shortage caused by dry weather and pumping restrictions in the Delta prompted the City to develop a more sustainable water supply portfolio with emphasis on local water supplies such as recycled water, groundwater cleanup, stormwater capture, and conservation. LADWP's reliance on MWD water supply is projected to be cut in half from the five-year average of 52 percent of the total demand between 2005-06 and 2009-10, to 24 percent by 2034-35 under average weather conditions.

The reliability of MWD's water supply is more fully discussed in Chapter 10, Integrated Resources Planning. The projected LADWP water purchase is further discussed in Chapter 11, Water Service Reliability Assessment under various weather scenarios.

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Exhibit 8P
MWD System Forecast Supplies and Demands, Average Year (1922 – 2004 Hydrology)

Forecast year	Supply (Thousands of AF per Year)				
	2015	2020	2025	2030	2035
Current Programs					
In-Basin Surface Reservoir and Groundwater Storage	685	931	1,076	964	830
State Water Project[1]	1,550	1,629	1,763	1,733	1,734
Colorado River Aqueduct					
Colorado River Aqueduct Supply[2]	1,507	1,529	1,472	1,432	1,429
Aqueduct Capacity Limit[3]	1,250	1,250	1,250	1,250	1,250
Colorado Aqueduct Capability	1,250	1,250	1,250	1,250	1,250
Capability of Current Programs	**3,485**	**3,810**	**4,089**	**3,947**	**3,814**
Demands					
Firm Demands on MWD	1,826	1,660	1,705	1,769	1,826
Imperial Irrigation District - San Diego County Water Authority Transfers and Canal Linings[4]	180	273	280	280	280
Total Demands on MWD	**2,006**	**1,933**	**1,985**	**2,049**	**2,106**
Surplus	**1,479**	**1,877**	**2,104**	**1,898**	**1,708**
Programs Under Development					
In-Basin Surface Reservoir and Groundwater Storage	206	306	336	336	336
State Water Project[1]	382	383	715	715	715
Colorado River Aqueduct					
Colorado River Aqueduct Supply	187	187	187	182	182
Aqueduct Capacity Limit[2]	0	0	0	0	0
Colorado Aqueduct Capability	0	0	0	0	0
Capability of Programs Under Development	**775**	**876**	**1,238**	**1,233**	**1,233**
Maximum MWD Supply Capability	**4,260**	**4,686**	**5,327**	**5,180**	**5,047**
Potential Surplus	**2,254**	**2,753**	**3,342**	**3,131**	**2,941**

1. Includes water transfers and groundwater banking associated with SWP.

2. Includes 296 TAF of non-MWD supplies conveyed in CRA for Imperial Irrigation District - San Diego County Water Authority Transfers and Canal Linings

3. CRA has a capacity constraint of 1.25 MAF per year.

4. Does not include 16 TAF subject to satisfaction of conditions specified in agreement among MWD, the US, and the San Luis Rey Settlement

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

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8.3 MWD Rate Structure and LADWP's Purchased Water Costs

8.3.1 MWD Rate Structure

MWD's rates are structured on a tier–based system with two tiers and a surplus category. Nine major elements determine the actual price a member agency will pay for deliveries. All of the elements are volumetric based except for two fixed rates, the Readiness-to Serve Charge and the Capacity Charge.

Tier 1 rates are reflective of actual costs of existing supplies and are designed to recover most of the supply costs. Member agencies are allocated a specified volume of Tier 1 water that can be purchased within a given year. In 2011 LADWP's Tier 1 limit is 304,970 AF. Any purchases above this are charged at the Tier 2 rate. MWD has instituted a temporary Delta surcharge to recover costs associated with lower SWP deliveries related to pumping restrictions. The surcharge will remain in effect until SWP yields improve.

Tier 2 rates send a price signal associated with MWD's costs of developing additional long-term firm supply options. Member agencies with growing demands on MWD will have a higher proportion of deliveries within the Tier 2 range.

Surplus water is water in excess of consumptive municipal and industrial demands. Surplus water is available at two discounted levels dependent upon the end use. Replenishment Program water is discounted for replenishing local agency supplies. The program has been suspended as a result of dry conditions and uncertain future supplies. The Interim Agricultural Water Program (IAWP) provides discounted water for agricultural use. This program is being phased out and will terminate beginning in 2013.

Exhibit 8Q summarizes the rates and charges for member agencies effective on January 1 of 2010, 2011, and 2012.

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Exhibit 8Q
MWD Rates and Charges

Rates and Charges	Effective Rate January 1		
	2010	2011	2012
Tier 1 Supply Rate ($/AF)	101	104	106
Delta Supply Surcharge ($/AF)	69	51	58
Tier 2 Supply Rate ($/AF)	280	280	290
System Access Rate ($/AF)	154	204	217
Water Stewardship Rate ($/AF)	41	41	43
System Power Rate ($/AF)	119	127	136
Full Service Untreated Volumetric Cost ($/AF)			
Tier 1	484	527	560
Tier 2	594	652	686
Replenishment Water Untreated ($/AF)	366	409	442
Interim Agricultural Water Untreated ($/AF)	416	482	537
Treatment Surcharge ($/AF)	217	217	234
Full Service Treated Volumetric Cost ($/AF)			
Tier 1	701	744	794
Tier 2	811	869	920
Treated Replenishment Water ($/AF)	558	601	651
Treated Interim Agricultural Water Program ($/AF)	615	687	765
Readiness-to-Serve Charge ($/M)	114	125	146
Capacity Charge ($/cfs)	7,200	7,200	7,400

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.3.2 LADWP's Purchased Water Costs

MWD's water rates vary from $484 per AF of tier 1 untreated water to $811 per AF of tier 2 treated water in 2010. The average unit cost of MWD water supply depends on the proportions of treated water and untreated water, tier 1 water and tier 2 water purchased in a given period. From 2003 to 2009, LADWP purchased 88 percent tier 1 water and 12 percent tier 2 water, and 70 percent untreated water and 30 percent treated water on average. The tier 2 water purchase varied from no purchase in 2005 and 2006 to 29 percent in 2007 and 2008. The treated water purchase varied from 20 percent in 2007 to 46 percent in 2005. Exhibit 8R illustrates the various combinations.

The Readiness-to-Serve Charge and Capacity Charge are predetermined fixed charges for each member agency and not affected by the quantity of MWD water purchased. However, they add on to the unit cost of the City's MWD water purchase. The City's current share of the Readiness-to-Serve Charge is 15.12 percent or $17.24 millions in 2010. The Capacity Charge is calculated based on the summer daily peak flow from the previous three years. LA's 2010 Capacity Charge is $5.9 millions based on the daily peak flow of 822 cfs in 2008 summer. Both charges added an additional $110 per AF to the unit cost of LADWP's MWD water purchase in 2010.

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Exhibit 8R
Percentage of LADWP's Purchased Water in Various MWD Rate Categories

MWD Deliveries	Tier 1		Tier 2		Total Tier 1	Total Tier 2	Total Untreated	Total Treated
Calender Year	Untreated	Treated	Untreated	Treated				
	%	%	%	%	%	%	%	%
2003	73%	22%	4%	2%	95%	5%	76%	24%
2004	71%	25%	3%	1%	96%	4%	74%	26%
2005	54%	46%	0%	0%	100%	0%	54%	46%
2006	58%	42%	0%	0%	100%	0%	58%	42%
2007	56%	15%	25%	5%	71%	29%	80%	20%
2008	48%	23%	23%	6%	71%	29%	71%	29%
2009	67%	20%	10%	3%	87%	13%	77%	23%
Average	61%	28%	9%	2%	88%	12%	70%	30%

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Other Potential Water Supplies

9.0 Overview

LADWP continually investigates other potentially feasible water supplies to ensure the sustainability of water supply for the City of Los Angeles. In recent years, LADWP has actively pursued and investigated various supply options including water transfers and banking and seawater desalination. Evaluating the viability of these and other water resource options is a key element to ensuring the City's future water supply reliability. Such options, with proper planning, can contribute toward fulfilling future demand under various conditions. Future water resource challenges, which include increased demand that must be met without increasing imported supply, warrant thoughtful consideration of these and other potentially feasible water supply resources.

Following is a discussion of each of the potential supply options described above, highlighting LADWP's progress in developing each alternative source of water. Factors that affect feasibility and influence potential implementation are also discussed, as well as advances that facilitate development of the resource option.

9.1 Water Transfers and Banking

Water transfers involve the lease or sale of water or water rights between consenting parties. Water Code Section 470 (The Costa-Isenberg Water Transfer Act of 1986) states that voluntary water transfers between water users can result in a more efficient use of water, benefiting both the buyer and the seller. The State Legislature further declared that transfers of surplus water on an intermittent basis can help alleviate water shortages, save capital outlay development costs, and conserve water and energy. This section of the Water Code also obligates the California Department of Water Resources (DWR) to facilitate voluntary exchanges and transfers of water.

The DWR is required to establish an ongoing program to facilitate the voluntary exchange or transfer of water and implement the various State laws that pertain to water transfers. In response to this mandate, DWR established an internal office dedicated specifically to water transfers in June 2001 and has developed various definitions and policies for transfers. Of particular importance are the rules protecting existing water rights. Water rights cannot be lost when they are transferred to another user if the transferor has an underlying right to the transferred water. DWR also developed three fundamental rules specifically regarding water transfers:

- There can be no injury to any legal user of water;
- There can be no unreasonable effect to fish and wildlife; and
- There can be no unreasonable economic effects to the economy of the county of origin.

Water banking, a form of conjunctive use, is the storage of water in groundwater basins for future use. Typically, during wet periods water is stored or banked within groundwater basins for potential extraction during dry periods. Water banking sets up accounts to track the volumes of water recharged and extracted per terms of contract agreements between water agencies. Water banking may occur outside of a water agency's service area. If the water agency's own conveyance facilities are not directly adjacent to the water bank, stored water can be extracted and transferred through wheeling and exchange via other

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conveyance and storage facilities. Such movements of water involve institutional transfer agreements among water users and agencies.

9.1.1 LADWP Opportunities

LADWP is considering opportunities to acquire water through transfers to replace a portion of LAA water used for environmental enhancements in the eastern Sierra Nevada. The City would purchase water when available and economically beneficial for storage or delivery to LADWP's transmission and distribution system. The City is seeking non-State Water Project water to replace the reallocation of LAA water supply for environmental enhancements. MWD holds an exclusive contractual right to deliver State Water Project entitlement water into its service territory, which includes the City of Los Angeles. Purchasing only non-State Water Project supplies will ensure the City's compliance with MWD's State Water Project contract.

To facilitate water transfers, LADWP is constructing an interconnection between the LAA and the State Water Project's California Aqueduct, located where the two aqueducts intersect in the Antelope Valley (Neenach, California). This interconnection, the Neenach Temporary Pumping Station (NTPS) will allow for water transfers from the East Branch of the State Water Project to the LAA System, as well as provide operational flexibility in the event of a disruption of flows along the LAA System. Construction of the NTPS required a four-way agreement between DWR, MWD, LADWP, and the Antelope Valley-East Kern Water Agency (AVEK). When completed, the NTPS facility will be owned by DWR but will be designated as an AVEK interconnection. The NTPS will be operated on behalf of the LADWP. MWD is involved in the agreement to provide consent for the transferred water to enter its service territory.

LADWP's current goal is to transfer up to 40,000 AF per year once the NTPS facilities are in place. This will provide LADWP with the ability to replace some Los Angeles Aqueduct supplies reallocated to environmental enhancement projects. This will also provide increased operational flexibility and the ability to yield cost savings.

A demonstration study will be performed during the NTPS's first two years of operations; this study will include an evaluation of the operational and water quality aspects of the NTPS.

Neenach Temporary Pumping Station, construction site, looking northerly, taken September 16, 2010, by Aqueduct Aerial Patrol.

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To supplement water transfers, LADWP is also investigating the possibility of water banking. A request for proposal (RFP) was issued in 2008 and five proposals were received for evaluation to determine the most mutually beneficial agreement for a water banking program. However, LADWP has decided to not pursue full scale water banking projects at this time and has instead chosen to proceed with the Indian Wells Valley Water District's proposal to explore a potential water banking opportunity directly adjacent to the LAA.

The City supports Statewide water transfer legislation that will ensure the efficient use of the State's limited water resources and provide safeguards to the environment, public facilities, water conservation efforts and local economies. LADWP will continue to develop a responsible water transfer program that can assist in replacing City supplies that have been reallocated to the environment in the Eastern Sierra Nevada.

9.1.2 MWD Opportunities

Regionally, MWD has been active with water transfers and banking, seeking and implementing agreements and cooperative arrangement opportunities to supplement southern California's water supply. MWD's water transfer activities are classified as *spot transfers*, *option transfers*, *core transfers*, *storage transfers*, or *exchanges*. Each activity is described briefly below.

- *Spot transfers* make water available through a contract entered into the same year that the water is delivered.
- *Option transfers*, through multi-year or single-year contracts, allow MWD to obtain water on an "as-needed" basis.
- *Core transfers* make water available through multi-year contracts that convey specific water entitlement to MWD each year.
- *Storage transfers* allow MWD to store and later recover available water that can then be transported immediately to southern California.
- *Exchange agreements* involve the transfer to MWD of another agency's entitlements in exchange for water entitled to MWD from another source.

MWD is in the process of developing and implementing transfer/storage projects in the Central Valley, and off-stream banking and dry year supplies of Colorado River water. Water transfers, including the programs highlighted below, are an important element of California's plan to live within its 4.4 million acre-feet per year entitlement to Colorado River water. These programs have also helped MWD adjust to regulatory restrictions on State Water Project pumping from the San Francisco Bay-Delta. Current and potential MWD transfer, storage, and exchange agreements/activities include:

- Semitropic Water Storage Program
- Kern Delta Water District Water Management Program
- Arvin-Edison Water Transfer and Storage Program, Kern County
- San Bernardino Valley Transfer and Storage Program
- Desert Water Agency/Coachella Valley Water District Exchange Program

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- Palo Verde Land Management, Crop Rotation, and Water Supply Program
- Hayfield Groundwater Storage Project (under development)
- Southern Nevada Water Authority and Metropolitan Storage and Interstate Release Agreement
- Central Valley Water Transfers
- Yuba Accord Dry Year Purchase Program
- Lower Colorado Water Supply Project
- Lake Mead Water Storage Program
- Drop 2 Reservoir Funding
- Arizona Exchange (under development)
- Yuma Desalter Exchange (under development)
- California Indians Exchange (under development)
- Expansion of Southern Nevada Water Authority Agreement (under development)
- ICS Exchange Program (under development)
- Expansion of Palo Verde Land Management, Crop Rotation, and Water Supply Program (under development)
- Mojave Water Agency Exchange Demonstration Program (under development)
- North of Delta/In Delta Transfers (under development)
- North Kern/Desert Water Agency Exchange (under development)
- Shasta Return Project
- Semitropic Agricultural Water Reuse Demonstration Project (under development)
- San Bernardino Valley MWD Central Feeder Project (under development)
- Chuckwalla Groundwater Storage Program (under development)
- Coachella Valley Water District Agreement (under development)

MWD's water rate structure is designed to allow water transfers using MWD infrastructure by establishing a water wheeling rate, which is a combination of the System Access Rate, Water Stewardship Rate, System Power Rate, and Treatment Surcharge. The wheeling rate applies to all water conveyed through MWD's infrastructure, regardless of the agency using the

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system. MWD's unbundled rate structure and its associated wheeling rate encourage development of water markets by providing for competition at the supply level; MWD's member agencies can purchase supplies from any source and pay MWD's wheeling rate to transmit the water. MWD's current water rate structure establishes charges for each component on a per acre foot basis for all water moving through MWD's system. As of January 1, 2010, current wheeling rate charges are:

- System Access Rate: $154/AF
- Water Stewardship Rate: $41/AF
- System Power Rate: $119/AF
- Treatment Surcharge: $217/AF

The System Access Rate recovers costs associated with conveyance and distribution capacity to meet average annual demands. The Water Stewardship Rate recovers the cost associated with providing financial incentives for investments in local water resources, such as water conservation and recycled water programs. The System Power Rate recovers the cost for power to move water through MWD's system. The treatment surcharge applies to all water that is treated at one of MWD's five treatment plants.

MWD's water rate structure also incorporates a tiered supply rate format. The first tier price applies to a fixed base quantity of water as defined by each MWD member agency's purchase order contract. The second tier price reflects the incremental cost for MWD to acquire additional supplies that are above the first tier contract base amount

9.2 Seawater Desalination

Seawater desalination, the process of removing salts and other impurities from seawater, has reached an all-time high in terms of worldwide production capacity. According to the International Desalination Association, between 2007 and 2009, worldwide seawater desalination capacity increased by approximately thirty percent to a total capacity of 9.5 bgd. This is partly driven by the fact that the cost to desalinate water has reached an all-time low due to technological and process advancements. Of the more than 14,000 seawater and groundwater desalination plants in operation worldwide, the majority are located in the Middle East, where energy costs are relatively low. The world's largest seawater desalination plant in Saudi Arabia produces 232 mgd of desalted water. In contrast, the largest facility in the US, located in Tampa Bay, FL, produces 25 mgd.

LADWP's current water resource strategy does not include seawater desalination as a water supply. There are concerns with cost and the environmental impacts associated with the implementation of desalination. LADWP is primarily focused on enhancing recycling and conservation. While someday desalination may be explored further, it currently remains as a supply alternative.

9.2.1 Desalination Technology

Technology to desalt seawater to produce potable water which meets or exceeds drinking water standards has been available for some time, but has not been widely implemented primarily due to its high cost. Although the cost to desalinate seawater is still more expensive than obtaining water from conventional sources, continued research and development, as well as large scale projects, are being implemented in the United States and other parts of the world to improve technology and further drive costs down. Additionally, increasing costs associated with new water supplies and existing supplies is reducing the cost

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differential between desalinated water and other water sources improving the viability of desalinated water as a part of an overall water supply portfolio.

The two basic seawater desalination processes are: 1) use of the distillation process to evaporate water from salts; and 2) use of semi-permeable membranes to filter the water while straining out the salts. While distillation has been the dominant seawater desalination technology (primarily in the Middle East), current worldwide desalination development is rapidly migrating toward membrane technology. Facilities using distillation are still prevalent in the Middle East. However, new plant installations are increasingly taking advantage of technological advancements (higher yield and lower energy requirements) in membrane-based process technology. Today, membrane filtration accounts for over half of the world's desalting capacity.

9.2.2 DWR Desalination Efforts

Recognizing the potential of seawater as a water resource, the DWR through a legislative mandate, convened a California Water Desalination Task Force in 2002. The task force was responsible for making recommendations to the Legislature on potential opportunities, impediments, and the State's role in furthering desalination technology.

The task force was effective in providing a forum where stakeholders could convene and discuss critical issues related to desalination. Key seawater desalination issues that have been raised through the task force fall into six general categories: environmental, economic, permitting, engineering, planning, and coordination.

To assist in addressing these issues, the California Water Desalination Task Force has developed draft guidelines for developing environmentally and economically acceptable desalination projects. These include the following:

- Each project should be considered on its own merits;
- Sponsoring agencies should be determined early in the planning process;
- Public and permitting agencies should be engaged early in the planning process;
- Collaborative processes should be used to enhance support for project implementation;
- A feedback loop should be incorporated to allow for continuously revisiting and revising the project at each step of the planning process; and
- Key decision points (e.g., costs, environmental acceptability) should be identified to test the general feasibility of the project as early in the planning process as possible.

After establishment of the task force, desalination was added to the California State Water Plan as an alternative for consideration in regional water supplies. Furthermore, in 2008, DWR published the *California Desalination Planning Handbook*, building upon the Task Force efforts. The handbook provides guidance on determining appropriate conditions for desalination plants, addressing concerns, and building public trust.

Proposition 50, Chapter 6, has provided funding for desalination research, feasibility studies, pilot projects, and construction of new facilities. Over $45 million was distributed under this proposition in two rounds of funding for both seawater and groundwater desalination. Fund recipients included LADWP.

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With increasing demand for water and limited new supply options, the future value of seawater desalination as a part of California's water supply portfolio has become apparent. Within southern California, a range of 270,000 AFY to 422,000 AFY of desalinated seawater could be potentially produced based on current efforts (see Exhibit 9A). While this production represents less than five percent of the region's total water supplies, it is nonetheless considered by water planners as an important part of the region's water supply portfolio.

9.2.3 MWD Desalination Efforts

MWD first incorporated desalinated seawater as a potential new water supply source in its 2003 Integrated Resources Plan Update. Subsequently in 2009, MWD's Board of Directors created a special committee on Desalination and Recycling to study MWD's role in regional efforts to develop desalination facilities.

In response to a proposal solicitation in 2001, MWD received proposals by five member agencies to provide up to 142,000 AFY of potable water. To provide an incentive for the development of desalinated seawater, MWD is offering subsidies of up to $250 for each acre-foot (326,000 gallons) of desalinated seawater produced. LADWP, Long Beach Water Department, West Basin Municipal Water District, Municipal Water District of Orange County, and San Diego County Water Authority submitted detailed proposals that qualified for the MWD's Seawater Desalination Program. Exhibit 9A summarizes the status of the desalination efforts in MWD's service area, including projects not in the Seawater Desalination Program. Each of these agencies serves coastal areas, and is looking to desalination as a means to further diversify their water supply sources.

Exhibit 9A
Desalination Efforts in MWD Service Area

Project Name	Member Agency	Capacity (AFY)	Status
MWD Seawater Desalination Program			
Long Beach Seawater Desalination	Long Beach	10,000	Pilot Study[1]
Los Angeles Seawater Desalination	LADWP	28,000	On-hold
South Coast Coastal Ocean Desalination	Municipal Water District of Orange County	16,000 - 28,000	Pilot Study
Carlsbad Seawater Desalination	San Diego County Water Authority	56,000	Permitting Complete
West Basin Seawater Desalination	West Basin Municipal Water District	20,000	Pilot Study[1]
Subtotal		130,000 - 142,000	
Other Potential Projects in MWD Service Area			
Huntington Beach Seawater Desalination	Municipal Water District of Orange County	56,000	Initiating Permitting
Camp Pendleton Seawater Desalination	San Diego County Water Authority	56,000 - 168,000	Planning
Rosarito Beach Seawater Desalination	San Diego County Water Authority	28,000 - 56,000	Feasibility Study
Subtotal		140,000 - 280,000	
Total		270,000 - 422,000	

1. Full scale feasibility studies in progress.

Source: Annual Progress Report to the State Legislature, Achievements in Conservation, Recycling, and Groundwater Recharge, February 2010.

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9.2.4 LADWP Seawater Desalination Efforts

Scattergood Generating Station Seawater Desalination Plant

LADWP initiated efforts in 2002 to evaluate seawater desalination as a potential water supply source with the goals of improving reliability and increasing diversity in its water supply portfolio. These efforts led to the selection of Scattergood Generating Station as a potential site for a seawater desalination plant. For the City, seawater desalination is a potential resource that could also offset supplies that had been committed from the LAA for environmental restoration in the eastern Sierra Nevada. LADWP has reallocated approximately fifty percent of its historical average LAA supplies to benefit the eastern Sierra Nevada environment. As an identified program in MWD's Seawater Desalination Program, the proposed full-scale project would have qualified for MWD's grant of $250 per acre-foot of water produced. However, in May 2008, LADWP decided to focus on water conservation and water recycling as the primary strategies in creating a sustainable water supply for the City.

While seawater desalination is not a potential water supply strategy at this time, studies performed to date have provided beneficial data that in the future can assist LADWP with any future evaluations of seawater desalination. Completed studies include the LADWP Proposed Seawater Desalination Plant Site Selection Fatal Flaw Analysis (2002), LADWP Seawater Desalination Facility Feasibility Study for the Scattergood Generating Station in Playa Del Rey (2004), Brine Dilution Study for the LADWP Desalination Project at Scattergood Generating Station (2005), and Scattergood Seawater Desalination Pilot Project Preliminary Evaluation Report (2008).

To determine the proper site location for a City desalination plant, LADWP conducted the LADWP Proposed Seawater Desalination Plant Site Selection Fatal Flaw Analysis evaluating three City-owned coastal power generating plants. Based on the findings from this analysis, LADWP initially decided to investigate development of a 12 to 25 mgd desalination facility at the Scattergood Generating Station.

Optimum capacity of a future desalting facility at the Scattergood Generating Station was evaluated in the LADWP Seawater Desalination Facility Feasibility Study. Results of the study indicated a 25 mgd facility would be the most economical. Estimated capital costs for a 25mgd facility were approximately $148.5 million in 2004 dollars with an annual operations and maintenance cost of $28.9 million (2004 dollars) resulting in a total water cost of approximately $1,257 per acre-foot. The study also identified the five-mile Hyperion Treatment Plant Outfall, which is adjacent to the Scattergood Generating Station, as the most environmentally advantageous method to dispose of the brine concentrate produced from the desalting process.

In an effort to develop an environmentally compatible project, LADWP evaluated the feasibility of discharging the desalted concentrate into Hyperion Wastewater Treatment Plant's 5-mile outfall. The Brine Dilution Study for the LADWP Desalination Project at Scattergood Generating Station performed by the Scripps Institute of Oceanography found that there are potential environmental benefits to the Santa Monica Bay's marine biology due to improved salt balance if the effluent discharged by the Hyperion Wastewater Treatment Plant were to include brine from a desalination facility.

In March 2008 the Preliminary Evaluation Report of the Scattergood Generation Station Seawater Desalination Pilot Project was completed. This was the first task of multiple tasks that was to ultimately result in the operation of a pilot plant. Co-funded by the US Bureau of Reclamation and DWR through Proposition 50 funding the overall goal was to further investigate the viability of seawater desalination for LADWP. Recommendations on site specific technologies and processes were provided for carry over to the pilot plant design stage. Items for further study included subsurface intake evaluation, cooling alternatives for warm water, second pass RO, post treatment stabilization, and finished water blending strategy.

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After completion of the first task, the other tasks were not initiated reflecting the City's new primary strategies of conservation and recycled water to create a sustainable water supply for the City. Studies completed to date and LADWPs other seawater desalination efforts discussed below have provided important data that can assist LADWP to move forward with seawater desalination in the future, if conditions are amenable.

Other LADWP Seawater Desalination Efforts

LADWP historically engaged in multiple partnerships to advance seawater desalination in southern California. Seawater desalination is hindered by multiple challenges including, but not limited to, capital costs, operating costs, environmental considerations, water quality, and public acceptance. To overcome these challenges, LADWP has supported efforts to lower the capital and operating costs of producing desalinated ocean water. LADWP also participated with California stakeholders through multiple venues, such as the MWD and the California Water Desalination Task Force to develop desalination study projects within southern California.

LADWP, the Long Beach Water Department (LBWD), and the United States Bureau of Reclamation partnered in the construction of a 300,000 gpd prototype seawater desalination facility to complete testing of LBWD's proprietary two-stage nanofiltration process (using membranes that require lower operating pressures and thus, the potential for lower operating costs). LBWD successfully performed a 9,000-gpd bench-scale testing of this technology and began testing on a larger scale in October 2006 at LADWP's Haynes Generating Station in Long Beach. By March 2010, LBWD has completed its testing and is currently preparing the final report.

LADWP also partnered with the West Basin Municipal Water District and other agencies in the American Water Works Association Research Foundation Tailored Collaboration project, "Water Quality Implications for Large-Scale Applications of MF/RO Treatment for Seawater Desalination." A 30,000-gpd pilot facility operating off the coast of El Segundo, California, from 2002 to 2008, was tested for membrane performance, water quality, and operational cost.

In a joint study by LADWP, LBWD, and West Basin Municipal Water District, preliminary sampling of raw seawater quality was initiated at three potential seawater desalination sites - Scattergood Generating Station in Playa Del Rey, Haynes Generating Station in Long Beach, and El Segundo Power Generating Station. Water quality analysis on the seawater was performed at various times of the year to analyze seawater quality variations during storm events when city surface runoffs drain into the ocean. The next step would be to collaborate with the California Department of Health Services on developing guidelines to ensure that product water from future desalting facilities will meet all State and Federal water quality regulations.

9.3 Potential Water Supply Yield and Cost

The range of potential water supply, the unit cost, risks, and other benefits besides reductions in water demands for these potential water supplies are presented in Exhibit 9B.

LADWP recognizes the value of potential water supplies to offset unanticipated changes to supply or demand. Strategic water planning necessarily includes continuous monitoring of existing and future alternative water resources in preparation of these needs.

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Exhibit 9B

Other Potential Water Supplies

Potential Water Supplies	Potential Water Yield (AFY)	Average Unit Cost ($/AF)	Implementation Risks	Additional Benefits
Seawater Desalination [1]	25,000	$1,500-$2,000	Environmental permitting may be difficult.	Replaces water committed to the environment. Hedges against climate change.
Water Transfer	40,000	$440-$540[2]	Wheeling and other institutional issues must be addressed.	Replaces water committed to the environment.

For Comparison Purposes:
Local Groundwater Pumping Unit Cost = $230/AF
MWD Treated Tier 2 Water Supply Unit Cost = $811/AF

Notes:

1. Source: LADWP Seawater Desalination Facility Feasibility Study for the Scattergood Generating Station in Playa Del Rey (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSA.While the ocean is a virtually unlimited supply, yield shown here is the maximum given available land, outfall capacity, and other constraints.
2. Cost includes cost of water and wheeling fees. Treatment costs not included.

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Chapter Ten
Integrated Resources Planning

10.0 Overview

Integrated resources planning is a process used by many water and wastewater providers to meet their future needs in the most effective way possible, and with the greatest public support. The integrated planning process incorporates:

- public stakeholders in an open, participatory process;
- multiple objectives such as reliability, cost, water quality, environmental stewardship, and quality of life;
- risk and uncertainty; and
- partnerships with other agencies, institutions, and non-governmental organizations.

LADWP has been actively involved in integrated resources planning since 1993, when the Metropolitan Water District of Southern California (MWD) initiated the region's first Integrated Resources Plan (IRP). LADWP was an active member of the technical workgroup that oversaw the development of alternatives and recommendations from MWD's IRP. In 1999, the City of Los Angeles embarked on its first IRP for wastewater, stormwater and water supply. The LADWP was a partner in this effort, working with the City's Bureau of Sanitation (BOS). In 2006, the Greater Los Angeles County IRWMP was approved. LADWP is a member of the IRWMP Leadership Committee and serves as the chair of the of the Upper Los Angeles River Watersheds sub-region for the IRWMP region.

10.1 City of Los Angeles Integrated Water Resources Plan

Description and Purpose

The City's Water Integrated Resources Plan (IRP) is a unique approach of technical integration and community involvement to guide policy decisions and water resources facilities planning. As part of the IRP development, an Environmental Impact Report (EIR) was prepared identifying the recommended alternatives for implementing the City's wastewater, runoff, and recycled water programs for 2020. On November 14, 2006, the City Council unanimously adopted the IRP recommendations and implementation strategy and certified the final EIR. The IRP development was a seven year stakeholder-driven process that at the time was an innovative approach to guide the City's policy decisions and facilities planning. The IRP recognizes the interrelationship of water, wastewater, and runoff management in forming a future vision for the City's water resources activities and functions. In the past, the City traditionally utilized single-purpose planning efforts for each agency, such as one plan for wastewater and a separate plan for water supply. With the IRP, the City can meet its 2020 needs in a more cost-effective and sustainable way by addressing and integrating all its water resources. Additionally, the IRP was designed to meet multiple objectives, including evaluation of innovative supply opportunities that were once thought of as being too expensive. The City's LADWP and BOS are partners in this effort, joined by public stakeholders and other agencies.

The objectives for the IRP were developed by the City and public stakeholders, and represent the major reasons why the plan was developed. These objectives are:

- Protect Public Health and Safety
- Effectively Manage System Capacity

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- Protect the Environment
- Enhance Cost Efficiency
- Protect Quality of Life
- Promote Education

The IRP was developed in three phases. The first phase set policy guidelines for managing the City's water resources for the next 20 years. The second phase had three main deliverables: (1) detailed facility plans for wastewater, stormwater, and recycled water; (2) comprehensive financial plans for wastewater and stormwater; and (3) a certified Environmental Impact Report (EIR). The third phase of the IRP, which is now underway, represents implementation of the facility plans and more detailed studies to support implementation.

Integrated Watershed Approach

By taking an integrated watershed approach, the IRP identified opportunities that would normally not have been identified if water, wastewater, and stormwater were planned separately. The IRP recognized that all of the City's water resources are linked from a technical, social, and institutional aspect.

The City's IRP has also assisted in identifying partnerships between City agencies for project implementation potentially leading to increases in outside funding from grants and low-interest loans.

An example is the potential three-way partnership between the City's Recreation and Parks Department, BOS, and LADWP. Land reclamation of blighted industrial and warehouse uses allows the City to create more parks and recreational areas while simultaneously allowing for underground storage of wet weather runoff for subsequent beneficial reuse. With this integrated approach, the City can potentially obtain more parkland, assist BOS in reducing wet weather runoff to improve water quality, and assist LADWP in increasing water supplies. The integrated approach also allows the City to better position itself for grants and loans that typically prioritize projects that demonstrate multiple benefits (e.g., water quality, water supply and recreation).

Stakeholder Involvement

A key element of the IRP was involvement of stakeholders at the beginning and throughout the entire IRP process. Stakeholders represent a wide range of the City's interests including, but not limited to, community, business, and environmental organizations. Stakeholders were instrumental in development of the guiding principles and identification of innovative water resource opportunities.

During Phase 2, stakeholders participated in a Steering Group. Steering Group members regularly attended scheduled workshops and provided on-going input on the technical, environmental, and financial development of the IRP. Members provided necessary feedback to keep the facilities planning efforts aligned with the decision-making process. The Steering Group also considered key project issues in regards to the development of alternatives, such as facilities siting, implementation risks, and acceptability of costs that will invariably arise during the project.

IRP Alternatives

The IRP evaluated a broad range of integrated alternatives. Each alternative represented different combinations of wastewater treatment options, wastewater collection system options, recycled water options, conservation options, and dry and wet weather urban runoff management options.

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Twenty-one (21) preliminary alternatives were created with different focuses, allowing stakeholders and decision-makers to see trade-offs in key planning objectives. Based on the evaluation of the preliminary alternatives, nine (9) hybrid alternatives were created that incorporated the best elements from the preliminary alternatives in order to improve overall performance. City staff recommended the top-scoring four (4) hybrid alternatives to be carried through to the EIR process. Public stakeholders concurred with staff recommendations.

In November 2006, City Council approved the staff-recommended alternative, which consists of "Go-Projects" , "Go-If-Triggered Projects" and "Go-Policy Directions". "Go-Projects" are projects recommended for immediate implementation because the flow and regulatory triggers have already been met. "Go-If-Triggered Projects" will only be implemented if or when additional information or circumstances, such as regulatory requirements, population growth, or increases in sewage flow are reached.. "Go-Policy Directions" are specific directions to City staff on the next studies and evaluations necessary to progress on programmatic elements.

IRP Implementation Status

The City's Department of Public Works (DPW) in partnership with the Department of Water and Power (DWP) has been working collaboratively along with other City departments on coordinating and implementing the various IRP recommendations. As part of the IRP implementation phase, the City has worked on keeping IRP stakeholders engaged through annual stakeholder meetings. Through these meetings, the City has provided updates on the IRP implementation and has obtained valuable input from stakeholders on IRP related issues. In addition, the Board of Water and Power and the Board of Public Works have held three public joint meetings to review the IRP progress and provide directions on policy issues. Since the adoption of the IRP by Council in November 2006, a number of initiatives have been undertaken by the City which fulfill the IRP goals, including the Green Streets and Green Alleys Committee, the development of a Low Impact Development Ordinance, Conservation Initiatives (Chapter 3), the Recycled Water Master Plan (Chapter 4), and Watershed Management (Chapter 7). Projects and policies in the IRP implementation strategy are detailed below. Some projects are currently being implemented, while others continue to be monitored for triggers or policy direction:

Go Projects

- Construct wastewater storage facilities at Tillman
- Construct wastewater storage facilities at Los Angeles-Glendale Water Reclamation Plant (LAG)
- Construct recycled water storage facilities at LAG
- Construct solids handling and truck loading facility at Hyperion
- Construct two new sewer lines, Glendale Burbank Interceptor Sewer (GBIS) and Northeast Interceptor Sewer (NEIS) Phase II

Go-If-Triggered Projects

- Potential upgrades at Tillman to advanced treatment at current capacity (if triggered by regulations and/or decision to reuse Tillman effluent for groundwater replenishment)

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- Potential expansion and upgrade of Tillman to 100 mgd (if triggered by an increase in population, regulations, and/or groundwater replenishment decision), In the unlikely event that the overall framework for recycled water changes to disallow its use, then Hyperion would be potentially expanded to 500 mgd instead.

- Potential upgrades at LAG to advanced treatment at current capacity (if triggered by regulations and/or availability of downstream sewer capacity)

- Design and construct additional secondary clarifiers at Hyperion to provide 450 mgd operational performance

- Design and construct up to 12 solids digesters at Hyperion (if triggered by increased biosolids production in the service area)

- Design/construction of Valley Spring Interceptor Sewer

Of the "Go-Policy Directions" which provide specific directions to City staff on the next studies and evaluations necessary to progress on programmatic elements., those applicable to or with the potential to impact LADWP operations include:

Recycled Water – Non-Potable Uses

- Direct LADWP and Public Works to work together to maximize use and identify recycled water for non-potable uses in the Terminal Island Treatment Plant service area, west side, and LAG service areas. LADWP is to conduct additional Tier 1 and 2 customer analyses to verify potential demands and feasibility. Develop a long-range marketing strategy for recycled water that includes a plan for recruiting and retaining new customers.

- Direct Building and Safety to evaluate and develop ordinances to require installation, where feasible, of dual plumbing for new multi-family, commercial and industrial development, schools, and government properties in the vicinity of existing or planned recycled water distribution systems in coordination with the LA River Revitalization Master Plan. Proximity and demand will be considered when determining feasibility. The dual plumbing will consist of separate plumbing and piping systems, one for potable water and the second for recycled water for non-potable uses, such as irrigation and industrial use

- Direct Public Works and LADWP to continue to coordinate, where feasible, the design/construction of recycled water distribution piping (purple pipe) with other major public works projects, including street widening, and LA River Revitalization Master Plan project areas. Also coordinate with other agencies, including the Metropolitan Transit Authority and Caltrans, on major transportation projects.

Recycled Water –Indirect Potable Uses (Groundwater Replenishment)

- Direct LADWP to develop a public outreach program to explore the feasibility of implementing groundwater replenishment with advanced treated recycled water.

Recycled Water – Environmental Uses

- Direct LADWP and Public Works to continue to provide water from Tillman to Lake Balboa, Wildlife Lake, and the Japanese Garden at Sepulveda Basin, and the LA River to meet baseline needs for habitat.

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Water Conservation

- Direct DWP to continue conservation efforts, including programs to reduce outdoor water usage, including using smart irrigation devices on City properties, schools, and large developments (those with 50 dwelling units or 50,000 gross square feet or larger), and to increase incentives to residential properties

- Direct LADWP to work with Building and Safety in continued conservation efforts, including evaluating and considering new water conservation technologies, including no-flush urinal technology

- Direct LADWP to continue conservation efforts, including working with Building and Safety to evaluate and develop a policy that requires developers to implement individual water meters for all new apartment buildings

- Direct LADWP to continue conservation awareness efforts, including increasing education programs on the benefits of using climate-appropriate plants with an emphasis on California friendly plants for landscaping or landscaped areas developed in coordination with the LA River Revitalization Master Plan, and to develop a program of incentives for implementation.

- Direct the Planning Department to consider development of a City Directive to require use of California friendly plants in all City projects where feasible and not in conflict with other facilities usage

Runoff Management – Wet Weather Runoff

- Direct Public Works to review SUSMP (Standard Urban Stormwater Management Plan) requirements to determine ways to require, where feasible, on-site filtration and/or treat/reuse, rather than treat and discharge, including in-lieu fees for projects where infiltration in infeasible

- Direct Building and Safety to evaluate and modify applicable codes to encourage all feasible Best Management Practices (BMPs) for maximizing on-site capture and retention and/or infiltration of stormwater instead of discharge to the street and storm drain, including using porous pavement.

- Direct Public Works and Planning to evaluate the possibility of requiring porous pavement in all new public facilities in coordination with the LA River Revitalization Master Plan, and large developments greater than one acre. Program feasibility should consider slope and soil conditions

- Direct Planning to evaluate ordinances that would need to be changed to reduce the area of on private properties that can be paved with non-permeable pavement

- Direct Public Works to evaluate and implement integration of porous pavements into sidewalks and street programs where feasible.

- Direct Public Works, LADWP, and Recreation and Parks to prepare a concept report and determine the feasibility of developing a powerline easement demonstration project for greening, public access, stormwater management, and groundwater replenishment.

- Direct Public Works and LADWP to work with the Los Angeles Unified School District to determine the feasibility of developing projects for both new and retrofitted schools, as well as for government/city-owned facilities, with

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stormwater management BMPs (cisterns to store runoff for irrigation, reduce paving and hardscapes, add infiltration basins).

- Direct Public Works, General Services, and Recreation and Parks, to identify sites that can provide on-site percolation of wet-weather runoff in surplus properties, vacant lots, parks/open spaces, abandoned alleys in the East Valley area, and along the LA River in the East Valley where feasible. Program feasibility should consider slope and soil conditions.

- Direct Public Works, General Services, and the Department of Transportation to maximize unpaved open space in City-owned properties and parking medians using all feasible BMPs and by removing all unnecessary pavement.

- In the context of developing Total Maximum Daily Load implementation plans, direct Public Works to consider diversion of dry weather runoff from Ballona Creek to constructed wetlands, wastewater system, or urban runoff plants for treatment and/or beneficial use. For inland creeks and storm drains tributary to the LA River, direct Public Works to consider diversion of dry weather runoff to the wastewater system or constructed wetlands or treatment/retention/infiltration basins.

- Direct General Services, in coordination with Planning and Public Works, to evaluate feasibility of all City properties identified as surplus for potential development of multiple-benefit projects to improve stormwater management, water quality, and groundwater recharge.

Los Angeles River

The IRP planning effort included the Los Angeles River (River). The Los Angeles River is a valuable resource to the City providing habitat as well as recreational and economic opportunities. Since the City's water reclamation plants were built, recycled water has been released to the River resulting in the development of significant environmental benefits from riparian habitat in the unlined portions of the River near Glendale, to regionally significant migratory shore bird habitat in Long Beach. As a result many efforts have been developed to protect existing habitat and interest in habitat restoration and river revitalization.

The IRP established that treated wastewater is needed for the operation of Lake Balboa, the Japanese Gardens, and the Wildlife Lake in the Sepulveda Basin. Treated wastewater flows through these features and ultimately is released to the River from the Donald C. Tillman Water Reclamation Plant. The remainder of the treated wastewater produced by the City's water reclamation plants is available for recycled water use and distribution to LADWP customers.

Shortly after work on the IRP began, the Los Angeles City Council Ad Hoc Committee on the Los Angeles River (Ad Hoc Committee) was formed to address River revitalization. LADWP staff routinely attends Ad Hoc Committee meetings and functions, and monitors River-related activities.

LADWP also funded the preparation of a Los Angeles River Revitalization Master Plan which was approved in 2007. This plan addresses economic development opportunities, water quality, water resources, flood control, and recreation along the Los Angeles River. The plan also discusses opportunities to improve access to the Los Angeles River and increase community awareness and pride.

In addition, LADWP staff also actively participates on the City Department Los Angeles River Task Force, which was formed in response to instructions by the Ad Hoc Committee to:

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- inventory all current and future City Department projects, studies, and programs along the River;
- assess opportunities for future funding, projects, and studies; and
- coordinate River related activities of City Departments and other agencies.
- partner with the United States Army Corps of Engineers for a Habitat Restoration Project Study

LADWP recognizes the importance of the Los Angeles River as a resource that provides multiple benefits to the City.

Agency Coordination

LADWP was a partner with the Bureau of Sanitation (BOS) in developing the IRP along with public stakeholders and other agencies. As with any integrated plan that extends beyond traditional departmental boundaries and government jurisdictions, close coordination is required with multiple City, state, and federal agencies including but not limited to, the Cities of Burbank and Glendale, County of Los Angeles, Caltrans, United States Army Corps of Engineers, United States Bureau of Reclamation, and City Parks and Recreation Department. Since approval of the IRP, ongoing project implementation and "Go-Policy Directions" continue to require close coordination with City departments and with the agencies listed above.

IRP Implications for City's Urban Water Management Plan

One of the primary purposes for developing the IRP was to explicitly consider the relationship between wastewater facility planning and other water resources issues, such as water supply and urban runoff. Implementation of the IRP has and will continue to result in increased beneficial reuse of water, water conservation, and groundwater supplies. IRP alternatives examined ways in which to decrease potable water needs by expanding the City's recycled water program; increase water efficiency by installing smart irrigation and other water efficient devices that reduce irrigation and indoor water demands; and increase groundwater resources by using wet weather runoff to recharge the aquifer. All of these options will have to be tested from a technical, institutional, and public acceptance perspective. Ongoing work on programmatic elements identified in the "Go-Policy Directions" applicable to LADWP will continue to investigate means of increasing local water supplies, water conservation, and groundwater recharge opportunities in an integrated manner. The IRP has demonstrated that by integrating water resources planning for the City, more opportunities for water supply development can be identified.

10.2 Greater Los Angeles County Integrated Regional Water Management Plan (IRWMP)

Description and Purpose

The Los Angeles County Department of Public Works led efforts to develop an Integrated Regional Water Management Plan (IRWMP) for the Greater Los Angeles County Region. Water quality, resource, and supply issues within the region are complex and managed by a myriad of government agencies subjected to a plethora of regulations. Exponential growth over the last century has required water managers to develop creative solutions to meet growing demands. Previously projects addressing water issues were designed to appease single-focused visions and solutions of organizations operating independently in silos. At the core of the plan a clear vision and direction for the sustainable management of water resources within the region for the next twenty years was formulated. Over 1,600 projects were collected and synthesized for inclusion in the plan bringing together hundreds of local government agencies all working cooperatively to develop cost-effective, sensible, and economically feasible solutions to address regional water issues. New partnerships were forged joining together potential funding partners from within and outside the region. An innovative partnership between agencies was formed

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creating a new model of integrated regional planning to address competing water demands, water supply reliability, and project financing.

An Interim Draft of the IRWMP was adopted by the Leadership Committee on June 28, 2006 with a final plan adopted on December 16, 2006. To date the plan has received $25 million from the Department of Water Resources (DWR) under Proposition 50, Chapter 8, for implementation of fourteen priority projects identified in the plan and $1.5 million from DWR for development of the IRWMP. Since completion of the document a revised Memorandum of Understanding (MOU) was executed by each of the sixteen agencies serving on the Leadership Committee for the purpose of developing, administering, updating, and implementing the IRWMP.

Region

The IRWMP region encompasses 92 cities, portions of four counties, and hundreds of government agencies and districts spread over 2,058 square miles. Approximately 10.2 million residents, or equivalent to roughly 28% of the population of California, reside within the region. To facilitate input, variations in geographic and water management strategies, and effective planning the region was further subdivided into five sub-regions:

- Lower San Gabriel and Los Angeles River Watersheds
- North Santa Monica Bay Watersheds
- South Bay Watersheds
- Upper Los Angeles River Watersheds
- Upper San Gabriel River and Rio Hondo Watersheds.

Mission and Purpose

A collaborative process resulted in the following mission statement of the IRWMP, "[T]o address the water resources needs of the Region in an integrated and collaborative manner." The IRWMP recognizes that in order to meet future needs water supply planning must be integrated with other resource strategies. Additionally, in a region with significant urban challenges, including population growth, densification, traffic congestion, poor air quality, and quality of life issues, it is imperative to consider water resources management in conjunction with other urban planning issues. The IRWMP's purpose is to proactively:

- Improve water supplies
- Enhance water supply reliability
- Improve surface water quality
- Preserve flood protection
- Conserve habitat
- Expand recreational access.

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Stakeholder Involvement

Over 1,400 invitations to participate in the IRWMP process were sent out to cities, counties, agencies, districts, disadvantaged communities, and community organizations. Stakeholders participated in workshops, project identification, and development of the IRWMP. Stakeholders were involved in plan development and through development of technical memorandums and participation in regional workshops, subregional workshops, and the Leadership Committee. Stakeholders assisted in the development of the following:

- Development of the IRWMP mission and objectives
- Refinement of procedures for incorporation of projects into the IRWM
- Identification of implementation strategies
- Recommendation of stakeholder workshop improvements.

Recommended Projects

Over 1,600 projects were submitted and analyzed for inclusion in the IRWMP. This list was narrowed down to fourteen priority projects that met the objectives and priorities established by the IRWMP process and assist in meeting the targets established for the planning region. Objectives and priorities were established to guide the project selection process. The IRWMP is a living document and will be updated as needed. Projects can continuously be submitted as they are identified by stakeholders.

Objectives and Priorities

Six objectives and six long-term priorities were developed through the stakeholder process to guide project selection based on stakeholder input and previously completed documents, including UWMPs, MWD's IRP, Common Ground, Santa Monica Bay Restoration Plan, and watershed plans for the major tributaries in the region. The objectives are:

- Optimize local water resources to reduce the Region's reliance on imported water
- Comply with water quality regulations (including TMDLs) by improving the quality of urban runoff, runoff, stormwater, and wastewater
- Protect and improve groundwater and drinking water quality
- Protect, restore, and enhance natural processes and habitats
- Increase watershed friendly recreational space for all communities
- Maintain and enhance public infrastructure related to flood protection, water resources, and water quality.

Long term regional priorities are:

- Maintain a regional and subregional structure to oversee plan implementation and assure continued stakeholder input
- Optimize use of recycled water, groundwater, desalination, and stormwater to enhance water supply reliability
- Reduce demand on imported water sources

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- Protect groundwater supplies
- Improve surface water quality to meet applicable water quality regulations, including TMDLs
- Preserve open space, conserve and restore functional habitats, and protect special-status species.

Targets

Targets for the region were developed to assist in prioritizing projects. Targets include:

- Increase water supply reliability by providing 800,000 AFY of additional water supply and demand reduction through conservation, including infiltration or reuse of 130,000 AFY of reclaimed water
- Reduce and reuse 150,000 AFY (40%) of dry weather urban runoff and capture and treat an additional 170,000 AFY (50%) for a total target of 90%
- Reduce and reuse 220,000 AFY (40%) of stormwater runoff from developed areas and capture and treat an additional 270,000 AFY (50%) for a total of 90%
- Treat 91,000 AFY of contaminated groundwater
- Restore 100+ linear miles of functional riparian habitat and associated buffer habitat
- Restore 1,400 acres of functional wetland habitat
- Develop 30,000 acres of recreational open space focused in under-served communities
- Repair/Replace 40% of aging water resources infrastructure.

Projects

Fourteen priority projects were developed for the greater Los Angeles County region. As a regional plan encompassing an area larger that LADWP's service area, many of the IRWMP projects do not directly benefit LADWP's service area, but rather provide benefits towards improving water resources in the region as a whole. However, for projects not within LADWP's service area LADWP can utilize the results of other projects and apply the knowledge to potentially develop similar programs within the service area. Brief descriptions of the priority projects are provided below.

Southeast Water Reliability Project

The Southeast Water Reliability Project consists of an 11.4 mile recycled water transmission pipeline from the City of Pico Rivera to the City of Vernon to complete Central Basin Municipal Water District's recycled water transmission system. Recycled water will be mainly provided by the County Sanitation Districts of Los Angeles County via the San Jose Creek Water Reclamation Plant.

Joint Water Pollution Control Plant Marshland Enhancement

The Joint Water Pollution Control Plant Marshland Enhancement Project is designed to improve and maintain plant and wildlife habitat at the seventeen acre freshwater marshland located at the Joint Water Pollution Control Plant (JWPCP) in

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Carson. As proposed the project will serve as a mitigation measure for upgrading the JWPCP to full secondary wastewater treatment. The JWPCP is operated by the County Sanitation Districts of Los Angeles County.

Large Landscape Water Conservation, Runoff Reduction, and Educational Program (Central Basin)

The Large Landscape Water Conservation, Runoff Reduction, and Education Program is an end use water management program to reduce runoff and address water/energy management associated with large landscapes, residential land uses, and street medians within the Central Basin Municipal Water District's Service Area. Weather-based irrigation controllers coupled with GIS to monitor runoff and two-way communication technologies will provide necessary information to address emergency, drought, and end use management challenges.

Large Landscape Water Conservation, Runoff Reduction, and Educational Program (West Basin)

West Basin Municipal Water District's Large Landscape Water Conservation, Runoff Reduction, and Educational Program is a four component project. The first component targets large landscape sites of 1 acre or more by providing centralized weather-based irrigation controllers with the goal of conserving 1 AFY per acre of land. The second component will provide 1,350 rebates for the purchase of smart irrigation controllers for the top residential water users. A third component will consist developing and offering classes on residential landscaping for residences and businesses. The last component involves installing ten "Ocean Friendly" demonstration gardens throughout watersheds in the service area.

Las Virgenes Creek Restoration Project

The City of Calabasas is initiating the Las Virgenes Creek Restoration Project to restore 450 linear feet of a concrete-lined section of the creek to a natural function. Native vegetation will be planted in place of the concrete liner to establish connectivity between riparian habitat north and south of the existing liner.

Malibu Creek Watershed Urban Water Conservation and Runoff Reduction Project

As proposed the Malibu Creek Watershed Urban Water Conservation and Runoff Reduction Project seeks to conserve water and reduce runoff in the City of Westlake Village and within the Las Virgenes Municipal Water District (LVMWD) service areas. Irrigation controllers on city-owned land in Westlake Village will be replaced with weather-based irrigation controllers. Within the LVWMD service area indoor conservation will be addressed by continuing rebates for residential and multi-family customers to install water saving devices. This project will also continue existing efforts to reduce urban runoff and outdoor conservation in the LVMWD service area by targeting customers with persistent and substantial irrigation runoff in the vicinity of stormdrains. These customers are offered water efficient equipment rebates and free on-site assistance to upgrade irrigation systems to eliminate runoff.

Morris Dam Water Supply Enhancement Project

The Morris Dam Water Supply Enhancement Project would allow the capture of additional local runoff (5,720 AF) for groundwater recharge and extraction in the San Gabriel River watershed. This project would reduce the minimum pool required by the Los Angeles County Flood Control District to prevent sediment damage to the outlet works of the dam by modifying the dam valves and control systems.

Pacoima Wash Greenway Project

The Pacoima Wash Greenway will treat storm runoff from neighborhoods adjacent to the wash in a series of parks incorporating stormwater treatment best management practices along the wash. Project development will be a joint effort between the City of San Fernando and the Mountains Recreation and Conservation Authority.

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San Gabriel Valley Riparian Habitat Arundo Removal Project

Arundo donax a non-native plant classified federally and by California as noxious weed will be removed from approximately 30 acres of riparian habitat in the San Gabriel Watershed. Removal will increase surface water flows to the Rio Hondo percolation basins and improve native habitat.

Solstice Creek Restoration Project

The Solstice Creek Restoration Project will restore side drainages of Solstice Creek and areas negatively impacting riparian habitat through sediment and invasive species introduction. This project is part of an overall larger project to restore Solstice Creek.

South Los Angeles Wetlands Park

The South Los Angeles Wetlands Park project will involve purchasing a 9 acre parcel in Los Angeles on Avalon Boulevard for conversion to a wetlands park. As proposed, the wetlands park will treat urban runoff from a 520 acre area through a series of best management practices. Park vegetation will consist of plants not requiring supplemental irrigation.

Whittier Narrows Water Reclamation Plant UV Disinfection

The Whittier Narrows Water Reclamation Plant UV Disinfection project will convert current disinfection processes at the 15 mgd plant to a UV disinfection process. Currently, tertiary-treated water is disinfected to Title 22 recycled water standards using chloramination resulting in the production of NDMA byproducts.

Wilmington Drain Restoration Multiuse

As proposed, the Wilmington Drain Restoration Multiuse Project involves restoration of the Wilmington Drain. Restoration will involve creation of a public park, improved public access, native revegetation, stormwater treatment, and educational signage. The drain is within the City of Los Angeles on an easement held by the Los Angeles County Flood Control District.

North Atwater Creek Restoration

As a component of the overall Los Angeles River Revitalization efforts, the North Atwater Creek Restoration Project will restore North Atwater Creek at North Atwater Park by providing stormwater runoff capture and treatment and the provision of habitat linkage to the Los Angeles River. Additionally, the project will provide an educational component and provide BMP implementation at adjacent horse stables and riding trails.

Implications of IRWMP for LADWP's Urban Water Management Plan

LADWP is a member of the IRWMP Leadership Committee and additionally serves as the chair of the of the Upper Los Angeles River Watersheds sub-region for the IRWMP region. As member of the Leadership Committee, LADWP is a signatory to the MOU for the IRWMP approved by the Board of Water and Power Commissioners on July 15, 2008.

Participating agencies in the IRWMP coordinate and share information concerning water resources management planning programs and projects, share grant funding information, and improve and maintain overall communication among the participants. Coordination and information sharing assists LADWP and other agencies in achieving their respective missions and contribute to overall IRWMP goals.

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10.3 MWD's Integrated Resources Plan

In 1993, MWD and its member agencies embarked on a three year process to develop Southern California's first IRP. Six main objectives for this plan were defined as:

- Supply and System Reliability
- Affordability
- Water Quality
- Diversity
- Environmental Issues
- Institutional Constraints

In order to meet these objectives, supply and conservation options that included everything from groundwater desalination, water transfers, Colorado River and SWP improvements, and new surface storage were evaluated. Complete portfolios, representing different combinations of supply and conservation options, were assembled. Based on extensive participation from water providers and other stakeholders as well as detailed evaluations, a "preferred resource mix" was recommended. The preferred resource mix balanced local and imported water supply projects with significant water conservation in order to best meet the needs of the region. This preferred resource mix also established regional targets for the development of water supply to be made by MWD, its member agencies, and retail water providers.

The 20-year plan was designed so that MWD and its member agencies would be able to meet their full service demands through 2020. MWD's Board of Directors formally adopted the IRP in January 1996.

MWD IRP 2004 Update

In 2001, the MWD Board of Directors developed a work plan to update the 1996 IRP in order to accommodate changed conditions and extend the targets through 2025. Specifically, the IRP Update has three main objectives: (1) review the resource development targets and implementation achievements of the 1996 IRP; (2) identify significant changed conditions for water resource development since the adoption of the 1996 IRP; and (3) evaluate the reliability of the IRP Preferred Resource Mix through 2020, adjust targets as needed to reflect changed conditions, and extend resource targets through 2025.

The results of the IRP Update analysis demonstrate that the resource targets of the 1996 IRP, factored in with the changed conditions discussed in this report, provide for 100 percent reliability in 2020 and up to 2025 (MWD, 2004). Although the current targets provide 100 percent reliability in 2020 and up to 2025, the IRP Update recommends a 10 percent supply buffer. The "planning buffer" identified additional supplies, both imported and locally developed, that could be implemented to address uncertainty in future supplies and demands. The most significant changed conditions include:

- Lower projected retail demands due primarily to conservation savings.
- Higher projected local water resource development.
- Lower projected dry-year MWD demands.
- Board revised targets for the SWP and Colorado River Aqueduct (CRA).

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- More stringent water quality regulations.
- Recognition of implementation risks.

MWD IRP 2010 Update

In 2008, the MWD and its member agencies updated the 2004 IRP in order to accommodate changed conditions and extend the targets through 2035. The 2010 IRP Update has three main objectives: (1) develop an Emergency Response Plan for hydrologic, regulatory, and other types of uncertainties in the Sacramento-San Joaquin Delta; (2) identify energy-efficient and cost-effective energy management initiatives; and (3) evaluate the reliability of the IRP Preferred Resource Mix through 2035, adjust targets as needed to reflect changed conditions, and extend resource targets through 2035.

The IRP Update modified the resource targets to take into account the changed conditions and recommended buffer. A summary of the 2004 IRP Update and 2010 Update targets are shown in Exhibit 10A.

Exhibit 10A

MWD's IRP Resource Targets

IRP Resource Targets	2004 IRP Update 2025	2010 IRP Update 2025	Change	2010 IRP Update 2035
Conservation	1,107,000	1,412,000	305,000	1,538,000
Local Projects*	750,000	905,000	155,000	926,000
Colorado River Aqueduct **	1,250,000	1,250,000	0	1,250,000
State Water Project	650,000	713,000	63,000	713,000
Groundwater Conjunctive Use	300,000	300,000	0	300,000
Central Valley/State Water Project Storage and Transfers	550,000	1,070,000	520,000	1,092,000
MWD Surface Water Storage***	620,000	620,000	0	620,000

* Includes recycled water, brackish groundwater desalination, and seawater desalination

** Target for specific year types, the CRA is not intended to be full at all times

*** Represents the total amount that can be withdrawn from surface reservoirs

Source: MWD (2010)

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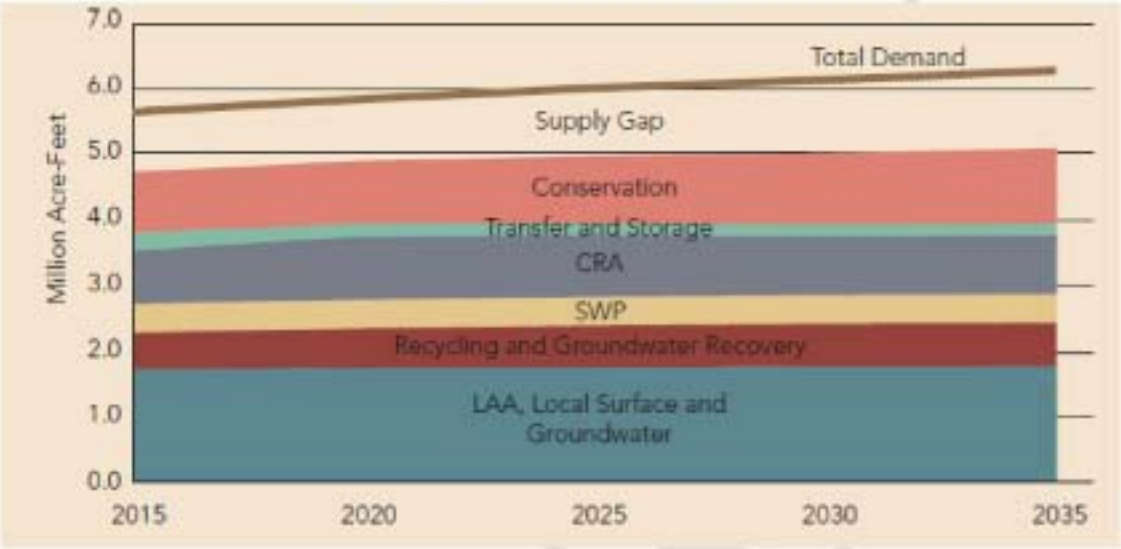
Exhibit 10B shows regional water demands without conservation from 2015 to 2035 under dry weather. The graph also depicts the supply sources and water conservation identified in MWD's 2010 IRP Update.

Exhibit 10B
Meeting Regional Water Needs Through MWD's IRP



Stakeholder Participation

MWD's 1996 IRP was developed in concert with its member agencies. A technical workgroup was established that consisted of MWD staff, member agency and local retail agency managers, and groundwater basin managers. This workgroup met frequently and spent hundreds of hours reviewing analyses and providing guidance. LADWP was an active participant in this workgroup.

To provide more direct involvement of MWD in the IRP Process, the IRP Steering Committee was created. The IRP Steering Committee, consisting of five MWD directors who are also members of the Water Planning and Stewardship Committee, recommended policy options, reviewed proposed resource strategies, and managed public forums.

In addition, regional assemblies were held at critical milestones of the IRP development that provided a platform to collectively discuss strategic direction and regional water solutions. Participants of these assemblies included Board members, water agency managers, local retail water providers, groundwater basin managers, and invited public stakeholders. Public forums and several member agency sponsored workshops attended by stakeholders from business, environmental, agricultural, and water interests were held throughout the IRP process. Finally, findings of the IRP 2010 Update were adopted in October 2010 to a diverse group of stakeholders including elected officials, environmental groups, and the general public.

Agency Coordination

In preparation of MWD's IRP, all member agencies were closely involved, including LADWP. LADWP was involved with providing data and reviewing documents. Additionally, LADWP was an active member of the technical workgroup.

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Funding MWD's IRP

In accordance with MWD's Board adoption of the IRP Update, a revised Long-Range Finance Plan (LRP) was developed and approved by MWD's Board. The LRP (2010) identifies MWD's planned capital improvement program (CIP) and operating expenses from 2015 to 2035.

The following summarizes the MWD's CIP and operating expenses needed to implement the IRP:

- **Core Resources (Fixed costs to maintain Delta habitat conservation and conveyance program, LRP contracts, CRA programs, and conservations funding)** – costs for water supply will increase from the current $853/AF in 2015 to $1,484/AF in 2035.
- **Water Use Efficiency** – costs for water supply will increase from the current $892/AF in 2015 to $1,608/AF in 2035.
- **Capital Expenditures** – costs for water supply will increase from $919/AF in 2015 to $1,844/AF in 2035.
- **Demand Management & Local Projects** – costs from water supply will increase from $953/AF to $2,021/AF in 2035.

IRP Implications for City's Urban Water Management Plan

As LADWP evaluates its water supply options, it is important to understand the significance of a reliable and cost-effective water supply from MWD. The City's water supply reliability is directly linked to MWD's reliability, and LADWP's local supply development uses the cost of MWD water as one of the benchmarks for feasibility evaluation. Through the IRP Update, MWD has shown that it will be able to meet the supplemental needs of all its member agencies reliably through 2035, even during prolonged drought events. MWD has also developed a plan to implement and finance the approved IRP targets.

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Water Supply Reliability and Financial Integrity

11.0 Overview

Providing for a reliable water supply in a semiarid climate with wet and dry years is challenging. This is mainly due to the fact that surface water supplies are imported from the LAA and MWD and vary substantially due to hydrology. LADWP has made significant investments in groundwater, recycled water, stormwater capture and water conservation. These supplies provide local water supplies that are more reliable due to variability of imported supply sources.

11.1 Unit Cost and Funding of Supplies

11.1.1 Unit Cost Summary of Supplies

Unit costs play an important role in planning future water supply sources and determining where supply investments provide the greatest benefits to LADWP. Unit costs vary dramatically by water supply sources. Exhibit 11A summarizes the unit cost for each water supply source.

Costs per acre-foot ranged from a high of $1,500 for certain recycled water projects to a low of $215 for locally produced groundwater among LA's existing and planned water supplies. Los Angeles Aqueduct supply has required operation and maintenance costs regardless of water availability. Therefore, hydrology and increased water for environmental commitments in the Eastern Sierras result in unit cost fluctuations year to year. Local groundwater supply is the least expensive source. However, its production is limited by contamination. Unit costs for MWD purchased water vary based on tier allocations. MWD's water rates vary from $484 per AF of tier 1 untreated water to $811 per AF of tier 2 treated water in 2010. LADWP has a Tier 1 allocation of 304,970 AF. Any purchases above this amount will be at the Tier 2 rates. Conservation is relatively inexpensive to offset water supplies that may otherwise be required to meet water demand. Conservation unit costs are based on costs of conservation rebate and incentive programs and their potential water use reduction. Recycled water cost is project specific and varies widely depending on the infrastructure requirements of each project. Water transfers using a future connection between the LAA and the California Aqueduct is planned. Its costs include the purchase price of water and conveyance fees.

Unit costs for potential water supplies including stormwater reuse (harvesting) and increased groundwater production (stormwater recharge) are highly variable based on factors such as the magnitude of the overall program, project locations, etc. Centralized stormwater capture unit cost is based on LADWP's current planned centralized stormwater capture projects and distributed stormwater capture unit costs are from various sources as referenced in Chapter 7, Watershed Management. These projects are joint efforts among agencies, city departments, stakeholders and community groups and yield additional benefits beyond water supply.

Seawater desalination unit costs are based on the estimate from MWD's 2010 IRP. Seawater desalination was a planned supply identified in the 2005 UWMP but is excluded from this 2010 UWMP. Its impacts to marine habitats and high energy consumption make seawater desalination less desirable comparing to options such as recycled water, conservation, and stormwater capture.

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Exhibit 11A
Unit Costs of Supplies

Exhibit 11A		
Water Source	**Chapter Reference**	**Average Unit Cost ($/AF)**
Los Angeles Aqueduct[1]	**Chapter 5 - Los Angeles Aqueduct System**	$563
Groundwater[1]	**Chapter 6 - Local Groundwater**	$215
Metropolitan Water District[2]	**Chapter 8 - Metropolitan Water District Supplies**	$484 - $811
Conservation	**Chapter 3 - Conservation**	$325 - $400
Recycled Water	**Chapter 4 - Recycled Water**	$600 - $1,500
Water Transfer	**Chapter 9 - Other Potential Supplies**	$440 - $540
Stormwater Capture	**Chapter 7 - Watershed Management**	
- Centralized Stormwater Capture		$60 - $200
- Distributed Stormwater Capture		
Urban Runoff Plants		$4,044
Rain Barrels		$701 - $1,875
Cisterns		$2,426
Rain Gardens		$308 - $5,000
Neighborhood Recharge		$3,351
Seawater Desalination	**Chapter 9 - Other Potential Supplies**	$1,300 - $2,000

[1] Los Angeles Aqueduct supply and groundwater supply are based on FY2005-06 to FY2009-10 five-year average.
[2] MWD Water Rates effective on January 1, 2010.

11.1.2 Funding of Supplies

Funding for water resource programs and projects are primarily provided through LADWP water rates, with supplemental funding provided by the Metropolitan Water District (MWD), and state and federal grants. Funding for water conservation, water recycling, and stormwater capture projects has increased significantly in recent years. Currently, approximately $100 million is collected annually through water rates for these initiatives. The current level of annual expenditures is believed to be sufficient to achieve projected goals.

Funding for groundwater cleanup will require water rate increases. LADWP will also seek reimbursement from potential responsible parties to assist with cleanup program costs.

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Water Resource Project Funding

- Water Rates – currently provides approximately $100 million annually for water conservation, water recycling, and stormwater capture programs.
- MWD – Currently provides funding up to $250 per AF for water recycling through their Local Resources Program. MWD also provides some water conservation incentive funding.
- State Funds – Funds for recycling, conservation, and stormwater capture have been available on a competitive basis though voter approved initiatives, such as Propositions 50 and 84. The proposed 2010 Water Bond, approved by the Legislature but not yet placed on the ballot, also includes potential funding for groundwater cleanup. Occasionally low or zero-interest loans are available though State Revolving Fund programs.
- Federal Funds – Funding for recycling may be obtained through periodic Water Resource Development Act legislation. Also, LADWP has received recycled water funds through the Bureau of Reclamation Title XVI program.
- Potentially Responsible Parties – LADWP may be able to recover some costs for groundwater cleanup through potentially responsible parties.

Receipt of state or federal funding will allow water resource goals to be achieved sooner than projected, or allow for increased local supply development.

11.2 Reliability Assessment Under Different Hydrologic Conditions

11.2.1 Los Angeles Aqueducts

Water supply from the LAA can vary substantially from year to year due to hydrology. In very wet years, LAA supply can exceed 500,000 AFY. During average year weather conditions the LAA supply is projected to gradually decrease from 254,000 AFY to 244,000 AFY by 2035 due to climate change impact. Critical dry year (defined as a repeat of a 1990/91 drought) supplies can be as low as 48,520 AFY.

11.2.2 Groundwater

Groundwater is also affected by local hydrology. However, with conjunctive use management of groundwater—storing imported water in the groundwater basins during wet and average years - groundwater production can actually be increased during dry years. During average weather conditions, LADWP projects it will pump approximately between 40,500 AFY and 111,500 AFY of groundwater during the projection period to fiscal year 2035. These projections are based on the Purification Complex in operation in 2018-19 and storage credit of 5,000 AFY is used to maximize the groundwater production thereafter. Although in dry years LADWP can pump larger quantities of groundwater, a more conservative approach was adopted by assuming the same level of projected groundwater production for both single dry year and multi dry year analysis.

11.2.3 Conservation

LADWP has developed conservation goals in the Water Supply Action Plan to decrease water use in the City and to comply with the new State 20 percent by 2020 requirements. Multiple actions will be taken to increase water conservation including education, targeting the CII sector, reducing outdoor water use, and continuing participation in MWD's rebate programs.

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LADWP is planning to increase water conservation levels during the projection period with an increase of over 60,000 AFY between 2010 and 2035, assuming average weather conditions.

11.2.4 Recycled Water

Recycled water is based on wastewater effluent flows, which do not vary significantly due to hydrology. Therefore, recycled water use is mainly limited by system capacities and demands. This makes recycled water a more reliable supply than imported water. As outlined in Chapter 4 on Recycled Water, LADWP is planning an extensive expansion of its recycled water system to not only include expansion of irrigation and industrial uses, but also groundwater replenishment. Under average weather conditions recycled water supply for irrigation and industrial purposes is projected to increase from 20,000 AFY in 2015 to 29,000 AFY in 2035. Groundwater replenishment with recycled water is projected at 30,000 AFY in 2035. For a critical dry year available supplies would not change.

11.2.5 Water Transfers

Water transfers are being developed to replace a portion of the City's Los Angeles Aqueduct water that has been dedicated for environmental enhancement uses in the eastern Sierra Nevada. Water acquired through transfers helps increase water supply reliability for the City. The Los Angeles Aqueduct and California Aqueduct interconnection is under construction and estimated to be completed in January 2013. LADWP is expected to enter into agreements to obtain 40,000 AF per year under average weather conditions beginning in FY2013-14 and continuing throughout the projection period.

11.2.6 MWD Imported Supplies

Historically, water from MWD (like supplies from the LAA) has been subject to severe variability (i.e., 1976/77, 1987-1992, and the current water shortage). This is due to the fact that MWD's core sources of water supply are the Colorado River and SWP, both of which are highly affected by hydrology. More recently restrictions to protect threatened fish species have further decreased pumping from the Bay-Delta, and limiting SWP supplies available to MWD. After the 1987-1992 drought, MWD started to diversify its water supplies. Partnering with its member agencies, MWD launched the IRP in 1993 and most recently updated it in 2010. As a result of the resource targets in the IRP, MWD implemented a variety of projects and programs designed to reduce its dependency on imported water during water shortages and environmental related SWP pumping restrictions. Efforts have included: (1) providing financial incentives for local projects and conservation; (2) increased surface storage via Diamond Valley Lake and use of the SWP terminus reservoirs; (3) groundwater storage programs in the Central Valley, Imperial Valley, and Coachella Valley; (4) short- and long-term water transfers; and (5) contracted groundwater storage programs with participating member agencies.

In the 2010 IRP Update MWD developed a three-part adaptive resource strategy: (1) meet demands by building on existing core resources to provide reliability under foreseen conditions; (2) implement a supply buffer of 10 percent of retail demand through multiple actions to adapt to short-term uncertainty; and (3) implement adaptive management through low-regret foundation actions, monitoring key vulnerabilities and bringing adaptive resources online, if required, and using a comprehensive approach to meet specific needs and degrees of shortages. The 2010 IRP adaptive management concept seeks to mitigate against supply uncertainty to further increase reliability.

The 2010 IRP Update concluded that the resource targets identified in previous updates, taking into consideration changed conditions identified since that time, will continue to provide for 100 percent reliability through 2035. The 2010 RUWMP also concluded the same full reliability through 2035 during average (1922 – 2004 hydrology), single dry (1977 hydrology), and

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multiple dry years (1990 - 1992 hydrology). For each of the scenarios there is a surplus in every forecast year (see Exhibit 11B).

Exhibit 11B
MWD Supply Capability and Projected Demands (in AFY)

Single Dry-Year MWD Supply Capability and Projected Demands					
Fiscal Year	2015	2020	2025	2030	2035
Capability of Current Supplies	2,457,000	2,782,000	2,977,000	2,823,000	2,690,000
Projected Demands	2,171,000	2,162,000	2,201,000	2,254,000	2,319,000
Surplus	286,000	620,000	776,000	569,000	371,000
Supplies under Development	762,000	862,000	1,036,000	1,036,000	1,036,000
Potential Surplus	1,048,000	1,482,000	1,812,000	1,605,000	1,407,000
Multiple Dry-Year MWD Supply Capability and Projected Demands					
Fiscal Year	2015	2020	2025	2030	2035
Capability of Current Supplies	2,248,000	2,417,000	2,520,000	2,459,000	2,415,000
Projected Demands	2,236,000	2,188,000	2,283,000	2,339,000	2,399,000
Surplus	12,000	229,000	237,000	120,000	16,000
Supplies under Development	404,000	553,000	733,000	755,000	755,000
Potential Surplus	416,000	782,000	970,000	875,000	771,000
Average Year MWD Supply Capability and Projected Demands					
Fiscal Year	2015	2020	2025	2030	2035
Capability of Current Supplies	3,485,000	3,810,000	4,089,000	3,947,000	3,814,000
Projected Demands	2,006,000	1,933,000	1,985,000	2,049,000	2,106,000
Surplus	1,479,000	1,877,000	2,104,000	1,898,000	1,708,000
Supplies under Development	588,000	689,000	1,051,000	1,051,000	1,051,000
Potential Surplus	2,067,000	2,566,000	3,155,000	2,949,000	2,759,000

Source: MWD 2010 Regional Urban Water Management Plan Tables 2-9 to 2-11

As part of the implementation of MWD's IRP, MWD and its member agencies worked together to develop MWD's Water Surplus and Drought Management Plan (WSDM Plan) in 1999. The WSDM Plan established broad water resource management strategies to ensure MWD's ability to meet full service demands at all times and provides principles for supply allocation if the need should ever arise. The WSDM Plan splits MWD's resource actions into two major categories: Surplus Actions and Shortage Actions. The Shortage Actions of the WSDM Plan are split into three sub-categories: Shortage, Severe Shortage, and Extreme Shortage. Under Shortage conditions, MWD will make withdrawals from storage and interrupt long-term groundwater basin replenishment deliveries. Under Severe Shortage conditions, MWD will call for extraordinary drought conservation in the form of voluntary savings from retail customers, interrupt 30 percent of deliveries to Agricultural Water Program users, call on its option transfer water, and purchase water on the spot market. Under Extreme Shortage conditions, MWD will equitably allocate supplies to its member agencies on the basis of agencies' needs. The overall objective of MWD's IRP and WSDM Plan is to ensure that shortage allocations of MWD water supplies are not required.

If shortage allocations are required, MWD will rely on the calculations established in its Water Supply Allocation Plan (WSAP) adopted in 2008. The plan equitably allocates shortages among its member agencies based on growth, local investments, changes in supply conditions, demand hardening, and water conservation programs for each of its member agencies.

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11.2.7 Potential Supplies

Other planned and potential water supplies that LADWP is exploring include capturing stormwater for reuse and infiltration leading to increased groundwater production (see Chapter 7). Development of these supplies will offset water purchased from MWD. The beneficial reuse of stormwater presents significant opportunity. The City must reduce pollutants in impaired receiving waters (rivers, creeks, and beaches in the Santa Monica and Los Angeles watersheds) as required by the Clean Water Act. By managing urban runoff during dry and wet periods, pollution will be reduced. Traditional ways of managing urban runoff would be to divert the runoff into existing wastewater treatment plants and/or build satellite treatment plants specifically designed to treat urban runoff.

During the City's IRP process, stakeholders expressed the desire to examine other ways to manage runoff that would reduce pollution and provide for other benefits such as water supply and open space. These methods involve local and regional storage of wet weather runoff for groundwater infiltration, on-site storage and recovery of wet weather runoff for irrigation using cisterns and other devices, and reuse of treated dry weather effluent for irrigation (much like recycled water). As an outgrowth of the IRP, neighborhood recharge concept efforts are moving from the conceptual stage visualized in the IRP to actual projects in the City to infiltrate wet weather runoff as close as possible to the point of origin with multiple projects either complete, under construction, or in final design.

Under average weather conditions LADWP is projecting stormwater capture and reuse in 2015 will potentially be 2,000 AFY increasing to 10,000 AFY by 2035. Increased groundwater production as a result of stormwater infiltration will potentially be 15,000 AFY in 2035. This potential is contingent on modifying the court judgment. If these resources reach fruition, LADWP will be able to reduce imported demands on MWD by 25,000 AFY in 2035 under average weather conditions.

11.2.8 Service Area Reliability Assessment

To determine the overall service area reliability, LADWP defined three hydrologic conditions: average (or normal weather); single dry year (such as a repeat of the 1990/91 drought); and multi-dry year period (such as a repeat of FY1988-89 to FY1992-93).

The water supply reliability summaries are shown in Exhibit 11C for the 5-year average from FY 2005-06 to FY 2009-10 and in Exhibit 11 D for FY 2034-35 under average weather conditions with new water conservation shown as a supply source. The exhibits show that the City's reliance on MWD supply will decrease from 52 percent to 24 percent by FY 2034-35 while the combined imported supplies of LAA and MWD water will decrease from 88 percent to 57 percent by FY 2034-35. The locally-developed supplies will increase from 12 percent to 43 percent by FY 2034-35.

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Exhibit 11C
LADWP Supply Reliability FYE 2006-2010 Average

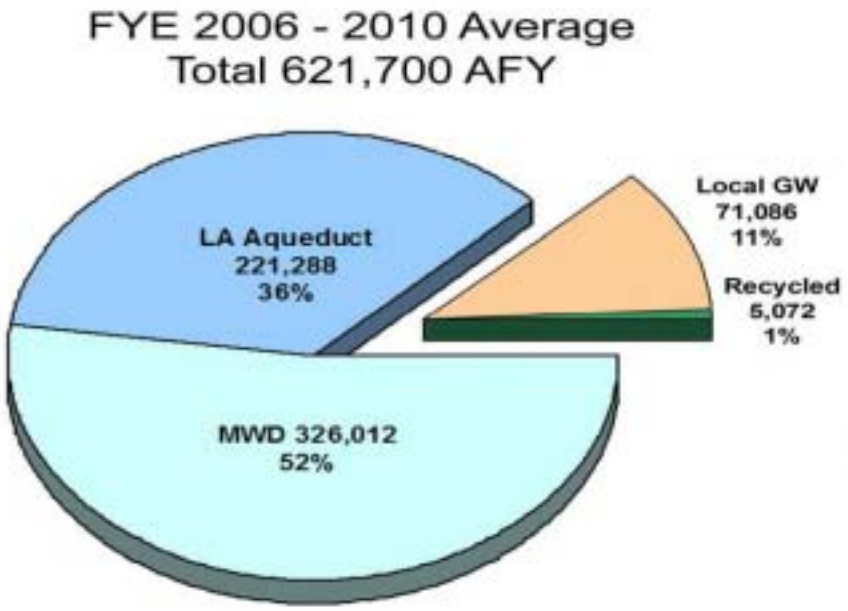
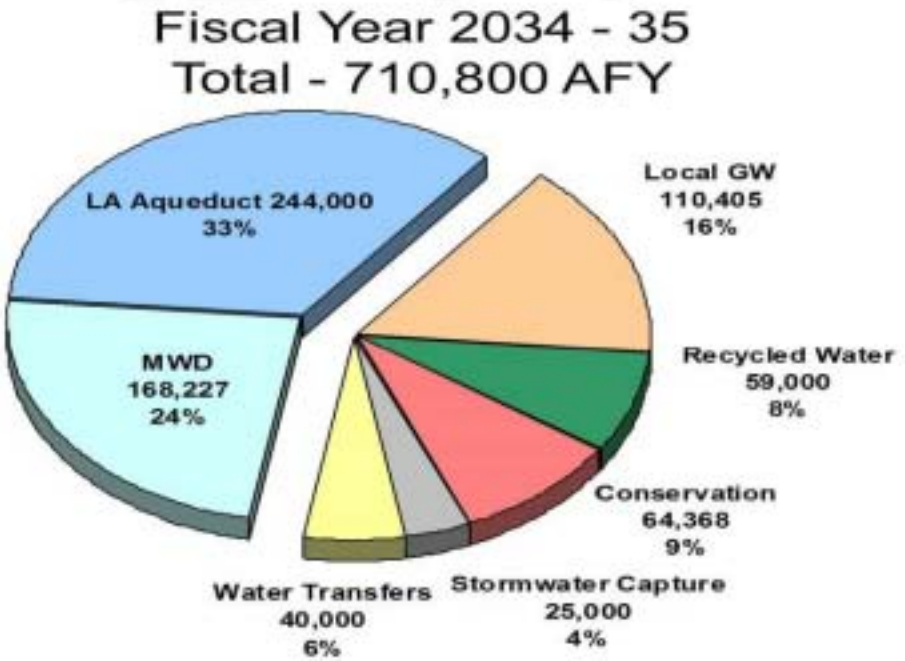


Exhibit 11D
LADWP Supply Reliability Under Average Weather Conditions in Fiscal Year 2034-35



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Exhibits 11E and 11F tabulate the service reliability assessment for normal and single dry year conditions, respectively. Exhibits 11G through 11K show reliability assessments in five year increments from 2010 to 2035 with each five year period assuming that a multiple dry year condition occurs. For these reliability tables, existing water conservation has been already subtracted from projected demands, but new water conservation is included as a supply source. Under all scenarios all demands are met by the available supplies.

Exhibit 11E
Service Area Reliability Assessment for Average Weather Year

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Average Weather Conditions Fiscal Year Ending on June 30				
		2015	2020	2025	2030	2035
Total Demand	**554,140**	**614,800**	**652,000**	**675,600**	**701,200**	**710,800**
Existing / Planned Supplies						
Los Angeles Aqueduct[1]	199,739	252,000	250,000	248,000	246,000	244,000
Groundwater[2]	76,982	40,500	96,300	111,500	111,500	110,405
Conservation	8,178	14,180	27,260	40,340	53,419	64,368
Recycled Water						
- Irrigation and Industrial Use	6,703	20,000	20,400	27,000	29,000	29,000
- Groundwater Replenishment	0	0	0	15,000	22,500	30,000
Water Transfers	0	40,000	40,000	40,000	40,000	40,000
Subtotal	291,602	366,680	433,960	481,840	502,419	517,773
MWD Water Purchases						
With Existing/Planned Supplies	262,538	248,120	218,040	193,760	198,781	193,027
Total Supplies	**554,140**	**614,800**	**652,000**	**675,600**	**701,200**	**710,800**
Potential Supplies						
Stormwater Capture						
- Capture and Reuse (Harvesting)	0	2,000	4,000	6,000	8,000	10,000
- Increased Groundwater Production (Recharge)	0	0	2,000	4,000	8,000	15,000
Subtotal	0	2,000	6,000	10,000	16,000	25,000
MWD Water Purchases						
With Existing/Planned/Potential Supplies	262,538	246,120	212,040	183,760	182,781	168,027
Total Supplies	**554,140**	**614,800**	**652,000**	**675,600**	**701,200**	**710,800**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11F
Service Area Reliability Assessment for Single Dry Year

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Single Dry Year (FY1990-91) Fiscal Year Ending on June 30				
		2015	2020	2025	2030	2035
Total Demand	**554,140**	**651,700**	**691,100**	**716,100**	**743,200**	**753,400**
Existing / Planned Supplies						
Los Angeles Aqueduct[1]	199,739	48,520	46,120	47,720	47,330	46,940
Groundwater[2]	76,982	40,500	96,300	111,500	111,500	110,405
Conservation	8,178	14,180	27,260	40,340	53,419	64,368
Recycled Water						
- Irrigation and Industrial Use	6,703	20,000	20,400	27,000	29,000	29,000
- Groundwater Replenishment	0	0	0	15,000	22,500	30,000
Water Transfers	0	40,000	40,000	40,000	40,000	40,000
Subtotal	291,602	163,200	232,080	281,560	303,749	320,713
MWD Water Purchases						
With Existing/Planned Supplies	262,538	488,500	459,020	434,540	439,451	432,687
Total Supplies	**554,140**	**651,700**	**691,100**	**716,100**	**743,200**	**753,400**
Potential Supplies						
Stormwater Capture						
- Capture and Reuse (Harvesting)	0	2,000	4,000	6,000	8,000	10,000
- Increased Groundwater Production (Recharge)	0	0	2,000	4,000	8,000	15,000
Subtotal	0	2,000	6,000	10,000	16,000	25,000
MWD Water Purchases						
With Existing/Planned/Potential Supplies	262,538	486,500	453,020	424,540	423,451	407,687
Total Supplies	**554,140**	**651,700**	**691,100**	**716,100**	**743,200**	**753,400**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11G
Service Area Reliability Assessment for Multi-Dry Years (2011-2015)

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
		2011	2012	2013	2014	2015
Total Demand	**554,140**	**588,900**	**607,300**	**626,000**	**602,700**	**627,100**
Existing / Planned Supplies						
Los Angeles Aqueduct[1]	199,739	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	76,982	61,090	53,660	46,260	47,300	40,500
Conservation	8,178	5,670	7,310	8,950	11,560	14,180
Recycled Water						0
- Irrigation and Industrial Use	6,703	7,500	8,300	9,000	15,500	20,000
- Groundwater Replenishment	0	0	0	0	0	0
Water Transfers	0	0	0	40,000	40,000	40,000
Subtotal	291,602	160,590	167,830	152,730	208,720	220,450
MWD Water Purchases						
With Existing/Planned Supplies	262,538	428,310	439,470	473,270	393,980	406,650
Total Supplies	**554,140**	**588,900**	**607,300**	**626,000**	**602,700**	**627,100**
Potential Supplies						
Stormwater Capture						
- Capture and Reuse (Harvesting)	0	0	0	0	0	2,000
- Increased Groundwater Production (Recharge)	0	0	0	0	0	0
Subtotal	0	0	0	0	0	2,000
MWD Water Purchases						
With Existing/Planned/Potential Supplies	262,538	428,310	439,470	473,270	393,980	404,650
Total Supplies	**554,140**	**588,900**	**607,300**	**626,000**	**602,700**	**627,100**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11H
Service Area Reliability Assessment for Multi-Dry Years (2016-2020)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2016	2017	2018	2019	2020
Total Demand	**647,100**	**661,200**	**675,400**	**644,600**	**665,100**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	37,350	37,350	37,350	42,280	96,300
Conservation	16,800	19,410	22,030	24,640	27,260
Recycled Water					0
- Irrigation and Industrial Use	20,000	20,200	20,300	20,400	20,400
- Groundwater Replenishment	0	0	0	0	0
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	200,480	215,520	168,200	221,680	289,730
MWD Water Purchases					
With Existing/Planned Supplies	446,620	445,680	507,200	422,920	375,370
Total Supplies	**647,100**	**661,200**	**675,400**	**644,600**	**665,100**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	2,400	2,800	3,200	3,600	4,000
- Increased Groundwater Production (Recharge)	400	800	1,200	1,600	2,000
Subtotal	2,800	3,600	4,400	5,200	6,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	443,820	442,080	502,800	417,720	369,370
Total Supplies	**647,100**	**661,200**	**675,400**	**644,600**	**665,100**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11I
Service Area Reliability Assessment for Multi-Dry Years (2021-2025)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2021	2022	2023	2024	2025
Total Demand	**683,000**	**694,500**	**706,100**	**670,900**	**689,100**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	111,500	111,500	111,500	111,500	111,500
Conservation	29,880	32,490	35,110	37,720	40,340
Recycled Water					0
- Irrigation and Industrial Use	20,400	21,000	23,000	25,000	27,000
- Groundwater Replenishment		15,000	15,000	15,000	15,000
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	288,110	318,550	273,130	323,580	339,610
MWD Water Purchases					
With Existing/Planned Supplies	394,890	375,950	432,970	347,320	349,490
Total Supplies	**683,000**	**694,500**	**706,100**	**670,900**	**689,100**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	4,400	4,800	5,200	5,600	6,000
- Increased Groundwater Production (Recharge)	2,400	2,800	3,200	3,600	4,000
Subtotal	6,800	7,600	8,400	9,200	10,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	388,090	368,350	424,570	338,120	339,490
Total Supplies	**683,000**	**694,500**	**706,100**	**670,900**	**689,100**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11J
Service Area Reliability Assessment for Multi-Dry Years (2026-2030)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2026	2027	2028	2029	2030
Total Demand	**707,900**	**720,100**	**732,400**	**696,100**	**715,200**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	111,500	111,500	111,500	111,500	111,500
Conservation	42,960	45,570	48,190	50,800	53,420
Recycled Water					0
- Irrigation and Industrial Use	27,500	28,000	28,500	29,000	29,000
- Groundwater Replenishment	16,500	18,000	19,500	21,000	22,500
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	324,790	341,630	296,210	346,660	362,190
MWD Water Purchases					
With Existing/Planned Supplies	383,110	378,470	436,190	349,440	353,010
Total Supplies	**707,900**	**720,100**	**732,400**	**696,100**	**715,200**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	6,400	6,800	7,200	7,600	8,000
- Increased Groundwater Production (Recharge)	4,800	5,600	6,400	7,200	8,000
Subtotal	11,200	12,400	13,600	14,800	16,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	371,910	366,070	422,590	334,640	337,010
Total Supplies	**707,900**	**720,100**	**732,400**	**696,100**	**715,200**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11K
Service Area Reliability Assessment for Multi-Dry Years (2031-2035)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2031	2032	2033	2034	2035
Total Demand	**731,200**	**740,300**	**749,300**	**708,800**	**725,000**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	110,405	110,405	110,405	110,405	110,405
Conservation	55,600	57,800	60,000	62,200	64,368
Recycled Water					0
- Irrigation and Industrial Use	29,000	29,000	29,000	29,000	29,000
- Groundwater Replenishment	24,000	25,500	27,000	28,500	30,000
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	345,335	361,265	314,925	364,465	379,543
MWD Water Purchases					
With Existing/Planned Supplies	385,865	379,035	434,375	344,335	345,457
Total Supplies	**731,200**	**740,300**	**749,300**	**708,800**	**725,000**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	8,400	8,800	9,200	9,600	10,000
- Increased Groundwater Production (Recharge)	9,400	10,800	12,200	13,600	15,000
Subtotal	17,800	19,600	21,400	23,200	25,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	368,065	359,435	412,975	321,135	320,457
Total Supplies	**731,200**	**740,300**	**749,300**	**708,800**	**725,000**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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11.3 Water Shortage Contingency Plan

The Los Angeles City Municipal Code Chapter XII, Article I, Emergency Water Conservation Plan is the City's water shortage contingency plan. It was developed to provide for a sufficient and continuous supply of water in case of a water supply shortage in the service area. There are two scenarios that can cause a water shortage: 1) a severe hydrologic drought affecting surface and groundwater supplies and 2) a catastrophic event that severs major conveyance and/or distribution pipelines serving water to the City. The following discusses LADWP's compliance with the Act as outlined in Section 10632 (a) through (i) of the California Water Code.

11.3.1 Stages of Action – 10632 (a)

As set forth in the Emergency Water Conservation Plan, the City has phases or stages of action that can be undertaken in response to water supply shortages. Phase I prohibited uses of water are in effect at all times within the City. These prohibited uses, defined in article 10632 (d) (see section 11.3.4), are intended to eliminate waste and increase public awareness of the need to conserve water. There are further stages of compounding actions in addition to the Phase I prohibited uses that might be imposed. Phase II to Phase V progressively responds to different severity of shortage with the authority to implement additional prohibited uses of water in Phase V in order to cope with up to a 50 percent reduction in water supply. They are described as follows:

Moderate Shortage, Phase II

1. Should Phase II be implemented, uses applicable to Phase I shall continue to be applicable, except as specifically provided herein.

2. No landscape irrigation shall be permitted on any day other than Monday, Wednesday, or Friday for odd-numbered street addresses and Tuesday, Thursday, or Sunday for even-numbered street addresses. Street addresses ending in ½ or any fraction shall conform to the permitted uses for the last whole number in the address. Watering times shall be limited to: (a) Non-conserving nozzles (spray head sprinklers and bubblers) – no more than eight minutes per watering day per station for a total of 24 minutes per week; (b) Conserving nozzles (standard rotors and multi-stream rotary heads) – no more than 15 minutes per cycle and up to two cycles per watering day per station for a total of 90 minutes per week.

3. Upon written notice to LADWP, irrigation of sports fields may deviate from non-watering days to maintain play areas and accommodate event schedules; however, to be eligible for this means of compliance, a customer must reduce his overall monthly water use by LADWP's Board of Water and Power Commissioner's (Board) adopted degree of shortage plus an additional 5 percent from the customer baseline water usage within 30 days.

4. Upon written notice to LADWP, large landscape areas may deviate from the non-watering days by meeting the following requirements (1) must have approved weather-based irrigation controllers registered with LADWP (eligible weather-based irrigation controllers are those approved by MWD or the Irrigation Association Smart Water Application Technologies (SWAT) initiative (2) must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus an additional 5 percent from the customer baseline water usage within 30 days; and (3) must use recycled water if it is available from LADWP.

5. These provisions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase II except between the hours of 9:00 am and 4:00 pm.

Severe Shortage, Phase III

1. Should Phase III be implemented, uses applicable to Phases I and II shall continue to be applicable, except as specifically provided herein.

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2. No landscape irrigation shall be permitted on any day other than Monday for odd-numbered street addresses and Tuesday for even-numbered street addresses. Street addresses ending in ½ or any fraction shall conform to the permitted uses for the last whole number in the address.

3. No washing of vehicles allowed except at commercial car wash facilities.

4. No filling of residential swimming pools and spas with potable water.

5. Upon written notice to LADWP, irrigation of sports fields may deviate from the specific non-watering days and be granted one additional water day (for a total of two watering days allowed). To be eligible for this means of compliance, a customer must reduce his overall monthly water use by LADWP's Board's adopted degree of shortage plus an additional 10 percent from the customer baseline water usage within 30 days.

6. Upon written notice to LADWP, large landscape areas may deviate from the specific non-watering days and be granted one additional watering day (for a total of two watering days allowed) by meeting the following requirements (1) must have approved weather-based irrigation controllers registered with LADWP (eligible weather-based irrigation controllers are those approved by MWD or the Irrigation Association Smart Water Application Technologies (SWAT) initiative (2) must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus an additional 10 percent from the customer baseline water usage within 30 days; and (3) must use recycled water if it is available from LADWP.

7. These provisions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase III except between the hours of 9:00 am and 4:00 pm.

Critical Shortage, Phase IV

1. Should Phase IV be implemented, uses applicable to Phases I, II, and III shall continue to be applicable, except as specifically provided herein.

2. No landscape irrigation allowed.

Super Critical Shortage, Phase V

1. Phase I, II, III, and IV shall continue to remain in effect.

2. The Board is hereby authorized to implement additional prohibited uses of water based on the water supply situation. Any additional prohibitions shall be published at least once in a daily newspaper of general circulation and shall become effective immediately upon such publication and shall remain in effect until cancelled.

11.3.2 Driest Three-Year Supply – 10632 (b)

In the event that three consecutive dry-years curtailing the City's LAA System deliveries should follow the 2010 water supply conditions, LADWP will rely on increased groundwater pumping and purchases from MWD to meet City water demands. This particular sequence is quantified in Exhibit 11L, including relevant assumptions.

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Exhibit 11L
Driest Three-Year Water Supply Sequence

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Followed by Repeat of Driest Three Consecutive Years FY1958-59 to 1960-61 Hydrology Fiscal Year Ending on June 30		
		2011	2012	2013
Total Demand	**554,140**	**588,900**	**607,300**	**626,000**
Existing / Planned Supplies				
Los Angeles Aqueduct[1]	199,739	104,530	50,849	59,382
Groundwater[2]	76,982	61,090	53,660	46,260
Conservation	8,178	5,670	7,310	8,950
Recycled Water				
- Irrigation and Industrial Use	6,703	7,500	8,300	9,000
- Groundwater Replenishment	0	0	0	0
Water Transfers	0	0	0	40,000
Subtotal	291,602	178,790	120,119	163,592
MWD Water Purchases				
With Existing/Planned Supplies	262,538	410,110	487,181	462,408
Total Supplies	**554,140**	**588,900**	**607,300**	**626,000**

1. Driest three consecutive years on record in LAA watershed (FY1958-59 to FY1960-61) averaged 28 percent of normal runoff.
2. LAA deliveries reflect increased releases for environmental restoration in the Owens Valley and Mono Basin.
3. Dry year demands are 5 percent greater than normal year demands
4. MWD's Water Surplus and Drought Management Plan actions sufficient to meet LADWP demands.

During such severe drought periods, the City's supplemental water supplier, MWD, may use an allocation strategy that is consistent with the framework developed in its Water Surplus and Drought Management (WSDM) Plan. Developed by MWD with substantial input from its member agencies, the WSDM Plan provides for a needs-based allocation strategy, and establishes priorities for the use of MWD's water supplies to achieve 100 percent retail reliability.

Following are actions that could be taken by MWD in accordance with their WSDM Plan to augment its water supplies prior to implementation of any drought allocation action:

1. Draw on Diamond Valley Lake storage
2. Draw on out-of-region storage in Semitropic and Arvin-Edison Groundwater Banks
3. Reduce/suspend local groundwater replenishment deliveries
4. Draw on contractual groundwater storage programs in MWD's service area

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5. Draw on State Water Project terminal reservoir storage (per Monterey Agreement)
6. Call for voluntary conservation and public education
7. Reduce deliveries from MWD's Interim Agricultural Water Program
8. Call on water transfer options contracts
9. Purchase transfers on the spot market
10. Allocate imported water if necessary

In 2008 MWD adopted the Water Supply Allocation Plan (WSAP) designed to allocate supplies among its member agencies in a fair and efficient manner. The WSAP establishes the formula for calculating member agency allocations if MWD cannot meet firm demands in a given year.

11.3.3 Catastrophic Supply Interruption Plan – 10632 (c)

LADWP has Emergency Response Plans (ERPs revised January 2010) in place to restore water service for essential use in the City if a disaster should result in the temporary interruption of water supply. Department personnel responsible for water transportation, distribution, and treatment have established ERPs to guide the assessment, prioritization, and repair process of City facilities that have incurred damage during a disaster. Citywide, an Emergency Operations Center (EOC) serves as a centralized point for citywide management of information about disasters and for coordination of all available resources. The EOC supports the City's Emergency Operations Organization to achieve its mission of saving lives, protecting property, and returning the City to normal operations in the event of a disaster. LADWP coordinates its efforts with the EOC and will utilize the EOC to resume water supply service after a catastrophic event.

11.3.4 Mandatory Water Use Prohibitions – 10632 (d)

Phase I prohibited uses of the Emergency Water Conservation Plan contain 13 wasteful water use practices that are permanently prohibited for all City of Los Angeles customers. These prohibited uses are intended to eliminate waste and increase public awareness of the need to conserve water. During times of shortage, education and enforcement of the following provisions will be increased:

1. No customer shall use a water hose to wash any paved surfaces including, but not limited to, sidewalks, walkways, driveways, and parking areas, except to alleviate immediate safety or sanitation hazards. This section shall not apply to LADWP approved water conserving spray cleaning devices. Use of water pressure devices for graffiti removal is exempt. A simple spray nozzle does not qualify as a water conserving spray cleaning device.
2. No customer shall use water to clean, fill, or maintain levels in decorative fountains, ponds, lakes, or similar structures used for aesthetic purposes unless such water is part of a recirculating system.
3. No restaurant, hotel, cafe, cafeteria, or other public place where food is sold, served, or offered for sale shall serve drinking water to any person unless expressly requested.
4. No customer shall permit water to leak from any pipe or fixture on the customer's premises; failure or refusal to affect a timely repair of any leak of which the customer knows or has reason to know shall subject said customer to all penalties

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for a prohibited use of water.

5. No customer shall wash a vehicle with a hose if the hose does not have a self-closing water shut-off device or device attached to it, or otherwise to allow a hose to run continuously while washing a vehicle.

6. No customer shall irrigate during periods of rain.

7. No customer shall water or irrigate lawn, landscape, or other vegetated areas between the hours of 9:00 a.m. and 4:00 p.m. During these hours, public and private golf courses greens and tees and professional sports fields may be irrigated in order to maintain play areas and accommodate event schedules. Supervised testing or repairing of irrigation systems is allowed anytime with proper signage.

8. All irrigating of landscape with potable water using spray head sprinklers and bubblers shall be limited to no more than ten minutes per watering station per day. All irrigating of landscape with potable water using standard rotors and multi-stream rotary heads shall be limited to no more than fifteen minutes per cycle and up to two cycles per watering day per station. Exempt from these irrigation restrictions are irrigation systems using very low drip type irrigation when no emitter produces more than four gallons of water per hour and micro-sprinklers using less than fourteen gallons per hour. This provision does not apply to Schedule F water customers or water service water service that has been granted the General Provision M rate adjustment under the City's Water Rates Ordinance, subject to the Customer having complied with best management practices for irrigation approved by the Department. The 9:00 a.m. to 4:00 p.m. irrigation restriction shall apply unless specifically exempt as stated in subsection 7 of the Emergency Water Conservation Ordinance.

9. No customer shall water or irrigate any lawn, landscape, or other vegetated area in a manner that causes or allows excess or continuous flow or runoff onto an adjoining sidewalk, driveway, street, gutter, or ditch.

10. No installation of single pass cooling systems shall be permitted in buildings requesting new water service.

11. No installation of non-recirculating systems shall be permitted in new conveyor car wash and new commercial laundry systems.

12. Operators of hotels and motels shall provide guests with the option of choosing not to have towels and linens laundered daily. The hotel or motel shall prominently display notice of this option in each bathroom using clear and easily understood language. LADWP shall make suitable displays available.

13. No large landscape areas shall have irrigation systems without rain sensors that shut-off the irrigation systems. Large landscape areas with approved weather-based irrigation controllers registered with LADWP are in compliance with this requirement.

11.3.5 Consumption Reduction Methods during Water Shortages – 10632 (e)

Short-Term Actions

During a water shortage or emergency condition, LADWP's existing rate structure (enacted in 1993) serves as a basis for further reducing consumption. First tier water allotments are reduced during shortages by the degree of the shortage. For single-family residential users, the adjusted first tier allotments apply for the entire year. For other users, the adjusted first tier allotments apply only during the high season (June 1 through October 31). Details of LADWP's water rate structure are provided in Appendix X – Water Rate Ordinance.

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Additional measures can be phased in as the dry cycle continues to provide some immediate demand reductions and increase public awareness of the need to conserve water. Included among these measures are water conservation public service announcements (through television and/or radio), billboard ads, flyer distributions, and conservation workshops. LADWP also actively participates in public exhibits to disseminate water conservation information within its service area. Conservation is a permanent and long-term application used within the City to counter the potentially adverse impacts of water supply shortages.

State law further regulates distribution of water in extreme water shortage conditions. Section 350-354 of the California Water Code states that when a governing body of a distributor of a public water supply declares a water shortage emergency within its service area, water will be allocated to meet needs for domestic use, sanitation, fire protection, and other priorities. This will be done equitably and without discrimination between customers using water for the same purpose(s).

Long-Term Actions

LADWP's long-range water conservation program is driven by the need to continuously increase water use efficiency. This will reduce demand, extend supply, and therefore, provide greater reliability. Dry cycle experiences, public trust responsibilities, and regulatory mandates have raised the level of awareness within the City of Los Angeles of the need to approach demand reduction from a permanent and long-term perspective.

LADWP will continue to maintain and increase its existing conservation programs and pursue the development of new and innovative programs as outlined in Chapter 3, Water Conservation with the goal of reducing potable water demands by 60,000 AFY by 2035. Emphasis continues to be placed on structural conservation for the residential and CII sectors (HETs, high-efficiency washing machine rebates, etc.) which result in permanent per capita water use reduction. Substantial efforts are also being placed on landscape water use efficiency and CII conservation opportunities. It should, however, be recognized that the ability to achieve water reduction during shortages by requesting additional voluntary measures is likely to be more difficult in the future. As customers adjust to a conservation ethic and adopt permanent measures to reduce water use, their water demands harden and become less susceptible to voluntary conservation.

11.3.6 Penalties for Excessive Use (Non-Compliance to Prohibited Use) – 10632 (f)

The Emergency Water Conservation Plan sets penalties for violations of prohibited uses outlined in Sections 10632 (a) and (d). The penalties vary by water meter size. For water meters smaller than two inches the following penalties shall apply:

1. The first violation consists of a written warning

2. The second violation within the preceding 12 month period will result in a surcharge in the amount of $100 added to the customer's water bill.

3. The third violation within the preceding 12 month period will result in a surcharge in the amount of $200 added to the customer's water bill.

4. The fourth violation within the preceding 12 month period will result in a surcharge in the amount of $300 added to the customer's water bill.

5. After a fifth violation or subsequent violation within the preceding 12 month period, LADWP may install a flow-restricting device of 1 gpm capacity for services up to 1 ½ inches in size and comparatively sized restrictors for larger services or

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terminate a customer's service, in addition to the aforementioned financial surcharges. Such action shall only be taken after a hearing held by LADWP.

For water meters two inches and larger the following penalties shall apply:

1. The first violation consists of a written warning
2. The second violation within the preceding 12 month period will result in a surcharge in the amount of $200 added to the customer's water bill.
3. The third violation within the preceding 12 month period will result in a surcharge in the amount of $400 added to the customer's water bill.
4. The fourth violation within the preceding 12 month period will result in a surcharge in the amount of $600 added to the customer's water bill.
5. After a fifth violation or subsequent violation within the preceding 12 month period, LADWP may install a flow-restricting device or terminate a customer's service, in addition to the aforementioned financial surcharges. Such action shall only be taken after a hearing held by LADWP.

11.3.7 Analysis and Effects on Revenues and Expenditures of Reduced Sales during Shortages – 10632 (g)

The City's Water Rate Ordinance, adopted in June 1995 and last amended in June 2008, provides a remedy to the impact of reduced water sales on revenues in the form of a Water Revenue Adjustment Factor (Adjustment). The Adjustment recovers any shortage in revenue due to variation in water sales. It is intended to support a fiscal year revenue target that is deemed sufficient to cover LADWP's essential expenses. The formula takes into account target and actual revenues as well as projected water sales to determine the appropriate Adjustment.

The Adjustment is currently limited to $.18 per hundred-cubic-feet. It cannot exceed this limit unless the Board determines that a surcharge in excess of $0.18 per hundred-cubic-feet is financially required and approval from the Los Angeles City Council is obtained. The Board also has the authority to reduce the factor to less than the formula-calculated amount.

A billing factor is calculated annually on January 1 and is added to the standard commodity charge. The factor is set to zero if a negative value is calculated. A Water Revenue Adjustment Account is maintained and updated each month by LADWP. This account is adjusted annually on July 1.

The City's Water Revenue Adjustment Factor ensures that the required funds are available to fund Department activities aimed at providing continuous water service to Los Angeles water users, even during periods of low water sales.

11.3.8 Water Shortage Contingency Resolution or Ordinance – 10632 (h)

A draft water shortage contingency resolution is shown in Exhibit 11M. Moreover, the City's Emergency Water Conservation Plan Section 121.07.B has the following conservation phase implementation procedures:

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"The Department (LADWP) shall monitor and evaluate the projected supply and demand for water by its Customers monthly, and shall recommend to the Mayor and Council by concurrent written notice the extent of the conservation required by the Customers of the Department in order for the Department to prudently plan for and supply water to its Customers. The Mayor shall, in turn, independently evaluate such recommendation and notify the Council of the Mayor's determination as to the particular phase of water conservation, Phase I through Phase V, that should be implemented. Thereafter, the Mayor may, with the concurrence of the Council, order that the appropriate phase of water conservation be implemented in accordance with the applicable provisions of this Article. Said order shall be made by public proclamation and shall be published one time only in a daily newspaper of general circulation and shall become effective immediately upon such publication. The prohibited water uses for each phase shall take effect with the first full billing period commencing on or after the effective date of the public proclamation by the Mayor. In the event the Mayor independently recommends to the Council a phase of conservation different from that recommended by the Department, the Mayor shall include detailed supporting data and the reasons for the independent recommendation in the notification to the Council of the Mayor's determination as to the appropriate phase of conservation to be implemented."

The City's Water Rate Ordinance No. 170435 also has specific provisions for LADWP's Board, through a resolution, to determine the degree of shortage and apply corresponding commodity charges in case of a water shortage (see Section 11.3.5 and Appendix X – Water Rate Ordinance). If a water shortage is declared, certified copies of the resolution will be transmitted to the offices of the Mayor and of the Los Angeles City Clerk, and the Los Angeles City Council for final approval. This particular water shortage act is included under Section 3 – General Provisions, Article R – Shortage Year Rates of the City's Water Rate Ordinance.

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Exhibit 11M
Draft Water Shortage Contingency Resolution

BE IT RESOLVED that the Board of Water and Power Commissioners (Board) recognizes that a Water Shortage Contingency Plan has been prepared and incorporated into the City of Los Angeles 2010 Urban Water Management Plan pursuant to the Urban Water Management Planning Act; the Urban Water Management Plan is on file with the Secretary of the Board; this Board has reviewed and considered the information and recommendations contained in this document, and makes the following findings and determinations:

1. The water supply available to the City of Los Angeles is insufficient to meet the City's normal water supply needs; and
2. The Department of Water and Power has developed a Water Shortage Contingency Plan for the City of Los Angeles that compiles with all the requirements of the Urban Water Management Planning Act; and
3. The Urban Water Management Plan has been developed, adopted, and implemented pursuant to Article 3, Sections 10640 through 10645 of the Urban Water Management Planning Act; and
4. The Water Shortage Contingency Plan includes stages of action that can be taken in response to water supply shortages, including up to a 50 percent reduction in water supply, a driest three-year water supply scenario, mandatory water use prohibitions, and penalties for non-compliance; and
5. The Water Shortage Contingency Plan identifies both short-term and long-term actions to maximize water use efficiency and minimize the effects of the current water shortage as well as future water supply shortages.

BE IT FURTHER RESOLVED that this Board has adopted the Water Shortage Contingency Plan as incorporated in the Urban Water Management Plan, and declares the provisions of the Water Shortage Contingency Plan in full force and effect during the duration of this period of water shortage.

I HEREBY CERTIFY that the foregoing is a full, true, and correct copy of the resolution adopted by the Board of Water and Power Commissioners of the City of Los Angeles at its meeting held

11.3.9 Methodology to Determine Actual Water Use Reductions during Shortages – 10632 (i)

Water use is monitored closely by LADWP throughout its service area regardless of the supply conditions. With 100 percent of its over 700,000 service connections metered, there is a high degree of accountability on the quantity of water used within the Los Angeles service area. Information from meter reads is collected for billing and accounting purposes, with reports prepared on a monthly basis from the data compiled.

LADWP also used a conservation model to estimate conservation efforts within the City since the early 1990s. The model estimated City water demand without conservation efforts using population and weather variables. A new conservation model was developed in 2010 to account for additional factors such as economic recession and drought conservation is discussed in Chapter 2, Water Demand. The conservation effort is derived by comparing estimated pre-conservation demand with actual demand. Conservation efforts derived from this model are shown in Chapter 3, Water Conservation.

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11.4 Water Supply Assessments

Background

In 1994, the California Legislature enacted Water Code section 10910 (Senate Bill 901), which requires cities and counties, as part of the California Environmental Quality Act (CEQA) review, to request the applicable public water system to assess whether the system's projected water supplies were sufficient to meet a proposed development's anticipated water demand. The intent was to link the land use and water supply planning processes to ensure that developers and water supply agencies communicate early in the planning process. However, a study of projects approved by local planning agencies revealed that numerous projects were exempted due to loopholes in the statute, and that the intent of the legislation has largely gone unfulfilled.

Subsequently, California Senate Bill (SB) 610 and SB 221, modeled after SB 901, amended State law effective January 1, 2002, to ensure that the original intent of the legislation is fulfilled. SB 610 and 221 are companion measures which seek to promote more collaborative planning between local water suppliers and cities and counties. These bills improve the link between information on water supply availability and certain land use decisions made by cities and counties. Both statutes require detailed information regarding water availability to be provided to the city and county decision-makers prior to approval of specified large development projects. Both statutes also require this detailed information be included in the administrative record that serves as the evidentiary basis for an approval action by the city or county on such projects. Both measures recognize local control and decision making regarding the availability of water for projects and the approval of projects.

Under SB 610 a water supply assessment (WSA) must be furnished to local governments for inclusion in any environmental documentation for certain development projects subject to the CEQA. Specifically, SB 610 requires that for certain projects, the CEQA lead agency must identify any public water system that may supply water to the proposed project and request the public water system to determine the water demand associated with the project and whether such demand was included as part of the most recently adopted UWMP. If the projected water demand associated with the proposed project was accounted for in the most recently adopted UWMP, the public water system may incorporate the supporting information from the UWMP in preparing the elements of the assessment. If the proposed project's water demand was not accounted for in the most recently adopted UWMP, the WSA for the project shall include a discussion with regard to whether the public water system's total projected water supplies available in normal, single dry, and multiple dry water years during a 20-year projection will meet the proposed project's water demand.

Per Section 10912 of the California Water Code, a project which is subject to the requirements of SB 610 includes: (1) a proposed residential development of more than 500 dwelling units; (2) a proposed shopping center or business establishment employing more than 1,000 persons or having more than 500,000 square feet of floor space; (3) a proposed commercial office building employing more than 1,000 persons or having more than 250,000 square feet of floor space; (4) a proposed hotel or motel, or both, having more than 500 rooms; (5) a proposed industrial, manufacturing, or processing plant, or industrial park planned to house more than 1,000 persons, occupying more than 40 acres of land, or having more than 650,000 square feet of floor area; (6) a mixed-use project that includes one or more of the projects specified in this subdivision; or (7) a project that would demand an amount of water equivalent to, or greater than, the amount of water required by a 500 dwelling unit project.

The assessment would include an identification of existing water supply entitlements, water rights, or water service contracts relevant to the identified water supply for the proposed project and water received in prior years pursuant to those

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entitlements, rights, and contracts. If the assessment concludes that water supplies will be insufficient, plans for acquiring additional water supplies would need to be presented.

Under SB 221, approval by a city or county of certain developments requires an affirmative written verification of sufficient water supply; which is a "fail safe" mechanism to ensure collaboration on finding the needed water supplies to serve a new large development occurs before construction begins.

Methodology

During the years from 2005 to 2010, LADWP has been requested to develop over 40 WSAs. Each WSA performed by LADWP is carefully evaluated within the context of the current adopted UWMP and current conditions, such as restrictions on State Water Project (SWP) pumping from the Sacramento-San Joaquin Delta imposed by a Federal Court. The Metropolitan Water District of Southern California (MWD), from whom the City purchases its State Water Project and Colorado River water supplies, has also been actively developing plans and making efforts to provide additional water supply reliability for the entire Southern California region. LADWP coordinates closely with MWD to ensure implementation of MWD's water resource development plans and supplemental water reliability report prepared by MWD.

LADWP's UWMP uses a service area-wide method in developing City water demand projections. This methodology does not rely on individual development demands to determine area-wide growth. Rather, the growth in water use for the entire service area was considered in developing long-term water projections for the City to the Year 2035. The driving factors for this growth are demographics, weather, and conservation. LADWP used anticipated growth in the various customer class sectors as provided by MWD who reallocated projected demographic data from the Southern California Association of Governments (SCAG) into member agencies' service areas. The data used was based on SCAG's 2008 Regional Transportation Plan Forecast.

As governed by City Charter Sections 673 and 677, LADWP can serve surplus water supplies to areas outside of the City boundaries. There are approximately 4,500 services for customers outside of the City, with a combined annual water use less than 1 percent of all water delivered. Water served outside of the City includes a surcharge to account for the increased MWD purchased water.

The water demand forecast model in the UWMP was developed using LADWP total water use, including the water served by LADWP for use outside of the City. The service area reliability assessment was performed for three hydrologic conditions: average year, single dry year, and multiple-dry years; and a Shortage Contingency Plan was developed to provide for a sufficient and continuous supply in LADWP's service area. This Shortage Contingency Plan included water provided for use outside of the City.

An important part of the water planning process is for LADWP to work collaboratively with MWD to ensure that anticipated water demands are incorporated into MWD's long-term water resources development plan and water supply allocation plan. The City's allotment of MWD water supplies under MWD's water supply allocation plan is based on the City's total water demand which includes services to areas outside the City. The ongoing collaboration between LADWP and MWD is critical in ensuring that the City's anticipated water demands are incorporated into the development of MWD's long-term Integrated Resources Plan (IRP). MWD's IRP directs a continuous regional effort to develop regional water resources involving all of MWD's member agencies. Successful implementation of MWD's IRP has resulted in reliable supplemental water supplies for the City from MWD.

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In summary, the WSAs are performed to ensure that adequate water supplies would be available to meet the estimated water demands of the proposed developments during normal, single-dry, and multiple-dry water years, as well as existing and planned future uses of the City's water system. LADWP will continue to perform WSAs as part of its long-term water supply planning efforts for its service area.

WSA Procedure

The CEQA lead agency, such as the Department of City Planning or the Community Redevelopment Agency of the City of Los Angeles, evaluates the proposed project against the requirements for a WSA in accordance with the Water Code. If the proposed project falls within the requirements for a WSA, a formal request is submitted to LADWP to perform a WSA.

In evaluating the proposed project's water demand, LADWP applies the Sewer Generation Factors (published by City of Los Angeles Bureau of Sanitation) to the development's project description for calculating indoor water use. Outdoor landscape water demand is calculated by using computer software which takes into account various factors such as landscape area square footage, location, and plant types. Historical billing records are used to establish existing baseline water demand on the property.

LADWP also encourages all projects to implement additional water conservation measures above and beyond the current water conservation ordinance requirements. As an example, if the proposed development is near an existing or future recycled water pipeline system, commitment to use recycled water for irrigation, toilet flushing and cooling towers is highly recommended as part of the additional conservation measures for the proposed development.

The net increase/decrease in water demand, which is the projected additional water demand of the development, is calculated by subtracting the existing baseline water demand and water saving amount from the total proposed water demand.

The net increase/decrease in water demand, which is the projected additional water demand of the development, is calculated by subtracting the existing baseline water demand and water saving amount from the total proposed water demand. If the land use of the proposed development is consistent with the City's General Plan, the projected water demand of the development is considered to be accounted for in the most recently adopted UWMP. The City incorporates the projected demographic data from the SCAG in its General Plan. MWD utilizes a land use based planning tool that allocates SCAG's projected demographic data into water service areas for their member agencies, which was adopted for water demand projection in the UWMP.

If the proposed land use is not consistent with the City's General Plan, the WSA will further evaluate if the projected supplies from the UWMP are able to accommodate the proposed project's water demand, which may include other resource options to offset the projected water demand.

All WSAs are subject to approval by the Board of Water and Power Commissioners. Upon approval, the lead agency is responsible for enforcing the requirements of the WSA as part of the approval for the project.

AR0071021

DRAFT Chapter Twelve
Climate Change

12.0 Overview

LADWP is considering impacts of climate change during development of its long-term water supply plan. Climate change is a global-scale concern, but is particularly important in the western United States where potential impacts on water resources can be significant to supplies for water agencies. Climate change can impact surface supplies from the LAA, imported supplies from MWD, and local demands. As a result, LADWP is completing a study to analyze the operational and water supply impacts of potential shifts in the timing and quantity of runoff along the LAA system due to climate change. Such potential shifts may require LADWP to develop, enhance, and modify management of local water resources. Projected changes in climate are expected to alter hydrologic patterns in the Eastern Sierra through changes in precipitation, snowmelt, relative ratios of rain and snow, winter storm patterns, and evapotranspiration.

To understand some of the key issues surrounding climate change impacts, it is important to put it into the context of LADWP's water supplies. California lies within multiple climate zones. Therefore, each region will experience unique impacts to climate change. Because LADWP relies on both local and imported water sources, it is necessary to consider the potential impacts climate change could have on the local watershed as well as the western and eastern Sierra Nevada watersheds where a portion of MWD's imported water originates and LADWP's imported LAA supplies originate, respectively, and the Colorado River Basin where the remainder of MWD's imported supplies originate.

Generally speaking, any water supplies that are dependent on natural hydrology are vulnerable to climate change, especially if the water source originates from mountain snow pack. For LADWP, the most vulnerable water sources subject to climate change impacts are imported water supplies from MWD and the LAA. However, local sources can expect to see some changes in the future as well. In addition to water supply impacts, changes in local temperature and precipitation are expected to alter water demand patterns. However, there is still general uncertainty within the scientific community regarding the potential impacts of climate change for the City of Los Angeles. LADWP will continue to stay abreast of developments in climate change to better understand its potential implications to the City's water supplies.

12.1 Potential Impacts of Climate Change on Water Service Reliability

Scientists predict future climate change scenarios using highly complex computer global climate models (GCMs) to simulate climate systems. Although most of the scientific community agrees that climate change is occurring and, as a result, mean temperatures for the planet will increase, the specific degree of this temperature increase cannot be accurately predicted. Predictions of changes in precipitation are even more speculative, with some scenarios showing precipitation increasing in the future and others showing the opposite.

It is important to acknowledge that the predictions of the GCMs lack the desired precision due to the presence of uncertainties inherent in the analyses. The uncertainty to future emissions of greenhouse gases and the chaotic nature of the climate system leads to uncertain response of the global climate system to the increases in greenhouse gases. In addition, the science of climate change still lacks the complete understanding of regional manifestations that will result from global changes, thus restraining the projecting capacity of these models. However, these projections are consistent with the state of science today, and they help predict the manner of which hydrologic variables are likely to respond to a range of possible future climate conditions, and thus provide invaluable insight to water managers in their decisions pertaining to water supply reliability.

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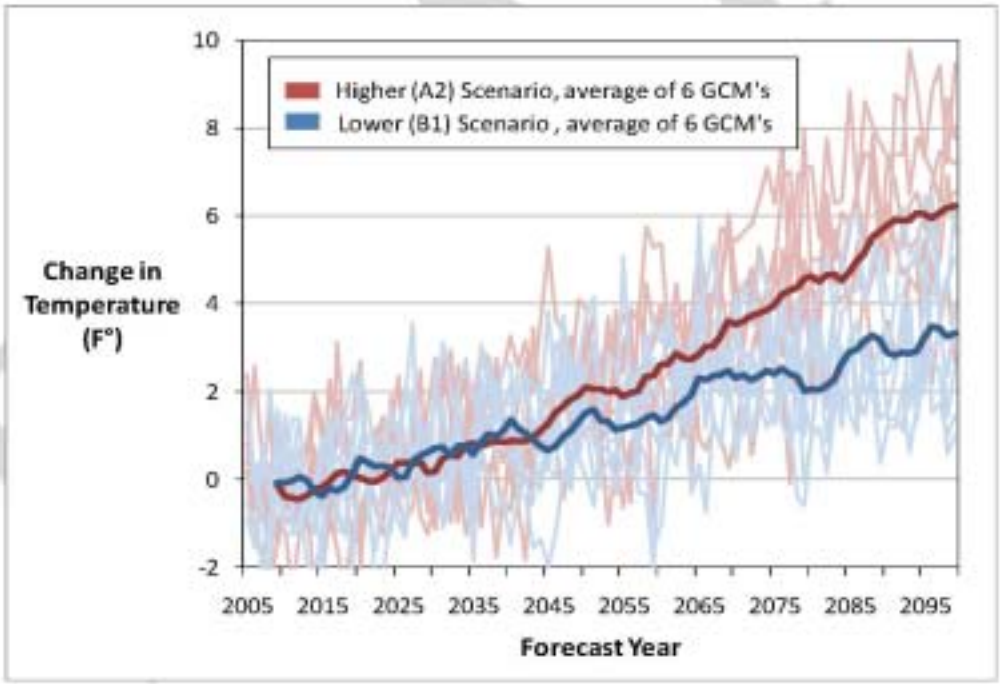
The regional areas of interest in assessing climate change impacts to LADWP include the local service area and sources of origination for imported water supplies in northern California, eastern Sierra Nevada Mountains, and the Colorado River Basin. Data regarding climate change impacts for the various regions of interest is provided in this section.

12.1.1 Local Impacts

Most scientific experts believe that because of the uncertainty involved with each model, several models should be used to test the potential impact of climate change. To downsize the global coarse-scale climate projections to a regional level incorporating local weather and topography, the GCMs are "downscaled". Future projections of precipitation and temperature were obtained for six GCMs under two greenhouse gas emission scenarios (A2 - higher and B1 - lower) for Los Angeles County.[1,2] Exhibits 12A and 12B plot the changes in projected average annual mean temperature and precipitation, respectively for the model scenarios. The bold line represents the running average of all six models for each emission scenario. The six models were also used in the preparation of the 2008 California Climate Change Scenarios assessment.

Note Exhibits 12X and 12X are placeholders and are for illustrative purposes only of the type of data that will be presented for Los Angeles. The data in the figures represent data obtained from the Scripps Institute of Oceanography for the Pasadena area. Similar data has been requested for Los Angeles.

Exhibit 12A
Climate Change Impacts to Local Temperatures for Los Angeles (Placeholder)



[1] Dan Cayan and Mary Tyree (University of California, San Diego, Scripps Institute of Oceanography) provided downscaled data for Pasadena under two emissions scenarios from six climate models: CNRM CM3, GFDL CM2.1, Miroc3.2 (medium resolution), MPI ECHAM5, NCAR CCSM3, NCAR PCM1.

[2] Note: These scenarios do not bracket the highest and lowest emission futures possible, but represent a status quo approach (A2) and a pro-active mitigation (B1) approach to reduce carbon emissions.

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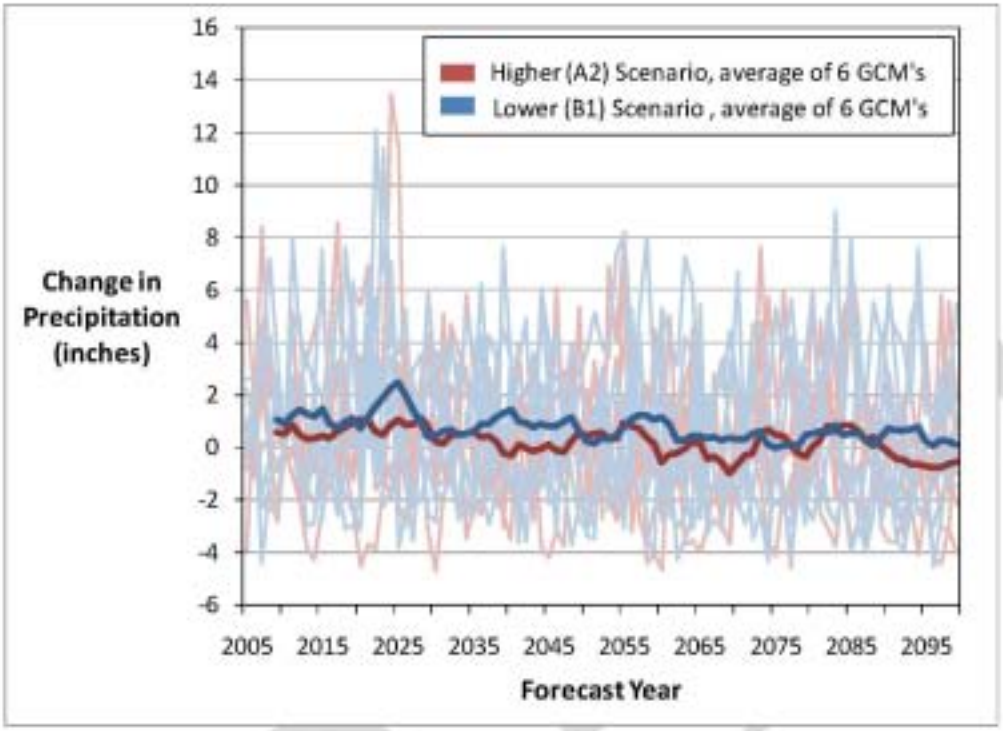
Exhibit 12B

Climate Change Impacts to Local Precipitation for Los Angeles (Placeholder)



Local climate changes within the vicinity of the LADWP service area are expected to include:

- An increase in average temperatures that will be more pronounced in the summer than in the winter with annual mean temperatures in 2100 increasing greater than 3°Fwhen lower greenhouse gas emission scenarios are used and may exceed 7°F when high higher emissions scenarios are used dependent upon the GCM utilized
- An increase in extreme temperatures
- An increase in heat waves and droughts that will extend for a longer duration
- A decrease in precipitation with the potential for 30 year deficits of more than 10% below historical levels that, coupled with higher temperatures, will increase evaporation/transpiration
- An increase in short-duration/high volume intense storm events during the winter

The impact of these climate effects will likely be increased water demands for irrigation and cooling purposes earlier in the year and for extended periods coupled with decreased local surface runoff available to recharge groundwater basins. Other impacts might include increased fire events that could impact water quality and sedimentation, decreased groundwater recharge due to lower soil moisture, and sea level rise increasing seawater intrusion into coastal groundwater basins.

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12.1.2 Los Angeles Aqueduct Impacts

The LAA is one of the major imported water sources delivering a reliable water supply to the City of Los Angeles. The LAA originates approximately 340 miles away from snowmelt runoff in the eastern Sierra Nevada; hence LAA is subject to hydrologic variability associated with climate change. Since the majority of precipitation occurs during winter in the eastern Sierra Nevada watershed, water is stored in natural reservoirs in the form of snowpacks, and is gradually released into streams that feed into the LAA during spring and summer. More detailed information regarding the LAA is presented in Chapter 5, Los Angeles Aqueduct Systems.

Higher concentrations of greenhouse gases in the atmosphere are often indications of pending climate change. These changes threaten the hydrologic stability of the eastern Sierra Nevada watershed through alterations in precipitation, snowmelt, relative ratios of rain and snow, winter storm patterns, and evapotranspiration, all of which have major potential impacts on the LAA water supply and deliveries.

To address the possible challenges posed by climate change on the LAA, LADWP commenced a climate change study in 2009 to evaluate the potential impacts of climate change on the eastern Sierra Nevada watershed and the LAA water supply and deliveries, and investigate opportunities to improve the LAA system as a result of these impacts over the next hundred years. In this study, future climate conditions are predicted using a set of sixteen GCMs and two greenhouse gas emission scenarios.

The impacts of these climate change scenarios and the associated hydrology on the LAA's eastern Sierra Watershed includes an analysis of historical temperature, precipitation, water quality, and runoff records. Hydrologic modeling will be performed to estimate runoff changes from current conditions and an evaluation will be provided to determine their effects on the performance of the existing infrastructure with regards to storage and conveyance capacity to Los Angeles. As part of the evaluation of potential adaptation measures if existing infrastructures are inadequate, recommendations will be provided to modify the existing infrastructure and operations to accommodate these impacts.

Preliminary results of the study are showing steady temperature increases throughout the 21st century and are consistent with other prior studies performed in the scientific community. Exhibit 12C displays the time series of 30-year running means of the projected temperature of one of the greenhouse gas emission scenarios considered in the study, A2 (higher greenhouse gas emissions), averaged over the simulation area for each of the sixteen GCMs. All GCMs project temperature increases throughout the 21st century.

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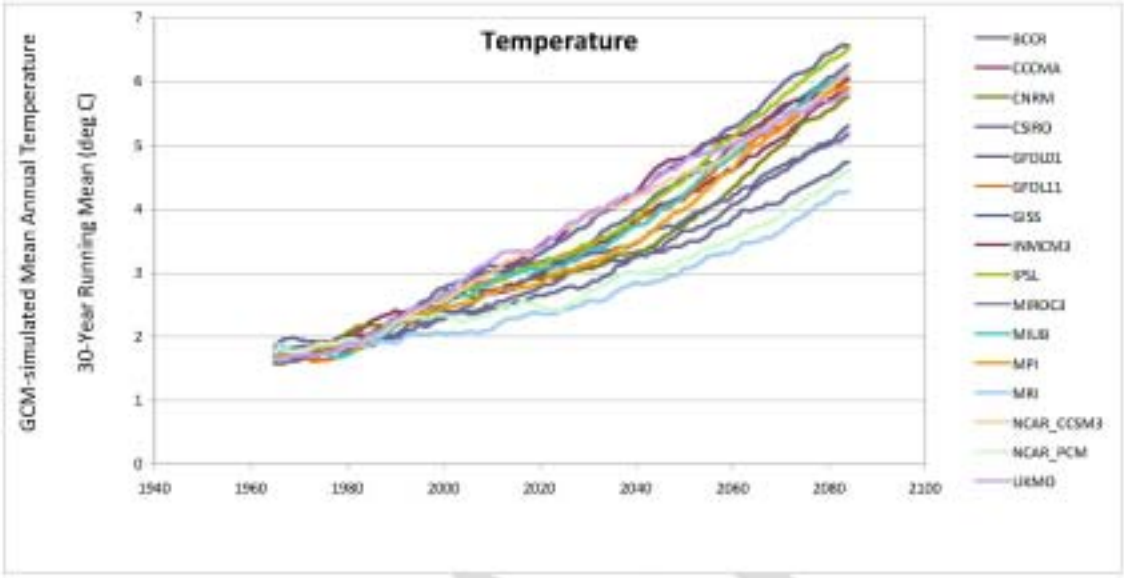
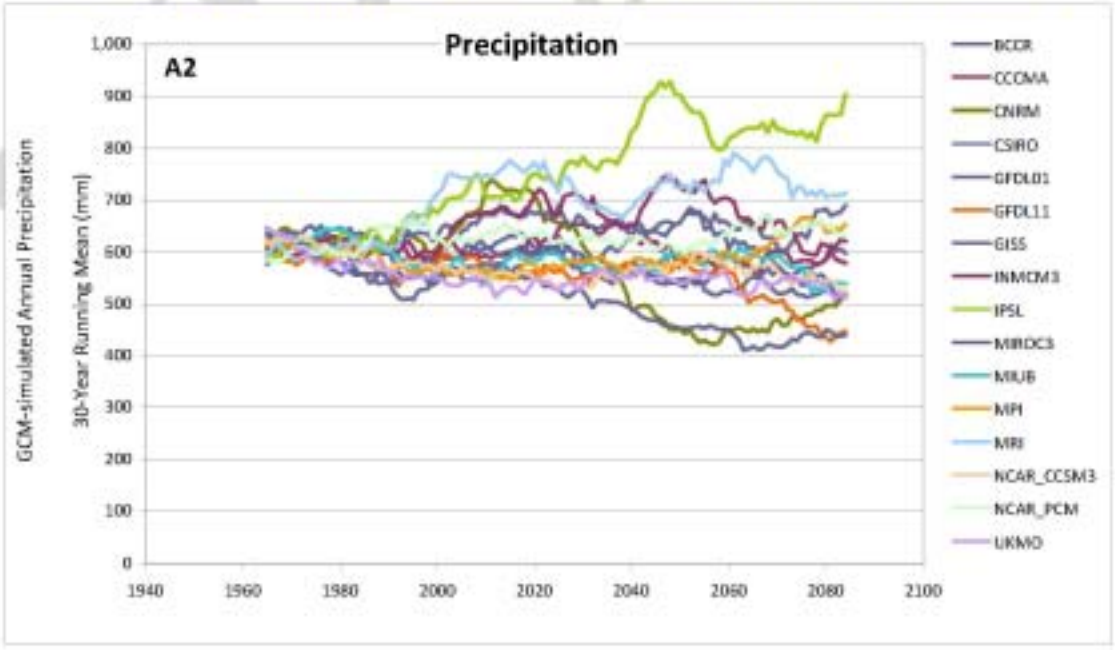
Exhibit 12C
30-Year Time Series Projected Temperature Means for Eastern Sierra Nevada Watershed



On the other hand, forecasts for precipitation differ greatly between the GCMs. Some GCMs are projecting increases, but the majority of the model outputs are projecting decreases in precipitation over the study period. Exhibit 12D displays the time series of 30-year running means of the projected precipitation using the A2 greenhouse gas emission scenario (higher greenhouse gas emissions) averaged over the simulation area for each of the sixteen GCM models.

Exhibit 12D
30-Year Time Series Projected Precipitation Means for Eastern Sierra Nevada Watershed



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Temperature is the main climate variable that is projected to rise significantly in the coming years and decades. The rise in temperature directly affects several variables including:

- Whether precipitation falls as snow or rain;
- The ground-level temperature determines the timing and rate of snowmelt; and
- The temperature profile in the canopy that determines the rate of evapotranspiration.

Preliminary results have shown that future predictions for the early-21st century suggested a warming trend of 0.9 to 2.7 °F and almost no change in average precipitation. Mid-21st century projections suggested a warming trend of 3.6 to 5.4 °F and a small average decrease in precipitation, approximately 5 percent. This warming trend is expected to increase by the end of 21st century, as the results suggest further warming of 4.5 to 8.1 °F and a decrease in precipitation of approximately 10 percent. In addition, preliminary results indicate an increase in the frequency and length of droughts in the end-of-century period.

Projected changes in temperature (warmer winters) will change precipitation patterns to rain with larger fractions than historically encountered. Consequently, peak Snow Water Equivalent (SWE) and runoff are projected to undergo a shift in timing to earlier dates.

At elevations of up to about 9,800 feet, the snowpack of the eastern Sierras is susceptible to earlier melt and less accumulation with a long term-shift in mean temperature of 3.6°F, especially in the southern Sierras. On average, mean temperature rises are in the range of 3.6 to 10.8 °F resulting in about a 17 to 50 percent loss in snowpack storage, respectively. This vulnerability shows up in average to warm winters and will directly affect the stream levels and stream discharge. This raises potential concerns for LADWP in the areas of adequate storage and operations, especially the capacity of the LAA system to store the early runoff in surface reservoirs.

The projected temperature and precipitation dataset form the basis of the hydrologic model projections for runoff, snow-water equivalent (SWE), and rain-to-snow ratio. To compare the future projections of these variables, the trends that dominated the second half of the 20th century are considered baselines for future trends. The baseline values for runoff, SWE, and rain-to-snow ratio are 0.6 million acre-feet (MAF), 15 inches, and 0.2, respectively. By Early 21st century (2010 – 2039), preliminary results illustrate runoff is projected to undergo increases and decreases averaging between 0.5 to 0.85 MAF; SWE is projected to undergo decreases and increases ranging between 10.6 to 19.0 inches, and the rain-to-snow ratio is projected to increase between 0.24 to 0.33. By mid-century (2040 – 2069), the same trends are expected to dominate, with runoff ranging between 0.34 to 0.9 MAF, SWE ranging between 7.0 to 19.7 inches, and the rain-to-snow ratio increasing between 0.25 to 0.43. These trends are expected to govern until the end-of-century (2070 -2099) with runoff ranging between 0.35 to 1.1 MAF, SWE ranging between 5.0 to 16.0 inches, and rain-to-snow ratio increasing between 0.28 to 0.54. Exhibit 12E summarizes the projections for runoff, SWE, and rain-to-snow ratio for the 21st century.

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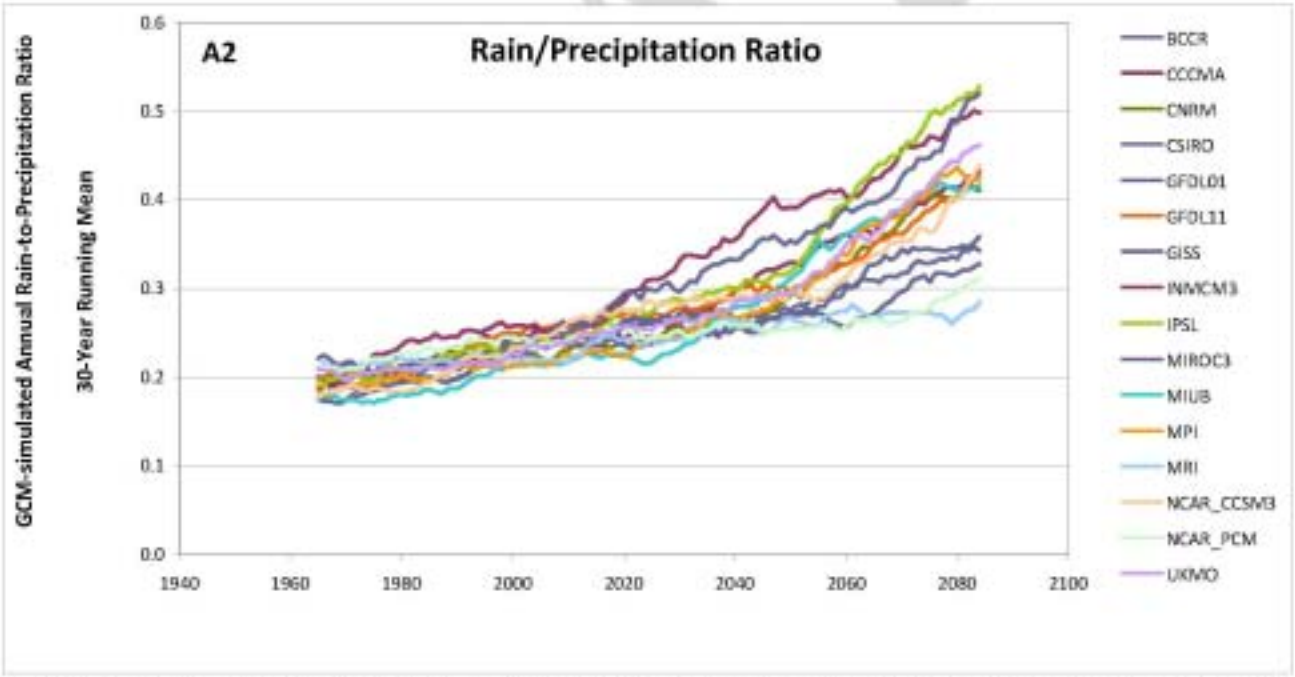
Exhibit 12E
Projected Runoff, Snow-Water Equivalent, and Rain-to-Snow Ratio for Eastern Sierra Nevada Watershed

	Runoff (MAF)	April 1 SWE (Inches)	Rain/Snow Ratio
Baseline (Second Half of 20th Century)	**0.6**	**15.0**	**0.2**
Early 21st-century (2010-2039)	0.5 - 0.85	10.6 - 19.0	0.24 - 0.33
Mid-century (2040-2069)	0.34 - 0.9	7.0 - 19.7	0.25 - 0.43
End-of-century (2070-2099)	0.35 – 1.1	5.0 - 16.0	0.28 - 0.54

Exhibit 12F displays the rain-to-snow ratio based on the projected precipitation and temperature for the 16 GCMs. The rain-to-snow ratio is projected to increase throughout the 21st century, ranging between 0.24 to 0.33 by early 21st century, between 0.25 to 0.43 by mid-century, and between 0.28 to 0.54 by the end-of-century.

Exhibit 12F
Projected Rain to Precipitation Ratio Based on Projected Precipitation and Temperature



The increase of rain-to-snow ratio indicates the shift from snowfall to rainfall, specifically at low to moderate elevations, where the temperature tends to be warmer. This shift indicates more precipitation as liquid, and in turn, leads to loss of the snowpack. The snowpack is critical in providing seasonal storage for water that releases winter precipitation in spring and summer to provide the soil moisture and stream flow needed to sustain both ecosystems and human populations. The climate change study work is still ongoing with remaining analyses to be performed on potential climate change impacts to existing infrastructures, water quality, and recommended adaptation measures.

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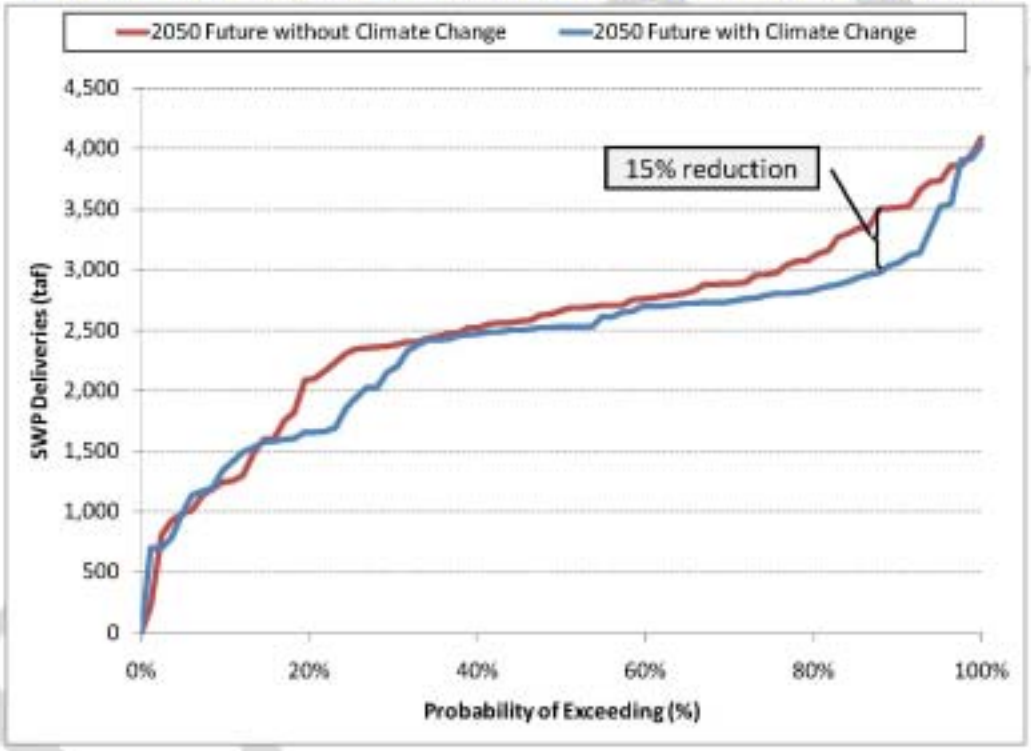
Although the results above are quantitative in nature, it is important to account for the uncertainties inherent in these predictions. The results of this study will help guide the water managers in planning and developing water supply and infrastructure to ensure the reliability and sustainability of adequate water supply and delivery.

12.1.3 State Water Project Impacts

To date, most studies on climate change impacts to California's water supply have been conducted for the Northern California region. In August 2010, DWR released the 2009 State Water Project Delivery Reliability Report, which specifically analyzes changes in volume of water available under various climate change scenarios. DWR projected that SWP deliveries could be reduced by as much as 15 percent in some cases as illustrated in Exhibit 12G.

Exhibit 12G
Projected Rain to Precipitation Ratio Based on Projected Precipitation and Temperature



To incorporate climate change into its reliability reports, DWR reviewed 6 GCMs for year 2050 projections using lower emission and higher emission scenarios contained in *Using Future Climate Projections to Support Water Resources Decision Making in California* prepared in April 2009 by DWR. DWR selected the model most representing median effects on the SWP, the MPI-ECHAM5 model run with a higher greenhouse gas scenario.

Climate change has the potential to disrupt SWP source supplies, impact conveyance, and alter storage levels in reservoir carryover storage. Annual Bay-Delta exports to areas south of the Delta are expected to decline 7 percent for the lower greenhouse gas emissions scenario and 10 percent for the higher emissions scenario. However, it should be noted that for the six GCMs under the lower and higher emission scenarios the range varies from a 2 percent increase to a 19 percent decrease illustrating the variability in the various GCMs.

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By 2050, median reservoir carryover storage is projected to decline by 15 percent for the lower emissions scenario and 19 percent for the higher emissions scenario thereby reducing operational options if water shortages were to occur. Furthermore, by 2050 it is projected a water shortage worse than the 1977 drought could potentially occur in 1 out of every 6 to 8 years requiring acquisition of other supplies, reductions in water demands, or a combination. An additional 575 to 850 TAF would be needed to maintain minimum SWP operation requirements and meet regulatory requirements. The main supply reservoirs on the SWP must maintain minimum water levels to allow water to pass through their lower release outlets in the dams. However, the April 2009 report does not consider the SWP vulnerable to a system interruption such as this under current conditions.

The primary effects of climate change on the SWP identified in the 2009 Reliability Report include, among others:

- More precipitation will fall as rain than snow
- Reductions in Sierra snowpack
- Sea level rise threatening the Bay-Delta levee system
- Increased salinity in the Bay-Delta due to sea level rise requiring releases of freshwater from upstream reservoirs to maintain water quality standards
- Shifted timing of snowmelt runoff into streams – spring runoff comes earlier resulting in increased winter flows and decreased spring flows
- Increased flood events

The most severe climate impacts in California are expected to occur in the Sierra watershed, where the SWP supply originates. Therefore, imported SWP water is extremely vulnerable to climate change.

12.1.4 Colorado River Aqueduct Impacts

Although many research efforts are underway, there have not yet been any reports quantifying potential changes in supply to California from the Colorado River via the CRA. At this time, the assumption is that there would be similar patterns as the SWP impacts.

12.2 Water and Energy Nexus

It is widely believed in the scientific community that the increase in concentrations of greenhouse gases (GHG) in the atmosphere is a major contributing factor to climate change. As such, California is leading the way with laws that require reductions in greenhouse gas emissions and requirements to incorporate climate change impacts into long range water resource planning.

Carbon dioxide emissions into the atmosphere and the emissions of other GHGs are often associated with the burning of fossil fuels like crude oil and coal in the generation of energy. As a significant amount of energy is required for the movement of water over long distances and elevations, a link was subsequently realized between water supply conveyance and corresponding GHG emissions through its energy consumption. An assessment of the GHG emissions, sometimes also known as **carbon footprint expressed in units of tons CO_2, could be estimated for water.** Once the size of a carbon footprint is known, a strategy can be developed to better manage and reduce its impact on climate change.

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LADWP has taken the initiative to study the nexus between water and energy consumption and to evaluate the associated carbon footprint of its water system. The most energy intensive source of water for LADWP is water purchased from MWD, which imports SWP supplies via the California Aqueduct and Colorado River supplies via the CRA. LADWP also imports water via the LAA, which is a net producer of energy. Local sources of water for LADWP include groundwater and recycled water. Exhibit 12H outlines the sources of LADWP's water supply as well as the energy profiles of each facility that provides water to LADWP. For those sources of water operated by LADWP, the energy intensity has been computed by dividing the total energy consumed/generated by the total water produced or processed by that source.

12.2.1 State Water Project Supplies

Water Supplied to Los Angeles via the SWP originates from Northern California and the Bay-Delta and is conveyed along the 444-mile long California Aqueduct to southern California. Six pump stations are required to lift the water to the point at which the California Aqueduct splits into two branches. At the zenith of the California Aqueduct in the Tehachapi Mountains, approximately 3,846 kilowatt hours per acre foot (kWh/AF) is required to lift the water from the start of the aqueduct. After the water passes through Edmonston Pumping Plant, the California Aqueduct separates into two branches, the West Branch and the East Branch. Along the West Branch, the water is lifted once more at the Oso Pumping Plant and then energy is recovered through hydro-electric generation at the Warne and Castaic Power Plants. By the time the West Branch reaches its terminus at Lake Castaic, the net energy consumed in transporting the water from the Bay-Delta is approximately 2,580 kWh/AF. Water supplied through the West Branch is provided to the San Fernando Valley, Western Los Angeles, and Central Los Angeles communities.

Along the East Branch, the water generates power at the Alamo Power Plant, is lifted once more at Pearblossom Pumping Plant, and then used for generation at Mojave Siphon and Devil Canyon Power Plants. At the East Branch terminus at Lake Perris, approximately 3,236 kWh/AF of energy has been expended in the transport. Water conveyed through the East Branch is provided to the Eastern Los Angeles and Harbor communities. The water supplied from the SWP is the most energy intensive source of water available to LADWP.

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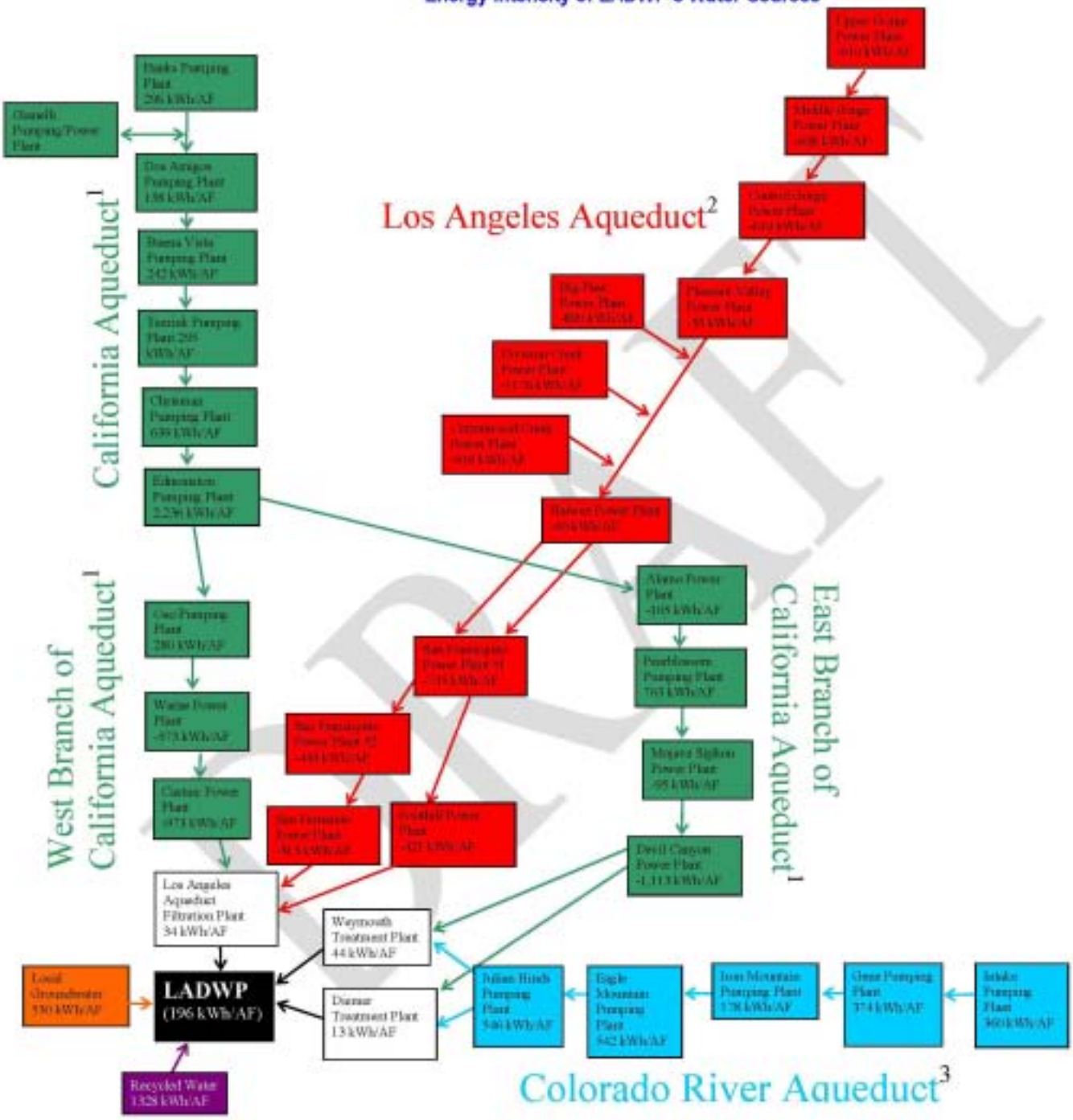
Exhibit 12H
Energy Intensity of LADWP's Water Sources



1. Source: *Methodology for Analysis of the Energy Intensity of California's Water Systems*, p. 27.
2. Generation on the Los Angeles Aqueduct is not considered in LADWP's total energy intensity.
3. Energy intensities for the Colorado River Aqueduct pumping stations were derived by multiplying the total energy intensity for the aqueduct by the proportion of load for each individual pumping station in relation to the total load for all five pump stations.
4. Positive numbers indicate power consumption due to pumping and negative numbers indicate power generation.

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12.2.2 Colorado River Aqueduct Supplies

Water supplied from the Colorado River is imported via the 242 mile CRA operated by MWD. From the start of the aqueduct at Lake Havasu to its terminus at Lake Mathews, the water is lifted approximately 1,617 feet. Five pumping stations along the aqueduct lift the water to MWD's service area requiring approximately 2,000 kWh/AF. CRA water is the second most energy intensive water source for Los Angeles and is supplied to the eastern Los Angeles and Harbor communities. Together SWP water and CRA water comprise the total imported provided by MWD to LADWP. MWD imported water is the most expensive water source for LADWP in terms of both cost and energy.

12.2.3 Los Angeles Aqueduct Supplies

The LAA provides water from the Eastern Sierra watershed and is entirely gravity fed. As a result, no energy is required to import LAA water, making it the most desirable source of water in terms of energy intensity. There are twelve power generation facilities along the aqueduct system. On average, the LAA generates approximately 6,848 kWh/AF from water directly used to generate power. This number was determined using the same methodology as was used to determine the energy intensity for the two branches of the SWP. The individual energy intensities for each individual generating facility were summed up to arrive at the total energy intensity for the water used to generate power. However, when considered from the perspective of total amount of water delivered to Los Angeles via the LAA, the energy generated along the aqueduct is approximately 2,456 kWh/AF. The variance between the numbers can be attributed to the fact that not all water wheeled through the aqueduct is used to generate power and the fact that a portion of the water is introduced into the aqueduct system at a point downstream of several of the power plants. For the purposes of determining LADWP's total energy intensity, the energy intensity of the LAA is considered to be zero since the power generated does not directly offset the energy required for other sources of water. However, in terms of supply the LAA is able to offset the more energy intensive sources of water, consequently reducing the overall energy intensity of LADWP's water supplies. As LAA flows to Los Angeles are decreased due to environmental enhancement efforts in the Owens Valley and Mono Basin, LADWP is forced to increasingly rely on energy intensive water purchased from MWD. LAA water currently supplies approximately 37 percent of the demand for Los Angeles.

12.2.4 Local Groundwater Supplies

Groundwater currently accounts for approximately 11 percent of LADWP's water supply and has an average energy intensity of approximately 530 kWh/AF. As LADWP continues with its cleanup of the contaminated water in the San Fernando Basin, groundwater will play an increasingly important role in Los Angeles' water supply. Although there is potential for a future increase in the energy required to produce groundwater due to the introduction of new treatment technologies, groundwater is expected to remain a low energy source of water when compared to imported supplies purchased from MWD. Increasing groundwater production will allow LADWP to offset the energy intensive MWD sources and reduce its overall energy intensity..

12.2.5 Recycled Water Supplies

Recycled water is currently the smallest component of LADWP's water supply portfolio, with municipal and industrial uses accounting for less than 1-percent of total supplies. Currently, LADWP directly receives recycled water from three wastewater treatment plants operated by Bureau of Sanitation (BOS), two of which provide recycled water treated to a tertiary level: LAG and DCT. The TITP performs advanced treatment of recycled water in addition to tertiary treatment. LADWP also directly receives a small portion of recycled water from the West Basin Municipal Water District (WBMWD), which provides additional treatment of wastewater from the Hyperion Treatment Plant (HTP) in El Segundo. Since all water at the plants directly supplying recycled water to LADWP is treated to at least a tertiary level regardless of disposal or reuse, the energy cost to

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treat the water to this level is considered a sunk cost because the water would be treated whether it offsets potable use or not. The advanced treatment process at the Terminal Island Treatment Plant (TITP) is beyond the requirements for discharge and is therefore not considered a sunk cost. The incremental energy required to treat water from tertiary levels to advanced treatment levels at TITP requires approximately 2,200 kWh/AF. Since the treatment energy at the other two plants is not considered additional energy, only the pumping energy is included in the overall LADWP recycled water energy intensity. For the Los Angeles Glendale (LAG) Treatment Plant, the pumping requires approximately 690 kWh/AF, and for the Donald C. Tillman (DCT) Treatment Plant, the pumping requires approximately 450 kWh/AF. A weighted average of these values gives recycled water an energy intensity of approximately 1,139 kWh/AF. In the future this number will likely change as the recycled water infrastructure is expanded. In addition to the municipal and industrial recycled water that is considered in LADWP's total supplies, the plants produce significant additional volumes of recycled water that is beneficially used. Beneficial uses include the seawater barrier for the Dominquez Gap using recycled water from TITP and the Japanese Garden and Los Angeles River from DCT.

12.2.6 Treatment Energy

Another factor in determining the energy intensity of LADWP's water is the energy required to treat water. All LAA water and nearly all West Branch SWP water purchased by LADWP are treated at the Los Angeles Aqueduct Filtration Plant (LAAFP). For the LAAFP, the average treatment energy intensity is approximately 34 kWh/AF. The East Branch SWP water and the CRA water are primarily treated at the Weymouth Treatment Plant in the San Gabriel Valley and the Diemer Treatment Plant in Orange County. Both of these treatment plants are operated by MWD. The average energy intensity for Weymouth Treatment Plant is approximately 42 kWh/AF and supplies water to the East Los Angeles Community. The average energy intensity for the Diemer Treatment Plant is 13 kWh/AF and supplies water to the Harbor Community. The mix of SWP East Branch water and CRA water that flows through these two treatment plants varies depending on the regional hydrology of the two sources, but on average approximately 55 percent SWP East Branch water and 45 percent CRA water flows through each of these MWD treatment plants.

The proportion that each of the above mentioned sources contributes to the LADWP's total supplies is displayed below in Exhibit 12I. Of note is the relationship that the volume of LAA flow has to the amount of SWP water imported into the system. In this case, the energy free LAA water is replaced by the energy intensive SWP water resulting in an increase in the overall energy intensity.

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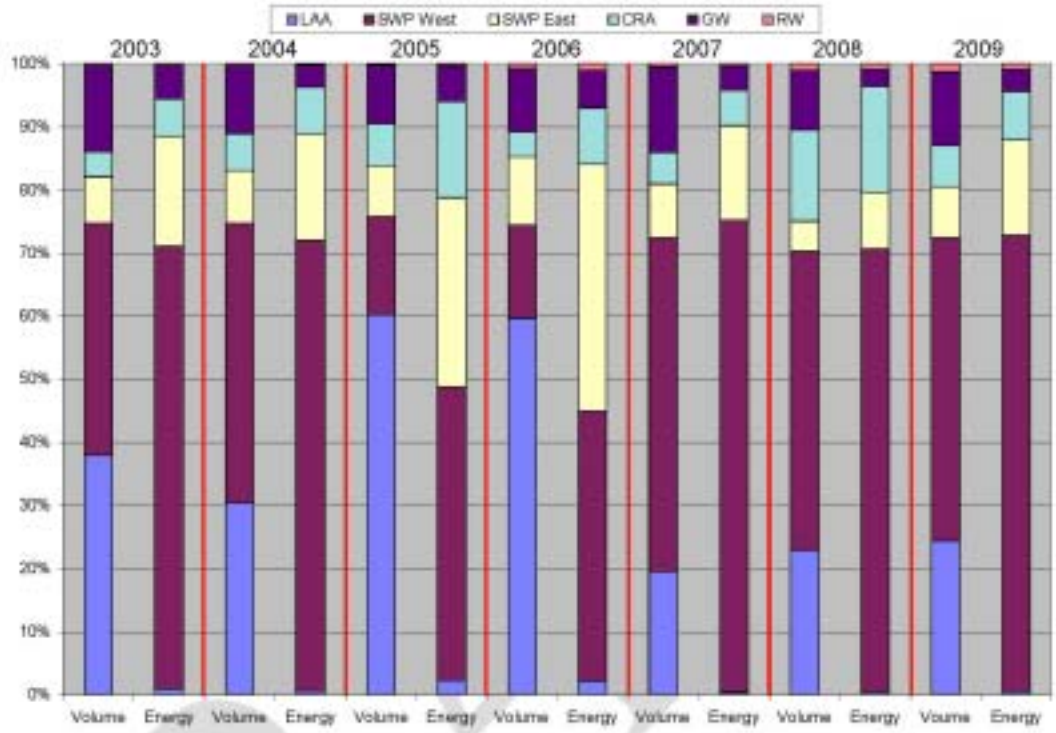
Exhibit 12I
Proportion of Volume Delivered and Total Energy Intensity (Inclusive of Treatment)



12.2.7 Distribution Energy

LADWP benefits from the topography of its service area in that much of the hydraulic head required for water distribution is provided by gravity. With the major sources of LADWP's water entering the service area at higher elevation than the rest of the City, the energy required for distribution is lower than much of the region. The average energy intensity for LADWP water distribution is approximately 196 kWh/AF.

Exhibit 12J shows the sum of the energy intensities for LADWP from each of the individual sources between 2003 and 2009. Exhibit 12K shows a graphical representation of the total energy intensity for LADWP for the same time period. An important detail is the influence that LAA water has on the total energy intensity for a given year. For those years with large volumes of LAA water, such as 2005 and 2006, the total energy intensity was correspondingly low. Alternatively, those years with low volumes of LAA water have high total energy intensity as a result of the energy requirements for imported MWD supplies

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. Exhibit 12J
LADWP Energy Intensity 2003-2009

		2003	2004	2005	2006	2007	2008	2009
Los Angeles Aqueduct (0 kWh/AF)	Volume (AF)	251,942	202,547	368,839	378,922	129,400	147,365	137,084
	Treatment Energy Intensity (kWh/AF)[1]	34	34	34	34	34	34	34
	Weighted Energy Intensity (kWh/AF)	13	10	20	20	7	8	8
State Water Project West Branch (2580 kWh/AF)	Volume (AF)	244,218	296,722	95,538	93,694	350,302	304,221	270,653
	Treatment Energy Intensity (kWh/AF)[1]	34	34	34	34	34	34	34
	Weighted Energy Intensity (kWh/AF)	961	1,161	408	386	1,384	1,237	1,258
State Water Project East Branch[3] (3236 kWh/AF)	Volume (AF)	48,980	56,301	49,526	68,796	56,357	31,016	45,246
	Treatment Energy Intensity (kWh/AF)[2]	27	27	27	27	27	27	27
	Weighted Energy Intensity (kWh/AF)	241	275	264	354	278	157	262
Colorado River Aqueduct[3] (2000 kWh/AF)	Volume (AF)	26,374	39,124	40,522	25,445	33,098	93,047	37,012
	Treatment Energy Intensity (kWh/AF)[2]	27	27	27	27	27	27	27
	Weighted Energy Intensity (kWh/AF)	80	119	134	81	101	293	133
Local Groundwater (530 kWh/AF)	Volume (AF)	90,835	71,831	56,547	63,270	89,018	60,149	64,996
	Weighted Energy Intensity (kWh/AF)	72	57	49	53	71	50	61
Recycled Water[4] (1,139 kWh/AF)	Volume (AF)	1,759	1,774	1,401	4,890	3,639	7,081	7,489
	Weighted Energy Intensity	3	3	3	9	6	13	15
Distribution (196 kWh/AF)	Volume (AF)	664,108	668,300	612,373	635,017	661,814	642,879	562,480
	Weighted Energy Intensity (kWh/AF)	196	196	196	196	196	196	196
Total Volume Delivered (AF)		664,108	668,300	612,373	635,017	661,814	642,879	562,480
Total Energy Intensity (kWh/AF)		1,567	1,820	1,074	1,098	2,043	1,954	1,934

1. Los Angeles Aqueduct and State Water Project West Branch supplies are treated at the Los Angeles Aqueduct Filtration Plant
2. Colorado River Aqueduct and State Water Project East Branch supplies are treated at Weymouth and Diemer Filtration Plants operated by Metropolitan Water District of Southern California. The listed energy intensity is based on an average of the energy intensity for the two plants.
3. Amount of SWP water and CRA water delivered is based on the reported average ratio of the two sources in Weymouth Treatment Plant and Diemer Treatment Plant effluent from MWD annual Water Quality Report
4. Recycled water volume is based on use for municipal and industrial uses, not all beneficial uses. Energy intensity is a weighted average of energy used for pumping to customers and the incremental energy to treat from tertiary to advanced treatment.

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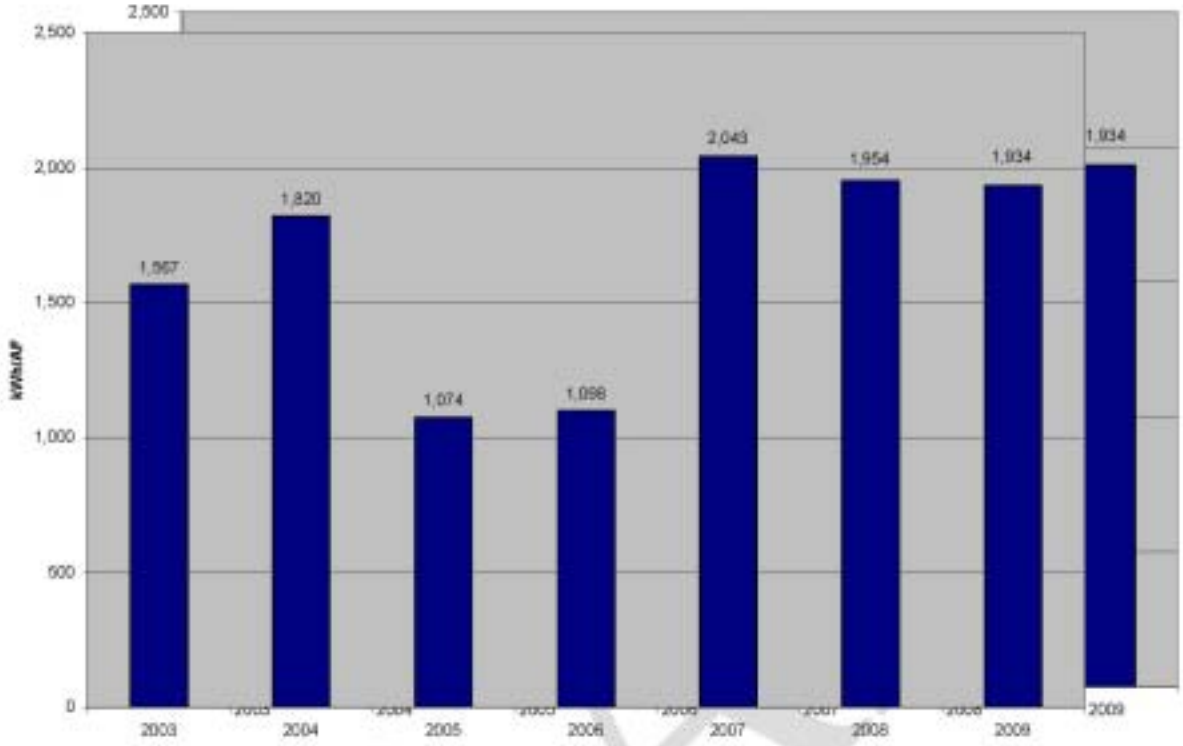
Exhibit 12K
LADWP Annual Energy Intensity



12.2.8 Carbon Footprint

All of LADWP's water supply sources have an associated carbon footprint related to the energy required to pump the water. Exhibit 12L provides the annual carbon footprint by water source. Exhibit 12M shows a graphical representation of the total annual carbon footprint for the same time period. For imported sources, the 2007 CAMX California average carbon emission of 0.72412 lbs CO2/kWh was used to estimate the amount of carbon emissions produced per acre-foot of water imported. For local sources the CO2 metric reported to the California Climate Action Registry in 2007 was used to estimate the carbon emissions released in the production of this water. LAA is a net producer of energy and produces only green hydropower. There are no carbon emissions associated with water imported through the LAA.

AR0071037

Exhibit 12L
Annual Footprint by Carbon Source

		2003	2004	2005	2006	2007	2008	2009
Los Angeles Aqueduct (0 kWh/AF)	Volume Delivered (AF)	251,942	202,547	368,839	378,922	129,400	147,365	137,084
	Energy Intensity (kWh/AF)	0	0	0	0	0	0	0
	Weighted Energy Intensity (kWh/AF)	13	10	20	20	7	8	8
	Carbon Footprint (tons CO_2)[2]	5,259	4,228	7,699	7,909	2,701	3,076	2,861
State Water Project West Branch (2,580 kWh/AF)	Volume Delivered (AF)	244,218	296,722	95,538	93,694	350,302	304,221	270,653
	Weighted Energy Intensity (kWh/AF)	961	1,161	408	386	1,384	1,237	1,258
	Carbon Footprint (tons CO_2)[3]	231,134	280,825	90,420	88,674	331,535	287,922	256,153
State Water Project East Branch (3,236 kWh/AF)	Volume Delivered (AF)	48,980	56,301	49,526	68,796	56,357	31,016	45,246
	Weighted Energy Intensity (kWh/AF)	241	275	264	354	278	157	262
	Carbon Footprint (tons CO_2)[3]	57,865	66,514	58,510	81,276	66,580	36,642	53,454
Colorado River Aqueduct[1] (2,000 kWh/AF)	Volume Delivered (AF)	26,374	39,124	40,522	25,445	33,098	93,047	37,012
	Weighted Energy Intensity (kWh/AF)	80	119	134	81	101	293	133
	Carbon Intensity (lbs CO2/kWh)	0.72412	0.72412	0.72412	0.72412	0.72412	0.72412	0.72412
	Carbon Footprint (tons CO_2)[3]	19,356	28,713	29,739	18,674	24,290	68,287	27,163
Local Groundwater (530 kWh/AF)	Volume Delivered (AF)	90,835	71,831	56,547	63,270	89,018	60,149	64,996
	Weighted Energy Intensity (kWh/AF)	72	57	49	53	71	50	61
	Carbon Footprint (tons CO_2)[2]	29,556	23,372	18,399	20,587	28,964	19,571	21,148
Recycled Water (1,139 kWh/AF)	Volume Delivered (AF)	1,759	1,774	1,401	4,890	3,639	7,081	7,489
	Weighted Energy Intensity (kWh/AF)	3	3	3	9	6	13	15
	Carbon Footprint (tons CO_2)[2]	1,230	1,240	980	3,419	2,545	4,951	5,237
Distribution (196 kWh/AF)	Volume Delivered (AF)	664,108	668,299	612,373	635,017	661,814	642,879	562,480
	Weighted Energy Intensity (kWh/AF)	196	196	196	196	196	196	196
	Carbon Footprint (tons CO_2)[3]	79,911	80,415	73,686	76,411	79,635	77,357	67,682
Total Volume Delivered (AF)		664,108	668,299	612,373	635,017	661,814	642,879	562,480
Total Energy Intensity (kWh/AF)		1,567	1,820	1,074	1,098	2,043	1,954	1,934
Total Carbon Footprint (tons CO_2)		424,310	485,308	279,432	296,950	536,250	497,807	433,698

1. Amount of SWP water and CRA water delivered is based on average of the proportion of the two sources delivered to MWD Weymouth Treatment Plant and Diemer Treatment Plant for the calendar year

2. Based on 2007 CO_2 metric of 1.22789 lbs CO_2/kWh reported to the California Climate Action Registry

3. Based on eGRID 2007 CAMX (California Average) of 0.72412 lbs CO_2/kWh

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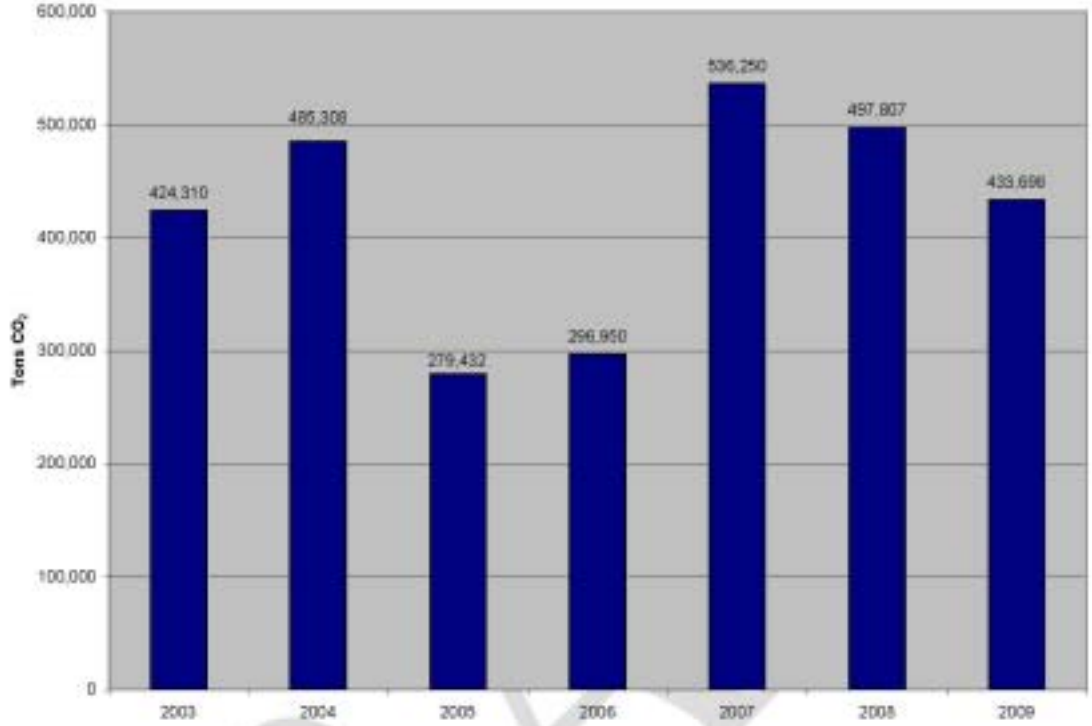
Exhibit 12M
Total Annual Carbon Footprint for Water Supply Portfolio



As Los Angeles increases its reliance on energy intensive imported supplies from MWD, its overall energy intensity will increase. Reductions in LAA flows due to environmental mitigation have the consequence of increasing Los Angeles' reliance on supplies imported through the SWP via the California Aqueduct, and Colorado River through the CRA.

12.3 Climate Change Adaption and Mitigation

Climate change strategies fall under two main categories: adaptation and mitigation. For water resources planning, a climate change adaptation strategy involves taking steps to effectively manage the impacts of climate change by making water demands more efficient and relying on supply sources that are less vulnerable to climate change. A mitigation strategy involves proactive measures that reduce greenhouse gas emissions, such as placing a stronger emphasis on using water resources requiring less greenhouse gas emissions. Both LADWP and its wholesale supplier for imported water, MWD, are implementing adaption and mitigation strategies as they become aware of potential climate change impacts.

It is imperative that supply options are carefully vetted and evaluated against both adaptation and mitigation goals, as they may conflict and work against each other. For example, desalination is a typical supply option that performs quite well in adapting to climate change impacts; however, due to the energy necessary to draw from and manage the supply source, it could result in higher greenhouse gas emissions if conventional energy sources are utilized.

12.3.1 LADWP Adaption and Mitigation

In the 2008 City of Los Angeles Water Supply Action Plan, LADWP and the City have outlined strategies to dramatically increase conservation and water recycling. Increasing conservation and water recycling encompasses both adaption and mitigation goals to address climate change. The Plan calls for reducing potable demands by an additional 50,000 AFY through

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conservation by fiscal year 2030 and 50,000 AFY through recycled water use. Additional adaption strategies under investigation by LADWP and the City includes beneficial reuse of stormwater as discussed in Chapters Seven and Nine, Watershed Management and Other Potential Water Supplies, respectively.

Conservation has a double savings in terms of energy intensity because not only does it save energy in importing or producing the water, but it also saves energy through reduction of end use, such as heating water for a shower or for a dishwasher and wastewater treatment. The anticipated conservation savings will not only help to provide Los Angeles a secure and dependable water supply, but it will also reduce the energy footprint of the water supply, and consequently the carbon footprint. A further discussion regarding conservation is provided in Chapter Three, Conservation.

Recycled water use reduces reliance on potable water imported through MWD and provides a year round drought resistant water supply source. While the energy consumption requirements to produce recycled water are greater than local and LAA supply sources, recycled water assists LADWP in bolstering its supply portfolio to address potential supply changes related to climate change. A further discussion regarding recycled water is provided in Chapter 4, Recycled Water.

The climate change study work for the LAA is still ongoing with remaining analyses to be performed on potential climate change impacts to existing infrastructures, water quality, and recommended adaptation measures. Hydraulic models will be performed to determine impacts to the LAA conveyance capacity. Adaptation measures may include upgrades to treatment processes in order to address degradation in water runoff quality, and/or changes in operational procedures to address shifts in runoff timing and quantity.

There is still general uncertainty within the scientific community regarding the potential impacts of climate change for the City of Los Angeles. LADWP will continue to stay abreast of developments in climate change to better understand its potential implications to the City's water supplies to assist in further developing adaption and mitigation strategies.

12.3.2 MWD Adaption and Mitigation

MWD is taking an active approach to adapt and mitigate against climate changes in its operations. Adaption and mitigation measures include:

- Investments in local resources to diversify MWD's water supply portfolio
- Tracking climate change legislation – MWD provides input and direction on legislation
- Collaborating on climate change with state, federal, and non-governmental agencies
- Monitoring state and local climate change actions
- Investigating the water supply and energy nexus
- Coordinating with large water retailers
- Integrating climate change into integrated resource planning as discussed in Chapter 10, Integrated Resource Planning

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- Sharing climate change knowledge and providing support – founding member of Water Utility Climate Alliance,
- Adopting energy management policies to support cost-effective and environmentally responsible programs, projects, and initiative

MWD has also taken structural adaption measures including construction of the Inland Feeder. The Inland Feeder completed in 2009 connects SWP supplies with MWD's CRA supplies and allows delivery of SWP supplies to MWD's major reservoir, Diamond Valley Lake. In relation to climate change, the project will increase conveyance capacity allowing more rain to be conveyed as projected snowpack levels decrease and allow MWD to capture rain associated with projected short duration high intensity storms.

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APPENDICES

Los Angeles LA DWP Department of Water & Power

A Quality Partnership

2010 Drinking Water Quality Report

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A Quality Partnership

In 2010, LADWP collected over 25,000 water samples across the city, and performed more than 240,000 water quality tests—not just for compliance, but also for research and operational improvements. We tested for over 200 different contaminants throughout the year including both, regulated contaminants such as arsenic, chromium, lead, and disinfection by-products, as well as unregulated contaminants such as sodium and boron. Every day, hundreds of LADWP employees work diligently to ensure that you receive the high-quality, low cost drinking water you've come to expect. This is our commitment to you.

After water completes multiple treatment processes, it is distributed throughout the City via trunk lines, distribution lines and ultimately service lines that feed the water to your meter. In 2010, LADWP delivered more than 200 billion gallons of water to 4.1 million residents that met or surpassed all health-based drinking water standards. However, in spite of all our efforts, some of our customers do not get to enjoy this high quality water within their home because degraded in-house plumbing negatively affects the ultimate quality of the tap water.

LADWP would like to invite you to partner with us by learning more about what we do to provide high quality drinking water and what you can do to get the best possible glass of water from your tap (See pages 3-4). Because, at the end of the day, we all want the same thing—the best!

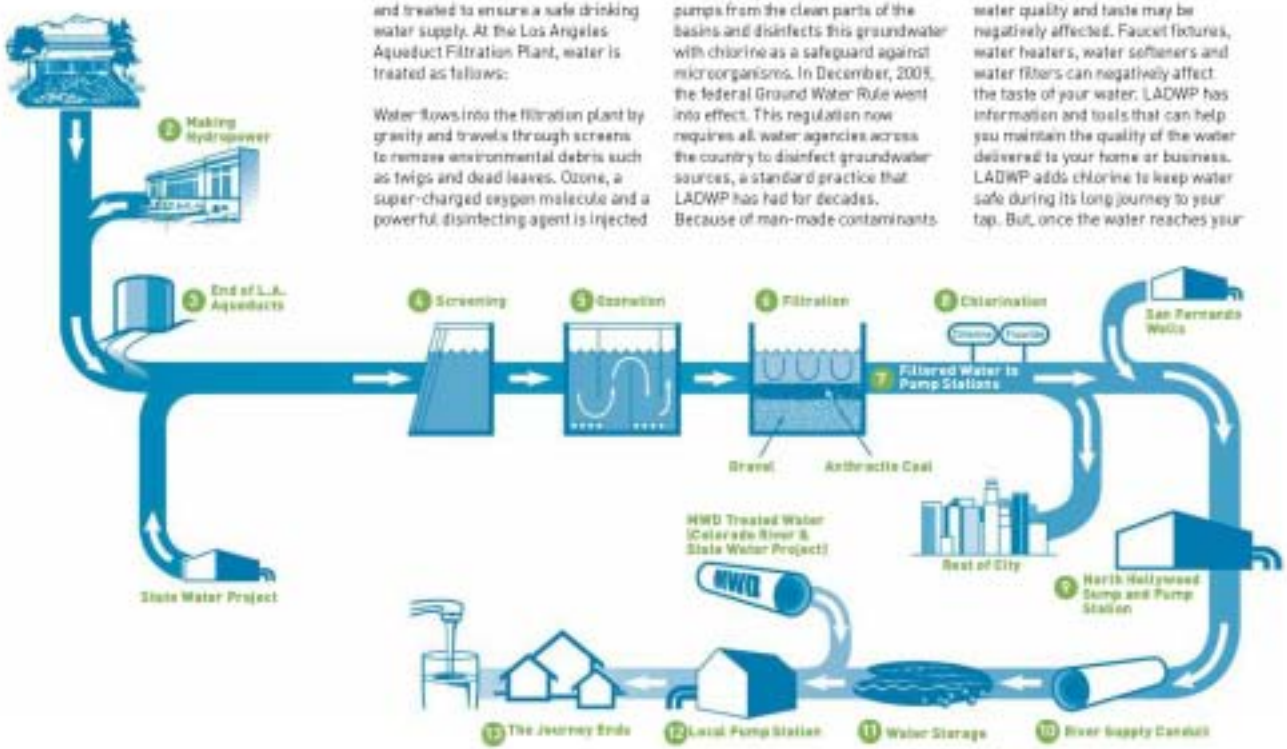
James B. McDaniel
Senior Assistant General Manager - Water

Dr. Pankaj Parekh
Director of Water Quality

Beginning of L.A. Aqueducts

The Journey Begins: Lee Vining Intake

The beginning of the Los Angeles Aqueducts. Water is collected from creeks in the Mono Basin and the Owens River in the Owens Valley and then carried to the City of Los Angeles by the Los Angeles Aqueducts, which operate completely by gravity, making clean hydroelectric energy along the way.



Water Treatment Processes

Surface Water Treatment

LADWP water comes from four very different water sources—three are from surface water sources like lakes and rivers, and the other is groundwater from local wells and springs. The taste and appearance of surface water can vary seasonally and groundwater generally contains more minerals. All these factors make for different tasting water. Despite these variations, LADWP water meets all drinking water standards for health and aesthetics.

All water coming from the Los Angeles Aqueducts, the California Aqueduct (a.k.a. State Water Project), and the Colorado River Aqueduct is filtered and treated to ensure a safe drinking water supply. At the Los Angeles Aqueduct Filtration Plant, water is treated as follows:

Water flows into the filtration plant by gravity and travels through screens to remove environmental debris such as twigs and dead leaves. Ozone, a super-charged oxygen molecule and a powerful disinfecting agent is injected into the water to destroy bacteria and other impurities that affect taste, odor and color. Treatment chemicals are quickly dispersed into the water to make fine particles called floc. A six-foot-deep filter (crushed coal over gravel) removes the floc and previously added chemicals. Chlorine added during the final step ensures lasting disinfection and protects the water as it travels through the City's distribution system to your tap. Fluoride is optimized to promote oral health by strengthening tooth enamel.

Groundwater Treatment

The City's vast groundwater supply in the San Fernando and Central Basins are generally clean. LADWP pumps from the clean parts of the basins and disinfects this groundwater with chlorine as a safeguard against microorganisms. In December, 2009, the federal Ground Water Rule went into effect. This regulation now requires all water agencies across the country to disinfect groundwater sources, a standard practice that LADWP has had for decades. Because of man-made contaminants found in San Fernando Valley groundwater wells, LADWP continuously monitors and ensures that all well water meets water quality standards and results are far below the maximum contaminant levels permitted by federal or state regulations. LADWP is formulating a comprehensive long term groundwater treatment plan for the San Fernando Basin that will allow us to extract more water and treat it so we can safely increase our local supply of water.

Improving Water Quality At Home

It is common for the integrity of pipes on the customer-side of the meter to degrade to the point that water quality and taste may be negatively affected. Faucet fixtures, water heaters, water softeners and water filters can negatively affect the taste of your water. LADWP has information and tools that can help you maintain the quality of the water delivered to your home or business. LADWP adds chlorine to keep water safe during its long journey to your tap. But, once the water reaches your

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7 Making Hydropower

San Francisquito Power Plant 1

Water generates electricity as it passes through the hydroelectric plant.

3 End of LA Aqueducts

The Cascades

Seen along Interstate 5, this is the terminus (end) of the Aqueducts. Water flows over the "steps" to release some of the water's energy.

tap, the chlorine is no longer needed. There are numerous home treatment options that can be implemented to improve the smell and taste of your water. To remove any objectionable chlorine odors, simply chill the water in the refrigerator. This alone can significantly improve the taste. You can also use a filter specific for the removal of chlorine or chloramine. Once filtered, be sure to keep the water in the refrigerator to prevent any new growth of bacteria.

If you intend to buy a water filter to improve the taste, odor, or appearance of your tap water, be sure to purchase one that is certified by the National Sanitation Foundation (NSF), an independent testing organization whose certification is the industry's seal of approval.

If you need a more comprehensive home water treatment device due to a health condition, such as a weakened immune system or chemical allergy, be sure the treatment device is certified by the California Department of Public Health (CDPH).

Purchasing and installing a faucet-mounted or under-the-sink filter is another way to improve the taste of your water. As with any filter, be sure to change the filter cartridges regularly according to the manufacturer's recommendation.

To learn more about water quality in your home visit www.ladwp.com, or call (213) 367-3182 Monday through Friday 8 a.m. – 4 p.m.

Water Quality News & Updates

Safeguarding Our Surface Water

The Surface Water Treatment Rule (SWTR), administered by CDPH, is a drinking water regulation that safeguards reservoir supplies from microbiological contamination that may occur when rain runoff from nearby hillsides and slopes enters the water. In Los Angeles, SWTR applied to four open water reservoirs – Lower Stone Canyon, Encino, and Upper and Lower Hollywood.

LADWP successfully met the compliance deadlines and treatment requirements for all four open reservoirs that were subject to SWTR. Upper and Lower Hollywood Reservoirs were successfully removed in July 2001 and replaced with two 33 million-gallon buried tanks. New support facilities were successfully commissioned to serve filtered water from Encino Reservoir in January 2006 and Lower Stone Canyon Reservoir in September 2008.

The latest drinking water regulation related to the treatment of surface water is the Long Term 2 Enhanced Surface Water Treatment Rule (LT2). This rule requires

4 Screening

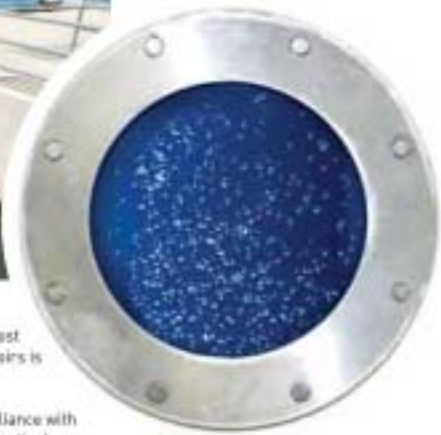
Los Angeles Aqueduct Filtration Plant (LAAFP) Inlet Structure

Water flows through the inlet of the LAAFP, where large pieces of debris or algae are removed by screens.

5 Ozonation

Ozone Contact Chamber, LAAFP

Water is exposed to ozone gas, a disinfectant that prepares the water for filtration.



6 Filtration

Anthracite Coal Filters, LAAFP

Water passes through 40 inches of anthracite coal filters, which remove particles smaller than can be seen through a microscope.

that LADWP cover or remove from service the remaining six uncovered distribution reservoirs, or provide additional treatment to achieve prescribed inactivation or removal of viruses, Cryptosporidium, and Giardia by April 1, 2009 or be in compliance with a state-approved schedule to meet the same requirements. The six reservoirs are Los Angeles, Upper Stone Canyon, Santa Ynez, Ivanhoe, Silver Lake, and Elysian Reservoirs. Santa Ynez Reservoir was removed from service in November 2010. It will be put back in service after a floating cover is installed in 2011.

On April 1, 2008, LADWP notified CDPH that it is fully committed to complying with the new regulations and requested an extension of the April 1, 2009 deadline. LADWP submitted an interim operations plan, a schedule for the required reservoir improvements, and executed a Compliance Agreement with CDPH on March 31, 2009. LADWP is working diligently to bring all reservoirs into compliance as quickly as possible and will provide the public with project updates in the annual water quality report. The estimated cost to modify the six reservoirs is $1.65 billion.

In preparation for compliance with LT2, LADWP has been routinely monitoring its water sources for microbial pathogens since 2005. Cryptosporidium and Giardia are occasionally detected in very low numbers in some of our reservoirs and in the L.A. Aqueduct and we are fully committed to achieving compliance with the LT2. To further inform our customers on this topic, below is a generic statement from CDPH regarding Cryptosporidium.

"Cryptosporidium is a microbial pathogen found in surface water throughout the U.S. Although filtration removes Cryptosporidium, the most commonly used filtration methods cannot guarantee 100 percent removal. Our monitoring indicates the presence of these organisms in our source water and finished water. Current test methods do not allow us to determine if the organisms are dead or if they are capable of causing disease. Ingestion of Cryptosporidium

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Sources of Water for City Areas

San Fernando Valley Communities
Sources: Los Angeles Aqueduct, local groundwater, and MWD State Water Project.

Arleta	Northridge	Tarzana
Canoga Park	Olive View	Toluca Lake
Chatsworth	Pacoima	Tujunga
Encino	Panorama City	Valley Village
Granada Hills	Porter Ranch	Van Nuys
Hollywood Hills	Reseda	Warner Center
Lake View	Sherman Oaks	West Hills
Terrace	Studio City	Winnetka
Mission Hills	Sun Valley	Woodland Hills
North Hills	Sunland	
North Hollywood	Sylmar	

Western Los Angeles Communities
Sources: Los Angeles Aqueduct and MWD State Water Project.

Bel Air Estates	Mar Vista	West Los Angeles
Beverly Glen	Pacific Palisades	Westchester
Brentwood	Palisades Highlands	Westwood
Castellamare	Palms	
Century City	Playa del Rey	
Cheviot Hills	Santello	
Culver City*	Venice	

Eastern Los Angeles Communities
Sources: MWD State Water Project and Colorado River Aqueduct.

Atwater Village	El Sereno	Montecito Heights
Boyle Heights	Glassell Park	Monterey Hills
Cypress Park	Highland Park	Mt. Washington
Eagle Rock	Lincoln Heights	
Echo Park		

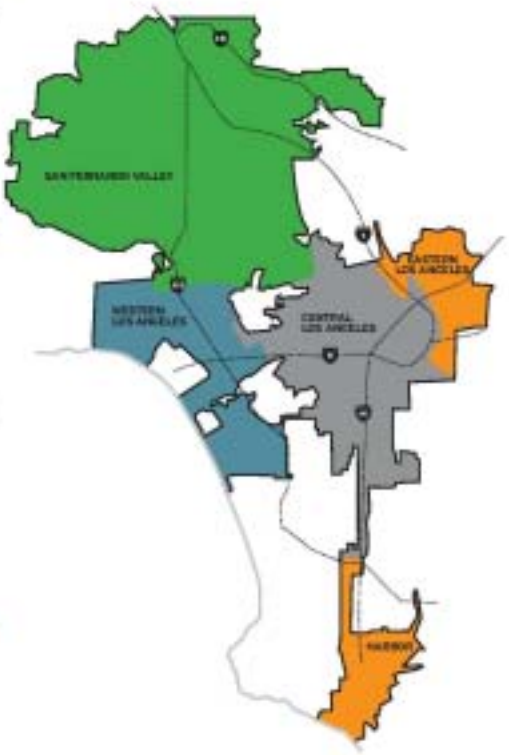
Central Los Angeles Communities
Sources: Los Angeles Aqueduct, MWD State Water Project, and local groundwater.

Baldwin Hills	Hollywood	Mt. Olympus
Chinatown	Hyde Park	Park La Brea
Country Club	Koreatown	Rancho Park
Park	L.A. City Strip*	Silverlake
Crenshaw	Little Tokyo	Watts
Griffith Park	Los Feliz	West Hollywood*
Hancock Park	Mid City	Westlake

Harbor Communities
Sources: MWD State Water Project and Colorado River Aqueduct.

East San Pedro (Terminal Island)	Harbor Gateway*	Wilmington
Harbor City	L.A. City Strip*	
	San Pedro	

* parts of



may cause cryptosporidiosis, an abdominal infection. Symptoms of infection include nausea, diarrhea, and abdominal cramps. Most healthy individuals can overcome the disease within a few weeks. However, immunocompromised persons are at greater risk of developing life-threatening illness. We encourage immunocompromised individuals to consult their doctor regarding appropriate precautions to take to avoid infection. Cryptosporidium must be ingested to cause disease, and it may be spread through means other than drinking water." (source: CDPH)

Special Population Precautions

There are certain health conditions for which customers may need specially treated water. Customers with weakened immune systems who may have undergone chemotherapy treatment, received organ transplants, suffer from HIV/AIDS, or other immune system disorders. Some elderly and infants can be particularly at risk from infection. Customers with these types of health challenges should seek advice about drinking water from their health care providers. Contact the EPA's Safe Drinking Water Hotline at (800) 426-4791, or visit www.epa.gov, for free guidelines on how to lessen the risk of infection by Cryptosporidium and other microbial contaminants.

Chlorine and Chloramine

LADWP is gradually switching from chlorine to chloramine to disinfect the water we serve. This will take several more years and, in the meantime, customers should expect to receive either type of disinfectant in their water at any time.

Both chlorine and chloramine are effective killers of bacteria and other microorganisms, but chloramine forms less by-products and does not have a chlorinous odor. Customers in the Harbor area of the City have received water treated with chloramine for more than 25 years. Customers in Eastern Los Angeles and the Sunland-Tujunga area are also receiving water treated with chloramine.

Since chlorine and chloramine are different chemicals, certain types of water users must adjust their additional treatment to handle either disinfectant. Operators of kidney dialysis machines should monitor their equipment more frequently for both "free" and "total" chlorine. The Southern California Renal Disease Council supports this recommendation.

Customers who maintain fish ponds, tanks, or aquaria should also make necessary adjustments in water quality treatment, as both chlorine and chloramine are toxic to fish. For further information, please visit www.ladwp.com or call our Water Quality Customer Services group at (213) 367-3182.

continued on page 9

Filtered Water to Pump Stations

7 **Filter Weir**
Water from each of the 24 filters combine at the Filter Weir before leaving the Filtration Plant.

Chlorination

8 **Chlorination Station**
Chlorinator controls the amount of chlorine added to protect against bacteria and pathogens as water travels through the distribution system.

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2010 Drinking Water Quality Monitoring Results

Tables I-IV list the results of water tests performed by LADWP and MWD from January to December 2010. LADWP tests for over 200 contaminants. These tables include only contaminants with values that are detected.

How to Read the Tables

The constituents/contaminants found in the water served in your area are listed as follows:

- For San Fernando Valley Area – water test results are under the Los Angeles Aqueduct Filtration Plant, the Northern Combined Wells, and MWD Jensen Filtration Plant columns
- For Western Los Angeles Area – water test results are under the Los Angeles Aqueduct Filtration Plant column
- For Central Los Angeles Area – water test results are under the Los Angeles Aqueduct Filtration Plant and the Southern Combined Wells columns
- For Harbor/Eastern Los Angeles Area – water test results are under the MWD Jensen, Weymouth, and Diemer Filtration Plants columns

Some constituents/contaminants are reported on a citywide basis as required by the California Department of Public Health.
The unregulated contaminants reported on an area-wide basis are included for additional information on the water served in your area.

continued from page 7

A Better Understanding of Radon

Radon is a naturally occurring radioactive gas that is not a significant issue in most of California. In 2010, very low levels of radon were detected in some of our ground water supplies (see Table II on page 12). There is no established drinking water standard or monitoring requirement for radon. In general, radon entering a home through tap water is a very small contributor to radon in indoor air. Although the radon levels were well below what the EPA is currently considering for a standard, the EPA has asked us to share the following general information with you to help you better understand radon.

"Radon is a radioactive gas that you can't see, taste, or smell. It is found throughout the U.S. Radon can move up through the ground and into a home through cracks and holes in the foundation. Radon can build up to high levels in all types of homes. Radon can also get into indoor air when released from tap water from showering, washing dishes, and other household activities. Compared to radon entering the home through soil, radon entering the home through tap

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North Hollywood Sump and Pump Station

Well Water Blending

Water flows by gravity from the LAAFP to the North Hollywood Pump Station. Well water from the San Fernando Valley mixes with the aqueduct water in the North Hollywood Sump before it is distributed into the city by large pumps.

Table I Calendar Year 2010 Water Quality Monitoring Results

Health-Based Primary Drinking Water Standards (MCLs) Constituents/Contaminants Detected in Treated Water

Contaminants	Units	Los Angeles Aqueduct Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Weymouth Plant		MWD Diemer Plant		MWD Jensen Plant		State Primary Standard (MCL) or [MRDL]	Meet Primary Standard? (Yes/No)	State PHG or Federal (MCLG)	Major Sources in Our Drinking Water
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range				
Aluminum	µg/L	<50	<50	<50	<58	<50	<50	170 (a)	<50 - 200	170 (a)	66 - 230	80 (a)	56 - 100	1000	YES	600	Erosion of natural deposits; residue from surface water treatment processes
Arsenic	µg/L	4 (a)	<2 - 6	2	<2 - 4	2	<2 - 3	2 (a)	<2 - 3	2 (a)	<2 - 3	3 (a)	2 - 3.2	10	YES	0.004	Erosion of natural deposits; runoff from orchards; glass and electronics production wastes
Barium	µg/L	<100	<100	<100	<100	<100	<100 - 127	110	<100 - 130	110	<100 - 130	<100	<100	1000	YES	2000	Erosion of natural deposits
Bromate (o, b)	µg/L	<5	<5 (b)	NA	NA	NA	NA	NA	NA	NA	NA	7 (a)	<5 - 11	10	YES	0.1	By-product of ozone disinfection; formed under sunlight
Gross Alpha Particle Activity (c)	pCi/L	4	4	5	5 - 5.2	5	<3 - 5	5	<3 - 8	8	4 - 9	3	<3 - 7	15	YES	(0)	Naturally present in environment
Gross Beta Particle Activity (c)	pCi/L	<4	<4 - 5	<4	<4 - 5	<4	<4 - 7	4	<4 - 10	4	<4 - 6	<4	<4 - 5	50	YES	(0)	Naturally present in environment
Nitrate (as NO_3)	mg/L	<2	<2 - 2	8	<2 - 14	8	<2 - 17	<2 (a)	<2 - 2	<2 (a)	<2	2.6 (a)	2 - 3	45	YES	45	Erosion of natural deposits; runoff and leaching from fertilizer use
Nitrate + Nitrite (as N)	mg/L	<0.4	<0.4 - 0.4	2	<0.4 - 3	2.0	<0.4 - 4	<0.4	<0.4 - 0.4	<0.4	<0.4	0.8	0.5 - 0.7	10	YES	10	Erosion of natural deposits; runoff and leaching from fertilizer use
Tetrachloroethylene (PCE)	µg/L	<0.5	<0.5	<0.5	<0.5 - 0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	YES	0.06	Discharge from factories, dry cleaners, auto shops (metal degreaser)
Trichloroethene (TCE)	µg/L	<0.5	<0.5	1	<0.5 - 3	1	<0.5 - 2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	YES	1.7	Discharge from metal degreasing sites and other factories
Turbidity (d)	NTU	100%	3.4 (a)	NA	NA	NA	NA	100%	0.05	100%	0.08	100%	0.05	TT	YES	none	Soil runoff
Uranium (c)	pCi/L	3	2 - 4	3	2 - 4	3	<1 - 6	3	2 - 3.4	3	2.9 - 4	1.8	1.6 - 3	20	YES	0.5	Erosion of natural deposits

Health-Based Primary Drinking Water Standards (MCLs) Constituents/Contaminants Detected in Treated Water and Reported on City-Wide Basis

Contaminants	Units	Average	Range	State Primary Standard (MCL) or [MRDL]	Meet Primary Standard ?	State PHG / [MRDLG] or Federal (MCLG)	Major Sources in Our Drinking Water
Bromate (f)	µg/L	City-wide Average = 5.7	Range = <5 - 5.8	10	YES	0.1	By-product of ozone disinfection; formed under sunlight
Chlorine Residual, Total	mg/L	Average = 1.8 (a)	Range = 1.6 - 1.8	[4]	YES	[4]	Drinking water disinfectant added for treatment
Copper (at the tap) AL = 1300 (g)	µg/L	90th Percentile value = 576	number of samples exceeding AL = 6 out of 110	TT	YES	300	Internal corrosion of household water plumbing systems
Fluoride	mg/L	Average = 0.8	Range = 0.7 - 0.9	2	YES	1	Erosion of natural deposits; water additive that promotes strong teeth
Lead (at the tap) AL = 15 (g)	µg/L	90th Percentile value = 5.6	number of samples exceeding AL = 3 out of 110	TT	YES	0.2	Internal corrosion of household water plumbing systems
Total Coliform Bacteria	% Positives	Average = 0.5% Coliform positive samples	Range = 0 - 0.9% Coliform positive samples	5% of monthly samples are coliform positive	YES	(0)	Naturally present in the environment
Total Haloacetic Acids (HAA5)	µg/L	City-wide Average = 27 (a)	Range = <2 - 103	60	YES	none	By-product of drinking water disinfection
Total Trihalomethanes (TTHM)	µg/L	City-wide Average = 56 (a)	Range = 13 - 109	80	YES	none	By-product of drinking water chlorination

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Table II Calendar Year 2010 Water Quality Monitoring Results

Aesthetic-Based Secondary Drinking Water Standards (SMCLs) Constituents/Contaminants Detected in Treated Water

Contaminants	Units	Los Angeles Aqueduct Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Weymouth Plant		MWD Diemer Plant		MWD Jensen Plant		State Secondary MCL	Meet Secondary Standard?	Major Sources in Our Drinking Water
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range			
Aluminum	µg/L	<50	<50	<50	<50	<50	<50	178 (a)	<50 – 308	110 (a)	86 – 230	87 (a)	56 – 160	200	YES	Erosion of natural deposits; residue from some surface water treatment process
Chloride	mg/L	42	33 – 57	43	33 – 58	43	25 – 62	93 (a)	84 – 94	93 (a)	83 – 93	79 (a)	67 – 86	500	YES	Runoff/leaching from natural deposits; seawater influence
Color (unfiltered)	ACU	3.5	3 – 5	3.3	3 – 5	3.2	3 – 7	1 (a)	1	1 (a)	1 – 2	1 (a)	1 – 2	15	YES	Naturally-occurring organic materials
Manganese (Mn)	µg/L	<20	<20	<20	<20	<20	<20 – 37	<20	<20	<20	<20	<20	<20	50	YES	Leaching from natural deposits
Odor	TON	<1	<1	<1	<1 – 1	<1	<1 – 1	2	2	2	2	3	3	3	YES	Naturally-occurring organic materials
Specific Conductance	µS/cm	380	361 – 518	623	320 – 738	616	486 – 750	950 (a)	460 – 1800	970 (a)	460 – 1000	580 (a)	580 – 580	900	YES	Substances that form ions when in water; seawater influence
Sulfate	mg/L	33	26 – 43	113	38 – 164	113	69 – 164	210 (a)	100 – 250	230 (a)	160 – 240	63 (a)	55 – 65	500	YES	Runoff/leaching from natural deposits
Total Dissolved Solids (TDS)	mg/L	236	210 – 267	391	225 – 491	391	326 – 522	570 (a)	470 – 630	598 (a)	470 – 618	350 (a)	290 – 330	980	YES	Runoff/leaching from natural deposits
Turbidity (b)	NTU	<0.1	<0.1 – 0.15	0.1	0.1 – 0.3	0.1	<0.1 – 0.3	0.05 (a)	0.03 – 0.06	0.04 (a)	0.03 – 0.16	0.04 (a)	0.03 – 0.08	5	YES	Soil runoff
Zinc	µg/L	<50	<50	<50	<50	<50	<50 – 1040	<50	<50	<50	<50	<50	<50	5000	YES	Run off/leaching from natural deposit

Abbreviations and Footnotes

mg/L = milligrams per liter (equivalent to ppm)
µg/L = micrograms per liter (equivalent to ppb)
ng/L = nanograms per liter (equivalent to ppt)
pCi/L = picoCuries per liter
% = percentage
µS/cm = microSiemens per centimeter
NTU = nephelometric turbidity unit
TON = threshold odor number
CFU = colony-forming unit
ACU = apparent color unit
< = less than
NA = not applicable
NT = not tested
HRAA = highest running annual average

(a) Values reflect Highest Running Annual Average (HRAA). HRAA is the highest of all Running Annual Averages (RAAs). RAA is a calculated average of all the samples collected within twelve months period.

(c) Bromate is tested in water treated with ozone. Bromate has also been found in chloramated treated water at some LADWP reservoirs exposed to sunlight. Metropolitan Water District of Southern California (MWD) only tests bromate at Jensen Filtration Plant.

(c) Radiological monitoring is performed in cycles of various periods of time. LADWP performed Gross Alpha testing in 2006 – 2009 and all other radiological testing in 2005 - 2010 for samples collected at Los Angeles Aqueduct Filtration Plant, Northern Combined Wells blend points, and Southern Combined Wells blend points. MWD performed all radiological testing in 2008 for samples collected at Weymouth, Diemer, and Jensen Plants.

(d) Turbidity is a measure of the cloudiness of the water and is a good indicator of water quality and filtration performance. High turbidity can hinder the effectiveness of disinfectants.

The Primary Drinking Water Standard for turbidity level at water filtration plants is less than or equal to 0.3 NTU in at least 95% of the measurements taken in any month and shall not exceed 1.0 NTU at any time. The reporting requirement for treatment plant turbidity is report the highest single measurement in the calendar year and the lowest monthly percentage of measurements that are less than or equal to 0.3 NTU.

(e) The highest turbidity at the Los Angeles Filtration Plant effluent was 2.4 NTU on December 30, 2010. This high turbidity reading reflects a single reading taken out of some 35,000 readings. Turbidity is monitored in 15 minute intervals all year round.

(f) Values reflect annual range and average of samples collected from six open reservoirs: Elysian, Ivanhoe, Los Angeles, Santa Ynez, Silver Lake, and Upper Stone Canyon.

(g) At-the-tap monitoring of lead and copper is conducted every three years as required by the Lead and Copper Rule. A system is out of compliance if the Regulatory Action Level is exceeded in the 90th percentile of all samples at the customers' tap. Although the City's treated water has little, if any, detectable lead, studies were conducted and corrosion control is scheduled for implementation.

(h) Values reflect testing at entry to the distribution system.

(i) NDMA was tested in 2009 – 2010 for compliance to Unregulated Contaminant Monitoring Rule (UCMR3).

10 **River Supply Conduit**

Water Travels through the City

Water from the pump station is carried through a 78" water main to Ivanhoe Reservoir in the Silver Lake area of the City.

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water is, in most cases, a small source of radon in indoor air. Radon is a known human carcinogen. Breathing air containing radon can lead to lung cancer. Drinking water containing radon may also cause increased risk of stomach cancer. If you are concerned about radon in your home, test the air in your home. Testing is inexpensive and easy. Fix your home if the level of radon in your air is 4 picoCuries per liter of air (pCi/L) or higher. There are simple ways to fix a radon problem that aren't too costly. For additional information, call your State radon program or call EPA's Radon Hotline (800-SOS-RADON)."

continued on page 14

11 **Water Storage**

Ivanhoe Reservoir

Shade balls floating the reservoir will protect the water from sunlight as the water travels onto nearby neighborhoods.

AR0071049

Table III Calendar Year 2010 Water Quality Monitoring Results

Unregulated Drinking Water Constituents/Contaminants Detected in Treated Water

Constituents/Contaminants	Units	Los Angeles Aqueduct Filtration Plant		Northern Combined Wells		Southern Combined Wells	
		Average	Range	Average	Range	Average	Range
Bicarbonate Alkalinity (as $CaCO_3$)	mg/L	168	88 – 125	144	104 – 176	144	128 – 201
Boron (NL = 1000)	µg/L	471	337 – 628	322	256 – 433	372	175 – 390
Bromide	µg/L	23	<20 – 38	25	<20 – 49	25	<20 – 77
Calcium	mg/L	25	23 – 27	57	27 – 74	57	44 – 86
Chromium, Hexavalent	µg/L	<1	<1	<1	<1 – 2	<1	<1 – 3.6
Heterotrophic Plate Count Bacteria (HPC)	CFU/mL	ND	ND	NA	NA	NA	NA
Magnesium	mg/L	8	7 – 9	15	8 – 19	15	10 – 23
N-Nitrosodimethylamine (NDMA) (NL = 10 ng/L)	ng/L	<2	<2	<2	<2	<2	<2
pH	Unit	7.4	7.2 – 7.6	7.4	7.1 – 7.8	7.4	7.2 – 7.8
Phosphate (as PO_4)	µg/L	51	40 – 64	100	48 – 156	100	77 – 1180
Potassium	mg/L	4	3 – 5	4	4 – 5	4	3 – 4
Radon (c)	pCi/L	<100	<100	<100	<100	<100	<100 – 150
Silica (as SiO_2)	mg/L	17	16 – 18	20	16 – 21	20	18 – 24
Sodium	mg/L	45	38 – 53	48	32 – 53	49	44 – 68
Total Alkalinity (as $CaCO_3$)	mg/L	106	88 – 125	144	104 – 176	144	128 – 201
Total Hardness (as $CaCO_3$)	mg/L	93	86 – 104	285	103 – 385	305	162 – 394
Total Organic Carbon (TOC)	mg/L	1.5	1.4 – 1.7	0.8	0.7 – 1.7	0.8	0.3 – 1.1
Vanadium (NL = 50)	µg/L	<3	<3	<3	<3 – 4	<3	<3 – 8

MWD Weymouth Plant		MWD Diemer Plant		MWD Jensen Plant		Major Sources in the Drinking Water
Average	Range	Average	Range	Average	Range	
NT	NT	NT	NT	NT	NT	Naturally-occurring dissolved gas; erosion of natural deposits
120	120 – 130	128	120 – 130	210	200 – 220	Erosion of natural deposits
NT	NT	NT	NT	NT	NT	Runoff/leaching from natural deposits; seawater influence
64 (a)	49 – 71	66 (a)	51 – 78	38 (a)	26 – 51	Erosion of natural deposits; natural hot springs
<1 (a)	< 1	<1 (a)	<1	<1 (a)	<1	Industrial discharge; erosion of natural deposits
<1	<1 – 1	1	<1 – 10	<1	<1 – 2	Naturally present in the environment
26 (a)	20 – 28	27 (a)	22 – 28	12 (a)	11 – 12	Erosion of natural deposits
<2	<2 – 3	<2	<2	3	<2 – 5	By-product of chloramination
7.9	7.6 – 8.6	7.9	7.5 – 8.0	8.2	8.1 – 8.4	Naturally-occurring dissolved gases and minerals
NT	NT	NT	NT	NT	NT	Erosion of natural deposits; agriculture run-off
5 (a)	4 – 5	5 (a)	4 – 5	2.7 (a)	2 – 3	Erosion of natural deposits
<100	<100	<100	<100	<100	<100	Decay of natural deposits
NT	NT	NT	NT	NT	NT	Erosion of natural deposits
94 (a)	83 – 98	95 (a)	78 – 95	67 (a)	58 – 85	Erosion of natural deposits
120 (a)	83 – 130	110 (a)	67 – 120	88 (a)	81 – 90	Erosion of natural deposits
360 (a)	84 – 300	270 (a)	57 – 300	120 (a)	86 – 130	Erosion of natural deposits
2.1 (a)	1.6 – 2.4	2.2 (a)	1.9 – 2.3	1.5 (a)	1.3 – 1.8	Erosion of natural deposits
<3	<3 – 3	3	<3 – 3.3	5.2	5 – 6	Erosion of natural deposits

Terms Used In The Tables

Compliance: A drinking water standard based on the health risk (primary standards) and aesthetics (secondary standards) exposure of a contaminant to consumers. For example, bacteria and nitrate have strict limits that must be met at all times due to the acute effects they can cause. Other standards, like small amounts of disinfection by-products and man-made chemicals, have standards that are based on a lifetime of exposure because the risk to consumers is very low. Compliance with most standards is based on an average of samples collected within a year. This allows for some fluctuation above and below the numerical standard, while still protecting public health.

Detection Limit for Reporting Purpose (DLR): DLR means the designated minimum level at or above which any analytical finding of a contaminant in drinking water resulting from monitoring required under Title 22 Code of Regulations shall be reported to the California Department of Public Health (CDPH).

Maximum Contaminant Level (MCL): MCL is the highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the Public Health Goals (PHGs) or Maximum Contaminant Level Goals (MCLGs) as is economically and technologically feasible. Secondary MCLs are set to protect odor, taste, and appearance of drinking water. For certain contaminants, compliance with the MCL is based on the average of all samples collected throughout the year.

Maximum Contaminant Level Goal (MCLG): MCLG is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. Environmental Protection Agency (USEPA).

Maximum Residual Disinfectant Level (MRDL): MRDL is the highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal (MRDLG): MRDLG is the level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants. MRDLGs are set by the USEPA.

Notification Level (NL): NL is the health-based advisory levels established by CDPH for chemicals in drinking water that lack maximum contaminant levels (MCLs).

Primary Drinking Water Standard (PDWS): MCLs and MRDLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.

Public Health Goal (PHG): PHG is the level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (OEHHA).

Regulatory Action Level (AL): AL is the concentration of a contaminant which, if exceeded, triggers treatment or other requirements that a water system must follow. ALs are set by the USEPA.

Secondary Drinking Water Standard (SDWS): SMCL is for contaminants that may affect the taste, odor or appearance for drinking water.

Treatment Technique (TT): TT is a required process intended to reduce the level of a contaminant in drinking water. For example, the filtration process is a treatment technique used to reduce turbidity (the cloudiness in water) and microbial contaminants from surface water. High turbidities may be indicative of poor or inadequate filtration.

Table IV Calendar Year 2010 Water Quality Monitoring Results

Drinking Water Disinfection By-Products Reported on Area-Wide Basis

Contaminants	Units	San Fernando Valley		Central Los Angeles		Western Los Angeles		Northern / Eastern Los Angeles		Major Sources in Our Drinking Water
		Average	Range	Average	Range	Average	Range	Average	Range	
Bromodichloromethane (BDCM)	µg/L	13	3 – 26	11	3 – 25	17	2 – 39	13	2 – 28	By-product of chlorine/ chloramine disinfection
Bromoform	µg/L	6	<1 – 26	5	1 – 22	7	<1 – 31	7	3 – 18	By-product of chlorine/ chloramine disinfection
Chloride (NL = 250)	µg/L	545	6 – 1044	210	66 – 377	213	60 – 550	71	28 – 116	By-product of chlorine disinfection
Chloroform	µg/L	11	1 – 44	9	1 – 33	25	1 – 97	11	1 – 32	By-product of chlorine/ chloramine disinfection
Dibromoacetic Acid (DBAA)	µg/L	5	<1 – 15	5	<1 – 14	6	<1 – 15	4	2 – 6	By-product of chlorine/ chloramine disinfection
Dibromochloromethane (DBCM)	µg/L	16	4 – 34	13	5 – 31	17	3 – 63	14	4 – 28	By-product of chlorine/ chloramine disinfection
Dichloroacetic Acid (DCAA)	µg/L	9	<1 – 25	9	<1 – 25	19	<1 – 85	6	<1 – 13	By-product of chlorine/ chloramine disinfection
Monobromoacetic Acid (MBAA)	µg/L	1	<1 – 4	1	<1 – 3	2	<1 – 4	1	<1 – 3	By-product of chlorine/ chloramine disinfection
Monochloroacetic Acid (MCAA)	µg/L	2	<2 – 7	2	<2 – 6	5	<2 – 17	<2	<2 – 5	By-product of chlorine/ chloramine disinfection
Trichloroacetic acid (TCAA)	µg/L	3	<1 – 10	3	<1 – 12	8	<1 – 58	4	<1 – 11	By-product of chlorine/ chloramine disinfection

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Shade Balls Minimize Bromate in City Reservoirs

LADWP continues to minimize bromate levels in open reservoirs, keeping them within regulatory requirements. A creative short-term intervention LADWP recently implemented was the use of "shade balls" to decrease the formation of Bromate. In 2008, shade balls were used to shade the water surfaces of Elysian and Ivanhoe Reservoirs. As a result, bromate levels have been consistently well below the current drinking water standard of 10 parts per billion.

In the long term, LADWP intends to permanently cover or replace all remaining uncovered reservoirs by 2022 as required by the LT2 regulation (please see Safeguarding our Surface Water, page 4). Meanwhile, all water served to our customers continues to meet all public health standards.

Lead Exposure from Plumbing Materials

LADWP monitors lead contents in source water and the distribution system and has not found detectable amounts. If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with home plumbing. The LADWP is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting in the pipes for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. This water can be collected and used to water plants. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at http://www.epa.gov/safewater/lead.

Pharmaceutical and Personal Care Products

Very low levels of pharmaceutical and personal care products (PPCPs) are increasingly being detected in U.S. drinking water supplies. PPCPs include medicines, shampoos, soaps, detergents, lotions, and perfumes. Currently, neither the state or federal government require LADWP to test for PPCPs. However, as a forward looking utility, LADWP conducts its own monitoring for these compounds.

In 2009, LADWP tested its source and treated waters for PPCPs. The amount of PPCPs detected was so minute that no adverse health effect from exposure has been reported. LADWP continues to study the issue with several other utilities and the Water Research Foundation. Customers can do their part by disposing of unwanted medications into a waste receptacle or by returning to a pharmacy—not down a toilet or drain.

12 Local Pump Station

Fletcher Pump Station
Additional chlorine is added before large pumps send the water to L.A. neighborhoods, east of Ivanhoe Reservoir.

13 The Journey Ends

At Home Treatment
Customers can further improve the taste of drinking water through chilling, filtration or by replacing older pipes, faucet fixtures, water heaters, water softeners and water filters.

CITY OF LOS ANGELES
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About This Report

The 2010 Drinking Water Quality Report was prepared by the Los Angeles Department of Water and Power (LADWP). This report is required by the California Department of Public Health (CDPH) and was prepared in accordance with CDPH guidelines. It was prepared, printed and mailed to you at a cost of 35 cents.

Contact Information

LADWP, the largest municipal utility in the nation, was established more than 100 years ago to provide a reliable and safe water and electric supply to the City's 4 million residents and businesses.

LADWP is governed by a five-member Board of Water and Power Commissioners, appointed by the Mayor and confirmed by the City Council. The Board meets regularly on the first and third Tuesdays of each month at 1:30 p.m. Meetings are held at:

Los Angeles Department of Water and Power
111 North Hope Street, Room 1555H
Los Angeles, CA 90012-2694

The meeting agenda is available to the public on the Thursday prior to the week of the meeting. You can access the Board agenda at www.ladwp.com or by calling (213) 367-1351.

For general information about LADWP, call 1-800-DIAL DWP (1-800-342-5397) or visit www.ladwp.com.

For questions regarding water quality, call the LADWP Water Quality Customer Services Group at (213) 367-3182.

For questions regarding this report, please call Mr. Nathan Aguayo at (213) 367-4561.

Want to know more about your drinking water and related regulations?

For more information about the NSF certification, call (800) 673-8010 or visit www.nsf.org.

For more information about CDPH certification, call (916) 449-5577 or visit www.cdph.ca.gov.

Los Angeles Department of Water and Power	www.ladwp.com
California Department of Public Health (CDPH)	www.cdph.ca.gov
U.S. Environmental Protection Agency (USEPA)	www.epa.gov

This report is printed on recycled paper.

This Message for Non-English Speaking Customers

This report contains important information about your drinking water. If you have any questions regarding this report, please contact us at (800) 342-5397.

Spanish
Este informe contiene información importante sobre su agua potable. Si tiene alguna pregunta sobre este informe, por favor comuníquese con nosotros llamando al (800) 342-5397.

Russian
В этом отчете содержится важная информация о вашей питьевой воде. Если у вас есть вопросы по этому отчету, вы можете позвонить по телефону (800) 342-5397.

Farsi
این گزارش حاوی اطلاعات مهمی در مورد آب آشامیدنی شماست. چنانچه سوالی در مورد این گزارش دارید لطفا با شماره تلفن (800)342-5397 با ما تماس بگیرید.

Japanese
この報告書には皆さんの飲料水に関する重要な情報が含まれています。この報告書に関して何かご質問があれば(800) 342-5397 までお問い合わせください。

Armenian
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2010 Drinking Water Quality Report
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Los Angeles Department of Water & Power

2011 POWER INTEGRATED RESOURCE PLAN

December 22, 2011

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Los Angeles Department of Water & Power

2011 Power Integrated Resource Plan

APPROVED BY:

RONALD O. NICHOLS
GENERAL MANAGER

ARAM BENYAMIN
SENIOR ASSISTANT GENERAL MANAGER
POWER SYSTEM

December 22, 2011

Integrated Resource Planning

Power System Planning & Development

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Los Angeles Department of Water and Power

2011 Power Integrated Resource Plan

December 22, 2011

Recommended by:

Michael A. Coia, Assistant General Manager – Power System

Randy S. Howard, Manager – Power System Planning & Development

John R. Dennis, Manager – Power Engineering

David B. Thrasher, Manager – Integrated Support Services

Eric Tharp – Manager – Power System External Generation

John C. Kokoska, Manager – Power System Internal Generation

Daniel Duffy, Manager – Power Transmission & Distribution

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Preface

This 2011 IRP represents an update of last year's 2010 IRP document, and addresses, among other things, updated renewable energy requirements, the latest load forecast, early divestiture of the Navajo coal plant, revenue and rate impacts, and the incorporation of public input.

The recent passage of legislation SB 2 (1X) establishes specific renewable energy requirements, enabling more near-term certainty on the near-term need and the associated plan for renewable energy resources. As a result, the strategic case options evaluated in this IRP reflect updated quantities and mix of renewables based on the recent load forecast and availability of renewable resources and their related transmission.

The current load forecast used in this IRP is lower than the one used in 2010. Compared to the prior forecast, electricity sales for year 2020 decreased by approximately 7 percent mostly due to updated econometric studies that indicate a more prolonged recovery from the recession. The lower load forecast results in less electricity demand and fewer replacement resources when compared to last year.

This IRP update recommends divestiture of the Navajo coal power plant by 2015, 4 years ahead of the 2019 end date. Regarding early Navajo coal divestiture, the analysis and findings of this IRP update are generally consistent with conclusions developed from last year's 2010 IRP process with more details of specific replacement resources and costs. Early divestiture of LADWP's other coal source—the Intermountain Power Project—while analyzed in greater detail in this IRP, will be subjected to further investigation and analysis in next year's 2012 IRP.

Also included in this 2011 IRP is an assessment of the revenue requirements and rate effects that support the recommended plan through 2020. The rate process which began earlier in 2011 is expected to conclude in 2012, from which a final budget and rate schedule will result. LADWP supports the City Council's efforts towards this process, and looks forward to the appointment of the Ratepayer Advocate so that these budget and revenue issues can be properly addressed in a collaborative and expeditious manner. Establishing the proper rate structure will allow LADWP to implement its plan and stay on track towards meeting its long-term goals and obligations.

Lastly, many of the recommendations contained in this IRP update address concerns raised during last year's IRP public outreach process, as well as from the summer 2011 rate process. Accelerating coal replacement, emphasizing energy efficiency, and expanding local solar were among the major issues that emerged from the public processes; these and others have been incorporated into the case analysis and long-term recommendations. Next year's 2012 IRP process will include a new outreach program that will build upon these themes, as well as identify any new concerns or issues that may emerge.

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I INTRODUCTION AND PURPOSE

The Los Angeles Department of Water and Power (LADWP) is currently facing some of the most serious environmental, regulatory, and economic challenges in its 100-year plus history. LADWP finds itself at a crossroads in terms of how the utility operates that will require revamping its power generation portfolio to continue providing the same reliable, low-cost electricity to the residents and businesses of Los Angeles. As the largest municipally owned utility in the nation, LADWP must continue to ensure reliable electricity service as it reduces greenhouse gas (CO_2) emissions and transitions from energy sources based on fossil fuels to sustainable forms of renewable energy.

This 2011 Power Integrated Resources Plan (IRP) is an update of last year's 2010 IRP, and reflects evolving environmental, regulatory, and economic developments since 2010. The purpose of this IRP remains as before—to provide a framework to assure the future energy needs of LADWP customers are met in a manner that balances the key objectives of:

- Maintain a high level of electric service reliability
- Maintain competitive rates
- Exercise environmental stewardship, including a reduced carbon footprint

In balancing these key objectives, LADWP's integrated resource planning efforts must be deliberate, comprehensive, and clear to our ratepayers as well as all other City stakeholders. LADWP's goal—and primary challenge—is to develop a long-term resource plan that is informative, sensitive to the local and regional economy, and adaptable to changes in state and federal regulations, fuel prices, and advances in power generation technologies.

This IRP presents several potential strategies for meeting LADWP's regulatory requirements and policy objectives, maintaining electric power service reliability, and minimizing any financial impact on ratepayers. LADWP rigorously evaluated each potential strategy to identify and recommend the best overall plan to meet its key objectives at the least cost.

This IRP is not a technical plan nor a compact to pursue all of the initiatives identified in this document. Instead, this plan establishes the overall vision for the power system and a broad discussion of the finances necessary to support that vision. LADWP needs to be free to react to market conditions and make corrections in its shorter term tactical plans. Additionally, short-term budgets will be refined and financial analysis published as they are recommended for approval by LADWP's Governing Board and the City Council.

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II PUBLIC OUTREACH

LADWP conducts a public review process on their IRP every other year. A review process was held last year in support of the 2010 IRP, and the results of that process are considered applicable to the 2011 IRP. A full scale public outreach program, similar to the one held in 2010, is planned for next year's 2012 IRP. In summary, following are the themes that emerged.

LADWP should:

- Emphasize a variety of energy resources
- Maximize energy efficiency and conservation
- Eliminate coal from its generation portfolio
- Emphasize local solar generation
- Avoid adverse impacts to vulnerable communities
- Clarify costs of IRP implementation and potential impacts to ratepayers
- Reduce environmental impacts
- Provide proactive leadership and transparency

For details regarding the 2010 Public Outreach effort, refer to Appendix N. The recommended strategy for addressing these themes is presented in Section 5.2.

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III 2011 IRP DEVELOPMENT PROCESS

The IRP is prepared by a group of engineers dedicated to LADWP resource planning and preparation of the IRP. This group is managed by a Supervising Engineer, with a direct reporting staff of four. While this group performs the production model and report preparation for the IRP, the bulk of the work is collaborative across the different work groups and functional areas of the Power System.

The IRP is developed in multiple stages, including:

1. Identifying and approving key assumptions
2. Establishing clear goals and objectives
3. Establishing strategic case alternatives
4. Completing computer modeling of power system operations
5. Recommending and approving a preferred case

Each of these stages includes coordination between multiple LADWP organizations responsible for different aspects of power system operations, preparing recommended positions for each stage, presenting recommendations to LADWP's leadership team, including Division and Section Heads, and ultimately presenting recommendations to the General Manager. At each of these presentations, modifications to recommendations are noted. The approval process for recommendations is based on consensus from the managers of each area of responsibility.

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IV RECENT ACCOMPLISHMENTS

A summary of recent LADWP accomplishments consistent with the objectives of this IRP are presented below in Table ES-1. These accomplishments promote the goals of maintaining high reliability and exercising environmental stewardship, while keeping rates competitive. See Section 1.5 for more details.

Table ES-1. LADWP RECENT ACCOMPLISHED PROJECTS/PROGRAMS

Project/Program	Time Period	Accomplishment
Milford II Wind Project	2011	Supply over 100 MW of wind energy
Electric Vehicles Incentive	2011	Provide a $2000 rebate for home EV charging systems
Southern Transmission System Upgrade	2011	Increased capacity of 480 MW was added to the existing transmission line
Navajo Generation Station Retrofits	2011	Retrofit burners reduce NO_X emission by 40% or 14,000 tons per year
Energy Efficiency Program	2000 to 2011	Reduced long-term peak period demand by 303 MW, 1,256 GWh of energy savings
Renewable Portfolio Standard	2003 to 2010	Increased renewable energy percentage from 3% to 20%
Castaic Upgrade	2004 to 2014	Project adds up to 80 MW renewable capacity
Green Power Program	1999 to 2011	Participants receive 104 GWh of renewable energy annually
Power Reliability Program	Ongoing	Improve reliability of Power System infrastructure
Solar Incentive Program	1999 to 2011	Provided funding that has enabled the installation of 41 MW of solar
CO_2 Emissions Reduction	1990 to 2010	CO_2 emission 23% lower than 1990 level
Once-through Cooling	1990 to 2011	OTC reduced by 17% from 1990 level

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V CHALLENGES AND CRITICAL ISSUES

LADWP faces a number of concurrent issues and challenges that require careful assessment. Long term strategies must focus on these issues so they can be addressed in the most cost effective manner without compromising reliability compliance and environmental stewardship. The major issues around which the strategies of this IRP are centered include: adequate funding to support initiatives, programs and projects; ensuring reliability; greenhouse gas emission reduction; increasing the amounts of renewable generation resources; and addressing once-through cooling.

Adequate Multi-year Funding to Support Programs

Based on last year's 2010 IRP, a multi-year rate increase was recommended beginning fiscal year 2011-12. The rate increase would have supported elements of last year's IRP, all of which remain as the foundation for LADWP's short and long term plans. Because the rate increase was not realized in July 2011, many of the programs that required funding were scaled down, delayed or deferred.

A multi-year funding plan is necessary to provide consistent and sustainable project and program development. Funding that is based on annual budgets are subject to year-to-year fluctuations which introduces uncertainty for our customers and the inefficient use of staff and financial resources that are necessary to meet LADWP's objectives and compliance requirements.

Properly funded programs will enable LADWP to achieve the following objectives:

- Modernize its coastal generation units to replace aging equipment and to satisfy once-through cooling regulatory requirements.
- Implement early coal divestiture.
- Secure the state-mandated amounts of renewable energy.
- Through the Power Reliability Program, reduce the number of distribution outages and improve system reliability.
- Implement necessary transmission improvements to maintain reliability.
- Achieve energy efficiency target levels.
- Implement Smart Grid initiatives.
- Comply with FERC-approved reliability standards.

A rate process that began earlier this year is addressing the revenue needs for LADWP. A proposed 3-year rate adjustment that would support the programs listed above is being considered. The expectation is that the rate process will conclude sometime in 2012. Securing adequate multi-year funding is crucial to ensure LADWP's ability to stay on track towards meeting its future long term goals and obligations.

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Ensuring Reliability

Challenges to ensuring continued reliable electric service include the replacement of aging generation facilities, maintaining grid reliability, the integration of intermittent renewable energy resources, and the replacement of poles, power cables, transformers and other elements of the local distribution system.

LADWP's Repowering Program, which began in 1994, is a long term program to upgrade LADWP's in-basin generating units. The program is a sequence of projects that extends to 2029, and will provide modern units that are more reliable than the units they are replacing.

To maintain grid reliability, LADWP's Ten-Year Transmission Assessment Plan has identified a number of necessary improvements. In addition, a recently completed Reactive Power Management Study recommends improvements to optimize grid performance and reduce system losses. More information can be found in Section 2.1.4.

The integration of renewable energy into the grid poses major reliability challenges. Because renewable resources like wind and solar produce electricity variably and intermittently (i.e., only when the wind is blowing or when the sun is shining), integration of these resources requires additional generator units to compensate for significant and often rapid swings in energy production. These swings present operational challenges and must be leveled by controllable generation capable of equally rapid changes of generation in the opposite direction. This stabilization is known as "regulation." A preferred solution would use energy storage to regulate delivery of energy and reduce the severity of integration problems. LADWP currently uses, among other resources, pumped water storage and hydro resources for regulation.

Between 2003 and 2005, LADWP experienced a growing number of distribution outages due to, among other things, aging infrastructure (poles, lines, transformers, etc.), and deferred maintenance and asset replacement.[1] In response, LADWP established a comprehensive Power Reliability Program (PRP) in 2006 which provided increased funding to address the growing maintenance backlog. The goals of the program include: (1) mitigating problem circuits and stations based on the types of outages specific to a given facility, (2) implementing proactive maintenance and capital improvements to avert problems before they occur, and (3) establishing replacement cycles for facilities that are in alignment with equipment life cycle.

Greenhouse Gas Emissions Reduction

LADWP's CO_2 emissions reduction strategy must comply with state and federal regulations. At the time of this writing, key legislation and regulations either promulgated or proposed include:

[1] To illustrate the age of the distribution system, over 50 percent of the City's 298,106 distribution poles are greater than 50 years old.

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- Assembly Bill (AB) 32, the California Global Warming Solutions Act of 2006, calls for reducing the state's CO_2 emissions to 1990 levels by 2020. The regulations for implementing a greenhouse gas emissions trading program under AB 32 were finalized and adopted on October 20, 2011 by the California Air Resources Board (ARB). Enforcement and compliance with the trading program will begin January 1, 2013. Electric distribution utilities, including LADWP, will receive an administrative allocation of emission allowances that reflects their respective annual emissions as they implement aggressive energy efficiency measures and the 33 percent Renewable Portfolio Standard. The ARB will continue to work with stakeholders to monitor the impacts of the regulation on all sectors, including the electricity sector.
- SB 1368, the California Greenhouse Gas Emissions Performance Standard Act, also enacted in 2006, prohibits LADWP and other California utilities from entering into long-term financial commitments for base load generation unless it complies with the CO_2 emissions performance standard. The CO_2 emissions level must be equal, or below, that of a gas-fired combined cycle units (i.e., 1,100 lbs. per MWh). This standard also applies to existing power plants for any long-term investments or contractual extensions.

LADWP has historically relied upon coal for base load generation. Currently, 39 percent of the energy delivered to LADWP customers is generated from two coal-fired generating stations: the Intermountain Power Project (IPP), located in Utah, and the Navajo Generating Station (NGS), located in Arizona. The NGS's land lease expires in 2019 but has a stipulation for a 25-year extension. IPP's contract is in effect until 2027. These stations provide dependable, low cost base load generation to Los Angeles. Coal-fired generation, however, emits about twice as much CO_2 as energy generated with natural gas. Accordingly, this 2011 IRP focuses on early coal divestiture options as a means to comply with AB 32 and lower LADWP's CO_2 emission levels. Sections 3 and 4 discuss the alternative strategic case options in detail.

Increasing Renewable Resources

Initiatives to utilize renewable resources to generate electricity support the goal of reducing CO_2 emissions and lessen our reliance on fossil fuels.

State legislation – SB 2 (1X) – which was passed in April 2011 and became effective on December 10, 2011, will subject all utilities to procurement of eligible renewable energy resources of 33 percent by 2020, including the following interim targets:

- Maintain at least an average of 20 percent renewables between 2011 and 2013
- Achieve 25 percent renewables by 2016

The legislation allows for the California Energy Commission to issue a notice of violation and correction, and to refer all violations to the California Air Resources Board. Failure to achieve the targets may result in significant penalties.

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Once Through Cooling

Once-through cooling (OTC) is the process of drawing water from a river, lake, or ocean, pumping it through a generating station's cooling system, and discharging it back to the original body of water. OTC is a major regulatory issue, stemming from the Federal Clean Water Act Section 316(b) and administered locally by the State Water Resources Control Board (SWRCB).

OTC regulations affect LADWP's three coastal generating stations – Scattergood, Haynes, and Harbor. To comply with OTC regulations, generation units at those stations that utilize ocean water for cooling will be repowered with new units that do not use ocean water. The total generation capacity affected by OTC is significant – approximately 2,162 MW, or roughly 35 percent of LADWP's annual peak demand in 2010. The total expenditures required are also significant, on the order of $2.4 billion. Because of the size and scope of the effort required, the work to comply with OTC regulation is a long term program, extending to 2029. Figure ES-1 is a timeline of the program target dates. More information regarding OTC is provided in Section 1.6.5.

Figure ES-1. Timeline for OTC compliance.

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VI STRATEGIC CASE ALTERNATIVES

IRP planning is an on-going process and as such, the development of the 2011 IRP strategic cases incorporates the latest changes that have occurred in the regulatory landscape, and tactical plans developed by the power system. This 2011 IRP also includes many updated assumptions that have been developed over the past year. These assumptions have influenced the composition of potential resource portfolios that can fulfill LADWP's goals of reliability, competitive rates and environmental stewardship.

Last year's 2010 IRP analyzed 6 strategic cases representing different potential renewable resource portfolio mixes, with and without the early divestiture of IPP, and recommended a comprehensive strategy that adopted elements of a number of the cases analyzed. The 2011-12 fiscal-year financial planning process included many of the assumptions and recommendations set forth in the 2010 IRP.

This year's IRP analyzes a focused set of strategic cases, expanding on the results from the 2010 IRP process. Cases from last year that included a variety of renewable percentage targets were eliminated, mostly due to the recent approval of SB 2(1X) which mandates a fixed set of renewable targets. Because the key remaining discretionary decision involves coal divestiture, a streamlined set of 3 new coal divestiture cases were analyzed. These cases are designed to assist policymakers and ratepayers to make informed decisions regarding accelerated coal divestiture, particularly with regard to the environmental benefits and resulting resource and electricity rate impacts. The time frames for coal divestiture for each strategic case are as follows:

- Case #1 provides a baseline without any early coal divestiture. Navajo Generating Station continues until 12/1/2019 and the Intermountain Power Project (IPP) until 6/15/2027.

- Case #2 considers an early divestiture of NGS, by 12/31/2015, with IPP until 6/15/2027.

- Case #3 considers early divestiture of both coal plants – NGS by 12/31/2015 and IPP by 12/31/2020.

Section 3 provides more information surrounding the development of the cases, including resource adequacy and net-short considerations. Table ES-2 provides a more detailed description of each strategic case. For comparison purposes, the recommended case from last year's IRP is included in the table.

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Table ES-2. CANDIDATE RESOURCE PORTFOLIOS FOR 2011 IRP

		2020	CO_2 or SB 1368 Compliance Date		New Renewables Installed Capacity (MW) 2011 – 2020					New Renewables Installed Capacity (MW) 2011 – 2030				
Case ID	Resource Strategy	RPS Target	Navajo Replacement	IPP Replacement[1]	Geo-thermal	Bio-mass	Wind	Non-DG Solar	Dist. Solar	Geothermal/ Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
1 (Base Case)	No Early Coal Divestiture	33%	12/1/2019	6/15/2027	183	60	492	401	325	308	492	451	466	162
2	Navajo Early Replacement	33%	12/31/2015	6/15/2027	183	60	492	401	325	308	492	451	466	162
3	Navajo and IPP Early Replacement	33%	12/31/2015	12/31/2020	183	60	492	401	325	308	492	451	466	162
Rec. Case 2010 IRP	33% RPS Balanced	33%	1/1/2014	6/15/2027	320	0	580	315	315	320	680	485	485	160

[1] Early replacement for IPP will be further evaluated in the 2012 IRP

VII EVALUATION OF STRATEGIC CASE OPTIONS

Key results for each model run were tabulated and compared against each other. Each strategy was ranked on average dollars per megawatt hour generation cost and the total million metric tons of CO_2 emissions. The selection of the best case for LADWP ratepayers hinges mainly upon the load forecast, price of natural gas, and CO_2 emission levels. All cases meet the mandated RPS percentage targets and reliability standards. The analytics performed for this IRP examined the associated costs of each strategic case.

The key modeling results are summarized below:

CO_2 Emissions Considerations

The reductions of CO_2 emissions are reflected in the production cost model simulations. Figure ES-2 illustrates a comparison of the resulting CO_2 emission levels of the three cases. Divestiture of Navajo results in an average 1.86 Million Metric Tons (MMT) reduction in CO_2 each year while IPP results in an average 3.26 MMT reduction each year. CO_2 reductions are accelerated in Cases 2 and 3 with the divestiture of Navajo and IPP prior to the expiration of existing power contracts with these facilities. Case 1 represents the normal course of emissions reductions with no early divestiture. Reduction levels are eventually reached in all cases in 2019 and then again in 2027 when SB 1368 essentially prohibits the importation of energy produced from coal when the existing power contracts expire.

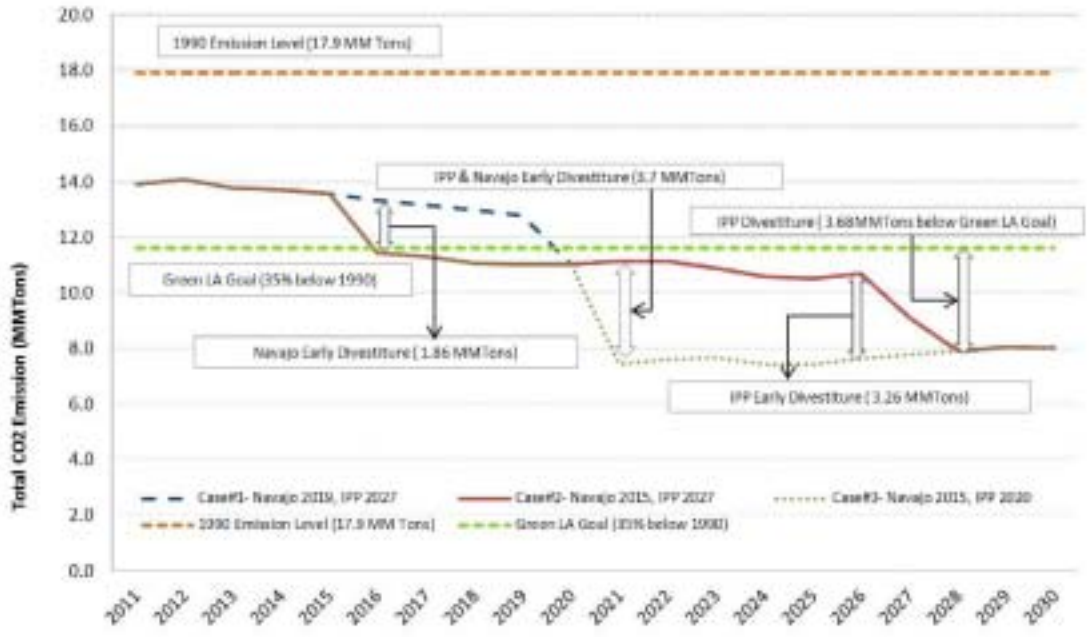

Figure ES-2. CO_2 emissions comparison by calendar year.

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Current CO_2 emissions levels are approximately 14.1 MMT which is 21 percent below 1990 levels due to the elimination of Mojave and Colstrip Coal, completed repowering of units at Haynes and Valley generating stations with cleaner gas-fired replacements, and increased renewable generation from 3% in 2003 to 20% in 2010. Early divestiture of Navajo shown in Cases 2 and 3 results in approximately 7.5 MMT less CO_2 emissions between 2016 and 2019 and early divestiture of IPP shown in Case 3 results in a reduction of CO_2 emissions of 21.1 MMT between 2020 and 2027.

Total Power System Cost Comparisons

The total power system cost for each case includes bulk power costs, depreciation costs related to transmission, distribution, and generation, bond debt-service, and city transfer costs. These costs assume full funding of the Power System programs including the Power Reliability Program and Energy Efficiency programs, among others. The Power System costs shown below in Figure ES-3 reflect short-term spending reductions through 2011-12 fiscal year with subsequent years reflecting a restoration of funding levels to insure that the IRP recommendations can be realized. The illustrated costs and rates presented below do not attempt to represent a thorough analysis of Power System finances. The main goal of this section is to illustrate the general trend of Power System costs relative to the 3 cases analyzed.

Figure ES-3 summarizes the total annual power system costs.

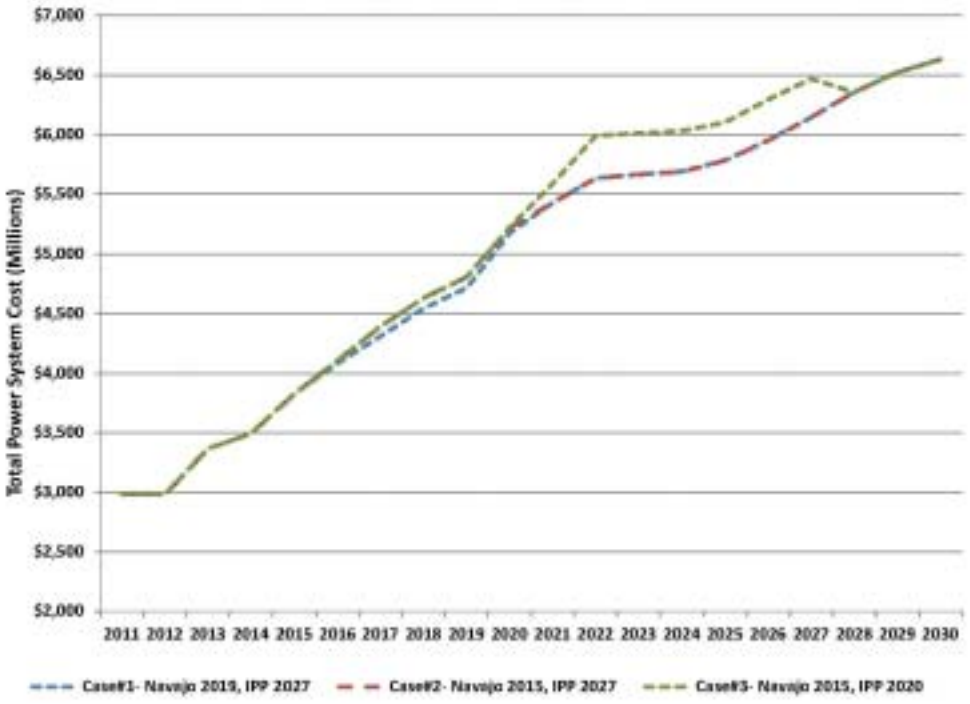

Figure ES-3. Comparison of annual power system costs over next 20 fiscal years.

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Sensitivity Analyses on the Recommended Cases

With the early divestiture of Navajo in 2015 and the IPP coal contract ending in June 2027, increased bulk power costs are expected to rise with the divestiture of each of these resources as shown on Figure ES-4. It is important to note that bulk power costs shown in Figure ES-4 include fuel, renewable and other purchase power costs in addition to coal divestiture related costs which are shown in Table 4-4. Applying high and low fuel prices to these bulk power costs, the divestiture of these resources could result in large cost increases should fuel prices remain at higher than expected levels. Conversely, lower than expected fuel prices could have the opposite effect on bulk power costs.

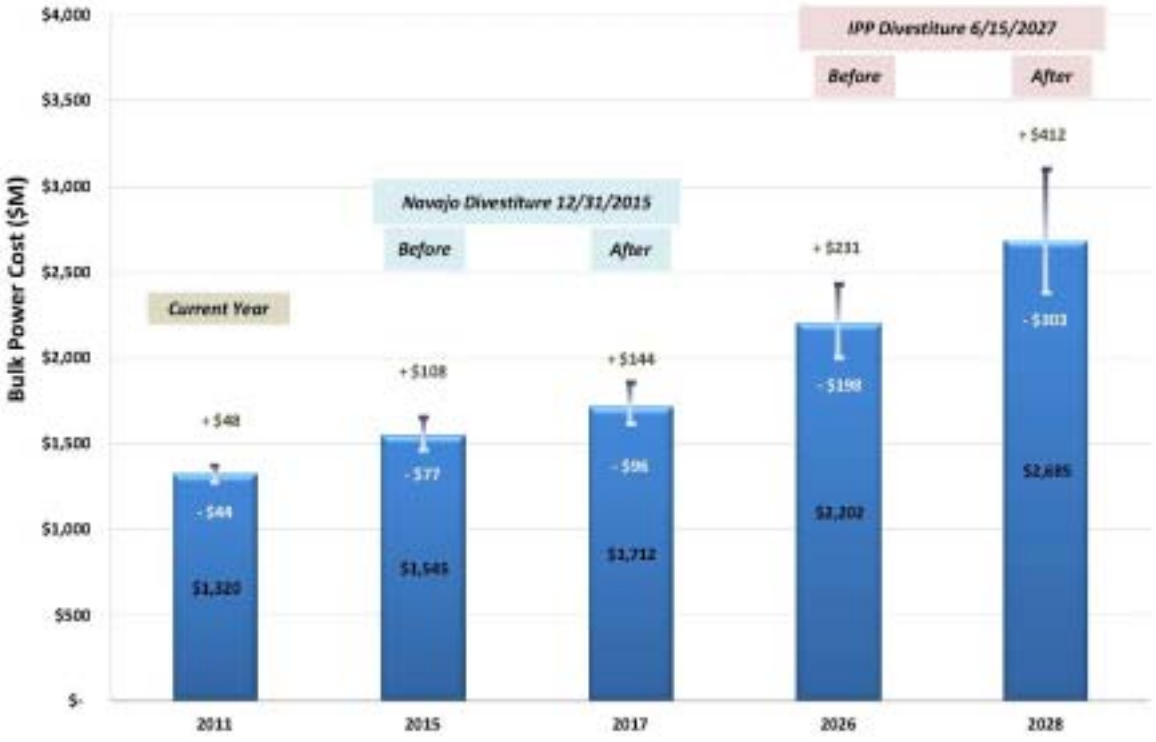

Figure ES-4. Recommended case - bulk power cost before and after coal divestitures with potential cost impacts from high and low fuel prices.

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Rate Contributions from Environmental and Reliability Programs

Summarized in Figure ES-5 is the cost contribution from various environmental and reliability programs towards the retail rates. One can draw the conclusion that there is a significant cost to comply with various reliability and regulatory requirements while divesting of Navajo in 2015 and IPP in 2027.

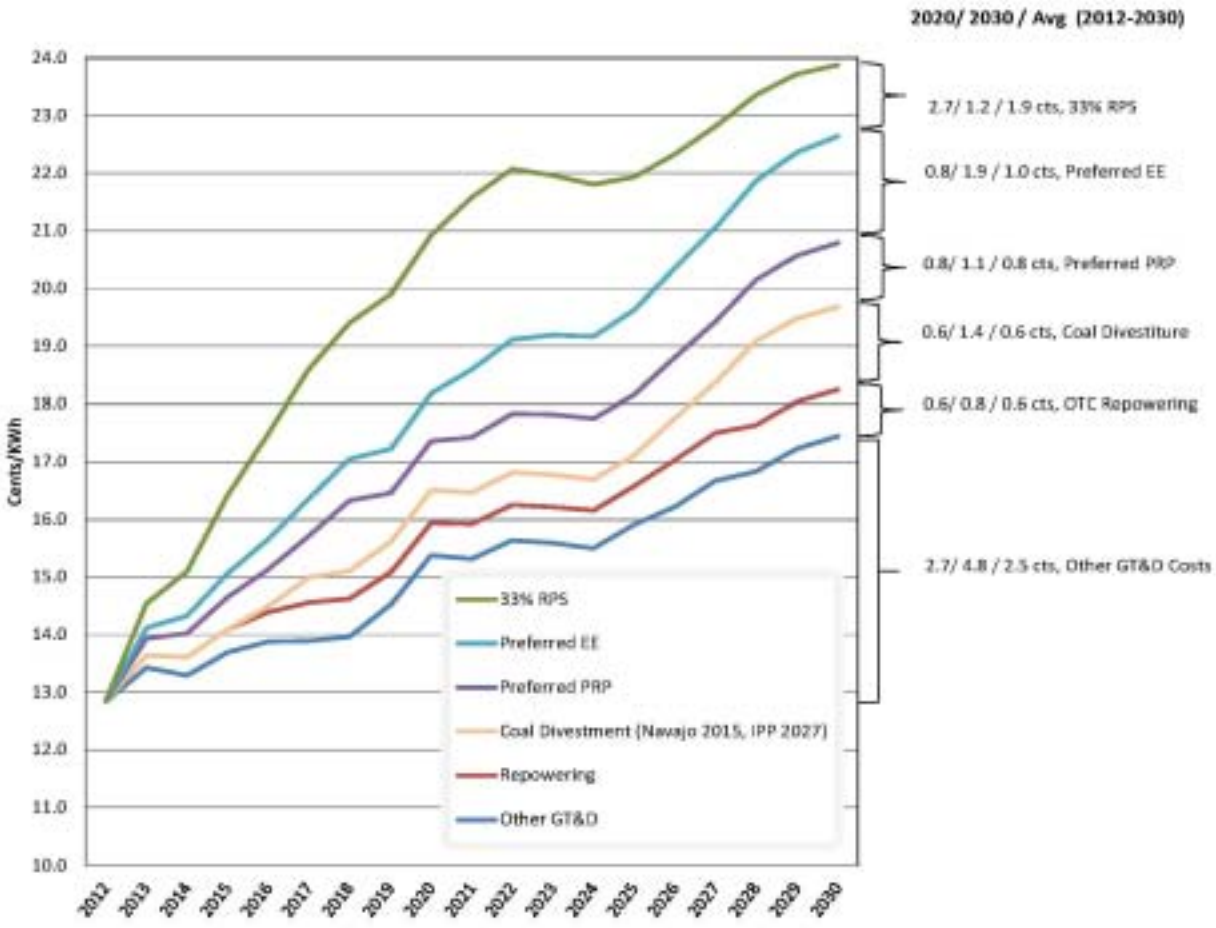

Figure ES-5. Electric rate contributions of environmental and reliability programs by fiscal year based on the 2011-12 budget forecast (preferred case).

A few observations from Figure ES-5 can be made regarding the RPS and EE program. Firstly, the influence of the RPS program on rates increases substantially through 2020 when the RPS percentage of sales reaches 33%. Beyond 2020, the RPS component of rates begins to decline as fuel savings increases over time with escalating fuel prices. Secondly, the EE program component of rates increases over time as power system fixed costs are distributed over the reduced energy sales attributable to the EE program.

Figures ES-6 and ES-7 further illustrate the effect that costs related to environmental and reliability programs will have on average residential and commercial/industrial customer

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monthly bills from these environmental and reliability programs.

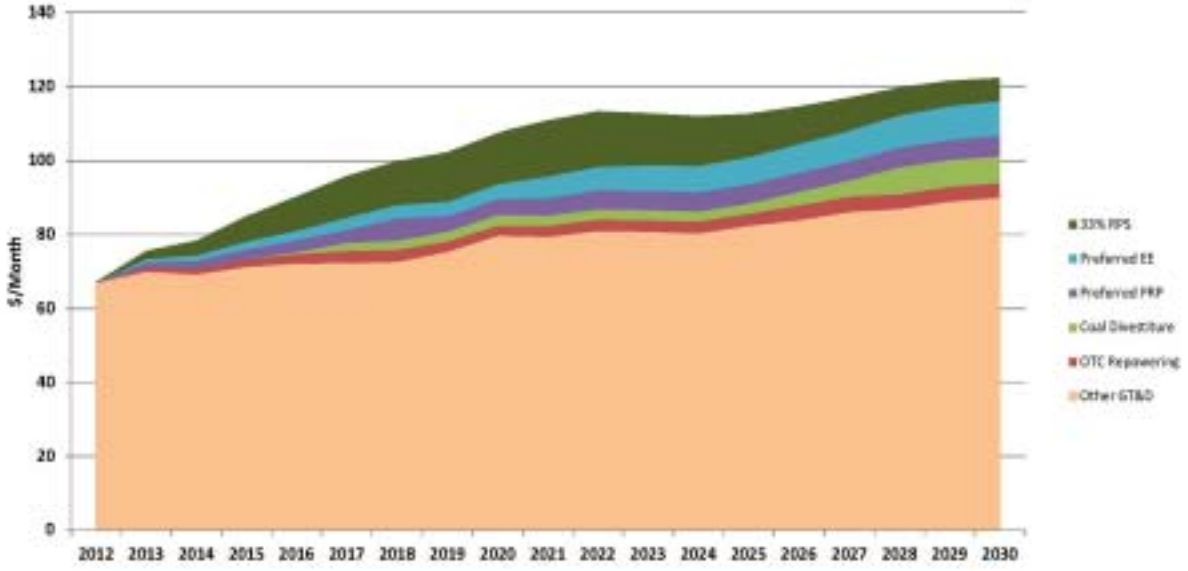

Figure ES-6. Average residential customer bill (500 kWh/month) with environmental and reliability programs by fiscal year based on the 2011-12 budget forecast (preferred case).

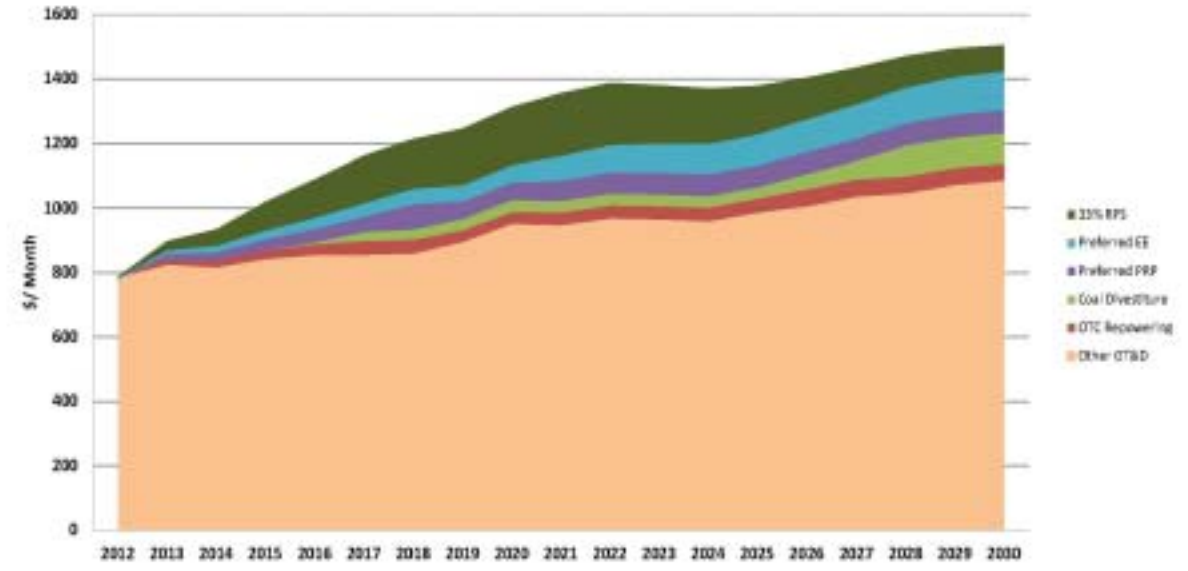

Figure ES-7. Average commercial/industrial customer bill (6,500 kWh/month) with environmental and reliability programs by fiscal year based on the 2011-12 budget forecast (preferred case).

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Recommended Strategic Case

Decisions to fund coal divestiture strategies cannot take place independent of other power system programs. Maintaining reliability and meeting regulatory requirements are primary considerations before any coal divestiture cases can be considered. However, this IRP presupposes funding of these programs so that the recommended coal divestiture case can be implemented.

Achieving the goals of reliability and environmental stewardship, while maintaining competitive rates, requires that costs be closely managed. Considering these factors, Case 2 (see Table ES-3 below) with early Navajo coal divestiture in 2015 becomes the recommended case for the 2011 IRP. Although Case 2 represents additional cost as compared to Case 1, the additional costs to rate payers appears to be reasonable in light of the environmental benefit of reducing CO_2 emissions by 7.5 MMT. Early divestiture of Navajo also provides additional time to insure a smooth transition in acquiring and implementing replacement resources. The 2010 IRP included the same recommendation to accelerate divestiture of Navajo and this IRP further clarifies and supports this prior recommendation. This recommended case presents a reasonable approach to achieving environmental goals without excessive costs to our ratepayers while limiting potential exposure to possible fuel price volatility to within manageable limits.

Table ES-3. 2011 IRP RECOMMENDED CASE

	2020	SB 1368 Compliance Date		New Renewables Installed (MW) 2011-2020			New Renewables Installed (MW) 2011-2030			
Case ID	RPS Target	Navajo Replacement	IPP Replacement	Geo/ Biomass	Wind	Solar	Geo/ Biomass	Wind	Solar	Generic
Case 2	33%	12/31/2015	6/15/2027	243	492	726	308	492	917	162

The changing generation energy mix for 2010, 2020, and 2030 based on the Recommended Case is illustrated in Table ES-4.

Table ES-4. ENERGY MIX FOR RECOMMENDED CASE

Year	2010	2020	2030
Coal	39%	26%	0%
Natural Gas	22%	21%	45%
Nuclear	11%	9%	8%
Hydro	3%	4%	4%
Renewable	20%	33%	33%
Energy Efficiency [1]	0%	7%	10%
Generic Purchase/ Other	5%	0%	0%

[1] Forward-looking, does not include 3% existing as of 2010.

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VIII CONCLUSIONS/RECOMMENDATION

LADWP's recommended strategy set forth in this IRP for meeting its key objectives can be separated into two areas: (1) Regulatory and Reliability Initiatives, and (2) Strategic Initiatives. Regulatory and Reliability Initiatives are required actions to ensure system reliability and compliance with regulatory and legislative mandates. Strategic Initiatives are policy actions to achieve objectives established by the LADWP Board of Water and Power Commissioners and the Los Angeles City Council, and reflect their vision and leadership.

The analysis performed in Section 4 to identify the 2011 IRP recommended case closely mirrors the same recommended strategy put forth in the 2010 IRP which incorporated feedback from LADWP's 2010 community outreach efforts (See Section 5.2 and Appendix N for details). The 2011 IRP recommended strategy differs slightly from the 2010 IRP in the timing of the Navajo coal divestiture which is now planned for 2015 instead of 2013. Another difference is in the renewable installed capacity by technology type (e.g. geothermal, wind, and solar). The reasons for these changes are further explained in Section 3.2.1.

Regulatory and Reliability Initiatives

- SB 2 (1X) - RPS Percentage

  LADWP must increase its percentage of renewable energy per recently enacted state law, from the current 20 percent at the end of 2010, to 33 percent by the end of 2020. SB 2 1(X) also establishes interim targets to ensure progress towards the 33 percent goal. Addressing this mandate requires the continued diligence LADWP has demonstrated in raising its renewable portfolio from 3 percent in 2003 to 20 percent in 2010.

- Power Reliability Program and System Infrastructure Investment

  LADWP must re-establish sustained funding to invest in replacing aging transmission and distribution infrastructure to ensure system reliability, especially during significant weather events. Recent funding shortfalls have resulted in an increase in system outages. Section 1.6.2 of this IRP discusses the negative consequences that continued underfunding poses to the city.

- Repowering for Reliability and to Address OTC

  LADWP will continue to repower older, gas-fired generating units at its coastal generating station for the reasons discussed previously. The repowering program is a long term series of projects that will increase reliability and eliminate the need for once-through ocean cooling.

- AB 32 – CO_2 Cap and Trade

  LADWP will participate in the mandated green house cap-and-trade system which is scheduled to start January 1, 2013. During the next year, LADWP will participate in the regulatory process that will clarify some outstanding details of the proposed program.

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- SB 1368 Compliance

  Navajo and IPP must be compliant with the mandates established in SB 1368 by 2019 and 2027, respectively. IRP modeling determined that these units will be replaced with a combination of renewable energy, demand response, EE, short term market purchases, and conventional gas-fired generation.

- Energy Efficiency

  LADWP will continue to pursue and implement energy efficiency programs per AB 2021 standards, including recommendations contained in its latest Market Potential Study.

- Castaic FERC Re-licensing Program

  On January 31, 2022, the Federal Energy Regulatory Commission's (FERC) license to operate Castaic Pumped-storage Hydroelectric Plant will expire. In 2016, LADWP expects to file a notice of intent (NOI) and initiate the formal studies and applications for re-license. Based on reviews of re-licensing activity for similar projects, LADWP could expect cumulative expenditures of approximately $10 million prior to filing the NOI and approximately $80 million before the license expires.

- Transmission

  LADWP should implement those recommendations of the latest Ten-Year Transmission Assessment Plan in order to maintain reliability in accordance with regulatory guidelines.

Strategic Initiatives

- Early Compliance with SB 1368

  Comments from the public workshops indicated the desire to comply with SB 1368 as early as possible. Navajo must be compliant with SB 1368 by 2019. LADWP recommends divestiture from Navajo by 2015. This will reduce LADWP's CO_2 emissions by 7.5 million metric tons and required additional revenue of about $343 million.

  In this 2011 IRP, LADWP recommends no change in IPP until 2027 at which time the site would be reconfigured, providing LADWP with firm transmission capacity for potential renewable projects. However, LADWP is actively investigating potential options in coordination with the Intermountain Power Agency (IPA) Board and the other participants, and will further address this issue in next year's 2012 IRP.

- Local Solar

  Comments received at the public workshops indicate local solar development should be a priority in LADWP's renewables procurement strategy. LADWP is recommending a policy action to allow approximately 40-50 percent of its solar resources be sited locally through initiatives including the Solar Incentive Program, feed-in tariffs, and installation of solar on City-owned properties. Local solar costs an estimated additional $50/MWh

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over utility-scale solar located outside the Los Angeles Basin, estimated to cost $120/MWh, primarily due to economies of scale and about 30% better solar insolation, even when considering transmission and distribution costs.

- Public Benefits

  LADWP should continue to pursue public benefit initiatives, including low-income and lifeline programs, refrigerator exchange, conservation, public outreach and education.

- Advanced Reliability Improvements

  LADWP is looking ahead to technologies that will enhance the reliability of its system, including smart grid technologies, enhanced information systems, automation of system functions, and advanced methods of outage management. These enhancements will also better integrate local generation such as solar into the distribution network, enable smart charging of electric vehicles, and advance demand-side management technologies.

- System Losses

  To reduce system losses, LADWP should implement the recommendations of the recently completed Reactive Power Management Study, including the installation of shunt capacitors and shunt inductors at appropriate locations within the system grid.

- Demand Response

  LADWP should begin the development of a formal Demand Response program that will initially provide 5 MW of peak demand capacity beginning in 2013 and gradually build to 200 MW by 2020 and 500 MW by 2026. Ramping the program in this manner will provide the development of in-house expertise, and will also allow time to deploy the supporting information systems necessary to implement these systems successfully.

Revenue Requirements

The reliability, regulatory, and strategic initiatives discussed above require revenue funding as shown in Table ES-5. In addition to funding for basic generation, transmission, and distribution, revenue is required to fund the Power Reliability Program, increase renewable energy, address OTC, energy efficiency and demand reduction, fund local solar programs, and transition away from coal.

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Table ES-5. RECOMMENDED REVENUE REQUIRED TO FUND PROGRAM INITIATIVES, 2011-2020

PROGRAM INITIATIVE	Revenue Requirement ($ Billion)
Power Reliability	$6.8
OTC Repowering of Power Plants	$1.2
Transition from Coal (Navajo GS)	$0.4
Increasing Renewable Energy	$6.0
Expand Renewable Transmission	$0.5
Expand Local Solar	$0.7
Increasing Energy Efficiency	$0.7
Smart Grid Investments	$0.3
SUBTOTAL	$16.6
Basic Generation, Transmission and Distribution	$23.4
TOTAL	$39.9

Some elements of the plan will take five to ten years to implement. It is important to commit to a direction so that critical time and resources are not lost. Subsequent IRPs will refine the direction as additional information becomes available. The recommended plan allows for flexibility to incorporate necessary adjustments over time. It is also important to set a steady course and pace to allow for reasoned and deliberate action by LADWP staff, Board, or City Council to avoid situations leading to unfavorable pricing or adverse rate impacts. The IRP implementation must be viable from a technical and financial perspective to best balance all the priorities of reliability, environmental stewardship, and cost.

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1.0 INTRODUCTION

1.1 Overview of the 2011 Integrated Resource Plan

This document represents the Los Angeles Department of Water and Power (LADWP) Integrated Resource Plan (IRP) for 2011. The goal of this IRP is to identify a portfolio of generation resources that meets the city's future energy needs at the lowest cost and risk consistent with LADWP's environmental priorities and reliability standards. The IRP is an important planning document for electric utilities, and many states and regulatory agencies require development of an IRP prior to approval of procurement programs or electric rate increases.

This IRP considers a 20 year planning horizon to guide LADWP as it executes major new projects and programs. The overriding purpose is to provide a framework to assure the future energy needs of LADWP customers are met in a manner that balances the key objectives of:

- High reliability of electric service
- Competitive electric rates consistent with sound business principles
- Responsible environmental stewardship meeting all regulatory obligations

In balancing these key objectives, LADWP's strategic planning efforts must ensure a high level of system reliability, consider impacts to the local and regional economy, allow for volatility in fuel and other cost factors, comply with federal, state, and local regulations, and guarantee fiscal responsibility.

The 2011 integrated resource planning process developed alternative strategic cases that assess different options of divestiture from coal-fired generation. These cases are modeled to determine their respective operational and fiscal impacts, as well as their effects on greenhouse gas emission levels. This document presents the results of this analysis and recommends the appropriate near-term actions and long-term plan to best meet the future electrical needs of Los Angeles.

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1.2 Organization of the IRP

This document begins with a brief discussion of the objectives of this IRP (Section 1.3).

Section 1.4 provides a brief overview of the current Power System—LADWP's electricity generation, transmission and distribution infrastructure. Power System upgrades are also addressed.

Section 1.5 summarizes LADWP's major recent accomplishments, underscoring LADWP's commitment to environmental leadership, maintaining a high level of electric service reliability, and competitive energy rates.

Section 1.6 summarizes the key issues and challenges facing LADWP. As the largest municipal utility in the U.S., LADWP faces unique challenges that are expected to become more complex and demanding over the timeframe considered in this IRP.

Section 1.7 summarizes the Public Outreach effort conducted in as part of the 2010 IRP process. The 2010 public outreach conclusions are considered applicable to this 2010 IRP. Next year's 2012 IRP process will include a new public outreach program.

Section 1.8 discusses the 2011 IRP development process that resulted in this document.

The remainder of this IRP is organized as follows:

- Section 2, "Load Forecast and Resources," provides forecasts of electricity demand, discusses the resources available or needed to meet that demand, and addresses the issues associated with each resource.
- Section 3, "Strategic Case Development," establishes potential alternatives available to LADWP to meet its projected electricity demand.
- Section 4, "Strategic Case Analysis," addresses the operational modeling used to assess the impact of each alternative on cost, energy rates, and levels of greenhouse gas emissions.
- Section 5, "Recommendations," provides an overview of recommendations, including near-term actions and long-term goals.

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1.3 Objectives of the IRP

This 2011 IRP documents the long term planning efforts for LADWP's power system. It includes a review of the various issues and considerations that LADWP must address moving forward, and summarizes the planning process used to identify future energy resource requirements. The recommended long term plan is presented, as are the actions and initiatives LADWP must undertake over the next several years. The key objectives of LADWP's long term planning efforts are: (1) maintaining a high level of electric service reliability, (2) exercising environmental stewardship, and (3) keeping its energy rates competitive.

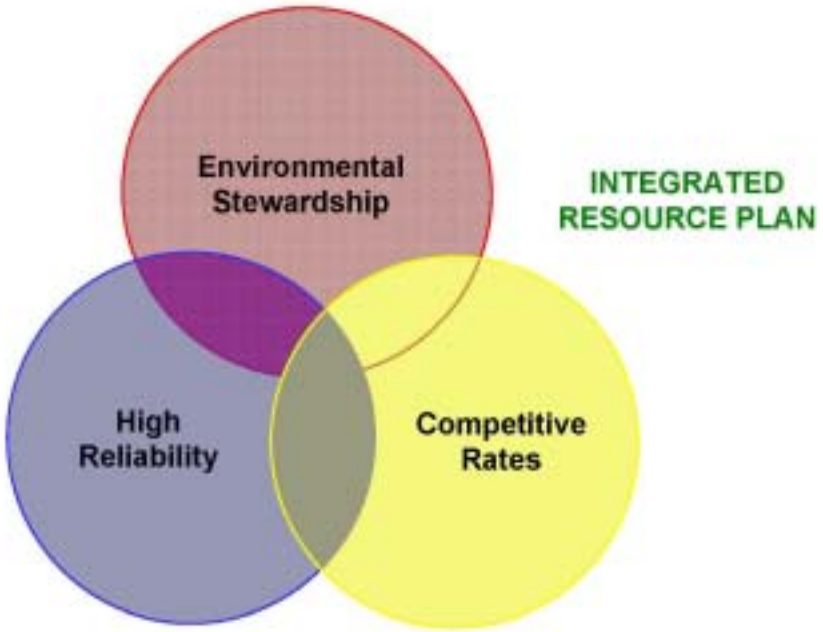

Figure 1-1. Objectives of this IRP.

1.3.1 Reliable Electric Service

Providing reliable electric service to the residents and businesses of Los Angeles has always been a cornerstone of LADWP. Some of the key principles, policies and program areas related to reliability are listed here:

- Reliability Standards

  LADWP will comply with all Federal Energy Regulatory Commission (FERC), North American Electric Reliability Corporation (NERC) and Western Electric Coordinating Council (WECC) standards regarding system reliability. NERC and WECC are electric utility organizations that enforce reliability standards on owners, operators and users of the bulk power system.

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- CAISO-RTO

  The California Independent System Operator or CAISO was established in 1998 as part of California's electric utility restructuring effort. CAISO was established as a non-profit corporation to provide an impartial link between power plants and utilities. LADWP is not a member of the CAISO but has recently been certified by the CAISO to be a scheduling coordinator which will authorize LADWP to buy and sell energy and/or ancillary services in the CAISO market. The ability to interface with CAISO increases the reliable operation of the bulk power system.

- Balancing Authority

  LADWP is a registered Balancing Authority with NERC and is responsible for coordinating and balancing the generation and delivery of electricity through its system. LADWP will continue to maintain its presence as a balancing authority.

- Self Sufficiency

  LADWP maintains a policy of owning or controlling its transmission and generation resources to serve its native load customers. This policy serves the City of Los Angeles well. However, in consideration of economic and environmental factors involved with the coal divestiture options discussed in Section 3 and 4, a limited amount of generation capacity is proposed to come from 3rd quarter purchases acquired in the wholesale electricity market. These purchases will be temporary in the 2015 to 2030 timeframe, will be called upon only in the third quarter of a given year, and will amount to less than 4% of the total system capacity needs.

- Coastal Power Plants

  LADWP operates three coastal natural gas fired power plants that are critical to its operations. These plants were built from the 1940s up to the 1970s. One of these plants was modernized in the 1990s, resulting in increased efficiency and reliability while reducing emissions and maintenance costs. The modernization of the remaining generation units is a long term program that is targeted for completion in 2029. LADWP must modernize these plants to comply with environmental regulations, improve efficiency, better integrate renewable resources, and provide for transmission import capability. See Section 1.6.3 and Appendix C for more details.

- Power Reliability Program.

  In response to an increasing frequency of power outages between 2003-2005, LADWP established the Power Reliability Program. The goals of the program include: (1) mitigating problem circuits and stations based on the types of outages specific to a given facility, (2) implementing proactive maintenance and capital improvements to avert/prevent problems before they occur, and (3) establishing replacement cycles for facilities that are in alignment with the equipment's life cycle. See Section 1.6.2 and Appendix E for more details.

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- Smart Grid

  Smart Grid refers to the application of advanced information-based technologies that will improve system operations in a variety of areas. Smart Grid technologies provide information that allows the implementation of real-time, self-monitoring communication networks that are predictive rather than reactive to system disturbances, and will enable LADWP and its customers to make decisions to optimize the use of energy, improve reliability, and reduce the consumption of fossil fuels. See Appendix L for more information.

- Distributed Generation

  Distributed Generation (DG) refers to the installation and operation of small-scale electric generators that are located at or near the electrical load. Cogeneration, solar photovoltaic, and fuel cells are examples of DG applications. As more DG is added within the city of Los Angeles, it is important that these generation sources be managed in a manner that does not reduce grid reliability. More information on DG is provided in Section 2.3.3 and Appendix G.

1.3.2 Competitive Rates Consistent With Sound Business Principles

Historically, LADWP's electric rates have been consistently among the lowest in California. As utilities throughout the industry address renewable energy, greenhouse gas emissions, ocean water cooling and other issues, it can be expected that rates for most, if not all utilities, will rise. By continuing its strategic planning and implementation activities, LADWP hopes to maintain its rates as among the lowest in the region.

Energy rates

As shown in Figure 1-2, LADWP's rates for Fiscal Year 2010/2011 were lower than other utilities in Southern California.

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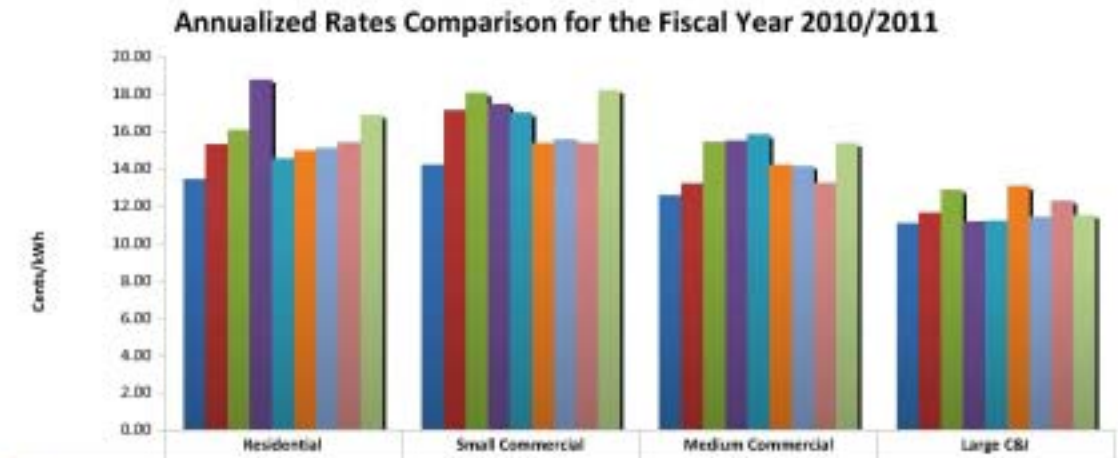

Figure 1-2. LADWP rate comparison among other electric utilities.

While LADWP provides electricity at competitively low rates, several factors challenge the current rate structure. These factors include new regulatory requirements for renewable energy, the reduction of greenhouse gas emissions and ocean water for power plant cooling, the costs to replace aging infrastructure, and the potential volatility of natural gas and coal prices. Transmission capacity upgrades, energy efficiency and demand response programs, and projects to implement coal divestiture will also exert upward pressure on energy rates. Because of these and other initiatives, it is expected that structural rate adjustments and amendments to the Energy Cost Adjustment Factor will be necessary to maintain appropriate debt ratios and bond ratings.

Financial Metrics

Since LADWP sells substantial amounts of bonds to sustain its capital expenditures, maintaining its high credit rating is essential to minimizing financial costs. To maintain its high credit rating, LADWP adheres to the following policies:

- Bond rating

  Maintain LADWP's current "AA" bond credit rating to keep financing costs as low as possible.

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- Debt service coverage

  Maintain a debt service coverage ratio of at least 2.25

- Adjusted debt service coverage

  Maintain an adjusted debt service coverage ratio of at least 1.75

- Full obligation coverage

  Maintain a full obligation coverage ratio of 1.5

- City transfer

  Maintain a level of net income sufficient to ensure stable transfer of funds to the City.

- Cash on hand

  110 days of operating cash or $300 million, whichever is greater.

- Capitalization ratio

  Maintain a capitalization ratio of 65% percent or less.

These financial parameters are used in the electric rates analysis, discussed in Section 5.5.

1.3.3 Environmental Stewardship

LADWP's mission includes a role as an environmentally responsible public agency. Programs and subject areas related to improving the environment include:

- Renewable energy

  LADWP will continue efforts to increase its use of renewable energy resources to provide electricity to Los Angeles. LADWP will, at a minimum, comply with local, state and federal mandates for levels of renewable energy as a percentage of electricity sales. Senate Bill SB 2 (1X) sets renewable energy targets of 20% for years 2011-2013, 25% by 2016 and 33% by 2020. For more information, see Sections 1.5, 1.6.4, 2.4, 3.4.2, and Appendix D.

- Carbon dioxide (CO_2) emissions

  LADWP will continue its efforts to reduce CO_2 emissions. The potential early divestiture from coal-fired generation, a key strategic focal point of this 2011 IRP, is one means of achieving reductions of CO_2 emissions. Additional recommended means of reducing CO_2 emissions include the continuation and expansion of energy efficiency programs, and the transition towards increasing amounts of energy generated from renewable resources. For further information, see Section 1.6.3 and Appendix C.

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- Once-Through Cooling

  LADWP has embarked on a series of repowering projects that are reducing the use of ocean water for cooling at its coastal generating stations. Completed projects to date have already reduced ocean water use by 17% from 1990 levels. The Haynes 5 & 6 repowering project, currently in construction and scheduled for completion in 2013, will further reduce ocean water use by another 25%. Within the 20-year planning horizon of this IRP, five additional repowering projects will totally eliminate the use of ocean water. More information on OTC can be found in Sections 1.6.5.

- Energy efficiency

  Since 2008, LADWP has spent approximately $282 million on its energy efficiency programs, and these programs have reduced long-term peak period demand and consumption by approximately 303 MW and 1,256 GWh, respectively. LADWP is committed to developing comprehensive programs with measurable, verifiable goals as well as implementing robust, cost effective energy efficiency programs. Further information regarding LADWP's EE Program can be found in Section 2.3.1 and Appendix B.

- Solar Incentive Program and Feed-in Tariff

  To date, LADWP has encouraged the installation of more than 41 MW of solar installations at over 4,500 customer locations through its ratepayer-funded Solar Incentive Program. Additionally, LADWP is developing a feed-in tariff program that will further promote solar development across the city. Solar energy will help LADWP achieve its environmental goals of increased energy generated from renewable resources and the reduction of greenhouse gas emissions.

- Demand Response Program

  This IRP recommends the development of a Demand Response (DR) program, which will lessen environmental impacts by deferring the need to build additional generation facilities and infrastructure, as well as reducing energy usage and the associated greenhouse gas emissions. Details regarding the proposed DR program are included in Section 2.3.2.

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1.4 LADWP's Power System

"Capacity" is an electric utility term referring to how much power a system can generate at a given instant in time, while "energy" refers to how much power the system generates over a given period of time. Capacity is expressed in megawatts (MW) or gigawatts (GW), while energy is expressed in megawatt-hours (MWh) or gigawatt-hours (GWh).

LADWP's Power System serves approximately 4.1 million people and is the nation's largest municipal electric utility. LADWP experienced an all-time peak demand of 6,142 megawatts (MW), which occurred on September 27, 2010, and has an installed net dependable generation capacity greater than 7,125 MW. Its service territory covers the City and many areas of the Owens Valley, with annual sales exceeding 23 million megawatt-hours (MWh). LADWP is the third largest California electric utility in terms of consumption, behind Southern California Edison and Pacific Gas & Electric—see Figure 1-3 below. Projected future demand growth for LADWP is less than one percent per year. The current economic recession has reduced energy demand slightly over the preceding three years.

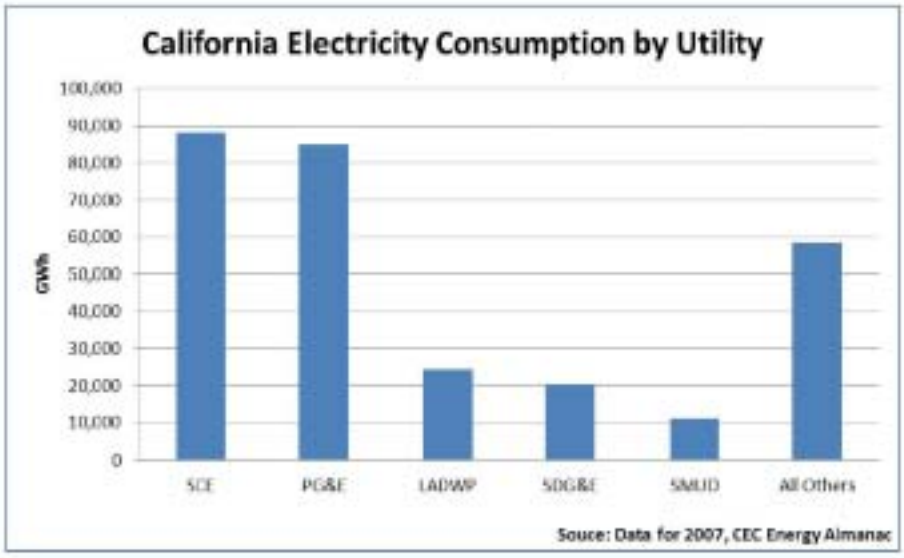

Figure 1-3. Comparison of California utilities by consumption.

LADWP is a "vertically integrated" utility—both owning and operating the majority of its generation, transmission, and distribution systems. LADWP is currently fully resourced to meet peak demand but maintains transmission and wholesale marketing operations to keep production costs low and increase system reliability.

While LADWP customers represent roughly 10 percent of California's electrical load, approximately 25 percent of the state's total transmission capacity is owned by LADWP. LADWP's transmission reach also extends beyond California, and enables the transport of power from a diversified set of generation resources from across the Western United States.

Additional information on the Power System's generation and transmission assets can be found in Section 2.4 and Appendices F and I.

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1.5 Recent Accomplishments

A summary of recent LADWP accomplishments consistent with the objectives of this IRP are presented below. These accomplishments promote the goals of maintaining high reliability and exercising environmental stewardship, while keeping rates competitive.

- Renewable portfolio standard

  Through the active procurement of renewable resources, LADWP has increased the renewable energy component of its resource mix from 3% in 2003 to 20% in 2010.

- Energy efficiency

  LADWP continues its commitment to energy efficiency through numerous programs and services to customers, encouraging the adoption of energy-saving practices and installation of energy-efficient equipment. Since 2000, LADWP energy efficiency programs have reduced long-term peak period demand by approximately 303 MWs, resulting in 1,256 GWh of energy savings.

- Emissions reduction

  As of 2010, CO_2 emissions from power generation are 23% lower than 1990 levels. The lower emissions are attributed to the respective sales of the Colstrip and Mohave Generation Stations, increased generation from renewable resources, and the ongoing repowering of the in-basin natural gas units.

  Due to the installation of advanced pollution control equipment at all of its in-basin generating stations, NO_X emissions from LADWP's local generating plants are at least 90 percent lower than 1990 level,

- Once-through cooling

  As a result of completed repowering projects, LADWP has reduced the use of once-through ocean water cooling by 17% from 1990 levels. The current plan calls for a complete phase-out of ocean water cooling by 2029.

- Haynes 5 & 6

  The September 2011 groundbreaking ceremony signified the start of construction for the replacement of Haynes Units 5 and 6. The original units, which date back to the mid 1960's, will be replaced with efficient modern units that can facilitate the integration of intermittent renewable energy. This project is also one of many that that will eliminate the use of ocean water for cooling by 2029.

- Castaic

  The seven units of the Castaic Hydroelectric Plant are currently being rotated out of service for modernization. This multi-phase process began in 2004 and is expected to continue through 2014. To date, five units have been completed. The associated increase in efficiency is projected to add up to 80 MW of renewable qualifying capacity to Castaic. The increased capacity also results in more reserves available to reliably meet peak system demands.

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- Power Reliability Program (PRP)

  The PRP is a comprehensive, long-term power reliability program developed by LADWP to replace aging infrastructure and make permanent repairs to generation, transmission, and distribution infrastructure. Through the program LADWP successfully reduced the number of distribution outages by 28% between 2006 and 2009, by accelerating the replacement of transformers, poles, underground cables, and other equipment. See Section 1.6.2 and Appendix E for more information.

- Green Power Program

  LADWP offers its customers an opportunity to participate in the Green Power Program. "Green Power" is produced from renewable resources such as wind energy, geothermal, or other renewable resources, rather than conventional generating plants. Over 17,100 LADWP customers participated in the program during 2010. These participants receive approximately 104,000 MWh of renewable energy annually. Since program inception, in 1999, to the end of 2010, 818,768 MWh of renewable energy was procured, making it one of the largest voluntary green pricing programs in the nation.

- Solar Incentive Program

  To date, LADWP has encouraged the installation of 41 MW of solar at approximately 4,500 customer locations through its ratepayer-funded Solar Incentive Program.

- Upgraded capacity on the Southern Transmission System (STS)

  In May 2011, 480 MW of additional capacity was added to the existing transmission line from Utah, of which LADWP's share is 288 MW. The increased capacity allows LADWP to increase procurement of renewable energy.

- Navajo Generating Station retrofitted with low NO_x burners

  In March 2011, Navajo completed a three year project that retrofitted the boilers of all three units with low NO_x burners and separated over-fire air systems. This project was successful in reducing NO_x emissions by 30% which represents an annual NO_x emission reduction of 14,000 tons per year.

- Barren Ridge Switching Station

  The Barren Ridge Switching Station, located 15 miles north of Mohave, was completed in 2009. This substation is a key component of the Barren Ridge Renewable Transmission Project, which will enable LADWP to interconnect approximately 1,400 MW of wind, solar, and other renewable resources that will be available in the next several years, from the Mohave Desert and Tehachapi Mountain areas. The next step for the project is to upgrade and build a new transmission line from the new substation to a new Haskell Canyon Station near Santa Clarita.

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- Milford II Wind Project

  In May 2011, LADWP began receiving over 100 MW of new wind energy. Milford II is an expansion of the 209 MW Milford I wind farm project. Together, Milford I and II are providing 2.6% of LADWP's total energy sales.

- Electric Vehicles Incentive for Home Chargers

  To encourage the transition towards electric vehicles, LADWP launched a demonstration program in April 2011 providing a $2,000 rebate for home charging systems. LADWP also worked with other City agencies to streamline the process time for permitting and installation of these systems.

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1.6 Key Issues and Challenges

LADWP faces a number of concurrent issues and challenges that require careful assessment. Long term strategies must focus on these issues so they can be addressed in the most cost effective manner without compromising reliability compliance and environmental stewardship. The major issues around which the strategies of this IRP are centered include: ensuring reliability, greenhouse gas emission reduction, increasing the amounts of renewable generation resources, and addressing once-through cooling.

However, the inability to fund the programs designed to address these issues warrants some discussion. Current budget constraints are deferring a number of initiatives and programs. The delays surrounding resolution of the Power System budget have the potential of impeding LADWP's ability to meet its long term plans and obligations.

1.6.1 Adequate Multi-year Funding to Support Programs

Based on last year's 2010 IRP, a multi-year rate increase was recommended beginning fiscal year 2011-12. The rate increase would have supported elements of last year's IRP, all of which remain as the foundation for LADWP's short and long term plans. Because the rate increase was not realized in July 2011, many of the programs that required funding were scaled down, delayed or deferred.

A multi-year funding plan is necessary to provide consistent and sustainable project and program development. Funding that is based on annual budgets are subject year-to-year fluctuations which introduces uncertainty for our customers and the inefficient use of staff and financial resources that are necessary to meet LADWP's objectives and compliance requirements.

Properly funded programs will enable LADWP to achieve the following objectives:

- Modernize its coastal generation units to replace aging equipment and to satisfy once-through cooling regulatory requirements.
- Implement early coal divestiture.
- Secure the state-mandated amounts of renewable energy.
- Through the Power Reliability Program, reduce the number of distribution outages and improve system reliability.
- Implement necessary transmission improvements to maintain reliability.
- Achieve energy efficiency target levels.
- Implement Smart Grid initiatives.
- Comply with FERC-approved reliability standards.

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A rate process that began earlier this year is addressing the revenue needs for LADWP. A proposed 3-year rate adjustment that would support the programs listed above is being considered. The expectation is that the rate process will conclude sometime in 2012. Securing adequate multi-year funding is crucial to ensure LADWP's ability to stay on track towards meeting its future long term goals and obligations.

1.6.2 Ensuring Reliability

Challenges to ensuring continued reliable electric service include the replacement of aging generation facilities, maintaining grid reliability, the integration of intermittent renewable energy resources, and the replacement of poles, power cables, transformers and other elements of the local distribution system.

Aging Facilities and Infrastructure

LADWP's generating units sited within the Los Angeles Basin were primarily built in the late 1950s and early 1960s. While these units have undergone extensive upgrades, they are approaching the end of their service lives. Repowering of these units began in 1994, and refurbishment is approximately one-third complete. Repowered units will be substantially cleaner, more efficient, and more reliable than the units they are replacing. Repowering LADWP's gas-fired units will also assist in integrating intermittent renewable resources into LADWP's energy mix by providing quick–response, back-up generation capacity.

LADWP's local transmission system cannot be reliably operated without generation from local thermal generating plants. The amount of generation required to provide transmission reliability is termed Reliability Must Run (RMR) generation. Repowering these local units will maintain transmission reliability by maintaining the reliability of RMR generation.

Historically, LADWP's local generation has provided voltage control for the basin transmission system. Over the years, as imports into the basin transmission system have increased, fewer local generators are on-line. No other means of voltage control, such as static capacitors and reactors, have been installed. As a result, LADWP's ability to control voltage has decreased. As more renewables become available, even fewer local generating units are likely to be on-line, and the ability to control nighttime voltage may become unmanageable.

Grid Reliability

LADWP's latest Ten-Year Transmission Assessment Plan has identified a number of infrastructure improvements that are needed to avoid potential overloads on key segments of the Basin transmission system. These overload conditions, if encountered, could lead to load shedding events (intentional power outages) to minimize the overall impact on the power system. LADWP has also investigated the system's reactive power needs, and

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recommends further improvements to reduce system losses and optimize performance. More information can be found in Section 2.4.4.

Integration of Intermittent Renewable Energy

The integration of renewable energy into the grid poses major challenges. Integrating renewables may, paradoxically, require additional gas fired generation. Because renewable resources like wind and solar produce electricity variably and intermittently (i.e., only when the wind is blowing or when the sun is shining), integration of these resources requires additional generation units to compensate for significant and often rapid swings in energy production. These swings present operational challenges and must be leveled by controllable generation capable of equally rapid changes of generation in the opposite direction. This stabilization is known as "regulation." A preferred solution would use energy storage to regulate delivery of energy and reduce the severity of integration problems. LADWP currently uses, among other resources, pumped water storage and hydro resources for regulation. Batteries and compressed air offer alternative storage solutions, but these technologies are still in development and have not yet been proven as commercially viable.

LADWP is conducting studies to determine the maximum levels of intermittent energy resources that can be integrated reliably and the investments necessary to maintain power grid reliability.

Power Reliability Program (PRP)

Between 2003 and 2005, LADWP experienced a growing number of distribution outages due to, among other things, aging infrastructure (poles, lines, transformers, etc.), and deferred maintenance and asset replacement.[1] In response, LADWP established a comprehensive Power Reliability Program (PRP) in 2006 which provided increased funding to address the growing maintenance backlog. The goals of the program include (1) mitigating problem circuits and stations based on the types of outages specific to a given facility, (2) implementing proactive maintenance and capital improvements to avert problems before they occur, and (3) establishing replacement cycles for facilities that are in alignment with equipment life cycle.

The PRP has clearly defined annual targets for various distribution, substation, and transmission assets. While cable replacements consistently reached ideal replacement rates, the overall number of underground related outages has been falling. However, the overhead distribution replacements did not reached their ideal replacement rates, and the number of overhead outages has continued to rise. This has also contributed to the overall aging of the overhead system. Overhead outages have increased and are expected to continue to degrade with less replacements moving forward. Since 72% of the distribution system is overhead, we can expect the overall distribution outage rate to continue to increase unless replacements are increased dramatically.

[1] To illustrate the age of the City's distribution system, over 50 percent of the 308,000 distribution poles are at least 50 years old.

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In the years since the program was implemented, a clear correlation has been established between the amount of funding for PRP and the successful reduction of outages. As shown on Figure 1-4, during the initial 3 years of the PRP, when the program was fully funded, total outages declined by 28%. Budget constraints since then, however, have resulted in program underfunding. As a consequence, outage frequency has flattened out and is on the up rise. The projected outage levels shown in Figure 1-4 reflect current budget shortfalls. Adequate funding is necessary to get the PRP back on track towards its goal of reducing outage levels.

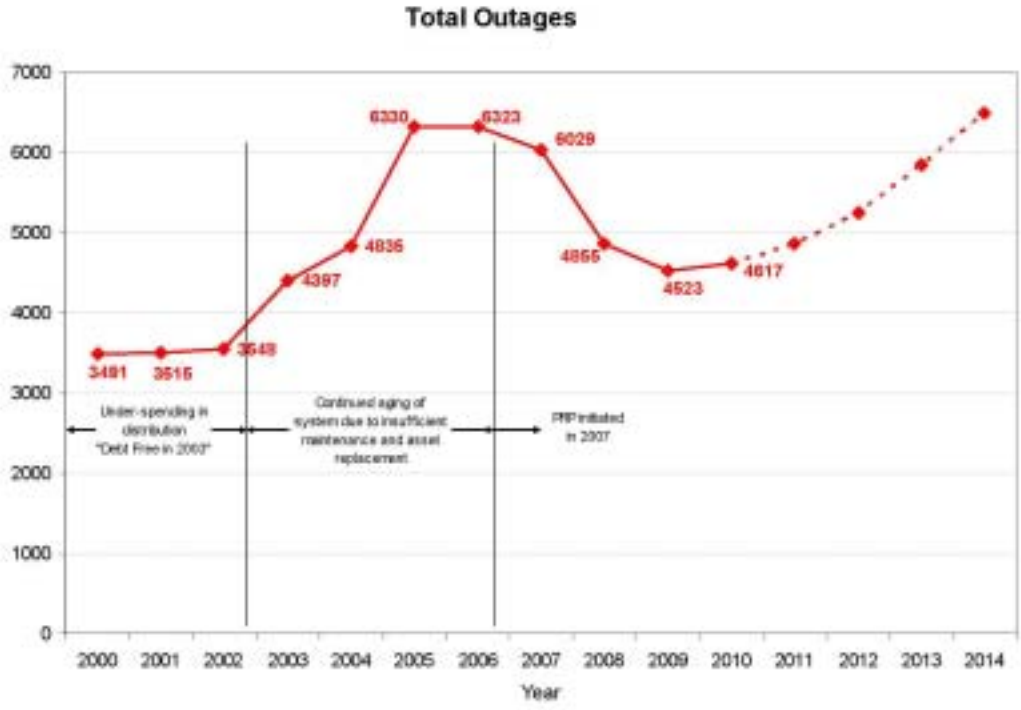

Figure 1-4. Total outages between 2000-2010, and projected to 2014.

Additional information on LADWP's PRP can be found in Appendix E.

1.6.3 GHG Emissions Reduction

LADWP's GHG emissions reduction strategy must comply with state and federal regulations. At the time of this writing, key legislation and regulations either promulgated or proposed include:

- Assembly Bill (AB) 32, the California Global Warming Solutions Act of 2006, calls for reducing the state's GHG emissions to 1990 levels by 2020. The regulations for implementing a greenhouse gas emissions trading program under AB 32 were finalized and adopted on October 20, 2011 by the California Air Resources Board (ARB). Enforcement and compliance with the trading program will begin January 1, 2013. Electric distribution utilities, including LADWP, will

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receive an administrative allocation of emission allowances that reflects their respective annual emissions as they implement aggressive energy efficiency measures and the 33 percent Renewable Portfolio Standard. The ARB will continue to work with stakeholders to monitor the impacts of the regulation on all sectors, including the electricity sector.

- SB 1368, the California Greenhouse Gas Emissions Performance Standard Act, also enacted in 2006, prohibits LADWP and other California utilities from entering into long-term financial commitments for base load generation unless it complies with the GHG emissions performance standard. The GHG emissions level must be equal, or below, that of a gas-fired combined cycle units (i.e., 1,100 lbs. per MWh). This standard also applies to existing power plants for any long-term investments or contractual extensions.

In the absence of comprehensive federal climate legislation, the U.S. Environmental Protection Agency (EPA) has taken steps toward regulating GHG emissions from electric power plants under authority of the federal Clean Air Act, and will be issuing a new revised schedule for regulations in the coming months.

LADWP has historically relied upon coal for base load generation. Currently, 39 percent of the energy delivered to LADWP customers is generated from two coal-fired generating stations: the Intermountain Power Project (IPP), located in Utah, and the Navajo Generating Station (NGS), located in Arizona. The NGS's land lease expires in 2019 but has a stipulation for a 25-year extension. IPP's contract is in effect until 2027. These stations provide dependable, low cost base load generation to Los Angeles. Coal-fired generation, however, emits about twice as much CO_2 as energy generated with natural gas. Accordingly, this 2011 IRP focuses on early coal divestiture options as a means to comply with AB 32 and lower LADWP's GHG emission levels. Sections 3 and 4 discuss the alternative strategic case options in detail.

1.6.4 Increasing Renewable Resources

Initiatives to utilize renewable resources to generate electricity support the goal of reducing GHG emissions and lessen our reliance on fossil fuels.

- The LADWP Board of Commissioners has adopted a policy to achieve 20 percent renewables by 2010, and 33 percent by 2020. The Board and City Council have approved projects and long-term power purchase agreements that achieved the 20 percent RPS goal in 2010. The policy has been revised to incorporate SB 2 (1X) requirements, and is included as Reference D-2 of Appendix D.

- State legislation – SB 2 (1X) – which was passed in April 2011 and became effective December 10, 2011, will subject all utilities to procurement of eligible renewable energy resources of 33 percent by 2020, including the following interim targets:

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- Maintain at least an average of 20 percent renewables between 2011 and 2013
- Achieve 25 percent renewables by 2016
- Achieve 33 percent renewables by 2020 and maintain this level in all subsequent years.

In addition, SB 2 (1X) sets certain conditions regarding renewable energy contracts entered into on or after 6/1/2010, as shown in Table 1-1.

Table 1-1. SB 2 (1X) CATEGORY REQUIREMENTS FOR RPS ENERGY CONTRACTS

Category[1]	RPS % Target		
	Compliance Period 1 (1/1/2011 – 12/31/2013)	Compliance Period 2 (1/1/2014 – 12/31/2016)	Compliance Period 3 (1/1/2017 – 12/31/2020)
A	Minimum 50%	Minimum 65%	Minimum 75%
B	See footnote 2	See footnote 2	See footnote 2
C	Maximum 25%	Maximum 15%	Maximum 10%

[1]Categories are defined as follows:

Category A = Energy and RECs from eligible resources that

- Have the first point of interconnection with a CA balancing authority or with distribution facilities used to serve end users within a CA balancing authority area; or
- Are scheduled into a CA balancing authority without substituting electricity from another source. If another source provides real-time ancillary services to maintain an hourly import schedule into CA, only the fraction of the schedule actually generated by the renewable resource will count; or
- Have an agreement to dynamically transfer electricity to a CA balancing authority.

Category B = Firmed and shaped energy or RECs from eligible resources providing incremental electricity and scheduled into a CA balancing authority.

Category C = Energy or RECs from eligible resources that do not meet the requirements of category A or B, including unbundled RECs.

[2]Remainder % of resources which are neither in Category A nor Category C.

The legislation allows for the California Energy Commission to issue a notice of violation and correction, and to refer all violations to the California Air Resources Board. Failure to achieve the targets may result in significant penalties.

The challenges of adopting more renewable resources such as wind, solar and geothermal, are: (i) obtaining local and environmental rights and permits for renewable projects and the associated transmission lines needed to deliver energy to Los Angeles; (ii) establishing reliable and cost-effective integration of large scale wind and/or solar farms into the LADWP power grid through the addition of regulation-capable generation; and (iii) developing geothermal sites which are potentially scarce, require large capital

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costs, impose exploration risks, and have limited transmission line access. In addition, energy from renewable resources is generally more expensive than energy from conventional fossil fuel resources.

1.6.5 Once-through Cooling

Once-through cooling (OTC) is the process of drawing water from a river, lake, or ocean, pumping it through a generating station's cooling system, and discharging it back to the original body of water. OTC is a major regulatory issue, stemming from the Federal Clean Water Act Section 316(b) and administered locally by the State Water Resources Control Board (SWRCB). The interpretation of rules and development of guidelines for OTC have been several years in the making. See Appendix C for details.

OTC regulations affect LADWP's three coastal generating stations – Scattergood, Haynes, and Harbor. To comply with OTC regulations, generation units at those stations that utilize ocean water for cooling will be repowered with new units that do not use ocean water. The total generation capacity affected by OTC is significant – approximately 2,162 MW, or roughly 35 percent of LADWP's annual peak demand in 2010. The total expenditures required are also significant, on the order of $2.4 billion. Because of the size and scope of the work required, and for various reasons discussed below, the work to comply with OTC is a long term program, extending to 2029.

It should be noted here that many of the units being replaced are older units that would have been replaced even without the OTC requirement. However, the OTC mandate requires some units to be replaced sooner than what may have been otherwise.

Discussions between LADWP and the SWRCB have resulted in the following timeline for OTC compliance (Figure 1-5).

Figure 1-5. Timeline for OTC compliance.

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There are many constraints and considerations that were factored into the development of the OTC compliance timeline. Because the LADWP power system relies on the in-basin units to provide transmission system reliability, as well as local sources of power generation, it is important to keep all of the units available to meet the peak summer demand. An older existing unit cannot be decommissioned (shut down) until the new replacement unit is built, tested, and ready to go on-line. This requires a strict sequencing of the separate repowering projects, as shown on Figure 1-5.

There are many challenges to meeting the target dates. The limited space available within some of the generating station property boundaries presents planning and construction difficulties. Other issues include the long lead times required for environmental permitting, engineering design, and equipment procurement. Any unforeseen delay – for example, a delay in acquiring an environmental permit or a delay in delivery of new plant components – will adversely affect the schedule. The timeline shown in Figure 1-5 represents LADWP's best effort to comply with the mandated compliance deadlines while also meeting its reliability responsibilities.

The effects of the repowering program on ocean water use are shown in Figure 1-6. As individual units are replaced with new units that do not use ocean water, OTC levels decrease. The overall goal of the program is the total elimination of OTC by 2029. Additional discussion regarding LADWP's compliance with OTC regulations can be found in Appendix C.

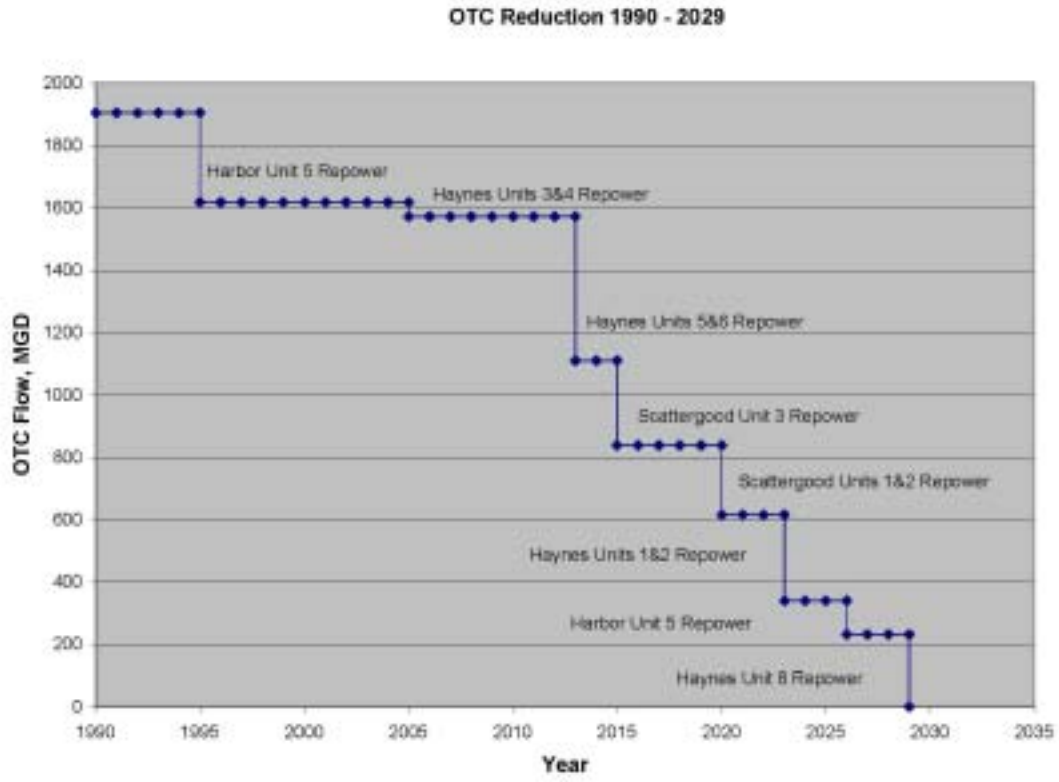

Figure 1-6. LADWP's reduction in once-through cooling from 1990 to 2029.

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1.6.6 Additional Challenges

Additional challenges that LADWP must address include an increased risk from natural gas price volatility, cyber security legislation, hydro-plant re-licensing, and improving system load factor:

- Natural Gas Price Volatility

  To the extent that LADWP seeks to reduce its GHG footprint, but cannot meet all its future needs through renewable resources and EE/DSM programs, a greater percentage of generation utilizing natural gas will be forthcoming. The energy profiles of all strategic cases analyzed in this IRP are composed of approximately 45 percent gas-fired generation by 2030. To reduce the price risk inherit when relying so much on a single fuel type, LADWP will need to continue to develop and implement strategies to hedge against natural gas price volatility. These strategies are designed to protect LADWP from potential future price fluctuations, and include financial hedging products, ownership of gas reserves to supply a portion of its fuel needs, and other potential products and contractual arrangements.

- Cyber Security Legislation

  Cyber security legislation which provides additional authority to the federal government, has been pending for several years. The Grid Reliability and Infrastructure Defense Act (GRID Act) of 2011 would grant new authority to the Federal Energy Regulatory Commission (FERC) to determine power system vulnerabilities and required actions by the power industry, and additional authority related to physical security and other threats. Public power is working with House and Senate representatives to develop a bill that focuses more on information sharing and which would allow a utility to take voluntary actions as they see best for their organization.

- Castaic FERC Re-licensing Program

  On January 31, 2022, the Federal Energy Regulatory Commission's (FERC) license to operate Castaic Pumped-storage Hydroelectric Plant will expire. The license is a co-license between LADWP and the Department of Water Resources (DWR) and includes a number of hydro power plants along the California Aqueduct. Both parties have initiated the joint re-licensing process that, on average, requires ten years to complete. Through 2015, LADWP expects to complete preliminary studies, contract negotiations, and prepare a filing strategy. In 2016, LADWP expects to file a notice-of-intent (NOI) and initiate the formal studies and applications. Based on reviews of re-licensing activity for similar projects, LADWP could expect cumulative expenditures of approximately $10

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million prior to firing the NOI and approximately $80 million before the license expires. From DWR's recent experience at re-licensing of Oroville Dam, they have informed LADWP that future mitigation cost could exceed $1 billion dollars for a new 50-year license period.

- Load Factor Improvement:

  Load factor represents how constant energy usage is over a given day. A 100 percent load factor means that the same amount of power is used off peak as on peak, so the system is getting full use of its generation, transmission, and distribution resources. A low load factor results in generators being started more often to serve load for a few hours a day, which is not optimum. As an analogy, a car traveling at constant speed will get the best gas mileage and reduced wear and tear than a car in stop-and-go traffic.

  From the 1990s through 2005, annual system load factors were trending slowly upward, which is a positive movement. Since 2006, however, system load factors are trending down. Some of this decline is due to the fact that much of the historic energy efficiency effort is directed at lighting, which has higher impact on sales when compared to peak. Also, most customers are making greater efforts to conserve energy but during extreme weather events safety and comfort predominate over conservation causing the peak to spike. It is imperative that LADWP implement tools to shift load from peak hours to off peak hours to reverse this trend and improve system performance.

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1.7 Public Process

LADWP conducts a public review process on their IRP every other year. A public review process was held in the fall of last year in support of the 2010 IRP. The review process included a series of public workshops and stakeholder meetings with representatives from neighborhood councils, environmental groups, and local business associations. The 2010 public review process is relatively recent, and the input gathered and the conclusions that emerged from that process remain mainly intact. A full scale public outreach program, similar to the one held in 2010, is planned for next year's 2012 IRP.

Therefore, this 2011 IRP relies on the findings from last year's public outreach effort (for details see Appendix N). In summary, following are the themes that emerged.

LADWP should:

- Emphasize a variety of energy resources
- Maximize energy efficiency and conservation
- Eliminate coal from its generation portfolio
- Emphasize local solar generation
- Avoid adverse impacts to vulnerable communities
- Clarify costs of IRP implementation and potential impacts to ratepayers
- Reduce environmental impacts
- Provide proactive leadership and transparency

Section 5 includes a discussion on how LADWP incorporated these ideas into its recommended strategy.

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1.8 2011 IRP Development Process

Note: The 2011 IRP process did not include public review. Next year's 2012 IRP process will include a public outreach program similar to the one conducted as part of the 2010 IRP.

The IRP is prepared by a group of engineers dedicated to LADWP resource planning and preparation of the IRP. This group is managed by a Supervising Engineer, with a direct reporting staff of four. While this group performs the production model and report preparation for the IRP, the bulk of the work is collaborative across the different work groups and functional areas of the Power System.

The IRP is developed in multiple stages, including:

1. Identifying and approving key assumptions

   The assumptions form the basis for subsequent analysis, and include such factors as load and fuel price forecasts, renewable resource percentages targets, CO_2 allowances and pricing, projected energy efficiency implementations, repowering schedules, etc. Assumptions are prepared and approved by the internal LADWP organizations responsible for the respective subject areas. The assumptions are then presented to LADWP management for comments and acceptance.

2. Establishing clear goals and objectives

   The overarching goal of LADWP's IRP planning efforts is to produce a long term plan that ensures the future supply of electricity that is reliable, competitively priced, and is secured in a manner consistent with environmental stewardship. Through the planning and development process, specific initiatives, programs and projects (many which are in progress) are identified and assessed. The planning effort is collaborative among cross functional organizations within LADWP. Each initiative, program and project will have its own appropriate set of goals and objectives, which in turn supports the collective goal of reliable, affordable electricity that is sensitive to the environment.

3. Establishing strategic case alternatives

   Each of the strategic cases is developed by IRP staff with input from each of the internal LADWP organizations. The strategic cases are designed to consider alternative future resource portfolios, and reflect real decision points and plans that LADWP will have to implement. The current major decision area for LADWP is coal divestiture; therefore, this IRP considers three alternative options for reducing coal-fired energy (whereas last year a decision area was the amount of renewable energy to adopt, it is no longer discretionary due to regulatory mandates, and is not a distinguishing feature among the current alternatives). Each case is vetted through LADWP management and working meetings are held to agree on final cases to be assessed.

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4 Completing computer modeling of power system operations

Simulations of the case alternatives are made using the Planning and Risk (PAR) software. PAR is a widely used hourly production cost model that commits and dispatches resources to minimize the cost of serving electric load. PAR is used by many utilities across the US and the world. The modeling results are vetted for quality, including a third party consultant review. Post model analysis is then conducted to account for non-generation system costs, including transmission and distribution. The final results compare each case in terms of reliability, costs, and CO_2 emissions reduction. The results are reviewed by management for comments and acceptance. If needed, modifications are made to the model input assumptions for new computer runs.

5 Recommending and approving a preferred case

Based on the results of the case alternative analysis, a recommended case is identified. The recommended case is presented to management for review and acceptance.

Each of these stages includes coordination between multiple LADWP organizations responsible for different aspects of power system operations, preparing recommended positions for each stage, presenting recommendations to LADWP's leadership team including Division and Section Heads, and ultimately presenting recommendations to the General Manager. At each of these presentations, modifications to recommendations are noted. The approval process for recommendations is based on consensus from the managers of each area of responsibility.

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1.9 Conclusions

Addressing all of these challenges requires considerable amounts of labor and capital resources, which applies upward pressure on LADWP's electric rates. It is important to note that LADWP cannot compromise on its responsibility to ensure adequate reliability of its power system. As facilities age, they must be repaired and eventually replaced.

LADWP is focusing on both near-term and long-term solutions. Attainment of the objectives and goals documented in this 2011 IRP will require the continued implementation of existing programs and projects, as well as the introduction and expansion of new initiatives and program areas. The following list shows the major activities that require action over the next 3-5 years (for more information, see the referenced IRP sections).

Major Power System Activities 2011-2016

Program Areas in Progress

- **Haynes 5&6 Repowering** (Sections 1.6.5, 2.4, 3.2.1, and 3.3; Tables 4-5, 5-3, and 5-4; Appendix F)
- **Scattergood Repowering** (same as Haynes 5&6 references)
- **Coal Divestiture Planning and Implementation** (Sections 1.6.3, 2.4, 3.2.1, 3.3, 3.5, 4, and 5)
- **Replacing aging distribution infrastructure** (Sections 1.6.2; Appendix E)
- **RPS procurement** (Sections 2.4, 3,4, and 5; Appendices D and M)
- **Solar Program Development** (Sections 2.4, 3.2, and 5; Appendices D, G, and M)
- **Existing EE program elements** (Section 2.3; Appendix B)

New Program Areas

- **Demand Response Program** (Sections 2.3.2, 3.2.1, 5.3, and 5.6; Table 4-3)
- **New EE program elements** (Section 2.3; Appendix B)
- **Smart Grid Implementation** (Section 2.3.4; Appendix L)
- **Transmission Line Improvements** (Sections 2.4.4 and 5; Appendix I; Tables 4-5 and 5-3)
- **Grid Reliability Improvements** (Sections 2.4.4 and 5)
- **Haynes 1&2 Repowering** (Sections 1.6.5 and 3.3)

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2.0 LOAD FORECAST AND RESOURCES

2.1 Overview

Through an IRP, utilities forecast the demand for energy and determine how that demand will be met. Meeting forecasted demand is accomplished by the planning and delivery of electric power generating ("supply-side") resources through transmission and distribution systems. Another key element of IRP planning is to determine how to reduce energy demand and increase the efficiency of the utility customer's use of electricity, known as "demand-side resources."

This section of the IRP addresses the following:

- Forecasting of future energy demand
- Demand-side Resources (DSR), including Energy Efficiency and Demand Response
- Supply-side Resources
- Transmission/Distribution
- Reserve requirements

The discussions include the technical, regulatory, and economic factors that affect LADWP's planning and execution of programs and projects.

Data for this analysis comes from publicly available reports from organizations like the California Energy Commission (CEC), California Public Utilities Commission (CPUC), the North American Electric Reliability Corporation (NERC), the Federal Energy Regulatory Commission (FERC), industry forecasts, and internal LADWP sources. Also highlighted in this IRP are additional studies that are either underway or will be performed in the near future to provide additional clarity regarding the boundaries and needs of the system.

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2.2 Forecast of Future Energy Needs

For this IRP, LADWP developed a forecast of customer demand for energy over the next 20 years (the complete 2011 load forecast is included in Appendix A). Econometric models are used to forecast retail sales and peak demand. Net Energy for Load (NEL) is defined as the production necessary to serve retail sales. NEL, and its allocation across various times of the day, are functions of the retail sales and peak demand forecasts. The retail sales forecast is the sum of seven separate customer class forecasts. The classes are residential, commercial, industrial, plug-in electric vehicle (PEV), intradepartmental, streetlight, and Owens Valley. The drivers in the retail sales models include normalized weather, population, employment, construction activity, and personal consumption. The NEL forecast is derived from the retail sales forecast by applying a normalized loss factor of 11.5 percent. Losses can vary depending on the sources of energy production. NEL load growth becomes a driver of the peak demand forecast. Peak demand is also a function of temperature, heat buildup, and time of year. The NEL forecast is allocated using the Loadfarm algorithm developed by Global Energy. The inputs into the algorithm are NEL, peak demand, minimum demand, and system load shape.

2.2.1 2011 Retail Electrical Sales and Demand Forecast

The effect of the recent recession and slower than normal recovery combined with cooler than normal weather depressed electricity sales by approximately 6 percent off their fiscal year 2007-08 peak. Losses in commercial sectors such as construction, real estate, retail, and leisure are forecasted to recover as the economy expands.

The electricity consumption within LADWP's service territory is forecasted to remain flat over the next three years. The load forecast predicts an increase of 1.6 percent in 2014-15 due to the expected completion of large mixed-use projects. The growth in annual peak demand over the next twenty years is predicted to be about 1.1 percent—approximately 65 MW per year—with less growth over the next few years due to the current recession. After 2016, some of the growth will not be realized at the meter depending on the adoption of energy efficiency and distributed generation technologies.

The 2011 Forecast is LADWP's official power system forecast. This forecast is used as the basis for LADWP power system planning activities including, but not limited to, integrated resource planning, transmission and distribution planning, and wholesale marketing. The forecast is a public document that uses only publically available information.

Table 2-1 summarizes the data sources used to develop the forecast and where these data sources have been updated from previously published forecasts.

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Table 2-1: LOAD FORECAST DATA SOURCES

Data Sources	*Updates*
1. Historical Sales through September 2010 are reconciled to the General Accountings Consumption and Earnings Report.	*Historical Sales, Net Energy for Load and weather data is updated through September 2010.*
2. Historical NEL, peak demand and losses through September 2010 are reconciled to energy accounting data.	
3. Historical weather data is provided by the National Weather Service and Los Angeles Pierce College.	*Weather is updated through March 2010.*
4. Historical Los Angeles County employment data is provided by the State of California Economic Development Division using the March 2009 benchmark.	*Employment data is updated through September 2010 using the March 2009 benchmark.*
5. Historical population and forecasts is provided by the State of California Department of Finance.	Population data is updated through January 2010.
6. The long-term Los Angeles County economic forecast is provided by UCLA Anderson Forecast.	
7. The construction activity forecast is provided by McGraw-Hill Construction.	*Building permit data is updated through September 2010.*
8. The plug-in electric vehicle (PEV) forecast is based on the CEC statewide PEV forecast.	
9. The port electrification forecast is provided by the Port of Los Angeles.	
10. The housing forecast is informed by the City of Los Angeles "Housing that Works" plan.	

2.2.2 Five-year Sales Forecast

The Retail Sales Forecast through 2016 represents sales that will be realized at the meter. In the forecast, energy efficiency and solar savings are expected to occur uniformly throughout the year as a simplifying assumption. Installation schedules are difficult to prepare because they rely on the customers allowing the installation to occur.

Energy efficiency and customer solar installations cause about a two percent drop in retail electricity sales. The remaining decreases in the next two years are attributed to economic conditions. Personal consumption should decrease as personal income flattens and savings and tax rates increase. Vacancy rates in the commercial sector are expected to increase short term. Manufacturing jobs are forecast to continue to decline. Retail electricity growth will lag growth in the economy somewhat. Businesses will become more efficient and begin to increase their operating margins as the economy improves. As shown in Figure 2-1, once the operating margins increase, new hiring will begin again and then retail electricity sales will begin to grow.

AR0071113

Figure 2-1. Retail sales net of energy efficiency and distributed generation.

Table 2-2 shows projections of short-term retail sales growth:

Table 2-2. SHORT-TERM GROWTH

Fiscal Year	Retail Sales		Additional Load if not for EE & Solar Savings
Ending June 30	(GWH)	YOY Growth Rate	(GWH)
2009-10	23,491	-4.2%	10
2010-11	23,051	-1.40%	176
2011-12	23,221	0.7%	383
2012-13	23,175	-0.2%	676
2013-14	23,258	0.4%	928

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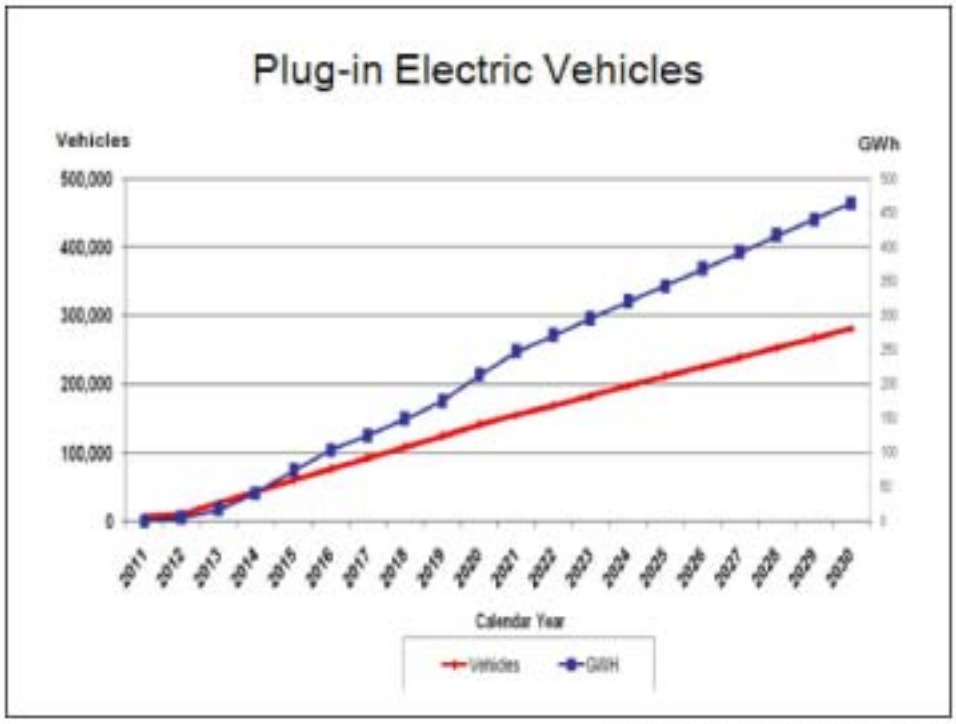
2.2.3 Electrification

A result of AB 32 will be to encourage increased electrification as a means to reduce GHG emissions. This has added a degree of uncertainty to the forecast of future electricity needs in terms of both additional resulting load and the speed of implementation of electrification programs.

In the transportation sector, fuel switching from diesel and gasoline to electric power can result in air quality improvements if the sources of electric power are clean. Figure 2-2 shows the forecasted number of plug-in electric vehicles (PEVs) within the LADWP service area over the next 20 years. To support the adoption of electric vehicles, LADWP launched a pilot program in May 2011 that provides 1000 customer rebates of up to $2,000 towards the purchase and installation of electric vehicle home charging systems. Supporting the City's electric vehicle infrastructure, LADWP is also in the process of retrofitting 117 vintage chargers on City property.



Based on 2009 CEC Forecast

Figure 2-2. Forecasted number of plug-in electric vehicles.

Other agencies in the LA air basin have initiatives underway for "electrification" to replace existing diesel fueled trucks and gasoline powered cars with electric power. In addition, planned expansions to light railway and the metro system would add additional electric load to the system.

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Another example of transportation sector electrification is the Clean Air Action Plan developed jointly by the Port of Los Angeles and the Port of Long Beach to reduce air pollution from their many mobile sources as well as some fixed sources. This includes trucks, locomotives, ships, harbor craft, cranes, and various types of yard equipment. One of the programs, Alternative Marine Power (AMP), allows AMP-equipped container vessels docked in port to "plug-in" to shore-side electrical power instead of running on diesel power while at berth.

Plug-in Electrical Vehicles (PEVs)

Large scale deployment of electric vehicles will significantly affect the way electricity is consumed. It is estimated that by 2015, the United States will have one million EVs in deployment, 10% of which is expected to be in California. The introduction of electric vehicles in Southern California brings a challenging set of planning, regulatory and cost issues. Because EVs require a unique infrastructure, including specialized charging equipment and adequate electric service, it is essential to anticipate and predict the grid impact in Southern California from the EV deployment.

Regulated utilities in California are now responding to regulatory direction to submit plans for large-scale EV initiative with full delineation of costs and benefits. This regulatory initiative is an aggressive step, seeking to promote accelerated adoption of EVs. The EV deployments and the associated utility customer features are proceeding throughout the State of California. Energy needed for PEVs will come partially from the utility electric grid. It is expected that the "fuel shift" from traditional transportation fuels will increase customers' demand for electricity from the electric grid.

PEVs also present an opportunity to influence charging patterns by incentivizing charging during off-peak time periods, resulting in better system load factor. Currently 80% of PEV charging in Los Angeles occurs during off peak hours (per US DOE)

LADWP will use a part of the $120 million Smart Grid demonstration grant award from DOE to demonstrate the integration of electric vehicles into the LADWP-managed electric system. The demonstration will use internal fleet equipment, privately owned EV chargers, and will include electric vehicle fleets from both UCLA and USC. These complementary fleets provide the opportunity to test EVs in both the controlled environment of a corporate fleet and the "real world" usage of individuals. These opportunities will test the integration of EVs into the grid, along with acquisition of EV communications to the grid management.

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2.2.4 Peak Demand Forecast

Growth in annual peak demand over the next ten years is 1.0 percent as shown in Table 2-3.

Table 2-3: FORECASTED GROWTH IN ANNUAL PEAK DEMAND

Fiscal Year End June 30	Base Case Peak Demand (MW)	Growth rate Base Year 2010-11	One-in-Ten Peak Demand (MW)
2010-11	5589[1]		6042
Forecast			
2015-16	5809	0.8%	6277
2020-21	6211	1.0%	6710
2030-31	7000	1.1%	7560
2040-41	7780	1.1%	8403

[1] Weather-normalized. Actual peak was 6142 MW

In 2010, the System set its all-time annual net energy for load peak at 6142 MW on September 27, 2010 on a day that was a one-in-thirty-five year weather event. The weather-adjusted one-in-two peak for 2009 is 5589 MW. Figure 2-3 presents the one-in-ten peak demand forecast, which is used for integrated resource planning. In the 1990s through 2005, annual system load factors were trending slowly upward. Since 2006, system load factors are trending down. Two factors are generally thought to be contributing to this effect. Most customers are making greater efforts to conserve energy but during extreme weather events safety and comfort predominate over conservation causing the peak to spike. Much of the historical and forecasted energy efficiency effort is lighting which has a greater impact on consumption rather than peak which lowers the load factor.

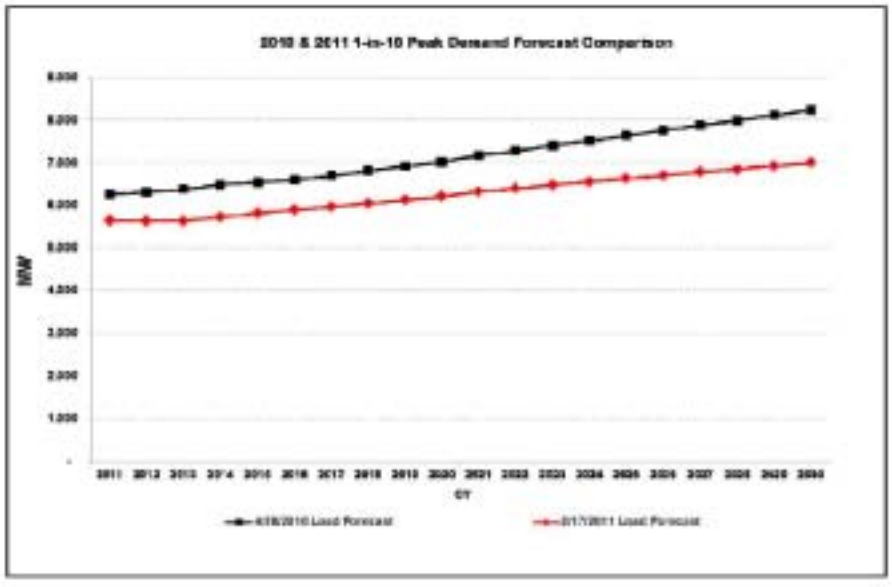

Figure 2-3. One-in-ten peak demand forecast comparison.

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2.3 Demand-Side Resources

Demand Side Resources (DSR) programs, including energy efficiency, have become important elements of IRP planning. Also known as Demand Side Management, DSR programs help to counter or minimize energy demand growth and thereby lessen the need to build more physical generation assets and improve load factor. This section discusses the following DSR initiatives and related support areas:

- Energy Efficiency (EE)
- Demand Response (DR)
- Distributed Generation (DG)
- Smart Grid

Key DSR data assembled for this IRP included:

- The energy efficiency forecast, which was based on the Board-approved AB 2021 objectives, the City of Los Angeles Green Plan, and Demand Forecast Energy Efficiency Quantification Project working papers. Historical installation rates were referenced as part of the forecast.
- An estimate of the amount of solar rooftop and other distributed generation.
- An assessment of existing and developing technological improvements in large scale battery systems for energy storage.
- Information regarding the impact of "Smart Grid" technology on customer load profile and resource requirement.

2.3.1 Energy Efficiency

Energy Efficiency (EE) is a key strategic element in LADWP IRP planning. EE is a very cost-effective resource in LADWP's supply portfolio, and serves an important and multi-faceted role in meeting customer demand. One of the most widely recognized examples of EE is the replacement of incandescent lights with compact fluorescent lamp (CFL) bulbs. CFLs consume up to 75 percent less energy than incandescent bulbs while producing an equivalent amount of illumination and last up to 10 times longer.

LADWP offers numerous EE programs and services for residential, commercial, industrial, governmental, and institutional customers to promote the efficient use of energy through the installation of energy efficient equipment. Examples include:

- The Commercial Lighting Efficiency Offer (CLEO), which provides rebates for a variety of high efficiency lighting measures to retrofit existing buildings. The CLEO program enjoys sustained high rates of participation and has achieved 433 GWh of energy savings since 2000.

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- The Chiller Efficiency Program, which provides incentives for customers to replace old electric chillers with new, high-efficiency units. Chillers provide space conditioning for larger buildings and the program has reduced associated peak electrical demand by more than 52 MW since 2001.
- The Small Business Direct Install (SBDI) Program, which assists eligible small businesses (A1 rate customers) in Los Angeles in becoming more energy efficient through free lighting assessments and free lighting retrofits (up to $2,500 in cost). SBDI began in 2008 and has achieved 149 GWh of energy savings since its inception.
- The Custom Performance Program, which provides performance-based incentives for energy efficiency measures not included in LADWP's menu-based EE programs. Measures supported include controls and control systems, high efficiency motors, and data server virtualization. The Custom Performance Program has achieved 200 GWh of energy savings since 2008.
- The Refrigerator Exchange Program, which delivers new Energy Star refrigerators to eligible residential customers, and picks-up/recycles customers' old, inefficient refrigerators. This program has replaced and recycled more than 53,000 refrigerators since 2007, achieving an energy savings of 49 GWh.
- A recent program, which distributed two free CFLs to LADWP's 1.2 million residential customers through direct-to-door distribution. The intent of the one-time direct-to-door distribution was to achieve cost effective energy savings and increase customer awareness of this inexpensive, yet effective, EE measure. CFLs were also distributed at events and in connection with other energy efficiency programs.

Since 2000, LADWP has spent approximately $282 million on its energy efficiency programs, and these programs have reduced long-term peak period demand and consumption by approximately 303 MW and 1,256 GWh, respectively. LADWP is committed to developing comprehensive programs with measurable, verifiable goals as well as implementing robust, cost-effective energy efficiency programs.

Per Assembly Bill 2021 (AB 2021), publically owned utilities such as LADWP, must identify and develop all potential achievable, cost-effective EE savings and establish annual targets. Furthermore, utilities are required to conduct periodic "Market Potential" studies to update their forecasts and targets. The most recent study was carried out in late 2010 and is the basis for the EE recommendations contained in this 2011 IRP.

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The study evaluated a multitude of measures for potential inclusion into LADWP's EE program; including:

- LADWP's existing program elements
- High-efficiency air conditioners (higher efficiency levels, variable refrigerant flow systems)
- High-efficiency lighting (CFLs, LED lamps)
- Upgraded insulation in buildings
- Retro-commissioning and routine maintenance
- Programmable communicating thermostats and energy management systems

The following recommendations resulted from the 2011 potential study:

Residential Sector

- LADWP should keep its existing programs, with the exception of CFL Distribution, which should be replaced with a broader Energy Efficient Lighting Program.
- Two new programs should be adopted: (1) Low-Income Energy Efficiency and (2) Whole House Performance.
- Continue public outreach to maintain and broaden public awareness of available EE benefits, and to promote participation.

Commercial and Industrial Sector

- LADWP should keep its existing program elements, but should modify its lighting program to educate customers on expanded choices that will comply with new lighting standards.

The ten-year EE plan, incorporating budget, capitalization, and driver considerations is shown in Table 2-4. These projections have been incorporated into the IRP production model and are factored into the case analysis described in Section 3 of this IRP.

Table 2-4. RECOMMENDED EE PROGRAM PLAN

FY Ending	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Program Cost ($Million)	50	50	67	87	100	100	100	100	100	100
Annual Net Savings (GWh)	118	224	164	182	217	183	96	98	99	63
Cumulative Net Savings (GWh)	118	362	526	708	925	1,108	1,204	1,302	1,400	1,463
Savings as a % of Baseline	0.5%	1.6%	2.3%	3.0%	3.9%	4.6%	5.0%	5.3%	5.6%	5.8%

Further information regarding LADWP's EE program is included in Appendix B.

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2.3.2 Demand Response

Demand Response (DR) is an important energy management tool that facilitates the reduction in energy use over a given time period, in response to a price signal, financial incentive, or other mechanism. The objective of DR is to lower energy usage at critical peak demand periods, which will lower overall system costs. DR programs are voluntary; customers that choose to participate are compensated through lower rates, rebates, or other financial incentive.

The benefits of demand response are many:

Increased Reliability. The ability to strategically lower energy consumption is one way to help overcome supply-demand constraints and reduce the chance of overload and power failure. This is especially important at those few critical peak times each year when demand is at its highest, as well as those times when generation units are off-line, whether due to a forced outage or scheduled maintenance.

Lower System Costs. DR eliminates or defers the need to build additional power plants and the associated transmission and distribution infrastructure. Additionally, DR reduces wholesale energy costs by reducing the amount of energy that would otherwise be purchased to meet load. The overall effect is to save money which helps keeps rates low.

Less Environmental Impact. By eliminating or deferring the need to build additional infrastructure, the associated construction and operational impacts are also eliminated or deferred. Furthermore, the reduction in energy usage results in less operational impacts, including less fuel consumption, less carbon emissions, and less transmission use.

Help Integrate Renewables. Under certain circumstances, DR can enable customer loads to respond to fluctuations in generation from wind and solar power.

DR is a relatively new demand-side resource, and LADWP plans to develop an active program over the next several years. As discussed in Section 5, one of the recommendations of this 2011 IRP is to provide funds to develop and implement DR. The analysis of all strategic cases considered in this 2011 IRP (discussed in more detail in Section 4) calls for a small 5 MW DR program beginning in 2013 that gradually builds to 200 MW by 2020 and 300 MW by 2030. This will provide adequate learning that will ensure a sound DR program by the end of this decade, and will also allow time to deploy the supporting IT infrastructure and to implement required IT systems and processes.

A variety of program elements are being considered for LADWP's DR program. The following are some of the offerings that are currently common in the industry. Depending on the circumstances of how energy is used, certain programs will be more suitable to particular customer segments than others.

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Direct Load Control Customers sign up and agree to be subjected to demand reductions as needed based on power system constraints. The typical example is a customer's central air conditioning system may be remotely shut down by the utility during high peak conditions. In exchange, the customer gets an incentive payment or bill credit.

Critical Peak Pricing Retail electric rates are temporarily adjusted up, typically as a response to events or conditions such as extreme high peak loads. Customers who participate are notified in advance of the event and can avoid the higher prices by decreasing their energy use during this time period. The customer incentive is a lower base rate throughout the year.

Peak Rebate Pricing Similar to Critical Peak Pricing, but instead of raising the customer's rate during an event (which creates a disincentive), a positive incentive is created where the customer receives a rebate for reducing or shifting their load during the peak load event.

Real Time Pricing Retail rates are varied on an hourly basis or other short term basis and are typically tied to variations in the commodity market prices for wholesale power supplies. Consumers are aware of the changing market prices on a continual basis, and can change their usage patterns accordingly to lower their energy costs. The premise is that customers will reduce usage during the expensive high peak periods.

Demand Bidding Commercial/Industrial customers are given the opportunity to receive a credit for voluntarily reducing load when an event is called. The customer is not penalized if they are unable to meet their reduction target.

Curtailable/Interruptible Commercial Industrial customers who sign up are on-call for curtailment of power, and are provided credit even if an event is not triggered. However, curtailments are firm and mandatory; penalties are assessed for under performance or non-performance.

Aggregation Programs DR aggregators are third party contractors who work with groups of customers to make combined loads available for reduction or interruption. The aggregator works with LADWP and the combined load is assigned to the appropriate DR program. Customers work directly with the aggregator. Terms, conditions and payment may vary per aggregator.

In designing the overall program, a number of parameters need to be established, such as the specific program elements to offer, and for each program element, customer eligibility, the type and size of incentives, contract duration, event duration, number of events, notification lead times, automation, billing requirements, etc.

This 2011 IRP recommends funding to initiate a formal DR program with the capacity targets as shown in Table 2-5.

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Table 2-5. DEMAND RESPONSE TARGET SCHEDULE (MW CAPACITY)

Yr.	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Target	5	10	20	40	75	100	150	200	250	300	350	400	450	500

DR will play a significant long-term role in securing adequate system capacity, especially in the case of early coal divestiture. Section 4 discusses the strategic cases in detail. As shown in the case analysis, DR is a key part of LADWP's future resource portfolio.

2.3.3 Distributed Generation

Distributed Generation (DG) is the concept of installing and operating small-scale electric generators located at or near the electrical load. These numerous small generators are "distributed" across the service area, as opposed to the traditional configuration of a few large centralized generating stations. DG sources can be utility-owned or customer owned. A large subset of DG is combined heat and power systems, also known as cogeneration, which are primarily owned and operated by industrial and commercial customers.

Many categories of electrical generation fall under the DG definition, with the key characteristic being that they are located at or near the service load. The most common technologies used today for DG are turbines and internal combustion engines. Solar PV is a newer technology that is forecasted to account for an increasing percentage of DG. Other DG technologies are microturbines and fuel cells. Under a pilot project, LADWP installed a total of four 200-250 kW fuel cell power plants in various locations in Los Angeles that have provided considerable experience and data. LADWP is closely monitoring fuel cell development.

More details regarding DG can be found in Appendix G.

2.3.4 Smart Grid

"Smart Grid" is a term used to describe a variety of advanced information-based utility improvements. Smart Grid refers to intelligent data gathering and advanced two-way digital communication capabilities overlaid on electric distribution networks to provide real-time data that enhances the utility's ability to optimize energy use. Smart Grid is a national policy evolving from the Energy Policy Act of 2005, and is a major enabler for many existing and potentially new DSR/EE programs.

Smart Grid technologies can turn every point in the existing network—including every meter, switch and transformer—into a potential information source, able to feed performance data back to the utility instantly. Smart Grid Technologies will provide utilities with the information required to implement real-time, self-monitoring networks that are predictive rather than reactive

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to instantaneous system disruptions. It can enable the utility and consumer to make decisions to optimize the use of energy, improve reliability, and reduce the consumption of fossil fuels.

LADWP is implementing eleven Smart Grid initiatives:

A smart grid has the following characteristics:

- *Enables new products, services and markets*
- *Enables active participation by consumers through self-monitoring and more responsible consumption decisions*
- *Auto-selects safest and most efficient forms of storage and generation based on real-time energy needs and concerns*
- *Provides power quality for the digital economy*
- *Optimizes asset utilization and operates efficiently*
- *Anticipates and responds to system disturbances (self-heals)*
- *Operates resiliently against attacks and natural disasters*

1. Renewable Integration
2. Transmission Automation
3. Substation Automation
4. Distribution Automation
5. Advanced Metering Infrastructure
6. Demand Response
7. Advance Telecommunications
8. System and Data Integration
9. Cyber Security
10. Feed-in Tariff
11. Solar Incentives

Through a US Department of Energy grant in 2009, LADWP is leading a group of local research institutions in a regional demonstration program. The program includes pilot projects in four interrelated areas – Demand Response, Consumer Behavior, Cyber Security and Electric Vehicle Integration.

More information on this demonstration program and all of LADWP's Smart Grid initiatives can be found in Appendix L.

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2.4 Generation Resources and Transmission Assets

The Supply-Side Resources discussed in this section include

- Existing Generation Resources
  - Natural Gas
  - Coal
  - Nuclear
  - Large Hydro
  - Existing Renewable energy resources (small hydro, wind, solar, biogas, and geothermal)
- Spot Purchases
- Spot Sales

The major issues affecting generation are then presented, including the need to repower the in-basin natural gas units and the future disposition of coal-fired generation.

This section concludes with:

- Future Renewable Resources
- Transmission and Distribution/Grid Reliability
- Reserve Requirements

The LADWP Power System has a diverse mix of generating resources. Figure 2-4 shows LADWP's Power System capacity and energy breakdown as of December 31, 2010 as well as what the capacity and energy mix was at the end of 2006.[1] The largest change between these two periods is the decrease in coal-fired energy from 47 percent in 2006 to 39 percent in 2010, and the corresponding increase in energy from renewable resources, from 7 percent in 2006 to 20 percent in 2010.

[1] "Capacity" and "Energy" are electric utility terms that distinguish between how much power the system is capable of generating at a given instant in time (capacity; in megawatts) and how much power the system generates over a given period of time (energy; in megawatt-hours). Capacity numbers are expressed in MW, and energy numbers are expressed in MWh.

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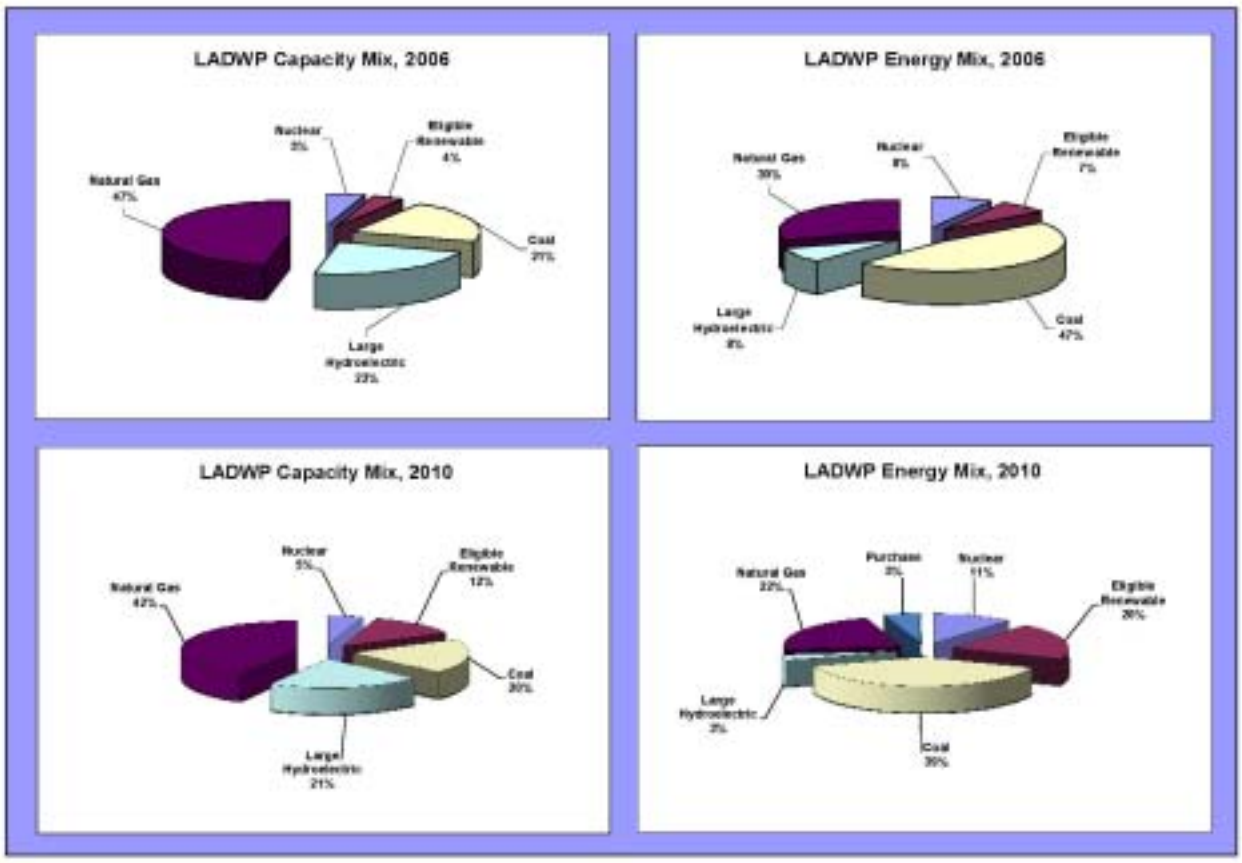

Figure 2-4: LADWP capacity and energy mix for 2006 and 2010.

2.4.1 Generation Resources

LADWP is vertically integrated, both owning and operating the majority of its generation, transmission and distribution systems. Generation resources that are not wholly owned by LADWP are available as entitlement rights resulting from undivided ownership interests in facilities that are jointly-owned with other utilities. Table 2-6 lists existing LADWP generation resources.

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Table 2-6: Capability of existing LADWP generating resources (as of September 2011)

Name of Plant	Fuel Source	Unit No.	In Service Date	Age (Years)	Net Maximum Unit Capability (MW) [2]	Net Maximum Plant Capability (MW) [3]	Net Dependable Plant Capability (MW) [4]	Comments
Harbor Generating Station	Natural Gas	1	1995	16	82	466	461	Units 1, 2 and 5 operate as a combined cycle unit. Once-through cooling (OTC)
		2	1995	16	82			
		5	1995	16	85			
		10	2002	9	47.4			
		11	2002	9	47.4			
		12	2002	9	47.4			
		13	2002	9	47.4			
		14	2002	9	47.4			
Haynes Generating Station	Natural Gas	1	1962	49	222	1555.8	1525	Units 8, 9 and 10 operate as a combined cycle unit. Unit 7 is used for auxiliary power only. OTC
		2	1963	48	222			
		5	1966	44	292			
		6	1967	44	243			
		7	1970	41	1.8			
		8	2005	6	250			
		9	2005	6	162.5			
		10	2005	6	162.5			
Scattergood Generating Station	Natural Gas	1	1958	53	163	817	798	Includes 16 MW for Hyperion digester gas. OTC
		2	1959	52	184			
		3	1974	37	450			
Valley Generating Station	Natural Gas	5	2001	10	43	576	556	Units 6, 7 and 8 operate as a combined cycle unit.
		6	2003	8	159			
		7	2003	8	159			
		8	2003	8	215			
Total Net Capability of Natural Gas Stations						**3415**	**3338**	
Intermountain Generating Station	Coal	1	1986	25	900	1100	1100	Reduced by current recall
		2	1987	24	900			
Navajo Generating Station	Coal	1	1974	37	750	477	477	
		2	1974	37	750			
		3	1975	36	750			
Mohave Generating Station	Coal	1	1971	40	0	0	0	Decommissioned on 12/31/05
		2	1971	40	0			
Total Net Capability of Coal Stations						**1577**	**1577**	
Palo Verde Generating Station	Nuclear	1	1986	26	1333	387	380	
		2	1986	26	1336			
		3	1988	24	1334			
Total Net Capability of Nuclear Stations						**387**	**380**	
Castaic Power Plant	Hydro	Various	1972-1978	33-38	1620	1247	1175	Pumped Storage
Hoover Power Plant	Hydro	Various	1936	75	491	491	436	
Total Net Capability of "Large" Hydro Stations						**1738**	**1611**	
Aqueduct System	Hydro	Various	1917-1987	24-94	126.7	83.1	24.2	11 Units total
Owens Valley System	Hydro	Various	1908-1958	53-103	16	12.5	1.2	7 Units total
Owens Gorge System	Hydro	Various	1952-1955	56-59	112.5	112.5	109.4	3 Units total
Owned & Contracted Renewables	Renewable/DG	Various	2002-2011	1-9	1141	1141	343	Note [5]
Total Net Capability of Small Hydro and Renewable / Distributed Generation						**1349**	**478**	
Total Net Capability of LADWP Resources						**8464**	**7384**	
State's Capacity Entitlement (See Note[6])						-120	-55	
Total Net Capability of LADWP System						**8346**	**7329**	Note [7]

Notes:

1. Power source data are based on Power System Engineering Division's January 2011 Generation Ratings and Capabilities Sheet and power purchase agreements for contract sources.
2. All units can attain maximum capability only when the weather and equipment are simultaneously at optimum conditions.
3. Reflects: water flow limits at hydro plants, sum of unit output at in-basin thermal or renewable plants, or LADWP contract entitlement of external thermal plants.
4. Reflects: year- round outputs adjusted for low-generation season. For hydro plants, winter is the low-generation season.
5. Owned or contracted renewable projects in wind, solar, hydro, landfill gas, biomass, and distributed generation in-service as of September 2011.
6. The maximum State (CDWR) Capacity Entitlement from Castaic Power Plant is 120 MW. The average for FY 09-10 was approximately 55 MW. The actual amount varies weekly.
7. Total Net Capability of LADWP System may vary due to unit outages, de-ratings and sales obligations.

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Natural Gas

LADWP is the sole owner and operator of the following four electric generating stations in the Los Angeles Basin (the "In-basin stations"):

- Haynes Generating Station, located in Long Beach
- Harbor Generating Station, located in Wilmington
- Scattergood Generating Station, located in Playa del Rey
- Valley Generating Station, located in the San Fernando Valley

A map of the in-basin stations is shown in Figure 2-5.

Figure 2-5. LADWP in-basin generating stations.

Each station consists of multiple generating units, with each unit ranging is size between 43 MW and 450 MW. A summary of each station's capabilities is shown in Table 2-5. Detailed information on each generating station is included in Appendix F.

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While all of these stations utilize natural gas as a fuel source, a special arrangement has been made that enables the Scattergood Generating Station to also use digester gas from the adjacent Hyperion Sewage Treatment Plant. The digester gas currently accounts for 16 MW of Scattergood's generation output. The agreement enabling this arrangement will end by 2015.

Securing continued local generation capacity is important for grid reliability. LADWP's local transmission system cannot be reliably operated without generation from local thermal generating plants. The amount of generation required to provide transmission reliability is termed Reliability Must Run (RMR) generation. RMR generation is incorporated into all of the strategic cases considered in this IRP.

The major issues facing the in-basin stations include the need to replace some of the older units that are approaching the end of their service life, compliance with regulations related to ocean water cooling and NO_x emissions, and fuel price volatility. Natural gas fuel prices and procurement issues are presented in detail in Appendix H.

Natural gas will continue to be the essential fuel for LADWP's generation due to abundant supply levels. Natural gas will be used to supply base load (as is currently used), and will also provide for the integration of intermittent renewable generation. Natural gas is also a major component of LADWP's coal replacement strategy.

Coal

LADWP's coal generating capacity comes from the Navajo Generating Station (NGS) and the Intermountain Generating Station (IGS). IGS is also referred to as the Intermountain Power Project (IPP). The amount of capacity available to LADWP's from these stations is 477 MW from NGS and approximately 1,200 from IPP. A summary of each station is included in Table 2-5. Further details and discussion is provided in Appendix F.

Contractual arrangements for power from IPP will expire on June 15, 2027 while NGS operates under a co-tenancy agreement that shall remain effective throughout the initial term of its land lease until December 31, 2019 and throughout the lease extension thereafter.

Nuclear

LADWP has contractual entitlements totaling approximately 387 MW of capacity from the Palo Verde Nuclear Generating Station (PVNGS). PVNGS, located approximately 50 miles west of Phoenix, Arizona, consists of three generating units. Of the 387 MW capacity available to LADWP, approximately 159 MW is available through a power sales agreement with the Southern California Public Power Authority (SCPPA). Further details are provided in Appendix F.

Large Hydro

LADWP's large hydroelectric facilities include the Castaic Pumped-storage Hydroelectric Plant and an entitlement portion of the capacity of Hoover Dam. The Castaic Pumped-storage

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Hydroelectric Plant, located in Castaic, California, is LADWP's largest source of hydroelectric capacity and consists of seven units. Hoover Dam, located on the Arizona-Nevada border, consists of seventeen units. Details of these plants are provided in Appendix F.

A distinction is made between "large hydro" and "small hydro". Small hydro consists of generating units with less than 40 MW of capacity generally located along the Los Angeles Aqueduct. They also qualify as a renewable resource for electricity generation. For discussion purposes they are grouped within renewable resources.

Current Renewable Energy Projects

Existing secured renewable resources total over 1200 MW of capacity, and consist of wind, small hydro, solar, biogas, and geothermal resources. More detailed information is presented in Section F.2.5 of Appendix F. A listing of existing renewable projects by resource type is as follows.

- Wind Resources
  - Linden
  - Pebble Springs
  - Pine Tree
  - PPM Wyoming
  - Willow Creek
  - Windy Point
  - Milford
- Small Hydro
  - Aqueduct and Owens Valley projects
  - Hydro Powerlex
  - North Hollywood
  - Sepulveda
  - Castaic Upgrade
- Solar
  - LADWP In-Basin
  - Customer Net Metered
- Biogas/Biomass
  - Bradley
  - Lopez Canyon
  - Toyon
  - Almos and Shell
  - Hyperion Digester Gas

Additional renewable energy (including geothermal) comes from market purchases.

Figure 2-6 presents the current energy profile for renewable resources in LADWP's portfolio.

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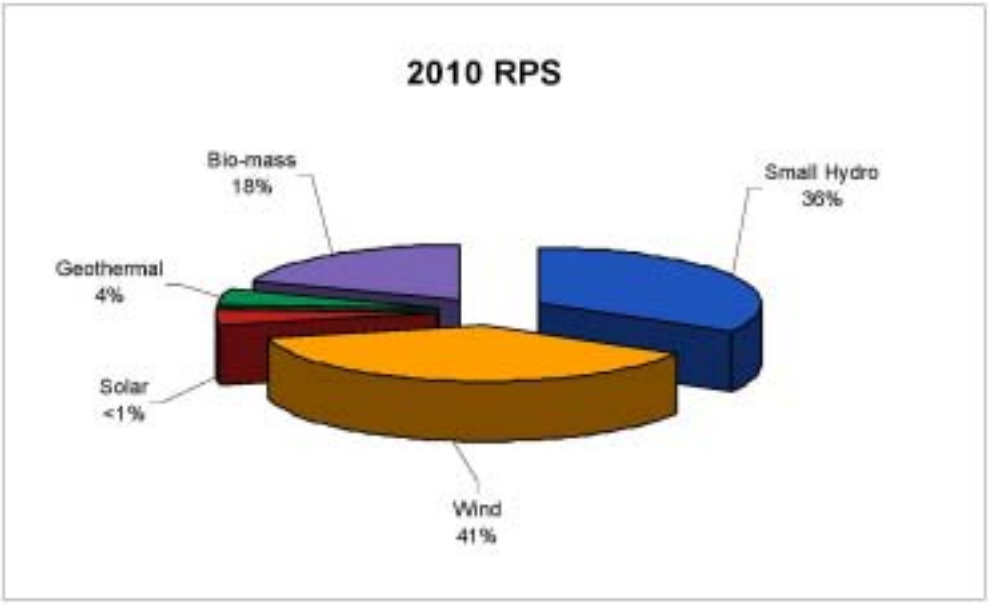

Figure 2-6: 2010 IRP renewable energy mix.

Spot Purchases

Although LADWP's policy has been to be self-sufficient and capable of generating all of its energy needs from resources it owns or controls, it also participates in energy markets if it is in the City's best economic interest. This happens when energy can be acquired from the wholesale market for a cost which is less than which LADWP can produce such energy. Periodically, capacity and energy is purchased from providers within the Western Electricity Coordinating Council (WECC) jurisdiction under short-term "spot" arrangements to be delivered to the LADWP transmission system. These purchases are used by LADWP in conjunction with other resources for economical Power System operation.

The cost and availability of economical energy on the spot market has fluctuated greatly in recent years. While LADWP currently continues to execute economical spot purchase opportunities, it cannot guarantee the future availability of economic energy from either the Pacific Northwest or the Southwest at prices below LADWP's costs for producing power from its own resources.

Spot Sales

LADWP often has a surplus of generating capacity and energy. Consistent with prudent utility practice, LADWP offers this surplus into wholesale electricity markets within the WECC at prices above LADWP's production costs. This way, LADWP's ratepayers benefit both by receiving the lowest cost energy in the Power System and from economic purchases, in addition to economic benefits resulting from wholesale revenue generated from sales.

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2.4.2 Major Issues Affecting Existing Generation Resources

Three major issues affecting LADWP's existing generation fleet are: (1) the need to rebuild or "repower" some of its in-basin generating units, (2) compliance with state and local regulations regarding once-through cooling and NO_X emissions, and (3) strategies for early divestiture from coal-fired energy to accelerate GHG reductions.

2.4.2.1 Repowering Program to Replace Aging Infrastructure

There is an urgent need to modify or replace some of LADWP's older gas-fired generation facilities located at the Haynes and Scattergood generating stations. These units were primarily built in the late 1950s and the early 1960s and are approaching the end of their service lives. LADWP must modernize these plants to maintain system reliability, improve efficiency, and better integrate renewable resources.

- System reliability
  As facilities age, they require more maintenance and become more susceptible to operational problems and outages. The units to be replaced at the Scattergood and Haynes generating stations are between 44 and 53 years old, and are among the oldest remaining units in LADWP's generation fleet. Minimizing outages at these locations close to the system load center is especially important for the reliable operation of the in-basin electrical network, including the transmission and distribution systems. Variable resources, such as solar or wind power, can augment existing in-basin gas-fired generation, but do not serve as adequate replacements for purposes of voltage support. LADWP's local transmission system cannot be reliably operated without generation from local generating plants. The amount of generation required to provide transmission reliability is termed Reliability Must Run (RMR) generation. Repowering these local units will maintain transmission reliability by maintaining the reliability of RMR generation.

- Increased efficiencies
  New units will operate more efficiently, generating more energy and less emissions with the same amount of fuel. Operational costs per energy output will decrease.

- Integrating renewables
  The new units will incorporate new technologies which will enable faster start-up and faster ramping of generation output. This ability to increase or decrease generation on short notice, measured by what is termed "ramp rate," is an important requirement for integrating renewable resources. Wind resources produce power when the wind is blowing. When the wind suddenly begins blowing or stops blowing, the energy being delivered also changes but the customer load (the amount of energy the power system requires) remains substantially the same. Solar photovoltaic resources are subject to even greater output variability as clouds pass overhead and vary the intensity of available sunlight. To compensate for these fluctuations, natural gas "peaker" units (which are included in the new unit configurations) are able to quickly start, stop, and ramp up and down so that the total energy generated continuously matches customer load. Integrating significant amounts of intermittent

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renewable resources, such as wind and solar photovoltaic, will not be possible without the fast load-following capability that the repowering program will provide.

2.4.2.2 Repowering Program to Comply With Regulatory Requirements

In addition to the reasons stated in Section 2.4.2.1, the repowering program is necessary to comply with local regulations related to once through cooling and NO_X emissions.

- Once-through cooling
  Once-through cooling (OTC) is the process where water is drawn from the ocean, is pumped through equipment at a power plant to provide cooling, and then is discharged back to the receiving water source. A cooling process is necessary for nearly every type of conventional electrical generating station and an OTC process utilizing ocean water is a major reason why many electrical generating stations were sited along the coastline. Typically, the water used for cooling is not chemically changed in the cooling process; however, the temperature of the water increases before it is returned to the ocean.

  LADWP operates three coastal generating stations – Scattergood, Harbor, and Haynes – that utilize OTC. The combined net capacity of these stations is 2,839 MW. Further information regarding repowering can be found in Section 1.6.5. Table 3-3 contains a listing of specific repowering projects.

  In addition to repowering, OTC interim mitigation measures will be required until a facility is fully compliant. These measures include the funding into projects to alleviate impacts, such as the installation of alternative technologies to reduce impingement and/or entrainment. These issues are discussed in more detail in Appendix C.

- NO_X compliance
  In mid-2000, during the statewide energy crisis, LADWP predicted that NO_X emissions from the in-basin generating units would exceed the available supply of NO_X RECLAIM Trading Credits issued by the South Coast Air Quality Management District (SCAQMD). Although LADWP's NO_X emissions ultimately did not exceed its allocation in 2000,on August 29, 2000 the SCAQMD Hearing Board issued a "Stipulated Order for Abatement" to the LADWP. Under the terms of the Order, LADWP was required to perform a series of repowering projects at its in-basin generating stations. The Stipulated Order was later superseded by a Settlement Agreement to accommodate scheduling and other issues. This agreement was revised in September 2011 and addresses the current repowering projects at the Haynes and Scattergood Generating Stations.

2.4.2.3 Coal-Fired Generation

SB 1368, the California Greenhouse Gas Emissions Performance Standard Act, enacted in 2006, prohibits California utilities from entering into long-term financial commitments for base load

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generation unless it complies with the GHG emissions performance standard. As this standard also applies to existing power plants for any long-term investments or contractual extensions, it affects LADWP's coal-fired generation resources.

- SB 1368 Compliant Coal-Fired Generation

  As presented in Section 5, the analysis of future potential resource portfolios includes a set of strategic cases that accelerate compliance with SB 1368 for coal-fired generation by year 2020. The feasibility of adopting and implementing this will depend on a number of factors, including: (1) resolving contractual issues, (2) the cost of alternatives (and LADWP's ability to cover its costs) and (3) regulatory factors that today are uncertain.

  SB 1368 compliant power will reduce the GHG emissions for LADWP, reduce regulatory compliance costs, and spur development of renewable resources in the western United States. SB 1368 established a greenhouse gas emissions performance standard that limits long term investments in baseload generation by the state's utilities to power plants that meet an emissions performance standard, which was jointly established by the California Energy Commission and the California Public Utilities Commission. Subsequently, the Energy Commission designed regulations that establish a standard for baseload generation owned by, or under long-term contract to publicly owned utilities, of 1,100 lbs CO2 per megawatt-hour (MWh).

  There are several methods to achieve SB 1368 compliance, for example, replace coal generation with natural gas-fired generation, carbon sequestration, coal gasification, or the application of other potentially emerging technologies. Since coal generation operates as a base load resource for LADWP, any replacement option would also need to provide base load generation around the clock while reducing GHG emissions.

- Intermountain Power Project

  The Intermountain Power Project (IPP) is a coal-fired generating station located near Delta, Utah. IPP consists of two generating units with a combined capacity of 1800 MW. LADWP is the operating agent. LADWP is also the largest single purchaser and has a power purchase agreement for 47.617 percent (803 MW) of IPP's total output. LADWP has additional purchase obligations for up to 22.368 percent (400 MW) of additional output. These additional obligations are dependent on the power usage of the Utah and Nevada participants. The power sales contract for IPP expires in 2027.

  In addition to the generating units, IPP includes four important transmission lines, a 500-kV DC transmission line from the generating station to Adelanto, California (a distance of 490 miles), two parallel 345-kV AC transmission lines from the generating station to Mona, Utah (50 miles away), and a single 230-kV AC transmission line from the generating station to the Gonder Switchyard near Ely, Nevada (about 144 miles away).

  At IPP, LADWP has no ownership rights. Rather, LADWP has a long-term power purchase contract which expires in 2027 and which also includes renewal option rights. With firm

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"take or pay" IPP contract obligations extending to 2027, LADWP has committed to continue to fulfill all contractual obligations. At the same time, LADWP is investigating ways to maintain compliance with SB 1368. LADWP is reviewing several options.

LADWP has called for a strategic business plan to be developed for IPP. This effort, which is currently underway, involves IPA as owners of the IPP assets and the 36 participants that have power sales contracts. This effort is seen as a way to focus on the current and future needs of the project owners and those with power contracts and seek ways to find mutually beneficial solutions. Many of the participants, including LADWP, would like to settle on solutions that can be implemented in the next few years thereby reducing uncertainty with regard to the future use of IPP.

The work product that was approved in 2010 directed the subcommittee to continue work in 5 strategic areas.

- An energy trading hub at the site
- Generation development (A plan for future generation)
- Asset optimization
- Transmission
- Communications (Preparing advocacy efforts to assure future success)

The Energy Trading Hub Subcommittee has completed the majority of its work and is launching a 1 year trial of the program starting February 1, 2012. The Generation Subcommittee has considered a number of alternatives using natural gas and has determined that several of these are possible. Currently, this subcommittee is directing its efforts at the various contracts and governances that oversee the project and is drafting language that will facilitate options for future generation. The other three committees are meeting on as needed basis.

- Navajo Generating Station

The Navajo Generating Station (NGS) is a coal-fired generation station located near Page, Arizona. It consists of three units with a combined capacity of 2,250 MW. Salt River Project is the Operating Agent. As one of six owners, LADWP has a 21.2 percent ownership share in the station's generation. NGS operates under a co-tenancy agreement which shall remain effective throughout the initial term of the land lease with the Navajo Nation and throughout the lease extension thereafter.

Replacement options for NGS are discussed in Section 3.5.

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2.4.3 Future Renewables for LADWP

The increase of renewables, as a percentage of electricity sales, from the current 20% to the regulatory mandated 33% by year 2020 requires the continued diligence of LADWP to pursue renewable projects and power purchase contracts. The development of a solar feed-in tariff and continued encouragement for rooftop solar is also necessary to support increased solar capacity. Because the acquisition of additional renewables is mandated by law, all of the strategic cases analyzed in this IRP include portfolios with the required amount of renewable resources. All strategic case alternatives include the following targets for new renewable acquisitions between 2011 and 2020:

New Renewable Installed Capacity (MW) 2011-2020			
Geothermal & Biomass	Wind	Non-DG Solar	Distributed Solar
243	492	401	325

Furthermore, maintaining at least 33% of renewables beyond 2020 requires additional renewables to account for load growth, project turnover, and output degradation as projects age. All strategic case alternatives include the following additional targets for new renewable acquisitions between 2021 and 2030:

New Renewable Installed Capacity (MW) 2021-2030			
Geothermal & Biomass	Generic	Non-DG Solar	Distributed Solar
65	162	50	141

Details regarding future renewables can be found in Appendices F and M.

2.4.4 Transmission and Distribution Facilities/Grid Reliability

Electricity from LADWP's power generation sources is delivered to customers over an extensive transmission and distribution system. To deliver energy from generating plants to customers, LADWP owns and/or operates approximately 20,000 miles of alternating current (AC) and direct current (DC) transmission and distribution circuits operating at voltages ranging from 120 volts to 500 kilovolts (kV). Major transmission lines connecting to out-of-basin generating resources are shown in Figure 2-8. Appendix I provides more details regarding LADWP's transmission system.

In addition to using its transmission system to deliver electricity from its power generation resources, LADWP arranges for the transmission of energy for others through its Open Access Same-Time Information System (OASIS) when surplus transmission capacity is available and saleable. LADWP uses its extensive transmission network to sell its excess energy and capacity in the California, Northwest, and Southwest energy markets. Revenues from these excess energy sales are used to reduce costs to ratepayers and for capital improvements. In the near future,

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LADWP anticipates that revenue from excess energy sales may be less due to aging facilities, anticipated load growth, and GHG emission regulations.

Transmission for Renewable Energy

Transmission infrastructure improvements to access renewable energy are in various phases of development or construction:

- Barren Ridge Renewable Transmission Project. Up-to-date information is available for this project at http://www.ladwp.com/ladwp/cms/ladwp009508.jsp. This project, scheduled to be completed in 2016, will increase the capacity of the existing 230kV Barren Ridge—Rinaldi transmission segment. As of August 2011, approximately 2800MW from a combination of wind and solar projects are being investigated for potential interconnection. Castaic Power Plant, with its flexibility as a pump storage facility, stores surplus variable energy for optimal dispatch.

  Important components of the Barren Ridge Renewable Transmission Project are as follows:

  - New Haskell Canyon Switching Station
  - New double-circuit 230kV transmission line from Barren Ridge Switching Station to new Haskell Canyon Switching Station
  - New 230kV circuit on existing structures from Haskell Canyon to the Castaic Power Plant
  - Reconductor the existing 230kV transmission line from Barren Ridge Switching Station to existing Rinaldi Substation, through Haskell Canyon Switching Station
  - Expand existing Barren Ridge Switching Station

- Pacific Direct Current Intertie (PDCI) Upgrade. LADWP and its PDCI partners are considering increasing the capacity of the PDCI from 3100MW to as much as 3650MW. The benefit of such an undertaking would be a higher-capacity corridor for renewable wind and hydro energy from the Pacific Northwest to Los Angeles. LADWP, as PDCI operator, is currently developing a cost estimate for the project that considers transmission and station upgrades and the increased dispatch and energy costs during construction to cover the reserve margin. Toward that end, preliminary estimates based on a recently commissioned and completed Light Detection and Ranging study indicate the transmission portion of the project may cost up to $150 million and require as much as six years to construct. Less aggressive options with lower capacity benefits are also being investigated to facilitate an informed decision by the PDCI partners.

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Regional transmission plans have shown that in order for LADWP and its Western counterparts to meet their renewable energy goals at the lowest cost, additional transmission improvements will be needed. While the projects listed here have a high priority and a high likelihood of construction, they may not be sufficient to meet future needs. LADWP will continue to evaluate transmission needs and opportunities as necessary.

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Grid Reliability

LADWP annually performs a Ten-Year Transmission Assessment Plan, in compliance with the North American Electricity Reliability Corporation (NERC) Compliance Enforcement Program. LADWP's 2011 plan has identified a number of transmission improvements that are needed to maintain reliability. These projects include:

- Installation of a new Scattergood Olympic 230kV Line 1.
- An upgrade of the existing Northridge-Tarzana 230 kV Line 1.
- Transmission upgrades between the Haskell, Olive, and Sylmar Switching Station
- Construction of a new Cottonwood 230 kV substation with a new 100 MVAR capacitor bank

These infrastructure improvements are critical to avoid potential overloads on key segments of the Basin transmission system. Certain of these overload conditions would require load shedding events (intentional power outages) to minimize the impact on the power system as a whole.

System Losses

LADWP Power System transmission and distribution losses are approximately 11.5 percent, and are higher than the industry average of 6-8 percent partly due to its long transmission reach to external generation from Utah, the Desert Southwest, and the Pacific Northwest. However, there may be opportunities to reduce some losses by addressing the system's reactive power needs. To optimize performance and reduce these system losses, LADWP commissioned a 2011 Reactive Power Management Study, which arrived at the following recommendations:

- Retire 9 synchronous condensers which are beyond their useful lives and in subpar operating condition
- Install shunt compensation to replace the retired synchronous condensers and to enhance system security

  Shunt capacitors totaling 1565MVAR with consideration given to dynamic devices at Rinaldi and Hollywood Stations. The capacitors would be located at receiving and distributing stations and distribution feeders

  Shunt inductors totaling 930MVAR, with consideration given to dynamic devices at Rinaldi and Hollywood Stations. The inductors would be located at receiving and distributing stations and distribution feeders
- Implement a customer power factor improvement program as the current aggregate customer power factor is less than 0.75, lagging.
- Install and implement a real-time MVAR reserve margin monitoring and alarm system to alert power system operators of decaying operating margins so outages might be averted

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FERC Order 1000 - The California Transmission Planning Group

With the release of Federal Energy Regulatory Commission (FERC) Order 1000 in July 2011, which directs regional and interregional transmission planning and cost allocation, FERC-jurisdictional (investor-owned) electric utilities are now required to reorganize transmission planning functions to collectively achieve state and federal public policy goals. Order 1000 builds upon the directives of FERC Order 890, issued in February 2007, to open regional and local planning to stakeholders to ensure transparency and non-discriminatory access to transmission service.

LADWP has a longstanding history of working with its Western Electricity Coordinating Council counterparts on regional transmission planning to ensure bulk power reliability and to leverage economies of scale; regional transmission plans are reviewed and approved through a formal process. Since the California Transmission Planning Group (CTPG) was formed in 2009, LADWP has been active in that transmission planning forum. CTPG was formed to comply with Order 890 by providing the increased coordination and public participation mandated while ensuring the electric needs and goals of Californians are reliably and efficiently met. In February 2011, the 2010 California Transmission Plan (California Plan) was released http://www.ctpg.us/images/stories/ctpg-plan-development/2011/02-Feb/2011-02-09_final_statewide_transmission_plan.pdf.

With Order 1000, CTPG must now consider reorganizing CTPG as an interregional planning organization with local and regional planning members or continue as a regional planning organization with WECC, or a yet unknown entity, serving as its interregional planner. CTPG and its members have up to eighteen months to formalize their positions with FERC. As the member utilities evaluate their options, they continue to press forward with their current transmission assessment to ensure California's electric power policy goals are reached efficiently and without undue hardship to the consumer or to the electric grid. California's electric power policy goals include:

- Attainment of renewable portfolio standard goals as promulgated by SB 2 (1X), which was signed into law on October 11, 2011
- Satisfaction of repowering/retirement deadlines of fossil-fueled Once-Through Cooling power plant units as negotiated with the State Water Resources Board to comply with Federal Clean Water Act §326(b)

As a municipal utility, LADWP is outside FERC jurisdiction, so, in a technical sense, Order 1000 is not a mandate. Consistent with its response to other FERC Orders, however, LADWP is seeking to conform to this order, with the same consideration as it would to an industry standard.

LADWP's extensive network of transmission resources is described in Appendix I; Figure 2-7 shows its major out-of-basin generation resources. Noteworthy is the fact that while LADWP customers represent roughly ten percent of California's electrical load, approximately 25 percent of the state's total transmission capacity is owned by LADWP. LADWP also differentiates itself from its counterparts by continuing to operate as a vertically integrated electric utility, owning and operating its generation, transmission, and distribution resources rather than as a parent company with subsidiaries carrying out the various functions that comprise the supply chain.

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Figure 2-7: Major out-of-basin generating stations and major transmission lines.

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2.4.5 Reserve Requirements

Reliability of the electric power system is dependent upon two elements: "resource adequacy" and "security." Resource adequacy refers to the availability of sufficient generation and transmission resources to meet customer's projected energy needs plus reserves for contingencies. Security refers to the ability of the system to remain intact after experiencing sudden disturbances, outages or equipment failures.

LADWP, as part of the electric power grid of the western United States and Canada (and a small section of northern Mexico), is required to meet operational, planning reserve and reliability criteria, and the resource adequacy standards of the WECC and the North American Electric Reliability Corporation (NERC). These standards define the system reserve margin requirements and other criteria for which LADWP must plan and operate and are defined as follows:

Generation Capacity Requirement = Net Power Demand + System Reserve Requirement
System Reserve Requirement = Operating Reserve + Replacement Reserve
Operating Reserve = Contingency Reserve + Regulation

The "Net Power Demand" is the total electrical power requirement for all of LADWP's customers at any time. The other reserve requirements are defined below, as well as numerically calculated.

The loss of the largest single contingency of generation or transmission, is a key reserve margin determinant for LADWP and defines the Contingency Reserve as well as the Replacement Reserve requirements. Under the current NERC Standards, at least 50 percent of the Contingency Reserves must be Spinning Reserve. The Replacement Reserve requirement is to restore Operating Reserves within 60 minutes of a contingency event. The Regulation Requirement of 25 MW is related to system load variations due to customer load changes. This regulation requirement is anticipated to increase in the future as additional amounts of intermittent renewable generation are added to the generation mix. Given LADWP's current total generation portfolio, the system reserve requirement is approximately 1,100 MW. Therefore, if the system demand is 5,000 MW, LADWP must have a total of 6,100 MW of stable and dispatchable generating capacity (and the transmission for that capacity) to meet the 5,000 MW demand.

Due to the variable and intermittent nature of some renewable resources, particularly resources such as wind and solar photovoltaic, their generation capacity cannot be depended upon to meet peak demand conditions. As LADWP acquires a larger proportion of such resources, studies on the characteristics of these variable and intermittent resources will need to be carried out to determine their effect on reserve and regulation requirements. Refer to Appendix J for additional information on issues associated with integrating intermittent energy resources.

The capacity value of a generating resource is based on its ability to provide dependable and reliable energy and capacity during peak periods when the system requires reliable resources for stable operation. Resources that can provide firm capacity will have a higher capacity value than

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resources that cannot. For purposes of planning LADWP's reserves adequacy calculations, it was assumed that the dependable capacity of wind would be 10 percent of its nameplate capacity and the dependable capacity of solar photovoltaic would be 27 percent of its nameplate capacity.

Local Resources for Grid Stability and Contingencies

As a subset of the reserve requirements, LADWP has located a significant amount of generating resources within the Los Angeles (LA) area. The specific amount of capacity that needs to be located in the LA Basin is approximately 3,400 MW, but varies, depending on the combination of which units are operating and how much power is flowing on the transmission system at the time. LADWP's local transmission system cannot be reliably operated without generation from local thermal generating plants. The amount of generation required to provide transmission reliability is termed Reliability Must Run (RMR) generation. RMR generation is incorporated into all of the strategic cases considered in this IRP.

This local requirement is particularly important in the context of deciding how to schedule the repowering of units that use once through cooling. It is for this reason that no unit will be taken out of service before an equivalently-sized, locationally-equivalent replacement unit is constructed, tested and ready to be placed in service.

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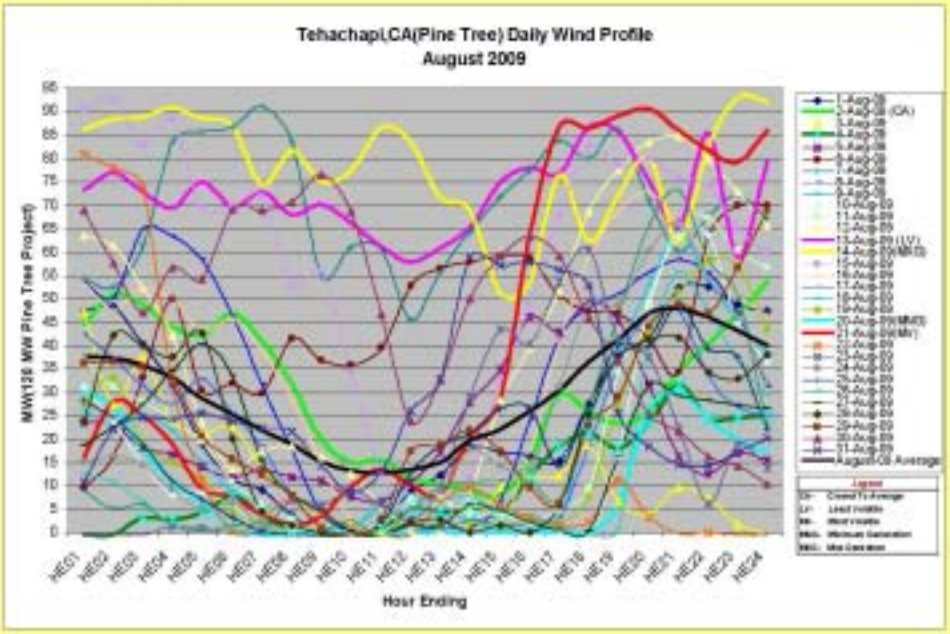
Integration of Intermittent Energy

One of the main responsibilities of power system operators is to maintain the balance between the total aggregate electrical demand of the power system's customers and the amount of energy generated to meet that demand on an instantaneous basis. Conventional electrical generation technologies, such as nuclear, coal, natural gas and large hydro are controllable and dispatchable by the power system operators throughout the day to maintain this instantaneous balance between demand and generation.

With the much higher percentage of renewables coming on line, a variety of modifications will need to be made to the Power System to successfully and reliably integrate these higher penetrations of renewable resources. In preparation, LADWP has conducted preliminary studies on integrating renewable resources, and has also reviewed many renewable resource integration studies published over the last several years.

Individual wind farms tend to have a high variability in the amount of energy produced (see figure below), but multiple wind farms located in diverse geographic areas are thought to reduce the overall variability in the amount of aggregated wind energy production.



Energy generated from Solar PV technology is highly sensitive to cloud cover. These PV systems can experience variations in output of ± 50 percent in 30 to 90 seconds, and ± 70 percent in five to 10 minutes. When a single large sized PV facility experiences these rapid changes in output, the Power System must also be able to react just as quickly with other generation resources to accommodate such rapid changes. The capabilities of a power system's dispatchable resources will limit the size of a single PV facility.

See Appendix J for more details regarding integrating intermittent resources.

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3.0 STRATEGIC CASE DEVELOPMENT

3.1 Overview

IRP planning is an on-going process and as such, the development of the 2011 IRP strategic cases incorporates the latest changes that have occurred in the regulatory landscape, and tactical plans developed by the power system. This 2011 IRP also includes many updated assumptions that have been developed over the past year. These assumptions have influenced the composition of potential resource portfolios that can fulfill LADWP's goals of reliability, competitive rates and environmental stewardship.

Last year's 2010 IRP analyzed 6 strategic cases representing different potential renewable resource portfolio mixes, with and without the early divestiture of IPP, and recommended a comprehensive strategy that adopted elements of a number of the cases analyzed. The 2011-12 fiscal-year financial planning process included many of the assumptions and recommendations set forth in the 2010 IRP.

The regulatory state of affairs was far from certain at the time the 2010 IRP was prepared, and many of the state laws and major regulations affecting generation resources such as AB32, SB1368, SB 2 (1X), and US EPA 316(b), were in process, and even today are still being finalized. This 2011 IRP attempts to incorporate the latest interpretation of these major regulations and state laws as we understand them today.

Section 3.2 summarizes the major changes from last year's model assumptions. Section 3.3 discusses the key parameters that have a bearing on the resource portfolios being considered for this IRP. Section 3.4 describes the development process for the candidate strategic cases, and Section 3.5 presents the final candidate cases that were analyzed. The analyses and comparison of the case results are presented in Section 4.

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3.2 2011 IRP Model Assumptions

At the heart of the IRP analysis effort is the computer-based production cost modeling of the LADWP Power System. In order to perform this modeling a significant amount of input data is developed. The production model and input assumptions are covered in detail in Section 3.2.2 and Appendix M. In this section, the major changes in the assumptions since last year's IRP are summarized, followed by a discussion of the general price inputs that were applied to this 2011 IRP.

3.2.1 Major Changes to 2010 IRP Assumptions

Major assumption changes from last year's IRP are summarized here. Additional detail regarding the assumptions can be found in Appendix M.

Load Forecast

As shown in Table 3-1, the new load forecast is lower than the previous forecast used in the 2010 IRP. Compared to the prior forecast, electricity sales in the calendar year 2020 decreased by 7.3 percent. The new forecast reduces the overall need for renewable energy (assuming 33% RPS) by approximately 631 GWh in 2020 and 1,309 GWh in 2030. The complete load forecast is included in Appendix A. Adjustments made to the approved load forecast to account for the latest projections of energy efficiency savings and customer-net-metered solar is shown in Appendix M.

Table 3-1. TOTAL ELECTRICITY SALES IN GWH

	2020	2030
Old Forecast – 2010 IRP	26,150	30,632
New Forecast – 2011 IRP	24,239	26,665
Difference	-1,911	-3,967

Demand Response

In the 2010 IRP, demand response (DR) started with a 50 MW program in 2011 and increased incrementally to a total of 500 MW installed by 2023. The lower load forecast used in the 2011 IRP delays the need to implement DR programs to provide added system capacity as can seen by the revised implementation schedule shown in Figure 3-1.

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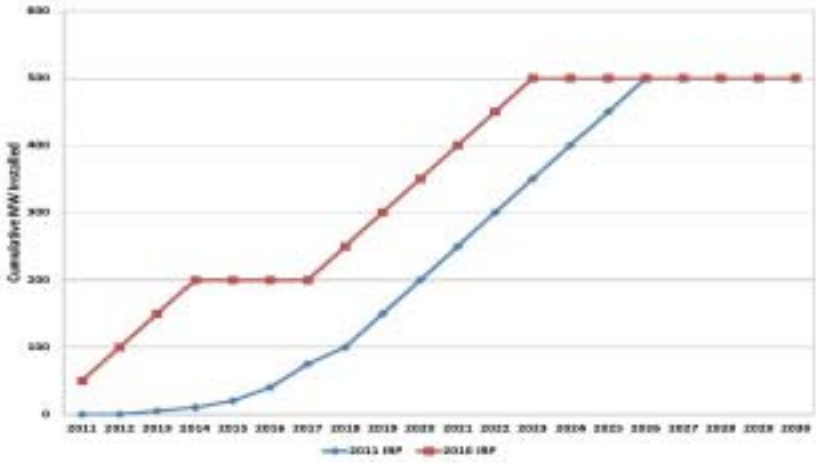

Figure 3-1. Comparison of 2010 and 2011 IRP demand response program implementation by calendar year.

Energy Efficiency

The Energy Efficiency (EE) forecast used in the 2011 IRP includes lower DSM funding levels for the 2011/12 through 2013/14 fiscal years due to short term budgetary constraints. Compared to last year, EE energy savings decrease after the 2015-16 fiscal year, even after funding levels return to normal. The main reason for this is that efficiency opportunities in lighting (which is the largest EE program component) will dissipate due to the implementation of new Federal and State lighting standards that raises the minimum efficiency level for a variety of electric products. These Federal and State efficiency standards create fewer opportunities to give financial incentives to customers to install products that exceed the higher efficiency standards and the resulting energy savings will be incrementally less. Although these standards result in fewer opportunities to provide incentives from the utility, the energy efficiency savings from these standards are nevertheless accounted for in the sales load forecast and do contribute to reducing overall sales and load growth. The cumulative EE savings incorporated in the 2011 IRP will reach 2,699 GWh in 2020 and 3,439 GWh in 2030 as shown in Figure 3-2. Efficiency savings prior to 2011 of 1,256 GWh and 303 MW from 2000 to 2010, equivalent to 5.5 percent of customer sales, are already reflected in the load forecast. The table below shows the projected cumulative savings from 2006 through 2030.

As of December 6th, 2011, the Board of Water and Power Commissioners approved an advanced EE program with a goal of 8.5 percent of sales by the end of fiscal year 2019-20 and beginning fiscal year 2010-11. The adoption of the advanced program results in approximately 920 GWh of additional gross EE savings by 2020. Due to the timing of this approval, this change could not be incorporated in the 2011 IRP, however, the advanced program will be considered in the 2012 IRP modeling results.

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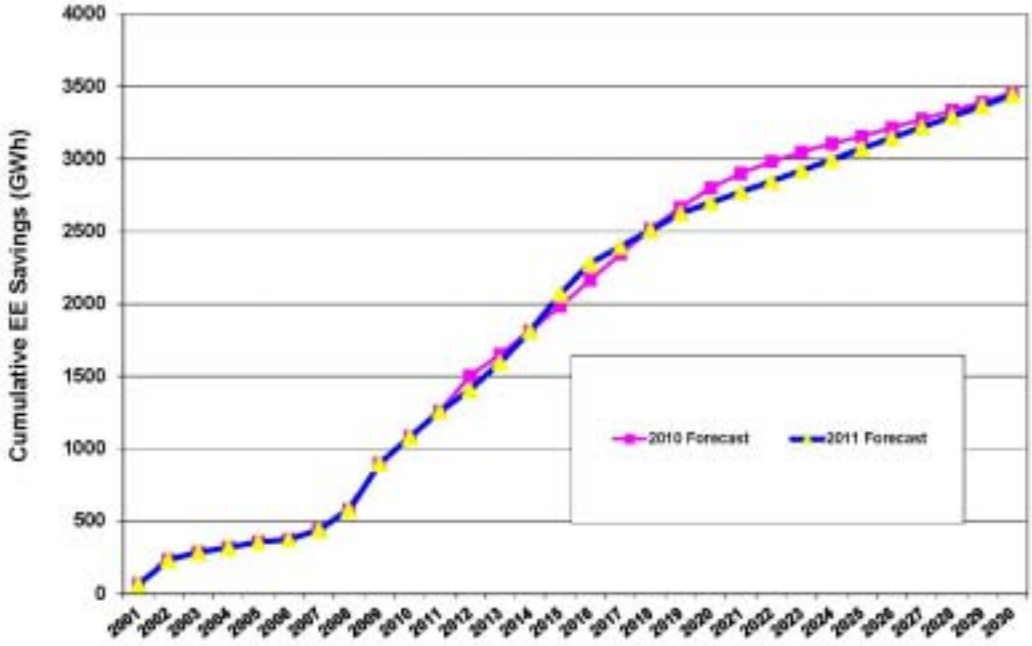

Figure 3-2. Comparison of 2010 and 2011 IRP gross energy efficiency forecasts by fiscal year.

Solar C-N-M and FIT

The solar Customer-Net-Metered (CNM) program (a.k.a. Solar Incentive Program) and Feed-In-Tariff (FIT) programs used in the 2011 IRP are based on projections dated October 2011. Figure 3-3 shows the comparison of CNM and FIT program projections used in the 2011 IRP vs. the 2010 IRP. The CNM solar is higher in years 2012-2016 primarily because of a dramatic increase in participation levels of the SIP program in 2010, and expected continued strong interest in the program given the tax benefits available and currently lower solar prices. FIT is lower in 2013-2015 due to a delay in implementation of the program due to budget constraints, but higher in 2017-2023 due to the plan to accelerate the program to take advantage of tax benefits available through 2016.

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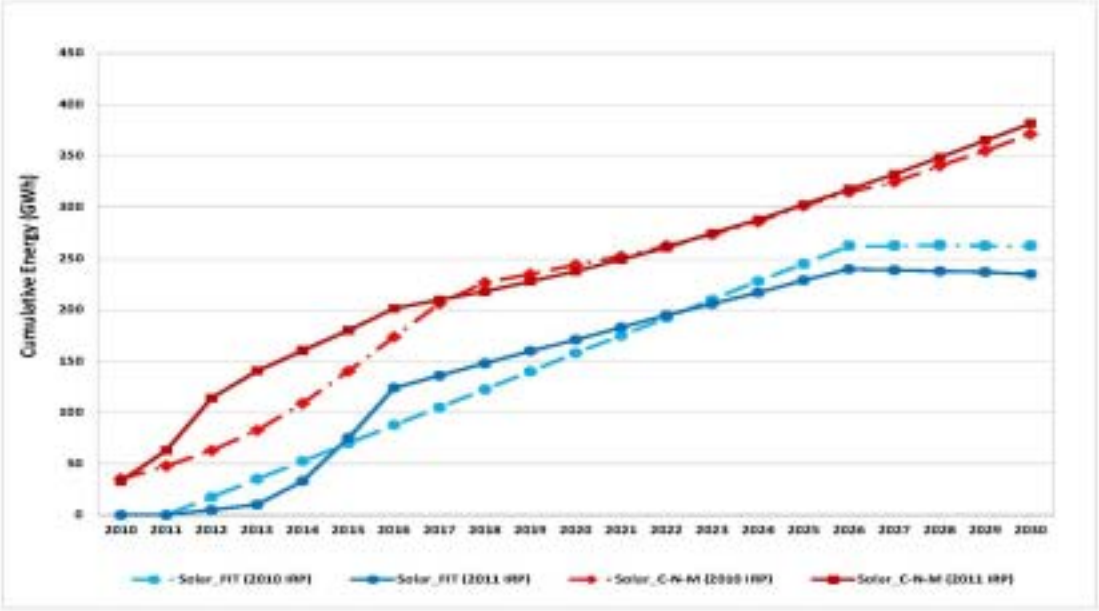

Figure 3-3. Comparison of solar projections, 2011 vs. 2010.

Renewables

Table 3-2 is a comparison of the overall renewable mix planned for the 2011 IRP vs. the 2010 IRP:

Table 3-2. RENEWABLE MIX, 2010 VS. 2011

		2020	New Renewable Installed Capacity (MW) 2011 – 2020					New Renewable Installed Capacity (MW) 2011 – 2030				
Case ID	Resource Strategy	RPS Target	Geothermal	Biomass	Wind	Non-DG Solar	Dist. Solar	Geothermal Biogas	Wind	Non-DG Solar	Dist. Solar	Generic
Recommended Case 2010 IRP	33% RPS Balanced	33%	320	0	580	315	315	320	680	485	485	160
All Cases in 2011 IRP	33% RPS SB 2 (1X) Compliant	33%	183	60	492	401	325	308	492	451	466	162

One major RPS change from the 2010 IRP was a large reduction in geothermal projects, especially in the short term. Suitable geothermal sites in accessible locations near existing transmission lines have been difficult to locate. The 2011 IRP lowers the amount of geothermal expected in 2020 by 43 percent. In the short term, increased use of low cost biogas will largely replace the energy that would have been generated by geothermal projects until more viable geothermal sites can be identified. Another change was the deferral of the Owens Valley Solar Project from 2013 to 2018 due to recent budget reductions and tax benefits for third party developed solar projects that are scheduled to end after 2016, making development of LADWP facilities that are not eligible for direct tax benefits more viable. As previously discussed, the revised load forecast decreases the need for renewables. This results in the lower overall capacity requirements in both the short term 2010 - 2020 and longer term 2020-2030 time periods as shown above.

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Navajo Early Divestiture

Divestiture of the Navajo Generating Station (NGS) on December 31, 2013 as described in the 2010 IRP recommended case, will be extended to December 31, 2015. Member utilities of NGS have "first rights of refusal" involving the sale of other member shares. After 6-months notification of their intent to exercise "first right of refusal" rights member utilities have 3 years to complete the purchase. Although NGS participants could potentially complete the purchase sooner, the most realistic estimate of a sale being completed has been extended to December 31, 2015.

GHG Costs

Projected GHG cost impacts resulting from AB32, and as incorporated in the 2010 IRP, have been significantly reduced as a direct result of recent changes in the final regulations approved by the California Air Resources Board (CARB). Although some uncertainty still remains regarding the final regulations, the expectation of allowance prices being applied to all GHG produced, as previously assumed in the 2010 IRP, have been replaced with allowance prices being applied only to the amount exceeding the CARB allowance allocation within a compliance period. Additionally, GHG regulations are expected to begin on January 1, 2013, one year later than the assumed start date in the 2010 IRP. The net effect of the allocation changes between the 2010 and 2011 IRP was a $1.25 billion reduction in anticipated allowance costs between 2010 and 2020.

Gas Prices

Natural gas costs continue to remain stable for the near term and spot market price forecasts for gas have changed little since the 2010 IRP. The Pinedale gas reserves owned by LADWP continue to provide a low cost source of gas and estimates of gas volumes to be produced from Pinedale have risen since the 2010 IRP. These production increases have lowered the overall system gas costs. Opal and SoCal expected gas prices used in the 2011 IRP were 7 and 10 percent lower on average, respectively, in the short term (2011-2020), but were 11 and 14 percent higher on average, respectively, in the long term (2021-2030) as compared to the 2010 IRP.

Coal Prices

IPP forecasted coal prices are 22 percent lower in the short term (2011-2020) and 34 percent lower in the longer term (2021-2027) as compared to the 2010 IRP. Navajo coal prices are 10 percent lower in the short term (2011-2019) as compared to the 2010 IRP.

IPP Recall

IPP capacity is a function of the capacity recalled by Utah participants. Estimates for this recall amount, or the capacity entitlement transferred from the Utah participants to LADWP, has risen by 112 MW in the short term (2011-2020) and 44 MW in the long term (2021-2027) as compared to the 2010 IRP, thereby increasing our share of IPP capacity entitlement. This raised the energy and capacity expected from IPP generation in the 2011 IRP as compared to the 2010 IRP.

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Once-Through Cooling

Recent OTC decisions by the State Water Resources Board have accelerated the compliance date for repowering the LA-basin coastal generation stations. Whereas December 31, 2040 was the date used in the 2010 IRP, the new "no later than" compliance date is December 31, 2029. The new repowering dates (see Table 3-3 below) and resulting efficiency improvements resulting from the more efficient replacement units have been incorporated into the 2011 IRP production model.

Table 3-3. BASIN PLANTS REPOWERING – TARGET SCHEDULE[1]

Unit	Nameplate Capability [1] (MW)	Action and Resulting Nameplate Capacity	Compliance Date (No Later Than)	LADWP Draft Target Date[3]
Haynes 1	230	Replace with 444 MW CC	12/31/2029	12/31/2023
Haynes 2	230			
Haynes 5	343	Replace with 600 MW CT	12/31/2013	6/1/2013
Haynes 6	343			
Scattergood 1	163	Replace with 367 MM CC	12/31/2024	12/31/2020
Scattergood 2	163			
Scattergood 3	497	Replace with 509 or 574 MW CC[2]	12/31/2015	12/31/2015
Harbor 1, 2 & 5	240	Repower with same MW	12/31/2029	12/31/2026
Haynes 8, 9 & 10	650	Repower with same MW	12/31/2029	12/31/2029

Notes:
1. Maximum or dependable capacity of the unit will be different based on permitting requirements as well as other constraints.
2. For Scattergood Generating Station, Unit 1 and 2 will be replaced with 300 MW (if unit 3 replaced with a 508 MW unit) or 233 MW (if unit 3 replaced with a 575 MW unit).
3. The LADWP target dates are very ambitious and based on many physical and budgetary assumptions, and are subject to change. They represent LADWP's best effort to comply with the regulations as fast as possible and assumes no unexpected complications or delays. Subject to further evaluations and studies.

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3.2.2 General Price Inputs

General price assumptions are presented here for supply side resources, fuel, and GHG allowances. More details are provided in Appendix M.

Supply-side Resources
Table 3-4 presents a summary of the major price assumptions for supply-side resources.

Table 3-4. SUMMARY OF SUPPLY-SIDE RESOURCE ASSUMPTIONS

Resource	Levelized Cost[1] ($/MWh)	Capacity Factors	Dependable Capacity
Solar Photovoltaic – PPA	$144	23% - 31%	27%
Solar Photovoltaic - LA Solar – Public/Private Partnership In-Basin	$177	21%	27%
Solar Photovoltaic – LA Solar – Public/Private Partnership Owens	$153	24%	27%
Solar Customer-Net-Metered	$136	18%	27%
Solar Feed-In-Tariff	$179	18%	27%
Wind	$106	24% - 42%	10%
Geothermal	$138	90%	90%
New Combined Cycle Gas (310 MW)	$63	58%	100%
New Simple Cycle Gas (50/100 MW)	$302	4%	100%

[1]Net Present Value (annual costs, 2011-2030) / NPV of Energy Produced

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Natural Gas Prices

High, low, and medium natural gas price forecasts were developed to test each portfolio against a range of potential natural gas prices. The medium or expected gas forecast originates from Platts and is the standard used by LADWP for financial and fuel procurement planning. The high and low forecast, shown on Figure 3-4, are fundamental forecasts obtained from Wood Mackenzie that consider a range of future assumptions including economic growth, supply and demand, and environmental regulations.

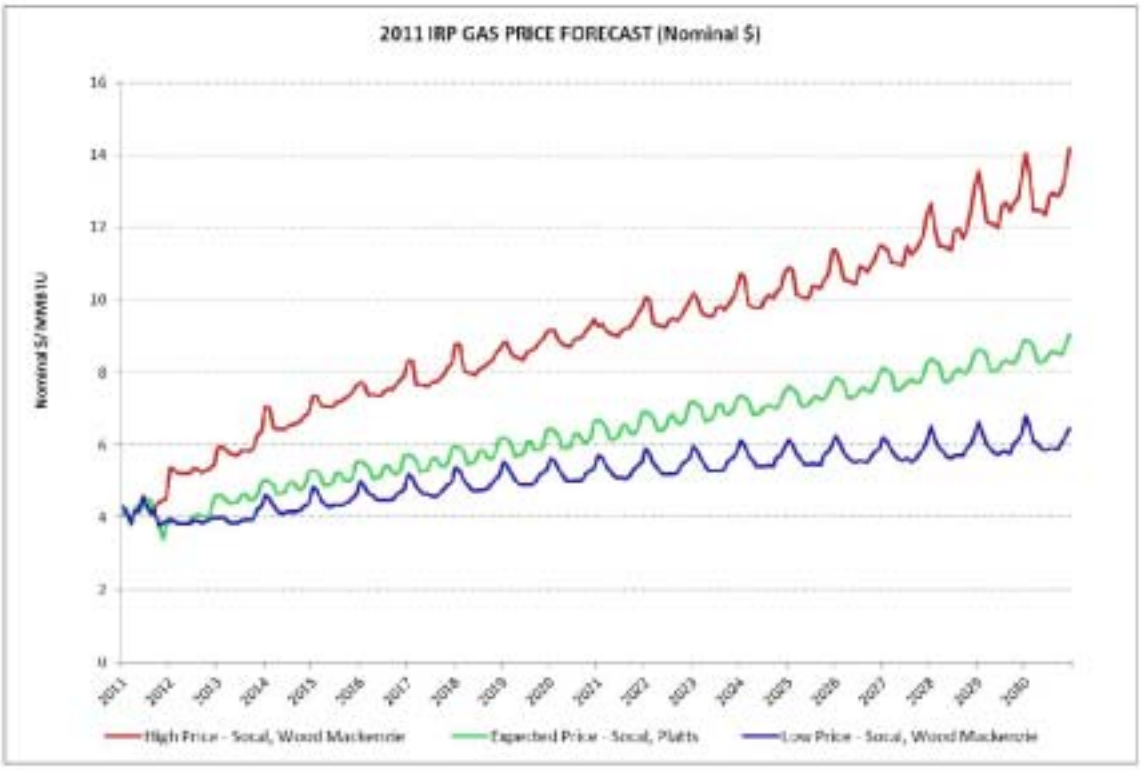

Figure 3-4. Natural gas price forecast (SoCal).

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Coal Prices

A ±20 percent factor was applied to the expected coal fuel price, provided by LADWP's External Generation Division, to determine a high and low range for coal prices. Actual coal fuel prices have intentionally been left out of this IRP to comply with non-disclosure agreements with coal suppliers.

GHG Emissions Allowance Prices

Price scenarios were also developed and tested for GHG allowance prices using staff estimates from experience, and agency models as a template. This template assumed GHG pricing starting at $24/metric ton in 2013 escalating to $45/metric ton in 2020. Beyond the year 2020, the AB32 Cap and Trade program ends and may be replaced by another State or Federal program. Assuming that there will be another program, allowance prices beyond 2020 were assumed to remain at $45/metric ton through 2030 and the allowance allocated by CARB was assumed to remain constant. Future IRP's will consider changing this assumption as new information about future programs becomes available. Unlike the 2010 IRP where a sensitivity analysis was done using high and low GHG prices, the 2011 IRP does not include high and low GHG prices because the expected costs are not as significant as other cost drivers. Figure 3-5 depicts the GHG allowance prices used to evaluate the portfolios.

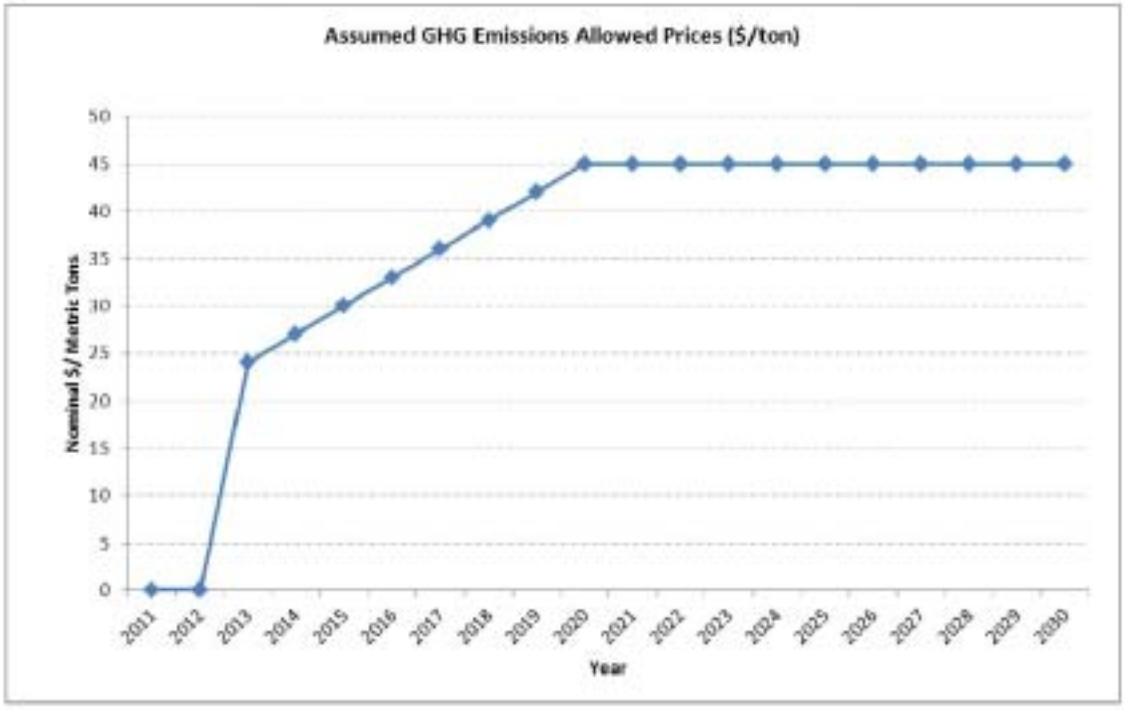

Figure 3-5. Assumed GHG emissions allowance prices.

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3.3 Strategic Case Key Parameters

The 2011 IRP strategic cases must reflect the requirements of the most-recently implemented environmental and RPS regulations. In many cases, the regulations have predetermined a limited set of resources that can be considered to meet future generation needs. The net effect is to constrain and limit the set of alternatives that can be analyzed.

SB1368

SB1368 requires that imported energy from outside California meet a GHG emissions standard of 1,100 lbs per MWh. To comply with this requirement, all future generation outside the LA Basin will need to come from either highly efficient combined cycle gas turbines (if fossil fueled), or from renewable energy resources. This eliminates the use of coal-fired generation, at least until future coal combustion and sequestration technology improves sufficiently to make this a viable option. As a result, three Coal divestiture cases have been considered in this 2011 IRP. The three divestiture cases will further define the costs and operational impacts that divestiture of these facilities will have in meeting future energy and capacity load requirements.

OTC

Once-through cooling regulations effectively prohibits the use of ocean water cooling in all of the coastal power stations, which comprises 3 of the 4 in-basin gas-fired generation facilities, and sets specific deadlines to repower this generation prior to 2029. The limited resources available to repower virtually all in-basin generation under the accelerated time frame further limits the flexibility of altering repowering schedules based on system operation and capital requirements. Therefore, all strategic cases considered include the same repowering schedule as shown in Figure 3-6 below:

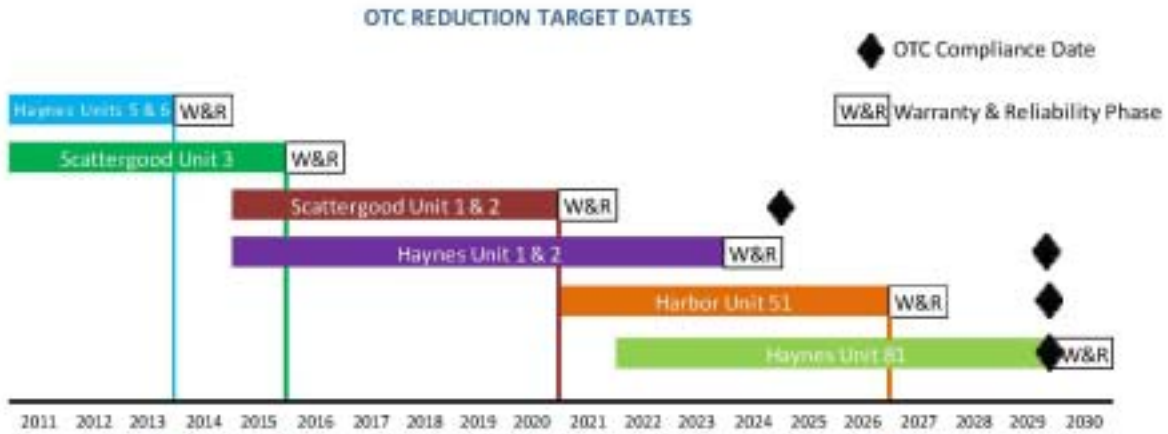

Figure 3-6. Timeline for OTC repowering projects.

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While developing the timeline for the repowering program, LADWP had to consider a number of reliability, financial, and other contingent requirements. Because the power system relies on the in-basin units to produce energy and provide voltage support and stability, it is important to keep all of the units continuously available during summer months. This means that during summer months the total capacity available from the in-basin units remain constant. This requires a strict sequencing of the separate repowering projects. Further studies will be required to determine the impact on system reliability from the accelerated repowering schedule.

Another consideration is the cost of the program. Repowering just one unit requires a significant amount of money – on the order of $500 million or more. Spreading the program over time minimizes the need for sudden and significant infusions of capital, and helps LADWP to preserve proper cash flow and capitalization ratios to maintain its credit rating.

Other issues include the long lead times required for environmental permitting, engineering design, and equipment procurement. The limited space available within some of the generating station property boundaries also presents planning difficulties. The timeline represents LADWP's best effort to comply with the mandated compliance deadlines while also meeting its reliability and fiscal responsibilities.

SB 2 (1X)

As discussed at the end of Section 1.6.4, SB 2 (1X) defines categories with predefined percentage limitations on the amount of out-of-state renewable generation and renewable energy credits that can be used to meet renewable portfolio standards. Wind, small hydro, and biogas provide the largest contributors to LADWP's portfolio as shown in Figure 2-6. Future renewable generation will rely heavily on solar PV and wind resources located within the State to fulfill the in-state percentage requirements of SB 2 (1X). This limits the potential use of renewable resources located outside of California. The strategic cases evaluated in the 2010 IRP established a diversified resource mix for the next 20 years including goals for estimated MW's installed for each renewable technology. The 2011 IRP retains the same diversified renewable mix goals set forth in the 2010 IRP recommended case while including the latest updates based on available resources. As shown in Table 3-2, all strategic case scenarios being considered in the 2011 IRP use the same renewable resource plan. Future IRP's will likely address different renewable resource mixes as the CEC further develops specific regulations to enforce SB 2 (1X).

Accelerated Coal Divestiture

To achieve a high level of Power System reliability, minimize the impact on ratepayer energy prices, and exercise environmental stewardship while complying with federal, state, and local regulations, the 2011 IRP Strategic Cases were developed to assist policymakers and ratepayers to make informed decisions regarding the accelerated divestiture of Coal resources to promote GHG reduction prior to SB1368 compliance which occurs in 2019 for Navajo and 2027 for IPP. Accelerated Coal divestiture is discretionary, unlike other mandated regulatory requirements described previously. It is

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important that the environmental benefits and resulting electricity rate and resource impacts be fully understood by ratepayers and policy makers.

3.4 Candidate Portfolios Development Process

A candidate portfolio is a set of renewable and non-renewable generation resources, DSR resources, regulatory constraints, policy goals, and assumptions that model strategic scenarios. Candidate portfolios are selected to cover a spectrum of possible scenarios, providing decision makers information on which portfolios are likely to be the most desirable. Additionally, each candidate portfolio must ensure resource adequacy—the ability to meet total peak demand.

3.4.1 Net Short and Resource Adequacy

The first step in developing the 2011 IRP candidate portfolios was to determine how LADWP can meet and maintain its renewable energy policy goals: 20 percent renewables in 2010 and 33 percent renewables by 2020. The net short—the gap between renewable energy policy goals and current renewable generation—was calculated, and the contribution of its renewable energy component towards resource adequacy was determined. Combined-cycle gas generation, energy efficiency, short term purchases, and demand response were then considered to supply the remaining deficiency in resource adequacy. Details regarding net short calculations and resource adequacy are included in Section 4.3.1.1 and Appendix M.

3.4.2 Renewable Resources Selection Process

Over the last ten years, LADWP has issued several requests for proposals for renewable energy and gained a thorough understanding of the nature and availability of the different renewable resource technologies. This knowledge was used in developing the candidate portfolios. Additionally, LADWP largely considered renewable resources within the Western Governors' Association's Western Renewable Energy Zones (WREZ). In the WREZ initiative, Qualified Resource Areas were defined as areas of dense, high-quality renewable energy resources, meeting various resource size, quality, environmental, and technical criteria. LADWP screened all resources to ensure they are located near available LADWP transmission infrastructure.

Assumptions were made for the cost and performance of each technology used to convert the renewable resources to electricity. A summary of the main assumptions made for biomass, geothermal, solar, and wind is presented in Appendix M.

A valuation process designed to provide a single ranking value to a resource was then applied. This step is intended to identify resources with the combination of lowest cost and highest value. The valuation approach is similar to the bid evaluation process many utilities use when procuring renewable resources. Specifics for the resource valuation methods are also covered in Appendix M.

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After applying the appropriate constraints, resources were selected and added progressively to its renewable resource mix based on lowest rank cost and transmission availability until the net short was mitigated.

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3.5 2011 IRP Strategic Cases

The 2011 IRP analyses a focused set of strategic cases, expanding on the results from the 2010 IRP process. Cases from last year that included a variety of renewable percentage targets were eliminated. A streamlined set of 3 coal divestiture cases where then included for the 2011 IRP. Unlike other areas that are constrained by mandated regulatory requirements (such as renewable resources), the decision to divest from coal earlier than legally required is discretionary and thus appropriate for analysis. The 2011 IRP strategic cases are designed to assist policymakers and ratepayers to make informed decisions regarding accelerated coal divestiture, particularly with regard to the environmental benefits and resulting resource and electricity rate impacts.

- Case #1 provides a baseline without any early coal divestiture. Navajo Generating Station continues until 12/1/2019 and the Intermountain Power Project (IPP) until 6/15/2027.
- Case #2 considers an early divestiture of NGS, by 12/31/2015.
- Case #3 considers early divestiture of both coal plants – NGS by 12/31/2015 and IPP by 12/31/2020.

Table 3-5 provides a more detailed description of each strategic case.

As mentioned earlier, the same renewable resource plan applies to all cases. Table 3-6 summarizes each candidate renewable portfolio. For comparison purposes, the recommended case from last year's IRP is also included.

The different cases require distinct resource strategies to replace the divested coal generation capacity and to meet future load growth. These strategies include the construction of new natural gas units, renewable generation, electricity purchases in the 3rd Qtr as needed to fill short term resource adequacy deficiencies, and the implementation of demand response and energy efficiency programs. A detailed breakdown of these strategies is discussed in Sections 4 and 5.

The candidate portfolios were modeled and the case results were compared against each other. The analysis included measurements of power costs, emissions, and fuel usage. High and low scenarios based on fuel prices were also modeled to quantify the risk associated with fuel price volatility on each case. Section 4 discusses the modeling results, and presents the 2011 IRP Recommended Case that emerged from the analysis process. Section 5 discusses in greater detail the recommended case and the resulting impact on rates as well as the actions required to implement the recommended case.

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Table 3-5. DESCRIPTION OF STRATEGIC CASES

Case ID	Description
Case 1 (Base Case)	No Early Coal Divestiture – This case assumes coal resources will be replaced with combined cycle natural gas and renewable resources upon the expiration of coal contracts with no early compliance with SB1368. Maintains the 33 percent standard renewables mix recommended to comply with SB 2 (1X).
Case 2	Navajo Early Replacement Strategy – This case considers early replacement of Navajo on 12/31/2015, or 4 years prior to contract expiration with IPP replacement at the end of contract expiration in 2027. Maintains the recommended 33 percent standard renewables mix to comply with SB 2 (1X).
Case 3	Navajo and IPP Early Replacement Strategy – This case considers early replacement of Navajo on 12/31/2015, 4 years prior to contract expiration, and early replacement of IPP on 12/31/2020 or 7 years prior to contract expiration. Maintains the recommended 33 percent standard renewables mix to comply with SB 2 (1X).
Recommended Case 2010 IRP	33% RPS Balanced Strategy – Primarily used to compare the other strategic cases to the recommended long term strategy described in the 2010 IRP with 33 percent renewable compliance by 2020. Considers early divestiture of Navajo on 1/1/2014 or five years prior to contract expiration and assumes replacement of IPP in 2027.

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Table 3-6. CANDIDATE RESOURCE PORTFOLIOS FOR 2011 IRP

		2020	GHG or SB 1368 Compliance Date		New Renewables Installed Capacity (MW) 2011 – 2020					New Renewables Installed Capacity (MW) 2011 – 2030				
Case ID	Resource Strategy	RPS Target	Navajo Replacement	IPP Replacement	Geo-thermal	Bio-mass	Wind	Non-DG Solar	Dist. Solar	Geothermal/ Biomass	Wind	Non-DG Solar	Dist. Solar	Generic
1 (Base Case)	No Early Coal Divestiture	33%	12/1/2019	6/15/2027	183	60	492	401	325	308	492	451	466	162
2	Navajo Early Replacement	33%	12/31/2015	6/15/2027	183	60	492	401	325	308	492	451	466	162
3	Navajo and IPP Early Replacement	33%	12/31/2015	12/31/2020	183	60	492	401	325	308	492	451	466	162
Rec. Case 2010 IRP	33% RPS Balanced	33%	1/1/2014	6/15/2027	320	0	580	315	315	320	680	485	485	160

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4.0 STRATEGIC CASE ANALYSIS

4.1 Overview

The analysis was performed on the generating resources using an hourly chronological production cost model. The model simulated the operation and electric loading of the LADWP Power System over a 20-year planning horizon with different portfolios of generating resources. The objective function of the production cost model is to minimize system cost, which is achieved by finding the least cost method to meeting the electric system demand using the specified generating resource portfolios.

The resources defined in the model consist of existing LADWP generating resources and generic types of future generating resources. The resource mix of renewable generating resources and thermal generating resources must satisfy: (1) resource adequacy requirements for reliability, and (2) specific increasing targets of renewable resources as a percentage of total energy sales.

For this 2011 IRP, the key strategic consideration is the accelerated reduction of GHG emissions by way of early divestiture of coal generation. The model runs analyzed different coal divestiture scenarios for LADWP's two coal projects, the Intermountain Power Project (IPP) and Navajo Generating Station (NGS). The results for each model run were tabulated and compared against each other. Each strategy was ranked on average dollars per megawatt hour generation cost and the total million metric tons of CO_2 emissions. All of the strategic cases meet electric system reliability requirements per NERC and FERC regulations, which dictated either replacing or re-powering aged infrastructure or end-of-life generating power plants.

The selection of the best case for LADWP ratepayers hinges mainly upon the load forecast, price of natural gas and coal, GHG emission levels, capital, and O&M costs. These factors are the major cost drivers for bulk power in the cases analyzed. All cases meet the mandated RPS percentage targets and renewable resources are included in the analysis and are the same for all cases analyzed.

Section 4.2 reviews the cases that were presented in Section 3, along with the model assumptions and analysis methodology. Section 4.3 presents the modeling results, including cost comparisons and the rate impact results of the different cases. Section 4.4 presents the strategic case conclusions and the recommended case.

Section 5 includes long and short-term actions that are recommended towards implementation of the recommended case, including an estimate of the revenues requirements and electricity rate schedule needed to support it, and the consequences of funding short falls.

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4.2 Strategic Case Runs

The cases analyzed in this 2011 IRP were introduced in Section 3.5 and are briefly reviewed here. The timing of coal divestiture (and the associated resource replacement) is the key parameter that differentiates the three strategic cases. Table 4-1 summarizes the portfolios for each case. For comparison purposes, the recommended case from last year's IRP is also included.

The following inter-related resource parameters were assumed to occur in each of the three strategies:

- OTC Repowering Schedule per Table 3-3
- Energy efficiency penetration of approximately 3071 GWh by 2030
- RPS Resource Mix, schedule per Table M-2 and M-3 of Appendix M
- GHG allowance methodology and prices on page M-17 of Appendix M
- Gas and Coal Fuel prices, as shown on Tables 4-6 and 4-7
- IPP capacity and recall schedule on Page M-16 of Appendix M

Each strategic case was also subjected to high and low scenario runs, which were based on high and low values for natural gas and coal prices. The high and low scenarios simulated production over the same 20-year horizon, and provided a measure of the level of risk due to potential future fuel price volatility.

4.2.1 Modeling Methodology

4.2.1.1 Planning & Risk (PROSYM)

Simulations were performed using Planning & Risk (PAR), a third-party software program sold and distributed by Ventyx Corporation based in Atlanta, GA. PAR is an hourly chronological production cost model that commits and dispatches resources to minimize the cost of serving electric load. It utilizes the PROSYM unit commitment and dispatch algorithm. PAR is a widely used production cost model used by many utilities across the US and the world to help plan and optimize power systems. Additional information on the model can be found in Appendix M.

4.2.1.2 Model Assumptions

To perform model simulations, a large set of input data is required. The key parameters that influence the analysis results are fuel prices, load forecast (including adjustments for energy efficiency and other demand side management programs), coal divestiture strategies, and operational inputs regarding future gas-fired units. Details regarding the model assumptions are provided in Section 3 and Appendix M

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4.2.1.3 Net Short of Renewables

In developing the future renewable portfolio mix, the primary requirement was to meet the SB 2 (1X) goals for RPS percentage (see Section 1.6.3 for details). Other considerations included costs, resource and geographical diversity, and proximity to existing transmission. The process by which the renewable resource portfolio was constructed is described in Section 3.3.2.

4.2.1.4 Resource Adequacy

As a prerequisite for any potential future portfolio, all cases considered must satisfy Resource Adequacy (RA) requirements. RA is the ability to supply the aggregate demand and energy requirements of customers at all times, taking into consideration future load growth and planning reserve margins. In calculating RA for a given portfolio, generation resources are assigned a percentage of their nameplate capacity, known as "Net Dependable Capacity" that can be counted towards fulfillment of the RA requirement. The net dependable capacity values vary depending on the type of generation resource. Throughout the energy industry there is an on-going debate on how much variable energy resources can be relied upon during the summer system peak. Table 4-2 lists the net dependable capacities of the different resource technologies assumed for this IRP analysis.

Table 4-2: NET DEPENDABLE CAPACITY ASSUMPTIONS FOR NEW RESOURCES

Plant Technology	Net Dependable Capacity
Natural Gas Combined-Cycle	100%
Natural Gas - Gas Turbine	100%
Wind	10%
Solar PV	27%
Solar Thermal	68%
Geothermal	90%

The specific RA analyses for each of the three strategic cases are presented later in Section 4.3.1.1.

4.2.1.5 Model Runs and Scorecards

The evaluation of each strategic case yielded a tremendous amount of information about the LADWP power system. In order to organize and interpret the modeling results, a scorecard system was developed to rank and check the output results. The scorecard is a very detailed and complex Microsoft Excel based spreadsheet that summarizes all the important inputs and outputs and includes metrics such as total system power costs, plant generation, CO_2 emissions, and fuel costs.

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4.2.1.6 Post Modeling Analysis

While the production cost modeling provides detailed information on estimated bulk power costs, reliability and mandated regulatory program revenue requirements are evaluated through analysis external to the production cost model. The results of this analysis are provided in Section 4.3.3 to provide a more complete view of the total cost components that make up total power system costs. This Section also illustrates the revenue requirements to fund these specific programs to maintain a reliable electric system while also complying with regulatory requirements for renewable portfolio standards, local solar, once-through-cooling, and energy efficiency.

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4.3 Modeling Results

The modeling results are presented in terms of LADWP's overall goals of: (1) reliability, (2) environmental stewardship and (3) economic, or cost, considerations.

4.3.1 Reliability Considerations

Resource strategies are not designed to totally avoid the chance of a power outage due to inadequate supply resources. Such a strategy would be very expensive and would mean that some resources would be built with a small chance of ever operating, or would have an unacceptably low capacity factor. Most power outages are distribution based (e.g., a winter storm that knocks down local distribution lines) and not a result of insufficient generation resources. The NERC/WECC reliability criteria of "1 day in 10 years" attempts to quantify what is an acceptable amount of loss of load (i.e. a power outage). The generally accepted industry interpretation of the criteria is that a system is considered reliable if there are no more than a total of 24 hours of loss of load in a 10 year period (87,600 hours). This criteria translates to a 0.03 percent chance that load will not be served.

Based on the reliability calculation, no single resource strategy is significantly more or less reliable than another strategy, and all strategies meet this criteria. The economic aspects of each of the resource strategies are only valid if the resource strategy meets the NERC reliability standard of "1 day in 10 years." For this evaluation on reliability, each resource strategy was considered equal in terms of the reliability criteria.

4.3.1.1 Resource Adequacy

The process of ensuring resource adequacy for each strategic case is iterative. Initially, a model run is made for each case without any resource additions. The results indicate the amount of resource surplus or shortfall into the future. Without any resource additions, a deficit is eventually reached as a result of coal divestitures, generation unit retirements and the expiration of power purchase contracts on the supply side, as well as load growth on the demand side. Figure 4-1 present the resource shortfalls for the three strategic cases prior to any resource additions. For planning purposes, the figures focus on the most critical months of each year – July through October.

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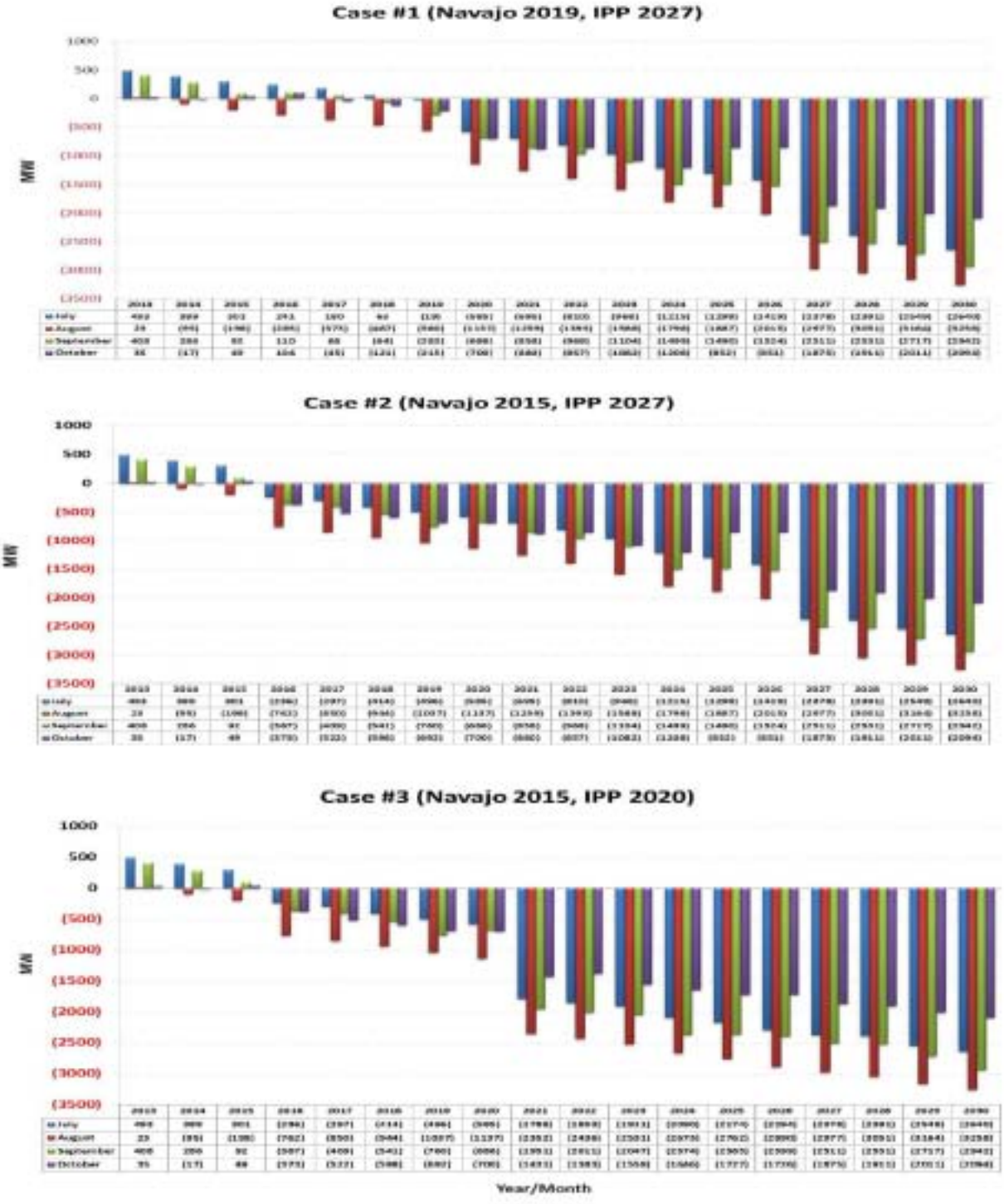

Figure 4-1. Summer months resource adequacy shortage with coal divestiture by calendar year (1 in 10)

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Once the deficits have been quantified, the means of satisfying the shortfall is assessed. Some of the considerations that LADWP accounted for in identifying potential solutions include:

- Because the analysis already includes renewable resources expected to be in place by the end of 2011, any additional renewables added will increase LADWP's overall resource portfolio and help achieve compliance with SB 2 (1X).
- Energy efficiency, demand response, short term purchases, and replacement gas fired generation were considered to provide the most economical and well diversified blend of resources.
- The additions had to be separate and distinct from the in-basin OTC repowering projects, which are already included in the shortfall calculation.
- Large scale generation additions were located out-of-basin to take full advantage of the existing transmission infrastructure and to comply with local environmental regulations.
- Where feasible, the new generation sites should make use of existing transmission and fuel supply infrastructure.
- As with all planning activities, the solution must address reliability, costs, and environmental stewardship.

After careful consideration, LADWP's IRP team consisting of the IRP staff, Power System Management, Environmental Affairs, and the Energy Efficiency Group, developed a recommended resource replacement strategy for each case and briefed the General Manager and Financial Services Organization. The recommended solution employs a mix of new renewable generation, energy efficiency, demand response, new gas-fired combined cycle units, and short term 3rd quarter energy purchases to replace Navajo and IPP Coal and to supplement load growth. Table 4-3 shows the breakdown of the replacement resources recommended for the three cases.

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Table 4-3. RESOURCES RECOMMENDED FOR RESOURCE ADEQUACY BY CALENDAR YEAR

Base Case (Navajo 2019, IPP 2027)

Capacity [MW]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	61	88	111	132	145	156	167	175	183	191	199	207	215	223	231	239	247	255
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500
New Renewable	30	47	120	199	251	310	356	403	448	500	528	575	606	623	631	646	656	662
Navajo Replacement CC	0	0	0	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0			0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150
Short Term QD Purchase								75	100	125	225	325	325	375	175	225	325	400
Total Replacement	96	145	251	330	471	665	674	1153	1279	1415	1602	1807	1884	2021	2992	3068	3177	3266

Case 2 (Navajo 2015, IPP 2027)

Capacity [MW]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	61	88	111	132	145	156	167	175	183	191	199	207	215	223	231	239	247	255
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500
New Renewable	30	47	120	199	251	310	356	403	448	500	528	575	606	623	631	646	656	662
Navajo Replacement CC				300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC					0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150
Short Term QD Purchase				125	100	75	75	75	100	125	225	325	325	375	175	225	325	400
Total Replacement	96	145	251	763	871	943	1049	1153	1279	1415	1602	1807	1884	2021	2992	3068	3177	3266

Case 3 (Navajo 2015, IPP 2020)

Capacity [MW]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	61	88	111	132	145	156	167	175	183	191	199	207	215	223	231	239	247	255
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500
New Renewable	30	47	120	199	251	310	356	403	448	500	528	575	606	623	631	646	656	662
Navajo Replacement CC				300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC					0	0	0	0	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
Short Term QD Purchase				125	100	75	75	75	25		25	50	50	100	175	225	325	400
Total Replacement	96	145	251	763	871	943	1049	1153	2354	2440	2552	2682	2769	2896	2992	3068	3177	3266

Figure 4-2 shows the net dependable capacity profiles for the 3 cases after including the recommended resources to satisfy resource adequacy requirements. In each case, Navajo is replaced with new renewable generation and a 300 MW replacement combined cycle gas-fired unit upon divestiture. Energy efficiency, demand response, and short-term purchases supply capacity that primarily contributes to peak load growth.

When IPP energy ceases in 2027 for Cases 1 and 2 and 2020 for Case 3, that production is replaced entirely with a 1,150 MW combined cycle natural gas unit. The larger combined cycle unit will be necessary to reduce short-term purchases and to provide for additional load growth. By 2020, most of the renewable portfolio will have already been built to replace Navajo with continued load growth being offset by renewables, energy efficiency, demand response, short-term purchases, and a portion of the 1,150 MW combined cycled gas-fired unit.

Short-term purchases are meant to satisfy peak load growth in the summer months where capacity is needed only over a short period of time. The planned addition of short-term purchases helps to limit the amount of capital intensive resources that would be necessary to supply peak load growth. Continual evaluation of future market conditions will be needed to insure that the market possesses adequate depth and reasonable pricing so that these purchases can be relied upon to fill system capacity needs.

In Cases 2 and 3 with Navajo divested in 2015, the 300 MW combined cycle gas-fired unit and demand response resources are fulfilling two purposes, (1) replacing capacity and energy that would have been provided by NGS and (2) providing dispatchable resources to enable

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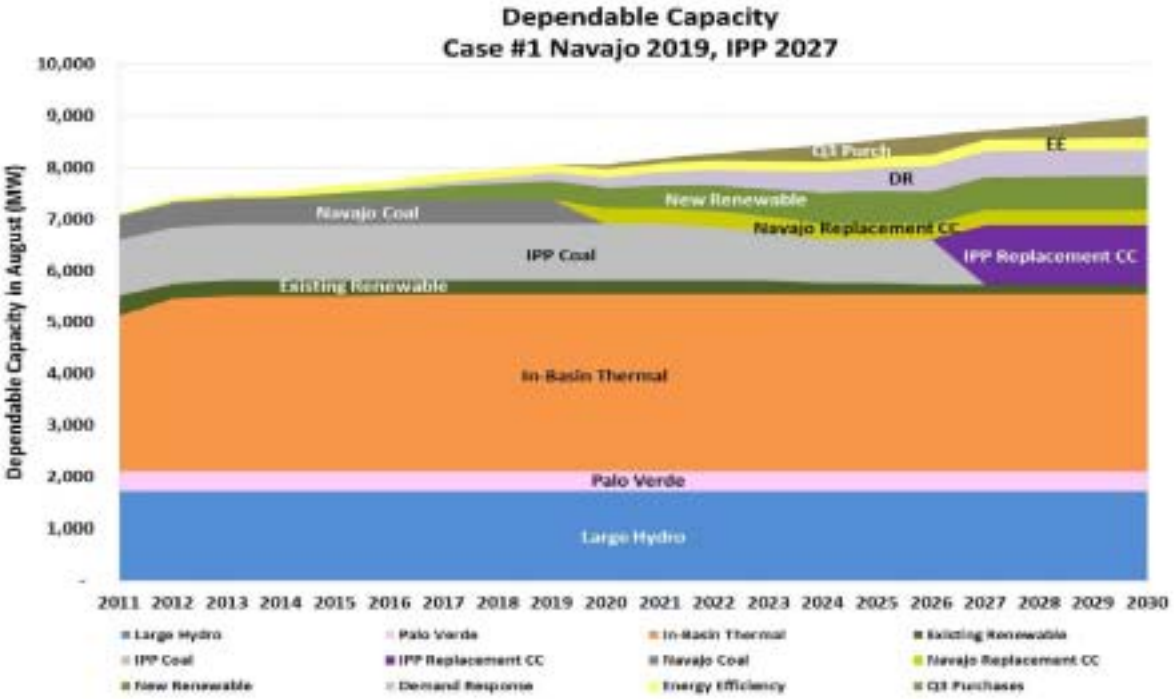
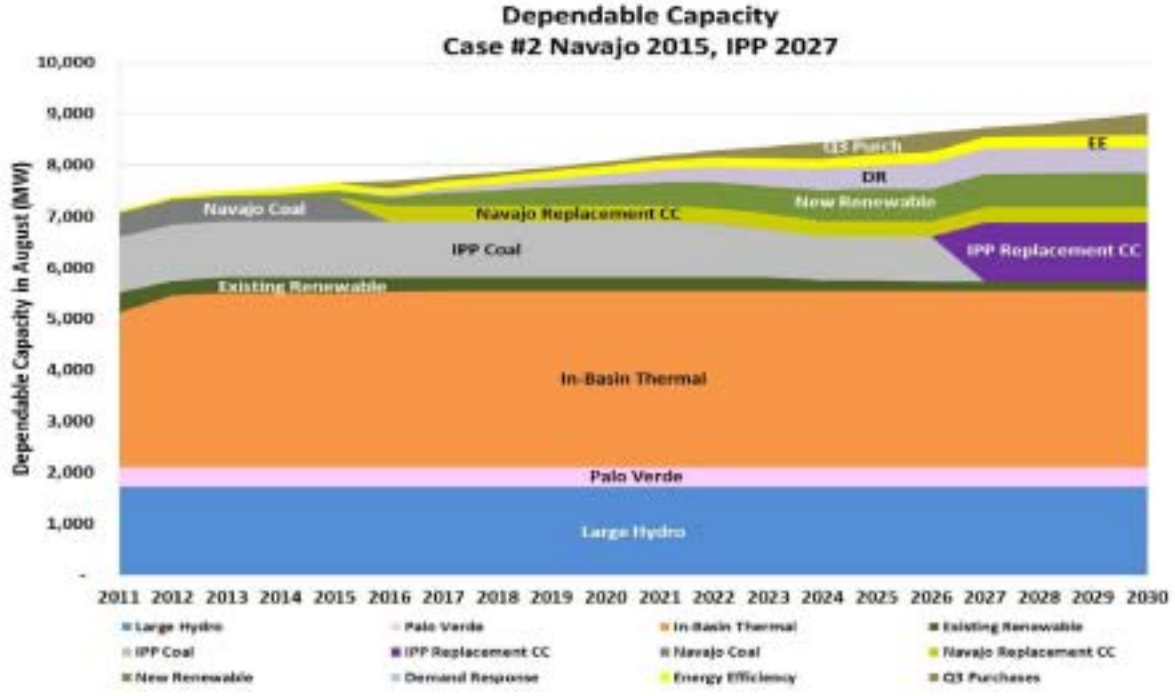
the integration of increasing amounts of intermittent renewable energy as these resources are ramped up from the current 20% RPS to 33% RPS in 2020.





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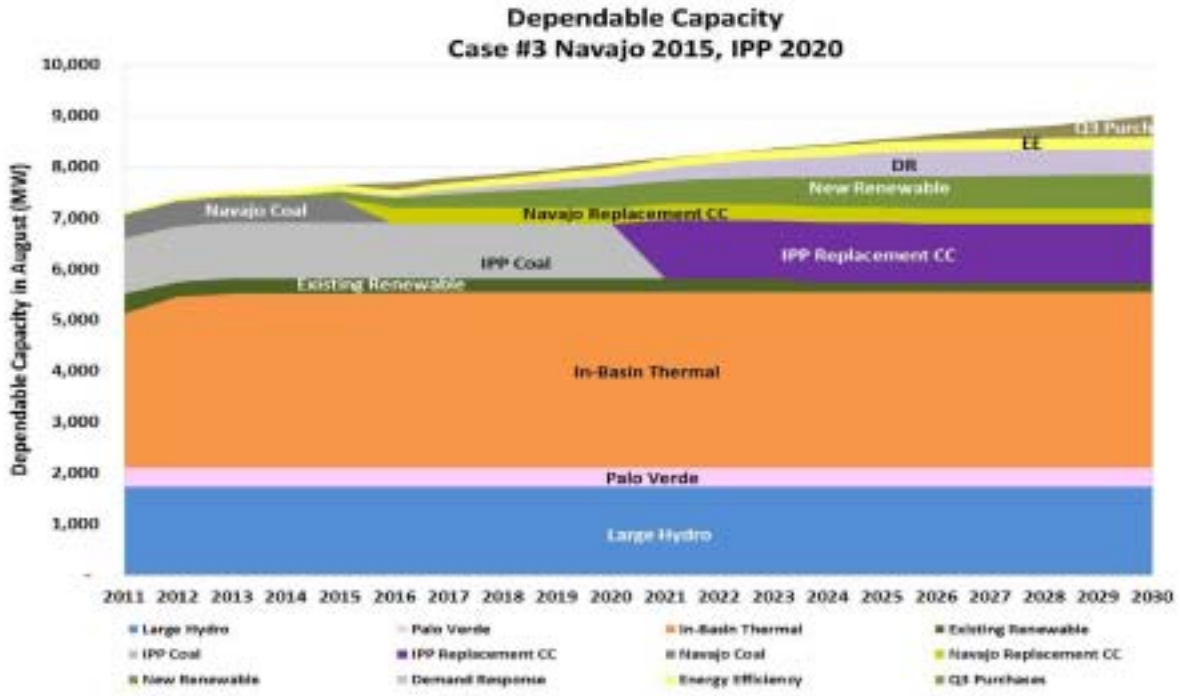

Figure 4-2. Dependable capacity mix by calendar year.

4.3.2 GHG Emissions Considerations

The primary objective of coal divestiture is to reduce overall GHG emissions. Energy produced from coal emits approximately twice the amount of GHG emissions on a lbs/mmbtu basis, when compared to energy produced from natural gas. The reductions of GHG emissions are reflected in the production cost model simulations. Figure 4-3 illustrates a comparison of the resulting GHG emission levels of the three cases. Divestiture of Navajo results in an average 1.86 Million Metric Tons (MMT) reduction in GHG each year while IPP results in an average 3.26 MMT reduction each year. GHG reductions are accelerated in Cases 2 and 3 with the divestiture of Navajo and IPP prior to the expiration of existing power contracts with these facilities. Case 1 represents the normal course of emissions reductions with no early divestiture. Reduction levels are eventually reached in all cases in 2019 and then again in 2027 when SB 1368 essentially prohibits the importation of energy produced from coal when the existing power contracts expire.

Current GHG emissions levels are approximately 14.1 MMT which is 21 percent below 1990 levels due to the elimination of Mojave and Colstrip Coal, completed repowering of units at Haynes and Valley generating stations with cleaner gas-fired replacements, and increased renewable generation from 3% in 2003 to 20% in 2010. Early divestiture of Navajo shown in Cases 2 and 3 results in approximately 7.5 MMT less GHG emissions between 2016 and 2019 and early divestiture of IPP shown in Case 3 results in a reduction of GHG emissions of 21.1 MMT between 2020 and 2027.

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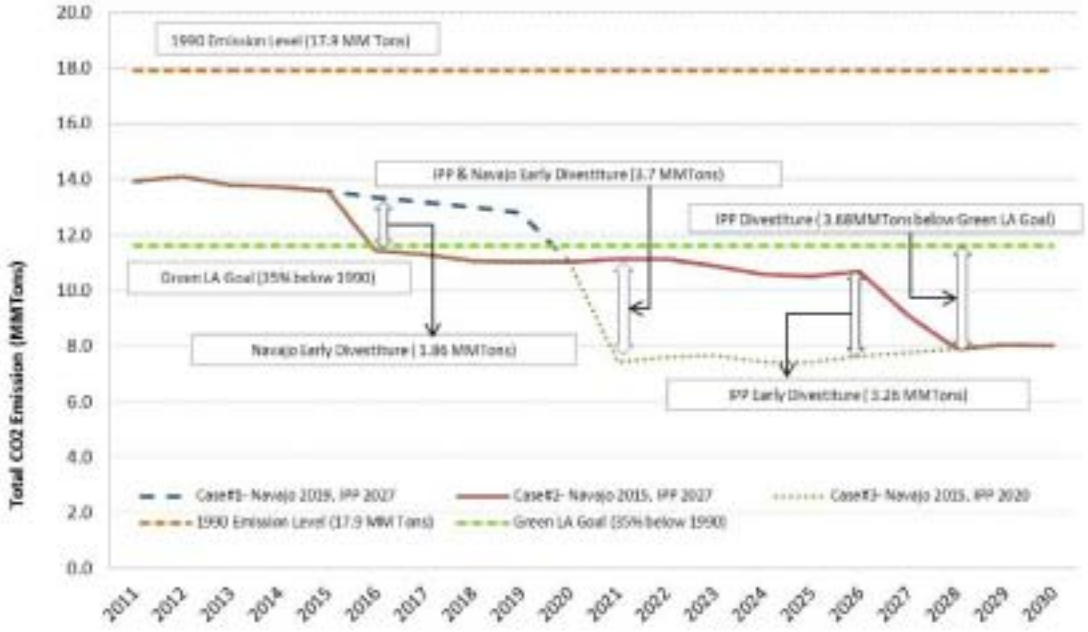

Figure 4-3. GHG emissions comparison by calendar year.

In addition to GHG, Oxides of Nitrogen (NO_X) were also measured within the production model. Figure 4-4 summarizes NO_X emissions for each of the three cases. With the installation of SCR equipment since 1989, NO_X emissions of in-basin generation has been reduced by 90 percent and represents approximately 0.5 percent of all LADWP NO_X emissions with the other 99.5 percent coming from out-of-basin coal-fired generation.

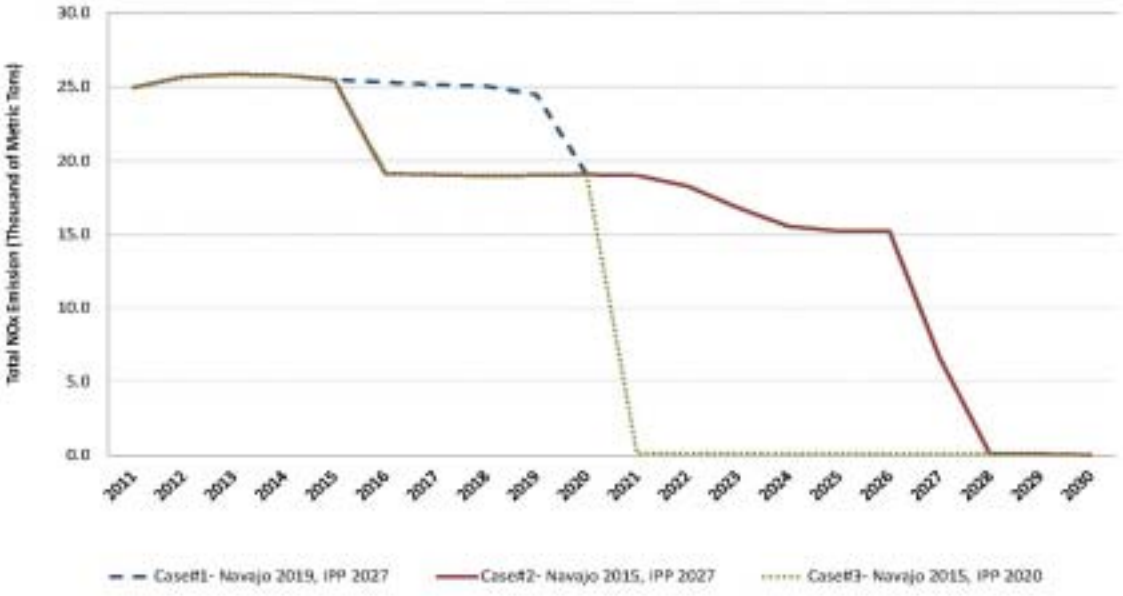

Figure 4-4. NO_X emissions comparison by calendar year

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4.3.3 Economic Considerations

The economic considerations for the three cases included a comparison of fuel and variable costs, and a fuel price stress test to account for potential future price volatility which affects possible ranges of bulk power costs. Reliability and regulatory revenue requirements are also addressed to quantify the impact of these programs on future total power system costs.

4.3.3.1 Cost Comparison Between Cases

The total fuel and variable costs for the 3 coal divestiture cases are shown in Figure 4-5 below. The natural gas price used in the production model was the 20-yr long-term natural gas price forecast from Platts and is also considered as the expected natural gas price in the stress test study in Section 4.3.3.2.

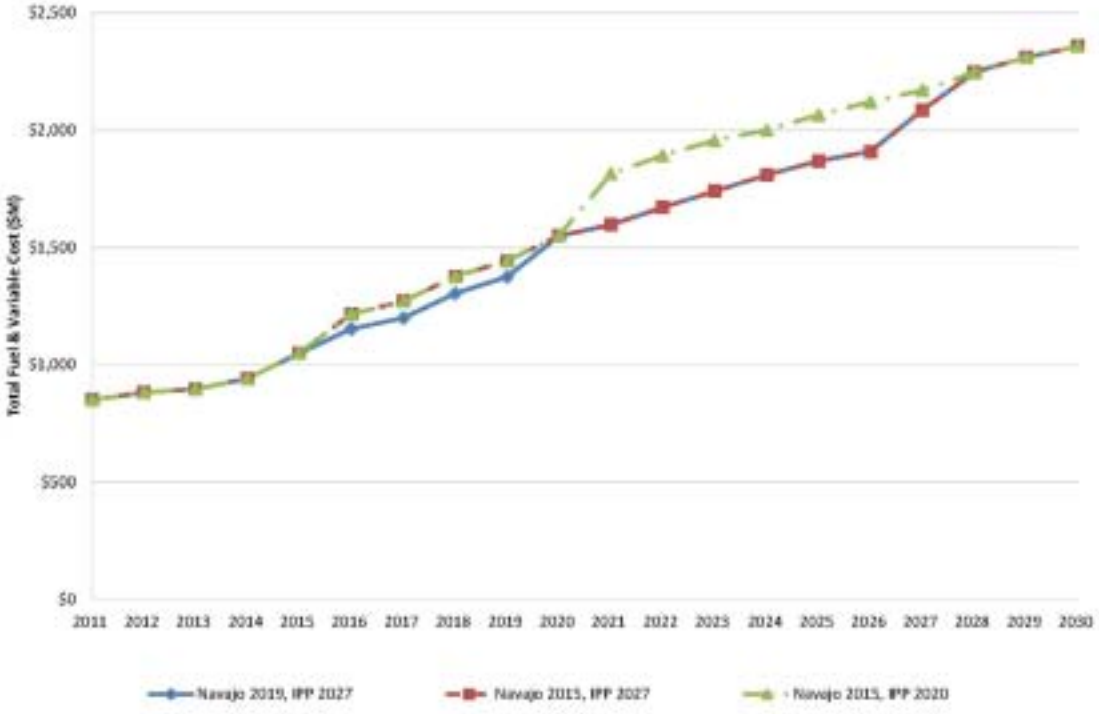

Figure 4-5. Total fuel and variable cost comparison by calendar year (Includes renewable project costs).

Divestiture of IPP and Navajo results in higher fuel and variable O&M costs, as less expensive coal is replaced with relatively higher cost gas-fired energy. The resulting increase in fuel costs from the Navajo divestiture is due to a blended increase of in-basin and out-of-basin gas fired generation. In reality, resources replacing Navajo consist of a blend of new replacement gas-fired combined cycle units and new renewable energy. The gas-fired

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replacement resources for Navajo can be better seen in Table 4-4. Because all 3 cases analyzed have the same renewable portfolio, the cost differences between the cases can only be attributed to increased gas cost; therefore, the costs shown in Table 4-4 do not include any costs associated with new renewable resources.

Table 4-4. Increased capital, fuel, and variable O&M costs related to divestiture of Navajo and IPP by fiscal year

Delta -Navajo Early Divestiture Study

(Case 2 - Case 1) [FYE]	2016	2017	2018	2019	2020	Total
Capital & Fixed OM Cost						
300 MW Navajo Replacement Cost	$9 M	$18 M	$18 M	$18 M	$6 M	$68 M
SubTotal	$9 M	$18 M	$18 M	$18 M	$6 M	$68 M
Additional Fuel Cost	$25 M	$65 M	$66 M	$74 M	$33 M	$264 M
Additional VOM Cost	$0 M	$4 M	$3 M	$3 M	$2 M	$12 M
Total Cost Delta	$ 34	$ 87	$ 87	$ 94	$ 41	$343 M
Billed Energy Sale (GWh)	23,390	23,567	23,755	23,977	24,239	Average
Est. Rate Increase (cents/kWh) *	0.15	0.37	0.36	0.38	0.17	0.36

Note: * Noncumulative rate increase.

Delta - IPP Early Divestiture Study

(Case 3 - Case 2) [FYE]	2021	2022	2023	2024	2025	2026	2027	Total
Capital & Fixed OM Cost								
1,150 MW IPP Replacement CC	$96 M	$133 M	$133 M	$133 M	$133 M	$133 M	$126 M	$856 M
Natural Gas Pipe line	$2 M	$4 M	$4 M	$4 M	$4 M	$4 M	$4 M	$26 M
SubTotal	$98 M	$137 M	$137 M	$137 M	$137 M	$137 M	$131 M	$884 M
Additional Fuel Cost	$88 M	$198 M	$190 M	$188 M	$170 M	$190 M	$180 M	$1,203 M
Additional VOM Cost	$ 9	$ 26	$ 26	$ 23	$ 18	$ 19	$ 18	$139 M
Total Cost Delta	195	361	353	348	325	346	328	$2,226 M
Billed Energy Sale (GWh)	24,601	24,820	25,046	25,280	25,519	25,750	25,983	Average
Est. Rate Increase (cents/kWh) *	0.67	1.46	1.41	1.38	1.27	1.34	1.26	1.36

Note: * Noncumulative rate increase.

4.3.3.2 Fuel Price Stress Test

The importance of stress testing the model results of the 3 cases is to determine the range of exposure to economic risk due to fuel price volatility. Historically, natural gas prices have tended to be volatile and unpredictable and LADWP employs hedging techniques to constrain volatility within acceptable ranges. However, diversification of fuel resources is also an effective means to mitigate economic exposure to a single fuel source. For example, renewable energy supplies a necessary hedge against increased fuel price exposure and eliminates the fuel cost for 20 percent of our current fuel supply.

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Coal purchased by LADWP over the last 30 years has traditionally been provided primarily through long term coal contracts where future costs are predictable. Additionally, a small portion of LADWP's coal supply is provided through short term coal purchases subject to market fluctuations. Therefore, natural gas prices become the primary concern when assessing future cost impacts. Replacing Navajo and IPP Generating Stations with gas fired generation would expose our ratepayers to fuel markets which may result in higher or lower fuel costs which are much less predictable.

Realizing the need for accurate fuel price forecasts, LADWP contracted with Wood Mackenzie Research and Consulting to provide natural gas price high and low forecasts to stress test future power production costs as shown in Figure 4-6. Also included in the high and low range forecasts were coal prices received from LADWP's External Generation Group. Based on the expertise and experience of the Coal Supply Group, a ±20 percent factor was applied to the expected coal fuel price to determine a high and low range for coal prices.

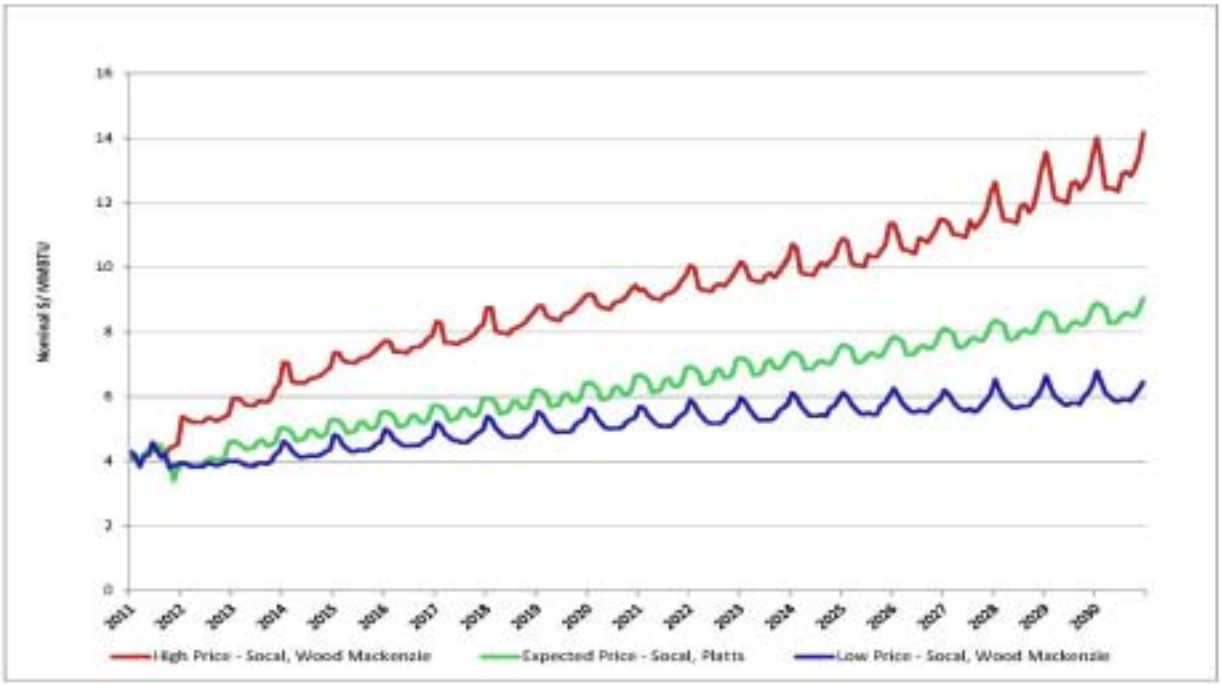

Figure 4-6. High, low, and expected natural gas price forecasts (So Cal Gas).

The natural gas price curves furnished by Wood Mackenzie Research and Consulting show a greater propensity towards higher than expected gas fuel prices, and less risk of lower than expected prices. This is wholly consistent with past historical gas prices which are shown in Figure 4-7 – the relative shape of the curve is asymmetrical with the forward tail (higher prices) extending further away from the mean of the curve.

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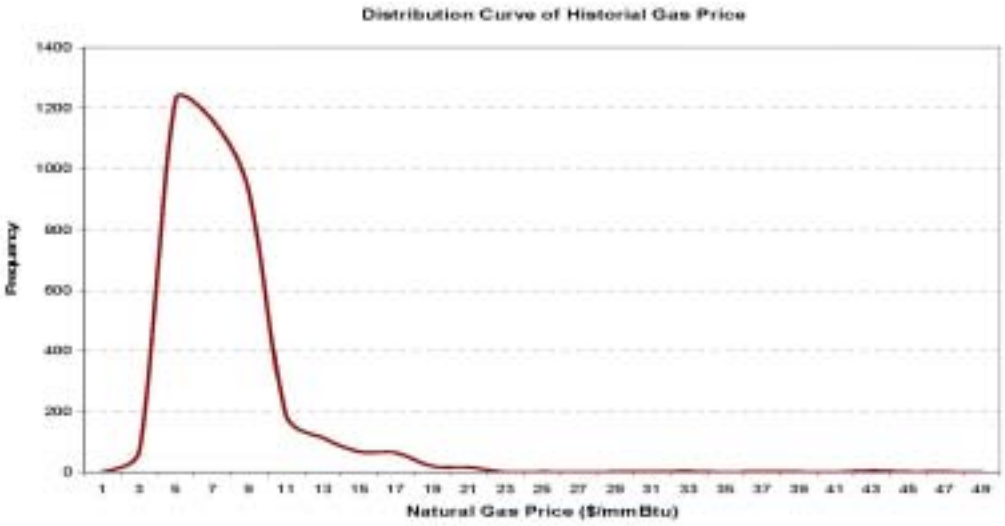
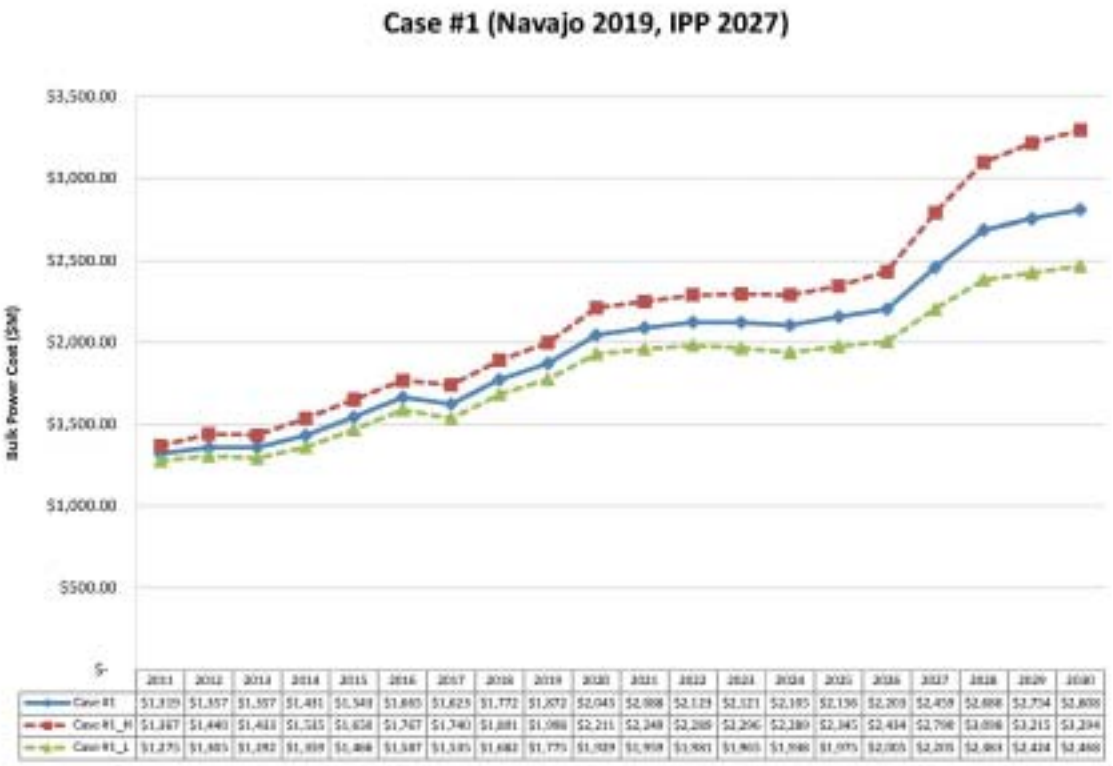


Figure 4-7. Historical distribution of natural gas prices (SoCal, 2005 through 2010).

The high and low fuel price ranges were then incorporated into the three strategic case model runs. The three charts shown in Figure 4-8 display the results of bulk power costs for each of the 3 cases. The wider the range from the high fuel case to the medium fuel case indicates increased exposure to risk from the higher fuel costs.



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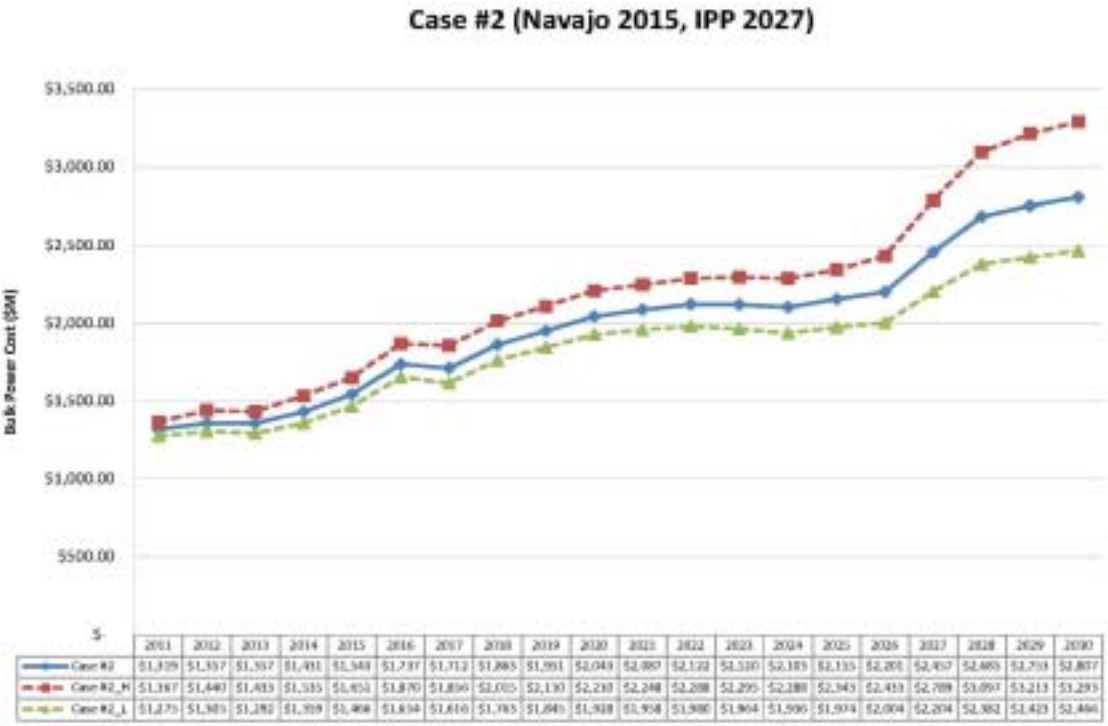

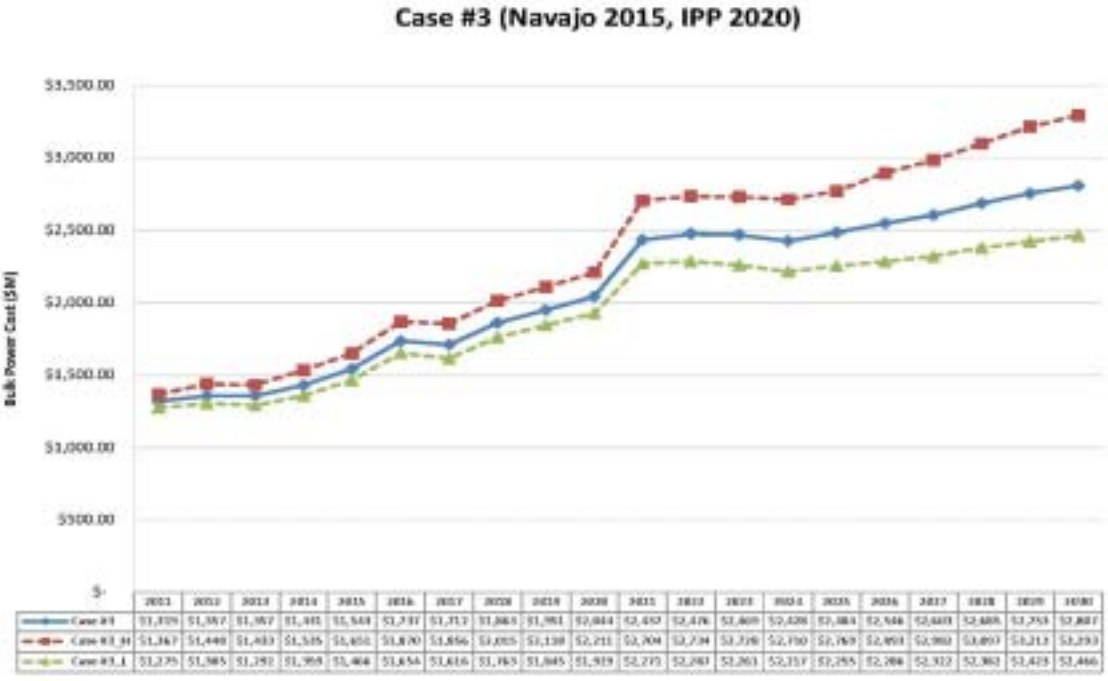

Figure 4-8. Bulk power cost comparison - high, low, and expected fuel prices.

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To better compare the risk associated with higher natural gas prices between the 3 strategic cases, three years - 2016, 2019, and 2021 - are used for comparison as shown in Figure 4-9 below.

In the year 2016, both Cases 2 and 3 show divestiture of NGS with 300 MW of gas-fired CC replacement generation. These cases are facing higher fuel and variable spending risk exposure to natural gas price fluctuations.

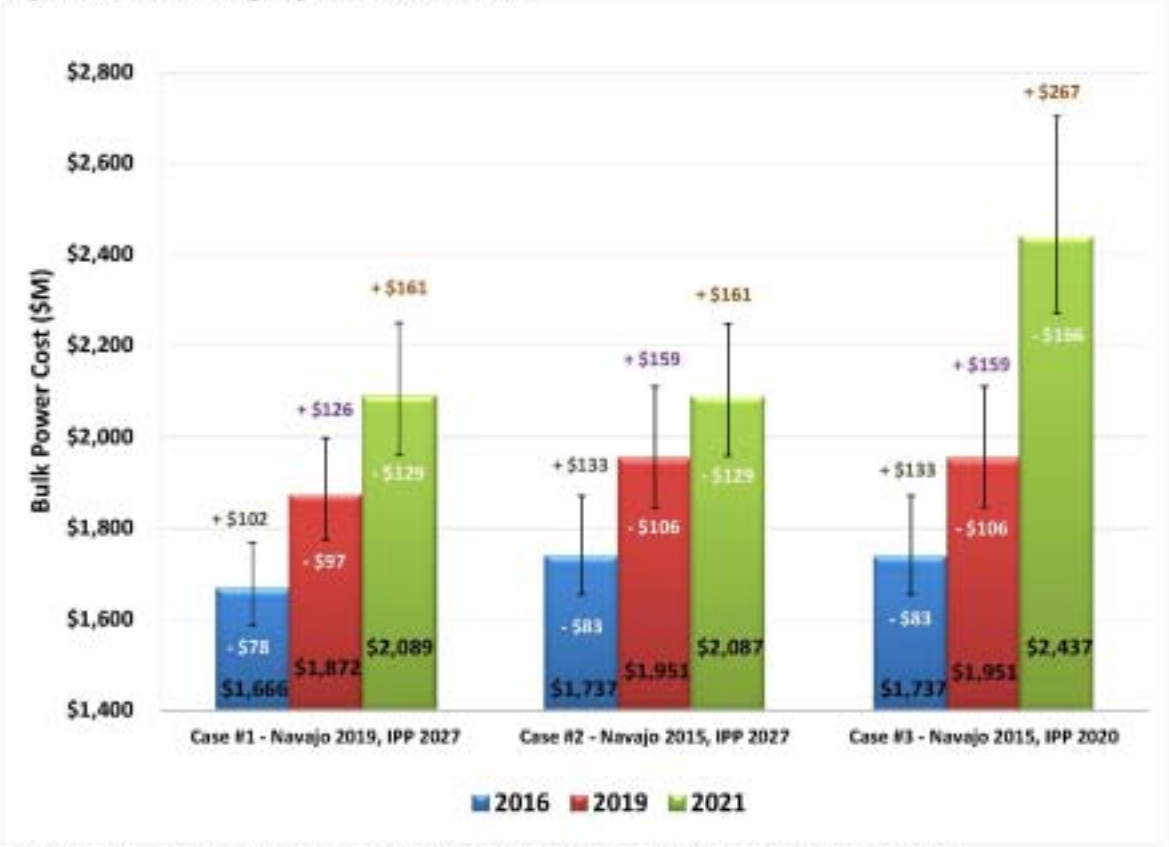

Figure 4-9. Bulk power cost with high and low comparison by calendar year.

By the year 2020 NGS will retire in all three cases, with Case 3 showing IPP also being replaced in 2020 with two 575 MW combined cycle units. With all coal generation being eliminated in 2021 for Case 3, the exposure risk of much higher spending on fuel and variable costs will be present.

Increased risk exposure from high fuel costs may translate into higher customer electric rates. Figure 4-10 shows the potential rates that could be experienced under the 3 cases given high, expected, and low fuel ranges.

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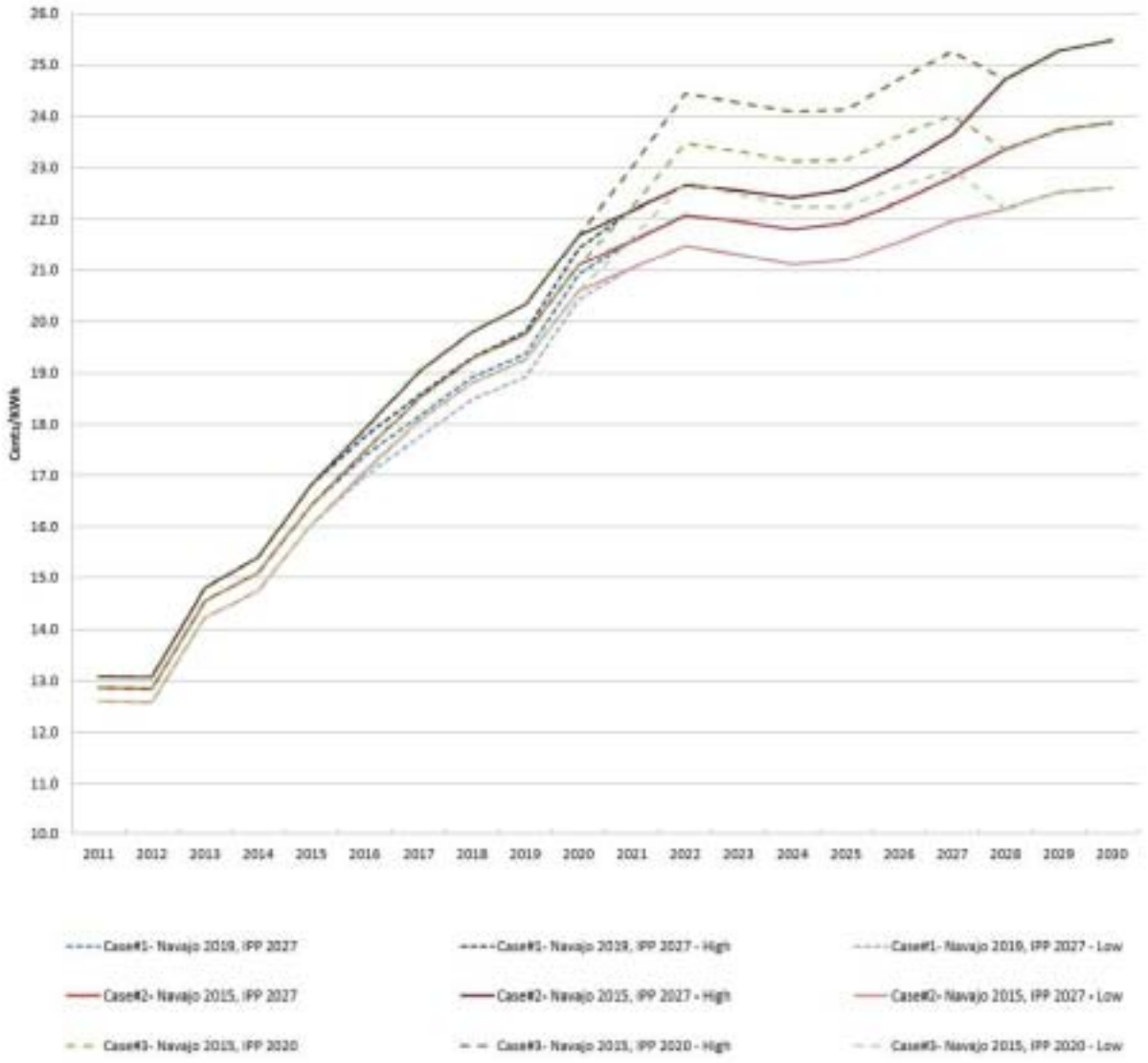

Figure 4-10. Estimated electric rate comparison over 20 years by fiscal year-ending.

4.3.3.3 Reliability and Regulatory Revenue Requirements

Bulk Power costs discussed previously make up less than half of the cost to operate the electric power system. Continued investments in transmission, distribution, and generation resources are required to maintain a reliable electric system. While specific regulatory and reliability programs such as RPS, OTC, and PRP attract the most attention, investments in these programs are a subset of the generation, transmission, and distribution system that comprises the power system. Besides fuel and inflation costs, these reliability and regulatory programs are the largest factors driving increases in power system costs.

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The revenue requirements of these programs are further illustrated in Figure 4-11 and Table 4-5. Today, these reliability and regulatory programs comprise 32% of all power system costs and in 2020 these same programs will grow to approximately 47%.

Table 4-5 shows the breakdown of these reliability and regulatory costs with RPS and PRP programs clearly being the major drivers behind overall increases in power system costs. The importance of adequately funding of these programs through consistent revenue increases over time is essential to achieving the goals of reliability, environmental stewardship, and maintaining competitive rates.

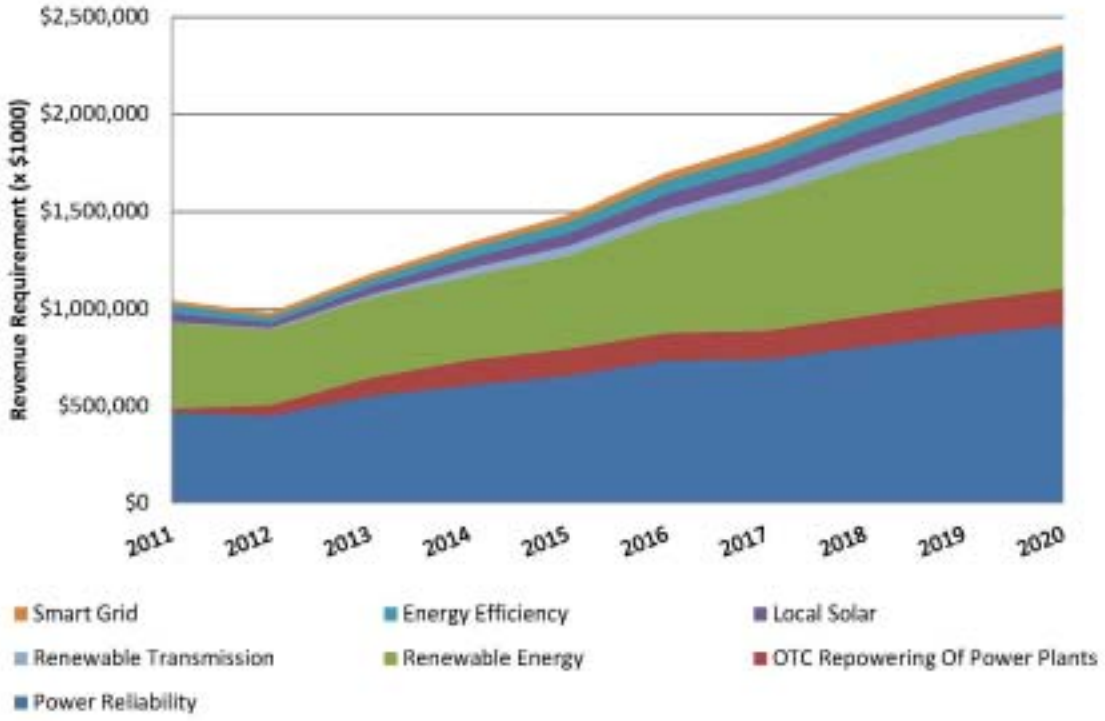

Figure 4-11. Annual revenue requirement for reliability and regulatory program for fiscal year ending 2011 through 2020.

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Table 4-5. Annual revenue requirements of power system programs, fiscal year ending 2011 through 2020 (x$1000)

(FYE)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Power Reliability										
Debt Serv. & Depr. (Less Smart Grid)	$72,749	$107,093	$141,693	$179,437	$211,448	$249,334	$290,677	$342,043	$388,167	$431,411
O&M	$392,788	$343,324	$409,122	$427,436	$443,833	$486,513	$449,644	$463,154	$481,992	$485,644
	$465,537	$450,417	$550,805	$606,873	$655,279	$735,847	$740,322	$805,197	$868,159	$917,055
Sum Total 2011-2020	**$6,795,489**									
OTC Repowering Of Power Plants										
Debt Serv. & Depr.	$19,828	$54,639	$94,439	$129,403	$138,530	$141,053	$147,519	$158,726	$171,669	$186,906
	$19,828	$54,639	$94,439	$129,403	$138,530	$141,053	$147,519	$158,726	$171,669	$186,906
Sum Total 2011-2020	**$1,242,713**									
Transition from Coal Early (NGS)										
Debt Serv. & Depr.	$0	$0	$0	$0	$0	$9,000	$18,000	$18,000	$18,000	$8,000
Fuel & VOM	$0	$0	$0	$0	$0	$25,000	$69,000	$69,000	$77,000	$33,000
	$0	$0	$0	$0	$0	$81,000	$88,000	$89,000	$82,000	$41,000
Sum Total 2011-2020	**$381,000**									
Renewable Energy										
Debt Serv. & Depr.	$48,556	$47,980	$48,673	$50,950	$53,526	$75,084	$126,605	$173,126	$205,001	$226,948
O&M	$93,524	$26,681	$25,812	$26,214	$29,041	$29,689	$28,272	$30,052	$31,272	$32,078
Purchased Power (PPA's)	$300,446	$314,249	$335,712	$354,527	$397,795	$476,395	$540,998	$576,960	$610,856	$652,051
	$442,525	$388,910	$410,198	$433,691	$480,364	$581,148	$695,875	$780,138	$847,129	$911,077
Sum Total 2011-2020	**$5,971,054**									
Renewable Transmission										
Debt Serv. & Depr.	$5,600	$8,298	$19,327	$39,676	$51,470	$56,878	$63,762	$82,743	$103,245	$118,611
	$5,600	$8,298	$19,327	$39,676	$51,470	$56,878	$63,762	$82,743	$103,245	$118,611
Sum Total 2011-2020	**$549,609**									
Local Solar										
SB1 Debt Serv. & Depr.	$5,047	$13,903	$22,825	$29,164	$31,972	$32,936	$33,509	$33,891	$34,146	$34,251
SB1 O&M	$33,937	$0	$0	$0	$0	$0	$0	$0	$0	$0
UBS Debt Serv. & Depr.	$5,349	$11,484	$13,245	$15,084	$16,959	$19,603	$23,281	$27,067	$30,919	$33,916
FIT (PPA)	$0	$1,699	$3,201	$7,922	$14,999	$23,558	$24,480	$26,639	$28,798	$30,781
	$44,333	$27,086	$39,270	$52,149	$63,930	$76,097	$81,270	$87,597	$93,863	$98,947
Sum Total 2011-2020	**$664,544**									
Energy Efficiency										
Debt Serv. & Depr.	$1,081	$5,959	$13,651	$22,282	$30,944	$39,378	$47,827	$56,276	$64,839	$73,288
O&M	$45,166	$22,906	$23,783	$29,054	$28,810	$30,682	$30,553	$30,556	$29,624	$30,552
	$46,247	$28,866	$37,434	$51,336	$59,754	$70,059	$78,380	$86,832	$94,462	$103,840
Sum Total 2011-2020	**$657,210**									
Smart Grid										
Debt Serv. & Depr. (Oper. Sup.)	$9,809	$15,022	$15,863	$18,849	$17,871	$20,317	$25,443	$27,998	$28,457	$13,411
Debt Serv. & Depr. (PRP)	$6,821	$7,878	$9,681	$8,701	$15,143	$16,643	$17,776	$8,979	$8,979	$8,979
	$16,690	$22,899	$25,543	$27,549	$33,014	$36,960	$43,219	$36,977	$37,436	$22,390
Sum Total 2011-2020	**$302,678**									
Basic Gen, Trans, Dist										
	$1,947,841	$2,010,184	$2,209,311	$2,190,998	$2,397,128	$2,456,837	$2,540,415	$2,616,531	$2,650,293	$2,890,785
Sum Total 2011-2020	**$23,910,313**									
Total Power System Revenue Requirement										
	$2,983,000	$2,983,000	$3,367,000	$3,492,000	$3,828,000	$4,179,000	$4,415,000	$4,661,000	$4,845,000	$5,172,000
Sum Total 2011-2020	**$39,926,000**									

4.3.3.4 Total Power System Cost Comparisons

The total power system cost for each case includes bulk power costs, depreciation costs related to transmission, distribution, and generation, bond debt-service, and city transfer costs. These costs assume full funding of the Power System programs including the Power Reliability Program and Energy Efficiency programs among others. Total annual Power

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System costs are shown in Figure 4-12 and reflect short-term spending reductions through 2011-12 fiscal year with subsequent years reflecting a restoration of funding levels to insure that the longer term IRP recommendations can be realized. The costs shown do not attempt to represent a thorough analysis of Power System finances. The main goal of this section is to illustrate the general trend of Power System costs relative to the 3 cases analyzed.

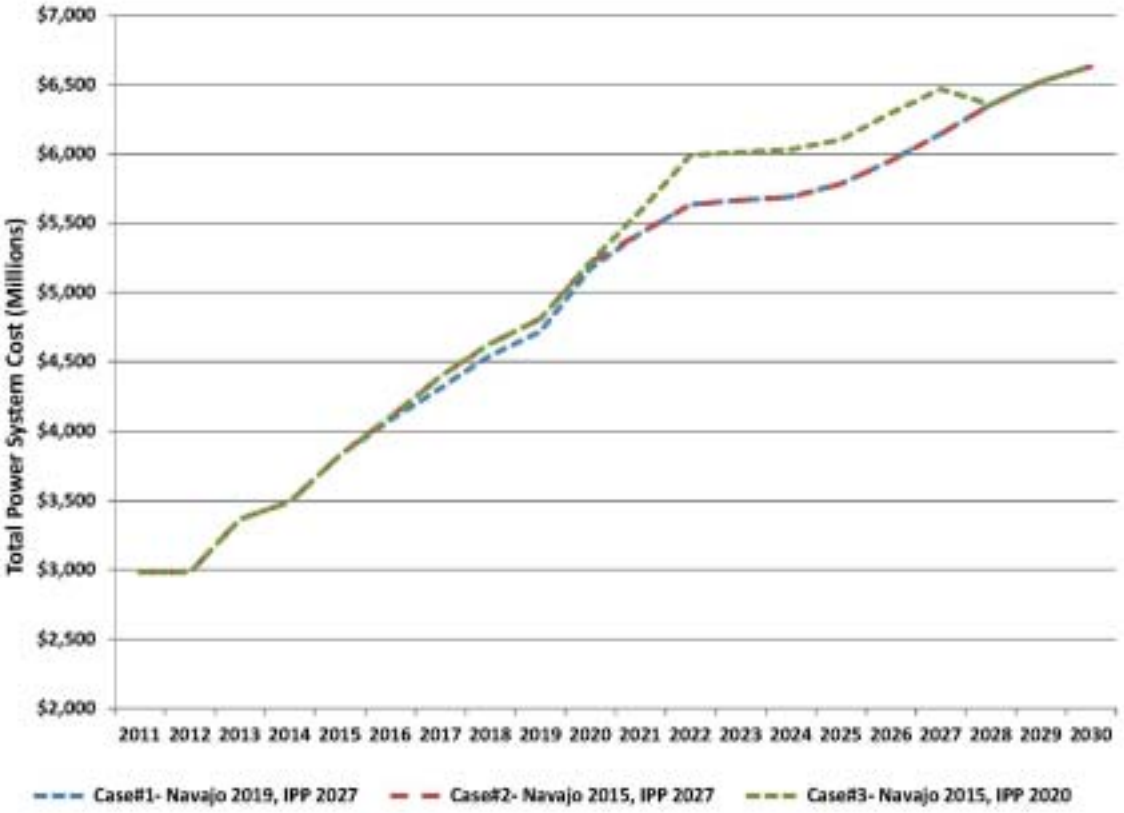

Figure 4-12. Comparison of annual power system costs over the next 20 fiscal years.

Figure 4-13 illustrates the net present value of the total power system costs for each of the strategic cases.

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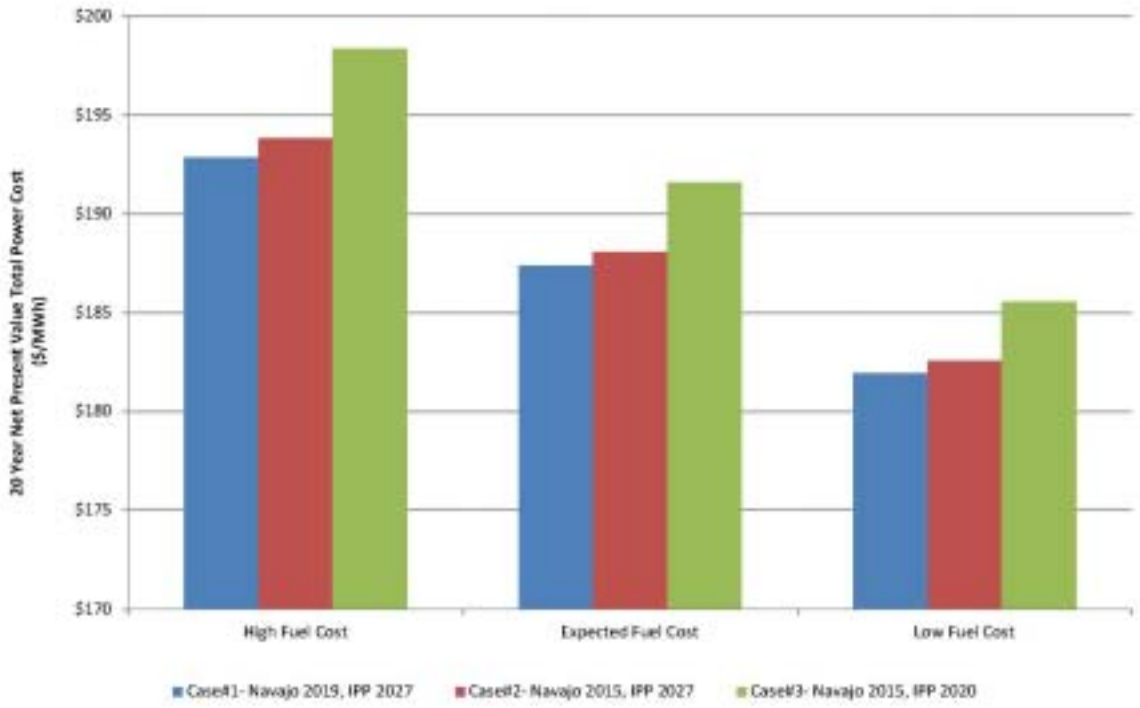

Figure 4-13. Total net present value comparison of power system costs.

4.4 Strategic Case Conclusions and Recommendations

4.4.1 Reliability

All three cases were designed to satisfy power system reliability requirements. Based on the loss of load probability and resource adequacy analysis discussed in Section 4.3.1, all three cases are considered equal in terms of meeting reliability. To insure that reliability is maintained during the divestiture of Navajo and IPP, specific replacement strategies should be employed to assure a smooth transition. Further analysis may be required to refine the appropriate blend of renewable, gas-fired, energy efficiency, and demand response resources to replace Navajo and IPP based on reliability considerations.

4.4.2 GHG Emissions Reduction

As expected, the sooner generation from coal is removed from LADWP's portfolio, the greater the reduction of GHG emissions is achieved. Case 2 removes NGS energy four years earlier than in Case 1 and results in 7.5 million metric tons less GHG emissions over the 20-year study period. In addition to early NGS divestiture, Case 3 accelerates the replacement of IPP seven years earlier than Case 2, results in a further reduction of 21.1 million metric tons over the 20-year period.

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4.4.3 Economic

While the Base Case appears the least cost assuming moderate GHG emission costs, it fails to make significant progress toward the reduction of GHG emissions goals set forth by LADWP. The choice between coal divestiture options of either Case 2 and 3 depends on the level of rate increases ratepayers are willing to support while achieving the 33% required RPS by 2020, repowering of in-basin gas fired generation, funding and implementing Demand Response and Energy Efficiency programs, and providing additional external generation to supplement the lost generation resulting from coal divestiture.

With early divestiture of Navajo, additional rate increases of 0.36 cents per kwh or a one time 2.0% increase in the average customer bill would be necessary to achieve GHG reductions of 7.5 million metric tons between years 2016 and 2019. However, as previously discussed in Section 4.3.3.2, the early divestiture of Navajo will expose ratepayers to potentially higher natural gas fuel prices that may result in rate increases up to 1 cent per kwh or a one time increase of 5.7% in the average customer bill if gas prices were to remain at these higher levels.

Considering Case 3 with early divestiture of IPP and Navajo, rate increases of approximately 1.35 cents per kwh or a one time 6.1% average increase in the typical customer bill would be necessary to achieve additional GHG reductions of 21.2 million metric tons between the years 2021 and 2027 due to the divestiture of IPP. With potentially higher natural gas fuel prices, resulting rate increases could be as high as 2.4 cents per kwh or a one time increase of 11% in the average customer bill if gas prices were to remain at these higher levels.

4.4.4 Recommended Case

Decisions to fund coal divestiture strategies cannot take place independent of other power system programs. Maintaining reliability and meeting regulatory requirements are primary considerations before any coal divestiture cases can be considered. However, this IRP presupposes funding of these programs so that the recommended coal divestiture case can be implemented.

Achieving the goals of reliability and environmental stewardship, while maintaining competitive rates, requires that costs be closely managed. Considering these factors, Case 2 with early Navajo coal divestiture in 2015 becomes the recommended case for the 2011 IRP. Although Case 2 represents additional cost as compared to Case 1, the additional costs to rate payers appears to be reasonable in light of the environmental benefit of reducing GHG emissions by 7.5 MMT. Early divestiture of Navajo also provides additional time to insure a smooth transition in acquiring and implementing replacement resources. The 2010 IRP included the same recommendation to accelerate divestiture of Navajo and this IRP further clarifies and supports this prior recommendation. This recommended case presents a reasonable approach to achieving environmental goals without excessive costs to our ratepayers while limiting potential exposure to possible fuel price volatility to within manageable limits.

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5.0 RECOMMENDATIONS

5.1 Overview

LADWP's recommended strategy set forth in this IRP for meeting its key objectives can be separated into two areas: (1) Regulatory and Reliability Initiatives, and (2) Strategic Initiatives. Regulatory and Reliability Initiatives are required actions to ensure system reliability and compliance with regulatory and legislative mandates. Strategic Initiatives are policy actions to achieve objectives established by the LADWP Board of Water and Power Commissioners and the Los Angeles City Council, and reflect their vision and leadership. These mandates include, for example, establishment of LADWP's RPS, early compliance with SB 1368, and investing in local solar.

The analysis performed in Section 4 to identify the 2011 IRP recommended case closely mirrors the same recommended strategy put forth in the 2010 IRP which incorporated feedback from LADWP's community outreach efforts which were conducted in 2010. The 2011 IRP recommended strategy differs slightly from the 2010 IRP in the timing of the Navajo coal divestiture which is now planned for 2015 instead of 2013. Another difference is in the renewable installed capacity by technology type (e.g. geothermal, wind, and solar). The reasons for these changes are further explained in Section 3.1.1.

Regulatory and Reliability Initiatives

- SB 2 (1X) - RPS Percentage

  LADWP must increase its percentage of renewable energy per recently enacted state law, from the current 20 percent at the end of 2010, to 33 percent by the end of 2020. SB 2 (1X) also establishes interim targets to ensure progress towards the 33 percent goal. Addressing this mandate requires the continued diligence LADWP has demonstrated in raising its renewable portfolio from 3 percent in 2003 to 20 percent in 2010.

- Power Reliability Program (PRP) and system infrastructure investment

  LADWP must re-establish sustained funding to invest in replacing aging transmission and distribution infrastructure to ensure system reliability, especially during significant weather events. Recent funding shortfalls have resulted in an increase in system outages. Section 1.6.4 of this IRP discusses the negative consequences that continued underfunding poses to the city.

- Re-powering for Reliability and to Address OTC

  LADWP will continue to re-power older, gas-fired generating units at its coastal generating station for the reasons discussed previously. The repowering program is a long term series of projects that will increase reliability and eliminate the need for once-through ocean cooling.

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- AB 32 – GHG Cap and Trade

  LADWP will participate in the mandated green house cap-and-trade system which is scheduled to start January 1, 2013. During the next year, LADWP will participate in the regulatory process that will clarify some outstanding details of the proposed program.

- SB 1368 Compliance

  Navajo and IPP must be compliant with the mandates established in SB 1368 by 2019 and 2027, respectively. IRP modeling determined that these units will be replaced with a combination of renewable energy, demand response, i.e., short term market purchases, and conventional gas-fired generation.

- Energy Efficiency

  LADWP must procure sufficient resources to meet load growth and maintain system reliability and will continue to pursue and implement energy efficiency programs per AB 2021 standards and as recommended in its latest Market Potential Study. Along with augmenting its generation portfolio, LADWP will implement EE to reduce energy demand. EE programs are not only crucial for meeting customer load growth, they also represent a cost-effective strategy for reducing GHG emissions, since the cleanest kilowatt-hour any utility can produce is one that is never generated.

- Castaic FERC Re-licensing Program

  On January 31, 2033, the Federal Energy Regulatory Commission's (FERC) license to operate Castaic Pumped-storage Hydroelectric Plant will expire. The license is a co-license between LADWP and the Department of Water Resources (DWR) and includes a number of hydro power plants along the California Aqueduct. Both parties have initiated the joint re-licensing process that, on average, requires ten years to complete. Through 2015, LADWP expects to complete preliminary studies, contract negotiations, and prepare a filing strategy. In 2016, LADWP expects to file a notice-of-intent (NOI) and initiate the formal studies and applications. Based on reviews of re-licensing activity for similar projects, LADWP could expect cumulative expenditures of approximately $19 million prior to filing the NOI and approximately $80 million before the license expires.

- Transmission

  LADWP should implement those recommendations of the latest Ten-Year Transmission Assessment Plan, in order to maintain reliability in accordance with regulatory guidelines.

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Strategic Initiatives

- Early Compliance with SB 1368

  Comments from the public workshops indicated the desire to comply with SB 1368 as early as possible. Navajo must be compliant with SB 1368 by 2020. LADWP recommends divestiture from Navajo by 2015. This will reduce LADWP's GHG emissions by 7.5 million metric tons and required additional revenue of about $343 million.

  LADWP recommends modeling and planning for IPP to be compliant with SB 1368 by 2027. However, LADWP will continue to evaluate options in future IRPs. LADWP will continue to work with the Intermountain Power Agency (IPA) Board and the other participants to secure IPP as a renewable energy hub and provide replacement generation compliant with SB 1368. LADWP recommends no change in IPP until 2027 at which time the site would be reconfigured, providing LADWP with firm transmission capacity for potential renewable projects.

- Local Solar

  Comments received at the public workshops indicate local solar development should be a priority in LADWP's renewables procurement strategy. LADWP is recommending a policy action to allow approximately 40-50 percent of its solar resources be sited locally through initiatives including the Solar Incentive Program, feed-in tariffs, and installation of solar on City-owned properties. Local solar costs an estimated additional $50/MWh over utility-scale solar located outside the Los Angeles Basin, estimated to cost $120/MWh, primarily due to economies of scale and about 30% better solar insolation, even when considering transmission and distribution costs.

- Public Benefits

  LADWP should continue to pursue public benefit initiatives, including low-income and lifeline programs, refrigerator exchange, conservation, public outreach and education.

- Advanced Reliability Improvements

  LADWP is looking ahead to technologies that will enhance the reliability of its system, including smart grid technologies, enhanced information systems, automation of system functions, and advanced methods of outage management. These advanced system enhancements are recommended from a planning perspective to not only increase reliability, but also to better integrate local generation such as solar into the distribution network, enable smart charging of electric vehicles, and advance demand side management technologies.

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- System Losses

  To reduce system losses, LADWP should implement the recommendations of the recently completed Reactive Power Management Study, including the installation of shunt capacitors and shunt inductors at appropriate locations within the system grid.

- Demand Response

  LADWP should begin the development of a formal Demand Response program that will initially provide 5 MW of peak demand capacity beginning in 2013 and gradually build to 260 MW by 2020 and 500 MW by 2026. Ramping the program in this manner will provide the development of in-house expertise, and will also allow time to deploy the supporting information systems necessary to implement these systems successfully.

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5.2 Incorporating Public Input

Through its public outreach efforts in 2010, LADWP received various suggestions from the community including increasing energy efficiency and conservation, eliminating coal from LADWP's resource mix, emphasizing local solar generation, maintaining competitive rates, and increasing transparency. This input played a key role in shaping the recommendations set forth in this IRP. A discussion of these themes is presented below.

- Theme: Emphasize a variety of energy resources

  Related IRP Recommendations

  - LADWP will procure 160 MW of generic renewable resources, potentially including biomass, ocean tidal power, and other emerging technologies.
  - LADWP will also continue to seek a diversified energy portfolio as well as continue to diversify its portfolio regionally to enhance system reliability.

  Discussion

  As LADWP continues to work towards attaining its state-mandated RPS requirement, it is also imperative that the renewable energy technologies support LADWP's objectives of providing reliable service at competitive rates while maintaining environmental stewardship. Of the aforementioned renewable technologies, those believed to be available in large quantities in the western US at competitive prices are geothermal, wind, biogas, and solar, which make up a bulk of LADWP's renewable portfolio. Recent advancements in these technologies have resulted in an increase in their capacity factors, therefore providing more energy at lower cost as well as benefiting from large economies of scale. Consumption of natural gas, which is already a major component of LADWP's generation resource portfolio, will increase to support increasing amounts of intermittent renewable resources and to help supply baseload power as LADWP transitions away from coal. Nuclear power, which makes up about nine percent of LADWP's energy mix, would likely remain at current levels in the next decade. In addition to "traditional" renewable resources such as wind and solar, LADWP will certainly consider up and coming technologies such as algae and wave power as these technologies become more mature and economically competitive.

- Theme: Maximize Energy Efficiency and Conservation to Meet Future Energy Needs

  Related IRP Recommendations

  - LADWP is recommending to increase energy efficiency to reduce at least seven percent of the total load by 2020 (three percent was achieved prior to

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2016). LADWP will pursue the recommended programs contained in the recently completed market potential study.

- LADWP is recommending 300 MW of demand-side management/response programs to shift load away from peak hours or to control load during peak hours. Tactical plans will be developed that may utilize smart grid technology, incentives, and rate designs to meet this objective.

Discussion

LADWP's Demand Side Management program, which includes the Energy Efficiency, Demand Response, and Combined Heat and Power programs, plays an integral role in shaping power system planning. With the goals of lowering overall energy consumption and shifting peak demand loads to off peak periods, the need to build additional generation is reduced, resulting in capital and fuel cost savings as well as emissions reduction.

LADWP is exploring ways which would educate and empower ratepayers to reduce energy consumption, whether that is in the form of technology, incentives, and programs, or a combination of these. Future installation of two-way smart meters will facilitate real time pricing based on current supply and demand, and customers will be able to make smarter choices on energy use based on market driven Time of Use rates. LADWP is formulating strategies that will include new incentives and Time of Use tiered rate structures allowing ratepayers to fully participate on the demand side of the equation. To increase efficient buildings, LADWP offers an incentive program to building owners and developers for construction of new buildings to conform to high efficiency LEED standards, which are 25 percent to 35 percent more energy efficient than regular buildings.

As discussed in this 2011 IRP, LADWP has completed its Energy Efficiency Market Potential Study and is preparing its implementation plans that will support program execution. Like many other areas, however, adequate funding is essential if the city is to realize the benefits that efficiency provides.

- Theme: Eliminate Coal from LADWP's Energy Portfolio

Related IRP Recommendations

- LADWP is recommending a policy action to replace Navajo Generating Station by 2015, four years ahead of the SB 1368 requirement. The Intermountain Power Project is modeled in this IRP through 2027, but LADWP is open to a mutually agreeable early compliance plan between the project participants that preserves the site and transmission for compliant fossil and renewable generation.
  LADWP is currently 21 percent below 1990 levels of GHG emissions and is planning further emissions reductions.

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Discussion

Recommendations set forth in this 2011 IRP include making the transition away from coal to other forms of generation earlier than the contract termination date, such as terminating the Navajo contract in 2015 instead of 2019. Depending on the outcome of legislation which may impose GHG emission taxes and cap and trade requirements, it may be prudent for LADWP to divest away from coal resources early and replace it with a combination of renewable technologies and combined cycle units. Securing renewable resources early may also substantially save LADWP and its ratepayers money, before demand for renewables increase as mandated levels of renewable energy increases over the next several years.

Since coal generation is a baseload resource, the optimal solution is to replace the coal generation with geothermal, a renewable baseload resource. However given the disparity between the amount of available geothermal resources and the amount of coal generation that needs to be replaced, the remainder would need to be made up of other renewable sources such as wind and solar with natural gas powered combined cycle plants to act as backup maintaining a constant level of generation when the wind is not blowing and when the sun is not shining. Combined cycle plants have operating characteristics which allow for a higher penetration of intermittent renewable resources than coal-fired generation. The characteristics assist in maintaining grid reliability with high levels of intermittent resources. Natural gas plants are also much more environmentally friendly than coal plants, emitting only half as much CO_2.

- Theme: Emphasize Local Solar Generation

Related IRP Recommendations

- LADWP is recommending a policy action to allow approximately 40-50 percent of its solar resources be sited locally through initiatives including the Solar Incentive Program, feed-in tariffs, and installation of solar on City-owned properties. LADWP recommends this as a balanced approach between the benefits of local solar and the benefits of large, controllable solar projects connected to LADWP's transmission lines. The actual percentage will vary based on the success of the local programs.

Discussion

As outlined in this 2011 IRP, LADWP has designated 40 percent of solar development to be in-basin, or approximately 325 MW, enough to power almost ninety thousand homes. In-basin solar eliminates transmission issues and losses, and improves local grid reliability. LADWP realizes that developing in-basin solar fosters local economic growth, and will utilize incentive programs, Feed-in-Tariff schemes, and other stimulus in order to promote development. In August 2011, LADWP resumed its solar incentive program

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which was redesigned to better accommodate customer demand. LADWP also hopes to implement a feed-in tariff over the next year.

- Theme: Avoid Adverse Impacts to Vulnerable Communities

  Related IRP Recommendations:

  - LADWP will continue to implement a low-income electric rate program.
  - LADWP will develop plans that address energy efficiency deployment and other incentive programs that effectively reach out to low income communities and may help mitigate impacts of future rate increases.
  - Local geographic diversity is critical to maintain high reliability of the electric grid, and LADWP will continue this policy so that no single community will experience an inequitable share of impacts from energy facilities.

  Discussion:

  Even though acquiring more renewable resources may result in potential future rate increases, this may not necessarily translate into higher bills for all customers. Increased adoption of Demand Side Management techniques could offset a rate increase, and may even result in lower bills. LADWP strives to provide low-income ratepayers as much assistance as possible, and will continue to offer a lower rate to those that are economically disadvantaged. LADWP also proposes to conduct free residential energy audits to low income customers first, so that additional savings achieved by increased energy efficiency could be realized immediately. An example of this is that such audits may provide low income ratepayers free energy efficient refrigerators, funded by the LADWP Energy Efficiency Program.

  Having geographical diversity in generation is important at both the regional and local levels. At the regional level, having resources that are geographically dispersed provides LADWP additional reliability, and results in efficient resource utilization and lower cost. For example, LADWP's system interconnects to BPA's network in the Pacific Northwest, fostering a symbiotic relationship that allows abundant inexpensive hydroelectric power to be delivered to LADWP in the spring and summer, when BPA's demand is low and LADWP's demand is high, at the same time enabling LADWP to sell excess power to BPA in the winter when BPA's demand is high and LADWP's is low. At the local level, it would be technically advantageous to distribute solar installations evenly throughout the LA basin, so that circuits will not be overloaded. This would ensure that there will be no unequal impact to any one community, since an equal distribution of distributed generation sources is necessary to maintain reliability.

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- Theme: Clarify Costs of IRP Implementation and Potential Impacts to Ratepayers

  Related IRP Recommendations

  - LADWP will incorporate a detailed financial analysis into the IRP development process to identify the costs of various planning alternatives and recommendations using computer modeling software

  Discussion

  Impacts of the Strategic Case Alternatives, including the recommended case, on electricity rates, as well as the strategic, regulatory and reliability investments recommended in this IRP are included in Sections 4.2. Included in the rate analysis is a sensitivity analysis that considers high and low forecasts for natural gas and coal fuel costs. Also presented is the annual revenue requirements of power system programs through 2020.

  While there are secondary costs associated with environmental and health impacts of fossil fuel plants, LADWP is not in a position to quantify these costs since there are governing bodies at the federal and state levels responsible for setting standards and legislation that would address these concerns. However, LADWP is working to make the transition from coal to renewables and clean natural gas earlier than originally scheduled so that GHG emissions can be curtailed sooner.

  As discussed previously, potential future increases may not necessarily translate into higher bills nor impact low-income communities. As for improved transparency and accountability, the Board of Water and Power Commissioners recently approved the establishment of an independent ratepayer advocate whose responsibility is to review, analyze, and provide expert independent advice to policy makers regarding utility rates and proposed rate changes, and to provide ongoing review and analysis regarding rate-related and budgetary issues.

- Theme: Reduce Environmental Impacts

  Related IRP Recommendations

  - To minimize environmental impacts, LADWP will maximize the use of existing transmission and facility infrastructure to generate and deliver energy. All projects will have the proper environmental review and impacts on the environment will be mitigated as necessary.

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Discussion

Being a good environmental steward is one of LADWP's main objectives, and we strive to meet that standard with the construction and maintenance of each and every project. As we look to making the transition away from coal, one strategy that we have adopted is to procure and develop renewable resources in close proximity to the coal plant, so that we can take advantage of the existing transmission infrastructure. For solar, we would maximize the use of rooftops as installation sites. This principal of siting new generation facilities on existing brownfield sites and reusing existing structures not only minimizes environmental impact but is also very cost effective.

- Theme: Provide Proactive Leadership and Transparency

Related IRP Recommendations

- LADWP will develop plans to better educate ratepayers on progress related to this IRP (e.g. energy efficiency) and will continue the IRP process of biannual updates to provide transparency on its long-term goals.
- LADWP will improve its system operations and run its power grid as effectively as possible. LADWP has recently completed a study on how it can increase the efficiency of the power delivery grid through advanced reliability improvements.
- This 2011 IRP sets forth LADWP's long-term plans and objectives, clarifying implementation of various initiatives and their potential impacts on ratepayers. A discussion of rate impact is included in Section 4 of this IRP.

Discussion

LADWP will take steps to expand public outreach programs to better educate the public about the critical roles that energy efficiency and conservation have on the power system. LADWP is also instituting programs to improve operations and system reliability, performing system wide technical studies, as well as identifying ways to incorporate smart meters. As discussed previously, a ratepayers' advocate would help facilitate transparency and accountability in any new actions undertaken by LADWP. An IRP public outreach effort similar to the one held in 2010, is scheduled for next year's 2012 IRP process.

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5.3 Recommended Strategic Case

Based on the results of LADWP's stakeholder meetings and public outreach effort, and rigorous cost-benefit analysis, LADWP has developed a Recommended Case for this 2011 IRP that includes the following:

- At least seven percent of Los Angeles' electric needs will be met through new customer energy efficiency measures by 2020.
- At least 500 MW of capacity reduction through Demand Response programs by 2026.
- Generate at least 33 percent of its electricity from renewable resources by 2020 and maintain that level through 2030. Although this IRP incorporates one combination set of renewable resources to achieve a 33% RPS, LADWP will not limit itself to only these types and amounts of resources to achieve its goals and needs flexibility in resource development for the best fit for the electrical system.
- Diversify LADWP's RPS through incorporating 162 MWs of generic renewable resources by 2030. These resources could be technologies such as biomass, ocean tidal power or other emerging technologies.
- Diversify LADWP's energy portfolio through a variety of fuels, technologies and power plant sites throughout the western United States to maintain a high level of reliability.
- Replace the Navajo Generating Station by 2015, 4 years ahead of the legally mandated date. IPP is recommended to be replaced in 2027 at the end of its contract, however LADWP is open to a mutually agreeable early compliance for GHG reduction between project participants that preserves the site and transmission for compliant fossil and renewable generation.
- Implement advanced reliability improvements.
- Emphasize local solar by proposing approximately 40 to 50 percent of solar capacity being proposed to be locally sited in Los Angeles. This will be accomplished through programs such as the Customer Solar Incentive Program, Feed-in tariffs, and Solar on Los Angeles properties under public/private partnership.

This recommended case is summarized in Table 5-1.

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Table 5-1. 2011 IRP Recommended Case

	2020	SB 1368 Compliance Date		New Renewables Installed (MW) 2011-2020			New Renewables Installed (MW) 2011-2030			
Case ID	RPS Target	Navajo Replacement	IPP Replacement	Geo/ Biomass	Wind	Solar	Geo/ Biomass	Wind	Solar	Generic
Case 2	33%	12/31/2015	6/15/2027	243	492	726	308	492	917	162

Figure 5-1 illustrates the changing generation resource percentages for 2010, 2020, and 2030 based on the Recommended Case. Energy efficiency savings of 1,256 GWh or 5.5 percent of sales that was implemented between 2000 and 2010 is already factored into the load and is not included as part of the generation resource mix shown below.

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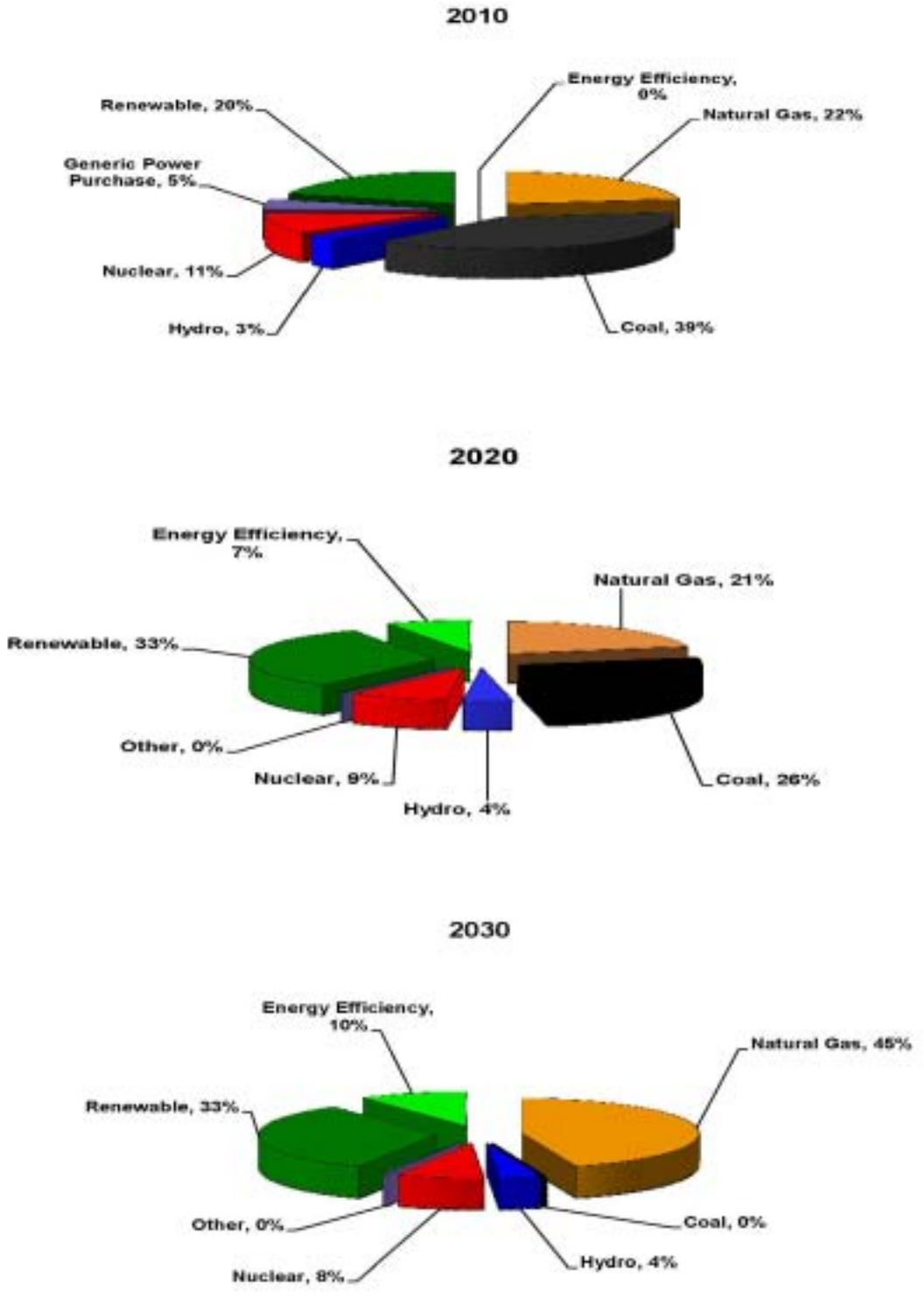

Figure 5-1. Generation resource percentages for 2010, 2020, and 2030.

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Figure 5-2 shows the renewable energy resource mix of the Recommended Case. The major change from the 2010 IRP is that biogas fills a critical gap in meeting RPS targets by replacing primarily geothermal generation in the short term.

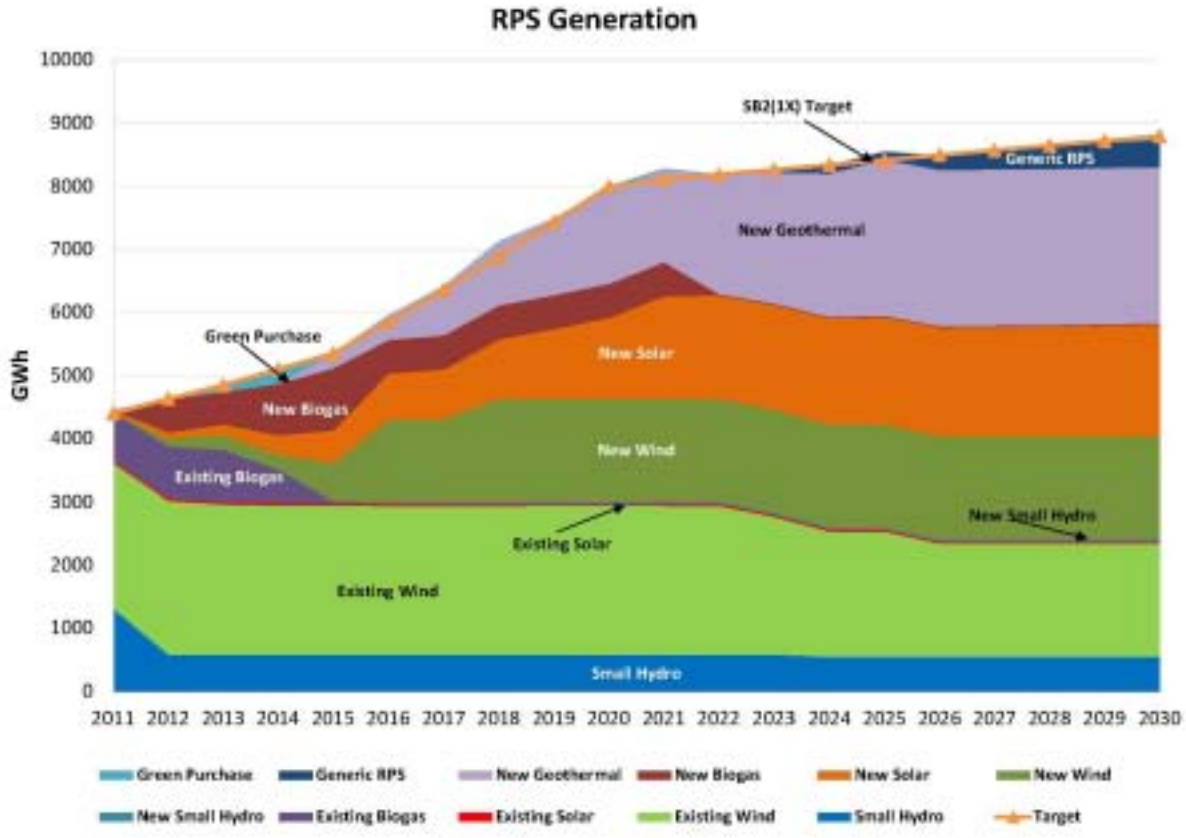

Figure 5-2. Recommended case renewable generation by technology.

With the early divestiture of Navajo in 2015 and the IPP coal contract ending in June, 2027, increased bulk power costs are expected to rise with the divestiture of each of these resources as shown on Figure 5-3. It is important to note that bulk power costs shown in Figure 5-3 include fuel, renewable and other purchase power costs in addition to coal divestiture related costs which are displayed in Table 4-4. Applying high and low fuel prices to these bulk power costs as discussed in Section 4.2.3.2, the divestiture of these resources could result in large cost increases should fuel prices remain at higher than expected levels. Conversely, lower than expected fuel prices could have the opposite effect on bulk power costs.

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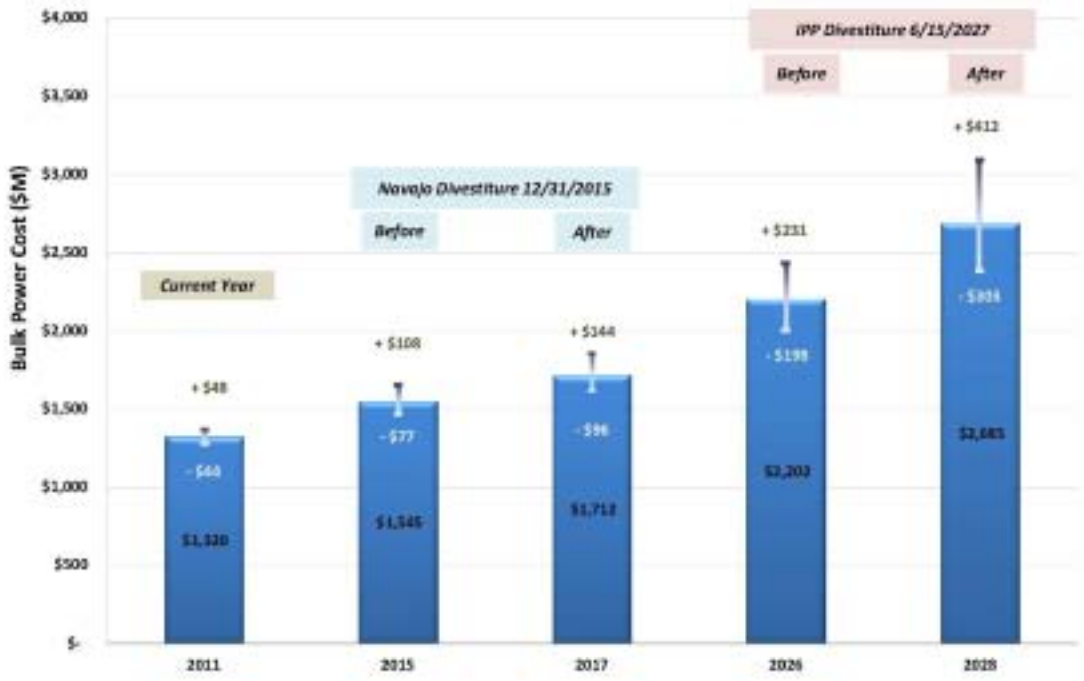

Figure 5-3. Recommended case - bulk power cost before and after coal divestitures with potential cost impacts from high and low fuel prices.

The Table 5-2 below illustrates the revenue requirements necessary to supply the recommended resources required to meet future load growth, reach and maintain the RPS requirement of 33% by 2020 and thereafter, and insure that the necessary replacement resources are in-service before divestiture of Navajo in 2015 and IPP in 2027 can occur.

AR0071201

Table 5-2. Revenue and resources recommended to replace coal and load growth ($ million)

FY	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy & Capacity Cost																				
Energy Efficiency	$ 46	$ 29	$ 37	$ 51	$ 60	$ 70	$ 78	$ 87	$ 94	$ 104	$ 112	$ 120	$ 129	$ 137	$ 146	$ 154	$ 163	$ 171	$ 180	$ 188
Demand Response	$ -	$ -	$ 0	$ 0	$ 1	$ 1	$ 3	$ 4	$ 6	$ 8	$ 10	$ 10	$ 11	$ 12	$ 12	$ 13	$ 14	$ 14	$ 14	$ 14
New Renewable																				
Solar	$ 3	$ 12	$ 25	$ 39	$ 67	$ 98	$ 115	$ 132	$ 158	$ 184	$ 225	$ 249	$ 250	$ 253	$ 256	$ 258	$ 261	$ 261	$ 261	$ 264
Wind	$ -	$ 2	$ 27	$ 27	$ 37	$ 127	$ 147	$ 177	$ 198	$ 201	$ 202	$ 203	$ 205	$ 208	$ 209	$ 211	$ 213	$ 216	$ 217	$ 219
Geo	$ -	$ -	$ -	$ -	$ 13	$ 28	$ 79	$ 113	$ 143	$ 176	$ 197	$ 224	$ 271	$ 302	$ 335	$ 353	$ 361	$ 361	$ 368	$ 373
Small Hydro	$ -	$ -	$ -	$ -	$ -	$ -	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 1	$ 2	$ 2
Generic RPS	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8	$ 38	$ 24	$ 38	$ 45	$ 53	$ 59
Green Purchase	$ -	$ 0	$ 4	$ 12	$ 9	$ -	$ -	$ -	$ -	$ 3	$ 3	$ 1	$ 3	$ 2	$ 0	$ 8	$ 1	$ 1	$ 2	$ 5
New Renewable Subtotal	**$ 3**	**$ 14**	**$ 55**	**$ 78**	**$ 126**	**$ 253**	**$ 343**	**$ 424**	**$ 501**	**$ 595**	**$ 628**	**$ 679**	**$ 731**	**$ 776**	**$ 820**	**$ 858**	**$ 874**	**$ 886**	**$ 904**	**$ 922**
Short Term Q3 Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ 14	$ 11	$ 8	$ 9	$ 10	$ 14	$ 18	$ 14	$ 12	$ 55	$ 67	$ 33	$ 44	$ 67
Replacement CC Capital Cost																				
Navajo Replacement CC	$ -	$ -	$ -	$ -	$ -	$ 9	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18
IPP Replacement CC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 6	$ 133	$ 133	$ 133
Total	**$ 58**	**$ 43**	**$ 83**	**$ 130**	**$ 186**	**$ 388**	**$ 442**	**$ 533**	**$ 619**	**$ 695**	**$ 767**	**$ 828**	**$ 889**	**$ 942**	**$ 996**	**$1,035**	**$1,075**	**$1,222**	**$1,247**	**$1,274**

These projected costs are in addition to the total annual power operating revenue requirement today of about 2.95 billion. In addition to the revenue required to replace coal and meet future peak load growth, additional revenue is required to fund the Power Reliability Program, modernize gas-fired in-basin generation to eliminate once-through cooling, support investments in smart grid to support energy efficiency and demand response programs, and maintain the basic funding of the existing generation, transmission, and distribution infrastructure as shown in Table 5-3.

Table 5-3. Recommended revenue to fund program initiatives, 2011-2020

PROGRAM INITIATIVE	Revenue Requirement ($ Billion)
Power Reliability	$6.8
OTC Repowering of Power Plants	$1.2
Transition from Coal (Navajo GS)	$0.4
Increasing Renewable Energy	$6.0
Expand Renewable Transmission	$0.5
Expand Local Solar	$0.7
Increasing Energy Efficiency	$0.7
Smart Grid Investments	$0.3
SUBTOTAL	$16.6
Basic Generation, Transmission and Distribution	$23.4
TOTAL	$39.9

AR0071202

The Recommended Case will meet the LADWP combined objectives of maintaining a reliable power system, environmental stewardship, and minimizing ratepayer impacts. The Recommended Case provides a roadmap for the LADWP to achieve its long-term planning goals, while providing the required reliability and necessary flexibility to adapt to dynamic economic, environmental, and regulatory conditions. The Recommended Case will put upward pressure on retail rates, but will maintain adequate reliability and avoid fines and penalties that may otherwise result from violations in state and federal laws. The recommended case also successfully reduces the amount of GHG emissions released into the environment.

AR0071203

5.4 Revenue Requirements

A brief discussion, repeated from Section 1, is in order here regarding budget shortfalls over the past few years. These shortfalls have prevented LADWP from fully funding existing and new programs during that timeframe. The delays surrounding resolution of the Power System budget have the potential of impeding LADWP's ability to meet its long term plans and obligations.

Based on last year's 2010 IRP, a multi-year rate increase was recommended beginning fiscal year 2011-12. The rate increase would have supported elements of last year's IRP, all of which remain as the foundation for LADWP's short and long term plans. Because the rate increase was not realized in July 2011, many of the programs that required funding were scaled down, delayed or deferred.

A multi-year funding plan is necessary to provide consistent and sustainable project and program development. Funding that is based on annual budgets are subject year-to-year fluctuations which introduces uncertainty for our customers and the inefficient use of staff and financial resources that are necessary to meet LADWP's objectives and compliance requirements.

Properly funded programs will enable LADWP to achieve the following objectives:

- Modernize its coastal generation units to replace aging equipment and to satisfy once-through cooling regulatory requirements.
- Implement early coal divestiture.
- Secure the state-mandated amounts of renewable energy.
- Through the Power Reliability Program, reduce the number of distribution outages and improve system reliability.
- Implement necessary transmission improvements to maintain reliability.
- Achieve energy efficiency target levels.
- Implement Smart Grid initiatives.
- Comply with FERC-approved reliability standards.

A rate process that began earlier this year is addressing the revenue needs for LADWP. A proposed 3-year rate adjustment that would support the programs listed above is being considered. The expectation is that the rate process will conclude sometime in 2012. Securing adequate multi-year funding is crucial to ensure LADWP's ability to stay on track towards meeting its future long term goals and obligations.

AR0071204

5.5 Electric Rates

LADWP currently uses an Excel-based financial model that has been developed and used for over a decade. This financial model has been used to develop forward-looking Power System financials for the Board of Water and Power Commissioners' annual budget approval and for rating agency presentation for debt issuances during the similar period.

The model is modified to analyze the three cases with their respective fuel expense, purchased power expense, and additional capital and O&M expenses for any new LADWP-owned resource additions as well as off-balance sheet resource additions. The nine strategic cases are overlaid on existing capital and O&M expenses for the approved FY11-12 budget data, which contains forward-looking budget data up until FY20-21. For years beyond FY20-21, general capital and O&M expenses are escalated at 3 percent per annum.

LADWP retail revenue comes from three billing factors: (1) base rate (2) energy cost adjustment (ECA) and reliability cost adjustment (RCA) factors. The interplay of these three factors is described briefly below.

The ECA is used to cover fuel, purchased power, RPS and energy efficiency-related expenses. The ECA is adjusted quarterly and currently has an adjustment cap of 0.1 cts/kWh (i.e., increasing by no more than 0.1 cts per kWh).

The RCA is used to cover power reliability related expenses. The RCA is adjusted annually and has a maximum factor of 0.3 cts/kWh. This maximum has been reached in FY10-11 and cannot be adjusted any higher. Since reliability related expenses are not projected to go lower than FY10-11 spending levels, significant RCA under-collection may exist.

The base rate is used to cover non-fuel, non-purchased power, and non-RPS related expenses. Base rate is used to cover expenses from debt service arising from capital projects except RPS projects, operational and maintenance expense except RPS related, public benefit spending, property tax, and pro-rated portion of the city transfer.

Since LADWP needs to sell substantial amounts of bonds in the near future to sustain its capital expenditures, maintaining an "AA" credit rating is essential to minimize financing costs. To maintain such a rating and mitigate potential rate increases, it is recommended the Board of Water and Power Commissioners approve the following policies: (1) maintain debt service coverage of 2.25, (2) maintain a minimum of $300 million of operating cash-on-hand, and (3) maintain a capitalization ratio not exceeding 65 percent, (4) maintain adjusted debt service coverage of 1.75, and (2) maintain full obligation coverage of 1.5.

Debt service coverage is the amount of cash available from operation divided by the debt service amount. The debt service amount contains only LADWP's direct debt. Adjusted debt service coverage has the debt service amount containing regular debt and off-balance sheet debt. Full obligation coverage deducted the city transfer from the cash available from operation and then divides the amount over the total of regular and off-balance sheet debt. Off-balance sheet debt is the debt owned by a third party, but LADWP will be responsible for the debt payment; for

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example, debt raised by Intermountain Power Agency and Southern California Public Power Authority. Capitalization ratio is the ratio of the total direct debt divided by the total asset.

To achieve these various financial coverage parameters, the base rate factor will need to be increased as necessary to meet the objectives of this IRP.

5.5.1 Rates Analysis for Cases

The retail electric rates, including estimated CO_2 emission expenses, for all 3 strategies are shown on Figure 5-3 below. Factors driving the increases over the twenty-year period are: rising fuel price, increased power reliability program spending, replacement of aging basin generating units to meet once-through cooling and South Coast Air Quality District emission requirements, replacement of coal generation to lower CO_2 emissions, installation of renewables generation according to legislative mandates, and payment for emission allowances due to anticipated CO_2 cap-and-trade program requirements.

The capital cost and the associated O&M expense of any new generation resource is priced at 2011 dollars with 1.5 percent escalation except for certain solar projects, which are priced at levelized 2011 dollars due to anticipated pricing declines.

For each year, the retail rate through either the base rate or the energy cost adjustment factor is raised sufficiently high enough to meet the various financial ratios recommended by financial advisors to maintain LADWP's "AA" bond rating.

Under the Recommended Case, customer rates are estimated to increase on average 6 percent to 7 percent per year over the next five years, and 3 percent to 4 percent per year over the next 20 years (see Figure 5-3).

The CO_2 emission allowance price is estimated to range from $24 per Metric Ton in 2013 to $45 per Metric Ton in 2030. The California Air Resources Board established an allocation cap, and emissions exceeding this cap will require purchases of additional allowances or in some cases, emissions below the cap can be used in future compliance periods.

AR0071206

Assumptions used to model rate impacts can change. In order to reflect the variability in model assumptions, a sensitivity analysis was performed to determine a realistic range of rate impact trajectories. Figure 5-3 shows the retail price impact comparison of the 2011 IRP recommended case bounded by a high and low range fuel price with a comparison to the 2010 IRP recommended case. The high range assumes higher natural gas and coal costs while the low range assumes minimal natural gas and coal costs. The current recommended case retail price rate forecast is much lower than the 2010 IRP rate impact forecast for two major reasons. As described in Section 3.2, the fuel price forecast is significantly lower for 2011, and the assumption for GHG emissions cost was significantly lowered for 2011 after AB 32 regulations were finalized in October 2011.

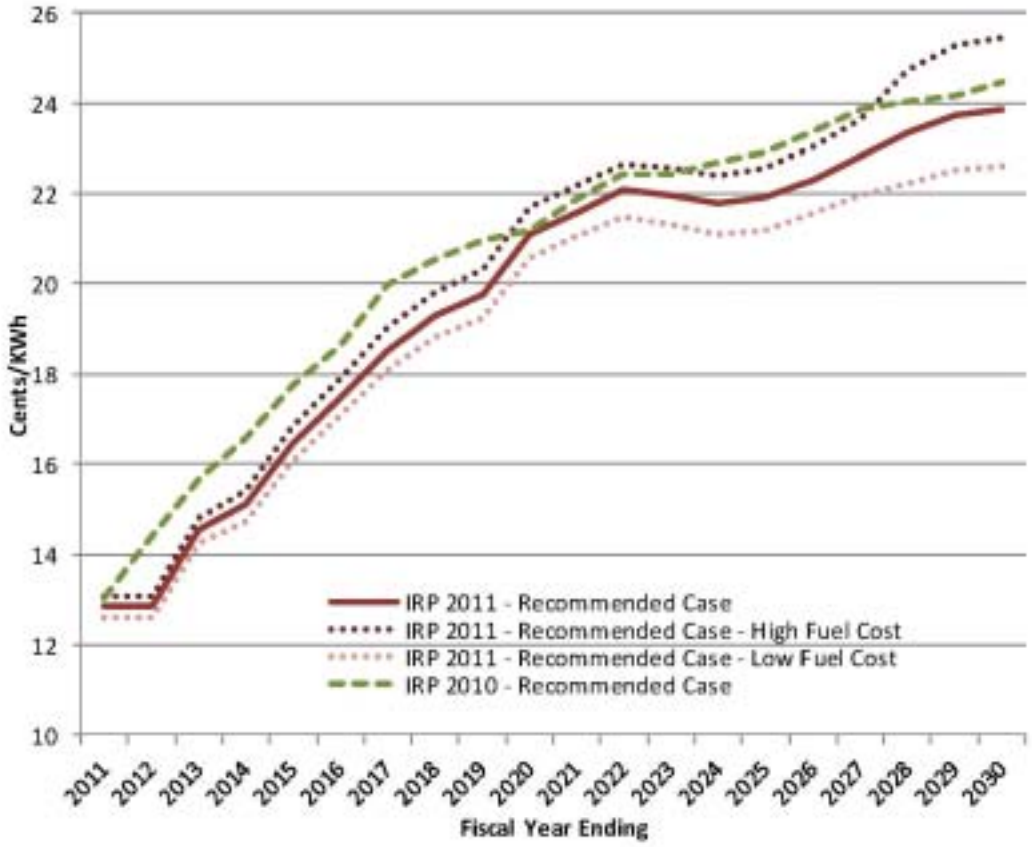

Figure 5-3. Recommended Case - retail price impact bounded by high and low range fuel with the 2010 IRP recommended case included for comparison.

Summarized in Figure 5-4 is the cost contribution from various environmental and reliability programs towards the retail rates. One can draw the conclusion that there is a significant cost to comply with various reliability and regulatory requirements while divesting of Navajo in 2015 and IPP in 2027.

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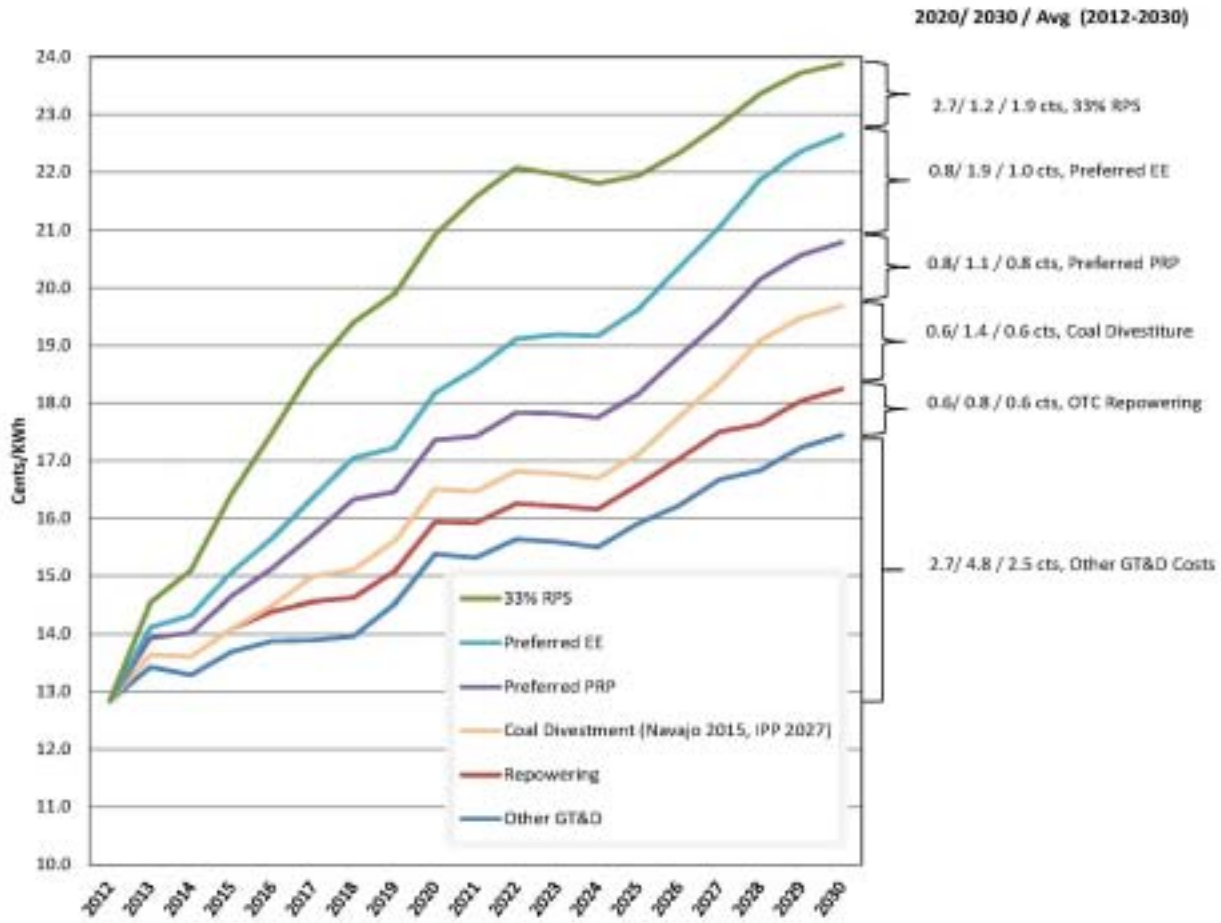

Figure 5-4. Electric rate contributions of environmental and reliability programs by fiscal year based on the 2011-12 budget forecast (preferred case).

A few observations from Figure 5-4 can be made regarding the RPS and EE program. Firstly, the influence of the RPS program on rates increases substantially through 2020 when the RPS percentage of sales reaches 33%. Beyond 2020, the RPS component of rates begins to decline as fuel savings increases over time with escalating fuel prices. Secondly, the EE program component of rates increases over time as power system fixed costs are distributed over the reduced energy sales attributable to the EE program.

The cost contributions from various environmental and reliability programs towards the retail rates are summarized in Table 5-4.

AR0071208

Table 5-4. Cost contributions from various environmental and reliability programs

Program	Retail Rate Impact at FY2020 (cents/kWh)	Retail Rate Impact at FY2030 (cents/kWh)	Average Retail Rate Impact 2011-2030 (cents/KWh)
33% RPS from 20% RPS	2.7	1.2	1.9
Preferred EE	0.8	1.9	1.0
Basic Power Reliability Program	0.5	0.4	0.3
Preferred Power Reliability Program	0.3	0.7	0.5
Coal Divestiture	0.6	1.4	0.6
OTC Repowering	0.6	0.8	0.6
Total - Recommended Case	**5.5**	**6.4**	**4.9**

Figures 5-5 and 5-6 further illustrate the impact to average residential and commercial/industrial customer monthly bills from these environmental and reliability programs.

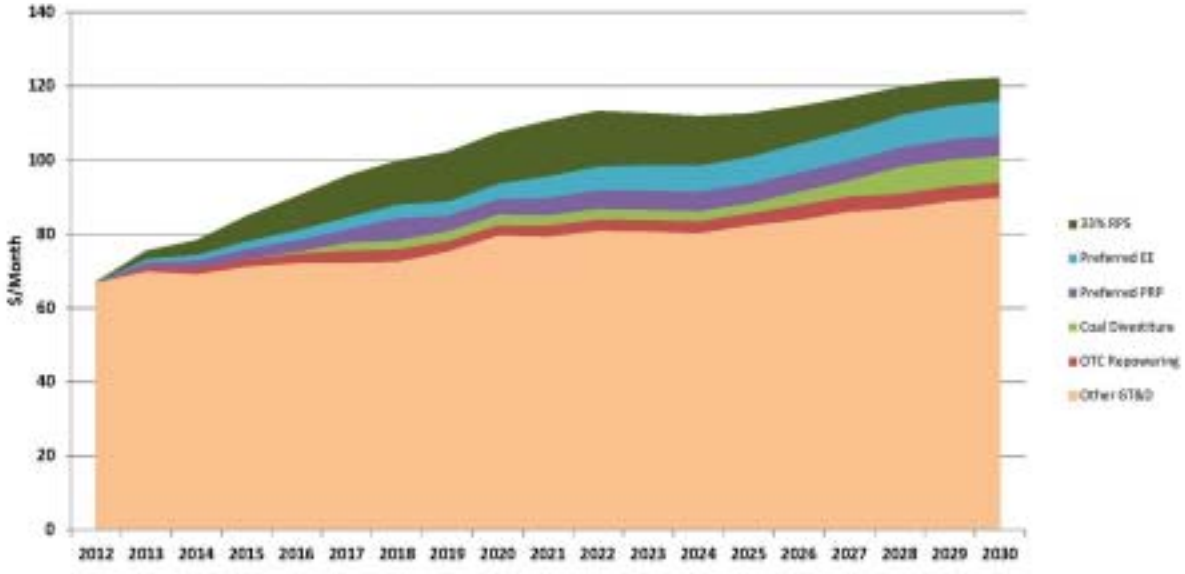

Figure 5-5. Average residential customer bill (500 kWh/month) with environmental and reliability programs by fiscal year based on the 2011-12 budget forecast (preferred case).

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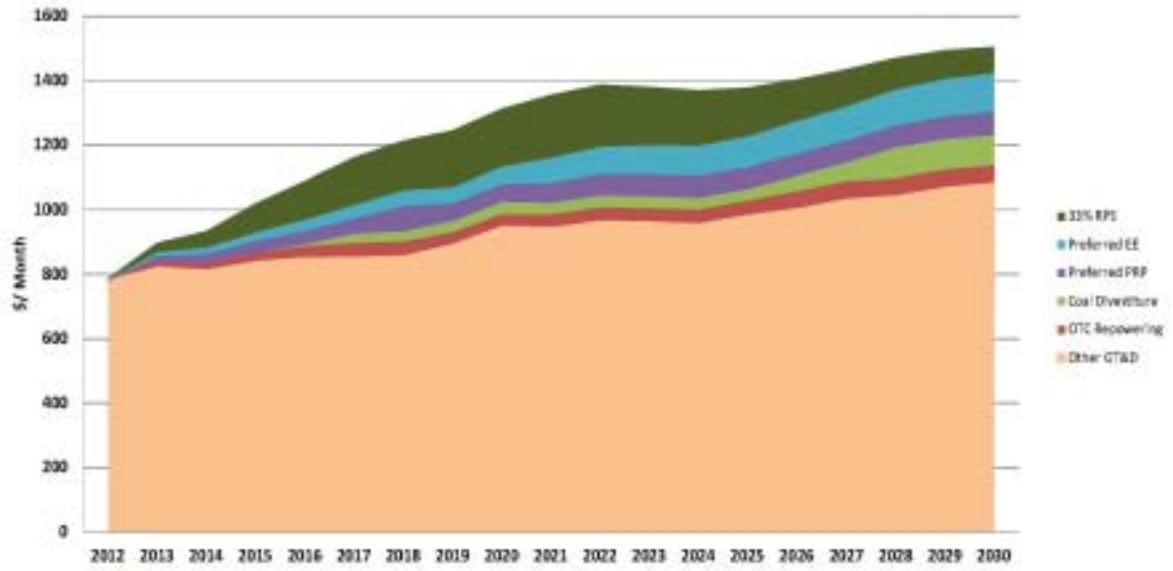

Figure 5-6. Average commercial/industrial customer bill (6,500 kWh/month) with environmental and reliability programs by fiscal year based on the 2011-12 budget forecast (preferred case).

Aside from the environmental and reliability improvement programs, increased fossil fuel expenses also drive the rate increase, for example: (1) coal that feeds IPP is projected to climb from 2011's $1.88/mmbtu to 2027's $3.72/mmbtu, and (2) natural gas at SoCal border is projected to climb from 2011's $4.10/MMBtu to 2030's $8.6/MMBtu. If these fuel increases do not materialize, then the average rate and cost curves shown in Figures 5-3 thru 5-6 will shift downward; however, the cost of environmental and reliability programs will remain substantially unchanged.

Because the analysis and conclusion are heavily dependent on a number of assumptions, LADWP will watch to see if these unfold as assumed. If expectations change (e.g., because of unanticipated technology changes, commodity price fluctuations, and policy changes), then the long-term plan will need to be revisited. Under all cases, it is assumed that the following items will occur, and that each will be central to LADWP regardless of the resource portfolio selected:

- Ensure that the power generation, transmission and distribution infrastructure operates in a reliable and efficient manner. Continue the Power Reliability Program initiated in 2007 which improves maintenance practices, addresses aging power system infrastructure, increases capital construction programs necessary to support load growth, and maintains staffing levels to support reliability related work.
- Support and advocate incremental requirements in Title 24 and other Green Building and appliance standards to reduce energy usage.

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- Re-power Scattergood, Haynes, and Harbor end of life in-basin generation consistent with power system needs and environmental requirements
- Continue to be self-sufficient, by maintaining system generation resources equal to or greater than customer's electrical needs
- Provide sufficient generation, demand response, and limited short term purchases in Q3 to cover operating and replacement reserves in accordance to applicable federal and regional reliability requirements
- Maintain full control of transmission assets and continue to augment those assets commensurate with load growth and renewable energy opportunities
- Work with the Water System to develop programs that reduce the usage of electricity and conserve water, as well as optimizing hydroelectric energy production
- Maintain a "AA" credit rating, a debt service of at least 2.25 times, operating cash of $300 million, capitalization ratio not greater than 65 percent, and electric rates lower than neighboring investor owned utilities. In addition, LADWP will maintain net income sufficient to ensure stable City Transfers

Each of the targets listed above will be tested in the future to meet requirements for system reliability, fiscal responsibility and environmental stewardship. Modifications will be made as necessary to assure that these core principles are met.

AR0071211

5.6 Near-term Actions

The actions needed to be taken by LADWP in the next two to four years are very similar no matter what resource procurement strategy is chosen. From the development assumptions listed above and projected resource procurement needs, the following actions are recommended to be taken in the near-term:

1. Proceed with re-powering plans for generation units at the Haynes and Scattergood Generation Stations.
2. Continue to investigate the technical and contractual options for coal-fired generation to be compliant with SB 1368.
3. Replace the Navajo Coal Plant by 2015.
4. Implement recommendations contained in the recently completed Energy Efficiency Market Potential Study.
5. Implement recommendations contained in the Ten-Year Transmission Assessment Plan and the Reactive Power Management Study.
6. Develop a Demand Response Program to initially provide 5 MW of peak load reduction capability by 2013 which will ramp up incrementally to 200 MW by 2020 and 500 MW by 2026.
7. Develop renewable strategies for geothermal, biogas, solar, and wind resources to ensure increasing levels of renewable procurement in accordance with SB 2 (1X).
8. Complete a comprehensive study of issues associated with integrating increasing amounts of variable energy resources such as wind and solar to reflect possible megawatt limits for the LADWP electric power system.
9. Procure and develop advanced technologies in the areas of: weather forecasting energy scheduling, customer kWh metering, high speed communications and information systems, and large scale energy storage systems.
10. Develop and incorporate strategies to:
    a. Fully utilize existing transmission assets;
    b. Locate renewables as close as practical to the load center to reduce transmission losses;
    c. Preserve existing brown field sites to be repurposed for renewable or natural gas generation;
    d. Incorporate the concept of O&M cluster zones to maximize operational efficiencies;
    e. Assess and develop necessary transmission facilities to deliver electricity generated from new facilities.
11. Develop a renewable energy feed-in tariff program to encourage 30 MW of renewable generation resources to be developed by July, 2015.
12. Sign Power Purchase Agreements for an additional 200-300 MW of cost effective renewable energy projects by 2014.
13. Encourage the development of an additional 50 MW of customer owned solar projects before 2015.
14. Develop up to 30 MW of Solar on Los Angeles properties under public/private partnership projects before 2015.

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15. Investigate the potential use of term physical gas supply arrangements, either with contracts for physical supplies or futures contracts to limit LADWP's exposure to volatile gas prices. Include the flexibility for closing these contracts as well.

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5.7 Long-term Goals

The analysis and conclusions contained in this IRP are heavily dependent on a number of assumptions, such as the projected fuel and purchase power costs, RPS target goals, renewable generation costs, proposed state and federal mandates, and GHG emissions costs. If these assumptions were to change, LADWP's long-term strategies will need to change accordingly.

Integrated resource planning is an on-going process. LADWP will continue to adapt and refine the IRP as the uncertainties are better understood, and policy direction and requirements are solidified. A new IRP will be issued in 2012, and every two years thereafter.

AR0071214

Appendix A. Load Forecasting

A.1 Overview

The 2011 Retail Sales and Demand Forecast (2011 Forecast) is a long-run projection of electrical energy sales, production, and peak demands in the City of Los Angeles (City) and Owens Valley. A flowchart of the forecast process is illustrated on Figure A-1. The sections which follow describe the four key components shown on the flow chart: data collection, sales and Net Energy for Load (NEL) forecast, peak demand forecast, and hourly allocation.

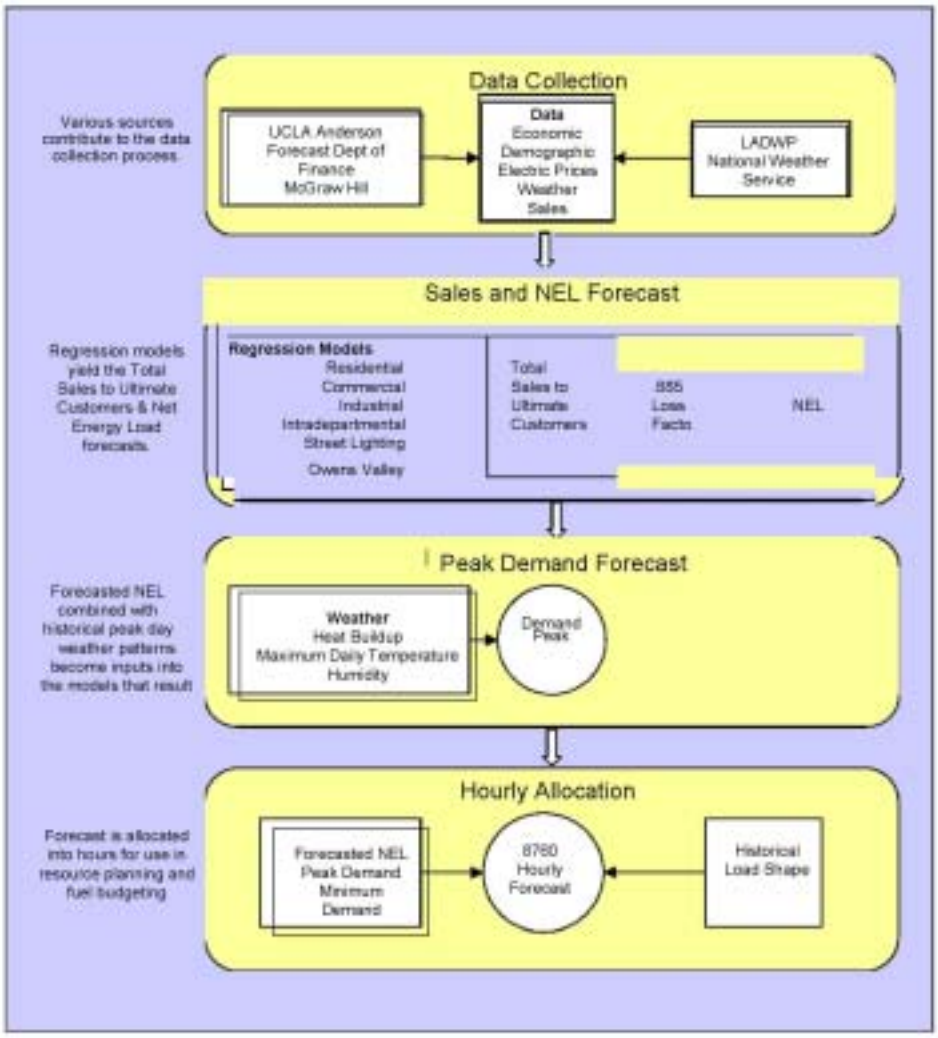

Figure A-1. Overview of the load forecasting process

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A.2 Data Collection

Data collection is the first step in the process. LADWP purchases an economic forecast of Los Angeles County from the Los Angeles Modeling Group of the University of California of Los Angeles (UCLA) Anderson Forecast Project. The Los Angeles County Forecast provides time series data for various demographic and economic statistics beginning with year 1991 and continuing through the forecast horizon. For demographic history and projections, LADWP uses the State of California Department of Finance Demographic Research Unit.. To gain further insight into development patterns, LADWP purchases a construction forecast from McGraw-Hill Construction service. The construction forecast gives a five-year view of construction projects detailed by building types. Weather also affects energy sales and demand. Weather data is collected from three key stations – Civic Center, Los Angeles Airport, and Woodland Hills. The other key components in the forecast are from LADWP's own internal data. Historical sales, Net Energy for Load (NEL), billing cycles, electric price, and budget data is incorporated into the forecast. The economic, demographic, weather, and electric price data provide the key inputs to the models that forecast retail electric sales.

A.3 Sales and NEL Forecast

The retail sales forecast is divided into seven separate customer classes; residential, commercial, industrial, plug-in electric vehicle (PEV), intradepartmental, streetlight and Owens Valley. The residential, commercial, industrial, and streetlight classes are commonly used sales classes throughout the electric industry because they represent relatively homogeneous loads. Intradepartmental sales are sales to the Water System and are primarily related to water pumping activities.

The California Energy Commission's PEV forecast has been adapted to the LADWP service area. Further, PEV load is forecast as a separate class, which will facilitate financial modeling due to the expected subsidies and production modeling as PEV load has a unique load shape when compared to the residential class.

Owens Valley sales include all of the above sales classes. The Owens Valley service area is separate and discrete from the Los Angeles service area. Because of limited land available to be developed, Owens Valley sales exhibit very slow growth rates, and total sales are relatively small compared to total LADWP system sales. As such, Owens Valley sales are rolled into a single class and forecast separately.

The forecast model consists of six single equations plus the adapted PEV forecast. For the residential, commercial, and industrial sales classes, the equations are estimated using Generalized Least Squares regression techniques. Historical sales for each customer class are the dependent variables. Sales are regressed against a combination of the demographic, economic, weather, and electric price variables. Binary variables are used to account for extraordinary events like earthquakes, civil

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disturbances, billing problems, and the California Energy Crisis. The equations fit historical data quite accurately, producing coefficients of determination (R-Squared) statistics greater than 80 percent. For the streetlight, intradepartmental, and the Owens Valley sales classes, time trend models are used. The results of the six equations plus the PEV forecast are summed to forecast Total Sales to Ultimate Customers (Sales).

The Retail Sales Forecast represents sales that will be realized at the meter. The NEL forecast is a function of the Sales forecast. The NEL is forecast by adjusting annual forecasted Sales upward by a historic average loss factor and then allocating a portion of the annual energy to each calendar month based on historical proportions. Loss factor has the potential to change on the way that the System is run. Electricity generated in distant places will have a higher loss factor than electricity generated located locally. The change in loss factor is accounted for in the resource planning models.

The 2011 Forecast includes committed energy efficiency and customer self-generation. Committed energy efficiency includes budgeted utility programs and expected energy efficiency gains from the Huffman Bill lighting standards. Expected Huffman Bill energy efficiency savings were developed by Global Energy for the 2010 LADWP Energy Potential study. Since the 2011 Forecast is created early in the planning process, budgeted utility energy efficiency programs are subject to change. Planners using the 2011 Forecast should be aware of the potential changes and make appropriate adjustments. Forecasting self-generation which currently is almost entirely focused on solar rooftops in the LADWP service area follows a process similar to the energy efficiency. Planners working with energy efficiency and self-generation data should be careful to include only the incremental impacts of the programs on retail sales In the Forecast, energy efficiency and self-generation savings are expected to occur uniformly throughout the year as a simplifying assumption.

A.4 Peak Demand Forecast

The next step is to forecast annual peak demand. The drivers for forecasted peak demand are temperature, load growth, and time of the summer. The temperature variable used in the estimation is the weighted-average of three weather stations. The temperature variable incorporates heat buildup effects and humidity. Temperature is then divided into splines using a unique megawatt- response per degree estimate for different levels of temperature. Ordinary Least Square regression techniques are used to model maximum weekday summer daily hourly demand against the temperature splines and the time of the summer. The constant that is estimated from the regression model is assumed to be the weather-insensitive demand at the peak hour. To forecast the peak demand, it is assumed that the peak will occur in August and that the peak day temperature is equal to the forty-year historical mean peak day temperature. Peak demand then is assumed to grow at the same rate as sales.

The forecast process described above produces the trend (or base case) forecast. LADWP also produces alternative peak demand forecasts. LADWP wants to ensure that it can meet native demand with its own resources. System response to weather is

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uncertain. Temperature and humidity are the primary influences, but other variables such as cloud cover and wind speed can also influence the load. The problem is further complicated by the fact that LADWP serves three distinct climate zones including the Los Angeles Basin, the Santa Monica Bay Coast, and the San Fernando Valley. To prepare for these uncertainties, LADWP formulates its alternative cases by examining expected demands at different temperatures. Based on the Central Limit theorem, it is assumed that the normal distribution produces unbiased and efficient estimators of the true distribution of peak day temperatures. The normal distribution is estimated from the 40 year historical sample of peak day temperatures. From the normal distribution, the probability that the peak day temperature will be below a given temperature can be determined. For the one-in-ten case, it is the given temperature where ninety percent of the time the actual peak day temperature is expected to be below it and ten percent of the time the actual temperature will be above it. Similar calculations are performed for the one-in-five and one-in-forty cases. These temperatures are input into the peak demand regression model to provide the alternative peak demand forecasts.

In the Integrated Resource Plan, LADWP uses the One-in-Ten Case Peak Demand forecast rather than the Base Case forecast. LADWP's policy regarding obligation to serve is to be self-sufficient in supplying native load and not rely on external energy markets. The Base Case Peak Demand forecast falls short of this standard since it is expected that fifty percent of the time actual peak demands will exceed the Base Case Peak Demand forecast. The One-in-Ten Case provides LADWP ninety percent confidence that the forecasted peak demand will not be exceeded in any given year.

A.5 Hourly Allocation

The final step of the process is to forecast a monthly peak demand and load for each hour in the year. Monthly peak demands, outside of the August annual peak, are forecast using the load factor formula. The historical average monthly load factor and the forecasted NEL for each month are the known inputs. To forecast load for each hour of the year, the Loadfarm algorithm developed by Global Energy is used. The inputs into Loadfarm are a historical system load shape, monthly forecasted energy, and monthly forecasted peak demand. The system load shape is developed using a ranked-average procedure permuting historical loads so that all peaks occur on the fourth Thursday in August. Table A-1 contains the numerical 2011 Forecast.

AR0071218

Table A-1. TREND CASE ENERGY SALES AND PEAK DEMAND

	SECTOR SALES					Total Sales to Ultimate Customers	Net Energy for Load	Peak Demand
Fiscal Year	Residential (GWh)	Commercial (GWh)	Industrial (GWh)	Miscellaneous* (GWh)	PHEV (GWh)	(GWh)	GWh	(MW)*
2000-01	7,542	12,103	2,564	521	0	22,824	25,668	5,289
2001-02	7,282	11,843	2,464	508	0	22,146	24,663	4,805
2002-03	7,358	12,077	2,363	545	0	22,363	25,370	5,185
2003-04	8,061	12,408	2,455	666	0	23,590	26,707	5,410
2004-05	7,907	12,374	2,447	551	0	23,279	26,336	5,418
2005-06	8,051	12,580	2,451	551	0	23,634	26,626	5,667
2006-07	8,486	12,956	2,332	504	0	24,278	27,502	6,102
2007-08	8,540	13,134	2,366	576	0	24,617	27,928	6,071
2008-09	8,578	13,094	2,303	560	0	24,535	27,447	6,006
2009-10	8,366	12,953	2,073	532	0	23,366	26,626	5,705
2010-11	8,181	12,879	2,116	485	1	23,053	25,942	5,742
2011-12	8,298	12,980	2,074	456	3	23,257	26,307	5,849
2012-13	8,382	12,936	2,095	457	14	23,058	26,206	5,850
2013-14	8,326	12,935	2,053	464	31	23,283	26,516	5,882
2014-15	8,383	12,931	2,037	477	67	23,510	26,637	5,913
2015-16	8,479	12,923	2,058	478	94	23,732	26,850	5,962
2016-17	8,588	12,750	2,058	479	170	24,010	27,063	5,940
2017-18	8,718	12,905	2,058	487	139	24,307	27,420	5,911
2018-19	8,882	13,048	2,059	483	166	24,612	27,772	5,990
2019-20	9,016	13,190	2,059	484	104	24,846	28,216	6,072
2020-21	9,172	13,380	2,060	486	236	25,335	28,582	6,160
2021-22	9,326	13,554	2,060	488	263	25,704	28,996	6,271
2022-23	9,479	13,589	2,060	490	287	25,906	29,334	6,345
2023-24	9,640	13,931	2,061	491	312	26,304	29,750	6,420
2024-25	9,807	13,919	2,061	492	330	26,610	30,070	6,468
2025-26	9,970	14,035	2,061	493	300	26,920	30,275	6,574
2026-27	10,122	14,151	2,062	494	354	27,220	30,420	6,650
2027-28	10,266	14,265	2,062	496	400	27,530	31,109	6,726
2028-29	10,454	14,375	2,063	500	434	27,826	31,302	6,726
2029-30	10,605	14,483	2,063	502	454	28,120	31,709	6,876
2030-31	10,771	14,594	2,064	504	481	28,423	32,075	6,948
2031-32	10,935	14,734	2,064	506	506	28,744	32,471	7,026
2032-33	11,096	14,864	2,064	507	570	29,061	32,767	7,106
2033-34	11,258	14,994	2,065	509	553	29,379	33,163	7,184
2034-35	11,421	15,123	2,065	510	577	29,697	33,512	7,263
2035-36	11,582	15,252	2,066	512	603	30,016	33,907	7,342
2036-37	11,743	15,380	2,066	514	636	30,328	34,165	7,420
2037-38	11,899	15,508	2,066	516	650	30,640	34,577	7,498
2038-39	12,054	15,636	2,067	517	674	30,948	34,927	7,574
2039-40	12,211	15,764	2,067	519	700	31,262	35,316	7,651

Table updated through December 2010

Annual Percent Change								
2001-2001	1.03%	0.55%	-1.03%	0.53%		0.53%	0.40%	-0.02%
2001-10	1.07%	0.32%	-3.11%	0.04%		0.21%	0.78%	0.87%
2010-16	0.36%	0.21%	-0.15%	-1.79%		0.28%	0.20%	0.18%
2010-20	0.89%	0.57%	-0.07%	-0.94%		0.85%	0.82%	0.82%
2020-30	1.24%	0.76%	-0.01%	-0.76%		0.93%	0.90%	0.93%
2030-40	1.30%	0.70%	-0.01%	-0.68%		0.97%	0.96%	0.98%

Includes Streetlighting, Owens Valley, and LA Aqueduct Load
Weather normalized

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CITY OF LOS ANGELES

DEPARTMENT

OF

WATER AND POWER

2011 RETAIL ELECTRIC SALES AND DEMAND FORECAST

Aram Shumavon
Senior Assistant General Manager
Power System

Ann M. Sarcilla
Interim Chief Financial Officer

February 18, 2013
Load Forecasting, Room 956
Financial Services Organization

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2011 Retail Electric Sales and Demand Forecast

Overview

The 2011 Forecast (Forecast) supersedes the April 2010 Retail Electric Sales and Demand Forecast as the City of Los Angeles Department of Water and Power's (LADWP) Official Power System Forecast. The Forecast is the basis for LADWP Power System planning activities including but not limited to Integrated Planning, Integrated Resource Planning (IRP), Transmission and Distribution Planning and Wholesale Marketing.

Because the Forecast is a public document, only publically available information is used in its development. This practice has become a standard among California electric utilities. LADWP Planners wishing to use their own proprietary data should adjust the Forecast accordingly. The Load Forecast Group (LFG) is available to help Planners make adjustments and produces an Unadjusted and Gross Forecast to facilitate those adjustments.

Data Sources

1. Historical Sales reconciled to the Consumption and Earnings Report prepared by General Accounting
2. Historical NCT, Peak Demand and Losses reconciled to the Powermaster database located at the Energy Control center
3. Historical weather data is provided by the National Weather Service and Los Angeles Pierce College
4. Historical Los Angeles County employment data is provided by the State of California Economic Development Division using the March 2009 benchmark.
5. Historical population estimates and projections are provided by the State of California Department of Finance
6. The forecast Los Angeles County economic forecast with quarterly short-term updates is provided by UCLA Anderson Forecast
7. The construction activity forecast is provided by McGraw-Hill Construction
8. The plug-in hybrid electric vehicle (PHEV) forecast is based on the California Energy Commission's (CEC) statewide PHEV forecast
9. The port electrification forecast is provided by the Port of Los Angeles.
10. The housing forecast is referenced by the City of Los Angeles "Housing that Works" plan
11. The energy efficiency forecast is based on approved LADWP based programs through fiscal year 2013 and the forecasted impacts of the Energy Independence Security Act of 2007 (EISA) and the Huffman Bill on residential lighting. Historical installation rates are provided by the Energy Efficiency group
12. Historical solar rooftop installations and objectives are provided by the Solar Energy Development group
13. Electric Price Forecast is developed by Financial Services organization

AR0071223

Historical data is current through December 2010

Five-Year Sales Forecast

The Retail Sales Forecast represents sales that will be realized at the meter through Fiscal Year-end 2015. After FY 2015, some of the forecasted sales will not be realized at the meter due to the incremental impacts of LADWP-sponsored energy efficiency programs. Available in-house is a Gross Forecast which forecasts sales before the impacts of energy efficiency and solar rooftop. The purpose of the Gross Forecast is to allow modeling of different energy efficiency and distributed generation scenarios.

The historical accumulated Energy Efficiency and Solar Savings are from 1999 forward and only include LADWP installed savings. Since July 1, 2006, LADWP installed Energy Efficiency savings are 715 GWH for which LADWP received Customer Incentives. In the Forecast, energy efficiency and solar savings are expected to occur uniformly throughout the year as a simplifying assumption. Installations schedules are difficult to prepare because they rely on the customers although the mid-Quarter target is 15

Retail sales decrease of 3.4 percent in Fiscal Year 2010-11 is partially attributed to a cooler than normal summer as well has directly occurred. Likewise, the 4.7 percent increase in Fiscal Year 2011-12 includes the cooler summer in 2010 compared against normal summer weather.

Forecasted Energy Efficiency is based on the California Energy Commission definition of "committed" energy efficiency which is LADWP budget through FY 2018 and forecasted Ballroom ball savings. The long-term LADWP energy efficiency goal is to reach the AB 2021 objective of 10 percent savings during the time period 2007 through 2016. The targeted goal for rooftop solar installations is 348 MW by 2020

Short Run Growth

Fiscal Year	Retail Sales		Accumulated EE & Solar Savings	Gross Sales
Ending June 30	GWH	YOY Growth Rate	GWH	GWH
2009-10	23369		1289	24658
Forecast				
2010-11	23085	-1.2%	1483	24568
2011-12	23221	0.6%	1672	24894
2012-13	23279	0.2%	1862	25140
2013-14	23258	-0.1%	2017	25275
2014-15	23611	1.5%	2311	25922

Table A-2 Updated December 2011

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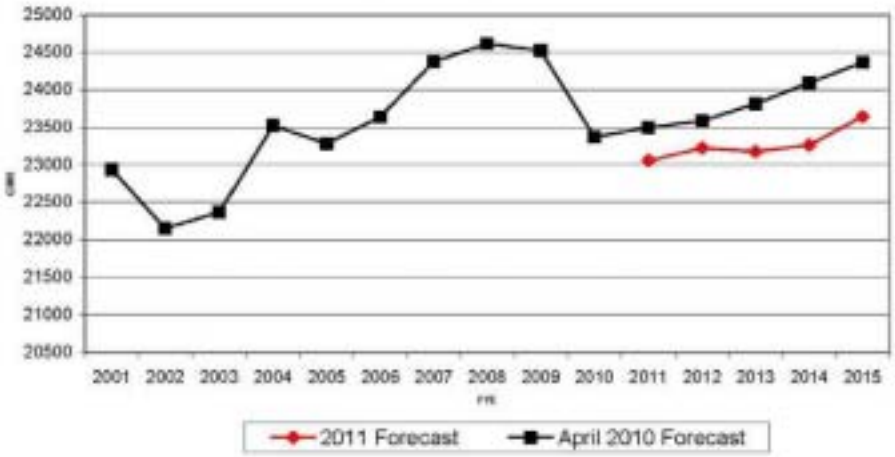
AR0071224

Retail Sales Net of Energy Efficiency and Distributed Generation



Peak Demand Forecast

Growth in annual peak demand over the next ten years is 0.8 percent.

Long-Run Growth

Fiscal Year End June 30	Base Case Peak Demand (MW)	Growth Rate Base Year 2010-11	One-in-Ten Peak Demand (MW)
2010-11	5589[1]		6042
Forecast			
2015-16	5809	0.8%	6277
2020-21	6211	1.0%	6710
2030-31	7000	1.1%	7560
2040-41	7780	1.1%	8403

[1]Weather-normalized. Actual peak was 6142 MW.

In 2010, the System set its calendar annual peak at 6142 MW on September 27, 2010 on a day that was a one-in-thirty-seven weather event. The weather-adjusted one-in-two peak for 2010 is 5589 MW. The following graph of the One-in-Ten peak demand forecast is used for the Integrated Resource Plan (IRP). In the 1990s through 2005, annual System load factors were trending slowly upward. Since 2006, System load factors are trending down. Two factors are generally thought to be contributing to this

Page 5

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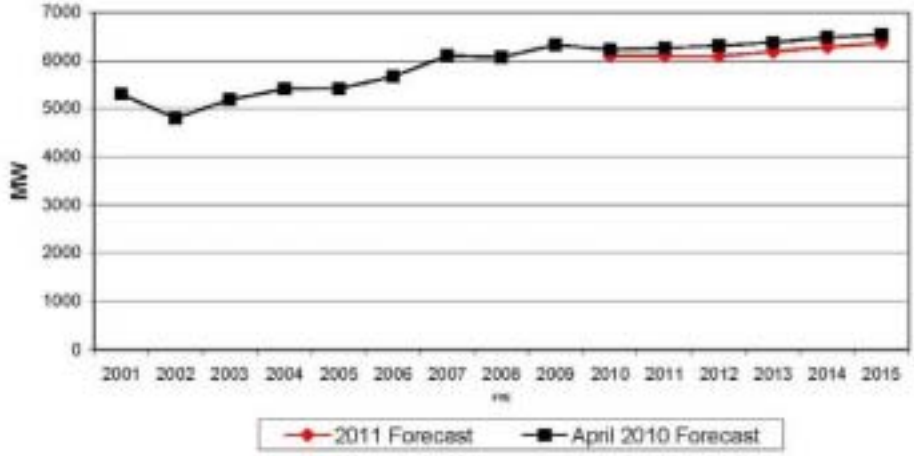
effect. Most customers are making greater efforts to conserve energy but during extreme weather events safety and comfort predominate over conservation causing the peak to spike. Much of the historical and forecasted energy efficiency effort is lighting which has a greater impact on consumption rather than peak which lowers the load factor.

One-in-Ten Peak Demand Comparisons



The Peak Demand Forecast is primarily used in the following areas:

1. Integrated Resource Planning
2. Wholesale Energy Marketing
3. Distribution Planning
4. Transmission Planning

In Integrated Resource Planning, LADWP uses the One-in-Ten Case Peak Demand forecast rather than the Base Case forecast. LADWP's policy is to ensure reliability in times of volatility by controlling its own generation capacity. Planning generation resources at the one-in-ten level has proven over the years to be an effective tool in meeting the reliability policy. The one-in-ten case is based on historical peak day weather events and uses a statistical model and the underlying retail sales forecast to forecast an annual peak demand.

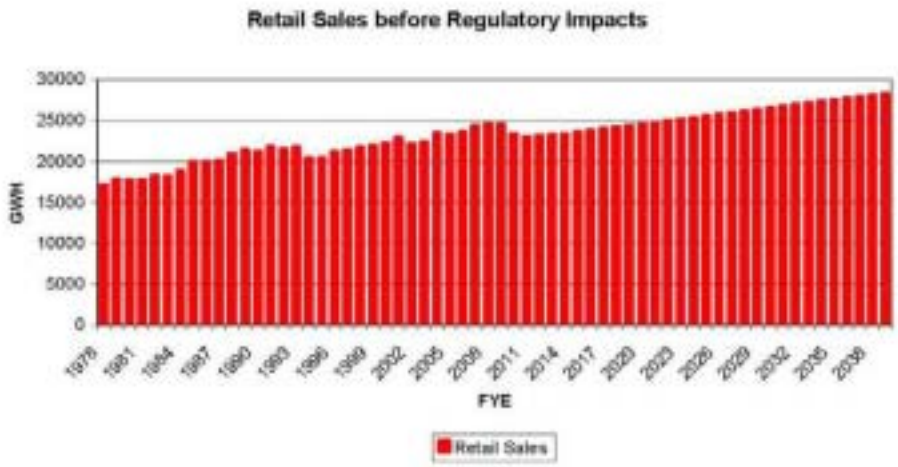
Plausibility

To measure plausibility we compare the current forecast to historical periods. Data is available electronically from 1978 forward. A direct comparison is not appropriate because the forecast period includes programs that reduce all forms of energy consumption due to an aggressive regulatory agenda primary aimed at reducing greenhouse emissions. Instead the unmitigated forecast is compared against history. The unmitigated forecast is the forecast that would occur before the impacts of AB 32 and AB 2021 are considered. It might also be considered a "business-as-usual" case.

AR0071226

The decline in forecasted sales 2008 through 2010 is most directly compared to the decline in sales between 1992 and 1994. The 1992 through 1994 time period was difficult for Los Angeles in many aspects. An economic slump occurred mostly created by the downsizing of the aerospace industry but it also was time of civil unrest and natural disaster. The combination of events caused a major migration of people leaving Los Angeles. Peak-to-Trough sales declined 7 percent in the 1992 through 1994 time period. The following table shows all the peak-to-through declines since 1978. The chart then gives visual evidence of the long-term perspective.

Peak-to-Trough Analysis		
Years	GWH Decline	Percent Decline
2008-2010	1,910	8.3%
1992-1994	1,421	7.0%
2000-2002	572	2.6%
1979-1980	322	1.8%
1981-1982	145	0.8%



Primarily due to the recession that began in December 2007 and ended in June 2009, the historical sales experienced a decline of 8.3 percent in the 2008 through 2010 time period. While the 1992-94 sales decline was specific to Los Angeles and the aerospace industry, in 2008-2010 the decline in Los Angeles mirrored the malaise in the national economy. Most economic models based on history would have predicted a faster economic recovery given the amount of publicly-announced fiscal and monetary stimulus. The actual fiscal stimulus was below the announced target. According to www.recovery.gov , only 40% of the funds made available by Recovery Act have been spent as September 2010. Monetary policy has worked for large firms that can reach international markets as the S&P 500 in 2010 neared historical peak earnings. S&P 500 companies have created over one million jobs in the USA according to Economy Policy

AR0071227

Institute. Small firms continue to struggle as loan requirements are stringent and there is reluctance to invest given the economic uncertainty. UCLA Anderson is forecasting the Los Angeles County to remain in the recovery phase until 2012. Historically, it will be the longest confirmed recession and recovery since World War II.

Variables in the Forecast

Population. Every United States Census was taken in April 2010. Local data is expected by June 2011. Historical population data is likely to be treated as interim data between forecasts is based on state total numbers. Los Angeles is particularly difficult place to estimate population due to the highly transient nature of the economy. Los Angeles experiences high levels of foreign immigration and domestic outmigration. It was thought that the majority of the outmigration was to Riverside and San Bernardino counties. Los Angeles workers moved to these counties to become homeowners. The housing crisis changed the migration pattern and there is uncertainty whether or not this long term historical pattern will resume.

SB 375. SB 375 favors statewide mandates onto local planning decisions. It favors infill development, known as brown field development, near transportation corridors over green field development. The goal is to reduce vehicle miles traveled thereby reducing emissions. Most development in Los Angeles is brown field development. However brown field development is more complicated and expensive than green field development so overall development could slow. The City of LA's Re-zoning the Way We Plan fits well into the SB 375 structure. Residential construction activity is forecasted to be historically slow during the recovery so it will take some time to see the ultimate outcome of SB 375 and the "Re-zoning the Way We Plan" plan.

Emission Allowances. AB 32 seeks to reduce emissions to 1990 levels using a cap-and-trade scheme to begin in 2012. Provisions are designed to avoid activities and companies that experience inflexible as that unintended consequences could arise as occurred during energy deregulation in the late 1990s.

Plug-in Hybrid Electric Vehicles (PHEVs). The Forecast adopted the CEC forecast for PHEV adoption rates. LADWP is making PHEVs a key strategic initiative so adoption rates could be faster. On the other hand, there are competing technologies to PHEVs that the public may choose. Other credible forecasts including the United States Energy Information Administration have significantly lower forecasts for PHEV adoption citing problems with battery technology. The forecast adopted an EPRI charging load profile for PHEVs. The LADWP may choose strategies to shift significantly alter that charging profile.

Energy Efficiency. According to the State of California's Strategic Plan, achieving the energy efficiency goals relies on new emerging technologies. The timing of the market availability and the adoption rates for these new technologies is unknown.

Smart Grid. It is unknown when LADWP will complete its Smart Grid program. Some believe that developing a Smart Grid system is a necessary precondition towards a successful PHEV program. The Smart Grid is an important component towards achieving energy efficiency goals in the residential sector.

AR0071228

Vacancy Factor in Residential Sector – Vacancy rose faster than expected in the recession. Some of the vacancy rate was due to households consolidating and living in the same structure. Vacancy could rapidly swing lower as the economy begins to expand. The forecast has vacancy rate returning to five percent which is the long term average by 2018.

Vacancy Factor in Commercial Sector – High vacancy factor is expected to remain more persistent in the commercial sector as models for delivery of services especially in retail change. The rise of big-box retail stores and the Internet have crowded out the small retail shop owner over the past twenty years. There is a smaller need for a physical presence.

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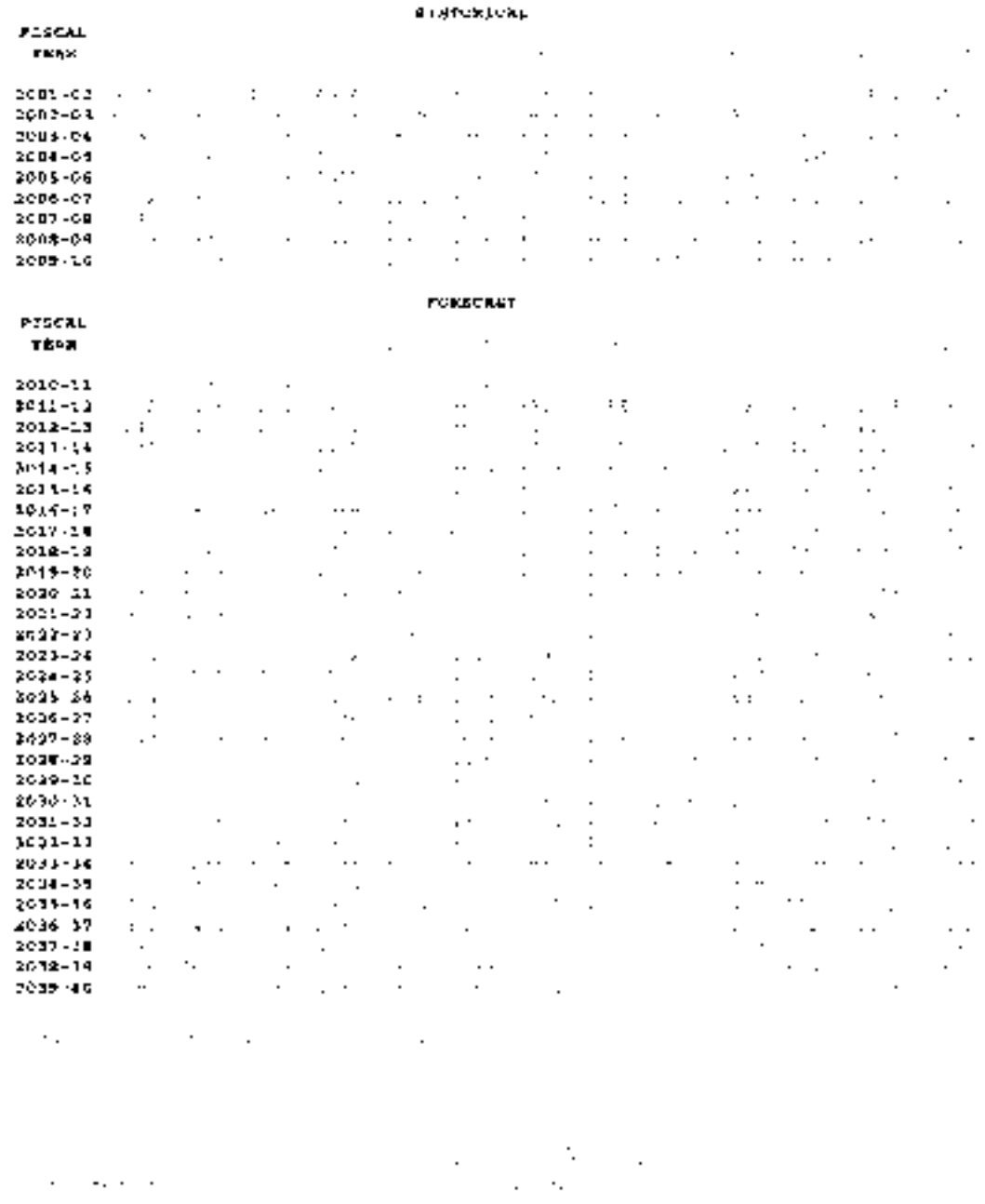
PEAK DEMAND - MW
2011 ENERGY AND DEMAND FORECAST
2001-2009 TRENDED 2009-2010
FISCAL YEAR



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MIDDLE DEMAND - MM
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
2002-03	
2003-04	
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2008-09	
2009-10	

FORECAST

FISCAL YEAR	
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NET ENERGY FOR LOAD- GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
2002-03	
2003-04	
2004-05	
2005-06	
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2007-08	
2008-09	
2009-10	

FORECAST

FISCAL YEAR	
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TOTAL SALES TO ULTIMATE CUSTOMERS- GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 VERSION 1035-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
2002-03	
2003-04	
2004-05	
2005-06	
2006-07	
2007-08	
2008-09	
2009-10	

FORECAST

FISCAL YEAR	
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2039-40	

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RESIDENTIAL SALES GWh
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
2002-03	
2003-04	
2004-05	
2005-06	
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FORECAST

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2039-40	

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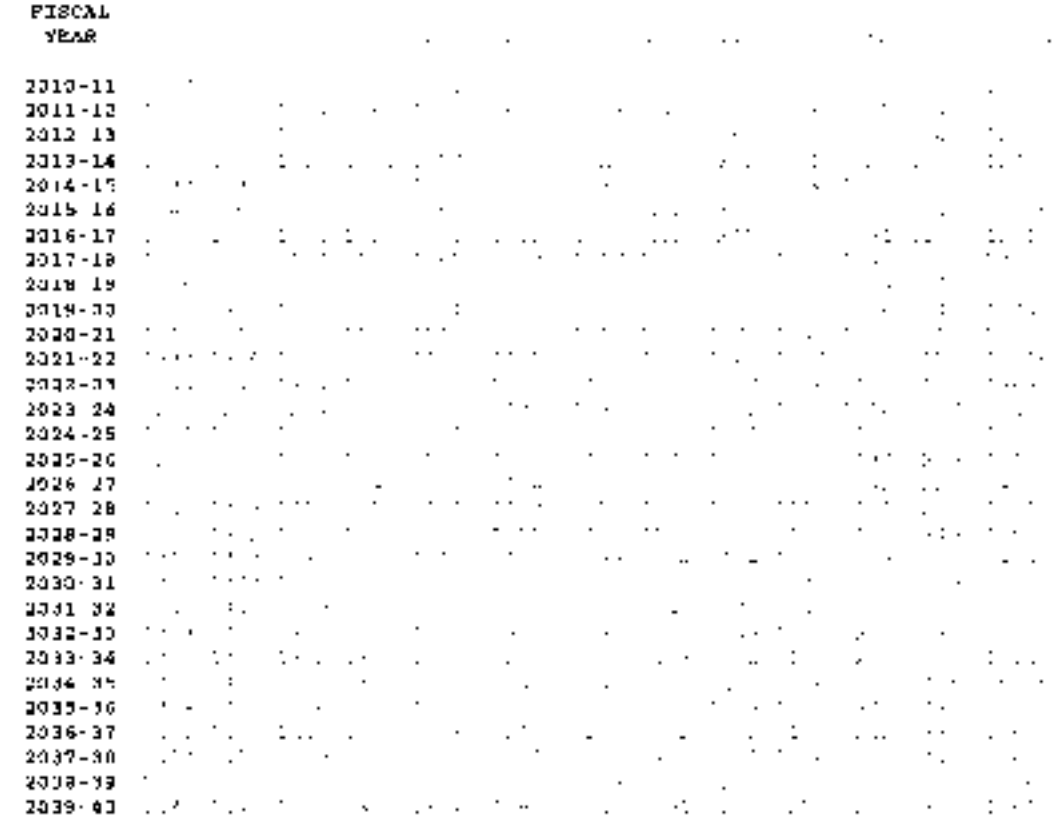
COMMERCIAL SALES - GWH
2011 ENERGY AND DEMAND FORECAST
2001 2002 THROUGH 2039 2040
FISCAL YEAR

HISTORICAL

FORECAST



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INDUSTRIAL SALES - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
2002-03	
2003-04	
2004-05	
2005-06	
2006-07	
2007-08	
2008-09	
2009-10	

FORECAST

FISCAL YEAR	
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2038-39	
2039-40	

AR0071237

R-1 NO LOW INCOME AND LIFE LINE SALES - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
2002-03	
2003-04	
2004-05	
2005-06	
2006-07	
2007-08	
2008-09	
2009-10	

FORECAST

FISCAL YEAR	
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LIFELINE SALES - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	[illegible]
2002-03	[illegible]
2003-04	[illegible]
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FORECAST

FISCAL YEAR	
2010-11	[illegible]
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LOW INCOME SALES - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR
2001-02
2002-03
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FORECAST

FISCAL YEAR
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A-1 SALES - GWH
2011 ENERGY AUTO DEMAND FORECAST
2001-2002 THROUGH 2049-2050
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
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FORECAST

FISCAL YEAR	
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AR0071241

A-2 SALES - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039 2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
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FORECAST

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A-1 SALES - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

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AR0071243

EXPERIMENTAL RATES - ELECTRICITY SALES - GWH
(Includes Real Time Pricing, Contract Demand, and Dispatchable Load Factor)
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2039-2040
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
2001-02	
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AR0071244

RESIDENTIAL ACCUMULATED ENERGY EFFIENCY SAVINGS - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2029-2030
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
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AR0071245

COMMERCIAL ACCUMULATED ENERGY EFFICIENCY SAVINGS - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2029-2030
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
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FORECAST

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AR0071246

HUFFMAN BILL ACCUMULATED ENERGY EFFICIENCY SAVINGS - GWH
2011 ENERGY AND DEMAND FORECAST
2001-2002 THROUGH 2029-2030
FISCAL YEAR

HISTORICAL

FISCAL YEAR	
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AR0071247

Retail Sales

- Key Change Factors from April 2010 to 2011
  - Balance Sheet Recession means lengthy recovery period.
  - Commercial vacancy rates remain high.
  - Construction activity remains at low level for extended period.
  - Higher electric prices to meet 33% renewable goal.
  - Includes Huffman Bill energy efficiency savings as a committed resource.

AR0071248

Forecasted Accumulated Savings
Energy Efficiency and Solar Rooftops

- Components of Change
  - "Committed" LADWP EE programs through FYE 2013.
  - Huffman Bill savings.
  - "Uncommitted" EE will be accounted for as a resource.
  - Solar Rooftop Goal – 148 MW installed by 2020

AR0071249

Retail Sales

- Accuracy
  - EE and Solar were not modeled explicitly in Historical Forecasts.
  - Historical accuracy is -0.1% with a 1.6% deviation. However expect larger variation in accuracy due to uncertainty of new programs.
  - Forecast variation is a function of weather, economic forecasts, meeting program goals and model specification.

AR0071250

Peak Demand

- Cases
  - The variance around the 1-in-2 forecasted peak has widened.
  - Climate change research expects more frequent heat storms to occur of longer duration.
  - Based on the climate change finding, it is now expected that the System will approach its potential more frequently so the distance between the 1-in-10 and 1-in-40 forecasts is compressed.

AR0071251

Peak Demand

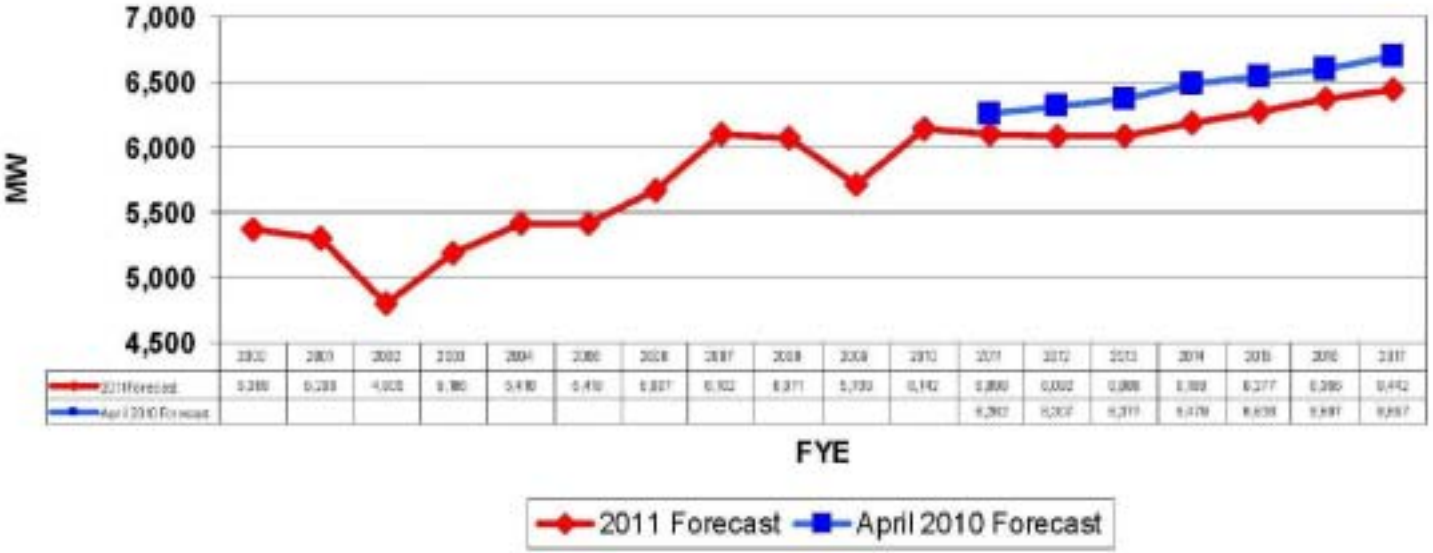
- Annual peak demand is dependent on the severity of the heat storms that are encountered during the year.
- The cases are built on the probability of a weather event occurring in a given year.

Fiscal Year	Base Case	1 in 5	1 in 10	1 in 20	1 in 40
2011-12	5,589	5,887	6,042	6,171	6,282
2012-13	5,639	5,939	6,096	6,226	6,338
2013-14	5,635	5,935	6,092	6,222	6,334
2014-15	5,633	5,933	6,089	6,219	6,331
2015-16	5,725	6,030	6,188	6,320	6,433
2016-17	5,809	6,117	6,277	6,411	6,525
2017-18	5,891	6,203	6,365	6,500	6,616
2018-19	5,952	6,268	6,432	6,569	6,686
2019-20	6,041	6,360	6,527	6,665	6,784
2020-21	6,123	6,447	6,616	6,756	6,876
2021-22	6,211	6,539	6,710	6,852	6,974
2022-23	6,323	6,656	6,830	6,974	7,098
2023-24	6,396	6,733	6,909	7,056	7,181
2024-25	6,471	6,812	6,990	7,137	7,265
2025-26	6,549	6,894	7,074	7,223	7,352
2026-27	6,625	6,975	7,157	7,308	7,438
2027-28	6,701	7,054	7,238	7,391	7,523
2028-29	6,778	7,135	7,321	7,475	7,608
2029-30	6,838	7,198	7,385	7,541	7,676
2030-31	6,926	7,291	7,481	7,639	7,775
2031-32	7,000	7,369	7,560	7,720	7,857
2032-33	7,078	7,450	7,644	7,806	7,945
2033-34	7,157	7,534	7,730	7,894	8,034
2034-35	7,236	7,617	7,815	7,980	8,122
2035-36	7,314	7,700	7,900	8,067	8,210
2036-37	7,393	7,783	7,985	8,154	8,299
2037-38	7,472	7,866	8,070	8,240	8,387
2038-39	7,549	7,946	8,153	8,329	8,478
2039-40	7,626	8,027	8,236	8,410	8,559
2040-41	7,703	8,108	8,319	8,495	8,646

AR0071252

1-in-10 Peak Demand

- Resource Planning.
  - Weather-normalized peak in Summer 2010 was 5589 MW compared to the April 2010 forecast of 5797 MW.
  - The 1-in-10 Peak Demand Forecast is used in the Integrated Resource Plan.



AR0071253

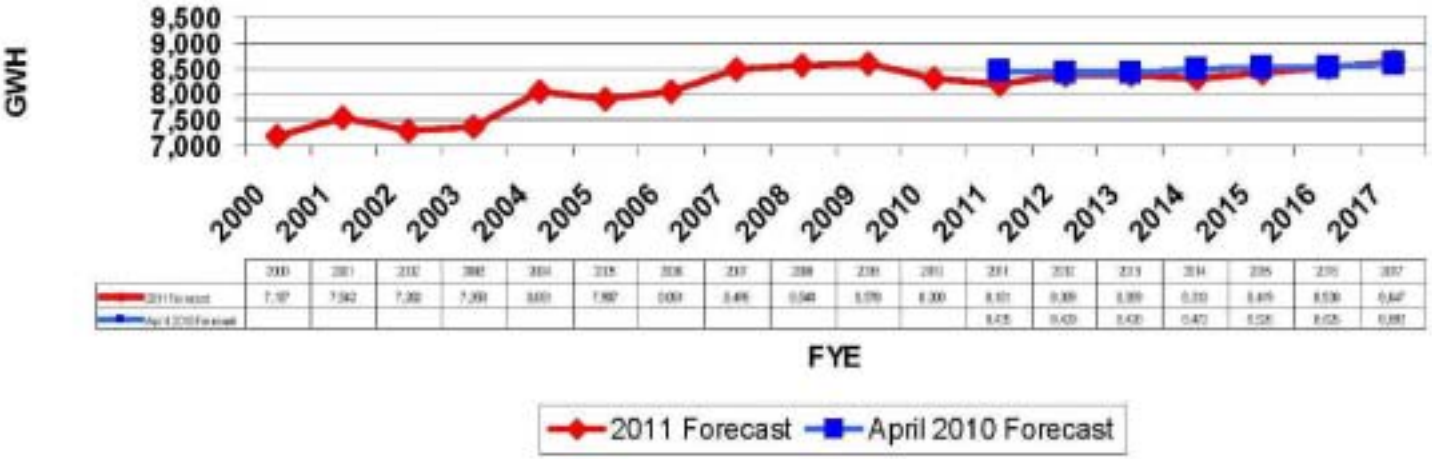
1-in-10 Peak Demand

- Probability accumulates over time.
  - There is a 69% chance of having a 1-in-10 weather event by 2020.
  - There is a 24% chance of having a 1-in-40 weather event by 2020.
  - $P_t=1-(1-P_e)^t$

AR0071254

Residential Energy Sales

- Components of Change
  - Higher weather response. All new units have air conditioning.
  - Fewer units built and higher vacancy factor.
  - Huffman Bill lighting impacts.



AR0071255

Residential Energy Sales

Number of Residential Customers

- Recent Evidence
  - Vacancy rising outstripping the growth in new units.
  - The majority of residential customers live in multi-family units.

2011 Forecast Chartbook

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AR0071256

Residential Sales

12-month Moving Average Sales per Customer

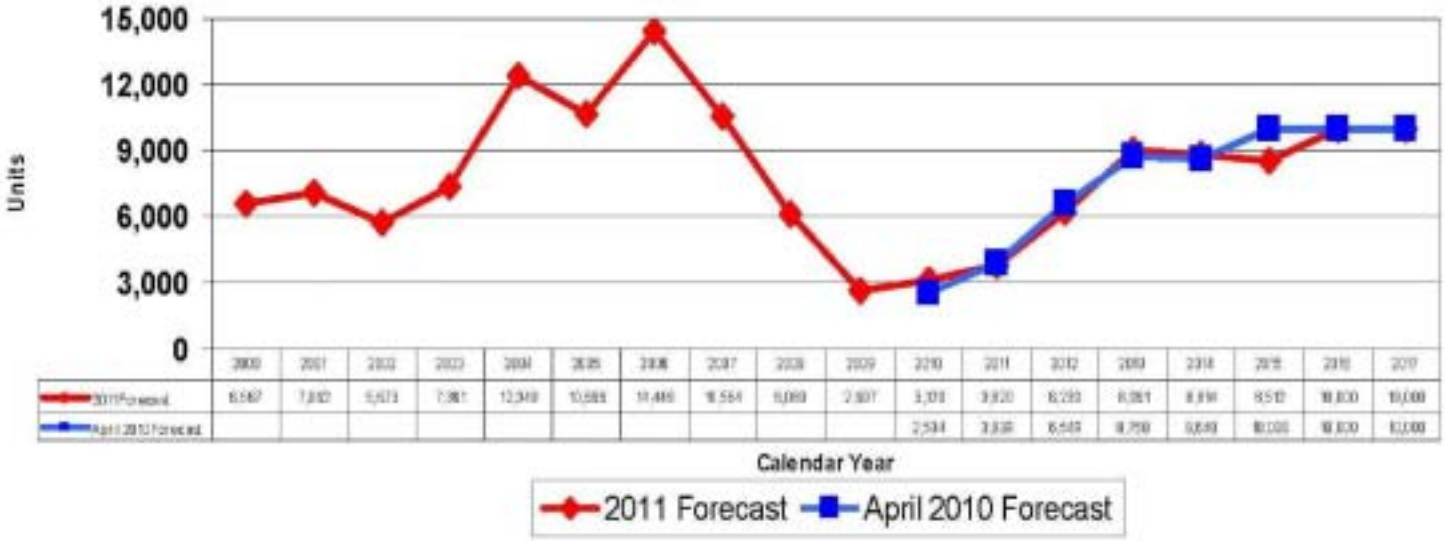
- Recent Evidence
  - Sales per residential customer reached an all-time high of 519 KWH per month in December 2008.
  - The November 2010 rate is 475 KWH per Month.
  - Replacing 2010 summer weather with normal adds 11 KWH to the November 2010 monthly rate.

AR0071257

Residential Energy Sales

New Residential Building Units

- Housing Forecast fundamentally unchanged.
- New units are 20% Single-Family and 80% Multi-family which lowers future average consumption per household.



AR0071258

Residential Energy Sales

Recent Economic Impact

- Real Personal Consumption.
  - Recovery ends and expansion begins in 2012.

39

2011 Forecast Chartbook

AR0071259

Commercial Energy Sales

- Components of Change
  - Commercial construction activity down.
  - Service employment forecast down slightly.
  - Higher real electric prices.
  - Committed energy efficiency included only through 2013. Some forecasted sales beyond 2013 will not be realized at the meter.

AR0071260

Commercial Energy Sales
Number of Commercial Customers

- Recent Evidence
  - The number of commercial customers peaked in June 2006.

2011 Forecast Chartbook

41

AR0071261

Commercial Energy Sales

Twelve-Month Moving Average Sales per Customer

- Recent Evidence
  - Sales per customer per month peaked in July 2008 at 9265 KWH per month.
  - Currently sales per customer per month are 8639 KWH.
  - Adjusting to normal summer weather for 2010 adds 262 KWH to current sales per customer.

AR0071262

Commercial Energy Sales

Local Employment in Service Sector

- LA County Commercial Services Employment
  - Balance Sheet Recession
  - Employment does not return to former level by 2020.

2011 Forecast Chartbook

43

AR0071263

Commercial Energy Sales

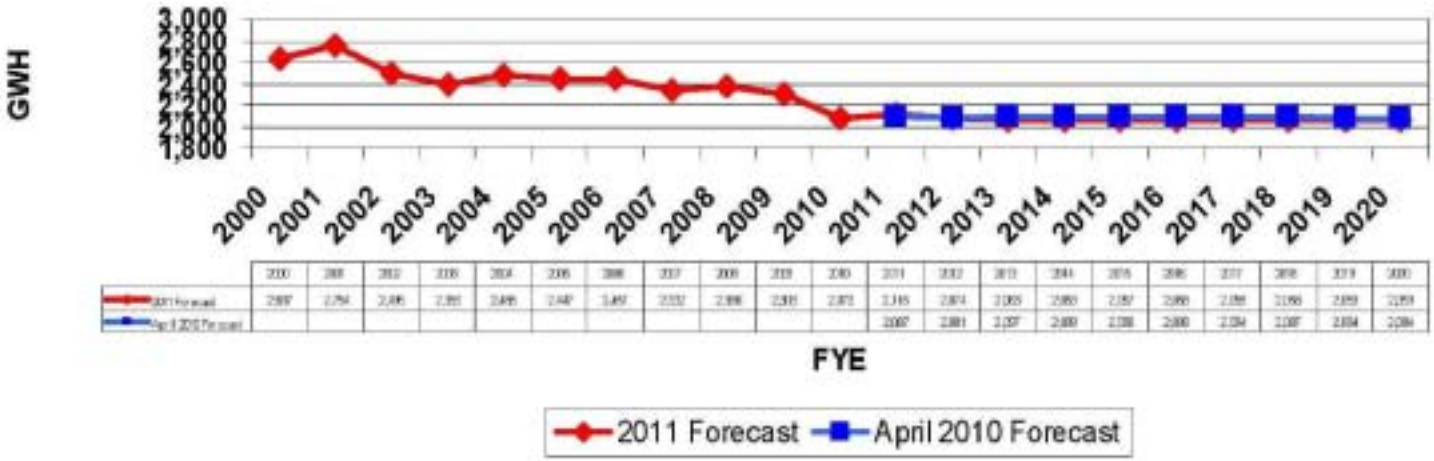
McGraw-Hill Construction Forecast

- Commercial Floorspace Additions
  - Construction activity at historically low levels.
  - Office vacancy rates in San Fernando Valley at 18 percent.
  - New models for delivering commercial services require smaller physical presence.
    - Big Box retailers
    - Internet

AR0071264

Industrial Energy Sales

- Components of Change
  - Land use issue: Once industrial land is vacated, residential and commercial building tend to replace it. 3 percent vacancy rates in the industrial sector.
  - Manufacturing continues to move offshore.
  - Higher real electric prices.
  - No EE or rooftop solar in the Industrial Forecast. All EE and solar assigned to Residential, Commercial and Streetlight sectors.



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Industrial Energy Sales
Number of Customers

- Recent Evidence
  - The number of Industrial customers is continually and relentlessly declining.
  - The decline began in the 1970s.
  - The forecast is for the heavy industries to remain although no new heavy industry will be built. It is the light industry and assembly jobs that are disappearing.

AR0071266

Industrial Sales

Twelve-Month Moving Average Sales per Customer

- Recent Evidence
  - Sales per customer per month peaked in October 2006 at 15018 KWH per month. High consumption partially attributed to a large self-generation unit being off-line at a refinery.
  - Currently sales per customer per month are 13666 KWH.

Industrial Sales
Employment Outlook

- LA County Manufacturing Employment
  - Future employment forecast is slightly positive. If Los Angeles continues to lose manufacturing jobs then there will be a mismatch with the education level of the population and available high paying jobs. It could lead to significant population out-migration.

2011 Forecast Chartbook 48

AR0071268

Plug-in Hybrid Electric Vehicles

Potential New Load Growth

- Adopted the California Energy Commission Forecast.
- Forecast dependent on:
  - Improved battery technology.
  - Implementation of Smart Grid.
  - Implementation of Charging stations

2011 Forecast Chartbook

49

AR0071269

Plug-in Hybrid Electric Vehicles

Uncertainty in Forecast

- California Energy Commission Forecast is approximately 10% of new car sales in 2020 which is at the higher end of independent forecasts.
- Chart courtesy of John Petersen on Seeking Alpha Website.

AR0071270

Plug-in Hybrid Electric Vehicles
Charging Profile Assumption

- Based on EPRI research.
- Load Shape potentially could be engineered to optimize LADWP production function.

2011 Forecast Chartbook

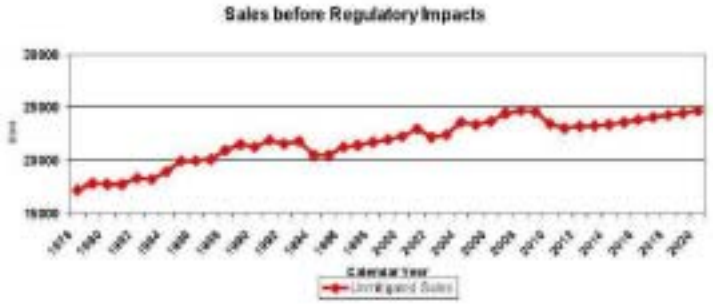
51

AR0071271

Plausibility

- Comparing unmitigated 2011 Sales Forecast to historical sales.
  - Unmitigated means forecasting sales based on economics alone before the impacts of environmental programs are considered.
  - Forecasted sales decline from 2008 to 2011 is largest in the past 30 years.
  - Next decade similar to what occurred in the 1990s before additional regulation.

Peak-to-Through Analysis		
Years	GWH Decline	Percent Decline
2008-2011	1,910	8.3%
1992-1994	1,421	7.0%
2000-2002	572	2.6%
1979-1980	322	1.8%
1981-1982	145	0.8%



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Appendix B Energy Efficiency

Energy Efficiency (EE) is a key strategic element in LADWP IRP planning efforts. EE is a very cost-effective supply-side resource, and serves an important and multi-faceted role in meeting customer demand. One of the most widely recognized examples of EE is the replacement of incandescent lights with compact fluorescent lamp (CFL) bulbs. CFLs consume up to 75 percent less energy than incandescent bulbs while producing an equivalent amount of illumination, and last up to 10 times longer.

The reduction in energy demand that EE enables, translates into a number of benefits:

- Deferred need to build physical generation assets
- Reduced RPS compliance costs
- Reduced environmental footprint, including lower GHG emissions
- Potential for local job creation opportunities

The following subsections summarize the background of LADWP's EE program, and then present the recently completed EE market potential study. Based on the study results, a plan is recommended with identified savings and costs targets. For more specific details regarding the potential study, see the reference at the end of this appendix.

B.1 Background

LADWP has active EE programs that have been in place for several years. Since 2000, LADWP has spent approximately $282 million on its EE programs, which have reduced long-term peak demand and consumption by approximately 303 MW and 1,256 GWh, respectively. LADWP continues its commitment to developing robust, cost-effective EE programs with measurable and verifiable goals.

LADWP offers numerous EE programs and services for residential, commercial, industrial, governmental, and institutional customers to promote the efficient use of energy through the installation of energy efficient equipment. Examples include:

- The Commercial Lighting Efficiency Offer (CLEO), which provides rebates for a variety of high efficiency lighting measures to retrofit existing buildings. The CLEO program enjoys sustained high rates of participation and has achieved 433 GWh of energy savings since 2000.
- The Chiller Efficiency Program, which provides incentives for customers to replace old electric chillers with new, high-efficiency units. Chillers provide space conditioning for larger buildings and the program has reduced associated peak electrical demand by more than 52 MW since 2001.
- The Small Business Direct Install (SBDI) Program, which assists eligible small businesses (A1 rate customers) in Los Angeles in becoming more energy efficient through free lighting assessments and free lighting retrofits (up to $2,500 in cost). SBDI began in 2008 and has achieved 149 GWh of energy savings since its inception.

AR0071273

- The Custom Performance Program, which provides performance-based incentives for energy efficiency measures not included on LADWP's menu-based EE programs. Measures supported include controls and control systems, high efficiency motors, and data server virtualization, The Custom Performance Program has achieved 200 GWh of energy savings since 2006.
- The Refrigerator Exchange Program, which delivers new Energy Star refrigerators to eligible residential customers, and picks-up/recycles customers' old, inefficient refrigerators. This program has replaced and recycled more than 53,000 refrigerators since 2007, achieving an energy savings of 49 GWh.
- A recent program, which distributed two free CFLs to LADWP's 1.2 million residential customers through direct-to-door distribution. The intent of the one-time direct-to-door distribution was to achieve cost effective energy savings and increase customer awareness of this inexpensive, yet effective, EE measure. CFLs are also distributed at events and in connection with other energy efficiency programs.

However successful LADWP's EE program has been, for a variety of reasons it did not meet targets that were set back in 2006. A summary the program since 2006 is presented in Table B-1.

Table B-1. LADWP EE PROGRAM PROGRESS-TO-DATE

	FY 06-07	FY 07-08	FY 08-09	FY 09-10	FY 10-11	Cumulative FY 06-11
LADWP Adopted Targets (2006) - Net GWh	58	275	315	300	280	1,228
Actual Energy Savings Achieved - Net GWh	58	118	270	156	154	756
Actual % of Adopted Target	100%	43%	86%	52%	55%	62%
Actual Energy Savings - Gross GWh	68	139	318	184	181	890
Approved EE Budget ($million)	28	79	77	93	69	346
Revised EE Budget ($million)	n/a	n/a	n/a	>50	50	
Actual EE Funds Spent ($million)	14	38	68	44	50	214
Actual % of Budget	51%	48%	88%	48%	72%	62%
Effective Cost - $/kWh	$0.018	$0.023	$0.018	$0.020	$0.023	

Some key points regarding Table B-1 are as follows:

- The economic outlook in 2006, which the targets were based on, was more elevated then what actually transpired. As the higher outlook in 2006 failed to materialize, in retrospect the prior EE targets were overly ambitious.
- Since 2006, regulatory requirements have increased (OTC, RPS, GHG, etc.), resulting in additional demands outside of the EE program.
- Revenue streams required to support EE programs did not materialize. A spending freeze in 2009 and spending cutback in 2010 resulted in underfunding which hindered the attainment of program goals.

AR0071274

- Actual load profiles were less than forecasted, further affecting program performance.

An assessment of LADWP's EE program was undertaken in 2010. The assessment, also known as a Market Potential Study, includes an updated plan for moving forward.

B.2 Market Potential Study

Per Assembly Bill 2021 (AB 2021), publically owned utilities such as LADWP, must identify and develop all potential achievable, cost-effective EE savings and establish annual targets. Furthermore, utilities are required to conduct periodic "Market Potential" studies to update their forecasts and targets. The most recent study was carried out in late 2010 and is the basis for the EE recommendations contained in this 2011 IRP.

For more in-depth information, see the study referenced at the end of this appendix. This section presents a brief summary of the methodology and findings.

The 2010 Market Potential Study objectives were as follows:

- To estimate savings possible through utility programs and other interventions (such as the American Recovery and Reinvestment Act)
- Identify energy-efficiency technologies and measures that will produce savings
- Link the energy saving measures with utility programs to achieve savings
- Provide guidance for setting 10-year targets for CEC

The analysis methodology is shown in Figure B-1.

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Figure B-1. 2010 Market Potential Study analysis approach.

Some of the key factors that were considered in the study include:

- Changes in the customer base since the last study
- Building codes
- Adoption of new appliance standards
- Naturally-occuring conservation
- Trends in appliance satuations
- How customers use electricity today
- Technological changes in appliances and equipment

The resulting baseline forecast for the overall customer base is shown in Figure B-2.

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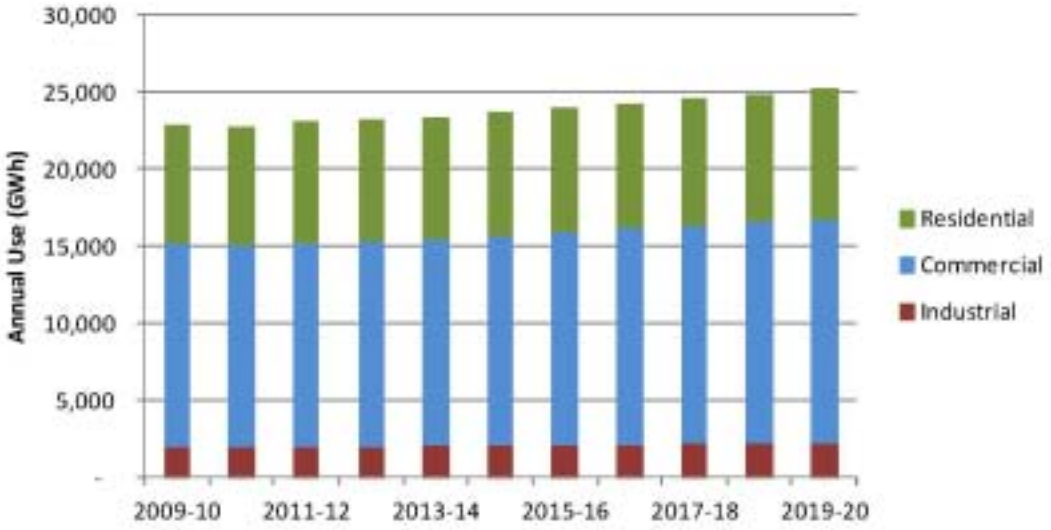

Figure B-2. Baseline forecast results through 2019-20.

Segmented forecasts for the industrial, commercial, and residential sectors are shown in Figures B-3, B-4, and B-5.

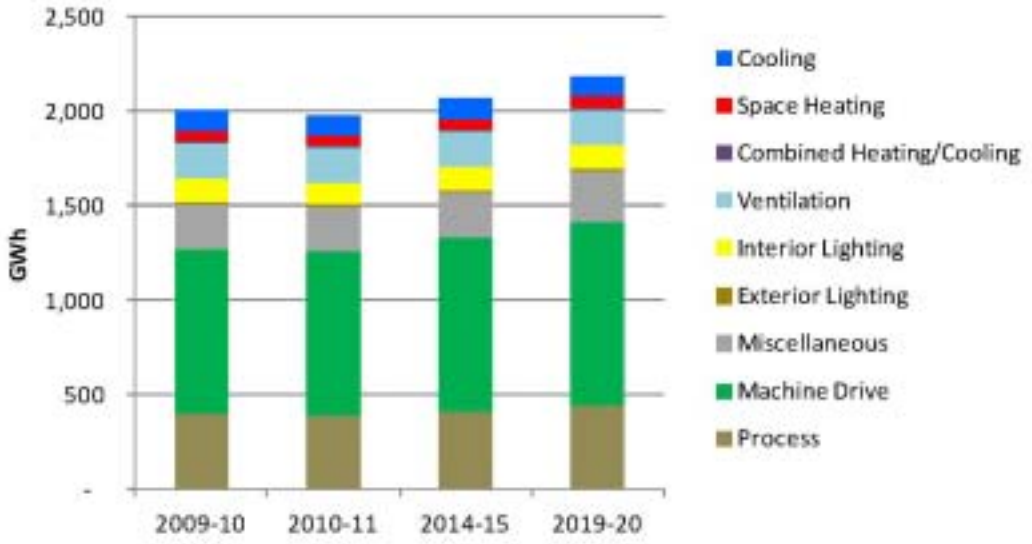

Figure B-3. Industrial sector baseline forecast results.

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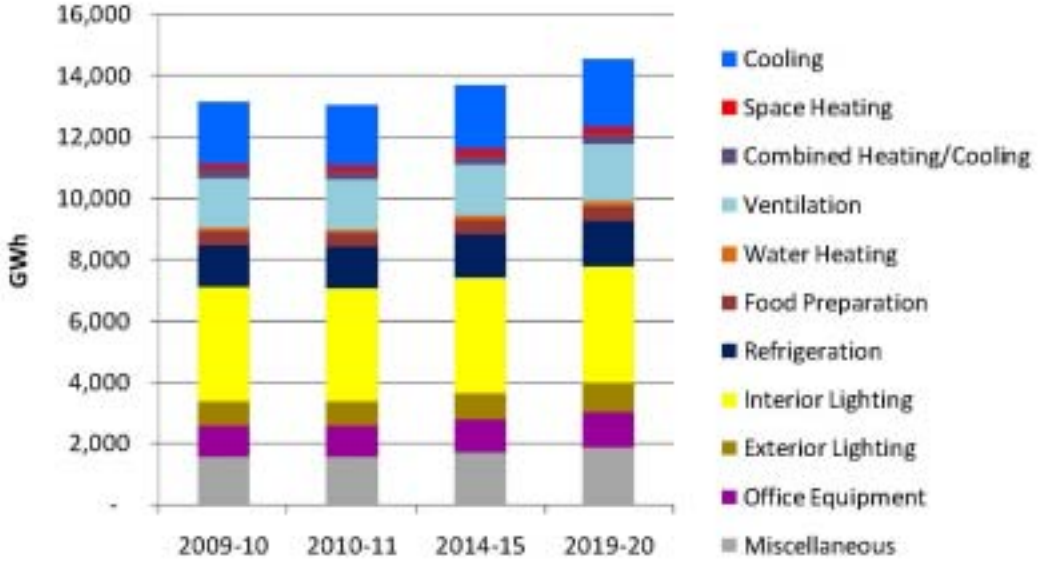

Figure B-4. Commercial sector baseline forecast results.

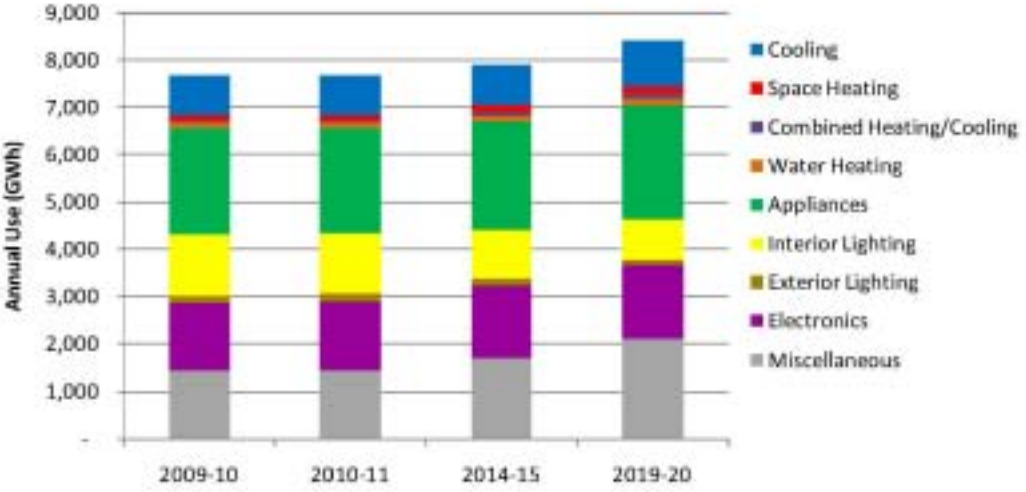

Figure B-5. Residential sector baseline forecast results.

The study evaluated a multitude of measures for potential inclusion into LADWP's EE program, including:

- Existing program elements
- High-efficiency air conditioners (higher efficiency levels, variable refrigerant flow systems)
- High-efficiency lighting (CFLs, LED lamps)
- Upgraded insulation in buildings
- Retrocommissiong and routine maintenance
- Programmable Communicating Thermostats and Energy Management Systems

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B.3 EE Study Results and Plan

To understand the study results the following terms are defined:

2010 Potential Study Definitions

Term	Definition
Technical Potential	Customers are assumes to install most efficient option regardless of costs.
Economic Potential	Customers are assumed to install most efficient cost-effective option.
Maximum Achievable Potential	Sets maximum targets for savings. Assumes "ideal" implementation conditions and customer preferences.
Realistic Achievable Potential	Includes realistic parameters for implementation; incorporates real-world limitations: Advance program potential: Utility pays 100% of incremental cost to upgrade to EE measures. Base program potential: Utility pays 50% of incremental cost.

Key drivers/assumptions influencing EE potential levels are:

- Program budgets are assumed to grow over time
  - Financing impacts
  - Federal grants impact
- Staffing levels and other required resources will increase with program expansion
- Avoided costs will rise with changes to the generations mix

The study found that there is a realistic potential to reduce energy consumption from the baseline forecast by 8.6% by year 2019-20. Figure B-6 shows the cumulative % energy savings through fiscal year 2019-20, and Figure B-7 shows the cumulative absolute savings.

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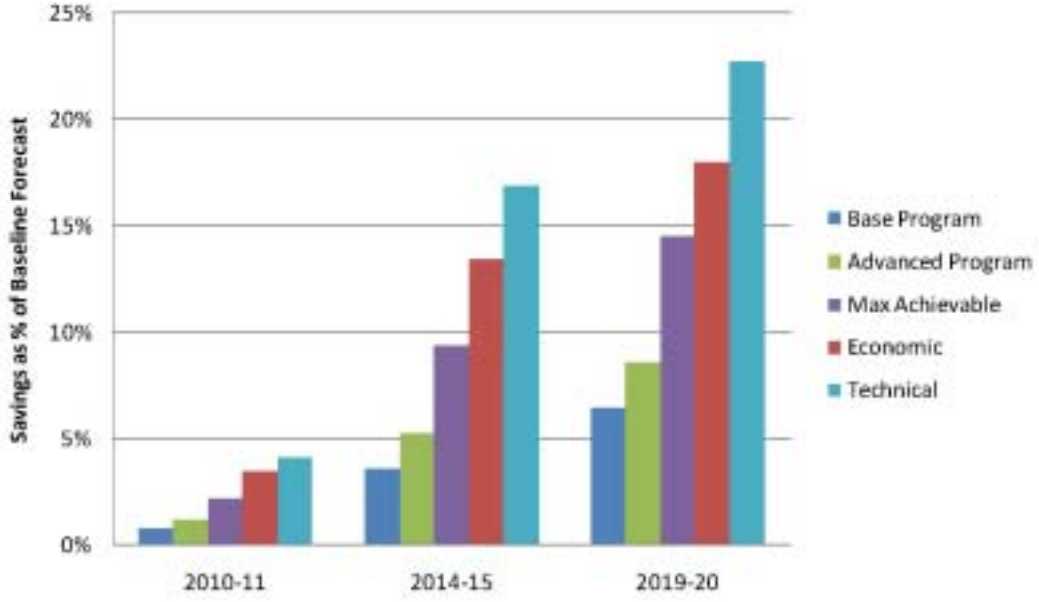

Figure B-6. Cumulative energy savings as a percentage of the baseline forecast.

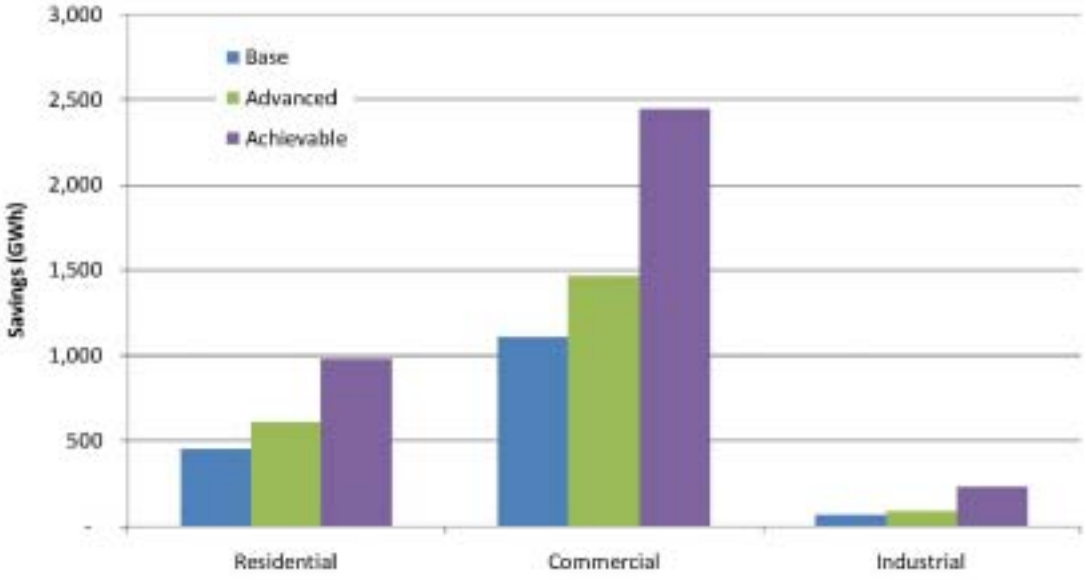

Figure B-7. Cumulative energy savings in GWh.

The Potential Study found that the net present value of avoided energy costs exceeds the NPV of program costs (including incentive payments, administrative costs and customer contributions) in both the Base and Advanced programs. Table B-2 and Figure B-8 illustrate the cost and benefit findings.

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Table B-2. Financial Metrics

	Total Savings (GWh)	Total Cost ($Million)	Total Benefits ($Million)	Net Benefits ($Million)	Benefit/ Cost	Cost of Conserved Energy (cents/kWh)
Base Program	18,719	$1,073	$1,092	$18	1.02	5.73
Advanced Program	25,290	$1,411	$1,483	$72	1.05	5.58
Max Achievable	46,209	$2,139	$2,681	$542	1.25	4.63

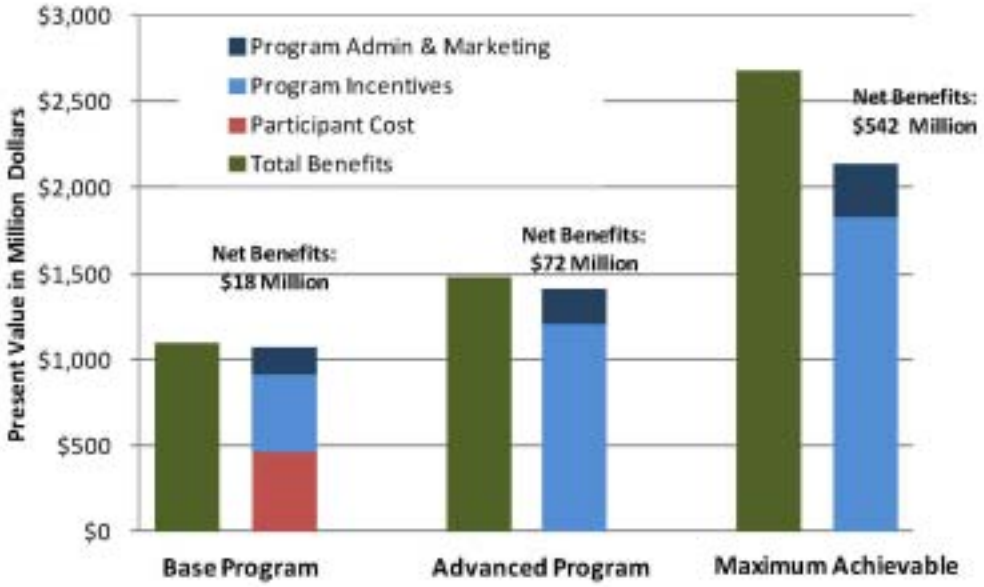

Figure B-8. Cost and benefits for base and advanced programs.

The analysis includes an assessment of the current program portfolio and the development of recommended changes.

Residential Programs

LADWP currently has the following existing residential EE programs:

Consumer Rebate
Refrigerator Turn-In and Recycle
Low Income Refrigerator Exchange
Compact Fluorescent Lamp (CFL) Distribution

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The following recommendations resulted form the 2010 potential study:

1. LADWP should keep its existing programs, with the exception of CFL Distribution which should be replaced with a broader lighting initiative adapted to revised lighting standards.
2. Two new programs should be adopted, (1) Low-income, and (2) Whole House Performance.

A continued effort towards public outreach is also recommended to maintain and broaden public awareness of available EE benefits, and to promote participation.

Figure B-10 illustrates potential residential EE program savings for fiscal year 2019-20.

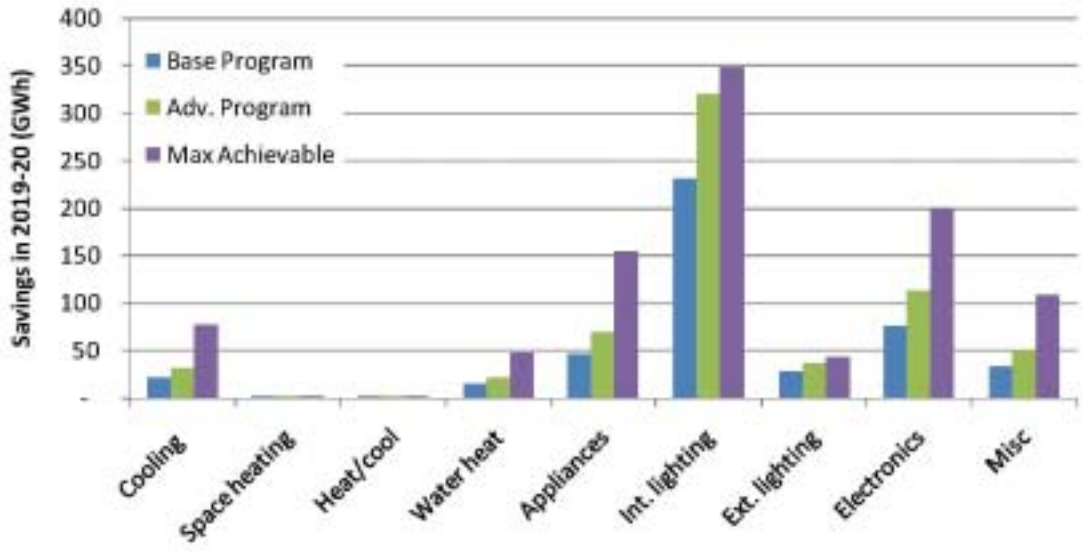

Figure B-10. Potential residential EE program savings in 2019-20.

Commercial and Industrial (C&I)

LADWP currently has the following existing C&I EE programs:

Commercial Lighting Efficiency
Chiller Efficiency
Refrigeration
Customer Performance
Small Business Direct Install
New Construction Incentive
Financing Programs
Energy Audits
Technical Assistance

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The following recommendations resulted form the 2010 potential study:

1. LADWP should keep its existing program elements, but should adapt the lighting program to educate customers on the expanded choices in energy efficiency bulbs available that will comply with new lighting standards.

Figures B-11 and B-12 illustrate potential commercial and industrial savings for year 2019-20.

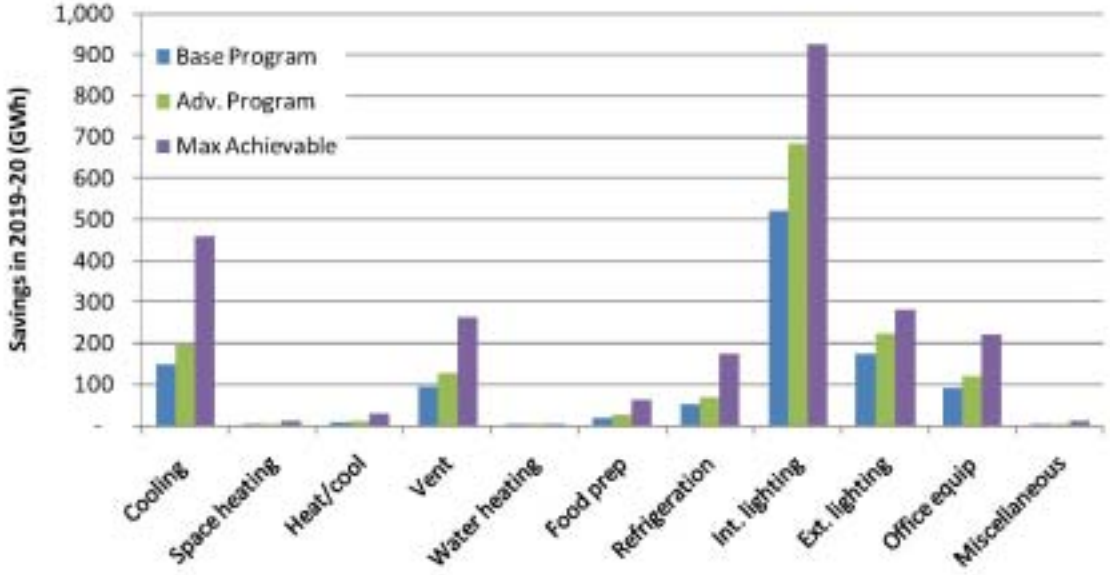

Figure B-11. Projected commercial EE savings in 2019-20.

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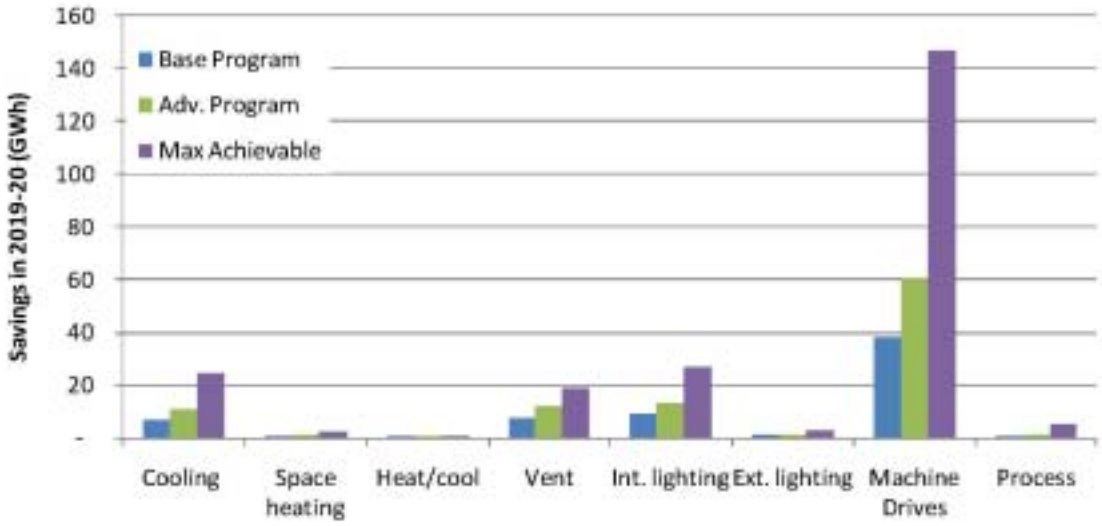

Figure B-12. Projected industrial EE savings in 2019-20.

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B.4 References

1. "LOS ANGELES DEPARTMENT OF WATER AND POWER ENERGY EFFICIENCY AND DEMAND RESPONSE POTENTIAL STUDY VOLUME 1 – ENERGY EFFICIENCY POTENTIAL" prepared by: Global Energy Partners, February 2011.

2. Assembly Bill: "BILL NUMBER: A.B. No. 2021, AUTHOR : Levine, TOPIC : Public utilities: energy efficiency." - "Assembly Bill No. 2021, CHAPTER 734, An act to add Section 25310 to the Public Resources Code, and to amend Section 9615 of the Public Utilities Code, relating to energy efficiency."

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Appendix C Environmental Issues

C.1 Overview

LADWP's mission includes a role as an environmentally responsible public agency. LADWP continues to develop and implement programs to improve the environment, including:

- Increasing the use of renewable energy to meet the needs of LADWP's customers (20 percent by December 31, 2010 and 35 percent by December 2020 through the development of wind, solar, geothermal, and biomass energy sources and acquiring the associated transmission required to transmit such energy to Los Angeles.
- Prioritizing the use of Energy Efficiency (EE), Demand Side Management (DSM), renewable Distributed Generation (DG), and other renewable resources.
- Continuing the modernization of LADWP's in-basin generating stations, including the repowering of four older, less-efficient utility steam boiler units with advanced gas turbine generating units.

This Appendix provides information on a number of environmental issues and policies including oxides of nitrogen (NO_X) emissions, GHGs and climate change, power plant once-through cooling, (OTC), and mercury emissions.

C.2 Emissions of Oxides of Nitrogen (NO_X)

Oxides of nitrogen, or NO_X, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the oxides of nitrogen are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2), is a major precursor for "smog," which can be seen as a reddish-brown layer over many urban areas. Oxides of Nitrogen is also a precursor to the formation of ozone, and the South Coast Air Basin (SCAB), in which Los Angeles is situated, has the one of the highest ozone levels in the United States.

NO_X forms when fuel is burned at high temperatures, as in a combustion process. Figure C-1 shows the primary man-made sources of NO_X as reported by the United States Environmental Protection Agency (U.S. EPA) in 2008.

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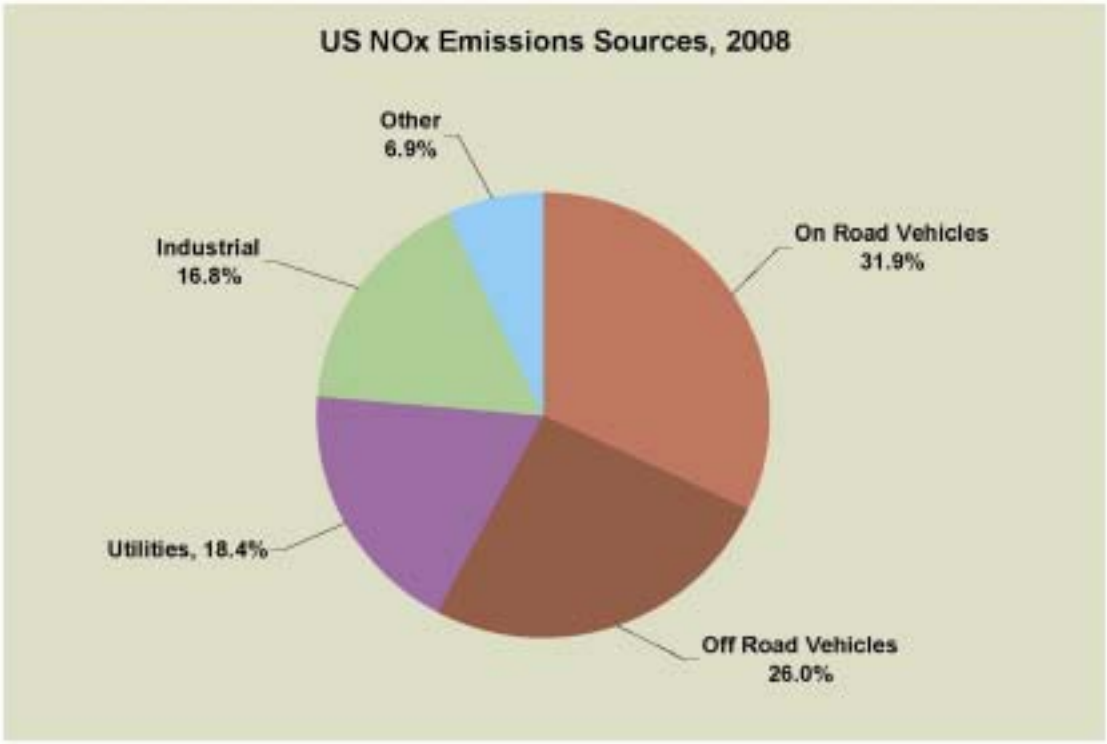

Source: U.S. Environmental Protection Agency

Figure C-1. NO_X emission sources in the U.S.

The SCAB (including Los Angeles, Orange, San Bernardino, and Riverside counties) has some of the worst air quality in the United States due in part to the level of NO_X emissions. The majority of NO_X emissions result from mobile sources such as on-road and off-road vehicles, and not stationary sources such as power plants. The California Air Resources Board (CARB) estimates in its 2010 Almanac of Emissions and Air Quality that emissions in the SCAB will be 742 tons of NO_X per day. This is down from 820 tons per day in 2008 due to greater regulation of stationary sources and more efficient vehicles. Roughly 90 percent of these emissions are from vehicles, as shown in Figure C-2.

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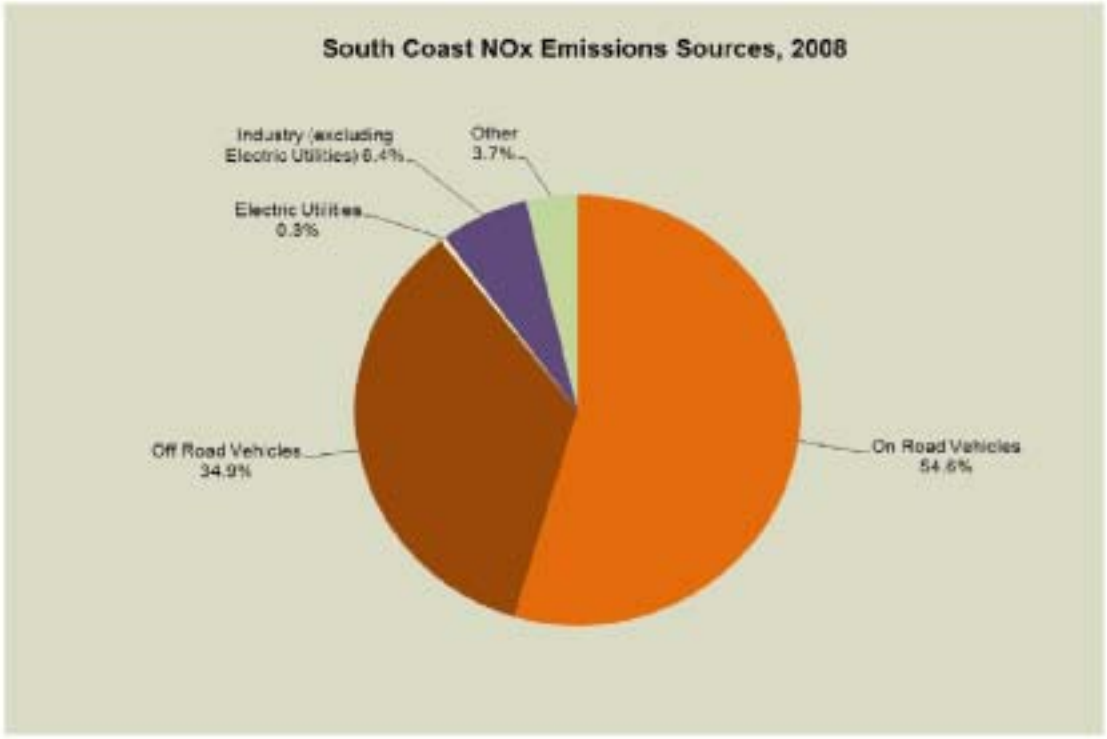

Source: California Air Resources Board, 2008 Estimate

Figure C-2. Local NO_X sources in 2010.

For comparison, the average daily NO_X emissions from LADWP's in-basin generating stations (Harbor, Haynes, Scattergood, and Valley) combined was 0.65 short tons of NO_X per day in 2008, which represents 0.08 percent of the 2008 average daily NO_X emissions in the South Coast Air Basin. The low NO_X emissions from LADWP's in-basin generating stations are due to the use of natural gas at all facilities and the installation of advanced emissions control systems.

Forecasts project that South Coast Air Basin NO_X emissions will continue to decrease over the next decade. Targets for 2015 are 580 tons per day, while the 2020 target is 468 tons per day. The majority of this reduction is expected to come from a reduction in vehicle emissions; total tons emitted from stationary sources during this time period are only projected to decrease from 56 tons per day to 52 tons per day.

A major tool employed by the SCAQMD to reduce NO_X emissions from stationary sources is the RECLAIM (Regional Clean Air Incentives Market) trading program. RECLAIM is a market-driven regulatory program started in 1994 that superseded the SCAQMD's existing NO_X rules for facilities with NO_X emissions exceeding 4 tons per year. These "command and control" rules limited the emission rates of stationary combustion equipment and have been replaced by a facility-wide emissions cap, which gradually declines each year. Facilities receive emission allocations, called RECLAIM Trading Credits (RTCs), in which one credit grants the right to emit one pound of NO_X. Facilities must have sufficient RTCs in their RECLAIM facility accounts to cover their actual emissions. RECLAIM is a market-driven program because the RTCs can

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be bought and sold, which allows for the emissions reductions to be made in the most cost-effective manner.

All of LADWP's in-basin power plants now have advanced pollution control equipment, which reduces NO_X emissions by at least 90 percent. However, the allocation of RTCs to each of LADWP's power plants declines over time, and the entire future allocation of RTCs was reduced about 22.5 percent by the SCAQMD in 2005. Using the resource planning studies and other considerations, the environmental assessment results show that the projections meet LADWP's NO_X goals.

C.3 Greenhouse Gas Emissions and Climate Change

C.3.1 Federal Efforts To Address Climate Change

Federal Climate Change Legislation

Several Congressional bills have been proposed in recent years to regulate GHG emissions under a federal cap-and-trade program, but none have garnered enough support for passage by both the House of Representatives and the Senate. In June 2009, the U.S. House of Representatives took historic action with the passage of H.R. 2454: The American Clean Energy and Security Act of 2009, introduced by Representatives Waxman (D-CA) and Markey (D-MA), which set a goal of 17 percent below 2005 levels by 2020, 83 percent by 2050. The U.S. Senate considered a similar cap-and-trade bill, S. 1733: The Clean Energy Jobs and American Power Act, introduced by Senators Kerry (D-MA) and Boxer (D-CA), which set a goal of 20 percent below 2005 levels by 2020, 83 percent by 2050. Other legislative proposals have offered different approaches, such as the Carbon Limits and Energy for America's Renewal Act, introduced by Senators Cantwell (D-WA) and Collins (R-ME) that focused on a cap-and-dividend that would return a portion of auction revenues to consumers directly or the American Power Act, introduced by Senators Kerry and Lieberman (I-CT). In 2010, focus shifted to the U.S. EPA and the authority it has to regulate GHG emissions under the Clean Air Act (discussed in more details below). Subsequently, four bills were introduced in 2011 that would limit U.S. EPA's authority to regulate GHG emissions in varying degrees, but none were successful.

Federal Regulation of Greenhouse Gases Under the Clean Air Act

In the absence of federal legislation, GHG emissions may still be regulated through the U.S. EPA through its authority under the Clean Air Act. In April 2007, the Supreme Court ruled in *Massachusetts v. EPA* that the U.S. EPA must make a determination when it comes to regulating motor vehicle emissions. The Supreme Court ruling gives the U.S. EPA the authority to regulate GHGs under the Clean Air Act for mobile and stationary sources. On December 7, 2009, the U.S. EPA Administrator signed two distinct findings regarding GHGs under section 202(a) of the Clean Air Act:

- Endangerment Finding: The Administrator found that the current and projected concentrations of the six key well-mixed GHGs--carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)--in the atmosphere threaten the public health and welfare of current and future generations.

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- Cause or Contribute Finding: The Administrator found that the combined emissions of these well-mixed GHGs from new motor vehicles and new motor vehicle engines contribute to the GHG emissions which threatens public health and welfare.

In December 2009, U.S. EPA published its findings in the *Federal Register*, stating: "The Administrator finds that greenhouse gases in the atmosphere may reasonably be anticipated both to endanger public health and to endanger public welfare." The impacts of climate change that will cause harm to human health and welfare of current and future generations include but are not limited to: increased drought; more heavy downpours and flooding; more frequent and intense heat waves and wildfires; greater sea level rise; more intense storms; and harm to water resources, agriculture, wildlife, and ecosystems.

EPA Tailoring Rule for Regulating Stationary Sources under the Clean Air Act

The Environmental Protection Agency finalized its "Tailoring Rule," which establishes a phased timetable for implementing Clean Air Act permitting requirements for GHG emissions from large stationary sources. The rule provides that Prevention of Significant Deterioration (PSD) requirements will first apply to GHG emissions effective January 2, 2011. This initial phase will apply to new and modified facilities that would already be required to obtain PSD permits as a result of their non-GHG emissions, and whose construction will result in an increase in GHG emissions of at least 75,000 tons CO_{2e} per year. A second phase of the program will commence on July 1, 2011, and will impose PSD requirements on new facilities that emit at least 100,000 tons CO_{2e} per year, as well as modified facilities whose emissions will increase by at least 75,000 tons CO_{2e} per year. In addition to these PSD requirements, the Tailoring Rule sets comparable emission thresholds and timetables for new and existing facilities to obtain operating permits under Title V of the Clean Air Act. It is anticipated that LADWP's Scattergood generating station will be subject to the new permitting requirements under the EPA's Tailoring Rule insofar as the permit will be completed in the 2011 timeframe.

C.3.2 Western Climate Initiative (WCI)

Originally established by the Western Governor's Association in February 2007, the WCI is currently a collaboration of California and four Canadian provinces (British Columbia, Manitoba, Quebec, and Ontario) to reduce GHG emissions 15 percent below 2005 levels by 2020 from their power generation, industrial, petrochemical, and transportation sectors. The primary mechanism for achieving this reduction would be through a regional cap-and-trade program.

The WCI finalized its design for a regional cap-and-trade program in July 2010. Under this plan, entities and facilities annually emitting 10,000 metric tons or more of the regulated GHGs, measured in CO_{2e}, will have to begin reporting their 2010 emissions in early 2011. Although the program is scheduled to begin in 2012, the jurisdictions that are expected to move forward have all indicated they will not be ready for compliance to begin until January 1, 2013. The first phase of the cap-and-trade program will cover power generation, including electricity imported into the WCI region, industrial fuel combustion, industrial processes, and petrochemical companies emitting 25,000 metric tons or more of CO_{2e} each year. The second phase will begin in 2015 and will cover emissions from transportation fuel use as well as residential and commercial fuel use. Before WCI jurisdictions will be able to trade allowances between each other, separate linkage agreements will be required that establish the conditions for interfacing between trading systems.

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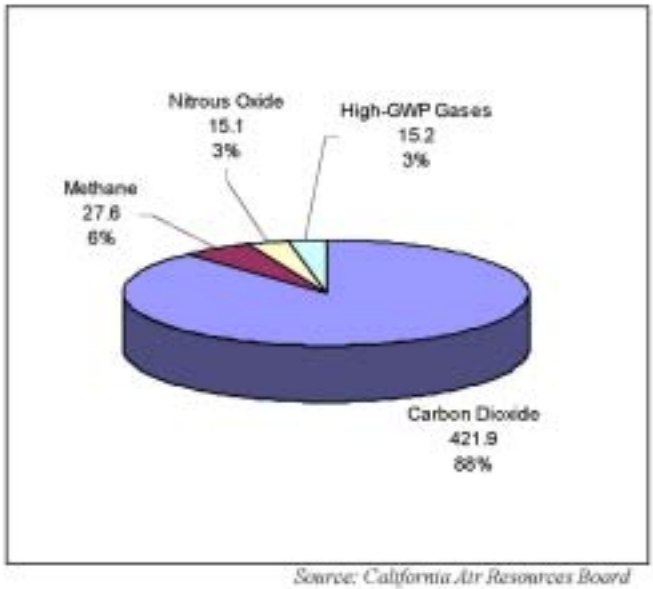
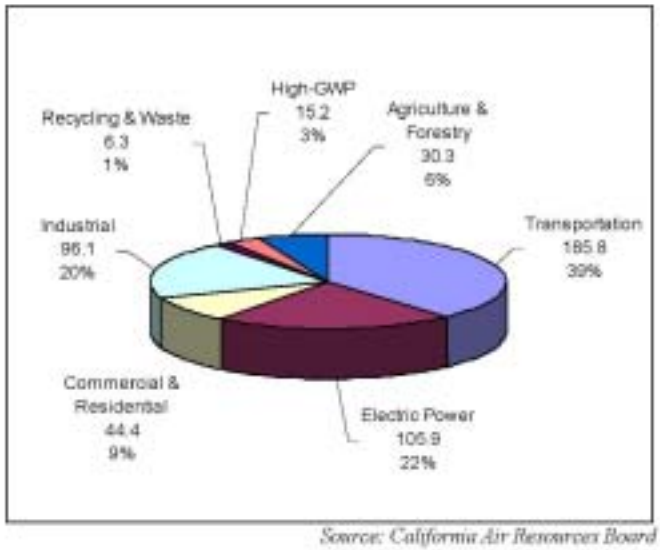
C.3.3 California Efforts to Address Climate Change

This section describes California's GHG emissions inventory and policies and actions to reduce GHG emissions. Figures C-3 and C-4 show California's 2006 statewide GHG emissions by pollutant and by sector.



Source: California Air Resources Board

Figure C-3. California GHG emissions by GHG (2006)



Source: California Air Resources Board

Figure C-4. California GHG emissions by sector (2006)

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Based on the ARB's Update to the Scoping Plan (2011), the 2020 emissions baseline used in the 2008 Scoping Plan is 596 $MMTCO_{2e}$. This estimate of statewide 2020 emissions was developed using pre-recession 2007 IEPR data and reflects GHG emissions expected to occur in the absence of any reduction measures in 2010. ARB staff re-evaluated the baseline in light of the economic downturn and updated the projected 2020 emissions to 545 $MMTCO_{2e}$. Two reduction measures (Pavley I and the Renewables Portfolio Standard (12% - 20%)) not previously included in the 2008 Scoping Plan baseline were incorporated into the updated baseline, further reducing the 2020 statewide emissions projection to 507 $MMTCO_{2e}$. The updated forecast of 507 $MMTCO_{2e}$ is referred to as the AB 32 2020 baseline. Reduction of an estimated 80 $MMTCO_{2e}$ are necessary to reduce statewide emissions to the AB 32 Target of 427 $MMTCO_{2e}$ by 2020.[1]

California Governor's Executive Order S-3-05

On the state level, Governor Schwarzenegger signed Executive Order #S-3-05 on June 1, 2005 which established the following GHG targets:

- By 2010, reduce emissions to 2000 levels
- By 2020, reduce emissions to 1990 levels
- By 2050, reduce emissions to 80 percent below 1990 levels.

California SB 1368: Greenhouse Gas Emissions Performance Standard

SB 1368 was signed into law on September 29, 2006 and requires the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) to establish a GHG emissions performance standard and implement regulations for all long-term financial commitments in baseload generation made by load serving entities (LSEs) including local publicly-owned electric utilities (POUs). The CPUC adopted its regulations for the investor-owned utilities and other LSEs in January, 2007. The CEC adopted similar regulations for POUs in August 2007. Strategies implemented by the CPUC and CEC under SB 1368 are expected to result in a combined GHGs emissions reduction of over 15 million metric tons (MMT) CO_{2e} by 2020. The GHG emissions performance standard is based on the emissions profile of combined-cycle, natural gas fired generating units. The CEC's regulations establish an emissions performance standard of 1,100 pounds (0.5 metric tons) of CO_2 per megawatt hour (MWh) of electricity. This standard was established in consultation with the CPUC and the CARB and is the same as the emissions performance standard adopted by the CPUC for the LSEs.

The broad objectives of these regulations are to internalize the significant and under-recognized cost of emissions and to reduce potential financial risk to California consumers for future emission control costs. Specifically, these regulations are intended to prohibit any LSE from entering into or renewing a long-term financial commitment for baseload generation that exceeds the GHG emissions performance standard, currently set at 1,100 pounds per MWh.

[1] ARB Status of Scoping Plan Recommended Measures.
http://www.arb.ca.gov/cc/scopingplan/status_of_scoping_plan_measures.pdf

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These regulations would require POUs, within 10 days of making a long-term financial commitment in a baseload facility, to certify to the CEC that such a commitment complies with these regulations and provide back-up material to support such commitment. The regulations then provide for CEC review of these compliance filings and a determination of whether or not the commitment, and the underlying facility as described in the commitment, complies with these regulations. Additionally, the CEC may open an investigatory proceeding and gather additional information if it believes that covered procurements made by a POU do not comply with these regulations.

AB 32: The California Global Warming Solutions Act of 2006

In 2006, the California Legislature passed and Governor Schwarzenegger signed Assembly Bill 32, the Global Warming Solutions Act of 2006, which declared that global warming poses a serious threat to the economic well-being, public health, natural resources, and environment of California. It set into law a 2020 GHG emissions reduction goal that would require the reduction of statewide emissions of GHGs[2]. In 2007, the ARB established a 1990 statewide greenhouse gas emissions baseline of 427 MMT of carbon dioxide equivalent (CO_2e)[3] and adopted a regulation for mandatory emissions reporting from the most significant sources that contribute to statewide emissions, including all electricity consumed in the state as well as imported electricity. The 2020 target was set at the 1990 baseline level of 427 MMT CO_2e.

The AB 32 Scoping Plan

In December 2008, the CARB adopted the AB 32 Scoping Plan, which serves as California's blueprint for reducing greenhouse GHG emissions. Key elements of the AB 32 Scoping Plan's recommendations for reducing California GHG emissions to 1990 levels by 2020 include:

- Expanding and strengthening existing energy efficiency programs as well as building and appliance standards
- Achieving a statewide renewables energy mix of 33 percent
- Developing a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system
- Expand use of Combined Heat and Power (CHP) by 30,000 GWh statewide
- Establishing targets for transportation-related GHG emissions for regions throughout California, and pursuing policies and incentives to achieve those targets.
- Adopting and implementing measures pursuant to existing State laws and policies, including California's clean car standards, goods movement measures, and the Low Carbon Fuel Standard.
- Creating targeted fees, including a public goods charge on water use, fees on high global warming potential gases, and a fee to fund the administrative costs of the state's long term commitment to AB 32 implementation.

[2] GHGs covered by AB 32 include the following: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

[3] Carbon dioxide equivalent or CO_2e means the amount of carbon dioxide by weight that would produce the same global warming impact as a given weight of another greenhouse gas, based on the best available science, including from the Intergovernmental Panel on Climate Change.

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All programs developed under AB 32 contribute to the reductions needed to achieve this goal, and will deliver an overall 15% reduction in greenhouse gas emissions compared to the "business-as-usual" scenario in 2020 if nothing was done at all. In 2010, the ARB made revisions to the expected 2020 emission reductions in consideration of the economic recession and the availability of updated information from development of measure specific regulations. ARB staff re-evaluated the baseline in light of the economic downturn and updated the projected 2020 emissions to 545 MMTCO$_2$e. Two reduction measures (Pavley I and the Renewables Portfolio Standard (12% - 20%)) not previously included in the 2008 Scoping Plan baseline were incorporated into the updated baseline, further reducing the 2020 statewide emissions projection to 507 MMTCO$_2$e. The updated forecast of 507 MMTCO$_2$e is referred to as the AB 32 2020 baseline. Reduction of an estimated 80 MMTCO$_2$e are necessary to reduce statewide emissions to the AB 32 Target of 427 MMTCO$_2$e by 2020.

Executive Order S-21-09

On September 15, 2009, Governor Schwarzenegger signed Executive Order S-21-09, which, among other things, ordered CARB to work with the Commissions to ensure that a regulation adopted under authority of AB 32 to encourage the creation and use of renewable energy sources shall build upon the RPS program developed to reduce GHG emissions in California and shall regulate all California publicly owned utilities, like LADWP. In addition, Executive Order S-21-09 provides that CARB may delegate policy development and implementation to Commissions, that CARB is to consult with the CAISO and other balancing authorities on impacts on reliability, renewable integration requirements and interactions with wholesale power markets in carrying out the provisions of Executive Order S-21-09, and that CARB is to establish the highest priority for those resources with the least environmental costs and impacts on public health that can be developed most quickly and that support reliable, efficient, and cost-effective electricity system operations including resources and facilities located throughout the Western Interconnection.

AB 32 Cap-and-Trade Regulation (Adopted October 20, 2011)

The cap-and-trade program is a key element in California's climate plan. The cap-and-trade program sets a statewide limit on sources responsible for 85 percent of California's greenhouse gas emissions, and establishes a price signal needed to drive long-term investment in cleaner fuels and more efficient use of energy. The program is designed to provide covered entities the flexibility to seek out and implement the lowest-cost options to reduce emissions. The program covers about 350 businesses, representing 600 facilities and it starts in 2013 for electric utilities and large industrial facilities, while distributors of transportation, natural gas and other fuels join in 2015. The ARB expects to link with similar trading programs in the four Canadian provinces of British Columbia, Manitoba, Quebec and Ontario on or after 2013. Starting in 2013, the cap starts at about 2 percent below the emissions level forecast for 2012 and declines about 2 percent in 2014. From 2015 to 2020, the cap trajectory declines about 3 percent annually from 2015 to 2020.

Although the program commences on January 1, 2012, compliance and enforcement with the program is delayed until January 1, 2013, with the first auctions scheduled for August and November 2012. At the time the ARB Board adopted the cap-and-trade regulation, the Board

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directed staff to address several key outstanding issues as part of a new rulemaking scheduled to take place in 2012 that will ultimately make further refinements to the program before compliance begins. Two of those issues that LADWP will focus on in 2012 include the provisions surrounding resource shuffling and point of regulation for electricity imports. The resource shuffling provision has potential implications for LADWP's coal transition as it relates to Navajo Generating Station if divestiture is not recognized by ARB as an emission reduction. The point of regulation for electricity imports was changed by ARB staff from the entity that owns the power being imported to California to the entity that schedules the power into California. LADWP will continue to work with other utilities and the ARB to better understand the potential implications this may have on reporting of specified electricity imports (high-emitting as zero-emitting electricity) by parties that do not retain ownership of that power.

C.3.4 The City of Los Angeles GREEN LA Plan

On May 15, 2007, Los Angeles Mayor Antonio Villaragosa released the "GREEN LA – An Action Plan to Lead the Nation in Fighting Global Warming" (GREEN LA Plan) that has an overall goal of reducing the GHG emissions by 35 percent below 1990 levels by 2030. This goal exceeds the targets set by both California and the Kyoto Protocol and is the greatest reduction target of any large U.S. city. Key strategies listed in the GREEN LA Plan related to energy and water include the following:

Energy

Green the Power from the Largest Municipal Utility in the United States

- Meet the goal to increase renewable energy from solar, wind, biomass, and geothermal sources to 20 percent by 2010.
- Increase the efficiency of natural gas-fired power plants.
- Increase biogas co-firing of natural gas-fired power plants.

Make Los Angeles a Worldwide Leader In Green Buildings

- Establish a comprehensive set of green building policies to guide and support private sector development designed to reduce carbon dioxide emissions by 80,000 tons by 2012. Approved on April 22, 2008, the Private Sector Green Building Plan makes Los Angeles the largest city in the nation to adopt such a plan.
- Implement other related Green Buildings efforts. For example, (e.g., all City-owned buildings over 7,500 square feet will be required to meet LEED Silver Standards). Other efforts, including the adoption of respective ordinances and updating of applicable building codes, will enable the City of Los Angeles to transform its building stock in both the public and private sector thereby facilitating all buildings to operate in a more energy efficient manner consistent with technological innovations and economic incentives whenever possible.

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Transform Los Angeles Into the Model of an Energy Efficient City

- Reduce energy use by all City departments to the maximum extent feasible
- Complete energy efficiency retrofits of all City-owned buildings to meet a 20 percent or more reduction in energy consumption.
- Install the equivalent of 50 "cool roofs" per year by 2010 on new or remodeled City buildings
- Install solar heating for all City-owned swimming pools
- Improve energy efficiency at drinking water treatment and distribution facilities. Maximize energy efficiency of wastewater treatment equipment
- Replace 140,000 conventional street lights with Light emitting diode (LED) green street lights, reducing carbon emissions by 40,500 tons per year and saving the city $10 million annually

Help Angelenos Be "Energy Misers"

- Distribute two compact fluorescent light (CFL) bulbs to each of the 1.2 million households in the City
- Increase the level and types of customer rebates for energy efficient appliances, windows, lighting, and heating and cooling systems.
- Increase the distribution of energy efficient refrigerators to qualified customers
- Create a fund to "acquire" energy savings as a resource from LADWP customers

Water

- Decrease Per Capita Water Use
- Meet all additional demand for water resulting from growth through water conservation and recycling.
- Reduce per capita water consumption by 20 percent.
- Implement the City's innovative water and wastewater integrated resources plan that will increase conservation and maximize use of recycled water, including capture and reuse of storm water.
- Meet city directives and ordinances with respect to water conservation. Monitor technological improvements with respect to equipment, appliances, and engineered systems that would reduce the water consumption of various buildings and related need to adopt relevant ordinances and update municipal codes consistent with cost-effective technology available in the marketplace

C.3.5 LADWP's Efforts To Address Climate Change

Since 1998, LADWP has taken steps to move away from dependence on coal generating resources, including the divestiture of power purchase agreements with Colstrip and Coronado Generating Stations, the shutdown of Mohave Generating Station in December 2005, and the discontinuation of involvement in the development of Unit 3 at Intermountain Generating Station. Table C-1 shows the downward trajectory in LADWP's power generation portfolio CO_2 emissions and CO_2 emissions intensity between 1990 and 2008.

Table C-1. HISTORICAL LADWP POWER GENERATION CO_2 EMISSIONS

Year	Total CO_2 Emissions from Owned & Purchased Generation (metric tons)	Total CO_2 Emissions from Owned & Purchased Generation minus Wholesale Power Sales (metric tons)	Total Owned & Purchased Generation (MWh)	LADWP System CO_2 Intensity Metric (lbs CO_2/MWh)
1990	17,925,410	17,764,874	25,481,532	1,551
2000	18,464,480	16,992,238	28,806,750	1,413
2001	18,086,034	16,663,305	28,032,375	1,422
2002	16,873,841	16,237,832	26,808,569	1,388
2003	17,274,623	16,710,232	27,337,694	1,393
2004	17,609,759	16,604,943	28,138,391	1,380
2005	16,928,681	15,854,278	28,301,700	1,319
2006	16,838,147	15,885,136	29,029,883	1,279
2007	16,461,774	15,523,035	29,141,703	1,245
2008	16,232,608	15,650,115	29,394,809	1,217
2009	14,651,016	13,834,001	28,041,998	1,152
2010	13,771,166	12,623,181	27,490,842	1,104
Difference between 1990 and 2010	-4,154,245	-5,141,693	2,009,310	-446
% Change from 1990	-23%	-29%	8%	-29%

Notes:
1. Calculated CO_2 emissions using fuel data and fuel-specific emission factors from the California Registry's reporting protocols.
2. Used source specific data where available, and 1100 lbs CO_2/MWh for unspecified power purchased.

SF6 Emissions

In February 2010, CARB adopted a new regulation to reduce SF6 emissions from gas insulated electrical switchgear as part of the AB 32 program. This new regulation, which is scheduled to take effect starting Jan 1, 2011, imposes a declining limit on a utility's annual average SF6

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emissions rate starting at 10 percent in 2011 and decreasing to 1 percent in 2020, as well as new recordkeeping and reporting requirements.

Over the past decade, LADWP has been proactive in reducing SF6 emissions by implementing its own internal program to reduce emissions through equipment replacement, repair, and process improvements. As a result, LADWP's 2008 SF6 emissions rate was slightly under 1 percent. This voluntary effort to reduce SF6 emissions demonstrates LADWP's commitment to environmental stewardship and puts LADWP in a good position to comply with the new emission limits imposed by the SF6 regulation.

LADWP's Historical Accomplishments in Reducing GHG Emissions

In 1995, LADWP signed a Climate Challenge Participation Accord with the U.S. Department of Energy (DOE), voluntarily committing to reduce GHG emissions from power generation to keep LADWP's average CO_2 emissions from 1991 - 2000 below its 1990 baseline. LADWP achieved this goal. In addition, LADWP voluntarily participated in DOE's EIA-1605b "Voluntary Reporting of Greenhouse Gases" program from 1995 – 2005, annually reporting CO_2 emissions from power generation as well as programs to reduce emissions.

In 2000, LADWP set a new goal in its Integrated Resource Plan to reduce GHG emissions five percent below 1990 levels by 2008. LADWP exceeded this goal (actual 2008 power generation portfolio CO_2 emissions were 9.3 percent lower than our 1990 baseline).

In 2002, LADWP became a charter member of the California Climate Action Registry, and has since reported and certified eight annual entity-wide GHG emissions inventories with the Registry.

C.3.6 LADWP Programs and Projects to Reduce CO_2 Emissions

Since 1990, LADWP has undertaken numerous programs to reduce CO_2 emissions. Tables C-2 and C-3 below show the variety of LADWP's emission reduction programs and reductions achieved.

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Table C-2. EMISSION REDUCTION PROGRAMS

Years	Program	Description	Cumulative CO_2 Emissions Avoided or Sequestered (short tons)
Renewable Energy			
2004-2008	Renewable Energy	LADWP's goals are to achieve 20% RPS by 2010 and 35% RPS by 2020.	3,521,102
Water Conservation			**3,129,099**
1991-2008	Water Conservation Program	Encourage customers to conserve water with rebates for installing hardware such as ultra-low-flush toilets and low-flow shower heads, a rate structure that rewards conservation, and public education.	Hardware: 1,771,814 Behavior: 1,311,324 3,083,139
1999-2008	High efficiency clothes washers	Rebates for purchase of energy efficient residential & commercial clothes washers.	45,960
Energy Efficiency			**1,738,544**
1999-2008	Refrigerator Replacement	Sale of high efficiency refrigerators at discount prices to multi-family residential units and non-profit organizations that are DWP customers, and removal & recycling of old refrigerators.	27,606
1999-2008	Commercial Lighting	Incentives for small commercial customers to install lighting equipment that exceeds Title 24 standards.	935,781
1999-2008	HVAC Replacement	Incentives for small commercial customers to install HVAC equipment that exceeds Title 24 standards. Expanded to include residential HVAC units from 2000-2002.	236,440
2000-2008	Chiller Replacement	Incentives for businesses and hospitals to install new high-efficiency water or air-cooled chillers that exceed Title 24 standards.	285,894
2002-2008	Consumer Rebate	Rebates to residential customers for purchase & installation of Energy Star appliances, lighting, windows, and HVAC.	105,737
2004-2008	Refrigerator Retirement	Free pick-up and recycling of old spare refrigerators for residential customers.	54,164
2004-2008	CFL Distribution	Free compact florescent light bulbs to residential customers.	42,818
2006-2008	Non-Residential Refrigeration	Rebates for non-residential customers to improve the energy efficiency of refrigeration equipment, reduce energy consumption in cold storage facilities, and install high efficiency refrigerated cases and equipment.	4,142

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Table C-2. EMISSION REDUCTION PROGRAMS

Years	Program	Description	Cumulative CO_2 Emissions Avoided or Sequestered (short tons)
(Continued from page C-15)			
2006-2008	Small Business Direct Install	Provide free energy assessments, recommend lighting improvements, and install lighting upgrades to assist small business customers become more energy efficient.	30,001
2007-2008	New Construction	Incentives for building to LEED or CHPS 2006 standards, or for installing equipment from an approved list of energy efficient products.	133
2007-2008	Custom Performance	Incentives for non-residential customers to install energy saving measures, equipment or systems that exceed Title 24 or minimum industry standards such as equipment controls, industrial processes and other innovative energy saving strategies.	15,826
Digester and Landfill gas-to-energy			**1,152,479**
1995-2008	Scattergood	Burn digester gas from Hyperion Wastewater Treatment Plant at Scattergood Generating Station to generate electricity.	1,139,881
2002-2007	Lopez Canyon	Burn landfill gas in micro turbines at Lopez Canyon Landfill to generate electricity.	12,599
Recycling			**159,034**
1998-2008	Recycling Program	Recycling of paper, cardboard, metals and other materials from LADWP facilities.	440,136
Electricity Generation & Distribution System			**61,497**
1999-2008	Solar Power	LADWP's Solar Power Program includes: • Customer systems (net metered) • LADWP and City facilities (grid connected).	61,497
Tree Planting (Urban Forestry)			**195,545**
1998-2008	Cool Schools	Planted 9274 trees (cumulative) at LA Unified School District campuses.	48,187
2001-2008	Trees for a Green LA	Distributed 114,427 trees (cumulative) for planting around customer homes and in community areas.	138,793
2007-2008	Million Trees LA	Distributed 23,958 trees (cumulative) for planting around the City of Los Angeles.	8,565
Miscellaneous			**3,638**
2000-2008	Energy Star Office Equipment	Use of Energy Star office equipment (computers & monitors, printers, copiers and FAX machines).	3,638
Total CO_2 Emissions Avoided / Sequestered (Current Programs)			**6,436,197**

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Table C-3. COMPLETED / DISCONTINUED PROGRAMS FOR EMISSION REDUCTION

Years	Program	Description	Cumulative CO_2 Emissions Avoided or Sequestered (short tons)
Energy Efficiency			**175,526**
1999-2001	Neighborhood Bill Reduction Service	Provide free CFLs, clean refrigerator condenser coils, distribute low-flow shower heads & aerators, and check for toilet leaks for residential low income customers.	154,108
1999-2001	Commercial Refrigeration Tune-up	Free audits and tune-ups of refrigeration equipment for small commercial customers.	3,856
2000-2002	HVAC Tune-up	Low cost tune-ups of A/C equipment for commercial and residential customers.	17,510
2005	Efficient Motors	Incentives for commercial & industrial customers to install premium efficiency electric motors.	52
Building Energy Efficiency Retrofits			**101,056**
1999-2004	John Ferraro Building Lighting Retrofit	Eliminated 50% of the light fixtures, replaced the remaining fixtures with energy efficient equipment, and installed automatic lighting controls in LADWP's corporate office building.	89,220
2001-2002	Cool Roofs	Incentives to install Energy Star roofing product on commercial or multi-family residential buildings (state funded).	4,164
2001-2004	Reflective Window Film	Incentives to install reflective film on windows to reduce building solar heat gain and reduce A/C load.	3,848
2004-2005	City Building Retrofit	Retrofit 37 City of LA facilities with energy efficient lighting.	2,604
2006	City Energy Efficiency Loan	Loans to other city departments to implement energy efficiency measures.	1,220
Electricity Generation & Distribution System			**9,266**
1996-2005	Energy Efficient Transformers	1592 Energy Star transformers were purchased in 1995 & installed in LADWP's distribution system.	9,266
Total CO_2 Emissions Avoided (Completed Projects / Discontinued Programs)			**297,610**

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Additional actions and changes in LADWP's generation resource mix from 1990 to 2009 include

- Replacement of two steam generators in each of Palo Verde Nuclear Generating Station's (PVNGS) three generating units, to provide for the continued use of the units to the end of their projected 40-year life and possibly through their 20-year extended life. The project began in 2003 and was completed in 2007. The replacement of the steam generators and the turbine rotors resulted in an increase in power output of approximately 210 MWs for PVNGS.
- The seven units of the Castaic Pump Storage Power Plant (Castaic Plant) are currently being rotated out of service for modernization. This multi-phase process, began in 2004 and is expected to continue through 2013. To date, modernization to five units have been completed. The refurbishment is projected to increase the efficiency of the units and add up to 80 MWs of capacity to the Castaic Plant.
- Certain IPP participants have a right under the IPP Excess Power Sales Agreement to recall from LADWP up to 38.2 percent of the capacity of IPP (currently equal to approximately 327 MWs) for defined future summer or winter seasons or both, following no less than 45 days notice and up to 43 MWs of such capacity on a seasonal basis following no less than 90 days notice. Such participants are currently recalling 48 MWs of winter season capacity from LADWP. Future capacity of IPP subject to recall from LADWP under the Excess Power Sales Agreement can vary.
- Recent drought conditions and low lake levels have reduced the LADWP's capacity entitlement at the Hoover Plant from 491 MWs of capacity (calculated based on 25.15 percent of 1,951 MWs of total contingent capacity) to an annual average of approximately 431 MWs (calculated based on 25.16 percent of 1,634 MWs annual average output capability). Future available capacity from Hoover Plant will depend on future drought condition.
- The LADWP Power RPS Policy was established to increase the amount of energy LADWP generates from renewable power sources to 20 percent of its energy sales to retail customers by 2010 and 33 percent renewable energy by 2020. Acquisitions of the renewable energy are based on a competitive bidding process through the issuance of Requests for Proposals. To date, renewable projects in-service or under construction, provide a total of 5,300 gigawatt per hour (GWh) of renewable energy annually.
- The Power Reliability Program (PRP) is a comprehensive, long-term power reliability program developed by LADWP to replace aging infrastructure or make permanent repairs to generation, transmission and distribution infrastructure that has failed during recent outages. Through the program, LADWP plans to accelerate the management and replacement of transformers, poles, underground cables, underground vaults, station transformers, new distribution and receiving stations, and modifications to existing stations. LADWP also plans to install new control, integrated central monitoring and dispatch systems needed to facilitate reliable and secure system operations and modify its staff training programs and increase staffing.

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- The LADWP continued its commitment to energy efficiency through numerous programs and services for customers to encourage the installation and use of energy efficient measures and equipment LADWP establish annual efficiency targets reducing total forecasted electricity consumption by 10 percent over the next 10 years. LADWP is on track to meet the requirements established under AB 2021. Since 2000, the LADWP energy efficiency programs have reduced long-term peak period demand and consumption by approximately 271.1 MWs and 894.1 GWh of energy savings. LADWP has budgeted funding for fiscal year 2009-10 to renew and expand its commitment to energy efficiency.
- LADWP offers its customers an opportunity to participate in the Green Power Program. "Green Power" is produced from renewable resources such as wind energy, geothermal, or other renewable resources, rather than conventional generating plants. Over 17,100 LADWP customers participated in the program during 2010. These participants receive approximately 104,000 MWh of renewable energy annually. Since program inception, in 1999, to the end of 2010, 818,768 MWh of renewable energy was procured, making it one of the largest voluntary green pricing programs in the nation.
- Completion of the Pine Tree Wind Project which is a 135 megawatt wind generating facility north of Mohave, California, consisting of 90 wind turbines The project began commercial operation on June 16, 2009.
- Numerous environmental laws and regulations, specifically those relating to air and water quality, affect the LADWP Power System's facilities and operations. LADWP monitors its compliance with laws and regulations and reviews its remediation obligations on an ongoing basis.

C.4 Power Plant Once-Through Cooling Water Systems

Power plants with "once-through cooling" (OTC) systems draw or take in water from coastal/estuarine water, via intake pipes, to cool turbines used to generate electricity. After the water is used for cooling it is discharged to a nearby water body. OTC systems can impact the marine environment.

LADWP has three coastal generating plants that utilize OTC. The new state wide OTC Policy and upcoming 316 b Federal Rule requires minimizing and/or reducing the impacts on marine life.

In order to reduce these impacts, LADWP has already implemented the following:

- In the 1970's LADWP installed a velocity cap (a large disk-shaped structure just upstream of the ocean water intake pipe) at its Scattergood Generating Station to control IM. In 2006, LADWP conducted an effectiveness study on its velocity cap and the results showed that it is 96% effective.

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- To date, LADWP has reduced the number of power plant units that utilize OTC from 14 to 9, reducing ocean water use from 1934 MGD to 1571 MGD, an overall reduction of ocean water usage by 17%.

- LADWP has spent over $600 million dollars to replace the older generating units with more efficient generating units (known as "repowering") at its Haynes and Harbor Generating Stations. This has resulted in a reduced use of coastal waters.

To further reduce impacts and completely eliminate OTC, LADWP plans to do the following:

- As a result of the Haynes 5&6 repowering project, reduce the number of OTC units to 7 by 2013. This will decrease ocean water use from 1571 MGD to 1110.2 MGD, an overall reduction of 42%, from 1990 ocean water usage levels.

- As a result of the Scattergood 3 repowering project, further reduce the number of OTC units to 6 by 2015, decreasing ocean water use from 1110.2 MGD to 830.8MGD, an overall reduction of 56% from the original ocean water usage level.

- As a result of the Scattergood 1&2 repowering project, further reduce the number of OTC units to 4 by 2020, decreasing ocean water use from 830.8 MGD to 503.1MGD, an overall reduction of 70% from the original ocean water usage level.

- As a result of the Haynes 1&2 repowering project, further reduce the number of OTC units to 2 by 2024, decreasing ocean water use from 563.3 MGD to 338.7 MGD, an overall reduction of 82%, from the original ocean water usage level.

- By 2020, further reduce of the number of OTC units to 1, decreasing ocean water use from 338.7 MGD to 231 MGD, an overall reduction of 87% from the original ocean water usage level.

- By 2029, final reduction of OTC units to 0, 100% elimination of OTC.

Figure C-5 shows LADWP's reduction in OTC usage from 1990 to 2029.

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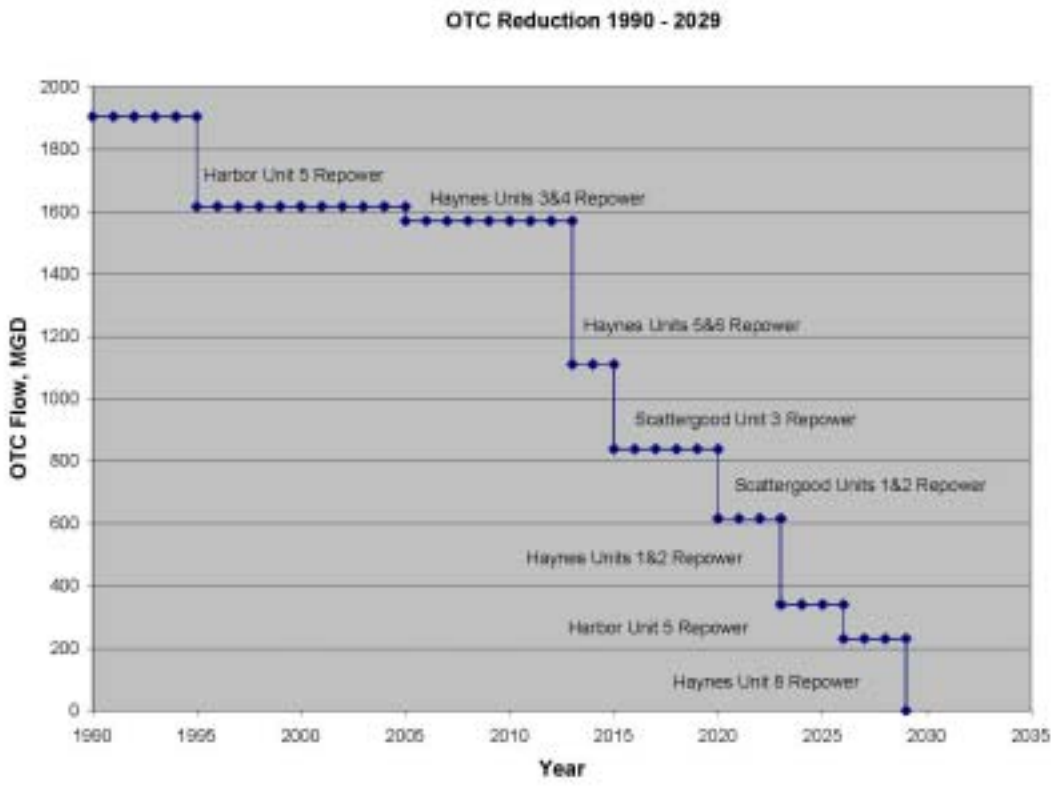

Figure C-5: LADWP OTC reduction from 1990 to 2029.

C.4.1 USEPA 316(b) Requirements for Cooling Water Intake Structures

EPA's Clean Water Act Section 316(b) Phase II Cooling Water Intake Structure Rule (Rule) released in 2004 was subsequently challenged and ultimately heard in both the Second Circuit Court and in the U.S. Supreme Court. The Second Circuit Court issued its decision on January 25, 2007, and determined that the restoration and cost-benefit elements of the original 2004 Rule were unlawful and that other fundamental components of the 2004 Rule, such as the impact reduction performance standards attainable for certain technologies, were to be remanded for further evaluation and demonstration by U.S. EPA. The U.S. Supreme Court was subsequently asked to weigh in on the ability to use the "wholly disproportionate" cost-benefit test in the application of the 316(b) regulations. On April 1, 2009, the Supreme Court affirmed that a cost-benefit analysis can be used by regulatory agencies. While the various challenges proceeded through the court processes, U.S. EPA gave the states permission to continue with implementation and enforcement of the Clean Water Act 316 (b) requirements using "Best Professional Judgment (BPJ) when reauthorizing facility National Pollutant Discharge Elimination System (NPDES) permits.

During this period, LADWP completed the required Characterization Study to identify baseline biological impacts in order to determine an appropriate impingement mortality (IM) and entrainment (E) reduction method. However, when the Rule was remanded to U.S. EPA to

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re-study and then re-propose a rule, it essentially placed remanded Rule and the fulfillment of its associated requirements on hold. At that point, LADWP stopped any further work necessary to comply with the suspended Rule and has been awaiting the outcome of U.S. EPA's effort to re-propose a new rule. The UP EPA publicly noticed the new proposed Rule for existing facilities on April 19, 2011 and the comment period ended on August 18, 2011. The UP EPA is targeting the end of 2012 to finalize its Rule. The use of BPJ by permitting authorities is still in effect.

C.4.2 SWRCB 316(b) Requirements for Cooling Water Intake Structures

On June 30, 2009, the SWRCB released its draft Once-Through Cooling Water Policy for public review and comment, with the accompanying Supplemental Environmental Document released on July 14, 2009. Comments were due September 30, 2009. Subsequent policy drafts were issued on November 23, 2009 and March 22, 2010 with corresponding comment periods. The final Policy version was adopted on May 4, 2010 and became effective on October 1, 2010. The adopted Policy has major implications for the coastal power plants making it extremely difficult to continue the use of OTC retrofitted with IM and E impact control technology; making the use of cooling towers the only certain compliance path. The Policy proposes a two-track compliance pathway. Track I requires OTC flows to be reduced commensurate with wet closed cycle cooling (CCC) or a 93 percent flow reduction and essentially requires the installation of cooling towers. If Track I can be demonstrated as "not feasible" a Track II compliance option is available. A Track II compliance pathway requires the biological impacts to be reduced on a unit by unit basis to a level comparable with (i.e., within 10 percent) what would exist with CCC. New consecutive 36-month IM and E baseline studies will be required if a Track II compliance pathway is pursued. Until compliance is achieved, interim measures are required, which include flow reductions when there is no unit load and mitigation measures (commencing five years from the effective date of the policy and continuing until the facility is in full compliance). Lastly, to prevent disruption in the state's electrical power supply during implementation of the Policy, a committee of state energy and resource agencies know as the Statewide Advisory Committee on Cooling Water Intake Structures (SACCWIS) will assist the SWRCB in reviewing the required utility implementation plans and in monitoring the schedules.

LADWP's implementation plan was the first plan to be reviewed by the SWRCB and SACCWIS. As a result, the SWRCB prepared and adopted an Amendment to the Policy on July 19, 2011. This Amendment modified LADWP's compliance schedule on a unit-by-unit basis with the following compliance dates ::12/31/2013 for Haynes Units 5&6; 12/31/2015 for Scattergood Unit 3; 12/31/2024 for Scattergood Units 1&2; 12/31/2029 for Haynes Units 1&2 and 8, and Harbor Unit 5. In addition, the Amendment requires LADWP to submit any additional information requested, by January 1, 2012, by the SACCWIS and submit the information responsive to SACCWIS to the SWRCB by December 31, 2012 in order for the SWRCB to evaluate whether further modifications to the dates are necessary. Furthermore, LADWP must commit to complete elimination of OTC and in the interim conduct a study or studies, singularly or jointly with other facilities, to evaluate new technologies or improve existing technologies to reduce impingement and entrainment. LADWP must submit the results of the study and a proposal to minimize entrainment and impingement to the Chief Deputy Director no later than December 31, 2015, and upon approval of the proposal by the Chief Deputy Director, complete implementation of the

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proposal no later than December 31, 2020. LADWP is in the process of commencing these studies and has begun the Haynes Units 5&6 repowering project in order to meet the 2013 deadline. Also, the conceptual planning and design for the Scattergood Unit 3 has commenced in order to meet the 2015 deadline.

C.5 Mercury Emissions

Mercury emissions are an issue for all coal fired power plants. However, the level of such emissions varies widely based on the type of coal burned and the type of emission controls on the plants.

Coal-burning power plants are the largest human-caused source of mercury emissions to the air in the United States, accounting for over 40 percent of all domestic human-caused mercury emissions. The EPA estimates that about 1/4 of U.S. emissions from coal-burning power plants are deposited within the contiguous U.S., and the remainder enters the global cycle.

The IGS in Utah, of which LADWP is the Operating Agent, has one of the lowest mercury emission rates in the country. This is due to the fact that the existing emission control devices, which are designed to reduce sulfur dioxide and particulate matter, have the co-benefit of removing about 96 percent of the mercury from bituminous coal which is burned at IGS.

On March 15, 2005 U.S. EPA promulgated the Clean Air Mercury Rule (CAMR), which established a nationwide cap-and-trade program for mercury emissions. CAMR was designed to reduce mercury emissions by 60 percent between 2010 and 2018. Several legal challenges of the CAMR ensued. As a result, the D.C. Circuit vacated U.S. EPA's Clean Air Mercury Rule on February 18, 2008. On May 3, 2011, EPA proposed NESHAPs for coal- and oil-fired EGUs under Clean Air Act (CAA) section 112(d) and proposed revised NSPS for fossil fuel-fired EGUs under CAA section 111(b). The proposed NESHAP would protect air quality and promote public health by reducing emissions of the hazardous air pollutants (HAP) listed in CAA section 112(b). In addition, these proposed amendments to the NSPS are in response to a voluntary remand of a final rule. EPA was scheduled to finalize its rule by December 2011.

C.6 Coal Combustion Residuals

On May 4, 2010, the U.S. Environmental Protection Agency released pre-publication co-proposals to regulate the management of coal ash from coal-fired power plants.

Coal combustion residuals (CCRs), commonly known as coal ash, are byproducts of the combustion of coal at power plants and are typically disposed of in liquid form at large surface impoundments and in solid form at landfills, most often on the properties of power plants. There are almost 900 landfills and surface impoundments nationwide.

Due to the metal constituents of the CCRs, EPA's co-proposals will establish control measures, such as liners and groundwater monitoring, which would be in place at new landfills to protect groundwater and human health. Existing surface impoundments would also require liners, with incentives to close the impoundments and transition to landfills, which store coal ash in dry form.

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The proposed regulations may change the way CCRs are handled and stored at Intermountain Power Plant and Navajo generating station. If implemented, the rules would require the phase-out of wet handling systems and surface impoundments of bottom ash and the subsequent permitting and installation of lining under fly ash landfills. The facilities would have to conduct additional groundwater monitoring, and provide closure and post closure care of the surface impoundments and landfills. For Mohave generating station, the rules, as proposed are expected to have minimal impacts because the facility did not operate any surface impoundment.

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Appendix D Renewable Portfolio Standard

D.1 Overview

LADWP has historically maintained that its major objectives concerning integrated resource planning are; (1) providing reliable service to its customers; (2) remaining committed to environmental leadership; and (3) maintaining a competitive price.

Since its 2007 IRP, LADWP has made great strides towards achieving the 2010 goal of increasing its supply of electricity from "eligible" renewable resources to 20 percent, measured by the amount of electric energy sales to retail customers, and has met the 20 percent goal for calendar year 2010.

On April 12, 2011, the California governor signed into law the Senate Bill 2 (1X) which extends the 20 percent target to 2013, and ramps up the target to 25 percent by December 31, 2016 and 33 percent by December 31, 2020.

On December 6, 2011, the LADWP Board approved the Renewables Portfolio Standard Policy and Enforcement Program and is included in Reference D-1 and D-2.

This 2011 IRP documents how LADWP expects to maintain 20 percent renewable energy and describes the process for LADWP's continuing commitment to increase the renewable energy goal to 25 percent by 2016 and 33 percent by 2020. Additionally, LADWP will continue to encourage voluntary contributions from customers to fund renewable resources above the stated Renewable Portfolio Standard (RPS) goal, as part of its Green Power for a Green LA Program (GREEN).

D.2 Renewable Energy Requests for Proposals (RFPs)

To help meet the renewable energy goals for the GREEN Program and the RPS policy, LADWP has issued four major Request for Proposals (RFP) for renewable energy projects: January 2001, June 2004, January 2007, and March 2009. LADWP performed detailed technical and economic analysis of the proposals on a least-cost, best-fit basis. This approach considered factors such as cost, technical feasibility, project status, transmission issues, and environmental impact.

Separately, the Southern California Public Power Authority (SCPPA), of which LADWP is a member, has issued five RFPs for renewable energy projects.

D.2.1 2001 Renewable RFP

In response to the 2001 RFP, a total of 21 projects were proposed. The 120 megawatts (MW) Pine Tree wind project met LADWP's renewable, economic, technical and least-cost, best fit criteria. The Pine Tree wind project is an eighty-turbine wind farm facility located in the

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Tehachapi area, and is owned and operated by LADWP. This project was put in-service in June 2009.

The Pine Tree wind farm was expanded with ten new wind turbines that added 15 MW, for a total of 135 MW. The expansion was completed in 2011.

D.2.2 2004 LADWP Renewable RFP and the 2005 SCPPA Renewable RFP

In June 2004, LADWP issued another RFP with the intent of securing an increased portion of its power requirements from renewable resources. The goal of LADWP's 2004 RFP was to obtain about 1,300 gigawatts hours (GWhs) per year of renewable energy per year to meet the then RPS interim goal of 13 percent by 2010. A total of 57 distinct proposals were received, covering nearly all types of renewables, although wind and geothermal represented the largest share of proposed energy. Most of the proposals were from new California projects, with only a few actually located in Los Angeles. The proposals offered a mix of power purchase and ownership options.

To ensure fairness and consistency during the evaluation process of the 2004 RFP, the evaluation team included two independent entities. The team evaluated proposals through a structured process consisting of two phases. The Phase 1 evaluation included completeness and requirements screening, a technical and commercial evaluation, and an economic assessment. Proposals short-listed were then evaluated in greater detail in the Phase 2 evaluation, which included a comparison of Net Levelized Cost (NLC). The NLC of each proposal equals the levelized busbar cost of energy, in units of $/MWh, less the avoided energy and capacity costs, and adding the levelized transmission costs to cover wheeling, losses, transmission upgrades, etc.

In 2005, the Southern California Public Power Agency (SCPPA), of which LADWP is a participant, also issued an RFP for renewable resources.

Five contracts for renewable energy resulting from the 2004 and 2005 RFPs have been entered into, which provide 1,179 GWhs/yr of renewable energy from landfills, small hydro and wind.

D.2.3 2006 SCPPA and 2007 LADWP Renewable RFPs

In 2006 SCPPA issued an RFP for renewable resources, in which LADWP participated.

In January 2007, LADWP issued another RFP with the intent of obtaining approximately 2,200 GWhs of renewable energy per year to meet the RPS goal of 20 percent by 2010. A total of 59 distinct proposals were received, covering wind, solar thermal, solar photovoltaic (PV), geothermal, and biomass renewable technologies. The proposals offered a mix of power purchase and ownership options.

Three contracts for renewable energy resulting from the 2006 and 2007 RFPs have been entered into, which provide 424 GWhs/yr of renewable energy from wind and small hydro projects. Several other proposals that were received are currently being negotiated.

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D.2.4 2008 SCPPA and 2009 LADWP Renewable RFPs

In 2008 SCPPA issued an RFP for renewable resources, in which LADWP participated.

In March, 2009, LADWP issued a fourth RFP for Renewable Resources. The intent of this RFP was to obtain a sufficient amount of renewable energy per year to achieve the RPS goals, set by the Mayor, of 20 percent by 2010 and 35 percent by December, 31, 2020.

The 2008 RFP process resulted in two contracts, which provide 834 GWhs/yr of renewable energy from wind resources. Several other proposals that were received are currently being negotiated.

D.2.5 2011 SCPPA RFP

In January 2011, the Southern California Public Power Agency (SCPPA) also issued an RFP for renewable resources, in which LADWP participated. LADWP participated in the evaluations of the RFP proposals. LADWP evaluated proposals through a structured process. The evaluation included a completeness and requirements screening, a technical and commercial evaluation, and an evaluation of deliverability of the product. The evaluation also considered the Net Levelized Cost (NLC) for each proposal. The NLC of each proposal is equal to the levelized busbar cost of energy, in units of $/MWh, less the avoided energy and capacity costs, and adding the delivery cost to LADWP's load. Other factors were also considered, including: compliance with pending State renewable portfolio standard legislation, utility scale project experience, capacity, commercial operation date, and labor issues.

In August 2011, SCPPA issued another RFP for renewable resources. The response deadline is November 30, 2012.

D.3 Renewable Project Strategy

LADWP (and SCPPA) has increased its renewable energy through successful project development and completed agreement negotiations with multiple developers and project entities resulting from the above described RFPs. Existing renewable projects that supply LADWP are geographically diverse; wind energy comes from the ridges of the California Tehachapi Mountains, the north-central hills of Oregon, the southern Washington Columbia River Gorge area, the Milford Valley of Utah, and Southwestern Wyoming. Planning for future renewable energy will continue to emphasize geographic diversity, as well as technology diversity.

The variety of renewable energy projects and technologies facilitates the Power System capability to integrate renewable energy reliably. As described in other sections of the IRP, LADWP will maintain its Balancing Authority responsibility by addressing system issues such as reserve sharing, reserve commitments, system voltage support, spinning reserves, existing and future quick response combustion turbine response units, etc.

This IRP describes several fundamental principles for the RPS progression from the current 20 percent renewable energy to a potentially higher goal of 33 percent by 2020. Issues and principles affecting the future of the RPS plans are discussed below:

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D.3.1 Issues

- The "Ramp Rate", i.e., the annual rate of progress from 20 percent to 33 percent renewables, will be subject to several factors. The time frame is 10 years, which would equate to a constant ramp of 1.33 percent per year. However, the projected ramp rate is not a straight line, but rather varies from year to year depending on factors both external and internal to the LADWP. These factors include SB 2 (1X) requirements, LADWP fiscal constraints, renewable energy technology improvement over time, renewable energy pricing, LADWP system integration limits, and transmission constraints, both in the LADWP systems and regionally.

- Steady investment in renewable resources is required to maintain a 20 percent RPS between 2010 and 2012 and to ramp to 33 percent between 2013 and 2020. There are several reasons for this path forward: Between 2010 and 2012, the projects maintaining the 20 percent RPS will become fully integrated into the system; reflecting 2010 economic conditions and allowing time for pricing adjustments and efficiencies of certain renewable industries such as solar PV to reach the marketplace. For budgeting and planning purposes, the assumed RPS implementation strategy is 1 percent annual RPS increases from 2013 thru 2015 and 2 percent from 2016 thru 2020. Of course, all of this strategy is dependent on adequate funding.

- Transmission limitations in several regions are constraining development activities. These constraints are being studied at regional, statewide, and Western Electricity Coordinating Council (WECC) levels and potential federal and state legislative actions will affect transmission availability. Further resource decisions are dependent on transmission availability and cost.

- Greenhouse Gas (GHG) and other climate change regulatory and legislative issues are pending. The eventual cap and trade methodology and market mechanisms that are implemented will influence RPS strategic and tactical decisions.

- Within the overall RPS plan, decisions as to specific projects, technologies, operational strategies, and project financial structures, will be made as the marketplace and regulatory environment change.

D.3.2 Principles

Future renewable projects will be strategically obtained with the following principles.

1. Geographic diversity is important to maintain and enhance power system reliability.

2. The use of existing LADWP assets such as transmission lines, land, and existing generation resources should be maximized.

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3. Pursue multi-faceted development with adequate back-up strategies to handle project delays, project failures, reduced generation output, and operation or maintenance impacts.

4. Projects shall be targeted to specifically meet the Power System/Renewables Policy objectives.

5. Flexible RPS goals will be established to address the variable nature of renewable energy while conforming to applicable state and federal requirements

6. Ownership, operation, and maintenance are core objectives to maintain power system reliability and cost stability. The Power System is interested in owning projects that are based on proven technology.

7. Operation and maintenance (O&M) management is a key criterion in clustering renewable projects. Keeping projects in close proximity would reduce O&M costs due to economies of scale and personnel efficiencies.

D.3.3 Balancing Renewable Resources

Several of these principles may be overlapping or even conflicting. For example, clustering of renewable projects would decrease O&M expenditures, but too many projects in an area will not meet the needs for geographic diversity. Also, ownership goals may impact project costs and immediate availability. Obtaining tax credits and/or grants may necessitate the need for developers to own a project for a certain number of years (typically 7-10 years) to capture tax advantages; thereby lowering the ultimate cost to LADWP.

Subject to further studies, given the wind and solar projects coming on-line, limitations on the percentage of intermittent resources may be required. There may be more stringent limitation in certain resource areas, or along certain transmission systems. It is possible that no more than 15-20 percent intermittent energy can be ultimately integrated in the current electric grid. Of the 20 percent renewable energy consumed in 2010, less than $1/5^{th}$ of that amount was of an intermittent type. Most renewable resources are either small hydro or biogas having a predictable energy pattern or wind projects that have their energy output firmed and shaped by outside balancing authorities before delivery to LADWP. The total amount of intermittent energy obtained will not be increased beyond current levels unless studies demonstrate that these resources can be reliably integrated.

Wind, as shown elsewhere in this IRP, is a volatile renewable energy resource. It is recommended that LADWP's wind forecasting tools and meteorological analysis capabilities be enhanced to provide efficient integration of wind energy.

Similar studies will be required for solar projects coming on line in the next few years, and limitations of the percentage of solar will be required. Photovoltaic solar systems can have dramatic voltage changes, resulting from passing cloud cover and/or storms. Large installations of solar PV will likely need to be limited in size within a geographical area, unless it is coupled with solar thermal systems or energy storage systems.

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The renewable energy mix of 2010 is shown on Figure D-1

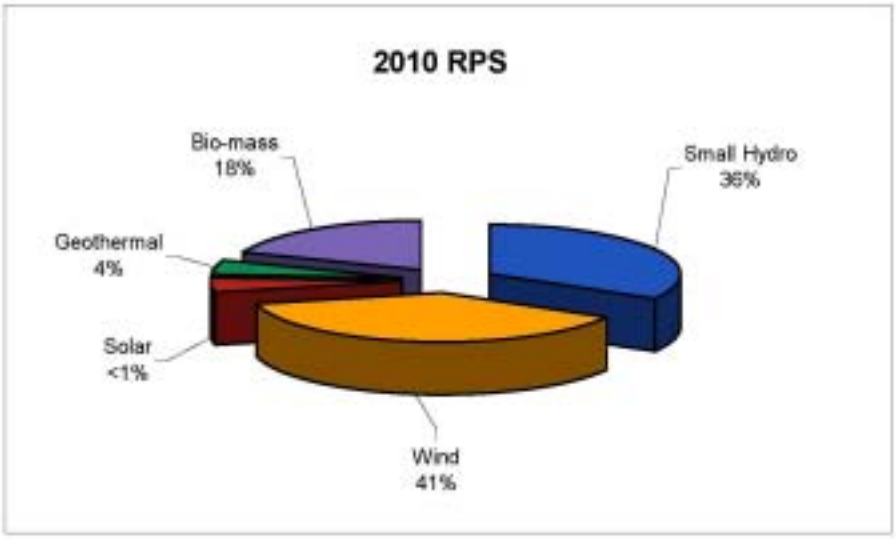

Figure D-1: 2010 Renewable Energy Mix

D.3.4 Impacts of CA Senate Bill SB 2 (1X)

On April 12, 2011, Governor Edmund G. Brown Jr. signed into law the California Renewable Energy Resources Act (herein referred to as "Act" or "SB 2 (1X)"). This Act sets new Renewable Portfolio Standard (RPS) procurement targets, new renewable resource eligibility definitions, and new reporting requirements applicable to Publicly Owned Electric Utilities (POUs). SB 2 (1X) becomes effective December 10, 2011, 90 days after the end of the special session in which it was enacted.

This bill expresses the intent that the amount of electricity generated from eligible renewable energy resources be increased to an amount that equals at least 20% of the total electricity sold to retail customers in California by December 31, 2013, 25% by December 31, 2016 and 33% by December 31, 2020. In addition, this bill requires POU governing boards to adopt a policy with similar goals imposed on IOUs to enforce the RPS Program on its respective utility.

According to the legislation, POU governing boards are directed to adopt "a program for the enforcement of this article" by January 1, 2012. As such, POU governing boards have discretion to interpret the following provisions:

- Procurement Target Goals
- Reasonable Progress to achieve such goals
- Procurement Requirements
- Rules to apply excess procurement for future compliance periods
- Conditions that allow for delaying timely compliance
- Cost limitations for procurement expenditures.

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Resources obtained in compliance with SB 2 (1X) must meet the following criteria:

Category (aka "Buckets")	Percentage of RPS Target
1. Either: Have a first point of interconnection with a California balancing authority, have a first point of interconnection with distribution facilities used to serve end users within a California balancing authority area, or are scheduled from the eligible renewable energy resource into a California balancing authority without substituting electricity from another source [PUC Section 399.16(b)(1)(A)]. Or, have an agreement to dynamically transfer electricity to a California balancing authority. [PUC Section 399.16(b)(1)(B)]	**Compliance Period 1 (2011-2013):** 50% of RPS minimum from this category. **Compliance Period 2 (2014-2016):** 65% of RPS minimum from this category. **Compliance Period 3 (2017 to 2020):** 75% of RPS minimum from this category. **Post – 2020** 75% of RPS minimum from this category.
2. Firmed and shaped eligible renewable energy resource electricity products providing incremental electricity and scheduled into a California balancing authority. [PUC Section 399.16(b)(2)]	Shall be calculated as the remainder of resources which are not in either Category 1 or Category 3.
3. Eligible renewable energy resource electricity products or any fraction of the electricity generated, including unbundled RECs that do not qualify under Bucket 1 or 2. [PUC Section 399.16(b)(3)]	**Compliance Period 1 (2011-2013):** 25% of RPS maximum from this category. **Compliance Period 2 (2014-2016):** 15% of RPS maximum from this category. **Compliance Period 3 (2017 to 2020):** 10% of RPS maximum from this category. **Post – 2020** 10% of RPS minimum from this category.

The regulations promulgating this legislation by the CEC over POUs have not yet been finalized.

D.3.5 Renewable Energy Credits

The Public Utilities Code Section 399.12 (h) defines a Renewable Energy Credit (REC) as "a certificate of proof, issued through the accounting system established by the California Energy Commission…that one unit of electricity was generated and delivered by an eligible renewable energy resource." RECs include all renewable and environmental attributes, including avoided greenhouse-gas (GHG) attributes, associated with the production of electricity from the eligible renewable energy resource.

The primary method of renewable energy resource procurement will be through the development and acquisition of physical generation assets and energy purchase contracts, in which LADWP will acquire the "renewable energy credit" (REC) from the renewable resource "bundled" with the associated energy.

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In order for RPS compliance targets to be managed effectively, LADWP may buy, sell, or trade RECs without the associated energy (unbundled). This procurement approach will be limited by the percentage requirements established by PUC Section 399.16(b)(3), and as described in the City of Los Angeles Department of Water and Power Renewable Portfolio Standard Policy and Enforcement Program, as amended on December 2011.

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D.4 Transmission of Renewable Energy

California and many of the western states contain a variety of resources (wind, solar, geothermal, and other "eligible" resources previously defined in the RPS Policy) that can be developed to ultimately generate electricity. However, the current transmission system was not primarily designed with these natural resources in mind.

Even with the substantial existing transmission system owned by LADWP, and the other transmissions systems in California, there is only a limited amount of transmission lines to many of the potential renewable resource locations. In order to gain access to these sources of renewable energy, LADWP is planning on building additional transmission lines and expanding the capabilities of several existing lines, and utilizing transmission lines as part of renewable purchase power agreements. These projects include:

1. Barren Ridge Renewable Transmission Project (BRRTP) - Transmission access and transmission line upgrades are needed to accommodate proposed wind projects in the Tehachapi area and solar thermal projects in the Mojave Desert, which total nearly 1,000 MW. The initial project was the construction of the Barren Ridge substation which supports the 135 MW Pine Tree Wind project. This substation interconnects with LADWP's existing 230 kV Inyo-Rinaldi transmission line (which was built to gain access to the renewable hydro-generated energy from LADWP's aqueduct system in the Owens Valley). The Inyo-Rinaldi transmission capacity needs to be increased in order to accommodate additional renewable energy projects. A full Environmental Impact Report (EIR) process is currently underway on this project.
2. Related to the BRRTP project, the potential Owens Valley Solar projects may require further upgrades to the Inyo-Barren Ridge segment of this transmission line and a generation tie-line into the project area. Depending on ultimate solar build-out in the Owens Valley, additional new transmission may be required.
3. The joint Southern California Edison/Imperial Irrigation District upgrade of Path 42 is critical for delivery of renewable generation from the IID area into the California ISO. Upgrading Path 42 requires improvements to facilities under the control of SCE and the California ISO as well as facilities under IID control. The IID upgrades consist of replacing the 220 kV circuits between the Coachella Valley Substation and the Mirage Substation with bundled circuits, two conductors per circuit. The IID portion of the upgrades would increase the capacity of IID's portion of the path by around 800 MW and could be completed by the end of 2011. The total renewable potential for the California ISO/IID Path 42 upgrades is approximately 1,400 MW.

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Figure D-2: Renewable Transmission Paths and Potential Resources, 2010 - 2030

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D.5 Funding the RPS

For LADWP to develop a responsible and prudent renewable energy policy, it must balance environmental objectives such as fuel diversity, energy efficiency and clean air against its core responsibility to provide and distribute safe, reliable, and low-cost energy to its customers. That means developing a RPS that ensures LADWP's continued financial integrity and striving to mitigate the financial impact on retail customers.

The financial impact of meeting a 33 percent RPS goal will vary depending on the mix of resource types and associated costs. Generally, renewable energy costs more than traditional energy sources such as natural gas and coal. However, a diversified energy portfolio, including a larger mix of renewables, may also reduce the risk of price spikes due to fuel supply shortages.

Estimated RPS revenue requirements to comply with SB 2 (1X) compliance targets of 25 percent renewable in 2016 and 33 percent in 2020 are shown in Figure D-3. Revenues required for an additional 4000 GWh annually for 2020 and beyond will require increasing annual renewable portfolio costs from 400 million to 950 million over the next 9 years.

During the early years of the RPS program, low cost, small hydro resources and biogas comprised the bulk of the portfolio with relatively higher cost wind energy being recently introduced over the last several years. Going forward, higher cost resources such as wind, solar, and geothermal must be used to comply with RPS standards as other lower cost alternatives have been largely exhausted. As can be seen in Figure D-4, contracts for renewable projects totaling 1,250 GWh or 28 percent of the renewable energy supply will expire over the next 4 years and will need to be replaced with higher cost renewable resources. Maintaining the current 20 percent RPS will require additional revenue to compensate for these higher cost replacement resources.

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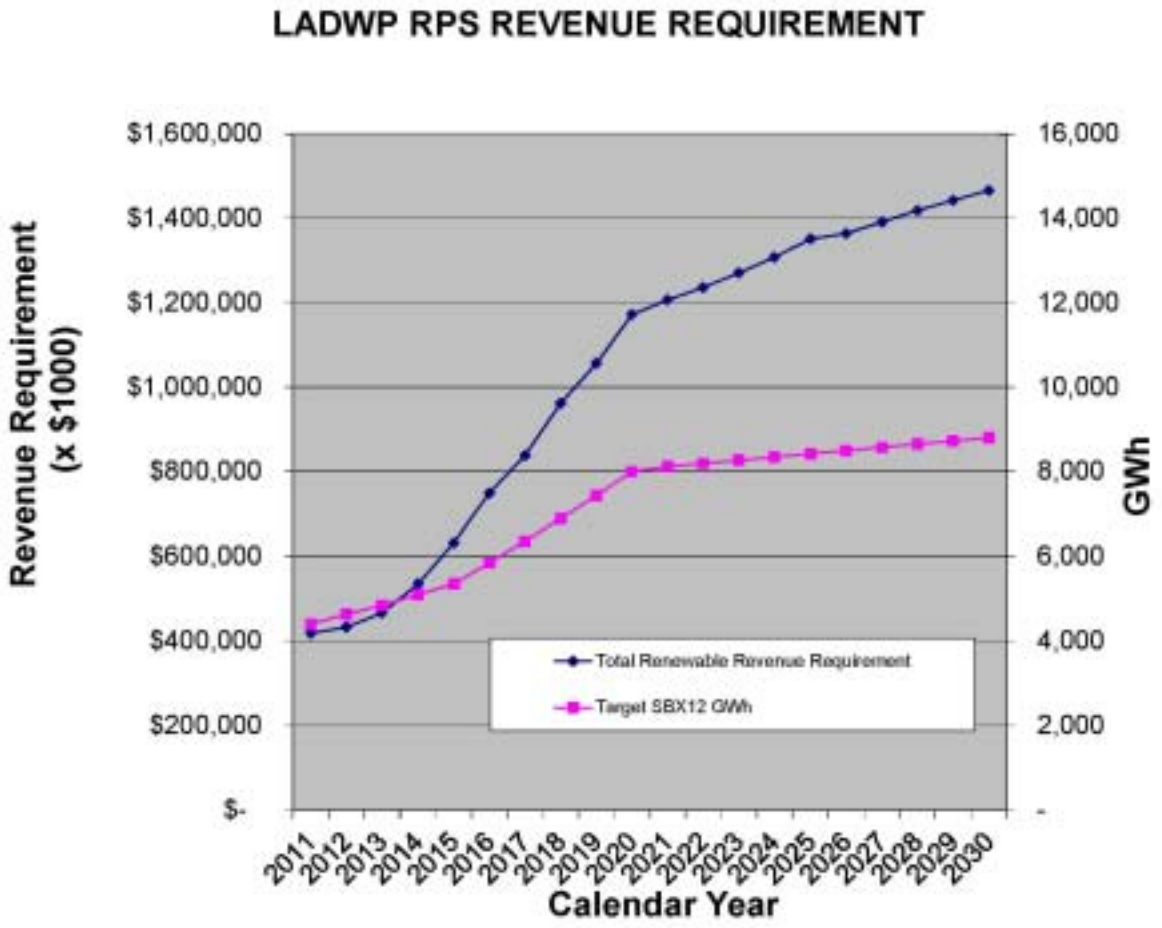

Figure D-3 – LADWP RPS Revenue Requirement 2011-2030.

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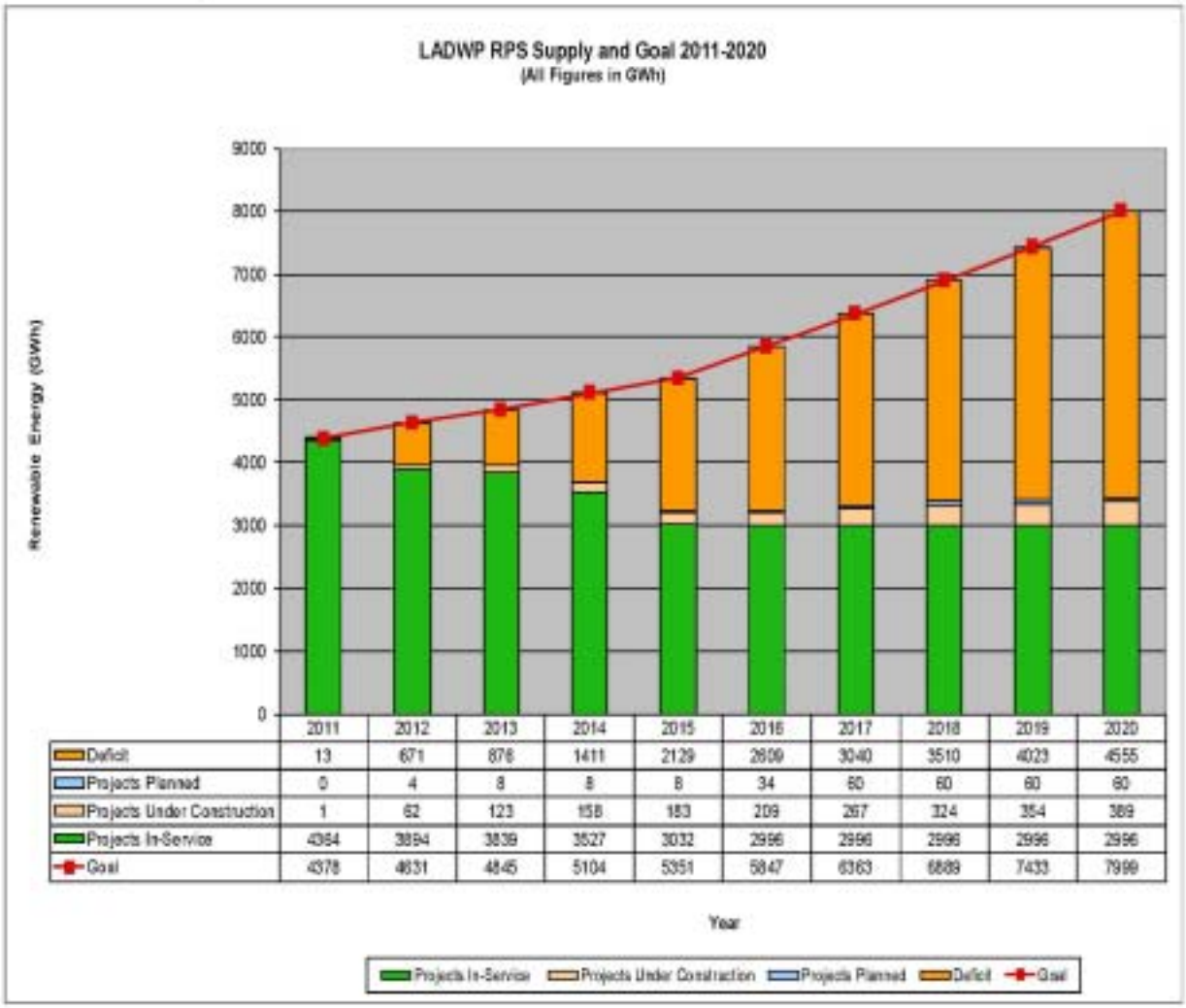

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Deficit	13	671	876	1411	2129	2809	3040	3510	4023	4555
Projects Planned	0	4	8	8	8	34	60	60	60	60
Projects Under Construction	1	62	123	158	183	209	267	324	354	389
Projects In-Service	4364	3894	3839	3527	3032	2996	2996	2996	2996	2996
Goal	4378	4631	4845	5104	5351	5847	6363	6889	7433	7999

Figur D-4. LADWP RPS supply and goals for 2011-2020.

D.6 Other LADWP Renewable Projects

LADWP has several additional projects that are in various stages of development. LADWP also has short-listed additional renewable energy projects that have been offered in response to past LADWP's Request for Proposal (RFPs) or SCPPA RFPs. These short-listed projects and other proposals from upcoming RFP's will be used to select future projects, subject to the criteria enumerated within this section.

The eligibility of wind, solar, and geothermal projects to count toward renewable energy targets is well understood. LADWP has also procured biogas and is considering the use of certain types of biomass. Energy generated from this category is RPS-eligible.

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D.6.1 Biogas

The current California Energy Commission (CEC) Overall Program Guidebook of January, 2011 defines biogas as "a gas derived from RPS-eligible fuel including biomass, digester gas, and/or landfill gas". CEC is currently working on a new Guidebook to comply with the SB 2 (1X) RPS requirements to further define eligible sources of Biogas.

Biogas or digester gas is typically derived from the anaerobic digestion of agricultural or animal waste and biomass is typically defined as any organic material not derived from fossil fuels, including agricultural crops, agricultural wastes and residues, waste pallets, crates, dunnage, manufacturing, construction wood wastes, landscape and right-of-way tree trimmings, mill residues that result from milling lumber, rangeland maintenance residues, biosolids, sludge derived from organic matter, and wood and wood waste from timbering operations.

In keeping with capturing the intent of the California legislature to increase use of renewable fuels, the LADWP amended its RPS policy when the CEC issued its third edition of the Guidebook in January 2008. Language from the CEC Guidebook states, "RPS-eligible biogas (gas derived from RPS-eligible fuel such as biomass or digester gas) injected into a natural gas transportation pipeline system and delivered into California for use in an RPS-certified multi-fuel facility may result in the generation of RPS-eligible electricity." The CEC also considers landfill gas (LFG) - gas produced by the breakdown of organic matter in a landfill - a renewable fuel.

The LADWP's gas-fired generating units capable of burning a mixture of biogas and conventional natural gas fall under the CEC multi-fuel designation. The CEC Guidebook states, "…only the renewable portion of generation will count as RPS eligible, and only when the Energy Commission approves a method to measure the renewable portion."

Pursuant to the CEC Guidebook, the LADWP calculates the amount of RPS-eligible electricity produced at its gas-fired generating units by multiplying the total generation of the facility by the ratio of the quantity of biogas used to the quantity of total gas used by the facility. Both the energy generated and the quantity of gas used must be measured on a monthly basis.

The LADWP currently produces RPS-eligible energy derived from biogas/biomass. Digester gas produced at the Hyperion Wastewater Treatment facility is piped to the adjacent Scattergood Generating Station, where it is used to produce RPS-eligible energy. Additionally, the LADWP procures biogas/biomass-derived renewable energy via gas-fired microturbines located at several landfills throughout Los Angeles.

The LADWP currently holds short-term contracts with developers to purchase LFG. Under these contracts, the LADWP obtains LFG from several landfill sites located outside California. LFG produced by the landfills is scrubbed and filtered to pipeline grade and injected into the interstate natural gas pipeline system for delivery to the LADWP's most efficient gas-fired generating units.

D.6.2 Municipal Solid Waste

- The current CEC criteria sets forth several conditions for RPS-eligibility of municipal solid waste (MSW) conversion facilities: The facility uses a two-step process to create energy whereby in the first step (gasification conversion) a non-combustion thermal process that consumes no excess oxygen is used to convert MSW into a clean burning fuel, and then in the second step this clean burning fuel is used to generate electricity.

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- The facility is located in-state or satisfies certain out-of-state requirements.
- The technology produces no discharges of air contaminants or emissions, including greenhouse gases as defined in Section 42801.1 of the Health and Safety Code.
- The technology produces no discharges to surface or groundwaters of the state.
- The technology produces no hazardous wastes.
- As much as possible, the technology removes all recyclable materials and marketable green waste compostable materials from the solid waste stream before the conversion process.

The facility certifies that any local agency sending solid waste to the facility diverted at least 30 percent of all solid waste it collects through solid waste reduction, recycling, and composting.

The LADWP currently does not procure energy from any MSW combustion or conversion facilities, but may consider projects that meet all CEC criteria.

D.7 Power Content Label

In 1997, Senate Bill 1305 was approved, which required Energy Service Providers (ESP) to report to their customers information about the resources that are used to generate the energy that they sell. A form, called the Power Content Label, would be used for this purpose, which would also provide a common reporting method to be used by all ESPs.

In addition, the 2002 Senate Bill 1078 established California's Renewable Portfolio Standard (RPS) which included both a requirement for electric utilities to report annually to their customers the resource mix used to serve its customers by fuel type, and to report annually to its customers the expenditures of public goods funds used for public purpose programs. The report should contain the contribution of each type of renewable energy resource with separate categories for those fuels considered eligible renewable energy resources, and the total percentage of eligible renewable resources that are used to serve the customers' energy needs.

LADWP's 2010 Power Content Label is shown in Table D-1. As LADWP has two separate renewable programs, the RPS policy and GREEN, both of these programs are reported on the Power Content Label.

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Table D-1: LADWP's 2010 Power Content Label

POWER CONTENT LABEL Annual Report of Actual Electricity Purchases for LADWP Calendar Year 2010			
ENERGY RESOURCES	LADWP Power ACTUAL MIX	LADWP Green Power ACTUAL MIX	2010 CA POWER MIX** (for comparison)
Eligible Renewable * **	**20%**	**100%**	**14%**
– Biomass & waste	4%	59%	2%
– Geothermal	1%	0%	5%
– Small hydroelectric	7%	41%	2%
– Solar	0%	0%	0%
– Wind	8%	0%	5%
Coal	39%	0%	7%
Large Hydroelectric	3%	0%	11%
Natural Gas	22%	0%	42%
Nuclear	11%	0%	14%
Other	0%	0%	0%
Unspecified sources of power*	**5%**	**0%**	**12%**
TOTAL	**100%**	**100%**	**100%**

* "Unspecified sources of power" means electricity from transactions that are not traceable to specific generation sources.

** Percentages are estimated annually by the California Energy Commission based on the electricity sold to California consumers during the previous year.

*** This is in accordance with Los Angeles City Council's action on 10-5-04 for File No. 03-2688 (RPS)

For specific information about this electricity product, contact LADWP at 1-800-DIAL-DWP. For general information about the Power Content Label, contact the California Energy Commission at 1-808-555-7794 or www.energy.ca.gov/consumer.

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Reference D-1 – LADWP Renewables Portfolio Standard Policy and Enforcement Program Amended December 2011 - Board Resolution:

WHEREAS in August 2000, the Board of Water and Power Commissioners (Board) approved a resolution that authorized the Los Angeles Department of Water and Power (LADWP) to adopt an Integrated Resource Plan that established a goal of meeting 50 percent of projected load growth through a combination of Demand-Side-Management, Distributed Generation, and Renewable Resources; and

WHEREAS in 2002, the California Legislature passed Senate Bill 1078 that established the California Renewables Portfolio Standard (RPS), and a goal for all investor-owned utilities to increase their use of renewable resources by at least 1 percent per year, until 20 percent of their retail sales were procured from renewables by 2017; and

WHEREAS publicly-owned utilities like LADWP were exempt from California Senate Bill 1078, however they were encouraged to establish renewable resource goals consistent with the intent of the California Legislature; and

WHEREAS on June 29, 2004, the Los Angeles City Council adopted a LADWP RPS Framework and requested that the Board establish a RPS Policy, including achieving "20 percent renewable energy by 2017" and "incorporating this RPS into all future energy system planning"; and

WHEREAS on October 15, 2004, the Los Angeles City Council adopted a resolution approving the inclusion of existing LADWP hydroelectric generation units greater than 30 megawatts in size, excluding the Hoover hydroelectric plant, as part of the City's RPS list of eligible resources; and

WHEREAS on June 29, 2005, the Los Angeles City Council approved LADWP's Renewables Portfolio Standard Policy, which was designed to increase the amount of energy LADWP generated from renewable power sources to 20 percent of its energy sales to retail customers by 2017, with an interim goal of 13 percent by 2010; and

WHEREAS in December of 2005, the Board recommended that LADWP accelerate the RPS goal to obtain 20 percent renewables by 2010, which recommendation included updating LADWP's Integrated Resource Plan to include this goal, proceeding with the negotiation and contract development for renewable resources proposed and selected in LADWP's 2004 RPS and Southern California Public Power Authority 2005 RPS, supporting the cost of accelerating the RPS, and maintaining the financial integrity of LADWP's Power System during times of natural gas price volatility; and

WHEREAS on April 11, 2007, the Board amended LADWP's RPS Policy by advancing the date of the goal that required 20 percent of energy sales to retail customers be

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generated from renewable resources to December 31, 2010, and by establishing renewable energy procurement ownership targets; and

WHEREAS, on May 20, 2008, the Board approved an amended RPS Policy which included an additional RPS goal that required 35 percent of energy sales to retail customers be generated from renewable resources by December 31, 2020, expanded the list of eligible renewable resources, and provided new energy delivery criteria; and

WHEREAS, the California Renewable Energy Resources Act will become effective on December 10, 2011, and requires the governing board of a local publicly owned electric utility, such as LADWP, to adopt a program for enforcement, in accordance with Public Utilities Code Section 399.30(e), by January 1, 2012;

NOW, THEREFORE BE IT RESOLVED that the Board of Water and Power Commissioners of the City of Los Angeles hereby adopts the Renewables Portfolio Standard Policy and Enforcement Program, Amended December 2011, approved as to form and legality by the City Attorney, and on file with the Secretary of the Board;

I HEREBY CERTIFY that the foregoing is a full, true, and correct copy of a resolution adopted by the Board of Water and Power Commissioners of the City of Los Angeles at its meeting held

Secretary

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Reference D-2 – LADWP Renewables Portfolio Standard Policy and Enforcement Program Amended December 2011:

City of Los Angeles Department of Water and Power
Renewables Portfolio Standard Policy
and
Enforcement Program
Amended December 2011

1. Purpose:

On April 12, 2011, Governor Jerry Brown signed into law the California Renewable Energy Resources Act (herein referred to as "Act" or "SB 2 (1X)"). This Act sets new Renewable Portfolio Standard (RPS) procurement targets, new renewable resource eligibility definitions, and new reporting requirements applicable to local Publicly Owned Electric Utilities (POUs). It is anticipated that SB 2 (1X) becomes effective on December 10, 2011, ninety days after the end of the special legislative session (1X) in which it was enacted.

This RPS Renewables Portfolio Standard Policy and Enforcement Program (RPS Policy) as amended, represents the continued commitment by the Los Angeles Department of Water and Power (LADWP) to renewable energy resources. It is being adopted in accordance with the newly added Section 399.30 (e) of the Public Utilities Code (PUC), requiring the governing boards of POUs to adopt "a program for enforcement of this article" on or before January 1, 2012.

The SB 2 (1X) also requires the California Energy Commission (CEC) to "adopt regulations specifying procedures for enforcement of this article", which include a public process under which the CEC may issue a notice of violation and correction against a POU for failure to comply. The CEC is further required to refer violations of its regulations to the California Air Resources Board which may impose penalties to enforce the Act consistent with California Assembly Bill 32, (AB32 - California Global Warming Solutions Act of 2006).

It is the intent of LADWP to comply with the provisions of the Act, and with applicable enforcement regulations adopted by the CEC pursuant to the Act. It is also the intent of LADWP to update this RPS Policy, as necessary, after the CEC adopts regulations specifying procedures for enforcement.

The Board of Water and Power Commissioners of the City of Los Angeles (Board) retains its jurisdiction to enforce the RPS Policy in accordance with PUC Section 399.30 (e).

2. Background:

In 2002, California Senate Bill 1078 (SB 1078) added Sections 387, 390.1 and 399.25, and Article 16 (commencing with Section 399.11) to Chapter 2.3 of Part I of Division 1 of

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the PUC, establishing a 20 percent RPS for California investor-owned electric utilities. SB 1078 provided that each governing board of a local POU be responsible for implementing and enforcing a RPS that recognizes the intent of the Legislature to encourage renewable resources and the goal of environmental improvement, while taking into consideration the effect of the standard on rates, reliability, and financial resources.

On June 29, 2004, the Los Angeles City Council passed Resolution 03-2064-S1 requesting that the Board adopt an RPS Policy of 20 percent renewable energy by 2017 setting applicable milestones to achieve this goal, and incorporate this RPS into a future Integrated Resource Plan (IRP).

On May 23, 2005, the Board adopted a LADWP RPS Policy that established the goal of increasing the amount of energy LADWP generates from renewable power sources to 20 percent of its energy sales to retail customers by 2017, with an interim goal of 13 percent by 2010. On June 29, 2005, the Los Angeles City Council approved the LADWP RPS Policy.

On April 11, 2007, the Board amended the LADWP RPS Policy by accelerating the goal of requiring that 20 percent of energy sales to retail customers be generated from renewable resources by December 31, 2010. In addition, the amended policy established a "Renewable Resource Surcharge" and also established renewable energy procurement ownership targets.

The Board subsequently approved a RPS Policy, as amended April 2008, which included an additional RPS goal of requiring that 35 percent of energy sales to retail customers be generated from renewable resources by December 31, 2020, expanded the list of eligible renewable resources, and provided new energy delivery criteria.

In 2010, LADWP achieved its RPS goal of 20 percent.

3. RPS Compliance Targets

To promote stable electricity prices, protect public health, improve environmental quality, provide sustainable economic development, create new employment opportunities, reduce reliance on imported fuels, and ensure compliance with applicable state law, the following RPS compliance targets are hereby adopted:

1. For the period of January 1, 2011 to December 31, 2013, LADWP will procure sufficient electricity products from eligible renewable energy resources to achieve an average of 20 percent of retail sales during such period.
2. LADWP will increase its procurement of electricity products from eligible renewable energy resources to achieve 25 percent of retail sales by December 31, 2016, based on an average percentage of retail sales calculations for the period of January 1, 2013 to December 31, 2016.

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3. LADWP will increase its procurement of electricity products from eligible renewable energy resources to achieve 33 percent of retail sales by December 31, 2020, based on an average percentage of retail sales calculations for the period of January 1, 2020 to December 31, 2020.
4. For each calendar year after 2020, LADWP will procure sufficient electricity products from eligible renewable energy resources to achieve a minimum 33 percent of retail sales based on an average percentage of retail sales calculations for the period of January 1 to December 31 in each such calendar year.

The LADWP will continue to encourage voluntary contributions from customers to fund renewable energy resources in addition to the stated RPS compliance targets, in accordance with its Green Power for a Green L.A. Program or any successor program.

4. Eligible Renewable Energy Resources:

Prior to the enactment of SB 2 (1X), the LADWP RPS Policy defined the following technologies as "eligible renewable resources": "biodiesel using biomass; conduit hydroelectric (hydroelectric facilities such as an existing pipe, ditch, flume, siphon, tunnel, canal, or other manmade conduit that is operated to distribute water for a beneficial use); digester gas; fuel cells using renewable fuels; geothermal; hydroelectric incremental generation from efficiency improvements; landfill gas; municipal solid waste; ocean thermal, ocean wave, and tidal current technologies; renewable derived biogas (meeting the heat content and quality requirements to qualify as pipeline-grade gas) injected into a natural gas pipeline for use in renewable facility; multi-fuel facilities using renewable fuels (only the generation resulting from renewable fuels will be eligible); small hydro 30 Mega Watts (MW) or less, and the Los Angeles Aqueduct hydro power plants; solar photovoltaic, solar thermal electric; wind; and other renewables that may be defined later."

All renewable energy resources approved by the Board as part of its renewables portfolio in accordance with applicable law and previous versions of this RPS Policy including without limitation those on Appendix A, will continue to be eligible renewable energy resources. These renewable energy resources will count in full towards LADWP's RPS targets adopted in section 3 under this updated RPS Policy.

For RPS resources procured after the effective date of SB 2 (1X), "eligible renewable energy resource" means a generation facility that meets eligibility criteria under applicable law, including a "Renewable Electrical Generation Facility" as defined in Section 25741 (a) of the Public Resources Code and "Eligible Renewable Energy Resource" as defined in PUC Sections 399.12 (e) and 399.12.5.

5. Long-Term Resource and Procurement Plan

The LADWP will integrate the RPS Policy into its long-term resource planning process and the RPS Policy will not compromise LADWP's IRP objectives of service reliability.

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competitive electric rates and environmental leadership. Future IRPs will incorporate and expand upon RPS compliance targets, and further define plans for procuring eligible renewable energy resources by technology type and geographic diversity.

Each year, the Board adopts an annual fiscal year budget, including a Fuel and Purchased Power Budget (FPP), which defines the specific expenditures for renewable energy resources. The annual fiscal year budget, including the FPP, will comprise the LADWP Renewable Energy Resources Procurement Plan, as required under SB 2 (1X).

6. Procurement of Eligible Renewable Energy Resources:

The LADWP will procure eligible renewable energy resources based on a competitive method and least-cost, best-fit evaluations. Furthermore, preference will be given to projects that are located within the City of Los Angeles or on City-owned property and are to be owned and operated by LADWP to further support LADWP's economic development and system reliability objectives.

Notwithstanding the foregoing, LADWP will also procure eligible renewable energy resources through programs such as a Distributed Generation Feed-in-Tariff, Senate Bill 1 (SB1) Customer Net Metered Solar PV, other local renewable energy programs, or similar procurement processes. These transactions will be made in as cost-effective a manner as is feasible in each respective instance, with pricing that reflects applicable legal requirements and market conditions, prevailing policy, and competitive methods. Short-term renewable energy transactions will be needed as well, on a limited basis, to manage LADWP's RPS eligible renewable energy resources portfolio effectively based on prevailing wholesale practices.

Before December 31, 2010, LADWP pursued its 20 percent RPS goal in a manner which resulted in a minimum of 40 percent renewable energy generation ownership that LADWP developed or that LADWP procured through contracts with providers of renewable energy. Further, with respect to the foregoing contracts with providers, such contracts provided for LADWP ownership or an option to own, either directly or indirectly (including through joint powers authorities).

On or after January 1, 2011, a minimum of 75 percent of all new eligible renewable energy resources procured by LADWP will either be owned or procured by the LADWP through an option-to-own, either directly or indirectly (including through joint powers authorities) until at least half of the total amount of eligible renewable energy resources, by Megawatt-hour (MWh), is supplied by eligible renewable energy resources owned or optioned either directly or indirectly (including through joint powers authorities) by LADWP.

The first priority for LADWP will be to pursue outright ownership opportunities, and the second priority will be consideration of procuring option-to-own, cost-based renewable energy resources. In comparing outright ownership to "option-to-own," option-to-own

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projects must show clear economic benefits such as pass-through of Federal or State tax credits or incentives which could not otherwise be obtained, or the need to evaluate new technology. The option-to-own will be exercisable with the minimum terms necessary to obtain and pass those tax credits and/or incentives to LADWP and/or upon a reasonable amount of time to evaluate the operation of the new technology.

7. Portfolio Content Categories

As required by SB 2 (1X), eligible renewable energy resources procured on or after June 1, 2010, will be in accordance with PUC Sections 399.16 (b) and (c). Section 399.16 (b) defines eligible renewable energy resources in three distinct portfolio content categories, commonly known as "buckets". LADWP will ensure that the procurement of its eligible renewable energy resources on or after
June 1, 2010 will meet the specific percentage requirements set out in Section 399.16 (c) for each bucket in each compliance period.

These buckets and percentage requirements are summarized in Table 1 below

Table 1: Procurement Content Categories and Percentage Requirements

	Category (aka "Buckets")	Percentage of RPS Target
4	Either: Have a first point of interconnection with a California balancing authority, have a first point of interconnection with distribution facilities used to serve end users within a California balancing authority area, or are scheduled from the eligible renewable energy resource into a California balancing authority without substituting electricity from another source [PUC Section 399.16(b)(1)(A)] Or, have an agreement to dynamically transfer electricity to a California balancing authority [PUC Section 399.16(b)(1)(B)]	**Compliance Period 1 (2011-2013):** 50% of RPS minimum from this category **Compliance Period 2 (2014-2016):** 65% of RPS minimum from this category **Compliance Period 3 (2017 to 2020):** 75% of RPS minimum from this category **Post 2020:** 75% of RPS minimum from this category.
5.	Firmed and shaped eligible renewable energy resource electricity products providing incremental electricity and scheduled into a California balancing authority [PUC Section 399.16(b)(2)]	Shall be calculated as the remainder of resources which are not in either Category 1 or Category 3.
6.	Eligible renewable energy resource electricity products, or any fraction of the electricity generated, including unbundled RECs, that do not qualify under Bucket 1 or 2. [PUC Section 399.16(b)(3)]	**Compliance Period 1 (2011-2013):** 25% of RPS maximum from this category **Compliance Period 2 (2014-2016):**

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	15% of RPS maximum from this category. **Compliance Period 3 (2017 to 2020):** 10% of RPS maximum from this category **Post 2020:** 10% of RPS maximum from this category

The LADWP will define the specific scheduling methods, including firming services, as needed, to maintain transmission system reliability and compliance with these procurement content categories and specified percentage requirements.

Subject to the provisions of PUC Section 399.16 (d), renewable electricity products procured prior to June 1, 2010, are exempt from these portfolio content categories and will continue to count in full toward LADWP's RPS compliance targets.

8. System Rate Impact.

The LADWP may not make any major financial commitment to procure renewable resources prior to evaluating the rate impact and any potential adverse financial impact on the City transfer.

9. Compliance Considerations:

In accordance with this RPS Policy, the Board will review the annual fiscal year budget and Renewable Energy Resources Procurement Plan, and will ensure that reasonable progress is being made towards compliance with the RPS compliance targets.

Reasonable progress may include activities that further the development and procurement of eligible renewable energy resources. Such activities may include, but are not limited to, real estate purchases for future project development, project planning and environmental permitting for either renewable energy projects or transmission in support of renewable energy projects, and other engineering, planning, budgeting, contracting and regulatory compliance activities.

In accordance with PUC Section 399.30 (d) (2), under exceptional circumstances the Board may adopt conditions that allow for delaying timely compliance with the RPS compliance targets, consistent with PUC Section 399.15 (b). Such conditions may include permitting, interconnection or environmental delays; transmission constraints; resource availability; or operational limitations.

In accordance with PUC Section 399.30 (d) (3), under exceptional circumstances the Board may adopt cost limitations for procurement expenditures consistent with PUC Sections 399.15 (c) and 399.15 (d).

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In accordance with PUC Section 399.30 (d) (1), under exceptional circumstances the Board may adopt rules permitting LADWP to apply excess procurement in one compliance period to subsequent compliance periods in the same manner as allowed for retail sellers pursuant to PUC Section 399.13

10. Reporting and Notice Requirements:

The LADWP will provide a monthly RPS Progress Report to the Board of Commissioners. Additionally an annual report will be provided to its customers and the CEC containing all information required to be reported pursuant to SB 2 (1X), SB 1078 SB 107 and related regulations

Per PUC Section 399.30 (e) the Board will adopt the program for enforcement at a publicly noticed Board meeting offering all interested parties an opportunity to comment. No less than 30 days' notice shall be given to the public of any meeting held for purposes of adopting the program. No less than 10 days' notice shall be given to the public before any meeting is held to make a substantive change to the program.

Per PUC Section 399.30 (f), LADWP will post notice whenever the Board will deliberate in public on its Renewable Energy Resources Procurement Plan. LADWP will either notify the CEC of the date, time, and location of the meeting in order to enable the CEC to post the information on its Internet Web site, or provide the CEC with the uniform resource locator (URL) that links to this information. In addition, upon distribution to the Board of information related to LADWP's renewable energy resources procurement status and future plans, for the Board's consideration at a noticed public meeting, LADWP shall make that information available to the public and shall provide the CEC with an electronic copy of the documents for posting on the CEC's Internet Web site, or provide the Uniform Resource Locator (URL) that links to the documents or information regarding other manners of access to the documents.

Per PUC Section 399.30 (g), LADWP shall annually submit to the CEC documentation regarding eligible renewable energy resources procurement contracts that it executed during the prior year

Per PUC Section 399.30 (l), LADWP shall report, on an annual basis, information on: (1) expenditure of public goods funds for eligible renewable energy resources development, (2) the resource mix used to serve its retail customers by energy source, and (3) status in implementing the RPS and progress toward attaining the RPS

LADWP will continue to provide a Power Content Label Report to its customers as required by SB 1305 (1997) and AB 162 (2009), and an annual report of the total expenditure for eligible renewable energy resources funded by voluntary customer contributions.

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11 Use of Renewable Energy Credits

The primary method of renewable energy resource procurement will be through the development and acquisition of physical generation assets and energy purchase contracts where the "Renewable Energy Credit" (REC) is "bundled" with the associated energy. PUC Section 399.12 (h) provides the REC definition.

In order for RPS compliance targets to be managed effectively, LADWP may buy, sell or trade RECs without the associated energy (unbundled). This procurement approach will be limited by the percentage requirements established by PUC Section 399.16 (b) (3), and as described in section 7 above.

RPS Policy & Enforcement Program
Appendix A – List of LADWP RPS Resources prior to SB 2 (1X)

PPM SW Wyoming – Pleasant Valley Wind
Linden Wind
PPM Pebble Springs Wind
Willow Creek Wind
Pine Tree Wind Power Project
Milford Wind Phase I
Milford Wind Phase II
Windy Point Phase II
Powerex - BC Hydro
MWD Sepulveda
Lopez Canyon Landfill
WM Bradley Landfill
Penrose Landfill
Toyon Landfill
Valley Generating Station (GS) – Multi-fuel
Scattergood GS – Multi-fuel
Haynes GS – Multi-fuel
Harbor GS – Multi-fuel
Shell Energy Landfill Gas
Atmos Energy Landfill Gas
Hyperion Digester Gas – Scattergood GS
LADWP Small Hydro Power Plants (PP)

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San Francisquito Power Plant 1
San Francisquito Power Plant 2
San Fernando Power Plant 2
Foothill Power Plant
Branch Power Plant
Sawtelle Power Plant
Harbor Power Plant
Owensdale Power Plant
Division Creek [illegible]
Big Pine Power Plant
Pleasant Valley [illegible]
Upper Gorge [illegible]
Middle Gorge [illegible]
Control Gorge [illegible]
North Hollywood Pump Station PP
Castaic Hydro Plant – Efficiency Upgrades
SB-1 Customer Net Metered Solar PV
DWP Built Solar
Silverlake Library
LA Convention Center Canopy
Sun Valley Library
Lake View Terrace Library
Canoga Park Library
North Central Animal Shelter
Ascot Library
Hyde Park Library
Ducommun Fitness Center
Truesdale Warehouse
Van Nuys Truck Shed
Distribution Station B (Vincent Thomas Bridge)
Main Street Yard
Exposition Park Library
Granada Hills Yard
LADWP - FB Parking Lot
LA Convention Center Cherry St Parking Lot
Council District 6 Field Office

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Appendix E Power Reliability Program

E.1 Overview

This Appendix describes LADWP's existing power reliability programs, which has provided high quality service to customers for more than 90 years. Recommendations are then presented for programs and actions to ensure high reliability in the future. Finally, statistical information is provided on the progress of the Power Reliability Program (PRP).

E.2 Historic Reliability of LADWP System

Reliable electric power has been a cornerstone objective of LADWP since it began offering municipal electricity in 1917. Historically, LADWP's Power System reliability has consistently placed in the top quartile of the electric utility industry, and it is LADWP's goal to continue this into the foreseeable future. However, as a result of aging electrical distribution infrastructure, there are significant challenges for LADWP to continue to maintain these reliability goals.

The City of Los Angeles (City) was founded in 1781 and incorporated in 1850. Since then, Los Angeles has grown to the Nation's second largest City with a population of almost 4 million residents. Historically, most of this growth occurred between 1920 when there were roughly 580,000 residents and 1970 when the City had grown to over 2.8 million residents. This incredible growth of 2.2 million residents (roughly 56 percent of today's population) coincided with the mass electrification of homes and businesses throughout the country and specifically the City. During this time, LADWP installed tremendous amounts of electrical infrastructure to ensure that these growing numbers of new homes and businesses were supplied with reliable electric service. Figure E-1 shows the number of electrical distribution poles categorized by age, and demonstrates that the installation of these poles (and the related electrical distribution infrastructure) was directly related to the historical population growth.

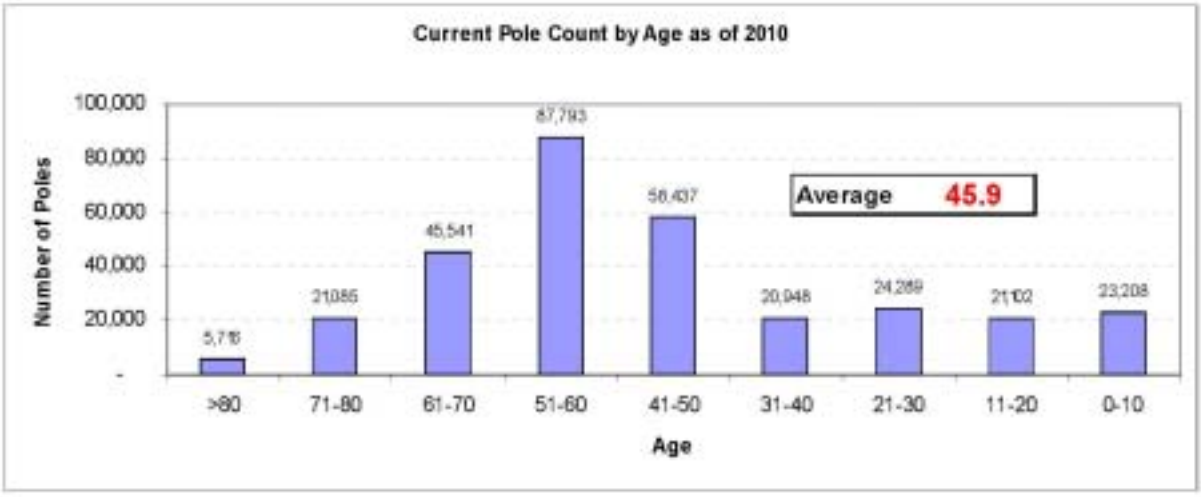

Figure E-1. Pole count by year range installed.

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As a testimony to the initial design and installation of this electrical infrastructure, it has reliably served the residents of the City over the last 40 to 70 years. However, data now shows that reliability is beginning to deteriorate. In the past few years, outage rates have increased, including several high profile outages, demonstrating that this equipment is at the end of its service life. As more of the infrastructure ages and there is related performance deterioration, it will create a significant backlog of deferred maintenance and require increased levels of reliability-enhancing capital work. Existing staffing and funding levels will not be sufficient to replace the infrastructure that is needed to maintain the reliability that LADWP customers have come to expect.

E.3 Recommendations to Improve System Reliability

System reliability can be measured in terms of the key SAIDI and SAIFI performance indicators, defined below:

- SAIFI – System Average Interruption Frequency Index -Total number of sustained customer interruptions divided by the total number of customers, expressed in interruptions per customer per year.
- SAIDI – System Average Interruption Duration Index -Total minutes of sustained customer interruption divided by the total number of customers, expressed in minutes per customer per year.

Power System staff and independent industry experts have reviewed the overall system and have developed the following set of initial recommendations to improve reliability. These are summarized in the following subsections.

E.3.1 Operations and Maintenance (O&M) Programs

- Abnormal Circuits and Open Circuits: Abnormal Circuits and Open Circuits are cables that have been temporarily repaired and not in an as designed condition. These temporary repairs were made in the interest of restoring service in a timely manner rather than making permanent repairs, which were planned later. However, because temporary repairs are increasing, more staff is needed to make permanent repairs. Expanding Distribution Construction and Maintenance (DC&M) crews and proceeding with the Cable Replacement program will facilitate timely permanent restoration.
- Station Equipment Maintenance: The current maintenance practice is generally reactive to failures, not proactive and/or preventative. There is a large backlog of maintenance jobs. Maintenance practices should be modified, increasing maintenance frequency and adjusting staffing as appropriate.
- Overhead Transmission Maintenance: There is substantial deferred maintenance and a large volume of new capital work. Maintenance frequency should be increased and staffing adjusted as required.

Figure E-2 shows the SAIDI per Calendar year, both achieved to date and projected, and the impact of the ongoing PRP to reduce the SAIDI to the long term goal of 60 minutes by 2015.

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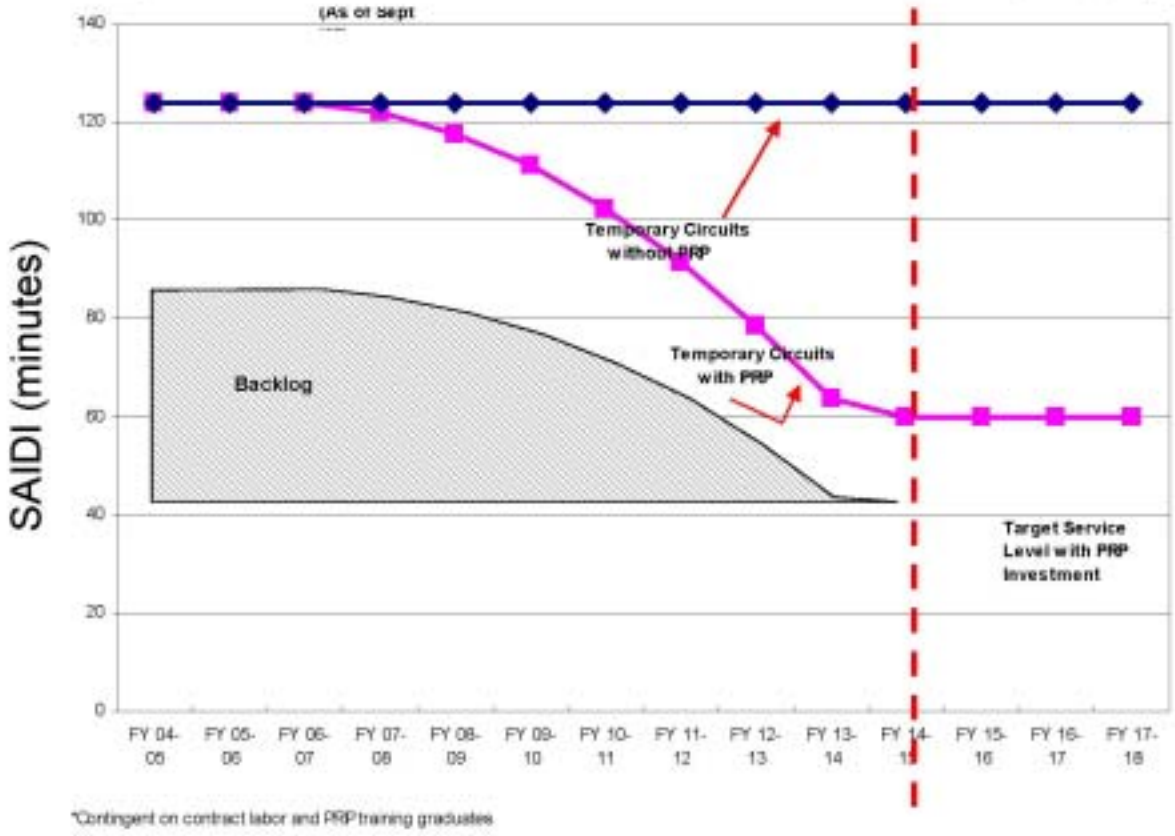

Figure E-2. Temporary circuit restoration and worst performing circuits and stations.

E.3.2 Capital Projects:

- Pole Replacement: The number of poles replaced annually should be increased with the goal of achieving an overall replacement cycle of 60 years.
- Cable Replacement: The amount of underground cable replacements should be increased from 40 miles per year to 60 miles, representing a 75-year replacement cycle. LADWP's Underground Transmission section is also planning to replace one 138-kV underground line per year.
- Distribution Transformers: A transformer management program is required to closely monitor transformer loading. Priority based transformer replacements take into account various factors such as loading, number of customers, age, and neighborhood conditions.
- Load Growth: Construction of new lines and stations to support load growth is a very important infrastructure improvement. Construction resources should be increased to support the timely installation of new facilities. Limited engineering staffing is restricting sufficient numbers of work packages for load growth, maintenance, and construction jobs. A 58,000 labor-hour backlog exists for various records, and approximately 60,000 as-built drawings from the Integrated Resource Plan require processing.

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- Deteriorated Vaults & Obsolete Equipment: Over 900 substructures require repair. Much of this work is deferred due to lack of resources. Various obsolete equipment has been identified as needing replacement. Necessary resources and funding should be provided.
- Station Transformers: There are 846 main transformer banks in Distribution, Receiving and Switching stations, some over 60 years old. We are currently changing 2 transformer banks per year. Increased funding is recommended to replace this aging equipment.
- Reliability Engineering Work Group: LADWP should establish this group and develop work processes for structured analysis of failure rates, outage rates, and testing data as input to prioritize the maintenance basis and capital jobs for transmission and delivery (T&D) reliability.
- Generation Reliability Engineering: Staffing should be increased in select generation engineering groups to improve analysis and evaluation of generation unit performance and other reliability related programs and projects.

E.3.3 Distribution Infrastructure Undergrounding Program

- In addition to aesthetic considerations, undergrounding overhead lines has a reliability benefit of reducing the frequency of outages to almost half that of overhead. Currently, LADWP is converting undergrounds at approximately 6 miles per year.

E.3.4 Funding and Resources

The recommendations above are based on the initial observations of the Power System staff and industry experts. As these programs are implemented, prioritizations and/or resources will be directed to the programs that will result in the maximum amount of increased reliability. LADWP's equipment was installed with significant resources over a long period of time; the program to replace the infrastructure will also require a long-term commitment.

In order to ensure that this program is implemented with the maximum impact on reliability and in the most efficient manner possible, LADWP has established a Power Reliability Oversight Committee. This committee conducts quarterly reviews of all facets of the reliability program and makes changes as needed to improve its effectiveness. This includes a review of percent completion of milestones, cost metrics, and impacts that the program is having on reliability metrics.

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E.4 Current Power Reliability Program

As discussed in Section E.1, the PRP provides a blueprint for ensuring continued reliable energy service for future generations of Los Angeles residents. LADWP implemented the PRP through a two-pronged approach—rebuilding infrastructure and providing proactive maintenance—and will invest more than $1 billion in the program over the next 5 to 15 years. The program is funded through a power reliability surcharge. Figure E-3 shows the historic and future planned PRP expenditures.

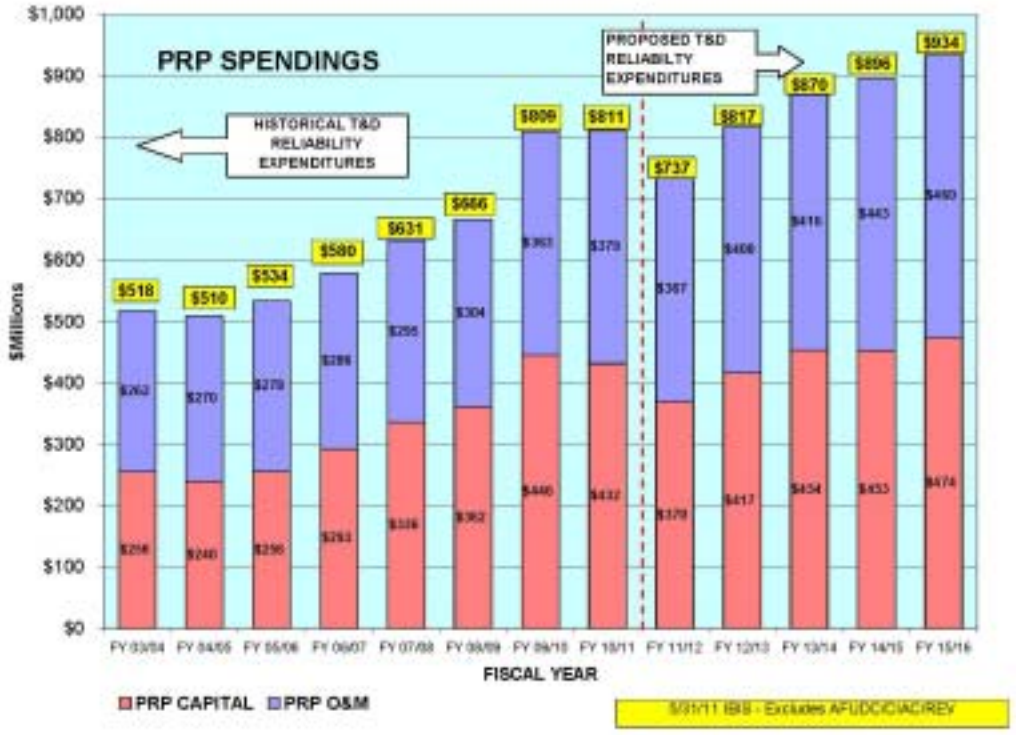

Figure E-3. PRP Expenditures.

The goals of the program include: 1) mitigating problem circuits and stations based on the types of outages specific to the facility, 2) implementing proactive maintenance and capital improvements that take into account system load growth and the inspections and routine maintenance that must take place to identify problems before they occur, and 3) establishing replacement cycles for facilities that are in alignment with the equipment's life cycle.

***The tables and* figures** below detail the progress of LADWP's Power Reliability Program. Figure E-4 and Tables E-1 and E-2 present the reliability achieved in terms of the SAIDI and SAIFI performance indicators, as compared to California's major investor-owned utilities.

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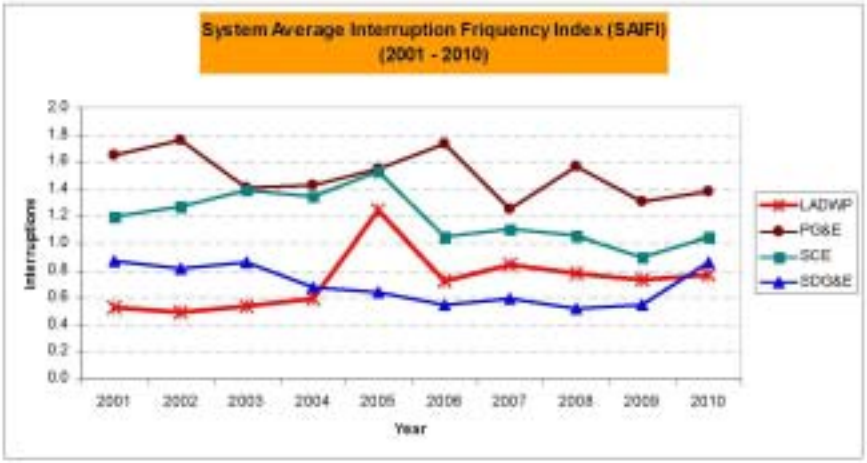

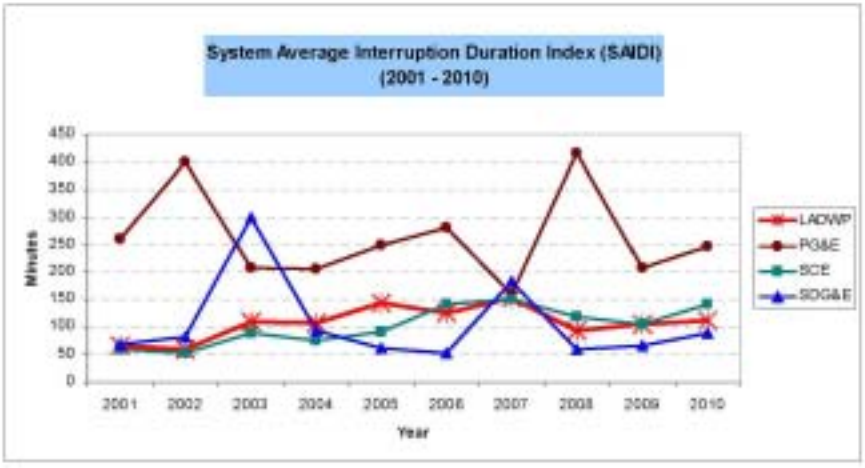

Figure E-4. LADWP PRP reliability comparisons with Investor Owned Utilities (IOUs).

Table E-1. LADWP SAIFI/SAIDI INDICATORS

Key Indicator	Units	2008	2009	2010
SAIFI	Outages / Year	0.78	0.73	0.77
SAIDI	Minutes / Year	93.1	104.5	112.8

Table E-2.1. UTILITY COMPARISON FOR 2009

Key Indicator	Units	LADWP	SCE	PG&E	SD&E
SAIFI	Outages / Year	0.73	0.90	1.31	0.54
SAIDI	Minutes / Year	104.5	105.8	208.2	67.06
Investor Owned Utility data from CPUC					

Table E-2.2. UTILITY COMPARISON FOR 2010

Key Indicator	Units	LADWP	SCE	PG&E	SD&E
SAIFI	Outages / Year	0.77	1.05	1.38	0.86
SAIDI	Minutes / Year	112.8	140.9	246.2	89.77

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Table E-3 summarizes the PRP activity as of December 1, 2009 while Figures E-4 to E-9 present actual progress compared to PRP target for key elements of LADWP's PRP program.

Table E-3. LADWP PRP ACTIVITY

Key Performance Indicators (KPI)	Units	*FY 08-09 Target*	FY 08-09 Final	*FY 09-10 Target*	FY 09-10 Final	*FY 10-11 Target*	FY 10-11 Final
System Average Interruption Frequency Index (SAIFI)	Outages per Year	*0.72*	0.69	*0.71*	0.84	*0.70*	0.82
System Average Interruption Frequency Index (SAIDI)	Minutes Out per Year	*125.3*	78.1	*122.7*	120.7	*120.1*	121.7
	System Total						
Abnormal & Temporary 4.8-kV Circuit Backlog Total	1630 Circuits	*118*	139	*110*	153	*102*	164
Priority A Circuits (carrying extra load due to failed components)	Circuits	-	47	-	29	-	47
Priority B Circuits (failed components with no load transfer)	Circuits	-	42	-	37	-	35
Priority C Circuits (extra load due to field work)	Circuits	-	50	-	87	-	82
New Priority	Circuits	-	-	-	-	-	-
Poles Replaced and Reinforced	308,100 Poles	*2975*	2780	*2975*	2815	*2600*	2325
Distribution Transformers Installed	126,000 Transformers	*2400*	2984	*2400*	3184	*2400*	2624
Underground Transmission Cable Replaced	123 Miles						
Length of Underground Cables Replaced	2,242 Miles	*40*	42	*40*	65	*40*	69
Preventive Maintenance for RS, DS and CS							

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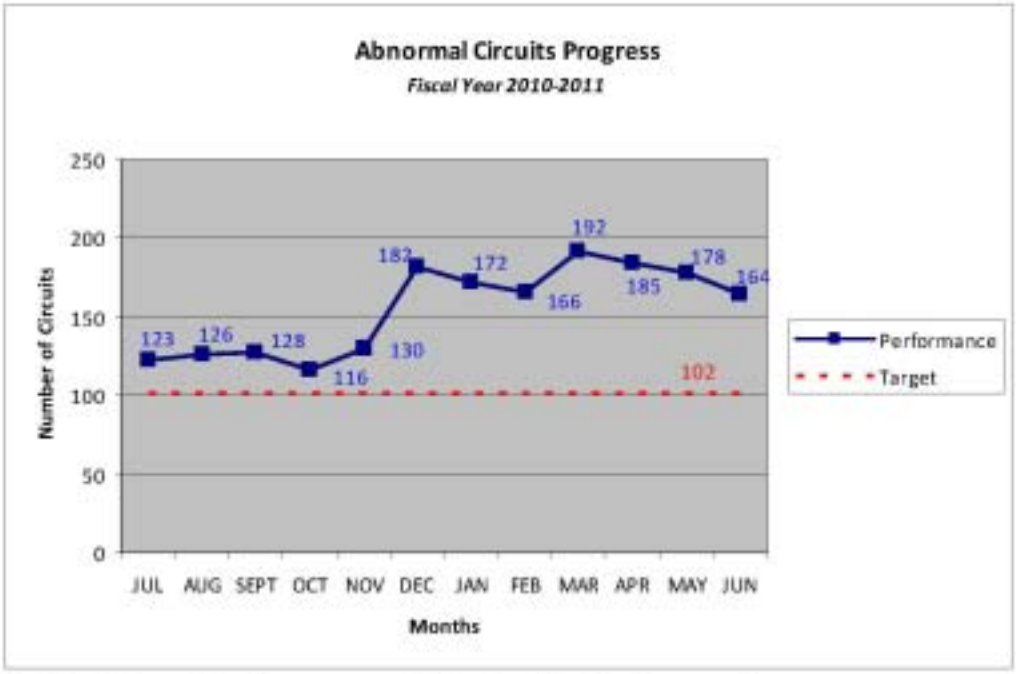

Figure E-5. PRP abnormal and temporary 4.8kV circuit backlog by month.

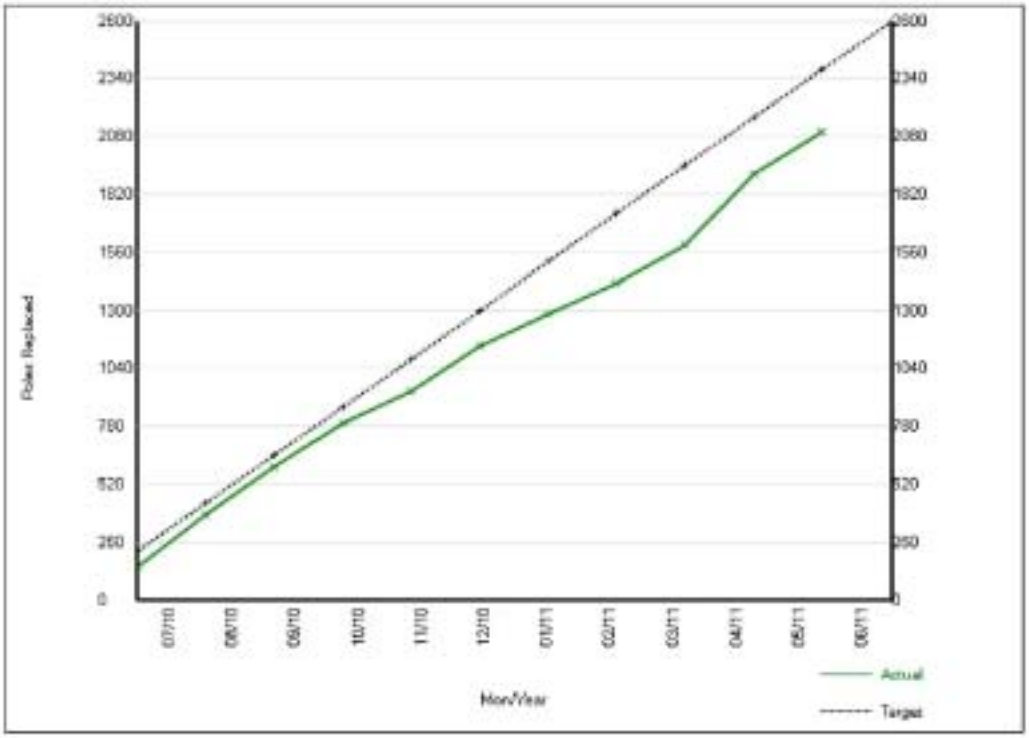

Figure E-6. PRP pole replacement by month, FY 2010-11.

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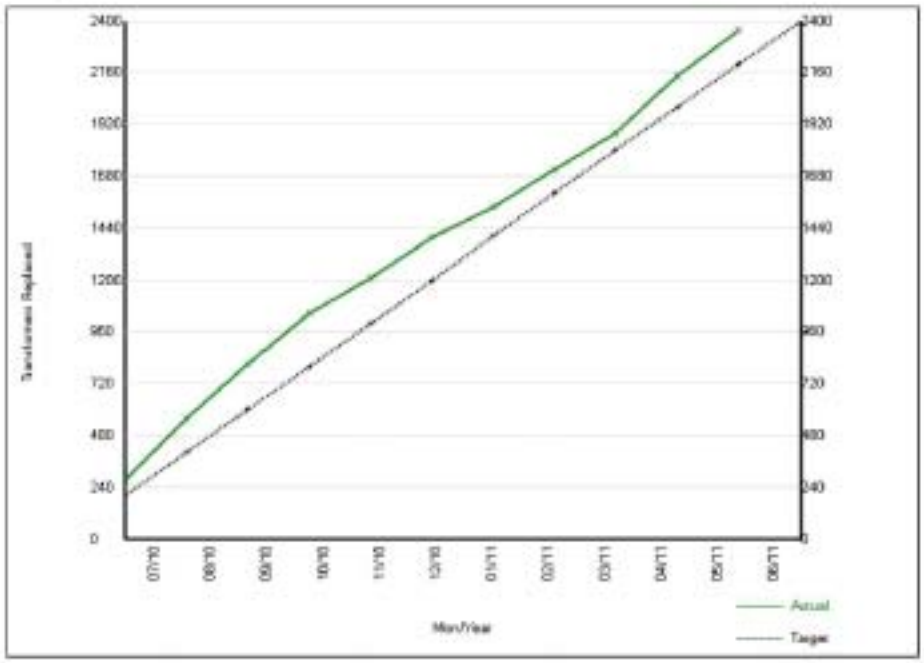

Figure E-7. PRP distribution transformer replacement by month, FY 2010-11.

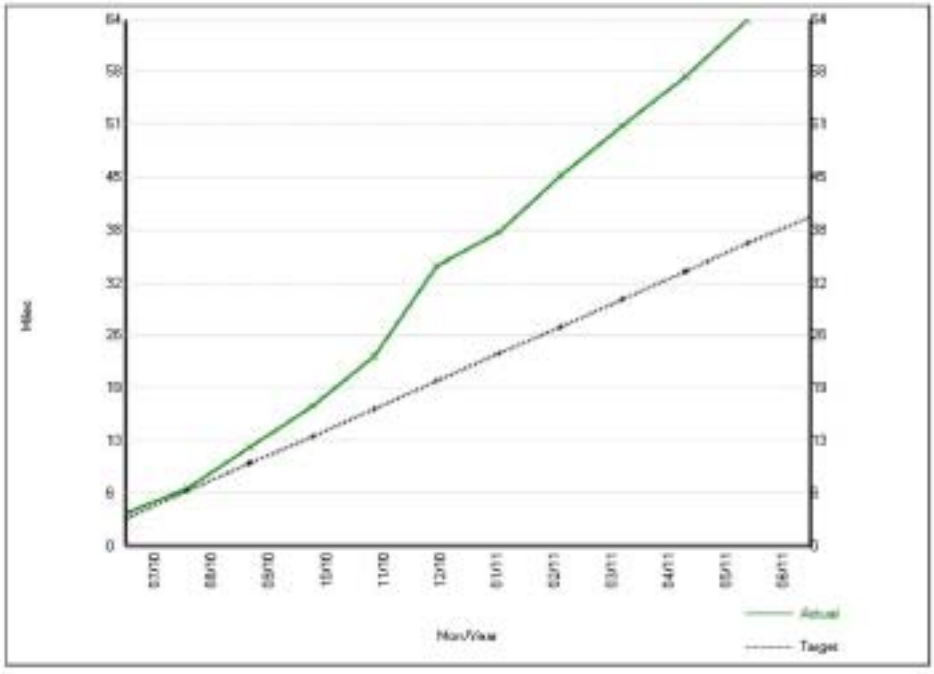

Figure E-8. PRP underground cable replacement by month, FY 2010-11.

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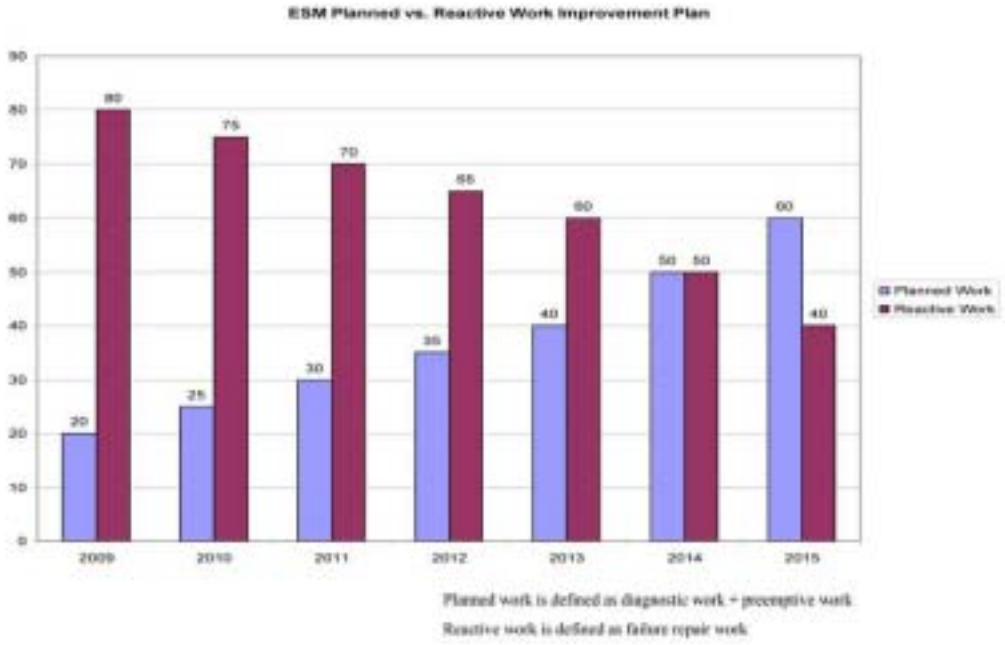

Figure E-9. Circuit load growth and substation maintenance.

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Appendix F Generation Resources

F.1 Overview

LADWP's generation resources are presented in this Appendix. Resources that are not wholly owned by LADWP are available either as long-term power purchase agreements or as entitlement rights resulting from undivided ownership interests in facilities that are jointly-owned with other utilities. Most of these additional resources are available through LADWP's participation in the Southern California Public Power Authority (SCPPA). Each project participant with respect to jointly-owned units is responsible for providing its share of construction, capital, operating, and maintenance costs.

F.2 Resources

Generation resources for LADWP are comprised of the following five categories:

- In-Basin Thermal Generation
- Coal Fired Thermal Generation
- Nuclear-Fueled Thermal Generation
- Large Hydroelectric Generation
- Renewable Resources and Distributed Generation

F.2.1 In-Basin Thermal Generation

LADWP is the sole owner and operator of four electric generating stations in the Los Angeles Basin (the "Los Angeles Basin Stations"), with a combined net maximum generating capability of 3,415 megawatts (MWs) and a combined net dependable generating capability of 3,337 MWs. Natural gas and digester gas are used as fuel for the Los Angeles Basin Stations. Low-sulfur, low-ash residual distillate is used for emergency back-up fuel for some of the stations.

LADWP's natural gas-fueled generating plant capabilities are shown in Table F-1.

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Table F-1. NATURAL GAS GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Capability (kW)	Net Dependable Capability (kW)
Harbor	1	1995	100,400	82,000	461,000[2]
	2	1995	100,400	82,000	
	5	1995	75,000	65,000	
	10	2002	60,500	47,400	
	11	2002	60,500	47,400	
	12	2002	60,500	47,400	
	13	2002	60,500	47,400	
	14	2002	60,500	47,400	
Haynes	1	1962	230,000	222,000	1,525,000[3]
	2	1963	230,000	222,000	
	5	1966	343,000	292,000	
	6	1967	343,000	243,000	
	7	1970	2,000	1,599	
	8	2005	264,350	250,000	
	9	2005	182,750	162,500	
	10	2005	182,750	162,500	
Scattergood	1	1958	163,200	183,000	796,000
	2	1959	163,200	184,000	
	3	1974	496,800	450,000	
Valley	5	2001	60,500	43,000	556,000[4]
	6	2003	182,750	159,000	
	7	2003	182,750	159,000	
	8	2003	264,350	215,000	
Total				3,414,599	3,337,000

Notes:

1. COD refers to Commercial Operation Date.
2. Harbor Generating Station Net Dependable Plant Capability is 461 MW, reflecting Units 1 and 2 reduced performance during hot-weather conditions.
3. Haynes Generating Station Net Dependable Capability is 1,525 MW reflecting 8, 9, and 10 reduced performances during hot weather conditions; and Unit 7 used for auxiliary power only. Unit 5 Net Maximum Unit Capability was decreased to 292 MW to reflect LP hot-reheat piping derating. Unit 6 Net Dependable Unit Capability is 238 MW reflecting 243 MW transformer derating during hot weather conditions. Unit 4 was decommissioned in November 2003 and Unit 3 was decommissioned in September 2004.
4. Valley Generation Station Net Dependable Capability limited to 556 MW reflecting reduced performance during hot weather conditions.

Haynes Generating Station

The largest of the Los Angeles Basin Stations is the Haynes Generating Station, located in the City of Long Beach, California . The Haynes Station currently consists of eight generating units (Unit 7 is used for auxiliary power only) with a combined net maximum capability of 1,556 MWs and a net dependable capability of 1,525 MWs. This station includes a 575 MW

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combined-cycle generating unit installed in February 2005. The combined-cycle generating unit includes two combustion turbines and a common steam turbine. The combustion turbines can each operate with the steam turbine independently or together in a two on one configuration (and are counted by LADWP as three generating units). LADWP plans to repower unit 5 and 6 with simple-cycle gas turbine units by December 2012.

Valley Generating Station

The Valley Generating Station is located in the San Fernando Valley. The Valley Station began its repowering in 2001 with a simple-cycle, 60.5 MW gas–turbine generator. Repowering was completed in 2004 with the installation of a combined-cycle generating unit consisting of two gas turbines with heat recovery steam generators, which supplies one steam turbine with 576 MWs of maximum capability. The total net dependable capacity for the Valley Station is 556 MWs.

Harbor Generating Station

The Harbor Generating Station is located in Wilmington, California. The Harbor Station was repowered in 1995 with a combined-cycle generating unit (counted as three units). Five additional peaking combustion turbines were installed in 2002 for a total of eight generating units. These activities resulted in the Harbor Station's net maximum capability of 466 MWs and a net dependable capability of 461 MWs.

Scattergood Generating Station

The Scattergood Station is located in Playa del Rey, California and is comprised of three steam generating units with a net maximum capability of 817 MWs from natural gas and a net dependable capability of 796 MWs from natural gas. Units 1 and 2 also burn digester gas from the adjacent Hyperion Wastewater Treatment Plant.

F.2.2. Coal-Fired Thermal Generation

LADWP's coal generating capacity comes from the Navajo Generating Station and the Intermountain Generating Station (IGS). IGS is also referred to as the Intermountain Power Project (IPP). Coal generating resources are summarized in Table F-2.

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Table F-2: COAL GENERATING RESOURCE

Plant Name	Unit	COD[1]	Nameplate (kW)	Net Max Capability (LADWP kW)	Net Dependable Capability (LADWP kW)	LADWP Expiration	LADWP Share
Intermountain	1 2	1986 1987	820,000 820,000	401,553 401,553	401,553 401,553	15Jun2027	44.617%
Intermountain	1 2	1986 1987	820,000 820,000	36,000 36,000	36,000 36,000	15Jun2027	4% (UP&L)
Intermountain	1 2	1986 1987	820,000 820,000	163,447 163,447	86,000 86,000	15Jun2027	18.161% (Recallable)
Total				1,202,000[2]	1,047,066[2]		
Navajo	1 2 3	1974 1974 1975	803,000 803,000 803,000	159,000 159,000 159,000	477,000[3]	31Dec2019	21.2%
Total				1,679,000	1,524,000		

Notes:

1. COD refers to Commercial Operation Date.
2. IPP's Net Capacity available maybe less than 1202 MW due to Excess Power Recall. The LADWP entitlement is 44.617% direct ownership plus a 4% purchase from Utah Power & Light Company, plus 86.281% of up to 21.057% of muni's and co-op's recallable entitlement which can vary. The nominal net Maximum Unit Capability and Net Dependable of both Units 1 and 2 is 900 MW.
3. LADWP's contract entitlement is 21.2% of Navajo's total net generation.

Intermountain Power Project (IPP)

General. The IPP consists of: (a) a two-unit coal-fired, steam-electric generating plant located near Delta, Utah, with net rating of 1,800 MWs and a switchyard located near Delta, Utah; (b) a rail car service center located in Springville, Utah; (c) certain water rights and coal supplies; and (d) certain transmission facilities consisting primarily of the Southern Transmission System. Pursuant to a Construction Management and Operating Agreement between the Intermountain Power Authority (IPA) and LADWP, IPA appointed LADWP as project manager and operating agent responsible for, among other things, administering, operating and maintaining IPP.

Power Contracts. Power is provided to LADWP under three separate agreements.

- Pursuant to a Power Sales Contract with IPA (the "IPP Contract") and a Lay-Off Power Purchase Contract with Utah Power & Light Company ("UP&L") and IPA, LADWP is entitled to 44.617 percent of the capacity of the IPP (currently equal to 803 MWs). The IPP Contract terminates in 2027 and may be renewed by LADWP under certain circumstances, subject, in addition, to legal and regulatory mandates.

- Pursuant to a Power Purchase Agreement with UP&L, LADWP purchases capacity and energy equivalent to the capacity and energy made available to UP&L pursuant

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to its 4 percent entitlement in the IPP (currently equal to approximately 72 MWs) until 2027, subject to certain renewal rights, which are dependant upon certain factors including the renewal of the IPP Contract.

- LADWP also has available additional capacity in the IPP through an excess power sales agreement with certain other IPP participants (the "IPP Excess Power Sales Agreement"). Under the IPP Excess Power Sales Agreement, LADWP is entitled to a maximum 18.168 percent of the capacity of IPP (equal to approximately 327 MWs). However, this amount varies as portions of it may be recalled by other participants. Of the maximum possible 327 MW allowed under this Agreement, approximately 172 MW is the current entitlement amount.

Fuel Supply: IPA sold its 50 percent undivided interest in the Crandall Canyon Mine in Emery County, Utah and 50 percent undivided interest in the West Ridge Mine in Carbon County, Utah, in 2010. As part of the sale, a continued long term contract for fuel from the West Ridge Mine for IPP was agreed to at about 20 percent of the annual 6,000,000 ton coal requirement. LADWP, in its role as Operating Agent, manages all fuel supply contracts on behalf of IPA, including several long-term coal supply agreements that can provide in excess of 60 percent of the coal requirements for the IPP. Spot market and opportunity purchases provide the balance of the fuel requirements for the facility. Additional information regarding IPP's fuel procurement strategy is found in Appendix H.

Over the past several years, the IPP units have had several substantial modifications, including cooling tower additions, high pressure turbine replacements, boiler capacity additions, distributed control system replacement, scrubber outlet modifications and rebuilds, and induced draft fan drive replacement. These modifications have decreased emissions and increased plant efficiency. They have also increased the plant's capacity by 110 MW, resulting in a 68 MW increase in capacity for LADWP.

Navajo Generating Station

The Navajo Generating Station (NGS) is located near the City of Page, Arizona. Salt River Project (SRP) is the operating agent for the Navajo Station. The Navajo Station is a coal-fired electric generating station and consists of three units with a combined capacity of 2,250 MWs. LADWP's entitlement of the Navajo Generating Station capability is 21.2 percent. On March 23, 1976, LADWP, Arizona Public Service Company (APS), Nevada Power Company (NPC), SRP, Tucson Electric Power Company (TEP), and the U.S. Department of Interior executed the Navajo Project Co-Tenancy Agreement effecting the co-owners' participation and the operation and maintenance of the Navajo Project for as long as the land lease with the Navajo Nation is in effect until December 31, 2019 and throughout the lease extension thereafter. Negotiations are currently under way between the Navajo Nation and SRP, on behalf of the NGS participant owners, to renew the terms of the lease and all rights of way (ROWs) and grants related to the NGS site, transmission and railroad until December 31, 2044.

The station's SO_2 scrubbers, which were installed in 1999, continue to operate in full compliance with federal regulations for SO_2. The plant-wide compliance number ranges around 0.60 pounds per million BTU relative to an emission limit of 0.10 pounds per million BTU.

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NGS also completed its Low NO_x burner Separated Overfire Air (SOFA) retrofit project in late March 2011 with the completion of the Unit 1 major overhaul. The Low NO_x/SOFA installation on all three units' boilers has contributed to a successful reduction of NO_x emissions by 40%, representing an annual NO_x emissions reduction of 14,000 tons/year.

Stringent NO_x emissions control standards currently being considered by the federal government for the pending Regional Haze Best Available Retrofit Technology (BART) ruling may require Navajo Generating Station to install Selective Catalytic Reduction (SCR) systems which carry a capital cost of approximately $550 million (or $117 million for LADWP). Should the new regulations require the installation of baghouses in addition to the SCRs, the combined capital cost of both SCRs and baghouses would amount to $1.13 billion (or $240 million for LADWP). The installation of these SCRs and baghouses could begin as early as 2017 and as late as 2029.

In March 2011, the Environmental Protection Agency (EPA) released another proposed rule called the Utility Maximum Achievable Control Technology (MACT) that sets the national emissions standards for hazardous air pollutants (HAP) for electric generating units (EGUs). This rule calls for compliance of monitoring systems for Hg, particulate matter, and SO_2 for HCl, hourly data collection, quarterly submission of emissions data, and new work practice standards for dioxins, furans, and other organic HAPs that would require regular "tune ups" of boilers to optimize combustion. These MACT modifications are estimated at $148.5 million (or $31.5 million for LADWP).

The EPA also proposed federal regulations governing the disposal of coal ash and other coal combustion byproducts (CCBs) under the Resource Conservation and Recovery Act (RCRA). Under this rule, CCBs may be classified as either RCRA Subtitle C hazardous waste or RCRA Subtitle D non-hazardous waste. The regulation of CCBs under RCRA Subtitle C would impose staggering compliance costs on the power industry, including NGS. An unfavorable ruling would jeopardize fly ash sales, trigger significant capital improvement to minimize environmental releases of coal ash and other byproducts, involve additional manpower to manage new programs, and require additional monitoring of the ash disposal landfill. Such coal ash disposal initiatives could amount to approximately $10 million (or $2.1 million for LADWP).

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F.2.3. Nuclear-Fueled Thermal Generation

LADWP's nuclear-fueled generating plant capabilities are shown in Table F-3.

Table F-3. NUCLEAR GENERATING RESOURCES

Plant Name	Unit	COD[1]	License Expiration	Nameplate (kW)	Net Max Capability (LADWP kW)	Net Dependable Capability (LADWP kW)	LADWP Share[2]
LADWP Direct Ownership Interest:							
Palo Verde	1 2 3	1986 1986 1988	2045 2046 2047	1,413,000 1,413,000 1,413,000	75,981 76,152 76,038	74,727 74,898 74,784	5.7%
LADWP Entitlement Interest Through SCPPA:							
Palo Verde	1 2 3	1986 1986 1988	2045 2046 2047	1,413,000 1,413,000 1,413,000	52,787 52,906 52,826	51,916 52,034 51,955	3.96% (SCPPA)
Total					386,690	380,314	

Notes:
1. COD refers to Commercial Operation Date.
2. LADWP's contract entitlement is 9.66 percent of generation comprised of 5.7 percent direct ownership in Palo Verde and another 67 percent power purchase of SCPPA's 5.91 percent ownership of Palo Verde.

Palo Verde Nuclear Generating Station (PVNGS) is located approximately 50 miles west of Phoenix, Arizona. PVNGS consists of three nuclear electric generating units (numbered 1, 2 and 3), with a design electrical rating of 1,333 MW (Unit 1), 1,336 MW (Unit 2) and 1,334 MW (Unit 3) and a dependable capacity of 1,311 MW (Unit 1), 1,314 MW (Unit 2) and 1,312 MW (Unit 3). PVNGS's combined design capacity is 4,003 MW, and its combined dependable capacity is 3,937 MW. All three units have been operating under 40-year Full-Power Operating Licenses from the Nuclear Regulatory Commission (NRC) expiring in 2025, 2026, and 2027, respectively. In April 2011, the NRC approved Palo Verde's application to extend the units' operating licenses to 20 years beyond the original term, allowing Unit 1 to operate through 2045, Unit 2 through 2046, and Unit 3 through 2047. APS is the operating agent for PVNGS. For the fiscal year ended June 30, 2011, PVNGS provided over 3.1 million megawatt-hours ("MWhs") of energy to the Power System. LADWP has a 5.7 percent direct ownership interest in the PVNGS (approximately 224 MW of dependable capacity). LADWP also has a 67.0 percent generation entitlement interest in the 5.91 percent ownership share of PVNGS that belongs to SCPPA through its "take-or-pay" power contract with SCPPA (totaling approximately 156 MWs of dependable capacity), a joint powers authority in which LADWP participates, so that LADWP has a total interest of approximately 380 MW of dependable capacity from PVNGS. Co-owners of PVNGS include APS; the SRP Agricultural Improvement and Power District, a political subdivision of the state of Arizona, and the Salt River Valley Water Users' Association, a

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corporation (together, the "Salt River Project"); Edison; El Paso Electric Company; Public Service Company of New Mexico; SCPPA, and LADWP.

The aftermath of the Fukushima earthquake and tsunami prompted the U.S. nuclear industry to form a task force under the direction of Palo Verde's Chief Nuclear Officer to take immediate actions in ensuring the reliability of all U.S. nuclear plants. Palo Verde itself has established a task force to evaluate the plant's safety and emergency preparedness. An initial assessment of the plant systems, safety policies, and emergency procedures revealed significant differences between Palo Verde and Fukushima. Palo Verde's low-seismic location, robust pressurized water reactor design, redundant safety features, ample effluent water supply, and multiple back-up power sources make a similar catastrophe in Arizona highly improbable. Despite the seemingly substantial advantages, Palo Verde, in conjunction with other nuclear agencies, is continuously working to make sure that the plant is adequately prepared to meet beyond design basis events, respond to extended loss of power situations, and mitigate potential fire and flood events. While evaluations are still in progress, among the initial recommendations are plans to accelerate fuel removal from the spent fuel pools and possibly purchase a standby diesel generator as reinforcement to the existing back-up power sources.

F.2.4 Large Hydroelectric Generation

LADWP's large hydroelectric facilities include the Castaic Pumped Storage Power Plant and an entitlement portion of the Hoover Power Plant. LADWP's hydroelectric plant capabilities are shown in Table F-4.

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Table F-4. LARGE HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Capability (LADWP kW)	Net Dependable Capability (LADWP kW)	LADWP Expiration	LADWP Share
Castaic[2]	1 2 3 4 5 6 7	1973 1974 1976 1977 1977 1978 1972	212,500 265,000 265,000 265,000 265,000 265,000 56,000	240,000 265,000 265,000 265,000 265,000 265,000 55,000	1,175,000	Owned Asset	100%
Hoover[3]		1936	2,079,000	491,000	436,000	30Sep2017	15.4229%
Total				1,763,000	1,611,000		

Notes:

1. Commercial Operation Date.
2. Castaic Power Plant is re-rated at 1,175 MW. Castaic Power Plant Units 2, 4, 5, 6 modernizations were completed September 2004, June 2006, July 2008, and December 2005 respectively. Unit 3 modernization was completed in June 2009.
3. LADWP's entitlement is 25.16% of the plant's contingent capability of 1,951 MW (or 491 MW). The reduced entitlement is due to lower lake levels resulting from the western drought, which causes plant capability to vary constantly. The current Hoover net plant capability as of July 28, 2011 is 1732 MW.

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Castaic Pump Storage Power Plant.

The Castaic Pump Storage Power Plant (the "Castaic Plant") is located near Castaic, California. The Castaic Plant is LADWP's largest source of hydroelectric capacity and consists of seven units with a net dependable capacity of 1,175 MWs. The Castaic Plant provides peaking and reserve capacity for LADWP's load requirements.

Hoover Power Plant.

General. The Hoover Power Plant (the "Hoover Plant") is located on the Arizona-Nevada border approximately 25 miles east of Las Vegas, Nevada and is part of the Hoover Dam facility, which was completed in 1935 and controls the flow of the Colorado River. The Hoover Plant consists of 17 generating units and two service generating units with a total installed capacity of 2,080 MWs. LADWP has a power purchase agreement with the United States Department of Energy Western Area Power Administration ("Western") for 491 MWs of capacity (calculated based on 25.16 percent of 1,951 MWs of total contingent capacity) and energy from the Hoover Plant through September 2017. The facility is owned and operated by the United States Bureau of Reclamation.

Drought Conditions. Due to recent drought conditions and low lake levels, LADWP's capacity entitlement at the Hoover Plant was reduced to an annual average of approximately 436 MWs (calculated based on 25.16 percent of 1,732 MW output capability as of July 28, 2011).

F.2.5 Renewable Resources and Distributed Generation

LADWP's Renewable Resources and Distributed Generation consists of

- Eligible renewable small hydro resources as shown in Tables F-5, F-6 and F-7.
- Wind resources as shown in Table F-8.
- Other resources and distributed generation as shown in Table F-9.

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Table F-5. OWENS VALLEY SMALL HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Unit Capability (LADWP kW)	Net Max Plant Capability (LADWP kW)	Net Dependable Capability (LADWP kW)
Haiwee[3]	1 2	1927 1927	2,800 2,800	3,600 3,600	4,200	0
Cottonwood[3]	1 2	1908 1909	750 750	1,200 1,200	1,900	400
Division Creek	1	1909	600	680	680	400
Big Pine[4]	1	1925	3,200	3,050	3,050	400
Pleasant Valley[5]	1	1958	3,200	2,700	2,700	0
Total					12,530	1,200[2]

Note:

1. Commercial Operation Date.
2. Owens Valley combined Net Dependable Plant Capability is 1.2 MW based on 20-years of historical data. 1.2 MW consists of 0 MW from Haiwee and Pleasant Valley and 0.4 MW each from Cottonwood, Division Creek and Big Pine.
3. Haiwee maximum unit capability is 3.6 MW each when feed is taken from North Haiwee Reservoir. Cottonwood Power Plant Units 1 and 2 were re-wound to higher Net Maximum Unit Capability of 1.2 MW.
4. Big Pine Net Maximum Unit Capability is limited to maximum flow through penstock.
5. Pleasant Valley Power Plant output is limited to Division of Safety of Dams (DOSD) reservoir level restriction.

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Table F-6. OWENS GORGE SMALL HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Unit Capability (kW)	Net Max Plant Capability (kW)	Net Dependable Capability (kW)
Upper Gorge	1	1953	37,500	37,500	37,500	36,500
Middle Gorge	1	1952	37,500	37,500	37,500	36,500
Control Gorge	1	1952	37,500	37,500	37,500	36,500
Total[2]					112,500	109,500

Notes:

1. Commercial Operation Date.
2. Owens Gorge Net Dependable Plant Capability was decreased to 109.5 MW to reflect re-watering flow.

The Owens Gorge and Owens Valley Hydroelectric generating units (the "Owens Gorge and Owens Valley Hydroelectric Generation") are located along the Owens Valley in the Eastern High Sierra. The Owens Gorge and Owens Valley Hydroelectric Generation are a network of hydroelectric plants which use water resources of the Los Angeles Aqueduct and three creeks along the Eastern Sierras. The water flow fluctuates from year to year; as a result, water flow may be reduced from seasonal norms from time to time.

San Francisquito Canyon and at the Los Angeles and Franklin Reservoirs. LADWP also owns and operates 12 units located north of the City along the Los Angeles Aqueduct in San Francisquito Canyon and at the Los Angeles and Franklin Reservoirs. The net aggregate dependable plant capability of these smaller units is 24 MWs under average water conditions. Table F-7 summarizes these 12 units.

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Table F-7. AQUEDUCT SMALL HYDROELECTRIC GENERATING RESOURCES

Plant Name	Unit	COD[1]	Generator Nameplate (kW)	Net Max Unit Capability (kW)	Net Max Plant Capability (kW)	Net Dependable Capability (kW)
Foothill (PP4)	1	1971	11,000	9,900	9,900	2,900
Franklin (PP5)	1	1921	2,000	2,000	2,000	400
San Francisquito 1	1A 3 4 5A	1983 1917 1923 1987	25,000 9,375 10,000 25,000	27,000 10,000 12,000 27,000	46,500	13,000
San Francisquito 2[2]	1 2 3	1919 1919 1912	14,000 14,000 14,000	0 14,000 18,000	18,000	5,700
San Fernando 1	1 2	1922 1922	2,800 2,800	3,200 2,900	6,000	2,100
Sawtelle (PP6)	1	1986	640	650	650	130
Total[3]					83,050	24,230

Note:

1. Commercial Operation Date.
2. San Francisquito Power Plant Unit 1 has been out of service since 1996. The plant's Unit 2 stator heating limits capacity to 8 MW during hot weather condition. The plant's Unit 3 has a new generator with refurbished turbine as of the end of 2006. The contract specification is 18 MW output, but the unit was tested to only 16 MW due to low water flow and restricted downstream capacity. Assumed maximum actual output is 18 MW.
3. Aqueduct combined Net Dependable Plant Capability reflects low water availability during winter.

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Table F-8. WIND GENERATING RESOURCES (In-service or Under Construction)

PLANT name	COD	Nameplate (kW)	NET MAX PLANT CAPABILITY[1] (LADWP kW)	NET DEPENDABLE CAPABILITY[2] [3] (LADWP kW)	LADWP Share
PPM SW Wyoming	2006	144,000	82,200	8,220	57%
Pine Tree	2009	120,000	120,000	12,000	100%
Willow Creek	2009	72,000	72,000	7,200	100%
Pebble Springs	2009	98,700	68,695	6,870	70%
Milford I	2009	200,000	185,000	18,500	93%
Windy Point	2010	202,400	202,400	20,240	100%
Windy Point Expansion	2010	59,800	59,800	5,980	100%
Linden Ranch	2010	50,000	50,000	5,000	100%
Pine Tree Expansion	2010	15,000	15,000	1,500	100%
Milford II	2011	102,000	102,000	10,200	100%
Subtotal			**957,095**	**95,710**	

Table F-9. OTHER RENEWABLE GENERATING RESOURCES (In-service or under Construction)

PLANT name	COD	Nameplate (kW)	NET MAX PLANT CAPABILITY[1] (LADWP kW)	NET DEPENDABLE CAPABILITY[2] [3] (LADWP kW)	LADWP Share
Lopez Microturbine	2002	1,500	1,500	1,350	100%
Penrose Landfill	2006	6,100	6,100	5,490	100%
Bradley Landfill	2006	6,400	6,400	5,760	100%
BC Hydro	2007	50,000	50,000	25,000	100%
MWD Supulveda Hydro	2008	8,540	8,540	4,270	100%
DWP Built PV Solar	2008	1,000	1,000	250	100%
SB1 PV Solar Rooftop Program	1999-2009	17,553	17,553	4,388	100%
Castaic U3&U5 Upgrade	2009	30,000	30,000	30,000	100%
Distributed Generation	1998-2000	303,000	45,000	45,000	15%
LFG 1	2009	0	0	0	0%
LFG 2	2009	0	0	0	0%
Subtotal			**166,093**	**121,508**	

Notes for Tables F-8 and F-9:

Tables include LADWP's renewables and distributed generating sources from LADWP-owned and contracted projects. This table is based on data from the January 2010 RPS Master Project List and contract sources

[1] The full-load continuous rating of a generator unit under specified conditions as designated by the manufacturer.

[2] Maximum Plant Capability reflects water flow limits at hydro plants; or sum of each unit at renewable plants.

[3] Net Dependable Plant Capability reflects the amount of generating capability that can depend on during the peak demand hours of a day. Dependable capacity of a renewable technology plant is estimated by applying a Dependable Capacity Factor (DCF) to the plant nameplate capacity.

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Appendix G Distributed Generation

G.1 Overview

Distributed Generation (DG) is a concept of installing and operating small-scale electric generators, typically less than 20 megawatts MW, at or near an electrical load and interconnected to the electric utility distribution system. The most common technologies used today for DG are turbines and internal combustion engines (ICEs). However, new technologies including fuel cells, microturbines, and solar PVs are now being developed. The promise of DG is to provide electricity to customers at a reduced cost and more efficiently than the traditional utility central generating plant with transmission and distribution wire losses. Other benefits that DG could potentially provide, depending on the technology, include reduced emissions, utilization of waste heat, improved power quality and reliability and deferral of transmission or distribution upgrades.

DG can be customer installed or utility installed. The benefits for customer installed DG include waste heat recovery, backup power and power quality. The benefits for utility installed DG include generation, transmission and distribution infrastructure deferral, and reduction of delivery losses.

This Appendix describes DG on the grid, ICE technologies, fuel cells, and PV technologies.

G.2 Distributed Generation on the Grid

The introduction of competition into the electric marketplace has driven the development of new electrical generation technologies. Most technologies being developed for DG applications are more costly than traditional generating resources. However, it is anticipated that, with advances in the technologies and a greater demand for DG, costs will decrease, and more systems will be installed.

LADWP currently has approximately 350 MW of customer installed DG on its electrical grid, producing approximately 1,700 Gigawatt hours (GWh) annually, most of which is consumed on-site, although some (approximately 40 MWh/h) is exported back to LADWP. Most of the customer installed DG (approximately 300 MW) is made up of 20 MW or larger natural gas combustion engines. The amount of customer DG installed in the future will depend on several factors including reliability, cost of the technologies, and natural gas and electricity prices. With stable electricity prices and high natural gas prices, customer generation becomes less attractive. Additionally, as of November 30, 2011, more than 4,500 LADWP customers have installed over 41 MW of solar PV energy systems with the help of LADWP's Solar Incentive Program.

LADWP has installed more than 1 MW of solar PV energy systems on LADWP and City of Los Angeles (City) facilities to generate clean, renewable energy for the LADWP grid. LADWP has also installed various other DG technologies for demonstration purposes to understand the

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operating issues and benefits associated with various equipment and to promote the development of new clean, efficient technologies. Future DG installations for demonstration purposes will showcase new technologies and should add approximately 1 MW in capacity every three years. These projects will be funded with Public Benefits funds, described in Section 2 of the IRP.

Utility installed DG may also play a role in meeting capacity needs in the future that have very low energy production requirements (low capacity factors). It is estimated that approximately 1 MW of DG will be installed annually beginning in 2010. Tables G-1 and G-2 provide projections of DG and Solar PV capacity and energy. The projections are summarized in Table G-3.

Table G-1. PROJECTED DISTRIBUTED GENERATION CAPACITY AND ENERGY - CUMULATIVE

Calendar Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Customer generated	MW	290	280	290	300	302	304	306	308	310	312	314	316
	GWh	1650	1600	1650	1700	1720	1730	1740	1760	1770	1780	1790	1800
Utility generated	MW	1	1	1	2	3	4	6	7	8	10	11	12
	GWh	4	4	4	8	9	10	15	16	17	22	23	24

Table G-2. PROJECTED SOLAR PV GENERATION CAPACITY AND ENERGY - CUMULATIVE

Calendar Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Customer generated	MW	9	11	13	18	28	54	85	101	113	125	138	143
	GWh	15	18	21	30	33	63	114	141	160	180	202	210
Utility generated	MW	1	1	1	1	1	1	3	6	9	12	21	37
	GWh	2	2	2	2	2	2	5	11	16	22	38	67

NOTE: The LADWP Solar Program is set to encourage the installation of 280 MW of customer-installed PV by 2016 with a budget of $313 million over 10 years.

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Table G-3. SUMMARY OF ANNUAL MW OF DISTRIBUTED GENERATION ADDITIONS

Summary of DG, Solar PV and Customer Electrification - Projected Annual Increases (MW)

Row		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Excess Customer DG	10	10	10	2	2	2	2	2	2	2	2
2	Utility DG	1	0	1	1	1	2	1	1	2	1	1
3	Customer PV	2	4	5	7	26	31	16	12	12	13	5
4	LADWP PV	0	0	0	0	0	2	3	3	3	9	16
5	Customer Electrification Program	-3	-5	-6	-8	-10	-11	-13	-15	-16	-18	-20
	Total Annual Projections	**10**	**9**	**10**	**2**	**11**	**27**	**8**	**-2**	**-2**	**-3**	**13**
	Total Cumulative Projections	**10**	**19**	**29**	**31**	**42**	**69**	**77**	**75**	**73**	**70**	**83**

Row Notes

1 See Table G-1. The October 2006 Load Forecast incorporates existing Customer DG. Future years are converted to annualized values.

2 See Table G-1. Converted to annualized values

3 See Table G-2. 10 MW of existing Customer PV is deducted. Future years are converted to annualized values.

4 See Table G-2. 1 MW of existing LADWP PV is deducted. Future years are converted to annualized values.

PV funding continues through 2011. This IRP assumes a continuation of the program for future years.

The October 2006 Load Forecast incorporates the existing 10 MW Customer PV and 1 MW LADWP PV

5 The values are negative as they act to add load.

G.3 Internal Combustion Engines

ICEs include reciprocating engines and combustion turbines. Improvements have been seen recently in the emissions and efficiencies of reciprocating engines and combustion turbines. Combustion turbines have typically been in the multi-MW size, but recently small-scale combustion turbines, or microturbines, have been developed.

Microturbines are machines ranging in size from 28 kilowatts (kW) to 500 kW, which include a compressor, combustor, turbine, alternator, recouperator, and generator. They have the potential to be located on sites that have space limitations to produce power. The advantages of microturbines are that there are a small number of moving parts, are compact in size, are lightweight, and can utilize waste fuels.

LADWP has installed nearly 2 MW of microturbines, the first of which was located at LADWP's Main Street Center in 1999. Additional microturbines have been installed at LADWP facilities and the Lopez Canyon landfill.

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G.4 Fuel Cells

A fuel cell combines hydrogen and oxygen to produce electricity through an electrochemical process. Besides electricity, fuel cells produce water and heat. If the oxygen source is air, then small amounts of NO_X may also be emitted. Fuel cells produce energy at relatively higher efficiencies and emit far fewer air pollutants than combustion technologies. Fuel-cell power plants are now becoming commercially available for use by electric power producers, industrial facilities, and large commercial buildings. Smaller systems for residential, small commercial buildings and transportation applications are expected to be commercially available in the near future. The pricing for these products is expected to become competitive due to several factors:

- A fuel cell is a fairly simple technology with reasonably priced components.
- Significant recent investments in the technology are accelerating the development of fuel cells, and costs are decreasing.
- Integrating fuel processing and power conditioning equipment can be a significant cost with regard to fuel cells, but reductions are likely as more fuel cells are manufactured and installed.

Under a pilot project, LADWP installed a total of four 200-250 kW fuel cell power plants in various locations in Los Angeles that have provided considerable experience and data. Three of the fuel cell plants have accomplished the task and the fuel cells have been removed from service. The fourth plant is being evaluated for viability of continued operation.

G.5 Photovoltaics

Solar energy is converted to electricity using two power technologies: PV systems and solar thermal power systems. PV systems convert sunlight directly into electricity. PV systems are modular, portable, highly reliable, and have low environmental impact, making them ideal for power applications of all sizes. Several large PV systems capable of powering hundreds of homes are now connected to utility grids throughout the United States. Many utilities are installing these systems on the rooftops of schools and their customers are installing them on the rooftops of their houses. LADWP has recently seen the popularity of local customer owned solar generation skyrocket due to the combination of utility paid incentives and recent federal tax law changes, as well as declining solar equipment costs.

A typical 4 kW alternating current (AC) residential rooftop solar power system produces 6,600 kW-hours per year. Presently, LADWP has installed about 1.3 MW of PV at LADWP facilities and other City facilities. LADWP incentives have supported the installation of over 41 MW on its customers' properties, as of November 30, 2011. In 2006 state legislation SB1 required all utilities to offer incentives to customers to install solar energy systems through 2016. LADWP's solar incentive program has been developed with a goal of encouraging the installation of 280 MW of customer installed solar PV systems by 2016 with a budget of $313 million over 10 years, however because of LADWP's lower electric rates, a higher incentive amount has been offered which will reduce the expected amount of customer installed solar to approximately 125MW. An additional 150MW of distributed solar is expected to be installed through a new feed-in tariff program.

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The energy generation characteristics of a typical PV installation are that the output peaks around 1:00 p.m., and that 90 percent of a solar PV system's energy is produced from 10:00 a.m. to 4:00 p.m. during a typical summer day in California. Another point worth noting is that a solar PV system can be designed to coincide more closely to the system load profile by altering the module's orientation. While this will increase the energy produced during the peak load of the utility, it will result in an overall lower amount of energy produced for the day. Cloud cover also affects the energy output of a solar photovoltaic installation. The type of clouds will either raise or lower the output of the PV system. Darker rain clouds will lower PV output, but a light marine layer may actually produce more energy than the nameplate rating of the modules due to light reflecting off of the modules, back to the atmosphere, and then back to the modules. This does not happen often but does cause design issues that must be taken into account.

G.6. Combined Heat and Power (CHP) Program

Combined heat and power (CHP) systems, or also known as thermal cogeneration, simply capture and utilize excess heat generated during the production of electric power. CHP systems offer economic, environmental and reliability-related advantages compared to power generation facilities that produce only electricity. Distributed power generation systems, which are frequently located near thermal loads, are particularly well suited for CHP applications.

Currently CHP installed in the LADWP Power System consists primarily of cogeneration projects of industrial and commercial customers. This totaled to approximately 265 MWs nameplate capacity operating in the LADWP's service area. Some cogeneration projects sell excess energy to the LADWP under interconnection agreements.

Current barriers to the expansion of CHP can be attributed to:

- Natural gas price volatility in recent years has caused uncertainty in the economic feasibility of CHP projects.
- Diminishing industrial customer base in recent years has reduced CHP developable potential.
- Reliability and economic issues made small systems infeasible.
- Added cost from utility replacement reserve requirements.
- Uncertain Green House Gas emissions add costs to CHP electric generation.
- Air quality sitting restriction for new carbon-based CHP electric generation.

LADWP is developing CHP target goals to incorporate CHP generation in its future resource mix. LADWP is currently considering development of the following self-owned CHP projects:

- Terminal Island Renewable Energy Project is a fuel cell plant to produce 4 MW of electricity and process heat using methane gas.

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- Los Angeles Bureau of Sanitation Alternative Technologies Projects to convert waste to heat

To encourage customer-developed CHP, shift demand from electric grid, and provide accurate price signals to customer, LADWP is currently offering a Standard Energy Credit (SEC) to its customers for excess energy they sell to LADWP. The SEC is based on LADWP marginal generation cost, and is updated and posted monthly. In the future, for renewable CHP, LADWP will provide a renewable premium based on the energy market plus the SEC. For non-renewable CHP, LADWP will continue to purchase CHP excess energy at the SEC.

Current Net Metering Incentives offered to customers require

- Customer must purchase electric services from LADWP to be eligible for interconnection
- Customer submits completed Standard Offer Agreement for interconnection and qualification for the CG Rate
- Customers pay for all costs associated with time of use metering, interconnection, and safe grid-parallel operation of the generation facilities
- For cogeneration facilities greater than one megawatt, the customer is required to install remote monitoring equipment for LADWP
- Customer maintains adequate insurance on generating facilities
- Excess power reimbursements are made to the customer at end of billing period at the CG Rate
- The interconnection agreement has a three year term and requires approval by the General Manager initially and for renewal and extension

Inclusion of the CHP goals under the IRP process will help communicate CHP program information and facilitate stakeholder feedback.

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Appendix H Fuel Procurement Issues

H.1 Overview

This Appendix presents issues and strategies related to LADWP procurement of both natural gas and coal.

H.2 Natural Gas

LADWP generates about 22 percent of energy from natural gas-fired generation. Or, in other words, almost one-fourth of LADWP's energy generation is exposed to the risks of gas price volatility. This percentage will increase in the future as coal is removed from LADWP's resource portfolio, and with the integration of additional variable energy resources. Figure H-1 below graphically illustrates the daily natural gas spot market price (including delivery charges to LADWP's gas plants) and the large price fluctuations from the year 2002 to 2006.

Figure H- 1. Natural gas daily spot prices.

As is shown on Figure H-1, the natural gas market has been very volatile with extreme variations of prices. Since gas currently plays such an important role in LADWP's generation portfolio, it is paramount that the impact of gas price volatility to the resource plan be mitigated.

To minimize LADWP's exposure to natural gas price volatility, LADWP has implemented a variety of actions since the 2000 IRP, which include:

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1. Created a financial risk management program to mitigate natural gas price spikes and a comprehensive gas procurement strategy to support renewable generation and long term financial goals.
2. Established executive controls over energy risk management and natural gas hedging activities by creating an Executive Risk Policy Committee to provide clearance for all major hedging decisions.
3. LADWP obtained approval from the Los Angeles City Council to delegate its award authority to LADWP's General Manager for approving limited term and price gas procurement contracts. LADWP also approved pro forma NAESB (North American Energy Standards Board) contracts for use in procuring natural gas.
4. LADWP has participated with SCPPA in purchasing an active gas reserve in the Pinedale anticline area of Wyoming. This reserve is currently producing approximately 25,000 million British thermal units (MMBtu)/day, of which LADWP receives approximately 83 percent of the project.
5. LADWP has also replaced approximately 1,100 megawatts (MW) of electrical generation with combined cycle technology. This technology is much more efficient in generating electricity than the generating units that were replaced, resulting in a 30 percent to 40 percent decreased usage of natural gas to generate the same amount of electricity.
6. As a result of implementing the greater use of renewable energy, LADWP's usage of natural gas and coal will be reduced considerably. A general discussion on natural gas pricing issues is provided in the following subsections.

H.2.1 Natural Gas Pricing Issues

Gas delivered to the burnertip for electric generation in California is comprised of three elements: 1) commodity costs; 2) interstate transportation; and 3) intrastate transportation. Other concerns include regulatory/legal issues, gas price volatility, support for renewables and gas supply issues.

Commodity Costs

Natural gas for electric generation is produced primarily outside California in areas known as basins, such as the Green River Basin near Opal, Wyoming; the San Juan Basin near San Juan, New Mexico; and the Permian Basin in west Texas. Gas produced from individual wells is gathered by small pipeline systems and delivered into a gas plant that processes the raw gas into pipeline quality gas for delivery to markets. Prior to the 1980s, this pipeline gas was sold as a bundled product by various interstate pipelines to distribution companies in the individual states, such as the Southern California Gas Company (SoCal) and the Pacific Gas & Electric Company (PG&E). Eventually interstate gas rates were restructured so that interstate pipelines became transport-only businesses with the gas marketing function spun off to the market via unregulated affiliates or independent marketers.

Intensified exploration in non-traditional producing areas of the country, chiefly the so called shale gas, has produced a surplus of gas, which has contained prices recently and will continue to do so in the foreseeable future. The development of Liquefied Natural Gas (LNG) import terminals in the United States has been delayed by a number of factors, including regulatory requirements,

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environmental issues, safety concerns, and economic uncertainty. Development of resources known to exist in the United States offshore continental shelf, especially in view of the blowout of a deep underwater well near the coast of Louisiana, continues to experience similar issues.

Interstate Transportation

The interstate pipeline companies that formally sold bundled gas along with their transportation services have now focused primarily on the transportation of gas from producing basins to interconnections with the individual state's local distribution companies. The jurisdiction for the regulation of these companies falls under the authority of the Federal Energy Regulatory Commission (FERC). California is currently served by seven interstate pipelines although only four are actually directly connected to supply basins. The other three redistribute gas from other interstates. Volatility in gas prices into California has arisen because of various supply-related issues, variations in liquidity stemming from fewer suppliers in the aftermath of the market adjustment following 2000-2001, financial trading of commodities by funds, and weather-related events throughout the country. Limited price discovery has also added an element of uncertainty in gas transactions. Additional pipeline capacity to California is readily available through expansions of existing pipelines and interruptible capacity. LADWP has firm capacity on the Kern River pipeline approximately equal to its forecasted average gas requirement although there is a certain amount of uncertainty in this forecast depending upon the degree of implementation of renewables.

Intrastate Transportation

SoCal is the sole provider of intrastate gas transportation services in Southern California. These services consist primarily of delivering gas from the interconnections with interstate pipelines near the California border, but also include storage, balancing, wheeling, parking, and loaning of gas. Ever since May 1988, SoCal has been relieved of its obligation to serve the so-called non-core customers, those who are able to make their own arrangements for procuring their own gas. All electric generators such as LADWP are deemed non-core or transport-only customers. The rate charged by SoCal for this transportation only service is regulated by the California Public Utilities Commission (CPUC). This rate is the lowest for any customer class (outside of any special negotiated rate) because it provides the minimum service and provides as close to cost-of-service pricing as possible. LADWP's active participation in SoCal's rate cases at the CPUC was instrumental in achieving this distinction.

Additional services relating to the delivery of gas are available from SoCal, but the rates are subject to negotiation and, usually, CPUC approval. Generally speaking, these services are of more value to marketers than to municipal generators, but in any case add to the cost of delivered gas.

One issue that has emerged from the recent price volatility in Southern California is whether or not SoCal has the ability to accept all the gas that will be filling the expanded interstates over the next few years. The CPUC has addressed this issue in a recent proceeding into the adequacy of SoCal's system to serve the expected load on its system. So far no conclusions can be made but SoCal is confident that they have the problem in hand because of their recent completion of various system upgrades increasing takeaway capacity by approximately 21 percent. SoCal has been able

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to settle rate allocation issues to allow its intrastate transmission system to accommodate the delivery of LNG Gas supplies into its system

Regulatory Legal Issues

Several issues at the CPUC and FERC also impact pricing. SoCal revised its rates on October 2008 to accommodate the delivery of LNG into California, through the implementation of what is known as the Firm Access Rights (FAR) decision. Implementation of FAR has affected the role of transportation pricing and the distribution of receipt point allocations for deliveries into the California market. The FAR program has been renewed for another three years under the name Basic Transportation Service (BTS). The Department has obtained BTS rights that match with its firm Kern River Interstate capacity. Another issue regarding the SoCal system, is the Wobbe Index. The Wobbe Index relates to the energy content of the natural gas delivered into SoCal's system which affects operating characteristics of gas turbines and emission levels. The Wobbe Index has risen to prominence due to environmental concerns which may substantially affect SoCal's service to electric generators. The CPUC has already allowed SoCal to set sufficiently high limits on the Wobbe Index for gas coming into its system. This will chiefly benefit LNG sourced gas although there is a challenge being mounted by the South Coast Air Quality Management District (SCAQMD). The SCAQMD has adopted a new rule, Rule 433, which proposes to monitor the effects of any increase in the Wobbe Index and could be interpreted as an attempt to regulate the distribution of natural gas. It is anticipated that the CPUC will oppose this initiative, and at this point in time, SoCal has filed a lawsuit to set aside Rule 433.

The FERC is presently preparing new tariff sheets for the Kern River pipeline in which LADWP has a substantial interest. Kern River had applied for a significant rate increase, but lost after a long proceeding at the FERC. The rate case was settled by most of the interested parties and refunds were distributed. Subsequently, one party that did not settle was able to halt the settlement pending further review by the FERC. The distribution of refunds stands until the FERC resolves the issue.

Gas Price Volatility

During the winter 2000-2001 gas prices were highly volatile. This was somewhat repeated in milder form briefly in early 2003 and the second half of 2005. For the most part, extreme volatility has subsided with prices remaining at substantially lower levels than in previous years due to the recession. Forward pricing indicates that gas prices will move relatively sideways with a slight bias upward, in part due to the competing effects of the economy and increased supplies of shale gas. The industry has endeavored to reduce volatility through a massive effort of injecting gas into storage for winter use, thereby eliminating the perception of a huge overhang of expected gas purchases during the winter heating season.

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Gas Supply Issues

- New drilling techniques make it possible to extract natural gas from deep shale rock formations. The advances mean the United States has more abundant natural gas resources than previously believed. Gas advocates say it could significantly alter the future U.S. energy market.
- Horizontal drilling ($1.06-$1.34 /thousand cubic feet (Mcf)) vs. vertical drilling ($1.71 Mcf): horizontal wells open up much larger area of the resource-bearing formation.
- Hydraulic Fracturing (or fracking): Injecting a mixture of water and sand at high pressure to create multiple fractures throughout the rock, liberating trapped gas.
- Combination of the Horizontal drilling and fracking.
- With more drilling experience, U.S natural gas reserves are likely to rise dramatically in the next few years. At current level of demand, U.S. has about 90 years of proven and potential supply.
- Preliminary estimates suggest that shale gas resources around the world could be equivalent to or even greater than current proven natural gas reserves.

H.2.2 Natural Gas Procurement Strategy

LADWP retained the services of PriceWaterhouse Coopers (PwC) in 2003 to assess, validate, and verify LADWP's current gas procurement strategy. Their report assessed the current strategy, suggested changes and enhancements to that strategy, and prepared a preliminary plan and timetable for implementing the changes.

As a result of PwC's review of gas operations, LADWP decided to adopt a program of protecting its gas costs from price volatility through financial hedging. The appropriate authority was sought and received by the City Council to employ financial hedges for up to ten years and physical hedges for up to five years, and to limit spending for this effort to no more than $15 million per year.

In addition, an Executive Risk Policy Committee was formed with senior management as members to provide oversight over the energy risk management activities of LADWP, including natural gas. Several actions have taken place.

First, LADWP's Financial Services Organization (FSO) negotiated individual ISDA (International Swaps and Derivatives Association) agreements with potential counterparties for the swaps to hedge gas prices. Fiscal Year 03-04 was the first complete year for using financial hedging to cap gas prices over a portion of forecasted gas requirements.

Second, LADWP obtained approval of two ordinances from the Council authorizing the Board of Water and Power Commissioners to delegate its award authority to the General Manager for approving gas procurement contracts. Subsequently the Board approved two separate pro forma NAESB (North American Energy Standards Board) contracts for use in procuring natural gas for up to one year, and for up to five years in duration. A number of the one-year NAESB

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agreements are now being used to buy gas. Five year strips of gas for physical risk management purposes were completed in late 2008 using the 5-Year NAESB authority. In addition, in mid 2009 the 5-Yr NAESB was used to obtain strips of biogas which contributes to the LADWP's Renewable Portfolio Standard goal.

Third, LADWP participated through SCPPA in a Request for Proposal (RFP) process soliciting proposals for a term supply of natural gas for 30 years for up to an average of 27,500 MMBtu/Day. The agreements were negotiated but the deal was never completed because difficulties with the economy greatly reduced the anticipated discount offered under the prepay.

Fourth, LADWP has participated with the SCPPA in purchasing an active gas reserve in the Pinedale anticline area of Wyoming. Savings from this purchase have totaled approximately $48,000,000 for the four years of ownership. Further production is indicated by virtue of the fact that neighboring production has been approved for drilling on 10-acre spacing, up from the current 20-acre spacing, by the Wyoming Division of Oil, Gas and Conservation. Other production adjacent to the SCPPA properties has already shown promise although development depends upon a number of environmental challenges.

PwC noted that LADWP's previous gas procurement strategy was highly dependent on spot market purchases and lacked the flexibility necessary to appropriately manage the price risk involved in gas buying, trading, and transportation activities. They argued at the time that price risk was a critical issue because gas was playing an increasingly important role in LADWP's future due to increased reliance on natural gas-fired generation. (Note that the 2006 IRP had recommended repowering four natural gas fired generating stations and adding six gas-fired simple cycle combustion turbines to make up for a sale of a portion of LADWP's interest in the coal-fired Mohave plant, to replace units that were over 40 years old, and to meet anticipated load growth). Additionally, the increased use of renewables, such as wind farms and solar projects, may require higher levels of reserve margins because of their variable and intermittent nature, with the higher reserve margins being provided by gas-fired generation. Also, gas price volatility and constraints on the SoCal intrastate transportation system required LADWP to place more importance on gas supply management.

Implementation Actions
LADWP has adopted strategies to reduce exposure to daily gas price swings, by the use of monthly spot purchases, implementation of index based financial swaps, physical term purchases, and ownership of gas reserves. Monthly spot purchases look to first of the month indexes and reducing the volumes subject to floating daily prices. The reserve acquisition will reduce overall costs through amortization of the purchase price for the reserve. Additional administrative procedures were put in place to further strengthen deal tracking and audit trails.

An important initiative was put into play to obtain delegated authority from the City Council to allow LADWP management to execute SoCal's Master Service Contracts. This contract allows the LADWP to take advantage of additional services offered by SoCal such as storage, parking, loaning and wheeling. The initiative was completed in early 2008.

Additional Actions To Be Considered

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With respect to transportation and storage options, LADWP will need to evaluate its options in view of the aggressive schedule adopted by the Board of Commissioners in meeting its goals for implementation of renewable technologies for generation and elimination of coal-fired generation. The successful completion of both these goals will significantly impact the need for natural gas generation. To this end, LADWP has begun to develop standardized methods for evaluating capacity projects. Factors to consider in evaluating options including:

- Cost of being short gas supply
- The amount of fuel carried in inventory for emergencies
- The type of fuel carried in inventory for emergencies
- Cost of alternatives
- Demand Side Management (DSM)
- Spot power purchases
- Alternative generation costs
- Service interruptions
- Political and budget impacts
- Cost of being over-contracted for off-peak periods
- Cost of new capacity (initial capital and demand and charges)
- Value of excess capacity sold on short term basis

These factors are applied to the contracting options that range from meeting baseload requirements to meeting peak requirements.

SoCal is LADWP's only available intrastate transportation supplier by virtue of its authorized franchise. Since SoCal provides 100 percent firm full requirements service, LADWP's transportation need is met. Storage is being developed by others. In the meantime, LADWP may participate in SoCal's auction to acquire an appropriate amount of inventory space, injection rights, and withdrawal capacity on a year to year basis. Storage is most effective contiguous to load centers. However, the most geologically effective sites in the greater Los Angeles area have already been developed by SoCal Storage service. Storage is primarily useful for minor load balancing and, to some extent, hedging. Given the robustness of SoCal's distribution system in particular, and the interstate transportation system in general, storage is not necessary for emergency backup supply for power generation.

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H.2.3 Proposed Actions

LADWP proposes to take the following actions to provide additional flexibility in implementing its natural gas procurement strategy:

- Increase the long-term natural gas hedging price cap. LADWP's authority for purchasing financial swaps for long-term natural gas is currently limited to $10.00 per MMBtu.
- Increase the short-term physical natural gas purchase price cap. LADWP's authority for purchasing short-term natural gas is currently limited to a rolling twelve months at $20.00 per MMBtu.
- Obtain delegated authority to execute SoCal's Master Services Contracts (MSC) along with the attachments for ancillary services as soon as the new MSC is published by SoCal after approval of its 2009 BCAP Phase II settlement.
- Increase the term limitation for its short-term power purchases. LADWP's authority for purchasing short-term power is currently limited to a rolling eighteen months from date of execution. And likewise increase to eighteen months the 1-year gas NAESB contracts for short term gas purchases.
- Seek authority to enter into long-term power purchase hedging contracts. LADWP is currently not authorized to enter into such arrangements.

In summary, LADWP has attempted to mitigate the impacts of volatile natural gas supplies and prices by acquiring a natural gas field, utilizing financial hedging contracts, and repowering over 1,000 MW of electrical generation with more efficient combined cycle technology.

H.2.4 Liquefied Natural Gas

LADWP has been carefully monitoring for years the development of LNG throughout the country, and in particular the many projects aimed at California. Generally, LADWP has been supportive of the concept but has not taken an active role in any proposed project. LADWP supports making additional supplies available to the market in California for reliability and cost reasons. This will be especially true as more states implement environmental regulations that will limit the amount of electricity produced from coal resources and shift much of the energy production to natural gas.

Currently there are no active LNG projects in California though several have been planned. Environmental issues and price containment from non-conventional shale gas have made project development a challenge.

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H.3 Coal Procurement Strategy for the Intermountain Generating Station

H.3.1 Intermountain Generating Station

The Intermountain Power Agency (IPA) owns the Intermountain Generating Station (IGS). LADWP receives part of the power from IGS under a power purchase agreement with IPA that currently runs through 2027. LADWP is additionally under contract with IPA to oversee the operations of IGS and is known in that role as the Operating Agent. One of LADWP's duties as the Operating Agent is to arrange for the procurement of coal or coal assets, including any transportation services needed to get the procured coal to IGS. All contracts for coal procurement or coal asset ownership are done under the name of IPA. Management approval for coal procurement or coal asset ownership is given by the Intermountain Power Project Coordinating Committee (IPPCC), which is made up of IGS power purchasers (including LADWP), and the IPA Board of Directors (which does not include LADWP). Future coal procurement and coal asset ownership and related strategic development are therefore, done at the discretion and approval of the IPPCC and IPA Board of Directors on behalf of the power purchasers and owners of IGS.

H.3.2 Coal Supply – A Role for the Operating Agent

In its role as Operating Agent, LADWP administers, on behalf of IPA, a diversified portfolio of coal supply contracts that should by design hedge IGS power purchasers against escalating coal prices. The portfolio contains a combination of long-term, mid-term, and short-term coal supply contracts, which are either market price-based, fixed price-based, or cost of production price-based.

H.3.3 Coal Portfolio

The current coal procurement portfolio mix is as follows:

Long-term fixed pricing (with contracts beyond 2013):	60 percent
Short-term market pricing (spot market purchases):	40 percent

In all, the Operating Agent procures about six million tons of coal per year for IGS based on current capacity factors. At present, IPA has in place coal contracts which can supply all of the coal needs of IGS through 2013, with a significant portion of the coal needs beginning 2014 also already in place.

Historically, the vast majority of coal procured for IGS has come from Utah sources. The procurement of coal in the near- and far-term will likely be done in a similar manner as described above, with the percentages of the pricing methodologies in the portfolio mix being determined with pricing and security of supply in mind. While Utah coal is expected to remain a key part of the IGS coal supply for the next 20 years, Utah sources of coal are diminishing. Thus, it is prudent for to the Operating Agent (with IPPCC and IPA Board of Directors guidance and approval) to seek out sources from new Utah mines and from other Rocky Mountain states. For

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several years the Operating Agent has procured short-term contract coal from more than a half dozen sources in Colorado and Wyoming. This will have to be done to a greater extent in the future. Since travel time using IPA-owned unit-trains increases while traveling greater distances to the out-of-state sources, the Operating Agent has already made arrangements to lengthen IPA's unit-trains, obtain additional railcar capacity, and expand IPA's railcar operation and maintenance facility.

H.4 Alternative Fuels for Basin Generation

Although there will be ample supplies and delivery capacity for natural gas to power all Basin generation for the foreseeable future, there is some concern that that LADWP will become too dependent on a single fuel. As a consequence, a great deal of thought has been put into identifying potential backup supplies in the event of an emergency.

Among those considered are liquefied natural gas and ultra-low sulfur (CARB) diesel. Both fuels present unique storage, handling, operational, and/or environmental problems. Both are deemed too expensive to implement.

The greatest disaster that could possibly affect the LADWP's ability to generate electrical energy for native load would be a massive earthquake such as the Northridge Earthquake that afflicted Los Angeles in 1994. During that event, due to transmission line problems, the entire power system in Los Angeles was islanded and all available basin generation was put on line. No power was brought in from the Pacific Intertie and minimal power from Palo Verde, Navajo, Mohave or Intermountain power was available. Natural gas demand for power increased by 200,000 MMBtu/Day and was provided by a minority supplier in a timely fashion. This situation persisted for over two weeks until field crews could repair damage to transmission lines. No power plants were damaged as a result of the quake, but some were temporarily taken off line until the situation stabilized. All generation was eventually brought on line within a few hours of the quake. If the quake were much more severe, damage to the power plants' turbines would have necessitated them to be taken off line. The gas delivery system, both SoCal's distribution system as well as the interstate transmission systems, were not harmed by the Northridge quake. Characteristically, gas pipelines are imbedded in sand-filled trenches that allow the pipes to move about when the earth shifts, thereby reducing the possibility of breaking. Major transmission lines bring gas from the East and cross the San Andreas Fault, which move all the time, but rarely cause delivery outages. Thus it would appear that the gas delivery infrastructure is more robust than the power plants that depend on it.

We can conclude from this that although it might seem desirable to maintain some type of backup supply of fuel for in-Basin power plants, the existing natural gas supply system is likely both adequate and reliable enough to withstand a major disruption event.

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Appendix I Transmission System

I.1 Transmission Resources

LADWP is one of only a handful of electric utilities that own and operate a system with both alternating current (AC) and direct current (DC) transmission lines. The typical utility is exclusively an AC system with a shorter geographical reach than the LADWP network. LADWP employs its DC lines to import bulk power across state lines from markets and plants in Utah/Wyoming, Washington and Oregon. To lower transmission losses, AC/DC conversion equipment is utilized to interconnect its long distance DC lines with the AC system. Table I-1 lists LADWP's transmission resources.

Table I-1. BREAKDOWN OF TRANSMISSION RESOURCES

Voltage Class	AC/DC	Circuit-Miles
Out-of-Basin		
±500kV	DC	1,068
500kV	AC	1,069
345kV	AC	189
287kV	AC	350
230kV	AC	353
Out-of-Basin Circuit-Miles		3,029 (81%)
In-Basin		
230kV	AC	521
138kV	AC	153
115kV	AC	44
In-Basin Circuit-Miles		718 (19%)
Total Circuit-Miles		**3,747 (100%)**

As Table I-1 shows, the majority of LADWP's transmission assets are located outside of the Los Angeles Basin. Originally constructed to supply lower cost electricity to its customers and thereby maintain lower electricity rates, these assets are vitally important to LADWP's attainment of its 33% RPS goal by 2020. Excess transmission capacity is sold on a non-discriminatory basis in a wholesale market under an open-access transmission tariff largely conforming to FERC Order 890.

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A one-line diagram of the key bulk power transmission lines is shown in Figure I-1. The transmission capabilities of the different systems are summarized in Table I-2.

Table I-2. IMPORT CAPABILITY OF TRANSMISSION RESOURCES

Transmission System	Transfer Rating (MW)	LADWP Share (MW)
East-to-LA Basin	4,000	3,566
West-or-River	10,623	3,373
East-of-River	9,300	1,109
Pacific DC Intertie @ NOB	2,990	1,196
Owens Valley Transmission	450	450
Intermountain	2,400	1,428

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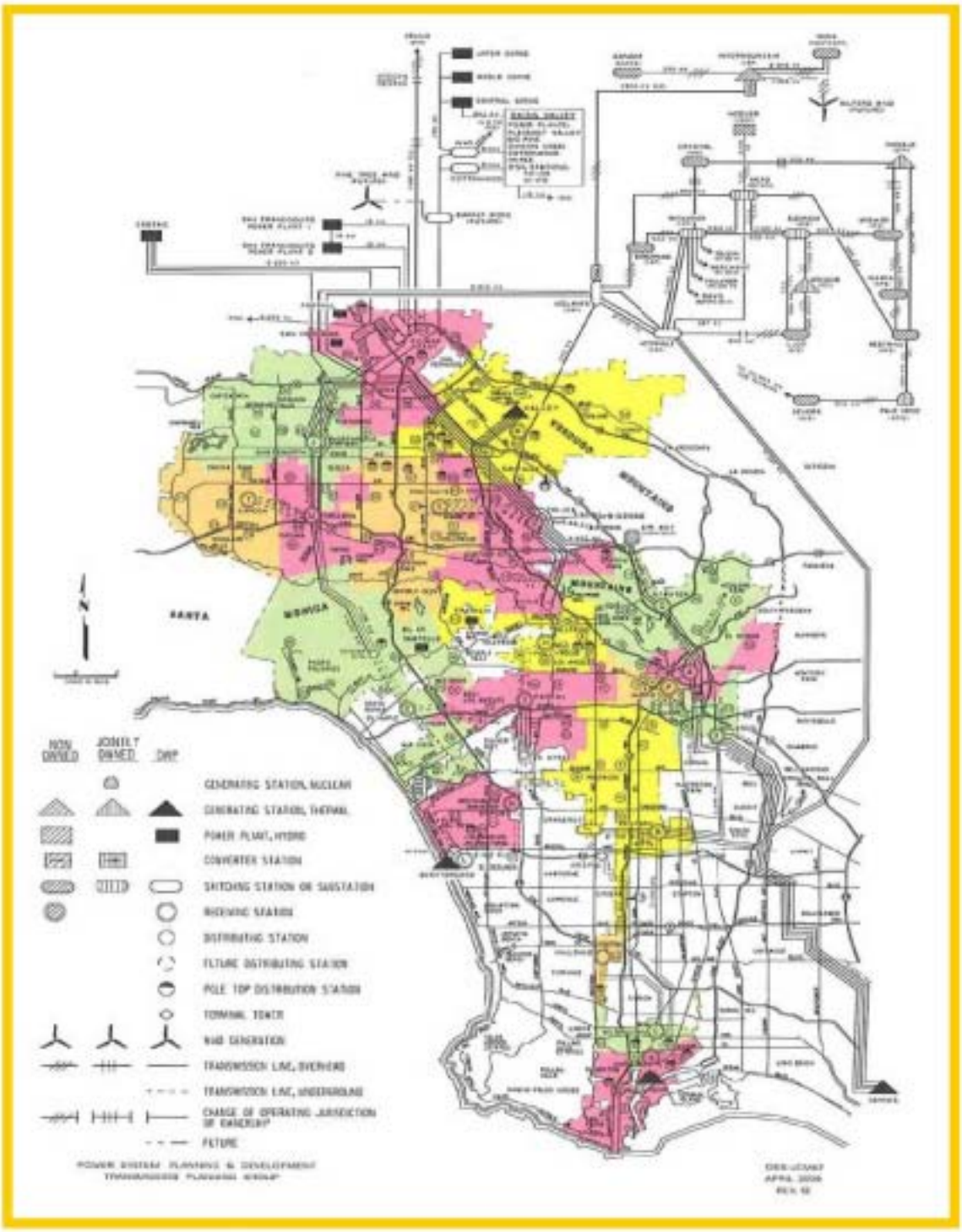

Figure I-1. LADWP Power System diagram.

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I.2 Basin Transmission System

LADWP's basin transmission network is comprised of overhead and underground lines ranging from 115kV to 230kV; 4 switching stations that tie together multiple Transmission System circuits; and 20 receiving stations that serve as gateways to the distribution system and as tie points for basin power plants.

Because LADWP serves a metropolis, system reinforcements, additions, and improvements are often challenging; construction in crowded thoroughfares inconveniences so very many people. Compounding this challenge is the very real need to invest in an aging transmission infrastructure, parts of which date back to 1916. LADWP continues to explore and exercise feasible options to increase the utility of its resources, including dynamically rating critical belt-line segments. Even so, it is clear that long-term investments must be made in the near-term. According to the Ten-Year Transmission Assessment released in November 2010, LADWP's transmission system is capable of handling expected system peak loads for the next four years when supported by approved remedial actions to address vulnerable, critical double contingencies.

Further, the annual Ten-Year Transmission Assessments have consistently identified the need to install Scattergood-Olympic –230kV Line 1 for many years now. With each passing year, the urgency becomes more apparent so that now even remedial actions have limited benefit. For this reason, LADWP is moving forward with the installation. With construction slated to begin in 2012, the new 15-mile long Scattergood-Olympic 230kV Line 1 in the Westside should be in-service before Summer 2015. Information on this project is available at the following website: http://www.ladwp.com/ladwp/cms/ladwp013744.jsp.

I.3 East-to-LA Basin Transmission System

The East-to-LA Basin System (see Table I-3) transmits power into the Los Angeles Basin from distant resources in Utah and the Desert Southwest. The Adelanto Station receives power from the Intermountain DC corridor. The Victorville Station is similarly joined to the task of receiving power from the West-of-River System.

Table I-3. EAST TO LA BASIN TRANSMISSION SYSTEM

Transmission Line	Voltage Class (kV)	Transfer Limit (MW)	LADWP Ownership (%)	LADWP Scheduling (%)
Victorville-Century Lines 1&2 Victorville-Rinaldi Adelanto-Toluca Adelanto-Rinaldi	287 500 500 500	4,000	100	100

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I.4 West-of-the-River System

LADWP's West of River (WOR) system transmits power from the McCullough/Marketplace area to the Adelanto/Victorville area along WECC's WOR (Path 46). Path 46 facilitates transportation of electricity from Navajo Generating Station (Page, Arizona) and Palo Verde Generating Station (Wintersburg, Arizona) to Southern Nevada and Southern California. Until the 1580 MW Mohave Generating Station was shut down in 2005, the Mohave-Lugo 500kV line primarily interconnected that station to the WECC power grid. Since 2006, LADWP has been selling available capacity in the wholesale markets via OASIS. The Palo Verde-Devers 500kV line, of which LADWP has contractual rights to 468MW, is common to both the West-of-River System and the East-of-River System. Both systems are also related in that the capacity ratings are seasonally adjusted according to the Southern California Import Transmission (SCIT) Operating Nomogram.

The WOR system is summarized on Table I-4 and shown on Figure I-2.

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Table I-4. WOR TRANSMISSION SYSTEM

	Transmission Line	Voltage Class (kV)	Allocation (MW)	LADWP Entitlement (MW)
North	McCullough-Victorville Lines 1&2 Hoover-Victorville	500 287	2,592	2,592
	Marketplace-Adelanto	500	1,291	313
	Eldorado-Lugo Eldorado-Pisgah Eldorado-Cima-Pisgah Mohave-Lugo Julian Hinds-Mirage	500 230 230 500 230	2,754	0
		North Subtotal	6,637	2,905
South	Palo Verde-Devers	500	1,802	468
	Ramon-Mirage Coachella-Devers	230 230	600	0
	North Gila-Imperial Valley El Centro-Imperial Valley	500 230	1,584	0
		South Subtotal	3,986	0
		WOR Total	10,623	6,278

Figure I-2. LADWP West-of-Colorado transmission resources.

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I.5 East-of-the-River (EOR) System

LADWP's East of the River (EOR) system transmits power from the north-central and central areas of Arizona to the McCullough/Marketplace/Mead area along the WECC EOR (Path 49). Path 49 facilitates transportation of electricity from Navajo Generating Station (Page, Arizona) and Palo Verde Generating Station (Wintersburg, Arizona) to Southern Nevada and Southern California. The Palo Verde-Devers 500kV line, of which LADWP currently has contractual rights to 468MW, is common to both the West-of-River System and the East-of-River System. Both systems are also related in that the capacity ratings are seasonally adjusted according to the Southern California Import Transmission (SCIT) Operating Nomogram.

The EOR system is summarized on table I-5 and shown on Figure I-3.

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Table I-5. EOR TRANSMISSION SYSTEM

Transmission Line	Voltage Class (kV)	Allocation (MW)	LADWP Entitlement (MW)
Navajo-Crystal	500	9,300, east to west non-simultaneous	1,109
Moenkopi-Eldorado	500		
Liberty-Peacock-Mead	345		
Palo Verde-Devers	500		
Hassayampa-North Gila	500		
Perkins-Mead	500		

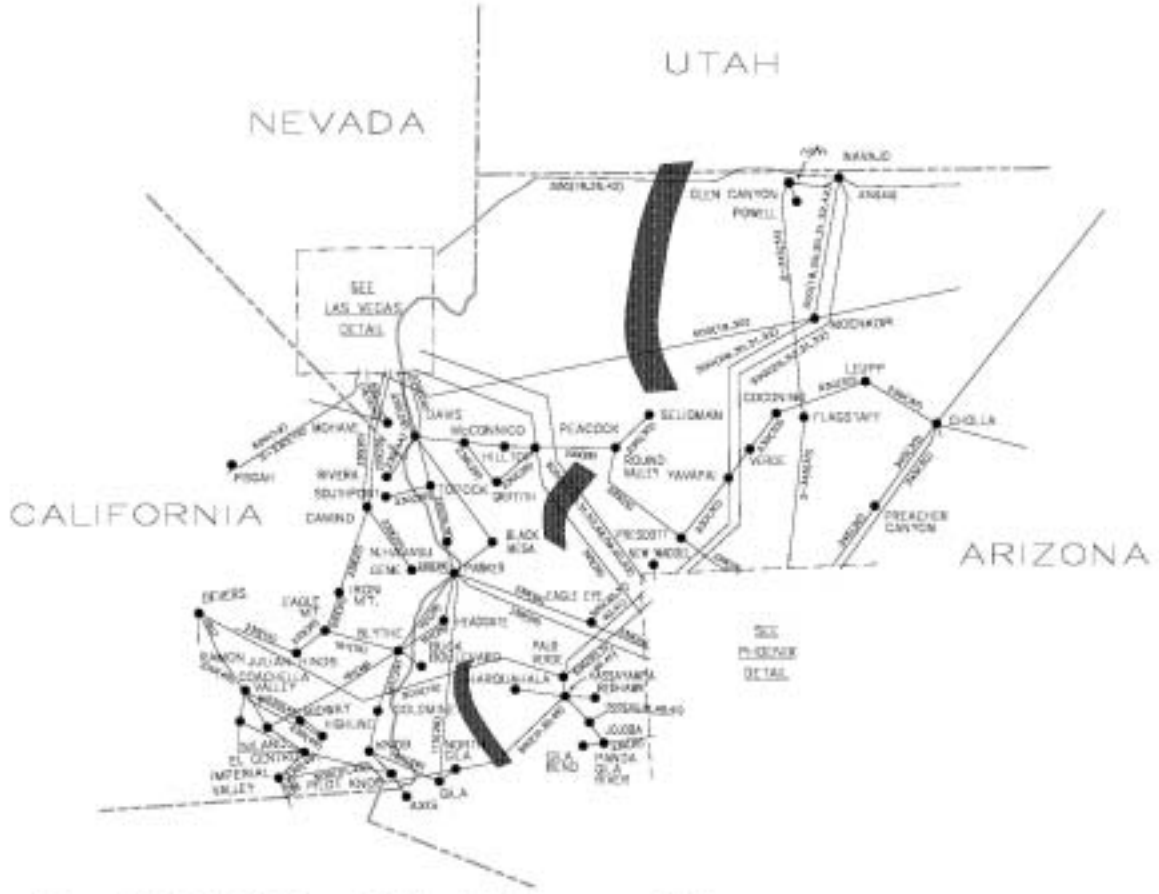

Figure I-3. LADWP East-of-Colorado River transmission resources.

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I.6 Owens Valley Transmission Line

Essentially a segmented single line, the Owens Valley System is becoming increasingly important as a corridor to import renewable resources that support LADWP's RPS goals. Developers have proposed interconnecting renewable resource projects totaling more than 2950MW. These projects have been placed in the interconnection queue but require the construction of LADWP's Barren Ridge Renewable Transmission Project, described in Section 2.4.8 of this IRP.

The Owens Valley transmission system is summarized on Table I-6 and shown on Figure I-4.

Table I-6: Owens Valley Transmission System

Transmission Line	Voltage Class (kV)	Approximated Allocation (MW)	LADWP Expiration	LADWP Entitlement (MW)
Owens Gorge-Inyo Inyo-Cottonwood Cottonwood-Barren Ridge Barren Ridge-Rinaldi	230 230 230 230	300[1]	Owned Asset	300

[1] The normal rating of the line is 459 MVA,

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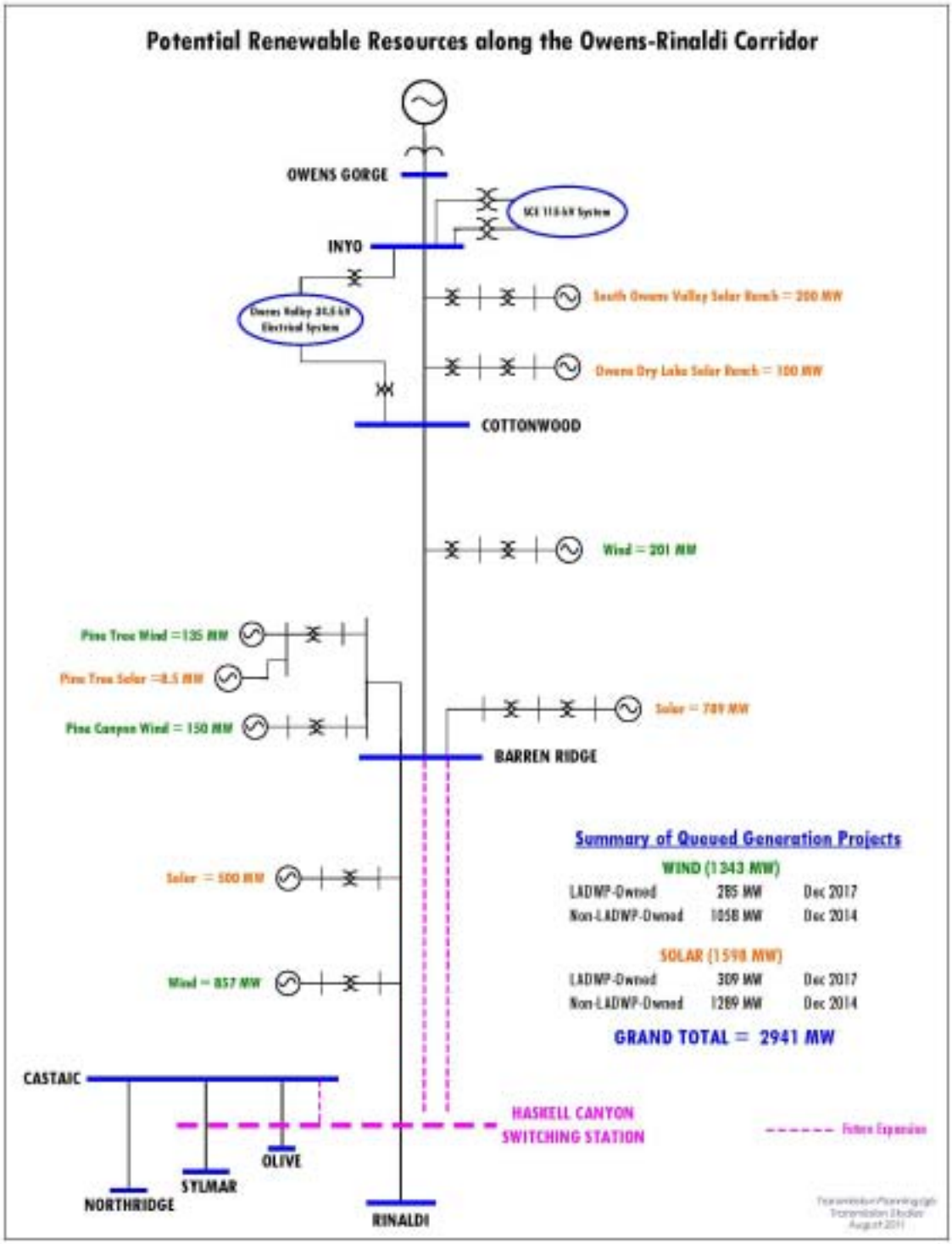

Figure I-4. Owens Valley transmission resources.

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I.7 Intermountain System

The Intermountain System is comprised of three WECC paths operated by LADWP on behalf of the Intermountain Power Authority:

- WECC Path 27, the 488-mile Intermountain Power Project DC Line, was upgraded from 1920MW to 2400MW in May 2011. The increased capacity has been accommodating transmission of wind energy from Utah (see Table I-7 and Figure I-5).
- WECC Path 28, the 50-mile Intermountain-Mona 345kV line ties Pacificorp to LADWP's Balancing Authority Area (see Table I-8 and Figure I-6).
- WECC Path 29, the 144-mile Intermountain-Gonder 230kV line ties NV Energy to LADWP's Balancing Authority Area (see Table I-9 and Figure I-7).

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Table I-7. WECC PATH 27

Transmission Line	Allocation (MW)	LADWP Expiration	LADWP Share (%)	LADWP Scheduling (%)
Intermountain-Adelanto Adelanto-Intermountain	2400 1400	15Jun2027	59.5	59.5

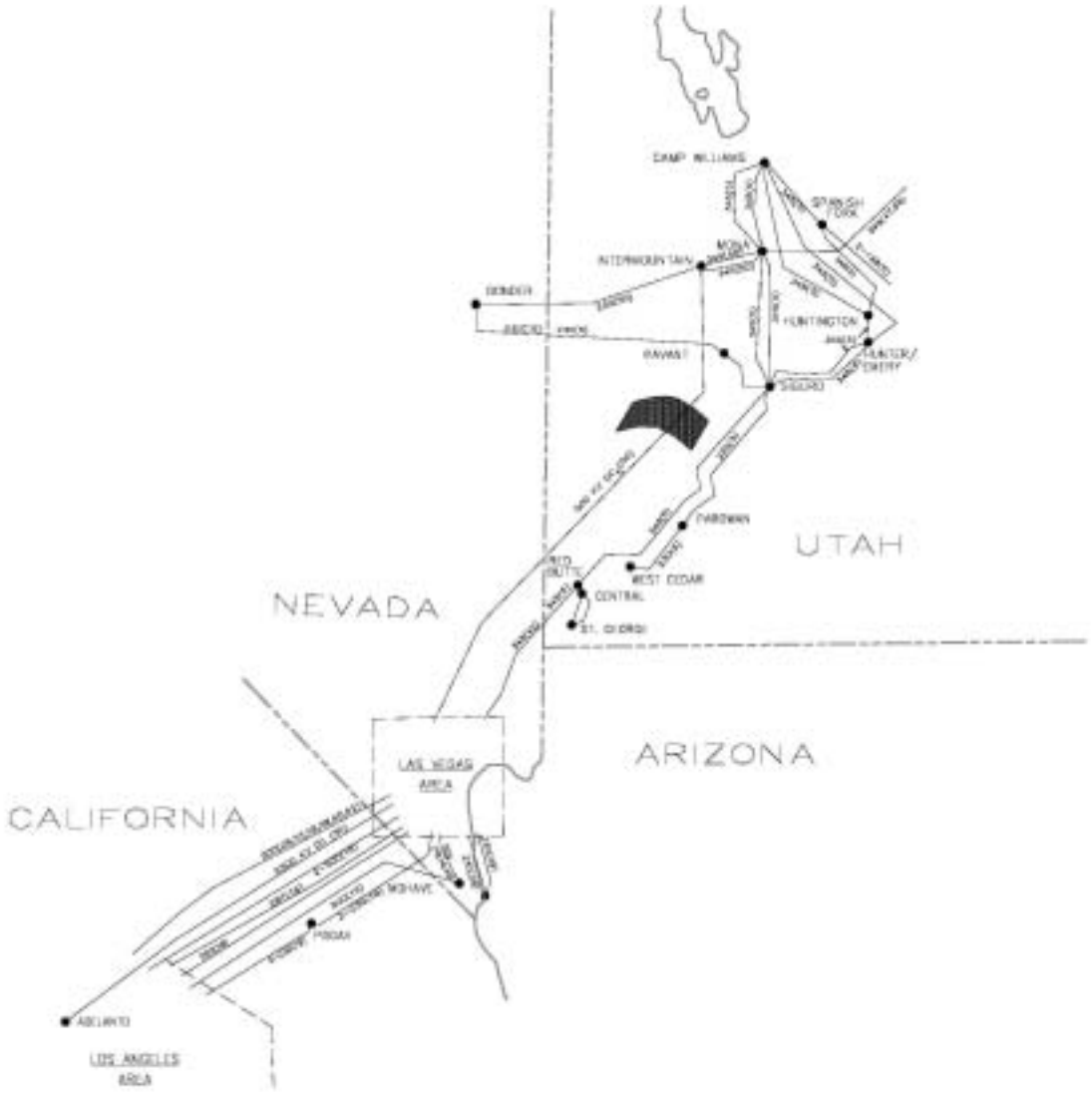

Figure I-5. WECC Path 27.

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Table I-8: WECC PATH 28

Transmission Line	Allocation (MW)	LADWP Expiration	LADWP Share (%)	LADWP Entitlement (MW)
Intermountain-Mona Mona-Intermountain	1200 1400	n/a	0	0

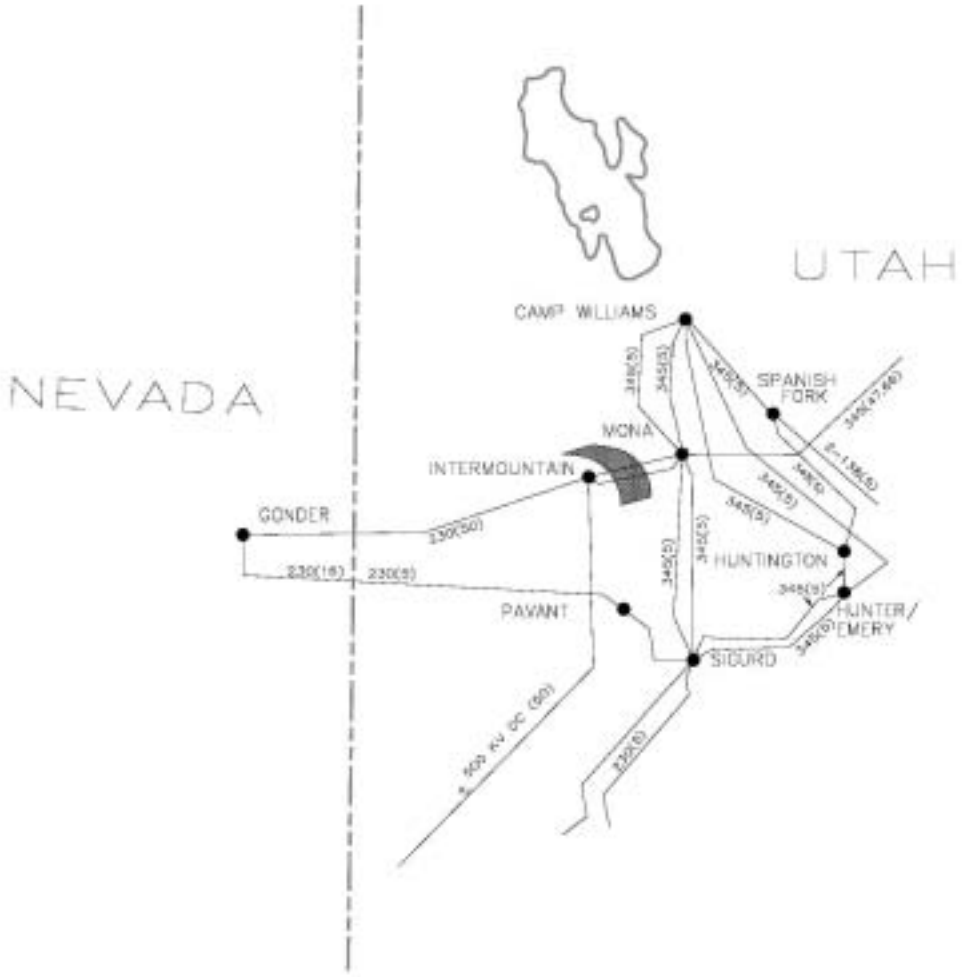

Figure I-6. WECC Path 28.

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Table I-9: WECC PATH 29

Transmission Line	Allocation (MW)	LADWP Expiration	LADWP Share (%)	LADWP Entitlement (MW)
Intermountain-Gonder	200 non-simultaneous bi-directional	n/a	0	0

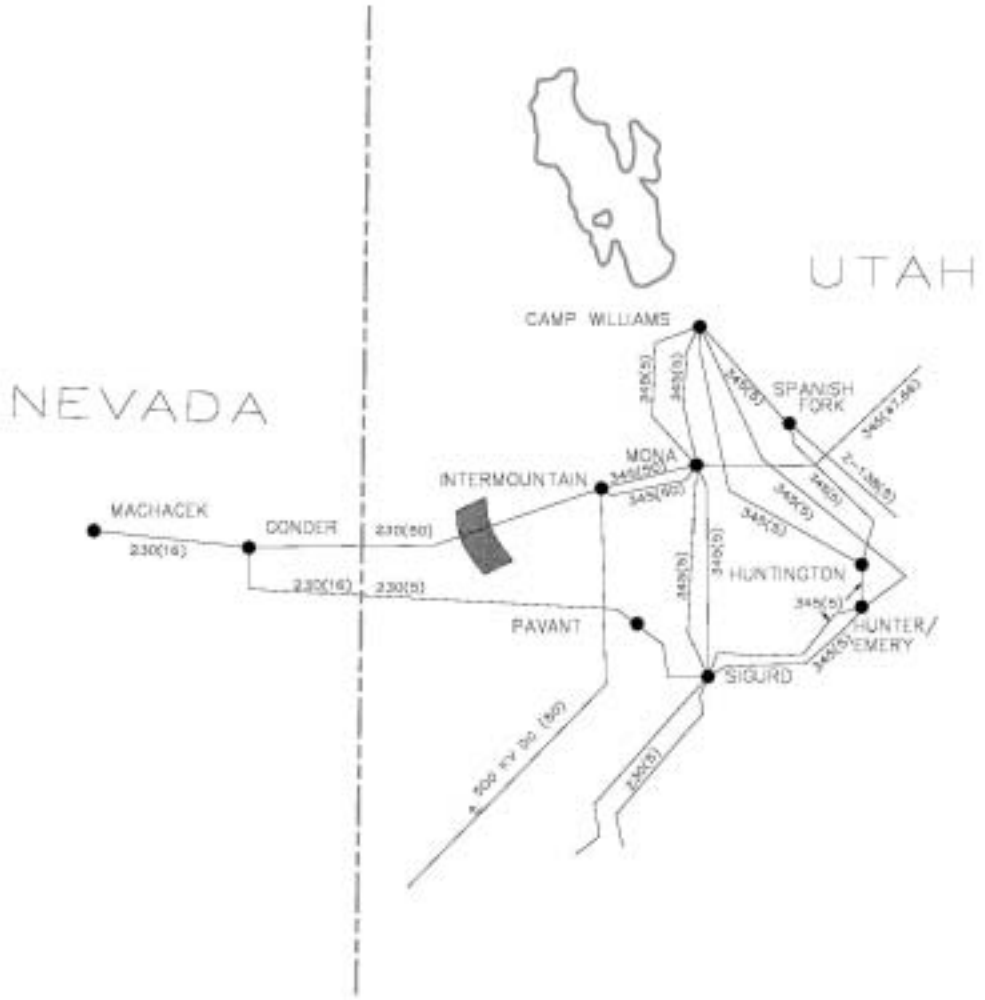

Figure I-7. WECC Path 29.

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I.8 Pacific DC Intertie System

Also known as WECC Path 65, the Pacific DC Intertie is a ±500kV DC line stretching from the Pacific Northwest to the Los Angeles Basin. This corridor provides the means for LADWP to import wind energy and hydroelectricity created from spring runoffs. For the Pacific Northwest, it provides access to low cost generation resources during cold winter months. As described in 2.4.8 of this IRP, research into the various technological options to increase the capacity of the Pacific DC Intertie is being conducted.

Table I-10. WECC PATH 65

Transmission Line	Voltage Class (kV)	Allocation (MW)	LADWP Ownership (%)	LADWP Scheduling (%)
Sylmar-Celilo	+/- 500 kV DC	3100, both directions	40	40

Figure I-8. WECC Path 65.

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I.9 Interconnections with Other Utilities

A number of utilities interconnect with LADWP's transmission system. The tie points are listed in Table I-11.

Table I-11. TRANSMISSION TIE POINTS WITH OTHER UTILITIES

Utility	Regional Transmission Organization	Location	Voltage Class (kV)
Arizona Public Service	--	Marketplace Switching Station	500
Bonneville Power Administration	--	Pacific DC Intertie @ North of Oregon Border	500
City of Anaheim	California ISO	Marketplace Switching Station	500
City of Azusa	California ISO	Marketplace Switching Station	500
City of Banning	California ISO	Marketplace Switching Station	500
City of Burbank	--	Marketplace Switching Station Toluca Receiving Station	500 69
City of Colton	California ISO	Marketplace Switching Station	500
City of Glendale	--	Marketplace Switching Station Airway Receiving Station	500 230
City of Pasadena	California ISO	Marketplace Switching Station St. John Receiving Station (emergency)	500 34.5
Cities of Modesto Redding Santa Clara	California ISO	Marketplace Switching Station	500
City of Riverside	California ISO	Marketplace Switching Station	500
City of Vernon	California ISO	Marketplace Switching Station	500
Intermountain Power Agency	--	Adelanto Switching Station, after 15Jun2027	500
NV Energy	--	McCullough Switching Station Gonder, until 15Jun2027	500 and 230 230
Pacificorp	--	Mona, until 15Jun2027	345
Salt River Project	--	Marketplace Switching Station	500
Southern California Edison	California ISO	Eldorado Substation Victorville-Lugo midpoint Velasco Receiving Station-Laguna Bell (emergency) Sylmar Switching Station Inyo Substation Haiwee (emergency)	500 500 230 220 115 115
Western Area Power Administration	--	Marketplace Switching Station McCullough Switching Station Mead Substation	500 500 and 230 287

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Appendix J Integration of Intermittent Energy From Renewable Resources

J.1 General Integration Principles

One of the main responsibilities of power system operators is to maintain the balance between the total aggregate electrical demand of the system's customers and the amount of energy generated to meet that demand on an instantaneous basis. Conventional electrical generation technologies, such as nuclear, coal, natural gas and large hydro are controlled and dispatched by the power system operators throughout the day to maintain this instantaneous balance between demand and generation.

However, some renewable resources generate energy according to nature in a variable and intermittent manner, and the energy from these renewable resources is generally neither controllable nor dispatchable by power system operators. For example, solar resources generally only produce energy when the sun is up, and wind resources only produce energy when the wind is blowing. Such renewable resources are often referred to as variable and intermittent renewable generation technologies.

It is anticipated that the amounts of energy generated from solar and wind resources will be substantial and increasing. The percentage of solar and wind resources compared to the total capability of a utility's power system may also be defined as "percent penetration." Percent penetration can be measured either by a capacity or energy method. Either measurement method is important, since a utility may use this information to determine the maximum amount of intermittent resources that a power system can absorb without impairing the utility's ability to reliably maintain the required instantaneous balance between demand and generation.

Because power system operators cannot control or dispatch the production of energy from most renewable resources, the remainder of the power system must be controlled and dispatched to accommodate both the changes in renewable energy production and the changes in customer demand. In general, with the addition of increasing amounts of renewable resources, the conventional resources of a power system must become more flexible in their ability to increase and decrease the amount of energy generated to successfully and reliably integrate new renewable generation.

J.2 Findings of System Integration Studies

In the last several years, LADWP has been increasing its efforts to acquire renewable resources. In 2009, 14 percent of energy sold to its customers was generated from renewable energy resources, 20 percent was generated in 2010, and 33% is mandated in 2020. With the much higher percentage of renewables coming on line, a variety of modifications will need to be made to the Power System to successfully and reliably integrate these higher penetrations of renewable resources. In preparation, LADWP has conducted preliminary studies on integrating renewable resources, and has also reviewed many renewable resource integration studies published over the last several years.

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These studies have some common observations and recommendations regarding the integration of intermittent renewable resources into power system generation portfolios. Some common observations of these studies include the following:

1) Larger power systems with robust transmission systems have a greater ability to integrate intermittent wind and solar resources.

2) Individual wind farms tend to have a high variability in the amount of energy produced (see Figure J-1).

3) Wind energy production impacts regulation (minute to minute variability), load following (hourly variability), and unit commitment decisions (day ahead flexibility). See Figure J-2.

4) Wind is usually categorized primarily as an energy resource. The dependable capacity value of a wind farm to the power system is much lower than the rated capacity of the wind turbines.

5) There is a financial cost to integrate intermittent wind and solar renewable projects into existing power systems, and this cost increases with increasing amounts of intermittent renewable resources.

6) Wind energy production patterns are not usually aligned with daily load patterns. Wind production tends to be greatest in the evenings when the daily load is at its minimum.

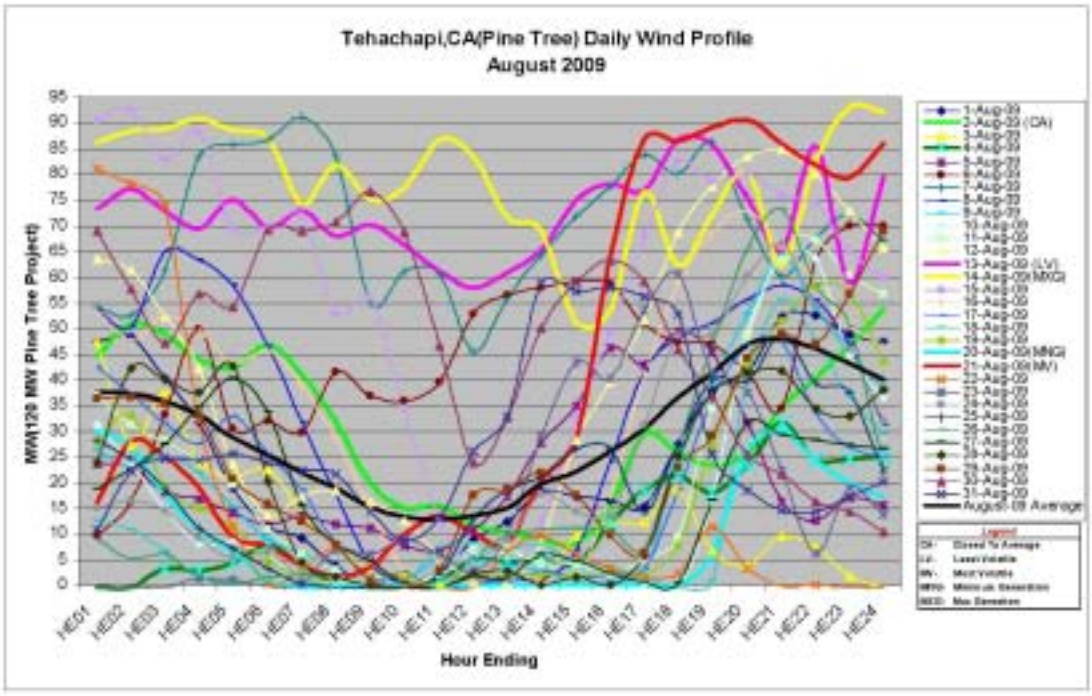

Figure J-1. Wind farm daily wind profiles.

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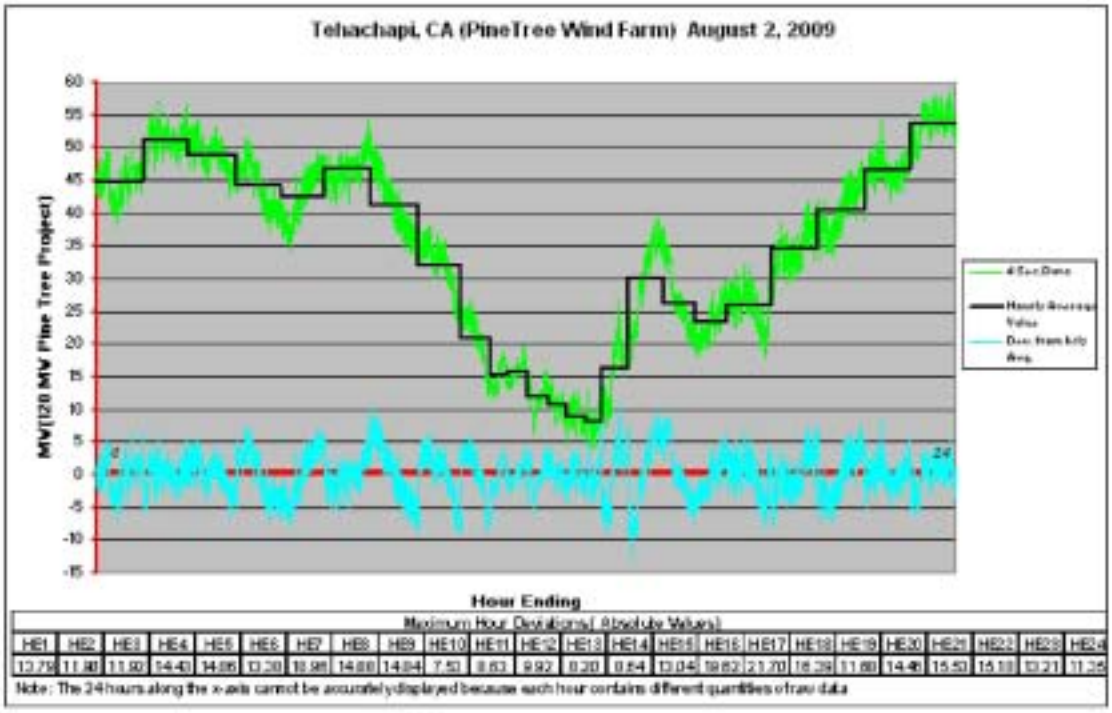

Figure J-2. Wind farm impact on load following capability.

7) High wind energy production during low power system energy demand hours in many cases represents the greatest challenges for power system operations.

8) Average daily and monthly wind energy production profiles are not representative of actual hourly production, due to the high variability in hourly energy production (see Figure J-1).

9) Solar energy production patterns are more closely aligned with daily load patterns than with wind energy production patterns (see Figure J-3).

10) Energy generated from Solar PV technology is highly sensitive to cloud cover. These PV systems can experience variations in output of $\pm$ 50 percent in 30 to 90 seconds, and $\pm$ 70 percent in five to 10 minutes. When a single large sized PV facility experiences these rapid changes in output, the Power System must also be able to react just as quickly with other generation resources to accommodate such rapid changes. The capabilities of a power system's dispatchable resources will limit the size of a single PV facility.

11) In the current energy market, the energy from renewable resource generation will tend to displace the marginal resource, which is typically natural gas. However, if future financial burdens are applied to carbon fuels such as coal, and coal becomes the marginal resource, then coal energy may be displaced by renewable resources.

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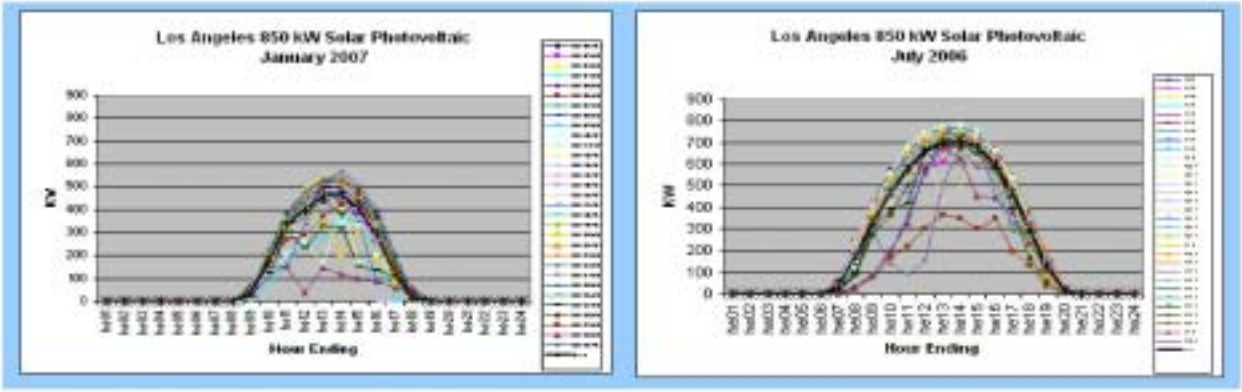

Figure J-3. Solar photovoltaic comparisons.

Some common recommendations from these studies include the following:

1) Successful integration of intermittent renewable resources requires an investment in transmission and generation resources, changes in power system operations and practices, and cooperation among power system operators and energy providers.

2) New generation should be able to operate flexibly, meaning it should be able to start and stop quickly and to cycle on and off many times throughout the year. It should also be able to ramp (change the amount of energy it produces) quickly, and operate at low generation levels.

3) State-of-the-art forecasting, particularly for wind resources, needs to be made available to power system operators.

4) Wind production equipment needs to have "grid friendly" features, including low voltage ride through, voltage control, and reactive power control.

5) Wind energy production must be curtailable by power system operators if wind production negatively affects power system reliability. The power system operators also must have the ability to set power ramp rates for wind projects if needed to ensure power system reliability.

6) Natural gas fired combustion turbines and pump-storage hydro plants are good complements to integrating intermittent renewable resources into existing power systems. Additionally, pump-storage hydro plants with variable speed pumping capability provide even more flexibility to a power system. Other energy storage devices described in Appendix K may also assist in integrating intermittent renewable resources.

7) Customer load shifting programs work well in integrating intermittent renewable resources.

Further studies, planning and system modeling will be needed as additional renewable resources come on-line to assure power system reliability.

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Appendix K Energy Storage

K.1 Overview

This Appendix provides a review of the general requirements of grid-scale energy storage systems (ESSs) and ESS technologies. A proposed ESS demonstration project is described, and a summary of Demonstration Program benefits is provided.

K.2 Requirements of Grid-Scale Energy Storage Systems

LADWP plans to meet its 33 percent renewable generation goal by acquiring and self-developing eligible renewable resources including wind and solar. Because wind and solar are intermittent resources by nature, integrating them into the power system is a major challenge. One method of integrating these intermittent generating resources will be large-scale ESSs. The LADWP currently has electrical storage capacity of 1175 megawatts (MW) of pumped storage at the Castaic Lake Hydroelectric Pumped Storage Plant. The plan is to augment this with large-scale battery-based and/or compressed air energy storage when feasible. The ESSs used in the system should be cost effective and provide economical benefit to LADWP.

The ESS power and energy requirements vary widely with the particular grid support application (Figure K-1). Power quality applications require ESSs with high power capability and short storage capacity, while grid support systems require high power output and medium storage capability. Grid-connected renewable energy generation requires large-scale energy storage and large power capability.

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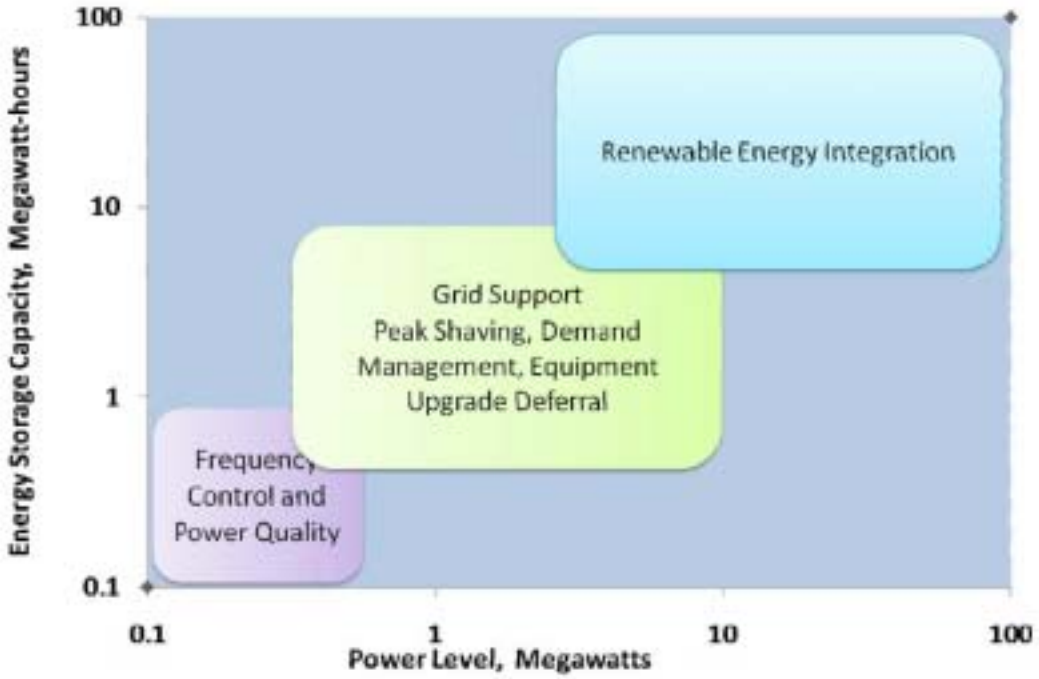

Figure K-1. Requirements of grid-scale ESS.

Electrical ESSs are critical for the integration of intermittent renewable energy sources, load shifting, and improving the stability and reliability of the electricity grid. Such electrical ESSs must be capable of storing hundreds of megawatt-hours (MWhs) and operating without significant degradation for 15-20 years at a cost comparable to today's power plants.

K.3 Energy Storage System Technologies

LADWP is presently in the process of assessing various advanced electrical energy storage technologies to meet its renewable energy program goals. The technologies that look promising for grid-scale energy storage are rechargeable batteries, compressed-air energy storage (CAES), pumped hydro-storage, flywheels energy storage (FES), and supercapacitors. Table K-1 summarizes the salient characteristics of the various energy storage technology options. Among these options, CAES and pumped hydroelectric systems are the technologies most suited for storing large quantities of electrical energy for long periods of time. Rechargeable batteries can support applications requiring a few minutes to a few hours of energy storage. However, hybrid ESSs consisting of rechargeable batteries and other electrical storage systems are likely to meet a wide range of requirements.

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Table K-1. COMPARISON OF VARIOUS ESS TECHNOLOGIES

Electrical Storage Technology	Power	Energy Storage Capacity	Duration of Discharge	Advantages	Challenges / Issues
Lead Acid	< 1 MW	0.1 kWh - 1 MWh	1 - 5 hours	low cost, mature technology	limited cycle life low energy density
Lithium-Ion	< 2 MW	0.1 kWh - 10 MWh	1 - 8 hours	high energy density, high power density	high cost, safety in large systems, life,
Sodium Sulfur	< 40 MW	< 250 MWh	1 - 24 hours	high energy density, modest power density	high temperature operation, cost, safety of large systems, life
Redox Flow	< 5 MW	< 15 MWh	1 - 24 hours	long life, safe, easily scalable, medium cost	low energy density, low power density
Compressed Air	25 MW - 3000 MW	1 GWh	1 - 24 hours	high capacity, low cost	special site requirements
Pumped Hydro	100 MW - 4000 MW	15 GWh	4 - 24 hours	mature, high capacity, low cost	special site requirements
Flywheels	< 1 MW	< 10 MWh	< 1 hour	high power density	low energy density, high cost
Supercapacitors	< 1 MW	< 100 kWh	< 1 minute	high power density, long life, high efficiency	low energy density, high cost
Superconducting Magnetic Storage	< 10 MW	< 1 MWh	< 30 minutes	high power density, high efficiency	high cost

K.3.1 Rechargeable Batteries

Rechargeable batteries, upon being charged, convert electrical energy into chemical energy within reactant materials. The chemical energy can be returned as electrical energy upon discharge of the batteries. The rechargeable batteries being considered for the grid support applications described in this appendix are Lithium-Ion Batteries, Sodium-Sulfur (NaS) Batteries, and Redox Flow Batteries.

Lithium-Ion Batteries

Figure K-2. Lithium-ion batteries.

The basic chemistry of these batteries is the same as that of the batteries used in cell phones, laptops, and other portable electronic devices. Large batteries can be fabricated using the same chemistry to provide ESSs for the grid. These batteries consist of carbon-based anode materials and lithiated metal oxide (metals such as cobalt, nickel, and manganese) cathode materials along with an organic electrolyte. Other material choices include lithium titanate for the anode and lithium iron phosphate for the cathode. The cells are sealed to prevent exposure of the battery chemistry to moisture and

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oxygen. These batteries offer specific energy values as high as 200 watt hour per kilogram (Wh/kg) and 400 watt hour per liter (Wh/L). They are three to six times lighter than lead acid batteries for the equivalent capacity and allow for fast charging and discharging. Operational life of about five years has been demonstrated. Further research is currently being done to improve battery-life characteristics for automotive applications. Cost and safety are the key challenges for widespread deployment of these types of batteries. Lithium iron phosphate and lithium titanate are particularly attractive for automotive applications because of their lower cost and higher abuse tolerance, albeit at a moderate reduction in energy density to 100 Wh/kg. AES Energy Storage is current installing a 32 MW lithium-ion storage system to regulate the 100-MW Laurel Mountain Wind Farm in West Virginia. Similarly, A123 Systems and AES have jointly deployed a 2 MW system (see Figure K-2). The current cost for lithium-ion batteries is between $650-$1000/kWh and $400-$2000/kW. Current costs of lithium-ion batteries are coming down because of ongoing developments in the automotive industry and are expected to reach $250/kwh by 2020.

Sodium-Sulfur Battery

This type of battery was developed prior to lithium ion batteries and uses metallic sodium and elemental sulfur. A sodium-ion conductive ceramic separates both electrodes. Redox and Lithium-Ion batteries can operate at ambient temperatures, but NaS batteries must operate at about 450°C and must be maintained at this high temperature by appropriate thermal insulation. Repeated heating and cooling cycles will reduce the life of NaS batteries. Since NaS batteries consist of reactive materials maintained at high-temperatures, engineering measures are required to ensure safe operations. Notwithstanding these challenges, large-scale NaS battery installations have been demonstrated worldwide, with the largest installed unit being 34 MW, 245 MWh for a wind power stabilization application in Northern Japan by NGK Insulators Inc. (see Figure K-3). Thus far in the U.S., about 40 MWs have been deployed for grid support and integration with wind energy systems. General Electric USA has recently announced its intention to develop and manufacture NaS batteries for renewable energy system integration. The projected cost of large-scale NaS batteries is $450/kW and $400/kWh.

Figure K-3. Sodium-sulfur batteries.

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Redox Flow Batteries

In a redox flow battery (see Figure K-4), the chemicals produced in the cell stack during electrical charging are pumped out of the cell stack and stored as a solution in tanks. The solutions are then re-circulated through the cell stack when the energy needs to be regenerated. Since large amounts of energy can be stored as solutions in tanks, the redox flow battery concept is particularly suitable for large-scale energy storage applications. The Vanadium Redox Battery (VRB) is one of the best known examples of a redox flow battery that has been scaled up to MWh sizes; systems with the power level of 2 MW and storage capacity of 12 MWh have been demonstrated. Many units based on VRB technology are in operation worldwide. Some of the flow battery systems have been in operation for over 30 years with minimal maintenance. The life cycle emission from these batteries is less than 25 percent of that of lead-acid batteries. The capital cost for these batteries is in the range of $1000/kW and $300/kWh. With a 15-year life span, the amortized cost of this system is comparable to that of lead acid batteries.

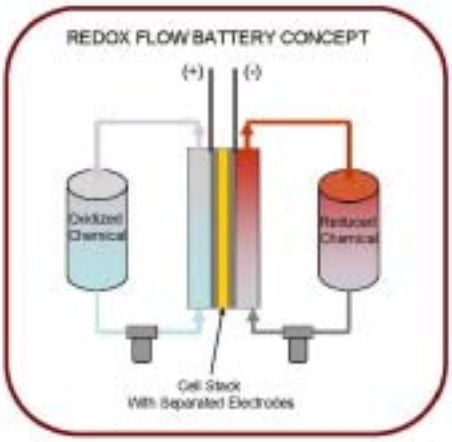

Figure K-4. Redox flow batteries.

K.3.2 Compressed Air Energy Storage

CAES systems compress large masses of air during periods of low energy demand (off-peak) and then expand the air in turbogenerators to produce power during periods of peak demand. Heating the compressed air before sending it through the turbogenerator results in a three-fold increase in the power that could otherwise be generated without the heater. Compressed air stores mechanical energy that can be released very rapidly. However, the stored energy density of CAES systems is relatively small compared to liquid fuel (gasoline, diesel). Currently, about 80-85 percent of the mechanical work for compressing the air is lost as waste heat during the compression. New air compressor devices that recover the heat generated will substantially increase the efficiency.

K.3.3 Pumped Hydroelectric Storage

Pumped Hydroelectric Storage (PHS) is one of the most widely used ESS technologies. The PHS system involves pumping water from a lower reservoir to a higher reservoir when electricity is available (generally at night) and then flowing water down through hydroelectric generators to produce electricity when additional power capacity is needed (typically at midday during periods of peak demand). PHS systems require a particular geographical topology where reservoirs can be situated at different elevations and where sufficient water is available. PHS systems constitute 3-4 percent of the current worldwide power generation capacity. The typical size of these PHS systems is around 1000 MW, and the storage capacity can exceed thousands of MWhs based on the size of the reservoirs and the hydroelectric generator assets involved. The round-trip efficiency of these systems usually exceeds 70 percent. Installation costs of these systems tend to be high because of the geographical siting requirements. System cost is estimated to be $4000/kW and $200/kWh.

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K.3.4 Flywheel Energy Storage

FES systems work by using an electric motor to accelerate a rotor (flywheel) to a very high speed, maintaining the energy in the system as rotational energy using very low-friction bearings and engaging an electric generator to convert the rotational energy back to electricity by decelerating the flywheel. FES technology is a good fit for managing relatively limited amounts of electricity for short periods of time and is being considered as a strong contender for frequency control of the grid. Beacon Power Corporation has developed a flywheel system for frequency control of the grid and is currently testing several installations of prototype equipment.

K.3.5 Supercapacitor Energy Storage

Supercapacitor Energy Storage (SES) and Ultracapacitor Energy Storage (UES) systems are targeted to fill the gap between capacitors and batteries. These devices can deliver large amounts of power for short periods of time and can be used to dampen the in-rush current noise caused by the start-up and shut down of large motors and generators in large power system facilities. However, these devices are not likely to be good candidates for large-scale energy storage.

K.3.6 Superconducting Magnetic Energy Storage

Superconducting Magnetic Energy Storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil, which has been cryogenically cooled to a temperature below its superconducting critical temperature. SMES technology is highly efficient, but manufacture of actual commercial equipment has been hard to achieve. This technology appears to be too immature for large scale commercialization.

K.4 Potential LADWP Barren Ridge ESS Integration Pilot Project

K.4.1 Background

The proposed Barren Ridge ESS Integration Pilot Project was formulated to demonstrate the benefits of energy systems to effectively utilize the energy generated by wind farms and effectively integrate it with the power grid.

Integrating renewable power systems from wind and solar generated power into the electric grid presents several challenges. These renewable power systems are by nature somewhat unpredictable and intermittent. Thus, the amount of electrical energy they produce varies over time and depends heavily upon a variety of random factors mostly tied to local weather conditions. Small wind power systems can be managed without an ESS, but large wind power systems (at rated capacities somewhere around 10 percent of a grid's capacity) are not grid manageable without an ESS. The is because even moderate fluctuations in wind speed could result in excessive fluctuations in grid-fed wind-generated electricity and hence force grid managers to disconnect wind generated power from the grid just when the potential energy yield is greatest.

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Installing large ESSs as part of a wind power system architecture will reduce the power fluctuation problem and will produce frequency-clean, voltage/current controlled, and uninterruptable power into the grid. Several studies have indicated that ESS integration with renewable energy resource power generators will enable clean and controlled delivery of more than 92 percent of the available generated power, while greatly reducing or eliminating the need for back-up fossil fuel power plants.

K.4.2 System Description

The overall system concept for the Barren Ridge ESS Integration Pilot Project is schematically shown on Figure K-5. The energy generated from the Pine Tree Wind Power Project (PTWPP) will be diverted into the ESS at the Barren Ridge Switching Station (BRSS) in California. Additional energy storage will be available at the pumped hydro storage at Castaic Lake. All the power control system equipment will be located at the BRSS.

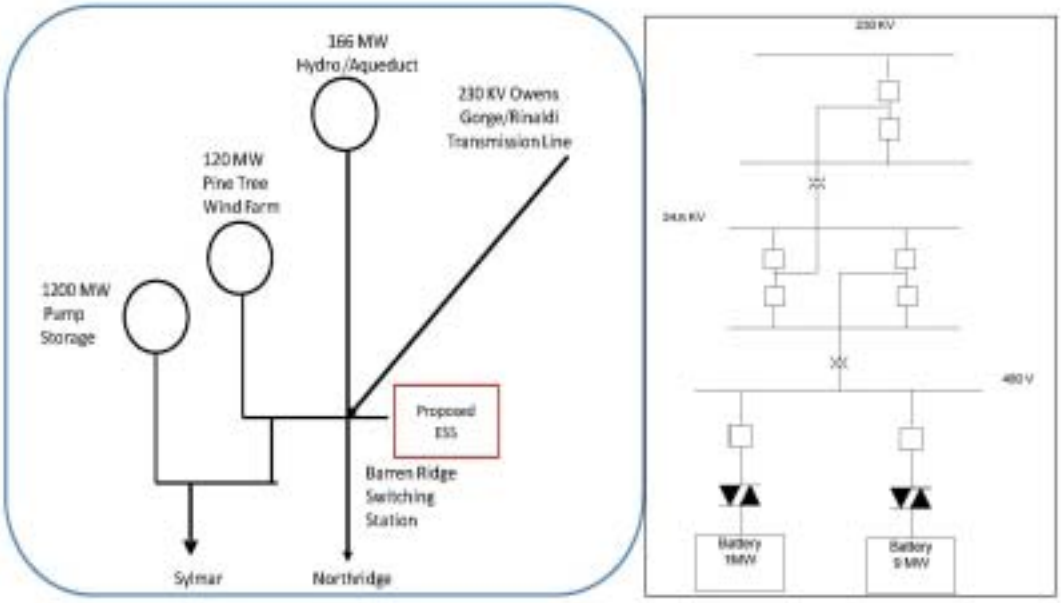

Figure K-5. System concept for Barren Ridge ESS Integration Pilot Project.

K.4.3 Project Site and Assets

The BRSS site was selected because the required assets for this demonstration project, namely, the wind farm generated power and its associated high voltage alternating current transmission lines, are available. Further, the auxiliary PHS facility is linked by other transmission lines to the BRSS.

The LADWP's PTWPP is the largest municipally-owned wind power farm in the U.S. and is located about 12 miles north of Mohave, CA. The PTWPP is sited on 8000 acres of rough terrain and consists of 90, 1.5 MW wind turbines to provide a rated wind power capacity of 135 MW.

A new 8.25-mile transmission line routes power from the PTWPP to the BRSS, where power is tied into the high voltage (230 kV) north-south transmission line that feeds Los Angeles.

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The LADWP could conceptually install about 75 miles of new 230 kilovolt (kV) conductors on both existing and new north-south transmission towers to a new Haskell Switching Station (HSS). The conductors would carry the wind and solar generated power between the BRSS and the HSS, which is linked to the Castaic Lake plant at Elderberry Forebay (462 m above sea level).

K.4.4 ESS

Integration of very large-scale wind and solar farms into the grid requires a low-cost, long life ESS capable of storing hundreds of MWh of electrical energy. The hybrid ESS described here combines a moderate amount of battery storage capacity with a large PHS capacity. This hybrid ESS concept is ideally suited for this application and enables the maximum dispatchability (or usability) of all generated renewable power so that the generated renewable power is not wasted.

Further, the battery storage system can be designed with adequate capacity to provide the necessary reserves for serving both frequency response and spinning reserve requirements, while also serving to dampen out the power quality fluctuations inherent in wind and solar power generators. The battery ESS can also provide ramp control as non-spinning reserves ramp up to capacity. The large PHS ESS will satisfy the needed utility load-shifting requirement by pumping water to a higher elevation during off-peak periods and generating power through the hydroelectric generators during peaking periods. Three primary battery ESS candidates being considered for this demonstration are: redox flow batteries, large-capacity lithium ion batteries, and NaS batteries.

Based on the intermittency and variability of wind-generated power, the ESS that will firm up the wind farm output from the PTWPP should be sized to have a power output of at least 80MW and a storage capacity of 560 MWh. This will be in addition to the pumped hydro storage capability at Castaic Lake. Initial design studies and demonstration of the overall design will be conducted at the 10 MW level. LADWP will then use the lessons learned to scale the system up to 80 MW.

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Table K-2: KEY CHALLENGES OF BATTERY SYSTEMS

Vanadium Redox Battery	Lithium Ion Battery	Sodium-Sulfur Battery
High cost of vanadium Negative environmental impact of using large quantities of a biologically active heavy metal such as vanadium Low-efficiency Low to Moderate power density Loss of efficiency by cross diffusion of constituents, Low storage capacity of solutions	Operational safety of large-scale batteries Degradation after 2000 cycles on deep discharge which translates to about 3-4 years of operation. High cost of materials to achieve high-energy density.	High temperature operation of the battery (400°C) adds to cost, maintenance and safety Rapid degradation of sealing elements when subjected to thermal cycling. Degradation of battery over 1000 cycles High cost arising from materials and manufacturing methods.

Advanced Lithium-Ion Batteries

Many of the safety features provided in small 18650 size cells, such as PRTs and CIDs, are not incorporated into large capacity Li-ion cells. One approach to improve the safety of Li-ion cells is to adopt the use of electrode materials that are inherently safer and still offer the high energy densities provided by lithium-ion technology. To this end, the demonstration project will scale up and implement new electrolytes and cathode materials under development at JPL.

Currently utilized electrolyte formulations, which are composed of organic alkyl carbonates, are highly flammable; there is a strong desire to reduce the inherent flammability of the electrolyte itself. This can be accomplished by the incorporation of flame retardant additives, such as phosphates, phosphites, and phosphonates, and/or the use of non-flammable electrolyte solvents, such as halogenated carbonates and esters. At JPL, development work has been focused upon both approaches, with the intent of developing safer electrolyte solutions for "human rated" aerospace applications.

Advanced Redox Flow Battery

An advanced redox flow battery that operates on iodate/iodide redox coupling has been under development and can potentially offer a superior system for large-scale energy storage compared to the vanadium redox battery. The key improvements achieved by this new concept over the state-of-art vanadium redox battereis are shown in Table K-3. A schematic of an iodide/iodate redox battery with the reactions occuring at either electrode is presented on Figure K-7.

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Table K-3: COMPARISON OF SOA AND ADVANCED REDOX BATTERIES

Parameter	Vanadium Redox Battery (State of the Art)	Iodide-Iodate Redox Battery (Advanced Concept)
Environmental Impact	Uses biologically active heavy metal	Uses iodide No heavy metals. Environmentally friendly
Energy Density	25 - 30 Wh/liter	> 50 Wh/liter
Energy losses through membrane	Yes. Cationic reactants diffuse through membrane	No. Anionic reactants cannot diffuse through membrane
Projected Life	10 - 15 years	> 15 years

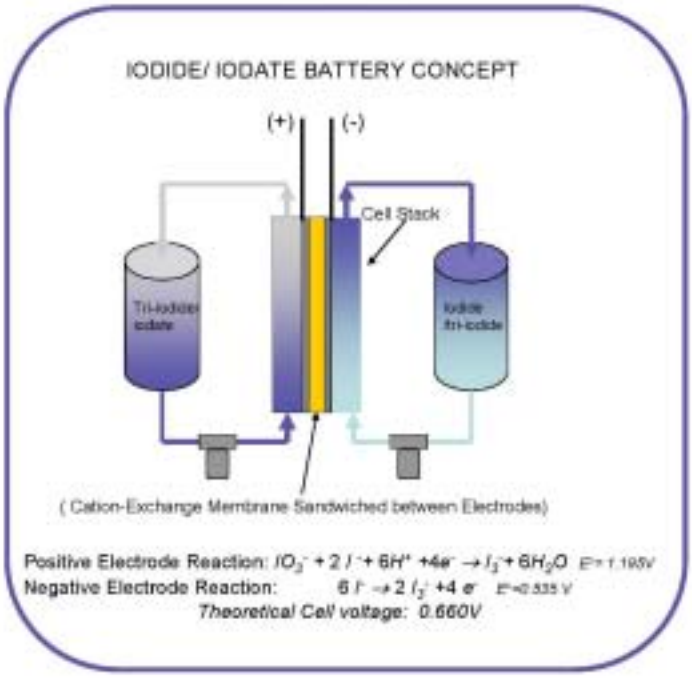

Figure K-7: Schematic of iodide/iodate redox battery.

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K-5 Benefits

Quantifiably advances in ESS technologies, and implementation will result in several benefits as shown on Table K-4.

Table K-4. BENEFITS OF ENERGY STORAGE SYSTEMS

LADWP Approach	Benefits	Metrics
Use Battery Energy Storage to supply energy when the generation dips from the wind or solar generators during peak demand periods or demand increases	Lower electricity cost	Lowering peak demand needed from expensive combustion turbine generators with wind and solar generation
Use Battery Energy Storage to supply energy when the generation dips from the wind or solar generators or during system disturbances	Reduced power interruptions and increase reliability	Fewer and Shorter outages
Use Battery Energy Storage to supply energy when the generation dips from the wind or solar generators or during system disturbances	Reduced costs from better power quality	Fewer momentary outages
		Fewer severe sags and swells
		Lower harmonic distortion
Use Battery storage energy from green power reduces CO2 Emissions	Reduced damages as a result of lower GHG/carbon emissions	Percentage of green power relative to total power generated.
Increase of battery storage from green power to reduce need for oil or gas		Percentage of green power relative to total power generated
Reduce reliance on non renewable resources	Greater energy security from reduced oil consumption	Percentage of green energy utilized

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Appendix L Smart Grid

LADWP's Smart Grid Program is described in the following "Smart Grid Deployment Plan" dated October 31, 2011

AR0071411

Smart Grid

Deployment Plan

Prepared by: Power System Engineering Division
Power System Information and Advanced Technologies (PSIAT) Section

Smart Grid Team

Version 1.0

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1 Introduction

1.1 Purpose of this document

The Los Angeles Department of Water and Power (LADWP) Smart Grid Deployment Plan represents a roadmap to address the anticipated future needs of the people of the City of Los Angeles. By meeting the requirements of both SB 17 and Title XIII, LADWP's Smart Grid Deployment Plan outlines the coordinated and integrated approach in implementing new technologies while maintaining or improving safety and reliability.

1.2 Smart Grid Initiative Background

Smart Grid is a national policy that grew as a response to The Energy Policy Act of 2005, which called for advanced metering. It, however, has been insufficient to achieve the desired goals of energy conservation, migration to renewable energy, and reduction of CO2 emissions from power plants. The federal Energy Independence and Security Act of 2007 called for the implementation of Smart Grid systems as a "Policy of the United States". The new Energy Independence and Security Act of 2007 authorizes $100 M each year from 2008 through 2012 to be divided between five Smart Grid demonstration projects throughout the nation. The Department of Energy is required to report within one year on the status of Smart Grid deployments and identify any regulatory or government obstacles.

Additionally, utility executives and regulators have become increasingly concerned about multiple issues that can only be addressed through an enterprise wide Smart Grid solution. The four main concerns are:

(a) Cost and uncertainty about New Generation and Transmission

(b) Environmental impacts ("Green House" gases emitted from fossil fuel power plants and proposed right-of-ways for transmission lines crossing through pristine forests, deserts and wild life areas to service urban areas) such as those proposed in AB 32, the *California Global Warming Solutions Act, 2006*.

(c) Increasing requirements for the use of Renewable and Distributed Generation (Wind, Solar, Geothermal, Hydro, and Biomass)

(d) Demographics: aging workforce

Regulated utilities in California are now responding to regulatory direction to submit plans for large-scale AMI and Smart Grid initiatives with full delineation of costs and benefits. This regulatory initiative is an aggressive step, seeking to promote customer awareness of peak load periods, and response to peak-sensitive pricing. The Smart

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Grid deployments and the associated utility customer features are proceeding through out the State of California.

1.3 Smart Grid Definition

The Los Angeles Department of Water and Power maintains that the definition of a smart grid is a system which facilitates the integration of advanced technologies in existing networks to improve system performance, power flow control, and reliability. Such a system is characterized by the following:

(a) Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid.

(b) Dynamic optimization of grid operations and resources, with cost-effective full cyber security.

(c) Deployment and integration of cost-effective distributed resources and generation, including renewable resources.

(d) Development and incorporation of cost-effective demand response, demand-side resources, and energy-efficiency resources.

(e) Deployment of cost-effective smart technologies, including real time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices for metering, communications concerning grid operations and status, and distribution automation.

(f) Integration of cost-effective smart appliances and consumer devices.

(g) Deployment and integration of cost-effective advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air-conditioning.

(h) Provide consumers with timely information and control options.

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(i) Develop standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

(j) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

1.4 Stakeholders

1.4.1 Customer

LADWP ratepayers are the Customers and will realize the monetary, social, and environmental benefits of the plan.

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2 LADWP Smart Grid Initiatives

2.1 Smart Grid Objectives

Currently, the Department is involved in two strategic initiatives related to Smart Grid. The first is the Smart Grid Regional Demonstration Project and the second is the Smart Grid Investment Program.

The Smart Grid Regional Demonstration Project began in December of 2009, when LADWP was awarded 60.2 million dollars grant from the Department of Energy for the American Reinvestment and Recovery Act for Smart Grid Demonstrations. As a result of the award, LADWP is managing a consortium of Los Angeles metropolitan area research institutions with established energy and technology transfer programs. Together, the team is carrying out a regionally unique demonstration by using innovative technology test beds located at LADWP's partner university campuses and technology transfer laboratories to prove the viability of the demonstration technology. Additional research is being conducted to explore options for informed, enabled customers based on historical usage and pricing data. This research uses a multi-tiered rate approach to address the diversity of customer demands by exploring time-varying and time-of-use products for the end consumer. The regional demonstration project includes four interrelated project initiatives, which will be incorporated into the long term investment program:

(a) A fully integrated demonstration of Smart Grid operation and technology as applied to Demand Response.

(b) A comprehensive portfolio of research empoying a unique test bed structure to identify historical usage and consumer adoption obstacles essential for succesful adoption of Smart Grid Technologies and improved energy usage patterns.

(c) Demonstration of next generation cyber security technologies using the Regional Project as the driving source of specific system architecture and models.

(d) The integration of electric vehicles into the LADWP managed grid, addressing solutions to overcome both technical and social impediments.

The Smart Grid investment plan is a 10-year project that incorporates 11 strategic initiatives.

2.1.1 Links with the Department's Strategic Objectives

The Smart Grid Implementation Plan continues to align LADWP's efforts to implement the technology with the goal of increasing LADWP's Power System monitoring,

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control and reliability while decreasing operating costs and gaining significant efficiencies.

2.2 LADWP Smart Grid Initiatives in Progress

"Smart Grid" is a term used to describe a variety of advanced information-based utility improvements. Smart Grid is a major enabler for many existing and potentially new Demand Side Resource programs. Smart Grid is a national policy evolving from the Energy Policy Act of 2005. Smart Grid refers to intelligent data gathering and advanced two-way digital communication capabilities overlaid on electric distribution networks to provide real-time data that enhances the utility's ability to optimize energy use. Smart Grid technologies can turn every point in the existing network—including every meter, switch and transformer—into a potential information source, able to feed performance data back to the utility instantly. Smart Grid Technologies will provide utilities with the information required to implement real-time, self-monitoring networks that are predictive rather than reactive to instantaneous system disruptions. It can enable the utility and consumer to make decisions to optimize the use of energy, improve reliability, and reduce the consumption of fossil fuels.

Section 8360 of the Senate Bill 17 defines the policy that governs the way utilities modernize transmission and distribution systems. LADWP's eleven Smart Grid Initiatives are designed to be collectively compliant with SB17. The following is the list of the initiatives:

(a) Renewable Integration

(b) Transmission Automation Initiative

(c) Substation Automation Initiative

(d) Distribution Automation Initiative

(e) AMI Metering Initiative

(f) Demand Response Initiative

(g) Communications Initiative

(h) Cyber Security Initiative

(i) System and Data Integration Initiative

(j) Feed-In Tariff Initiative

(k) Solar Incentives Program

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2.3 Renewable Integration

LADWP has a comprehensive Integrated Resource Plan where new Wind, Solar, and Geothermal Power Plants, as well as Energy Storage, and Electric Vehicles will be incorporated into the power generation mix. Currently, the ECS/Historian Servers have been installed at Pine Tree Generation Station, and there are plans to install more of these servers at each of the power plants. These servers allow for real-time monitoring and control of renewable sources, which will be equipped with automation equipment in order to facilitate peak shaving activities and to better support the adoption and utilization of renewables.

2.4 Transmission Automation Initiative

For years, LADWP has worked in substations to meter the transmission lines and record Phasor Measurement Units (PMU). These measurements are used to determine the health of the Electrical System. LADWP will install PMUS, and upgrade Tie-Line Meters to improve measurement, provide backup metering at Tie Points, collect dynamic reads, and reroute power. The real-time data provided by PMU will be used for predicting instability in the transmission system and undertaking preventive actions.

2.5 Substation Automation Initiative

For the past five years, LADWP has implemented a comprehensive program to install a new Power System Substation Automation System (SAS) from the Energy Control Center to the Substations, transmission, and Generation Stations. Currently, 80 of the approximate 200 substations and generation stations have been updated to the new Substation Automation, and a new SCADA system has been implemented. There are approximately 70 more stations in the inventory that will be implemented over the next two to three years. Approximately 840 feeders now have remotely controlled circuit breakers and remote monitoring of megawatt loading of wire/cables. A significant amount of data is already being processed through the SCADA system and is available to the load dispatchers and other personnel on an as needed basis. At the conclusion of this project, the vast majority of feeders at all substations will be observable and controllable from the Energy Control Center.

2.6 Distribution Automation Initiative

There have been several pilot projects for the Distribution Automation relating to devices outside the substation walls (Current's Broadband over Power Line project, Ricochet Spread Spectrum project, and Telemetric Cellular project). These projects were never rolled out as the industry was still being developed and LADWP's decision was to wait until more robust solutions were available. Additionally, some of the pilot programs were never considered industry standard since it was using obsolete

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technology. The LADWP is currently evaluating fault indicators, remotely controlled switches and automatic cap banks. These devices can be used for dynamic optimization of the distribution system.

2.7 AMI Metering Initiative

LADWP has been progressing over the past few years with the AMI Metering Initiative.

- As of 6/01/11, the LADWP has installed 162,200 AMR meters
  - Residential Meters (F meters) – 85,000 (using RF Technology and one way communication providing billing information for walk or drive by meter reading)
  - Small Commercial Demand Meters (FM meters) – 68,000 (using RF Technology and one way communication providing billing information)
  - Large Commercial Wireless Meters (A meters) – 9,000 (using Cellular Technology and two way communication providing billing information and load profile information)
- AMR meters represent approximately 10.6% of the total meters in the system but over 45% of the power revenue

Wireless meter reading and real-time pricing are available for 9,000 Large Commercial Customers with demand greater than 200kW. The newest AMI meters have the capability of short range connectivity. This feature will be used by the Home Area Network devices that display various real-time energy consumption data to the customers.

2.8 Demand Response Initiative

LADWP has had a Demand Response (DR) rate for years for large industrial users. Currently, there are 30 Megawatts of interruptible load, but very rarely has this been used because LADWP has had a philosophy to cover all its loads. This pilot program is also voluntary in that when a load reduction is required, the customer has the option to not participate and pay for the higher cost of energy. Currently, the LADWP is planning to develop a formal demand response program that will allow the Department to reduce generation cost and distribution system strain during peak consumption periods.

2.9 Communications Initiative

The component that pulls all of the initiatives together is the common communication network. Over the past ten years, thousands of miles of fiber optic cable has been installed in over 72 substations as part of a fiber optic broadband infrastructure. The plan is for all substations to have fiber optic connections within the next two years.

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LADWP evaluates different communication protocols that can be used for the real-time control and observation of deployed automation equipment.

2.10 Cyber Security Initiative

The implementation of Smart Grid will involve a wide deployment of smart remotely controlled network capable devices. These devices can be potential points of cyber attack due to network connectivity. This is why NERC and FERC have developed strict procedures and guidelines that require utilities to treat any critical cyber asset (CCA) with great attention. The breach of CCA can result in critical damage to the power distribution system.

Due to the importance of Cyber Security, the Smart Grid will need to better understand and improve the cyber security, and more importantly, three key items will be developed:

- Grid Resilience: this effort will show how the Smart Grid can operate resiliently against physical and cyber attack.
- Operational Effectiveness: this effort will demonstrate a complete cyber security testing approach for components and installed systems.
- Redefinition of Security Perimeter: this effort will demonstrate new cyber security measures that address the expansion of this perimeter by Smart Grid technologies to the meter in residential and commercial sites.

2.11 System and Data Integration Initiative

Significant progress has been made in the Power System in implementing the best of breed systems (see **Figure 2.11-1** Power System Technology Architecture). These systems are the backbone of the business and information processes in the Power System. Additionally, significant integration between these and the corporate systems is in place.

In particular, OSIsoft's Pi Historian is a fast real time data processing system that has been purchased and installed by LADWP. The next Pi Historian initiative is to use it as a central repository for all of LADWP's real-time data and to allow access to the appropriate users of the data throughout the utility. LADWP has currently installed the Pi Historian in two locations (ECC and JFB) with a tag count of 20,000 data points. There are three pilot Pi Historian applications running at this time: 1) door/gate alarm; 2) Operation logger; and 3) Power System Dashboard real time data. Five user groups (Reliability, Planning, Station Operators, Grid Operations, and Meter) are also currently developing new applications.

In addition, LADWP is working on integrating the Meter Data Management System (MDMS), Outage Management System (OMS), and Customer Information System

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(CIS) with various Web services. These services will be designed to provide accurate and timely information to customers regarding their consumption, billing, any pending outages and restoration statuses. The customers will have the option to adjust their accounts to set up their profile and notification preferences.

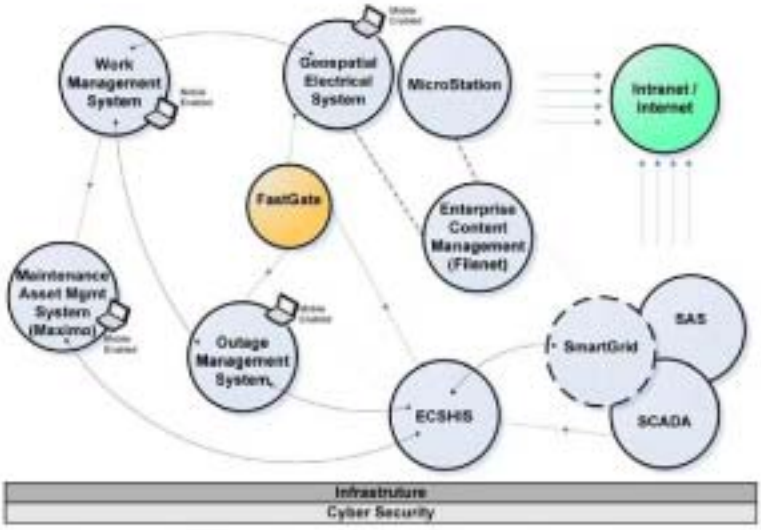

Figure 2.11-1 Power System Technology Architecture

2.12 Feed-In Tariff Initiative (FiT)

FiT seeks to purchase energy from small and medium-scale renewable energy projects (from 30 kilowatts up to one megawatt in AC capacity) within the service territory of LADWP under a long-term Standard Offer Power Purchase Agreements (SOPPA). The SOPPA terms are standard for all participants, can be up to 20 years in duration, and participants will be paid the bid base price of energy plus Time-of-Delivery (TOD) multipliers. FIT is a distributed generation (DG) program designed for the local Los Angeles market, and gives LADWP customers the opportunity to sell energy to LADWP from using their property as the DG site.

2.13 Solar Incentive Program (SIP)

The LADWP Solar Photovoltaic Incentive Program provides financial incentives to LADWP customers who purchase and install their own solar power systems. LADWP currently also provides an additional incentive payment for systems using PV modules manufactured in the City of Los Angeles.

LADWP currently provides a Los Angeles Manufacturing Credit (LAMC) for qualifying photovoltaic equipment manufactured in Los Angeles as approved by the LADWP guidelines. The goal of the LAMC is to promote local economic development through

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manufacturing and job creation within the City of Los Angeles and to reduce costs through increased volume and competition.

3 Proposed Deployment Plan

The overall scope of the Smart Grid Deployment Plan includes the following three overlapping phases:

3.1 Implement a short term plan (one year horizon)

This plan includes the following coordinated activities:

- Create a Smart Grid System Architecture (**Table 3.1-1** ***SG Architecture (Phase 1) Schedule*** & **Table 3.1-2 SG Architecture (Phase 2) Schedule**)
- Create a Comprehensive Business Plan/Case (**Table 3.1-3 SG Business Plan Schedule**)
- Integration of Various Information Systems
- Participate in Standard Development
- Creation of a Multi Disciplinary matrix team

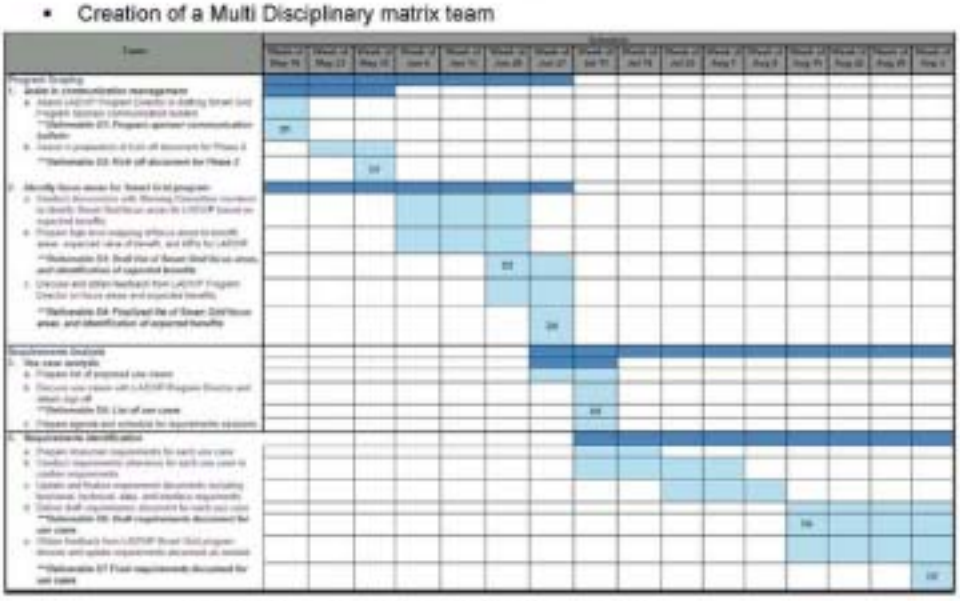

Table 3.1-1 SG Architecture (Phase 1) Schedule

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Table 3.1-2 *SG Architecture (Phase 2) Schedule*

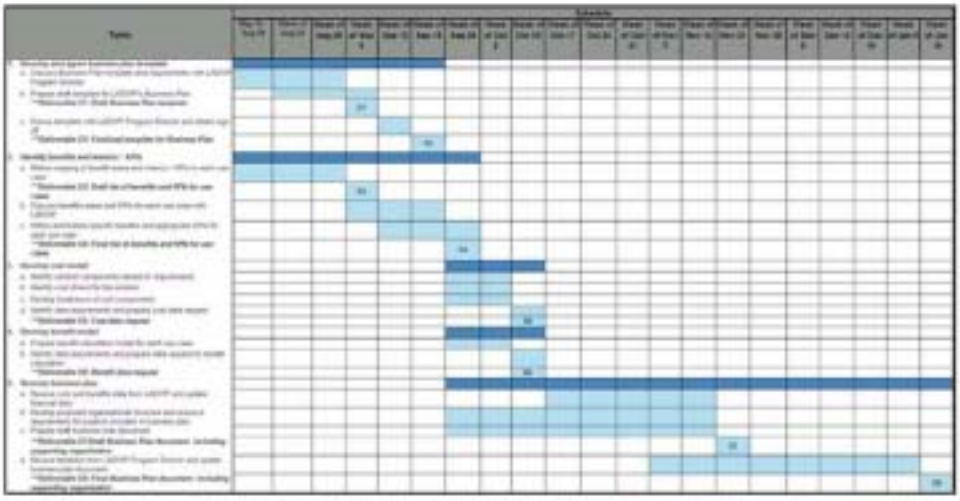

Table 3.1-3 *SG Business Plan Schedule*

3.2 Implement a mid term plan (up to five years horizon)

This plan includes the following coordinated activities:

- Complete and implement LADWP's ARRA Smart Grid Regional Demonstration Project, which focuses on Customer and Behavioral Studies, Cyber Security, Demand Response, and Electric Vehicles.

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Figure 3.2-1 *Smart Grid Regional Demonstration Project Schedule* below shows the implementation schedule of the Smart Grid Regional Demonstration Project.

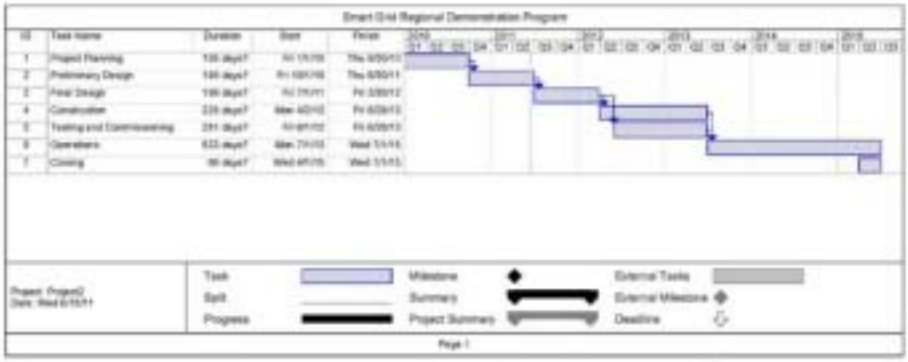

Figure 3.2-1 Smart Grid Regional Demonstration Project Schedule

- Implement the balance of the SAS project to automate all generation, substation, and transmission with the SCADA system. **Table 3.2-1** *Substation Automation Project Installation Progress Schedule* below shows the overall schedule of activities to implement the SAS project.

Stations for Site Acceptance Test (SAT)			
RS-T	Monday, January 09, 2012	Friday, February 10, 2012	5 Weeks
IS-1221	Monday, February 13, 2012	Friday, February 24, 2012	2 Weeks
IS-1263	Monday, March 01, 2012	Friday, March 16, 2012	2 Weeks
RS-N	Monday, March 19, 2012	Friday, April 02, 2012	3 Weeks
DS-24	Monday, April 05, 2012	Friday, April 16, 2012	2 Weeks
RS-C	Monday, April 19, 2012	Friday, May 07, 2012	3 Weeks
DS-135	Monday, May 10, 2012	Friday, May 21, 2012	2 Weeks
RS-E	Monday, May 24, 2012	Friday, June 25, 2012	5 Weeks
DS-61	Monday, June 28, 2012	Friday, July 09, 2012	2 Weeks
DS-30	Monday, July 12, 2012	Friday, July 23, 2012	2 Weeks
RS-M	Monday, July 26, 2012	Friday, August 06, 2012	2 Weeks
DS-36	Monday, August 09, 2012	Friday, August 20, 2012	2 Weeks
DS-76	Monday, August 23, 2012	Friday, September 03, 2012	2 Weeks
RS-U	Monday, September 06, 2012	Friday, September 24, 2012	3 Weeks
DS-21	Monday, September 27, 2012	Friday, October 08, 2012	2 Weeks
RINALDI	Monday, October 11, 2012	Friday, October 29, 2012	3 Weeks
DS-26	Monday, November 01, 2012	Friday, November 12, 2012	2 Weeks
HALLDALE	Monday, November 15, 2012	Friday, December 03, 2012	3 Weeks
DS-143	Monday, December 06, 2012	Friday, December 17, 2012	2 Weeks
DS-15	Monday, December 20, 2012	Friday, December 31, 2012	2 Weeks
RS-J	Monday, January 03, 2013	Friday, January 21, 2013	3 Weeks

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DS-2	Monday, January 24, 2013	Friday, February 04, 2013	2 Weeks
RS-Q	Monday, February 07, 2013	Friday, February 25, 2013	3 Weeks
DS-95	Monday, February 28, 2013	Friday, March 11, 2013	2 Weeks
RS-L	Monday, March 14, 2013	Friday, April 01, 2013	3 Weeks
DS-50	Monday, April 04, 2013	Friday, April 15, 2013	2 Weeks
RS-S	Monday, April 18, 2013	Friday, May 06, 2013	3 Weeks
DS-58	Monday, May 09, 2013	Friday, May 20, 2013	2 Weeks
RS-R	Monday, May 23, 2013	Friday, June 10, 2013	3 Weeks
DS-105	Monday, June 13, 2013	Friday, June 24, 2013	2 Weeks
RS-F	Monday, June 27, 2013	Thursday, June 30, 2013	1 Weeks
RS-Q	Sunday, July 03, 2013	Thursday, July 21, 2013	3 Weeks
IS-3115	Sunday, July 24, 2013	Thursday, July 28, 2013	1 Weeks
IS-3130	Sunday, July 31, 2013	Thursday, August 04, 2013	1 Weeks
IS-1671	Sunday, August 07, 2013	Thursday, August 11, 2013	1 Weeks

Table 3.2-1 Substation Automation Project Installation Progress Schedule

- Implement the balance of the projects at ECC to use all of the features and upgrades of the SAS and other systems with the new technology. **Figure 3.2-2** ***ECC Plans to be Implemented*** below shows the activities and systems to be implemented.

Figure 3.2-2 ECC Plans to be Implemented

- Implement the balance of the projects at ETC to use all of the features and upgrades of the Smart Grid systems with the new technology. **Figure 3.2-3** ***ETC Plan and Enhancements*** below shows the various activities to be implemented.

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Figure 3.2-3 ETC Plan and Enhancements

- Implement a new CIS and Supply Chain System

The effort must be made to implement a new CIS, and a new Supply Chain Corporate System. These systems will be able to manage the new information and transaction of a Smart Grid system.

Other activities to be implemented during this phase are as follows:

- Implement the balance of the electric model with the GIS system and engineering design tools
- Create and advertise Multiple RFPs as needed to start the implementation of the Smart Grid components
- Create Multiple contracts as needed to bring the vendors on-board

3.3 Implement the full Smart Grid Features (up to 10 years)

Implement all the remaining features indicated in this plan in various phases based on the requirements and needs identified, and with the dynamics of the utility and technology environment. The phases of this significant program could include two large pilot periods where various telecommunication technologies will be tested while Smart Grid technology will be utilized to cover overhead, underground, single family residences, multi-family residences, and medium and large customers in a couple of neighborhoods. The final phase would be the full city wide implementation assuming the data and results from the pilot programs are satisfactory.

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The full functionality of the Smart Grid could include all of the following aspects:

(a) Outage Notifications

(b) Transformer Monitoring

(c) Capacitor Controls

(d) Line Switch Controls

(e) Automatic Meter Reading

(f) Load Control of residential and commercial devices (DSM Program)

(g) Video Surveillance via Smart Grid

(h) Fault Management

(i) Transformer Deterioration

(j) Transformer Overloading

(k) Current Monitoring

(l) Cable Management

(m) Surge Protection

(n) Lighting Controls

(o) Weather

(p) Municipal Applications

(q) Other applications as they become available.

Other features could include:

- Installation of Smart Grid equipment in the City of Los Angeles Facilities
- Installation of Smart Grid equipment and potentially replacement all of the water meters
- Access to broadband capabilities (Internet access, VoIP, video) for City of Los Angeles Municipality
- Access to City of Los Angeles Municipal information via broadband connections

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- Set up an internal LADWP organization to maintain and operate the Smart Grid equipment
- Maintain, install, and operate the Smart Grid equipment through the following organization and service components:

  1. Services
  2. Customer response center
  3. Network Operation Center (NOC)

3.4 Related Projects

The following projects are related to the Smart Grid as follows:

1. Substation Automation System: Extension and upgrade of the remaining Switching, Receiving, and Distribution Systems
2. Telecommunications system: Extension and upgrade of the telecommunications to support the Power System operations through the implementation of a fiber optic broadband network.
3. Subtransmission and distribution switches: Automation of subtransmission and distribution switches, implementing line monitoring, line switch control, and 4.8 kV line capacitor bank control.
4. Fault and outage detectors: Installation of remotely monitored fault and outage detectors which would provide a means to locate faults and outages on selected 4.8 kV distribution lines.
5. Operating orders, procedures, and processes: Re-engineering of operating orders and processes as required for monitoring and controlling changes of the Power System.

3.5 Constraints

The following are potential constraints:

- Budget/Cost
- Regulatory environment which may limit Smart Grid installations
- Internal Resources
- Political environment (City/State/Federal)

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3.6 Urgency

The timing of LADWP's Smart Grid Deployment coincides with the initiatives by other major U.S. utilities. Additionally, the Department of Energy is encouraging utilities to invest in Smart Grid by offering grants and the regulatory environment seems to support Smart Grid as an alternative to the existing utility practice.

3.7 Procurement Process

The Smart Grid Plan will utilize the procurement process as follows:

(a) Determination of requirements

(b) Preparation of RFP(s)

(c) Vendor(s) Selection

(d) Preparation of Agreements

(e) Initial Implementation – Phase 1

(f) Phase 1 Evaluation

(g) Multi-phase Implementation over the next 10 years.

4 Critical Milestones

4.1 Schedules and Critical Milestones

The Smart Grid Plan assumes a 1-year, 5-year, and 10-year implementation.

4.1.1

4.1.2 Critical Milestones

Table 4.1.2-1 Critical Milestones illustrates the critical milestones:

Milestone or Event	Significance
Smart Grid Business/Project Plan and Architecture Presentation	Get concurrence from Management
Setup of Smart Grid Project Committee	Establish Project Committee
Preparation of Smart Grid Project Requirements	Establish project requirements
Advertise Request for Proposals	Request for Proposals
Vendors Selection	Selection of qualified bidder
Board Approval	Contract approval by LADWP Board of Commissioners

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City Council Approval	Contract approval by City of Los Angeles
Contracts Award	Execution of contract award
Implementation Phase 1	Implement Smart Grid Phase 1 (Pilot Programs)
Evaluation of Phase 1	To continue Full Implementation
Begin full deployment	Implement city wide

Table 4.1.2-1 Critical Milestones

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5 Budget

Smart Grid equipment costs are expected to continue to drop due to technology advances and significant market changes, **Table 4.1-1** Budget Estimates for various Systems given below is our best estimate for various alternatives at this point. As RFPs are produced and responses are received, we will have a better idea as to the cost of these types of systems and process.

	Single Unit				Total			
	P2P	Single Unit RF	RF Mesh	BPL/PLC	P2P	RF	RF Mesh	BPL/PLC
AMI (w/o communications)								
Residential	200.00	160.00	200.00	220.00	248,992,000.00	199,193,600.00	261,992,000.00	273,991,200.00
Commercial	317.50	347.50	387.50	337.50	57,029,032.50	62,417,602.50	69,602,362.50	60,621,412.50
Industrial	367.50	367.50	367.50	376.50	17,050,597.50	17,050,597.50	48,485,525.50	17,468,470.50
					323,071,630.00	**278,662,100.00**	**400,079,888.00**	**351,981,083.00**
DA 4.8 kv (w/o communications)								
switches	950.00	-	950.00	1,150.00	12,831,650.00	-	12,831,650.00	15,533,050.00
capacitors	950.00	-	950.00	1,150.00	2,998,200.00	-	2,998,200.00	3,629,400.00
transformers	950.00	-	950.00	1,150.00	96,215,050.00	-	96,215,050.00	116,470,850.00
DA 35.5 kv (w/o communications)								
switches	1,700.00	-	1,700.00	-	8,746,500.00	-	8,746,500.00	-
capacitors	950.00	-	950.00	-	-	-	-	-
					120,791,400.00	**-**	**120,791,400.00**	**135,633,300.00**
DR (w/o communications)								
Residential	77.00	-	77.00	77.00	95,881,020.00	-	95,881,020.00	95,881,020.00
Commercial	77.00	-	77.00	77.00	13,830,663.00	-	13,830,663.00	13,830,663.00
					109,692,583.00	**-**	**109,692,583.00**	**109,692,583.00**
Communications					**7,671,847.47**	**10,407,798.40**	**10,407,798.40**	**48,624,600.00**

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SAS					60,000,000.00	60,000,000.00	90,000,000.00	60,000,000.00
Applications					110,000,000.00	110,000,000.00	110,000,000.00	110,000,000.00
				TOTAL	731,227,790.47	458,069,898.40	746,537,041.40	616,631,599.00

Table 4.1-1 Budget Estimates for various Systems

The pie chart below (**Figure 4.1-1** P2P Cost Graph) depicts the P2P estimated cost in the nine different categories of the smart Grid.

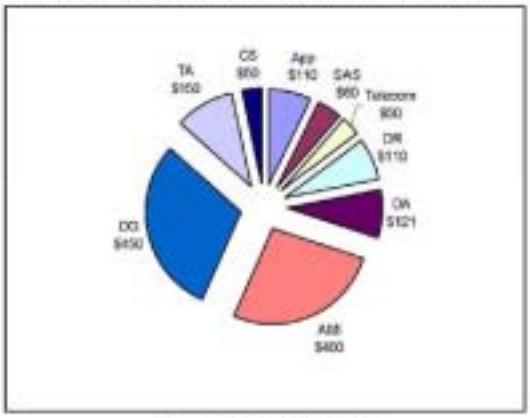

Figure 4.1-1 P2P Cost Graph

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6 Impacts

6.1 Internal

The Smart Grid equipment will impact several areas within LADWP. **Table 6.1-1** Potential Impacts within LADWP shows some potential impacts on these organizations:

Area within LADWP	Nature of impact
Meter Reading	Automated method reading of electric meters
Control System Operations	may gain capability to control devices at all levels
Customer Service	Establish direct communications with customer
Electric Trouble Dispatch	Will process trouble calls using Smart Grid information
Engineering Design	Power network design process (OH/UG)
Distribution Line Crews	Maintain and operate new Smart Grid equipment
ITS	Provides support of Smart Grid network equipment
Water Meters	Automated method of reading water meters

Table 6.1-1 Potential Impacts within LADWP

Area within the department	Nature of impact
Energy Control Center	Will use SAS for real-time data instead of current RTU
Electric Trouble Center	Will use real-time data
Plant Control System Operations	Will use real-time data access and archived data
Substation Operations	Selected station status information will be available
Substation Maintenance	Will access intelligent relay settings and logs without having to connect directly to the devices
ITS	Provides support of ECS WAN network.
Power Systems Operation and Maintenance	Provides support of SAS application software and hardware
Engineering	Will use archived data

Table 6.1-2 Potential Impacts within department

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6.2 External

Table 6.2-1 Potential Impacts external to LADWP shows some potential impacts on organizations that are external to LADWP:

Area external to LADWP	Nature of impact
City of Los Angeles	Gain fiber optic broadband infrastructure
Broadband Companies	May perceive competition from LADWP and receive services.
Gas Utility	Opportunities to collaborate with LADWP
State of California (CPUC)	May encourage Smart Grid installation at Los Angeles

Table 6.2-1 Potential Impacts external to LADWP

7 Smart Grid Business Plan & Evaluation Strategy

A Smart Grid business plan will be developed in conjunction with the roadmap and architecture development activities which will include cost-benefit analysis of projects for implementation of the functionality identified in the Smart Grid architecture and roadmap. The business plan documentation will outline the project description; costs associated with the implementation; and expected benefits. The financial analysis will be based on estimated benefits and costs information and will be updated throughout the course of the implementation of the projects as the actual cost data become available. The business plan development process will include an assessment to identify the benefit areas and develop an estimate of actual quantifiable benefits expected from investment into particular Smart Grid area. The benefits resulting from LADWP's Smart Grid investments could be in various areas including but not limited to better customer service, reduced operational costs, higher operational efficiency, and achievement of environmental goals. The benefit estimation will be developed using LADWP KPIs and other relevant metrics. The business plan will also include a cost model to estimate the implementation costs of each project. The cost estimates will be based on assumptions of the technology and implementation choices, and will be updated during implementation of the projects with actual costs and implementation plans.

8 Smart Grid Safety

Smart Grid Deployment Plan requires specific installation, maintenance, and operation procedures, which LADWP personnel will need training on. Additionally, the Smart Grid equipment will require compliance and resolution of issues relating to the following state regulations:

(a) California Public Utilities Commission - General Order 128 – Construction of underground electric supply and communication systems.

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(b) California Public Utilities Commission - General Order 95 – Overhead electric line construction.

(c) California Public Utilities Commission - General Order 165 – Inspection Cycles for electric distribution facilities

(d) The Smart Grid vendors and utilities are currently handling all of these issues with success.

9 Smart Grid Operational issues

LADWP intends to own and operate the Smart Grid equipment. The ownership entails the support and ability to operate the Smart Grid network by LADWP personnel.

The following are potential operational issues:

- 24/7 operational support of the Smart Grid equipment
- Training of Crews for the operation and maintenance of the Smart Grid equipment
- 24/7 operational support of the telecommunications and fiber optic broadband infrastructure access

10 Smart Grid Performance Measurement

The critical success factors essential for plan success are as shown in **Table 10-1** Critical Success Factors:

Critical Success Factors	Measurement method
Plan Buy-in from LADWP Board	LADWP Board Approval
Plan Buy-in from City	City Council approval
Appropriate plan budget	Budget approval
Smart Grid Technical Feasibility	Market proven Smart Grid technology
Secure staffing resources	Appropriate resource leveling based on project scope
Regulatory Support for Smart Grid	City, State legislative approvals for Smart Grid implementation

Table 10-1 Critical Success Factors

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11 Smart Grid Product Benefits Realization

The benefits will be measured as shown in **Table 11-1** Benefits:

Potential Benefits	Measurement method
Municipal fiber optic broadband Capability	No. of City of Los Angeles Broadband users
Smart Grid enabled Automated meter reading	No. of automated meter reads
Customer Energy Management Programs	No. of devices under Direct load control
Improved reliability	No. of Utility applications in service
Additional Revenue Sources	Capitalize on revenue generating opportunities

Table 11-1 Benefits

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12 Conclusion

The Los Angeles Department of Water and Power is dedicated to integrating new technologies to improve system performance, power flow control, safety and reliability. By maintaining a high level of commitment and service for the City of Los Angeles, LADWP is taking the necessary steps to:

(a) Coordinate efforts across multiple stakeholders

(b) Integrate new technologies to supplement the power system

(c) Deliver safe, secure, and efficient electrical service well into Los Angeles's future

LADWP's overall strategic plan is inclusive of the Smart Grid Deployment plan. LADWP's focus is the City of Los Angeles, customer enhancement, utility services, and operations. LADWP looks forward to further collaborate with policymakers, customers, and stakeholders as the process of Smart Grid implementation unfolds.

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Appendix M Model Description and Assumptions

M.1 Overview

The study horizon for the model analysis is the 20 year period 2011 through 2030. In performing this modeling, it is necessary to assume certain actions are taken in each of the next 20 years. However, it must be understood that the Integrated Resource Plan (IRP) is an ongoing process. A new IRP is developed every two years. Between each 2-year interval, the most recent IRP is modified if appropriate. The key results from this IRP analysis is the action plan that will be put in place for the next 1 to 5 years. These near-term actions are important recommendations that will enable and support the goals and objectives of the long term plan.

This Appendix presents the Model Analysis and is organized as follows:

- Section M.2, Model Description, provides a description of the model selected by LADWP to simulate the operation of its power system under different futures and with different resource portfolios.
- Section M.3, Renewable Resources Selection Process/Gap Analysis, describes the method used to assess the amount of future renewables required, and the valuation process used in selecting the future renewable resource portfolio.
- Section M.4, Case Options, reviews the key resource distinctions between the 3 case options under consideration.
- Section M.5, Model Inputs and Assumptions, presents the major input parameters that were used in the production cost model runs.

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M.2 Model Description

LADWP has chosen a widely used and industry accepted hourly chronological unit commitment and dispatch model to simulate the operation of the LADWP power system under different futures and with different resource portfolios. The model is the Planning & Risk model (PaR) licensed from Ventyx (an Atlanta based software firm). It uses the PROSYM unit commitment and dispatch algorithm.

PROSYM is designed for performing planning and operational studies, and as a result of its chronological structure, accommodates detailed hour-by-hour investigation of the operations of electric utilities. Because of its ability to handle detailed information in a chronological fashion, planning studies performed with PROSYM closely reflect actual operations. PROSYM considers a complex set of operating constraints to simulate the least-cost operation of the utility. This simulation, respecting chronological, operational, and other constraints, is the essence of the model.

This model looks at the LADWP load for each hour and then dispatches LADWP generation supplies on an economic basis (lowest variable cost units first) until the load is met. The model output reflects all the variable costs incurred in meeting the load for each study performed. The fixed costs for the resources are added to the modeled variable costs to develop the total power cost incurred in meeting the load.

The model is also capable of representing certain transmission constraints on a utility system. LADWP load is generally confined to the geographic area of Los Angeles. An IRP would not generally be a replacement for transmission planning activities needed in the service area. However, LADWP does have generation outside of Los Angeles and has transmission rights to other areas of the Western Interconnect. To better represent the constraints and opportunities related to these remote facilities, the modeling topology depicted on Figure M-1 was developed for this IRP.

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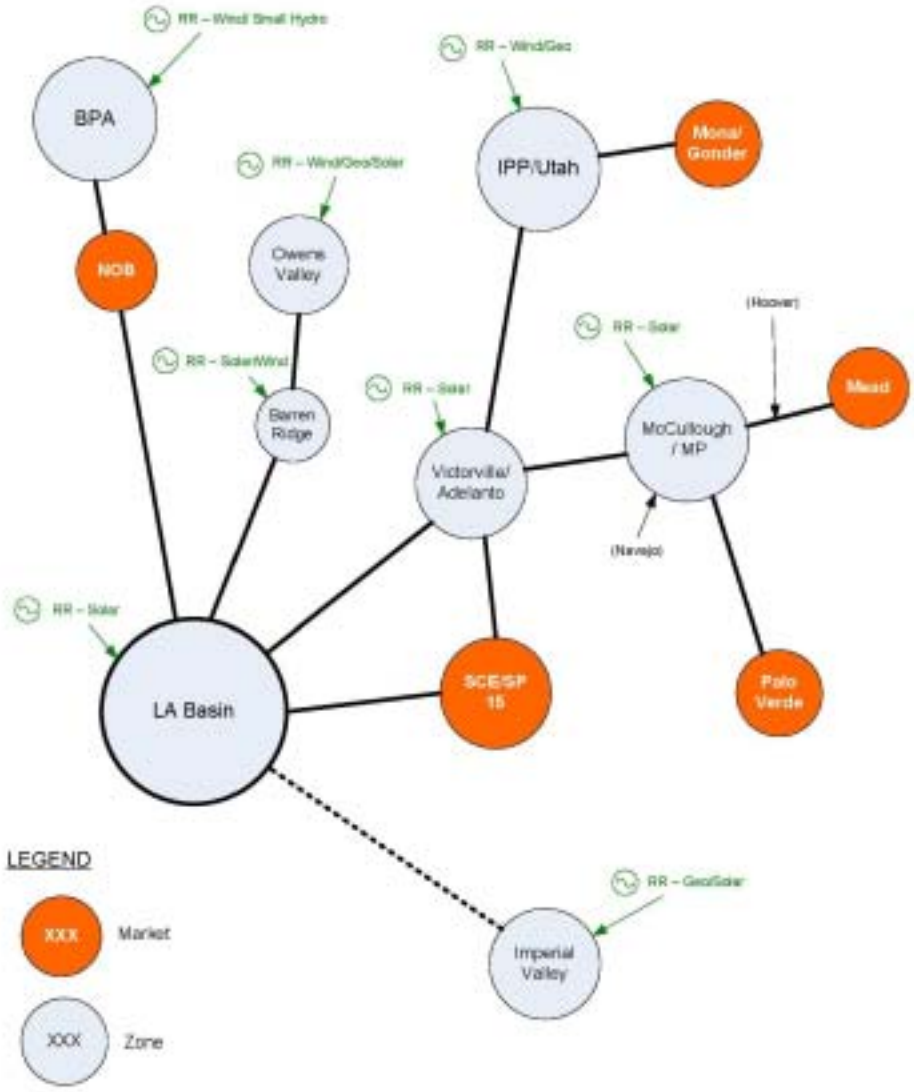

Fig M-1: LADWP Modeling Topology.

On a day-to-day basis, LADWP will buy power in spot markets if such a purchase can be done both without causing a reliability problem and if the price of the spot market power is less than the operating cost of its own power plants. Similarly, on a day-to-day basis, LADWP will sell power in spot markets if the price of power in the spot market is greater than the cost of operating an LADWP resource and the power is not needed to meet LADWP load. In an IRP analysis, it may or may not be desirable to attempt to reflect spot market activity. For this IRP, short term and long term market purchases and sales were included in the overall energy mix. For resource adequacy, some limited Q3 purchases were included to supply short term capacity deficits in future years resulting from coal divestment and load growth.

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M.3 Renewable Resources Selection Process/Gap Analysis

The gap analysis in this IRP evaluated both a Resource Adequacy (RA) need as well as a need to meet certain goals for renewables as a percentage of billed energy (renewable need). The RA need compares available generation supplies to the load that needs to be served. For LADWP, this comparison was based on the annual peak load plus a planning reserve margin. In addition to a system wide demonstration of RA, a certain amount of generation needs to be located in the Los Angeles service territory to assure local reliability. Sections 2.4.5, 3.4.1, 4.2.1.4 and 4.3.1 of this report discuss the LADWP approach to RA.

M.3.1 Amount of Renewables Needed

To determine the amount of renewable energy necessary to meet future targets, forecasts were made for the future power demand and the amount of existing renewable capacity available to meet these requirements. The difference between the projected amount required and the amount currently being utilized is the net short that will need to be acquired to meet RPS guidelines. A description of the methodology undertaken to define the future renewable needs is outlined below.

LADWP Renewable Net Short

The net short is the generation target to be met with resources identified in this project. The calculation for the net short was performed using the following equation:

Net Short(GWh) = (Forecasted Energy Sales) x (Annual Renewable Percent Goal) – (Operating Renewable Resources – Under Construction and Pre-construction Renewable Resources - Renewable Energy Purchases)

SB 2 (1X) has established the level of renewables required by 2020 and beyond, and also sets interim targets between now and 2020. These levels and targets represent the *Annual Renewable Percent Goal* parameter in the equation. By incorporating forecasted sales, existing renewable projects, and current and forecasted renewable energy purchases, the net short can be calculated.

M.3.2 Renewable Resources Selection Process

Over the last ten years, LADWP has issued several requests for proposals for renewable energy and gained a thorough understanding of the nature and availability of the different renewable resource technologies. This knowledge was used in developing the renewable portfolio. Additionally, LADWP largely considered renewable resources within the Western Governors' Association's Western Renewable Energy Zones (WREZ). In the WREZ initiative, Qualified Resource Areas were defined as areas of dense, high-quality renewable energy resources, meeting various resource size, quality, environmental, and technical criteria. LADWP screened all resources to ensure they are located near available LADWP transmission infrastructure. Assumptions were made for the cost and performance of each technology used to convert the

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renewable resources to electricity. These assumptions were used in calculating the levelized cost of electricity.

A valuation process designed to provide a single ranking value to a resource was then applied. The valuation process is a method to rank the total value of separate renewable resource projects, and accounts for such parameters as transmission costs, integration costs, supply curves, load shapes, the capacity benefit provided by the resource, capital and O&M costs, financial factors and other measures This step is intended to identify resources with the combination of lowest cost and highest value. The valuation approach is similar to the bid evaluation process many utilities use when procuring renewable resources.

After applying the appropriate constraints, resources were selected and added progressively to the renewable resource mix based on lowest rank cost and transmission availability until the net short was mitigated. To assess and rank projects consistently, a method must be developed to measure the economics of all resources on a consistent basis. Renewable technologies all have different characteristics, with different cost requirements and energy delivery patterns. Resource valuation is a way to measure different renewable resources on a comparable basis.

M.3.3 Renewable Generation Cost

The cost of generation is calculated as a levelized cost of energy ("LCOE") at the point at which the project will interconnect to the existing transmission system. The LCOE for a project is the total life-cycle cost of generating electricity at the facility normalized by the total generation from the facility and is calculated in terms of dollars per megawatt hour ($/MWh). LCOE provides a consistent basis for comparing the economics of disparate projects across all technologies and ownership.

For each project or resource class, a pro forma financial analysis was conducted to determine the life-cycle cost. This pro forma model uses input assumptions for key project variables to determine expected revenues, costs, and year-by-year after-tax cash flow over the project life. The pro forma model used is consistent with the model used in CEC's Cost of Generation model, as well as those used in WREZ and California's Renewable Energy Transmission Initiative. It is also very similar to the model used by the CPUC to calculate the Market Price Referent (MPR), with the necessary modifications to make the calculations appropriate for renewable resources, including the modeling of tax incentives, accelerated depreciation, and other incentives.

The analysis included appropriate assumptions for each project. Some assumptions were tailored to be technology specific, such as financing terms and appropriate tax incentives. Other assumptions such as capacity factor and capital cost depended on geography and the available natural resource. Specific costs included in the generation costs were:

- Capital costs
- Generation interconnection costs ("gen-tie")
- Fixed operation and maintenance
- Variable operation and maintenance

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- Heat rate (if applicable)
- Fuel costs (if applicable)
- Incentives
- Net plant output
- Capacity factor
- Economic life

M.3.4 Renewable Generation Cost

The integration cost of a project is the indirect operational cost to the transmission system to accommodate the generation from the project into the grid. The addition of substantial amounts of intermittent and as-available renewable resources could result in substantial generation swings on the transmission system, and the grid operator must accommodate these swings by ensuring there is sufficient regulation service, modifications to current daily ramps, additional reserve capacity, and voltage support. Additional integration costs will include wear-and-tear on resources if they are required to repeatedly cycle to adjust for the intermittent resource output.

M.3.5 Renewable Resource Capacity Value

The capacity value of a generating resource is based on its ability to provide dependable and reliable capacity during peak periods when the system requires reliable resources for stable operation. Resources that can provide firm dependable capacity will have a higher capacity value than resources that cannot. In the WREZ model, the ability of a renewable resource to generate power during the top 10 percent of the model's yearly load was used as the capacity credit. LADWP uses a more conservative approach by considering the dependable capacity which varies depending on the resource type and is a fraction of the total available capacity as shown in Table 3-4.

The baseline value of capacity is the cost of the next most likely addition of low-cost capacity, defined as the fixed carrying costs of a simple cycle gas turbine generator. This includes the capital costs, fixed operations and maintenance costs, and other fixed charges associated with the gas turbine generator capacity, expressed as a dollar per kilowatt per year ($/kW-year). The fixed carrying cost assumed in the model is $100/kW-yr. The baseline capacity value does not include variable costs, such as fuel purchases. For new projects, the capacity factor is derived from the projected generation profile for the resource. The formula for calculating capacity value ($/kW-yr) is:

*Capacity Value ($/MWh) = (Dependable Capacity Factor) x (Baseline Capacity Value) / (Project Capacity Factor * 8760/1000)*

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M.3.6 Renewable Resource Energy Value

The energy value of a resource assesses the value of its hourly output to the energy markets. Resources that produce more power during high-price, peak demand periods will have a higher energy value than resources that provide power primarily during low demand periods.

The formula for calculation of energy value is:

$$\textit{Energy Value (\$/MWh)} = \Sigma\,[\textit{(Energy Value in Time Period)} \times \textit{(Energy Output in Time Period)}] \,/\, \textit{Total Energy Output}$$

M.3.7 Renewable Energy Portfolio

Utilizing the methodology described in the previous subsections, a best-value portfolio of renewable resources was developed. This portfolio was applied to all case options considered in this IRP. Because regulation mandates the procurement of specific levels of renewables, the quantities are predetermined for compliance periods in accordance with SB 2 (1X). The renewable capacity and energy production schedules shown in Figures M-2 and M-3 were used in all cases including the recommended case (Case 2) and are consistent with the procurement targets established by SB 2 (1X).

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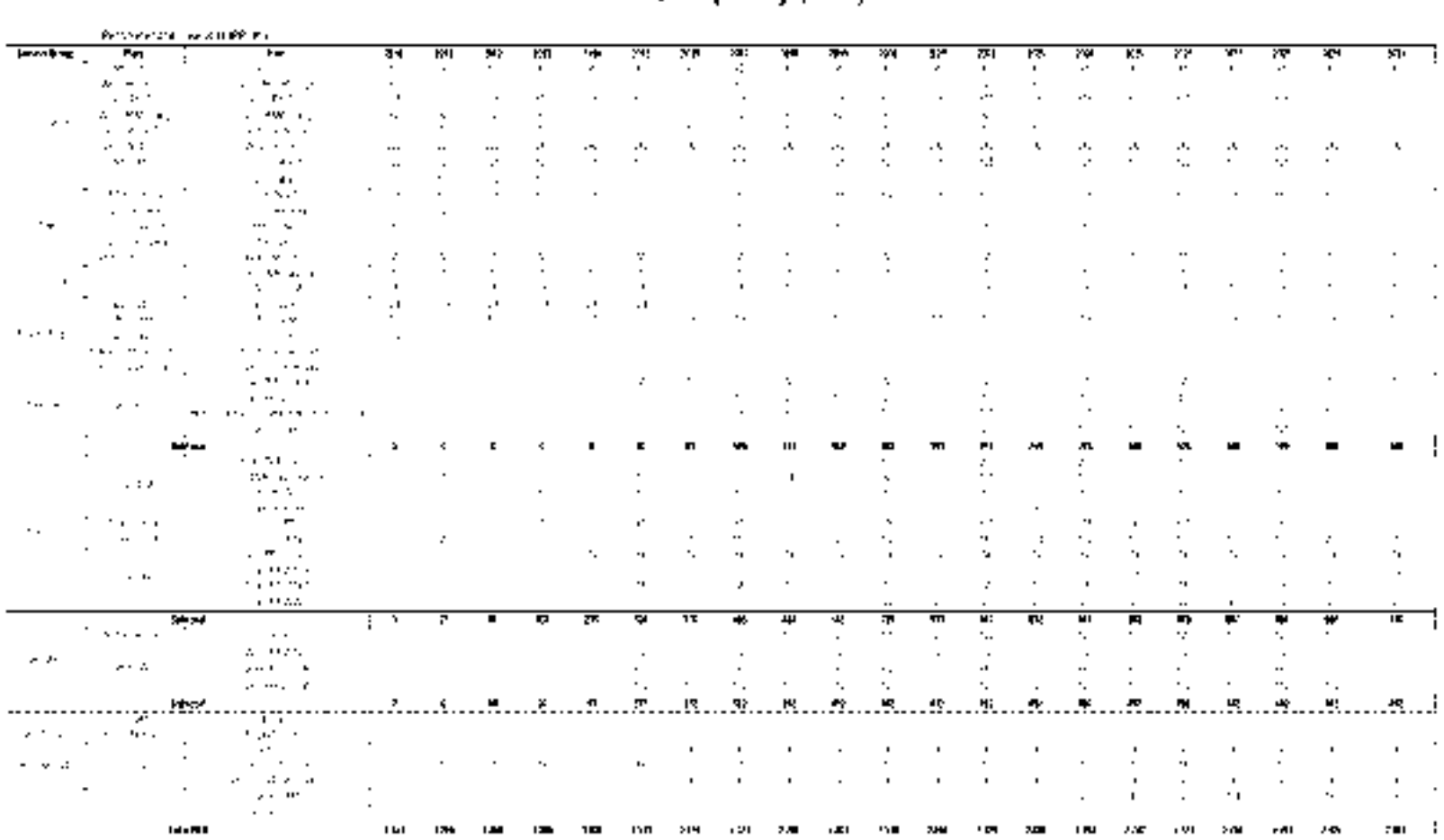

Figure M-2. Renewable resource capacity in MW for all cases.

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RPS Energy (GWh)

Recommended Case 2011 IRP (GWh)																					
Station Group	Plant	Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing Wind		Wind_Linden	134	145	158	158	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131
		Wind_PebbleSprin	218	190	190	190	190	190	190	190	190	190	190	190	190	190	190					
		Wind_PineTree	368	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362
		Wind_PPMWyoming	253	171	171	171	171	171	171	171	171	171	171	171								
		Wind_Willow Ck	199	197	197	197	197	197	197	197	197	197	197	197	197							
		Wind_WindyPoint	627	634	645	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641
		Wind_Wilford 1	429	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434	434
		Wind_Wilford2	144	217	217	212	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206
Existing Small Hydro		AQ & DVS OG	538	552	552	552	552	552	552	552	552	552	552	552	552	552	552	552	552	552	552	552
		Hydro_Pawnee	107																			
		North Hollywood	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		Hydro_Sepulveda	33	38	38	38	38	38	38	38	38	38	38	38	38							
		Castaic 3 & 5 Upgrade	6	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Existing Solar		Solar_DWP_Basin	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Solar_C-N-M	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Existing Biogas		Bio_Bradley	41	38	38	38	38															
		Bio_Lopez	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Bio_Tajon	9																			
		Acmpa & Shell Gas Credit	591	638	638	343																
		Hycenon Digester Gas	151	147	147	147																
		Existing Subtotal	4,424	3,881	3,925	3,563	3,067	2,989	2,989	2,989	2,989	2,989	2,989	2,989	2,989	2,674	2,674	2,582	2,582	2,582	2,582	2,582
New Geo	Geothermal	Geo PPA 2014 M					237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237
		Geo PPA 2016 T						150	441	441	441	441	441	441	441	441	441	441	441	441	441	441
		Imperial County Joint Geothermal Project - 1,2,3,4							180	333	533	808	808	808	808	808	808	808	808	808	808	808
		Generic Geo												430	860	860	1,060	1,060	1,060	1,060	1,060	1,060
		Subtotal					237	387	778	1,011	1,211	1,478	1,478	1,916	2,346	2,346	2,546	2,546	2,546	2,546	2,546	2,546
New Solar	DWP	Solar_DWP_Owens								118	228	338	448	455	450	433	431	429	427	425	425	423
		Solar_DWP_Basin_Remed	1	4	10	15	21	27	88	96	127	157	151	151	170	170	177	177	175	175	174	174
		Adelanto Solar		11	20	20	20	20	20	19	19	19	19	19	19	19	19	19	19	19	19	19
		Solar_PineTree		3.8	17	17	17	17	17	17	16	16	16	16	16	16	16	16	16	16	16	16
	Solar_Feed_In	Solar_RT		5	10	33	75	134	136	148	168	171	193	195	200	217	228	240	239	238	237	235
	Solar C-N-M	Solar_C-N-M-EIR)	33	61	108	127	147	169	177	189	199	205	218	225	241	254	269	284	299	315	332	349
	Solar_PPA	Solar PPA 2014 M				11	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129
		Solar PPA 2015 R					12	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146
		Solar PPA 2014 S				85	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93
		Solar PPA 2023 S										23	196	196	196	196	196	196	196	196	196	196
		Subtotal	34	105	165	308	514	735	784	944	1,105	1,266	1,629	1,641	1,681	1,682	1,705	1,729	1,730	1,752	1,764	1,779
New Wind	Wind_PineCanyon	Wind_PineCYN								315	315	315	315	315	315	315	315	315	315	315	315	315
	GenericWind	Wind PPA 2012 L		119	239	239	239	286	286	286	286	286	286	286	286	286	286	286	286	286	286	286
		Wind PPA 2015 B					46	552	552	552	552	552	552	552	552	552	552	552	552	552	552	552
		Wind PPA 2015 W					316	541	541	541	541	541	541	541	541	541	541	541	541	541	541	541
		Subtotal PPA's		119	239	239	602	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379
		Subtotal		119	239	239	602	1,379	1,379	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694
New Bio Gas	Bio GAS	Bio Gas		538	538	538	538	538	538	538	538	538	538									
	Biogas Extension	Biogas Extension				295	470															
New Small Hydro	New Small Hydro	SB Hydro						11	22	22	22	22	22	22	22	22	22	22	22	22	22	22
		Castaic Lit Upgrade		4	6	6	9	9	9	9	6	6	6	6	6	6	6	6	6	6	6	6
		Aqueduct FP Improvement						15	30	30	30	30	30	30	30	30	30	30	30	30	30	30
		Generic RPS														125	125	225	300	350	400	425
		Green Purchase		7	66	230						60		17	43	10		10	2	21	27	60
		Total RPS	4,457	4,823	4,943	5,158	5,158	5,955	6,429	7,030	7,209	7,800	8,262	8,191	8,356	8,343	8,556	8,606	8,574	8,657	8,726	8,908

Figure M-3. Renewable energy production in GWh for all cases.

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M.4 Case Options

Coal divestiture is the key parameter distinguishing the different 2011 IRP strategic cases. Unlike other areas that are constrained by mandated regulatory requirements (such as renewable resources), the decision to divest from coal earlier than legally required is discretionary and thus appropriate for analysis. The 2011 IRP strategic cases are designed to assist policymakers and ratepayers to make informed decisions regarding accelerated coal divestment, particularly with regard to the environmental benefits and resulting resource and electricity rate impacts. Included in Table M-1 is a description of the strategic cases.

Table M-1. Description of strategic cases

Case ID	Description
Case 1 (Base Case)	No Early Coal Divestiture – This case assumes coal resources will be replaced with combined cycle natural gas and renewable resources upon the expiration of coal contracts with no early compliance with SB1368. Maintains the 33 percent standard renewables mix recommended to comply with SB 2 (1X).
Case 2	Navajo Early Replacement Strategy – This case considers early replacement of Navajo on 12/31/2015, or 4 years prior to contract expiration with IPP replacement at the end of contract expiration in 2027. Maintains the recommended 33 percent standard renewables mix to comply with SB 2 (1X).
Case 3	Navajo and IPP Early Replacement Strategy – This case considers early replacement of Navajo on 12/31/2015, 4 years prior to contract expiration, and early replacement of IPP on 12/31/2020 or 7 years prior to contract expiration. Maintains the recommended 33 percent standard renewables mix to comply with SB 2 (1X).
Recommended Case 2010 IRP	33% RPS Balanced Strategy – Primarily used to compare the other strategic cases to the recommended long term strategy described in the 2010 IRP with 33 percent renewable compliance by 2020. Considers early divestiture of Navajo on 1/1/2014 or five years prior to contract expiration and assumes replacement of IPP in 2027.

The displaced energy from early coal divestment is generally replaced with a combination of renewable energy and new gas-fired combined cycle generation. Energy efficiency, demand response, and short term 3rd quarter market purchases are used to primarily satisfy load growth. Table M-2 summarizes the different replacement resources for the different cases and Table M-3 summarizes the costs associated with the replacement resources selected for the recommended case (Case 2).

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Table M-2. Resources recommended for resource adequacy by calendar year

Base Case (Navajo 2019, IPP 2027)

Capacity (MW)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	61	86	111	132	145	156	167	175	183	191	199	207	215	223	231	239	247	255
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500
New Renewable	30	47	120	166	251	310	356	403	446	500	526	575	605	623	637	646	656	662
Navajo Replacement CC	0	0	0	0	0	0	0	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC	0	0			0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150
Short Term Q3 Purchase								75	100	125	225	325	325	375	175	225	325	400
Total Replacement	**96**	**145**	**251**	**338**	**471**	**565**	**674**	**1153**	**1279**	**1415**	**1602**	**1807**	**1884**	**2021**	**2582**	**3060**	**3177**	**3266**

Case 2 (Navajo 2015, IPP 2027)

Capacity (MW)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	61	86	111	132	145	156	167	175	183	191	199	207	215	223	231	239	247	255
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500
New Renewable	30	47	120	166	251	310	356	403	446	500	526	575	605	623	637	646	656	662
Navajo Replacement CC				300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC					0	0	0	0	0	0	0	0	0	0	1150	1150	1150	1150
Short Term Q3 Purchase				125	100	75	75	75	100	125	225	325	325	375	175	225	325	400
Total Replacement	**96**	**145**	**251**	**763**	**871**	**940**	**1049**	**1153**	**1279**	**1415**	**1602**	**1807**	**1884**	**2021**	**2582**	**3060**	**3177**	**3266**

Case 3 (Navajo 2015, IPP 2020)

Capacity (MW)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Efficiency	61	86	111	132	145	156	167	175	183	191	199	207	215	223	231	239	247	255
Demand Response	5	10	20	40	75	100	150	200	250	300	350	400	450	500	500	500	500	500
New Renewable	30	47	120	166	251	310	356	403	446	500	526	575	605	623	637	646	656	662
Navajo Replacement CC				300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
IPP Replacement CC					0	0	0	0	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
Short Term Q3 Purchase				125	100	75	75	75	25		25	50	50	100	175	225	325	400
Total Replacement	**96**	**145**	**251**	**763**	**871**	**940**	**1049**	**1153**	**2354**	**2441**	**2552**	**2682**	**2768**	**2896**	**2992**	**3060**	**3177**	**3266**

Table M-3. Resource costs for the recommended case (Case 2) by calendar year

(FY)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy & Capacity Cost																				
Energy Efficiency	$ 46	$ 29	$ 37	$ 51	$ 60	$ 70	$ 78	$ 87	$ 94	$ 104	$ 112	$ 118	$ 129	$ 137	$ 146	$ 154	$ 163	$ 171	$ 180	$ 188
Demand Response	$ -	$ -	$ 0	$ 0	$ 1	$ 1	$ 3	$ 4	$ 6	$ 8	$ 10	$ 10	$ 11	$ 12	$ 12	$ 13	$ 14	$ 14	$ 14	$ 14
New Renewable																				
Solar	$ 3	$ 11	$ 15	$ 39	$ 67	$ 88	$ 115	$ 132	$ 158	$ 184	$ 225	$ 248	$ 258	$ 253	$ 256	$ 259	$ 261	$ 261	$ 261	$ 264
Wind	$ -	$ 2	$ 27	$ 27	$ 37	$ 127	$ 147	$ 177	$ 188	$ 201	$ 202	$ 203	$ 205	$ 208	$ 209	$ 211	$ 213	$ 216	$ 217	$ 219
Geo	$ -	$ -	$ -	$ -	$ 13	$ 38	$ 79	$ 113	$ 143	$ 176	$ 187	$ 224	$ 271	$ 282	$ 335	$ 353	$ 361	$ 361	$ 368	$ 373
Small Hydro	$ -	$ -	$ -	$ -	$ -	$ -	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2
Generic RPS	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8	$ 18	$ 34	$ 38	$ 45	$ 53	$ 58
Green Purchase	$ -	$ 0	$ 4	$ 12	$ 9	$ -	$ -	$ -	$ -	$ 3	$ 3	$ 1	$ 3	$ 2	$ 8	$ 0	$ 1	$ 1	$ 2	$ 5
New Renewable Subtotal	**$ 3**	**$ 14**	**$ 55**	**$ 78**	**$ 126**	**$ 253**	**$ 343**	**$ 424**	**$ 531**	**$ 565**	**$ 628**	**$ 679**	**$ 731**	**$ 776**	**$ 828**	**$ 853**	**$ 874**	**$ 886**	**$ 904**	**$ 922**
Short Term Q3 Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ 14	$ 11	$ 9	$ 8	$ 10	$ 14	$ 18	$ 34	$ 52	$ 55	$ 67	$ 33	$ 44	$ 67
Replacement CC Capital Cost																				
Navajo Replacement CC	$ -	$ -	$ -	$ -	$ -	$ 9	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18
IPP Replacement CC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 6	$ 133	$ 133	$ 133
Total	**$ 53**	**$ 43**	**$ 93**	**$ 130**	**$ 186**	**$ 333**	**$ 442**	**$ 533**	**$ 619**	**$ 695**	**$ 767**	**$ 838**	**$ 889**	**$ 942**	**$ 996**	**$1,035**	**$1,075**	**$1,222**	**$1,247**	**$1,274**

Each case was modeled using low, medium and high assumptions for gas and coal prices. Results of the model runs were tabulated to compare power costs and GHG emission reduction. See Section 4.3 for a discussion regarding the analysis of the model results for the three cases. The analysis concludes with Case 2 as the recommended case for this 2011 IRP. Additional analysis, including non-generation costs and a rate-impact assessment, are included in Section 5.

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M.7 Model Input and Assumptions

The following pages represent the major input parameters and assumptions that were incorporated into the production cost model for this 2011 IRP.

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Load Forecast

	October 2010 Forecast (Approved February 2011)						2011 IRP					
Year	Net Energy for Load (A)	Energy Efficiency (B)	Solar Rooftop Program (C)	Forecasted Sales (D)	% Annual Sales Change before EE	% Annual Sales Change after EE	Net Energy for Load for Modelling (E)	Solar Rooftop Program (F)	Energy Efficiency (G)	IRP Calculated Sales (H)	% Annual Sales Change before EE	% Annual Sales Change after EE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Notes: [illegible]

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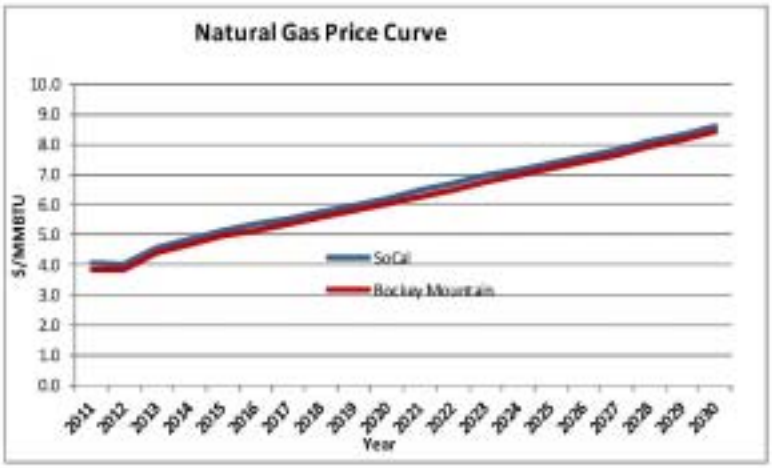
Natura Gas Prices

Gas Price used in IRP 2011		
Year	SoCal	Rockey Mountain
2011	4.1	3.8
2012	4.0	3.9
2013	4.6	4.4
2014	4.9	4.7
2015	5.1	4.9
2016	5.3	5.1
2017	5.5	5.4
2018	5.8	5.6
2019	6.0	5.8
2020	6.2	6.0
2021	6.4	6.2
2022	6.7	6.5
2023	7.0	6.7
2024	7.1	7.0
2025	7.4	7.2
2026	7.6	7.4
2027	7.8	7.7
2028	8.1	7.9
2029	8.3	8.2
2030	8.6	8.4



Natural Gas Prices and Volume for Pinedale Reserves

Pinedale Gas Price	
Date	$/MMBTU
7/1/2011	3.45
7/1/2012	4.00
7/1/2013	4.17
7/1/2014	4.20
7/1/2015	4.24
7/1/2016	4.28
7/1/2017	4.32
7/1/2018	4.36
7/1/2019	4.40
7/1/2020	4.44
7/1/2021	4.48
7/1/2022	1.53
7/1/2023	1.57
7/1/2024	1.62
7/1/2025	1.67
7/1/2026	1.72
7/1/2027	1.77
7/1/2028	1.82
7/1/2029	1.88

Pinedale Gas Volume	
Date	MMBTU/Day
7/1/2011	30.65
7/1/2012	32.25
7/1/2013	23.54
7/1/2014	19.68
7/1/2015	18.27
7/1/2016	15.97
7/1/2017	14.49
7/1/2018	13.22
7/1/2019	12.34
7/1/2020	11.47
7/1/2021	10.66
7/1/2022	9.91
7/1/2023	9.91
7/1/2024	9.91
7/1/2025	9.91
7/1/2026	9.91
7/1/2027	9.91
7/1/2028	9.91
7/1/2029	9.91

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LADWP Existing Generation Resources

LADWP Generator Ratings and Capabilities of Power Sources (as of August 2011)[1]

NAME OF PLANT	UNIT NO.	DATE FIRST CARRIED SYSTEM LOAD	GENERATOR NAMEPLATE[2] (kVA)	GENERATOR NAMEPLATE[2] (kW)	NET MAXIMUM UNIT CAPABILITY[3] (kW)	NET Maximum PLANT CAPABILITY[4] (kW)	NET DEPENDABLE PLANT CAPABILITY[5] (kW)
	1A	12/1[illegible]983	20,000	25,000	27,000		
San Francisquito	3	4/16/1917	11,719	9,375	10,000		
Power Plant 1	4	9/21/1923	12,500	10,000	12,000		
(PP1)	5A	4/9/1987	25,000	25,000	27,000	46,000	13,800
San Francisquito	1	7/8/1919	17,500	14,000	0		
Power Plant 2	2	8/7/1919	17,500	14,000	14,000		
(PP2)	3	9/26/1932	17,500	14,000	18,000	18,000	5,700
San Fernando	1	10/23/1922	3,500	2,800	3,200		
Power Plant (PP3)	2	10/23/1922	3,500	2,800	2,900	6,000	2,100
Foothill Power Plant (PP4)	1	12/6/1971	11,000	11,000	9,900	9,900	2,900
Franklin Power Plant (PP5)	1	4/3/1921	2,500	2,000	2,000	2,000	600
Sawtelle Power Plant (PP6)	1	8/5/1986	711	640	650	650	130
Aqueduct Hydro Subtotal					**126,650**	**93,650**	**31,230**
Haiwee Power Plant	1	11/8/1921	3,500	2,800	3,000		
	2	11/8/1921	3,500	2,800	3,600	4,200	0
Cottonwood	1	11/13/1988	937	750	1,200		
Power Plant	2	10/13/1989	937	750	1,200	1,300	400
Division Creek P. P.	1	3/23/1999	750	600	680	680	400
Big Pine Power Plant	1	10/8/1925	4,000	3,200	3,050	3,050	400
Pleasant Valley P. P.	1	3/5/1988	4,000	3,200	2,700	2,700	0
Owens Valley Hydro Subtotal					**16,030**	**12,530**	**1,200**
Upper Gorge P. P.	1	6/19/1963	37,500	37,500	37,500	37,500	36,500
Middle Gorge P. P.	1	5/1/1962	37,500	37,500	37,500	37,500	36,500
Control Gorge P. P.	1	4/1/1962	37,500	37,500	37,500	37,500	36,500
Owens Gorge Hydro Subtotal					**112,500**	**112,500**	**109,500**
	1	11/1/1972	250,000	212,500	240,000		
	2	7/9/1974	287,500	265,000	265,000		
	3	7/13/1976	287,500	265,000	265,000		
Castaic Power Plant	4	6/18/1977	287,500	265,000	265,000		
	5	12/18/1977	287,500	265,000	265,000		
	6	8/11/1978	287,500	265,000	265,000		
	7	10/7/1972	70,000	56,000	65,000	1,247,800	1,175,900
Castaic Hydro Subtotal					**1,620,000**	**1,247,800**	**1,175,900**
Hoover Power Plant (Capacity and energy purchase from IIAPA through Sep. 2017)					**491,000**	**491,000**	**438,000**
TOTAL HYDRO (Based on average hydro conditions)					**2,386,180**	**1,946,880**	**1,745,530**
	1	10/1/1995	100,400	85,340	82,000	82,000	79,500
	2	10/1/1995	100,400	85,340	82,000	82,000	79,500
	5	10/1/1995	93,750	75,000	85,000	85,000	85,000
Harbor Generating	10	1/4/2002	71,176	60,500	47,400	47,400	47,400
Station	11	1/4/2002	71,176	60,500	47,400	47,400	47,400
	12	1/4/2002	71,176	60,500	47,400	47,400	47,400
	13	1/4/2002	71,176	60,500	47,400	47,400	47,400
	14	1/4/2002	71,176	60,500	47,400	47,400	47,400
Harbor Generating Station Subtotal					**480,000**	**480,800**	**481,900**
	5	8/17/2001	71,176	60,500	43,000	43,000	43,000
Valley Generating	6	8/4/2003	215,000	182,750	189,000	188,800	186,900
Station	7	8/8/2003	215,000	182,750	189,000	188,800	186,900
	8	11/13/2003	311,000	264,350	215,000	215,800	201,300
Valley Generating Station Subtotal					**576,000**	**576,800**	**558,900**
Scattergood	1	12/7/1958	192,000	163,200	193,000	193,800	174,900
Generating Station	2	7/1/1958	192,000	163,200	184,000	184,800	177,800
	3	10/8/1974	582,000	486,800	490,000	458,800	445,900
Scattergood Generating Station Subtotal					**817,000**	**817,800**	**798,600**
	1	9/2/1962	270,000	230,000	222,800	222,800	222,800
	2	4/7/1963	270,000	230,000	222,800	222,800	222,800
	3	7/14/1964	270,000	230,000	0	0	0
	4	3/9/1965	270,000	230,000	0	0	0
Haynes Generating	5	6/12/1966	351,000	343,000	282,800	282,800	282,800
Station	6	3/18/1967	351,000	343,000	243,800	243,800	238,800
	7	9/1/1970	2,500	2,000	1,596	1,596	0
	8	10/5/2005	311,000	264,350	250,000	250,000	235,800
	9	10/5/2005	215,000	182,750	182,800	182,800	167,800
	10	10/5/2005	215,000	182,750	182,800	182,800	167,800
Haynes Generating Station Subtotal					**1,565,800**	**1,566,800**	**1,524,800**
Total Basin Thermal					**3,414,500**	**3,414,500**	**3,337,800**
Mohave Generating	1	4/1/1971	909,000	818,000	0	0	0
Station	2	10/1/1971	909,000	818,000	0	0	0
Mohave Generating Station Subtotal					**0**	**0**	**0**
Navajo Generating	1	2/1/1974	892,400	803,000	750,000	159,000	159,000
Station	2	12/2/1974	892,400	803,000	750,000	159,000	159,000
	3	11/29/1975	892,400	803,000	750,000	159,000	159,000
Navajo Generating Station Subtotal					**2,250,000**	**477,000**	**477,000**
Intermountain	1	6/9/1986	991,000	828,000	960,000	546,200	546,200
Generating Station	2	4/30/1987	991,000	828,000	960,000	546,200	546,200
Intermountain Generating Station Subtotal					**1,893,800**	**1,092,400**	**1,092,400**
Palo Verde Nuclear	1	1/30/1986	1,550,000	1,413,000	1,333,000	128,768	126,643
Generating Station	2	9/19/1986	1,550,000	1,413,000	1,336,000	129,056	126,932
	3	1/19/1988	1,550,000	1,413,000	1,334,000	128,864	126,739
Palo Verde Generating Station Subtotal					**4,083,800**	**386,826**	**380,314**
Total External Thermal (Coal and nuclear fuels)					**8,053,800**	**1,956,826**	**1,949,714**
TOTAL THERMAL					**11,467,800**	**5,370,800**	**5,286,714**
NET MAXIMUM AND NET DEPENDABLE SYSTEM CAPABILITY w/o CDWR Transfer						**7,316,768**	**7,032,844**
State's Capacity Entitlement						**-120,000**	**-85,000**
NET MAXIMUM AND NET DEPENDABLE SYSTEM CAPABILITY						**7,196,768**	**6,977,844**
Renewables/Distributed Generation as of August 12, 2011 [6]						**1,188,636**	**316,380**
NET MAXIMUM AND NET DEPENDABLE SYSTEM CAPABILITY w/ REDG						**8,385,404**	**7,294,224**

Notes:

[1] This table is based on data from Power System Engineering Division January 1, 2011 Generation Rating and Capabilities of Power Sources sheet. This table also include data for the renewables and distributed generating resources owned and contracted by LADWP. The data are from the August 12, 2011 RPS Master Project List and project contracts.

[2] Nameplate capability is the full-load continuous rating of a generating unit under specified conditions as designated by the manufacturer.

[3] Unit can attained Maximum Capability when the weather and equipment are simultaneously at optimal conditions.

[4] Maximum Plant Capability reflects water flow limits at hydro plants; or sum of each unit at in-basin thermal plants; or entitlements from external thermal plants.

[5] Net Dependable Plant Capability reflects year-round outputs adjusted for low generation season. For hydro plants, winter is the low generation season. Thermal plants experience reduced performance during hot weather conditions.

[6] Dependable capacity of renewable technology plants are estimated by applying a Dependable Capacity Factor (DCF) to the plant nameplate capacity. The conservative factor is used until LADWP gains more actual account of operating experience with renewable technologies. DCFs currently used are as follow:

- Digester Gas 1.00
- Geothermal 0.95
- Landfill Gas 0.90
- Municipal Solid Waste Conversion 0.90
- Small Hydroelectric 0.50
- Solar Photovoltaic 0.25
- Solar Thermal 0.25
- Wind 0.10 (projects with firming contracts are rated at firming levels)

IPP Capacity for LADWP

IPP Capacity (MW)

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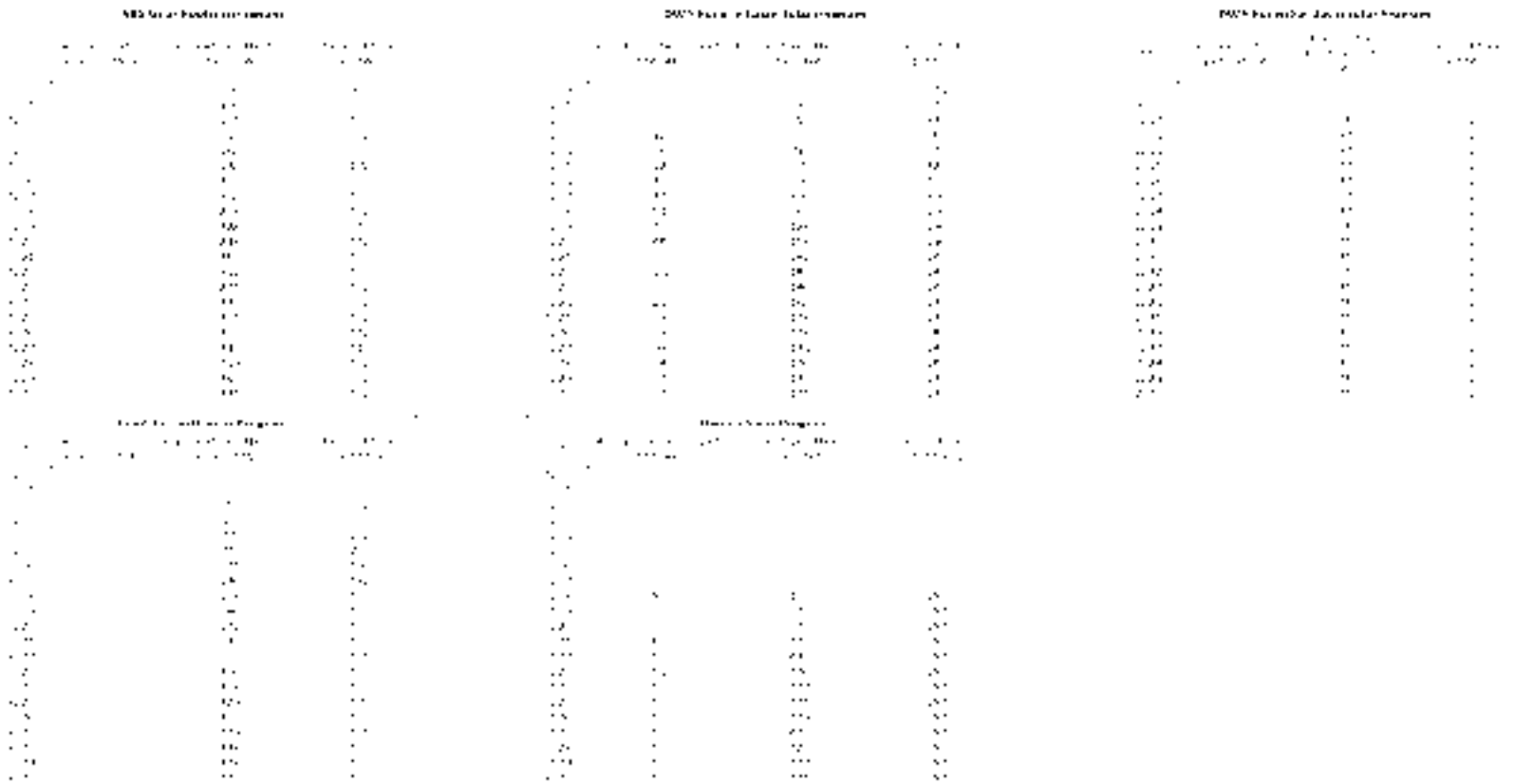
IPP Debt Service and O&M and Generation Expenses

FY	IPA Generation Debt Service									IPA Generation O&M	IPA Generation O&M and CWM	DWP's Share of IPA Generation Expense
	Principal ($)			Interest ($)			Debt Service ($)			($)	($)	($)
	Repay	Reserve	Total	Repay	Subsidy	Total	Principal	Interest	Total			
2012									$ 7,132	$ 7,132	$ 184,212	$ 191,344
2013									$ 7,132	$ 7,132	$ 177,140	$ 184,272
2014	$ 5,245	$ 1,887	$ 7,132	$ 1,887	$ (1,887)	$ 0	$ 5,358	$ 1,774	$ 7,132	$ 7,132	$ 170,140	$ 177,272
2015	$ 5,358	$ 1,774	$ 7,132	$ 1,774	$ (1,774)	$ 0	$ 5,474	$ 1,658	$ 7,132	$ 7,132	$ 162,940	$ 170,072
2016	$ 5,474	$ 1,658	$ 7,132	$ 1,658	$ (1,658)	$ 0	$ 5,593	$ 1,539	$ 7,132	$ 7,132	$ 155,539	$ 162,671
2017	$ 5,593	$ 1,539	$ 7,132	$ 1,539	$ (1,539)	$ 0	$ 5,715	$ 1,417	$ 7,132	$ 7,132	$ 147,939	$ 155,071
2018	$ 5,715	$ 1,417	$ 7,132	$ 1,417	$ (1,417)	$ 0	$ 5,840	$ 1,292	$ 7,132	$ 7,132	$ 140,139	$ 147,271
2019	$ 5,840	$ 1,292	$ 7,132	$ 1,292	$ (1,292)	$ 0	$ 5,968	$ 1,164	$ 7,132	$ 7,132	$ 132,139	$ 139,271
2020	$ 5,968	$ 1,164	$ 7,132	$ 1,164	$ (1,164)	$ 0	$ 6,099	$ 1,033	$ 7,132	$ 7,132	$ 123,939	$ 131,071
2021	$ 6,099	$ 1,033	$ 7,132	$ 1,033	$ (1,033)	$ 0	$ 6,233	$ 899	$ 7,132	$ 7,132	$ 115,539	$ 122,671
2022	$ 6,233	$ 899	$ 7,132	$ 899	$ (899)	$ 0	$ 6,370	$ 762	$ 7,132	$ 7,132	$ 106,939	$ 114,071
2023	$ 6,370	$ 762	$ 7,132	$ 762	$ (762)	$ 0	$ 6,511	$ 621	$ 7,132	$ 7,132	$ 98,139	$ 105,271
2024	$ 6,511	$ 621	$ 7,132	$ 621	$ (621)	$ 0	$ 6,655	$ 477	$ 7,132	$ 7,132	$ 89,139	$ 96,271
2025	$ 6,655	$ 477	$ 7,132	$ 477	$ (477)	$ 0	$ 6,803	$ 329	$ 7,132	$ 7,132	$ 79,939	$ 87,071
2026	$ 6,803	$ 329	$ 7,132	$ 329	$ (329)	$ 0	$ 6,955	$ 177	$ 7,132	$ 7,132	$ 70,539	$ 77,671
2027	$ 6,955	$ 177	$ 7,132	$ 177	$ (177)	$ 0	$ 7,110	$ 22	$ 7,132	$ 7,132	$ 60,939	$ 68,071
2028	$ 7,110	$ 22	$ 7,132	$ 22	$ (22)	$ 0	$ 7,269	$ (137)	$ 7,132	$ 7,132	$ 51,139	$ 58,271
2029	$ 7,269	$ (137)	$ 7,132	$ (137)	$ 137	$ 0	$ 7,431	$ (299)	$ 7,132	$ 7,132	$ 41,139	$ 48,271
2030	$ 7,431	$ (299)	$ 7,132	$ (299)	$ 299	$ 0	$ 7,597	$ (465)	$ 7,132	$ 7,132	$ 30,939	$ 38,071
2031	$ 7,597	$ (465)	$ 7,132	$ (465)	$ 465	$ 0	$ 7,767	$ (635)	$ 7,132	$ 7,132	$ 20,539	$ 27,671
2032	$ 7,767	$ (635)	$ 7,132	$ (635)	$ 635	$ 0	$ 7,941	$ (809)	$ 7,132	$ 7,132	$ 9,939	$ 17,071
2033	$ 7,941	$ (809)	$ 7,132	$ (809)	$ 809	$ 0	$ 8,119	$ (987)	$ 7,132	$ 7,132	$ (0)	$ 7,132
2034	$ 8,119	$ (987)	$ 7,132	$ (987)	$ 987	$ 0	$ 8,301	$ (1,169)	$ 7,132	$ 7,132	$ (0)	$ 7,132
2035	$ 8,301	$ (1,169)	$ 7,132	$ (1,169)	$ 1,169	$ 0	$ 8,487	$ (1,355)	$ 7,132	$ 7,132	$ (0)	$ 7,132
2036	$ 8,487	$ (1,355)	$ 7,132	$ (1,355)	$ 1,355	$ 0	$ 8,677	$ (1,545)	$ 7,132	$ 7,132	$ (0)	$ 7,132
2037	$ 8,677	$ (1,545)	$ 7,132	$ (1,545)	$ 1,545	$ 0	$ 8,872	$ (1,740)	$ 7,132	$ 7,132	$ (0)	$ 7,132

Demand Response Schedule

CV	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
MW	2	5	10	20	40	75	100	150	200	250	300	350	400	450	500
Cost ($/KW/yr)	45	45	45	45	45	45	45	45	45	12.5	12.5	12.5	12.5	12.5	12.5

LADWP Solar Program



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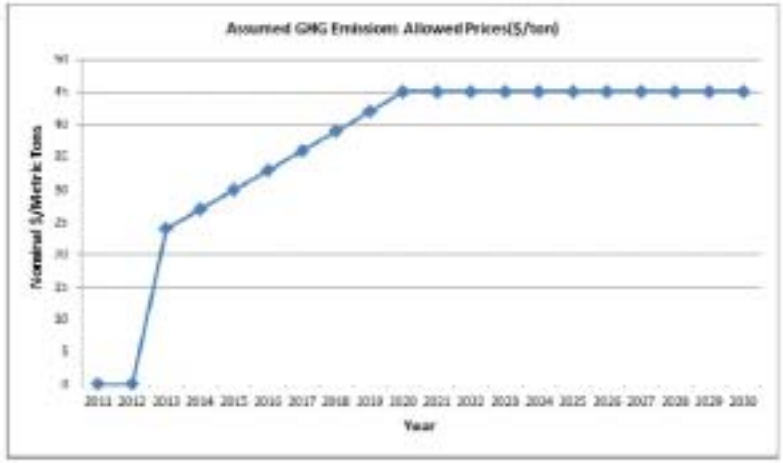
Once-through Cooling Costs

2029 OTC Cost Estimates

2029 Plan - No OTC	FY 10/11	FY 11/12	FY 12/13	FY 13/14	FY 14/15	FY 15/16	FY 16/17	FY 17/18	FY 18/19	FY 19/20	FY 20/21	FY 21/22	FY 22/23	FY 23/24	FY 24/25	FY 25/26	FY 26/27	FY 27/28	FY 28/29	FY 29/30
HyGS Units 5&6 Repowering	176.9	357.3	128.6	10.9																
SGS Unit 3 Repowering	3.7	5.9	265.2	377.4	101.8	23.3														
SGS Units 1&2 Repowering					1.5	4.2	71.0	124.2	143.0	136.5	74.7									
HyGS Units 1&2 Repowering						1.0	2.2	2.7	3.5	36.0	36.0	307.3	260.9	58.0						
HGS Unit 1, 2 & 5 Repowering											1.2	2.6	3.1	5.2	312.1	104.0	57.2			
HyGS Unit 8, 9, &10 Repowering												1.0	2.0	3.0	4.0	34.4	357.7	320.0	165.0	120.0
TOTAL CAPITAL EXPENDITURES	179.6	363.2	393.9	388.3	103.3	28.5	73.2	126.9	146.5	172.5	111.9	310.9	266.0	66.2	316.1	138.4	414.9	320.0	165.0	120.0

CO_2 Allocations and Costs Assumptions

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electrical Sector Total	95.8437	94.9951	92.2269	90.3725	89.6139	85.7576	84.9013	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427	83.1427
DWP Factor	0.14168509	0.14168282	0.14089639	0.14034701	0.14614139	0.15031655	0.14893207	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137	0.14048137
DWP Allocation (MMT)	13.584	13.360	12.920	13.945	13.216	13.258	12.704	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680
Cost Assumption ($/ton)	$24.0	$27.0	$30.0	$33.0	$36.0	$39.0	$42.0	$45.0	$45.0	$45.0	$45.0	$45.0	$45.0	$45.0	$45.0	$45.0	$45.0	$45.0



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Appendix N Public Outreach

N.1 Overview

This section outlines the public outreach that will be carried out as part of the 2010 IRP process to provide information and increase awareness of LADWP's long-term power resource plans.

N.2 Community workshops

A series of regional public workshops are being scheduled in mid-July 2010 throughout Los Angeles.

Workshops will be publicized through newspaper advertisements, press releases, a dedicated Website and social media.

A dedicated, interactive Website, www.LAPowerPlan.org, will be established and will enable visitors to provide comments directly online.

The workshops will be professionally facilitated.

Following the workshops, LADWP will summarize feedback and post frequently asked questions and responses on the Website.

N.3 Public Comments

This section will address comments received during the Public Outreach effort related to the 2010 Integrated Resource Plan.

N.4 Questions and Answers

This section will address questions received during the Public Outreach effort related to the 2010 Integrated Resource Plan. These will be posted on the Website as well as presented to the Board of Water and Power Commissioners.

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2010 INTEGRATED RESOURCES PLAN
Community Outreach Summary

Prepared for:
Los Angeles Department of Water and Power
111 North Hope Street
Los Angeles, CA 90012

Prepared by:
AECOM
1420 Kettner Boulevard, Suite 500
San Diego, CA 92101

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Report Overview

This report provides a summary of input received through the community outreach program conducted for the Los Angeles Department of Water and Power's (LADWP's) 2010 Power Integrated Resource Plan (IRP). The community outreach program consisted of a series of regional public workshops, a website (www.lapowerplan.org), and an online survey, along with stakeholder meetings, which were intended to inform the public about the 2010 IRP and to solicit feedback.

The kickoff public workshop was held on August 12, 2010, at the LADWP headquarters in downtown Los Angeles. Seven regional workshops were held between September 11, 2010, and September 30, 2010. The regional workshops were held throughout Los Angeles to gather input that reflects the City of Los Angeles' geographic and demographic diversity and to maximize participation opportunities. A website was also created for the 2010 IRP; it included an electronic version of the 2010 IRP and associated documents, promoted the public workshops, and provided an interactive online survey consisting of questions similar to the workshop discussion questions. All the presentation materials from the public workshops were also made available on the website. A series of stakeholder meetings were also held in August through October, 2010, with representatives from business and environmental groups with a specific interest in the 2010 IRP.

This summary is arranged into four sections: Report Overview, Community Outreach Program, Discussion Theme Synthesis, and Exhibits. The information contained in each of the remaining sections is described below:

- Community Outreach Program: Provides an overview of all aspects of the outreach related to the 2010 IRP, including the public workshops, website, stakeholder meetings, and elected/appointed official briefings.

- Discussion Theme Synthesis: Contains a summary of the input contributed during the community outreach program. The input has been synthesized to reflect the breadth and depth of the input received and incorporates reoccurring themes that were expressed by participants.

- Exhibits: Includes the project fact sheet, a transcription of the notes from the public workshops, comment cards submitted at the workshops and through the website, and online survey results, as well as other comments collected as part of the community outreach program.

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Community Outreach Program

Purpose

The community outreach program was designed to collect broad input on issues, ideas, and concerns related to the 2010 IRP. Input was collected with the intention of providing guidance to LADWP staff in the formulation of a final long-term strategy, and to inform the LADWP Board of Commissioners prior to adoption of a final document. An overview of the 2010 IRP is provided in Exhibit A, Project Fact Sheet.

Specific objectives of the community outreach program were to:

- Prioritize transparency and inclusiveness in the 2010 IRP process
- Receive feedback and public comments to be incorporated into the Final 2010 IRP document
- Educate and create awareness about the 2010 IRP among stakeholders and community members.
- Communicate strategies for reducing carbon emissions and integrating renewable resources, while meeting forecasted demand, maintaining reliability, and keeping costs as low as possible
- Communicate the potential impact on costs and customer rates for various alternative cases analyzed in the 2010 IRP

To achieve these objects, LADWP developed a multipronged outreach approach to allow community members and stakeholders different opportunities to provide input on the 2010 IRP. Community involvement opportunities were provided through a website, stakeholder meetings, and a series of public workshops. Elected and appointed official briefings were also held to keep local representatives abreast of outreach opportunities and the community's contributions. Input collected through each of these programs is considered of equal importance when considered by LADWP staff.

Public Workshops

The public workshops were held in different locations throughout the city to reflect the geographic and demographic diversity of Los Angeles. Workshops were also held on various days of the week at different times to allow many options for participants to find a convenient workshop schedule.

Workshop Schedule and Location

A kick-off workshop was held in Downtown Los Angeles on August 12, 2010, in the LADWP headquarters. Seven regional workshops were held between September 11, 2010, and September 30, 2010, throughout Los Angeles. Table 1 shows the meeting location and schedule.

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Table 1: Location and Time of Community Workshops

Downtown
Thursday, August 12, 2010
7:00 pm – 9:00 pm
Central Public Library
Mark Taper Auditorium
630 W. 5th Street
Los Angeles, CA 90071

East Valley
Saturday, September 11, 2010
10:00 am – 12:00 pm
Los Angeles Mission College
13356 Eldridge Avenue
Sylmar, CA 91342

West LA
Monday, September 13, 2010
6:00 p.m. – 8:00 pm
Stephen S. Wise Temple
15500 Stephen S Wise Drive
Los Angeles, CA 90077

South LA
Tuesday, September 14, 2010
6:00 pm – 8:00pm
California State University
Dominguez Hills
1000 E. Victoria Street
Carson, CA 90747

East LA
Wednesday, September 15, 2010
6:00 pm – 8:00 pm
California State University
5151 State University Drive
Los Angeles, CA 90032

Harbor
Monday, September 20, 2010
6:00 pm – 8:00 pm
Cabrillo Marine Aquarium
Harbor
3720 Stephen M. White Drive
San Pedro, CA 90731

West Valley
Wednesday, September 22, 2010
6:00 pm – 8:00 pm
Pierce College
Performing Arts Theater
6201 Winnetka Avenue
Woodland Hills, CA 91371

Northeast LA
Thursday, September 30, 2010
6:30 pm – 8:30 pm
Occidental College
Thorne Hall
1600 Campus Road
Los Angeles, CA 90041

Attendance

Attendance varied between each of the public workshops as shown in Table 2. Most attendees identified themselves as customers of LADWP when they signed in, although individuals were not required to be customers to attend the meetings and provide input. Several attendees also identified themselves as being associated with industry groups or environmental organizations, such as solar developers or the Sierra Club. There were also a number of people who attended multiple meetings.

Table 2: Workshop Attendance by Location

Meeting	Attendees
Downtown	36
East Valley	41
West LA	34
South LA	38
East LA	17
Harbor	19
West Valley	50
Northeast LA	17

Workshop Publicity

LADWP conducted extensive publicity to maximize inclusiveness and diversity among participants. To publicize the workshops, meeting information was detailed on the project website, advertisements were placed in local and regional newspapers, and press releases and Twitter messages were issued. Targeted outreach was also conducted to inform the Council Districts and engage the Neighborhood Councils.

Web, Email, and Social Networking

LADWP placed electronic advertisements on the City Watch Website, which averages between 220,000 and 500,000 hits daily, beginning August 24 and running through the final workshop September 30. LADWP also used Twitter to send messages ("tweets") about the entire workshop series and to promote each individual workshop. Issued Neighborhood Council and stakeholder email blasts, and included the workshop series in customer e-newsletters (*LADWP at Work* and *At Home*), which are emailed to all LADWP residential and commercial customers.

Media

Advertisements that featured the locations and dates of all workshops were placed in community and regional newspapers, including:

- *Daily News*
- *Daily Breeze*
- *L.A. Watts Times*
- *L.A. Sentinel*
- *Korean Daily*
- *Chinese Daily*
- *La Opinion*
- *Philippine Media*
- *Downtown News*
- *Korean Times Daily*
- *Beverly Press Park La Brea News*
- *Torchanon Chronicle*
- *Tolucan Times*
- *L.A. Business Journal*
- *San Fernando Valley Business Journal*
- Wave Independent/Equal Access Media
- Eastern Group Publications

A general news release was issued to announce the first workshop followed by a second release announcing the entire workshop series, emphasizing the desire for public feedback on the 2011 IRP, which includes an invitation to the IRP website to take the online survey. Media advisories were also issued the morning of each workshop.

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Additional Outreach

To reach additional members of the public, LADWP distributed flyers at public libraries throughout the city. Flyers announcing the workshops, along with fact sheets, were distributed to all Council District field offices, at the Mayor's Office, and at the Council District 2 National Night Out Finale community event at Valley Plaza Park.

LADWP conducted extensive outreach to engage Neighborhood Councils, including announcements at Neighborhood Council meetings, distribution of flyers, and email blasts, which encouraged Neighborhood Councils and community members to attend the regional workshops. LADWP staff also made announcements about the regional workshops to over 30 Neighborhood Council meetings throughout the city in August and September.

Workshop Format

The community workshops consisted of four main components: (1) a presentation on the 2010 IRP by Michael Webster, LADWP Assistant Director of Power System Planning and Development; (2) small group discussions led by facilitators; (3) report back and workshop wrap up; and (4) written comment cards. Please see Exhibit B for the workshop agenda.

Presentation

The workshop presentation established a foundation for the community to get a better understanding of the 2010 IRP. Important contextual information was presented, which provided a historical overview of LADWP's mission, operations, and vertical approach to service, background and objectives of the IRP, and challenges of balancing the objectives. The presentation also outlined specific strategies for reducing carbon emissions and integrating renewable resources, while meeting forecasted demand, maintaining reliability, and keeping costs as low as possible. A video of the presentation was posted on the project website for all community members to view the presentation outside of the workshops.

Small Group Discussions

After the presentation, participants joined smaller breakout sessions ranging from 10 to 15 people, depending on the number of attendees. Through a guided discussion, the small groups provided a forum for participants to provide input and identify issues, share ideas, and voice concerns related to the 2010 IRP. The small groups were also designated to make the complex and technical information in the IRP more accessible by creating an environment where all attendees felt comfortable asking questions and sharing thoughts about the complex technical information in the long-range plan.

Each group was led by a facilitator and an LADWP staff member familiar with the details of the 2010 IRP. Each of the group discussions began by having the group's LADWP staff member lead attendees through the 2010 IRP Executive Summary, which was distributed to each participant as they entered the meeting. The staff member presented the details for each of the six case options, including the mix of resources, estimated costs, estimated reduction in greenhouse gas emissions, and the potential impact on customer rates. This overview was

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followed by a question and answer period. The LADWP staff member answered technical questions and provided clarification on the 2010 IRP.

Following the LADWP staff presentation and the question and answer period, participants were then given the opportunity to share their perspectives related to the 2010 IRP. Participants were eager to express viewpoints on many issues during the group discussion session.

Discussion Questions

The facilitator assisted the group in communicating priorities, issues, and concerns related to the 2010 IRP by asking the following questions:[1]

1. What priorities does LADWP need to consider when making a recommendation on the IRP long-term strategy?

2. How much more per bill are you willing to pay to implement some of the types of concepts in the IRP?
   - 5%?
   - 15%?
   - 25%?
   - 0% (Nothing!)

3. Are there any other comments or ideas you would like LADWP to consider related to the 2010 IRP?

The facilitator maintained a record of the participant responses to each question. After a period of sharing the priorities that were important for consideration in the 2010 IRP as part of the discussion on Question 1, four sticky dots were distributed to each member of the group. Group members were asked to use the dots to identify the priorities, or priority, that were most important to them out of those that were shared among the group. Each dot represented an identification of a priority, and participants were allowed to place multiple dots on a priority to indicate relative importance of a topic over another. The priorities identified by each group were considered in the development of the Discussion Themes.

Exhibit C contains detailed transcriptions of all the notes collected during the discussion group for each public workshop, as well as the results of all the input collected during the dot prioritization exercise.

[1] The following questions were used for the August 17, 2010 morning and evening public workshops: (1) What priorities does LADWP need to consider when making a recommendation on the IRP long-term strategy? (2) How much more per bill are you willing to pay to implement some of the types of concepts in the IRP? (3) Are there any other comments or ideas you would like LADWP to consider related to the 2010 IRP? The following questions were used for the August 18, 2010 workshop: (1) What priorities does LADWP need to consider when making a recommendation on the IRP long-term strategy? (2) How much more per bill are you willing to pay to implement some of the types of concepts in the IRP? (3) Are there any other comments or ideas you would like LADWP to consider related to the 2010 IRP? The following questions were used for the August 19, 2010 workshop: (1) What priorities does LADWP need to consider when making a recommendation on the IRP long-term strategy? (2) How much more per bill are you willing to pay to implement some of the types of concepts in the IRP? (3) Are there any other comments or ideas you would like LADWP to consider related to the 2010 IRP?

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Additional Notes on Question 2

After the group members finished with the prioritization exercise, the facilitator asked Question 2. Participants were asked if they were willing to pay 5%, 15%, 25%, or 0% (nothing) more per bill to implement some of the types of concepts in the IRP. Attendees were asked to raise their hands to indicate support for any amount they felt comfortable supporting. Some group members were uncomfortable answering the question and asked to provide comments instead of, or in conjunction with, raising their hand. This question was intended to understand group members' sentiment about costs. There is no statistical significance associated with the informal poll that was taken during each group discussion. Instead, this question is more appropriately understood as feedback from a focus group that identified larger opinions and attitudes of group members that relate to costs, as well as the priority participants placed on renewable energy development.[1]

Report Back and Wrap Up

To allow participants to get a sense of the discussions that occurred in the other groups, participants reconvened as an audience at the conclusion of the breakout session, where a representative from each group recapped his/her group discussion. To accomplish this, a volunteer from each group reported back on the top three priorities that were collectively identified by the group as the topics with the most dots from the prioritization exercise.

The workshops concluded with an explanation of how workshop input and input collected by other outreach programs would be documented into a summary. It was also explained that the summary would be considered by the project team in formulating the 2012 Final IRP that would be presented to the LADWP Board of Commissioners, and posted on the project website.

Written Comment Cards

At the beginning of the meeting, attendees were also provided a comment card with questions that mirrored the small group discussion questions. The comment card provided a medium for detailed written comments to be submitted. The comment cards were collected at the conclusion of the meeting or could be mailed afterwards to LADWP. In addition, participants were invited to submit additional comments through the website or directly to LADWP. All comment cards, letters, and other input received electronically can be found in Exhibit D.

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[1] For results of the analysis of Question 2, the following statements were made by participants during the breakout discussions:

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Website and Online Survey

A project website (www.lapowerplan.org) was created specifically for the 2010 IRP. The website provided access to a complete version of the 2010 IRP and associated technical appendices, as well as a stand-alone version of the Executive Summary, which was formatted to improve readability for the public. A fact sheet about the IRP, which was prepared to convey the complex material in visual and written format, was also made available on the website. The website included a schedule of public workshops, and a section that allowed the public to submit comments and questions about the plan online. Comments submitted through the website can be found in Exhibit D.

In addition, the website contained an online survey that mirrored the questions asked in the public workshops, as well as the comment card distributed during the workshops. Members of the public who were unable to attend a public workshop were given the same opportunity to provide input on the 2010 IRP through the website survey. There were 55 responses to the online survey, all of which can be found in Exhibit E.

Stakeholder Meetings

LADWP conducted meetings targeting specific stakeholders, including business and industry representatives, as well as environmental groups. These meetings were conducted in a similar fashion as the public workshops. Input collected at these meetings is included in the discussion themes found in the next section of this document, and discussion notes can also be found in
Exhibit C.

Business and Industry

LADWP offered presentations for the following business and industry stakeholders:

- Central City Association – meeting on September 21, 2010
- LA Business Council – meeting on September 24, 2010
- Large Commercial Customers – meeting on September 30, 2010
- Valley Industry and Commerce Association – meeting on October 6, 2010

Environmental Groups

Representatives of key environmental groups—including the Sierra Club, National Resources Defense Council, Environment Now and the Green L.A. Coalition—were invited to briefings and contacted directly to attend the kick-off workshop and regional workshops.

Elected/Appointed Officials Briefings

LADWP also met with various elected and appointed officials to provide an overview of the contents of the 2010 IRP and to inform them about the community outreach process. The briefings were intended to inform decision makers about the 2010 IRP and the process, and are not reflected in the discussion themes found in the next section of this document.

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- Board of Water and Power Commissioners – Presentation to Board, July 22, 2010
- Briefings were conducted for staffs of City Council members, Mayor's office, Chief Legislative Analyst (CLA), and Chief Administrative Officer (CAO) on August 12, 2010, and September 16, 2010. A follow-up briefing will be scheduled in October
- Neighborhood Council Memorandum of Understanding Oversight Committee briefing August 7, 2010.
- Additional Outreach

  A summary of the first workshop was emailed to Council staff

  An additional IRP summary after the first week of regional workshops was emailed to Council staff

  LADWP requested a special IRP briefing with Council members (Energy & Environment Committee), Mayor, CLA, CAO.

  LADWP requested to have a special IRP outreach meeting with stakeholders selected by Council members

  LADWP requested that the IRP workshop schedule be placed in individual Council community newsletters (it was placed in newsletter of Councilmember Bernard Parks

  A final IRP analysis will be provided to Mayor/Council/CAO/CLA staff

Discussion Theme Synthesis

The public workshops, stakeholder meetings, online survey, and comment cards yielded a significant amount of information from LADWP customers related to the 2010 IRP. This information has been synthesized into a set of discussion themes that reflect the major ideas provided by participants during the community outreach program.

Methodology for Identifying Discussion Themes

During the community outreach program, attendees provided broad input about issues, ideas, and concerns related to the 2010 IRP. The discussion themes provide a synopsis of this input and represent expansive discussion topics for the community outreach program. For a comprehensive understanding of the richness and range of input, the major discussion themes should be reviewed in connection with the transcription of the notes from the small group discussions and stakeholder meetings, the comment cards, and responses to the online survey.

An "initial" series of broad themes was first identified to categorize all of the statements gathered during the public outreach program. Coding strategies were then used to validate and refine the themes.[1] Using Atlas/TI, a computer software program for qualitative data analysis, codes were established for each theme and applied to all of the public input that was collected through the community outreach program. Codes were applied to individual comments and enabled comparison between different comments relating to the same topic. For example, a statement such as "Educate consumers about how to conserve." was ultimately coded as (1) "Energy Efficiency and Conservation" because it was one of many statements provided by workshop participants that related to using less energy or using energy more efficiently, and (2) "Education and Community Outreach" because it relates to efforts by LADWP to inform and engage the community.

After coding all the input, the initial set of themes was refined. A narrative on each theme was also created to provide context and understanding. The narrative is based upon the comments that were tagged with a code relating to specific themes. The comments were reviewed to understand the frequency of certain discussion topics, the breadth of all discussion topics, and the relationships between the topics.

Discussion Themes

The discussion themes listed below are not representative of the city at large, and only encompass input from participants in the public workshops, attendees at the stakeholder meetings, and members of the public who completed the online survey or comment card. All the ideas that were prioritized during the public workshops are included within the discussion themes, however, each theme is considered to be of equal importance, and the themes are not listed in any order of priority.

[1] For more information on the methodologies employed to identify themes, please see Ryan, Gary W., and H. Russell Bernard. 2003. "Techniques to Identify Themes." *Field Methods* 15(1): 85–109.

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Emphasize a *Variety* of Energy Sources

Many participants were supportive of the resource strategies presented in the 2010 IRP. Recognizing that over-reliance on a single energy source could lead to instability, attendees advocated for a strategy that integrates a variety of resources. In particular, participants were concerned that natural gas was especially subject to fluctuations in price and relied heavily on delivery pipelines, which could jeopardize reliability. Some attendees expressed a desire to see a wider variety of energy sources beyond wind and solar. Some of the suggested energy sources included:

- Algae
- Biofuels
- Fuel Cells
- Geothermal
- Hydroelectric
- Natural Gas
- Nuclear
- Solid Waste
- Wave

The discussion of these other energy sources varied greatly. Nuclear and geothermal sources were mentioned by various participants. Many attendees indicated that LADWP should stay on the forefront of new advancements, and all viable sources of energy should continually be evaluated as modern technology evolves.

Maximize *Energy Efficiency and Conservation* to Meet Future Energy Needs

Energy efficiency and conservation efforts were strongly supported by participants and were recognized as necessary components in meeting the future energy needs of Los Angeles. Participants expressed that LADWP could use several strategies to encourage customers to use less energy, as well as take steps to make the entire power system (both customer-side and utility-side) more energy efficient.

Many participants recommended that LADWP incorporate additional financial incentives to customers who use less energy. Suggestions included the installation of smart meters to provide information about real-time energy use, enabling customers to make smarter

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decisions about how they use power. In addition, some attendees believed that an increase in energy rates would also lead to an overall reduction in energy consumption. Participants also suggested that charging higher prices during peak periods than during off-peak periods could encourage conservation when demand is highest, and could potentially shift energy use to periods with a lower demand.

Participants also emphasized the need for education programs for customers on the importance of conservation and ways to conserve energy. Political and cultural challenges in encouraging energy efficiency and conservation were identified as well.

In addition, many participants recommended that LADWP look for ways to improve the efficiency of the power system as a whole. This included suggestions to improve the efficiency of generating and transmitting energy. Several attendees also commented that technical improvements on the customer-side could lead to more efficient energy use, such as using more energy-efficient appliances. There was support for requirements that newly constructed buildings be designed for energy efficiency and it was suggested that older buildings should be retrofitted. Participants also proposed that LADWP provide/expand energy audits to demonstrate to customers what changes or improvements could be made in homes or businesses to use less energy.

Eliminate Coal from LADWP's Energy Portfolio

Many participants expressed concern over the continued use of coal, recommended its removal from LADWP's energy portfolio, and suggested that it be replaced with renewable energy sources as much as possible. These participants noted that the elimination of coal would reduce greenhouse gas emissions and improve air quality, and some said that replacing coal with natural gas would not be a significant improvement. Other participants believed that the secondary costs of coal were not totally being accounted for, and that impacts to the environment and public health have a cost not always reflected in energy prices.

In addition, there was some discussion of the need to insulate the energy portfolio from anticipated cost increases of coal, such as compliance with new regulatory requirements including a cap and trade program. It was recommended by some attendees that this insulation should be created by the development of renewable sources because the cost of natural gas is also predicted to increase. Furthermore, some participants recognized that the preserve development of renewable sources could stabilize cost increases and avoid potential market-driven/investor-influenced cost spikes.

Finally, some attendees said developing more renewable sources now will allow LADWP to hedge against future uncertain energy market fluctuations and experience lower renewable development prices from early market entry. Other suggestions included increasing the renewable sources in the near-term portfolio while high-yield development sites are still available.

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Expand *Local* Solar Generation

There was widespread support for LADWP to expand solar power generation in-basin. However, out-of-basin solar generation was also viewed favorably. Many participants noted that in-basin solar has environmental benefits because of the decreased need for transmission facilities. In addition, some participants felt that distributed, in-basin generation would improve reliability, especially on summer days when both energy demand and solar radiation are typically high. In-basin solar had an additional perceived benefit of creating local jobs and improving the local economy.

Participants suggested that LADWP offer additional incentives to promote small scale, in-basin photovoltaic systems, which could include subsidized loans to offset construction costs and/or feed-in tariff programs. Some attendees suggested that LADWP advance initiatives to install solar panels on roofs throughout Los Angeles, including on public buildings and parking lots.

Some participants expressed frustration over the current billing system related to individual solar systems, and an owner's inability to sell energy back to LADWP for cash. It was suggested that LADWP consider reevaluating this program and the way in which credits are applied.

Avoid Adverse Impacts to Vulnerable Communities

A number of participants expressed concern over the possibility that some communities in the region may experience unequal impacts from implementing particular components of the IRP. Low-income households, seniors, disabled persons, and others on a fixed income were identified as populations that may be impacted financially by potential costs associated with repowering. There was support for LADWP continuing to provide some protection against overly burdensome costs of electricity to customers who are economically disadvantaged. Many participants believed that costs could also be minimized through incentive programs that encourage energy efficiency. Additionally, some participants voiced opinions that communities with a disadvantaged socioeconomic status have historically received more than their fair share of major infrastructure and suggested that equal distribution of facilities throughout the city should be prioritized.

There was also concern on how facilities would impact communities outside of Los Angeles. Some participants questioned if it is ethical [illegible] to allow out-of-basin communities to bear

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the environmental impacts of providing power to Los Angeles and expressed a desire to see out-of-basin generation minimized. However, most understood the benefits of out-of-basin generation, such as greater resource diversity and reliability, and recognized continued collaborative relationships with other out of basin utilities.

Clarify Costs of IRP Implementation and *Potential Impacts* to Ratepayers

Nearly all participants felt there was a need to clarify costs of IRP implementation and the potential impacts to ratepayers. Many participants thought that clarifying the different costs associated with generation, transmission, and distribution would provide a more accurate assessment of the overall costs associated with the IRP. Others considered it important to clarify labor and administrative costs of LADWP operations and their relation to the IRP. There was also discussion of the need to demonstrate the relationship between the costs associated with the IRP and LADWP's Strategic Plan.

The relative costs of different energy sources were also of interest to attendees. Many participants were concerned with the externalities associated with the IRP, including the secondary costs of the different case options. Secondary costs of interest to participants include the environmental and public health impacts, which were perceived by many to be costs incurred by the community but not reflected in energy rates. In contrast, other participants suggested that implementing the IRP would create local jobs and provide an economic benefit.

Some participants were adamantly opposed to potential future increases in their energy bills, while others supported an increase with caveats such as the need for improved transparency and accountability, or that additional revenues would be used exclusively for providing more renewable energy and/or getting off coal early. Participants who supported a potential increase often argued that an increase could be offset by reduced energy consumption, which could ultimately lower bills. There was also a desire to avoid any adverse impacts that a potential increase would have on low-income communities and individuals with a fixed income. Many people expressed concern that increasing energy costs would be detrimental to businesses in Los Angeles, especially during the current economic climate.

Reduce Environmental Impacts

Environmental protection was a priority for many participants. Some participants expressed a general concern for the environment, while other participants were interested in specific impacts to wildlife and landscapes, water quality, and aesthetics, as well as the storage of nuclear waste. Many attendees indicated that their concern for the environment extended

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beyond air quality and global warming/climate change issues.

The environmental impacts of construction, maintenance, and operation of generation, transmission, and/or distribution facilities were all among the activities that participants were concerned about. It was noted that environmental impacts could be reduced by maximizing existing infrastructure and locating new facilities on already disturbed sites, such as rooftops and brownfields, where possible.

Provide Proactive Leadership and Transparency

Participants saw an opportunity for LADWP to take proactive steps to educate the public about existing LADWP programs and incentives, ways to improve energy efficiency and conservation, and the power system in general. Some participants advocated LADWP to make information easily accessible and clearly identify the decision-making process.

Some participants felt that LADWP needed to lead-by-example with their operations and facilities, invest in research and development, and demonstrate the viability of new technologies. Participants supported LADWP continuing outreach to the public by partnering with existing local groups, schools, and other institutions to disseminate important information, especially related to energy efficiency and conservation. Suggestions were also expressed that clear and accessible information about LADWP's power system be made readily available to the public.

Organizational transparency and accountability were important to participants. Participants emphasized that the planning and facility development process continue to involve the public. There was also support for an independent ratepayer advocate to provide transparency and accountability in LADWP's finances and promote the interest of ratepayers in decisions. Some participants felt that billing statements should explicitly separate water and power costs and provide clear information and education on how bills are calculated. There were also suggestions that a program be established to monitor progress in achieving goals outlined in the IRP.

Exhibits

A – Project Fact Sheet

B – Workshop Agenda

C – Discussion Group Notes

D – Comment Cards

E – Online Survey

To view these exhibits, please visit www.lapowerplan.org.

Appendix O Abbreviations and Acronyms

O.1 Overview

This appendix presents acronyms for agencies and other entities, facilities and locations, electric industry terms, miscellany, and units of measure.

O.2 Agencies and Other Entities

APS	Arizona Public Service Company
BPA	Bonnerville Power Administration
BOS	Bureau of Sanitation
CAISO	California Independent System Operator
CARB	California Air Resources Board
CEC	California Energy Commission
City	City of Los Angeles
CPUC	California Public Utilities Commission
DOD	U.S. Department of Defense
DOE	U. S. Department of Energy
EPA	U. S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
FSO	LADWP Financial Services Organization
IID	Imperial Irrigation District
IOU	California investor owned utilities
IPA	Intermountain Power Agency
IPCC	Intergovernmental Panel on Climate Change
IPPCC	Intermountain Power Project Coordinating Committee
ISDA	International Swaps and Derivatives Association
JPL	NASA Jet Propulsion Laboratory
LADWP	Los Angeles Department of Water and Power
NAESB	North American Energy Standards Board
NASA	National Aeronautic Space Administration
NERC	North American Electric Reliability Corporation
NPC	Nevada Power Company
NREL	National Renewable Energy Laboratory
PG&E	Pacific Gas and Electric Company
PwC	PriceWaterhouse Coopers
RTO	Regional Transmission Organization
RWQCB	Regional Water Quality Control Board
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SCPPA	Southern California Public Power Agency
SoCal	Southern California Gas Company
SRP	Salt River Project

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SWRCB	State Water Resources Control Board
TEC	Tucson Electric Company
UCLA	University of California at Los Angeles
UCSD	University of California at San Diego
USC	University of Southern California
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council

O.3 Facilities and Locations

BPA	Bonnerville Power Administration
BBRTP	Barren Ridge Renewable Transmission Project
BRSS	Barren Ridge Switching Station
COB	California-Oregon Border
COI	California-Oregon Intertie
EOR	East-of-the-River
HSS	Haskell Switching Station
IGS	Intermountain Generating Station
IPP	Intermountain Power Project
NOB	Nevada-Oregon Border
NTS	Northern Transmission System
PACI	Pacific AC Intertie
PDCI	Pacific High Voltage Direct Current Intertie
PTWPP	Pine Tree Wind Power Project
PVD2	Palo Verde-Devers Line No. 2
PVNGS	Palo Verde Nuclear Generating Station
SHARE	Scattergood-Hyperion Alternative Renewable Energy Project
SRP	Salt River Project
STS	Southern Transmission System
UGPP	Upper Gorge Power Plant
US	United States
WREZ	Western Renewable Energy Zone
WOR	West-of-the-River
WSPP	Western Systems Power Pool

O.4 Electric Industry Terms

A/C	air conditioning
AC	Alternating Current
AEDP	Advanced ESS Demonstration Project
AMI	Advanced Metering Infrastructure
AQMP	Air Quality Management Plan
BACT	Best Available Control Technology
BIGCC	Biomass Integrated Gasification Combined Cycle
BPJ	Best Professional Judgment

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CAES	compressed air energy storage
CAMR	Clean Air Mercury Rule
CAP	Climate Action Plan
CCC	closed cycle cooling
CH_4	methane
CHP	combined heat and power
CLEO	Commercial Lighting Efficiency Offer
CNG	compressed natural gas
CLFR	compact linear fresnel reflector
CO_2	carbon dioxide
CSP	concentrating solar thermal power plants
CY	calendar year
DC	Direct Current
DC&M	Distribution Construction and Maintenance
DG	distributed generation
DNI	direct normal insolation
DR	Demand Response
DSM	Demand Side Management
E&L	Environment and Lands
ECAF	Energy Cost Adjustment Factor
EDS	Energy Dissipation Station
EE	Energy Efficiency
EHV	Extra-High Voltage
ESPs	energy service providers
ESS	energy storage system
ETD	Electric Trouble Dispatch
FAR	Firm Access Rights
FES	flywheel energy storage
GHG	greenhouse gas
GHGs	greenhouse gases
GREEN	Green Power for Green LA Program
GWP	global warming potential
HHV	higher heating value
HRSG	heat recovery steam generator
HVAC	heating, ventilating, and air conditioning
ICEs	internal combustion engines
IGCC	integrated gasification combined cycle
IM	impingement mortality
LCOE	levelized cost of energy
LF	Load Factor
LFG	landfill gas
LNG	liquefied natural gas
LPG	propane
LSE	loadserving entities
NaS	sodium-sulfur
NEL	Net Energy for Load

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N_2O	nitrous oxide
NO_2	nitrogen dioxide
NOx	oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NPHR	net plant heat rate
O&M	operations and maintenance
OASIS	open-access same-time information systems
OATTS	open access transmission tariffs
OTC	once-through cooling
PFCs	perfluorocarbons
PHEV	plug-in hybrid electric vehicle
PHS	pumped-hydro storage
PMU	power measurement units
POUs	publicly-owned electric utilities
PTC	production tax credit
PV	photovoltaic
QRAs	Qualified Resource Areas
RASS	Residential Appliance Saturation Survey
RECLAIM	Regional Clean Air Incentive Market
RETI	Renewable Energy Transmission Initiative
RPS	Renewable Portfolio Standard
RS	receiving station
RTCs	RECLAIM Trading Credits
Rule	Cooling Water Intake Structure Rule
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAS	Substation Automation System
SCADA	supervisory control and data acquisition
SEC	Standard Energy Credit
SES	super capacitor energy storage
SF_6	sulfur hexafluoride
SMES	Superconducting Magnetic Energy Storage
SNCR	selective non-catalytic reduction
SOx	sulfur oxide
T&T	transmission and delivery
UES	ultra capacitor energy storage
VRB	Vanadium Redox Battery
WEC	Wave Energy Converter
XRT	experimental curtailment response contract
ZIA	Zone Identification and Technical Analysis
ZNE	Zero Net Energy

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O.5 Miscellany

A	Category of Flow Meter
AB	Assembly Bill
AMR	Automatic Meter reading
CFL	compact fluorescent light
CI	commercial/industrial
CIS	Customer Information System
CS	Customer Service
CSA	Candidate Study Aras
ECC	Energy Control Center
EIR	Environmental Impact Report
F	Category of flow meter
FM	Category of flow meter
GDP	gross domestic product
JFB	John Ferraro Building
LED	light-emitting diode
MFR	multi-family residence
NLC	net levelized cost
OH	overhead
QRAs	Qualified Resource Areas
RF	Radio Frequency
RFP	Request for Proposal
SB	Senate Bill
SBDI	Small Business Direct Install
SFR	single family residence
UG	Underground

O.6 Units of Measure

BTU	British thermal unit
GWh	gigawatt-hour
kV	kilovolt
kW	kilowatts
MMBtu	Million British thermal units
MMT	million metric tons
$MMTCO_2E$	million metric ton CO2 equivalent
MVA	mega volt amperes
MW	megawatt
MWhs	megawatt hours
TWh	terawatt hour

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CITY OF LOS ANGELES
DEPARTMENT OF WATER AND POWER

DRAFT 2010 URBAN WATER MANAGEMENT PLAN

JANUARY 14, 2011

The Draft 2010 UWMP is available for review at www.ladwp.com.

Written comments are due by March 15, 2011 to:
LADWP – Water System
111 N. Hope St, Room 1460
Los Angeles, CA 90012
Attn: Simon Hsu
or
simon.hsu@ladwp.com

** The report is not in the final format.

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Executive Summary

Executive summary will be included following public review.

Presentation at February 2011 public workshops provides an overview of the Urban Water Management Plan findings.

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DRAFT Chapter One
Introduction

1.0 Overview

The availability of water has significantly contributed towards the tremendous growth and development of the City of Los Angeles (City). Since 1902, when the City's population was approximately 102,000, the Los Angeles Department of Water and Power (LADWP) has supported the City's transformation into the nation's second largest city with over 4 million residents, encompassing a 464 square mile area, and comprising the world's sixteenth largest economy. The largest municipal utility in the nation, LADWP was established in 1902 to deliver safe and reliable water and electricity supplies at an affordable price to the residents and businesses of Los Angeles.

With increasing demands for additional water supplies, LADWP along with all other water agencies in Southern California, are faced with the challenge of providing a reliable water supply for a growing population. LADWP will meet the City's water needs through the following actions:

- Pursue cost-effective water conservation, stormwater capture and recycling projects to increase supply reliability.
- Ensure continued reliability of the City's supplemental water supplies from the Metropolitan Water District of Southern California (MWD) through active representation of City interests on the MWD Board
- Protect existing groundwater supplies from contamination and provide treatment to optimize their use
- Maintain the operational integrity of the Los Angeles Aqueduct and in-City water distribution systems
- Meet or exceed all Federal and State standards for drinking water quality

1.1 Purpose

The LADWP 2010 Urban Water Management Plan (UWMP) serves two purposes: (1) achieving compliance with requirements of California's Urban Water Management Planning Act (Act); and (2) serving as a master plan for water supply and resources management consistent with the City's goals and policy objectives.

1.1.1 UWMP Requirements and Checklist

This 2010 Urban Water Management Plan (UWMP) complies with Sections 10610 and 10657 of the California Water Code, Urban Water Management Planning Act (Act), and details how LADWP plans to meet all of the City's customer water needs. The Act became effective on January 1, 1984 and requires that every urban water supplier that provides municipal and industrial water to more than 3,000 customers (or supplies more than 3,000 acre-feet per year) prepare and adopt an Urban Water Management Plan, in accordance with prescribed requirements, every five years. Appendix A contains the Act.

The Act was originally developed due to concerns for potential water supply shortages throughout the State. Therefore, it required information that focused primarily on water supply reliability and water use efficiency measures. Since its original passage in 1983, there have been several amendments added, the most recent adopted in 2009. Some of the recent amendments include: providing assessment of present and proposed future demands to achieve per capita water use reductions by 20 percent by 2020, projecting water use for low-income single family and multi-family residential housing, and the addition of "indirect potable reuse" to the list of recycled water uses. A copy of the 2010 UWMP Act requirements is

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provided in Appendix B. A checklist of the Urban Water Management Plan cross-referencing Act requirements to applicable pages in this UWMP is provided in Appendix C.

With the passage of Senate Bills 610 and 221 in 2001, Urban Water Management Plans took on even more importance. SB 610 and 221 require that counties and cities consider the availability of adequate water supplies for certain new large developments. These statutes require written verification of sufficient water supply to serve these new developments, and Urban Water Management Plans are identified as key source documents for this verification. Based on this statute the LADWP prepares individual Water Supply Assessments for these new large developments.

LADWP's 2010 Urban Water Management Plan is not only designed to meet the current requirements of the Act, but also serves as the City's master plan for water supply and resource management. The UWMP is not only intended for officials in Sacramento, but also helps guide policy makers in the City and the Metropolitan Water District of Southern California (MWD), as well as providing information to the citizens of Los Angeles. The UWMP provides the basic policy principles that guide LADWP's decision-making process to secure a sustainable water supply for Los Angeles.

1.1.2 Water Supply Action Plan

LADWP has a long history of working to ensure that its customers have enough water. These efforts go back to the early 20th century with the building of the Los Angeles Aqueduct. Investments in water rights, aqueducts, reservoirs, conservation and more recently recycled water and stormwater capture have allowed Angelinos to enjoy a water supply that they can rely on. Sound planning and timely investments in water have played a critical role in meeting the water needs of the City despite the fact that Southern California is a semi-arid region

In May of 2008, LADWP's Water Supply Action Plan (Plan), "Securing L.A.'s Water Supply", was released to address a number of critical water supply reliability issues. These water supply issues included: (1) the lowest snowpack on record in the Eastern Sierras in 2007, where Los Angeles historically received the greatest share of its water supply; (2) the driest year on record in 2007 for the Los Angeles basin; (3) anticipated regional water allocations by MWD in response to reductions in imported water available from the San Francisco Bay Delta due to drought and regulatory restrictions; (4) local groundwater contamination in the San Fernando basin, restricting the ability to fully utilize this local resource; (5) Los Angeles Aqueduct delivery reductions due to environmental mitigation and enhancements in the Owen's Valley and Mono Lake Basins, representing nearly one-half of historic water supplies from the Eastern Sierra watershed; and (6) uncertain climate change impacts which threaten traditional water supply sources.

The convergence of these critical issues has far-reaching implications for the City of Los Angeles' water supply that requires long-range planning to sustain a reliable supply of water to meet current and future demand. The Plan was a blueprint for creating sustainable water resources to serve the future needs of the City, and outlined responsible water management and long-term planning. By 2028, the Plan envisioned a six-fold increase in recycled water supplies to a total of 50,000 AFY. Similarly, by 2030, an increase of 50,000 AFY was planned for conservation. As described in the Plan, this aggressive approach included: investments in state-of-the-art technology; a combination of rebates and incentives; efficient clothes washers, and urinals; and long-term measures such as expansion of water recycling and remediating contaminated groundwater supplies. A multi-faceted approach to developing a locally sustainable water supply was developed incorporating the following key short-term and long-term strategies:

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Short-Term Conservation Strategies

- Enforcing prohibited uses of water
- Expanding prohibited uses of water
- Extending outreach efforts
- Encouraging regional conservation measures

Long-Term Strategies

- Increasing water conservation through reduction of outdoor water use and new technology
- Maximizing water recycling
- Enhancing stormwater capture
- Accelerating groundwater basin clean-up
- Expanding groundwater storage
- Green Building Initiatives (added subsequent to the release of the Plan)

As an integral part of the UWMP, the Water Supply Action Plan is incorporated into the associated chapters of the UWMP. The UWMP outlines how the strategies contained in the Water Supply Action Plan will be implemented and how these strategies will increase the reliability of LADWP's water supplies through 2035.

1.2 Service Area

In order to properly plan for water supply, it is important to understand the factors that influence water demands over time. These factors include land use, demographics, and climate.

1.2.1 Land Use

The City of Los Angeles is comprised of approximately 302,165 acres. Residential development constitutes over 51percent of the total land use within the City. Within the residential land use category, single-family residential is the largest at approximately 121,500 acres or 40 percent of the total land use within the City. Multi-family residential is approximately 34,000 acres or 11 percent of the total land use within the City. Open space/parks is the second largest land use within the City occupying approximately 13 percent of the total land use. Commercial and manufacturing land uses combined account for approximately 18 percent of total. Commercial land uses are inclusive of public facilities, such as libraries, public schools, and other government facilities. Exhibit 1A provides a breakdown of the land uses within the City of Los Angeles. The "Other" category includes specific plans, transportation, freeways, rights of way, and other miscellaneous uses that are not zoned.

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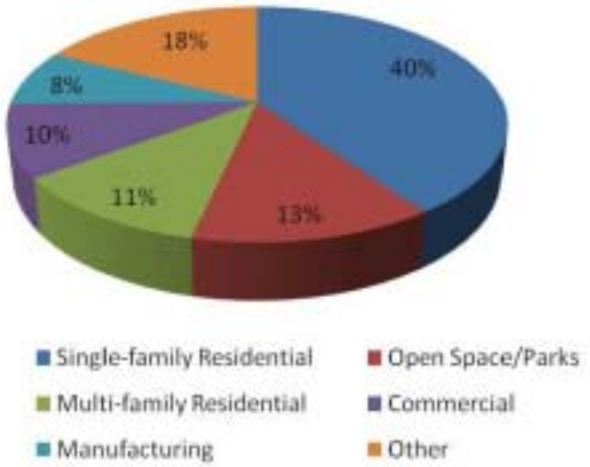
Exhibit 1A
City of Los Angeles Land Uses



Land Use Type	Acres
Single-family Residential	121,470
Open Space/Parks	40,263
Multi-family Residential	34,189
Commercial	30,083
Manufacturing	23,353
Other	52,806
Total	302,165

Source: Data aggregated from City of Los Angeles, Department of City Planning, November, 2009

1.2.2 Demographics

With over 4 million people residing in the LADWP service area, it is slightly larger than the legal boundary of the City of Los Angeles. LADWP provides water service to portions of West Hollywood, Culver City, Universal City, and small parts of the County of Los Angeles.

The population within LADWP's service area increased from 2.97 million in 1980 to 4.1 million in 2009, representing an average annual growth rate of 1.3 percent. The total number of housing units increased from 1.10 million in 1980 to 1.38 million in 2009, representing an average annual growth rate of 0.9 percent. During this time, average household size increased from 2.7 persons in 1980 to 2.9 persons in 2009. Employment grew by about 1.0 percent annually from 1980 to 1990, but declined from 1990 to 2000 as a result of an economic recession that started in 1991. Another decline began in 2008 reflecting the recent economic recession. Overall, employment increased by about 0.3 percent annually from 1990 to 2009. Exhibit 1B summarizes the historical demographics for the LADWP service area.

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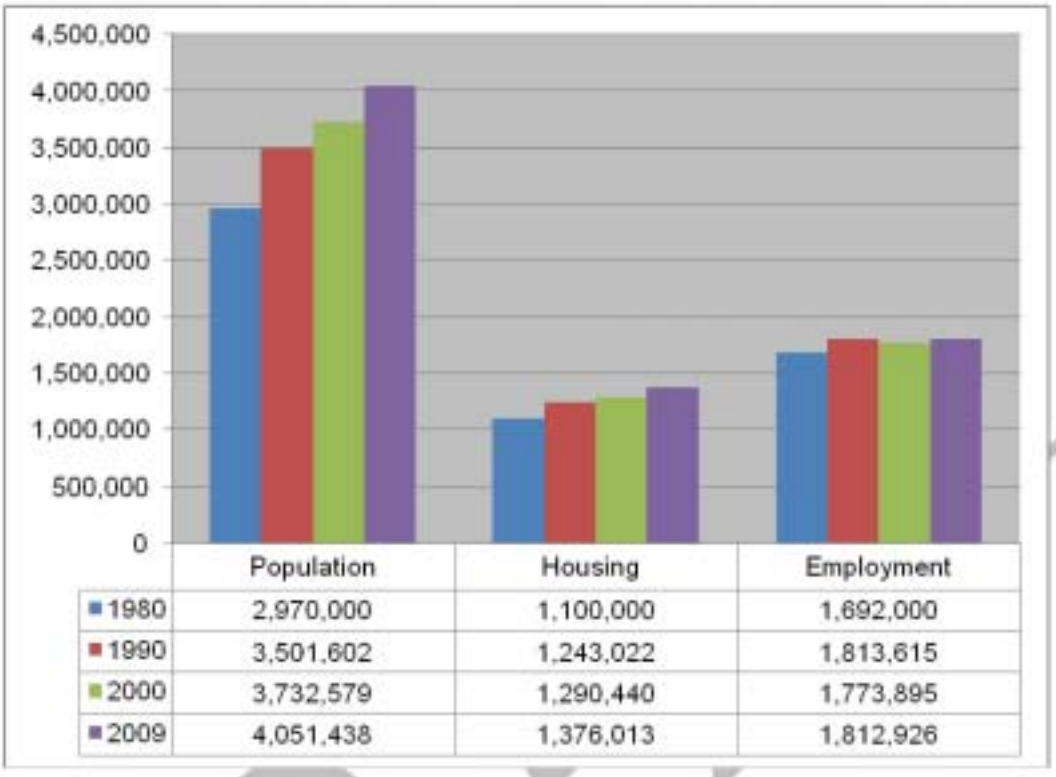
Exhibit 1B
Historical Demographics for LADWP Service Area



	Population	Housing	Employment
1980	2,970,000	1,100,000	1,692,000
1990	3,501,602	1,243,022	1,813,615
2000	3,732,579	1,290,440	1,773,895
2009	4,051,438	1,376,013	1,812,926

Demographic projections were obtained for the LADWP service area from the MWD utilizing a land-use based planning tool that allocates projected demographic data from the Southern California Association of Governments (SCAG) into water service areas for their member agencies. MWD's demographic projections use data reported in SCAG's 2008 Regional Transportation Plan (RTP). Exhibit 1C summarizes these demographic projections for the LADWP service area.

LADWP's service area population is expected to continue to grow over the next 25 years at a rate of 0.4 percent annually. While this is substantially less than the historical 1.3 percent annual growth rate from 1980 to 2009, it will still lead to approximately 367,300 new residents over the next 25 years. According to SCAG's 2008 RTP, housing is expected to grow faster than population over the next 25 years at 0.7 percent annual growth versus 0.4 percent annual growth for population, and it is anticipated that household size will continue to decline over the projection period.

The 2008 RTP projects that by 2035 the average household size will decrease to 2.65 persons per household. Throughout the projection period, multi-family housing units are expected to increase at slightly less than twice the rate of single-family housing units (0.93 percent annual growth vs. 0.47 percent annual growth).

Employment is expected to increase by 0.4 percent annually throughout the projection period. This growth is primarily driven by the current and long-term opportunities available from the economic base within the five-county metropolitan region of Southern California. The economic base is wide-ranging and includes services, wholesale and retail trade, manufacturing, government, financial service industries, transportation, utilities, construction, education, and tourism. Over the 25 year

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forecast period, industrial growth is expected to decline and experience a subtle annual negative growth of -0.4 percent, while commercial employment is expected to increase by about 0.5 percent annually.

Exhibit 1C
Demographic Projections for LADWP Service Area

Demographic	2010	2015	2020	2025	2030	2035
Population	4,100,260	4,172,760	4,250,861	4,326,012	4,398,408	4,467,560
Housing						
Single-Family	627,395	646,067	665,261	678,956	691,703	701,101
Multi-Family	764,402	804,013	846,257	880,580	914,125	942,846
Total Housing	1,391,797	1,450,080	1,511,518	1,559,536	1,605,828	1,643,947
Persons per Household	2.88	2.81	2.75	2.71	2.67	2.65
Employment						
Commercial	1,674,032	1,724,106	1,754,998	1,790,798	1,828,765	1,865,156
Industrial	163,382	157,652	155,012	152,426	150,009	147,508
Total Employment	1,837,415	1,881,758	1,910,010	1,943,224	1,978,773	2,012,664

Source: SCAG Regional Transportation Plan (2008), modified using MWD's land use planning to represent LADWP's service area.

The SCAG demographic projections for population, households, and employment included in their 2008 RTP, and presented in LADWP's 2010 UWMP, vary from what was presented in LADWP's 2005 UWMP. The demographic projections in the 2005 UWMP were based on SCAG's 2004 RTP. The current 2008 projections incorporate the latest population, households, and employment data from multiple local, state and federal agencies. Projected 2008 RTP data reflect adjustments in future population growth related to declining fertility, mortality, labor force participation, and household headship rates; leveling in net migration; fluctuating net domestic migration in response to economic cycles; and an employment shift from the manufacturing sector to the service sector. The SCAG 2008 RTP was adopted in May 2008 prior to the recent recession beginning in 2008. Additionally, MWD has further adjusted the service area boundaries based on LADWP input. Exhibit 1D shows the differences between the SCAG demographic projections for the RTP in 2004 and 2008.

For the forecast year 2030 population was projected to be 4.30 million under the SCAG 2004 RTP and 4.40 million under the 2008 RTP, a difference of about 100,000. Housing was projected to be 1.60 million in 2030 under SCAG 2004 RTP and slightly more under the SCAG 2008 RTP at 1.61 million. Employment was forecast to be less in 2030 under the newest RTP. It is projected to be 2.20 million under the SCAG 2004 RTP versus 1.98 million with the 2008 RTP. It is important to recognize that projected total employment under both the 2004 RTP and 2008 RTP continue to increase from 2010 to 2035. The 2008 RTP simply projects a lower *rate* of increase than does the 2004 RTP. Conversely, the *rate* at which the population increases is expected to be higher with the 2008 RTP as compared with the 2004 RTP.

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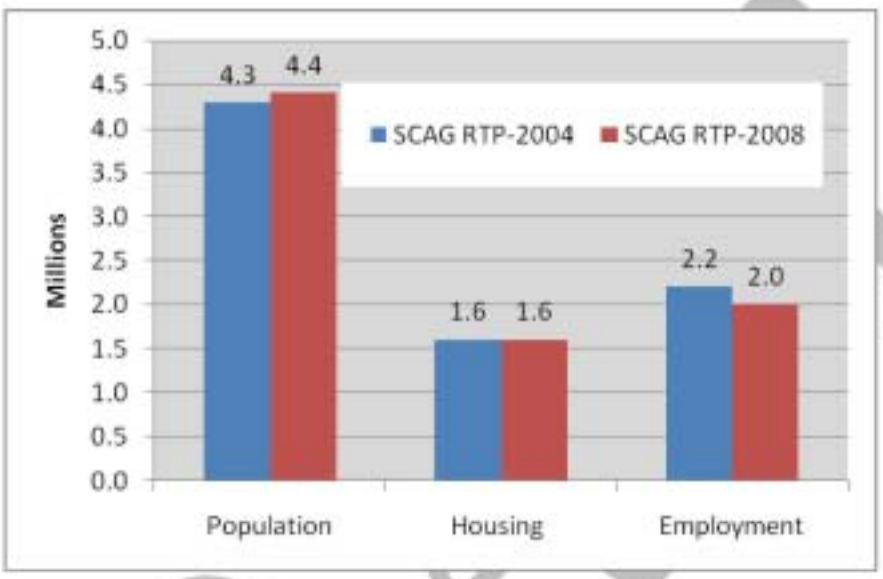
Exhibit 1D
Comparison of SCAG Demographic Projections for LADWP Service Area Between 2004 and 2008 RTP Forecasts for Year 2030



1.2.3 Climate

Weather in Los Angeles is considered mild, which is a major attribute that attracts businesses, residents, and tourists to the City. The City experiences a sizable and popular portion of sunshine throughout the year. Because of its relative dryness, Los Angeles' climate has been characterized as Mediterranean. Exhibit 1E provides a summary of average monthly rainfall, maximum temperatures, and evapotranspiration readings.

The City's average monthly maximum temperature is 76 degrees Fahrenheit based on the period of 1990-2010. This is based on data from the Los Angeles Downtown weather station. The standard annual average evapotranspiration rate (ETo) for the Los Angeles area is 50.29 inches per year. ETo measures the loss of water to the atmosphere by evaporation from soil and plant surfaces and transpiration from plants. ETo serves as an indicator of how much water plants need for healthy growth. Total precipitation averages 14.8 inches per year, with over 90 percent of the total amount typically falling during the period of November through April.

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Exhibit 1E
Average Climate Data for Los Angeles

Average Climate Data for Los Angeles 1990-2008

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum Temperature (°F)[1]	91	95	97	102	101	112	101	104	104	107	99	88	112
Average Maximum Temperature (°F)[1]	82	83	85	89	89	90	93	94	97	94	87	81	89
Average Precipitation (inches)[1]	3.73	4.30	2.48	0.74	0.37	0.08	0.01	0.00	0.08	0.60	0.77	2.11	15.26
Average Eto (inches)[2,3]	1.98	2.26	3.66	4.96	5.46	6.08	6.46	6.31	4.87	3.63	2.56	2.03	50.29

1. 1990-2008, Los Angeles Downtown
USC Weather Station ID 5115
2. Average of Hollywood Hills (Station Id. 73), Glendale (Station Id. 133), and Long Beach (Station Id. 174)
3. www.cimis.water.ca.gov/cimis/welcome.jsp

1.2.4 Water Demand and Supply Overview

Primary sources of water for the LADWP service area are the Los Angeles Aqueducts (LAA), local groundwater, and imported supplemental water purchased from MWD. An additional fourth source, recycled water, is increasingly becoming a larger source in the overall supply portfolio. Two of the supply sources, LAA and water purchased from MWD, are classified as imported as they are obtained from outside LADWP's service area. Groundwater is local and is obtained within the service area. Historical supply sources are increasingly under multiple constraints including potential impacts of climate change, groundwater contamination, and reallocation of water for environmental concerns. To mitigate these impacts on supply sources, LADWP is modifying its water supply portfolio through conservation, water recycling, and stormwater capture.

The primary water supply sources are vital to maintaining LADWP's water system reliability. Pressure on one resource, such as little snowfall in the eastern Sierra Nevada Mountains, will result in an increased reliance on another resource, such as MWD. Supplies available from each source are determined using various computer models in an attempt to balance total projected supplies with projected demands. Exhibit 1F illustrates historical water supplies from 1980 to 2010. As a result of supply shortages, overall demands decreased by over 124,000 AFY in 2009-10 as compared to 2006-07. In 2009-10, approximately 36 percent of the water supply was from the LAA, 14 percent from local groundwater, 48 percent from MWD, and 1 percent from recycled water. From 2005-06 to 2009-10, the five–year average of the water supply portfolio was divided into the following percentages: 36 percent LAA, 11 percent local groundwater, 52 percent MWD, and less than 1 percent recycled water. The imported water (LAA water plus MWD water) supplied on average approximately 88 percent of demands.

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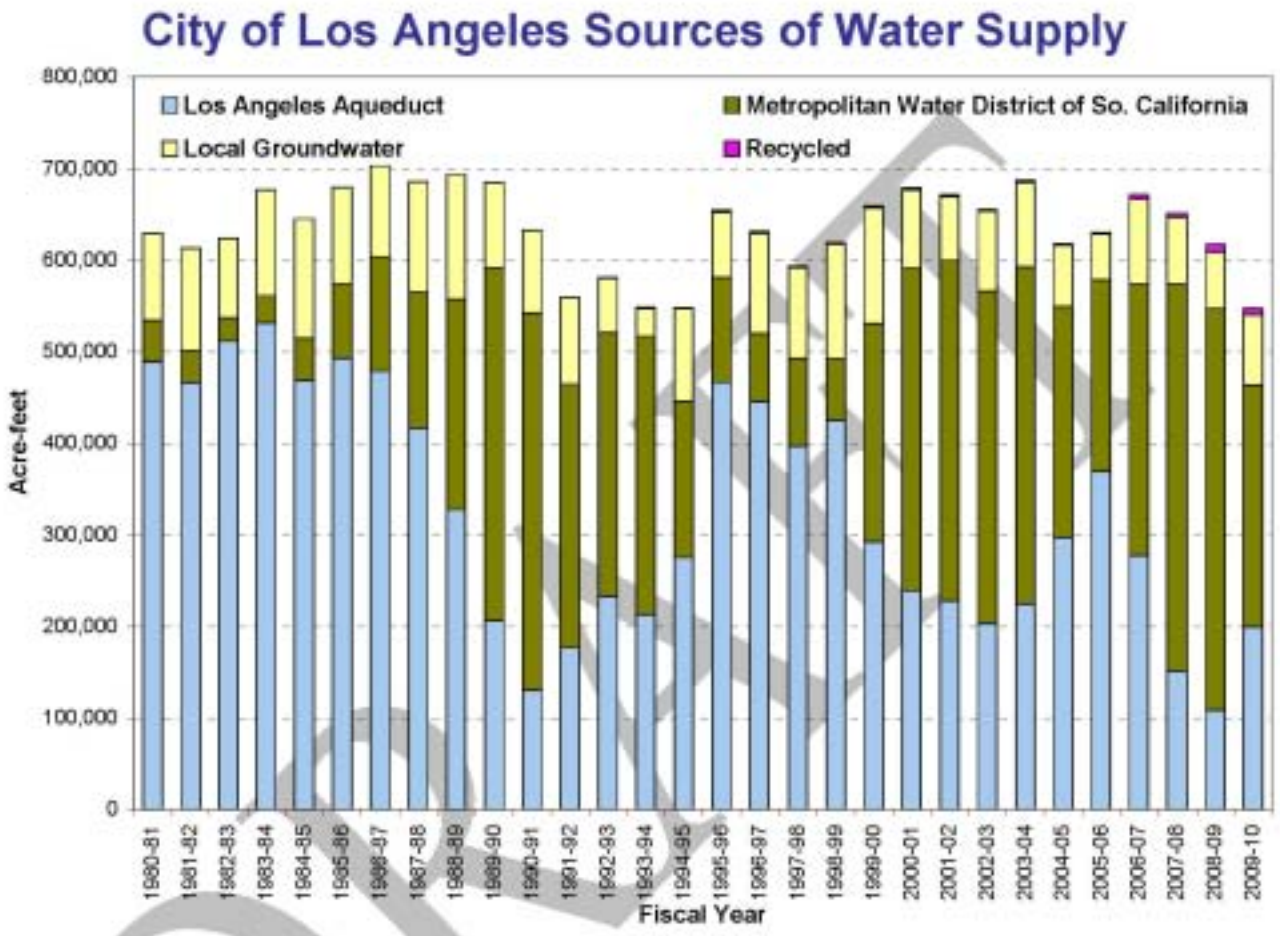
Exhibit 1F
LADWP Historical Water Supply Sources 1980-2010



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Chapter Two
Water Demand

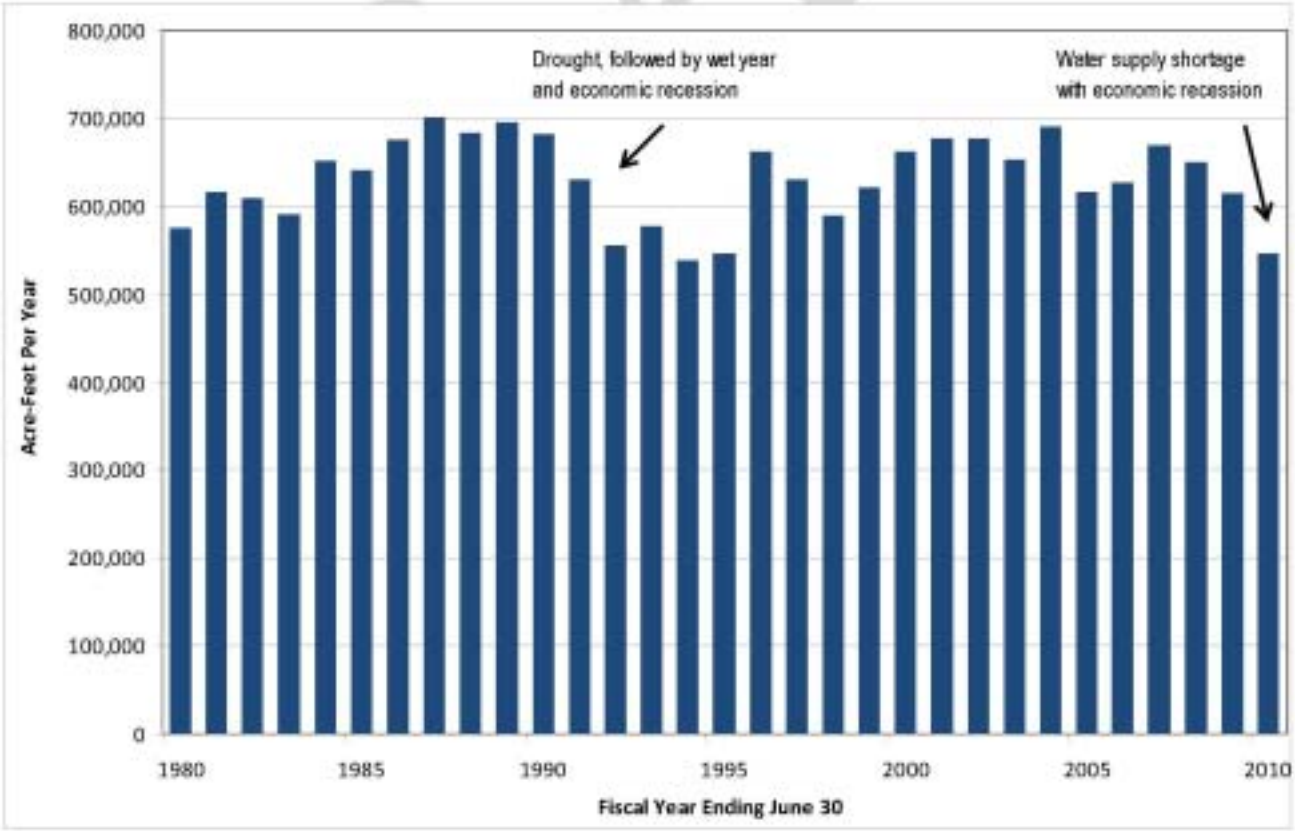
2.0 Overview

In order to properly plan for water supply, it is important to understand water demands and the factors that influence demands over time. LADWP maintains historical water use data separated into the following categories: single-family residential, multifamily residential, commercial, industrial, government, and non-revenue water. This categorization of demands allows better evaluation of trends in water use over time and more precise targeting of water conservation measures.

2.1 Historical Water Use

Exhibit 2A presents the historical water demand for LADWP. As seen in this exhibit, total water demand varies from year to year and is influenced by a number of factors such as population growth, weather, water conservation, drought, and economic activity. In 1991 mandatory conservation imposed on LADWP's customers in response to a six year drought resulted in water use dropping by 8 percent. An economic recession and wet weather in 1992 caused water use to continue to decrease another 12 percent. In 2009 a 3-year water supply shortage coinciding with an economic recession required LADWP to impose mandatory conservation. In 2010 mandatory conservation continued and the economic recession became more severe. This resulted in 2009-10 water use decreasing by 19 percent from 2006-07 levels.

Exhibit 2A
Historical Total Water Demand in LADWP's Service Area



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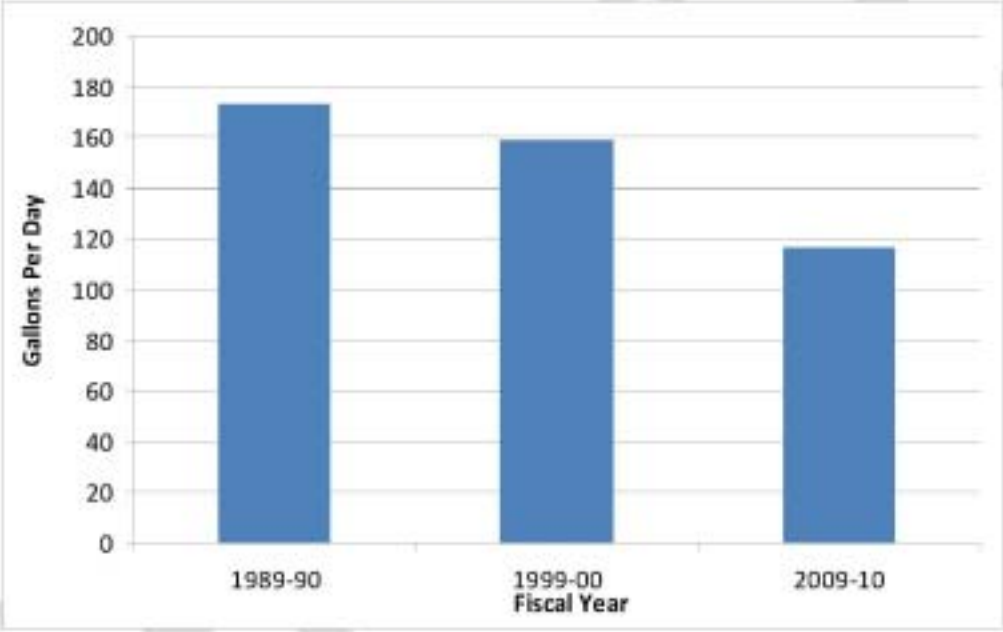
Prior to 1990, population growth in Los Angeles was a good indicator of total demands. From 1980 to 1990, population in the City grew at 1.7 percent annually. Water demands during this same ten year period also grew at 1.7 percent annually. However, after 1991, LADWP began implementing water conservation measures which prevented water demands from returning to pre-1990 levels. Average water demands in the last five years from 2004-05 to 2009-10 are about the same as they were in 1980-81 despite the fact that over 1.1 million additional people now live in Los Angeles. This is evidenced by examining per person (or per capita) water use since 1980 (see Exhibit 2B). In 1989-90, per capita water use was 173 gallons per day (gpd). By 1999-00, per capita water use fell to 159 gpd (or a 10 percent reduction from 1990). In 2009-10, per capita water use is estimated to be 117 gpd – but it is important to note that mandatory conservation and a severe economic recession were occurring at this time.

Exhibit 2B
Historical Per Capita Water Use in LADWP's Service Area



Water Use by Sector

Exhibit 2C shows the breakdown in average total water use between LADWP's major billing categories and non-revenue water in five-year interval for the past 25 years. Non-revenue water, which is the difference between total water use and billed water use, includes water for fire fighting, reservoir evaporation, mainline flushing, system losses, and theft. Single-family residential water use comprises the largest category of demand in LADWP's service area, representing about 36 percent of the total. Multifamily residential water use is the next largest category of demand, representing about 29 percent of the total. Industrial use is the smallest category, representing only 4 percent of the total demand. Although total water use has varied substantially from year to year, the breakdown between the major billing categories of use has not.

Non-revenue water has significantly decreased in recent years. Historically, non-revenue water has averaged 7 percent of total water demand. Since 2005, non-revenue water levels have averaged 5 percent. This may be attributed to a number of steps that LADWP has taken to improve its water system. In 2001, LADWP began replacing its large and intermediate meters. Work was focused on improving accuracy of the meters as well as their strategic placement. In fiscal year 2007-08, an

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accelerated mainline replacement program was launched to repair and replace deteriorating pipelines. In addition, work to replace smaller customer meters was finally completed in fiscal year 2009-10 which also contributes to water loss control. Furthermore, LADWP's ongoing program to remove or cover large open-air reservoirs reduces water loss due to evaporation and infiltration.

Exhibit 2C
Breakdown in Historical Water Demand for LADWP's Service Area

Fiscal Year Ending	Single-Family		Multifamily		Commercial		Industrial		Government		Non-Revenue		Total
	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%	AF
1986-90 Avg	238,248	35%	197,312	29%	123,324	18%	30,502	4%	43,378	6%	52,830	8%	685,594
1991-95 Avg	197,322	35%	177,104	31%	110,724	19%	21,313	4%	38,600	7%	24,100	4%	569,164
1996-00 Avg	222,748	35%	191,819	30%	111,051	18%	23,560	4%	39,830	6%	43,617	7%	632,626
2001-05 Avg	239,754	36%	190,646	29%	109,685	17%	21,931	3%	41,888	6%	58,299	9%	662,203
2005-10 Avg	236,154	38%	180,279	29%	106,955	17%	23,201	4%	42,940	7%	31,929	5%	621,458
25-yr Avg	226,845	36%	187,432	29%	112,348	18%	24,101	4%	41,327	6%	42,155	7%	634,209

Indoor and Outdoor Water Use

In order to assess the potential for water use efficiency and target conservation programs, it is important to characterize water use in terms of indoor and outdoor demands. As with most water utilities, LADWP does not have separate irrigation meters for most of its customers. Only a small fraction of LADWP's customers, mostly parks and golf course, have designated irrigation meters. Therefore, measuring indoor vs. outdoor water demands involves the use of other data and assumptions.

There are two methods that LADWP uses to estimate total outdoor water use: (1) estimation of supplemental water needed for landscape irrigation in accordance with the California Model Water Efficient Landscape Ordinance; and (2) comparing wastewater flows to total water consumption. The first method uses the following formula to estimate the water needed to supplement outdoor landscape irrigation beyond the effect of natural precipitation:

$$LW = (Eto - Eppt) \times 0.62 \times A \times ETAF$$

Where:
LW = Estimated total supplemental water needed for landscape irrigation;
Eto = Reference evapotranspiration for the City of Los Angeles;
Eppt = Effective precipitation (25% of monthly precipitation);
0.62 = Conversion factor to gallons;
A = Total greenscape area; and
ETAF = Et adjustment factor

In 2007, an infrared analysis of the City was conducted as part of the City's Million Trees Program to determine tree canopy and landscape coverage. The infrared analysis methodology used two types of remotely sensed data, infrared imagery and aerial imagery, to determine the total greenscape areas within the City. Results of this effort indicated there is approximately 83,699 acres of greenscape area in Los Angeles. The ETAF (or Et adjustment factor) of 0.8 for the City was derived from types of plants to be irrigated and an assumed irrigation efficiency. It is consistent with the ETAF for non-rehabilitated landscapes as defined in the California Model Water Efficient Landscape Ordinance. The 2004-2007 average total water demand was selected as the basis for calculating outdoor water use percentage. This period was considered to be about average in terms of weather for Los Angeles and had no water restriction implemented by the City. Using the formula described previously, the supplemental water for outdoor landscaping in the City was estimated to be 249,000 AFY. During

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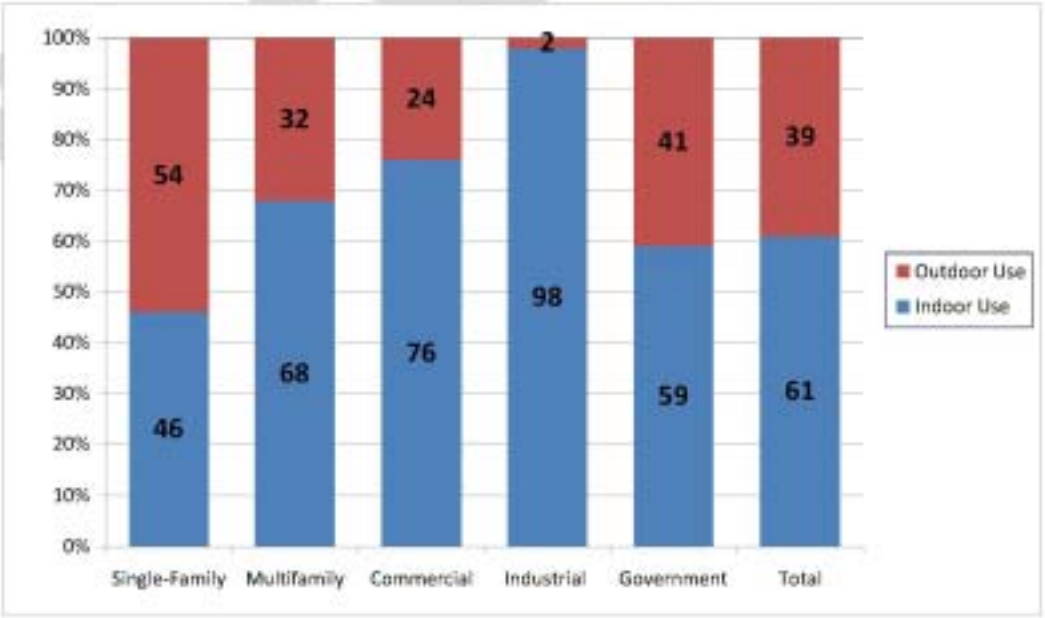
this same period, total water demand averaged 647,000 AFY. Therefore, the City's total outdoor water use represents approximately 39 percent of the total demand.

Comparing wastewater flows to total water consumption is another useful method to assess overall outdoor water use. Since wastewater flow represents indoor water use that flows into the sanitary sewer system, the difference between total water consumption and wastewater flows represents outdoor water use. However, groundwater infiltration and wet weather runoff may enter sanitary sewer systems through cracks and/or leaks in the sanitary sewer pipes or manholes and results in overestimation of the indoor water use. To reduce their impact, only summer months were used to estimate average monthly wastewater attributable to indoor water use. In Los Angeles, the summer months typically have little or no measurable rainfall. Using the same pre-water restriction period of 2004-2007 selected in the first method, the average monthly wastewater flow (only the months of June through September) yields approximately 365 million gallons per day (MGD) or 403,000 AFY of estimated indoor water use. Subtracting this estimated indoor water use from the total water consumption of 647,000 AFY results in an estimated total outdoor demand of 244,000 AFY or 38 percent, which is similar to the 39 percent obtained with the landscape irrigation method. Therefore, two entirely different methods produced very similar results in estimating the total outdoor water use for the City.

To obtain an estimate of indoor vs. outdoor water use for each major billing category, a minimum-month method was used. Monthly water use for single-family, multifamily, commercial, industrial and government was obtained for 2004-2007. The water use in the minimum month, usually one of the cool/wet winter months, is assumed to be mostly indoor use. The difference between any month and the minimum month is all attributed to outdoor water use. But based on the two prior methods, a certain amount of outdoor water use occurs even in the minimum month for some customers. Estimates of the outdoor water use that occurs in the minimum month were developed for each major billing category. Then the outdoor use of each major billing category was summed up to compare with the total outdoor water use obtained from the previous two methods. Exhibit 2D presents the estimated indoor and outdoor water use for the City using all three methods.

Exhibit 2D
Indoor vs. Outdoor Water Use in LADWP's Service Area



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2.2 Quantification of Historical Water Conservation

LADWP has invested hundreds of millions of dollars in water conservation since 1990. These conservation investments include various active programs such as high efficiency toilet rebates, commercial/industrial water audits, education and public outreach and much more. During periods of water shortage, public education and outreach is especially important and has contributed to significant reductions in water use. In an effort to quantify its water conservation efforts, LADWP developed a statistical Conservation Model that correlates total monthly water use in the City with population, weather, the presence of mandatory water conservation, and economic recessions. The model can be used to predict what the water demand would be under actual weather conditions, population growth and economy; but without active or drought water conservation in place. This modeled water consumption without conservation is then compared to actual water consumption—with the difference being attributed to water conservation. In order to assess the model's accuracy, the model is used to "back cast" the period 1980 to 1990 when conservation was not implemented. In this case, the modeled water consumption should be very close to the actual water consumption. After 1990, it is expected that the modeled water consumption will be greater than actual water consumption as LADWP has implemented increasing levels of water conservation measures. Exhibit 2E presents modeled and actual monthly water consumption from 1980 to 2009. As seen, the Conservation Model is performing as expected. The modeled water consumption (red line) is nearly identical to the actual water consumption (blue line) up until 1990. After 1990, the modeled water consumption is greater than actual water consumption.

Exhibit 2E
Modeled vs. Actual Monthly Water Consumption for LADWP

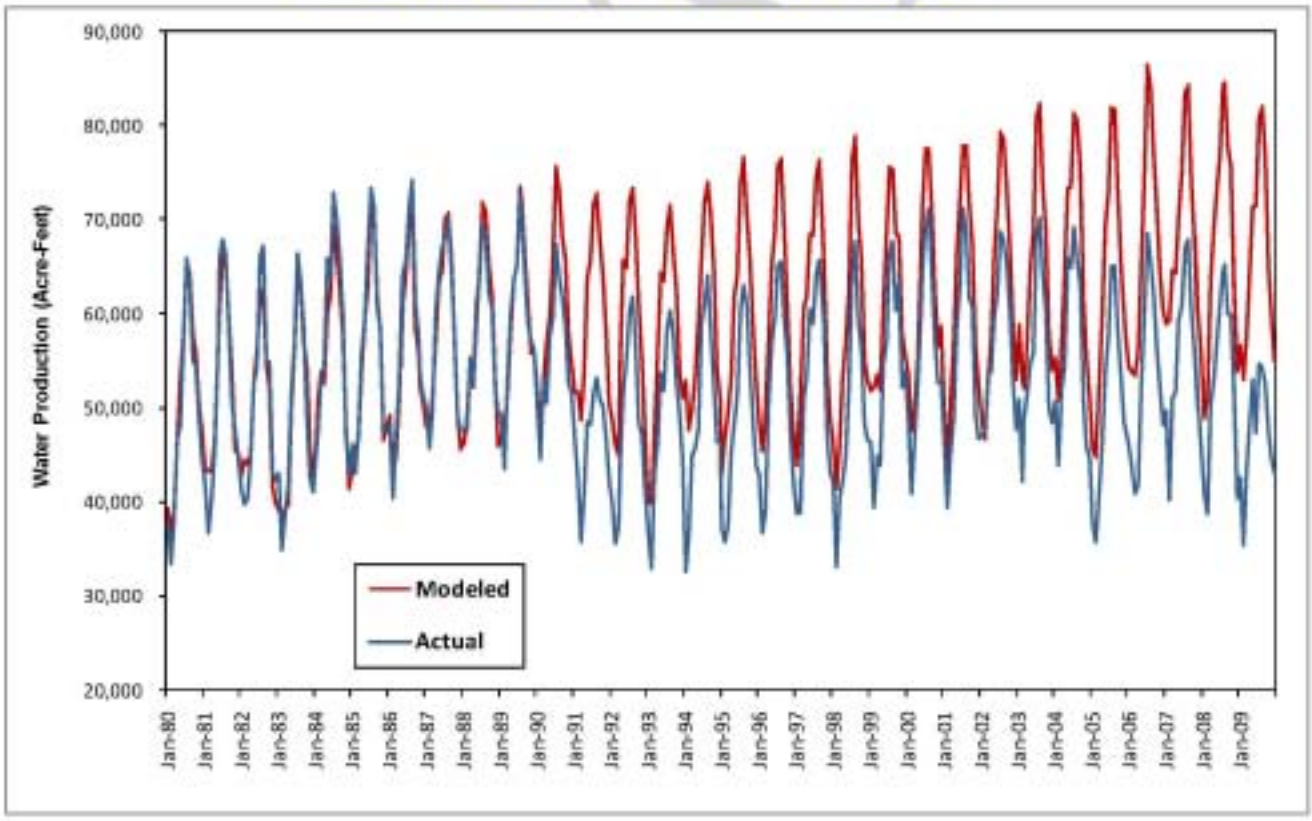

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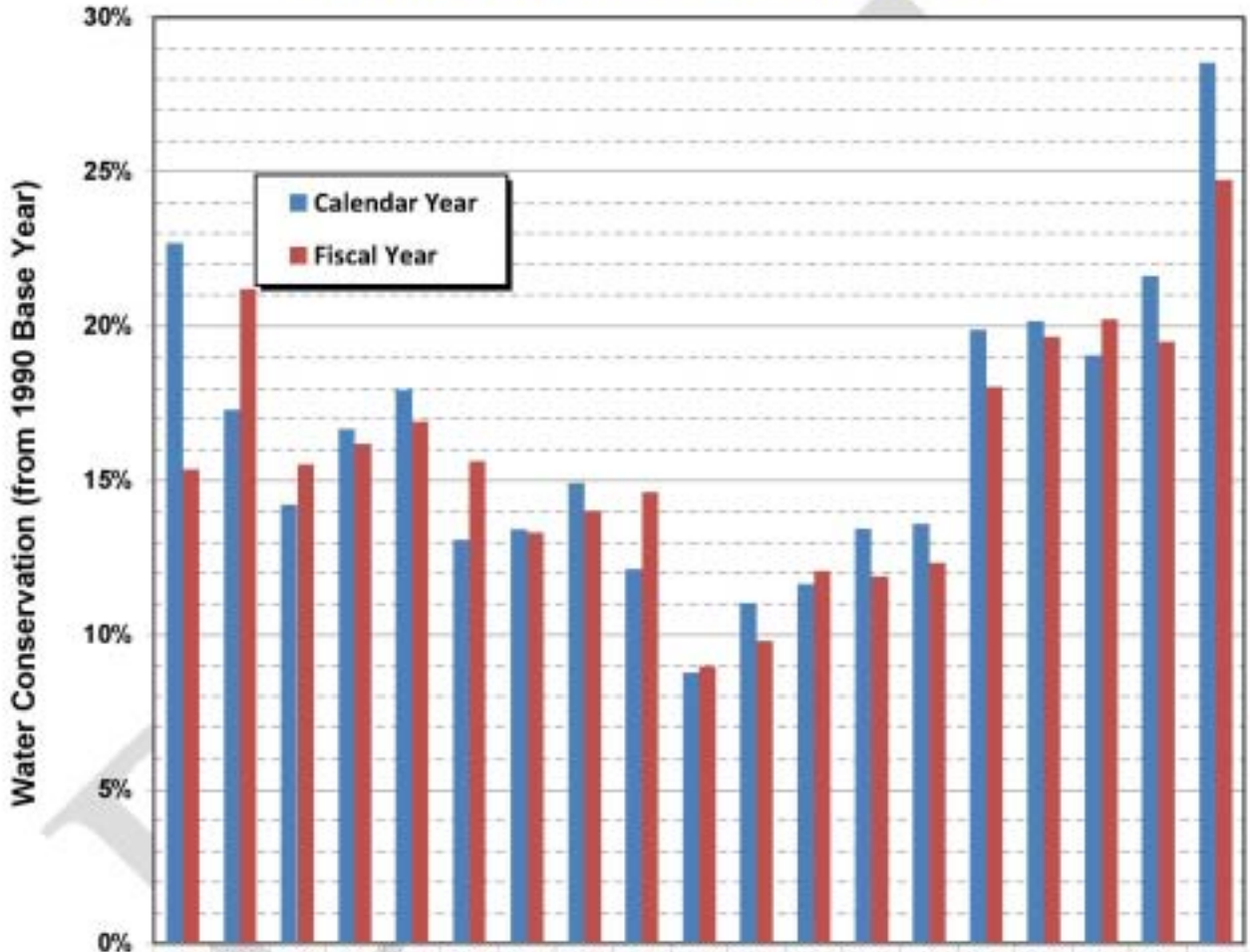
Exhibit 2F summarizes the annual estimated water conservation using the Conservation Model. During periods of water shortage, even when mandatory water conservation is not in place, there is more conservation occurring due to extensive public education and outreach. Water conservation in 2009 represents the highest levels of conservation so far, which reflects a combination of active conservation programs, heightened public education and outreach, and mandatory conservation measures.

Exhibit 2F
Estimates of Total Water Conservation in LADWP's Service Area



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Calendar Year	23%	17%	14%	17%	18%	13%	13%	15%	12%	9%	11%	12%	13%	14%	20%	20%	19%	22%	29%
Fiscal Year	15%	21%	16%	16%	17%	16%	13%	14%	15%	9%	10%	12%	12%	12%	18%	20%	20%	20%	25%

2.3 Water Demand Forecast

Demand Forecast Methodology

LADWP has developed a water demand forecast for each of its major categories of demand. This allows the City to better understand trends in water use and target conservation programs. The methodology used for the demand forecast is called a modified unit use approach. The following steps are used in this approach:

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Step 1: Estimate baseline per unit water use – take each billed category of water demand (e.g., single-family, industrial, etc.) for a base (or starting) period and divide by associated demographic driver (e.g., number of single-family homes or number of industrial employees). This yields for instance, a baseline of 359 gallons used each day in a single-family residence.

Step 2: Modify the estimated baseline per unit water use to account for future changes in the following socioeconomic variables: price of water, personal income, family size, economy, drought conservation effect, and passive water conservation (which accounts for efficiencies in water use from state and local plumbing codes and ordinances).

Step 3: Multiply modified per unit water use for each category in Step 2 by the associated projected demographic drivers (see Exhibit 2G) in order to obtain projected water demands by billed category that does not include active water conservation (which is defined as conservation that LADWP incentives through rebates and programs).

Exhibit 2G
Projected Demographic Drivers
(Based on MWD allocated 2008 SCAG forecast data with corrected service area boundary, 5-17-2010)

Fiscal Year Ending	Single-Family (# Homes)	Multi-Family (# Homes)	Commercial/ Government (# Employees)	Industrial (# Employees)	Landscaping (# of MF Homes)	NRW* (%)
2010	627,395	764,402	1,674,032	163,382	764,402	6.9%
2015	646,067	804,013	1,724,106	157,652	804,013	6.9%
2020	665,261	846,257	1,754,998	155,012	846,257	6.9%
2025	678,956	880,580	1,790,798	152,426	880,580	6.9%
2030	691,703	914,125	1,828,765	150,009	914,125	6.9%
2035	701,101	942,846	1,865,156	147,508	942,846	6.9%

* Calculated from difference between historical production and billing data

Step 4: Estimate non-revenue water (the difference between total water consumption and billed water use) by applying a non-revenue water use factor, and add non-revenue water to the billed category water demands in Step 3 in order to get a forecast of total water consumption without active water conservation.

Step 5: Subtract future projections of active water conservation from the total water consumption in Step 4 in order to determine the water demand forecast that is fully inclusive of both passive and active water conservation.

Applying the Methodology

In Step 1 of this method, historical water demands for single-family, multifamily, commercial/government, and industrial were averaged from 2005 to 2008 to determine the baseline. This period was used because on average, it represented normal weather conditions, and it was before mandatory water use restrictions that occurred in 2009 and 2010. For each of these categories, the water demand was divided by a demographic driver that could be projected into the future. The result of this calculation is a water demand expressed as a unit use water rate. Exhibit 2H presents this unit use calculation for the baseline.

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Exhibit 2H
Baseline Unit Use Water Rates (2005-2008)

Demand Category	Average Water Demand (AFY)	Average Demographic Driver *	Average Unit Use Rate (gallons/day/driver)
Single-Family	244,407	607,301 (homes)	359
Multifamily	184,428	734,461 (homes)	224
Commercial/Gov	153,199	1,631,896 (employees)	84
Industrial	23,613	160,328 (employees)	132

* Source: California Department of Finance and Employment Development Department

Step 2 in the methodology involves modifying these baseline unit use rates to account for changes in the following socioeconomic variables: price of water, personal income, family size, economy, drought conservation effect and passive water conservation. MWD has developed an econometric water demand model as part of its 2010 Integrated Water Resources Plan that is able to account for the impact that personal income, family size and price of water have on water demands. For each of these factors, a statistical coefficient or elasticity was estimated from MWD's Econometric Water Demand. The elasticity is generally interpreted as a percent change in water use resulting from a percent change in the socioeconomic variable. For example, a price elasticity of -0.131 would imply that a 10 percent increase in the real price of water would result in a 1.24 percent decrease in water demand (e.g. $1.24\% = 1-(1+10\%)^{-0.131}$). The following elasticities used in MWD's econometric water demand model were also used for LADWP's water demand forecast:

	Price of Water	Income	Family Size
Single-Family	-0.131	+0.270	+0.550
Multifamily	-0.109	+0.310	+0.450
Commercial/Government	-0.107		
Industrial	-0.107		

Source: MWD 2010 Integrated Water Resources Plan Update Appendix A.1 Demand Forecast

The price elasticities reflect a reduction of approximately 1/3 from those tabulated in MWD's 2010 IRP. However, MWD's 2010 IRP Appendix A.1 states that consumers respond to price increase by installing water-conserving fixtures and appliances. As more water efficient fixtures are installed, the impact of changing water-using behavior through rates is reduced. This is known as "demand hardening". Reducing the price elasticity is to avoid double-counting conservation savings and to account for demand hardening.

Exhibit 2I presents the modified per unit water use over time that incorporates future real increases in the price of water, personal income, and projected changes in family size. Also incorporated are the residual drought conservation effect from the significant public education and mandatory water restrictions that occurred during the drought period of 2009 through 2010, and the effect of passive conservation due to mandated efficiencies from plumbing codes and ordinances.

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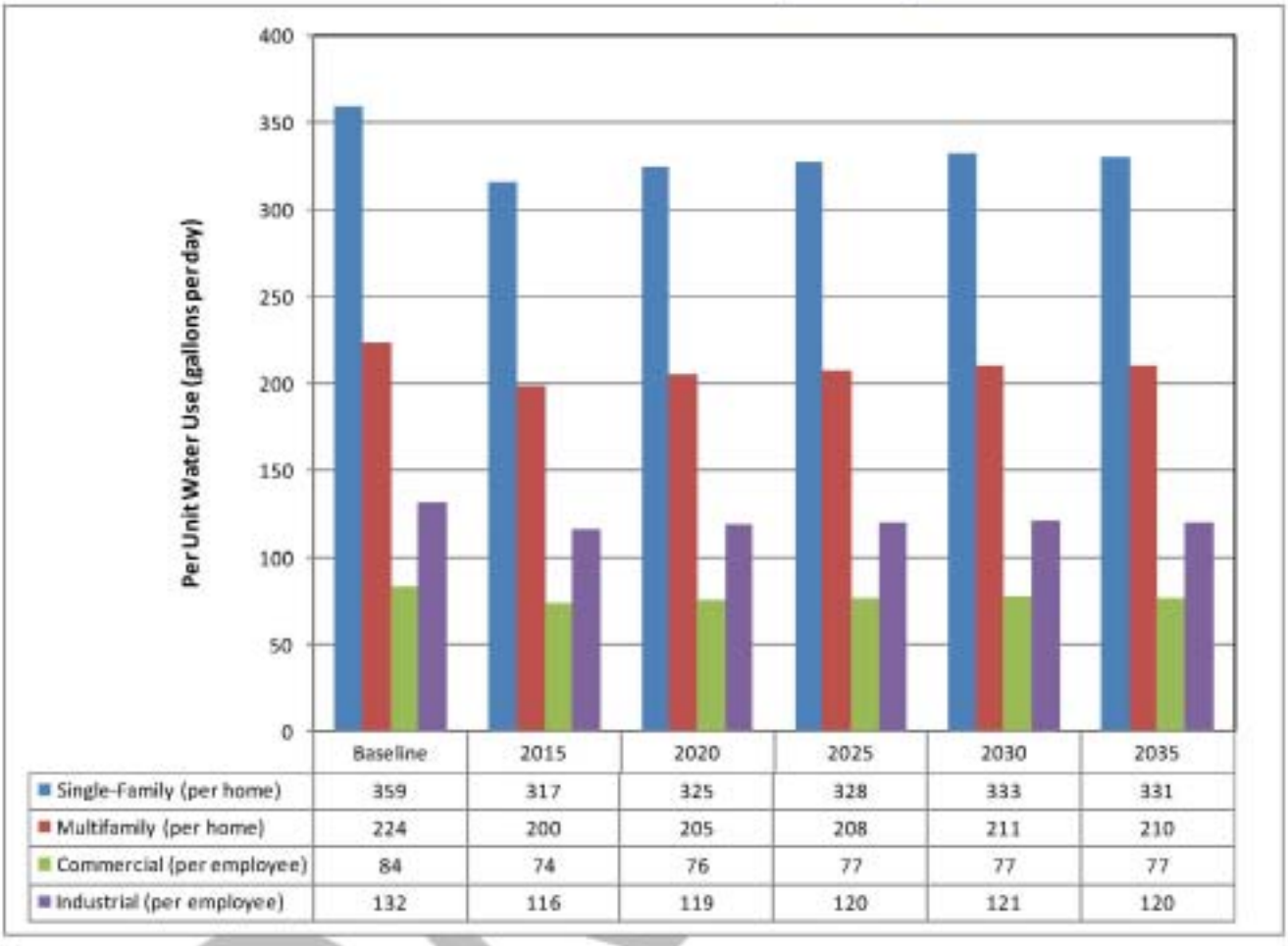
Exhibit 2I
Baseline Unit Use Water Rates (2005-2008)



	Baseline	2015	2020	2025	2030	2035
Single-Family (per home)	359	317	325	328	333	331
Multifamily (per home)	224	200	205	208	211	210
Commercial (per employee)	84	74	76	77	77	77
Industrial (per employee)	132	116	119	120	121	120

Water Demand Forecast Results

Steps 3, 4, and 5 involve applying the modified per unit water use factors shown in Exhibit 2J to the projected demographics for LADWP (see Chapter 1), then adding non-revenue water, and subtracting projected active water conservation (that is summarized in Chapter 3). The result of these steps is the water demand forecast for each of the major categories of demand.

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Exhibit 2J
Water Demand Forecast and Conservation Savings Under Average Weather

Demand Forecast with Passive Water Conservation	2010	2015	2020	2025	2030	2035
Single-Family	208,099	229,115	241,977	249,528	257,693	259,904
Multifamily	158,238	179,653	194,724	205,136	216,054	221,912
Commercial/Gov	129,708	143,081	149,597	153,791	158,628	160,049
Industrial	19,861	20,524	20,726	20,532	20,408	19,852
Non-Revenue	38,236	42,421	44,989	46,617	48,380	49,042
Total	554,140	614,794	652,013	675,604	701,164	710,760
Demand Forecast with Passive & Active Water Conservation	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Single-Family	206,154	225,699	236,094	241,180	246,879	247,655
Multifamily	157,749	178,782	193,220	202,999	213,284	218,762
Commercial/Gov	125,094	135,112	133,597	129,761	126,567	120,420
Industrial	18,729	18,600	16,852	14,708	12,634	10,513
Non-Revenue	37,630	41,370	42,969	43,627	44,421	44,272
Total	545,355	599,563	622,733	632,275	643,786	641,622
Active Water Conservation Savings	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Single-Family	1,944	3,416	5,882	8,349	10,815	12,249
Multifamily	489	871	1,504	2,137	2,770	3,150
Commercial/Gov	4,614	7,969	16,000	24,030	32,061	39,629
Industrial	1,132	1,924	3,874	5,824	7,774	9,339
Non-Revenue	606	1,051	2,020	2,990	3,959	4,771
Total	8,785	15,231	29,280	43,329	57,379	69,138

Water Demand Forecast with Average Weather Variability

Using the weather coefficients from the statistical water conservation model (see Exhibit 2E), annual weather adjustment factors can be derived to determine the range in forecasted water demands due to historical weather variability. This is accomplished by projecting water demands assuming long-term normal weather, and then comparing this normal-weather demand to actual demands. After adjusting for economy and drought conditions, projected water demands can vary by approximately ± 5 percent in any given year due to average historical weather variability. Meaning that water demands under cool/wet weather conditions could be as much as 5 percent lower than normal demands on average; while water demands under hot/dry weather conditions can be as much as 5 percent higher than normal demands on average. Exhibit 2K presents LADWP's historical and forecasted total water demands with both passive and active conservation, under the full range of historical weather variability.

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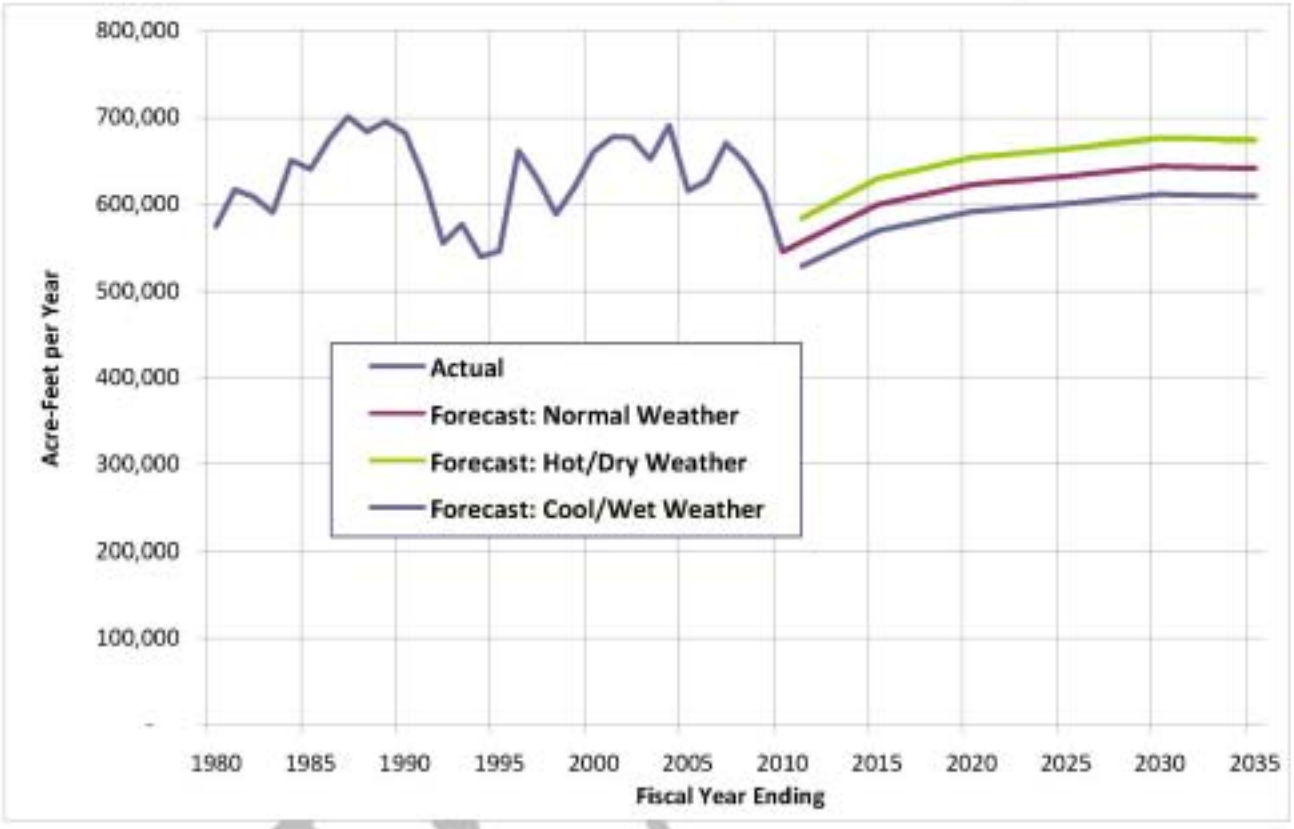
Exhibit 2K
Water Demand Forecast with Average Weather Variability



Low-Income Water Demand Projections

The requirements for the 2010 UWMP call for projections of water demands for low-income customers. For rate relief purposes, LADWP maintains records of low-income water customers. For the fiscal year 2009 - 2010, approximately 6.6 percent of the total number of single-family homes in the City was classified as low-income. On average, these customers used about 20 percent less water per household than overall single-family customers. To forecast low-income single-family water demand, the 6.6 percent ratio of low-income to total single-family homes was applied to the total projection of single-family homes for a projection of low-income single-family homes. The system wide per unit water use for single-family homes was reduced by 20 percent and multiplied by the projection of low-income single-family homes.

Because the water services of LADWP's multifamily residential customers are mostly not individually metered—meaning a multifamily water account can represent 2 or even 100 homes—a different approach was used. LADWP's power system does individually meter multifamily homes and also classifies homes as low-income for rate relief purposes. Therefore, the ratio of current low-income to total multifamily homes in the City was applied to the total projection of multifamily homes in order to get a projection of low-income multifamily homes. For the fiscal year 2009 – 2010, approximately 16.3 percent of the total number of multifamily homes in the City was classified as low-income. Assuming that low-income multifamily homes also use 20 percent less water than overall multifamily homes, an adjusted per unit water use for multifamily homes was multiplied by the projection of low-income multifamily homes. Exhibit 2L presents the water demand forecast for low-income residential water customers.

AR0071518

Exhibit 2L
Water Demand Forecast for Low-Income Residential Customers

Low-Income Single-Family Customers	2015	2020	2025	2030	2035
Number of Homes	42,640	43,907	44,811	45,652	46,273
Household Water Use (Gallons/Day)*	250	253	254	255	252
Demand Forecast (Acre-Feet/Year)	11,917	12,466	12,734	13,035	13,076
Low-Income Multifamily Customers	**2015**	**2020**	**2025**	**2030**	**2035**
Number of Homes	131,054	137,940	143,535	149,002	153,684
Household Water Use (Gallons/Day)*	159	163	165	167	166
Demand Forecast (Acre-Feet/Year)	23,313	25,196	26,471	27,812	28,527
Total Low-Income Residential Customers	**2015**	**2020**	**2025**	**2030**	**2035**
Demand Forecast (Acre-Feet/Year)	35,230	37,662	39,205	40,847	41,603

* Assumes same percent conservation as system for single-family and multifamily homes.

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DRAFT Chapter Three
Water Conservation

3.0 Overview

Multiple factors are increasingly restricting LADWP's traditional water supply sources. The City of Los Angeles has long recognized water conservation as one of multiple methodologies to reduce demands and improve overall water supply reliability. In May of 2008, LADWP's Water Supply Action Plan (Plan), "Securing L.A.'s Water Supply", was released in response to factors impacting LADWP's major water supply sources beginning in 2007. This plan calls for reducing potable water demands by an additional 50,000 AFY by 2030 through conservation, with multiple conservation strategies to increase the sustainability of LADWP's water supply.

Los Angeles has historically taken a leadership role in managing its demand for water. Los Angeles consistently ranks among the lowest in per person water consumption when compared to California's largest cities. This significant accomplishment has resulted from the City's sustained implementation of effective water conservation programs since the 1980s.

One of LADWP's most effective conservation tools is its customers. During past droughts and water shortages, residents and businesses have aggressively implemented conservation to achieve demand reductions. During FY 09/10, water use was below 1979 water use levels thanks to extraordinary conservation efforts by LADWP customers. Specifically, water use in FY 09/10 was almost 20% lower than water use in FY 06/07 with single-family residential water use 25% lower, multi-family water use 11% lower, commercial water use 16% lower, industrial water use 15% lower, and governmental water use 33% lower.

LADWP has continually invested in water conservation programs and measures targeting cost-effective reductions in water use. Looking forward, LADWP plans to continue to make investments in conservation programs and expand its focus on landscape water use efficiency and conservation opportunities in the commercial/industrial/institutional (CII) customer sectors. LADWP's conservation planning process includes working with other City departments to ensure that mutual needs are addressed and goals are achieved (e.g., landscape water use efficiency and dry weather runoff reduction).

The civic culture of water conservation in Los Angeles began with the installation of water meters on all services in the early 1900's. At that time, this foundational conservation measure resulted in a 30 percent reduction in water use. Throughout the recurrence of periodic water shortages, LADWP customers have demonstrated the necessary concern and responsiveness. When faced with significant supply shortages, City residents have responded with unprecedented reductions in their water use. Los Angeles was one of the cities in southern California to invoke mandatory water rationing during the 1976 through 1977 drought. While severe, the two-year drought resulted in only a temporary reduction in water use, as a subsequent series of wet years erased memories of the water shortage experienced during the brief drought period. However, it was the drought that followed the 1978 through 1986 wet cycle that would prove to be the turning point in Los Angeles' water use awareness.

The drought of 1987-1992 left a permanent imprint on Los Angeles water customers. In response to this drought, LADWP expanded a voluntary water conservation program in 1990. Prompted by an extensive public awareness program and education campaign, LADWP customers responded not only with water saving practices but also by installing conservation measures in their homes and businesses. Devices such as low-flow showerheads and ultra-low-flush (ULF) toilets replaced existing non-water saving devices. These hardware changes, coupled with more responsible use habits, have significantly reduced the amount of imported water that the City would have to otherwise buy as the City's population and commerce has

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continued to grow. In response to the current water shortage conditions the City has reinitiated its extensive public awareness campaigns in addition to campaigns launched by MWD to encourage water saving practices and installation of conservation devices in homes and businesses.

With the recent water supply shortage and reduced deliveries of imported water from MWD, residential customers have repeated conservation levels exceeding 20 percent in the period between 2007 and 2010 as a result of mandatory conservation. During the current water supply shortage, the City has updated its Emergency Water Conservation Plan Ordinance with enforceable water waste provisions and implemented mandatory outdoor watering restrictions. In addition, the City has implemented water shortage year rates reducing Tier 1 water allotments for customers by 15%. Since July 2007, 63 billion gallons of water were saved through conservation. As a direct result of conservation, imported water purchases from MWD are 23% below baseline allocations for fiscal year 2009/2010. In response to recently enacted State laws, LADWP has developed new water conservation goals which aim to reach approximately 64,000 AFY in hardware conservation savings by 2035.

Conservation has had a tremendous impact on Los Angeles' water use patterns and has become a permanent element of LADWP's water management philosophy. Water usage in the City in 2010 was less than it was in 1979 despite an increase in population of over 1,000,000 people (see Exhibit 3A). Exhibit 3B shows historical conservation savings from fiscal year 1990/1991 through 2009/2010 based on installation of distributed conservation devices and rebates/incentives claimed as well as conservation achieved through customers' behavior and lifestyle changes to use water more responsibly. Cumulative yearly savings for the period total 223,593 AFY.

Exhibit 3A
Historical City of Los Angeles Water Use

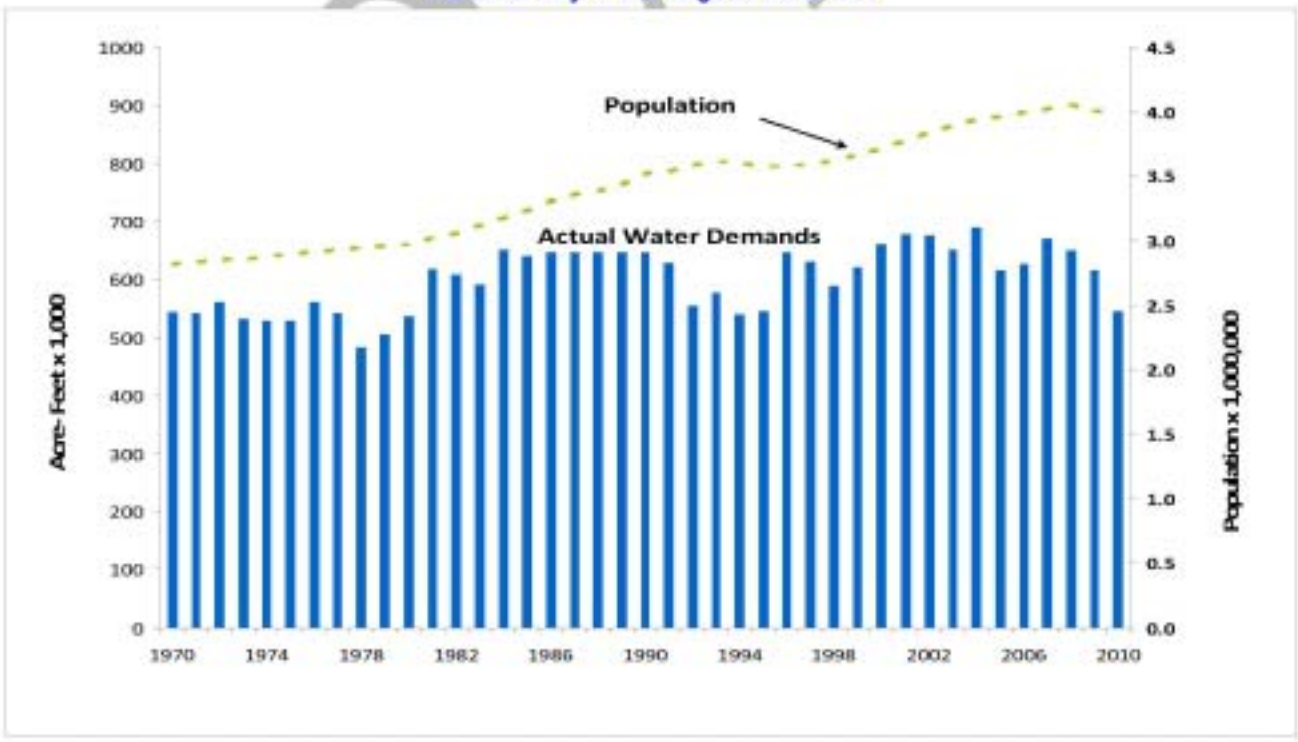

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Exhibit 3B
Historical City of Los Angeles Conservation

Fiscal Year	Additional Yearly Hardware Installed Savings (AF)	Cumulative Yearly Hardware Savings (AF)	Annual Non-Hardware Savings (AF) [1]	Annual Total Savings (AF)
Prior to 1990/1991	30,260	30,260	-	-
1990/1991	3,908	34,168	78,098	112,267
1991/1992	7,456	41,624	108,555	150,179
1992/1993	4,583	46,207	60,210	106,417
1993/1994	4,210	50,417	63,344	113,761
1994/1995	4,761	55,178	63,780	118,958
1995/1996	4,116	59,294	54,871	114,164
1996/1997	3,283	62,576	35,036	97,612
1997/1998	2,650	65,227	31,737	96,964
1998/1999	2,721	67,948	39,666	107,614
1999/2000	3,038	70,986	-4,406	66,580
2000/2001	3,565	74,552	-2,038	72,513
2001/2002	2,263	76,814	16,688	93,502
2002/2003	2,507	79,321	10,405	89,726
2003/2004	3,047	82,368	14,999	97,366
2004/2005	3,124	85,492	48,932	134,423
2005/2006	3,030	88,522	63,664	152,186
2006/2007	2,197	90,719	77,982	168,701
2007/2008	782	91,501	65,587	157,088
2008/2009	3,127	94,628	106,307	200,935
2009/2010	4,269	98,897	124,696	223,593

1. Negative non-hardware savings are due to overestimation in hardware savings due to years with extreme wet weather conditions.

Conservation benefits the City by improving water supply reliability and reducing embedded energy use for water treatment and pumping. Conserving customers see a tangible benefit as well through monetary savings on their water bill. Another ancillary benefit of conserving water is that the need for costly sewer facility expansions is deferred by reducing wastewater discharge into the sewer collection and treatment systems, thus increasing the lifespan of current sewer infrastructure. Water conservation also has the added benefits of reducing greenhouse gas emissions and energy use associated with delivering water supplies to and within the LADWP service area. In the end, the primary beneficiaries of conservation are the water customers and the environment from where the sources of supply originates. Furthermore, increased conservation will result in decreased dry weather runoff which will decrease the amount of pollutants flowing into the rivers and oceans.

Los Angeles has been implementing permanent conservation since the 1980's. In 1988, the City adopted a plumbing retrofit ordinance to mandate the installation of conservation devices in all properties and to require water-efficient landscaping in new construction. The ordinance was amended in 1998, requiring the installation of ULF toilets and water saving showerheads in single-family and multi-family residences prior to resale. A new ordinance adopted in 2009, the Water Efficiency Requirements ordinance, establishes water efficiency requirements for new developments and renovations of existing buildings by requiring

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installation of high efficiency plumbing fixtures in all residential and commercial buildings. LADWP's past water conservation programs have assisted customers affected by the ordinances by offering free ULF toilets and showerheads, free installation of ULF toilets, showerheads and faucet aerators, as well as rebates for ULF toilets purchased and installed. Current water conservation programs co-sponsored by MWD through the SoCal Water$mart Program for residential customers and the Save Water Save a Buck Program for CII customers continue to assist customers in complying with ordinances and reducing overall water demands.

3.1 Water Conservation Goals

Water conservation reduces demand that typically rises over time with growth in population and commerce. By mitigating those increases in demand, water supply reliability is improved while costs are reduced. In the early 1990s, City residents responded with conservation levels exceeding 20 percent due to increasingly drier conditions and mandatory conservation. As normal water supply conditions returned and with continuation of LADWP's conservation program, conservation levels stabilized at approximately 15 percent. With the recent drought and reduced deliveries of imported water from MWD, residential customers have repeated conservation levels exceeding 20 percent in the period between 2007 and 2010 as a result of mandatory conservation. Since July 2007, 63 billion gallons of water were saved through conservation. As a direct result of conservation, imported water purchases from MWD are 23% below baseline allocations for fiscal year 2009/2010. In response to the goals provided in the Plan and recently enacted State laws, LADWP has developed water conservation goals.

3.1.1 Water Supply Action Plan Conservation Goal

To continue increased conservation levels once mandatory outdoor watering restrictions are lifted, LADWP has set a water conservation goal in the Water Supply Action Plan of reducing potable water demands by an additional 50,000 AFY by 2030. This conservation level will further lessen the City's reliance on imported water while providing a drought-proof resource that is not subject to weather conditions. This aggressive approach includes multiple strategies: investments in state-of-the-art technology; a combination of rebates and incentives promoting installation of weather-based irrigation controllers (WBICs), efficient clothes washers and urinals; expansion and enforcement of prohibited water use; reductions in outdoor water use; extending education and outreach efforts; and encouraging regional conservation.

LADWP's commitment to conservation is a proven multi-faceted approach that includes tiered water pricing, education and awareness, financial incentives for the installation of a variety of conservation measures, free water saving showerheads, Technical Assistance Program (TAP) incentives for business and industry, and large landscape irrigation efficiency programs. Conservation is a key component of LADWP's water resource planning efforts and will continue to be implemented over the long term.

3.1.2 Water Conservation Act of 2009

The Water Conservation Act of 2009, Senate Billx7-7, requires water agencies to reduce per capita water use by 20% by 2020 (20x2020). This includes increasing recycled water use to offset potable water use. Water suppliers are required to set a water use target for 2020 and an interim target for 2015 using one of four methods. The 2020 urban water use target may be updated in a supplier's 2015 UWMP. Failure to meet adopted targets will result in the ineligibility of a water supplier to receive water grants or loans administered by the State unless one of two exceptions is met. Exception one states a water supplier may be eligible if they have submitted a schedule, financing plan, and budget to DWR for approval to achieve the per capita water use reductions. Exception two states a water supplier may be eligible if an entire water service area qualifies as a disadvantaged community.

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Four methodologies are stipulated for calculating the water use target. Three of the methods are listed in Water Code § 10608.20(a)(1). The fourth method was developed by DWR. The four methodologies are:

- Method 1 - Eighty percent of the water supplier's baseline per capita water use
- Method 2 – Per capita daily water use estimated using the sum of performance standards applied to indoor residential use; landscape area water use, and commercial, industrial, and institutional uses
- Method 3 – Ninety-five percent of the applicable state hydrologic region target as stated in the state's *draft 20x2020 Water Conservation Plan.*
- Method 4 – Description to be added at end of 2010 once developed by DWR

In 2015, urban retail water suppliers will be required to report interim compliance followed by actual compliance in 2020. Interim compliance is halfway between the baseline water use and 2020 target. Baseline, target, and compliance-year water use estimates are required to be reported in gallons per capita per day (gpcd).

For consistent application of the Act, DWR produced *Methodologies for Calculating Baseline and Compliance Urban Water Per Capita Use* in October 2010. Following requirements provided in the document, LADWP has calculated baseline per capita water use, an urban use target for 2020, and an interim water use target for 2015. Reporting compliance daily per capita water use is not required until the 2015 UWMP cycle as it compares the interim target to actual water use in 2015. Exhibit 3C presents results of the calculations. Calculations and technical bases for the calculations are presented in Appendix X.

Baseline per capita water use is 154 gpcd using a ten-year average ending between December 31, 2004 and December 31, 2009 and 146 gpcd using a five-year average ending between December 31, 2007 and December 31, 2009.

LADWP has adopted Method 3 to set its 2015 interim and 2020 water use targets. Method 3 requires setting the 2020 water use target to 95% of the applicable State hydrologic region target as provided in the *State's Draft 20x2020 Water Conservation Plan.* LADWP is within State hydrologic region 4, the South Coast region. LADWP was required to further adjust the calculated 2020 target to achieve a minimum reduction in water use. The gpcd at 95% of the hydrologic region was 142 gpcd and using 95% of the five-year average base daily per capita water use was equal to 138 gpcd. Therefore, LADWP was required to set the 2020 target at the smaller of the two resultant values. LADWP's interim 2015 target is 146 gpcd and the 2020 target is 138 gpcd.

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Exhibit 3C
20x2020 Base and Target Data

20x2020 Required Data	Gallons Per Capita Per Day (GPCD)
Base Per Capita Daily Water Use	
10-Year Average[1]	154
5-Year Average[2]	146
2020 Target Using Method 3[3]	
95% of Hydrologic Region Target (149 gpcd)	142
95% OF Base Daily Capita Water Use 5-Year Average (146 gpcd)	138
Actual 2020 Target	**138**
2015 Interim Target	146

1. Ten-year average based on calendar year ending between 12/31/04 and 12/31/10.

2. Five-year average based on calendar year ending between 12/31/07 and 12/31/10.

3. Methodology requires smaller of two results to be actual water use target to satisfy minimum water use target.

3.2 Existing Programs, Practices, and Technology to Achieve Water Conservation

LADWP has developed aggressive water conservation programs to address recently enacted State laws and to meet its goal of achieving an additional 50,000 AFY conservation by 2030. LADWP uses multiple programs, practices, and technologies in conjunction with enactment of ordinances to achieve its current water conservation levels throughout its service area and customer classes.

3.2.1 State Laws and City Ordinances

State Laws

In addition to the Water Conservation Act of 2009 multiple legislative bills have been enacted in the past few years requiring water agencies to enact measures to increase water conservation, establishing new plumbing standards, and linking grants and loans to implementation of best management practices (BMPs).

The Water Conservation in Landscaping Act of 2006, Assembly Bill 1881, reduces outdoor water waste through improvements in irrigation efficiency and selection of plants requiring less water. The Act required an update to the existing Model Water Efficient Landscape Ordinance and adoption by location agencies or an equivalent ordinance no later than January 1, 2010. If any agency failed to adopt the ordinance or its equivalent then the ordinance was automatically adopted by statute. The ordinance requires development of water budgets for landscaping, reduces erosion and irrigation related runoff, utilization of recycled water if available, irrigation audits, requirements for landscape and irrigation design, and scheduling of irrigation based on localized climate for new construction and redevelopment projects.

In 2009, Assembly Bill 1465, Urban Water Management Planning, was approved to include language in the UWMP Act that deem water suppliers that are members of the California Urban Water Conservation Council (CUWCC) and comply with the "Memorandum of Understanding Regarding Urban Water Conservation in California," dated December 10, 2008, as it may be

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amended, to be in compliance with the requirement to describe the supplier's water demand management measures in its urban water management plan. A more detailed discussion of the CUWCC and BMP compliance is provided in Section 3.2.3.

Assembly Bill 1420 links state funding for water management by urban water suppliers to implementation of water conservation measures. Urban water suppliers are required to be in compliance with the CUWCC MOU to be eligible for water management grants or loans. Senate Bill X7-7 further clarifies the grant funding conditions required by AB 1420 are repealed on July 1, 2016 and replaced with eligibility determined by compliance with 20x2020 targets.

In the recent years there has been a lot of regulations approved increasing the water use efficiency requirements of plumbing devices, specifically, Assembly Bill 715 (2007), Senate Bill 407 (2009), and the CALGreen Building Standards. AB 716 requires that all toilet and urinal fixtures sold through retail or installed in existing and new residential and commercial building meet the high efficiency standards by January 1, 2014. SB 407 does not address the sale of plumbing fixtures but adds a requirement that beginning in January 1, 2017 all residential and commercial property sales must disclose all non-efficient plumbing fixtures. CALGreen has an effective date of January 1, 2011 and requires use of water efficient plumbing fixtures for all new construction and renovations of residential and commercial properties.

City Ordinances

Los Angeles has utilized ordinances as a tool to reduce water waste since 1988, beginning with the adoption of its first version of a plumbing retrofit ordinance. The ordinance mandated installation of conservation devices in all existing residential and commercial properties and installation of water-efficient landscaping in all new construction. Toilets were required to use less than 3.5 gallons per flush (gpf), urinals less than 1.5 gpf, and showerheads less than 2.5 gallons per minute (gpm). Customers with three acres or more of turf were required to reduce water consumption by 10 percent from 1986 levels or face a 100 percent surcharge on their water bills.

In 1998 the ordinance was amended, requiring the installation of ULF toilets and water saving showerheads in single-family and multi-family residences prior to the close of escrow. This progressive requirement is implemented with the help of local real estate professionals. LADWP has explored the expansion of the City's Retrofit on Resale Ordinance to include nonresidential properties

Los Angeles further increased its water efficiency mandates in 2009 with adoption of the Water Efficiency Requirements ordinance. This ordinance establishes water efficiency requirements for new developments and renovations of existing buildings by requiring installation of high efficiency plumbing fixtures in all residential and commercial buildings. Exhibit 3D summarizes the minimum requirements for new construction and replacement of fixtures in existing buildings.

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Exhibit 3D
Water Efficiency Requirements Ordinance Summary

Device	Requirement
High Efficiency Toilets	1.28 gallons per flush
Urinals	0.125 gallons per flush
Faucets	
Indoor Faucets (Maximum)	2.2 gallons per minute
Private Lavatory Faucets	1.5 gallons per minute
Public Use Lavatory Faucets[1]	0.5 gallons per minute
Showerheads	2 gallons per minute
Dishwashers	
Commercial Dishwashers	varies by type between 0.62 and 1.16 maximum gallons per rack
Domestic Dishwashers	5.8 gallons per cycle
Cooling Towers	5.5 cycles of concentration
Single-Pass Cooling Systems	Prohibited[2]

1. Metering faucets shall not deliver more than 0.25 gallons per cycle.

2. Single pass cooling systems are prohibited unless installed for health and safety purposes that cannot otherwise safely operate.

In an effort to lead by example, LADWP has been retrofitting all its facilities with high efficiency plumbing fixtures since before the effective dates of the ordinance. As of early June 2010, LADWP is 57 percent complete in upgrading its 600 buildings to high efficiency faucets, toilets, urinals, showers, flexible hose connectors, angle valves, as well as correcting leaks and removing existing water damage.

In May 1996, the City's Landscape Ordinance (No. 170,978) became effective with an overarching goal to improve the efficient use of outdoor water. This ordinance was recently amended in 2009 to comply with the previously discussed Water Conservation in Landscaping Act of 2006 and the Model Water Efficient Landscape Ordinance.

LADWP first adopted an Emergency Water Conservation Plan ordinance in the early 1990's in response to drought conditions. Subsequently in the current water shortage LADWP has adopted two amendments expanding prohibited uses, increasing penalties for violating the ordinance, and modifying water conservation requirements. Five phases of water conservation are incorporated into the plan with prohibitions and water conservation measures steadily increasing by phase. Regardless of water supply availability, at a minimum Phase I conservation requirements are in effect unless a more stringent phase is in effect. In response to the ongoing drought conditions, LADWP implemented Phase III restrictions on June 1, 2009, allowing outdoor irrigation only two days per week. Upon the recent ordinance amendment, Phase II implementation began on August 25, 2010 which allows outdoor watering three days per week. Exhibit 3E summarizes the five phases as defined in the latest amendment approved in August 2010.

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Exhibit 3E
Emergency Water Conservation Plan Ordinance Restrictions by Phase

Phase	Restrictions
I	No use of a water hose to wash paved surfaces
	No use of water to clean, fill, or maintain levels in decorative fountains, ponds, lakes or similar structures used for aesthetic purposes unless a recirculating system is used
	No drinking water shall be served unless expressly requested in restaurants, hotels, cafes, cafeterias, or other public places where food is sold, served, or offered for sale
	No leaks from any pipes or fixtures on a customer's premises; failure or refusal to fix leak in a timely manner shall subject the customer penalties for a prohibited use of water
	No washing vehicles with a hose if the hose does not have a self-closing water shut-off device attached or the hose is allowed to run continuously while washing a vehicle
	No irrigation during rain
	No irrigation between 9am and 4pm, except for public and private golf courses and professional sports fields to maintain play areas and event schedules. System testing and repair is allowed if signage is displayed.
	All irrigation of landscape with potable water using spray head and bubblers shall be limited to no more than ten minutes per water day per station. All irrigation of landscape with potable water using standard rotors and multi-stream rotary heads shall be limited to no more than 15 minutes per cycle and up to 2 cycles per water day per station. Exempt from these restrictions are irrigation systems using very low-flow drip-type irrigation when no emitter produces more than 4 gallons of water per hour and micro-sprinklers using less than 14 gallons per hour. This restriction does not apply to Schedule F water customers or water service that has been granted the General Provision M rate adjustment under the City's Water Rate Ordinance, subject to the customer having complied with best management practices for irrigation approved by LADWP.
	No watering or irrigation of any lawn, landscape, or other vegetated area shall occur in a manner that causes or allows excess or continuous water flow or runoff onto an adjoining sidewalk, driveway, street, gutter, or ditch
	No installation of single-pass cooling systems shall be permitted in buildings requesting new water service.
	No installation of non-recirculating systems shall be permitted in new conveyor car wash and new commercial laundry systems.
	Operators of hotels and motels shall provide guests with the option of choosing not to have towels and linens laundered daily.
	No large landscape areas shall have irrigation systems without rain sensors that shut off the irrigation systems.
II	All prohibited uses in Phase 1 shall apply, except as provided.
	No landscape irrigation shall be permitted on any day other than Monday, Wednesday, or Friday for odd-numbered street address and Tuesday, Thursday, or Sunday for even-numbered street addresses. If a street address ends in 1/2 or any fraction it shall conform to the permitted uses for the last whole number in the address. For non-conserving nozzles (spray head sprinklers and bubblers) watering times shall be limited to no more than 8 minutes per watering day per station for a total of 24 minutes per week. For conserving nozzles (standard rotors and multi-stream rotary heads watering times shall be limited to no more than 15 minutes per cycle and up to two cycles per watering day per station for a total of 90 minutes per week.
	Irrigation of sports fields may deviate from non-watering days to maintain play areas and accommodate event schedules with written notice from LADWP. However, a customer must reduce overall monthly water use by LADWP's Board of Water and Power Commissioners adopted degree of shortage plus an additional 5% from the customer baseline water usage within 30 days.

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	If written notice is received from LADWP, large landscape areas may deviate from the non-watering days if the following requirements are met: 1) approved weather-based irrigation controllers registered with LADWP 2) Must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus and additional 5% from the customer baseline within 30 days 3) Must use recycled water if available
	These restrictions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase II, except between the hours of 9am and 4pm.
III	All prohibited uses in Phases I and II shall apply, except as provided.
	No landscape irrigation shall be permitted on any day other than Monday for odd-numbered street address and Tuesday for even-numbered street addresses. If a street address ends in 1/2 or any fraction it shall conform to the permitted use for the last whole number in the address.
	No washing of vehicles allowed except at commercial car washes.
	No filling of residential swimming pools and spas with potable water.
	Irrigation of sports fields may deviate from non-watering days and be granted one additional watering days for a total of two watering days with written notice from LADWP. However, a customer reduce overall monthly water use by LADWP's Board of Water and Power Commissioners adopted degree of shortage plus an additional 10% from the customer baseline water usage within 30 days.
	If written notice is received from LADWP, large landscape areas may deviate from the non-watering days and be granted one extra day of watering for a total of 2 watering days if the following requirements are met: 1) approved weather-based irrigation controllers registered with LADWP 2) Must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus and additional 10% from the customer baseline within 30 days 3) Must use recycled water if available
	These restrictions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase III, except between the hours of 9am and 4pm.
IV	All prohibited uses in Phases I, II, and III shall apply, except as provided.
	No landscape irrigation is allowed.
V	All prohibited uses in Phases I, II, III, and IV shall apply, except as provided.
	The LADWP Board of Water and Power Commissioners is authorized to implement additional water prohibitions based on the water supply situation.

Specific procedures for determining the initiation of a phase and termination of a phase are provided in the Emergency Water Conservation Plan Ordinance. Phases are initiated through recommendations provided by LADWP to the Mayor and City Council (Council).

3.2.2 Conservation Pricing

In 1993, Los Angeles restructured its water rates to provide customers with a clear financial signal to use water more efficiently. It was the first time in LADWP's history that an ascending tiered rate structure was used. This conservation-based rate structure remains in use and applies a lower first tier rate for water used within a specified allotment, and a higher second tier rate for every billing unit (748 gallons) that exceeds the first tier allotment. A unique feature of the rate structure is that the first tier allotment considers factors that influence individual residential customer's water use patterns (i.e. lot size, climate zone, and family size).

The goals of LADWP's two-tiered water rate structure are to:

- Use price as a signal to encourage the efficient use of water

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- Provide basic water needs at an affordable price
- Provide equity among customers
- Use price to stabilize water use during a shortage
- Generate adequate revenue for maintaining and upgrading the water system

In a period where increasing demands and reductions in water supply are becoming more commonplace, a rate structure that provides appropriate signals to encourage efficient water use has become a necessity for many areas, including Los Angeles.

The substantial investments required for water quality improvements, security, and supply development have significantly raised the cost of delivering water. As rates increase, water agencies have noticed a change in use patterns. Because there is a known correlation between price and use, agencies use rates to encourage conservation activities and to postpone the need to construct new facilities or purchase even larger quantities of imported water.

LADWP's tiered rate structure, first implemented in 1993 with assistance from a broad-based group of stakeholders, applies a lower tier block rate for responsible water use within a specified amount of water, and a much higher rate for every billing unit above this block. The higher block rate reflects the "marginal cost," or the projected cost for additional water that would be required to meet these needs.

To further emphasize the conservation message, water charges are based solely on water used. This eliminates the inclusion of fixed charges. There are automatic adjustments triggered when a water shortage exists. In June 2009 shortage year rates went into effect reducing first tier allotments for all customers by 15%. These adjustments are based on the actual water use patterns that occurred during the 1991 period of mandatory water rationing. The purpose of these adjustments is to use price to encourage additional conservation and to provide LADWP with the revenue necessary to operate the system efficiently during a shortage.

3.2.3 CUWCC Best Management Practices

The CUWCC is the voice of urban water conservation in California, and LADWP has been active in the CUWCC since its inception in 1991. Instrumental in the development of the MOU, LADWP was also one of the original signatories. The MOU identifies BMPs as proven conservation measures as determined by the CUWCC. The most recent amendment to the MOU was adopted on June 9, 2010 updating compliance alternatives with the adopted BMPs. A water agency can now comply with the MOU through one of three methodologies: BMP compliance, accomplishing water conservation through a set of measures equal or greater than the water savings provided by the BMPs (Flex Track Menu), or accomplishing water conservation goals as measured in gpcd. All Group One (water suppliers) signatories to the MOU are committed to implement the BMPs.

Over the last 19 years, LADWP has played a significant role in the governance and policy making at the CUWCC, holding a seat on the Board of Directors, Strategic Planning Committee, By-Laws Committee, Research and Evaluation Committee, CII Committee, co-chair of the Membership Committee, and chair of the Group 1 Representation Selection Committee. LADWP also has been actively involved in all of the revisions that the MOU has undergone to date.

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One of the obligations as a signatory to the MOU is to submit a Best Management Practices Retail Water Agency Report to the CUWCC. Previously submitted annually, this report is now submitted biennially and details progress in implementing the foundational and programmatic BMPs as currently specified in the MOU. LADWP actively implements the BMPs and the CUWCC BMP reports are available for review through the internet by accessing CUWCC's website at www.cuwcc.org.

In the early 1990s, the State Water Resources Control Board identified urban water conservation as a major means for resolving problems in the Bay-Delta. Large water agencies, including LADWP, actively participated in work groups to develop conservation strategies. The result of this effort is in the aforementioned MOU.

The MOU commits signatory water suppliers to develop comprehensive conservation programs using sound economic criteria and to consider water conservation on an equal footing with other water management options. The MOU established the CUWCC to monitor implementation of the BMPs and to maintain the list of BMPs.

A BMP is defined as:

(a) An established and generally accepted practice among water suppliers resulting in more efficient use or conservation of water.

(b) A practice for which sufficient data are available from existing water conservation projects to indicate that significant conservation or conservation-related benefits can be achieved; that the practice is technically and economically reasonable and not environmentally or socially unacceptable; and that the practice is not otherwise unreasonable for most water suppliers to carry out.

LADWP implements all of the BMP requirements in the MOU except for wholesale agency assistance programs, which applies only to wholesale water agencies. Foundational BMPs are considered as essential BMPs for any water utility and are ongoing practices not subject to time limitations. Programmatic BMPs are minimal activities required to be completed by each utility within the timeframe of the implementation schedules provide in the MOU. A listing of the BMPs is shown in Exhibit 3F.

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Exhibit 3F
CUWCC BMPs and Implementation Status

Category	Sub-category	Practices	Status
		Foundational	
Utility Operations	Operations Practices	Maintain the position of a trained conservation coordinator	Implemented
		Prevent water waste – enact, enforce or support legislation, regulations, and ordinances	Implemented
		Wholesale agency assistance programs	Not applicable
	Water Loss Control	Conduct Standard Water Audit and Water Balance	Implemented
		Measure performance using AWWA software	Implemented
		Locate and Repair all leaks and breaks	Implemented
	Metering with Commodity Rates	100% of existing unmetered accounts to be metered and billed by volume of use	Implemented
	Conservation Pricing	Maintain a water conserving retail rate structure	Implemented
Education	Public Information Programs	Maintain active public information program to promote and educate customers about water conservation	Implemented
	School Education Programs	Maintain active program to educate students about water conservation and efficient water use	Implemented
		Programmatic	
Residential		Residential Assistance – provide leak detection assistance	Implemented
		Landscape Water Surveys for single family residential accounts	Implemented
		High efficiency clothes washer incentive program	Implemented
		WaterSense Specification (WSS) for toilets	Implemented
Commercial/ Industrial/ Institutional (CII)		Implement unique conservation programs to meet annual water savings goals for CII customers	Implemented
Landscape		Implement Large Landscape custom programs	Implemented
		Offer technical assistance and surveys upon request	Implemented
		Implement and maintain incentive program(s) for irrigation equipment retrofits	Implemented

3.2.3 LADWP Conservation Programs

LADWP develops cost effective programs to achieve multiple goals of cost-effective demand reduction, customer service, environmental responsibility, and compliance with CUWCC BMPs. Conservation potential is considered in determining program approach and duration. Some types of conservation programs result in savings that are more easily measured than others. LADWP's programs include traditional demand-side management measures, as well as infrastructure improvement programs that contribute to water waste reductions. Demand-side management programs, like the rebate programs for water-saving toilets and high-efficiency washing machines, produce results that are measurable. Public information, education, and other general conservation awareness programs are intended to alter customers' behavioral patterns on water use and thus, are more difficult to quantify. It is such behavioral change in water use, however, that the City can point to as the primary reason for significant reduction in water consumption during drought periods. Combined with LADWP's conservation pricing

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structure discussed in Section 3.2.2, these programs increase system reliability and efficiency and will provide a secondary benefit of reducing runoff.

Specific conservation programs (past and present) associated with these categories are broken down in Exhibit 3G, and are fully discussed below. Appendix XX contains the latest biennial reports provided to the CUWCC.

Exhibit 3G
Current and Past Conservation Programs

CUWCC Category	Conservation Measures	pre 1985	Year in Service
	Awareness/Support		
	Pricing		
Utility Operations - Pricing and Operations	Tiered Rate Structure		2009
Utility Operations - Metering	Full Metering and Volumetric Pricing	x	
Utility Operations - Pricing	Sewer Charge using Volumetric Pricing	x	
Education - Public Information Programs	**Public Information**		
	Drought Response Outreach		2008
	Hotel & Restaurant Water Conservation Campaign		2008
	ULFT Customer Satisfaction Survey		1992
	Advertising	x	
	Bill Inserts	x	
	Brochures	x	
	Community Involvement Program	x	
	Exhibits	x	
	Hotline	x	
	Speakers Bureau	x	
	School Education		
	LAUSD MOU		2008
	High School in concert with the Environment - Student Home Water/Energy Survey		1994
	Lower Elementary	x	
	Upper Elementary	x	
	Junior High	x	
	Residential		
Residential	Residential Drought Resistant Landscape Incentive Program		2009
Residential	High Efficiency Clothes Washer Incentive Program		1998
Residential	Better Idea/Neighborhood Bill Reduction Service Program --Showerhead installation		1993
Residential	Community-Based Organization Toilet Distribution Centers, Direct Install		1992
Residential	High Efficiency Toilet Rebate		1990
Residential	Home Water Surveys		1990
Residential	Retrofit Kits Distribution		1988

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Commercial/Industrial/Government			
Commercial/Industrial/Institutional	Commercial/Industrial Drought Resistant Landscape Incentive Program		2009
Commercial/Industrial/Institutional	Water Efficiency Requirements Ordinance		2009
Commercial/Industrial/Institutional	General Services Dept. MOU to Retrofit Plumbing		2009
Commercial/Industrial/Institutional	Public Agency Plumbing Audit and Training Program		2009
Education - Public Information Programs	Targeted Literature Mailing		1993
Commercial/Industrial/Institutional	Commercial/Industrial Conservation Guidebook		1992
Commercial/Industrial/Institutional	Cooling Tower Manual and Workshops		1992
Commercial/Industrial/Institutional	Commercial Rebate Program		1991
Commercial/Industrial/Institutional	Interior Water Use Audits		1991
Commercial/Industrial/Institutional	Technical Assistance Program (TAP)		1991
Landscape; Commercial/Industrial/Institutional	Typical Audits		1991
Landscape			
Landscape	Recreation and Parks MOU		2007
Landscape	Large Turf Irrigation Controller Pilot Program		2000
Landscape	Protector del Agua – English and Spanish Language Workshops		1995
Landscape	Improving Irrigation Performance Manual & Workshop		1993
Landscape	Large Turf Audits and Audit Training		1993
Education - Public Information Programs	Lawn Water Guide Direct Mailing (as requested)		1989
Education - Public Information Programs	Demonstration Gardens		1988
Landscape	Ten Percent Large Turf Water Reduction Program		1988
System Maintenance Measures			
Utility Operations - Water Loss Control	Fire Hydrant Shutoffs		1991
Utility Operations - Water Loss Control	Meter Replacement Program		1988
Utility Operations - Water Loss Control	Cement Mortar Lining of Pipelines	x	
Utility Operations - Water Loss Control	Corrosion/Cathodic Protection	x	
Utility Operations - Water Loss Control	Infrastructure Program	x	

Awareness/Support Measures

Awareness/support measures can be active or passive. Active components include full metering of water use, assessment of volumetric sewer charges, and a conservation rate structure. Passive components typically include providing educational materials for schools, community and customer presentations, maintaining a conservation hotline, and a wide range of information distributed through customer bills, advertising in public venues, LADWP's website, and direct mail. Passive awareness/support measures provide the foundation for the conservation movement to build upon by raising water use awareness, water conservation program visibility, and encouraging community involvement.

In 2008, LADWP entered into an MOU with the Los Angeles Unified School District to further improve our water conservation outreach program. In fiscal year 2009/2010 LADWP budgeted approximately $500,000 in funding for educational programs within area schools. Programs included:

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- Los Angeles Times in Education – provided newspapers to 50,000 students in grades 4-12 and lesson packages for teachers on supply sources and conservation
- "Thirsty City" Live Performances – Play presented to more than 4,300 students introducing students to water supply sources, water supply challenges, and conservation
- Renewable Energy and Conservation Curriculum – 660 teachers were trained in an extensive model conservation program reaching approximately 50,000 6th grade students
- Renewable Energy and Conservation Center – Funding was provided for a science teacher position to set up and establish a Renewable Energy and Conservation Center with students to be bused to center for hands-on lessons focusing on conservation and renewable energy
- Outdoor Education Multi-Day Environmental Experiences – Approximately 700 students in 20 classes in grades 4-12 attended two or three days of outdoor education experiences focusing on environmental measures, including lessons on energy and water
- Eastern Sierra Institute – Training of 25 teachers over three days about the environment and geology of the Eastern Sierra
- Teacher Fellowships – Ten math and science teachers from middle and high schools served in fellowships at LADWP for six weeks during the fall and summer of 2008 working in multiple offices with the intent of developing classroom lessons based on the experiences.
- Infrastructure Academy – 40 students from the Infrastructure Academy completed water conservation audits at 120 schools, including fixture counts, analysis of toilet makes and models, and analysis of irrigation controllers and field conditions

Included within the short-term strategies of the City of Los Angeles' Water Supply Action Plan is a strategy to increase water conservation in the City through an aggressive $2.3 million conservation education campaign. LADWP Public Affairs Office implemented a media campaign that included radio, TV, and newspaper advertisements, billboards, outreach to Neighborhood Councils; and marketing of City rebates for water-efficiency.

Another aspect of awareness/support is that of advocacy. LADWP has been instrumental in the development of more stringent standards for toilets (e.g. Supplementary Purchase Specification for ULF toilets) that are in use within the City as well as by other water agencies in California and other areas. LADWP also assisted in the adoption of higher residential clothes washer efficiency standards by the California Energy Commission. Recognizing the importance of this activity, LADWP actively participates in advocating local and statewide conservation research and planning.

Residential Category

Multiple residential conservation programs were first developed and launched by LADWP during the drought of 1987 through 1992. In 1990, the ULF Toilet Rebate Program was initiated, followed two years later by the ULF Toilet Distribution Program. In 2003, a well-received free installation service component was added to the ULF Toilet Distribution Program that included

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free water-saving showerheads, faucet aerators and replacement toilet flapper valves. Today distribution of free faucet aerators and showerheads continues for all single-family, multi-family, and commercial customers.

In 2008 MWD initiated the region-wide SoCal Water$mart Program for residential water conservation replacing previous LADWP rebate programs and rebate programs offered by individual water service providers throughout the MWD service area. This program sponsored by MWD sets uniform rebate requirements across the MWD service area and provides a clearinghouse for processing rebates for all MWD member agency customers. Local agencies have the option of supplementing baseline rebate amounts to their customers through the program. LADWP has increased baseline rebates for several of the qualifying products. Eligible customers include residential customers residing in single-family and multi-family homes, even if multi-family residents do not receive a water bill.

Although the SoCal Water$mart Program has discontinued rebates for high efficiency toilets (HET), LADWP continues to provide local funding for rebates for its customers of $100 per HET which has proven to be highly successful with over 1900 units installed in fiscal year 09/10 which equates to over 80 AFY savings.

Prior to the SoCal Water$mart Program, LADWP was assisted by community-based organizations (CBOs) to reach the milestone of more than 1.27 million toilets installed through December 31, 2006. CBOs were integral to LADWP's success, reaching into the communities they serve to convey the conservation message and directly undertake conservation activities. Benefits of this approach accrued to community participants through reduced water bills, to the CBOs through employment opportunities and revenues earned, and to the City through significant water savings achieved. Prior to its discontinuation, the program was funded at more than $7 million annually. The toilets replaced through the program continue to produce estimated water savings of more than 20,600 AFY today.

LADWP initiated a High Efficiency Washer Rebate Program in 1998 promoting the purchase and installation of high efficiency washing machines saving both water and energy. As of January 2009, rebates have been paid for more than 66,100 machines purchased and installed throughout the City. The program's minimum efficiency requirements for rebate eligibility were increased in January 1, 2004, resulting in the promotion of higher efficiency models. Initial co-funding of the program was provided by the City's Department of Public Works Bureau of Sanitation, and by the Southern California Gas Company.

In February of 2009 the High Efficiency Washer Rebate Program transferred from LADWP to the SoCal Water$mart Program with co-funding provided by MWD. Since the inception of the SoCal Water$mart Program and through June 2010, over 11,800 rebates for washing machines were issued to LADWP customers with a total annual savings of 368 AFY. Generally rebates are $300 per washing machine with a water factor (a measure of efficiency) of 4.0 or less. As of April 22, 2010 an additional $100 rebate was available for a limited time through the California Cash for Appliances program for a total rebate of $400 per washing machine.

A sprinklerhead rotating nozzle retrofit rebate of $8 per nozzle is available through the SoCal Water$mart Program for a minimum of 25 nozzles. Replacing standard sprinkler heads with rotating nozzles can use up to 20% less water. Rotating nozzles are able to distribute water in a water-efficient manner more uniformly across a landscape than standard sprinklers. Spray from rotating nozzles is less likely to result in misting conditions, misdirection from winds, and reduces runoff onto pervious surfaces thus reducing dry-weather runoff. Between March 2009 and June 2010 2,878 rotating nozzle rebates were issued to LADWP customers saving approximately 12.7 AFY.

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Rebates for installation of weather-based irrigation controllers are also available through the SoCal Water $mart Program. Rebates amounts are $200 per controller for landscape areas of less than one acre and $25 per station for landscape areas greater than one acre. Weather-based irrigation controllers provide customized irrigation schedules based on local site conditions and in response to weather changes. These smart controllers receive weather updates to automatically adjust the schedule and amount of water applied. Between March 2009 and June 2010 81 LADWP customers received rebates for installation of the controllers saving approximately 6.2 AFY.

Initially a synthetic turf rebate program was offered through the SoCal Water$mart Program, but has been discontinued as of June 1, 2010. The program provided rebates of $1.00 per square foot. Approximately 316,547 square feet of synthetic turf was installed by LADWP customers between February 2009 and June 2010 saving approximately 44.3 AFY.

LADWP through the SoCal Water$mart program is offering turf removal rebates of $1 per square foot up to $2,000 per residence. Not all MWD member agencies are participating in the turf removal program and participating agencies have additional requirements beyond MWD's requirements. Areas targeted for turf removal must currently be turf irrigated with potable water for a minimum of one year. All replacement materials must be permeable and either hand watered or irrigated with drip irrigation. A minimum of 250 square feet must be converted to be eligible for a rebate. No invasive plants are permitted and all exposed soil must be covered with mulch. Synthetic turf is an acceptable replacement if it is not used in right of ways or parkways. Applicants are required to maintain the converted area for ten years. The program commenced in December 2009, and as of fiscal year 09/10, over 280,000 square feet of turf area has been converted saving over 39 AFY. In conjunction with the turf removal program, LADWP is conducting a drip system pilot program and is offering free residential drip starter kits.

Water-saving showerheads and faucet aerators remain available to LADWP customers, free of charge, upon request. Approximately 12,124 showerheads and 14,792 faucet aerators were distributed between July 2007 and June 2010 saving approximately 241 AFY. During past droughts, more than 1.5 million water conservation retrofit kits were distributed throughout Los Angeles; the kits included one-gallon toilet displacement bags, low-flow showerheads, and toilet leak detection tablets.

As part of past programs promoting residential water conservation measures, students conducted home water surveys through a resource efficiency education program implemented by LADWP in Los Angeles area high schools. Additionally, local community based organizations visited many Los Angeles residences throughout the year, assessing water conservation opportunities in the home and installing applicable measures to immediately capture water savings.

Another element of LADWP's past efforts was a toilet flapper valve replacement pilot program. Although long-term water savings from ULF toilets are predicated on timely replacement of leaking toilet flapper valves with appropriate replacement units, findings from the pilot program indicate a small incidence of leaking flapper valves in toilets rebated or distributed by LADWP. However, toilet leak testing and flapper valve replacement was added to the past ULF Toilet Distribution Program's installation service component for toilets not replaced through the program.

Commercial/Industrial/Institutional Category

This category represents some of the largest volume water users in LADWP's customer base, and represents a great deal of conservation potential. LADWP, in partnership with MWD, developed and has implemented a commercial rebate program, Save Water Save a Buck Program, designed specifically for customers in the CII sector and multi-family residences with five

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or more units represented by a homeowners association. In the CII sector, the program provides rebates for water saving plumbing fixtures, food service equipment, and landscaping equipment. Within the multi-family sector the program provides rebates for high efficiency washers, high efficiency toilets, and landscape equipment. In addition, packaged water use efficiency solutions are being developed for specific business sectors. Efforts are also underway to better promote the financial incentives available that make water conservation retrofits more cost effective for business and industry. LADWP takes full advantage of regional programs offered through MWD for the CII sector and for many product rebates, provides supplemental funding to boost the base rebate provided by MWD.

The Save Water Save a Buck Program was launched in 2001 to provide menu-based rebates for water conserving measures applicable to many types of CII facilities. Categories of products eligible for rebates, rebate amounts, number of rebates for the LADWP service area, and estimated savings are provided in Exhibit 3H for the period July 2007 through June 2010. During the period, an estimated annual savings of 6,585 AFY, inclusive of LADWP inhouse programs and the Technical Assistance Program (TAP). The program design provides for ease of participation and has been well-received by LADWP customers. The program has been so successful that the SoCal Water$mart Program for residential customers was modeled after it.

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Exhibit 3H
CII Conservation Programs and Savings July 2007 through June 2010

Device Type	Rebate Amount Retrofit	Devices Installed	Estimated Annual Savings (AFY)
Save Water Save a Buck Program			
Current Programs			
High Efficiency Toilets (1.28 gpf or less)	$150 each ($50 new construction)	58,432	2,408.6
Zero and Ultra Low Water Urinals	$500 each ($250 new construction)	6,063	630.9
Cooling Tower pH Conductivity Controller	$3000 each	41	79.7
Cooling Tower Conductivity Controller	$625 each	57	36.7
Air Cooled Ice Machine	$300 each	0	0.0
Connectionless Food Steamer	$600 compartment	23	5.8
Dry Vacuum Pump (maximum 2.0 horsepower)	$125 per 0.5 horsepower	8	0.7
Water Broom	$150 each	73	11.2
Weather Based Irrigation Controller	$50 per station	391	127.1
Central Computer Irrigation Controller	$50 per station	0	0.0
Rotating Nozzles for Pop-up Spray Heads (25 minimum)	$8 each	22,534	99.1
High Efficiency Spray Nozzles for Large Rotary Sprinklers	$13 per head	8,558	308.1
Past Programs			
High Efficiency Coin Clothes Washer	-	1,738	186.8
Pre-Rinse Sprayhead	-	5	0.8
Steam Sterilizer Retrofit	-	6	7.8
X-Ray Processor Recirculation System	-	1	3.2
Synthetic Turf (square feet)[1]	-	15,177	2.1
Subtotal Save a Buck Program	-		**3,908.7**
LADWP Inhouse Programs			
Commercial Showerheads	-	5,180	85.3
Commercial Faucet Aerators	-	20,844	96.5
Water Brooms	-	262	40.2
CII Landscape Program Turf Removal[2]	-	1,251,043	95.6
Technical Assistance Program[3]	-	-	2358.4
Subtotal LADPW Inhouse	-		**2676.0**
Total CII	-		**6584.8**

1. Synthetic Turf rebates as of June 1, 2010 are available through LADWPs Technical Assistance Program.

2. Rebate amount varies and is determined during pre-approval process.

3. Rebates for Technical Assistance Program are $1.75 per 1,000 gallons saved over a two year period with a cap not to exceed the actual cost of the project. Devices installed vary per project.

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LADWP created the Technical Assistance Program (TAP) in 1992 to provide custom-type incentives for retrofitting water-intensive equipment. Different from the Save Water Save a Buck Program, the TAP encourages site-specific projects and TAP incentives are based on a given project's water savings. Financial incentives up to $250,000 are available for products demonstrating water savings. Incentives are calculated at the rate of $1.75 per 1,000 gallons saved over a two-year period with a cap not to exceed the actual cost of the installed product. Projects must save a minimum of 150,000 gallons over a two-year period and operate for a minimum of five years. Eligible customers are CII or multi-family residential customers. Past TAP projects include cooling tower controller upgrades and x-ray processor recirculation systems. The estimated unit cost for TAP overall is about $228 per acre-foot saved with an annual savings of 2,358.4 AFY based on projects installed between July 2007 and programs until June 2010.

Similar to the residential turf removal program, LADWP has a turf removal program for commercial properties. This program started in September 2009 and the rebate is $1.00 per square foot of turf with the total project rebate amount as defined in the pre-approval letter provided by LADWP. Areas targeted for conversion must have live healthy turf irrigated with potable water (recycled water is ineligible) via automatic sprinkler valves when a project approval letter is provided by LADWP. Converted areas must contain enough plants to create at least 30% landscape coverage at maturity. Converted areas may not contain turf or synthetic turf (synthetic turf rebates are available through the TAP). All replacement materials must be permeable and plants must be drought tolerant or California native plants. A minimum of 250 square feet must be converted to be eligible for a rebate. No invasive plants are permitted and all exposed soil must be covered with three inches of mulch. If an irrigation system is used it must be a low flow drip or bubbler system. Applicants are required to maintain the converted area for 15 years.

Water-saving showerheads and faucet aerators are available to LADWP commercial customers, free of charge, upon request. Bathroom faucet aerators are provided in 1.5, 1.0, or 0.5 gallons per minute (gpm), kitchen faucet aerators are provided in 1.5 gpm, and showerheads are provided in 2.0 gpm. Approximately 5,180 showerheads and 20,844 faucet aerators were distributed between July 2007 and June 2010 saving approximately 181.8 AFY combined. LADWP additionally offers an inhouse water broom program in addition to the rebates offered through the Save Water Save a Buck Program.

Landscape Category

Recognizing that a substantial amount of water is used outdoors for irrigation, LADWP continues to invest in landscape irrigation efficiency programs and projects. In addition to the previously discussed landscape ordinances (Section 3.21.), LADWP has sponsored free training courses specifically targeting the City's large turf customers to help these customers comply with the landscape ordinance. To further assist this group, LADWP developed a guidebook, "Improving Irrigation Performance" to demonstrate ways for enhancing existing irrigation systems.

LADWP has also sponsored conservation and garden expos to highlight various aspects of efficient outdoor water use and planting practices, and emphasizing native, drought-tolerant plants. Funding was provided for three demonstration gardens to showcase the use of drought-tolerant plants and flowers, including the landmark Lummis Home in Highland Park. Lawn watering guides were mailed to all single-family and duplex residences. Planting guides for native and drought-tolerant plants are also available upon request. Additionally, to demonstrate the beauty and appeal of a water-conserving landscape, LADWP's John Ferraro Building facility (below) has a drought-tolerant garden that is open to visitors year-round.

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In addition to the Residential and Commercial Landscape Incentive Programs for turf removal, other types of landscape irrigation improvement projects are also funded through the TAP, with incentives calculated on the basis of a project's water savings. LADWP staff includes certified landscape auditors, and large landscape audits are available upon request.

LADWP is also investigating new programs using data obtained through pilot program efforts. A pilot program was conducted to determine the effectiveness of weather based irrigation controllers in large landscape applications. On the basis of the pilot program results showing water savings, financial incentives are available to LADWP customers for the purchase and installation of weather based irrigation controllers through the SoCal Water$mart and Save Water Save a Buck Programs. Additional efforts are being undertaken to make available a landscape irrigation education program for homeowner associations and other large landscape customers. This program would focus on common green areas in multi-unit complexes to improve irrigation efficiency, including irrigation system maintenance and repair, and plant selection.

LADWP has been implementing an internal program to retrofit outdoor landscaping at department-owned facilities to California-friendly and native plantings with efficient irrigation systems. Additionally, a joint effort between the Department of Recreation and Parks and LADWP is targeting public parks through the City Park Irrigation Efficiency Program. City parks with inefficient irrigation systems, leaks, and runoff problems are identified and upgraded with water efficient distribution systems and sprinkler heads, installation of smart irrigation controllers, and planting of California-friendly landscaping. Since the program began in 2007, seven parks have been completed and 4 new weather stations have been installed. An additional benefit of this program is the educational, trade training, and employment opportunity given to the youth of Los Angeles.

There is also potential for the use of non-potable water for irrigation, which can help extend the utility of the City's traditional water supplies. Through increased stormwater capture, groundwater recharge with captured storm and irrigation runoff, and recycled water, imported surface water and local groundwater used for landscape irrigation can be conserved. The potential to use such non-potable water supplies is further discussed in the Recycled Water and Watershed Management chapters (Chapters 4 and 7 respectively).

New Low Impact Development (LID) projects implemented within the City and innovative work by non-profit organizations demonstrate pioneering ways to conserve water for landscapes. As discussed in Chapter 7, LADWP's Watershed Management Group is proactively developing programs in conjunction with other departments to highlight water conservation through LID and implementing stormwater Best Management Practices (BMPs). A local non-profit, TreePeople, has partnered with various City departments, including LADWP on a number of stormwater capture projects.

For over a decade, TreePeople has demonstrated that rainwater is a viable local water resource. The Open Charter Elementary School Stormwater Project is one of several sustainable stormwater management systems that TreePeople installed in Los Angeles. Other examples include: the Center for Community Forestry which harvests rainwater from its entire hardscape into a 216,000 gallon underground cistern for landscape irrigation use; a retrofitted single family residential home in South Los Angeles that captures a 100 year storm event on site; a 7,600 square foot subsurface stormwater infiltration gallery on the Broadous Elementary School campus in Pacoima. Most recently, TreePeople partnered with the Los Angeles and San Gabriel Rivers Watershed Council, LADWP, and other state and federal agencies to retrofit an entire residential block on Elmer Avenue in Sun Valley. This project now intercepts stormwater from 40 acres upstream and infiltrates it back to the aquifer while also demonstrating effective distributed stormwater BMPs on residential homes.

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In partnership with the Los Angeles County Department of Public Works, TreePeople was instrumental in developing the Sun Valley Watershed Management Plan: an alternative stormwater management plan that prioritizes green infrastructure and multi-benefit stormwater capture projects instead of stormdrains. Many projects have been completed, and more are scheduled for construction. These activities create the foundation that will lead to further landscape water conservation and stormwater capture to enhance the City's limited water supplies.

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CASE STUDY:
Los Angeles River Revitalization and the North Atwater Park Project

Background

The Los Angeles (LA) River flows 51 miles through some of the most diverse communities in Southern California—its first 32 miles are within the City of LA. The River has a year-round low flow due to contributions from upstream wastewater treatment plants, urban runoff, groundwater inflow, and natural springs, but can become a torrent of racing flows during the rainy season. The River is almost entirely concrete-lined except for a few reaches. Although the design of the River has served its flood control purpose, the River holds far greater potential to serve as a focal point for environmental restoration, economic growth, community revitalization, and recreation.

Realizing that the River should stand as a symbol of pride for the City of LA and its residents and that it should be a landmark for the public to enjoy and admire, the LA City Council established the Ad Hoc Committee on the River in 2002 and adopted the LA River Revitalization Master Plan (LARRMP) in 2007 (www.lariver.org). Led by the City's Bureau of Engineering and funded by the LA Department of Water and Power, the LARRMP was created through a collaboration of elected officials, city departments and agencies, residents, multi-disciplinary experts, and a wide variety of private and non-profit environmental and recreational groups as the 25-to-50 year blueprint for transforming the City of LA's stretch of the River into an extensive network of parks, walkways, bike paths, and diverse land uses that will ensure the growth and sustainability of healthy communities.

Key Features

In October 2010, the City celebrated the groundbreaking of the North Atwater Park Expansion and Creek Restoration project as the first project to emerge from the LARRMP, which is expected to be open to the public by December 2011. The project was undertaken in connection with the settlement of two Clean Water Act enforcement action, Santa Monica Baykeeper v. City of Los Angeles and United States, and State of California ex. Rel. California Regional Water Quality Control Board, Los Angeles Region v. City of Los Angeles and also funded in part by Proposition 50 through the California Resources Agency to improve River Parkways and the Integrated Resources Water Management. The project will use both structural and natural solutions to restore a degraded creek that is a tributary of the River while also expanding River-adjacent parkland with multiple recreational, wildlife habitat, and water quality benefits. The project will add nearly 3 acres to an existing 5-acre City park, connecting it to the River, where visitors will enjoy watching a wide variety of bird species that presently live in that soft-bottomed stretch of the River, framed by stunning views of Griffith Park in the distance. Some of the project's highlights include:

Outdoor Classroom

The project will encourage young children to explore nature via an educational gathering space near the LA River. This "outdoor classroom" will feature a nature-based art area for independent and guided activities—designed particularly for local students to learn about nature, native plants, and the opportunities and challenges associated with revitalizing the LA River.

Native Demonstration Garden

The park's central focus will be a demonstration garden, which will contain a variety of native plants that are used throughout the park, with interpretive displays to educate visitors about the plant species' characteristics, care, and relationship to water conservation. The park will only include native plants because they are considered "drought-tolerant" given their abilities to thrive in Southern California's climate, requiring much less water than other plants. The park's landscape design aims to set an example in the use of such plants, but also to educate the public on the merits of embracing native vegetation as an important component of solving the region's water crisis.

Creek Restoration

North Atwater Creek currently conveys polluted runoff to the River from an upstream stormdrain system that receives flow from a 40-acre urban area. The Creek will be restored and landscaped with native plants to prevent erosion and to naturally filter stormwater before it is discharged to the River, featuring a 1000-foot-long meandering streambed sustained by intermittent street runoff flows. Water quality improvements will include installation of a device at the entrance of the creek to intercept and capture trash and bacteria and special treatment of flows from adjacent equestrian facilities.

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Accommodating Visitors

While the park's landscape design capitalizes on the opportunity to educate visitors about the many connections between urban life, nature, and water, its structural features do also. For example, the parking lot will be transformed by installing a gravel bioswale along the borders and replacing existing parking spaces with permeable surfaces. These changes will not only address surface water contamination, but also allow stormwater to infiltrate so that it will assist with groundwater augmentation.

Summary

The North Atwater Park project will utilize innovative Low Impact Development (LID) and Best Management Practice (BMP) technologies to simultaneously achieve a variety of benefits, including responsible water conservation, improved water quality, expanded wildlife habitat connectivity, co-located multi-generational recreation, and public education.

The park's goals recognize that, while it is important to transform the existing park into a beautiful, scenic landmark and natural resource, it is equally important to educate the public about the huge potential such achievements have in encouraging wiser water use practices. Fundamentally, the park is about water—respecting LA's water supply and celebrating the River—by simultaneously improving the survivability of our wildlife and human habitat. North Atwater Park is an example of what can happen when public agencies and residents tackle complicated problems with creative planning and successful collaboration.

"The LA River cause is reaching more and more people every day. We are incredibly encouraged by the USEPA's July 2010 decision regarding the River's federal protection status and particularly because of the context in which it was announced—President Obama's America's Great Outdoors initiative is exactly the kind of support we need now and the visit of so many distinguished Administration officials to the River reinforces the belief that the River is important to millions of people here and across the country."

Carol Armstrong, Ph.D., Environmental Supervisor, Project Manager, LA River Project Office

"The City's commitment to LA River revitalization has only gained in momentum over the years and we have now reached an important crossroads for answering the big questions—such as how to capture and reuse storm flows, how to expand our recycled water uses, how to ensure we have enough water to maintain critical wildlife habitat, and how much flood capacity can we add? The River is central to each and every one of the answers."

Larry Hsu, P.E., Senior Civil Engineer, Project Manager, LA River Project Office

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System Maintenance Category

Maintaining system infrastructure reduces water waste and allows for greater water accountability. Infrastructure maintenance is a high priority for LADWP. On-going programs such as pipeline replacement, pipeline corrosion control, and meter replacement preserve the operational integrity of City water facilities, and aims to reduce unaccounted water losses.

In recent years, the LADWP has ramped up its pipeline replacement program from 70,000 LF annually to 130,000 LF annually. LADWP has also made significant progress in replacing and/or retrofitting water meters through its meter replacement program that started in 1988. As a result of extended flow or usage, the moving parts in a water meter can wear down and begin to under-register the actual water consumption. The meter replacement program has been valuable in ensuring the accuracy of the approximately 700,000 meters within the City. Recently, all of the large-sized meters (3-in and larger) in the system were replaced as part of a Large Meter Replacement Program, and the LADWP is also replacing 35,000 small meters annually.

3.3 Future Programs, Practices, and Technology to Achieve Water Conservation

LADWP, on its own, and in cooperation with other agencies continues to investigate future programs, practices, and technology to improve water conservation.

3.3.1 Graywater

As defined by State regulations, graywater is untreated household wastewater which has not come into contact with toilet waste or unhealthy bodily wastes. It includes water sources from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs. It specifically excludes water from kitchen sinks and dishwashers. Graywater is a drought-proof source of supply for subsurface landscape irrigation. Graywater regulations do not allow for its application using spray irrigation. Graywater is also not allowed to pond or runoff, discharge to or reach a storm drain system or surface water body, and is not permitted for irrigation of root crops or edible food crops that are directly in contact with the surrounding soil.

The Graywater Systems for Single Family Residences Act of 1992 legally incorporated the use of graywater as part of the California Plumbing Code. In September 1994, the City approved an ordinance that permitted the installation of graywater systems in residential homes. However, installing graywater systems under the Act was costly in terms of both installation and maintenance. To address the current water shortage and reduce water demands, emergency graywater regulations added Chapter 16A (Part I) "Nonpotable Water Reuse Systems" to the 2007 California Plumbing Code. These regulations were approved by California Building Standards Commission in 2009 and became effective on August 4, 2009. Further revisions were made to the regulations and the regulations became permanent on January 12, 2010 with an effective date of January 20, 2010. These new code changes allow the use of certain types of untreated graywater systems as long as specific health requirements are met as defined by the authority having jurisdiction. The ordinance can be acquired from the City of Los Angeles Department of Building and Safety (LADBS) website at the following link.

http://ladbs.org/LADBSWeb/LADBS_Forms/InformationBulletins/IB-P-PC2008-012Graywater.pdf

Graywater systems in residential buildings are regulated by LADBS. LADBS requires a plumbing permit prior to construction, reconstruction, installation, relocation, or alteration of any graywater systems, treated or untreated. As of fiscal year 2009-10,

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LADWP does not offer any rebates or incentives for graywater systems, but continues to assess the potential for this water conservation technology.

Untreated Graywater Systems

Untreated graywater systems are systems where graywater is collected from non-toilet and non-kitchen sources and is utilized without treatment, for uses such as landscape irrigation. According to a 1999 study prepared by the Soap and Detergent Association, the average untreated graywater system in the US uses 6.3 gallons per day. In a 2010 White Paper prepared by Bahman Sheikh, for the WateReuse Association, Water Environment Federation, and American Water Works Association the potential for graywater generation in 2030, adjusted for conservation devices, is estimated at approximately 75.5 gallons per household per day. Potentially 50 percent of indoor potable water use could be re-used as graywater. Multiple manufacturers have developed untreated graywater systems and many households have installed such systems. However, these systems are not typically monitored, thus health and safety risks associated with the products have not been determined.

Under the recently approved revisions to the graywater system regulation, LADBS does not require a permit for untreated graywater systems supplied by only a clothes washer in a one or two-family dwelling as long as the system does not require modification of existing plumbing. Multiple requirements must be met for a system to be exempt from a permit including, but not limited to:

- Discharge shall be released not less than two inches below the surface of rock, mulch, or soil;
- Designs shall incorporate a means to allow the user to divert flow to the disposal area or the building sewer;
- Design of the system shall not allow contact with humans or pets;
- Water from diapers or other similarly soiled or infectious garments shall be diverted to the building sewer;
- Hazardous chemicals from washing activities, such as soiled rags, shall be diverted to the building sewer;
- An operation and maintenance manual shall be provided and remain with the building.

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CASE STUDY:
Single-Family Home Graywater System

As a community environmental leader, Janie Thompson is taking extraordinary steps in efficient use of water and conservation. With the help of her husband, her household has become an excellent example of a rainwater capture residence, catching rain in 18 separate rain barrels with 60 gallons each. To save even more water, the couple is installing an impressive graywater network, distributing water to the furthest extent of their large 14,850 square foot property.

"In June 2009, when the Mayor announced the ordinance limiting watering to two days per week, we freaked out, and originally thought most of our landscaping would die. With all of our conservation, rainwater capture, and use of graywater, our usage has dropped from 117 hcf to around 54 hcf per month in the summer months. We couldn't be happier. It just goes to show you how much most people in the City over water." – Janie Thompson

Their existing graywater system currently uses the drainage pump from the clothes washer to pump water slightly up grade to tree and flower areas of the backyard. Upon exiting the washer, a 3-way valve reserves the option to divert washer effluent to the sewer system. The graywater piping travels beneath their raised foundation home, into the subsoil, and onto the areas it serves. Once construction is complete, all piping (left) will be buried with existing soil or mulch.

When the stream is pumped to the highest point of the yard, it is sent to numerous subsoil infiltration chambers, through a distribution system of 1" HDPE (High-density polyethylene) pipe. The infiltration chambers are made from 1 gallon paint buckets turned upside down with holes cut in the bottoms (below). The chambers allow for unobstructed exit flow and appropriate soil surface area for infiltration. In addition, they provide a significant volume for water storage during the surge of a pumped load of laundry. Plant roots are attracted toward these water outlets, essentially feeding on nutrients and organics in the graywater. The tops of the chambers are cutout for frequent access, and covered with mulch or stepping stone. The pipe exits can be checked as necessary to ensure free flow.

The next steps in the construction are connection of the bathtub and bathroom sinks. Effluent from these water sources will enter a surge tank and float switch assembly. A graywater dedicated pump will then automatically push water to existing and newly installed infiltration chambers throughout the yard.

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Graywater used from these indoor sources will provide two main benefits. It will displace water used for irrigation and prevent additional water from entering the sewer. This decreases the load on the City sewer system lowering the overall cost of treatment for the Bureau of Sanitation.

The water savings are approximated in the following table. Please note that the clothes washer is a high efficiency front loading model. Showers are estimated at 10 minutes long with a head using 2.5 gallons per min.

Yearly Water Savings				
Washer	14 gal/use	10 uses/wk	140 gal/wk	7,280 gal/yr
Bathtub	40 gal/person/day	3 people	840 gal/wk	43,680 gal/yr
Bath Sink	2 gal/person/day	3 people	42 gal/wk	2,184 gal/yr
			Total	53,144 gal/yr

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Treated Graywater Systems

Treated graywater systems treat water collected from non-kitchen and non-toilet sources for nonpotable reuse indoors and outdoors. Treated graywater systems for indoor use of graywater are not currently permitted by LADBS as there are no water quality standards nor mean to certify onsite treatment systems. Testing agencies are working to address safety concerns while manufacturers are working to improve the technology gap in the systems. Both manufacturers and testing agencies are working together to address gaps in standards to allow the future use of treated graywater for outdoor surface irrigation and for indoor uses in toilets and urinals.

The National Center for Disease Control and Prevention in conjunction with North Carolina State University is developing a program to examine the public health values and impacts associated with decentralized water reuse at eight project sites across the country. Under this program wastewater from homes would be treated to Title 22 standards as required by local health regulators. One of the proposed sites is located in Los Angeles County.

On the international level, treated graywater systems are used in both Europe and Australia. However, treated graywater systems in the United States are not common. A lack of accepted standards for graywater systems imposes a financial risk to companies manufacturing graywater systems. The International Association of Plumbing and Mechanical Officials (IAMPO) and NSF International are the two testing agencies working to develop standards for uniform treated graywater systems applicability in the US. LADWP is closely following the development of the NSF Standard 350 and IAPMO standards to ensure that once a set of standards have been approved by model codes and adopted by the Building Standards Commission, the citizens of Los Angeles can safely install treated graywater systems to maximize water reuse without any health and safety risks.

3.3.2 Demand Hardening

Although LADWP regularly assesses new water conservation opportunities, conservation programs may, at some point in time, diminish a customer's ability to further conserve water, in particular during short-term water supply shortages caused by droughts or other emergencies. This phenomenon is known as "demand hardening." The California Urban Water Agencies defines demand hardening as, "the diminished ability or willingness of a customer to reduce demand during a supply shortage as the result of having implemented long-term conservation measures." Long term conservation measures can include hardware conservation measures, such as the installation of high efficiency toilets and behavioral conservation, such as watering during specified periods of the day.

Demand hardening occurs when options available for reducing water use are limited as the customer base is saturated with hardware conversions causing efficient water usage patterns to prevail. During "dry" years, utility customers who have actively participated in water conservation programs can be disproportionately impacted by water reductions as there is a limited ability for further conservation. The impact of demand hardening would be most prevalent during water supply shortages where customers have already been implementing long-term water conservation measures. Proponents of demand hardening believe that implementation and saturation of new hardware-based conservation devices would generally not occur rapidly enough during a water supply shortage, such as a drought, to reduce short-term water use.

However, it can be argued that hardware-based conservation devices will continue to be developed, piloted and implemented, such as the previously discussed weather based irrigation controllers, thus improving the ability to further conserve in the future. During droughts, consumers will respond to the call for more conservation by behaviorally adjusting their water use

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through methods such as not leaving water running and taking shorter showers. Additionally, full saturation of current conservation devices has not occurred. For these reasons, others believe demand hardening is irrelevant and there is a continued need for aggressive conservation programs.

Full implementation of current conservation measures, including reducing leaks, has the potential to reduce per capita water demands even further. Past water conservation efforts have reduced water use within LADWP's service area even though the population has continued to expand as illustrated in Exhibit 3A. It is expected that future water conservation efforts will continue this trend as increased saturation of water saving hardware devices occurs and new hardware devices are developed.

Though not easily quantifiable, saturation of current water saving hardware devices and installation of future water saving hardware devices combined with potential demand hardening have the ability to impact demand forecasts. As a worst case scenario, demand hardening and its effects are considered in LADWP's water demand forecasts to ensure that the appropriate supply of water is planned for. However, LADWP will continue to maintain its aggressive water conservation program discussed within this section. In the future, LADWP's water demand forecasts will continue to be examined and adjusted accordingly to compensate for additional implementation of long-term water conservation measures as saturation increases and new technology results in new hardware devices.

3.3.3 Projected Water Conservation Savings

To assist in planning future water demands, meeting the Water Supply Action Plan goal, and complying with 20x2020 requirements, LADWP has taken numerous steps to project future water conservation savings by major customer classification for indoor and outdoor use.

Indoor and outdoor active conservation through 2035 has been estimated by major billing sectors as provided in Exhibit 3I. Values presented are cumulative year to year. The bulk of conservation is expected to occur in the indoor portion of the commercial/government sector followed by the industrial sector. Past conservation programs have heavily focused on residential conservation reflecting the smaller residential conservation projections. Residential conservation initially provided the greatest volume saved for the cost. Water use in the CII sector is varied and relatively more expensive to achieve than in the residential sector.

Exhibit 3I
Active Conservation Projections by Sector

Sector	Acre-feet per Fiscal Year				
	2014/2015	2019/2020	2024/2025	2029/2030	2034/2035
Single-Family Residential	3,416	5,882	8,349	10,815	12,249
Multi-Family Residential	871	1,504	2,137	2,770	3,150
Commercial/Government	7,969	16,000	24,030	32,061	39,629
Industrial	1,924	3,847	5,824	7,774	9,339
Total Active Conservation Projections	14,180	27,260	40,340	53,420	64,368

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To determine potential conservation savings for indoor water use in the CII sector, LADWP conducted a high-level study to first estimate CII water use for each subsector (e.g. hospitals, refineries, schools, business parks, restaurants, etc.) and indoor end-use (e.g., toilets, showers, kitchen, laundry, food processing, cooling/heating, etc.), and second determine the potential for indoor water savings for each subsector and end-use. This study involved a sample of water use for approximately 150 of LADWP's largest CII customers to estimate total sector water use, along with employment data from Dunn & Bradstreet. Additional data sources listed below were used to determine indoor end-use estimates for each subsector, as well as the potential for water savings. :

- *BMP 9: A Handbook for Implementing Commercial Industrial & Institutional Conservation Programs.* (2001). California Urban Water Conservation Council.
- *Commercial and Institutional End Uses of Water.* (2000). American Water Works Association Research Foundation.
- *Waste Not, Want Not: The Potential for Urban Water Conservation in California.* (2003). Pacific Institute.
- *Water Efficiency in the Commercial and Institutional Sector: Considerations for a WaterSense Program.* (2009). U.S. Environmental Protection Agency.
- *Watersmart Guidebook---A Water-Use Efficiency Plan-Review Guide for New Businesses.* (2008). East Bay Municipal Utility District.
- *Santa Clara Valley Water District Commercial Institutional Industrial Water Use & Conservation Baseline Study.* (2008). CDM.
- *Water and Energy Efficiency Program for Commercial, Industrial, and Institutional Customer Classes in Southern California.* (2009). U.S. Bureau of Reclamation.
- *Water Use Efficiency Comprehensive Evaluation.* (2006). CALFED Bay-Delta Program.

The study concluded that by targeting just the top 100 or so largest CII users, approximately 4,600 AFY of water could be saved (representing about 3 percent of total CII water use). The study also found that the subsectors that use the most water in the city are: health care (18%), education (14%), food services/drinking places (9%), accommodation (5%), fabricated metal product manufacturing (5%), textile mills (5%), amusement (4%), and food manufacturing (4%). The study also concluded that the potential for indoor water conservation was approximately 23,000 AFY or 15 percent of total CII water use. Exhibit 3J presents the breakdown of this potential indoor water conservation for subsectors and end-uses.

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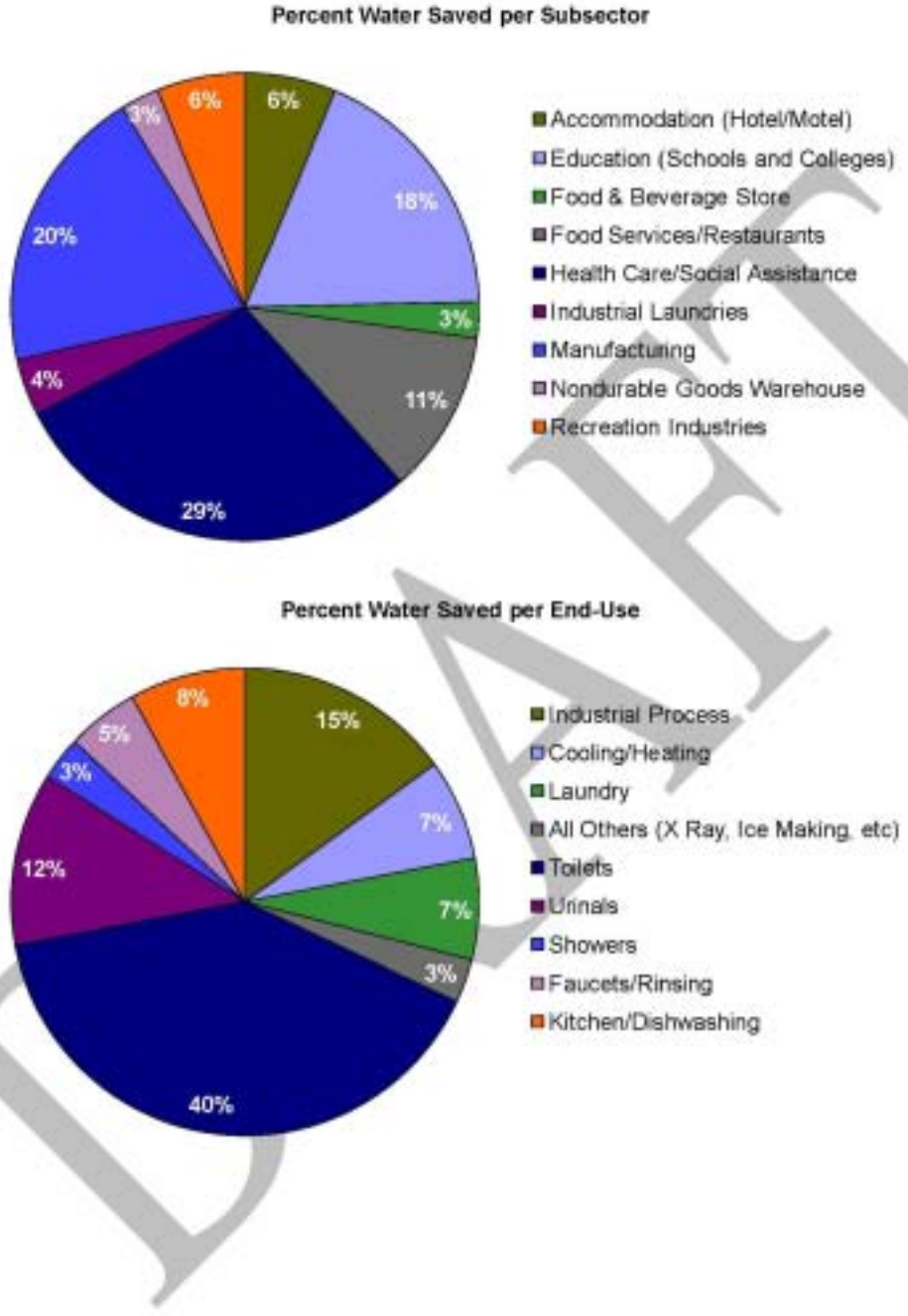
Exhibit 3J
Breakdown of Estimated CII Indoor Water Conservation Potential of 23,000 AF



Outdoor water use as a percentage of water use was approximated using three methodologies to determine the potential for outdoor water conservation savings. The methodologies and percent outdoor water use determined for each methodology are:

- Minimum-Maximum Methodology (outdoor water use is approximately 39.98%) – based on the premise that during wet months outdoor water use is minimal and during dry months outdoor water use is at its peak

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- Wastewater Treatment Plant Influent Methodology (outdoor water use is approximately 38.32%) – based on determining the average monthly influent flows to the City's four wastewater treatment plants during the dry-weather months of June through September and adjusting for contract agency flows and dry-weather stormwater diversions

- Infrared Analysis Methodology (outdoor water use is 39.67%) – based on an infrared analysis of the City to determine tree canopy and landscape coverages for use in estimating applicable water use requirements for greenscapes based on rainfall data, plant factors, evapotranspiration rates, and irrigation efficiencies

The resultant range between the low and high outdoor water use percentage is approximately 1.35%. This narrow range resulting from the three methodologies confirms the methodologies are fairly accurate.

Greenscape areas related to commercial and residential land uses are the most likely areas to be targeted for outdoor water conservation. Rehabilitation of these areas to meet or exceed the evapotranspiration adjustment factor (ETAF) of 0.7 as required in the Model Water Efficient Landscape Ordinance would result in significant savings ranging from 21,774 to 165,870 AFY. Currently, these savings are not represented in the projected active conservation in Exhibit 3I. Exhibit 3K illustrates the potential savings under three scenarios by customer sectors. Scenario 1 represents an improvement in average irrigation efficiencies and/or installation of less water intensive vegetation to achieve and ETAF of 0.7. Scenario 2 represents an improvement in average irrigation efficiencies and/or replacement of high water use vegetation with less water intensive vegetation in the moderate to low water use range to achieve an ETAF of 0.49. Scenario 3 represents an improvement in average irrigation system efficiency and replacement of all vegetation with very low water use vegetation almost entirely dependent upon effective precipitation to achieve an ETAF of 0.07. This would require incentive programs, such as cash for grass programs. Other large greenscape area, including parks, cemeteries and golf courses, were not considered in the analysis as they would more than likely be preserved as turf or tree canopy areas to retain quality of life benefits. These areas are likely to be targets for recycled water use.

Exhibit 3K
Potential Outdoor Water Use Savings by Sector

Customer Sector	Scenario 1	Scenario 2	Scenario3
	(AFY)		
Single-Family Residential	13,246	42,464	100,901
Multi-family	5,956	19,095	45,371
Commercial	2,573	8,247	19,597
Total	**21,774**	**69,806**	**165,870**

3.4 Cost & Funding

The average cost of conservation rebates, incentives, and hardware installation programs ranges from approximately $325/AF to $400/AF based on current LADWP conservation programs. More than $200 million has been invested in water conservation since 1991. Conservation is the cornerstone of LADWP's water demand management activities and ongoing investments will be made in viable programs, subject to funding availability and LADWP's ability to implement such programs. Outside sources of funding are sought to complement the City's resources. A stronger commitment is also being made to acquire outside grant funding for City conservation projects.

Currently, the funding sources for conservation are:

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- ***Water Rates*** – Water conservation programs are primarily funded through water rates.

- ***MWD Conservation Credits Program*** - MWD offers both commercial and residential rebates to member agency customers that install specified conservation devices. The rebates equate to $195 per AF of water saved, or half the project cost. In addition, MWD reimburses the LADWP for pre-approved projects when completed. In 2009 MWD reimbursed the Department $139,000 for a water broom distribution program. LADWP also expects to be reimbursed in 2011 through the MWD Member Agency Administered funding program for $968,000. The monies are reimbursement for 22.2 acres of turf reduction projects through the Department's Commercial/Industrial Drought Resistant Landscape Incentive Program.

- ***Outside Agency Co-Funding*** - Other agencies realizing benefits from conservation programs are solicited for co-funding of program costs.

- ***Grant Funding*** - LADWP has successfully received grant funding from the State under Proposition 13. A grant for $615,000 supplemented the rebate funding available for commercial ULF toilets and high efficiency clothes washers. LADWP expects to receive a final payment totaling $128,299 for the Commercial High Efficiency Clothes Washer and Ultra Low Flow Toilet Consolidated Water Use Efficiency grant. LADWP has already received $164,691 in support of 1,498 commercial high efficiency washer rebates. LADWP was awarded three grants in 2005 under Proposition 50, which are summarized below:
  - The Cooling Tower Conductivity Controller Replacement Program: Grant to improve the water efficiency of 100 cooling towers in the city of Los Angeles. Total grant amount up to $350,000. Expect completion in 2012.
  - The Los Angeles City Park Irrigation Efficiency Program: Grant to improve the irrigation efficiency at 15 City of Los Angeles municipal parks by installing Weather Based Irrigation Controllers and by upgrading irrigation piping and rotors. Total grant amount up to $362,000. Expect completion in 2011.
  - The Large Landscape "Smart Irrigation" Program: Grant to replace existing manually-adjusted irrigation controllers with "smart irrigation" Weather Based Irrigation Controllers at 75 large landscape customer sites. Total grant amount $131,000. Expect completion in 2011.

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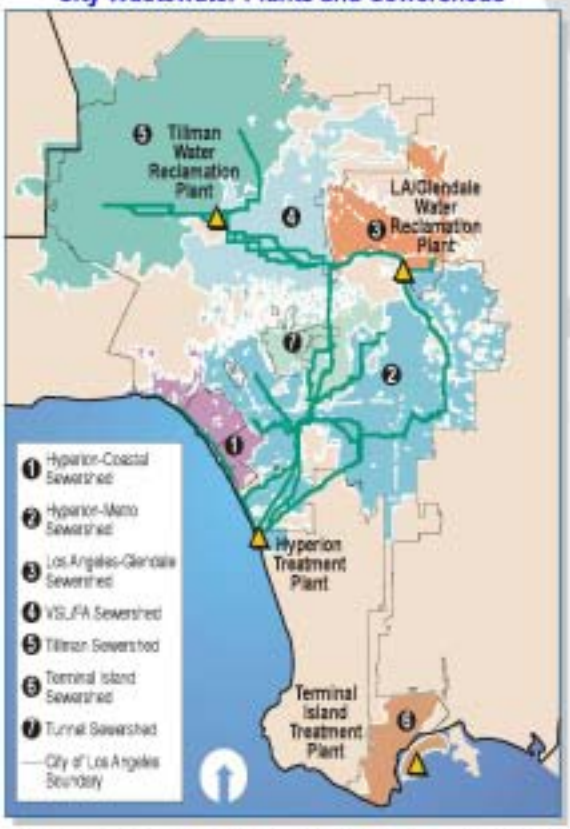
DRAFT Chapter Four
Recycled Water

LADWP is committed to significant expansion of recycled water in the City's water supply portfolio. Realizing multiple factors are decreasing the reliability of imported water supplies, LADWP released the City of Los Angeles Water Supply Action Plan (Plan), "Securing L.A.'s Water Supply" in May of 2008. The Plan established the goal of using 50,000 AFY of recycled water to offset demands on potable supplies. In order to meet this goal, LADWP, in conjunction with the Department of Public Works Bureau of Sanitation (BOS), are working together to develop a Recycled Water Master Plan (RWMP). Opportunities to expand the water recycling program are being studied through development of the RWMP. These include expanding the recycled water distribution system for Non-Potable Reuse (NPR) such as for irrigation and industrial use, along with replenishment of groundwater basins with highly purified recycled water. Beyond 50,000 AFY, LADWP expects to increase recycled water use by approximately 1,500 AFY annually, bringing the total to 59,000 AFY by 2035.

LADWP's water recycling program is dependent on the City's wastewater treatment infrastructure. Wastewater in the City of Los Angeles is collected and transported through some 6,500 miles of major interceptors and mainline sewers, more than 11,000 miles of house-sewer connections, 46 pumping plants, and four treatment plants. BOS is responsible for the planning and operation of the wastewater program. The City's wastewater system serves 515 square miles, of which 420 square miles are within the City. In addition to the City, service is provided to 29 non-City agencies through contract services. Exhibit 4A shows the City's four wastewater treatment plants and seven sewersheds that feed those plants.

Exhibit 4A
City Wastewater Plants and Sewersheds



A portion of the treated effluent from the wastewater plants is utilized by LADWP to meet recycled water demands.

As early as 1960, the City recognized the potential for water recycling and invested in infrastructure that processed water to tertiary quality, a high treatment standard for wastewater. This resulted in the building of tertiary wastewater treatment plants upstream instead of enlarging the two existing terminus treatment plants. These system enhancements brought about the City's expanded recycled water projects, which now supplement local and imported water supplies. The original policy allowing the use of recycled water was adopted by the State Legislature in 1969.

In 1979, LADWP began delivering recycled water to the Department of Recreation and Parks for irrigation of areas in Griffith Park. This service was later expanded to include Griffith Park's golf courses. In 1984, freeway landscaping adjacent to the park was also irrigated with recycled water. In addition, the Japanese Garden, Balboa Lake and Wildlife Lake in the Sepulveda Basin now utilize recycled water for environmentally beneficial reuse purposes. The Greenbelt Project, which carries recycled

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water from the Los Angeles-Glendale Water Reclamation Plant to Forest Lawn Memorial Park, Mount Sinai Memorial Park, Lakeside Golf Club of Hollywood and Universal Studios, began operating in 1992, and represents LADWP's first attempt at water recycling. LADWP continues to successfully implement the use of recycled water for various purposes. In 2009 phase 1 of the Playa Vista development began receiving recycled water. Playa Vista is the first planned development in the City that uses recycled water for all landscape needs. Future recycled water projects will continue to build on the success of these prior projects so that recycled water becomes a more prominent component of the City's water supply portfolio.

The City's water recycling projects seek to displace the use of potable water with recycled water for non-potable uses where infrastructure is available. In compliance with Chapters 7.0 and 7.5 of the California Water Code, the quality of LADWP's Recycled water meets all of the following conditions:

- The source of recycled water is of adequate quality for those uses;
- The recycled water may be furnished for these uses at a reasonable cost to the user;
- The use of recycled water from the proposed source will not be detrimental to public health; and
- The use of recycled water will not adversely affect downstream water rights or degrade water quality.

In addition, the California Water Code requires public agencies, such as the LADWP, to serve recycled water for non-potable uses if suitable recycled water is available.

LADWP is expanding irrigation, industrial/commercial, and studying groundwater replenishment uses of recycled water. Demand for recycled water is driven by customer acceptance of recycled water as a viable alternative to traditional potable supplies. Outreach efforts designed to educate the public on the viability of recycled water and its potential uses are an essential part of the process as the City's recycled water program expands.

4.1 Regulatory Requirements

Recycled water use is governed by regulations at the State and local levels. These regulations are based on multiple factors including the type of use and water quality. LADWP currently uses recycled water for non-potable reuse and is pursuing in-direct potable reuse through groundwater replenishment (GWR) using advanced treated recycled water. Requirements for these two categories of recycled water use are different. This section provides a summary of the complex recycled water regulations, a more in-depth description of these regulations will be included as part of the RWMP.

4.1.1 Non-Potable Reuse Regulations

Non-potable water reuse (NPR) regulations in the City of Los Angeles are governed by the California Department of Public Health (CDPH), State Water Resources Control Board (SWRCB), Los Angeles Regional Water Quality Control Board (LARWQCB) and the Los Angeles County Department of Public Health (LACDPH).

California Department of Public Health

Criteria and guidelines for the production and use of recycled water were established by the CDPH in the California Code of Regulations, Title 22, Division 4, and Chapter 3 (Title 22). Title 22, also known as Water Recycling Criteria, establishes required wastewater treatment levels and recycled water quality levels dependent upon the end use of the recycled water. Title 22 additionally establishes recycled water reliability criteria to protect public health.

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Title 22 specifies recycled water use restrictions based on the potential degree of public exposure to the water and the distance of drinking water wells and edible crops from the area of intended use. Recycled water use applicability also depends on the different levels of treatment. A higher quality water will have a wider variety of applicable uses than a lower quality water. At a minimum, secondary treatment of wastewater is required for recycled water use. In the City of LA, however, all recycled water used is treated, at a minimum, to tertiary levels with additional disinfection. Wastewater treatment levels are discussed in detail in subsection 4.2 of this chapter. Title 22 allows for other treatment methods, subject to CDPH approval. The reliability of the treatment process and the quality of the product water must meet the Title 22 requirements specified for each allowable treatment level. Exhibit 4B provides a summary of the currently approved recycled water uses.

Exhibit 4B
Allowable Title 22 Recycled Water Uses

Irrigation Uses
Food crops where recycled water contacts the edible portion of the crop, including all root crops
Parks and playgrounds
School yards
Residential landscaping
Unrestricted access golf courses
Any other irrigation uses not prohibited by other provisions of the California Code of Regulations
Food crops, surface irrigated, above ground edible portion, and not contacted by recycled water
Cemeteries
Freeway landscaping
Restricted access golf course
Ornamental nursery stock and sod farms with unrestricted public access
Pasture for milk animals for human consumption
Non edible vegetation with access control to prevent use as park, playground or school yard
Orchards with no contact between edible portion and recycled water
Vineyards with no contact between edible portion and recycled water
Non food bearing trees, including Christmas trees not irrigated less than 14 days before harvest
Fodder and fiber crops and pasture for animals not producing milk for human consumption
Seed crops not eaten by humans
Food crops undergoing commercial pathogen destroying processing before consumption by humans
Supply for impoundment
Non restricted recreational impoundments, with supplemental monitoring for pathogenic organisms
Restricted recreational impoundments and publicly accessible fish hatcheries
Supply for Impoundment Uses
Non restricted recreational impoundments, with supplemental monitoring for pathogenic organisms
Restricted recreational impoundments and publicly accessible fish hatcheries
Landscape impoundments without decorative fountains
Supply for cooling or air conditioning
Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist
Industrial or commercial cooling or air conditioning not involving cooling tower, evaporative

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condenser, or spraying that creates a mist
Other Uses
Dual plumbing systems (flushing toilets and urinals)
Priming drain traps
Industrial process water that may contact workers
Structural fire fighting
Decorative fountains
Commercial laundries
Consolidation of backfill material around potable water pipelines
Artificial snow making for commercial outdoor uses
Commercial car washes, not heating the water, excluding the general public from washing process
Industrial process water that will not come into contact with workers
Industrial boiler feed
Nonstructural fire fighting
Backfill consolidation around non potable piping
Soil compaction
Mixing concrete
Dust control on road and streets
Cleaning roads, sidewalks and outdoor work areas
Flushing sanitary sewer
Groundwater recharge

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Non-Potable Reuse Regulatory and Policy Assessment TM, September 8, 2009

Areas where recycled water is used occurs within defined boundaries. Title 22 stipulates use area requirements to protect public health. Use area regulations include requirements addressing recycled water application methods and runoff near domestic water supply wells, drinking fountains, and residential areas. Other requirements include posting signs notifying the public where recycled water is being used, utilization of quick couplers instead of hose bibs, and the prohibition against connecting recycled water systems with potable water systems. Dual plumbed recycled water systems in buildings are also addressed; these systems must meet additional reporting and testing requirements.

To protect public health, Title 22 requires reliability mechanisms. During the design phase, a Title 22 Engineering Report is required to be submitted to CDPH and the local Regional Water Quality Control Board (RWQCB) for approval. Contents of the report include a description of the system and an explanation regarding how the system will comply with Title 22 requirements. Redundancy in treatment units or other means to treat, store, or dispose of recycled water are required in case the treatment unit is not operating within specified parameters. Alarms for operators are required to indicate treatment plant process failures or power failures. In case of power failures, either back-up power, automatically activated short-term or long-term recycled water storage, or a means of disposal is required. Furthermore, system performance must be monitored by water quality sampling and analyses.

As mentioned previously, cross-connections between the potable and recycled water systems are not permitted. The California Code of Regulations, Title 17, Division 1, Chapter 5, Group 4 prevents cross-connections between potable water supply systems and recycled water supply systems. Title 17 specifies that water suppliers must implement cross-connection control programs and backflow prevention systems.

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In addition to Title 22 and Title 17 requirements, CDPH has additional regulations and guidance established in the following documents:

- Guidelines for the Preparation of an Engineering Report for the Production, Distribution, and Use of Recycled Water (2001)
- Treatment Technology Report for Recycled Water (2007)
- Guidance Memo No. 2003-02: Guidance for the Separation of Water Mains and Non-Potable Pipelines (2003)

State Water Resources Control Board and Los Angeles Regional Water Quality Control Board

In May 2009, the SWRCB adopted "Recycled Water Policy" developing uniform standards across all Regional Water Quality Control Boards for interpreting the "Anti-Degradation Policy". When planning and implementing recycled water projects the following must be taken into consideration:

- Mandate for recycled water use – encourages recycled water use and establishes targets to increase use
- Salt/nutrient management plans – requires submittal of salt/nutrient management plans by 2014
- Landscape irrigation projects' control of incidental runoff and streamlined permitting – addresses controlling incidental runoff and streamlining permit processes for recycled water use in landscape areas
- Groundwater recharge – establishes requirements for groundwater recharge projects
- Anti-degradation – establishes that salt and nutrient management plans can address groundwater quality impacts
- Chemicals of emerging concern – establishes a blue-ribbon advisory panel to develop a report on chemicals of emerging concern and update the report every five years.

Water Recycling Requirements (WRR) for each of the City's applicable wastewater treatment plants engaged in water recycling are issued by the LARWQCB. These requirements specify end-users of recycled water and enforce treatment and use area requirements.

In July 2009, the SWRCB adopted a general landscape irrigation permit, "General Waste Discharge Requirements for Landscape Irrigation Uses of Municipal Recycled Water" (General Permit). The General Permit streamlines the regulatory approval for landscape irrigation using recycled water. Agencies with existing WRRs, such as the City, are not required to apply for the General Landscape Irrigation Permit.

Earlier in April 2009, the LARWQCB adopted a general region-wide permit, "General Waste Discharge and Water Recycling Requirements for Non-Irrigation Uses over the Groundwater Basins Underlying the Coastal Watersheds of Los Angeles and Ventura Counties" for non-irrigation uses of recycled water. Similar to the General Permit, this permit streamlines the permitting process and specifies the application process for qualifying projects.

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Los Angeles County Department of Public Health

Title 22 and Title 17 water use regulations are enforced by the LACDPH, Environmental Health Division. LACDPH has published "A Guide to Safe Recycled Water Use, Pipeline Construction and Installation" requiring compliance with Title 22, CDPH, and LARWQCB requirements. After CDPH has approved the plans and specifications and the City has an agreement to serve the customer, LACDPH reviews and approves all plans and specifications prior to construction. After construction LACDPH inspects the systems and conducts cross-connection, pressure, and back-flow prevention device tests. Recycled water use must occur in compliance with the Los Angeles County Recycled Water Advisory Committee's "Recycled Water Urban Irrigation User's Manual". Each site must also have a site supervisor responsible for recycled water use.

City of Los Angeles

Recycled water responsibilities of the City of Los Angeles include complying with all LARWQCB permits for the wastewater treatment plants and production of recycled water, approving recycled water use sites, conducting post-construction inspections, and periodically inspecting use areas and site supervisor records.

LADWP customers are permitted to use recycled water when service is available and per LADWP Ordinance No. 170435 (subsequently amended by Ordinance No. 178902 in 2008). Users are responsible for operations and maintenance of their recycled water systems up to the connection point with LADWP. Users are required to use recycled water in accordance with Titles 22 and 17 and the "Recycled Water Urban Irrigation User's Manual". If a customer is violating these requirements, LADWP may stop providing recycled water to the customer.

4.1.2 Groundwater Replenishment Regulatory Requirements

The regulations governing recharge of groundwater or groundwater replenishment (GWR) with recycled water are established by the CDPH and LARWQCB. Additional approval is required by the SWRCB and California Department of Fish and Game (DFG) if flows will be diverted from surface waters, such as in Los Angeles where recycled water is currently discharged by two treatment plants into the Los Angeles River. The City's GWR project as described in section 4.4.3 will be subject to these regulations.

For groundwater replenishment, LADWP will implement advanced treatment that includes reverse osmosis, microfiltration, and advanced oxidation. This level of treatment will address water quality concerns for the health of the basin along with emerging contaminants of concern.

California Department of Public Health

Regulatory oversight of groundwater recharge projects is provided by the CDPH. CDPH regulates groundwater recharge projects under Title 22 requiring the CDPH to make recommendations on a case by case basis after a public hearing. Requirements for recharge are not provided in Title 22. Draft Groundwater Recharge Reuse Criteria, released in August 2008, are used by the CDPH to evaluate projects for approval or denial. The draft regulations are designed to protect public health through the establishment of stringent requirements by:

- Requiring recycled water to meet maximum contaminant levels (MCLs) established for drinking water;
- Establishing the volume of recycled water used based on Total Organic Carbon (TOC), dilution, and treatment levels;
- Requiring retention of groundwater for six months before reaching a well used for drinking water with validation by a tracer study;

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- Monitoring on a quarterly basis for specified pollutants and chemicals and yearly monitoring of constituents indicating the presence of wastewater in produced recycled water and in downgradient monitoring wells;
- Implementing a source control program; and
- Establishing additional requirements for projects with recycled water contributions greater than 50%, including a review by an Independent Advisory Panel.

Similar to non-potable reuse, project proponents must submit a Title 22 Engineering Report to the CDPH and LARWQCB for review. After completion of the report, the CDPH holds a public hearing followed by issuance of Findings of Fact and Conditions for submission to the LARWQCB.

Los Angeles Regional Water Quality Control Board

Prior to the issuance of a permit, the LARWQCB reviews CDPH's Findings of Fact and Conditions and considers provisions in the adopted Los Angeles Basin Plan (Basin Plan) for the LARWQCB region, applicable State policies (including the SWRCB Recycled Water Policy), and applicable federal regulations if recycled water is discharged to water of the US. The Basin Plan establishes water quality objectives for surface water and groundwater to protect beneficial uses. The LARWQCB then holds a public hearing to consider the permit. Ultimately, if approved, the LARWQCB issues permits in the form of water reclamation requirements and waste discharge requirements.

4.2 Wastewater Treatment Plants

There are four wastewater treatment plants owned and operated by the BOS. City wastewater treatment consists of a series of processes that, at a minimum, remove solids to a level sufficient to meet regulatory water quality standards. During the preliminary, primary, secondary, and tertiary treatment processes, progressively finer solid particles are removed. Preliminary treatment removes grit and large size particles through grit removal basins and screening. Primary treatment relies on sedimentation to remove smaller solids. With most of the grit, large sized particles, and solids already removed, secondary treatment converts organic matter into harmless by-products and removes more solids through biological treatment and further sedimentation. At the end of secondary treatment, most solids will have been removed from the water. Tertiary treatment follows secondary treatment to eliminate the remaining impurities through filtration and chemical disinfection. At this stage, sodium hypochlorite (the chemical contained in household bleach) provides disinfection. All recycled water used within the City is given, at a minimum, tertiary treatment and disinfection. In the Harbor, recycled water is also given advanced treatment with microfiltration/reverse osmosis (MF/RO). MF/RO is a two-stage process using high-pressure membrane filters to remove microscopic impurities from the source water. Exhibit 4C summarizes the treatment levels, capacity, and average flows at the four plants.

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Exhibit 4C
Wastewater Treatment Plants Summary

WastewaterTreatment Plants	Treatment Level	Capacity (mgd)	Average Flows (mgd)[1]
Donald C. Tillman Water Reclamation Plant	Tertiary to Title 22 standards with Nitrification/Denitrification	80	53
Los Angeles - Glendale Water Reclamation Plant	Tertiary to Title 22 standards with Nitrification/Denitrification	20	17
Terminal Island Water Reclamation Plant	Tertiary; Advanced treatment (MF/RO) of 5 mgd	30	15
Hyperion Treatment Plant	Full secondary[2]	450	320

1. Average dry weather flows 2008, except for DCT January 2005 through December 2008.

2. 31 mgd of full secondary treated water delivered to West Basin Water Reclamation Plant operated by West Basin Municipal Water District. Water treated to Title 22 standards for recycled water use.

Sources: City of Los Angeles Recycled Water Master Plan Technical Memorandum, DCT Data Summary, January 29, 2010

City of Los Angeles Recycled Water Master Plan Technical Memorandum, Wastewater Treatment, November 2, 2009

4.2.1 Donald C. Tillman Water Reclamation Plant

In service since 1985, the Donald C. Tillman Water Reclamation Plant (DCT) has an average dry-weather flow capacity of 80 million gallons per day (mgd) and currently treats about 53 mgd. During wet weather, treatment capacity is limited to 40 mgd to prevent downstream infiltration surcharges on the sewer system while utilizing the remaining capacity for limited wet weather storage. Currently, the Bureau of Engineering (BOE) is designing wet-weather storage basins to allow year around operation at 80 mgd. The current level of treatment is Title 22 (tertiary) with nitrogen removal (nitrification/denitrification (NdN). Currently, this plant is providing recycled water to the Japanese Garden, Wildlife Lake, Lake Balboa, treatment plant reuse, irrigation, and industrial uses. Irrigation uses in the adjacent areas include golf courses, parks, and a sports complex. Industrial uses include the Valley Generating Station. The remaining tertiary-treated water is discharged into the Los Angeles River. The city intends on implementing a groundwater replenishment project supplied with tertiary treated Title 22 recycled water from DCT that is purified through advanced treatment to recharge the San Fernando Groundwater Basin. The project will initially recharge 15,000 AFY with the eventual goal of achieving 30,000 AFY.

4.2.2 Los Angeles-Glendale Water Reclamation Plant

The Los Angeles-Glendale Water Reclamation Plant (LAG) is a joint project of the City of Los Angeles and City of Glendale. LAG began treating wastewater in 1976. Originally the plant was designed without considering nutrient removal. Its average dry-weather flow design capacity is 20 mgd and it currently treats about 17.7 mgd. Each city is entitled to 50 percent of the plant's capacity. The City of Pasadena purchased rights to 60 percent of Glendale's capacity but has not yet exercised these rights. The current level of treatment is Title 22 (tertiary) with nitrogen removal (NdN). Recycled water from the LAG provides landscape irrigation to Griffith Park and the Los Angeles Greenbelt Project, including Forest Lawn Memorial Park, Mount Sinai Memorial Park, Universal Studios, and the Lakeside Golf Course. The City of Glendale retains the right to half of the recycled water produced at the plant and serves a number of customers in their service area. As with the DCT, the remaining tertiary-treated water from LAG is discharged into the Los Angeles River.

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4.2.3 Terminal Island Water Reclamation Plant

Originally built in 1935, the Terminal Island Water Reclamation Plant (TIWRP) has been providing secondary treatment since the 1970s. Tertiary treatment systems were added in 1996. The current average dry-weather flow capacity is 30 mgd with average flows of about 15 mgd. Recent completion of the Advanced Wastewater Treatment Facility added MF/RO treatment to a portion of the wastewater effluent producing approximately 3.0 mgd of recycled water. Recycled water is supplied to the Dominguez Gap Seawater Intrusion Barrier to reduce seawater intrusion into drinking water aquifers and to LADWP's Harbor Generating Station for landscape irrigation. Effluent in excess of the MF/RO component is discharged to the Los Angeles Harbor. Future recycled water use is expected to increase to more fully supply the Dominguez Gap Seawater Intrusion Barrier along with other potential customers in the Harbor Area.

4.2.4 Hyperion Treatment Plant

Operating since 1894, the Hyperion Treatment Plant (HTP) is the oldest and largest of the City's wastewater treatment plants. Its $1.2 billion construction upgrade, completed in 1999, allows for full secondary treatment. The current average dry-weather flow capacity of HTP is 450 mgd during dry weather, with an average wastewater flow of 342 mgd. A majority of the treated water is discharged through a 5-mile outfall into the Santa Monica Bay, and the rest, approximately 31 mgd, is delivered to the West Basin Water Reclamation Plant to meet recycled demands in the West Basin Municipal Water District (WBMWD) service area and parts of the City of Los Angeles. As of 2008, approximately 37,000 AFY of water from HTP Plant is sold to West Basin for additional treatment. A portion of this water is sold back to LADWP for the Westside Water Recycling Project, and the rest is then used to meet recycled water demands in West Basin's service area. Users of the Westside Water Recycling Project include Loyola Marymount University and Playa Vista.

4.2.5 Projected Wastewater Volume

Average dry-weather wastewater influent projections for the City's wastewater treatment plants are expected to increase by approximately 20 percent over the next 25 years. Projections include 29 agencies outside of the City with contracts for wastewater treatment. Wastewater effluent that is not recycled is discharged to either the Los Angeles River to the Pacific Ocean or outfalls leading directly to the Pacific Ocean. Wastewater treatment projections for average dry-weather flows to 2035 and disposal methods are provided in Exhibit 4D.

Exhibit 4D
Wastewater Treatment Plant Average Dry-Weather Flows, Reuse and Dischargel Method

Wastewater Treatment Plants	Reuse and Discharge Method	Average Dry-Weather Flow Projections (AFY)					
		2010	2015	2020	2025	2030	2035
Donald C. Tillman Water Reclamation Plant	Recycling and Pacific Ocean via Los Angeles River	82,779	84,347	85,915	87,483	90,283	93,084
Los Angeles - Glendale Water Reclamation Plant	Recycling and Ocean via Los Angeles River	23,299	25,427	27,331	29,460	31,588	33,716
Terminal Island Water Reclamation Plant	Recycling and Outfall to Ocean	18,258	18,594	18,818	19,154	19,715	20,163
Hyperion Treatment Plant	Conveyance to WBMWD for Recycling and Ocean outfall	333,690	339,739	345,788	362,814	366,063	400,899

Sources: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Wastewater Flow Projection, September 30, 2009

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4.3 Existing Recycled Water Deliveries

The City has several recycled water projects currently providing recycled water for landscape irrigation, industrial, and commercial uses spread throughout four service areas:

- Harbor – located in the southern portion of the City and currently served from the water reclamation plant at the TIWRP
- Central City (Metro) – located in the central/eastern portion of the City and is served by LAG
- San Fernando Valley – located in the northern portion of the City and is served by DCT
- Westside – location in the central/western portion of the City and is served by HTP through the WBMWD West Basin Water Reclamation Plant

Locations of the service areas are depicted in Exhibit 4E. Recycled water service areas coincide with potable water service areas. Recycled water deliveries for 2009 were 35,939 AFY, inclusive of municipal and industrial, environmental, and in-plant reuse. Estimated annual demands for online projects were 38,614 AFY.

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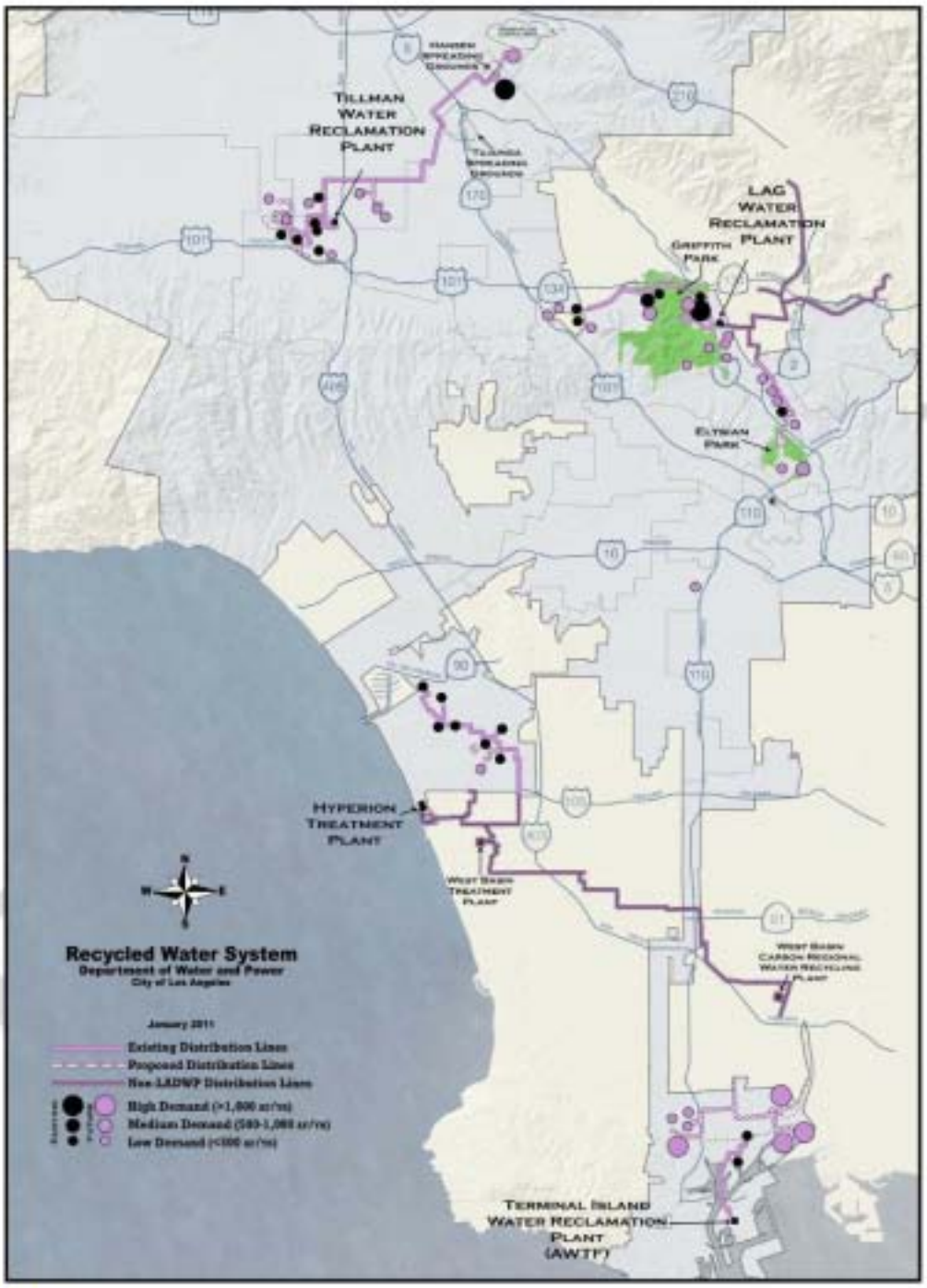
Exhibit 4E
Recycled Water System



4.3.1 Harbor Area

Recycled water in the Los Angeles Harbor area is currently produced at the Advanced Water Treatment Plant (AWTP) located at the TIWRP. The AWTP was online in 2002 with first deliveries to customers commencing in 2006. This project was

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developed jointly by LADWP, BOS, and BOE. Operations and maintenance is provided by BOS with funding from LADWP. Recycled water, treated using microfiltration and reverse osmosis, is currently used for landscape irrigation and groundwater injection with current demands of approximately 3,050 AFY. Treatment capacity of the AWTP is approximately 5,600 AFY. Excess recycled water is discharged into the Los Angeles Harbor. Exhibit 4F summarizes typical annual demands in the Harbor area. Currently two customers are served; LADWP's Harbor Generating Station and the Water Replenishment District (WRD).

Exhibit 4F
Harbor Recycling

Program	Existing Annual Demand (AFY)
Irrigation	
Harbor Generating Station	50
Subtotal Irrigation	50
Groundwater Barrier	
Dominguez Gap Barrier (Water Replenishment District)	3,000
Subtotal Groundwater Barrier	3,000
Total Harbor Water Recycling Project	**3,050**

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Harbor Generating Station

The Harbor Generating Station's demands that could potentially be met with recycled water are approximately 50 AFY including industrial cooling and landscape irrigation. Initially, recycled water was intended for use in the station's cooling tower and boiler make-up feed system components, however, recycled water is not used for these purposes currently as a result of concerns about potential incompatibility between recycled water and these systems. Connections have been installed for recycled water use in these systems and future use will be further investigated as part of the Recycled Water Master Plan.

Water Replenishment District

The WRD's recycled water demands are approximately 3,000 AFY for groundwater injection in the Dominguez Gap Seawater Intrusion Barrier. A blend of 50 percent recycled water and 50 percent imported water is injected into the barrier. The Dominguez Gap Barrier protects the West Coast Groundwater Basin from seawater intrusion.

LADWP is currently expanding recycled water infrastructure in the Harbor area that will increase recycled water usage at least 9,300 AFY by 2014/2015.

4.3.2 Metro Area

The Metro Recycled Water System has supplied the Metro Service Area with recycled water produced at LAG to irrigation customers since 1979. LAG provides recycled water treated to a tertiary level meeting Title 22 standards with Nitrogen removal to customers in the eastern San Fernando Valley. As previously stated, recycled water produced at LAG is equally split between the cities of Los Angeles and Glendale. Current recycled water demands for the Metro Service Area are 1,933

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AFY. Unused recycled water is discharged to the Los Angeles River. Exhibit 4G summarizes current demands for Metro Recycled Water System. Currently 11 customers are served by the Metro Recycled Water System.

Exhibit 4G
Metro Recycling

Program	Existing Annual Demand (AFY)
Irrigation	
Greenbelt Project	1120
Griffith Park	720
Taylor Yard Project	93
Total Irrigation	1,933

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Griffith Park Project

Started in 1979, the Griffith Park project was the City's first recycled water project. Recycled water is used to irrigate two golf courses, parkland, The Los Angeles Zoo Parking Lot, and a seven-mile stretch along the Golden State Freeway (Interstate 5) adjoining the park. Current demands in the Griffith Park Project's service area are 1,120 AFY.

Greenbelt Project

Dedicated in 1992, the Los Angeles Greenbelt Project was the City's first commercial recycling project. Recycled water is used for landscape irrigation at Forest Lawn Memorial Park-Hollywood Hills, Mount Sinai Memorial Park, Lakeside Golf Course and Universal Studios. Current demands in the Greenbelt Project's service area are 720 AFY.

Taylor Yard Project

Rio de LA State Park was connected as the first Taylor Yard project in July 2009. Recycled water is used for landscape irrigation on the park. Current demands in the Taylor Yard Project's service area are 93 AFY.

4.3.3 San Fernando Valley Area

The Valley Recycled Water System receives water from DCT to satisfy irrigation, environmental, and industrial demands. Recycled water is treated to a tertiary level meeting Title 22 standards with Nitrogen removal. Water for in-plant uses at DCT and for environmental uses is dechlorinated. Current estimated recycled water demands for the San Fernando Valley Area are 33,594 AFY. Recycled water produced in excess of demand is discharged to the Los Angeles River providing added environmental benefits. Exhibit 4H summarizes current demands for the Valley Recycled Water System. The East Valley trunkline, a 54 inch diameter pipeline, was previously constructed as the initial backbone of the Valley Recycled Water System's distribution system to deliver water throughout the San Fernando Valley for irrigation, commercial, and industrial use. Eleven customers are currently served by the Valley Recycled Water System, excluding DCT reuse and environmental use.

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Exhibit 4H
Valley Recycling

Program	Existing Annual Demand (AFY)
Irrigation	
Sepulveda Basin Project	*1570*
Van Nuys Area Project	14
Subtotal Irrigation	1,584
Industrial	
Hansen Area Project	
Valley Generating Station	2,100
DCT Reuse[1]	2,920
Subtotal Industrial	5,020
Environmental Use[2]	
Japanese Garden	4,590
Wildlife Lake	7,700
Balboa Lake	14,700
Subtotal Environmental Use	26,990
Total Valley Recycled Water System	**33,594**

1. Based on 2006-2008 actual use, use varies year to year.

2. Does not include environmental benefits provided to Los Angeles River.

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Sepulveda Basin Project

LADWP began serving recycled water to portions of the Sepulveda Basin area in 2007. The latest project was added in 2010. Current recycled water customers in the Sepulveda Basin recreation area include Woodley Golf Course, Balboa Golf Course, Encino Golf Course, Anthony C. Beilenson Park, Van Nuys Golf Course and the Balboa Sports Complex. Current demands in the recreation area are 1,570 AFY.

Van Nuys Area Project

The Van Nuys Area project currently provides recycled water for irrigation purposes to St. Elisabeth's Church, the First Foursquare Church of Van Nuys, Van Nuys High School, and LADWP's Power Distribution Station 81. Current Van Nuys Area Project demands are 14 AFY.

Hansen Area Project

The Hansen Area project currently provides recycled water for industrial purposes to the Valley Generating Station. Recycled water service began in 2008 and demands are approximately 2,100 AFY. Recycled water is used in a cooling tower for one of the generation units at the power generating facility.

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Donald C. Tillman Water Reclamation Plant Reuse

Recycled water is used at DCT for in-plant purposes. Demands vary from year to year based on needs. Between 2006 and 2008 2,920 AFY were used on average.

Environmental Use

Recycled water from DCT has provided environmental benefits since 1984 commencing with deliveries to the Japanese Garden followed by Balboa Lake in 1990 and Wildlife Lake in 1991. Approximate demands are 26,990 AFY. Overflows from these facilities are discharged to the Los Angeles River providing additional environmental benefits in conjunction with unused recycled water discharges to the river.

Japanese Garden

The 6.5 acre Japanese Garden is located at the Sepulveda Dam Recreation Area. The Garden receives more than 10,000 visitors per year. DCT provides about 4,590 AFY of recycled water for the lake and landscaping at the Japanese Garden.

Wildlife Lake

Located in the Sepulveda Basin, the Wildlife Lake uses about 7,700 AFY of recycled water from DCT for wildlife habitat management.

Lake Balboa

Lake Balboa is the centerpiece of the Sepulveda Dam Recreation Area and is a popular recreational facility located in Anthony C. Beilenson Park. About 14,700 AF per year of recycled water is provided for this lake from DCT.

4.3.4 Westside Area

Recycled water supplied to the Westside Recycled Water System is provided by WBMWD via the Edward C. Little Water Recycling Plant (WBWRP), located in the City of El Segundo, for irrigation and commercial (toilet flushing) demands. The WBWRP further treats secondary-treated effluent received from HTP to a tertiary level meeting Title 22 standards. Under an agreement between WBMWD and the City, WBMWD purchases secondary-treated effluent from HTP and LADWP has a right to purchase up to 25,000 AFY of recycled water following tertiary treatment at the WBWRP. Approximately 37,300 AFY of secondary-treated effluent was purchased from HTP in 2008 and LADWP purchased 380 AF of recycled water to serve the Westside of Los Angeles. The WBWRP can treat up to 40 mgd. Recycled water not purchased by LADWP is sold to users within WBMWD's service area.

Deliveries of recycled water from the Westside Recycled Water System first began in 1996. To increase the use of recycled water on the Westside, LADWP has constructed more than five miles of distribution trunk lines to serve the Westchester, Los Angeles International Airport, and Playa Vista development areas. Current estimated recycled water demands for the Westside Area are 676 AFY as shown in Exhibit 4I. Currently 106 customers are served by the system.

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Exhibit 4I
Westside Recycled Water System Estimated Existing Annual Demand

Program	Estimated Annual Demand (AFY)
Irrigation	
Playa Vista Phase 1 (95 customers)	205
Coldwell Banker	2
Cal Trans at Playa Vista	5
Los Angeles International Airport	158
Westchester Golf Course	62
Loyola Marymount University	64
Westchester Park	43
Scattergood Generating Station	31
Carl Nelson Youth Park	16
The Parking Spot	1
Street Medians	4
Hyperion Treatment Plant[1]	85
Subtotal Irrigation	676
Total Valley Recycled Water System	**676**

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Playa Vista, Phase 1

Playa Vista is the first planned development in the City to use recycled water for irrigation of all of its landscaping including residential outdoor use. This project began receiving recycled water in 2009 as part of Phase 1. Phase 2 is considered as a "Near-Term" project (or "Tier 1" use), which are projects to be implemented by the year 2015. Outdoor recycled water is required under the development's mitigation requirements established during the environmental review process. Recycled water is additionally used for toilet flushing in commercial buildings. Annual demands are approximately 200 AFY for Phase 1.

Los Angeles International Airport

Los Angeles International Airport began using recycled water in 1996 for landscape irrigation purposes along its boundaries. Current demands for the airport are 158 AFY.

Westchester Golf Course

Westchester Golf Course began using recycled water in 2009 for irrigation. Current demands for the airport are 62 AFY.

Loyola Marymount University

Loyola Marymount University has been connected to the Westside system since 1996. Recycled water is used to irrigate a portion of the campus landscaping area. Average annual demands are approximately 65 AFY. In 2006, Loyola Marymount

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University installed an on-site disinfection system using hydrogen peroxide to address odor problems related to stagnant water in an oversized pipeline servicing the university.

Westchester Park and Carl Nelsen Youth Park

Westchester and Carl Nelsen Youth Parks both use recycled water for irrigation purposes. Both parks were connected to the system in 1996. Westchester Park demands are approximately 43 AFY and Carl Nelsen Youth Park demands are 16 AFY.

Scattergood Generating Station

Scattergood Generating Station operated by LADWP and located in El Segundo receives recycled water to meet irrigation demands. Average annual demand is approximately 31 AFY. The pipeline servicing the facility is oversized to potentially provide cooling water in the future.

Street Medians and The Parking Spot

Street medians on Manchester Avenue and The Parking Spot were connected to the recycled water system in 2008 and 2003, respectively. Recycled water is served to both facilities to meet irrigation demands. The Parking Spot is a commercially operated parking facility near Los Angeles International Airport. Demands for The Parking Spot are approximately 1 AFY and demands for the street medians are approximately 5 AFY.

Hyperion Treatment Plant

HTP uses recycled water for both landscaping and toilet flushing within the administration building. HTP was connected to the system in 1996. About 65 AFY of recycled water are provided to HTP per year. HTP also provides additional treatment for recycled water use onsite similar to Loyola Marymount University to address odor problems associated with stagnant water in an oversized supply pipe. The pipeline to HTP was oversized to accommodate expanded deliveries to the Scattergood Generating Station in the future. HTP uses filters and disinfection to treat the water prior to its use onsite.

4.3.5 Comparison of 2010 Projections Versus Actual Use

LADWP has made substantial progress in increasing recycled water use in the interim period between completion of the 2005 and 2010 UWMPs. Municipal and industrial recycled water use between 2005 and 2010 increased from 4,870 AFY to 10,651 AFY. The 2005 UWMP projected municipal and industrial recycled water use in 2010 would be approximately 19,870 AFY, however actual use was lower than estimated as shown in Exhibit 4J. Environmental water use of recycled water fluctuates slightly year to year based on lake levels, but is typically 26,990 AFY. For 2010 actual use was 25,129 AFY, or approximately 7 percent less than estimated. Overall total recycled water use in 2010 was approximately 23 percent less than projected.

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Exhibit 4J
2005 UWMP Recycled Water Projections for 2010 versus Actual Use

Program	2005 Projection for 2010 (AFY)	09/10 Actual Use (AFY)
Municipal & Industrial Purposes[1]	19,870	6,864
Environmental Use[2]	26,990	25,008
Total	**46,860**	**31,872**

1. These recycled water supplies offset the demand for imported water within LADWP's service area and include DCT reuse of 2,920 AFY, but do not include deliveries to WBMWD of 34,000 AFY. DCT reuse was not included in 2005 UWMP projections for 2010.

2. Water is ultimately discharged into the Los Angeles River, providing additional environmental benefit. 2005 UWMP projections for 2010 is based on average demands.
Sources: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009; 2005 Urban Water Management Plan for the Los Angeles Department of Water Power, and LADWP Water Recycling Staff

Although LADWP did not meet the 2010 recycled water projection, significant progress has been made including the completion of multiple projects since 2005 as described in Section 4.3.1 through 4.3.4. Additional projects that are proposed for construction in the near future are described in Section 4.4, Recycled Water Master Planning Documents. Additionally, LADWP in conjunction with the BOS is currently developing the City's Recycled Water Master Plan (RWMP) to guide future optimization of this supply source with the goal of increasing municipal and industrial use of recycled water to 50,000 AFY, inclusive of indirect potable reuse.

4.4 Recycled Water Master Planning Documents

LADWP in partnership with BOS is developing the RWMP Documents to replace 50,000 AFY of potable water supplies with recycled water by 2029 and to plan for long-term recycled water use. As previously discussed, the City of Los Angeles' Water Supply Plan, "Securing LA's Water Supply", the City has established a goal of 50,000 AFY with recycled water to reduce the need for potable water and diversify LADWP's available water supply options. Exhibit 4K summarizes LADWP's timeline to achieve the goal of recycling 50,000 AFY by fiscal year (FY) 2029. This goal can be achieved sooner if additional funds are made available such as state and federal grants. The RWMP efforts were initiated in 2009 and are forecast for completion by the middle of 2011. To meet near-term challenges and plan for long-term recycled water the following major tasks were outlined for inclusion in the RWMP Documents:

- Groundwater Replenishment Report;
- Non-Potable Reuse Report;
- Groundwater Replenishment Treatment Pilot Study;
- Max Reuse Concept Report;
- Satellite Feasibility Concept Report;
- Existing System Reliability Concept Report; and

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Within these tasks the RWMP Documents will determine where the existing recycled water system (purple-pipe network) should be expanded to satisfy needs of new customers. A cost benefit analysis will be conducted to identify potential customers considering location and projected use. A review of the wastewater treatment plants will be performed to determine which plants can supply the recycled water and the treatment technologies required. The RWMP Documents will also review available options for maximizing reuse through a combination of alternatives including expansion of non-potable uses, groundwater replenishment with advanced treated recycled water, and/or injection of recycled water as a seawater intrusion barrier. A set of alternatives will then be developed and analyzed for both the near-term and long-term goals. Alternatives will be evaluated as part of an integrated analysis.

The RWMP Documents will include Near-Term recycled water projects (projects to be implemented through 2015 to achieve 20,000 AFY of recycled water use), expansion of the non-potable distribution system beyond 20,000 AFY, and groundwater replenishment with advanced treated recycled water options. When combined with existing reuse, these options are expected to result in 50,000 AFY of reuse by FY 2029, exclusive of environmental reuse, DCT in plant reuse, and sales to WBMWD. Exhibit 4K provides a timeline for projects featured in the RWMP Documents.

Exhibit 4K
Recycled Water Master Planning Documents Implementation Timeline

Timeline	Reuse Volume[1] (AFY)	Description
Existing as of Fiscal Year 2009/2010	6,700	Existing demands already being served
Recycled Water Use by 2015	20,000	Near-Term projects already identified for implementation by 2015
Groundwater Recharge by 2021	15,000	New groundwater replenishment opportunities as identified as part of the Groundwater Master Plan task
Non-Potable Reuse Recycled Water by 2029	Up to 15,000	New projects identified between 2015 and FY 2029 to serve existing potable customers as part of the non-potable reuse master plan

1. Volume to offset municipal and industrial potable water demands. Does not include environmental use, DCT plant reuse, and sales to WBMWD.

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Tier 1 Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Recycled water projections in five year increments beginning in 2015 through 2035 are presented in Exhibit 4L. Total recycled water production is estimated to increase by 42,000 AFY over the projection period or 84 percent. Environmental reuse and seawater intrusion barrier water are expected to remain constant at 26,990 AFY and 3,000 AFY, respectively. Municipal and industrial use, inclusive of DCT reuse, is expected to increase by 27,000 AFY or approximately 136 percent. Indirect potable reuse (groundwater recharge) with advanced treated recycled water is forecast to provide 15,000 AFY of groundwater recharge beginning in 2021. Recycled water use up to 2025 is inclusive of the near-term options under development in the RWMP. Projections for 2030 and 2035 assume that long-term options being developed as part of the RWMP will increase recycled water use by approximately 1,500 AFY annually beyond FY 2029. Once the alternatives for the RWMP are finalized, the allocation of recycled water use by the municipal, industrial, and groundwater recharge categories may change to achieve the RWMP's recycled water goal of 50,000 AFY.

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Exhibit 4L
Recycled Water Use Projections

Category	Projected Use (AFY)[1]				
	2015	2020	2025	2030	2035
Municipal and Industrial	20,000	20,400	27,000	29,000	29,000
Indirect Potable Reuse (Groundwater Recharge)	0	0	15,000	22,500	30,000
Subtotal[2]	**20,000**	**20,400**	**42,000**	**51,500**	**59,000**
Environmental[3]	26,990	26,990	26,990	26,990	26,990
Seawater Intrusion Barrier (Dominguez Gap Barrier)	3,000	3,000	3,000	3,000	3,000
Total	**49,990**	**50,390**	**71,990**	**81,490**	**88,990**

1. Projected use by category is subject to change per completion of Recycled Water Master Plan, but overall total will not change. Does not include deliveries of 34,000 AFY of secondary treated water to WBMWD for further treatment to recycled water standards.

2. To offset potable use and included in supply reliability tables in Chapter 11.

3. Environmental use includes Wildlife Lake, Balboa Lake, and the Japanese Gardens. Additional environmental benefits associated with recycled water discharges to the Los Angeles River are not included.

Estimates of projected use and implementation timelines in the tables above as well as the annual demands and service dates for individual customers in the following sections may be affected by varying usage patterns of potential customers, timelines to reach agreements, as well as potential financial constraints and changing regulatory requirements.

4.4.1 Near-Term Projects through 2015

"Near-Term" projects are classified in the RWMP Documents as projects that will result in recycled water service between July 1, 2009 and 2015 to achieve 20,000 AFY of recycled water use to displace potable water. All Near-Term projects are either in the planning, design, or construction stage. Near-Term target customers have already been identified as potential recycled water users with a total demand of 15,021 AFY. Implementation of Near-Term projects will result in the connection of approximately 40 additional recycled water customers adding to the existing 130 customers. Full implementation of Near-Term projects with existing projects will result in annual recycled water demand of 20,000 AFY, exclusive of both environmental use and DCT in-plant use (26,990 and 2,920 AFY, respectively). Near-Term reuse is the largest in the commercial/industrial sector followed by the irrigation sector.

Harbor Area

Two projects are planned to meet Near-Term demands in the Harbor area, the Harbor Refineries Water Recycling Project (HRWRP) and the Port of LA Harry Bridges Development, for an estimated total demand of 9,461 AFY. Uses include industrial, irrigation, and toilet flushing in commercial facilities. Most of the recycled water, approximately 9,520 AFY, will be used for industrial purposes, including cooling towers and boiler make-up water at oil refineries. Exhibit 4M summarizes Near-Term demands for the Harbor area.

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Exhibit 4M
Harbor Area Near-Term Estimated Demands

Type	Estimated Annual Demand (AFY)	Estimated Service Date
Harbor Irrigation	300	2014
Port of LA Irrigation/Commercial/Industrial	220	2015
Harbor Commercial/Industrial	9,000	2014-2015
Total Harbor Area Near-Term Demands	**9,520**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Meeting demands in the Harbor Area will require construction of additional infrastructure. Approximately 12 miles of 8 to 30-inch diameter pipeline and a 1 million gallon storage tank are proposed. All infrastructure to serve the Port of LA Harry Bridges Development will be constructed by the Los Angeles Harbor Department.

Through an agreement with WBMWD, LADWP intends on acquiring nitrified Title 22 water from the WBMWD Juanita Millender-McDonald Water Treatment Plant (JMMWTP) to supply recycled water to these customers.

Metro Area

Nine water recycling projects and connection of three miscellaneous customers are planned in the Metro Area with annual demands of approximately 1,813 AFY. Almost all recycled water customers propose to use recycled water for irrigation. Commercial uses of recycled water include street sweeping, vehicle washing, train washing, and laundry. LAG will continue to meet all recycled water demands in the Metro area. Exhibit 4N summarizes Near-Term demands for the Metro area.

Exhibit 4N
Metro Area Near-Term Estimated Demands

Type	Estimated Annual Demand (AFY)	Estimated Service Date
Irrigation	1,713	2010-2015
Commercial/Industrial	100	2011-2013
Total Metro Area Near-Term Demands	**1,813**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

Multiple facilities are required in the Metro area to meet near-term demands. Approximately five pump stations ranging in size from 600 to 1,800 gallons per minute are planned for construction. Three water tanks with a combined capacity 4.75 million gallons, including the conversion of an abandoned potable water tank in Griffith Park into non-potable water storage tank, are necessary to meet demands. Pipeline construction will consist of 10 additional miles of pipeline ranging from 8 to 30-inch diameters, including conversion of an existing 16-inch pipeline to a 30-inch pipeline beneath Forest Lawn Road.

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Valley Area

In the Valley area DCT will provide the potential Near-Term annual demands approximating 769 AFY. Almost all Near-Term use, except for 75 AFY, will be for irrigation purposes. These users are all located within close proximity to the existing recycled water system. Exhibit 4O summarizes the potential Near-Term demands for the Valley area.

Exhibit 4O
Valley Area Near-Term Estimated Demands

Type	Estimated Annual Demand (AFY)	Estimated Service Date
Irrigation	769	2010-2013
Commercial/Industrial	75	2010-2013
Total Metro Area Near-Term Demands	**844**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling staff

Only minor facilities will be required to connect near-term users to the existing system. Over 2 miles of pipeline ranging from 16 to 20-inch in diameter are proposed. Additionally, 1 storage tank between 1 to 1.5 million gallons and a pump station of an undetermined volume will be required to meet demands.

Westside Area

LADWP will continue to acquire recycled water from WBMWD to serve Near-Term demands of approximately 350 AFY in the Westside area. Near-Term demands include increasing use at Playa Vista and LAX and adding five new customers. Approximately two-thirds of the water will be for irrigation purposes and one-third for commercial/industrial uses in cooling towers located at LAX. Exhibit 4P summarizes Near-Term demands for the Westside Area.

Exhibit 4P
Westside Area Near-Term Estimated Demands

Project	Estimated Annual Demand (AFY)	Estimated Service Date
Irrigation		
Playa Vista Phase 2	100	2015
Westchester High School	10	2012
Subtotal Irrigation	100	
Commercial/Industrial		
LAX Cooling Towers	240	2015
Subtotal Commercial/Industrial	240	
Total Metro Area Near-Term Demands	**350**	

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Existing and Near-Term Recycled Water Systems TM, December 14, 2009 and LADWP Water Recycling Staff

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Serving Near-Term demands will require limited expansion of the existing recycled water system in the area as additional users will connect to the existing system. Connection of the cooling towers at LAX will require construction of an additional 0.7 miles of 12-inch diameter pipeline.

4.4.2 Non-Potable Reuse (NPR) Projects to be completed between 2015 - 2029

NPR projects to be completed between 2015 – 2029 are being identified through the development of the RWMP. These projects will make up the balance of recycled water demand up to 15,650 AFY to achieve the overall city goal of 50,000 AFY of recycled water displacing potable water uses.

As presented in Exhibit 4Q, the project options will have a total demand of approximately 23,100 AFY, inclusive of demands greater than 5 AFY, which is larger than the goal of up to 15,650 AFY and larger than the initial targeted customer demand of 14,390 AFY. Ultimately, an implementation plan will be developed for the recommended project options with a goal of beginning operations for all projects included in the implementation plan by FY 2029.

Exhibit 4Q
Project Option Demands by Service Area

Service Area	Total Demand[1] (AFY)
Harbor	3,300
Metro	6,100
Valley	10,100
Westside	3,600
Total	**23,100**

1. Includes customers with non-potable demand estimates greater than 5 AFY.

Source: City of Los Angeles Recycled Water Master Plan Technical Memorandum, Draft Tier 2 Non-Potable Reuse Project Options, February 26, 2010

Project Selection

An initial step for evaluating these projects involves identification of potential potable customers that can utilize recycled water. These customers need to have sufficient demand and a viable use for recycled water. A preliminary list of potential of customers and associated demands was completed, identifying targeted customer demands of 14,390 AFY. Irrigation-only demands were focused on first as it is generally easier to convert irrigation-only customers to recycled water use than commercial or industrial users. As described below, during development of the project options potential additional recycled water customers were identified based on their non-potable water demands and distance from recycled water sources.

Next, recycled water project options were developed to meet the goal of maximizing recycled water use, while promoting cost efficiency as well as implement ability and adaptability. Two primary steps were utilized to develop recycled water project options:

- Identification of project segments to serve each customer with non-potable demands in excess of 50 AFY
- Identification of project options combining project segments that are linked and have similar unit costs

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The first step in the development of project options was to define general project areas based on customers with non-potable demands in excess of 50 AFY. In the project areas, transmission pipeline alignments (backbone alignments) and laterals were defined to connect customers with demands greater than 50 AFY to existing recycled water infrastructure. Alignments were then redefined to connect demand clusters of less than 50 AFY, but large enough for consideration as a large demand. Finally, distribution pipeline (laterals) alignments were determined to connect customers with demands less than 50 AFY to backbone alignments.

Initial projects options and unit costs are being identified in the current phase of the RWMP. Refinement of these options will occur prior to development of the integrated alternatives for near-term recycled water use. Options for non-potable reuse transmission (purple) pipelines are considered in conjunction with options developed for groundwater replenishment (see section 4.4.3), maximizing reuse, and satellite plants to develop integrated alternatives. Additional information on recycled water unit cost is presented in section 4.4.5 – RWMP Cost and Funding.

Recycled Water Supply Sources

Recycled water availability varies by service area. Additional supplies may be required to meet longer term demands between 2015 – 2029 that may require a combination of expanding existing facilities, service connections to neighboring agencies outside the City, new facilities, and satellite treatment facilities. Satellite treatment facilities are being investigated in the Metro, Valley, and Westside service areas. The RWMP is investigating options to ensure adequate supplies are available for each service area. As part of the RWMP, LADWP met with neighboring agencies in 2009 to explore potential opportunities for regional development of recycled water reuse facilities. These agencies are listed in Exhibit 4T, in section 4.4.6, Stakeholder Process and Agency Coordination.

4.4.3 Groundwater Replenishment

As part of the RWMP, LADWP is pursuing a Groundwater Replenishment Project (GWR), also known as indirect potable reuse, using highly purified advanced treated recycled water from DCT for spreading in existing spreading basins in the San Fernando Valley area. A minimum goal of 15,000 AFY by 2021 has been set for recharging the San Fernando Basin, a major potable water supply for LADWP. The city anticipates having the ability to eventually deliver greater amounts of up to 30,000 AFY to the GWR. The RWMP includes a groundwater recharge plan providing a capital improvement program and outlines regulatory approval steps required to complete the "Phase 1". Additionally, the RWMP outlines various operational and infrastructure improvements required to meet the goal. When complete the RWMP will contain a recommended GWR alternative. Regulatory requirements for groundwater recharge are discussed in sub-section 4.1.2, Groundwater Recharge Regulatory Requirements.

Currently, LADWP uses multiple spreading grounds located in the eastern portion of the San Fernando Basin to recharge the underlying San Fernando Basin with stormwater and imported water. A detailed discussion of the San Fernando Basin and existing recharge operations is provided in Chapter 6, Local Groundwater. This project would recharge a minimum of 15,000 AFY of advanced treated water in the existing Hansen Spreading Grounds and possibly Pacoima Spreading Basins by allowing the water to percolate into the aquifer. It is expected that native stormwater recharge would continue to occur at the spreading grounds in conjunction with the project.

Infrastructure improvements are required to implement the groundwater replenishment program including an advanced water treatment facility and pipelines to convey the product water to the spreading basins.

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An advanced water treatment facility is necessary to further treat tertiary effluent from DCT to produce highly purified recycled water for recharge. Goals for the advanced water treatment plant include as described in the RWMP are:

- Minimum capacity of 15,000 AFY; with the potential to expand to 30,000 AFY
- Initially in service by 2021;
- Utilization of proven technologies that have demonstrated effective removal of regulated chemicals, constituents of emerging concern, and microorganisms; additional removal of constituents of wastewater origin of interest to CDPH, including pharmaceuticals, personal care products, and endocrine disrupting compounds; and
- Product water shall comply with requirements from the CDPH, RWQCB, and SWRCB and be suitable for indirect potable reuse.

To develop and implement the project within the short-time frame, the advanced wastewater treatment plant will be based on the recently permitted Orange County Water District Groundwater Replenishment System Project. This system provides product water for indirect potable reuse by recharging a groundwater basin used for potable water and preventing seawater intrusion. Proposed technologies include microfiltration or ultrafiltration, reverse osmosis, advanced oxidation using ultraviolet light with hydrogen peroxide, and post-treatment for product water stabilization.

As a by-product of advanced water treatment brine is created. Multiple brine disposal alternatives are presented in the RWMP and a final alternative will be selected upon completion of the plan.

Pipelines to convey water to the Hansen spreading grounds are already in place and were constructed as a part of the previous recycled water initiatives for the East Valley Water Recycling Project. However, if the Tujunga spreading basin will also receive water for spreading then additional pipeline infrastructure will be required.

LADWP is working closely with BOS and regulatory agencies to expedite completion of the project by 2021. Current ongoing tasks include completion of the RWMP, public outreach, pilot testing of processes, and formation of an independent advisory panel. Environmental documentation is expected to be initiated in 2011 and completed in 2013.

Independent Advisory Panel

GWR projects typically have the involvement of an independent third party with scientific and technical expertise to provide expert peer review of key aspects of the project, which can ensure the technical viability of the GWR and facilitate the regulatory process. To accomplish this, LADWP awarded a contract with National Water Research Institute (NWRI) to form an Independent Advisory Panel (IAP) to provide expert peer review of the technical, scientific, regulatory, and policy aspects of the proposed groundwater replenishment project, pilot project testing, and other potential groundwater replenishment projects to maximize reuse as part of the LADWP Recycled Master Planning Documents. The IAP process will provide a consistent, thorough, and transparent review of any proposed GWR projects and pilot testing during their critical formation phase, as well as during the long- term implementation phase.

NWRI has vast experience in the organization and administration of the IAP processes for other agencies such as the Orange County Water District Groundwater Replenishment System Project. NWRI will assist the IAP process by assembling the IAP

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members, developing a detailed scope and approach for the IAP's review, coordinating and facilitating meetings, and preparing IAP reports.

Some of the immediate activities that have been identified for the IAP to address during the initial participation include, but are not limited to review of the following:

- General approach for Recycled Water Master Planning
- Hydrogeology (in-basin groundwater blending)
- Treatment (barriers to replace the fifty-percent blend criteria)
- Reliability features of the Advanced Water Treatment Facility
- Source Control Evaluation for groundwater replenishment
- Draft Engineering Report for groundwater replenishment
- Response to technical concerns raised by regulators and the public

The "Independent Advisory Panel for the City of Los Angeles Groundwater Replenishment Project" consists of 13 members with scientific and/or professional expertise in issues related to the implementation of groundwater replenishment projects. Members with different areas of expertise are based on the requirements of the California Department of Public Health Draft Groundwater Recharge Reuse Regulations dated August 2008, as well as the composition of panels used by the Orange County District and the City of San Diego for the implementation of similar groundwater replenishment projects.

NWRI convened the Independent Advisory Panel for the first time in October 2010 to receive introductory information about the recycled water program and groundwater replenishment project. The Panel is expected to be involved throughout the planning, permitting, design, environmental documentation, and implementation of the groundwater replenishment project.

4.4.4 Efforts Beyond 50,000 AFY

As part of the RWMP, LADWP is developing long-term alternatives to maximize recycled water use beyond 50,000 AFY. After 2029 and through 2035 LADWP expects to increase recycled water use by approximately 1,500 AFY anually. To maximize recycled water use LADWP is investigating the following options in its RWMP:

- Recycled water satellite treatment facilities;
- Expansion of recycled water systems;
- Increasing treatment levels at HTP to tertiary and advanced treatment;;
- Reviewing opportunities for partnerships with agencies within the City and outside the City
- Treatment plant upgrades at DCT and LAG; and
- Methods to increase reliability of the system.

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Additionally, the RWMP will identify how the city can maximize recycled water usage unto the future beyond the 50,000 AFY goal. The long-term recycled water alternatives analysis as part of the RWMP has not been completed. However, LADWP forecasts that in 2035 municipal and industrial recycled water demands along with groundwater replenishment will be approximately 59,000 AFY. In addition to this, 26,990 AFY will also be used for environmental beneficial reuse.

4.4.5 RWMP Cost and Funding

The capital cost of expanding the recycled water system to achieve the initial goal of 50,000 AFY to displace the need of potable water was initially estimated to cost approximately $1 billion. Exhibit 4R summarizes the initial estimated capital costs for the RWMP. However, these estimates are being refined as part of the RWMP that are expected to be updated by early 2011.

Exhibit 4R
RWMP Estimated Capital Costs

Phase	Capital Cost[1] ($ million 2008)
Near-Term projects through 2015	$ 265
Long-Term projects through 2029	$ 435
Groundwater Recharge Project	$ 300
Total RWMP Capital Cost	**$ 1,000**

1. Capital costs will be updated and refined as part of the RWMP.

Unit Cost

Non-Potable Reuse (NPR) and Groundwater Replenishment (GWR) projects are diverse, and result in a wide range of costs to implement and sustain. NPR projects present numerous challenges including distance from treatment plant and the associated transmission pipeline construction costs. This factor is weighed against customer size as well as the adaptability to a particular commercial site or process. For GWR projects, nearby spreading grounds must be acquired, along with the construction of a conveyance pipeline. Initial findings of the RWMP have determined the approximate range of unit cost for recycling to be from $600 - $1,500 / AF. This approximation includes capital, operation and maintenance costs.

Funding

Capital costs for RWMP projects will be covered by the sources identified below, as well as other sources as they become available.

- Water Rates – LADWP water rates are the primary funding source for the recycled water program.
- Federal Funding – LADWP will pursue federal funding as it becomes available. In the past LADWP has received funding for recycled water projects from the Federal Water Project Authorization and Adjustment Act of 1992, Public Law 102-575 (HR429), and the United States Bureau of Reclamation Title XVI Program.
- State Funding – LADWP will pursue state funding as it becomes available, through the SWRCB and DWR for recycled water projects. Propositions 13 and 50 had funds specifically marked for recycled water projects. Funding is available through Proposition 84, Integrated Regional Water Management, for implementation projects, including recycled water projects. Low-interest loans are available through the SWRCB for eligible projects.

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- MWD Local Resources Program Incentive – The Local Resources Program provides funding for water recycling and groundwater recovery projects that prevent a new demand on MWD or displace an existing demand on MWD. Financial incentives up to $250 per acre-foot are available dependent upon MWD water rates and projects costs. Funding is not received until production occurs and terminates upon the expiration of the funding agreement for the project.

4.4.6 Stakeholder Process and Agency Coordination

Stakeholder outreach and coordination with agencies plays a key role in LADWP's recycled water program and the RWMP.

Stakeholder Process

To encourage input as recycled water strategies are developed over the next few years in conjunction with the RWMP, LADWP has initiated an extensive stakeholder process. LADWP has developed two formats for participation of stakeholders, a more intensive Recycled Water Advisory Group (RWAG) and a less intensive Recycled Water Forum.

Over 200 stakeholders were invited to participate in the RWAG representing broad interests across the City, including community groups, environmental groups, neighborhood councils, homeowners' associations, and others. Approximately 60 stakeholders are participating in the process. The RWAG first met in 2009 and will continue to have approximately 5 workshops per year over the next 3 to 4 years. Through the RWAG, stakeholders are provided the opportunity to represent their respective organizations and share input with LADWP and BOS and convey they knowledge gained to their organizations. Two main roles of the RWAG are:

1) Allow stakeholders to provide input on recycled water options from technical, environmental, financial, and social viewpoints

2) Consider key project issues and discuss implementation challenges and acceptability.

Less intensive stakeholder participation opportunities are available through the Recycled Water Forums. The Recycled Water Forums will provide stakeholders the opportunity to hear briefings on recycled water efforts through several weekend or evening meeting throughout the year held within local communities. Stakeholders will have the opportunity ask questions and provide comments and suggestions.

Agency Coordination

To maximize recycled water use and move forward with RWMP efforts, LADWP closely coordinated with agencies at the local and state levels. Coordination is necessary to ensure adequate funding, identification of end-users, adequate availability of supplies, permitting and regulatory approvals, and regional cooperation. If federal funding opportunities become available, LADWP will also coordinate with the applicable federal agencies. Exhibit 4S provides a summary list of agencies LADWP is currently coordinating with to maximize recycled water use. LADWP also coordinates recycled water end use with potential customers by assisting with facility retrofits, providing financial incentives, and public education.

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Exhibit 4S
Recycled Water Agency Coordination

Burbank Water and Power[1]	Los Angeles County Department of Public Works[1]
Central Basin Municipal Water District[1]	Metropolitan Water District of Southern California[1]
Glendale Water and Power[1]	Pasadena Water and Power[1]
Los Angeles County Sanitation Districts[1]	Water Replenishment District of Southern California[1]
Long Beach Water Department[1]	West Basin Municipal Water District[1]
Las Virgenes Municipal Water District[1]	Los Angeles Regional Water Quality Control Board
State Water Resources Control Board	Los Angeles County Department of Public Health
City of Los Angeles Department of Public Works, Bureau of Sanitation, Watershed Protection Division	City of Los Angeles Department of Public Works, Bureau of Sanitation
California Department of Public Health	

1. Met with agencies individually to discuss potential regional recycled water use.

4.4.7 Recycled Water Quality

All recycled water provided by LADWP meets at minimum Title 22 standards. Title 22, Chapter 4, of the California Code of Regulations establishes water quality standards and treatment reliability criteria for water recycling to ensure public safety as discussed in Section 4.1. Title 22 standards are achieved with tertiary treatment and disinfection.

Advanced wastewater treatment is currently provided at the TIWRP by the AWTP. Advanced treatment, which includes microfiltration and reverse osmosis, removes many of the impurities remaining after tertiary treatment and disinfection. Water treated with advanced treatment techniques has the potential to be used for seawater barriers and groundwater recharge. As part of the RWMP, advanced treatment is proposed for DCT to provide indirect potable reuse through groundwater recharge. Exhibit 4C, located in Section 4.2, summarizes the level of treatment provided by each of the City's wastewater treatment plants.

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Chapter Five
Los Angeles Aqueduct System

5.0 Overview

Water has been an integral part of the City's history. The City's population and economy was initially supported through a combination of local surface flows primarily from the Los Angeles River, and groundwater pumping primarily from the San Fernando Basin. When it became apparent that much of the local groundwater supply and local surface flows were fully utilized, the citizens of Los Angeles under the leadership of William Mulholland, then Chief Engineer of the Los Angeles Water Bureau, approved by a 10 to 1 margin a $23 million bond measure to construct the First Los Angeles Aqueduct in 1913. This investment was equal to 12 percent of the entire City's assessed valuation at that time. Then in 1940, an additional $40 million was spent to extend the first aqueduct 40 miles north from the Owens River to streams that were tributaries to Mono Lake, see Exhibit 5A.

Finally, to meet the additional water needs of its population, the City decided to construct the second barrel of the Los Angeles Aqueduct in 1963, later to become known as the Second Los Angeles Aqueduct. Construction of the Second Los Angeles Aqueduct was completed in 1970. The second aqueduct increased the City's capacity to deliver water from the Mono Basin and the Owens Valley to Los Angeles from 485 cubic feet per second (cfs) to 775 cfs.

The value of the City's historical investment in the Los Angeles Aqueduct System is substantial. For nearly a century, the City has benefited from the delivery of high-quality, cost-effective water supplies from the eastern Sierra Nevada.

Over time, environmental considerations have required that the City reallocate approximately one-half of the Los Angeles Aqueduct (LAA) water supply to environmental enhancement projects. As a result, the City has used approximately 205,800 AF of water supplies for environmental enhancement in the Owens Valley and Mono Basin regions in 2010, which is in addition to the almost 107,300 acre-ft per year (AFY) supplied for agricultural, stockwater, and Native American Reservations. Limiting water deliveries to the City from the LAA has directly led to increased dependence on imported water supply from the Metropolitan Water District of Southern California (MWD). LADWP purchase of supplemental water from MWD in 2008-09 is at an all time high.

As indicated in Exhibit 5B, LAA deliveries comprise 39 percent of the total runoff in the Eastern Sierra in an average year. The vast majority of water collected in the Eastern Sierra stays in the Mono Basin, Owens River, and Owens Valley for ecosystem and other uses.

Exhibit 5A
Los Angeles Aqueduct System

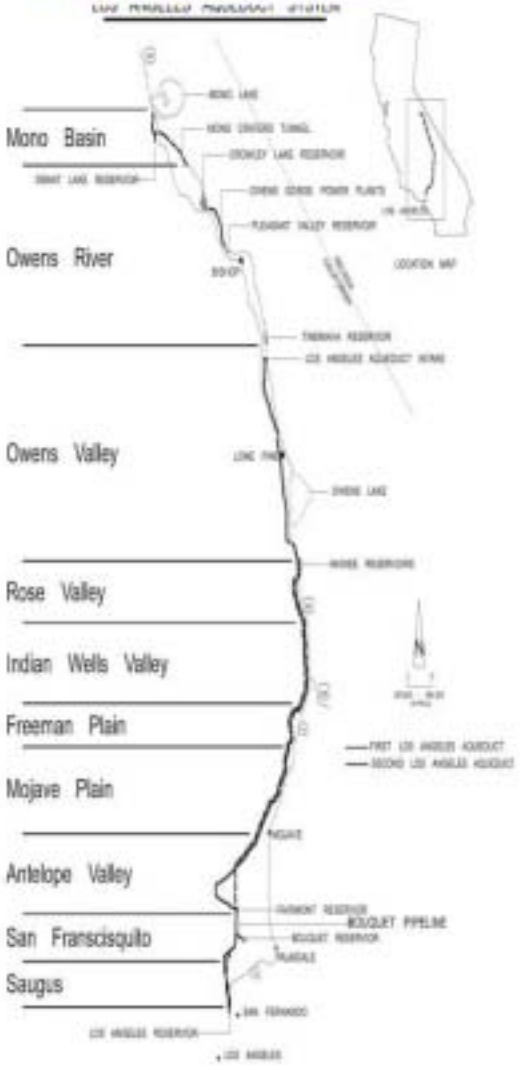

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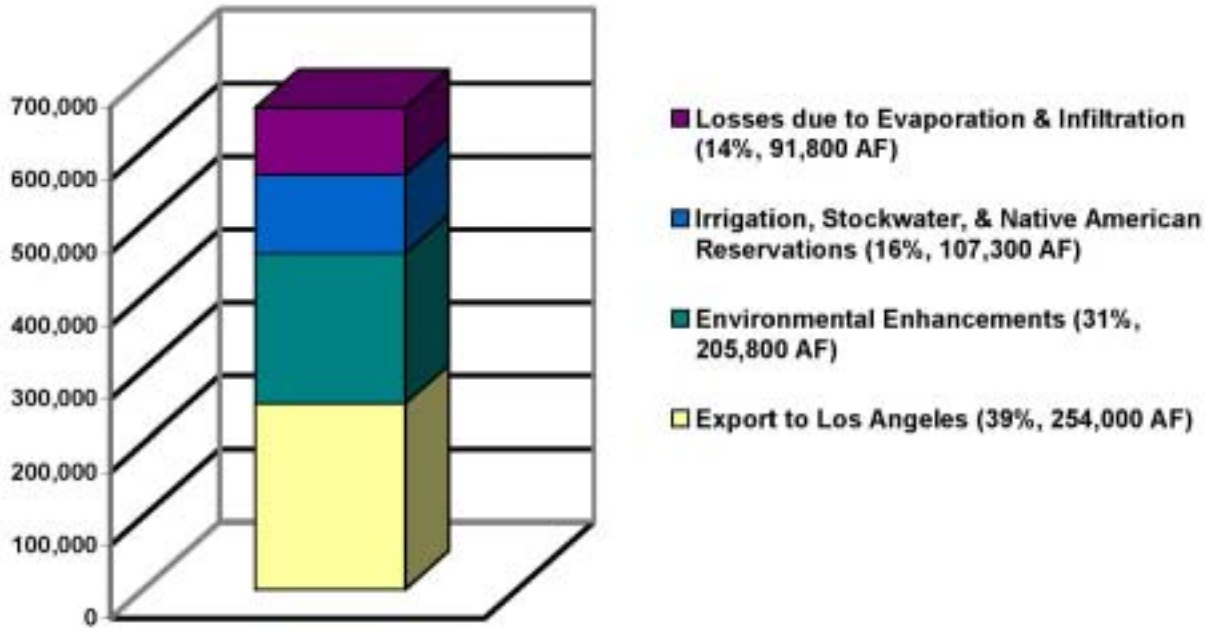
Exhibit 5B
Mono Basin and Owens Valley Water Use Allocations



5.1 Historical Deliveries

Annual LAA deliveries are dependent on snowfall in the eastern Sierra Nevada. Years with abundant snowpack result in larger quantities of water deliveries from the LAA, and typically lower supplemental water purchases from MWD. Unfortunately, a given year's snowpack cannot be predicted with certainty, and thus, deliveries from the LAA system are subject to significant hydrologic variability.

The impact to LAA water supplies due to varying hydrology in the Mono Basin and Owens Valley is amplified by the requirements to release water for environmental restoration efforts in the eastern Sierra Nevada. Since 1989, when City water exports were significantly reduced to restore the Mono Basin's ecosystem, LAA deliveries from the Mono Basin and Owens Valley have ranged from 108,503 AF in 2008-09 to 466,584 AF in 1995-96. Average LAA deliveries since 1989-90 have been approximately 264,799 AF, about 42 percent of the City's total water needs.

The cyclical nature of hydrology is exhibited best by Los Angeles Aqueduct (LAA) deliveries over the last ten years. This general period was characterized by a series of wet years, followed by a series of dry years. From 2000-01 through 2009-10, LAA deliveries supplied an average of 36 percent of the City's water needs. The reliability impact of hydrologic cycles on LAA supplies is evident through historical deliveries. A broader look at how deliveries from the LAA have fluctuated from year to year is shown in Exhibit 5C.

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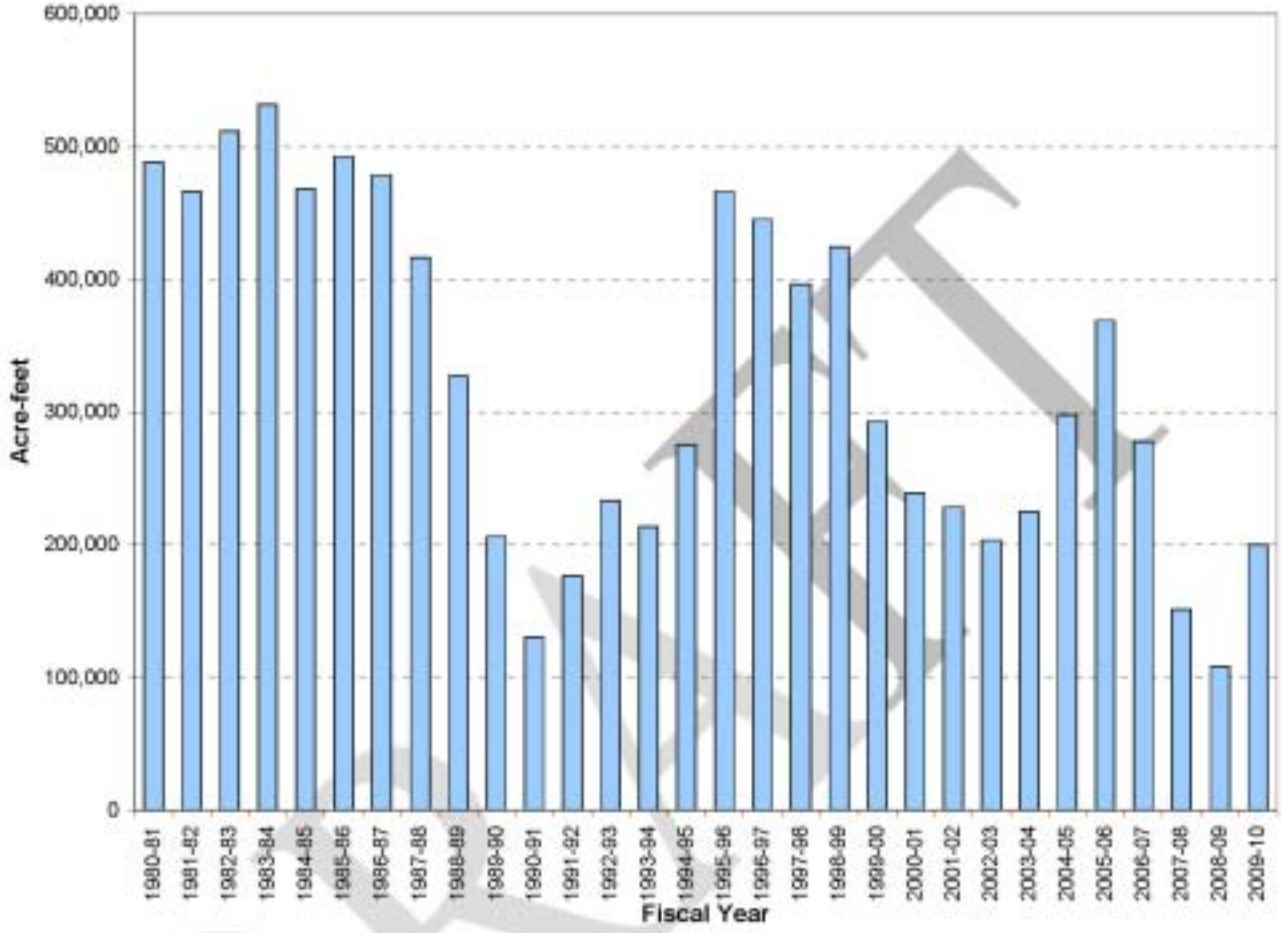
Exhibit 5C
Historical Los Angeles Aqueduct Deliveries



A long term perspective of the general cycle of wet and dry years for the Owens Valley is evident in Exhibit 5D, particularly since the late 1960s. As illustrated, reliance solely on one water supply source is not practical. Therefore, the City relies on the LAA in combination with the Colorado River Aqueduct and the State Water Project as the City's primary imported water sources. These imported sources combined with local groundwater, recycled water, and conservation make up the City's total water supply portfolio. This portfolio of water resources is fundamental to LADWP's ability to deliver a reliable water supply to meet the needs of over 4 million residents of Los Angeles.

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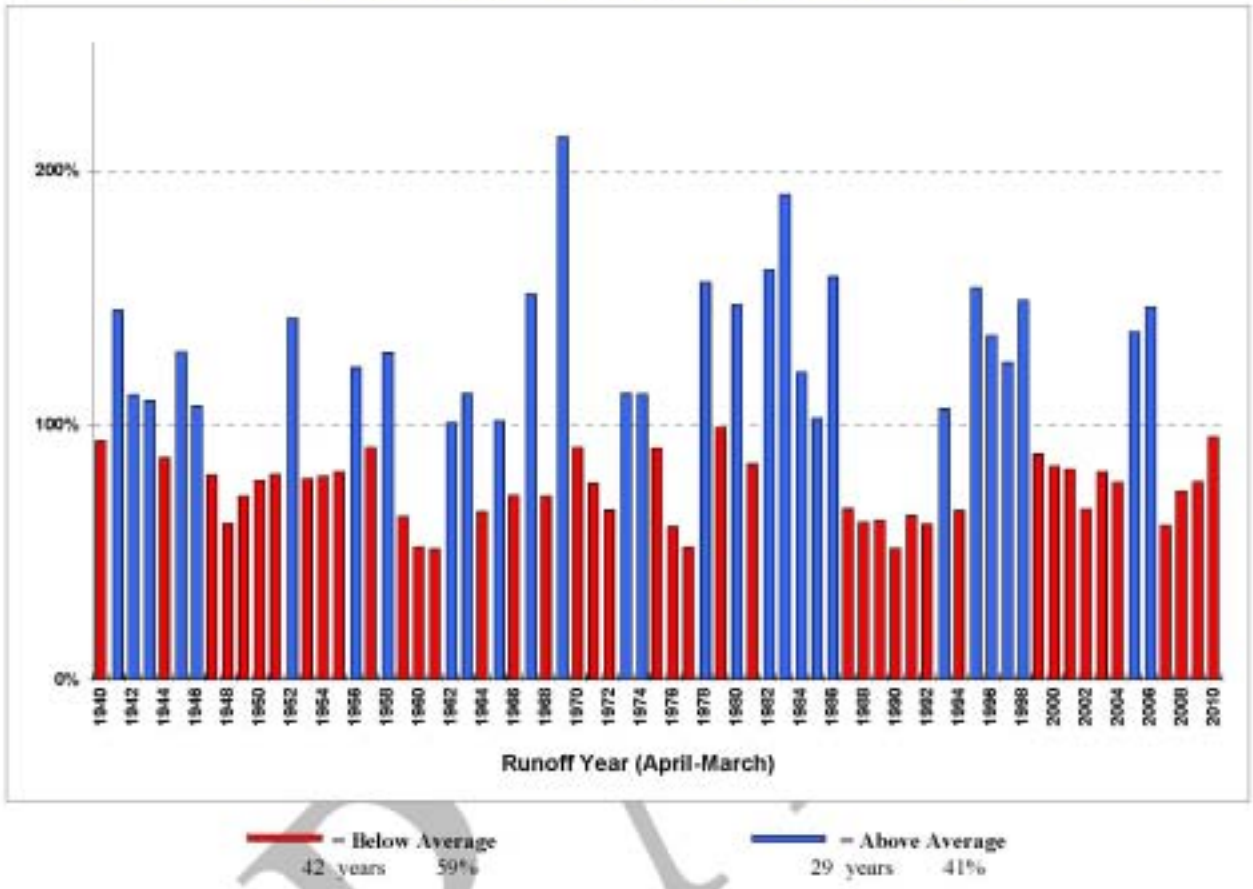
Exhibit 5D
Eastern Sierra Nevada Runoff Owens Valley – Percent of Normal



5.2 Mono Basin and Owens Valley Supplies

Surface runoff from snowmelt in the eastern Sierra Nevada Mountains is the primary source of supply for the LAA. The LAA extends approximately 340 miles from the Mono Basin to Los Angeles. Water is conveyed the entire distance by gravity alone. LADWP regulates system output through storage control at seven reservoirs, beginning with Grant Lake Reservoir to the north and ending with Bouquet Reservoir to the south. The total combined reservoir storage capacity of the system is 300,560 AF. Hydroelectric power is also generated from 12 power plants along the LAA. Combined maximum capability of the power generation facilities is 205 mega-watts. Water-gathering activities for the LAA have a junior priority to meeting the Owens Valley and Mono Basin water obligations for environmental, domestic, agricultural, and recreational water needs.

The LAA is fed by runoff from the eastern slope of the Sierra Nevada. Runoff from the eastern slope reaches its maximum in the late spring and summer, after most of the year's precipitation has already occurred. The snowpack in the eastern Sierra Nevada provides natural storage for the LAA system. This snowpack storage is necessary in light of the minimal primarily regulatory storage capacity along the LAA system.

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Water Rights

The City's export of water from the eastern Sierra Nevada is based on 166 Pre-1914 and 16 Post-1914 water right diversion licenses on various streams in the Mono Basin and Owens Valley. The majority of the City's water rights were filed prior to 1914 with the Counties of Mono and Inyo Recorder's Office. All Post-1914 licenses were granted by the State Water Resources Control Board. The most significant basis for export of surface water from the Eastern Sierra Nevada is an appropriation claim in 1905 to divert up to 50,000 miner's inches (1,250 cubic feet per second) from the Owens River at a location approximately 15 miles north of the town of Independence into the LAA for transport to Los Angeles. The City has since filed Supplemental Statements of Water Diversion and Use forms with the State Water Resources Control Board (SWRCB) for all LADWP diversions and licenses.

The City's water right licenses in the Mono Basin were amended by the SWRCB in 1994 through the Mono Lake Basin Water Right Decision 1631. Currently, water export from the Mono Basin is limited to 16,000 AF per year based on a court order to raise the target elevation of Mono Lake and restore four streams that flow to Mono Lake.

The primary groundwater right through which Los Angeles has developed groundwater resources in the Owens Valley is based on ownership of a majority of the land (approximately 314,000 acres) and associated water rights in the Owens Valley. Management of the groundwater supply in the Owens Valley is according to a 1991 agreement between Inyo County and LADWP. The goal of this agreement is to avoid defined decreases and changes in vegetation, and to cause no significant effect on the environment which cannot be acceptably mitigated, while providing a reliable supply of water for export to Los Angeles and for use in Inyo County.

5.3 Environmental Issues and Mitigation

Over time an increasingly larger portion of the LAA water supply has been reallocated to the environment. As a result, the City's current supply for environmental enhancement in the Owens Valley and Mono Basin is approximately 205,800 AF per year. To accommodate LAA delivery reductions due to these environmental enhancements, LADWP has funded conservation and water recycling programs to improve water use efficiency within the City. Exhibit 5E illustrates the breakdown of LAA water supply commitments by category for Environmental Enhancement and Mitigation Projects have been implemented as part of the City's commitment to meet the environmental water needs of the Owens Valley. Among these environmental projects, LADWP is diverting 10,700 AF of water from the LAA for Owens Valley Enhancement and Mitigation Projects, 10,400 AF for Recreation and Wildlife Projects, and 15,700 AF for the Lower Owens River Project. These annual environmental project diversions are in addition to water that provides environmental benefits in the Mono Basin and Owens Lake.

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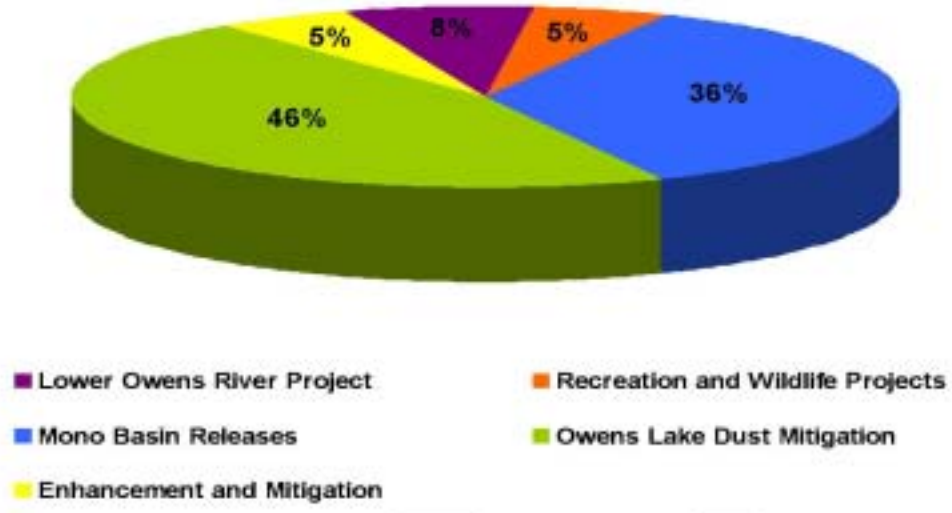
Exhibit 5E
Mono Basin and Owens River Environmental Enhancement Commitments



Environmental Enhancement Commitments	AFY
Lower Owens River Project	15,700
Recreation and Wildlife Projects	10,400
Mono Basin Releases	74,000
Owens Lake Dust Mitigation	95,000
Enhancement and Mitigation	10,700
Total	205,800

Mono Basin

Currently, Mono Basin exports will remain at no more than 16,000 AF per year until Mono Lake reaches its target elevation of 6,391 feet above mean sea level. Exhibit 5F provides the maximum export levels from the Mono Basin under specified conditions as defined in the State Water Resources Control Board Decision D1631 that was issued on September 28, 1994. Since the long-term average of Mono Basin exports before 1994 was approximately 90,000 AFY, the net reduction in water exports in the Mono Basin is estimated at 74,000 AFY of water mainly from Grant Lake Reservoir, Lee Vining Creek, Walker Creek, Parker Creek, and Rush Creek. As of January 2010, Mono Lake is at elevation 6,381 feet. Extensive restoration and monitoring programs in the Mono Basin have improved the streams, riparian, fishery, and waterfowl habitats. With reduced diversions from the basin, Mono Lake's elevation has risen, but has also been fluctuating due to lack of runoff as illustrated during the period of 2000 to 2005 on Exhibit 5F.

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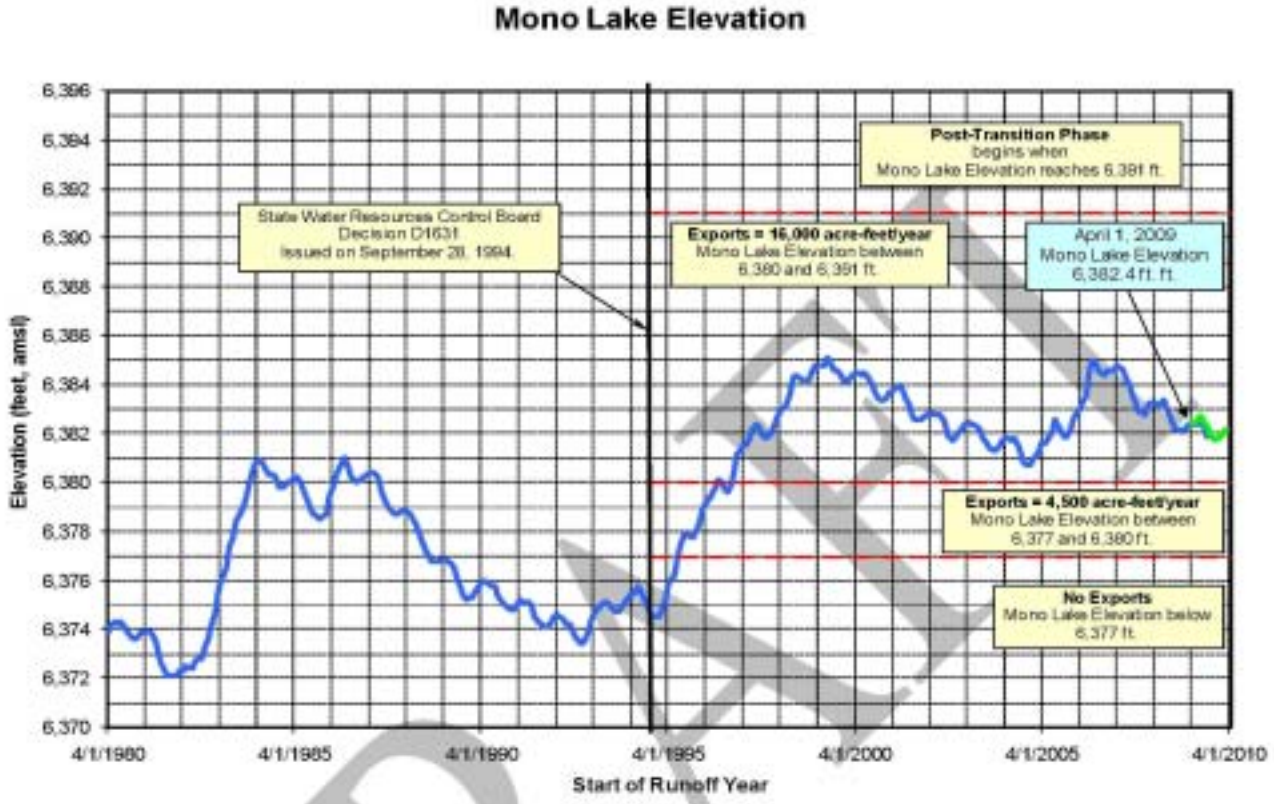
Exhibit 5F
Historical Mono Lake Elevations



To effectively maintain continuous base and peak water flows to the ecosystem restoration area of Lower Rush Creek in the Mono Basin, LADWP completed construction of the Mono Gate One diversion facility upgrade in November 2009. Exhibit 5G summarizes the base and peak flow requirements for Lower Rush Creek. Base and peak flow requirements vary in relation to seven hydrologic conditions ranging from dry to extreme wet as identified by forecasted runoff for Mono Basin. Mono Gate One was originally constructed to release excess water from the aqueduct system during high flows by diverting water into Lower Rush Creek with a system of diversion boards. However, it had no monitoring or flow control capabilities and was not designed for precise flow metering or full-time diversion. Construction completed in the fall of 2009, the new Mono Gate has enabled LADWP to greatly improve measuring and flow capabilities, satisfying one of the operational requirements of the SWRCB.

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Exhibit 5G
Lower Rush Creek Base and Peak Flow Requirements

Hydrologic Condition	Base Flow (cfs)							Peak Flows (cfs)
	Apr	May - Jul	Aug - Sep	Apr - Sep	Oct- Mar	May - Aug	Sep - Mar	
Dry (runoff ≤ 83,665 AF)	N/A	N/A	N/A	31	36	N/A	N/A	None
Dry-Normal I (runoff 83,665 - 91,590 AF)	N/A	N/A	N/A	47	44	N/A	N/A	200 for 7 days
Dry-Normal II (runoff 91,590 - 100,750 AF)	N/A	N/A	N/A	47	44	N/A	N/A	250 for 5 days
Normal (runoff 100,750 - 130,670 AF)	N/A	N/A	N/A	47	44	N/A	N/A	380 for 5 days follows 300 for 7 days
Wet-Normal (130,750 - 166,700 AF)	N/A	N/A	N/A	47	44	N/A	N/A	400 for 5 days followed by 350 for 10 days
Wet (166,700 - 195,400 AF)	N/A	N/A	N/A	68	52	N/A	N/A	450 for 5 days followed by 400 for 10 days
Extreme Wet (runoff > 195,400 AF)	N/A	N/A	N/A	68	52	N/A	N/A	500 for 5 days followed 400 for 10 days

Source: Mono Basin Operations, Guidelines A-G

Lower Owens River Project

Beginning December 2006, the Lower Owens River Project, depicted in Exhibit 5H, releases water from the LAA to create a warm water fishery along a 62-mile section of the Owens River. Water is released near the LAA intake facility and a pump back station is located downstream to return flows to the LAA or to Owens Dry Lake for dust control measures. In accordance with the Memorandum of Understanding between LADWP and Inyo County and the approved Environmental Impact Report, annual monitoring reports are to be prepared to measure project success. The first Lower Owens River Project Annual Monitoring Report was prepared in 2008.

The MOU prescribes requirements for project flows. Both base flows and seasonal habitat peak flows are required by the project. A flow schedule is provided in Exhibit 5I. Seasonal habitat peak flows vary between 40 cfs (zero additional flows beyond the base flow requirements) to 200 cfs. For below average runoff years, seasonal habitat flows may be incrementally lowered from the average runoff year requirements of 200 cfs to 40 cfs (base flow) in proportion to the forecasted runoff flows in the watershed. Base flows are constant at 40 cfs regardless of forecasted runoff flows. It is estimated that the long-term use and transit losses from the project will be approximately 15,700 AFY.

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Exhibit 5H
Lower Owens River Project Area

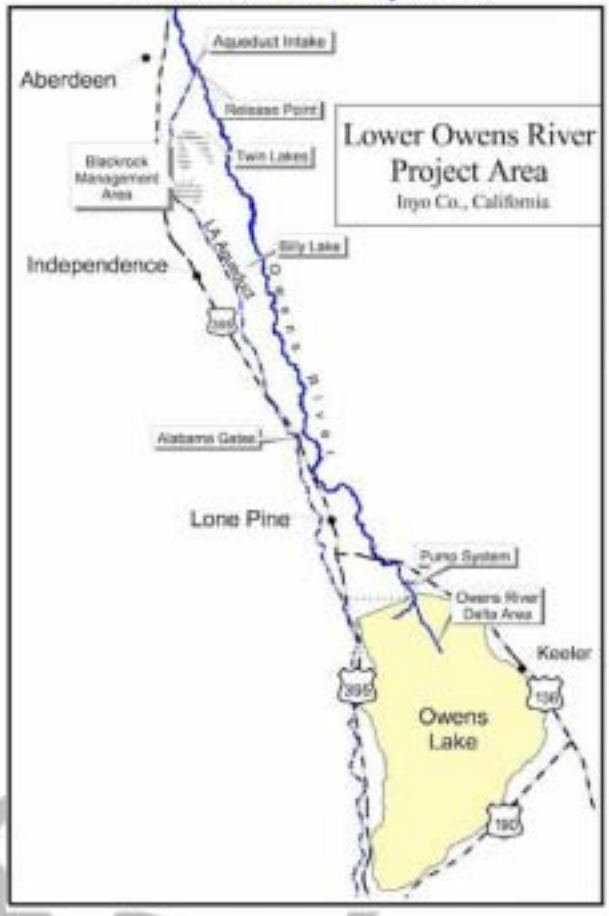

Exhibit 5I
Lower Owens River Base and Peak Seasonal Habitat Flow Requirements

Hydrologic Condition Forecasted[1] (Percent of Average Runoff)	Base Flow (cfs)	Peak Seasonal Habitat Flow (cfs)
50 percent or less	40	Base flow only
70 percent	40	100
100 percent or greater	40	200

1. Runoff forecast determined by LADWP's Runoff Forecast Model for Owens River Basin based on April 1st snow survey.

2. Peak season habitat flows are proportionately ramped up from 40 cfs to 200 cfs based on the percent of average runoff forecasted greater than 50 percent and less than 100 percent.

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5.4 Owens Lake Dust Mitigation

Historically, the Owens River was the main source of water for Owens Lake. Diversion of water from the river, first by farmers in the Owens Valley and then by the City, resulted in the lake being reduced to a small brine pool. The exposed lakebed became a major source of windblown dust resulting in the United States Environmental Protection Agency (EPA) classifying the southern Owens Valley as a serious non-attainment area for particulates (dust) also known as PM_{10} emissions in 1991.

As a result of PM_{10} emissions exceeding regulations, the EPA required California to prepare a State Implementation Plan (SIP) to bring the region into compliance with Federal air quality standards by 2006. In July 1998, LADWP entered into a Memorandum of Agreement with the EPA that: 1) delineated the dust producing areas on the lakebed that needed to be controlled; 2) specified what measures must be used to control the dust; and 3) outlined a timetable for implementation of the control measures. The Memorandum of Agreement was incorporated into a formal air quality control SIP by the Great Basin Unified Air Pollution Control District (District). The plan was approved by the EPA in October 1999.

LADWP's water use for Owens Lake Dust Mitigation has been gradually increased over the years. Exhibit 5J summarizes yearly water use for the Owens Lake Dust Control Project. The 2005 UWMP estimated that up 55,000 AFY of water would be all that was required for the Project. Currently, up to 95,000 AF per year of water is expected to be diverted from the Aqueduct for dust mitigation at the Owens Lake.

Exhibit 5J
Yearly Water Use on Owens Lake (Fiscal Year)

Fiscal Year	Total AF
2002/2003	23,937
2003/2004	31,362
2004/2005	29,494
2005/2006	29,413
2006/2007	54,849
2007/2008	67,262
2008/2009	59,187
2009/2010	75,428
2010/2011	95,000

* Fiscal year 2010/2011 is projected

Since 2001, LADWP has diverted water from the LAA for the Owens Lake Dust Control Project. A combination of shallow flooding, managed vegetation, and a small amount of gravel are used at various lakebed locations as Best Available Control Measures (BACM) for dust control mitigation on almost 40 square miles. Exhibit 5K provides a description of the best accepted control methods. LADWP has completed 9.2 square miles of shallow flooding, 0.5 square miles of modified shallow flooding, and 0.4 square miles of sand fence as part of the Phase 7 project in accordance with the 2008 SIP. However, LADWP had proposed 3.1 square miles of a new waterless dust control measure called Moat and Row which was disallowed by the California State Lands Commission in April 2010. LADWP is working with the District to develop an alternative solution for the areas originally proposed for Moat and Row. LADWP has been ordered to complete an additional 2 square miles of dust control known as the Phase 8 project. LADWP is seeking a lease from the California State Lands Commission to construct Gravel BACM for Phase 8 as it does not require water for operation.

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Exhibit 5K
Dust Control Mitigation Measures

Dust Control Measures		Description
Shallow Flooding	Sheet Flooding	Releases water from arrays of low-flow water outlets spaced at intervals of between 60 and 100 feet along pipelines laid along lake bed contours. Pipelines are spaced between 500 and 800 feet apart. This arrayed configuration of water delivery creates large, very shallow sheets of braided water channels. Water depths in sheet flooded areas are typically at most a few inches deep. The lower edge of sheet flooded areas has containment berms to capture and pond excess flows. The water slowly flows across the typically very flat lake bed surfaces downhill to tail-water ponds where pumps recirculate the water back to the outlets. To maximize project water use efficiency, flows to sheet flow areas are regulated at the outlets so that only sufficient water is released to keep the soil wet. Any water that does reach the lower end of the control area is collected and recirculated back through the water delivery system.
	Shallow Flooding (Pond Flooding)	Water containment berms that allow ponds to be formed that submerge the emissive lake bed areas. These ponds are up to four feet deep. The containment berms are typically rock-faced to protect them from delivery to the pond area until the pond reaches a size and depth sufficient to submerge the required amount of emissive water. Water delivery then ceases until evaporation reduces the pond size to a set minimum.
Managed Vegetation		Control measure consists of creating a farm-like environment from barren playa. The saline soil must first be reclaimed with the application of relatively fresh water and then planted with salt-tolerant plants that are native to the Owens Lake basin. Thereafter, soil fertility and moisture inputs must be managed to encourage rapid plant development and maintenance. Existing Managed Vegetation areas are irrigated with buried drip irrigation tubing and a complex network of buried drains to capture excess water for reuse on the Managed Vegetation area or in Shallow Flooding areas. Managed Vegetation is sustainable at Owens Lake only if salt from the naturally occurring shallow groundwater is prevented from rising back into the rooting zone.
Gravel Blanket		A four-inch layer of coarse gravel laid on the surface of the Owens Lake playa will prevent emissions by preventing the formation of efflorescent evaporate salt crusts, because the large pore spaces between the gravel particles disrupt the capillary movement of saline water to the surface where it can evaporate and deposit salts. The gravel also creates a surface that has a high threshold wind velocity so that direct movement of the large gravel particles is prevented and the finer particles of the underlying lake bed soils are protected. Gravel Blankets are effective on essentially any type of soil surface.

As part of an Interim Management Plan, LADWP and Inyo County have agreed to conduct a joint study to explore the feasibility of extracting and utilizing groundwater beneath Owens Lake to supplement the water supply necessary for dust mitigation activities. This feasibility study is scheduled for completion by November 2011. If groundwater pumping is considered feasible and acceptable, LADWP will first need to obtain required approval from Great Basin Unified Air Pollution Control District, California State Lands Commission, California Department of Fish and Game, and Inyo County.

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5.5 Water Quality

As land owners of much of the Mono Basin and Owens River watersheds, LADWP has placed strict limits on the extent of development impacting the City-owned watersheds. Snowmelt from the eastern Sierra Nevada contains low total organic carbon (TOC), bromide concentrations, and other constituents that can form disinfectant byproducts during the water treatment process. LADWP conducts routine monitoring of all of its water supplies for over 170 constituents and contaminants. Ninety-eight of the constituents and contaminants have enforceable standards.

The LAA supply is the main source of arsenic in LADWP's water supply. Arsenic is collected as the Owens River makes its way down through volcanic formations in the vicinity of Hot Creek in Long Valley. Geothermal springs in these areas have arsenic concentrations of around 200 parts per billion (ppb). Concentrations are dramatically reduced as water in the area mixes with snow melt and other pristine water sources. Historic untreated LAA water arsenic concentrations have ranged from 10 to 74 ppb. During the latest 3-year routine compliance monitoring cycle from 2007 to 2009, the highest arsenic concentration after treatment was 8.1 ppb, while the average arsenic concentration within LADWP's water distribution system was 3.3 ppb, well below the current Federal and State drinking water standard of 50 ppb. In light of potential, more stringent arsenic regulations, LADWP is taking a proactive approach in addressing this issue by investing enhanced coagulation treatment.

LADWP completed an evaluation and preliminary design report for enhanced coagulation at the Los Angeles Aqueduct Filtration Plant in December 2006 as a means of addressing future water quality regulations faced by LADWP, including arsenic. An enhanced coagulation facility using the process as outlined in the report is planned as part of the treatment process at the Los Angeles Aqueduct Filtration Plant by 2021.

To comply with the Stage 2 Disinfectants and Disinfection Byproducts Rule, another water quality improvement effort being implemented is the conversion from chlorine to chloramine residual disinfectant. This transition, which is expected to be completed by April 2014, will allow LADWP to maintain the same high level of disinfection in its water supply while freeing itself from other potential disinfection issues associated with the use of chlorine. The use of chloramines will provide additional operational flexibility by allowing the blending of purchased MWD water (which is chloraminated) into the LADWP distribution system without the problems associated with creating a chlorine/chloramines interface when blending the two supplies.

5.6 Projected Deliveries

Near-term water deliveries are forecasted for the LAA using two models, the Runoff Forecast Model and the Los Angeles Aqueduct Simulation Model (LAASM). These two models used jointly and accurately predict the amount of water available from this the LAA.

The Runoff Forecast Model is used to predict total Owens Valley and Mono Basin stream runoff. The model's estimating equations were developed using historic rainfall and snowfall, as well as streamflow data of each year. Model input consists of 6 months of antecedent rainfall and streamflow data, as well as the final snowpack levels on April 1st. The model's output is the forecasted runoff for the Owens Valley and Mono Basin during the twelve month period following April 1st, assuming that median rainfall occurs during those twelve months.

Runoff flows from the Owens Valley to the City of Los Angeles are modeled by the LAASM. LAASM uses the output of the Forecast Model as input, along with estimates of various uses within the Owens Valley. LAASM uses historically derived

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estimating equations to forecast various losses, including evaporation and infiltration, as well as other inflows such as unmetered springs. The final output from LAASM is the volume of LAA water projected to be delivered to the City of Los Angeles.

Taking the foreseeable factors discussed earlier in this chapter into consideration, the average annual long-term LAA delivery over the next 25 years is expected to be approximately 254,000 AFY and gradually decline to 244,000 AFY due to climate change impact. Deliveries for a series of dry years, using 1988/89 through 1992/93 hydrology, are expected to range from approximately 48,520 AFY to 105,770 AFY. A single dry year minimum of 48,520 AFY is expected with a repeat of the 1990/91 hydrology. Detailed LAA projected deliveries by year are provided in Chapter 11, Water Service Reliability Assessment.

5.7 LAA Delivery Cost

The costs associated with LAA water supply are primarily operation and maintenance costs. Therefore, the unit cost of exporting water from LAA to the City varies mainly with the quantity of water delivered and is highly dependent on hydrological conditions. During dry years, the amount of water delivered to the City decreases, which results in an increase to the unit cost. Over the years, eastern Sierra Nevada environmental enhancement projects also contributed to the overall LAA delivery cost, with increasing expenditures when the Owens Lake Dust Mitigation and Lower Owens River Project were initiated. Exhibit 5L summarizes the historical unit cost of treated water from LAA. The peaks occurred when LAA deliveries significantly decreased during fiscal years 1990-91, 2002-03, and 2008-09 with the LAA deliveries of 130,300 AF at $499/AF; 203,400 AF at $419/AF; and 108,500 AF at $1,003/AF respectively.

Exhibit 5L
Historical Cost of LAA Treated Water

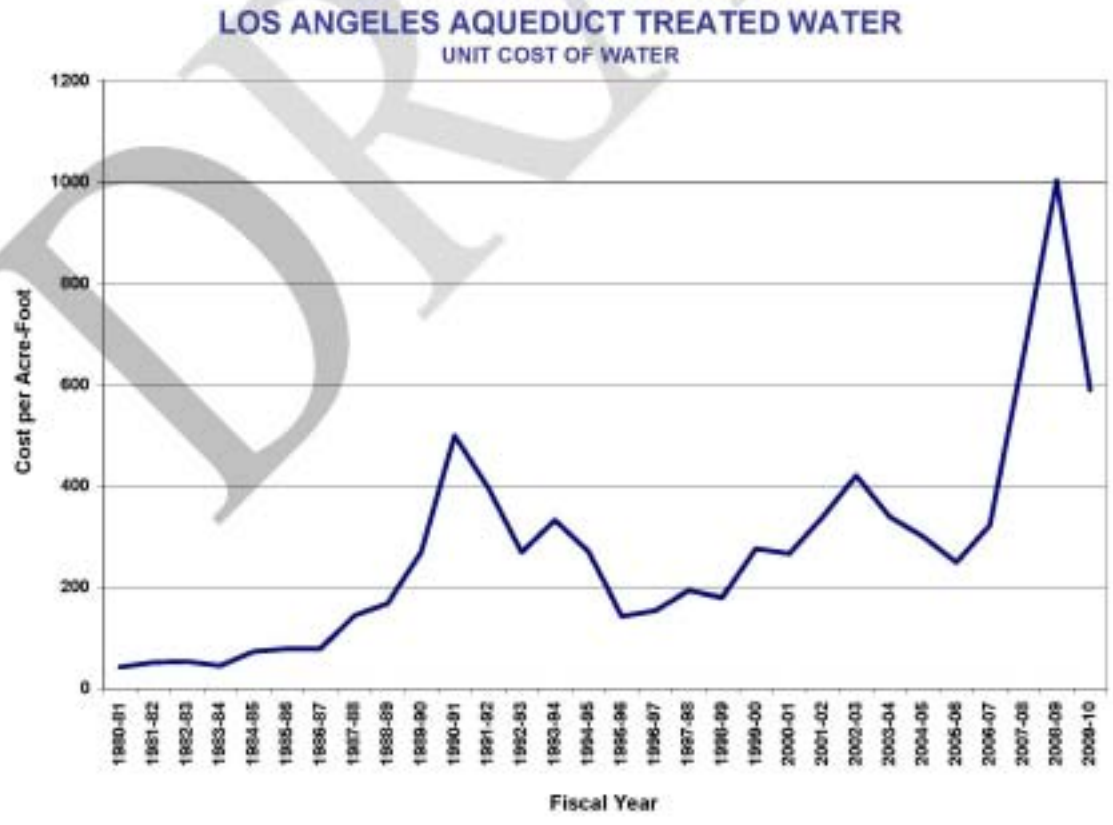

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Exhibit 5M shows the unit cost of LAA treated water from 2005/06 to 2009/10. The 5-year average was $563/AF. The sharp increase in 2008/09 was due to LAA delivery being the lowest on records.

Exhibit 5M
Annual Unit Cost

Fiscal Year	2005-06	2006-07	2007-08	2008-09	2009-10
Unit Cost	$248	$321	$654	$1,003	$589

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DRAFT Chapter Six
Local Groundwater

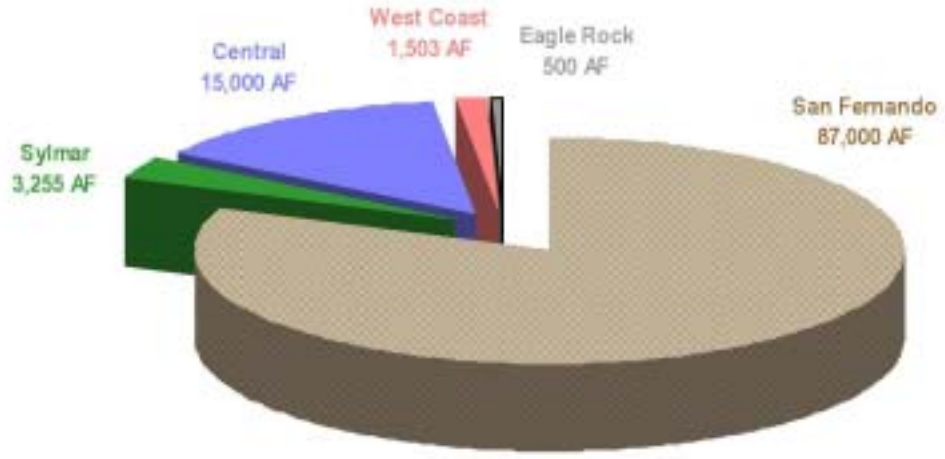
6.0 Overview

A key resource that the City has relied upon as the major component of its local supply portfolio is local groundwater. Over the last ten years local groundwater has provided approximately 12 percent of the total water supply for Los Angeles, and historically has provided nearly 30 percent of the City's total supply during droughts when imported supplies become unreliable. In recent years, contamination issues have impacted LADWP's ability to fully utilize its local groundwater entitlements. Additionally, reduction of natural infiltration due to expanding urban hardscape and channelization of stormwater runoff has resulted in declining groundwater elevations. In response to contamination issues and declining groundwater levels, LADWP is working clean-up of the San Fernando Groundwater Basin, and is making investments to recharge local groundwater basins through stormwater recharge projects, while at the same time replacing or rehabilitating old or deteriorating facilities.

6.1 Groundwater Rights

The City owns water rights in the San Fernando, Sylmar, Eagle Rock, Central, and West Coast Basins. Combined, these water rights total approximately 107,408 AFY. Water rights in the Upper Los Angeles River Area (ULARA), which comprises of the San Fernando, Sylmar, and Eagle Rock basins, total approximately 90,905 AFY which translates into approximately 87,000 AFY in the San Fernando Basin (SFB), 500 AFY in the Eagle Rock Basin, and 3,405 AFY in the Sylmar Basin. Water rights in the Central and West Coast Basin are 15,000 AFY and 1,503 AFY, respectively. However, LADWP does not exercise its pumping rights in Eagle Rock Basin and West Coast Basin at this time. Exhibit 6A summarizes the City's annual local groundwater entitlements by basin. Superior Court Judgments for the San Fernando, Sylmar, Eagle Rock, Central, and West Coast groundwater basins are attached in Appendices X, X, and X, respectively.

Exhibit 6A
Annual Local Groundwater Entitlement



Total: 107,258 AF per year

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The ULARA Groundwater Basin Adjudication

The City's entitlements in the San Fernando, Sylmar, and Eagle Rock Basins were established in a Judgment by the Superior Court of the State of California for the County of Los Angeles in Case No. 650079, *The City of Los Angeles, Plaintiff, vs. Cities of San Fernando, et. al., Defendants*, dated January 26, 1979 (San Fernando Judgment) and the 1984 Sylmar Basin Stipulation (1984 Stipulation). Appendix X contains the Judgment and 1984 Stipulation. The Judgment was based on maintaining a safe yield operation for the basin, whereby groundwater extractions over the long-term will be maintained in a manner that does not create an overdraft condition in the basin. The City has no entitlement in the Verdugo Basin but may have the right to recapture a portion of its import return waters upon application to the Watermaster and issuance of an order after a hearing by the Court. The Judgment and 1984 Stipulation limit groundwater extraction from all four groundwater basins and establish a court-appointed Watermaster and an Administrative Committee made up of a representative from each of the five water supply agencies overlying the ULARA Basins. The five public agencies are the City of Los Angeles, the City of Glendale, the City of San Fernando, the City of Burbank, and the Crescenta Valley County Water District.

The Watermaster assists the Court in administering and enforcing the provisions of the 1979 Judgment and 1984 Stipulation. Among other duties, the Watermaster monitors groundwater levels, recharge operations, recycled water use, extractions, water imports and exports, and reports all significant water-related events in the Basin to the Court and to the parties to the Judgments. The activities of the Watermaster are key components for the effective management of the groundwater resources in the ULARA Basins. Key tasks of the Watermaster for the SFB include:

- Monitoring of radiological and synthetic organic compounds (SOCs) every three years;
- To continue to work with key regulators, such as the Los Angeles Regional Water Quality Control Board (LARWQCB), California Department of Public Health (CDPH), California Department of Toxic Substance Control (CDTSC), and the United States Environmental Protection Agency (USEPA), to expedite clean-up of groundwater at or near known contamination sites
- To continue to support the ongoing activities of the City of Los Angeles and others to recharge the groundwater basin at existing spreading basins on the east side of the San Fernando Valley;
- To help determine the technical feasibility of using advanced treated recycled water to recharge the groundwater basin;
- To continue to work with the Los Angeles Department of Public Works, Bureau of Sanitation, Watershed Protection Division, to enhance groundwater recharge of local basins via the Standard Urban Stormwater Mitigation Plans (SUSMP) procedures for stormwater infiltration at new development and redevelopment project sites; and
- To work with local purveyors in an effort to increase the quantity and quality of the groundwater database for the entire ULARA basin.

Historical Groundwater Production

On average over the past five years, about 83 percent (58,575 AFY) of the City's local groundwater supply was extracted from ULARA groundwater basins, while the Central Basin provided 17 percent (12,512 AFY). Exhibit 6B summarizes the City's local groundwater production by basin over the last five years.

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Exhibit 6B
Local Groundwater Basin Supply
Fiscal Year (July through June in AF)

Groundwater Basin	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	Average	Percentage
San Fernando	35,486	75,640	57,060	49,106	62,218	55,902	79%
Sylmar	1,844	3,901	4,046	576	2,998	2,673	4%
Central	13,290	13,358	12,207	11,937	11,766	12,512	17%
Total	50,620	92,899	73,313	61,619	76,982	71,087	100%

Historically, LADWP operates groundwater production by utilizing conjunctive use of surface water and groundwater to optimize the supply and demand balance. Through conjunctive use, the timing of groundwater extractions can be used to meet varying demands. Furthermore, in the past, LADWP prevented against groundwater overdraft during multiple dry years through strategic pumping. When successive dry years occur, LADWP pumped at greater than average rates for the first few years of the drought, and then pumped at lower rates in subsequent years.

However, since 2007, groundwater contamination issues in the SFB have greatly limited LADWP's ability to pump its full groundwater entitlement. As a result, LADWP has been pumping the maximum amount capable that is not impacted by contamination sources, and therefore, has not been able to utilize its conjunctive use strategies for its groundwater operation. When the clean-up of the SFB is complete, LADWP will be able to return to these strategies to ensure reliability and protect from groundwater overdraft.

6.1 San Fernando Basin

The primary source of local groundwater for the City is the SFB providing over 79 percent of the City's groundwater supply ranging from 35,486 AF to 75,640 AF during the period Fiscal Year 2005-2006 to Fiscal Year 2009-2010. The SFB is the largest of the four ULARA basins. It consists of 112,000 acres and comprises 91.2 percent of the total valley in ULARA. It is bounded on the east by the Verdugo Mountains; on the north by the Little Tujunga Syncline and the San Gabriel and Santa Susana Mountains; on west by the Simi Hills; and on the south by the Santa Monica Mountains. A map of the basin is shown in Exhibit 6C. (ULARA Watermaster Service Report, Water Year 2008-2009)

LADWP has ten major wellfields within the SFB containing 115 wells: the Crystal Springs, Headworks, Tujunga, Rinaldi-Toluca, North Hollywood, Erwin, Verdugo, Whitnall, Pollock, and North Hollywood Operable Unit Wellfields. Of the ten major wellfields, LADWP is currently not pumping at Headworks. These wells were generally installed over a period spanning from 1924 to 1991, with the most recent installations being the Rinaldi-Toluca Wellfield in 1988 and the Tujunga Wellfield in 1991. Collectively these ten wellfields have the ability to pump and serve approximately 547 cubic feet per second (cfs) of water, of which the recent Rinaldi-Toluca and Tujunga wells comprise about 38 percent or 210 cfs.

Groundwater Rights

In accordance with the 1979 San Fernando Judgment, the City has the right to all native water within the SFB, based on its Pueblo Rights, and the right to imported water that is delivered and returned to the SFB by the City. With the native safe yield being fixed at 43,660 AFY and the return of imported water averaging approximately 43,000 AFY, the combined total equates to an average SFB entitlement for the City of approximately 87,000 AFY. The return of imported water right for LADWP is based on 20.8 percent of all water delivered within the San Fernando Basin including recycled water. The Judgment provides for storage of water within the basin when the amount pumped is less than the annual entitlement, and a portion of these stored water credits can be pumped in future years to supplement the City's water supply. The direct

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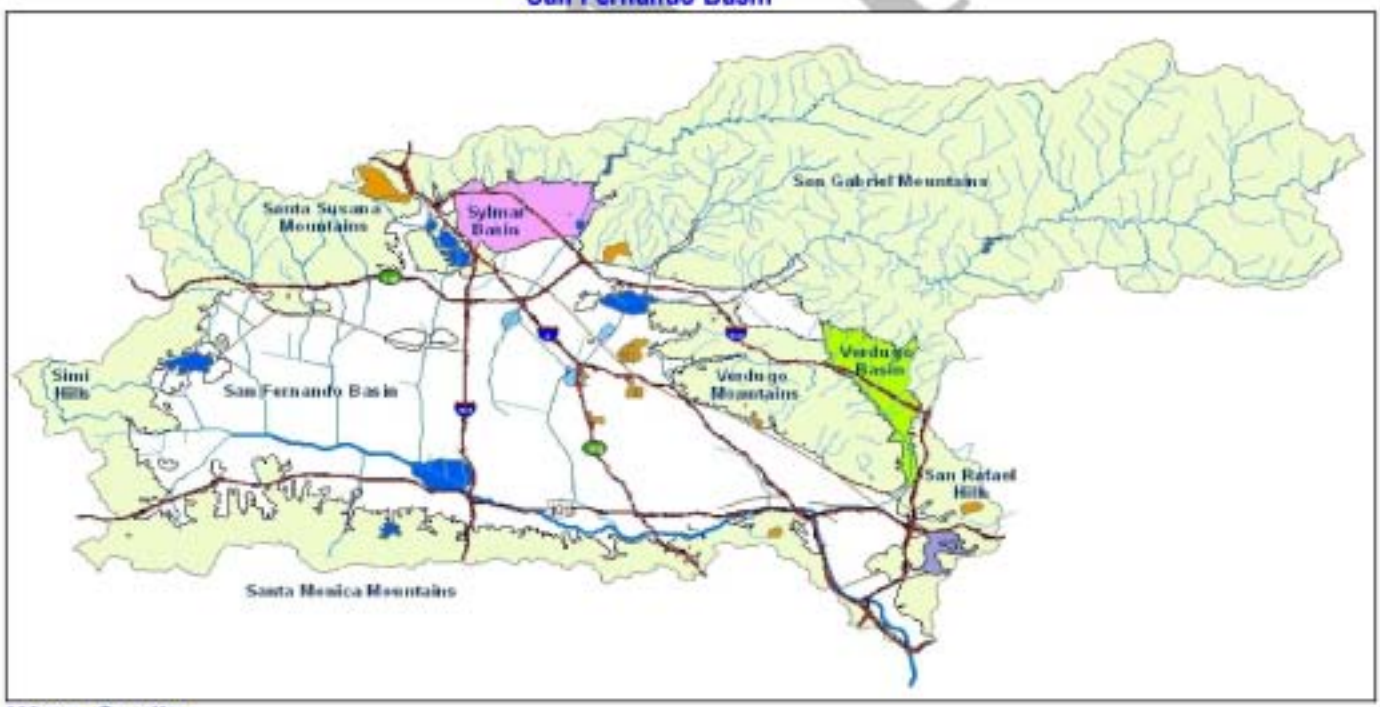
spreading of both imported or recycled water receives 100 percent stored water credit. Increased groundwater pumping due to stormwater capture activities will require an amendment to the Judgment to increase LADWP's groundwater pumping rights based on a demonstrated increase in groundwater levels.

In September 2007, the Cities of Los Angeles, Glendale and Burbank entered into a ten-year Interim Agreement for the Preservation of the San Fernando Basin Water Supply (Interim Agreement). The Interim Agreement is intended to address the overall long-term decrease in stored groundwater within the basin. The Interim Agreement restricts withdrawal of stored water credits and incorporates basin losses into groundwater basin accounting.

Under the Interim Agreement, stored water credits will be reduced for each party by 1 percent annually to account for outflow from the basin. Additionally as described in the Interim Agreement, a proportion of stored water credits available for use during a water year will be calculated for each year, and proportion not available for use during a given year will be reserved for later use. As of October 1, 2009, the City had a stored water credit of nearly 406,313 AF in the SFB, however LADWP's Available Credit or maximum allowable withdrawal of stored water credits for the year beginning October 1 was 108,574 AF. LADWP's Reserve Credits total was 321,316 AF. Reserve Credits (stored water credits minus available stored water credits) will not be available until groundwater levels in the basin recover to a level that will allow for their safe withdrawal. Total Reserve Credits held by all parties in the basin were 376,433 AF as of October 1, 2009.

Exhibit 6C
San Fernando Basin



Water Quality

During well testing in the SFB, trace levels of the contaminants trichloroethylene (TCE), perchloroethylene (PCE), and other volatile organic compounds (VOCs) were detected in the past. The presence of these contaminants is due to improper chemical disposal practices historically conducted by numerous companies in the San Fernando Valley utilizing such materials. Additionally, in the 1990s, detectable amounts of hexavalent chromium and perchlorate were found in various

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wells within the SFB. Since the 1990s, SFB wells have also shown a trend of increasing nitrate levels. The source of nitrates is the result of decades of agricultural activity in the San Fernando Valley.

While LADWP is permitted to withdraw its allotted entitlement of 87,000 AFY from the SFB including a portion of its additional stored water, 2007 was the first year LADWP was unable to pump its allotted entitlement due to contamination impacts. LADWP has 115 wells in the SFB of which 54 wells have been inactivated due to contamination. These inactive wells represent a lost pumping capacity of approximately 221 cfs or 40 percent of LADWP's pumping capacity. Of the remaining 61 active wells, with a combined pumping capacity of approximately 326 cfs, 44 have recorded concentrations for various contaminants above the Maximum Contaminant Level (MCL). Most notable among these contaminants of concern are the VOCs (especially TCE, PCE, and carbon tetrachloride), nitrates, and perchlorate. The remaining 17 wells have recorded marginal levels of contamination, mostly due to VOCs. Hexavalent chromium threatens to be a significant future risk to LADWP's wells. Lastly, LADWP's two largest wellfields, Tujunga and Rinaldi-Toluca, which were the most recently-installed wells in an area believed to be outside the known contamination areas, are being significantly impacted by unknown contamination sources.

LADWP has developed programs to accelerate clean-up of the San Fernando Basin which includes a comprehensive Groundwater System Improvement Study, installing monitoring wells, interim wellhead treatment, and working with regulatory agencies and government officials to hold individuals responsible for the contamination responsible to help clean-up efforts.

Agency Cooperation of SFB Remediation

LADWP actively coordinates with the California Department of Public Health (CDPH), Los Angeles Regional Water Quality Control Board (LARWQCB), California Department of Toxic Substance Control (CDTSC), and the United States Environmental Protection Agency (USEPA) to pursue protective and remedial measures for the SFB. The CDPH, LARWQCB, and CDTSC are the three regulatory agencies with enforcement responsibilities within the SFB. The LARRWQCB and the CDTSC issue enforcement directives for pollutant sites and guide the development of cleanup workplans and the cleanup of polluted groundwater sites. The CDPH oversees the quality of potable water from groundwater sources.

In 1987, LADWP entered into a Cooperative Agreement with the USEPA to conduct the "Remedial Investigation of Groundwater Contamination in the San Fernando Valley." Under this agreement, LADWP has received more than $23 million in Federal grants from the USEPA's Superfund Program to carry out: (1) construction, operation, and maintenance of the North Hollywood Operable Unit, which consists of a groundwater treatment facility and a system of eight production wells (construction completed in 1989); and (2) completion of the Remedial Investigation (RI) to characterize the SFB and the nature and extent of its groundwater contamination. The RI included: (a) the installation in 1992 of 88 shallow and clustered monitoring wells that were developed to monitor contamination plumes of TCE, PCE, and nitrates in the SFB; (b) the development of a groundwater flow model (Flow Model) and the preparation of the RI report that was completed for the USEPA in 1992; and (c) on-going monitoring for TCE, PCE, nitrates, and emerging contaminants.

The Flow Model is a three-dimensional computer simulated model of the SFB based on the MODFLOW model program code that was developed by the United States Geological Survey. It consists of four layers that represent the various depth zones of the SFB. Geologic and hydrogeologic data for the basin, which was generated through field investigation, was analyzed to develop the physical site characterization of the basin for the MODFLOW Flow Model. The Flow Model produced simulated groundwater levels, gradients, and their fluctuations as a function of time. Based on field monitoring and

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Flow Model simulations, groundwater production strategies are reviewed and adjusted monthly to balance the City's water supply need with SFB management.

San Fernando Basin Contamination Clean-Up Programs

In coordination with other agencies, LADWP has completed or is planning various projects to maintain its rights to use the SFB as a reliable local water supply for the City. The following are some of LADWP's completed, current, and planned projects for the SFB. Recharge projects are discussed separately in Chapter 7, Watershed Management.

Groundwater System Improvement Study

LADWP is working on a 6-year, $19.0-million Groundwater System Improvement Study (GSIS) in the SFB that will provide vital information to assist in developing both short- and long-term projects to maximize the use of the SFB. The $11.5-million GSIS professional service contract was awarded to Brown and Caldwell in February 2009.

The GSIS will aim to cover the following main objectives:

- Provide an independent study to identify, characterize, and evaluate emerging water quality constituents for the San Fernando Basin.
- Provide an independent expert evaluation of LADWP's existing groundwater facilities and its current operational strategies to address current issues on water quality regulations and groundwater treatments. Provide expert advice on the need of refurbishing existing groundwater wells.
- Research and evaluate the need for the installation of new monitoring wells in the SFB to characterize the basin for the constituents of concern.
- Develop a research monitoring program to characterize the nature and extent of the various constituents of concern that may pose a risk to LADWP maximizing the utility of the SFB.
- Provide independent expert recommendations on economically feasible short and long-term capital improvement projects to address all regulatory agency requirements.

Through the GSIS, the LADWP has begun developing a conceptual layout for Groundwater Treatment Facilities in the SFB that will include treatment facilities in the vicinity of LADWP's North Hollywood, Rinaldi-Toluca, and Tujunga Well Fields. It is anticipated that construction of the Groundwater Treatment Facilities could begin as early as July 2015. Construction of the Groundwater Treatment Facilities will greatly reduce LADWP's reliance on costly and scarce imported water supplies and will compliment LADWP's strategies for securing the City of Los Angeles' future water supply through sustainable means. The Groundwater Treatment Facilities will also enable LADWP to benefit from its activities to enhance local supplies through groundwater recharge and stormwater projects. An integral part of LADWP's Groundwater Treatment Facilities will be to work closely with the USEPA and the Cities of Burbank and Glendale to ensure that the facilities operations do not adversely affect the on-going cleanup activities being conducted by the aforementioned agencies. Towards this end, LADWP plans to enter into a Groundwater Management Plan with the USEPA.

As of November 2010, the work progress has included a technical review of USEPA's Focused Feasibility Study for the North Hollywood Operable Unit, preparation of conceptual layouts and renderings for the proposed Groundwater Treatment Facilities in the vicinity of the North Hollywood, Rinaldi-Toluca and Tujunga Well Fields, providing assistance in the planning

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aspects for the installation of approximately 40 new monitoring wells in the San Fernando Basin, and providing an independent study to identify, characterize and evaluate emerging water constituents.

Tujunga Wellfield Joint Project. LADWP and MWD have developed a joint project utilizing simple liquid-phase granular activated carbon (GAC) to recover the use of two of the City's contaminated groundwater production wells in the Tujunga Wellfield. The total estimated cost of this project was approximately $7.0 million and was completed in November 2009. LADWP received the permit from the Department of Public Health in May 2010 and started to discharge into the distribution system on May 18, 2010.

Tujunga Wellfield Contamination. The Initial Discovery of the source of contamination at the Tujunga Wellfield by the USEPA and CDTSC is ongoing. Phase I is completed and has not conclusively identified the source of the contamination. The next phase will involve drilling 4-7 deep monitoring wells immediately up gradient of the wellfield to determine the direction of the contamination plumes. The well drilling is expected to be completed late 2011. LADWP is intending to construct up to 22 additional monitoring wells near other wellfields south of the Tujunga Wellfield. Water quality data from the new monitoring wells will assist with further characterizing the groundwater contamination in the SFB. Drilling of these additional wells is expected to begin in Fall 2011 and continue until Winter 2012.

North Hollywood Operable Unit. In 1989, the North Hollywood Operable Unit (NHOU) was placed into service with a capacity of 2,000 gallons per minute (GPM), or 3,230 AF per year. This facility has one aeration tower with vapor-phase granular activated carbon (GAC) air emissions control system. This technology uses air to remove the VOCs from the groundwater and uses the vapor-phase GAC to remove the VOCs from the air stream before it exits into the atmosphere. The fifteen year consent decree expired on December 31, 2004, however, the VOC plume has not been completely remediated. In Water Year 2008-2009, 1,038 AF of VOC contaminated groundwater was treated.

The USEPA is expected to start construction of the NHOU Second Remedy possibly as soon as 2014 to improve containment of contamination from two sites, the Honeywell and Lockheed sites. The primary plume contains high concentrations of VOCs, chromium, and other contaminants of concern. The USEPA issued the Record of Decision (ROD) in December of 2009. The first technical meeting with the potentially responsible party was held in July 2010. A consent decree is expected in early 2011. The ROD recommends more than doubling the capacity plus adding liquid phase GAC (a secondary treatment), construction of 37 monitoring wells, three new extraction wells, deepen existing abandoned well #1, rehabilitation of existing wells, and treatment of chromium and 1-4 Dioxane. As of 2010, Honeywell is continuing its removal of chromium plume at the source of contamination.

Chromium Treatment Research. A cost-effective treatment technology to remove low levels of hexavalent chromium from water does not exist for large scale applications. In 2001, LADWP, along with the Cities of Burbank, Glendale, and San Fernando, and the National Water Research Institute, entered into a research partnership with the American Water Works Association Research Foundation to identify and bench-test new technologies that can remove hexavalent chromium to extremely low levels. This research is being conducted in anticipation of a new standard for hexavalent chromium.

Pollock Wells Treatment Plant. In 1999, the Pollock Wells Treatment Plant was constructed and placed in service. This project was funded by LADWP, and it includes a groundwater treatment facility with four liquid-phase GAC units. Over 3,000 gallons per minute (4,840 AF per year) of groundwater is treated by direct adsorption with GAC to remove VOCs before delivery to customers.

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Remedial Investigation. In 1992, the Remedial Investigation to characterize the nature and extent of groundwater contamination in the SFB was completed for the USEPA. The Remedial Investigation activity included the construction of 88 shallow and clustered monitoring wells, which were developed to monitor contamination plumes of TCE, PCE, and nitrates in the SFB. These monitoring wells are also being used to monitor for emerging chemicals. Updated information and reports can be found on USEPA Region 9 Superfund web page.

Biological Treatment Pilot Test . LADWP will be studying the effectiveness of biological treatment on removal of VOCs contaminants from the Tujunga Wellfield groundwater. Biological treatment is a proven technology for removal of perchlorate and nitrate contaminants from groundwater which are also present in the Tujunga Wellfield groundwater. If biological treatment can also effectively remove VOCs from the groundwater, LADWP can significantly reduce the capital as well as future operations and maintenance costs associated with cleanup and removal of contaminants from the Tujunga Wellfield groundwater.

Pilot Test of Advance and Emerging Groundwater Treatment Technologies. LADWP is investigating the utilization of other advance and/or emerging groundwater treatment technologies for removal of VOCs and perchlorate for possible pilot study(ies) at the Rinaldi-Toluca Wellfield within the next few years.

6.2 Sylmar and Eagle Rock Basins

The Sylmar Basin has provided slightly over 4 percent of the City's local groundwater ranging from 576 AF to 4,046 AF from Fiscal Year 2005-2006 through Fiscal Year 2009-2010. The Sylmar Basin, in the northern part of ULARA, consists of 5,600 acres and comprises 4.6 percent of the valley in ULARA. It is bounded on the north and east by the San Gabriel Mountains; on the west by a topographic divide in the valley fill between the Mission Hills and the San Gabriel Mountains; and on the south by the Little Tujunga syncline, which separates it from the SFB. (ULARA Watermaster Service Report, Water Year 2008-2009) LADWP originally had a total of 3 production wells installed in the Sylmar Basin between 1961-1977. One of these wells was removed from service and is no longer utilized. The remaining wells have the capacity to pump 5 cfs.

The Eagle Rock Basin is the smallest of the four basins. It is located in the extreme southeast corner of ULARA. It consists of 800 acres and comprises 0.6 percent of the total valley. LADWP is not pumping in the Eagle Rock Basin currently. The safe yield of Eagle Rock Basin is derived from imported water delivered by LADWP. There is no measurable native safe yield. LADWP has the right to extract the entire safe yield of the basin. Currently, the groundwater is being pumped by a private party and LADWP is reimbursed for such pumping in accordance with the San Fernando Basin Judgment.

Groundwater Rights

In 1996 upon the recommendation of the Watermaster, the ULARA Administrative Committee approved a temporary safe yield increase for the Sylmar Basin thus temporarily increasing LADWP's rights from 3,105 AFY to 3,255 AFY for a ten-year period. Per the 1984 Stipulation, the safe yield minus private party overlying rights are to be equally split between LADWP and the City of San Fernando. In 2006, a subsequent evaluation of the safe yield was conducted and completed in accordance with Section 8.2.10 of the 1984 Stipulation. Upon recommendation of the parties, the Court approved a new stipulation further increasing the temporary safe yield of the basin and resulting in a temporary increase in LADWP's rights to 3,405 AFY subject to multiple conditions. Conditions imposed on LADWP and the City of San Fernando include installing groundwater monitoring wells to assist in determining basin outflows. This new stipulation became effective on October 1, 2006 and is set to expire on October 1, 2016. As required by the 2006 Stipulation, the safe yield will be re-evaluated by October 1, 2011 and may result in a recommendation for additional changes to the safe yield of the Sylmar Basin.

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Stored water credits accumulated in the basin are determined by adding the previous years stored water credit and the extraction right for the previous year together and then subtracting the actual extractions for the previous year. As of October 1, 2009, LADWP has accrued 9,423 AF of stored water credits in the Sylmar Basin. In 2006, the Watermaster recommended LADWP begin pumping these rights due to the large amount of stored water credits. LADWP has proposed the Mission Wells Improvement Project to initiate pumping the credits and to replace the existing wells that have significantly deteriorated. As proposed, the project consists of constructing a water tank, three wells, and other operational facilities at the Mission Wellfield. Phase 1 was completed in February 2009 and involved replacement of the water tank that was beyond its useful life. Phase 2 is in the planning stages and consists of three new wells with operational facilities and is forecast for completion in August 2014. These new facilities will allow LADWP to pump its current entitlement of 3,405 AFY on an annual basis and draw from its existing stored water credits.

Water Quality

Groundwater quality issues have occurred in the Sylmar Basin related to TCE contamination at one of the two production wells. The effluent from the wellfield is managed in such a way that the groundwater quality meets or surpasses water quality standards. Primary limitations on pumping are related to the deterioration of pumping facilities and not contamination. However, the Mission Wells Improvement Project as previously discussed, will replace the deteriorated wells and increase production capacity to allow LADWP to pump its annual water rights.

6.3 Central Basin

From Fiscal Year 2005-2006 through Fiscal Year 2009-2010 the Central Basin has provided on average approximately 17 percent of LADWP's local groundwater supply ranging from 11,766 AF to 13,358 AF through wells in two major production fields. The Central Basin Watermaster Service area overlies about 227 square miles of the Central Basin in the southeastern part of the Los Angeles Coastal Plain in Los Angeles County. The Watermaster Service Area is bounded by the Newport-Inglewood Uplift on the southwest, the Los Angeles-Orange County line on the southeast, and an irregular line that approximately follows Stocker Street, Martin Luther King Boulevard, Alameda Street, Olympic Boulevard, the boundary between the City of Los Angeles and unincorporated East Los Angeles, and the foot of the Merced and Puente Hills on the north. Twenty-three incorporated cities and several unincorporated areas are within the Central Basin Watermaster Service Area. Groundwater within the basin provides a large portion of the water supply needed by overlying residents and industries. In Fiscal Year 2008-2009 there were 140 parties with rights to water within the Central Basin (Central Basin Watermaster Service Report, Fiscal Year 2009-2010).

Two LADWP facilities provide groundwater supplies in the Central Basin, the Manhattan Wells and the 99th Street Wells. The active Manhattan Wells were installed between 1928-1974 and have a production capacity of 16.9 cfs. Wells at the 99 th Street location were installed between 1974-2002 and have a production capacity of 7.4 cfs. While the 99th Street Wells are newer and have relatively little mechanical or other problems, the Manhattan Wells are much older and have experienced maintenance problems and are approaching the end of their useful life. To restore the City's pumping capacity, LADWP is working on plans to install two new production wells, replace two deteriorated wells, and improve other related facilities at the Manhattan site.

Groundwater Rights

More than 50 years ago, groundwater overdraft and declining water levels in the Central Basin threatened the area's groundwater supply and caused seawater intrusion in the southern part of the Basin. However, timely legal action and adjudication of the water rights halted the overdraft and prevented further damage to the Basin. Today, groundwater use in the Basin is restricted to the allowed pumping allocations by a 1966 Superior Court Judgment and is monitored by a court-

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appointed Watermaster, the Department of Water Resources (DWR). Annually, the Watermaster prepares a Watermaster Service Report indicating groundwater extractions, replenishment operations, imported water use, recycled water use, finances of Watermaster services, administration of the water exchange pool, and significant water-related events in the Basin.

The City's entitlement in the Central Basin of 15,000 AFY was established in a judgment by the Superior Court of the State of California for the County of Los Angeles through the Central Basin Judgment (Case No. 786,656 –second amended judgment). In addition to its annual entitlement, the Central Basin Judgment allows for carryover of unused water rights up to a maximum total cumulative amount of 20 percent of the purveyor's pumping allocation and also allows for over extraction of an additional 20 percent under emergency situations that would be debited against the purveyor's following year entitlement. The City uses its carryover storage right for operational flexibility and conjunctive use. LADWP has allowable carryover storage of 3,000 AF into Fiscal Year 2010-2011.

The Central Basin Judgment does not permit storing water in the basin for later extraction. Through the assistance of a facilitator, multiple parties with groundwater rights within the Central Basin have developed draft framework to allow conjunctive use groundwater storage in the basin and have filed to request amendment of the Judgment to allow groundwater storage.

Water Quality

Although the Manhattan and 99th Street Well fields in the Central Basin are located only approximately 4 miles apart, there is a large difference in water quality between the facilities. One of the Manhattan Wells currently exceeds the MCL of 5 ppb for TCE. The effluent from the wellfield is managed in such a way that the groundwater quality meets or surpasses water quality standards.

Water from 99th Street Wellfield complies with the National Primary Drinking Water Regulations, but requires treatment to comply with the National Secondary Drinking Water Regulations for manganese and iron. These contaminants are not considered to present a risk to human health, but at existing concentrations the contaminants may present taste, color, and odor problems. Corrosion control treatment using zinc orthophosphate as a sequestering agent and sodium hypochlorite to oxidize manganese has been in place at the wellfield for twenty years. Hydrogen sulfide is also present but not an imminent threat to the reliability of this well supply when chlorinated. In 2002, two new wells were drilled and placed into operation. During the first several months of operation of the new wells, numerous color complaints were received from customers. Adjustments in the treatment process were made which improved water quality.

6.4 West Coast Basin

LADWP has not been able to pump its water entitlement from the West Coast Basin since 1980 due to localized groundwater contamination issues and deterioration of the wells at the Lomita Wellfield. The West Coast Basin underlies 160 square miles in the southwestern part of the Los Angeles Coastal Plain in Los Angeles County. The Basin is bounded on the west by Santa Monica Bay, on the north by Ballona Escarpment, on the east by the Newport-Inglewood Uplift, and on the south by San Pedro Bay and the Palos Verdes Hills. Twenty incorporated cities and several unincorporated areas overlie the Basin (West Coast Basin Watermaster Service Report, Fiscal Year 2009-2010).

Groundwater Rights

In 1945, when intrusion of sea water caused by declining water levels threatened the quality of the groundwater supply, legal action was taken to halt the overdraft and prevent further damage to the West Coast Basin. In 1955, the Superior Court of

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Los Angeles County appointed the DWR as the Watermaster to administer an Interim Agreement, and in 1961, the Court retained the DWR as the Watermaster of the Final West Coast Basin Judgment (Case No. 506,806 –amended judgment). Similar to the Central Coast Basin, an annual Watermaster Service Report is prepared. The West Coast Basin Judgment provided the City with a right to 1,503 AFY of groundwater.

Water Quality

Groundwater quality problems in the West Coast Basin were previously related to high levels of total dissolved solids and chlorides. LADWP abandoned operations in the basin in September of 1980 with closure of the Lomita Well Field, and intends to study the feasibility and cost of restoring groundwater pumping.

6.5 Water Quality Goals and Management

The groundwater management efforts that LADWP has undertaken have resulted in all groundwater delivered to customers meeting or exceeding all water quality regulations. As part of its regulatory compliance efforts, LADWP works with the California Department of Public Health (CDPH) to perform water quality testing on production and monitoring wells.

Groundwater Monitoring

LADWP conducts nearly 250,000 field and laboratory tests on more than 25,000 samples collected throughout the year for hundreds of different chemicals such as arsenic, chromium, lead, and disinfection by-products to ensure that they are will within the safe levels before we serve the water to our customers

Every well that is pumped to supply water to the City is actively monitored by LADWP as required by CDPH. LADWP's groundwater monitoring program is comprised of several distinct components, including monitoring of metals, coliform bacteria, inorganics, volatile organic compounds (VOCs) and unregulated compounds such as vanadium, boron, and perchlorate. The frequency and level of monitoring (i.e., annually, quarterly, or monthly), depending on the level of contamination found in each well.

Monitoring for all contaminants is performed at entry points into the distribution system in close proximity to where the water is being pumped from the wells. If water quality problems are detected, the well source is immediately isolated and retested.

Operating Goals

LADWP has established operating goals for TCE, PCE, nitrates, perchlorate, and total chromium that are more stringent than the maximum contaminant levels (MCLs) permitted by Federal or State regulations. These stricter operational goals provide an additional safety margin from these contaminants for City customers. Exhibit 6D summarizes these water quality goals and compares them with the State-regulated requirements, which are generally more stringent than Federal requirements.

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Exhibit 6D
Operating Limits of Regulated Compounds

Compound	State of California Limit	LADWP Operational Goals	LADWP Added Safety Margin
Trichloroethylene (TCE)	5 ppb	3 ppb	40%
Perchloroethylene (PCE)	5 ppb	3 ppb	40%
Nitrate (N03)	45 ppm	30 ppm	33%
Perchlorate (ClO4)	6 ppb	4 ppb	33%
Total Chromium	50 ppb	30 ppb	40%

TCE and PCE compounds are commonly used in industries requiring metal degreasing. PCE is also used in dry cleaning and automotive repair industries.

Nitrate is a concern because of its acute effect of impeding the uptake of oxygen to the blood. Infants (who are in the earliest stages of development) are most sensitive to the effects of nitrates. The current standard for nitrate is 45 parts per million (ppm). A single exceedence of the nitrate standard is classified as an acute violation requiring immediate public notification. Treatment for nitrates may eventually become necessary for affected City groundwater supplies.

In October 2007, a MCL was adopted for perchlorate of 6 ppb. Perchlorate is an inorganic compound that is most commonly used in the manufacture of rocket fuels, munitions, and fireworks. In addition to its detection in groundwater, the compound has also been detected in Colorado River Aqueduct water.

Managing Emerging Contaminants of Concern

LADWP addresses emerging contaminants on many levels: 1) by encouraging the development of standardized testing to enable early detection, and supporting the regulatory framework by providing early occurrence data, 2) by advocating good science and a balanced approach to risk assessment, 3) by seeking to gain a risk perspective with other existing contaminants to manage the emerging contaminants in the absence of regulations, 4) by supporting early interpretation of emerging contaminants in collaboration with research and regulatory agencies, and 5) by supporting the research to develop cost-effective treatment for the removal and management of these emerging contaminants.

An example of how LADWP addresses an emerging contaminant is chromium VI (otherwise known as hexavalent chromium). Hexavalent chromium does not have an enforceable drinking water standard at this time. However, hexavalent chromium is included in the State total chromium standard of 50 ppb. CDPH is expected to establish drinking water standards for the compound in the near future. Chromium is a heavy metal that has been used in industry for various purposes including electroplating, leather tanning, and textile manufacturing, as well as controlling biofilm formation in cooling towers. LADWP began low level monitoring of hexavalent chromium long before monitoring was required by regulators. LADWP supported new health-effects research needed to support risk assessment, and advocated a balanced approach to risk management. LADWP funded research to develop new treatment technologies to reduce hexavalent chromium detection levels.

Most recent among emerging contaminants are pharmaceutically active compounds and personal care products that are finding their way into rivers, lakes, and waterways from urbanized areas. There are concerns about the occurrence and effects of endocrine disrupters, hormone-shifting compounds, and pharmaceuticals. Technology now allows the detection of compounds down to the parts per trillion levels, thus some of these compounds are now being detected. The risk

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assessment field is finding it difficult to keep pace with advances in analytical technology. The question of these contaminants posing a health risk at low levels needs more investigation. LADWP will continue to proactively address emerging contaminants through early monitoring and utilization of a balanced approach to risk management.

LADWP will be incorporating appropriate treatment processes into future groundwater treatment facilities. LADWP has and will continue to solicit input from stakeholders to properly plan and develop processes for removal and treatment of emerging contaminants. LADWP's Recycled Water Advisory Group (RWAG) is an example of ongoing efforts to solicit input.

6.6 Groundwater Pumping Cost

The costs associated with groundwater pumping are primarily operation and maintenance costs. Therefore, the unit cost of groundwater pumping varies mainly with the quantity of water delivered. Exhibit 6F summarizes the historical unit cost of groundwater pumping.

Exhibit 6F
Historical Cost of Groundwater Pumping

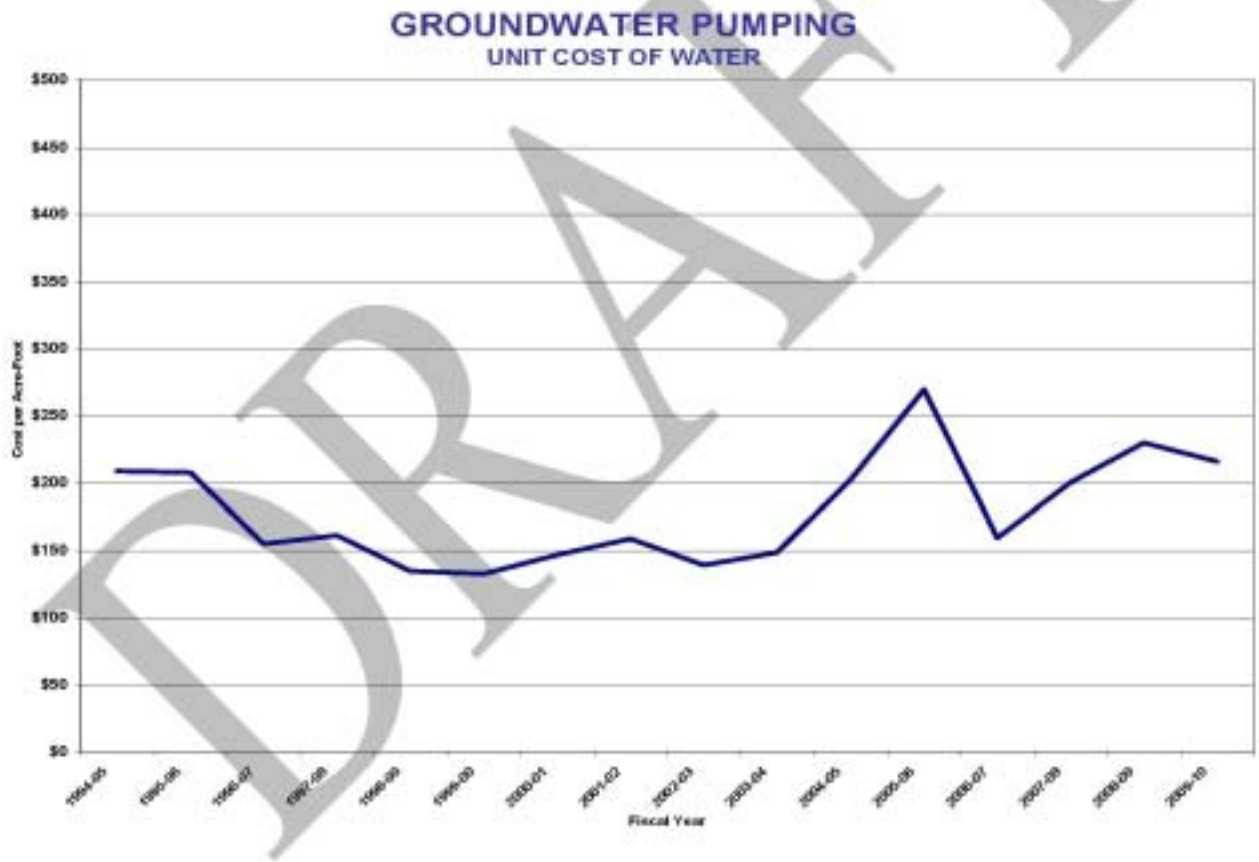

Exhibit 6G shows the unit cost of groundwater pumping from fiscal year 2005/06 to 2009/10. The 5-year average was $215/AF.

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Exhibit 6G
Annual Unit Cost

Fiscal Year	2005-06	2006-07	2007-08	2008-09	2009-10
Unit Cost	$270	$160	$200	$230	$216

6.7 Groundwater Production Projections

Historically, with conjunctive use management of groundwater, storing imported water in the groundwater basins during wet and normal years, groundwater production can actually be increased during dry years. LADWP operated its groundwater resources in this manner. On average, LADWP pumped its adjudicated right of approximately 107,000 AFY, but in dry years LADWP could pump larger quantities of groundwater. For the purposes of an average, single-dry, and multi-dry year drought analysis, after the implementation of the purification complex for SFB and completing the construction of new wells in Sylmar and Central Basins, 110,405 AFY is assumed to be the City's local groundwater production in 2035. After completion of the purification complex for the SFB, if successive dry years occur, LADWP would likely pump at greater-than-average levels for the first few dry years, then start pumping at lower levels in order to prevent groundwater overdraft. LADWP would then replenish the groundwater in wet or normal years following the successive dry period. Exhibit 6E provides groundwater pumping projections by basin between 2010 and 2035 for average, single-dry, and multi-year dry weather conditions in five-year increments.

Exhibit 6E
Groundwater Production 2010 to 2035 for Average, Single-Dry, and Multi-Year Dry Weather Conditions
By Fiscal Year

Basin	FY 2009-10	FY 2014-15	FY 2019-20	FY 2024-25	FY 2029-30	FY 2034-35
	AFY					
San Fernando	62,218	21,000	76,800	92,000	92,000	92,000
Sylmar	2,998	4,500	4,500	4,500	4,500	3,405
Central	11,766	15,000	15,000	15,000	15,000	15,000
Total	76,982	40,500	96,300	111,500	111,500	110,405

- 2015 San Fernando pumping levels are decreased due to anticipated well contamination from plume migration.
- Assumes existing annual rights to 87,000 AFY in SFB will remain unchanged. The Purification Complex is expected to be in operation in 2018-19. Storage credit of 5,000 afy will be used to maximize the pumping thereafter.
- Sylmar Basin production temporarily increases to 4,500 AFY to avoid the expiration of stored water credits then return back to the entitlement of 3,405 AFY in 2030-31.

Not included in the figures above is increased groundwater pumping due to groundwater replenishment of advanced treated wastewater, as well as enhanced stormwater recharge. This Urban Water Management Plan projects increased groundwater pumping through groundwater replenishment of advanced treated wastewater of 15,000 AFY, and increased groundwater pumping through enhanced storm water recharge of and additional 15,000 AFY, both by 2035.

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Watershed Management

7.0 Overview

This Urban Water Management Plan projects stormwater capture providing increased groundwater pumping rights in the San Fernando Basin of 15,000 AFY, and 10,000 AFY of additional water conservation from capture and reuse solutions such as rain barrels and cisterns, for a total of 25,000 AFY by fiscal year ending 2035. The Stormwater Capture Master Plan (refer to Section 7.3 below) will comprehensively evaluate stormwater capture potential within the City.

Stormwater runoff from urban areas is an underutilized resource. Within the City of Los Angeles, the majority of stormwater runoff is directed to storm drains and ultimately channeled into the ocean. Unused stormwater reaching the ocean also carries with it many pollutants that are harmful to marine life. In addition, local groundwater aquifers that should be replenished by stormwater are receiving less recharge than in the past due to increased urbanization. Urbanization has increased the City's hardscape, which has resulted in less infiltration of stormwater and a decline in groundwater elevations.

In addition, development has encroached onto the floodplains requiring the channelization of large waterways that once recharged the groundwater aquifers with large volumes of stormwater runoff. When the floodplains were undergoing rapid development, LADWP and the Los Angeles County Flood Control District (LACFCD) reserved several parcels of land for use as spreading facilities, which are adjacent to some of the largest tributaries of the Los Angeles River, and the Pacoima and Tujunga Washes.

During average and below average years, these spreading facilities are very effective at capturing a large part of the stormwater flowing down the tributaries. However they are incapable of capturing a significant portion of the flows during wet and extremely wet years. Weather patterns in Los Angeles historically are highly varied between very wet years and very dry years. Some climate studies predict that these patterns may become more extreme.

Furthermore, a significant portion of the watershed is not located adjacent to large tributaries and therefore, cannot be served by existing spreading facilities. These areas are the urbanized low-lying flatlands that also produce stormwater, therefore a strategy to create and implement distributed stormwater infiltration solutions is needed. These distributed solutions include widespread, smaller projects at the neighborhood scale and landscape changes at the individual parcel scale.

With the increased attention being placed on stormwater capture, other challenging conditions beyond imperviousness and climate patterns have been identified. These include antiquated spreading facilities, landfills adjacent to spreading, floodplain encroachment, substructures, and other man-made conditions that limit the ability to capture stormwater for later use. Some conditions such as the antiquated delivery systems at the spreading facilities can easily be retrofitted with new gates and telemetry. Whereas other conditions such as the presence of large sanitary landfills adjacent to recharge facilities, are more difficult to rectify.

In January 2008, LADWP created the Watershed Management Group which is responsible for developing and managing the water system's involvement in emerging issues associated with local and regional stormwater capture. The Watershed Management Group coordinates activities with other agencies, departments, stakeholders and community groups for the purpose of planning and developing projects and initiatives to improve stormwater management within the City. The Group's primary goal is to increase stormwater capture by enhancing existing centralized stormwater capture facilities and promoting

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distributed stormwater infiltration systems to achieve the City's long-term strategy of enhancing local stormwater capture. While working to increase stormwater capture for improving long-term groundwater reliability, other watershed benefits can be achieved including increased water conservation, improved water quality, open space enhancements, and flood control.

Additionally, the City is investigating recharge of the San Fernando Basin (SFB) with advanced treated recycled water. A more in-depth discussion of efforts to maximize groundwater recharge with advanced treated recycled water is provided in Chapter 4, Recycled Water.

7.1 Importance of Watershed Management to Groundwater Supplies

Managing native stormwater is a necessary step towards maintaining groundwater elevations in the underlying groundwater basin. Urbanization and its associated increase in impervious surfaces has altered the ability of groundwater basins to naturally replenish pumped groundwater. Stormwater systems in the City were designed primarily for flood control to convey stormwater runoff to the Pacific Ocean as quickly as possible, therefore minimizing the potential for flooding or damage to structures while maximizing land available for development. Within LADWP's service area, the SFB is the most amenable to regional stormwater capture and recharge through spreading basins because of its predominantly sandy soils. However, stormwater once percolated into the groundwater in the underlying SFB is being channeled across impervious surfaces then through concrete-lined canals or conduits to areas outside of the San Fernando Valley.

The essential task of watershed management is to retain as much stormwater runoff as possible for groundwater recharge. Groundwater recharge is the process of increasing an aquifer's water content through percolation of surface water. This occurs in the SFB primarily with captured stormwater, and imported water. Groundwater recharge is essential to maintain groundwater supplies, address the overall long-term decrease in stored groundwater within the SFB, and ensure the long-term water supply reliability of the basin. Furthermore, increasing groundwater recharge and improving the groundwater levels of the SFB could potentially lead to larger pumping rights for LADWP in the future.

During storm events, large portions of stormwater are captured with existing facilities for spreading purposes. LADWP coordinates these activities with the Los Angeles County Department of Public Works Flood Control District (LACFCD) to effectively recharge the SFB through the spreading of native stormwater. Flood control facilities are the primary means to divert native runoff into the spreading ground facilities listed and mapped on Exhibits 7A and 7B. LACFCD oversees operations at the Branford, Hansen, Lopez, and Pacoima Spreading Grounds. The Tujunga Spreading Grounds are operated by LACFCD in partnership with LADWP. LADWP has the ability to spread imported supplies at the Tujunga Spreading Grounds and the Pacoima Spreading Grounds for storage in the SFB, but LADWP has not utilized imported water for groundwater recharge since 1998.

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Exhibit 7A
SFB Spreading Grounds Operations Data

		Annual Spreading (AF)	
Facility	Location	Average[1]	Historic High
Branford	Mission Hills, CA	549	2,142
Hansen	Sun Valley, CA	13,834	35,192
Lopez	Lake View Terrace, CA	527	1,735
Pacoima	Pacoima, CA	6,453	22,972
Tujunga	Sun Valley, CA	4,419	21,115
	Total	25,782	83,156

1. Historic average through water year ending September 2009.

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Exhibit 7B
Spreading Ground Facility Locations

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7.2 Additional Benefits of Watershed Management

Watershed management provides additional important benefits to the City of Los Angeles, including surface water quality improvements, water conservation, open space enhancements, and flood control.

Water quality improvements are necessary because stormwater runoff is a conveyance mechanism that transports pollutants from the watershed into waterways and ultimately the Pacific Ocean. Pollutants include, but are not limited to, bacteria, oils, grease, trash, and heavy metals. The City must also comply with adopted Total Maximum Daily Loads (TMDLs) for pollutants. TMDLs set maximum limits for a specific pollutant that can be discharged to a water body without causing the water body to become impaired or limiting certain uses, such as water body contact during recreation. In 2008, the Los Angeles Board of Public Works adopted the Water Quality Compliance Master Plan for Urban Runoff (WQCMPUR). This 20-year plan provides a strategy for cleaning stormwater and runoff to protect the City's waterways and the Pacific Ocean. Capturing stormwater runoff for groundwater recharge removes a portion of the pollutant conveyance mechanism reducing downstream pollution thereby assisting the City with water quality compliance and improving the overall health of its waterways.

Water conservation is achieved by enhancing the capture and management of localized runoff for local uses. Centralized and distributed mechanisms that provide for water conservation include spreading grounds, rain barrels, and residential cisterns.

Open space enhancement is an added benefit of groundwater recharge projects, which typically provide additional open space areas that may include passive and/or active recreation, educational opportunities, and habitat restoration. Most projects involve increasing vegetation and recreational amenities to create opportunities for wildlife habitat and a recreational/educational resource for the local community. Additionally, open space enhancements assist the City in improving the overall quality of life for residents.

Flood control benefits are achieved when additional storage capacity is added to the storm drain system. Groundwater recharge projects reduce potential flooding by diverting a portion of storm flows into recharge areas, thereby increasing the overall capacity of the storm drain system.

7.3 Stormwater Capture Master Plan

The Stormwater Capture Master Plan (Master Plan) will investigate potential strategies for advancement of stormwater and watershed management in the City. The Master Plan will be used to guide decision makers in the City when making decisions affecting how the City will develop both centralized and distributed stormwater capture goals. The Master Plan will include evaluation of existing stormwater capture facilities and projects, quantify the maximum stormwater capture potential, develop feasible stormwater capture alternatives (i.e., projects, programs, potential policies, etc.), and provide potential strategies to increase stormwater capture. The Master Plan will also evaluate the multi-beneficial aspects of increasing stormwater capture, including potential open space alternatives, improved downstream water quality, and peak flow attenuation in downstream channels, creeks, and streams such as the Los Angeles River.

The Master Plan will recommend stormwater capture projects, programs, policies, and incentives for the City of Los Angeles.

Benefits of the Master Plan include:

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- Investigate stormwater capture models such as the Groundwater Augmentation Model and the Watershed Management Modeling System to identify maximum potential groundwater recharge
- Increased water conservation
- Improved water quality
- Reduced peak flow in the Los Angeles River

Project partners and supporters include:

- City of Los Angeles Department of Water and Power
- City of Los Angeles Department of Public Works
- County of Los Angeles Department of Public Works
- TreePeople, Inc.

7.4 Tree People – Memorandum of Agreement

The Memorandum of Agreement (MOA) with TreePeople has been forged to facilitate a high-level of collaboration between LADWP and TreePeople with the aim of fostering a more sustainable Los Angeles. The partnership it outlines leverages TreePeople's experience in public education and agency integration to further the long-term sustainability objectives of LADWP. Specifically, LADWP and TreePeople are working together to research opportunities within LADWP's facilities and operations for widespread groundwater recharge. This research includes an educational component wherein LADWP and TreePeople learn about each other's initiatives and core business. Ultimately, this exchange of ideas will help the two partners develop concepts for projects that will increase stormwater capture for groundwater recharge.

LADWP was an early sponsor for the TreePeople Trans-agency Resources for Environmental and Economic Sustainability (T.R.E.E.S.) Project, during which time TreePeople developed best management practices for capturing, cleaning and using stormwater; published the handbook Second Nature; created a computerized cost-benefit model; and facilitated a number of design workshops for public agencies. TreePeople has also been integral to the construction and management of three demonstration sites -- a single-family home (Hall House) retrofitted to capture all the rainwater onsite, and two elementary schools (Broadous and Open Charter) that feature strategic landscaping and a cistern or underground infiltrators. LADWP has supported public tours and educational materials for Hall House, and is a key partner in the school projects which were partially funded through the Cool Schools and Sustainable Schools programs.

The overlap between the objectives of LADWP and those of TreePeople is notable in the Tujunga Wash and Sun Valley watersheds, where both have been especially active. Stakeholder processes where the two have worked successfully to further mutual goals including the City's Integrated Resources Plan, the Integrated Regional Water Management Plan, and objectives of the California Urban Water Conservation Council.

7.5 Centralized Stormwater Capture Projects

Existing stormwater capture facilities are inadequate for capturing runoff during very wet years. Weather patterns vary dramaticly in Los Angeles with very wet years and very dry years. Therefore, new projects are necessary to expand the

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capability to capture a larger portion of stormwater flows during wet years. LADWP is working proactively in close partnership with LACFCD on multiple stormwater projects, as listed in Exhibit 7C. These projects will increase centralized stormwater recharge capacity by approximately 26,000 AFY in the SFB, raising groundwater levels and ensuring the future water supply reliability of the SFB. These projects are designed to maximize groundwater recharge into the basin by increasing the total average recharge to approximately 51,700 AFY.

Multiple opportunities exist to develop new recharge projects and improve existing recharge projects in the SFB. LADWP, in collaboration with LACFCD has supported and contributed resources toward the design, construction, and implementation of a variety of projects to increase groundwater recharge of the SFB. Additionally, multiple agreements between LADWP and LACFCD have been approved to facilitate preparing recharge studies, design work, and construction of projects in the SFB for groundwater recharge, flood protection, and other benefits.

Exhibit 7C
Planned LADWP Centralized Stormwater Capture Projects and Expected Annual Recharge

Project	Current Annual Recharge (AFY)	Increased Annual Capture/ Recharge (AFY)	Expected Annual Recharge (AFY)	Estimated Project Completion	Total Project Cost (millions)	LADWP Share (millions)
Sheldon-Arleta Gas Collection System	-	4,000 [1]	-	Complete Nov 2009	$8.2	$6.3
Big Tujunga Dam Rehabilitation [3]	-	4,500	-	Sep 2011	$105.7	$9.0
Hansen Spreading Grounds Upgrade	13,834	1,200	17,284 [2]	Dec 2011	$9.3	$4.8
Tujunga Spreading Grounds Upgrade	4,419	8,000	18,669 [4]	2015	$24.0	$24.0
Pacoima Spreading Grounds Upgrade	6,453	2,000	8,453	2015	$32.0	$16.0
Lopez Spreading Grounds Upgrade	527	750	1,277	2016	$8.0	$4.0
Strathern Wetlands Park	-	900	900 [5]	2016	$46.0	$4.0
Hansen Dam Water Conservation	-	3,400	3,400	2017	$5.0	$2.5
Valley Generating Station Stormwater Capture	-	700	700	2018	$9.7	$9.7
Branford Spreading Basin Upgrade	549	500	1,049	2018	$4.0	$2.0
Total Estimated Yield	**25,782**	**25,950**	**51,732**		**$251.9**	**$82.3**
Total Expenditure-to-date						$18.6
Total Expenditure Remaining						$63.7

1. This will allow increased collection of 4,000 AFY at Tujunga Spreading Grounds.
2. Includes 1/2 benefits from Big Tujunga Dam Rehabilitation Project.
3. No recharge occurs at the facility. All additional capture has been divided between Hansen & Tujunga Spreading Grounds.
4. Including benefits from Sheldon-Arleta Project and 1/2 benefits from Big Tujunga Dam Rehabilitation Project.
5. To be recharged at Sun Valley Park.

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Sheldon-Arleta Methane Gas Collection Project. In 1998, a Task Force comprised of representatives from LADWP, other City Departments (Bureau of Sanitation (BOS), Bureau of Engineering, and Environmental Affairs) and the Upper Los Angeles River Area Watermaster was formed to review the issues surrounding the recharge of groundwater through spreading at the Tujunga Spreading Grounds. The objective of this Task Force was to maximize water spreading at the Tujunga Spreading Grounds without causing off-site landfill gas migration. An outcome of the Task Force was the Sheldon-Arleta Methane Gas Collection Project. The project is designed to restore the original Tujunga Spreading Grounds capacity of 250 cubic feet per second (cfs) with the potential for future enhancement by bringing the Tujunga Spreading Basins closest to the Sheldon-Arleta landfill back online. The Tujunga Spreading Grounds are located adjacent to the closed Sheldon-Arleta Landfill. During spreading operations, water displaces air from the ground potentially increasing migration of methane gas generated by the landfill. In the past, elevated levels of methane gas have been detected in the surrounding communities. Therefore, restrictions were enacted curtailing spreading operations to 20 percent of their original capacity. This project is a joint effort between LADWP and BOS to replace the methane gas collection system within the landfill and thereby contain methane gas onsite. The project is being implemented by LADWP through LABOS's Proposition "O" Clean Water Bond program. Proposition "O" funded approximately $3 million of the $9 million cost. Construction began in 2007 and was completed in November 2009.

Big Tujunga Dam – San Fernando Groundwater Enhancement Project. LADWP and LACFCD approved Cooperative Agreement No. 47717 on September 18, 2007 for the Big Tujunga Dam –San Fernando Groundwater Enhancement Project. This Project will increase stormwater capture and provide other benefits including improvements in flood prevention and environmental enhancement through seismically retrofitting the dam and spillway. Annual stormwater capture will increase by 4,500 AFY for a total capture amount of 6,000 AFY. The project is integrated with the following projects in this section: Hansen Spreading Grounds Enhancement Project, Tujunga Spreading Grounds Enhancement Project, and the Sheldon-Arleta Methane Gas Collection Project. Both the Integrated Regional Watershed Management Plan for the Upper Los Angeles River Watershed and the Tujunga/Pacoima Watershed Plan are being incorporated into the Project. LADWP is contributing $9 million of the $105 million project cost. Construction of the Project is in progress with an anticipated completion date by September 2011.

Hansen Spreading Grounds Enhancement Project. The Hansen Spreading Grounds is a 120 acre parcel located adjacent to the Tujunga Wash Channel downstream from the Hansen Dam. Under Cooperative Agreement No. 47739, the Los Angeles County Flood Control District (LACFCD) and LADWP propose to modernize the facility to increase intake and storage capacity thereby improving groundwater recharge, flood protection and water quality while providing recreational benefits and native habitat improvements. To accomplish the goals of the project, a phased approach is being proposed. Phase 1A will deepen and reconfigure the existing basins; Phase 1B will improve the intake capacity by replacing a radial gate with a new rubber dam and telemetry system; and Phase 2 will develop other compatible uses such as recreational trails and native habitat for the community. Estimated recharge is 17,284 AFY, and estimated cost of this project is $10 million of which LADWP will fund $5 million. The reconstruction of the spreading grounds was completed in December 2009 and the intake structure will be completed in December 2011.

Tujunga Spreading Grounds Enhancement Project. The Tujunga Spreading Grounds Enhancement Project is designed to increase average annual stormwater capture by 8,000 AFY through relocating and automating the current intake structure on the Tujunga Wash, installation of an automated intake structure on the Pacoima Wash, and reconfiguration of the Tujunga Spreading Basins. Other multiple benefits include habitat improvements, passive recreation, educational opportunities, flood protection, and water quality improvements. Owned by LADWP, the Tujunga Spreading Grounds are

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operated by LACFCD in conjunction with other facilities along the Tujunga and Pacoima Wash Channels. Construction is expected to begin in 2012.

Valley Generating Station Stormwater Capture Project. LADWP is leading efforts to capture and infiltrate stormwater from the Valley Generating Station, from adjacent streets, and from the Tujunga Wash Channel. Phase 1 will capture and infiltrate all stormwater from the Valley Generating Station. Phase 2 will divert water from the Tujunga Wash Channel for infiltration at the abandoned gravel pit at the generating station. Total stormwater capture is estimated at 700 AFY. Project designs are expected to be completed at the end of 2011.

Pacoima Spreading Grounds Enhancement Project. LADWP in conjunction with LACFCD is proposing to upgrade the Pacoima Spreading Grounds by improving the intake and stormwater storage capacity. Annual average stormwater capture is expected to increase by approximately 2,000 AFY with completion of the project. Other project benefits include flood protection, water quality improvements, and passive recreation. The final concept report and design has an expected completion date by the end of 2012.

Lopez Spreading Grounds Enhancement Project. The Lopez Spreading Grounds Enhancement Project involves deepening the existing Lopez Spreading Grounds and improving the intake and delivery system. LACFCD is the lead agency for the project. Additional groundwater recharge to the SFB of approximately 750 AFY is expected from the project. Project designs are anticipated to begin in 2013.

Strathern Wetlands Park Project. The Strathern Wetlands Park Project involves the conversion of a 45-acre gravel pit into a multipurpose facility for flood protection, stormwater retention, treatment, groundwater recharge, habitat restoration, and recreation. Estimated stormwater capture is approximately 900 AFY. Proposition "O" funding of $17.8 million has been approved for acquisition of the site. LACFCD purchased the land and project planning is underway. Designs are expected in 2012, and construction is expected to occur in two phases from 2013 to 2016.

Hansen Dam Water Conservation Project. In 2000 the Army Corps of Engineers (ACOE) completed a feasibility study to examine operational changes and facility improvements at the Hansen Dam as part of a cost-shared study with LACFCD. Four scenarios are recommended with additional stormwater capture amounts of up to 3,400 AFY depending on the selected scenario. Designs for the project are anticipated in 2013.

Pacoima Dam Reservoir Sediment Removal Project. The Pacoima Dam Reservoir Sediment Removal Project involves removing sediment from behind Pacoima Dam to increase storage volume. The sediment build-up behind the Dam has decreased the capacity to about 3,300 acre-feet. In the fall of 2009 approximately 80 percent of the Pacoima Dam watershed was burned. This damage will likely increase sediment flow into the reservoir above the estimates provided based on 2005 topography. The Project will involve excavating 5 million cubic yards of sediment and increasing the storage volume by 3,000 acre-feet. Increased storage would decrease the number of reservoir spill events and increase the available recharge flow for the Pacoima and Lopez Spreading Grounds. The excavation will extend over 7,000 feet upstream of the existing dam. The project will produce an additional annual water recharge benefit of 670 AFY.

Branford Spreading Basin Upgrade. The Branford Spreading Basin Project will remove fine silts from the basin and install new pumps to drain the basin. These pumps could be used to drain the existing facility into the Tujunga Spreading Grounds. The expected additional recharge for this project is approximately 500 AFY.

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7.6 Distributed Stormwater Capture

Throughout the City of Los Angeles there are opportunities to capture localized dry and wet weather runoff for local reuse. However, Los Angeles' storm drain systems have historically been designed to protect life and property from flood impacts by quickly redirecting rainfall and runoff from impervious surfaces into the City's storm drain system and ultimately the Pacific Ocean without regard to water quality impacts. The September 2, 2002 Municipal Stormwater National Pollutant Discharge Elimination System Permit (NPDES Permit No. CAS004001) for the Los Angeles region requires all new development or redevelopment projects to develop and comply with a Standard Urban Stormwater Mitigation Plan (SUSMP) to reduce runoff leaving the project site and to improve the project's water quality impacts.

Recently the City has taken initial steps towards promoting distributed capture and infiltration of runoff through development of a suite of distributed runoff demonstration projects. Distributed stormwater capture (also known as decentralized stormwater capture) is defined as any groundwater recharge system less then 500 af or any direct stormwater capture system capturing less then 10 af. In addition, the City is developing a Low Impact Development (LID) ordinance requiring retention of stormwater onsite for new and redevelopment projects which extends beyond SUSMP regulations. The Watershed Management Group is working with the Los Angeles and San Gabriel Rivers Watershed Council (LASGRWC), TreePeople, Los Angeles Department of Public Works Bureau of Sanitation (BOS), Department of Building and Safety (DBS), Los Angeles County Department of Public Works (LACDPW), The River Project and others to evaluate and study the impacts of localized stormwater capture and source control within the City.

LADWP is providing various resources for projects that would enhance the City's ability to capture additional dry and wet weather runoff for beneficial use. Both dry and wet weather runoff can be beneficially used. Dry weather runoff occurs in the absence of rainfall while wet weather runoff occurs as a direct result of rainfall. Dry weather runoff is typically related to inefficient irrigation systems, overwatering, and other wasteful outdoor water use practices. Wet weather runoff represents a significantly larger volume of water than dry weather runoff. Exhibit 7D summarizes the potential water yield and average unit cost of the different resources available to increase localized capture and infiltration of runoff.

7.6.1 Watershed Council – Water Augmentation Study

The Los Angeles Basin Water Augmentation Study (WAS) is a long-term research project, initiated in 2000, created to determine the benefits of implementing a broad-based approach to stormwater infiltration within the Los Angeles Region. The study was led by the Los Angeles & San Gabriel Rivers Watershed Council in partnership with local, state, and federal agencies and organizations, with major support from the federal Bureau of Reclamation. LADWP assisted in the funding and creation of the study report as part of the Technical Advisory Committee.

While centralized strategies such as spreading basins and dams are reliable and effective methods to capture stormwater, increased urbanization, high land costs, and scarcity of imported water for recharge signal the need to pursue additional stormwater capture methods. Furthermore, centralized stormwater infiltration is unable to capture the entire watershed which leaves a large quantity of additional stormwater to be tapped into. The WAS research has concluded that decentralized strategies (distributed stormwater capture such as rainbarrels & cisterns) would provide a local and reliable supply of water that would not negatively impact groundwater quality. Distributed stormwater capture and infiltration systems techniques provide a viable means of augmenting groundwater recharge and reducing the overall cost of treating urban runoff. Based on the findings of this study, the WAS partnership moved forward on a demonstration project in a 24-single family residential home neighborhood in northeast San Fernando Valley to validate study findings.

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CASE STUDY:
Elmer Avenue Neighborhood Retrofit Project

The Background

Initiated in 2000, the Los Angeles Basin Water Augmentation Study (WAS) is a long-term research project led by the Los Angeles & San Gabriel Rivers Watershed Council in partnership with eight local, state, and federal agencies of which LADWP is an active partner. The study is evaluating the practical potential to improve surface water quality and increase local groundwater supplies through infiltration of urban stormwater runoff.

Based on positive findings of the study, the WAS partnership moved forward with a demonstration project to display an integrated and comprehensive approach to water management by retrofitting a neighborhood with strategies to address water conservation, pollution reduction and treatment, flooding, and habitat restoration. The Elmer Avenue Neighborhood Retrofit Project was chosen after an extensive selection process that evaluated neighborhoods based on more than 80 criteria.

The Project

The Elmer Avenue Neighborhood Retrofit Project commenced in July 2009 and was completed in June 2010 and cost approximately $2.5 million. Elmer Avenue receives stormwater runoff from approximately 40 acres of upstream residential area causing flooding in most storms. To address these 40 acres, the project encompasses improvements to both the public right-of-way as well as the private residences. As such, the project required active interaction and cooperation between the WAS partnership and the residents to work together and come up with a solution for the neighborhood.

Public Right-of-Way Improvements:

Infiltration Gallery-

A large infiltration gallery was installed underneath the street right-of-way which is estimated to infiltrate 16 acre-feet annually. The gallery is a sub-surface groundwater collection system, shallow in depth, constructed with perforated pipes where runoff water flows into and then is allowed to infiltrate into the ground to recharge the local groundwater basin.

Bioswale-

The newly installed sidewalks include bio-swales in the parkways to capture and treat stormwater runoff from the local sub-watershed mostly from residential landuse. The bioswales are open shallow channels with gently sloped sides and bottoms filled with vegetation and rip rap where stormwater runoff is collected. Bioswales help reduce the flow velocity and treat stormwater runoff through filtering by the vegetation in the channel, through the subsoil matrix, and/or into the underlying soils. In addition, bioswales trap particulate pollutants (suspended solids and trace metals), promote infiltration and serve as part of the whole stormwater drainage system installed for this project.

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Private Residence Improvements:

Numerous improvements were offered to residents who chose to participate to help reduce runoff as well as exercise better outdoor water conservation such as porous pavers, rain gardens, rain barrels, and drought-tolerant and native landscaping.

The Benefits

The finished project incorporates a mixture of strategies to produce multiple levels of benefits (to the neighborhood but also to the local, regional, and national community whom can take this work as an encouraging model):

- Capture stormwater and dry-weather runoff to prevent flooding and decrease pollution of local rivers and oceans
- Reduce impermeable surfaces and increase groundwater recharge
- Improve neighborhood aesthetics through increased green space and public right-of-way improvements
- Increase community awareness of watershed issues
- Encourage community awareness to being more water and environmentally responsible.

As a result of the success and positive feedback from citizens for the Elmer Avenue Neighborhood Retrofit Project, a second phase is currently underway to Elmer Avenue to retrofit its alleyway. These small projects aim to spark large change by showing citizens and other communities that they too can make changes and improve their neighborhoods to be more water and environmentally friendly.

"By turning our yards into rain gardens and our streets into water recharge facilities, we can ensure clean water for the future. In contrast to a typical urban street, Elmer Avenue now reduces flooding and water pollution, improves water quality, replenishes groundwater supplies, and increases native habitat."

Nancy Steele, Executive Director
Los Angeles and San Gabriel Rivers Watershed Council

"This project is a prime example of how homeowners and the city can work together on a project that demonstrates smart watershed management through stormwater capture and water conservation measures that are beautiful and effective"

Edward Belden, Water Programs Manager
Los Angeles and San Gabriel Rivers Watershed Council

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7.6.2 Integrated Water Resources Plan Analysis

As part of the City of Los Angeles Integrated Water Resources Plan (IRP), further described in Chapter 10, the City investigated the beneficial reuse of urban runoff for both dry and wet weather conditions.

7.6.2.1 Dry Weather Runoff Options

The beneficial use option for dry weather runoff consists of runoff capture, treatment, and reuse. For dry weather flow, most of the runoff could potentially be diverted directly for beneficial use, particularly during the summer months when demands for non-potable water are high (due to the higher irrigation demands in the summertime). The level of treatment of the runoff before being beneficially used would be determined by the ultimate use of the water.

A computer modeling analysis was performed during development of the IRP based on the recycled water demands in Los Angeles and the available dry weather runoff. Based on the data, the model determined which of the recycled water demands could be realistically met through treated runoff. The dry weather runoff available for reuse throughout the City is estimated at 97 mgd (approximately 26,000 million gallons per year). Exhibit 7E identifies the amount of this runoff that could, after treatment, be used to meet the recycled water demands.

Exhibit 7E

Potential Non-Potable Water Demands Met with Dry Weather Treated Runoff

Service Area	Total Demand Served	
	(AF per year)	(million gallon per year)
Aliso Wash	1,400	460
Canoga	3,250	1,050
Reseda	2,900	950
Tujunga / Burbank	9,050	2,950
LA River Reach 3	1,100	360
Dominguez Channel	8,500	2,770
Compton Creek	1,450	470
Ballona	10,850	3,530
Verdugo Wash	100	30
LA River/Arroyo	9,600	3,130
Total	48,200	15,700

Source: City of Los Angeles Integrated Resources Plan, Facilities Plan, Volume 3: Runoff Management

7.6.2.2 Wet Weather Runoff Options

Rain Barrels

Rain barrels are distributed stormwater capture devices used to store rainwater collected from roofs via roof rain gutter systems. Harvested water can be used for outdoor irrigation at a later time. Rain barrels vary in size with a typical rain barrel holding approximately 55 gallons that can be readily installed under any residential roof gutter downspout. Installation of rain barrels at residences throughout Los Angeles, assuming 400,000 residences, could potentially capture 6,400 AFY assuming an annual average rainfall of 17.8 inches, one 55-gallon rain barrel installed per residence, and an average roof area of 500

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square feet. If overflow infiltration is provided, and/or greater roof area is utilized, annual rainfall volume captured can be significantly greater.

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Case Study:
Ballona Creek Watershed Rainwater Harvesting Pilot Program

Funded by the Safe Neighborhood Parks, Clean Water, Clean air and Coastal Protection Bond Act of 2000 (Prop 12) through the Santa Monica Bay Restoration Commission and the California Coastal Conservancy, the City of Los Angeles, Department of Public Works, Bureau of Sanitation, Watershed Protection Division (Stormwater Program) began the City's first free Rainwater Harvesting pilot program in July 2009. The goal of this program is to engage as many property owners as possible, and limiting the installation to one downspout per property allows the City to reach the maximum number of residences.

Liz Herron, Land Use Chair of Mt. Washington Association, supports rainwater harvesting systems: "Rain barrel systems serve environmental purposes by allowing homeowners to collect the rainwater for personal irrigational purposes. It also reduces the amount of rainwater entering into the streets and ocean. These residential systems are successful programs that save water and prevent pollution."

Designed to conserve potable water and reduce the amount of polluted rainwater that runs untreated into the ocean, the $1-million pilot plan has enough funds to install 490 residential rain barrels, disconnect 100 barrels implemented with consultation on rain gardens, and provide one custom-made commercial planter box for each of ten businesses. It is estimated to save 584,100 gallons of water each year. The City estimates there are roughly 18 rain events in LA each year filling each barrel at least once each time.

In a typical year, about 9,600 gallons of water is generated on an average 1,000-square foot residential LA roof top. If each of the 400,000 residential parcels in LA were to install a single rain barrel, the City estimates that about 400 million gallons of water would be saved, which would reduce the demand for water. An evaluation of the program is scheduled for completion in Spring 2011.

The 55-gallon capacity rain barrel was chosen because the weight of 200 pounds is relatively manageable. The rain barrels are also made from food-grade plastic, repurposed from containers in case the harvested rainwater is used to grow food. They are equipped with mesh netting to keep out debris and mosquitoes and connected to the downspouts by a trained rain barrel installation specialist.

Planter boxes that businesses are eligible for will be custom-made to fit the layout and dimensions of the property. The City will be working with the business to make sure they are content with the presentation of the planter box.

The program addresses the City's broad problems of water scarcity and stormwater pollution. Currently outdoor water usage accounts for 1/3 of the average family's overall water consumption. The Rainwater Harvesting program helps to meet the City's water conservation goals by reducing the amount of potable water used for irrigation and other outdoor purposes.

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Cisterns

Cisterns are larger than rain barrels and can range from 100 to 10,000 or more gallons. They store diverted runoff from roof areas and other impervious surfaces. This stored runoff can provide a source of untreated water for gardens and compost, free of most sediment and dissolved salts. Because residential irrigation can account for up to 40 percent of domestic water consumption, water conservation measures such as cisterns can be utilized to reduce demands, especially during hot summer months.

An analysis of the effect of installing cisterns in all single family and multi-family residences in the City was conducted as part of the IRP, which was based on projected household demands, irrigation needs, and historical rainfall data. The results showed that during a storm event of 0.45 inches, the result of installing 1,000-gallon cisterns at all single-family and multi-family residences in the City would be a maximum capture of approximately 440 million gallons. This provides a substantial amount of water conservation and reduction in potable water demands within the City.

The primary beneficial use of dry and wet weather runoff is to meet irrigation demands. These demands are typically non-existent during rain events and low throughout the rainy season. Therefore, the wet weather runoff would need to be stored until the demand exists. This can be done through a regional and/or a localized approach. A regional approach to seasonal storage could include the use of out-of-service reservoirs for seasonal storage. A localized approach would be to construct distributed underground storage facilities, located in open spaces, parks, schools, etc. throughout the City.

Exhibit 7F demonstrates a modular storage media that holds the runoff in a honeycomb-like box under the ground. The storage media has approximately 95 percent voids, so almost all of the storage volume would be filled with water. The maximum depth is 8 feet, which translates to approximately 2.44 million gallons per acre of water storage potential. The containers can also be constructed to be impermeable to prohibit infiltration.

Exhibit 7F
Construction of Underground Cistern for Stormwater Capture

(Photo courtesy of TreePeople)

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According to studies conducted during the development of the IRP, the City currently has an estimated open space area of 6,000 acres, which includes parks, open space, and vacant lots. School sites are also a potential option for installing modular storage media under playgrounds and athletic fields. The total school area in the City is approximately 6,000 acres. Assuming that only 25 percent of this area has no buildings or other structures, this equals approximately 1,500 acres of potentially suitable land. Additionally, there are approximately 900 abandoned or no longer maintained alleys of various unknown dimensions that could potentially be converted to underground storage facilities. Exhibit 7G summarizes the approximate underground storage potential throughout the City.

Exhibit 7G

Underground Storage Potential throughout the City

Land Use	Acres (acres)	Potential Storage Volume[1] (million gallons)
Open space	6,000	15,000
Schools (assume only ~ 25 percent suitable land)	1,500	4,000
Alleys	900 count	Unknown
Total	7,500	19,000

Note: 1. Maximum storage potential shown assumes 4.22 million gallons of storage per acre of land. Actual usable volume may be less.
Source: City of Los Angeles Integrated Resources Plan, Facilities Plan, Volume 3: Runoff Management

The City has the potential to store a considerable volume of wet weather runoff in order to meet the potential future surface water quality regulations if the underground storage options were utilized. This stored water could then be drawn down and beneficially used during the dry weather months.

Rain Gardens

Rain Gardens are another simple form of relatively small scale rainwater harvesting. As gardens or depressions, usually constructed sub-grade, they act as small retention/percolations basins for rainwater collection. Not only do they provide for an attractive landscape, but they are effective in treating and infiltrating stormwater for local groundwater recharge.

While extremely functional, these are basically regular gardens and can be designed to fit well into the surrounding landscape. Many cities and states across the country have extensive rain garden programs, and years of research have gone into their design and performance. Acting as a bio-retention systems, rain gardens treat runoff naturally as it seeps underground. In the case of lowered percolation rates or in hillside developments, rain gardens are typically installed with impermeable liners and supplied with under drains.

Unit cost of rain gardens are similar to that of rain barrels, as the mechanism for collecting water is the same. Cost is dependent upon the form and extent of construction and on the type and quantity landscape used, as well as the associated maintenance. Installation of rain gardens at residences throughout Los Angeles, assuming 400,000 residences, could potentially capture 6,400 AFY assuming an annual average rainfall of 17.8 inches, and an average roof area of 500 square feet. Under these conditions, assuming a 10-15 year lifespan, the cost of rain gardens varies from $308-$5,000 / AF.

Neighborhood Recharge

Neighborhood recharge involves installing recharge facilities in portions of vacant urban lots, abandoned alleys, and City parklands, where the soil is highly permeable. This option involves installing underground storage (such as a honeycomb

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shaped device shown in Exhibit 7F, but without the lining to allow infiltration). This would allow the runoff to be stored underground, while still maintaining a safe area above ground for human activity. The runoff would be pumped or would flow by gravity to the site where it would be collected temporarily until it is able to infiltrate.

The amount of runoff that could be managed by neighborhood recharge was determined as part of the IRP by assuming that only the east San Fernando Valley area has predominantly permeable soils appropriate for infiltration (though there may be other areas within the City that could be usable for recharge with smaller-scale projects). Based on an analysis of the City's Geographical Information System, the maximum total area available for neighborhood recharge facilities is approximately 831 acres, which includes vacant urban lots, abandoned alleys, and 25 percent of City parklands. Assuming an infiltration rate of 2 feet per day, the maximum runoff that could potentially be managed by recharge facilities would be 550 million gallons per day (mgd).

7.6.3 Distributed Stormwater Capture Projects

As an outgrowth of the IRP, neighborhood recharge concept efforts are moving from the conceptual stage visualized in the IRP to actual identified projects in the City which infiltrate wet weather runoff as close as possible to the point of origin. A few of the identified projects are highlighted here.

Whitnall Highway Power Line Easement Stormwater Capture Project. This project involves the capture, treatment, and infiltration of stormwater from streets in the eastern San Fernando Valley using LADWP's Whitnall Power Line Easement in the lower Sun Valley Watershed. Average annual recharge is estimated at 110 AFY. Additional uses of the project site may include open space and recreational enhancements. Designs are anticipated for completion by the end of 2011.

Elmer Avenue Neighborhood Retrofit Project. In December of 2008, the City of Los Angeles partnered with TreePeople and the LASGRWC to retrofit an existing neighborhood in the Sun Valley portion of Los Angeles that is prone to flooding during wet weather events. A combination of Best Management Practices (BMPs); including vegetated swales, infiltration trenches, rain gardens, rain barrels, native and drought tolerant landscaping, roof gutters, street tree plantings, and aligning driveways to drain to vegetated swales are incorporated into this project. This project was designed to capture and infiltrate the equivalent of a 2-year storm, increasing groundwater recharge. Project funding was provided by the US Bureau of Reclamation, DWR, LACDPW, MWD, Water Replenishment District of Southern California and LADWP. Construction was completed in June 2010.

Woodman Avenue Median Retrofit Demonstration Project. LADWP in partnership with the BOS Watershed Protection Division and The River Project, a non-profit organization, are developing the Woodman Avenue Median Retrofit Demonstration Project to capture, treat, and infiltrate stormwater runoff along a portion of Woodman Avenue. The Project will replace the existing median with pre-treatment devices, a vegetated swale, and an underground retention system. Project benefits include reductions in localized flooding, open space enhancements, groundwater recharge, and native habitat enhancement. The CalFed Watershed Program awarded the project a $1.6 million grant. Construction is expected to be completed by the end of 2012.

North Hollywood Alley Retrofit BMP Demonstration Project. The Project's goal is to demonstrate the ability to infiltrate stormwater near the point of origin while increasing groundwater recharge, reducing flooding, and improving water quality. Four segments of alleyways in the San Fernando Valley are proposed to be retrofitted with pervious surfaces and diversion of flows from intersecting streets into these alleyways. Construction is anticipated to begin in early 2011.

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Laurel Canyon Parkway Infiltration Swale Project. Construction of the Laurel Canyon Parkway Infiltration Swale Project will involve construction of an infiltration trench and parkway swale between the street curb and sidewalk near LADWP's Tujunga Spreading Grounds in the San Fernando Valley. Stormwater will be collected and infiltrated into the groundwater from the local residential neighborhood. Construction of the project is anticipated to occur in late 2011.

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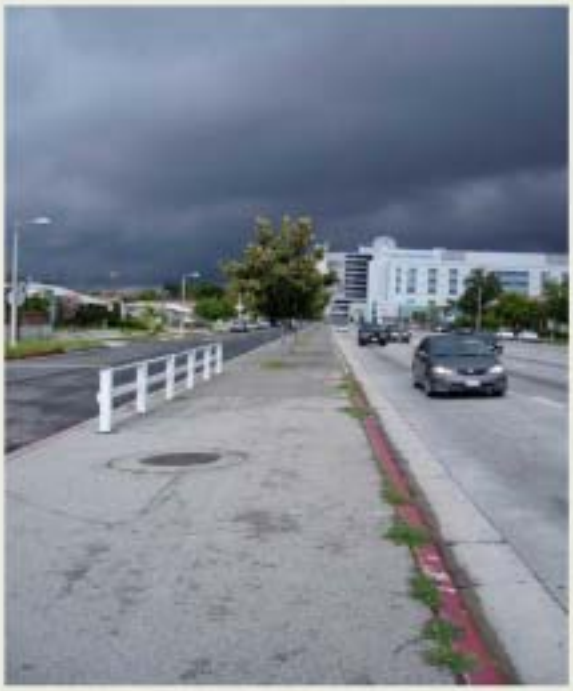
CASE STUDY:
Woodman Avenue Multi-Beneficial Storm Water Capture Project

Originally proposed by the local Panorama City Neighborhood Council for the Tujunga-Pacoima Watershed Plan, the Woodman Avenue project represents an innovative example of stormwater capture, which includes extensive benefits for the environment, the City's groundwater basin, and the surrounding community. The Woodman Avenue median is located along the west side of Woodman Avenue from Lanark Street to Saticoy Street.



The Project's construction will be relatively simple but effective. The Project will capture surface runoff from approximately 130 acres that currently flows along street gutters to storm drains, through the Tujunga Wash and ultimately down the Los Angeles River and into the Pacific Ocean. Instead flows will now be directed through pre-treatment devices into a vegetated swale and an underground retention system for groundwater basin infiltration. The vegetated swale and underground retention/infiltration system will replace an existing 16-foot wide, 3,500-foot long concrete median. After construction of the project, participants will conduct active monitoring of water flows, water quality, and vegetation for approximately three years. This data should provide valuable information to facilitate the development of future projects, and optimize system processes.

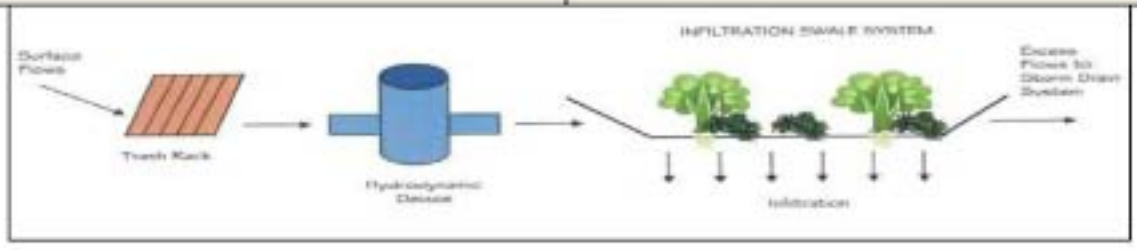
The direct water resource related benefits from this project are three fold. First, the additional water captured will recharge the San Fernando Groundwater Basin with approximately 80 AF per year. This replenishes the City's local groundwater supply, and helps protect pumping rights for City, which ultimately guarantees a more reliable water supply. Secondly, diverted flow alleviates local flooding, particularly during sizable rain events. Finally, the infiltration prevents contaminant carrying runoff and debris from entering local waterways and ultimately coastal areas.

Also recognized are the Community benefits associated with this project. These include creation of open space enhancements such as improved aesthetics and pedestrian access near schools, a walking path, benches, and native vegetation. The River Project will be running an active education program with the local community, including workshops with nearby business owners/residents and the introduction of a curriculum for students at the local elementary school. The organization's goal is to get the students involved in monitoring and maintenance of the project as part of their service learning requirements. Establishing knowledge of sustainable water supplies with the City's youth is an investment in constituent water use practices for generations to come.

Project participants include the Panorama City Neighborhood Council, Council District 6, the Los Angeles Bureau of Sanitation, the Los Angeles Bureau of Street Services, the State of California Water Resources Control Board (SCWRCB), The River Project, and LADWP. This cooperative partnership is anticipating the project's construction to be completion around the end of 2012.

State funding used for the project is provided through Proposition 50. SCWRCB has dedicated $1.6 million through the CALFED Watershed Grant Program, which covers roughly half of the overall project cost.

Melanie Winter from The River Project speaks positively of this stormwater capture project: "The community's involvement in the watershed planning process helped them identify a prime opportunity site that maximizes all the potential benefits. It helps reduce our dependence on imported supplies, addresses peak flows, improves water quality, and re-establishes habitat. It's gratifying to receive State funding to work in a well-rounded partnership to implement this integrated watershed project conceived at the grassroots level."



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7.6.4 Low Impact Development and Best Management Practices

LADWP, in conjunction with other City Departments, is developing programs to highlight water conservation through Low Impact Development (LID) and installation of BMPs. Low Impact Development (LID) is a stormwater management strategy that has been adopted by many localities across the country for the past several years. It is a stormwater management approach that is designed to reduce runoff of water and pollutants from the site(s) at which they are generated.

The past few decades of stormwater management have resulted in the current convention of control-and-treatment strategies. They are largely engineered, end-of-pipe practices that have been focused on controlling peak flow rate and suspended solids concentrations. Conventional practices, however, fail to address the widespread and cumulative hydrologic modifications within the watershed that increase stormwater volumes and runoff rates and cause excessive erosion and stream channel degradation.

In general, implementing integrated LID practices into new development and retrofit of existing facilities can result in enhanced environmental performance while at the same time reducing development costs when compared to traditional stormwater management approaches.

According to the USEPA, infrastructure costs associated with LID practices as compared to traditional stormwater treatment practices result in significant cost savings ranging between 15 percent and 80 percent less than traditional practices. BMPs consist of practices designed to infiltrate runoff for groundwater recharge, reduce runoff volume, and capture rainwater for reuse. Programs under development include pilot projects, retrofitting of existing facilities, new development standards, and assistance in ordinance development.

Retrofit of LADWP Facilities to Meet LID Standards

LADWP is assessing its existing facilities for potential retrofits using LID BMPs. LID BMPs under consideration include pervious pavement, stormwater capture, curb cuts, bioretention cells, and amended soils. Expected benefits include:

- Increased groundwater recharge;
- Decreased outdoor water use;
- Increased compliance with stormwater regulations;
- Improved environmental conditions for employees and the public;
- Improved public image;
- Increased awareness of LID and provide examples for residents; and
- Compliance with Model Water Efficient Landscape Ordinance.

New LADWP Facility Development Using LID Standards

LADWP's Watershed Management Group is developing a framework for implementation of LIDs and BMPs during the new facility development process. Within the framework, LID and BMPs are taken into consideration during the planning, design, implementation, and maintenance processes associated with new LADWP facilities. Benefits include:

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- Reductions in costs associated with stormwater infrastructure and landscape maintenance;
- Reduced costs for grading by using natural drainage;
- Reduced sidewalk costs by using narrower sidewalks;
- Increased groundwater recharge;
- Reduced runoff volume and pollutant loading;
- Reductions in long-term maintenance and operation costs by using drought tolerant landscaping;
- Reduction in life cycle costs of replacing or rehabilitating pipe and below ground infrastructure.

Assistance in Ordinance Development

LADWP is represented on the City of Los Angeles Landscape & Stream Protection Ordinances Joint Meeting Committee through the Watershed Management Group. Other committee members include the Department of Parks and Recreation, the Department of Public Works, the Department of Environmental Affairs, the Department of City Planning, and the Department of Building and Safety. The committee is tasked with developing ordinances for city-wide implementation that in combination reduce water use and improve groundwater recharge among other multiple benefits. Ordinances under review include the:

- Green Building Ordinance using the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System;
- LID Ordinance to incorporate improvements in stormwater management at the point of origin;
- Stream Protection Ordinance to incorporate methodologies for improving surface and groundwater quality;
- Hillside Ordinance revisions to include modifications in policies regarding front yards, side yards, height, fire protection, street access, lot coverage, off-street parking requirements, and exceptions in relation to the ordinances above.

7.6.5 Future Distributed Stormwater Programs

LADWP continues to investigate the potential for implementation of future distributed stormwater programs. Through its Watershed Management Group, LADWP will continue to develop partnerships and programs to improve utilization of stormwater runoff for outdoor water use and groundwater recharge. Potential programs that could be considered in the future include rain barrel/cistern rebates and retrofit incentives for installation of LID BMPs.

7.7 Integrated Regional Water Management Plan (IRWMP) Program

LADWP is a participating agency for the IRWMP which encompasses 92 cities in the Greater Los Angeles County Region. The IRWMP aims to address the water quality, resource, and supply issues of the region. A final plan was adopted on December 16, 2006.

Highlights of the plan that pertain to Watershed issues include:

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- Short and long term objectives to comply with water quality regulations (including TMDLs) by improving the quality of urban runoff, stormwater, and wastewater
- Optimize local water resources to reduce the Region's reliance on imported water
- Long term priority to protect groundwater supplies through stormwater recharge
- Target goal to reduce and reuse 150,000 AFY (40%) of dry weather urban runoff and capture and treat an additional 170,000 AFY (50%) for a total target of 90%
- Target goal to reduce and reuse 220,000 AFY (40%) of stormwater runoff from developed areas and capture and treat an additional 270,000 AFY (50%) for a total of 90%

For more detailed information on the IRWMP, please refer to Chapter 10.

7.8 Cost Analysis

Exhibit 7H compares side by side the various watershed management opportunities LADWP is pursuing and/or investigating to add to its water portfolio.

Exhibit 7H

Water Source	Water Yield (AFY)	Average Unit Cost ($/AF)
Centralized Stormwater Capture[1]	25,950	$60 - $200
Distributed Stormwater Capture		
Urban Runoff Plants[2]	5,000	$4,044
Rain Barrels[3]	6,400	$701 - $1,875
Cisterns[4]	8,000	$2,426
Rain Gardens[5]	6,400	$308 - $5,000
Neighborhood Recharge[6]	12,000	$3,351

Notes:

1. Water Yield and cost is based on LADWP's current planned centralized stormwater capture projects. Additional centralized stormwater capture potential will be identified once the Stormwater Master Plan is complete. Cost assumes 50 year project life.

2. Source: City of Los Angeles Integrated Resources Plan (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSA.

3. Source: Tree People. Assumes 10 - 15 year life, 55 gallon barrels, 1 barrel per residence, 17.8 in annual rainfall, $200-$300 per barrel installed, average used roof area 500 square feet, and 400,000 residences for yield (AFY); 2010 dollars

4. Source: City of Los Angeles Integrated Resources Plan (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSA; capturing and reusing stormwater on-site for schools and government only.

5. Source: Tree People. Assumes 10 - 15 year life, 17.8 in annual rainfall, $3.30 - $25.66 / ft² for rain garden construction, average used roof area 500 square feet, and 400,000 residences for yield (AFY); 2010 dollars

6. Source: City of Los Angeles Integrated Resources Plan (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSMSA.

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It is important to note that the centralized stormwater capture values are based on the planned projects listed in Section 7.5. LADWP is currently compiling a Stormwater Master Plan (see Section 7.3) which will investigate the maximum potential for stormwater capture within the City (for both centralized and distributed capture). Nevertheless, even with this fraction of the potential, it is clear that centralized stormwater capture is a very cost effective, plentiful water supply asset to be pursued. Recognizing its great potential, LADWP will proceed with its efforts on the centralized stormwater capture projects listed in Section 7.5, and closely monitor findings of the Stormwater Master Plan to determine future potential centralized stormwater capture projects.

Distributed stormwater capture values are based on the maximum potential achievable by the City. While the cost listed is high, distributed stormwater capture options are highly variable based on a variety of factors such as the magnitude of the overall program, project locations, etc. Furthermore, distributed stormwater capture projects yield additional benefits to the public outside of water supply generation such as community beautification, public right of way improvements, as well as private residence safety and aesthetic improvements. LADWP will continue to investigate these options to evaluate the best approach to establish a cost effective program that will help add to LADWP's water portfolio.

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Chapter Eight
Metropolitan Water District Supplies

8.0 Overview

As a member agency, the City of Los Angeles purchases water from the Metropolitan Water District of Southern California (MWD) to supplement its supplies from local groundwater, LAA deliveries, and recycled water. LADWP has historically purchased MWD water to make up the deficit between demand and other City supplies. As a percentage of the City's total water supply, MWD water varies from 4 percent in 1983-84 to 71 percent in 2008-09 with the 5-year average of 52 percent between 2005-06 and 2009-10. Exhibit 1F in Chapter 1 illustrates the City's reliance on MWD water during dry years and increasingly in recent years when LAA supply is being cut back for environmental enhancement projects. Although the City plans to reduce its reliance on imported water including LAA and MWD supplies, it has made significant investments in MWD and will continue to rely on the wholesaler to meet its current and future supplemental water needs.

MWD is the largest water wholesaler for domestic and municipal uses in California providing nearly 19 million people with on average 1.7 billion gallons of water per day to a service area of approximately 5,200 square miles. MWD was formed by the MWD Act, and exist pursuant to this statute which was adopted by the California legislature in 1927. MWD's adopted purpose is to develop, store, and distribute water to southern California residents. Additionally, the MWD Act allows MWD to sell additional water when it is available for other beneficial uses. In 1928 MWD was incorporated as a public agency following a vote by residents in 13 cities in southern California. Operating solely as a wholesaler, MWD owns and operates the Colorado River Aqueduct (CRA), is a contractor for water from the California State Water Project (SWP), manages and owns in-basin surface storage facilities, stores groundwater within the basin via contracts, engages in groundwater storage outside the basin, and conducts water transfers to provide additional supplies for its member agencies. Today MWD has 26 member agencies consisting of 11 water districts, one county water authority, and 14 cities, including the City of Los Angeles.

This Urban Water Management Plan projects LADWP's reliance on MWD water supplies will be reduced by half; from the five-year average of 52 percent of total demand between 2005-06 and 2009-10, to 24 percent by 2034-35 under average weather conditions.

8.0.1 History

Initially formed to import water into the southern California region from, MWD's first project was to build the CRA to import water from the Colorado River. The City of Los Angeles originally provided the capital dollars to initiate and complete land surveys of all proposed alignments for the project. Construction was financed through $220 million in bond sales during the Great Depression. Ten years after initiating construction Colorado River water reached southern California in 1941. To meet further water demands in the southern California region, MWD contracted with the SWP in 1960 to deliver almost half of the SWP's water from the San Francisco Bay-Delta region via the California Aqueduct into southern California. After completion of the California Aqueduct, deliveries of SWP water were first received in 1972.

8.0.2 Governance

MWD is governed by a Board of Directors composed of 37 individuals with a minimum of one representative from each of MWD's 26 member agencies. The allocation of the directors and voting rights are determined by each agency's assessed valuation. The city of Los Angeles has four Directors on MWD's Board and controls 19.44 percent of the vote. MWD's Administrative Code defines various tasks which the Board has delegated to MWD staff. A General Manager oversees MWD

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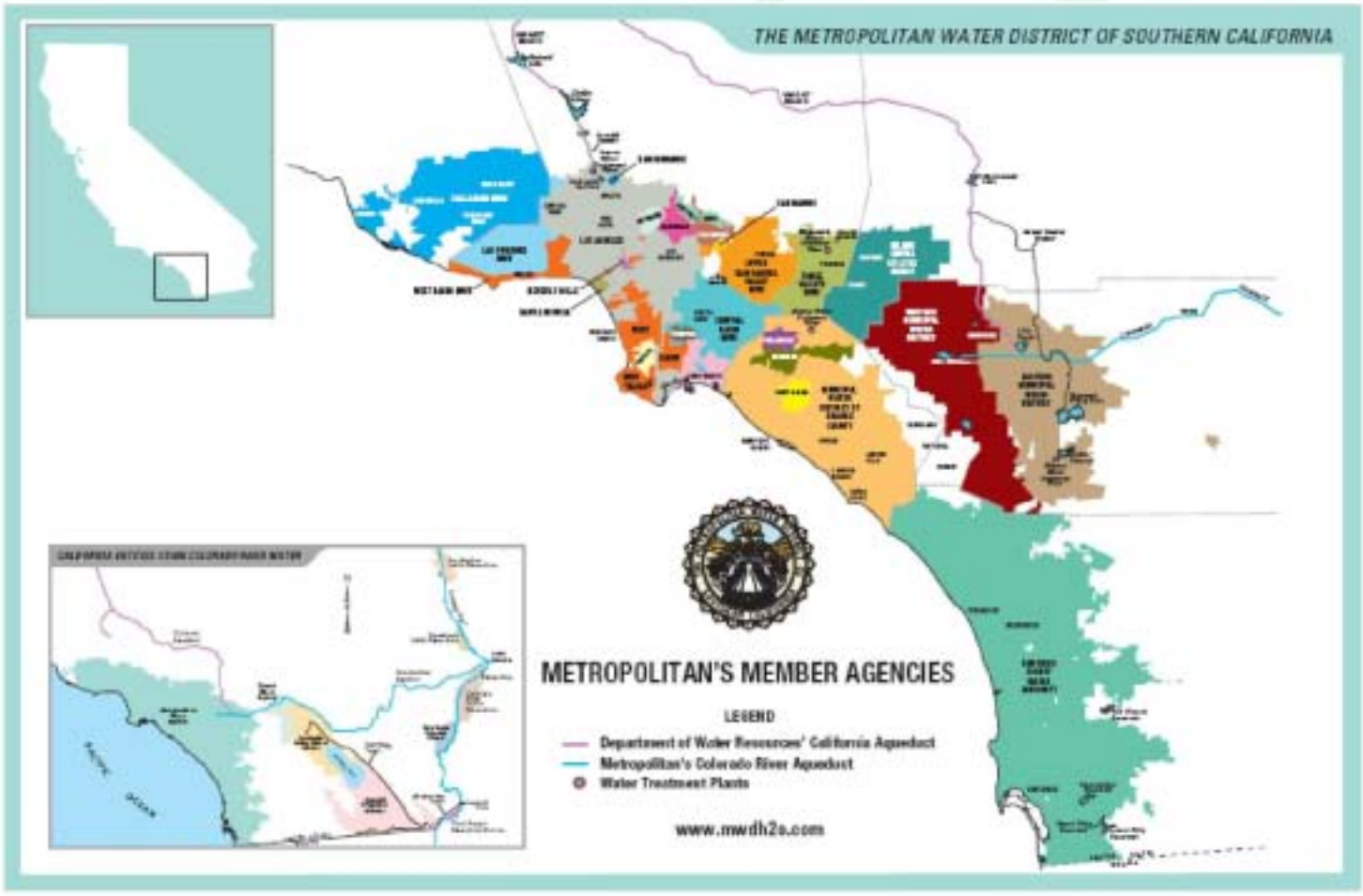
staff. The General Manager, General Auditor, General Counsel, and Ethics Officer serve under direction and authority given directly by the Board.

8.0.3 Service Area

Originally serving an area of 675 square miles in 1928, MWD's service area has grown to approximately 5,200 square miles serving 19 million people via its 26 member agencies. MWD's service area covers portions of Los Angeles, Ventura, Orange, Riverside, San Bernardino, and San Diego counties as depicted in Exhibit 8A. MWD member agencies serve 152 cities and 89 unincorporated areas. Member agencies provide wholesale, retail, or a combination of wholesale/retail water sales in their individual service territories.

Exhibit 8A
MWD Service Area



8.0.4 Major Infrastructure

MWD delivers approximately 6,000 AF per day of treated and untreated water to its member agencies through its vast infrastructure network. Major facilities include the CRA, pumping plants, pipelines, treatment plants, reservoirs, and

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hydroelectric recovery power plants. A summary of the major facilities and capacities are provided in Exhibit 8B and Exhibit 8C illustrates the geographic locations of the facilities.

Exhibit 8B
Major MWD Facilities Summary

Facility	Units	Capacity
Colorado River Aqueduct		
Aqueduct	242 miles	1.3 million AFY
Pumping Plants	5 plants	1,617 feet of total lift
Pipelines	819 miles	
Water Treatment Plants		
Joseph Jensen		750 mgd
Robert A. Skinner		630 mgd
F.E. Weymouth		520 mgd
Robert B. Diemer		520 mgd
Henry J. Mills		220 mgd
Total Treatment Capacity		2,640 mgd
Reservoirs		
Diamond Valley Lake		810,000 AF
Lake Matthews		182,000 AF
Lake Skinner		44,000 AF
Copper Basin		24,200 AF
Gene Wash		6,300 AF
Live Oak		2,500 AF
Garvey		1,600 AF
Palos Verdes		1,100 AF
Orange County		212 AF
Total Reservoir Capacity		1,071,912 AF
Hydroelectric Recovery Plants	16 plants	122 megawatts

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Exhibit 8C
Major MWD Facilities

8.1 Supply Sources

Colorado River supplies, State Water Project supplies, In-Basin Storage, Outside-Basin Storage, and Water Transfers together comprise MWD's total system water supply sources. These sources provide supplemental water to meet the demands in Venture, Los Angeles, Riverside, Orange, San Bernardino and San Diego Counties.

8.1.1 Colorado River

The Colorado River forms California's border with Arizona to the east. The drainage area in California that contributes water to the Colorado River is relatively small and has an arid climate. Accordingly, California has no major tributaries contributing water to the Colorado River.

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The Colorado River Board of California (CRB) is the California state agency given authority to protect the interests and rights of the state and its citizens in matters pertaining to the Colorado River. The Board is comprised of 10 gubernatorial appointees representing the LADWP, MWD, San Diego County Water Authority, Palo Verde Irrigation District, Coachella Valley Water District, Imperial Irrigation District, Department of Water Resources, Department of Fish and Game, and two public members.

8.1.1.1 The Law of the River

The Secretary of the Interior (Secretary) is vested with the responsibility to manage the mainstream waters of the Colorado River pursuant to applicable federal law. This responsibility is carried out consistent with a body of documents referred to as the Law of the River. Water rights to Colorado River water are governed by a complex collection of federal laws, state laws, a treaty with Mexico, other agreements with Mexico, Supreme Court decrees, contracts with the Secretary, interstate compacts, state, and administrative actions at the federal and state levels. Collectively, these documents and associated interpretations are commonly referred to as the "Law of the River" and govern water rights and operations on the Colorado River.

Particularly notable among these documents are:

1) the Colorado River Compact of 1922, which apportioned beneficial consumptive use of water between the Colorado River Upper Basin and Lower Basin; and defined the term "States of the Lower Division" to mean the States of Arizona, California, and Nevada. Serving as the basis of the "Law of the River" the Compact apportioned water to each basin in anticipation of a dam on the Colorado River. The Upper Basin is the portion of the Basin upstream of Lee Ferry, Arizona, while the Lower Basin is downstream of this point. Each basin was apportioned 7.5 million MAF annually and the Lower Basin received the option to an additional 1 MAF annually based on excess flows. California is within the Lower Basin along with Arizona and Nevada;

2) the Boulder Canyon Project Act of 1928 was enacted by Congress to authorize construction of Hoover Dam and the All-American Canal, the Act required that water users in the Lower Basin have a contract with the Secretary, and established the responsibilities of the Secretary to direct, manage, and coordinate the operation of Colorado River dams and related works in the Lower Basin. The Act stipulated conditions, one of which required California to limit Colorado River water use to 4.4 MAF annually plus one-half of the excess water unapportioned by the Colorado River Compact. To satisfy the condition, the California Legislature enacted the Limitation Act in 1929 limiting its use of Colorado River water to the basic apportionment of 4.4 MAF;

3) the California Seven Party Agreement of 1931 was developed in response to the Limitation Act and through regulations adopted by the Secretary, established the relative priorities of rights among major users of Colorado River water in California. The Seven Party Agreement apportioned California's share of Colorado River water to California contractors. Within the agreement priorities were established for each of the four agencies holding contracts for Colorado River Water with the U.S. Bureau of Reclamation. These priorities are shown in Exhibit D. Seven priorities were established with the first four priorities satisfying California's allocation of 4.4 MAF annually and the fifth and sixth priorities relating to California's share of excess Colorado River flows. MWD holds the fourth and fifth priorities. The fourth priority allocates 550 thousand acre-feet (TAF) of California's apportionment to MWD and the fifth priority allocates 662 TAF of California's share of excess flows to MWD.

4) the 1944 Treaty (and subsequent minutes of the International Boundary and Water Commission) related to the quantity and quality of Colorado River water delivered to Mexico. The Treaty guaranteed an annual quantity of 1.5 MAF to be delivered in accordance with the provisions of the Treaty.

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5) the 1963 United States Supreme Court Decision in *Arizona v. California* which confirmed the Lower Basin mainstream apportionments of:

2.8 million acre-feet per year (AFY) for use in Arizona,
4.4 million AFY for use in California, and
0.3 million AFY for use in Nevada;

provided water for Indian reservations and other federal reservations in Arizona, California, and Nevada; and confirmed the significant role of the Secretary in managing the mainstream Colorado River within the Lower Basin;

6) the 1964 United States Supreme Court Decree (Decree) in *Arizona v. California* which implemented the Supreme Court's 1963 decision; allocated 50 percent of the surplus water available for use in California; and allowed the Secretary to release water apportioned to but unused in one state for use in the other two states; the Decree was supplemented over time after its adoption and the Supreme Court entered a Consolidated Decree in 2006 which incorporates all applicable provisions of the earlier-issued Decrees; and

7) the Colorado River Basin Project Act of 1968, which authorized construction of a number of water development projects including the Central Arizona Project (CAP), provided existing California, Arizona, and Nevada water contractors a priority over the CAP and other users of the same character in Arizona and Nevada whenever less than 7.5 million afy is available, and required the Secretary to develop the Long Range Operating Criteria and issue an Annual Operating Plan for mainstream reservoirs.

Exhibit 8D

Listing of Priorities - Seven Party Agreement		
Priority Number	**Agency and Description of Service Area**	**Beneficial Consumptive Use (Acre-feet/year)**
1	Palo Verde Irrigation District - 104,500 acres	
2	Yuma Project, California Portion, not exceeding 25,000 acres	
3(a)	Imperial Irrigation District	
3(b)	Palo Verde Irrigation District - 16,000 acres	3,850,000
4	Metropolitan Water District, City of Los Angeles and/or others on the coastal plain	550,000
5	Metropolitan Water District, City of Los Angeles and/or others on the coastal plain	662,000
6(a)	Imperial Irrigation District	
6(b)	Palo Verde Irrigation District - 16,000 acres of adjoining mesa	300,000
	Total	**5,362,000**

8.1.1.2 Colorado Supply Reliability

Reliability of CRA water for MWD has decreased overtime as a consequence of multiple events. Historically California had used up to 5.4 million afy as Arizona and Nevada were not using their normal apportionments of Colorado River water and surplus water was made available by the Secretary. The 1964 Decree and the 2006 Consolidated Decree of the US Supreme

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Court in *Arizona v. California* confirmed California's allocation was limited to 4.4 MAF annually. As a result MWD can now only rely on its fourth priority allocation of 550 TAF annually. Prior to this, MWD was able to satisfy its fifth priority allocation with Nevada and Arizona's unused water. However, in 1985 Arizona began increasing deliveries to its Central Arizona Project reducing the availability of unused apportionment to fill MWD's fifth priority.

Because of dry years on the Colorado River system and Arizona and Nevada using their full apportionment, the U.S. Secretary of Interior asserted that California must come up with a plan to live within its 4.4 MAF apportionment. Therefore, users from California have developed California's Colorado River Water Use Plan (California Plan). The users included: MWD, Palo Verde Irrigation District (PVID), Imperial Irrigation District (IID), and Coachella Valley Water District (CVWD). This plan identifies actions that California will take to operate within its 4.4 million acre-foot entitlement.

California currently consumes its normal apportionment of 4.4 million AFY, Exhibit 8E and Exhibit 8F illustrate the order of priority, is as follows:

1. PVID - gross area of 104,500 acres of land in the Palo Verde Valley.
2. Yuma Project-Reservation Division - not exceeding a gross area of 25,000 acres in California.

3(a). IID - lands in the Imperial Valley served by the All-American Canal. Export out of basin, primarily agricultural usage. Also, second 63,000 AF in priority 6(a) and balance of any remaining priority 6(a) and 7 water available.

3(b). CVWD - lands in the Coachella Valley served by the Coachella Branch of the All-American Canal. Export out of basin, agricultural usage. Also third 119,000 AF in priority 6(a) and balance of any remaining priority 6(a) and 7 water available.

3(c). PVID - 16,000 acres of land on the Lower Palo Verde Mesa, also priority 6(b).

4. MWD – 550,000 af, also 662,000 af in priority 5, and first 38,000 af in 6(a)

Exhibit 8E
Historical Total Colorado River Basin Storage

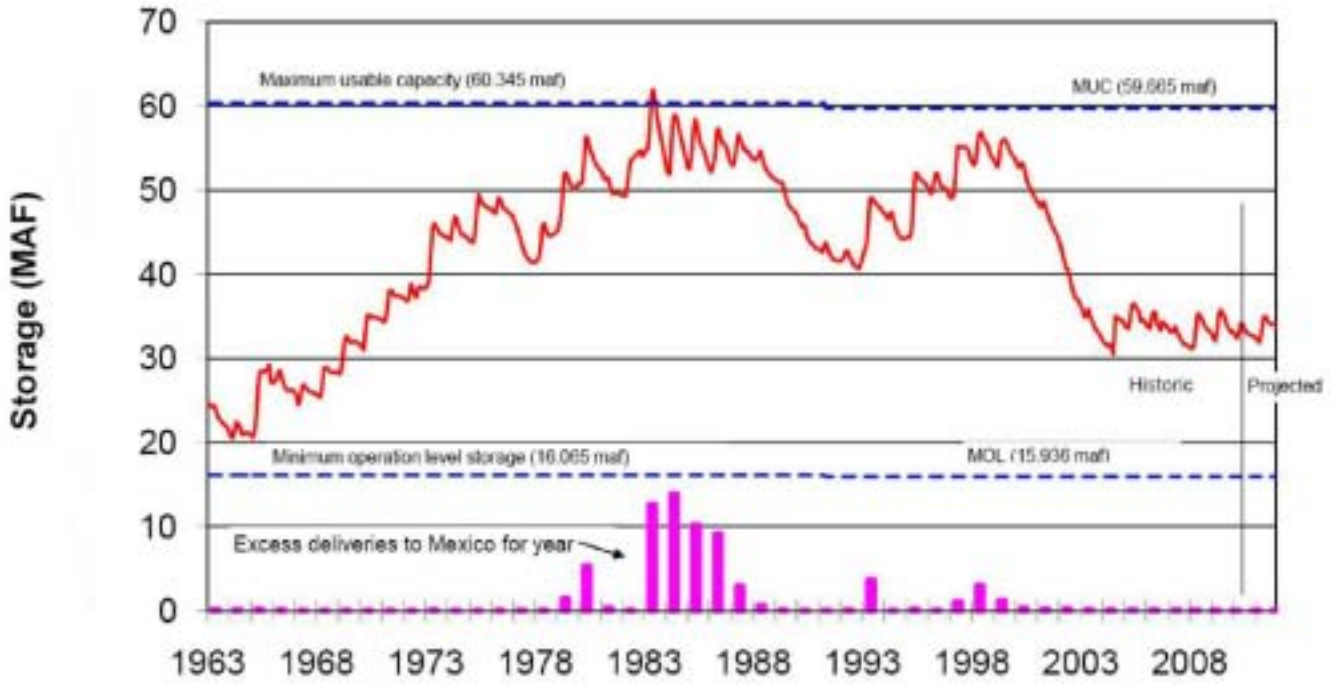

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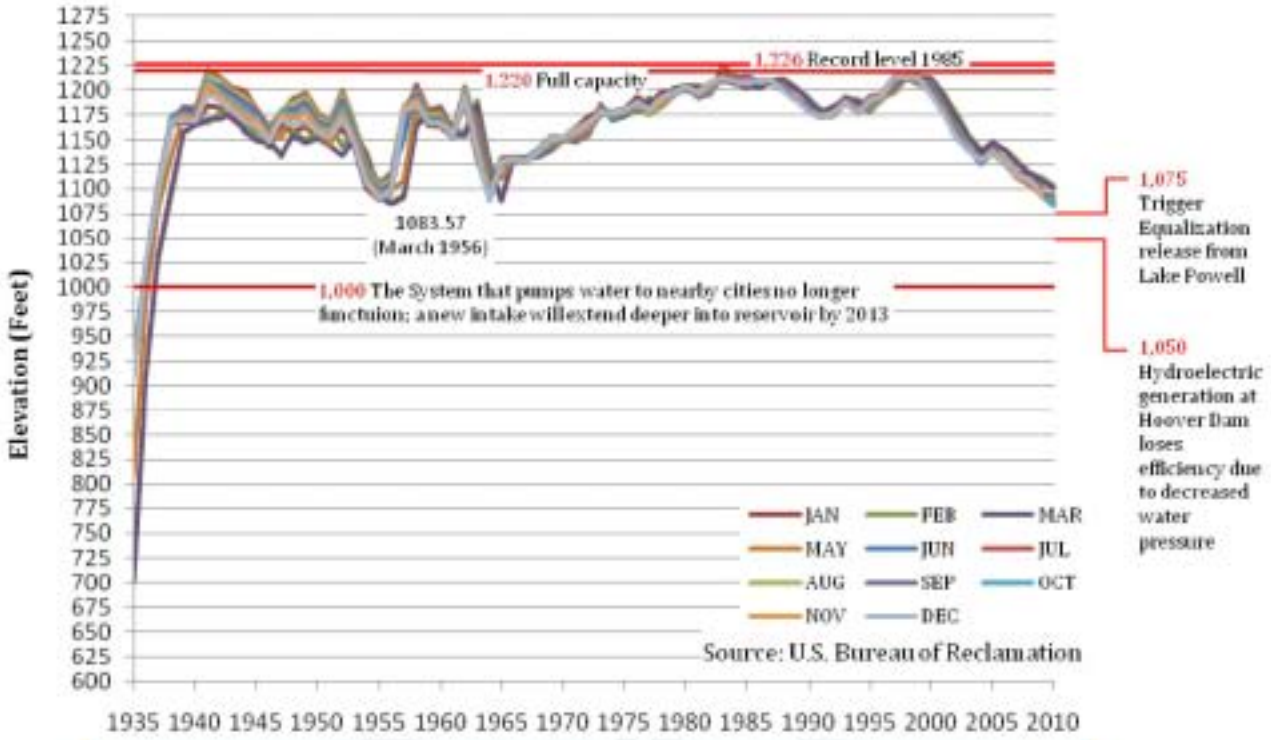
Exhibit 8F
Historical Lake Mead Elevation



The bathtub ring at Lake Mead, August 2010, lake elevation 1,087 feet.

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A component of the California Plan was completion of the Quantification Settlement Agreement (QSA) in 2003, which established baseline water use for each California party with Colorado River water rights. Key to the agreement is the quantification of IID at 3.1 MAF, and CVWD at 330 TAF. Completion of the QSA facilitates the transfer of water from agricultural agencies to urban water suppliers by allowing water conserved on farm land to be made available for urban use. As a result of litigation, the QSA and eleven other agreements were ruled as invalid on February 11, 2010. MWD in conjunction with, CVWD and the SDCWA, have appealed the court's decision. Ultimately, the total impact of the court's decisions on MWD's Colorado River supplies cannot be determined at this time pending the outcome of the appeal. However, MWD's existing conservation, land fallowing, and transfer programs for Colorado River supplies are independent of the QSA and will not be impacted by the QSA lawsuit.

Along with MWD's apportionment, MWD has developed a number of water supply programs to improve reliability of Colorado River supplies, such as agricultural water transfers and storage programs, and has multiple programs under development as listed in Exhibit 8F. Developed programs in conjunction with MWD's apportionment will provide MWD with approximately 1.14 MAF in 2035 under an average year (1922 – 2004 hydrology). Proposed programs under development could add another 182 TAF per year. Non-MWD supplies conveyed through the CRA are forecast at 296 TAF for a total CRA supply capability of 1.61 MAF. However, the CRA has a supply capacity constraint of 1.25 MAF. After subtracting MWD's conveyance obligation of non-MWD supplies, MWD's supplies for 2035 under average year, single-dry year (1977 hydrology), and multi-dry year (1990 – 1992 hydrology) scenarios are all forecast at 954 TAF. Exhibit 8G summarizes the CRA supply forecast for 2035 under an average year.

Exhibit 8G
MWD's CRA Forecast Supplies in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF)/ Year
Current	
Basic Apportionment - Priority 4	550
Imperial Irrigation District/MWD Conservation Program	85
Priority 5 Apportionment (Surplus)	13
Palo Verde Irrigation District Land Management Crop Rotation and Water Supply Program	133
Lower Colorado Water Supply Project	5
Lake Mead Storage Program	400
Quechan Settlement Agreement Supply	7
Forbearance for Present Perfected Rights	-47
Coachella Valley Water District State Water Project/QSA Transfer Obligation	-35
Desert Water Agency and Coachella Valley Water District SWP Table A Obligation	-155
Desert Water Agency and Coachella Valley Water District SWP Table A Transfer Callback	82
Desert Water Agency and Coachella Valley Water District Advance Delivery Account	73
Drop 2 Reservoir Funding	25
Southern Nevada Water Authority Agreement	0
Subtotal of Current Programs	**1,136**
Programs Under Development	

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Additional Palo Verde Irrigation District Transfers	62
Arizona Programs - Central Arizona Project	50
California Indians/Other Agriculture	10
ICS Exchange	25
Agreements with Coachella Valley Water District	35
Hayfield Groundwater Extraction Project	0
Subtotal of Proposed Programs	**182**
Additional Non-MWD CRA Supplies	
San Diego County Water Authority/ Imperial Irrigation District Transfer	200
Coachella and All-American Canal Lining	
To San Diego County Water Authority	80
To San Luis Rey Settlement Parties[1]	16
Subtotal of Non-MWD CRA Supplies	**296**
Maximum CRA Supply Capability[2]	**1,614**
Minus Supply CRA Capacity Constraint of 1.25 MAF Annually	**-364**
Maximum Forecast CRA Deliveries	**1,250**
Minus Non-MWD Supplies[3]	**-296**
Maximum MWD Supply Capability[4]	**954**

1. Subject to satisfaction of conditions specified in agreement among MWD, the US, and the San Luis Rey Settlement Parties
2. Total amount of supplies available without taking into consideration of CRA capacity constraint of 1.25 MAF annually.
3. Exchange obligation for San Diego County Water Authority - Imperial Irrigation District transfer and the Coachella and All-American Canal Lining Projects
4. The amount of CRA water available to MWD after meeting exchange obligations.

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.1.3 Water Quality Issues

Water quality issues for Colorado River supplies encompass high salinity levels, perchlorate, nutrients, uranium, chromium VI, N-nitrosodimethlamine (NDMA), and pharmaceuticals and personal care products (PPCPs). High salinity levels present the most significant issue and the only foreseeable water quality constraint for the Colorado River supply. MWD expects its source control programs for the CRA to adequately address the other water quality issues. MWD has also bolstered its water security measures across all of its operations since 2001, including an increase in water quality tests. Details of MWD's water quality initiatives are available in MWD's 2010 Regional Urban Water Management Plan (RUWMP).

Salinity

Water obtained from the Colorado River has the highest salinity levels of all MWD supply sources averaging 630 mg/L since 1976. Salts are eroded from saline sediments deposited in prehistoric marine environments in the Basin, dissolved by precipitation, and conveyed into the Basin's water courses.

Salinity issues have been recognized in the Basin for over 30 years. The seven basin states formed the Colorado River Basin Salinity Control Forum (Forum) to mutually cooperate on salinity issues in the Basin. The Forum recommended the U.S. Environmental Protection Agency (USEPA) to act upon the Forum's proposal and in response the USEPA approved water quality standards and established numeric criteria for controlling salinity increases. Each Basin State adopted the water quality

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standards, which are designed to limit the flow-weighted average annual salinity level to 1972 levels or below. An outgrowth of the Forum was the Colorado River Basin Control Program. At the core of the program is the reduction in salts entering the river system by intercepting and controlling non-point sources, wastewater, and saline hot springs. Salinity reduction projects have reduced salinity concentration of Colorado River water by over 100mg/L approximating $264 million per year, in 2005 dollars, in avoided damages.

MWD adopted a Salinity Management Policy in 1999 with the goal of achieving salinity concentrations of less than 500 mg/L at delivery. To reduce salinity levels, Colorado River supplies are blended with SWP water supplies to achieve the salinity target in seven out of ten years. In the other three years the target is not possible to achieve as a result of hydrologic conditions that increase salinity on the Colorado River and less SWP water is available for blending. Additionally, to maximize the use of recycled water in agriculture, MWD is trying to obtain lower salinity imported water during the spring/summer months to reduce salinity levels in recycled water.

Perchlorate

In 1997 perchlorate was first detected in the Colorado River attributed to an industrial site upstream of the Las Vegas Wash in Nevada, ultimately draining to the river. Subsequently, an additional groundwater plume was found to be migrating from an additional industrial site, but had not reached the Las Vegas Wash. Since the initial discovery of contamination, remediation efforts have significantly reduced perchlorate loading from the Las Vegas Wash. At Lake Havasu, downstream of the convergence of the Las Vegas Wash and Colorado River, perchlorate levels have decreased from 9 µg/L at their peak in 1998 to less than 6 µg/L in October 2002. Since June 2006 typical levels have been less than 2 µg/L.

Nutrients

Excessive nutrient levels in water can stimulate algal and aquatic weed growth leading to taste and odor concerns. Nutrients include both phosphorous and nitrogen compounds. Other impacts of algal and aquatic weed growth include reductions in operating efficiencies and potentially provide an additional food source for invasive aquatic species, such as quagga and zebra mussels.

Naturally, the Colorado River system has relatively low concentrations of phosphorous. Additional loading to the system as upstream urbanization increases has the ability to increase phosphorous concentrations and impact MWD's ability to blend low nutrient concentration CRA water with high nutrient concentration SWP water. MWD continues to work with agencies located along the lower Colorado River to improve their wastewater management to reduce phosphorous loading.

Uranium

Near Moab, Utah a 16-million ton pile of uranium tailings located approximately 750 feet from the Colorado River is a potential source of uranium loading to the river. In 1999, the US Department of Energy began remediating the site by removing tailings and treating contaminated groundwater. Complete removal of the pile is expected by 2025 or 2019 if additional funding is secured. MWD is tracking clean-up progress and continues to support rapid clean-up of the site.

To address recent uranium mining claims in the vicinity of the Colorado River and the Grand Canyon Area, MWD has sent letters to the Secretary of Interior to highlight MWD's concern of source water protection and recommended close federal oversight. In 1999, the Department of Interior placed a two-year hold on mining claims for 1 million acres adjacent to the Grand Canyon area to conduct additional analyses and H.R. 644, Grand Canyon Watersheds Protection Act, was introduced in 2009. H.R. 644, if approved, would prohibit new mining activities around the Grand Canyon area.

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Chromium VI

Chromium VI has been detected in a groundwater aquifer in the vicinity of the Colorado River near Topock, Arizona. The source of the contamination is a natural gas compression site operated by Pacific Gas and Electric (PG&E) that previously used chromium VI in its operations. Currently, PG&E is engaged in interim clean-up operations to protect the Colorado River. A final treatment alternative is anticipated to be released in 2010. Monitoring upstream and downstream of the site range from non-detect (0.03 µg/L) to 0.06 µg/L which are considered within the background range for the river. MWD is actively involved in the corrective action process through its participation in stakeholder workgroups and partnerships with State and federal regulators, Indian tribes, and other stakeholders.

NDMA and Pharmaceuticals and Personal Care Products

N-nitrosodimenthylamine is a by-product formed by secondary disinfection of some natural waters with chloramines. MWD is involved with projects to understand the potential sources of NDMA precursors in its source watersheds and to develop treatment strategies to minimize NDMA formation at its water treatment facilities. In 2007, MWD initiated monitoring efforts to measure Pharmaceuticals and Personal Care Projects (PPCPs) in its source supplies. PPCPs have been detected at very low levels (low ng/L level; parts per trillion) consistent with monitoring results from other utilities. MWD is involved with programs to improve analytical testing methods, characterize PPCP in drinking water sources in California, and effects of PPCPs on groundwater recharge and recycled water use.

8.1.2 State Water Project

MWD began receiving water from the State Water Project (SWP) in 1972. MWD is the largest of 29 contractors for water from the SWP, holding a contract for 1.912 MAF per year, or 46 percent of the total contracted amount, of the 4.173 MAF ultimate delivery capacity of the project. Variable hydrology, environmental issues, and regulatory restrictions in the San Francisco Bay/Sacramento-San Joaquin River Delta (Bay-Delta) have historically reduced the quantity of water that the SWP delivers to MWD.

8.1.2.1 Major State Water Project Facilities

The SWP is owned by the State of California and operated by the Department of Water Resources (DWR) delivering water to two-thirds of the population of California and 750,000 acres of farmland. Major facilities in the SWP system consist of 701 miles of aqueduct, 34 storage facilities totaling 5.8 MAF of storage, five hydro-electric power plants, four pumping-generating plants, 17 pumping plants, and three pump stations. Exhibit 8H illustrates the location of major SWP facilities. SWP facilities originate in Northern California at Lake Oroville on the Feather River. Water released from Lake Oroville flows into the Feather River, goes downstream to its confluence with the Sacramento River, and then travels into the Bay-Delta. Water is pumped from the Bay-Delta region to contractors in areas north and south of the San Francisco Bay and south of the Bay-Delta. SWP deliveries consist solely of untreated water. In addition to delivering water to its contractors, the SWP is operated to improve water quality in the Delta region, control flood waters, and provide recreation, power generation, and environmental enhancement.

MWD receives SWP water at three locations, Castaic Lake in Los Angeles County, Devil Canyon Afterbay in San Bernardino County, and Box Spring Turnout at Lake Perris in Riverside County. In addition, MWD has flexible storage rights of 65 TAF at Lake Perris at the terminus of the East Branch of the SWP and 153.95 TAF at Castaic Lake at the terminus of the West Branch.

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8.1.2.2 Contract Allocations

Contract allocations, also known as entitlements, for SWP contractors are provided by DWR in a table commonly referred to as Table A. Allocations are based on the original projected SWP maximum yield of 4.173 MAF. Table A is a tool used by DWR to allocate fixed and variable SWP costs and yearly water entitlements to the contractors. Table A contract amounts do not reflect actual deliveries a contractor should expect to receive. MWD has a Table A contract amount of 1.912 MAF. MWD's full Table A contract amount was made available to MWD for the first time in 2006.

Table A Maximum Annual SWP Amounts (acre-feet)

Contractor	Maximum SWP Table A
North Bay	
Napa County Flood Control and Water Conservation District	29,025
Solano County Water Agency	47,756
Subtotal	**76,781**
South Bay	
Alameda County Flood Control and Water Conservation District, Zone 7	80,619
Alameda County Water District	42,000
Santa Clara Valley Water District	100,000
Subtotal	**222,619**
San Joaquin Valley	
Oak Flat Water District	5,700
Kings County	9,305
Dudley Ridge Water District	57,343
Empire West Side Irrigation District	3,000
Kern County Water Agency	998,730
Tulare Lake Basin Water Storage District	95,922
Subtotal	**1,170,000**
Central Coastal	
San Luis Obispo County Flood Control and Water Conservation District	25,000
Santa Barbara County Flood Control and Water Conservation District	45,486
Subtotal	**70,486**
Southern California	
Antelope Valley-East Kern Water Agency	141,400
Castaic Lake Water Agency	95,200
Coachella Valley Water District	121,100
Crestline-Lake Arrowhead Water Agency	5,800
Desert Water Agency	50,000
Littlerock Creek Irrigation District	2,300

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Mojave Water Agency	75,800
Metropolitan Water District of Southern California	1,911,500
Palmdale Water District	21,300
San Bernardino Valley MWD	102,600
San Gabriel Valley MWD	28,800
San Gorgonio Pass Water Agency	17,300
Ventura County Flood Control District	20,000
Subtotal	**2,593,100**
Delta Delivery Total	**4,132,986**

Feather River

Butte County	27,500
Plumas County Flood Control and Water Conservation District	2,700
Yuba City	9,600
Subtotal	**39,800**
Total	**4,172,786**

DWR annually approves the amount of contract allocations SWP contractors will receive. The contract allocation amount received by contractors varies based on contractor demands and projected available water supplies. Variables impacting projected water supplies include snowpack in the Sierra Nevada, capacity available in reservoirs, operational constraints, and demands of other water users. Operational constraints include pumping restrictions related to fish species listed as either threatened or endangered under the federal or state Endangered Species Acts. Contractors' requests for portions of their entitlements cannot always be met. In some year there are shortages and in other years surpluses. In 2008 and 2009 SWP contractors received only 35 percent and 40 percent, respectively, of their SWP contract allocations. In 1991 and 1992 MWD received 391 TAF and 710 TAF, respectively, less than their requests.

DWR bi-annually prepares the State Water Project Delivery Reliability Report to provide contractors with current and projected water supply availability for SWP. The 2009 draft released in January 2010 indicates expected deliveries for multiple-dry year periods will vary from 32 to 38 percent of maximum Table A amounts and for multiple-year wet periods 72 to 94 percent of maximum Table A amounts. Overall the report shows increased reductions in water deliveries on average when compared to the previous 2007 report. Factors impacting deliveries include environmental constraints and hydrologic changes as a result of climate change.

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Exhibit 8H
State Water Project Major Facilities

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In addition to MWD's Table A amount, MWD has long term agreements in place to obtain additional SWP supplies through four other programs:

- Article 21
- Turnback Pool
- Yuba River Accord
- San Luis Carryover Storage
- Desert Water Agency and Coachella Valley Water District Table A Transfer.

Article 21 is in reference to a provision in the SWP contract with DWR that allows SWP contractors, such as MWD, to take additional water deliveries in addition to Table A amounts. Article 21 water is only available under certain conditions as outlined in Article 21. SWP Article 21 of the contracts permits delivery of water excess to delivery of SWP Table A and some other water types to those contractors requesting it. SWP Article 21 water is apportioned to those contractors requesting it in the same proportion as their SWP Table A.

Turnback Pool (Pool) water allows a contractor that has been allocated Table A annual entitlement that the contractor will not use to sell that water to other SWP Contractors through the Pool. If there are more request from contractors to purchase water from the Pool than the amount in the Pool, the water in the Pool is allocated among those contractors requesting water in proportion to their Table A entitlements. If requests to purchase water from the Pool total less than the amount of water in the Pool, the sale of water is allocated to the selling contractors in proportion to their respective amounts of water in the Pool.

In 2007, MWD and DWR signed an agreement allowing MWD to participate in the Yuba Dry Year Water Purchase Program. Under this program, transfers are available from the Yuba County Water Agency during dry years up to 2025. MWD completed purchases of 26.4 TAF and 42.9 TAF in 2008 and 2009, respectively.

As part of the Monterey Amendment, which modified the contractors' long term contracts with DWR, the use of carryover storage by contractors was permitted in the San Luis Reservoir for use during dry years. Carryover storage is curtailed if it impedes with the storage of SWP water for project needs.

MWD entered into a transfer agreement with the Desert Water Agency (DWA) and Coachella Valley Water District (CVWD) for their Table A contract amounts in exchange for an equal amount of water from the CRA. Both DWA and CVWD are SWP contractors, but have no physical connections to obtain SWP water. MWD is able to transfer CRA water to both agencies as a result of their locations adjacent to CRA facilities. DWA and CVWD have a combined Table A amount of 1.912 MAF per year. MWD additionally can provide DWA and CVWD with deliveries of MWD's other SWP water supplies and non-SWP supplies utilizing SWP facilities, thus allowing MWD additional flexibility in managing its water supply portfolio.

MWD also engages in short-term transfer agreements using SWP facilities to bolster supplies as opportunities become available as discussed in the Groundwater Storage and Transfers sub-section. Historically, MWD has obtained transfers through the Governor's Water Bank, Dry-Year Purchase Programs, and the State Water Contractors Water Transfer Program.

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MWD expects to receive 2.046 MAF through its SWP supplies in 2035 under average conditions (1922 – 2004 hydrology). Exhibit 8I summarizes MWD's SWP supplies by program. Current programs are expected to result in 1.441 MAF and programs under development are expected to add an additional 605 TAF. Under multi-year dry conditions (1990 -1992 hydrology), MWD expects to receive only 956 TAF and 1,003 TAF under a single-dry year (1977 hydrology).

Exhibit 8I
MWD Forecast Supplies of SWP Water in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF)
Current	
MWD Table A	1,026
Desert Water Agency and Coachella Valley Water District SWP Table A Transfer	155
San Luis Carryover Storage[1]	208
Article 21 Supplies	52
Yuba River Accord Purchase	0
Subtotal of Current Programs[2]	**1,441**
Programs Under Development	
Delta Conveyance Improvements	605
Integrated Resources Plan SWP Target[3]	0
Subtotal of Proposed Programs[2]	**605**
Maximum SWP Supply Capability[2]	**2,046**

1. Includes carryover water from Desert Water Agency and Coachella Valley Water District.
2. Does not include transfers and water banking associated with SWP.
3. Remaining supply needed to meet Integrated Resources Plan target.

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.2.3 Water Quality Issues

Water quality issues for SWP supplies include total organic carbon (TOC), bromide, arsenic, nutrients, NDMA, and pharmaceuticals and personal care products (PPCPs). TOC and bromide in SWP water present the greatest water quality issues and have restricted MWD's ability to use SWP water at various times as the contaminants form disinfection byproducts during water treatment processes. MWD has initiated a process to upgrade its treatment processes to ozone disinfection to reduce formation of disinfection byproducts and lift potential restrictions on SWP water usage. MWD requires low salinity levels of SWP water to meet blending requirements for CRA water, therefore any increase in salinity levels in SWP supplies is a concern to MWD.

MWD supported DWR in the establishment of a policy regarding water quality of non-SWP water transported through the SWP system and in the expansion of Municipal Water Quality Investigations Programs to include additional monitoring and advanced warnings to Contractors that may impact water treatment processes.

MWD is utilizing its water supply portfolio options to conduct water quality exchanges to reduce total organic compounds and bromide MWD has stored SWP water during periods of high water quality in groundwater storage basins for later use when

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SWP is at a lower water quality. These storage programs were initially designed to provide water during dry SWP conditions, but a few of these programs are now operated for dual-purposes.

TOC and bromide in high concentrations lead to the formation of disinfection byproducts when source water is treated with disinfectants, such as chlorine. Agricultural drainage to the Delta and seawater comingling with Delta supplies increases these contaminants. The Bay Delta Conservation Plan (BDCP) has outlined multiple options to improve the water supply reliability and habitat protection, which is being prepared through a collaboration of state, federal, and local water agencies, state and federal fish agencies, environmental organizations, and other interested parties. The overall goal of BDCP is identifying water flow and habitat restoration actions to both improve water supply reliability and recover endangered and sensitive species and their habitats in California's Sacramento-San Joaquin River Delta. MWD is in the process of computing upgrades to its water treatment plants to use ozone as the primary disinfectant. Ozone disinfection is very effective treatment for control of bromate formation and will allow MWD to treat higher quantities of SWP supplies without blending those supplies with CRA water.

Arsenic

SWP supplies not banked in MWD's SWP groundwater storage programs naturally contain low levels of arsenic ranging from non-detect to 4.0 µg/L and do not require additional treatment for arsenic removal. SWP supplies banked in at least one of these groundwater storage programs contain arsenic levels close to or at the regulatory threshold of 10 µg/L requiring additional treatment for arsenic removal. Historically, MWD has at times restricted flows from one groundwater storage program as a result of arsenic levels. One groundwater storage partner has initiated a pilot arsenic removal program, albeit raising the cost of the groundwater storage program. Arsenic can also be removed at water treatment plants by increasing coagulant doses. To handle arsenic removed during water treatment processes, MWD has had to invest in solids handling facilities.

Nutrients

Nutrient levels in SWP water are significantly higher than in Colorado River water. Both phosphorous and nitrogen compounds are a concern in SWP water, but similar to CRA supplies phosphorous is the limiting nutrient. Nutrient sources in SWP water include wastewater discharges, agricultural drainage, and sediments from nutrient rich soils in the Delta. MWD reservoirs have been temporarily by-passed at times as a result of taste and odor events related to nutrients leading to short-term supply impacts.

MWD is working with other water agencies also receiving SWP water from the Delta region to reduce the impact of nutrient loading from wastewater plants discharging to the Delta. To assist in managing its operations, MWD has implemented an algae monitoring and management program designed to provide warnings in advance of algae and taste and odor issues at its reservoirs allowing adjustments in other system operations.

NDMA and Pharmaceuticals and Personal Care Products

Similar to all of its water supply sources, NDMA and PPCPs are constituents of emerging concern. As described above for Colorado River supplies, MWD is involved with efforts to address both NDMA and PPCPs.

Salinity

Over the long term salinity concentrations in SWP water are significantly lower than in CRA water, but the timing of supply availability and TDS concentrations can vary in response to hydrologic conditions. Additionally, salinity concentrations vary in

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the short term in response to seasonal and tidal flow patterns. MWD requires lower salinity SWP water to blend with CRA water to meet salinity requirements for its member agencies. MWD's blended salinity objective is 500 mg/L.

Environmental constraints also impact MWD's ability to meet its salinity objective. Since 2007 pumping operations in the Bay-Delta have been limited to prevent environmental harm (as discussed in the Delta Issues subsection below). MWD must rely on higher salinity CRA water resulting in an exceedance in MWD's salinity objective at times.

SWP salinity concentrations as specified in the SWP Water Service Contract have not been met. Article 19 of SWP Water Service Contract specifies ten-year average salinity concentrations of 220 mg/L and a monthly maximum of 440 mg/L. MWD is working with DWR and other agencies to reduce salinity in SWP Delta supplies through multiple programs. These programs include modifying agricultural drainages and completing basin plans on the San Joaquin River, modifying levees around flooded islands in the Delta, and installing gates to reduce transportation of salts from seawater.

8.1.2.4 Bay-Delta Issues

The San Francisco Bay-Delta is a major waterway at the confluence of the Sacramento and San Joaquin rivers serving multiple and at times conflicting purposes exacerbated during dry years when water to meet the needs of both people and the environment is in short supply. Approximately two-thirds of Californians receive at least a portion of their water from the Bay-Delta. Almost all water delivered via the SWP to southern California must pass through the Bay-Delta. Runoff from more than 40 percent of the State is also conveyed through the Bay-Delta forming the eastern edge of the San Francisco bay's estuary. A large portion of the Bay-Delta region lies below sea level and is protected by more than 1,100 miles of levees to prevent flooding. Deterioration of the Bay-Delta ecosystem coupled with infrastructure concerns, hydrologic variability, climate change, litigation, regulatory restrictions, and previously discussed water quality issues have resulted in supply reliability challenges for SWP contractors who depend upon the Bay-Delta for water supplies.

Environmental

As an estuarine environment, the Bay-Delta provides habitat for migratory and resident fish and birds, including those placed on the threatened or endangered species list under the federal or California Endangered Species Act (ESA). Five fish species residing in the Bay-Delta were listed as endangered under the ESA, and one additional species was listed as threatened in 2009 under the California ESA. As a result of a combination of lawsuits regarding the ESA listed species and biological opinions and incidental take permits (permits for inadvertently harming ESA listed species) from the U.S. Fish and Wildlife Service and National Marine Fisheries Service, SWP exports and pumping operations in the Bay-Delta have been significantly curtailed. However, DWR prepared a Water Allocation Analysis in 2010 indicating that MWD could receive 150 to 200 TAF less water than forecast for 2010 under average hydrologic conditions. Ongoing litigation, additional species listing, and regulations could further curtail pumping operations and have an additional adverse impact on MWD's supplies and reserves. MWD has filed a lawsuit in conjunction with other SWP contractors challenging one of the biological opinions. As discussed below under the Delta Plan, the Delta Vision process is designed to develop long term solutions to these issues.

Infrastructure

Bay-Delta channels are constrained by a levee system to protect below sea level islands in the Bay-Delta from flooding. Land in the Bay-Delta subsides mainly from ongoing oxidation of aerated peat soils. Some islands are presently twenty feet or more below sea level. Land subsidence is expected to continue increasing the risk of levee failure and island flooding. Many of the levees are old and do not meet modern engineering standards. A catastrophic earthquake could cause widespread levee failure shutting down SWP operations for an extended period of time. Following a levee failure he flow of water onto an island

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can pull saline water fro the San Francisco Bay into the central Delta area and if coupled with pumping in the south Delta draw saline water into the south Delta area. Therefore, pumping in the south Delta may need to be stopped or slowed down for an extended period, and additional flows may need to be released from Lake Oroville to flush saline water out of the Delta. Any salinity introduced into Delta may also impact Delta water quality for an extended period of time.

Recognizing the need for protecting these vulnerable Delta levees, the Bay-Delta Levees Program was formed to coordinate improvements to and maintenance of the Delta levees. Over the next few years the DWR and other agencies will conduct a Comprehensive Program Evaluation. This Program will supplement existing risk studies, develop a strategic plan, recommend priorities, and provide estimates for the Bay-Delta Levees Program.

8.1.2.5 Delta Plan

Former California Governor Arnold Schwarzenegger established the Delta Vision Process in 2006 to address ongoing Bay-Delta conflicts through long-term solutions. The independent Blue Ribbon Task Force completed their vision for sustainable management of the Bay-Delta in 2008. After delivery of the Delta Vision recommendations and goals, the State Legislature initiated the process to conduct information hearings and draft legislation. Ultimately, the Governor called the Seventh Extraordinary Session to address the Delta and water issues in the State. Resulting legislation included the approval of SB 1 X7 addressing Delta policy reforms and governance of the Delta.

A key concept of SB 1 X7 is the formation of a Delta Stewardship Council (Council). The Council is an independent State agency tasked to equally further the goals of Delta restoration and water supply reliability. One of the Council's first major tasks is to develop, adopt, and begin implementation of a Delta Plan by January 1, 2012. Key requirements of the plan as summarized in the MWD RUWMP are:

- Further the coequal goals of ecosystem restoration and water supply reliability;
- Attempt to reduce risks to people, property, and State interests;
- Promote Statewide water conservation, water use efficiency, and sustainable use of water to achieve the coequal goals;
- Improvements to water conveyance/storage and operations of such facilities to achieve the coequal goals;
- Consider including the Bay Delta Conservation Plan (BDCP) into the Delta Plan and allow the BDCP to be eligible for State funding if specific conditions are met.

The BDCP is a joint effort of State and federal fish agencies; State, federal, and local water agencies; environmental organizations; and other parties with the goal of providing for both improvements in water reliability through securing long-term permits to operate the SWP and species/habitat protection in the Delta. MWD is a member of the Steering Committee. An outcome of the plan will be the identification of water flow and habitat restoration actions that assist in recovery of ESA listed and sensitive species and their associated habitats in the Bay-Delta. A range of options to accomplish the outcome will be carried forward to the environmental review phase.

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8.1.3 In-Basin Storage

In basin-storage facilities play a key role in maintaining MWD's reliability during droughts or other imported water curtailments and emergency outages. In-basin storage facilities consist of surface reservoirs and contracted groundwater basin storage. Conjunctive use of surface reservoirs and groundwater basins was first initiated by MWD in the 1950's. Long term storage goals for in-basin storage facilities were established in MWD's Water Surplus and Drought Management Plan (WSDM). The WSDM plan allows storage for hydrology variances, water quality, and SWP and CRA issues.

MWD has established emergency in-basin storage requirements based on a major earthquake that could potentially cutoff all supplies for six months from the all aqueducts serving the region, the CRA, both SWP branches, and LADWP's LAA. Under this scenario, MWD would maintain deliveries by suspending interruptible deliveries, implementing mandatory water use reductions of 25 percent of normal-year demands, water would be made available from surface reservoir and groundwater supplies stored as part of MWD's interruptible supply program, and full local groundwater production would occur. MWD's emergency storage requirement is a function of projected demands and varies with time.

8.1.3.1 Surface Reservoirs

MWD owns and operates seven in-basin surface storage reservoirs. Four of the reservoirs, Live Oak, Garvey, Palos Verdes, and Orange County, are used for regulatory purposes and do not provide drought or emergency storage. Additionally, MWD owns and operates two reservoirs, Copper Basin and Gene Wash, along the CRA outside of the basin for system regulation purposes. Outside its basin, MWD has 1.45 MAF storage rights in Lake Mead on the Colorado River pursuant to its intentionally created surplus agreement with the U.S. Bureau of Reclamation. MWD also has storage rights in DWR's SWP terminal reservoirs, Lake Perris and Castaic Lake, as previously discussed. The total capacity of all in-basin surface reservoirs, inclusive of the rights in the terminal reservoirs, is 1.26 MAF, as listed in Exhibit 8J.

Exhibit 8J
Major MWD Facilities Summary

Reservoir	Capacity (AF)
Dry Year/Emergency/Seasonal Storage Purposes	
Diamond Valley Lake	810,000
Lake Matthews	182,000
Lake Skinner	44,000
Lake Perris (Storage Rights)[1]	65,000
Castaic Lake (Storage Rights)[1]	153,940
Subtotal	1,254,940
Regulatory Purposes	
Live Oak	2,500
Garvey	1,600
Palos Verdes	1,100
Orange County	212
Subtotal	5,412
Total Reservoir Capacity	**1,260,352**

1. MWD holds storage rights for flexible use in DWR terminal storage facilities, Lake Perris and Castaic Lake. In addition, MWD has emergency storage of 334 TAF in DWR's reservoirs.

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MWD operates its three main storage reservoirs, Diamond Valley Lake, Lake Skinner and Lake Matthews, for dry-year, emergency, and seasonal storage. MWD has identified a dry-year storage capacity goal of 620 TAF by 2020. To date this goal has been met and will be sustained with storage at Diamond Valley Lake and the two terminal reservoirs. Under an average year scenario for 2035 (1922-1994 hydrology), 576 TAF per year of in-basin surface storage is projected to be available, exclusive of emergency supplies, as summarized in Exhibit 8K.

Exhibit 8K
MWD Forecast Supplies of In-Basin Surface Storage Supplies in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF)/Year
In-Basin Surface Storage (Diamond Valley Lake, Lake Skinner, Lake Matthews)	444
Lake Perris and Castaic Lake MWD Storage Rights	132
Maximum MWD Supply Capability	**576**

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

MWD reserves a portion of its in-basin surface reservoir storage capacity for emergencies. MWD's emergency surface reservoir storage portfolio is split between storage in its three main reservoirs and DWR reservoirs. MWD's emergency storage capacity, based on demands for 2030, is forecast to be approximately 610 TAF. Approximately 276 TAF is projected to be stored in MWD's facilities and the balance of 334 TAF in DWR's facilities. The balance of available storage capacity, 975 TAF, is for dry-year and seasonal storage.

Any additional reservoir capacity is used for seasonal storage and system operations. Seasonal storage is required to meet peak demands. MWD incorporates reserves of 5 percent into reservoir operations to account for imported water transmission infrastructure maintenance that would restrict or temporarily halt imported water flows.

8.1.3.2 Contracted Groundwater Basin Storage

To improve reliability MWD engages in contracted groundwater basin storage within the basin area. By 2020 MWD aims to develop an annual dry supply of 300 TAF. To meet this goal MWD has worked with local water agencies to increase groundwater storage. Groundwater storage occurs using the following methods:

- Direct delivery – Water is delivered directly by MWD to local groundwater storage facilities including through the use of injection wells and spreading basins.
- In-lieu delivery – Water is delivered directly to a member agency's distribution system and the member agency uses the delivered water and forgoes pumping allowing water to remain in storage.

MWD engages in three main types of contracted storage programs, replenishment, cyclical, and conjunctive use. These programs are designed to deliver water to agencies prior to the actual need for the demands allowing MWD to store supplies for use in dry years. Since 2007 MWD has used these programs to address SWP shortages. MWD provides financial incentives and funding to assist agencies to assist with developing contracted storage programs.

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Replenishment programs provide water to agencies at a discounted cost and can be withdrawn by the recipient after one year. Cyclic storage contracts allow surplus imported water to be delivered for recharge in advance of the actual water purchase. The delivered water is in excess of an agency's planned and budgeted deliveries. The agency purchases the water at a later time when they have a need for groundwater replenishment deliveries.

Conjunctive use contracts allow MWD to request an agency to withdraw previously stored MWD water from storage during dry periods or emergencies. Agencies must pay MWD the current water rate when they are requested to withdraw water from storage. Water withdrawn from storage allows MWD to temporarily curtail delivers by an equal amount. MWD currently has ten conjunctive use programs with a combined storage capacity of 421.9 TAF and a dry-year yield of 117.3 TAF per year as summarized in Exhibit 8L.

Exhibit 8L
In-Basin Conjunctive Use Programs

Program	Storage Capacity (Thousands of AF)	Dry-Year Yield (Thousands of AF/Year)	Balance 12/31/09 (Thousands of AF)
Los Angeles County			
Long Beach Conjunctive Use Project	13	4.3	**6.4**
Foothill Area GW Storage Project	9	3.0	**0.6**
Long Beach Conjunctive Use Project: Expansion in Lakewood	4	1.2	1.8
City of Compton Conjunctive Use Program	2	0.8	0.0
Upper Claremont Heights Conjunctive Use	3	1.0	0.0
Orange County			
Orange County GW Conjunctive Use Program	66	22.0	8.6
San Bernardino County			
Chino Basin Programs	100	33.0	23.0
Live Oak Basin Conjunctive Use Project	3	1.0	0.7
Riverside County			
Elsinore Groundwater Storage Program	12	4.0	0.0
Ventura County			
North Las Posas Groundwater Storage Program	210	47.0	43.5
Total	421.9	117.3	84.6

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

MWD prepared a Groundwater Assessment Study in 2007 in conjunction with local agencies and groundwater basin managers. As indicated in the report there is substantial groundwater storage available in the basin, but there are multiple challenges that must be met to utilize the identified storage. Challenges include infrastructure limitations, contamination, legal issues, and funding.

To further increase the availability of in-basin groundwater storage, MWD has identified nine potential storage programs in the basin and an additional two programs are under development. The Raymond Basin Conjunctive Use Program and the LADWP Groundwater Recovery Project are expected to add an additional 34 TAF per year in 2035 under an average year (1922 – 2004 hydrology).

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In 2009 a reconnaissance-level analysis was prepared for analyzing the potential for using recycled water as a supply source for a conjunctive use program. The study concluded up to 100 TAF of groundwater storage and production could be potentially developed in four major groundwater basins using Los Angeles County Department of Sanitation supplies. MWD initiated a formal study in 2010 to further study. This concept along with the potential to use City of Los Angeles recycled water supplies from the Hyperion Waste Water Treatment Plant as an additional source.

Exhibit 8M provides a summary of forecast groundwater storage supplies available in 2035 under an average year (1922 - 2004 hydrology). Approximately 289 TAF per year are forecast to be available.

Exhibit 8M
MWD Forecast Supplies of In-Basin Groundwater Storage in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF/Year)
Current	
Conjunctive Use	115
Cyclic Storage	139
LADWP Tujunga Well Field Groundwater Recovery Project	12
Subtotal of Current Programs	266
Programs Under Development	
Raymond Basin Conjunctive Use	22
Subtotal of Programs Under Development	34
Maximum MWD Supply Capability	**288**

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.4 Groundwater Storage and Water Transfers

MWD engages in groundwater storage outside of the basin and water transfers to increase the reliability of SWP dry-year supplies. Groundwater storage and water transfers were initiated by MWD in response to concerns that MWD's supply reliability objectives could not be met by the SWP. Groundwater storage and transfer programs were developed to allow MWD to reach its SWP reliability goal. All groundwater storage and water transfer programs designed to bolster SWP reliability are located within the vicinity of the SWP or Central Valley Project (CVP) facilities to facilitate the ultimate deliver of water to MWD. Groundwater storage programs involve agreements allowing MWD to store its SWP contract Table A water in excess of MWD demands and to purchase water for storage. MWD calls for delivery of the stored water during dry years. Transfers involve purchases by MWD from willing sellers during dry years when necessary.

Exhibit 8N summarizes MWD's out of basin groundwater storage and transfer programs supplies in 2035, under an average year (1922 – 2004 hydrology). Current programs are expected to deliver 293 TAF in 2035. Five programs under development are forecasted to deliver an additional 110 TAF for a total of 403 TAF in 2035.

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Exhibit 8N
MWD Forecast Supplies of Groundwater Storage and Transfers in 2035, Average Year (1922 – 2004 Hydrology)

Program	Supply (Thousands of AF/Year)
Current	
San Bernardino Valley MWD Minimum Purchase	20
San Bernardino Valley MWD Option Purchase	29
Central Valley Storage and Transfers	
Semitropic Water Banking and Exchange Program	69
Arvin-Edison Water Management Program	75
San Bernardino Valley MWD Program	50
Kern Delta Water Management Program	50
Subtotal of Current Programs	**293**
Programs Under Development	
Mojave Groundwater Storage Program	43
North of Delta/In-Delta Transfers	33
San Bernardino Valley MWD Central Feeder	5
Shasta Return	18
Semitropic Agricultural Water Reuse	11
Subtotal of Proposed Programs	**110**
Maximum Supply Capability	**403**

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.1.4.1 Groundwater Storage

MWD has four Central Valley groundwater storage programs with a fifth program under development as described below.

The Semitropic Water Banking and Exchange Program is a partnership formed in 1994 between Semitropic Water Storage District (SWSD) MWD, and five other banking partners. The bank has a total storage capacity of 650 TAF, of which MWD has 350 TAF of storage volume. During years of excess SWP deliveries, beyond MWD's demands, a portion of MWD's SWP entitlement water is stored for withdrawal during dry years. Deliveries for storage are transferred via SWP facilities for direct use by agricultural users that in turn forgo pumping an equal volume of water. In dry years water is pumped from storage to SWP facilities for delivery to MWD or entitlements are exchanged. MWD's average annual supply capability for a dry year (1977 hydrology) is 125 TAF and for multiple dry years (1990 – 1992 hydrology) 107 TAF. By the end of 2009, MWD had 45 TAF in storage.

Since 1997 MWD has had an agreement with Arvin-Edison Water Storage District to use 350 TAF of storage in their groundwater basins. The agreement was amended in 2008 to include the South Canal Improvement project to deliver higher quality water to MWD. During wet years MWD delivers SWP water in excess of its demands for storage and receives return water in dry years in a similar manner as the Semitropic program, except a combination of SWP and CVP facilities are used to

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transfer the water and water can be stored by a combination of direct spreading or in lieu use by agricultural users. MWD's average supply capability is 75 TAF for either a single dry year (1977 hydrology) or multiple dry years (1990 – 1992 hydrology). In 2009 MWF had 95 TAF in storage.

The San Bernardino Municipal Water District Program allows for the purchase and storage of SWP water on behalf of MWD. MWD has a minimum purchase agreement with San Bernardino Municipal Water District (SBMWD) of 20 TAF per year of SBMWD's SWP Table A amount. Additionally, MWD has the option to purchase SBMWD's additional SWP allocation when available and the first right-of-refusal to purchase additional SWP supplies available to SBMWD beyond the minimum and option agreements. If MWD does not require the minimum purchase amount for operations, MWD can store up to 50 AF for future use in dry years within SBMWD's groundwater basins. Water is delivered to MWD via SWP facilities and groundwater pumping conveyed through local connections to MWD's service area. MWD's average annual supply capability for a dry year (1977 hydrology) is 70 TAF and for multiple dry years (1990 – 1992 hydrology) 37 TAF. By the end of 2009, MWD had no water in storage and deliveries have been suspended upon a mutual agreement between MWD and SBMWD.

MWD entered into an agreement with the Kern Delta Water District (Kern-Delta) for the Kern-Delta Water Management Plan in 2001 to allow up to 250 TAF of groundwater storage. During wet years MWD delivers SWP water in excess of its demands for storage and receives return water in a similar manner as the Semitropic program, except the water can be stored by direct recharge or in lieu use by agricultural users. Per terms of the agreement MWD can potentially store beyond 250 TAF. In dry years water is pumped from storage to SWP facilities for delivery to MWD or entitlements are exchanged. When the project is completed 50 TAF per year of dry year supply can be withdrawn. At the close of 2009 MWD had 10 TAF in storage and expects to fully withdraw the amount in 2010.

The Mojave Groundwater Storage Program is currently a demonstration project between MWD and Mojave Water Agency. Similar to the other groundwater storage programs, MWD's excess SWP water will be stored during wet years for withdrawal during dry years. When fully operational, the program is expected to have a dry year yield of 35 TAF.

8.1.4.2 Transfers

MWD utilizes Central Valley water transfers to obtain additional supplies originally destined for agricultural users on an as needed basis. Past transfer agreements have used both spot markets and option contracts. Spot markets occur when there are willing sellers and buyers. Option contracts lock-in MWD's ability to have the option to purchase supplies if needed. Additionally, MWD has multiple long-term transfer programs under development. MWD's ability to conduct transfers and the amount of water to be transferred using SWP facilities are a function of hydrologic conditions, market conditions, and pumping restrictions in the Bay-Delta region. Transfers may require the use of the Bay-Delta for conveyance dependent upon the origin of the water. Historic transfers, as listed in Exhibit 8O, indicate MWD is capable of negotiating contracts with agricultural districts and the State's Drought Water Bank to obtain transfers. MWD also has demonstrated it can work with DWR and the U.S. Bureau of Reclamation (USBR). Cooperation of both agencies is required as transfers use a combination of DWR's SWP and USBR's CVP facilities. Transfers from north of the Delta result in the loss of 20 percent of the water during conveyance while transfers via the California Aqueduct to MWD's service area result in the loss of 3 percent water during conveyance. During dry years and when pumping capacity in the Bay-Delta is available, MWD expects to be able to transfer 125 TAF through SWP facilities.

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Exhibit 8O
MWD Historic Central Valley Water Transfers

Program	Purchases by MWD[1] (AF/Year)
1991 Governor's Water Bank	215,000
1992 Governor's Water Bank	10,000
1994 Governor's Water Bank	100
2001 Dry Year Purchase Program	80,000
2003 MWD Transfer Program	126,230
2005 State Water Contractors Water Transfer Program[2]	0
2008 State Water Contractors Water Transfer Program	26,621
2009 Governor's Water Bank	36,900

1. Transfers requiring use of Bay-Delta result in a water loss of 20 percent. Transfers requiring the California Aqueduct for delivery to MWD's service area result in a 3 percent water loss.

2. 127,275 in options were secured, but not needed.

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.2 MWD Supply Reliability and Projected LADWP Purchases

MWD's 2010 Integrated Water Resources Plan (IRP) Update serves as the foundation for supply forecasts discussed in the RUMWP and continues to ensure system reliability for its member agencies. The 2010 IRP update concluded that the resource targets identified in previous updates, taking into consideration changed conditions identified since that time, will continue to provide for 100 percent reliability through 2030. MWD's subsequent evaluation to extend the resource targets by an additional five years through their 2010 draft RUWMP also concluded the same full reliability during average (1922 – 2004 hydrology), single dry (1977 hydrology), and multiple dry years (1990 - 1992 hydrology). For each of the scenarios there is a surplus in every forecast year. Exhibit 8P summarizes MWD's reliability in five year increments extending to 2035.

The City purchases MWD water to make up the deficit between demand and other City supplies. Whether LADWP can provide reliable water services to the residents of Los Angeles is highly dependent on MWD's assurance on supply reliability. However, the recent water supply shortage caused by dry weather and pumping restrictions in the Delta prompted the City to develop a more sustainable water supply portfolio with emphasis on local water supplies such as recycled water, groundwater cleanup, stormwater capture, and conservation. LADWP's reliance on MWD water supply is projected to be cut in half from the five-year average of 52 percent of the total demand between 2005-06 and 2009-10, to 24 percent by 2034-35 under average weather conditions.

The reliability of MWD's water supply is more fully discussed in Chapter 10, Integrated Resources Planning. The projected LADWP water purchase is further discussed in Chapter 11, Water Service Reliability Assessment under various weather scenarios.

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Exhibit 8P
MWD System Forecast Supplies and Demands, Average Year (1922 – 2004 Hydrology)

Forecast year	Supply (Thousands of AF per Year)				
	2015	2020	2025	2030	2035
Current Programs					
In-Basin Surface Reservoir and Groundwater Storage	685	931	1,076	964	830
State Water Project[1]	1,550	1,629	1,763	1,733	1,734
Colorado River Aqueduct					
Colorado River Aqueduct Supply[2]	1,507	1,529	1,472	1,432	1,429
Aqueduct Capacity Limit[3]	1,250	1,250	1,250	1,250	1,250
Colorado Aqueduct Capability	1,250	1,250	1,250	1,250	1,250
Capability of Current Programs	**3,485**	**3,810**	**4,089**	**3,947**	**3,814**
Demands					
Firm Demands on MWD	1,826	1,660	1,705	1,769	1,826
Imperial Irrigation District - San Diego County Water Authority Transfers and Canal Linings[4]	180	273	280	280	280
Total Demands on MWD	**2,006**	**1,933**	**1,985**	**2,049**	**2,106**
Surplus	**1,479**	**1,877**	**2,104**	**1,898**	**1,708**
Programs Under Development					
In-Basin Surface Reservoir and Groundwater Storage	206	306	336	336	336
State Water Project[1]	382	383	715	715	715
Colorado River Aqueduct					
Colorado River Aqueduct Supply	187	187	187	182	182
Aqueduct Capacity Limit[2]	0	0	0	0	0
Colorado Aqueduct Capability	0	0	0	0	0
Capability of Programs Under Development	**775**	**876**	**1,238**	**1,233**	**1,233**
Maximum MWD Supply Capability	**4,260**	**4,686**	**5,327**	**5,180**	**5,047**
Potential Surplus	**2,254**	**2,753**	**3,342**	**3,131**	**2,941**

1. Includes water transfers and groundwater banking associated with SWP.

2. Includes 296 TAF of non-MWD supplies conveyed in CRA for Imperial Irrigation District - San Diego County Water Authority Transfers and Canal Linings

3. CRA has a capacity constraint of 1.25 MAF per year.

4. Does not include 16 TAF subject to satisfaction of conditions specified in agreement among MWD, the US, and the San Luis Rey Settlement

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

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8.3 MWD Rate Structure and LADWP's Purchased Water Costs

8.3.1 MWD Rate Structure

MWD's rates are structured on a tier–based system with two tiers and a surplus category. Nine major elements determine the actual price a member agency will pay for deliveries. All of the elements are volumetric based except for two fixed rates, the Readiness-to Serve Charge and the Capacity Charge.

Tier 1 rates are reflective of actual costs of existing supplies and are designed to recover most of the supply costs. Member agencies are allocated a specified volume of Tier 1 water that can be purchased within a given year. In 2011 LADWP's Tier 1 limit is 304,970 AF. Any purchases above this are charged at the Tier 2 rate. MWD has instituted a temporary Delta surcharge to recover costs associated with lower SWP deliveries related to pumping restrictions. The surcharge will remain in effect until SWP yields improve.

Tier 2 rates send a price signal associated with MWD's costs of developing additional long-term firm supply options. Member agencies with growing demands on MWD will have a higher proportion of deliveries within the Tier 2 range.

Surplus water is water in excess of consumptive municipal and industrial demands. Surplus water is available at two discounted levels dependent upon the end use. Replenishment Program water is discounted for replenishing local agency supplies. The program has been suspended as a result of dry conditions and uncertain future supplies. The Interim Agricultural Water Program (IAWP) provides discounted water for agricultural use. This program is being phased out and will terminate beginning in 2013.

Exhibit 8Q summarizes the rates and charges for member agencies effective on January 1 of 2010, 2011, and 2012.

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Exhibit 8Q
MWD Rates and Charges

Rates and Charges	Effective Rate January 1		
	2010	2011	2012
Tier 1 Supply Rate ($/AF)	101	104	106
Delta Supply Surcharge ($/AF)	69	51	58
Tier 2 Supply Rate ($/AF)	280	280	290
System Access Rate ($/AF)	154	204	217
Water Stewardship Rate ($/AF)	41	41	43
System Power Rate ($/AF)	119	127	136
Full Service Untreated Volumetric Cost ($/AF)			
Tier 1	484	527	560
Tier 2	594	652	686
Replenishment Water Untreated ($/AF)	366	409	442
Interim Agricultural Water Untreated ($/AF)	416	482	537
Treatment Surcharge ($/AF)	217	217	234
Full Service Treated Volumetric Cost ($/AF)			
Tier 1	701	744	794
Tier 2	811	869	920
Treated Replenishment Water ($/AF)	558	601	651
Treated Interim Agricultural Water Program ($/AF)	615	687	765
Readiness-to-Serve Charge ($/M)	114	125	146
Capacity Charge ($/cfs)	7,200	7,200	7,400

Source: 2010 Regional Urban Water Management Plan, Metropolitan Water District of Southern California

8.3.2 LADWP's Purchased Water Costs

MWD's water rates vary from $484 per AF of tier 1 untreated water to $811 per AF of tier 2 treated water in 2010. The average unit cost of MWD water supply depends on the proportions of treated water and untreated water, tier 1 water and tier 2 water purchased in a given period. From 2003 to 2009, LADWP purchased 88 percent tier 1 water and 12 percent tier 2 water, and 70 percent untreated water and 30 percent treated water on average. The tier 2 water purchase varied from no purchase in 2005 and 2006 to 29 percent in 2007 and 2008. The treated water purchase varied from 20 percent in 2007 to 46 percent in 2005. Exhibit 8R illustrates the various combinations.

The Readiness-to-Serve Charge and Capacity Charge are predetermined fixed charges for each member agency and not affected by the quantity of MWD water purchased. However, they add on to the unit cost of the City's MWD water purchase. The City's current share of the Readiness-to-Serve Charge is 15.12 percent or $17.24 millions in 2010. The Capacity Charge is calculated based on the summer daily peak flow from the previous three years. LA's 2010 Capacity Charge is $5.9 millions based on the daily peak flow of 822 cfs in 2008 summer. Both charges added an additional $110 per AF to the unit cost of LADWP's MWD water purchase in 2010.

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Exhibit 8R
Percentage of LADWP's Purchased Water in Various MWD Rate Categories

MWD Deliveries	Tier 1		Tier 2		Total Tier 1	Total Tier 2	Total Untreated	Total Treated
Calender Year	Untreated	Treated	Untreated	Treated				
	%	%	%	%	%	%	%	%
2003	73%	22%	4%	2%	95%	5%	76%	24%
2004	71%	25%	3%	1%	96%	4%	74%	26%
2005	54%	46%	0%	0%	100%	0%	54%	46%
2006	58%	42%	0%	0%	100%	0%	58%	42%
2007	56%	15%	25%	5%	71%	29%	80%	20%
2008	48%	23%	23%	6%	71%	29%	71%	29%
2009	67%	20%	10%	3%	87%	13%	77%	23%
Average	61%	28%	9%	2%	88%	12%	70%	30%

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Other Potential Water Supplies

9.0 Overview

LADWP continually investigates other potentially feasible water supplies to ensure the sustainability of water supply for the City of Los Angeles. In recent years, LADWP has actively pursued and investigated various supply options including water transfers and banking and seawater desalination. Evaluating the viability of these and other water resource options is a key element to ensuring the City's future water supply reliability. Such options, with proper planning, can contribute toward fulfilling future demand under various conditions. Future water resource challenges, which include increased demand that must be met without increasing imported supply, warrant thoughtful consideration of these and other potentially feasible water supply resources.

Following is a discussion of each of the potential supply options described above, highlighting LADWP's progress in developing each alternative source of water. Factors that affect feasibility and influence potential implementation are also discussed, as well as advances that facilitate development of the resource option.

9.1 Water Transfers and Banking

Water transfers involve the lease or sale of water or water rights between consenting parties. Water Code Section 470 (The Costa-Isenberg Water Transfer Act of 1986) states that voluntary water transfers between water users can result in a more efficient use of water, benefiting both the buyer and the seller. The State Legislature further declared that transfers of surplus water on an intermittent basis can help alleviate water shortages, save capital outlay development costs, and conserve water and energy. This section of the Water Code also obligates the California Department of Water Resources (DWR) to facilitate voluntary exchanges and transfers of water.

The DWR is required to establish an ongoing program to facilitate the voluntary exchange or transfer of water and implement the various State laws that pertain to water transfers. In response to this mandate, DWR established an internal office dedicated specifically to water transfers in June 2001 and has developed various definitions and policies for transfers. Of particular importance are the rules protecting existing water rights. Water rights cannot be lost when they are transferred to another user if the transferor has an underlying right to the transferred water. DWR also developed three fundamental rules specifically regarding water transfers:

- There can be no injury to any legal user of water;
- There can be no unreasonable effect to fish and wildlife; and
- There can be no unreasonable economic effects to the economy of the county of origin.

Water banking, a form of conjunctive use, is the storage of water in groundwater basins for future use. Typically, during wet periods water is stored or banked within groundwater basins for potential extraction during dry periods. Water banking sets up accounts to track the volumes of water recharged and extracted per terms of contract agreements between water agencies. Water banking may occur outside of a water agency's service area. If the water agency's own conveyance facilities are not directly adjacent to the water bank, stored water can be extracted and transferred through wheeling and exchange via other

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conveyance and storage facilities. Such movements of water involve institutional transfer agreements among water users and agencies.

9.1.1 LADWP Opportunities

LADWP is considering opportunities to acquire water through transfers to replace a portion of LAA water used for environmental enhancements in the eastern Sierra Nevada. The City would purchase water when available and economically beneficial for storage or delivery to LADWP's transmission and distribution system. The City is seeking non-State Water Project water to replace the reallocation of LAA water supply for environmental enhancements. MWD holds an exclusive contractual right to deliver State Water Project entitlement water into its service territory, which includes the City of Los Angeles. Purchasing only non-State Water Project supplies will ensure the City's compliance with MWD's State Water Project contract.

To facilitate water transfers, LADWP is constructing an interconnection between the LAA and the State Water Project's California Aqueduct, located where the two aqueducts intersect in the Antelope Valley (Neenach, California). This interconnection, the Neenach Temporary Pumping Station (NTPS) will allow for water transfers from the East Branch of the State Water Project to the LAA System, as well as provide operational flexibility in the event of a disruption of flows along the LAA System. Construction of the NTPS required a four-way agreement between DWR, MWD, LADWP, and the Antelope Valley-East Kern Water Agency (AVEK). When completed, the NTPS facility will be owned by DWR but will be designated as an AVEK interconnection. The NTPS will be operated on behalf of the LADWP. MWD is involved in the agreement to provide consent for the transferred water to enter its service territory.

LADWP's current goal is to transfer up to 40,000 AF per year once the NTPS facilities are in place. This will provide LADWP with the ability to replace some Los Angeles Aqueduct supplies reallocated to environmental enhancement projects. This will also provide increased operational flexibility and the ability to yield cost savings.

A demonstration study will be performed during the NTPS's first two years of operations; this study will include an evaluation of the operational and water quality aspects of the NTPS.

Neenach Temporary Pumping Station, construction site, looking northerly, taken September 16, 2010, by Aqueduct Aerial Patrol.

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To supplement water transfers, LADWP is also investigating the possibility of water banking. A request for proposal (RFP) was issued in 2008 and five proposals were received for evaluation to determine the most mutually beneficial agreement for a water banking program. However, LADWP has decided to not pursue full scale water banking projects at this time and has instead chosen to proceed with the Indian Wells Valley Water District's proposal to explore a potential water banking opportunity directly adjacent to the LAA.

The City supports Statewide water transfer legislation that will ensure the efficient use of the State's limited water resources and provide safeguards to the environment, public facilities, water conservation efforts and local economies. LADWP will continue to develop a responsible water transfer program that can assist in replacing City supplies that have been reallocated to the environment in the Eastern Sierra Nevada.

9.1.2 MWD Opportunities

Regionally, MWD has been active with water transfers and banking, seeking and implementing agreements and cooperative arrangement opportunities to supplement southern California's water supply. MWD's water transfer activities are classified as *spot transfers*, *option transfers*, *core transfers*, *storage transfers*, or *exchanges*. Each activity is described briefly below.

- *Spot transfers* make water available through a contract entered into the same year that the water is delivered.
- *Option transfers*, through multi-year or single-year contracts, allow MWD to obtain water on an "as-needed" basis.
- *Core transfers* make water available through multi-year contracts that convey specific water entitlement to MWD each year.
- *Storage transfers* allow MWD to store and later recover available water that can then be transported immediately to southern California.
- *Exchange agreements* involve the transfer to MWD of another agency's entitlements in exchange for water entitled to MWD from another source.

MWD is in the process of developing and implementing transfer/storage projects in the Central Valley, and off-stream banking and dry year supplies of Colorado River water. Water transfers, including the programs highlighted below, are an important element of California's plan to live within its 4.4 million acre-feet per year entitlement to Colorado River water. These programs have also helped MWD adjust to regulatory restrictions on State Water Project pumping from the San Francisco Bay-Delta. Current and potential MWD transfer, storage, and exchange agreements/activities include:

- Semitropic Water Storage Program
- Kern Delta Water District Water Management Program
- Arvin-Edison Water Transfer and Storage Program, Kern County
- San Bernardino Valley Transfer and Storage Program
- Desert Water Agency/Coachella Valley Water District Exchange Program

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- Palo Verde Land Management, Crop Rotation, and Water Supply Program
- Hayfield Groundwater Storage Project (under development)
- Southern Nevada Water Authority and Metropolitan Storage and Interstate Release Agreement
- Central Valley Water Transfers
- Yuba Accord Dry Year Purchase Program
- Lower Colorado Water Supply Project
- Lake Mead Water Storage Program
- Drop 2 Reservoir Funding
- Arizona Exchange (under development)
- Yuma Desalter Exchange (under development)
- California Indians Exchange (under development)
- Expansion of Southern Nevada Water Authority Agreement (under development)
- ICS Exchange Program (under development)
- Expansion of Palo Verde Land Management, Crop Rotation, and Water Supply Program (under development)
- Mojave Water Agency Exchange Demonstration Program (under development)
- North of Delta/In Delta Transfers (under development)
- North Kern/Desert Water Agency Exchange (under development)
- Shasta Return Project
- Semitropic Agricultural Water Reuse Demonstration Project (under development)
- San Bernardino Valley MWD Central Feeder Project (under development)
- Chuckwalla Groundwater Storage Program (under development)
- Coachella Valley Water District Agreement (under development)

MWD's water rate structure is designed to allow water transfers using MWD infrastructure by establishing a water wheeling rate, which is a combination of the System Access Rate, Water Stewardship Rate, System Power Rate, and Treatment Surcharge. The wheeling rate applies to all water conveyed through MWD's infrastructure, regardless of the agency using the

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system. MWD's unbundled rate structure and its associated wheeling rate encourage development of water markets by providing for competition at the supply level; MWD's member agencies can purchase supplies from any source and pay MWD's wheeling rate to transmit the water. MWD's current water rate structure establishes charges for each component on a per acre foot basis for all water moving through MWD's system. As of January 1, 2010, current wheeling rate charges are:

- System Access Rate: $154/AF
- Water Stewardship Rate: $41/AF
- System Power Rate: $119/AF
- Treatment Surcharge: $217/AF

The System Access Rate recovers costs associated with conveyance and distribution capacity to meet average annual demands. The Water Stewardship Rate recovers the cost associated with providing financial incentives for investments in local water resources, such as water conservation and recycled water programs. The System Power Rate recovers the cost for power to move water through MWD's system. The treatment surcharge applies to all water that is treated at one of MWD's five treatment plants.

MWD's water rate structure also incorporates a tiered supply rate format. The first tier price applies to a fixed base quantity of water as defined by each MWD member agency's purchase order contract. The second tier price reflects the incremental cost for MWD to acquire additional supplies that are above the first tier contract base amount

9.2 Seawater Desalination

Seawater desalination, the process of removing salts and other impurities from seawater, has reached an all-time high in terms of worldwide production capacity. According to the International Desalination Association, between 2007 and 2009, worldwide seawater desalination capacity increased by approximately thirty percent to a total capacity of 9.5 bgd. This is partly driven by the fact that the cost to desalinate water has reached an all-time low due to technological and process advancements. Of the more than 14,000 seawater and groundwater desalination plants in operation worldwide, the majority are located in the Middle East, where energy costs are relatively low. The world's largest seawater desalination plant in Saudi Arabia produces 232 mgd of desalted water. In contrast, the largest facility in the US, located in Tampa Bay, FL, produces 25 mgd.

LADWP's current water resource strategy does not include seawater desalination as a water supply. There are concerns with cost and the environmental impacts associated with the implementation of desalination. LADWP is primarily focused on enhancing recycling and conservation. While someday desalination may be explored further, it currently remains as a supply alternative.

9.2.1 Desalination Technology

Technology to desalt seawater to produce potable water which meets or exceeds drinking water standards has been available for some time, but has not been widely implemented primarily due to its high cost. Although the cost to desalinate seawater is still more expensive than obtaining water from conventional sources, continued research and development, as well as large scale projects, are being implemented in the United States and other parts of the world to improve technology and further drive costs down. Additionally, increasing costs associated with new water supplies and existing supplies is reducing the cost

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differential between desalinated water and other water sources improving the viability of desalinated water as a part of an overall water supply portfolio.

The two basic seawater desalination processes are: 1) use of the distillation process to evaporate water from salts; and 2) use of semi-permeable membranes to filter the water while straining out the salts. While distillation has been the dominant seawater desalination technology (primarily in the Middle East), current worldwide desalination development is rapidly migrating toward membrane technology. Facilities using distillation are still prevalent in the Middle East. However, new plant installations are increasingly taking advantage of technological advancements (higher yield and lower energy requirements) in membrane-based process technology. Today, membrane filtration accounts for over half of the world's desalting capacity.

9.2.2 DWR Desalination Efforts

Recognizing the potential of seawater as a water resource, the DWR through a legislative mandate, convened a California Water Desalination Task Force in 2002. The task force was responsible for making recommendations to the Legislature on potential opportunities, impediments, and the State's role in furthering desalination technology.

The task force was effective in providing a forum where stakeholders could convene and discuss critical issues related to desalination. Key seawater desalination issues that have been raised through the task force fall into six general categories: environmental, economic, permitting, engineering, planning, and coordination.

To assist in addressing these issues, the California Water Desalination Task Force has developed draft guidelines for developing environmentally and economically acceptable desalination projects. These include the following:

- Each project should be considered on its own merits;
- Sponsoring agencies should be determined early in the planning process;
- Public and permitting agencies should be engaged early in the planning process;
- Collaborative processes should be used to enhance support for project implementation;
- A feedback loop should be incorporated to allow for continuously revisiting and revising the project at each step of the planning process; and
- Key decision points (e.g., costs, environmental acceptability) should be identified to test the general feasibility of the project as early in the planning process as possible.

After establishment of the task force, desalination was added to the California State Water Plan as an alternative for consideration in regional water supplies. Furthermore, in 2008, DWR published the *California Desalination Planning Handbook*, building upon the Task Force efforts. The handbook provides guidance on determining appropriate conditions for desalination plants, addressing concerns, and building public trust.

Proposition 50, Chapter 6, has provided funding for desalination research, feasibility studies, pilot projects, and construction of new facilities. Over $45 million was distributed under this proposition in two rounds of funding for both seawater and groundwater desalination. Fund recipients included LADWP.

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With increasing demand for water and limited new supply options, the future value of seawater desalination as a part of California's water supply portfolio has become apparent. Within southern California, a range of 270,000 AFY to 422,000 AFY of desalinated seawater could be potentially produced based on current efforts (see Exhibit 9A). While this production represents less than five percent of the region's total water supplies, it is nonetheless considered by water planners as an important part of the region's water supply portfolio.

9.2.3 MWD Desalination Efforts

MWD first incorporated desalinated seawater as a potential new water supply source in its 2003 Integrated Resources Plan Update. Subsequently in 2009, MWD's Board of Directors created a special committee on Desalination and Recycling to study MWD's role in regional efforts to develop desalination facilities.

In response to a proposal solicitation in 2001, MWD received proposals by five member agencies to provide up to 142,000 AFY of potable water. To provide an incentive for the development of desalinated seawater, MWD is offering subsidies of up to $250 for each acre-foot (326,000 gallons) of desalinated seawater produced. LADWP, Long Beach Water Department, West Basin Municipal Water District, Municipal Water District of Orange County, and San Diego County Water Authority submitted detailed proposals that qualified for the MWD's Seawater Desalination Program. Exhibit 9A summarizes the status of the desalination efforts in MWD's service area, including projects not in the Seawater Desalination Program. Each of these agencies serves coastal areas, and is looking to desalination as a means to further diversify their water supply sources.

Exhibit 9A
Desalination Efforts in MWD Service Area

Project Name	Member Agency	Capacity (AFY)	Status
MWD Seawater Desalination Program			
Long Beach Seawater Desalination	Long Beach	10,000	Pilot Study[1]
Los Angeles Seawater Desalination	LADWP	28,000	On-hold
South Coast Coastal Ocean Desalination	Municipal Water District of Orange County	16,000 - 28,000	Pilot Study
Carlsbad Seawater Desalination	San Diego County Water Authority	56,000	Permitting Complete
West Basin Seawater Desalination	West Basin Municipal Water District	20,000	Pilot Study[1]
Subtotal		130,000 - 142,000	
Other Potential Projects in MWD Service Area			
Huntington Beach Seawater Desalination	Municipal Water District of Orange County	56,000	Initiating Permitting
Camp Pendleton Seawater Desalination	San Diego County Water Authority	56,000 - 168,000	Planning
Rosarito Beach Seawater Desalination	San Diego County Water Authority	28,000 - 56,000	Feasibility Study
Subtotal		140,000 - 280,000	
Total		270,000 - 422,000	

1. Full scale feasibility studies in progress.

Source: Annual Progress Report to the State Legislature, Achievements in Conservation, Recycling, and Groundwater Recharge, February 2010.

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9.2.4 LADWP Seawater Desalination Efforts

Scattergood Generating Station Seawater Desalination Plant

LADWP initiated efforts in 2002 to evaluate seawater desalination as a potential water supply source with the goals of improving reliability and increasing diversity in its water supply portfolio. These efforts led to the selection of Scattergood Generating Station as a potential site for a seawater desalination plant. For the City, seawater desalination is a potential resource that could also offset supplies that had been committed from the LAA for environmental restoration in the eastern Sierra Nevada. LADWP has reallocated approximately fifty percent of its historical average LAA supplies to benefit the eastern Sierra Nevada environment. As an identified program in MWD's Seawater Desalination Program, the proposed full-scale project would have qualified for MWD's grant of $250 per acre-foot of water produced. However, in May 2008, LADWP decided to focus on water conservation and water recycling as the primary strategies in creating a sustainable water supply for the City.

While seawater desalination is not a potential water supply strategy at this time, studies performed to date have provided beneficial data that in the future can assist LADWP with any future evaluations of seawater desalination. Completed studies include the LADWP Proposed Seawater Desalination Plant Site Selection Fatal Flaw Analysis (2002), LADWP Seawater Desalination Facility Feasibility Study for the Scattergood Generating Station in Playa Del Rey (2004), Brine Dilution Study for the LADWP Desalination Project at Scattergood Generating Station (2005), and Scattergood Seawater Desalination Pilot Project Preliminary Evaluation Report (2008).

To determine the proper site location for a City desalination plant, LADWP conducted the LADWP Proposed Seawater Desalination Plant Site Selection Fatal Flaw Analysis evaluating three City-owned coastal power generating plants. Based on the findings from this analysis, LADWP initially decided to investigate development of a 12 to 25 mgd desalination facility at the Scattergood Generating Station.

Optimum capacity of a future desalting facility at the Scattergood Generating Station was evaluated in the LADWP Seawater Desalination Facility Feasibility Study. Results of the study indicated a 25 mgd facility would be the most economical. Estimated capital costs for a 25mgd facility were approximately $148.5 million in 2004 dollars with an annual operations and maintenance cost of $28.9 million (2004 dollars) resulting in a total water cost of approximately $1,257 per acre-foot. The study also identified the five-mile Hyperion Treatment Plant Outfall, which is adjacent to the Scattergood Generating Station, as the most environmentally advantageous method to dispose of the brine concentrate produced from the desalting process.

In an effort to develop an environmentally compatible project, LADWP evaluated the feasibility of discharging the desalted concentrate into Hyperion Wastewater Treatment Plant's 5-mile outfall. The Brine Dilution Study for the LADWP Desalination Project at Scattergood Generating Station performed by the Scripps Institute of Oceanography found that there are potential environmental benefits to the Santa Monica Bay's marine biology due to improved salt balance if the effluent discharged by the Hyperion Wastewater Treatment Plant were to include brine from a desalination facility.

In March 2008 the Preliminary Evaluation Report of the Scattergood Generation Station Seawater Desalination Pilot Project was completed. This was the first task of multiple tasks that was to ultimately result in the operation of a pilot plant. Co-funded by the US Bureau of Reclamation and DWR through Proposition 50 funding the overall goal was to further investigate the viability of seawater desalination for LADWP. Recommendations on site specific technologies and processes were provided for carry over to the pilot plant design stage. Items for further study included subsurface intake evaluation, cooling alternatives for warm water, second pass RO, post treatment stabilization, and finished water blending strategy.

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After completion of the first task, the other tasks were not initiated reflecting the City's new primary strategies of conservation and recycled water to create a sustainable water supply for the City. Studies completed to date and LADWPs other seawater desalination efforts discussed below have provided important data that can assist LADWP to move forward with seawater desalination in the future, if conditions are amenable.

Other LADWP Seawater Desalination Efforts

LADWP historically engaged in multiple partnerships to advance seawater desalination in southern California. Seawater desalination is hindered by multiple challenges including, but not limited to, capital costs, operating costs, environmental considerations, water quality, and public acceptance. To overcome these challenges, LADWP has supported efforts to lower the capital and operating costs of producing desalinated ocean water. LADWP also participated with California stakeholders through multiple venues, such as the MWD and the California Water Desalination Task Force to develop desalination study projects within southern California.

LADWP, the Long Beach Water Department (LBWD), and the United States Bureau of Reclamation partnered in the construction of a 300,000 gpd prototype seawater desalination facility to complete testing of LBWD's proprietary two-stage nanofiltration process (using membranes that require lower operating pressures and thus, the potential for lower operating costs). LBWD successfully performed a 9,000-gpd bench-scale testing of this technology and began testing on a larger scale in October 2006 at LADWP's Haynes Generating Station in Long Beach. By March 2010, LBWD has completed its testing and is currently preparing the final report.

LADWP also partnered with the West Basin Municipal Water District and other agencies in the American Water Works Association Research Foundation Tailored Collaboration project, "Water Quality Implications for Large-Scale Applications of MF/RO Treatment for Seawater Desalination." A 30,000-gpd pilot facility operating off the coast of El Segundo, California, from 2002 to 2008, was tested for membrane performance, water quality, and operational cost.

In a joint study by LADWP, LBWD, and West Basin Municipal Water District, preliminary sampling of raw seawater quality was initiated at three potential seawater desalination sites - Scattergood Generating Station in Playa Del Rey, Haynes Generating Station in Long Beach, and El Segundo Power Generating Station. Water quality analysis on the seawater was performed at various times of the year to analyze seawater quality variations during storm events when city surface runoffs drain into the ocean. The next step would be to collaborate with the California Department of Health Services on developing guidelines to ensure that product water from future desalting facilities will meet all State and Federal water quality regulations.

9.3 Potential Water Supply Yield and Cost

The range of potential water supply, the unit cost, risks, and other benefits besides reductions in water demands for these potential water supplies are presented in Exhibit 9B.

LADWP recognizes the value of potential water supplies to offset unanticipated changes to supply or demand. Strategic water planning necessarily includes continuous monitoring of existing and future alternative water resources in preparation of these needs.

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Exhibit 9B

Other Potential Water Supplies

Potential Water Supplies	Potential Water Yield (AFY)	Average Unit Cost ($/AF)	Implementation Risks	Additional Benefits
Seawater Desalination [1]	25,000	$1,500-$2,000	Environmental permitting may be difficult.	Replaces water committed to the environment. Hedges against climate change.
Water Transfer	40,000	$440-$540[2]	Wheeling and other institutional issues must be addressed.	Replaces water committed to the environment.

For Comparison Purposes:
Local Groundwater Pumping Unit Cost = $230/AF
MWD Treated Tier 2 Water Supply Unit Cost = $811/AF

Notes:

1. Source: LADWP Seawater Desalination Facility Feasibility Study for the Scattergood Generating Station in Playa Del Rey (2004); updated from 2004 to 2009 dollars using annual CPI index for LA-Riverside-Orange County MSA. While the ocean is a virtually unlimited supply, yield shown here is the maximum given available land, outfall capacity, and other constraints.
2. Cost includes cost of water and wheeling fees. Treatment costs not included.

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Chapter Ten
Integrated Resources Planning

10.0 Overview

Integrated resources planning is a process used by many water and wastewater providers to meet their future needs in the most effective way possible, and with the greatest public support. The integrated planning process incorporates:

- public stakeholders in an open, participatory process;
- multiple objectives such as reliability, cost, water quality, environmental stewardship, and quality of life;
- risk and uncertainty; and
- partnerships with other agencies, institutions, and non-governmental organizations.

LADWP has been actively involved in integrated resources planning since 1993, when the Metropolitan Water District of Southern California (MWD) initiated the region's first Integrated Resources Plan (IRP). LADWP was an active member of the technical workgroup that oversaw the development of alternatives and recommendations from MWD's IRP. In 1999, the City of Los Angeles embarked on its first IRP for wastewater, stormwater and water supply. The LADWP was a partner in this effort, working with the City's Bureau of Sanitation (BOS). In 2006, the Greater Los Angeles County IRWMP was approved. LADWP is a member of the IRWMP Leadership Committee and serves as the chair of the of the Upper Los Angeles River Watersheds sub-region for the IRWMP region.

10.1 City of Los Angeles Integrated Water Resources Plan

Description and Purpose

The City's Water Integrated Resources Plan (IRP) is a unique approach of technical integration and community involvement to guide policy decisions and water resources facilities planning. As part of the IRP development, an Environmental Impact Report (EIR) was prepared identifying the recommended alternatives for implementing the City's wastewater, runoff, and recycled water programs for 2020. On November 14, 2006, the City Council unanimously adopted the IRP recommendations and implementation strategy and certified the final EIR. The IRP development was a seven year stakeholder-driven process that at the time was an innovative approach to guide the City's policy decisions and facilities planning. The IRP recognizes the interrelationship of water, wastewater, and runoff management in forming a future vision for the City's water resources activities and functions. In the past, the City traditionally utilized single-purpose planning efforts for each agency, such as one plan for wastewater and a separate plan for water supply. With the IRP, the City can meet its 2020 needs in a more cost-effective and sustainable way by addressing and integrating all its water resources. Additionally, the IRP was designed to meet multiple objectives, including evaluation of innovative supply opportunities that were once thought of as being too expensive. The City's LADWP and BOS are partners in this effort, joined by public stakeholders and other agencies.

The objectives for the IRP were developed by the City and public stakeholders, and represent the major reasons why the plan was developed. These objectives are:

- Protect Public Health and Safety
- Effectively Manage System Capacity

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- Protect the Environment
- Enhance Cost Efficiency
- Protect Quality of Life
- Promote Education

The IRP was developed in three phases. The first phase set policy guidelines for managing the City's water resources for the next 20 years. The second phase had three main deliverables: (1) detailed facility plans for wastewater, stormwater, and recycled water; (2) comprehensive financial plans for wastewater and stormwater; and (3) a certified Environmental Impact Report (EIR). The third phase of the IRP, which is now underway, represents implementation of the facility plans and more detailed studies to support implementation.

Integrated Watershed Approach

By taking an integrated watershed approach, the IRP identified opportunities that would normally not have been identified if water, wastewater, and stormwater were planned separately. The IRP recognized that all of the City's water resources are linked from a technical, social, and institutional aspect.

The City's IRP has also assisted in identifying partnerships between City agencies for project implementation potentially leading to increases in outside funding from grants and low-interest loans.

An example is the potential three-way partnership between the City's Recreation and Parks Department, BOS, and LADWP. Land reclamation of blighted industrial and warehouse uses allows the City to create more parks and recreational areas while simultaneously allowing for underground storage of wet weather runoff for subsequent beneficial reuse. With this integrated approach, the City can potentially obtain more parkland, assist BOS in reducing wet weather runoff to improve water quality, and assist LADWP in increasing water supplies. The integrated approach also allows the City to better position itself for grants and loans that typically prioritize projects that demonstrate multiple benefits (e.g., water quality, water supply and recreation).

Stakeholder Involvement

A key element of the IRP was involvement of stakeholders at the beginning and throughout the entire IRP process. Stakeholders represent a wide range of the City's interests including, but not limited to, community, business, and environmental organizations. Stakeholders were instrumental in development of the guiding principles and identification of innovative water resource opportunities.

During Phase 2, stakeholders participated in a Steering Group. Steering Group members regularly attended scheduled workshops and provided on-going input on the technical, environmental, and financial development of the IRP. Members provided necessary feedback to keep the facilities planning efforts aligned with the decision-making process. The Steering Group also considered key project issues in regards to the development of alternatives, such as facilities siting, implementation risks, and acceptability of costs that will invariably arise during the project.

IRP Alternatives

The IRP evaluated a broad range of integrated alternatives. Each alternative represented different combinations of wastewater treatment options, wastewater collection system options, recycled water options, conservation options, and dry and wet weather urban runoff management options.

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Twenty-one (21) preliminary alternatives were created with different focuses, allowing stakeholders and decision-makers to see trade-offs in key planning objectives. Based on the evaluation of the preliminary alternatives, nine (9) hybrid alternatives were created that incorporated the best elements from the preliminary alternatives in order to improve overall performance. City staff recommended the top-scoring four (4) hybrid alternatives to be carried through to the EIR process. Public stakeholders concurred with staff recommendations.

In November 2006, City Council approved the staff-recommended alternative, which consists of "Go-Projects" , "Go-If-Triggered Projects" and "Go-Policy Directions". "Go-Projects" are projects recommended for immediate implementation because the flow and regulatory triggers have already been met. "Go-If-Triggered Projects" will only be implemented if or when additional information or circumstances, such as regulatory requirements, population growth, or increases in sewage flow are reached.. "Go-Policy Directions" are specific directions to City staff on the next studies and evaluations necessary to progress on programmatic elements.

IRP Implementation Status

The City's Department of Public Works (DPW) in partnership with the Department of Water and Power (DWP) has been working collaboratively along with other City departments on coordinating and implementing the various IRP recommendations. As part of the IRP implementation phase, the City has worked on keeping IRP stakeholders engaged through annual stakeholder meetings. Through these meetings, the City has provided updates on the IRP implementation and has obtained valuable input from stakeholders on IRP related issues. In addition, the Board of Water and Power and the Board of Public Works have held three public joint meetings to review the IRP progress and provide directions on policy issues. Since the adoption of the IRP by Council in November 2006, a number of initiatives have been undertaken by the City which fulfill the IRP goals, including the Green Streets and Green Alleys Committee, the development of a Low Impact Development Ordinance, Conservation Initiatives (Chapter 3), the Recycled Water Master Plan (Chapter 4), and Watershed Management (Chapter 7). Projects and policies in the IRP implementation strategy are detailed below. Some projects are currently being implemented, while others continue to be monitored for triggers or policy direction:

Go Projects

- Construct wastewater storage facilities at Tillman
- Construct wastewater storage facilities at Los Angeles-Glendale Water Reclamation Plant (LAG)
- Construct recycled water storage facilities at LAG
- Construct solids handling and truck loading facility at Hyperion
- Construct two new sewer lines, Glendale Burbank Interceptor Sewer (GBIS) and Northeast Interceptor Sewer (NEIS) Phase II

Go-If-Triggered Projects

- Potential upgrades at Tillman to advanced treatment at current capacity (if triggered by regulations and/or decision to reuse Tillman effluent for groundwater replenishment)

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- Potential expansion and upgrade of Tillman to 100 mgd (if triggered by an increase in population, regulations, and/or groundwater replenishment decision), In the unlikely event that the overall framework for recycled water changes to disallow its use, then Hyperion would be potentially expanded to 500 mgd instead.

- Potential upgrades at LAG to advanced treatment at current capacity (if triggered by regulations and/or availability of downstream sewer capacity)

- Design and construct additional secondary clarifiers at Hyperion to provide 450 mgd operational performance

- Design and construct up to 12 solids digesters at Hyperion (if triggered by increased biosolids production in the service area)

- Design/construction of Valley Spring Interceptor Sewer

Of the "Go-Policy Directions" which provide specific directions to City staff on the next studies and evaluations necessary to progress on programmatic elements., those applicable to or with the potential to impact LADWP operations include:

Recycled Water – Non-Potable Uses

- Direct LADWP and Public Works to work together to maximize use and identify recycled water for non-potable uses in the Terminal Island Treatment Plant service area, west side, and LAG service areas. LADWP is to conduct additional Tier 1 and 2 customer analyses to verify potential demands and feasibility. Develop a long-range marketing strategy for recycled water that includes a plan for recruiting and retaining new customers.

- Direct Building and Safety to evaluate and develop ordinances to require installation, where feasible, of dual plumbing for new multi-family, commercial and industrial development, schools, and government properties in the vicinity of existing or planned recycled water distribution systems in coordination with the LA River Revitalization Master Plan. Proximity and demand will be considered when determining feasibility. The dual plumbing will consist of separate plumbing and piping systems, one for potable water and the second for recycled water for non-potable uses, such as irrigation and industrial use

- Direct Public Works and LADWP to continue to coordinate, where feasible, the design/construction of recycled water distribution piping (purple pipe) with other major public works projects, including street widening, and LA River Revitalization Master Plan project areas. Also coordinate with other agencies, including the Metropolitan Transit Authority and Caltrans, on major transportation projects.

Recycled Water –Indirect Potable Uses (Groundwater Replenishment)

- Direct LADWP to develop a public outreach program to explore the feasibility of implementing groundwater replenishment with advanced treated recycled water.

Recycled Water – Environmental Uses

- Direct LADWP and Public Works to continue to provide water from Tillman to Lake Balboa, Wildlife Lake, and the Japanese Garden at Sepulveda Basin, and the LA River to meet baseline needs for habitat.

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Water Conservation

- Direct DWP to continue conservation efforts, including programs to reduce outdoor water usage, including using smart irrigation devices on City properties, schools, and large developments (those with 50 dwelling units or 50,000 gross square feet or larger), and to increase incentives to residential properties

- Direct LADWP to work with Building and Safety in continued conservation efforts, including evaluating and considering new water conservation technologies, including no-flush urinal technology

- Direct LADWP to continue conservation efforts, including working with Building and Safety to evaluate and develop a policy that requires developers to implement individual water meters for all new apartment buildings

- Direct LADWP to continue conservation awareness efforts, including increasing education programs on the benefits of using climate-appropriate plants with an emphasis on California friendly plants for landscaping or landscaped areas developed in coordination with the LA River Revitalization Master Plan, and to develop a program of incentives for implementation.

- Direct the Planning Department to consider development of a City Directive to require use of California friendly plants in all City projects where feasible and not in conflict with other facilities usage

Runoff Management – Wet Weather Runoff

- Direct Public Works to review SUSMP (Standard Urban Stormwater Management Plan) requirements to determine ways to require, where feasible, on-site filtration and/or treat/reuse, rather than treat and discharge, including in-lieu fees for projects where infiltration in infeasible

- Direct Building and Safety to evaluate and modify applicable codes to encourage all feasible Best Management Practices (BMPs) for maximizing on-site capture and retention and/or infiltration of stormwater instead of discharge to the street and storm drain, including using porous pavement.

- Direct Public Works and Planning to evaluate the possibility of requiring porous pavement in all new public facilities in coordination with the LA River Revitalization Master Plan, and large developments greater than one acre. Program feasibility should consider slope and soil conditions

- Direct Planning to evaluate ordinances that would need to be changed to reduce the area of on private properties that can be paved with non-permeable pavement

- Direct Public Works to evaluate and implement integration of porous pavements into sidewalks and street programs where feasible.

- Direct Public Works, LADWP, and Recreation and Parks to prepare a concept report and determine the feasibility of developing a powerline easement demonstration project for greening, public access, stormwater management, and groundwater replenishment.

- Direct Public Works and LADWP to work with the Los Angeles Unified School District to determine the feasibility of developing projects for both new and retrofitted schools, as well as for government/city-owned facilities, with

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stormwater management BMPs (cisterns to store runoff for irrigation, reduce paving and hardscapes, add infiltration basins).

- Direct Public Works, General Services, and Recreation and Parks, to identify sites that can provide on-site percolation of wet-weather runoff in surplus properties, vacant lots, parks/open spaces, abandoned alleys in the East Valley area, and along the LA River in the East Valley where feasible. Program feasibility should consider slope and soil conditions.

- Direct Public Works, General Services, and the Department of Transportation to maximize unpaved open space in City-owned properties and parking medians using all feasible BMPs and by removing all unnecessary pavement.

- In the context of developing Total Maximum Daily Load implementation plans, direct Public Works to consider diversion of dry weather runoff from Ballona Creek to constructed wetlands, wastewater system, or urban runoff plants for treatment and/or beneficial use. For inland creeks and storm drains tributary to the LA River, direct Public Works to consider diversion of dry weather runoff to the wastewater system or constructed wetlands or treatment/retention/infiltration basins.

- Direct General Services, in coordination with Planning and Public Works, to evaluate feasibility of all City properties identified as surplus for potential development of multiple-benefit projects to improve stormwater management, water quality, and groundwater recharge.

Los Angeles River

The IRP planning effort included the Los Angeles River (River). The Los Angeles River is a valuable resource to the City providing habitat as well as recreational and economic opportunities. Since the City's water reclamation plants were built, recycled water has been released to the River resulting in the development of significant environmental benefits from riparian habitat in the unlined portions of the River near Glendale, to regionally significant migratory shore bird habitat in Long Beach. As a result many efforts have been developed to protect existing habitat and interest in habitat restoration and river revitalization.

The IRP established that treated wastewater is needed for the operation of Lake Balboa, the Japanese Gardens, and the Wildlife Lake in the Sepulveda Basin. Treated wastewater flows through these features and ultimately is released to the River from the Donald C. Tillman Water Reclamation Plant. The remainder of the treated wastewater produced by the City's water reclamation plants is available for recycled water use and distribution to LADWP customers.

Shortly after work on the IRP began, the Los Angeles City Council Ad Hoc Committee on the Los Angeles River (Ad Hoc Committee) was formed to address River revitalization. LADWP staff routinely attends Ad Hoc Committee meetings and functions, and monitors River-related activities.

LADWP also funded the preparation of a Los Angeles River Revitalization Master Plan which was approved in 2007. This plan addresses economic development opportunities, water quality, water resources, flood control, and recreation along the Los Angeles River. The plan also discusses opportunities to improve access to the Los Angeles River and increase community awareness and pride.

In addition, LADWP staff also actively participates on the City Department Los Angeles River Task Force, which was formed in response to instructions by the Ad Hoc Committee to:

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- inventory all current and future City Department projects, studies, and programs along the River;
- assess opportunities for future funding, projects, and studies; and
- coordinate River related activities of City Departments and other agencies.
- partner with the United States Army Corps of Engineers for a Habitat Restoration Project Study

LADWP recognizes the importance of the Los Angeles River as a resource that provides multiple benefits to the City.

Agency Coordination

LADWP was a partner with the Bureau of Sanitation (BOS) in developing the IRP along with public stakeholders and other agencies. As with any integrated plan that extends beyond traditional departmental boundaries and government jurisdictions, close coordination is required with multiple City, state, and federal agencies including but not limited to, the Cities of Burbank and Glendale, County of Los Angeles, Caltrans, United States Army Corps of Engineers, United States Bureau of Reclamation, and City Parks and Recreation Department. Since approval of the IRP, ongoing project implementation and "Go-Policy Directions" continue to require close coordination with City departments and with the agencies listed above.

IRP Implications for City's Urban Water Management Plan

One of the primary purposes for developing the IRP was to explicitly consider the relationship between wastewater facility planning and other water resources issues, such as water supply and urban runoff. Implementation of the IRP has and will continue to result in increased beneficial reuse of water, water conservation, and groundwater supplies. IRP alternatives examined ways in which to decrease potable water needs by expanding the City's recycled water program; increase water efficiency by installing smart irrigation and other water efficient devices that reduce irrigation and indoor water demands; and increase groundwater resources by using wet weather runoff to recharge the aquifer. All of these options will have to be tested from a technical, institutional, and public acceptance perspective. Ongoing work on programmatic elements identified in the "Go-Policy Directions" applicable to LADWP will continue to investigate means of increasing local water supplies, water conservation, and groundwater recharge opportunities in an integrated manner. The IRP has demonstrated that by integrating water resources planning for the City, more opportunities for water supply development can be identified.

10.2 Greater Los Angeles County Integrated Regional Water Management Plan (IRWMP)

Description and Purpose

The Los Angeles County Department of Public Works led efforts to develop an Integrated Regional Water Management Plan (IRWMP) for the Greater Los Angeles County Region. Water quality, resource, and supply issues within the region are complex and managed by a myriad of government agencies subjected to a plethora of regulations. Exponential growth over the last century has required water managers to develop creative solutions to meet growing demands. Previously projects addressing water issues were designed to appease single-focused visions and solutions of organizations operating independently in silos. At the core of the plan a clear vision and direction for the sustainable management of water resources within the region for the next twenty years was formulated. Over 1,600 projects were collected and synthesized for inclusion in the plan bringing together hundreds of local government agencies all working cooperatively to develop cost-effective, sensible, and economically feasible solutions to address regional water issues. New partnerships were forged joining together potential funding partners from within and outside the region. An innovative partnership between agencies was formed

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creating a new model of integrated regional planning to address competing water demands, water supply reliability, and project financing.

An Interim Draft of the IRWMP was adopted by the Leadership Committee on June 28, 2006 with a final plan adopted on December 16, 2006. To date the plan has received $25 million from the Department of Water Resources (DWR) under Proposition 50, Chapter 8, for implementation of fourteen priority projects identified in the plan and $1.5 million from DWR for development of the IRWMP. Since completion of the document a revised Memorandum of Understanding (MOU) was executed by each of the sixteen agencies serving on the Leadership Committee for the purpose of developing, administering, updating, and implementing the IRWMP.

Region

The IRWMP region encompasses 92 cities, portions of four counties, and hundreds of government agencies and districts spread over 2,058 square miles. Approximately 10.2 million residents, or equivalent to roughly 28% of the population of California, reside within the region. To facilitate input, variations in geographic and water management strategies, and effective planning the region was further subdivided into five sub-regions:

- Lower San Gabriel and Los Angeles River Watersheds
- North Santa Monica Bay Watersheds
- South Bay Watersheds
- Upper Los Angeles River Watersheds
- Upper San Gabriel River and Rio Hondo Watersheds.

Mission and Purpose

A collaborative process resulted in the following mission statement of the IRWMP, "[T]o address the water resources needs of the Region in an integrated and collaborative manner." The IRWMP recognizes that in order to meet future needs water supply planning must be integrated with other resource strategies. Additionally, in a region with significant urban challenges, including population growth, densification, traffic congestion, poor air quality, and quality of life issues, it is imperative to consider water resources management in conjunction with other urban planning issues. The IRWMP's purpose is to proactively:

- Improve water supplies
- Enhance water supply reliability
- Improve surface water quality
- Preserve flood protection
- Conserve habitat
- Expand recreational access.

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Stakeholder Involvement

Over 1,400 invitations to participate in the IRWMP process were sent out to cities, counties, agencies, districts, disadvantaged communities, and community organizations. Stakeholders participated in workshops, project identification, and development of the IRWMP. Stakeholders were involved in plan development and through development of technical memorandums and participation in regional workshops, subregional workshops, and the Leadership Committee. Stakeholders assisted in the development of the following:

- Development of the IRWMP mission and objectives
- Refinement of procedures for incorporation of projects into the IRWM
- Identification of implementation strategies
- Recommendation of stakeholder workshop improvements.

Recommended Projects

Over 1,600 projects were submitted and analyzed for inclusion in the IRWMP. This list was narrowed down to fourteen priority projects that met the objectives and priorities established by the IRWMP process and assist in meeting the targets established for the planning region. Objectives and priorities were established to guide the project selection process. The IRWMP is a living document and will be updated as needed. Projects can continuously be submitted as they are identified by stakeholders.

Objectives and Priorities

Six objectives and six long-term priorities were developed through the stakeholder process to guide project selection based on stakeholder input and previously completed documents, including UWMPs, MWD's IRP, Common Ground, Santa Monica Bay Restoration Plan, and watershed plans for the major tributaries in the region. The objectives are:

- Optimize local water resources to reduce the Region's reliance on imported water
- Comply with water quality regulations (including TMDLs) by improving the quality of urban runoff, runoff, stormwater, and wastewater
- Protect and improve groundwater and drinking water quality
- Protect, restore, and enhance natural processes and habitats
- Increase watershed friendly recreational space for all communities
- Maintain and enhance public infrastructure related to flood protection, water resources, and water quality.

Long term regional priorities are:

- Maintain a regional and subregional structure to oversee plan implementation and assure continued stakeholder input
- Optimize use of recycled water, groundwater, desalination, and stormwater to enhance water supply reliability
- Reduce demand on imported water sources

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- Protect groundwater supplies
- Improve surface water quality to meet applicable water quality regulations, including TMDLs
- Preserve open space, conserve and restore functional habitats, and protect special-status species.

Targets

Targets for the region were developed to assist in prioritizing projects. Targets include:

- Increase water supply reliability by providing 800,000 AFY of additional water supply and demand reduction through conservation, including infiltration or reuse of 130,000 AFY of reclaimed water
- Reduce and reuse 150,000 AFY (40%) of dry weather urban runoff and capture and treat an additional 170,000 AFY (50%) for a total target of 90%
- Reduce and reuse 220,000 AFY (40%) of stormwater runoff from developed areas and capture and treat an additional 270,000 AFY (50%) for a total of 90%
- Treat 91,000 AFY of contaminated groundwater
- Restore 100+ linear miles of functional riparian habitat and associated buffer habitat
- Restore 1,400 acres of functional wetland habitat
- Develop 30,000 acres of recreational open space focused in under-served communities
- Repair/Replace 40% of aging water resources infrastructure.

Projects

Fourteen priority projects were developed for the greater Los Angeles County region. As a regional plan encompassing an area larger that LADWP's service area, many of the IRWMP projects do not directly benefit LADWP's service area, but rather provide benefits towards improving water resources in the region as a whole. However, for projects not within LADWP's service area LADWP can utilize the results of other projects and apply the knowledge to potentially develop similar programs within the service area. Brief descriptions of the priority projects are provided below.

Southeast Water Reliability Project

The Southeast Water Reliability Project consists of an 11.4 mile recycled water transmission pipeline from the City of Pico Rivera to the City of Vernon to complete Central Basin Municipal Water District's recycled water transmission system. Recycled water will be mainly provided by the County Sanitation Districts of Los Angeles County via the San Jose Creek Water Reclamation Plant.

Joint Water Pollution Control Plant Marshland Enhancement

The Joint Water Pollution Control Plant Marshland Enhancement Project is designed to improve and maintain plant and wildlife habitat at the seventeen acre freshwater marshland located at the Joint Water Pollution Control Plant (JWPCP) in

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Carson. As proposed the project will serve as a mitigation measure for upgrading the JWPCP to full secondary wastewater treatment. The JWPCP is operated by the County Sanitation Districts of Los Angeles County.

Large Landscape Water Conservation, Runoff Reduction, and Educational Program (Central Basin)

The Large Landscape Water Conservation, Runoff Reduction, and Education Program is an end use water management program to reduce runoff and address water/energy management associated with large landscapes, residential land uses, and street medians within the Central Basin Municipal Water District's Service Area. Weather-based irrigation controllers coupled with GIS to monitor runoff and two-way communication technologies will provide necessary information to address emergency, drought, and end use management challenges.

Large Landscape Water Conservation, Runoff Reduction, and Educational Program (West Basin)

West Basin Municipal Water District's Large Landscape Water Conservation, Runoff Reduction, and Educational Program is a four component project. The first component targets large landscape sites of 1 acre or more by providing centralized weather-based irrigation controllers with the goal of conserving 1 AFY per acre of land. The second component will provide 1,350 rebates for the purchase of smart irrigation controllers for the top residential water users. A third component will consist developing and offering classes on residential landscaping for residences and businesses. The last component involves installing ten "Ocean Friendly" demonstration gardens throughout watersheds in the service area.

Las Virgenes Creek Restoration Project

The City of Calabasas is initiating the Las Virgenes Creek Restoration Project to restore 450 linear feet of a concrete-lined section of the creek to a natural function. Native vegetation will be planted in place of the concrete liner to establish connectivity between riparian habitat north and south of the existing liner.

Malibu Creek Watershed Urban Water Conservation and Runoff Reduction Project

As proposed the Malibu Creek Watershed Urban Water Conservation and Runoff Reduction Project seeks to conserve water and reduce runoff in the City of Westlake Village and within the Las Virgenes Municipal Water District (LVMWD) service areas. Irrigation controllers on city-owned land in Westlake Village will be replaced with weather-based irrigation controllers. Within the LVWMD service area indoor conservation will be addressed by continuing rebates for residential and multi-family customers to install water saving devices. This project will also continue existing efforts to reduce urban runoff and outdoor conservation in the LVMWD service area by targeting customers with persistent and substantial irrigation runoff in the vicinity of stormdrains. These customers are offered water efficient equipment rebates and free on-site assistance to upgrade irrigation systems to eliminate runoff.

Morris Dam Water Supply Enhancement Project

The Morris Dam Water Supply Enhancement Project would allow the capture of additional local runoff (5,720 AF) for groundwater recharge and extraction in the San Gabriel River watershed. This project would reduce the minimum pool required by the Los Angeles County Flood Control District to prevent sediment damage to the outlet works of the dam by modifying the dam valves and control systems.

Pacoima Wash Greenway Project

The Pacoima Wash Greenway will treat storm runoff from neighborhoods adjacent to the wash in a series of parks incorporating stormwater treatment best management practices along the wash. Project development will be a joint effort between the City of San Fernando and the Mountains Recreation and Conservation Authority.

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San Gabriel Valley Riparian Habitat Arundo Removal Project

Arundo donax a non-native plant classified federally and by California as noxious weed will be removed from approximately 30 acres of riparian habitat in the San Gabriel Watershed. Removal will increase surface water flows to the Rio Hondo percolation basins and improve native habitat.

Solstice Creek Restoration Project

The Solstice Creek Restoration Project will restore side drainages of Solstice Creek and areas negatively impacting riparian habitat through sediment and invasive species introduction. This project is part of an overall larger project to restore Solstice Creek.

South Los Angeles Wetlands Park

The South Los Angeles Wetlands Park project will involve purchasing a 9 acre parcel in Los Angeles on Avalon Boulevard for conversion to a wetlands park. As proposed, the wetlands park will treat urban runoff from a 520 acre area through a series of best management practices. Park vegetation will consist of plants not requiring supplemental irrigation.

Whittier Narrows Water Reclamation Plant UV Disinfection

The Whittier Narrows Water Reclamation Plant UV Disinfection project will convert current disinfection processes at the 15 mgd plant to a UV disinfection process. Currently, tertiary-treated water is disinfected to Title 22 recycled water standards using chloramination resulting in the production of NDMA byproducts.

Wilmington Drain Restoration Multiuse

As proposed, the Wilmington Drain Restoration Multiuse Project involves restoration of the Wilmington Drain. Restoration will involve creation of a public park, improved public access, native revegetation, stormwater treatment, and educational signage. The drain is within the City of Los Angeles on an easement held by the Los Angeles County Flood Control District.

North Atwater Creek Restoration

As a component of the overall Los Angeles River Revitalization efforts, the North Atwater Creek Restoration Project will restore North Atwater Creek at North Atwater Park by providing stormwater runoff capture and treatment and the provision of habitat linkage to the Los Angeles River. Additionally, the project will provide an educational component and provide BMP implementation at adjacent horse stables and riding trails.

Implications of IRWMP for LADWP's Urban Water Management Plan

LADWP is a member of the IRWMP Leadership Committee and additionally serves as the chair of the of the Upper Los Angeles River Watersheds sub-region for the IRWMP region. As member of the Leadership Committee, LADWP is a signatory to the MOU for the IRWMP approved by the Board of Water and Power Commissioners on July 15, 2008.

Participating agencies in the IRWMP coordinate and share information concerning water resources management planning programs and projects, share grant funding information, and improve and maintain overall communication among the participants. Coordination and information sharing assists LADWP and other agencies in achieving their respective missions and contribute to overall IRWMP goals.

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10.3 MWD's Integrated Resources Plan

In 1993, MWD and its member agencies embarked on a three year process to develop Southern California's first IRP. Six main objectives for this plan were defined as:

- Supply and System Reliability
- Affordability
- Water Quality
- Diversity
- Environmental Issues
- Institutional Constraints

In order to meet these objectives, supply and conservation options that included everything from groundwater desalination, water transfers, Colorado River and SWP improvements, and new surface storage were evaluated. Complete portfolios, representing different combinations of supply and conservation options, were assembled. Based on extensive participation from water providers and other stakeholders as well as detailed evaluations, a "preferred resource mix" was recommended. The preferred resource mix balanced local and imported water supply projects with significant water conservation in order to best meet the needs of the region. This preferred resource mix also established regional targets for the development of water supply to be made by MWD, its member agencies, and retail water providers.

The 20-year plan was designed so that MWD and its member agencies would be able to meet their full service demands through 2020. MWD's Board of Directors formally adopted the IRP in January 1996.

MWD IRP 2004 Update

In 2001, the MWD Board of Directors developed a work plan to update the 1996 IRP in order to accommodate changed conditions and extend the targets through 2025. Specifically, the IRP Update has three main objectives: (1) review the resource development targets and implementation achievements of the 1996 IRP; (2) identify significant changed conditions for water resource development since the adoption of the 1996 IRP; and (3) evaluate the reliability of the IRP Preferred Resource Mix through 2020, adjust targets as needed to reflect changed conditions, and extend resource targets through 2025.

The results of the IRP Update analysis demonstrate that the resource targets of the 1996 IRP, factored in with the changed conditions discussed in this report, provide for 100 percent reliability in 2020 and up to 2025 (MWD, 2004). Although the current targets provide 100 percent reliability in 2020 and up to 2025, the IRP Update recommends a 10 percent supply buffer. The "planning buffer" identified additional supplies, both imported and locally developed, that could be implemented to address uncertainty in future supplies and demands. The most significant changed conditions include:

- Lower projected retail demands due primarily to conservation savings.
- Higher projected local water resource development.
- Lower projected dry-year MWD demands.
- Board revised targets for the SWP and Colorado River Aqueduct (CRA).

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- More stringent water quality regulations.
- Recognition of implementation risks.

MWD IRP 2010 Update

In 2008, the MWD and its member agencies updated the 2004 IRP in order to accommodate changed conditions and extend the targets through 2035. The 2010 IRP Update has three main objectives: (1) develop an Emergency Response Plan for hydrologic, regulatory, and other types of uncertainties in the Sacramento-San Joaquin Delta; (2) identify energy-efficient and cost-effective energy management initiatives; and (3) evaluate the reliability of the IRP Preferred Resource Mix through 2035, adjust targets as needed to reflect changed conditions, and extend resource targets through 2035.

The IRP Update modified the resource targets to take into account the changed conditions and recommended buffer. A summary of the 2004 IRP Update and 2010 Update targets are shown in Exhibit 10A.

Exhibit 10A

MWD's IRP Resource Targets

IRP Resource Targets	2004 IRP Update 2025	2010 IRP Update 2025	Change	2010 IRP Update 2035
Conservation	1,107,000	1,412,000	305,000	1,538,000
Local Projects*	750,000	905,000	155,000	926,000
Colorado River Aqueduct **	1,250,000	1,250,000	0	1,250,000
State Water Project	650,000	713,000	63,000	713,000
Groundwater Conjunctive Use	300,000	300,000	0	300,000
Central Valley/State Water Project Storage and Transfers	550,000	1,070,000	520,000	1,092,000
MWD Surface Water Storage***	620,000	620,000	0	620,000

* Includes recycled water, brackish groundwater desalination, and seawater desalination

** Target for specific year types; the CRA is not intended to be full at all times

*** Represents the total amount that can be withdrawn from surface reservoirs

Source: MWD (2010)

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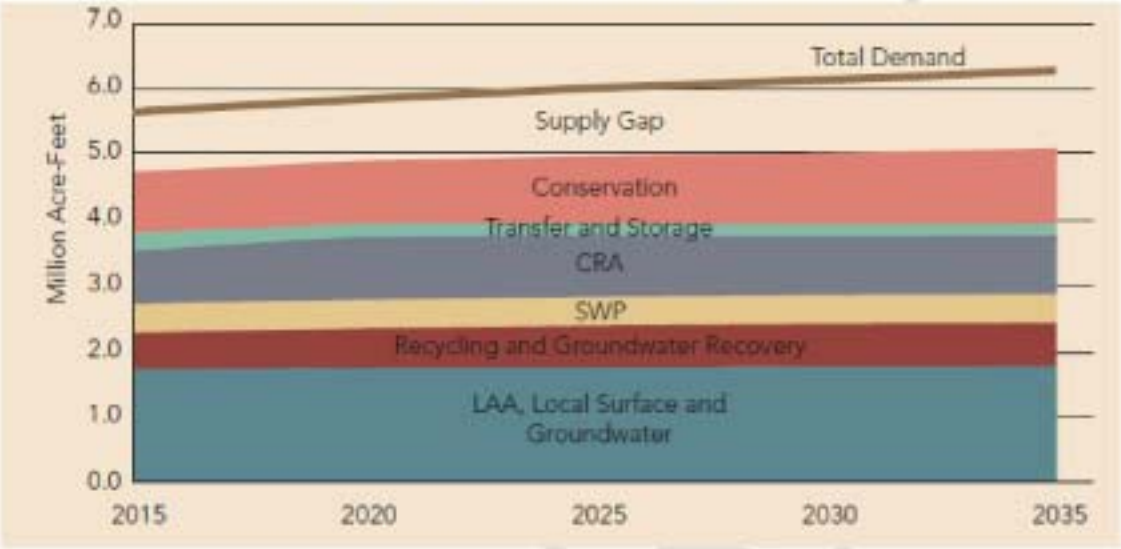
Exhibit 10B shows regional water demands without conservation from 2015 to 2035 under dry weather. The graph also depicts the supply sources and water conservation identified in MWD's 2010 IRP Update.

Exhibit 10B
Meeting Regional Water Needs Through MWD's IRP



Stakeholder Participation

MWD's 1996 IRP was developed in concert with its member agencies. A technical workgroup was established that consisted of MWD staff, member agency and local retail agency managers, and groundwater basin managers. This workgroup met frequently and spent hundreds of hours reviewing analyses and providing guidance. LADWP was an active participant in this workgroup.

To provide more direct involvement of MWD in the IRP Process, the IRP Steering Committee was created. The IRP Steering Committee, consisting of five MWD directors who are also members of the Water Planning and Stewardship Committee, recommended policy options, reviewed proposed resource strategies, and managed public forums.

In addition, regional assemblies were held at critical milestones of the IRP development that provided a platform to collectively discuss strategic direction and regional water solutions. Participants of these assemblies included Board members, water agency managers, local retail water providers, groundwater basin managers, and invited public stakeholders. Public forums and several member agency sponsored workshops attended by stakeholders from business, environmental, agricultural, and water interests were held throughout the IRP process. Finally, findings of the IRP 2010 Update were adopted in October 2010 to a diverse group of stakeholders including elected officials, environmental groups, and the general public.

Agency Coordination

In preparation of MWD's IRP, all member agencies were closely involved, including LADWP. LADWP was involved with providing data and reviewing documents. Additionally, LADWP was an active member of the technical workgroup.

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Funding MWD's IRP

In accordance with MWD's Board adoption of the IRP Update, a revised Long-Range Finance Plan (LRP) was developed and approved by MWD's Board. The LRP (2010) identifies MWD's planned capital improvement program (CIP) and operating expenses from 2015 to 2035.

The following summarizes the MWD's CIP and operating expenses needed to implement the IRP:

- **Core Resources (Fixed costs to maintain Delta habitat conservation and conveyance program, LRP contracts, CRA programs, and conservations funding)** – costs for water supply will increase from the current $853/AF in 2015 to $1,484/AF in 2035.
- **Water Use Efficiency** – costs for water supply will increase from the current $892/AF in 2015 to $1,608/AF in 2035.
- **Capital Expenditures** – costs for water supply will increase from $919/AF in 2015 to $1,844/AF in 2035.
- **Demand Management & Local Projects** – costs from water supply will increase from $953/AF to $2,021/AF in 2035.

IRP Implications for City's Urban Water Management Plan

As LADWP evaluates its water supply options, it is important to understand the significance of a reliable and cost-effective water supply from MWD. The City's water supply reliability is directly linked to MWD's reliability, and LADWP's local supply development uses the cost of MWD water as one of the benchmarks for feasibility evaluation. Through the IRP Update, MWD has shown that it will be able to meet the supplemental needs of all its member agencies reliably through 2035, even during prolonged drought events. MWD has also developed a plan to implement and finance the approved IRP targets.

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DRAFT Chapter Eleven
Water Supply Reliability and Financial Integrity

11.0 Overview

Providing for a reliable water supply in a semiarid climate with wet and dry years is challenging. This is mainly due to the fact that surface water supplies are imported from the LAA and MWD and vary substantially due to hydrology. LADWP has made significant investments in groundwater, recycled water, stormwater capture and water conservation. These supplies provide local water supplies that are more reliable due to variability of imported supply sources.

11.1 Unit Cost and Funding of Supplies

11.1.1 Unit Cost Summary of Supplies

Unit costs play an important role in planning future water supply sources and determining where supply investments provide the greatest benefits to LADWP. Unit costs vary dramatically by water supply sources. Exhibit 11A summarizes the unit cost for each water supply source.

Costs per acre-foot ranged from a high of $1,500 for certain recycled water projects to a low of $215 for locally produced groundwater among LA's existing and planned water supplies. Los Angeles Aqueduct supply has required operation and maintenance costs regardless of water availability. Therefore, hydrology and increased water for environmental commitments in the Eastern Sierras result in unit cost fluctuations year to year. Local groundwater supply is the least expensive source. However, its production is limited by contamination. Unit costs for MWD purchased water vary based on tier allocations. MWD's water rates vary from $484 per AF of tier 1 untreated water to $811 per AF of tier 2 treated water in 2010. LADWP has a Tier 1 allocation of 304,970 AF. Any purchases above this amount will be at the Tier 2 rates. Conservation is relatively inexpensive to offset water supplies that may otherwise be required to meet water demand. Conservation unit costs are based on costs of conservation rebate and incentive programs and their potential water use reduction. Recycled water cost is project specific and varies widely depending on the infrastructure requirements of each project. Water transfers using a future connection between the LAA and the California Aqueduct is planned. Its costs include the purchase price of water and conveyance fees.

Unit costs for potential water supplies including stormwater reuse (harvesting) and increased groundwater production (stormwater recharge) are highly variable based on factors such as the magnitude of the overall program, project locations, etc. Centralized stormwater capture unit cost is based on LADWP's current planned centralized stormwater capture projects and distributed stormwater capture unit costs are from various sources as referenced in Chapter 7, Watershed Management. These projects are joint efforts among agencies, city departments, stakeholders and community groups and yield additional benefits beyond water supply.

Seawater desalination unit costs are based on the estimate from MWD's 2010 IRP. Seawater desalination was a planned supply identified in the 2005 UWMP but is excluded from this 2010 UWMP. Its impacts to marine habitats and high energy consumption make seawater desalination less desirable comparing to options such as recycled water, conservation, and stormwater capture.

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Exhibit 11A
Unit Costs of Supplies

Exhibit 11A		
Water Source	**Chapter Reference**	**Average Unit Cost ($/AF)**
Los Angeles Aqueduct[1]	**Chapter 5 - Los Angeles Aqueduct System**	$563
Groundwater[1]	**Chapter 6 - Local Groundwater**	$215
Metropolitan Water District[2]	**Chapter 8 - Metropolitan Water District Supplies**	$484 - $811
Conservation	**Chapter 3 - Conservation**	$325 - $400
Recycled Water	**Chapter 4 - Recycled Water**	$600 - $1,500
Water Transfer	**Chapter 9 - Other Potential Supplies**	$440 - $540
Stormwater Capture	**Chapter 7 - Watershed Management**	
- Centralized Stormwater Capture		$60 - $200
- Distributed Stormwater Capture		
Urban Runoff Plants		$4,044
Rain Barrels		$701 - $1,875
Cisterns		$2,426
Rain Gardens		$308 - $5,000
Neighborhood Recharge		$3,351
Seawater Desalination	**Chapter 9 - Other Potential Supplies**	$1,300 - $2,000

[1] Los Angeles Aqueduct supply and groundwater supply are based on FY2005-06 to FY2009-10 five-year average.
[2] MWD Water Rates effective on January 1, 2010.

11.1.2 Funding of Supplies

Funding for water resource programs and projects are primarily provided through LADWP water rates, with supplemental funding provided by the Metropolitan Water District (MWD), and state and federal grants. Funding for water conservation, water recycling, and stormwater capture projects has increased significantly in recent years. Currently, approximately $100 million is collected annually through water rates for these initiatives. The current level of annual expenditures is believed to be sufficient to achieve projected goals.

Funding for groundwater cleanup will require water rate increases. LADWP will also seek reimbursement from potential responsible parties to assist with cleanup program costs.

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Water Resource Project Funding

- Water Rates – currently provides approximately $100 million annually for water conservation, water recycling, and stormwater capture programs.
- MWD – Currently provides funding up to $250 per AF for water recycling through their Local Resources Program. MWD also provides some water conservation incentive funding.
- State Funds – Funds for recycling, conservation, and stormwater capture have been available on a competitive basis though voter approved initiatives, such as Propositions 50 and 84. The proposed 2010 Water Bond, approved by the Legislature but not yet placed on the ballot, also includes potential funding for groundwater cleanup. Occasionally low or zero-interest loans are available though State Revolving Fund programs.
- Federal Funds – Funding for recycling may be obtained through periodic Water Resource Development Act legislation. Also, LADWP has received recycled water funds through the Bureau of Reclamation Title XVI program.
- Potentially Responsible Parties – LADWP may be able to recover some costs for groundwater cleanup through potentially responsible parties.

Receipt of state or federal funding will allow water resource goals to be achieved sooner than projected, or allow for increased local supply development.

11.2 Reliability Assessment Under Different Hydrologic Conditions

11.2.1 Los Angeles Aqueducts

Water supply from the LAA can vary substantially from year to year due to hydrology. In very wet years, LAA supply can exceed 500,000 AFY. During average year weather conditions the LAA supply is projected to gradually decrease from 254,000 AFY to 244,000 AFY by 2035 due to climate change impact. Critical dry year (defined as a repeat of a 1990/91 drought) supplies can be as low as 48,520 AFY.

11.2.2 Groundwater

Groundwater is also affected by local hydrology. However, with conjunctive use management of groundwater—storing imported water in the groundwater basins during wet and average years - groundwater production can actually be increased during dry years. During average weather conditions, LADWP projects it will pump approximately between 40,500 AFY and 111,500 AFY of groundwater during the projection period to fiscal year 2035. These projections are based on the Purification Complex in operation in 2018-19 and storage credit of 5,000 AFY is used to maximize the groundwater production thereafter. Although in dry years LADWP can pump larger quantities of groundwater, a more conservative approach was adopted by assuming the same level of projected groundwater production for both single dry year and multi dry year analysis.

11.2.3 Conservation

LADWP has developed conservation goals in the Water Supply Action Plan to decrease water use in the City and to comply with the new State 20 percent by 2020 requirements. Multiple actions will be taken to increase water conservation including education, targeting the CII sector, reducing outdoor water use, and continuing participation in MWD's rebate programs.

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LADWP is planning to increase water conservation levels during the projection period with an increase of over 60,000 AFY between 2010 and 2035, assuming average weather conditions.

11.2.4 Recycled Water

Recycled water is based on wastewater effluent flows, which do not vary significantly due to hydrology. Therefore, recycled water use is mainly limited by system capacities and demands. This makes recycled water a more reliable supply than imported water. As outlined in Chapter 4 on Recycled Water, LADWP is planning an extensive expansion of its recycled water system to not only include expansion of irrigation and industrial uses, but also groundwater replenishment. Under average weather conditions recycled water supply for irrigation and industrial purposes is projected to increase from 20,000 AFY in 2015 to 29,000 AFY in 2035. Groundwater replenishment with recycled water is projected at 30,000 AFY in 2035. For a critical dry year available supplies would not change.

11.2.5 Water Transfers

Water transfers are being developed to replace a portion of the City's Los Angeles Aqueduct water that has been dedicated for environmental enhancement uses in the eastern Sierra Nevada. Water acquired through transfers helps increase water supply reliability for the City. The Los Angeles Aqueduct and California Aqueduct interconnection is under construction and estimated to be completed in January 2013. LADWP is expected to enter into agreements to obtain 40,000 AF per year under average weather conditions beginning in FY2013-14 and continuing throughout the projection period.

11.2.6 MWD Imported Supplies

Historically, water from MWD (like supplies from the LAA) has been subject to severe variability (i.e., 1976/77, 1987-1992, and the current water shortage). This is due to the fact that MWD's core sources of water supply are the Colorado River and SWP, both of which are highly affected by hydrology. More recently restrictions to protect threatened fish species have further decreased pumping from the Bay-Delta, and limiting SWP supplies available to MWD. After the 1987-1992 drought, MWD started to diversify its water supplies. Partnering with its member agencies, MWD launched the IRP in 1993 and most recently updated it in 2010. As a result of the resource targets in the IRP, MWD implemented a variety of projects and programs designed to reduce its dependency on imported water during water shortages and environmental related SWP pumping restrictions. Efforts have included: (1) providing financial incentives for local projects and conservation; (2) increased surface storage via Diamond Valley Lake and use of the SWP terminus reservoirs; (3) groundwater storage programs in the Central Valley, Imperial Valley, and Coachella Valley; (4) short- and long-term water transfers; and (5) contracted groundwater storage programs with participating member agencies.

In the 2010 IRP Update MWD developed a three-part adaptive resource strategy: (1) meet demands by building on existing core resources to provide reliability under foreseen conditions; (2) implement a supply buffer of 10 percent of retail demand through multiple actions to adapt to short-term uncertainty; and (3) implement adaptive management through low-regret foundation actions, monitoring key vulnerabilities and bringing adaptive resources online, if required, and using a comprehensive approach to meet specific needs and degrees of shortages. The 2010 IRP adaptive management concept seeks to mitigate against supply uncertainty to further increase reliability.

The 2010 IRP Update concluded that the resource targets identified in previous updates, taking into consideration changed conditions identified since that time, will continue to provide for 100 percent reliability through 2035. The 2010 RUWMP also concluded the same full reliability through 2035 during average (1922 – 2004 hydrology), single dry (1977 hydrology), and

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multiple dry years (1990 - 1992 hydrology). For each of the scenarios there is a surplus in every forecast year (see Exhibit 11B).

Exhibit 11B
MWD Supply Capability and Projected Demands (in AFY)

Single Dry-Year MWD Supply Capability and Projected Demands					
Fiscal Year	2015	2020	2025	2030	2035
Capability of Current Supplies	2,457,000	2,782,000	2,977,000	2,823,000	2,690,000
Projected Demands	2,171,000	2,162,000	2,201,000	2,254,000	2,319,000
Surplus	286,000	620,000	776,000	569,000	371,000
Supplies under Development	762,000	862,000	1,036,000	1,036,000	1,036,000
Potential Surplus	1,048,000	1,482,000	1,812,000	1,605,000	1,407,000
Multiple Dry-Year MWD Supply Capability and Projected Demands					
Fiscal Year	2015	2020	2025	2030	2035
Capability of Current Supplies	2,248,000	2,417,000	2,520,000	2,459,000	2,415,000
Projected Demands	2,236,000	2,188,000	2,283,000	2,339,000	2,399,000
Surplus	12,000	229,000	237,000	120,000	16,000
Supplies under Development	404,000	553,000	733,000	755,000	755,000
Potential Surplus	416,000	782,000	970,000	875,000	771,000
Average Year MWD Supply Capability and Projected Demands					
Fiscal Year	2015	2020	2025	2030	2035
Capability of Current Supplies	3,485,000	3,810,000	4,089,000	3,947,000	3,814,000
Projected Demands	2,006,000	1,933,000	1,985,000	2,049,000	2,106,000
Surplus	1,479,000	1,877,000	2,104,000	1,898,000	1,708,000
Supplies under Development	588,000	689,000	1,051,000	1,051,000	1,051,000
Potential Surplus	2,067,000	2,566,000	3,155,000	2,949,000	2,759,000

Source: MWD 2010 Regional Urban Water Management Plan Tables 2-9 to 2-11

As part of the implementation of MWD's IRP, MWD and its member agencies worked together to develop MWD's Water Surplus and Drought Management Plan (WSDM Plan) in 1999. The WSDM Plan established broad water resource management strategies to ensure MWD's ability to meet full service demands at all times and provides principles for supply allocation if the need should ever arise. The WSDM Plan splits MWD's resource actions into two major categories: Surplus Actions and Shortage Actions. The Shortage Actions of the WSDM Plan are split into three sub-categories: Shortage, Severe Shortage, and Extreme Shortage. Under Shortage conditions, MWD will make withdrawals from storage and interrupt long-term groundwater basin replenishment deliveries. Under Severe Shortage conditions, MWD will call for extraordinary drought conservation in the form of voluntary savings from retail customers, interrupt 30 percent of deliveries to Agricultural Water Program users, call on its option transfer water, and purchase water on the spot market. Under Extreme Shortage conditions, MWD will equitably allocate supplies to its member agencies on the basis of agencies' needs. The overall objective of MWD's IRP and WSDM Plan is to ensure that shortage allocations of MWD water supplies are not required.

If shortage allocations are required, MWD will rely on the calculations established in its Water Supply Allocation Plan (WSAP) adopted in 2008. The plan equitably allocates shortages among its member agencies based on growth, local investments, changes in supply conditions, demand hardening, and water conservation programs for each of its member agencies.

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11.2.7 Potential Supplies

Other planned and potential water supplies that LADWP is exploring include capturing stormwater for reuse and infiltration leading to increased groundwater production (see Chapter 7). Development of these supplies will offset water purchased from MWD. The beneficial reuse of stormwater presents significant opportunity. The City must reduce pollutants in impaired receiving waters (rivers, creeks, and beaches in the Santa Monica and Los Angeles watersheds) as required by the Clean Water Act. By managing urban runoff during dry and wet periods, pollution will be reduced. Traditional ways of managing urban runoff would be to divert the runoff into existing wastewater treatment plants and/or build satellite treatment plants specifically designed to treat urban runoff.

During the City's IRP process, stakeholders expressed the desire to examine other ways to manage runoff that would reduce pollution and provide for other benefits such as water supply and open space. These methods involve local and regional storage of wet weather runoff for groundwater infiltration, on-site storage and recovery of wet weather runoff for irrigation using cisterns and other devices, and reuse of treated dry weather effluent for irrigation (much like recycled water). As an outgrowth of the IRP, neighborhood recharge concept efforts are moving from the conceptual stage visualized in the IRP to actual projects in the City to infiltrate wet weather runoff as close as possible to the point of origin with multiple projects either complete, under construction, or in final design.

Under average weather conditions LADWP is projecting stormwater capture and reuse in 2015 will potentially be 2,000 AFY increasing to 10,000 AFY by 2035. Increased groundwater production as a result of stormwater infiltration will potentially be 15,000 AFY in 2035. This potential is contingent on modifying the court judgment. If these resources reach fruition, LADWP will be able to reduce imported demands on MWD by 25,000 AFY in 2035 under average weather conditions.

11.2.8 Service Area Reliability Assessment

To determine the overall service area reliability, LADWP defined three hydrologic conditions: average (or normal weather); single dry year (such as a repeat of the 1990/91 drought); and multi-dry year period (such as a repeat of FY1988-89 to FY1992-93).

The water supply reliability summaries are shown in Exhibit 11C for the 5-year average from FY 2005-06 to FY 2009-10 and in Exhibit 11 D for FY 2034-35 under average weather conditions with new water conservation shown as a supply source. The exhibits show that the City's reliance on MWD supply will decrease from 52 percent to 24 percent by FY 2034-35 while the combined imported supplies of LAA and MWD water will decrease from 88 percent to 57 percent by FY 2034-35. The locally-developed supplies will increase from 12 percent to 43 percent by FY 2034-35.

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Exhibit 11C
LADWP Supply Reliability FYE 2006-2010 Average

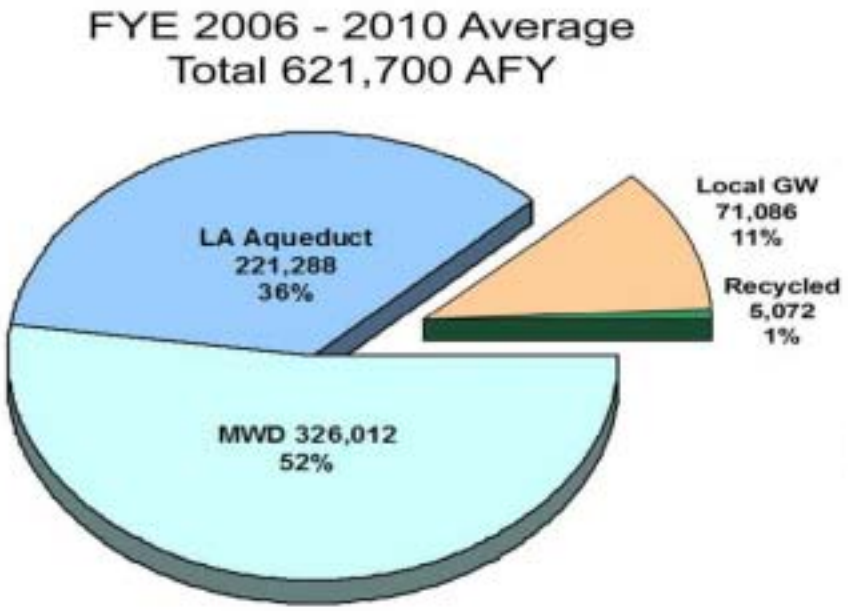
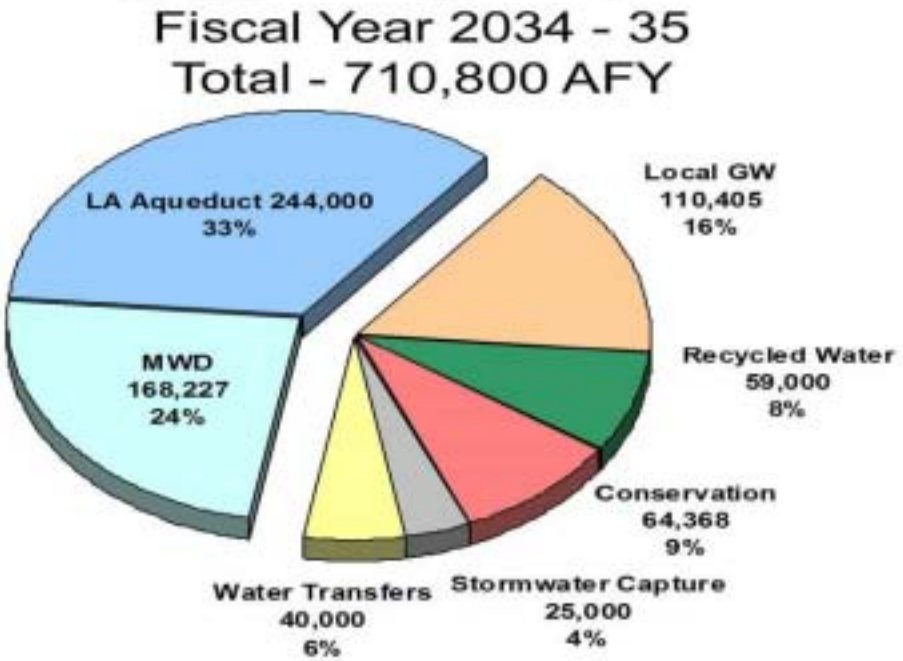


Exhibit 11D
LADWP Supply Reliability Under Average Weather Conditions in Fiscal Year 2034-35



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Exhibits 11E and 11F tabulate the service reliability assessment for normal and single dry year conditions, respectively. Exhibits 11G through 11K show reliability assessments in five year increments from 2010 to 2035 with each five year period assuming that a multiple dry year condition occurs. For these reliability tables, existing water conservation has been already subtracted from projected demands, but new water conservation is included as a supply source. Under all scenarios all demands are met by the available supplies.

Exhibit 11E
Service Area Reliability Assessment for Average Weather Year

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Average Weather Conditions Fiscal Year Ending on June 30				
		2015	2020	2025	2030	2035
Total Demand	**554,140**	**614,800**	**652,000**	**675,600**	**701,200**	**710,800**
Existing / Planned Supplies						
Los Angeles Aqueduct[1]	199,739	252,000	250,000	248,000	246,000	244,000
Groundwater[2]	76,982	40,500	96,300	111,500	111,500	110,405
Conservation	8,178	14,180	27,260	40,340	53,419	64,368
Recycled Water						
- Irrigation and Industrial Use	6,703	20,000	20,400	27,000	29,000	29,000
- Groundwater Replenishment	0	0	0	15,000	22,500	30,000
Water Transfers	0	40,000	40,000	40,000	40,000	40,000
Subtotal	291,602	366,680	433,960	481,840	502,419	517,773
MWD Water Purchases						
With Existing/Planned Supplies	262,538	248,120	218,040	193,760	198,781	193,027
Total Supplies	**554,140**	**614,800**	**652,000**	**675,600**	**701,200**	**710,800**
Potential Supplies						
Stormwater Capture						
- Capture and Reuse (Harvesting)	0	2,000	4,000	6,000	8,000	10,000
- Increased Groundwater Production (Recharge)	0	0	2,000	4,000	8,000	15,000
Subtotal	0	2,000	6,000	10,000	16,000	25,000
MWD Water Purchases						
With Existing/Planned/Potential Supplies	262,538	246,120	212,040	183,760	182,781	168,027
Total Supplies	**554,140**	**614,800**	**652,000**	**675,600**	**701,200**	**710,800**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11F
Service Area Reliability Assessment for Single Dry Year

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Single Dry Year (FY1990-91) Fiscal Year Ending on June 30				
		2015	2020	2025	2030	2035
Total Demand	**554,140**	**651,700**	**691,100**	**716,100**	**743,200**	**753,400**
Existing / Planned Supplies						
Los Angeles Aqueduct[1]	199,739	48,520	46,120	47,720	47,330	46,940
Groundwater[2]	76,982	40,500	96,300	111,500	111,500	110,405
Conservation	8,178	14,180	27,260	40,340	53,419	64,368
Recycled Water						
- Irrigation and Industrial Use	6,703	20,000	20,400	27,000	29,000	29,000
- Groundwater Replenishment	0	0	0	15,000	22,500	30,000
Water Transfers	0	40,000	40,000	40,000	40,000	40,000
Subtotal	291,602	163,200	232,080	281,560	303,749	320,713
MWD Water Purchases						
With Existing/Planned Supplies	262,538	488,500	459,020	434,540	439,451	432,687
Total Supplies	**554,140**	**651,700**	**691,100**	**716,100**	**743,200**	**753,400**
Potential Supplies						
Stormwater Capture						
- Capture and Reuse (Harvesting)	0	2,000	4,000	6,000	8,000	10,000
- Increased Groundwater Production (Recharge)	0	0	2,000	4,000	8,000	15,000
Subtotal	0	2,000	6,000	10,000	16,000	25,000
MWD Water Purchases						
With Existing/Planned/Potential Supplies	262,538	486,500	453,020	424,540	423,451	407,687
Total Supplies	**554,140**	**651,700**	**691,100**	**716,100**	**743,200**	**753,400**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11G
Service Area Reliability Assessment for Multi-Dry Years (2011-2015)

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
		2011	2012	2013	2014	2015
Total Demand	**554,140**	**588,900**	**607,300**	**626,000**	**602,700**	**627,100**
Existing / Planned Supplies						
Los Angeles Aqueduct[1]	199,739	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	76,982	61,090	53,660	46,260	47,300	40,500
Conservation	8,178	5,670	7,310	8,950	11,560	14,180
Recycled Water						0
- Irrigation and Industrial Use	6,703	7,500	8,300	9,000	15,500	20,000
- Groundwater Replenishment	0	0	0	0	0	0
Water Transfers	0	0	0	40,000	40,000	40,000
Subtotal	291,602	160,590	167,830	152,730	208,720	220,450
MWD Water Purchases						
With Existing/Planned Supplies	262,538	428,310	439,470	473,270	393,980	406,650
Total Supplies	**554,140**	**588,900**	**607,300**	**626,000**	**602,700**	**627,100**
Potential Supplies						
Stormwater Capture						
- Capture and Reuse (Harvesting)	0	0	0	0	0	2,000
- Increased Groundwater Production (Recharge)	0	0	0	0	0	0
Subtotal	0	0	0	0	0	2,000
MWD Water Purchases						
With Existing/Planned/Potential Supplies	262,538	428,310	439,470	473,270	393,980	404,650
Total Supplies	**554,140**	**588,900**	**607,300**	**626,000**	**602,700**	**627,100**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11H
Service Area Reliability Assessment for Multi-Dry Years (2016-2020)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2016	2017	2018	2019	2020
Total Demand	**647,100**	**661,200**	**675,400**	**644,600**	**665,100**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	37,350	37,350	37,350	42,280	96,300
Conservation	16,800	19,410	22,030	24,640	27,260
Recycled Water					0
- Irrigation and Industrial Use	20,000	20,200	20,300	20,400	20,400
- Groundwater Replenishment	0	0	0	0	0
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	200,480	215,520	168,200	221,680	289,730
MWD Water Purchases					
With Existing/Planned Supplies	446,620	445,680	507,200	422,920	375,370
Total Supplies	**647,100**	**661,200**	**675,400**	**644,600**	**665,100**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	2,400	2,800	3,200	3,600	4,000
- Increased Groundwater Production (Recharge)	400	800	1,200	1,600	2,000
Subtotal	2,800	3,600	4,400	5,200	6,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	443,820	442,080	502,800	417,720	369,370
Total Supplies	**647,100**	**661,200**	**675,400**	**644,600**	**665,100**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11I
Service Area Reliability Assessment for Multi-Dry Years (2021-2025)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2021	2022	2023	2024	2025
Total Demand	**683,000**	**694,500**	**706,100**	**670,900**	**689,100**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	111,500	111,500	111,500	111,500	111,500
Conservation	29,880	32,490	35,110	37,720	40,340
Recycled Water					0
- Irrigation and Industrial Use	20,400	21,000	23,000	25,000	27,000
- Groundwater Replenishment		15,000	15,000	15,000	15,000
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	288,110	318,550	273,130	323,580	339,610
MWD Water Purchases					
With Existing/Planned Supplies	394,890	375,950	432,970	347,320	349,490
Total Supplies	**683,000**	**694,500**	**706,100**	**670,900**	**689,100**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	4,400	4,800	5,200	5,600	6,000
- Increased Groundwater Production (Recharge)	2,400	2,800	3,200	3,600	4,000
Subtotal	6,800	7,600	8,400	9,200	10,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	388,090	368,350	424,570	338,120	339,490
Total Supplies	**683,000**	**694,500**	**706,100**	**670,900**	**689,100**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11J
Service Area Reliability Assessment for Multi-Dry Years (2026-2030)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2026	2027	2028	2029	2030
Total Demand	**707,900**	**720,100**	**732,400**	**696,100**	**715,200**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	111,500	111,500	111,500	111,500	111,500
Conservation	42,960	45,570	48,190	50,800	53,420
Recycled Water					0
- Irrigation and Industrial Use	27,500	28,000	28,500	29,000	29,000
- Groundwater Replenishment	16,500	18,000	19,500	21,000	22,500
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	324,790	341,630	296,210	346,660	362,190
MWD Water Purchases					
With Existing/Planned Supplies	383,110	378,470	436,190	349,440	353,010
Total Supplies	**707,900**	**720,100**	**732,400**	**696,100**	**715,200**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	6,400	6,800	7,200	7,600	8,000
- Increased Groundwater Production (Recharge)	4,800	5,600	6,400	7,200	8,000
Subtotal	11,200	12,400	13,600	14,800	16,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	371,910	366,070	422,590	334,640	337,010
Total Supplies	**707,900**	**720,100**	**732,400**	**696,100**	**715,200**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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Exhibit 11K
Service Area Reliability Assessment for Multi-Dry Years (2031-2035)

Demand and Supply Projections (in acre-feet)	Multiple Dry Years (FY1988-89 to FY1992-93) Fiscal Year Ending on June 30				
	2031	2032	2033	2034	2035
Total Demand	**731,200**	**740,300**	**749,300**	**708,800**	**725,000**
Existing / Planned Supplies					
Los Angeles Aqueduct[1]	86,330	98,560	48,520	94,360	105,770
Groundwater[2]	110,405	110,405	110,405	110,405	110,405
Conservation	55,600	57,800	60,000	62,200	64,368
Recycled Water					0
- Irrigation and Industrial Use	29,000	29,000	29,000	29,000	29,000
- Groundwater Replenishment	24,000	25,500	27,000	28,500	30,000
Water Transfers	40,000	40,000	40,000	40,000	40,000
Subtotal	345,335	361,265	314,925	364,465	379,543
MWD Water Purchases					
With Existing/Planned Supplies	385,865	379,035	434,375	344,335	345,457
Total Supplies	**731,200**	**740,300**	**749,300**	**708,800**	**725,000**
Potential Supplies					
Stormwater Capture					
- Capture and Reuse (Harvesting)	8,400	8,800	9,200	9,600	10,000
- Increased Groundwater Production (Recharge)	9,400	10,800	12,200	13,600	15,000
Subtotal	17,800	19,600	21,400	23,200	25,000
MWD Water Purchases					
With Existing/Planned/Potential Supplies	368,065	359,435	412,975	321,135	320,457
Total Supplies	**731,200**	**740,300**	**749,300**	**708,800**	**725,000**

[1] Los Angeles Aqueduct supply is estimated to decrease 0.1652% per year due to climate change impact.

[2] North Hollywood/Rinaldi-Toluca Treatment Complex is expected in operation in 2019-20. Tujunga Groundwater Treatment Plant is expected in operation in 2020-21. Storage credit of 5,000 afy will be used to maximize the pumping in 2020-21 and thereafter. Sylmar Basin production was increased to 4,500 AFY from 2014-15 to 2029-30 to avoid the expiration of stored water credits, then go back to its entitlement of 3,405 AFY in 2030-31.

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11.3 Water Shortage Contingency Plan

The Los Angeles City Municipal Code Chapter XII, Article I, Emergency Water Conservation Plan is the City's water shortage contingency plan. It was developed to provide for a sufficient and continuous supply of water in case of a water supply shortage in the service area. There are two scenarios that can cause a water shortage: 1) a severe hydrologic drought affecting surface and groundwater supplies and 2) a catastrophic event that severs major conveyance and/or distribution pipelines serving water to the City. The following discusses LADWP's compliance with the Act as outlined in Section 10632 (a) through (i) of the California Water Code.

11.3.1 Stages of Action – 10632 (a)

As set forth in the Emergency Water Conservation Plan, the City has phases or stages of action that can be undertaken in response to water supply shortages. Phase I prohibited uses of water are in effect at all times within the City. These prohibited uses, defined in article 10632 (d) (see section 11.3.4), are intended to eliminate waste and increase public awareness of the need to conserve water. There are further stages of compounding actions in addition to the Phase I prohibited uses that might be imposed. Phase II to Phase V progressively responds to different severity of shortage with the authority to implement additional prohibited uses of water in Phase V in order to cope with up to a 50 percent reduction in water supply. They are described as follows:

Moderate Shortage, Phase II

1. Should Phase II be implemented, uses applicable to Phase I shall continue to be applicable, except as specifically provided herein.

2. No landscape irrigation shall be permitted on any day other than Monday, Wednesday, or Friday for odd-numbered street addresses and Tuesday, Thursday, or Sunday for even-numbered street addresses. Street addresses ending in ½ or any fraction shall conform to the permitted uses for the last whole number in the address. Watering times shall be limited to: (a) Non-conserving nozzles (spray head sprinklers and bubblers) – no more than eight minutes per watering day per station for a total of 24 minutes per week; (b) Conserving nozzles (standard rotors and multi-stream rotary heads) – no more than 15 minutes per cycle and up to two cycles per watering day per station for a total of 90 minutes per week.

3. Upon written notice to LADWP, irrigation of sports fields may deviate from non-watering days to maintain play areas and accommodate event schedules; however, to be eligible for this means of compliance, a customer must reduce his overall monthly water use by LADWP's Board of Water and Power Commissioner's (Board) adopted degree of shortage plus an additional 5 percent from the customer baseline water usage within 30 days.

4. Upon written notice to LADWP, large landscape areas may deviate from the non-watering days by meeting the following requirements (1) must have approved weather-based irrigation controllers registered with LADWP (eligible weather-based irrigation controllers are those approved by MWD or the Irrigation Association Smart Water Application Technologies (SWAT) initiative (2) must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus an additional 5 percent from the customer baseline water usage within 30 days; and (3) must use recycled water if it is available from LADWP.

5. These provisions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase II except between the hours of 9:00 am and 4:00 pm.

Severe Shortage, Phase III

1. Should Phase III be implemented, uses applicable to Phases I and II shall continue to be applicable, except as specifically provided herein.

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2. No landscape irrigation shall be permitted on any day other than Monday for odd-numbered street addresses and Tuesday for even-numbered street addresses. Street addresses ending in ½ or any fraction shall conform to the permitted uses for the last whole number in the address.

3. No washing of vehicles allowed except at commercial car wash facilities.

4. No filling of residential swimming pools and spas with potable water.

5. Upon written notice to LADWP, irrigation of sports fields may deviate from the specific non-watering days and be granted one additional water day (for a total of two watering days allowed). To be eligible for this means of compliance, a customer must reduce his overall monthly water use by LADWP's Board's adopted degree of shortage plus an additional 10 percent from the customer baseline water usage within 30 days.

6. Upon written notice to LADWP, large landscape areas may deviate from the specific non-watering days and be granted one additional watering day (for a total of two watering days allowed) by meeting the following requirements (1) must have approved weather-based irrigation controllers registered with LADWP (eligible weather-based irrigation controllers are those approved by MWD or the Irrigation Association Smart Water Application Technologies (SWAT) initiative (2) must reduce overall monthly water use by LADWP's Board adopted degree of shortage plus an additional 10 percent from the customer baseline water usage within 30 days; and (3) must use recycled water if it is available from LADWP.

7. These provisions do not apply to drip irrigation supplying water to a food source or to hand-held hose watering of vegetation, if the hose is equipped with a self-closing water shut-off device, which is allowed everyday during Phase III except between the hours of 9:00 am and 4:00 pm.

Critical Shortage, Phase IV

1. Should Phase IV be implemented, uses applicable to Phases I, II, and III shall continue to be applicable, except as specifically provided herein.

2. No landscape irrigation allowed.

Super Critical Shortage, Phase V

1. Phase I, II, III, and IV shall continue to remain in effect.

2. The Board is hereby authorized to implement additional prohibited uses of water based on the water supply situation. Any additional prohibitions shall be published at least once in a daily newspaper of general circulation and shall become effective immediately upon such publication and shall remain in effect until cancelled.

11.3.2 Driest Three-Year Supply – 10632 (b)

In the event that three consecutive dry-years curtailing the City's LAA System deliveries should follow the 2010 water supply conditions, LADWP will rely on increased groundwater pumping and purchases from MWD to meet City water demands. This particular sequence is quantified in Exhibit 11L, including relevant assumptions.

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Exhibit 11L
Driest Three-Year Water Supply Sequence

Demand and Supply Projections (in acre-feet)	FY2009-10 Actual	Followed by Repeat of Driest Three Consecutive Years FY1958-59 to 1960-61 Hydrology Fiscal Year Ending on June 30		
		2011	2012	2013
Total Demand	**554,140**	**588,900**	**607,300**	**626,000**
Existing / Planned Supplies				
Los Angeles Aqueduct[1]	199,739	104,530	50,849	59,382
Groundwater[2]	76,982	61,090	53,660	46,260
Conservation	8,178	5,670	7,310	8,950
Recycled Water				
- Irrigation and Industrial Use	6,703	7,500	8,300	9,000
- Groundwater Replenishment	0	0	0	0
Water Transfers	0	0	0	40,000
Subtotal	291,602	178,790	120,119	163,592
MWD Water Purchases				
With Existing/Planned Supplies	262,538	410,110	487,181	462,408
Total Supplies	**554,140**	**588,900**	**607,300**	**626,000**

1. Driest three consecutive years on record in LAA watershed (FY1958-59 to FY1960-61) averaged 28 percent of normal runoff.
2. LAA deliveries reflect increased releases for environmental restoration in the Owens Valley and Mono Basin.
3. Dry year demands are 5 percent greater than normal year demands
4. MWD's Water Surplus and Drought Management Plan actions sufficient to meet LADWP demands.

During such severe drought periods, the City's supplemental water supplier, MWD, may use an allocation strategy that is consistent with the framework developed in its Water Surplus and Drought Management (WSDM) Plan. Developed by MWD with substantial input from its member agencies, the WSDM Plan provides for a needs-based allocation strategy, and establishes priorities for the use of MWD's water supplies to achieve 100 percent retail reliability.

Following are actions that could be taken by MWD in accordance with their WSDM Plan to augment its water supplies prior to implementation of any drought allocation action:

1. Draw on Diamond Valley Lake storage
2. Draw on out-of-region storage in Semitropic and Arvin-Edison Groundwater Banks
3. Reduce/suspend local groundwater replenishment deliveries
4. Draw on contractual groundwater storage programs in MWD's service area

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5. Draw on State Water Project terminal reservoir storage (per Monterey Agreement)
6. Call for voluntary conservation and public education
7. Reduce deliveries from MWD's Interim Agricultural Water Program
8. Call on water transfer options contracts
9. Purchase transfers on the spot market
10. Allocate imported water if necessary

In 2008 MWD adopted the Water Supply Allocation Plan (WSAP) designed to allocate supplies among its member agencies in a fair and efficient manner. The WSAP establishes the formula for calculating member agency allocations if MWD cannot meet firm demands in a given year.

11.3.3 Catastrophic Supply Interruption Plan – 10632 (c)

LADWP has Emergency Response Plans (ERPs revised January 2010) in place to restore water service for essential use in the City if a disaster should result in the temporary interruption of water supply. Department personnel responsible for water transportation, distribution, and treatment have established ERPs to guide the assessment, prioritization, and repair process of City facilities that have incurred damage during a disaster. Citywide, an Emergency Operations Center (EOC) serves as a centralized point for citywide management of information about disasters and for coordination of all available resources. The EOC supports the City's Emergency Operations Organization to achieve its mission of saving lives, protecting property, and returning the City to normal operations in the event of a disaster. LADWP coordinates its efforts with the EOC and will utilize the EOC to resume water supply service after a catastrophic event.

11.3.4 Mandatory Water Use Prohibitions – 10632 (d)

Phase I prohibited uses of the Emergency Water Conservation Plan contain 13 wasteful water use practices that are permanently prohibited for all City of Los Angeles customers. These prohibited uses are intended to eliminate waste and increase public awareness of the need to conserve water. During times of shortage, education and enforcement of the following provisions will be increased:

1. No customer shall use a water hose to wash any paved surfaces including, but not limited to, sidewalks, walkways, driveways, and parking areas, except to alleviate immediate safety or sanitation hazards. This section shall not apply to LADWP approved water conserving spray cleaning devices. Use of water pressure devices for graffiti removal is exempt. A simple spray nozzle does not qualify as a water conserving spray cleaning device.
2. No customer shall use water to clean, fill, or maintain levels in decorative fountains, ponds, lakes, or similar structures used for aesthetic purposes unless such water is part of a recirculating system.
3. No restaurant, hotel, cafe, cafeteria, or other public place where food is sold, served, or offered for sale shall serve drinking water to any person unless expressly requested.
4. No customer shall permit water to leak from any pipe or fixture on the customer's premises; failure or refusal to affect a timely repair of any leak of which the customer knows or has reason to know shall subject said customer to all penalties

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for a prohibited use of water.

5. No customer shall wash a vehicle with a hose if the hose does not have a self-closing water shut-off device or device attached to it, or otherwise to allow a hose to run continuously while washing a vehicle.

6. No customer shall irrigate during periods of rain.

7. No customer shall water or irrigate lawn, landscape, or other vegetated areas between the hours of 9:00 a.m. and 4:00 p.m. During these hours, public and private golf courses greens and tees and professional sports fields may be irrigated in order to maintain play areas and accommodate event schedules. Supervised testing or repairing of irrigation systems is allowed anytime with proper signage.

8. All irrigating of landscape with potable water using spray head sprinklers and bubblers shall be limited to no more than ten minutes per watering station per day. All irrigating of landscape with potable water using standard rotors and multi-stream rotary heads shall be limited to no more than fifteen minutes per cycle and up to two cycles per watering day per station. Exempt from these irrigation restrictions are irrigation systems using very low drip type irrigation when no emitter produces more than four gallons of water per hour and micro-sprinklers using less than fourteen gallons per hour. This provision does not apply to Schedule F water customers or water service water service that has been granted the General Provision M rate adjustment under the City's Water Rates Ordinance, subject to the Customer having complied with best management practices for irrigation approved by the Department. The 9:00 a.m. to 4:00 p.m. irrigation restriction shall apply unless specifically exempt as stated in subsection 7 of the Emergency Water Conservation Ordinance.

9. No customer shall water or irrigate any lawn, landscape, or other vegetated area in a manner that causes or allows excess or continuous flow or runoff onto an adjoining sidewalk, driveway, street, gutter, or ditch.

10. No installation of single pass cooling systems shall be permitted in buildings requesting new water service.

11. No installation of non-recirculating systems shall be permitted in new conveyor car wash and new commercial laundry systems.

12. Operators of hotels and motels shall provide guests with the option of choosing not to have towels and linens laundered daily. The hotel or motel shall prominently display notice of this option in each bathroom using clear and easily understood language. LADWP shall make suitable displays available.

13. No large landscape areas shall have irrigation systems without rain sensors that shut-off the irrigation systems. Large landscape areas with approved weather-based irrigation controllers registered with LADWP are in compliance with this requirement.

11.3.5 Consumption Reduction Methods during Water Shortages – 10632 (e)

Short-Term Actions

During a water shortage or emergency condition, LADWP's existing rate structure (enacted in 1993) serves as a basis for further reducing consumption. First tier water allotments are reduced during shortages by the degree of the shortage. For single-family residential users, the adjusted first tier allotments apply for the entire year. For other users, the adjusted first tier allotments apply only during the high season (June 1 through October 31). Details of LADWP's water rate structure are provided in Appendix X – Water Rate Ordinance.

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Additional measures can be phased in as the dry cycle continues to provide some immediate demand reductions and increase public awareness of the need to conserve water. Included among these measures are water conservation public service announcements (through television and/or radio), billboard ads, flyer distributions, and conservation workshops. LADWP also actively participates in public exhibits to disseminate water conservation information within its service area. Conservation is a permanent and long-term application used within the City to counter the potentially adverse impacts of water supply shortages.

State law further regulates distribution of water in extreme water shortage conditions. Section 350-354 of the California Water Code states that when a governing body of a distributor of a public water supply declares a water shortage emergency within its service area, water will be allocated to meet needs for domestic use, sanitation, fire protection, and other priorities. This will be done equitably and without discrimination between customers using water for the same purpose(s).

Long-Term Actions

LADWP's long-range water conservation program is driven by the need to continuously increase water use efficiency. This will reduce demand, extend supply, and therefore, provide greater reliability. Dry cycle experiences, public trust responsibilities, and regulatory mandates have raised the level of awareness within the City of Los Angeles of the need to approach demand reduction from a permanent and long-term perspective.

LADWP will continue to maintain and increase its existing conservation programs and pursue the development of new and innovative programs as outlined in Chapter 3, Water Conservation with the goal of reducing potable water demands by 60,000 AFY by 2035. Emphasis continues to be placed on structural conservation for the residential and CII sectors (HETs, high-efficiency washing machine rebates, etc.) which result in permanent per capita water use reduction. Substantial efforts are also being placed on landscape water use efficiency and CII conservation opportunities. It should, however, be recognized that the ability to achieve water reduction during shortages by requesting additional voluntary measures is likely to be more difficult in the future. As customers adjust to a conservation ethic and adopt permanent measures to reduce water use, their water demands harden and become less susceptible to voluntary conservation.

11.3.6 Penalties for Excessive Use (Non-Compliance to Prohibited Use) – 10632 (f)

The Emergency Water Conservation Plan sets penalties for violations of prohibited uses outlined in Sections 10632 (a) and (d). The penalties vary by water meter size. For water meters smaller than two inches the following penalties shall apply:

1. The first violation consists of a written warning

2. The second violation within the preceding 12 month period will result in a surcharge in the amount of $100 added to the customer's water bill.

3. The third violation within the preceding 12 month period will result in a surcharge in the amount of $200 added to the customer's water bill.

4. The fourth violation within the preceding 12 month period will result in a surcharge in the amount of $300 added to the customer's water bill.

5. After a fifth violation or subsequent violation within the preceding 12 month period, LADWP may install a flow-restricting device of 1 gpm capacity for services up to 1 ½ inches in size and comparatively sized restrictors for larger services or

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terminate a customer's service, in addition to the aforementioned financial surcharges. Such action shall only be taken after a hearing held by LADWP.

For water meters two inches and larger the following penalties shall apply:

1. The first violation consists of a written warning
2. The second violation within the preceding 12 month period will result in a surcharge in the amount of $200 added to the customer's water bill.
3. The third violation within the preceding 12 month period will result in a surcharge in the amount of $400 added to the customer's water bill.
4. The fourth violation within the preceding 12 month period will result in a surcharge in the amount of $600 added to the customer's water bill.
5. After a fifth violation or subsequent violation within the preceding 12 month period, LADWP may install a flow-restricting device or terminate a customer's service, in addition to the aforementioned financial surcharges. Such action shall only be taken after a hearing held by LADWP.

11.3.7 Analysis and Effects on Revenues and Expenditures of Reduced Sales during Shortages – 10632 (g)

The City's Water Rate Ordinance, adopted in June 1995 and last amended in June 2008, provides a remedy to the impact of reduced water sales on revenues in the form of a Water Revenue Adjustment Factor (Adjustment). The Adjustment recovers any shortage in revenue due to variation in water sales. It is intended to support a fiscal year revenue target that is deemed sufficient to cover LADWP's essential expenses. The formula takes into account target and actual revenues as well as projected water sales to determine the appropriate Adjustment.

The Adjustment is currently limited to $.18 per hundred-cubic-feet. It cannot exceed this limit unless the Board determines that a surcharge in excess of $0.18 per hundred-cubic-feet is financially required and approval from the Los Angeles City Council is obtained. The Board also has the authority to reduce the factor to less than the formula-calculated amount.

A billing factor is calculated annually on January 1 and is added to the standard commodity charge. The factor is set to zero if a negative value is calculated. A Water Revenue Adjustment Account is maintained and updated each month by LADWP. This account is adjusted annually on July 1.

The City's Water Revenue Adjustment Factor ensures that the required funds are available to fund Department activities aimed at providing continuous water service to Los Angeles water users, even during periods of low water sales.

11.3.8 Water Shortage Contingency Resolution or Ordinance – 10632 (h)

A draft water shortage contingency resolution is shown in Exhibit 11M. Moreover, the City's Emergency Water Conservation Plan Section 121.07.B has the following conservation phase implementation procedures:

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"The Department (LADWP) shall monitor and evaluate the projected supply and demand for water by its Customers monthly, and shall recommend to the Mayor and Council by concurrent written notice the extent of the conservation required by the Customers of the Department in order for the Department to prudently plan for and supply water to its Customers. The Mayor shall, in turn, independently evaluate such recommendation and notify the Council of the Mayor's determination as to the particular phase of water conservation, Phase I through Phase V, that should be implemented. Thereafter, the Mayor may, with the concurrence of the Council, order that the appropriate phase of water conservation be implemented in accordance with the applicable provisions of this Article. Said order shall be made by public proclamation and shall be published one time only in a daily newspaper of general circulation and shall become effective immediately upon such publication. The prohibited water uses for each phase shall take effect with the first full billing period commencing on or after the effective date of the public proclamation by the Mayor. In the event the Mayor independently recommends to the Council a phase of conservation different from that recommended by the Department, the Mayor shall include detailed supporting data and the reasons for the independent recommendation in the notification to the Council of the Mayor's determination as to the appropriate phase of conservation to be implemented."

The City's Water Rate Ordinance No. 170435 also has specific provisions for LADWP's Board, through a resolution, to determine the degree of shortage and apply corresponding commodity charges in case of a water shortage (see Section 11.3.5 and Appendix X – Water Rate Ordinance). If a water shortage is declared, certified copies of the resolution will be transmitted to the offices of the Mayor and of the Los Angeles City Clerk, and the Los Angeles City Council for final approval. This particular water shortage act is included under Section 3 – General Provisions, Article R – Shortage Year Rates of the City's Water Rate Ordinance.

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Exhibit 11M
Draft Water Shortage Contingency Resolution

BE IT RESOLVED that the Board of Water and Power Commissioners (Board) recognizes that a Water Shortage Contingency Plan has been prepared and incorporated into the City of Los Angeles 2010 Urban Water Management Plan pursuant to the Urban Water Management Planning Act; the Urban Water Management Plan is on file with the Secretary of the Board; this Board has reviewed and considered the information and recommendations contained in this document, and makes the following findings and determinations:

1. The water supply available to the City of Los Angeles is insufficient to meet the City's normal water supply needs; and
2. The Department of Water and Power has developed a Water Shortage Contingency Plan for the City of Los Angeles that compiles with all the requirements of the Urban Water Management Planning Act; and
3. The Urban Water Management Plan has been developed, adopted, and implemented pursuant to Article 3, Sections 10640 through 10645 of the Urban Water Management Planning Act; and
4. The Water Shortage Contingency Plan includes stages of action that can be taken in response to water supply shortages, including up to a 50 percent reduction in water supply, a driest three-year water supply scenario, mandatory water use prohibitions, and penalties for non-compliance; and
5. The Water Shortage Contingency Plan identifies both short-term and long-term actions to maximize water use efficiency and minimize the effects of the current water shortage as well as future water supply shortages.

BE IT FURTHER RESOLVED that this Board has adopted the Water Shortage Contingency Plan as incorporated in the Urban Water Management Plan, and declares the provisions of the Water Shortage Contingency Plan in full force and effect during the duration of this period of water shortage.

I HEREBY CERTIFY that the foregoing is a full, true, and correct copy of the resolution adopted by the Board of Water and Power Commissioners of the City of Los Angeles at its meeting held

11.3.9 Methodology to Determine Actual Water Use Reductions during Shortages – 10632 (i)

Water use is monitored closely by LADWP throughout its service area regardless of the supply conditions. With 100 percent of its over 700,000 service connections metered, there is a high degree of accountability on the quantity of water used within the Los Angeles service area. Information from meter reads is collected for billing and accounting purposes, with reports prepared on a monthly basis from the data compiled.

LADWP also used a conservation model to estimate conservation efforts within the City since the early 1990s. The model estimated City water demand without conservation efforts using population and weather variables. A new conservation model was developed in 2010 to account for additional factors such as economic recession and drought conservation is discussed in Chapter 2, Water Demand. The conservation effort is derived by comparing estimated pre-conservation demand with actual demand. Conservation efforts derived from this model are shown in Chapter 3, Water Conservation.

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11.4 Water Supply Assessments

Background

In 1994, the California Legislature enacted Water Code section 10910 (Senate Bill 901), which requires cities and counties, as part of the California Environmental Quality Act (CEQA) review, to request the applicable public water system to assess whether the system's projected water supplies were sufficient to meet a proposed development's anticipated water demand. The intent was to link the land use and water supply planning processes to ensure that developers and water supply agencies communicate early in the planning process. However, a study of projects approved by local planning agencies revealed that numerous projects were exempted due to loopholes in the statute, and that the intent of the legislation has largely gone unfulfilled.

Subsequently, California Senate Bill (SB) 610 and SB 221, modeled after SB 901, amended State law effective January 1, 2002, to ensure that the original intent of the legislation is fulfilled. SB 610 and 221 are companion measures which seek to promote more collaborative planning between local water suppliers and cities and counties. These bills improve the link between information on water supply availability and certain land use decisions made by cities and counties. Both statutes require detailed information regarding water availability to be provided to the city and county decision-makers prior to approval of specified large development projects. Both statutes also require this detailed information be included in the administrative record that serves as the evidentiary basis for an approval action by the city or county on such projects. Both measures recognize local control and decision making regarding the availability of water for projects and the approval of projects.

Under SB 610 a water supply assessment (WSA) must be furnished to local governments for inclusion in any environmental documentation for certain development projects subject to the CEQA. Specifically, SB 610 requires that for certain projects, the CEQA lead agency must identify any public water system that may supply water to the proposed project and request the public water system to determine the water demand associated with the project and whether such demand was included as part of the most recently adopted UWMP. If the projected water demand associated with the proposed project was accounted for in the most recently adopted UWMP, the public water system may incorporate the supporting information from the UWMP in preparing the elements of the assessment. If the proposed project's water demand was not accounted for in the most recently adopted UWMP, the WSA for the project shall include a discussion with regard to whether the public water system's total projected water supplies available in normal, single dry, and multiple dry water years during a 20-year projection will meet the proposed project's water demand.

Per Section 10912 of the California Water Code, a project which is subject to the requirements of SB 610 includes: (1) a proposed residential development of more than 500 dwelling units; (2) a proposed shopping center or business establishment employing more than 1,000 persons or having more than 500,000 square feet of floor space; (3) a proposed commercial office building employing more than 1,000 persons or having more than 250,000 square feet of floor space; (4) a proposed hotel or motel, or both, having more than 500 rooms; (5) a proposed industrial, manufacturing, or processing plant, or industrial park planned to house more than 1,000 persons, occupying more than 40 acres of land, or having more than 650,000 square feet of floor area; (6) a mixed-use project that includes one or more of the projects specified in this subdivision; or (7) a project that would demand an amount of water equivalent to, or greater than, the amount of water required by a 500 dwelling unit project.

The assessment would include an identification of existing water supply entitlements, water rights, or water service contracts relevant to the identified water supply for the proposed project and water received in prior years pursuant to those

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entitlements, rights, and contracts. If the assessment concludes that water supplies will be insufficient, plans for acquiring additional water supplies would need to be presented.

Under SB 221, approval by a city or county of certain developments requires an affirmative written verification of sufficient water supply; which is a "fail safe" mechanism to ensure collaboration on finding the needed water supplies to serve a new large development occurs before construction begins.

Methodology

During the years from 2005 to 2010, LADWP has been requested to develop over 40 WSAs. Each WSA performed by LADWP is carefully evaluated within the context of the current adopted UWMP and current conditions, such as restrictions on State Water Project (SWP) pumping from the Sacramento-San Joaquin Delta imposed by a Federal Court. The Metropolitan Water District of Southern California (MWD), from whom the City purchases its State Water Project and Colorado River water supplies, has also been actively developing plans and making efforts to provide additional water supply reliability for the entire Southern California region. LADWP coordinates closely with MWD to ensure implementation of MWD's water resource development plans and supplemental water reliability report prepared by MWD.

LADWP's UWMP uses a service area-wide method in developing City water demand projections. This methodology does not rely on individual development demands to determine area-wide growth. Rather, the growth in water use for the entire service area was considered in developing long-term water projections for the City to the Year 2035. The driving factors for this growth are demographics, weather, and conservation. LADWP used anticipated growth in the various customer class sectors as provided by MWD who reallocated projected demographic data from the Southern California Association of Governments (SCAG) into member agencies' service areas. The data used was based on SCAG's 2008 Regional Transportation Plan Forecast.

As governed by City Charter Sections 673 and 677, LADWP can serve surplus water supplies to areas outside of the City boundaries. There are approximately 4,500 services for customers outside of the City, with a combined annual water use less than 1 percent of all water delivered. Water served outside of the City includes a surcharge to account for the increased MWD purchased water.

The water demand forecast model in the UWMP was developed using LADWP total water use, including the water served by LADWP for use outside of the City. The service area reliability assessment was performed for three hydrologic conditions: average year, single dry year, and multiple-dry years; and a Shortage Contingency Plan was developed to provide for a sufficient and continuous supply in LADWP's service area. This Shortage Contingency Plan included water provided for use outside of the City.

An important part of the water planning process is for LADWP to work collaboratively with MWD to ensure that anticipated water demands are incorporated into MWD's long-term water resources development plan and water supply allocation plan. The City's allotment of MWD water supplies under MWD's water supply allocation plan is based on the City's total water demand which includes services to areas outside the City. The ongoing collaboration between LADWP and MWD is critical in ensuring that the City's anticipated water demands are incorporated into the development of MWD's long-term Integrated Resources Plan (IRP). MWD's IRP directs a continuous regional effort to develop regional water resources involving all of MWD's member agencies. Successful implementation of MWD's IRP has resulted in reliable supplemental water supplies for the City from MWD.

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In summary, the WSAs are performed to ensure that adequate water supplies would be available to meet the estimated water demands of the proposed developments during normal, single-dry, and multiple-dry water years, as well as existing and planned future uses of the City's water system. LADWP will continue to perform WSAs as part of its long-term water supply planning efforts for its service area.

WSA Procedure

The CEQA lead agency, such as the Department of City Planning or the Community Redevelopment Agency of the City of Los Angeles, evaluates the proposed project against the requirements for a WSA in accordance with the Water Code. If the proposed project falls within the requirements for a WSA, a formal request is submitted to LADWP to perform a WSA.

In evaluating the proposed project's water demand, LADWP applies the Sewer Generation Factors (published by City of Los Angeles Bureau of Sanitation) to the development's project description for calculating indoor water use. Outdoor landscape water demand is calculated by using computer software which takes into account various factors such as landscape area square footage, location, and plant types. Historical billing records are used to establish existing baseline water demand on the property.

LADWP also encourages all projects to implement additional water conservation measures above and beyond the current water conservation ordinance requirements. As an example, if the proposed development is near an existing or future recycled water pipeline system, commitment to use recycled water for irrigation, toilet flushing and cooling towers is highly recommended as part of the additional conservation measures for the proposed development.

The net increase/decrease in water demand, which is the projected additional water demand of the development, is calculated by subtracting the existing baseline water demand and water saving amount from the total proposed water demand.

The net increase/decrease in water demand, which is the projected additional water demand of the development, is calculated by subtracting the existing baseline water demand and water saving amount from the total proposed water demand. If the land use of the proposed development is consistent with the City's General Plan, the projected water demand of the development is considered to be accounted for in the most recently adopted UWMP. The City incorporates the projected demographic data from the SCAG in its General Plan. MWD utilizes a land use based planning tool that allocates SCAG's projected demographic data into water service areas for their member agencies, which was adopted for water demand projection in the UWMP.

If the proposed land use is not consistent with the City's General Plan, the WSA will further evaluate if the projected supplies from the UWMP are able to accommodate the proposed project's water demand, which may include other resource options to offset the projected water demand.

All WSAs are subject to approval by the Board of Water and Power Commissioners. Upon approval, the lead agency is responsible for enforcing the requirements of the WSA as part of the approval for the project.

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DRAFT Chapter Twelve
Climate Change

12.0 Overview

LADWP is considering impacts of climate change during development of its long-term water supply plan. Climate change is a global-scale concern, but is particularly important in the western United States where potential impacts on water resources can be significant to supplies for water agencies. Climate change can impact surface supplies from the LAA, imported supplies from MWD, and local demands. As a result, LADWP is completing a study to analyze the operational and water supply impacts of potential shifts in the timing and quantity of runoff along the LAA system due to climate change. Such potential shifts may require LADWP to develop, enhance, and modify management of local water resources. Projected changes in climate are expected to alter hydrologic patterns in the Eastern Sierra through changes in precipitation, snowmelt, relative ratios of rain and snow, winter storm patterns, and evapotranspiration.

To understand some of the key issues surrounding climate change impacts, it is important to put it into the context of LADWP's water supplies. California lies within multiple climate zones. Therefore, each region will experience unique impacts to climate change. Because LADWP relies on both local and imported water sources, it is necessary to consider the potential impacts climate change could have on the local watershed as well as the western and eastern Sierra Nevada watersheds where a portion of MWD's imported water originates and LADWP's imported LAA supplies originate, respectively, and the Colorado River Basin where the remainder of MWD's imported supplies originate.

Generally speaking, any water supplies that are dependent on natural hydrology are vulnerable to climate change, especially if the water source originates from mountain snow pack. For LADWP, the most vulnerable water sources subject to climate change impacts are imported water supplies from MWD and the LAA. However, local sources can expect to see some changes in the future as well. In addition to water supply impacts, changes in local temperature and precipitation are expected to alter water demand patterns. However, there is still general uncertainty within the scientific community regarding the potential impacts of climate change for the City of Los Angeles. LADWP will continue to stay abreast of developments in climate change to better understand its potential implications to the City's water supplies.

12.1 Potential Impacts of Climate Change on Water Service Reliability

Scientists predict future climate change scenarios using highly complex computer global climate models (GCMs) to simulate climate systems. Although most of the scientific community agrees that climate change is occurring and, as a result, mean temperatures for the planet will increase, the specific degree of this temperature increase cannot be accurately predicted. Predictions of changes in precipitation are even more speculative, with some scenarios showing precipitation increasing in the future and others showing the opposite.

It is important to acknowledge that the predictions of the GCMs lack the desired precision due to the presence of uncertainties inherent in the analyses. The uncertainty to future emissions of greenhouse gases and the chaotic nature of the climate system leads to uncertain response of the global climate system to the increases in greenhouse gases. In addition, the science of climate change still lacks the complete understanding of regional manifestations that will result from global changes, thus restraining the projecting capacity of these models. However, these projections are consistent with the state of science today, and they help predict the manner of which hydrologic variables are likely to respond to a range of possible future climate conditions, and thus provide invaluable insight to water managers in their decisions pertaining to water supply reliability.

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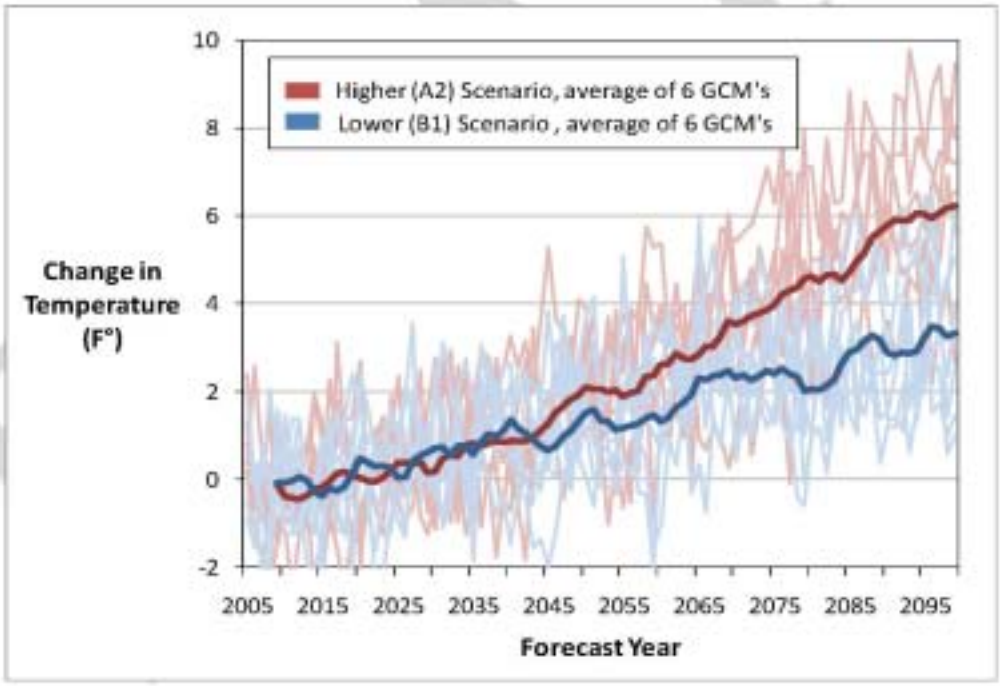
The regional areas of interest in assessing climate change impacts to LADWP include the local service area and sources of origination for imported water supplies in northern California, eastern Sierra Nevada Mountains, and the Colorado River Basin. Data regarding climate change impacts for the various regions of interest is provided in this section.

12.1.1 Local Impacts

Most scientific experts believe that because of the uncertainty involved with each model, several models should be used to test the potential impact of climate change. To downsize the global coarse-scale climate projections to a regional level incorporating local weather and topography, the GCMs are "downscaled". Future projections of precipitation and temperature were obtained for six GCMs under two greenhouse gas emission scenarios (A2 - higher and B1 - lower) for Los Angeles County. [1,2] Exhibits 12A and 12B plot the changes in projected average annual mean temperature and precipitation, respectively for the model scenarios. The bold line represents the running average of all six models for each emission scenario. The six models were also used in the preparation of the 2008 California Climate Change Scenarios assessment.

Note Exhibits 12X and 12X are placeholders and are for illustrative purposes only of the type of data that will be presented for Los Angeles. The data in the figures represent data obtained from the Scripps Institute of Oceanography for the Pasadena area. Similar data has been requested for Los Angeles.

Exhibit 12A
Climate Change Impacts to Local Temperatures for Los Angeles (Placeholder)



[1] Dan Cayan and Mary Tyree (University of California, San Diego, Scripps Institute of Oceanography) provided downscaled data for Pasadena under two emissions scenarios from six climate models: CNRM CM3, GFDL CM2.1, Miroc3.2 (medium resolution), MPI ECHAM5, NCAR CCSM3, NCAR PCM1.

[2] Note: These scenarios do not bracket the highest and lowest emission futures possible, but represent a status quo approach (A2) and a pro-active mitigation (B1) approach to reduce carbon emissions.

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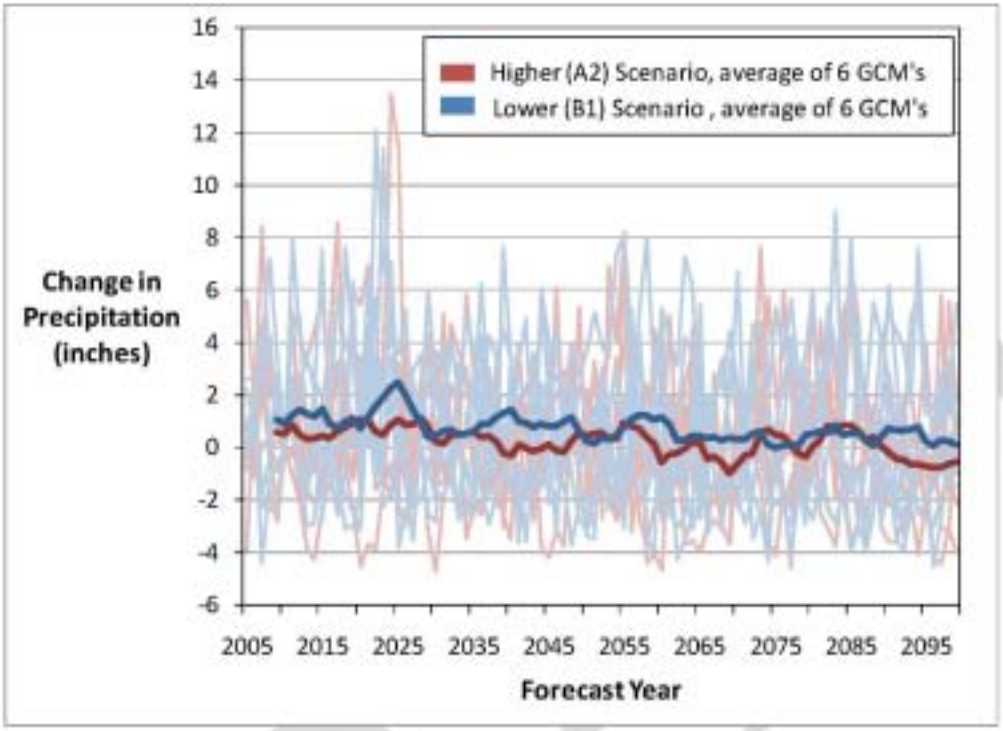
Exhibit 12B

Climate Change Impacts to Local Precipitation for Los Angeles (Placeholder)



Local climate changes within the vicinity of the LADWP service area are expected to include:

- An increase in average temperatures that will be more pronounced in the summer than in the winter with annual mean temperatures in 2100 increasing greater than 3°Fwhen lower greenhouse gas emission scenarios are used and may exceed 7°F when high higher emissions scenarios are used dependent upon the GCM utilized
- An increase in extreme temperatures
- An increase in heat waves and droughts that will extend for a longer duration
- A decrease in precipitation with the potential for 30 year deficits of more than 10% below historical levels that, coupled with higher temperatures, will increase evaporation/transpiration
- An increase in short-duration/high volume intense storm events during the winter

The impact of these climate effects will likely be increased water demands for irrigation and cooling purposes earlier in the year and for extended periods coupled with decreased local surface runoff available to recharge groundwater basins. Other impacts might include increased fire events that could impact water quality and sedimentation, decreased groundwater recharge due to lower soil moisture, and sea level rise increasing seawater intrusion into coastal groundwater basins.

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12.1.2 Los Angeles Aqueduct Impacts

The LAA is one of the major imported water sources delivering a reliable water supply to the City of Los Angeles. The LAA originates approximately 340 miles away from snowmelt runoff in the eastern Sierra Nevada; hence LAA is subject to hydrologic variability associated with climate change. Since the majority of precipitation occurs during winter in the eastern Sierra Nevada watershed, water is stored in natural reservoirs in the form of snowpacks, and is gradually released into streams that feed into the LAA during spring and summer. More detailed information regarding the LAA is presented in Chapter 5, Los Angeles Aqueduct Systems.

Higher concentrations of greenhouse gases in the atmosphere are often indications of pending climate change. These changes threaten the hydrologic stability of the eastern Sierra Nevada watershed through alterations in precipitation, snowmelt, relative ratios of rain and snow, winter storm patterns, and evapotranspiration, all of which have major potential impacts on the LAA water supply and deliveries.

To address the possible challenges posed by climate change on the LAA, LADWP commenced a climate change study in 2009 to evaluate the potential impacts of climate change on the eastern Sierra Nevada watershed and the LAA water supply and deliveries, and investigate opportunities to improve the LAA system as a result of these impacts over the next hundred years. In this study, future climate conditions are predicted using a set of sixteen GCMs and two greenhouse gas emission scenarios.

The impacts of these climate change scenarios and the associated hydrology on the LAA's eastern Sierra Watershed includes an analysis of historical temperature, precipitation, water quality, and runoff records. Hydrologic modeling will be performed to estimate runoff changes from current conditions and an evaluation will be provided to determine their effects on the performance of the existing infrastructure with regards to storage and conveyance capacity to Los Angeles. As part of the evaluation of potential adaptation measures if existing infrastructures are inadequate, recommendations will be provided to modify the existing infrastructure and operations to accommodate these impacts.

Preliminary results of the study are showing steady temperature increases throughout the 21st century and are consistent with other prior studies performed in the scientific community. Exhibit 12C displays the time series of 30-year running means of the projected temperature of one of the greenhouse gas emission scenarios considered in the study, A2 (higher greenhouse gas emissions), averaged over the simulation area for each of the sixteen GCMs. All GCMs project temperature increases throughout the 21st century.

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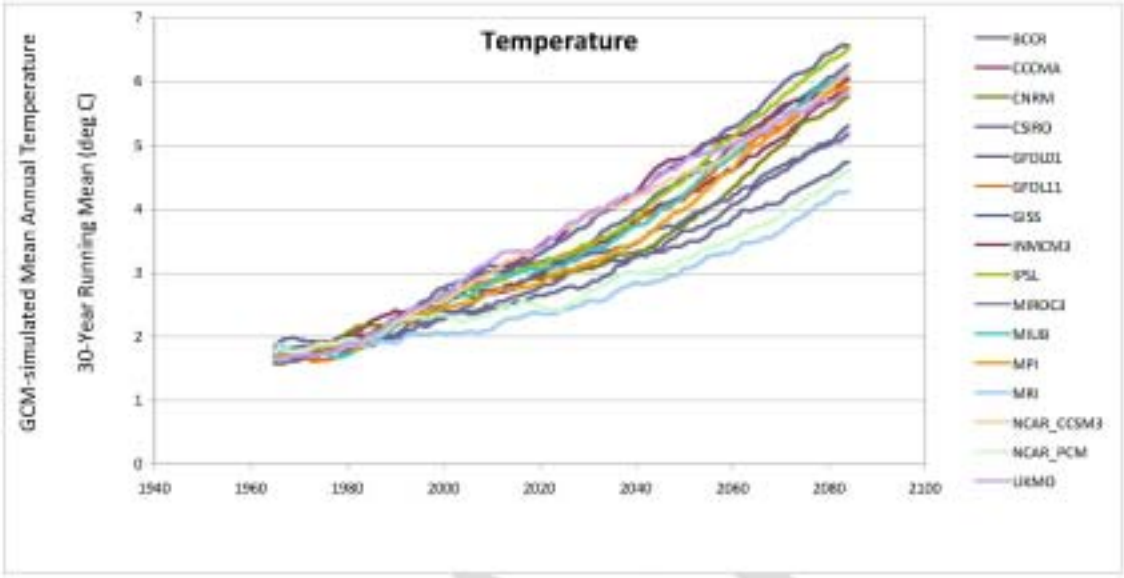
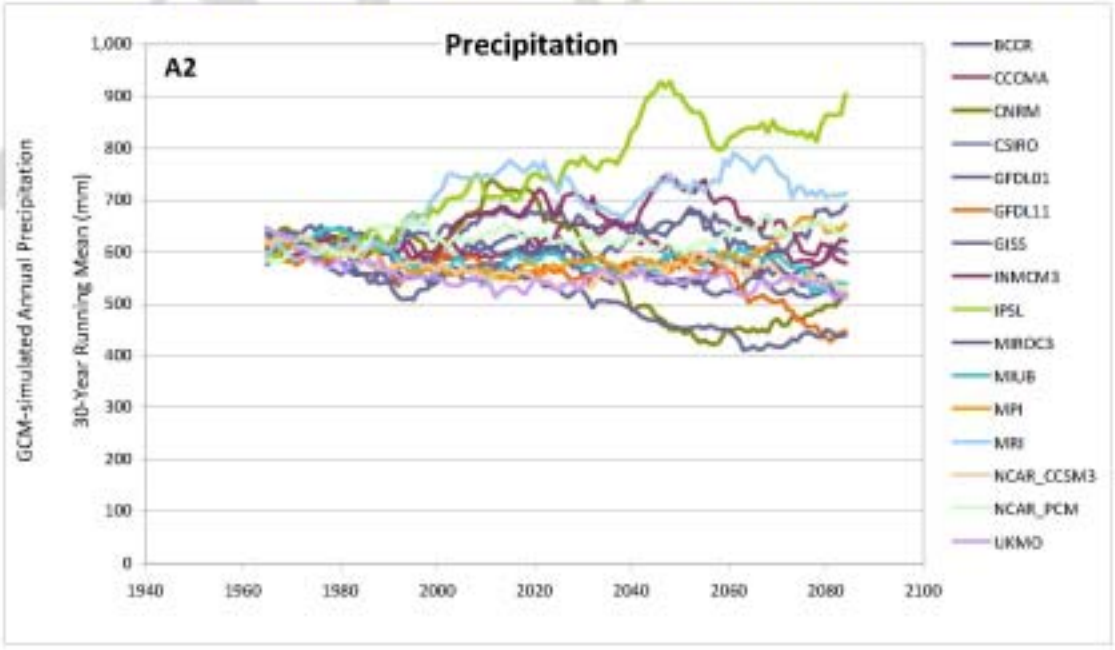
Exhibit 12C
30-Year Time Series Projected Temperature Means for Eastern Sierra Nevada Watershed



On the other hand, forecasts for precipitation differ greatly between the GCMs. Some GCMs are projecting increases, but the majority of the model outputs are projecting decreases in precipitation over the study period. Exhibit 12D displays the time series of 30-year running means of the projected precipitation using the A2 greenhouse gas emission scenario (higher greenhouse gas emissions) averaged over the simulation area for each of the sixteen GCM models.

Exhibit 12D
30-Year Time Series Projected Precipitation Means for Eastern Sierra Nevada Watershed



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Temperature is the main climate variable that is projected to rise significantly in the coming years and decades. The rise in temperature directly affects several variables including:

- Whether precipitation falls as snow or rain;
- The ground-level temperature determines the timing and rate of snowmelt; and
- The temperature profile in the canopy that determines the rate of evapotranspiration.

Preliminary results have shown that future predictions for the early-21st century suggested a warming trend of 0.9 to 2.7 °F and almost no change in average precipitation. Mid-21st century projections suggested a warming trend of 3.6 to 5.4 °F and a small average decrease in precipitation, approximately 5 percent. This warming trend is expected to increase by the end of 21st century, as the results suggest further warming of 4.5 to 8.1 °F and a decrease in precipitation of approximately 10 percent. In addition, preliminary results indicate an increase in the frequency and length of droughts in the end-of-century period.

Projected changes in temperature (warmer winters) will change precipitation patterns to rain with larger fractions than historically encountered. Consequently, peak Snow Water Equivalent (SWE) and runoff are projected to undergo a shift in timing to earlier dates.

At elevations of up to about 9,800 feet, the snowpack of the eastern Sierras is susceptible to earlier melt and less accumulation with a long term-shift in mean temperature of 3.6°F, especially in the southern Sierras. On average, mean temperature rises are in the range of 3.6 to 10.8 °F resulting in about a 17 to 50 percent loss in snowpack storage, respectively. This vulnerability shows up in average to warm winters and will directly affect the stream levels and stream discharge. This raises potential concerns for LADWP in the areas of adequate storage and operations, especially the capacity of the LAA system to store the early runoff in surface reservoirs.

The projected temperature and precipitation dataset form the basis of the hydrologic model projections for runoff, snow-water equivalent (SWE), and rain-to-snow ratio. To compare the future projections of these variables, the trends that dominated the second half of the 20th century are considered baselines for future trends. The baseline values for runoff, SWE, and rain-to-snow ratio are 0.6 million acre-feet (MAF), 15 inches, and 0.2, respectively. By Early 21st century (2010 – 2039), preliminary results illustrate runoff is projected to undergo increases and decreases averaging between 0.5 to 0.85 MAF; SWE is projected to undergo decreases and increases ranging between 10.6 to 19.0 inches, and the rain-to-snow ratio is projected to increase between 0.24 to 0.33. By mid-century (2040 – 2069), the same trends are expected to dominate, with runoff ranging between 0.34 to 0.9 MAF, SWE ranging between 7.0 to 19.7 inches, and the rain-to-snow ratio increasing between 0.25 to 0.43. These trends are expected to govern until the end-of-century (2070 -2099) with runoff ranging between 0.35 to 1.1 MAF, SWE ranging between 5.0 to 16.0 inches, and rain-to-snow ratio increasing between 0.28 to 0.54. Exhibit 12E summarizes the projections for runoff, SWE, and rain-to-snow ratio for the 21st century.

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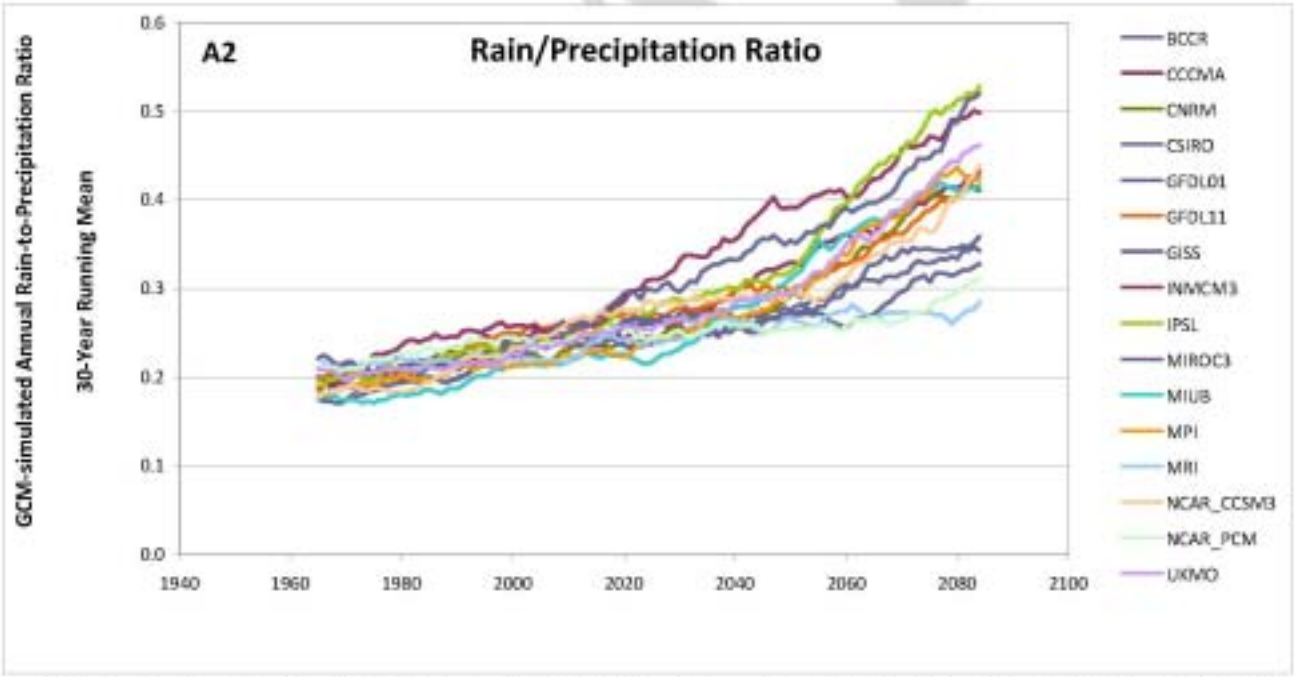
Exhibit 12E
Projected Runoff, Snow-Water Equivalent, and Rain-to-Snow Ratio for Eastern Sierra Nevada Watershed

	Runoff (MAF)	April 1 SWE (Inches)	Rain/Snow Ratio
Baseline (Second Half of 20th Century)	**0.6**	**15.0**	**0.2**
Early 21st-century (2010-2039)	0.5 - 0.85	10.6 - 19.0	0.24 - 0.33
Mid-century (2040-2069)	0.34 - 0.9	7.0 - 19.7	0.25 - 0.43
End-of-century (2070-2099)	0.35 – 1.1	5.0 - 16.0	0.28 - 0.54

Exhibit 12F displays the rain-to-snow ratio based on the projected precipitation and temperature for the 16 GCMs. The rain-to-snow ratio is projected to increase throughout the 21st century, ranging between 0.24 to 0.33 by early 21st century, between 0.25 to 0.43 by mid-century, and between 0.28 to 0.54 by the end-of-century.

Exhibit 12F
Projected Rain to Precipitation Ratio Based on Projected Precipitation and Temperature



The increase of rain-to-snow ratio indicates the shift from snowfall to rainfall, specifically at low to moderate elevations, where the temperature tends to be warmer. This shift indicates more precipitation as liquid, and in turn, leads to loss of the snowpack. The snowpack is critical in providing seasonal storage for water that releases winter precipitation in spring and summer to provide the soil moisture and stream flow needed to sustain both ecosystems and human populations. The climate change study work is still ongoing with remaining analyses to be performed on potential climate change impacts to existing infrastructures, water quality, and recommended adaptation measures.

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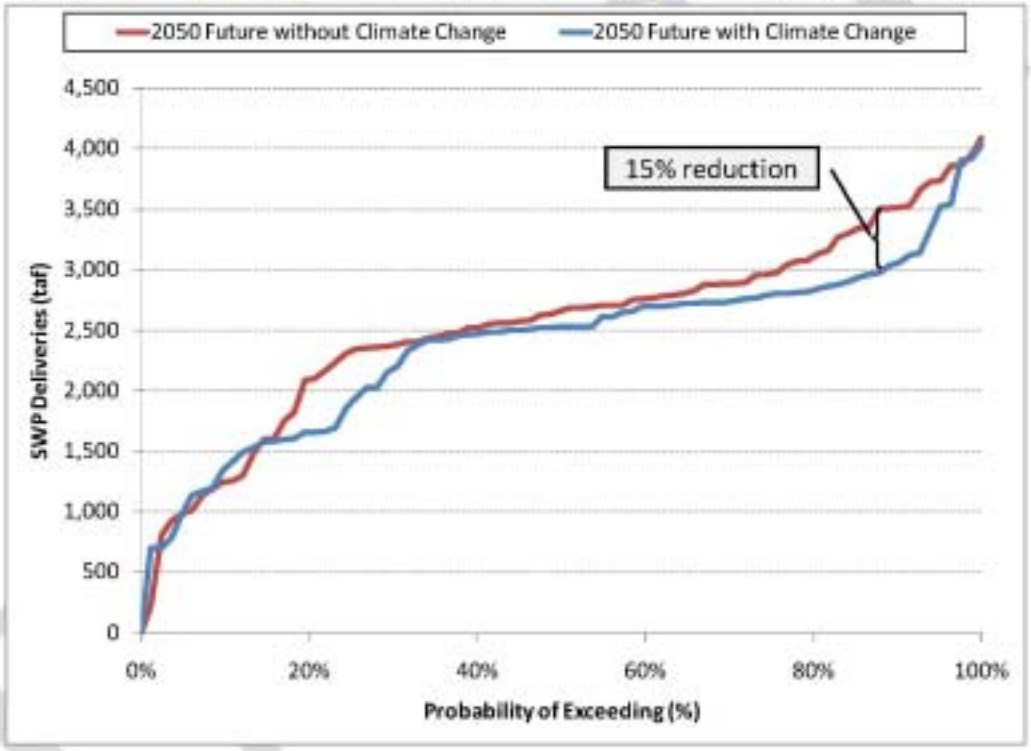
Although the results above are quantitative in nature, it is important to account for the uncertainties inherent in these predictions. The results of this study will help guide the water managers in planning and developing water supply and infrastructure to ensure the reliability and sustainability of adequate water supply and delivery.

12.1.3 State Water Project Impacts

To date, most studies on climate change impacts to California's water supply have been conducted for the Northern California region. In August 2010, DWR released the 2009 State Water Project Delivery Reliability Report, which specifically analyzes changes in volume of water available under various climate change scenarios. DWR projected that SWP deliveries could be reduced by as much as 15 percent in some cases as illustrated in Exhibit 12G.

Exhibit 12G
Projected Rain to Precipitation Ratio Based on Projected Precipitation and Temperature



To incorporate climate change into its reliability reports, DWR reviewed 6 GCMs for year 2050 projections using lower emission and higher emission scenarios contained in *Using Future Climate Projections to Support Water Resources Decision Making in California* prepared in April 2009 by DWR. DWR selected the model most representing median effects on the SWP, the MPI-ECHAM5 model run with a higher greenhouse gas scenario.

Climate change has the potential to disrupt SWP source supplies, impact conveyance, and alter storage levels in reservoir carryover storage. Annual Bay-Delta exports to areas south of the Delta are expected to decline 7 percent for the lower greenhouse gas emissions scenario and 10 percent for the higher emissions scenario. However, it should be noted that for the six GCMs under the lower and higher emission scenarios the range varies from a 2 percent increase to a 19 percent decrease illustrating the variability in the various GCMs.

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By 2050, median reservoir carryover storage is projected to decline by 15 percent for the lower emissions scenario and 19 percent for the higher emissions scenario thereby reducing operational options if water shortages were to occur. Furthermore, by 2050 it is projected a water shortage worse than the 1977 drought could potentially occur in 1 out of every 6 to 8 years requiring acquisition of other supplies, reductions in water demands, or a combination. An additional 575 to 850 TAF would be needed to maintain minimum SWP operation requirements and meet regulatory requirements. The main supply reservoirs on the SWP must maintain minimum water levels to allow water to pass through their lower release outlets in the dams. However, the April 2009 report does not consider the SWP vulnerable to a system interruption such as this under current conditions.

The primary effects of climate change on the SWP identified in the 2009 Reliability Report include, among others:

- More precipitation will fall as rain than snow
- Reductions in Sierra snowpack
- Sea level rise threatening the Bay-Delta levee system
- Increased salinity in the Bay-Delta due to sea level rise requiring releases of freshwater from upstream reservoirs to maintain water quality standards
- Shifted timing of snowmelt runoff into streams – spring runoff comes earlier resulting in increased winter flows and decreased spring flows
- Increased flood events

The most severe climate impacts in California are expected to occur in the Sierra watershed, where the SWP supply originates. Therefore, imported SWP water is extremely vulnerable to climate change.

12.1.4 Colorado River Aqueduct Impacts

Although many research efforts are underway, there have not yet been any reports quantifying potential changes in supply to California from the Colorado River via the CRA. At this time, the assumption is that there would be similar patterns as the SWP impacts.

12.2 Water and Energy Nexus

It is widely believed in the scientific community that the increase in concentrations of greenhouse gases (GHG) in the atmosphere is a major contributing factor to climate change. As such, California is leading the way with laws that require reductions in greenhouse gas emissions and requirements to incorporate climate change impacts into long range water resource planning.

Carbon dioxide emissions into the atmosphere and the emissions of other GHGs are often associated with the burning of fossil fuels like crude oil and coal in the generation of energy. As a significant amount of energy is required for the movement of water over long distances and elevations, a link was subsequently realized between water supply conveyance and corresponding GHG emissions through its energy consumption. An assessment of the GHG emissions, sometimes also known as **carbon footprint expressed in units of tons CO_2, could be estimated for water.** Once the size of a carbon footprint is known, a strategy can be developed to better manage and reduce its impact on climate change.

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LADWP has taken the initiative to study the nexus between water and energy consumption and to evaluate the associated carbon footprint of its water system. The most energy intensive source of water for LADWP is water purchased from MWD, which imports SWP supplies via the California Aqueduct and Colorado River supplies via the CRA. LADWP also imports water via the LAA, which is a net producer of energy. Local sources of water for LADWP include groundwater and recycled water. Exhibit 12H outlines the sources of LADWP's water supply as well as the energy profiles of each facility that provides water to LADWP. For those sources of water operated by LADWP, the energy intensity has been computed by dividing the total energy consumed/generated by the total water produced or processed by that source.

12.2.1 State Water Project Supplies

Water Supplied to Los Angeles via the SWP originates from Northern California and the Bay-Delta and is conveyed along the 444-mile long California Aqueduct to southern California. Six pump stations are required to lift the water to the point at which the California Aqueduct splits into two branches. At the zenith of the California Aqueduct in the Tehachapi Mountains, approximately 3,846 kilowatt hours per acre foot (kWh/AF) is required to lift the water from the start of the aqueduct. After the water passes through Edmonston Pumping Plant, the California Aqueduct separates into two branches, the West Branch and the East Branch. Along the West Branch, the water is lifted once more at the Oso Pumping Plant and then energy is recovered through hydro-electric generation at the Warne and Castaic Power Plants. By the time the West Branch reaches its terminus at Lake Castaic, the net energy consumed in transporting the water from the Bay-Delta is approximately 2,580 kWh/AF. Water supplied through the West Branch is provided to the San Fernando Valley, Western Los Angeles, and Central Los Angeles communities.

Along the East Branch, the water generates power at the Alamo Power Plant, is lifted once more at Pearblossom Pumping Plant, and then used for generation at Mojave Siphon and Devil Canyon Power Plants. At the East Branch terminus at Lake Perris, approximately 3,236 kWh/AF of energy has been expended in the transport. Water conveyed through the East Branch is provided to the Eastern Los Angeles and Harbor communities. The water supplied from the SWP is the most energy intensive source of water available to LADWP.

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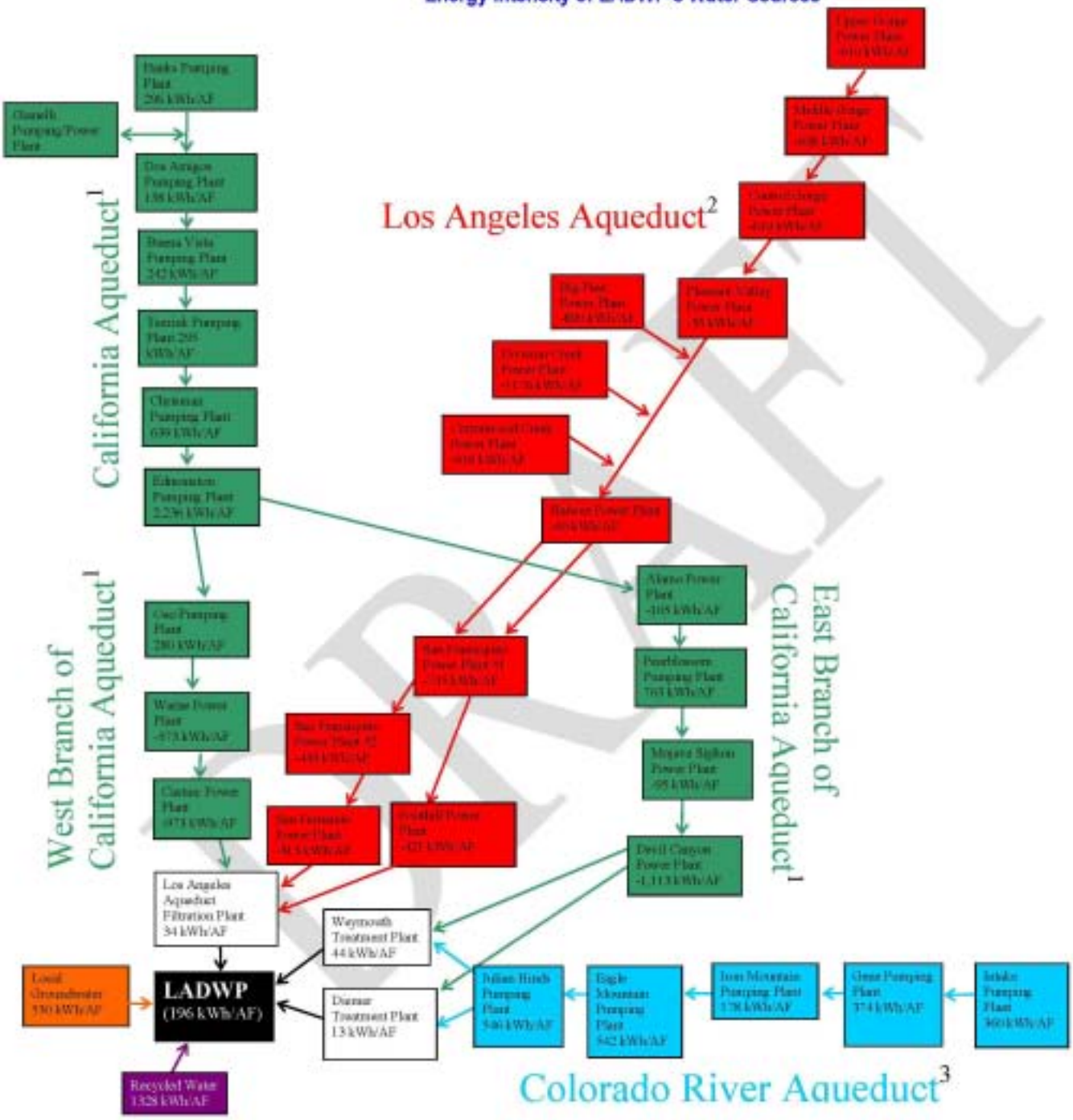
Exhibit 12H
Energy Intensity of LADWP's Water Sources



1. Source: *Methodology for Analysis of the Energy Intensity of California's Water Systems*, p. 27.
2. Generation on the Los Angeles Aqueduct is not considered in LADWP's total energy intensity.
3. Energy intensities for the Colorado River Aqueduct pumping stations were derived by multiplying the total energy intensity for the aqueduct by the proportion of load for each individual pumping station in relation to the total load for all five pump stations.
4. Positive numbers indicate power consumption due to pumping and negative numbers indicate power generation.

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12.2.2 Colorado River Aqueduct Supplies

Water supplied from the Colorado River is imported via the 242 mile CRA operated by MWD. From the start of the aqueduct at Lake Havasu to its terminus at Lake Mathews, the water is lifted approximately 1,617 feet. Five pumping stations along the aqueduct lift the water to MWD's service area requiring approximately 2,000 kWh/AF. CRA water is the second most energy intensive water source for Los Angeles and is supplied to the eastern Los Angeles and Harbor communities. Together SWP water and CRA water comprise the total imported provided by MWD to LADWP. MWD imported water is the most expensive water source for LADWP in terms of both cost and energy.

12.2.3 Los Angeles Aqueduct Supplies

The LAA provides water from the Eastern Sierra watershed and is entirely gravity fed. As a result, no energy is required to import LAA water, making it the most desirable source of water in terms of energy intensity. There are twelve power generation facilities along the aqueduct system. On average, the LAA generates approximately 6,848 kWh/AF from water directly used to generate power. This number was determined using the same methodology as was used to determine the energy intensity for the two branches of the SWP. The individual energy intensities for each individual generating facility were summed up to arrive at the total energy intensity for the water used to generate power. However, when considered from the perspective of total amount of water delivered to Los Angeles via the LAA, the energy generated along the aqueduct is approximately 2,456 kWh/AF. The variance between the numbers can be attributed to the fact that not all water wheeled through the aqueduct is used to generate power and the fact that a portion of the water is introduced into the aqueduct system at a point downstream of several of the power plants. For the purposes of determining LADWP's total energy intensity, the energy intensity of the LAA is considered to be zero since the power generated does not directly offset the energy required for other sources of water. However, in terms of supply the LAA is able to offset the more energy intensive sources of water, consequently reducing the overall energy intensity of LADWP's water supplies. As LAA flows to Los Angeles are decreased due to environmental enhancement efforts in the Owens Valley and Mono Basin, LADWP is forced to increasingly rely on energy intensive water purchased from MWD. LAA water currently supplies approximately 37 percent of the demand for Los Angeles.

12.2.4 Local Groundwater Supplies

Groundwater currently accounts for approximately 11 percent of LADWP's water supply and has an average energy intensity of approximately 530 kWh/AF. As LADWP continues with its cleanup of the contaminated water in the San Fernando Basin, groundwater will play an increasingly important role in Los Angeles' water supply. Although there is potential for a future increase in the energy required to produce groundwater due to the introduction of new treatment technologies, groundwater is expected to remain a low energy source of water when compared to imported supplies purchased from MWD. Increasing groundwater production will allow LADWP to offset the energy intensive MWD sources and reduce its overall energy intensity..

12.2.5 Recycled Water Supplies

Recycled water is currently the smallest component of LADWP's water supply portfolio, with municipal and industrial uses accounting for less than 1-percent of total supplies. Currently, LADWP directly receives recycled water from three wastewater treatment plants operated by Bureau of Sanitation (BOS), two of which provide recycled water treated to a tertiary level: LAG and DCT. The TITP performs advanced treatment of recycled water in addition to tertiary treatment. LADWP also directly receives a small portion of recycled water from the West Basin Municipal Water District (WBMWD), which provides additional treatment of wastewater from the Hyperion Treatment Plant (HTP) in El Segundo. Since all water at the plants directly supplying recycled water to LADWP is treated to at least a tertiary level regardless of disposal or reuse, the energy cost to

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treat the water to this level is considered a sunk cost because the water would be treated whether it offsets potable use or not. The advanced treatment process at the Terminal Island Treatment Plant (TITP) is beyond the requirements for discharge and is therefore not considered a sunk cost. The incremental energy required to treat water from tertiary levels to advanced treatment levels at TITP requires approximately 2,200 kWh/AF. Since the treatment energy at the other two plants is not considered additional energy, only the pumping energy is included in the overall LADWP recycled water energy intensity. For the Los Angeles Glendale (LAG) Treatment Plant, the pumping requires approximately 690 kWh/AF, and for the Donald C. Tillman (DCT) Treatment Plant, the pumping requires approximately 450 kWh/AF. A weighted average of these values gives recycled water an energy intensity of approximately 1,139 kWh/AF. In the future this number will likely change as the recycled water infrastructure is expanded. In addition to the municipal and industrial recycled water that is considered in LADWP's total supplies, the plants produce significant additional volumes of recycled water that is beneficially used. Beneficial uses include the seawater barrier for the Dominquez Gap using recycled water from TITP and the Japanese Garden and Los Angeles River from DCT.

12.2.6 Treatment Energy

Another factor in determining the energy intensity of LADWP's water is the energy required to treat water. All LAA water and nearly all West Branch SWP water purchased by LADWP are treated at the Los Angeles Aqueduct Filtration Plant (LAAFP). For the LAAFP, the average treatment energy intensity is approximately 34 kWh/AF. The East Branch SWP water and the CRA water are primarily treated at the Weymouth Treatment Plant in the San Gabriel Valley and the Diemer Treatment Plant in Orange County. Both of these treatment plants are operated by MWD. The average energy intensity for Weymouth Treatment Plant is approximately 42 kWh/AF and supplies water to the East Los Angeles Community. The average energy intensity for the Diemer Treatment Plant is 13 kWh/AF and supplies water to the Harbor Community. The mix of SWP East Branch water and CRA water that flows through these two treatment plants varies depending on the regional hydrology of the two sources, but on average approximately 55 percent SWP East Branch water and 45 percent CRA water flows through each of these MWD treatment plants.

The proportion that each of the above mentioned sources contributes to the LADWP's total supplies is displayed below in Exhibit 12I. Of note is the relationship that the volume of LAA flow has to the amount of SWP water imported into the system. In this case, the energy free LAA water is replaced by the energy intensive SWP water resulting in an increase in the overall energy intensity.

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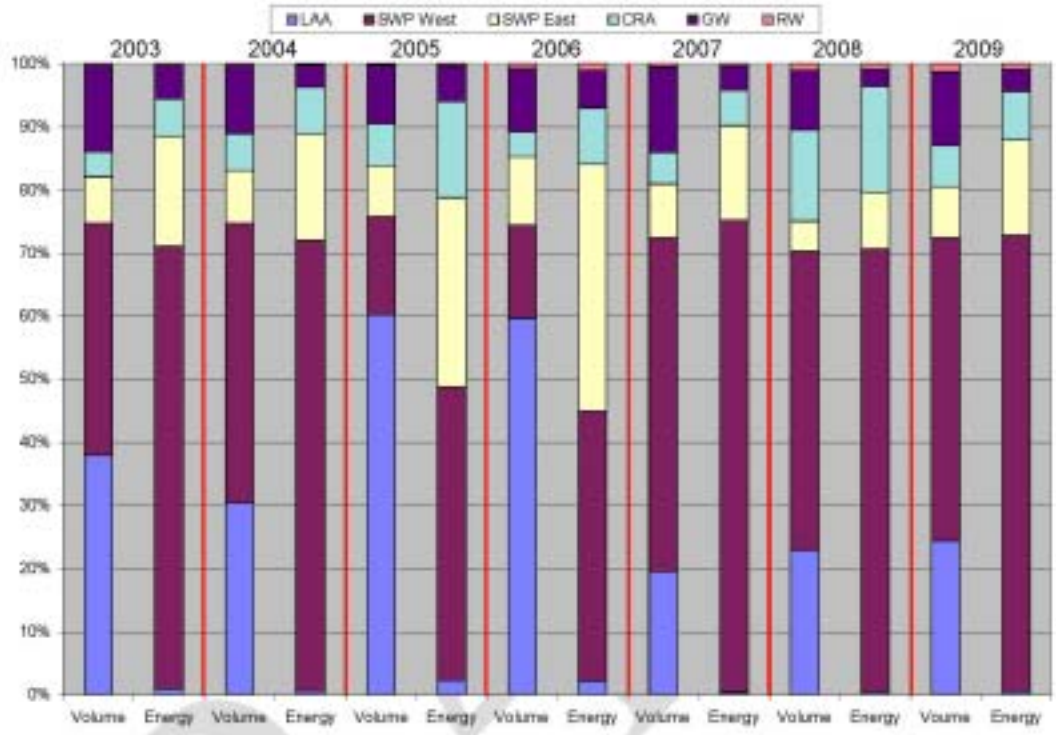
Exhibit 12I
Proportion of Volume Delivered and Total Energy Intensity (Inclusive of Treatment)



12.2.7 Distribution Energy

LADWP benefits from the topography of its service area in that much of the hydraulic head required for water distribution is provided by gravity. With the major sources of LADWP's water entering the service area at higher elevation than the rest of the City, the energy required for distribution is lower than much of the region. The average energy intensity for LADWP water distribution is approximately 196 kWh/AF.

Exhibit 12J shows the sum of the energy intensities for LADWP from each of the individual sources between 2003 and 2009. Exhibit 12K shows a graphical representation of the total energy intensity for LADWP for the same time period. An important detail is the influence that LAA water has on the total energy intensity for a given year. For those years with large volumes of LAA water, such as 2005 and 2006, the total energy intensity was correspondingly low. Alternatively, those years with low volumes of LAA water have high total energy intensity as a result of the energy requirements for imported MWD supplies

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. Exhibit 12J
LADWP Energy Intensity 2003-2009

		2003	2004	2005	2006	2007	2008	2009
Los Angeles Aqueduct (0 kWh/AF)	Volume (AF)	251,942	202,547	368,839	378,922	129,400	147,365	137,084
	Treatment Energy Intensity (kWh/AF)[1]	34	34	34	34	34	34	34
	Weighted Energy Intensity (kWh/AF)	13	10	20	20	7	8	8
State Water Project West Branch (2580 kWh/AF)	Volume (AF)	244,218	296,722	95,538	93,694	350,302	304,221	270,653
	Treatment Energy Intensity (kWh/AF)[1]	34	34	34	34	34	34	34
	Weighted Energy Intensity (kWh/AF)	961	1,161	408	386	1,384	1,237	1,258
State Water Project East Branch[3] (3236 kWh/AF)	Volume (AF)	48,980	56,301	49,526	68,796	56,357	31,016	45,246
	Treatment Energy Intensity (kWh/AF)[2]	27	27	27	27	27	27	27
	Weighted Energy Intensity (kWh/AF)	241	275	264	354	278	157	262
Colorado River Aqueduct[3] (2000 kWh/AF)	Volume (AF)	26,374	39,124	40,522	25,445	33,098	93,047	37,012
	Treatment Energy Intensity (kWh/AF)[2]	27	27	27	27	27	27	27
	Weighted Energy Intensity (kWh/AF)	80	119	134	81	101	293	133
Local Groundwater (530 kWh/AF)	Volume (AF)	90,835	71,831	56,547	63,270	89,018	60,149	64,996
	Weighted Energy Intensity (kWh/AF)	72	57	49	53	71	50	61
Recycled Water[4] (1,139 kWh/AF)	Volume (AF)	1,759	1,774	1,401	4,890	3,639	7,081	7,489
	Weighted Energy Intensity	3	3	3	9	6	13	15
Distribution (196 kWh/AF)	Volume (AF)	664,108	668,300	612,373	635,017	661,814	642,879	562,480
	Weighted Energy Intensity (kWh/AF)	196	196	196	196	196	196	196
Total Volume Delivered (AF)		664,108	668,300	612,373	635,017	661,814	642,879	562,480
Total Energy Intensity (kWh/AF)		1,567	1,820	1,074	1,098	2,043	1,954	1,934

1. Los Angeles Aqueduct and State Water Project West Branch supplies are treated at the Los Angeles Aqueduct Filtration Plant
2. Colorado River Aqueduct and State Water Project East Branch supplies are treated at Weymouth and Diemer Filtration Plants operated by Metropolitan Water District of Southern California. The listed energy intensity is based on an average of the energy intensity for the two plants.
3. Amount of SWP water and CRA water delivered is based on the reported average ratio of the two sources in Weymouth Treatment Plant and Diemer Treatment Plant effluent from MWD annual Water Quality Report
4. Recycled water volume is based on use for municipal and industrial uses, not all beneficial uses. Energy intensity is a weighted average of energy used for pumping to customers and the incremental energy to treat from tertiary to advanced treatment.

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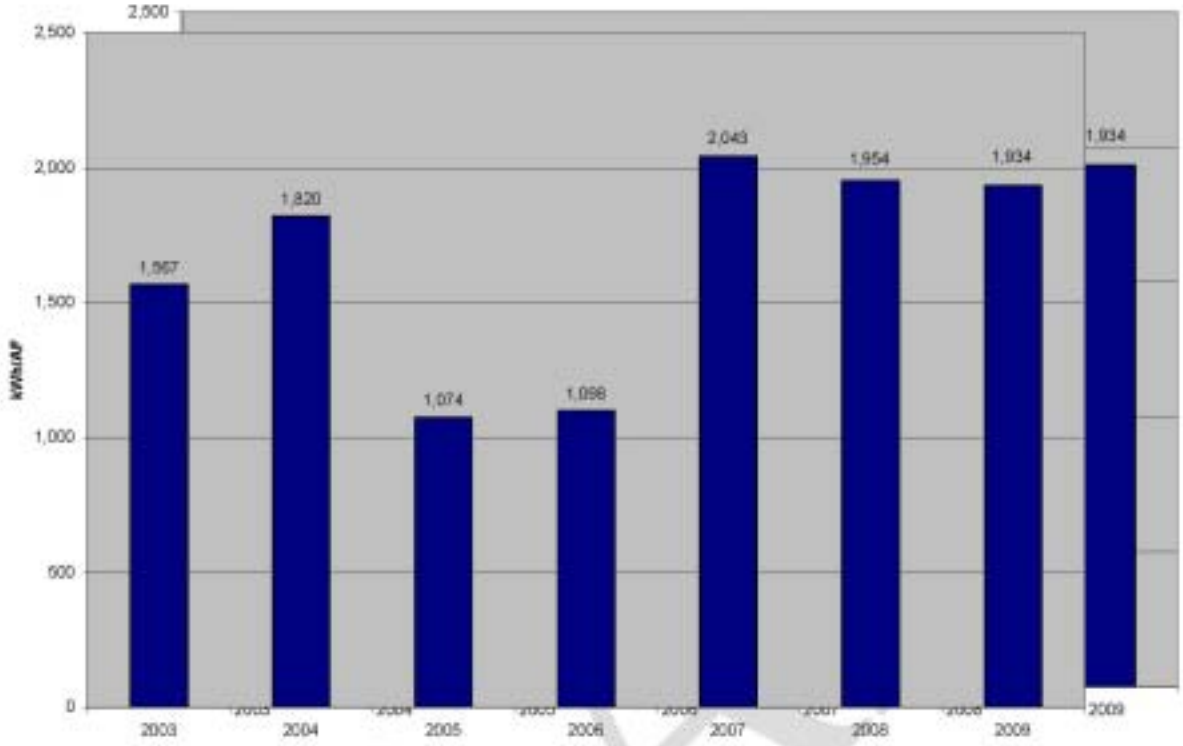
Exhibit 12K
LADWP Annual Energy Intensity



12.2.8 Carbon Footprint

All of LADWP's water supply sources have an associated carbon footprint related to the energy required to pump the water. Exhibit 12L provides the annual carbon footprint by water source. Exhibit 12M shows a graphical representation of the total annual carbon footprint for the same time period. For imported sources, the 2007 CAMX California average carbon emission of 0.72412 lbs CO2/kWh was used to estimate the amount of carbon emissions produced per acre-foot of water imported. For local sources the CO2 metric reported to the California Climate Action Registry in 2007 was used to estimate the carbon emissions released in the production of this water. LAA is a net producer of energy and produces only green hydropower. There are no carbon emissions associated with water imported through the LAA.

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Exhibit 12L
Annual Footprint by Carbon Source

		2003	2004	2005	2006	2007	2008	2009
Los Angeles Aqueduct (0 kWh/AF)	Volume Delivered (AF)	251,942	202,547	368,839	378,922	129,400	147,365	137,084
	Energy Intensity (kWh/AF)	0	0	0	0	0	0	0
	Weighted Energy Intensity (kWh/AF)	13	10	20	20	7	8	8
	Carbon Footprint (tons CO_2)[2]	5,259	4,228	7,699	7,909	2,701	3,076	2,861
State Water Project West Branch (2,580 kWh/AF)	Volume Delivered (AF)	244,218	296,722	95,538	93,694	350,302	304,221	270,653
	Weighted Energy Intensity (kWh/AF)	961	1,161	408	386	1,384	1,237	1,258
	Carbon Footprint (tons CO_2)[3]	231,134	280,825	90,420	88,674	331,535	287,922	256,153
State Water Project East Branch (3,236 kWh/AF)	Volume Delivered (AF)	48,980	56,301	49,526	68,796	56,357	31,016	45,246
	Weighted Energy Intensity (kWh/AF)	241	275	264	354	278	157	262
	Carbon Footprint (tons CO_2)[3]	57,865	66,514	58,510	81,276	66,580	36,642	53,454
Colorado River Aqueduct[1] (2,000 kWh/AF)	Volume Delivered (AF)	26,374	39,124	40,522	25,445	33,098	93,047	37,012
	Weighted Energy Intensity (kWh/AF)	80	119	134	81	101	293	133
	Carbon Intensity (lbs CO2/kWh)	0.72412	0.72412	0.72412	0.72412	0.72412	0.72412	0.72412
	Carbon Footprint (tons CO_2)[3]	19,356	28,713	29,739	18,674	24,290	68,287	27,163
Local Groundwater (530 kWh/AF)	Volume Delivered (AF)	90,835	71,831	56,547	63,270	89,018	60,149	64,996
	Weighted Energy Intensity (kWh/AF)	72	57	49	53	71	50	61
	Carbon Footprint (tons CO_2)[2]	29,556	23,372	18,399	20,587	28,964	19,571	21,148
Recycled Water (1,139 kWh/AF)	Volume Delivered (AF)	1,759	1,774	1,401	4,890	3,639	7,081	7,489
	Weighted Energy Intensity (kWh/AF)	3	3	3	9	6	13	15
	Carbon Footprint (tons CO_2)[2]	1,230	1,240	980	3,419	2,545	4,951	5,237
Distribution (196 kWh/AF)	Volume Delivered (AF)	664,108	668,299	612,373	635,017	661,814	642,879	562,480
	Weighted Energy Intensity (kWh/AF)	196	196	196	196	196	196	196
	Carbon Footprint (tons CO_2)[3]	79,911	80,415	73,686	76,411	79,635	77,357	67,682
Total Volume Delivered (AF)		664,108	668,299	612,373	635,017	661,814	642,879	562,480
Total Energy Intensity (kWh/AF)		1,567	1,820	1,074	1,098	2,043	1,954	1,934
Total Carbon Footprint (tons CO_2)		424,310	485,308	279,432	296,950	536,250	497,807	433,698

1. Amount of SWP water and CRA water delivered is based on average of the proportion of the two sources delivered to MWD Weymouth Treatment Plant and Diemer Treatment Plant for the calendar year

2. Based on 2007 CO_2 metric of 1.22789 lbs CO_2/kWh reported to the California Climate Action Registry

3. Based on eGRID 2007 CAMX (California Average) of 0.72412 lbs CO_2/kWh

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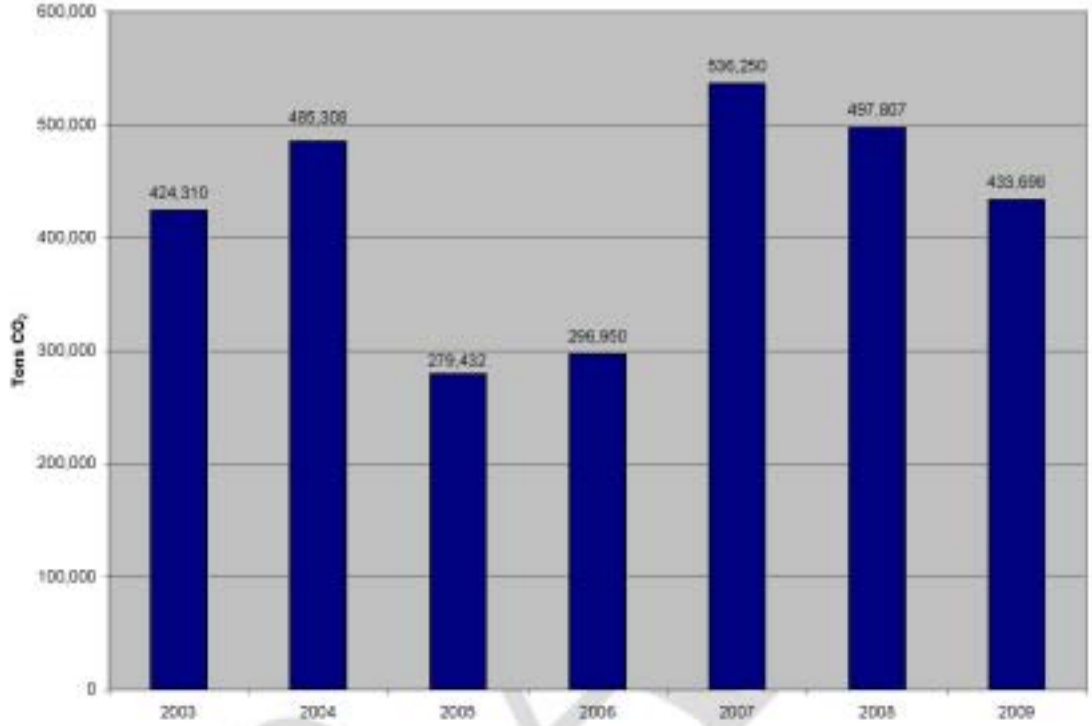
Exhibit 12M
Total Annual Carbon Footprint for Water Supply Portfolio



As Los Angeles increases its reliance on energy intensive imported supplies from MWD, its overall energy intensity will increase. Reductions in LAA flows due to environmental mitigation have the consequence of increasing Los Angeles' reliance on supplies imported through the SWP via the California Aqueduct, and Colorado River through the CRA.

12.3 Climate Change Adaption and Mitigation

Climate change strategies fall under two main categories: adaptation and mitigation. For water resources planning, a climate change adaptation strategy involves taking steps to effectively manage the impacts of climate change by making water demands more efficient and relying on supply sources that are less vulnerable to climate change. A mitigation strategy involves proactive measures that reduce greenhouse gas emissions, such as placing a stronger emphasis on using water resources requiring less greenhouse gas emissions. Both LADWP and its wholesale supplier for imported water, MWD, are implementing adaption and mitigation strategies as they become aware of potential climate change impacts.

It is imperative that supply options are carefully vetted and evaluated against both adaptation and mitigation goals, as they may conflict and work against each other. For example, desalination is a typical supply option that performs quite well in adapting to climate change impacts; however, due to the energy necessary to draw from and manage the supply source, it could result in higher greenhouse gas emissions if conventional energy sources are utilized.

12.3.1 LADWP Adaption and Mitigation

In the 2008 City of Los Angeles Water Supply Action Plan, LADWP and the City have outlined strategies to dramatically increase conservation and water recycling. Increasing conservation and water recycling encompasses both adaption and mitigation goals to address climate change. The Plan calls for reducing potable demands by an additional 50,000 AFY through

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conservation by fiscal year 2030 and 50,000 AFY through recycled water use. Additional adaption strategies under investigation by LADWP and the City includes beneficial reuse of stormwater as discussed in Chapters Seven and Nine, Watershed Management and Other Potential Water Supplies, respectively.

Conservation has a double savings in terms of energy intensity because not only does it save energy in importing or producing the water, but it also saves energy through reduction of end use, such as heating water for a shower or for a dishwasher and wastewater treatment. The anticipated conservation savings will not only help to provide Los Angeles a secure and dependable water supply, but it will also reduce the energy footprint of the water supply, and consequently the carbon footprint. A further discussion regarding conservation is provided in Chapter Three, Conservation.

Recycled water use reduces reliance on potable water imported through MWD and provides a year round drought resistant water supply source. While the energy consumption requirements to produce recycled water are greater than local and LAA supply sources, recycled water assists LADWP in bolstering its supply portfolio to address potential supply changes related to climate change. A further discussion regarding recycled water is provided in Chapter 4, Recycled Water.

The climate change study work for the LAA is still ongoing with remaining analyses to be performed on potential climate change impacts to existing infrastructures, water quality, and recommended adaptation measures. Hydraulic models will be performed to determine impacts to the LAA conveyance capacity. Adaptation measures may include upgrades to treatment processes in order to address degradation in water runoff quality, and/or changes in operational procedures to address shifts in runoff timing and quantity.

There is still general uncertainty within the scientific community regarding the potential impacts of climate change for the City of Los Angeles. LADWP will continue to stay abreast of developments in climate change to better understand its potential implications to the City's water supplies to assist in further developing adaption and mitigation strategies.

12.3.2 MWD Adaption and Mitigation

MWD is taking an active approach to adapt and mitigate against climate changes in its operations. Adaption and mitigation measures include:

- Investments in local resources to diversify MWD's water supply portfolio
- Tracking climate change legislation – MWD provides input and direction on legislation
- Collaborating on climate change with state, federal, and non-governmental agencies
- Monitoring state and local climate change actions
- Investigating the water supply and energy nexus
- Coordinating with large water retailers
- Integrating climate change into integrated resource planning as discussed in Chapter 10, Integrated Resource Planning

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- Sharing climate change knowledge and providing support – founding member of Water Utility Climate Alliance,
- Adopting energy management policies to support cost-effective and environmentally responsible programs, projects, and initiative

MWD has also taken structural adaption measures including construction of the Inland Feeder. The Inland Feeder completed in 2009 connects SWP supplies with MWD's CRA supplies and allows delivery of SWP supplies to MWD's major reservoir, Diamond Valley Lake. In relation to climate change, the project will increase conveyance capacity allowing more rain to be conveyed as projected snowpack levels decrease and allow MWD to capture rain associated with projected short duration high intensity storms.

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APPENDICES

SheppardMullin

Sheppard Mullin Richter & Hampton LLP
333 South Hope Street, 43rd Floor
Los Angeles, CA 90071-1422
213.620.1780 main
213.620.1398 main fax
www.sheppardmullin.com

FAX COVER SHEET

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Date: June 6, 2012

Total number of pages: 2
(including 1-page cover sheet)

If all pages are not received, please call Phillip M. Tate at 213.617.5575

TO:	Fax No.	Telephone No.
Developer Fee Program Office	213-241-8022	213-241-0716

From: Phillip M. Tate Direct Dial: 213.617.5575

Re: Request for LAUSD Student Generation Rate Calculation and LAUSD Commercial/Industrial School Fee Justification Study

Sender's Name: Time Started:

MESSAGE:

NOTE: THIS MESSAGE IS INTENDED ONLY FOR THE USE OF THE INDIVIDUAL OR ENTITY TO WHICH IT IS ADDRESSED AND MAY CONTAIN INFORMATION THAT IS PRIVILEGED, CONFIDENTIAL AND EXEMPT FROM DISCLOSURE UNDER APPLICABLE LAW. IF THE READER OF THIS MESSAGE IS NOT THE INTENDED RECIPIENT, OR THE EMPLOYEE OR AGENT RESPONSIBLE FOR DELIVERING THE MESSAGE TO THE INTENDED RECIPIENT, YOU ARE HEREBY NOTIFIED THAT ANY DISSEMINATION, DISTRIBUTION OR COPYING OF THIS COMMUNICATION IS STRICTLY PROHIBITED. IF YOU HAVE RECEIVED THIS COMMUNICATION IN ERROR, PLEASE NOTIFY US IMMEDIATELY BY TELEPHONE AND RETURN THE ORIGINAL MESSAGE TO US AT THE ABOVE ADDRESS VIA THE U.S. POSTAL SERVICE. THANK YOU

Student Generation Factor

In determining the impact of new development, the District is required to show how many students will be generated from the new developments. In order to ensure that new development is paying only for the impact of those students that are being generated by new homes and businesses, the student generation factor is applied to the number of new housing units to determine development-related growth. The District may either use the local student yield rate or the State wide average student generation factor.

The student generation factor identifies the number of students per housing unit and provides a link between residential construction projects and projections of increased enrollment. The State-wide factor used by the Office of Public School Construction is 0.70 for grades K-12. For the purposes of this report we will use the State factors to determine the students generated from new housing developments. Table 3 shows the student generation factors for the various grade groupings.

Table 3

STUDENT GENERATION FACTORS

Grades	Students per Household
K-6	0.4
7-8	0.1
9-12	0.2
Total	0.7

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New Residential Development Projections

The Los Angeles Unified District has experienced an average new residential construction rate of approximately 5,121 units per year. Projecting the average rate forward, we would expect that 25,605 units of residential housing will be built within the District boundaries over the next five years.

To determine the impact of residential development, an enrollment projection is done. Applying the student generation factor of 0.7 to the projected 5,121 units of residential housing, we expect that 17,924 students will be generated from the new residential construction over the next five years. This includes 10,242 elementary school students, 2,561 middle school students and 5,121 high school students.

The District is required to use the development-based enrollment projection for the purposes of this study. This is utilized as the cost basis for development impact throughout this study, unless otherwise noted.

Table 4

LOS ANGELES UNIFIED
FIVE YEAR ENROLLMENT PROJECTIONS

Grades	Current Enrollment	Development Projection	Projected Enrollment
K to 6	346960	10242	357 192
7 to 8	92250	2561	94811
9 to 12	195646	5121	200766
SDC	29388		29388
Totals	664233	17924	682157

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IV. Existing Facility Capacity

To determine the need for additional school facilities, the capacity of the existing facilities must be identified and compared to current and anticipated enrollments. The District's existing building capacity will be calculated using the State classroom loading standards shown at Table 6. The following types of "support-spaces" necessary for the conduct of the District's comprehensive educational program, are not included as "teaching stations," commonly known as "classrooms" to the public:

Table 5

Los Angeles Unified School District
List of Core and Support Facilities

Library	Resource Specialist
Multipurpose Room	Gymnasium
Office Area	Lunch Room
Staff Workroom	P.E. Facilities

Because the District requires these types of support facilities as part of its existing facility and curriculum standards at its schools, new development's impact must not materially or adversely affect the continuance of these standards. Therefore, new development cannot require that the District house students in these integral support spaces.

Classroom Loading Standards

The following maximum classroom loading-factors are used to determine teaching-station "capacity," in accordance with the State legislation and the State School Building Program. These capacity calculations are also used in preparing and filing the baseline school capacity statement with the Office of Public School Construction.

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Table 6

State Classroom Loading Standards

Kindergarten	25 Students/Classroom
1st-3rd Grades	25 Students/Classroom
4th-6th Grades	25 Students/Classroom
7th-8th Grades	27 Students/Classroom
9th-12th Grades	27 Students/Classroom
Non Severe Special Ed	13 Students/Classroom
Severe Special Ed	9 Students/Classroom

Existing Facility Capacity

The State determines the baseline capacity by either loading all permanent teaching stations plus a maximum number of portables equal to 25% of the number of permanent classrooms or by loading all permanent classrooms and only portables that are owned or have been leased for over 5 years. As allowed by law and required by the State, facility capacities are calculated by multiplying the number of teaching stations at each campus. All qualified teaching stations were included in the calculation of the capacities. To account for activity and changes since the baseline was established, the student grants for new construction projects funded by OPSC have been added. Using these guidelines the District's current State calculated capacity is shown in Table 7

Table 7

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LOS ANGELES UNIFIED
Summary of Existing Facility Capacity

School Facility	Permanent Classrooms	Portable Classrooms	Chargable Portables	Total Chargable Classrooms	State Loading Factor	State Funded Projects	District Capacity Added	Total State Capacity
Grades K-6	9326	9407	3485	19312	26	99850	2875	371,125
Grades 7-8	1496	534	432	1929	27	31435	7467	80,903
Grades 9-12	4294	1370	440	5334	37	58238	8261	203,415
SDC N-S	2008	3	0	2008	13	104	0	26,104
SDC Severe	1009	8	0	1016	9	0	0	9,016
Totals	16633	9318	4357	29599		189627	18603	700,663

As Table 7 shows, the total State capacity of the District facilities is 700,663 students.

Unhoused Students by State Housing Standards

This next chart compares the capacity with the space needed to determine if there is available space for new students from the projected developments. The space needed is determined based on the maximum seats needed to house the students within the existing homes. The historic and projected enrollments were reviewed to determine the space needed for each grade grouping.

Table 8

LOS ANGELES UNIFIED
Summary of Available District Capacity

School Facility	State Capacity	Space Needed	Available Capacity
Grades K-6	371,125	364,086	7,039
Grades 7-8	80,903	100,009	(19,046)
Grades 9-12	203,415	208,240	(4,827)
SDC N-S	26,104	21,992	4,112
SDC - Severe	9,016	7,395	1,649
Totals	700,663	701,776	0

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Since the enrollment space needed exceeds the District capacity there is no excess capacity available to house students from new development.

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V. Calculation of Development's Fiscal Impact on Schools

This section of the study will demonstrate that a reasonable relationship exists between residential, commercial/industrial development and the need for additional school facilities in the Los Angeles Unified School District. To the extent this relationship exists, the District is justified in levying developer fees as authorized by Education Code Section 17620.

School Facility Construction Costs

For the purposes of estimating the cost of building schools we have used the State School Building Program funding allowances. These amounts are shown in Table 9. In addition to the basic construction costs, there are site acquisition costs of $3,347,093 per acre and approximately $1,622,689 per acre for allowable service-site, utilities, off-site and general site development costs.

Table 9

New Construction Costs

Grade Level	Construction Cost Per Student
Elementary	$22,096
Middle	$23,406
High	$28,700
Average	$24,632

Impact of Residential Development:

The next table compares the development-related enrollment projection to the available district capacity for each grade level and then multiplies the unhoused students by the new school construction costs to determine the total school facility costs related to the impact of new residential housing developments.

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In addition, the State provides that each District shall be reimbursed for site acquisition costs, including appraisals, surveys and title reports. The District needs to acquire 110.69 acres to meet the needs of the students projected from the new developments.

Table 10

LOS ANGELES UNIFIED
Summary of Residential Impact

Service Facility	Development Projection	Available Space	Net Unhoused	Construction Cost Per Student	Total Facility Costs
Elementary	10,849	0	10,849	$22,606	$228,204,812
Middle	7551	0	2,551	$23,405	$59,947,655
High & Cont.	5121	0	5,121	$20,707	$152,093,700
Site Purchase: 110.69 acres					$369,334,046
Site Development					$179,936,551
			New Construction Needs:		$1,011,518,997
			Modernization Needs:		$0
			TOTAL NEEDS:		$1,011,518,997
			Average cost per student:		$56,434

The total need for school facilities based on the impact of the 25,605 new housing units projected over the next five years totals $1,011,518,997. To determine the impact per square foot of residential development, this amount is divided by the total square feet of the projected developments. As calculated from the historic Developer Fee Permits, the average size home built has averaged 1,585 square feet. The total area for 25,605 new homes would therefore be 40,583,925 square feet. The total residential fee needed to be able to collect $1,011,518,997 would be $24.92 per square foot. Since the State Maximum Fee is currently $3.20 for residential construction, the District is justified in collecting the maximum fee.

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Impact of Commercial/Industrial Development

There is a correlation between the growth of commercial/industrial firms/facilities within a community and the generation of school students within most business service areas. Fees for commercial/industrial can only be imposed if the residential fees will not fully mitigate the cost of providing school facilities to students from new development.

The approach utilized in this section is to apply statutory standards, U.S. Census employment statistics, and local statistics to determine the impact of future commercial/industrial development projects on the District. Many of the factors used in this analysis were taken from the U.S. Census, which remains the most complete and authoritative source of information on the community in addition to the "1990 SanDAG Traffic Generators Report"

Employees per Square Foot of Commercial Development

Results from a survey published by the San Diego Association of Governments "1990 San DAG Traffic Generators" are used to establish numbers of employees per square foot of building area to be anticipated in new commercial or industrial development projects. The average number of workers per 1,000 square feet of area ranges from 0.06 for Rental Self Storage to 4.79 for Standard Commercial Offices. The generation factors from that report are shown in the following table.

Table 11

Commercial/Industrial Category	Average Square Foot Per Employee	Employees Per Average Square Foot
Banks	354	0.00283
Community Shopping Centers	652	0.00152
Neighborhood Shopping Centers	369	0.00271
Industrial Business Parks	284	0.00352
Industrial Parks	742	0.00135
Rental Self Storage	15641	0.00006
Scientific Research & Development	328	0.00304
Lodging	882	0.00113
Standard Commercial Office	209	0.00479
Large High Rise Commercial Office	233	0.00431
Corporate Offices	372	0.00269
Medical Offices	234	0.00427

Source: 1990 SanDAG Traffic Generators report

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Students per Employee

The number of students per employee is determined by using the 2010 U.S. Census data for the City of Los Angeles. According to the census, there were 1,494,895 employees in the City and a total of 1,739,802 in the district. There were 641,240 school age children in the District. This is a ratio of 0.3686 students per employee. This ratio, however, must be reduced by including only the percentage of employees that worked in their community of residence (73%), because only those employees living in the District will impact the District's school facilities with their children. The actual ratio of students per employee in the district is 0.2691.

School Facilities Cost per Student

State costs for housing commercially generated students are the same as those used for residential construction. The cost factors used to assess the impact from commercial development projects are contained in Table 10.

Residential Offset

When additional employees are generated in the District as a result of new commercial/industrial development, fees will also be charged on the residential units necessary to provide housing for the employees living in the District. To prevent a commercial or industrial development from paying for the portion of the impact that will be covered by the residential fee, this amount has been calculated and deducted from each category. The residential offset amount is calculated by multiplying the following factors together and dividing by 1,000 (to convert from cost per 1,000 square feet to cost per square foot).

- Employees per 1,000 square feet (varies from a low of 0.06 for rental self storage to a high of 4.70 for office building).
- Percentage of employees that worked in their community of residence (73 percent). This was derived from 2010 Census data for the District.
- Housing units per employee (0.9459). This was derived from 2010 census data for the District, which indicates there were 1,413,095 housing units and 1,494,895 employees.

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- Average square feet per dwelling unit: (1,585).
- Residential fee charged by the District ($3.20 per square foot).

The following table shows the calculation of the school facility costs generated by a square foot of new commercial/industrial development for each category of development.

Table 12

LOS ANGELES UNIFIED

Summary of Commercial and Industrial Uses

Use	Employees per 1,000 Sq. Ft.	Students per Employee	Students per 1,000 Sq. Ft.	Average Cost per Student	Cost per Sq. Ft.	Revenue to offset per Sq. Ft.	Net Cost per Sq. Ft.
Banks	3.81	0.2691	0.751	$56,434	$42.07	$9.91	$33.06
Community Shopping Centers	1.93	0.2691	0.519	$56,434	$29.22	$5.36	$17.87
Neighborhood Shopping Centers	2.71	0.2691	0.720	$56,434	$41.15	$9.49	$31.66
Non-Shelf Grocery Store	3.82	0.2691	0.647	$56,434	$53.45	$12.20	$41.12
Industrial Park	1.35	0.2691	0.363	$56,434	$20.48	$4.71	$15.77
Rental Self Storage	0.06	0.2691	0.015	$56,434	$0.81	$0.21	$0.60
Scientific Research & Development	3.84	0.2691	0.816	$56,434	$46.10	$10.65	$35.51
Lodging	1.13	0.2691	0.304	$56,434	$17.16	$3.85	$13.20
Standard Commercial Office	4.79	0.2601	1.358	$56,434	$76.63	$16.78	$59.86
Large High Rise Commercial Office	4.81	0.2691	1.160	$56,434	$65.41	$16.06	$49.35
Corporate Offices	2.69	0.2691	0.724	$56,434	$40.86	$8.42	$31.42
Medical Offices	4.27	0.2691	1.148	$56,434	$64.81	$14.05	$50.76
Parking Structures	0.0852	0.2691	0.022	$56,434	$1.26	$0.34	$0.91

*Based on 1990 SanDAG Trade Generator Report

Net Cost per Square Foot

Since the State Maximum Fee is now $0.51 for commercial/industrial construction, the District is justified in collecting the maximum fee for all categories.

Verifying the Sufficiency of the Development Impact

Education Code Section 17620 requires districts to find that fee revenues will not exceed the cost of providing school facilities to the students generated by the development paying the fees. This section shows that the fee revenues do not exceed the impact of the new development.

AR0071755

The total need for school facilities totals $1,011,518,097. The amount the District would collect over the five year period at the maximum rate of $3.20 for residential and $0.51 for commercial/industrial development would be as follows.

$3.20 x 35,603 homes x 1,585 sq ft per home = $129,868,960 for Residential
$0.51 x 3,300,000 sq ft per year x 5 years = $8,415,000 for Commercial/Industrial
Total projected 5 year income: $138,283,960

The income is less than the projected needs.

AR0071756

In accordance with Government Code Sections 65995.5 and 65995.6

The Developer Fee Rates Within

The Los Angeles Unified School District

Are As Follows:

Construction Project Type	Rate Per Square Foot	
Residential	$3.36	per square foot of assessable space
Commercial / Industrial	$0.54	per square foot of chargeable and enclosed space
Self-Storage	$0.26	per square foot
Parking Structure	$0.07	per square foot

Developer Fee Program Office
Tel. (213) 241-0715 / Fax (213) 241-6022

C.1 Residential Student Generation Impacts

In order to analyze the impact on the School District's student enrollment from future residential units, Dolinka Group utilized SGRs calculated in the SGR Study prepared by Dolinka Group. The SGR Study calculated SGRs for SFD units, SFA units (e.g. condominiums, townhomes) and MF units (e.g. apartments, duplexes, triplexes). The SFA and MF categories of the SGR Study were combined to create the MFA category for this Study. The process of calculating SGRs involved cross-referencing the School District's enrollment data against the County Assessor's residential data (see the Residential Study for more information). The resulting SGRs are shown in Table 8.

Table 8
Student Generation Rates

School Level	Single Family Detached Units	Multi-family Attached Units
Elementary School	0.1958	0.1266
Middle School	0.0933	0.0692
High School	0.1062	0.0659
Total	**0.3953**	**0.2617**

To blend the SGRs of the two (2) land uses into a single SGR for each school level, the land uses were weighted in proportion to each type's percentage of the future residential units to be constructed within the School District. Applying these weighting factors yields the following blended SGRs.

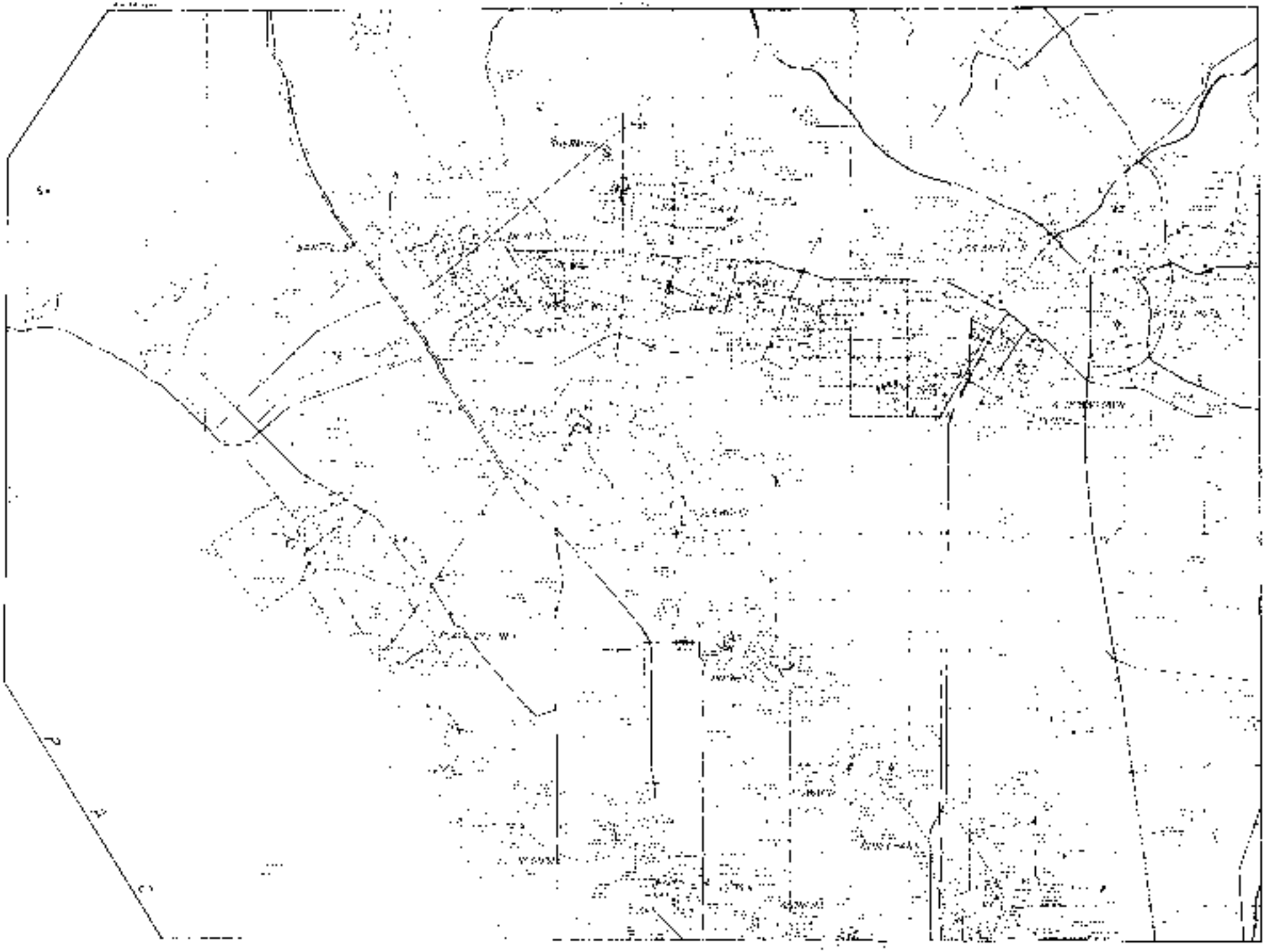
Table 9
Blended Student Generation Rates

School Level	Student Generation Factors
Elementary School	0.1400
Middle School	0.0730
High School	0.0737
Total	**0.2876**

C.2 Total Student Generation Impacts

Multiplying net school district household impacts shown in Table 7 by the blended SGRs shown in Table 9 results in the average student generation impacts per 1,000 square feet of GLD. These average student generation impacts are shown by school level in Table 10.

AR0071758



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How to Determine Quantities

Print

Tonnage Quantity Calculator

Measuring a Pavement Job

To determine the amount of asphalt you will need for a paving job you first need to know the area to be paved. This may be simple if the area to be paved is square or rectangle and you know the constant width of the road. However, this is rarely the case since there may be portions of the area to be paved, the width of the road may vary or there are curves. This may seem to be impossible in some cases, but by dividing the pavement area into simple geometric shapes and adding and subtracting these areas the area to be paved can be quickly determined. The following are basic formulas for calculating the area of several geometric shapes.

Rectangle		Area = Length x Width
Triangle		Area = Length x Width ÷ 2
Circle		Area = Diameter^2 x 3.14
Half Circle		Area = Diameter^2 ÷ 2 x 3.14
Pipe		Area = 3.14 x Length^2

Let's look at the parking lot in Figure 1, since may often have many features that complicate the calculation of area.

When you first look at this it may seem comparable since it is not a square, triangle or circle. However, it is a combination of squares, triangles and a circle as can be seen in Figure 2.

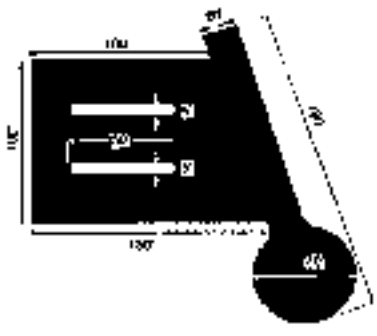

Figure 1 Parking Lot

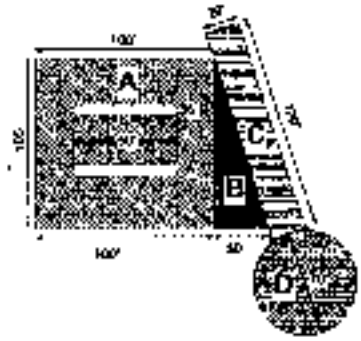

Figure 2 Parking Lot Divided into Geometric Shapes

By dividing a project into these simple shapes you can now easily calculate the area to be paved.

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Area A = a rectangle 100 x 100 = 10,000 square feet

Area B = a triangle 30 x 100 / 2 = 1,500 square feet

Area C = a rectangle 5 x 120 = 2,400 square feet

Area D = a circle 70/2 = 4 x 3.14 = 7,850 square feet

To determine the total area of paving all we have to do is add the areas together with the exception of the planters in the middle of the parking area. All we have to do now is calculate the area of the planters and subtract that area from the sum of the other areas. But for this example we will leave the calculation of the planter areas up to you. Just remember to apply the area of a triangle and semi-circle as shown above.

Therefore the total paving area is:

10,000 + 1,500 + 2400 + 3846.5 = Paving Area = 17,757 square feet

OK... so calculating the planter area, if you wanted to, would only slightly affect the overall area number. This is all the accuracy you will likely ever need on a paving job.

You may notice that there are some areas around the curb returns at the cul-de-sac that were not calculated. In this case the areas are small and will not make a significant difference in the total area. If you have many curb returns on a project, I would probably attempt to draw the area to scale on clean paper and estimate the area by counting the number of squares and multiplying the number of squares by the area of each square. For example if you drew the area at a scale of 1"=20' and the graph paper was divided into 0.1" increments each square would represent an area of 4 square feet (2*2). If you counted 20 squares the total area would be 80 square feet (20*4).

Figure 3 illustrates an example of this. In this case there are approximately 22 squares. One of the keys is to try to find matching areas. For example 1/2 of square A is covering the area and 1/4 of another square is also covered by the area they can be combined and counted as 1 full square.

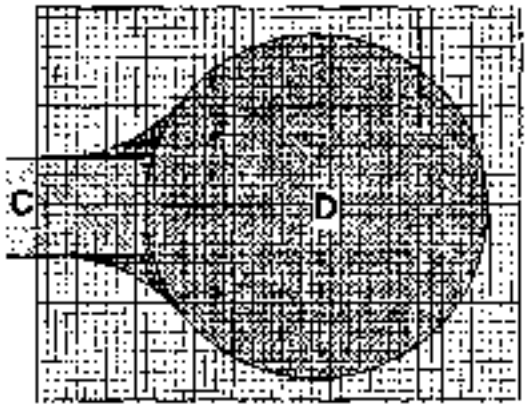


Figure 3 - Graph Paper Method for Calculating Area

Now that you have the area calculated, you next need to calculate the quantities. Quantities are usually specified by weight (tons) or volume (cubic yards). No matter how it is specified you will first need to calculate the volume. Volume is easy to calculate since it is simply Area x Thickness. One of the keys in calculating volume is to always use the same dimension. Therefore, if we measure the area in square feet we have to convert thickness measurement to feet also. For example if you were placing 3" of aggregate base the thickness would be converted to:

3" / 12 feet = 0.3 feet

To calculate the volume we simply multiply the thickness by the area previously computed.

Volume = Area * Thickness = (17,757 square ft.) * (0.3 feet) = 5329.5 cubic ft.

Aggregate base and other materials are often specified or purchased by the cubic yard. therefore, you need to convert cubic feet to cubic yards. 5 mat there are 27 cubic feet per cubic yard (3 yard x 3 yard x 3 yard), you would need to divide the cubic foot volume by 27.

Volume = 3025 cubic ft ÷ 27 cubic feet/cubic yard = 336 cubic yds.

To calculate the weight of material needed for a project you will need to know the compacted density of the material. Density is the weight of material per volume. For example pounds per cubic foot. The density of Hot Mix Asphalt (HMA) does vary depending on the proportions and type of aggregate. If you do not know the in place density of mixes you use ask your supplier.

To determine the weight of material, multiply the volume by the density of material.

Weight = Volume * Density

Using the previous example and assuming an HMA density of 145 pounds per cubic foot (pcf), and 4" (inches of it we would perform the following calculations:

1. Volume = 1,725 sq. ft. x (4" ÷ 12"/ft) = 575.2 cu. ft.
   (note that the thickness was converted from inches to feet)
2. Weight = 575.2 cu. ft. x 145 pcf = 83,404 lbs.
3. Convert to tons = 83,404 lbs. ÷ 2,000 lbs/ton = 41.7 tons

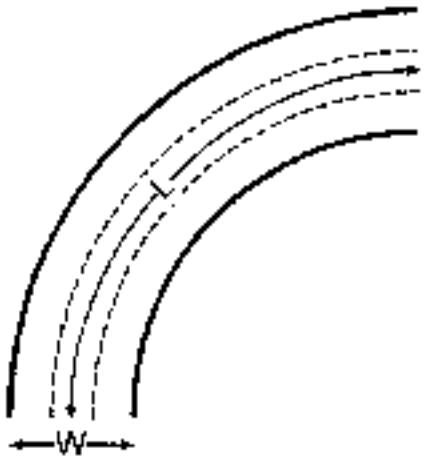
Now it's your turn to try your new skills. Using the paving areas in Figure 2 calculate the cubic yards of aggregate base and tons of HMA needed, assuming the following:

1. Areas A & B are to be paved using 4" of Aggregate Base and 3" of HMA
2. Areas C & D are to be paved using 6" of Aggregate Base and 4" of HMA

Answers: Areas A & B: Agg. Base = 130 cu. yds. HMA = 200 tons
Areas C & D: Agg. Base = 110 cu. yds. HMA = 151 tons

A note about measuring areas of roadways with curves

When determining the area of a roadway with a curve it is important that the length be measured along the centerline of the road. By doing this the area is simply the width of the road along the centerline times the width.



Download Quantity Calculator

AR0071762

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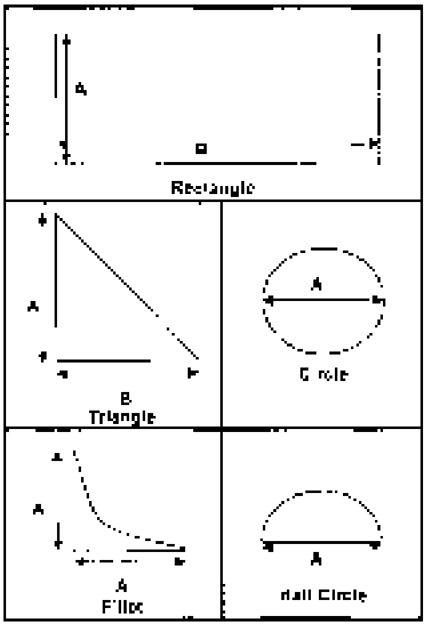
Instructions Area Calculations

A. Divide area into basic shapes as shown in [illegible] "Area Calculations" Word document)
B. Enter a basic description of the area for your reference
C. Pick the basic shape of the area from the drop-down menu in the Shape column
D. Enter the dimension(s) in feet in A and/or B. (Some shapes only require one dimension)
E. If more than one area has the same shape and dimension(s) enter the number of areas with the same shape and [illegible]
F. [illegible]

Area Calculation

Description	Shape	A, ft	B, ft	Area, Sq. Ft.	Number of Areas	[illegible]	Total Area Sq. Ft.
Main Parking	Rectangle	[illegible]	100	[illegible]	[illegible]		[illegible]
Main Parking	Triangle	[illegible]	30	[illegible]	[illegible]		[illegible]
Driveway	Fillet	[illegible]		[illegible]	[illegible]		[illegible]
Cul-de-sac	Circle	70		3848.5	[illegible]		3848.5
Planter	Rectangle	45	5	225	2		450
Planter	Half Circle	5		[illegible]	4		[illegible]
Total						Total	14,20[illegible]



Instructions Volume and Weight Calculations

[illegible] The Target Density Calculator can be used to determine your target density based on any reference density [illegible]

Volume & Weight Calculation

Material	Thickness, Inches	Unit Weight, pcf	Compacted Volume, Cubic Yards	Weight, Tons
Asphalt	5	[illegible]	[illegible]	[illegible]

Target Density Calculator

Ref. Density [illegible]	[illegible]	[illegible]
% Ref. Density	[illegible]	
Target Density, pcf	[illegible]	
Spread Rate, lbs./SY-inch	[illegible]	

Note on Unbound Granular Materials – [illegible]

[illegible]

NCHRP

Web-Only Document 117A:

Accessible Pedestrian Signals: A Guide to Best Practices

David L. Harkey
Daniel L. Carter
University of North Carolina
Chapel Hill, NC

Janet M. Barlow
Billie Louise Bentzen
Accessible Design for the Blind
Asheville, NC

Contractor s Guide for NCHRP Project 3-62
Submitted June 2007

National Cooperative Highway Research Program
TRANSPORTATION RESEARCH BOARD
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CHAPTER 1

Introduction to Accessible Pedestrian Signals: Definition and Current Guidance

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This chapter provides a definition of accessible pedestrian signals and an overview of their use. This chapter also includes an overview of accessible pedestrian signal (APS) standards development in the United States and current guidance on the use of APS devices.

Appendix A includes the portions of the *Manual on Uniform Traffic Control Devices* (1) and the *Draft Public Rights of Way Accessibility Guidelines* (2) that pertain to APS

Accessible Pedestrian Signals

What Is an Accessible Pedestrian Signal?

According to the *Manual on Uniform Traffic Control Devices* (MUTCD), an accessible pedestrian signal (APS) is a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces (*1*, Section 4A.021).

According to the *Draft Guidelines for Accessible Public Rights of Way* (Draft PROWAG), an APS is a device that communicates information about the "Walk" phase in audible and vibrotactile formats (*2*, R105.5).

Note that the Draft PROWAG definition states that an APS provides information in both audible and vibrotactile formats, while the MUTCD says an APS provides information in audible formats "and/or" vibrating surfaces.

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Figure 1-1. Examples of pushbutton-integrated accessible pedestrian signals from various manufacturers.

APS devices are known by different names in different countries, including the following:

- Acoustic signals,
- Audiotactile signals,
- Audible pedestrian signals,
- Audible traffic signals,
- Audible pedestrian traffic signals, and
- Audible crossing indicators.

Major Functions of APSs

APSs can provide information to pedestrians about

- The existence and location of the pushbutton that activates the "Walk" signal (Figure 1-1),
- The beginning of the walk interval,
- The direction of the crosswalk and the location of the destination curb,
- Intersection street names in braille, raised print, or speech messages,
- Intersection signalization with a speech message, and

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- Intersection geometry through tactile maps and diagrams or through speech messages.

Benefits of APSs

Research has found that APSs improve crossing performance by blind pedestrians. The devices:

- Allow more accurate judgments of the onset of the walk interval.
- Reduce the number of crossings begun during the "Don't Walk" interval (flashing "Don't Walk").
- Reduce delay, and
- Result in significantly more crossings being completed before the signal changes.

In addition, sighted pedestrians also begin crossing faster at intersections with APSs. (See Appendix C for details of research.)

Use in the United States

Although audible crossing indicators have been available for more than 25 years, they have not been commonly installed in the United States. This is probably attributable to the following two factors:

- Disagreement among blind people on the need for, and effectiveness of, audible pedestrian signals, and
- Noise pollution and consequent community opposition.

In the past 10 years, changes in intersection design and signalization (see Chapter 3) have affected the traditional street crossing techniques used by blind pedestrians, making the pedestrian phase harder to recognize for those who cannot see the visual pedestrian signal. In addition, it has become essential to cross during the pedestrian phase at many intersections. These changes have led to more requests for accessible pedestrian signals and to increased advocacy for their installation in recent years.

In addition, developments in technology have occurred. New types of accessible pedestrian signals, which provide more information and address some of the noise concerns, are now available in the United States.

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In Japan, Australia, and some European countries, APS devices have been routinely installed at many intersections for at least 20 years. Information about policies in those countries is included in Chapter 10.

History of Accessible Pedestrian Signals in the United States

Although there are reports of audible pedestrian signals in the United States as early as 1920, they were not included in U.S. standards and regulations until the *MUTCD 2000* (3). Typical devices were bells or buzzers designed by engineers in response to requests from individuals who were blind. The earliest reported installations were near schools for the blind.

Mass marketing of accessible pedestrian signals first occurred in the 1970s, when cuckoo/chirp signals were incorporated on pedestrian signal heads (pedheads) to form APSs. These signals, based on a Japanese system, emitted sound from an overhead speaker only during the walk interval, and the speakers were typically aimed toward the opposite end of the crosswalk (Figure 1-2).

Other types of devices that had been developed in Europe and Australia were not marketed in the United States (see sections on Sweden and Australia in Chapter 10).

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Figure 1-2. Pedhead-mounted APS. The speaker is mounted on top of the pedestrian signal head.

Controversy Over the Use of Accessible Pedestrian Signals

Early installations of APSs generated complaints about noise from residents living near the signals. In addition, the two main consumer groups representing blind people—the American Council of the Blind (ACB) and the National Federation of the Blind (NFB)—disagreed about the need for accessible pedestrian signals. Until the early 1990s, ACB supported use of APSs as a means of providing additional information at all intersections, while NFB opposed all use of APSs.

Each of these consumer groups has a membership of approximately 25,000 people, which combined represents less than 1% of people who are blind or who have low vision in the United States. Their disagreement was often very confusing to community officials who were trying to determine the best course of action. Although NFB now states that APSs should be used in some situations, the organization is still opposed to "wholesale" installation at every intersection.

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Problems with Pedhead-Mounted APS

Pedhead-mounted APS devices provide limited information. The two-sound system (cuckoo/chirp) provides an ambiguous indication of "Walk", and it requires blind pedestrians to know their direction of travel at all times.

The devices also only provide sound during the walk interval. While the signal sound is loud and is intended to provide directional guidance across the street, the short duration of the walk interval at most locations means that the sound ends before pedestrians have completed crossing.

The devices also fail to provide any information about the presence or location of the pushbutton that activates the signal.

See Appendix C for more information about the research results.

Pushbutton-Integrated Devices

In the mid 1990s, accessible pedestrian signals that were integrated into the pushbutton, similar to European and Australian systems, began to be available in the United States (Figure 1-5). These signals provide audible instructions at a relatively low volume, which are intended to be heard at a distance 6 to 12 ft from the pushbutton.

Additional features of the devices include the following:

- Vibrotactile "Walk" indication, in addition to audible "Walk" indications,
- Pushbutton locator tone, which repeats constantly at once per second to provide information about the presence and location of a pushbutton,
- Tactile arrow that points in the direction of travel on the crosswalk, and
- Automatic volume adjustment, allowing the APS to respond to ambient sound and provide louder indications when the traffic is louder and quieter indications when the traffic is quiet.

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Figure 1-3. Pushbutton-integrated APS.

Proper Location

The functioning of a pushbutton-integrated APS is based on proximity to the crosswalk location. The closer the APS is located to the departure location, the quieter it can be. In addition, the vibrotactile indication and tactile arrow are not usable when located too far back from the street. Figure 1-4 illustrates installation recommendations.

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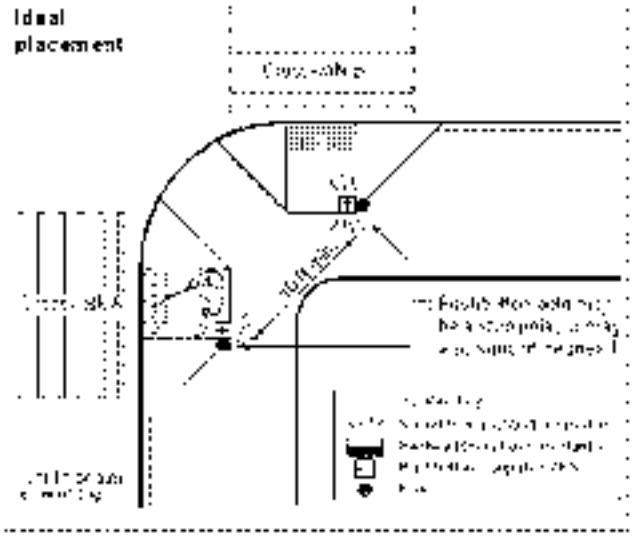

Figure 1-4. Ideal installation of a pushbutton-integrated APS—within 5 ft of the crosswalk extended, within 10 ft of the curb, and separated by more than 10 ft from other APSs on the corner, adjacent to a level landing.

Changes in intersection design, traffic, and signalization have affected the ability of pedestrians who are blind to cross streets using traffic sounds, as discussed in detail in Chapter 2.

Accessible Pedestrian Signals Currently Available in the United States

Accessible pedestrian signals provide an auditory (tone or speech) indication of the walk interval. Vibrotactile indication of the walk interval is required by the Draft PROWAG, but not all APS devices are capable of providing vibrotactile indications. Numerous other features are available, and detailed descriptions of the various features can be found in Chapter 4.

In the previous version of this document, accessible pedestrian signals were described as one of four design types: pedhead mounted, pushbutton integrated, vibrator only, and receiver based (4). These device design types were mainly categorized by the location and type of "Walk" indication provided, although there were characteristic differences in other features at that time. As technology has developed, several combinations of these different types have emerged, and modifications have been made that prevent easy grouping of devices into four "types." A discussion of accessible pedestrian signals and

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their features using those terms becomes confusing. This guide, the Draft PROWAG, and the MUTCD all recommend accessible pedestrian signals that have audible and vibrotactile "Walk" indications, which are only available when APS is integrated into the pushbutton. However, other features, such as additional beaconing speakers, may also be provided.

In this guide, the labeling of types of accessible pedestrian signals has generally been dropped, except in this chapter and in Chapter 9. The types are described here for clarification and as background information. Some manufacturers and distributors may continue to use these terms to describe available products.

Pushbutton-integrated APS devices have the following characteristics:

- They are common in Europe and Australia and are rapidly becoming common in the United States.
- The speaker and vibrating surface are located at the pushbutton.
- A regularly repeating quiet locator tone provides information about the presence of the pushbutton and its location during the flashing and steady "Don't Walk" intervals.
- The pushbutton locator tone and "Walk" indication volumes respond to ambient sound.
- The volume is typically adjusted so it can be heard only at the beginning of crosswalks.
- They may provide other information about the name of streets, the geometry of the intersection, or signalization.

Pedhead mounted accessible pedestrian signals can be described as follows:

- They are the most common type installed between 1960 and 2000 in the United States.
- The speaker is mounted on top of the pedestrian signal head.
- A bell, buzzer, cuckoo, chirp, tone, or verbal message is audible during the walk interval only.
- Because it is usually intended to be heard across the street and to act as a beacon, it is thus relatively loud.

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Receiver-based APS devices typically have the following features:

- The message is transmitted by infrared or LED technology from the pedestrian signal to a personal receiver held by the individual.
- Blind pedestrians must have and use the appropriate receiver for the technology installed.
- It may provide other information about the name of streets, geometry of the intersection, direction of travel, and address information.

With vibrotactile-only accessible pedestrian signals, either the arrow or the pushbutton housing or the pushbutton itself vibrates during the walk interval. Such devices are no longer available in the United States, and they do not conform to the Draft PROWAG.

U.S. Legislation, Standards, and Guidance Applicable to APS

Transportation Equity Act for the 21st Century

The Transportation Equity Act for the 21st Century (TEA-21) states that pedestrian safety considerations should be included in new transportation plans and projects.

Section 1202(g)(2) of the act directed that safety considerations "…shall include the installation, where appropriate, and maintenance of audible traffic signals and audible signs at street crossings."

TEA-21 also required the Federal Highway Administration (FHWA) to develop guidance on pedestrian and bicycle facility design. The resultant Policy Statement on Accommodating Bicyclists and Pedestrians in Transportation Projects includes the following statement: "Sidewalks, shared use paths, street crossings (including over- and underpasses), pedestrian signals, signs, street furniture, transit stops and facilities, and all connecting pathways shall be designed, constructed, operated and maintained so that all pedestrians, including people with disabilities, can travel safely and independently" (5).

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MUTCD

The MUTCD includes two sections on accessible pedestrian signals—Section 4E.06, Accessible Pedestrian Signals, and Section 4E.09, Accessible Pedestrian Signal Detectors. In addition, Section 4D.03, Provisions for Pedestrians, addresses the need for accessible pedestrian signals in the following standards and guidance:

> "*Standard:*
>
> The design and operation of traffic control signals shall take into consideration the needs of pedestrians as well as vehicular traffic. If engineering judgment indicates the need for provisions for a given pedestrian movement, signal faces conveniently visible to pedestrians shall be provided by pedestrian signal heads or a signal face for an adjacent vehicular movement.
>
> *Guidance:*
>
> Safety considerations should include the installation, where appropriate, of accessible pedestrian signals (see Sections *4E.06* and *4E.09*) that provide information in nonvisual format (such as audible tones, verbal messages, and/or vibrating surfaces)." (3)

Section 4E.06 includes standards for APS use, guidance on installation of APSs, and standards and guidance on "Walk" indications and features of APS. Section 4E.09 provides standards and guidelines that address features and locations of accessible pedestrian signal detectors (pushbuttons), pushbutton locator tones, and volume of signals.

The Federal Highway Administration publishes the MUTCD, with revisions made on a regular basis. Major input to the MUTCD is provided by the National Committee on Uniform Traffic Control Devices (NCUTCD), which meets twice a year to consider revisions.

Changes to the MUTCD are published in the *Federal Register* as a Notice of Proposed Rulemaking, which is followed by a comment period and other standard federal rulemaking procedures. The next major revision of the MUTCD is expected to be completed in 2009, and the NCUTCD has recommended major revisions to the sections

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on APSs for that edition. A Notice of Proposed Amendments was published in January 2008 (6).

The current MUTCD sections on APSs and the revisions proposed by the NCUTCD are included in Appendix A.

Section 504 of the Rehabilitation Act of 1973

The requirement for nondiscrimination on the basis of disability dates from well before the 1998 TEA-21 or the 1990 Americans with Disabilities Act. Section 504 of the Rehabilitation Act of 1973 prohibits discrimination on the basis of disability in programs and activities receiving or benefiting from federal financial assistance:

> "No qualified handicapped person shall…be denied the benefits of…any program or activity that receives or benefits from Federal financial assistance administered by the DOT." (Rehabilitation Act, 1973)

The act specifically requires the installation of curb ramps on federally funded projects.

Americans with Disabilities Act of 1990

The Americans with Disabilities Act (ADA) is a landmark law that protects the civil rights of persons with disabilities. It prohibits discrimination on the basis of disability in employment, state and local government services, transportation, public accommodations, commercial facilities, and telecommunications. The ADA has five parts, as follows:

- Title I—Employment
- Title II—Public services
- Title III—Public accommodations and commercial facilities
- Title IV—Telecommunications
- Title V—Miscellaneous

The ADA applies to all programs and facilities of state and local government, regardless of funding source. Guidelines for implementation of each part of the ADA were developed by the agencies charged with that responsibility.

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The U.S. Access Board (formerly known as the Architectural and Transportation Barriers Compliance Board), an independent federal agency devoted to accessibility for people with disabilities, develops and maintains accessibility guidelines for buildings, facilities, technologies, and transit vehicles covered by Titles II and III of the ADA. These guidelines are known as the *ADA Accessibility Guidelines* (ADAAG) (7).

The ADAAG serves as the basis of enforceable standards issued by the U.S. Department of Justice (DOJ) and the U.S. Department of Transportation (USDOT).

The implementing regulations for Title II of the ADA require state and local government programs and properties to be accessible to persons with disabilities.

ADAAG provides minimum technical provisions for access. The guidelines implementing the ADA were published in 1991 and were adopted as final rule (an enforceable standard) by the DOJ and USDOT in 1992. Section 14, Public Rights-of-Way, was not, however, issued as a final rule at that time.

ADA Standards Development Process

The development of accessibility standards is a long process, with numerous opportunities for public input and comment. The development of public rights-of-way standards is under way, but will probably not be completed for several more years. The following steps are involved in developing accessibility standards for public rights-of-way:

- A Public Rights-of-Way Access Advisory Committee (PROWAAC) was formed by the Access Board in 1999 to develop recommendations for public rights-of-way.
- Recommendations were provided in a 2001 report to the Access Board, *Building a True Community: Final Report—Public Rights-of-Way Access Advisory Committee* (8). Discussion and advisory notes in that document may be helpful in understanding some of the provisions in the Draft PROWAG.
- The Access Board took the PROWAAC recommendations and developed the Draft PROWAG, which was first published on June 17, 2002, for comment. A revised draft was published on November 23, 2005. The APS sections of the Draft PROWAG are included in Appendix A.

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- This draft will be followed by a regulatory analysis of the cost of implementing the rule and development of text, commentary, figures, and preamble of guidelines. After approval of a rule by the Access Board, the regulatory analysis and rule will be reviewed by the Office of Management and Budget before release for publication.
- A Notice of Proposed Rulemaking (NPRM) will be published in the *Federal Register*. After publication of the NPRM, comments will be solicited from the public, and staff and the Access Board will evaluate the comments and propose any changes deemed necessary. After that, final guidelines will be approved and issued by the Access Board and eventually adopted as standards by DOJ and USDOT.

Information about the process and progress of development of the guidelines is available at www.access-board.gov, under "Public Rights of Way."

Responsibility under ADA Implementing Regulations

ADA implementing regulations require programs of state and local governments to be accessible. *Barden v. Sacramento*, a 2004 court decision, defined sidewalks and street crossings as programs and facilities of state and local government; thus, they must be accessible under Title II of the ADA.

Several specific sections of the ADA implementing regulations require accessibility.

- Section 35.151, New Construction and Alterations, states that "Each facility ... constructed by, on behalf of, or for the use of a public entity shall be designed and constructed in such manner that the facility ...is readily accessible to and usable by individuals with disabilities ..."
- "Readily accessible to and usable by" means that it can be approached, entered, and used easily and conveniently by individuals with disabilities (including mobility, sensory, and cognitive impairments). As stated in the preamble to the regulation, "To the extent that a particular type or element of a facility is not specifically addressed by the standards, [the above] language...is the safest guide" (9).

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- Section 35.160, General, states "A public entity shall take appropriate steps to ensure that communications with... members of the public with disabilities are as effective as communications with others."

The bottom line is that ADA requires newly constructed facilities to be accessible even if there are no specific guidelines covering that type of facility. ADA compliance is a civil rights issue.

Draft PROWAG Sections on APS

Section R208 of the Draft PROWAG requires accessible pedestrian signals be used where pedestrian signals are installed. Section R306 provides specifications regarding walk interval indications, location of devices, volume, pushbutton locator tones, pushbutton operation, size and contrast, signs and tactile arrows, and optional features. Further description and details can be found in Chapter 6 of this guide.

In a memo published January 26, 2006, FHWA states the following:

> The Draft Guidelines are not standards until adopted by the U.S. Department of Justice and the U.S. Department of Transportation. The present standards to be followed are the ADA Accessibility Guidelines (ADAAG) standards. However, the Draft Guidelines are the currently recommended best practices, and can be considered the state of the practice that could be followed for areas not fully addressed by the present ADAAG standards. Further, the Draft Guidelines are consistent with the ADA's requirement that all new facilities (and altered facilities to the maximum extent feasible) be designed and constructed to be accessible to and useable by people with disabilities.*(10)*

Note: The "Draft Guidelines" to which the FHWA memo refers are referred to as "Draft PROWAG" throughout this guide.

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CHAPTER 2

Travel by Pedestrians Who Are Blind or Who Have Low Vision

Blindness and Vision Loss 2

Travel Tools and Techniques of People Who Are Blind or Who Have Low Vision 6

How People Who Are Blind or Visually Impaired Cross Streets 9

Changes in the Travel Environment 12

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This chapter provides demographic information about individuals who are blind or who have low vision, as well as information about types of vision loss. Travel techniques are explained, and the effect of changes in traffic control and signalization on the travel of pedestrians who are blind or visually impaired is discussed.

Blindness and Vision Loss

Definitions

Visual impairment is defined as a functional limitation in seeing, including "nonsevere limitation" (difficulty seeing words and letters), and "severe limitation" (unable to see words and letters).

Legal blindness is a level of visual impairment defined in law, which is used to determine eligibility for government disability benefits. Legal blindness refers to a central visual acuity of 20/200 or less in the better eye with the best possible correction, as measured on a Snellen vision chart, or a visual field of 20 degrees or less.

Vision correctable to 20/20 with at least 180 degree field is considered "normal" vision. A simplified explanation of visual acuity is that a person who is legally blind with 20/200 vision sees at approximately 20 ft what a person with 20/20 vision sees at 200 ft. A person with a visual field of 20 degrees or less is able to see no more than a 20-degree field without scanning.

Types of Vision Loss

General types of vision loss include

- Reduced acuity,
- Restricted fields (central or peripheral),
- Combination of reduced acuity and restricted fields, and
- Total blindness, or light perception only.

Reduced acuity can refer to a large range of functional vision, from vision tested as 20/20 to totally blind. Lighting and contrast affect functional vision and are not reflected in the clinical measurements.

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The general category of restricted fields can be further divided into central field loss and peripheral field loss.

Reduced Acuity

Figure 2-1 represents a street crossing as it might be seen by a person with general reduced visual acuity. An overall loss of acuity, sensitivity to glare, and loss of contrast sensitivity is common in the elderly population.

Figure 2-1. A street crossing as might be seen by a person with general reduced visual acuity.

Central Field Loss

Individuals with a central field loss usually will have difficulty seeing pedestrian signals, some signs, and details directly in front of them (Figure 2-2). Central field loss is typical of macular degeneration, the leading cause of blindness in those over 60.

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Figure 2-2. The same street crossing as in Figure 2-1, but now as might be seen by a person with central field loss.

Peripheral Field Loss

Individuals with peripheral field loss, sometimes referred to as tunnel vision, may clearly see details directly in front of them, but have difficulty with objects and signs off to the side. In addition, depth perception is often impaired (Figure 2-3). Glaucoma and retinitis pigmentosa are the main causes of peripheral field loss.

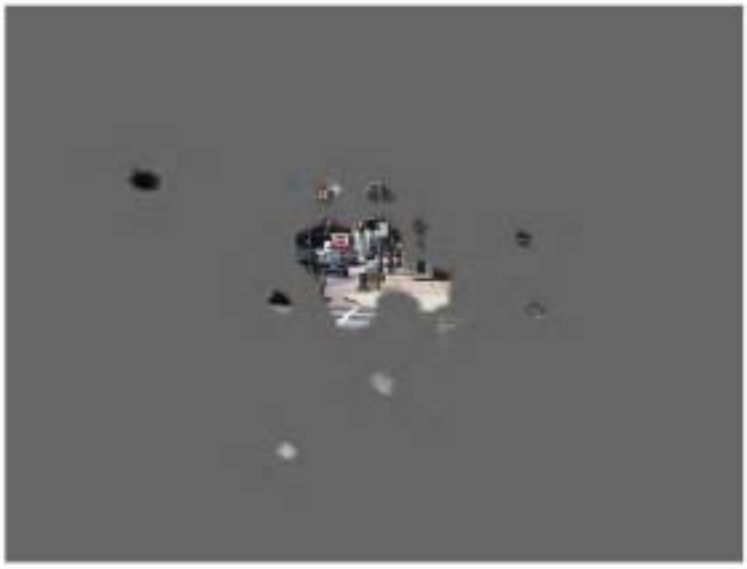

Figure 2-3. A street crossing as might be seen by a person with peripheral field loss.

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Decrease in Attentional Field

Research by Bralyn et al. demonstrated that over age 60 the prevalence of problems detecting objects in the peripheral visual field increases dramatically (*17*). This is known as a decrease in attentional field, and it may be present with or without other types of visual impairment. By age 90, 40% of people have an attentional field of less than 10 degrees left and right. Thus, if they are looking at a pedestrian signal head, they are likely to be visually unaware of vehicles that may be turning across their path of travel until it is too late to take appropriate action.

Total Blindness or Light Perception

Individuals who are considered totally blind usually cannot see any differences in light and dark. Individuals who have light perception may be able to tell if it is dark or light and to determine the direction of a bright light source, but they do not have vision that is usable for discerning objects or a travel path.

Prevalence of Blindness

Different sources provide different estimates of the prevalence of blindness in the United States. There is no registry of individuals with vision loss, and different methodologies are used to derive estimates.

Adams et al. estimate that 8.3 million (3.1%) Americans of all ages are affected by some degree of vision impairment (*12*).

According to the Centers for Disease Control and Prevention (CDC), more than 1 million Americans are legally blind, and 12 million are visually impaired. The number of blind and visually impaired people is projected to double by 2030 (*13*).

A Lighthouse National Survey found that 8.7 million (9%) Americans age 45 and older report a severe vision impairment, defined as an inability to recognize a friend at arm's length even when wearing corrective lenses, an inability to read ordinary newspaper print with corrective lenses, poor or very poor vision even when wearing corrective lenses, or blindness in both eyes (*14*).

A survey by Statistics Canada reported that 655,000 Canadians identified themselves as having a "seeing disability" (*15*). Of those Canadians reporting a seeing disability,

- 511,000 were adults living in households.

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- 94,000 were adults living in institutions, and
- 30,000 were children age 14 and under.

Area of Residence

Of people with vision impairments, 33% live in cities, 37% live in suburbs, 28% live in nonmetropolitan areas (e.g., small towns), and 1% live in farm areas (16). In comparison with the general population, persons who are visually impaired are somewhat underrepresented in the suburbs (i.e., 48% of the general population lives in suburbs versus 37% of the visually impaired) and overrepresented in cities.

Travel Tools and Techniques of People Who Are Blind or Who Have Low Vision

People who are blind or visually impaired make choices when it comes to traveling. At any given time, they can travel using

- A human guide, which involves holding onto someone's arm;
- A long white cane that identifies and helps avoid obstacles or elevation changes;
- A guide dog;
- Special optical or electronic aids; or
- No additional aid.

The choice of tools depends on the extent and nature of visual impairment, personal preference, lighting, and familiarity with the area.

To travel independently, people with visual impairments use whatever vision they have, auditory and tactile information, and any gathered knowledge of an area to keep track of their location and make travel decisions.

Human Guide

At one time or another, most people who are blind will make use of the human guide technique (sometimes referred to as a sighted guide), in which a person with sight serves as a guide to a person who is blind or visually impaired.

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Long White Cane

Many individuals who are blind or visually impaired use a long white cane as a mobility device. In the most common technique, the cane is extended and swung back and forth across their body in rhythm with their steps to provide information about the environment directly in front of them, such as elevation changes or obstacles (Figure 2-4).

In another technique, often used by people with low vision, the cane is held diagonally across their body, with the tip about an inch above the ground. When those individuals are unsure about what they are seeing, they use the cane to check the object or sidewalk surface.

Figure 2-4. Pedestrian with long white cane.

Guide Dogs

Guide dogs are carefully trained service animals used as travel tools by approximately 2% of people who are blind (Figure 2-5). The dog responds to the commands of its handler, such as "right," "left," and "forward." The dog guides the handler around obstacles and stops at curbs or stairs. The handler must, however, know where they are going and must make decisions about the proper time to begin a street crossing. Dog guides move in response to directions from their handlers, but may disobey commands to avoid danger.

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Figure 2-5. Pedestrian with guide dog.

No Aid

Not all persons considered blind use a long white cane or a guide dog. People who are visually impaired often rely on their remaining sight and auditory and tactile cues in their surroundings for orientation and travel. Some may also use aids such as telescopes for specific tasks.

Orientation and Mobility Training

Many pedestrians who are visually impaired or blind have received orientation and mobility (O&M) training from an O&M specialist (Figure 2-6). O&M specialists usually have an undergraduate or graduate degree in teaching travel skills to persons who have visual impairments.

Orientation is the ability to understand where one is located in space, and *mobility* refers to being able to travel through that space safely. The goal of most O&M training is to prepare a person who is visually impaired to travel in a variety of environments, both familiar and unfamiliar, and to assess new intersections and travel new routes (Figure 2-6). It is important to note that orientation training and assistance is not provided for every route that a person who is blind needs to travel.

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Figure 2-6. Visually impaired pedestrian crossing street with O&M specialist.

How People Who Are Blind or Visually Impaired Cross Streets

Techniques and cues used in crossing streets are diverse and vary by the type of location and by the individual and his or her level of vision. Individuals who are blind or visually impaired often travel to unfamiliar areas and intersections, and they gather information from available sources in order to travel safely.

The following discussion describes typical techniques used at unfamiliar intersections. Although pedestrians who are blind probably travel mostly on routes with which they are familiar, it is not uncommon for bus drivers or taxi drivers to provide incorrect information about a location or to drop off a person at a slightly different location than expected. It is thus necessary for blind pedestrians to regularly confirm location and other information using nonvisual techniques.

Once pedestrians who are blind are familiar with an intersection, they do not usually need to analyze the intersection and traffic control system at length every time. They may still, however, need to listen long enough to determine that they are at the correct location and that the signal is functioning as usual. They will still need to detect the street, align to cross, identify the walk interval, and maintain alignment while crossing. Accessible pedestrian signals can particularly assist with the task of identifying the walk interval both at familiar and unfamiliar locations.

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Detecting the Street

The information first needed by pedestrians who are blind is **"Have I arrived at a street?"** People who are blind or visually impaired use a combination of cues to recognize the street edge. These may include:

- Curb or the slope of the ramp,
- Truncated dome detectable warnings, if available,
- End of building line and open sound of the intersection,
- Sound of traffic on the street beside them (the parallel street),
- Sound of traffic stopping on the street they are approaching (the perpendicular street),
- Presence of pedestrians, and
- Presence of an intersecting sidewalk.

Identifying the Street

The information next needed for decision making at unfamiliar intersections is **"Which street is this?"** This information is only occasionally provided in an accessible format.

Pedestrians who are visually impaired develop a mental map and keep track of where they are within that map, usually by counting blocks and street crossings. Where necessary and available, assistance is sometimes sought from other pedestrians.

Analyzing Intersection Geometry

The next information needed is **"What is the geometry of this intersection?"** The pedestrian needs to know the answers to the following questions:

- Is my destination curb straight in front of me, or must I angle to the left or right to reach it?
- How many streets intersect here?
- How wide is this street?
- Should I expect to encounter any islands or medians as I cross this street?
- Am I standing within the crosswalk?

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This information may be immediately available to pedestrians having full vision, but pedestrians who are blind may find it impossible to determine this information by listening to traffic patterns. Incorrect or missing answers to any of these questions may result in the pedestrian missing the destination curb or median.

Analyzing the Traffic Control System

Next, pedestrians with visual impairments need to know **"What is the type of traffic control system at this intersection?"** They must be able to determine answers to the following questions:

- Is this a signalized intersection?
- Do I need to push a button to activate the walk interval? If so, where is the button?
- Is the button close enough to the crosswalk that I will have time to push the button, position myself correctly at the crosswalk, and reestablish my alignment facing the destination curb before the onset of the walk interval?
- Which button controls the walk interval for the street I want to cross?
- Does it stop traffic on one street, or all traffic?
- Do cars still turn during the walk interval?
- Is there a second button on the median or crossing island that I must push?
- Will there be a surge of parallel traffic telling me the walk interval has begun? Will I be able to hear it over other, concurrent traffic sounds?

Techniques for gathering this information include listening to traffic patterns through several signal cycles and searching the sidewalk area for poles with pushbuttons. Missing information for any of these questions may result in failure to use pedestrian pushbuttons, not beginning the crossing during the walk interval, not completing the crossing before perpendicular traffic begins moving, and crossing at times other than the pedestrian phase.

Aligning to Cross

Before starting to cross, the pedestrian must align to cross or choose a heading for the crossing. Typical techniques for this task include maintaining the alignment used on the approach to the intersection and listening to parallel traffic through a signal cycle to

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constant alignment to parallel traffic. The need to use pedestrian pushbuttons often prevents the use of parallel traffic for alignment. After pushing the button, the pedestrian must cross on the next pedestrian phase, which is usually the next time that traffic begins moving parallel to the pedestrian's crosswalk.

Identifying the Walk Interval

After determining the geometry of the intersection, aligning to face the destination curb, determining that the intersection is signalized, and having pushed a button, where necessary, pedestrians who are blind need to know **"When does the walk interval begin?"**

In the most common technique for crossing at signalized intersections, pedestrians who are blind or visually impaired begin to cross the street when there is a surge of traffic on the street parallel to their direction of travel. This technique is dependent on the presence of traffic and on consistent signal phasing. Various types of phasing and intermittent or low volumes of traffic traveling parallel to the pedestrian may affect the reliability of the technique.

Maintaining Crossing Alignment

Once the pedestrian who is blind has begun to cross the street, the next question is **"Am I headed straight towards my destination curb?"**

Traffic going in the same direction on the parallel street, if present, provides helpful auditory guidance. In addition, pedestrians who are blind may use traffic waiting on the perpendicular street as a partial alignment cue.

Turning traffic can, however, make it difficult to hear and align with the traffic traveling straight through the intersection.

In the absence of traffic on the parallel street, pedestrians who are blind are more likely to veer toward or away from the intersection.

Changes in the Travel Environment

In the past 20 years, significant changes in intersection geometry, signalization, driver behavior, and the automotive technology have affected the ability of blind travelers in the United States to use the above-mentioned techniques.

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Intersection Design Changes and Their Effect on Travel Techniques

Intersection design changes have had the following effects on travel techniques:

- Wider streets require more precise alignment.
- Large radius corners make alignment more difficult and increase crosswalk length.
- Curb ramps and depressed corners make street detection and alignment difficult.
- Medians and islands complicate wayfinding and alignment.
- Presence of slip lanes and splitter islands requires crossing in gaps in traffic even at signalized intersections.
- Crosswalk alignment is not consistent.
- Curb extensions, also called bulb-outs or intersection chokers, sometimes complicate wayfinding.
- Raised crosswalks and tabled intersections may obliterate the sidewalk/street boundary.

Driver Behavior and Automotive Technology

Changes in driver behavior and vehicle technology also effect travel techniques, as follows:

- Aggressive and inattentive drivers are moving faster and are less likely to stop for pedestrians.
- Automotive technology, including hybrid and electric cars, has become quieter, making vehicles harder to hear by pedestrians.
- There is less pedestrian traffic in many areas, and drivers are less aware of pedestrians.

Signalization Changes

Intersection signalization has become more complex. Details on signalization and the effect on travel by pedestrians who are blind are provided in Chapter 4.

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CHAPTER 3

Understanding Traffic Signals and Modern Intersection Design

MUTCD Warrants and Signalization 2

Intersection Signalization and Timing Plans 6

Vehicular Signals and Timing 15

Pedestrian Signals and Timing 18

Collaboration 23

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This chapter provides a description of the terminology and characteristics of traffic signals and intersection design. It is intended to educate O&M specialists who must interact with the travel environment and with traffic engineers, but who may not be familiar with all the terminology and design techniques.

Intersections and signals have become more complex, and it is important that O&M specialists and blind travelers understand these changes. Skills and strategies used by pedestrians who are blind or visually impaired to cross streets at signalized intersections were developed at intersections that had pretimed signals, which meant the signal changed on a regular basis. Signalization has become more complex with the introduction of vehicular and pedestrian actuation and multiple signal phases. This increased complexity has made some previously accessible intersections now inaccessible for pedestrians with visual impairments.

It is essential that O&M specialists understand these changes so that the changes can be incorporated into the curriculum, instructional techniques can be adapted in response to these changes, and O&M specialists can better advocate for their consumers' needs

MUTCD Warrants and Signalization

What Is a Signal Warrant?

A warrant is a condition that an intersection must meet to justify a signal installation. The MUTCD specifies eight "traffic control signal needs studies," known as warrants. The MUTCD advises, however, that "the satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal." (1A-01). The final decision is to be made based on the traffic engineer's judgment.

Process to Determine if a Signal Is Warranted

To determine whether or not an intersection warrants a traffic control signal, the traffic engineer analyzes vehicle traffic volume, pedestrian activity, intersection crash history, and the physical environment. The intersection analysis may include a review of the following factors:

- Number of vehicles entering the intersection from all directions during 4-hour and 8-hour periods,

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- Vehicular volumes during peak hours, classified by vehicle type for traffic movement in all directions.
- Pedestrian volume on each crosswalk in all directions, including children, the elderly, and/or persons with disabilities, during each hour of the day;
- Requests from participants attending nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities;
- Posted speed limit;
- Physical layout; and
- Crash experience/history.

Different warrants require detailed analysis of different aspects of the above information.

The current *MUTCD* can be downloaded from http://mutcd.fhwa.dot.gov.

Examples of Signal Warrants

Information on two of the signal warrants is included below to illustrate some of the considerations.

Warrant 1—8-Hour Vehicular Volume

Engineers evaluate the number of vehicles traveling through the intersection per hour; a certain volume must be met in order to justify installation of a traffic signal. A complex table is used, which includes the number of lanes of moving traffic for each approach, vehicles per hour on the major street, and vehicles per hour on the higher volume minor street approaches.

According to the MUTCD:

> Standard
>
> The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:
>
> A. The vehicles per hour given in both of the 100 percent columns of Condition A in [Table 3-1] exist on the major street and the

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higher-volume minor-street approaches, respectively, to the intersection; or

B. The vehicles per hour given in both of the 100 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

In applying each condition the major street and minor street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours…

Option: If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes of the 70 percent volumes in Table 3-1 may be used in place of the 100 percent columns. (V. Section 4C.02)

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Table 3-1. Example of Signal Warrant 1.

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)			Vehicles per hour on higher-volume minor-street approaches (one direction only)		
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	100%[a]	80%[b]	70%[c]
2	1	500	400	350	150	120	105
2 or more	1	600	480	420	150	120	105
2 or more	2 or more	600	480	420	200	160	140
1	2 or more	500	400	350	200	160	140

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)			Vehicles per hour on higher-volume minor-street approaches (one direction only)		
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	100%[a]	80%[b]	70%[c]
1	1	750	600	525	75	60	53
2 or more	1	900	720	630	75	60	53
2 or more	2 or more	900	720	630	100	80	70
1	2 or more	750	600	525	100	80	70

[a]Basic minimum hourly volume.

[b]Use for combination of Conditions A and B after adequate trial of other remedial measures.

[c]May be used when the major-street speed exceeds 70 km/h (40 mph) or in an isolated community with a population of less than 10,000

Warrant 4 Pedestrian Volume

Engineers evaluate the level of pedestrian activity at an intersection to see if a signal is warranted. The MUTCD describes Warrant 4 as being "intended for application where

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the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street" (*I. 40.05*).

As currently written, the warrant requires a fairly large volume of pedestrians crossing at a location:

> The need for a traffic control signal at an intersection or mid-block crossing shall be considered if an engineering study finds that both of the following criteria are met:
>
> A. The pedestrian volume crossing the major street at an intersection or mid-block location during an average day is 100 or more for each of any 4 hours or 190 or more during any 1 hour; and
>
> B. There are fewer than 60 gaps per hour in the traffic stream of adequate length to allow pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for pedestrians to wait, the requirement applies separately to each direction of vehicular traffic (*I. 40.05*)

In addition, "the Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic" (*I. 40.05*).

However, "the criterion for the pedestrian volume crossing the major roadway may be reduced as much as 50 percent if the average crossing speed of pedestrians is less than 1.2 m/sec (4 ft/sec)" (*I. 40.05*).

Intersection Signalization and Timing Plans

Intersection Signalization

Intersections are generally designed to provide optimal vehicle traffic flow. Timing plans may be of the following two general types:

- Fixed time (or pretimed), or
- Actuated.

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A signal at a given intersection may be designed to change from actuated to pretimed to flashing mode depending upon the following factors:

- Time of day (peak periods versus nonpeak periods),
- Day of week, and
- Malfunctions due to power outages.

It is important that O&M specialists understand signal design and terminology so they might teach these concepts to their students.

There is some variability in timing plans in different municipalities and in different locations, depending on the roadway needs and local practices.

Signal Design Terms

Phase—The right-of-way, yellow change, and red clearance intervals in a cycle that are assigned to an independent traffic movement or combination of movements.

Interval—The part of a signal cycle during which signal indications do not change.

- In other words, a phase is the time allotted to a specific movement, such as northbound traffic, whereas an interval is how long the light stays green, yellow, or red for vehicles or "Walk," flashing "Don't Walk," or "Don't Walk" for pedestrians.
- Busier intersections typically have separate phases for left-turn movements (i.e., protected left turns). When a major road intersects a minor road, the green intervals for the major road will be longer than those for the minor road to accommodate the heavier traffic on the major road.
- Although the MUTCD gives specific definitions to "phase" and "interval," these terms are often used interchangeably by traffic engineers.

Cycle—Sum total of all phases at a signal.

- A cycle is timed from the start of one phase to the time when that same phase starts again.
- Larger, busier intersections will commonly have longer cycles.

Pretimed (Fixed Time) Signals

Pretimed intersections operate in predetermined and predictable fashion.

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- The sequence of phases (often 30 s or longer) is repeated regularly, regardless of traffic flow.
- The length of phases may change at different times of day. Based on a consistent timing plan for example, one street may have longer phases at peak hours than at nonpeak hours.
- Pretimed signals are still found in many locations, particularly in downtown areas.

Actuated Signals

Actuated signals change the length and/or the order of the phases in response to variations in vehicle or pedestrian traffic. Actuated signals are used where traffic volumes fluctuate or where it is desirable to minimize interruptions to traffic flow on the major street. Detectors are often placed on minor roads and in turn lanes (see Figures 3-1 and 3-2).

- Detectors monitor traffic and send notifications to the traffic signal controller. Detectors are most often inductive loops (electric), though they may also involve magnetic, microwave, video, and other technologies.
- Pushbuttons are most often used for pedestrian detection, although other "pedestrian sensing" technologies (microwave, infrared, piezoelectric) are also used.
- Because vehicular actuation allows the cycle to skip phases, pedestrians with visual impairments cannot accurately predict, based on previous experience, when the pedestrian phase will begin in the cycle.
- Some actuated signals may provide very short phases to accommodate a single vehicle, without provision of a pedestrian phase during that cycle. A pedestrian who is blind and crossing parallel to that vehicle may not realize that a pedestrian phase is not provided during that vehicle's movement.

The extent of actuation is dependent on geometric and operational requirements, but is generally categorized as either semi-actuated or fully actuated.

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Figure 3-1. Vehicle detector loops in pavement.

Figure 3-2. Vehicle detector loop in pavement.

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Semiactuated Signals

Semiactuated signals are common at the intersection of a main road and a minor side street.

- The main roadway signal stays green until a side-street detection is received, causing the traffic signal to change (the "Walk" signal for crossing the main roadway may not come on unless the pedestrian pushbutton is pressed).
- Vehicle detectors are in place only on the side street; pedestrian detectors are also installed only on the side street.
- Pedestrian activation (usually with a pushbutton) tells the signal to provide a "Walk" interval for pedestrians crossing the major street.
- The pedestrian signal for the side-street crossing may "rest in Walk" (give the "Walk" indication during the green signal for the major street) when no pushbutton is installed.

Fully Actuated Signals

Fully actuated signals are common at the intersection of two main roads (arterials). They are used when traffic volumes on each approach vary by time of day. Because they allow phases within a cycle to be skipped when vehicles are not present, they minimize delay.

- All movements/phases are actuated.
- Vehicle detectors are installed in all approach lanes.
- Pushbuttons are used to activate the "Walk" signal at pedestrian crossings.
- Changing traffic volumes can result in different timing and sequencing of phases for every cycle.

Basic Turning Phases

Protected Turn

A protected turn is made when no opposing through vehicular traffic or pedestrian crossing is allowed. The protected turn is denoted by a green arrow (Figure 3-3).

- It is typically activated by a vehicle detector.

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- The signal phasing "protects" vehicles by prohibiting any opposing movements, including pedestrian movements.
- Protected turns require a separate signal phase, which leads to multiphase signalization (more than two phases at the intersection).

Figure 3-3. Protected left-turn signal.

Permissive Turn

A permissive turn is made across an opposing flow of through vehicles and/or pedestrians. This is the most common type of left-turn phasing at signalized intersections, and it is used both when left-turn volumes are not excessive and when adequate gaps of sufficient size exist in the opposing traffic to safety accommodate turns.

- It is typically denoted by a circular green (green ball) signal (Figure 3-4).
- The driver is "permitted" to cross the opposing through flow, but must identify and select an appropriate gap in the opposing traffic stream through which to turn.
- The driver must also yield to pedestrians who are crossing lawfully within the intersection.

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Figure 3-4. Permissive green ball signal.

Design of Turning Movements

Concurrent (Dual) Left Turns

Concurrent, or dual, left turns are where two directions of turning traffic (e.g., eastbound and westbound) proceed together while the opposing through traffic (e.g., northbound and southbound) is stopped (protected left-turn phasing).

Concurrent left-turn signals can be activated either before or after the opposing through flows have had their green phase.

- If the left turn comes before the opposing through movement, it is called a "leading left turn." Leading left turns, which are much more common than lagging left turns, can create safety problems for blind pedestrians, since the surging left-turn traffic may be mistaken for the parallel through-traffic surge.
- If the left turn comes after the opposing through movement, it is called a "lagging left turn."

Split or Nonconcurrent Phasing

Split phasing provides separate green time to vehicles on opposing approaches. In typical signal design, the northbound and southbound through movements run simultaneously, as do the eastbound and westbound through movements.

- At offset intersections and locations where there are heavy turn movements, split phasing may be used to allow movements on each approach to move independently of other approaches.

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- Pedestrian phases for parallel crosswalks will be activated at different times. The pedestrian phase for a crosswalk will coincide with the through traffic movement immediately adjacent to that crosswalk.
- Where there is split phase timing, the surge of parallel vehicles beside the pedestrian could be mistaken as indicating the onset of the "Walk" interval, and blind pedestrians could thus cross into the path of left-turning vehicles. In addition, the heavy flow of running traffic could be mistaken for the surge of traffic on the street beside the blind pedestrian, when the traffic is actually on the street the pedestrian is crossing.

An example of northbound/southbound movements running under split phasing is shown in Figure 3.5. Northbound traffic, including traffic turning east and west, moves on one signal phase (southbound traffic and all traffic on the east-west street have a red signal at that point). The pedestrian phase usually is provided at this time for pedestrians on the east crosswalk.

Northbound traffic then receives a red light while all southbound traffic, including turning traffic, is allowed to go. The pedestrian phase usually provided at this time is for pedestrians crossing on the west crosswalk.

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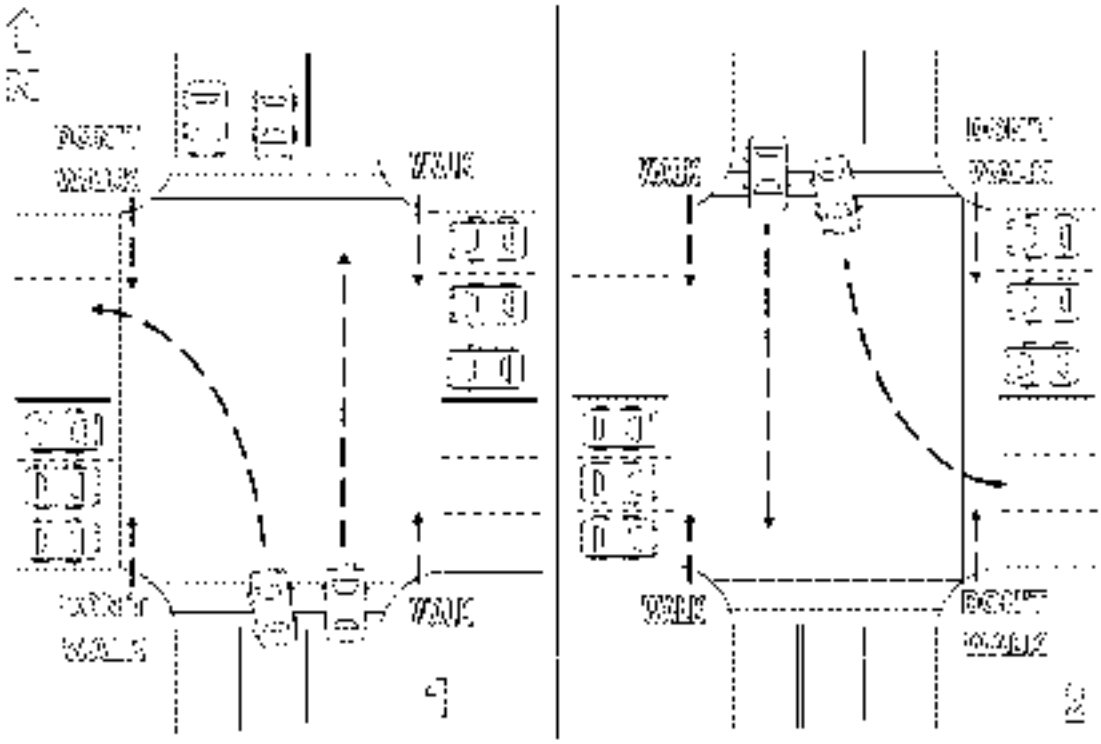

Figure 3-5. Illustration of split phasing.

Flashing Operation

Signals may only operate during peak periods of the day, switching to flashing operation at nonpeak hours, late at night, or in response to a signal malfunction.

- The signals no longer operate under stop-and-go sequencing.
- The signals usually flash red for side streets and flash yellow for the main street, or the signals flash red for both streets.
- The pedestrian signal heads ("Walk/Don't Walk" signs) are dark, and the accessible pedestrian signals are silent.

Coordinated Systems

Coordinated systems provide automated control of signal timing at two or more signalized intersections. Instead of looking at an intersection in isolation, coordinated systems look at an entire arterial or network of intersections and make signal timing adjustments that benefit (optimize) the operation of the entire system.

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System changes are a result of traffic volume and travel times. Most often, a central controller computer provides the primary control and communicates with individual controllers located at each intersection.

Coordinated control has a number of advantages from a vehicle perspective:

- Signals can be controlled from a central traffic management center.
- The detection elements of the system can be used to predict future flows within the network and adjust the signal timing proactively instead of reactively.

Signals in a coordinated system can, however, present problems for blind pedestrians.

- The green time given to vehicles on the intersecting road (or the road whose signals are uncoordinated) may be less than normal to fit into the timing scheme of the coordination.
- This shorter time can be insufficient for pedestrians to cross the major road. Pedestrians who are blind will not know that there is insufficient time and may directly conflict with the approaching platoon of traffic on the major road. This demonstrates a need for accessible pedestrian signals at the intersection.

Vehicular Signals and Timing

Meaning of Signals

The use and meaning of particular traffic signal colors and symbols are described in Part 4 of the MUTCD. Signs and pavement marking used at signalized intersections are covered in Parts 2 and 3 of the MUTCD, respectively.

Although this section presents basic traffic laws concerning signals, O&M specialists should be well educated on the specific laws of the state of interest. Some laws, such as right turn on red arrow, vary from state to state. Most states provide a driver handbook that presents this sort of information.

Steady Green Signal

Circular Green (Green Ball)—Traffic, except pedestrians, may proceed straight through or turn right or left except when prohibited by signs or markings. Vehicles

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turning right or left shall yield the right-of-way to pedestrians lawfully within the intersection.

Green Arrow—Traffic may make the movement indicated by the green arrow. Opposing vehicle and pedestrian movements will be given a red signal or a "Don't Walk" indication.

Pedestrian Movement—Pedestrians may cross or use a green arrow indicates or if turning traffic will cross into their path or a pedestrian signal indicates they may not cross.

Steady Yellow Signal

A steady yellow signals warns that the green interval has ended and the red signal will begin. Pedestrians should not initiate a crossing as they will not have enough time to complete their crossing before the signal turns red.

Steady Red Signal

At a steady red signal, traffic must stop at the stop line, before the crosswalk lines, or before the intersecting street.

Right Turn on Red—Unless prohibited by local law or a sign, right turn on red is permissible for vehicles, but they must first come to a complete stop before proceeding with the turn if a safe gap in traffic is available. Turning vehicles must yield to pedestrians and to traffic already in the intersection. Right turn on red makes it harder for blind pedestrians to determine the surge of traffic at the onset of the vehicular green phase on the street parallel to the crossing direction. Because blind travelers wait to hear a car traveling straight across the intersection in order to determine if the light has changed, they are frequently delayed in initiating crossing.

Left Turn on Red—This maneuver involves a left turn from a one-way street onto another one-way street on a red signal (same procedure as stated above for right turn on reds). This maneuver is not allowed in all states.

Red Arrow—Vehicles must stop at a stop line, before the crosswalk lines, or before the intersection. Some states allow vehicles to turn right on red after stopping.

Pedestrian Movements—Pedestrians should not enter the roadway in the direction of travel controlled by a steady red signal.

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Flashing Yellow

The flashing yellow signal should be treated like a "Yield" sign, and travelers should proceed with caution.

Flashing Red

The flashing red signal should be treated like a "Stop" sign, travelers must come to a complete stop and proceed only when safe to do so.

Flashing Red Arrow and Flashing Yellow Arrow

Flashing red arrows and flashing yellow arrows typically have the same meaning as flashing circular signal indications, except they apply only to vehicular traffic intending to make the movement indicated by the arrow.

- In some states, flashing circular yellow and yellow arrow indications may be used during stop and go traffic signal operations for permissive left turn indications (same control as a green ball for left turns).
- In some states, flashing circular red and red arrow indications may be used during stop and go traffic signal operations for permissive left turn indications.

Other Intersection Terminology

A **channelized turn lane (slip lane)** (see Figure 3-6) is a turn lane that channels turning drivers to a position where they will either yield to oncoming traffic or they will complete a "free flowing" turn, which means the turning vehicles have a dedicated lane on the road they are entering and therefore do not need to stop or yield to traffic.

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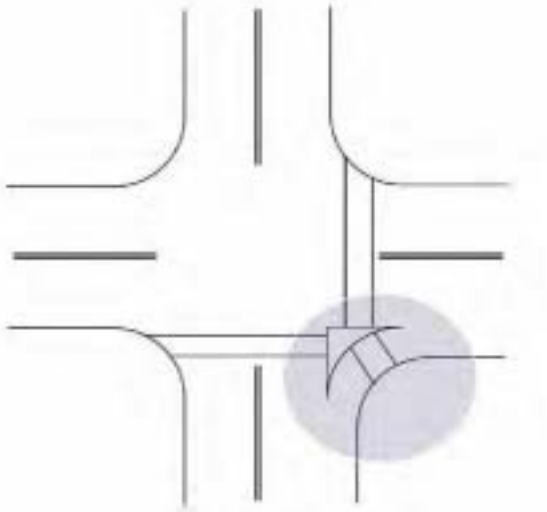

Figure 3-6. Channelized right turn lane.

Pedestrian Signals and Timing

Visual Pedestrian Signals

Pedestrian signal heads instruct pedestrians when it is lawful to cross (see Figure 3-7). Pedheads are typically installed where there is a significant amount of pedestrian activity or when there are safety issues, such as the possibility of pedestrians being confused by the cues from the traffic signal.

Pedestrian signals have three intervals:

- "Walk" interval—A white "Walk" message or a white symbol of a person walking indicates that pedestrians should begin crossing, after yielding to any vehicular traffic still in the street.
- Change interval—An orange flashing "Don't Walk" message or an orange symbol of a flashing hand indicates pedestrians should not begin a crossing because there is not enough time left in the phase for most pedestrians to get all the way across the street. Pedestrians who have already begun to cross should finish crossing.
- "Don't Walk" interval—A steady orange "Don't Walk" message or a steady orange symbol of a hand indicates pedestrians are not supposed to be in the crosswalk.

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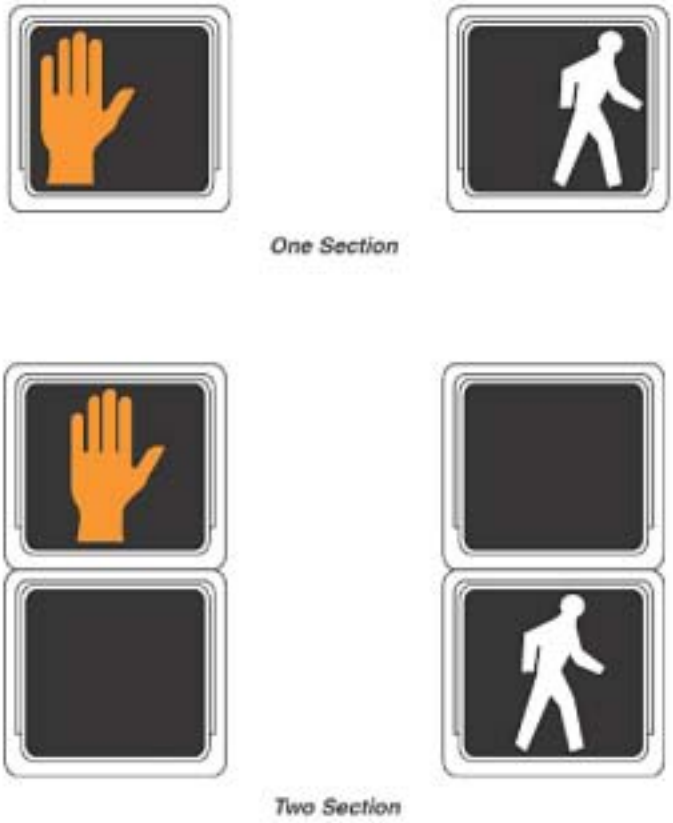

Figure 3-7. Typical pedestrian signal symbols.

Some locations also use pedestrian countdown signals (see Figure 3-8), which provide a countdown, in seconds, of the time remaining in the change interval.

- The countdown signal supplements the "Walk/Don't Walk" signals; it does not replace them.
- MUTCD guidance stipulates that the countdown should only be displayed during the flashing "Don't Walk" interval because of inconsistencies of the countdown during the "Walk" interval at actuated signals. Nonetheless, many cities are still using signals that display the countdown during the "Walk" interval (see Figure 3-9). Pedestrians with low vision have had problems distinguishing the countdown numbers from the orange flashing hand symbol when they are displayed alongside the white symbol of a man walking.

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Figure 3-8. Correct display of pedestrian countdown signal (counting down during flashing "Don't Walk").

Figure 3-9. Incorrect countdown display, showing countdown during the "Walk" interval.

Pedestrian Signal Timing

Pedestrian signal timing design deals with the length of the "Walk" and change intervals. The "Walk" interval is typically short (4 to 7 s). The change interval is designed to be long enough for a pedestrian to cross the street. This is typically calculated assuming a walking speed of 3.5 to 4 ft/s. Parking lanes are sometimes excluded from the calculation.

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The green time for the parallel traffic movement is calculated based on the time necessary for a pedestrian to cross the street, as in the following equation:

$$\text{Minimum Green Time} = \text{WALK interval} + \frac{\text{Crosswalk Length}}{4.0 \text{ ft/sec}}$$

Flashing DON'T WALK

Figure 3-10, which is a typical signal timing diagram used by traffic engineers in the design of signal timing, illustrates how the vehicle and pedestrian phases overlap. Time is the horizontal axis in the figure.

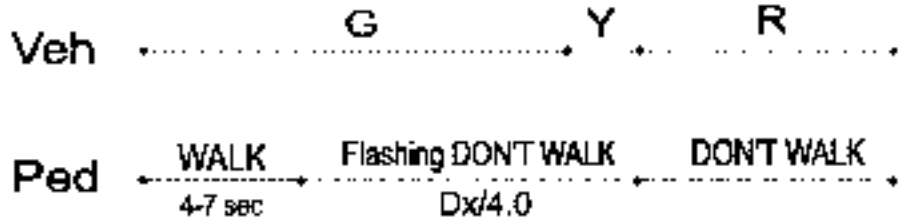

Figure 3-10. Illustration of the overlap of vehicle signal and pedestrian signal timing.

Pedestrian Phase Actuation

Some signals are designed so that the pedestrian phase is actuated by a pushbutton.

- Pressing the pushbutton calls for a pedestrian phase that allows enough time for a pedestrian to cross at average walking pace.
- If the button is not pressed, there may not be sufficient time programmed into the vehicle phase for a pedestrian to cross the street. Once the button is pressed, the pedestrian phase may begin immediately, or it may begin at a certain point during the following cycle.

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- The extent of the delay before the beginning of the pedestrian phase will vary depending on the programming of the phases for that intersection and on when the button was pushed within the cycle.
- Blind pedestrians have traditionally waited through a light cycle to assess and refine their location by listening to vehicular trajectories; they then cross on the next pedestrian phase. At a pedestrian-actuated intersection, however, pedestrians have to cross on the next pedestrian phase after pushing the button. If they do not cross at that time, they will have to locate and push the button again (and then re-establish their alignment).

Passive Pedestrian Detection

Pedestrians approaching a crosswalk area can also be detected passively (i.e., without having to push a button) through the use of microwave, infrared, or piezoelectric technologies. Future developments may affect whether an accessible pedestrian signal with a locator tone is necessary at an intersection that uses passive detection. One issue for consideration is whether pedestrians realize they have been detected.

Leading Pedestrian Intervals

Leading pedestrian intervals provide a pedestrian "Walk" interval 2 to 4 s before the vehicular green, giving pedestrians a head start so they are already in the intersection before vehicles begin moving. This can, however, be a disadvantage to blind or visually impaired pedestrians who rely on the surge of traffic to indicate when the signal is green. If these pedestrians want to begin crossing with the surge of parallel traffic at an intersection where a leading pedestrian interval is used, they will have less time to cross than designed. In addition, when pedestrians do not initiate their crossing at the onset of the "Walk" interval, drivers may interpret this to mean that the pedestrians do not intend to cross.

Pedestrians who are blind or visually impaired will have no way of knowing about the leading pedestrian interval at an unfamiliar intersection unless there is an accessible pedestrian signal installed.

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Exclusive Pedestrian Phasing

During an exclusive pedestrian phase, all vehicles have a red light during the "Walk" interval, and all crosswalks have the "Walk" signal at the same time. This is typically done to increase pedestrian safety. At some locations, right turn on red is allowed during the pedestrian phase. For efficiency, pedestrian crossings may be made diagonally.

- Exclusive pedestrian phasing may be followed by an extended time for one or more of the crosswalks
- Exclusive pedestrian phasing may be beneficial to pedestrians with mobility impairments and cognitive disabilities as it allows for crossing when few or no vehicles are moving through the intersection. It is, however, a disadvantage for pedestrians who rely on traffic sounds to determine the signal phases. In addition, determining initial alignment and maintaining alignment during crossing may be difficult due to the absence of parallel moving traffic.

Pedestrian Recall

With pedestrian recall, the "Walk" indication is provided every cycle, regardless of whether the button has been pushed.

Rest in "Walk"

When a signal rests in "Walk," the pedestrian signal for crossing the minor street remains in "Walk" as long as the major street has the green signal and there is no call on the minor street.

- When a vehicle approaching on the minor street is detected, the pedestrian signal to cross the minor street changes to flashing "Don't Walk."
- Some APS manufacturers provide a switch on their devices that limits the length of the audible "Walk" indication to 7 or 8 s while the signal rests in "Walk," but recalls the audible and vibrotactile indications of the "Walk" message if the button is pressed when there is adequate clearance time remaining.

Collaboration

O&M specialists should contact local transportation professionals with responsibility for signal design and maintenance. These professionals include traffic engineers, public

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works personnel, signal technicians, and transportation planners. The ownership of the signal—whether township, county, city, or state—determines who is in charge of the intersection. In some cases, consulting firms are contracted to provide operation and maintenance control of signalized intersections.

Understand Municipality Structure

The structure varies from one municipality to the next. In some cases, engineering may be part of the public works department, and in other cases it may be a separate department. Intersection signals may be part of a state or county traffic management network, even if they are located within a town or city, or the signals may be managed by a consulting firm.

- New intersection construction may be contracted out to a traffic engineering or electrical contractor.
- Signals may be maintained by a department other than the one that installed them.
- Find out if there is a local jurisdiction or statewide ADA coordinator and/or a DOT/public works department ADA coordinator. This coordinator may be responsible for ensuring that the local jurisdiction's streets, sidewalks, and facilities are accessible to pedestrians with disabilities. The coordinator may also have more influence in getting traffic engineers to install accessible signals than someone from outside the local jurisdiction.

To learn about the structure of a city department, check the city website or a phone directory.

Contact the Traffic Engineering Department

The O&M specialist should call the department that manages traffic signals to find out who to talk to about a specific intersection. The O&M specialist should work collaboratively to develop a productive working relationship.

- Call the transportation professional and explain what you do and why you are inquiring about the intersection (keeping in mind that the persons responsible for the traffic signals may not have considered all travel strategies and may not know that professionals are available to consult with about the travel needs of pedestrians with

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visual impairments. Ask for more information about who does what and how to ask for information.

- Ask about signal phasing and timing plans at particular intersections and how pedestrians are accommodated.
- Find out the procedure for requesting changes or modifications to an intersection. Talk with the transportation professional and familiarize yourself with the procedures for handling and accommodating your request.
- Understand that additional parties and factors may be involved in addressing your request (because of funding, politics, etc.).

Attend Meetings

O&M specialists should consider attending the following meetings:

- Local pedestrian advisory/advocacy meetings. Many towns set up these groups to solicit feedback on pedestrian issues and to gather advice on potential solutions.
- Local meetings of the Institute of Transportation Engineers or other engineering organizations.
- Local disability advisory committee meetings. The disability advisory committee reports directly to elected officials (mayor, city council, and county board of supervisors) of the local jurisdiction.

If the disability advisory committee has a physical access subcommittee, an O&M specialist may want to become a permanent member in order to have an opportunity to advocate for and influence future installations of accessible signals.

Participate in Public Hearings

O&M specialists should also consider attending public hearings on state transportation improvement plans. The hearings provide opportunities to meet DOT staff, including traffic engineers, and they also provide opportunities to present comments on the needs of pedestrians.

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Educate Yourself

O&M specialists should familiarize themselves with APS installations in their area or nearby areas. They should also

- Learn the language used by traffic engineers;
- Familiarize themselves with state regulations and practices, such as the MUTCD, ADA Title II, and Draft PROWAG;
- Learn the desires of others in the community;
- Remain informed on current APS technology;
- Follow up on any requests for information and not assume someone else is doing everything right; and
- Learn where to report problems or malfunctions.

Educate Students

O&M specialists should teach their students about changes in signalization and intersection geometry.

- Explain the necessity of using pushbuttons at actuated intersections.
- Remind students that timing plans can vary, so the signal timing they identify when crossing the intersection at a specific time of day or day of week may be different the next time they travel the same intersection.
- Assist students in requesting an accessible pedestrian signal.
- Teach students how to use an APS.

Advocate for Accessible Pedestrian Signals

O&M specialists should serve as advocates for APSs, especially at intersections where

- Pedestrians are unable to discern the "Walk" interval;
- A pedestrian pushbutton controls the pedestrian crossing phase;
- Signalization includes a leading pedestrian interval or an exclusive pedestrian phasing; and
- Many electric or hybrid vehicles are present.

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CHAPTER 4

Features of Accessible Pedestrian Signals

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Integrated Information Devices 35

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This chapter provides a description of APS features, including "Walk" indications. The features currently available on APS devices marketed in the United States and abroad and their use by pedestrians who are blind or who have low vision are discussed.

Intersection geometry, signalization, and installation location can affect the features needed to provide adequate, unambiguous information to pedestrians who are blind or who have low vision. Poor installation can result in ambiguous "Walk" information from an APS. (More information on designing installations and determining needed features is provided in Chapters 6 and 7.)

Because APS technology is changing rapidly, additional choices of features may become available. Those making purchasing decisions should consider the background information provided in this chapter when evaluating new technology.

Criteria for "Walk" Indications

"Walk" Indication Is Critical

The "Walk" indication provides critical safety information. It should be

- Readily detectable in the presence of ambient vehicular sound,
- Highly localizable,
- Uniquely recognizable as a "Walk" signal, and
- Unambiguous with regard to which crosswalk has the walk interval.

Criteria

In the United States, the MUTCD and the Draft PROWAG provide some specific criteria for walk interval indications.

- There shall be audible and vibrotactile indications of the walk interval. Audible indications shall be tone or speech message (2, R306.2, Pedestrian Signals, and R306.2.3, Audible "Walk" Indication).
- The information provided "shall clearly indicate which pedestrian crossing is served by each device" (1, 4E.06).
- The audible tones shall be audible from the beginning of the associated crosswalk (1, 4E.06).

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- The volume shall be 2 dB minimum and 5 dB maximum above the ambient noise level in standard operation (2. R306.2.3.2 Volume. *1.* 4E.06)
- The volume should be no louder than the associated pushbutton locator tone unless a louder audible beaconing feature is actuated (*1.* 4E.06: 2, Advisory R306.2.3.2 allows beaconing to exceed volume limits).
- If the tone for the walk interval is similar to the pushbutton locator tone, the "Walk" interval tone shall have a faster repetition rate than the associated pushbutton locator tone (*1.* 4E.06).

Appropriate APS Location

The Draft PROWAG requires accessible pedestrian signals to be located at the pushbutton (i.e., pushbutton integrated) to enable use of the vibrotactile feature. *The material presented in this chapter assumes that the APS device is integrated into the pushbutton, unless another mounting location is specifically discussed.*

There are a number of APS devices available that meet the above listed criteria; however, proper installation is also critical to their effective functioning. Chapter 6 includes a detailed discussion of installation location requirements.

Current Recommendations for "Walk" Indications

Audible and Vibrotactile Indications Required

Audible (speech or tone) and vibrotactile indications of the walk interval are required by the Draft PROWAG.

The MUTCD does not currently provide specifications for audible "Walk" indications, but does caution about the use of tones that could be confused with birds or vehicle back-up beepers.

"Walk" indications can be provided by the use of

- Tones,
- Speech messages (also referred to as verbal messages), and
- Vibrating surfaces.

More information about the use of each is provided on the following pages.

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Recent research recommends tones be used in locations where the speakers for APS devices for two different directions of travel can be separated. Speech messages are recommended where the speakers must be located on the same pole or less than 10 ft apart.

Associating Tones with Direction of Travel

In the past in the United States, audible pedestrian signals have utilized two different tones, which are associated with two different crossing directions, broadcast from speakers mounted at the pedestrian signal head. The most common tones used were bird sounds, specifically "cuckoo" and "chirp," with the cuckoo used for north-south crosswalks and the chirp used for east-west crosswalks. Research since 1988, however, has documented that such a system is often ambiguous and confusing (see Appendix C).

Using a different tone for each direction of travel is no longer recommended in the United States.

Use of a Single Tone for Crossings in All Directions

In Europe and Australia, a single tone emanating from speakers located at the pedestrian pushbutton has been used successfully for years to indicate the walk interval. There is some variability in the tones used. Typically, the tone for "Walk" is the same as the pushbutton locator tone, but repeated at a faster rate (usually about 10 times faster). The same tone is used for all crossing directions.

A single tone works because the standardized location of the pushbutton-integrated speaker in relation to the crosswalk provides information about which crosswalk has the "Walk" interval. Pedestrians are beside or within arm's reach of the appropriate APS device when they are wanting to cross and are at some distance from the APS for another crosswalk. Speakers located in this manner are now included in the Draft PROWAG.

See the Chapter 6 discussion of installation decisions for more about the location of APS speakers and vibrotactile "Walk" indications.

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"Walk" Indication—Tones

Description

A tone is provided during the walk interval. In the United States, the "Walk" indication for an accessible pedestrian signal has typically been provided by an audible signal, such as a beep, buzz, percussive sound, or cuckoo/chirp. Current recommendations are that the tone used to indicate the walk interval should be a ticking tone that repeats 8 to 10 times per second, otherwise known as a rapid tick. That tone emanates from the pedestrian pushbutton location.

Additional Information

The rapid tick tone repeating at least 8 times per second) has been found to result in faster response than verbal messages or a two-tone system (cuckoo/chirp/cuckoo/chirp). Errors in responding to the correct signal were also reduced with the rapid tick tone, when two APS devices at a corner were separated by at least 10 ft and each was located close to the crosswalk it signaled. For information about the research on tones, see Appendix C.

The walk indication should also have a faster repetition rate than the pushbutton locator tone; the MUTCD specifies the repetition rate and duration of the pushbutton locator tone at once per second (see the section on pushbutton locator tones later in this chapter).

Tones consisting of multiple frequencies, high and low, with a low component at 880 Hz have been found to be highly detectable and localizable in the presence of traffic sound. Frequencies above 1 kHz are difficult for persons with age-related upper frequency hearing loss to detect. For persons with normal hearing, however, the presence of multiple higher harmonics aids localization.

When to Use

An audible "Walk" indication is needed on any APS device.

Tone indications should be used where speakers are separated by adequate distance and are located close to the crosswalk they serve, so that it is clear which speaker is sounding. Generally, tone indications should be provided from pushbutton-integrated speakers, rather than from speakers mounted on pedestrian signal heads.

AR0071831

References

Currently the MUTCD states "When accessible pedestrian signals have an audible tone(s), they shall have a tone for the WALK interval. The audible tone(s) shall be audible from the beginning of the associated crosswalk. If the tone for the WALK interval is similar to the pushbutton locator tone, the WALK interval tone shall have a faster repetition rate than the associated pushbutton locator tone." (4E.06). Revisions to standards and guidance are anticipated in the 2009 edition of the *MUTCD*.

The Draft PROWAG provides information on tones: "Tones shall consist of multiple frequencies with a dominant component at 880 Hz. The duration of the tone shall be 0.15 s and shall repeat at intervals of 0.15 s" (2. R306.2.3.1.1.

It is expected that the Draft PROWAG and the MUTCD will be harmonized in future revisions.

Research has been completed on detectability and localizability of tones and on use of two different tones versus a single tone. See Appendix C for more information.

Use by Pedestrians Who Are Blind or Who Have Low Vision

The audible "Walk" indication provides a clear cue of the beginning of the pedestrian phase. Pedestrians will evaluate traffic and the intersection and listen for the "Walk" indication. Upon hearing the "Walk" indication, they typically check that traffic has stopped and that no cars are turning across their path before beginning their crossing.

"Walk" Indication—Speech Messages

Description

A speech message is provided during the walk interval, usually from a speaker located at the pushbutton. The message should follow the recommended model: "Maple. Walk sign is on to cross Maple." The recommended message for an intersection with an exclusive pedestrian phase is "Walk sign is on for all crossings."

Additional Information

The speech "Walk" message must be detectable, localizable, and recognizable, and it must also be correctly understood by all users. Speech messages from pushbutton integrated APS devices seem very user friendly and have become popular in the U.S.

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market. However, the words and their meaning must be correctly understood by all users in the context of the street environment where they are used.

The use of speech messages will not automatically solve all ambiguity problems. In even moderate traffic conditions, people who have age-related or other hearing losses, people who are not native English speakers, and people with cognitive disabilities are likely to miss hearing some words or to misunderstand what they hear, possibly resulting in misinterpreting entire messages.

Model messages have been determined through research (see Appendix C). Recommendations on word order and on wording of messages should be strictly followed. Where complete sentences are used in the models, complete sentences should also be used in actual messages. In the model messages, such words as street, avenue, and road are not used, however, in some locations, these words may be needed to avoid ambiguity.

Pedestrians have to know the names of streets they are crossing in order for speech "Walk" messages to be unambiguous. In getting directions to a new location, travelers do not always get the name of each street to be crossed. They may only know, for example, that they have to cross four streets before looking for their destination. Therefore, the accessible pedestrian signal has to give the user the name of the street controlled by the pushbutton. This can be done by means of a pushbutton information message during the flashing or steady "Don't Walk" intervals.

The user must then combine the information from the pushbutton information message or a braille label, the tactile arrow, and the speech "Walk" message in order to correctly respond to the speech "Walk" message. It may be necessary to have all forms of information for the traveler to correctly identify the street and crossing interval at an unfamiliar intersection. This complex process is much more cognitively demanding and more liable to result in errors or delay than the use of a tone from a speaker located right beside the crosswalk.

A speech and tone "Walk" indication may be combined (i.e., "Maple, Walk sign is on to cross Maple"); and may be followed by rapid tick for the rest of the walk interval.

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When to Use

An audible walk indication is needed on any accessible pedestrian signal. Speech "Walk" messages are recommended only where more than one pushbutton speaker must be located on the same pole or where speakers are less than 10 ft apart.

References

The Draft PROWAG allows the "Walk" indication to be provided by speech messages but does not provide additional specifications (2, R306.3.3).

The 2003 MUTCD provides minimal information regarding speech "Walk" messages. It states that "when verbal messages are used to communicate the pedestrian interval, they shall provide a clear message that the WALK interval is in effect, as well as to which crossing it applies. The verbal message that is provided at regular intervals throughout the timing of the WALK interval shall be the term "WALK sign," which may be followed by the name of the street to be crossed" (1, 4E.06).

Revisions and additional language have been approved by the National Committee on Uniform Traffic Control Devices and recommended for inclusion in the 2009 MUTCD. These revisions incorporate recommended messages.

Recent research evaluated localizability and detectability of speech messages, developed recommended message wording, and determined that response to speech messages was more accurate than responses to two different tones when pushbuttons were on the same pole (see Appendix C).

Use by Pedestrians Who Are Blind or Who Have Low Vision

The audible "Walk" indication provides a clear cue to the beginning of the pedestrian phase. Pedestrians who are blind or who have low vision will evaluate traffic and the intersection and then listen for the "Walk" indication. After hearing the "Walk" indication, they typically check that traffic has stopped and no cars are turning across their path before beginning their crossing.

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Vibrotactile "Walk" Indication

Description

The pushbutton or a raised arrow on the APS housing vibrates during the "Walk" interval.

Additional Information

Vibrotactile information is useful when pedestrians can be aligned and prepared for crossing while still keeping a hand on the accessible pedestrian signal.

Those who are deaf or hard of hearing must also know where to find the device since the pushbutton locator tone is not helpful.

When to Use

The vibrotactile indication of the walk interval is needed at most locations and is required by the Draft PROWAG. However, it is useful only when the device is located close to the crossing departure location.

It is important to note that Draft PROWAG requires audible information in addition to vibrotactile indications of the walk interval. Without specific training on the device, blind pedestrians may not find or use the vibrotactile indication, particularly if it is not located on the actual pushbutton.

References

The MUTCD standard states that "vibrotactile pedestrian devices, where used, shall indicate that the WALK interval is in effect, and for which direction it applies, through the use of a vibrating directional arrow or some other means" (*1*, 4E.06). Guidance states that the devices should be adjacent to the intended crosswalk.

The Draft PROWAG requires a vibrotactile indication of the walk interval at each crosswalk with pedestrian signal indications (*2*, R306.2).

Use by Pedestrians Who Are Blind or Who Have Low Vision

Pedestrians will stand beside the pushbutton with their hand on the vibrating arrow while waiting to cross (see Figure 4-1). The vibrotactile indication communicates to pedestrians who are deaf-blind that the walk interval is in effect, and at particularly noisy

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intersections it may also provide confirmation of the walk interval to pedestrians who are blind.

Figure 4-1. Pedestrian waiting to feel the vibrotactile "Walk" indication.

Pushbutton Locator Tone

Description

A pushbutton locator tone is "a repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing and that enables pedestrians who have visual disabilities to locate the pushbutton" (*1*, 4E.09).

The pushbutton locator tone is referred to by different names in manufacturer's brochures, including

- Pole locator,
- Locator signal,
- Locator tone,
- Locating tone, and

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- Locator audible.

Additional Information

Pushbutton locator tones typically sound from the pushbutton during the flashing and steady "Don't Walk" signals. The locator tone informs pedestrians of the need to push a button and provides an audible cue to the location of the pushbutton. During the street crossing, the locator tone may be audible in the last lane and thus provide a cue to the direction of the destination.

In available products, the pushbutton locator tone varies from a click sound to a beep tone. Repetition rate and length of tone are standardized by language in the MUTCD. "Pushbutton locator tones shall be easily locatable, shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals" (*I*, 4E.09).

Volume of this slowly repeating tone should be adjusted to be heard *no more than 6 to 12 ft (2 to 4 m) from the pushbutton or at the building line, whichever is less* (4E.09). The Draft PROWAG states that the volume of the pushbutton locator tone is to be adjusted to between 2 dB and 5 dB above ambient sound levels in standard operation. (2. R306.3.2). Although these requirements may appear to be in conflict, both can generally be met. Perceived loudness can vary, depending on the environment near the sound source.

Both the MUTCD and the Draft PROWAG allow an increased volume of the locator tone to provide audible beaconing in response to a repeat user actions or extended button press and audible beaconing.

The pushbutton locator tone typically has automatic volume control. A microphone or sensing device is installed in the APS device or in the pedestrian signal head to monitor intersection sound levels and adjust the volume of the locator tone. This technology is also used to adjust the volume of the "Walk" indication. (Sample locator tones are available at www.walkinginfo.org/aps.)

When to Use

The pushbutton locator tone can be useful whenever there is a pushbutton that a pedestrian should use.

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References

The Draft PROWAG requires a pushbutton locator tone wherever there is a pushbutton (2. R306.3.2).

The MUTCD states that pushbutton locator tones may be used (7. 4E.09).

Both the Draft PROWAG and the MUTCD have additional information regarding pushbutton locator tone volume.

Use by Pedestrians Who Are Blind or Who Have Low Vision

Pedestrians who are unfamiliar with an intersection will approach the intersection and take the following actions:

- Upon hearing the locator tone, or two locator tones if there are two pushbuttons, they will realize that there is a pushbutton for the crossing.
- They will probably continue to the curb or curb ramp location in order to become familiar with the corner, determine proper alignment, and become familiar with the intersection layout and sounds by listening to traffic.
- They will return to, if they are not already standing next to, the pushbutton locator tone that is believed to be the correct pushbutton for the crossing and check that the tactile arrow alignment is parallel to the desired crosswalk.
- They will push the button and return to the curb to realign themselves for crossing the intersection.
- They may repeat this process if the pedestrian phase begins before they are properly aligned to cross.
- If the pushbutton locator tone for the APS device on the opposite side of the street is audible as they cross the street, they may home in on the sound for verification of alignment.

Tactile Arrow

Description

A raised (tactile) arrow may be part of the pushbutton, as seen in Figure 4-2, may be above the pushbutton (Figure 4-3), or may be on top of the device (Fig 4-4). It is used to communicate to pedestrians which crosswalk is controlled by the pushbutton. The tactile

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arrow provides confirmation similar to the printed sign and arrow that are commonly provided for pedestrians who are sighted.

The arrow should contrast with its background. On most APS devices, this arrow also vibrates during the walk interval.

Figure 4-2. This accessible pedestrian signal has a high-contrast, raised tactile arrow on the pushbutton and a high-contrast, recessed tactile arrow on the sign above the button.

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Figure 4-3. The tactile arrow above the pushbutton on this accessible pedestrian signal is superimposed on a larger visual arrow.

Figure 4-4. The tactile arrow is located on top of this APS housing (note the lack of required color contrast between the arrow and housing).

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Additional Information

It is important that the arrow point in the direction of travel on the crosswalk, as it indicates which crosswalk is controlled by that pushbutton. Tactile arrows provide general alignment information for all pedestrians. However, it is important to note that tactile arrows do not seem to enable the extremely accurate alignment required for blind and visually impaired pedestrians. To align the arrow properly, the installer needs to understand that pedestrians are expecting the arrow to be pointing toward the destination across the street — *not* toward the beginning of the crosswalk or toward the curb ramp location. Misalignment of the arrow may cause a blind pedestrian to be directed into the center of the intersection.

For arrows on the face of the device, the alignment is determined by the installation of the pushbutton on the pole. Arrows on the top of the pushbutton housing are typically glued into place after the pushbutton is installed, and their alignment can be adjusted separately from the pushbutton.

When to Use

Tactile arrows are recommended at all locations with an accessible pedestrian signal.

References

Pushbuttons and arrows should be within 5 ft of the extended crosswalk lines (*7*, 4E.09) and aligned in the direction of pedestrian travel control ed by the pushbutton (*2*, 4E.09; *3*, R306.4.1).

Arrows should have good visual contrast with their background so that all users, including those with low vision, may readily see them (*7*, 4E.09; *3*, R306.4.1).

The Draft PROWAG provides specifications for the arrow: "Include a tactile arrow aligned parallel to the crosswalk direction. The arrow shall be raised 0.8 mm (.03 in.) minimum and shall be 4 mm (1.5 in.) minimum in length. The arrowhead shall be open at 45 degrees to the shaft and shall be 33 percent of the length of the shaft. Stroke width shall be 10 percent minimum and 15 percent maximum of arrow length. The arrow shall contrast with the background" (*3*, R306.4.1).

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Use by Pedestrians Who Are Blind or Who Have Low Vision

Pedestrians who are blind use tactile arrows to determine and confirm which crosswalk the pushbutton controls and to determine the general direction of travel. Clues from traffic sounds are also used to confirm alignment and crossing direction.

Blind pedestrians typically proceed in as straight a line as possible from the pushbutton to the curb of the perpendicular street in the direction of the arrow. This means that the APS should be within or as close as possible to the crosswalk lines.

Automatic Volume Adjustment

Description

Automatic volume adjustment is a term for volume control that is automatically responsive to ambient background sound.

- A louder signal is produced when vehicle and other noise at an intersection is high (as during traffic surge or when a truck is passing).
- A quieter sound is produced when background noise volume is lower (as during nighttime hours or a lull in traffic).
- A microphone continuously samples the noise levels and varies the volume in response to the existing sound levels. The microphone may be incorporated into the pushbutton housing or located at the pedestrian signal head.

Automatic volume adjustment is also known as automatic gain control (AGC) or ambient sound adjustment.

Additional Information

Some signals can be preset to vary volume within particular ranges.

Most signals with automatic volume control have a minimum limit placed at about 30 dB and a maximum limit of about 90 dB.

Some APS devices allow the installer to separately set the range of the locator tone and the "Walk" indication, others have one setting for both.

A signal that is 2 to 5 dB above ambient sound, as perceived at the departure curb, is loud enough to be heard by pedestrians waiting at that location. If the microphone is

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installed at the pedestrian signal head that is set back from the curb, the traffic volume sensed by the microphone is not as loud as that perceived by pedestrians waiting at the curb. Therefore, the setting may need to be adjusted at each installation, depending on the location of the microphone relative to pedestrians waiting to cross.

Some APS devices have adjustments for microphone sensitivity, as well as "Walk" indication and pushbutton locator tone volume.

When to Use

Automatic volume adjustment is recommended at all locations with access for pedestrian signals.

References

The MUTCD states: "Automatic volume adjustment in response to ambient traffic sound level should be provided up to a maximum volume of 89 dBA. Where automatic volume adjustment is used, tones should be no more than 5 dBA louder than ambient sound" (Ref. 4E.06).

The Draft PROWAG requires devices to be responsive to ambient sound (R306.3.2 and R306.2.3.2).

Use by Pedestrians Who Are Blind or Who Have Low Vision

Automatic volume adjustment provides flexibility and allows APSs to adjust so they will not disturb neighbors at night or during times of low traffic volume. This is also helpful to blind or visually impaired pedestrians, as the accessible pedestrian signal does not drown out the traffic sounds necessary for crossing.

Actuation Indicator

Description

An actuation indicator is a light, a tone, a voice message, or a combination of audible and visual indicators that informs pedestrians that the button has been pressed and that their desire to cross has been communicated to the controller.

Audible indicators include a click, a beep, and the word "wait" when the pushbutton is pushed.

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Additional Information

If there is a light, it is at or near the pushbutton and remains illuminated until the walk interval begins (see Figures 4-5 and 4-6). The light is dark during the "Walk" and flashing "Don't Walk" intervals. A light may be helpful to persons with low vision, but persons who are blind require a tone.

Figure 4-5. A red actuation light is near located just above and to the left of the pushbutton.

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Figure 4-6. A red actuation indicator light is illuminated directly above the pushbutton.

When to Use

An audible indication is particularly useful to pedestrians who are blind when the pushbutton is a pressure-sensitive electromagnetic button that does not depress when pushed.

References

The MUTCD refers to a pilot light and specifies that the "pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation. Once it is actuated, it shall remain illuminated until the pedestrian's green or WALKING PERSON (symbolizing WALK) signal indication is displayed" (*1*, 4E.08).

Activation indicators are not mentioned in the Draft PROWAG.

Use by Pedestrians Who Are Blind or Who Have Low Vision

The indicator assures all pedestrians that the device is working, thereby encouraging pedestrians to wait until the onset of the "Walk" signal.

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Extended Button Press

Description

Extended button press is an option that activates additional accessibility features. The pushbutton must be pushed and held for more than 1 s to activate the features.

Other names for this feature (as listed in manufacturers' literature) include:

- Button activated tutor (BAT), and
- Extended push.

Additional Information

Possible features called by the extended button press include:

- Pushbutton information message,
- Audible beaconing, and
- An extended crossing time.

Any or all of these features could be called by pressing and holding the same button used by all pedestrians.

Recent research (see Appendix C) has standardized the length of the button press at 1 s or longer. Some devices have previously been installed with a 3-s press, but 1 s has been found to be adequate.

When to Use

An extended button press should be used whenever there are optional additional features provided at a crossing that should be available "on request."

References

The Draft PROWAG permits an extended button press to activate additional features (2, R306.3.4 Optional Features).

The MUTCD states that "the audible tone(s) may be made louder (up to a maximum of 89 dBA) by holding down the pushbutton for a minimum of 3 seconds" (1, 4E.09). Draft language changing the minimum length to 1 s has been approved by the NCUTCD and is expected to appear in the 2009 revision of the MUTCD.

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Use by Pedestrians Who Are Blind or Who Have Low Vision

Use will depend on the features set called by the extended button press. (See the sections on audible beaconing and pushbutton information messages for further discussion of the use of those features.) The intent is to allow individuals who are blind to have some choice in the use of the accessible features and to provide optional features upon request.

As the extended button press feature becomes more common, pedestrians who are blind or visually impaired will be likely to hold the button longer at unfamiliar intersections in order to determine what features are installed before deciding how they want to cross the street.

The extended button press allows for installation of additional features that are activated only occasionally rather than every time the button is pressed, thus minimizing nuisance to neighbors. For example, individuals who are unfamiliar with an intersection can get intersection street name information (the pushbutton information message), but the message is not played every time the button is pressed. In addition, pedestrians can decide which accessible features they want to use at an intersection. For example, a user may want to use audible beaconing only at certain times and with certain traffic patterns.

Pushbutton Information Message

Description

A pushbutton information message is a recorded message that provides the name of the street and intersection with which that pushbutton is associated. It can also provide other information about the intersection signalization or geometry.

Manufacturers refer to this feature by different names, including:

- Voice or location.
- Informational message.
- Verbal message.
- Additional message, and
- Instructional/location message.

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Additional Information

The pushbutton information message is provided from a speaker located at the pushbutton, and it sounds only during the flashing and steady "Don't Walk" intervals. The message is intended to be audible to pedestrians standing at the pushbutton location. Pedestrians may be able to access additional verbal messages by pressing the pushbutton for more than 1 s (see extended button press).

The pushbutton information message, in conjunction with the tactile arrow, can clarify street names and the crosswalk controlled and signaled by the device. This is particularly important if speech "Walk" messages are used. To be effective, the pushbutton information message must indicate which street is actuated by the pushbutton, and the arrow must point in the direction of travel on the described crosswalk.

A message that includes only the intersection street names, without clarifying which street is actuated by the pushbutton, provides ambiguous information. See recommendations below for pushbutton message wording.

A combination of information formats, including raised characters, braille, and audible information, will accommodate the most users.

Message Wording

Pushbutton information messages should be developed according to the following models (7) (see additional information in Appendix C):

- Model pushbutton message: "Wait to cross Howard at Grand."
- Model pushbutton message for intersections having an exclusive pedestrian phase with right turns on red prohibited: "Wait to cross Howard at Grand. Wait for red light for all vehicles."
- Model pushbutton message for intersections having an exclusive pedestrian phase with right turns on red permitted: "Wait to cross Howard at Grand. Wait for red light for all vehicles. Right turn on red permitted."
- Model pushbutton message for angled crosswalks: "Wait to cross Howard at Grand. Crosswalk angles right."

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- Model pushbutton message for crosswalks to medians where a second button push is required: "Wait to cross Howard at Grand. Short Walk phase. Raised [or cut through] median with second pushbutton."
- Model pushbutton message for signalized crosswalks to splitter islands: "Wait to cross right turn lane to island for Howard and Grand crosswalks."
- Model pushbutton message for crosswalks at T-intersections: "Wait to cross Howard at Grand." (No different from standard intersection identification message.)

Use "street," "avenue," etc., where needed to avoid ambiguity.

Keep the word order illustrated in the above model messages.

Some model messages have complete sentences for best comprehension.

When to Use

Pushbutton information messages are necessary where speech "Walk" messages are used. If pedestrians do not know the name of the street they are crossing, the speech "Walk" message does not clarify which street is being signaled.

A pushbutton information message can be helpful in providing location information on demand to pedestrians who are blind or who have low vision.

References

The MUTCD states that "pushbuttons should clearly indicate which crosswalk signal is actuated by each pushbutton" [1, 4E.08].

The Draft PROWAG requires APSs to include street name information in braille or in audible format [2, R306.4.2]. Pushbutton information messages can provide information about the street name.

An APS pushbutton should not be used for landmark information or to inform pedestrians with visual impairments about detours or temporary traffic control, according to recent research [71].

Use by Pedestrians Who Are Blind or Who Have Low Vision

Pedestrians who are unfamiliar with an intersection or who wish to confirm their location will

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- Locate and depress the pushbutton for 1 s or more.
- Stand beside the pushbutton speaker to listen to the pushbutton information message, and
- Push the button again, if desired, to hear the message repeated.

At a location with two pushbuttons on the same pole and with speech "Walk" messages, it is particularly important that users understand and recognize the street name.

Audible Beaconing

Description

Audible beaconing is the use of an audible signal in such a way that blind pedestrians can home in on a signal coming from the target corner as they cross the street.

Building a True Community defined an audible beacon as "a permanently fixed source emitting sound for directional orientation" (5). The MUTCD and Draft PROWAG include recommendations that the beaconing be called up by special actuation, rather than having the accessible pedestrian signal function in a louder mode all the time. The recommended form of special actuation is an extended button press (holding the pushbutton in for more than 1 s).

Additional Information

A majority of crosswalks require audible beaconing, in which the sound source provides directional orientation. Where audible beaconing is activated, the volume of the "Walk" indication and the subsequent locator tone during the called pedestrian phase is increased and may be operated in one of the following ways:

- Increased sound comes from all speakers for the crossing.
- A louder locator tone comes from the speaker at the far end of the crosswalk during the pedestrian phase.
- The louder audible "Walk" indication and louder locator tone are broadcast from an additional, pedestal-mounted speaker aimed at the center of the crosswalk.
- The audible "Walk" indication alternates back and forth from speakers at each end of the crosswalk.

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Audible beaconing speakers must be oriented in line with the relevant crosswalk.

- If the speaker is not carefully oriented, the signal may give ambiguous information about which street has the "Walk" interval and ambiguous information for traveling straight across the street.
- Beaconing is enhanced by the presence of a locator tone that users can home in on as they approach the destination corner, island, or median having an accessible pushbutton.

See Chapter 6, Designing APS Installations, for additional recommendations regarding audible beaconing.

References

The Draft PROWAG does not specifically mention audible beaconing, but provides for optional features (2, R306.3.4).

The MUTCD states: "The audible tones(s) may be made louder (up to a maximum of 89 dBA) by holding down the pushbutton for a minimum of 3 seconds. The louder audible tone(s) may also alternate back and forth across the crosswalk, thus providing optimal directional information" (1, 4E.09).

Revisions have been made in meetings of NCUTCD and are expected to be included in the 2009 revision of the MUTCD. Recommendations are that the beaconing be called up by special actuation, rather than the APS functioning in the louder mode all the time. The recommended form of special actuation is an extended button press (holding the pushbutton in for more than 1 s).

When to Use

Not all crosswalks at an intersection need beaconing. Audible beaconing can actually cause confusion if used at all crosswalks at some intersections. Audible beaconing is probably not appropriate at locations with channelized turns or split phasing due to the possibility of the signal being heard at the wrong crosswalk.

Audible beaconing should only be considered at the following locations:

- Crosswalks longer than 70 ft, unless they are divided by a median that has another accessible pedestrian signal with a locator tone.

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- Crosswalks that are skewed.
- Intersections with irregular geometry, such as five or more legs.
- Crosswalks where audible beaconing is requested by an individual with visual disabilities.
- Other locations where a study indicates audible beaconing would be beneficial

Use by Pedestrians Who Are Blind or Who Have Low Vision

Pedestrians may be able to home in on the signal to assist with maintaining alignment while crossing the street.

Alert Tone

Description

An alert tone is a very brief burst of high frequency sound at the beginning of the audible "Walk" indication, which rapidly decays to the frequency of the "Walk" tone. It is intended to alert pedestrians to the beginning of the walk interval.

Additional Information

An alert tone may be useful if the "Walk" tone is not easily audible in some traffic conditions. As used in Australia, the alert tone is 14 dB above the ambient sound level

Australian engineers believe the alert tone encourages faster initiation of crossing, which decreases the likelihood of a conflict between pedestrians and turning vehicles. Also, when crossings are initiated faster, pedestrians exit the intersection faster.

When to Use

In locations with high ambient noise levels, an alert tone may be particularly helpful in alerting pedestrians to the start of a speech "Walk" message or to a tone "Walk" indication.

Reference

The alert tone is not mentioned in the Draft PROWAG or the MUTCD.

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Use by Pedestrians Who Are Blind or Who Have Low Vision

The alert tone gets the attention of pedestrians at the beginning of the "Walk" indication.

Tactile Map

Description

A tactile map is a raised schematic map showing what will be encountered as the pedestrian negotiates the crosswalk controlled by that pushbutton (figure 4-7). This feature is currently available from one manufacturer.

Additional Information

Map information may include

- Number of lanes to be crossed,
- Whether the lanes are vehicular or bicycle lanes or trolley tracks,
- Which direction traffic will be coming from in each lane, and
- Whether there is a median.

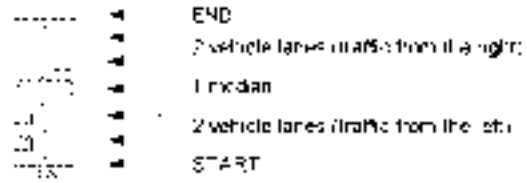

Figure 4-7. This tactile map from a Swedish APS is read from the bottom to the top and indicates lanes as they would be encountered by pedestrians.

Each map is made up of changeable "slugs" inserted into the side of the pushbutton housing. It must be set up for each crosswalk or an intersection. The map information is for the crosswalk controlled by that signal only, rather than the entire intersection.

The symbols used are not standardized in the United States, but one manufacturer has developed a standard set that is used in other countries.

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When to Use

A map of the crosswalk may be particularly useful at intersections with medians or islands.

References

The Draft PROWAG states that "where provided, graphic indication of the crosswalk shall be tactile" (2, R306.4.3).

Use by Pedestrians Who Are Blind or Who Have Low Vision

Pedestrians unfamiliar with the intersection or crossing locate the locator tone and locate the pushbutton and map. Standing facing the crossing, they "read" the map and they learn how wide the street is and what they will encounter in the crosswalk before they begin to cross. The map also indicates whether the pedestrian signal controlled by that pushbutton provides a crossing time for the entire crossing or only to a median or island. If the signal is just for a portion of the street, the map will show the crossing ending on a median, indicating that there is another crossing, either controlled or uncontrolled.

Braille Signs

Description

Braille signs should indicate the name of the street that the pushbutton controls on the sign above the pushbutton housing (see Figure 4-8).

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Figure 4-8. A braille street name is included on a sign above the pushbutton. The street name is also provided in high contrast large print (but not raised print) at this location.

Additional Information

Although braille signs may be helpful to some pedestrians who are blind, the signs and braille lettering may not be readily found by many blind pedestrians without orientation to the device.

Many individuals who are blind do not read braille; however, those who do would prefer braille information that confirms which street is controlled by the pushbutton

The street name on the device should be the name of the street whose crosswalk is controlled by the pushbutton.

A combination of information formats, including raised characters, braille, and audible information, will accommodate the most users.

References

The MUTCD states: "Name of the street…may also be provided in accessible format: (*1*, 4E.08).

The Draft PROWAG requires street name information in braille or in an audible format. (*2*, R306.4.2)

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Use by Pedestrians Who Are Blind or Who Have Low Vision

A pedestrian who is familiar with the installation of braille signs but unfamiliar with a particular intersection would search the sign for braille characters that would indicate or confirm the name of the street whose crosswalk is controlled by the pushbutton.

Braille signs may be helpful to individuals who are deaf-blind and who would not benefit from audible pushbutton information messages.

Raised Print or Large Print Signs

Description

The name of the street that the pushbutton controls is printed in high contrast raised print or large print on the sign above the pushbutton housing or on the pole (see Figure 4-9).

Figure 4-9. Example from Australia: a sign with raised print and braille characters is mounted vertically on a round pole to the right of an accessible pedestrian signal. The sign reads "GEORGE ST. 275-339R."

Additional Information

Some individuals who do not read braille may be able to read large print or raised print. However, raised print must be large enough to be read with fingertips. Imprinting the street name in the area available can be problematic.

The street name on the device should be the name of the street whose crosswalk is controlled by the pushbutton.

A combination of information formats, including raised characters, braille characters, and audible information, will accommodate the most users.

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When to Use

Raised print signs may be particularly useful in areas with large numbers of senior citizens.

References

The MUTCD states: "Name of the street ... may also be provided in accessible format (cf. 4E.08)."

The Draft PROWAG provides specifications for raised characters on signs (cf. R409.3). However, at this time, directional information and signs are only required to comply with Section R409.3 (Braille) or provide street name information in audible format.

Use by Pedestrians Who Are Blind or Who Have Low Vision

A pedestrian who is familiar with the installation of raised or large print but unfamiliar with the particular intersection would search the sign to learn or confirm the name of the street that is controlled by the pushbutton.

Passive Pedestrian Detection

Description

Passive pedestrian detection is sometimes used to call the pedestrian phase, and it can extend the clearance interval. The authors are not aware of U.S. installations of passive detection that include audible signals as well as visual signals, but the combination of passive pedestrian detection and audible signals is being used in the United Kingdom, Australia, New Zealand, and the Netherlands (see Figures 4-10 and 4-11).

One available APS device provides the option of triggering the pushbutton locator tone through sensors (piezoelectric, infrared, or microwave) when a pedestrian enters the detection zone. If a pedestrian is not detected, the locator tone is silent.

Additional Information

An example of passive pedestrian detection technology is the "pedestrian user-friendly intelligent" (PUFFIN) crossing in use in England since 1993 (*18*). PUFFIN crossings employ pedestrian detectors for both the pedestrian waiting area and the

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crosswalk. Waiting area detectors consist of pressure mats with piezoelectric sensors, infrared or microwave detectors mounted on the signal pole, or video cameras serving remote sensor software.

Figure 4-10. Detail of an APS at midblock crossing in Australia. Sign reads "Push button then wait on red mat."

Figure 4-11. This midblock crossing has sensors in a specific area of the sidewalk. A red mat area is labeled "Push button then wait here."

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References

The MUTCD states: "Accessible pedestrian signal detectors may be pushbuttons or passive detection devices" (7–4b.09).

Use by Pedestrians Who Are Blind or Who Have Low Vision

While passive detection of pedestrians for activating the locator tone may be helpful in reducing noise near the intersections, pedestrians who are blind may not approach the crosswalk or intersection within the detection zone. They also may not know about it unless they are familiar with the intersection.

Pedestrians who are blind may also not stand or travel in the exact waiting or crossing area to trigger passive detection for the "Walk" signal or to extend the clearance interval.

Remote Activation

Description

At least one manufacturer offers the option of a handheld pushbutton that sends a message to the APS to call the pedestrian phase. It operates on a limited range radiofrequency (such as used with a garage door opener or car door unlocking device) within 100 ft of the signal.

Additional information

The manufacturer's information does not clarify how the device would differentiate between locations at the intersection or if using the device would place a pedestrian call for all crossings of the intersection.

Reference

Handheld pushbuttons are not mentioned in the MUTCD or the Draft PROWAG.

Use by Pedestrians Who Are Blind or Who Have Low Vision

Pedestrians could place a pedestrian call as they approach the intersection, without having to travel to the pushbutton location. This would make it unnecessary to deviate from the travel path and may be particularly advantageous for wheelchair users.

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Tones or Audible Messages During Clearance Interval

Description

A tone or other message sounds during the pedestrian clearance interval at a different rate or tone or with a different speech message than the "Walk" indication or push button locator tone. This can include audible pedestrian countdowns.

APS devices typically revert to the push button locator tone during the flashing and steady "Don't Walk" interval. That is not considered to be a clearance interval indication/tone.

Additional Information

Clearance interval information is sometimes provided by accessible pedestrian signals in Japan and in some parts of Canada

- In Japan, a variety of alternatives are available, including a European emergency vehicle "hee haw" sound and various melodies.
- In Canada, clearance interval information may be provided by a tone that repeats at a faster rate than the "Walk" signal. For example, if the "Walk" signal is a "cuckoo" sounded at 1 time per second, during the clearance interval the "cuckoo" is sounded 2 times per second.

The advantage of tones or audible messages during the clearance interval is that pedestrians who are visually impaired and who have begun to cross the street know that the clearance interval prevails.

Disadvantages include the following

- The clearance interval sound might be mistaken for the "Walk" signal by persons who approach during the clearance interval, leading them to begin crossing during the flashing "Don't Walk" interval
- Pedestrians who are blind generally want to be able to hear traffic while crossing the street. The clearance tone or audible message could distract them from hearing traffic or mask the sound of traffic. The continuous nature of a speech countdown has more potential for masking other sounds than the shorter duration of the push button locator tone.

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- Additional cognitive processing may be required to interpret a verbal clearance interval message, such as an audible countdown.
- For a blind person, knowing the remaining length of the flashing "Don't Walk" signal is not useful since they do not have information about the remaining distance to the destination curb.

References

The MUTCD states that the accessible pedestrian signal shall indicate the walk interval and that the word "wait" must precede any message during the clearance interval (FHWA, 2000).

Use by Pedestrians Who Are Blind or Who Have Low Vision

This feature is not currently used in the United States and is not recommended due to the potential confusion of the walk interval with the clearance interval.

As noted in the disadvantages listed above, pedestrian countdown information is unlikely to provide any advantage to the individual who is blind or visually impaired.

Integrated Information Devices

Description

Personal pagers, cellular telephones, and other mobile digital communication devices could potentially receive transmitted pedestrian signal messages. The increased use of these devices suggests that there may be other technologies and methods to provide information to pedestrians and for pedestrians to call the walk interval in the future.

Development is ongoing on an integrated handheld computer type device to provide geographic global positioning system (GPS), intersection layout, and real time signal information to pedestrians who are blind. Communication of a pedestrian call is also being investigated. Such technology is, however, in the very early stages of development.

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CHAPTER 5

When to Install Accessible Pedestrian Signals

Where Are Accessible Pedestrian Signals Required? 2

Prioritizing APS Installations 4

APS Prioritization Tool 6

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This chapter provides guidance on when and where accessible pedestrian signals should be installed. It contains information on requirements for installation and a tool for prioritizing APS installations.

Where Are Accessible Pedestrian Signals Required?

Current Practice

Currently in the United States, APSs are typically installed upon request along a specific route of travel for a particular individual or group of individuals who are blind or visually impaired. Various states and municipalities have established policies on installation of APS devices, some of which may not be in accordance with ADA requirements.

Section 504 and ADA Requirements

As discussed in Chapter 1, Section 504 of the Rehabilitation Act has since 1973 required nondiscrimination in all programs, services, and activities receiving federal financial assistance. The ADA requirements for state and local governments extend and increase the requirements in the Rehabilitation Act, requiring newly constructed or altered public facilities to be accessible, regardless of the funding source.

Effective Communication

The ADA requirement for effective communication was discussed in Chapter 1. A recent publication by the Federal Highway Administration specifically mentions accessible pedestrian signals as a means to communicate information:

> Implementing regulations for Title II of the ADA, which covers State and local governments, also address "communications and information access," requiring "effective communications" with persons with disabilities. In the sidewalk/street crossing environment, this would include accessible pedestrian signals, markings and signage. [19]

Where there are pedestrian signals, this may require the installation of accessible pedestrians signals to provide access to signal information for pedestrians who are blind or who have low vision.

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ADA Standards for Public Rights-of-Way

As discussed in Chapter 1, ADA standards that specifically address the public rights-of-way have not yet been finalized. The Draft PROWAG was published for comment on June 17, 2002, and was revised on November 23, 2005. These minimum technical standards would require accessible pedestrian signals at all newly constructed or reconstructed intersections where visual pedestrian signals are installed.

Accessibility Still Required

ADA accessibility guidelines are minimum guidelines for new construction or reconstruction, and they must be applied to the maximum extent feasible in alterations, renovations, or additions.

While the ADA does not require going back and reconstructing all intersections and locations, it does require improving accessibility when work is performed at a location. When an intersection is being completely reconstructed, the expectation is that new construction guidelines can and will be met. (See the section in Chapter 6 on new construction for a description of the elements covered by the Draft PROWAG.)

When certain elements of an intersection are being upgraded, the accessibility features should also be upgraded to new construction standards to "the maximum extent feasible." The "maximum extent feasible" is explained in the Title II regulations issued by the Department of Justice.

Self-Evaluation and Transition Plans

When the ADA regulations were published in 1992, the Department of Justice extended the Section 504 requirement for transition plans and required a "self evaluation" by all public entities (28 C.F.R. Part 35.105, Self Evaluation). The goal was that each service, facility, and activity of the state or local government, when viewed in its entirety, would eventually be accessible to individuals with disabilities. If structural changes are required to existing facilities to provide program accessibility, a transition plan is required; the elements of a transition plan are discussed in 28 C.F.R., Part 35.150(d). A summary from the FHWA Office of Civil Rights provides a short description of requirements:

> A public entity may not deny the benefits of its programs, activities, and services to persons with disabilities because existing facilities are inaccessible.

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- State and local governments of 50 employees or more were required to prepare a self-evaluation plan to identify program access issues (Rehabilitation Act (1973), section 504).
- From this, a transition plan was to be developed to modify inaccessible services, policies and practices. This includes removing barriers and inaccessible features.
- Transition plan work was to have been completed by January 1995.
- If work was not completed by that date, these entities are out of compliance.
- Many states and localities are out of compliance and this makes them more susceptible to lawsuits.
- Ways of complying with the law are to have an ongoing transition plan for improving existing facilities and providing a citizen's request program for accessible parking, curb ramps, Accessible Pedestrian Signals (APS) and removing sidewalk and street crossing barriers. (20)

APSs in Transition Plans

Some municipalities have considered the addition of APSs at intersections part of their ADA transition plan, but many have not. As part of their compliance with ADA, municipalities may need to establish a plan to prioritize and make decisions about installation of APS at "unaltered" intersections

- Where a request for APS is received, and
- Where there is insufficient information for street crossing using non-visual clues

Prioritizing APS Installations

The information regarding prioritizing intersections for installation of APSs is not intended to apply to new or reconstructed intersections. In new construction or reconstruction projects, it is appropriate to consider the Draft PROWAG as the best guidance available at this time (20). In new construction, accessible pedestrian signals should be installed wherever pedestrian signals are installed

Where Are Accessible Pedestrian Signals Needed?

When considering and prioritizing crossings and intersections for retrofit with accessible pedestrian signals, consideration needs to be given to the information available to pedestrians

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who are blind and to which crossings are in greater need of an APS. A number of factors enter into that decision.

MUTCD Guidance

The *MUTCD* recommends the following:

> The installation of accessible pedestrian signals at signalized locations should be based on an engineering study, which should consider the following factors:
>
> - Potential demand for accessible pedestrian signals;
> - A request for accessible pedestrian signals;
> - Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;
> - The complexity of traffic signal phasing; and
> - The complexity of intersection geometry. (*Id.*, 4E.06.)

Additional Considerations

Locations that may need accessible pedestrian signals include those with:

- Vehicular and/or pedestrian actuation.
- Very wide crossings.
- Crossings of major streets where minor streets have minimal or intermittent traffic (an APS may be needed for crossing the major street).
- T-shaped intersections.
- Nonperpendicular or skewed pedestrian crossings.
- Low volumes of through vehicles.
- High volumes of turning vehicles.
- Split phase signal timing.
- Exclusive pedestrian phasing, especially where right turn on red is permitted, and
- Leading pedestrian intervals.

Where these conditions occur, it may be impossible for pedestrians who are visually impaired or blind to determine the onset of the "Walk" interval by listening for the onset of parallel traffic. It would also be difficult to obtain usable orientation and directional information about the

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crossing from the cues that are available. Too little traffic is as great a problem for pedestrians who are blind as is too much traffic. In the absence of an APS, blind pedestrians must be able to hear a surge of traffic parallel to their direction of travel in order to know when the walk interval begins.

Advisory Committee Involvement

Some jurisdictions may wish to set up a process where ratings are reviewed by an advisory committee of stakeholders, including blind citizens, O&M specialists, and transportation professionals, who can assist the traffic engineering department in the study process.

In many of the current systems used, crossings with the highest number of points are generally considered the highest priority. However, date of request, plans for other construction at the intersection, and other local issues may affect priority of installations.

APS Prioritization Tool

As discussed previously, prioritizing existing intersections for retrofit with accessible pedestrian signals should be done either in response to requests or when updating an ADA transition plan. Prioritization schemes should place only limited emphasis on factors related to frequency or likelihood of use by blind pedestrians. The information provided by an accessible pedestrian signal may be necessary at any time, along any route, by residents, occasional travelers, and visitors. Intersections having high pedestrian volumes are likely to have pedestrians whose vision is sufficiently impaired so as to have difficulty using conventional pedestrian signals.

Of greater importance in prioritizing crosswalks are factors related to determining whether sufficient acoustic information exists — at all times — to permit safe crossing at a particular intersection or crosswalk.

Past Rating Scales

Several rating scales have been developed in cities across the country, some of which have been utilized for more than 20 years. These rating scales have been used in different ways in different cities. In some locations, they were developed as warranting schemes, and APSs were installed only if the intersection met a required minimum number of points. Other cities used rating scales only to aid in prioritization.

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Generally, points are assigned to specific intersection features, as well as proximity to services for all pedestrians (such as transit, governmental offices, or shopping). The cities of San Diego, Los Angeles, and Portland and the state of Maryland have used point rating scales as part of their process.

The parties responsible for rating the intersections vary according to the locality. In San Diego, a traffic engineer and an O&M specialist rate separate aspects of the intersections. In Los Angeles and Portland, the rating is conducted jointly by an O&M specialist and a traffic engineering department staff member. In Maryland, the DOT engineer determines the rating.

APS Prioritization Tool Overview

The APS Prioritization Tool was developed as part of this research (*21*). The tool provides traffic engineers and other technical practitioners with the means to take observable characteristics of a pedestrian crosswalk and produce a rating that reflects the relative crossing difficulty for pedestrians who are blind, thus enabling prioritization of crosswalks for installation of accessible pedestrian signals. Practitioners can use this tool to determine these ratings for each crosswalk. The crosswalks with the highest ratings will have the highest priority for APS installation. While an overview of the tool and an example of use are shown in this chapter, the full instruction manual and blank Prioritization Tool forms can be found in Appendix D.

The Prioritization Tool calculates the prioritization score for a crosswalk based on characteristics of the crosswalk itself and the intersection at which it is located. Characteristics that cause a crosswalk to have a greater need for APSs are assigned higher point values.

Intersection characteristics include the following:

- Number of intersection legs.
- Signal design (e.g., pretimed, actuated).
- Proximity of transit facilities.
- Proximity to facilities providing services for people who are blind or visually impaired, and
- Proximity to major pedestrian attractors (e.g., sports arena, downtown area).

Crosswalk characteristics include the following:

- Crosswalk width.
- Street speed limit.

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- Approach and crosswalk geometrics (e.g., skewed crosswalks, large curb radii, islands or medians).
- Pedestrian signal control (e.g., pushbutton actuation required for "Walk" signal, leading pedestrian interval).
- Vehicle signal control (e.g., right turn on red, leading protected left turn phase).
- Off-peak traffic presence.
- Distance to alternative APS crosswalk.
- Pedestrian pushbutton location, and
- Requests for accessible pedestrian signals.

APS Prioritization Tool Validation Process

Although prior rating scales included many relevant factors, the point values assigned to these factors were not thoroughly tested in a field validation. The APS Prioritization Tool underwent validation through comparison with expert opinion from O&M specialists and blind pedestrians. The steps in producing and validating the tool were as follows:

1. The research team selected factors (e.g., crosswalk width, signal design) to include in the tool. Factors that made crossing more difficult for blind pedestrians were given higher point values. This produced the initial form of the prioritization tool.
2. The team selected crosswalks in three cities (Cambridge, MA; Tucson, AZ; and Charlotte, NC). Each crosswalk was rated with the initial prioritization tool. The same crosswalks were then rated by O&M specialists and blind travelers, who ranked them in order of difficulty for blind pedestrians.
3. The two sets of rankings were compared. The places where the prioritization tool results differed from the expert results showed where the tool's point values needed to be raised or lowered.

This process produced a tool that was validated by comparison to expert opinion in real-world situations.

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Example of the APS Prioritization Tool

The following example shows how the Prioritization Tool would be used to score a crosswalk that would be relatively difficult (an additional example of a relatively easy crosswalk is included in Appendix D).

This example rates a crosswalk at a large intersection of a major arterial and a minor side street. The crosswalk of interest is on the east leg (highlighted in Figure 5-1; shown at street level in Figure 5-2).

Figure 5-1. Overhead view of example crosswalk (reprinted from Google Earth © 2005).

Figure 5-2. Street view of example crosswalk.

The first worksheet deals with the intersection characteristics (Figure 5-3). Points were given for the following reasons:

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- The signal is actuated but also uses split phasing, which is a higher point value than actuation, so the intersection gets six points for split phasing. Split phasing is a less commonly used signal design, and the typically heavy turning movements make it harder to effectively use the traffic movement cue to determine signal changes. Accessible pedestrian signals would provide a definitive cue to the onset of the walk interval for pedestrians who are unable to see the pedestrian signal.
- There is a single bus route on the main street, which earns another point. The presence of public transit increases the likelihood that visually impaired pedestrians will travel at this intersection, thereby increasing the priority for an APS.

There are no facilities specifically providing services for individuals who are visually impaired or major pedestrian attractors within 0.5 mi, so no points are given for those categories. The total intersection score is seven points.

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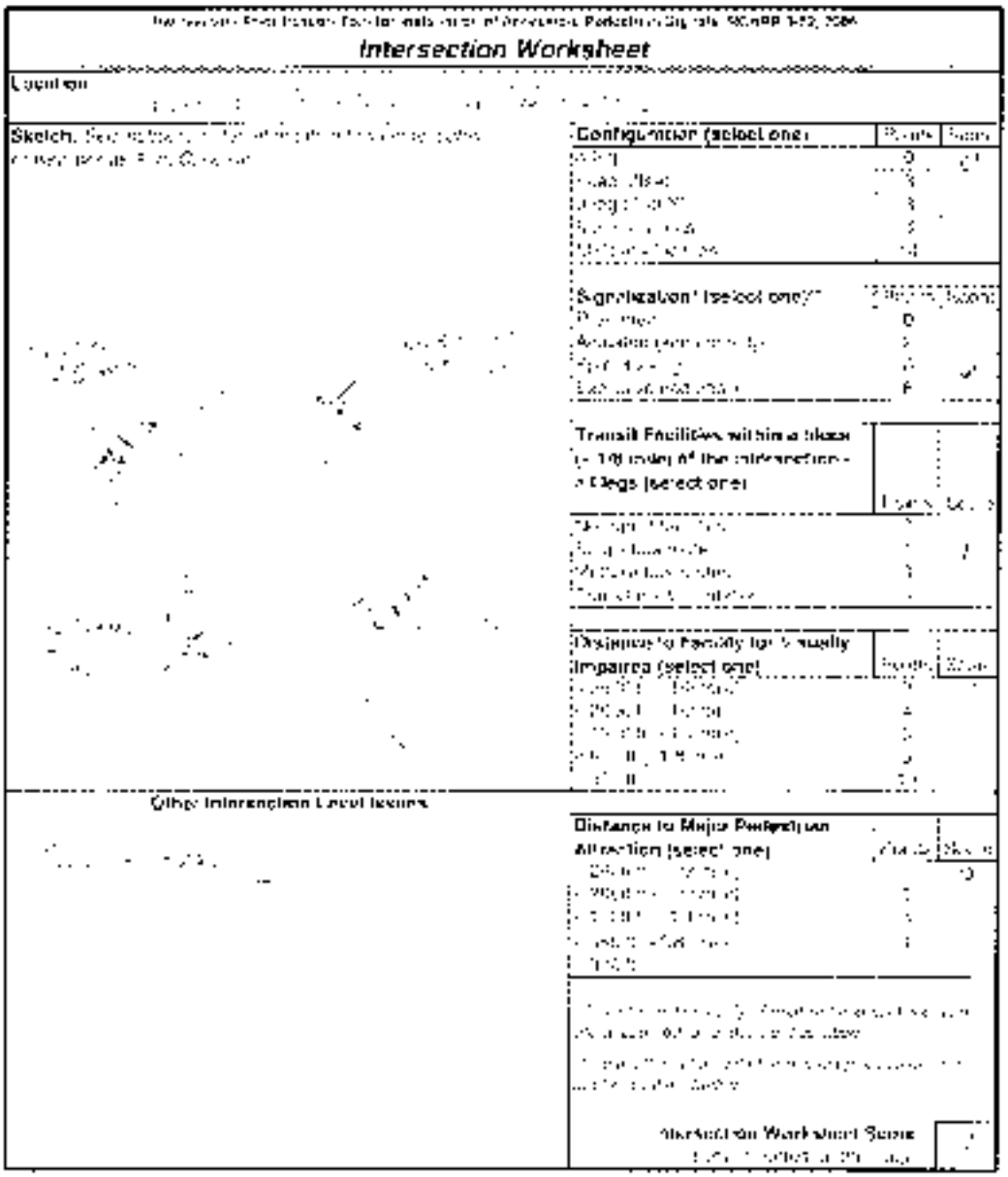

Figure 5-3. Intersection worksheet for example crosswalk.

The second worksheet deals with the crosswalk (Figure 5-4). Points were given for the following reasons:

- The crosswalk width of 120 ft and the speed limit of 45 mph on the main street earn the crosswalk four and five points, respectively. Wider crosswalks and faster traffic increase the

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crossing difficulty and risk to visually impaired pedestrians; an APS may help expedite their crossing.

- The curb radius on one of the corners bordering the crosswalk is greater than 25 ft, so one point is given in the geometrics category. Larger curb radii create orientation problems for visually impaired pedestrians that may be decreased with the use of an APS.
- The signal requires pushbutton activation for the pedestrian "Walk" signal, so four points are given for the pedestrian signalization category. An APS locator tone would help a pedestrian who is visually impaired recognize that there is a pushbutton at that crosswalk and help in locating the pushbutton.
- Right turn on red (RTOR) is permitted at the crosswalk, so two points are given in the vehicle signal control category. RTOR may produce misleading traffic cues, and an APS would provide a definitive cue of the appropriate time to cross.
- During off-peak hours, there was enough parallel traffic to provide audible cues (two or more vehicles per cycle) about 75% of the time. This earns two points.
- There is not an alternative APS crosswalk within 0.5 mi, so four points are given toward the prioritization of an APS installation at this crosswalk.
- The pedestrian pushbutton at one end of the crosswalk is located more than 10 ft from the curb, which is contrary to the recommendations in Section 4E.09 of the MUTCD. Three points are given for this drawback, since a correctly installed APS would position the pushbutton closer to the curb, which facilitates orientation alignment for blind and visually impaired pedestrians.

The crosswalk worksheet score is 25 points. When added to the intersection score of 7 points, this yields a total crosswalk score of 32 points. In practice, this score of 32 points would be compared with other crosswalks under consideration for APS installations. Those crosswalks with the highest scores would have the highest priority for installation of accessible pedestrian signals.

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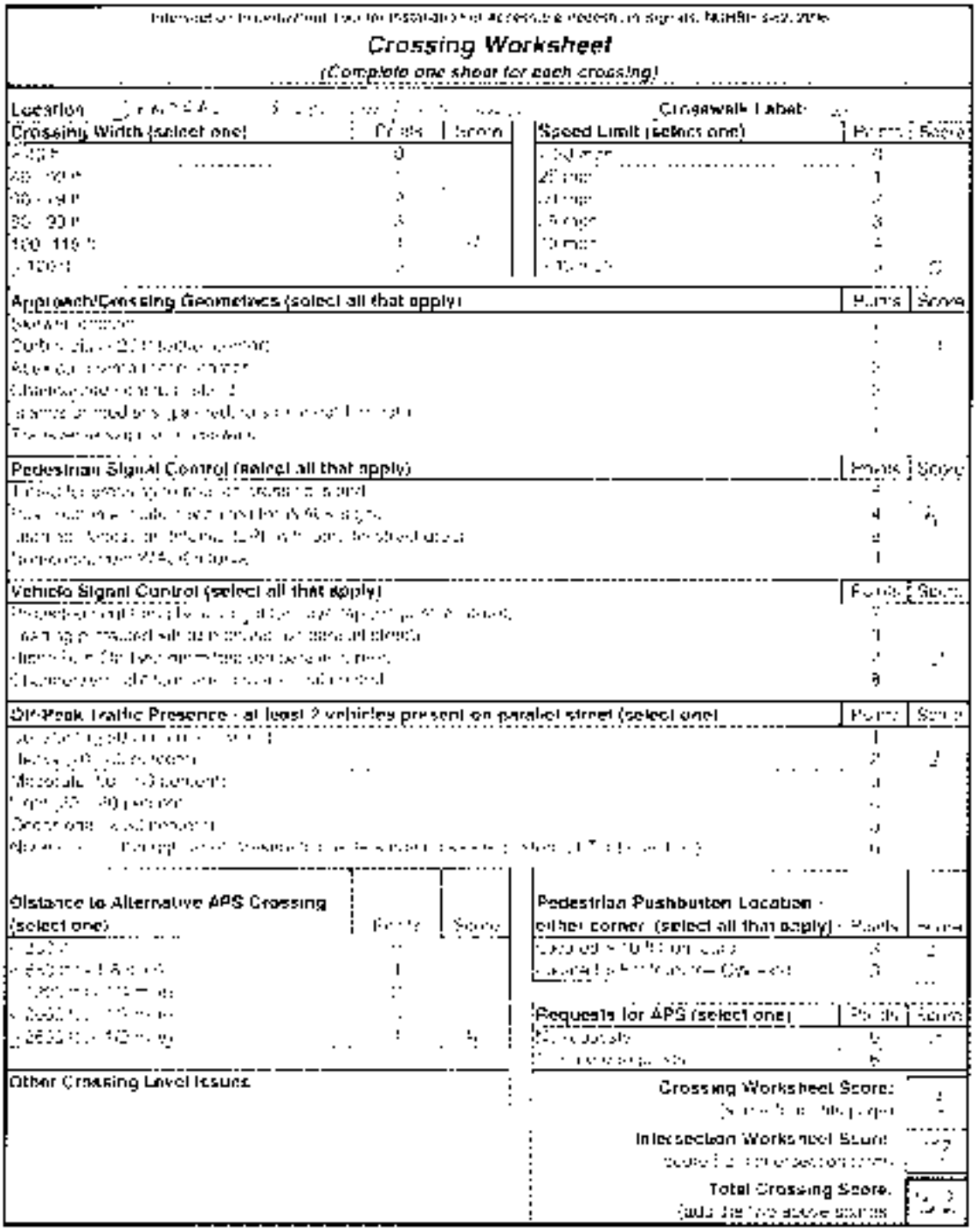

Crossing Worksheet

(Complete one sheet for each crossing)

Location:

Crosswalk Label:

Crossing Width (select one)	Points	Score
< 60 ft	0	
60 - 79 ft	1	
80 - 99 ft	2	
100 - 119 ft	3	
120 - 139 ft	4	4
> 139 ft	5	

Speed Limit (select one)	Points	Score
≤ 30 mph	0	
35 mph	1	
40 mph	2	
45 mph	3	
50 mph	4	
> 50 mph	5	5

Approach/Crossing Geometrics (select all that apply)	Points	Score
Several lanes	1	
Curb radius > 20 ft (either corner)	1	1
Wide curb radius (> 50 ft)	2	
Channelized right-turn lane	2	
Skewed crosswalk (> 15° from perpendicular)	1	
Two-stage crossing	1	

Pedestrian Signal Control (select all that apply)	Points	Score
Timed to allow pedestrian to cross	2	
Pedestrian signal phase (WALK/DON'T WALK)	4	4
Leading pedestrian interval (LPI) with pedestrian head start	2	
Concurrent with WALK phase	1	

Vehicle Signal Control (select all that apply)	Points	Score
Protected right-turn (vehicle right-turn phase with green arrow)	2	
Right-turn-on-red restricted (sign or signal)	1	
Channelized right-turn lane (no control)	2	2
Channelized right-turn lane (yield control)	3	

Off-Peak Traffic Presence - at least 2 vehicles present on parallel street (select one)	Points	Score
Rarely (0-10 vehicles/hour)	0	
Intermittent (11-30 vehicles/hour)	2	2
Moderate (31-50 vehicles/hour)	3	
Frequent (51-80 vehicles/hour)	4	
Constant (> 80 vehicles/hour)	5	
Alternative crossing (signalized crossing within 1/4 mile)	0	

Distance to Alternative APS Crossing (select one)	Points	Score
< 1/10 mi	0	
1/10 - 1/4 mi	1	
1/4 - 1/2 mi	2	
1/2 - 3/4 mi	3	
> 3/4 mi	4	4

Pedestrian Pushbutton Location - other corner (select all that apply)	Points	Score
Curb ramp (10 ft from curb)	0	0
Curb ramp (> 10 ft from curb)	0	0

Requests for APS (select one)	Points	Score
Rarely	0	0
Frequently	5	

Other Crossing Level Issues:

Crossing Worksheet Score: (sum of scores above) 17

Intersection Worksheet Score: (score from intersection worksheet) 17

Total Crossing Score: (add the two above scores) 34

Figure 5-4. Crosswalk worksheet for example crosswalk.

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CHAPTER 6

Designing APS Installations

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Optimal APS Location 3

Signal Phasing Considerations 7

Intersection Geometry Considerations 12

APS Design in New Construction 15

APS Design at an Existing Intersection 20

Needs Assessment 21

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Specifications 28

Mounting and Wiring Issues 29

APS Microphones and Speakers 39

Summary of Recommended Features and Installation Practice 57

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Accessible pedestrian signal installations require engineering drawings and detailed specifications. Complex intersections require complex decisions and engineering judgment. A number of factors must be considered in designing the installation. This chapter contains guidance on how to design an APS installation that works well for the user and the environment.

Principles

General principles in the decision to install an APS include the following:

- Provide pedestrian signal information to those who cannot see the pedestrian signal head across the street.
- Provide information to pedestrians about the presence and location of pushbuttons, if pressing a button is required to actuate pedestrian timing.
- Provide unambiguous information about the walk indication and which crossing is being signaled.
- Use audible beaconing only where necessary.
  - Put as little additional sound in the environment as possible.
  - Avoid disturbing neighbors.
  - Allow pedestrians who are blind or visually impaired to hear the traffic sounds, as well as the APS.

Features

In many cases, a municipality or state will wish to purchase one style of APS device for all installations. However, there are engineering and design decisions in the installation of an APS, as well as in the choice of equipment.

More latitude in specifications may be applied when the APS is an addition to an existing intersection. The ADA typically requires new construction to meet ADA guidelines, while it requires additions or alterations to existing intersections to meet the guidelines to the maximum extent feasible. Understanding the basic considerations is necessary to designing usable installations in both new and retrofit situations.

In new construction or reconstruction, where the APS can be located consistently, it is likely possible to use standardized device features and mounting locations for all installations. When retrofitting intersections with an APS, it may be necessary to use different features to provide

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unambiguous information at different intersections. (See Chapter 4 for a listing and description of APS features.)

Device Location

Device location is critical to the functioning of the APS and needs to be planned. The APS may provide ambiguous information if located incorrectly, just as pedestrian or vehicular signal heads can provide ambiguous, or even dangerous, information if located incorrectly. Engineering judgment is required to determine the best way to install APSs at a given intersection and crossing. Differences in curb radius, width of right-of-way, presence of a parkway (grass buffer), curb ramp design and location, and existing infrastructure on corners make each installation different.

Whenever possible, two poles should be installed for APS speakers to be located close to the pedestrian departure location and crosswalk, as described in detail below. Recommendations about location and the walk indication have been updated as a result of recent research. (See Appendix C for research results.)

Optimal APS Location

The optimal location for a pushbutton-integrated APS is between the edge of the crosswalk line (extended) farthest from the center of the intersection and the side of the curb ramp. The APS should be between 1.5 ft and 6 ft from the edge of the curb, shoulder, or pavement, but no further than 10 ft from the edge of the curb, shoulder, or pavement. The control face and tactile arrow should be carefully aligned with the direction of travel on the associated crosswalk. In order to provide wheelchair users with access to the pushbutton, the pushbutton must be located adjacent to a level, all-weather surface.

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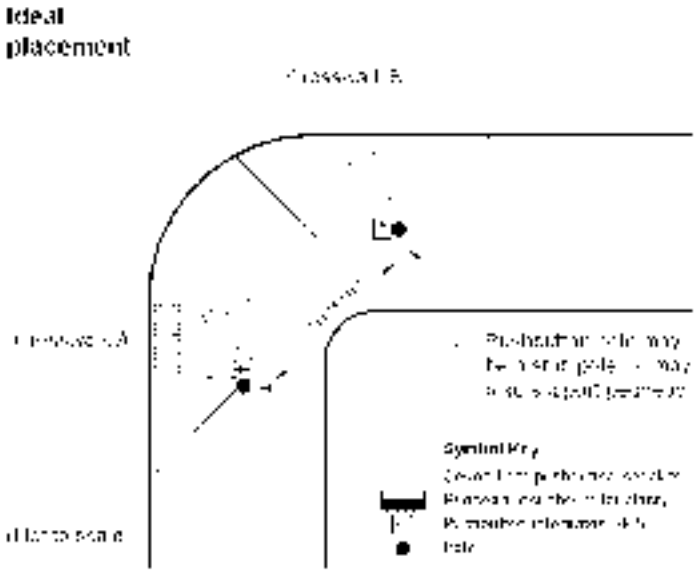

Figure 6-1. Optimal location of pushbutton-integrated APS (two pushbuttons on one corner, mounted on two separated poles; rapid tick "Walk" indication).

The pushbutton and speakers for the APS need to be less than 5 ft from the edge of the crosswalk line (extended) farthest from the center of the intersection. At corners of signalized locations where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 10 ft (see Figure 6-1). A rapid tick "Walk" indication is recommended for installations following these guidelines for location.

When pushbuttons are precisely and consistently located in this way, identification of which crossing is being signaled can be based solely on which pushbutton the "Walk" signal comes from. There is no need to remember a code (such as cuckoo for a north-south crossing and rapid tick for an east-west crossing) or to understand speech messages. Figure 6-2 provides examples of pole arrangements that meet the requirements for corners having different geometries. Figure 6-3 demonstrates acceptable APS placement at a corner with an improper ramp design.

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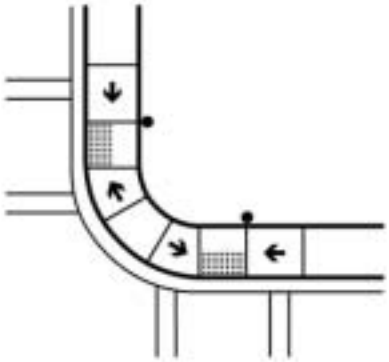
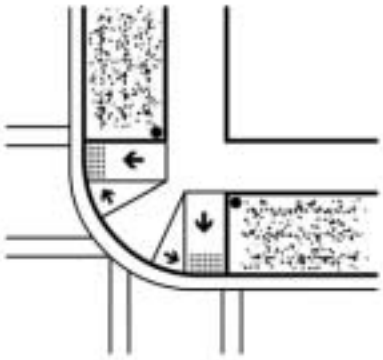


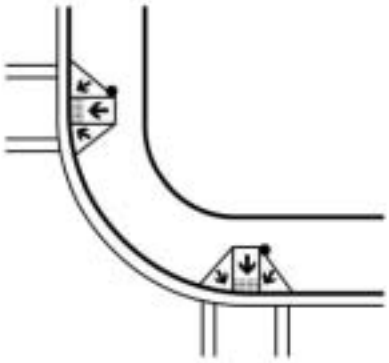
10 ft radius, 5 ft sidewalk, parallel ramps



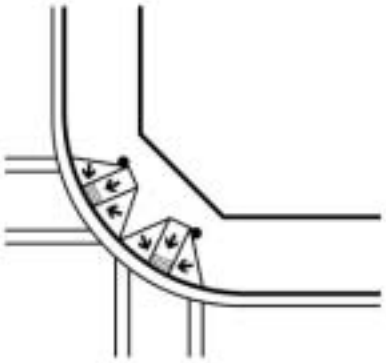
10 ft radius, 5 ft sidewalk with parkway, perpendicular ramps

Legend

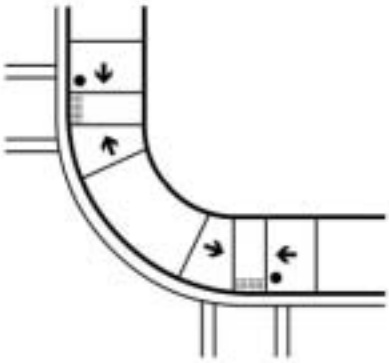
- Level space
- APS pole
- Detectable warning
- Parkway
- Ramp indication



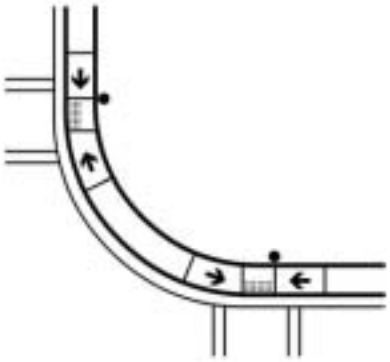
30 ft radius, 12 ft sidewalk, perpendicular ramps



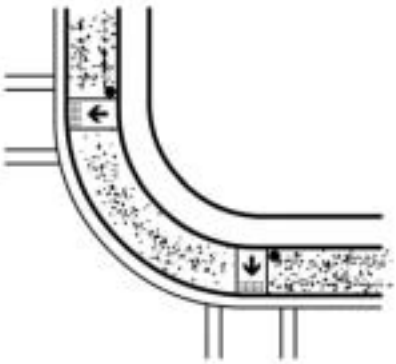
30 ft radius, 12 ft sidewalk, perpendicular ramps



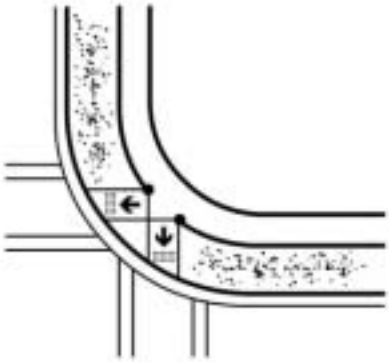
30 ft radius, 12 ft sidewalk, parallel ramps



30 ft radius, 5 ft sidewalk, parallel ramps



30 ft radius, 5 ft sidewalk with parkway, perpendicular ramps



30 ft radius, 5 ft sidewalk with parkway, perpendicular ramps

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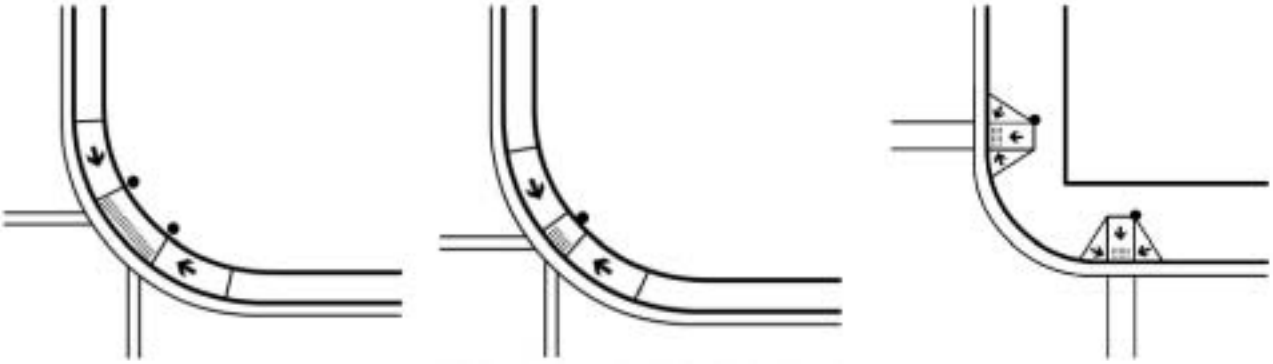

30 ft radius, 5 ft sidewalk, single ramp, APS poles separated by 10 ft

20 ft radius, 5 ft sidewalk, single ramp, APS on single pole with speech messages

Right-angle right-of-way, 8 ft sidewalk, perpendicular ramps

Figure 6-2. Examples of locations for APSs on corners with various geometries.

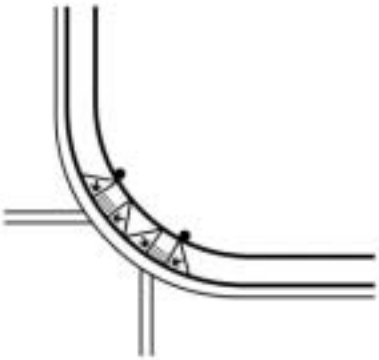

Figure 6-3. Acceptable APS placement, but inaccessible ramp design (no level space for passage through the sidewalk).

APS Installation Where Two Separated Poles Are Not Possible

Where the only work being done is the addition of APSs to existing poles, or where it is technically infeasible to install two APS devices on separate poles because of limited right-of-way, topography, or the location of other essential equipment, it may be necessary to install two APSs on a single pole. However, the APS features required for this situation are different from those where accessible pedestrian signals and their associated sounds are separated.

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When it is necessary to mount two pushbuttons on one pole without a separation of 10 ft or more.

- Speech "Walk" messages, rather than tones, are recommended, and
- Pushbutton information messages identifying the intersection and the street to be crossed are needed to ensure users know the street name to listen for in the "Walk" message.

Research in Portland demonstrated that the pedestrian's identification of which crosswalk had the "Walk" signal was significantly more accurate when the APS provided speech "Walk" signals from both signals than when the APS used two tones—cuckoo and signid tick (see Appendix C).

Need for Audible Beaconing

Audible beaconing is the use of an audible signal in such a way that blind pedestrians can home in on the signal from the opposite corner to aid in alignment during the crossing. The need for audible beaconing may affect the type of device to be installed and the installation location. Not all devices are capable of providing audible beaconing. The need for beaconing should be evaluated and considered early in the design of the APS installation. A minority of crossings is likely to require beaconing; not all crosswalks at an intersection may need beaconing. Beaconing may actually cause confusion if used at some locations. (See Chapter 4 for suggested criteria for audible beaconing.)

Signal Phasing Considerations

Introduction

Some signalization schemes, such as exclusive pedestrian phasing and split phasing, need careful adjustment and consideration to avoid confusing pedestrians who are blind. Crossings with pedestrian signals that rest in "Walk" may need special treatment. These issues must be considered in the design phase in determining type of device and location. In addition, careful adjustment of APS volume after installation is essential.

Split Phasing

Split phasing is a signal design that gives a green phase for all vehicle movements in one direction (e.g., northbound through, right, and left), followed by a phase for all movements in the

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opposite direction (e.g., southbound through, right, and left). At a location with split phasing, an APS that can be heard from the parallel crosswalk provides incorrect, confusing, and dangerous information. It is critical that the "Walk" indication be audible only from the ends of the crosswalk being signaled so that pedestrians at other crosswalks do not begin to cross at a time when vehicles are turning across their path in a protected vehicular movement.

This can be accomplished by locating the APS very close to the crossing location so pedestrians can readily determine which signal applies to their crosswalk. Careful adjustment of the APS volume at all times of the day and night, as well as careful aiming of the speakers, is critical. Audible beaconing may not be appropriate at locations with split phasing due to the possibility of confusion of signals.

Possible strategies include the following:

- An APS mounted at the pushbutton location with volume carefully set to be heard only at the crossing location (see photos and further discussion in Chapter 7).
- A pushbutton that actuates the audible "Walk" indication only for the crosswalk that receives the pedestrian call.

Actuated Turn Phasing

In some timing plans for actuated turn phasing, traffic in one direction may be held longer to allow the opposing traffic to complete left turning movements. In many such cases, the pedestrian phases on parallel crosswalks begin at different times. An APS that can be heard from the parallel crosswalk provides incorrect, confusing, and dangerous information and could mislead pedestrians into crossing when vehicles are turning across their path in a protected vehicular movement.

Possible strategies include the following:

- An APS with speakers mounted at the pushbutton or pedestrian signal head, with carefully set volume and very careful placement and adjustment, to be heard only at the crossing location (see photos and discussion in Chapter 7).
- A pushbutton that actuates an audible "Walk" indication only for the crosswalk that receives the pedestrian call.
- Having the audible "Walk" indication sound only during that part of the "Walk" interval that is common to both of the parallel lanes, provided that the pedestrian clearance time remains

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long enough to enable pedestrians crossing with audible cues to complete their crossing before the end of the clearance interval.

Exclusive Pedestrian Phasing

Exclusive pedestrian phasing (also known as scramble phasing) is a signal phase in which all vehicle movements are stopped and all pedestrian crosswalks are given the "Walk" signal. This makes it difficult for pedestrians who are blind or visually impaired to recognize the onset of the walk interval, particularly at locations where right turns on red are permitted. In addition, there is no vehicle flow to aid in crossing straight to the destination corner.

In some locations, pedhead mounted accessible pedestrian signals have been installed on all corners, and two different sounds for different crossing directions have been set to sound during the "Walk" indication. This is not recommended, as it is confusing to all pedestrians, and the assumption of pedestrians who are blind may be that the signals are broken.

In a pilot project in Morgantown, West Virginia, a pushbutton information message, followed by a "Walk" tone, was used in an intersection with exclusive pedestrian phasing, in association with a "Walk" tone. The pushbutton information message was recorded after the following phrase: "Want to cross Howard at Grand. Wait for red light for all vehicles. Right turn on red permitted." During the walk interval, all pushbutton integrated devices at the intersection emit the same, rapidly repeating tone. Only one APS may be installed on some corners, with a modified tactile arrow installed on the top of the device, with arrows pointing in two directions. (See the Morgantown case study in Chapter 9.)

Rest in "Walk"

At locations where the pedestrian signal to cross the minor street rests in "Walk," the "Walk" indication would sound constantly for that crossing. In many locations, that might prove to be irritating to neighbors.

Some APS manufacturers provide a limit switch that restricts the length of the audible "Walk" indication to 7 or 8 s, but allows recall of the audible and vibrotactile indications of the "Walk" if the button is pressed when there is adequate clearance time remaining. The availability of that feature should be investigated in the installation planning.

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APSs Where Pedestrian Timing Is Pushbutton Actuated

Pushbutton-actuated pedestrian timing requires that a pedestrian locate the pushbutton and push it to request the pedestrian phase. A pedestrian who is blind needs to know a button-press is required to actuate pedestrian timing, and he or she needs to be able to easily find the pushbutton. The most appropriate way to convey that information is with a locator tone at the pushbutton. The Draft PROWAG requires that accessible pedestrian signals have a locator tone when there are pedestrian pushbuttons. Likewise, the MUTCD states that "APS pushbuttons should be audibly locatable" (*1*, 4E.09).

Location of APS Pushbuttons for Actuated Signals

To be useful to pedestrians who are visually impaired, pushbuttons must be installed as near to the crosswalk as possible, preferably on the sidewalk within the width of the crosswalk connection or adjacent to the crosswalk, and as close to the curb as possible.

Pedestrians who are blind must locate and push the pushbutton and then align themselves to cross, as discussed in Chapter 3. Even with an accessible signal, a pedestrian who is blind or visually impaired may not cross on the first "Walk" indication, but rather may need to listen to traffic and the accessible signal for a full cycle to confirm alignment, signal functioning, and traffic direction before pushing the pushbutton again, realigning, and crossing on the following pedestrian phase.

APS Where Pedestrian Timing Is Not Pushbutton Actuated

When pedestrian timing is pretimed, on recall, or called by passive pedestrian detection, pedestrians generally do not need to locate the pushbutton at the intersection. However, accessible pedestrian signals typically have the speakers, a vibrotactile "Walk" indication, and a tactile arrow provided at the pushbutton location. At new or reconstructed intersections, wiring and poles can be added to install the poles and APS in the recommended locations close to the crosswalk and curb ramps.

- When an APS pushbutton with a pushbutton locator tone is installed in a location that is not close to the crosswalk, blind pedestrians may have to deviate from their course of travel to push the button, potentially causing problems in orientation and alignment for the crossing.

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- Many downtown areas with wide sidewalks have pretimed pedestrian phases. Poles are rarely located in optimal locations for installation of an APS with audible and vibrotactile "Walk" indications (see location recommendations in Figure 6-2 and 6-3).

Other Options

It may be appropriate to consider other options when the addition of the APS is the only change planned at an intersection with pretimed signals. The following suggestion does not apply at new or reconstructed intersections. If a pushbutton cannot be installed in a location where the tactile arrow and vibrotactile information associated with the pushbutton are usable, it makes little sense to install an APS with those features.

Note, however, that an installation without the tactile arrow and vibrotactile "Walk" indication would not comply with the Draft PROWAG requirements for new construction. Such an installation might be considered to be meeting those requirements "to the maximum extent feasible" where existing conditions and structures prevent installation of additional poles for mounting the APS beside the crosswalk.

In that case, a pedhead-mounted APS without a pushbutton or location tone may be appropriate. However, a "Walk" message or tone and volume levels should be carefully determined to avoid confusion to pedestrians and to prevent disturbance to neighbors. Unless audible beaconing is determined to be necessary, the APS speaker should be oriented down toward the pedestrian waiting location. Use of a small mast arm to locate the APS over the crosswalk location might be appropriate (Figure 6-4).

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Figure 6-4. The mast arm is used in this installation in Toronto, Canada, to position the pedestrian signal head and speaker closer to the crosswalk.

Intersection Geometry Considerations

Effect on Accessible Pedestrian Signals

An APS that is audible at the wrong crossing location may lead a visually impaired pedestrian to begin to cross at the incorrect time and place. Geometric features such as unsignalized and signalized right-turn lanes are recognized as situations of concern in the MUTCD.

The type of accessible pedestrian signal may not be as important as the location of the sound source and the volume of the "Walk" indication. These issues must be considered in the design phase, when determining type of device and location. In addition, the APS volume must be carefully adjusted after installation.

Unsignalized Right-Turn Lanes and Splitter Islands

An unsignalized right-turn lane can pose a problem if the APS for crossing the signalized main through lanes of the intersection is too loud. Pedestrians who are unaware of the existence of an unsignalized right-turn lane may reach the curb, hear the APS sounding, and cross the unsignalized lane, thinking that it is signalized.

This concern is the reason that the MUTCD urges careful selection of tones at locations with free right turns (*1*, 4E.06). But tone selection does not really provide a solution; it is the volume of the sound and the placement of the speaker that are the important issues.

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The APS must be adjusted so it is heard only from the location where the pedestrian is waiting to cross and is only audible for the crosswalk being signaled. It is generally not appropriate to use audible beaconing where there are splitter islands because the volume cannot be controlled precisely enough. As discussed in the section on split phasing, volume and placement of the sound source are critical considerations in designing and installing the APS.

A pedestrian standing on the corner at location A in Figure 6-5 should not be able to easily hear the APS that is located on the splitter island and that is intended for use by pedestrians crossing the through lanes.

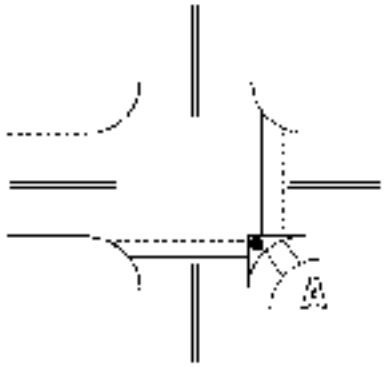

Figure 6-5. APS at channelized turn lane.

Signalized Channelized Right-Turn Lanes

Where crosswalks from corners to splitter islands are signalized, the signals to cross to the island might not, depending on crossing location, be concurrent with traffic movement parallel to the pedestrian who is blind. The APS should be located precisely next to the associated crosswalks, and the volume should be carefully adjusted. Pedestrians waiting on the island must not confuse the "Walk" indication for the turn lane with the "Walk" indication for the through lanes of the intersection. Pedestrians approaching the corner can also be guided to the crosswalk by a locator tone in combination with curb ramp location. Because signalized right turn lanes can be confusing for pedestrians who are blind, installation of APS with pushbutton locator tones at signalized right-turn lanes should be given high priority.

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Medians

If the pedestrian clearance time is sufficient only to cross to a median having an additional pushbutton, it is very important that the pushbutton on that median be an APS with a locator tone. This will help inform the pedestrian who is visually impaired that a second button press is needed to complete the crossing, and it will aid in locating the median and the pushbutton. If only one APS device is on the median, the pushbutton should have a double-ended arrow.

If the pedestrian phases for the two halves of the street are timed separately, then two pushbutton-integrated accessible pedestrian signals are needed on the median, separated by as much distance as possible and located as close to each crossing departure location as possible. In European and Australian cities, a fence and offset crosswalks are used, in addition to the locator tone of an APS, to alert all pedestrians about the need to stop on the median and wait for the next pedestrian phase.

Figure 6-6. APS at median midblock crossing.

At the median island in Ireland shown in Figure 6-6, an APS is provided for each crossing, and a fence prevents pedestrians from continuing straight across the street; instead, pedestrians must turn and walk to the location of the other crosswalk and pushbutton.

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APS Design in New Construction

Draft PROWAG

The Draft PROWAG was released on November 23, 2005 [21]. Although the Draft PROWAG has not been published as a final rule, it should be considered as the best guidance available at this time [19].

APS Characteristics

The Draft PROWAG requires accessible pedestrian signals with the following features in new construction and reconstruction projects where pedestrian signals are installed (see Figure 6-7):

- APS devices integral with the pushbutton.
- Audible and vibrotactile indications of the walk interval.
- "Walk" indication by tone or speech message.
- Pushbutton locator tone whenever there is a pedestrian pushbutton.
- Pushbutton that is a minimum of 0.5 cm (2 in.) across in one direction and that contrasts visually with its housing or mounting.
- Tactile arrow indicating the direction of travel on the crosswalk, and
- Braille or verbal information about the name of the street.

Optional Features

The Draft PROWAG states that an extended button press shall be permitted to activate additional features. However, no information is provided that specifies what those features may include (see Chapter 4 for discussion of extended button press and possible features).

Location in New Construction

The Draft PROWAG specifies that APS devices shall be located as follows:

- In such a way that the vibrotactile feature can be contacted from the level landing of a curb ramp or from clear ground space in line with the crosswalk line adjacent to the vehicle stop line.
- Within specified reach ranges from a level landing.

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- 3 m (10 ft) minimum from other accessible pedestrian signals at the crossing, with an exception to that distance for devices installed on medians, and
- With control face of the device installed facing the intersection, parallel to the direction of the crosswalk it serves.

In addition, clear floor or ground space at the pushbutton shall connect to, or overlap, the pedestrian access route.

Figure 6-7. APS installation in new construction.

MUTCD-Recommended Locations

The MUTCD does not specify locations for new construction in the same manner, but the recommendations are substantially the same as that required by the Draft PROWAG for new construction and reconstruction. The MUTCD states the following:

Pushbuttons for accessible pedestrian signals should be located…as follows:

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- Adjacent to a level all-weather surface to provide access from a wheelchair, and where there is an all-weather surface, wheelchair accessible route to the ramp;
- Within 1.5 m (5 ft) of the crosswalk extended;
- Within 3 m (10 ft) of the edge of the curb, shoulder, or pavement; and
- Parallel to the crosswalk to be used. (*Ref.* 4E.09)

See Figures 6-8 through 6-13 for examples of proper positioning of accessible pedestrian signals.

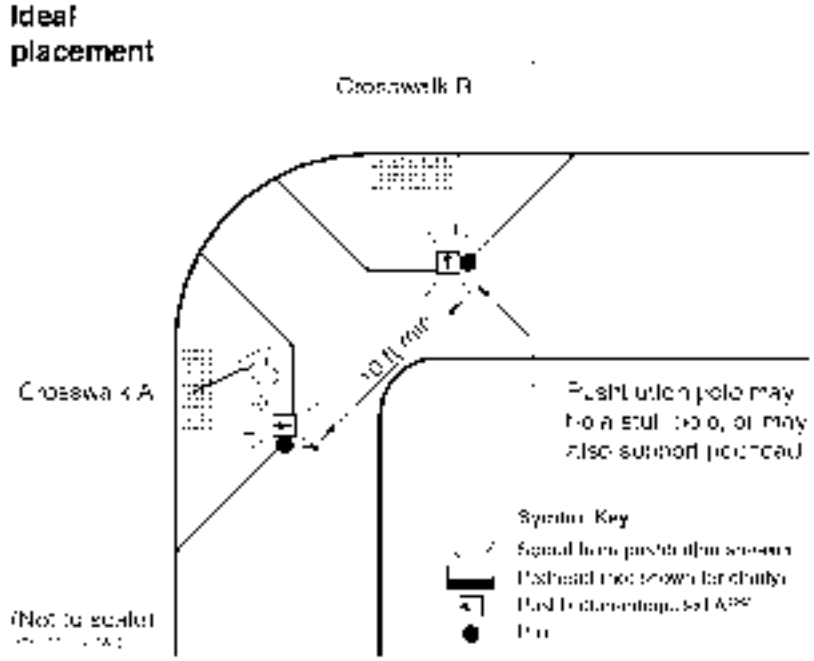

Figure 6-8. Ideal placement for a pushbutton-integrated APS.

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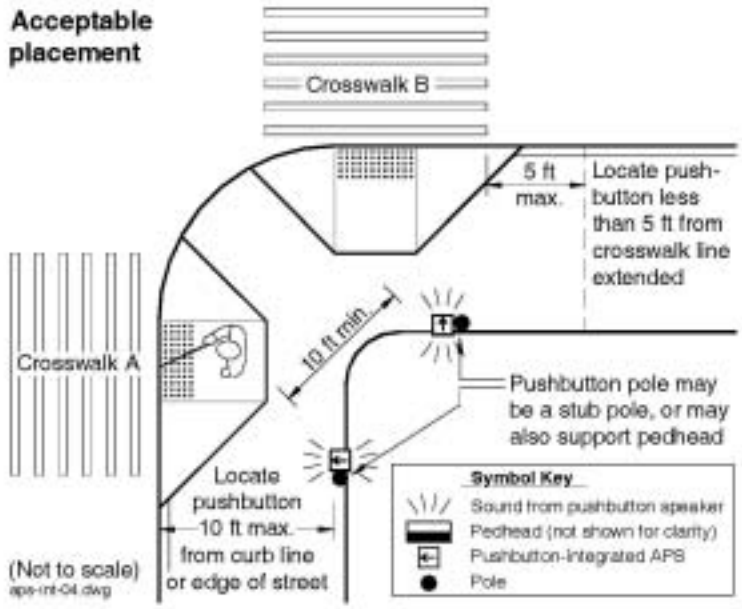

Figure 6-9. Acceptable placement for a pushbutton-integrated APS.

Figure 6-10. The APS should be located on the intersection side of the pole, as shown in this photo.

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Figure 6-11. The MUTCD states that the APS should be within 5 ft of the crosswalk line extended.

Figure 6-12. The APS should be within 10 ft of the curb.

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Figure 6-13. APSs installed in this reconstruction location are in accordance with the Draft PROWAG in that they are beside a level landing and separated from each other by at least 3 m. Both APS devices are located on the intersection side of their poles.

APS Design at an Existing Intersection

Application of New Construction Guidelines

In retrofit situations, the ADA requires that new construction guidelines be followed to the maximum extent feasible, if compliance with those guidelines is technically infeasible. The determination of technical infeasibility will vary depending on the scope of the project and the existing situation.

The new construction guidelines, as described in the previous section, should be applied as much as possible given the constraints of the project and the site.

The following sections provide guidance to assist the engineer/designer in understanding the effects of location and actuation on the usability of the information provided by APS.

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Avoiding Ambiguity

The goal of the new construction location requirements and guidelines is to provide unambiguous information about which crosswalk has the "Walk" indication and to make pushbuttons accessible to and usable by all pedestrians, including those with visual and mobility impairments. Poor location and installation can not only render APSs unusable by a pedestrian who is blind or mobility impaired, but can also provide the pedestrian with dangerously incorrect information.

Pedhead mounted and pushbutton integrated APSs in the United States have typically been mounted on the same pole as the pedestrian signals for that crosswalk, regardless of whether the pedhead is the one closest to that crosswalk. This does not always provide unambiguous audible "Walk" indications.

In Australia and some European countries, it is common to install a separate stub pole so as to mount the APS in a consistent location relative to crosswalks. This consistent location makes it easy to determine which device the "Walk" indication is coming from and therefore provides unambiguous information regarding which crosswalk has the walk interval. The Draft PROWAG implements this strategy in new construction in the United States.

Issues to Consider

In designing retrofit installations, an understanding of the effect of certain intersection features on accessible pedestrian signals use will be helpful in making decisions. Another factor that becomes critical when adding an APS to an existing intersection is the location of existing poles and the possible need for new poles to position the APS close to the crosswalk. Details on these issues and recommended solutions are given in the following sections.

Needs Assessment

Strategies

After an engineering study determines that APSs should be installed at an existing signal, strategies for integrating the APS into the sidewalk environment need to address certain issues and/or questions. Those in charge of installing an APS at an intersection must conduct a needs assessment to determine which features are suitable and to develop detailed installation plans. It is important that the installation designer visit the intersection to gain an understanding of the

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particular issues that must be dealt with. Some manufacturers require detailed information about the location and infrastructure of the intersection where the APS will be installed in order to send equipment with appropriate arrows or other features (such as speech "Walk" messages or pushbutton information messages, if needed).

Pushbutton and Pole Locations

A high-priority part of the needs assessment is to determine how much of the existing infrastructure can be used and how much will have to be installed or modified. It is essential to look at each crossing and the anticipated location of the pushbutton in relation to the departure location.

Questions to consider include the following:

- Does the pushbutton and pole location fit within MUTCD and Draft PROWAG recommended locations?
- Is existing wiring adequate for installation of the APS? The manufacturer's devices may have different wiring needs. Some require four wires to be available at the pushbutton, while others require two wires. There may be different requirements where audible beaconing is used.
- Is it possible to separate the pushbuttons for two crossings on the same corner by at least 3 m (10 ft)?
- Is the speaker nearest to the crosswalk it signals than it is to the other crosswalk?
- Are the pushbuttons located adjacent to a level all-weather surface that is free of hazards and obstacles?
- Is there sufficient turning room for a wheelchair if the pedestrian must turn to push the button and then return to the crosswalk?
- If the existing pole is in a "poor" location, can a stub pole be installed? Or are there other poles nearby that are more appropriately located than the signal pole (e.g., utility poles or lamp posts)?
- Depending upon the pushbutton or pole location, should tones or speech messages be utilized? If two pushbuttons must be installed on the same pole, speech messages should be used for the "Walk" indication.)

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Intersection Geometry and Need for Audible Beaconing

Audible beaconing is not needed at many intersections, although accessible pedestrian signals in the United States have traditionally been installed with beaconing.

The following questions should be considered:

- Is audible beaconing needed at the intersection? (See discussion of audible beaconing in Chapter 4 for suggested criteria.)
- Would audible beaconing create the potential for confusion? (Confusion is possible at an intersection with channelized right turns or other free-flowing lanes.)

Preference and Requests

When installation is in response to a request for an APS, the needs assessment should consider whether the needs of the individual making the request have been addressed.

Pole Location

Existing Pole Location

When the only change is the addition of an APS at an intersection, the existing pole location at the intersection often restricts the location of the APS components (such as pushbuttons, speakers, and tactile arrows), which can affect the device features needed.

- The location of pushbuttons and tactile arrows and the location of speakers must be carefully engineered to provide accessible and usable information to pedestrians with disabilities.
- These issues must be considered in designing the installation and ordering the devices to ensure that information provided by the APS will not be ambiguous. Before ordering devices, the designer needs to look at the poles available and determine the locations where devices will be installed.
- Pole location may affect the type of "Walk" indication to be used.
  - If two accessible pedestrian signals are located on one pole, separate speech "Walk" indications, additional mast arms, or other provisions will be necessary to separate the sounds.
  - APS loudspeakers may be located at the pushbutton location or on the pedhead. The location of the speakers can be critical.

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Location of the Tactile Arrow

If the poles are located too far away from the center of the intersection, outside the extension of the crosswalk lines, a pedestrian who is blind may attempt to cross at a location that is not within the crosswalk area. As discussed in Chapter 4, pedestrians typically align with the tactile arrow and proceed to the curb from that location.

The installation shown in Figure 6-14 is far more than 5 ft outside the extended crosswalk lines. While the arrow does clarify which street the device controls, it provides misleading information, which can be dangerous to pedestrians who cannot see.

Figure 6-14. If pedestrians proceed directly to the curb from the pushbutton in this photo, they will be well outside the crosswalk area when beginning their crossing.

Options for Intersections with No Existing Poles

If there are no existing poles at the recommended locations, options to consider in retrofit situations, in order of decreasing desirability (from the standpoint of minimizing ambiguity), include the following:

- Reposition pedestrian signals and poles, or add stub pole(s) and associated conduit and wiring.
- Install two accessible pedestrian signals with speech messages on a pole (see Chapter 4 for recommended wording of speech messages).

AR0071898

- Mount speakers on the pedestrian signal head, possibly with mast arms or other provisions in order to locate the "Walk" tone speakers as near to the associated crosswalk as possible

Figure 6-15. Well-located pedestrian signal poles provide APS audible indications from the optimal location, close to the pedestrian waiting area.

Reposition Pedestrian Signals and Poles or Add Stub Poles

In some renovation projects, repositioning poles may be considered a major change, but may be less difficult when the addition of the APS is part of an upgrading of the curb ramp. The optimal choice is positioning speakers and pushbuttons on poles that are located close to the crosswalk (Figure 6-15). Possible ways to accomplish this should be strongly considered before other options are explored.

In some locations, the addition of stub poles may be fairly simple (Figure 6-16). Different jurisdictions have different wiring requirements. The wires to pushbuttons are low voltage wires, and it may be possible to run the wires in a saw cut to a pushbutton pole that is mounted with bolts to the sidewalk surface. Looking at the wiring and the use of stub poles in unconventional ways may provide acceptable solutions to problems.

AR0071899

Figure 6-16. APSs are positioned appropriately at this intersection by the addition of a stub pole for one crosswalk. The stub pole holding the APS for the crosswalk at right is simply bolted to the sidewalk. The other APS is mounted on the pole that supports the pedhead.

Installing Two APSs on One Pole

Many jurisdictions use a standard design of two pedestrian signal heads and pushbuttons on one pole. In new or reconstructed intersections, separate poles should be provided at the end of each crosswalk, so that the pushbutton can provide unambiguous APS information and be maximally useful to all pedestrians. Where two APS pushbuttons are mounted on two separate poles at a corner, their arrows can be readily aligned with each crosswalk. Correct alignment can be difficult to accomplish with two APSs on the same pole, particularly at larger radius intersections.

However, if two pushbuttons must be on the same pole, it is essential that speakers be located as close as possible to the pedestrian waiting location and fit the following recommendations for installations of two APSs on one pole.

- A speech "Walk" message is needed, so the user can determine which street has the "Walk" indication (see discussion of "Walk" indications in Chapter 4).

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- A pushbutton message and tactile arrow are also needed so that pedestrians can know the direction of the crosswalk served by that pushbutton and the name of the street to be crossed. Without the pushbutton message, the name of the street in the "Walk" message may be ambiguous to pedestrians who are unfamiliar with the intersection.

Positioning Pedhead-Mounted Speakers Near Crosswalk

If the available pole is not close enough to the crosswalk location, pedhead-mounted speakers may be mounted to extend from the pole to provide the appropriate separation of sounds (see Figure 6-4). Provision of the "Walk" information at the proper crossing location, even when pushbutton and poles cannot be relocated, may provide some auditory guidance about the crosswalk location to a pedestrian who is blind. Because this type of installation may not provide the best location for tactile arrows and signs, the pushbutton, if used, should also provide a locator tone and tactile arrow.

In Figure 6-17, the speakers are positioned on the outside of the pedheads, which somewhat separates the sounds, although more separation is preferred. In these photos the speakers are aimed across the street. In most instances, the speakers may be aimed directly down for communicating the beginning of the "Walk" phase to the pedestrian who actuated the signal. When audible beaconing is needed, the speaker may be aimed toward the center of the street.

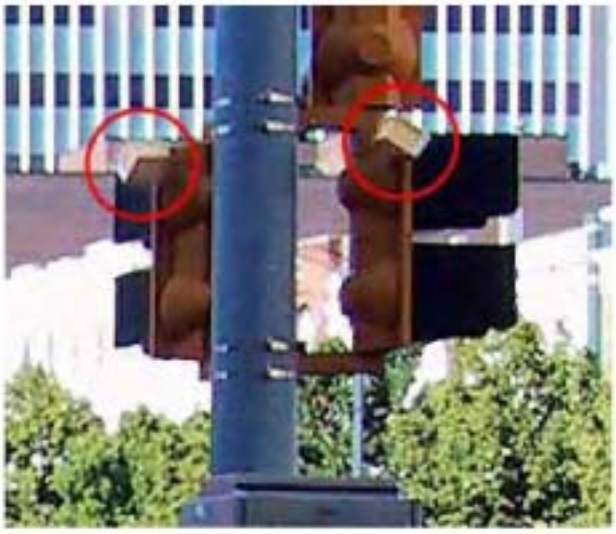

Figure 6-17. Two pedhead-mounted speakers, aimed at right angles to each other, are separated by the width of the pedheads and the mounting pole. More distance is preferred and careful aiming and volume control is important.

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Specifications

When ordering APS units from the manufacturer, practitioners will need to be specific about the features and settings they desire or require. The level of detail required by the manufacturer varies depending on the company.

Elements of a specification sheet should inform the manufacturer of the characteristics of the location where the APS will be installed, as well as which APS features will be required by the city or state. The following list contains suggested elements for a detailed specification sheet. APS units do not necessarily need to have all these features, but the practitioner should consider the appropriateness of all features and then specify which ones are required for the selected APS installation.

- Type of "Walk" indication required (tone or speech message).
- Text and name of street for speech "Walk" indication (if used).
- Requirement for "extended button press" function and specification as to what this function would need to do (e.g., provide pushbutton information message, provide louder "Walk" indication).
- Requirement for vibrotactile arrow.
- Requirement for pushbutton information message.
- Text for pushbutton information message (if used).
- Requirement for audible, visual, and/or tactile feedback of pushbutton activation.
- Orientation of tactile arrow for each unit.
- Text to be encoded into braille for imprinting on pushbutton or informational sign.
- Anticipated mounting (wood or metal pole).
- Required location of control unit (pedhead or cabinet).
- Required factory settings for
  - "Walk" indication volume (minimum and maximum and amount over ambient), and
  - Locator tone volume (minimum and maximum and amount over ambient).
- Electrical operating requirements (e.g., voltage).
- Wiring requirements (e.g., number of wires, gauge).
- Required operating temperature range.
- Requirement for built-in "Walk/Don't Walk" conflict detection.

AR0071902

- Warranty duration and coverage
- Follow-up support and assistance available from the manufacturer.

It is also useful to include an intersection diagram showing

- Crosswalks to be controlled,
- Pushbutton locations, and
- Speaker locations and angle (if pedhead-mounted speakers are desired).

Mounting and Wiring Issues

Location of Controller Boards and Wiring

Wiring

Pushbutton integrated devices generally require an extra set of wires to power the audible indications. Those APSs with actuation ind cators may need to receive an actual signal from the controller that the call has been accepted. If the conduit is not adequate for extra wiring, installation plans may require conduit and wiring replacement. However, some manufacturers now provide devices that can replace typical pushbuttons and require only two wires and an additional control unit in the controller cabinet.

Some APSs manufactured abroad initially required 110 V AC power, rather than DC power, to the pushbutton. Those manufacturers now supply APS models to the U.S. market that have been adapted to provide DC power to the pushbutton. It may be necessary to specify that devices meet U.S. requirements.

Traffic Signal Controllers

APS devices work with current controllers used in the United States. In installations made between 2000 and 2003, some controller conflicts were reported, mainly related to a change in voltage that leads to the malfunction management unit (MMU) override. These conflicts have been addressed by the manufacturers and seem to be resolved. In 2002, the Access Board funded a project to investigate problems, which found that many reported issues were due to incorrect installation or sound adjustment problems. The final project report is available on the Access Board website (www.access-board.gov).

AR0071903

Mounting APS Controller Boards

Some APSs have a control board that is completely contained within the device. Other APSs require a separate control board that is mounted in the pedhead (see Figure 6-18), while still others require a control unit mounted in the controller cabinet. The control board often includes voice or sound chips and switches to control volume, microphone response, and other features.

Figure 6-18. APS device with control board in pedhead (speaker opened for illustration).

Some types of pedheads do not have adequate space to mount APS control boards. For example, incandescent, 12-in. over/under pedheads may not have adequate space. These pedestrian signal heads can be replaced. Other options may include the following:

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- Manufacturers may be able to supply a separate case for the APS control board (see Figure 6-19).
- APS control boards may be mounted in the signal controller (Figure 6-20). However, the correct gauge wires must be calculated to drive the speakers when wiring is extended across the street/intersection. Included wiring is usually only adequate to drive the speakers when run from the pedhead.

Figure 6-19. External mount for controller board is visible on the left side of the pedestrian signal head.

Figure 6-20. Controller board mounted behind 18-in. pedestrian signal head.

If an area typically experiences high winds, it may be necessary to mount the APS speaker on a strong surface. Engineers in Nova Scotia found that speakers mounted on the plastic pedhead were prone to cracking during times of high wind. Their solution was to mount the speakers directly to the metal pole, as shown in Figure 6-21.

AR0071905

Figure 6-21. APS speaker mounted directly to the metal pole provides more support during high wind.

Vibrating Surfaces

Vibration-only devices are not recommended. However, pushbutton-integrated APS devices should have a vibrotactile arrow that vibrates during the walk interval. The vibrotactile arrow can be useful in confirming the audible "Walk" indication and providing "Walk" signal information to individuals with impaired hearing. Designers/engineers and installers must remember that the vibrating surface will be usable only if it is installed within the width of the crosswalk, or very near the crosswalk, and near the curb line. Pedestrians must be in an appropriate position to begin their crossing while waiting with their hand on the vibrating surface.

Orientation of Tactile Arrow

The tactile arrow must be oriented parallel to the direction of travel on the crosswalk controlled by the pushbutton. Arrows on several manufacturers' devices are positioned by the installer; however, with some devices, the direction of arrow must be specified when ordering the units (Figure 6-22). The pole location in relation to the crosswalk can affect the direction of the arrow.

AR0071906

Figure 6-22. The direction of the cast-in-place arrow on this device must be specified when ordering.

Wooden Poles

In areas where pushbuttons are installed on wooden poles (Figures 6-23 through 6-25), the wiring usually runs within a conduit on the outside of the pole. A mounting bracket is needed on some devices for wiring the pushbutton. This bracket needs to be ordered with the APS.

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Figure 6-23. When the APS is mounted on a wooden pole, an additional mounting bracket is installed to allow the wires to run from the conduit into the top of the pushbutton-integrated device.

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Figure 6-24. Typical installation without extra mounting plate, with wire running from inside the metal pole into the back of the device.

Figure 6-25. This APS is mounted on a wooden pole by drilling a hole through the pole and running wires through the back of the device.

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Pedestrians who are blind have expressed concerns about nails and staples that are common on wooden poles and that present a hazard when they are locating the button with their hands (see Figure 6-26). Innovative solutions include the use of a shield for the pole area near the pushbutton, as shown in Figure 6-27.

Figure 6-26. Wooden pole with nails and staples that are a source of concern.

Figure 6-27. Coated canvas shield used in Charlotte, NC.

Stub Poles

The use of stub poles for mounting pedestrian pushbuttons is common in some areas of the United States. They provide an opportunity to locate the pushbutton where it is most usable to pedestrians and may encourage pedestrians to more frequently use the pushbutton (see Figures 6-28 through 6-31).

AR0071910

Figure 6-28. A stub pole is used to locate the pushbutton beside the sidewalk.

Figure 6-29. Stub pole.

AR0071911

Figure 6-30. Stub pole installed near sidewalk signal box simplifies wiring and locates ped pushbutton by the crosswalk

Figure 6-31. Stub pole example.

Braille Labels and Signs

Before ordering APSs with braille labels on the faceplate, you must know

- The location of the pole, and

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- Which side of the pole the APS will be mounted on.

The direction of the faceplate and associated arrow is determined when the braille raised dots are added. The braille characters are generally just punched into the metal plate (see Figure 6-32).

Figure 6-32. Braille label is below the raised print street name.

APS Microphones and Speakers

As part of the automatic sound adjustment feature, some APSs require microphones be installed for monitoring ambient sound. By measuring the sound levels, the microphones can adjust the volume as necessary at the waiting location. If the microphone is mounted too far from the intersection, it will not adequately sample and adjust the volume levels, and the "Walk" indication will likely be too quiet for a pedestrian at the curb to hear above the sound of traffic.

Speakers for APSs may be pedhead-mounted or pushbutton-integrated. There are different issues to be considered, depending on the speaker location, though the majority of APS speakers are pushbutton integrated and the Draft PROWAG requires APSs to be integrated with pushbuttons. Figures 6-33 and 6-34 indicate the different locations of speakers.

Some manufacturers also provide the option of having a speaker at the pedhead in addition to a speaker at the pushbutton location. This may be particularly in focusing the audible beaconing signal.

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Pushbutton-Integrated Speakers

Sound Dispersion from Pushbutton-Integrated Speakers

Although the speaker is usually built into the pushbutton-integrated device, different devices have slightly different speaker locations, which can affect the volume settings and the mounting of the device.

If possible, particularly in a location with audible beaconing, the devices should have speakers oriented toward the street, as well as the sidewalk and pedestrian waiting location. Beaconing is unlikely to be successful when provided by a device without speaker openings on the curb side. The addition of a pedhead-mounted speaker may need to be considered in a situation requiring beaconing. Some manufacturers sell optional add-on speakers or baffles to control direction of sound, when needed.

Figure 6-33. Speaker grille on side of APS.

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Figure 6-34. Speaker grille on front and side of APS.

H-Frame for Pushbuttons

An H-frame is used for mounting pushbuttons in some northwestern states (see Figure 6-35), but not all APS devices work properly when mounted in this configuration. The type of device and the location of speaker components should be considered before ordering. The arrow of the APS is often part of the pushbutton and may not be oriented properly in the H-frame. In addition, the design of the frame makes it difficult to hear the sound of the locator tone from both the approach direction and the crossing direction.

Figure 6-35. Example of H-frame pushbutton.

It can be helpful for pedestrians who are blind to hear the locator tone as they complete their street crossings, as the "Walk" indication is seldom still sounding by that time. In this type of mounting, the pushbutton locator tone is not audible from the street because the speaker is aimed back toward the building line.

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If two pushbutton-integrated APSs in H-frames are mounted on a single pole, they will provide ambiguous "Walk" indications because the APS closest to each crosswalk will be indicating the perpendicular crosswalk, not the closest crosswalk.

Figure 6-36. H-frame APS mounted to pole.

The speaker for the locator tone in Figure 6-36 is oriented toward the building line, rather than toward the street (in the location shown in the photo, the "Walk" indication comes from an overhead speaker). One of the arrows points toward the pole and the other device, as well as toward the street, but it would be hard to use the arrow for direction when standing on the sidewalk side of the pole.

Illustrations of Ideal, Acceptable, and Unacceptable Locations of Pushbutton-Integrated Devices and Speakers

The drawings on the following pages illustrate proper and improper positioning of pushbutton-integrated devices and speakers (Figures 6-37 through 6-42). In the following captions, "retrofit" refers to the installation of APSs at existing intersections. A retrofit might involve some constraints on the installation process, such as the inability to have two separate poles on a single corner. It is assumed that the sidewalk beside the pushbutton is firm and level, as required by the Draft PROWAG.

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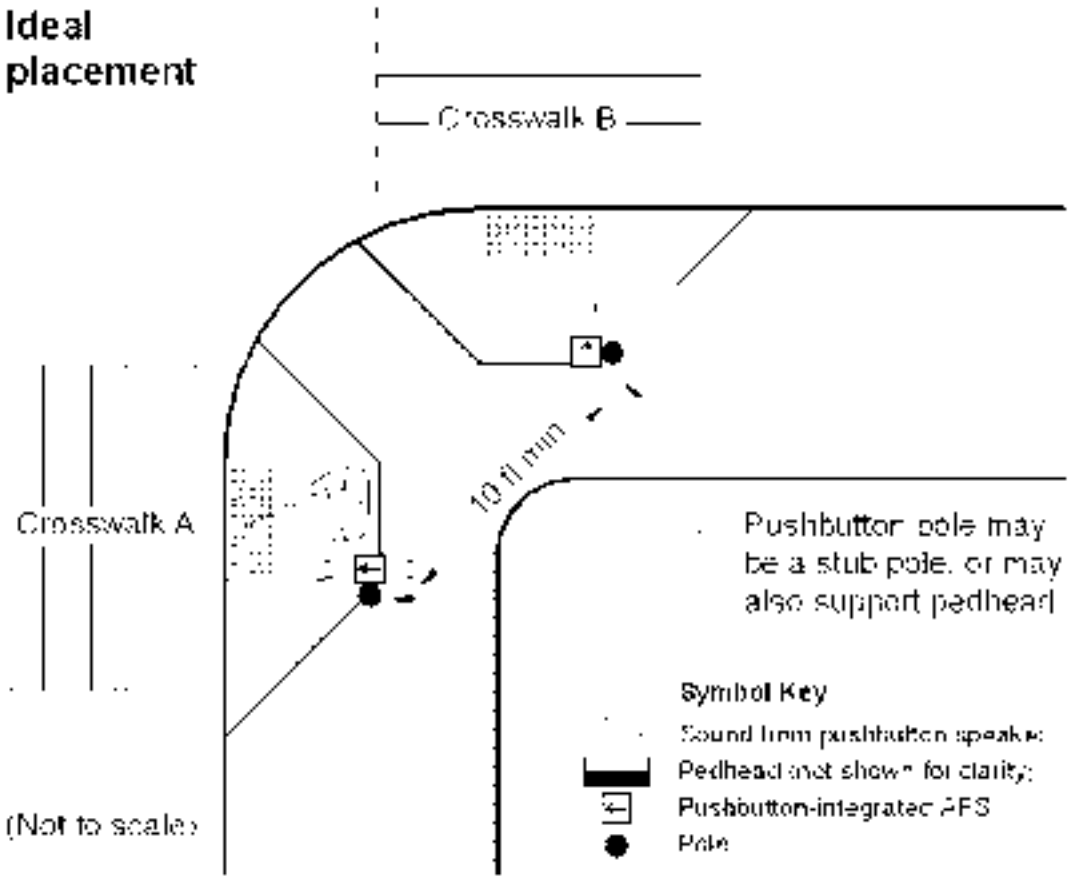

Figure 6-37. Ideal placement for pushbutton-integrated APS.

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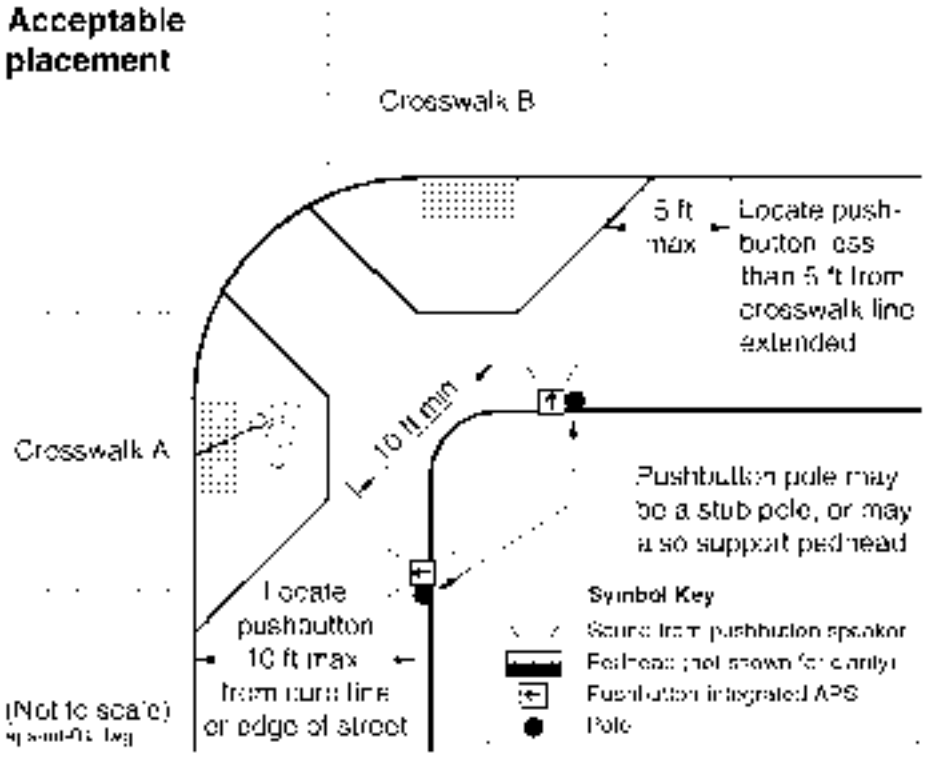

Figure 6-38. Acceptable placement for pushbutton-integrated APS.

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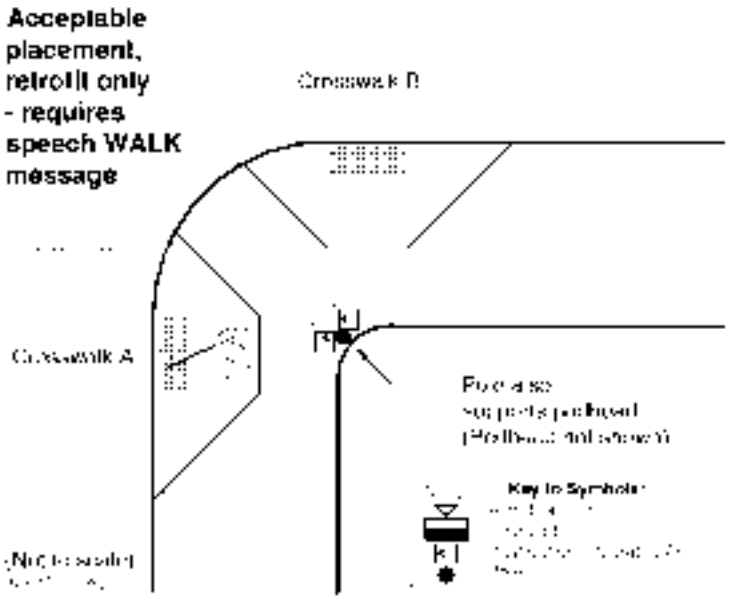

Figure 6-39. Acceptable placement for pushbutton-integrated APS. only when installing in a retrofit situation on an existing pole (if APSs cannot be separated, there will need to be a speech pushbutton information message and speech "Walk" message to prevent ambiguity).

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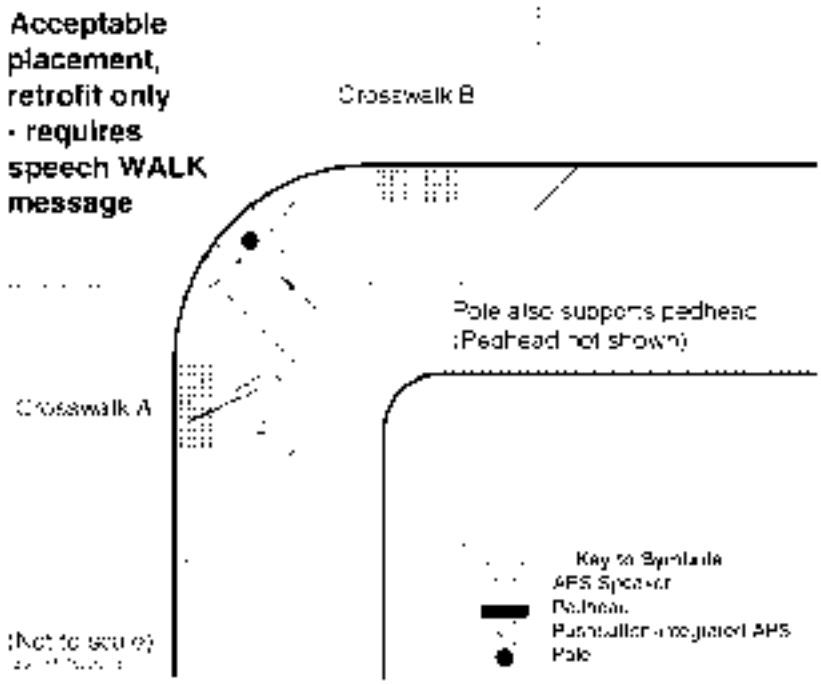

Figure 6-40. Acceptable placement for pushbutton-integrated APS, only when installing in a retrofit situation on an existing pole (if APSs cannot be separated, there will need to be a speech pushbutton information message and "Walk" message to prevent ambiguity).

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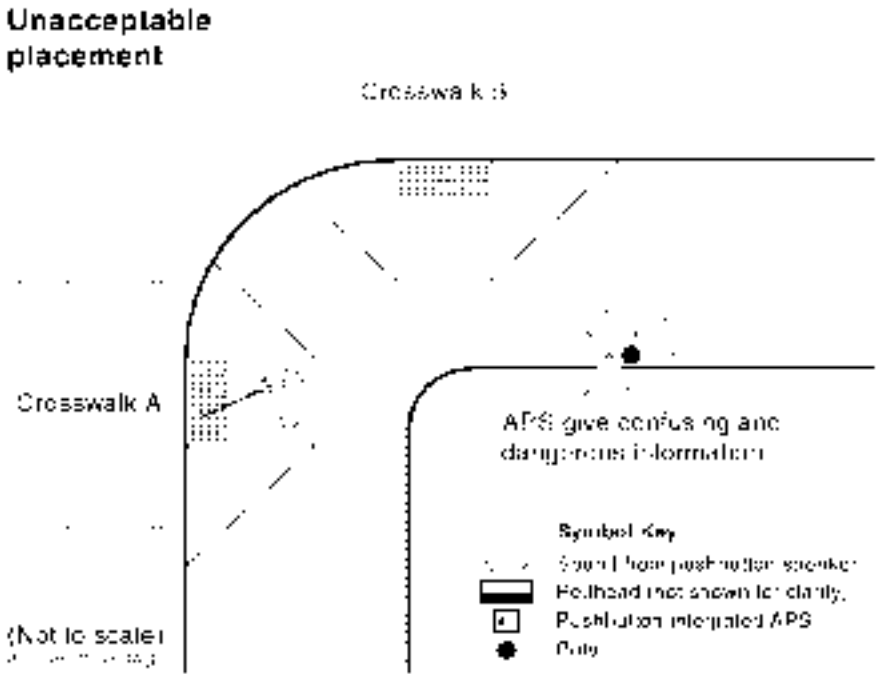

Figure 6-41. Unacceptable placement of APS speakers (the positioning provides ambiguous information).

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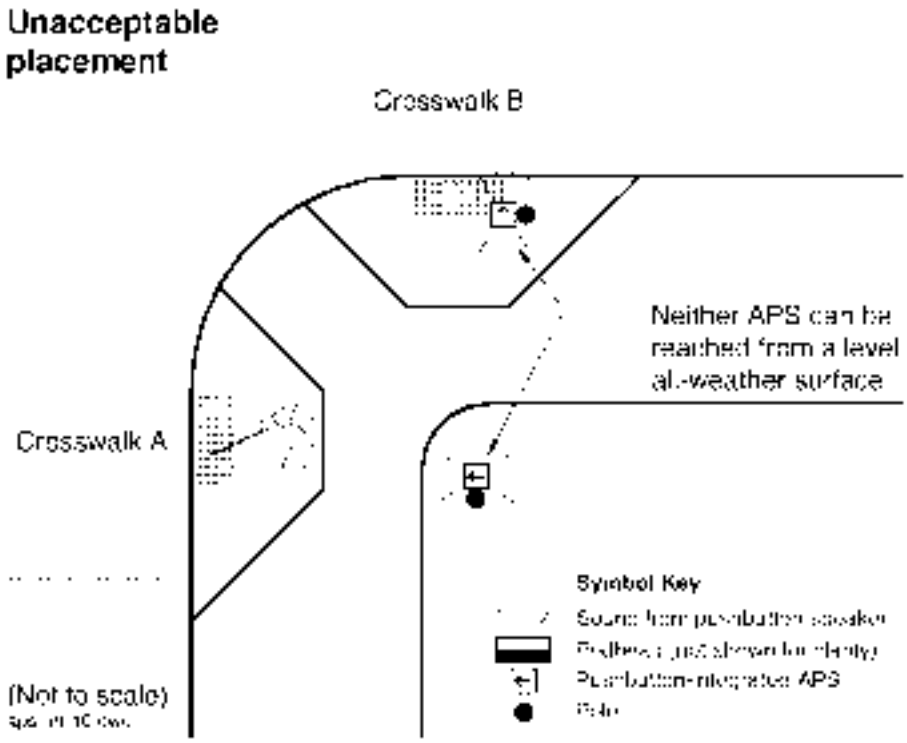

Figure 6-42. Unacceptable placement for pushbuttons and tactile arrows of an APS (not reachable from level all-weather surface).

Pedhead-Mounted Speakers

Sound from Pedhead Mounted Speakers

The sound from pedhead-mounted speakers is not very useful for providing guidance about the location of the opposite curb. Unless audible beaconing is required, speakers should be aimed down, toward the pedestrian waiting location (see Figure 6-43).

Speakers may be aimed toward the center of the street at crosswalks where beaconing is needed. With pedhead-mounted speakers, some will travel farther the more nearly horizontal the radiation pattern of the speaker is.

- Where beaconing is not needed, speakers should be pointed down toward the location of pedestrians waiting to cross the associated crosswalk, which will also minimize noise in neighborhoods.

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- Where beaconing is needed, the speaker must be pointed toward the middle of the associated crosswalk (centerline of the road). A side effect of this design is that the APS will produce more noise in the neighborhood.

Figure 6-43. This photo shows a view from below of a speaker attached to the pedhead support and aimed straight down.

Speaker Location

While the direction of the speaker does make a difference, overhead speakers attached to pedheads commonly provide ambiguous information. Figure 6-44 illustrates such a speaker and pedhead placement. In both cases, the mounting is problematic because the speakers are mounted on a pedhead that is not over the departure location of the crosswalk they signal.

AR0071923

Figure 6-44. The pedhead and APS speaker for the north-south crosswalk is located over the pushbutton for the east-west crosswalk.

The speaker in Figure 6-44 is located on the side of the pedhead and sounds for the north-south crosswalk. It is situated directly over the waiting area to cross to the east and some distance from the north-south departure point. This configuration can be very confusing to pedestrians who are blind.

Acceptable and Unacceptable Locations of Pedhead-Mounted Speakers

The drawings on the following pages illustrate proper and improper positioning of pedhead-mounted devices and speakers (Figures 6-45 through 6-51).

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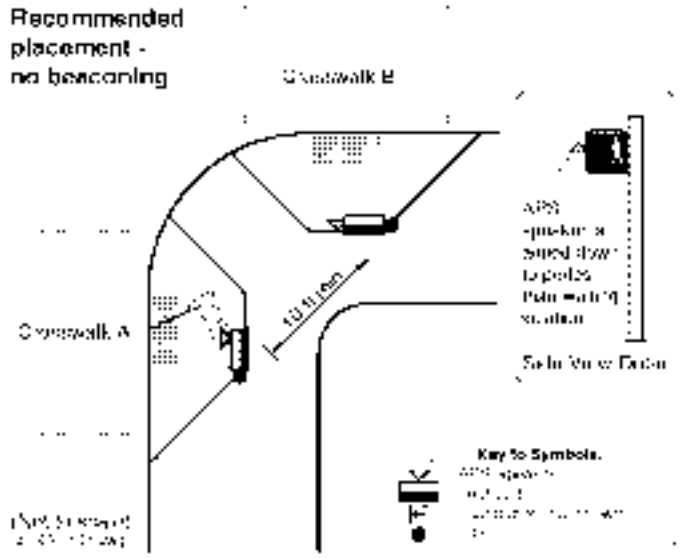

Figure 6-45. Possible placement for APS speakers mounted on the pedestrian signal head at pretimed signals: no beaconing.

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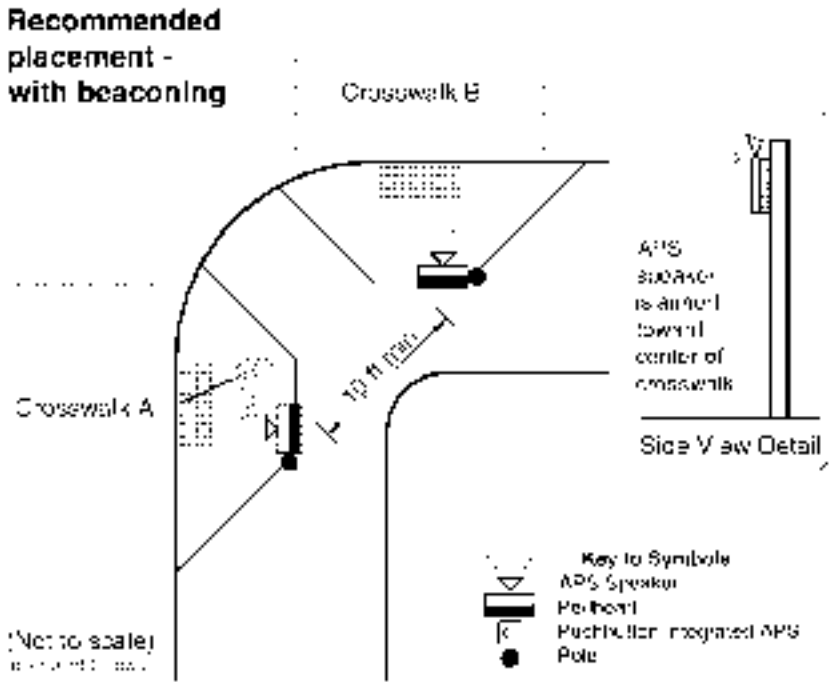

Figure 6-46. Recommended placement for pedhead-mounted speakers where beaconing is needed.

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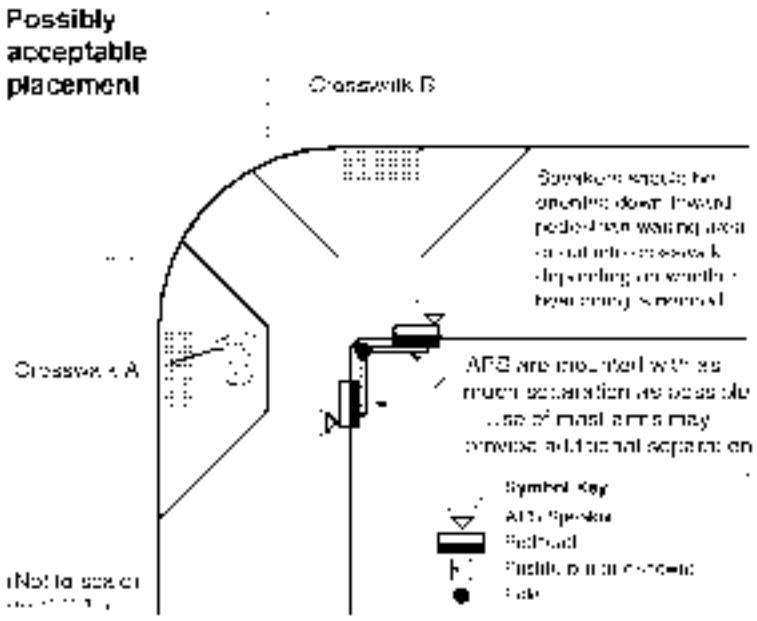

Figure 6-47. Possibly acceptable placement for pedhead-mounted APS on the outside of the pedheads. Provide as much separation as possible.

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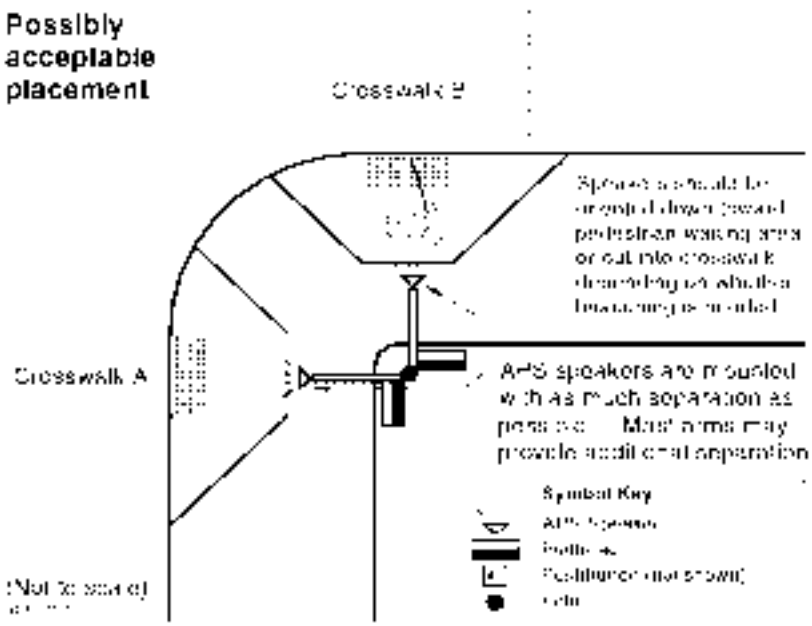

Figure 6-48. Possibly acceptable placement for pedhead-mounted APS using mast arms to provide additional separation.

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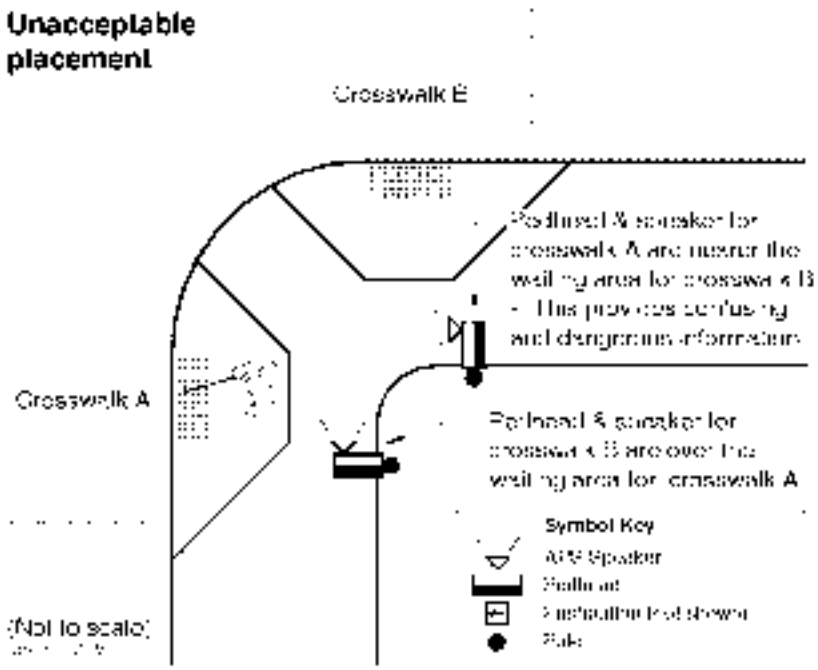

Figure 6-49. Unacceptable placement for pedhead-mounted speakers, regardless of how speakers are aimed.

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Unacceptable placement

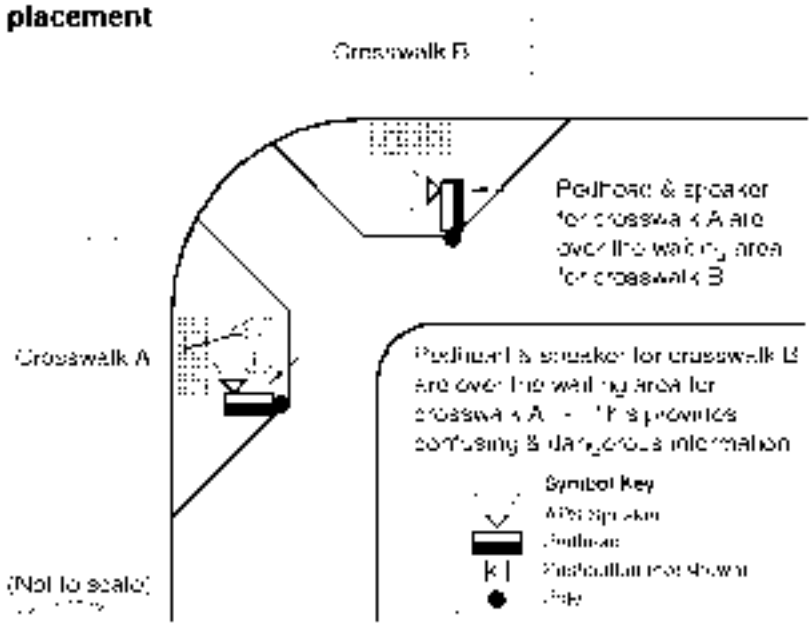

Figure 6-50. These APS speaker placements are unacceptable, regardless of how speakers are aimed.

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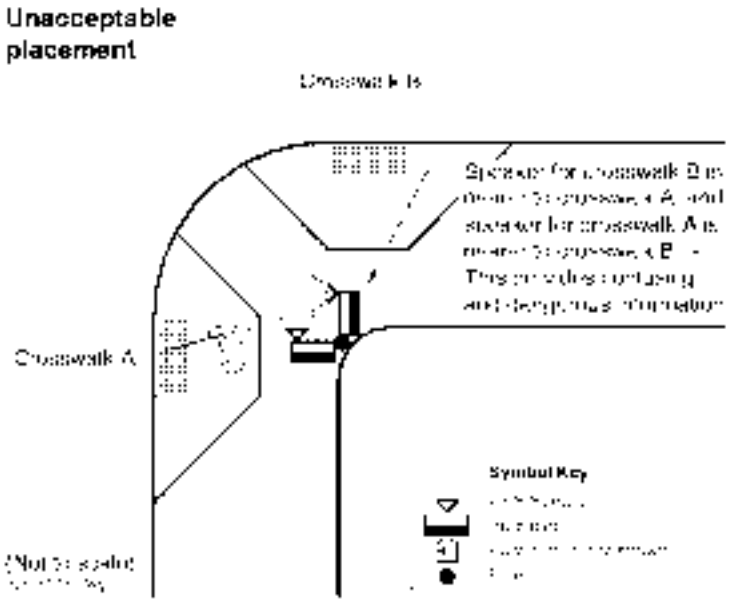

Figure 6-51. These APS placements are unacceptable, regardless of how speakers are aimed.

Summary of Recommended Features and Installation Practice

APS Installation in New Construction

Recommended Features

- Rapid tick "Walk" indication, no more than 3 to 5 dBA above ambient sound
- Vibrotactile "Walk" indication.
- Speaker and vibrotactile indication located at pushbutton.
- Pushbutton locator tone.
- Tactile arrow on each device aligned in direction of travel on the crosswalk.
- Braille or audible street name.

Recommended Installation

- Precise location of the APS is very important to prevent ambiguity about which crosswalk is being signaled.

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- APS should be reachable from the level landing of the curb ramp for the crossing or from a level surface with an accessible path to the ramp (Draft PROWAG).
- APS should be within 5 ft of the extension of the crosswalk lines and within 10 ft of the curb (MUTCD).
- Tactile arrow should be aligned with the direction of travel on the crosswalk.
- Face of the device toward the intersection (APS should be located on the intersection side of the pole).
- APSs on the same corner should be a minimum of 3 m (10 ft) apart.
- Pushbutton should be located within reach range of wheelchair users.

APS Installation at Existing Locations (Not New Construction)

New construction guidelines should be met to the maximum extent feasible.

- Pushbutton-integrated APSs must be located close to the crosswalk (see section in this chapter on optimal APS locations).
- If it is not possible to mount two APSs a minimum of 10 ft apart on the same corner, an APS providing a speech message during the walk interval, as well as a pushbutton message, is recommended.
- If a pedhead-mounted APS speaker is used, it must be above the waiting location of the crosswalk being signaled (see section on pedhead-mounted speakers in this chapter).

Configuration-Specific Recommendations

Below are listed some specific situations in which there are installation recommendations in addition to the ones listed above for new construction and existing construction. The recommendations listed for each situation below are only the areas where they *differ* from the general recommendations listed above. Unless otherwise specified, all other above recommendations apply to each situation.

APS Installations Where Beaconing Is Needed

APSs at intersections where beaconing is needed should have certain features, whether they are used in connection with pretimed or actuated signals.

- Loud locator tone during the flashing "Don't Walk" of the subsequent pedestrian phase only, in response to an extended button press, from speakers at the pushbutton or pedestrian signal

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head. If mounted high, speakers should be aimed diagonally down and out into the center of crosswalk indicated by that APS. If possible, beaconing sound should come from the far-side speaker only (this requires special equipment and wiring).

- Sound should be increased *only* over the requested crosswalk.
- Location of all speaker components of the APS within the width of the crosswalk is essential, as users will direct their travel toward the source of the sound (see Figures 6-46 through 6-51 for examples).

APS at Pretimed Intersections Where Beaconing Is Not Needed (Not New Construction)

If a pushbutton-integrated APS cannot be located at the pedestrian waiting area, pedestal-mounted APSs (which do not provide vibrotactile indications) must be above the waiting location of the crosswalk being signaled and should be aimed down toward the waiting location.

APS at Corners Where Two Pushbuttons Must Be Mounted on the Same Pole (Not New Construction)

If two pushbuttons must be mounted on the same existing pole (see Figure 6-52), then

- A speech "Walk" indication should be 2 to 5 dBA above ambient sound.
- A pushbutton-generated information message should provide intersection and crosswalk identification information, and
- Speech messages should follow the recommendations for wording, and the APS should be positioned within 10 ft of the curb (see Figures 6-39 through 6-41 and Figures 6-47 and 6-48).

AR0071933

Figure 6-52. Example of pushbutton information messages and speech "Walk" messages for two APSs located on the same pole.

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CHAPTER 7

Installation, Operation, and Maintenance

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Lessons Learned from APS Installations 26

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This chapter provides guidance for signal technicians who will work directly on the installation of the APS units. In many places, this chapter refers to illustrations in Chapter 6, so readers should have access to both chapters. Lessons learned from project research are included.

Review of Design Guidance

Current Guidance

Section 4E.06 of the MUTCD recommends the following:

> The installation of accessible pedestrian signals at signalized intersections should be based on an engineering study, which should consider the following factors:
>
> - Potential demand for accessible pedestrian signals.
> - A request for accessible pedestrian signals.
> - Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes.
> - The complexity of traffic signal phasing.
> - The complexity of intersection geometry. (2)

The Draft PROWAG requires audible and vibrotactile indications of the walk interval when new pedestrian signals are installed (see Chapter 5).

Principles

When installing an APS, there are several guiding principles that should be kept in mind. The APS installation should:

- Provide pedestrian signal information to those who cannot see the pedestrian signal head across the street.
- Provide information to pedestrians about the presence and location of pushbuttons, if pressing a button is required to actuate pedestrian timing.
- Provide unambiguous information about the "Walk" indication, as well as which crossing is being signaled.
- Use audible beaconing only where necessary; and

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- Put as little additional sound into the environment as possible to avoid disturbing neighbors and to allow pedestrians who are blind or visually impaired to hear the traffic sounds, as well as the APS.

New Construction—Ideal Installation

Providing audible and vibrotactile indications of the walk interval, as specified in the Draft PROWAG, means that devices should be integrated into a pushbutton unit in order to provide vibrotactile "Walk" indications. The vibrotactile feature is usually a tactile arrow incorporated into the pushbutton device.

The ideal location for a pushbutton-integrated APS is between the edge of the crosswalk line (extended onto the sidewalk) farthest from the corner of the intersection and the side of the curb ramp. If at all possible, the APS should be between 1.5 ft and 6 ft from the edge of the curb, shoulder, or pavement. To allow wheelchair access to the pushbutton, the pushbutton must also be located adjacent to a level all-weather surface. The control face and tactile arrow should be carefully aligned with the direction of travel on the associated crosswalk.

At corners of signalized locations where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 10 ft (see Figure 7-1). A rapid tick "Walk" indication is recommended for installations that follow these location guidelines.

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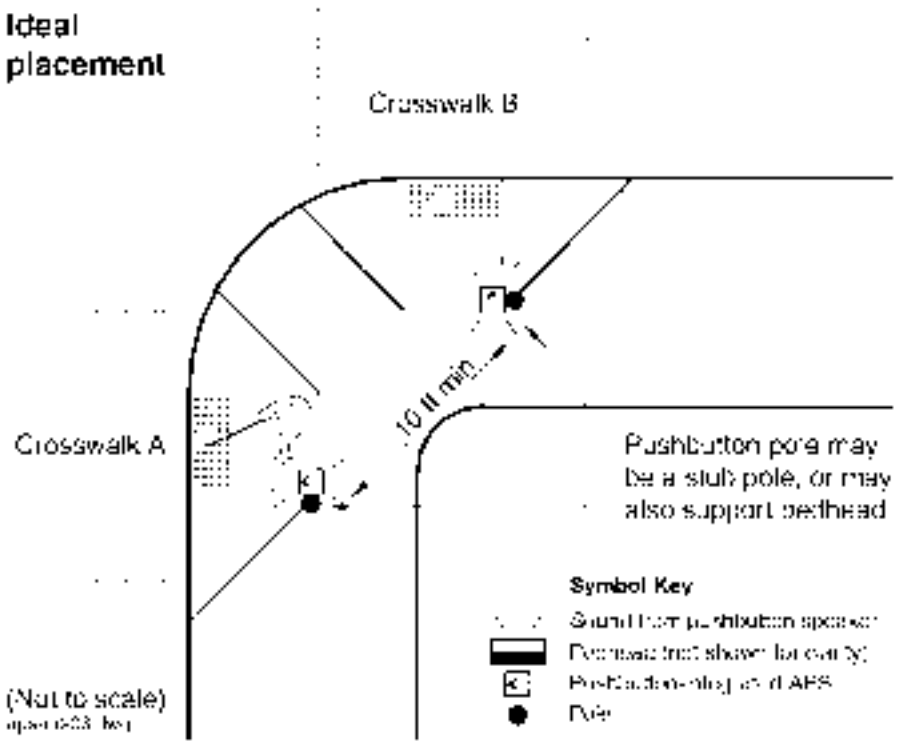

Figure 7-1. Ideal placement for pushbutton-integrated APS in the top corner of the flare of the curb ramp, next to the level landing.

Retrofit Installation—Constraints and Acceptable Solutions

Many APS installations will be a retrofit situation (i.e., they are being installed at an existing signalized intersection that is not being completely reconstructed). There will likely be infrastructure constraints that will make an ideal installation difficult.

If there are no poles at the recommended location, the following options should be considered, in order of decreasing desirability from the standpoint of ambiguity:

- Reposition the pedestrian signals and poles or add a stub pole(s) and associated conduit and wiring.
- Install two APSs on a single pole with speech messages for the "Walk" indication, and provide the additional features that are required with speech messages.
- Use pedhead-mounted speakers, possibly with mast arms or another provision, to locate the "Walk" indication speakers as near to the associated crosswalk as possible.

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Installation

Wiring

Wiring needs and availability should be considered before ordering devices because some devices and features require additional wires between the pedestrian signal head, the pushbutton, and the controller. APSs typically require an additional control board in the pedestrian signal head or in the controller cabinet.

The manufacturer's instructions should be reviewed, as wiring may be more complex than expected due to additional features such as the vibrotactile "Walk" indication (vibrating surface) and additional messages or tones. Other potential wiring issues are as follows:

- Additional wire may be needed, beyond what is provided with the APS.
- Wire types may range from phone-type wire to standard wire.
- APSs that require four wires may need to have extra wiring installed at the pushbutton poles.
- Some manufacturers provide a two-wire APS model that uses the existing wiring from previously installed standard pushbuttons. For those installations, a control unit is installed in the controller cabinet. Wiring of this device requires correct connection of wires from pedestrian signal heads, particularly where two parallel crosswalks do not operate concurrently to provide accurate messages. In addition, replacing standard pushbuttons with APSs may not be as easy as it appears. New holes will have to be drilled so that the APS will be mounted in a correct position, if the previous pushbutton was not positioned correctly (e.g., the previous pushbutton was angled toward the center of the intersection instead of parallel to crosswalk).
- APSs that provide audible beaconing from the far side only (opposite end of crosswalk from where the button was pressed) may require additional wiring to provide proper signals between the pedestrian signal and the beacon controller.

APS Control Units

As mentioned above, APSs often have control units that must be installed in the pedhead or in the traffic signal controller. An example of a control board being installed in the pedhead is shown in Figure 7-2. As can be seen in the photo, the technician found a hinged cord to be helpful in holding the pedhead lens while he was installing and adjusting the APS control unit. (Additional photos and information on control units can be found in Chapter 6.)

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Figure 7-2. Technician installing APS control board in pedhead.

Traffic Signal Controllers

As stated earlier, APS devices work with current controllers used in the United States. While malfunction management unit (MMU) problems seem to have been solved by manufacturers, functioning of the intersection and devices should be carefully checked after installation.

Pushbuttons, Tactile Arrows, Vibrating Surfaces, and Signs

Height of Pushbuttons

The pushbutton must be within accessible reach range of a level landing to allow it to be used by someone in a wheelchair (see Figures 7-3 and 7-4). The MUTCD specifies 42 in. for the mounting height, which is well within the reach ranges specified by the Draft PROWAG.

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Figure 7-3. This pushbutton may be 42 in. from the bottom of the pole, but it is almost 60 in. above the landing, making it inaccessible to a wheelchair user and not likely to be located by a person who is blind.

Figure 7-4. Not only is the pushbutton in the bushes and out of reach range from the sidewalk, but construction barriers have been stored against the pole, preventing all pedestrians from reaching the pushbuttons.

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The Draft PROWAG (2. R306.2.2) requires APS pushbuttons to be installed within specified reach ranges of the curb ramp landing or of a level surface with an accessible path to the curb ramp. A level surface is defined as a surface with less than 2% slope in any direction. This allows a person on a wheelchair to push the button without having to hold the wheelchair steady on a slope.

Reach ranges in ADA guidelines are described as forward reach or side reach and unobstructed or obstructed. Forward or side reach refers to the position in relation to a level surface and whether the pushbutton can be approached directly (forward) or must be approached from the side. Obstructed or unobstructed describes whether the wheelchair can be pulled immediately next to the pushbutton mounting surface or whether the user has to reach over an obstruction, such as a wall, pole base, or an uneven or tilt surface, to access the pushbutton from a wheelchair.

Reach depths (distance from level surface) are specified at 25 in. maximum for forward reach and 24 in. maximum for side reach. For unobstructed forward or side reach, the Draft PROWAG allows the pushbutton to be mounted between 15 in. and 48 in. above the level surface. Obstructed high reach varies depending on the depth of the obstacle, but ranges from 42 to 46 in.

Locations that are "convenient" to the installer may not be usable by all pedestrians.

Vibrating Surfaces

Vibrotactile "Walk" indication should be provided during the associated walk interval by each APS equipped with a vibrating surface. The vibrating surface feature will be usable only if it is installed within the width of the crosswalk, or very near the crosswalk, and near the curb line. Pedestrians must be able to wait to cross while keeping a hand on the vibrating surface.

When two APS pushbuttons with vibrotactile indications are installed on the same pole, they may require insulation and a rubber gasket to prevent the user from feeling vibrations generated from the other pushbutton.

Shape and Type of Mounting Pole

Municipalities in the United States use a great variety of poles for mounting pedheads and pushbuttons. When the tactile arrow is part of the pushbutton and located on the face of the pushbutton integrated device, the orientation of the device on the pole determines whether the tactile arrow is aligned with the crosswalk. A new mounting hole may need to be drilled for the

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pushbutton in order to be sure the arrow points in the correct direction. A person who is blind may attempt to determine their heading for crossing based on the arrow. The arrow should thus point toward the destination corner.

Figure 7-5. Well-located APS on a square pole.

Most pushbutton-integrated devices are designed to be installed on round poles. Poles that are not round may require a special mounting bracket or shim to orient the arrow correctly (see Figures 7-5 and 7-6).

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Figure 7-6. A mounting bracket or shim is needed on this square pole to properly orient the arrow . Without it, the arrow points to the center of the intersection.

Location and Orientation of Tactile Arrows

Before devices are ordered, the pushbutton and tactile arrow (vibrating surface) location should be determined and specified. Any adjustment from the intended design must be carefully considered. If poles are located too far away from the center of the intersection, outside the extension of the crosswalk lines, a pedestrian who is blind may attempt to cross at a location that is not within the crosswalk area. (An example of a poorly placed pole is shown in Figure 6-14 in Chapter 6.)

Pushbuttons should be within reach from a level landing, within 5 ft of the crosswalk lines extended and within 10 ft of the curb. Specifications on pushbutton location are provided in Chapter 6.

The tactile arrow must be oriented parallel to the direction of travel on the crosswalk controlled by the pushbutton. It may be helpful to stand behind the unit and look across the street to check the orientation before and after installation. The arrow should point to a location within the crosswalk along the opposite curb. Arrows on several manufacturers' devices can be turned or repositioned by the installer. However, with other devices the direction of the arrow must be specified when ordering the unit. Pole location in relation to the crosswalk can affect the arrow direction.

Where speech messages are used for the "Walk" indication or where there is a pushbutton information message, the installer should check that arrow direction and speech messages agree.

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APSs have accidentally been installed with the message providing notification about the wrong street.

Figure 7-7. A misaligned APS, with the arrow pointing into the bushes.

The fluted pole in Figure 7-7 made correct alignment more difficult. The installer said he had to orient it that way because he did not have any shims. The specifications given to the manufacturer for this unit should have included shims to allow for the necessary angle adjustment.

Wooden Poles

In areas where pushbuttons are installed on wooden poles, the wiring usually runs in a conduit on the outside of the pole. A mounting bracket, which must be ordered with the APS, is needed on some devices for wiring the pushbutton. Other options are discussed in Chapter 6, in the section on mounting and wiring issues.

Braille Labels and Signs

The direction of the face plate and associated arrow is determined when the raised dots of braille characters are added. Braille characters are generally punched into the metal plate. Printed street names may not be provided on the APS, since printed street signs may already be available at the intersection. Typically, the faceplate can be flipped to show a right arrow or a left arrow, and the manufacturer includes a printed label on the faceplate that translates the braille characters

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for installers, so that they can install the sign at the appropriate location. The printed label should be installed on the inside of the faceplate (facing the pole), not on the outside (see Figure 7-8). If the braille sign has been installed correctly, the braille dots will be raised to the touch. An example of an incorrect installation is shown in Figure 7-8.

Figure 7-8. The faceplate at this location was mounted backwards, with the braille characters indented rather than raised and the small paper label, intended for translating the braille for the installers, is on the outside rather than the inside.

APS Microphones and Speakers

Microphone Location

Some APSs require microphones be installed to monitor ambient sound as part of the automatic sound adjustment feature. The microphones measure the sound levels to adjust the volume at the waiting location, and they are usually mounted in the pedhead or are part of the pushbutton unit. If the microphone is mounted too far from the intersection, it will not adequately sample and adjust the volume levels, which will result in a "Walk" indication that is too quiet for a pedestrian to hear above the sound of traffic.

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APS Speakers

The speakers for an APS may be mounted on the pedhead or located in the pushbutton unit. There are different issues to be considered, depending on the speaker location. If possible, APS devices should have speakers oriented toward the street, as well as the sidewalk and pedestrian waiting location. In locations with audible beaconing, a speaker oriented toward the middle of the crosswalk is needed. The addition of a pedhead mounted speaker may need to be considered in that situation. some manufacturers sell optional add on speakers. One manufacturer provides baffles to better control the direction of sound.

An H-frame is used for mounting pushbuttons in some northwestern states. The design of the frame makes it difficult to hear the sound of the locator tone from both the approach direction and the crossing direction.

Sound from Pedhead-Mounted Speakers

Unless audible beaconing is needed, speakers should be aimed down toward the pedestrian waiting location. Speakers may be aimed toward the center of the street at crosswalks where audible beaconing is needed. For pedhead-mounted speakers, sound will travel farther the more nearly horizontal the radiation pattern of the speaker

Installation of Speakers and Microphones

Confirming Speaker Location and Orientation

Speaker location and orientation should be checked against the specifications. Installers should make no change in speaker location or orientation without checking with the responsible signal engineer. Poorly located speakers can result in

- Ambiguous information about which crosswalk has the walk interval,
- Failure of blind pedestrians to begin or end crossings within the crosswalk, and
- Veering of blind pedestrians outside the crosswalk, possibly into conflicting traffic.

For more information on the effects of speaker location and orientation, see Chapter 6

Speaker Location

Incorrect speaker location can make a difference in the ability of pedestrians who are visually impaired or blind to discern which APS is sounding

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- Each APS speaker at a corner must always be closest to the crosswalk it signals
- For pedhead mounted APSs, speakers should not be automatically located on the pedhead that signals the same crosswalk. The pedhead closest to one crosswalk may signal the perpendicular crosswalk. In this case, speakers must be mounted on the pedhead for the perpendicular crosswalk.

Speaker Orientation

The speakers should be adjusted so the pushbutton locator tone can be heard by a pedestrian approaching the corner from both the sidewalk side and the street. However, it is most critical that the "Walk" indication be heard at the beginning of the crosswalk.

Precise orientation of the APS speaker is especially critical at locations with audible beaconing. If a speaker or transmitter is oriented even a few degrees out of alignment with the associated crosswalk, pedestrians may inadvertently travel out of the crosswalk, perhaps into the path of vehicular traffic.

Pedhead mounted speakers in existing installations are often mounted in positions that make the messages more ambiguous. See more information on correct mounting of pedhead speakers in Chapter 6 in "APS Microphones and Speakers."

For pushbutton integrated devices, the speaker is in the pushbutton housing. Location of the pushbutton and orientation of the speaker can be critical to hearing the "Walk" indication at the crosswalk. If the speaker is located too far from the crosswalk location, pedestrians who are blind may not hear the "Walk" indication.

Adjustments

Introduction

Devices should be carefully adjusted in the field and evaluated after installation to be sure they are working properly from an engineering perspective and from the perspective of pedestrians who are visually impaired.

- If the APS has been added in response to a request from a pedestrian who is blind or visually impaired, that individual should also be involved in the post-installation evaluation.
- Because installers may be unfamiliar with new types of APS devices, extra attention and supervision will be required during the first few installations by any crew or contractor

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- Even when carefully specified, installations sometimes do not match the specifications because installers do not understand that failure to exactly follow specifications may lead to an installation that cannot be accessed by pedestrians who use wheelchairs or that could cause a pedestrian who is blind to push the wrong pushbutton, veer from the crosswalk, or mistake which crosswalk has the walk interval and start crossing at an unsafe time.

The sound level of the speakers must be carefully set and evaluated at the time of installation and then checked when traffic volumes are different to ensure that the settings are correct. It is better to install an APS with volumes that may be too low and adjust upwards as needed. If volumes are set too high initially, problems can arise with neighboring residents and businesses that could lead to the removal of the APS and difficulties for future installations.

Setting and Evaluating Sound Levels

How to Adjust APS Sound Levels

The controls for adjusting the settings of the APS vary among the different manufacturers. The settings may be adjusted by

- Screws on a control board, which may be mounted in the pedhead or in the APS speaker unit, or
- A remote handheld device, using infrared communication, which must be used in close range to the APS (Figure 7-9).

Figure 7-9. Resetting APS settings with handheld device supplied by manufacturer.

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Settings

Most devices require the following controls be set:

- Microphone sensitivity or automatic gain control (AGC) sensitivity.
- Volume of the pushbutton locator tone.
- Volume of the "Walk" indication.

The microphone sensitivity or AGC controls how the other tone/message volumes respond to ambient noise levels. The setting must be adjusted by the installer to provide output at one of a number of ranges between the maximum and minimum. The number and width of ranges varies by manufacturer.

How Loud Should the Sound Be?

In general, installers have a tendency to set volume levels too loud. Loud overhead audible signals have caused problems for neighbors of APS installations. In addition, the loud sound of the signal may prevent pedestrians who are visually impaired from:

- Hearing critical traffic sounds used for alignment.
- Determining that cars have stopped.
- Hearing cars that may be turning across their path, and
- Localizing on the signal source.

Installers should set volume levels according to the following guidance:

- The "Walk" indication must be audible from the beginning of the associated crosswalk (Z. 4E.06 Standard).
- The MUTCD states that the locator tone and the "Walk" tone of an APS should be at the same volume (except by special actuation, providing a louder tone for a single pedestrian phase) and specifies that the locator tone should be audible 6 to 12 ft from the pushbutton or to the building line, whichever is less (Z. 14E.06 and 4E.09 Guidance).
- Manufacturers typically set a default maximum and minimum output level on APS devices. The settings should be checked to ensure that the device is set for 30 dB minimum and 80 dB maximum.

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- At no time should the sound be more than 5 dB above ambient sound (except by special actuation for audible beaconing). The sound level should be between 2 and 5 dBA above ambient sound (*cf.* 4E.06 and 4E.09 Guidance: and 2. 2.5.2.2 Gt.

Volume Level Considerations

The correct setting will vary depending on whether there are buildings close to the APS and whether there is split phasing or slip lanes.

- When buildings are close to the APS, the sound reflected from the buildings will make the sound seem louder. The reflected sound may also influence the microphone and AGC such that the APS will sound louder than if the APS, at the same setting, was in an open area.
- At intersections having split phasing, APSs at parallel crosswalks must not be audible across the street (at the other parallel crosswalk), else users may begin crossing with the wrong "Walk" signal. Check this at times of low ambient sound, as well as at times with normal sound. In Figure 7-10, the APS giving the "Walk" indication on corner B should not be heard by someone standing on corner A.
- APSs at intersections having channelized turn lanes must not be audible from the corners of the intersection. If an APS on the splitter island is too loud, pedestrians who are blind may believe the turn lane is signalized or that the intersection crosswalk extends all the way to the corner. If the volume is too loud, pedestrians might assume that they have a "Walk" indication to begin crossing, when, in fact, they may be entering an uncontrolled slip lane, yield or stop sign controlled slip lane, or a separately signalized turn lane. In Figure 7-11, a pedestrian standing on the corner at location A should not be able to easily hear an APS located on the splitter island.

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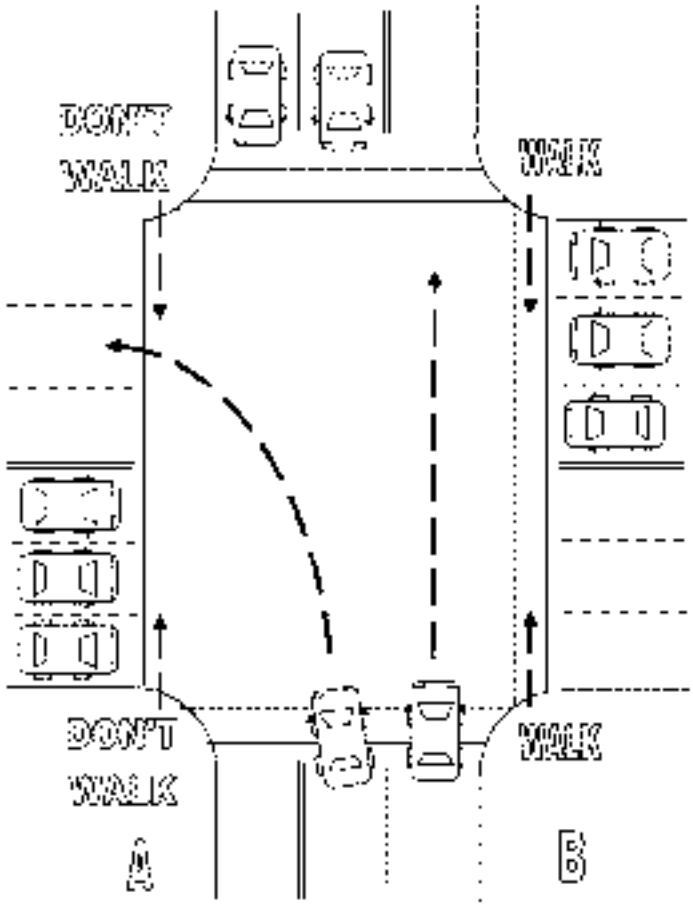

Figure 7-10. Illustration of pedestrian signals at an intersection with split phasing.

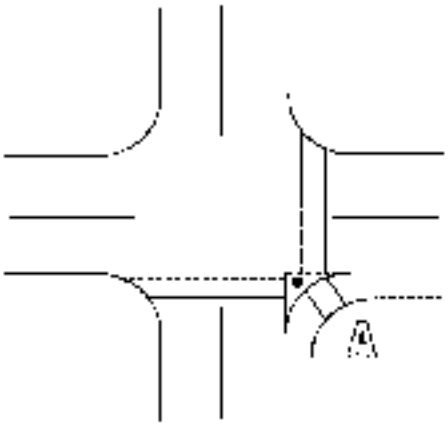

Figure 7-11. Channelized turn lane illustration.

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Automatic Volume Adjustment

Preset automatic volume adjustment or automatic gain controls cannot ensure that the volume meets the criterion for distance at which the APS should be audible. Similar automatic volume adjustment settings on APS devices by different manufacturers may seem to provide quite different levels of loudness, as judged by listeners.

- Automatic volume adjustment technology used by different manufacturers varies in the rate of sampling of ambient sound and in the speed with which output adjusts to changes in ambient sound
- Some APS devices and some installations will be more subject to responding to their own noise than others. For example, as the "Walk" signal continues throughout the walk interval, the signal may get louder and louder in response to its own noise.
- Different tones or speech will seem louder or quieter depending on their frequency content, although they may measure the same on the dBA scale.

Measuring the Sound Level

Due to the short duration of the pushbutton locator tone and "Walk" tone pulses, conventional analog or digital sound level meters are not able, in the crosswalk environment, to accurately measure the absolute sound level (dBA) of APS tones or the sound level of APS tones relative to ambient sound.

At present, setting and evaluating APS sound level is typically done by ear. There can be errors in making the sound too quiet or too loud. It is critical that the "Walk" indication be loud enough to be audible at the crosswalk waiting location. Both the locator tone and "Walk" indication should be audible within 10 to 12 ft of the device, but not beyond that distance. It has been the authors' experience that many APS installations have been set louder than was optimal either for blind pedestrians or nearby neighbors.

Measuring Sound Where Audible Beaconing Is Needed

At crosswalks where audible beaconing is needed, the sound level should be evaluated from the middle of the street, when the loud "Walk" indication has been called, to be sure beaconing will be provided throughout the crossing. However, current MUTCD language limits the maximum output of an APS to 89 dB, and most manufacturers preset this maximum. Therefore, at exceptionally wide crossings, and when and where there is high ambient sound, there may be a

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point in the middle of the crosswalk where the beaconing is not readily heard. Changes to the MUTCD limits have been recommended by NCUTCD and may be incorporated into the 2009 edition.

Microphone Location and Effect on Perceived Loudness

APS devices that respond to ambient sound have microphones to pick up ambient sound.

- Microphones for pedhead-type devices are typically in or on the pedhead, incorporated into the APS.
- Pushbutton-integrated devices may have microphones at the pedhead, or the microphones may be incorporated into the pushbutton housing.

An APS microphone should be mounted as close as possible to the position of the pedestrian who is waiting to cross the associated crosswalk, because sound pressure is halved for each doubling of the distance from the sound source in a free field.

The farther from that ideal position the microphone is for a given APS device, the greater will be the following problems.

- The ambient traffic sound when a microphone is located on a signal pole 10 ft from the curb line will be quieter at the microphone than at the street; therefore, the resulting output will be quieter than it would be if the ambient sound were measured near the street.
- The "Walk" indication, if it comes from the same pole location, may already be too quiet because the ambient sound level has been measured too far from waiting pedestrians, and it will be quieter still when its sound reaches the ears of pedestrians waiting at the crosswalk because the sound has traveled farther to reach them.
- If the microphone is closer to the intersecting street than to the street the pedestrian is waiting to cross, or if the microphone is oriented toward the intersecting street, it will respond to the traffic sound on that street instead of the street the pedestrian is waiting to cross. This may result in "Walk" signals that are too loud or too quiet, as perceived by pedestrians waiting to cross.

Ideal Microphone Location

The best location for the microphone is as close as possible to the position of pedestrians who are waiting to cross the associated street. This results in pedestrians being clearly able to hear

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APS signals with no need to set the automatic volume adjustment so high that sound levels will be too high or that APS neighbors will be annoyed.

Post-Installation Checklist

Checklist

Once installation is complete, the installer should perform the following steps (detailed in sections below). A checklist is shown in Figure 7-12).

- Evaluate and adjust the locator tone volume.
- Evaluate and adjust the "Walk" indication volume.
- Evaluate and set the sensitivity level of the automatic volume adjustment.
- Confirm proper functioning of the "Walk" indicators.
- Check height and location of pushbutton.
- Check the tactile arrow.
- Check optional features.
- Check audible beaconing.
- Recheck the functioning at a later time.

Locator Tone Volume

Evaluate and adjust locator tone volume.

- Approach the intersection from both directions along the sidewalk and note where the pushbutton locator tone is audible. If there are two pushbutton locator tones at the corner, each should be audible. The pushbutton locator tone should be audible 6 to 12 ft from the pushbutton or at the building line, whichever is closer to the pushbutton.
- Approach the corner from the crosswalk and note where the pushbutton locator tone is audible. The pushbutton locator tone should be audible at 6 to 12 ft (or approximately one lane) from the pushbutton.
- Listen through several cycles at times when traffic is noisy and at times when traffic is quiet.
- Adjust the locator tone volume as necessary.

"Walk" Indication Volume

Evaluate and adjust the volume of the "Walk" indication.

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- Stand at the curb-cut end of the curb ramp at the crosswalk and listen for the "Walk" indication. It should be audible from the crossing location.
- Confirm that the "Walk" indication for each crosswalk sounds closer than the "Walk" indication for the perpendicular crosswalk.
- Listen through several cycles at times when traffic is noisy and at times when traffic is quiet.
- Adjust the "Walk" indication volume as necessary.

Automatic Volume Adjustment

Evaluate and set the sensitivity level of the automatic volume adjustment.

- If volumes are adequate in quiet conditions, but do not increase enough or quickly enough when ambient noise increases, the microphone sensitivity, or automatic gain control, may need to be increased.
- Increase the microphone sensitivity in 10% to 20% steps until the response is as desired.
- It might be necessary to readjust the volume of the locator tone and "Walk" indications after the microphone is adjusted.

Confirm Proper Functioning of the "Walk" Indication

Determine if the vibrating surface, speech messages, or other features of the "Walk" indication work properly.

- Press the button and wait for the "Walk" indication. The tactile arrow or vibrating surface should vibrate rapidly only during the walk interval.
- The "Walk" indication (tone or speech message) should sound for the duration of the walk interval, unless there is a special setting due to a rest in "Walk" situation.
- If the "Walk" indication is a speech message, confirm that it refers to the correct street and is appropriately worded and understandable.

Check Height and Location of the Pushbutton

Confirm that pushbutton height and location conform to specifications and can be reached by a person in a wheelchair, from a level landing.

Check Tactile Arrow

Examine the tactile arrow.

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- Check that it is aligned in the direction of travel on the crosswalk
- Confirm that it points to the street that is controlled by that pushbutton

Check Optional Features

Confirm that optional features, if ordered, are present and functioning correctly

- Confirm that braille dots are raised to the touch. If possible, have a person who reads braille confirm that it is the correct label.
- Press the pushbutton for an extended button press to see if the pushbutton information message plays and that it accurately identifies the crossing controlled by the pushbutton and that other information, if provided, is accurate.
- Confirm that a tactile map accurately represents the crossing features.

Check Audible Beaconing

If the intersection requires audible beaconing.

- Press the pushbutton for an extended button press and confirm that the sound is boosted during the following pedestrian phase for the "Walk" tone and for the locator tone, and
- Walk across the street during the pedestrian phase and evaluate placement and aim of devices for providing sound in the crosswalk area.

Recheck Device Functioning at a Later Time

Follow up during the first few weeks after installation, checking device and volume at different times of day to ensure proper functioning.

Designate a person and phone number to call and report any malfunctioning device. Share that information with agencies serving individuals who are blind and with community organizations of individuals who are blind.

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APS Post-Installation Checklist	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	APS 7	APS 8
Evaluate and adjust the locator tone volume								
Evaluate and adjust the WALK indication volume								
Evaluate and set the sensitivity level of the automatic volume adjustment								
Confirm proper functioning of the WALK indicators								
Check height and location of pushbutton								
Check the tactile arrow								
Check optional features								
Check audible beaconing								
Recheck the functioning at a later time								

Figure 7-12. APS post-installation checklist.

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Maintenance

When and How Often the APS Installation Should Be Checked

As with any complex device, an APS has many features that could malfunction or fail in the course of its operation. If features such as "Walk" indication, locator tone, or signal interaction fail to work correctly, the resulting lack of information or misinformation can be dangerous for pedestrians who are blind. It is important that municipalities who have taken steps to install these devices also take steps to ensure correct functioning through the years.

The overseeing agency should conduct an audit or checkup of the APS installations on a regular basis. Checkups should be conducted frequently if factors such as harsh weather may have affected the devices. At the very least, the APS should be checked

- Every 6 months.
- After any repairs to the intersection signals, poles, or controller, and
- After any changes to signal timing.

What Should Be Checked

On each regular visit to conduct a checkup of the APS units, the evaluator should recheck *each of the items on the original post-installation checklist* (see previous section). The following list comprises some of the most common failures that have been observed on installed APS devices:

- Vibrating arrow/button—may stop working or have very weak vibration
- "Walk" indication—tone or speech message may have stopped working or be delayed in sounding after the walk interval begins.
- Raised arrow—may be missing or pointing in the wrong direction
- Pushbutton—may be jammed or malfunctioning.
- Ambient noise response—may be slow to respond or have ceased responding at all.

These items should be specifically checked since some may not be obvious in a cursory glance.

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Other Operation and Maintenance Issues

Repairing an APS After a Crash

It is essential that all maintenance personnel understand the functioning of the APS and consider it when making any repairs to the APS location.

One municipality had a problem when the pole holding the APS was knocked down in an accident and the repair team that replaced the pole oriented the APS toward the wrong street (see Figure 7-13). Because the speech message and arrow did not match up; pedestrians heard "Walk sign is on to cross Harford Road" (at the correct time), but the arrow on the device pointed toward Taylor Avenue.

In another instance, an APS was damaged by a car that left the roadway. The APS was just strapped back onto the pole with no attention to the alignment of the tactile arrow. The APS continued to function, but was pointing to the center of the intersection, rather than being aligned with the appropriate crosswalk.

Figure 7-13. The APS was temporarily replaced on the pole, but the tactile arrow points to the center of the intersection, rather than being aligned with the direction of travel on the crosswalk.

Lessons Learned from APS Installations

New Technology

Not unlike any new technology, the first installations of new types of APS devices did not always operate flawlessly. There were sometimes issues that had to be resolved. In addition,

AR0071960

reports from older installations sometimes brought up recurring problems that had to be addressed in the installation. All of the issues were easily solvable.

The following list of issues should provide information that will prevent such problems from reoccurring:

- Wiring to pedhead and/controller,
- Pushbutton installation,
- Signal phasing,
- Volume adjustment,
- Use and wording of speech messages,
- Pushbutton and pole location,
- Tactile arrow location and position,
- Speaker positioning and volume, and
- Braille signage and correct installation.

Wiring

Some minor problems have been experienced with wiring and color code.

- Prisma, a Swedish company, uses a European wire color standard. Since this standard is not consistent with the U.S. NEMA color code standard, some wiring problems were created. Installers of these products should take care to be certain the devices are wired correctly.
- Prisma APSs have also drawn concern from signal technicians over the voltage (120 V AC) sent to the pushbutton location. Technicians are concerned about pedestrian safety if the pushbutton is damaged or removed by a passing vehicle and a pedestrian comes in contact with the live wires or the electrically charged metal pole. Step-down transformers for mounting in the pedhead are provided upon request for U.S. installation.

Other problems may be related to incorrect wiring of the pushbutton units.

- In one location, the technician attached the vibrator wire to the speech "Walk" indication instead of the speech "Walk" indication and the vibration of the arrow that were expected. there was a rapid buzzing sound from the unit during the walk interval and no vibration of the arrow. This was easily corrected by switching the wires, once the problem was noticed and diagnosed.

AR0071961

- At another location, wires from the parallel crosswalks were switched when attached to the control unit in the controller. Those units were programmed for the extended button press to call audible beaconing on the crosswalk, but the sound came from the APS on the parallel crosswalk, rather than from the other end of the called crosswalk. This problem could lead blind pedestrians to cross the intersection diagonally.

Pushbutton Installation and Vibrotactile Indication

When two APS pushbuttons with vibrotactile indications are installed on the same pole, they may require insulation and a rubber gasket to eliminate vibrations generated from the other pushbutton.

A problem was experienced when two pushbuttons were on the same pole with no vibratory insulation (Figure 7-14). Pedestrians were unable to determine which pushbutton was vibrating, since it appeared that both were. Proper insulation of the pushbutton will prevent this problem from occurring.

Figure 7-14. Incorrect installation of two APSs on a single pole (no vibratory insulation).

Phasing

An installation had a problem when the signals went into flash mode and the APS device remained in "Walk" mode. This scenario presented an unsafe condition and message for pedestrians. This problem was resolved by correctly wiring the APS device into the

AR0071962

controller/signal system so the controller logic and conflict monitor detected and changed the pedheads to the appropriate indications.

Volume Adjustment

Although current standards call for the APS volume to only be 2 to 5 dB above ambient sound and for the locator tone to be heard at a distance of 6 to 12 ft from the pushbutton, the volume is often set much louder than that.

- Installers used to devices using audible beaconing think that APSs are supposed to be loud enough to hear across the street.
- There is no easy way to measure the volume of the locator tone and the "Walk" indication because of the short duration of the tones or messages, the requirement to measure relative to ambient sound, and the signal's quick response to ambient sound.
- For pushbutton-integrated devices, the speaker is in the pushbutton housing. Location of the pushbutton and orientation of the speaker can be critical to hearing the "Walk" indication at the crosswalk.

One installation experienced a different problem in adjusting the volume of an APS unit. They had used the pushbutton control units that install in the cabinet (as opposed to those that install in the pedhead). The wiring was too small of a gauge to drive the speaker to provide a loud enough message (compensated by the pole and speaker being more than 10 ft back from the crosswalk).

The manufacturer's guidelines and specifications should be followed for proper operation. Speakers can be provided for each control unit.

Speech Messages

The speech messages used for the "Walk" indication, as well as the descriptive pushbutton message, must be understandable.

- In one case, poorly recorded "Walk" messages, by an individual with a strong accent, made the street names indistinguishable ("Plant" and "Calvert").
- Use of a standard message, "Walk sign is on," at locations with two pushbuttons on the same pole can be confusing, as a pedestrian waiting to cross and who is unable to see the "Walk" signal cannot tell which "Walk" message is being conveyed.

AR0071963

- A speech message that does not have additional information clarifying which street the pushbutton applies to can be confusing to pedestrians unfamiliar with the intersection. For example, at the intersection of Harford and Taylor Streets, the pushbutton information message for all devices said "Harford" and "Taylor." If the pedestrians do not know which street they are facing, the message "Walk sign is on for Taylor" is ambiguous.
- One jurisdiction wanted to use a male voice for one crossing direction and a female voice for the other direction to distinguish crossing directions and add to the safety of the crossing. Most APS devices provide only a male voice; however, all APS devices use messages recorded on speech chips, and a different voice can be specified. Most devices now provide capabilities for self-recording messages. However, care should be taken to provide clear and understandable messages.
- Speech "Walk" indications should be in the form "Maple, Walk sign is on to cross Maple." Some problems have resulted from using different message wording.

Pushbutton and Pole Location

Some problems have been observed with pushbutton and pole location for APS devices:

- Poles that are more than 10 ft from the curb line create real problems for blind pedestrians who must find the pushbutton and then realign to cross the street.
- Pushbuttons are often placed where they are not reachable from the sidewalk area, are in the bushes, or are behind a fence.

Tactile Arrow and Position

The tactile arrow is supposed to point in the direction of pedestrian travel on the crosswalk, and the face of the device is supposed to be parallel to the crosswalk it controls.

Installation issues include the following:

- If the pole is in a poor location, the arrow may be pointing at the street and crosswalk direction, but may not be within the crosswalk area.
- If installers do not understand the purpose of the arrow, they may install it angled in the wrong direction. For example, if they use the holes from a previous pushbutton, the arrow may be pointing diagonally across the intersection rather than in line with the crosswalk.

AR0071964

Speaker Positioning

Pedhead-mounted speakers in existing installations are often mounted in positions that make the messages more ambiguous. (See examples in Chapter 6 and also earlier in this chapter.)

For pushbutton-integrated devices, the speaker is in the pushbutton housing. Location of the pushbutton and orientation of the speaker can be critical to hearing the "Walk" indication at the crosswalk. If the speaker is located too far from the crosswalk location, pedestrians who are blind may not hear the "Walk" indication.

Figure 7-15. APS pushbuttons installed incorrectly.

As shown in Figure 7-15, the pushbuttons are installed incorrectly; as a result, the APS is too far from the crosswalk it signals, and the sound for the other crosswalk at the intersection comes from a speaker closer to the crosswalk.

AR0071965

Figure 7-16. APS pushbuttons installed correctly.

In Figure 7-16, the APSs are installed correctly (close to the crosswalk they signal) and provide accurate information through proximity to the crosswalk.

Braille Signing and Location

Braille indications on pedestrian signals have sometimes been mounted backwards; in other cases, the braille sign has been installed at the wrong street.

- Manufacturers ship braille signs with a label to clarify positioning for nonbraille-readers. However, technicians might later make adjustments to the sign and reverse or mix up the braille plaques.
- When a braille message is added, the sign cannot later be turned around without reversing the braille, which would make the braille dots depressed, rather than raised. The braille characters must remain raised to the touch. If the original specification was not correct, the arrow cannot be turned without making the braille characters unreadable.

AR0071966

CHAPTER 6

Public Education about Accessible Pedestrian Signals

Need for Education 2

Providing Information to the Public 3

One-Page Flyer about APS Installation 4

Techniques to be Used by Pedestrians Who Are Blind at Intersections Equipped with APSs 5

Requesting an APS 7

AR0071967

This chapter provides instruction on methods and materials for providing the public with appropriate educational information about APSs.

Need for Education

Many people in the United States have had no experience with the newer types of APSs. It is important that pedestrians, both blind and sighted, have some understanding of the functioning of an APS, as well as the various features of the APS installed at a location. In particular, it is important that pedestrians know and understand the difference between the pushbutton locator tone and the "Walk" indication.

Individuals who live close to newly installed APSs may not be aware of how useful an APS is for pedestrians who are visually impaired. Advance publicity about the APS to be installed will help people understand the need for the device and may result in a higher level of neighborhood acceptance. Many individuals are not familiar with pushbutton locator tones and may benefit from an explanation of how they are used by pedestrians who are blind or who have low vision.

Education Needs Documented by Research Project

Research completed as part of this project indicates that education is needed to give blind pedestrians a better understanding of pushbutton locator tones, response to ambient sound, and "Walk" indications.

Some participants thought that the increase in volume of the locator tone, in response to ambient sound, was a new kind of "Walk" indication.

In addition, most participants were not familiar with the need to use pushbuttons. Most of the pedestrians who were blind stated that they did not use pushbuttons, unless they knew the pushbuttons were present and knew where they were located. They were unclear on the purpose or function of the pedestrian pushbuttons. Pushbutton locator tones should provide more information. All pedestrians seem to need more education about the use and function of pushbuttons.

It is important that pedestrians who are blind understand the placement of an APS. The MUTCD 2000 (3, 41[08]) provided more specific location guidance for APS pushbuttons. It was noted in this research project that many of the blind pedestrians were unfamiliar with arrows and were unable to immediately determine which direction the tactile arrow was pointing. An

AR0071968

explanation that includes actual hands-on experience with the APS and pushbuttons can be helpful.

Providing Information to the Public

Information about APSs is commonly distributed through **radio and TV publicity**, which reaches many people, including those who are blind or who have low vision. Newspaper articles, in contrast, may not reach individuals who are blind or visually impaired, particularly those in the growing elderly blind population.

Radio reading services, which provide live spots and informational programs aimed at individuals who are blind or who have low vision, [illegible] in many cities. Radio reading services broadcast the reading of newspapers and books and magazines to the blind, physically impaired, and those who have difficulty reading small print. Because of copyright law, reading service radio broadcasts are restricted to a closed channel that is not available to the general public. Listeners can usually hear the service only by ordering a special "subchannel" radio through special cable service, or through a subscription webstream service.

The radio reading service serving a specific area can usually be found through an internet or phone book search.

Rehabilitation centers that provide services to individuals who are blind or who have low vision are located in many cities. These centers may have telephone- or email-based bulletin boards providing news of interest to individuals who are blind. Usually the posting information or notices is free. Centers may also provide meeting space or facilitate regular support group meetings.

There are two main **consumer groups** of individuals who are blind and who have low vision—American Council of the Blind and National Federation of the Blind. Each organization has affiliate groups and local chapters that usually meet monthly. Speaking at a group meeting is an excellent way to reach a number of individuals who are blind or who have low vision. Information about local chapters and contact information for each chapter is available from the national office and is usually listed on the national organization web pages (www.acb.org and www.nfb.org).

Offering to provide information and speakers at various **community organizations**, ranging from Parent Teacher Association meetings to business association meetings, can be another

AR0071969

avenue for educating individuals in the community where APSs are being installed. Individuals who are blind or who have low vision are often members of these groups as well.

One-Page Flyer about APS Installation

Public agencies may find it useful to distribute flyers to inform the public about APSs. The following sections list important information to include on the flyer, as well as some suggested text for each topic. Notes in italics are for the flyer designer and should not be included on the flyer.

[SAMPLE FLYER]

New accessible pedestrian signals are being installed at *[list intersections]*

[Insert a photo of an APS of the type being installed.]

The accessible pedestrian signals provide audible and vibrotactile "Walk" indications that help people who have trouble seeing the pedestrian signal. The sounds come from the pushbutton and automatically adjust to ambient sound so they will be louder when the traffic is loud and quieter when traffic is quiet.

Audible and vibrotactile "Walk" indications tell a visually impaired pedestrian that the "Walk" signal is on, but it is still important that they check traffic before crossing to be sure that cars are not running the red light or turning across the crosswalk.

Each accessible pedestrian signal has the following features:

- Pushbutton locator tone—a tone that constantly sounds once per second from each pushbutton to help people who are blind or who have low vision find the pushbutton.
- Audible and vibrotactile "Walk" indications—a sound and vibration during the "Walk" signal.

[Insert applicable "Walk" indication description.]

- Rapid tick "Walk" indication—a rapidly repeating tick from the pushbutton location to indicate that the "Walk" signal is on.
- Speech "Walk" message—provides the name of the street to be crossed, then "walk sign is on to cross" and the street name again. For example, "Haywood. Walk sign is on to cross Haywood."

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- A tactile arrow either on the pushbutton or above the pushbutton points in the direction of travel on the crosswalk. The arrow vibrates during the "Walk" signal.
- Actuation indicator—a tone, a click, or a spoken "wait" that is generated when the pushbutton is pushed to confirm the button has been pushed.
- Braille street name—the name of the street with the crosswalk that the pushbutton controls is listed in braille on the plate above the pushbutton.

[If optional features are installed, add the applicable text below:]

- Optional features when you hold the pushbutton in for more than 1 second:
  - Pushbutton information message—names the street that the pushbutton controls and the other streets at the intersection. Example: "Wait to cross Vermont at Haywood."
  - Audible beaconing—The volume of the locator tone is boosted during the flashing "Don't Walk" interval to allow a person who is blind to home in on the opposite corner of the street.

[Provide contact information for questions or concerns.]

Techniques to be Used by Pedestrians Who Are Blind at Intersections Equipped with APSs

The following section, intended for O&M specialists, is adapted from *Crossroads: Modern Interactive Intersections and Accessible Pedestrian Signals* (22).

It is particularly important to recognize that the APS information is supplemental to traffic and environmental cues and only provides information about the status of the signal. The APS "Walk" indication indicates that the "Walk" signal is on, not that it is safe to cross. Cars can still be turning across the crosswalk or might be running a red light. The APS "Walk" sound can be compared to the "on your mark" instruction at the beginning of a race, though it means that the signal has changed, it is still important to "get set" (assess the traffic) and then "go" (begin to cross).

Suggested Techniques in Using APS

The only place in the O&M literature where specific techniques are suggested for crossing at intersections using APSs is a section in a curriculum on APS developed for Easter Seals Project ACTION (22). Based on the experience of the authors and the Project ACTION curriculum, the following techniques are suggested:

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- Approach the intersection and stop at the curb ramp/street edge, maintaining initial alignment; check alignment for crossing by listening to traffic. Even if a pushbutton locator tone is noticed during approach, continue to the curb or edge of street first.
- Determine the starting location for crossing and identify tactile cues for use in realigning after pressing the pushbutton, because once the button is pushed, there may be insufficient time to listen for parallel traffic and realign before the next "Walk" signal.
- Listen and evaluate the intersection. Determine traffic patterns and intersection geometry and listen for a pushbutton locator tone or for a tone or speech "Walk" information. It is important that students/clients understand and can recognize the difference between a pushbutton locator tone and typical "Walk" indications.
- Search for a pushbutton using a systematic pattern. Even where there is a pushbutton locator tone, a systematic search pattern is needed to maintain orientation. Because guide dogs/guides are trained to avoid obstacles, they may be reluctant to approach a pole supporting a pedestrian pushbutton. It may be more efficient for the handler to initially use a cane to search before teaching the dog to locate the pole.
- Once the APS is located, explore the device and its functioning, including locating the tactile arrow to confirm that the arrow is pointing in the direction of the street being crossed.
- Hold the pushbutton down for more than 3 s and listen if more information is provided.
- Listen to APS and traffic for a full cycle to make sure that the tones or speech messages correspond with traffic information.
- Press the button and return to the predetermined spot at the curb, realign, and prepare to cross.
- When the "Walk" indication is heard, confirm that traffic on the perpendicular street is stopping or stopped and listen for initial parallel traffic movements, when available. Traffic may still be legally clearing the crosswalk when the "Walk" begins, so careful listening is important.
- Cross the street using typical alignment techniques (traffic, straight line travel, etc.) while continuing to listen for turning cars. In many cases, cars can turn right and left across the crosswalk during the pedestrian phase. Although drivers are supposed to yield to pedestrians, they often do not.

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- Be aware that a locator tone on the destination curb may provide additional wayfinding information.
- Continue to be vigilant of traffic even though the "Walk" indication is on.

Requesting an APS

The following was copied from the website of the Environmental Access Committee of the Orientation and Mobility Division of the Association for Education and Rehabilitation of the Blind and Visually Impaired (23). A sample letter for requesting an APS is also reprinted.

- Educate yourself about types of APS available and the applicable regulations.
- Find out who controls the intersection where you're making the request. Sometimes it's a city department of traffic engineering, sometimes it's the county, and sometimes, if it's a state or federal highway, it's the state Department of Transportation. You can just call the number listed in the phone book for traffic engineering or public works and ask who you need to contact about the traffic signals at that intersection. Get a name, address and phone number. If you get to talk to someone on that phone call, ask what their policy is on APS.
- The request for an APS is strongest if it comes from a consumer who is blind or visually impaired. So, the consumer should make the actual request for modification in a letter to the individual in the traffic engineering department that manages that intersection. (A sample letter is below.)
- Include wording in the first letter about the need for "access to information" about the status of the pedestrian signal. If you have to, you can refer back to the ADA and requirements to make the right of way accessible if they refuse or delay installation.
- With the consumer's permission, follow their letter with a letter of support on your professional letterhead, restating the reasons for the need for the APS at that intersection.
- Follow up with a phone call about a week later to the person who is responsible for that intersection. Remember that most traffic engineers will never have heard of an Orientation and Mobility Specialist and O&M in traffic engineering

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terminology is Operations and Maintenance, so don't shorten your title) and may not have thought about a blind person crossing an intersection independently. Remind them of the letter of request and see how they respond. If they have no idea about APS and where to get them, share that you have a list of manufacturers and would like to meet with them to discuss solutions.

- If you can get the engineer to meet you and the consumer on the street corner, and discuss it there, do it. Be sure to include the consumer at that time. Demonstrate the problems and talk about what the APS would do to help.
- If you have not talked to the engineer within two weeks after they should have gotten the letter, you or the consumer should send a follow-up letter asking them to contact you.
- If you need to send a third letter, it needs to be copied to the department head, the city ADA coordinator, and a local elected official.
- If they refuse to meet with you or refuse to put in the APS, ask them to send a letter to that effect to the client with a copy to you. Say it nicely, but they'll know why you're asking and don't settle for a non-response. Documentation can be useful if you have to file an ADA complaint. You and the client should document any phone conversations (date, who, what they said, etc.). Hopefully, you won't need that information later, but just in case, keep track. (2.5)

Sample letter requesting an APS:

[Date]

[Address to traffic engineer in charge of the intersection]

This letter is to request the installation of an Accessible Pedestrian Signal (APS) at the intersection [insert street names]. As a pedestrian who is blind, I am unable to use the visual pedestrian signals currently installed at this location and need access to the information in order to cross the street. As you may be aware, there is a bus stop at this intersection. I must cross the street safely to reach the bus stop. [change that last sentence to fit the specifics of the intersection, particularly if there are some

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issues that make it particularly hard to cross such as poor traffic sounds, lots of right turning traffic, T-intersection, etc.].

I would like to meet with you or someone from your department at the intersection in question to discuss appropriate modifications. I would also like for [insert O&M instructor name], an orientation and mobility specialist at [insert agency name] to join us. You may contact me at [insert phone number or address] or [insert O&M instructor name] at [insert phone number] to set up an appointment. Thank you for your attention to this matter.

Sincerely,
[signature]

cc: [O&M specialist name, agency affiliation]

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CHAPTER 9

U.S. Case Studies

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Case Study—Montgomery County, Maryland

Date: May 2002

History and Background

The intersection of Fenton Street and Wayne Avenue is the first of 11 locations in the Silver Spring central business district (CBD) to be equipped with APS under a pilot program initiated by the county executive.

Process and Procedure

There is no formal procedure to request an APS. A committee was formed, in coordination with the Montgomery County Commission on Persons with Disabilities, to make decisions about type and features of APS to be installed.

Most signalized intersections in the county are on state roads, so final decisions of the State Highway Administration on APS policy will affect installation at those locations.

Funding

Costs for the pilot project are absorbed as part of the traffic engineering department budget. An additional line item for APS installation was requested in the budget but was not funded.

Description of Intersection

These traffic signals are being rebuilt as part of the redevelopment of the CBD. Fenton Street and Wayne Avenue was the first one to be rebuilt and hence the first to receive APSs. All intersection legs are four lanes wide. Fenton Street runs approximately north-south and Wayne Avenue runs east-west. There is a leading left turn phase from westbound Wayne to southbound Fenton.

Date Installed

September 2001

APS Type and Features

Pushbutton integrated devices from Polara Engineering.

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The intersection is pretimed, with walk intervals associated with each crossing being provided each cycle, but the APSs are actuated (audible and vibrotactile "Walk" indications are not provided unless the pushbutton is pushed).

APS features:

- Speech "Walk" message.
- Vibrotactile "Walk" indication.
- Pushbutton locator tone.
- Tactile arrow.
- Pushbutton information message called by extended button press.
- Automatic volume adjustment in response to ambient sound.
- Speech "Walk" message: "Walk sign is on to cross Fenton Street" for Wayne Avenue).
- Pushbutton information message, provided after an extended button press (3-s depression of pushbutton):
  - Includes both street names.
  - Clarifies to which crossing the button applies.
  - Example: "Crossing Wayne Ave at Fenton St."

APS Installation

Devices are installed on all four corners, using stub poles for all in order to place the pushbuttons and APS at the top of the ramp for each direction, separated by at least 10 ft (see Figures 9-1 and 9-2).

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Figure 9-1. Pushbutton-integrated APS located on a stub pole beside the level landing of the curb ramp.

Figure 9-2. Pedestrian with guide dog at an APS located in line with crosswalk.

Each pole is approximately 5 ft tall with a substantial base; locations vary somewhat but are generally

- Within 5 ft of the crosswalk lines extended, and
- 6 to10 ft from the curb (except on the northwest corner, where further construction is planned; thus those poles were located farther from the curb).

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The Polara control unit and the microphone, which monitors sound for the automatic volume adjustment, are typically installed inside 18-in. pedestrian traffic signal heads. At this location, which has 12-in. pedestrian signal heads, the control units were installed in an exterior box attached to the top of the pedestrian traffic signal heads. The microphone was attached to the box, which located it much higher than usual; however, that placement seems acceptable.

Installation Issues

There were no real problems with the installation. However, locating the poles and APS properly in relation to the curb ramp and as recommended in the MUTCD is difficult. While it may be less of a problem in new construction, it requires thought and planning, as well as extra poles, conduit, wiring, and construction in retrofit situations.

Maintenance

Except for some minor adjustments after installation, there have been no maintenance issues or failures.

Evaluation

No formal evaluation has been conducted. Committee members visited the installation and were generally pleased with the functioning.

Contact

Bruce Mangum, Senior Engineer
Transportation Systems Management Section
Division of Public Works and Transportation
Montgomery County Maryland
101 Monroe Street, 11th Floor
Rockville, MD 20850
Phone: 240-777-8378 - Fax: 240-777-8350
E-mail: bruce.mangum@montgomerycountymd.gov

Case Study—Portland, Oregon

Date: July 2003

AR0071980

History and Background

The City of Portland has had some form of audible pedestrian signal for over 20 years. In installing these devices, staff worked closely with the requester to identify specific needs.

- In the late 1970s, city staff installed buzzer-like devices at three intersections on request basis. These buzzers were inexpensive devices purchased from a local electronics store. The buzzer was only activated with a normal pedestrian pushbutton call.
- During the late 1980s the city began using an inexpensive Mallory chime as an audible device. It was installed in some fixed time intersections, as well as actuated intersections.
- By 1995 the city had 10 signalized intersections with audible devices.
- In 1996 the city decided that a more formal policy was necessary and a process was implemented, which was revised by a Citizens Advisory Committee in 1999.

During the past 5 years the city has greatly expanded its program. By mid-2003, Portland had 53 signalized intersections with some form of audible signal (Figure 9-3).

The City of Portland was awarded a Pedestrian Project Award for 2003 from the Institute of Transportation Engineers and the Partnership for a Walkable America. The award, in the elderly and mobility category, recognized Portland's project to retrofit existing signals with APSs.

Figure 9-3. An APS mounted over 12 ft high on the pole broadcast speech messages at this location in Portland. City engineers expressed concerns about intelligibility of the message.

Process and Procedure

A formal policy was established in 1996.

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- City staff assembled a stakeholders group, which included representation from the Oregon Council of the Blind, the National Federation of the Blind, the Oregon Commission for the Blind, Independence Living Resources, and other groups representing both the visually impaired community and mobility instructors.
- The policy was developed over a series of three meetings.

Key points of that policy include the following:

- Audible signals are installed only on a request basis.
- The intersection has to have some unique or unusual characteristics that warrant the addition of an audible signal.
- Referral to a mobility specialist is required; this service is provided through an agreement with Oregon Commission for the Blind. In some instances the crossing problems may be related to a lack of user skills that might be better addressed by further training.

In mid-1999 the requests for audible signals outstripped city resources for the program. A citizens advisory committee (CAC) was activated to review and rank the requests.

- The CAC and city staff started with a ranking process similar to that used by the City of Los Angeles.
- Staff applied the criteria to 10 intersections on the request list. The CAC made some revisions to the scoring criteria (see Appendix D).
- Scoring materials were developed. The electrician responsible for the installations and a mobility instructor from the Oregon Commission for the Blind meet with the requester at the candidate intersection to better understand the user's needs and concerns. After agreeing that some sort of audible signal is a viable solution, the city staff person and the mobility instructor complete field aspects of the scoring form. Information such as volumes and accidents is gathered by office staff from existing city records and added to the scoring form.
- The CAC meets semiannually to rank the requests.

Funding

From 1996 through 2000, the city used approximately $150,000 in general transportation funds to install APSs. That funding source for APS has since been lost. To continue with new

AR0071982

installations, the city received over $200,000 in transit mobility funds from the local transit agency. However, that grant expires in July 2004 and no replacement funding source has yet been identified.

APS Types and Features

Pedhead mounted at numerous intersections. Pushbutton-integrated at two intersections.

Pedhead-mounted devices manufactured by Novax and Mallory.

Pedhead-mounted APS features include

- "Walk" indication—cuckoo/chirp, beep, or chime, and
- Extended button press to call accessible features on some devices (no locator tone is used.).

Pushbutton-integrated devices, manufactured by Polara Engineering and Campbell Company, have been installed recently with locator tones and additional features.

The City of Portland has also evaluated the Vibrawalk pushbutton manufactured by Novax Industries (see Figure 9-4).

Figure 9-4. Vibrawalk pushbutton installed in Portland includes a locator tone. The arrow vibrates during the walk interval and a "Walk" indication is provided from the pushbutton or speaker mounted on the pedhead.

Special Features

Portland staff has worked with manufacturers on developing device features.

- After 1996, in deference to requests of members of the National Federation of the Blind, a technology was used that requires the user to hold the button for at least 1 s to place a call for an audible signal to make the technology "refusable." The button actuated timer, from Novax

AR0071983

Industries of British Columbia, requires that the button be depressed for at least 1 s to call the audible indication.

- Staff worked with Novax and McCain to take the speaker and electronics out of the exterior Novax housing and mount them directly on the pedhead to afford more protection from vandalism and to place the speaker closer to the users' ears

In 1999, the CAC and city staff expressed a desire to find lower cost options so that more intersections could be treated. City staff received approval from the CAC to install lower cost Mallory devices. Since the Mallory device has neither automatic volume adjustment nor the button activated timer, city staff is careful to use the device only in locations that are that are not close to residences.

Date Installed

Between 1970s and present.

Installation

Installation varies greatly from intersection to intersection. Portland transportation engineering staff report that the largest problem faced is with existing infrastructure. The aging transportation system makes installing new wires in old, undersized conduits a challenge. The location of existing poles also poses a problem. As intersections evolve throughout their life span, poles for pushbutton locations are often located in areas that are less than desirable for accessible pedestrian installations.

Obstructions, such as utility and sign poles, are also a significant challenge. These obstacles often make placement of pushbutton locations difficult, translating into higher installation costs.

Proximity of poles, in relation to one another, also has to be taken to account. Volume level of the "Walk" cue and locator tone must be loud enough to tell pedestrians to go, but quiet enough to not give a false "Walk" cue to someone at a conflicting pedestrian lane. This can be difficult at intersections with odd configurations, such as islands with separately actuated pedestrian lanes.

AR0071984

Maintenance

Maintenance of equipment has been almost a nonissue. There have been few maintenance problems, although it should be noted that most of the equipment with electronics mounted in the pedhead or pushbutton is relatively new. These installations are only 1 to 6 years old, so there is not a long maintenance history on those devices.

Evaluation

Portland tested a variety of "Walk" indications.

- The earliest sounds for the walk interval were a buzzer and Mallory chime.
- A trial installation used voice messages. The voice message typically said "The Walk light is now on to cross 81st Street." Although equipped with ambient sound adjustment to increase the output as background noise increased, the voice message was often difficult to hear.
- Tones seem to be better for cutting through background noise in an urban street environment. After the initial test with voice and tones, the city decided to use the cuckoo and chirp sounds.

The community had the following reactions to the APS:

- Buzzer—Staff received some calls regarding the annoying sound and usually responded by placing some sort of baffling material around the buzzer.
- Mallory chime—The chime was a more pleasing sound and the city seldom received any noise complaints, even though the chime was installed in some fixed time intersections.

Contacts

Bill Kloos, Signal and Street Lighting Manager
Portland Department of Transportation
1120 SW 5th Avenue / Suite 800
Portland, OR 97204-1971
Phone: 503-823-5382
E-mail: Bill.Kloos@pdxtrans.org

Jason McRobbie, District Electrician
Portland Department of Transportation

AR0071985

1120 SW 5th Avenue / Suite 800
Portland, OR 97204-1971
Phone: 503-823-1173
E-mail: Jason.McRobbie@pdxtrans.org

Case Study—Newton, Massachusetts

Date: July 2003

History and Background

Accessible pedestrian signals were installed at major intersections in Newton, Massachusetts, in 2001, as part of a major signalization upgrade project and at the recommendation of the Mayor's Committee for People with Disabilities (Mayor's Committee). This is Newton's first experience with this signal type.

Process and Procedure

New Construction and Signal Upgrades

When new signals are installed in Newton, the Mayor's Committee considers whether they should have accessible pedestrian signals. Their recommendation is then referred to the Departments of Public Works and Planning. For example, when signalization at an intersection is being upgraded from a flashing beacon to full signalization, input is obtained from the Mayor's Committee.

Handling Individual Requests

Individual requests are referred simultaneously to the Mayor's Committee and to the Traffic Council. The Traffic Council is required to respond to requests by making a decision within 12 weeks.

Consultation with Local Agency for the Blind

The City Traffic Engineer also consults with the orientation and mobility specialist at the Carroll Center for the Blind regarding the need for APS and for suggestions regarding the most appropriate type of APS for a particular intersection.

AR0071986

Funding

APS installations in Newton were funded jointly by the Departments of Public Works and Planning, with a portion of the cost being covered through the Community Development Block Grant program.

The City of Newton currently has $10,000/year earmarked for APS installations.

Description of Intersection

The APSs were installed at a complex intersection with high pedestrian and vehicular traffic volumes. At this intersection, three crosswalks share the same exclusive pedestrian phase timing:

- One is a midblock arterial crossing (Figure 9-5);
- One is a minor street intersecting the arterial in a "T," near the mid-block crossing (Figure 9-6).
- The other is across a third street that enters the arterial diagonally, close to the T-intersection of the minor street.

Because of abundant turning traffic during all vehicular phases, there is no safe crossing time for pedestrians, except during the exclusive pedestrian phase.

APS Type and Features

Pushbutton-integrated APS manufactured by Bob Panich Consultancy.

APS features include the following:

- "Walk" indication – audible rapidly repeating tones;
- Vibrotactile "Walk" indication;
- Pushbutton locator tone;
- Alert tone;
- Tactile arrow; and
- Automatic volume adjustment in response to ambient sound.

AR0071987

Figure 9-5. Panich APS at midblock crossing, Newton, MA. The APS should have been mounted on the side of pole closest to the crosswalk, with the arrow parallel to the crosswalk rather than pointing up.

Figure 9-6. Panich APS for crossing the stem of a T-intersection.

APS Installation

At another intersection at which APS devices were added, a stub pole was installed in order to locate the pushbutton properly for one crosswalk (Figure 9-7).

AR0071988

Figure 9-7. Panich APS on stub pole in Newton, MA. Arrow oriented parallel to crosswalk.

Installation Issues

Installation presented no technical difficulties.

Initially, the APS volume was set so loud at one location that the "Walk" signal was audible from a nearby intersection, possibly leading pedestrians at that intersection to incorrectly believe they had the walk interval. The volume was turned down several months after the APSs were installed.

Although the basic requirement for conduit in public rights-of-way in Newton is a 36-in. trench, actual construction may be less than 36 in. depending on site conditions. It is important that such an installation be based on direct field knowledge, rather than be designed in the shop.

Maintenance

No maintenance, except for volume adjustment, has been necessary since the audio-tactile pushbuttons were installed. Weather does not seem to affect their performance, and there has been no vandalism.

Evaluation

The APSs have been well-received by blind users, and there have been no objections from neighbors.

The APSs are located in a small business area, not close to any residences.

Contact

Roy Lamotte

AR0071989

City Traffic Engineer
City of Newton, MA
Phone: 617-796-1020
E-mail: rianiorio@ci.newton.ma.us

Case Study—New Jersey DOT—Washington, New Jersey

Date: July 2003

History and Background

The New Jersey Department of Transportation (NJDOT) has been sensitive to the needs of the visually impaired. The first vibratory pushbuttons (with raised directional arrow) in New Jersey were installed in 1992 at the Rowan College signalized pedestrian crossing across Route 322. As of August 2000, NJDOT had installed APS devices at four intersections. The devices at the location described here and pictured in Figure 9-8, Route 31 and Route 57, were installed in the fall of 2000. NJDOT has recently installed APS devices at other intersections and expects to install more devices.

A project involving the installation and evaluation of four types of APS devices at intersections in Morristown, NJ, was funded by NJ Highway Traffic Safety and was conducted by Edwards and Kelcey in cooperation with The Seeing Eye. (More information is provided in the Appendix.)

Process and Procedure

There is no formal process for deciding to install an APS.

These APS devices were installed at the request of a blind person in conjunction with reconstruction of the intersection. An O&M specialist provided information useful in making the decision about the type of APS selected.

Funding

The APSs are funded under the general state fund, with no special funding sources.

The devices cost $400 per device to NJDOT, plus installation by NJDOT forces. NJDOT went out to bid for the devices.

AR0071990

Date Installed

Fall 2001

Description of Intersection

Route 31 and Route 57 is a major intersection of a four-lane undivided road and a two- and three-lane road with a parking lane at the edge of small downtown CBD. There are four traffic islands, with signalized crossings to the islands. Pushbuttons were installed at all crossings for a total of 12 devices at the intersection.

APS Type and Features

Pushbutton-integrated APS manufactured by Polara Engineering.

APS features include

- Vibrotactile "Walk" indication,
- Pushbutton locator tone,
- Tactile arrow,
- Braille street name, and
- Actuation indicator—tone.

APS Installation

Figure 9-8. Installation of two pushbuttons on a single pole (only a single pushbutton is visible in the photo). Although the pushbutton is in line with the crosswalk, the pedestrian must travel more than 10 ft before reaching the street and the beginning of the crosswalk.

AR0071991

APS devices were installed at all crosswalks to provide the signal information at all possible crossings used by the blind person. It is a state standard to put two pushbuttons on the same pole with no standalone pole for the APS. This meant that some devices were located a distance from the beginning of the crosswalk. Because the only "Walk" indication was vibrotactile, the walk interval was lengthened to provide time for a pedestrian who is visually impaired to reach the departure curb after the "Walk" signal began.

These devices were installed as a retrofit before various recommendations and guidelines were issued. Currently, recommendations of PROWAAC and the Draft PROWAG state that devices should provide audible and vibrotactile information about the walk interval. These APSs are vibrotactile only and thus do not conform to those recommendations. The MUTCD and Draft PROWAG recommendations also encourage installation of devices on two poles separated by at least 3 m. If separation is not possible, the Draft PROWAG recommends speech messages for the walk interval; vibrotactile indication was used here.

Installation Issues

No major installation issues.

Maintenance

There have been no reported maintenance problems, except for the vibrating arrows on a couple of devices that got stuck and stopped vibrating.

There has been no vandalism.

Evaluation

There are no reports of complaints or comments received from the general public or individuals in the community. With other installations, there have been complaints due to the locator tone increasing in response to the traffic noise and bothering persons who live close to the intersection.

There were complaints at first from a blind woman regarding placement of the devices and inability to line up and cross while keeping her hand on the vibrating arrow. After she was trained by an O&M specialist, however, she was able to adequately use the APS (see Figure 9-9).

AR0071992

Figure 9-9. APS mounted on signal pole for crossing signalized right-turn lane. A pedestrian who is blind is waiting with her hand on the pushbutton for the vibrotactile "Walk" indication. After the "Walk" indication begins, she must turn and cross the sidewalk before beginning to cross the street.

Placement is problematic for a device that is vibrotactile only. In order to keep her hand on the device, the user must stand back from the crosswalk and then turn toward the crosswalk after the "Walk" indication begins.

There has been no research or evaluation regarding the APS either before or after installation.

Contacts

Tim Szwedo
Traffic Safety and Engineering
NJ Dept. of Transportation
P.O. Box 613
Trenton, NJ 08625
Phone: 609-530-2601
E-mail: Timothy.Szwedo@ dot.state.nj.us

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Paul Veeter
Director, Traffic Engineering
Edwards and Kelcey
E-mail: pveeter@ekmail.com

Case Study—West Virginia Division of Highways—Morgantown, West Virginia

Date: July 2003

History and Background

APSs were installed in 2002 at the request of blind citizens. These are the first APSs that have been installed in the state.

Process and Procedure

Morgantown does not have a process or procedure for determining which intersections will be equipped with APS. Typically, all traffic signal installations in West Virginia are done by contractors working under the purview of the West Virginia Division of Highways.

Funding

This demonstration project was fully funded by the West Virginia Division of Highways.

Description of Intersections

APSs were installed at two downtown intersections that have pedestrian actuation and exclusive pedestrian phasing with right turns on red permitted.

APS Type and Features

Pushbutton-integrated APS manufactured by Precise Traffic (model TS-903).

APS features include:

- Tone "Walk" indication—fast tick, a rapid repetition of the pushbutton locator tone for crossing in both directions.
- Pushbutton locator tone.
- Tactile arrow.
- Actuation indicator.
- Tactile map of crossing, and

AR0071994

- Automatic volume adjustment in response to ambient sound.

Signals are being modified to include pushbutton information messages modeled after "Wait to cross Willey St. at High St. Wait for red light for all vehicles. Right turn on red permitted."

APS Installation

Two pushbuttons have been mounted on some corners so the standard single arrow can be correctly oriented in the same direction at each crosswalk (Figure 9-10). This was necessary where the two crosswalks at a corner were not at right angles to each other.

Since these locations used exclusive pedestrian phases, a right-angle, double-ended arrow was installed so that a single pushbutton could be located on one corner or quadrant, controlling the "Walk" signal for two crossing directions. The right angle arrow will be installed where both crossings are 90 degrees from a particular quadrant.

Figure 9-10. Mounting of two Prisma pushbutton units on a single pole. See arrows on insert detail for the orientation of the tactile arrow on the top of each unit. Both devices make the same sound during the "Walk" indication, which is acceptable in this installation since there is exclusive pedestrian phasing.

AR0071995

Installation Issues

Wiring of the APS was little different than typical (non-APS) pushbuttons. APSs are mounted to signal uprights using two 0.25-in. stainless steel screws. In the future, stainless steel bands may be placed at the top and bottom sections of the APS in high-vandalism areas.

Diligence is needed in the initial design of a complete intersection so as to correctly locate APS according to the MUTCD.

Maintenance

No weather-related maintenance issues have been reported.

Cabinets and signals are well guarded against transient voltage surges, including high speed surges that are accompanied by lightning.

To date, APSs have been installed at six intersections in West Virginia. At one intersection in downtown Charleston in a high vandalism area, three APSs have been knocked off the signal upright.

Evaluation

The APSs have performed as expected according to manufacturer's literature.

Negative comments have been received from nearby businesses about the noise level of the locator tone. The entrance to one business is less than 10 ft from the pole on which two APSs are mounted.

Blind users have objected to the location of some APS units (in some cases at a distance of about 20 ft from the crosswalk).

Positive comments have been received about the protective installation of APS.

Contacts

Barry Wahrwig
Traffic Engineering Division
West Virginia Div. of Highways
Building 5, Room 550
1900 Kanawha Blvd. E.
Charleston, WV 25305
Phone: 304 558-3722

AR0071996

E-mail: BWarlsvbig@dot.state.wv.us

Bruce Kenney
Traffic Engineering Division
West Virginia Div. of Highways
Building 5, Room 550
1900 Kanawha Blvd. E.
Charleston, WV 25305
Phone: 304 558-3063
E-mail: Bkenney@dot.state.wv.us

Case Study—Dunedin, Florida

Date: July 2003

History and Background

There are two downtown intersections and one at Patricia Avenue and Beltrees in Dunedin where APSs have been installed at the request of citizens who are blind.

The City of Dunedin received the Inspired Leadership Award for 2003 from the Florida Alliance for Assistive Services and Technology (FAAST) for their APS installations.

Process and Procedure

Requests for APSs are received by the City of Dunedin ADA coordinator and reviewed and recommended by the ADA Committee appointed by the city manager.

APSs were requested by one person who is blind and who also has limited hearing in one ear. She consulted with an O&M specialist and requested pushbutton-integrated devices, and she also worked with the engineer on installation details.

Funding

The intersection modifications were part of a redevelopment project.

Description of Intersections

One of the downtown intersections, Douglas and Main Streets, is a fairly small square intersection of two-lane streets with a pushbutton-actuated exclusive pedestrian phase

AR0071997

The other downtown intersection is at Broadway and Main, which is a more complex intersection where a very busy state road intersects with the city's Main Street.

The third intersection, at Patricia and Beltrees, is a T-intersection of a minor street with very busy street with a right turn lane.

APS Type and Features

Pushbutton-integrated devices from Polara Engineering.

APS features include the following:

- Speech "Walk" message:
  - At Douglas and Main (with exclusive pedestrian phasing): "Walk sign is on."
  - At Broadway and Main: "Walk sign is on to cross Main" or "Walk sign is on to cross Broadway."
- Vibrotactile "Walk" indication.
- Pushbutton locator tone.
- Actuation indicator—tone.
- Tactile arrow.
- Automatic volume adjustment in response to ambient sound.
- Extended button press—increases the volume of the "Walk" indication and locator tone.

Figure 9-11. Two pushbuttons are located on fluted pole at this location with exclusive pedestrian phasing. Tactile arrow of each device points in the direction of travel on the crosswalk.

AR0071998

APS Installation

Two APSs were mounted on each pole.

At one crossing the APSs were about 15 ft back from the crosswalk location and approximately 5 ft toward the intersection from the extension of the crosswalk lines. The volume of the locator tone and the "Walk" message was quite loud.

At the Patricia and Belcrest location, APSs were installed on only one crosswalk, for crossing the through street, as needed and requested by the person who lived near the intersection.

Installation Issues

Installers stated that they had difficulty figuring out the new devices, but that the devices seemed to work fine after they figured them out.

Fluted poles were used in the redesign, which made it difficult to align the tactile arrow (see Figure 9-11).

Maintenance

No maintenance issues have been reported except for the need to adjust volume levels.

Evaluation

The installation generated complaints from patrons of a restaurant/bar with outdoor seating at one corner of the intersection. The locator tone was loud enough to hear from more than 30 ft away.

The woman who requested the installation was initially unhappy with some parts of the installation. The original plans included a stub pole close to the crosswalk, but the stub pole was not installed at first. Even with the signal adjusted to the maximum volume, the woman was unable to hear the "Walk" indication when she was standing at the crosswalk location. A stub pole was later installed that allows a reduction in volume of the device and diminishes problems for neighbors as well.

Contacts

Barbara Fidler, ADA Coordinator
City of Dunedin
542 Main Street
Dunedin, FL 34698

AR0071999

Phone: 727-298-3030 x4dd
Fax: 727-298-3012
E-mail: bridler@dunedinfl.net

Michael Gust, P.E.
Division Dir. of Traffic Control
City of Dunedin, Traffic Division
822 Lake Haven Road
Dunedin, FL 34698
Phone: 727-298-3224
Fax: 727-298-3219
E-mail: mgust@dunedinfl.net

Case Study—Maryland DOT

Date: July 2003

History and Background

During the 1980s and 1990s, Maryland installed APSs of the cuckoo/chirp type at some locations throughout the state, including in Montgomery County, Frostburg, Cutherville, and Towson.

In response to concerns about mobility for persons who are visually impaired traveling through unique intersections, such as roundabouts, and the addition of the APS section in the MUTCD, Maryland DOT convened a committee in November 2000 to develop criteria for installation and prioritization plans for installation of APSs.

The committee consisted of representatives of the visually impaired community, traffic engineers, O&M specialists, local ADA coordinators, and DOT staff. The goals of the committee included

- Identifying factors affecting mobility of the visually impaired through intersections.
- Identifying and reconciling differences of approach to mobility issues within the visually impaired community, and
- Developing a rating and prioritizing process for APS.

AR0072000

Process and Procedure

The committee developed a prioritization checklist. This checklist has been used at approximately 60 intersections to date, with scores ranging from 14 to 46 out of a possible total of 60. While each crossing receives a rating, the highest rating for any crossing is used for the intersection.

At this time, Maryland is considering any intersection with a rating greater than 36 to be a high priority. Eleven intersections are rated at this level and either have had APS installed or are under design for installation.

Funding

Maryland considers an APS to be a traffic control device, and as such, funding comes from traffic control, highway construction, and federal funds.

Type of APS Used

Pushbutton integrated APS manufactured by Polara Engineering.

APS features include:

- Speech "Walk" message, with option of cuckoo/chirp if desired for a specific location;
- Vibrotactile "Walk" indication;
- Pushbutton locator tone;
- Tactile arrow;
- Actuation indicator;
- Pushbutton information message in response to extended button press; and
- Automatic volume adjustment in response to ambient noise levels.

Maryland is also testing and evaluating equipment from other manufacturers.

First Intersection with APS Example

The first installation example, Lord Raven and Taylor, is a large intersection with right-turn islands, heavy traffic volumes, and left-turn lanes on all approaches (Figures 9-12 and 9-13).

Existing poles were used at this location with channelizing islands and uncontrolled right-turn lanes in three of the four quadrants.

AR0072001

The "Walk" indication is a speech message. The volume levels of the APS were carefully adjusted to prevent the "Walk" indication from being audible to pedestrians before they crossed the right-turn lane. The speaker is blocked on the side away from the intersection. However, wind, humidity, and large trucks can affect the sound levels, and the signals may be audible from the sidewalk under certain conditions. In this case, the person who requested the signals is familiar with the geometry.

Figure 9-12. Two APSs are mounted on the existing pole on this island.

Figure 9-13. APS as seen from right-turn lane crossing.

Second Intersection with APS Example

The second installation, Loch Raven and Glen Keith, is an intersection with low side-street volumes. The APS is for crossing the major street (Loch Raven) only. There are no pedestrian indications to cross the minor street (Glen Keith); thus, APSs were not installed for those crossings. The major street is quite wide, with a median island and a stop sign controlled service road along the west side of Loch Raven. Again, the volumes needed to be carefully adjusted. A

AR0072002

vehicular signal pole was used for one APS, but others were located close to the crosswalk on pedestrian signal poles (Figures 9-14 through 9-16).

Figure 9-14 APS installed on pedestrian signal pole.

Figure 9-15. View across Loch Raven toward two median islands and stop sign controlled service road.

AR0072003

Figure 9-16. APS installed on signal pole beside crosswalk waiting location.

Installation Issues

Edward Paulis of the Office of Traffic and Safety states that the location of pushbuttons and other APS equipment is of high importance in providing a properly operating system for pedestrians who are visually impaired. In many cases, it is not desirable to use only existing poles for the installation of APS. The installation of additional pedestal poles is often necessary to ensure the proper location of APS relative to crosswalks and curb cuts.

Adjusting the initial volume levels has been an issue. Obtaining the proper balance between the needs of the persons who are visually impaired and the surrounding community, while not presenting misleading information to pedestrians, has proved to be difficult. Complicating the process are uncontrollable factors—namely, traffic noise and weather conditions, such as wind and rain.

Maintenance

There have been some failures of the control boards, but these may not be excessive when considering that the equipment is a new and of relatively recent design, and that new technology often has growing pains.

Evaluation

No formal evaluation has been conducted of installations. Most individuals who have requested the installations seem to be pleased.

AR0072004

Contacts

Edward T. Paulis, Jr., Office of Traffic and Safety

Maryland State Highway Administration

7491 Connelley Drive

Hanover, MD 21076

Phone: 410-787-4092

E-mail: epaulis@sha.state.md.us

Case Study—Charlotte, North Carolina

Date: July 2003

History and Background

Charlotte began installing pushbutton-integrated APSs in 1999 after discussions with the Charlotte/Mecklenburg Advocacy Council of People with Disabilities Committee. Approximately 12 intersections are now outfitted with 42 pushbutton-integrated APS devices. Before that, pedhead-mounted APSs had been installed upon request; current staff are not sure when those devices were installed or how the decision was reached to install them. They state that they are replacing current "chirpers" with pushbutton-integrated devices.

O&M specialists helped evaluate APS products in advance and made recommendations to engineers.

Figure 9-17. An early Polara installation in Charlotte.

AR0072005

Process and Procedure

APSs are requested by citizens and installed after review by staff of Metrolina Association for the Blind. In general, devices are installed in the order of request, depending on how much construction is involved.

The Charlotte/Mecklenburg Advocacy Council for People with Disabilities Committee and the Metrolina Association for the Blind serve as liaisons between the person who is visually impaired and the city.

Funding

The city council approved $95,000 in a restricted fund that is earned over year to year for purchase of equipment. The installation cost is covered in the normal budget. The public and individuals who are blind were involved in making the request for funding and getting it approved.

APS Type and Features

Pedhead mounted devices before 1999

Pushbutton-integrated devices from Polara Engineering since July 1998 (see Figure 9-17).

APS features (pushbutton-integrated device installations) include

- Speech "Walk" indication,
- Vibrotactile "Walk" indication,
- Pushbutton locator tone,
- Tactile arrow,
- Actuation indicator,
- Pushbutton information message in response to an extended button press, and
- Automatic volume adjustment in response to ambient sound

Installation Issues

The first generation Polara device did not accommodate pretimed or "ped recall" locations. It was designed to look for a logic common signal from the controller. Using instructions provided by Polara, city technicians in the signal shop modified the printed circuit board, including adding a resistor and two jumpers. This being done, the devices were usable in those situations.

AR0072006

A simple jumper setting has addressed this problem with the newer Polara product. The first generation Polara (installed at four locations) was also more labor intensive to install. Installers drilled holes in the top of the device to accept conduit on wood pole locations.

The newer version Polara Navigator has addressed all installation concerns (Figure 9-18).

Figure 9-18. Recent Polara Navigator installation.

When it is necessary to install new poles to locate the device more appropriately, it takes longer and requires more funds because traffic engineering has to coordinate with various departments to fix curb ramps and work around other utilities. Installation can be time-consuming when a new pole is needed.

Maintenance

No problems reported.

In early installations where two devices were on the same metal pole, it was possible to feel the vibration during the "Walk" signal on both devices at the same time (separate walk phases). This was solved by insulating between the device and pole. A speaker problem was resolved by improving the installation method through the efforts of the city electronics tech and the manufacturer.

AR0072007

Evaluation

The Public Service Department has no complaints regarding the devices. However, the staff of Metrolina Association for the Blind received some complaints about the noise level of the locator tones, especially in residential areas. The volume can easily be adjusted.

The City of Charlotte placed in the top 10 U.S. cities in the Accessible America contest a year ago and in the top seven this past year. Metrolina Association for the Blind has provided very favorable input and review of this project. Communication between all agencies involved has made this project a success.

Contacts

Tamara (Tammy) Drozd, Signal System Specialist
City of Charlotte NC
600 East Fourth Street, Charlotte, NC, 28202-2858
Phone: 704-336-4385
Fax: 704-336-4100
E-mail: tdrozd@ci.charlotte.nc.us

Case Study—Atlanta, Georgia

Date: May 2003

History and Background

Atlanta has installed APSs upon specific request since 1992. Until April 2003, all devices installed had been pedhead-mounted devices. The city is evaluating pushbutton-integrated devices as part of a research project. There have been requests from citizens who are blind for devices with pushbutton locator tones at pushbutton actuated locations; however, the city has not generally installed them to date.

Process and Procedure

Individuals who are blind or visually impaired make a request to the traffic engineering department. The engineer evaluates the intersection and current timing and signalization. He may meet the blind person and an O&M specialist (usually from the Center for the Visually Impaired) at the intersection to discuss the problems.

Requests are prioritized by date of request and volume of traffic.

AR0072008

If the request is for an APS at a signalized intersection and devices are in stock, they can usually be installed in less than a month.

Funding

Funding comes from city traffic engineering funds; however, some private developers have paid for street improvements as part of a development project.

APS Type and Features

Pedhead-mounted devices from IDC/US Traffic are installed at approximately 15 intersections (Figure 9-19).

APS features include

- "Walk" indication—cuckoo/chirp,
- No pushbutton locator tone, and
- No automatic volume adjustment.

Atlanta has recently installed pushbutton-integrated APSs from Polara Engineering and a receiver-based system from Relume as part of a research project.

Figure 9-19. Pedhead-mounted speaker mounted on the pole as typically installed in Atlanta.

Date Installed

1992 to present

Installation Issues

Pedhead-mounted devices are simple to wire and install on the pole or on the pedhead.

AR0072009

The signal shop found the pushbutton-integrated device to be very difficult to install, requiring additional wiring and careful adjustment. After installation, the control unit of one APS was malfunctioning and the device was not sounding; the manufacturer replaced the unit.

Maintenance

Many pedhead-mounted units have been functioning for 5 to 10 years or more without problems. Recently, two units failed two consecutive times until engineers found that water was getting into the devices, probably through the speaker holes. They recommend rechecking the seals and mounting the speakers under the pushbuttons to protect them from the impact of heavy rain.

In general, Atlanta's traffic engineering department considers pedhead mounted devices very reliable and serviceable. Vandalism has not been a problem.

Evaluation

The traffic engineering department has received some complaints about the noise levels of pedhead mounted speakers (ones currently installed do not have automatic volume adjustment), but complaints have usually stopped a couple weeks after installation. At times, the department has adjusted the volume after installation.

The city looked at pushbutton-integrated devices with locator tones to address concerns about finding the pushbuttons by persons who are blind. However, the signal maintenance department prefers to install the pedhead-mounted devices, as long as there are no complaints.

Contacts

Santana Herrera, Traffic Systems Engineer
City of Atlanta Traffic and Transportation
68 Mitchell Street, SW
4900 City Hall South, Atlanta, GA 30303
Phone: 404 330 6591
E-mail: sherrera@ci.atlanta.ga.us

Case Study—Halifax, Nova Scotia

Date: April 2005

AR0072010

History and Background

Halifax has been using pedhead-mounted APSs since 1998. Pushbutton-integrated units were introduced in 2003 and are now in operation at five intersections. The APS units were installed in response to requests from the Canadian National Institute for the Blind (CNIB). All installations were retrofits to existing signals and were performed by a contractor.

Process and Procedure

Requests for APS installations come from the CNIB, which typically provides the city with a list of intersections where they would like APS installed. The city reviews the list and selects intersections for APS installations based on design of the intersection and available funding. If an intersection is suitable for pushbutton integrated units, Novax Vibrawalks are installed in addition to the overhead speaker. Factors that affect the decision about pushbuttons include suitability of pole location and availability of wiring.

Funding

APS installations in Halifax were funded by the capital budget from a specified fund for pedestrian safety issues. There was also a federal 50-50 funding match in 2004 for APS installations.

APS Type and Features

Pedhead mounted and pushbutton integrated devices from Novax Industries (DS2000 for overhead speaker units and Novax Vibrawalk for pushbuttons).

APS features on installations where pushbutton-integrated devices are installed) include:

- Vibrotactile "Walk" indication,
- Audible "Walk" indication only in response to an extended button press;
- Pushbutton locator tone;
- Tactile arrow;
- Actuation indicator; and
- Automatic volume adjustment in response to ambient sound.

Installation Issues

The APS speaker is mounted on top of the pedestrian head and faces across the street. A typical configuration for a crossing in Halifax involves two APS speakers, one at each end of the

AR0072011

crossing. The volume is adjusted so the sound only reaches three-fourths of the way across the street; this is intended to enable the user to detect the second APS when part way across the street, which will provide guidance on the proper direction. Setups with only one APS per crossing generated numerous noise complaints because the volume has to be higher to be heard across the street.

Most APSs are installed on aluminum poles, but some locations have wooden poles, as shown in Figure 9-20. The overhead APS devices on wooden poles are clamped to the signal arm or pedestrian head. Novax pushbuttons typically are wired through the back of the device. To wire the pushbuttons, 0.5-in. PVC conduit is strapped to the wooden pole, and an LB or liquid tight flex pipe runs into a hole drilled into the bottom of the pushbutton.

The overhead speakers are typically mounted to the pedestrian signal head. When the APS speakers were mounted into plastic (polycarbonate) signal heads, strong winds would push on the speaker and crack off the thin plastic of the signal head into which the speaker was mounted. Where there were plastic pedestrian signal heads, the speaker was mounted on the pole or some other metal or wood surface, as shown in Figure 9-21. Pedestrian signal heads made of aluminum did not have this issue. In areas with less of a problem with strong winds, this may not be a concern.

Availability of wiring at the pole is an important issue. If sufficient wiring is installed with the signal, installing an APS later is much easier. Pulling wire later can become prohibitively expensive.

AR0072012

Figure 9-20. APS pushbutton mounted on wooden pole, showing conduit installed into the bottom of the pushbutton device.

Figure 9-21. APS speaker mounted on signal head support arm.

Maintenance

The city handles the maintenance of the devices. As the city is near the ocean, moisture and salt in the air is a problem, as is salt placed on the roads for deicing. The overhead speakers generally start having problems at the 5-year mark as a result of salt and moisture. The speakers usually last from 5 to 10 years. The Vibrawalk pushbutton devices have not evidenced any problems during the 2 years they have been in service.

AR0072013

Cold Weather Issues

Snow is a constant problem in the Halifax climate. Snow banks, when not cleared properly, can prevent access to the pushbuttons. Pole placement is an important issue at intersections where pushbuttons are used, so that all pedestrians can reach the pushbutton. If pushbuttons are located to the immediate left or right of the crosswalk, there is a better chance pedestrians will be able to reach the button and that the sidewalk near the button will be cleared properly. Because Halifax uses miniplows for clearing sidewalks, the city believes the action of clearing snow could cause problems for stub poles (e.g., knocking them over); the use of stub poles is thus generally avoided.

Other problems are caused by freezing temperatures. Pulling additional wire for a retrofit installation cannot be done in the winter due to ice in the wire conduits. Extreme cold can cause some signals cabinets to fail and thus the APS to fail.

Evaluation

The initial installations of pedhead-mounted APS installations were configured to give the audible "Walk" tone at every cycle. The city received complaints about noise, especially in the summer months when people had their windows open. Because of concerns about noise, these units were set to be off (give no audible indication) from 11:00 pm to 6:00 am.

The pushbutton integrated installations, as installed in Halifax, can be accessed 24 hours per day; the "Walk" indication is provided only when the button is held for 3 s or more. No feedback on the pushbutton integrated devices was reported.

Contact

Michael Filippone
Traffic Signal Supervisor
City of Halifax, Nova Scotia
Phone: 902-490-4971
Email: filippm@halifax.ca

Case Study—Waukesha, Wisconsin

Dates: April 2005

AR0072014

History and Background

Waukesha has been using pushbutton-integrated APS devices with speech messages since 2002. Prior to that, they used overhead speaker units that provided a cuckoo or chirp, but that were not activated by pushbutton. There are approximately 84 pushbutton-integrated APSs in service in Waukesha, most of which were installed during summer 2004. The move to pushbutton integrated devices was motivated by requests from the local Blind community and the Sight Loss Network Support Group, who introduced the city to the speech message capability of new types of APSs.

Process and Procedure

The initial APS installations were done in one large campaign in the summer of 2004. These installations were scattered about town, but mainly focused on center city intersections. Another installation campaign—of approximately 100 units—is planned, which will focus on installing devices at the rest of the center city intersections and moving outward from there. Current Waukesha policy states that any new signal installation will include an APS.

Funding

APSs in Waukesha are currently fully funded by the Waukesha County Community Development Block Grant Program, up to a specified amount per year. This funding includes time and materials.

APS Type and Features

Pushbutton-integrated devices from Polara Engineering (Navigator four-wire devices with remote configuration capability).

APS features include:

- Speech "Walk" indication;
- Vibrotactile "Walk" indication;
- Pushbutton locator tone;
- Tactile arrow;
- Actuation indicator—click and light;
- Pushbutton information message, called by extended button press; and
- Automatic volume adjustment in response to ambient sound.

AR0072015

Installation Issues

Installation of the devices is done by city staff. If a signal to be retrofitted already has pushbuttons, this greatly facilitates the APS installation. However, the four-wire models still necessitate pulling extra wire.

Most of the signal poles are steel and accommodate the APS devices fairly easily. The city attempts to have two poles per corner for every intersection. Sometimes stub poles are necessary, if the signal poles are not close enough to the crosswalk. In one case, a lamppost was used successfully as a mount for an APS unit (Figure 9-22), since aesthetics of the area placed restrictions on installing additional poles.

All but one of the existing APS installations were retrofits. However, all new signals will include APS devices.

Figure 9-22. APS mounted on lamppost.

Maintenance

There have been no maintenance issues for the APS units in their first year of service.

AR0072016

There have been no significant issues related cold weather. Waukesha uses miniplows for removing snow from sidewalks, and the manager of city snow plowing has, however, expressed concern that stub poles may be damaged by these plows.

Evaluation

Devices in residential areas initially drew noise complaints. The city had been leaving the sound settings at the factory default. Once the volume was turned down, there were no complaints.

Contact

Cheri Shook

City of Waukesha, Wisconsin

Phone: 262-524-3590

Email: cshook@ci.waukesha.wi.us

Case Study—Ann Arbor, Michigan

Date: April 2005

History and Background

Ann Arbor has been using pushbutton-integrated APSs since 2001. Five were installed that year, and some have been added since then.

Process and Procedure

APSs are installed on the basis of recommendations from the Ann Arbor Commission on Disability Issues.

Funding

Funding approval for APS devices comes through the City Council. The money is budgeted from the Major Street Fund, which is a non-transportation fund. Currently, $50,000 is designated for the purchase, installation, and maintenance of five APS devices.

APS Type and Features

Pushbutton integrated devices (Navigator) from Polara Engineering.

AR0072017

APS features include

- "Walk" indication—speech message.
- Vibrotactile "Walk" indication.
- Push-button locator tone.
- Tactile arrow.
- Actuation indicator—tone and light.
- Push-button information message called by extended button press; and
- Automatic volume adjustment in response to ambient sound levels

Installation Issues

All APS installations were retrofits to existing signals on steel poles, and existing wiring was sufficient to accommodate the APS installations. Some units are installed on pedestrian signal poles, and some are mounted on the vertical pole of a signal mast arm.

Maintenance

When many of the APS units began to malfunction in 2004, the city sent them back to the manufacturer for repair/replacement. The problem was observed to be rusting of the devices.

Vandalism was also an issue. There were several instances where the unit was knocked off the pole. The attachment bolts were replaced with bigger diameter bolts.

Locator tone effect was seen from cold weather conditions. However, the use of salt may have contributed to rust that was experienced. The city engineers do not believe that the winter conditions contributed much to the problems.

Evaluation

There were several complaints about the noise of the locator tones, especially in the summer when people keep windows open. The locator tone volume was lowered in response, and where there were two APS units on a single pole, one of the locator tones was switched off to control noise. To explain how the APS devices work, the city publicized the devices through a newspaper article and local cable broadcast.

Contact

Les Sipowski

Senior Project Manager, City of Ann Arbor Public Services Department

AR0072018

Ann Arbor, Michigan
Phone: 734-996-3286
Email: LSipowski@ci.ann-arbor.mi.us

CHAPTER 10

International Practice

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AR0072020

The information in this chapter is based primarily on visits Janet Barlow and Billie Louise Bentzen made during 2001 to four countries whose use of APSs has been long term, extensive, systematic, and positively accepted by blind pedestrians and traffic engineers. Many other countries have a long history of using accessible pedestrian signals. This chapter is not an attempt to review all international experience.

During trips to Japan, Sweden, Australia, and Denmark, the authors met with traffic engineers, O&M specialists, APS manufacturers, and representatives of consumer groups to discuss APSs. Installations were observed and photographed. At times Barlow and Bentzen, both of whom have unimpaired vision, traveled under blindfold and crossed intricate intersections using typical O&M techniques and APSs.

AR0072021

Japan

Functioning of Pedestrian Signals

- A "red man, green man" signal is used (Figure 10-1).
- Pedestrian signal timing:
  - "Walk" or "green man" timing is figured based on walking time of 1 m/s and is calculated to the centerline of the intersection.
  - Flashing "Don't Walk" timing was reported to be based on a walking speed of 1 m/s; however, this timing seemed to average about 3 s regardless of the width of streets.

Figure 10-1. "Red man, green man" type signal used in Japan.

- Mr. Sugimoto at the Japanese National Police Agency (JPNA), which manages all intersections, stated that intersection timing always includes a pedestrian phase, and at locations with vehicular actuation, pedestrian buttons are provided to lengthen the phase and/or actuate an audible signal.
- Many intersections have pretimed signalization.

AR0072022

Intersection Geometry

Streets are generally wide. Driving is on the left.

Even where there is a very wide median, it is not considered or used as a pedestrian refuge.

Most intersections have pedestrian crosswalks; a fence is typically used where crossing is prohibited.

At areas with high levels of pedestrian traffic, there may be exclusive pedestrian phasing. Most intersections with exclusive pedestrian phasing have audible signals.

Japan has very few nonsignalized turn lanes or pork-chop-type islands.

Tactile walking surface indicators, such as "dot tiles" (called detectable warnings in the United States) are ubiquitous in urban areas and have been in use since the 1960s to indicate danger or a need to make a travel decision. Dot tiles are used in combination with "bar tiles," a directional surface (Figure 10-2). Together they provide a continuously demarcated route for pedestrians who are blind.

Figure 10-2. At this intersection, a chain fence is used where crossing is prohibited, and bar tiles indicate a travel route.

Number of APSs

Japan has 170,000 signalized intersections, 10,570 of which have APSs.
There are a variety of APS systems, most with sound broadcast from the pedestrian signal head (pedhead). A number of melodies and tones are used to indicate the walk interval.

AR0072023

The tone or melody varies from municipality to municipality; each is allowed to choose its own. JPNA has also developed a receiver-based system called PICS.

- 7,978 intersections have cuckoo or chirp sounds from the pedhead during the walk interval (Figure 10-3).
- 2,592 intersections have melodies from the pedhead during the walk interval.
- 300 intersections in 20 cities have an infrared APS system (PICS-A) compatible with the Smith-Kettlewell/Talking Signs standard, as developed and evaluated under the direction of JPNA.

Figure 10-3. Pedhead with APS speaker is mounted on a mast arm overhanging the crosswalk below.

Functioning of Broadcast APSs

Cuckoo/Chirp

- Cuckoo and chirp are the most common sounds for a walk interval.
- An alternating signal is now the recommended signal and costs a "trivial amount" more than a nonalternating signal. The signal usually uses birdcalls. They are beginning to install alternating signals with different sounds (chirp and chirp-chirp) on different sides of the street, to improve beaconing.

AR0072024

Melody

- A variety of melodies is broadcast into the intersection, with a change in melody during the clearance interval.
- The sound was often quite loud; sometimes it is possible to hear the melody of one intersection from a block away.

Speech Message

- The speech message was "Walk" followed by the street name in Japanese.
- The speaker in the pedestrian signal head may be pointed straight down toward the pedestrian below (Figure 10-4).

Other Characteristics

- Some APSs in Tokyo used increased repetition rate of cuckoo or chirp during the clearance interval.
- Very few APSs had locator tones at the pushbutton.
- The APS may have a sound for the pedestrian clearance interval. Yokohama used a sound like that of an emergency vehicle.
- It is fairly common in Tokyo to center the APS speaker over the crosswalk on a mast arm extending from the pole.
- The APS sound is usually turned off at 8:00 p.m. because nearby residents are bothered by the noise.

Figure 10-4. Japanese pedhead with APS speaker pointing straight down toward the pedestrian below.

AR0072025

Functioning of PICS System

The PICS system is being developed, evaluated, and installed under the direction of JPNA.

- The system communicates from an infrared transmitter called an "IR station" and a short-range radio transmitter installed at the intersection to a receiver carried by pedestrians.
- There are two types of PICS systems: PICS-A and PICS-B.

PICS-A Speech System

The PICS-A speech system (Figure 10-5) provides visually impaired pedestrians with pedestrian traffic signal information and location information about bus stops and public facilities. As the traveler approaches within 10 m of the intersection where the PICS-A system is installed, an FM radio message is received by the hybrid radio/IR receiver in either a speech or vibration mode. The vibration alerts users to the presence of the transmitted signal. The speech message identifies the intersection. When pedestrians arrive at a corner and are within the crosswalk, they aim the receiver aimed toward the infrared transmitter on the opposite corner to receive IR-transmitted speech information about the status of the pedestrian signal. A third function extends the pedestrian phase when a button on the receiver is pushed.

Figure 10-5. The PICS-A system is shown with four infrared transmitters mounted on a horizontal mast arm.

AR0072026

PICS-B Image System

The PICS-B image system extends green lights and provides route guidance and information about the surrounding area on a visual display for people with mobility or hearing impairments. Portable receivers (transceivers) are pointed at IR stations located near pedestrian traffic signals to extend the pedestrian signal timing, make emergency contacts, and obtain route guidance and information about the surrounding area.

Comments

The authors found the variety of audiotactual speakers (loudly broadcasting musical sounds or birdcalls) to be confusing and distracting. Although these systems have been in use in Japan for about 40 years, there is growing concern in Japan about the noise pollution they cause.

The PICS-A system provided signal and directional guidance quite efficiently. Radio-transmitted information was useful for general intersection information on approach. A large array of transmitters is required for this system, as shown in Figure 10-5.

- A head-mounted receiver has now been developed by Mitsubishi Precision Corp. Barlow and Bentzen used this receiver at one intersection and found it effective.
- The standard receiver is handheld and can hang on a neck cord or be stowed in a pocket when not in use.

Sources of information

Kunio Kuraoka, Mitsubishi Precision Co., Ltd. Tokyo

Takahiro Nakamura, Okayama Prefectural University, Okayama

Hirohiko Okubo, Mitsubishi Precision Co., Ltd., Tokyo

Michiko Shinriza, Orientation and Mobility Specialist, Tokyo

Osamu Sueda, Rehabilitation Engineering Society of Japan and University of Tokushima

Miako Sugimoto, National Police Agency, Government of Japan, Tokyo

Masaki Tanaka, Okayama Prefectural University, Okayama

AR0072027

Australia

Functioning of Pedestrian Signals

Pedestrian Signals

- Red and green man signals are used, with the red man set to flash during the flashing "Don't Walk" interval.
- All pedestrian pushbuttons were located in very standardized locations, on the side of the crosswalk away from the parallel street, aligned with the crosswalk line, about 0.5 to 1.0 m from the curb line (Figure 10-6). Most fixed time intersections in downtown Sydney had pushbuttons with audible and vibrotactile features.

Pedestrian Signal Timing

The "Walk" and flashing "Don't Walk" were similar to the U.S. system, with clearance interval timed at 1 m/s.

Intersection Geometry

Streets can be wide and complex, sometimes having narrow medians and channelized turn lanes, which were signalized in some locations.

Roundabouts are used extensively, and O&M specialists and blind travelers state that roundabouts are a barrier to travel.

Detectable warnings or "TWSIs" (tactile walking surface indicators) are used to define the edge of the street on the curb ramp, but they are not consistently installed from state to state. The edge of the TWSI is intended to be aligned perpendicular to the crosswalk direction, to provide additional directional information to blind pedestrians.

AR0072028

Figure 10-6. Signalized left-turn lane with APS mounted close to the crosswalk locations. Three APSs are on the splitter island, one for each crossing.

Number of APSs

Each state is responsible for its own area.

The overall number was not available.

Since the 1980s, APSs have been fairly extensively installed in areas where there is pedestrian traffic.

APS Functioning

A pushbutton integrated type of signal is used. The pushbutton and sound are standardized nationally.

There are several APS manufacturers in the Australian market, but the pole mounted control box overhead was the only visible difference. All pushbuttons looked identical, whether they had APS or not, except that those with APS features had an additional raised bar on the arrow to indicate that they had APS (Figure 10-7). All pushbuttons with audiotactile features functioned identically.

AR0072029

Figure 10-7. This APS has a tactile arrow within a larger visible arrow. A raised bar on the tactile arrow indicates that this is an APS. Other features include a locator tone and audible and vibrotactile "Walk" indication.

Locator Tone

The locator tone has a repetition rate of once every 2 s.

The "Walk" indication has the following characteristics:

- Fast repetition of low-frequency thumping sound during the walk interval.
- May have the capability to be set so that the "Walk" sound is limited to 8 s even when the "Walk" indication is longer.
- The alert tone at the beginning of the "Walk" indication is set to sound at 14 dB above ambient sound.
- All devices respond to ambient sound, both for the locator tone and the "Walk" indication.
- Vibrotactile information at the arrow panel pulses at the same rate as the audible tone.
- Placement has been standardized at the line of the crosswalk away from the center of the intersection. The orientation of the face of the APS varied (Figure 4-9). The speaker for the APS is at face of the arrow, so sound emanates from the face of the unit. Orientation of the device can make a difference in hearing the APS when approaching or from the street.

AR0072030

- APSs are sometimes turned off at night due to neighbors' complaints about noise.

Comments

The standard location of the pushbutton, located beside the waiting location for the crossing, provided a clear indication of which crossing the APS was signaling (Figure 10-8). There was no need for different sounds for different directions of travel. Even on pork-chop-type islands with three devices sounding, it was possible to distinguish the location and crossing being signaled.

The placement of the tactile arrows was inconsistent, which caused confusion in some cases (Figure 10-9).

Figure 10-8. Typical APS location in relation to the crosswalk and sidewalk. Australian curb ramp standards allow a steeper slope than allowed by U.S. standards.

AR0072031

Figure 10-9. Installation of tactile arrows was not consistent and provided misleading information in some cases.

Sources of Information

George Carnazolla, Transport SA, Adelaide

Gayle Clark, Orientation and Mobility Specialist, Guide Dogs Association of SA and NT, Inc., Adelaide

Susan Lockhart, Orientation and Mobility Specialist, Sydney

Murray Mountain, Access Design Solutions, Melbourne

Bob and Jelena Panich, Bob Panich Consultancy, Ryde (Sydney)

Stephen Purtill, Specifications and Standards, VIC Roads, Melbourne

John Samperi, Signal Engineer

Roley Stuart, Client Services Manager, Guide Dogs Association of SA and NT, Inc., Adelaide

Jack Vankuyk, Traffic Signals Supervisor, RTA Operations, Sydney

AR0072032

Sweden

Functioning of Pedestrian Signals

Pedestrian Signals

- Sweden uses a "red man, green man" symbol signal.
- Use of a flashing or clearance interval seems to be a local decision. In Göteborg, there is no flashing interval, while in Skövde, a flashing "red man" is used. Pedestrian actuation is common, and the location of the pushbutton is fairly standard, approximately 0.5 to 1.0 m from the curb line and near the farthest crosswalk line from the center of the intersection.

Pedestrian Signal Timing

- Pedestrians rarely had to cross more than two lanes without coming to an island or median.
- The walk interval is timed according to the width of the street, using 1 m/s, with a change interval of about 4 s.

Intersection Geometry

In cities, streets were generally narrow, with lots of islands. In general, medians or islands separated traffic. Most channelized turn lanes were signalized.

Arterials typically have bicycle lanes on both sides of the street (Figure 10-10). Bicycle lanes are usually signalized separately, using small ball signals and separate pushbutton actuation.

AR0072033

There are no curb ramps as such; all curbs at corners are typically 3 to 4 cm high, which is said to be acceptable to persons with mobility impairments.

Figure 10-10. This intersection in Göteborg, Sweden, has a bike lane (seen on left side of photo) with its own signal head, and an APS is mounted on the same pole.

Number of APSs

The overall number of APSs was not available. APSs have been in use in Sweden since the 1960s and are APSs are fairly extensively installed in downtown areas. In suburban areas, signals are installed at the request of persons who are blind or visually impaired and may be installed only at some crosswalks of the intersection, depending on the request.

APS Functioning

There is no Swedish standard for APSs, but most APSs have a ticking sound that repeats at 60 pulses per minute for the locator tone and 600 pulses per minute for the "Walk" interval.

The APS is typically placed on a signal pole or stub pole near the edge of the crosswalk furthest from the intersection, about 0.5 m from the curb.

Signal volume is typically set to be audible 3 m from the pole. Signals respond to ambient sound, within a range set by the installer. APS can also be set to a constant volume.

AR0072034

Each intersection had a number of APSs and pedestrian signal heads because there was an APS on each island/median; many medians had an additional pedhead as well (Figure 10-11).

The APS is differentiated from the standard pedestrian pushbutton by different colored panels on the side of the device.

A raised tactile arrow on top of the device points across the crosswalk (Figures 10-12 and 10-13). At median locations where the signal actuated a simultaneous "Walk" for pedestrians crossing in both directions from the median, arrowheads were on both ends of the shaft.

Signals were of a type that could include vibrotactile information through a separate button on the bottom of the device. However, that feature was not commonly provided.

Figure 10-11. This street crossing in Göteborg, Sweden, includes two islands and numerous APSs (indicated in the photo by circles or half-circles).

AR0072035

Figure 10-12. The Swedish APS displays a tactile map on one side.

Figure 10-13. A pedestrian uses the tactile map.

Additional information

Most devices had a crosswalk map feature on the side of the device, indicating the number of vehicular or bicycle lanes to be crossed and, where present, the locations of islands or transit rails across the crosswalk. However, Kaj Nordquist of the Swedish Blind Association stated that most blind people in Sweden only travel on familiar routes so the tactile maps are not used much. He stated that orientation to new routes is generally available to blind citizens of Sweden.

AR0072036

Comments

Although there were a number of APSs at each intersection, it was possible to locate the devices and use the "Walk" indication of the device to cross efficiently.

Because of the precise location of each APS, the information provided was unambiguous as to which crosswalk had the walk interval.

A pedestrian waiting to cross could always be within arm's reach of the APS, so there was no question regarding which APS was sounding during the walk interval.

Sources of Information

Jan Lund, Prisma Teknik, Tibro

Roger Peterson, Prisma Teknik, Tibro

Bengt Ekdahl, Traffic Engineering, Göteborg

Kay Nordquist, Swedish Blind Society, Stockholm

Denmark

Functioning of Pedestrian Signals

Denmark uses a "red man, green man" symbol signal.

The length of the walk interval varies by time of day. The walk interval is usually calculated using a walking speed formula of 1.3 m/s, but up to 1.5 m/s can be used.

There is no flashing clearance interval.

Most of the central business district has fixed time signals.

AR0072037

Intersection Geometry

Streets typically were narrow (by U.S. standards) with a great deal of pedestrian and bicycle traffic. Streets included wide bike lanes, often slightly raised from the street level.

There are no unsignalized right-turn lanes for cars, but there are right-turn lanes for bicycles.

Curbs are typically 3 to 4 cm high, which is said to be acceptable to persons with mobility impairments.

Detectable warning surfaces are installed in some locations at the curb, usually in a 1-ft band. There are no detectable warnings at edges of cut-through medians.

Number of APSs

APSs are very common in central business districts; outside of the central business district, APSs are installed at the request of the Danish Blind Association and only at requested crosswalks.

Tactile arrows are installed on the top of the APS (Figures 10-14 and 10-15).

Figure 10-14. Illustration of tactile arrow.

AR0072038

Figure 10-15. The tactile arrow on the APS in Denmark was on top of the device, which was located on a pole near the crosswalk line. Most intersections were pretimed, so no pushbutton was included on this device.

APS Functioning

Most installations have audible signals coming from devices at pushbutton height, whether they have pushbuttons or the signals are fixed time; overhead beaconing speaker devices are currently installed in combination with pushbutton locator tones at a few trial locations.

Signals must conform to a national standard.

The locator tone and "Walk" indication have the following characteristics:

- Both are 880-Hz square or sawtooth wave tones. The locator tone is pulsed at 30/min, and the "Walk" indication pulsed faster.
- The Danish standard requires that the "Walk" indication be five times the rate of the locator tone.
- The pulse length of the locator tone is 400 ms, and the pulse length of the "Walk" tone is 200 ms.

Volume

All APSs respond to ambient sound, unless special permission is received to set the signal to a constant low level.

AR0072039

- Although the standard for setting the volume is that the signal should be audible 3 m from the pole, the signal was quite often audible as far as 10 m from the pole.
- The installer determines the volume by listening.

Additional Information

Location

The APSs were located consistently at the end of the crosswalk line so the location tone could be used to line up for crossing.

The consistency of location is considered very important: the APS is installed no more than 0.6 m from the curb line, and the horizontal distance from the crosswalk line is not more than 0.3 m.

Stub poles are installed if signal poles are not available in the appropriate location.

Crosswalk Information

A knob on the end of the bar indicates the far side of the street, and additional knobs indicate the number of islands or medians that will be encountered prior to the far side.

All APS devices have a bar aligned with the crosswalk, which functions as an arrow, on top of the device (Figure 10-16).

Other

Where there is a pushbutton, it is usually located on the backside of the APS, toward the pole, with sufficient space for fingers to reach between the APS and the pole.

In general, there is no need to push a button, as most intersections have pedestrian phases.

AR0072040

Figure 10-16. Danish APS with tactile bar (arrow) mounted on the top. The bar is aligned with the crosswalk, and two knobs at the end of the bar indicate a median and the far side of the street.

Comments

The locator tone was same tone as the "Walk" interval tone and of the same intensity. Repetition rates at some locations in Copenhagen did not seem to conform to the published standard.

At a multileg intersection, the APSs were very useful for crossing and alignment.

- APSs were very consistently located in relation to the crosswalk.
- The directional bar (arrow) was useful, as were the crosswalk maps on the side of the signals.
- Medians were cut through, without detectable warnings, but the sound of the APS at the median gave some information about the median location.

The representative of the Danish Blind Association mentioned that some people have expressed concerns that the signals were too loud, causing noise pollution.

Contact

Mohammed Abazza, Traffic Engineer, Copenhagen

Neils Christian Johanneson, Siemens

Inge Kyhl, Orientation and Mobility Specialist, Institute for the Blind and Partially Sighted in Denmark

Mehta Rohe, Danish Blind Association

Jørn Vammen, Signals Engineer, Danish Department of Transportation

AR0072041

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Abbreviations

ACB—American Council of the Blind

ADAAG—ADA Accessibility Guidelines

ADA—Americans with Disabilities Act

AER—Association for Education and Rehabilitation of the Blind and Visually Impaired

AGC—automatic gain control

CAC—citizens advisory committee

CBD—central business district

CDC—Center for Disease Control and Prevention

DOJ—Department of Justice

FHWA—Federal Highway Administration

GPS—global positioning system

LED—light-emitting diode

MMU—malfunction management unit

MUTCD—*Manual on Uniform Traffic Control Devices for Streets and Highways*

NCUTCD—National Committee on Uniform Traffic Control Devices

NEMA—National Electrical Manufacturers Association

NFB—National Federation of the Blind

NPRM—Notice of Proposed Rulemaking

O&M—orientation and mobility

pedheads—pedestrian signal heads

PROWAAC—Public Rights-of-Way Access Advisory Committee

PROWAG—*Public Rights-of-Way Accessibility Guidelines*

PUFFIN—Pedestrian user-friendly intelligent crossing

RTOR—right turn on red

TEA-21—Transportation Equity Act for the 21st Century

TWSI—truncated warning surface indicator

USDOT—U.S. Department of Transportation

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Appendix A—Current Guidelines

For the convenience of the reader, this appendix contains excerpts from the MUTCD (current and proposed language) and Draft PROWAG concerning guidance on accessible pedestrian signals (7, 2). The organization of this appendix is as follows.

Document	Dated	Sections Included in this Appendix	Starting Page in this Appendix
MUTCD 2003	November 2004	sections 4D.03, 4E.06, and 4E.09	A-2
NCUTCD approved changes to the next version of the MUTCD	June 30, 2006	sections 4A.02, 4D.03, 4E.06, 4E.08, and 4E.09	A-9
Draft PROWAG	November 25, 2005	Chapters R1 through R4	A-26

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Excerpts from MUTCD - 2003 Edition with Revision No. 1 Incorporated, dated November 2004

Section 4D.03 Provisions for Pedestrians

Support:

Chapter 4E contains additional information regarding pedestrian signals.

Standard:

The design and operation of traffic control signals shall take into consideration the needs of pedestrian as well as vehicular traffic.

If engineering judgment indicates the need for provisions for a given pedestrian movement, signal faces conveniently visible to pedestrians shall be provided by pedestrian signal heads or a signal face for an adjacent vehicular movement.

Guidance:

Safety considerations should include the installation, where appropriate, of accessible pedestrian signals (see Sections 4E.06 and 4E.09) that provide information in nonvisual format (such as audible tones, verbal messages, and/or vibrating surfaces).

Where pedestrian movements regularly occur, pedestrians should be provided with sufficient time to cross the roadway by adjusting the traffic control signal operation and timing to provide sufficient crossing time every cycle or by providing pedestrian detectors.

Option:

It is desirable to prohibit certain pedestrian movements at a traffic control signal, a PEDESTRIANS PROHIBITED (R9-3) or No Pedestrian Crossing (R9-3a) sign may be used (see Section 2B.44).

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Section 4E.06 Accessible Pedestrian Signals

Support:

The primary technique that pedestrians who have visual disabilities use to cross streets at signalized locations is to initiate their crossing when they hear the traffic in front of them stop and the traffic alongside them begin to move, corresponding to the onset of the green interval. This technique is effective at many signalized locations. The crossing environment is often sufficient to provide the information that pedestrians who have visual disabilities need to operate reasonably safely at a signalized location. Therefore, many signalized locations will not require any accessible pedestrian signals.

Guidance:

If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross reasonably safely and effectively, an engineering study should be conducted that considers the safety and effectiveness for pedestrians in general, as well as the information needs of pedestrians with visual disabilities.

Support:

The factors that might make crossing at a signalized location difficult for pedestrians who have visual disabilities include: increasingly quiet cars, right turn on red (which masks the beginning of the through phase), continuous right turn movements, complex signal operations, traffic circles, and wide streets. Further, low traffic volumes might make it difficult for pedestrians who have visual disabilities to discern signal phase changes.

Local organizations providing support services to pedestrians who have visual and/or hearing disabilities can often act as important advisors to the traffic engineer when consideration is being given to the installation of devices to assist such pedestrians. Additionally, orientation and mobility specialists or similar staff also might be able to provide a wide range of advice. The U.S. Access Board's Document A-37, "Accessible Pedestrian Signals," provides various techniques for making pedestrian signal information available to persons with visual disabilities (see Addresses for the address for the U.S. Access Board).

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Accessible pedestrian signals provide information in nonvisual format (such as audible tones, verbal messages, and/or vibrating surfaces).

Information regarding detectors for accessible pedestrian signals is found in Section 4E.09.

Standard:

When used, accessible pedestrian signals shall be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device.

Under stop-and-go operation, accessible pedestrian signals shall not be limited in operation by the time of day or day of week.

Guidance:

The installation of accessible pedestrian signals at signalized locations should be based on an engineering study, which should consider the following factors:

A. Potential demand for accessible pedestrian signals;
B. A request for accessible pedestrian signals;
C. Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;
D. The complexity of traffic signal phasing; and
E. The complexity of intersection geometry.

Support:

Technology that provides different sounds for each nonconcurrent signal phase has frequently been found to provide unambiguous information.

Standard:

When choosing audible tones, possible extraneous sources of sounds (such as wind, rain, vehicle back-up warnings, or birds) shall be considered in order to eliminate potential confusion to pedestrians who have visual disabilities.

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Guidance:

Audible pedestrian tones should be carefully selected to avoid misleading pedestrians who have visual disabilities when the following conditions exist:

A. Where there is an island that allows unsignalized right turns across a crosswalk between the island and the sidewalk.
B. Where multileg approaches or complex signal phasing require more than two pedestrian phases, such that it might be unclear which crosswalk is served by each audible tone.
C. At intersections where a diagonal pedestrian crossing is allowed, or where one street receives a WALKING PERSON (symbolizing WALK) signal indication simultaneously with another street.

Standard:

When accessible pedestrian signals have an audible tone(s), they shall have a tone for the walk interval. The audible tone(s) shall be audible from the beginning of the associated crosswalk. If the tone for the walk interval is similar to the pushbutton locator tone, the walk interval tone shall have a faster repetition rate than the associated pushbutton locator tone.

Support:

A pushbutton locator tone is a repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing, and that enables visually impaired pedestrians to locate the pushbutton (see Section 4E.09).

Guidance:

The accessible walk signal tone should be no louder than the locator tone, except when there is optional activation to provide a louder signal tone for a single pedestrian phase.

Automatic volume adjustment in response to ambient traffic sound level should be provided up to a maximum volume of 89 dBA. Where automatic volume adjustment is used, tones should be no more than 5 dBA louder than ambient sound. The A-weighted sound pressure level should conform to the requirements of "ISO 1996-1:1982" and "ISO

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1996-2:1987" (see Addresses for the address for the International Organization for Standards).

Standard:

When verbal messages are used to communicate the pedestrian interval, they shall provide a clear message that the walk interval is in effect, as well as to which crossing it applies.

The verbal message that is provided at regular intervals throughout the timing of the walk interval shall be the term "walk sign," which may be followed by the name of the street to be crossed.

A verbal message is not required at times when the walk interval is not timing, but, if provided:

A. It shall be the term "wait."

B. It need not be repeated for the entire time that the walk interval is not timing.

Option:

Accessible pedestrian signals that provide verbal messages may provide similar messages in languages other than English, if needed, except for the terms "walk sign" and "wait."

Support:

A vibrotactile pedestrian device communicates information about pedestrian timing through a vibrating surface by touch.

Standard:

Vibrotactile pedestrian devices, where used, shall indicate that the walk interval is in effect, and for which direction it applies, through the use of a vibrating directional arrow or some other means.

Guidance:

When provided, vibrotactile pedestrian devices should be located next to and on the same pole as, the pedestrian pushbutton, if any, and adjacent to the intended crosswalk.

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Section 4E.09 Accessible Pedestrian Signal Detectors

Standard:

An accessible pedestrian signal detector shall be defined as a device designated to assist the pedestrian who has visual or physical disabilities in activating the pedestrian phase.

At accessible pedestrian signal locations with pedestrian actuation, each pushbutton shall activate both the walk interval and the accessible pedestrian signals.

Option:

Accessible pedestrian signal detectors may be pushbuttons or passive detection devices.

Pushbutton locator tones may be used with accessible pedestrian signals.

Guidance:

At accessible pedestrian signal locations, pushbuttons should clearly indicate which crosswalk signal is actuated by each pushbutton. Pushbuttons and tactile arrows should have high visual contrast as described in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11). Tactile arrows should point in the same direction as the associated crosswalk. At corners of signalized locations with accessible pedestrian signals where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 3 m (10 ft). This enables pedestrians who have visual disabilities to distinguish and locate the appropriate pushbutton.

Pushbuttons for accessible pedestrian signals should be located (see Figure 4E-2) as follows:

A. Adjacent to a level all-weather surface to provide access from a wheelchair, and where there is an all-weather surface, wheelchair accessible route to the ramp,
B. Within 1.5 m (5 ft) of the crosswalk extended,
C. Within 3 m (10 ft) of the edge of the curb, shoulder, or pavement, and

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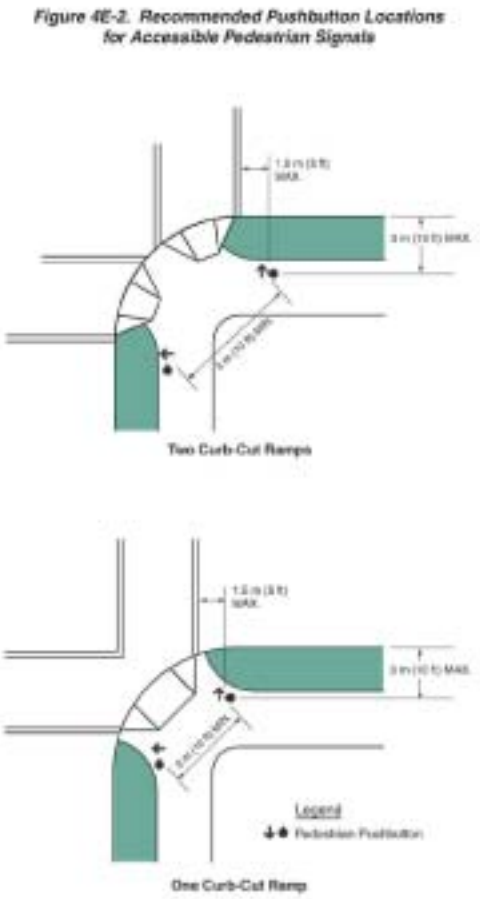
D. Parallel to the crosswalk to be used.

Figure 4E-2 Recommended Pushbutton Locations for Accessible Pedestrian Signals



If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and accessible pedestrian detectors are used, an additional accessible pedestrian detector should be provided in the median.

Standard:

When used, pushbutton locator tones shall be easily locatable, shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.

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Guidance:

Pushbuttons should be audibly locatable. Pushbutton locator tones should be intensity responsive to ambient sound, and be audible 1.8 to 3.7 m to 16 to 12 ft) from the pushbutton, or to the building line, whichever is less. Pushbutton locator tones should be no more than 5 dBA louder than ambient sound.

Pushbutton locator tones should be deactivated during flashing operation of the traffic control signal.

Option:

At locations with pretimed traffic control signals or nonactuated approaches, pedestrian pushbuttons may be used to activate the accessible pedestrian signals.

The audible tones may be made louder (up to a maximum of 89 dBA) by holding down the pushbutton for a minimum of 3 seconds. The louder audible tones may also alternate back and forth across the crosswalk, thus providing optimal directional information.

The name of the street to be crossed may also be provided in accessible format, such as Braille or raised print.

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National Committee on Uniform Traffic Control Devices (NCUTCD) approved changes to the next version of the MUTCD

As approved by the National Committee June 30, 2006.

TECHNICAL COMMITTEE RECOMMENDATION

TECHNICAL COMMITTEE:	Signals Technical Committee
DATE OF ACTION:	January 19, 2006
TOPIC:	**Sections 4A.02 Definitions Relating To Highway Traffic Signals, Section 4D.03 Provisions for Pedestrians, Section 4E.06 Accessible Pedestrian Signals, Section 4E.08 Pedestrian Detectors, and Section 4E.09 Accessible Pedestrian Signal Detectors**
ORIGIN OF REQUEST:	Signals Technical Committee

DISCUSSION:

The STC has been working for over six years to incorporate the results of research and practice regarding accessible pedestrian signals (APS) into the MUTCD. The 2000 MUTCD included new sections on APS (4E.06) and Accessible Pedestrian Detectors (4E.08 – now 4E.09). The language in these sections was revised in the 2003 MUTCD, based on research results available at that time. Recommended modifications to the 2003 MUTCD have been reviewed and approved by the NCUTCD. Additional changes are now proposed based on results of research, practice, and technical development on APS.

Both the Rehabilitation Act of 1973 (Section 504) and the Americans with Disabilities Act of 1990 require that facilities, programs and services be accessible to persons with disabilities. Both require that all new construction and alterations be

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accessible to persons with disabilities. This requirement means that pedestrian signals at new construction and alterations must be accessible to persons with disabilities, including vision impairment, vision and hearing impairment, cognitive impairment, and mobility impairment. Pedestrian signals are required to communicate WALK signal information in both audible and vibrotactile modes so they are usable by pedestrians with vision, and vision and hearing impairment. Pushbuttons to actuate pedestrian signals must be able to be located by persons with vision impairments and able to be actuated by persons with mobility impairments. Proposed changes have been demonstrated to result in accurate communication of pedestrian signal information to pedestrians having vision, vision and hearing, or cognitive disabilities. Proposed changes also result in making accessible pedestrian detectors easy to locate and actuate by persons with visual or mobility impairments.

Proposed changes to 4A.02, 4E.06, 4E.08, and 4E.09 are based primarily on additional research conducted under NCHRP 3-62 Accessible Pedestrian Signals, and a 5-year project sponsored by the National Institutes of Health, National Eye Institute, Blind Pedestrians' Access to Complex Intersections. Major changes are the following.

- Standards for the nature of audible and vibrotactile WALK indications
- Change from Guidance to Standard for volume of audible WALK indications
- Guidance on accessible pedestrian signal timing when pedestrian signals rest in walk
- Standard restricting the use of speech WALK indications to locations in which it is not technically feasible to locate two accessible pedestrian signal devices on separate poles at a corner
- Guidance on the use of audible beaconing to aid users in maintaining a straight direction of travel across a crossing
- Standards for ways to provide audible beaconing; Standard for location of tactile arrows on devices
- Change from Guidance to Standard requiring an additional accessible pedestrian detector on a median where pedestrian timing is sufficient only to cross from a curb or shoulder to a median
- Options for an alert tone at the onset of the walk interval and for a tactile map of the crosswalk

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Additional changes clarify the intent of existing language, reduce redundancy, or provide a more logical organization.

Since the 2000 MUTCD, 4E.06 has required that "The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device." However at that time there were no Standards and little Guidance on how this should be accomplished. Research has documented that requirements for both the nature of the tone or speech message provided by an accessible pedestrian signal, and the location of accessible pedestrian signal devices are needed to avoid ambiguity in determining which crosswalk has the WALK signal. Further, a tactile arrow is necessary for pedestrians who are blind to determine which pushbutton should be used to actuate the WALK signal at a particular crossing.

Under NCHRP 3-62, research was conducted to determine which device features best facilitated safe and independent street crossings by pedestrians who are blind. Four different types of pushbutton-integrated APS were used at one intersection in each of two cities. (Only pushbutton integrated APS make pedestrian signal information accessible to the large proportion of people who are blind and who also have hearing impairments.) All devices had a pushbutton locator tone, an audible actuation indicator, an audible WALK indication, a tactile arrow that vibrated during the walk interval, and automatic volume adjustment. Acoustic characteristics of the locator tone, the WALK signal, and the actuation indicator varied across devices, as did style of pushbutton and tactile arrow. In each city, 20 blind participants made two or three crossings using each device. Objective data included participants' location at the onset of crossing and at the end of crossing, with relation to the location and direction of the crosswalk; heading at the onset of crossing; intervals during beginning and ending of crossing; starting delays; searching for, locating and using pushbuttons; use of particular device features; and independence in crossing.

Results of NCHRP 3-62, supplemented by research sponsored by the National Eye Institute, demonstrate that for pedestrians with varying amounts of visual impairment and varying types of cognitive impairment, the least ambiguous information was provided when two APS on a corner were located on separate poles close to the curb that were separated by a distance of at least 10 feet. Both speed and accuracy in determining which

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crosswalk had the walk interval were also significantly better when both APS on a corner, located as described above, had the same rapid tick tone as compared with two different tones. Although subjective preference for WALK indications revealed that speech WALK signals were preferred, in the interest of minimizing the occasions on which pedestrians who have visual or cognitive impairments begin crossing with the wrong signal, the Final Report for NCHRP 3-62 recommends that the WALK indication should be a rapid tick.

Nonetheless, it is not always possible to locate APS on two different poles at a corner. NCHRP 3-62 results indicated that where two pushbuttons were located on a single pole, speed and accuracy in determining which crossing has the WALK signal were greater when the WALK indication was a speech message providing the name of the street being crossed than when a different WALK tone was provided by each of the two APS on one pole. While it is technically infeasible to locate APS on two different poles, the only way to provide unambiguous information regarding which crossing has the WALK signal is a speech message. However, speech messages are not understandable to all pedestrians under all ambient sound conditions. Therefore the use of speech WALK indications should be restricted to those situations in which it is necessary to locate two pushbuttons on a single pole.

Devices having the vibrating tactile arrow located on the pushbutton were used more quickly and accurately, and were preferred over devices in which the vibrating arrow was not incorporated into the pushbutton.

Research on APS sponsored by the National Eye Institute indicates that safety and independence of pedestrians with visual impairments at street crossings is enhanced by some form of audible beaconing at some crossings having complex geometry. Sixteen blind pedestrians in each of four cities made crossings at two complex signalized intersections before and after installation of APS having different means of providing beaconing. Objective measures included participants' accuracy in locating the crosswalk, aligning for crossing, crossing within the crosswalk, starting within the walk interval, and completing crossings within the pedestrian phase, as well as completing crossing independently.

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Based on results of this research, Guidance is proposed for identifying those crossings where audible beaconing should and should not be used. There are currently four potential ways of providing audible beaconing. Thus a Standard requiring the use of one of these four ways to provide beaconing is proposed, where audible beaconing is needed. All of the ways to provide beaconing require increased signal volume. To minimize the impact of increased signal volume on neighbors, while making it available to persons who need it, audible beaconing is provided only in response to an extended button press.

Also, the use of the term "speech" instead of "spoken" or "verbal" is recommended when referring to accessible pedestrian signals and has been incorporated into the proposed changes.

The Signals Technical Committee recommends that the National Committee submit the following proposed MUTCD changes to sponsors for comments.

COMMITTEE ACTION: See following pages for proposed text. New text is shown as underline. Deleted text is shown as ~~double strikethrough~~.

VOTE:	For	25
Opposed		0
Abstentions		0

REFERENCE TO AFFECTED PAGE NUMBERS IN MUTCD: Pages 4A-1 to 4A-3, 4D-2, and 4E-3 to 4E-5, 2003 Edition of MUTCD, Rev. 1

AR0072059

Section 4A.02 Definitions Relating to Highway Traffic Signals

Standard:

Accessible Pedestrian Signal—a device that communicates information about pedestrian timing in nonvisual format such as audible tones, ~~verbal~~ speech messages, and/or vibrating surfaces.

Pedestrian Change Interval—an interval during which the flashing UPRAISED HAND (symbolizing DONT WALK) signal indication is displayed. ~~When a verbal message is provided at an accessible pedestrian signal, the verbal message is~~ "wait."

Pushbutton Locator Tone—a repeating sound that informs approaching pedestrians that ~~they are required to push~~ there is a pushbutton to actuate pedestrian timing or to receive additional information and that enables pedestrians who have visual disabilities to locate the pushbutton.

Vibrotactile Pedestrian Device—~~a device~~ an accessible pedestrian signal feature that communicates, by touch, information about pedestrian timing using a vibrating surface.

Section 4D.03 Provisions for Pedestrians

Guidance:

Safety considerations should include the installation, where appropriate, of accessible pedestrian signals (see Sections 4E.06 and 4E.09) that provide information in nonvisual format (such as audible tones, ~~verbal~~ speech messages, and/or vibrating surfaces).

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Section 4L.06 Accessible Pedestrian Signals

Support.

The primary technique that pedestrians who have visual disabilities use to cross streets at signalized locations is to initiate their crossing when they hear the traffic in front of them stop and the traffic alongside them begin to move corresponding which often corresponds to the onset of the green interval. ~~This technique is effective at many signalized locations.~~ The existing environment is often not sufficient to provide the information that pedestrians who have visual disabilities need to operate safely cross a roadway at a signalized location. ~~Therefore, many signalized locations will not require any accessible pedestrian signals.~~

Guidance.

If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross safely and effectively the roadway, an engineering study should be conducted that considers the safety and effectiveness for needs of pedestrians in general, as well as the information needs of pedestrians with visual disabilities. The engineering study should consider the following factors:

A. Potential demand for accessible pedestrian signals;

B. A request for accessible pedestrian signals;

C. Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn on red volumes;

D. The complexity of traffic signal phasing (such as split phases, protected turn phases leading pedestrian intervals, and exclusive pedestrian phases); and

E. The complexity of intersection geometry.

Support.

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The factors that ~~might~~ make crossing at a signalized location difficult for pedestrians who have visual disabilities include: increasingly quiet cars, right turn on red which masks the beginning of the through phase, combination right turn movements, complex signal operations, traffic circles, and wide streets. Further, low traffic volumes might make it difficult for pedestrians who have visual disabilities to discern signal phase changes.

Local organizations providing support services to pedestrians who have visual and/or hearing disabilities can often act as important advisors to the traffic engineer when consideration is being given to the installation of devices to assist such pedestrians. Additionally, orientation and mobility specialists or similar staff also might be able to provide a wide range of advice. The U.S. Access Board's **Document A-37, "Accessible Pedestrian Signals"** (www.access-board.gov) provides various techniques for making pedestrian signal information available to persons with visual disabilities (see **Page** i for the address for the U.S. Access Board).

Accessible pedestrian signals provide information in nonvisual format (such as audible tones, ~~spoken~~ speech messages, and/or vibrating surfaces).

Information regarding detectors for accessible pedestrian signals is found in Section 4E.09.

Standard:

When used, accessible pedestrian signals shall be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device.

Under stop-and-go operation, accessible pedestrian signals shall not be limited in operation by the time of day or day of week.

~~Guidance:~~

~~The installation of accessible pedestrian signals at signalized locations should be based on an engineering study which should consider the following factors:~~

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~~A. Potential demand for accessible pedestrian signals;~~

~~B. A request for accessible pedestrian signals;~~

~~C. Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turning movement volumes;~~

~~D. The complexity of traffic signal phasing; and~~

~~E. The complexity of intersection geometry.~~

Support:

Accessible pedestrian signals that are located as close as possible to pedestrians waiting to cross the street provide the clearest and least ambiguous indication of which pedestrian crossing is served by a device. Technology that provides different sounds for each nonconcurrent signal phase has frequently been found to provide unambiguous information.

~~Some~~ Research indicates that a rapid tick tone for each crossing on separated poles located close to each crosswalk provides unambiguous information to pedestrians who are blind or visually impaired. Vibrotactile indications provide information to pedestrians who are blind and deaf and are also used by pedestrians who are blind or who have low vision to confirm the walk signal in noisy situations.

Standard:

~~**When choosing audible tones, possible extraneous sources of sounds (such as wind, rain, vehicle back-up warnings, or birds) shall be considered in order to eliminate potential confusion to pedestrians who have visual disabilities.**~~

Accessible pedestrian signals shall have both audible and vibrotactile walk indications.

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Accessible pedestrian signals shall have an audible walk indication during the walk interval only. The audible tone(s) shall be audible from the beginning of the associated crosswalk.

Accessible pedestrian signals shall not provide an audible pedestrian change interval indication.

Audible walk indications shall be a percussive tone. Audible tone walk indications shall repeat at 8 to 10 ticks per second. Audible tones used as walk indications shall consist of multiple frequencies with a dominant component at 880 Hz.

Vibrotactile walk indications shall be provided by a tactile arrow on the pushbutton which vibrates during the walk interval (see Section 4E.09).

Guidance

The sound level of audible pedestrian tones indications should be adjusted to be low enough ~~centrally-elected~~ to avoid misleading pedestrians who have visual disabilities when the following conditions exist:

A. Where there is an island that allows unsignalized right turns across a crosswalk between the island and the sidewalk.

B. Where multiple approaches or complex signal phasing require more than two pedestrian phases, such that it might be unclear which crosswalk is served by each audible tone

C. At intersections where a diagonal pedestrian crossing is allowed, or where one street receives a WALKING PERSON (symbolizing WALK) signal indication simultaneously with another street

~~Standard~~

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When accessible pedestrian signals have an audible tone(s), they shall have a tone for the walk interval. The audible tone(s) shall be audible from the beginning of the associated ~~crosswalk. If the tone for the walk interval is similar to the pushbutton locator tone, the walk interval tone shall have a faster repetition rate than the associated pushbutton locator tone.~~

Support:

A pushbutton locator tone is a repeating sound that informs approaching pedestrians that ~~they are required to push~~ there is a pushbutton to activate pedestrian timing or to receive additional information, and that enables ~~visually impaired~~ pedestrians who have visual disabilities to locate the pushbutton (see Section 4E.09).

Guidance **Standard**:

~~The accessible walk signal tone should be no louder than the locator tone, except where there is optional activation to provide a louder signal tone for a single pedestrian phase.~~

~~Automatic volume adjustment in response to ambient traffic sound level should be provided up to a maximum volume of 80 dBA.~~ **Where automatic volume adjustment is used,** Tones **should** shall be set to be no more than 5 dBA louder than ambient sound except when a louder signal is provided in response to an extended button press. Automatic volume adjustment in response to ambient traffic sound level shall be provided up to a maximum volume of 100 dBA. ~~The A-weighted sound pressure level should be measured according to "ISO 1996-1:2003" and "ISO 1996-2:1987" at a distance of 1 m (3.3 ft) from the transmitter (see Page i for the address for the International Organization for Standards).~~

The accessible walk signal shall have the same duration as the pedestrian walk signal except when the pedestrian signal rests in walk.

Guidance:

When the pedestrian signal rests in walk, the accessible walk signal should be limited to the first 7 seconds of the walk interval. The accessible walk signal should be repeated by a button

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press during the walk interval provided that the crossing time remaining is greater than the pedestrian change interval.

Option

An alert tone, which is a very brief burst of high frequency sound at the beginning of the audible walk indication which rapidly decays to the frequency of the walk tone, may be used to alert pedestrians to the beginning of the walk interval. An alert tone may be particularly useful if the walk tone is not easily audible in some traffic conditions.

Support

~~Spoken~~ Speech messages communicate to pedestrians which street has the walk interval. ~~Spoken~~ Speech messages might be either directly audible or transmitted, requiring a personal receiver to hear the message. To be a useful system, the words and their meaning must be correctly understood by all users in the context of the street environment where they are used. Because of this, tones are the preferred means of providing audible walk indications.

Where speech messages are used, pedestrians have to know the names of streets they are crossing in order for ~~spoken~~ speech walk messages to be unambiguous. In getting directions to travel to a new location, pedestrians who are blind do not always get the name of each street to be crossed. Therefore, it is desirable to give users of accessible pedestrian signals the name of the street controlled by the pushbutton. This can be done by means of a speech pushbutton information message during the flashing or steady don't walk intervals, or by raised print and Braille labels on the pushbutton housing.

Users must combine the information from the pushbutton message or Braille label, the tactile arrow aligned in the direction of travel on the relevant crosswalk, and the ~~spoken~~ speech walk message in order to correctly respond to ~~spoken~~ speech walk messages, particularly if there are two pushbuttons on the same pole.

Standard:

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When spoken speech messages are used to communicate the pedestrian interval, they shall provide a clear message that the walk interval is in effect, as well as to which crossing it applies. Speech walk messages shall be used only at intersections where it is technically infeasible to install two accessible pedestrian signals at one corner separated by a distance of 3 m (10 ft).

When spoken speech messages are used during the walk interval at intersections having concurrent pedestrian phasing they shall be patterned after the model: "Broadway. Walk sign is on to cross Broadway."

When spoken speech messages are used at intersections having exclusive pedestrian phasing they shall be patterned after the model: "WALK sign is on for all crossings."

Walk interval messages shall not contain any additional information, except they shall include designations such as "Street or "Avenue" where this information is necessary to avoid ambiguity in a particular locale.

~~The spoken message shall be repeated for the first 7 seconds of the walk interval, unless the walk interval is less than 7 seconds in which case the spoken message shall be repeated for the duration of the walk interval. Pedestrian actuations occurring during walk intervals of longer than 7 seconds shall cause the spoken message to be repeated for up to 7 seconds.~~

Guidance:

Messages should not be worded in a way that seems to provide a command to the pedestrian, such as "cross Broadway Street now". Messages should not tell users that it is "safe to cross." It should always be the pedestrian's responsibility to check actual traffic conditions.

Standard:

A spoken speech message is not required at times when the walk interval is not timing, but, if provided:

A. It shall begin with the term "wait."

AR0072067

B. It need not be repeated for the entire time that the walk interval is not timing.

Support

Section 4E.09 contains additional ~~material~~ information regarding ~~spoken~~ speech pushbutton information messages when the walk interval is not timing.

Option

Accessible pedestrian signals that provide ~~spoken~~ speech messages may provide similar messages in languages other than English, if needed, except for the terms "walk sign" and "wait."

~~Support:~~

~~A vibrotactile pedestrian device communicates information about pedestrian timing through a vibrating surface by touch.~~

~~Standard:~~

Vibrotactile pedestrian devices, where used, shall indicate that the walk interval is in effect, and for which direction it applies, through the use of a vibrating directional arrow or some other means.

~~Guidance:~~

~~When provided, vibrotactile pedestrian devices should be located next to, and on the same side as, the pedestrian pushbutton, if any, and adjacent to the intended crosswalk.~~

~~Option:~~

Pedestrians may be provided with additional features such as increased crossing time, audible beaconing, or a pushbutton information message as a result of an extended pushbutton press.

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Standard:

If an extended pushbutton press is used to provide any additional feature(s), such as audible beaconing, a pushbutton press of less than one second shall actuate only the pedestrian timing and any associated accessible WALK signal, and a pushbutton press of one second or more shall actuate the pedestrian timing, any associated accessible WALK signal, and any additional feature(s).

Support:

Audible beaconing is the use of an audible signal in such a way that blind pedestrians can home in on the signal from the target corner as they cross the street.

Not all crosswalks at an intersection need audible beaconing; audible beaconing can actually cause confusion if used at all crosswalks at some intersections. Audible beaconing is not appropriate at locations with channelized turns or split phasing, because of the possibility of confusion.

Guidance:

Audible beaconing should only be considered following an engineering study at:

A. Crosswalks longer than 21 m (70 ft), unless they are divided by a median that has another accessible pedestrian signal with a locator tone;

B. Crosswalks that are skewed;

C. Intersections with irregular geometry such as multiple legs;

D. Crosswalks where audible beaconing is requested by an individual with visual disabilities; or

E. Other locations where a study indicates audible beaconing would be beneficial.

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Option:

Audible beaconing may be provided in several ways, any of which are initiated by an extended button press.

Standard:

If audible beaconing is used, the volume of the locator tone during the pedestrian change interval of the called pedestrian phase shall be increased and operated in one of the following ways:

A. The louder locator tone comes from the target corner, as pedestrians cross the street; or

B. The louder locator tone comes from both ends of the crosswalk; or

C. The louder locator tone comes from an additional pedestrian-signal-head-mounted speaker aimed at the center of the crosswalk.

Section 4E.08 Pedestrian Detectors

Support:

The following guidance places pushbuttons within easy reach of pedestrians who are intending to cross each crosswalk and makes it obvious which pushbutton is associated with each crosswalk. This location also positions pushbutton poles optimally for subsequent installation of accessible pedestrian signals. Guidance regarding reach ranges can be found in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)," (see Section 1A.11).

~~Guidance~~ Standard:

AR0072070

When pedestrian actuation is used, pedestrian pushbutton detectors ~~should~~ shall be capable of easy activation and conveniently located near each end of the crosswalks. Except as described in the ~~Option~~ Guidance below, pushbuttons ~~should~~ shall be located to meet all of the following:

A. Unobstructed and adjacent to a level all-weather surface to provide access from a wheelchair;

B. Where there is an all-weather surface, a wheelchair accessible route from the pushbutton to the ramp;

C. Between the edge of the crosswalk line (extended) farthest from the center of the intersection and the side of a curb ramp (if present), but not greater than 1.5 m (5 ft) from said crosswalk line;

D. Between 0.45 m (1.5 ft) and 1.8 m (6 ft) ~~, but not greater than 3 m (10 ft)~~ from the edge of the curb, shoulder, or pavement; ~~and~~

F. With the ~~control surface~~ face of the pushbutton parallel to the crosswalk to be used; and

E. At a maximum mounting height of 1.2 m (4 ft) above the sidewalk.

Guidance:

Where there are constraints that make it infeasible to place the pedestrian detector adjacent to a level all-weather surface, the surface should be as level as feasible.

Where there are constraints that make it infeasible to place the pedestrian detector between 0.45 m (1.5 ft) and 1.8 m (6 ft) from the edge of curb, shoulder, or pavement, it should not be further than 3 m (10 ft) from the edge of curb, shoulder, or pavement.

A mounting height of approximately 1.1 m (3.5 ft) above the sidewalk should be used for pedestrian pushbutton detectors.

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At corners of signalized locations where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 3 m [10 ft] (see Figure 4E-2).

Option:

Where there are constraints that make it impractical infeasible to meet the Guidance on pedestrian detector separation in this Section, on a corner requiring pedestrian actuation of signals for two crosswalks, a single pole may be used.

Guidance:

Where two accessible pedestrian ~~detectors~~ pushbuttons are used ~~at corners having~~ on a single pushbutton pole, the accessible pedestrian detectors pushbuttons should have the features described in Section 4E.09 for this situation.

Option:

Pedestrian signal detectors may be pushbuttons or passive detection devices.

Standard:

Signs (see Section 2B.44) shall be mounted adjacent to or integral with pedestrian pushbutton detectors, explaining their purpose and use.

Option:

At certain locations, a sign at a more visible location may be used to call attention to the pedestrian detector.

Guidance Standard:

AR0072072

If two crosswalks, oriented in different directions, end at or near the same location. The positioning of pedestrian detectors and/or the legends on the pedestrian detector signs ~~should~~ shall clearly indicate which crosswalk signal is actuated by each pedestrian detector.

Standard:

If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and the signals are pedestrian actuated, an additional pedestrian detector shall be provided in the median.

Guidance:

The use of additional pedestrian detectors on islands or medians where a pedestrian might become stranded should be considered.

~~A mounting height of approximately 1.1 m (3.5 ft) above the sidewalk should be used for pedestrian pushbutton detectors.~~

If used, special purpose pushbuttons to be operated only by authorized persons should include a housing capable of being locked to prevent access by the general public and do not need an instructional sign.

Standard:

If used, a pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation. Once it is actuated, it shall remain illuminated until the pedestrian's green or WALKING PERSON (symbolizing WALK) signal indication is displayed.

If a pilot light is used at an accessible pedestrian signal location, each actuation shall be accompanied by the speech message "wait".

Option:

AR0072073

At signalized locations with demonstrated need and subject to equipment capabilities pedestrians with special needs may be provided with additional crossing time by means of an extended pushbutton press.

Section 4E.09 Accessible Pedestrian Signal Detectors

Standard:

An accessible pedestrian signal detector shall be defined as a device designated to assist the pedestrian who has visual or physical disabilities in activating the pedestrian phase.

At accessible pedestrian signal locations with pedestrian actuation, each pushbutton shall activate both the walk interval and the accessible pedestrian signals.

An accessible pedestrian pushbutton shall incorporate a locator tone.

Pushbutton locator tones shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.

Pushbutton locator tones shall be intensity responsive to ambient sound, and be audible 1.8 (6 ft) to 3.7 m (12 ft) from the pushbutton, or to the building line, whichever is less. Pushbutton locator tones shall be no more than 5 dBA louder than ambient sound.

Pushbutton locator tones shall be deactivated during flashing operation of the traffic control signal.

Option:

Accessible pedestrian signal detectors may be pushbuttons or passive detection devices.

Standard:

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At accessible pedestrian signal locations, pushbuttons shall clearly indicate by means of tactile arrows which crosswalk signal is actuated by each pushbutton. by means of Tactile arrows shall be located on the pushbutton, ~~having~~ have visual contrast (light on dark or dark on light), and Tactile arrows shall be aligned parallel to the direction of travel on the associated crosswalk.

Guidance:

At corners of signalized locations with accessible pedestrian signals where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 3 m [10 ft] such that they clearly indicate which crosswalk has the WALK indication.

Pushbuttons should be located as close as possible to the crosswalk line farthest from the center of the intersection and as close as possible to the curb ramp.

Standard:

Where it is impractical to install accessible pedestrian detectors on two separate poles at a corner, each accessible pedestrian detector shall have the following features, in addition to the pushbutton locator tone and tactile arrow: ~~pushbutton locator tone,~~ a verbal speech walk message for the WALK indication (see Section 4E.06), tactile arrow aligned parallel to the direction of travel on the crosswalk, and a speech pushbutton information message.

Guidance:

If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and accessible pedestrian detectors are used, an additional accessible pedestrian detector should shall be provided in the median.

~~Standard:~~

~~When used, pushbutton locator tones shall be easily localizable, shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.~~

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~~Guidance:~~

~~Pushbuttons should be audibly locatable. Pushbutton locator tones should be intensity responsive to ambient sound and be audible 1.5 to 3.7 m (5 to 12 ft) from the pushbutton or to the building line, whichever is less. Pushbutton locator tones should be no more than 5 dB(A) louder than ambient sound.~~

~~Pushbutton locator tones should be deactivated during flashing operation of the traffic control signal.~~

Option:

At locations with protected traffic signals or unmarked approaches, pedestrian pushbuttons may be used to activate the accessible pedestrian signals.

~~Pedestrians may be provided with~~ Additional features may be provided for pedestrians such as increased crossing time, audible beaconing, or a spoken pushbutton information message as a result of an extended pushbutton press.

Standard:

If an extended pushbutton press is used to provide any additional feature(s), a pushbutton press of less than one second shall actuate only the pedestrian timing and any associated accessible WALK signal, and a pushbutton press of one second or more shall actuate the pedestrian timing, any associated accessible WALK signal, and any additional feature(s).

Option:

The name of the street to be crossed may also be provided in accessible format, such as Braille or raised print.

Tactile maps of crosswalks may be provided.

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Spoken Speech pushbutton information messages may be made available by actuating the accessible pedestrian signal detector when the walk interval is not timing. These messages may provide intersection identification, as well as information about unusual intersection signalization and geometry, such as notification regarding exclusive pedestrian phasing, leading pedestrian intervals, split phasing, diagonal crosswalks, and medians or islands.

Standard:

If ~~spoken~~ speech pushbutton information messages are made available by actuating the accessible pedestrian signal detector, they shall only be actuated when the walk interval is not timing. They shall begin with the term "Wait," followed by intersection identification information modeled after: "Wait to cross Broadway at Grand." If information on intersection signalization or geometry is also given, it shall follow the intersection identification information.

Guidance:

Spoken Speech pushbutton information messages should not be used to provide landmark information or to inform pedestrians with visual impairments about detours or temporary traffic control situations.

Support:

Additional information on structure and wording of pushbutton messages is included in ITE's "Electronic Toolbox for Making Intersections More Accessible for Pedestrians Who Are Blind or Visually Impaired," which is available at ITE's website.

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Excerpts from Draft Public Rights-of-Way Accessibility Guidelines (Draft PROWAG)

November 23, 2005

Updates are expected. Please check www.access-board.gov for latest information.

Sections on Accessible Pedestrian Signals

CHAPTER R1: APPLICATION AND ADMINISTRATION

R101 Purpose

R101.1 General. This document contains scoping and technical requirements for accessibility to facilities for pedestrian circulation and use located in the public right of way. Advisory notes are for informational purposes only. These requirements are to be applied during the design, construction, additions to, and alterations of facilities in the public right-of-way to the extent required by regulations issued by Federal agencies.

Advisory R101.1 General. Access requirements are also addressed in the Manual on Uniform Traffic Control Devices (MUTCD) [HWA/FHS DOT, 2003 (http://mutcd.fhwa.dot.gov). MUTCD is a reference standard in this guideline.

Key transportation industry guidance documents also address accessibility in the public right-of-way and can provide useful information on design and construction. They include 'Guide for the Planning, Design, and Operation of Pedestrian Facilities', American Association of State Highway and Transportation Officials, July 2004 (www.aashto.org) and 'Designing Sidewalks and Trails for Access', FHWA/FHS DOT September 2001 (http://www.fhwa.dot.gov/environment/sidewalk2/index.htm).

R101.2 Effect on Existing Facilities. This document does not address existing facilities unless they are included in the scope of an alteration undertaken at the discretion of a covered entity. The U.S. Department of Justice and U.S. Department of Transportation

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have issued and enforce separate regulations for existing facilities subject to their requirements for program accessibility under the Americans with Disabilities Act.

Advisory R101.2 Effect on Existing Facilities. The U.S. Department of Justice ADA regulations require that the usability of accessible features be maintained (28 CFR 35.133 and 36.211).

Federal agencies and entities receiving federal funds may also have an obligation for program accessibility under section 504 of the Rehabilitation Act of 1973 as amended. For example, state departments of transportation that receive Federal-aid Highway funds must comply with program accessibility requirements issued by the U.S. Department of Transportation at 49 CFR part 27.

R102 Equivalent Facilitation Nothing in these requirements prevents the use of designs, products, or technologies as alternatives to those prescribed, provided they result in substantially equivalent or greater accessibility and usability.

R103 Conventions R103.1 Dimensions. Dimensions that are not stated as "maximum" or "minimum" are absolute.

R103.1.1 Construction and Manufacturing Tolerances. All dimensions are subject to conventional industry tolerances except where the requirement is stated as a range with specific minimum and maximum end points.
Advisory R103.1.1 Construction and Manufacturing Tolerances. Conventional industry tolerances recognized by this provision include those for field conditions and those that may be a necessary consequence of a particular manufacturing process. Recognized tolerances are not intended to apply to design work.

Information on specific tolerances may be available from industry or trade organizations, code groups and building officials, and published references.

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[Sections R103.2 – R103.4 not included]

R104 Referenced Guidelines and Standards

R104.1 General. The guidelines and standards listed in R104.2 are incorporated by reference in this document and are part of the requirements to the prescribed extent of each such reference. The Director of the Federal Register has approved these guidelines and standards for incorporation by reference in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. Copies of the referenced guidelines and standards may be inspected at the Architectural and Transportation Barriers Compliance Board, 1331 F Street, NW, Suite 1000, Washington, DC 20004; at the Department of Justice, Civil Rights Division, Disability Rights Section, 1425 New York Avenue, NW, Washington, DC; at the Department of Transportation, 400 Seventh Street, SW, Room 10424, Washington DC; or at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call (202) 741-6030, or go to **www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html**

R104.2 Referenced Guidelines and Standards. The specific edition of the guidelines and standards listed below are referenced in this document. Where differences occur between this document and the reference, this document applies.

R104.2.1 MUTCD Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), 2003 edition. Copies of the referenced standard may be obtained on-line from the Federal Highway Administration at **mutcd.fhwa.dot.gov** (see R305 and R302.4).

[Sections 104.2.2 – 104.2.3 not included]

R105 Definitions

R105.1 General. For the purpose of this document, the terms defined in R105.5 have the indicated meaning.

R105.2 Terms Defined in Referenced Guidelines and Standards. Terms not defined in R105.5 or in regulations issued by Federal agencies, but specifically defined in a

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referenced guideline or standard, shall have the specified meaning from the referenced guideline or standard unless otherwise stated.

R105.3 Undefined Terms. The meaning of terms not specifically defined in R105.5 or in regulations issued by Federal agencies or in referenced guidelines and standards shall be as defined by collegiate dictionaries in the sense that the context implies.

R105.4 Interchangeability. Words, terms and phrases used in the singular include the plural and those used in the plural include the singular.

R105.5 Defined Terms.

Accessible. Describes a facility in the public right-of-way that complies with this part.

Accessible Pedestrian Signal. A device that communicates information about the WALK phase in audible and vibrotactile formats.

[Rest of Section 105.5 not included]

CHAPTER R2: SCOPING REQUIREMENTS

R201 Application

R201.1 Scope. All newly designed and newly constructed facilities located in the public right-of-way shall comply with these requirements. All altered portions of existing facilities located in the public right-of-way shall comply with these requirements to the maximum extent feasible.

Advisory R201.1 Scope. This document (see R101.1 General) covers facilities for pedestrian circulation and use in the right of way. Examples of facilities include, but are not limited to, walkways and sidewalks, street or highway shoulders where pedestrians are not prohibited, crosswalks, islands and medians, overpasses and underpasses, on-street parking spaces and loading zones, and equipment - signals, signs, street furniture, and other appurtenances provided for pedestrians. Examples of facilities not included are manholes and utility vaults.

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These requirements are to be applied to all areas of a facility within the scope or limits of the planned project unless expressly exempted or limited with respect to the number of multiple elements required to be accessible. For example, not all benches are required to be accessible; those that are not required to be accessible are not required to comply with these requirements or to be served by a pedestrian access route.

R201.2 Temporary and Permanent Facilities. These requirements shall apply to temporary and permanent facilities.

Advisory R201.2 Temporary and Permanent Facilities. Temporary facilities covered by these requirements include, but are not limited to, temporary routes around work zones, portable toilets in the public right-of-way, sidewalk vending facilities, street fair booths performance stages and reviewing stands, and the pedestrian access routes that serve them. As presumed in R203.1.1, structures and equipment directly associated with the actual processes of construction are not required to be accessible.

[rest of 201.2 advisory and section 201.3 not included]

R202 Alterations and Additions to Existing Facilities

R202.1 General. Additions and alterations to existing facilities shall comply with R202.

Advisory R202.1 General. Alterations include, but are not limited to, remodeling, rehabilitation, reconstruction, historic restoration, resurfacing of circulation paths or vehicular ways, or changes or rearrangement of structural parts or elements of a facility.

[Rest of sections R202 – R207 not included]

R208 Accessible Pedestrian Signals (APS) Where pedestrian signals are provided at pedestrian street crossings, they shall comply with R306.

[Sections R209 – R222 not included]

CHAPTER R3: TECHNICAL PROVISIONS

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[Sections R301 – R305 not included]

R306 Accessible Pedestrian Signals (APS)

R306.1 General. Pedestrian signals shall comply with R306.

R306.2 Pedestrian Signals. Each crosswalk with pedestrian signal indication shall have an accessible pedestrian signal which includes audible and vibrotactile indications of the WALK interval. Where a pedestrian pushbutton is provided, it shall be integrated into the accessible pedestrian signal and shall comply with R306.2.
Advisory R306.2 Pedestrian Signals. Signals should generally sound and vibrate throughout the WALK interval. Where signals rest in WALK, audible operation may be limited to a repetition at short intervals rather than continuous sounding for several minutes.

R306.2.1 Location. Accessible pedestrian signals shall be located so that the vibrotactile feature can be contacted from the level landing serving a curb ramp, if provided, or from a clear floor or ground space that is in line with the crosswalk line adjacent to the vehicle stop line.

R306.2.1.1 Crossings. Accessible pedestrian signal devices shall be 3.0 m (10.0 ft) minimum from other accessible pedestrian signals at a crossing. The control face of the accessible pedestrian signal shall be installed to face the intersection and be parallel to the direction of the crosswalk it serves.

R306.2.1.2 Medians and Islands. Accessible pedestrian signals located in medians and islands shall be 1.5 m (5.0 ft) minimum from other accessible pedestrian signals.

R306.2.2 Reach and Clear Floor or Ground Space. Accessible pedestrian pushbuttons shall be located within a reach range complying with R404. A clear floor or ground space

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complying with R402 shall be provided at the pushbutton and shall connect to or overlap the pedestrian access route.

R306.2.3 Audible Walk Indication. The audible indication of the WALK interval shall be by tone or speech message.

R306.2.3.1 Tones. Tones shall consist of multiple frequencies with a dominant component at 880 Hz. The duration of the tone shall be 0.15 s and shall repeat at intervals of 0.35 s.

Advisory R306.2.3.1 Tones. Many new accessible pedestrian signal installations in the US use speech messages, which are perceived as being more user-friendly than tones. However, such messages may not be intelligible under high-ambient-noise conditions or to non-English speakers. Electronic tones are more universal and unambiguous. Section 4E.06 of the MUTCD specifies content of speech messages.

R306.2.3.2 Volume. Tone or voice volume measured at 92 cm (3.0 ft) from the pedestrian signal device shall be 2 dB minimum and 5 dB maximum above ambient noise level in standard operation and shall be responsive to ambient noise level changes.

Advisory R306.2.3.2 Volume. Where additional volume or beaconing features are available on pedestrian actuation, these will momentarily exceed volume limits.

R306.3 Pedestrian Pushbuttons. Pedestrian pushbuttons shall comply with R306.3.

R306.3.1 Operation. Pedestrian pushbuttons shall comply with R405.4.

R306.3.2 Pushbutton Locator Tone. Pedestrian pushbuttons shall incorporate a locator tone at the pushbutton. Pushbutton locator tone volume measured at 92 cm (3.0 ft) from the pushbutton shall be 2 dB minimum and 5 dB maximum above ambient noise level and shall be responsive to ambient noise level changes. The duration of the locator tone shall be 0.15 s maximum and shall repeat at intervals of one second. The locator tone

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shall operate during the DON'T WALK and flashing DON'T WALK intervals only and shall be deactivated when the pedestrian signal is not operative.

R306.3.3 Size and Contrast. Pedestrian pushbuttons shall be a minimum of 0.5 cm (2 in) across in one dimension and shall contrast visually with their housing or mounting.

R306.3.4 Optional Features. An extended button press shall be permitted to activate additional features. Buttons that provide additional features shall be marked with three braille dots forming an equilateral triangle in the center of the pushbutton.

R306.4 Directional Information and Signs. Pedestrian signal devices shall provide tactile and visual signs complying with 306.4 on the face of the device or its housing or mounting to indicate crosswalk direction and the name of the street containing the crosswalk served by the pedestrian signal.

R306.4.1 Arrow. Signs shall include a tactile arrow aligned parallel to the crosswalk direction. The arrow shall be raised 0.8 mm (.03 inch) minimum and shall be 4 mm (1.5 in) minimum in length. The arrowhead shall be open at 45 degrees to the shaft and shall be 33 percent of the length of the shaft. Stroke width shall be 10 percent minimum and 15 percent maximum of arrow length. The arrow shall contrast with the background.

R306.4.2 Street Name. Accessible pedestrian signals (APS) shall include street name information aligned parallel to the crosswalk direction and shall comply with R409.3 or shall provide street name information in audible format.

R306.4.3 Crosswalk Configuration. Where provided, graphic indication of crosswalk configuration shall be tactile.

[Sections R307 – R309 not included]

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Sections referenced in R306.2.2 Reach and Clear Floor or Ground Space:

R402 Clear Space

R402.1 General. Clear space at accessible pedestrian signals (APS), street furniture, and operable parts shall comply with R402.

R402.2 Surface Characteristics. Surfaces of clear spaces shall comply with R501.5 and shall have a slope and cross slope of 2 percent maximum.

R402.3 Size. The clear space shall be 760 mm (30 in) minimum by 1220 mm (48 in) minimum.

R402.4 Knee and Toe Clearance. Unless otherwise specified, clear space shall be permitted to include knee and toe clearance complying with R403.

R402.5 Position. Unless otherwise specified, clear space shall be positioned for either forward or parallel approach to an element.

R402.6 Approach. One full unobstructed side of the clear space shall adjoin a pedestrian access route or adjoin another clear space.

R402.7 Maneuvering Space. Where a clear space is located in an alcove or otherwise confined on all or part of three sides, additional maneuvering space shall be provided in accordance with R402.7.1 and R402.7.2.

R402.7.1 Forward Approach. Alcoves shall be 915 mm (36 in) wide minimum where the depth exceeds 610 mm (24 in).

R402.7.2 Parallel Approach. Alcoves shall be 1525 mm (60 in) wide minimum where the depth exceeds 380 mm (15 in).

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R404 Reach Ranges

R404.1 General. Reach ranges shall comply with R404.

R404.2 Forward Reach.

R404.2.1 Unobstructed. Where a forward reach is unobstructed, the high forward reach shall be 1220 mm (48 in) maximum and the low forward reach shall be 380 mm (15 in) minimum above the finish surface.

R404.2.2 Obstructed High Reach. Where a high forward reach is over an obstruction, the clear space shall extend beneath the element for a distance not less than the required reach depth over the obstruction. The high forward reach shall be 1220 mm (48 in) maximum where the reach depth is 510 mm (20 in) maximum. Where the reach depth exceeds 510 mm (20 in), the high forward reach shall be 1120 mm (44 in) maximum and the reach depth shall be 635 mm (25 in) maximum.

R404.3 Side Reach.

R404.3.1 Unobstructed. Where a clear space allows a parallel approach to an element and the side reach is unobstructed, the high side reach shall be 1220 mm (48 in) maximum and the low side reach shall be 380 mm (15 in) minimum above the finish surface. An obstruction shall be permitted between the clear space and the element where the depth of the obstruction is 255 mm (10 in) maximum.

R404.3.2 Obstructed High Reach. Where a clear space allows a parallel approach to an element and the high side reach is over an obstruction, the height of the obstruction shall be 865 mm (34 in) maximum and the depth of the obstruction shall be 610 mm (24 in) maximum. The high side reach shall be 1220 mm (48 in) maximum for a reach depth of

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255 mm (10 in) maximum. Where the reach depth exceeds 266 mm (10 in), the high side reach shall be 1170 mm (46 in) maximum for a reach depth of 610 mm (24 in) maximum.

Section referenced in R306.3.1 Pedestrian Pushbuttons, Operation:

R405.4 Operation. Operable parts shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate operable parts shall be 22 N (5 lbsf) maximum.

Section referenced in R306.4.2 Street Name

R409.3 Braille. Braille shall be contracted (Grade 2) and shall comply with R409.3 and R409.4.

R409.3.1 Dimensions and Capitalization. Braille dots shall have a domed or rounded shape and shall comply with Table R409.3.1. The indication of an uppercase letter or letters shall only be used before the first word of sentences, proper nouns and names, individual letters of the alphabet, initials, and acronyms.

R409.3.1 Braille Dimensions

Measurement Range	**Minimum in Millimeters** **Maximum in Millimeters**
Dot base diameter	1.5 mm (0.059 in) to 1.6 mm (0.063 in)
Distance between two dots in the same cell	2.3 mm (0.090 in) to 2.5 mm (0.100 in)
Distance between corresponding dots in adjacent cells	6.1 mm (0.241 in) to 7.6 mm (0.300 in)
Dot height	0.6 mm (0.025 in) to 0.9 mm (0.037 in)
Distance between corresponding dots from one cell directly below	10 mm (0.395 in) 10.2 mm to (0.400 in)

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* Measured center to center

R409.3.2 Position. Braille shall be positioned below the corresponding text. If text is multi-lined, braille shall be placed below the entire text. Braille shall be separated 9.5 mm (.375 in) minimum from any other tactile characters and 9.5 mm (.375 in) minimum from raised borders and decorative elements. Braille provided on elevator car controls shall be separated 4.8 mm (.1875 in) minimum and shall be located either directly below or adjacent to the corresponding raised characters or symbols.

R409.4 Installation Height and Location.
Signs with tactile characters shall comply with R409.4.

R409.4.1 Height Above Finish Floor or Ground. Tactile characters on signs shall be located 1.2 m (4.0 ft) minimum above the finish floor or ground surface, measured from the baseline of the lowest tactile character and 1.5 m (5.0 ft) maximum above the finish floor or ground surface, measured from the baseline of the highest tactile character. Tactile characters for elevator car controls shall not be required to comply with R409.4.1.

AR0072089

Appendix B—Product Information

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Introduction

Information on accessible pedestrian signal (APS) manufacturers was obtained directly from manufacturers and manufacturers' websites and is accurate as of May 2007. Be sure to confirm features, functioning, and installation requirements of APS with the manufacturer before purchase, as APS product offerings are constantly changing. New manufacturers may enter the U.S. market at any time; this appendix lists ones that authors of this report are aware of at the time of publication.

Leader Dogs for the Blind in Rochester, Michigan, has plans to develop an APS based on the previously available Relume system. Talking Signs and Mitsubishi are continuing development and testing of their product for street crossings devices in Japan. Talking Signs is working with Polara on a combined system for U.S. installation. There are a number of companies manufacturing and distributing APS in other countries, and more development can be expected.

The descriptions of features of APS, as well as how these features are used by pedestrians who are blind and visually impaired, can be found in Chapter 4. If the manufacturer uses a term different from the terms commonly used in this document for a feature, the manufacturer's term is listed in parentheses.

In the descriptions of each product, "Standard features" refer to features that are included in the standard price of on all models. "Optional features" refer to features that

AR0072090

must be ordered extra or need special specifications on ordering (i.e., speech messages or pushbutton information messages that may need to be recorded by the manufacturer).

Campbell Company

221 West 37th Street, Suite C

Boise, Idaho 83714

Phone: 208-345-7459

Fax: 208-345-7481

www.pedsafety.com

Models

- Advisor Fully integrated Pedestrian Station – Advisor FIPS
- Advisor Base Broadcast Unit – BBU
- Vibrotactile Only – VTO

Photos

Figure B-1. Advisor FIPS 57.

AR0072091

Figure B-2. Advisor FIPS H.

Figure B-3. VTO Unit.

Figure B-4. BBU, showing speaker mounted on bottom of pedestrian signal head.

Standard Features

Advisor FIPS

"Walk" Indication:

AR0072092

- Speech Message or Cuckoo/Chirp.
- Vibrotactile Arrow

Other:

- Speaker at pushbutton.
- Pushbutton Locator tone.
- Tactile arrow.
- Automatic volume adjustment.
- Actuation indicator, tone, message, acknowledgement tone or message, LED (visual feedback).

BBU

"Walk" Indication:

- Cuckoo/chirp

Other:

- Speaker in pedestrian signal head

VFO

"Walk" Indication:

- Vibrating arrow

Other:

- No speaker: vibrotactile only.

Optional Features:

- Also available in H frame style (used mainly in Northwest U.S. states).
- Custom tones and messages.
- Fixed audible walk time for use with rest in "Walk".
- Braille street names.
- Extended button push functions:
  - Pushbutton information message (pushbutton message).

AR0072093

- Volume increase, and
- APS actuation

Installation Notes:

- Advisor control unit/driver typically mounts in the pedestrian signal head or separate enclosure (available on request) to existing screws, or with industrial hook and loop
- Volume adjustments are on the control unit board which mounts in the pedestrian signal head
- Sound dish mounts to pedhead and plugs into driver board
- Factory made cable plugs into driver and back of pushbutton.

Comments

Advisor PIPS provides both audible and vibrotactile indications and other features as required in Draft PROWAG.

BBU provides an audible "Walk" indication only, and VTO units provide vibrotactile indications only.

Mallory Sonalert

4411 S. High School Rd.

Indianapolis, IN 46241

Phone: 317-612-1000

www.mallory-sonalert.com

Models

- VSB 120

Photo

Figure B-5. Mallory Sonalert unit.

AR0072094

Standard features

VSB 110

"Walk" indication:

- Cuckoo – 800 Hz and 1200 Hz, every 1.5 s.
- Chirp – 2000 Hz, every 1 s.

Other:

- Speaker intended for mounting in pedestrian signal head.

Optional Features

None

Installation Notes

Usually mounted inside the pedestrian signal head and directly wired to the "Walk" indication.

Comments

No pushbutton locator tone, vibrotactile indication, or automatic volume adjustment, which are features required by Draft PROWAG 12.

Mallory also sells sound generators in various beeps, siren and chime sounds; these are not recommended sounds for use as APS.

Novax Industries

658 Derwent Way

New Westminster, BC, Canada V3M 5P8

Phone: 866-977-4APS (1-866-977-4277)

Phone: 604-525-5644

Fax: 604-525-2739

WWW.NOVAX.COM

Models

- DS100

AR0072095

- DS3000

Additional components for DS3000: Vibrawalk, with functions of pushbutton and vibrating arrow integrated.

Photos

Figure B-6. The DS100 mounted on pedestrian signal heads.

Figure B-7. The Vibrawalk2 unit for use with the DS3000 to provide a pushbutton locator tone and a vibrotactile arrow.

AR0072096

Figure B-8. DS3000 is the company's newest product.

Standard Features

DS100

"Walk" indication:

- Two or four tones standard, cuckoo and chirp (peep-peep) and two additional custom tones.

Other:

- Speaker unit mounts on pedestrian signal head.

DS3000

"Walk" indication:

- Two or four tones standard: cuckoo, chirp, short beep, and long beep.
- Dip switch setting to provide either concurrent sound from both ends of the crosswalk or sound that alternates from each end of the crosswalk.
- Optional additional unit (VibraWalk) to provide vibrotactile indication.

Other:

- Typically mounted on pedestrian signal head.
- Automatic volume adjustment (dynamic proportional volume compensation).
- Separate volume settings for locator tone and "Walk" signal.
- External sound adjustment screws.

AR0072097

- Separate circuit to drive the optional vibrating tactile feature.

Optional Features

- VibraWalk2 unit, which provides pushbutton locator tone, actuation indicator (button lamp indicator), RUI, pushbutton information message (pedestrian acknowledge), and vibrotactile arrow at pushbutton
- Custom speech messages for DS100 (up to 1.5 s) and DS3000 (up to 3.2 s).
- Sound inhibit interacts with traffic signal controller to disable audible indications as required.
- Maximum walk timer for rest in "Walk" intersections.
- DS3000i option provides a control board, which is mounted inside the pedestrian signal head, to drive VibraWalk2 unit and provide all sounds from pushbutton, or for use with optional additional loudspeaker.

Installation Notes

4 wire 20 gauge.

120 VAC derived from "Walk" and "Don't Walk" indicator

Comments

Optional VibraWalk unit is needed to provide pushbutton locator tone, tactile arrow and vibrotactile "Walk" indications, as required by Draft PROWAG.

Bob Panich Consultancy

PO Box 360

Ryde NSW 1680

Australia

Phone: 61 2 9809 6409

Fax: 61 2 9809 6962

www.bobpanich.com.au/

Models

- BPC

AR0072098

Photos

Figure B-9. Panich BPC.

Figure B-10. Driver unit for Panich BPC.

Standard Features

"Walk" indication:

- Tone—500 Hz with a repetition rate of 8.5 Hz—series of rapid thump sounds.
- Vibrating arrow.

Other:

- Pushbutton locator tone (locating tone)—880 Hz with a repetition rate of 1 Hz for US market or 1000 Hz with a repetition rate of 0.55 Hz for Australian market.
- Tactile arrow.
- Automatic volume adjustment, with three standard settings for response.

AR0072099

- Alert tone (transitional tone) – brief burst of 3500 Hz tone, decreasing exponentially to 700 Hz, and then going to 500 Hz "Walk" tone.

Optional Features

- Cuckoo and chirper other sounds
- Fixed "Walk" message length of 8, 16, or 32 sec "Walk" message can be cut during the full "Walk" interval
- Actuation indicator (steward indicator/demand tone) – light and tone.
- Long button press – allows pedestrians to request a "Walk" tone at 12 dB above the sound of the locator tone (higher volume demand, HVD).

Installation Notes

Driver unit is mounted in a housing on the pole near the pedhead, wired to the pedhead.

Automatic gain control level is set during installation.

Comments

Complies with specifications of the Australian standard; standard pushbutton in Australia.

Polara Engineering

4115 Artesia Avenue

Fullerton, CA 92833

Phone: 888-340-4872

Phone: 714-521-0900

Fax: 714-521-5587

www.polara.com

Models

Navigator

Photos

Figure B-11. Polara Navigator APS mounted on pole.

Standard Features

"Walk" indication:

- Speech message or cuckoo/chirp
- Vibrating tactile arrow

Other:

- Speaker at pushbutton.
- Pushbutton locator tone (locating tone).
- Tactile arrow.
- Automatic volume adjustment—60 dB range.
- Separate minimum and maximum volume settings for pushbutton locator tone (locate sound), clearance, and "Walk" sounds.
- Actuation indicator – tone, LED light, and tactile bounce back.
- Depression in the arrow enables pushbutton operation with a head stick.
- Push button failures or system failures default to transmitting a constant pedestrian call.

AR0072101

Optional Features

- Custom speech messages.
- Fixed "Walk" message timing or "Walk" message can be on during full interval
- Braille street name on the faceplate
- Face plate with informational sign.
- Optional clearance sounds or audible countdown of remaining seconds during clearance available.
- Direction of travel message.
- Extended pushbutton functions:
  - Pushbutton information message (pushbutton message)
  - Audible beaconing – volume increase of "Walk" indication and pushbutton locator tone during the subsequent pedestrian phase
  - Extended push priority (mutes entire intersection except selected crosswalk to minimize confusion caused by other sounds).
- Talking Signs receiver-based system available as additional option.

Installation Notes

Two-Wire System

Operates with only two wires from the intersection traffic control cabinet to the pushbutton and is programmable after installation by the installer using a handheld PDA type device. Control unit is mounted in the signal controller. Numerous options programmable with PDA.

Four Wire System

Used when pushbutton wires from the traffic control cabinet to each button location do not exist. Two pair of 18-22 gauge wires run from the control unit that mounts in the pedestrian signal head to the pushbutton unit. All features programmed after installation by the installer using a handheld PDA type device.

AR0072102

If Navigator is used in combination with Talking Signs transmitter, the transmitter must be carefully positioned to provide information only within the width of the crosswalk.

A PDA-type device called a Configurator is an additional piece of equipment that is needed for setting the features and volume of their two-wire and four-wire APS. Jurisdictions will need to purchase one or two for technician use. (See Figure 7-9 in Chapter 7 for an example of use of the PDA.)

Comments

Combination of Polara Navigator with Talking Signs transmitter can transmit messages to a handheld receiver to provide orientation and alignment information.

Prisma Teknik

Box 5 Mariestadsvägen 28

543 21 TIBRO, Sweden

Tel: +46 (0)504-460 40

Fax: +46 (0)504-141 41

www.prismateknik.se

Models

- TS 903F, TS 904F, TS-907F, TS 908F very similar with slightly different features.
- Digital Acoustic Pedestrian Signal, DAPS.

AR0072103

Photos

Figure B-12. Prisma TS-907F.

Figure B-13. Prisma TS-995 pedhead-mounted beaconing loud speaker.

Standard Features—TS-903F, TS-904F, TS-907F, TS-908F

"Walk" indication:

- Rapidly repeating percussive tone.
- Vibrating arrow on TS-907 and TS-908 only.

Other

- Speaker at pushbutton.
- Pushbutton locator tone.
- Tactile arrow.
- Automatic volume adjustment within range of 55-95 dB.

AR0072104

- Actuation indicator—light and tone—on TS 903 and TS 907 only.
- Crosswalk tactile map (braille map).
- Fault indicator.

Optional Features

- 10 different tones available.
- Night switch to deaden sound
- Double-ended arrow available for use on medians and right-angle arrow available for use with exclusive pedestrian phasing, where there is a single pushbutton on a corner

Standard Features - DAPS

"Walk" indication:

- Rapidly repeating percussive tone.
- Vibrating arrow.

Other

- Speaker in pushbutton
- Pushbutton locator tone.
- Tactile arrow.
- Automatic volume adjustment within range of 55-95 dB.
- Actuation indicator—light and tone.
- Crosswalk tactile map (braille map).
- Fault indicator.

Optional Features

- 10 different tones available by setting with PDA
- Custom speech "WALK" messages, recorded and programmable with PDA.
- Additional beaconing speaker (TS 9951) for mounting at overhead location
- Night switch to deaden sound
- Double-ended arrow available for use on medians and right-angle arrow available for use with exclusive pedestrian phasing, where there is a single pushbutton on a corner.

AR0072105

- Extended button press features:
  - Pushbutton information message 1.2 s.

Installation Notes

Numerous features of D-APS model are programmable with PDA.

Volume min/max levels are adjustable by installer.

Step-down transformer available for mounting in the pedestrian signal head for U.S. installation.

Tactile arrow is mounted horizontally on top of device, allowing some latitude in placement of APS on pole, while still making it possible to align the arrow parallel with the associated crosswalk.

Wiring colors may conform to European standards rather than U.S. standards.

U.S. Traffic Corporation

9605 John Street

Santa Fe Springs, CA 90670

Phone: 800-735-7872

Phone: 562 923 9600

Fax: (562) 923 7555

www.ustraffic.net

Model

- APS 10

Photos

AR0072106

Figure B-14. APS 10 from U.S. Traffic Corporation.

Standard Features

"Walk" indication:

- Chirps or chirp/peep-peep

Other

- Speaker unit mounted on the pedestrian signal head.
- Volume adjustment – self switching to one of two output levels depending on ambient noise conditions.

Optional Features

None

Installation Notes

Speaker is mounted on the pedhead and wired to the "WALK" indication

Comments

No push button locator tone, vibrotactile indication, or automatic volume adjustment as required by Draft PROWAG

Manufacturer is developing a device that provides audible countdown information

Wilcox Sales

1738 Fifteenth Dr

Claremont, CA 91711-2411

Phone: 909-624-6674

Fax: 909-624-8207

www.wilcoxsales.com

Model

- PS/A 10

AR0072107

Photos

Figure B-15. Wilcox APS unit mounted on pedhead.

Figure B-16. Wilcox APS units.

Standard Features

"Walk" indication:

- Cuckoo and chirp (peep-peep).

Other:

- Speaker unit mounted on the pedestrian signal head.

Optional Features

None

Installation Notes

Fixed volume is adjusted by installer.

AR0072108

Comments

No pushbutton locator tone, vibrotactile indication, or automatic volume adjustment, which are features required by Draft PROWAG.

AR0072109

Appendix C—Research on Accessible Pedestrian Signals

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AR0072110

Introduction

Throughout the preceding chapters of this guide, references were made to various studies to support the recommendations given in those chapters. Interested readers may wish to see more details on the studies underlying these recommendations. This appendix was designed for such readers. This appendix reviews the research literature on APS including

- Research on problems of blind pedestrians,
- Effects of APSs on particular street crossing tasks,
- Effects of APSs on independence and confidence,
- Effects of "Walk" signal characteristics,
- Accuracy and speed in identifying "Walk" indications for a given crossing,
- Research on source of the "Walk" signal,
- Research on other APS features,
- Other concerns and needs, and
- Need for additional research.

Research on Problems of Blind Pedestrians

Introduction

Although APSs have been widely used in Japan and Sweden since the 1960s, the early development of APS in these countries was not, as far as these authors have been able to ascertain, based on research. Nor was there any research basis for the "cuckoo/chirp" APS that has been most commonly used in the U.S.

The first substantial research on APS appears to have been done in 1976 by Frank Bulsher, an electrical engineer with the Department of Motor Transport, New South Wales, Australia. Bulsher's research was the basis for the well developed, fully standardized, and highly successful APS system in use in Australia today.

Substantial research on APS in the U.S. began with a project undertaken by the San Diego Association of Governments in 1988. The results of this project were the basis for a policy of implementing standard signals at intersections in San Diego where audible access committee recommended them, following a systematic evaluation.

AR0072111

Since 1996, there has been a concerted research effort related to APS. Several research studies and surveys have documented problems of pedestrians who are blind or who have low vision at signalized intersections without APSs (Barlow, Bentzen, and Bond, 2005; Bentzen, Barlow and Bond, 2004; Bentzen, Barlow, and Franck, 2000; Carroll and Bentzen, 1999; Murakami, Ishikawa, Ohkura, Sawai, Takano and Tanchi, 1998; San Diego Association of Governments, 1988). Several studies in the United States have contrasted travel by blind pedestrians with and without APSs (Barlow, Bentzen, Bond and Guthie, 2006; Crandall, Bentzen and Myers, 1998; Crandall, Brabyn, Bentzen, and Myers, 1999; Crandall, Bentzen, Myers and Brabyn, 2001; Marston and Golledge, 2000; Ponam, Peck and Waddell, 1988; Williams, Van Houten, Ferraro, and Blasch, 2005). In these studies, some of the APSs have been signals mounted on the pedestrian signal head, while others have been receiver-based systems, and others been pushbutton-integrated devices. Information in this section is drawn from these studies. A brief summary of each follows.

Surveys of Blind Pedestrians and Orientation and Mobility Specialists

The San Diego Association of Governments (1988, and Szatos, Valerio, and Nowak, 1991a, b, c, hereafter referred to collectively as San Diego research) surveyed 71 national, regional, and local organizations representing and/or serving elderly persons and persons who were visually impaired to determine their involvement in installation of audible signals and the level of support for audible signals; 36 responses were received. A separate survey was also sent to members of California Association of Orientation and Mobility Specialists to gather information about their experience with audible signals. Surveys were mailed to 67 members, and 27 responses were received.

In 1998, the American Council of the Blind (ACB) and the Association for Education and Rehabilitation of the Blind and Visually Impaired (AER) conducted similar surveys to determine problems experienced by blind pedestrians during street crossings. Problems with audible signals currently installed were also identified by the surveys.

- ACB survey (Carroll and Bentzen, 1999, hereafter referred to as ACB survey) – Surveys were administered orally, in groups, to 158 pedestrians who were visually impaired.
- AER survey (Bentzen, Barlow, and Franck, 2000, hereafter referred to as AER survey) – Surveys were mailed to 1000 orientation and mobility specialists; 349 surveys were returned.

AR0072112

Murakami et al. (1998) conducted a survey of 80 blind pedestrians in Japan.

More details about the survey results, and references to studies which support the results, are provided in the section on crossing problems.

Crossing Data

Ustan, Peck, and Waddell (1988) compared crossings by 27 legally blind pedestrians at three intersections in Huntington Beach, California, having "chirp call" signals and one control intersection without APS.

In research by the Smith-Kettlewell Eye Research Institute (Crandall, Bentzen, and Myers, 1998; Crandall, Bentzen, Myers and Brabyn, 2001; Crandall, Brabyn, Bentzen, and Myers, 1999; hereafter referred to collectively as SKERI research), 20 blind participants made a total of 80 crossings at four fixed-time signalized intersections in downtown San Francisco, both with and without Talking Signs, which are receiver-based APSs. Intersection signal phases were permissive, so no pushbutton was required. There were nine measures, including measures of crossing timing (safety), orientation (precision), and independence.

Marston and Golledge (2000) compared crossings by blind participants with and without APSs, using the receiver based APS system, Talking Signs, in a study investigating the use of Talking Signs to provide infrared audible signs for a number of transit tasks.

The effects of a pushbutton integrated APS, a receiver based APS manufactured by ReZume, and typical visual pedestrian signals without APS on the street crossing behavior of 24 totally blind participants were compared by Williams, Van Houten, Bertamo, and Blasch (2005).

As part of a project on blind pedestrians at complex intersections, which was funded by the National Eye Institute of the National Institutes of Health, a series of studies on crossings by blind pedestrians with and without APS is in progress in four cities -- Portland, Oregon; Charlotte, North Carolina; Tucson, Arizona; and Cambridge, Massachusetts. Objective data on measures of street crossing performance by 16 participants who were blind was obtained at two complex signalized intersections in each city. Measures were similar to those used in the SKERI research, including nine broad measures of crossing timing, orientation, and independence.

Results from all four cities are not yet analyzed, but slightly different analyses have been reported in several articles. Results from preinstallation testing in two cities, Portland and Charlotte, are reported by Bentzen, Barlow, and Bond (2004), hereafter referred to as NCHRP

AR0072113

cities, and reports on three cities—Portland, Charlotte, and Cambridge—are reported by Barlow, Bentzen, and Bond (2005), hereafter referred to as NEI-3 cities. Barlow, Bentzen, Bond, and Gubbe (2006), hereafter referred to as NEI Portland pre-post, compare results of testing with and without APS in Portland.

Problems with Specific Tasks at Signalized Intersections

Locating the Crosswalk

Pedestrians who are visually impaired use a variety of nonvisual cues and strategies to locate crosswalks, none of which is absolutely reliable. Cues include proximity to the corner or to traffic on the street parallel to the pedestrian's direction of travel, location of curb ramps when present, location of idling cars on the street to be crossed, and presence of other pedestrians. When APSs are present, they may also be used as an indication of the location of crosswalks.

ACB and AER surveys did not include specific questions about locating the crosswalk. In the Japanese survey, 78% of individuals indicated that locating the crosswalk was difficult at intersections without APSs.

In the SKERI research, at locations without an APS, participants requested assistance in locating the crosswalk at 19% of street crossings. Participants were permitted to begin a crossing from any location that satisfied them, whether or not it was actually within the crosswalk lines. On 30% of trials, subjects who located the crosswalk independently began crossing from outside the crosswalk. (Participants were permitted to start crossing from any location so long as they were in no immediate danger.)

The NEI-3 cities results indicated that participants started from outside the crosswalk area on 28.3% of crossings and requested or required assistance locating the crosswalk on 15% of crossings.

Orientation (Aligning to Cross and Maintaining Alignment While Crossing)

Pedestrians who are visually impaired typically use a number of clues to help them align to face the direction of travel on the crosswalk before beginning to cross. These include vehicular sounds such as the detection of parallel traffic flow and the location of idling traffic on the street to be crossed. Another good cue, or strong predictor, of the direction of the destination corner is the direction pedestrians are traveling before they arrive at the starting corner. Additional cues

AR0072114

that are useful in familiar locations are walls, fences, hedges, grass lines, and objects near the curb that have a straight surface that is either parallel or perpendicular to the direction of travel across the crosswalk. The direction of slopes of the curb ramp and the alignment of a truncated dome detectable warning near the bottom of the curb ramp are not reliable indicators of the direction of travel on the crosswalk, and when used either intentionally or inadvertently, they may lead pedestrians who are visually impaired into the center of an intersection. Although there are numerous clues to the direction of travel on the crosswalk, none of them alone or in combination provide a definitive direction to pedestrians who are crossing at unfamiliar crosswalks.

Two clues used to help pedestrians who are blind maintain their alignment while crossing are the distance and direction of parallel traffic flow and the location of idling vehicles on the perpendicular street. Even at familiar crossings these clues may not be sufficient to provide positive guidance to pedestrians who are blind as they are crossing a street.

In the ADR survey, 97% of O&M specialists who responded indicated that their students had difficulty aligning to cross the street, while 66% indicated that their students sometimes had difficulty knowing when the destination corner was. The most important reasons stated were that traffic was intermittent or the intersection was offset. In the ACB survey, 79% of respondents indicated that they sometimes have difficulty figuring out where the destination corner is.

Respondents to the Japanese survey indicated that "direction facing at the starting position" and "keeping direction while walking in the crosswalk" were a problem, even with an APS.

The broadcast sound from speakers mounted on the pedestrian signal head has not seemed to provide usable directional information. ACB and ADR surveys indicated that pedestrians who are blind are sometimes not able to localize the sound of an APS in order to use it for guidance across the street (ACB, 6%; ADR, 39%). Eighty-five percent of ACB respondents indicated that they were sometimes confused by unexpected features such as medians or islands, while 64% of O&M respondents indicated that their students had difficulty with medians or islands.

In the SKERI research, participants started crossing from an aligned position at 48% of crossings without an APS and completed their crossings within the crosswalk on 58% of crossings. In the NEI-3 cities research (without APS), participants started from an aligned position on 73.4% of crossings. Participants requested assistance or required intervention for

AR0072115

safety while aligning to cross on 10% of crossings. Of participants who aligned independently, 58.1% completed their crossings within the crosswalk.

Using Pushbuttons

At 90% to 95% of signalized intersections today, signal timing is constantly adjusting to accommodate current vehicular and pedestrian traffic, and pedestrians are required to push a button to actuate a pedestrian timing to cross the street. Unless a pedestrian pushes the button, the "Walk" signal will not come on, and, when there is a green signal for parallel traffic, it is timed to accommodate vehicular traffic, not pedestrians. A pedestrian who does not push the button and who crosses with the green signal for parallel traffic may not have enough time to cross the street. The vehicular signal timing may be as much as 20 s less than the pedestrian signal timing (Barlow and Bentzen, 2003). Therefore it is very important that pedestrians who are visually impaired use pushbuttons.

Blind pedestrians experience a number of problems with pushbuttons.

In the ACB and AER surveys, many respondents indicated that they or their students had difficulty with pushbuttons (ACB, 90%; AER, 94%). The following reasons were given:

- Users couldn't tell whether they needed to push a button.
- Users had difficulty locating the button.
- Users couldn't tell which crosswalk was activated by the button.
- The pushbutton was so far from the crosswalk that users couldn't push the button and then return to the crosswalk and align to cross before the walk interval began.

Ulfan et al. (1998) also found that, with "bird call" type APSs, 27 legally blind participants had major problems locating the pole and the pushbutton and determining which pushbutton was for which crosswalk. Participants traveling with guide dogs experienced the most difficulty locating the pole. Sometimes participants first located the incorrect button and subsequently located and pushed the correct button after waiting and listening through one or more cycles.

The San Diego research also identified problems with locating the pushbuttons and poles (Szlyk et al., 1995). Gallagher and Montes de Oca (1998) also noted this in research on vibrotactile only APSs.

AR0072116

In the NEI-2 cities results, at crossings where pushbutton activation was required, participants looked for, found, and pushed the button on only 16.3% of these crossings in Portland and none (0%) of the crossings in Charlotte.

In research under NCHRP 3-62 (see NCHRP 3-62 Final Report and Bentzen, Scott and Barlow, 2006), blind participants crossing at signalized intersections with APS in Tucson, but without having any instruction in use or purpose of the APS, failed to even search for pushbuttons at 29% of crossings.

Identifying the Onset of the Walk Interval

In the absence of an APS, pedestrians who are visually impaired rely on the stopping of perpendicular traffic, followed by the onset of parallel traffic, to indicate the onset of the walk interval. Pedestrians who do not quickly and accurately identify the onset of the walk interval are likely to be delayed in starting to cross, may miss crossing on the first pedestrian phase, or may begin crossing when the walk interval is not in effect. Complex geometry and intersection signalization make the use of traditional clues to the onset of the walk interval unreliable.

Many respondents to the surveys indicated that they or their students sometimes had difficulty knowing when to begin crossing (ACB, 91%; AER, 98%). The following reasons were identified:

- The surge of traffic was masked by right turning traffic.
- Traffic flow was intermittent.
- The intersection was too noisy.
- The surge of traffic was too far away.

In the AER survey, 79% of respondents indicated that blind students sometimes had difficulty determining the onset of the walk interval at intersections having exclusive pedestrian phasing.

In the Japanese survey, 46% of respondents stated that "to take a timing to start" was difficult without APS.

Ulzan found that, at the control intersection without APS, which was considered the easiest to cross without APS, 4 out of 15 participants began crossing during the "Don't Walk" interval.

AR0072117

In the SKERI research, on 24% of trials when APS information was not available, blind pedestrians requested assistance in knowing when to start crossing. On 34% of trials on which they independently initiated crossings, participants began crossing during the flashing or steady "Don't Walk."

The NCHRP cities research found that pedestrians who were blind began crossing independently during the walk interval on only 48.6% of crossings and completed crossings after the onset of perpendicular traffic on 26.9% of crossings. The need for pushbutton actuation of the walk interval affected the likelihood that participants would begin crossing during the walk interval. On the pedestrian actuated crossings, participants began crossing during the walk interval on only 19.5% of the crossings, compared with 71.7% of crossings where the pedestrian phase was on recall (i.e., the pedestrian phase was actuated in every cycle).

Mean latency in beginning crossing (the time between onset of the "Walk" signal or near-side parallel traffic and the participant beginning to cross) was 6.41 s.

Problems with APS

The ACB and AER surveys were not limited to information about crossings that did not have APS; they also had questions about APS volume and about confusion of tones.

Volume The 1998 ACB and AER surveys reported the experience of pedestrians with visual impairments in using APS that had "bird call" signals, bells and buzzers. There were problems both with APS being considered too quiet and too loud. In the ACB survey, 45% of participants considered signals to be too loud, while 71% considered them too quiet. In the AER survey, 24% of participants considered signals to be too loud, while 32% reported that the signals were too quiet.

When APS are too loud, and are at intersections that are close together, the APS for one intersection may be heard from another, leading some pedestrians to incorrectly think they have the walk interval. The surveys noted this problem (ACB—19%; AER 25%).

In addition, complex phasing can contribute to problems with APS volume. Ustan et al (1988) found that at one intersection with split phase timing, where the bird call signals for parallel crosswalks had separate timing, three of 15 blind participants initiated their crossings with the signal for the parallel crosswalk, walking into the paths of left-turning vehicles.

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Problems with APS: Knowing Which Street Has the "Walk" Signal—Researchers particularly evaluated data from the AER and ACB surveys of blind pedestrians and O&M specialists from California, whose experience with APS is almost exclusively with "bird call" signals that are intended to provide unambiguous information regarding which street has the walk interval. Many respondents indicated that they or their students sometimes did not know which crosswalk had the walk interval (ACB, 68%; AER, 72%). The reasons cited included the following:

- Users forgot which signal was associated with which crossing direction.
- Users didn't know which direction they were traveling, and
- The intersection was not aligned with primary compass directions.

The San Diego research also indicated that blind pedestrians had difficulty remembering which sound was for which crossing direction.

Recent research in the NIH project and the NCHRP Project 3-62 addressed this issue. (See Chapter 5 in this guide.)

Problems with APS: Confusion of Tones with Other Sounds—Anecdotal evidence has existed for some time that some birds in the United States have calls that are like the chirp sound of some APSs, and that other birds may mimic this sound. This has led to confusion between APS sounds, particularly the chirp sound and the sounds of birds.

AER and ACB surveys confirmed that blind pedestrians really do confuse the sounds of birds with APS sounds. In the AER survey, 11% of respondents stated that their students had crossed the street with an actual bird, and 10% stated that their students had not crossed because they thought the signal was a bird. Lasky et al. (1988) and the San Diego research also noted this as a problem.

Pedestrian Crashes

To obtain a rough measure of the incidence of intersection crashes and near crashes for pedestrians who are visually impaired, the ACB survey asked respondents whether they had been struck by a car at an intersection or whether their long canes had been run over. In the ACB survey, 12 of 158 (8%) of respondents had been struck by a car at an intersection, and 45 (28%) had had their long canes run over.

AR0072119

Effect of APSs on Specific Crossing Tasks

Introduction

Since it is known that pedestrians with visual impairments have difficulty with many of the tasks that, taken together, compose the action of crossing a street, it would be desirable to think that APSs improve all measures of crossing at signalized intersections. To determine the extent to which this is true, a number of research projects have obtained objective data comparing street crossing with and without APSs on one or more of the following measures:

- Locating the crosswalk,
- Aligning to cross and maintaining alignment while crossing,
- Use of pushbuttons,
- Identifying the walk interval,
- Delay before beginning to cross, and
- Independence in any or all crossings tasks

Projects that have already been mentioned are SKERT research, NEI Portland pre-post, Uslan et al. (1988), Marston and Golledge (2000), and Williams et al. (2005).

There are several additional studies that shed light on this topic. As part of NEI research, in three different experiments, blind and blindfolded sighted participants made crossings at a simulated intersection, in the presence of recorded traffic sound, to determine the effect on crossing accuracy with signals composed of bird calls, percussive "ticks," a chirp train, or a female voice (Wall et al. 2004). The signals, all of which were mounted at a height of 8 ft, came either simultaneously from both ends of a crosswalk (typical practice), alternated from one end to the other, or came from the far end of the crosswalk only. These researchers also compared crossing accuracy when signals came from two parallel crosswalks (typical practice) or from a single crosswalk. A further comparison was between "Walk" signals with a typical 7 s duration versus a 7 s "Walk" signal followed by a locator tone.

Hulscher (1976) reported an estimate by Leith (personal communication) comparing starting delay pre- and post-APS installation.

Wilson conducted a pre- and post-APS installation study of behavior of adult, non-assisted pedestrians at one intersection.

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Further, the research undertaken for NCHRP 3-62 contributed to the understanding of the effects of APSs on specific crossing tasks.

Results of Research

Locating the Crosswalk

SKERI research found that starting crossing from within the crosswalk increased from 70% to 97% with use of an APS.

NEI Portland pre-post research found significant increases in participants' ability to begin crossings from within the crosswalk at locations where pushbutton use was required and pushbutton locator tones were installed. Preinstallation, 77% of crossings began from within the crosswalk; post-installation, 97% of crossings began within the crosswalk, indicating that locating the crosswalk was significantly improved by the presence of a pushbutton-integrated APS (Barlow, Bentzen, Bond and Gubbe, 2006).

Orientation (Aligning to Cross and Maintaining Alignment While Crossing)

APSs have some affect on aligning to cross, but results have not been as positive as desired.

On 48% of crossings in the SKERI research, where APS information was not available, blind pedestrians were not facing directly toward the opposite corner when they started their crossings; rather, they were facing somewhat toward or away from the center of the intersection. With the use of receiver-based APSs, participants were well aligned when beginning 80% of crossings.

However, in NEI Portland pre-post research, alignment showed only a very small trend toward improvement, with 70% of independent crossings starting from an aligned position preinstallation and 84% postinstallation.

NEI research (Wall et al. 2004) found the presence of a locator tone during the second half of the crossing had a positive effect on alignment.

In the NCHRP 3-62 research on device features, statistical analyses revealed no differences in orientation attributable to device in Tucson, and only a few minor differences in Charlotte. These differences are easily explained by unique characteristics of the given intersection or pole placements, and taken together with the lack of findings in Tucson they suggest that none of the differences in APS device features on different manufacturer's APS had an important impact on pedestrian orientation. (See NCHRP 3-62 Final Report, and Bentzen et al. 2006.)

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Various means of beaconing and providing directional information to blind pedestrians are being investigated in the NEI research, including increasing the volume of the locator tone and providing it from a directional speaker, and providing an orientation tone that involves increasing the volume of the locator tone on the opposite end of the crosswalk before the crossing interval, in response to a request. Data collection and analysis of results from these experiments are not complete.

Using Pushbuttons

Data reported in NEI pre-APS installation testing (NEI 2 cities, NEI-5 cities) indicated that blind pedestrians typically didn't search for and use pedestrian pushbuttons at unfamiliar intersections. In Portland, after installation of APS with locator tones (NEI Portland pre-post), participants were not instructed to use the pedestrian pushbuttons, nor were they provided with instruction about the fact that pushbuttons were needed to call the walk interval at some of the crossings. However, the addition of pushbutton locator tones and the knowledge that an APS might be installed resulted in participants looking for the pushbuttons on over 98% of crossings, although looking for the pushbutton did not always result in finding and using the correct pushbutton. Participants independently looked for and used the pushbuttons on 93% of the crossings after pushbutton locator tones were installed. In the pre-test situation, pedestrians had looked for and used pushbuttons on only 16% of crossings.

NCHRP 3-62 research (see NCHRP 3-62 Final Report and Bentzen et al., 2006) reported that while pedestrians who are blind do not typically use pushbuttons when making unfamiliar crossings, after being made aware of the function of the pushbuttons to call the walk interval, and hearing the demonstration locator tones, 100% of participants in Tucson and Charlotte searched for the pushbutton. Participants in both cities said they used the locator tone when locating the pushbutton on most trials, regardless of device. However, the presence of a pushbutton locator tone did not guarantee that participants would find and push the correct pushbutton. Errors in finding the correct pushbutton were reported, leading to recommendations for instruction in understanding and using tactile arrows, as well as maintaining orientation while looking for pedestrian pushbuttons.

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Initiating the Crossing

APSs have been found to positively affect measures of delay in beginning to cross, starting crossing during the walk interval, and completing crossings before the onset of perpendicular traffic.

Delay in Beginning to Cross - Ulusche (1976) cites a personal communication from Leith (1975) in which Leith estimated that, following APS installation, delay in beginning crossings was reduced an average of 2 to 3 s for all pedestrians.

Watson (1980) in a pre- and post-APS installation study of adult nonestablished pedestrian behavior at one intersection, found the following results:

- For pedestrians using the pushbutton, delay in beginning crossings was reduced by 20%, from 2.7 s to 2.1 s.
- The time taken to cross by persons who started during the walk interval decreased by about 5%; crossing time for other pedestrians was unchanged.
- For pedestrians who arrived at the crossing during the flashing or steady "Don't Walk" and who waited to cross until the onset of the walk interval, the proportion who failed to complete their crossings before the onset of opposing traffic was reduced by one-half, from 32% to 17%.

Williams et al. (2005) found that mean latency in beginning crossing without APS was more than 5 s, which was reduced to 2.2 s with a receiver-based APS device with a tone "Walk" indication and 3.8 s with a pushbutton-integrated APS using speech messages.

In NCHRP/Portland pre-post research, in 144 crossings at two intersections, the weighted mean starting delay for blind pedestrians without APS was 5.1 s, and after APS installation, the delay was reduced to 2.9 s. Ulstan et al. (1988) also found significant differences between speed of crossing at control intersections and intersections where APS were installed; crossings at locations with APS were completed faster.

Williams et al. (2005) assessed participants on total number of signal cycles missed before crossing. Without APS, mean wait time was almost 2 full cycles, while with either type of APS, the mean wait time was just over half a cycle.

In NCHRP research, different "Walk" indications have been found to affect latency to begin crossing. (See NCHRP 3-62 Final Report, Chapter 2.)

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Starting During "Walk" and Completing Crossing Before the Onset of Perpendicular Traffic—In SKERI research, participants began crossing during the walk interval on only 66% of crossings without APS, but on 99% of crossings with APS.

In NE Portland pre-post research, without APS the pedestrian actuated crossings were highly problematic for pedestrians who are blind. Preinstallation, participants began crossing during "Walk" on only 25% of crossings. Postinstallation, there was dramatic improvement in participants correctly determining the appropriate time to start crossing, with 84% of crossings initiated during "Walk." Similarly, participants completed crossing after the onset of perpendicular green on 56% of crossings preinstallation, with a significant decrease, postinstallation to 12% of crossings completed after the onset of perpendicular green.

Furthermore, only 37% of decisions about when to start crossing were made independently preinstallation, as opposed to 95% postinstallation. Preinstallation, the total number of crossings where the individual independently determined a start time and actually began crossing during the walk interval was less than a quarter of crossings. Postinstallation, with the addition of the APS, there was a significant increase both in independence and in beginning to cross at the appropriate interval.

For crosswalks where the pedestrian phase was on recall, the APS activated at the beginning of the walk interval, regardless of whether the pushbutton was used or not. The "Walk" indication only sounded for the first 7 s of the walk interval, unless the pushbutton was pushed again. Preinstallation, 70% of independent crossings began during the walk interval; postinstallation, this increased to 100%.

Marston and Golledge (2000) found that at crossings without an APS, almost half (48%) of the participants attempted to cross during the steady "Don't Walk" interval, a time recorded as unsafe by the researcher. With access to the pedestrian signal information provided by an APS, no participant started crossing at an unsafe time.

Effect of APSs on Independence and Confidence

Both independence and confidence affect the likelihood that people who are blind will cross streets independently. Lack of independence and low confidence in ability to cross safely result in lack of participation in normal community life.

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Independence

Both the NEI research and the earlier SKERI research on which the method was based measured independence on three street-crossing tasks both with and without APS—i.e., locating the crosswalk, starting to cross within the walk interval, and completing the crossing. The NEI research also measured independence on aligning to cross. The percent of crossings on which participants were independent on each task is shown in Table C-1.

Task	Without APS		With APS	
	SKERI	NEI	SKERI	NEI
Locating crosswalk	81%	81%	99%	95%
Aligning to cross	NA	94.5	NA	97%
Starting to cross during WALK	76%	79%	100%	92%
Completing the crossing	81%	86%	97%	96%

Table C-1. Percentage of crossing tasks on which participants were independent.

Confidence

Marston and GeDodge (2000) measured confidence in street crossing at intersections with and without APSs. The range of responses for the no APS condition, by street crossing task, was 2.7 to 3.5 (5 point scale: 1 = no confidence, 5 = very confident), while the range of responses by task for the APS condition was 4.8 to 5.0.

Effect of "Walk" Signal Characteristics

Introduction

Both the Access Board Draft Guidelines for Accessible Public Rights-of-Way (revised 2005) and this APS Guide recommend using a rapid tick "Walk" indication. Research on "Walk" signal characteristics, described in this section, formed the basis for that recommendation.

It is important that any audible "Walk" signal be detectable and localizable, and, if it is a speech message, it must also be intelligible. Two factors make it difficult to satisfy these requirements. First, both detection and localization are influenced by ambient sound, especially the sounds of vehicles. Second, any degree of hearing impairment makes it more difficult to

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detect and localize sounds and to understand speech. One might think that simply making the "Walk" signal loud enough would overcome both problems. However, the problems are much more complex.

Not only volume, but also the nature of the sound (that is, the spectral and temporal characteristics) must also be taken into account. A body of research, reported below, describes efforts to identify the characteristics of sounds or messages that make them detectable, localizable, and intelligible. Some of this research particularly addresses detectability, localizability, and intelligibility for people with hearing impairments.

There are also important limits to the amount of "Walk" signal noise that will be tolerated in neighborhoods, and limits to signal volume that are based on Occupational Health and Safety Administration (OSHA) requirements. Furthermore, if the "Walk" signal is too loud, it may make it difficult for pedestrians who are blind to hear the sound of vehicles that are about to cross their path.

APS devices available today respond to ambient sound, providing "Walk" signals that are louder when the ambient sound is high, such as when a large truck accelerates, and quieter when the ambient sound is low, such as at night. This greatly increases the public's acceptance of APSs.

APS users must not only be able to detect the "Walk" signal and localize it, they must also be able to quickly and unerringly determine which crosswalk the signal is for. The nature of the signal and its location are critical to the performance of this important part of the street-crossing task.

Results of Research

Hearing Loss and Blind Pedestrians

A majority of persons who are severely visually impaired are age 65 or older, and they typically also have some amount of upper frequency, age-related hearing loss. In addition, the incidence of hearing loss in people with visual impairments is higher than for the general population because a number of causes of blindness also result in hearing loss.

Upper frequency hearing loss results in a decrease in the ability to localize sound and to understand speech, particularly in noisy environments (Wiener and Lawson, 1969).

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Characteristics of Traffic Sounds

The sound produced by vehicular traffic is concentrated in the low frequencies, especially for vehicles that are accelerating from a stop. The noise produced by accelerating vehicles is approximately 10 dB louder than that of vehicles traveling at a constant rate of speed. The mean intensity of accelerating traffic, measured from the position of a pedestrian waiting to cross streets in residential and small business areas, was found by Wiener and Lawson (1997) to be 89 dB, equal to the maximum APS volume currently permitted by the MUTCD. (The 89 dB maximum in the MUTCD was based on OSHA 8-hour exposure limits.) This means that signals at their maximum permitted volume will sometimes be difficult to hear.

Detectability

Hulscher (1976) found that, because of the masking of high frequency signals by predominantly low frequency traffic noise, and because a majority of blind pedestrians have some upper frequency hearing loss, the optimal fundamental frequency of the "Walk" tone is between 500 Hz and 1000 Hz, and the tone should be composed of multiple short bursts of sound to aid localization.

Staffeldt (1968), in research cited by Hulscher (1976), conducted extensive testing of APSs at crossings where they were mounted on the pedestrian signal head and found that an 880 Hz signal was most detectable in a background of traffic noise.

Hulscher's recommendation and Staffeldt's result was supported by Poulsen (1982), who compared the noise spectrum of traffic as attenuated by windows to arrive at a recommended signal frequency (880 Hz) that would not be largely masked by traffic noise, but would also not transmit through windows and become a public annoyance.

In San Diego research, laboratory measurements of "chirpcall" signals from Nagoya Electric Works of Japan found that neither signal was highly directional. However, the cheep was more detectable than the cuckoo. The cheep was produced by a continuous frequency variation with a fundamental frequency base of 2800 Hz, and the cuckoo consisted of two frequencies with a combined frequency base of 1100 Hz. (Currently available "cuckoo/cheep" signals may vary from this manufacturer's standard.)

Hall, Rabelle, and Zabihaylo (1996) worked with audiologists to develop a signal that provided the most localizable melody for an accessible signal and recommended a melody that

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was composed of fundamental frequencies between 300 Hz and 1000 Hz, but including harmonics extending to 7000 Hz.

In NEI research unpublished data, Wall, Ashmead, Barlow, and Bentzen carried out a series of experiments on detectability of "Walk" signal indications in a laboratory setting. Experiment 1 evaluated the detectability of signals in white noise. Experiment 2 evaluated the detectability in traffic noise, and Experiment 3 evaluated detectability in traffic noise for subjects with age-related hearing loss. Signals evaluated were an 880-Hz square wave, a bird chirp, a cuckoo, two click trains, two percussive signals ("chink" and "tok"), a four-tone melody, and female and male voice signals.

Results indicated that audible signals of a more percussive nature with predominantly lower frequencies were best heard in background traffic noise. In addition to one of the percussive signals, participants with age-related hearing loss were better able to detect male voice signals. Signals with a simple percussive nature tended to need less gain to be heard in noise, relative to the levels necessary to be heard in quiet. In other words, percussive signals were more detectable at lower volumes.

When asked their preference, most participants liked voice signals best, but all of the voice signals needed more gain to be heard. Note that the measurement in these studies was the point at which the signal was detected, not the point at which the message was easily understandable. Intelligibility of voice messages was not evaluated or assessed by participants. The cuckoo and chirp, most commonly used in the U.S. as an audible signal at the time of the study, required the most gain to be detectable amidst background noise.

Localizability of "Walk" Signal

An additional factor of audible pedestrian signals are to be used as beacons to guide pedestrian with visual impairments across a street, is how well signals can provide directional information. Laroche, Gigure, and Poirier (1999) compared localization of cuckoo and chirp signals to localization of 4-four note melodies varying in fundamental frequencies, harmonics, note duration, and temporal separation between notes. In combined objective and subjective testing, the chirp and a melody with minimal harmonics were found to be less localizable than the cuckoo and the other three melodies. In a follow-up study, Laroche, Laroux, Giguere and Poirier (2000) compared the typical cuckoo-chirp sounds used in Canada with a cuckoo having a

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lower fundamental frequency and the melody that was recommended as a result of their 1999 research. In both studies, the signal was 30 s long (much longer than typical U.S. "Walk" indications) and the measurements were in a simulated pedestrian corridor in a quiet environment. In situations with actual traffic sounds, the chirp was found to result in significantly greater veering and longer crossing times than any of the other signals, which did not differ from each other.

In NLI research, Wall, Ashmead, Bentzen, and Barlow (2004) found no significant differences in localizability among several disparate signals including cuckoo, chirp, "cos," and voice messages when tested in research that involved multiple crossings on a simulated street, in the presence of recorded vehicular sound. The five signals used were representative of signals in wide use or that showed promise for directional beaconing. None of the analyses indicated any systematic differences between the five signals. Further experiments focused on presentation mode and signal location, rather than signal sound characteristics.

Speech "Walk" Indications

Several APS systems used in the United States are capable of producing directly audible speech messages, either from a speaker that is integrated into the pushbutton housing or from a speaker at the pedestrian signal head. When demonstrations are given indoors, to an audience for whom English is the predominant first language, APSs with speech messages are considered by many people to be especially user friendly. However if messages are not correctly understood by users, APSs with speech messages, especially speech "Walk" indications, can lead to catastrophe.

Intelligibility of speech messages is influenced not only by the relationship between signal volume and ambient sound, but also by the nature of the message, how familiar the hearer is with the English language, and any kind of hearing impairment that the user may have.

Understanding Speech in Noise Listeners with "normal" hearing require that speech be 15 dB louder than background noise for intelligibility to reach 90% (Killion 1999). This means that, in order to be intelligible, speech messages should be louder than tone indications. The effect of that louder sound level on the ability of blind pedestrians to hear other sounds in the intersection, or the effect of the louder sound level on nearby neighbors, may limit the acceptability of speech messages. At this time, the MUTCD and Draft PROWAG limit the output of APSs to 5 dB

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above ambient sound, except when special actuation requests a louder pedestrian signal for a single pedestrian phase. As noted in the section on detectability, speech messages can be detected in traffic sounds, but that does not guarantee that they can be understood.

Speech "Walk" Message Structure and Wording—Bentzen, Barlow and Franck (2000) conducted research to obtain information from stakeholders regarding the structure and content of speech messages for APS "Walk" messages and for "pushbutton information messages" that are available only during flashing and steady "Don't Walk." "Walk" messages convey that the "Walk" signal is on and provide the name of the street being crossed. Pushbutton messages provide intersection and crosswalk identification information, and may also provide information about unusual intersection signalization and geometry.

The research utilized an expert panel of stakeholders, who prepared a survey composed of sample messages to rate, as well as items to determine respondent understanding of messages. The survey was administered to people who are visually impaired, O&M specialists, transportation engineers, and APS manufacturers.

Speech "Walk" messages should provide pedestrians who are blind with information that is similar to the information being provided to pedestrians who are sighted. The message should not be worded in a way that seems to provide a "command" to the pedestrian. For example, "Cross Howard Street now" would not be an appropriate message.

Messages also should not tell users that it is "safe to cross."

Research resulted in recommended messages for the walk interval, which include beginning with the name of the street being crossed — for example, "Broadway. Walk sign is on to cross Broadway." Recommended messages are included in Chapter 4 of this guide.

Effect of Speech Messages on All Pedestrians—Van Houten, Malenfant, Van Houten, and Retting (1997) found that redundant information conveyed by audible pedestrian signals increases the attention of all pedestrians to turning traffic and may contribute to a reduction in pedestrian-vehicular conflicts and crashes at signalized intersections. Their research in Clearwater, Florida, used prototype speech message technology in which speech messages were broadcast from the pedestrian signal head. When the pedestrian pushbutton was pressed, the message was "Please wait for 'Walk' signal." The message "Look for turning vehicles while crossing [street name]" began 200 ms before "Walk" signals were illuminated.

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The signal also gave participants who were blind precise information about the onset of the walk interval and about which street had the walk interval.

Accuracy and Speed in Identifying "Walk" Indication for a Given Crossing

Introduction

Both the Access Board Draft PROWAG and this guide emphasize the importance of installation location for APS. Installation location is critical for accurate and fast identification of which crosswalk has the "Walk" signal. Research on the "Walk" signal location and tone, described in this section, was the basis for that recommendation.

APSs must provide unambiguous information regarding which crosswalk has the "Walk" indication. A pedestrian who mistakes the signal for one crossing as a cue for a signal for the other crossing is at risk of making a crossing when vehicular traffic has the right of way and pedestrian crossing is not permitted. A two-tone system such as cuckoo/chirp has long been assumed to provide unambiguous information; however, San Diego surveys and Uslan et al. (1988) noted problems with such systems. ACB and AER surveys confirmed that there were numerous problems with it.

Speed in identifying the "Walk" signal for the desired crossing is related to delay in starting to cross. The most desirable signal from this perspective is one that is quickly identified, enabling users to initiate crossings promptly, and to finish crossing before the onset of perpendicular traffic.

Results of Research

In NEI research, Ashmead, Wall, Bentzen, and Barlow (2004) investigated the effects of location of APS speakers on accuracy and speed in identifying the correct crosswalk (see Figure C-1 for APS positioning used in research), using typical placements seen in the United States.

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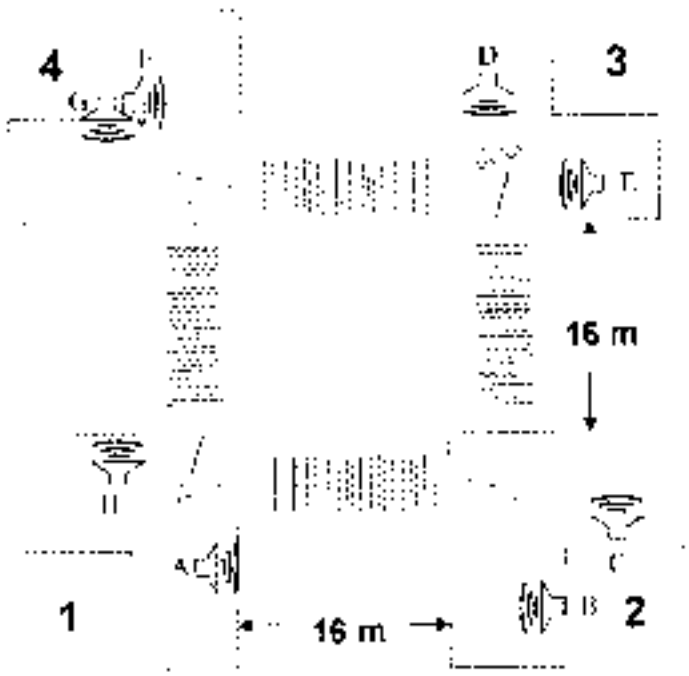

Figure C-1. Positions and headings of loudspeakers and pedestrians at each corner in NEI research. (Figure from Ashmead et al., 2004) Note: The question to the pedestrian always was, "Which has the "Walk" signal, the crosswalk straight in front of you or the one to your right?" Corner 1: loudspeakers near curb, on outside of crosswalk line. Corner 2: loudspeakers near back edge of sidewalk, on outside of crosswalk line. Corner 3: loudspeakers near curb but facing across pedestrian's position. Corner 4: loudspeakers near back edge of sidewalk mounted on the same pole. (Figure is not drawn to scale.)

Under the most typical signal mode, simultaneous presentation from both ends of the crosswalk, the most accurate performance occurred when signals were placed close to the curb line, near the side of the crosswalk that was furthest from the center of the intersection (see Corner 1 in Figure C-1). The pedestrian could easily tell which of the two loudspeakers at the corner was active because each loudspeaker was close to the position of the pedestrian waiting to cross at the associated crosswalk. Note that this was true despite the fact that both signals on the corner had the same sound. Other arrangements of loudspeakers resulted in somewhat worse performance. Accuracy at Corner 3 was poor, with participants answering correctly on only 25%

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of trials in the simultaneous presentation condition and 80% of trials in the alternating presentation condition.

There was no evidence that response time differed across the four corners—that is, for different speaker arrangements. This suggests that the inaccurate judgments made from Corner 3 about which crosswalk had the "Walk" signal did not reflect uncertainty, but rather were mistakes of which the participants were largely unaware.

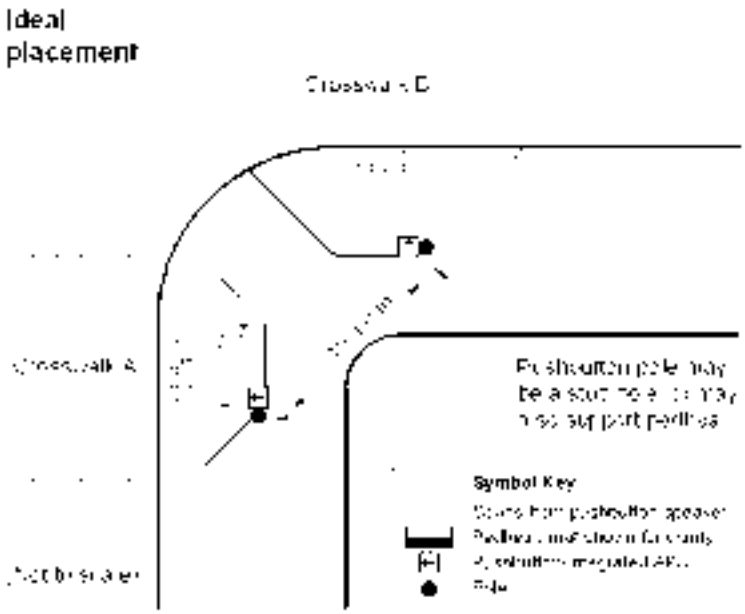

Figure C-2. Optimal location of pushbutton-integrated APS.

Figure C-2 illustrates the recommended placement of APS devices in relation to the crosswalk provided in the APS synthesis in 2003. This arrangement was based on the NEI research described above. However, the panel for the NCHRP Project 3-62 asked for additional research to determine if use of two poles at each corner was necessary, or if installation of two devices on one pole could result in accurate and fast identification of which crosswalk had the "Walk" indication.

Both the location of pushbutton-integrated APS and various associated signals were investigated under NCHRP Project 3-62 in an intersection in Portland, Oregon. (See Figure C-3 for the location of APSs on each corner and the sounds associated with each.) Ninety participants who were blind, who had low vision, or who had cognitive disabilities made all eight

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approaches to a four-way intersection, were asked to push the button for to cross the street in front of them, and then to indicate when the "Walk" signal came on for the street in front of them. Participants did not cross the street except as they were guided from one corner to the next. (See NCHRP 3-62 Final Report and Scott, Myers, Barlow, and Bentzen, 2006.)

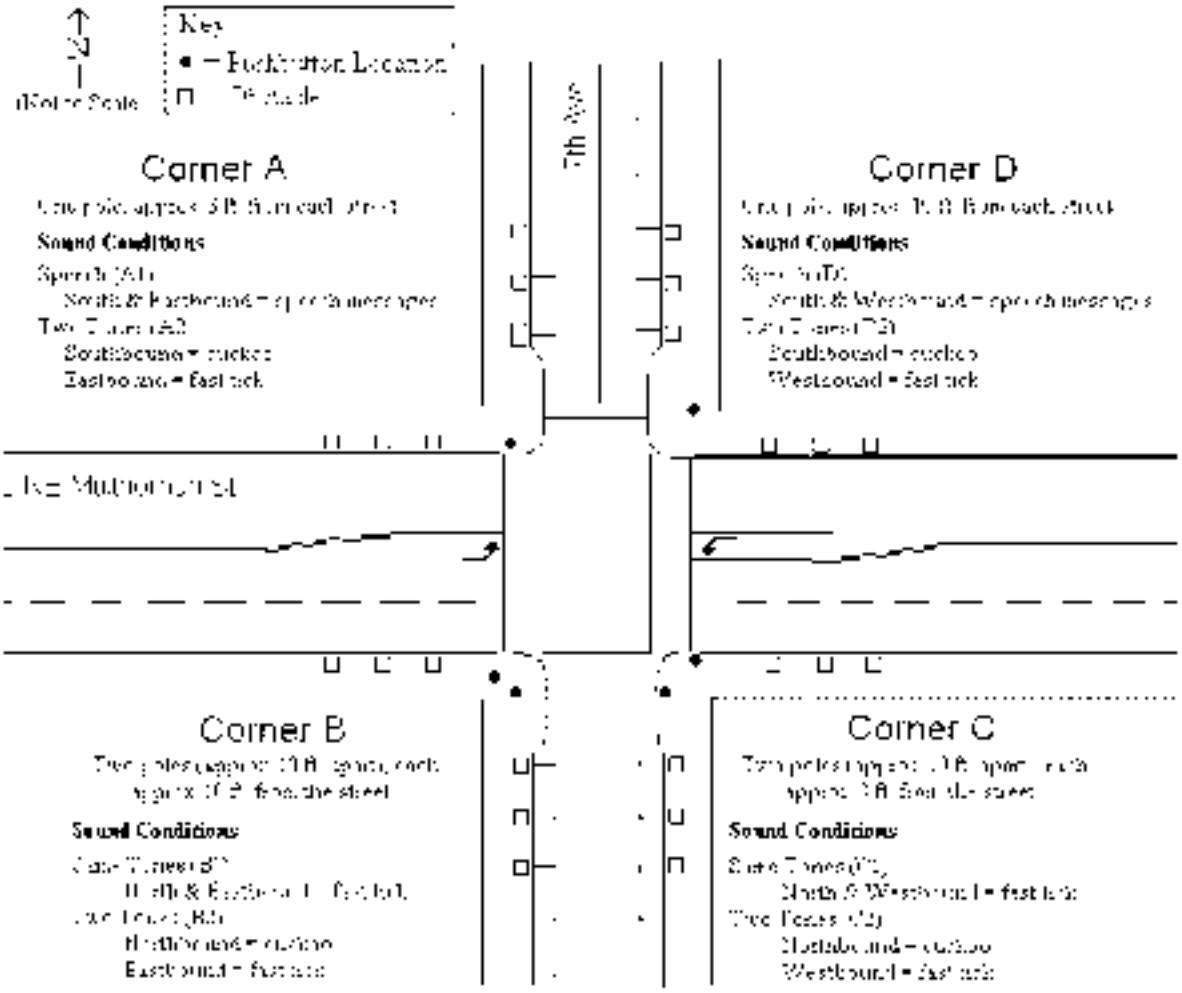

Figure C-3. Locations of pushbutton-integrated APS and associated "Walk" signals in NCHRP 3-62 research.

Results indicated that when pushbutton integrated APSs were mounted on separate poles, near the crosswalk line furthest from the center of the intersection, approximately 3 ft from the curb line, and approximately 10 ft apart, accuracy in judging when the correct crosswalk had the "Walk" signal was significantly better than when APSs were located according to other criteria (see Corner C, Figure C-3). On Corner C, participants in the totally blind and legally blind

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subgroups indicated that the street in front of them had the "Walk" signal, when in fact the "Walk" signal was to cross the street beside them, in only 7.55% of trials. For all other tested arrangements, the same participants made this type of error in at least 26.9% of trials. Responses to the onset of the correct "Walk" signal were also significantly faster at Corner C.

For the two subgroups with the least vision, use of two different tones, when APS speakers were located on the same pole, resulted in errors in determining which street had the "Walk" interval on 50% of trials. Even when APSs were located on two separated poles, accuracy in identifying the onset of the correct "Walk" signal was significantly greater when both APSs on the same corner used the same tone (rapid tick) than when the two APSs used two different tones (cuckoo and rapid tick).

Speech "Walk" messages, when two APSs were located on the same pole, were also evaluated in this research. Speech messages resulted in a much lower error rate than two tones (19% versus 50%); however, locating the APSs on two separate poles and using the same tone on each for the "Walk" indication resulted in an error rate of less than 4%. Locating the APS speakers close to the crosswalk being signaled resulted in much better accuracy in identifying which street had the walk interval than variation in "Walk" indications.

The research recommended use of the rapid tick "Walk" indication because it produced the fastest and most accurate responses regarding which crosswalk has the "Walk" indication. This recommendation was in conjunction with recommendations for specific locations for the APS.

Participants who had enough vision to see the pedestrian signal (identified in the study as persons with low vision or cognitively impaired) reported that they used the visual signal. However, the results for these groups are in the same direction as the results for the two subgroups with the least vision. It thus appears that the participants who could see the visual pedestrian signals might nonetheless have been influenced by the APS pole arrangement and signal sound.

In research comparing devices having various features, conducted in Tucson and Charlotte under NCHRP Project 3-62, (see NCHRP 3-62 Final Report: Barlow et al., 2005; Bentzen et al., 2006), there were three types of "Walk" indications used in the devices—speech messages, birdcalls (cuckoo/cheep), and the rapidly repeating tone indication (rapid tick). Once pedestrians understood the crossing signal, the rapid tick provided the best cue in terms of starting to cross quickly in both cities. The faster response to the rapid tick signal confirms results of previous

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research on pushbutton location and nature of "Walk" signal, in which responses were faster to the rich than to two different tones or to speech messages.

Research on Source of "Walk" Signal

Introduction

Signals typically installed in the United States have provided a loud beaconing "Walk" indication simultaneously from both ends of the crosswalk, and usually from two parallel crosswalks at the same time. As shown in the ACB and AER surveys, pedestrians who are blind often have difficulty if they try to use the APS to indicate the direction of travel on the associated crosswalk. Research has taken place in Canada, Japan, and the United States on the effect of source of the "Walk" signal on accuracy of aligning to cross and of making actual crossings.

Results of Research

Presentation Mode—Simultaneous, Alternating, and Far Side

Stevens (1993) and Barlow, Sawai, Takano, Yoshimura and Takeuchi (1998) tackled the problem of improving localization of "Walk" signals (beacons) by varying the source of the sound. They found that blind pedestrians could cross more quickly and with less veering when the "Walk" signal alternated back and forth from one end of the crosswalk to the other.

Barlow et al. (2000) confirmed the superiority and subjective preference for an alternating signal for beaconing at a simulated intersection, but found no advantage of the alternating signal when data were collected at an intersection with steady traffic on both streets. This was true for all tones tested (chirp, cuckoo, low cuckoo, and melody). It may have been that blind participants had good directional information from vehicular sound at the intersection or it may have been related to the shorter duration of the APS sound when installed at the intersection. In the previous testing at a simulated intersection (in quiet), the "Walk" signal continued for 36 s, more than the time required for participants to complete the curve crossing. Testing at the simulated intersection was also in a quiet environment.

Poulsen (1982) reported more accurate walking in a simulated crossing setting with a far end signal, than when a signal came simultaneously from both ends, and that far end signal was regarded favorably by a group of blind pedestrians in a field test at a real intersection.

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Iiuchi, Takumi, Suzuki, Kai, Takakura, and Fujiura (2000) examined the effects of alternating "Walk" signals in which the sounds from both ends of a 60-ft-long crosswalk at the top of a T-intersection with alternating "Walk" signals were different. Participants were better aligned and maintained alignment better with the APS with different tones at the end of the crosswalk than with the APS having the same tone at the end of the crosswalk.

Wall et al. (2004) compared the usefulness of auditory signals in guiding crossing behavior in three signal presentation modes—simultaneous, alternating, and far side only. In several experiments, blind adults and blindfolded sighted adults crossed a simulated crossing with recorded traffic noise approximating street sounds. Audible signals were presented simultaneously from both ends of the crosswalk, alternating from one end to the other, or from the far end of the crosswalk only. The signals continued only for the typical U.S. "Walk" interval of 7 s, stopping when participants were approximately halfway across the simulated street.

The principal findings were the same for blind and sighted participants and applied across a range of specific signals (e.g., chirps, clicks, voices). Crossing was more accurate when audible signals came only from the far end of the crossing, rather than the typical practice of presenting signals simultaneously from both ends. Alternating the signal between ends of the crossing was not helpful. However, providing a locator tone at the end of the crossing during the pedestrian clearance interval improved crossing accuracy. These findings offer less promise for the usefulness of the alternating signal mode, especially when the findings for single versus dual crosswalks are considered. In previous studies, only one crosswalk was signaled, but this research compared signaling a single crosswalk versus two parallel crosswalks in two experiments. Errors were fewer in the alternating mode than the simultaneous mode, but only when a single crossing was signaled. The customary practice of signaling two parallel crossings at the same time seemed to draw participants somewhat toward the center of the intersection.

Research on Other APS Features

Previously described research has also looked at other specific features of APSs, including the pushbutton locator tone. The following sources are referred to: NCHRP Project 3-62 research; Barlow et al. 2005; Bentzen et al., 2006; Poulsen, 1982; San Diego research; and Williams et al., 2005.

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Pushbutton Locator Tones

Pushbutton locator tones are a standard feature of almost all pushbutton-integrated APSs in use worldwide. In the United States, they are standardized to repeat once per second, and are to be audible only 6 to 12 ft from the pushbutton unless there is special actuation to raise the volume during the following pedestrian phase (Manual on Uniform Traffic Control Devices 2003 4E.09; Guidelines for Accessible Public Rights-of-Way, revised 2005). Pushbutton locator tones inform blind pedestrians that they need to push a button to actuate a "Walk" signal and/or pedestrian timing. Because the sound comes from the pushbutton, it indicates the location of the pushbutton.

Bentzen, Barlow, and Gabbert (2000) compared the speed of blind pedestrians on locating and working to an APS with a pushbutton locator tone (880 Hz square wave, with multiple harmonics, 3 ms attack time, 15 ms sustained tone at three repetition rates and three loudness levels relative to traffic sound along an eight-lane artery in Los Angeles. Best performance was with a repetition rate of once per second and loudness of 2 to 5 dBA above ambient sound measured at 1 m from the locator tone speaker.

Tactile Arrow

Tactile arrows aligned in the direction of travel on the associated crosswalk are features of all known pushbutton integrated APSs in use worldwide. Arrows vary in size and location on the APS. Some are on the pushbutton, some are on the vertical face of the housing, and some are on the top (horizontal) surface. The length of the arrow varies from approximately 1.5 in. to 2.5 in.; stroke thickness varies from approximately 0.09 in. to 0.25 in.; height above the surface varies from approximately 0.16 in. to 0.25 in.

The only research on usefulness of the tactile arrow for establishing crossing alignment was done in Denmark by Poulsen (1982). The "arrow" tested was a rod on top of the APS that was approximately 2.5 in. in length, 0.25 in. in width, and 0.25 in. high, with a bump indicating the far side of the crossing and additional bumps indicating the presence of islands or medians, if any. Alignment was equal with or without use of the arrow. The size and graspability of this unique arrow, as well as its location on the top of the APS, are thought to make it a better indicator of direction than smaller, nongraspable arrows and those mounted on the vertical face

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of the APS. The failure to find any positive effect on alignment indicates that such an arrow for probably any arrow) should not be considered a primary cue for alignment.

Nonetheless, tactile arrows do serve the important purpose of indicating the crosswalk with which a particular APS is associated. Research under NCHRP 3-62 (See Final Report and Bentzen et al., 2006) found that increased familiarity with tactile arrows in Tucson and Charlotte resulted in an increase in use of tactile arrows, with arrows actually on the pushbutton being used more frequently than arrows that were not on the pushbutton itself. While participants looked at the incorrect (not desired crossing) arrows at 28 trials in Tucson, after extensive familiarization, they then found and pushed the correct pushbutton on all of these trials. In Charlotte, while there was a decrease in use of the wrong pushbutton following extensive familiarization, use of the wrong pushbutton on some trials remained. Under the same research, subjective responses indicating preference for various features indicated strong support for use of a tactile arrow to identify the correct pushbutton.

Vibrotactile Indications

Most pushbutton integrated APSs worldwide have vibrating tactile arrows or other surfaces that vibrate during the "Walk" interval. The vibration is required by pedestrians who are deaf-blind to inform them that the "Walk" signal is on. It is also used by some pedestrians without hearing loss to confirm which crosswalk has the "Walk" signal, especially in very noisy conditions.

Because it is necessary for pedestrians who are deaf-blind, as well as helpful for blind pedestrians in some situations, a vibrotactile "Walk" indication is required along with an audible "Walk" indication in the Draft Guidelines for Accessible Public Rights-of-Way. A signal having vibrotactile indication only is not permitted. An APS that is vibratory only gives no indication of whether there is a pushbutton, or where the pushbutton is located, and it gives no audible directional guidance.

Gallagher and Montesdeoca (Oct. 1998) surveyed blind pedestrians who were familiar with vibrotactile signals that did not have audible "Walk" indications and on which a vibrating arrow was located on a horizontal surface above the pushbutton. They found the vibrotactile signal to be well liked. In field research, they also found that use of the vibrotactile indication resulted in accurate crossing timing.

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Tactile Map of the Crosswalk

Maps of the crosswalk are standard features of pushbutton-integrated APSs in Sweden, are in wide use in countries where Swedish devices are used, and are required in Austria for all APSs regardless of the equipment manufacturer (see Chapter 4 for photos and more information). There does not appear to be any research on the legibility or effectiveness of these maps of the crosswalk, but they do have the potential to enable users who are unfamiliar with a particular crosswalk to anticipate such characteristics as the number of vehicular lanes in each direction, and the presence of islands or medians, rail tracks, and bicycle lanes.

In NCHRP 3-62 research (see final report and Bentzen et al., 2006), one of four devices compared had a tactile map of the crosswalks. Mean ratings of participant agreement in Tucson and Charlotte with the statement "The crossing map was useful and easy to understand" were 4.00 and 4.17, respectively, on a 5-point scale (5 = strongly agree). However, even when they were thoroughly familiar with the map, only 9 of 49 participants used it across the two cities.

Pushbutton Information Message

On some pushbutton-integrated APSs, an optional feature is a speech message that comes from the pushbutton either whenever the button is pushed, or whenever the button is pushed and held for an extended time (see extended button press, above). This message always begins with the word "Wait," as it comes on only during the flashing and steady "Don't Walk" intervals. The next information identifies the intersection and the street to be crossed. The recommended format for this message is "Wait, to cross Howard at Grand." Additional information may be provided regarding unusual signalization (e.g., split phasing) or geometry (e.g., narrow median in the roadway).

In research conducted under NCHRP 3-62 (NCHRP 3-62 Final Report, Chapter 3, Bentzen et al., 2006), three of four devices used in field research in Tucson and Charlotte had pushbutton information messages. On all three devices, the pushbutton had to be depressed for at least 3 s to activate the full pushbutton information message. One device did not have the standard pushbutton information message when used in Tucson. The objective measure most closely related to the pushbutton information message was only whether participants used the extended button press, which activated the pushbutton information message; it was not possible to observe whether participants actually understood or used the information provided by the pushbutton

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information message. However, when asked to rate the extent of their agreement with the statement "The pushbutton information message was easy to understand," the mean ratings for each city were above 4.0 on a 5-point scale (5 = strongly agree), indicating that the message was usually understood.

Extended Button Press

Additional features on pushbutton integrated APSs may be activated by an extended button press. These features include a pushbutton information message, a louder (beaconing) signal, and extended crossing time.

Noyce and Bentzen (2005) found that it was unusual for pedestrians to push pushbuttons for as long as 2 s. Therefore an extended button press of only 2 s is being standardized to activate any optional features that are available at an APS.

In NCHRP 3-62 research (NCHRP 3-62, Final Report, Chapter 3; Bentzen et al, 2006) the extended button press feature was installed on three or four types of APSs. The extended button press was little used except following familiarization with each device. The extended button press was used on 65% to 85% of crossings in Tucson and Charlotte following familiarization to device features. This may indicate that specific information and training are necessary for pedestrians who are blind, if use of the extended button press is expected. Desirability of a pushbutton information message, as well as beaconing, both of which were activated by an extended button press, was supported by subjective data.

Audible Beaconing

An optional feature on some currently available APSs is audible beaconing, which is usually activated only by an extended button press. Beaconing is provided by a louder signal during the next pedestrian phase. The beacon is intended to aid initial alignment and crossing within the crosswalk.

In NCHRP 3-62 research (NCHRP 3-62 Final Report, Chapter 3; Bentzen et al. 2006), one of four devices tested had the audible beaconing feature. On this device, the "Walk" signal and subsequent locator tone increased in volume for the next pedestrian phase following a button press of at least 3 s. No objective measure of the use of audible beaconing could be made. The only measure possible was use of the extended button press feature that also activated a pushbutton information message. However, when asked to rate the extent of their agreement with

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the statement "The louder signal was helpful," the mean responses for Tucson and Charlotte were 3.86 and 4.00, respectively, on a 5-point scale (5 = strongly agree), indicating that this feature is desirable.

Additional research on the usefulness of APS for alignment and crossing within the crosswalk is provided in the section on effect of APS on specific crossing tasks (results of research orientation).

Other Concerns and Needs

Engineering Concerns

Noyce & Barlow (2003a) investigated problems reported with the interface between APS devices and signal controllers to determine whether there were systematic problems with the APS/controller interface. Most problems were found to be installation errors or wiring problems that had already been corrected by the manufacturer by the time research was conducted.

While the adjustment of the volume of the APS is critical for neighborhood acceptance and for usability by pedestrians who are blind, it continues to be an issue in many jurisdictions. In NCHRP 3-62 research on effect of device features (NCHRP 3-62 Final Report) researchers found that it was not possible to adjust all devices to have the same perceived loudness, despite extensive efforts and adjustments and involvement by manufacturers' representatives. Perceived loudness is not amenable to objective measurement and is influenced by conditions such as wind, humidity, precipitation, and nearby reflective surfaces.

APS devices, as with much new technology, have continued to generate maintenance and engineering concerns. As part of NCHRP 3-62 research, devices that were installed for human factors testing were monitored for a year by signal maintenance staff (see NCHRP 3-62 Final Report, Chapter 7). Concerns were expressed about more failures than expected, particularly of the vibratory feature of the devices. Manufacturers were said to be responsive to concerns and were continuously modifying devices to provide better durability.

Case studies of devices installed in cold weather areas were also developed as part of Project 3-62 (see NCHRP 3-62 Final Report, Chapter 6).

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Training Needs

In NCHRP 3-62 research in Tucson and Charlotte, experimenters observed that some participants did not have adequate information or techniques for using pushbuttons and APS devices in crossing streets and many did not have good information and understanding about the complexity of intersection signalization. Of concern to researchers were comments from some participants (prior to any explanation or training in the use of APS) who seemed to be trying to use the fact that the locator tone was sometimes louder in response to ambient sound as a "Walk" indication. These participants generally did not look for or push the pushbutton, but heard the audible locator tone and, without knowledge of locator tones and their functions, made an assumption that it was some kind of "Walk" indication. This misunderstanding of ambient sound adjustment and the locator tone could lead to dangerous crossings. Where APSs with locator tones are installed, it may be necessary to make a concerted effort to provide information about the devices to individuals in the community.

The major reason for the tactile arrow is to enable users to identify which street the pushbutton controls. Many participants in NCHRP 3-62 research and in NEI research needed to be shown the arrows on the devices to understand which way the arrow pointed. Use of the tactile arrow and the incorrect pushbutton presented a very different picture in Charlotte than in Tucson. In Tucson, participants who looked at the arrow on the incorrect pushbutton always correctly rejected the incorrect pushbutton. However, in Charlotte, even after familiarization, participants looked at the arrow on the incorrect pushbutton and varied in rejection in 20% of trials. This confusion in using the correct pushbutton seemed to be related to participants' lack of strategies to maintain their orientation; some would completely turn to face the street parallel to their travel path while examining the arrow on the device, then push the button and line up to cross the parallel street. Strategies for looking for pushbuttons and aligning to cross need to be taught.

Need for Additional Research

At a meeting in September 2005, the project panel for NCHRP 3-62 developed the following list of issues for additional research:

- Guidance on the need for pushbutton APS on side streets.
- Wayfinding/beaconing (NEI project may address this need).

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- Location/size/color of tactile arrow.
- Speech message clarity (consistency, programming and downloading messages, standardized library).
- Tactile map (consistency, availability, info on median refuge, guidelines).
- Cold weather issues (future follow-up on case studies, comparison study).
- Tone types (acceptability to nearby residences, which are appealing).
- APS effect on general pedestrian population (perhaps tie-in to tone acceptability study).
- Sound volume (best response to ambient sound, range and speed of response, range of decibel levels).
- Beaconing (volume, duration after press).
- Combining speech message and tones.
- Audible message during flashing "Don't Walk" (tone versus speech, countdown).
- Design of curb ramps (use in orientation/wayfinding, integration with signal design, effects on pole location).

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Appendix D—Prioritization Tool Instructions and Forms

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Purpose of the Prioritization Tool

Municipalities responsible for the installation and operation of traffic signals are often required to make decisions about the use of accessible pedestrian signals. In many cases, there is a need to prioritize existing signalized intersections for APS installations. Two such cases include:

- where the number of requests exceeds the funding available in a given fiscal year, and
- where transition plans for making intersections accessible are being completed and decisions must be made about the order of installations.

This prioritization tool provides practitioners with the means to take observable characteristics of a pedestrian crosswalk and produce a score that reflects the relative crossing difficulty for pedestrians who are blind or visually impaired. This scoring system enables a prioritization of APS installations within a jurisdiction.

The information regarding prioritizing intersections for installation of APS is **not intended** for application to new or reconstructed intersections. In new construction or reconstruction projects, it is appropriate to consider the Draft PROWAG as the best guidance available at this time. This guidance states that in new construction, APSs should be installed whenever pedestrian signals are installed.

Understanding How Blind Pedestrians Cross at Signalized Intersections

Before discussing how intersection and crosswalk characteristics affect the travel of blind pedestrians, it is important to understand how blind and low vision pedestrians travel. This section gives an overview of this issue.

At any given time, people who are blind or visually impaired use travel and cross streets using a human guide, a long, white cane to identify and avoid obstacles, using a guide dog guide; special optical or electronic aids, or no additional aid. Whatever aid is used, street crossing is composed of a number of tasks.

1) Locating the Street —First, pedestrians who are blind must determine when they reach a street. This is typically accomplished using a combination of cues, including the curb or slope of the ramp, traffic sounds, and detectable warnings.

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2) Street Recognition —Next, blind pedestrians recognize or determine which street they have come to. This information is only occasionally provided in any accessible format, so pedestrians who are visually impaired develop a mental map and keep track of where they are within that map, usually by counting blocks and street crossings. Assistance may be sought from other pedestrians.

3) Intersection Assessment — Next, pedestrians who are blind obtain critical information about intersection geometry, including the location of the crosswalk, the direction of the opposite corner, the number of intersecting streets, the width of the street to be crossed, and whether there are any islands or medians in the crosswalk. Vehicular sounds, where there is a stream of traffic on each street at the intersection, are used to infer intersection geometry.

Pedestrians with visual impairments also need to identify the type of traffic control system at an intersection. This may be determined by listening to traffic patterns through several light cycles and searching the sidewalk area for poles with pushbuttons. However, it has become difficult or impossible to determine the type of traffic control at many intersections by listening. The inability to determine whether a crosswalk is pedestrian actuated may result in failure to use pedestrian pushbuttons and in crossing at times other than the pedestrian phase.

4) Cross the Roadway —After determining the geometry of the intersection, aligning to face towards the destination curb, determining that the intersection is signalized, and having pushed a button (where necessary), pedestrians who are blind must recognize the onset of the walk interval. In the most common technique utilized for crossing at signalized intersections, pedestrians who are blind begin to cross the street when there is a surge of through traffic on the closest side of the street parallel to their direction of travel. Once pedestrians who are blind have begun to cross the street, they must maintain a heading toward the opposite corner. Turning traffic can make it difficult to establish a correct initial heading, and in the absence of traffic on the parallel street, pedestrians who are blind may veer toward or away from the intersection.

Optimal crossing conditions occur when crossing right angle signalized intersections with a moderate but steady flow of traffic through the intersection on each leg with a minimum of turning movements.

Pedestrian detection requires blind pedestrians to locate and push a pushbutton and then cross on the next pedestrian phase to be assured of having enough time to cross. Blind pedestrians have three types of problems at these locations:

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- They cannot wait through a light cycle to assess and refine their heading by listening to vehicular trajectories before crossing at the next pedestrian phase, because they have to locate and push the button again (and reestablish their heading).
- At a location with little vehicular traffic, even if pedestrians who are blind know there is a pushbutton and use it, they may not be able to detect the onset of the walk interval if there is no through traffic on the street parallel to their crossing.
- Blind pedestrians may not be aware that there is a pushbutton and/or they may be unable to locate the pushbutton. In addition, some locations do not include a pedestrian phase, and at times when vehicular volume is low, there may not be enough time to cross the street.

In the past 20 years, significant changes in intersection geometry, signalization, driver behavior, and automotive technology have affected the ability of blind travelers in the United States to obtain the information they need to cross streets independently and safely. Traffic clearing the intersection also commonly overlaps the pedestrian phase by as many seconds as the duration of the walk interval. In such cases, blind pedestrians will first perceive the pedestrian phase, and then initiate crossing after the onset of the pedestrian change interval. These changes have increased the requests for APSs by blind pedestrians. Municipalities and states need a documented procedure to respond to such requests as required by the program access requirements of the Americans with Disabilities Act.

Overview of Prioritization Tool Worksheets

The prioritization tool includes three separate worksheets that should be used for rating each intersection. Blank forms included are included later in this appendix. The first worksheet is the *intersection worksheet* and is used for describing characteristics of the intersection as a whole, including space for a sketch of the intersection. The second worksheet is the *crosswalk worksheet* and is used for describing the features associated with each crosswalk at the intersection. A separate crosswalk worksheet should be completed for each crosswalk at the intersection. Each of these forms includes variables that either provide an assessment of level of difficulty that may be present for pedestrians who are blind or provide an indicator of the level of pedestrian activity in the vicinity of the intersection. The variables are further defined in the later sections of this document. Each form also includes space for additional comments to be

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provided. Finally, a *supplemental form* is provided for those locations where more drawings or additional notes may be required.

Scoring System

The APS prioritization tool provides a score for an individual crosswalk. Higher scores indicate a greater priority for APS installation. Lower scores indicate a lower priority for APS. There is no particular score that indicates whether APS should be installed or not. The scores are intended to provide a *relative prioritization scheme* among a group of crosswalks.

The system of scoring is based on the premise that it is the individual crosswalk that is critical, as opposed to the intersection as a whole. Therefore, priorities for installation should be established on the basis of individual crosswalks, rather than complete intersections. Jurisdictions may choose to install APS at all crosswalks of an intersection when installing them at one crosswalk. However, the intent is to rank and consider each crosswalk separately. If a scoring system were used that is based on the combined score of all crosswalks at an intersection, a very difficult crosswalk for blind pedestrians combined with three crosswalks that are relatively easy could result in low ranking for the intersection as a whole. Such an intersection-based system could result in critical crosswalks being missed on a priority list.

The total score for a crosswalk is calculated as the sum of the individual crosswalk score and the intersection score. The intersection worksheet includes the intersection worksheet score in the bottom right corner. The total crosswalk scores are found in the bottom right corner of each of the crosswalk worksheets. Each crosswalk worksheet includes the crosswalk worksheet score and the intersection worksheet score (transferred from the intersection worksheet), which are added together to get the resulting total crosswalk score. The total crosswalk scores can be listed on the cover sheet for quick reference.

Intersection Worksheet Sketch

The intersection worksheet includes space for a simple sketch of the intersection being rated. At a minimum, the sketch should capture the following:

- Crosswalk location and orientation, including skew and any change in direction (each one should be labeled—e.g., A, B, C, and D) for correct reference to the crosswalk worksheets.
- Location of pushbuttons and other signal features.
- Geometrics, such as islands and lane configuration.

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Additional sketches and notes, as required, should be recorded on the supplemental worksheet.

Intersection Worksheet Variables

Configuration

Pedestrians who are blind or visually impaired use the sound of traffic moving beside them as an alignment cue and as a cue for determining when the traffic signal changes. Therefore, the number of approaches to an intersection and the geometric configuration affects the difficulty of crossing. A standard four-leg intersection with perpendicular approaches is the easiest configuration. If those approaches are offset while still controlled by the same signal, the crossing becomes more difficult as it becomes harder to recognize the parallel traffic flow from the minor street. T intersections are more difficult for similar reasons. Crossing the top of a T intersection can be problematic due to the fact that the simultaneous traffic flow is from the stem of the T and is either turning right or left. Intersections with more than four legs can also result in ambiguous traffic flow cues for pedestrians with visual impairments.

Mid-block signalized locations are most difficult for blind pedestrians because there is no traffic stream parallel to the crosswalk to provide an audible cue. Given this, signalized mid-block crosswalks receive the highest point value in the configuration category (14 points). Since completing the remainder of the worksheets for a mid-block crossing may prove confusing, the categories that apply to a mid-block crossing have been listed in Table 1.

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Table 1. Applicable Variables for Mid-Block Crossings

Intersection Worksheet Variable	**Applies to Mid-Block Crossing?**
Configuration	Yes
Signalization	Yes, Actuated
Transit Facilities	Yes
Distance to Facilities for Visually Impaired	Yes
Distance to Major Ped Attraction	Yes
Crosswalk Worksheet Variable	**Applies to Mid-Block Crossing?**
Crosswalk width	Yes
Posted Speed Limit	Yes
Curb radius > 25 feet	No
Islands or medians	Yes
Transverse slope	No
Apex curb ramp	No
Channelized right turn island	No
Skewed crosswalk	No
Pushbutton actuation required	Yes
Non-concurrent WALK interval	No
Leading Pedestrian Interval	No
Timed for crossing to median island	Yes
RTOR permitted	No
Leading protected left turn	No
Protected right turn overlap	No
Channelized right turn under signal	No
Off-Peak Traffic Presence	Yes
Pushbutton location	Yes
Requests for APS	Yes

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Signalization

The sequence of phases at a signalized intersection and other features of the signal operation, such as interval lengths and actuation-only phases, affects the ability of a blind pedestrian to determine when it is appropriate to cross. This information is captured in two places. The *signalization* variable captures information about the general signal operation that may affect the difficulty of crossing any or all streets. The *crosswalk signalization* variable on the crosswalk worksheet captures details about the signal operation that impact a particular crosswalk.

The following signalization options are given on the form. The user should select the option that has the highest point value AND applies to the intersection of interest. For example, if an actuated intersection has an exclusive pedestrian phase, then the user should select only "exclusive pedestrian phase", since that option has a higher point value than actuation.

Pretimed —Pretimed signalized intersections are the easiest for a blind pedestrian to understand, since the phase sequence and intervals remain the same every cycle.

Actuated — Actuated signals are more difficult for blind pedestrians since the interval timing may change or phases may be skipped on each cycle. In addition, some actuated signals require the pedestrian to find and push a pushbutton to obtain a "Walk" interval. *Note: This intersection signalization variable is intended to capture actuation associated with vehicular traffic. Pedestrian actuation is captured within the crosswalk signalization variable on the crosswalk worksheet.*

Split phasing (on either street) —The auditory cues of split phasing can provide confusing information. Split phasing on the street parallel to the crosswalk can lead a blind pedestrian to believe they have the "Walk" interval because the cross-street traffic is stopped and they hear a surge on the parallel street, not knowing that left turning vehicles may be present.

In the image on the left in Figure D-1, a pedestrian going north on the east crosswalk (bottom right corner) will have the "Walk" indication. A pedestrian going north on the west crosswalk (bottom left corner) will have "Don't Walk" since the northbound left turning traffic has a protected turn. Without APS, if a blind pedestrian on the bottom left corner hears the northbound through traffic, they might assume that they have the "Walk" indication and cross the street — presenting a potentially dangerous conflict with northbound left-turning traffic which has a protected turn.

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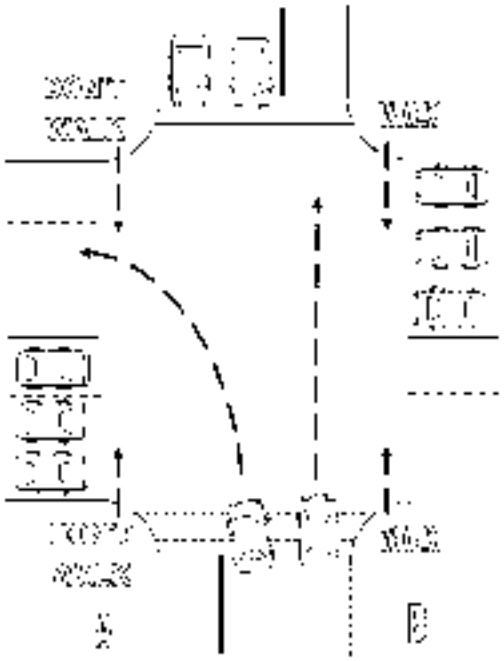

Figure D-1. Split phase illustration.

Split phasing on the street to be crossed can also be confusing in that the left-turning traffic onto the parallel street may be mistaken for the parallel street traffic surge. This variable does not include leading protected left turns, that signal feature is covered as a crosswalk-level variable.

Exclusive pedestrian phase – An exclusive pedestrian phase locks all vehicular traffic at an intersection to stop. It is much more difficult for a blind pedestrian to determine the onset of a walk interval when there is no vehicular movement and thus no surge of traffic. A lull in traffic flow may be perceived as the onset of the "Walk." However, a lull in traffic may also be perceived as gaps in traffic or changes between phases, rather than the onset of an exclusive pedestrian phase.

Where RTOR is permitted in combination with exclusive pedestrian phasing, an intersection may never be quiet enough for pedestrians who are blind to be sure that the pedestrian interval has begun. If they cross at such intersections independently, they are likely to begin crossing well into the pedestrian clearance interval. Additional points should be added for RTOR (separate variable described below) when present.

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Transit Facilities Within a Block (~ 0.12 mi) of Intersection—Any Leg

The availability of transit facilities within close proximity to an intersection will increase the likelihood of blind pedestrians, as well as sighted pedestrians, crossing at that intersection. The probability increases as the number of stops and routes increases, with the greatest probability occurring when there is a major transfer facility present, such as a transit mall or rail station. The levels on the prioritization tool account for transit activity by recording the number of routes that have stops within a block of the intersection. A single route will most likely be on the major street of an intersection. Multiple routes may include multiple major street routes or a combination of major- and minor-street routes.

Distance to Facility Providing Services to the Blind or Visually Impaired

The closer a facility for persons who are visually impaired is to an intersection, the more likely it is that pedestrians who are blind or visually impaired will need to cross at that intersection. Facilities that fall into this category include an adult rehabilitation center, library for the blind, residential school for the blind, offices of rehabilitation counselors, and other centers providing services for people who are blind or visually impaired.

Knowing the locations of these facilities will be difficult for any transportation department without good communication with the blind community. It is the responsibility of the department and the blind community to maintain a working relationship with each other. Organizations such as regional associations for the blind would be able to inform the department of any new schools or facilities that provide services to persons who are blind or visually impaired.

Distance to Major Pedestrian Attractions

The intent of this variable is to serve as a surrogate measure for pedestrian usage at the intersection without having to make pedestrian counts. *Most agencies simply do not have such counts or the resources to acquire such.* Major pedestrian attractions include, but are not limited to, major shopping areas, major cultural venues, educational campuses, recreational areas and medical facilities. The designation of "major attraction" will depend on the characteristics of the municipality. The idea behind this variable is that higher pedestrian activity will increase the chance of blind or visually impaired pedestrians crossing at the intersection, which would increase the need for APS.

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Crosswalk Worksheet Variables

Crosswalk Width

Crosswalk width is defined as the curb to curb measurement taken at the midpoint of the crosswalk. A longer crosswalk increases the potential that pedestrians who are blind will veer out of the crosswalk, as well as making it more critical for the blind pedestrian to start as quickly as possible after the onset of the walk interval. In the case of a channelized right turn island, the crosswalk length should be measured from curb to island (Figure D-2). Widths less than 40 ft receive no points.

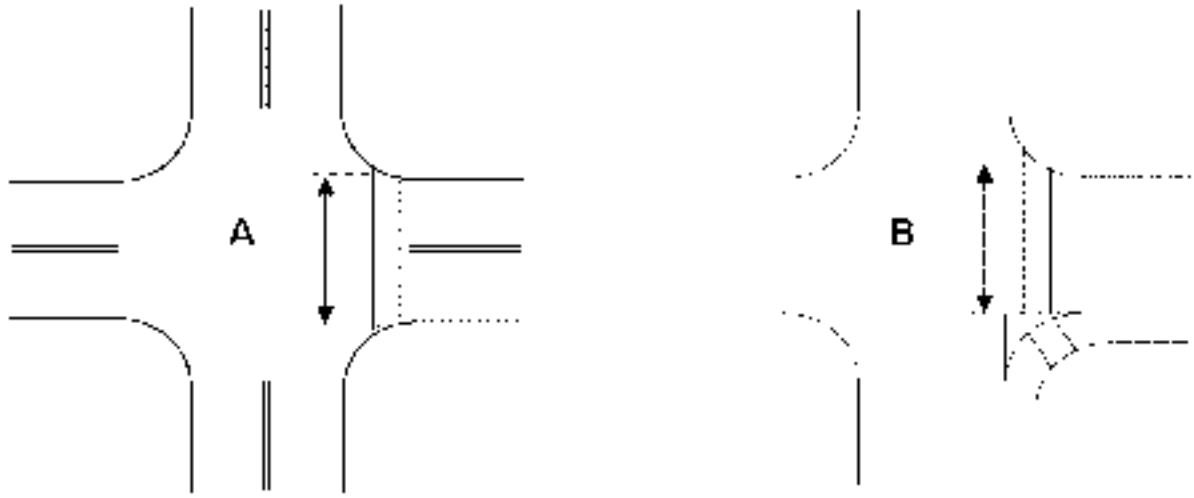

Figure D-2. Diagram A demonstrates the crosswalk width measurement of a standard crosswalk. Diagram B demonstrates crosswalk width measurement of a crosswalk at a channelized right turn lane.

Speed Limit (Street Being Crossed)

The higher the speed of the vehicles on the street being crossed, the lower the probability of avoiding an incident should a visually impaired pedestrian mistakenly step into the street, and the higher the probability of injury should a crash occur. Since operating speeds are not always available, the posted speed limit can be used as a surrogate measure. Speed limits of 20 mph and lower receive no points.

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Approach/Crosswalk Geometrics

There are several geometric factors at a crosswalk that can negatively impact upon the ability of a blind pedestrian to safely cross the street. Each of the factors on the form under this heading is defined below.

Curb Radius > 25 ft (Either Corner)

It is more difficult to establish an "ideal" corner heading where curb radii are wide. Incorrect headings can result in pedestrians who are blind walking toward the center of the intersection.

Islands or Medians

Raised or painted crossing islands and medians can confuse blind pedestrians during their crossing, slow or delay their crossing, affect crossing alignment, and generally make the crossing more difficult. Points should be added for any median or island, painted, raised, or cut-through, that crosses the crosswalk, particularly where the crosswalk changes direction at the island. **Islands that are present for channelized right turns are taken into account in the "channelized right turn island" factor.**

Transverse Slope on Crosswalk (Cross Slope)

Crosswalks with a severe cross slope (> 5 %) can lead to veering toward the downhill side by a blind pedestrian during the crossing. Depending on the direction of the cross slope, they could either veer into the intersection or into the approach leg. A beaconing APS may counter this tendency to veer.

Apex (Diagonal) Curb Ramp (Either Corner)

Where the slope of the curb ramp is not aligned with the direction of travel on the crosswalk, blind pedestrians may misalign for the crossing and walk into the flow of parallel traffic. This misalignment most commonly occurs with "apex" curb ramp configurations (Figure D-3). This apex configuration occurs when the corner only has one ramp that points toward the center of the intersection, usually for the purpose of serving two perpendicular crosswalks. If the corner has two ramps that each serves one crosswalk, the corner has a perpendicular ramp configuration (Figure D-4).

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Figure D-3. Photo and sketch of an apex ramp configuration.

Figure D-4. Photo and sketch of a perpendicular ramp configuration.

Channelized Right-Turn Lane Island

Crossings at a channelized right-turn lane normally require the pedestrian to cross to the island in one direction, reorient themselves, and then complete the crossing in a different direction (see Figure D-5). This direction change is potentially confusing to blind pedestrians. Most of the right-turn lanes where such islands are present are unsignalized. Therefore, an APS will not be installed for the right-turn lane crossing unless a traffic signal is being added. The APS installation that should be considered at these locations is on island for the crosswalks that

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cross the through travel lanes. The locator tones, as well as the "Walk" interval tones and speech messages, on an APS device under these conditions may assist the visually-impaired pedestrian with the reorientation that is required to find the correct crosswalk.

Note: Islands and medians separating traffic lanes in the middle of the road are taken into account by the "islands or medians" variable. If the right-turn lane is signalized, refer to the "channelized right turn lane under signal control" variable.

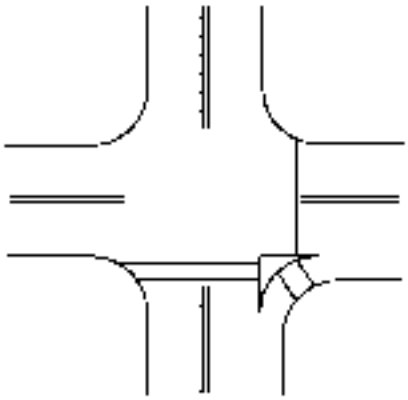

Figure D-5. Crosswalks at a channelized turn island.

Skewed crosswalk

If the direction of travel on a crosswalk is different from the direction of travel on the approaching sidewalk (is skewed), the consequence of failure to establish a heading toward the opposite corner is often that blind pedestrians will walk toward the center of the intersection and into the path of parallel traffic.

The degree of skew can vary from crosswalk to crosswalk. *Skew, in this case, is not defined by the angle at which the streets intersect.* If a blind pedestrian walking a straight line from the approaching sidewalk is headed toward parallel traffic lanes, the crosswalk is skewed (see crosswalk A in Figure D-6). If the blind pedestrian would end up deviating from the crosswalk but would still arrive at the opposite corner, the crosswalk is not defined as skewed for this rating tool (see crosswalk B in Figure D-6).

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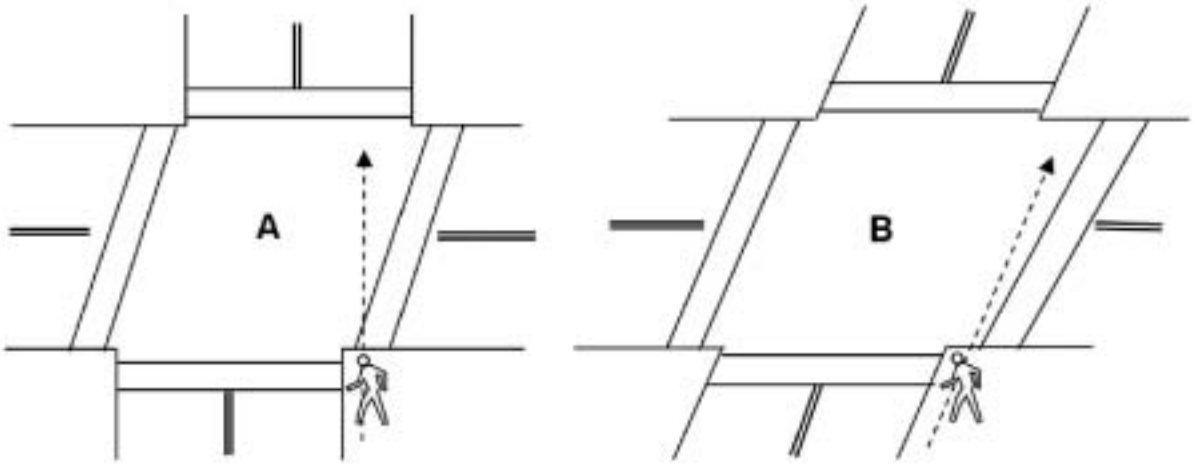

Figure D-6. Crosswalk A is defined as skewed because a pedestrian following the sidewalk line is headed toward the parallel traffic Crosswalk B is not skewed because a pedestrian following the sidewalk line is headed toward the opposite corner.

Skewing can also occur at crosswalks where the pedestrian walk signal only gives enough time for the pedestrian to reach a median. In this case, the blind pedestrian must be able to find the median to wait for the next signal cycle. A skewed or bent crosswalk may cause the pedestrian to miss the median. In this situation, the crosswalk is defined as skewed (Figure D-7).

Figure D-7. This crosswalk is defined as skewed because it is timed for median crossing (two-stage), and a blind pedestrian might miss the median due to the bent crosswalk.

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Determination of skew should not consider the island of a channelized right turn (Figure D-5). Although crossing from curb to curb may involve a crooked path due to a direction change at the island, this disadvantage is already accounted for in the fields relating to channelized turn islands.

Pedestrian Signal Control

The ability of a pedestrian who is visually impaired to safely cross at a crosswalk can be impacted by the walk interval timing and other pedestrian signal control features. Each of these factors is defined below.

Pedestrian Actuation Required for "Walk"

At unfamiliar intersections, pedestrians who are blind have no way to know pedestrian actuation is required unless there is an APS with a locator tone. Therefore, pedestrians who are blind are unlikely to use pushbuttons at unfamiliar intersections and are more likely to cross relying only on the use of traffic surge, whether or not it corresponds to the onset of the walk interval. Even if the parallel traffic surge is interpreted correctly, the green phase timing may not be sufficient to allow a pedestrian to safely cross the street. The problem is compounded when the pushbutton is not right beside the probable location of a pedestrian who is wanting to cross; this may require pedestrians who are blind or visually impaired to repeatedly leave their chosen starting location and heading and push the button again, and then return to their chosen starting location and reestablish their heading.

Nonconcurrent Walk Interval

Some signal timing plans at multi-leg intersections display the pedestrian "Walk" signal at a different time than the green phase for adjacent parallel traffic (
Figure D-8). Pedestrians who are blind or visually impaired will typically assume that the walk interval will begin with the onset of through traffic on the parallel street. Without an APS, they will not know the appropriate time to cross at such locations.

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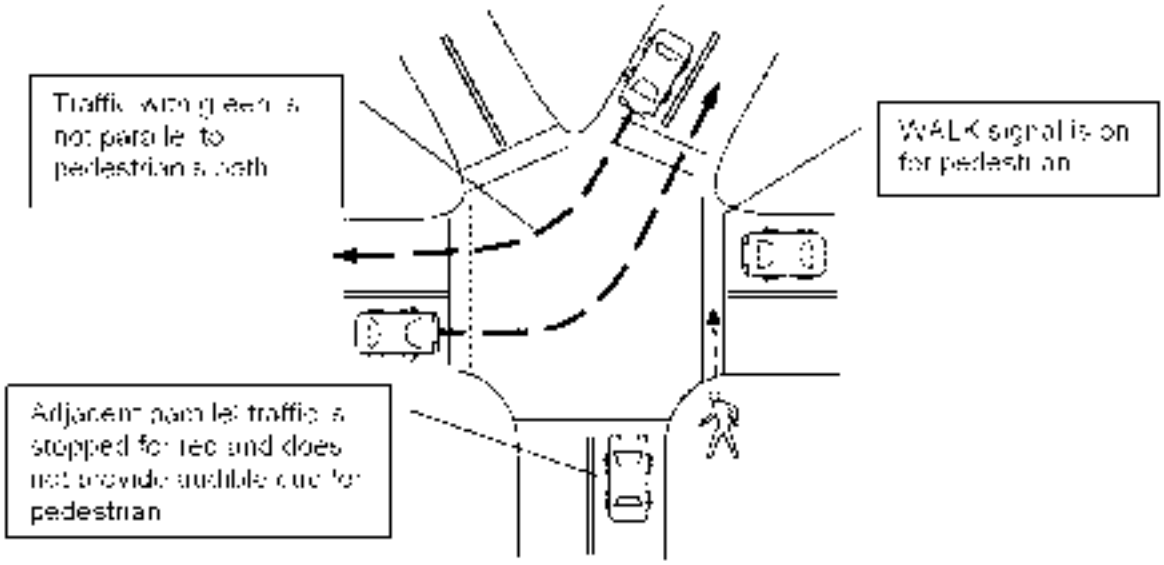

Figure D-8. Pedestrian crosswalk with nonconcurrent "Walk" interval.

Leading Pedestrian Interval – LPI (with Parallel Street Green)

The LPI permits pedestrians parallel to a traffic stream to move prior to the vehicles receiving a green signal, with a goal of allowing pedestrians to "claim" the crosswalk space prior to vehicles that may be turning right (Figure D-9). Unfortunately, this treatment creates a scenario in which blind pedestrians are unable to detect the beginning of the walk interval if there is no audible indication. Subsequently, they may begin crossing only when the parallel traffic starts, which may be too late in the pedestrian phase and at a time when drivers are not expecting them.

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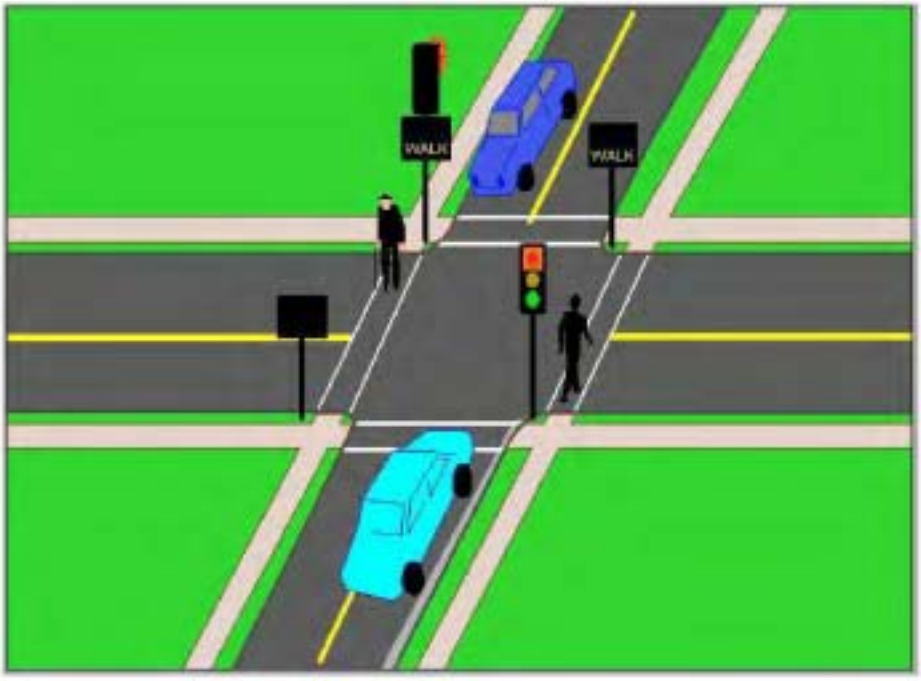

Figure D-9. Leading Pedestrian Interval (source: Insurance Institute for Highway Safety).

Timed for Crossing to Median Island

On wide streets with medians or crossing islands, blind pedestrians cannot easily determine whether the "Walk" signal is intended to allow them to cross the entire street or only to the mid-point. Without an APS providing an audible cue at the median, blind pedestrians are unable to recognize that they must stop there, which may place them in a high-risk situation. The MUTCD states: *"Where the pedestrian clearance time is sufficient only for crossing from the curb or shoulder to a median of sufficient width for pedestrians to wait, additional measures should be considered, such as median-mounted pedestrian signals or additional signing."* (MUTCD 2003)

Vehicle Signal Control

The types of signal phases available for vehicle traffic can greatly impact upon the ability of the pedestrian who is visually impaired to understand the audible cues from the traffic surges of various movements and make correct decisions about when it is appropriate to cross the street. Each type of signal phasing that may lead to this ambiguity is defined below.

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Right-Turn-On-Red (RTOR) Permitted on Parallel Street)

The allowance of RTOR on the parallel street may create a false audible cue for the blind pedestrian

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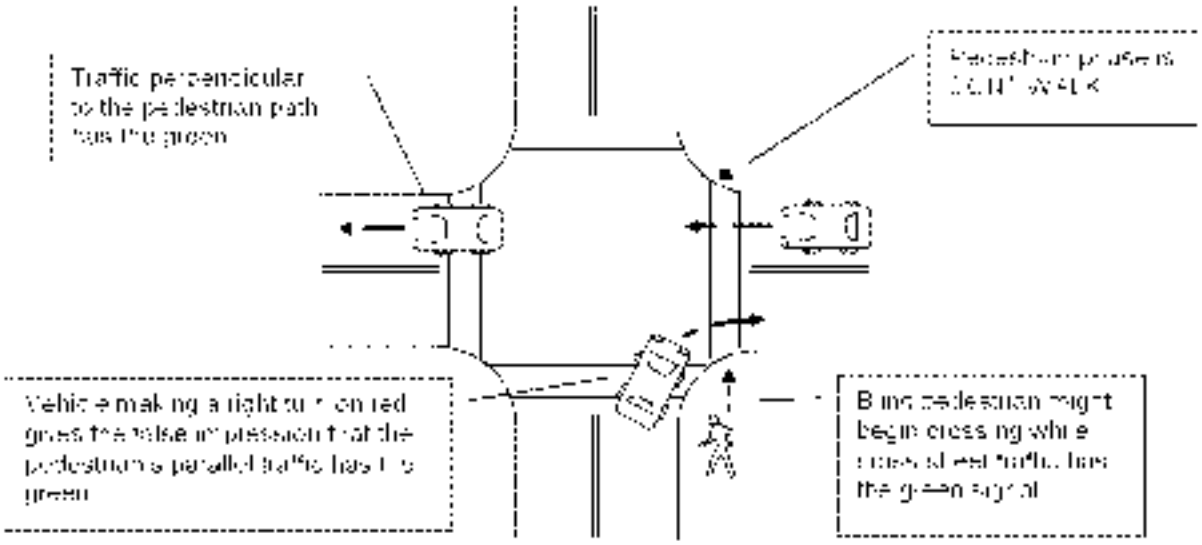

Figure D-10. Vehicles turning right after stopping may be interpreted as indicating the onset of the parallel green phase, and pedestrians who are blind or visually impaired may begin to cross the street at the wrong time. RTOR vehicles also make it harder to audibly recognize the onset of the parallel traffic movement

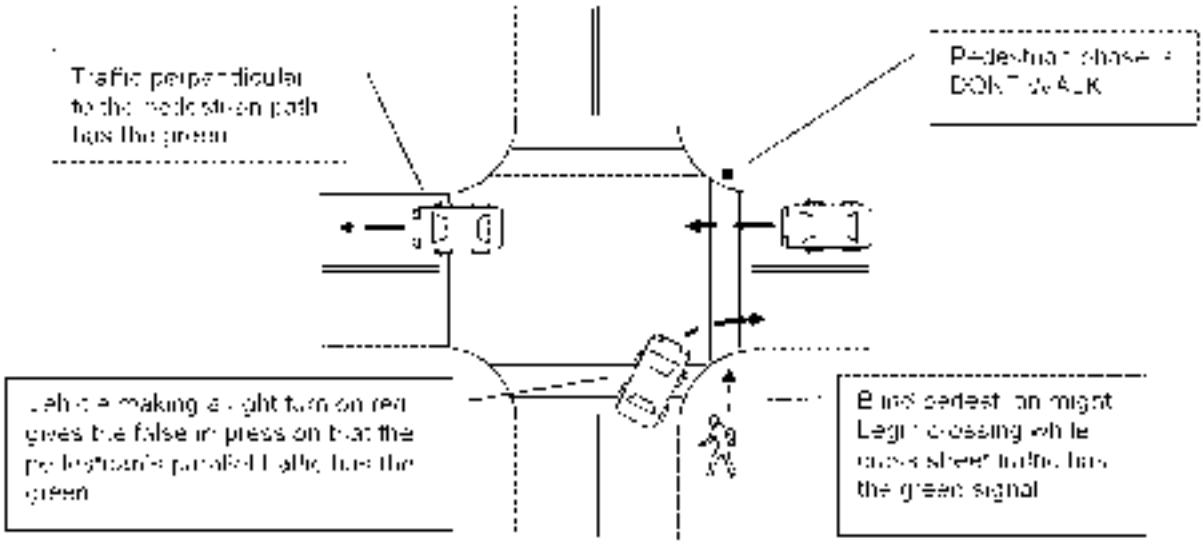

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Figure D-10. Right turns on red can mislead blind pedestrians.

The allowance of RTOR during an exclusive pedestrian phase also sends mixed signals. If vehicles are turning, blind pedestrians may not be aware that they have a walk interval. If they do recognize it, there may be a delayed initiation of crossing which means they may not begin crossing on the walk interval and may still be in the street during the "Don't Walk" interval.

Leading Protected Left-Turn Phase (on Parallel Street)

It can be difficult for a blind pedestrian to audibly distinguish between the surge of traffic at the beginning of a protected left-turn phase and the beginning of the through traffic phase

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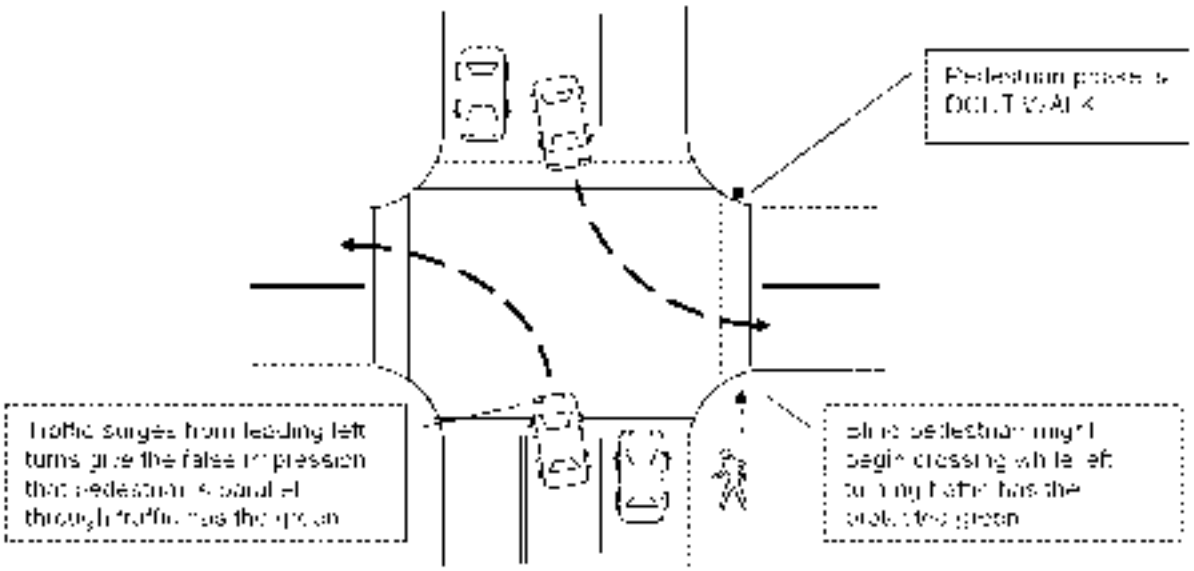

Figure D-11). The moving cars of the leading left-turn phase may also mask the sounds of the parallel through traffic beginning to move, particularly if the protected left-turn interval is followed by a permissive left-turn interval.

Note: Permits are not given for lagging left-turn phases, which are much better for a blind pedestrian. With a lagging left turn interval, the through traffic on the parallel street is the first vehicular maneuver after traffic stops on the cross street. The onset of the walk interval usually occurs at the same time and allows all pedestrians, including blind pedestrians to initiate the crossing. The pedestrians are then typically clear of the intersection by the time the lagging left-turn interval begins.

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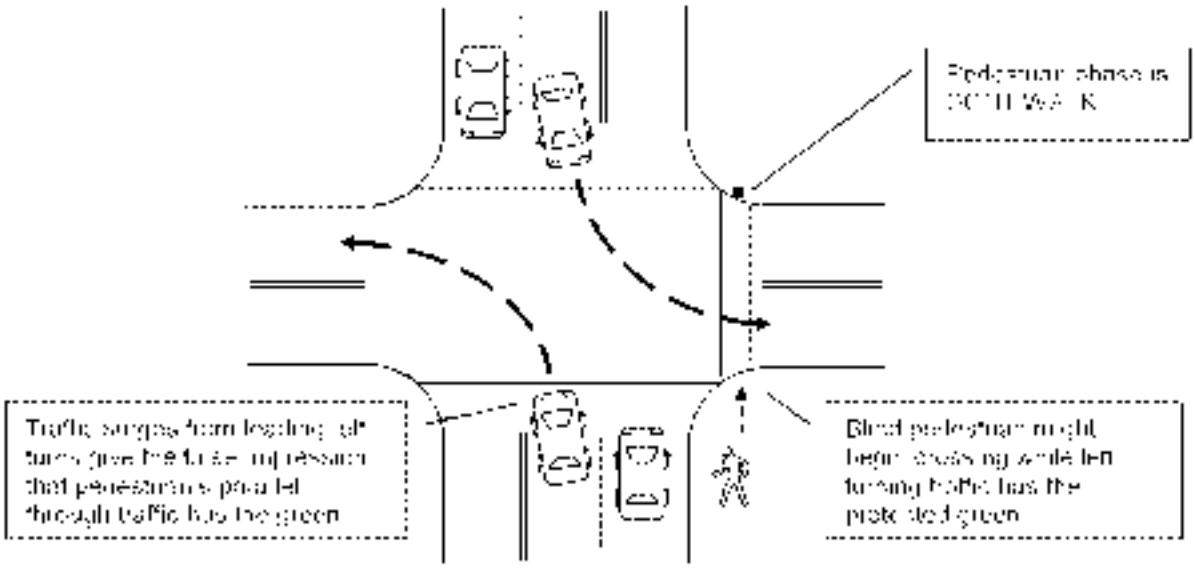

Figure D-11. Leading protected left turns can mislead blind pedestrians.

Protected Right-Turn Only Phase on Parallel Street

The surge of traffic by right-turning vehicles using a protected right-turn phase may be incorrectly interpreted as the beginning of the parallel through traffic surge and the simultaneous onset of the walk interval (figure D-12).

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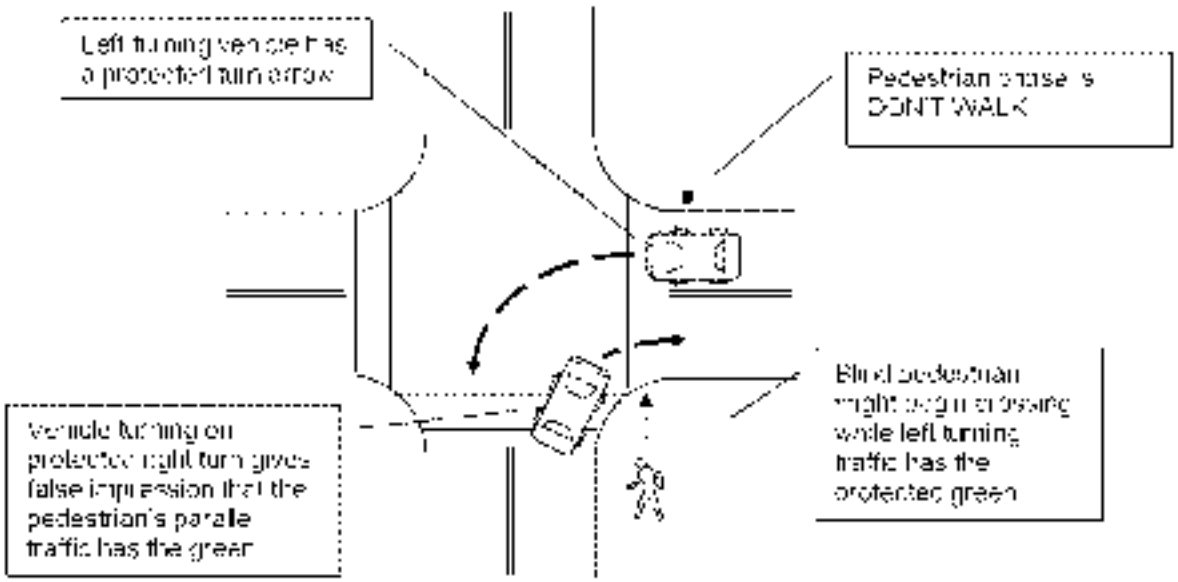

Figure D-12. Protected right turn phase can mislead blind pedestrians.

Channelized Right-Turn Lane under Signal Control

Turning vehicles at channelized turns are typically under yield control. They must stop only if there is traffic approaching intersection the cross street or if a pedestrian is in the crosswalk. However, at some channelized right-turn lanes, vehicles are controlled by a signal that prohibits turns if the signal is red (figure D-13). Without an audible indication, a blind pedestrian will not know that traffic at the channelized turn lane is under signal control and may attempt to cross when the traffic has a green signal. This confusion of priorities may lead to an unsafe crossing.

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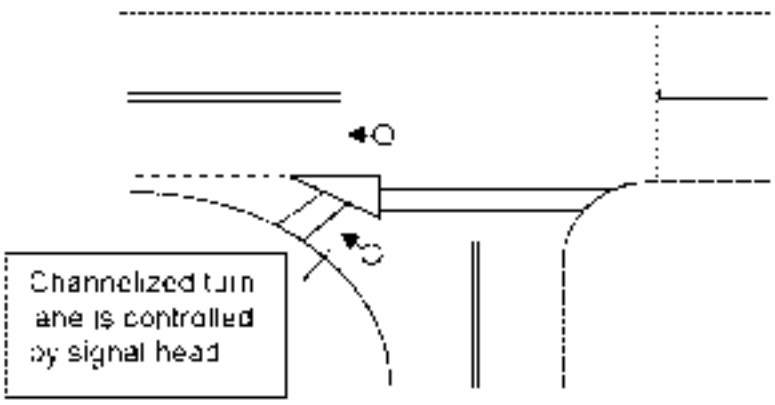

Figure D-13. Channelized turn lane under signal control.

Note: The point values for this factor are for the "signalization" component only. A channelized right-turn lane that is signalized will also receive points under "Channelized right turn island".

Off-Peak Traffic Presence

Traffic volume may impede or assist visually impaired pedestrians. Traffic flow that is very light or erratic (which most often occurs in off-peak periods) makes it difficult to use traffic sound to recognize signal changes. In such cases, audible signals can help to determine the onset of the walk interval. While many municipalities may have turning movement counts or average daily traffic counts, it is not a simple or uniform process to translate these numbers into a meaningful measure for assessing off-peak traffic presence. Instead, this variable is scored on the basis of the proportion of time that at least two vehicles are present at the beginning of a green phase in through lanes that are parallel to the path of the pedestrian.

Note that traffic presence in this category refers to traffic that is parallel to the crosswalk and passes straight through the intersection. If there is no through traffic at the intersection (no lanes continuing straight), there is no reliable traffic available for the blind pedestrian to use as a cue that the walk interval has begun, and the crosswalk would get a rating of "None" and receive the maximum number of points. An example of such a configuration is a T intersection (Figure D-14).

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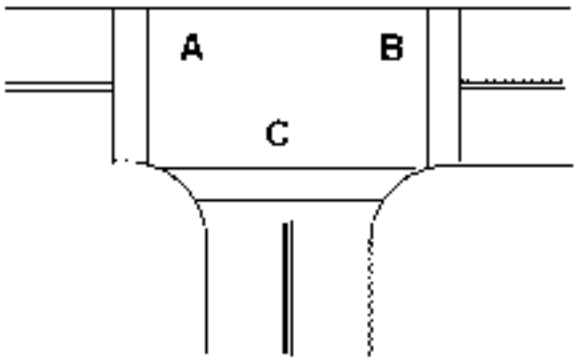

Figure D-14. Crosswalks A and B, across top of the T, at a T-intersection, have no parallel through traffic. In contrast, Crosswalk C has parallel through traffic.

Noting the number of signal cycles with two or more through vehicles over 5 to 10 cycles during the off peak should be sufficient for determining the percentage for scoring this variable. The levels provided on the worksheet reflect the results that may be acquired in such an exercise.

Distance to Alternative APS Crossing

If there is another signalized crosswalk with APS in close proximity to the intersection being rated, the intersection should receive a lower score (lower priority for APS) than a similar intersection where there is no nearby crossing alternative.

If an alternative accessible crossing is present and scored as such, care must be taken to ensure that the alternative crossing meets the need of the blind traveler by getting them to/from the destination. Just because a crossing is close, it may not always be in a location that helps get the person to their destination. A local orientation and mobility specialist or a pedestrian who has requested an APS can assist with making this determination.

Pedestrian Pushbutton Location (Either Corner)

Section 4E.09 of the MUTCD provides guidance on where pedestrian pushbuttons with APS should be located, as follows:

A. Adjacent to a level all-weather surface to provide access from a wheelchair, and where there is an all-weather surface, wheelchair accessible route to the ramp;
B. Within 1.5 m (5 ft) of the crosswalk extended;
C. Within 3 m (10 ft) of the edge of the curb, shoulder, or pavement; and

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D. Parallel to the crosswalk to be used. (MUTCD 2003)

The crosswalk worksheet provides for points to be added if the location of pedestrian pushbuttons on either side of a crosswalk does not meet either B or C above. In essence, this variable will give an intersection with poorly located pushbuttons a higher priority for the installation of APS over an intersection with properly located pushbuttons (assuming all other characteristics of the two intersections are the same). Poorly located pushbuttons create much greater difficulty for blind pedestrians in terms of being easily accessible, being positioned in a manner to provide alignment cues, and being located close enough to the curb to be pushed and then cross on the same cycle.

Requests for an APS

Requests for an APS may come from a pedestrian who is visually impaired or from an orientation and mobility professional. These requests are usually very specific—the individual needs to travel from their home to their workplace and needs to cross this street using this crosswalk. Such requests should increase the priority for APS.

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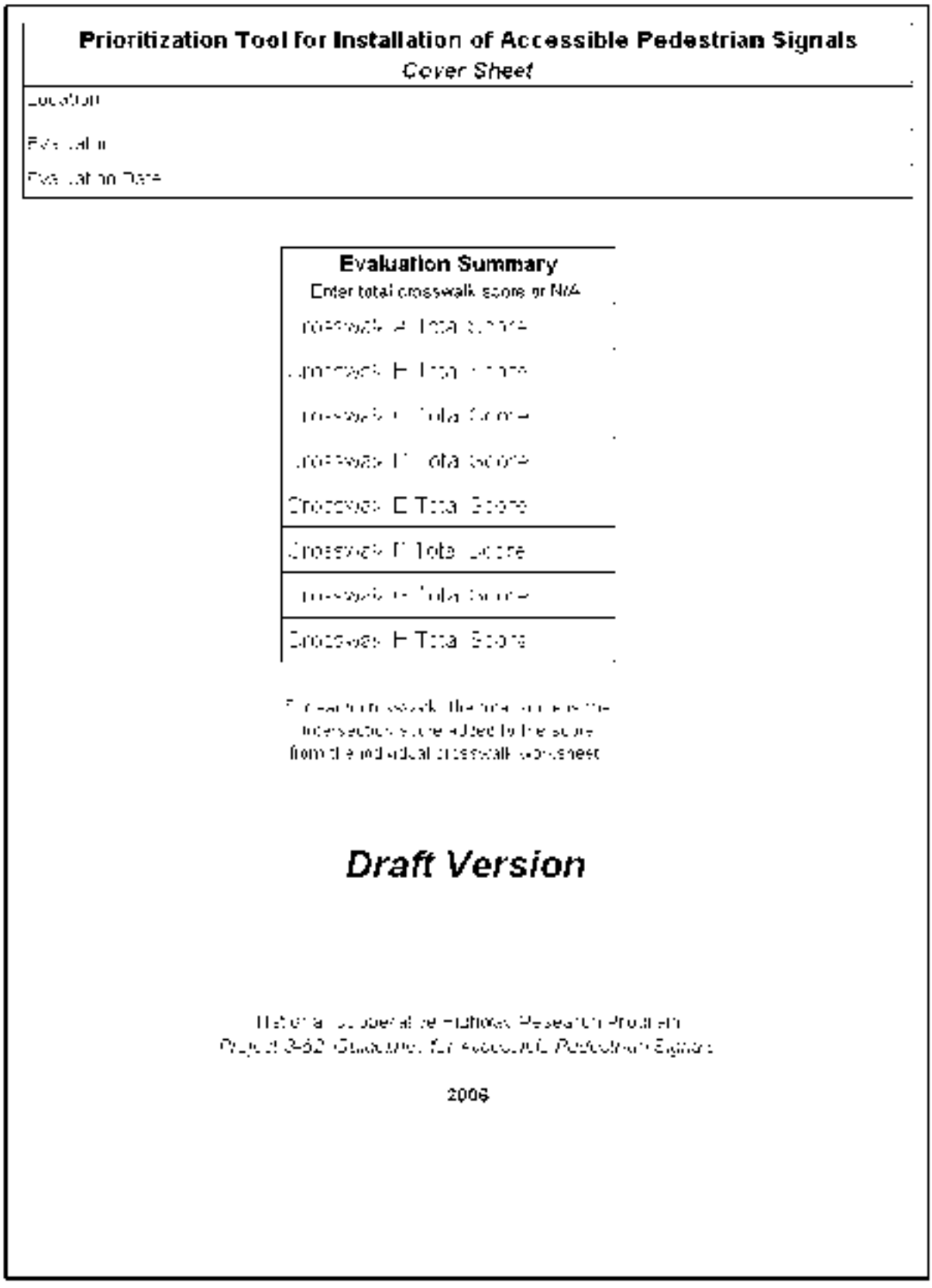
Blank Prioritization Tool Worksheets

On the following pages are blank forms that may be reproduced for use in the field when evaluating intersections and crosswalks. There are three separate forms to be used at all intersections – an *intersection worksheet*, a *crosswalk worksheet*, and *supplemental form* – as well as a cover sheet for easy reference of the crosswalk scores.

AR0072175



Prioritization Tool for Installation of Accessible Pedestrian Signals

Cover Sheet

Location

Evaluator

Evaluation Date

Evaluation Summary

Enter total crosswalk score or N/A

Crosswalk A Total Score

Crosswalk B Total Score

Crosswalk C Total Score

Crosswalk D Total Score

Crosswalk E Total Score

Crosswalk F Total Score

Crosswalk G Total Score

Crosswalk H Total Score

For each crosswalk, the total score is the intersection score added to the score from the individual crosswalk worksheet

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2006

Figure D-15. Cover Sheet of APS prioritization tool.

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Prioritization Tool for Installation of Accessible Pedestrian Signals, NCHRP 3-62, 2006

Intersection Worksheet

Location:

Sketch: *See instructions for information to include. Label crosswalks as A, B, C, D, etc.*

Indicate North

Configuration (select one)	Points	Score
4-leg	0	
4-leg offset	3	
3-leg (T or Y)	3	
5 or more legs	12	
Midblock location	14	

Signalization* (select one)	Points	Score
Pre-timed	0	
Actuated (semi or fully)	2	
Split phasing	6	
Exclusive ped phase	8	

Transit Facilities within a block (~ 1/8 mile) of the intersection - all legs (select one)	Points	Score
No transit facilities	0	
Single bus route	1	
Multiple bus routes	3	
Transit rail/rail station	5	

Distance to Facility for Visually Impaired (select one)	Points	Score
> 2600 ft (~1/2 mile)	0	
< 2600 ft (~1/2 mile)	4	
< 1300 ft (~1/4 mile)	6	
< 650 ft (~1/8 mile)	8	
< 300 ft	10	

Other Intersection Level Issues

Distance to Major Pedestrian Attraction (select one)	Points	Score
> 2600 ft (~1/2 mile)	0	
< 2600 ft (~1/2 mile)	2	
< 1300 ft (~1/4 mile)	3	
< 650 ft (~1/8 mile)	4	
< 300 ft	5	

*** Select the option with the highest point value that applies to the situation*

*** The accompanying instructions are essential for accurate completion of this form ***

Intersection Worksheet Score: (sum of scores on this page)

Figure D-16. Intersection worksheet of APS prioritization tool.

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Prioritization Tool for Installation of Accessible Pedestrian Signals, NCHRP 3-62, 2006

Crosswalk Worksheet

(Complete one sheet for each crosswalk)

Location: | **Crosswalk Label:**

Crosswalk Width (select one)	Points	Score
< 40 ft	0	
40 - 59 ft	1	
60 - 79 ft	2	
80 - 99 ft	3	
100- 119 ft	4	
≥ 120 ft	5	

Posted Speed Limit (select one)	Points	Score
< 20 mph	0	
25 mph	1	
30 mph	2	
35 mph	3	
40 mph	4	
≥ 45 mph	5	

Approach/Crosswalk Geometrics (select all that apply)	Points	Score
Curb radius> 25 ft (either corner)	1	
Islands or medians (painted, raised or cut-through)	1	
Transverse (cross) slope on crosswalk	1	
Apex (diagonal) curb ramp (either corner)	2	
Channelized right turn island	2	
Skewed crosswalk	7	

Pedestrian Signal Control (select all that apply)	Points	Score
Push button actuation required for WALK signal	4	
Non-concurrent WALK interval	4	
Leading Pedestrian Interval (LPI) with parallel street green	8	
Timed for crossing to median island	8	

Vehicle Signal Control (select all that apply)	Points	Score
Right-Turn-On-Red permitted (on parallel street)	2	
Leading protected left-turn phase (on parallel street)	3	
Protected right turn phase / right turn overlap (on parallel street)	7	
Channelized right turn lane under signal control	8	

Off-Peak Traffic Presence - at least 2 vehicles present on parallel street (select one)	Points	Score
Constant (≥ 90 percent of ten cycles)	1	
Heavy (70 - 80 percent)	2	
Moderate (50 – 60 percent)	3	
Light (30 – 40 percent)	4	
Occasional (< 30 percent)	5	
None (i.e., no through lanes present to create surge noise - e.g., stem of T-intersection)	6	

Distance to Alternative APS Crosswalk (select one)	Points	Score
< 300 ft	0	
< 650 ft (~ 1/8 mile)	1	
< 1300 ft (~ 1/4 mile)	2	
< 2600 ft (~ 1/2 mile)	3	
> 2600 ft (~ 1/2 mile)	4	

Pedestrian Pushbutton Location - either corner (select all that apply)	Points	Score
Located > 10 ft from curb	3	
Located > 5 ft from the CW extd.	3	

Requests for APS (select one)	Points	Score
No requests	0	
1 or more requests	6	

Other Crosswalk Level Issues

Crosswalk Worksheet Score: (score from this page)	
Intersection Worksheet Score: (score from intersection form)	
Total Crosswalk Score: (add the two above scores)	

*** The accompanying instructions are essential for accurate completion of this form ***

Figure D-17. Crosswalk worksheet of APS prioritization tool.

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Prioritization Tool for Installation of Accessible Pedestrian Signals, NCHRP 3-62, 2006

Supplemental Worksheet

Location:

Supplemental Sheet

Supplemental Notes:

Figure D-18. Supplemental worksheet of APS prioritization tool

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Examples of Completed Prioritization Tool Worksheets

The following two examples show how the prioritization tool would be used to rate two crosswalks. The first example is a crosswalk that would be relatively easier for pedestrians who are blind or visually impaired. The second example is a crosswalk that would be relatively difficult.

Example Crosswalk 1

This example uses the APS prioritization tool to rate a crosswalk at an intersection in a dense urban area. Both streets of the intersection are fairly narrow and have 35 mph speed limits. The signal is pretimed. Figure 5-1 shows an overhead view of the intersection, with the crosswalk of interest outlined.

Figure D-19. Overhead view of Crosswalk 1 (© Google Earth 2005).

The first worksheet deals with the intersection characteristics (Figure D-20). The total intersection score was zero, since the intersection was a simple four-legged configuration with a pretimed signal and was not located near transit facilities, facilities for the visually impaired, or major pedestrian attractions.

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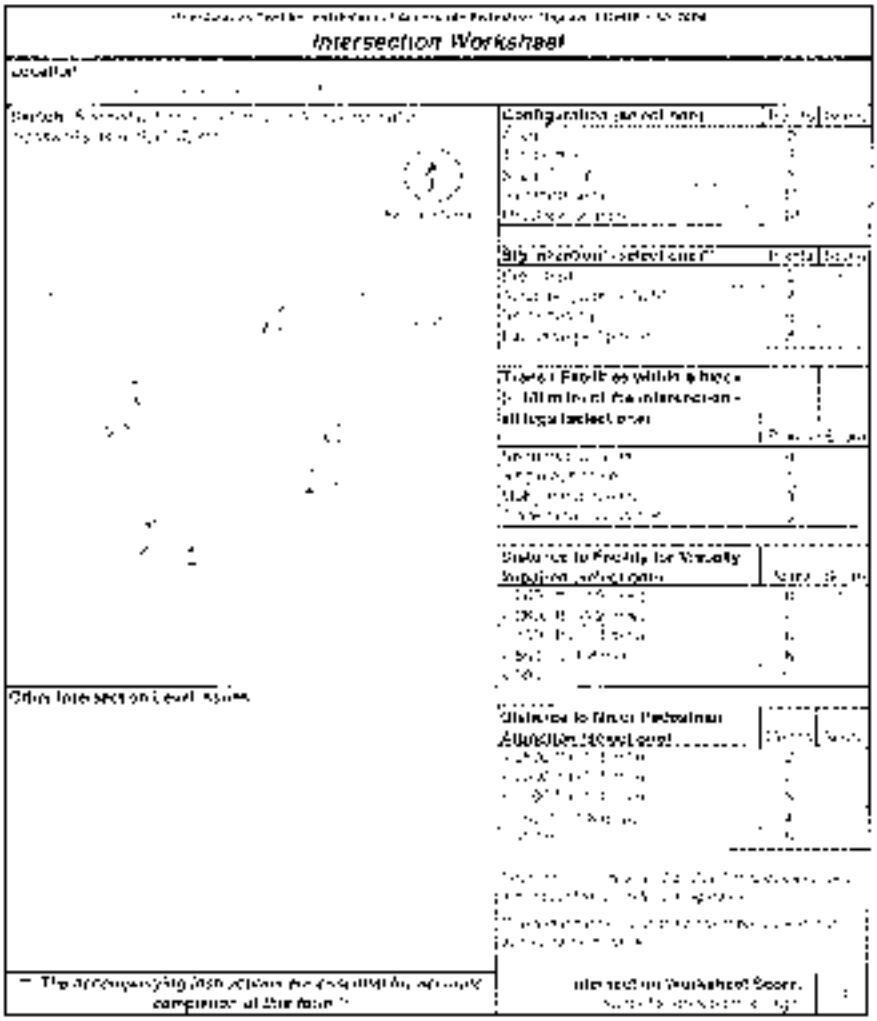

Figure D-20. Intersection worksheet for Crosswalk 1.

The second worksheet deals with the crosswalk (Figure D-21). Points were given for the following reasons:

- The crosswalk width is 50 ft. The worksheet range of 40–59 ft earns one point.
- The posted speed limit on Prospect (the street being crossed) is 35 mph. This earns three points.
- The traffic on Broadway (the parallel street) is constant, thereby giving constant audible cues for the pedestrian. This variable earns only one point.
- There is another APS-equipped crosswalk within 0.25 mi. Thus, the crosswalk being rated earns two points in this category.

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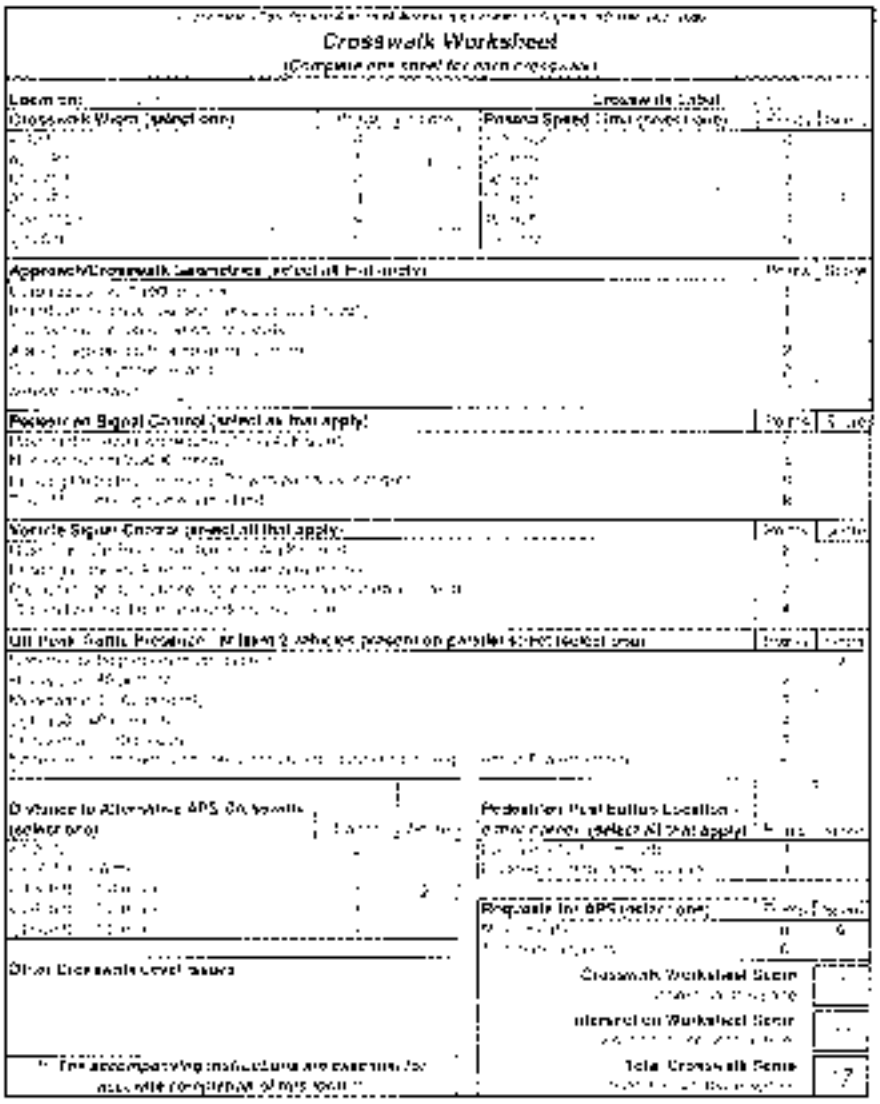

Figure D-21. Crosswalk worksheet for Crosswalk 1.

There are no characteristics of this crosswalk that would qualify under the sections for "Approach/Crosswalk Geometries," "Pedestrian Signal Control," or "Vehicle Signal Control." In addition, the pushbutton poles are located close to the curb and within the crosswalk lines extended and there have been no requests for an APS at this crosswalk; both receive zero points on the prioritization worksheet.

The crosswalk worksheet score is seven points. When added to the intersection score of zero points, this yields a total crosswalk score of seven points. In practice, this score of seven points would be compared to other crosswalks under consideration for APS installations. Those crosswalks with the highest scores would have the highest priority for APS.

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Example Crosswalk 2

This example rates a crosswalk at a large intersection of a major arterial and a minor side street. The crosswalk of interest is on the east leg (highlighted in Figure D-22; shown at street level in Figure D-23).

Figure D-22. Overhead view of Crosswalk 2 (©Google Earth 2005).

Figure D-23. Street view of Crosswalk 2.

The first worksheet deals with the intersection characteristics (Figure D-24). Points were given for the following reasons:

- The signal is actuated but also uses split phasing, which is a higher point value than actuation, so the intersection gets the six points for split phasing. Split phasing is a less commonly used signal design, and the typically heavy turning movements make it harder to

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effectively use the traffic movement cue to determine signal changes. APS would provide a definitive cue to the onset of the walk interval for pedestrians who are unable to see the pedestrian signal.

- There is a single bus route on the main street, which earns another point. The presence of public transit increases the likelihood that visually impaired pedestrians will travel at this intersection, thereby increasing the priority for APS.

There are no facilities specifically providing services for individuals who are visually impaired or major pedestrian attractors within 0.5 mi, so no points are given for those categories. The total intersection score is seven points.

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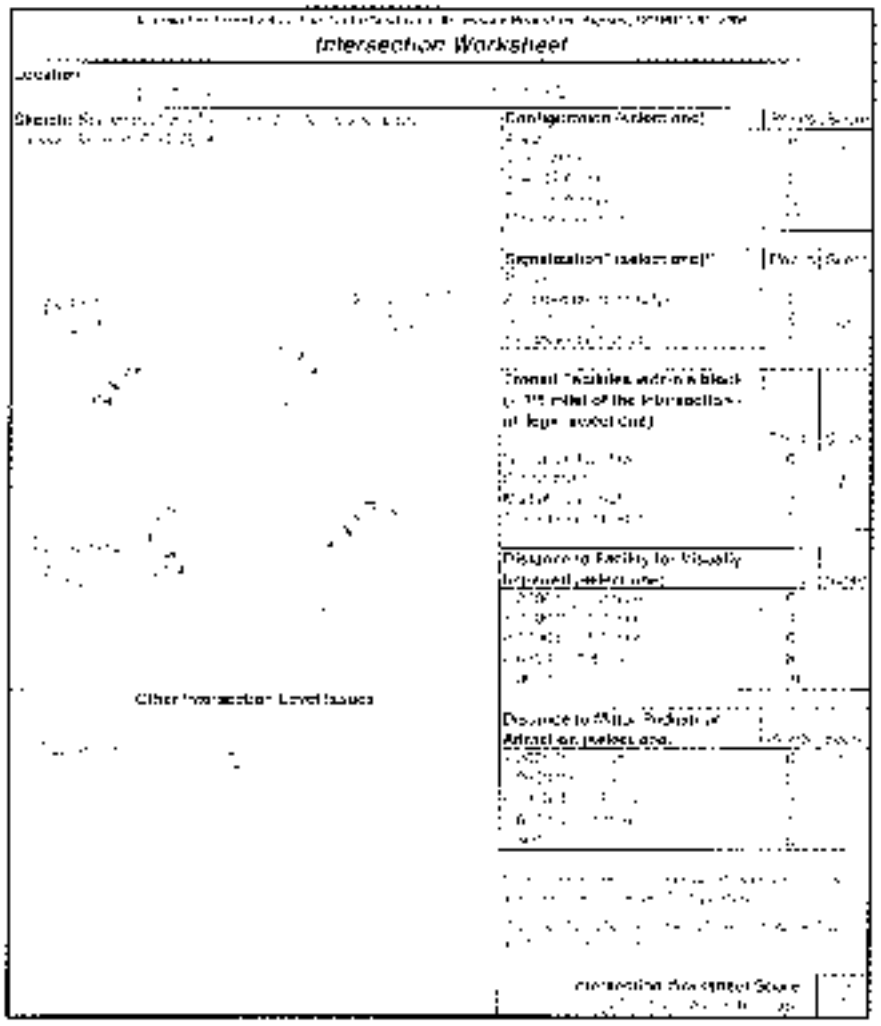

Figure D-24. Intersection worksheet for Crosswalk 2.

The second worksheet deals with the crosswalk (figure D-25). Points were given for the following reasons:

- The crosswalk width of 120 ft and speed limit of 45 mph on the main street earn the crosswalk four and five points, respectively. Wider crosswalks and faster traffic increase the crossing difficulty and risk to visually impaired pedestrians, and an APS may help expedite their crossing.
- The curb radius on one of the corners bordering the crosswalk is greater than 25 ft, so one point is given in the geometrics category. Larger curb radii create orientation problems for visually impaired pedestrians that may be decreased with the use of an APS.

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- The signal requires pushbutton actuation for the pedestrian "Walk" signal, so four points are given for the pedestrian signalization category. An APS locator tone would help a pedestrian who is visually impaired recognize that there is a pushbutton at that crosswalk and help in locating the pushbutton.
- Right-turn-on-red (RTOR) is permitted at the crosswalk, so two points are given in the vehicle signal control category. RTOR may produce crossing traffic cues, and an APS would provide a definitive cue of the appropriate time to cross.
- During off-peak hours, there was enough parallel traffic to provide audible cues (two or more vehicles per cycle) about 75% of the time. This earns two points.
- There is not an alternative APS crosswalk within 0.5 mi, so four points are given towards the prioritization of an APS installation at this crosswalk.
- The pedestrian pushbutton at one end of the crosswalk is located more than 10 ft from the curb, which is contrary to the recommendations in Section 4E.09 of the MUTCD. Three points are given for this drawback, since a correctly installed APS would position the push button closer to the curb which facilitates orientation alignment for blind and visually impaired pedestrians.

The crosswalk worksheet score is 25 points. When added to the intersection score of seven points, this yields a total crosswalk score of 32 points. In practice, this score of 32 points would be compared with scores for other crosswalks under consideration for APS installations. Those crosswalks with the highest scores would have the highest priority for APS.

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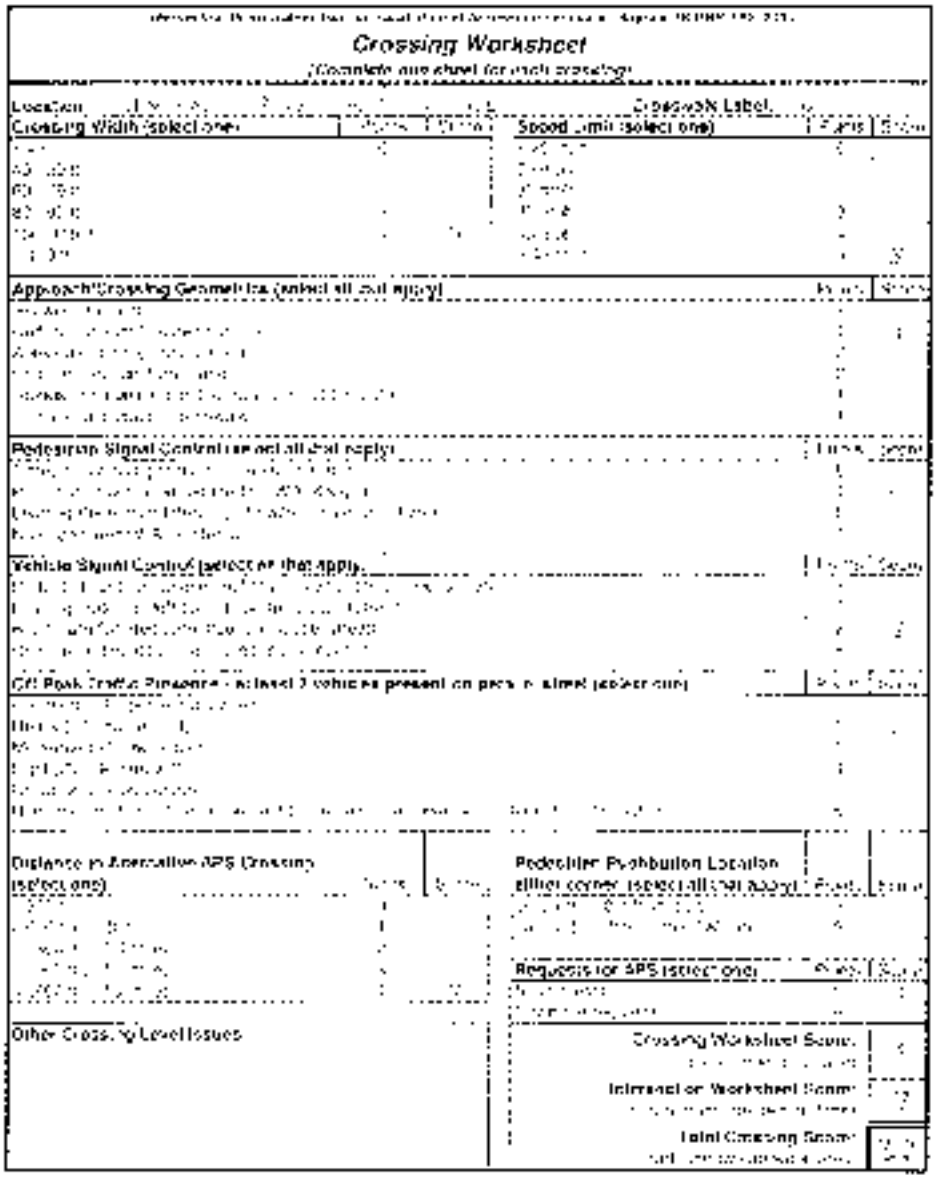

Crossing Worksheet

(Complete one sheet for each crossing)

Figure D-25. Crosswalk worksheet for Crosswalk 2.

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References

Manual on Uniform Traffic Control Devices, 2003 Edition, with Revision No. 1 incorporated. Federal Highway Administration, Washington, DC, November 2004.

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Appendix E - Glossary

In the following list, *MUTCD* refers to definitions taken from Section 4A.02 Definitions Relating to Highway Traffic Signals of the *Manual on Uniform Traffic Control Devices*

Accessible pedestrian signal (APS) A device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces. (*MUTCD*)

Actuated operation. A type of traffic control signal operation in which some or all signal phases are operated on the basis of actuation. (*MUTCD*)

Actuation. Initiation of a change in or extension of a traffic signal phase through the operation of any type of detector. (*MUTCD*)

Actuation indicator. Either a light, a tone, a voice message, or both audible and visual indicators that indicate to pedestrians that the button press has been accepted.

Alert tone at onset of WALK interval. A very brief burst of high frequency sound, rapidly decaying to a 500 Hz WALK tone, to alert pedestrians to the exact onset of the WALK interval.

APS. See *Accessible pedestrian signal.*

Audible beacon. Use of a sound source to provide directional orientation and alignment information.

Automatic volume adjustment. An APS volume control that is automatically responsive to ambient (background) sound; automatic gain control.

Braille street name. Provision of the name of the associated street in Braille above the APS pushbutton.

Button actuated timer (BAT). See *Extended button press.*

Clearance interval indicator Tones sounding during the pedestrian clearance interval that are differentiated from the WALK interval indicator (tones).

Controller unit. That part of a controller assembly that is devoted to the selection and timing of the display of signal indications. (*MUTCD*)

Crosswalk. (a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the centerline; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface. (*MUTCD*)

Crosswalk map. See *Tactile map.*

Cycle Length. The time required for one complete sequence of signal indications. (*MUTCD*)

Detectable warning. A standardized surface feature built in or applied to walking surfaces or other elements to warn visually impaired people of hazards on a circulation path.

Detector A sensing device used for determining the presence or passage of vehicles or pedestrians. (*MUTCD*)

Extended button press. On APS, holding the ped button down between 1-3 sec. may activate special features, including audible beaconing and

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extended pedestrian clearance interval.

Fixed time operation. See *Pretimed operation.*

Flashing (flashing mode). A mode of operation in which a traffic signal indication is turned on and off repetitively. (*MUTCD*)

Full-actuated operation. A type of traffic control signal operation in which all signal phases function on the basis of actuation. (*MUTCD*)

Intersection. (a) the area embraced within the prolongation or connection of the lateral curb lines, or if none, the lateral boundary lines of the roadways of two highways that join one another at, or approximately at, right angles, or the area within which vehicles traveling on different highways that join at any other angle may come into conflict; (b) the junction of an alley or driveway with a roadway or highway shall not constitute an intersection. (*MUTCD*)

Interval. The part of a signal cycle during which signal indications do not change. (*MUTCD*)

Interval sequence. The order of appearance of signal indications during successive intervals of a signal cycle. (*MUTCD*)

Locator signal. See *Pushbutton locator tone*

Long button press. See *Extended button press.*

Long cane. A cane individually prescribed to provide safety and orientation information to persons who are blind or visually impaired; typically much longer than a support cane and not intended for support, typically has a white, reflective surface.

Major street. The street normally carrying the higher volume of vehicular traffic. (*MUTCD*)

Minor street. The street normally carrying the lower volume of vehicular traffic. (*MUTCD*)

Passive pedestrian detection. A feature that uses sensors (piezo-electric, infrared, microwave, or video camera serving remote sensor software) to trigger, cancel, or lengthen pedestrian timing, or to trigger the pushbutton locator tone when the pedestrian enters the detection zone.

Pedestrian. People who travel on foot or who use assistive devices, such as wheelchairs, for mobility.

Pedestrian change interval. An interval during which the flashing UPRAISED HAND (symbolizing DON'T WALK) signal indication is displayed. When a verbal message is provided at an accessible pedestrian signal, the verbal message is "wait." (*MUTCD*)

Pedestrian clearance time. The time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the center of the farthest traveled lane or to a median. (*MUTCD*)

Pedestrian phase (or ped phase). The cycle of pedestrian timing consisting of three parts: (1) the WALK interval (WALK sign); (2) the pedestrian clearance interval (flashing DON'T WALK); and the pedestrian change interval (steady DON'T WALK).

Pedestrian signal head. A signal head, which contains the symbols WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DON'T WALK), that is installed to direct pedestrian traffic at a traffic control signal. (*MUTCD*).

Pedhead. See *Pedestrian signal head.*

Permissive mode. A mode of traffic control signal operation in which, when a CIRCULAR GREEN signal indication

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is displayed, left or right turns may be made after yielding to pedestrians and/or oncoming traffic. (*MUTCD*)

Preemption control. The transfer of normal operation of a traffic control signal to a special control mode of operation. (*MUTCD*)

Pretimed operation. A type of traffic control signal operation in which none of the signal phases function on the basis of actuation. (*MUTCD*)

Priority control. A means by which the assignment of right-of-way is obtained or modified. (*MUTCD*)

PROWAAC Public Rights of Way Access Advisory Committee of the U.S. Access Board, that includes advocates, engineers, architects, and public works officials

Protected mode. A mode of traffic control signal operation in which left or right turns may be made when a left or right GREEN ARROW signal indication is displayed. (*MUTCD*)

Pushbutton. A button to activate pedestrian timing. (*MUTCD*)

Pushbutton locator tone A repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing and that enables pedestrians who have visual disabilities to locate the pushbutton. (*MUTCD*)

Pushbutton message. A speech message that provides additional information when the APS pedestrian pushbutton is pushed.

Remote activation. A handheld pushbutton device allowing a pedestrian to send a message over a short distance to call the ped phase.

Semiactuated operation A type of traffic control signal operation in which at least one, but not all, signal phases function on the basis of actuation. (*MUTCD*)

Signal head. An assembly of one or more signal faces together with the associated signal housings. (*MUTCD*)

Signal Indication. The illumination of a signal lens or equivalent device. (*MUTCD*)

Signal phase The right-of-way, yellow change, and red clearance intervals in a cycle that are assigned to an independent traffic movement or combination of movements. (*MUTCD*)

Signal section. The assembly of a signal housing, signal lens, and light source with necessary components to be used for providing one signal indication. (*MUTCD*)

Signal timing. The amount of time allocated for the display of a signal indication. (*MUTCD*)

Signal warrant. A threshold condition that, if found to be satisfied as part of an engineering study, shall result in analysis of other traffic conditions or factors to determine whether a traffic control signal or other improvement is justified. (*MUTCD*)

Steady (steady mode). The continuous illumination of a signal indication for the duration of an interval, signal phase, or consecutive signal phases. (*MUTCD*)

Tactile. An object that can be perceived using the sense of touch.

Tactile arrow (aligned in direction of travel). A raised (tactile) arrow in an APS pushbutton that helps users know which crosswalk is actuated by the pushbutton.

Tactile map. A raised schematic map (located on an APS pushbutton housing) that shows what will be encountered as the pedestrian negotiates the crosswalk controlled by that push button.

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Traffic control signal (traffic signal). Any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed. (*MUTCD*)

Vibrotactile pedestrian device. A device that communicates, by touch, information about pedestrian timing using a vibrating surface. (*MUTCD*)

WALK interval. An interval during which the WALKING PERSON (symbolizing WALK) signal indication is displayed. When a verbal message is provided at an accessible pedestrian signal, the verbal message is "WALK sign." (*MUTCD*)

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NCHRP

Web-Only Document 117B:

Guidelines for Accessible Pedestrian Signals

Final Report

David L. Harkey
Daniel L. Carter
University of North Carolina
Chapel Hill, NC

Janet M. Barlow
Billie L. Bentzen
Linda Myers
Alan Scott
Accessible Design for the Blind
Asheville, NC

Contractor s Final Report for NCHRP Project 3-62
Submitted 2007

National Cooperative Highway Research Program
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Summary

In 2000, two sections on APS were added to the *Manual on Uniform Traffic Control Devices (MUTCD)*, which became the first set of national standards for APS in the U.S. The *MUTCD* defines an APS as "...a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces" (1). The rest of the *MUTCD* language provides standards, guidance and options, but does not specify walk messages or address many possible device features. In 2002, the U.S. Architectural and Transportation Barriers Compliance Board (Access Board) published draft recommendations and requirements for APS installation in *Draft Guidelines for Accessible Public Rights of Way* (2). The *Draft Guidelines* call for the use of pushbutton-integrated signals that provide audible **and** vibrotactile indications of the walk interval.

The objective of this research was to develop guidelines and training materials for implementation of accessible pedestrian signals (APS). The guidelines explain how APS provide optimal information through media such as tones and tactile or verbal indicators, and under what circumstances their installation is recommended. The training materials are intended to facilitate application of the guidelines and installation and operation of APS. This training is oriented toward technical issues and public education.

Two separate research experiments were undertaken in this project to develop the recommended guidelines for APS features and APS installation. The purpose of first study was to determine the effect of APS features, which are commonly found on most of the APS equipment marketed in the U.S., on the ability of pedestrians who are blind to locate and use pushbuttons, determine time to cross, determine appropriate heading for crossing, and maintain alignment while crossing. The second study was conducted to evaluate the effects of pole location, number of poles used in relation to number of APS devices, and type of WALK indication on the ability of pedestrians with visual or cognitive impairments to determine which crosswalk at a corner had the WALK signal. In addition to these two research studies, additional information about APS performance was gleaned from an engineering evaluation of the equipment installed during this research study, as well as from a series of cold weather case studies.

This research was the basis for more precise and well-supported standards and guidance on APS for inclusion in the *MUTCD* and the U.S. Access Board *Guidelines*. The research results have been forwarded to the Signals Technical Committee of the NCUTCD and to the Federal Highway Administration (FHWA) as background and support for changes in Part 4 of the *MUTCD* as well as to the U.S. Access Board.

The training materials consist of a set of PowerPoint presentations that comprise a one-day training course and a companion resource document, *Accessible Pedestrian Signals: A Guide to Best Practices*. These materials are available at www.walkinginfo.org/aps and provide guidance on where and how APS should be installed. The training is directed at three main audiences – traffic engineers, orientation and mobility (O&M) instructors, and signal technicians.

One of the first questions that must be answered by local engineers and others responsible for the installation of APS devices is when and where is it appropriate to

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install such devices in other than new construction and alteration/reconstruction. In many cases, there is a need to prioritize intersections for APS installations. The *MUTCD* currently provides some guidance on this matter, but a more definitive approach is needed by practitioners. As part of this research effort, an intersection prioritization tool was developed, applied by practitioners, and then validated by comparing the objective ratings achieved with the tool to the subjective ratings of pedestrians with visual impairments and O&M specialists. The tool itself, which includes a set of instructions for application, is also available on the web at www.walkinginfo.org/aps.

The results of this research have produced a set of recommended guidelines for APS installation and operation that will make it easier and safer for pedestrians with visual impairments to cross streets at signalized intersections. In time, the results will make their way into the *MUTCD* and other guides, which will lead to greater uniformity in the field.

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CHAPTER 1
INTRODUCTION

SUMMARY OF THE PROBLEM

All pedestrians, including those with visual impairments, must accomplish five primary tasks to safely cross a street at a signalized intersection:

1) Locate the street and the crosswalk.
2) Determine the form of signal actuation for the walk interval (and locate the pushbutton if required).
3) Establish the appropriate heading (alignment) for initiating the crossing.
4) Identify the time at which it is legal and safe to begin crossing, and
5) Maintain the appropriate heading during the crossing.

In the technique most often utilized for crossing at signalized intersections, pedestrians who are blind or visually impaired begin to cross when they hear a surge of traffic parallel to their direction of travel. While many intersections pose little difficulty, some intersection geometries and traffic conditions make it very difficult for persons with visual impairments to cross safely and independently. To assist visually impaired pedestrians and make street crossings a task that can indeed be done independently and safely, pushbuttons and audible signals have been used in this country with varying degrees of success. In fact, the Transportation Equity Act for the 21st Century (TEA-21) modified 23 USC 217(g) by directing that pedestrian safety considerations be incorporated for all transportation plans and projects, including installation of audible traffic signals and signs at street crossings where appropriate. However, research indicates that some of the current audible signals, widely used in some parts of the United States, have a number of problems, including the following:

a) Users did not know whether a pushbutton was present.
b) Users found it difficult to locate the pushbutton.
c) Users could not tell which signal (crosswalk) was actuated by the button.
d) Users could not push the button and return to the point of crossing before the Walk interval began due to the long distance between the button and the intersection corner.
e) The signal was too quiet or too loud.
f) Users could not localize the sound and use it for guidance across the street.
g) Where the "chirp" or "cuckoo" sounds were used, users crossed against the signal when they "heard a bird rather than the signal, and
h) Users failed to cross with the signal due to thinking it was an actual bird.

The research undertaken in this project, in coordination with research on accessible pedestrian signals (APS) that was conducted under concurrent related projects, discovered or developed solutions to most of the user-oriented problems identified above. In addition, guidance for design and installation of APS that provide information for pedestrians who are deaf-blind was developed. The research under this project also obtained engineering data and knowledge

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required for addressing issues such as general installation requirements, and physical installation, operation, and maintenance requirements.

This research was the basis for more precise and well supported standards, guidance and support on APS for inclusion in the *Manual on Uniform Traffic Control Devices (MUTCD)* and in the *Guidelines for Accessible Public Rights of Way*, the Access Board was providing minimum design guidelines implementing the ADA in public rights of way (*U.S.*). The research results were forwarded to the Signals Technical Committee of the National Committee on Uniform Traffic Control Devices (NCUTCD) and to the Federal Highway Administration (FHWA) as background and support for changes in Part 4 of the *MUTCD*, as well as to the U.S. Architectural and Transportation Barriers Compliance Board (Access Board). The NCUTCD approved revisions to Part 4E of the *MUTCD*, which would implement the recommendations of this report at their June 2000 meeting, and sent them to FHWA for their consideration for the next *MUTCD* edition.

The results and products of this research may be used to increase the safety and mobility of pedestrians at signalized intersections, including those persons who are blind or visually impaired as well as those persons who are both visually and hearing impaired, by providing them with standardized information functionally equivalent to that provided to other pedestrians.

OBJECTIVE

The objective of this research was to develop guidelines and training materials for implementation of accessible pedestrian signals (APS). The guidelines explain how APSs provide optimal information through media such as tones and tactile or verbal indicators, and under what circumstances their installation is recommended. The training materials are intended to facilitate application of the guidelines and installation and operation of APS. This training is oriented toward technical issues and public education.

ORGANIZATION OF REPORT

This report provides a summary of prior research on APS, documents the results of all human subject experiments and other evaluations conducted, and provides recommended guidelines for APS installation and operation. The components of this report are as follows:

- Chapter 2 – Research Synthesis – includes a summary of research on APS that was used in designing the trials in this project and developing the recommendations.
- Chapter 3 – Experimental Trials on Accessible Pedestrian Signal Features – includes the trials conducted in Tucson and Charlotte, which included an evaluation of multiple pushbutton-integrated APS devices and their effects on crossing behaviors by pedestrians with visual impairments.
- Chapter 4 – Experimental Trials on Pushbutton Location and WALK Indicator – includes the trials conducted in Portland to specifically evaluate the effect of number of poles and pole placement, as well as type of WALK indication, on crossing behaviors by both visually impaired and cognitively impaired pedestrians.

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- Chapter 5 – Cold Weather Case Studies – includes a summary of the case studies prepared as related to the installation, operation, and maintenance of APS in cold weather environments.
- Chapter 6 – Engineering Evaluation – includes the results of the engineering evaluation that has been completed to date.
- Chapter 7 – Recommended Guidelines – provides a discussion of the guidance recommended on the basis of the experimental results.
- Chapter 8 – Intersection Prioritization Tool – includes a discussion of the effort to develop a tool for assessing and prioritizing intersections with respect to crossing difficulty by pedestrians with visual impairments.
- Chapter 9 – Training and Resources – provides a discussion of the plans for the development of the training materials in the next phase of the study and includes an outline for the materials.
- Chapter 10 – Conclusions – includes a summary of the study objectives, project findings, and recommended guidelines.

ADDITIONAL RESOURCES

- *Accessible Pedestrian Signals: A Guide to Best Practice* – This companion document (referred to hereafter as the *Guide*) provides training information for engineers, orientation and mobility specialists, and signal technicians on when, where, and how to install APSs. See more information on the *Guide* in Chapter 9.
- PowerPoint Presentations – these presentations are the materials for a one-day training course that covers the most critical information in the *Guide*. The presentation files include scripts to ensure that they can be read and understood outside of the course. See more information on the presentations in Chapter 9.
- Web site (www.walkinginfo.org/aps) – This site includes all of the materials produced as part of this project, including this report, the *Guide*, the PowerPoint presentations for training, and the Intersection Prioritization Tool to assist practitioners in prioritizing locations for APS installation.

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CHAPTER 2

Research Synthesis

Provided in this chapter is a summary of the APS research that is related to the research undertaken in this effort. A more comprehensive synthesis of this research can be found in Appendix C of the *Guide*.

INTRODUCTION

Although APSs have been widely used in Japan and Sweden since the 1960s, the early development of APS in these countries was not, as far as these authors have been able to ascertain, based on research. The first substantial research on APS appears to have been done in 1976 by Frank Hulscher, an electrical engineer with the Department of Motor Transport, New South Wales, Australia. Hulscher's research was the basis for the well developed, fully standardized, and highly successful pushbutton-integrated APS system in use in Australia today.

Substantial research on APS in the U.S. began with a project undertaken by the San Diego Association of Governments in 1988 to investigate the "bird call signals" widely used in Japan, and being imported into the U.S. at that time. The results of this project were the basis for a policy of implementing standard signals at intersections in San Diego where a city access committee recommended them, following a systematic evaluation including use of a rating scale.

Since 1996, there has been a concerted research effort related to APS. Several research studies and surveys have documented problems of pedestrians who are blind or who have low vision at signalized intersections without APS (*3, 4, 5, 6, 7, 8*). Several studies in the U.S. have compared travel by blind pedestrians with and without APS (*9, 10, 11, 12, 13, 14, 15*). In these studies, some of the APSs have been signals mounted on the pedestrian signal head, while others have been receiver based systems, and others been pushbutton integrated devices. Methods of these studies are described below; results and conclusions are cited topically.

San Diego Association of Governments surveyed 71 national, regional, and local organizations representing and/or serving elderly persons and persons who were visually impaired to determine their involvement in installation of audible signals and the level of support for audible signals; 36 responses were received (*8, 16, 17, 18*, hereafter referred to collectively as San Diego research). A separate survey was also sent to members of California Association of Orientation and Mobility Specialists to gather information about their experience with audible signals. Surveys were mailed to 67 members, and 27 responses were received.

In 1998, the American Council of the Blind (ACB) and the Association for Education and Rehabilitation of the Blind and Visually Impaired (AER) conducted similar surveys to determine problems experienced by blind pedestrians during street crossings. Problems with audible signals currently installed were also identified by the surveys.

- ACB survey – surveys administered orally, in groups, to 158 pedestrians who are visually impaired (*6*, hereafter referred to as ACB survey).
- AER survey – mailed to 1000 orientation and mobility specialists. 549 surveys returned (*5*, hereafter referred to as AER survey).

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Murakami et al. conducted a survey of 50 blind pedestrians in Japan (7). Ishaque et al. compared crossings by 27 legally blind pedestrians at three intersections in Huntington Beach, California, having "bird call" signals and one control intersection without APS (14).

In research by The Smith-Kettlewell Eye Research Institute, 20 blind participants made a total of 80 crossings at 4 fixed-time signalized intersections in downtown San Francisco, both with and without Talking Signs® (10, 11, 12, hereafter referred to collectively as SKERI research). Talking Signs is a receiver-based APS. Intersection signal phases were pretimed, and pushbutton use was not required. There were nine measures, including measures of crossing timing, safety, orientation (precision), and independence.

Marston and Golledge compared crossings by blind participants with and without APS, using the receiver-based APS system, Talking Signs, in a study investigating the use of Talking Signs remote infrared audible signs for a number of transit tasks (13).

The effects of a pushbutton-integrated APS, a receiver-based APS manufactured by Relume, and typical visual pedestrian signals without APS on the street crossing behavior of 24 totally blind participants were compared by Williams, Van Houten, Ferraro, and Blasch (15).

As part of a project on blind pedestrians at complex intersections, funded by the National Eye Institute, National Institutes of Health, a series of studies on crossings by blind pedestrians with and without APS is in progress in four cities, Portland, Oregon; Charlotte; Tucson; and Cambridge, Massachusetts. Objective data on measures of street crossing performance by sixteen participants who were blind was obtained at two complex, signalized intersections in each city. Measures were similar to those used in the SKERI research, including nine broad measures of crossing timing, orientation, and independence. Results from all four cities are not yet analyzed, but slightly different analyses have been reported in several articles. Results from pre-installation testing in two cities, Portland and Charlotte, are reported in Bentzen et al. (4, hereafter referred to as NEI-2 cities) and Barlow et al. (3, hereafter referred to as NEI-3 cities); reports on three cities, Portland, Charlotte, and Cambridge (Barlow et al. (9, hereafter referred to as NEI Portland pre-post) compares results of testing with and without APS in one of these cities, Portland, Oregon.

PROBLEMS WITH SPECIFIC TASKS AT SIGNALIZED INTERSECTIONS BY PEDESTRIANS WHO ARE BLIND OR WHO HAVE LOW VISION

Locating the Crosswalk

In SKERI research and NEI research-3 cities, research participants requested assistance in locating the crosswalk on about 17% of street crossings. On approximately 29% of crossings in both studies, subjects who located the crosswalk independently began crossing from outside the crosswalk.

Establishing and Maintaining the Correct Heading

In the AER survey, 97% of O&M specialists who responded indicated that their students had difficulty aligning to cross the street, while 66% indicated that their students sometimes had difficulty knowing where the destination corner was.

In SKERI research, participants started crossing from an aligned position on 48% of crossings without use of APS, and completed their crossings within the crosswalk on 58% of

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crossings. In the NLI-3 cities research (without APS), participants started from an aligned position on 73.4% of crossings. Participants requested assistance or required intervention for safety while aligning to cross on 10% of crossings. Of participants who aligned independently, 58.4% completed their crossings within the crosswalk.

The broadcast sound from speakers mounted on the pedestrian signal head has not seemed to provide usable directional information. ACB and AER surveys indicated that pedestrians who are blind are sometimes not able to localize the sound of an APS in order to use it for guidance across the street. ACB – 67%, AER – 39% – 85% of ACB respondents indicated that they were sometimes confused by unexpected features such as medians or islands, while 64% of O&M respondents indicated that their students had difficulty with medians or islands.

Finding and Using Pushbuttons

In the ACB and AER surveys, many respondents indicated that they or their students had difficulty with pushbuttons (ACB – 90%; AER – 94%). Reasons were: 1) they couldn't tell whether they needed to push a button; 2) they had difficulty locating the button; 3) they couldn't tell which crosswalk was actuated by the button; or 4) the pushbutton was so far from the crosswalk that they couldn't push the button and then return to the crosswalk and establish a heading before the WALK interval began.

Uslan et al. also found that the major problems 27 legally blind participants had with "bird call" type APSs were in locating the pole and the pushbutton and determining which pushbutton was for which crosswalk (74). Participants traveling with guide dogs experienced the most difficulty locating the pole. Sometimes participants first located the incorrect button and subsequently located and pushed the correct button after waiting and listening through one or more cycles.

This replicated the findings of San Diego's research (76). Gallagher and Montes de Oca also noted this problem in research on vibrotactile-only APSs (79).

In the NLI-2 cities results, at crossings where pushbutton-actuation was required, participants looked for, found, and pushed the button on only 16.3% of these crossings in Portland, and none (0%) of the crossings in Charlotte.

Identifying the Onset of the WALK Signal

In the surveys conducted by ACB and AER, many respondents indicated that they or their students sometimes had difficulty knowing when to begin crossing (ACB – 91%; AER – 98%). Reasons were: 1) the surge of traffic was masked by right-turning traffic; 2) traffic flow was intermittent; 3) the intersection was too noisy; and 4) the surge of traffic was too far away. In the AER survey, 79% of respondents indicated that blind students sometimes had difficulty determining the onset of the WALK interval at intersections having exclusive pedestrian phasing.

On 24% of trials at SKERI research, blind pedestrians requested assistance in knowing when to start crossing at crosswalks where they did not use APS. On 34% of trials on which they independently initiated crossings, they began crossing during the flashing or steady DON'T WALK.

In the Japanese survey, 46% of respondents stated that "To take a moment to start" was difficult without APS, and Uslan found that, at the control intersection without APS, which was

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commenced the earliest to cross without APS. 4 out of 15 participants began crossing during DON'T WALK.

The NEI 3 cities research found that pedestrians who were blind independently began crossing during the walk interval on only 48.6% of crossings and completed crossings after the onset of perpendicular traffic on 26.9% of crossings. The need for push-button activation of the walk interval affected the likelihood that participants would begin crossing during the walk interval. On the pedestrian-actuated crossings, participants began crossing during the walk interval on only 19.5% of the crossings compared to 71.7% of crossings where the pedestrian phase was on recall (the pedestrian phase was indicated in every cycle). Mean latency in beginning crossing (the time between onset of the WALK signal or near-side parallel traffic and the participant beginning to cross) was 6.41 seconds without APS.

Common Problems with APS in the United States

ACB and AER surveys reported the experience of pedestrians with visual impairments in using APS that had "bird call" signals, bells, and buzzers. There were problems both with APS being considered too quiet and too loud. Ushai et al. found that at one intersection with split phase timing, where the bird call signals for parallel crosswalks had separate timing, three of 15 blind participants initiated their crossings with the signal for the parallel crosswalk, walking into the path of left-turning vehicles (14).

These surveys also looked at data from blind pedestrians and O&M specialists from California, whose experience with APS is almost exclusively with "bird call" signals that are intended to provide unambiguous information regarding which street has the WALK interval. Many respondents indicated that they or their students sometimes did not know which crosswalk had the WALK interval (ACB = 68%; AER = 72%). Reasons were: 1) users forgot which signal was associated with which crossing direction; 2) users didn't know which direction they were traveling; and 3) the intersection was not aligned with primary compass directions.

Ushai et al. found that on many trials blind participants failed in their attempts to cross streets because of indecision regarding the pole or button, even though all participants were fully familiar with the "bird call" signal, they knew what to listen for at each intersection, and they could listen through as many cycles as they desired (14). Sometimes participants located the incorrect button and then pushed the correct button after waiting and listening through one or more cycles.

AER and ACB surveys confirmed that blind pedestrians rarely do confuse the sounds of birds with APS sounds. These surveys also indicated that many blind pedestrians are sometimes unable to localize the sound of an APS and use it for guidance across the street. Furthermore, when APSs are too loud, and are at intersections that are close together, the APS for one intersection may be heard from another, leading some pedestrians to incorrectly think they have the WALK interval.

Respondents to the Japanese survey indicated that "direction taking at the starting position" and "keeping direction while walking in the crosswalk" were a problem, even with APS.

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EFFECT OF APS ON STREET CROSSINGS BY BLIND PEDESTRIANS

Since it is known that pedestrians with visual impairments have difficulty with many of the tasks that, taken together, comprise street crossing, it would be convenient to assume that APS would improve all measures of crossing at signalized intersections. To determine the extent to which this is true, a number of research projects have obtained objective data comparing street crossings with and without APS on one or more of the following measures:

- Locating the crosswalk.
- Aligning to cross and maintaining alignment while crossing.
- Use of pushbuttons.
- Identifying the walk interval.
- Delay before beginning to cross.
- Independence in any or all crossings tasks.

Projects that have already been mentioned are: SKERI research, NEI Portland pre-post; Uslan et al. (14); Marston and Golledge (15); and Williams et al. (17). There are several additional studies that shed light on this topic. Hulscher reported an estimate by Leith (personal communication) comparing starting delay pre- and post-APS installation (20). Wilson conducted a pre- and post-APS installation study of behavior of adult, non-disabled pedestrians at one intersection (21). As part of NEI research, in three different experiments Wall, Ashmead, Bentzen and Barlow, blind and blindfolded sighted participants made crossings at a simulated intersection, in the presence of recorded traffic sound to determine the effect on crossing accuracy with signals comprised of bird calls, percussive "ticks," a click train, or a female voice (22). The signals, all of which were mounted at a height of eight feet, came either simultaneously from both ends of a crosswalk (typical practice), alternated from one end to the other, or came from the far end of the crosswalk only. These researchers also compared crossing accuracy when signals came from two parallel crosswalks (typical practice), or from a single crosswalk. A further comparison was between Walk signals with a typical 7 sec. duration versus a 7 sec. Walk signal followed by a locator tone.

Locating the Crosswalk

SKERI research found that starting crossing from within the crosswalk increased from 70% to 93% with use of the APS.

NEI Portland pre-post research found significant increases in participants' ability to begin crossings from within the crosswalk at locations where pushbutton use was required, and pushbutton locator tones were installed. Pre-installation, 77% of crossings began from within the crosswalk; post-installation, 97% of crossings began within the crosswalk, indicating that locating the crosswalk was significantly improved by the presence of pushbutton-integrated APS. (9)

Orientation (Aligning to cross and maintaining alignment while crossing)

On 48% of crossings in SKERI research, where APS information was not available, blind pedestrians were not facing directly toward the opposite corner when they started their crossing;

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they were facing somewhat toward or away from the center of the intersection. With the use of receiver-based APSs, participants were well aligned when beginning 80% of crossings.

However, in NEI Portland pre-post research, alignment showed only a very small trend toward improvement, with 70% of independent crossings starting from an aligned position pre-installation and 84% post-installation. NEI research in a simulated crossing found the presence of a locator tone during the second half of the crossing had a positive effect on alignment (22).

Using Pushbuttons

Data reported in NEI pre-APS installation testing indicated that blind pedestrians typically didn't search for and use pedestrian pushbuttons at unfamiliar intersections without APS (3, 4). However, the addition of pushbutton locator tones and the knowledge that an APS might be installed resulted in participants looking for the pushbuttons on over 98% of crossings, although looking for the pushbutton did not always result in finding and using the correct pushbutton. Participants independently looked for and used the pushbuttons on 93% of crossings after pushbutton integrated signals with locator tones were installed (9).

Initiating the Crossing

Delay in beginning to cross

Hulscher cites a personal communication from Lamb in which Lamb estimated that, following APS installation, delay in beginning crossings was reduced an average of 2.3 seconds for all pedestrians (20).

Wilson, in a pre- and post-APS installation study of adult non-disabled pedestrian behavior at one intersection, found the following results (21):

- For pedestrians using the pushbutton, delay in beginning crossings was reduced by 20%, from 2.7 sec to 2.1 sec.
- The time taken to cross by persons who started during the walk interval decreased by about 5%; crossing time for other pedestrians was unchanged.
- For pedestrians who arrived at the crossing during the flashing or steady Don't Walk and who waited to cross until the onset of the walk interval, the proportion who failed to complete their crossings before the onset of opposing traffic was reduced by one half, from 22% to 11%.

Williams et al. found that mean latency in beginning crossing without APS was more than 5 seconds, which was reduced to 2.2 seconds with a receiver-based APS device with a tone WALK indication and 3.8 seconds with a pushbutton integrated APS using speech messages (15). Williams also assessed participants on total number of signal cycles missed before crossing. Without APS, mean wait time was almost 2 full cycles, while with either type of APS the mean wait time was just over a half a cycle.

In NEI Portland pre- post research, in 144 crossings pre- and post-APS installation at two intersections in Portland, Oregon, the weighted mean starting delay for blind pedestrians without APS was 5.1 seconds, and after APS installation, the delay was only 2.9 seconds. Ustan et al. also found significant differences between speed of crossing at a control intersection and intersections where APS were installed; crossings at locations with APS were completed faster (14).

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Starting during WALK and completing crossing before the onset of perpendicular traffic

In SKERI research, participants began crossing during the walk interval on only 66% of crossings without APS, but on 99% of crossings with APS.

In NEI Portland pre-post installation, pre-installation, the pedestrian actuated crossings were highly problematic for pedestrians who are blind. Pre-installation, participants began crossing during WALK on only 25% of crossings. Post-installation, there was dramatic improvement in participants correctly determining the appropriate time to start crossing, with 84% of crossings initiated during WALK. Similarly, participants completed crossing after the onset of perpendicular green on 50% of crossings pre-installation, with a significant decrease post-installation to 12% of crossings completed after the onset of perpendicular green.

Furthermore, only 77% of decisions about when to start crossing were made independently pre-installation as opposed to 95% post-installation. Pre-installation, the total number of crossings where the individual independently determined a start time and actually began crossing during the walk interval was less than a quarter of crossings. Post-installation, with the addition of the APS, there was a significant increase both in independence and in beginning to cross at the appropriate interval.

For crosswalks where the pedestrian phase was on recall, the APS sounded at the beginning of the walk interval, regardless of whether the pushbutton was used or not. However, the WALK indication only sounded for the first seven seconds of the walk interval, unless the pushbutton was pushed again. Pre-installation, 70% of independent crossings began during the walk interval; post-installation, this increased to 100%.

Marston and Golledge found that at crossings without APS, almost half (48%) of the participants attempted to cross during the steady don't walk interval, a time recorded as unsafe by the researcher (*13*). With access to the pedestrian signal information provided by APS, no participant started crossing at an unsafe time.

Effect of APS on Independence and Confidence

Both the NEI research and the earlier SKERI research on which the method was based measured independence on three street crossing tasks both with and without APS: locating the crosswalk, starting to cross within the walk interval, and completing the crossing. The NEI research also measured independence on aligning to cross. The percentage of crossings on which participants were independent on each task is as follows:

Task	Without APS		With APS	
	SKERI	NEI	SKERI	NEI
Locating crosswalk	81%	82%	99%	95%
Aligning to cross	NA	94.5	NA	97%
Starting to cross during WALK	76%	79%	100%	92%
Completing the crossing	81%	86%	97%	96%

Table A-1. **Percentage** of crossing tasks on which participants were independent.

Marston and Golledge measured confidence in street crossing with and without APS (*13*). The range of responses for the no APS condition, by street crossing task, was 4.7–5.5 (5 pt. scale).

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1=no confidence, 5=very confident), while the range of responses by task for the APS condition was 4.8-5.0.

Detectability of WALK Signal

Holscher found that, because of the masking of high frequency signals by predominantly low frequency traffic noise, and because a majority of blind pedestrians have some upper frequency hearing loss, the optimal "fundamental" frequency of the WALK tone should be between 300 Hz and 1000 Hz, and the tone should be comprised of multiple short bursts of sound to aid localization (20)

Stuffeldt, in research cited by Holscher, conducted extensive testing of APS at crossings where they were mounted on the pedestrian signal head, and found that an 880 Hz signal was most detectable in a background of traffic noise (20)

Holscher's recommendation and Stuffeldt's result was supported by Poulsen, who compared the noise spectrum of traffic as attenuated by windows to arrive at a recommended signal frequency (880 Hz) that would not be largely masked by traffic noise, but would also not transmit through windows and become a public annoyance (23)

At San Diego research laboratory measurements of "birdcall" signals from Nagoya Electric Works of Japan found that neither signal was highly directional, however, the cheep was more detectable than the cuckoo. The cheep was produced by a continuous frequency variation with a fundamental frequency base of 2800 Hz, and the cuckoo consisted of two frequencies with a combined frequency base of 1100 Hz. (Currently available "cuckoo/cheep" signals may vary from this manufacturer's standard.)

Hall, Rabelle, and Zabilsky worked with audiologists to develop a signal that provided the most localizable melody for an accessible signal, and recommended a melody that was composed of fundamental frequencies between 300 Hz and 1000 Hz, but including harmonics extending to 7000 Hz (24)

At NBI research (unpublished data), Wall, Ashmead, Barlow, and Bentzen carried out a series of experiments on detectability of WALK signal alternations in a laboratory setting (25) Experiment 1 evaluated the detectability of signals in white noise, Experiment 2 evaluated the detectability in traffic noise, and Experiment 3 evaluated detectability in traffic noise for subjects with age-related hearing loss. Signals evaluated were an 880 Hz square wave, a bird chirp, a cuckoo, two click trains, two percussive signals ("blink" and "tick"), a four-tone melody, and female and male voice signals. Results indicated that audible signals of a more percussive nature with predominantly lower frequencies were best heard in background traffic noise. In addition to one of the percussive signals, participants with age-related hearing loss were better able to detect male voice signals. Signals with a simple percussive nature tended to need less gain to be heard in noise, relative to the levels necessary to be heard in quiet. In other words, percussive signals were more detectable at lower volumes. When asked their preference, most participants liked voice signals best, but all of the voice signals needed more gain to be heard. Note that the measurements in these studies was the point at which the signal was detected, not the point at which the message was easily understandable. Intelligibility of voice messages was not evaluated or assessed by participants. The cuckoo and chirp, most commonly used in the U.S. as an audible signal at the time of the study, required the most gain to be detectable amid background noise.

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Localizability of WALK Signal

An additional factor, if audible pedestrian signals are to be used as beacons to guide pedestrians with visual impairments across a street, is how well signals can provide directional information. Laroche, Giguère, and Poirier compared localization of cuckoo and cheep signals to localization of 4 four-note melodies varying in fundamental frequencies, harmonics, note duration, and temporal separation between notes (26). In combined objective and subjective testing, the cheep and a melody with minimal harmonics were found to be less localizable than the cuckoo and the other three melodies. In a follow-up study, Laroche, Giguère, and Lemoyne compared the typical cuckoo-cheep sounds used in Canada with a cuckoo having a lower fundamental frequency, and the melody that was recommended as a result of their 1999 research (27). In both studies, the signal was 56 seconds long (much longer than typical U.S. WALK indications) and the measurements were in a simulated pedestrian corridor in a quiet environment. In situations with actual traffic sounds, the cheep was found to result in significantly greater veering and longer crossing time than any of the other signals, which did not differ from each other.

At NEI research, Wall Ashmead, Bentzen, and Barlow found no significant differences in localizability among several disparate signals, including cuckoo, chirp, "tok" and voice messages, when tested in research that involved multiple crossings of a simulated street, in the presence of recorded vehicular sound (22). The five signals used were representative of signals in wide use or that showed promise for directional beaconing. None of the analyses indicated any systematic differences between the five signals. Further experiments focused on presentation mode and signal location, rather than signal sound characteristics.

Speech WALK Indications

Listeners with normal hearing require that speech be 15 dB louder than background noise for intelligibility to reach 90% (28). This means that, in order to be intelligible, speech messages should be louder than tone indications. The effect of that louder sound level on the ability of blind pedestrians to hear other sounds in the intersection, or on our near neighbors, may limit the acceptability of speech messages.

Bentzen, Barlow and Franck conducted research to obtain information from stakeholders regarding the structure and content of speech messages for APS WALK messages and for "pushbutton messages" that are only available during the flashing and steady DON'T WALK intervals (29). WALK messages convey that the WALK signal is on and provide the name of the street being crossed. Pushbutton messages provide intersection and crosswalk identification information, and they may also provide information about unusual intersection signalization and geometry. The research utilized an expert panel of stakeholders, who prepared a survey comprised of sample messages (verbal and forms to determine respondent understanding of messages. The survey was administered to people who are visually impaired, O&M specialists, transportation engineers, and APS manufacturers. The resultant recommended model messages are contained in the *Guide*.

Van Houten, Malenfant, Van Houten, and Retting found that redundant information conveyed by audible pedestrian signals increases the attention of all pedestrians to turning traffic and may contribute to a reduction in pedestrian vehicular conflicts and crashes at signalized intersections (30). This signal also gave participants who were blind precise information about the onset of the walk interval and which street had the walk interval.

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Accuracy and Speed in Identifying WALK Indication for a Given Crossing

In NEI research, Ashmead, Wall, Bentzen, and Barlow investigated how location of APS speakers in different positions relative to the crosswalk affected the accuracy and speed of identifying the correct crosswalk (see Figure 2-1 below for APS positioning used in research, using typical placements seen in the U.S. (Ref.)). All loudspeakers emitted the same WALK indication.

Note: The question to the pedestrians always was, "Which has the WALK signal, the crosswalk straight in front of you or the one to your right?"

Corner 1: loudspeakers near curb, on outside of crosswalk line.
Corner 2: loudspeakers near back edge of sidewalk, on outside of crosswalk line.
Corner 3: loudspeakers near curb but facing across pedestrian's position.
Corner 4: loudspeakers near back edge of sidewalk mounted on the same pole.

Under the most typical signal mode, simultaneous presentation from both ends of the crosswalk, the most accurate performance occurred when signals were placed close to the curb line, near the side of the crosswalk that was furthest from the corner of the intersection (see corner 1 in Figure 2-1). The pedestrian could easily tell which of the two loudspeakers at the corner was nearer because each loudspeaker was close to the position of the pedestrian waiting to cross at the associated crosswalk. Note that this was true despite the fact that both signals on the corner had the same sound. Other arrangements of loudspeakers resulted in somewhat worse performance. Accuracy at corner 3 was poor, with participants answering correctly on only 25% of trials in the simultaneous presentation condition and 50% of trials in the alternating presentation condition.

There was no evidence that response time differed across the four corners, that is, for different speaker arrangements. This suggests that the inaccurate judgments made from corner 3 about which crosswalk had the walk signal did not reflect uncertainty, but rather were mistakes of which the participants were largely unaware.

Figure 2-2 illustrates the recommended placement of APS devices in relation to the crosswalk provided in the APS Synthesis in 2003. This arrangement was based on the NEI research described above. The NEI research was the basis for additional research on

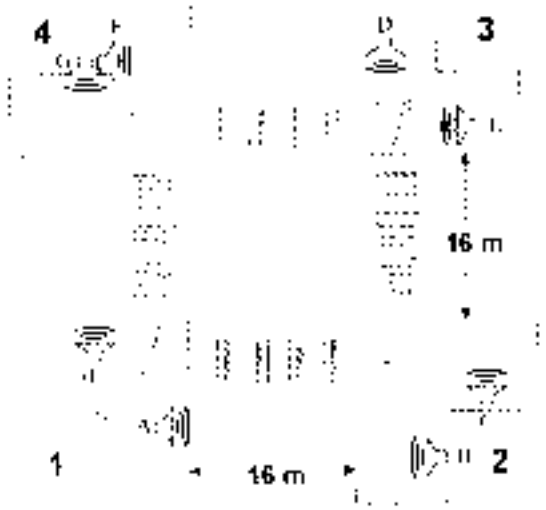

Figure 2-1. Positions and headings of loudspeakers and pedestrians at each corner in NEI research. (Figure from Ashmead, et al., 2004a). The figure is not drawn to scale.

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pushbutton location within the current project.

Research on Source of WALK Signal

A number of investigators have tackled the problem of improving localization of WALK signals by varying the source of the sound. All investigators used some measure of the straightness of the path of travel from one end of the crosswalk to the other; some also measured mental loading.

Stevens (*41*) and Tauchi, Sawai, Takato, Yoshinuma, and Takeuchi (*42*) found that alternating acoustic signals result in performance superior to that of simultaneous signals, as did Lovelock et al. (*27*). However, when Lovelock et al. compared simultaneous and alternating signals at a real intersection, there was no significant difference. Tauchi, Takano, Suzuki, Kai, Takahara, and Jojima found better performance when the alternating signals at each end of the crosswalk were different (e.g. "chirp" vs. "cheep, chirp") than when they were the same (e.g. "chirp" and "chirp") (*43*).

Poulsen compared simultaneous acoustic WALK signals with signals at the far end of the crosswalk and found superior performance with signals at the far end (*24*). Wall et al. compared simultaneous, alternating (same sounds), and far-end signals, and found the far-end signals resulted in significantly better performance than either simultaneous or alternating signals, which were equal (*22*).

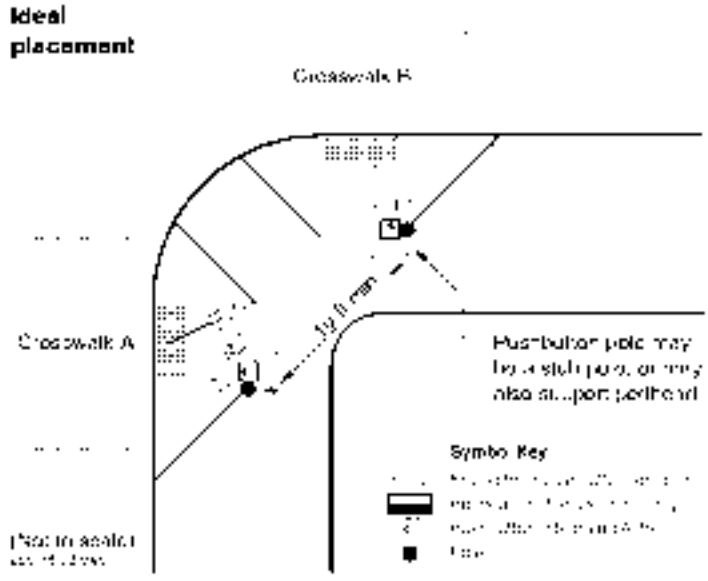

Figure 2-2. Optimal location of pushbutton integrated APS.

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CHAPTER 3

Experimental Trials on Accessible Pedestrian Signal Features

INTRODUCTION

The most commonly used accessible pedestrian signals (APSs) in the U.S. have been pedhead-mounted devices, where speakers are attached to the visual pedestrian signals. These APSs can make a variety of sounds, but commonly use birdcalls (cuckoo and cheep). A different type of APS, known as a pushbutton-integrated APS, has been used in much of Europe and in Australia and is now becoming more common in the U.S. On pushbutton-integrated APSs, the speaker is located in the pushbutton housing, and the device typically provides a pushbutton locator tone in addition to an audible WALK indication. The pushbutton locator tone repeats constantly, at one-second intervals to tell pedestrians that there is a pushbutton and to help them locate and use the pushbutton. Tactile arrows are also a standard feature to help blind pedestrians determine which street the device serves (*see Figure 3-1*). The arrow vibrates during the walk interval to communicate walk signal information to pedestrians who cannot hear or who want to tactually confirm audible signal information. Various other features are currently available on some devices.

Until 2000, when two sections on APS were added to the *MUTCD*, there were no national standards for APS in the U.S. The *MUTCD* now defines an APS as "…a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces" (*1*) The rest of the *MUTCD* language provides standards, guidance and options, but does not specify walk messages or address many possible device features. In 2002, the U.S. Access Board published draft recommendations and requirements for APS installation in *Draft Guidelines for Accessible Public Rights-of-Way*, which were further updated in November 2005 (*2*). The *Draft Guidelines* call for the use of pushbutton-integrated signals that provide audible **and** vibrotactile indications of the walk interval.

Figure 3-1. Pushbutton-integrated APS with tactile arrow.

Research was needed to expand upon or modify the APS guidance now available to ensure that the information being provided to pedestrians who are blind or who have low vision (including those with hearing loss) is consistent among

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intersections and will allow users to safely, efficiently, and independently cross at signalized intersections. The purpose of the study documented in this chapter was to determine the effect of APS features, which are available on devices of the type recommended in the Access Board's *Draft Guidelines*, on the ability of pedestrians who are blind to locate and use pushbuttons, determine time to cross, determine appropriate heading for crossing, and maintain alignment while crossing.

In this experiment, four pushbutton-integrated APSs were evaluated in comparison to each other. APSs from each of four manufacturers were installed at all crosswalks at one of four intersections in each of two cities. Psychophysical data on street crossings by approximately 20 blind pedestrians were obtained for each manufacturer's APS installed with their "standard features" in each city. These technologies differed from one another in interface designs and features, such as the pushbutton locator tone, pushbutton size and shape, design, and location of tactile arrow, type of actuation indicator/confirmation tone/speech, tick, burst, type of walk indication (speech message, rapid tick, bird call tones), and availability of additional features such as tactile map of the crosswalk, additional information about the intersection or audible beaconing. APS features are described in detail in the *Guide*. The following descriptions of features are condensed from that report.

- Pushbutton locator tone: "A repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing and that enables pedestrians who have visual disabilities to locate the pushbutton." (*MUTCD 2000*, 4E.08; 17). Pushbutton locator tones sound during the flashing and steady DON'T WALK intervals. The locator tone informs pedestrians of the need to push a button, provides an audible cue to the location of the pushbutton, and may provide a clue as to the destination corner when approaching on the crosswalk. In available products, the pushbutton locator tone varies from a click sound to a beep type tone. *MUTCD* standard requires that "... the tone shall repeat at 1 second intervals and shall have a duration of 0.15 seconds or less" (17). The pushbutton locator tone typically has automatic volume control that adjusts the volume according to changes in ambient sound level.
- Pushbutton size and shape: Pushbuttons are required by the *Draft Guidelines* to be at least 2 inches in diameter and to require less than 5 lbs force to push (2).
- Tactile arrow: A raised (tactile) arrow is incorporated into the device to help users know which crosswalk is actuated by the pushbutton. The arrow may be part of the pushbutton, above the pushbutton, or on top of the device. This arrow also vibrates during the WALK interval.
- Actuation indicator: A tone or voice message indicates to pedestrians that the button has been pushed and a WALK signal requested.
- Additional intersection information (pushbutton information message): A pushbutton information message is a speech message that provides additional information when the pedestrian pushbutton is pushed during the flashing or steady DON'T WALK intervals. When used, this message identifies the intersection, provides the name of the street that the pushbutton controls, and may provide other intersection geometry or signalization information. The message is intended to be audible when standing at the pushbutton location. Pedestrians may be required to press the pushbutton for approximately three seconds (see extended button press) to call up this additional speech message. Recent

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research indicates that pressing the button for one second or longer is optimal timing [24].

- Walk indication: The walk indication provides an audible and vibrotactile indication of the WALK interval. The audible indication can be provided by tones or speech messages and generally repeats for the entire WALK interval. Different manufacturers currently provide different walk indications, but any of the devices could provide any of the sounds used. In this research, one manufacturer provided bird calls (cuckoo chirp), one provided a rapidly repeating tone, and two provided speech messages. The *MUTCD* and *Draft Guidelines* recommend that the walk indication be the same volume as the locator tone, and no more than 5 dB above ambient sound levels, unless there is special activation of audible beaconing. The vibrotactile indication of the WALK interval is typically provided by a tactile arrow on the pushbutton device that vibrates during this interval.
- Audible beaconing: Beaconing is the use of an audible signal in such a way that blind pedestrians can home in on the signal from the opposite corner as they cross the street. This is intended to provide directional orientation. APS currently provide audible beaconing in one of two ways: from pedhead-mounted speakers aimed in the center of the crosswalk approximately one third of the way across the street, and by using pushbutton integrated speakers that elevate the volume of the walk indication and the subsequent locator tone for one pedestrian phase, which is called by an extended button press.
- Crosswalk map: One manufacturer's signal incorporates a raised schematic map showing what will be encountered as the pedestrian negotiates the crosswalk controlled by that pushbutton. The map shows just the crosswalk controlled by that signal, not the entire intersection, and includes: number of lanes to be crossed; whether these are vehicular or bicycle lanes or tracks for rail vehicles; which direction traffic will be coming from in each lane; and whether there is a median.

METHOD

Overview

Data were collected in two cities (Tucson, Arizona, and Charlotte, North Carolina) for 40 visually impaired participants (20 in each city) crossing at four intersections. Each intersection was equipped with pushbutton integrated APS devices from a different manufacturer. The full range of features currently in use on pushbutton-integrated devices in the U.S. was represented across these four manufacturers. In each city, participants crossed at the same intersections two or three times under two or three information conditions designed to represent typical experiences of pedestrians who are blind.

One information scenario, defined as the "no information" condition, represented the situation in which pedestrians who are blind know that there will be an APS at the intersection, but do not have any information about the APS features and probably have not had previous experience with pushbutton integrated APS. This condition was only used in Tucson. The "general information" condition represented the situation in which the participants had heard a general description of the devices. They knew there would be a new type of APS at the intersection and had been told about possible features of APS devices, similar to someone who has heard or read about new types of APSs, but has had no experience with them (Tucson and Charlotte). A third information condition, defined as the "specific information" scenario,

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represented the situation in which a blind pedestrian knows the intersection will have an APS and knows from prior experience and instruction with the APS device how it will function and what features it will have (Tucson and Charlotte). During the break between the general information and specific information conditions, participants were shown a working demonstration unit of each device and given the opportunity to manipulate it and to experience all the types of information that it provided. Immediately before beginning each crossing in the specific information condition, participants were told which of the devices would be present at that crossing, and the features of the device were reviewed.

In Tucson, each participant crossed at each intersection 3 times, once for each condition, for a total of 12 crossings. In Charlotte, the no information condition was dropped due to the amount of time required to travel between intersections, so each participant made eight crossings, two at each intersection. Although participants returned to each intersection two or three times, several procedures minimized the possibility of learning about specific intersections or about the APS at specific intersections. Participants were not told that they would be returning to the same intersections; order of intersections was different in each block of crossings; each approach to the intersection was different; and parking locations were usually different. Few participants indicated that they recognized that they were returning to the same intersections.

Measures recorded included speed and accuracy in locating and pushing the correct pushbutton, speed and accuracy in beginning crossing during the WALK interval, crossing alignment, and crossing path. Data on the traffic sound levels and movement were also collected. After each crossing, a series of questions was asked to learn what information participants used to make the crossing and to obtain their perceptions about the APS at that crossing.

Participants

Twenty participants who are blind were tested in each city. All had insufficient vision to see crosswalk lines, pushbutton poles, or pedestrian signals. All participants were accustomed to crossing independently at signalized intersections using a long cane or guide dog and none were familiar with the intersections being used for testing. Ages were similar across cities, ranging from 24 to 70, with a mean age of 44. There were 24 male and 16 female participants. The majority of participants used a long cane as their travel aid, with only four in each city using a guide dog. Thirty-nine of the participants rated themselves as good to excellent travelers; one participant rated his travel ability as fair. Thirty-two (16 in each city) of the participants stated that they traveled independently more than 5 times a week.

An attempt was made to recruit up to five participants in each city who met the criteria for vision loss and independent street crossing, and who also had moderate to severe hearing loss. Recruiters were unable to obtain this number of deaf-blind persons in each city who cross streets independently. In Tucson, two participants were identified with mild hearing loss and one other had moderate to severe hearing loss, with bilateral hearing aids. Only one participant in Charlotte reported mild hearing loss, three others may have had some hearing loss, based on researcher observations and notes, but such loss was not diagnosed or self reported in participant interviews.

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Location

Cities and Intersections

Several cities were considered to participate in this study, including: Boston, MA; Cambridge, MA; Charlotte, NC; Milwaukee, WI; Minneapolis/St. Paul, MN; Portland, OR; San Diego, CA; and Tucson, AZ. Charlotte and Tucson were selected for participation as field sites on the basis of meeting the following criteria:

- Availability of appropriate intersections (see criteria for intersections below).
- Willingness to temporarily install APSs at four intersections.
- Ability to provide necessary technical support for data collection during human factors testing.
- Ability to provide engineering evaluation of the different technologies.
- Willingness to provide information on installation and maintenance of the equipment.
- Population that enabled the recruitment of 20 blind or deaf-blind participants.
- Availability of a local orientation and mobility specialist who is capable, willing and able to participate in subject recruitment, scheduling, and data collection.

Four intersections were selected for APS installation in each city. The criteria originally established for these locations included:

- Semi-actuated or fully actuated, with pedestrian push buttons for each crossing direction.
- Concurrent pedestrian signal phasing.
- Four-way intersection of a busy arterial and a minor street with little traffic.
- Arterial with four travel lanes and minor street with two travel lanes.
- Similar geometric and operational characteristics.
- Similar pedestrian signal head and push button configurations (each pole and pushbutton controls the signal for one crosswalk).
- Within easy walking distance of each other (i.e., walking the circuit can be completed within 1 hour).

Upon visiting the various cities and examining sites, it was determined that the last criterion could not be met. In order to obtain locations with enough similarities, it was necessary to use intersections that were not within walking proximity. Thus the subjects were transported between sites by vehicle. The other criterion that was adjusted was the number of lanes and traffic volume on the minor street. Information on the number of lanes and traffic volumes is provided below, in the descriptions of intersections in each city. Controllers and wiring also had to be capable of accommodating the pushbutton-integrated APS equipment.

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Tucson

Intersections used in Tucson were quite wide and relatively busy. Major street volumes were between 30,000 and 40,000 vehicles per day. Traffic counts were not available on the minor streets at each intersection. Each intersection had two phase signalization, fully actuated, with a 7 second WALK signal. The major street crossings required the traversal of four through lanes and a left turn lane; total crossing widths varied from approximately 60 ft to 78 ft. The minor street configuration required crossing one through lane and a left turn lane; total crossing widths ranged from approximately 41 ft to 58 ft. Curb ramps were diagonal and pedestrian pushbutton poles were fairly consistently located near the outside line of each crosswalk. Location in relation to the sidewalk (back of sidewalk or on street side) varied. An illustration of one of the Tucson intersections is shown in Figure 3-2.

One site had a right-turn-only lane (northbound to eastbound) from the minor onto the major crossings in both the general and specific information conditions were made on the west crosswalk of the major street to keep all crossings as comparable as possible and to avoid possible conflicts and auditory confusion. At this crosswalk, one crossing was made in one direction, and one was made in the other direction, which minimized learning about the specific crosswalk or corners.

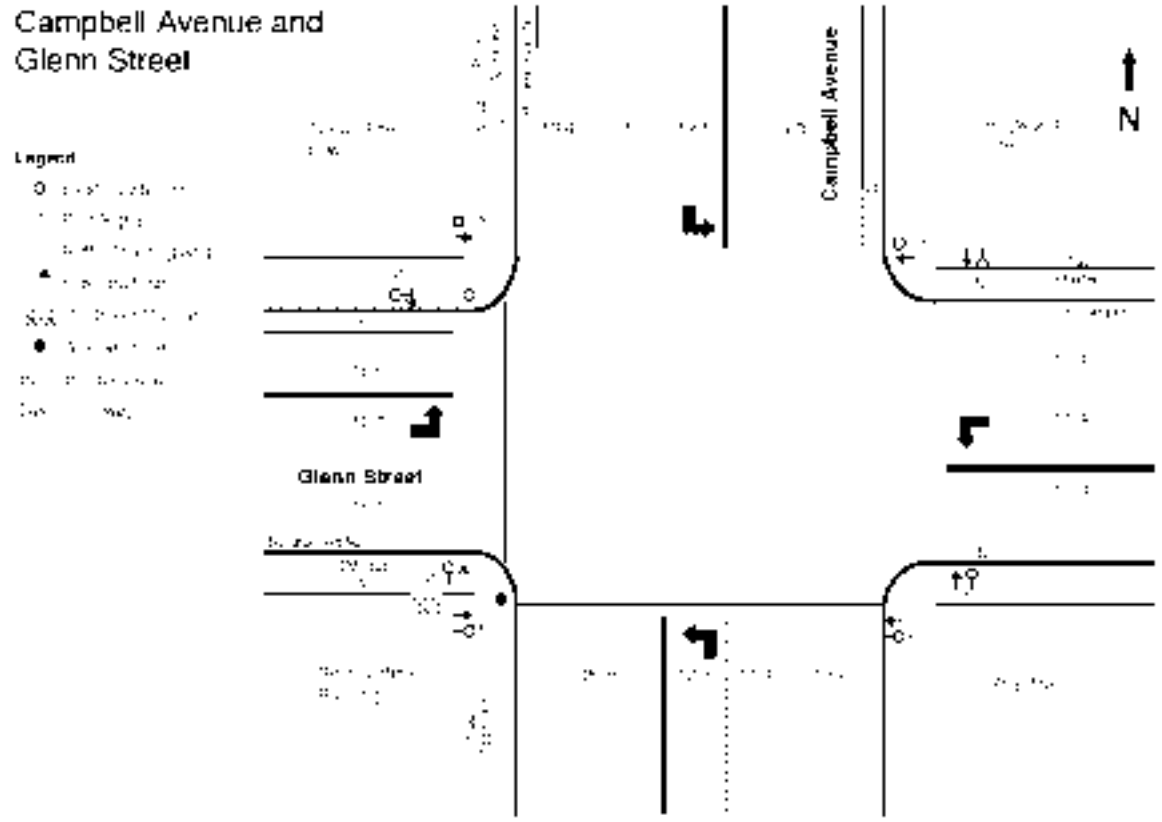

Figure 3-2. Intersection of Campbell Avenue (major street) and Glenn Street (minor street) in Tucson, AZ where APS devices were installed for the experiments.

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Charlotte

Intersections selected in Charlotte were, on average, somewhat narrower than the Tucson intersections. Major street crossings at three sites required traversal of four through lanes and ranged in width from 49 feet to 83 feet. The fourth intersection (with approach widths of 79 and 83 ft) had parking lanes on each side of the street and an exclusive left-turn lane on both approaches. Minor street crossings were 34 to 55 ft in width. Traffic volumes on the major roads ranged from 20,000 to 25,000 vehicles per day, while minor street volumes ranged from 3,000 to 6,000 vehicles per day. Most curb ramps were in line with the crossing. Originally, pushbuttons were provided only for the major street crossing or two pushbuttons were located on the same pole. Additional stub poles were installed in order to provide separation of the APS. An illustration of one of the Charlotte intersections is shown in Figure 3.3. At two intersections, sidewalk location or street geometry made it impossible to install separate poles on one of the intersection corners. That corner of each intersection was used as a destination corner only during the experimental trials.

APS Device Features

Four manufacturers (Campbell Company, Novax Industries Corporation, Polara Engineering, Inc., and Prisma Teknik) of pushbutton integrated APS were asked to provide

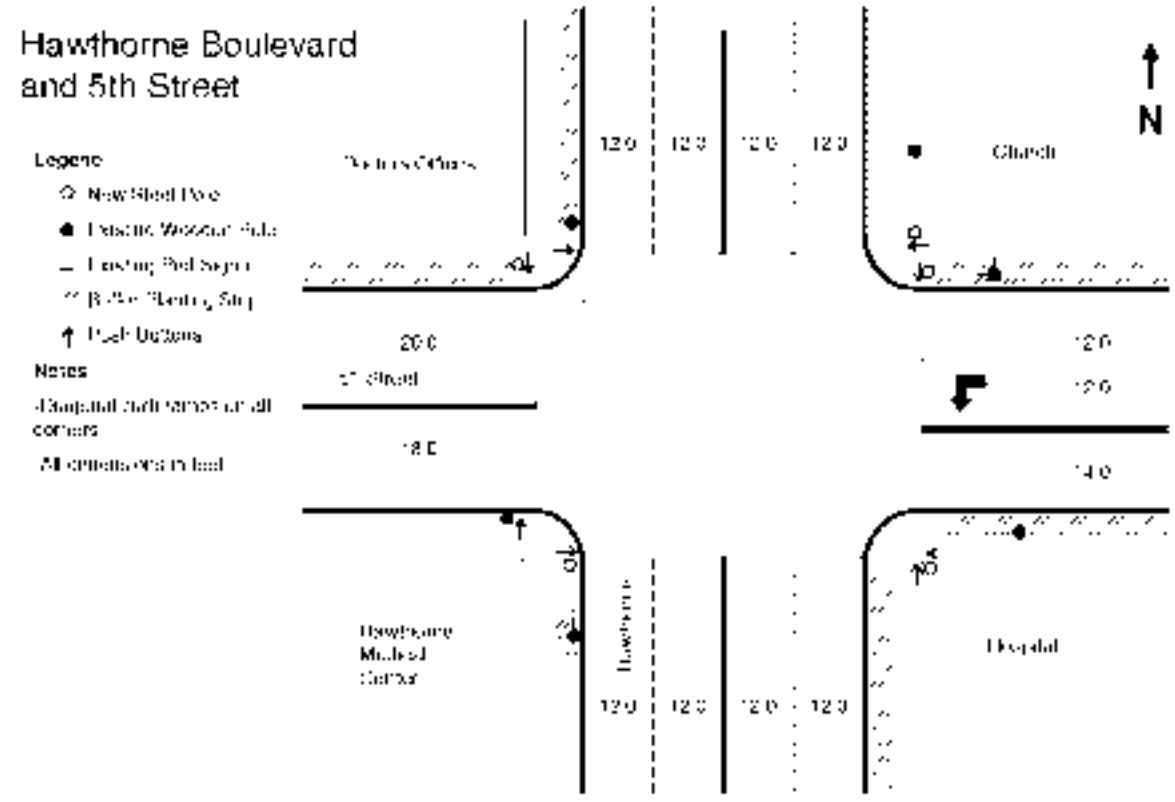

Figure 3-3. Intersection of Hawthorne Boulevard (major street) and 5th Street (minor street) in Charlotte, NC where APS devices were installed for the experiments.

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devices with their 'standard features' for the project. The devices provided and tested are shown in Figure 3-4. These four APSs represented all that were being actively marketed in the U.S. at the onset of this research. While all pushbutton-integrated APS devices are capable of providing most of the features evaluated in this project, some manufacturers provide certain features as standard and others as optional. All APS had a pushbutton locator tone, an audible actuation indicator, an audible walk indication, a tactile arrow that vibrated during the walk interval and automatic volume adjustment. Because more than a year elapsed between data collection in Tucson and Charlotte, the manufacturers of devices B and C had developed new models, so the devices used in the two cities were not identical.

In the analysis that follows, the results are presented in terms of APS A, B, C and D. The purpose of the project was NOT to assess each product, but rather to determine the effectiveness of the specific features (e.g., pushbutton style, locator tone, etc.) on the ability of a pedestrian with visual impairments to safely cross the street. The recommended guidelines developed as a result of the research discuss the required features, which may be provided by multiple manufacturers.

Figure 3-4. Pushbutton-integrated APS units from four manufacturers were deployed for the experiments.

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APS A

The locator tone was a bright beep (same tone as APS C) from a speaker at the pushbutton. The APS pushbutton unit was a rectangular box approximately 4 in wide x 7.1 in high x 2.5 in deep, with a 2-inch diameter rounded plastic pushbutton, a speaker below the pushbutton, and an arrow above the pushbutton. Apertures for the sound were located on the front and the side of the pushbutton speaker unit. There was an additional speaker attached to the pedestrian signal head. The tactile arrow was on a panel above the pushbutton, inside a raised circle. A relatively loud pushbutton actuation tone sounded when the button was pushed. The WALK indication was a cheep or a chirp that came from an overhead speaker installed on the pedestrian signal head. The arrow also vibrated during the WALK signal.

APS B

This APS had an electronic sounding locator tone. In Tucson, this unit had a 2-inch diameter, rounded metal pushbutton which protruded out at the bottom of the device below a rectangular sign (pedestrian symbol and print arrow); the tactile arrow was on the sign above the pushbutton. In Charlotte, the pushbutton was still rounded and at the bottom of the device, but it was plastic and the arrow was part of the pushbutton itself. A speech message, stating "Wait," sounded in response to pushing the button as a pushbutton actuation tone. If the pushbutton was held for three seconds or longer, additional information about the crossing was provided by a speech message "Wait to cross [street name] at [street name]." When the WALK signal was illuminated, a speech message "[Street name]. Walk sign is on to cross [street name]," which was repeated approximately three times. The arrow vibrated during the WALK interval in both cities, but had a noticeable clicking sound in Charlotte.

APS C

APS C had a beeping locator tone (very similar or identical to tone of APS A). The APS was a combination pushbutton and pedestrian sign, available with either a print pedestrian symbol and arrow or an informational plaque. It was basically rectangular with a rounded bottom and measured 14 in high x 6 in wide x 2 in deep. The pushbutton was in the middle of a flat tactile circle near the bottom of the device, and there was a raised tactile arrow on the pushbutton. A quiet click tone indicated to users that they had successfully pushed the button; the button was electromagnetic and did not seem to move or push. If the pushbutton was pressed for three or more seconds, it provided additional information about the crossing following the same model as APS B. The WALK signal was a speech message following the same model as used in APS B. The arrow on the pushbutton vibrated when the walk signal came on. Also, in response to an extended button press, the WALK signal and subsequent locator tone increased in volume for that pedestrian phase to provide beaconing. The housing of the device was slightly different in Charlotte than the Tucson devices.

APS D

APS D had a clicking locator tone. The entire flat smooth front panel of the rectangular box-like device was the electronic pushbutton. The tactile arrow was on top of the pushbutton device. There was a short beep to indicate that the button had been pushed to request a WALK signal. When the pushbutton was held in for three or more seconds, a pushbutton information message was heard. In Tucson, the pushbutton information message did not use the same format as the others. The message was "We want to help you cross the street." In Charlotte, the

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information message followed the format described in description of APS B. The WALK signal was a rapid ticking sound and the arrow on top of the device vibrated during the WALK. There was a tactile crosswalk map made up of raised symbols on the side panel of the device, on the side away from the street.

APS Installation and Sound Adjustment

General Description

Although an attempt was made to find four intersections in each city with comparable features, it was impossible to find four that were truly identical, even within one city. Because APS were being installed at existing intersections, there were slight differences in location in relation to the crosswalk, curb ramps and sidewalk configuration at each intersection. APSs were installed on poles that were present at the intersection where possible. In general, Tucson uses mast arms for signal installation, while Charlotte typically uses span wire installations. This results in differences in pole and APS location. Tucson already had two pushbuttons on each corner, mounted on poles separated by at least 10 feet, usually beyond the outside crosswalk lines. Most poles were behind the sidewalk, although some were on the curb side of the sidewalk. In Charlotte, 15 additional poles were installed to locate the APS so the pushbuttons (and APS speakers) were separated by at least 10 feet on all corners on which participants began their crossings (two target corners had two APS on some poles). This separation was created in order to follow the Guidance in *MUTCD* 4E.09 *G1*. Most APSs were in line with the crosswalk lines and between one foot and 10 feet from the curb face.

Signal technicians were not familiar with all the devices to be installed. There was a learning curve in understanding the installation specifications and other requirements. Adjustments were also made after researchers arrived in each city to ensure all devices were installed and operating as designed. Particular attention was paid to alignment of arrows and speakers and adjustment of volume of the WALK messages and locator tones.

Sound Levels

There are two criteria for sound level. One addresses the distance from which sounds should be audible, and the other addresses the difference in sound between ambient sound and signals. *MUTCD* 4E.06 Guidance reads "The accessible walk signal tone should be no louder than the locator tone, except when there is optional activation to provide a louder signal tone for a single pedestrian phase." *MUTCD* 4E.09 Guidance reads "Pushbutton locator tones should be intensity responsive to ambient sound, and be audible 1.8 to 3.7 m [6 to 12 ft] from the pushbutton, or to the building line, whichever is less. Pushbutton locator tones should be no more than 5 dBA louder than ambient sound" [1]. There are several problems with implementation of this guidance, although, in practice, when attended to, it works fairly well.

The distance at which a signal is audible cannot be objectively measured. This is always a subjective measure, so the distance at which signals are heard is always subject to individual differences in perception by the individual who installs or adjusts the volume on any APS. Furthermore, audible distance is influenced by humidity, atmospheric pressure, and reflective surfaces such as buildings or controller boxes nearby. Therefore, it is never a constant even for the same individual. A locator tone that can be heard no more than 6 feet away by one person on a still day, may be heard more than 20 feet away by the same individual on a windy day.

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Humidity, reflective surfaces nearby, and obstacles between the APS and the pedestrian can also affect the ability to hear the locator tone or signal from particular positions.

Another difficulty is that the automatic volume adjustment response is not very precise and varies among the devices because manufacturers use different algorithms. The rate of response to changes in ambient sound can greatly affect differences in perceived loudness. For example, if a loud truck passes by and there is a slight delay in the response to this loud ambient sound, the signal will still be heard as loud after the truck is well away from the intersection and the ambient sound level is lower.

In addition, the amount by which ambient sound and signal volume differ is not capable of easy measurement in the field because the individual bursts of signal sound are too short to be accurately measured by normal sound level meters. Optimal volume adjustment has not yet been adequately researched. An informal survey of jurisdictions having experience installing APS, as well as of APS manufacturers, indicates that in practice, technicians typically adjust the volume by listening to it in the relevant environment (35).

An APS may need to be carefully adjusted before the volume is perceived as loud enough by most users who are blind or who have low vision, but not too loud to be tolerated within the neighborhood. After installation of devices, researchers went to each intersection with the traffic signal technicians to check and adjust the volume on all devices. In general the volume was adjusted downward in an attempt to meet the recommendations of the *MUTCD*. Standing at each crosswalk departure location, researchers listened to each device while the signal technician adjusted the volume and consensus was reached on the volume level. APS A and APS B required adjustments at the pedestrian signal head; at times the volume would seem to change after the pedestrian signal head was reassembled. APS C and APS D are adjusted with handheld PDA type devices from the ground.

Manufacturers were available during the installation and final adjustments and provided invaluable assistance in getting devices adequately adjusted. In Tucson, all were in contact by phone or e-mail. In Charlotte, three manufacturers sent representatives to work with the signal technicians and researchers on final adjustments. Despite every effort, there were differences in perceived loudness between devices, between intersections, and between cities.

Device Functioning

Tucson

APS A did not seem to respond well to ambient sound, although the manufacturer's representative suggested that their adjustments were so little that it was imperceptible to individuals listening to the signal.

The adjustment for ambient sound also did not seem satisfactory in APS B. The locator tones seemed quite loud at all times, audible as much as 50 feet away from the devices, despite a great deal of time spent attempting to adjust the devices.

There were some variations in the functioning of APS C, which were not completely diagnosed and were inconsistent. The devices installed in Tucson were prototypes of the new model and that may have caused some problems. Automatic volume adjustment seemed to work well. However, at times, the locator tone seemed to shut off at one of the devices. There was also a slight delay in the beginning of the speech walk message after the visual WALK signal was

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displayed. The WALK and green ball for vehicles would be displayed for approximately a second before the speech walk message began, the reason for this could not be determined although a controller or wiring issue was suspected. Near the end of the experimental trials, it was determined that the beaconing function was not working because the devices were not wired correctly for it to function.

It was necessary to change some of the settings of APS D so the locator tone would sound during flashing DONT WALK. Some devices were not functioning properly, but the experimental trials could be conducted with the devices available. The automatic volume adjustment seemed to work well.

Charlotte

Even after numerous adjustments with the manufacturer's representative, APS A didn't seem to respond to ambient sound but was quite loud all the time. The locator tone could be heard from 50 feet away.

APS B was really adjusted to be too quiet due to complaints from an office/residence on one corner. Baffles were installed to block sound traveling back toward the residential neighborhood. It was very hard to hear the locator tone when approaching the intersection along the sidewalk, although it could be heard when standing at the street waiting to cross. The APS did adjust to ambient sound within a narrow range (low maximum volume).

The locator tone of APS C seemed somewhat louder than other devices. It did vary with ambient sound but could be heard from 50 feet away as the intersection was approached. There was a building on one corner and controller on same corner that reflected the sound.

APS D needed some changes in the settings but seemed to respond well to ambient sound.

Procedure

Participants were tested in individual sessions lasting approximately four hours. Much of the time was used in traveling between intersections in an air conditioned vehicle, so the session was not excessively strenuous or stressful. Each block of trials consisted of the following:

- Participant and three researchers traveled by passenger car to the first intersection.
- After parking about ½ block from the intersection, participant and researchers walked to the starting point for each crossing (a randomized distance of 50-100 feet from the corner), where instructions were given to the participant.
- Participant made one street crossing with O&M specialist monitoring for safety, using typical O&M procedures.
- Participant and O&M specialist returned across the street.
- All returned to the car and proceeded to the second intersection.
- While riding to the next intersection, O&M specialist obtained subjective data about the participant's experience with the previous crossing.
- The same process was repeated at each of the four intersections.

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A minimum of a half-hour refreshment break was taken between the general information and the specific information conditions. During the break, participants were familiarized with demonstration units of each type of APS.

At each intersection, participants made one crossing of the major street in a counterclockwise direction (with the street and parallel traffic on the left), and one crossing of the major street in a clockwise direction. In the no information condition, participants in Tucson made one crossing of the minor street in a counter-clockwise direction. (The no information condition crossing was always a minor street crossing.) Order of intersections and approach (clockwise or counterclockwise) were counterbalanced so each participant made two clockwise and two counterclockwise crossings in each block of trials, and crossed the major street clockwise and counterclockwise with each type of APS. No two crossings were identical.

Before beginning the experimental trials, after review of the consent form, the following information was provided to participants:

> *We're going to be traveling to different intersections. At each intersection, you will make one street crossing; then we'll go on to another intersection.*

This was followed by the following instructions, according to the information condition. For the no information condition, participants were given the following instructions before each crossing:

> *There is a street in front of you. When you come to the street, cross it the way that you usually do. If you think you don't have enough information to make the crossing please ask me for assistance. You may request assistance for any part of the street crossing task. For instance you might like to have help locating the crosswalk, aligning to cross, or knowing when the walk interval begins, or you may request to be guided for the entire task. If you think you'd ask another pedestrian for assistance, just ask me. I will intervene only if necessary for your safety.*
>
> *Researchers (names of those on site provided) will be recording information about the traffic at the intersection, your use of the pushbutton, where you began crossing from, when you began your crossing and where you end your crossing. We will ask you about what information you used to cross the street after you complete the crossing.*

Before the general information condition, a description of the features of the pushbutton integrated APS used in the study was read. The script for this description was as follows:

> *At each of these intersections, new types of Accessible Pedestrian Signals or APS are installed. These APS have some features that you might not have experienced before.*
>
> *First, all of them have what is called a locator tone. Locator tones are intended to notify you that there is a pushbutton at the intersection and to help you in finding the pushbutton. Some individuals have found that they are able to hear the locator tone while crossing, as they approach the other side of the street, and use it for directional assistance. The locator tones on these APS are different tones, but have one quality that is standardized: they repeat at a repetition rate of once per second.*

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The WALK indication on these APS may be provided by a speech message, or a rapidly repeating tone that is just a faster version of the locator tone, or a cuckoo or chirp. Both the walk indication and the locator tone may get louder or softer, depending on the sound of traffic. Each device also has an arrow that points toward the crosswalk it controls and in the direction of travel on the crosswalk. That arrow vibrates when that crossing has the WALK signal. That may be useful when you are having trouble hearing the WALK indication.

There are some other features that these APS may have; not all of them have all of these. They may provide a tone or a speech message to let you know that the button has been pushed. There may be a tactile map of the crosswalk on the side of the device.

They may have a feature called extended button press that calls additional features when the button is pressed for three seconds or more. If you hold the button in, you may get a louder signal and/or a speech message that provides additional information about the crossing.

The whole description, or any part of it, was read again if participants had questions, or requested a review.

Before each crossing in the general information condition, the following instructions were provided to each participant:

There is a street in front of you. At all of these crossings, it is necessary to push the pedestrian pushbutton to get the walk signal. There is an accessible pedestrian signal for the crosswalk. Do your best to figure it out and use its information to help you make your crossing.

If you think you don't have enough information to make the crossing, please ask me for assistance. You may request assistance for any part of the street crossing task. For instance, you might like help locating the crosswalk, aligning to cross, or knowing when the walk interval begins, or you may request to be guided for the entire task. If you think you'd ask another pedestrian for assistance, just ask me. I won't tell you how to use the Accessible Pedestrian Signal, but will help you with other aspects of the crossing if you ask. I will intervene only if necessary for your safety.

Researchers (Barlow and Huang or Barlow and Carter) will be recording information about the traffic at the intersection, your use of the pushbutton, where you begin crossing from, when you begin your crossing and where you end your crossing. We will ask you about what you used to cross the street after you complete the crossing and ask questions about your perception of the APS or this intersection.

Before beginning the crossings in the specific information condition, participants and researchers took a break in a quiet room with refreshments. During this time, each participant was familiarized with functioning demonstration units of each APS installed for the research. A description of the pushbutton, rather than device labels or manufacturers' names, was used in discussing the devices. APS A was referred to as the one with the round plastic pushbutton; APS B was the one with the round metal pushbutton in Tucson and one with the plastic pushbutton

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with the arrow on it in Charlotte. APS C was the one with the flat metal pushbutton with the arrow on it and APS D was the one with the flat panel pushbutton. Participants were allowed to examine each device, and they were shown the pushbutton, the tactile arrow, and the tactile map of the crosswalk if available. They could hear the actuation indicator tone or message, the pushbutton locator tone, the walk indicator, and the pushbutton information message if available. The ambient sound response of the devices was explained and demonstrated. The researcher also confirmed participants' understanding of the tactile arrow, by asking each person to point in the direction the arrow was pointing. Those who were incorrect were shown the correct orientation of the arrow and demonstrated their understanding. They were encouraged to ask questions about the devices and their features.

Before each crossing in the specific information condition, each participant was told which type of APS was installed at that crossing, and the features of that type of APS were reviewed.

> *There is a street in front of you. There is an Accessible Pedestrian Signal for the crosswalk. You've now been introduced to the various signals and I'll just review briefly some of the features of this one. As at previous crossings, if you need assistance with any part of the task, just ask me. I will intervene only if necessary for your safety. We will ask you about what you used to cross the street after you complete the crossing and ask questions about your perception of the APS at this intersection. I'll briefly review the features of the device installed here, followed by appropriate description from a script.*

Each description was different to fit the device installed at that intersection. For example,

- *This is the one with the flat panel pushbutton.*
- *It has a tapping or clicking locator tone.*
- *The entire flat front panel is the pushbutton. The raised part at the bottom is a light that lights up when the button has been pushed. You will hear a short beep to indicate that you have pushed the button.*
- *There is an arrow on top of the pushbutton device that indicates the direction of the street that it controls and vibrates during the walk phase.*
- *There is a tactile crosswalk map on the side panel of the device, on the side away from the street.*
- *If you hold the pushbutton in for more than three seconds, you will hear a speech pushbutton information message.*
- *When the walk signal comes on, you will hear a rapid ticking sound.*

Following completion of all crossings, participants were asked to use a Likert scale to rate the extent of their agreement with four questions. These subjective data allowed for comparing the four APS types in terms of interface issues, special features, and beaconing.

In Tucson, in the no information condition, all crossings were of the minor street. Traffic on the major street was relatively steady even in off peak hour conditions. In Charlotte, it became clear during piloting that the distance and travel time between intersections was too great

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to complete crossings in all three conditions in less than five hours. The no information condition was dropped due to these time constraints.

RESULTS AND DISCUSSION

Results have been organized according to: 1) use of the pushbutton, 2) results most closely associated with crossing timing, 3) results most closely associated with wayfinding, and 4) subjective results. Within the first three sections, results are also broken down by information condition and city, and by device and city.

As previously discussed, there were differences between Tucson and Charlotte in intersection characteristics such as the volume of traffic, width of streets, location of pedestrian pushbuttons, as well as minor differences in some of the devices installed in the two cities. There were also differences in the procedure followed. Therefore, data were analyzed separately for each city, and not combined. Any statistical comparison between cities would be confounded by these differences; therefore no inferential analyses of differences between cities were conducted.

Inferential analysis of all measures at all levels of all factors was made difficult by a large amount of systematically missing data. For example, if 16 of 20 participants searched for the pushbutton at a given intersection, and 10 found it, there were data on use of the pushbutton features for the 10 participants who found the pushbutton. If 4 participants asked for assistance in finding the pushbutton (i.e., did not find it independently), there was information on the use of the tactile arrow and use of the extended button press for 14 participants, thus, 4 in addition to the 10 participants who found the pushbutton independently. For the 2 who searched and did not find a pushbutton or request assistance finding one, and for the other 4 participants who did not search for the pushbutton, there is no pushbutton-related data available.

The data were analyzed in three primary ways. For those variables that provided interval level data (e.g., latencies), median replacement was used to replace missing data. Appropriate inclusion criteria were then determined for investigating each question of interest. For example, in order to ask which of the various devices allowed for more rapid onsets of crossing following the audible signal, it was statistically appropriate to include only those participants who had used all of the pushbuttons in a given information condition and thus had available WALK information to use at each intersection in that information condition. Listwise deletion was used to eliminate those individuals from the analysis who did not meet the inclusion criteria, and paired-samples t-tests or repeated-measures ANOVAs were conducted.

A second method was used to analyze data pertaining to information condition (ignoring device differences) or device differences (ignoring information condition). In order to determine whether observed differences were statistically significant, it was necessary first to transform the data into interval level. The following is an example of how this was done. In order to investigate whether or not participants were more likely to use the tactile arrow feature on one device than another, a new variable was calculated for each device type. Imagine that for a given device type a participant did not use the feature in the 'no information condition,' but did in the 'general' and 'specific information' conditions. This individual thus used the feature two-thirds (67%) of the time for this device. Percentages were calculated in this way for each device and for each participant. The data could thus be treated as interval level, and either a repeated-measures ANOVA or a paired samples t-test could be used to look for differences between the devices.

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Finally, basic descriptive statistics are provided for many of the categorical level variables. Once again inclusion criteria were established for each category (e.g., only those participants who searched for the pushbutton) and then percentages were calculated for the number of these participants who used a certain feature or performed in a given way.

Interpretation of data across information conditions is always confounded somewhat by the possibility of learning about the particular intersections. The no information, general information and specific information trials could logically only take place in that order; that is, order could not be randomized or counterbalanced. However, procedures were used that minimized the likelihood that participants learned specific crosswalk or intersection characteristics, or the locations of APS at particular corners. Therefore significant differences across information conditions are most likely due to the effect of the level of information with APS devices unless otherwise noted. In the general information condition, these participants (most of them who used the APS at most of the crossings) gained some 'hands on' familiarity with the APS. In the specific information condition, this was supplemented by participants' use of demonstration devices of each APS, as well as by knowing which APS would be present at each crossing, as they prepared to make that crossing. The additional information was consistent with the intent of that condition, which was to represent the common situation in which pedestrians who are blind or visually impaired know what kind of an APS they will find at a crossing, and know its features. While many pedestrians who are blind or who have low vision travel novel routes at least occasionally, most travel by these pedestrians, like travel of pedestrians who have unimpaired vision, is on familiar routes. Also, many jurisdictions prefer to work with certain manufacturers and may have installed a number of devices with similar or 'standard' features in their jurisdiction, so it is not unusual for pedestrians who are blind to have had experience with the type or types of devices installed in their area.

Use of the Pushbutton

Finding and Using Pushbutton

Data were collected on searching for the pushbutton, time to find and use the pushbutton, using the wrong pushbutton, correctly rejecting or incorrectly using the wrong pushbutton, use of the tactile arrow, use of the tactile map, use of the extended button press feature, and listening to the intersection information message resulting from the extended button press. Results are reported for only the most informative measures, including searching for the pushbutton, finding the pushbutton, using the wrong pushbutton, use of the tactile arrow, use of the extended button press feature and use of the tactile map.

In Tucson, at many intersections throughout the city, signals are installed on mast arms and each corner has two pushbuttons on poles that are separated, and located near the end of each crosswalk. Use of a pushbutton is required to actuate the WALK signal for both the major and minor streets at most signalized intersections. Thus, participants should have had prior experience crossing at intersections where pushbuttons were installed in predictable locations. However, participants were asked, at the end of all trials, whether they usually use pushbuttons when they are present. Nine of 20 said they usually do not use pushbuttons, while six said that they usually do, and the other five said they use pushbuttons only when they know that the pushbuttons are there or it is a particularly difficult intersection.

In Charlotte, which has many curving streets resulting in skewed intersections, it is very common to have two pushbuttons on the same pole, or to require pushbutton actuation for only

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the major street at an intersection. Two pushbuttons on one corner are occasionally mounted on two separate poles, one at the end of each crosswalk, but that is not common. Therefore participants may not have had experience with consistent pushbutton placement, and may have been familiar with situations where pushbutton actuation was not necessary for all crossings. Because no data was collected in the no-information condition in Charlotte, we have no data indicating use of pushbuttons. However, following all experimental trials, participants were asked whether they typically used pushbuttons when crossing streets. Seven out of 20 said they usually do not use pushbuttons, six said that they usually do, and the other seven said they do only when they know that the pushbuttons are there. Also, in related research in Charlotte, UNC sixteen blind participants crossing at complex, unfamiliar signalized crossings, without APS, did not look for pushbuttons on any of the 64 crossings at which pushbutton actuation was necessary.

Information Condition

Tucson – Based upon participants' reports of their typical pushbutton use, it is not surprising that in the no-information condition in Tucson, only five participants looked for the pushbutton on every crossing, and at each of three intersections, one additional person (different people) looked for the pushbutton. Of the 28.8% of 80 trials on which participants looked for the pushbutton, the correct pushbutton was found and used on 83% of trials, while the incorrect pushbutton was used on 13% of trials (*see Table 3-1*). A few participants requested assistance in finding the pushbutton, and then pushed it. So the button was pushed on more trials than it was found independently.

Information condition appears to have had a significant effect on participants' choosing to search for the pushbuttons. In trials following general information, participants searched on 97.5% of trials, and participants searched on 100% of trials following specific information. The overall analysis is significant ($F(2,38) = 51.37$, $p<.001$), as is the comparison between no information and general information conditions ($F(1,19) = 49.76$, $p<.001$).

There are several likely explanations for the large increase in looking for pushbuttons between the no information and general information conditions. First, a possible cause of the low incidence of looking for the pushbutton in the no information condition may have been that all crossings in this condition were across the minor street. Because pedestrian timing was concurrent, and because there was always adequate traffic on the parallel street, there was sufficient information from vehicular flow for participants to cross without using the pushbutton.

TABLE 3-1 Pushbutton measures by information condition – Tucson

	No information	General information	Specific information	F or t
Looked for PB	28.8	97.5	100.0	$F(2,38) = 51.370^{***}$
Found Correct PB		80.6	79.2	$t(17) = 0.223$
Used Tactile Arrow		68.6	72.9	$t(21) = 0.432$
Used Wrong PB		18.8	14.1	$t(35) = 0.764$
Used Extended Push		88.8	77.5	$t(21) = 2.750^{*}$

* Significant at $p < 0.05$

*** Significant at $p < 0.001$

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Second, prior to the general information trials, participants were told that pushbuttons were needed to activate the WALK signal and its associated timing at every crossing. Finally, prior to the general information trials, participants were told that all pushbuttons would have a locator tone coming from the pushbutton, so they knew they could use the sound of the locator tone to help them find the pushbutton. Therefore, the increase in looking for the pushbutton (as well as in use of the pushbutton—see below) was likely attributable to several factors, most of which are amenable to increased training in the function of signalized intersections, with emphasis on the use of a pushbutton, which is often required to actuate a pedestrian timing of adequate length. The presence of a locator tone to inform pedestrians of the presence of a pushbutton and its location may also influence the use of pushbuttons, since five participants in Tucson and seven in Charlotte said they only used pushbuttons if they knew they were there and where to find them.

The looking for the pushbutton variable was used as an inclusion variable for analysis of the use of the wrong pushbutton, and the interaction with the pushbutton variable (i.e., those who found the pushbutton with or without assistance) was used as an inclusion variable for the analyses of specific pushbutton features (i.e., use of arrow, extended push). Where these criteria were applied across all three levels of information, the result was too few participants to provide sufficient power. This is the result of having so few participants look for the pushbutton in the no information condition. Using the same inclusion criteria but restricting the analysis to the general information and specific information conditions where the number of participants who searched for the pushbuttons is much higher, there was no significant difference in participants' looking for the pushbutton, finding the pushbutton, using the wrong pushbutton, or using the tactile arrow. However, the increase in use of the extended button press, from 38.8% to 77.8%, was significant ($\chi^2(1) = 2.750$, $p \leq .05$).

Although there was no significant difference between the general and specific information conditions with regard to the number of participants who pushed the wrong pushbutton, it is nonetheless interesting to consider the implication of the use of the wrong pushbutton. The primary reason for inclusion of the tactile arrow on APS is to enable pedestrians who are blind or who have low vision to accurately determine which pushbutton controls which crosswalk. In Tucson, across the general and specific information conditions, participants looked at the arrow on the incorrect pushbutton on 25 trials. However, on 100% of these trials they correctly rejected the incorrect pushbutton (*see Table 3-2*).

Charlotte – In Charlotte, where no data was collected in the no-information condition, increasing familiarity from general information to specific information condition had no effect on participants' looking for the pushbutton. With one exception, every participant searched for the pushbutton on every trial. This was similar to the result from Tucson. However, increasing information between the general information and specific information conditions did lead to participants finding the pushbutton on a greater percentage of trials, which was not the case in

TABLE 3-2 Percentage and proportion of trials on which participants correctly rejected the incorrect pushbutton (i.e., checked the tactile arrow on the incorrect pushbutton, and then chose not to push that button), by information condition

City	General Information	Specific Information
Tucson	100% (12/12)	100% (16/16)
Charlotte	52% (17/33)	80% (24/30)

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Tucson. As shown in Table 2-3, 19 participants searched for the pushbutton on every trial, and participants found the button on average 67.1% of the time following general information, while the same participants found the button on average 84.2% of the time following specific information ($t(18) = 2.233$, $p<.05$).

There was a trend towards increasing information leading to lower use of the incorrect pushbutton. Following general description, participants used the wrong pushbutton on average 25% of the time. Following specific information, participants used the wrong pushbutton only 10.3% of the time. This difference approaches significance ($t(16) = 1.975$, $p = .066$).

Use of the incorrect pushbutton presented a very different picture in Charlotte than in Tucson (see Table 3-3). In Tucson, participants looked at the arrow on the incorrect pushbutton on 28 trials, but they always correctly rejected the incorrect pushbutton. However, in Charlotte, participants looked at the arrow on the incorrect pushbutton on 63 trials, and correctly rejected it on only 41 trials (65%). While the improvement in overall use of the wrong pushbutton from the general to the specific information condition approached significance, participants still failed to reject the incorrect pushbutton on 30% of trials (6/20) following specific information. To observers, participants in Charlotte seemed less skilled, particularly in orientation, which may have related to the generally curving and hilly streets of the area as contrasted to Tucson's square flat grid pattern. The confusion of pushbuttons seemed to be related to the participants' lack of strategies to maintain their orientation; some would completely turn to face the street parallel to their travel path, while examining the arrow on the device, and then push the button and "line up" to cross the parallel street.

The increased information also led to significantly greater use of the tactile arrows from 86.7% of trials following general information, to 100% of trials following specific familiarization ($t(14) = 2.48$, $p<.05$). Increased information also resulted in a significant increase in use of the extended button press feature (from 17.7% to 71.1%; $t(14) = 6.804$, $p<.001$).

Devices

Tucson – When considering APS devices with regard to locating and using pushbuttons, and when collapsing across information conditions, there is a slight trend such that the percentages of participants finding the correct pushbutton was higher for APS A and B than for

TABLE 3-3 Pushbutton measures by information condition – Charlotte

	General Information	Specific Information	T
Looked for pushbutton	95.0	100	$T_{19} = 1.00$
Found Correct PB	67.1	84.2	$T_{18} = 2.233^{*}$
Used Arrow	86.7	100	$T_{14} = 2.477^{*}$
Used Wrong PB	25.0	10.3	$T_{16} = 1.975$
Used Extended Push	17.7	71.1	$T_{14} = 6.804^{**}$

* Significant at $p < 0.05$

** Significant at $p < 0.001$

Example: On average, each participant used the arrow on 86.7% of crossings in the general information condition.

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APS C and D. This difference did not appear following the specific information condition (see *Table 3-4*). Additionally, a slight trend in Charlotte was in a different direction.

APS D resulted in the highest rates of using the wrong pushbutton in the specific information condition; however there were not large differences in this regard, and there were no trials on which participants failed to reject the incorrect pushbutton after checking the arrow, so the arrow was apparently well understood. These results may suggest that it was more difficult to locate the arrow on APS D than on the other APS, but not more difficult to "read" the arrow. The arrow was on top of the APS, while it was on the front surface of all the other APS. The high rate of using the wrong pushbutton, attributable entirely to participants who did not reference the arrow, may also reflect the location of the APS D device in Tucson, for the parallel (uncrossed) street, which was on a pole that was within the approach sidewalk rather than at the back of the sidewalk as most others were.

A fairly clear trend emerges when examining the data for use of the tactile arrow on the correct device. In the general information condition, participants used the tactile arrow 76% and 89% of the time on APS A and APS C, respectively. On APS B and APS D, the equivalent rates were 61% and 56%, respectively. In the specific information condition, this trend continued. APS A and C both resulted in 89% using the tactile arrow, while APS B and D resulted in 68% and 56% using the tactile arrow. This trend does not appear in the Charlotte data, suggesting that arrow use is therefore unlikely to be due to differences in device characteristics. However, the arrow position on APS B was different between the two cities and may help explain the much higher rates of use in Charlotte. Furthermore, although arrow use for APS D was higher in Charlotte than in Tucson, it remained the lowest between devices within Charlotte.

It was possible to use the data on use of the tactile arrow to compute inferential statistics regarding device differences by collapsing across the general and specific information conditions, as described near the beginning of the results section. This required using only those participants who interacted with all four pushbuttons in both conditions, providing a sample of 12 participants. The resulting analysis is significant ($F(3, 33) = 4.64$, $p<.01$). The average percentages match the frequency analysis from above quite well, APS A 85.4%, APS C 87.5%, APS B 66.7%, and APS D 50.0%. A comparison of the two devices with the greatest difference, APS C and APS D, is significant ($F(1, 11) = 9.00$, $p<.05$). APS C was only marginally better than APS B ($F(1, 11) = 4.66$, $p = .054$). However, it is unclear if there is a meaningful difference between device characteristics, as an identical pattern of results did not appear in the Charlotte data.

There is no clear picture with regard to the use of the extended pushbutton features of the three devices in which they were present.

On the whole, the Tucson data associating devices with use of the pushbutton does not present a very clear picture. There were not large differences in the numbers of participants finding the various APS devices under the general or specific information conditions. The one clear conclusion is that the tactile arrow was more likely to be used on the APS C devices than on APS B, and the trend suggests more so on both APS C and A devices than on APS B and D.

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TABLE 3-4 Pedestrian interaction by device and information condition – Tucson

	APS A	APS B	APS C	APS D
No information condition				
% that searched for PB*	25% (5/20)	30% (6/20)	30% (6/20)	30% (6/20)
Of the # that searched for the PB				
% that found the PB**	100% (5/5)	100% (6/6)	67% (4/6)	67% (4/6)
% used wrong PB	0% (0/5)	17% (1/6)	17% (1/6)	17% (1/6)
Of the # that interacted with the correct PB				
% that used tactile arrow***	40% (2/5)	0% (0/6)	50% (2/4)	25% (1/4)
% that used extended push	NA	0% (0/6)	25% (1/4)	0% (0/4)
% that used tactile map	NA	NA	NA	0% (0/4)
General information condition				
% that searched for PB*	90% (18/20)	100% (20/20)	100% (20/20)	100% (20/20)
Of the # that searched for the PB				
% that found the PB	83% (15/18)	85% (17/20)	75% (15/20)	70% (14/20)
% that used wrong PB	17% (3/18)	10% (2/20)	20% (4/20)	21% (4/19 ****)
Of the # that interacted with the correct PB				
% that used tactile arrow	76% (13/17)	61% (11/18)	89% (16/18)	56% (9/16)
% that used extended push	NA	50% (9/18)	39% (7/18)	38% (6/16)
% that used tactile map	NA	NA	NA	13% (2/16)
Specific information condition				
% that searched for PB*	100% (20/20)	100% (20/20)	100% (20/20)	100% (20/20)
Of the # who searched for the PB				
% that found the PB	85% (17/20)	75% (15/20)	75% (15/20)	70% (14/20)
% that used wrong PB	5% (1/20)	10% (2/20)	12% (2/17 ****)	25% (5/20)
Of the # that interacted with the correct PB				
% that used tactile arrow	89% (17/19)	68% (13/19)	89% (16/18)	56% (10/18)
% that used extended push	NA	79% (15/19)	89% (16/18)	78% (14/18)
% that used tactile map	NA	NA	NA	17% (3/18)

* PB = pushbutton

** Of the 25% who looked for the pushbutton in the No information condition 100% found the pushbutton (5 of 5)

*** Of the 100% who found the pushbutton in the No information condition, 40% used the tactile arrow (2 of 5)

**** Missing data

NA Feature not available on device

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The arrow on APS C was on the pushbutton and the arrow on A was large and the main feature on the front of the device.

Charlotte – In Charlotte, it is also difficult to say anything about differences in rates of finding the pushbutton attributable to device (*see Table 3-5*). By the time participants were familiarized with the devices, the rates were fairly similar. In the general information condition, APS C led to the highest rates of finding the pushbutton (79%), while APS A resulted in the lowest (53%). These differences may be attributable to the large numbers of participants who found and used the incorrect pushbutton at APS A and quit looking for a pushbutton, even when they checked the arrow and it pointed the wrong way. In the specific information condition, all devices resulted in rates of finding the correct pushbutton between 80% and 90%. There were unavoidable differences in volume setting between devices in Charlotte. The locator tones of APS A and C were louder than the others, and several participants complained about the sound of APS C echoing off of a nearby building.

In the general information condition, about 20% of participants used the wrong pushbutton when at intersections with APS D, B and C, and 43% of the time when using APS A. The intersection with APS A was also the one with the lowest rates of use of the correct pushbutton. This may have been due to an idiosyncrasy in locations of APS A devices at this intersection: one was close to the crosswalk, making the sound echo, and the other was behind the sidewalk.

However, by the time the participants had received specific information, no more than two participants used the wrong pushbutton at any given intersection. The most noteworthy thing that appears from the data following the specific information is that some participants who checked the tactile arrow nonetheless pushed the incorrect button. The fundamental problem here may be a lack of understanding of arrows, even with the demonstration of arrows that was provided. It could also be because the demonstration was at a corner, not on a barrier, and no information was provided regarding the usual geometric relationships between corner, crosswalk, and pushbutton. Some participants seemed to decide that the correct pushbutton was always on the right, or always on the left, when, in fact, the side of the pedestrian on which the pushbutton was located was determined by whether the parallel street was to participants' left or right and varied depending on whether the pedestrian was making a clockwise or counterclockwise crossing (part of the counterbalancing scheme).

Possibly of more interest is the difference in occurrence of situations in which participants checked the wrong pushbutton and then decided it was incorrect (correct rejection). Following general information, the APS D devices led to an 80% correct rejection rate, APS B a 57% rate, and the APS C and A devices around 50%. Following specific information, the results did not closely match those following general information. Although APS C had the lowest rate of correct rejection, there were only 3 participants who ever checked the wrong pushbutton and thus this is not a stable measure. For the other three devices, the rates were at or above 75%, with APS A leading the category with 90% correct rejections.

It should be noted, in examining these results and comparing to Tucson, that APS B had been significantly redesigned and the arrow was actually on the pushbutton rather than above the pushbutton in Charlotte. This seems to have affected the use of the tactile arrow on the device. With regard to tactile arrow use following general description, APS A, B, and C resulted in 88% or higher rates of use. Only 65% of participants used the feature on APS D. Following specific

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TABLE 3-5 Pedestrian interaction by device and information condition – Charlotte

	APS A	APS B	APS C	APS D
General information condition				
% that searched for PB*	95% (19/20)	95% (19/20)	95% (19/20)	**100%** (20/20)
Of the # that searched for the PB				
% that found the PB	53% (10/19)	68% (13/19)	**79%** (15/19)	65% (13/20)
% that used wrong PB	42% (8/19)	21% (4/19)	21% (4/19)	**15%** (3/20)
Of the # that interacted with the correct PB				
% that used tactile arrow	88% (15/17) **	**100%** (19/19)	89% (16/18) ***	65% (11/17)
% that used extended push	NA	22% (4/18) ***	**26%** (5/19)	6% (1/17)
% that used tactile map	NA	NA	NA	0% (0/17)
Specific information condition				
% that searched for PB*	**100%** (20/20)	**100%** (20/20)	**100%** (20/20)	**100%** (20/20)
Of the # who searched for the PB				
% that found the PB	**80%** (16/20)	**80%** (16/20)	**90%** (18/20)	**90%** (18/20)
% that used wrong PB	5% (1/20)	10% (2/20)	5% (1/19) ****	**11%** (2/18) ****
Of the # that interacted with the correct PB				
% that used tactile arrow	**100%** (18/18)	**100%** (20/20)	**100%** (20/20)	**95%** (19/20)
% that used extended push	NA	65% (13/20)	**80%** (16/20)	65% (13/20)
% that used tactile map	NA	NA	NA	**28%** (5/18) *****

* PB = pushbutton

** Of the 95% who looked for the pushbutton in the general information condition, 53% found the pushbutton (10 of 19).

*** Of the 53% who found the pushbutton in the general information condition, 88% used the tactile arrow (15/17).

**** Missing data—1 participant

***** Missing data—2 participants

NA Feature not available on device

familiarization, the rate on APS D was up to 95% and all other devices reached 100% usage rates. This may indicate that when pedestrians who are blind or visually impaired know what kind of arrow they will encounter, they are quite likely to use it at unfamiliar crossings, or it may simply be that following specific information, they understood arrows better and were more inclined to check them out. The rate of arrow usage in Charlotte appears to be somewhat higher than that for Tucson, but pushbutton location was fairly consistent in Tucson. In Tucson, some participants may have decided that they could be sure which crosswalk was controlled by the pushbutton solely on the basis of location of the pushbutton. However, even with the higher rate

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of arrow usage in Charlotte, participants pushed the wrong button, after using the arrow, on more trials in Charlotte than in Tucson (*see Table 3-5 above*).

The rates of use for the extended pushbutton feature look similar to those for the tactile arrow. In the general information condition, 6% of participants (1 participant) used the extended press feature on APS D, while .22% and .36% used the feature on APS B and C, respectively. Following specific information, the rates of use were equivalent for APS B and D (.65% ea.), but were used slightly more on APS C (.80% ea.

Latency to Find and Use Correct Pushbutton (Pushbutton Latency)

Tucson

With regard to time to locate the pushbutton in Tucson, there were so few participants who looked for and found the pushbutton in the no information condition, that no statistical tests could be done for either information condition or device.

In the general information condition, median replacement resulted in the replacement of four to six data points for each device. (Since all analyses were conducted using paired-samples or repeated measures methods, the estimates of error used in the t-tests and ANOVAs are not a matter of variability around the mean but rather a measure of covariability across conditions. Therefore, this method of data replacement does not artificially inflate power.) The subsequent ANOVA revealed significant differences attributable to device. The mean amount of time to locate and use the correct pushbutton varied between 29 and 50 seconds, with the times for APS A and B being similar (28.95 and 29.55 seconds, and those for APS C and D being longer, 50.30 and 45.50 seconds. The overall analysis was significant ($F(3,57) = 3.56$, $p<.05$). A comparison between the averaged latencies on APS A and B devices, and the averaged latencies on APS C and D revealed a significant difference, ($F(1,19) = 11.12$, $p<.01$). Finally, no statistically significant difference was found between APS C and APS D (*see Figure 3-5*). The difference between these two pairs of devices, in time to locate and push the correct pushbutton, may be that APS A and APS B had very typical, rounded, pushbuttons, while the pushbuttons of APS C and APS D were unique. Although it is impossible to differentiate, it is possible that participants found all devices in approximately equal amounts of time, but it then took longer to find the actual button for APS C and D.

In the specific information condition, the use of median replacement resulted in the replacement of between three and six data points per device, and the ANOVA revealed no significant differences between latencies ($F(3,57) = 2.706$, $p>.05$). The lack of significance clearly differs from the analysis in the general information condition, and furthermore, a closer look at the means reveals a different pattern than was present in the general information condition as well. With specific information, the means for the APS A, B, and C are very similar, and APS D had a trend towards faster latencies (*see Figure 3-6*).

Looking from one Tucson figure to the other, it appears that there is a considerable improvement for the APS C and D buttons between the general information and specific information conditions. For the APS C and D, this does represent a significant improvement ($t(19) = 2.32$, $p<.05$, and $t(19) = 4.85$, $p<.001$, respectively). Furthermore, it appears that the average latency to find the pushbutton has decreased between the general information and specific information blocks. This is statistically confirmed ($t(19) = 4.147$, $p<.001$) and reveals

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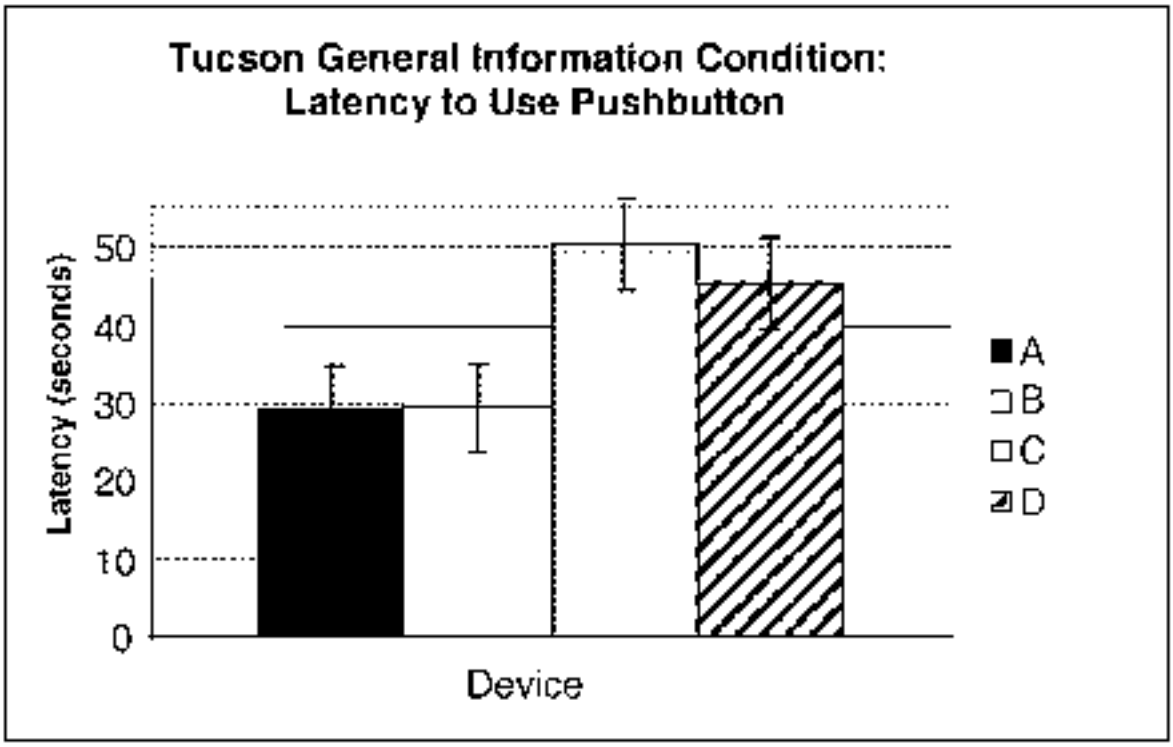
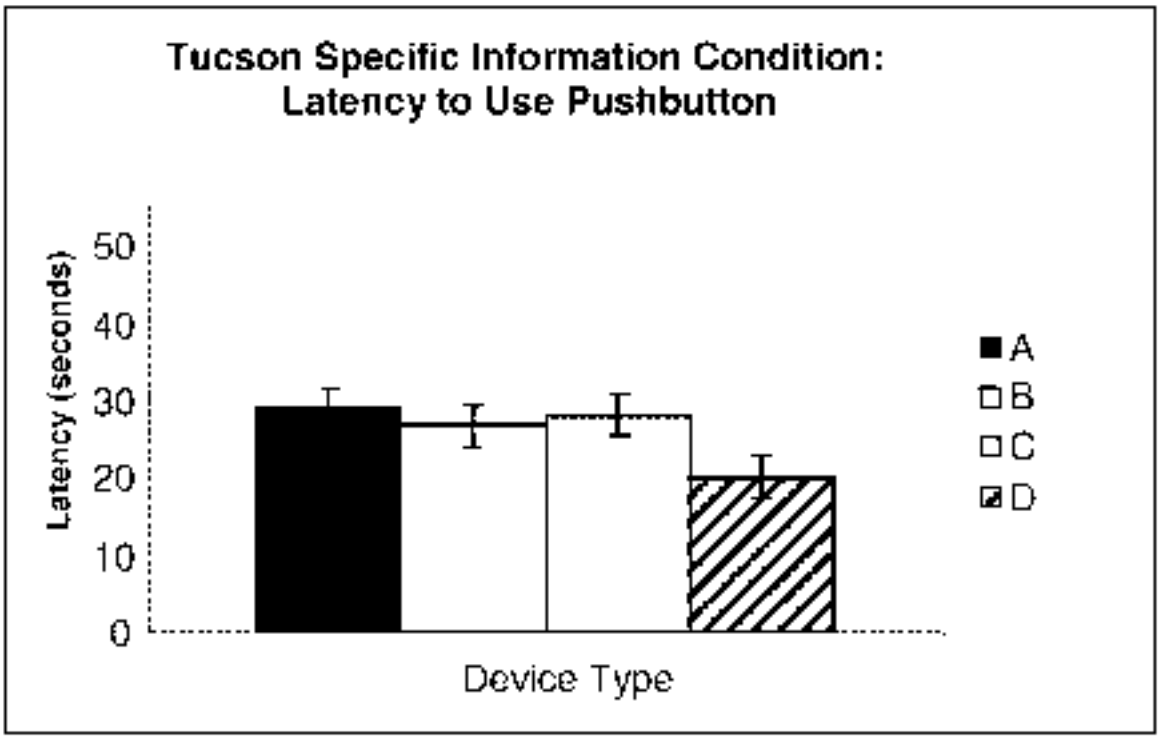


F(3,57) = 3.560, p≤.05, N=20

Figure 2-5. Latency to use the pushbutton: general information condition – Tucson.



F(3,57) = 2.106, p≤.05, N=20

Figure 2-6. Latency to use pushbutton: specific information condition – Tucson.

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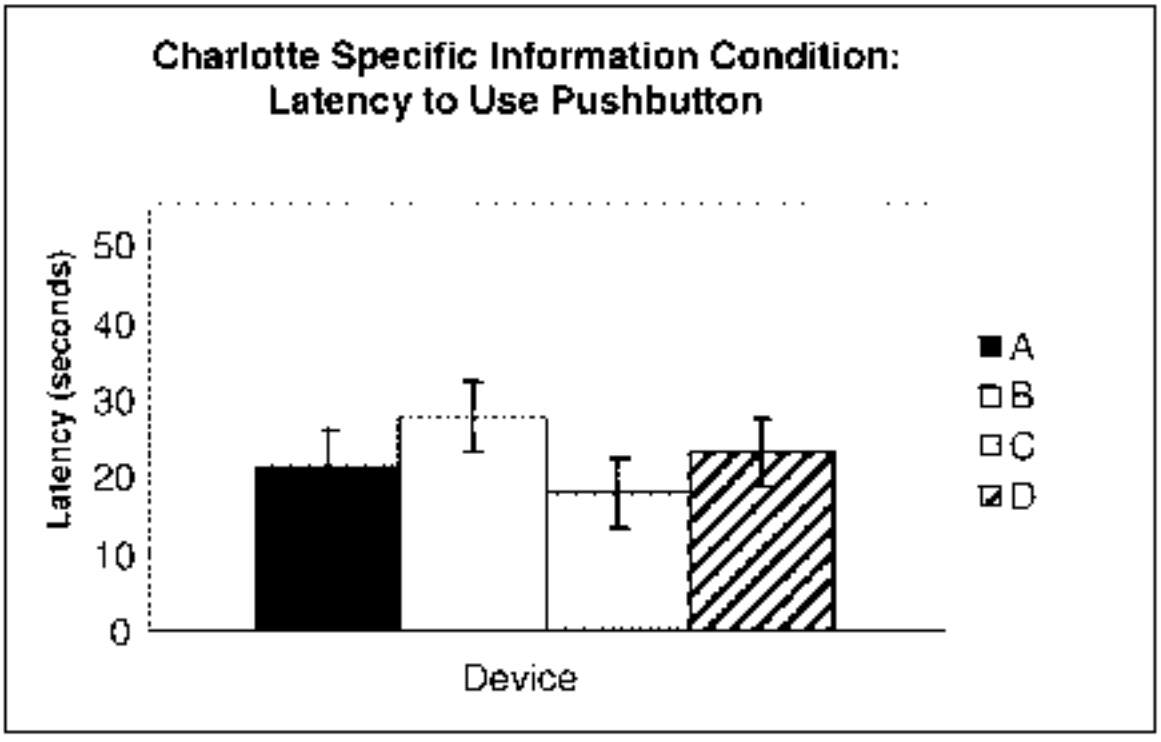
that the average amount of time to use the pushbutton in the specific information condition (25.70 sec) is faster than that in the general information condition (38.58 sec).

The measure of latency to find and push the correct pushbuttons includes any time taken to use the tactile arrow on the incorrect APS and to reorient it and to find and push the pushbutton on the device. Therefore the improvement in latency for APS C and D may not indicate a decrease in latency for finding the pushbutton pole and the device, but a decrease in time taken to actually locate and push the button on the device. APS C and D both had unique pushbuttons, so until participants had specific hands-on familiarization, and knew what sort of pushbutton they would encounter at each intersection, they took some time in deciding what part of the device to actually push. This was particularly evident to researchers in the case of the flat panel pushbutton of APS D.

Charlotte

With regard to time to locate the pushbutton in Charlotte, although more than 80% of participants found each pushbutton individually, only five participants found all four pushbuttons. Thus, the limited amount of latency data available in the general information condition makes running any within subjects statistical tests inappropriate.

Analysis of data from the specific information condition required median replacement of up to four missing values per device and revealed no significant differences attributable to device ($F(3,57) < 1.00$). (see *Figure 3-7*). The average amount of time to use the pushbutton following



F(3,57) < 1.00, N=20

Figure 3-7. Latency to use pushbutton: specific information condition – Charlotte.

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the specific information was similar between the two cities (22.4 seconds in Charlotte and 25.7 seconds in Tucson).

In comparing the specific information results across the two cities, both analyses are non significant, and the trends are not the same, but the average amount of time to find the pushbuttons is rather similar. One reason for the difference in trend may be that pushbutton-integrated APS were more familiar to the Charlotte participants; there are a number of pushbutton-integrated APS in Charlotte, and none in Tucson.

Crossing Timing

Measures associated with crossing timing included time to begin crossing (Starting Latency), interval during which participants began crossing (Start Interval), interval during which participants finished crossing (Finish Interval), and whether participants finished crossing before the onset of perpendicular traffic (Finish Before Perpendicular). The longer participants delayed starting to cross, the greater was the likelihood that they would still be in the crosswalk when perpendicular traffic received a green signal.

Information Condition

Tucson – There was only one participant who began each crossing without assistance and who had the audible WALK signal for all 12 crossings. Furthermore, there were only four participants who had the audible WALK and crossed independently at each of the eight crossings in the general and specific information blocks. Therefore, analyses of starting latency were undertaken with all 20 participants while keeping in mind the potential confounds. There are differences in measures of crossing timing across information conditions; these significant differences are exclusively between the no information condition and both the general information and specific information conditions, which did not differ from one another on any of these measures.

The overall analysis of differences in starting latency across information conditions, using 19 participants to the instance of missing data), is significant ($F(2,38) = 11.580$, $p<.001$). No information differs from both general information ($F(1,19) = 9.699$, $p<.01$), and specific information ($F(1,19) = 16.307$, $p<.001$), which are not significantly different from one another (*see Table 3-6*).

TABLE 3-6 Measures of crossing timing by information condition – Tucson (N = 19)

	No Information	General Information	Specific Information	F (2,36)
Starting Latency in sec. [1]	5.36	3.53	3.21	11.580*
Started during WALK [2]	18.42%	64.05%	72.84%	21.293*
Completed during WALK or FDW [2]	2.50%	31.58%	42.11%	10.926*
Completed before perpendicular Green [2]	92.37%	93.84%	94.74%	< 1.00

* Significant at $p < 0.001$

[1] Latency in seconds measured from the onset of WALK

[2] Each value represents the average percentage of trials within the given block in which each participant performed accordingly.

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There are no significant differences on measures of crossing timing between the general and specific information conditions, and the improvement in all measures of crossing timing between the no information and the general and specific information conditions is likely attributable to increasing use of the pushbutton and thus presence of the audible WALK signal. In the no information condition, in 80 possible trials, participants used the pushbutton on only 16 trials. By the general information condition this had increased to 66 of 80 trials. However, in the no information condition, participants were always crossing a minor street and had good traffic cues indicating the onset of vehicular green, which was concurrent with the WALK signal if it had been present. In the absence of the WALK signal, the length of the parallel vehicular green nonetheless allowed ample time for most participants to complete their crossings before the onset of perpendicular green. The picture might have been different if participants were crossing a major street instead of a minor street on crossings in the no information condition. Note, however, that latency in the no information condition was more than five seconds, even though participants were crossing the minor street in the presence of good vehicular cues. If greater use of the pushbutton, and consequent presence of the WALK signal, accounts for increased starting during the WALK interval, starting during the WALK interval may be increased by participants knowing there is a pushbutton and being able to find the pushbutton and the same training as suggested under Use of the Pushbutton.

Of concern to the researchers in the no information condition were comments of some participants who seemed to be trying to use the locator tone changes in volume (in response to ambient sound) as a walk indication. These participants generally did not look for or push the button, but heard the audible pushbutton locator tone, and without knowledge of locator tones and their function, made an assumption that it was some kind of walk indication. This misunderstanding of the ambient sound adjustment and of the locator tone could lead to dangerous crossings. Where pushbutton integrated devices with locator tones are installed, a concerted effort should be made to provide information about the devices to pedestrians in the community.

Charlotte – In Charlotte, there were nine participants who crossed independently and had audible WALK signals at every crossing. Analysis of crossing timing measures with these nine individuals revealed no significant differences attributable to level of information (see *Table 3-7*).

TABLE 3-7 Measures of crossing timing by information condition – Charlotte (N=9)

	General information	Specific information	t(8)
Starting Latency in sec. **	3.19	2.82	1.214
Started during WALK *	86.21%	94.44%	1.355
Completed during WALK or FDW *	68.89%	77.78%	1.170
Completed before perpendicular Green *	91.67%	97.22%	1.512

* Significant at $p < 0.05$

** Latency in seconds measured from the onset of WALK.

* Each value represents the average percentage of trials within the given information condition in which each participant performed accordingly

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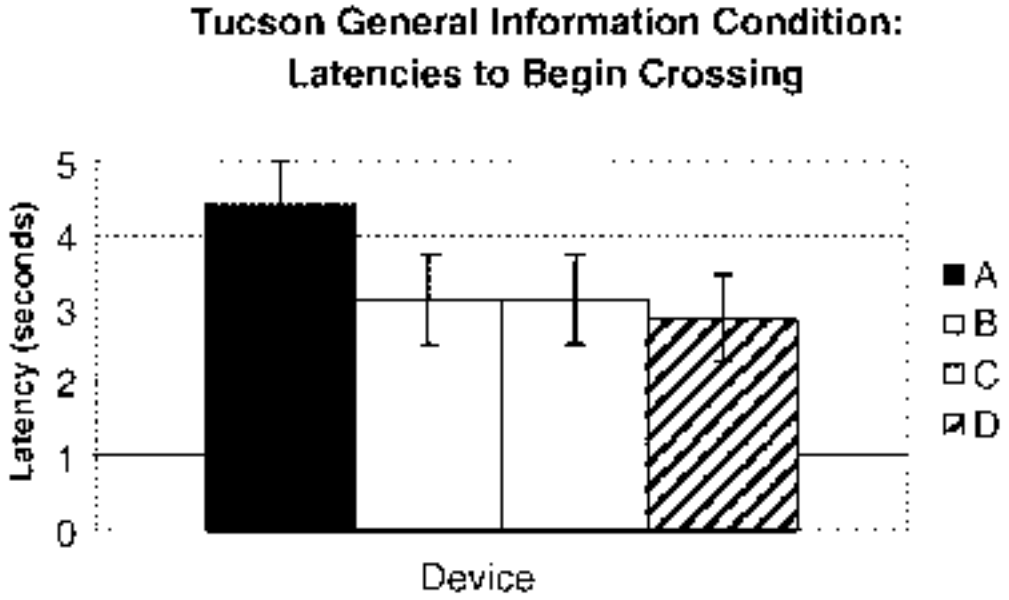
When analyzing measures of crossing timing, including all 20 participants, as was done with the Tucson data, keeping in mind the possible confounds, all measures showed significant differences (results not presented here). This lends support to the hypothesis that significant differences present in the Tucson analysis were the result of participants' increasing use of the pushbuttons and thus higher rates of audible WALK signals, rather than increasing understanding of the APS features.

Device

Tucson Data were not analyzed by device for the no information condition, as there was little use of APS. However, data for the general information condition was analyzed using the presence of audible WALK information at each intersection as the inclusion criterion, which resulted in only seven participants. The overall analysis failed to achieve significance ($F(3,18) = 1.390$, $p>.05$) – (*see Figure 3-8*).

In order for comparisons between devices to be meaningful, it is important that the conditions be as similar as possible in every other respect. Therefore, participants who were included in the analyses of measures of crossing timing entered all four streets independent of assistance in determining crossing timing and had the audible WALK signal from each of the four devices during the given information condition. This resulted in an analysis of data from 7 participants in the general information condition and 17 participants in the specific information



$F(3,18) = 1.390$, $p>.05$, $N = 7$

Figure 3-8. Latency to begin crossing by device: general information condition – Tucson.

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condition. Occasionally, one of these individuals would be missing a piece of data, and descriptive statistics were calculated from the remaining individuals (see *Table 3-8*).

The numbers above represent those who had APS at all four intersections and entered all four without assistance. But consider for a moment if we just look at the assistance with crossing timing variable (one of two inclusion criterion variables). In the general information block the number of participants who began crossings without assistance for APS A, B, C, and D were 18, 20, 18, and 13 respectively. In the specific information block, they were 20, 20, 20, and 19. When we consider the numbers of participants who had the APS and entered independently, they are 14, 18, 16, and 10 in the general information condition, and 19, 19, 18, and 18 in the specific information condition. The fewer number of participants included in the above calculations (7 and 17) is a result of the specific effects of the listwise deletion procedure necessary for meaningful comparisons.

Although most participants did perform the majority of their crossings independently and with audible WALK information, the relatively low number of participants who did so at the intersection with APS D in the general information condition (n=10) greatly limited the number of participants included in the full analysis. Participants had a great deal of difficulty locating and pushing the pushbutton on APS D in the general information condition and some were observed to be quite frustrated and requested assistance with starting crossing. In addition, some seemed confused on hearing the rapid tick walk indication and asked for confirmation from the orientation and mobility specialist (which was recorded as a request for assistance on the crossing). Interestingly considering the trouble discussed here, starting latencies were faster for APS D than for the other three APS in both information conditions (statistically confirmed in the specific information condition only, see below).

Following specific familiarization, the majority of participants were using the APS devices and thus the sample size for the analysis of latency following listwise deletion is 17. In this case, the analysis of latency to begin crossing by device is significant ($F(3,48) = 3.466$, $p < .05$). The means look rather similar between APS A, B and C: 3.35, 3.59, and 3.71 seconds, respectively. The mean amount of time to begin crossing with the APS D was 2.24 seconds. A

TABLE 3-8 Measures of crossing timing by device and information condition – Tucson

Measure	A		B		C		D	
Information Condition	**G**	**S**	**G**	**S**	**G**	**S**	**G[3][4]**	**S[3][4]**
Starting latency in sec[1]	4.43	3.35	3.14	3.59	3.14	3.71	2.86	2.24
Started during WALK[2]	57%	58%	71%	65%	86%	50%	71%	94%
Completed during WALK or FDW[2]	14%	53%	29%	41%	29%	29%	43%	75%
Completed before perpendicular green[2]	100%	100%	100%	94%	100%	88%	100%	94%

General information: n = 7

Specific information: n = 17

[1] latency in seconds after the onset of WALK. Latency was measured from the onset of WALK.

[2] % of participants who started or ended their crossings under the listed parameters.

[3] [4] G = general information; S = specific information.

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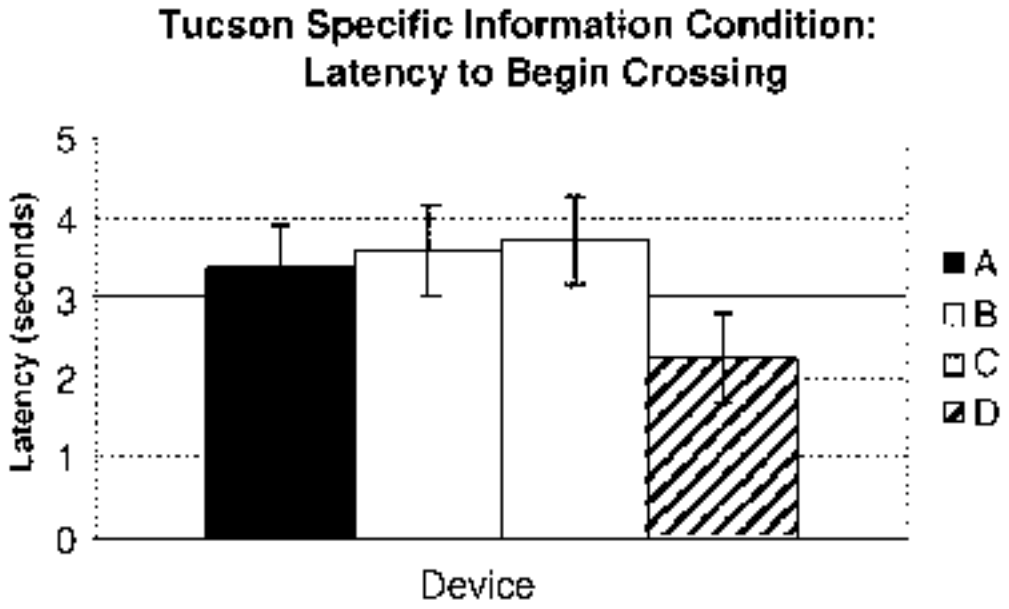
comparison between the averaged latencies for APS A, B and C and APS D, shows that the average amount of time to begin crossing for these three APS was significantly slower than for APS D ($F(1,16) = 41.86$, $p < .001$), and the various devices each produced slower responses than APS D when compared directly (*see Figure 3-9*), confirming the results of our previous research finding the most rapid response to the correct WALK signal was when it consisted of rapid ticks.(5,6)

Looking back at general information (*see Figure 3-8*), there was a similar trend amongst the means even though there were not significant differences. APS D resulted in the fastest latencies (but keep in mind the large amount of missing data), APS C and B had identical latencies (to a hundredth of a second). The exception was that APS A resulted in the slowest latencies following general information. APS A was the device with pedhead-mounted walk indications and participants may have been momentarily confused by the fact that the WALK signal was coming from a different place than the locator tone. On the other hand, participants in Tucson were somewhat more familiar with cuckoo/chirp pedhead-mounted APS than they were with the other types, since APS having cuckoo/chirp WALK signals are commonly installed there.

It should be expected that the faster starts in response to the APS D devices will result in other positive consequences related to the crossings. An analysis of the frequencies for a number of other measures of crossing timing following specific information supports this notion. Participants at the intersection with APS D devices were equivalently or more likely to begin



$F(3,48) = 5.466$, $p < 0.05$, $N = 17$

Figure 3-9. Latency to begin crossing by devices: specific information condition – Tucson.

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crossing during the WALK signal than at other intersections. These individuals finished their crossings during the WALK or flashing DON'T WALK 75% of the time versus 53% for APS A, 47% for APS B, and 29% for APS C. There was very little variability between devices in the number of participants failing to complete crossings before the onset of perpendicular traffic, with no more than 2 participants remaining in the crosswalk at the end of the WALK phase for any device. APS A also faired well in this analysis, with 88% of participants entering during the WALK signal, and 53% completing during the WALK or flashing DON'T WALK. There was no one left in the crossing when opposing traffic began to flow at intersections where APS A were installed. APS C resulted in the worst scores on all measures, however the poor performance may have been caused by irregularities in the functioning of APS C that were observed by the researchers in Tucson (see discussion of devices in Method). Following specific familiarization, participants were slowest to respond to APS B and C, the two devices with speech walk messages. Participants were fastest with the walk signal of APS D. Furthermore, this analysis matches up well with the frequency analysis such that the faster responses lead to more starting during walk interval, and higher rates of crossing completion before the end of the flashing don't walk interval.

Charlotte – Conducting analysis of starting latency by device, following general information was based on a sample size of only 10 participants who were presented with WALK signals for each device, and who independently initiated a total four crossings. The overall analysis failed to achieve significance, $F < 1.00$ (*see Figure 3-10 and Table 3-9*).

Following specific information, the majority of participants were using the APS and thus the sample size improved to 18. However, the analysis of latency to begin crossing was once again non-significant (*see Figure 3-11*).

In addition to having mean latencies in each information condition which were not significantly different from one another, the relative orders from fastest to slowest between the two information conditions was not the same. For example, following general information, the slowest mean response latency was at the intersection with the APS D (3.70 seconds), but in the

TABLE 3-9 Measures of safety by device and information condition – Charlotte

Measure	A		B		C		D	
Information Cond.	**G*****	**S*****	**G**	**S**	**G**	**S**	**G**	**S**
Starting latency in sec.*	3.30	3.11	2.80	3.39	2.60	3.11	3.70	2.28
Started during WALK**	80%	89%	80%	94%	90%	94%	80%	89%
Completed during WALK or FDW**	70%	72%	50%	50%	70%	65%	60%	88%
Completed before perpendicular green**	90%	100%	90%	94%	80%	100%	100%	94%

General information: n = 10
Specific information: n = 18

* latency in seconds after the onset of WALK. Latency was measured from either the onset of WALK, or the onset of parallel through traffic when there was no WALK signal.

** % of trials on which participants started or ended their crossings under each condition

*** G = general information, S = specific information

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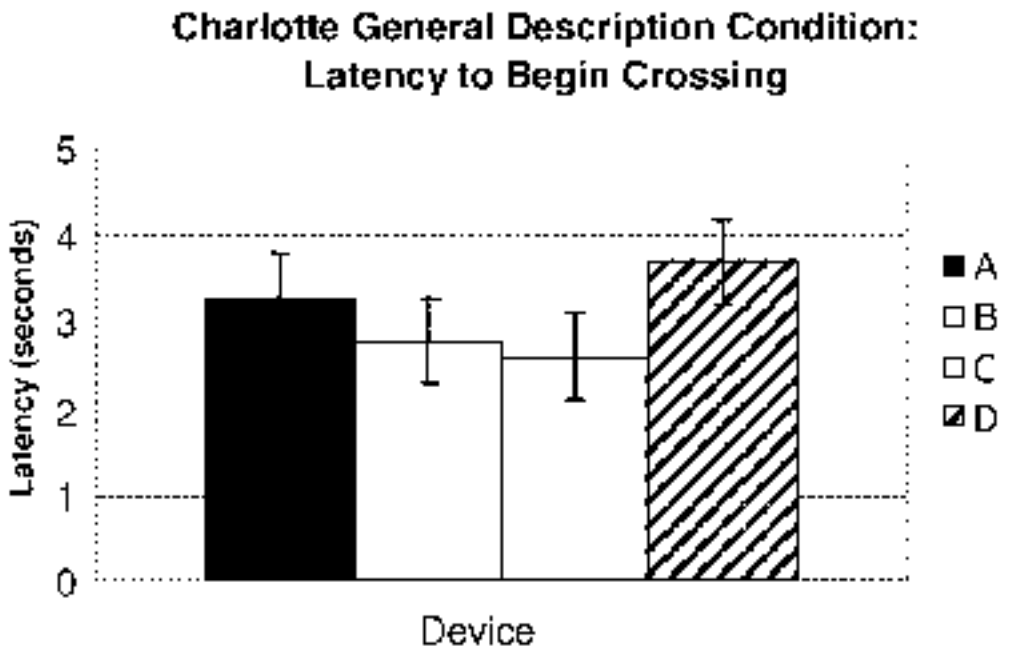
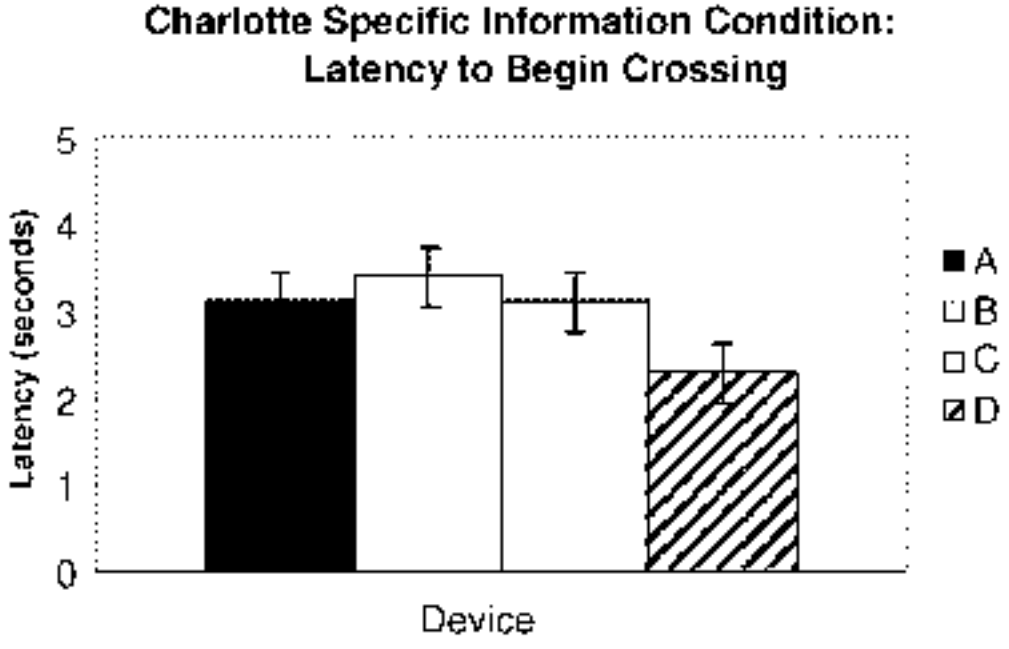


[13.27] < 1.00, N=10

Figure 3-10. Latency to begin crossing by device: general description condition – Charlotte.



[13.52] < 1.00, N=18

Figure 3-11. Latency to begin crossing by device: specific information condition – Charlotte

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specific information condition, this intersection had the fastest mean latency (2.28 seconds). In the general information conditions, participants in Charlotte were observed to hesitate more on first hearing the rapid tick WALK signal at APS D, possibly to decide if what they were hearing was really the WALK signal. However, in the specific information condition, the pattern in Charlotte is very similar to that in Tucson; that is, the fastest responses were for APS D while responses to the other APS were similar to one another.

There was very little variability in the percentage of individuals who began crossing during the WALK signal (80-90% – general information, and 89-94% – specific information), or the percentage of participants who completed their crossings before the onset of perpendicular green (80-100% – general information, and 94-100% – specific information). There was slightly more variability in the percentage of individuals who finished during the WALK or flashing DON'T WALK (50-70% – general information, and 59-88% – specific information).

In comparing performance on latency to cross in the general information condition, the patterns between Tucson and Charlotte are not the same. In Tucson, the speech messages and rapid tick signal all produced equally fast starts (~5 seconds), while in Charlotte the rapid tick resulted in the slowest mean start, and the two speech messages provided the most rapid starts. Recall that within each city, these were not significant differences and no statistical tests were computed between the cities.

WAYFINDING

Measures associated with wayfinding were whether participants 1) were within the width of the crosswalk when they began crossing (Began Within), 2) were correctly aligned so that they were facing directly parallel to the crosswalk when they began crossing (Correctly Aligned), 3) traveled within the crosswalk lines at all points in the crossing between the beginning and ending (Crossed Within), and 4) ended the crossing within the crosswalk lines (Ended Within).

Information Condition

Tucson

Table 3-10 shows the percentages of all participants who performed in the given way on each measure, divided out by both device type and information condition, without concern for whether or how each participant used each device. There is no systematic difference attributable to information condition that is apparent in the data. Between general and specific conditions, performance for some devices improved slightly for one or two measures, but declined for other measures. Inferential analysis was conducted to reveal any significant differences attributable to device or an interaction between device and information condition (see below under Device).

Charlotte

Again, there are no systematic differences attributable to information condition that are apparent from the data. Between general and specific conditions, performance for some devices improved for one or two measures, but declined for another measure or two (*see Table 3-11*).

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Because of observations in Tucson, it was noted in Charlotte if participants were standing immediately beside the pushbutton to begin their crossing, this sometimes resulted in their being outside the crosswalk lines when beginning. Therefore this table includes percent of participants who either began within the crosswalk or at the pushbutton. When that is considered, almost all participants began at one of these locations. This behavior has some implications for placement of pushbuttons closer to or within the extension of the crosswalk lines.

TABLE 3-10 Measures of wayfinding by device and information condition – Tucson

Measure	APS A		APS B		APS C		APS D	
Information Condition	**G**	**S**	**G**	**S**	**G**	**S**	**G**	**S**
Began within	83%	84%	78%	78%	75%	65%	72%	82%
Correctly aligned	79%	78%	70%	79%	84%	85%	63%	74%
Crossed within	69%	58%	53%	58%	53%	79%	80%	79%
Ended within	69%	74%	42%	58%	37%	68%	80%	68%

G = general information, S = specific information
N = 20

TABLE 3-11 Measures of wayfinding by device and information condition – Charlotte

Measure	APS A		APS B		APS C		APS D	
Information Condition	**G**	**S**	**G**	**S**	**G**	**S**	**G**	**S**
Began within *	84%	67%	90%	79%	77%	74%	88%	70%
			100		100	100	100	
Began within or at PB *	100%	94%	%	100%	%	%	%	95%
								100
Correctly aligned	79%	77%	95%	80%	78%	79%	88%	%
Crossed within	84%	79%	95%	100%	85%	95%	69%	80%
Ended within	80%	74%	84%	95%	78%	84%	56%	65%

* In many cases, participants stayed near the pushbutton to either use the vibrotactile signal or to better be able to hear the signal. More listening near the pushbutton occurred in the specific information condition than general information condition shown by the reduction in participants who began within the crosswalk.

G = general information, S = specific information
N = 20

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Device

The measures of wayfinding are all categorical. To enable statistical analysis with regard to device, the categorical level variables were transformed into interval level variables (percentages) collapsing across familiarization level, using the method outlined near the beginning of the results section.

Tucson

Table 3-12 shows the average percentage of trials on which each participant performed accordingly for a given APS in Tucson.

Collapsing across information conditions, it doesn't appear that any APS reliably provided more useful information than any other with respect to wayfinding. Furthermore, no specific type of interaction (general interaction, use of tactile arrow, or use of extended message; not presented in these tables) shows reliable improvement or impoverishment of ability to find and align to the crossing. One can also look at a given APS following general information and compare it with the same APS following specific information to see if type of information has specific effects on measures of wayfinding. There are no significant differences here, either.

One-way ANOVAs were computed in order to investigate whether the various devices produced differences in the percentage of trials participants began within the crosswalk, collapsing across information conditions, and no significant differences were found ($F(3,57) < 1.00$), correctly aligned with the crosswalk ($F(3,57) = 1.58$, $p > 0.05$), traveled within the crosswalk ($F(3,57) = 1.86$, $p > 0.05$), or ended within the crosswalk ($F(3,57) = 1.67$, $p > 0.05$).

Charlotte

Table 3-13 shows the average percentage of trials on which each participant performed accordingly for a given APS in Charlotte.

Device did not result in differences between the percentage of trials in which participants began their crossing within the crosswalk ($F(3,57) < 1.00$). Some participants lined up at the pushbutton, with their hand on the tactile arrow as shown in Table 11, probably to use the vibration to confirm the WALK. In many cases, because of the location of the pushbuttons, this meant participants were not within the crosswalk when starting to cross.

An analysis of alignment by device was significant ($F(3,57) = 2.79$, $p < 0.05$). Participants aligned themselves correctly more often at the intersection with APS D than those with APS C ($F(1,19) = 5.63$, $p < 0.05$) and APS A ($F(1,19) = 7.107$, $p < 0.05$). Better alignment at the intersection with APS D is probably attributable to the sidewalk and ramp configuration at

TABLE 3-12 Participant performance by device – Tucson

Measure	APS A	APS B	APS C	APS D	F(3,57)
Began within	86.65%	79.10%	77.55%	81.70%	< 1.00
Correctly aligned	83.40%	69.20%	81.75%	76.00%	1.58
Crossed within	61.65%	56.70%	70.10%	71.75%	1.86
Ended within	68.35%	81.40%	61.85%	63.30%	1.67

$p < 0.05$

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that intersection, rather than to a specific device feature since APS D had the lowest use of the tactile arrow (*see page 26*). At that intersection, the approach to the crosswalk was straight, and confined by landscape strips, and pushbuttons were near the street.

The analysis for travel within the crosswalk in Charlotte was also significant ($F(3,57) = 5.19$, $p < 0.01$). Comparisons revealed that the percentage of trials the participants traveled within the crosswalk at APS D intersection was significantly lower than that for APS C ($F(1,19) = 7.027$, $p < 0.05$), and APS B, ($F(1,19) = 12.67$, $p < 0.01$). This may seem surprising, given that alignment was very good at the intersection having APS D. However, that intersection had the widest crossing. Furthermore, the percentage of the trials that participants traveled within the crosswalk for APS A was significantly lower than that for APS B ($F(1,19) = 5.65$, $p < 0.05$). The clockwise crossing at APS A had one diagonal curb ramp rather than two perpendicular ramps, which may have affected maintaining alignment as participants stepped off the curb.

The analysis of percentage of crossings in which participants ended their crossing within the crosswalk was also significant, ($F(3,57) = 3.95$, $p < 0.05$). For crossings having APS D, participants ended their crossing within the crosswalk on 57.7% of trials, but in this case it was only significantly lower than crossings at APS B (85.0%, $F(1,19) = 10.50$, $p < 0.01$). A very small deviation, especially one occurring early in a crossing, can easily take the traveler outside the crosswalk at a wide crossing, for participants who had traveled within the crosswalk for most of the crossing and felt they should have completed their crossing (who thought the road was narrower than it was) might correct by turning away from their parallel street looking for the curb and thus veer out of the crosswalk. The crossings at APS D were the widest (79 ft and 83 ft) and one of the crossings at APS B was the narrowest in Charlotte (49 ft). The other crossing at APS B was in the middle (58 ft).

The results regarding wayfinding in Charlotte are quite different from those in Tucson, where there were no significant differences attributable to device. It should be noted that almost all traffic in Charlotte turned right or left at the intersections, so there were few traffic cues for alignment or for correcting crossing alignment during crossing, while straight-through traffic was more plentiful in Tucson. Because of these differences in vehicular flow across cities, it is difficult to argue that specific information was being used to guide participants across the street. In Tucson, analyses of where participants traveled and where they ended their crossings were both non-significant, and the lowest percentages were both recorded at the intersection with the APS B. However, that intersection had the steadiest traffic on the minor roadway. These analyses seem to tell us little more than which intersections were particularly difficult with respect to

TABLE 3-13 Participant performance by device – Charlotte

Measure	APS A	APS B	APS C	APS D	F(3,57)
Began within	77.50%	85.00%	75.00%	80.00%	< 1.00
Correctly aligned	77.50%	87.50%	75.00%	95.00%	2.79 *
Crossed within	77.50%	97.50%	90.00%	67.50%	5.19 **
Ended within	75.00%	85.00%	75.00%	57.50%	3.95 *

* $p < 0.05$
** $p < 0.01$

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crossing within the crosswalk, and do not directly address the usefulness of the signals for guidance across the street.

It was the observation of the orientation and mobility specialists involved in data collection that most participants did not use any type of consistent strategy to maintain their alignment when having to orient with a pushbutton, then realign to cross. Most deviated on their approach to the street to detect any pushbutton and locator tone they heard, and some became completely disoriented and lined up to cross the wrong street. The most common techniques taught for aligning to cross streets involve maintaining initial approach alignment and utilizing traffic traveling through the intersection to align. Where pushbuttons are used, the individual often must turn off the approach path to push the button, and the crossing must be made on the next through traffic phase without waiting through a cycle to align, which prevents the use of those techniques.

SUBJECTIVE RESULTS

Likert Ratings

In both cities and following each street crossing in all information conditions, participants were asked to rate their level of agreement with four statements using a 5-point Likert scale (1=strongly disagree; 5=strongly agree). Also in both cities, responses to an additional 11 statements were recorded following completion of all crossings in the specific information condition only.

Questions Asked after Every Trial in Every Condition

The four statements rated after all crossings in both cities were the following:

1. It was easy to find the pushbutton.
2. I was sure I pushed the button for the street I wanted to cross.
3. I was certain the signal was for the crosswalk I wanted.
4. I used the signal to help me find the opposite corner.

Questions 1 and 2 were not asked if participants had not used the pushbutton. Question 3 was not asked if there was no WALK signal. Question 4 was asked after all crossings since the participant could possibly have used the pushbutton locator tone to find the opposite corner, even when there was no audible walk signal.

In the no information condition in Tucson (not conducted in Charlotte), so few participants interacted with the pushbutton that results are not informative. In the general and specific information conditions, results by device and by city are quite similar, while across information conditions they vary (*see Table 3-14 and Figure 3-11*). For all but one statement, ratings were as favorable or more favorable following specific information than following general information. In both information conditions in Tucson, 78% of participants replied agree or strongly agree in response to the statement, "It was easy to find the pushbutton."

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Although there was little improvement in objective measures between the general and specific information conditions, participants rated statements regarding their ability to use the APS more positively following specific information. Thus, even though participants were not familiar with a specific intersection, having specific information and experience with the APS at that intersection, and knowing which APS they would encounter, increased participants' perception of ease and confidence in interacting with the APS.

Following specific information, more than three fourths of participants generally felt that finding pushbuttons was easy, and most of the participants (approx. 90%) were confident that they pushed the correct button and started crossing with the correct WALK signal. Not nearly as many agreed that they used the signal to help them find the opposite corner. The lack of reported use of the signal to find the opposite corner is likely attributable to a number of factors. Participants who used dog guides (4 in each city) reported that they just followed their dog's guidance in the street. Others stated that they were using vehicles for their alignment cues or that they couldn't hear the locator tone of the APS until they were within a step or two of the opposite curb, so they didn't really use it.

Two devices, APS C and A, were specifically designed to provide beaconing to the opposite corner. Beaconing by the APS C consisted of a louder WALK, followed by a louder

TABLE 3-14 Range of mean response ratings for the various APS by question, collapsed across devices

Questions	Tucson Range of Mean Response Ratings	Charlotte Range of Mean Response Ratings
5. The locator tone helped me find pushbutton.	3.58 – 3.79	3.95 – 4.37**
6.[a] The vibration during walk was helpful.		
7. The tactile arrow helped me know the pushbutton was for the correct street	3.83 – 4.17	4.42 – 4.47
8. The tactile arrow helped me align for crossing.	2.00 – 2.57	3.38 – 4.00
9. The tone or message helpful in letting me know the button had been activated.	3.58 – 4.58*	4.28 – 4.61
10. The speech walk message easy to understand.	3.95 – 4.25	4.00 – 4.68*
11. The pushbutton message easy to understand.	4.42 – 4.67	4.38 – 4.75
12.[b] The crossing map useful and easy to understand.	4.00	4.17
13.[c] The louder signal feature was helpful.	3.86	4.00

[a] Insufficient data for statistical analysis.
[b] Only APS D had this feature, and only 3 (Tucson) and 6 (Charlotte) participants used it.
[c] Only APS C had this feature.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.0001$

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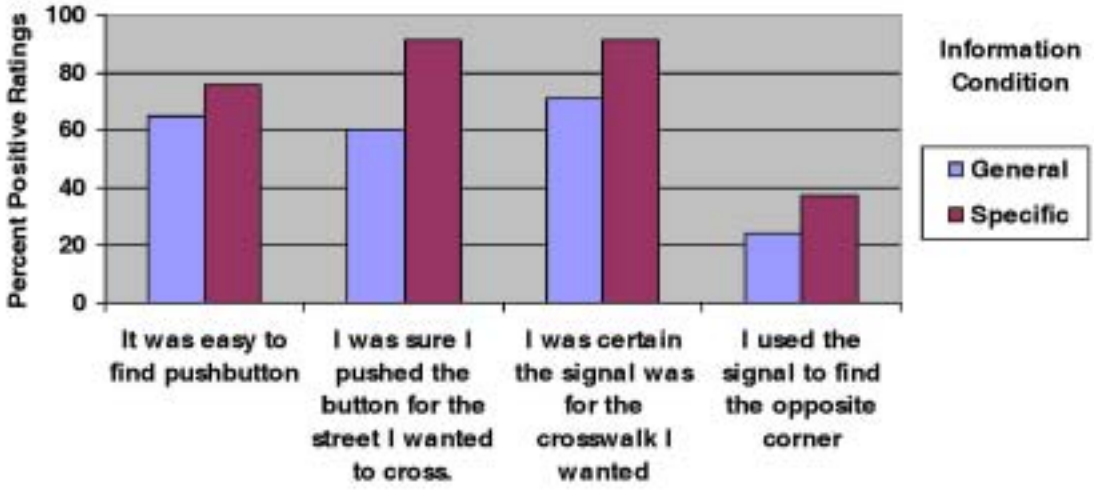

Figure 3-11. Percent of positive ratings (agree or strongly agree with statements) by information condition and statement, collapsing across devices and cities.

locator tone for the duration of the pedestrian phase, a strategy that was expected to be beneficial based on the laboratory findings in related research (*36*). The beaconing feature on the APS C was available only after an extended button press. This feature was not working correctly on APS C in Tucson, due to some wiring problems that were not discovered until the end of data collection, however, it was functioning in Charlotte. APS A provided beaconing from overhead speakers aimed at the center of the crosswalk during the WALK signal only. Other research had not found this system to be very useful for the alignment task (*22, 5*). For most trials in which participants reported that they used APS signals to help them find the opposite corner, the signal available would have been the relatively quiet locator tone.

The most interesting finding here is that, for each city and each information condition, the numbers of participants who reported using the APS to help them find the opposite corner are very similar for all devices. That is, even though the locator tone from only one device (APS C) became louder when the user used the extended button press (80% of participants used this feature in the specific information condition), there is no clear pattern that participants reported using the beaconing of APS C more than other devices. Researchers observed some participants altering their path to travel straight toward the pushbutton (and louder locator tone) of APS C in Charlotte, but participants did not seem to realize that they had done so.

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In the general information condition, with regard to these first four measures, participants in Charlotte did not rate their experience using APS as highly as participants in Tucson for three of the four devices. This could have been attributable to having less experience with the experimental task than participants in Tucson, who had already had one block (no information condition) of testing (*see Figure 3-12*).

The poorer ratings for the APS B in Charlotte, following general information, were probably because the volume of both the locator tone and the speech walk message were lower than those for any other device, with baffles preventing sound traveling back down the sidewalk. These volume restrictions were in response to a neighbor's objection. Nonetheless, following specific information and despite the low volume, its ratings increased to essentially equal the ratings in Tucson. With the exception of APS B, ratings following specific information were higher in Charlotte than in Tucson.

The poor ratings for APS D in the general information condition in Charlotte may have been because the crossings at the intersection in Charlotte where APS D were installed were wider than those in Tucson, and there was initial confusion for some participants about whether the WALK indication was really the WALK indication. Following specific information, ratings for the APS D, like those for the APS B, increased markedly, to be even higher than comparable ratings in Tucson.

Questions Asked During the Specific Information Condition Only

After each crossing in the specific information condition only, participants were asked to state the extent to which they agreed with an additional nine statements (statements 5 – 13) using a 5-point Likert scale (1=strongly disagree; 5=strongly agree).

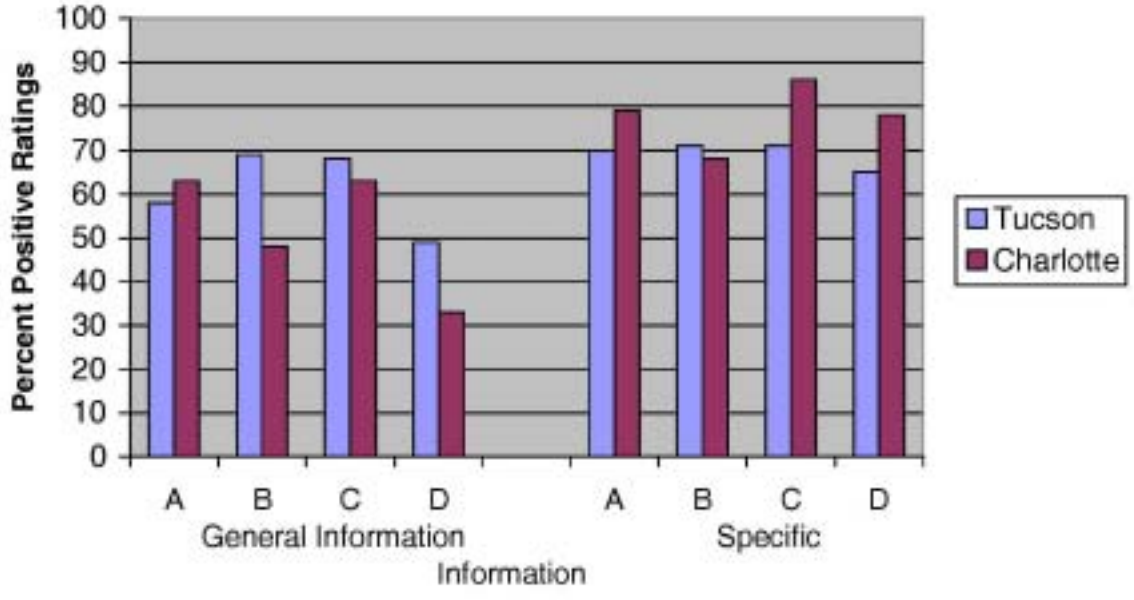

Figure 3-12. Percentage of positive ratings (agree or strongly agree with statements) by information condition and device.

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In order to be included in repeated-measures ANOVA testing for significant differences between devices within a given city, each participant had to have a valid response on the question of interest for each device. Questions were not asked if they were not applicable (i.e., a participant who did not use the tactile arrow would not be asked if the tactile arrow was helpful in aligning to cross). Thus, for analysis of subjective evaluations of device differences in the usefulness of the tactile arrows for aligning to cross, only those participants who used the tactile arrow on each of the four devices were included. Similar inclusion criteria were used for each of the questions, thus resulting in varying sample sizes for the analyses of responses to statements 5 – 13. Overall, there were few significant differences between the various APS for any question in either city (see *Table 3-14*).

Regarding helpfulness of the locator tone for finding the pushbutton (Question 5), there was a significant difference only in Charlotte ($F(3,54)=4.88$, $p<0.01$). The mean rating for APS B (3.05) was significantly worse than for APS C (4.37; $F(1,18)=7.58$, $p<0.05$) and for APS A (4.32; $F(1,18)=13.75$, $p<0.01$). This was undoubtedly because of the low volume setting of APS B in Charlotte, which was also rated as having the volume too low (see question 14 below). The range of all other mean ratings across both cities was 3.21 to 3.79, indicating a generally positive view of the information provided by a locator tone.

Participants in Charlotte may have had greater exposure to locator tones due to a fair number of APS C devices installed elsewhere around the city, and the most positive ratings were obtained for APS C in Charlotte. When asked, 11 participants reported having used locator tones before, however other ratings of the usefulness of the locator tone for finding the pushbutton were fairly equivalent between the two cities. After completing crossings in which the participants located the pushbutton independently, participants were asked how they knew where to find the pushbutton. Collapsing across all device types and information conditions, participants in Tucson reported using the locator tone 95% of the time, while the rate was at 83% in Charlotte. The lower percentage in Charlotte is largely the result of low rates of locator tone use on APS B. As discussed below, there were some considerable volume concerns for the locator tone on APS B which may have been the primary cause of diminished reliance on the feature in Charlotte.

Regarding helpfulness of the vibratory walk signal (Question 6), across both cities, only 2 participants used the feature at each of the four intersections, and thus no statistical analysis could be computed. Overall, the feature was used 11 times in Tucson and resulted in a mean response rating of 4.36, and it was used 27 times in Charlotte with a mean response rating of 4.37. Use of the vibratory feature may have been by participants who wanted to be sure they knew which APS was providing the WALK signal or some participants may have been just trying out the vibratory feature.

The mean rating for whether the tactile arrow was useful for knowing the pushbutton was for the street to be crossed (Question 7), collapsing across devices in both cities, was 4.34. There were no significant differences between the devices for either city. The high mean rating, however, indicates that participants regarded the tactile arrow as being very useful in determining which pushbutton was for which street.

The mean rating for whether the tactile arrow was useful for crossing alignment (Question 8), also showed no significant differences between devices within each city, but the

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mean ratings were all on the positive side of the scale in Charlotte and on the negative side of the scale in Tucson.

With regard to the helpfulness of the activation tone or message (Question 9), mean ratings for each city were strongly positive. There were no significant differences between devices in Charlotte, but in Tucson, differences were significant ($F(3,54)=2.90$, $p<0.05$). APS C was rated significantly worse (3.58) than both APS B (4.58, $F(1,18)=6.33$, $p<0.05$) and APS D (4.26, $F(1,18)=6.61$, $p<0.05$) devices. However, APS C, which had the lowest mean in Tucson, had the highest mean in Charlotte (4.61), perhaps because some participants in Charlotte had prior experience with APS C. The most important conclusion that can be taken from ratings on this question is, therefore, that a good activation tone or message was very important to participants.

The speech walk message was available only on APS B and APS C (Question 10). The mean ratings, by city, indicate that participants found the speech messages quite understandable in both cities. In Tucson, there was no significant difference between devices, but in Charlotte, APS C (4.68) was rated significantly higher than the APS B (4.00; $t(18)=2.25$, $p<0.05$).

The pushbutton information message was available on APS B, C and D (Question 11). There was no significant difference between devices in either city, but mean ratings for each device at each city were all at or above 4.00, demonstrating participants' agreement that "The pushbutton information message was easy to understand."

The tactile map was used by only 9 participants across both cities. The mean rating for the statement "The crossing map was useful and easy to understand." (Question 12) was 4.00 in Tucson and 4.17 in Charlotte, with all participants rating it 3.00 or above. There was insufficient data for further analysis. Researchers observed that many participants seemed to like the tactile map feature during the indoor demonstration, but most did not use it during experimental trials.

Regarding the helpfulness of the locator (beaconing) signal feature (Question 13), this feature was available only on APS C and only in response to an extended button press. Collapsing across both cities, 31 participants used the feature, giving it a mean response of 3.94 across cities, with only 4 participants rating it on the negative side of the scale.

Additionally, participants were asked to rate the volume of both the locator tone and the walk signal (items 14 & 15) on a 5-point scale (1=too quiet; 5=too loud). The means for the locator tone and WALK signal volumes in both cities were less than, but close to, 3.00, halfway between too quiet and too loud (*see Table 3-15*). The two most extreme mean ratings regarding the volume of the locator tone were APS A (2.20—Tucson) and APS B (1.80—Charlotte). APS A did not seem to respond well to ambient sound, which might have contributed to the lower rating in Tucson, where traffic was quite noisy much of the time. In addition, one APS A device was installed several feet behind the stop line, so it was somewhat further away from the approach sidewalk. The volume of the locator tone of APS B was very quiet in Charlotte with baffles installed on the approach side of the device due to neighbor complaints, so most of its sound was directed at the curb area and into the street, which was not very helpful in hearing the locator tone when approaching on the sidewalk. The most extreme rating regarding the volume of the WALK signal was also on APS B (Charlotte), probably for the same reason. The speech message was very difficult to hear. On the whole, participants were comfortable with APS volumes, although they would have liked them slightly louder.

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TABLE 3-15 Mean rating of satisfaction with the volume levels of devices by locator tone and WALK signal within each city – N = 20 (1=too quiet; 3=just right; 5=too loud)

	APS A	APS B	APS C	APS D	F(3,57)
14. Level of locator tone					
Tucson	2.20	3.05	2.75	3.00	4.23*
Charlotte	2.75	1.80	2.75	2.25	13.08***
15. Level of WALK signal					
Tucson	2.80	2.50	2.70	3.05	2.89*
Charlotte	2.70	2.20	2.95	2.90	5.89**

* p≤0.05
** p≤0.01
*** p≤0.001

Despite the relative similarity in ratings, there were nonetheless significant differences by device for the locator tone and the WALK signal volume in both cities. In Tucson, the analysis of locator tone volume was significant (F(3,57)=4.23, p≤0.01), with participants indicating that the volume was too quiet on APS A when compared to the nearly perfect ratings obtained on APS B (3.05; F(1,19)=8.99, p≤0.01) and APS D (3.00; F(1,19)=8.94, p≤0.01). The analysis of ratings for the WALK signal volume were also significant (F(3,57)=2.89, p≤0.05). The mean rating for the APS D (3.05) indicated that it was considered about right, while APS B (2.50) was considered somewhat quiet in comparison (F(1,19)=8.88, p≤0.01).

In Charlotte, mean ratings for both the locator tone and WALK signal indicate that participants considered them somewhat too quiet. The analysis of responses to the level of the locator tone was significant (F(3,57)=13.08, p≤0.001). The mean rating for APS B (1.80) was significantly worse than for all others: APS D (2.25; F(1,19)=5.15, p≤0.05); APS C (2.75; F(1,19)=31.32, p≤0.001); APS A (2.75; F(1,19)=26.48, p≤0.001). This was to be expected considering APS B was set to a lower volume. Furthermore, the rating on APS D was significantly worse than that on the APS C (F(1,19)=7.31, p≤0.05), and that on APS A (F(1,19)=10.56, p≤0.01). The analysis of responses to the level of the WALK signal was also significant (F(3,57)=5.89, p≤0.01). The mean rating for APS B is significantly worse than all others: APS A, F(1,19)=4.52, p≤0.05; APS D F(1,19)=13.11, p≤0.01; APS C F(1,19)=12.04, p≤0.01. Once more, this was to be expected and no other significant differences emerged.

Although there are significant differences in the ratings for locator tone and for WALK signal volumes in each city, the fact that the differences in rank order change order across cities and across locator tones vs. WALK signals, makes it difficult to draw any firm conclusion about volume. This variation probably is indicative of the difficulty of regulating the signals to have equivalent perceived loudness between each other, within each city, and of the fluctuation of volume of both locator tones and WALK signals according to ambient sound. Although the accommodation to ambient sound is intended to make locator tones and WALK signals detectable and understandable in an easy moment with changing sound, response time and delay

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both vary somewhat across devices. In addition, all devices were subject to a maximum permitted volume of 89dB. Perceived loudness is affected by several other factors in addition to volume setting of devices and their response to ambient sound. These include the comparative spectrum of the signal to the ambient sound at any time, wind, humidity, and reflective surfaces.

Subjective Responses

After completing each crossing in the final block of trials, and after responding to all of the above discussed statements, participants were asked what they liked most and liked least about the devices at the intersection they had just crossed. Participants were not limited in the number of features that they could list in either of these two categories.

In an attempt to quantify these responses, positive and negative comments for each device were categorized. By the time these questions were asked, most participants had had experience with pushbutton locator tones, the pushbuttons, the activation tones/messages, the tactile arrow, and the WALK signals. The vibrating arrow was present on all devices, but used by few participants, so it had few comments. Features such as the crossing map, the extended button press, and the louder (beaconing) signal feature were not present on every device and were not used by all participants even when present, so these features drew few comments.

Categories of positive comments were the following.

- Location and Type of Button
- Location and Type of Arrow
- Walk Signal Type (Speech vs. Other)
- Walk Signal Information Distinguishing Streets
- Locator Tone
- Pushbutton Activation Tone
- Vibrating Arrow
- Pushbutton Information Message (after extended push)
- Volume Increase Feature (beaconing)
- Tactile Map
- Responsiveness to Ambient Noise

Categories of negative comments included the following. Note that there is some overlap between positive and negative comments. Some features some participants liked, other participants disliked.

- Location and Type of Button
- Location and Type of Arrow
- Walk signal type (speech vs. other)
- Walk Signal is Confusing
- Lack of Info. Distinguishing Streets
- Difficulty Understanding the Walk Signal
- Pushbutton Activation Tone or Volume
- Locator Tone

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- General Volume Complaints (Locator or Walk Signal)
- Lack of Features (Info Message or Volume Increase)
- Crossing Map Difficult to Read

With one exception, in each city, all devices had more positive comments than negative comments. In Charlotte, the APS D had more negative responses. The number of total positive comments, by device, in Tucson was between 31 and 48, while in Charlotte, it was between 22 and 29. The number of total negative responses, by device, in Tucson was between 18 and 37, while in Charlotte, it was between 14 and 20. APS B and C had more positive comments in both cities than APS A and D.

Across both cities, APS A and B had the location and type of pushbutton that garnered the most positive comments. Both of these devices have large, rounded pushbuttons, more closely resembling typical pushbuttons than those of APS C and D. Also across both cities, the pushbutton of APS D had the most negative comments. It was a flat panel electronic pushbutton on the face of the device. During experimental trials, researchers observed considerable exploration of APS D before the button was actually pushed. In fact, in the general information condition, researchers observed a number of incidents when the button was pushed by accident while participants were exploring the device and trying to figure out where the pushbutton was located. The lack of anything that felt like a pushbutton was clearly confusing to many participants and they pushed on the light, map symbols, or the arrow while exploring the device, and often were not aware of what they pushed to get the confirmation tone.

In Tucson, APS D also received the most negative comments regarding the type of arrow. The arrow was only 1.5 inches long, with a stroke width of 3/4 inch, while the next smallest arrow was that of the APS C device, at 2 inches long, with a stroke width of 1 inch. Also, the arrow of APS D was the only one located on the top (horizontal) surface of the device. In the objective data, in the general information condition, the pushbutton and arrow of APS D appeared to be more problematic than the pushbuttons and arrows of the other devices. Following specific familiarization, this difference had largely disappeared, however. In Tucson, the location and type of arrow of APS C received more favorable comments than those of any other device. That arrow was the only one that was located on the pushbutton for the Tucson experiments in Charlotte. APS B also had the arrow on the pushbutton.

There were many comments regarding the type of WALK signal (speech—APS B and C vs. bird calls—APS A vs. rapid tick—APS D). In Tucson, there were between 9 and 13 positive responses to the WALK signals of all devices, and no negative responses. The higher numbers of responses were for APS B (13) and APS C (11), which both had speech messages, although the difference in numbers may not be meaningful. However there were 7 (negative) comments categorized as "Walk signal is confusing," for both APS A and APS D, the two devices having tone signals. There was a similar pattern in Charlotte, for both positive and negative responses, although the number of responses was less. Therefore, the general trend is that participants preferred the speech messages to either type of tone signal. It should be recalled, however, that in objective measures of latency in starting to cross, there was some advantage to the rapid tick signals. This pattern, in which subjective preference favors speech signals, but objective performance favors tone signals, was also found in research on pushbutton location and WALK signal conducted as part of this project (*see Chapter 4* (1,37)).

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There was a notable preference for devices providing speech information to distinguish between streets having the WALK signal, that is, APS B and C, and a smaller number of negative comments regarding the lack of this information from APS A and D. There were comments that the speech messages of APS B were difficult to understand, but no such comments for APS C.

Something as simple as having a clear and audible tone to indicate that the pushbutton had been activated appears to be particularly appreciated by pedestrians who are blind, as this feature was mentioned positively by many participants. Both APS A and D received positive comments in both cities, and APS B also received positive comments in Charlotte. Those who commented positively regarding APS B specifically commented that they liked the "Wait" message (the pushbutton actuation indicator) that they heard immediately when they pushed the button during the flashing or steady don't walk intervals. There were a few negative comments on the sound of the activation indicator, mentioning APS C and A. Overall, the actuation tone of APS A received the highest number of positive comments across both cities (12), and APS D next (7).

Regarding location tones, all devices across both cities received an approximately equal number of positive and negative comments.

There were scattered positive comments about the pushbutton information message and beaconing that could be activated by an extended button press, the vibrating button or arrow, the tactile map, and the responsiveness to ambient sound. Negative comments regarding these features were all with regard to APS A, which lacked the pushbutton information message and the tactile map. In Tucson and Charlotte, APS A also did not seem to respond to ambient sound, although it has that capability. There were five positive comments about the tactile map, but three comments that it was hard to read.

In addition to reporting which features they liked most and liked least for each device immediately following use of the device in the specific information condition, participants were also asked a series of questions after completing all crossings. These questions were:

1. Which location tone did you like best?
2. Which location tone was easiest to home in on?
3. Which pushbutton was easiest to find? (after finding the device)
4. Which walk signal gave you the best info for which street had the walk signal?
5. Which walk signal was easiest to hear?

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Participants were not limited to one device in answering the questions and could also respond with a "none" response (see *Table 3-16*).

It appears that preference for locator tones was fairly well distributed, with a slight preference for the locator tone on APS C followed by APS D. Interestingly, APS A and C have use the same locator tone, which some participants noted. Ease of finding the pushbutton was not related to reports of usefulness of the locator tone, as participants reported APS A to be the easiest to find, followed by APS B. This seems related to the rounded shape of the pushbuttons on those devices, about which many participants commented favorably. The clearest picture emerges in reports of which WALK signal gave the best information. Participants believed that those devices with speech messages (APS B and APS C) provided the least ambiguous information regarding the WALK signal. Finally, participants showed no clear preference for which walk signal was easiest to hear. APS A (bird calls) received the most votes across both cities, while APS C (speech) received nearly as many.

Attempting to amass all of this subjective information, the most desirable APS would have the following features:

- A locator tone (any)
- A rounded pushbutton
- A clear pushbutton activation tone
- Responsiveness to ambient sound
- A tactile arrow that is incorporated into the pushbutton itself
- A speech walk signal that indicates the name of the street to be crossed

TABLE 3-16 Frequencies of responses to questions on preference questionnaire

	None	APS A	APS B	APS C	APS D
Which locator tone did you like the best?					
Tucson	2	7	6	8	10
Charlotte	1	4	2	10	5
Which locator tone was easiest to hear in on?					
Tucson	4	3	3	8	8
Charlotte	1	5	3	10	5
Which pushbutton was easiest to find?					
Tucson	2	9	10	6	3
Charlotte	0	12	4	2	5
Which walk signal gave you the best info for which street had the walk signal?					
Tucson	2	4	14	15	1
Charlotte	0	1	10	14	5
Which walk signal was easiest to hear?					
Tucson	1	10	6	5	8
Charlotte	1	7	5	10	3

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- Easily understood speech
- Beaconing in response to an extended button press
- A pushbutton information message

SUMMARY AND CONCLUSIONS

This research evaluated what features of pushbutton-integrated APS were useful to pedestrians who are blind and how much information or training was needed in order to enable them to make use of those features. The results do not present a focused picture of one device and set of features that will provide unambiguous information to pedestrians who are blind or who have low vision at a range of intersections. So many factors are involved in the street crossing tasks that it is difficult to determine what features affected performance. Among the devices, some features seemed more useful or to be used more frequently, but even this information seemed to vary between the two cities. The results seem to support that when pedestrians who are blind have used a device and know what kind of APS they will use at an intersection, device characteristics or features, such as the physical design of the pushbutton or tactile arrow, do not make much difference.

A fact that became clear in this research was that pedestrians who are blind do not have adequate information about using pushbuttons and APS devices in crossing streets and many did not have good information about the complexity of modern intersection signalization. When participants had some general information about new types of APS, they performed better at locations with APS installed than they did when no information was given to them about the APS. Although there was little improvement in objective measures between the general and specific information conditions, participants' ratings regarding their ability to use the APS were more positive following after receiving specific information. Thus, even though participants were not familiar with a specific intersection, having specific information and experience with the APS at that intersection, and knowing which APS they would encounter, increased participants' perceptions of ease and confidence at interacting with the APS.

Device Adjustments and Volume

Despite all efforts by cities and researchers involved in this project, it was difficult to install devices within the existing infrastructure in locations that were truly comparable. Both cities made every effort to install the devices for this project in optimal locations, but slight differences in pole locations, such as distance from the curb or sidewalk, or position in relation to the curb ramp, made some pushbuttons more difficult to find than others. Even when everyone was enthusiastic to get installations, it was impossible to locate all devices in accordance with current *MUTCD* guidance and the *Draft Guidelines* (1, 2). On one corner this was due to the curb radius and a fire hydrant. On another, the sidewalk and curb ramp would have had to be completely rebuilt to locate a second pushbutton pole. Many poles, and consequently pushbuttons, in Tucson were more than 5 feet outside the extension of the crosswalk lines, which may have contributed to some participants crossing outside the crosswalk, or to crossing alignment problems. These locations are examples of the real-world conditions that will be faced by engineers at most intersections. Unless the intersection is new or being completely rebuilt, it will often be difficult to achieve the optimum placement of APS.

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The adjustment of the volume of the APS is critical for neighborhood acceptance and for usability by pedestrians who are blind. Even with ambient sound response, this is a difficult balance to strike. While most blind pedestrians felt the volumes were slightly too quiet, researchers thought some of them were too loud for neighborhood acceptance, particularly if they had been in residential locations. At one intersection in this research, volume of devices was turned down and severely baffled in response to a neighbor's complaints. Part of the problem may have been that the device had been installed and left over the weekend with the locator tone volume much too loud, due to a misunderstanding of the volume adjustment. Community objections to APS and locator tones are likely to affect the installation of APS, so proper volume adjustment is critical. In this research, the sound levels and ambient sound response of APS C and D were adjustable with handheld PDA-type devices and they seemed to be much easier to install and adjust.

Development in placement of APS and refinements in techniques used by pedestrians who are blind may also change their expectations about the volume of locator tones. If pedestrians who are blind continue to the edge of the street, then listen for the locator tones, it may be easier to adjust the sounds to be heard in the street vicinity and not on the approach sidewalk. And location of pushbuttons closer to the street and crosswalk location allows the volume of the locator tone and walk indication to be lower.

Use of Pushbutton

The results regarding the use of pedestrian pushbuttons by pedestrians who are blind indicates that typically, pedestrians who are blind do not use pedestrian pushbuttons. In Charlotte, where it is common to require pushbutton actuation for only the major street crossing at an intersection, 7 out of 20 participants said they usually do not use pushbuttons, 6 said that they usually do, and the other 7 said they do only when they know that the pushbuttons are there. In related research in Charlotte, 16 blind participants crossing at complex, unfamiliar signalized crossings, without APS, did not look for pushbuttons on any of the 64 crossings at which pushbutton actuation was necessary (*26*). Even in Tucson, where use of a pushbutton is required to actuate the WALK signal for both the major and minor street crossings at most signalized intersections, 9 of 20 participants said they usually do not use pushbuttons, 6 said that they usually do, and the other 5 said they do only when they know that the pushbuttons are there or the intersection is particularly difficult. In the Tucson experimental trials under the no information condition, only five participants looked for the pushbutton on every crossing, and at each of these intersections, one additional person (different people) looked for the pushbutton.

Learning Pole/Device

In the general and specific information conditions in both cities, most participants (98%) searched for the pedestrian pushbuttons, probably because they had been told that the pushbutton had to be used to actuate the APS, and the locator tone had been explained. In the no information condition, some were observed to wonder out loud about the locator tones that they heard, but few had actually investigated the pushbuttons or tried to determine where the tones were coming from.

Two types of subjective data support the usefulness of locator tones. First, participants were asked, following each crossing for which they used the pushbutton, how they located the pushbutton. This was an open-ended question, permitting multiple responses. Participants said they used the locator tone on most trials, regardless of device (Tucson 95%, Charlotte 83%). The

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lower percentage in Charlotte is largely the result of low rates of locator tone use on one device, where the volume was too quiet. Furthermore, when asked following each trial on which they had specific familiarization and experience with the four APS devices, to rate their agreement with the statement "The locator tone helped me find the pushbutton," mean responses for each device at each city were all in the positive direction. All APS across both cities received an approximately equal number of positive and negative comments, and no particular APS locator tone resulted in a higher percentage of participants finding the pushbutton.

The presence of a locator tone to inform pedestrians of the presence of a pushbutton and its location may also influence the use of pushbuttons, since five participants in Tucson and seven participants in Charlotte said they used pushbuttons if they knew they were there and where to find them.

However, the presence of a locator tone does not guarantee that pedestrians who are blind will find the pushbutton, even with specific information about the type of APS. In the specific information condition when participants looked for the pushbutton on 100% of trials, they failed to find the correct pushbutton on 21% of trials in Tucson and 16% of trials in Charlotte. Possible reasons for this failure are that participants were not experienced at the task of looking for a pushbutton and maintaining orientation, so some found and used the wrong pushbutton (recorded as did not find pushbutton) or participants may have had difficulty locating the pushbutton and requested assistance (also recorded as did not find pushbutton). When data are examined for finding both correct and incorrect pushbutton for a crossing, participants found a pushbutton on over 90% of trials in both the general and specific information conditions. In the specific information condition, participants found a pushbutton on 95% of trials in Tucson and 99% of trials in Charlotte. However, some still found and used the incorrect pushbutton while others found the incorrect pushbutton and identified it as such without activating it, but then did not proceed to find the correct pushbutton. This may indicate the need for additional training and techniques for locating pushbuttons and recognizing the correct pushbutton, along with the provision of APS with longer tones.

Of concern to the researchers in the no information condition were comments of some participants who seemed to be trying to use changes in the locator tone volume (in response to ambient sound) as a walk indication. These participants generally did not look for or push the button, but heard the audible locator tone, and without knowledge of locator tones and their function, made an assumption that it was some kind of walk indication. This misunderstanding of the audible sound adjustment and of the locator tone could lead to dangerous crossings. Where pushbutton-integrated devices with locator tones are installed, it may be necessary to make a concerted effort to provide information about the devices to individuals in the community.

Pushbutton Design and Features

Pushbutton Style

Indirect evidence for difficulty in finding the two pushbuttons that were atypical, the flat-panel pushbutton, and the flat recessed circular pushbutton, was found in the latency to find and push the correct pushbutton. The time included both the time to find the pole and the device, and the time to locate and use the button on the device. In the condition in which participants only had a general description of APS features, the two unusual pushbuttons took significantly longer to locate and push than the two buttons that were typical. When participants had specific

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information about and experience with the various pushbuttons, all differences in latency disappeared.

Style of pushbutton was frequently mentioned when participants were asked what they like most and least regarding each APS. The two APS having two inch diameter rounded pushbuttons "that pushed" drew a number of positive comments to the open-ended question.

On the basis of the objective latency results and the subjective preferences, it is recommended that the APS have a clearly defined pushbutton that is actually identifiable. While protruding buttons did receive positive comments from participants, there was not enough evidence to warrant such a recommendation. It is also important to remember that any pushbutton needs to be designed to deter vandalism. The greatest design in the world is useless if the button has become inoperable as a result of vandals.

Tactile Arrow

In Tucson, increased information did not significantly affect use of tactile arrows. Almost 69% of participants used the arrow in the general information condition and 73% used it in the specific information condition. However, in Charlotte, increased information also led to significantly greater use of the tactile arrows, from 87% of trials following general information to 100% of trials following specific familiarization.

In Tucson, the tactile arrow was more likely to be used on the APS C devices than on others. The tactile arrow was on the pushbutton of APS C. It was also on the pushbutton of APS B in Charlotte and may have contributed to more use of the arrow on APS B there. However, the increased usage of the arrow on the pushbutton was not enough evidence to support a recommendation along these lines. While the arrow may have been "identified" more often when located on the pushbutton, there was no evidence that it was used more often for wayfinding when compared to arrows located at other places on various APS.

One of the purposes of the tactile arrow is to identify which street the pushbutton controls. Use of the tactile arrow and the incorrect pushbutton presented a very different picture in Charlotte than in Tucson. In Tucson, while participants looked at the arrow on the incorrect pushbutton on 28 trials, they always correctly rejected the incorrect pushbutton. However, in Charlotte, participants found the arrow on the incorrect pushbutton on 63 trials, and correctly rejected it on only 41 trials (65%). While there was a decrease in overall use of the wrong pushbutton from the general to the specific information condition, participants still failed to reject the incorrect pushbutton on 20% of trials (6/30) following specific information. To observers, participants in Charlotte seemed less skilled, particularly in orientation. The confusion of pushbuttons seemed to be related to the participants' lack of strategies to maintain their orientation. Some would completely turn to face the street parallel to their travel path, while examining the arrow on the device and then push the button and line up to cross the parallel street. See additional comments on this subject under wayfinding.

Extended Button Press

Additional optional features on pushbutton-integrated APS are activated by an extended button press. These features included street name information provided in the pushbutton information message and a louder signaling (beaconing) feature. Where speech messages are used for this information, it may be necessary for pedestrians to know the street names in order to recognize which street is being signaled. This is particularly true at corners where two

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pushbuttons are mounted on the same pole, although that situation was not included in this research. In both cities, the increase in use of the extended button press following specific information was significant, from 38.8% to 77.8% in Tucson, from 17.7% to 71.1% in Charlotte. This may indicate that more specific information and training is necessary if use of the extended button press is expected.

Pushbutton Information Message

The pushbutton information message provided additional intersection information (street names) in response to an extended button press during the flashing or steady don't walk intervals. As mentioned above, in the general information condition, few participants used the extended button press that was required to actuate the message. However, following hands-on familiarization with each of the three APS having this feature, participants chose to use the feature on more than 70% of crossings in both cities. When asked to mention features they liked most or least on each APS, there were a number of positive comments regarding the pushbutton information message, and there were no negative comments. Mean ratings for the statement "The pushbutton information message was easy to understand" were all at or above 4.0 (=Agree).

Crossing Timing

WALK Signals

There was significant improvement in all measures of crossing timing between the no information and the general and specific information conditions in Tucson. The measures were latency (time to start crossing), starting during the walk interval, completing crossing during the flashing DON'T WALK, completing crossing during the steady DON'T WALK, and completing crossing before the onset of perpendicular green. This is likely attributable to increasing use of the pushbutton and thus presence of the audible WALK signal. If greater use of the pushbutton, and consequent presence of the WALK signal, accounts for increased starting during WALK, then starting during the walk interval may be increased by education and training of individuals who are blind about the use of pushbuttons and their effect on signal timing. In Tucson and Charlotte, there were no significant differences on measures of crossing timing between the general and specific information conditions.

There were three types of WALK indications used in the devices installed in this research – speech messages, bird calls (cuckoo-cheep) and the rapidly repeating tone indication (rapid tick). In Tucson, in the specific information condition, starting to cross was significantly faster at APS D (rapid tick) than at any of the other devices. The pattern was similar in Charlotte, but did not reach significance. It appears that once pedestrians understood the crossing signal, the rapid tick crossing signal provided the best cue in terms of starting to cross quickly in both cities. The bird call tones and speech messages work all quite similar in both cities. The faster response to the rapid tick signal is supported by results of research on pushbutton location and nature of WALK signal, conducted under this same project, in which responses were quicker to the rapid tick than to cuckoo/chirp tones or to speech messages (see *Chapter 4*) (37).

Beaconing/Locator Signal

One APS provided beaconing with a locator signal that was re-activated by the same extended button push that actuated the pushbutton information message when it was present. Therefore data on use of the extended button press does not clearly indicate whether the extended press was used to actuate the pushbutton information message, the locator signal, or

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both. When asked to rate the extent of their agreement with the sentence, "The louder signal feature was helpful," the mean rating was positive (3.94), with only four participants giving it a negative rating, possibly because they did not think the signal got loud enough.

Another APS provided a pedhead-mounted speaker that was aimed toward the middle of the street and possibly provided beaconing during the WALK interval. However, for all signals, collapsing across cities and information conditions, less than 35% agreed that they used the signal to help them find the opposite corner. The most interesting finding here is that, for each city and each information condition, the numbers of participants who reported using the APS to help them find the opposite corner are very similar for all devices. That is, even though APS C and A had beaconing features, there is no clear pattern that participants reported using those signals more than other devices to find the opposite corner. Researchers observed some participants altering their path to travel straight toward the pushbutton (and louder locator tone) of APS C in Charlotte, but participants did not seem to realize that they had done so.

The lack of reported use of the signal to guide the pedestrian to the opposite corner is likely attributable to a number of factors. Participants who used dog guides (4 in each city) reported that they just followed their dog's guidance in the street. Others stated that they were using vehicles for their alignment cues, or that they could not hear the locator tone of the APS until they were within a step or two of the opposite curb, so they did not really use it. Ongoing research in another project is investigating additional beaconing options and may provide more insight in this area (76).

Wayfinding

Collapsing across information conditions, it does not appear that any APS reliably provided more useful information than any other with respect to wayfinding. Furthermore, no specific type of interaction (general interaction, use of tactile arrow, or use of extended message) shows reliable improvement or impoverishment of ability to find and align to the crossing. Because of observations in Tucson, data were collected in Charlotte on whether participants were standing immediately beside the pushbutton to begin their crossing. This sometimes resulted in them being outside the crosswalk lines when beginning their crossing. Almost all (97%) were either at the pushbutton or within the crosswalk when beginning their crossing. This behavior indicates that APS pushbuttons should be placed close to, or within, the extension of the crosswalk lines.

It was the observation of the orientation and mobility specialists involved in data collection that most participants did not use any type of consistent strategy to maintain their alignment or to realign when having to interact with a pushbutton. Most deviated on their approach to the street to check any pushbutton and locator tone they heard, and some became completely disoriented and "lined up to cross the wrong street. The most common techniques taught for aligning to cross streets involve maintaining initial approach alignment and utilizing traffic traveling through the intersection to align. Where pushbuttons are used, the individual often must depart from the approach path to push the button, and the crossing must be made on the next through traffic phase without waiting through a cycle to align, which prevents the use of those techniques. Additional techniques and strategies are needed by blind pedestrians where pushbuttons are used.

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Recommended Features of Pushbutton-integrated APS

As noted at the beginning of this summary, the results do not present a completely focused picture of one device and set of features that will provide unambiguous information. However, they do provide insight into use of various features and the information needed by pedestrians who are blind to use the APS and their features efficiently. Based on the objective data recorded for the 40 participants who made crossings, as well as subjective information obtained from these individuals, the APS should have the following features at all installations:

- Pushbutton locator tone (any)
- Clearly defined pushbutton that is tactually identifiable
- Tactile arrow (exact location on APS unit is not defined)
- Audible WALK indication (see discussion below on speech vs. tones)
- Vibrotactile WALK indication
- Responsive to ambient sound

Subjective preference for speech WALK signals was much greater than for tones. However, it is impossible to make speech WALK signals understandable to all users, including the large population having age-related upper frequency hearing loss in addition to visual impairment, under all ambient sound conditions. Furthermore, other research conducted in this study and described in the next chapter showed that understanding of which crosswalk has the WALK indication is significantly more accurate with rapid tick walk indicators located close to the crosswalk than with speech signals or two different tone signals. Finally, response to the correct WALK indication was faster with the rapid tick signal, leading to less delay in starting to cross the street, and increasing the likelihood that crossings would be completed during the flashing DON'T WALK interval. So despite the subjective preference, rapid tick is recommended for the WALK signal. Nonetheless, where two pushbuttons must be installed on the same pole, speech message WALK indications are needed to resolve ambiguity in which crossing has the WALK interval (see Chapter 5).

Under certain circumstances, the following secondary APS features are also desirable:

- Pushbutton information message
- Louder signal (audible beaconing)
- Tactile map of crosswalk

The recommended guidelines in Chapter 7 provide more guidance on when these secondary features may be desired.

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CHAPTER 4

Experimental Trials on Pushbutton Location and WALK Indicator

INTRODUCTION

It is critical that any APS system provide clear information as to which crosswalk has the walk interval. Presently, APSs in the United States are not located at intersections in any consistent pattern, nor do APSs use consistent sounds to convey the WALK indication. Pedestrian pushbutton location is also not standardized in the United States, which makes it difficult to provide unambiguous audible WALK indications when an APS is added to an existing pedestrian signal.

Many cities in the U.S install pedestrian pushbuttons for crosswalks in both directions on a corner on a single pole. There are various reasons for this practice:

- Many installations use a single pole on a corner for span wires or mast arms to support traffic signals; money is saved by placing both pushbutton units on the same pole rather than installing additional poles with associated wiring and conduit.
- Poles are sometimes installed at various locations on the corner due to limited right of way or infrastructure constraints (e.g., underground utilities).
- AASHTO design guidelines discourage poles near the curb for vehicular safety reasons and to prevent turning trucks from damaging poles.

The *Manual on Uniform Traffic Control Devices* (*MUTCD*) 4E.08 reads "Pedestrian pushbutton detectors should be capable of easy activation and conveniently located near each end of the crosswalks" (1). However, poles where pushbuttons are located vary greatly in distance from the crosswalk. *MUTCD* 4E.09 provides that "At corners of signalized locations with accessible pedestrian signals where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 3 m (10 ft)", and pushbuttons for APS should be located "adjacent to a level all-weather surface to provide access from a wheelchair, and where there is an all-weather surface, wheelchair accessible route to the ramps within 1.5 m (5 ft) of the crosswalks extended, within 3 m (10 ft) of the edge of the curb, shoulder, or pavement and parallel to the crosswalk to be used" (1). The U.S. Access Board's *Draft Guidelines for Accessible Public Rights-of-Way*, applicable to new construction and alterations, would also require that accessible pedestrian signals (APSs) be separated by at least 10 ft (2).

This set of experiments was undertaken to build on the knowledge base of why APSs are needed and to understand the importance of appropriate installation techniques. The primary purpose of this study was to determine the effect of three factors on the ability of pedestrians with visual or cognitive impairments to determine which crosswalk at a corner had the WALK signal. The factors under investigation were as follows:

1) Whether there were significant advantages to installing two poles on a corner, each with its own pushbutton-integrated APS, over installing two pushbutton-integrated APSs on a single pole.

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2) whether proximity of these poles to the curb influenced the ability of participants who had visual or cognitive impairments to push the correct pushbutton and to know when the WALK signal came on for the street in front of them.

3) Whether there were significant advantages to using the same sound, versus two different sounds, versus two speech messages to indicate the walk interval.

METHOD

Participants

Participants for this effort were selected with the goal of comprising groups that included persons with a wide age-range, balanced as closely as practical to frequency of independent travel and frequency of crossing at unfamiliar intersections. Altogether, there were 90 adults who were visually or cognitively impaired and who, by self-report, independently traveled outdoors on at least one route and crossed signalized intersections. Half of the participants had some degree of visual impairment, and half of the participants were cognitively impaired.

Local recruiters having extensive knowledge of, and contacts within, agencies or organizations relevant to each group of participants were hired, and the participants were recruited by word of mouth, flyers, and distributed e-mails. Many participants were associated with one of the following agencies: the Oregon Commission for the Blind, the ARC (formerly Association for Retarded Citizens) of Multnomah and Clackamas Counties, Independent Living Resources, the Brain Injury Association of Oregon, Traumatic Brain Injury Club, Legacy Good Samaritan Hospital, and Medical Center Young Adult Support Group.

The following information was gathered during personal interviews with persons with visual impairments who had expressed an interest in participating: date of birth, highest level of education, amount of vision (including ability to see walk/don't walk signs, poles, and crosswalk lines), etiology, date of onset of disability, additional disabilities, type of travel aid used, self rating of travel ability, frequency of independent travel, and frequency of crossing at unfamiliar intersections. Interviews with participants who were cognitively impaired gathered similar information: date of birth, highest level of education, amount of vision, date of onset of disability, additional disabilities including seizures, living situation, street crossing practices, frequency of independent travel, and frequency of crossing at unfamiliar intersections.

Forty-five participants with visual impairments were divided into three subgroups, of 15 participants each, based on their ability to see pedestrian signals, crosswalk lines, and poles. The group that had the least vision (referred to as totally blind) reported that they were totally blind or had only light perception and could not see pedestrian signals, crosswalk lines, or poles. This group ranged in age from 21 to 78, with a mean age of 47.6 years. Another group (referred to as legally blind) reported they were legally blind, some of them could occasionally see pedestrian signals and either occasionally or usually could see crosswalk lines and poles. This group ranged in age from 22 to 85, with a mean age of 51.6 years. A third group (referred to as low visual acuity) had visual impairments, but they were not necessarily legally blind and could usually see pedestrian signals, crosswalk lines, and poles. This group ranged in age from 19 to 74, with a mean age of 48.6 years. Participants who normally used a long cane as a travel aid in all the subgroups used a long cane during the research. No participant used a guide dog as a travel aid.

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Forty-five adults with cognitive disabilities were also divided into three subgroups of 15 participants. One group was composed of people who had had head injuries. This group ranged in age from 22 to 57, with a mean age of 45.9 years. Another group was composed of people who had had strokes and whose vision and hearing might have been affected, but who were not legally blind. This group ranged in age from 35 to 78, with a mean age of 52.5 years. A third group was composed of people who were developmentally delayed. This group ranged in age from 19 to 85, with a mean age of 49.1 years. All participants were cognitively capable of personally consenting to participation, and all said they independently crossed streets at signalized intersections.

Location and APS Equipment

The intersection of NE 7th Avenue and NE Multnomah Street in Portland, Oregon was equipped with eight pushbutton-integrated APS units that were mounted on temporary poles, with pushbuttons located 42 inches from the ground. In pushbutton-integrated APS, audible signals come from the pushbutton housing, unlike pedhead-mounted APS, in which the audible signals come from a speaker mounted in or on the pedhead. The pushbutton-integrated APS units used in this study included a pushbutton locator tone, automatic volume adjustment in response to ambient noise level, a tactile arrow that vibrated during walk interval (aligned in the direction of travel on the associated crosswalk), an audible "click" sound and red LED to confirm that the button had been pressed, and an audible WALK indication that varied during the experimental conditions.

The pushbutton locator tone is intended to aid approaching pedestrians with locating the pushbutton and to inform them that they need to push a button to receive a pedestrian signal and the extended green time needed to cross the street. The tone repeated once per second and was adjusted to be audible only six to twelve feet from the pushbutton. The audible WALK indications varied during the experimental conditions and were changed by the researchers with the use of a handheld programming unit supplied by the manufacturer (Polara Engineering).

Two APSs mounted on a single pole were used on two corners, and APSs mounted on two separated poles were used on the other two corners. On corners A and D (the northwest and northeast corners), the two APSs for crossing both streets at each corner were mounted on a single pole; on corners B and C (the southwest and southeast corners), the two APSs on each corner were mounted on two poles separated by at least 10 feet (*see Figures 4-1 and 4-2*), meeting the guidelines of the *MUTCD* as previously described.

Distance of the poles from the street was also varied. On corner A, the pole was installed approximately 3 feet from each street, and on corner D, the pole was installed approximately 10 feet from each street. The same was true for the corners with two pushbutton poles: on corner C, each pole was installed approximately 3 feet from the street, and on corner B, each pole was installed approximately 10 feet from the street.

The choice of tones and speech messages used in the experiment was based on current practice and on recent laboratory research (*58, 59*). The single tone used was a rapid tick, as this tone has been found to be more highly detectable than other tones in use or proposed for APS. When two tones were used, they were the rapid tick and cuckoo. The cuckoo sound was selected over the chirp sound (both are often used together at an intersection) because it is not the same as any birdcall in the U.S., it is not mimicked by any birds common to the U.S., and it is more

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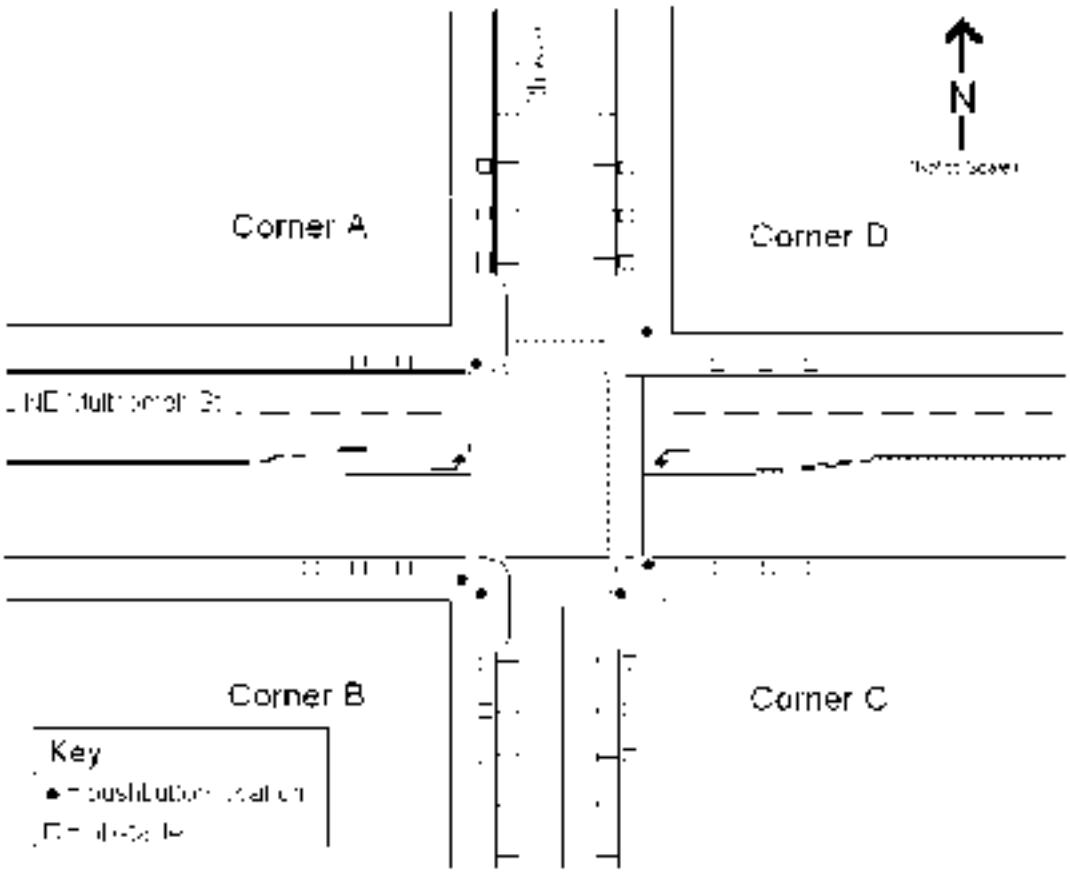

Figure 4-1. Intersection diagram for NE Multnomah Street and NE Seventh Avenue in Portland, OR.

detectable than the clamp sound. However, the cuckoo sound is not as detectable and localizable as the rapid tick.

There were two possible sound conditions on each corner. The audible WALK indication was set by the researchers for either: two different tones (cuckoo and rapid tick) or two same tones (rapid tick) on the corners having two poles. On the corners with just one pole (see *Table 4-1*), the audible WALK indication was either two different tones (cuckoo and rapid tick) or two speech messages ("7th, walk sign is on to cross 7th" or "Multnomah, walk sign is on to cross Multnomah."

The total duration of all audible and visual WALK indications was seven seconds. There was a 0.5 second pause between repetitions for all sound conditions. Each speech message repeated twice during each WALK interval, and the cuckoo and rapid tick messages repeated three times during each WALK interval. This variability was due to the length of the messages. Each speech message was approximately 3 seconds, and each repetition of the cuckoo or rapid tick was approximately 2 seconds.

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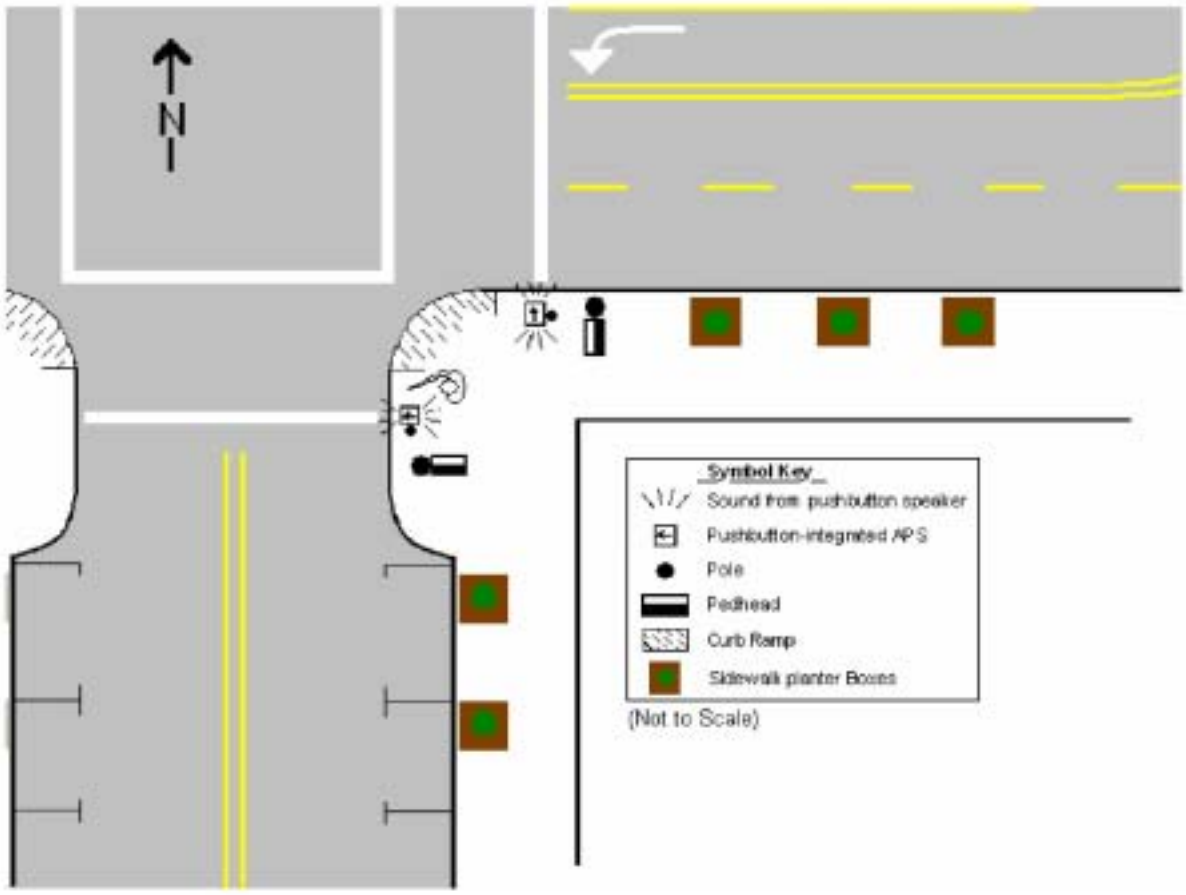

Figure 4-2. Diagram of Corner C (southeast corner of NE Multnomah Street and NE Seventh Avenue in Portland, OR).

To reiterate, two sound conditions (two tones or two speech messages) were assigned to corners having a single pole (corners A and D), and two sound conditions (two different tones or same tone) were assigned to corners having two poles (corners B and C). Testing every sound condition at every corner would have resulted in an experiment that required two sessions. Additionally, testing the same tone from each APS at corners having a single pole would have been noninformative. If both APSs have the same tone coming from the same location, there is no cue to indicate which crosswalk is being signaled. However, on corners having two pushbutton poles separated by at least 10 feet, it may be possible to hear which pushbutton is sounding. Researchers recognized that either two different tones or speech messages could have been used in APSs at corners having two poles; both would have provided information that was redundant to the cue that was provided by the location of the APS. A decision was made to use the most commonly used strategy in the U.S., which is the use of two different tones.

Procedure

All 90 participants were individually tested in approximately one-hour sessions. First the participants were familiarized with a nonfunctioning demonstration unit of the APS that included the tactile arrow indicating the direction of the associated crosswalk. Participants then listened to

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a tape recording of the various sounds that would come from the APS. The sounds included a locator tone and the three possible WALK indications. The participants were told that they were to identify the walk interval on the street in front of them by raising their hand. Participants were told that they could use the visual WALK signal if they could see it, the pushbutton sounds or messages, or the traffic. They were encouraged to use any information that they would normally use to determine when the WALK signal comes on. Then the participants were guided to the starting location for the first trial.

Before the participant arrived at the corner, the APS devices were configured to one set of the possible WALK indication sound conditions. The APS devices on corners having two poles were randomly set to either the same tone condition (rapid tick – condition 1) or two tones condition (cuckoo and rapid tick – condition 2). While the starting settings were determined randomly, the two corners with two poles were always set up for the same condition (#1 or #2) for each block of trials. The two APS units on each corner having a single pole were randomly set to either the two-tones condition or the speech message condition. Both APSs on the single pole corners were always set for the same condition within a block of trials. (*See Table 4-1.*)

Each participant completed 16 trials, which were conducted in two blocks of 8 trials with a short rest period (usually five to ten minutes) in between. For an intersection such as was used in this experiment, a pedestrian can approach each of the four corners from two different directions. Therefore, as shown in the Table 4-1, there are eight possible unique approaches/crossings at the intersection. Each participant completed all eight approaches in a randomly determined order both prior to and after the rest period. During the rest period, the

TABLE 4-1 Sound conditions and crossing direction

Corner A – one pole close to the curb	Sound condition A1: speech messages	Sound condition A2: two tones
APS for crossing southbound	Multnomah. walk sign is on to cross Multnomah	Cuckoo
APS for crossing eastbound	Seventh. Walk sign is on to cross seventh	Rapid tick
Corner B – two poles 10 feet from the curb	Sound condition B1: same tone	Sound condition B2: two tones
APS for crossing northbound	Rapid tick	Cuckoo
APS for crossing eastbound	Rapid tick	Rapid tick
Corner C – two poles close to the curb	Sound condition C1: same tones	Sound condition C2: two tones
APS for crossing northbound	Rapid tick	Cuckoo
APS for crossing westbound	Rapid tick	Rapid tick
Corner D – one pole 10 feet from the curb	Sound condition D1: speech messages	Sound condition D2: two tones
APS for crossing westbound	Seventh. WALK sign is on to cross Seventh	Rapid tick
APS for Crossing southbound	Multnomah. WALK sign is on to cross Multnomah	Cuckoo

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APS devices at each corner were reconfigured to use the alternate sound condition.

For all trials, participants were positioned to start 30 feet from the pushbutton. For each trial, participants were instructed as follows:

> *"When I say Go, first, go push the button to cross the street in front of you. Then, stand where you would wait to cross the street. Raise your hand when the WALK comes on for the street in front of you, which is [street name]."*

When participants were 20 feet from the pushbutton, a stopwatch was started, it was stopped when participants pushed the correct pushbutton. If a participant pressed the incorrect pushbutton, but continued to search for the other APS, the time continued to run and was stopped it and when the participant pressed the correct pushbutton. On the other hand, when participants pressed the incorrect pushbutton and went and stood at the street demonstrating their belief that they had pressed the correct button, no time was recorded. In this instance, the experimenter would then press the correct pushbutton, and the remainder of the trial would be recorded. A stopwatch was also used to time the delay between the onset of the correct WALK signal and when participants raised a hand indicating their judgement that the WALK signal had come on for the street in front of them.

Once participants had pressed a pushbutton and taken up a position where they would normally wait to cross the street, one of the researchers always pressed the other pushbutton. By doing so, and in combination with beginning participants at certain times during the intersection phasing, the researchers attempted to ensure that on half of all trials, the first WALK signal to come on was that for the street in front of the participants while on the other half of the trials the first WALK signal was for the street beside participants. However, it was not entirely possible to achieve this balance given testing constraints.

For every trial, as soon as participants raised their hands to indicate their belief that the WALK signal for the street in front of them had come on, the trial ended, and the experimenter directed or guided them to the next starting point. A trial was also ended if, after pressing the pushbutton, a participant waited through four consecutive WALK intervals without responding.

Other information recorded on each trial included which pushbuttons the participants investigated and in which order, and which walk signal was the first to come on after the participants pressed the correct pushbutton. After the participants had completed all 16 trials, a short survey was administered to learn the attitudes and preferences of the participants towards the various pushbutton arrangements and sounds. The questionnaire addressed:

- which corner was the easiest and hardest,
- how easy it was to find and use the pushbuttons when the poles were near to or away from the curb and when the APS were on one pole or two poles,
- whether the participant used the arrow to determine which crosswalk the button controlled,
- which cues the participant used (i.e., visual signal, audible signal, or motion) to decide when the WALK had come on, and
- which walk indication was the participant's favorite and least favorite.

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Also included was the researcher's observation of what cue the participant seemed to be using during the trials.

RESULTS

The vast majority of significant findings, both practically and statistically, were found in the data collected from the two sub-groups having the least vision, referred to as totally blind and legally blind. Most of the results presented here will therefore focus upon these 30 participants. Relevant findings from the low visual acuity subgroup and the cognitively impaired group follow. Mean substitution was used to deal with all missing WALK signal response delays and pushbutton location times. For example, if a given totally blind subject was missing pushbutton location data on corner A-southbound approach-speech condition, the mean for the totally blind subjects on corner A-southbound approach-speech condition was substituted.

Accuracy in Recognizing Correct Walk Signal

For the purposes of analysis and discussion, a correct response was one in which the hand raise occurred during one of the 7-second periods in which the visual pedestrian signal for the street in front of them was in WALK. It was possible for a correct response to occur following either a correct or an incorrect pushbutton activation. This resulted from the fact that an experimenter always pushed whichever pushbutton the participant had not. This allowed response data to be collected on trials in which an incorrect button push had occurred. An incorrect response was defined a bit more narrowly than a correct response. An incorrect response was recorded when the hand raise occurred during the first WALK interval for the side street. That is, after the participants pressed a pushbutton and took up a position to wait to cross the street, the visual and audible WALK signal to cross the street beside them came on first, and participants mistook this information to mean the WALK signal had come on for the street in front of them.

As explained in the procedure section, it was not possible to ensure that for each trial there would be an equal probability that the first WALK signal to come on would be for the street in front of the participant vs. the street beside the participant. Therefore, the number of trials in which an "error" was possible varies between corners and individual pushbutton position and sound conditions. The error rates presented in this section reflect the number of incorrect responses divided by the number of trials in which an error was possible (i.e., trials in which the first WALK signal after a pushbutton was pushed was for the street beside the participant). Error rates were calculated using a few different operational definitions of what constituted an error, and regardless of the method chosen the rank order of the corners remained the same. Therefore, this method for calculating error rates was chosen because the researchers felt that it best addressed the issue of whether or not the pole placements and sound conditions provided either ambiguous or unambiguous cues for the onset of the WALK signal.

One of the most striking findings of this study was the very low error rate at the two pole near the curb configuration of corner C (4.53, 7.55%); see *table 4-2*. No other pushbutton configuration resulted in less than a 26.9% error rate. Next, the other two pole configuration (corner B) resulted in a lower error rate than both of the single pole corners. However, due to a lack of independence of the measures (i.e., repeated measures design), no statistical test could confirm whether or not the two pole configurations resulted in overall lower error rates than the

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TABLE 4-2 Error in recognizing correct WALK signal, by corner

Corner	# of incorrect responses/total possible instances	error rate
A	17/56	30.36%
D	19/52	36.54%
C	4/53	7.55%
B	14/52	26.92%

corners with a single pole. Nevertheless, the actual differences between error rates in most of the situations discussed here are quite substantial.

For the corners with two poles, there were two possible audible signal conditions, same tone (sound condition 1) or two different tones (sound condition 2). In the same tone condition, a rapid tick indicated the onset of the WALK signal for both street crossings, while in the two different tone condition, a cuckoo signaled the northbound or southbound crossing and the rapid tick signaled the eastbound or westbound crossing. For the corners with a single pole, there were also two possible audible signal conditions, two different tones (condition 2) or two speech messages (condition 1). The two tone sound condition produced higher error rates on each corner than the corresponding same tone condition or speech message condition. (*see Table 4-3*) Overall, the two different tone/sound conditions resulted in a 36.27% error rate (37/102). For the two pole APS arrangements at corners B and C, the two different tone sound condition resulted in 12 errors on 52 possible trials (23.08%), while the same tone sound condition resulted in half as many errors (6/53, 11.32%). On corner C (two pole near the curb configuration), the error rate was a mere 3.57% (1/28) for same tone condition. For the single pole APS arrangements at corners A and D, the two tone sound condition was especially troublesome, causing errors on 50% of the possible trials (25/50). The speech message condition resulted in much reduced error rate of 18.97% (11/58).

Walk Signal Response Delay

For pedestrians to safely cross at signalized intersections, they should begin crossing during a walk interval for the street they wish to cross. It is also important that they begin crossing as soon after the onset of the WALK signal as possible to allow themselves adequate time

TABLE 4-3 Error in recognizing correct WALK signal, by corner and sound condition

Corner/sound condition	# of incorrect responses/ total possible instances	Error Rate (%)
A1 / Speech	7/33	21.21
A2 / 2 Tones	10/23	43.48
D1 / Speech	4/25	16.00
D2 / 2 Tones	15/27	55.56
C1 / Same Tones	1/28	3.57
C2 / 2 Tones	3/25	12.00
B1 / Same Tones	5/25	20.00
B2 / 2 Tones	9/27	33.33

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to cross the street before the onset of perpendicular traffic.

WALK signal response delays measured from the onset of the corner WALK interval for totally blind and legally blind participants were both low and consistent for the two-pole, near the curb pushbutton arrangement at corner C. Regardless of the sound condition (same tone vs. two different tones) on approach direction, it took participants approximately 2.0 seconds to correctly respond to the onset of the WALK signal at corner C. Planned comparisons revealed significantly faster responses to the signals at corner C than those at corner A ($F(1,29)=8.598$, $p\leq0.011$, corner B ($F(1,29)=6.156$, $p\leq0.051$, and corner D ($F(1,29)=31.459$, $p\leq0.0001$), (see *Figure 4-3*).

It was discussed earlier that for corners with a single pole, the two speech messages condition resulted in a much reduced error rate compared to the two different tones conditions. The effect of the speech messages on the walk signal response delay is not as clearly defined or, in most instances, as positive. At corner A, the speech message WALK indication resulted in significantly faster responses than did the rapid tick WALK signal ($F(1,29)=8.533$, $p<0.011$), however, the mean response delay for the speech condition (2.5 sec) was slower

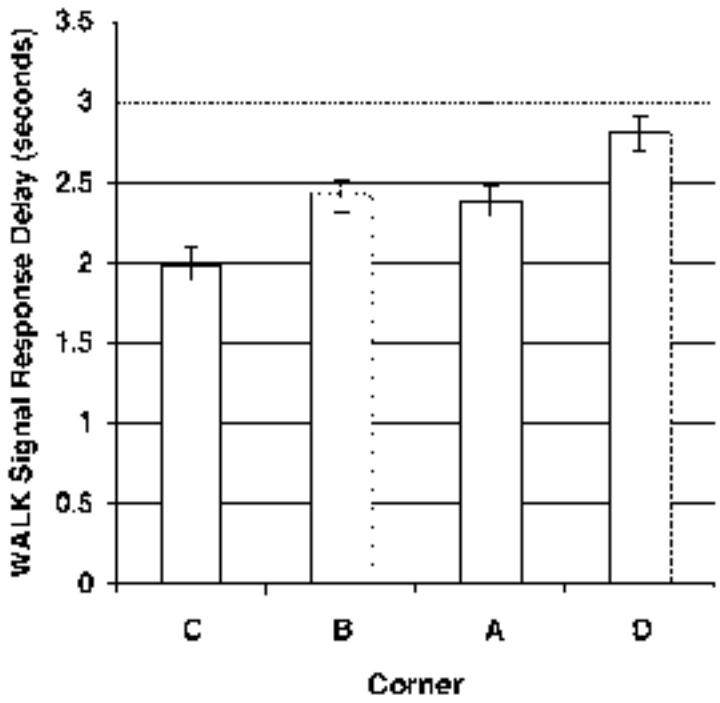

Figure 4-3. Mean WALK signal response delay by corner.

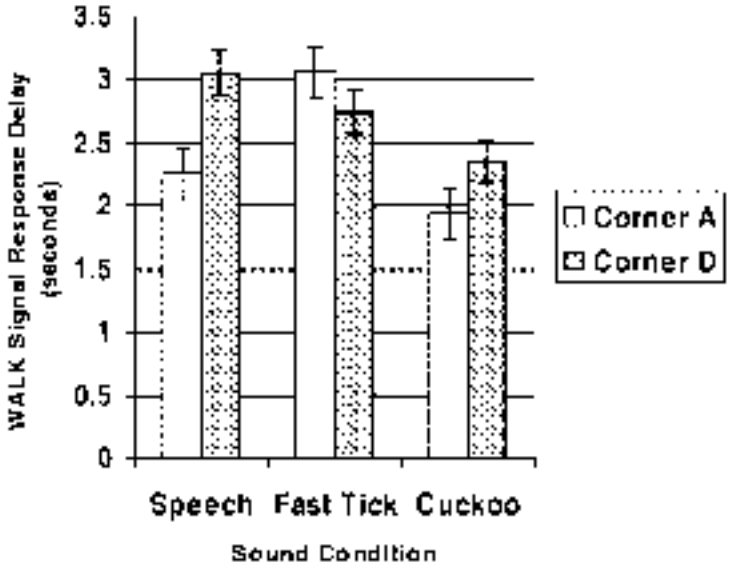

Figure 4-4. Effect of sound condition on WALK signal response delay at corners with two APS on one pole.

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than that for the cuckoo WALK signal (1.9 sec; *see Figure 4-4*). This difference did not however achieve significance ($F(1,29)=1.604$, $p > 0.05$). At corner D, the mean response delay for the speech message WALK signal was quite high (3.1 sec) and was slower than the mean response delays for the rapid tick WALK signal (2.7 sec) and for the cuckoo WALK signal (2.4 sec). The speech message WALK signal resulted in significantly slower responses than the cuckoo ($F(1,29)=6.976$, $p < 0.05$), while the difference between response delays for the speech message and the rapid tick failed to reach significance ($F(1,29)=2.407$, $p > 0.05$).

Pushbutton Location Times

Another factor of particular interest is how quickly blind participants were able to locate and press the appropriate pushbutton given the different APS arrangements at the four corners of the intersection. The pushbutton location times were measured from the time the participant crossed a line that was 20 feet away from the appropriate pushbutton to the time that they pressed the correct pushbutton. Again, when participants were unable to find the correct pushbutton or pressed the incorrect pushbutton and stopped searching for the correct button, no pushbutton location time was recorded. On average, pushbutton location times were fastest at corners D (13.6 seconds) and A (14.95 seconds; *see Figure 4-5*). While the difference between mean pushbutton location time at corners D and A was not statistically significant ($F(1,29)=2.497$, $p>0.05$), the mean pushbutton location time at corner D was significantly faster than that at corners C ($F(1,29)=8.838$, $p<0.05$) and B ($F(1,29)=20.156$, $p<0.005$). The mean pushbutton location time at corner A was significantly faster than that at corner B ($F(1,29)=13.049$, $p< 0.1$), but was not significantly faster than that at corner C ($F(1,29)=1.395$, $p>0.05$).

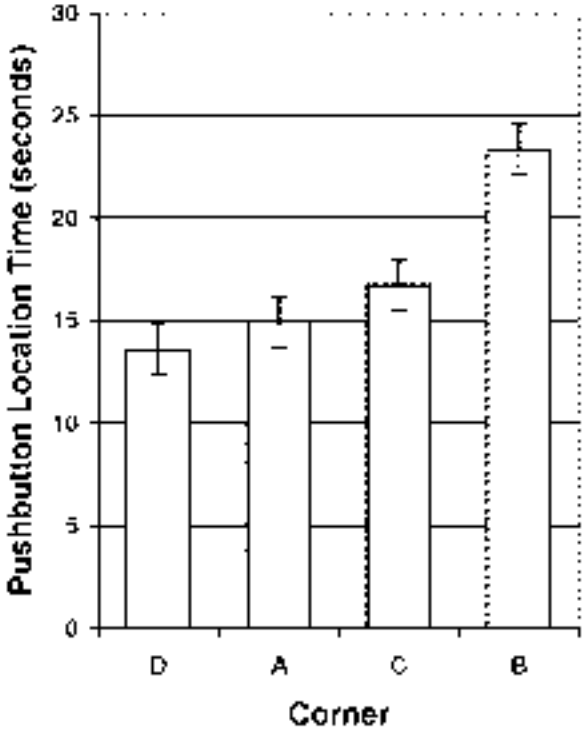

Figure 4-5. Pushbutton Location Time by Corner.

One result of interest was the very large discrepancy in pushbutton location times between northbound approaches to corner C (12.0 seconds), and westbound approaches to the same corner (21.6 seconds). Figure 4-6 clearly shows that the mean pushbutton location time for the northbound approaches to corner C was amongst the fastest across all approaches and corners. Also, the mean pushbutton location time for northbound approaches to corner C was significantly faster than the mean pushbutton location time for westbound approaches to the

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same corner ($t_{(1,29)}=-81.968$, $p<0.001$). Possible reasons for this discrepancy will be addressed in the discussion.

Low Visual Acuity Subgroup

The analysis of the data collected from participants with low visual acuity (the subgroup with the most vision) demonstrated very few statistically significant differences; however, the majority of the trends in the data matched those for the totally blind and legally blind sub-groups. While the overall error rate for the low acuity group was only 5.36% (6/112), five of the six errors occurred on trials with the two different tone sound condition on corners A and D, the two most difficult conditions for the totally and legally blind participant sub groups. Also similar to the analysis described above, mean WALK signal response delay at corner C (1.1 sec) was faster than those at all of the other corners (corner D, 1.2 sec, corner B, 1.3 sec, and corner A, 1.4 sec). The differences were moderately significant between mean WALK signal response delays at corners C and A ($p=.066$) and those at corners C and B ($p=.077$). It is of particular interest that although most members of this group of participants could see the visual walk signal, the same pattern of results as those obtained from participants with less vision emerges. This point will be addressed further in the discussion.

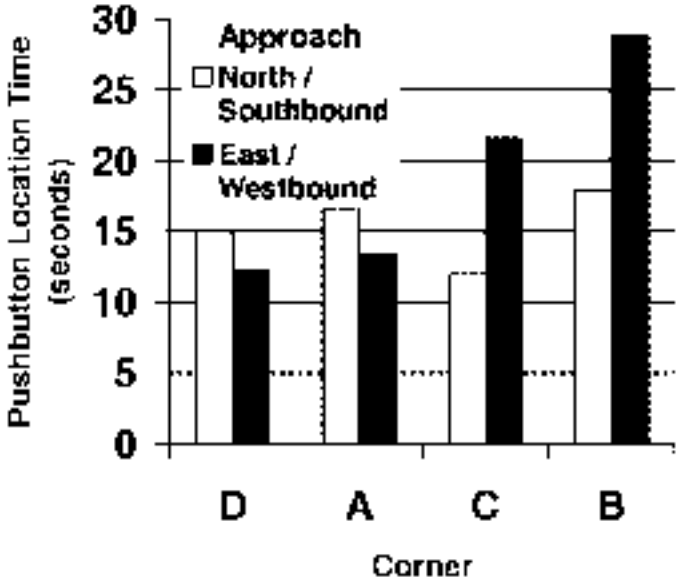

Figure 4-6. Pushbutton Location Time by Corner and Approach.

Although the speech command resulted in no errors with this subgroup, it did result in the slowest response times at both corners A and D. At corner A, the speech message resulted in significantly slower responses than did the cuckoo ($t_{(1,29)}=-6.230$, $p<0.01$), but the mean WALK signal response delay for the speech message (1.6 sec) was not significantly slower than that for the rapid tick (1.4 sec). At corner D, no comparisons reached significance; however the mean WALK signal response delay for the speech message (1.3 sec) was slower than the delays for the cuckoo (1.1 sec) and the rapid tick (1.2 sec).

One difference from the participants who are totally blind or legally blind is in the ability of the participants with low visual acuity to efficiently find the correct pushbutton. The low visual acuity participants had little difficulty finding the correct pushbutton for the westbound approach to corner C. As a result, the fastest pushbutton location times for this subgroup were obtained at corner C (0.6 sec), although all pairwise comparisons failed to reach significance. Mean pushbutton location times at corners A and D were again similar to one another (both were

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7.2 seconds due to rounding), and the slowest pushbutton location times were again recorded at corner B (7.7 sec).

Cognitively Impaired Group

The analysis of the data collected from the 45 participants with cognitive impairments similarly has few statistically significant differences; however the majority of trends in the data again matched those of the 50 totally blind or legally blind participants. The participants with cognitive impairments made very few errors (10/3621) resulting in an overall error rate of 2.76%. The few errors committed did follow a pattern similar to those of the visually impaired participants. Only two of the ten errors occurred on corners with two poles (corners B and C), and more errors were committed in the two different tone conditions (6/10) than in the same tone or speech message conditions (4/10). Once again, the mean WALK signal response delay at corner C (0.9 sec) was faster than those at all of the other corners; however, there was no significant main effect for corner ($F < 1.0$) and all mean WALK signal response delays were less than 1.05 sec. Once more, all of these participants had sufficient vision to be able to see the visual walk signal, and yet the pattern of results is again similar to the visually impaired participants.

Mean pushbutton location times at corners D (6.19 sec) and C (6.22 sec) were both significantly faster than those at corners A (6.59 sec) and B (6.57 sec). The very small difference between the most extreme mean pushbutton location times (0.40 sec) does, however, qualify the importance of the significant differences. Once more, it is noted that for these participants the westbound approaches to corner C did not cause greater difficulty in finding the correct pushbutton than northbound approaches to the same corner.

Survey Results

The self-report questionnaire data is similar to the behavioral results in some ways and dissimilar in others. While corner C produced the most favorable behavioral results, the 45 participants with visual impairments gave the single vote close to the curb configuration (Corner A) the most votes as the overall easiest corner (27/45, 60.0%), while the two-poles-near-the-curb configuration (Corner C) received the second most votes (13/45, 28.9%). Corner B (the two-poles-further-from-the-curb configuration), which produced some of the worst pushbutton location times and walk signal response delays, received the most votes as the most difficult pushbutton arrangement (34/45, 75.6%). The survey questions that most conflicted with behavioral results assessed participants favorite and least favorite sounds. Even though the rapid tick resulted in the best response accuracies and consistently fast walk signal response delays, it only received 17.8% of the vote as the favorite sound (8/45), and received the most votes as the least favorite sound (25/45, 56.6%). The speech message was the most popular of the sound messages (29/45, 64.4%), and also received the least votes as the least favorite sound (6/45, 13.3%).

DISCUSSION

Safe and legal pedestrian crossings at signalized intersections require that pedestrians correctly identify which crosswalk has the WALK indication. Positive information is provided by visual pedestrian signals and by APS (audible and vibrotactile) where they are available. Where pedestrian phasing is concurrent with vehicular phasing, the onset of the WALK signal can also be inferred by a surge of vehicular traffic going parallel to the crosswalk, from the lanes closest to

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the pedestrian. In the absence of APS, pedestrians who are unable to see visual pedestrian signals typically attempt to begin crossing with this vehicular surge.

At complex, unfamiliar, signalized intersections without APS, pedestrians who are blind often fail to begin crossing within the WALK interval for the desired crosswalk [36]. Even when APS are present, pedestrians who are blind sometimes find audible signal information ambiguous in terms of which crosswalk is being signaled [5]. It is critical that any APS system provide unambiguous information. The results indicate that pushbutton location affects the ambiguity of WALK signal information.

Accuracy in Recognizing Correct Walk Signal

On the corner having pushbutton-integrated APS on two poles near the street, participants in the totally blind and legally blind sub groups indicated that the street in front of them had the WALK signal, when, in fact, the WALK signal was to cross the street beside them, on only 7.55% of possible trials. This pole arrangement for APS devices corresponds to the arrangement that is required in some other countries, including Sweden, Denmark, and Australia [40]. For all other pushbutton-integrated APS arrangements tested in this study, participants in the totally blind and legally blind sub groups indicated that the street in front of them had the WALK signal, when it was actually the WALK signal to cross the street beside them, on at least 26.9% of trials. On these trials, if they had been crossing the street, they were likely to have started crossing at the onset of traffic on the street perpendicular to their direction of travel.

Use of the configuration with two pushbutton poles with APS near the curb, both having the same tone, resulted in excellent accuracy by participants who were unable to use visual pedestrian signals (totally and legally blind sub-groups). This pole configuration and use of same tone sound was also beneficial to participants having more vision (low visual acuity sub group and cognitively impaired groups) in determining which crosswalk had the WALK signal. This corresponds to the pushbutton pole arrangement plus WALK signal system that is common in countries using pushbutton-integrated APS [40].

Those participants who had vision sufficient to see visual pedestrian signals (i.e. the cognitively impaired participants and the low visual acuity participants) were recorded by experimenters as having typically used the visual pedestrian signals to determine the onset of the correct walk interval and they also typically reported reliance on the visual pedestrian signals. It is therefore of interest that their results are in the same direction as those for the two sub groups who were always or usually unable to see the visual pedestrian signals. It appears that, whether or not it was on a conscious level, or observable to experimenters, the participants who could see the visual pedestrian signal information were nonetheless influenced by both the pushbutton pole arrangement and the WALK signal sound. If they were not influenced by pole arrangement and the nature of the walk sound, accuracy would be expected to be the same under all pole arrangements and sounds.

Walk Signal Response Delay

Pedestrians who do not begin crossing promptly following the onset of the WALK interval may not complete their crossings before the onset of perpendicular traffic, at which time they are particularly at risk for crashes. Recent research on pedestrians who are blind making crossings at complex, unfamiliar, signalized intersections, found that on 51.4% of trials, crossings were not initiated during the WALK interval, and on 26.9% of trials, crossings were completed after the

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onset of perpendicular traffic (36). Therefore, it was of interest to measure the delay in response to the onset of the WALK signal for the correct crosswalk.

In this study, for participants who were always or usually unable to see visual pedestrian signals (totally and legally blind sub-groups), responses to the onset of the WALK signal for the correct crosswalk were significantly fastest on the corner having two pushbutton poles with APS near the curb (corner C), and responses were uniformly fast at this corner regardless of sound condition. Although the overall mean walk signal response delay for this corner was approximately two seconds and well within the normal walk interval, delay would likely be longer if actually making crossings, as pedestrians who are blind typically require a little time to determine whether there are vehicles turning across the crosswalk. Mean WALK signal response delay for blind pedestrians crossing at complex, unfamiliar signalized intersections without APS has been found to be 6.4 seconds (36).

Responses to the correct WALK signal were also fastest at the corner having two pushbutton poles with APS near the curb for the participant groups who always or usually could see the visual pedestrian signal. Mean WALK signal response delays were lower for these groups than for the groups who were always or usually unable to see visual pedestrian signals.

It appears that, whether or not it was on a conscious level, or observable to experimenters, the response delay of participants who could see the visual pedestrian signal information was influenced by the pushbutton pole arrangement. Installing pushbuttons on two poles near the curb seems to promote fast reaction time to the onset of the WALK signal, and is thus likely to promote faster initiation of crossings for pedestrians with visual and cognitive disabilities.

Pushbutton Location

By comparing the time to press the correct pushbutton at corners having pushbuttons in different pole configurations, we are able to infer the participants' ability to easily locate the correct pushbutton. This task includes deciding which pushbutton controls the street they are preparing to cross. Nearly all participants were observed to visually or tactually use the tactile and/or visual arrows on APS to confirm which crosswalk was associated with the APS, and 82 of 90 participants (91%) reported that they used the arrows. The results of this research, therefore, would not necessarily be applicable to pushbuttons that did not have tactile and visual arrows that were carefully aligned with the direction of travel on the associated crosswalk.

For the participant sub-groups in this study who had the least amount of vision and who were rarely or never able to see visual pedestrian signals, time to press the correct pushbutton was marginally faster at the two corners having two pushbuttons on a single pole. The mean pushbutton location time for the corner having two pushbutton poles far from the curb was longest. However, any advantage in speed of pressing the correct push button is far outweighed in importance by the greater accuracy in identifying which crosswalk had the WALK signal. Errors in determining which crosswalk has the WALK signal may result in crashes, while delay in locating the correct pushbutton does not typically have negative consequences for life safety.

For the low visual acuity sub-group, unlike the sub-groups having even less vision, mean pushbutton location time was fastest for the corner having two pushbutton poles near the curb. However, as for the sub-groups having less vision, mean pushbutton location time was slowest for the corner having two pushbutton poles far from the curb. For the group having cognitive

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impairments, the corner having two pushbuttons near the curb resulted in one of the two fastest times, which were not statistically different from one another.

Therefore, although the results for time needed to find and press the correct pushbutton are not as clear-cut or definitive as for speed and accuracy in identifying the crosswalk being signaled, having two pushbutton poles near the curb generally appeared to promote speed and, by inference, ease of locating the correct pushbutton.

Speed in locating the pushbutton appears to have been significantly influenced by the relationship between pushbutton location as designed to test the hypotheses of this experiment, and pushbutton location with relation to geometric idiosyncrasies at each corner. There may have been some difference attributable to slight differences in perceived loudness of each APS device as well. It was extremely difficult to make the perceived loudness of the APS signal the same from each device. Simply setting all devices the same for volume and ambient noise response is not sufficient because differences in the nature and distance of reflective surfaces at each corner also influence perceived loudness. At each corner, there was a significant difference in time to press the correct pushbutton depending on the direction from which the corner was approached.

For example, at the corner having two pushbutton poles near the curb, corner C (see *Figure 4-2*), mean time for pushing the correct pushbutton on westbound approaches was much longer than northbound approaches to the same corner. When approaching westbound, participants passed very close to the pushbutton to cross the street beside them (the parallel street) and the locator tone of that APS was usually very audible to participants. They may have been able to hear the locator tone for the pushbutton to cross the street in front of them (correct pushbutton) when they approached the incorrect pushbutton, but the loudness of the sound would have been much less. (Recall that locator tones are only intended to be heard 6 to 12 feet from the pushbutton, and the pushbuttons were approximately 10 feet apart.) Therefore it commonly occurred that participants would check the arrow for the APS for crossing the parallel street before finding and pressing the pushbutton for the street in front of them. When approaching the corner northbound, participants did not pass quite as close to the pushbutton for the parallel street because the pushbutton pole was on a bulb out in the curb line, so they did not delay to check the arrow for the parallel street before finding and pushing the correct button.

Sound Condition

The two different tone condition may have produced more errors than the same tone condition at all corners because some participants with visual impairments had previous experience with cuckoo signals at other locations in the city and may thus have been primed to respond to the cuckoo, regardless of whether it was the correct signal. This could also explain why the cuckoo resulted in the fastest response rates at the single pole corners. Nonetheless, when pushbuttons were on two poles near the curb, accuracy was equally good with two tone and same tone conditions.

The two different tone condition may have had particularly high error rates on the single-pole corners because there was no redundant APS location information to indicate which crosswalk was associated with which sound. The speech message condition resulted in lower error rates than the two tone condition, but mean WALK signal response delays for the speech message WALK condition were slower. This may reflect greater cognitive demand for processing the speech messages than the tones, or may reflect the different lengths of the sounds and

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messages themselves. A single complete speech message lasted approximately three seconds, whereas a single cuckoo lasted somewhat over one second.

Comparison of Objective Measures and Subjective Judgments

Subjective judgments of participants, recorded on the survey, were variance with objective measures in three important ways. First, corner A was the pole close to the curb and the most preferred pole arrangement with corner C (two poles far from the curb) a somewhat distance second choice. This is in contrast to objective measures in which corner C produced the fastest and most accurate responses to the walk indications. Because accuracy in responding to the walk indication is essential to safe street crossing at signalized intersections, despite the subjective preferences, the arrangement at corner C is recommended.

Second, speech messages were used at the locations with two pushbuttons on a pole and resulted in better accuracy than two tones sound condition, but less accuracy than the rapid tick. Speech messages also resulted in slower response times than the rapid tick indication. When it is possible to separate the poles, the rapid tick WALK indication is recommended.

Third, the rapid tick was the least preferred WALK indicator, but it produced the fastest and most accurate responses to the walk indication. Because accuracy in responding to the WALK signal, that is, beginning the crossing when the wrong WALK signal comes on, has direct consequences for safety in crossing, the rapid tick is preferred over other WALK indications used in this research. Verbal messages may have been rated highly simply because participants were primarily native English speakers, because ambient sound was never excessively loud, and because it provided additional information, that is, the name of the street to be crossed. The cuckoo may have been rated more highly than the rapid tick simply because it was a more familiar walk indication to some participants. Therefore despite some dislike of the rapid tick WALK indication, it is the recommended sound because it results in fast and more accurate decisions regarding which crosswalk has the WALK.

RECOMMENDATIONS

The recommended location for two pushbutton integrated APS on a single corner is consistent with Guidance in *MUTCD* 4L.09.

- Place each APS device on a separate pole, located as close as possible to the curb line.
- Place each APS as close as possible to the line of the associated crosswalk that is furthest from the center of the intersection.
- Place the two APS at least 10 feet apart.

The recommended WALK indication for APS that are located according to these recommendations is a rapid tick, or percussive sound, at 10 repetitions per second. Both APS should have the same WALK indication. Where it is technically infeasible to install two pushbuttons on a corner on two separate poles, it is recommended that verbal WALK messages following the model "*Mulnomah. Walk sign is on to cross Multnomah*" be used. Two different tones to indicate which crosswalk has the WALK interval at an intersection where there are two pushbutton-integrated APS on a single pole provides ambiguous information and may result in pedestrians crossing with the wrong signal. Speech WALK indications should be used sparingly.

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however, as it is not possible to make them understandable under all ambient sound conditions, and to all pedestrians. In this experiment, speech messages were evaluated in a situation where all participants were told the name of the street that they were approaching. If the pedestrian is not familiar with the area or is confused about the street names, the speech message, which begins with the street name, will not clarify which crossing has the WALK. If speech messages are used, additional features may be needed on the device to provide street name information to the pedestrian who is unfamiliar with the intersection. These features would include a high-contrast tactile arrow oriented parallel to the direction of travel on the associated crosswalk, and a pushbutton information message that provides the name of the street controlled by the pushbutton. Braille street name information on the APS is also desirable.

Jurisdictions desiring to standardize the WALK indication should also standardize the location of APS so that they will provide unambiguous information regarding which crosswalk has the WALK interval. Where APS are installed in a variety of locations, engineering judgment is required to determine, for each intersection, whether the rapid tick or a speech WALK indication will provide the most unambiguous information to pedestrians.

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CHAPTER 5
COLD WEATHER CASE STUDIES

INTRODUCTION

Cold weather case studies were conducted in order to ensure that this research covered a wide variety of climates in the evaluation of APS devices. Cities in cold weather climates could potentially face unique issues due to cold temperatures, snow, ice, and removal methods such as snowplowing and salting. The goal of these case studies was to find out what effects these cold weather characteristics had on the installation, operation, and maintenance of the APS devices, as well as the interaction with pedestrians who are visually impaired. The information acquired from these case studies will be used to develop additional recommendations for practitioners and will be part of the training materials to be developed later in this study.

Selection of cities for these case studies was based on several criteria. A study city needed to have a climate that experienced freezing temperatures and received precipitation (snow and ice) that warranted removal methods, including snowplowing and salting. The APS units employed by the city needed to be pushbutton-integrated devices. A study city needed to have multiple APS installations, not just an isolated occurrence. Since one of the goals was to find out the long term effect of cold weather on the devices, cities with longer histories of APS use were preferred over those with shorter histories.

The research team used their knowledge of APS installation locations to draw up a list of cities that would be potential study sites. To add to this list, the team contacted distributors for the various manufacturers to learn of cities with APS installations. Of the 36 contact attempts made, two cities were selected for site visits. Another city provided written feedback but was not visited. Other cities were excluded due to lack of appropriate APS devices, short histories with devices (1 year or less), lack of sufficiently cold weather, and failure to establish contact with the appropriate individuals.

The two cities that were visited were Halifax, Nova Scotia and Waukesha, Wisconsin. These cities primarily use Novax and Polara equipment, respectively. Pushbutton-integrated APS have been in service in these cities for 1-2 years. Cities with long maintenance histories are difficult to find, due to the fact that pushbutton-integrated APS models have not been on the market for long. The city of Ann Arbor, Michigan provided written feedback but was not visited by the research team. Their APS devices, which had been in service for 5 years, had been sent to the manufacturer due to malfunction and it was unknown when they would be reinstalled at the intersections.

HALIFAX, NOVA SCOTIA

History and Background

Halifax has been using overhead-mounted Novax APS since 1998. Pushbutton-integrated units (Novax Vibrawalk) were introduced in 2003 and are now in operation at five intersections. The APS units were installed in response to requests from the Canadian National Institute for the

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Blind (CNIB). All installations were retrofits to an existing signal and were performed by a contracted party.

Process and Procedure

Requests for APS installations come from the CNIB. They typically provide the city with a list of intersections where they would like APS installations. The city reviews the list and selects intersections for APS installations based on design of the intersection and available funding. If the intersection is suitable for pushbutton-integrated units, they install Novax Vibrawalks in addition to the overhead speaker APS units. Factors that affect the decision for pushbuttons include suitability of pole location and availability of wiring.

Funding

APS in Halifax were funded by the capital budget in a specified fund for pedestrian safety issues. There was also a federal 50-50 funding match in 2004 for APS installations.

APS Type and Features

Novax DS2000 Audible Pedestrian Signal for overhead speaker units

Novax Vibrawalk for pushbutton

APS features (pushbutton-integrated device installations):

- Locator tone
- Vibrotactile WALK indication
- Extended button press – when button is held for 3 seconds, the audible cuckoo will sound at the next WALK phase. Otherwise there will be no audible indication of the WALK phase.

Installation Issues

The APS unit is mounted on top of the pedestrian head and faces across the street. A typical configuration for a crossing in Halifax involves two APS units, one at each end of the crossing. The volume is set up so that the sound only reaches ¾ the way across the street. This enables the user to detect the second unit part way across the street and guide them in the proper direction. Setups with only one APS per crossing generated numerous noise complaints as the volume has to be higher to be heard across the street.

Most units are attached to aluminum poles but some locations have wooden poles, as shown in Figure 5-1. The APS units on wooden poles are clamped to the signal arm or pedestrian head. To access the pushbuttons, ½-inch PVC conduit is strapped to the wooden pole and an LB or liquid tight flex pipe provides access to the bottom of the pushbutton.

Figure 5-1. APS mounted on wooden pole.

The overhead speakers are typically mounted to the pedestrian signal head. Plastic (polycarbonate) signal heads gave problems with breaking when the APS speakers were mounted into them. Strong winds would push on the speaker and crack off the thin plastic of the signal head into which the speaker was mounted. In these cases, the speaker was mounted on the pole or

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some other metal or wood surface, as shown in Figure 5-2. Pedestrian signal heads made of aluminum did not have this issue. In areas with less of a problem with strong winds, this may not be a concern.

Availability of wiring at the pole is an important issue. If sufficient wiring is installed with the signal, installing an APS later is much easier. Pulling wire later can become prohibitively expensive.

Figure 5-2. APS overhead speaker mounted on signal head support arm.

Maintenance

The city handles the maintenance of the devices. The APS overhead speakers generally will start having problems at the 5-year mark. They usually last from 5 to 10 years. Damage is usually due to salt and moisture. The Vibrawalk devices have not shown any problems during the two years they have been in service. Halifax engineers have also noted that moisture and insects can cause pushbuttons to short out, thereby causing the APS to activate every cycle.

Cold Weather Issues

Snow is a constant problem in the Halifax climate. Snow banks can prevent access to the pushbuttons when not cleared properly. For intersections where pushbuttons are used, pole placement becomes an important issue so that the all pedestrians can reach the button. Poles with pushbuttons located to the immediate left or right of the crosswalk give a better chance of being reached by pedestrians and having the snow cleared properly. Halifax uses mini-plows for clearing sidewalks. They anticipate that this could be a problem with stub poles (i.e., knocking them over), so the use of stub poles is generally avoided.

Being near to the ocean, moisture and salt in the air is a problem for Halifax, as is salt on the roads for de-icing. Current Novax APS units (overhead-mounted speakers) last about five years before problems arise. There have been no problems or failures with the Vibrawalks yet.

Other issues are caused by freezing temperatures. Pulling additional wire for a retrofit installation cannot be done in the winter due to ice in the wire conduits. Extreme cold can cause some signals cabinets to fail and thus the APS to fail.

Evaluation

The initial installations of non-pushbutton-integrated APS installations were configured to give the audible WALK cuckoo at every cycle. The city received complaints about noise, especially in the summer months when people had their windows open. Due to concerns about noise, these units were set up to be off (give no audible indication) from 11:00 pm to 6:00 am. Pushbutton-integrated installations, however, can be accessed 24 hours per day, but the audible

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indication is given only when the button is held for three seconds. No feedback was reported on the pushbutton-integrated devices.

Contact

Michael Flippone
Traffic Signal Supervisor
City of Halifax, Nova Scotia
Phone: 902 490 4971
Email: flippm@halifax.ca

WAUKESHA, WISCONSIN

History and Background

Waukesha has been using pushbutton-integrated APS with speech messages since 2002. Prior to that, they used overhead speaker units which gave a chirp or chirps but were not activated by pushbutton. There are approximately 84 Polara Navigator units in service in Waukesha, most of which were installed during summer 2004. The move to pushbutton-integrated devices was motivated by requests from the local blind community, the Sight Loss Network, who introduced the city to the speech message capability of the Polara Navigator.

Process and Procedure

The initial APS installations were performed in one large campaign in the summer of 2004. These installations were scattered about town, but mainly focused on center city intersections. There is another installation campaign planned that will involve approximately 100 units. This will focus on installing devices at the rest of the center city intersections and moving outwards from there. It is also current Waukesha policy that any new signal installation will be accompanied by an APS installation.

Funding

APS in Waukesha are currently fully funded by Waukesha County Community Development Block Grant Program up to a specified amount per year. This funding includes time and materials.

APS Type and Features

Polara Navigator for pushbutton-integrated devices (the model type mainly in use) has four wires for installation and a separate control board that is configured remotely.

APS features:

- Pushbutton locator tone
- Vibrotactile WALK indication
- Extended button press
- Speech WALK indication
- Pushbutton information message by extended button press

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Installation Issues

Installation of the devices is done by the city. If a signal to be retrofitted already has pushbuttons, this greatly facilitates APS installation. Even in these cases, however, the four-wire models still necessitate the pulling of extra wire.

Most of the signal poles are steel and accommodate the APS devices fairly easily. They try to have two poles per corner for every intersection. Sometimes stub poles are necessary if the signal poles are not close enough to the crosswalk. In one case, a lamp post was used successfully as a mount for an APS unit (*see Figure 5-3*), since aesthetics of the area placed restrictions on the number of poles that could be installed.

All but one of the existing APS installations were retrofits. However, all new signals in the future will have APS devices installed at the time of the signal installation.

Figure 5-3. APS mounted on lamp post.

Maintenance

There have been no maintenance issues for the APS units in their one year of service.

Cold Weather Issues

There were no significant issues related to APS units in cold weather during their one year of service. Previous pushbuttons (non-APS) had an estimated life of 10 years. The problems were mainly corrosion at the wire connections due to salt and moisture.

Waukesha uses mini-plows for removing snow from sidewalks. The manager of city snow plowing has expressed concern that stub poles may be damaged by these plows.

Evaluation

Devices in residential areas initially drew noise complaints. The city had been leaving the sound settings as the factory default. Once the volume was reduced, there were no complaints.

Contact

Cheri Shook
City of Waukesha, Wisconsin
Phone: 262-524-3590
Email: cshook@ci.waukesha.wi.us

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ANN ARBOR, MICHIGAN

History and Background

Ann Arbor has been using pushbutton-integrated APS since 2001. Five Polara Navigators were installed that year and none have been added since.

Process and Procedure

APS units are installed on the basis of recommendations from the Ann Arbor Commission on Disability Issues.

Funding

Approval for APS funding comes through the City Council. The money is budgeted from the Major Street Fund, which is a transportation fund. Currently, $50,000 is designated for the purchase, installation and maintenance of five APS.

APS Type and Features

Polara Navigator (pushbutton-integrated unit)

APS features:

- Pushbutton locator tone
- Extended button press
- Speech WALK indication
- Pushbutton information message by extended button press

Installation Issues

All APS installations were retrofits to existing signals. All poles were steel poles, and existing wiring was sufficient to accommodate APS installation. Some units are installed on pedestrian signal poles and some are mounted on the vertical pole of a signal mast arm.

Maintenance

Many of the APS units began to malfunction in 2004 and the city sent them back to the manufacturer. The problem was observed to be rusting of the devices.

Vandalism was an issue. There were several instances where the unit was knocked off the pole. The attachment bolts were replaced with bigger diameter bolts.

Cold Weather Issues

Little direct effect was seen from cold weather conditions. However, the use of salt may have contributed to rust that was experienced. The city engineers do not believe that the winter conditions contributed much to the signal operation.

Evaluation

There were several complaints about the noise of the locator tones, especially in the summer when people keep windows open. The locator tone sound was lowered in response.

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When there were two APS units on a single pole, the locator tone for one was switched off to control noise.

To explain how the APS devices work, the city publicized the devices through a newspaper article and local cable broadcast.

Contact

Les Sipowski
Senior Project Manager, City of Ann Arbor Public Services Department
Ann Arbor, Michigan
Phone: (734) 996-3286
Email: LSipowski@a2gov.org

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CHAPTER 6
ENGINEERING EVALUATION

INTRODUCTION

The engineering evaluation was conducted to acquire feedback on the physical installation, operation, and maintenance of APS devices in the two cities where the primary experiments were conducted – Tucson, Arizona and Charlotte, North Carolina. This section comprises the notes made by the city staffers on the installation of the APS and subsequent monitoring of the operation and maintenance performance. The information in this chapter may be helpful to engineers and signal technicians who have not worked with APS before. It covers the installation process for both cities as well as approximately one year of post-installation observation for the Charlotte sites and one and a half years of post-installation observation for the Tucson sites.

As with any technology, the design of APS is an ever-evolving field. Manufacturers of APS are constantly updating their products to address usability and design concerns. This engineering evaluation presents issues that were known at the time of this report and should be understood in that context.

INSTALLATION

Instructions

- Instructions provided by the manufacturer were generally very good and helpful for installers who had not previously dealt with APS. Manufacturers and their representatives were also very helpful in answering questions and making personal visits to the sites to solve installation problems.

Mounting

- In some cases, installers were able to use some or all of the pre-drilled mounting holes in the APS pushbutton unit. In cases where this was not possible, new holes had to be drilled.

Wiring

- Some APS types required four wires at the pushbutton; others required only two. If four wires were not available at locations where they were needed, extra wire needed to be pulled, making the installation more difficult.
- Some APS types had a central control board in the cabinet, others had individual control boards in the pushbutton or in the corresponding pedestrian signal head.
- Some APS types required wiring between the pushbutton unit and the pedestrian signal head. This added another level of difficulty to the installation. Sometimes this extra wire was not included from the manufacturer, or the included wire was not long enough.
- One APS type required the installation of a terminal block into each pedestrian signal head for the termination of wires.

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Setup

- Setting up the timing on units that use remote controllers (specialized remote control or PDA with special software) was fairly easy and user-friendly. Other types of APS required the setup to be done inside the pushbutton or overhead unit, which was more difficult.
- One of the devices required a specialized screwdriver, which was sent later.

Volume adjustment

- For APS types that used remote control, adjusting the volume of the APS was fairly easy.
- However, some APS types required that the volume adjustment be done on the control board in the overhead pedestrian signal, which was much more difficult. This process required the installer to turn a volume adjustment screw while on top of a ladder, then climb down to evaluate the volume at street level. This proved to be a time-consuming process.
- The volume on most APS had to be adjusted after installation. The default settings from the manufacturer were typically too loud or too volume (silent).
- Upon activation, one installation had a locator tone that was extremely loud. The solution from the manufacturer's representative was to muffle the sound by placing foam inside the speaker unit.

OPERATION AND MAINTENANCE

Observed failures

- No response to ambient sound
- Weak or no vibration
- Malfunction of audible message or tone
- Delay between onset of walk interval and start of speech message
- Failure due to wire shorting to the vibrator cover/pushbutton.
- Mechanical failure of pushbutton magnetic switch
- Failure of control board
- Faulty pot driver

Weather

- The pushbutton of some units operated intermittently since water possibly sensitive to temperature

Damage

- One device was damaged by a turning vehicle but continued functioning.
- One unit was knocked off the pole.

Several of the directional arrow indicators came unglued and are missing

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CHAPTER 7
RECOMMENDED GUIDELINES

INTRODUCTION

The best approach to installing APS would be to ensure that all installations are standardized, i.e., have the same features and placed at the same locations on every corner of every intersection. This approach should still the ultimate goal. Unfortunately, increasing complexity in intersection geometry and signalization make a "one size fits all" approach to specifying APS features and installation difficult in the U.S. In particular, variations in pushbutton location, variations in location and direction of slope of curb ramps, the presence of islands and medians, the presence of very wide, sometimes skewed crossings, and the presence of yield-controlled right-turn lanes, mean that the use of the same features on all APS will result in some crossings that have adequate information for most users, but others that have insufficient information for many users, and still others that are made more dangerous by the installation of APS whose volume is not properly adjusted. Engineering judgment is needed at APS installations to determine the appropriate features for the APS and the best location for the installation. The recommendations included in this chapter are intended to provide practitioners with the information needed to choose the most appropriate APS features and make sound installation decisions.

Guidelines suggested in this chapter are supported by the results of two experiments conducted as part of this project. Research was conducted to determine what features of pushbutton-integrated APS best promote safe and independent street crossings by pedestrians who are blind. This research was conducted in Tucson, Arizona and Charlotte, North Carolina and is reported in full in Chapter 3. In addition, research was conducted to examine the effect of pushbutton location on the accuracy and speed of determining which crosswalk at a corner has the WALK signal. The research also examined the effect of type of WALK indication on accuracy and speed of determining which crosswalk had the WALK signal. This research involved groups of participants with varying levels of visual impairment and varying types of cognitive impairment. All significant results were for the group whose participants were totally blind; however the findings for all other groups were consistently in the same direction. This research was conducted in Portland, Oregon and is reported in full in Chapter 3.

Fortunately, all the pushbutton-integrated APS currently marketed in the U.S. have most of the features mentioned below as either standard or optional features. Often it is a simple matter of programming the APS to add, cancel, or change a feature. APS installed with default settings at all crossings do not always provide accessible and usable information to all pedestrians who are blind or who have low vision. Selection of features necessary at a particular crossing requires engineering judgment, and some circumstances may require input from an orientation and mobility specialist and any individual who had requested installation of an APS at that crossing. While primary features are recommended on all APS, not all crossings at an intersection will need secondary features. For example, audible beaconing may be needed for the major street crossing, but unnecessary for the minor street crossing.

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In countries such as Australia and Sweden, where the relationship between the crosswalk and the pushbutton is tightly controlled, and the curb ramp always slopes in the direction of the crosswalk, standard APS features and standard installation guidelines are very workable. This is not always the case in the U.S. The following sections on features and on installation guidelines will take into account the varied device and installation needs at crossings having different geometries and different signalization schemes.

FEATURES OF PUSHBUTTON-INTEGRATED APS

This section is divided into primary features and secondary features. Primary APS features are those that, on the basis of psychophysical research as well as subjective data, should be included in all pushbutton-integrated APS, regardless of intersection geometry or signalization. Secondary features are those that have been shown to facilitate crossings by some pedestrians who are blind, but which may 1) not be indicated for use at all intersections, 2) not be desired or needed by all pedestrians who are blind or who have low vision, or 3) have limited research support.

Primary APS features

Pushbutton Locator Tone

It is recommended that a pushbutton-integrated APS be required to have pushbutton locator tones that sound at one second intervals during flashing and steady DON'T WALK intervals, as described in *MUTCD* 4E.09. No particular tone is recommended. Pushbutton locator tones are intended to notify pedestrians who are approaching a crosswalk of the need to press a button to get a WALK indication (and pedestrian timing); they also help users locate pushbuttons.

The strongest support for these recommendations is from two types of subjective data (see *Chapter 5*). First, participants were asked, following each crossing for which they used the pushbutton, how they located the pushbutton. This was an open-ended question, permitting multiple responses. Participants said they used the pushbutton locator tone on most trials, regardless of device (Tucson 95%, Charlotte 85%). Furthermore, when asked following each trial on which they had specific familiarization and experience with the four APS devices, to rate their agreement with the statement "The locator tone helped me find the pushbutton," mean responses for each device in each city were all in the positive direction.

It is not possible to clearly measure the effect of locator tones on finding the pushbutton. In the condition in which participants had no information about the crossing other than that it would have an APS, and they did not know that the APS would be of the pushbutton-integrated type and may have been completely unfamiliar with this type of APS, participants searched for the pushbutton on very few trials. When they had general or specific information on the pushbutton-integrated APS, knew that there were pushbuttons at each crossing, and knew that each pushbutton had a locator tone, participants searched for pushbuttons on 98% of trials across both cities, suggesting that the locator tone was helpful in locating the pushbutton.

Among the four APS installed for this research, there were three different tones used as locator tones: one was a click tone, and one was an 880 Hz electronic tone, and two were a bright beep tone, all repeating at once per second. All APS across both cities received an approximately equal number of positive and negative comments, and no particular APS locator tone resulted in

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a higher percentage of participants finding the pushbutton. Participants said, after most trials, that they used the locator tone to help find the pushbuttons, regardless of the nature of the locator tone.

Pushbutton Style

It is recommended that the APS have a clearly defined pushbutton that is tactually identifiable. Psychophysical tests provided no direct evidence of performance differences attributable to pushbutton style. However, style of the pushbutton was frequently mentioned when participants were asked what they liked most and least regarding each APS. The two APS having two-inch diameter rounded buttons "that pushed" drew a number of positive comments to an open-ended question (*see Chapter 3*). It should be noted that APS with mechanical pushbuttons (providing the desired mental feedback) may be more susceptible to vandalism than those with electronic (pressure-sensitive) pushbuttons.

Incorrect evidence for difficulty in finding the two pushbuttons that were atypical, the flat-panel pushbutton, and the flat recessed circular pushbutton, is found in the latency to find and push the correct pushbutton. In the condition in which participants only had a general description of APS features, the two unusual pushbuttons took significantly longer to locate and push than the two buttons that were typical. The time included both the time to find the pole and the device and the time to locate and use the button on the device. However, when participants had specific information about and experience with the various pushbuttons, all differences in latency disappeared.

Tactile Arrow

It is recommended that tactile arrows be required on all pushbutton-integrated APS as indications of which crosswalk is controlled by which pushbutton. Tactile arrows are typically also used as an aid to alignment, however most users are unable to align with precision to tactile arrows. Style of arrow, within the range of the four APS tested, did not consistently make a difference. Therefore there is no recommendation for a specific type of arrow or location of the arrow, particularly since the *Draft Guidelines* include some specifications of arrow size and shape.

Results of subjective research (*see Chapter 3*) confirm that the tactile arrow is an important feature for helping APS users know which crosswalk is associated with a pushbutton. All mean ratings were positive for the question "The tactile arrow helped me know which pushbutton was for the correct street."

The performance measure that best indicates how effective the tactile arrows were at conveying which street was controlled by a pushbutton is the number of trials on which participants looked at the arrow on the incorrect pushbutton and correctly rejected it. In Tucson, although participants looked at the arrow on the incorrect pushbutton on 28 of 160 trials when general or specific information was provided, they correctly rejected the incorrect pushbutton on 100% of those trials. Participants in Charlotte looked at the arrow on the incorrect pushbutton on 63 of 160 trials, and rejected the incorrect pushbutton on 65% of these trials. The difference between cities was probably due to the different levels of participant skill in independent travel, observed by researchers as inefficient or ineffective strategies for some tasks. Participants in Charlotte were more successful in rejecting the incorrect pushbutton when they had specific information about the APS they were to encounter.

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An additional subjective measure of the effectiveness of tactile arrows in communicating which crosswalk was controlled by a pushbutton was the ratings of agreement with the statement "I was sure I pushed the button for the street I wanted to cross." Participants responded positively to the statement on 90% of trials when they just had general information, and on 90% of trials when they had specific information. The increase in confidence, as well as in performance, following specific information was probably due to the brief training participants received interpreting arrow direction during their specific familiarization with demonstration devices.

Thus, the inclusion of a tactile arrow on APS quite successfully conveys which crosswalk is controlled by which pushbutton when users are accustomed to using arrows and understand their meaning. The arrow is also highly regarded for identifying which crosswalk is controlled by which pushbutton.

There were no significant differences attributable to style of arrow, with regard to correct rejection of the incorrect pushbutton. There were also no subjective differences related to the style of the arrow.

A different use of a tactile arrow is for aligning for crossing. However, mean ratings for the statement "The tactile arrow helped me align for crossing" were negative for all devices in Tucson, and slightly positive in Charlotte, showing no clear pattern of support for use of tactile arrows for this purpose. The data for alignment showed no differences attributable to style of arrow.

Precise alignment of tactile arrows with direction of travel on the associated crosswalk is nonetheless essential, because researchers observed that, at many crossings in Tucson and Charlotte, participants who used the arrow not only used it to confirm that the pushbutton was for the street they wanted to cross, but also used it as well as they could to align for crossing that street.

Actuation Indication

It is recommended that an audible actuation indication be required on pushbutton integrated APS. This may be either a tone or a speech message. There is no support for specifying the nature of the actuation indication at this time.

The only data on the usefulness of the audible actuation indication is ratings of agreement with the statement "The tone or message was helpful in letting me know the button had been activated." Mean ratings were quite positive, ranging from 3.58 to 4.58 in Tucson and 4.28 to 4.61 in Charlotte, indicating a strong desire for an audible actuation indication (*see Chapter 3*). There were no meaningful differences in ratings attributable to differences in actuation indications in either city. However, the indication message "Wait" received a number of positive comments on the open-ended question regarding most and least liked features. It received no negative comments.

Audible WALK Indication

The recommended WALK indication is a rapid tick signal, a signal that differs markedly from the locator tone in its repetition rate, and should be on for the duration of the walk interval except where the pedestrian signal rests in WALK, in which case it may be limited to approximately seven seconds. The WALK indication should repeat at ten times per second, while

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the locator tone repeats at once per second. However, accuracy in understanding which crossing is being signaled is dependent on excellent location of APS (*see below*) or which two APS at one corner are located on individual poles and spaced apart as described in *MUTCD 4E.09*.

In retrofit situations where it is necessary to place two APS on the same pole or closer than is recommended, the WALK indication should be a speech message with the following format: "Oakdale walk sign is on to cross Oakdale." The message should repeat for the duration of the walk interval (except where the pedestrian signal rests in WALK), and should be used in conjunction with a pushbutton information message.

Prompt initiation of crossing in response to the WALK indication contributes to the likelihood that crossings will be completed before steady DON'T WALK, so the choice of WALK indication should be one which promotes fast starting to cross. Equally important is accuracy in understanding which crossing is being signaled. A fast start across the wrong street can be deadly. It is therefore even more important that the WALK indication result in accurate understanding of which crossing has the WALK signal. Research in this project addressed both of these issues, and concluded that the rapid tick WALK indication provides for both the fastest starts and the most accurate judgment regarding which crossing has the WALK signal—provided that the APS is located optimally. (*See General Installation Guidelines below.*)

There are three fundamental types of walk indications that are in use on pushbutton-integrated APS currently in use in the U.S.: cuckoo/chirp signals, rapid tick signals, and speech messages. All were included both in the research in Charlotte and Tucson (Chapter 3) and in research in Portland (Chapter 4). In Portland, all three kinds of indications were produced by the same APS. (The indications were switched by a hand-held controller during the course of the experiment.) Because there were no other device differences in Portland, the results are free from confounds with other device characteristics.

In Portland, both the location of pushbutton-integrated APS and APS WALK indications were explored. Cuckoo/rapid tick and rapid tick signals only were compared where two pushbuttons were located on two different poles at a corner, separated by approximately ten feet. Cuckoo/rapid tick and speech messages were compared where two pushbuttons were located on the same pole. Participants performed two tasks in preparation for crossings (but did not make crossings independently). They located the pushbutton to cross the perpendicular street, and they indicated when the WALK signal came on for that street. Measures that are meaningful in the context of specifying a WALK indication are speed and accuracy in indicating when the correct WALK indication appeared.

There were significant differences in response time and accuracy attributable to the nature of the WALK. The rapid tick used on the two-pole corners produced the fastest and most accurate responses to the WALK indication. When two pushbuttons were on the same pole, the fastest responses were to cuckoo/rapid tick signals, but responses were more accurate to speech messages.

Research in Tucson and Charlotte confirmed that when users knew the type of device they were going to be using, the fastest starts were for the APS having rapid ticks. In Tucson, initiation of crossings having the rapid tick WALK indication were significantly faster than crossings having other indications; the pattern was the same in Charlotte, although results were not statistically significant. There was no measure for accuracy in identifying the crossing being signaled by the WALK indication.

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Vibrotactile WALK Indication

It is recommended that every pushbutton-integrated APS have a vibrating arrow to indicate the WALK interval to persons who have both vision and hearing impairments (deaf-blind). All the pushbutton-integrated APS currently marketed in the U.S. have this feature, and it is the accepted means of providing pedestrian signal information to deaf-blind pedestrians in the U.S.

It was the intent of this project to include a total of eight to ten participants who were deaf-blind and who traveled and crossed streets independently. However, it was not possible to recruit this number of deaf-blind participants in the two cities involved. Nonetheless, there were seven participants who reported, or who were suspected of having, some degree of hearing loss in addition to blindness.

Participants used the vibrotactile arrow on a total of 38 trials in the experiment. Some of this use was likely to have been by persons with no hearing loss who wanted to confirm which APS was providing the WALK signal.

The mean subjective rating regarding the helpfulness of the vibratory WALK signal was 6.36 in Tucson and 4.37 in Charlotte, both strongly positive. There were positive comments regarding the vibrotactile arrow in response to an open-ended question asking participants to identify what APS features they liked most and least. There were no negative comments.

Response to Ambient Sound

All APS should be responsive to ambient sound. APS volume must be loud enough to be heard by users, but quiet enough to be tolerated by neighbors. Current Guidance provided in *MUTCD* 4E is the best that can be offered at this time.

All pushbutton-integrated APS currently marketed in the U.S. are responsive to ambient sound, according to guidance in *MUTCD* 2003 4E.

> 4E.06 — The accessible walk signal tone should be no louder than the locator tone, except when there is optional activation to provide a louder signal tone for a single pedestrian phase.
>
> Automatic volume adjustment in response to ambient sound should be provided up to a maximum volume of 89 dBA. Where automatic volume adjustment is used, tones should be no more than 5 dBA louder than ambient sound.
>
> 4E.09 — Pushbutton locator tones should be intensity responsive to ambient sound, and be audible 1.5 to 3.7 m (6 to 12 ft) from the pushbutton, or to the building line, whichever is less.

APS manufacturers differ in the ways in which they accomplish the automatic volume adjustment. First, the rates for sampling ambient sound vary. Second, the algorithm varies for how fast the signal responds to increases in ambient sound and in how fast the increased volume decays. Third, sensitivity of the automatic volume adjustment differs. In addition, the microphone unit is housing also affect response to ambient sound.

It will never be possible to satisfy the volume requirements of all users, while causing minimal noise pollution. It was apparent in the research in Tucson and Charlotte that some participants found some sounds too loud, and others found them too quiet. The most common

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response was that they were too quiet. Nonetheless one neighbor strongly objected to the sound of the APS on the corner where he lives, and it had to be turned down. Differences in user need for APS volume make the possibility of individual actuation of a louder signal for one pedestrian phase appealing. APS can be adjusted to be very quiet, yet offer users the opportunity to elevate the volume when they desire it (*see Louder Signal below*).

Secondary APS Features

Pushbutton Information Message

A pushbutton information message is recommended, as it is particularly helpful to some users. A pushbutton information message is essential on APS where the WALK indication is a speech message. This is a message emitted from the APS when the button is pushed during flashing or steady DON'T WALK intervals. The message should be "Wait, to cross Oakdale at North Avenue." (Emphasis and pause after Wait are intentional.) This message provides users with the name of the street controlled by that pushbutton and the name of the other street at the intersection. The message may come on with any button press during DON'T WALK intervals, but it may also come on only in response to an extended button press. The message should sound immediately if the pushbutton is depressed for one second or longer (74).

In Tucson and Charlotte, during trials when they had only a general description of APS features, few participants used the extended button press that was required to actuate the pushbutton information message. However, following hands-on familiarization with each of the three APS having this feature, participants chose to use the feature on more than 70% of crossings in both cities. When asked to mention features they liked most or least on each APS, there were a number of positive comments regarding the pushbutton information message, and there were no negative comments. Mean ratings for the statement "The pushbutton information message was easy to understand." were all at or above 4.0.

Louder Signal (Beaconing Signal)

The inclusion of the opportunity to obtain louder signals during the pedestrian phase is recommended. This feature may assist some pedestrians who are blind or who have low vision, including those who have hearing loss, in locating the opposite corner. The louder signal is actuated by an extended button press, and operates only during the next pedestrian phase. It includes both the WALK signal and the subsequent locator tone for that pedestrian phase. Because it requires special actuation, and is operative for a single pedestrian phase, the louder signal is rarely obtrusive in the environment, while it is available to users when they have need for it.

Because the majority of pedestrians with blindness or low vision are over the age of 60, by which age they also have some upper frequency (age-related) hearing loss, and because the population of older pedestrians with vision impairments is increasing, the availability of louder signals on request is potentially useful to a great many pedestrians who are blind or who have low vision. By 2010, it is estimated that there will be 20 million people in the U.S. over the age of 45 who are blind or who have low vision.

In the Tucson and Charlotte research, there was only one APS that had a louder signal available at the time of the experiment. The louder signal was requested by the same extended button push that actuated the pushbutton information message when it was present, so data on use of the extended button press does not clearly indicate whether the extended press was used to actuate the pushbutton information message, the louder signal, or both. Therefore the best

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demonstration regarding the usefulness and desirability of the louder beaconing feature, available on request, is from subjective data.

When asked to rate the extent of their agreement with the statement, "The louder signal feature was helpful," the mean rating was positive (3.94), with only four participants giving it a negative rating.

Tactile Map at Crosswalk

A tactile map of what will be encountered in a crosswalk may be helpful to some pedestrians who are blind or who have low vision, at some crossings. Where used, it should have standard symbols. Refer to the *Guide* for recommended symbols for tactile crosswalk maps.)

A tactile map of the associated crosswalk was available on only one APS used in this research, and it was a feature that was totally unfamiliar to all participants. Tactile maps, on the whole, are only moderately familiar to and are only occasionally used by people who are blind. Nonetheless, after participants were familiarized with this feature, 17% chose to use the map in Tucson, and 28% in Charlotte.

Participants were asked to rate the extent of their agreement with the statement: "The crossing map was useful and easy to understand." Mean ratings were 4.0 in Tucson, and 4.2 in Charlotte, indicating that the map was relatively desirable and easy to read. With additional experience with this particular map, it is possible that many people would find it easy to read and understand. We have no data to indicate with certainty what proportion of users would choose to use such a map at unfamiliar crossings, and it is unlikely that it would be used when making familiar crossings.

GENERAL INSTALLATION GUIDELINES

As for selection of APS features, a single standard for installation is not workable in the U.S., particularly for retrofit situations. Engineering judgment is required to determine the best way to install APS at a given intersection and crossing. Differences in curb radius, width of right of way, presence of parkway, curb ramp design and location, and existing infrastructure on corners make each installation different.

Described below are two different installation scenarios that will be applicable in most situations:

- Two Pushbuttons on One Corner, Mounted on Two Poles – Rapid Tick Walk Indication
  This design will apply most often in new construction and alterations, particularly when other alterations are being done on a corner, two poles should be installed for pushbutton integrated APS, as described in detail below.
- Two Pushbuttons on One Corner, Mounted on a Single Pole – Speech Walk Indication
  This design will apply most often where it is technically infeasible because of limited right-of-way, topography, or locations of other essential equipment on corners, to install two pushbutton integrated APS on a corner on separate poles. However, the APS features required for this situation are different than where each pushbutton-integrated APS is on its own pole.

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Two Pushbuttons on One Corner, Mounted on Two Poles – Rapid Tick

Optimal location for pushbutton-integrated APS is between the edge of the crosswalk line (extended) farthest from the center of the intersection and the side of the curb ramp. APS should be between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement. The control face and tactile arrow should be carefully aligned with the direction of travel on the associated crosswalk. In order to provide wheelchair users with access to the pushbuttons, all pushbuttons shall be located adjacent to a level all-weather surface.

Pushbutton-integrated APS shall be a maximum of 5 feet from the edge of the crosswalk line (extended) farthest from the center of the intersection. They shall be a maximum of 10 feet from the edge of the curb, shoulder, or pavement. At corners or signalized locations where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 10 feet (*see Figure 7-2*).

A rapid tick WALK indication is recommended for installations following these guidelines for location and the use of two poles on a corner.

The research conducted in Portland (*see Chapter 4*) found that where pushbutton-integrated APS were mounted on separate poles, near the crosswalk line furthest from the corner of the intersection (approximately 3 feet from the curb line and approximately 10 feet apart), speed and accuracy in judging when the correct crosswalk had the WALK signal was significantly better than when APS were located according to other criteria (*see corner C, Figure 7-3*). Moreover, accuracy in identifying the onset of the correct WALK signal was significantly greater when both APS on the same corner used the same tone (rapid tick) than when the two APS used two different tones (cuckoo and rapid tick).

When pushbuttons are precisely and consistently located in this way, identification of which crossing is being signaled can be based solely on which pushbutton the WALK signal comes from. There is no need to remember a code (such as cuckoo for a north/south crossing and rapid tick for an east/west crossing) or to understand speech messages. Figure 7-4 provides examples of pole arrangements that meet the requirements for corners having different geometries.

Two Pushbuttons on One Corner, Mounted on a Single Pole – Speech

When it is necessary to mount two pushbuttons on one pole, it is recommended that they should be required to use speech message WALK signals rather than tone signals. Moreover, to be sure users know the street name to listen for in the WALK message.

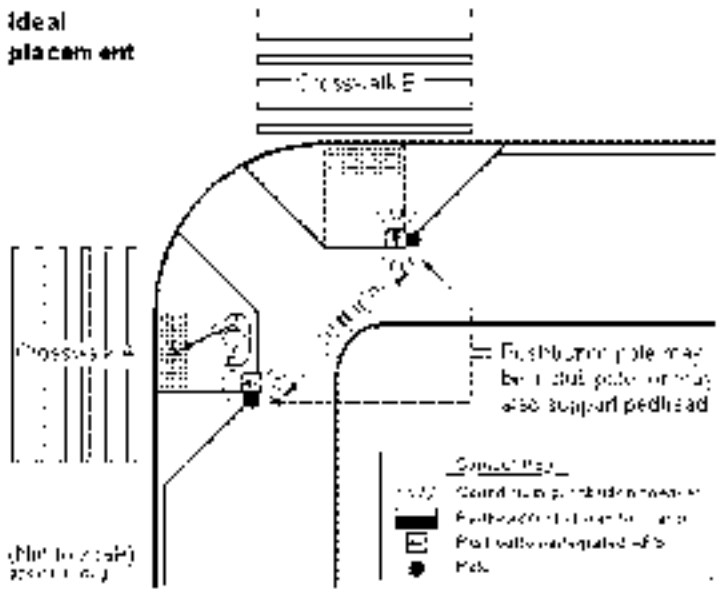

Figure 7-2. Optimal location of pushbutton-integrated APS.

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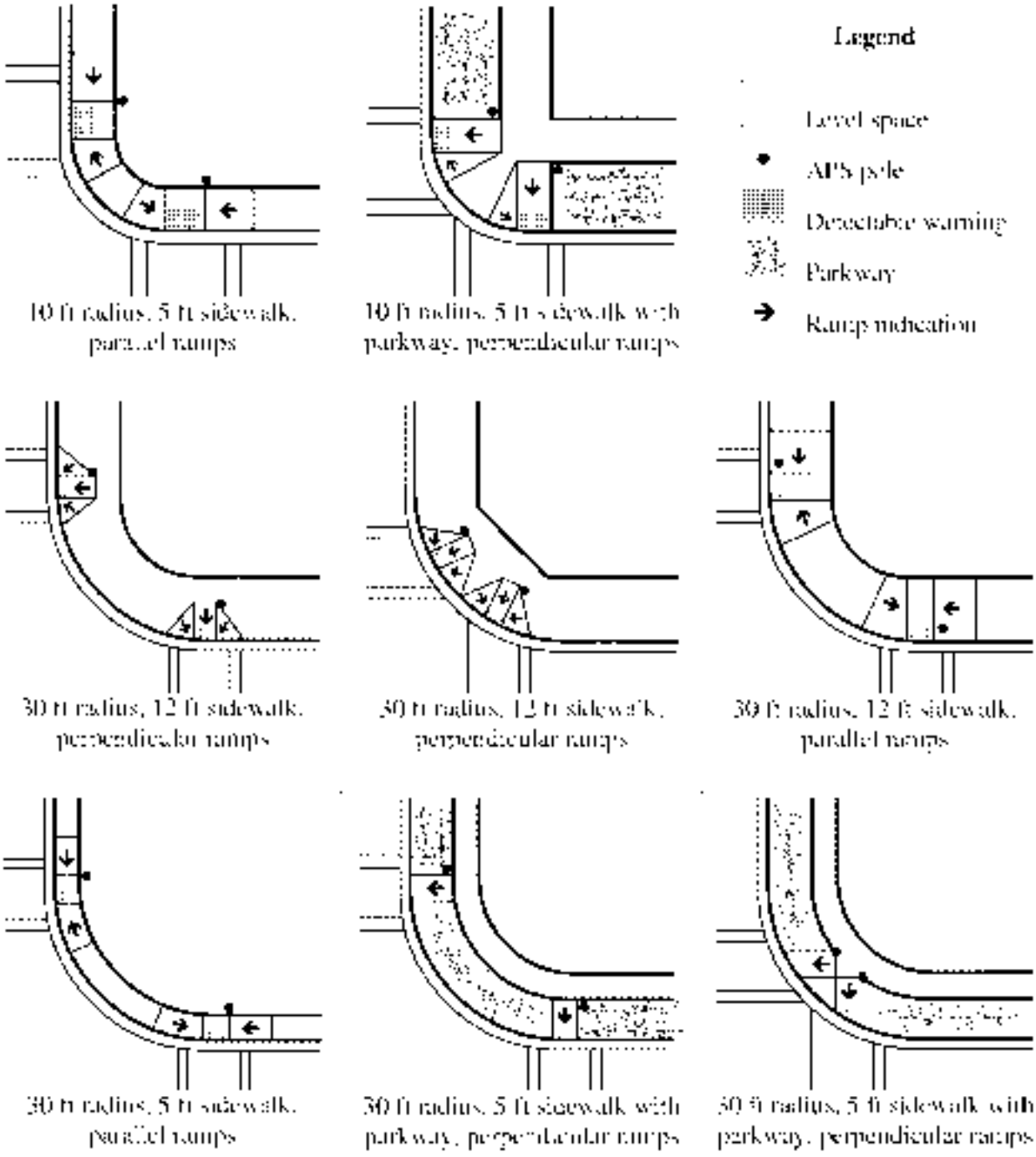

Figure 7-5. Examples of locations for pushbutton integrated APS on corners having various geometries.

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pushbutton information messages identifying the intersection and the street to be crossed should also be required.

Research in Portland demonstrated that response to identifying which crosswalk had the WALK signal was significantly more accurate when the APS provided speech WALK signals from both APS than when the APS used two tones – cuckoo and rapid tick (see Chapter 4). The same rapid tick system was not used in the research when there were two pushbuttons on one pole because there would be no way for users to know which pushbutton was signaling, other than use of the vibrating arrow. When two pushbuttons are on a single pole, and particularly when that pole is at the back of the sidewalk, it is not practical for the pedestrian who is blind or who has low vision to stand with a hand on the vibrating arrow while simultaneously preparing to cross.

CAREFUL VOLUME ADJUSTMENT

Volume adjustment of APS is both very important and somewhat difficult. The *MUTCD* provides guidance for APS (*see above under Response to Ambient Sounds*). There is no evidence provided by this research that the current *MUTCD* guidance should be changed. But there was certainly evidence that sound level is closely related to such tasks as recognizing the presence and location of a locator tone, quickly responding to the onset of a WALK signal, and walking straight across the street.

MUTCD guidance discusses a minimum sound level that a locator tone or walk tone should exceed ambient sound (5 dBA), and an absolute maximum sound level in decibels on the A scale (89 dBA). While manufacturers can limit devices to a maximum of 89 dBA, setting an automatic sound level adjustment system to consistently provide a signal that is approximately 5 dBA above ambient sound is more art than science at the present time. Reasonably priced sound level meters, which are amenable to use in the field, are not capable of accurately measuring the sound levels of very short bursts of sound in comparison with more persistent, but still widely varying, sound levels of vehicles.

A more useful measure in the field is the guidance that APS sounds should be audible 6 to 12 feet from the APS, or to the building line, whichever is less. However, audible distance is a subjective measure that is inevitably influenced by each listener's own hearing, and by such influences on the audible distance of sounds as wind, humidity, and nearby reflective surfaces. Fine-tuning of sound levels in the field should be planned for in every APS installation. Visits may need to be made in both peak and off peak hours to get a setting that is appropriate in both situations.

There are some intersection geometries that make careful attention to sound level settings critical. Where a signalized intersection has a right turn lane that is not signalized, it is very important that an APS on a splitter island not be audible from across the unsignalized turn lane. If it the APS is heard from the opposite side of the unsignalized turn lane, a pedestrian who is blind or who has low vision may mistakenly believe that the APS indicates a WALK interval for the unsignalized lane.

At intersections having split phasing, it is very important that APS signals not be audible across the street. For example, a northbound pedestrian who is blind or who has low vision is waiting to cross an east/west street, and the north/south street is to her left (she is at the east crosswalk). She hears the APS on the opposite side of the north/south street (for the west

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crosswalk) and assumes that there is a pedestrian phase for all pedestrians crossing the east/west street. She may cross directly into the path of southbound vehicles turning left across her path, which have a protected green left turn arrow.

SUMMARY

Experience with the installation and evaluation of APS indicates that particular attention is necessary in the installation process. Engineers and signal technicians need to take additional care in planning installations and making adjustments for the location of the pushbutton. For the devices to be effective for pedestrians with visual impairments, details matter. For example, the APS needs to be carefully positioned on the pole so that the tactile arrows are aligned with the intended crossing direction. There is also a need to become familiar with adjusting volume levels of the various tones and messages. It may be necessary to re-evaluate the sound level or devices at peak and off-peak hours to assure that the volume is properly adjusted. It is also important to be aware of the effect of installing an APS and not completing sound level adjustments before leaving. In one installation during this research, an APS was installed and became operational on Friday. The volume adjustment was not done until Monday, which resulted in a very loud locator tone operating over the weekend. By Monday, nearby residents were quite negative about the APS, which could have been avoided by either leaving it off until the technician had time to adjust the volume correctly, or adjusting the volume at the time of installation.

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CHAPTER 8
INTERSECTION PRIORITIZATION TOOL

INTRODUCTION

One of the first questions that must be answered by local engineers and others responsible for the installation of APS devices is when and where is it appropriate to install such devices in other than new construction and alteration/reconstruction. In many cases, there is a need to prioritize intersections for APS installations. The *MUTCD* currently provides some guidance on this matter, but a more definitive approach is required to assist practitioners.

Several cities in the U.S. have highly structured rating scales that they have found useful in making decisions about which intersections or crosswalks should have APS (*40*). Factors that are typically included are:

- proximity to a facility for persons who are blind;
- proximity to alternate crossings;
- proximity to transit stops;
- proximity to key facilities used by all pedestrians;
- intersection geometry;
- vehicle speed;
- traffic volume (both heavy and light);
- number of vehicles per surge per crosswalk;
- signal complexity;
- pedestrian crash records;
- demonstrated need or user request;
- presence of pedestrian push buttons;
- surrounding land use and neighborhood acceptance; and
- existence of a signal which is susceptible to retrofitting (consideration should be given to both the physical infrastructure and the operational parameters, i.e., phasing, splits, and cycle length).

One of the weaknesses with the previous tools was a lack of validation with respect to the scoring system and the relative weights assigned to the different variables. In this project, an effort was made to develop a tool, have practitioners apply the tool, and then compare the objective ratings achieved with the tool to the subjective ratings of pedestrians with visual impairments and orientation and mobility (O&M) specialists. Provided in the remainder of this chapter is a discussion of the methodology used in the development of the tool. The tool itself, which includes a set of instructions for application, is provided in the companion documents, *Accessible Pedestrian Signals: A Guide to Best Practice*, and is also available on the web at www.walkinginfo.org/aps.

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FIELD DATA COLLECTION

In each of three cities (Cambridge, Tucson, and Charlotte), a project staff member and one or more local transportation engineers and/or planners applied the Intersection Prioritization Tool to rate crosswalks at the intersections. The number of crossings in each city is shown in Table 8-1. These intersections were selected to capture the full range of crossing difficulty that may be experienced by a blind pedestrian, from very simple two-phase signals at relatively small intersections to large intersections with multiple phases and complex geometries. The scores from the tool were used to rank-order the crossings from most difficult (and in need of an APS) to least difficult.

TABLE 8-1 Number of crossings rated in each city

City	Number of Crossings
Charlotte, NC	33
Tucson, AZ	36
Cambridge, MA	40

A local O&M specialist and two blind pedestrians who were skilled independent travelers and who were selected by organizations of blind persons in that locale used their expert judgment to review each crossing and also prioritize the crosswalks in terms of difficulty and in most need of an APS. Following the evaluation of all crossings in each city, the evaluators met to compare their results, discuss areas of agreement and disagreement with respect to what made each crossing easy or difficult, and to suggest ways in which the Intersection Prioritization Tool could be revised so that results were consistent with the subjective scores of the blind travelers and O&M specialists.

CALIBRATION AND MODIFICATION

The objective scores from the practitioners and the subjective scores from the blind pedestrians and O&M specialists were used to calibrate and modify the tool. The goal of this task was to create a tool that would take observable characteristics of a pedestrian crossing and produce a score that would reflect the relative crossing difficulty and subsequent need for APS. Appropriately designed, the tool would include higher point values for characteristics that indicated a greater need for APS. The resulting scores could then be used to develop a prioritization of crossings based on need for APS.

The point values given to the various site characteristics included in the tool were initially drawn from the research team's knowledge of the relative importance of the characteristics and from the other similar tools that were previously mentioned. Starting with these initial point values, the calibration of the prioritization tool became an iterative process.

The characteristics of each crossing, which were captured in the field on paper, were entered into an electronic version (Excel workbook) of the prioritization tool. These data included intersection-wide characteristics, such as the type of signalization, and crosswalk-specific characteristics, such as crossing width and curb ramp configuration. Once all characteristics were entered, the prioritization tool calibration followed the iterative process explained below.

Step 1 – Use the Prioritization Tool to Calculate Scores for Each Crosswalk

The prioritization tool assigns point values based on the influence of a particular variable on a blind pedestrian's travel on the crossing. Higher point values indicate a greater difficulty for

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the blind individual and therefore a greater potential benefit from an APS installation. The score for a particular crosswalk is a sum of two scores – the score for the intersection at which the crosswalk is located and a score for the crosswalk itself. The variables included on each worksheet are as follows:

Intersection Worksheet Variables

- Configuration
- Signalization
- Proximity to transit facilities
- Proximity to facilities for the visually impaired
- Proximity to major pedestrian attractions

Crossing Worksheet Variables

- Crossing width
- Speed limit
- Approach/crossing geometrics
- Pedestrian signal control
- Vehicle signal control
- Off peak traffic presence
- Proximity to alternative crossing with APS
- Pedestrian push button location
- Requests for APS

Step 2 – Rank Crosswalks by Prioritization Tool Score

The crosswalks are ranked from greatest to least according to the score from the prioritization tool.

Step 3 – Compare Prioritization Tool Rankings to Rankings Given by Evaluators

It was then necessary to compare the prioritization tool rankings to the evaluator rankings to determine how well the tool was emulating the subjective rankings of the visually-impaired pedestrians and O&M specialists. The calibration of the tool was performed by looking at the top group of sites (greatest need for APS) and the bottom group of sites (least need for APS) in each set of rankings. Since each evaluator has a different priority ranking of sites, it cannot be expected that the tool would match the evaluator rankings place-for-place. Instead, the calibration process seeks to have as many sites as possible in the top group of the prioritization tool rankings also be found in the top groups of the evaluator rankings, and likewise for the bottom group.

The method used in this calibration took each site in the prioritization tool ranking and counted how many times the site appeared in the evaluator rankings. The sum of these counts reflected how well the prioritization tool rankings compared to the evaluator rankings. The goal of the calibration was to maximize this sum.

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Step 4 – Adjust Point Values; Repeat Steps 1 through 3

To attempt to maximize the sum obtained at Step 3, the point value for a particular variable was sometimes adjusted. For instance, if the presence of islands or medians on a crosswalk was worth 3 points in the previous run, that value may have been increased to 4 to determine what effect the point value increase had on the overall fit of the prioritization tool. Once any point value was changed, Steps 1 through 3 were run again. Point values for different characteristics were increased and decreased until the sum produced at Step 3 could not be increased.

Adjustment of point values was guided in large part by the comments made by the evaluators on each crosswalk. For instance, if the evaluators made comments to the effect that the presence of a vehicular right-turn-only phase increased their concern about a particular crossing, then the point value for right-turn-only phase would be increased to better align the tool with the evaluator rankings. Point values for characteristics that were not mentioned by an evaluator were adjusted on an exploratory basis.

Other Point Value Adjustments

Some variables could not be included in the calibration process, due to lack of data or small sample size. In these cases, point values were assigned based on the team's assessment of the hazard of each variable with respect to other variables that had been calibrated.

Data were not available for the following variables:

- Proximity of transit facilities
- Distance to facilities for visually impaired
- Distance to major pedestrian attraction
- Leading pedestrian interval
- Distance to alternative APS crossing
- Requests for APS

There were too few crossings with the following characteristics to allow for point calibration:

- Non-concurrent WALK signal
- Channelized right-turn lane under signal control

SUMMARY

The final, calibrated prioritization tool provides practitioners with a method for prioritizing locations for APS installation. The forms and instructions for the tool can be found in the companion document, *Accessible Pedestrian Signals: A Guide to Best Practice*.

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CHAPTER 9
TRAINING AND RESOURCES

INTRODUCTION

As APSs are being installed in more and more cities, there is a need for guidance for decision-makers and practitioners. To this end, training materials were developed to provide guidance on when, where, and how APS devices should be installed. The materials consist of the companion resource document and a set of PowerPoint presentations that can be covered in a one-day course. These materials were organized to meet the needs of three specific audiences:

- Technicians, who are responsible for the installation, operation, and maintenance;
- Engineers/Administrators, who are involved in making decisions about when and where APS devices are needed and the features required; and
- Orientation and Mobility Specialists, who train pedestrians to use the devices and serve as advisors to the engineers.

The companion document, *Accessible Pedestrian Signals: A Guide to Best Practices*, is intended as a stand-alone document that contains all the training information developed in this project. It is also intended to be a resource document to accompany the one-day training course. While the course covers the basics of each topic area, the *Guide* contains more detail. In addition to the topics covered in the course (see below), the *Guide* also contains chapters on public education on APS, case studies in the U.S. and abroad, product-specific information, and an instruction manual for the APS Prioritization Tool.

The training course developed as part of this project is intended to be a one-day session that will cover the issues related to travel by those who are blind, traffic signalization, and when, where, and how APS devices should be installed. The course makes use of images, drawings, videos, and in-class demonstrations, as well as examples from real-world installations. The PowerPoint presentations contain scripts of the instructors' dialogue so that they may be read and understood outside of the course. Provided below is an outline of the modules covered in the training course and a brief description of the content of each module.

MODULE DESCRIPTIONS

Module A

Accessible Pedestrian Signals and Accessible Public Rights-of-Way (all audiences)

- Purpose and Description of APS – why APS are needed, scope of problems addressed, terminology
- History of Legislation and Current Guidance – TEA-21, *MUTCD*, 1973 Rehab Act, ADA, Draft PROWAG
- Resources – Federal agencies (FHWA, Access Board), consumer groups (ACB, NFB), professional organizations, local agencies

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Module B

Travel Needs of Blind/Low-Vision Pedestrians (targeted at engineers)

- Blindness and Vision Loss – types of vision loss, definitions
- Travel Techniques and Aids – types of aids (dog guides, canes, etc.), O&M training
- Street crossings – analysis of situation, crossing techniques, crossing cues
- Challenges and Problems – examples (split phasing, mid-block signals, etc.)

Understanding Traffic Signals and Math in Intersection Design (targeted at O&M professionals)

- Terminology (e.g., cycles, phases, etc.)
- Signal Warrants (understanding why a signal may be installed)
- Type of Operation (pretimed, semi-actuated, full-actuated)
- Signal Timing (timing plans, walking speeds, understanding signal displays)

Module C

APS Features (all audiences)

- APS Features – locator tones, WALK interval tones and speech messages, vibrotactile feedback, tactile arrow, ambient noise adjustment, tactile maps, etc.
- Recommended Features – recommendations on type of WALK indication, etc. (from project research)

Module D

When to Install APS (targeted at engineers)

- Where APS are required – current guidance
- Application of ADA – new construction, alteration projects, existing facilities (retrofit)

APS Prioritization Tool (targeted at engineers)

- Overview – intended use and audience for Prioritization Tool
- Development – brief overview of the development and validation process
- Intersection and Crosswalk Worksheets – walks through each variable that was included in the Tool
- Example of Prioritization Tool use

Module E

Designing Installations (targeted at engineers)

- General Considerations for Installations – pole locations, intersection geometry
- Design Guidance for New Installations – Draft PROWAG, *MUTCD*
- Designing Installations in Retrofit Situations – how to conduct site evaluations and needs assessment, how to design in a non-ideal situation

Design Exercises

- Before/after photos of APS installations for group discussion

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Module F

Installation, Operation, and Maintenance (targeted at technicians)

- Installation – infrastructure (poles, wiring, and other hardware), device mounting, adjustments (sound levels, ambient noise response, etc.)
- Adjusting Sound Settings – how to set volume for locator tone, WALK indication, etc.
- Post-Installation Checklist
- Maintenance – what to check and when

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CHAPTER 10
CONCLUSIONS

In 2000, two sections on APS were added to the *Manual on Uniform Traffic Control Devices (MUTCD)*, which became the first set of national standards for APS in the U.S. The *MUTCD* defines an APS as "…a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces" (*1*). The rest of the *MUTCD* language provides standards, guidance and options, but does not specify walk messages or address many possible device features. In 2002, the U.S. Architectural and Transportation Barriers Compliance Board (Access Board) published draft recommendations and requirements for APS installation in *Draft Guidelines for Accessible Public Rights-of-Way* (*2*). The *Draft Guidelines* call for the use of pushbutton-integrated signals that provide audible **and** vibrotactile indications of the walk interval.

This research was the basis for more precise and well supported standards and guidance on APS for inclusion in the *MUTCD* and the U.S. Access Board *Guidelines*. The research results have been forwarded to the Signals Technical Committee of the NCUTCD and to the Federal Highway Administration (FHWA) as background and support for changes in Part 4 of the *MUTCD*, as well as to the U.S. Access Board.

Two separate research experiments were undertaken in this project to develop the recommended guidelines for APS features and APS installation. The purpose of first study was to determine the effect of APS features, which are commonly found on most of the APS equipment marketed in the U.S., on the ability of pedestrians who are blind to locate and use pushbuttons, determine time to cross, determine appropriate heading for crossing, and maintain alignment while crossing. The second study was conducted to evaluate the effects of pole location, number of poles used in relation to number of APS devices, and type of WALK indication on the ability of pedestrians with visual or cognitive impairments to determine which crosswalk at a corner had the WALK signal. In addition to these two research studies, additional information about APS performance was gleaned from an engineering evaluation of the equipment installed during this research study, as well as from a series of cold weather case studies.

The result of these efforts is a set of recommended guidelines to help practitioners choose the most appropriate APS features to fit the needs of each application and make sound installation decisions. The recommendations are briefly summarized below; a more extensive description and justification for each can be found in Chapter 5.

Primary APS Features

Primary APS features are those that, on the basis of psychophysical research as well as subjective data, should be included in all pushbutton integrated APS, regardless of intersection geometry or signalization.

Pushbutton Locator Tone – It is recommended that all pushbutton-integrated APS be required to have pushbutton locator tones that sound at one second intervals during flashing and steady DON'T WALK intervals, as described in *MUTCD* 4E.09. No particular tone is recommended.

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Pushbutton Style – Pushbuttons should be clearly defined and be tactually identifiable.

Tactile Arrow – It is recommended that tactile arrows be required on all pushbutton-integrated APS as indications of which crosswalk is controlled by which pushbutton. There is no recommendation for changes to arrow specifications currently provided in the *Draft Guidelines*.

Actuation Indication – It is recommended that an audible actuation indication be required on pushbutton-integrated APS. This may be either a tone or a speech message.

Audible WALK Indication – The recommended WALK indication is a rapid tick signal, a signal that differs markedly from the locator tone in its repetition rate, and should be on for the duration of the walk interval except where the pedestrian signal rests in WALK, in which case it may be limited to approximately seven seconds. The WALK indication should repeat at ten times per second, while the locator tone repeats at once per second. However, accuracy in understanding which crossing is being signified is dependent on excellent location of APS (see below) in which two APS at one corner are located on individual poles and spaced apart as described in *MUTCD* 4E.09.

Vibrotactile WALK Indication – It is recommended that every pushbutton-integrated APS have a vibrating arrow to indicate the WALK interval to persons who have both vision and hearing impairments (deaf-blind).

Responsive to Ambient Sound – All APS should be responsive to ambient sound. APS volume must be loud enough to be heard by users, but quiet enough to be tolerated by neighbours. All pushbutton-integrated APS currently marketed in the U.S. are responsive to ambient sound, according to guidance in *MUTCD* 2003, Section 4E, which remains the best that can be offered at this time.

Secondary APS Features

Secondary features are those that have been shown to facilitate crossings by some pedestrians who are blind, but which may (1) not be indicated for use at all intersections, (2) not be desired or needed by all pedestrians who are blind or who have low vision, or (3) have limited research support.

Pushbutton Information Message – A pushbutton information message is recommended, as it is particularly helpful to some users. A pushbutton information message is essential on APS where the WALK indication is a speech message. This is a message emitted from the APS when the button is pushed during flashing or steady DON'T WALK intervals. The message should be "Wait, to cross Oakdale at North Avenue." (Emphasis and pause after Wait are intentional.) This message provides users with the name of the street controlled by that pushbutton and the name of the other street at the intersection. This message is typically called with an extended button press. (pushbutton is depressed for one second or longer) during DON'T WALK intervals (34).

Louder Signal (Audible Beaconing) – The inclusion of the opportunity to obtain louder signals during the pedestrian phase is recommended. This feature may assist some pedestrians who are blind or who have low vision, including those who have hearing loss, in locating the opposite corner. The louder signal is actuated by an extended button press, and operates only during the next pedestrian phase. It includes both the WALK signal and the subsequent locator tone for that pedestrian phase.

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Tactile Map of Crosswalk – A tactile map of what will be encountered in a crosswalk may be helpful to some pedestrians who are blind or who have low vision, at some crossings. Where used, it should have standard symbols (*see Figure 5-1 for recommended symbols for tactile crosswalk maps*).

Installation Guidance

A single standard for installation is not workable in the U.S., particularly for retrofit situations. Engineering judgment is required to determine the best way to install APS at a given intersection and crossing. Differences in curb radius, width of right-of-way, presence of parkway, curb ramp design and location, and existing infrastructure on corners make each installation different. The recommendations summarized below apply to two types of installation scenarios and are intended to provide general guidance to the practitioner. For more details on and the justification for these recommendations, refer to Chapter 5.

Two Pushbuttons on One Corner, Mounted on Two Poles – Rapid Tick

This design will apply most often on new construction and major alterations that result in reconstruction of the corners of the intersection (e.g., new sidewalks, curb ramps, signal poles, etc.). In this case, two poles should be installed on each corner with pushbutton-integrated APS on each pole.

Optimal location for the pushbutton-integrated APS is between the edge of the crosswalk line (extended) furthest from the corner of the intersection and the side of the curb ramp. APS should be between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement. The control face and tactile arrow should be carefully aligned with the direction of travel on the associated crosswalk. In order to provide wheelchair users with access to the pushbutton, all pushbuttons shall be located adjacent to a level all-weather surface.

Pushbutton-integrated APS shall be a maximum of 5 feet from the edge of the crosswalk line (extended) farthest from the center of the intersection. They shall be a maximum of 10 feet from the edge of the curb, shoulder, or pavement. In this two-pole scenario, the pushbuttons should be separated by a distance of at least 10 feet.

A rapid tick WALK indication is recommended for installations following these guidelines. When pushbuttons are precisely and consistently located in this way, identification of which crossing is being signaled can be based solely on which pushbutton the WALK signal comes from. There is no need to understand speech messages or to remember a cycle (such as cuckoo for a north/south crossing and rapid tick for an east/west crossing).

Two Pushbuttons on One Corner, Mounted on a Single Pole – Speech

This design will apply most often where it is technically infeasible because of limited right-of-way, topography, or locations of other essential equipment on corners, to install two pushbutton-integrated APS on a corner on separate poles. However, the APS features required for this situation are different than where each pushbutton-integrated APS is on its own pole.

For this one-pole scenario, it is recommended that the APS be required to use speech message WALK signals rather than tone signals. Moreover, to be sure users know the street name to listen for in the WALK message, pushbutton information messages identifying the intersection

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and the street to be crossed are also necessary. Wording of speech WALK indications and pushbutton information messages should conform to recommended format (see Chapter 7, Recommended Guidelines).

Volume Adjustment

Volume adjustment of APS is both very important and somewhat difficult. The *MUTCD* Guidance discusses a maximum sound level by which a pushbutton locator tone or walk tone should exceed ambient sound (5 dBA), and an absolute maximum sound level in decibels on the A scale (89 dBA). While manufacturers can limit devices to a maximum of 89 dBA, setting an automatic sound level adjustment system to consistently provide a signal that is approximately 5 dBA above ambient sound is more an art than science at the present time.

A more useful measure in the field is the guidance that APS sounds should be audible 6 to 12 feet from the APS, or to the building line, whichever is less. However, audible distance is a subjective measure that is inevitably influenced by each listener's own hearing, and by such influences on the audible distance of sounds as wind, humidity, and nearby reflective surfaces. Fine tuning of sound levels in the field should be planned for in every APS installation. Visits may need to be made in both peak and off-peak hours to get a setting that is appropriate in both situations.

INTERSECTION PRIORITIZATION

One of the first questions that must be answered by local engineers and others responsible for the installation of APS devices is when and where is it appropriate to install such devices in other than new construction and alteration/reconstruction. In many cases, there is a need to prioritize intersections for APS installations. The *MUTCD* currently provides some guidance on this matter, but a more definitive approach is needed by practitioners.

As part of this research effort, a tool was developed, applied by practitioners, and then validated by comparing the objective ratings achieved with the tool to the subjective ratings of pedestrians with visual impairments and orientation and mobility (O&M) specialists. The tool itself, which includes a set of instructions for application, is provided in the companion document, *Accessible Pedestrian Signals: A Guide to Best Practice*, and is also available on the web at www.walkinginfo.org/aps.

TRAINING AND RESOURCES

Training materials were developed to provide guidance on where and how APS should be installed. The training is directed at three main audiences – traffic engineers, O&M instructors, and signal technicians. The materials consist of a set of PowerPoint presentations that comprise a one-day training course, and a companion resource document, *Accessible Pedestrian Signals: A Guide to Best Practice*.

ADDITIONAL RESEARCH NEEDED

The results of this research have produced a set of recommended guidelines for APS installation and operation that will make it easier and safer for pedestrians with visual impairments to cross streets at signalized intersections. In time, the results will make their way

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into the *MUTCD* and other guides, which will lead to greater uniformity in the field. At the same time, this research discovered a number of issues requiring further investigation. Provided below is a list of topics to be considered for future research:

- Tone types (best accepted by nearby residents)
- Sound volume (best means of providing response to ambient sound, range and speed of response, range of decibel levels)
- Speech message clarity (consistency, programming and downloading messages, standardized library)
- Combining speech message and tones
- Audible message during flashing DON'T WALK (tone vs. speech, countdown)
- Use of APS to aid alignment before crossing and while crossing
- Beaconing (volume, duration after press)
- Guidance on the need for pushbutton APS on side streets.
- Location/Size/Color of tactile arrow
- Tactile map (consistency, availability, guidelines)
- Cold weather issues (future follow-up on case studies, comparison study)
- APS effect on general pedestrian population (use of pushbutton, latency to begin crossing)

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June 20, 1995

PROJECT DOCUMENTATION

FOR:

Capital Records
1750 N. Vine Street
Hollywood, CA 90028

Attn: Mr. John Piro

Project Name/Address:

Capitol Records
First Fl. Crawl Space
1750 N. Vine Street
Hollywood, CA 90028

Prepared by:

Derrin McElroy

17300 South Ave., Ste. 240, Irvine, CA 92714 (714) 724-9979 FAX: (714) 724-9968
In California: 800-540-5802

June 20, 1995

John Piro
Capitol Records
1750 N. Vine Street
Hollywood, CA 90028

RE: Capitol Records, First Fl. Crawl Space, 1750 N. Vine Street, Hollywood, CA 90028.

Job Description: Removal of 160 Ln. Ft. of TSI., completed on June 2, 1995.

Dear Mr. Piro:

QHI, INC. has successfully completed the above referenced project during the period noted.

Enclosed please find QHI, INC.'s documentation of our activities for this project. Certain portions of this documentation may have been replicated for your agent or third party monitoring firm.

Should you have any questions regarding this submittal, please contact me at (714) 724-9979.

Sincerely,

QHI, INC.

Darrin McElroy

7500 Redhill Ave., Ste. 240, Irvine, CA 92714 (714) 724-9979 FAX: (714) 724-9968
In California: 800-540-5502

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SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT (SCAQMD)
NOTIFICATION OF DEMOLITION OR ASBESTOS REMOVAL

SCAQMD USE ONLY	SCREEN BY	RECEIVED	POSTMARK	ENTERED BY	NOTIFICATION #
COMPLETED BY Ray Escobar	COMPANY QHI, Inc.	PHONE (714) 724-9979			
DATE 05/18/95	CHECK #	FEE $	PROJECT # Capital Rec./1 Fl.		
NOTIFICATION TYPE	ORIGINAL X	REVISION DATES	REVISION OTHER (explain)	CANCELLATION	
PROJECT TYPE	DEMOLITION	ORDERED DEMO	RENOVATION (removal) X EMERGENCY RENO	PLANNED RENO (annual)	
REQUIRED	ASBESTOS PRESENT? Yes	ASBESTOS SURVEY? Yes	ASBESTOS REMOVED? NO		
SITE INFORMATION	SITE NAME Capital Records				
ADDRESS 1750 N. Vine St.					
CITY Hollywood	STATE CA	ZIP 90028	COUNTY Los Angeles		
DESCRIBE WORK LOCATION First floor crawl space					
BUILDING SIZE (sq ft) 92,000	NUMBER OF FLOORS 12	BUILDING AGE (years) 39	NUMBER OF DWELLING UNITS		
PRESENT & PRIOR USE Office					
SITE OWNER Capital Records	ADDRESS 1750 N. Vine St.				
CITY Hollywood	STATE CA	ZIP 90028	CONTACT	PHONE (213) 871-5116	

ASBESTOS AMOUNT TO BE REMOVED	FRIABLE	CLASS I	CLASS II	DESCRIBE THE ASBESTOS MATERIALS	
ON PIPES (in square feet)	160			TSI	
SURFACE AREAS (in square feet)					
TOTALS (add columns)	160			160	GRAND TOTAL (add rows)

FEE IS BASED ON GRAND TOTAL. SEE PAGE 2. TO CONVERT LINEAR FEET TO SQUARE FEET: SQUARE FEET = 3.14 X DIAMETER X LENGTH

REMOVAL DATES	START 06/01/95	END 06/02/95	WORK SHIFT (hr/shift) AM		
PROJECT DATES	START 06/01/95	END 06/02/95	WORK SHIFT (hr/shift)		
CONTRACTOR INFORMATION	CSLB LICENSE # 519811	OSHA REG # 70	SCAQMD ID # 98805		
NAME QHI, Inc.	ADDRESS 17500 Redhill Ave, Ste240				
CITY Irvine	STATE CA	ZIP 92714	SITE SUPVR B. Neeley	PHONE (714) 724-9979	

WASTE TRANSPORTER #1 BDC	LANDFILL Azusa Landfill
ADDRESS 766 S. Ayon	ADDRESS 1201 W. Gladstone St.
CITY Azusa STATE CA ZIP 91702	CITY Azusa STATE CA ZIP 91702

AR0072335

WASTE TRANSPORTER #2	WASTE STORAGE SITE
ADDRESS	ADDRESS
CITY STATE ZIP	CITY STATE ZIP

CONTROLS: DESCRIBE WORK PRACTICES AND CONTROLS TO BE USED AT THE DEMOLITION AND RENOVATION SITE. FOR ASBESTOS REMOVAL WORK, INDICATE RULE 1403 PROCEDURE # 1, 2, 3, 4 OR 5, OR COMBINATIONS OF PROCEDURES USED. FOR PROCEDURES 4 AND 5, SUBMIT PLANS FOR SCAQMD APPROVAL. PROCEDURE #:

1 - & 3

ASBESTOS DETECTION PROCEDURE: DESCRIBE THE METHODS AND PROCEDURES USED TO DETERMINE WHETHER ASBESTOS IS PRESENT AT THE SITE, INCLUDING THE ANALYTICAL METHODS:

PLM

FOR ORDERED DEMOLITION SEND A COPY OF THE ORDER AND GIVE THE AGENCY NAME.

AUTHORIZING PERSON: TITLE:

DATE OF ORDER: DATE ORDERED TO BEGIN:

FOR EMERGENCY REMOVAL GIVE DATE AND HOUR OF EMERGENCY AND DESCRIBE THE SUDDEN, UNEXPECTED EVENT:

EXPLAIN HOW THE EVENT WOULD CAUSE UNSAFE CONDITIONS, EQUIPMENT DAMAGE OR UNREASONABLE FINANCIAL BURDEN

CONTINGENCY PLAN: DESCRIBE ACTIONS AND PROCEDURES TO BE FOLLOWED IF UNEXPECTED ASBESTOS IS FOUND DURING DEMOLITION OR REGULATED ASBESTOS MATERIAL BECOMES CRUMBLED, PULVERIZED, OR REDUCED TO POWDER

Stop work, reevaluate materials and procedures before proceeding.

TRAINING CERTIFICATION: I CERTIFY THAT AN INDIVIDUAL TRAINED IN THE PROVISIONS OF REGULATION SCAQMD RULE 1403 AND NESHAP WILL BE ON SITE DURING THE REMOVAL AND EVIDENCE THAT THE REQUIRED TRAINING HAS BEEN ACCOMPLISHED BY THIS PERSON WILL BE AVAILABLE FOR INSPECTION DURING NORMAL BUSINESS HRS

PRINT NAME OF OWNER/OPERATOR: Jerry L. Hendrickson SIGNATURE OF OWNER/OPERATOR: DATE: 05/18/95

INFORMATION CERTIFICATION: I CERTIFY THAT THE ABOVE INFORMATION IS CORRECT AND THAT ENCLOSED AND ATTACHED ATTACHMENTS

SIGNATURE OF OWNER/OPERATOR: Jerry L. Hendrickson DATE: 05/18/95

THIS NOTIFICATION WILL NOT BE ACCEPTED WITHOUT THE REQUIRED ASBESTOS FEE (SCAQMD RULE 301). PLEASE MAKE CHECK PAYABLE TO "SCAQMD". THE FEE VARIES AND DEPENDS ON THE GRAND TOTAL OF ASBESTOS AMOUNT TO BE REMOVED. FEES ARE NOT REFUNDABLE AND ARE AS FOLLOWS:

FROM 161 TO 1,000 SQUARE FEET	$40.12
FROM 1,001 TO 5,000 SQUARE FEET	$75.90
FROM 5,001 TO 10,000 SQUARE FEET	$177.10
MORE THAN 10,001 SQUARE FEET	$278.30
DEMOLITIONS	$25.30
REVISIONS	$10.12

CANCELLATION OF NOTIFICATIONS, REMOVAL PROJECTS AT OWNER-OCCUPIED SINGLE FAMILY DWELLINGS, AND REMOVAL PROJECTS OF LESS THAN 160 SQUARE FEET ARE EXEMPT FROM ASBESTOS FEES.

NOTE: STATE LAW REQUIRES THAT YOU PROVIDE A COPY OF DEMOLITION NOTIFICATIONS TO YOUR LOCAL FIRE AND SAFETY DEPARTMENT. PLEASE ASK A COPY.

MAIL TO: SCAQMD, RULE 1403 ASBESTOS NOTIFICATIONS, P.O. BOX 4950, DIAMOND BAR, CA 91765-0960

TELEPHONE: (909) 396 - 2336

[illegible] Notification Form REV 9/10/94 [illegible]

AR0072336

05/18/95

TEMPORARY WORKSITE NOTIFICATION FOR ASBESTOS and METHYLENEDIANILINE-RELATED WORK

COMPANY/EMPLOYER NAME: QHI, Inc.

HEADQUARTERS ADDRESS: 17500 Redhill Ave, Ste240 Irvine CA 92714

*CONTRACTOR'S STATE LICENSE BOARD LICENSE NUMBER: 519811

DOSH-ACRU (CAL/OSHA) *ASBESTOS REGISTRATION NUMBER: 70
and/or *REPORT OF USE' REGISTRY NUMBER:

ADDRESS OF TEMPORARY WORKSITE and PRECISE LOCATION: Capital Rec./1 Fl.

1750 N. Vine St. Hollywood

NEAREST INTERSECTION: Sunset

TYPE OF BUSINESS: Office

*NAME OF CERTIFIED SUPERVISOR: Bill Neeley

*NAME OF QUALIFIED PERSON IN CHARGE OF AIR MONITORING, LABORATORY WORK, AND RESPIRATORS: Bill Neeley

*NAME OF CERTIFIED CONSULTANT: N/A

PROJECTED JOB STARTING DATE 06/01/95 PROJECTED COMPLETION DATE: 06/02/95

DESCRIBE TYPE, SCOPE AND WORK PRACTICES OF JOB: Removal of 160 Ln. Ft. of TSI.

EVALUATION OF POTENTIAL FOR EXPOSURE: less than .1

ESTIMATED NUMBER OF EMPLOYEES ON THIS JOB: 3

ACCORDING TO THE TITLE 8 CCR SECTION 341.9 AND 1529(r) for ASBESTOS and 5200(p) for MDA, PLEASE SEND THIS COMPLETED NOTICE TO THE NEAREST DISTRICT COMPLIANCE OFFICE (SEE ATTACHED LISTING), NOT TO DOSH HEADQUARTERS OR TO DOSH CONSULTATION, PRIOR TO COMMENCEMENT OF ANY SUCH WORK ACTIVITY.

NOTE: ANY CHANGE IN THE INFORMATION PROVIDED TO THE DISTRICT OFFICE BY THE WRITTEN NOTICE SHALL BE REPORTED TO THE DISTRICT OFFICE WITHIN 24 HOURS OF SUCH CHANGE.

* The star denotes asbestos inquiry only.

(Rev. June, 1993)

CAL/OSHA 183B
May, 1993

AR0072337

SAFETY MEETING	QHI, INC.
PROJECT: Laguna Beach Building	17500 RED HILL AVE. SUITE 240, IRVINE, CALIFORNIA 92714 714 / 724-9979
LOCALE	
AREA/PHASE: Roof Demo MANAGER: Dedel	DATE: 6/1/15 JOB #:
SHIFT: D / N TIME: AM/PM TO: AM/PM	

CONDUCTED BY: M. Dedel	GUEST SPEAKER: N/A
TRANSLATED FROM: [illegible] TO: SPANISH	TRANSLATOR'S NAME: Justo Sosa

ATTENDANCE	
01 [illegible]	11
02 [illegible]	12
03 [illegible]	13
04 [illegible]	14
05	15
06	16
07	17
08	18
09	19
10	20

TOPICS OF DISCUSSION
GLOVE BAG PROCEDURES, SAFETY WORKING ON LADDERS, SAFTY POINTS ABOUT WORK AREAS & TOXIC (LEAD) POTENTIAL HAZARDS

PROJECT MANAGER'S SIGNATURE: [signature] PAGE 1 OF

PROJECT SIGN-IN				OBI, INC.
PROJECT CaliforniaMart (Capitol Records)				17500 RED HILL AVE. SUITE 240, IRVINE, CALIFORNIA 92714 714 / 724-9979
LOCALE 110 E. Ninth St., Los Angeles, CA 90079				
AREA/PHASE ~~Sprinkler~~ Retrofit (Tel Wiring)		MANAGER M. Dodd		DATE 6/11/93 JOB #
SHIFT (D) / N	TIME 10:00 (AM/PM)	TO 7:30 AM/(PM)		

	PRINT OBI EMPLOYEE NAME	EMPLOYEE SIGNATURE	IN	OUT	IN	OUT	INITIAL WORK IN CONTAIN.
01.	Mark Dodd		1000	300	330	930	MD
02.	Jose Molina		1000	300	330	930	MD
03.	Marcos Alvarez		1000	300	330	930	MD
04.	Jose Soza		1000	300	330	930	MD
05.	Ricardo Alvarez		1000	300	330	930	MD
06.							
07.							
08.							
09.							
10.							
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							

FOREMAN'S SIGNATURE: PAGE 1 OF 1

DAILY LOG				QEI, INC.
PROJECT Capitol Records				17500 RED HILL AVE. SUITE 240, IRVINE, CALIFORNIA 92714 714 / 724-9979
LOCALE				
AREA/PHASE Glove Bag		MANAGER Dodd		DATE / JOB #
SHIFT (D) / N	TIME 10 :00 (AM)/PM	TO 7 :30 AM/(PM)		6 / 1 / 95

EQUIPMENT MOVEMENT AND/OR SET-UP OF WORK AREA ONLY TODAY? (Y) / N .	
IDENTIFY SUB-CONTRACTORS WORKING TODAY: NONE	N/A
ANY PERSONS IN CONTAINMENT TODAY? (Y) / N . { INITIAL PROJECT SIGN-IN }	
NUMBER OF SAMPLES TODAY: 6 { INCLUDING THE MIN. 2 FIELD BLANKS }	
THE PERSON RESPONSIBLE FOR PERSONAL SAMPLES TODAY? M. Dodd	
POST RESULTS WITHIN 48 HOURS! DATE OF RESULTS POSTED TODAY: / /	

TIMES OF EVENTS	DETAIL DESCRIPTION OF DAILY EVENTS
10 :00 (AM) / PM	GET MATERIALS AND EQUIPMENT READY
: AM / PM	TO MOBILIZE TO JOB LOCATION
11 :45 (AM) / PM	UNLOAD TRUCK & START TO PREP BOILER RM
3 :00 AM / (PM)	ALL BAGS ARE IN PLACE IN BOILER RM
: AM / PM	AND CRAWL SPACE IS FINISHED
4 :00 AM (PM)	START PREP IN STORAGE RM (UPSTAIRS LOFT
: AM / PM	AND START REMOVAL IN BOILER RM
6 :00 AM / (PM)	START TSI REMOVAL BY GLOVE BAG IN
: AM / PM	STORAGE LOFT, CONT. REMOVAL BY GLOVE BAG
: AM / PM	IN BOILER RM
7 :30 AM / (PM)	FINISH LOFT AREA & BEGIN CLEAN-UP
DETAILS OF PROBLEMS ON PROJECT. MARK FOR SEPARATE PAGES ATTACHED: ___	
PROJECT MANAGER MUST COMPLETE LOG AND SIGN:	

DAILY LOG	QEI, INC.
PROJECT CAPITOL RECORDS	17500 RED HILL AVE. SUITE 240, IRVINE, CALIFORNIA 92714 714 / 724-9979
LOCALE	
AREA/PHASE GLOVEBAG MANAGER Dodd	DATE JOB #
SHIFT (D / N) TIME 10 : 00 (AM) / PM TO 9 : 30 AM (PM)	6/1/95

EQUIPMENT MOVEMENT AND/OR SET-UP OF WORK AREA ONLY TODAY? (Y) / N .	
IDENTIFY SUB-CONTRACTORS WORKING TODAY: NONE.	N/A
ANY PERSONS IN CONTAINMENT TODAY? (Y) N . (INITIAL PROJECT SIGN-IN)	
NUMBER OF SAMPLES TODAY: 6 (INCLUDING THE MIN. 1 FIELD BLANKS)	
THE PERSON RESPONSIBLE FOR PERSONAL SAMPLES TODAY? M. Dodd	
POST RESULTS WITHIN 48 HOURS! DATE OF RESULTS POSTED TODAY: / /	

TIMES OF EVENTS	DETAIL DESCRIPTION OF DAILY EVENTS
7:30 AM / (PM)	TEAR DOWN LOPS AREA OFF SHOP. / CONT. TO
: AM / PM	REMOVE BY GLOVEBAG PROCEDURES IN BOILER RM
8 :00 AM / (PM)	START CLEAN-UP OF BOILER RM -
8 :30 AM / (PM)	TAKE ALL BAGS TO GAS METER ROOM FOR
: AM / PM	TEMP STORAGE.
9 :40 AM / (PM)	ALL EQUIPMENT / TOOLS / MATERIAL STORED
: AM / PM	/ AREA IS ALL TORE DOWN / CLEAN
: AM / PM	
: AM / PM	
: AM / PM	
: AM / PM	

DETAILS OF PROBLEMS ON PROJECT. MARK FOR SEPARATE PAGES ATTACHED: _____

PROJECT MANAGER MUST COMPLETE LOG AND SIGN: [signature]

1 of 2

DAILY LOG	QET, INC.
PROJECT Capitol Records	17500 RED HILL AVE. SUITE 240, IRVINE, CALIFORNIA 92714 714 / 724-9979
LOCALE	
AREA/PHASE MANAGER Dodd	DATE 6/12/95 JOB #
SHIFT (D) / N TIME 12 :00 AM/(PM) TO : AM/PM	

EQUIPMENT MOVEMENT AND/OR SET-UP OF WORK AREA ONLY TODAY? (Y) / N .	
IDENTIFY SUB-CONTRACTORS WORKING TODAY: NONE	N/A
ANY PERSONS IN CONTAINMENT TODAY? (Y) / N . (INITIAL PROJECT SIGN-IN)	
NUMBER OF SAMPLES TODAY: 12 (INCLUDING THE MIN. 2 FIELD BLANKS)	
THE PERSON RESPONSIBLE FOR PERSONAL SAMPLES TODAY? M. Dodd	
POST RESULTS WITHIN 48 HOURS! DATE OF RESULTS POSTED TODAY: / /	

TIMES OF EVENTS	DETAIL DESCRIPTION OF DAILY EVENTS
12 :00 AM / (PM)	START ABOVE CORRIDOR IN CRAWL HOLE
: AM / PM	REMOVING SETUPS UP FOR GLOVEBAG
: AM / PM	START PREPPING VIDEO LIBARY RM
1 :45 AM / (PM)	START REMOVING P.T.S.T USING GLOVEBAG
: AM / PM	PROCEDURES IN LIBARY
3 :00 AM / (PM)	FINISH IN LIBRARY / START PREPPING
: AM / PM	LOWER PART OF SHOP AREA / START BLOW-OUT
: AM / PM	FROM CRAWL HOLE
5 :00 AM / (PM)	START VERTICAL PIPE IN ELEC. SHOP
6 :30 AM / (PM)	ELEC SHOP IS COMPLETED
7 :00 AM / (PM)	START PREP MAIL ROOM

DETAILS OF PROBLEMS ON PROJECT. MARK FOR SEPARATE PAGES ATTACHED: ____

PROJECT MANAGER MUST COMPLETE LOG AND SIGN:

AR0072342

Environmental Monitoring Group

PHASE CONTRAST MICROSCOPY ANALYTICAL REPORT

LIENT NAME: QHT, INC.
17500 Redhill ave. #240
Irvine, CA 92714

EMG #QH72403

OJECT SITE: CAPITOL RECORDS

Date Received: 06/08/95
Date Analyzed: 06/08/95

ie sampling and analytical methods described below present the elements of ie available methods such as NIOSH 7400 method which OSHA considers to be sential to achieve adequate employee exposure monitoring. All employers who e required to utilize analytical laboratories that use this procedure for llecting and analyzing samples. E.P.A recommends re-occupancy level of .01 f/cc or less before clean up is considered complete. If employees of M.G company did not collect the samples, the flow rates and calibration formation used to calculate the results were provided by the client.

AIR SAMPLE RESULTS

Client ID / Lab ID	Sample Type	Sample Date	Location/ Work Area	Total Volume	Fibers Field/100	S/TWA	f/cc
7852 379	Blank	06/01/95	Field Blank	NA	0.0	NA	NA
7853 380	Blank	06/01/95	Field Blank	NA	0.0	NA	NA
7854 881	P	06/01/95	Jorge Moran Boiler Room	407.0	19.5	0.009	0.024
7855 882	P	06/01/95	Jorge Moran Boiler Room	407.0	17.0	0.007	0.021

ENVIRONMENTAL CONSULTANT
14211 EUCLID ST., SUITE DD, GARDEN GROVE, CA 92643 * TEL: (714) 530-0779 FAX: (714) 530-1191

PHASE CONTRAST MICROSCOPY ANALYTICAL REPORT

PROJECT SITE: CAPITOL RECORDS

EMG #QH72403
Date Received: 06/08/95
Date Analyzed: 06/08/95

AIR SAMPLE RESULTS

Client ID / Lab ID	Sample Type	Sample Date	Location/ Work Area	Total Volume	Fibers Field/100	B/TWA	f/cc
37856 3883	B	06/01/95	Jorge Moran Boiler Room	33.0	5.0	NA	<0.089
37857 3884	P	06/01/95	Jorge Moran Boiler Room	180.0	12.0	0.006	0.033
37858 3885	Blank	06/02/95	Field Blank	NA	0.0	NA	NA
37859 3886	Blank	06/02/95	Field Blank	NA	0.0	NA	NA
37860 3887	P	06/02/95	Justo Sosa Crawl Space	180.0	14.5	0.007	0.040
37861 3888	B	06/02/95	Justo Sosa Crawl Space	30.0	5.5	NA	<0.098

AR0072344

PHASE CONTRAST MICROSCOPY ANALYTICAL REPORT

PROJECT SITE: CAPITOL RECORDS

EMG #QH72403
Date Received: 06/08/95
Date Analyzed: 06/08/95

AIR SAMPLE RESULTS

Client ID / Lab ID	Sample Type	Sample Date	Location/ Work Area	Total Volume	Fibers Field/100	S/TWA	f/cc
37862 3889	P	06/02/95	Justo Sosa Elec. Shop	200.0	14.0	0.007	0.034
37863 3890	P	06/02/95	Justo Sosa Mail Room	280.0	16.0	0.008	0.020

G = Gross
A = Half Face
P = Personal
E = Excursion Limit

Dr. Kiet Ho
Laboratory Administrator

AR0072345

CLIENT Capitol Records DATE 6/1/95 PHASE Glove Bag

JOB # TECH. NAME M. Dodd

LOCALE TECH. SIGN. [signature]

[ ] PREWORK [X] REMOVE
[ ] CLEANUP [ ] CLEARANCE
[ ] OTHER [ ] SURVEY

Q H I, I N C.
17500 RED HILL AVENUE
SUITE 240
IRVINE, CA 92714-5629
(714) 724-9979

FIELD DATA | LAB ANALYSIS

SAMPLE ID #	LOCALE/ACTIVITY NAME / SS #	PUMP ID #	RESP TYPE	LITERS/MIN INIT/FINAL	TIME OFF / ON	TOTAL MIN.	TOTAL VOL. LIT.	TOTAL FIB. FIL.	ACTUAL f/cc	REPORT f/cc	METHOD AND/OR NOTES
37852	CODE Blank			IN 0 FN 0							
37853	CODE Blank			IN 0 FN 0							
37854	CODE PRS Jorge Moran Parker KM	15	2	IN 2.2 FN 2.2	1305	1610	185				
37855	CODE PRS Jorge Moran Parker KM	15	2	IN 2.2 FN 2.2	1615	1920	185				
37856	CODE E Jorge Moran Parker KM	15	2	IN 2.2 FN 2.2	AM0	1955	15				
37857	CODE PRS Jorge Moran Parker KM	24	2	IN 2.0 FN 2.0	2005	2155					

INDICATE CODES ABOVE
PRS: PERSONAL SAMPLE. (FULL NAME & SS#)
TWA: TIME WEIGHTED AVERAGE.
STA: STATIONARY WORK AREA.
D/C: IN CLEAN ROOM OR DECONTAMINATION CHAMBER.
C B: AT/NEAR CRITICAL BARRIER
REM: REMOTE TO WORK AREA.
G/B: CLEAN AREA DURING DECON., BAG REMOVAL
A/D: AT A.F.D. EXHAUST

1. 1/2 FACE NEG. PRESSURE
2. FULL FACE NEG. PRESSURE
3. P.A.P.R. 5. S.C.B.A.
4. TYPE "C" 6. OTHER

ANALYSIS-DATES-PROMISED
VERBAL / / AM/PM
WRITTEN / / AM/PM

VERBAL OR FACSIMILE TRANSMISSION OF DATA
1.
PH#/FAX#( )
2.
PH#/FAX#( )

FEILD CALIBRATION ACCEPTABLE Y/N
LEAK CHECK ACCEPTABLE Y/N
CALIB. DATE 5/10/95
ROTO # 808 1907

RELINQ. BY: DATE / / REP. SIGN:

AR0072346

CLIENT Capitol Records DATE 6/12/95 PHASE Glovebags

JOB # TECH. NAME M. Dodd

LOCALE TECH. SIGN. M. Dodd

[ ] PREWORK [ ] REMOVE
[ ] CLEANUP [ ] CLEARANCE
[ ] OTHER [ ] SURVEY

QHI, INC.
17500 RED HILL AVENUE
SUITE 240
IRVINE, CA 92714-5629
(714) 724-9979

FEILD DATA — LAB ANALYSIS

SAMPLE ID #	LOCALE/ACTIVITY NAME / SS #	PUMP ID #	RESP TYPE	LITERS/MIN INIT/FINAL	TIME OFF / ON	TOTAL MIN.	TOTAL VOL. LIT.	TOTAL FIB. FIL.	ACTUAL f/cc	REPORT f/cc	METHOD AND/OR NOTES
37858	CODE BLANK	/	/	IN / FN /	/	/	/				
37859	CODE BLANK	/	/	IN / FN /	/	/	/				
37860	CODE PRS Justo Sosa Crawl Space	24	Z	IN 2.0 FN 2.0	1215	1345	90				
37861	CODE E Justo Sosa Crawl Space	24	Z	IN 2.0 FN 2.0	1345	1400	15				
37862	CODE PRS Justo Sosa Elk Shop	24	Z	IN 2.0 FN 2.0	1805	1945	100				
37863	CODE PRS Justo Sosa Mail Rm	24	Z	IN 2.0 FN 2.0	2010	2230	140				

INDICATE CODES ABOVE
PRS: PERSONAL SAMPLE. (FULL NAME & SS#)
TWA: TIME WEIGHTED AVERAGE.
STA: STATIONARY WORK AREA.
D/C: IN CLEAN ROOM OR DECONTAMINATION CHAMBER.
C B: AT/NEAR CRITICAL BARRIER
REM: REMOTE TO WORK AREA.
G/B: CLEAN AREA DURING DECON., BAG REMOVAL
AFD: AT A.F.D. EXHAUST
PRE: PRE TEST
CLR: CLEARANCE TEST

1. 1/2 FACE NEG. PRESSURE
2. FULL FACE NEG. PRESSURE
3. P.A.P.R. 5. S.C.B.A.
4. TYPE "C" 6. OTHER

ANALYSIS DATES PROMISED
VERBAL / / AM/PM
WRITTEN / / AM/PM

VERBAL OR FACSIMILE TRANSMISSION OF DATA
1.
PH#/FAX#( )
2.
PH#/FAX#( )

FEILD CALIBRATION ACCEPTABLE Y/N
LEAK CHECK ACCEPTABLE Y/N
CALIB. DATE 5/10/95
ROTO # 1007

RELINQ.BY: DATE / / REP. SIGN:
RECEIV.BY: METRO DATE 06/08/95 REP. EMG SIGN: M. Ramirez

WHITE — FIELD CANARY — LABORATORY PINK — OFFICE

AR072347

CITY OF LOS ANGELES
CALIFORNIA

BOARD OF PUBLIC WORKS MEMBERS

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PRESIDENT

MONICA RODRIGUEZ
VICE PRESIDENT

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ALEXANDER E. HELOU
ASSISTANT DIRECTORS

VACANT
CHIEF FINANCIAL OFFICER

1149 SOUTH BROADWAY, 10TH FLOOR
LOS ANGELES, CA 90015
TEL.: (213) 485-0587
FAX: (213) 485-3939
WWW.LACITYSAN.ORG

June 27, 2014

Mr. Samuel Unger, Executive Officer
California Regional Water Quality Control Board
Los Angeles Region
320 West Fourth Street, Suite 200
Los Angeles, CA 90013

Dear Mr. Unger:

SUBMITTAL OF WATERSHED MANAGEMENT PROGRAM FOR THE CITY OF LOS ANGELES AREA IN JURISDICTIONAL GROUP 7 OF THE SANTA MONICA BAY WATERSHED

Please find attached the Watershed Management Program (WMP) for the City of Los Angeles area in Jurisdictional Group 7 of the Santa Monica Bay watershed. The City of Los Angeles, as lead agency for this area, has prepared this WMP on behalf of itself and the Los Angeles County Flood Control District (LACFCD). LACFCD has reviewed the draft WMP prior to submission to the Regional Water Board, and we appreciate their collaboration in the preparation of the document.

The City of Los Angeles and LACFCD originally intended to develop an Enhanced Watershed Management Program (EWMP) for the City of Los Angeles area in Jurisdictional Group 7, as indicated in our Notice of Intent jointly submitted with the Notice of Intent or Jurisdictional Groups 2 and 3 on June 27, 2013. However, Regional Board staff requested the City of Los Angeles and LACFCD to develop a WMP instead of an EWMP because of antidegradation conditions in Jurisdictional Group 7 and limited opportunities for implementation of regional projects capable of capturing and retaining runoff from the 85th percentile storm event. Accordingly, the City of Los Angeles and LACFCD submitted a revised Notice of Intent for a WMP for the City of Los Angeles area in Jurisdictional Group 7 on December 16, 2013.

The WMP for the City of Los Angeles area in Jurisdictional Group 7 mostly relies on implementing the Minimum Control Measures as provided by section VI.D of the new MS4 Permit (Order No. R4-2012-0175), because of the aforementioned antidegradation conditions and limited opportunities for regional projects with groundwater recharge. In addition, water quality data pertaining to this area and information of potential sources and quantities of urban runoff pollutants are very limited at this

time. Accordingly, implementation of the Coordinated Integrated Monitoring Program will indicate if there is a need to identify additional structural watershed control measures through the adaptive management process for the WMP for the City of Los Angeles area in jurisdictional Group 7.

We appreciate the discussions with and the input received from Regional Water Board staff during the development of this WMP and we look forward to the comments on the WMP by your staff and finalizing this document.

Should you have any questions about this submittal, please contact me at Shahram.Kharaghani@lacity.org or phone (213) 485-0587, or your staff may contact Dr. Huub Cox at Hubertis.Cox@lacity.org or phone (213) 485-3984.

Sincerely,

Robert Vega for

SHAHRAM KHARAGHANI, Ph.D., P.E., BCEE
Program Manager

SK:HC
WPDCR9133

Attachment

cc: Renee Purdy, California Regional Water Quality Board, Los Angeles Region
Ivar Ridgeway, California Regional Water Quality Board, Los Angeles Region
Adel Hagekhalil, City of Los Angeles, Bureau of Sanitation
Donna Chen, City of Los Angeles, Bureau of Sanitation
Gary Hildebrand, County of Los Angeles, Department of Public Works

Watershed Management Program for Santa Monica Bay Jurisdictional Group 7 with the City of Los Angeles

Prepared by:
City of Los Angeles
Los Angeles County Flood Control District

The MWH Team

MWH. Geosyntec consultants CWE M2 Resource Consulting, Inc.

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List of Acronyms

Acronym	Definition
ALD	Allowable Exceedance Day
ASBS	Areas of Special Biological Significance
Basin Plan	Basin Plan for the Ocean Watersheds of Los Angeles and Ventura Counties
BIOL	Preservation of Biological Habitats of Special Significance Beneficial Use Designation
BMP	Best Management Practice
CALTRANS	California Department of Transportation
CASQA	California Stormwater Quality Association
CEDEN	California Environmental Data Exchange Network
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CIMP	Coordinated Integrated Monitoring Program
City	City of Los Angeles
COMM	Commercial and Sport Fishing Beneficial Use Designation
CSMP	Coordinated Shoreline Monitoring Plan
CWA	Clean Water Act
DDT	Dichlorodiphenyltrichloroethane
ED	Exceedance Day
EMC	Event Mean Concentration
ES	Executive Summary
ESA	Environmentally Sensitive Area
ESCP	Erosion and Sediment Control Plan
EWMP	Enhanced Watershed Management Program
FC	Fecal Coliform
FIB	Fecal Indicator Bacteria
g/yr	Grams per Year
GM	Geometric Mean
ICIDs	Illicit Connections and Illicit Discharges
IND	Industrial Service Supply Beneficial Use Designation
JG	Jurisdictional Group
JG7	Jurisdictional Group 7 of the City of Los Angeles
LA-SWPPP	Local Storm Water Pollution Prevention Plan
LACFCD	Los Angeles County Flood Control District
LFD	Low-Flow Diversion
LID	Low Impact Development
MAR	Marine Habitat Beneficial Use Designation

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List of Acronyms

Acronym	Definition
MCM	Minimum Control Measure
mg/	Milligrams per Liter
MIGR	Migration of Aquatic Organisms Beneficial Use Designation
MPN/ml	Most Probable Number of Organisms per Milliliter
MRP	Monitoring and Reporting Program
MS4	Municipal Separate Storm Sewer System
MWH	MWH Americas, Inc.
N	Nitrogen
NA	Not Applicable
NAICS	North American Industry Classification System
NAV	Navigation Beneficial Use Designation
ND	Non Detects
ng/L	Nanograms per Liter
NH_3	Ammonia
NO_3	Nitrate
NPDES	National Pollutant Discharge Elimination System
OPTI	On-line Project Tracking and Integration System
PCB	Polychlorinated Biphenyl
Permit	Los Angeles Regional Water Quality Control Board Order No. R4-2012-0175
PIPP	Public Information and Participation Program
PMRP	Plastic Pellet Monitoring and Reporting Program
POTW	Publically Owned Treatment Works
PR	Percent Removal
QA/QC	Quality Assurance/Quality Control
RAA	Reasonable Assurance Analysis
RARE	Rare, Threatened, or Endangered Species Beneficial Use Designation
Regional Board	Los Angeles Regional Water Quality Control Board
RWL	Receiving Water Limitation
SCBPP	Southern California Bight Pilot Project
SCCWRP	Southern California Coastal Water Research Project
SHELL	Shellfish Harvesting Beneficial Use Designation
SIC	Standard Industrial Classification
SMB	Santa Monica Bay
SMBB	Santa Monica Bay Beaches
SMB JG7 WMP Group	Santa Monica Bay Jurisdictional Group 7 Watershed Management Program Group
SMB WMA	Santa Monica Bay Watershed Management Area
SMURRF	Santa Monica Urban Runoff Recycling Facility
SPWN	Spawning, Reproduction, and/or Early Development Beneficial Use Designation

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List of Acronyms

Acronym	Definition
SQMP	Stormwater Quality Management Plan
SUSMP	Standard Urban Stormwater Mitigation Plan
SWAMP	Surface Water Ambient Monitoring Program
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
TMRP	Trash Monitoring and Reporting Plan
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WBPCs	Water Body-Pollutant Combinations
WDID	Waste Discharger Identification
WLD	Wildlife Habitat Beneficial Use Designation
WMA	Watershed Management Area
WMP	Watershed Management Program
WQBEL	Water Quality Based Effluent Limitation

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1 Introduction

1.1 Background and Regulatory Framework

The National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit No. R4-2012-0175 (Permit) was adopted November 8, 2012 by the Los Angeles Regional Water Quality Control Board (Regional Board) and became effective December 28, 2012. The purpose of the Permit is to ensure the MS4s in Los Angeles County are not causing or contributing to exceedances of water quality objectives set to protect the beneficial uses in the receiving waters in the Los Angeles region.

The Permit allows Permittees to customize their stormwater programs through the development and implementation of a Watershed Management Program (WMP) or an Enhanced Watershed Management Program (EWMP) to achieve compliance with receiving water limitations (RWLs) and water quality based effluent limits (WQBELs). The City of Los Angeles (City) has been a participating agency of Jurisdictional Group 7 (JG7) of the Santa Monica Bay Watershed since the adoption of the Santa Monica Bay Beaches Bacteria Total Maximum Daily Loads (TMDLs) in 2003. However, the City of Los Angeles and the other MS4 permittees in JG7 could not reach an agreement for a collaborative approach to satisfying the requirements of the MS4 permit. Therefore, on November 21, 2013 the Regional Board requested that the City and the Los Angeles County Flood Control District (LACFCD, collectively referred to as the Santa Monica Bay JG7 WMP Group (SMB JG7 WMP Group), pursue a WMP instead of an EWMP. The primary reasons for this request included: 1) MS4 discharges to Santa Monica Bay are anticipated to be minimal due to the small contributing drainage areas; and 2) opportunities for structural best management practices (BMPs) implementation are limited due to the geography of the WMP area (e.g., cliffs at bluffs, landslide and liquefaction hazards, etc.). In December of 2013, the SMB JG7 WMP Group submitted a revised Notice of Intent to develop a WMP for the City of Los Angeles land area within the JG7 area to fulfill the requirements of the Permit.

This WMP, in combination with the JG7 Coordinate Integrated Monitoring Program (CIMP), was prepared to satisfy Part V.C.1 of the Permit, which includes the following tasks:

1. Prioritize water quality issues resulting from stormwater and non-stormwater discharges from the MS4 to receiving waters within each Watershed Management Area (WMA);
2. Identify and implement strategies, control measures, and BMPs to achieve the outcomes specified in Part VI.C.1.d;
3. Execute an integrated monitoring program and assessment program, pursuant to Attachment E – MRP, Part VI, to determine progress towards achieving applicable limitations and/or action levels in Attachment G;
4. Modify strategies, control measures, and BMPs as necessary, based on analysis of monitoring data collected pursuant to the monitoring and reporting program (MRP) to ensure that applicable WQBELs, RWLs and other milestones set forth in the WMP are achieved in the required timeframes; and
5. Provide appropriate opportunity for meaningful stakeholder input, including but not limited to, a permit-wide watershed management program technical advisory committee (TAC) that will advise and participate in the development of the WMPs and EWMPs from month 6 through the date of program approval.

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1.2 SMB JG7 WMP Group Geographical Area

The SMB JG7 WMP Group area is located within the southern portion of the Santa Monica Bay WMA, which encompasses an area of approximately 414 square miles and includes the Santa Monica Bay and land area that drains into the Bay. The boundary of the Santa Monica Bay, as defined for the National Estuary Program, extends from the Los Angeles/Ventura County line to the northwest, southeast toward Point Fermin located on the Palos Verdes Peninsula. The land area that drains into the Bay follows the crest of the Santa Monica Mountains on the north to Griffith Park; then extends south and west across the Los Angeles coastal plain to include the area east of Ballona Creek and north of the Baldwin Hills. South of Ballona Creek, the natural drainage is a narrow coastal strip between Playa del Rey and Palos Verdes (Regional Board 2011). **Figure 1-1** depicts the location of the SMB JG7 WMP Group within the Santa Monica Bay Watershed.

The SMB JG7 area includes the Cities of Rancho Palos Verdes, Palos Verdes Estates, Rolling Hills, Rolling Hills Estates, and the City of Los Angeles. This SMB JG7 WMP only addresses the area owned by the City and LACFCD within JG7, which includes the following water bodies as listed in the Basin Plan:

- Los Angeles County Coastal Nearshore Zone
- Royal Palms Beach
- Whites Point County Beach

The SMB JG7 WMP area, which consists of land owned by the City and includes any LACFCD infrastructure, totals approximately 977 acres, which is approximately 9% of the entire JG7 area within the Santa Monica Bay Watershed. **Figure 1-1** illustrates the extent of the SMB JG7 WMP Group Area. The geographical scope of the SMB JG7 WMP Group area excludes areas of land totaling approximately 47 acres for which the MS4 permittees do not have jurisdiction, including land owned by the Los Angeles Air Force Base Pacific Crest Housing Area. With the exclusion of these areas, the SMB JG7 WMP area covers 907 acres. The majority of the land uses within the WMP area consist of residential (approximately 69%) and vacant/open space (approximately 26%), with the remaining area consisting of a mixture of commercial, educational, and industrial land uses. There are no designated transportation or agricultural land uses in the WMP area. The open space area includes 102 acres of restored coastal sage scrub habitat and hiking trails located within the White Point Nature Preserve Wild Park.

Table 1-1
SMB JG7 WMP Land Use Summary

Land Use	% of Total
Commercial	3%
Industrial	0.1%
Education	3%
Multi-Family Residential	12%
Single Family Residential	56%
Open Space	26%
Total	100%

The City of Los Angeles JG7 WMP area includes 218 catch basins and seven storm drain outfalls owned and operated by either the City of Los Angeles or the LACFCD. The majority of the storm drain outfalls in the SMB JG7 WMP area are circular pipes extending from the Cliffside, around one hundred feet above the rocky shoreline. The majority of the outfalls themselves are inaccessible at the pipe outlet.

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The coastline along and several inland sites within the SMB JG7 WMP area is characterized as being subject to landslide and liquefaction hazards (City of Los Angeles Bureau of Engineering, 2011). This characterization was exemplified by the destruction of the SMB 7 7 1 MDL shoreline monitoring site due to landslide in 2009

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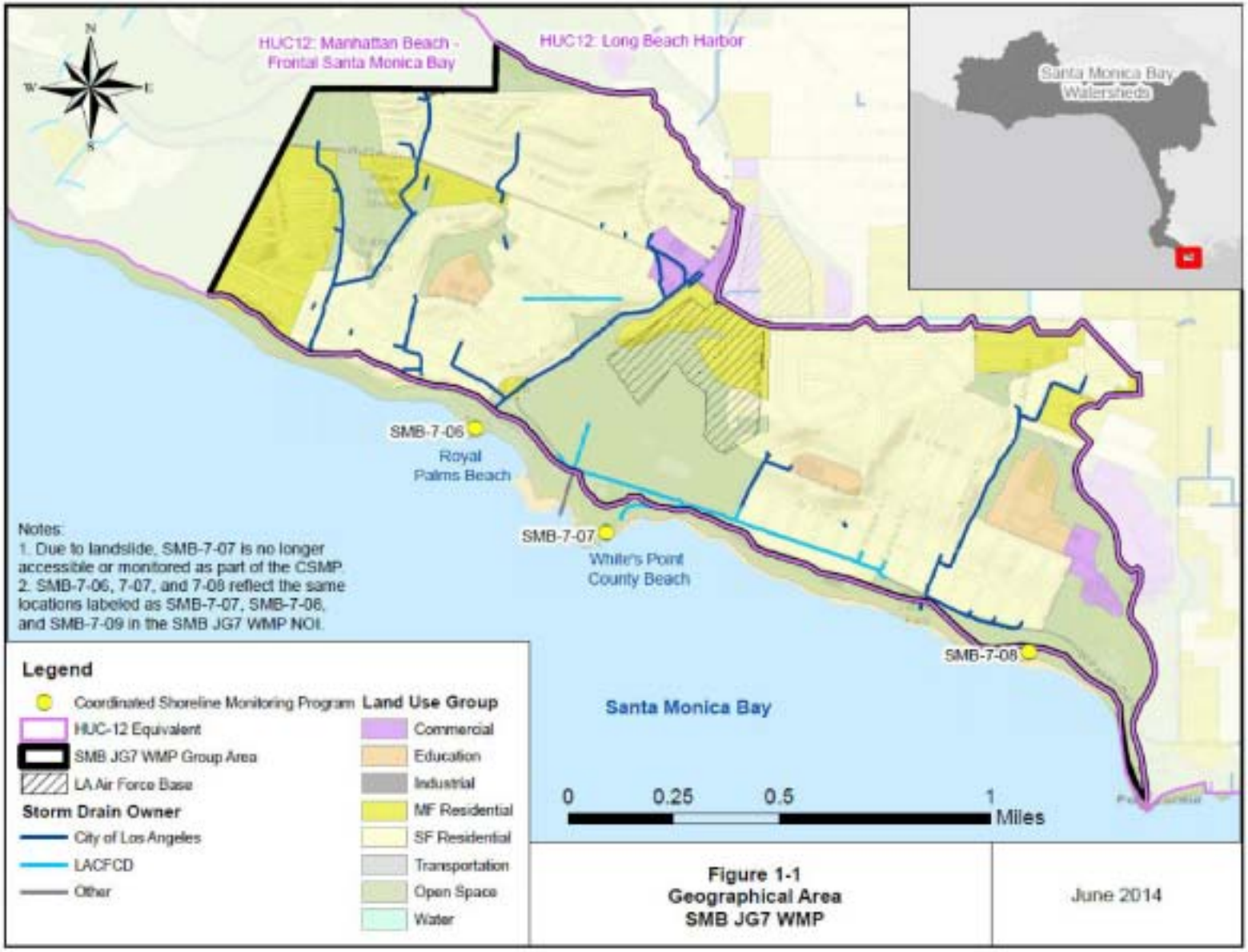

Figure 1-1
Geographical Area
SMB JG7 WMP

June 2014

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1.3 Watershed Management Program Development Process

The WMP for the SMB JG7 WMP Group includes four major components, as follows:

1. **Water Quality Priorities:** The identification of water quality priorities is an important first step in the WMP process. Water quality priorities, described in Section 2, are defined for individual constituents within a specific water body, termed as Water Body-Pollutant Combinations (WBPCs). Categories of the WBPCs are defined in the Permit. Priorities are assigned to the WBPCs based on the categorization. The water quality priorities will provide the basis for prioritizing implementation activities within the WMP.

2. **Watershed Control Measures/Minimum Control Measures:** Development of the WMP requires identification of control measures/BMPs, as described in Section 4, expected to be sufficient to meet receiving water and effluent limitations set forth in the MS4 Permit (Regional Board, 2012). BMPs vary in function and type, with each BMP providing unique design characteristics and benefits from implementation. The overarching goal of BMPs in the WMP is to reduce the impact of stormwater and non-stormwater runoff on receiving water quality.

3. **Reasonable Assurance Analysis:** A key element of each WMP is the reasonable assurance analysis (RAA), described in Section 4, which is used to demonstrate *"…that the activities and control measures…will achieve applicable WQBELs and/or RWLs with compliance deadlines during the Permit term"* (Section C.5.b.(v), page 63). The Permit presumes the RAA as a quantitative demonstration that control measures, specifically BMPs, will be effective. In other words, the RAA not only demonstrates the cumulative effectiveness of BMPs to be implemented, but it also supports their selection. However, due to zero target load reductions and alternative compliance measures for the identified WBPCs, a quantitative analysis is not necessary at this time. Therefore, the SMB JG7 WMP group has decided to present a qualitative RAA discussion, acknowledging that a quantitative RAA may become necessary in the future based on results of future CIMP monitoring.

4. **Adaptive Management Process:** The WMP is intended to be implemented as an adaptive program, as described in Section 5. As new program elements are implemented and information is gathered over time, the WMP will undergo modifications to reflect the most current understanding of the watershed and present a sound approach to addressing changing conditions. As such, the WMP will employ an adaptive management process that will allow the WMP to evolve over time.

1.4 Watershed Management Program Overview

This WMP has been prepared to outline the steps that will be taken by the SMB JG7 WMP Group in compliance with the requirements and deadlines set forth within the MS4 Permit. This document is organized into the following sections:

- **Section 1** – Introduction
- **Section 2** – Identification of Water Quality Priorities
- **Section 3** – Watershed Control Measures
- **Section 4** – Reasonable Assurance Analysis Approach
- **Section 5** – Adaptive Management Process
- **Section 6** – References

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2
Identification of Water Quality Priorities

To develop the WMP, the Permit requires that SMB JG7 WMP Group establish water quality priorities within their WMA. In accordance with the Permit Section IV.C.5(a), this section characterizes the water quality conditions within the SMB JG7 WMP area, identifies water quality priorities, determines water body-pollutant classifications, and assesses pollutant sources. The water quality priorities identified in this section provide the basis for prioritizing project implementation; selecting and scheduling BMPs (if needed); and focusing monitoring activities developed in the CIMP.

2.1 Water Quality Characterization

Figure 2-1 identifies the receiving waters in the SMB JG7 WMP Group area, as depicted in the Water Quality Control Plan, Los Angeles Region (Basin Plan) (Regional Board, 1995, Updated 2011). **Table 2-1** summarizes the beneficial uses for each of these water bodies, as designated in the Basin Plan. As beneficial uses designated as "potential" have not yet been established, these uses will not be evaluated further in the WMP. The SMB JG7 WMP Group area includes the water bodies listed below.

- Los Angeles County Coastal Nearshore Zone
- Royal Palms Beach
- Whites Point County Beach

Beneficial use designations for these water bodies include the following:

- **Water Contract Recreation (REC-1):** Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.
- **Non-Contact Water Recreation (REC-2):** Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
- **Industrial Services Supply (IND):** Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, firs protection, or oil well re-pressurization.
- **Navigation (NAV):** Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.
- **Commercial and Sport Fishing (COMM):** Uses of water for commercial or recreational collection of fish, shellfish, or other organisms intended for human consumption or bait purposes.
- **Marine Habitat (MAR):** Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).
- **Preservation of Biological Habitats (BIOL):** Uses of water that support designated areas of habitats, such as Areas of Special Biological Significance (ASBS), established refuges, parks,

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sanctuaries, ecological reserves, or other areas where the preservation or enhancement of natural resources requires special protection.

- **Migration of Aquatic Organisms (MIGR):** Uses of water that support habitats necessary for migration, acclimatization between fresh and salt water, or other temporary activities by aquatic organisms, such as anadromous fish.
- **Spawning, Reproduction, and/or Early Development (SPWN):** Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.
- **Shellfish Harvesting (SHELL):** Uses of water that support habitats suitable for the collection of filter feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.
- **Wildlife Habitat (WILD):** Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.
- **Rare, Threatened, or Endangered Species (RARE):** Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.

Table 2-1
Beneficial Uses of Water Bodies and Coastal Features Designated in the Basin Plan

Water Body (and Tributaries)	Beneficial Uses											
	REC-1	REC-2	WILD	RARE	IND	NAV	COMM	MAR	BIOL	MIGR	SPWN	SHELL
Los Angeles County Coastal Nearshore Zone[a]	E	E	E	E[c]	E	E	E	E	E[an]	E	E[f]	E
Royal Palms Beach	E	E	E			E	E	E			P	E
Whites Point County Beach	E	E	E			E	E	E			P	E

E = Existing beneficial use

P = Potential beneficial use

c = One or more rare species utilizes all or part of bays, estuaries, and coastal wetlands for foraging and/or nesting.

f = Aquatic organisms (e.g., all life stages of anadromous species and certain species of estuarine fishes) migrate through all bays, estuaries, lagoons, and coastal wetlands to a certain extent for spawning and early development. This may include migration into areas that are already influenced by freshwater inputs.

an = Areas of Special Biological Significance (ASBS) along coast from Latigo Point to Laguna Point and Big Sycamore Canyon and Arrowhead Cove Ecological Reserves and Point Fermin Marine Life Refuge.

a = Nearshore is defined as the zone bounded by the shoreline and the 30 foot depth contours, whichever is further from the shoreline, throughout the area from Rincon Creek to the San Gabriel River Estuary.

2.1.1 Water Quality Objectives/Criteria

The Clean Water Act (CWA) requires that the State Water Resources Control Board (SWRCB) and Regional Boards conduct a water quality assessment that addresses the condition of its surface waters [required in Section 305(b) of the CWA] and provides a list of impaired waters [required in CWA Section 303(d)] that is then submitted to the U.S. Environmental Protection Agency (USEPA) for review and approval. The 2010 Integrated Report and updated 303(d) list were approved by the SWRCB on August 4, 2010 and by the USEPA on October 11, 2011. The 2010 303(d) listed water bodies and associated pollutants within the SMBRWQ WMP Group area are summarized in **Table 2-2**.

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Table 2-2
2010 303(d)-Listed Water Bodies in the SMB JG7 WMP Group Area

Water Body	Pollutant Class	Pollutant	Notes
Santa Monica Bay Beaches	Pathogens	Coliform Bacteria	Addressed by Bacteria TMDL
	Pesticides	DDT	Addressed by PCB/DDT TMDL
	Other Organics	PCBs	Addressed by PCB/DDT TMDL
Santa Monica Bay (Los Angeles County Coastal Nearshore Zone)	Trash	Debris Plastic Pellets	Addressed by Trash TMDL
	Pesticides	DDT (tissue & sediment)	Addressed by PCB/DDT TMDL
	Other Organics	PCBs (tissue & sediment)	Addressed by PCB/DDT TMDL
	Toxicity	Sediment Toxicity	Addressed by PCB/DDT TMDL
	Miscellaneous	Fish Consumption Advisory	Addressed by PCB/DDT TMDL

Water bodies are subject to water quality objectives in the Basin Plan or Basin Plan Amendments, such as those to implement TMDLs. There are currently three TMDLs in effect for the water bodies within the SMB JG7 WMP Group area as listed in Attachment M of the Permit. These TMDLs are summarized in **Table 2-3**

Table 2-3
Santa Monica Bay TMDLs

TMDL Name	Agency	Effective Date
SMB Beaches Bacteria TMDL, Reconsideration of Certain Technical Matters of the SMB Beaches Bacteria TMDL, Resolution R12-007[1]	Regional Board	Not yet effective
SMB TMDL for DDT and PCBs	USEPA	March 26, 2012
SMB Nearshore Debris TMDL, Resolution R10-010	Regional Board	March 20, 2012
SMB Beaches Bacteria TMDL, Dry Weather, Resolution 2002-022[2]	Regional Board	July 15, 2003
SMB Beaches Bacteria TMDL, Wet Weather, Resolution 2002-022[2]	Regional Board	July 15, 2003

[1] This TMDL revision is not yet approved by USEPA
[2] This TMDL was revised pursuant to Resolution R12-2007

Table 2-4 identifies the applicable WQBELs and/or RWLs established pursuant to TMDLs included in Attachment M of the Permit. The water quality objectives as listed in the Basin Plan are also applicable to water bodies based on the designated beneficial uses. The Trash TMDL final WQBELs are effective March 26, 2020. The effective date of the polychlorinated biphenyl (PCB) and

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dichlorodiphenylchloroethane (DDT). final WQBELs will be specified later in this document, since the USEPA-developed TMDL lacks a compliance schedule. The Bacteria TMDL final WQBELs and RWLs are currently effective for both dry weather and wet weather.

Table 2-4
Final Permit RWLs and WQBELs for SMB TMDLs

Reference	Parameter	Effluent Limitation/ Receiving Water Limitation
SMB Nearshore Debris TMDL	Trash – WQBEL	Zero
	Plastic Pellets – WQBEL	Zero
TMDL for PCBs/DDTs (for LA County MS4)	DDT – WLA	27.08 g/yr (based on 3-year averaging period)[2]
	PCBs – WLA	140.25 g/yr (based on 3-year averaging period)[2]
	Total coliform (daily maximum) – WQBEL	10,000 Most Probable Number (MPN)/100 mL
	Total coliform (daily maximum) if the ratio of fecal- to total coliform exceeds 0.1 – WQBEL	1,000 MPN/100 mL
SMB Beaches Bacteria TMDL	Fecal coliform (daily maximum) – WQBEL	400 MPN/100 mL
	Enterococcus (daily maximum) – WQBEL	104 MPN/100 mL
	Total coliform (geometric mean[1]) – WQBEL/RWL	1,000 MPN/100 mL
	Fecal coliform (geometric mean[1]) – WQBEL/RWL	200 MPN/100 mL
	Enterococcus (geometric mean[1]) – WQBEL/RWL	35 MPN/100 mL

[1] The rolling 30-day geometric mean is calculated based on the previous 30 days. The modified 2012 TMDL which has not yet been approved by USEPA, requires the weekly calculation of a rolling six-week geometric mean using five or more samples taken on all calculation weeks on Sunday.
[2] Group-based WQBELs that apply to all SMB MS4 permittees. The individual-based WQBELs for SMB JRP WMP Group members would be an area-weighted fraction of this.
MPN/100 mL = most probable number of organisms per milliliter.

Grouped RWLs for the Santa Monica Bay Beaches Bacteria TMDL are also expressed in the Permit in terms of allowable exceedance days (AEDs), which vary by season and by Coordinated Shoreline Monitoring Plan (CSMP) monitoring station. AEDs applicable to SMB 7-6 and 7-8 are summarized and discussed in **Table 2-6**, presented in the following Section 2.1.4.

[illegible] Resolution 2020-048, the [illegible] elects to participate in the Water Quality Equivalency Option for SMB Beaches Bacteria TMDL compliance. [illegible] Permit, [illegible] compliance [illegible] Final [illegible] Permit for [illegible] by 15 [illegible] http://[illegible].ca.gov/losangeles/[illegible]/Resolution_No_2020-048.pdf.

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2.1.2 QA/QC Criteria

Quality assurance/quality control (QA/QC) criteria have been established to verify that data referenced in this water body characterization are qualified for use. All data used have either been peer reviewed; were submitted as part of an official record, such as in an agency's Annual Report to the Regional Board; or have met QA/QC criteria established by another party, such as the County, City Environmental Health Division, Regional Board, or California Environmental Data Exchange Network (CEDEN), which includes the Bight Program. Data not meeting these criteria have not been used in this water body characterization.

2.1.3 Detailed Data Analysis

A detailed monitoring data analysis was conducted to:

1. Evaluate the status of TMDL compliance;
2. Evaluate the status of 303(d) listings (i.e., whether any WBPCs meet the SWRCB's 303[d] delisting criteria);
3. Identify other WBPCs that meet 303(d) listing criteria; and
4. Identify remaining WBPCs demonstrating exceedance(s) of applicable receiving water limitations.

Monitoring data analyzed are summarized in **Table 2-5**, and existing monitoring stations are shown in **Figure 2-1**. It should be noted that the data presented are receiving water quality data and do not imply MS4 contributions.

Table 2-5
Existing Monitoring Programs

Program Name	Monitoring Period	Monitoring Locations	Parameters Analyzed	Frequency
Coordinated Shoreline Monitoring Program	2004-2013	Santa Monica Bay Beaches	Bacteria	Varies by site, weekly or daily
Southern California Bight Regional Monitoring	1994 - 2013	Santa Monica Bay Offshore/Nearshore	General suite in 1995 and 1998; PCBs and DDTs in 2003 and 2008	Varies by site

2.1.4 TMDL Compliance Status

Table 2-6 summarizes the shoreline monitoring bacteria data for 2003 through 2013 with respect to the number of exceedance days (EDs) at SMB-7-06 and SMB-7-08, as defined in the TMDL (exceeding one of four single sample daily maximum REC-1 WQOs). Both sites are open beach locations, and as such, any exceedance is not necessarily directly attributable to the MS4. Compliance at SMB-7-07 is not reported here because it was destroyed in a landslide in 2009 and is neither accessible nor monitored. Geometric mean exceedance days are not reported here. A summary of the average, median, minimum, and maximum water quality results from sampling at SMB 7-06 and SMB 7-08 is included in Attachment A. If follow-up samples were collected for weekly sites then those were included in this analysis, which may increase the number of reported EDs. As shown in **Table 2-6**, the summer dry weather AEDs have been exceeded eight out of the eleven years (73%) and three out of the eleven years (27%) between 2003 and 2013 for stations SMB-7-6 and SMB-7-8, respectively. The winter dry weather AEDs have been exceeded six out of the eleven years (55%) and one out of the eleven years (9%) between 2003 and 2013 for stations SMB-7-6 and SMB-7-8, respectively. The wet weather AEDs have been exceeded four out of the eleven years (36%) and two out of the eleven years (18%) between 2003 and 2013 for stations SMB-7-6 and SMB-7-8, respectively. It should be noted that 2005 recorded the most annual rainfall in Los Angeles County history (34 inches), which likely contributed to the abnormal number of exceedances.

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Figure 2-1
Existing Monitoring Stations
SMB JG7 WMP

June 2014

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Table 2-6
Summary of Exceedance Days
(bold text signifies Exceedance Days > Allowable Exceedance Days)

Station (type)	Season	AEDs	Number of Exceedance Days per TMDL Year										
			2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
SMB-7-6 (open beach)	Dry-Summer[1]	0	1	1	1	2	0	2	0	1	0	1	1
	Dry Winter[2]	1	**3**	1	**11**	1	**2**	0	**5**	1	2	**2**	0
	Wet[3]	1*	1	1	**28**	1	0	2	1	**3**	**2**	1	0
SMB 7 0 (open beach)	Dry Summer[1]	0	1	1	0	0	0	0	0	0	0	3	0
	Dry-Winter[2]	1	0	0	**2**	0	0	0	1	0	1	0	0
	Wet[3]	1*	0	0	**13**	0	0	0	1	0	**2**	1	0

[1] Summer Dry Weather: April 1 - October 31
[2] Winter Dry Weather: November 1 - March 31
Wet Weather: November 1 - October 31 days with > 0.1 inches of rain and the three days following
[3] 2003 3 occasions in November and December
AEDs are based on weekly sampling. Exceedance days were calculated based on the raw data. For example, in cases where more than one sample was collected in a single week, these results were still considered against the weekly AEDs. This approach is consistent with annual monitoring reports but overestimates actual exceedance weeks.

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2.1.5 Other Water Body-Pollutant Combinations that meet 303(d) Listing Criteria

There were no WBPCs identified within the SMB JG7 WMP geographical scope that were found to meet the 303(d) listing criteria.

2.1.6 Remaining Water Body-Pollutant Combinations Demonstrating Exceedance(s) of Applicable Receiving Water Limitations

Water quality data were compared to WQBELs and/or water quality objectives to determine if exceedances occurred within the last five (5) years. Those constituents that either had no exceedances within the past five (5) years or did not meet the 303(d) listing criteria for impairment, are discussed below but will not be considered in the prioritization process at this time.

USEPA's Santa Monica Bay DDTs and PCBs TMDL (USEPA 2012) relies on a limited dataset to establish stormwater load allocations, relying on a single study (Curren *et al.* 2011) from a single creek (Ballona Creek, which is outside the SMB JG7 WMP area) to extrapolate MS4 wasteload allocations to other SMB watersheds based on percent urban area. The Santa Monica Canyon, Ballona Creek, and Hermosa Beach watersheds combined represent 94% of the developed area draining to Santa Monica Bay. The TMDL does not present sufficient data to assign MS4 contributions to the DDT and PCB concentrations observed in Santa Monica Bay.

The Bight Regional Monitoring program includes six[1] offshore sampling locations within the SMB JG7 WMP geographical scope that were sampled between 1994 and 2008. Two sites (1267 SCBPP and 808 3389) were only sampled in 1994 and 1998, respectively, which is outside the range of recent data (10 years). The other sampling locations include sediment-based data from 2003 and 2008. The only TMDL sediment-based targets applicable to the SMB JG7 WMP area are for DDTs and PCBs; therefore, DDTs and PCBs are the only analytes included in this analysis. The sampling sites containing these data from 2003 and 2008 were located between 0.5 and 2 miles off the coastline of the SMB JG7 WMP Area. **Table** 2-7 summarizes the results from these sampling sites.

[1] The Bight regional monitoring program includes sediment chemistry data from 94 stations in the Santa Monica Bay region. Of these stations, sediment data from only six locations during the 2003 and 2008 sampling events were located within the SMB JG7 WMP area.

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Table 2-7
Bight '03 and '08 PCB and DDT Monitoring Results[a]

Station ID	Station Description	Date	PCB[b] (ug/kg OC)	DDT[b] (ug/kg OC)
B08-7324	Approximately 0.5 miles off the coast of Point Fermin Park Beach	7/24/2008	103	**3,865**
B03-4042/ B08-7321	Approximately 0.6 miles off the coast of Point Fermin Park Beach	8/19/2003	**5,318**	**60,400**
		7/24/2008	**2,923**	**5,171**
B03-4170	Approximately 0.75 miles off the coast of Point Fermin Park Beach	8/21/2003	**1,051**	**22,984**
B03-4202/ B08-7320	Approximately 2 miles off the coast of White's Point Beach	8/20/2003	**9,419**	**111,497**
		7/24/2008	**19,420**	**125,515**

[a] Bold text signifies an exceedance of the sediment targets (normalized to total organic carbon) set forth in the PCBs and DDT TMDL for Santa Monica Bay. These established targets are 2,300 ug/kg OC for total DDT and 700 ug/kg OC for total PCBs.
[b] These are estimated values that assume one half of the method detection limit for all non-detect results.

Since the Bight samples were collected 0.5 to 2 miles off the coast away from any MS4 outfalls, this does not represent sufficient evidence to establish potential linkage of MS4 discharges to observed sediment concentrations.

2.2 Water Body-Pollutant Prioritization

Based on the water quality characterization, the WBPCs identified in **Table 2-8** have been classified into one of three categories, in accordance with Section IV.C.5(a)ii of the Permit. This categorization is intended to prioritize WBPCs in order to guide the implementation of structural and institutional BMPs.

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Table 2-8
Water Body Pollutant Prioritization
(Listed in order of compliance deadline, interim and final are included, passed deadlines are shown in bold font)

Category	Water Body	Pollutant	Compliance Deadline
1	SMB Beaches	Summer dry weather bacteria	**7/15/2006 for single sample AEDs**
		Winter dry weather bacteria	**7/15/2009 for single sample AEDs**
		Wet weather bacteria	**7/15/2013 for single sample AEDs**[1]
			7/15/2013 for geometric mean (GM)[1]
	SMB Offshore/ Nearshore	Debris	9/20/2016 (20% load reduction)
			9/20/2017 (40% load reduction)
			9/20/2018 (60% load reduction)
			9/20/2019 (80% load reduction)
			9/20/2020 (100% load reduction)
	SMB	DDTs	[No compliance deadline specified in TMDL][2]
		PCBs	[No compliance deadline specified in TMDL][2]
2	No Category 2 WBPCs have been identified at this time		
3	No Category 3 WBPCs have been identified at this time		

[1] Per Resolution 2006-008, the Regional Board is pursuing a non-integrated water resources approach to SMB Beaches Bacteria TMDL compliance, which results in a final wet weather compliance deadline of at most 10 years after July 15, 2003 (http://www.waterboards.ca.gov/losangeles/board_decisions/adopted_orders/resolutions/2006/Res_2006-008_SMB_Bac_TMDL.pdf).

[2] Although the TMDL does not have a formal compliance schedule for the WLAs, Table 6-5 of the TMDL does specify a timeline for the DDT PCB targets in water and sediment. Additionally, the WLA target was set at existing waste load so full implementation considered over

As part of the adaptive management process, categorization of future WBPCs may be adjusted based on data obtained from monitoring, source evaluations, and BMP implementation. Data collected as part of the approved CIMP may result in future Category 3 designations in instances when receiving water limits are exceeded and MS4 discharges are identified as contributing to such exceedances. Under these conditions, the appropriate agencies will adhere to Section VI.C.2.a.iii of the Permit.

2.2.1 Category 1 – Highest Priority

WBPCs under Category 1 (highest priority) are defined in the Permit as "*water body-pollutant combinations for which water quality-based effluent limitations and/or receiving water limitations are established in Part VI.E and Attachments I through R of the Permit).*"

The WMP of bacteria over and dry weather at the Santa Monica Bay Beaches within the SMB 1G7 WMP area (including Royal Palms Beach, White Point Beach, and Point Fermin Park Beach) fall within Category 1 because they are listed in the Santa Monica Bay Beaches Bacteria TMDL.

Similarly, a Debris TMDL exists for Santa Monica Bay. Section VI.E.5.b(i) of the Permit states, "*Pursuant to California Water Code section 13360(a), Permittees may comply with the trash [debris] effluent limitations using any lawful means. Such compliance options are broadly classified as full capture, partial capture, institutional controls, or combined frequency of cleaning and collection… and any combination of these may be employed to achieve compliance.*" While trash will not be modeled as

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part of the RAA, the RAA will address how the JG7 agencies will comply with the TMDL WQBELs by providing details on the planned implementation of the methods listed above, primarily through their Trash Monitoring and Reporting Program.

Although a USEPA TMDL exists for DDTs and PCBs for Santa Monica Bay, the TMDL relies on a limited dataset outside of the JG7 watershed area to establish stormwater load allocations. The TMDL mass-based waste load allocations for DDTs and PCBs are equivalent to the estimated existing stormwater loads (i.e., based on data used in the TMDL), so MS4 load reduction is required. As a result, it is anticipated that for the WMP RAA, no reductions in DDT and PCB loading from the JG7 MS4s are required to meet the TMDL WQBELs. And while DDTs and PCBs cannot be modeled as a stormwater pollutant for the RAA (due to the lack of land use event mean concentrations and BMP performance data), it will be qualitatively evaluated. It is also noted that the implementation of future institutional and/or structural BMPs throughout the SMB JG7 WMP area will lead to a reduction in runoff volume and associated sediment loading from the MS4s, thereby further reducing the existing mass load of any sediment bound DDTs and/or PCBs to the Santa Monica Bay. For these reasons, while DDT and PCBs will be included as Category 1 pollutants, they will be prioritized lower than bacteria and debris within Category 1, and will continue to be evaluated further through the CIMP monitoring effort.

2.2.2 Category 2 – High Priority

Category 2 (high priority) WBPCs are defined as *"pollutants for which data indicate water quality impairment in the receiving water according to the State's Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List (State Listing Policy) and for which MS4 discharges may be causing or contributing to the impairment."*

There are no WBPCs within the SMB JG7 WMP area that currently qualify as Category 2.

2.2.3 Category 3 – Medium Priority

Category 3 (medium priority) designations are to be applied to WBPCs that are not 303(d) listed but which exceed applicable receiving water limitations contained in the Permit and for which MS4 discharges may be causing or contributing to the exceedance.

There are no WBPCs within the SMB JG7 WMP area that currently qualify as Category 3.

2.3 Source Assessment

The following data sources have been reviewed as part of the source assessment for bacteria and DDT/PCBs in the Santa Monica Bay subwatersheds:

- Findings from the Permittees' Illicit Connections and Illicit Discharge (IC/ID) Elimination Programs;
- Findings from the Permittees' Industrial/Commercial Facilities Programs;
- Findings from the Permittees' Development Construction Programs;
- Findings from the Permittees' Public Agency Activities Programs;
- TMDL source investigations;
- Watershed model results;
- Findings from the Permittees' monitoring programs, including but not limited to TMDL compliance monitoring and receiving water monitoring; and
- Any other pertinent data, information, or studies related to pollutant sources and conditions that that contribute to the highest water quality priorities.

Since the only receiving water in the SMB JG7 WMP area is the Santa Monica Bay, the following source assessment is broken down by pollutant.

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2.3.1 Indicator Bacteria

Wet weather runoff event mean concentrations (EMCs) for fecal coliform, based on the Southern California Coastal Water Research Project (SCCWRP) land use data for the Los Angeles region (Stein *et al.* 2007), indicate that the highest concentrations are expected from agricultural land uses (there are none in the SMB JG7 WMP area), followed by commercial and educational, single family residential, multi-family residential, open space, industrial, and transportation. The SCCWRP study also found that in some cases the levels of fecal indicator bacteria at the recreational (beach) and agricultural land use sites were as high as those found in primary wastewater effluent in the United States. Tetra Tech *et al.* (2011) also found that horse stable sites contributed to significantly higher wet weather EMCs than other land use types.

The Santa Monica Bay Beaches Bacteria TMDL for both dry and wet weather was the first bacteria TMDL adopted by the Regional Board in the State of California. The Santa Monica Bay Beaches Bacteria TMDL was recently opened for reconsideration, although the source assessment was not part of this update. As a result, the general findings from the original source assessment remain unchanged. These findings are summarized in the 2012 Basin Plan Amendment for the reopened Santa Monica Bay Beaches Bacteria TMDL (Attachment A to Resolution No. R12-007):

> *"With the exception of isolated sewage spills, dry weather urban runoff and storm water conveyed by storm drains and creeks is the primary source of elevated bacterial indicator densities to beaches. Limited natural runoff and groundwater may also potentially contribute to elevated bacterial indicator densities during certain dry weather."* (Regional Board, 2012c).

The Santa Monica Bay Beaches Bacteria TMDL source assessment maintains that dry weather urban runoff and storm water runoff is the primary source of elevated bacteria concentrations at Santa Monica Bay beaches. Although definitive information regarding the specific sources of bacteria within the watershed is not presented, speculation provided in the dry weather staff report provides some insight into possible sources.

> *"Urban runoff from the storm drain system may have elevated levels of bacterial indicators due to exposure to sewage leaks and spills, illicit connections of sanitary lines to the storm drain system, runoff from homeless encampments, illegal discharges from recreational vehicle holding tanks, and malfunctioning septic tanks among other things. Stormwater can also be a direct source of bacteria to recreational waters. The bacteria indicators used to assess water quality are not specific to human sources; therefore, fecal matter from animals and birds can also be a source of elevated levels of bacteria, and vegetation and fecal waste can be a source of elevated levels of total coliform bacteria, specifically."* (Regional Board, 2002).

The 2010-2011 and 2011-2012 Los Angeles County Municipal Stormwater Permit Individual Reports for the JG7 agencies report that both sanitary sewer overflows and IC/ID, while eliminated shortly after being reported, do sometimes occur in their jurisdictions (but not necessarily within the SMB JG7 WMP area).

Additionally, information on non-MS4 sources of surfzone bacteria were compiled and based on a comprehensive review of Southern California published literature, as part of comments on the reopened Bacteria TMDL (City of Malibu, 2012):

> *"A number of recent Santa Monica Bay studies have further identified and confirmed natural non-anthropogenic sources of fecal indicator bacteria (FIB) including plants, algae, decaying organic matter, beach wrack and bird feces … implicating these as potentially significant contributors to exceedances (Boehm et al. 2011, Ishii et al. 2012). Beach sands, sediments*

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and beach wrack have been shown to be capable of serving as reservoirs of FIB, possibly by providing shelter from ultraviolet (UV) inactivation and predation to allow for regrowth (Imamura et al. 2011; Ishii et al. 2012; Lee et al, 2006; Ferguson et al, 2005; Gipson et al, 2011; Griffith, 2012; Litton et al. 2010; Phillips et al. 2011; Song et al. 2013; Solarno et al. 2011, and Weston Solutions, 2010). In wet environments include semi-feral or "natural" strains that live and grow in water, soil, plants and insects (Griffith, 2012). Thus, elevated levels of enterococci in water could be related to input from natural sources. The phenomenon of regrowth of FIB from other anthropogenic or natural sources has been suggested by several studies as a possible source of beach bacteria exceedances (Griffith, 2012; Litton et al, 2010; Weston Solutions, 2010; Ishii et al. 2013; Wertheim et al, 2010)."

Other sources of bacteria during wet weather are anticipated to include other non-MS4 permitted stormwater discharges such as Industrial General Permit sites, Construction General Permit sites, Phase II MS4 Sites (e.g., college campuses), State/Federal owned lands, non-MS4 open space areas such as wildlife habitat, and the California Department of Transportation (Caltrans).

2.3.2 DDT and PCBs

As stated previously, limited data are available to characterize DDT and PCBs within Santa Monica Bay, particularly since direct discharges of these pollutants from publically-owned treatment works (POTWs) have ceased. The largest concentration of DDT and PCBs within Santa Monica Bay is contained within the Palos Verdes shelf, which is being addressed by the USEPA as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. Loadings from the shelf to the Bay are large and have been well characterized (USEPA, 2013).

With respect to stormwater, the TMDL does not specifically characterize MS4 loadings, though it does recognize that *"DDT and PCBs are no longer detected in routine stormwater sampling from Ballona Creek to Malibu Creek."* However, the TMDL also states that current detection limits used to analyze DDT and PCB concentrations are too high to appropriately assess the water quality.

No other data or source information is available at this time. Once three years of water quality data are collected from Ballona Creek and Santa Monica Canyon 4 channel and evaluated consistent with the recommendations by USEPA in the TMDL to utilize a three-year averaging period", then further source assessment will be considered and the categorization and prioritization of PCB and DDTs as MS4-related pollutants of concern will be reevaluated.

The three-year averaging period is recommended by the USEPA TMDL to account for wet and dry years. Three years of data should be sufficient to capture a representative range of wet and dry years. USEPA states specifically, in the Attachment A to the TMDL, that exceptions to the PCB and DDT water quality objectives shall not be determined based on fewer than three years of data.

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3
Watershed Control Measures

The Permit specifies that control measures, also referred to as BMPs, shall be identified to ensure that stormwater discharges meet RWLs and WQBELs as established in the Permit and to reduce overall impacts to receiving waters from stormwater and non-stormwater runoff.

BMPs are typically grouped into two broad categories, structural and institutional. Structural BMPs are physically-constructed control measures that alter the hydrology or water quality of stormwater or non-stormwater within the MS4 and are designated as either centralized or distributed based on their location within a watershed and size of contributing drainage area. Institutional BMPs are source control measures that prevent the release of flow/pollutants or transport of pollutants within the MS4 area, but do not involve construction of physical facilities. Minimum control measures (MCMs) are a subset of institutional BMPs.

Due to the zero required load reductions and the SMB JG7 WMP geography (outfalls are located on unstable cliffs and there are landslide and liquefaction hazards throughout the SMB JG7 WMP area), there are currently no centralized or distributed BMPs planned in the SMB JG7 WMP area at this time. In the event that CIMP monitoring demonstrates a need for quantitative RAA modeling and BMP implementation, BMPs may be selected based on performance data, subsurface conditions, land uses within the contributing drainage areas, and other relevant characteristics.

3.1 Minimum Control Measures/Institutional BMPs

The Permit requires the implementation of MCMs in Parts VI.D.4 through VI.D.10. These MCMs are similar to the programs required under the previous MS4 Permit (Order No. 01-182).

Although the previous MS4 Permit required implementation of MCMs, some of the key modifications introduced by the current MS4 Permit related to MCMs include:

- The Permit calls for more outreach and education as part of the Public Information and Participation Program (PIPP). Permittees, for example, will be required to maintain a website with stormwater-related educational materials.
- Permittees are expected to record additional information on industrial and commercial facilities within their jurisdiction as part of their Industrial/Commercial Facilities Program. For example, industrial/commercial facilities records will need to list receiving waters for which each respective facility is tributary to.
- The Permit provides more detailed criteria on BMP sizing and specification for use in the Permittees' Planning and Land Development Program, formerly the Development Planning Program, and calls for annual reporting of implemented mitigation projects.
- An Erosion and Sediment Control Plan (ESCP), which includes elements of a Storm Water Pollution Prevention Plan (SWPPP), replaces the Local SWPPP (L-SWPPP) as a required document for construction activities meeting certain criteria as a prerequisite to building/grading permit issuance.
- The Permit also requires Permittees to use an electronic tracking system to track construction activities within their jurisdiction and mandates slightly more aggressive inspection schedules.
- The Public Agency Activities Program remains largely unchanged with the exception of requiring Permittees to inventory existing developments for BMP retrofitting opportunities.

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A comprehensive comparison between program requirements of the previous and current MS4 Permits is summarized in **Table 3-1**. Permittee activities under the Storm Water Management Program are summarized in the Los Angeles County Unified Annual Stormwater Reports; the report for the most recent reporting year is available at http://ladpw.org/wmd/npdesrsa/annualreport/index.cfm (Los Angeles County Department of Public Works, 2012).

As required by the Permit, the agencies in the SMB JG7 WMP group are continuing to implement the MCMs required under the 2001 MS4 Permit until the WMP is approved by the Regional Board. Applicable new MCMs will be implemented by the time the WMP is approved by the Regional Board. A brief description of each Program MCM and the tasks associated with each are summarized next. The implementation summaries of the Program MCM tasks identified are available in the Unified Annual Stormwater Report published by the Los Angeles County Department of Public Works.

The agencies in the SMB JG7 WMP group have also developed mechanisms for tracking information related to new development/re-development projects that are subject to post-construction BMP requirements in Part VI.D.7 of the MS4 Permit.

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Table 3-1
Comparison of Stormwater Management Program MCMs

Program Element	Activity	Previous Permit (Order No. 01-182)	Current Permit (Order No. R4 2015-0175)
Public Participation / Participation - Public	Public Education Program - Actively communicate monthly (once per year)	X	
	Not Discharging Wastewater or Stormwater - annually (by 2 2004)	X	
	Reporting not to exceed publicly (888) FAX - All	X	X
	Consider pollutants	X	X
	Make reporting "Consumer Hotline" public	X	X
	Public participation requirements - working with local agencies	X	X
	Public participation materials - program - annually	X	X
	Public education materials - activity specific	X	X
	Education and outreach - household hazardous	X	X
	Summary of public participation strategy - annually (by 2 2002)	X	
	Communication about stormwater information materials - annually (by 2 2002)	X	X
	Business Assistance Program	X	
	Encourage all home improvement companies - Stormwater - annually	X	
	Maintain storm water website		X
	Provide education materials - annually (by 2 2002 - annually (by 2 2012 - annually (by 2 every (W) years	X	X
	Provide opportunities with local - formal - annually (by 2 2002 - annually (by 2 2012 - annually (by 2 every (W) years	X	X
	Program - annually (by 2 2002 - annually (by 2 2012 - annually (by 2 every (W) years	X	
	Encourage all Phase I and II municipal - annually (by 2 2002 - annually (by 2 2012 - annually (by 2 every (W) years	X	
Public Participation / Participation - Public	Document public participation - annually (by 2 2002 - annually (by 2 2012 - annually (by 2 every (W) years	X	X
	Reporting not to exceed publicly (888) FAX - All	X	X
	Public participation - Brochures	X	X
	Public participation - Automated system - number	X	X
	Public participation - NGOs	X	X
	Public participation - Water quality - annually		X
	Public participation - US EPA Publication	X	X
	Public participation - Other - Industry mandated (at the (2) Code of Federal Regulations (CFR) 122.26(b)(14)(viii) - (x))	X	X
	Public participation - Other - Commercial - industrial - Residential - Construction - may contribute to pollutants of concern - not limited to VOC		X
Public Participation / Participation - Public	Facility information - Name of facility	X	X
	Facility information - Contact information - person name	Name only	X
	Facility information - Address	X	X
	Facility information - North American Industry Classification System (NAICS) code		X
	Facility information - Standard Industrial Classification (SIC) code	X	X
	Facility information - Name of receiving water(s) and/or municipal storm sewer system	X	X
	Facility information - physical location - latitude/longitude		X
	Facility information - Name of receiving water		X
	Facility information - ID number - Industry to 303(d) - total maximum daily load (TMDL) - water body pollutant		X
	Facility information - NPDES permit number - current status	X	X
	Facility information - Site Representative information		X
	Location - facility discharges to - Sanitary Sewer	X	X
	Business Assistance Program	Optional	X
	Notify municipal regarding commercial - industrial - Residential - Construction		Once - 1 years
	Public education - Commercial - industrial - Residential - Construction - Municipal - Municipal facilities - Illicit discharges - Illegal connections - Illegal dumping - Spills - Industrial - Commercial - Residential - Construction	Twice - 5 years	Twice - 5 years
	Public education - Commercial - industrial - Residential - Construction - Municipal facilities - Illicit discharges - Illegal connections - Illegal dumping - Spills - Industrial - Commercial - Residential - Construction	Twice - 5 years	Twice - 5 years
	Verify Public Storage identification (SID) - Number - public facilities		X
	Verify Public Storage identification (SID) - Number - public facilities	X	X
	Source control - BMPs	X	X
	Physical - Structural - Treatment - Areas (STAs) - Permanently Structural Areas (PSA)	X	X
	Program - Stormwater - Compliance with Stormwater requirements	X	X
	Emergency contact - 24	X	
Public Participation / Participation - Public	Public education - Commercial - industrial - Residential - Construction - Municipal facilities - Illicit discharges - Illegal connections - Illegal dumping - Spills - Industrial - Commercial - Residential - Construction	X	X
	Optional - not - Comply Plan	Permittee - Specific pollutants	
	BMP - by SIC	X	
	Watershed protection - control - SWQDs - BMPs	X	X
	Low Impact Development - LID - BMPs	X	X
	Document - implementation - of - post-construction - Storm Water Quality Projects - low impact development - and - pollutant - storm water quality - by SIC/NAICS	X	X
	Document - implementation - of - post-construction - storm water quality - BMPs	X	X
	Control - of - pollutants - discharged - to - MS4 - process - update - to - include - consideration - of - potential - stormwater - quality - impacts	X	
	Section - Plan - update - to - include - storm water - quality - and - quality - management - considerations - and - practices	X	
	Target - the - pollutants - of - concern - in - the - receiving - waters	X	
	Promote - maintenance - of - systems		X
	BMP - guidance - manual	X	
	Annual - submittal - of - target - pollutants - plans		X
	Emphasis - on - BMPs	X	X
	Submission - of - BMPs	X	X
	Non-storm - water - contaminant - projects	X	X
	Maintenance - of - projects	X	X
	Document - implementation - of - Storm - Water - Pollution - Prevention - Plans - (SWPPP) - for - applicable - facilities	X	X
	Protection - structural - controls - for - receiving - bodies		X
	Pollutant - control - strategies - targeted - for - reduction	2 - pollutants	Other - every (W)

Program Element	Activity	Previous Permit (Order No. 01-182)	Current Permit (Order No. R9-2012-0[illegible] (5)
Public Agency Activities Program	[illegible]	[illegible]	[illegible]
	Implement mapping system database and/or Geographic Information System		X
	Revise ordinances to update storm water quality requirements	[illegible]	[illegible]
	Implement and/or enforce BMP ordinances		X
	Inspection activities	X	X
	Permit tracking	X	X
	Public agency activities pollution prevention	X	X
	Public agency training		X
	Provide or participate in training opportunities		X
	Public agency and activity maintenance	X	X
	Municipal maintenance yard pollution prevention/good housekeeping	X	X
	Landscape pesticide and fertilizer management	X	X
	Storm drain system cleaning	X	X
	Structural and treatment control operation and maintenance	X	X
	Parking lot runoff management	X	X
	Emergency procedures	X	X
	Alternative treatment control BMPs assessment	X	
	Municipal employee and contractor training		X
	Sewage system maintenance and sewer overflow prevention	X	
	Implement IPM program	X	X
	MS4 flushing, cleaning of channels, culverts, and other conveyances to the MS4	X	X
	Procedures for conducting source investigations for IC/ID	X	X
	Procedures for monitoring IC/ID	X	X
	Procedures for public reporting of IC/ID		X
	IC/ID response plan	X	X
	IC/ID elimination and control ordinance	X	X

[illegible]

3.1.1 Customization of MCMs

In lieu of the requirements of Parts VI.D.4 through VI.D.10 of the Permit, the SMB JG7 WMP Group may customize MCMs within each of the general categories. The motivation for considering customization is made more apparent in the Regional Board's response to a comment that the Permit should establish criteria that will be used to support any customization of MCMs; the Regional Board responded with the following:

> *The Order specifies that at a minimum, Permittees' programs shall be consistent with 40 CFR section 122.26(d)(2)(iv)(A)-(D). In response to comments that the Order is overly prescriptive, specifying criteria could restrict customization within these categories of minimum control measures. The criterion to allow customization is based on showing equivalent effectiveness, for example, a municipality who has identified a group of facilities within their jurisdiction as the largest source of constituents could be allowed to focus their inspection efforts on controlling the constituents from this subset of facilities.*
> (http://www.waterboards.ca.gov/losangeles/water_issues/programs/stormwater/municipal/StormSewer/CommentLetters/E_MCM%20Matrix%2010-26-12%20Final.pdf)

The opportunity for customization may provide benefit by allowing the SMB JG7 WMP Group to assess the effectiveness of their current programs and to modify their programs to better serve local conditions and objectives. If an effectiveness assessment is conducted on a specific MCM activity and it can be reasonably shown that customization of the MCM would result in equal or improved effectiveness on attitudes or knowledge, behavior or implementation, load reduction, or water quality, then a defensible recommendation for modification of that activity can be made, resulting in greater resources available for more effective activities.

The SMB JG7 WMP Group is not planning to customize MCM activities at this time. However, in the event that MCM customization would be beneficial to the identified WBPCs or if CIMP results indicate adjustments would be beneficial and/or needed, the first step in customizing MCM activities would be the development of a framework to assess the effectiveness of each MCM in its current implementation. For each MCM that can be assessed in this manner, recommendations for customizations can be developed with reasonable assurance of impact to effectiveness.

The California Stormwater Quality Association (CASQA) provides such a framework for the effectiveness assessment of Stormwater Management Programs (CASQA, 2006). The outcome is a hierarchy that categorizes the classification of outcome types (levels) that will allow MCMs to be placed into one or more categories for subsequent outcome assessment. The outcome levels, Level 1 through Level 6, are summarized in **Figure 3-1**.

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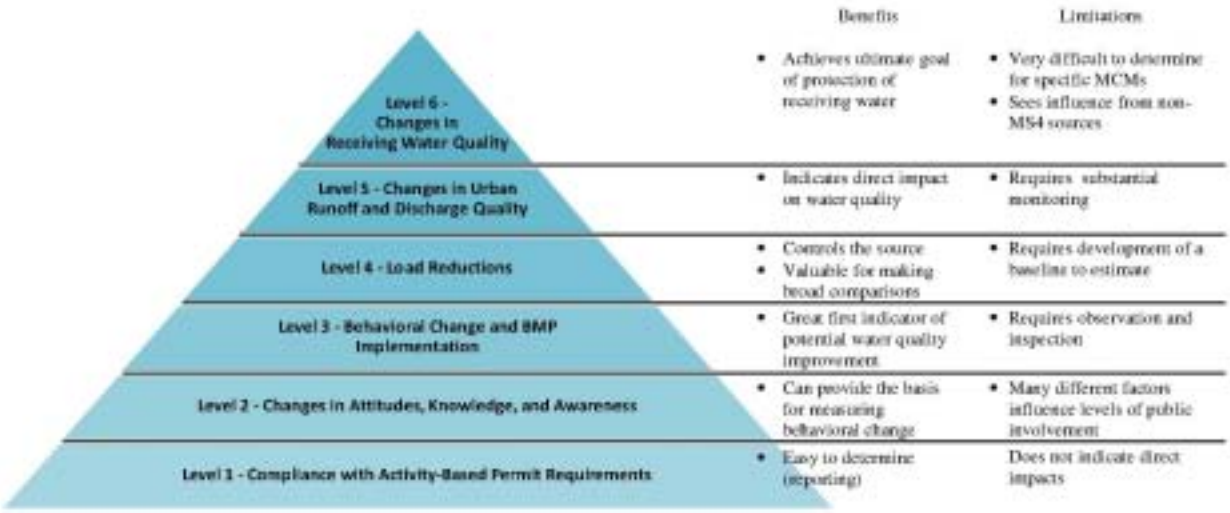
Figure 3-1
General Classification of Outcome types (adapted from CASQA)



3.1.2 MCMs and Outcome Levels

The outcome types in this effectiveness assessment framework are interrelated. The Permit's stormwater management program is, by design, intended to improve the water quality in receiving waters. The means by which this goal is intended to be met is through the implementation of compliance measures by the SMB JG7 WMP Group. Compliance with these activity-based measures results in Level 1 outcomes. Assessments of these activities can provide further understanding of the outcomes they have. Ideally, each activity will contribute to the improvement at the Level 6 receiving water quality level; however, tracking effectiveness at this level is difficult.

A summary of the MCM activities of the agencies within the SMB JG7 WMP Group is included in the 2011-12 Annual Stormwater Report (Los Angeles County Department of Public Works, 2012). In addition to the standard reporting, the agencies answered a list of questions in an Assessment of Program Effectiveness. This summary largely includes responses that may be considered as Level 1 outcomes (compliance) with Level 2, Level 3, and Level 4 outcomes for select MCMs. Several obstacles inhibit the ability to achieve a Level 5 or Level 6 assessment, including:

- Available budget;
- Lack of comprehensive monitoring;
- Timing of MCM activities and corresponding runoff events; and/or
- General complexity of the hydrology and conveyance.

All SMB JG7 WMP Group members were in compliance with the Permit during the 2011-12 reporting year (Level 1 outcome). **Table 3-2** summarizes effectiveness assessment metrics and potential outcomes associated with select MCMs within each Program Element of the Storm Water Management Program. The following is a brief description of the Program MCMs and outcome levels that can be achieved through the effectiveness assessment framework described.

3.1.2.1 Public Information and Participation Program

The PIPP is intended primarily to reach out and educate the general public, students, business owners, facility operators, city staff, and others on stormwater. This outreach is accomplished in many ways; examples include "No Dumping" messages on storm drain inlets; public education materials; information

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websites; community events; reporting hotlines; and specialized awareness programs, such as the used oil program. The program elements are intended to directly impact awareness and the behavior of different target audiences (Level 2 and Level 3 outcomes). Consequently, these behavioral changes may impact constituent loads to the MS4 indirectly, but the actual Level 4 through Level 6 impact of a specific MCM in this category may be difficult to quantify.

3.1.2.2 Industrial/Commercial Facilities Program

Permittees are required to conduct an Industrial/Commercial Facilities Program designed to prevent illicit discharges, reduce discharges of stormwater, and prevent industrial/commercial discharges to the MS4 from causing or contributing to receiving water quality exceedances. These facilities are tracked and inspected to ensure use of BMPs to control stormwater discharges. In addition, the program aims to contribute to the education of business owners and facility operators regarding SWPPP. The effectiveness of this program can be assessed leading to insight on how awareness (Level 2) and BMP implementation (Level 3) are affected.

3.1.2.3 Planning and Land Development Program

The Planning and Land Development Program involves developers early in the land development stage, with the integration of BMPs and Low Impact Development (LID) controls to reduce constituent loading to the MS4 and minimize runoff intensity generated from impervious areas. Behavioral change (Level 3) can be assessed through permitting staff observations. Also, it may be possible to assess constituent load reductions (Level 4) through land developer BMP choices and water quality of runoff entering the MS4 (Level 5) if monitoring stations are considered during the planning stage of development and redevelopment.

3.1.2.4 Development Construction Program

Similar to the Planning and Land Development Program, the Development Construction Program establishes requirements for construction activities to eliminate illicit discharges and prevent water quality violations from stormwater discharges from the construction site. The Program establishes criteria for BMPs and controls through an Erosion and Sediment Control Plan, with elements of a SWPPP. The effectiveness of this program can be assessed through inspections to verify BMP implementation (Level 3), Level 2 awareness outcomes can be assessed through the use of a website that informs contractors on proper BMP selection and prerequisite checklists for permitting.

3.1.2.5 Public Agency Activities Program

Activities ranging from street sweeping, catch basin cleaning, public facility maintenance, and storm drain operation fall under the Public Agency Activities Program. These activities are essential MCMs that can also be measured for effectiveness. Level 3 through Level 5 outcomes (behavior, load reduction, MS4 water quality) can all be assessed through appropriate evaluation metrics. The impact to receiving water quality (Level 6) may be possible to determine if appropriate monitoring is in place, with phased implementation of MCM activities to isolate performance evaluation.

3.1.2.6 Illicit Connections and Illicit Discharges Elimination Program

IC/IDs are controlled through the IC/ID Elimination Program and by implementing a procedure for reporting, tracking, and responding to reports of IC/IDs, as well as establishing protocols for the regular inspection of storm drains. The effectiveness of the reporting procedure can be assessed on a Level 2 (awareness) basis, and response activities can have their effectiveness determined directly through monitoring of the MS4 water quality (Level 5). A quantitative analysis of behavioral change (Level 3) as a result of enforcement actions is also achievable.

3.1.3 Next Steps to MCM Customization

The assessment framework outlines the process to determine baseline MCM effectiveness, providing the foundation for customization. Pending the results of the approved CIMP, opportunities for modifying

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MCM activities may be proposed by the SMB JG7 WMP Group as part of the adaptive management process.

It should be noted, however, that institutional BMPs for MCMs such as street and median sweeping implementations, storm inlet and conveyance system cleaning, pet waste program enhancements, etc. are anticipated to cumulatively result in a pollutant load reduction between 5% and 8%. Additionally, assuming past data also reflect future trends, it is anticipated that 0.1 – 0.2% of residential, commercial, and industrial properties will implement LID annually through development or redevelopment projects*. Although RWLs are currently being met, it is anticipated that implementation of LID will further enhance the water quality in this region.

* LID is any technique or practice that reduces the impacts of development/redevelopment projects with the SMB JG7 WMP Group agrees over the next 10 years to encourage LID. Examples of LID techniques include, but are not limited to, rainwater harvesting, green roofs, permeable pavement, bioretention, and vegetated swales. LID techniques must be approved by the City prior to their use in MS4 Improvement Plans.

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Table 3-2
Effectiveness Assessment Measures for Various Activities under the Storm Water Management Program

Program MCM	Permittee Activity	Possible Assessment Metric	Outcome Level
Public Information and Participation Program	Advertising / media campaigns (e.g., Used Oil / Used Oil Filter Program)	Year-over-year change in no. of impressions	L2
		Survey results	L2, L3
	Educational programs (e.g., Generation Earth, Environmental Defenders, public workshops)	Year-over-year change in attendance	L2
		Quiz results	L2, L3
	E-Waste collection events	Amount of Household Hazardous Waste/E-Waste	L3, L4
	888-CLEAN-LA hotline	Change in no. of calls	L2
	www.888CleanLA.com	No. of unique visitors / document downloads	L2
Industrial/Commercial Facilities Program	Website on program details	No. of unique visitors / document downloads	L2
	Electronic tracking	Inspections: change in no. of Notices of Violation (NOV) / non-compliance	L3
Planning and Land Development Program	Pre-permitting assessment	No. of developers incorporating BMPs and LID in early-stage	L3
	Annual reporting	% of stormwater capture	L3, L4
	Integrated control measures	Measure performance through planned monitoring	L5
Development Construction Program	Website on program details	Number of hits / document downloads	L2
	Electronic tracking	Inspections: change in no. of NOV / non-compliance	L3
Public Agency Activities Program	Street sweeping	Street sweeper fleet (technology)	L3
		Year-over-year change in debris collected	L3, L4
	Catch basin cleaning	Year-over-year change in trash collected	L3, L4
	Installation of trash receptacles	Observations: cleanliness of public roadways	L3
	Sanitary sewer overflow response	Monitoring results of MS4 water quality	L5
IC/ID Elimination Program	IC/ID reporting hotline	Year-over-year change in no. of calls	L2
	Termination of IC/ID	Outfall monitoring: change in water quality	L5
	Enforcement actions	Change in occurrence	L3
Other	Support for Senate Bill (SB) 346 (Brake Pad Initiative)	% of vehicles with reduced-copper-content brake pads	L4

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4
Reasonable Assurance Analysis

Typically, an important component of the WMP is the RAA. The RAA is a process that is used to demonstrate that institutional and structural control measures are expected to be sufficient for achieving applicable WQBELs and/or RWLs for the water body pollutant combinations that have compliance deadlines within the Permit term. In addition to using the RAA as a means to determine the efficacy of existing and potential control measures, the RAA also facilitates the selection of BMPs as well as the prioritization of BMP implementation.

For the SMB JG7 WMP, there are currently zero required load reductions for the Category 1 WBPCs: bacteria at the Santa Monica Bay Beaches and PCBs/DDTs in the Santa Monica Bay. Compliance with the Trash TMDL is being demonstrated through retrofitting of catch basins as outlined in the Trash Monitoring and Reporting Program (City of Los Angeles Department of Public Works, 2012). No Category 2 or Category 3 WBPCs have been identified based on currently available monitoring data. Furthermore, it is anticipated that implementation of MCMs and related activities will progressively improve water quality.

Therefore, no quantitative RAA modeling is required for this WMP. For purposes of completeness, however, each Category 1 WBPC is qualitatively discussed below.

4.1 Bacteria

The Implementation Plan for compliance with the Wet Weather Santa Monica Bay Beaches Bacteria TMDL for the larger JG7 documents historical monitoring at eight sampling locations between 1997 – 2000 for indicator bacteria. Based on the historical monitoring having fewer exceedances than the reference beach, the Implementation Plan concluded that *"as JG7 already meets the baseline goals and only needs to implement provisions to prevent "backsliding"; the non-integrated approach will be selected. No milestones are proposed, as existing conditions are the equivalent of compliance with the TMDL"* (Regional Board, 2012). As a result, the Implementation Plan states that JG7 should continue to implement BMPs, review the LA County Sanitation Districts' data, and perform investigations as necessary. Tables M-1 and M-2 of Attachment M to the MS4 Permit also show that the compliance monitoring locations within the SMB JG7 WMP geographical area, SMB 7-6 and SMB 7-8 are subject to antidegradation conditions because the beaches have fewer exceedance days than the reference beach. Therefore, there is a zero required load reduction for bacteria, and reasonable assurance is demonstrated.

As part of the adaptive management process based on monitoring data collected through the approved CIMP, structural and/or nonstructural BMPs may be proposed if needed.

4.2 PCBs and DDTs

The Santa Monica Bay TMDL for DDTs and PCBs developed WLAs for stormwater throughout the Santa Monica Bay watershed. Because the SMB JG7 WMP group area is not distinctly defined in the TMDL, the WLAs assigned to the entire Santa Monica Bay WMA are being used for this discussion. Table 6-3 in the TMDL lists the existing annual DDT and PCB loads as compared to the annual maximum allowable loads. The existing estimated loads for all of Santa Monica Bay and most of the individual watersheds are lower than the maximum allowable loads. As such, the WLAs for the entire Santa Monica Bay WMA were set equal to the existing annual loads for DDTs and PCBs as 28 grams per year (g/yr) and 145 g/yr, respectively. Therefore, there is a zero required load reduction for PCBs and DDTs, and reasonable assurance is demonstrated.

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As part of the adaptive management process based on monitoring data collected through the approved CIMP, additional structural and/or nonstructural BMPs may be proposed if needed.

4.3 Debris, and Plastic Pellets

Compliance with the Debris TMDL will be met through a phased retrofit of all 218 catch basins throughout the JC7 WMP area (182 City owned and 38 County owned) by 2016, ahead of the Regional Board implementation goal's for 2020 completion date. Consistent with the City's Trash Monitoring and Reporting Plan (TMRP) of City of Los Angeles Department of Public Works, 2012, *"vertical inserts with 5-mm openings and flow activated operable screen covers are the best suited for implementation within the City to achieve compliance with Trash TMDLs."*

There are no industrial facilities within the SMB JC7 WMP area that use, store, transport, manufacture, or handle plastic pellets. Therefore, the City's Plastic Pellet Monitoring and Reporting Plan (PMRP) will only include an emergency response plan.

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5
Adaptive Management Process

The Notice of Intent submitted to the Regional Board in December 2013 provided a schedule of interim milestones for the development of the CIMP and WMP Plan. At this time, the SMB JG7 WMP Group does not anticipate any deviations from the schedule. Completed milestones and projected completion dates for future milestones are presented in **Table 5-1.** The catch basin retrofit schedule, as provided in the TMRP, is also included in the table.

Table 5-1
WMP Schedule of Interim and Final Milestones

Deliverable	Planned Date of Completion
Submit Final Draft WMP to the Regional Board	June 2014
Submit Final Draft CIMP to the Regional Board	June 2014
57 catch basin opening cover and/or insert retrofits (cumulative) (26%)	December 2015
161 catch basin opening cover and/or insert retrofits (cumulative) (100%)	July 2016

The WMP is intended to be implemented as an adaptive program. As new program elements are implemented and information is gathered over time, the WMP will undergo modifications to reflect the most current understanding of the watershed and present a sound approach to addressing changing conditions. As such, the WMP will employ an adaptive management process that will allow the WMP to evolve over time.

5.1 Compliance Schedule

The compliance deadlines in the Santa Monica Bay Beaches Bacteria TMDL are currently in effect for SMB 7-6 and SMB 7-8. The TMDL for PCBs and DDTs does not include a compliance schedule for the WLAs for the Santa Monica Bay WMA, but because the WLAs were set based on the existing loads, the Santa Monica Bay WMA is considered to be in compliance, and therefore a compliance schedule for this TMDL is not being proposed at this time. The compliance schedule for the Santa Monica Bay Nearshore and Offshore Debris TMDL is provided in **Table 5-1.**

Part VI.C.8 of the Permit details the adaptive management process to be included in the WMP that includes the following requirements:

i. Permittees shall adapt the WMP to become more effective every two years from the date of program approval based on, but not limited to, a consideration of:

   (1) Progress toward achieving WQBELs and/or RWLs;

   (2) Permittee monitoring data;

   (3) Achievement of interim milestones;

   (4) Re-evaluation of water quality priorities and source assessment;

   (5) Non-Permittee monitoring data;

   (6) Regional Board recommendations; and

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(7) Recommendations through a public participation process.

i. Permittees shall report any modifications to the WMP in the annual report.

ii. Permittees shall implement any modifications to the WMP upon approval by the Regional Board or within 60 days of submittal if the Regional Board expresses no objections.

The adaptations to the WMP as called for in the adaptive management process essentially include a re-evaluation of water quality priorities, an updated source assessment, an effectiveness assessment of watershed control measures, and a RAA. The CIMP will gather additional data on receiving water conditions and stormwater/non-stormwater quality to inform these analyses. This process will be repeated every two years as part of the adaptive management process.

5.2 Re-Characterization of Water Quality Priorities

Water quality within the SMB IGT WMP Group will be re-characterized using data collected as part of the approved CIMP. WBPC's may be updated as a result of changing water quality. Category 2 WBPC's will be identified based on data collected as part of the approved CIMP. These classifications will be important for refocusing improvement efforts and informing the selection of future watershed control measures.

Demonstration that MS4 discharges have caused or contributed to the exceedance of receiving water limitations will be made by meeting both of the following criteria:

- Simultaneously collected water samples, as consistent with the CIMP, exceed the receiving water limitations as sampled in the receiving water and exceed the WQBELs, action levels as defined in Appendix G, or receiving water limits, in that order, at the MS4 outfall; and
- The number of simultaneous samples and simultaneous exceedances meet the criteria in Tables A.1 and A.2 in California's Water Control Policy (Regional Board, 2004).

5.3 Source Assessment Re-evaluation

The assessment of possible sources of water quality constituents will be re-evaluated based on new information from the CIMP implementation efforts. The identification of non-MS4 and MS4 pollutant sources is an essential component of the WMP because it determines whether the source can be controlled by watershed control measures. As further monitoring is conducted and potential sources are better understood, the assessment becomes more accurate and informed.

5.4 Effectiveness Assessment of Watershed Control Measures

The evaluation of BMP effectiveness is an important part of the adaptive management process and the overall WMP. Implementation of the CIMP can provide a quantitative assessment of structural BMP effectiveness, if BMPs are implemented in the future, as it relates to actual pollutant load reduction to determine how selected BMPs have performed at addressing established water quality priorities. In addition, the adaptive management process is a required step for the customization of MCMs as detailed previously. Effectiveness assessment becomes important for the selection of future control measures to be considered.

5.5 Update of Reasonable Assurance Analysis

The RAA is an iterative process that depends on the continuous refinement and calibration of the watershed models when used. Data gathered as a result of the CIMP will support adaptive management at multiple levels, including (1) generating data not previously available to support model updates (i.e. through the course of the CIMP, modeling becomes necessary in the SMB IGT WMP); and (2) tracking

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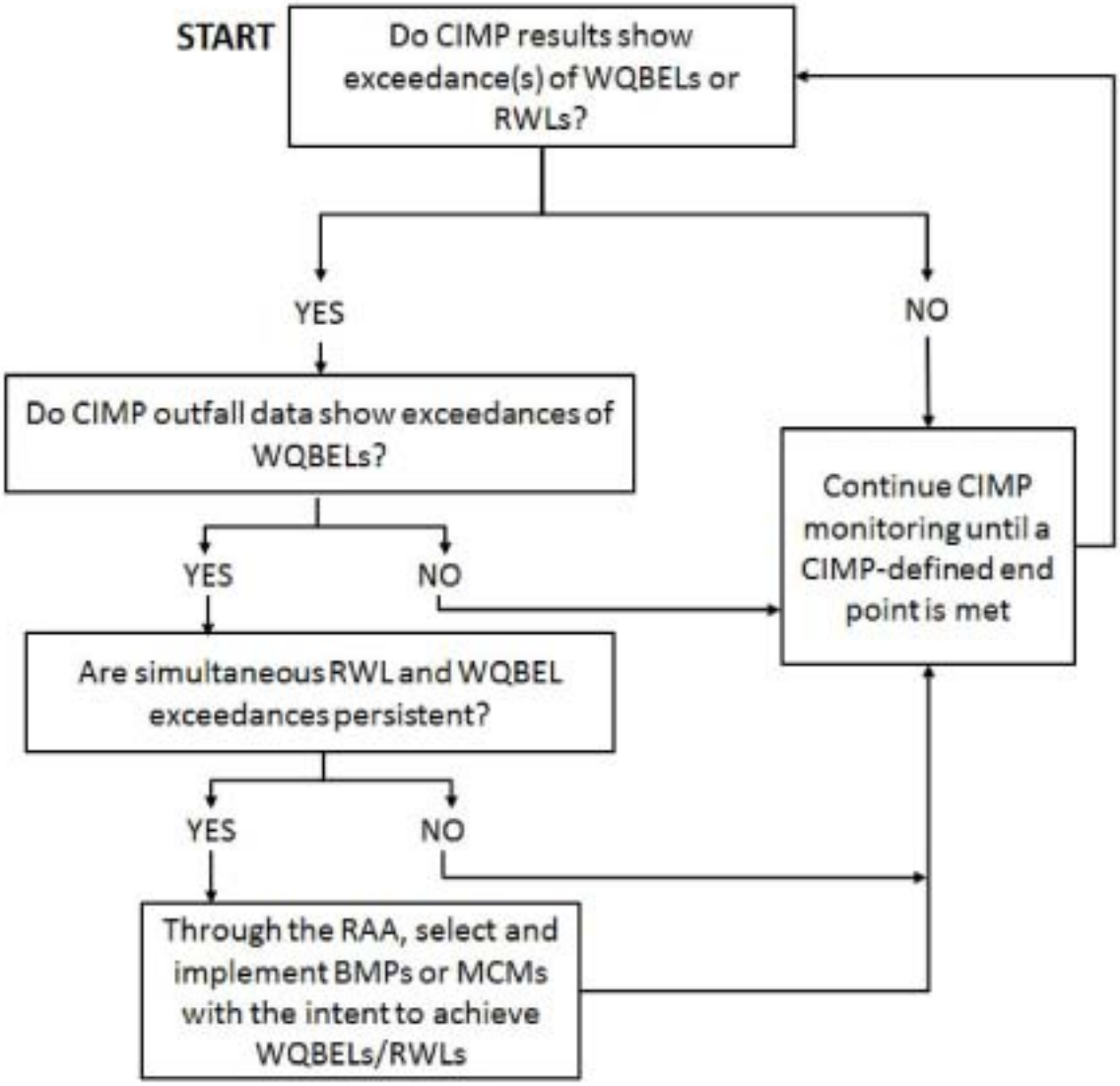
improvements in water quality over the course of WMP implementation. This process is illustrated in **Figure 5-1**.

Figure 5-1
Adaptive Management Process



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Weston Solutions. 2010. "Escondido Creek Microbial Source Tracking Summary – Phases I, II and III."

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AR0072391

Table A1 – Average, Median, Minimum, and Maximum of Results for Santa Monica Bay Shoreline Monitoring Data (SMB JG7 WMP Group Area)

Analyte	Event Type	Station	Average (MPN/100ml)						Median (MPN/100ml)						Min (MPN/100ml)						Max (MPN/100ml)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Total Coliform	Dry-Summer	SMB 7-6	82.6	34.2	42.9	28.1	102.1	94.7	12	18	31	18	36	59	1	3	3	1	1	4	950	140	240	120	1400	340
Total Coliform	Dry-Winter		21	391.1	29.2	131.3	91.1	39.3	8.5	30.5	16	19.5	33.5	18	3	1	1	4	5	8	160	3600	78	570	540	120
Total Coliform	Wet		101.6	352.3	244.1	172.6	796.1	93.8	98	230	73	71	90	65.5	4	18	4	4	4	12	240	1000	1600	800	8000	310
Fecal Coliform	Dry-Summer		24.8	9.6	9.3	11.6	41.3	14.2	2.5	3.5	4	5.5	9	6	1	1	1	1	1	1	580	50	56	72	580	110
Fecal Coliform	Dry-Winter		9.9	34	13.3	101.4	52.4	16.4	2	8.5	3.5	7	15.5	8	1	1	1	1	1	4	100	250	78	480	470	62
Fecal Coliform	Wet		11.3	26.5	21.2	23.6	43	35.3	6.5	31.5	5	13	11	8	1	5	1	3	1	1	44	40	100	78	260	160
Enterococcus	Dry-Summer		24.7	11.6	16.2	17.1	17.4	11.1	2	3	4	7.5	4	4	1	1	1	1	1	1	360	78	260	90	120	160
Enterococcus	Dry-Winter		11.1	197	38.5	158.1	34.5	12.8	4	16	14	7.5	10	4	1	1	1	1	1	1	44	2600	140	1700	190	62
Enterococcus	Wet		119.4	75.8	82	99	141.8	6.8	46	69	24	14	42	6	1	12	1	1	1	3	560	170	270	1000	1200	16
Total Coliform	Dry-Summer	SMB 7-8	53.4	23.2	12.3	47	460.8	46.2	9	4	6.5	10	18	12	1	1	1	1	1	1	1200	200	73	200	8800	600
Total Coliform	Dry-Winter		22.9	60.1	11.4	1210	102.6	97.9	15.5	12	8	35	14	27	1	1	1	1	1	1	120	600	36	13000	1000	410
Total Coliform	Wet		73	126.2	59	230.3	95.5	193	55	82	36	115.5	54.5	27.5	1	18	1	1	3	8	200	290	200	1200	200	690
Fecal Coliform	Dry-Summer		4.8	3.1	1.8	5.1	35.3	6.6	1	1	1	1	4	1	1	1	1	1	1	1	30	27	5	33	660	74
Fecal Coliform	Dry-Winter		6.8	16.4	1.8	2.4	3	2.8	4	1	1	1	2	1	1	1	1	1	1	1	20	170	4	8	8	15
Fecal Coliform	Wet		4.6	16.5	6.9	25	13.5	10.4	5	11	3	4.5	4	3	1	4	1	1	1	1	9	46	36	200	100	50
Enterococcus	Dry-Summer		5	5.2	2.9	6.7	32.5	2	1	1	1	1	1	1	1	1	1	1	1	1	44	62	19	97	780	19
Enterococcus	Dry-Winter		7.9	37.5	4	20.7	3.3	2.2	3	4	1	3	1	1	1	1	1	1	1	1	54	540	17	180	13	11
Enterococcus	Wet		23	44.2	19.9	116.6	35.2	10.5	9.5	31	8	12	5.5	1.5	1	4	1	1	1	1	70	120	100	1100	280	49

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110% Adjustment toward County Distribution

County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
SCAG Region		23.7%	15.2%	19.1%	42.0%	100%	166,457	110,649	129,715	293,547	699,368
Imperial	Brawley city	24.5%	15.6%	16.0%	43.9%	100%	757	511	494	1,326	3,088
Imperial	Calexico city	24.0%	16.2%	15.7%	43.9%	100%	615	405	391	1,096	2,496
Imperial	Calipatria city	25.0%	15.0%	15.0%	45.0%	100%	50	32	32	87	200
Imperial	El Centro city	24.0%	16.6%	16.1%	43.6%	100%	720	461	467	1,230	2,878
Imperial	Holtville city	25.4%	16.7%	15.9%	42.0%	100%	35	23	22	59	138
Imperial	Imperial city	26.0%	17.1%	16.3%	40.7%	100%	470	309	295	736	1,810
Imperial	Westmorland city	25.6%	16.5%	15.7%	44.1%	100%	61	42	40	113	256
Imperial	Unincorporated	24.7%	16.3%	15.7%	43.2%	100%	3,017	2,191	2,109	5,006	12,427
Los Angeles	Agoura Hills city	26.6%	16.6%	17.4%	39.4%	100%	29	18	19	43	110
Los Angeles	Alhambra city	24.5%	15.5%	16.6%	43.2%	100%	379	239	260	668	1,546
Los Angeles	Arcadia city	25.5%	15.6%	17.1%	41.5%	100%	548	340	368	893	2,149
Los Angeles	Artesia city	25.2%	15.3%	16.8%	42.7%	100%	33	20	22	56	132
Los Angeles	Avalon city	25.2%	15.3%	17.0%	42.5%	100%	37	23	25	64	148
Los Angeles	Azusa city	24.0%	15.4%	16.5%	43.9%	100%	184	115	124	323	745
Los Angeles	Baldwin Park city	24.9%	15.4%	16.5%	43.1%	100%	186	115	122	321	744
Los Angeles	Bell city	23.4%	14.9%	17.0%	44.7%	100%	11	7	8	21	47
Los Angeles	Bell Gardens city	24.3%	14.9%	16.5%	44.6%	100%	29	18	20	54	122
Los Angeles	Bellflower city	24.7%	15.4%	16.5%	43.3%	100%	263	164	178	462	1,067
Los Angeles	Beverly Hills city	25.5%	16.7%	17.8%	40.7%	100%	111	71	77	178	436
Los Angeles	Bradbury city	25.7%	17.1%	17.1%	40.0%	100%	9	6	6	14	35
Los Angeles	Burbank city	25.3%	15.6%	16.9%	42.3%	100%	947	587	642	1,620	3,796
Los Angeles	Calabasas city	26.4%	16.5%	17.8%	39.3%	100%	137	86	93	205	521
Los Angeles	Carson city	25.4%	15.8%	16.9%	41.8%	100%	451	287	307	797	1,842
Los Angeles	Cerritos city	26.5%	16.3%	17.3%	40.4%	100%	25	15	16	38	95
Los Angeles	Claremont city	25.5%	16.1%	17.4%	40.8%	100%	117	74	80	187	457
Los Angeles	Commerce city	23.8%	15.3%	15.9%	44.4%	100%	15	10	10	28	64
Los Angeles	Compton city	23.5%	14.7%	17.5%	44.1%	100%	16	10	12	30	69
Los Angeles	Covina city	25.1%	15.8%	16.9%	42.2%	100%	330	211	220	564	1,337
Los Angeles	Cudahy city	23.5%	14.8%	16.7%	44.9%	100%	94	60	67	180	399

Note: There is a one unit rounding difference in some localities between the total housing need and the sum of the 4 income groups.
In such cases, communities may choose which of the income categories it will adjust by one unit to maintain consistency with the approved local housing need.

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County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Los Angeles	Culver city	25.6%	15.8%	16.8%	41.8%	100%	129	80	85	211	504
Los Angeles	Diamond Bar city	26.1%	16.4%	17.2%	40.3%	100%	284	175	189	440	1,090
Los Angeles	Duarte city	25.0%	15.7%	16.8%	42.4%	100%	277	174	187	470	1,108
Los Angeles	Duarte city	25.1%	15.5%	17.1%	41.9%	100%	92	59	65	154	367
Los Angeles	El Monte city	24.1%	15.1%	16.8%	44.1%	100%	557	339	378	973	2,378
Los Angeles	El Segundo city	26.2%	16.1%	16.7%	41.1%	100%	34	27	29	69	160
Los Angeles	Gardena city	24.4%	15.5%	17.0%	43.1%	100%	273	171	188	478	1,105
Los Angeles	Glendale city	24.5%	15.7%	17.0%	42.8%	100%	767	491	534	1,340	3,131
Los Angeles	Glendora city	25.7%	16.0%	17.1%	41.2%	100%	192	119	127	307	744
Los Angeles	Hawaiian Gardens city	24.3%	15.5%	16.7%	43.5%	100%	35	22	24	64	145
Los Angeles	Hawthorne city	24.1%	15.1%	16.8%	44.1%	100%	219	137	153	401	910
Los Angeles	Hermosa Beach city	26.2%	16.2%	17.4%	39.8%	100%	147	93	99	224	562
Los Angeles	Hidden Hills city	26.5%	17.6%	17.6%	38.2%	100%	9	6	6	13	34
Los Angeles	Huntington Park city	23.7%	14.8%	16.8%	44.6%	100%	241	150	170	452	1,013
Los Angeles	Industry city	33.3%	16.7%	16.7%	33.3%	100%	2	1	1	2	6
Los Angeles	Inglewood city	24.0%	15.4%	16.8%	43.8%	100%	398	255	279	727	1,659
Los Angeles	Irwindale city	23.8%	16.4%	16.4%	43.2%	100%	16	11	11	29	68
Los Angeles	La Canada Flintridge city	26.2%	16.7%	18.0%	39.1%	100%	82	39	42	92	235
Los Angeles	La Habra Heights city	25.7%	16.4%	18.1%	39.8%	100%	21	13	14	31	80
Los Angeles	La Mirada city	25.8%	16.0%	17.3%	40.9%	100%	452	280	303	716	1,751
Los Angeles	La Puente city	24.8%	15.4%	16.8%	42.9%	100%	201	124	136	346	807
Los Angeles	La Verne city	25.3%	15.9%	17.3%	41.6%	100%	220	136	148	351	854
Los Angeles	Lakewood city	25.5%	16.3%	17.1%	41.2%	100%	172	108	116	277	673
Los Angeles	Lancaster city	24.6%	15.5%	16.9%	43.0%	100%	3,140	1,989	2,165	5,501	12,789
Los Angeles	Lawndale city	24.8%	15.4%	16.9%	43.4%	100%	116	73	77	200	466
Los Angeles	Lomita city	25.1%	15.6%	16.8%	42.5%	100%	87	54	59	147	346
Los Angeles	Long Beach city	24.2%	15.6%	17.1%	43.2%	100%	2,321	1,485	1,631	4,149	9,586
Los Angeles	Los Angeles city	24.1%	15.6%	17.1%	43.2%	100%	27,230	17,495	19,304	48,935	112,964
Los Angeles	Lynwood city	24.4%	15.3%	16.4%	43.9%	100%	80	55	60	159	360
Los Angeles	Malibu city	26.1%	16.5%	17.9%	39.6%	100%	115	73	79	175	441
Los Angeles	Manhattan Beach city	25.4%	16.0%	17.9%	39.1%	100%	239	146	158	353	896

Note: There is a one unit rounding difference in some localities between the total housing need and the sum of the 4 income groups.
In such cases, jurisdictions' percentage which of the income categories will adjust by one unit to maintain consistency with the Approved total housing need.

AR007239

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for Jurisdictions within the Six County SCAG Region (approved by the SCAG Regional Council on July 12, 2007)

County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Los Angeles	Maywood city	22.7%	13.6%	18.2%	45.5%	100%	5	3	4	10	22
Los Angeles	Monrovia city	25.1%	15.5%	16.9%	42.5%	100%	142	89	96	241	567
Los Angeles	Montebello city	24.5%	15.5%	16.9%	43.2%	100%	132	73	85	217	502
Los Angeles	Monterey Park city	24.6%	15.5%	17.0%	43.0%	100%	280	177	194	490	1,141
Los Angeles	Norwalk city	25.2%	15.5%	16.7%	42.6%	100%	75	45	50	126	297
Los Angeles	Palmdale city	25.0%	15.9%	16.8%	42.3%	100%	4,481	2,822	3,024	7,540	17,867
Los Angeles	Palos Verdes Estates city	38.4%	15.7%	16.1%	29.8%	100%	19	12	13	28	72
Los Angeles	Paramount city	24.4%	15.4%	16.6%	43.7%	100%	248	156	168	444	1,017
Los Angeles	Pasadena city	24.8%	15.8%	17.1%	42.3%	100%	711	452	491	1,215	2,869
Los Angeles	Pico Rivera city	24.6%	15.7%	16.7%	42.9%	100%	211	134	143	367	855
Los Angeles	Pomona city	24.5%	15.5%	16.8%	43.1%	100%	381	571	615	1,587	3,678
Los Angeles	Rancho Palos Verdes city	38.7%	16.7%	17.0%	29.5%	100%	18	10	11	23	60
Los Angeles	Redondo Beach city	25.0%	15.9%	17.5%	40.5%	100%	580	363	387	934	2,264
Los Angeles	Rolling Hills city	27.3%	18.2%	18.2%	36.4%	100%	6	4	4	8	22
Los Angeles	Rolling Hills Estates city	26.9%	15.4%	19.2%	38.5%	100%	7	4	5	10	26
Los Angeles	Rosemead city	24.3%	15.2%	16.8%	43.6%	100%	190	119	131	340	780
Los Angeles	San Dimas city	25.0%	15.1%	17.2%	40.8%	100%	162	101	107	265	635
Los Angeles	San Fernando city	24.7%	15.1%	16.7%	43.6%	100%	62	38	42	108	251
Los Angeles	San Gabriel city	24.0%	15.4%	17.0%	43.6%	100%	206	127	140	354	827
Los Angeles	San Marino city	26.9%	15.4%	19.2%	38.5%	100%	7	4	5	10	26
Los Angeles	Santa Clarita city	25.0%	16.2%	17.3%	40.5%	100%	2,494	1,560	1,657	3,988	9,699
Los Angeles	Santa Fe Springs city	25.0%	15.6%	16.7%	42.5%	100%	115	73	77	196	461
Los Angeles	Santa Monica city	24.8%	16.0%	17.3%	41.9%	100%	164	105	114	277	662
Los Angeles	Sierra Madre city	26.1%	15.9%	17.4%	40.6%	100%	36	22	24	56	139
Los Angeles	Signal Hill city	25.3%	15.8%	15.7%	43.2%	100%	56	35	37	93	221
Los Angeles	South El Monte city	24.5%	15.0%	17.0%	43.5%	100%	48	30	34	89	202
Los Angeles	South Gate city	24.6%	15.1%	16.6%	43.5%	100%	322	198	218	575	1,313
Los Angeles	South Pasadena city	25.7%	15.8%	17.0%	41.5%	100%	42	26	28	69	165
Los Angeles	Tempe city	25.3%	15.8%	16.8%	42.1%	100%	249	156	165	416	987
Los Angeles	Torrance city	25.6%	16.0%	17.1%	41.4%	100%	468	292	312	756	1,828
Los Angeles	Vernon city	0.0%	0.0%	0.0%	0.0%	0%	0	0	0	0	0

Note: There is a rare and rounding difference in some localities between the total housing need and the sum of the 4 income groups.
In such cases, communities may choose which of the income categories will adjust by one unit to maintain consistency with the approved total housing need.

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County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	Total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Los Angeles	Walnut city	25.1%	16.5%	17.8%	35.5%	100%	150	97	105	212	587
Los Angeles	West Covina city	25.6%	15.8%	16.9%	41.7%	100%	631	388	417	1,025	2,461
Los Angeles	West Hollywood city	24.4%	15.5%	16.9%	43.2%	100%	142	91	99	282	584
Los Angeles	Westlake Village city	26.5%	17.3%	17.3%	38.5%	100%	14	9	9	20	52
Los Angeles	Whittier city	25.2%	15.7%	17.0%	42.1%	100%	225	140	151	375	892
Los Angeles	Unincorporated	25.2%	15.8%	17.2%	41.7%	100%	14,625	9,075	9,815	23,662	57,176
Orange	Aliso Viejo city	22.6%	15.0%	19.4%	43.0%	100%	209	155	179	397	915
Orange	Anaheim city	20.8%	17.0%	19.7%	42.5%	100%	1,971	1,618	1,874	4,035	9,498
Orange	Brea city	21.5%	17.4%	19.7%	41.4%	100%	441	356	404	847	2,048
Orange	Buena Park city	21.0%	17.1%	19.5%	42.3%	100%	142	116	132	286	677
Orange	Costa Mesa city	21.0%	17.2%	19.6%	42.2%	100%	333	285	330	716	1,662
Orange	Cypress city	21.7%	17.5%	19.7%	41.0%	100%	98	79	89	195	460
Orange	Dana Point city	22.1%	17.8%	19.1%	41.2%	100%	16	13	15	28	53
Orange	Fountain Valley city	22.1%	17.7%	19.7%	40.5%	100%	109	89	99	195	466
Orange	Fullerton city	20.9%	17.2%	19.7%	42.2%	100%	399	329	376	856	1,910
Orange	Garden Grove city	20.7%	17.1%	19.8%	42.5%	100%	116	96	110	239	560
Orange	Huntington Beach city	21.7%	17.6%	19.2%	43.9%	100%	454	365	414	899	2,092
Orange	Irvine city	21.7%	18.0%	20.8%	40.3%	100%	7,735	6,408	7,393	14,078	35,660
Orange	La Habra city	20.7%	17.2%	19.5%	42.6%	100%	53	44	50	110	258
Orange	La Palma city	25.0%	18.8%	18.8%	37.5%	100%	4	3	3	6	16
Orange	Laguna Beach city	23.3%	16.7%	20.0%	40.0%	100%	7	5	6	12	30
Orange	Laguna Hills city	25.0%	12.5%	25.0%	37.5%	100%	2	1	2	3	8
Orange	Laguna Niguel city	22.4%	17.9%	19.9%	39.8%	100%	80	64	71	141	356
Orange	Laguna Woods city	18.7%	17.2%	20.1%	44.0%	100%	25	23	27	60	135
Orange	Lake Forest city	20.7%	17.2%	20.7%	41.4%	100%	8	6	8	17	41
Orange	Los Alamitos city	22.0%	17.1%	19.5%	41.5%	100%	9	7	8	17	41
Orange	Mission Viejo city	22.6%	17.6%	19.9%	39.7%	100%	33	26	29	59	147
Orange	Newport Beach city	22.0%	16.0%	20.3%	39.7%	100%	392	322	362	708	1,784
Orange	Orange city	21.4%	17.5%	19.8%	41.4%	100%	1,086	887	1,004	2,102	5,079
Orange	Placentia city	21.5%	17.5%	19.6%	41.2%	100%	21	17	19	40	99
Orange	Rancho Santa Margarita city	22.8%	17.9%	19.5%	39.8%	100%	28	22	24	49	124

Note: There is a small rounding difference in some localities between the total housing need and the sum of the 4 income groups.
In such cases, communities may choose which of the income categories it will adjust by one unit to maintain consistency with the approved total housing need.

AR0072396

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County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Orange	San Clemente city	21.6%	17.6%	19.9%	40.8%	100%	125	103	116	239	584
Orange	San Juan Capistrano city	21.6%	17.7%	19.6%	41.0%	100%	229	186	210	436	1,062
Orange	Santa Ana city	20.5%	16.8%	19.0%	43.8%	100%	694	574	665	1,461	3,393
Orange	Seal Beach city	19.0%	17.5%	21.1%	42.4%	100%	11	10	12	24	57
Orange	Stanton city	19.5%	17.1%	19.7%	43.8%	100%	108	95	107	236	544
Orange	Tustin city	21.6%	17.2%	19.6%	41.6%	100%	512	410	466	991	2,380
Orange	Villa Park city	27.3%	18.2%	18.2%	36.4%	100%	6	4	4	8	22
Orange	Westminster city	20.5%	17.1%	19.9%	42.5%	100%	30	25	29	62	147
Orange	Yorba Linda city	22.6%	18.2%	20.2%	39.0%	100%	460	371	412	796	2,039
Orange	Unincorporated	23.3%	18.1%	20.0%	38.6%	100%	1,777	1,445	1,557	3,159	7,578
Riverside	Banning city	25.7%	18.1%	18.4%	42.8%	100%	673	518	705	1,645	3,841
Riverside	Beaumont city	22.4%	16.2%	18.7%	42.7%	100%	1,536	1,146	1,320	3,015	7,017
Riverside	Blythe city	22.7%	18.5%	18.5%	42.3%	100%	177	138	144	329	778
Riverside	Calimesa city	23.2%	16.2%	18.4%	42.2%	100%	528	367	419	957	2,271
Riverside	Canyon Lake city	25.0%	17.0%	19.0%	39.0%	100%	25	17	19	39	101
Riverside	Cathedral city	23.6%	16.5%	18.5%	42.0%	100%	782	542	609	1,397	3,329
Riverside	Coachella city	22.5%	15.6%	18.5%	43.5%	100%	1,288	893	1,056	2,493	5,733
Riverside	Corona city	21.8%	16.5%	18.5%	43.8%	100%	719	560	611	1,417	3,308
Riverside	Desert Hot Springs city	21.8%	15.8%	16.9%	45.5%	100%	2,161	1,570	1,671	4,322	9,923
Riverside	Hemet city	22.1%	15.6%	18.5%	43.8%	100%	2,484	1,701	2,060	4,090	11,240
Riverside	Indian Wells city	24.8%	17.4%	15.4%	38.4%	100%	61	43	47	94	244
Riverside	Indio city	23.1%	16.1%	18.1%	42.7%	100%	955	667	752	1,769	4,143
Riverside	La Quinta city	24.6%	18.7%	18.4%	40.3%	100%	1,065	784	796	1,741	4,387
Riverside	Lake Elsinore city	23.5%	16.5%	18.6%	41.4%	100%	1,311	921	1,041	2,318	5,590
Riverside	Moreno Valley city	24.2%	16.6%	18.2%	41.0%	100%	1,835	1,035	1,382	3,068	7,474
Riverside	Murrieta city	24.0%	16.5%	18.6%	38.6%	100%	1,568	1,087	1,171	2,497	6,303
Riverside	Norco city	24.9%	17.1%	18.6%	39.4%	100%	236	162	177	374	949
Riverside	Palm Desert city	24.1%	16.5%	18.5%	40.9%	100%	1,135	759	847	1,875	4,566
Riverside	Palm Springs city	23.1%	16.2%	18.6%	42.1%	100%	523	366	421	951	2,261
Riverside	Perris city	23.2%	16.1%	18.3%	42.5%	100%	907	669	748	1,778	4,103
Riverside	Rancho Mirage city	24.3%	16.9%	18.8%	40.1%	100%	761	539	603	1,285	3,238

Note: There is a one unit rounding difference in some localities between the total housing need and the sum of the 4 income groups.
In such cases, communities may choose which of the income categories it will adjust by one unit to maintain consistency with the approved total housing need.

AR0072397

Final Regional Housing Need Allocation Plan - Planning Period (January 1, 2006 - June 30, 2014)
for Jurisdictions within the Six-County SCAG Region (approved by the SCAG Regional Council on July 12, 2007)

County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Riverside	Riverside city	23.6%	16.9%	18.4%	41.1%	100%	2,667	1,865	2,089	4,728	11,351
Riverside	San Jacinto city	22.5%	16.1%	18.3%	43.1%	100%	2,707	1,931	2,206	5,180	12,026
Riverside	Temecula city	24.8%	17.0%	18.5%	39.7%	100%	1,014	693	757	1,622	4,086
Riverside	Unincorporated	20.7%	16.6%	19.5%	43.4%	100%	12,349	9,267	10,429	25,991	58,036
San Bernardino	Adelanto city	22.6%	16.0%	18.5%	42.9%	100%	1,908	1,344	1,561	3,618	8,432
San Bernardino	Apple Valley town	23.5%	16.1%	18.9%	41.4%	100%	912	627	736	1,611	3,887
San Bernardino	Barstow city	22.7%	16.9%	18.8%	42.2%	100%	1,018	758	842	1,860	4,478
San Bernardino	Big Bear Lake city	22.8%	16.1%	19.3%	41.8%	100%	113	80	96	207	495
San Bernardino	Chino city	24.0%	16.9%	19.1%	39.8%	100%	739	519	581	1,212	3,045
San Bernardino	Chino Hills city	25.2%	17.2%	19.7%	37.8%	100%	262	180	205	393	1,040
San Bernardino	Colton city	23.1%	16.1%	18.7%	42.2%	100%	854	595	693	1,563	3,706
San Bernardino	Fontana city	23.9%	16.4%	18.9%	40.9%	100%	1,365	952	1,079	2,329	5,699
San Bernardino	Grand Terrace city	24.7%	16.9%	19.8%	38.9%	100%	80	55	63	131	329
San Bernardino	Hesperia city	20.5%	16.2%	19.8%	41.6%	100%	2,135	1,489	1,707	3,784	9,094
San Bernardino	Highland city	23.3%	16.5%	19.0%	41.3%	100%	562	385	409	890	2,196
San Bernardino	Loma Linda city	23.1%	16.3%	18.9%	41.7%	100%	610	432	501	1,109	2,640
San Bernardino	Montclair city	23.5%	16.7%	19.8%	41.4%	100%	476	353	343	748	1,919
San Bernardino	Needles city	21.2%	16.7%	19.7%	42.4%	100%	14	11	13	28	67
San Bernardino	Ontario city	23.8%	16.5%	19.6%	41.3%	100%	1,838	1,242	1,426	3,155	7,662
San Bernardino	Rancho Cucamonga city	24.7%	16.8%	19.1%	39.3%	100%	317	216	245	504	1,282
San Bernardino	Redlands city	24.0%	16.5%	18.9%	40.8%	100%	682	469	538	1,156	2,845
San Bernardino	Rialto city	23.7%	16.2%	19.8%	41.4%	100%	1,033	709	812	1,769	4,323
San Bernardino	San Bernardino city	27.4%	18.1%	19.0%	40.6%	100%	1,275	913	1,079	2,420	5,687
San Bernardino	Twentynine Palms city	22.5%	15.6%	19.8%	42.9%	100%	702	488	579	1,317	3,076
San Bernardino	Upland city	23.9%	16.4%	19.2%	40.5%	100%	476	328	382	809	1,995
San Bernardino	Victorville city	23.6%	16.3%	18.9%	41.3%	100%	1,972	1,401	1,636	3,514	8,518
San Bernardino	Yucaipa city	25.2%	16.2%	19.0%	41.5%	100%	470	332	389	850	2,048
San Bernardino	Yucca Valley town	22.3%	15.9%	18.5%	42.9%	100%	560	399	474	1,076	2,510
San Bernardino	Unincorporated	23.0%	16.1%	18.9%	41.7%	100%	4,800	3,374	3,893	8,598	20,692
Ventura	Camarillo city	21.6%	17.7%	20.6%	40.3%	100%	727	591	687	1,335	3,340
Ventura	Fillmore city	20.6%	17.3%	20.9%	41.6%	100%	203	170	202	410	985

Note: There is a one unit rounding difference in some localities between the total housing need and the sum of the 4 income groups.
In such cases, communities may choose which of the income categories it will adjust by one unit to maintain consistency with the approved total housing need.

AR0072398

Final Regional Housing Need Allocation Plan - Planning Period (January 1, 2006 - June 30, 2014)
for Jurisdictions within the Six-County SCAG Region (approved by the SCAG Regional Council on July 12, 2007)

County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Ventura	Moorpark city	22.4%	18.1%	20.7%	38.8%	100%	363	293	335	627	1,617
Ventura	Ojai city	20.8%	17.1%	20.8%	41.3%	100%	90	74	90	179	433
Ventura	Oxnard city	21.0%	17.2%	20.4%	41.4%	100%	1,491	1,221	1,445	2,936	7,093
Ventura	Port Hueneme city	20.0%	17.2%	20.6%	42.2%	100%	36	31	37	75	180
Ventura	San Buenaventura (Ventura)	21.2%	17.5%	20.3%	41.0%	100%	849	703	818	1,643	4,011
Ventura	Santa Paula city	20.2%	17.4%	20.6%	41.8%	100%	468	388	462	936	2,241
Ventura	Simi Valley city	22.0%	17.9%	20.2%	39.9%	100%	764	635	694	1,388	3,360
Ventura	Thousand Oaks city	22.3%	16.0%	20.6%	38.9%	100%	411	303	385	718	1,847
Ventura	Unincorporated	21.7%	17.6%	20.7%	39.7%	100%	305	250	291	558	1,404

Note: There is a one unit rounding difference in some localities between the total housing need and the sum of the 4 income groups.
In such cases, communities may choose which of the income categories it will adjust by one unit to maintain consistency with the approved total housing need.

AR0072399

Final Regional Housing Need Allocation Plan - Planning Period (January 1, 2006 - June 30, 2014)
for Jurisdictions within the Six-County SCAG Region (approved by the SCAG Regional Council on July 12, 2007)

County	City	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Summary by County											
Imperial		24.8%	16.4%	15.8%	43.0%	100%	6,025	4,000	3,851	10,451	24,327
Los Angeles		24.7%	15.7%	17.1%	42.6%	100%	70,117	44,465	48,472	120,868	283,922
Orange		21.5%	17.7%	19.9%	40.9%	100%	17,733	14,566	16,380	33,653	82,332
Riverside		23.4%	16.3%	18.5%	41.8%	100%	40,849	28,535	32,295	73,329	174,705
San Bernardino		23.9%	16.2%	16.8%	41.6%	100%	25,051	17,420	20,275	44,797	107,543
Ventura		21.4%	17.6%	20.5%	40.5%	100%	5,682	4,660	5,444	10,748	26,534
SCAG		23.7%	16.2%	18.1%	42.0%	100%	165,457	113,646	126,715	293,547	699,363

For information only

County	Subregion	% very low income households	% low income households	% moderate income households	% above moderate income households	% total	Number of very low income households	Number of low income households	Number of moderate income households	Number of above moderate income households	Total
Summary by Subregion											
Imperial	IVAG	24.8%	16.4%	15.8%	43.0%	100%	6,025	4,000	3,851	10,451	24,327
Los Angeles	North LA	25.2%	15.8%	17.1%	41.8%	100%	18,499	11,661	12,554	30,539	73,253
Los Angeles	LA City	24.1%	15.5%	17.1%	43.3%	100%	27,455	17,620	19,443	49,180	113,698
Los Angeles	Arroyo Verdugo	24.6%	15.8%	17.9%	42.3%	100%	1,871	1,197	1,365	3,184	7,624
Los Angeles	San Gabriel Valley Assoc	25.2%	15.7%	17.0%	42.1%	100%	10,550	6,575	7,220	17,993	42,478
Los Angeles	Westside Cities	25.4%	16.0%	17.2%	41.4%	100%	892	564	605	1,457	3,518
Los Angeles	South Bay Cities Assoc.	25.1%	15.8%	17.1%	42.0%	100%	3,450	2,173	2,345	5,755	13,723
Los Angeles	Gateway Cities	24.6%	15.4%	16.8%	43.2%	100%	6,914	4,360	4,777	12,185	28,236
Los Angeles	Las Virgenes, Conejo	26.3%	16.6%	17.7%	39.5%	100%	364	229	246	548	1,387
Orange	Orange	21.5%	17.7%	19.9%	40.9%	100%	17,733	14,566	16,380	33,653	82,332
Riverside	WRCOG	23.5%	16.4%	18.5%	41.7%	100%	30,758	21,501	24,208	54,525	131,192
Riverside	CVAG	23.1%	16.1%	18.8%	42.2%	100%	10,090	7,034	8,084	18,804	43,513
San Bernardino	SANBAG	23.3%	16.2%	16.8%	41.6%	100%	25,051	17,420	20,275	44,797	107,543
Ventura	VCOG	21.4%	17.6%	20.5%	40.5%	100%	5,682	4,660	5,444	10,748	26,534
SCAG		23.7%	16.2%	18.1%	42.0%	100%	165,457	113,646	126,715	293,547	699,363

For information only

AR007240

SOUTHERN CALIFORNIA
ASSOCIATION of GOVERNMENTS

Regional Transportation Improvement Program (RTIP)

The Regional Transportation Improvement Program (RTIP) is a capital listing of all transportation projects proposed over a six-year period for the SCAG region. The projects include highway improvements, transit, rail and bus facilities, high occupancy vehicle lanes, signal synchronization, intersection improvements, freeway ramps, etc. In the SCAG region, a biennial RTIP update is produced on an even-year cycle.

The RTIP is prepared to implement projects and programs listed in the Regional Transportation Plan (RTP) and is developed in compliance with state and federal requirements. County Transportation Commissions have the responsibility under State law of proposing county projects using the current RTIP's policies, programs, and projects as a guide, from among submittals by cities and local agencies. The locally prioritized list of projects are forwarded to SCAG for review. From this list, SCAG develops the RTIP based on consistency with the current RTP, inter-county connectivity, financial constraint and conformity satisfaction.

Annual Listing of Obligated Projects

- 2011-2012 Annual Listing of Obligated Projects
  - State and Highway Projects
  - Transit Projects
  - FMIS Program Codes
- 2010-2011 Annual Listing of Obligated Projects (Continued)
  - State and Highway Projects
  - Transit Projects
  - FMIS Program Codes
- 2009-2010 Annual Listing of Obligated Projects (Continued)
  - FMIS Program Codes

2008 RTIP Amendments

2008 RTIP Index

Status

Proposed

Currently Approved

Adopted

Contact

If you have any questions or comments, please contact Rosemary Avila at (213) 236-1927 or email avila@scag.ca.gov.

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- 2009-2010 Annual Listing of Obligated Projects (SCAG)
  - Fund Codes
- 2008-2009 Annual Listing of Obligated Projects (SCAG)
- 2006-2007 Annual Listing of Obligated Projects
- 2007-2008 Annual Listing of Obligated Projects (Caltrans)
- 2007-2008 Annual Listing of Obligated Projects (SCAG)

Complete/Deleted FTIP Project Listing

2011

- 2011 SCAG Completed/Deleted Project Listing

2009

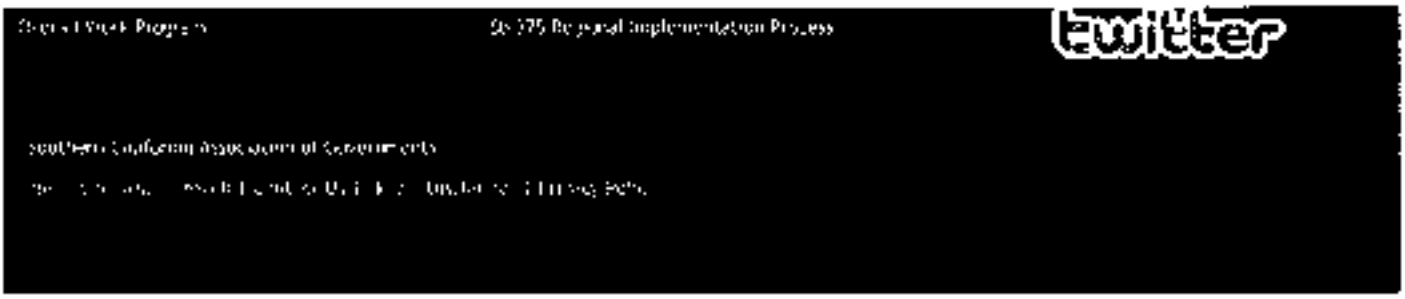
- 2009 SCAG Completed/Deleted Project Listing

2008

- 2008 SCAG Completed/Deleted Project Listing

Links to Our Past RTIPs

- 2008 Regional Transportation Improvement Program
- 2007 Regional Transportation Improvement Program
- 2002 Regional Transportation Improvement Program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SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS
RTP
2008
REGIONAL TRANSPORTATION PLAN
Making the Connections
ADOPTED
MAY 2008

To the Region:

The Regional Council of the Southern California Association of Governments (SCAG) proudly presents the 2008 Regional Transportation Plan (RTP): Making the Connections, adopted on May 8, 2008. Success in transportation and transportation planning is about making the connections, whether it's connecting from bike to bus or truck to rail, relating the travel choices we make with environmental consequences, ensuring that land-use and transportation planning go hand-in-hand, or more equitably linking our transportation finance mechanisms to those who benefit directly from the use of the system.

Southern California's transportation network is severely overburdened and underfunded. For at least the last two decades, we have consistently ranked as the nation's most congested metropolitan area. It is anticipated that over the next 25 years, the region's population will increase by 6 million people and cargo trade through our ports and airports will triple in the same time period, doubling our truck traffic. As a result, roadway speeds are expected to decrease and traffic delays to increase over the next 25 years, all changes that directly impact our environment and air quality.

The 2008 RTP strives to provide a regional investment framework to address the region's transportation and related challenges. It is a $531.5 billion Plan (in nominal or year-of-expenditure dollars) that emphasizes the importance of system management, goods movement, and innovative transportation financing. It looks to strategies that preserve and enhance the existing transportation system and integrate land use into transportation planning.

The RTP was developed in collaboration with agencies from across the region, including our 14 subregions. We worked with county transportation commissions, subregional organizations, transit agencies, tribal nations, non-profits and advocacy groups, and other interested stakeholders. The majority of projects that you will see in the Plan were submitted by our region's five county transportation commissions and the Imperial Valley Association of Governments.

Our region faces great challenges, and we cannot afford to try to solve them solely on a city or even county level. We must look at the bigger picture of Southern California as a region, to look at strategies and new transportation systems that will make this region function the best that it can, and at the end of the day, to make Southern California a place that we are all proud to call our home.

Sincerely,

Gary Ovitt

President, Southern California Association of Governments
Fourth District Supervisor, County of San Bernardino, California

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS

REGIONAL TRANSPORTATION PLAN 2008

MISSION STATEMENT

Leadership | Vision | Progress

Leadership, vision and progress which promote economic growth, personal well-being, and livable communities for all Southern Californians.

The Association will accomplish this Mission by:

- Developing long-range regional plans and strategies that provide for efficient movement of people, goods and information; enhance economic growth and international trade; and improve the environment and quality of life.
- Providing quality information services and analysis for the region.
- Using an inclusive decision-making process that resolves conflicts and encourages trust.
- Creating an educational and work environment that cultivates creativity, initiative, and opportunity.

Funding: The preparation of this document was financed in part through funds from the Federal Highway Administration and Federal Transit Administration. Additional financial assistance was provided by the California State Department of Transportation.

AR0072407

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10/2007

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AR0072408

RESOLUTION NO. 08-497-2

RESOLUTION OF THE SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS APPROVING THE 2008 REGIONAL TRANSPORTATION PLAN (2008 RTP) AND RELATED CONFORMITY DETERMINATION

WHEREAS, the Southern California Association of Governments (SCAG) is a Joint Powers Agency established pursuant to Section 6500 et seq. of the California Government Code;

WHEREAS, SCAG is the designated Metropolitan Planning Organization (MPO) pursuant to 23 U.S.C. §134(d) for the counties of Los Angeles, Riverside, San Bernardino, Ventura, Orange, and Imperial, and as such is responsible for preparing the Regional Transportation Plan (RTP) and Regional Transportation Improvement Program (RTIP) pursuant to 23 U.S.C. §134 et seq., 49 U.S.C. §5303 et seq., and 23 C.F.R. §450.312;

WHEREAS, SCAG is the designated Regional Transportation Planning Agency (RTPA) under state law, and as such is responsible for preparing, adopting and updating the RTP pursuant to Government Code Sections 65080 et seq.;

WHEREAS, the projects included in the RTP must be based on the continuing, cooperative, and comprehensive transportation planning process mandated by 23 U.S.C. §134(c) (3) and 23 C.F.R. §450.312;

WHEREAS, on August 10, 2005, the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law, Pub. L. No. 109-59, Title VI, Section 6001(a), 119 Stat. 1839. SAFETEA-LU includes new and revised metropolitan transportation planning provisions and requires that all state and MPO actions on RTPs and RTIPs (including amendments, revisions or updates) comply with the SAFETEA-LU planning provision beginning July 1, 2007;

WHEREAS, SCAG staff conducted an analysis of the 2004 Regional Transportation Plan ("2004 RTP") which was in place at the time of the enactment of SAFETEA-LU, and thereafter identified the key issues or "gaps" in the 2004 RTP which needed to be addressed in order to comply with SAFETEA-LU. The effort led to the Regional Council's adoption in March 1, 2007 of an Administrative Amendment to the 2004 RTP (hereinafter referred to as the "Administrative Amendment") addressing these gaps. The Administrative Amendment to the 2004 RTP also allowed SCAG to take advantage of the four-year update cycle under SAFETEA-LU such that SCAG can adopt the next RTP update by the spring of 2008;

WHEREAS, in accordance with SAFETEA-LU, SCAG also approved and adopted a Public Participation Plan on March 1, 2007, to serve as a guide for SCAG's public involvement process. This Public Participation Plan was further amended on October 4, 2007, to provide more explicit details as to SCAG's strategies, procedures and techniques for public participation on the RTP, RTIP and the Overall Work Program (OWP);

WHEREAS, the Metropolitan Transportation Planning Final Planning Rule ("Final Rule") was promulgated by the U.S. Department of Transportation Federal Highway Administration and Federal Transit Administration on February 14, 2007, and became effective on March 16, 2007. The Final Rule included, among other things, more specific requirements relating to the content of metropolitan transportation plans (also known as RTPs).

WHEREAS, updates to the RTP must be consistent with all other applicable provisions of federal and state law including:

(1) SAFETEA-LU (23 U.S.C. §134 et seq.);

(2) The metropolitan planning regulations at 23 C.F.R. Part 450, Subpart C (i.e. the provisions of 23 C.F.R. §450.300 et seq. as set forth in the Final Rule);

(3) California Government Code §65080 et seq.; Public Utilities Code §130058 and 130059; and Public Utilities Code §44243.5;

(4) §§174 and 176(c) and (d) of the Federal Clean Air Act (42 U.S.C. §§7504 and 7506(c) and (d));

(5) Title VI of the 1964 Civil Rights Act and the Title VI assurance executed by the State pursuant to 23 U.S.C. §324;

(6) The Department of Transportation's Final Environmental Justice Strategy (60 Fed. Reg. 33896 (June 29, 1995)) enacted pursuant to Executive Order 12898, which seeks to avoid disproportionately high and adverse impacts on minority and low-income populations with respect to human health and the environment; and

(7) Title II of the 1990 Americans with Disabilities Act (42 U.S.C. §§12101 et seq.) and accompanying regulations at 49 C.F.R. §27, 37, and 38;

WHEREAS, SCAG staff has been engaged in the preparation of the 2008 RTP update since the spring of 2007, with a focus on maintaining and improving the transportation system through a balanced approach that considers system preservation, system operation and management, improved coordination between land-use decisions and transportation investments, and strategic system expansion to accommodate future growth through the year 2035;

WHEREAS, the 2008 Draft RTP was released by SCAG's Transportation and Communications Committee (TCC) on December 6, 2007 for public review and comment, and a Notice of Availability was issued. The 2008 Draft RTP included a financially constrained plan and a strategic plan. The constrained plan includes transportation projects that have committed, available or reasonably available revenue sources, and thus are probable for implementation. The strategic plan is an illustrative list of additional transportation investments that the region would pursue if additional funding and regional commitment were secured; and such investments are potential candidates for inclusion in the constrained RTP through future amendments or updates. For purposes of the 2008 RTP update, the strategic plan is provided for information purposes only and is not part of the financially constrained and conforming RTP;

WHEREAS, the 2008 Draft RTP also included a financial plan identifying the revenues available to support the SCAG region's surface transportation investments. The financial plan was developed following basic principles including incorporation of county and local financial planning documents in the region where available, and utilization of published data sources to evaluate historical trends and augment local forecasts as needed;

WHEREAS, pursuant to 23 C.F.R. §450.316(b)(1)(iv), SCAG must provide adequate public notice of public involvement activities and time for public review and comment at key decision points, including approval of plans and transportation improvement programs. SCAG followed the provisions of its adopted Public Participation Plan and subsequent Amendment No. 1 regarding public involvement activities for the 2008 RTP. For example, three duly-noticed public hearings were conducted within the SCAG region to allow stakeholders, elected officials and the public to comment on the 2008 Draft RTP;

WHEREAS, the 2008 Draft RTP serves as the basis of the 2008 Final RTP, and addresses public comments and issues relating to projects and other relevant data which arose subsequent to the release of the 2008 Draft RTP. The public comment period for the 2008 Draft RTP closed on February 19, 2008. SCAG received approximately 150 written comments. Staff has fully considered these comments in preparing the 2008 Final RTP;

WHEREAS, there were several comments relating to the Growth Forecast/Land Use discussion in the 2008 Draft RTP. In part because of the public comments, the Regional Council on March 6, 2008, approved the Baseline Growth Forecast with a statement of advisory land use policies/ strategies for the 2008 Final RTP;

WHEREAS, there were also project-specific comments made as part of the public comment period. Additional information was also provided regarding certain transportation projects that were included in the 2008 Draft RTP, contingent upon adequate documentation that these projects meet the fiscal constraint requirements. Based upon staff's analysis as well as input from the TCC and Regional Council, the projects in the 2008 Final RTP represent projects which meet the fiscal constraint requirements of SAFETEA-LU and the Final Rule;

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WHEREAS, in non-attainment and maintenance areas for transportation-related criteria pollutants, the MPO, as well as the FHWA and FTA, must make a conformity determination on any updated or amended RTP in accordance with the Federal Clean Air Act to ensure that federally supported highway and transit project activities conform to the purpose of the State Implementation Plan (SIP);

WHEREAS, transportation conformity is based upon a positive conformity finding with respect to the following tests: (1) regional emissions analysis, (2) timely implementation of Transportation Control Measures, (3) financial constraint, and (4) interagency consultation and public involvement;

WHEREAS, the 2008 Draft RTP included the Draft Conformity Report which concluded with a positive transportation conformity determination for all applicable non-attainment areas in the SCAG region. After the release of the Draft Conformity Report, SCAG was informed that the U.S. Environmental Protection Agency (EPA)'s review of the ozone and PM2.5 motor vehicle emission budgets for the South Coast Air Basin submitted by the California Air Resources Board (ARB) raised concerns such that the ARB was required to revise and resubmit the emission budgets to EPA. This requirement led to SCAG making appropriate revisions to the draft conformity analysis to reflect the new emissions budgets and release a subsequent Draft Conformity Report for an additional 30-day public review period ending April 28, 2008;

WHEREAS, the Conformity Report contained in the 2008 Final RTP makes a positive transportation conformity determination. Using the final motor vehicle emission budgets released by ARB and found to be adequate by EPA, this conformity determination is based upon staff's analysis of the applicable transportation conformity tests;

WHEREAS, in accordance with the interagency consultation requirements, 40 C.F.R. 93.105, SCAG consulted with the respective transportation and air quality planning agencies, including but not limited to, extensive discussion of the Draft Conformity Report before the Transportation Conformity Working Group (a forum for implementing the interagency consultation requirements) throughout the update process;

WHEREAS, SCAG is required to comply with the California Environmental Quality Act ("CEQA") [Cal. Pub. Res. Code § 21000 et seq.] in updating the Regional Transportation Plan;

WHEREAS, SCAG released for public review and comment a Draft 2008 Regional Transportation Plan Program Environmental Impact Report ("Draft PEIR") on January 3, 2008;

WHEREAS, the public comment period for the Draft PEIR closed on February 19, 2008. SCAG has fully considered these comments, and written responses to comments received are included in the Final PEIR Addendum;

WHEREAS, prior to the adoption of this resolution, the Regional Council certified the Final PEIR prepared for the 2008 Final RTP to be in compliance with CEQA;

WHEREAS, the Final Rule stipulates that each project or project phase included in the RTIP shall be consistent with the approved RTP (23 C.F.R. Section 450.324(g));

WHEREAS, this RTIP consistency requirement would be applicable with the Regional Council's adoption of the 2008 Final RTP. SCAG staff, therefore, amended the 2006 RTIP so as to be consistent with the 2008 Draft RTP. Such amendment to the 2006 RTIP was referred to as "Amendment #06-13" to the 2006 RTIP, and was released for public review by a Notice of Availability along with the 2008 Draft RTP and the Draft Conformity Report. The majority of changes to the 2006 RTIP included as part of RTIP Amendment #06-13 are modeling network changes (due to changes in project completion dates) and there are a few changes due to project description changes;

WHEREAS, the Regional Council has had the opportunity to review the 2008 Final RTP and its related appendices, and consideration of the 2008 Final RTP was made by the Regional Council as part of a public meeting held on May 8, 2008.

NOW, THEREFORE BE IT RESOLVED, by the Regional Council of the Southern California Association of Governments as follows:

1. The Regional Council approves and adopts the 2008 Final RTP for the purpose of complying with the requirements of SAFETEA-LU and all other applicable laws and regulations as referenced in the above recitals. In adopting this 2008 Final RTP, the Regional Council finds as follows:

a. The 2008 Final RTP complies with all applicable federal and state requirements, including the SAFETEA-LU planning provisions. Specifically, the 2008 Final RTP fully addresses the requirements relating to the development and content of metropolitan transportation plans as set forth in 23 C.F.R.§450.322 et seq., including issues relating to: transportation demand, operational and management strategies, safety and security, environmental mitigation, the need for a financially constrained plan, consultation and public participation, and transportation conformity.

b. The 2008 Final RTP represents the SCAG region's collective vision for addressing our transportation needs through 2035 within the constraints of committed, available, and reasonably available revenue resources.

2. The Regional Council hereby makes a positive transportation conformity determination of the 2008 Final RTP. In making this determination, the Regional Council finds as follows:

a. The 2008 Final RTP passes the four tests and analyses required for conformity, namely: regional emissions analysis; timely implementation of Transportation Control Measures; financial constraint analysis; and interagency consultation and public involvement.

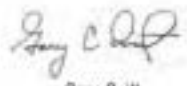
b. The effective date of the transportation conformity determination is deferred to the effective date of the adequacy findings made by the U.S. EPA regarding applicable emission budgets for the SCAG region.

3. In approving the 2008 Final RTP, the Regional Council also approves and adopts Amendment #06-13 to the 2006 RTIP, in order to address the consistency requirement of the federal law.

4. In approving the 2008 Final RTP, the Regional Council approves the staff findings as set forth in its reports and incorporates all of the foregoing recitals in this resolution.

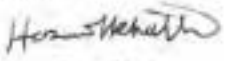
5. SCAG's Executive Director or his designee is authorized to transmit the 2008 Final RTP and its conformity findings to the Federal Transit Administration and the Federal Highway Administration to make the final conformity determination in accordance with the Federal Clean Air Act and EPA Transportation Conformity Rule at 40 C.F.R. Parts 51 and 93.

APPROVED AND ADOPTED by the Regional Council of the Southern California Association of Governments at a regular meeting this 8th day of May 2008.



Gary Ovitt
President
Fourth District Supervisor,
San Bernardino County

Attested by:



Hasan Ikhrata
Executive Director

Approved as to Form:

Joe Burton
Chief Counsel

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EXECUTIVE SUMMARY

Success in transportation and transportation planning is about making the connections, whether it's connecting from bike to bus or truck to rail; relating the travel choices we make with environmental consequences; ensuring that land-use and transportation planning go hand in hand, or more equitably linking our transportation financing mechanisms to those who benefit directly from use of the system. The 2008 Regional Transportation Plan (RTP) connects the six-county region of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties to a future vision in which innovative solutions address the daunting challenges we face today.

The 2008 RTP presents the transportation vision for this region through the year 2035 and provides a long-term investment framework for addressing the region's transportation and related challenges. The Plan is the culmination of a multi-year effort focusing on maintaining and improving the transportation system through a balanced approach that considers system preservation, system operation and management, improved coordination between land-use decisions and transportation investments, and strategic expansion of the system to accommodate future growth.

Leadership, vision, and progress are three main components of the Southern California Association of Government's (SCAG) Mission Statement that apply to the RTP development process. In demonstrating a commitment to leadership, SCAG identified regional goals that reflect a balanced approach to transportation planning and decision-making. In providing a vision, the SCAG Regional Council adopted policies to guide the development of the RTP and identified transportation priorities for the region. Lastly and most importantly, in its commitment to demonstrate progress, SCAG continues to rely extensively on performance measurement as a means to identify the most beneficial investments for the region (see Table 1). Together, these elements contribute to a strong and focused RTP.

TABLE 1 RTP GOALS AND RELATED PERFORMANCE OUTCOMES

RTP Goals	Mobility	Accessibility	Reliability	Productivity	Safety	Sustainability	Preservation	Cost-Effectiveness	Environmental	Environmental Justice
Maximize mobility and accessibility for all people and goods in the region	✓	✓						✓		✓
Ensure travel safety and reliability for all people and goods in the region	✓		✓		✓					
Preserve and ensure a sustainable regional transportation system						✓	✓		✓	✓
Maximize the productivity of our transportation system	✓			✓						
Protect the environment, improve air quality and promote energy efficiency						✓			✓	✓
Encourage land use and growth patterns that complement our transportation investments and improve the cost-effectiveness of expenditures	✓	✓							✓	
Maximize the security of our transportation system through improved system monitoring, rapid recovery planning, and coordination with other security agencies*										

* SCAG does not yet have an agreed-upon security performance measure; therefore, it is not included in this table.

This forward-looking Plan consists of two sections: a financially constrained plan and a strategic plan. While the constrained plan includes strategies that have committed, available, or reasonably available revenue sources, the stra-

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tegic plan identifies further needs that require further study and consensus building before difficult decisions can be made as to whether the region is willing to commit funds to include them in a future RTP's constrained plan.

Transportation Planning Challenges

The SCAG Region is one of the largest and most complex metropolitan areas in the nation, and its transportation challenges are equally large and complex. Growth trends and travel patterns in the SCAG Region pose difficult challenges for our multimodal transportation system.

THE SHAPE AND PATTERN OF FUTURE GROWTH

Southern California is running out of land to support low-density future growth. The ocean and mountains pose natural barriers to development. Environmentally sensitive areas, such as coastal wetlands and natural habitat areas, hem in the region and dot the urbanized area. A significant amount of land is also owned by the state and federal governments for the public benefit and is off limits to development. The centrifugal force of growth continues to push the development footprint of the urbanized area outward. At the same time, pushing back on dispersed development are natural barriers, financial constraints to pay for outward expansion, and public resistance to unsustainable "leap frog" growth into green fields and sensitive habitat areas. Nearly all natural locations for urban development have been consumed, leaving us with hard choices about how we are to grow and change to meet the demands of the future.

The SCAG Region is the second-most populated metropolitan area in the United States. Nearly one-half of all Californians live in the SCAG Region, and 1 in 17 people living in the entire United States resides here. By July 1, 2007, the region's population had reached 18.6 million residents, having grown by 2 million residents (12 percent) from just seven years ago. Furthermore, the region saw greater population growth between 2000 and 2007 (2 million residents) than that which occurred throughout the 1990s (1.9 million residents). By the year 2035, the region is projected to be home to 24 million residents.

As the region grows, the average person will be older due to aging "baby boomers," and Hispanics will become the majority ethnic group. These shifting demographic patterns will influence future travel behavior as the elderly tend to travel less and recent immigrants tend to use public transportation more than other population groups.

MOBILITY CHALLENGES

The projected growth is expected to place even greater demands on the transportation system. The SCAG Region is served by an extensive multimodal transportation system addressing all aspects of travel in the region, including commuters; shoppers; public transit patrons; truckers delivering goods both regionally and locally, such as groceries to the local supermarkets; as well as fire, police, and other emergency personnel. The roadway and freight rail networks serve the largest maritime ports system in the United States (the Ports of Long Beach, Los Angeles, and Hueneme) and a number of large airports, including the fifth-largest airport in the world (Los Angeles International Air-

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port—LAX). But as impressive as this system may seem, it has not kept pace with population growth and transportation demand.

Although the region's population has more than doubled since 1970, expenditures on the roadway system have actually decreased significantly since then. As a result, traffic delays have nearly tripled over the last twenty years, and 5.7 million person-hours are lost each day to traffic delays. Additionally, traffic bottlenecks (caused by merges, weaves, lane drops, stalls, accidents, and other factors) result in reduced roadway productivity. This "lost" capacity in the AM peak period, attributable to a large extent to non-recurring incidents such as accidents, weather conditions, stalled vehicles, etc., could have the effect of the loss of approximately 286 lane-miles of freeway capacity when it is needed the most. The cost of physically adding this lost capacity by widening existing facilities would exceed $4 billion.

Beginning in the 1980s, a major shift occurred away from building roadways and into transit projects and services. Between 2000 and 2005, regional transit use increased by more than 16 percent, and in 2005, our region reached the highest ridership per capita in about 20 years. However, as we are far from having a "complete" public transportation system with frequent service, extensive coverage, and good connectivity, less than 3 percent of all trips and person-miles traveled are taken on public transit.

AGING INFRASTRUCTURE

The need to preserve our transportation assets adequately was brought to the nation's attention after the Minnesota I-35W bridge collapse during the summer of 2007. We must recognize that our roadway network and transit systems developed over the past decades are aging. These regional assets represent hundreds of billions of dollars of investments that must be protected in order to serve us and future generations. Without these assets, or even a portion of these assets, the region's mobility would be significantly compromised.

Unfortunately, our region's roadways, especially the State Highway System, owned and operated by Caltrans, have not been maintained adequately due to constrained state and federal funding. Deferred maintenance leads to higher costs. Whereas pavement surface damage requires an investment of $64,000 per lane-mile to bring it to a state of good repair, the costs escalate significantly if these investments are not secured in a timely manner. The costs for minor damage repair escalate more than fivefold to $387,000, and the costs for major damage repair escalate to an astronomical $900,000 per lane-mile.

EXPLOSIVE GROWTH IN GOODS MOVEMENT

The SCAG region's goods movement system serves as the gateway for both international and domestic commerce. Supported in part by its geographical advantages such as deep-water marine ports, highly developed network of highways and railways, availability of transloading facilities, and its large internal market, goods movement is the fastest-growing segment of the region's transportation sector. Every state in the nation receives goods that pass through Southern California, and the region is a cornerstone of the nation's global competitiveness.

The San Pedro Bay Ports, which include the Los Angeles and Long Beach Ports, currently handle approximately 40 percent of the volume imported into the country and approximately 24 percent of the nation's exports, and one out of every seven jobs in Southern California depends on this trade. Container volume processed by the San Pedro Bay Ports grew by almost 60 percent in volume between the years 2000 and 2006, and is expected to nearly triple by 2030.

As the only deep-water port between Los Angeles and San Francisco, the Port of Hueneme in Ventura County is a major shipping point for automobiles, fresh fruit, and produce. Approximately $7 billion in cargo traverses through this Port annually, and trade-related activity generated by the Port contributes significantly to the local economy.

Cross-border trade activity also contributes to the region's international trade growth, with the growth in Mexico's manufacturing industry increasing truck trips through Calexico East in Imperial County by 77 percent between 1994 and 2005.

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More than 75 percent of the containers processed by the ports in 2006 and 2007 involved a truck trip within the SCAG Region, either to a rail intermodal facility, a warehouse, or a transload facility. These trucks contribute to the existing congestion in the region and will contribute to future congestion even more, as the number of trucks is projected to more than double for several major freeways by 2030.

Recent projections included in SCAG's Inland Empire Railroad Main Line Study suggest that the number of freight trains on most Burlington Northern Santa Fe (BNSF) and Union Pacific (UP) lines will more than double between 2000 and 2025 in response to a tripling of container volume at the San Pedro Bay Ports. Freight rail poses serious quality-of-life issues for many communities. Some towns and cities witness 100 trains per day that literally split their communities into two sections for extended periods of time.

AVIATION CAPACITY AND GROUND ACCESS CONSTRAINTS

The SCAG Region supports the nation's largest regional airport system in terms of number of airports and aircraft operations, operating in a very complex airspace environment. These airports support both growing passenger and freight movement, and there are significant challenges in meeting the future airport capacity needs of Southern California. Work on SCAG's 2004 RTP concluded that an Aviation Decentralization Strategy is needed to meet the forecast doubling of air passenger demand by 2030, from the current 90 million annual passengers (MAP) to 170 MAP (according to the 2004 RTP). This is because the four urban air carrier airports in Los Angeles and Orange Counties are all highly constrained. Their collective acreage amounts to 5,540 acres, which is less than 17 percent of the 34,000 acres of Denver International, and less than the 7,700 acres of Chicago O'Hare. At 3,500 acres, LAX is a very small international airport despite being the third-busiest airport in the country and fifth-busiest in the world in terms of passengers served. All of these urban airports have little room to expand because of severe encroachment by surrounding communities.

AIR QUALITY, CLIMATE CHANGE, AND ENERGY CHALLENGES

The SCAG Region continues to have the worst air quality in the nation despite improvements gained in the last two decades. The recently documented health impacts of air pollution on people living in the South Coast Air Basin are staggering. Of all the people nationwide who are exposed to PM2.5 levels that exceed the federal health-based standard, 52 percent live here. Of all the people statewide who are exposed to these levels, 82 percent live here. This is estimated to result in 5,400 premature deaths and 980,000 lost work days per year.[1]

Much of the region continues to exceed the National Ambient Air Quality Standards (NAAQS) identified in the Clean Air Act. Most of the SCAG Region is classified as non-attainment areas for some criteria pollutants. Further, as demonstrated by the recent Air Quality Management Plan (AQMP)/State Implementation Plan (SIP) efforts of local air districts and the Air Resources Board (ARB), the region's efforts to attain the NAAQS continue to be challenging, as the South Coast Air Basin, the Ventura County portion of the South Central Coast Air Basin, the Western Mojave Air Basin, and the Riverside County portion (Coachella) and the Imperial County portion of the Salton Sea Air Basin will all be "bumping up" to worse ozone non-attainment designations since they cannot achieve the NAAQS in the time previously assumed. Further, the attainment plan to meet the ozone standard in the South Coast Air Basin includes undefined long-term ("black box") measures of approximately 200 tons per day of nitrogen oxides (NOx), which is a daunting amount of as-yet-unidentified emission reductions. Of additional concern are the upcoming 24-hour PM2.5 standards, which will require even greater reductions as well as possibly more stringent ozone standards. Consequently, the ARB, South Coast Air Quality Management District (SCAQMD), and SCAG are committed to producing a white paper that identifies strategies to address the shortfall issues. Furthermore, there are strategies and programs in this Plan that will be incorporated into the white paper.

[1] Personal Communication, Richard Bode, California Air Resources Board, 2007.

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In addition to the aforementioned challenges, efforts to reduce greenhouse gases (GHG) will present another tremendous challenge to the transportation sector. Transportation is the largest source of GHG emissions in California, representing 38 percent of emissions, and emissions from the transportation sector have grown more rapidly than from other sources over the past ten years.[2] California is the second-largest emitter of GHG emissions in the United States and the twelfth-largest emitter in the world, exceeding most nations.

At the same time, environmental and geopolitical factors are causing energy experts to question the long-term viability of a fossil fuel–based energy future. Travel demand forecasts generally assume that the future will include an abundant and relatively inexpensive supply of transportation fuels. If transportation fuel prices continue to increase, it would have a ripple effect on numerous areas including construction costs, gas tax revenue, travel and aviation demand, air emissions, mode choice and growth patterns. One area of uncertainty is how commuters may respond to higher gasoline prices. For example, a recent study suggests that with a ten percent increase in the gas price, there is a less than one percent change in gas consumption, while other data show that an increase in gas prices coincides with an increase in transit ridership. In addition, growth patterns may alter future demand for transportation fuels. Mixed land uses (i.e., residential developments near work places, restaurants, and shopping centers) with access to public transportation have been shown to save consumers over 500 gallons of gasoline per year.[3] Energy uncertainty requires serious consideration and further study.

TRANSPORTATION FINANCE CHALLENGES

While this region does not lack the creativity and resolve to develop innovative solutions to our problems, we continue to face shortfalls in transportation funding. As the critical factor that often determines whether beneficial projects can be implemented, transportation finance is perhaps the region's most imminent challenge. The following briefly describes current and projected challenges that are likely to impact transportation revenues within the 2008 RTP time frame.

Over the past four decades, transportation revenues (from gasoline taxes collected per gallon) in California have not kept pace with the state's ever-evolving demographic characteristics. Indicators such as vehicle miles traveled, population, and personal income growth have all outpaced the rate of transportation revenue growth. In addition, gas taxes are collected in cents per gallon. Without periodic adjustment or indexing, these funds will not keep pace with needs. Although the passage and recent renewal of local "self-help" transportation sales taxes have greatly improved funding for transportation, gasoline tax revenues continue to decline in value due to inflation.

The viability of the State Highway Account also remains a critical issue. The state's gasoline tax revenues are now exclusively dedicated to funding the

[2] United States Department of Transportation, Federal Highway Administration. Transportation and Global Climate Change: A Review and Analysis of the Literature. (June 1998.) DOT-T-97-03.

[3] Victoria Transport Policy Institute. Transportation Demand Management Encyclopedia.

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needs of the State Highway Operation and Protection Program (SHOPP)—at a level, however, that is considerably less than actual needs. Continued underinvestment in the rehabilitation and maintenance needs of the state highway system has serious ramifications—rapidly increasing the number of distressed lane-miles on the state highway system and eroding the condition of the state's bridges. In recent years, transportation has relied heavily on the State General Fund to pay for capacity-enhancing projects. Reliance on the State General Fund means that transportation funding is subject to the state's annual budget process, which can be lengthy and unpredictable.

The need to establish a reliable and sustainable transportation funding source is even stronger, as the Federal Highway Trust Fund may not have enough resources to meet all of its obligations by the end of the decade. Expenditures authorized under SAFETEA-LU have outstripped revenues generated by the federal per-gallon gasoline tax. Accordingly, the viability of the Highway Trust Fund will be a critical issue in the discussions for the next round of the federal transportation reauthorization legislation, which will start in 2009.

Finally, over the last four years, construction costs in California and the nation have increased at an unprecedented rate and much faster than general inflation. The recent run-up in construction prices is due to a variety of factors, including a residential and commercial building boom as well as higher demand for construction materials in developing countries, most notably, China. Although these trends are likely to fluctuate, they have caused many transportation projects to exceed their budgets in the short term and made long-term project cost forecasting uncertain.

Transportation Strategy

SECURITY AND SAFETY FIRST

The SCAG Region is vulnerable to many types of catastrophic events including earthquakes, floods, fires, hazardous material incidents, dam failures, civil unrest, transportation accidents, tsunamis and terrorism. Through hard experience, California has in place an emergency and response structure designed to be innovative for the different locations and types of emergencies. There are many agencies that will participate in the response to a disastrous event and ensure that their jurisdictions are prepared to respond to these hazards. This Plan details nine measures that SCAG, as a planning agency, will undertake to enhance the region's ability to achieve and sustain at-risk target levels of capability to prevent, protect against, respond to, and recover from major human-caused or natural events in order to minimize the threat and impact to lives, property, and the region.

The mantra, "Safety First," applies to our transportation system no less than to any other sector of our region. When examined historically, fatal and injury collisions (rate per million vehicle miles traveled) have steadily decreased in California since the 1930s. As SCAG and Caltrans both recognize the continuation of this positive trend as a priority, in 2007, the region fully funded highway collision reduction and emergency response needs, estimated at $317 million and $110 million, respectively. In addition, this Plan forecasts expenditures of $10 billion for safety-related projects and services. Furthermore, in 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) required that each state develop a Strategic Highway Safety Plan (SHSP), which this RTP must be and is consistent with. These actions emphasize the level of collaboration among SCAG, Caltrans, and its stakeholders to examine safety on a system basis so that the region can use all the tools available to decrease traffic injuries and fatalities.

MANAGING OUR TRANSPORTATION SYSTEM WISELY

Since our challenges are multifaceted, our approach to tackling them must be as well. The region recognizes that maintaining and improving mobility will no longer depend solely on expanding its transportation system. Instead, an integrated approach is needed to maximize mobility. State transportation stakeholders have developed a tiered approach based on the idea that transportation investments would have more impact if they were prioritized strategically. Represented by the pyramid below, this approach frames the following discussion.

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FIGURE 1 MOBILITY PYRAMID

SYSTEM MONITORING AND EVALUATION

First, it is imperative that we understand the problem in order to fix it. We must have an in-depth understanding of how our system performs and why it performs that way so that we can identify the optimal mix of strategies and projects that yield the highest returns on the region's investments. The base of the mobility pyramid, entitled "System Monitoring and Evaluation," is the foundation of sound system management. SCAG has developed performance measures to improve data collection and to track and monitor the progress of the transportation system so that the region can make informed decisions regarding transportation investments. For example, the Freeway Performance Measurement System (PeMS), developed by UC Berkeley, Caltrans, and the California Partners for Advanced Transit and Highways (PATH), has the ability to measure freeway speeds, delay, and reliability for the regional freeway system. Additionally, transportation professionals and decision-makers have recently committed to improving the region's ability to properly fund the investments needed to comprehensively monitor and evaluate system performance. These investments include detection, closed-circuit television systems, bus global positioning systems, and automatic ridership counting systems. Although funding is modest for these activities, they lead to more informed decisions.

MAINTENANCE AND PRESERVATION

Over the decades, the region has invested hundreds of billions of dollars in our multimodal transportation system. Preserving these assets is a critical priority, especially as preservation needs have been historically underfunded in our region. On top of existing funding for preservation and maintenance, our highway system needs an additional $30 billion through 2035, and our arterial and transit system needs another $10 billion.

Recognizing that every dollar expended today toward maintenance and preservation will save much more in the future, this Plan commits $8 billion of new funding to preservation.

INTEGRATED LAND USE AND DEMAND MANAGEMENT

Integrated Growth Forecast

The Baseline Growth Forecast sets the stage for a future regional growth scenario, as it ties housing to transportation planning, considering both needs simultaneously in communities throughout the region. This approach ensures that the resulting assumptions are consistent with planned transportation infrastructure. Based on a combination of recent and past trends, reasonable key technical assumptions, and existing and new local policy options, the Baseline Growth Forecast provides the basis for developing the land use assumptions at the regional and small-area levels which build the 2008 RTP Plan Alternative.

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Advisory Land Use Policies and Strategies

The 2008 RTP Plan Alternative incorporates the Baseline Growth Forecast and the approved transportation network. However, in the rapidly growing SCAG Region, these trends could be tempered, and in some cases bolstered, by policies and strategies designed to improve future travel patterns and vehicle emissions. In response, SCAG adopted a set of advisory land use policies and strategies for future regional planning efforts and for localities to consider as they accommodate future growth. These policies and strategies were founded upon the principles developed through the regional growth visioning efforts begun in 2001.

- Identify regional strategic areas for infill and investment
- Structure the plan on a three-tiered system of centers development
- Develop "complete communities"
- Develop nodes on a corridor
- Plan for additional housing and jobs near transit
- Plan for a changing demand in types of housing
- Continue to protect stable existing single-family areas
- Ensure adequate access to open space and preservation of habitat
- Incorporate local input and feedback on future growth

Travel Demand Management (TDM)

In an effort to address travel demand, TDM strategies are designed to influence an individual's travel behavior by making alternatives to the single-occupant automobile more attractive, especially during peak commute periods, or by enacting regulatory strategies. Some examples of TDM strategies are carpools and vanpools, public transit, non-motorized modes, congestion pricing, and providing the public with reliable and timely traveler information.

In total, this Plan dedicates over $1.3 billion to TDM investments.

Increasing Rideshare (Carpool and Vanpool)

The SCAG Region continues to invest heavily in High-Occupancy Vehicle (HOV) infrastructure that provides incentives for commuters to share rides with others. While HOV utilization is growing over time, the percent of total travelers using carpools and vanpools is not. SCAG and its partners will strengthen their efforts to encourage this efficient mode, which reduces travel time and improves air quality.

Increasing Work at Home

Increasing the number of workers who work at home (self-employed, home-based business owners) or who telework/telecommute (wage and salary employees conducting some or all of their work from home) decreases home-based work trips, vehicle-miles of travel, congestion, and vehicle emissions. National and regional surveys of those who telecommute indicate that it is a lack of support and trust from "management," rather than the provision of equipment or the desire of workers to telecommute, that hampers the growth of telecommuting. Therefore, this Plan recommends formalizing and

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expanding partnerships among public- and private-sector stakeholders, and to promote telecommuting to increase opportunities for workers regionally to telecommute in lieu of daily commuting.

Non-Motorized Transportation

Bicycling and walking play an important role in our transportation system. According to the 2001 National Household Travel Survey, 50 percent of all trips made nationwide in urban areas were shorter than 3 miles, and 28 percent of all trips were under 1 mile. These trips are ideal for biking, walking, and transit or a combination of those modes of travel.

Regionwide, however, our average commute distance to work is 19.2 miles, too far for many bicyclists and all pedestrians. However, the integration between bicycle and transit nodes offers the opportunity to extend the commuting range of bicyclists. Bicycle transportation infrastructure has a role in regional mobility and air quality improvements. Every automobile driver that switches to an alternative transportation choice (walking, bicycling, using transit) reduces air pollution, congestion, the need for increasing roadway capacity, and improves public health.

Bicycle and pedestrian improvements are included as part of many larger street maintenance and construction projects, and should always be included in general plan updates, with which SCAG can assist in the development through the Compass Blueprint Program. These investments and the supporting policies all aim to maximize the benefits of this efficient mode of transportation. In addition, this Plan supports several policies that aim to work with local governments and increase the safety, convenience, and attractiveness of bicycling and walking as modes of travel.

The RTP allocates over $1.8 billion for non-motorized transportation.

MAXIMIZING TRANSPORTATION SYSTEM PRODUCTIVITY

Beyond managing our travel demand, this region needs to invest in maximizing the productivity of our existing system and increase its efficiency. The region has built a vast and expensive transportation system, which can be tweaked and modernized to carry more people and goods in a day or during peak commute conditions. Such investments include implementing advanced traffic control strategies such as signal coordination and ramp metering, improved incident management, and smaller physical infrastructure modifications such as auxiliary lanes.

Recognizing that funding productivity improvements provides a higher return on investments than most other transportation projects, this Plan allocates an additional $2 billion, representing 20 percent of the region's operations improvement shortfall. As these allocations are programmed and implemented, SCAG hopes that the benefits will become apparent to decision-makers and the public, and that additional funding can be secured to address the remaining shortfall.

Strategic Transit Service Policies

In an effort to maximize transit productivity, this Plan calls upon regional transit operators to address significant challenges to achieve better operational efficiency, maintain a discipline of cost recovery through a consistent fare policy, embrace the use of performance metrics to better serve their existing customer base, and attract new transit users. The Plan encourages the regional transit operators to work cooperatively to offer complementary services, with ease of transfer between modes and operators. It further encourages utilization of new intelligent transportation system (ITS) technologies that measure system performance and offer their customers reliable "on-time" performance and real-time information.

SYSTEM COMPLETION AND EXPANSION

Beyond the preceding strategies and improvements that have been evaluated thus far, the past and future growth in transportation demand calls for the expansion of our existing transportation system. As such, more than half of the available transportation revenues in the region are dedicated to the completion and expansion of our people and goods movement transportation systems.

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Highway Improvements

Major categories of highway improvements included in this Plan are HOV lanes and connectors, mixed-flow (or general purpose) lanes, toll facilities and High-Occupancy Toll (HOT) lanes, and strategic arterial improvements. A significant number of system expansion projects have already been committed through SCAG's Regional Transportation Improvement Program (RTIP) for the highway network. These priority projects close critical gaps in the system, relieve significant bottlenecks, and address inter-county travel needs.

HOV Gap Closures and Connectors

Southern California has invested heavily in HOV lanes, producing one of the nation's most comprehensive HOV networks and highest rideshare rates. Several experiments involving HOV lanes are being conducted throughout the region in an effort to improve the functionality of this already-proven TDM strategy. In 2007, the first continuous-access HOV lanes opened on SR-22 in Orange County. Since the HOV lane system is a regional network, operations should be coordinated across jurisdictional boundaries to optimize performance and minimize confusion. SCAG supports further study and evaluation of these proposed operational changes to the HOV lane system to fully understand the mobility, safety, and air quality impacts, as well as any implications for a proposed regional HOT lane system.

This Plan includes many additional investments to extend the HOV network, strategically close gaps in the HOV network, and construct additional direct freeway-to-freeway connectors to maximize the overall system performance by minimizing weaving conflicts and maintaining travel speeds.

Mixed Flow

Since mixed-flow lanes carry more traffic than any other component of our transportation system, mixed-flow capacity enhancements are also necessary to address traffic bottlenecks and relieve congestion on heavily traveled corridors. This is especially true in areas outside of the urban core where transit service and the HOV network are not fully developed. This Plan includes a variety of mixed-flow lane additions, the majority of which are located outside of Los Angeles County.

Toll and High-Occupancy Toll (HOT) Lane Corridors and Facilities

This Plan also includes the expansion of the existing HOT lane and toll road system in Orange County to address the congested commuter corridor between housing-rich Riverside County and job-rich Orange County. Additionally, improvements to several major corridors in other parts of the region are proposed to be financed by tolls, including the SR-710 Gap Closure and the High Desert Corridor.

Transit

The RTP's Integrated Land Use and Transit policies and strategies work hand in hand to improve mobility and air quality. The investment in new rail and bus transit corridors has spawned investment throughout the region in new housing, retail, and business development at and near transit stations. Since 2003, the region has experienced substantial growth in daily regional transit

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trips as transit has become an increasingly integral mode of transportation for the movement of people to and from home, work, school, shopping, and cultural and recreational activities.

This Plan recommends closing critical gaps in the transit system to improve service, and extending routes to serve a greater number of passengers. In addition, the coordination of development in and around transit stations and corridors, improved service reliability and performance, and a highly focused transit capital investment program appear to yield the best results within the budget limitations that the region faces.

Heavy and light rail projects are planned for Los Angeles County, while Orange County focuses on several new bus rapid transit (BRT) corridors. Riverside and San Bernardino Counties are planning a mix of new rail and BRT projects.

Aviation

SCAG's Regional Aviation Decentralization Strategy is very similar to the 2030 decentralized regional aviation system adopted for the 2004 RTP. It respects all legally enforceable policy and physical-capacity constraints at urban airports. It also assumes much more willingness on the part of the airlines to invest in new flights at new and emerging airports, and a package of market and ground access incentives to promote decentralization at underutilized suburban airports.

Airport Ground Access

The Regional Aviation Decentralization Strategy calls for making substantial airport ground access improvements throughout the region, in both the short term and long term.

The short-term program emphasizes relieving immediate bottlenecks around airports through arterial, intersection and interchange improvements, and increasing transit access to airports. To this end, SCAG is working with Los Angeles World Airports (LAWA) on planning and programming a regional system of FlyAways, based on the very successful Van Nuys FlyAway, where passengers park their cars and take a bus to LAX. The locations of the proposed new FlyAways can be optimized by taking advantage of the region's developing HOV and light and heavy rail networks that can provide direct linkages to Ontario and Palmdale as well as LAX. Making seamless HOV and rail connections with enhanced service to those and other suburban airports will also compose SCAG's short- and medium-range airport ground access strategy. The FlyAway, HOV and rail improvements to the suburban airports will help establish a pattern of decentralization, by attracting a critical mass of passengers and airline service at those emerging airports.

In the long run, however, the region will need a high-speed rail system, discussed below, to reach our adopted air passenger and air cargo forecasts. The high speed, reliability, and predictability of high-speed airport access will be needed to overcome the increasing unpredictable traffic congestion. For example, the Initial Operating Segment (IOS) of SCAG's proposed High-Speed Regional Transport (HSRT) system from West Los Angeles to Ontario will take only 33 minutes to travel from end to end. Therefore, the regional high-speed rail system is an integral component of the 2008 RTP Preferred 2035 regional aviation demand forecast.

High-Speed Regional Transport (HSRT)

SCAG has advanced a vision of regional transport based on high-performance, high-speed, and environmentally sensitive alternatives. An HSRT system has the potential for relieving both airport and freeway congestion in urbanized areas by providing an alternative to the automobile as well as making less-congested airports more accessible to air travelers, and providing alternative capacity for freight movement in the region.

The HSRT system is a long-term vision connecting the region's ports, airports, and urban activity centers. The system can be constructed in multiple stages that can each be financially viable. The financial performance will be enhanced as the system is extended throughout the region and the volume of users increases. The HSRT plan is constructed on three core components: a goods movement/logistics component to connect the San Pedro Bay Ports

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with an inland port facility via the high-speed, high-capacity link; an aviation system component to create a direct and reliable link capable of connecting airports and urban centers; and a surface transport system component to link urban activity centers throughout the region.

Another high-speed regional transport project being studied is a magnetically levitated train between Las Vegas and Anaheim by the California-Nevada Super Speed Train Commission (CNSSTC) that would include a critical Anaheim-Ontario segment, which would further the airport decentralization strategy for the region. Also, the California High-Speed Rail Authority (CHSRA) is charged with planning, designing, constructing, and operating a high-speed steel wheels on steel rails train system that would connect Northern and Southern California. This system contains 210 miles planned in the SCAG Region, including a 30-mile segment between Orange County and LA Union Station.

Goods Movement Strategies

To enable the region to handle the dramatic growth in the goods movement sector, the Plan calls for approximately $13 billion in freight rail investments, nearly $18 billion in a freight HSRT system, and over $5 billion in highway investments. These investments integrate air quality mitigation into the goods movement system improvements, yielding substantial air quality benefits and reducing its current and long-term impacts on public health and the environment.

Dedicated Lanes for Clean-Technology Trucks

Over the past several RTP updates, the region has been exploring dedicated truck-lane facilities and continues to refine the concept of such user-supported corridors to improve the flow of goods. More recent effort has focused on adding dedicated truck lanes for clean-technology vehicles along truck-intensive corridors in Southern California. Operationally, such a corridor would be aligned to connect freight-intensive locations such as the Ports, warehousing/distribution center locations, and manufacturing locations. These dedicated facilities would have fewer entrance/egress locations than typical urban interstates to smooth the flow of goods.

This proposal has the potential to relieve many of the negative truck impacts in Southern California such as recurrent delay, pavement deterioration, safety, emissions, and design deficiencies. Dedicated truck lanes would also increase reliability in the freeway system. Despite these benefits, substantial financial constraints as well as environmental impact considerations could hinder project implementation. Recognizing these challenges, the 2008 RTP funds the I-710 segment as the first phase of a comprehensive system that addresses truck-related issues in the region. This segment includes roughly 78 lane-miles (two lanes in each direction) of dedicated lanes for clean-technology trucks along alignments extending from Ocean Blvd. in Long Beach to the intermodal railroad yards in Commerce/Vernon. This represents an investment of over $5 billion.

The region's longer-term strategic vision would include an east-west corridor and the I-15 freeway, serving strategic distribution centers in Barstow. Major corridor studies have already been completed for I-710, SR-60, and I-15. An Environmental Impact Report/Environmental Impact Statement (EIR/EIS) and preliminary engineering are currently underway for the I-710. The techni-

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cal analysis for the 2008 RTP assumes the implementation of dedicated lanes accommodating clean-technology vehicles along the I-710 corridor until a preferred alternative is identified by the EIR/EIS.

Regional Freight Rail Investment and Emission-Reduction Package

Freight rail investments consist of additional mainline capacity, grade separations, and locomotive engine upgrades. About half of the rail-related investments are for grade crossing separations, which reduce traffic congestion, improve safety, and reduce pollution. Substantial air quality benefits can be realized by accelerating fleet modernization with cleaner technologies.

The UP and BNSF mainlines east of downtown Los Angeles will reach capacity before the end of the decade and will need to be triple-tracked or even quadruple-tracked in some segments. Investments in this Plan include $3.2 billion in mainline rail capacity improvements, $6.0 billion to build an estimated 131 highway-rail grade separations east of downtown Los Angeles, and a total of $3.8 billion for accelerating upgrades to cleaner diesel locomotive engines—namely, Tier 4 engines.

In March of 2007, the US Environmental Protection Agency (EPA) proposed new standards to reduce emissions from diesel locomotives: Tier 3 and Tier 4 exhaust emission standards for newly built engines with high-efficiency catalytic after-treatment technology. Tier 3 engines will be available in 2009 and the associated estimated reduction in emissions is to less than 50 percent of current conditions. The reduction in emissions from Tier 4 engines is estimated at 90 percent of current conditions. This Plan assumes nearly $2 billion in federal EPA funding to subsidize the deployment of Tier 4 engines in the region.

Alternative Technology–Based Goods Movement/Logistics

The region is also exploring new alternative technology–based systems that can provide greater throughput and reliability with near zero emissions (the emissions would be only those associated with electricity generation). A recent analysis carried out by the IBI Group considered the application of an HSRT system for the movement of containers (logistics and systems technology) to

and from the San Pedro Bay Ports. This container movement system would provide a high-capacity, fast, and efficient method of moving containerized cargo from the Ports to an inland port facility in San Bernardino. The system capitalizes on the inherent savings of multiple uses on a single infrastructure by operating on shared alignments with the HSRT passenger system. The technology permits operation of HSRT freight vehicles on a shared guideway with passenger vehicles even during peak hour service. Freight vehicle trips can be interspersed with passenger trips while still meeting required passenger vehicle headways. Additionally, full utilization of the freight line can be achieved during the passenger system's off-peak hours. The deployment of the HSRT system would create value in associated components which could in turn contribute to the HSRT's total financial performance.

The connection for the HSRT system would begin at the Ports and join up with the IOS[4] at a point just east of the Los Angeles Union Passenger Terminal (LAUPT). This alignment runs north-south and is assumed to follow a route parallel to the I-710/Alameda Corridor. After connecting to the IOS and other segments, the freight-only service would be interspersed with passenger service.

[4] The Initial Operating Segment (IOS) is discussed in further detail in the supplemental HSRT Report and Appendices.

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TABLE 2 SUMMARY OF SYSTEM COMPLETION AND EXPANSION PROJECT TYPES

Project Type	Cost
Highway Improvements	**$77.2 billion**
Mixed Flow Lanes and Interchanges/Ramps	$26.2 billion
HOV	$8.3 billion
Toll Lanes	$25.6 billion
Arterial	$17.1 billion
Transit Improvements	**$44.0 billion**
Commuter Rail	$6.2 billion
Heavy Rail	$5.7 billion
Light Rail	$1.7 billion
Bus Rapid Transit	$0.9 billion
Bus	$21.3 billion
Other Transit	$8.2 billion
High-Speed Regional Transport	**$29.1 billion**
Goods Movement Strategies	**$36.4 billion**
Mainline Rail Capacity Improvements	$3.2 billion
Highway-Rail Grade Separations	$6.0 billion
Upgrade to Tier 4 Engines	$3.8 billion
Alternative Technology–Based Goods Movement System	$17.9 billion
Dedicated Lanes for Clean-Technology Trucks	$5.1 billion
Truck Climbing Lanes	$0.4 billion
Total	**$186.7 billion**

Figures reflect investments above current commitments in the Regional Transportation Improvement Program (RTIP).

MITIGATING ENVIRONMENTAL IMPACTS

California law requires SCAG to prepare and certify a Program Environmental Impact Report (PEIR) prior to adopting the RTP. The PEIR evaluates the environmental impacts of the RTP and proposes specific measures to mitigate impacts to the maximum extent feasible. Although this RTP, in and of itself, is a plan to mitigate the transportation-related effects of population growth, such as traffic congestion and poor air quality, because the transportation improvements can result in additional growth, the PEIR goes further by recommending additional environmental mitigation at the program level for those resource areas that would be affected by the Plan (and associated growth) such as land use, open space, biological resources, water and energy. The section below summarizes the mitigation program. A list of all the mitigation measures included in the 2008 RTP PEIR will be included in the Environmental Mitigation Report of the Final 2008 RTP.

The general purpose of the mitigation measures included in the PEIR and summarized below is to identify how to protect the environment, improve air quality, and promote energy efficiency in concert with the proposed transportation improvements and related planning. They provide a framework through which implementing agencies and subregions can address the environmental impacts of RTP projects, while implementing RTP goals and policies. The PEIR provides three different types of mitigation measures. The first type can be implemented by SCAG at the regional level. These measures are generally aimed at gathering additional information that can assist in measuring impacts and determining appropriate mitigation and promoting policies that reduce impacts. The second type of measures are to be implemented at the local level by implementing agencies, and individual cities and counties. These measures can strengthen planning documents to ensure for provision of mitigation in the planning process. The third type of measures are project specific and seek to reduce impacts for the myriad different types of projects anticipated in the region. As a programmatic document, many of the measures in the PEIR refer to performance standards because site-specific conditions are not reasonably evaluated at the programmatic level.

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SUMMARY OF THE ENVIRONMENTAL MITIGATION PROGRAM

This Plan discusses mitigation for the following areas:

- Open Space
- Energy
- Air Quality and Climate Change
- Transportation
- Population and Housing
- Land Use
- Aesthetics
- Public Services
- Biological Resources
- Geology, Soils, and Seismicity
- Cultural Resources
- Water Resources
- Hazardous Materials
- Safety and Security
- Noise

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Financial Plan

The 2008 RTP financial plan identifies how much money is available to support the region's surface transportation investments including transit, highways, local road improvements, system preservation and demand management goals. It also addresses the need for investment in goods movement infrastructure. Improving ground access in and around major goods movement facilities, and enhancing major highways and railways are critical to maintaining the health of Southern California's economy. The 2008 RTP calls for traditional and non-traditional revenue sources for implementing a program of infrastructure and environmental improvements to keep both freight and people moving.

The 2008 RTP financial plan identifies a number of new revenue sources to provide additional funding beyond existing transportation dollars. The SCAG Region's financially constrained plan includes a core revenue forecast of existing local, state, and federal sources along with new funding sources that are reasonably available over the time horizon of the RTP. The plan also includes action steps to obtain the revenues necessary for implementing the region's transportation vision.

In developing the financial plan, SCAG followed a few basic principles to guide its regional financial forecast:

- Incorporate financial planning documents developed by local county transportation commissions and transit operators in the region where available;
- Ensure consistency with both local and state planning documents;
- Utilize published data sources to evaluate historical trends and augment local forecasts as needed; and
- Recommend new funding sources that target beneficiaries of transportation investments.

REASONABLY AVAILABLE REVENUES

There are several new funding sources that are reasonably expected to be available. These sources will increase the revenues available for the 2008 RTP. The region also expects to leverage innovative financing strategies.

Table 3 presents twelve categories of funding sources and financing techniques that were evaluated for the RTP. They were selected as a result of their use in other areas of the state, the burgeoning potential, historical precedence and likelihood of implementation within the time frame of the 2008 RTP. These funding sources are considered to be reasonably available and are included in the financially constrained plan. For each funding source, SCAG has examined the policy and legal context of implementation and has prepared an estimate of the revenue potential.

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TABLE 3 NEW REVENUE SOURCES AND INNOVATIVE FINANCING STRATEGIES (IN NOMINAL DOLLARS, BILLIONS)

Revenue Source	Description	Amount	Actions to Ensure Availability	Responsible Party
Value Capture Strategies	Various techniques assumed: formation of special districts, including Benefit Assessment Districts, Mello-Roos Community Facility Districts, as well as tax increment financing and joint development to provide gap financing for specific transit investments (Gold Line extension, Purple Line extension, and the HSRT system). SCAG also assumes one-time proceeds from the sale of Caltrans-owned property within the SR-710 tunnel vicinity.	$3.7	Pursue necessary approvals for special districts by 2012 (Benefit Assessment Districts require majority approval by property owners; Mello-Roos tax requires two-thirds approval); work with private entities for joint development opportunities; also, work with Caltrans to utilize proceeds from real estate sales to partially fill funding gap for the SR-710 tunnel; pursue legislation to enable sales and to establish escrow account for the proceeds	MPO, transit operators, local jurisdictions, property owners along project corridors, developers, Caltrans
Local Option Sales Tax Extension	Half-cent sales tax measure extension for Imperial County—existing Measure D expires in 2010	$0.8	Local sales tax measure to be placed on ballot by 2010	Imperial County
Highway Tolls (includes toll revenue bond proceeds)	Toll revenues generated from SR-710 tunnel, I-710 dedicated truck lanes, High Desert Corridor, and CETAP Corridor	$22.0	Region was granted authority under AB 1467 (2006) to impose tolls and work with private entities for the financing of goods movement-related facilities including the I-710 dedicated truck lanes; additional state legislative approval needed for SR-710 tunnel	MPO, local county transportation commissions (LACMTA, SANBAG, RCTC), State Legislature
State and Federal Gas Excise Tax Adjustment to Maintain Historical Purchasing Power	Estimate equivalent to additional ten cent per gallon gasoline tax imposed by the state and federal government starting in 2012—extrapolation of historical trend	$17.0	Congressional and state legislative approval	MPO, State Legislature, Congress
Container Fees (includes container fee bond proceeds)	Charge imposed on containerized cargo moving through the Ports of LA/LB (includes railroad user fees for rail capacity improvement program); fees are directly linked to specific goods movement projects	$41.5	Negotiated by Ports, shipping community, regional stakeholders or state legislative approval (upon passage of SB 974 or other legislative effort)	Ports, shippers, goods movement stakeholders (MPO, railroads, local county transportation commissions), State Legislature
Private Equity Participation	Public-Private Partnership arrangement whereby a private entity designs, finances, builds, operates, and maintains a facility under a lease arrangement for a fixed period of time	$4.4	Region was granted authority under AB 1467 (2006) to work with private entities for the financing of freight-related projects; additional state legislative approval needed for SR-710 tunnel	MPO, local county transportation commissions, private consortium, State Legislature

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Revenue Source	Description	Amount	Actions to Ensure Availability	Responsible Party
Private Activity Bonds (PAB)	Interest savings from the issuance of tax-exempt private activity bonds	$0.4 (included in container fees)	Work with railroads and other regional stakeholders to receive federal PAB allocation	MPO, freight railroads, local county transportation commissions, US DOT
U.S. Environmental Protection Agency (EPA) funding for clean freight rail technology	EPA subsidies to help mitigate locomotive emissions per the 2007 State Implementation Plan (SIP)	$1.9	Work with railroads, AQMD, ARB and US EPA for federal clean technology funding allocation	MPO, freight railroads, AQMD, ARB, US EPA
Interest Earnings	Interest earnings from toll bond proceeds (High Desert Corridor, CETAP, SR-710 tunnel, and I-710 truck lanes)	$0.4	See Highway Tolls	See Highway Tolls
Riverside County Measure A (Bond Anticipation Notes)	Short-term debt to help fund the CETAP Corridor in anticipation of the sale of Measure A revenue bonds	$1.5	Issuance of debt subject to RCTC Board policy	RCTC
Transportation Infrastructure Finance and Innovation Act (TIFIA) Loan	The TIFIA Loan program provides credit assistance for transportation investments of national/regional significance; TIFIA loan assumed for the CETAP Corridor	$0.9	Work with USDOT and RCTC to evaluate applicability of the TIFIA loan program for the CETAP Corridor; further feasibility work necessary to assess traffic and revenue potential on CETAP Corridor	MPO, RCTC, USDOT TIFIA Office
HSRT Passenger System (Private Contribution & User Fee)	User-fee supported initiative for HSRT system. Assumes private-sector development: design, finance, build, operate and maintain. See HSRT Report for further details	$26.2	For the IOS: form JPA, finalize development of a comprehensive business plan; work with private entity to ensure commitment	MPO, Private Consortium, local/regional stakeholders

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SUMMARY OF REVENUE SOURCES AND EXPENDITURES

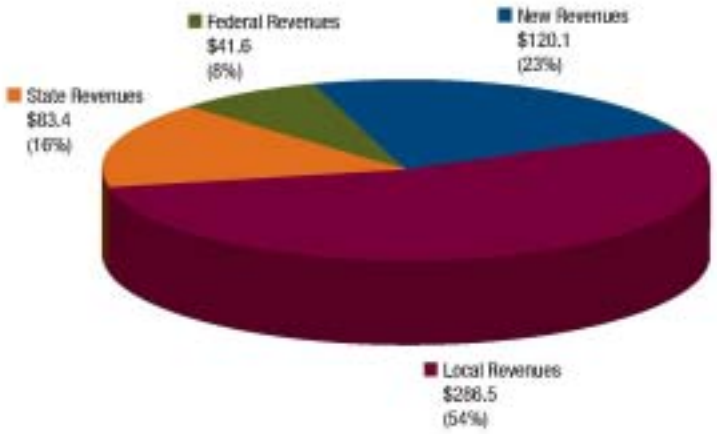
The SCAG Region's financially constrained RTP includes revenues from both the core and reasonably available revenue sources. A summary of these forecasted revenues and expenditures is presented in Figures 3 and 4. As shown in these figures, the SCAG Region's budget over the next 30 years totals an estimated $531.5 billion.

As shown in Figure 2, transit and highway expenditures are roughly comparable at 41 and 36 percent, respectively, of the RTP costs for each category. About 12 percent of costs are attributable to an "other" category, reflecting proposed investments in HSRT systems as well as freight rail capacity and grade separation improvements. Consistent with historical practice, agencies in the region are expected to bond against future revenues to provide additional funding in the early years of the plan. As a result, debt service equal to historical payments and future bonding needs has been included as part of the RTP. Anticipated debt service payments make up 11 percent of total costs.

FIGURE 2 REVENUES COMPARED TO COSTS BY MODE

Note: Numbers may not add due to rounding

FIGURE 3 2008 RTP REVENUE SOURCES
$531.5 BILLION (IN NOMINAL DOLLARS) FY2007–FY2036



Note: Numbers may not add due to rounding

FIGURE 4 2008 RTP EXPENDITURE SUMMARY
$531.5 BILLION (IN NOMINAL DOLLARS) FY2007–2036

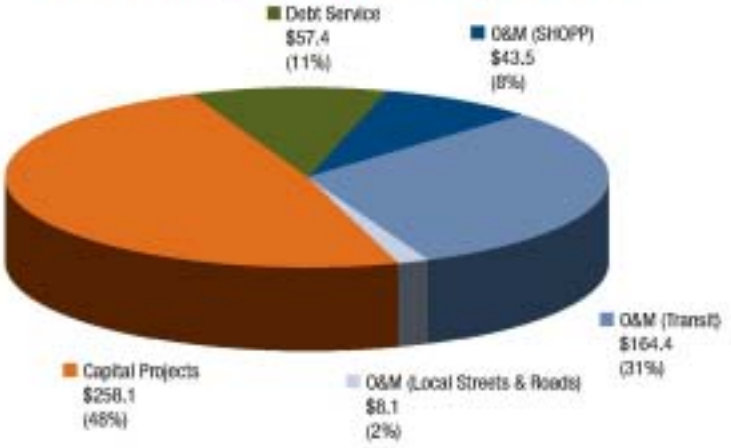


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TABLE 4 PERFORMANCE MEASURES

Performance Measure	Measure(s)	Definition	Performance Target	Performance Outcome Summary
Mobility	Speed Delay	Speed – experienced by travelers regardless of mode Delay – excess travel time resulting from the difference between a reference speed and actual speed Delay per capita can be used as a supplemental measure to account for population growth impacts on delay.	Improvement over Base Year	Between the Baseline and Plan scenarios: • Speed increases by 8 percent • Total daily person delay decreases by 16 percent • Daily delay per capita decreases by 16 percent
Accessibility	Percent PM peak period work trips within 45 minutes of home Distribution of work trip travel times		Improvement over Base Year	Between the Base Year and Plan scenarios: • Accessibility increases by 2 percent
Reliability	Percent variation in travel time	Day-to-day change in travel times experienced by travelers. Variability results from accidents, weather, road closures, system problems and other non-recurrent conditions.	Improvement over Base Year	Between the Base Year and Plan scenarios: • Percent variation decreases in both the AM and PM peak periods by approximately 10 percent
Productivity	Percent capacity utilized during peak conditions	Transportation infrastructure capacity and services provided. Roadway Capacity – vehicles per hour per lane by type of facility Transit Capacity – seating capacity by mode	Improvement over Base Year	Between the Base Year and Plan scenarios: • Lost lane-miles decreases in both the AM and PM peak periods by 20 percent
Safety	Accident rates	Measured in accidents per million vehicle-miles by mode for: • Fatalities • Injuries • Property	"0" for all accident types and modes	Between the Base Year and Plan scenarios: • Fatalities, injuries, and property damage per million persons decrease by at least 4 percent
Sustainability	Total cost per capita to sustain system performance at Base Year levels	Focus is on overall performance, including infrastructure condition. Preservation measure is a subset of sustainability.	Improvement over Base Year	Between the Base Year and Plan scenarios: • Reliability, productivity, safety, and preservation improve
Preservation	Maintenance cost per capita to preserve system at Base Year conditions	Focus is on infrastructure condition. Subset of sustainability.	Improvement over Base Year	Between the Base Year and Plan scenarios: • Percent of lane-miles requiring rehabilitation decreases by 14 percent • Percent of bridges requiring rehabilitation decreases by 45 percent
Cost-Effectiveness	Benefit-to-Cost (B/C) Ratio	Ratio of benefits of travel alternatives to the costs of travel including infrastructure, maintenance, travel time, environmental, accident, and vehicle operating costs. This can be used to evaluate impacts of mode split changes resulting from RTP investments.	Improvement over Base Year	The Plan provides $2.21 return for every $1.00 invested.
Environmental	Emissions generated by travel	Measured/forecast emissions include CO, NOX, PM2.5, PM10, SOX, and VOC. CO2 as secondary measure to reflect greenhouse gas emissions.	Meet SIP Emission Budgets & Transportation Conformity requirements	The conformity analysis indicates a positive conformity finding for the Draft Plan based on the draft emission budgets received by the Air Resources Board and the other required tests. The formal conformity finding will be based on the finalized emission budgets analyzed in comparison to the RTP as prepared for adoption.
Environmental Justice	Distribution of benefits and costs Accessibility Environmental Emissions Noise	Share of net benefits and costs by mode, household income, race/ethnicity: • RTP expenditures • Taxes paid (e.g., income, sales & use, gas) • Access to jobs (see "Accessibility") • Travel time savings by mode • Environmental impacts from PEIR	Equitable distribution of benefits and costs	The Plan results in no disproportionate negative impacts on the grounds of income, race, color, or national origin.

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Plan Performance

This Plan follows the success of recent RTPs in the use of the following system performance measures to demonstrate the effectiveness of this Plan:

- Mobility
- Accessibility
- Reliability
- Productivity
- Safety
- Sustainability
- Preservation
- Cost-Effectiveness
- Environment
- Environmental Justice

Using quantifiable performance measures, three scenarios are compared to determine the performance of the Plan:

- Base Year 2003 scenario—Existing conditions based on the transportation network as of 2003
- Baseline 2035 scenario—Future conditions in 2035 based on the existing transportation system and near-term constrained projects
- Plan 2035 scenario—Future conditions in 2035 based on the existing transportation system, near-term constrained projects, and long-term constrained projects

In every category, the Plan 2035 scenario shows improvement over the Baseline 2035 scenario (Table 4).

TRANSPORTATION CONFORMITY ANALYSIS

Transportation conformity is required under the federal Clean Air Act (CAA) to ensure that federally supported highway and transit project activities are consistent with ("conform to") the purpose of the SIP.[5] Conformity to the purpose of the SIP means that transportation activities will not cause new air quality violations, worsen existing violations, or delay timely attainment of the relevant NAAQS. Conformity applies to areas that are designated non-attainment, and those redesignated to attainment after 1990 ("maintenance areas") for the following transportation-related criteria pollutants: ozone, particulate matter (PM2.5 and PM10), carbon monoxide (CO), and nitrogen dioxide (NO2).

This Plan must pass the following tests and analyses to meet the requirements for a positive conformity finding:

- Regional Emission Analysis
- Timely Implementation of Transportation Control Measures (TCMs) Analysis
- Financial Constraint Analysis
- Interagency Consultation and Public Involvement Analysis

Due to recent litigation relative to U.S EPA's Eight-Hour Ozone Phase 2 Rule, EPA has instructed ARB to revise the established method of demonstrating Reasonable Further Progress (RFP) in ozone non-attainment areas that utilize reductions from other areas to demonstrate attainment (e.g., upwind areas). In the SCAG Region, such areas include the Ventura County portion of the South Central Coast Air Basin (SCCAB), the Western Mojave Desert Air Basin (MDAB) (Antelope Valley and a portion of San Bernardino County), and the Coachella Valley portion of the Salton Sea Air Basin (SSAB). Therefore, at this time, there are no AQMPs or SIPs and, thus, no 8-hour ozone transportation

[5] To comply with the CAA in achieving the NAAQS, the ARB develops SIPs for federal non-attainment and maintenance areas. In California, SIP development is a joint effort of the local air agencies and ARB working with federal, state, and local agencies (including the MPOs). Local Air Quality Management Plans (AQMPs) are prepared in response to federal and state requirements.

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emission budgets for these areas. SCAG has worked closely with the ARB and EPA to resolve this issue. As agreed upon by ARB and EPA, ARB has adopted Early Progress Plans (i.e., emissions inventories and transportation emission budgets) for areas that need upwind reductions to show RFP. The Early Progress Plans establish the transportation emission budgets while EPA decides how to respond to the RFP issue raised by the litigation. EPA found these emission budgets adequate in April 2008.

In addition, EPA's review of the South Coast ozone and PM2.5 emission budgets raised concerns such that the ARB was required to revise and resubmit the emission budgets to EPA. This requirement dictated that SCAG make appropriate revisions to the conformity analysis to reflect the new emission budgets and re-release the Draft Conformity Report. SCAG staff worked closely with the federal reviewing agencies regarding the emission budget adequacy and conformity approval review process timeline. From these efforts, all agencies confirmed they will expedite their respective reviews to allow for approval of SCAG's conformity finding before the current (2004) RTP conformity finding expires on June 7, 2008.

The conformity analysis indicates a positive conformity finding for the 2008 RTP. The detailed transportation conformity analyses for the 2008 RTP are included in the 2008 RTP Conformity Report.

ENVIRONMENTAL JUSTICE

As a government agency that receives federal funding, SCAG is responsible for implementing Title VI of the Civil Rights Act of 1964 and for conforming to federal Environmental Justice (EJ) principles, policies, and regulations. As part of meeting these requirements, SCAG has performed an EJ analysis to demonstrate responsiveness to potential imbalances caused by the development of the plans, programs, and policies in the 2008 RTP.

SCAG's EJ analysis examined performance measures to determine any disproportionate negative impacts. Performance measures provide a way to quantitatively assess the impact of the Plan. In the development of the Plan, SCAG utilized a number of performance measures designed to assess the overall equity. An overview of the findings is listed below:

- Accessibility to Employment: The results indicate that low-income and minority communities in the region will have higher levels of access to employment via local bus and rail with the 2008 RTP. The results indicate that on a regional scale, no disproportionate impacts are anticipated between income groups as a result of the Plan.
- Accessibility to Parks: All income groups for the whole region will have greater park accessibility due to the infrastructure investments proposed in the 2008 RTP. However, a multi-agency effort must be undertaken in order to further address and remedy the issue of inequity of park access.
- Distribution of Plan Expenditures (Investments): SCAG analyzed the distribution of Plan expenditures based on mode usage information by income quintile. Under the Plan, approximately 28 percent of investments will go to modes predominantly used by the lowest quintile group, while 16 percent will be invested in modes most likely to be used by the highest income category (Quintile V). The current analysis also reveals that under the 2008 RTP, Plan investments will be distributed more equitably on the basis of system usage by ethnic/racial groups. In other words, transportation investments would go to modes likeliest to be used by low-income and minority households.
- Taxes Paid: Overall, tax burdens are anticipated to fall heavily on higher income groups. The lower-income groups (Quintile I and Quintile II), which use bus and light rail as their primary modes of travel, are anticipated to pay 22 percent of taxes.
- Distribution of Transit Travel Time Savings: The results in the 2008 analysis also reveal that the two lowest-income quintiles will pay just over 20 percent of total taxes collected in the region, but will enjoy 65 percent of the local transit time savings. The two highest-income quintiles' share of taxes (60 percent) will exceed the benefits they receive in local transit time savings (16 percent), accounting for only 9 percent of total bus and light rail usage. The findings indicate that transit travel times for

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lower-income groups for both work and non-work trips are expected to decrease due to the number of new bus and rail improvements proposed in the 2008 RTP.

- Distribution of Auto Travel Time Savings: The amount of taxes paid by those in Quintile V (36 percent) will exceed their share of benefits (27 percent). The lowest-quintile group will benefit the least, accounting for 12 percent of auto usage and 11 percent of auto travel time savings. Higher-income groups are anticipated to have the most benefit in auto travel time savings, but will also incur the highest taxes.
- Auto Travel Distance Reductions: The lowest quintile group is expected to have the least amount of benefits, accounting for 12 percent of auto usage and travel distance savings. They will also pay the least amount of taxes at 9 percent. The taxes paid by the highest-income group (35 percent) are anticipated to exceed their share of benefits (27 percent). Similar to the findings for Auto Travel Time Savings, higher-income groups are anticipated to have the most benefits because their primary mode of travel will be the automobile.
- Air Pollutant Emissions: Overall, the region as a whole will generally experience an improvement in air quality via reductions in transportation-related emissions due to ongoing mobile source emission controls and investments in the Plan. On a regional scale, the analysis did not reveal any disproportionate impact between ethnic/racial categories.
- Noise: The results in the 2008 RTP analysis indicate that low-income and minority groups will be disproportionately impacted by aviation and highway noise.

Future Connections: The Strategic Plan

The strategies in the Constrained Plan represent the region's collective vision for addressing our transportation needs within the constraints of committed, available, or reasonably available revenue sources. The Strategic Plan goes beyond the Constrained Plan, and includes projects that merit further consideration for inclusion in the Constrained Plan in the future as consensus evolves and funding becomes available.

Supplemental Reports (Appendices)

Additional detail on the various topics discussed in this Plan is contained in 18 standalone reports that also act as the appendices for the 2008 RTP. The reports include all backup data that support assumptions made in the development of the Plan, as well as additional information on areas of interest in regards to our regional transportation system.

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I. OVERVIEW

Success in transportation and transportation planning is about making the connections, whether it's connecting from bike to bus or truck to rail relating the travel choices we make with environmental consequences, ensuring that land-use and transportation planning go hand in hand, or more equitably linking our transportation financing mechanisms to those who benefit directly from use of the system. The 2008 RTP connects the SCAG Region to a future vision where innovative solutions address the daunting challenges we face today.

The 2008 RTP presents the transportation vision for this region through the year 2035 and provides a long-term investment framework for addressing the region's transportation and related challenges. The Plan is the culmination of a multi-year effort focusing on maintaining and improving the transportation system through a balanced approach that considers system preservation, system operation and management, improved coordination between land-use decisions and transportation investments, and strategic expansion of the system to accommodate future growth.

The SCAG Region is economically, culturally, and ethnically one of the most diverse metropolitan regions in the world. It has a complex transportation system that includes extensive roadway, transit (bus and rail), and freight rail networks, along with major intermodal, seaport, and airport facilities. Exhibit 1.1 shows the major transportation infrastructure in the SCAG Region. Highlights of our vision for our region and the regional transportation system in 2035, embodied in this document, may be summarized as follows:

- A well-maintained and managed roadway network free of potholes and other roadway hazards
- A transportation system where most of the gaps have been addressed
- A safe, secure, reliable, and equitable public transportation system
- A seamless public transportation system that provides efficient access to jobs, shopping, recreation, education, health care and other activities

- More travel choices in addition to solo driving and public transportation, such as improved access to non-motorized transportation
- More people living closer to job centers and transit corridors and hubs
- Improved air quality for all, and
- A vibrant economy supported by an efficient goods-movement system

The 2008 RTP, built on regional consensus, is flexible and recognizes the unique and complex nature of the region. The 2008 RTP is an update to the 2004 RTP, and it replaces the 2004 RTP in its entirety.

Leadership, Vision, Progress

Leadership, vision and progress are three main components of SCAG's Mission Statement that apply to the Regional Transportation Plan (RTP) development process. In demonstrating a commitment to leadership, the region identified seven goals that reflect a balanced approach to transportation planning and decision-making. In providing a vision, the SCAG Regional Council adopted

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policies to guide the development of the RTP and identified transportation priorities for the region. Lastly and most importantly, in its commitment to demonstrate progress, SCAG continues to rely extensively on performance measurement as a means to identify the most beneficial investments for the region. Together, these elements contribute to a strong and focused RTP.

REGIONAL GOALS

The goals of the 2008 RTP have expanded from 2004 to encompass transportation security. These seven goals are in no particular order and demonstrate the need to balance many priorities in the most cost-effective manner.

TABLE 1.1 RTP GOALS

RTP Goals
• Maximize mobility and accessibility for all people and goods in the region
• Ensure travel safety and reliability for all people and goods in the region
• Preserve and ensure a sustainable regional transportation system
• Maximize the productivity of our transportation system
• Protect the environment, improve air quality and promote energy efficiency
• Encourage land use and growth patterns that complement our transportation investments
• Maximize the security of the regional transportation system through improved system monitoring, rapid recovery planning, and coordination with other security agencies

These priorities are identified in the following:

- The region's vast investments in multimodal transportation infrastructure must be protected. This infrastructure is maturing and requires attention and maintenance. The region cannot afford to replace the existing infrastructure and must protect it for future generations.
- A maturing system dictates an increased operational focus that leverages technology to maximize the system's productivity. This same investment will also increase reliability by minimizing the variations of travel time due to incidents, weather, and other factors. The region cannot expand the transportation system significantly, so the existing system must be utilized to its fullest. The vitality of the region's economy is inextricably linked to efficient and reliable transportation. The region must be able to respond to and recover from major human-caused or natural events in order to minimize the threat and impact to lives, property, the transportation network and the regional economy.
- Air quality for the region's residents must be improved and meet federal regulations. Not doing so would undermine the health of our population and risk losing billions of federal funding to the region.
- The investments in the RTP must address travel safety and modal balance; recognize the importance of providing safe travel choices; meet the needs of the transit dependent and the goods movement community; and provide connections among the highway system, ports, and airports.
- The RTP must also integrate land-use policies as a means to influence transportation performance and the economy. Without such integration, transportation needs in the future will significantly outpace the ability to pay for them.
- The RTP must address all these priorities in the most cost-effective manner so that outcomes/benefits can be maximized and so that users get the most for their expenditures.

RTP GUIDING POLICIES

The SCAG Regional Council (RC) adopted five policies to guide the development of the RTP (Table 1.2). These RTP policies, unchanged since 2004, emphasize the importance of tracking the Plan's performance through specific indicators.

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TABLE 1.2 RTP POLICIES

	RTP Policies
1	Transportation investments shall be based on SCAG's adopted Regional Performance Indicators.
2	Ensuring safety, adequate maintenance, and efficiency of operations on the existing multi-modal transportation system will be RTP priorities and will be balanced against the need for system expansion investments.
3	RTP land-use and growth strategies that differ from currently expected trends will require a collaborative implementation program that identifies required actions and policies by all affected agencies and subregions.
4	HOV gap closures that significantly increase transit and rideshare usage will be supported and encouraged, subject to Policy #1.
5	Progress monitoring on all aspects of the Plan, including timely implementation of projects, programs, and strategies, will be an important and integral component of the Plan.

PERFORMANCE-BASED PLAN

As with previous RTPs, this is an outcome-/performance-based plan. The first RTP policy requires that performance measures play a critical role in the plan development. Performance measures quantify the outcomes that are important to individuals, businesses, and the region. They quantify regional goals and provide a way to evaluate progress over time. This is SCAG's fourth performance-based RTP. Starting in 1998, SCAG was the first Metropolitan Planning Organization (MPO) to rely extensively on performance measurement as a means to identify the most effective investments for the region. The performance indicators for the 2008 RTP represent an evolution that builds on earlier successes and adds specificity and technical depth to the original indicators.

Assessing the degree to which the impacts of the 2008 RTP investments meet the regional goals requires complex technical analysis. Performance measurement is a critical part of this analysis, and is used for estimating the potential impacts of investments. The same measures will be used to monitor progress in meeting the performance expectations of the RTP. This monitoring will allow the region to correct its course over time as lessons are learned and new trends are established. Performance measures are closely tied to the broader goals to ensure that the implementation of this Plan moves us closer to achieving these goals. Table 1.3 depicts the relationship between the RTP goals and performance measures, while Table 1.4 describes the performance measures in greater detail.

TABLE 1.3 RTP GOALS AND RELATED PERFORMANCE MEASURES

RTP Goals	Mobility	Accessibility	Reliability	Productivity	Safety	Sustainability	Preservation	Cost-Effectiveness	Environmental	Environmental Justice
Maximize mobility and accessibility for all people and goods in the region	✓	✓						✓		✓
Ensure travel safety and reliability for all people and goods in the region	✓		✓		✓					
Preserve and ensure a sustainable regional transportation system						✓	✓		✓	✓
Maximize the productivity of our transportation system	✓			✓						
Protect the environment, improve air quality and promote energy efficiency						✓			✓	✓
Encourage land use and growth patterns that complement our transportation investments and improve the cost-effectiveness of expenditures	✓	✓							✓	
Maximize the security of our transportation system through improved system monitoring, rapid recovery planning, and coordination with other security agencies*										

* SCAG does not yet have an agreed-upon security performance measure; therefore, it is not included in this table.

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EXHIBIT 1.1 SCAG REGION

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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TABLE 1.4 PERFORMANCE MEASURES

Performance Measure	Measure(s)	Definition	Performance Target	Calculation Data Sources
Mobility	Speed Delay	Speed – experienced by travelers regardless of mode Delay – excess travel time resulting from the difference between a reference speed and actual speed Delay per capita can be used as a supplemental measure to account for population growth impacts on delay.	Improvement over Base Year	Travel demand model outputs AM peak, PM peak, Off-peak, Daily Link speeds, travel times, trips
Accessibility	Percent PM peak period work trips within 45 minutes of home Distribution of work trip travel times		Improvement over Base Year	Travel demand model outputs • PM peak • OD travel times • OD person trips
Reliability	Percent variation in travel time	Day-to-day change in travel times experienced by travelers. Variability results from accidents, weather, road closures, system problems and other non-recurrent conditions.	Improvement over Base Year	Highways – PeMS Transit – National Transit Database or triennial audit reports
Productivity	Percent capacity utilized during peak conditions	Transportation infrastructure capacity and services provided. Roadway Capacity – vehicles per hour per lane by type of facility Transit Capacity – seating capacity by mode	Improvement over Base Year	Highways – PeMS Transit – National Transit Database or triennial audit reports
Safety	Accident rates	Measured in accidents per million vehicle-miles by mode for: • Fatalities • Injuries • Property	"0" for all accident types and modes	Highways – freeway accident rates from Caltrans Transit – National Transit Database or triennial audit reports
Sustainability	Total cost per capita to sustain system performance at Base Year levels	Focus is on overall performance, including infrastructure condition. Preservation measure is a subset of sustainability.	Improvement over Base Year	Subregional submittals Regional population forecast
Preservation	Maintenance cost per capita to preserve system at Base Year conditions	Focus is on infrastructure condition. Subset of sustainability.	Improvement over Base Year	Subregional submittals Regional population forecast
Cost-Effectiveness	Benefit-to-Cost (B/C) Ratio	Ratio of benefits of travel alternatives to the costs of travel including infrastructure, maintenance, travel time, environmental, accident, and vehicle operating costs. This can be used to evaluate impacts of mode split changes resulting from RTP investments.	Improvement over Base Year	Travel demand model outputs Revenue forecasts RTP project expenditures Other cost estimates
Environmental	Emissions generated by travel	Measured/forecast emissions include CO, NOX, PM2.5, PM10, SOX, and VOC. CO2 as secondary measure to reflect greenhouse gas emissions.	Meet SIP Emission Budgets & Transportation Conformity requirements	Travel demand model outputs EMFAC2007
Environmental Justice	Distribution of benefits and costs Accessibility Environmental Emissions Noise	Share of net benefits and costs by mode, household income, race/ethnicity: • RTP expenditures • Taxes paid (e.g., income, sales & use, gas) • Access to jobs (See "Accessibility") • Travel time savings by mode • Environmental impacts from PEIR	Equitable distribution of benefits and costs	Travel demand model outputs Revenue forecasts RTP project expenditures PEIR

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WHY UPDATE THE RTP?

SCAG is the federally designated MPO for the counties of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura. As the MPO, SCAG develops the RTP and updates it every four years through a continuous, comprehensive and cooperative process. Transportation investments in the SCAG Region that receive state and federal funds or require federal approvals (such as environmental clearance) must be consistent with the RTP and must be included in SCAG's Regional Transportation Improvement Program (RTIP) when ready for funding. As the programming document for funds, the RTIP complements the corresponding years of the RTP. The RTIP is a six-year program and is coordinated with the State Transportation Improvement Program (STIP) every two years. Following are key reasons the RTP should be updated.

REFLECT CURRENT CONDITIONS

As the economy, demographics, finances, and other factors change, SCAG has a responsibility to modify the RTP to reflect the latest information and conditions. Factors that have changed since the 2004 RTP was adopted include:

- New information on population and employment growth
- New or reauthorized transportation funding sources
- 2007 South Coast Air Quality Management Plan (AQMP) and new motor vehicle emission budgets and emission factors
- Rapid increases in construction costs in the past four years, and
- Other shifts in regional priorities determined by SCAG and the county transportation commissions (CTCs)

COMPLY WITH FEDERAL REQUIREMENTS

The Safe, Accountable, Flexible, Efficient Transportation Equity Act – A Legacy for Users (SAFETEA-LU) was signed into law in August 2005, and expands upon previous planning requirements. The federal requirements for metropolitan transportation plans include the following key provisions:

- An open, inclusive process that ensures public input and considers the needs of those traditionally underserved by the existing system
- A plan horizon period of not less than 20 years into the future
- The most recent assumptions for population, travel and congestion, land use, vehicle fleet mix, employment and economic activity
- A financially constrained plan funded by revenues that are committed, available, or reasonably available over the time frame of the RTP
- Conformity to State Implementation Plans (SIPs) for air quality
- A discussion of potential environmental mitigation activities
- Consistency with state and local planned growth and economic development patterns, and
- Consideration of eight planning factors and strategies, in the local context, that address: economic vitality through global competitiveness, productivity and efficiency; safety; security; accessibility and mobility for people and freight; the environment, energy conservation, and the quality of life; integration and connectivity of the multimodal transportation system; efficient system management and operation; and preservation of the existing transportation system

COMPLY WITH STATE REQUIREMENTS

The state, whose requirements largely mirror the federal requirements, has adopted extensive RTP guidelines. Key state requirements include:

- Compliance with the California Environmental Quality Act (CEQA)
- Consistency with the five-year STIP as incorporated into SCAG's six-year RTIP
- Program-level performance measures that include objective criteria that reflect the goals and objectives of the RTP, and
- A policy element (Chapter 1), an action element (Chapter 3) and a financial element (Chapter 4)

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Our Approach

The development of the 2008 RTP is based on a collaborative and bottom-up process involving numerous parties. Each of the six counties in the SCAG Region has a transportation commission or authority, with the exception of Imperial County, where the Imperial Valley Association of Governments (IVAG) serves as the countywide transportation agency. These agencies are charged with implementing countywide transportation planning activities, allocating locally generated transportation revenues and, in some cases, operating transit services.

Additionally, there are 14 subregions within the SCAG Region. These subregional councils of governments (COGs) are groups of neighboring cities and communities (sometimes an entire county) that work together to identify, prioritize and seek transportation funding for needed investments in their respective areas.

The SCAG Region also includes all or part of thirteen air quality non-attainment or maintenance areas in five air basins. Federal law requires that transportation and air quality planning are coordinated in these non-attainment and maintenance areas. The SCAG Region further includes all of Caltrans Districts 7, 8 and 12, and the Imperial County portion of District 11. SCAG develops the RTP primarily in coordination and consultation with the county transportation commissions (CTCs), COGs, transit operators, Caltrans, air districts and other transportation stakeholders. Key stakeholders involved in the development and update of the RTP are identified in Table 1.5.

TABLE 1.5 STAKEHOLDERS IN THE DEVELOPMENT OF THE 2008 RTP

County Transportation Commissions/Agencies
Imperial
Los Angeles
Orange
Riverside
San Bernardino
Ventura
Subregional Councils of Governments (COGs)
Arroyo Verdugo Cities
Coachella Valley Association of Governments
Gateway Cities COG
Imperial Valley Association of Governments
Las Virgenes-Malibu-Conejo COG
City of Los Angeles
North Los Angeles County
Orange County COG
San Bernardino Associated Governments
San Gabriel Valley COG
South Bay Cities COG
Ventura County COG
Western Riverside County COG
Westside Cities COG
Local and County Governments
Other Operators and Implementing Agencies
California Department of Transportation (Caltrans)
Airport Authorities
Port Authorities
Transit/Rail Operators
Transportation Corridor Agencies
Resource/Regulating Agencies
US Department of Transportation - FHWA, FTA, FAA, FRA
US Environmental Protection Agency (EPA)
CA Air Resources Board
CA Environmental Protection Agency (Cal/EPA)
Air Districts
Tribal Governments (See Exhibit 1.2)

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EXHIBIT 1.2 FEDERALLY RECOGNIZED TRIBAL GOVERNMENTS IN THE SCAG REGION

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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TECHNICAL APPROACH

The technical approach to the RTP update is depicted in Figure 1.1. The first step in the process, which was initiated over three years ago, starts with the review and update of the basic assumptions in the existing RTP, including the goals and objectives. It is important to validate the basic planning assumptions and to ensure that the goals and objectives still speak to the region's needs, challenges, and aspirations.

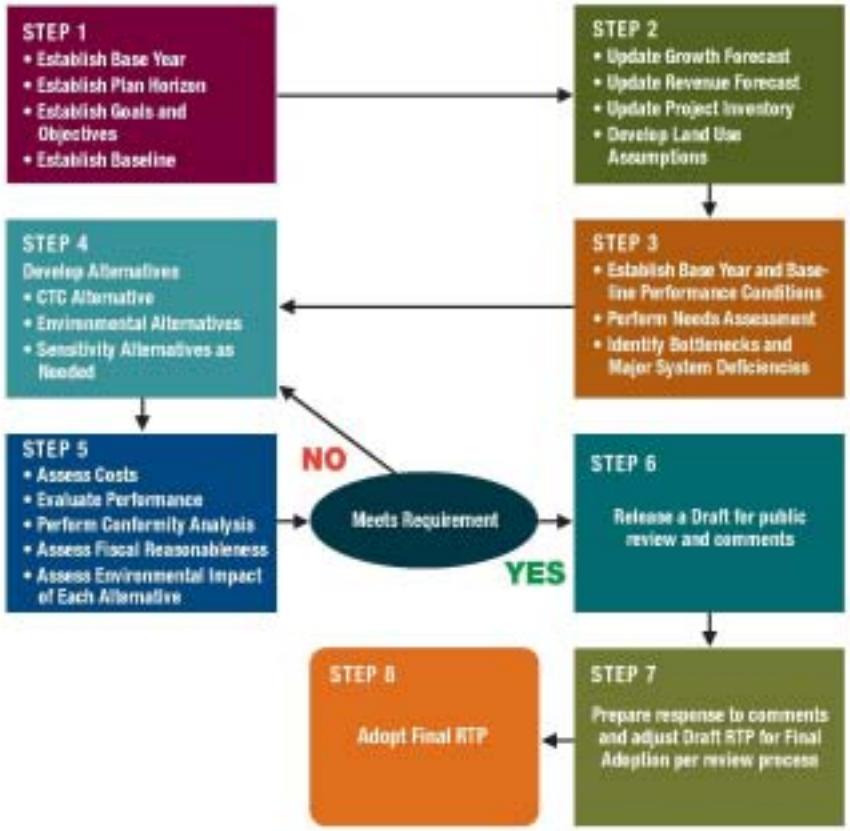
The second step is to ensure that all the data, including growth forecast, revenue forecast, cost information, project scope changes, etc., are updated. It is critical to involve key project sponsors, such as the CTCs, local jurisdictions, Caltrans, and transit operators during this step. Updating and validating the technical data and building the necessary consensus to move forward is a lengthy process.

The third step in the RTP development process involves taking the updated data and reassessing system deficiencies, bottlenecks, and chokepoints in the system to identify system improvement needs.

The fourth step targets improvements and strategies, including growth strategies, in developing alternative scenarios to be considered and tested against performance standards for potential inclusion in the updated Plan. Evaluation of the alternatives is based on a set of performance measures established through a consensus process. Additionally, fiscal reasonableness, transportation conformity and programmatic environmental impacts of the alternatives are also assessed. The best-performing alternative is forwarded as the preferred alternative recommendation to SCAG's policy board if it meets all of the requirements. If it fails to meet any of the requirements, the alternatives are adjusted and reevaluated until a preferred alternative meets all the requirements.

A Draft RTP that documents the preferred alternative as the Plan is then released for public review and comments for a minimum of 45 days. Finally, all comments received and appropriate staff responses are documented prior to finalizing the Plan. The Draft Plan is adjusted if and as needed to address the comments and issues raised during this period before recommending its final adoption as the new RTP for the region.

FIGURE 1.1 RTP UPDATE/DEVELOPMENT PROCESS



PUBLIC PARTICIPATION

A key component of the RTP development process is seeking public participation. Public input helps SCAG prioritize and address transportation needs in

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the region. SCAG seeks participation and comment on the RTP from an array of stakeholders, listed in Table 1.6. The RTP is developed in consultation with all interested parties, and SCAG ensures that they have a reasonable opportunity to comment on the contents of the RTP.

TABLE 1.6 NON-GOVERNMENTAL GROUPS FROM WHICH SCAG SEEKS PARTICIPATION AND INPUT

Participatory Non-Governmental Groups
• Citizens
• Public transit users
• Pedestrians
• Users of bicycle transportation facilities
• Transportation agency employees
• Freight shippers
• Providers of freight transportation services
• Private providers of transportation
• Representatives of the disabled
• Nonprofit organizations
• Ethnic and minority groups
• Older and retired persons
• Special-interest nonprofit agencies
• Environmental groups
• Educational institutions
• Women's organizations
• Private sector

To ensure compliance with federal and state requirements, SCAG implements a public involvement process to provide complete information, timely public notice and full public access to key decisions, and to support early and continuing public involvement in developing its regional plans. Since its inception, SCAG has engaged in a public involvement process in developing its regional transportation plans and programs. As a result of changes in SAFETEA-LU in 2005, SCAG has broadened its current participation activities to engage a more extensive group of stakeholders in its planning and programming processes, as reflected in SCAG's Public Participation Plan adopted by the Regional Council in March 2007 and subsequently amended in October 2007. SCAG consulted with a range of interested parties as required by SAFETEA-LU in developing the public participation strategies, procedures and techniques noted herein. SCAG solicited comments and feedback from a diverse number of stakeholders through mailings, email correspondences, workshops, presentations, meetings, telephone communications and website postings.

By using the feedback and comments received on SCAG's Public Participation Plan, SCAG has implemented the following techniques and strategies for RTP outreach:

- Development of an Integrated Inter-Departmental Outreach Team that encourages innovative outreach efforts and is comprised of staff from various divisions, including Communications, Member Relations, and Transportation Planning
- Development of presentation materials for the public in a variety of formats to reach broader audiences: translated materials into languages other than English; developed interactive PowerPoint presentations, fact sheets, surveys, brochures, and maps
- Enhancement of website capabilities that allows SCAG to post all RTP-related information on its website to ensure that it is accessible and transparent to the public. The website is compliant with the 1990 Americans with Disabilities Act.
- Coordination of outreach efforts with other stakeholder organizations to maximize outreach opportunities

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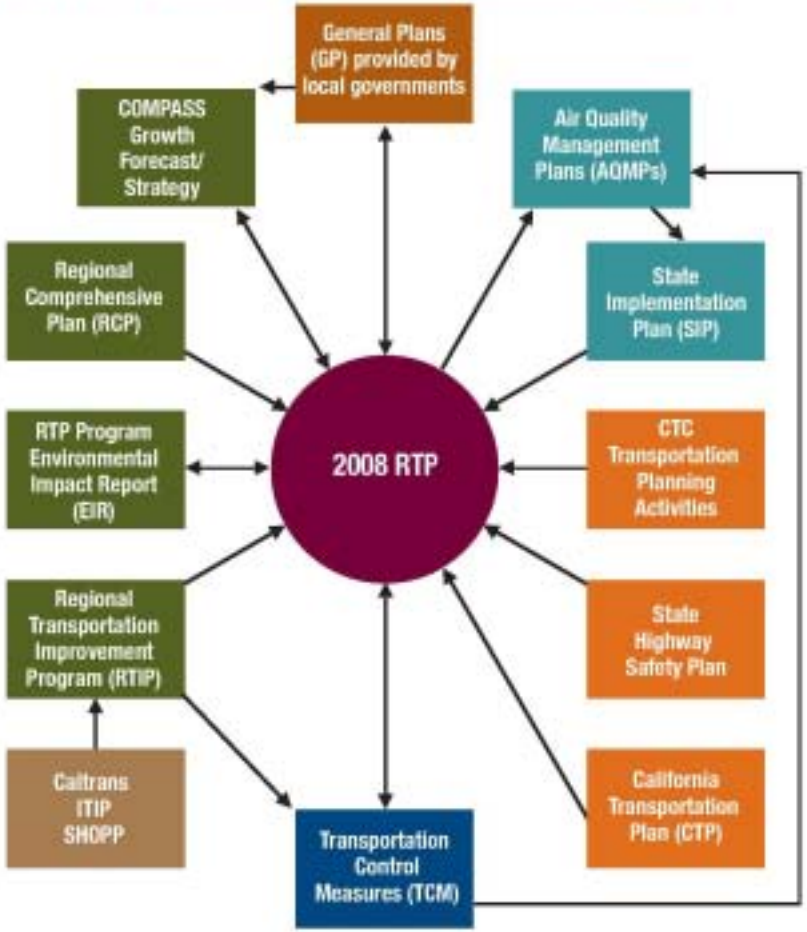
- Development of an outreach schedule that notifies all individuals and groups of activities where SCAG will be presenting the RTP and encourages attendance
- Supporting multiple committees and task forces involving our partners, stakeholders, and interested groups that developed the key components of the Plan
- Holding multiple public workshops before the release of the RTP to allow direct participation by interested parties
- Reaching out to traditionally underrepresented and/or underserved audiences
- Considering comments received in the deliberations regarding proposed plans and programs
- Evaluation of public participation activities to continually improve the outreach process

RTP outreach consists of three phases: Pre-Draft (February 2007 to November 2007), Post-Draft (December 2007 to February/March 2008), and Post-RTP adoption (March/April 2008 to July 2008). SCAG has developed an RTP hotline and email address exclusively for RTP inquiries at 213-236-1960 and RTPinfo@scag.ca.gov.

In addition to these targeted outreach efforts, all regular and special meetings of the RTP task forces, the Transportation and Communications Committee (TCC) and the SCAG RC are publicly noticed and opportunities for public comment are provided. There are currently seven RTP task forces and key transportation subcommittees: Goods Movement, Transportation Finance, High-Speed Regional Transport, Aviation, Plans & Programs Technical Advisory Committee (TAC), Regional Transit Technical Advisory Committee, and the Compass Blueprint Partnership. Also, federally required interagency consultation is done through the monthly meetings of the Transportation Conformity Working Group (TCWG). Specific public comments on the RTP are being recorded and considered by SCAG in the development of the 2008 RTP.

RELATING OTHER PLANS AND PLANNING ACTIVITIES TO THE RTP

FIGURE 1.2 RELATIONSHIP OF PLANNING ACTIVITIES TO THE RTP



A number of SCAG planning activities directly impact the RTP development and update, as depicted in Figure 1.2. The Regional Comprehensive Plan (RCP) is a vision of how the region can balance resource conservation, economic vitality, and quality of life. The RTP Program Environmental Impact Report (PEIR) fulfills legal requirements by identifying potential environmen-

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tal effects of the RTP Alternatives and identifying ways to mitigate the effects. Lastly, the Regional Transportation Improvement Program (RTIP) is the critical implementation document that provides funding for all major transportation projects in the region for the next six years.

There are several other related planning activities initiated and managed outside of SCAG by partner agencies. Caltrans is responsible for developing and administering the Interregional Transportation Improvement Program (ITIP) and the State Highway Operations and Protection Program (SHOPP). These programs feed directly into SCAG's RTIP and form the basis of the baseline for the RTP. Furthermore, the RTIP is an integral part of the RTP and represents the first six years of the long-range plan. Caltrans is also responsible for developing and updating a statewide Long-Range Transportation Plan, which is a policy document called the California Transportation Plan (CTP). SCAG must consider and incorporate the CTP in the update of the RTP.

The CTCs are responsible for the development and administration of their respective countywide TIPs. Some also choose to develop county-specific long-range transportation plans even though they are not legally required to do so. SCAG must consider and coordinate such activities of the CTCs in developing and updating the RTP.

Local governments, including city and county governments, are responsible for preparing, updating and administering their local General Plans. Existing General Plans serve as input to the growth forecast work, and the adopted RTP, in turn, should influence future updates of the General Plans.

Finally, local air districts are responsible for developing Air Quality Management Plans (AQMP) for their respective air districts, which feed into the State Implementation Plan (SIP) and establish allowable emission budgets for criteria pollutants. The RTP serves as the input to the development of the AQMPs, and the emission budgets identified by the SIP through this process, in turn, establish the thresholds with which subsequent conformity analyses must comply.

RTP Framework

Federal planning and conformity rules require that a conforming RTP be financially constrained. It must demonstrate that all projects identified in the constrained plan have adequate funding. A conforming RTP cannot simply be a wish list of projects. If we were to rely on existing funding sources, the fiscal reality is that our region would not have enough money to fund all of our transportation needs. Figure 1.3 depicts the funding framework for this RTP.

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FIGURE 1.3 RTP FRAMEWORK

At the core of the Plan is the RTIP, which not only represents the first six years of the Plan, but also represents ongoing operations and maintenance commitments. Every project that seeks federal, state or local funding for implementation must be included in the RTIP. The first ring outside of the core, together with the core, represents the fiscally constrained plan that is used to demonstrate transportation conformity. These projects can be reasonably funded within the planning horizon of the RTP.

The outer ring, called the Strategic Plan, represents projects of merit that currently do not have sufficient funding or regional commitment. They should be considered for funding in the future as it becomes available. Projects typically flow from the outer ring to the core, as funding and commitments for these projects materialize and as they continue to meet the performance criteria established for the Plan.

Another way to look at the outer ring is to view projects in this domain as potential candidates for inclusion in the financially constrained RTP through future amendments. This helps streamline the RTP amendment process. However, given the time horizon of the RTP and the dynamic environment in which transportation projects get funded and implemented, it is foreseeable that there are current projects outside our vision that may warrant inclusion in future RTP amendments. This framework is flexible enough to allow for amending projects into the RTP that are not in the Strategic Plan.

Overview of the Plan

First and foremost, this Plan puts forth a collective vision for the future of our regional transportation system. Our vision is based on a careful analysis of our transportation system, the future growth of our region, our mobility needs, air quality improvement needs, and our need to preserve the environment and mitigate harmful environmental impacts of the proposed transportation improvements.

The Plan carefully and deliberately articulates major challenges associated with our transportation system as well as achieving our vision. Key challenges addressed in the Plan include dramatic growth as well as changes in the characteristics of our demographics, the aging infrastructure, and the unprecedented demand on our goods movement system and our airports. The Plan also articulates our air quality and environmental challenges, and the constraints that they will place on our ability to make necessary improvements to our transportation system, particularly our goods movement infrastructure. On top of all of this, the region will continue to face serious funding shortfalls that will challenge our ability to simply keep our system afloat if we were to do nothing to improve our transportation funding situation.

Given our vision and the challenges, this Plan recognizes that our approach must be balanced, systematic, multimodal, and at the same time targeted to yield the best performance outcomes based on the established set of performance measures. Our integrated system investment approach is depicted by the Mobility Pyramid shown in Figure 3.3. According to this approach, our first priority is to invest in system monitoring and evaluation strategies so that decision-makers can better understand how the system performs and make

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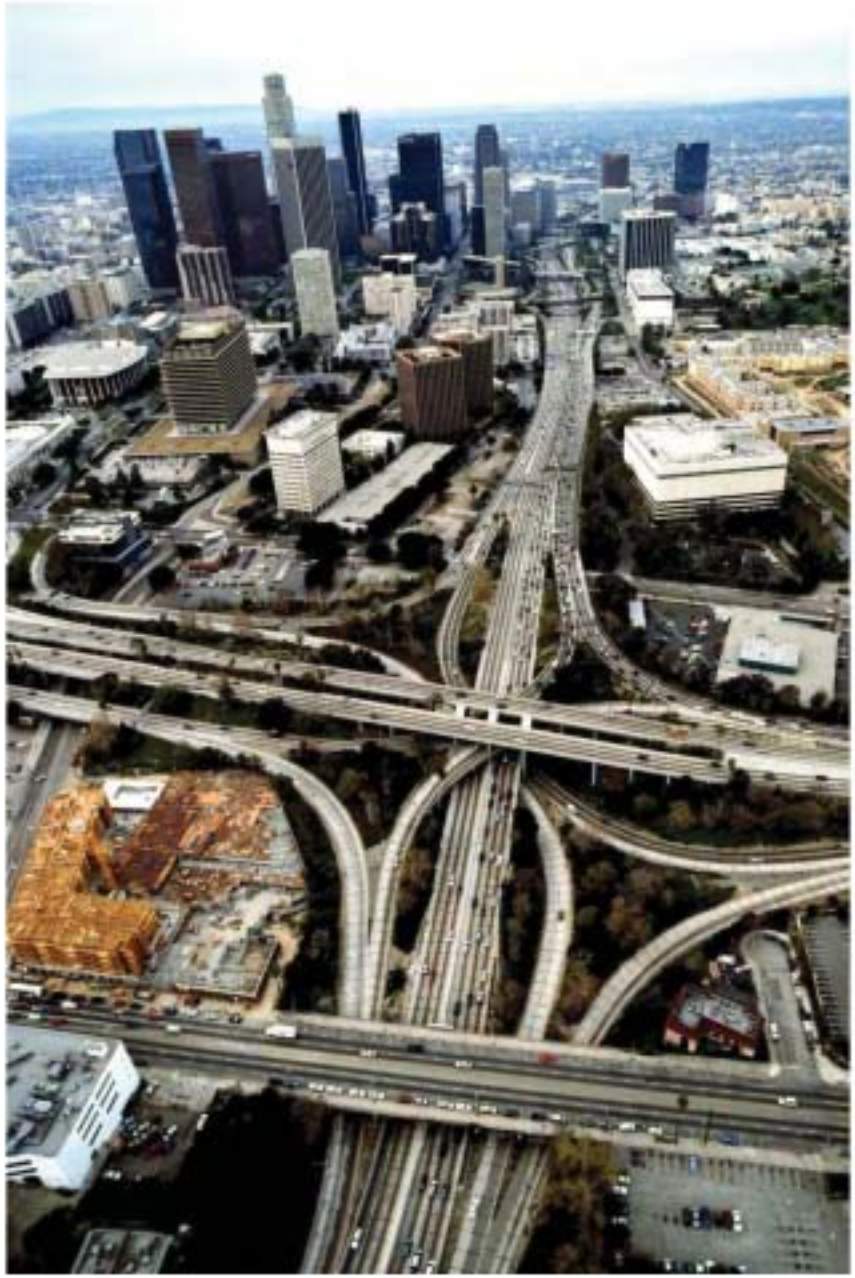
well-informed decisions on how to fix our problems. Next, we must preserve our multimodal transportation system, which has cost the region hundreds of billions of dollars to build. The next strategy recognized in this hierarchy is the tremendous potential of coordinating and integrating land use choices with transportation-investment decisions. Effective implementation would not only result in more efficient and effective utilization of available system capacity, but also in the preservation of our environment. We must also make sure that we are getting the most out of our available system by managing our system and our demand better. Such strategies are cost-effective, easy to implement, and environmentally superior to the more capital-intensive system expansion-options. Having monitored and maintained our existing system, and having maximized system efficiency and system productivity through system management, land use coordination, and demand management, the Plan recognizes that targeted system expansion will still be needed to accommodate future growth. Therefore, the Plan proposes a balanced investment approach that would address all modes of transportation, including highways, the public transportation system, the goods movement system, non-motorized transportation, as well as airport ground access improvements.



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Finally, while recognizing financial constraints, the Plan puts forth a suite of new and innovative funding strategies that are realistic, practical, and achievable within the time frame of the Plan. The Plan also recognizes that in spite of our best efforts, there simply will not be enough money to implement solutions to all of our transportation needs. The Plan includes a strategic component that identifies projects that cannot be funded at this point, but merit further consideration in future plan updates based on additional studies, funding support, and stakeholder consensus.

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II. TRANSPORTATION PLANNING CHALLENGES

The SCAG Region is one of the largest and most complex metropolitan areas in the nation, and its transportation challenges are equally large and complex. This chapter describes growth trends and travel patterns in the SCAG Region and the challenges that these trends and other factors pose for our multimodal transportation system.

The Shape and Pattern of Future Growth

Southern California is running out of land to support low-density future growth. The ocean and mountains pose natural barriers to development. Environmentally sensitive areas, such as coastal wetlands and natural habitat areas, hem in the region and dot the urbanized area. A significant amount of land is also owned by the state and federal governments for the public benefit and is off limits to development.

Freeways provide access to farmland and grazing areas that could be used to accommodate future growth along the east-west axis of the region. There is little access to the north except through mountain passes that are choked with car and truck traffic. The centrifugal force of growth continues to push the development footprint of the urbanized area outward. At the same time, pushing back on dispersed development are natural barriers, financial constraints to pay for outward expansion, and public resistance to unsustainable "leap frog" growth into green fields and sensitive habitat areas. Nearly all natural locations for urban development have been consumed, leaving us with hard choices about how we are to grow and change to meet the demands of the future.

Much of the urbanized area is fighting gridlock as 95 percent or more of the population drives back and forth to work to accomplish the tasks of daily living, and another 3 to 5 percent take transit or walk. Growth management strategies and ballot initiatives are aimed at preserving and protecting prime farm and grazing land from residential development pressures, while preserving historic buildings, single-family neighborhoods and prime industrial land for economic development.

Many are starting to realize that, as large as the region is in total area, it is running out of developable land to support a significantly unbalanced auto-oriented development pattern. There is an increasing need for reinvestment and increased development near public transit, along corridors and in-town, mixed-use urban centers. Southern California has the nation's largest bus ridership and an emerging metro, commuter, and light rail transit network that provides a better balance of transportation choices that can reduce auto travel and support more pedestrian, mixed-use and transit-oriented development.

This section describes the population, employment, and demographic changes that happened in the recent past and may be expected in the SCAG Region over the next 30 years without a change in regional policy. These demographic and economic changes are an integral part of planning the transportation system to ensure that the users' needs are addressed.

POPULATION GROWTH

The SCAG Region is the second most populated metropolitan area in the United States. Nearly one-half of all Californians live in the SCAG Region, and 1 in 17 people living in the entire United States resides here. By July 1, 2007, the region's population had reached 18.6 million residents, having grown by 2 million residents (12 percent) from 16.6 million people just seven years ago. The population growth (2 million residents) of the SCAG Region between 2000 and 2007 was higher than the population growth (1.9 million residents) that occurred throughout the 1990s. Figure 2.1 shows the growth pattern of population, households, and employment between 2000 and 2007. Population growth slows down in the middle 2000s (2004-2007), while both household and employment growth are much faster in the middle 2000s than in the early 2000s.

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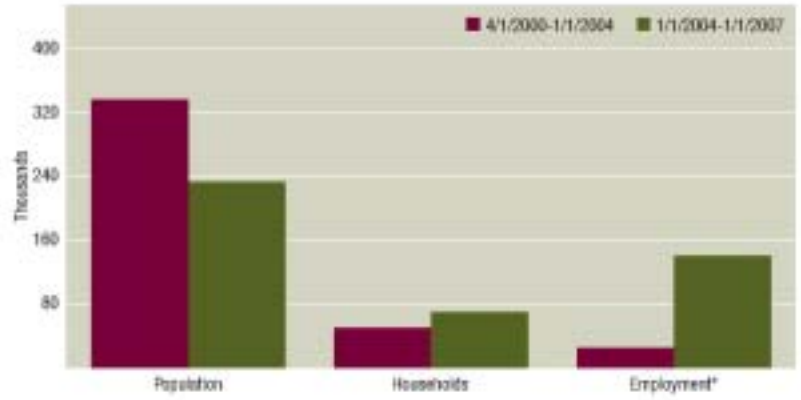
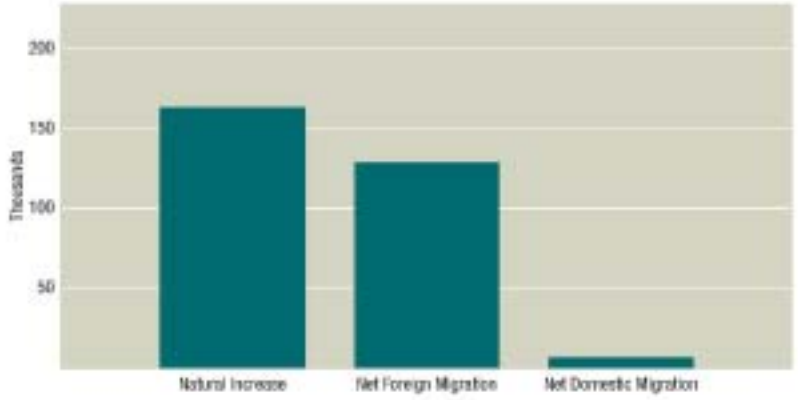
FIGURE 2.1 ANNUAL AVERAGE GROWTH IN POPULATION, EMPLOYMENT, AND HOUSEHOLDS, 2000-2004 AND 2004-2007



Source: California Department of Finance, California Employment Development Department, SCAG Employment Estimates

FIGURE 2.2 COMPONENTS OF ANNUAL POPULATION GROWTH, 2000-2006



Source: California Department of Finance

Two major sources of population growth since the 2000 Census are natural increase (births minus deaths) and net foreign immigration (people who move here from foreign countries minus those who move away to foreign countries). Natural increase accounted for 55 percent of the population gain in the region. Although the total fertility rate of women of child-bearing ages remains stable in recent years, Hispanic women still maintain a relatively higher total fertility rate. The life expectancy of Southern California residents increased while the death rate decreased.

Net foreign immigration, mostly from Mexico, Central America, and Asia, accounted for 43 percent of the population gain in the region. Foreign immigration, including unauthorized immigrants, was not affected by the region's economic cycle. Southern California is still an attractive destination and a gateway for new immigrants, although international migration to the region has leveled off in recent years.

As of July 1, 2007, there is no racial or ethnic majority in the region. Hispanics constitute 44 percent of the region's population, followed by Non-Hispanic (NH) Whites at 36 percent, NH Asians and Others at 13 percent, and NH Blacks at 7 percent. Since 2000, Hispanics have increased their share of the population by 3 percent, while NH Whites have decreased their share by the same percentage. There has been little change in the share of other racial/ethnic groups between 2000 and 2007. The region is moving toward a Hispanic majority.

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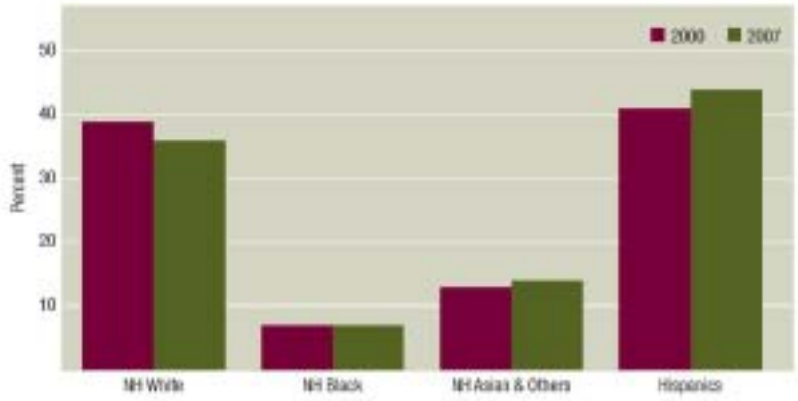
FIGURE 2.3 ETHNIC COMPOSITION OF POPULATION, 2000 AND 2007



Source: California Department of Finance

The region shows an aging pattern of population growth between 2000 and 2007. According to California Department of Finance (DOF) estimates, nearly 80 percent of population growth occurred in the age group of 36 years old or older. Age groups of 4-10 years old and 27-35 years old declined by 6 percent and 8 percent, respectively, over the same period. The absolute decline of school-age children and younger adults raises a concern about future school construction needs and labor force in younger workers.

TABLE 2.1 AGE COMPOSITION OF POPULATION, 2000 AND 2007

Age	7/1/2000	7/1/2007	Change	% Change
0-3	1,017,000	1,078,000	62,000	6%
4-10	1,977,000	1,868,000	(109,000)	-6%
11-26	3,885,000	4,528,000	642,000	14%
27-35	2,413,000	2,227,000	(187,000)	-8%
36+	7,333,000	8,860,000	1,526,000	17%
Total	16,626,000	18,560,000	1,934,000	12%

Source: SCAG Baseline Growth Forecast

Los Angeles County accounted for 41 percent of the region's growth over the last seven years, adding 813,000 residents, while Riverside and San Bernardino Counties together added 804,000 residents. In terms of relative growth, the Inland Empire and Imperial Valley are the fastest-growing areas in the region. Riverside County grew by 40 percent, San Bernardino County by 19 percent and Imperial County by 22 percent. Nearly 46 percent of the region's growth occurred in areas outside of Los Angeles and Orange Counties. Los Angeles and Orange Counties were the slowest-growing counties, adding only 9 percent each to its populations during the same period.

FIGURE 2.4 POPULATION GROWTH BY COUNTY, 2000-2007

Source: California Department of Finance

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FIGURE 2.5 PERCENT GROWTH IN POPULATION BY COUNTY, 2000-2007

Source: California Department of Finance

HOUSEHOLD GROWTH

Since the 2000 US Census, there was a net addition of 410,000 households, bringing the regional total to nearly 5.8 million in 2007. However, population growth outpaced household growth with only one household for every five persons added. The rapidly growing population is reflected in larger households rather than in the formation of new households. The average persons-per-household ratio in the region has increased from 3.07 in 2000 to 3.19 in 2007. The increasing household size may be caused by the cultural propensity of some groups such as recent immigrants to form large inter-generational families or by the limited supply of affordable housing units. Workforce housing affordability and availability issues have affected the quality of life in the region. The insufficient supply of affordable housing in job-rich urban areas maintains existing trends in urban sprawl, longer commute patterns, congested freeways and worsening air quality.

EMPLOYMENT GROWTH

In 2006, the region's total employment, including self-employment, was estimated to be nearly 8 million, having grown by 500,000 jobs (7 percent) from 2000. The region's economy is robust in terms of the number and the types of jobs available to residents looking for jobs, with the unemployment rate of the region at a historic low of 4.6 percent in 2006. The previous record in the region was 5 percent in 2000. The region's employment has been steadily growing since the recession of the early 1990s. The region experienced a net loss of 500,000 jobs during the recession period between 1990 and 1993, then overcame the recession by adding a net 780,000 jobs between 1996 and 2000. After slow growth in jobs in 2002 and 2003, the region is regaining its economic strength by increasing new annual job growth beyond these early decade levels.

The overall pattern of employment change is driven by the decline in manufacturing sector jobs due to globalization. Between 2000 and 2005, the manufacturing sector jobs dropped from 1,023,000 jobs to 835,000 jobs, a loss of 188,000 jobs. The share of the manufacturing sector jobs declined by 3 percent. Other significant economic sectors experiencing the absolute loss of jobs include 1) information, 2) agriculture and mining, and 3) transportation and warehousing, and utility. In contrast, 1) construction, 2) financial activity, 3) leisure and hospitality, 4) retail trade, and 5) other service sectors added a significant number of additional jobs to the regional economy. The growth in the construction and financial activity sectors was caused by the strong residential housing development. The increases in some service-sector jobs are directly associated with the increase in total population and an increase in the aged population in the region. The growth of service-sector jobs, in particular, population-serving jobs, is likely to continue in the future.

The strong regional job growth directly influences domestic migration, because it induces more domestic in-migration than domestic out-migration, while weak job growth causes more domestic out-migration than domestic in-migration. More net in-migration influences the job growth in the "population-serving" retail and service sectors.

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TABLE 2.2 EMPLOYMENT BY SECTOR, 2000 AND 2005

Sectors (NAICS)	2000		2005		Change		
	Number	%	Number	%	Number	% Change	Change in %
Agriculture & Mining	84,000	1%	78,000	1%	(6,000)	-7%	0%
Construction	369,000	5%	465,000	6%	96,000	26%	1%
Manufacturing	1,023,000	14%	835,000	11%	(188,000)	-18%	-3%
Wholesale Trade	374,000	5%	386,000	5%	12,000	3%	0%
Retail Trade	770,000	10%	841,000	11%	71,000	9%	1%
Transportation and Warehousing, and Utility	354,000	5%	349,000	4%	(5,000)	-1%	0%
Information	324,000	4%	278,000	4%	(46,000)	-14%	-1%
Financial Activities	415,000	6%	504,000	6%	89,000	21%	1%
Professional and Business Services	1,167,000	16%	1,197,000	15%	30,000	3%	0%
Education and Health Services	1,429,000	19%	1,546,000	20%	117,000	8%	1%
Leisure and Hospitality	664,000	9%	746,000	10%	82,000	12%	1%
Other Services	293,000	4%	313,000	4%	20,000	7%	0%
Public Administration	217,000	3%	234,000	3%	17,000	8%	0%
Total	**7,482,000**	**100%**	**7,771,000**	**100%**	**289,000**	**4%**	**0%**

Source: California Employment Development Department, SCAG Employment Estimates

INCOME

Income is one of most important indicators of economic well-being of residents in the region. In 1999, per capita income of the region, as a measure of the wealth of the residents, was approximately $21,000. By 2006, this amount grew to $25,000, an increase of 20 percent. After adjusting for inflation, per capita income of the region has declined from 1999 to 2006 (-5.7%). Per capita income of the region remains at the same level as the nation, but is lower than that of California by 6 percent. The relative income level of the region to the nation has declined from 1.27 in 1959 to 0.98 in 1999. Over the last three decades, the SCAG Region's per capita income ranking dropped from the 4th highest in 1969 to 7th in 1989, and 16th in 1999. The SCAG region continued to rank last in terms of per capita income among the 17 largest metropolitan regions in the nation in 2005.

Median household income increased by 22 percent from 1999 to 2006. However, this increase was only about 80 percent of what was required to keep up with inflation. Thus, real median household income was down by 4%. In 2006, median household income of the region was 15 percent above the national average, but was lower than that of California by 1.5 percent. The relative income level of the region to the nation has remained 9 percent to 23 percent above the national average for the periods of 1969, 1979, 1989, and 1999. The relative median household income level of the region has increased from 1.09 in 1999 to 1.15 in 2006.

Average income statistics, however, mask how much poverty is present in the region. In 2006, nearly 14 percent of the region's residents lived in poverty compared to around 13 percent for California and the nation as a whole. Around 18 percent of Imperial County residents live in poverty, followed by Los Angeles County at 15 percent. The poverty rates of Ventura, Orange, and Riverside County residents are lower than those of California or the nation.

Partly because of the higher than national average poverty levels and partly because of the high cost of home ownership in California, the region lags the nation in homeownership rates. During the last decade, median home values in California and the most populous areas of the region have risen due to construction activity lagging population growth, low inventory and historically low interest rates. Median home values in California now reach the $462,000 mark, which is more than double the national median. In 2006, 56.5 percent of regional residents owned their own home compared to 67.3 percent for the nation as a whole.

PATTERNS OF FUTURE GROWTH

A baseline growth forecast is a future snapshot of the most likely population and employment distribution without regional policy input. It reflects historical trends, based on reasonable key technical assumptions and existing and

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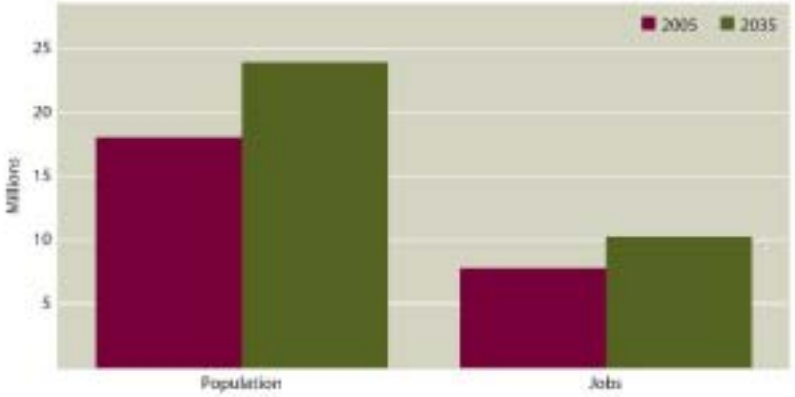
newly approved local or regional projects. Specifically, the baseline growth forecast is a result of updating the 2004 RTP no-project growth forecast with the current demographic and economic trends, the latest land use changes, newly approved regionally significant projects, general plan or specific plan update, and/or zoning revisions. Also included are demand forecasts for cargo and passengers at the regional ports and airports. The port and airport demand forecasts include projects that improve operations and increase capacity. Intermodal expansion was assumed in terms of additional capacity at the ports for goods movement growth, and the trips associated therewith were assumed to be located in the Inland Empire. The VMT and related emissions regarding such trips are incorporated into the modeling analysis.

According to the baseline growth forecast summarized in Figure 2.6, the region will add 5.9 million people to reach 24 million people by 2035. Supporting this population in 2035 will be a total of 10.3 million jobs in 2035 with 2.5 million new jobs. This level of population and job growth is expected to yield 2 million additional households in the region at an average of three persons per household. The substantial amount of projected growth will pose serious transportation and air quality challenges for the region.

FIGURE 2.6 POPULATION AND EMPLOYMENT, 2005 AND 2035



Source: California Department of Finance, California Employment Development Department, SCAG Employment Estimates, SCAG Baseline Growth Forecast

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TABLE 2.3 SOCIOECONOMIC INDICATORS, 2005 AND 2035

	2005**	2035	Change	% Change
Total population ('000), % Change (2005-2035)	18,147	24,057	5,910	33%
Persons under 16 years old (%)	24.4	21.4	-2.9	
Persons 16-64 years old (%)	65.7	62.7	-3.0	
Persons 65 years old and over (%)	9.9	15.9	6.0	
Median age	32.9	35.9	3.1	
Total dependency ratio*	52.1	59.5	7.4	
Child dependency ratio	37.1	34.2	-2.9	
Old-age dependency ratio	15.1	25.3	10.3	
Births per 1,000 population	15.9	14.4	-1.4	
Total fertility rate (per woman)	2.05	2.02	-0.03	
Deaths per 1,000 population	6.3	6.9	0.7	
Natural increase (%) (2000-2005, 2005-2035)	55.0	84.0		
Net migration (%) (2000-2005, 2005-2035)	45.0	16.0		
Non-Hispanic White persons (%)	36.0	21.9	-14.1	
Non-Hispanic Black persons (%)	7.1	5.8	-1.2	
Non-Hispanic Asian & Other persons (%)	13.8	17.0	3.3	
Hispanic persons (%)	43.1	55.2	12.0	
Households ('000), % Change (2005-2035)	5,687	7,711	2,024	36%
Total population per household (PPH)	3.19	3.12	-0.07	
Householders 65 years old and over (%)	17.3	26.5	9.2	
Total employment ('000), % Change (2005-2035)	7,771	10,287	2,516	32%
Agriculture & Mining (%)	1.0	0.8	-0.2	
Manufacturing (%)	10.7	7.7	-3.0	
Service (%)	**88.3**	**91.5**	**3.2**	

Notes: ** A measure showing the number of dependents (aged 0-15 & over 65) per 100 working age population (aged 16-64). Dependents per 100 working-age population.*
*** Model estimate*
Source: SCAG Baseline Growth Forecast

Where will all these people come from? Approximately 85 percent of the region's population growth in the future is due to natural increase. The region is expected to experience a net loss in domestic migration, but this will be more than offset by international immigration. As the region grows, the average person will be older, and Hispanics will become the majority ethnic group. The population in the region will become older because of aging "baby boomers" born between 1946 and 1964. The median age will rise from 32.9 years in 2005 to 35.9 in 2035. The population aged 65 and older will grow four-and-a-half times faster than the working-age population (16-64 years old) between 2005 and 2035. As a result, workers in the region will support a larger share of the older "baby boomer" population in 2035.

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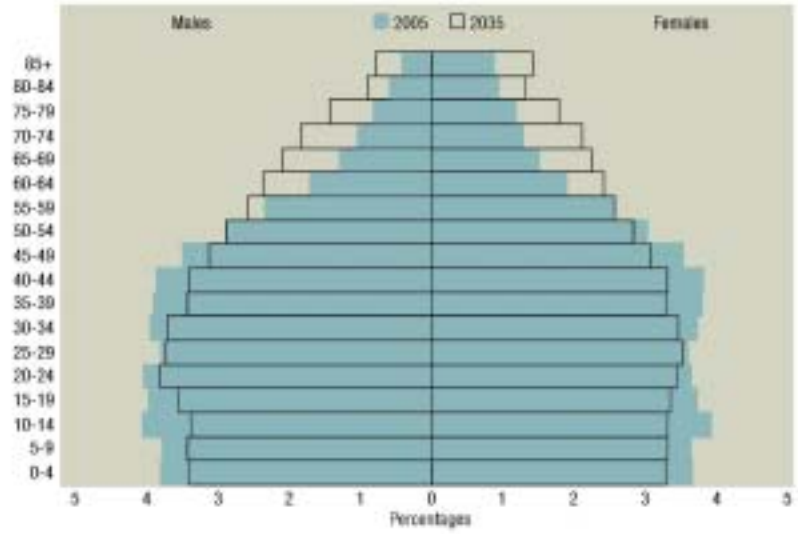
FIGURE 2.7 POPULATION AGE PYRAMID, 2005 AND 2035



Source: SCAG Baseline Growth Forecast

Due to the retirement of "baby boomers," the region may experience severe shortages of skilled labor. The aging baby boomers may postpone the retirement or the female labor force may increase the labor force participation. If domestic migration does not make up the shortage of skilled labor, then more foreign immigration will be needed. The skills of the new labor force, particularly recent immigrants, will probably not match the requirements of the skilled jobs. This could depress the overall income level of the workers and households. Long-term strategies to achieve growth and equitable distribution of income should be considered, including appropriate and enhanced educational opportunities and a phased retirement system.

Shifting demographic patterns will also influence travel behavior. The elderly people travel less than the younger population and the elderly workers tend to work at home. If necessary, they commute to work for a shorter distance. Recent immigrants tend to use public transportation much more than other population groups. Urban density levels may also increase since foreign-born residents urbanize less land. Many SCAG Region foreign-born, Hispanic, and Asian residents have modest incomes, larger household sizes, and tend to double up in existing urban areas, thereby increasing population density. The socioeconomic characteristics and lifestyle choices associated with immigration are consistent with a more compact urban form.

The overall number of persons per household will be smaller in the region in 2035 as downward pressures are exerted by aging "baby boomers" and lower birth rates, while there are upward pressures from increasing Hispanic populations with relatively large households (especially recent immigrants). The number of persons per household may increase in some built-out areas over the projection horizon due to the limited availability of developable land. The racial and ethnic composition of households will reflect the population diversity and create demand for a wider variety of housing types than are most prevalent today. Specifically, there will be more need for close-in and infill housing, condominiums and multi-family housing.

Jobs will be created across all employment sectors, except the manufacturing sector. The largest gains will be in service-sector jobs as the shift in the region from manufacturing jobs to service-sector jobs continues. Between 2005 and 2035, service-sector jobs will lead in total growth and comprise the largest share of total jobs. The makeup of service sector jobs will also change, with different employment opportunities. Three top leading sectors include 1) education and health services, 2) professional and business services, and 3) construction. These fast-growing sectors are supported by the continued growth of population and demographic changes (e.g., aging of baby boomers). With continued globalization, the share of the manufacturing sector will continue to decline from 11 percent in 2005 to 8 percent in 2035. The manufacturing sector still remains important and there are growth opportunities in the high-tech manufacturing sector. The decline of the manufacturing sector might result in the lower income level of workers and households. The policy strategies might focus on creating more high-wage and salary service sectors, which include 1) information, 2) public administration, 3) financial activities, 4) wholesale trade, and 5) transportation and warehousing, and utilities. The

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logistics sector, comprising wholesale trade, transportation, and warehousing, might become more important in the region's economic growth as the region's foreign trade activities continue to grow. The significant growth of the construction sector might influence the future traffic congestion in the region. The workers in the construction sector tend to commute to work for longer distances, but they use carpooling much more than other workers.

TABLE 2.4 EMPLOYMENT BY SECTOR, 2005 AND 2035

Sectors (NAICS)	2005		2035		Change		
	Number	%	Number	%	Number	% Change	Change in %
Agriculture & Mining	78,000	1%	86,000	1%	8,000	10%	0%
Construction	465,000	6%	687,000	7%	222,000	48%	1%
Manufacturing	835,000	11%	792,000	8%	(43,000)	-5%	-3%
Wholesale Trade	386,000	5%	458,000	4%	72,000	19%	-1%
Retail Trade	841,000	11%	1,122,000	11%	281,000	33%	0%
Transportation and Warehousing, and Utility	349,000	4%	418,000	4%	69,000	20%	0%
Information	278,000	4%	362,000	4%	84,000	30%	0%
Financial Activities	504,000	6%	601,000	6%	97,000	19%	-1%
Professional and Business Services	1,197,000	15%	1,770,000	17%	573,000	48%	2%
Education and Health Services	1,546,000	20%	2,299,000	22%	753,000	49%	2%
Leisure and Hospitality	746,000	10%	1,027,000	10%	281,000	38%	0%
Other Services	313,000	4%	366,000	4%	53,000	17%	0%
Public Administration	234,000	3%	301,000	3%	67,000	29%	0%
Total	**7,771,000**	**100%**	**10,287,000**	**100%**	**2,516,000**	**32%**	**0%**

Source: SCAG Baseline Growth Forecast

The overall economic well-being of residents in the region improves during the planning period. The median household income of the region is expected to increase by one-half percent per year from $46,000 (in 1999 dollars) in 2005 to $53,000 (in 1999 dollars) in 2035. The higher-income households with more than $100,000 (in 1999 dollars) increase two or three times faster than low- and middle-income households. The projected income level and

distribution affects auto ownership, trip generation, and mode choice. For example, higher household income implies more cars available for travel, more trip generation, and more driving than transit use.

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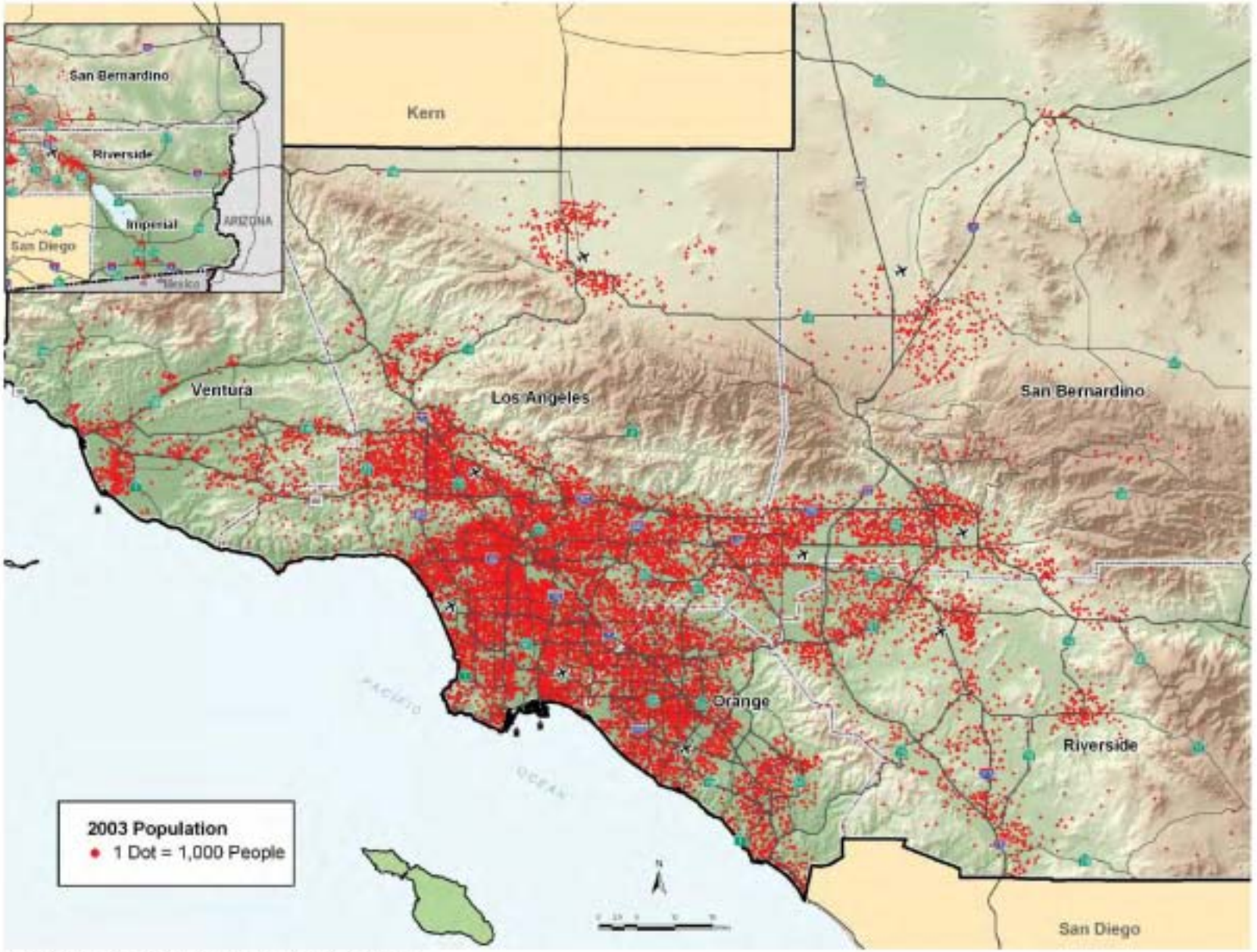
EXHIBIT 2.1 2003 POPULATION



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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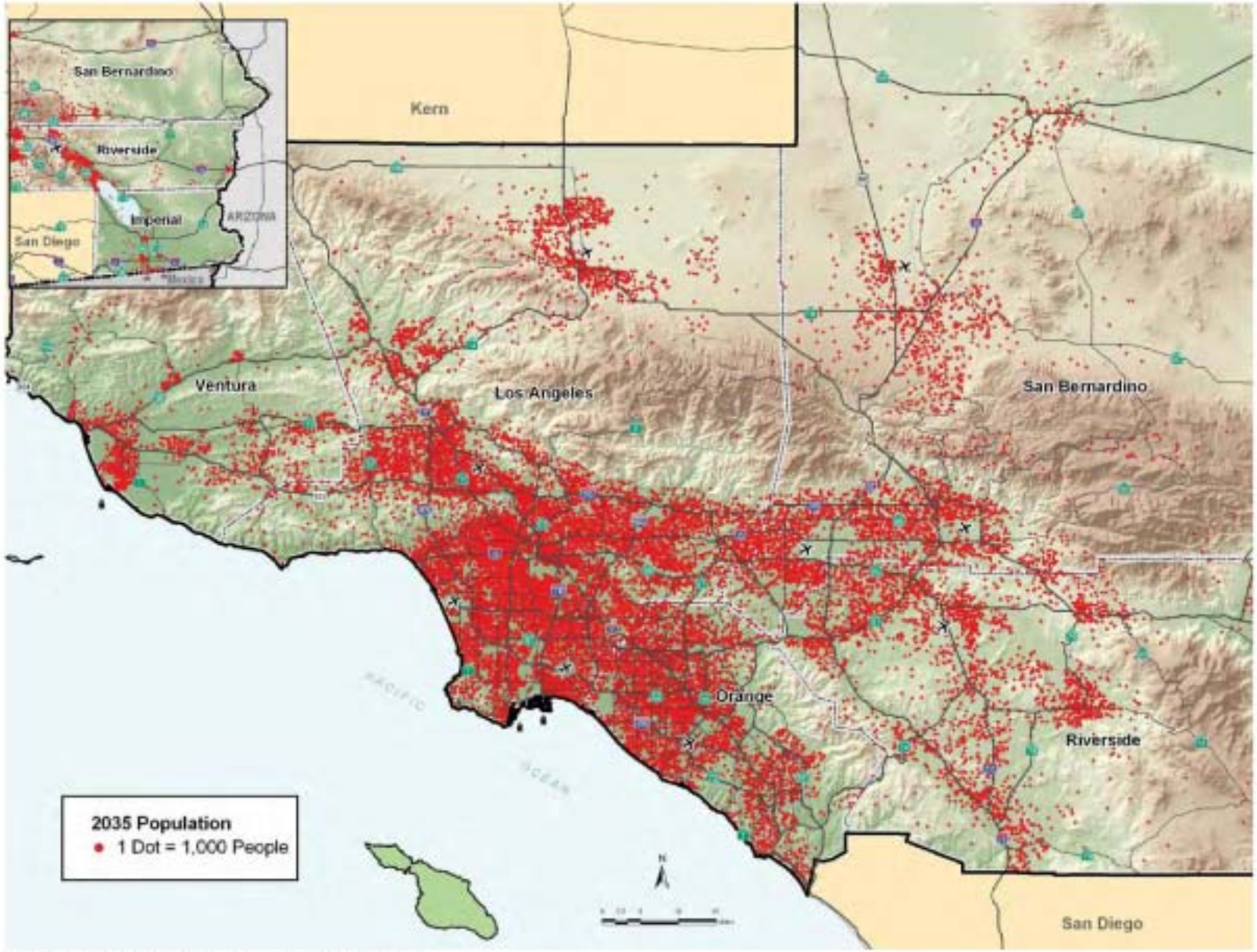
EXHIBIT 2.2 2035 POPULATION



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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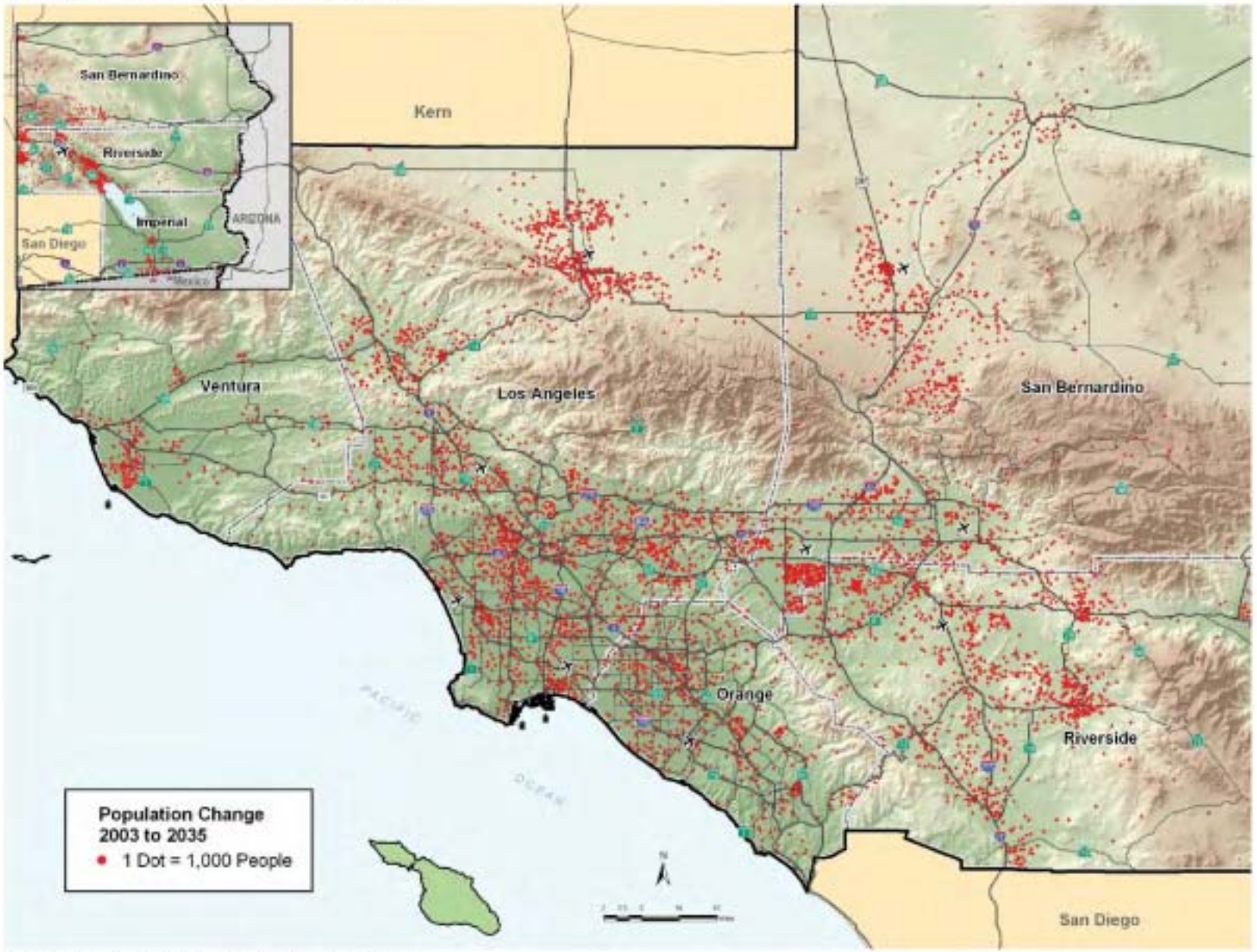
EXHIBIT 2.3 POPULATION INCREASE, 2003-2035



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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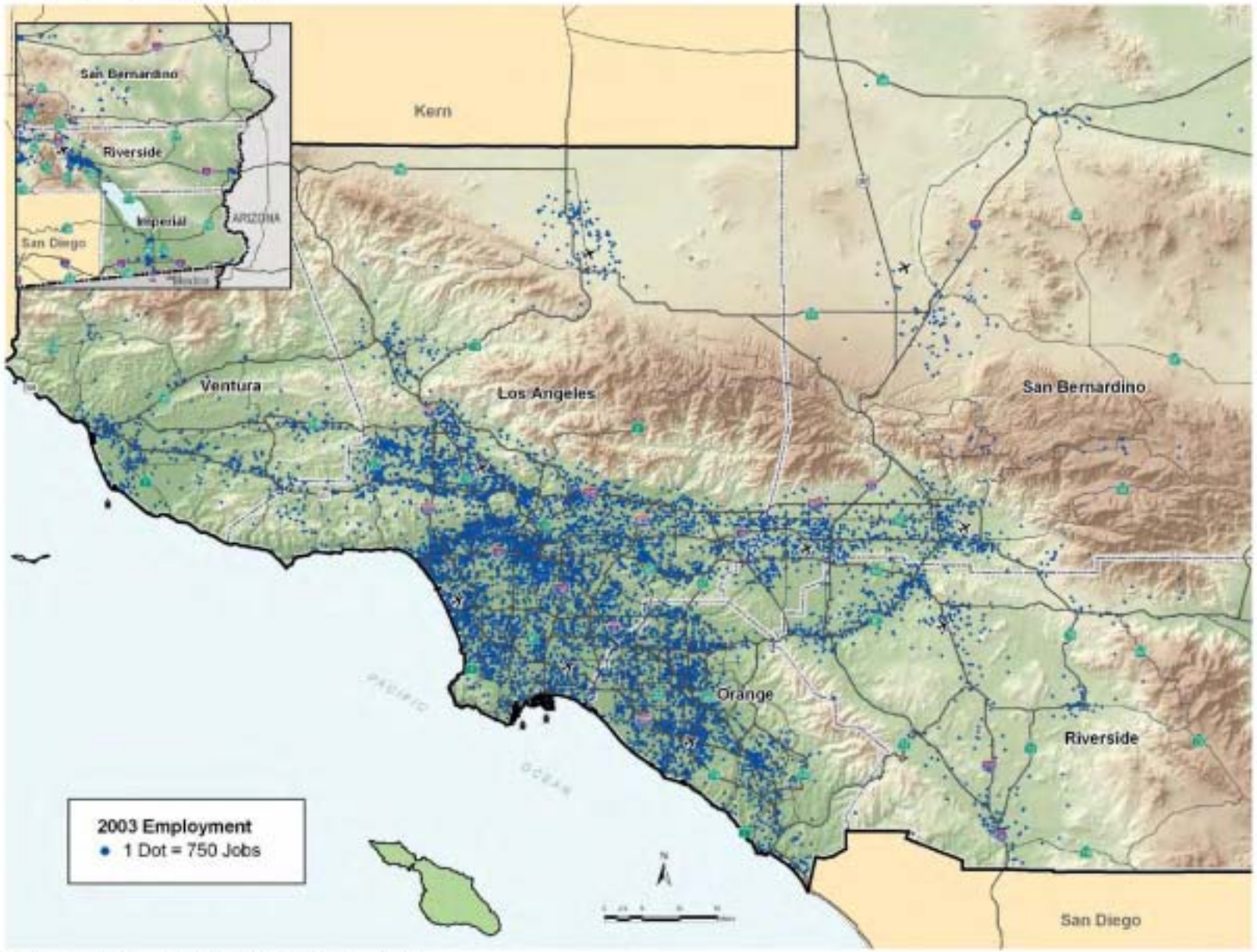
EXHIBIT 2.4 2003 EMPLOYMENT



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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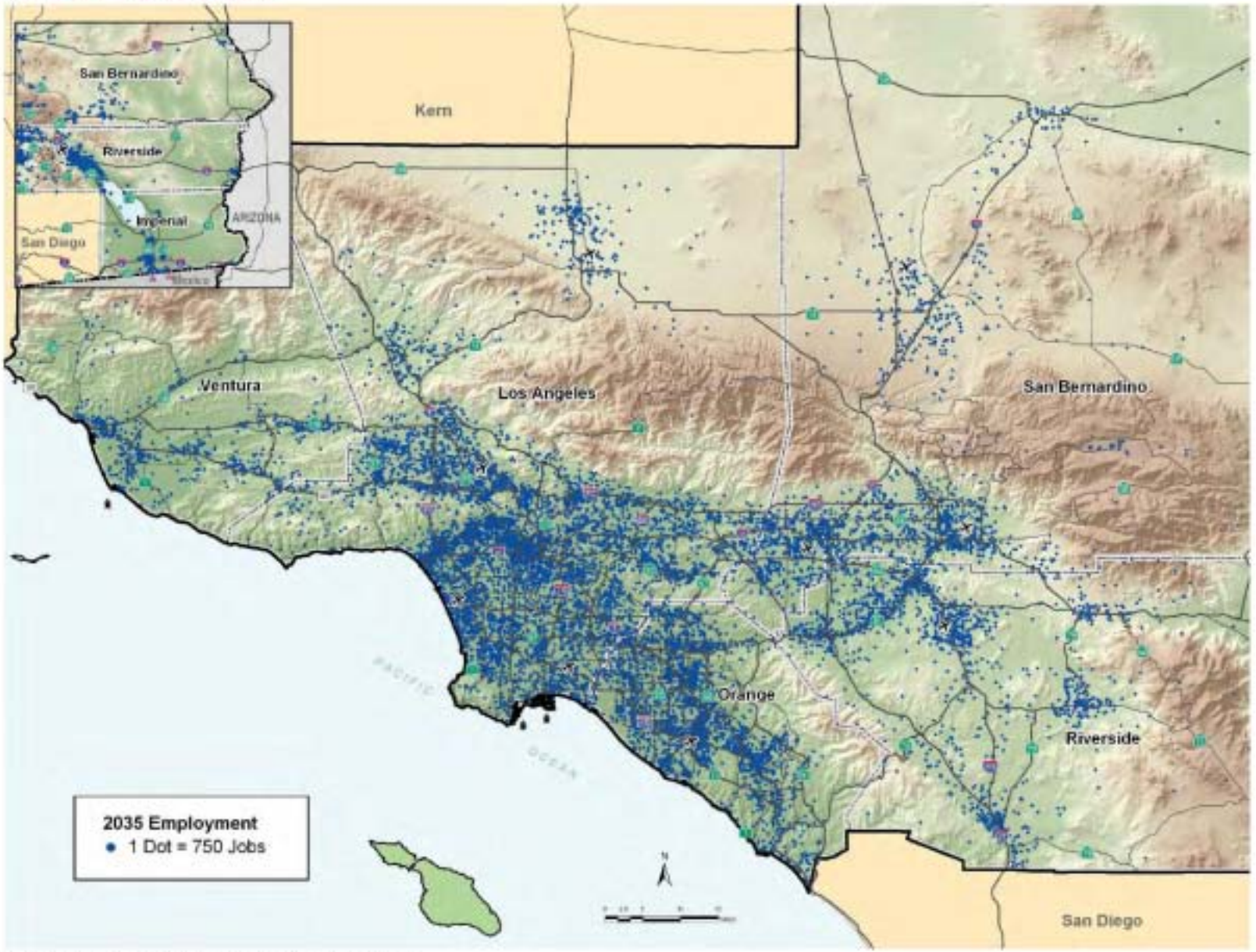
EXHIBIT 2.5 2035 EMPLOYMENT



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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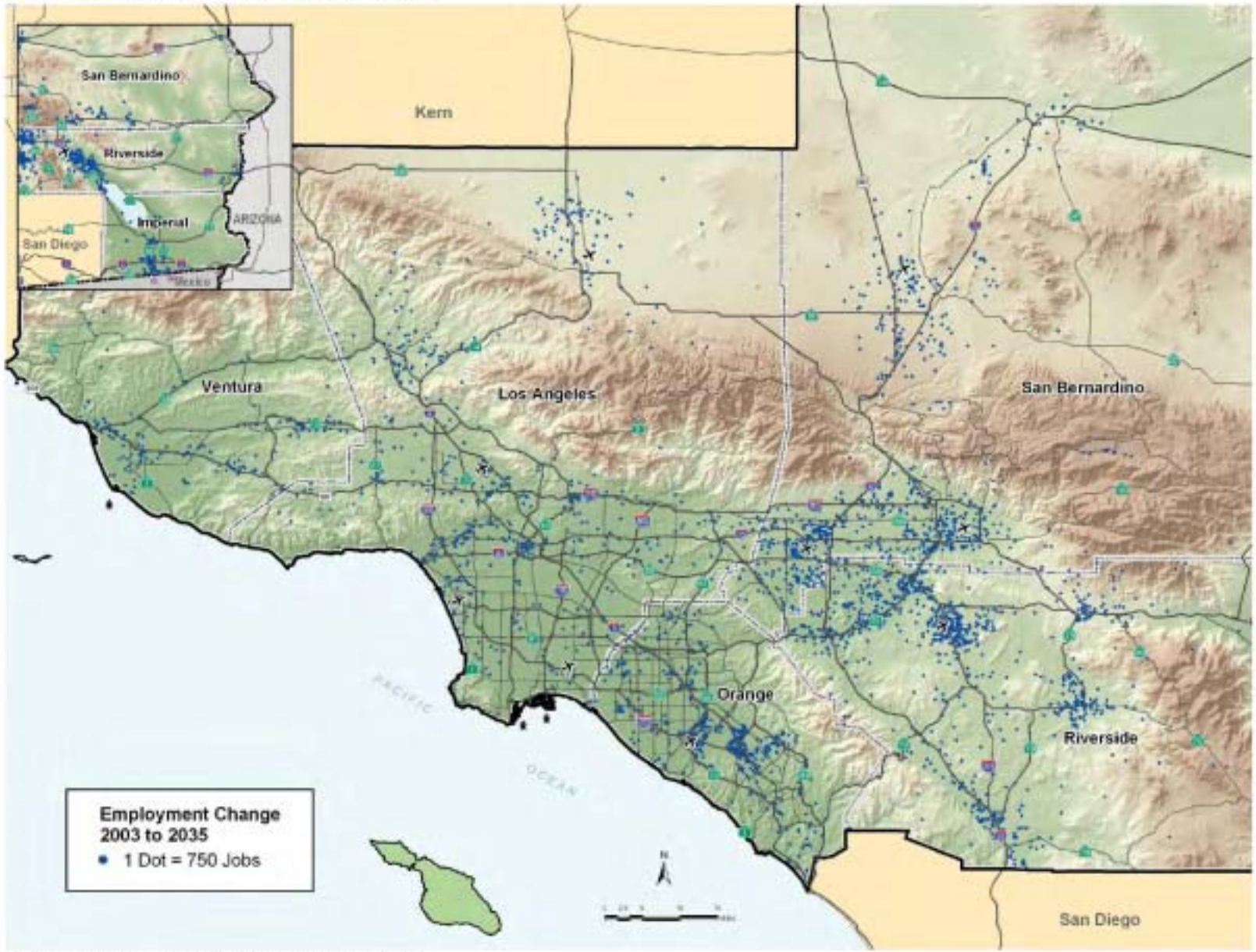
EXHIBIT 2.6 EMPLOYMENT INCREASE, 2003-2035



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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Table 2.5 summarizes the baseline growth forecast by county for 2035 population, households, and employment. The baseline growth represents a forecast based on current and expected demographic and economic trends, as well as previously adopted local land use policies within the SCAG Region.

TABLE 2.5 2035 POPULATION, HOUSEHOLDS, AND EMPLOYMENT (THOUSANDS)

	Baseline		
County	Population	Households	Employment
Imperial	320	103	133
Los Angeles	12,339	4,004	5,041
Orange	3,654	1,118	1,982
Riverside	3,597	1,183	1,414
San Bernardino	3,134	973	1,255
Ventura	1,014	330	463
SCAG Region	**24,057**	**7,711**	**10,287**

Source: SCAG Baseline Growth Forecast

Where do we live and work now, and where will we live and work in the future? The regional baseline forecasts are distributed to counties, subregions, and smaller geographies through an interactive collaborative process in which cities, subregions, regional agencies, experts, and stakeholders participated. Input from local jurisdictions plays an important role in determining the baseline growth distribution within their boundaries. Exhibit 2.1 shows where we lived in 2003 and Exhibit 2.2 shows where we are forecast to live in 2035. Exhibit 2.3 shows the difference between the two time periods. In terms of where we work, Exhibit 2.4 shows 2003 employment clusters, while Exhibit 2.5 shows anticipated 2035 employment clusters. Exhibit 2.6 shows the difference between the two time periods.

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Mobility Challenges

The projected growth in the region is expected to place even greater demands on the transportation system. The SCAG Region is served by an extensive multimodal transportation system addressing all aspects of travel in the region, including commuters; shoppers; public transit patrons; truckers delivering goods both regionally and locally, such as groceries to the local supermarkets; as well as fire, police, and other emergency personnel. The roadway and freight rail networks serve the largest maritime ports system in the United States (the Ports of Long Beach, Los Angeles, and Hueneme) and a number of large airports, including the fifth-largest airport in the world (Los Angeles International Airport–LAX).

The region has over 20,750 centerline miles and over 65,000 lane-miles of roadways, including one of the most extensive High-Occupancy Vehicle (HOV) lane systems in the country. Additionally, the region has a growing network of tolled lanes and High-Occupancy Toll (HOT) lanes. Regionally significant arterials provide access to the freeway system and often serve as parallel alternate routes; in some cases, they are the only major system of transportation available to travelers.

The public transit network in the SCAG Region has been growing significantly over the last two decades, and this growth accelerated since the 2004 RTP. The region has approximately 640 bus routes and about 50 local bus operators, four commuter express bus services, two subway lines and three light rail lines operating in Los Angeles County, and the Metrolink commuter rail network spanning five of the six counties and northern San Diego County.

Despite this vast multimodal network, transportation in the SCAG Region is facing serious, unprecedented challenges. Although the first thought about Southern California transportation is congestion, other major related challenges are equally (or more) serious.

To truly understand these challenges, it is important to understand how we got to this point. How did we become the most congested metropolitan region in the country? Only by developing an in-depth understanding of the current situation and the factors that led to this situation can we try to develop consensus on the tough choices that are before us.

ROADWAY CONGESTION

The second-largest metropolitan area in the United States with over half of California's residents, the Southern California region is the most congested metropolitan area in the country. Over the past twenty years, traffic delays have nearly tripled in the region, and SCAG's Regional Transportation Model estimates the following alarming traffic delay statistics (defined as the difference in travel time between free-flow conditions and actual conditions):

- 3.9 million vehicle-hours of daily delay
- 5.7 million person-hours of daily delay
- 15 minutes of delay per capita during peak commute periods

Almost as frustrating as daily recurrent delay is the variability of travel time. For example, trips that on average take 30 minutes often last much longer due to incidents, collisions, weather, special events, construction activities, or other difficult-to-predict conditions. The frequency of such unpredictable delays over and beyond the "normal" congestion has been increasing steadily on our roadways. The combination of increasing congestion and decreasing predictability of travel times has led to our region's status as the capital of congestion in the country.

ROADWAY PRODUCTIVITY LOSSES

Roadways are built to provide traffic capacity to vehicles. For instance, freeways are generally built to provide a capacity of between 1,600 and 2,000 vehicles per hour per lane. When a segment of the freeway provides this "design" capacity, it is considered productive. However, the roadway system loses its productivity when it is unable to provide the capacity that it was designed to serve. This occurs at locations commonly referred to by transportation planners and engineers as bottlenecks and the queues building up behind

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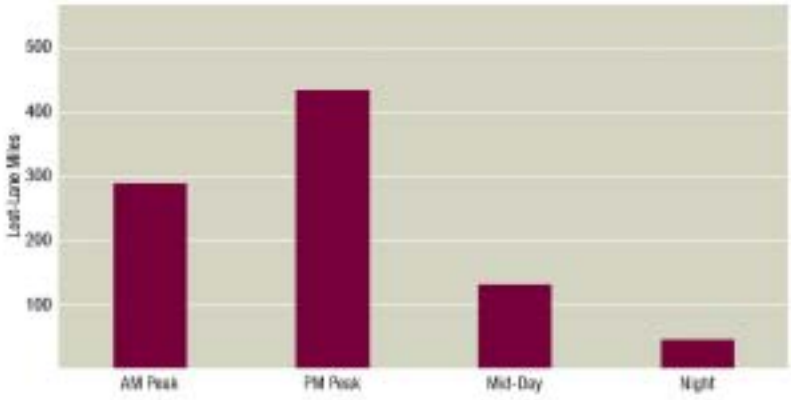
these bottlenecks (e.g., at freeway-to-freeway interchanges). The resulting productivity losses of the system occur generally during peak demand periods and are caused by merges, weaves, lane drops, stalls, accidents, and other factors. So, in effect, when demand is highest, system productivity actually decreases. Many freeway segments in the SCAG Region experience productivity losses and end up serving between 1,000 and 1,500 vehicles per hour per lane instead of the almost 2,000 vehicles per hour per lane for which they were designed.

When these productivity losses are aggregated, they can be presented in terms of "Lost Lane-Miles," which reflect the equivalent capacity subtracted from the roadway system. Figure 2.8 presents the results of an analysis to estimate the lost productivity in the SCAG Region based on actual traffic data from the region's freeway system during the four major time periods of the day: AM Peak, PM Peak, Mid-Day, and Night.

This "lost" capacity in the AM peak period, attributable to a large extent to non-recurring incidents such as accidents, weather conditions, stalled vehicles, etc., could have the effect of the loss of approximately 286 lane-miles of freeway capacity when it is needed the most. The cost of physically adding this lost capacity by widening existing facilities would exceed $4 billion.

FIGURE 2.8 PRODUCTIVITY RESULTS BY TIME PERIOD



Source: Freeway Performance Measurement System (PeMS)

SUPPLY NOT KEEPING UP WITH DEMAND

As mentioned previously, people are moving further away from established urban areas, at least partly because of housing costs. This creates incremental demand for travel. The size of the roadway system, however, has not kept pace with population and transportation demand. Figure 2.9 illustrates this problem. The figure shows that while California's population and total vehicle miles traveled have more than doubled since 1970, expenditures on this vital system have decreased significantly beginning in the early 1970s and still have not reached the level of investments made during the 1960s. Once the preservation and operations costs are subtracted from these expenditures and the high construction inflation is accounted for, it is easy to understand why the supply of roadways did not keep up with the demand growth for over three decades.

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FIGURE 2.9 CALIFORNIA POPULATION, TRAVEL, AND HIGHWAY EXPENDITURE TRENDS*

* Includes expenditures for local assistance and state highway capital outlay. Office of Transportation Economics/DOTP 9/2006

Source: California Department of Transportation

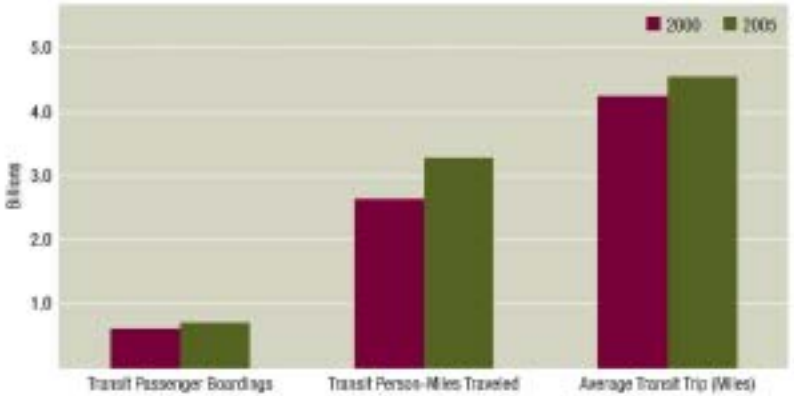
Note that these trends were not altogether unintentional. In fact, starting in 1980, a major shift occurred away from building roadways and into transit projects and services. This trend was planned and executed deliberately and understandably.

GROWING, BUT STILL MODEST PUBLIC TRANSIT USAGE

The investments in public transit since the 1980s have started to pay off. This success of transit is easily measured. Between 2000 and 2005, regional transit use increased by more than 16 percent, from 622 million annual unlinked passenger trips to more than 722 million, as shown in Figure 2.10. Transit person-miles traveled (PMT) increased by more than 24 percent to nearly 3.3 billion person-miles in 2005.

Continuing a trend of more per capita transit use that began in the mid-1990s, transit ridership per capita has reached nearly 40 boardings per person in the region by 2005. This rate had not been seen since the mid-1980s. Our regional investments in new transit modes and innovative services are a significant factor in achieving this growth. Additionally, more people are traveling longer distances, as shown in Figure 2.10. The length of an average transit trip increased from under 4.3 miles in 2000 to more than 4.5 miles in 2005. This represents a seven percent increase.

FIGURE 2.10 TRANSIT BOARDINGS AND PERSON-MILES TRAVELED, 2000-2005



Source: Federal Transit Administration (FTA) National Transit Database

However, regional transit operators still struggle to attract a significantly higher share of the traveling public. Despite the increase in boardings and per capita transit use, SCAG's Regional Travel Demand Model estimates that in 2003, less than 3 percent of all trips and person-miles traveled in the region were taken on public transit. A bright note is that since the rate of growth in transit use has outpaced growth in highway and arterial VMT by more than threefold since the year 2000, there are indications that regional investments may attract a greater share of the public in the future, especially with rising gasoline prices.

The development of new rail and bus transit corridors has spawned investment in new housing, retail, and business development at and near transit

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stations. These changes in land use, as outlined in the Compass Blueprint program, primarily through transit-oriented development, may result in fewer auto trips and reduced VMT by creating urban environments that provide better access to jobs and services, which in turn encourages more walking, bicycling and transit use.

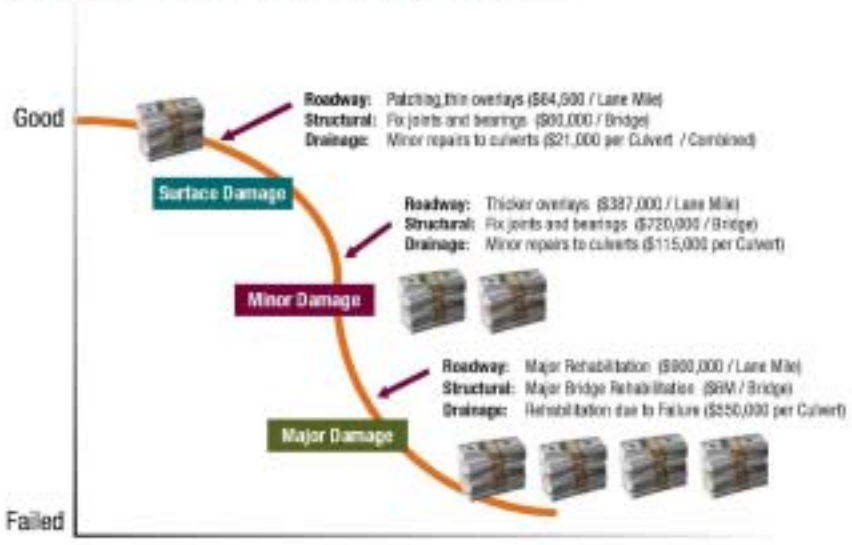
AGING INFRASTRUCTURE

The need to preserve our transportation assets adequately was brought to the nation's attention after the Minnesota I-35W bridge collapse during the summer of 2007. We must recognize that our roadway network and transit systems developed over the past decades are aging. These regional assets represent hundreds of billions of dollars of investments that must be protected in order to serve us and future generations. Without these assets, or even a portion of these assets, the region's mobility would be significantly compromised.

Unfortunately, our region's roadways, especially the State Highway System that is owned and operated by Caltrans, have not been maintained adequately. Caltrans reports that 28 percent of its pavement requires rehabilitation (based on 2005 statistics). Regional arterial studies have concluded similar needs.

Deferred maintenance leads to higher costs, as shown in Figure 2.11. Whereas pavement surface damage requires an investment of $64,000 per lane-mile to bring it to a state of good repair, the costs escalate significantly if these investments are not secured in a timely manner. In fact, the costs for minor damage repair escalate more than fivefold to $387,000, and the costs for major damage repair escalate to an astronomical $900,000 per lane-mile.

FIGURE 2.11 PRESERVATION COST-EFFECTIVENESS



EXPLOSIVE GROWTH IN GOODS MOVEMENT

The SCAG Region's goods movement system serves as the gateway for both international and domestic commerce. Supported in part by its geographical advantages such as deep-water marine ports, and highly developed network of highways and railways, availability of transloading facilities and its large internal market, goods movement is the fastest-growing segment of the region's transportation sector. Every state in the nation receives goods that pass through Southern California, and the region is a cornerstone of the nation's global competitiveness.

The San Pedro Bay Ports, which include the Los Angeles and Long Beach Ports, currently handle approximately 40 percent of the volume imported into the country and approximately 24 percent of the nation's exports, and one out of every seven jobs in Southern California depends on this trade. Figure 2.12 reflects the explosive growth in container volume processed by the San Pedro

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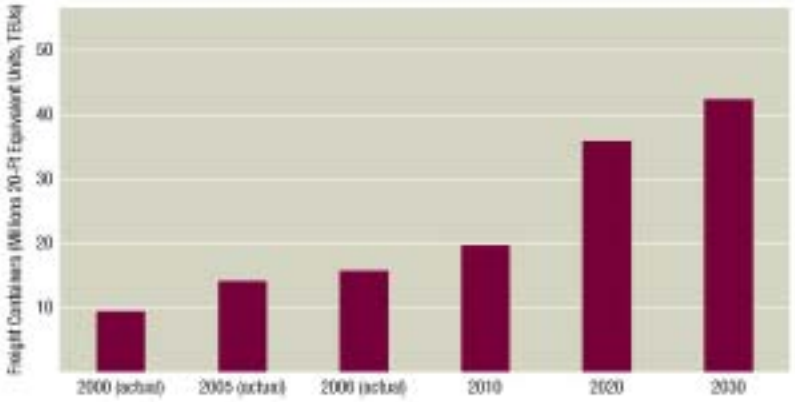
Bay Ports. It shows an almost 60 percent increase in volume between the years 2000 and 2006. Moreover, it also shows that this type of growth will continue, leading to an almost tripling of container volume by 2030.

FIGURE 2.12 SAN PEDRO BAY PORTS CONTAINER VOLUME TREND AND PROJECTIONS



Source: Port of Long Beach and Port of Los Angeles

As the only deep-water port between Los Angeles and San Francisco, the Port of Hueneme in Ventura County is a major shipping point for automobiles, fresh fruit and produce. Approximately $7 billion in cargo traverses through this Port annually, and trade-related activity generated by the Port contributes significantly to the local economy.

Cross-border trade activity also contributes to the region's international trade growth, with the growth in Mexico's manufacturing industry increasing truck trips through Calexico East in Imperial County by 77 percent between 1994 and 2005.

More than 75 percent of the containers processed by the ports in 2006 and 2007 involved at least one truck trip within the SCAG Region, either to a rail intermodal facility, a warehouse, or a transload facility. These trucks contribute to the existing congestion in the region and will contribute to future congestion even more, as the number of trucks is projected to increase significantly for several major freeways, as shown in Table 2.6.

TABLE 2.6 DAILY TRUCK VOLUMES BY CORRIDOR (THOUSANDS)

Freeway	2003*	2035*
I-110	21.1	27.8
I-405	33.2	39.4
I-10	26.3	47.0
US-101	32.3	40.2
I-105	20.8	30.8
I-5	35.7	62.1
I-710	38.6	63.3
SR-60	30.6	43.2
SR-111	1.8	6.2

* Daily Truck Volumes based on the maximum volume for a segment per freeway

Source: SCAG Model

Recent projections included in SCAG's Inland Empire Railroad Main Line Study suggest that the number of freight trains on most Burlington Northern Santa Fe (BNSF) and Union Pacific (UP) lines will more than double between 2000 and 2025 in response to a tripling of container volume at the San Pedro Bay Ports. Although freight rail does not add to freeway congestion, it does pose serious quality of life issues for many communities. Some towns and cities witness 100 trains per day that literally split their communities into two sections for extended periods of time. Exhibit 2.8 shows the Colton crossing and suggests how rail traffic can seriously affect the quality-of-life and safety of a community.

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EXHIBIT 2.7 SCAG REGION REGIONAL AIR CARRIER SYSTEM

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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EXHIBIT 2.8 COLTON AT-GRADE RAIL CROSSING

Source: Google Maps

As the expanding goods movement sector continues to have a positive impact on our economy, it will also have critical and far-reaching impacts on our region's transportation system and public health. An essential element to improving the region's goods movement system will be to reduce its current and long-term impacts on public health and the environment.

AVIATION CAPACITY AND GROUND ACCESS CONSTRAINTS

The SCAG Region supports the nation's largest regional airport system in terms of number of airports and aircraft operations, operating in a very complex airspace environment. Exhibit 2.7 shows the SCAG regional air carrier airport system. The system has six established air carrier airports, including Los Angeles International (LAX), Bob Hope (formerly Burbank), John Wayne, Long Beach, Ontario and Palm Springs. There are also four new and emerging air carrier airports in the Inland Empire and North Los Angeles County. These include San Bernardino International Airport (formerly Norton Air Force Base [AFB]), March Inland Port (joint use with March Air Reserve Base), Southern California Logistics Airport (formerly George AFB) and Palmdale Airport (joint use with Air Force Plant 42). The regional system also includes 45 general aviation airports and two commuter airports (Oxnard and Imperial), for a total of 57 public use airports.

There are significant challenges in meeting the future airport capacity needs of Southern California. Work on SCAG's 2004 RTP concluded that an Aviation Decentralization Strategy is needed to meet the forecast doubling of air passenger demand by 2030, from the current 90 million annual passengers (MAP) to 170 MAP (according to the 2004 RTP). This is because the four urban air carrier airports in Los Angeles and Orange Counties—LAX, Bob Hope, Long Beach and John Wayne—are all highly constrained. Their collective acreage amounts to 5,540 acres, which is less than 17% of the 34,000 acres of Denver International, and less than the 7,700 acres of Chicago O'Hare. At 3,500 acres, LAX is a very small international airport despite being the third-busiest airport in the country and fifth-busiest in the world in terms of passengers served. All of these urban airports have little room to expand because of severe encroachment by surrounding communities. In addition, two of these airports—Long Beach and John Wayne—have strict limits on allowable flights that are legally enforceable (one is a city ordinance and the other is a court settlement agreement) since they predate the Federal Airport Noise and Capacity Act of 1990 (ANCA).

The challenge of meeting future aviation demand in the SCAG Region is inextricably tied to airport ground access, since in order to meet that demand the region will need to get future air passengers from the urban areas of Los Angeles and Orange Counties to available airport capacity in the Inland Empire and North Los Angeles County. The challenge is complicated by the fact that the regional roadway system will become increasingly unreliable, with daily delay on the system expected to more than double. This will place a great

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burden on the air traveler, who will have to allow for more time to get to the airport to catch his or her flight. It will make it difficult to expand the new airports with available capacity, since until they fully mature they will have few alternative flights to offer air travelers who miss their flights because of unreliable ground access. Unless the regional airport ground access system is substantially improved, many potential air travelers will choose not to fly at all, which will translate to substantial economic loss to the region.

Southern California airports play a crucial role in international trade, particularly with Pacific Rim countries, and to the regional economy. The value of airborne commodity exports out of the Los Angeles Customs District are about equal to waterborne exports, and airborne export values would be significantly greater if service exports, including impacts from tourism, were added to total export values. Therefore, the airport constraints our region faces pose a threat to our regional economy and well-being. A regional strategy is needed to help address this inter-regional mobility challenge.

Air Quality Challenges

The SCAG Region continues to have the worst air quality in the nation, even despite improvements gained in the last two decades. The recently documented health impacts of air pollution on people living in the South Coast Air Basin are staggering. Of all the people nationwide who are exposed to PM2.5 levels that exceed the federal health-based standard, 52% live here. Of all the people statewide who are exposed to these levels, 82% live here. This is estimated to result in 5,400 premature deaths and 980,000 lost work days per year.[1] These impacts, and the fact that a substantial portion of emissions are outside of local and state control, led SCAG to urge via Resolution the declaration of a state and federal emergency to address the air quality health crisis. Subsequently, the South Coast Air Quality Management District (SCAQMD), the California Air Resources Board (ARB), and SCAG collaboratively completed the difficult task of developing a plan to achieve the federal health-based PM2.5 and ozone standards in the South Coast Air Basin. Implementation of this plan will require vigorous effort and significant resources from both public and private stakeholders.

[1] Personal communication, Richard Bode, California Air Resources Board, 2007.

ATTAINMENT OF AIR QUALITY STANDARDS

Much of the region continues to exceed the National Ambient Air Quality Standards (NAAQS) identified in the Clean Air Act. The table below summarizes the non-attainment and maintenance areas within the SCAG Region.

TABLE 2.7 SCAG REGION NON-ATTAINMENT AND MAINTENANCE AREAS

Ozone	PM10	PM2.5	CO	NO_2
South Coast Air Basin (SCAB),	SCAB	SCAB	SCAB	SCAB
Coachella Valley portion of Salton Sea Air Basin (SSAB),	Coachella Valley portion of SSAB			
Ventura County portion of South Central Coast Air Basin (SCCAB),	San Bernardino portion of MDAB			
Western portion of Mojave Desert Air Basin (MDAB),	Imperial County portion of SSAB			
Imperial County portion of SSAB				

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Further, as demonstrated by the recent AQMP/SIP efforts of local air districts and the ARB, the region's efforts to attain the NAAQS continue to be challenging, as the South Coast Air Basin, the Ventura County portion of the South Central Coast Air Basin, the Western Mojave Air Basin, and the Riverside County portion (Coachella) and the Imperial County portion of the Salton Sea Air Basin will all be "bumping up" to worse ozone non-attainment designations since they cannot achieve the NAAQS in the time previously assumed. Further, the attainment plan to meet the ozone standard in the South Coast Air Basin includes undefined long-term ("black box") measures of approximately 200 tons per day of nitrogen oxides (NOx), which is a daunting amount of as-yet-unidentified emission reductions. Of additional concern are the upcoming 24-hour PM2.5 standards, which will require even greater reductions as well as possibly more stringent ozone standards. Consequently, the ARB, SCAQMD, and SCAG are committed to producing a white paper that identifies strategies to address the shortfall issues. Furthermore, there are strategies and programs in this Plan that will be incorporated into the white paper.

AIR QUALITY IMPACTS AND PROJECT IMPLEMENTATION

Another important consideration for air quality and transportation planning is the general inability of project sponsors to move proposed projects through the environmental review process. Community opposition is demanding mitigation of emissions from existing as well as future transportation facilities. Of equal concern, the failure to implement adequate SIPs for the region could result in federal sanctions, such as a ban on approval of new highway projects, loss of highway funding, and restrict our ability to spend local and private dollars, as well as more stringent emissions offsets for stationary sources.

Given the challenges that lie ahead, increased public awareness and a reinvigorated collaborative effort from all agencies and stakeholders are critical to bring this region into attainment of the federal air quality standards and to begin to address greenhouse gas (GHG) reduction targets. SCAG's contribution to this collaborative effort is essential, as emissions reductions from

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goods movement, marine ports, aviation and land use have come to be front and center of the air quality challenge.

Climate Change

In addition to the aforementioned challenges, efforts to reduce GHGs will present another tremendous challenge to the transportation sector. Transportation is the largest source of GHG emissions in California, representing 38 percent of emissions (Figure 2.13), and emissions from the transportation sector have grown more rapidly than other sources over the past ten years.[2] California is the second-largest emitter of GHG emissions in the United States and the twelfth-largest emitter in the world, exceeding most nations. The Intergovernmental Panel on Climate Change of the United Nations has found overwhelming evidence that global climate change is occurring and is caused by human activity.[3] Global climate change involves an increase in the average atmospheric temperature of the earth caused by an enhanced greenhouse effect. Changes to the atmospheric temperatures would likely cause an increase in sea levels and alter weather patterns, thereby increasing the frequency and severity of extreme weather worldwide. Climate change also poses serious risks to our economy, water supply, biodiversity, and public health.[4]

These potentially catastrophic impacts have led to new efforts to reduce the amount of GHG emissions released into the atmosphere. In 2006, California passed the Global Warming Solutions Act, or AB 32, which requires a reduction of the state's GHG emissions to 1990 levels by 2020. This emissions target is equal to a 25% reduction from current levels. Longer-term targets have also been set through Executive Order S-3-05, which calls for a reduction of GHG emissions to 80% below 1990 levels by 2050. These reduction targets will have implications on the transportation sector and alter the way we fuel our future. For example, California's Low Carbon Fuel Standard (Executive Order S-01-07) requires a reduction in the carbon intensity of California's passenger vehicle fuels by at least 10 percent by 2020. The California Air Resources Board identified the Low Carbon Fuel Standards as a discrete early action item under AB 32, with a regulation to be adopted and implemented by 2010. Other transportation-related discrete early action items include green ports, Smart Way truck efficiency, and a tire inflation program.[5] In addition, AB 1007 requires the development and adoption of a state plan to increase the use of alternative transportation fuels by establishing a roadmap to help reduce our dependence on foreign oil. The State Alternative Fuels Plan was adopted by the California Energy Commission on December 5, 2007.

[2] California Air Resources Board, Greenhouse Gas Emissions Inventory (November 2007); United States Department of Transportation, Federal Highway Administration. Transportation and Global Climate Change: A Review and Analysis of the Literature. (June 1998.) DOT-T-97-03.

[3] Intergovernmental Panel on Climate Change. (February 2007.) Fourth Assessment Report of the IPCC, Climate Change 2007: The Physical Science Basis, Summary for Policy Makers.

[4] California Energy Commission. Our Changing Climate: Assessing the Risks to California (July 2006) CEC-500-2006-077. Retrieved March 26, 2007, from http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF

[5] California Air Resources Board. Expanded List of Early Action Measures to Reduce GHG Emissions in California Recommended for Board Consideration. October 2007.

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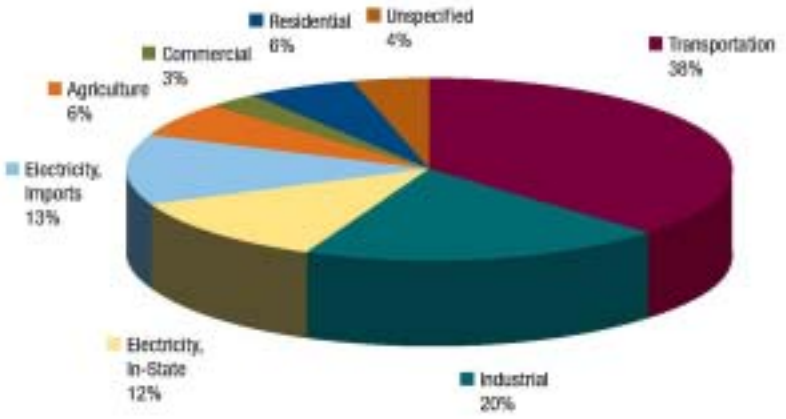
FIGURE 2.13 2004 CALIFORNIA CLIMATE GREENHOUSE GAS EMISSIONS BY SECTOR



Source: California Air Resources Board, Greenhouse Gas Emissions Inventory (November 2007)

Energy

Environmental and geopolitical factors are causing energy experts to question the long-term viability of a fossil fuel-based energy future. The 2008 RTP begins to recognize the uncertainty of petroleum-based future, and seeks to better understand the implications of potential energy constraints. Travel demand forecasts generally assume that the future will include an abundant and relatively inexpensive supply of transportation fuels. If transportation fuel prices continue to increase, it would have a ripple effect on numerous areas including construction costs, gas tax revenue, travel and aviation demand, air emissions, mode choice and growth patterns. One area of uncertainty is how commuters may respond to higher gasoline prices. For example, a recent study suggests that with a ten percent increase in the gas price, there is a less than one percent change in gas consumption,[6] while other data show that an increase in gas prices coincides with an increase in transit ridership.[7] In addition, growth patterns may alter future demand for transportation fuels. Mixed land uses (i.e., residential developments near work places, restaurants, and shopping centers) with access to public transportation have been shown to save consumers over 500 gallons of gasoline per year.[8] Energy uncertainty requires serious consideration and further study. SCAG, with input from stakeholders, will continue to research the relationship between transportation, land use and energy uncertainty. The following issues have been recommended for additional study and deliberation prior to development of the next Regional Transportation Plan:

- How the price and availability of transportation fuels affects revenues and demand
- How increases in fuel efficiency could affect revenues and emissions

[6] Jonathan Hughes, Christopher R. Knittel, and Dan Sperling, "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand," February 14, 2007.

[7] California Energy Commission. Weekly Fuel Prices 1996-2007 and SCAG Transit Ridership data.

[8] Victoria Transport Policy Institute. Transportation Demand Management Encyclopedia.

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- How the cost of commuting and personal travel affects mode choice and growth patterns
- How the cost of goods movement affects international trade and employment, and
- How the escalation of fuel prices affects the cost of infrastructure construction, maintenance and operation

Transportation Finance Challenges

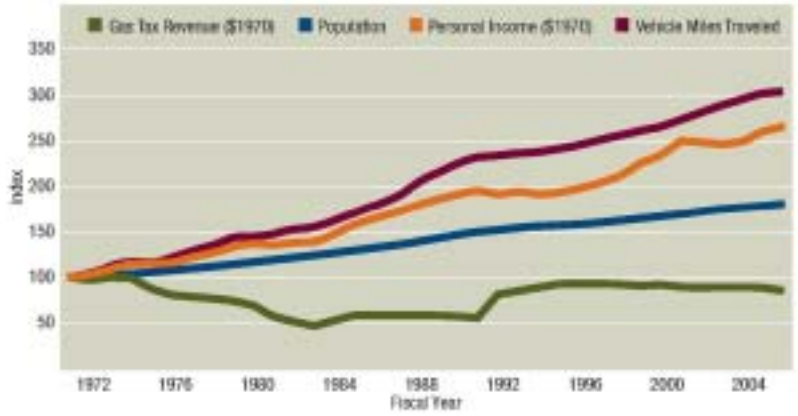
ONGOING FISCAL CHALLENGES

The SCAG Region continues to face shortfalls in transportation funding. The following briefly describes current and projected challenges that are likely to impact transportation revenues flowing to the region.

EROSION OF GASOLINE TAX REVENUES DUE TO INFLATION

Over the past four decades, transportation revenues (from gasoline taxes collected per gallon) in California have not kept pace with the state's ever-evolving demographic characteristics. Figure 2.14 shows how these tax revenues have fluctuated in real-dollar terms (adjusted for inflation) in relation to the steady growth in the demographic indicators. Indicators such as vehicle miles traveled, population, and personal income growth have all outpaced the rate of transportation revenue growth. The largest contributing factor is that the gasoline taxes are collected in cents per gallon. Without periodic adjustment or indexing, these funds will not keep pace with needs. Although the passage and recent renewal of local "self-help" transportation sales taxes have greatly improved funding for transportation, gasoline tax revenues continue to decline in value due to inflation.

FIGURE 2.14 REVENUE AND DEMAND TRENDS IN THE SCAG REGION



Sources: California Department of Transportation, California Department of Finance, U.S. Department of Labor

STATUS OF THE STATE HIGHWAY ACCOUNT

The viability of the State Highway Account remains a critical issue. The state's gasoline tax revenues are now exclusively dedicated to funding the needs of the State Highway Operation and Protection Program (SHOPP)—at a level, however, that is considerably less than actual needs. Continued underinvestment in the rehabilitation and maintenance needs of the State Highway System has serious ramifications—rapidly increasing the number of distressed lane-miles on the State Highway System and eroding the condition of the state's bridges. In recent years, transportation has relied heavily on the State General Fund to pay for capacity-enhancing projects. For example, funding for the State Transportation Improvement Program (STIP) has been dependent on Proposition 42 transfers (sales tax on gasoline). Reliance on the State General Fund means that transportation funding is subject to the state's annual budget process, which can be lengthy and unpredictable. Although the

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recently passed transportation bond measure (Proposition 1B) serves as an important down payment, reliable and sustainable funding sources for transportation are necessary to meet the needs of a growing population.

STATUS OF THE FEDERAL HIGHWAY TRUST FUND

The need to establish a reliable and sustainable transportation funding source is even stronger, as the Federal Highway Trust Fund may not have enough resources to meet all of its obligations by the end of the decade. Expenditures authorized under SAFETEA-LU have outstripped revenues generated by the federal per-gallon gasoline tax. As a result, the viability of the Highway Trust Fund will be a critical issue in discussions for the next round of the federal transportation reauthorization legislation, which will start in 2009.

CONSTRUCTION COST INCREASES

Over the last four years, construction costs in California and the nation have increased at an unprecedented rate and much faster than general inflation. Figure 2.15 shows increases in the California Highway Construction Cost Index since the 1970s compared to the Consumer Price Index. The recent run-up in construction prices is due to a variety of factors, including a residential and commercial building boom as well as higher demand for construction materials in developing countries, most notably, China. Although these trends are likely to fluctuate, they have caused many transportation projects to exceed their budgets in the short term and made long-term project cost forecasting uncertain.

FIGURE 2.15 CALIFORNIA HIGHWAY CONSTRUCTION COST & CONSUMER PRICE INDEX TRENDS

Source: California Department of Transportation and U.S. Bureau of Labor Statistics

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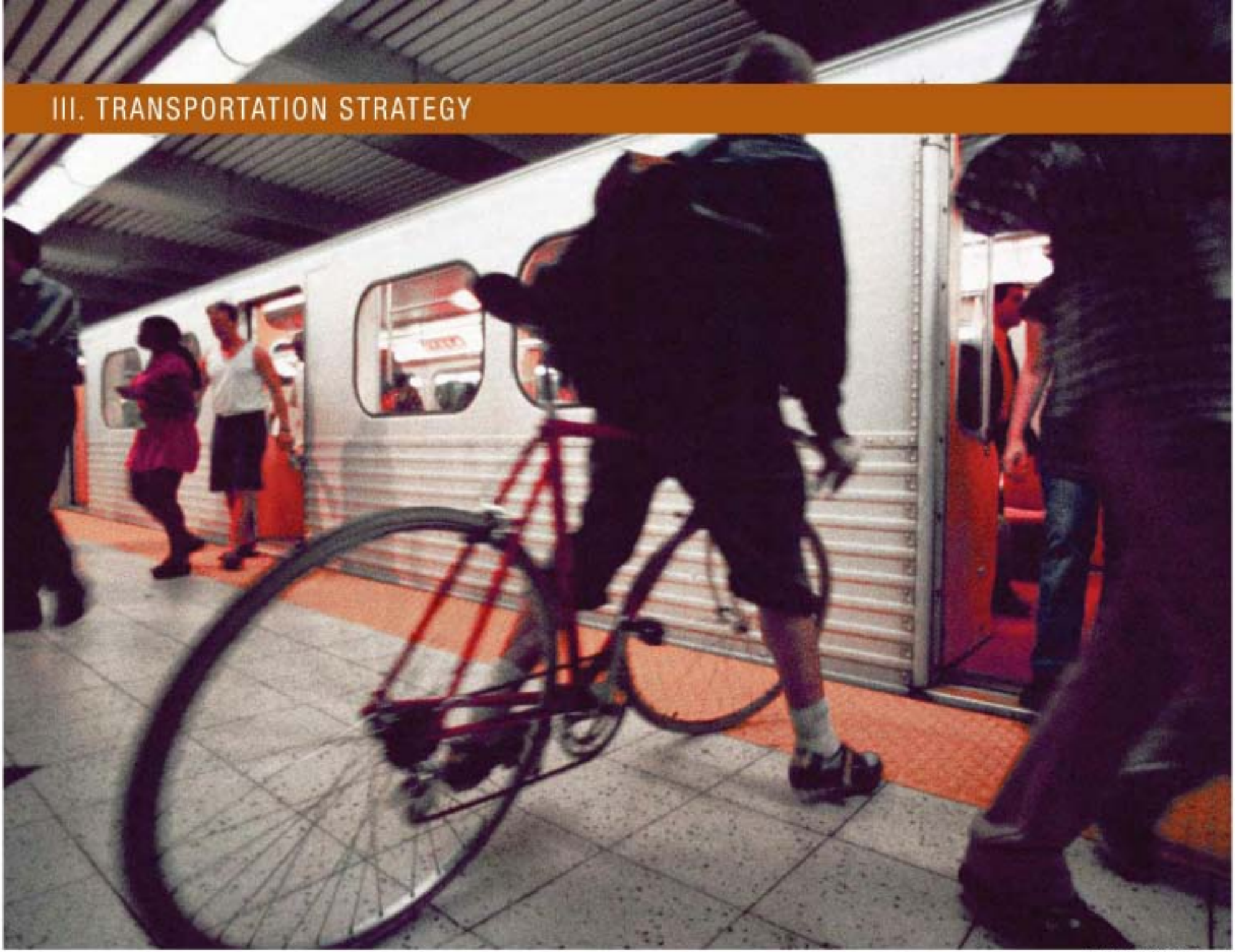
III. TRANSPORTATION STRATEGY



The mobility challenges presented in Chapter II are linked to the continued growth of the SCAG Region. The demographic, economic, and geographic constraints unique to our region exacerbate the condition of an already burdened transportation system. To address these challenges, this chapter identifies the policies, strategies, and investments necessary to maintain, manage, and improve the region's transportation system through the year 2035. This vision reflects a regional consensus achieved over the last four years.

This chapter is organized into three main sections. The first section discusses SCAG's efforts to enhance transportation security and safety measures in the region, and specifically lists SCAG's responsibilities in emergency preparedness. The second section describes the various transportation strategies the SCAG Region has agreed to fund and implement through 2035. Particular focus is given towards the regional goods movement system because of the critical impact it has on the region's mobility, economy, and public health. The complete listing of RTP investments is contained in the separate RTP Project List available at www.scag.ca.gov. The third and last section identifies the environmental impacts posed by the transportation strategies listed in this chapter, and describes feasible approaches to mitigate those impacts.

Security and Safety First

TRANSPORTATION SECURITY

The SCAG Region is vulnerable to many types of catastrophic events including earthquakes, floods, fires, hazardous material incidents, dam failures, civil unrest, transportation accidents, tsunamis and terrorism.

California, through hard experience, has in place an emergency and response structure designed to be innovative for the different locations and types of emergencies. There are many agencies that will participate in the response to a disastrous event and ensure that their jurisdictions are prepared to respond to these hazards. To assist in this effort, this chapter identifies SCAG's potential role and responsibility in regards to the relationship between transportation and emergency preparedness.

SECURITY AND EMERGENCY PREPAREDNESS

SCAG's Regional Preparedness Goal is stated as, "to achieve and sustain at-risk target levels of capability to prevent, protect against, respond to, and recover from major human-caused or natural events in order to minimize the threat and impact to lives, property, and the region."

SCAG'S ROLE

SCAG does not intend to undertake a first response or emergency management role. As a metropolitan planning organization (MPO), SCAG is limited to essentially three roles:

1. Provide a policy forum to help develop regional consensus and education on security policies and emergency response
2. Assist in the planning and programming of transportation infrastructure repairs, and
3. Leverage projects and planning functions (including Intelligent Transportation Systems, also known as ITS) that can enhance or provide benefit to transportation security efforts and those responsible for planning and responding to emergencies:
   - Integrate security into the regional ITS architecture, and
   - Become a central repository/mirror for regional Geodata that can be used for planning, training, response and relief efforts of law enforcement personnel and emergency responders

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POLICIES

Within the goal of transportation security, SCAG aims to help prevent, protect from, respond to, and recover from major human-caused or natural events in order to minimize the threat and impact to lives, property, the transportation network and the regional economy.

Through stakeholder input, the Southern California Association of Governments (SCAG) developed an action plan and constrained policies detailing nine measures that the agency will undertake in the region's transportation security planning.

1. SCAG should help ensure the rapid repair of transportation infrastructure in the event of an emergency.
   a. SCAG, in cooperation with local and state agencies, should identify critical infrastructure needs necessary for: a) emergency responders to enter the region; b) evacuation of affected facilities; and c) restoration of utilities.
   b. SCAG, in cooperation with CTCs, California, and the federal government, should develop a transportation recovery plan for the emergency awarding of contracts to rapidly and efficiently repair damaged infrastructure.
2. SCAG should continue to deploy and promote the use of intelligent transportation system technologies that enhance transportation security.
   a. SCAG should work to expand the use of ITS to improve surveillance, monitoring and distress notification systems and to assist in the rapid evacuation of disaster areas.
   b. SCAG should incorporate security into the Regional ITS Architecture.
   c. Transit operators should incorporate ITS technologies as part of their security and emergency preparedness and share that information with other operators.
   d. Aside from deploying ITS technologies for advanced customer information, transit agencies should work intensely with ethnic, local and disenfranchised communities through public information/outreach sessions ensuring public participation is utilized to its fullest. In case of evacuation, these transit-dependent persons may need additional assistance to evacuate to safety.

3. SCAG should establish transportation infrastructure practices that promote and enhance security.
   a. SCAG should work with transportation operators to plan and coordinate transportation projects, as appropriate, with the Department of Homeland Security grant projects, to enhance the regional transit security strategy (RTSS).

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b. SCAG should establish transportation infrastructure practices that identify and prioritize the design, retrofit, hardening, and stabilization of critical transportation infrastructure to prevent failure; to minimize loss of life and property, injuries; and avoid long-term economic disruption.

c. SCAG should establish a Transportation Security Working Group (TSWG) with goals of RTP consistency with RTSS, and to find ways SCAG programs can enhance RTSS.

4. SCAG should establish a forum where policy-makers can be educated and regional policy can be developed.

   a. SCAG should work with local officials to develop regional consensus on regional transportation safety, security, and safety/security policies.

5. SCAG will help enhance the region's ability to deter and respond to acts of terrorism and human-caused or natural disasters through regionally cooperative and collaborative strategies.

   a. SCAG should work with local officials to develop regional consensus on regional transportation safety, security, and safety/security policies.

   b. SCAG should encourage all SCAG elected officials to be educated in National Incident Management System (NIMS).

   c. SCAG should work with partner agencies and federal, state and local jurisdictions to improve communications and interoperability and to find opportunities to leverage and effectively utilize transportation and public safety/security resources in support of this effort.

6. SCAG will work to enhance emergency preparedness awareness among public agencies and with the public at large.

   a. SCAG should work with local officials to develop regional consensus on regional transportation safety, security, and safety/security policies.

7. SCAG should work to improve the effectiveness of regional plans by maximizing the sharing and coordination of resources that would allow for proper response by public agencies.

   a. SCAG should encourage and provide a forum for local jurisdictions to develop mutual aid agreements for essential government services during any incident recovery.

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8. SCAG will help to enhance the capabilities of local and regional organizations, including first responders, through provision and sharing of information.
    a. SCAG should work with local agencies to collect regional GeoData in a common format, and provide access to the GeoData for emergency planning, training and response.
    b. SCAG should establish a forum for cooperation and coordination of these plans and programs among the regional partners including first responders and operations agencies.
    c. SCAG should develop and establish a regional information sharing strategy, linking SCAG and its member jurisdictions for ongoing sharing and provision of information pertaining to the region's transportation system and other critical infrastructure.
9. SCAG should provide the means for collaboration in planning, communication, and information sharing before, during, or after a regional emergency.
    a. SCAG should develop and incorporate strategies and actions pertaining to response and prevention of security incidents and events as part of the ongoing regional planning activities.
    b. SCAG should offer a regional repository of GIS data for use by local agencies in emergency planning and response in a standardized format.
    c. SCAG should enter into mutual aid agreements with other MPOs to provide this data, in coordination with the California OES in the event that an event disrupts SCAG's ability to function.

TRANSPORTATION SAFETY

The safety of the region's multimodal system is a critical priority for SCAG and the California Department of Transportation (Caltrans), which owns and operates the State Highway System. When examined historically, fatal and injury collisions (rate per million vehicle miles traveled) have steadily decreased in California since the 1930s.

While traffic fatalities in the SCAG Region are below the rest of California (the SCAG Region represents almost half of California's population), the number of fatalities has increased every year since 1999 after declining in the latter part of the 1990s.

In 2005, just over 1,800 people in the SCAG Region were killed in traffic accidents. Statewide, 4,304 were killed. Every year since 2002, the total number of traffic injuries in the SCAG Region has surpassed that in the rest of the state. Much of that can be attributed to the growth in vehicle miles traveled.

Additionally, in 2005, 372 pedestrians and 66 bicyclists were killed in the SCAG Region, representing 50 percent of pedestrians and 57 percent of bicyclists killed in California.

The 2008 RTP continues the commitment to improve safety for the region. In 2007, the region fully funded highway collision reduction and emergency response needs, estimated at $317 million and $110 million, respectively. This was the only category that was fully funded. Activities within this category include the construction of median barriers and response to landslides, as depicted in Exhibits 3.1.1 and 3.1.2.

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EXHIBIT 3.1.1 HIGHWAY COLLISION REDUCTION MEASURES

EXHIBIT 3.1.2 EMERGENCY RESPONSE NEEDS

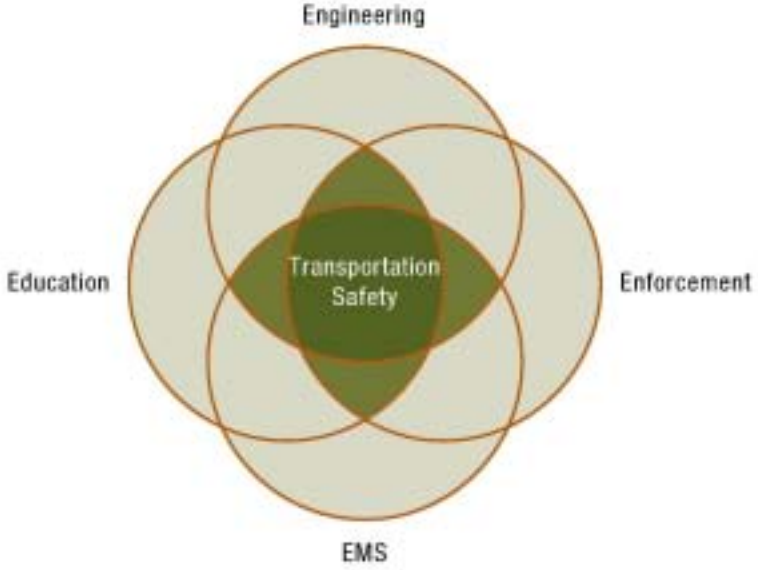
Through 2035, the RTP forecasts expenditures of $10 billion for safety-related projects and services. This is in addition to safety standards considered as part of every project design. The scope of this RTP goes beyond specific funding for safety preparedness or emergency response. It emphasizes the collaboration among SCAG, Caltrans, and their stakeholders to examine safety on a system basis so the region can use all the tools available to decrease traffic injuries and fatalities. The result of this collaboration is the California Strategic Highway Safety Plan.

CALIFORNIA STRATEGIC HIGHWAY SAFETY PLAN

In 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was passed. The legislation required that each state develop a Strategic Highway Safety Plan (SHSP) and that all metropolitan long-range transportation plans should be consistent with the SHSP.

When addressing transportation safety, the four Es are frequently referenced to describe the multidisciplinary nature of transportation safety planning. The four Es are Engineering, Education, Emergency Medical Services (EMS), and Enforcement. The area in which planners have the most ability to effect change is likely to be engineering and the development of physical improvements to the transportation system.[1]

FIGURE 3.1 THE FOUR "E" ELEMENTS IN TRANSPORTATION SAFETY PLANNING



Additionally, a fifth E, or Evaluation, can be applied to this paradigm. Evaluation refers to monitoring and reviewing the effectiveness of the other four Es, allowing modifications where applicable. The California draft SHSP lists 16 challenge areas designed to reduce accidents, fatalities and injuries. Figure 3.2 presents the 16 Challenge Areas and resultant strategies that were developed during several workshops held by Caltrans for various stakeholder agen-

[1] Transportation Planner's Safety Desk Reference, Report No. FHWA-HEP-07-005.

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FIGURE 3.2 CHALLENGE AREAS AND THE CORRESPONDING REGIONAL RESPONSE AS OUTLINED IN THE STRATEGIC HIGHWAY SAFETY PLAN (SHSP)

SAFETEA-LU requires that the region's plan be consistent with the California Strategic Highway Safety Plan

SHSP Challenge Area	RTP Discussion	Regional Response
• Reduce the Occurrence and Consequence of leaving the roadway and head-on collisions • Improve Driver Decisions about Rights of Way and Turning • Improve Intersection and Interchange Safety for Roadway Users • Make Walking and Street Crossing Safer • Improve Safety for Older Roadway Users • Improve Commercial Vehicle Safety • Improve Bicycle Safety	In Safety Chapter	• Identify projects that address safety in designated "hot spots" • Encourage transportation projects that specifically enhance safety or complement education, enforcement or EMS for each challenge area • Request RTP project submissions that identify the portion of the project that is applied to safety elements and/or project components for motorized and non-motorized users, including older drivers, bicyclists and pedestrians.
• Reduce Impaired Driving Related Fatalities • Ensure Drivers are Licensed and Competent • Increase Use of Safety Belts and Child Safety Seats • Reduce Young Driver Fatalities • Reduce Speeding and Aggressive Driving • Improve Motorcycle Safety • Enhance Work Zone Safety • Improve Post Crash Survivability • Improve Safety Data Collection, Access and Analysis	Outside of SCAG's RTP Role	• Endorse Cooperation with regional and local law enforcement, emergency response and education agencies as they address these transportation safety challenges. • Work with the state and county transportation commissions to determine if various project submissions have potential benefit to safety in these challenge areas.

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cies statewide, including SCAG. Each Challenge Area contains the following elements:

- Establishment of a goal for improving safety by 2010
- Background information on the Challenge Area including a history of fatalities from 1995 – 2004
- Strategies being considered for implementation to achieve the Challenge Area goal
- Institutional and other issues that could affect the success of the implementation

Separate security and safety reports elaborate on the contents of this table.

Managing Our Transportation System Wisely

The region recognizes that maintaining and improving mobility will no longer depend solely on its ability to expand its multimodal transportation system. Instead, an integrated approach--based on the statewide GoCalifornia initiative--is needed to maximize mobility. Depicted in Figure 3.3, the five elements of the pyramid represent integrated strategies that work cooperatively to maximize mobility. The pyramid depicts the idea that transportation investments would have more impact if they were prioritized strategically as suggested. System monitoring and evaluation is the basic foundation upon which the other strategies are built. System expansion and completion will provide the desired mobility benefits to the extent that investments in, and implementation of, the strategies below it achieve progress. An improvement in mobility will occur when strategic investments in each of the elements are coordinated between the elements. The mobility pyramid provides the framework for the discussion of the RTP's transportation investment strategies.

Complementing our transportation investment philosophy is the performance-measures approach utilized in developing this Plan. While the pyramid approach ensures that our funding priorities are clear and rational, performance measures ensure that the best performing projects are included in the Plan for funding.

FIGURE 3.3 MOBILITY PYRAMID

SYSTEM MONITORING AND EVALUATION

In order to be effective system managers, we must have an in-depth understanding of how our system performs and why it performs that way. For instance, we all know congestion is a problem in the region. But we must also be able to quantify congestion and understand its various causes. Only by understanding these causes can we identify the optimal mix of strategies and projects that yield the highest returns on the region's investments. The same holds true for transit, goods movement, and aviation.

The base of the mobility pyramid, entitled "System Monitoring and Evaluation," is the foundation of sound system management. It calls for the use of

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performance measures to track and monitor the progress of the transportation system so that the region can make informed decisions regarding transportation investments. Transportation professionals and decision-makers have recently committed to improving the region's ability to properly fund the investments needed to comprehensively monitor and evaluate system performance. These investments include detection, closed-circuit television systems, bus global positioning systems, and automatic ridership counting

systems. Although funding is modest for these activities, they lead to more informed decisions. Further discussion of system monitoring is contained in Chapter VI.

As we move forward, our focus will evolve into a comprehensive system management approach, which aims to protect, maximize the productivity of, and strategically expand our transportation system.

PROTECTING OUR REGION'S TRANSPORTATION ASSETS

Over the decades, the region has invested hundreds of billions of dollars in our multimodal transportation system. The system is now aging and requires immediate attention. Preserving our assets is a critical priority of this RTP.

In a sense, the region must make up for past funding shortfalls. As discussed in Chapter II, roadway expenditures have not kept up with demand over the last three decades. As a result, we have not properly funded roadway preservation needs. The recent passage of the Infrastructure Bond injected much needed funding to highway preservation. However, SCAG estimates that an additional $30 billion is required to bring the system into a comprehensive state of adequate repair.

SCAG also estimates that an additional $10 billion is required for arterials and transit preservation needs. The subsequent shortfall for highway, arterial, and transit preservation needs totals $40 billion. Deferring maintenance only increases this shortfall over time.

Recognizing that every dollar expended today to address this shortfall would save much more in the future, the region committed $8 billion of new funding to preservation, thereby addressing at least 20 percent of preservation needs. As more funding becomes available, additional commitments will be made. These additional investments will ensure that over the next thirty years, our infrastructure will be in a better condition than it is today. This also

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means that user costs (e.g., vehicle maintenance costs) will decline compared to today.

SCAG will continue to work with its stakeholders, particularly county transportation commissions and Caltrans, to prioritize funding for preservation and maintenance.

INTEGRATED LAND USE AND DEMAND MANAGEMENT

The next set of strategies on the mobility pyramid focus on better managing demand on the transportation system through the integrated growth forecast, a statement of advisory land use policies and strategies, and encouraging alternative modes of travel.

INTEGRATED GROWTH FORECAST

In February 2005, SCAG initiated the 2008 RTP Growth Forecast Update Process, now known as the 2008 "Integrated Growth Forecasting" process. The resulting Baseline Growth Forecast established the projected population, employment, households and housing units for use in the 2008 RTP.

The Baseline Growth Forecast sets the stage for a future regional growth scenario, as it ties housing to transportation planning, considering both needs simultaneously in communities throughout the region. This approach ensures that the resulting assumptions are consistent with planned transportation infrastructure. Based on a combination of recent and past trends, reasonable key technical assumptions, and existing and new local policy options, the Baseline Growth Forecast provides the basis for developing the land use

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assumptions at the regional and small-area levels which build the 2008 RTP Plan Alternative. A detailed description of the growth forecast methodology is available in the 2008 RTP Growth Forecast Report.

Advisory Land Use Policies and Strategies

The 2008 RTP Plan Alternative incorporates the Baseline Growth Forecast and the approved transportation network. However, in the rapidly growing SCAG Region, these trends could be tempered, and in some cases bolstered, by policies and strategies designed to improve future travel patterns and vehicle emissions. In response, SCAG adopted a set of advisory land use policies and strategies for future regional planning efforts and for localities to consider as they accommodate future growth. These policies and strategies were founded upon the principles developed through the regional growth visioning efforts begun in 2001.

- **Identify regional strategic areas for infill and investment**

  Identify strategic opportunity areas for infill development of aging and underutilized areas and increased investment in order to accommodate future growth. This strategy makes efficient use of existing and planned infrastructure, revitalizes communities, and maintains or improves quality of life.

  Strategic areas are primarily identified as those with potential for:

  - Transit-oriented development (TOD)
  - Existing and emerging centers
  - Small mixed-use areas

- **Structure the plan on a three-tiered system of centers development**

  Identify strategic centers based on a three-tiered system of existing, planned, and potential, relative to transportation infrastructure. This strategy more effectively integrates land use planning and transportation investment.

- **Develop "complete communities"**

  Create mixed-use districts or "complete communities" in strategic growth areas through a concentration of activities with housing, employment, and a mix of retail and services, located in close proximity to each other. Focusing a mix of land uses in strategic growth areas creates complete communities wherein most daily needs can be met within a short distance of home, providing residents with the opportunity to patronize their local area and run daily errands by walking or cycling rather traveling by automobile.

- **Develop nodes on a corridor**

  Intensify nodes along corridors with people-scaled, mixed-use developments. Many existing corridors lack the residential and commercial concentration to adequately support non-auto transit uses, without which the existing transit system cannot fully realize its potential for accommodating additional trips and relieving the transportation system. These nodes along the corridor also create vibrant, walkable communities with localized access to amenities, further reducing reliance on the automobile for a variety of trips.

- **Plan for additional housing and jobs near transit**

  Pedestrian-friendly environments and more compact development patterns in close proximity to transit serve to support and improve transit use and ridership. Focusing housing and employment growth in transit-accessible locations through this transit-oriented development approach will serve to reduce auto use and support more multimodal travel behavior.

- **Plan for a changing demand in types of housing**

  Shifts in the labor force, as the large cohort of aging "baby boomers" retires over the next 15 years and is replaced by new immigrants and "echo boomers," will likely induce a demand shift in the housing market for additional development types such as multi-family and infill housing in central locations, appealing to the needs and lifestyles of these large populations.

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- **Continue to protect stable existing single-family areas**

  Continue to protect stable existing single-family neighborhoods as future growth and a more diverse housing stock are accommodated in infill locations near transit stations, in nodes along corridors and in existing centers. Concurrently, focusing growth in central areas and maintaining less development in outlying areas preserves the housing option for large-lot single-family homes, while reducing the number of long trips and vehicle miles traveled to employment centers.

- **Ensure adequate access to open space and preservation of habitat**

  Ensure access to open space and habitat preservation despite competing quality-of-life demands driven by growth, housing and employment needs, and traditional development patterns. Development patterns that focus growth in centers and corridors make the most efficient use of developed land and minimize encroachment on public open space and natural habitat. This approach would ensure improved access to existing large-scale and neighborhood-scale open space.

- **Incorporate local input and feedback on future growth**

  Continue public outreach efforts and incorporate local input through the Integrated Growth Forecast process. This innovative approach provides a more accurate forecast that integrates future land use and transportation planning through growth projections for population, employment, households and housing units. Public workshops, scenario planning, and stakeholder outreach improve the accuracy and feasibility of pursuing regional plans at the local level.

These policies have evolved since 2001, when SCAG initiated one of the first large-scale regional growth visioning efforts in the nation. Through its Compass Blueprint Growth Vision, SCAG sought to integrate land use and transportation through a consensus-built regional plan. Compass Blueprint was developed with the goal of accommodating the six million additional residents expected by 2030, while improving mobility for all residents, fostering livability in all communities, and enabling prosperity for all people, and promoting sustainability for future generations. The 2004 Growth Vision Alternative was approved and adopted by the Regional Council as the Preferred Growth Alternative for the 2004 Regional Transportation Plan. The Compass Blueprint principles that were established provide the foundation for the advisory land use policies and strategies adopted in the 2008 Regional Transportation Plan.

These advisory policies and strategies encourage changes to the urban form that improve accessibility to transit and create more compact development, which yields a number of transportation benefits to the region, including reductions in travel time, vehicle miles traveled, vehicle hours traveled, and vehicle hours of delay, as well as increased transit use and mode share. All of these effects lead to tangible air quality improvements.

SCAG's Compass Blueprint Program has become a model for turning regional vision into local reality. Since 2004, SCAG has used innovative planning tools, creative strategies and dynamic partnerships to expand its Suite of Services and Demonstration Project consulting services that are available to all local governments in the region, free of charge.

As a voluntary program, SCAG provides these cutting-edge tools, analyses and comprehensive planning services to cities that seek additional technical expertise or strategic planning in order to implement a plan, ordinance or program consistent with the Compass Blueprint Principles.

Popular tools in the Compass Blueprint Suite of Services include photo-morph and 3D video "fly-through" visualizations, a sophisticated "Tipping Point" return-on-investment tool that simulates a developer's pro forma for potential projects and the "Envision" GIS based land use scenario-building tool. Building upon the Suite of Services, Compass Blueprint Demonstration Projects combine public participation, design and financial analysis to produce local plans that respond to community interests and are market feasible, i.e., plans that will be adopted and realized because of their benefits to all stakeholders. Demonstration Projects range from parcel-specific zoning analyses to county-wide plans around transit stations, and include an array of services including tipping point and business functionality analyses, design charrettes and com-

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munity workshops, housing prototypes and conceptual land use plans, parking studies, and transit-oriented development strategies.

With an ever-growing portfolio of completed, documented Demonstration Projects, an expanding Suite of Services, and significant improvements to existing tools, implementation efforts have seen sustained improvement since the Growth Vision was adopted. SCAG recently launched "Toolbox Tuesdays," a series of training seminars for local planning staff through which they can learn the skills and software capabilities necessary to build their own in-house capacities for using the Compass Blueprint-developed tools. This transferability is a cornerstone of the implementation strategy. Demonstration Projects are scoped to be just that -- examples for others to emulate. The Compass Blueprint website and annual Awards Program event are other important vehicles for sharing lessons learned. Services have been sought through the Compass Blueprint program for over 50 sites in jurisdictions all over the region.

- Azusa
- Baldwin Park
- Brea
- Coachella
- Colton
- Compton
- Corona
- Covina
- El Centro
- El Monte
- Fillmore
- Fontana
- Fullerton
- Glendora
- Hawthorne
- Hemet
- Highland
- Imperial County
- Irwindale
- La Habra
- Lake Elsinore
- Lancaster
- Lawndale
- Los Angeles
- Los Angeles County
- Montclair
- Moreno Valley
- Ontario
- Perris
- Placentia
- Rancho Cucamonga
- Rialto
- Riverside
- Rolling Hills Estates
- San Bernardino
- San Gabriel
- South Pasadena
- Temecula
- Upland
- Ventura (City)
- Ventura County

TRAVEL DEMAND MANAGEMENT

Travel demand management (TDM) strategies are designed to influence an individual's travel behavior by making alternatives to the single-occupant automobile more attractive, especially during peak commute periods. There are two types of TDM strategies: voluntary, or "soft," strategies – such as preferential parking for carpoolers – that aim to lure some to alter their travel behavior in response to voluntary inducements; and "hard" strategies – such as congestion pricing – that shift the behavior of a large number of travelers by changing the price of travel. TDM also can include regulatory strategies, such as regional employer ridesharing mandates.

TDM strategies that encourage the use of alternatives modes of transportation to the single-occupant vehicle include rideshare (carpools and vanpools), transit (bus and rail), and non-motorized modes (bicycling and walking). Additional TDM strategies include alternative work-hour programs, such as compressed work-week programs, flextime (variable work schedules), and work at home (telework-part time and home-based businesses/self-employed-full time) and parking management (preferential parking for carpoolers and parking pricing). Providing the public with reliable and timely traveler information is an operational strategy that allows people to make better decisions about when and how to travel. Knowledge about current travel conditions on the transportation system can be used by travelers to select among alternatives to driving alone or by avoiding making the trip altogether, which is also known as congestion avoidance.

The potential effectiveness of TDM now and in the future depends largely on social and institutional commitments that cause individual travelers to choose a mode of travel other than solo driving, as well as funding (marketing and incentives that change travel behavior). If we were to do nothing beyond our current efforts, the region would not sustain the current levels of ridesharing, non-motorized and telework/telecommute/work at home, let alone expand them over the 2008 RTP period. The region recognizes the importance of TDM strategies and includes a significant level of funding to meet the TDM goals.

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The "soft" strategies identified in this Plan include increasing ridesharing, work at home, and non-motorized transportation. For rideshare, telecommute, and park-n-ride activities, the RTP provides investments of over $1.3 billion through 2035. In the future, we will need to emphasize some of the "hard" strategies, especially parking and congestion pricing. This will require significant analysis, consensus building, and public education. However, pricing benefits have proven to be more sustainable over time and complement the integrated land use strategies adopted by the region.

Increasing Rideshare (Carpool and Vanpool)

The SCAG Region continues to invest heavily in High-Occupancy Vehicle (HOV) infrastructure that provides incentives for commuters to share rides with others. While HOV utilization is growing over time, the percent of total travelers using carpools and vanpools is not. SCAG and its partners will strengthen their efforts to encourage this efficient mode, which reduces travel time and improves air quality. These efforts will include:

- Program public funds in the RTIP to help maintain the public sector share of the existing rideshare market and to increase the number of carpools
- Provide "seamless" intra- and inter-county carpool services to the regional traveler
- Formalize and expand partnerships among public- and private-sector stakeholders to improve delivery of vanpool services regionally
- Increase the number of commuter vanpools through more effective marketing and the provision of non-monetary public-sector incentives
- Identify current dedicated funding sources and work with county transportation commissions and partners on identifying additional new funding sources
- Expand the provision for vanpool services in the region by encouraging employers to offer incentives, and develop policies that encourage employers to provide such services
- Maintain and sustain a regionally coordinated marketing strategy among the public and private sectors to enhance vanpool programs, increase ridership and improve outreach efforts

Increasing Work at Home

Increasing the number of workers who work at home (self-employed, home-based business owners) or who telework/telecommute (wage and salary employees conducting some or all of their work from home) decreases home-based work trips, vehicle-miles of travel, congestion and vehicle emissions. National and regional surveys of those who telecommute indicate that it is a lack of support and trust from "management," rather than the provision of equipment or the desire of workers to telecommute, that hampers the growth

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of telecommuting. The 2008 RTP, therefore, recommends the following actions:

- Formalize and expand partnerships among public- and private-sector stakeholders to increase opportunities for wage and salary workers regionally to telecommute in lieu of daily commuting
- Promote telecommuting to increase opportunities for wage and salary workers regionally to telecommute in lieu of daily commuting.

Non-Motorized Transportation

Commuter trips within the region average a self-reported distance to work of 19.2 miles, too far for many bicyclists and all pedestrians. However, the integration between bicycle and transit nodes offers the opportunity to extend the commuting range of bicyclists. In addition to work trips, there are many ways that bicycling and walking are playing an important role in our transportation system. According to the 2001 National Household Travel Survey, in urban areas, 50 percent of all trips were less than 3 miles, and 28 percent of all trips were less than 1 mile. These trips are ideal for biking, walking, and transit or a combination of those modes of travel.

Bicycle transportation infrastructure has a role in regional mobility and air quality improvements. Every single percent of automobile drivers that switch to alternative transportation choice (walking, bicycling, using transit) reduces air pollution, congestion, the need for increasing roadway capacity, and, in the case of walking and bicycling, improves public health.

Bicyclist and pedestrian improvements are included as part of many street maintenance and construction projects. These investments and the supporting policies summarized below all aim to maximize the benefits of these efficient modes of transportation.

1. Decrease bicyclist and pedestrian fatalities and injuries in the state to 25% below 2000 levels. Ways to address non-motorized safety were discussed under Transportation Safety.
2. Increase accommodation and planning for bicyclists and pedestrians: The needs of non-motorized travel (including pedestrian, bicyclists and persons with disabilities) need to be fully considered for all transportation planning projects.
3. Increase bicycle and pedestrian use in the SCAG Region as an alternative to utilitarian vehicle trips: Create and maintain an atmosphere conducive to non-motorized transportation, including well-maintained bicycle and pedestrian facilities, easy access to transit facilities, and increasing safety and security. While pedestrian sidewalks are fairly well established in most areas, it is estimated that there are only 3,218 miles of dedicated bicycle facilities in the region, with an additional 3,170 miles planned.
4. Increase non-motorized transportation data: To make non-motorized modes an integral part of the region's intermodal transportation planning process and system, reliable data for planning are needed. Non-motorized transportation data needs include, but are not limited to, comprehensive user statistics; user demographics; bicycle travel pat-

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terns/corridors; accident mapping; bikeway system characteristics; and sub regional improvement projects and funding needs.

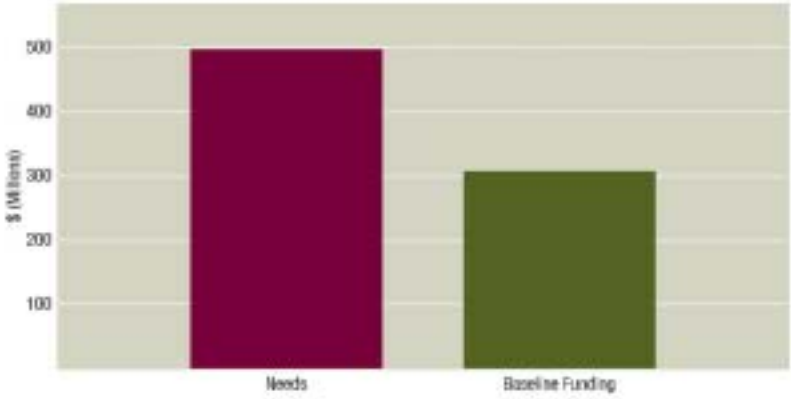
5. Bicyclists and pedestrians should always be included in general plan updates. SCAG also encourages the development of local Non-Motorized Plans. Also, Non-Motorized Plans that have been created or updated within the previous five years are eligible for bicycle transportation account (BTA) funds. SCAG can assist in the development of these plans through the Compass Blueprint Program.
6. Develop a Regional Non-Motorized Plan: SCAG will work with all counties and their cities to coordinate and integrate all Non-Motorized Plans from counties and jurisdictions in the SCAG Region in a collaborative process, including interested stakeholders.

The RTP allocates over $1.8 billion for non-motorized transportation.

The region has built a vast and expensive transportation system. Like any system, it can be operated to be much more productive. Just like a factory can be refined and modernized to produce more output per day or hour, our transportation system can be refined and modernized to carry more people and goods in a day or during peak commute conditions.

Chapter II of this document discussed the lost productivity quantified in terms of "lost lane-miles" on the State Highway System. Similar productivity losses occur for all modes when they are not operated adequately. The investments needed to maximize the productivity of our system through 2035 total $308 million, and include implementation of advanced traffic control strategies (e.g., signal coordination, ramp metering), improved incident management, and smaller physical infrastructure modifications (e.g., auxiliary lanes). Figure 3.4 shows that originally planned investments in operational strategies for the highway system reflect a shortfall of approximately $190 million per year.

FIGURE 3.4 SCAG REGION HIGHWAY OPERATIONS NEEDS VS. BASELINE FUNDING, 2007-2035



Source: SCAG estimates based on Caltrans SHOPP and county transportation commission project submittals

The shortfall through 2035 adds up to $8.4 billion once inflation is taken into account. Similarly, SCAG estimates a deficit of $1.6 billion through 2035 for implementing operational strategies for arterials of regional significance and transit.

Recognizing that funding these provide a higher return on investments than most other transportation projects, this RTP allocates an additional $2 billion, representing 20 percent of the shortfall. As these allocations are programmed and implemented, it is SCAG's hope that the benefits will become apparent to decision-makers and the public, and additional funding is secured to address the remaining shortfall.

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SCAG will work with stakeholders, particularly the county transportation commissions and Caltrans, to better determine the benefits and cost effectiveness of operational strategies. SCAG will also continue to partner with Caltrans on corridor system management plans.

Transit Operations

In addition to funding for operations, the 2008 RTP highlights the following policies to improve the performance of the regional transit system.

Strategic Transit Service Policies

In an effort to maximize transit productivity, the 2008 RTP calls upon regional transit operators to address significant challenges to achieve better operational efficiency, maintain a discipline of cost recovery through a consistent fare policy, embrace the use of performance metrics to better serve their existing customer base, and attract new transit users. The Plan encourages the regional transit operators to work cooperatively to offer complementary services, with ease of transfer between modes and operators. It further encourages utilization of new intelligent transportation system (ITS) technologies that measure system performance and offer their customers reliable "on-time" performance and real-time information.

Reliability and On-Time Performance

On-time performance is the key to delivering the greatest customer satisfaction. Wait times are affected by service irregularities and therefore customers are more sensitive to unpredictable delays. Reliability can also be related to transfer times between buses or between modes (bus to train). When customers experience long unscheduled gaps in service and if timely connections are not made, they are less likely to see transit as a viable alternative.

The Plan recommends that SCAG and transit operators analyze and assess the use of ITS technologies to track, report, and improve on-time performance of transit systems. In addition, operators should utilize this data to identify the causes of delay and use it to improve performance of transit systems through operational improvements, rapid bus implementation, and better scheduling of services. SCAG will seek funding in the next OWP (FY08-09) to conduct this assessment.

Transit Service Levels

Frequency of service is also a concern for transit customers. Long waits for service make transit service inconvenient and deter the use of transit. Poor service levels limit the potential use of transit for non-work trips for social, retail, recreational, and tourism purposes. SCAG should work cooperatively with regional and local transit operators to develop service delivery policies to optimize transit service levels, including frequency, coverage, and hours of operation to achieve maximum potential use of our transit investments. SCAG will seek funding in the next OWP (FY08-09) to conduct this assessment.

Fare Policies, Fare Media, and Subsidies to Transit

SCAG recommends that an analysis be conducted to identify and recommend appropriate adjustments to transit fares to maximize transit usage, including fare-free concepts. This includes utilizing new automated fare media to allow for ease of transit use; increasing subsidy levels to maximize transit usage; and analyzing regional transit fare policies to assess the proper level of fares, optimal fare media to allow for ease of connectivity among transit systems, appropriate subsidy policies, and appropriate mechanisms to assure stable operational funding to maximize transit use in the region. SCAG will seek funding in the next OWP (FY08-09) to conduct this assessment.

Increase Transit Service Connectivity

SCAG recommends that transit operators assess how to better restructure transit services, as needed, to more effectively connect different urban centers and activities. SCAG also recommends that transit operators assess ways to enhance connectivity and ease of transfer between transit modes. In consultation with transit operators, SCAG will conduct an analysis of transit operations; identify existing and emerging hubs and centers; and analyze how to more effectively ensure optimal coverage, access, and connectivity to regional centers. SCAG will also work with transit operators to develop service poli-

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cies and route structures that support the RTP land use concepts, facilitate intermodal transit connectivity, and maximize transit usage. SCAG will seek funding in the next OWP (FY08-09) to conduct this assessment.

SYSTEM COMPLETION AND EXPANSION

Despite the increases in funding commitments to both preservation and operations, more than half of the available transportation revenues in the region are dedicated to the completion and expansion of our people and goods movement transportation systems. This section first summarizes the expansion investments for the SCAG Region by mode, and then presents additional regionally significant expenditures to facilitate and mitigate the movement of goods in the SCAG Region.

HIGHWAY IMPROVEMENTS

Major categories of highway improvements included in the 2008 RTP are High- Occupancy Vehicle (HOV) lanes and connectors, mixed-flow (or general purpose) lanes, toll facilities and High-Occupancy Toll (HOT) lanes, and strategic arterial improvements.

A significant number of system expansion projects have already been committed through SCAG's RTIP for the highway network. These priority projects close critical gaps in the system, relieve significant bottlenecks, and address inter-county travel needs. Recent extraordinary increases in the costs of concrete and steel have resulted in substantial project cost increases and forced implementing agencies to piece together enough additional funding to deliver the improvements. Voter approval of Proposition 1B in November 2006 brought much-needed revenue to the table, through programs such as the Corridor Mobility Improvement Account (CMIA). Much of the additional improvements recommended in the 2008 RTP, beyond those projects that are already in the delivery pipeline, have been committed through local sales tax revenues such as those recently approved by voters in Orange, Riverside, and San Bernardino Counties. The proposed projects and strategies are based on a performance framework established for the 2004 RTP and updated for the 2008 RTP.

Recently completed Regionally Significant Transportation Investment Studies (RSTIS) have helped to identify additional corridor improvements needed in the SCAG Region. These corridor projects provide capacity enhancements and mobility improvements to address rapidly growing inter-county travel, often on already congested facilities with few alternatives. These projects have been incorporated into the RTP, and they will depend in part on financial contributions from the private sector for their construction, operation, and maintenance.

HOV Gap Closures and Connectors

Southern California has invested heavily in HOV lanes, producing one of the nation's most comprehensive HOV networks and highest rideshare rates. The HOV projects proposed in the RTP focus on strategic gap closures and freeway-to-freeway direct HOV connectors to complete the system. The HOV lane network could eventually serve as the backbone of a regional HOT lane or managed lane system. Determining the feasibility of such a regional system will require further study and discussion before inclusion in a future RTP update.

In 2007, the new SR-22 HOV lanes in Orange County opened as the first continuous-access HOV lanes in Southern California. Monitoring and evaluation of these HOV lanes will conclude in 2008 and transportation officials will decide whether the continuous access will be made permanent.

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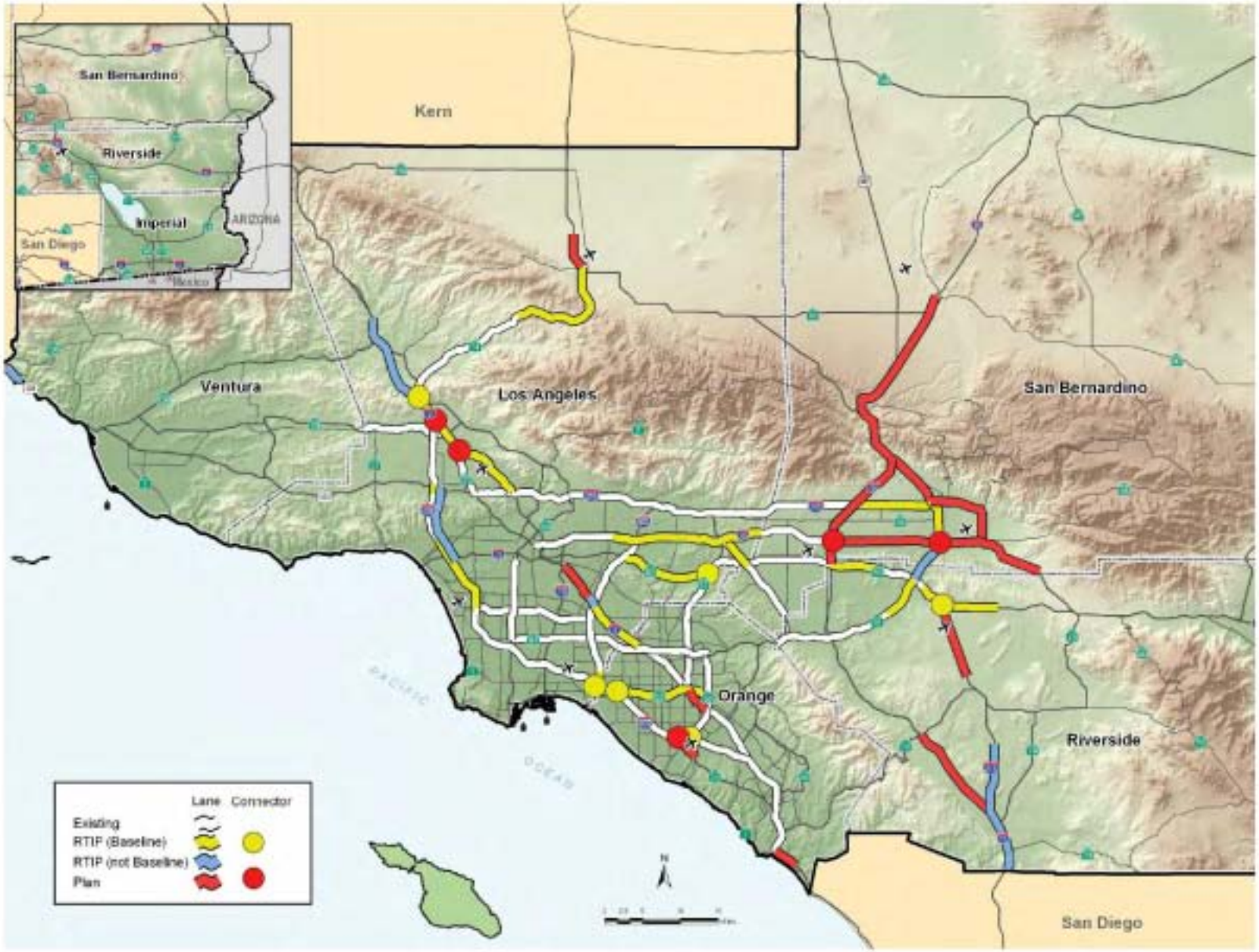
EXHIBIT 3.2 HOV GAP CLOSURES AND CONNECTORS



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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The HOV lane system is a regional network and operations should be coordinated across jurisdictional boundaries to optimize performance and minimize confusion. SCAG supports further study and evaluation of these proposed operational changes to the HOV lane system to fully understand the mobility, safety, and air quality impacts, as well as any implications for a potential regional HOT lane system.

Projects in the Pipeline

The RTIP includes HOV gap closures and connectors as shown in Exhibit 3.2.

- I-405 in the Westside of Los Angeles
- SR-91 in Riverside
- I-5 and SR-14 connecting the San Fernando Valley to North Los Angeles County
- I-5 and I-605 connecting Los Angeles and Orange Counties
- I-10 and SR-60 connecting Los Angeles and San Bernardino Counties
- SR-60 and I-215 connecting Riverside and San Bernardino Counties
- US-101 connecting Ventura and Santa Barbara Counties
- HOV connectors at I-5/SR-14, SR-57/SR-60, SR-22/I-405, I-405/I-605, and SR-60/I-215

Additional Investments

The 2008 RTP calls for additional investments to extend the HOV network and construct additional connectors, as shown in Table 3.1 and in Exhibit 3.2. It invests close to $8 billion for HOV improvements through 2035. These gap closures and connectors help users to maximize the overall system performance by minimizing weaving conflicts and maintaining travel speeds.

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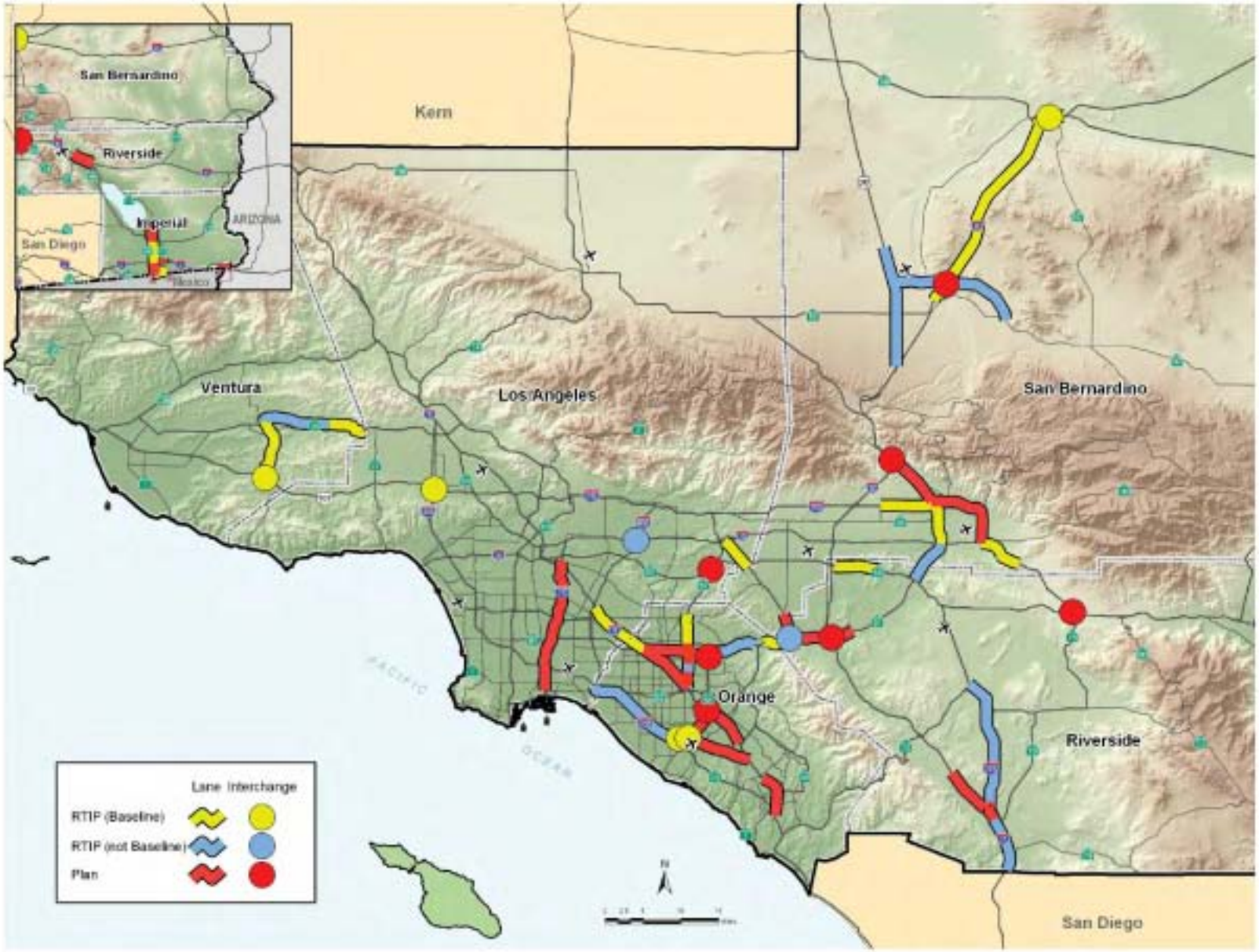
EXHIBIT 3.3 MIXED FLOW LANE ADDITIONS



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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TABLE 3.1 HOV AND HOV CONNECTOR PROJECTS

Project	County	Implementation Schedule*
I-5 (SR-19 to I-710)	Los Angeles	2035
SR-14 (Ave P-8 to Ave L)	Los Angeles	2030
I-5/I-170 connector	Los Angeles	2030
I-5 / I-405 connector	Los Angeles	2030
I-5 (Avenida Pico to Coast Hwy)	Orange	2018
I-5 (SR-55 to SR-57)	Orange	2035
SR-73 (I-405 to MacArthur)	Orange	2035
SR-73/I-405 connector	Orange	2035
I-15 (I-215 to SR-74)	Riverside	2020
I-215 (Nuevo to Box Springs)	Riverside	2020
I-10 (Haven to Ford)	San Bernardino	2020
I-10 (Ford to Riverside County)	San Bernardino	2030
I-10/I-15 connector	San Bernardino	2030
I-10/I-215 connector	San Bernardino	2030
I-15 (Riverside County to I-215)	San Bernardino	2020
I-15 (I-215 to SR-18)	San Bernardino	2020
SR-210 (I-215 to I-10)	San Bernardino	2020
I-215 (SR-210 to I-15)	San Bernardino	2030

** Represents the Plan network year for which a project was analyzed for the RTP modeling and regional emissions analysis*

Mixed Flow

Since mixed-flow lanes carry more traffic than any other component of our transportation system, mixed-flow capacity enhancements are necessary to address traffic bottlenecks and relieve congestion on heavily traveled corridors. This is especially true in areas outside of the urban core where transit service and the HOV network are not fully developed. The majority of mixed-flow projects in the pipeline and proposed in the 2008 RTP are located outside of Los Angeles County.

Projects in the Pipeline

The RTIP contains mixed-flow lane additions on the following routes (see Exhibit 3.3).

- Brawley Bypass in Imperial County
- I-5, I-405, and SR-57 connecting Los Angeles and Orange Counties
- SR-91 connecting Orange and Riverside Counties
- CETAP Mid-County Parkway in Riverside County
- SR-60 and I-215 connecting Riverside and San Bernardino Counties
- I-15 and I-215 connecting Riverside and San Diego Counties
- US-395 in northern San Bernardino County
- Completion of the 210 freeway in San Bernardino County
- SR-23, SR-118, and US-101 in Ventura County

Additional Investments

The 2008 RTP invests $26.2 billion through 2035 for mixed-flow improvements and interchange ramps. Major mixed-flow improvements are listed in Table 3.2 and shown in Exhibit 3.3.

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TABLE 3.2 MIXED-FLOW HIGHWAY PROJECTS

Project	County	Implementation Schedule*
SR-111 (SR-98 to I-8)	Imperial	2030
I-710 (Ocean Blvd in Long Beach to intermodal railroad yards in Commerce/Vernon)	Los Angeles	2020
I-5 (SR-73 to El Toro)	Orange	2035
I-5 (SR-133 to SR-55)	Orange	2030
I-5 (SR-57 to SR-91)	Orange	2030
SR-55 (I-405 to SR-22)	Orange	2030
SR-57 (Orangewood to Katella)	Orange	2018
SR-57 (Lincoln to Orangethorpe)	Orange	2020
SR-91 westbound (SR-57 to I-5)	Orange	2018
SR-91 eastbound (SR-57 to SR-55)	Orange	2023
SR-91 westbound (SR-241 to Gypsum Cyn)	Orange	2018
I-405 (I-5 to SR-55)	Orange	2035
I-10 (Monterey to Dillon)	Riverside	2030
I-15 (Bundy Cyn to I-215)	Riverside	2014
SR-71 (SR-91 to San Bernardino County)	Riverside	2035
SR-91 (Pierce to Orange County)	Riverside	2018
I-215 (Murrieta Hot Springs to I-15)	Riverside	2014
SR-210 (I-215 to I-10)	San Bernardino	2020
I-215 (SR-30 to I-15)	San Bernardino	2030

** Represents the Plan network year for which a project was analyzed for the RTP modeling and regional emissions analysis*

Toll and High-Occupancy Toll (HOT) Lane Corridors and Facilities

The 2008 RTP proposes to expand upon the existing HOT lane and toll road system in Orange County to address the congested commuter corridor between housing-rich Riverside County and job-rich Orange County. Additionally, improvements to several major corridors elsewhere in the region are proposed to be financed by tolls.

Projects in the Pipeline

The RTIP includes lane additions to each of the toll roads in Orange County and the construction of the Foothill South corridor connecting to I-5 in San Diego County (see Exhibit 3.4).

- SR-73 – San Joaquin Hills Corridor
- SR-133/SR-241/SR-261 – Eastern Transportation Corridor
- SR-241 – Foothill Transportation Corridor North
- SR-241 – Foothill Transportation Corridor South (extension to I-5)

Additional Investments

The recommendations from several recent major RSTIS efforts examining inter-county travel have been considered in the development of the 2008 RTP. First, the Riverside County to Orange County study completed in 2006 identifies a comprehensive set of improvements that includes extending the SR-91 Express Lanes into Riverside County and providing direct connections to and from the Express Lanes. Additionally, the study identifies two major new facilities, one parallel to the SR-91 and one on a new alignment further south. Secondly, a North Los Angeles County study completed in 2004 recommended a new east-west facility called the High Desert Corridor to connect the high-growth areas of Lancaster/Palmdale and Victor Valley. While the RSTIS provides input to the RTP on a locally preferred strategy, SCAG recognizes and respects the local processes that must continue to solidify community consensus and further refine each project.

In 2006, MTA completed a technical feasibility study examining the potential for constructing the SR-710 Gap Closure between the I-10 and I-210 freeways as a tunnel. SCAG has further assessed the potential for the Gap Closure to be financed in part through a public-private partnership. A number of tolling structures were considered in the financial analyses, including both flat-rate

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EXHIBIT 3.4 HOT LANES AND TOLL FACILITIES

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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and variable-toll rate structures. SCAG anticipates that structuring financing alternatives with lower-cost Private Activity Bonds (PABs) and 30- to 50-year -term bonds could help to improve shareholders' internal rate of return.

Additionally, SCAG's current evaluations to date indicate that the project is feasible from a construction standpoint. Two 46-foot inner diameter tunnels could provide two levels of lanes. The upper level could include three lanes for passenger vehicles, and two lanes in the middle level could accommodate truck and high-occupancy vehicles. The SR-710 Gap Closure is estimated to cost $4.6 billion.

The 2008 RTP invests $25.6 billion for toll and HOT lane facilities. These additional investments are listed in Table 3.3 and shown in Exhibit 3.4.

TABLE 3.3 HOT LANES AND TOLL FACILITIES

Project	County	Implementation Schedule*
SR-710 Tunnel Gap Closure (710/Valley Blvd to California Blvd/Pasadena Ave)	Los Angeles	2020
High Desert Corridor (I-5 to US-395)	Los Angeles/ San Bernardino	2030
SR-91/SR-241 HOT connectors	Orange	2020
CETAP Riverside County to Orange County Corridor A (Parallel to SR-91 from I-15 to SR-241)	Orange/Riverside	2035
CETAP Riverside County to Orange County Corridor B (I-15/Mid-County Pkwy to SR-133/SR-241) Preliminary Engineering and Environmental Impact Report/Statement	Orange/Riverside	PE/EIR/EIS ONLY
SR-91 Express Lanes (extend east to I-15)	Riverside	2020
I-15 HOT Lanes (SR-74 to San Bernardino County)	Riverside	2020
SR-91/I-15 HOT connectors	Riverside	2020

** Represents the Plan network year for which a project was analyzed for the RTP modeling and regional emissions analysis*

Arterial Improvements

Local streets and roads account for over 80 percent of the total road network and carry a high percentage of total traffic. In many cases, arterials serve as alternate parallel routes to congested freeway corridors. In mature urban areas there is often little right-of-way available for capacity enhancements. In the fast-growing suburban and exurban parts of the region, local jurisdictions ensure that roadway capacity improvements keep pace with new developments by implementing mitigation fees. In all parts of the region, operational and technological improvements have the potential to maximize system productivity in a more cost-effective way than simply adding capacity. Such strategic "smart street" improvements include spot widening, signal prioritization, driveway consolidation and relocation, and grade separations at high-volume intersections. The 2008 RTP invests approximately $17.1 billion for arterial system improvements as shown in Table 3.4.

TABLE 3.4 ARTERIAL INVESTMENT SUMMARY

County	Investment (in billions, nominal dollars through 2035)
Imperial	$1.0
Los Angeles	$1.5
Orange	$2.0
Riverside	$6.9
San Bernardino	$4.8
Ventura	$0.9
Regional Total	$17.1

Note: Numbers may not add due to rounding

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TRANSIT STRATEGIES

Public transit has grown in recent years to become an increasingly integral mode of transportation for the movement of people to and from jobs, school, shopping, and cultural and recreational activities. The region has experienced substantial growth in daily regional transit trips since 2003, and anticipates the trend to continue.

The goals of public transportation services are to ensure mobility for people without access to automobiles, and to provide attractive alternatives for drive-alone motorists or discretionary riders. The public transportation strategies and programs presented in the RTP are developed with these goals in mind. As listed previously in this chapter, these strategies target improving customer service and system reliability, achieving financial stability for operators, and enhancing the safety and security of the system for all riders and operators.

Transit Expansion

The RTP recommends closing critical gaps in the transit system to improve service, and extending routes to serve a greater number of passengers. Our regional transit investments in new modes and innovative services are a significant factor in achieving increased transit use. The development of new rail and bus transit corridors has also spawned investment in new housing, retail, and business development at and near transit stations.

Projects in the Pipeline

The transit projects that are programmed in the RTIP and ready for implementation include expansions to the Bus Rapid Transit (BRT) system, commuter rail, and light rail. Refer to Exhibit 3.5 for an illustration of bus transit projects, and Exhibit 3.6 for rail projects that are included in the 2008 RTP.

Bus Rapid Transit (BRT) is designed to provide fast, high-quality bus service to passengers by taking advantage of signal priority at intersections, operating in mixed traffic or in a dedicated right-of-way, and providing improved bus stop spacing at planned stations. The following BRT projects are programmed in the RTIP:

- Metro Rapid Bus Expansion (to 28 lines) in LA County
- San Fernando Valley North-South BRT (Reseda/Sepulveda & Canoga Corridor) in LA County
- Wilshire Metro Rapidway in LA County
- Harbor Blvd. BRT (Fullerton to Costa Mesa) in Orange County
- Westminster/17th BRT (Santa Ana to Long Beach) in Orange County
- 28-Mile BRT (Brea Mall to Irvine Transportation Center) in Orange County
- E Street Transit Corridor (San Bernardino to Loma Linda) in San Bernardino County

Metrolink is the commuter rail service that operates in five Southern California counties. The Southern California Regional Rail Authority (SCRRA) provides and maintains Metrolink services and facilities. The following commuter rail project is programmed in the RTIP.

- Perris Valley Line (Riverside to Perris) in Riverside County

Light Rail Transit (LRT) utilizes electric-powered vehicles that operate primarily on exclusive rights-of-way. The Metro Rail system comprises the Metro Blue, Green, Red, Purple and Gold Lines. LRT projects programmed in the RTIP include:

- Gold Line Eastside Extension (Union Station to Atlantic) in LA County
- Exposition Corridor Phase 1 (Downtown LA to Culver City - Washington/National) in LA County
- Exposition Corridor Phase 2 (Culver City - Washington/National to Santa Monica) in LA County
- Gold Line Foothill Extension Phase 1 (Pasadena to Azusa-Citrus) in LA County
- Crenshaw Corridor in LA County (may be BRT or LRT)

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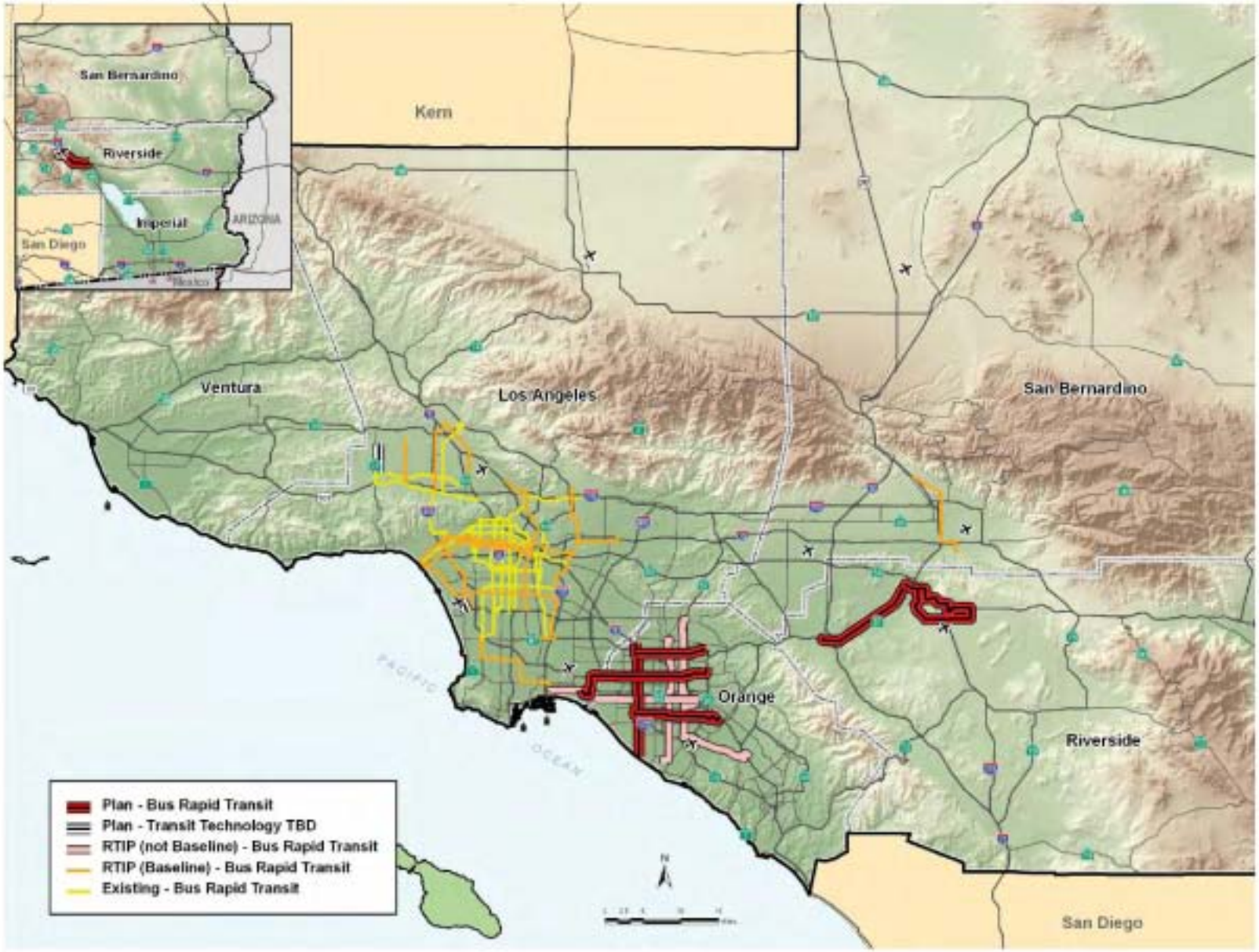
EXHIBIT 3.5 BUS RAPID TRANSIT PROJECTS



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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EXHIBIT 3.6 RAIL TRANSIT PROJECTS

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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Additional Investments

The 2008 RTP invests over $44.0 billion in transit projects. Of this amount, nearly $23.3 billion is allocated to bus and intermodal facilities; nearly $6.2 billion to commuter rail projects; and close to $14.5 billion to heavy rail, light rail, and other projects. The major projects included in the RTP that address system gaps and provide strategic corridor expansion are listed in Table 3.5.

TABLE 3.5 TRANSIT CORRIDOR PROJECTS

Project	County	Implementation Schedule*
Regional Connector LRT (Union Station to 7th St/Metro Center)	Los Angeles	2035
Gold Line Foothill Extension Phase 2 (Azusa-Citrus to Montclair)	Los Angeles	2020
Westside Extension (Metro Purple/Red Line Extension)	Los Angeles	2020
Green Line Extension (Mariposa/Nash to Century/Sepulveda LAX, technology TBD)	Los Angeles	2030
Katella BRT (Orange Transportation Center to Long Beach/Blue Line)	Orange	2014
Edinger BRT (Tustin to Huntington Beach)	Orange	2018
Beach Blvd BRT (Huntington Beach to Buena Park)	Orange	2012
La Palma BRT (Anaheim to Buena Park)	Orange	2018
Great Park/Spectrum 5-Mile Transit System	Orange	2012
Western Riverside BRT (Magnolia Corridor Phase 1 City of Riverside; Moreno Valley Corridor Phase 2 City of Moreno Valley)	Riverside	2018
Coachella Valley BRT	Riverside	2018
Perris Valley Line Extension (Perris to San Jacinto)	Riverside	2030
Perris Valley Line Extension (Perris to Temecula)	Riverside	2030
Redlands Extension (4th St/Mt. Vernon to Grove/Central, rail technology TBD)	San Bernardino	2014

** Represents the Plan network year for which a project was analyzed for the RTP modeling and regional emissions analysis*

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AVIATION

The SCAG Region supports the nation's largest regional airport system in terms of number of airports and aircraft operations, operating in a very complex airspace environment. The system has six established air carrier airports including Los Angeles International (LAX), Bob Hope (formerly Burbank), John Wayne, Long Beach, Ontario and Palm Springs. There are also four new and emerging air carrier airports in the Inland Empire and North Los Angeles County. These include San Bernardino International Airport (formerly Norton AFB), March Inland Port (joint use with March Air Reserve Base), Southern California Logistics Airport (formerly George AFB) and Palmdale Airport (joint use with Air Force Plant 42). Southern California airports play a crucial role in international trade, particularly with Pacific Rim countries, and to the regional economy. The value of airborne commodity exports out of the Los Angeles Customs District are about equal to waterborne exports, and airborne export values would be significantly greater if service exports, including impacts from tourism, were added to total export values.

The aviation strategy is very similar to the 2030 decentralized regional aviation system adopted for the 2004 RTP. It respects all legally enforceable policy and physical-capacity constraints at urban airports. It assumes much more willingness on the part of the airlines to invest in new flights at new and emerging airports, and a package of market and ground access incentives to promote decentralization at underutilized suburban airports.

The aviation strategy incorporates the HSRT system Initial Operating Segment (IOS) running from West Los Angeles to Ontario Airport, and extending west to LAX and east to San Bernardino International. The region is projected to reach 165.3 million annual passengers (MAP) in 2035 (190.7 MAP including San Diego).

TABLE 3.6 2035 AIR PASSENGER ALLOCATIONS BY AIRPORT

Commercial Airports	Annual Air Passengers (in millions)
Bob Hope	9.4
John Wayne	10.8
LAX	78.9
Long Beach	4.2
March Inland Port	2.5
Ontario	31.6
Palmdale	6.3
Palm Springs	4.1
San Bernardino	9.4
So. Cal. Logistics	2.9
Imperial*	3.5
Oxnard*	1.7
Region Total	**165.3**

** Existing commuter airport with potential to accommodate short-haul service*

Regional Aviation Policies

New regional aviation policies have been developed for the 2008 RTP with input from both the SCAG Aviation Task Force and the SCAG Aviation Technical Advisory Committee. They respond to changing circumstances and new priorities in the regional aviation system. The policies are divided into Aviation Guiding Principles and Aviation Action Steps, as follows:

Aviation Guiding Principles:

- Provide for regional capture of economic development opportunities and job growth created by the prospect of significant regional air traffic growth between now and 2035

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- Distribute maximum opportunity to Southern California airports where population and job growth are expected to be strong and where local communities desire air traffic for economic development
- Reflect environmental, environmental justice and local quality-of-life constraints at existing airports that operate in built-out urban environments
- Reflect that each county should have both the obligation and the opportunity to meet its own air traffic needs where feasible
- Reflect that the region as a whole has an obligation to help pay the costs of airport environmental mitigation and ground access improvement in counties that serve a disproportionate share of regional air travel demand at their airports

Aviation Action Steps:

- Support capacity enhancements at existing and potential airports to handle anticipated increases in passengers and cargo volume where it is desired
- Mitigate the effects of expanding airports and maximize air passenger and air cargo utilization of outlying airports in less-populated areas so that community impacts are minimized
- Support the continued responsibility of SCAG for developing regional aviation and ground access plans for the region
- Support the close cooperation between SCAG and other aviation organizations to facilitate the implementation of adopted regional aviation plans prepared by SCAG
- Support legislative, marketing and ground access initiatives that promote the decentralization of aviation demand to underutilized suburban airports where it is desired
- Support more flexible use of airport revenues for off-airport ground access projects
- Support giving priority to key airport ground access projects in the programming of transportation projects in the RTP and the RTIP
- Support the development of a regional network of new FlyAways that connect to multiple airports via HOV, light rail and commuter rail facilities, to help decentralize aviation demand to underutilized suburban airports where it is desired
- Support efforts to redesign the regional airspace system that may be needed to reduce significant conflicts and delays associated with future air traffic in SCAG's adopted 2035 regional aviation forecast
- Support a more active role by the federal government in developing substantial incentives for airlines to upgrade their aircraft fleet to cleaner and quieter aircraft

Air Cargo Forecasts

The aviation strategy forecasts a total of almost 8.3 million tons of air cargo for the region's airports in 2035. The adopted 2030 air cargo forecast for the 2004 RTP was 8,724 tons. There is a variety of reasons why the new air forecast is lower than the adopted forecast in the last RTP. These include more domestic cargo being transported by truck and train, more international air cargo over-flying the region on longer-range aircraft or flying the Arctic Circle route with a stop at Anchorage, and high value-to-weight goods such as computers forecast to be lighter per unit volume. The 2035 modeling results of the air cargo forecast are shown in Table 3.7.

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TABLE 3.7 2035 TOTAL ANNUAL AIR CARGO TONNAGE BY AIRPORT (THOUSANDS)

Air Carrier Airports	Air Cargo Tonnage (thousands)
Bob Hope	86
John Wayne	45
LAX	2,496
Long Beach	134
March Inland Port	1,130
Ontario	1,959
Palmdale	781
Palm Springs	129
San Bernardino	1,290
So. Cal. Logistics	230
Region Total	**8,280**

Airport Ground Access

The 2008 RTP may have localized ground access impacts at a number of airports. The RTP will result in significant increases in airport activities (people as well as cargo) at Ontario, San Bernardino International, and Palmdale Airports. Regional Airport Demand Allocation Model (RADAM) modeling for the Preferred Scenario shows that airport ground access deficiencies are concentrated near airport areas but that background congestion affects both airports and local communities.

SCAG's adopted Regional Aviation Decentralization Strategy calls for making substantial airport ground access improvements throughout the region, in both the short term and long term. The short-term program emphasizes relieving immediate bottlenecks around airports through arterial, intersection and interchange improvements, and increasing transit access to airports. Many of these improvements were programmed in the RTIP, and have been updated with strong local input from airport, city and county transportation planners.

SCAG is currently working with Los Angeles World Airports (LAWA) on planning and programming a regional system of FlyAways, based on the very successful Van Nuys FlyAway, where passengers park their cars and take a bus to LAX. The locations of the proposed new FlyAways can be optimized by taking advantage of the region's developing high-occupancy vehicle (HOV) and light and heavy rail networks that can provide direct linkages to Ontario and Palmdale as well as LAX. Making seamless HOV and rail connections with enhanced service to those and other suburban airports will also compose SCAG's short- and medium-range airport ground access strategy. The FlyAway, HOV and rail improvements to the suburban airports will help establish a pattern of decentralization, by attracting a critical mass of passengers and airline service

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at those emerging airports. SCAG is also working with the newly reactivated SCRAA in its ongoing efforts to restructure and redefine its mission, with the focus of helping to implement the Regional Aviation Decentralization Strategy through facilitating key airport ground access improvements.

Over the long term, SCAG aviation demand modeling indicates that the region will also need a system of high-speed rail to the suburban airports to reach our adopted air passenger and air cargo forecasts, which are moderate and even conservative when compared to other forecasts for the region such as those developed by the FAA. The high speed, reliability and predictability of high-speed airport access will be needed to overcome mounting and increasingly unpredictable traffic congestion. For example, the Initial Operating Segment of SCAG's proposed high-speed rail system from West Los Angeles to Ontario Airport will take only 33 minutes to travel from end to end, compared to over two hours by car in 2030. The regional high-speed rail system is an integral component of the 2008 RTP Preferred 2035 regional aviation demand forecast.

Provision of high-speed rail service to the suburban airports would also provide significant economic benefits to region. It is estimated that the regional aviation system with a full high-speed rail network would create an additional 76,600 direct, indirect and induced jobs by 2035, compared to a system with no high-speed access. These would include an additional 28,900 jobs from high-speed access to Palmdale Airport, and an additional 27,100 jobs from high-speed access to San Bernardino International Airport.

HIGH-SPEED REGIONAL TRANSPORT

SCAG has advanced a vision of regional transport based on high-performance, high-speed, and environmentally sensitive alternatives. A High-Speed Regional Transport (HSRT) system has the potential for relieving both airport and freeway congestion in urbanized areas by providing an alternative to the automobile as well as making less-congested airports more accessible to air travelers, and providing alternative capacity for freight movement in the region.

The HSRT system is a long-term vision connecting the region's ports, airports, and urban activity centers. The system can be constructed in multiple stages that can each be financially viable. The financial performance will be enhanced as the system is extended throughout the region and the volume of users increases. The HSRT plan is constructed on three core components:

- **Goods Movement/Logistics:**
  Connect the San Pedro Bay Ports with an inland port facility via the high-speed, high-capacity link. This would provide capacity to handle containers, relieving a major constraint to port expansion, and facilitate efficient and environmentally sensitive goods handling in areas that have sufficient space outside of the urban areas. A detailed discussion on goods movement strategies is included in this chapter.
- **Aviation System:**
  Create a direct and reliable link capable of connecting airports and urban centers. Continue use of LAX as a major hub and sharing de-

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mand with other regional airports such as Ontario International Airport (ONT), Palmdale Regional Airport (PMD) and San Bernardino International Airport (SBD) based on a high-speed connection via the HSRT. This would enable a higher level of service for airport access and connecting passengers, improved operation of the aviation system for passengers and airborne cargo, and optimize investment in aviation system infrastructure.

- **Surface Transport System:**

  Link urban activity centers throughout the region, serving the needs of commuters while reducing the number of private vehicles on the road. This would lead to reduced traffic congestion, enhanced accessibility between activity centers, as well as reduced air and noise pollution from automobiles. Additionally, enhanced accessibility at transit stations would enable intensification of land uses and thereby encourage more effective land use patterns.

The SCAG HSRT system will ultimately grow to cover over 275 miles of corridors in the SCAG Region, and will move up to 500,000 riders a day. When fully deployed, the HSRT system could complement the regional state highway transportation system. The HSRT program also envisions a longer-term connection to San Diego and other southern airports in the SCAG Region, a connection between San Bernardino and Palmdale via a high desert alignment, an LAX to Orange County route, and a San Bernardino to the Coachella Valley segment, intertwining with the proposed state high-speed rail system.

The California High-Speed Rail Authority (CHSRA) has been commissioned to do preliminary development work on several north-south corridors. SCAG has supported the Antelope and San Joaquin Valley corridors (Resolution #96-357-1-B). The State of California should coordinate all high-speed rail-planning activities with SCAG and other stakeholders within the state, especially with regard to HSRT, aviation, environment, growth, access, finance, and community development. SCAG is supportive of CHSRA's efforts to build a high-speed rail system in Southern California.

Three phases have been developed to implement the HSRT deployment program:

- **Phase 1**, Pre-Deployment Analysis, was completed in October 2003 and includes right-of-way assessment on the freeway system and railroad corridors, assessment of ridership and interaction with other transportation systems, Los Angeles Union Passenger Terminal (LAUPT) capacity analysis, stakeholder outreach, financial feasibility, public-private partnership, technology transfer, and identification of an Initial Operating Segment (IOS).
- **Phase 2**, Preliminary Engineering, was completed in 2006 for the IOS, and focused on defining the project to prepare preliminary engineering for the purpose of environmental assessment and analysis (EIR/EIS) for public-private investment.
- **Phase 3**, Project Deployment Strategy, was initially done via a consultant study completed in 2007. It focused on an extended IOS with a link to the Ports of Los Angeles and Long Beach. The goal was to provide an initial investment quality analysis necessary to take the deployment program to the private market. The next step in this phase (date to be determined) will include an investment-grade ridership and revenue forecast, operation plans, a detailed financial plan, and creation of a public-private consortium for project deployment.

In December 2002, SCAG's Regional Council approved the deployment of a 54-mile IOS of the HSRT system that would connect West Los Angeles via LAUPT to Ontario Airport. It is a component of an 81-mile corridor between LAX and the San Bernardino Airport. In selecting the IOS, SCAG considered the RTP performance measures, stakeholder support and environmental issues. At the same time, SCAG's Regional Council approved the advance planning of the LAX to Palmdale corridor and Los Angeles to Orange County corridor (Orangeline).

The feasibility studies for the four corridors demonstrated that the HSRT system could be constructed and deployed through a public-private partnership

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structure administered through a public agency, a joint powers authority (JPA), a public nonprofit (PNP), or a public-private partnership (PPP) format using a number of innovative and traditional funding mechanisms.

A JPA is in the process of being formed for the express purpose of implementing the IOS (West Los Angeles/LAX to Ontario Airport). Voting members of the yet-to-be-named JPA are the City of Los Angeles, the City of West Covina, and the City of Ontario. SCAG would be one of several non-voting members of the JPA.

TABLE 3.8 2008 RTP REGIONAL HSRT MILESTONES

Milestone	Capital Cost (in nominal dollars, billions)	Implementation Schedule*
IOS: Ontario – West Covina-LA Union Station – West LA/LAX	$19	2020
IOS extension to San Bernardino	$3.5	2020
San Pedro Ports to the IOS	$18	2020
Anaheim - Ontario	$6.7	2020
California High-Speed Train (Union Station - Anaheim)	$4.0**	2020

** Represents the network year for which a project was analyzed for the RTP modeling and regional emissions analysis.*
*** Assumes cost covered by state HSRT Bond Act. State bond revenues for HSRT are not included in the regional revenue forecast.*

Implementation and operation of the HSRT is being proposed on the basis of a business plan approach whereby it will be largely self-financed based on the goods movement, aviation, and commuter operations. The use of public rights-of-way is a critical component of the system as is some level of financial commitment from the public sector. The net performance of the HSRT will be further bolstered by related development in real estate property. A business and institutional structure for the movement of goods, movement of people, and associated development patterns has been developed by SCAG to serve as the basis for implementation of the movement systems.

The HSRT would enhance airport access and connections between regional airports by allowing passengers to bypass the congested highway network. It is envisioned that the HSRT would serve as the basis for a regional airport system and aviation system users would become a key component of HSRT passenger ridership.

Next Steps:

- Prepare preliminary engineering for the Ontario – West Covina-LA Union Station – West LA/LAX IOS for the purpose of preparation of the federal Environmental Impact Statement (EIS) and/or State Environmental Impact Report (EIR) to a level necessary for public-private investment.
- Form a Joint Powers Authority (JPA) for the IOS, and market projects to public-private stakeholders.
- Secure federal, state and local funds to supplement private investment to complete deployment of the IOS and coalesce community support
- Seek legislative support at the regional, state and federal levels for the HSRT deployment
- Continue working on public-private partnerships (PPP) to fund HSRT projects and to fast-track institutional issues

Anaheim-Ontario Maglev Segment

The California-Nevada Super Speed Train Commission (CNSSTC) was formed in 1988 to promote the development of, and issue a franchise to build, a superspeed train system connecting Las Vegas with Anaheim and other points in Southern California. In 1991 the Commission selected Transrapid International (TRI) Maglev technology for the corridor.

The critical segment of this route for Southern California is the Anaheim to Ontario Airport link. This would further the airport decentralization strategy for the region and provide a viable transit system to help mitigate transportation congestion/pollution caused by the jobs/housing imbalance between Orange and Riverside Counties.

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EXHIBIT 3.7 IOS WITH EXTENSION TO SAN BERNARDINO AND LINK TO SAN PEDRO PORTS

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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EXHIBIT 3.8 PROPOSED HIGH-SPEED REGIONAL TRANSPORT SYSTEM

Source: Southern California Association of Governments, ESRI StreetMap USA, TeleAtlas

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According to a feasibility study done by CNSSTC in 2000, the Anaheim to Ontario Airport segment will be 32 miles long and take 14.5 minutes with no stops between the two end points and 18 minutes with a station stop mid-route. The capital cost is estimated at $6.7 billion. Annual ridership projections are 13.9 million passengers per year (approximately 38,000 riders per day) with 10-minute headways.

It is not yet determined whether the primary route for this segment will be in the SR-91 corridor or the SR-57. These routes need to be re-examined in future feasibility and planning studies. For modeling purposes, the SR-91 corridor was the selected route.

CNSSTC is seeking funding for future studies and construction of the project from the U.S. federal government.

In 2002, the Western States Maglev Alliance was formed between SCAG and the California-Nevada Super Speed Train Commission and was approved by the Regional Council. As a result of this alliance, the Plan supports continued analysis of the proposed Las Vegas to Anaheim Maglev, especially the segment from Anaheim to Ontario.

California High-Speed Train

Established in 1996, the California High-Speed Rail Authority (CHSRA) is charged with planning, designing, constructing, and operating a high-speed steel wheels on steel rails train system. The financing plan is to pass statewide bonds to pay for the capital infrastructure. The first bond to fund the project is $9.95 billion and is currently on the ballot for November 2008.

The proposed system stretches from San Francisco, Oakland and Sacramento in the north -- with service to the Central Valley -- to Los Angeles and San Diego in the south. With bullet trains operating at speeds up to 220 mph, the express travel time from downtown San Francisco to Los Angeles is just under 2 ½ hours. Intercity travelers (trips between metropolitan regions) along with longer-distance commuters would enjoy the benefits of a system designed to connect with existing rail, air and highway systems.

In the SCAG Region there is a planned 210 miles of rail. One line covers 30 miles from Orange County to Union Station and the other from Union Station veering east to Riverside and then down Interstate 15 (I-15) to San Diego. Northbound from Union Station, the route heads through Burbank to Palmdale and then to the Central Valley. If built out, the state system is planned to connect up with SCAG's HSRT system in Palmdale, Union Station and Ontario. Funding ($7 million) to begin a project-specific EIR/EIS in the Union Station to Orange County segment in the LOSSAN corridor is being provided to CHSRA from OCTA.

SPOTLIGHT ON GOODS MOVEMENT

The goods movement strategies identified in the 2008 RTP merit a focused discussion because of the critical and far-reaching impacts on our region's transportation system, economy, and public health. The goods movement sector of transportation is growing at a tremendous pace and will continue to do so over the time frame of the RTP. The San Pedro Bay Ports (Port of Los Angeles and the Port of Long Beach) forecast that by 2030 container volume could triple. The productivity gains that are realized by Southern California's geographical advantage and the extraordinary logistics network of ports, warehouses and distribution systems are the primary reasons for this growth.

Cross-border trade activity also contributes to the region's international trade growth. The growth in the manufacturing industry in Mexico has increased truck trips through Calexico East in Imperial County by 77 percent between 1994 and 2005. Also, the Port of Hueneme plays an important role in facilitating the movement of goods. Approximately $7 billion in cargo traverses through the Port annually, and trade-related activity generated by the Port contributes significantly to the local economy.

To continue to provide this critical service, a combination of federal, state, local and private investment is needed. The 2008 RTP calls for approximately $13 billion in freight rail investments, nearly $18 billion in a freight HSRT system, and over $5 billion in highway investments to enable the region to handle the dramatic growth in goods movement. Rail investments consist of

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additional mainline capacity, grade separations, and locomotive engine upgrades. About half of the rail-related investments are for highway-rail grade separations, which reduce traffic congestion, improve safety, and reduce pollution. Highway investments include the first phase of a dedicated, toll clean technology truck lane system and truck climbing lanes. Additionally, the proposed alternative technology system for freight includes a shared guideway with passenger vehicles. Service would be operating between passenger intervals, effectively utilizing the available capacity of the system (see Exhibit 3.8).

An essential element of improving the region's goods movement system is reducing its current and long-term impacts on public health and the environment. Accordingly, the 2008 RTP includes investments that integrate air quality mitigation into the goods movement system improvements. Substantial air quality benefits can be realized by accelerating fleet modernization with cleaner technologies.

Further, this Plan maximizes the utilization of the scarce land area near the ports, includes the development of inland port capacity, and has dedicated ground access systems that enable the region to protect communities and meet demand. Specific elements of this Plan are described in the following sections.

PORT ACCESS IMPROVEMENTS

Port access improvements include short-term initiatives to improve access to Terminal Island and to remove bottlenecks to truck movements. They include the replacement of the Gerald Desmond Bridge, SR-47 Truck Expressway/Heim Bridge replacement, I-110/SR-47 Connectors Improvement Program, and the SR-47/Navy Way Interchange. These projects are programmed over the short-term in the 2006 RTIP.

To provide for the landside port access improvements in Imperial County, the 2006 RTIP includes the Brawley Bypass project, which is a four-lane expressway connecting SR-78 and SR-111. The completion of the project will provide continuity between the California/Baja California border to Riverside County, ensuring smooth and reliable movement of goods through the border.

DEDICATED LANES FOR CLEAN TECHNOLOGY TRUCKS

Over the past several RTP updates, the region has been exploring dedicated truck-lane facilities and continues to refine the concept of such user-supported corridors to improve the flow of goods. More recent effort has focused on adding dedicated truck lanes for clean technology vehicles along truck-intensive corridors in Southern California. Operationally, such a corridor would be aligned to connect freight-intensive locations such as the Ports, warehousing/distribution center locations, and manufacturing locations. These dedicated

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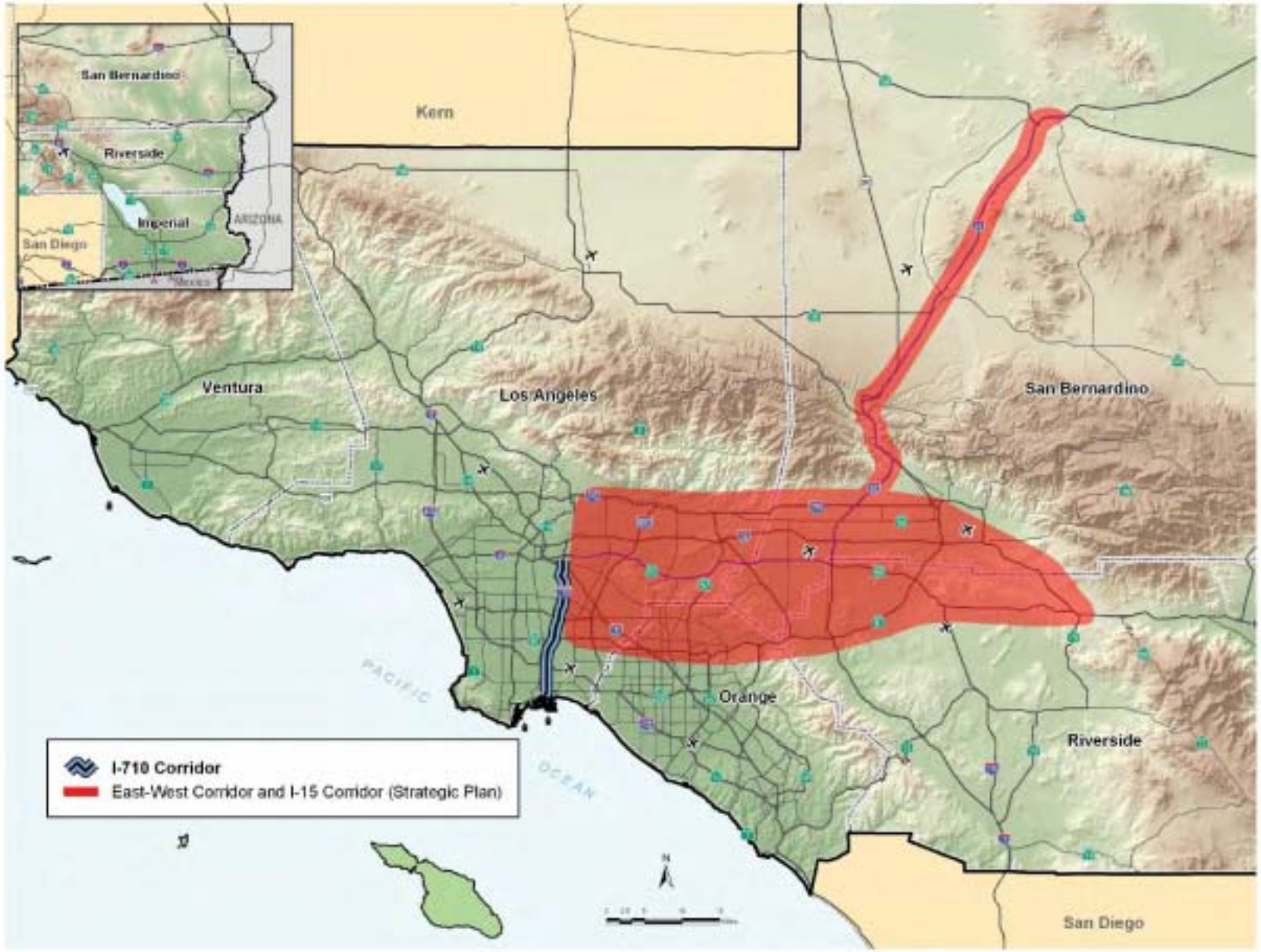
EXHIBIT 3.9 DEDICATED LANES FOR CLEAN TECHNOLOGY TRUCKS



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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facilities would have fewer entrance/egress locations than typical urban interstates to smooth the flow of goods.

This proposal has the potential to relieve many of the negative truck impacts in Southern California such as recurrent delay, pavement deterioration, safety, emissions, and design deficiencies. Dedicated truck lanes would also increase reliability in the freeway system. Despite these benefits, substantial financial constraints as well as environmental impact considerations could hinder project implementation. Recognizing these challenges, the 2008 RTP funds the I-710 segment as the first phase of a comprehensive system that addresses truck-related issues in the region (Exhibit 3.9). This segment includes roughly 78 lane-miles (two lanes in each direction) of dedicated lanes for clean technology trucks along alignments extending from Ocean Blvd. in Long Beach to the intermodal railroad yards in Vernon/Commerce. This represents an investment of over $5 billion.

The region's longer-term strategic vision would include an east-west corridor and the I-15 freeway, serving strategic distribution centers in Barstow. Major corridor studies have already been completed for I-710, SR-60, and I-15. An EIR/EIS and preliminary engineering are currently underway for I-710. The technical analysis for the 2008 RTP assumes the implementation of dedicated lanes accommodating clean technology vehicles along the I-710 corridor until a preferred alternative is identified by the EIR/EIS.

REGIONAL FREIGHT RAIL INVESTMENT AND EMISSION REDUCTION PACKAGE

Recent projections included in SCAG's *Inland Empire Railroad Main Line Study* suggest that the number of freight trains on most BNSF and UP lines will more than double between 2000 and 2025 in response to a tripling of container volumes at the San Pedro Bay Ports. Passenger train volumes are expected to experience similar volume growth.

The UP and BNSF mainlines east of downtown Los Angeles will reach capacity before the end of the decade and will need to be triple-tracked or even quadruple-tracked in some segments. Investments in the 2008 RTP include $3.2 billion for mainline rail capacity improvements, $6.0 billion to build an estimated 131 highway-rail grade separations east of downtown Los Angeles, and a total of $3.8 billion for accelerating upgrades to cleaner diesel locomotive engines—namely, Tier 4 engines.

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In March of 2007, the US Environmental Protection Agency (EPA) proposed new standards to reduce emissions from diesel locomotives: Tier 3 and Tier 4 exhaust emission standards for newly built engines with high-efficiency catalytic after-treatment technology. Tier 3 engines will be available in 2009 and the associated estimated reduction in emissions is less than 50 percent of current conditions. The reduction in emissions from Tier 4 engines is estimated at 90 percent of current conditions. The 2008 RTP assumes nearly $2 billion in federal EPA funding to accelerate the deployment of Tier 4 engines in the region.

Exhibit 3.10 shows planned projects for regional rail capacity enhancement in Southern California. Most of the BNSF system south and west of Colton Crossing will need additional track by 2025, and several of these segments will require additional track as soon as 2010. By 2025 this line will require grade-separated crossings at junctions where the two railroads have lines crossing. North of Colton Crossing over the Cajon Pass to Barstow substantial additional mainline capacity will be needed by 2010 as well as new connections to the system. In the UP system, most of the Yuma line will require double-tracking by 2025 and the San Gabriel line may require double-tracking over major segments during the same time frame. Also by 2025, UP will require several grade-separated junctions.

Exhibits 3.11, 3.12, 3.13, and 3.14 show the grade separation projects by county planned in the region. Stakeholder agencies throughout the region have identified priority grade separations that were analyzed in the Inland Empire Railroad Main Line Study and it was determined that without additional grade separations, motor vehicle delay at grade crossings will more than triple between 2000 and 2025. Analysis of vehicle delay from high-priority grade separations shows that these could reduce growth in vehicle hours of daily delay (VHDD), cutting delay in half by 2025. This will reduce motor vehicle idling delay and associated idling emissions, and by increasing train speeds, will reduce train emissions through more efficient operations.

ALTERNATIVE TECHNOLOGY-BASED GOODS MOVEMENT/LOGISTICS

The region is also exploring new alternative technology-based systems that can provide greater throughput and reliability with near zero emissions (the emissions would be only those associated with electricity generation). A recent

TABLE 3.9 SBD CAPACITY SHARED GUIDEWAY WITH PASSENGER SERVICE - 9.2M TEU

Operating Period				Trains/Day/Direction		Potential Capacity				
	Hr/Day	Trains/Hr/Direction		Passenger	Freight	Per Day and Direction				Per Year and Direction
		Passenger	Freight			Passenger	Freight			(24/7 Operation)
							20 ft	40 ft	TEU	TEU
Peak	8	6	6	48	48	42,528	96	1,824	3,744	1,366,560
Off-Peak	10	3	9	30	90	26,580	180	3,420	7,020	2,562,300
Night	2	0	12	0	24	-	48	912	1,872	683,280
Maintenance	4	0	0	0	0	-	-	-	-	-
Total	24	9	27	78	162	69,108	324	6,156	12,636	4,612,140
Total Passengers/Freight in Both Directions						**138,216**	**648**	**12,312**	**25,272**	**9,224,280**

Source: BB Group

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EXHIBIT 3.10 PLANNED PROJECTS FOR REGIONAL RAIL CAPACITY ENHANCEMENT

Rail Capacity Improvements

No	Railroad	County	Improvements
1A	BNSF	Orange/Los Angeles	3rd main track, Fullerton(Beds) - City of Commerce (Bandini)
1B	BNSF	Orange/Los Angeles	4th main track, Hobart-Fullerton
2A	BNSF	Orange	3rd main track, Placentia(Atwood) - Yorba Linda(Esperanza), Prado Dam-Riverside, and Highgrove to MP 2.9
2B	BNSF	Orange	3rd main track, Fullerton-Placentia(Atwood)
3	BNSF	Riverside/San Bernardino	4th main track, Riverside-Colton
4	BNSF	Riverside	Flying Junction at Riverside
5	BNSF	San Bernardino	Colton Crossing to Barstow
6	UP	Riverside/San Bernardino	2nd main track, W. Riverside-Riverside (Streeter), Riverside (Arlington)-Padley, Box View-Ontario(Tower)
7	UP	Los Angeles	2nd main track, Pomona(Dale)-Montclair (Fossdrove)
8	UP	Los Angeles	2nd main track, Alhambra - Walnut
9	UP	San Bernardino	Flying junction of Palmdale Line at West Colton (Rancho)
10	UP	Riverside/San Bernardino	Colton Crossing to Indio
11		San Bernardino	Grade Sep. @ Colton Crossing (Red to Red)
12	UP	Los Angeles	Flying junction at Pomona

Source: Southern California Association of Governments, ESRI StreetMap USA, Tele Atlas

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EXHIBIT 3.11 GRADE SEPARATION PROJECTS IN LOS ANGELES COUNTY

No	Project Description
1	Nogales Street/SP - Industry (Completed)
2	Ramona Boulevard/SP - El Monte
3	East End Avenue/SP&UP - Pomona
4	Reservoir Street/SP&UP - Pomona
5	Temple Avenue/SP - Pomona
6	Brea Canyon Road/UP - Industry
7	Sunset Avenue/SP - Industry
8	Baldwin Avenue/SP - El Monte
9	Nogales Street/UP - Industry
10	Valley Boulevard/SP - Los Angeles
11	Passons Boulevard/BNSF - Pico Rivera
12	Valley View Avenue/BNSF - Santa Fe Springs
13	Rosecrans Avenue/BNSF - Santa Fe Springs
14	Norwalk/BNSF - Santa Fe Springs/Gateway
15	Durfee Avenue/UP - Pico Rivera
16	San Gabriel Trench - San Gabriel
17	Turnbull Canyon Road/UP - Industry
18	Rose Hills/UP - Industry
19	Puente Avenue/SP - Industry
20	Fairway Drive/SP - Industry
21	Fairway Drive/UP - Industry
22	Montebello Boulevard/UP - Montebello
23	Fullerton Road/SP - Industry
24	Temple Avenue/SP - Industry
25	Lemon Avenue/SP - Industry
26	Brea Canyon Road/SP - Industry
27	San Antonio Avenue/SP&UP - Pomona
28	Lower Azusa Road/SP - Temple City
29	Fullerton Road/UP - Industry
30	Hamilton Boulevard/SP&UP - Pomona
31	Park Avenue/SP&UP - Pomona
32	Temple City Boulevard/SP - El Monte
33	California Avenue/SP - Industry
34	Walnut Grove Avenue/SP - Rosemead
35	Lemon Avenue/UP - Industry
36	Vineland Avenue/SP - Industry
37	Arden Drive/SP - El Monte
38	Stimson Avenue/UP - Industry
39	Palomares Street/SP&UP - Pomona
40	Cogswell Road/SP - El Monte

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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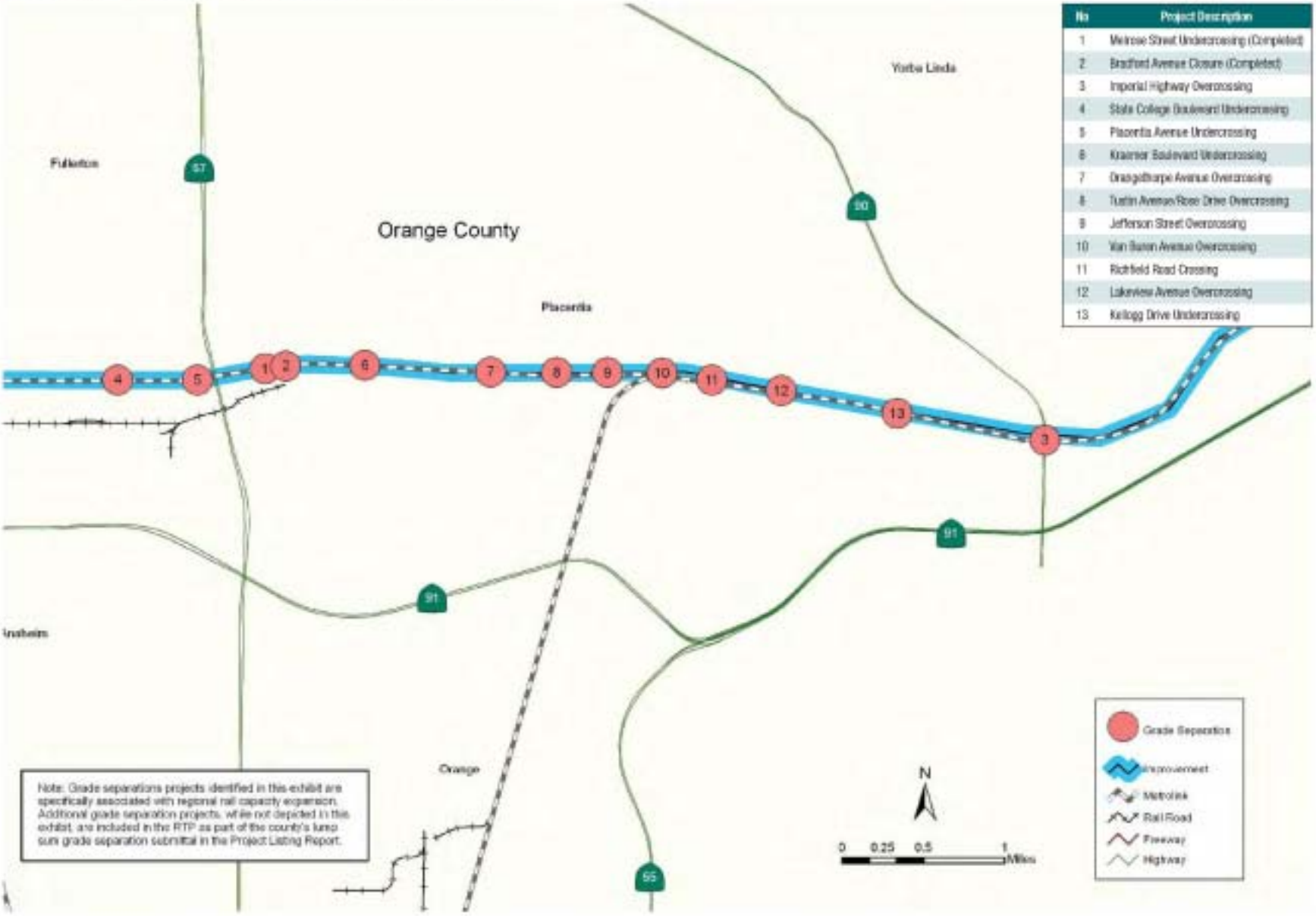
EXHIBIT 3.12 GRADE SEPARATION PROJECTS IN ORANGE COUNTY



No	Project Description
1	Melrose Street Undercrossing (Completed)
2	Bradford Avenue Closure (Completed)
3	Imperial Highway Overcrossing
4	State College Boulevard Undercrossing
5	Placentia Avenue Undercrossing
6	Kraemer Boulevard Undercrossing
7	Orangethorpe Avenue Overcrossing
8	Tustin Avenue/Rose Drive Overcrossing
9	Jefferson Street Overcrossing
10	Van Buren Avenue Overcrossing
11	Richfield Road Crossing
12	Lakeview Avenue Overcrossing
13	Kellogg Drive Undercrossing

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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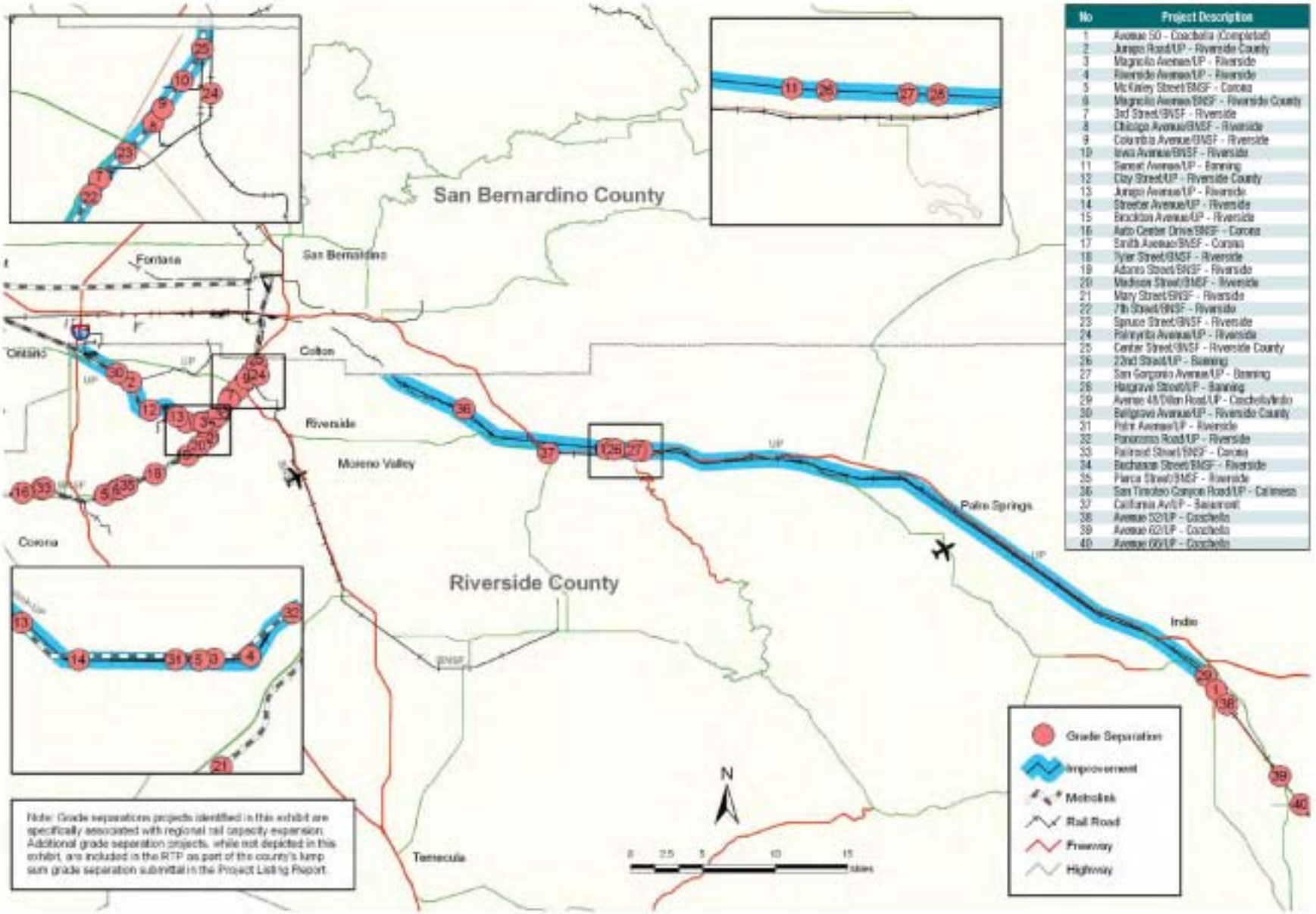
EXHIBIT 3.13 GRADE SEPARATION PROJECTS IN RIVERSIDE COUNTY



No	Project Description
1	Avenue 50 - Coachella (Completed)
2	Jurupa Road/UP - Riverside County
3	Magnolia Avenue/UP - Riverside
4	Riverside Avenue/UP - Riverside
5	Mc Kinley Street/BNSF - Corona
6	Magnolia Avenue/BNSF - Riverside County
7	3rd Street/BNSF - Riverside
8	Chicago Avenue/BNSF - Riverside
9	Columbia Avenue/BNSF - Riverside
10	Iowa Avenue/BNSF - Riverside
11	Sunset Avenue/UP - Banning
12	Clay Street/UP - Riverside County
13	Jurupa Avenue/UP - Riverside
14	Streeter Avenue/UP - Riverside
15	Brockton Avenue/UP - Riverside
16	Auto Center Drive/BNSF - Corona
17	Smith Avenue/BNSF - Corona
18	Tyler Street/BNSF - Riverside
19	Adams Street/BNSF - Riverside
20	Madison Street/BNSF - Riverside
21	Mary Street/BNSF - Riverside
22	7th Street/BNSF - Riverside
23	Spruce Street/BNSF - Riverside
24	Palmyrita Avenue/UP - Riverside
25	Center Street/BNSF - Riverside County
26	22nd Street/UP - Banning
27	San Gorgonio Avenue/UP - Banning
28	Hargrave Street/UP - Banning
29	Avenue 48/Dillon Road/UP - Coachella/Indio
30	Bellgrave Avenue/UP - Riverside County
31	Polvo Avenue/UP - Riverside
32	Panorama Road/UP - Riverside
33	Railroad Street/BNSF - Corona
34	Buchanan Street/BNSF - Riverside
35	Pierce Street/BNSF - Riverside
36	San Timoteo Canyon Road/UP - Calimesa
37	California Av/UP - Beaumont
38	Avenue 52/UP - Coachella
39	Avenue 62/UP - Coachella
40	Avenue 66/UP - Coachella

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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EXHIBIT 3.14 GRADE SEPARATION PROJECTS IN SAN BERNARDINO COUNTY

No	Project Description
1	Grove Avenue Alhambra (UP) Line (Completed)
2	Grove Avenue Los Angeles (UP) Line (Completed)
3	Ramona Avenue Alhambra and Los Angeles (UP) Lines
4	Monte Vista Avenue Alhambra and and Los Angeles (UP) Lines
5	State/University Cajon (UP) Line
6	Hunts Lane Yarna (UP) Line
7	Milliken Avenue Alhambra (UP) Line
8	Central Avenue Alhambra and Los Angeles (UP) Lines
9	San Antonio Avenue Alhambra and Los Angeles (UP) Lines
10	Salinas Avenue Alhambra and Los Angeles (UP) Lines
11	Campus Avenue Alhambra and Los Angeles (UP) Lines
12	Vineyard Avenue Alhambra (UP) Line
13	Mt. Vernon Avenue Alhambra (UP) Line
14	Vine Avenue Los Angeles (UP) Line
15	Bon View Avenue Los Angeles (UP) Line
16	Vineyard Avenue Los Angeles (UP) Line
17	Archibald Avenue Los Angeles (UP) Line
18	Milliken Avenue Los Angeles (UP) Line
19	Valley Boulevard San Bernardino (BNSF & UP) Line
20	Laurel Street San Bernardino (BNSF & UP) Line
21	Main Street San Bernardino (BNSF & UP) Line
22	Olive Street San Bernardino (BNSF & UP) Line
23	Mt. Vernon Avenue San Bernardino (BNSF & UP) Line
24	Other Improvements: E Street, H Street San Bernardino (BNSF & UP) Line
25	Palm Avenue Cajon (BNSF & UP) Line
26	Glen Helen Parkway Cajon (BNSF & UP) Line
27	Ranchero Road Cajon (BNSF & UP) Line
28	Vista Road Cajon (BNSF & UP) Line
29	Hinkley Road Cajon (BNSF & UP) Line
30	Lenwood Road Cajon (BNSF & UP) Line
31	Oro Grande (BNSF & UP) Line
32	Other Improvements: Indian Trail Cajon (BNSF & UP) Line
33	Ranchero Road Cutoff (UP) Line
34	Phelan Road Cutoff (UP) Line
35	Other Improvements: Johnson Road Cutoff (UP) Line
36	Whittier Avenue Yarna (UP) Line
37	Beaumont Avenue Yarna (UP) Line
38	Alessandro Road Yarna (UP) Line
39	Other Improvements: San Timoteo Canyon Road Yarna (UP) Line

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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analysis carried out by the IBI Group considered the application of an HSRT system for the movement of containers (logistics and systems technology) to and from the San Pedro Bay Ports. This container movement system would provide a high-capacity, fast, and efficient method of moving containerized cargo from the Ports to an inland port facility in San Bernardino. The system capitalizes on the inherent savings of multiple uses on a single infrastructure by operating on shared alignments with the HSRT passenger system. The technology permits operation of HSRT freight vehicles on a shared guideway with passenger vehicles even during peak hour service. Freight vehicle trips can be interspersed with passenger trips while still meeting required passenger vehicle headways. Additionally, full utilization of the freight line can be achieved during the passenger system's off-peak hours. The deployment of the HSRT system would create value in associated components which could in turn contribute to the HSRT's total financial performance.

The connection for the HSRT system would begin at the Ports and join up with the IOS2 at a point just east of LAUPT. This alignment runs north-south and is assumed to follow a route parallel to the I-710/Alameda Corridor. After connecting to the IOS and other segments, the freight-only service would be interspersed with passenger service.

As Table 3.9 shows, current estimates indicate that the HSRT container movement system is capable of moving over 9.2 million Twenty-foot Equivalent Units (TEUs) annually. The total freight component is estimated to cost nearly $18 billion in nominal dollars.

For a more detailed discussion of the regional HSRT system and associated documentation on its financial performance, refer to the supplemental HSRT Report. Critical to the implementation of an alternative technology system, such as this HSRT system, the location of inland port facilities and associated costs need to be further evaluated. The development of inland ports served by the system would reduce truck VMT, lower emissions, and encourage efficient patterns of industrial development and land use.

[1] Initial Operating Segment, or IOS, is discussed in further detail in the supplemental HSRT Report and Appendices.

Mitigating Environmental Impacts

California law requires SCAG to prepare and certify a Program Environmental Impact Report (PEIR) prior to adopting the RTP. The PEIR evaluates the environmental impacts of the RTP and proposes specific measures to mitigate impacts to the maximum extent feasible. Although the 2008 RTP, in and of itself, is a plan to mitigate the transportation-related effects of population growth, such as traffic congestion and poor air quality, because the transportation improvements can result in additional growth, the PEIR goes further by recommending additional environmental mitigation at the program level for those resource areas that would be affected by the Plan (and associated growth) such as land use, open space, biological resources, water and energy. The section below summarizes the mitigation program. A list of all the mitigation measures included in the 2008 RTP PEIR will be included in the Environmental Mitigation Report of the Final 2008 RTP.

The general purpose of the mitigation measures included in the PEIR and summarized below, is to identify how to protect the environment, improve air quality, and promote energy efficiency in concert with the proposed transportation improvements and related planning. They provide a framework through which implementing agencies and subregions can address the environmental impacts of RTP projects, while implementing RTP goals and policies. The PEIR provides three different types of mitigation measures. The first type can be implemented by SCAG at the regional level. These measures are generally aimed at gathering additional information that can assist in measuring impacts and determining appropriate mitigation and promoting policies that reduce impacts. The second type of measures are to be implemented at the local level by implementing agencies, and individual cities and counties. These measures can strengthen planning documents to ensure for provision of mitigation in the planning process. The third type of measures are project specific and seek to reduce impacts for the myriad different types of projects anticipated in the region. As a programmatic document, many of the measures in the PEIR refer to performance standards because site-specific conditions are not reasonably evaluated at the programmatic level.

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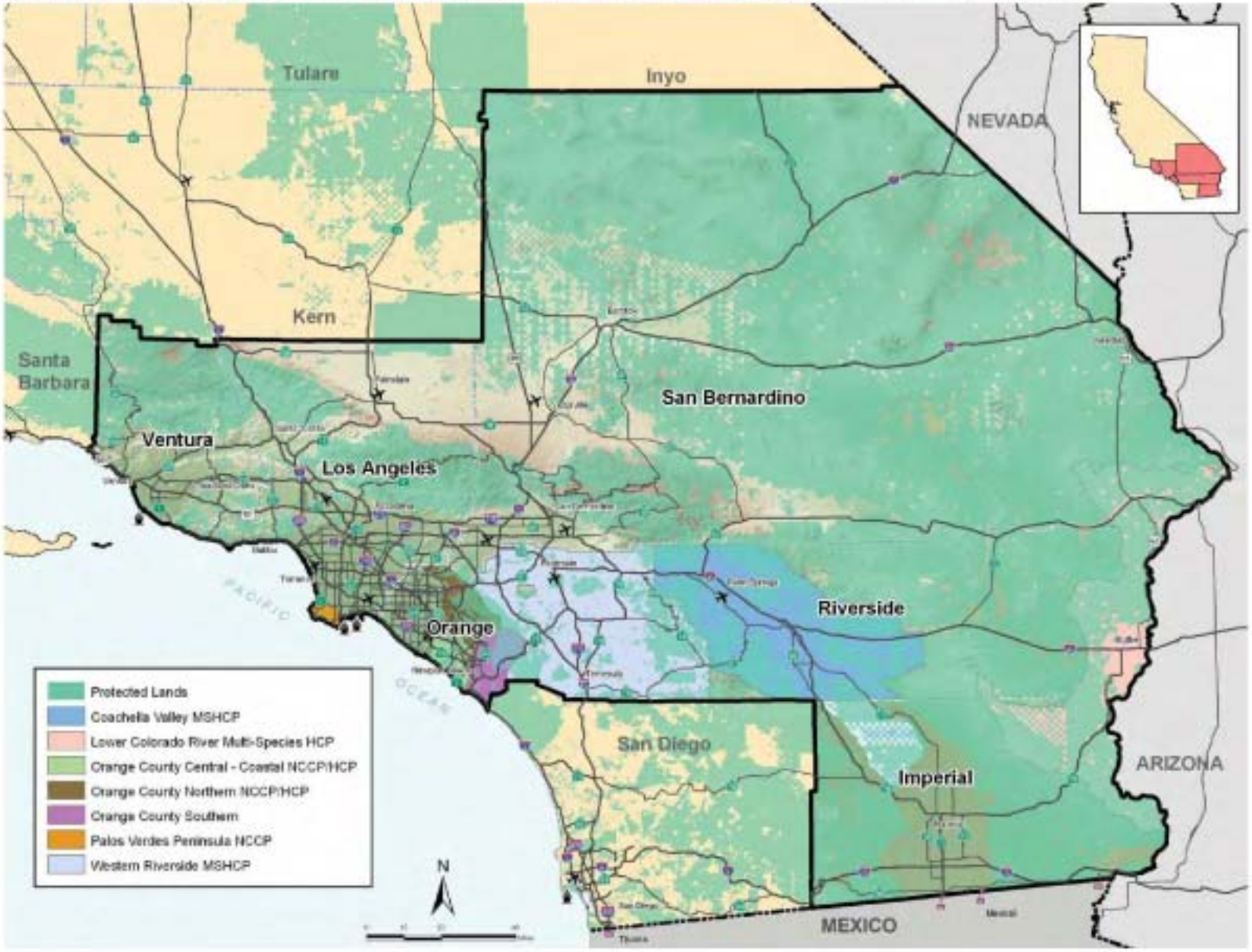
EXHIBIT 3.15 PROTECTED LANDS, NATURAL COMMUNITY CONSERVATION PLANS (NCCP) AND HABITAT CONSERVATION PLANS (HCP)



Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas, California Legacy Project 2005

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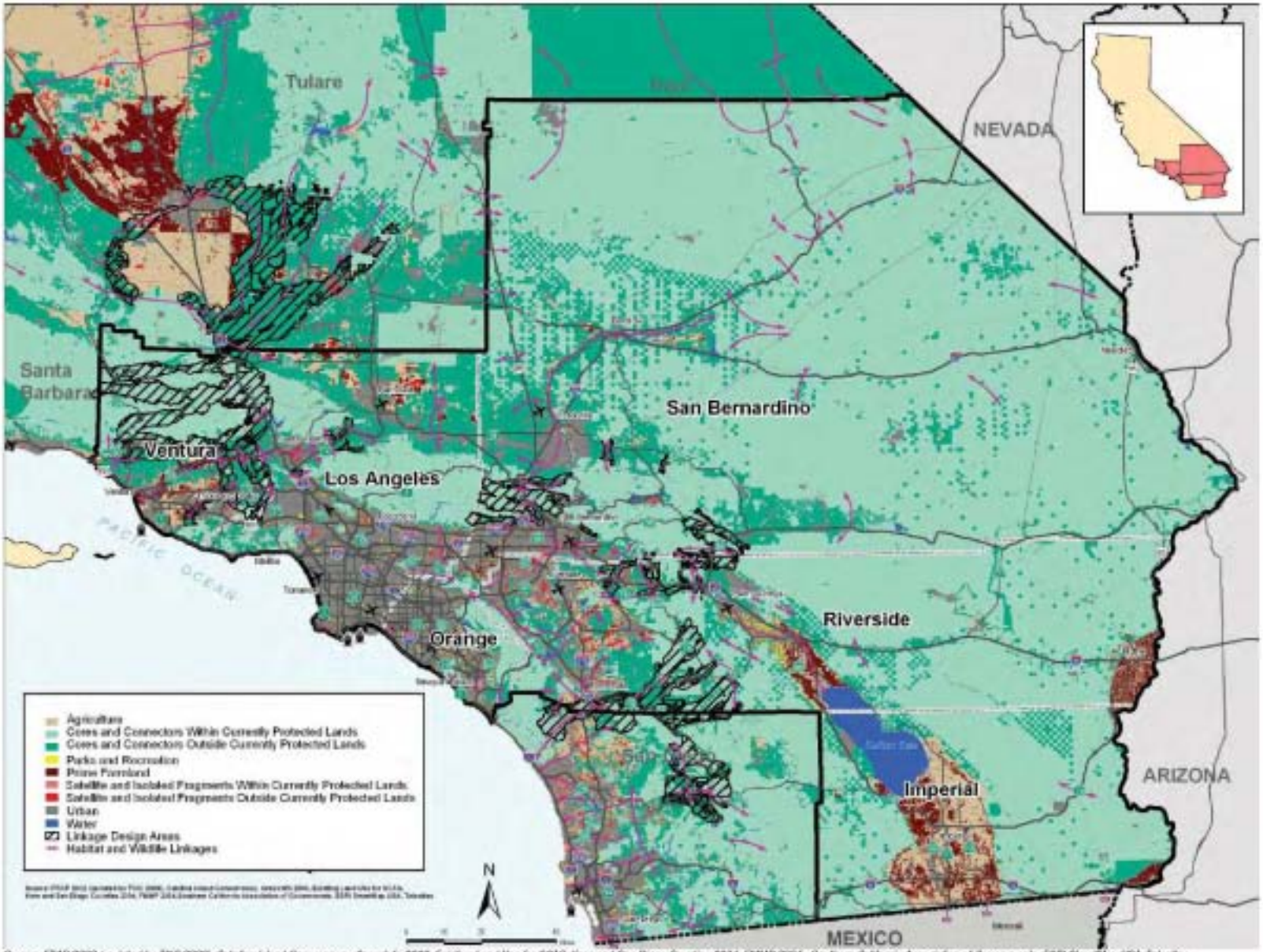
FIGURE 3.16 REGIONAL OPEN SPACE INFRASTRUCTURE



Source: FRAP 2002 (updated by DNC 2008), Catalina Island Conservancy, Greeninfo 2008, Existing Land Use for SCAG, Kern and San Diego Counties 2004, FMMP 2004, Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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Summary of the Environmental Mitigation Program

As required by SAFETEA-LU, the RTP includes an environmental mitigation program that links transportation planning to the environment. Building on its strong commitment to the environment as demonstrated in the 2004 PEIR, SCAG's mitigation program creates an implementation strategy to show varying levels of authority (state, regional, and local). This mitigation discussion also utilizes documents created by the federal agencies to guide environmental planning for transportation projects.

OPEN SPACE

Section 6001(i) of SAFETEA-LU requires that long-range transportation plans such as the RTP include a discussion of potential environmental mitigation activities along with potential sites to carry out these activities. As a result of this expanded requirement, SCAG enhanced its Open Space Program to evaluate potential sites to mitigate the impacts associated with transportation activities. The RTP includes two regional scale maps (Exhibits 3.15 and 3.16) that identify sensitive environmental resources, such as protected lands and sensitive habitats. As part of the open space planning effort undertaken for the Regional Comprehensive Plan, SCAG completed a comprehensive evaluation of open space resources in the region, including Kern and San Diego Counties. SCAG collected GIS data from existing sources to assist with and inform the evaluation of open space planning issues. SCAG then evaluated and analyzed the data to show the distribution of existing open space resources, levels of existing and planning protection, and areas of key habitat linkages. Concurrent with this mapping effort, and as required under SAFETEA-LU, SCAG reviewed existing plans and programs to determine which areas were covered by conservation strategies.

According to the Federal Highways Administration, there are more than 3.9 million centerlane miles of public roads that span the United States. Each day, an estimated one million animals are killed on roads, making road kill the greatest human cause of wildlife mortality in the country. The open space program seeks to minimize transportation-related impacts on wildlife, and also better integrate transportation infrastructure into the environment.

Locations for Mitigation

Exhibit 3.15 shows the distribution of protected and unprotected lands within the SCAG Region and its vicinity. It also shows the location of county-level conservation efforts such as Habitat Conservation Plans (HCPs) and Natural Communities Conservation Plans (NCCPs). Although portions of these areas fall within the "protected" category, large portions of habitat within these areas remain "unprotected" and therefore should still be considered for mitigation activities. Beyond looking at just protected and unprotected lands, SCAG mapped locations of the protected and unprotected areas in relation to wildlife linkages, linkage design areas, park and recreation areas (from SCAG's 2005 land use inventory), agricultural lands, and developed lands. Together, these form the region's open space infrastructure. Exhibits 3.15 and 3.16 demonstrate areas where project sponsors should consider directing mitigation activities. Specifically, those areas that are "unprotected" could be possible locations for mitigation. Although SCAG does not have the authority to purchase or manage lands, conservation of these areas will be achieved through already-established programs or through compacts facilitated by SCAG.

Types of Mitigation Activities

The mitigation program of the 2008 RTP generally includes strategies to reduce impacts where transportation and sensitive lands intersect and also encourages smart land use strategies that maximize the existing system and eliminate the need for new facilities that might impact open space and habitat. Potential mitigation programs include better planning of transportation projects to avoid or lessen impacts to open space, recreation land, and agricultural lands through information and data sharing, increasing density in developed areas, and minimizing development in previously undeveloped areas that may contain important open space.

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The mitigation program also emphasizes the importance of integrating consideration of wildlife and habitat into the design of transportation facilities in those areas where impacts cannot be avoided. SCAG encourages project sponsors to review Ventura County's Wildlife Crossing Guidelines and FHWA's Critter Crossings. Both documents provide examples of context-sensitive solutions (CSS) which is a way of involving all stakeholders to develop transportation facilities that fit their physical setting and preserve scenic, aesthetic, historic and environmental resources, while maintaining safety and mobility. CSS is an approach that considers the total context within which a transportation improvement project will exist. CSS principles include the employment of early, continuous, and meaningful involvement of the public and all stakeholders throughout the project development process. Additional information on CSS is available on FHWA's website at: http://www.fhwa.dot.gov/context/index.cfm

In summary, the open space mitigation programs include the following types of measures:

- Identifying open space areas that can be preserved and developing mitigation measures such as mitigation banking, transfer of development rights (for agricultural lands), and payment in lieu of fees
- Updating General Plan information from cities to provide the most recent land use data to the region
- Coordinating with cities and counties to implement growth strategies that maximize the existing transportation network
- Evaluating project alternatives and alternative route alignments where projects intersect with sensitive habitats
- Integrating the planning of transportation facilities with context-sensitive design elements such as wildlife crossings

ENERGY

As the region continues to add more people, households and jobs, the demand for energy will continue to grow. Every day, the SCAG Region consumes over 23 million gallons of oil and the SCAG Region's vehicle fuel consumption has increased 20 percent over the last ten years.[1] In the face of this growth in energy demand and concerns about future oil supplies, there is the mounting realization that we are living in an energy-constrained world. As such, the 2008 RTP includes strategies to reduce Vehicle Miles Traveled (VMT), and as a result, per capita energy consumption from the transportation sector. The PEIR also includes mitigation measures relating to energy designed to reduce

[1] California Department of Transportation, Division of Transportation System Information. (December 2006.) California Motor Vehicle Stock, Travel and Fuel Forecast.

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consumption and increase the use and availability of renewable sources of energy in the region.

The mitigation program in the PEIR generally includes opportunities to reduce petroleum vehicle fuel consumption and increase energy efficiency in the region. Potential mitigation programs include coordinating transportation, land use and air quality planning to reduce VMT, energy use and greenhouse gas emissions as well as increasing automobile fuel efficiency and construction of infrastructure to accommodate increased use of motor vehicles powered by alternative fuels. In California, efforts are underway to reduce petroleum use, reduce emissions from light-duty vehicles, reduce the carbon intensity of fuels, improve transportation energy efficiency, and encourage smart land use and intelligent transportation strategies.

In addition to transportation strategies, building design and housing types also have a strong relationship to energy use and efficiency. The mitigation program generally includes energy-efficient building practices, smarter land use planning with a focus on access to public transportation, and participation in energy efficiency incentive programs. All publicly owned utilities and most municipality-owned utilities that provide electric or natural gas service also administer energy conservation programs. These programs typically include home energy audits; incentives for replacement of existing appliances with new, energy-efficient models; and provision of resources to inform businesses on development and operation of energy-efficient buildings.

In summary, the energy mitigation program includes the following types of measures:

- Considering best practices and technological improvements that can reduce the consumption of fossil fuels such as modernizing older engines and equipment
- Developing programs to reduce single-occupancy vehicle trips such as telecommuting, ridesharing, alternative work schedules, and parking cash-out (offering employees a cash allowance in lieu of a parking space)
- Creating communities where people live closer to work, bike, walk, and take transit as a substitute for personal auto travel
- Integrating green building measures into project design and zoning such as those identified in the U.S. Green Building Council's Leadership in Energy and Environmental Design, Energy Star Homes, Green Point Rated Homes, and the California Green Builder Program

As stated above, energy experts have suggested that there is a potential for energy demand to exceed supply. Recommendations to reduce energy consumption are included in the EIR as mitigation measures. Over the next RTP planning cycle, as technology evolves, SCAG will continue to refine recommendations to reduce regional energy consumption.

AIR QUALITY AND CLIMATE CHANGE

The 2008 RTP includes programs, policies and measures to address air emissions including greenhouse gases. Measures that help mitigate air emissions, including GHG emissions, are comprised of strategies that reduce congestion, increase access to public transportation, improve air quality, and enhance coordination between land use and transportation decisions. SCAG's vision includes the introduction of a high-speed, high-performance regional transport system that may potentially reduce airport and freeway congestion and provide an alternative to the single-occupancy automobile. In order to disclose potential environmental effects of the RTP, SCAG has prepared an estimated inventory of the region's existing GHG emissions, identified mitigation measures, and compared alternatives in the PEIR. The mitigation measures seek to achieve the maximum feasible and cost-effective reductions in emissions. There are difficulties in quantifying reductions in GHG emissions due to insufficient data. During the next RTP cycle, SCAG will focus on refining techniques to better estimate emission reductions associated with identified mitigation measures.

The air quality mitigation program includes, but is not limited to, the following types of measures:

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- ARB measures that set new on-road and off-road engine standards and accelerate turnover of higher emitting engines from the in-use fleet;
- Project specific measure to reduce impacts from construction activities such as the use of water and dust suppressants and restrictions on trucks hauling dirt, sand and soil.
- Encouragement of green construction techniques such as using the minimum amounts of GHG emitting construction equipment; and
- Incorporating planting of shade trees into construction projects where feasible

In addition, the RTP includes Transportation Control Measures (TCMs), which are those projects that reduce congestion and improve air quality in the region.

TRANSPORTATION

The 2035 transportation model takes into account the population, households, and employment projected for 2035, and therefore the largest demand on the transportation system expected during the lifetime of the 2008 RTP. In accounting for the effects of regional population growth, the model output provides a regional, long-term and cumulative level of analysis for the impacts of the 2008 RTP on transportation resources. The regional growth and thus cumulative impacts are captured in the VMT, VHT, and heavy-duty truck VHT data.

Implementation of the 2008 RTP would include implementation of a series of projects which are described in the Regional Transportation Plan. The 2035 transportation system performance is compared to the performance of the existing (2008) system for the purpose of determining the significance of impacts.

The transportation mitigation program includes the following types of measures:

- Increasing rideshare and work-at-home opportunities to reduce demand on the transportation system
- Investments in non-motorized transportation and maximizing the benefits of the land use-transportation connection
- Travel Demand Management (TDM) measures
- Goods movement capacity enhancements
- Key transportation investments targeted to reduce heavy-duty truck delay

POPULATION AND HOUSING

Transportation projects including new and expanded infrastructure are necessary to improve travel time and can enhance quality of life for those traveling throughout the region. However, these projects also have the potential to induce population growth in certain areas of the region. Although SCAG does not anticipate that the RTP would affect the total growth in population in the region, the RTP has the ability to affect the distribution of that growth. In addition to induced population growth, transportation projects in the RTP

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also have the potential to divide established communities, primarily through acquisition of rights-of-way.

The population and housing mitigation program includes the following types of measures:

- Develop advisory land use policies and strategies that utilize the existing transportation network and enhance mobility while reducing land consumption
- Require project implementation agencies to provide relocation assistance, as required by law, for residences and businesses displaced
- Require project implementation agencies to design new transportation facilities that consider existing communities

LAND USE

The 2008 RTP contains transportation projects to help more efficiently distribute population, housing, and employment growth. These transportation projects are generally consistent with the county- and regional-level general plan data available to SCAG. However, general plans are not updated consistently. In addition, the RTP's horizon year of 2035 is beyond the timeline of even the most recent general plans.

The land use mitigation program includes the following types of measures:

- Encourage cities and counties to update their general plans and provide the most recent plans to SCAG
- Work with member cities to ensure that transportation projects are consistent with the RTP and general plans
- Work with cities and counties to ensure general plans reflect RTP policies

AESTHETICS

The SCAG Region includes several highway segments that are recognized by the State of California as designated scenic highways or are eligible for such designation. Construction and implementation of projects in the RTP could impact designated scenic highways and restrict or obstruct views of scenic resources such as mountains, ocean, rock outcroppings, etc. In addition, some transportation projects could add urban visual elements, such as transportation infrastructure (highways, transit stations) to previously natural areas.

In summary, the aesthetics mitigation program includes the following types of measures:

- Require project implementation agencies to implement design guidelines to protect views of scenic corridors
- Require project implementation agencies to use construction screens and barriers that complement the existing landscape
- Require project implementation agencies to complete design studies for projects in designated or eligible scenic highways
- In visually sensitive areas, require local land use agencies to apply development standards and guidelines that maintain compatibility

PUBLIC SERVICES

Impacts to public services from the 2008 RTP generally include additional demands on fire and police services, schools and landfills. Additional police and fire personnel would be needed to adequately respond to emergencies and routine calls, particularly on new or expanded transportation facilities. The 2008 RTP's influence on growth could contribute to impacts on public schools, requiring additional teachers and educational facilities. Additional population growth could result in a greater demand for solid waste disposal facilities. Furthermore, collecting solid waste and transporting it to an available disposal facility would impact roads and railways.

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In summary, the public services mitigation program includes the following types of measures:

- Require the project implementation agencies to identify police protection, fire service, emergency medical service, waste collection and public school needs and coordinate with local officials to ensure that the existing public services would be able to handle the increase in demand for their services
- Require the project implementation agencies to identify the locations of existing utility lines and avoid all known utility lines during construction
- Encourage green building measures to reduce waste generation and reduce the amount of waste sent to landfills
- Encourage the use of fire-resistant materials and vegetation when constructing projects in areas with high fire threat

BIOLOGICAL RESOURCES

Impacts to biological resources generally include displacement of native vegetation and habitat on previously undisturbed land; habitat fragmentation and decrease in habitat connectivity; and displacement and reduction of local, native wildlife including sensitive species. Building new transportation routes and facilities through undisturbed land or expanding facilities and increasing the number of vehicles traveling on existing routes will directly injure wildlife species, cause wildlife fatalities, and disturb natural behaviors such as breeding and nesting. This will result in the direct reduction or elimination of species populations (including sensitive and special-status species) and native vegetation (including special-status species and natural communities) as well as the disruption and impairment of ecosystem services provided by native habitat areas.

The biological resources mitigation program includes the following types of measures:

- Planning transportation routes to avoid/minimize removal of native vegetation, displacement of wildlife, and impacts to regionally and locally significant habitat types such as oak woodlands, vernal pools, estuaries, lagoons, and other riparian areas
- Including provisions for habitat enhancement such as mitigation banking, improving/retaining habitat linkages, preserving wildlife corridors and wildlife crossings to minimize the impact of transportation projects on wildlife species and habitat fragmentation
- Conducting appropriate surveys to ensure no sensitive species' habitat or special-status natural communities is unnecessarily destroyed
- Avoiding and minimizing impacts to wildlife activities (such as breeding, nesting, and other behaviors) during construction of the project by avoiding construction during critical life stages or sensitive seasons
- Avoiding and minimizing impacts to habitat during project construction through actions such as fencing off sensitive habitat, minimizing vehicular accessibility, and salvaging native vegetation and topsoil
- Minimizing further impacts to wildlife and their habitats after project construction by replanting disturbed areas; providing vegetation buffers at heavily trafficked transportation facilities; and restoring local, native vegetation

GEOLOGY, SOILS, AND SEISMICITY

Impacts to geological resources generally include the disturbance of unstable geologic units (rock type) or soils, causing the loss of topsoil and soil erosion, slope failure, subsidence, project-induced seismic activity and structural damage from expansive soils. These activities, in addition to building projects on and around Alquist-Priolo Fault Zones and other local faults, could expose people and/or structures to the risk of loss, injury, or death.

The geological mitigation program includes the following types of measures:

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- Employing appropriate grading, construction practices, siting, and design standards, such as adherence to the California Building Code and State of California design standards
- Obtaining site-specific geotechnical data from qualified geotechnical experts
- Complying with all relevant local, state, and federal construction and design requirements for structures located on or across Alquist-Priolo Fault Zones and other local faults

CULTURAL RESOURCES

Impacts to cultural resources generally include substantial adverse changes to historical and archaeological resources and direct or indirect changes to unique paleontological resources or sites or unique geological features. Adverse changes include the destruction of culturally and historically (recent or geologic time) significant and unique historical, archaeological, paleontological, and geological features.

The cultural resources mitigation program includes the following types of measures:

- Obtaining consultations from qualified cultural and paleontological resource experts to identify the need for surveys and preservation of important historical, archaeological, and paleontological resources
- Implementing design and siting measures that avoid disturbance of cultural and paleontological resource areas, such as creating visual buffers/landscaping or capping/filling the site to preserve the contextual setting of the resource
- Monitoring construction activity in areas with moderate to high potential to support paleontological resources and overseeing salvage operations of paleontological resources
- Consulting local tribes and the Native American Heritage Commission for project impacts to sacred lands and burial sites

WATER RESOURCES

Impacts to water resources from the 2008 RTP include potential water quality impairment from increased impervious surfaces. Increased impervious surfaces in water recharge areas potentially impact groundwater recharge and groundwater quality. Cumulative impacts from the projected growth induced by the RTP include increased impervious surfaces; increased development in alluvial fan floodplains; and increased water demand and associated impacts, such as drawdown of groundwater aquifers. Increased output of greenhouse gases from the region's transportation system impacts the security and reliability of the imported water supply.

The water resources mitigation program includes the following types of measures:

- Utilizing advanced water capture and filtration techniques, showing a preference for naturalized systems and designs, to control stormwater at the source
- Avoiding any new construction of impervious surfaces in non-urbanized areas, such as wetlands, habitat areas, parks, and near river systems
- Avoiding any new construction that provides access to flood-prone areas, such as in alluvial fans and slide zones
- Protection and preservation of existing natural flood control systems, such as wetlands and riparian buffers, and expansion of such systems in areas where they do not currently exist
- Constructing projects according to Best Management Practices for water quality protection and water conservation, including low-impact development and green building standards

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- Coordinating project development and construction efforts across jurisdictional, agency, and departmental boundaries, to increase project benefits

HAZARDOUS MATERIALS

Implementation of the 2008 RTP would affect the transportation and handling of hazardous materials in the SCAG Region. Expected significant impacts include risk of accidental releases due to an increase in the transportation of hazardous materials and the potential for such releases to reach neighborhoods and communities adjacent to transportation facilities.

The hazardous materials mitigation program aims to minimize the significant hazard to the public or the environment that involves the release of hazardous materials into the environment. Potential mitigation programs include active coordination with regulatory agencies and first responders in order to ensure proper handling and transport of hazardous materials and their containers. Mitigation measures also involve ensuring that the project implementation agency complies with all applicable laws, regulations, and health and safety standards set forth by federal, state, and local authorities that regulate the proper handling of such materials and their containers and that the routine transport, use, and disposal of hazardous materials does not create a significant hazard to the public or the environment.

The hazardous materials mitigation programs include the following types of measures:

- Coordinating with regulatory agencies and first responders in order to continue to govern goods movement and hazardous materials transportation throughout the region
- Considering existing and known planned school locations when determining the alignment of new transportation projects and modifications to existing transportation facilities
- Encouraging project sponsors to consider published lists of contaminated properties, which are continually updated, in order to identify cases where new development would involve the disturbance of contaminated properties
- Developing appropriate mitigation measures to assure that worker and public exposure is minimized to an acceptable level and to prevent any further environmental contamination as a result of construction
- Ensuring that project implementation agencies comply with all applicable laws, regulations, and health and safety standards set forth by federal, state, and local authorities that regulate the proper handling of such materials and their containers and that the routine transport, use, and disposal of hazardous materials does not create a significant hazard to the public or the environment

SAFETY AND SECURITY

The SCAG Region is vulnerable to numerous threats that include both natural and human-caused incidents. A large-scale evacuation would be difficult in the SCAG Region. Impacts to safety and security resulting from the 2008 RTP include: 1) impairment of transportation safety, security, and reliability for all people and goods in the region; 2) prohibiting the prevention, protection, response to, and recovery from major human-caused or natural events that would create a significant hazard to the public, threatening and impacting lives, property, the transportation network and the region; and 3) exposure of people or structures to a significant risk of loss, injury or death involving wildland fires. As such, the mitigation programs for Safety and Security in the 2008 RTP aim for extensive coordination, collaboration and flexibility among all of the agencies and organizations involved in planning, mitigation, response and recovery.

The Safety and Security mitigation programs include the following types of measures:

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- Continuing deployment and promotion of intelligent transportation system technologies that enhance transportation security
- Establishing transportation infrastructure practices that promote and enhance security
- Establishing a forum where policy-makers can be educated and regional policy can be developed
- Helping to enhance the region's ability to deter and respond to terrorist incidents, and human-caused or natural disasters by strengthening relationships and coordination with transportation agencies
- Working to enhance emergency preparedness awareness among public agencies and with the public at large

NOISE

Some of the principal noise generators within the SCAG Region are associated with transportation (i.e., airports, freeways, arterial roadways, seaports, and railroads). Additional noise generators include stationary sources, such as industrial manufacturing plants and construction sites. Noise impacts resulting from the 2008 RTP generally include exposure of sensitive receptors to noise in excess of normally acceptable noise levels or substantial increases in noise as a result of the operation of expanded or new transportation facilities. As such, the noise mitigation program includes mitigation measures designed to minimize the impact of noise on sensitive receptors as a result of the implementation of the 2008 RTP.

These mitigation measures include ensuring that project implementing agencies comply with all local sound control and noise level rules, regulations, and ordinances; utilizing the best available noise control techniques (including mufflers, intake silencers, ducts, engine enclosures and acoustically attenuating shields or shrouds) in order to minimize construction noise impacts; and utilizing land use planning measures, such as zoning, restrictions on developments, buffers, etc., to minimize exposure to sensitive receptors.

The noise mitigation programs include the following types of measures:

- Encouraging project implementing agencies to comply with all local sound control and noise level rules, regulations, and ordinances
- Developing the best available noise control techniques in order to minimize construction noise impacts
- Conducting a project-specific noise evaluation as part of the appropriate environmental review of each project
- Encouraging project implementation agencies to maximize the distance between noise-sensitive land uses and new roadway lanes, roadways, rail, transit centers, park-and-ride lots, and other new noise-generating facilities

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IV. FINANCIAL PLAN

The financial plan identifies how much money is available to support the region's surface transportation investments including transit, highways, local road improvements, system preservation and demand management goals. It also addresses the need for investment in goods movement infrastructure. Improving ground access in and around major goods movement facilities, and enhancing major highways and railways are critical to maintaining the health of Southern California's economy. The 2008 RTP calls for traditional and non-traditional revenue sources for implementing a program of infrastructure and environmental improvements to keep both freight and people moving.

The 2008 RTP financial plan identifies a number of new revenue sources to provide additional funding beyond existing transportation dollars. The SCAG region's financially constrained plan includes a core revenue forecast of existing local, state, and federal sources along with new funding sources that are reasonably available over the time horizon of the RTP. The plan also includes action steps to obtain the revenues necessary for implementing the region's transportation vision. The region has successfully secured the necessary resources to support transportation investments proposed in past RTPs and this plan will continue to meet the necessary milestones for implementation. Since 2002, three counties within the SCAG region (Riverside, San Bernardino, and Orange) reauthorized their local sales tax measures with overwhelming voter approval. More recently, the general electorate of California approved Proposition 1B, the Highway Safety, Traffic Reduction, Air Quality, and Port Security Bond Act of 2006, which provides $19.9 billion in infrastructure bonds for transportation improvements throughout the state. Additional legislative gains include the protection of Proposition 42 revenues (sales tax on gasoline) for transportation purposes with the passage of Proposition 1A.

In 2006, the State Legislature also reviewed the potential for using public-private partnerships to facilitate project delivery. With the passage of AB 1467 (Nunez, Chapter 32, Statutes of 2006), the state established a framework for moving forward with partnership demonstration projects. Further, AB 521 (Runner, Chapter 542, Statutes of 2006) clarified the State Legislature's role in evaluating partnership proposals, mandating that the Legislature can only disapprove of the proposals. AB 1467 authorizes two public-private partnerships related to goods movement in Southern California. The bill also authorizes the implementation of high-occupancy toll (HOT) lanes, which would allow the region to better utilize its High-Occupancy Vehicle (HOV) lanes and generate toll revenues. Recent passage of AB 1467 and AB 521 provides a sound basis for SCAG's 2008 RTP financial strategies.

In developing the financial plan, SCAG followed a few basic principles to guide its regional financial forecast:

- Incorporate financial planning documents developed by local county transportation commissions and transit operators in the region where available
- Ensure consistency with both local and state planning documents
- Utilize published data sources to evaluate historical trends and augment local forecasts as needed, and
- Recommend new funding sources that target beneficiaries of transportation investments

The rest of the plan outlines our financial strategies and provides documentation of the financial assumptions and methodologies used for forecasting revenues and expenditures.

The Economic Outlook

Overall economic conditions play a large role in determining the level of revenues available for transportation. Although it is difficult to predict the future, SCAG's financial model takes a conservative approach in forecasting the latter years of the RTP planning horizon. The approach also includes maintaining historical growth trends for key revenue sources, including locally generated sales tax revenues as well as both state and federal gas tax revenues.

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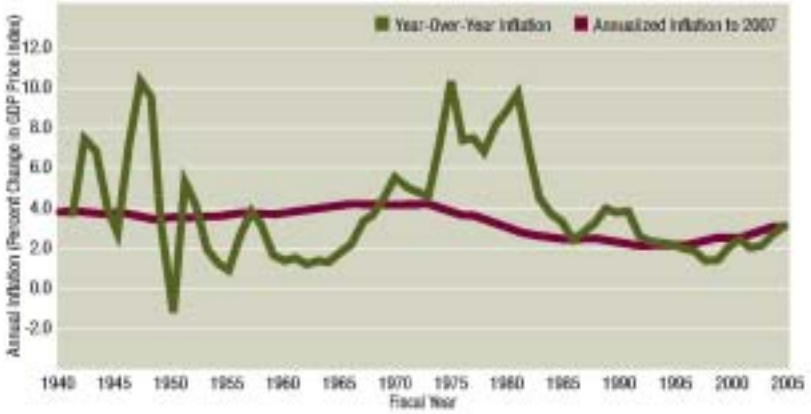
INFLATION

The effect of inflation over a long-range plan is significant, particularly in the last few years when inflation has had nearly 30 years to erode the value of money. This causes both costs and revenues to be higher in nominal dollar terms. Figure 4.1 shows inflation trends since World War II as measured by the Gross Domestic Product (GDP) Price Deflator. Inflation has varied considerably over the long term, but has trended between 2 and 4 percent, as illustrated by the red line. In recent years, inflation has increased. SCAG's revenue model utilizes historical inflation trends as measured by the GDP Price Deflator – an approach consistent with that used by the Federal Office of Management and Budget in preparing the Budget of the United States Government. On the basis of this information, a 3.8 percent inflation rate is used to adjust revenue model data to nominal dollars (year-of-expenditure dollars).

FIGURE 4.1 HISTORICAL INFLATION TRENDS



Source: Office of Management and Budget, Budget of the United States Government, Fiscal Year 2008 Budget (FY08).

CONSTRUCTION COST INCREASES

While revenues can be eroded by inflation, construction costs in California and the nation have escalated considerably over the last four years. This has been a major impediment to delivering transportation projects. The recent large increase in construction costs is due to a variety of factors, including a building boom and higher demand for commodities in developing countries, especially China with construction for the 2008 Olympics. Figure 4.2 shows the increase in California highway construction costs. It is unlikely that costs will continue to increase at a such a rapid rate in the future. The increase over the last few years is unprecedented. The financial plan uses a 5.3 percent annual inflation factor to estimate future, nominal costs.

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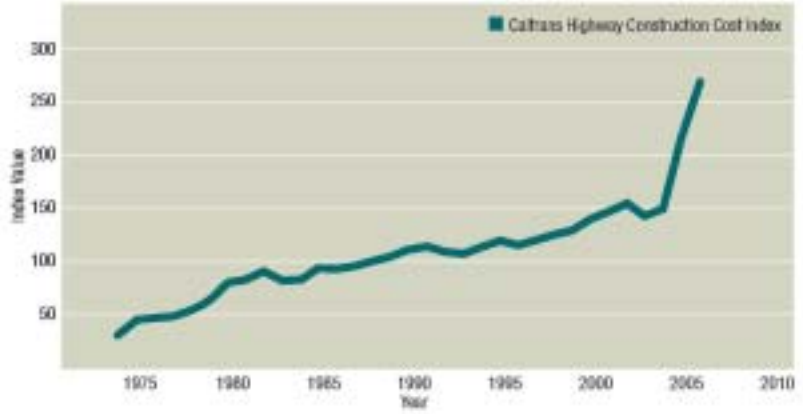
FIGURE 4.2 HIGHWAY PROJECT COSTS



Source: California Department of Transportation

RETAIL SALES GROWTH

Available land, population increases, and new retail locations are the biggest contributors to growth in retail sales. According to statistics from the California Board of Equalization, retail sales grew by 2.3 percent in the SCAG region from FY1978 to FY2004, a period roughly equal in length to the 2008 RTP. Growth was uneven, ranging from 1.3 percent in Los Angeles County to 5.5 percent in Riverside County. The financial plan assumes that uneven growth will continue, with retail sales growth ranging from 1.2 to 4.7 percent.

FUEL CONSUMPTION

Taxes on gasoline and diesel fuels are the basis of many transportation revenue sources. These types of revenues are solely dependent on fuel consumption. Over the next several decades, fuel consumption will continue to be impacted by increases in vehicle-miles traveled, increases in conventional vehicle fuel economy, and the adoption of alternative fuel vehicles. While Caltrans estimates that fuel consumption statewide will increase by 1.7 percent between 2004 and 2030, the financial plan takes a more conservative approach and assumes that fuel consumption will not increase over the RTP planning horizon.

STATUS OF THE FEDERAL HIGHWAY TRUST FUND

The Federal Highway Trust Fund provides federal highway and transit funding from a nationally imposed 18.3-cent-per-gallon gasoline tax. The Federal Highway Trust Fund has grown by 3.4 percent annually due to historical increases in fuel consumption, but recently, a larger share is being devoted to transit, as shown in Figure 4.3.

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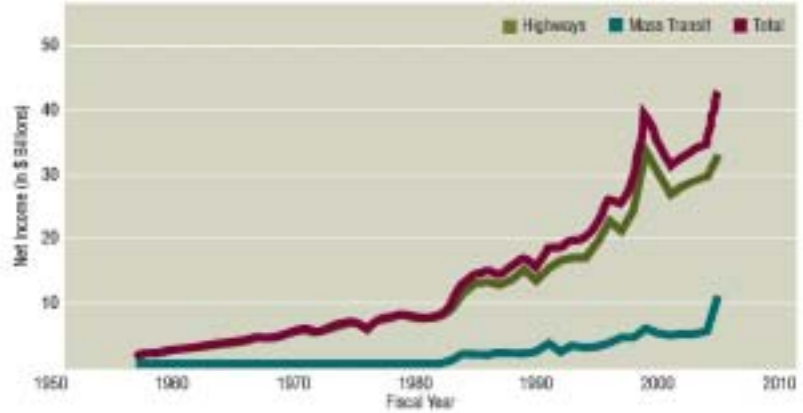
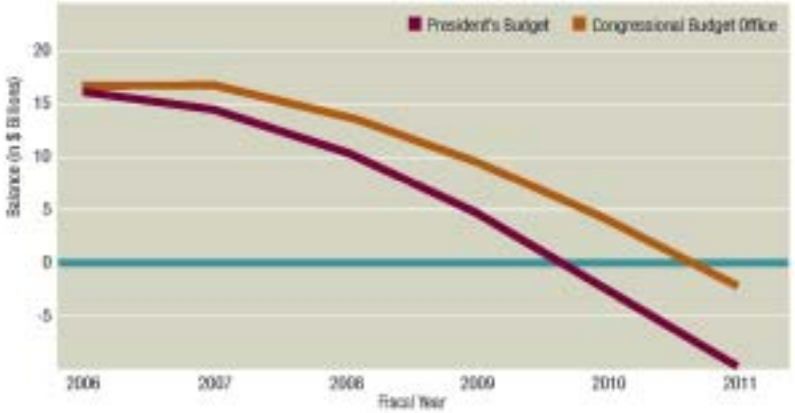
FIGURE 4.3 STATUS OF THE FEDERAL HIGHWAY TRUST FUND



Source: Federal Highway Administration, Federal Highway Statistics 2005

FIGURE 4.4 CURRENT HIGHWAY TRUST FUND YEAR-END BALANCE ESTIMATES



Source: United States Government Accountability Office, Highway Trust Fund: Overview of Highway Trust Fund Estimates, GAO Testimony Before the Subcommittee on Highways, Transit, and Pipelines, Committee on Transportation and Infrastructure, GAO-06-572T

Many public officials and transportation professionals have become concerned about the health of the Federal Highway Trust Fund, as expenditures authorized under Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) have outstripped revenues generated by the tax. Figure 4.4 shows a chart from a recent Government Accountability Office (GAO) analysis of Federal Highway Trust Fund forecasts. Congressional leadership has shown concern over the problem and the SCAG 2008 RTP assumes that Congress will take action to ensure that the Highway Trust Fund maintains current funding levels.

STATUS OF THE STATE HIGHWAY ACCOUNT

The viability of the State Highway Account remains a critical issue. The state's gasoline tax revenues are now exclusively dedicated to funding the State Highway Operation and Protection Program (SHOPP). As shown in Figure 4.5, previous levels of funding have been considerably less than actual needs. Continued under investment in the rehabilitation and maintenance needs of the State Highway System has serious ramifications—rapidly increasing the number of distressed lane-miles on the State Highway System and eroding the condition of the state's bridges.

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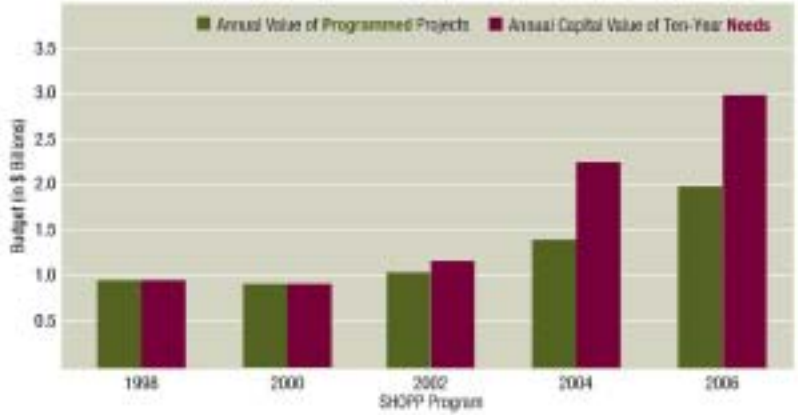
FIGURE 4.5 STATE HIGHWAY OPERATION AND PROTECTION PROGRAM



Source: California Department of Transportation, 2007 Ten-Year SHOPP Plan

Statewide, the 2007 Ten-Year SHOPP Plan identifies $4.2 billion in annual needs, while fiscally constrained funding plan for the next four years are only $1.9 billion annually. The RTP assumes that the State Legislature will address this need through an adjustment in the state gas excise tax and that other revenues will continue to be available for capital projects.

AIR QUALITY ATTAINMENT

Air quality determines the amount of Congestion Mitigation and Air Quality (CMAQ) funding available to the SCAG region. The 2008 RTP assumes that the region will be in attainment for a number of pollutants. It also assumes the severity level for other pollutants will lessen as of 2020. As a result, CMAQ funding is halved.

LOCAL SALES TAX MEASURES

Most of the counties in the SCAG region impose a local sales tax to fund transportation projects. Ventura County is the only county in the region without a dedicated sales tax. In recent years, several local sales taxes have been renewed and the 2008 RTP reflects these additional revenues:

- San Bernardino County renewed Measure I through 2040.
- Riverside County renewed Measure A through 2039.
- Orange County recently renewed Measure M through 2041.

Los Angeles County levies a permanent 1 percent tax (a combination of two half-cent sales taxes). In Imperial County, Measure D will expire in 2010. However, the 2008 RTP assumes an extension of Measure D as part of new revenue sources.

TRANSIT OPERATING AND MAINTENANCE (O&M) COSTS

Future transit O&M costs are difficult to predict because they depend on a variety of factors, such as future revenue-miles of service, labor contracts, and the age of rolling stock. The addition of new transit service and capital proj-

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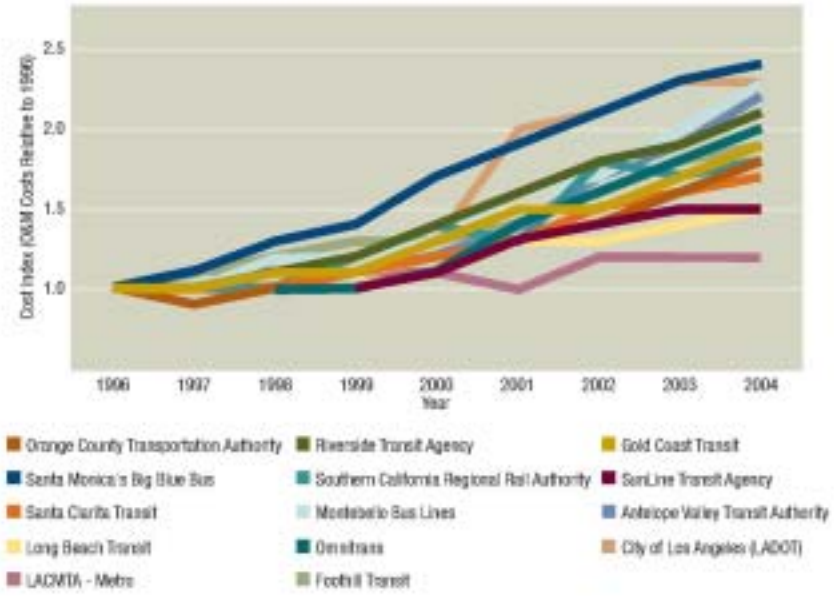
ects, such as the Mid-City/Exposition Corridor Light Rail Transit (LRT), can add to ongoing O&M costs. Over the last decade, these O&M costs grew 1 to 10 percent annually, depending on the transit operator (see Figure 4.6). Some of the differences in O&M growth are due to rapid expansion among the newer operators and outsourcing among the older operators.

FIGURE 4.6 GROWTH IN TRANSIT OPERATING AND MAINTENANCE COSTS



Source: SCAG Analysis of National Transit Database Statistics

For the 2008 RTP, transit O&M costs are estimated based upon historical increases:

- The regional average increase (4 percent) is used for most operators. This assumes that some of the extraordinary increases for individual operators due to rapid expansion will not continue into the future.
- For Los Angeles County, the financial plan relies on detailed forecasts from the county transportation commission. These forecasts are consistent with historical data and take into account large shifts in O&M costs due to major capital projects.

DEBT SERVICE

Local agencies in the SCAG region have historically relied on debt financing to ensure that revenues are available to meet the cash flow requirements of future expenditures. The Los Angeles County Metropolitan Transportation Authority (LACMTA - Metro) has a detailed county financial model that estimates debt service on a project basis. Other county transportation commissions prepare debt service forecasts for rating agencies and report current debt service in their comprehensive annual financial reports (CAFRs). The 2008 RTP includes all outstanding commitments and interest payments on future bonds and commercial paper. Issued debt is expected to remain under debt ceilings. For counties without an established policy, debt service is assumed to be constrained to 50 percent of revenues.

Definition of Revenue Scenarios and Expenditure Categories

CORE AND REASONABLY AVAILABLE REVENUE SCENARIOS

For the 2008 RTP, SCAG prepared two types of revenue forecasts. Both are included in the financially constrained plan:

- Core revenues
- Reasonably available revenues

The *core revenues* identified are those that have been committed or historically available for the building, operations, and maintenance of the current roadway and transit systems in the SCAG region. Essentially, these revenues are existing transportation funding sources projected to FY2036. The core forecast includes neither future increases in tax rates nor extensions of tax

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measures beyond their expiration date—unless already approved through ballot initiatives. These revenues provide a benchmark from which additional funding can be identified.

The region's *reasonably available revenues* include new sources of transportation funding likely to materialize within the 2008 RTP time frame. These new sources include adjustments to state and federal gas tax rates based on historical trends, extension of a local option sales tax, localized value capture strategies, container fees, as well as passenger and commercial truck tolls for specified facilities. Reasonably available revenues also include innovative financing strategies, such as private equity participation. In accordance with federal guidelines, the plan includes strategies for ensuring the availability of these sources.

EXPENDITURE CATEGORIES

Transportation expenditures in the SCAG region can be summarized into three main categories:

- Capital costs for state highways, regionally significant arterials, local streets and roads, as well as transit
- Operating and maintenance costs for state highways, regionally significant arterials, local streets and roads, as well as transit
- Debt service payments for current and anticipated bond issuances

Core Revenues

A regional revenue model was developed to forecast the revenues over the entire RTP time horizon. The revenue model is detailed and supports analysis by county or funding source. The basic process for developing the revenue forecast is as follows:

- Build on the revenue forecasts provided by the county transportation commissions
- Add assumptions based on historical data
- Compare historical data to Short-Range Transit Plans and other agency documents
- Work with the transportation commissions to modify assumptions and forecasts as needed

The region's revenue forecast horizon for the 2008 RTP is FY2007 through FY2036. Consistent with federal guidelines, the 2008 RTP takes into account inflation and reports statistics in nominal (year of expenditure) dollars. Table 4.1 shows these core revenues in five-year increments by county.

TABLE 4.1 CORE REVENUE FORECAST FY 2007-2036 (IN NOMINAL DOLLARS, BILLIONS)

County	FY2007-11	FY2012-16	FY2017-21	FY2022-26	FY2027-31	FY2032-36	Total
Imperial	$0.4	$0.4	$0.3	$0.4	$0.4	$0.4	$2.3
Los Angeles	$29.1	$30.5	$32.8	$39.7	$45.3	$53.2	$230.6
Orange	$6.8	$7.8	$9.2	$11.5	$14.4	$17.9	$67.7
Riverside	$4.3	$5.3	$6.8	$9.0	$12.9	$18.5	$56.8
San Bernardino	$5.2	$5.7	$6.6	$7.1	$8.9	$11.4	$44.9
Ventura	$1.0	$1.1	$1.2	$1.5	$1.9	$2.4	$9.1
Total	**$46.8**	**$50.7**	**$56.9**	**$69.2**	**$83.8**	**$103.9**	**$411.4**

Note: Numbers may not add due to rounding.

As shown in Figure 4.7, the majority of revenues in the SCAG region come from local sources. The share of state sources (20 percent) has increased since the last RTP (15 percent) as a result of two propositions. Proposition 1A protects funding from the state gasoline sales tax, and Proposition 1B authorizes $19.9 billion in bonds over the next several years to fund existing and new statewide transportation-related infrastructure programs.

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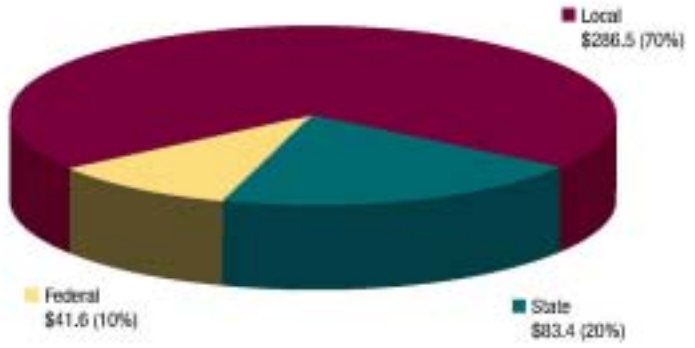
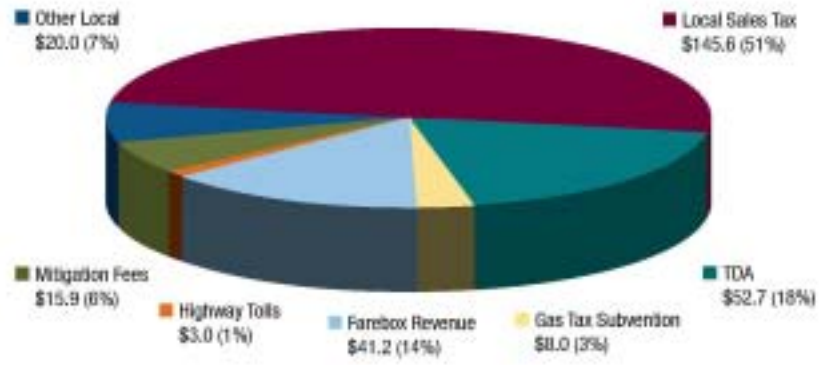
FIGURE 4.7 SCAG REGIONAL REVENUES (IN NOMINAL DOLLARS) $411.4 BILLION TOTAL



Source: SCAG Revenue Model 2007

Note: Numbers may not add due to rounding.

FIGURE 4.8 SCAG REGIONAL REVENUES, LOCAL SOURCES (IN NOMINAL DOLLARS) $286.5 BILLION TOTAL



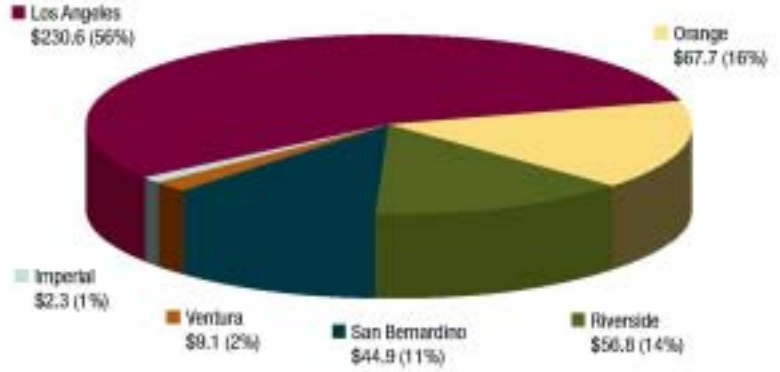
Source: SCAG Revenue Model 2007

Note: Numbers may not add due to rounding.

Local option sales taxes provide the largest single source of local funding as shown in Figure 4.8 and compose roughly a third (35.6 percent) of overall funding for the RTP. Local sales tax revenues have been boosted by the renewal of several local measures.

Specifically, sales tax extensions have significantly increased the funding available in San Bernardino and Riverside Counties and their shares of overall regional transportation revenues. Figure 4.9 shows the breakdown of revenues by county.

FIGURE 4.9 SCAG REGIONAL REVENUES BY COUNTY (IN NOMINAL DOLLARS) $411.4 BILLION TOTAL



Source: SCAG Revenue Model 2007

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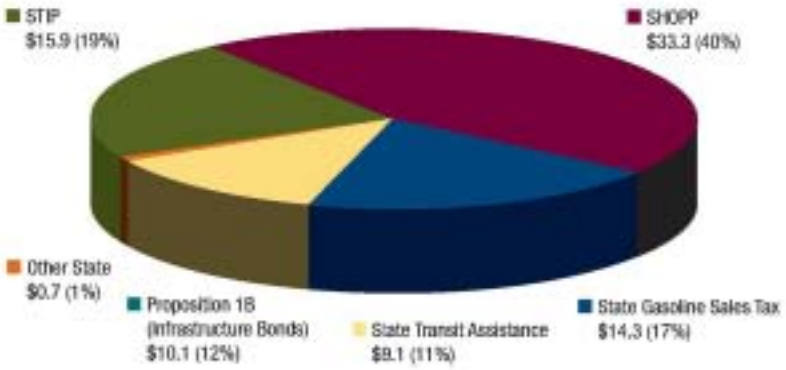
State sources generate a larger share of revenues than in the 2004 RTP, mostly due to the infrastructure bonds (Proposition 1B) and state gasoline sales tax protection (Proposition 1A). The infrastructure bonds and state gasoline sales taxes make up roughly 30 percent of the total $83.4 billion in forecasted state revenues (see Figure 4.10).

FIGURE 4.10 SCAG REGIONAL REVENUES, STATE SOURCES (IN NOMINAL DOLLARS) $83.4 BILLION TOTAL

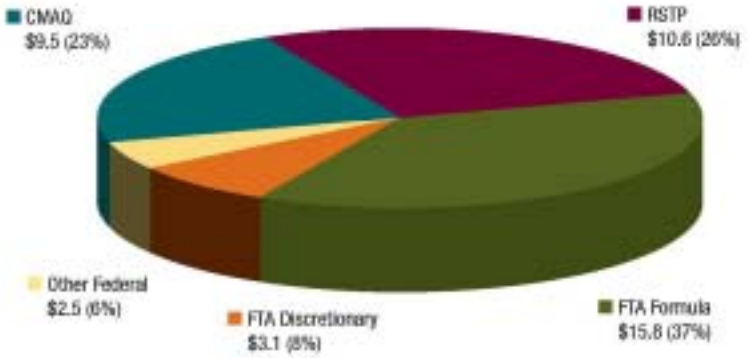


Source: SCAG Revenue Model 2007

Note: Numbers may not add due to rounding.

As shown in Figure 4.11, federal sources are anticipated to remain steady and represent a small portion of overall transportation funds ($41.6 billion). One of the largest declines in federal funding will be due to the region achieving attainment for a number of pollutants by 2020. This will result in less CMAQ funding.

FIGURE 4.11 SCAG REGIONAL REVENUES, FEDERAL SOURCES (IN NOMINAL DOLLARS) $41.6 BILLION TOTAL



Note: Numbers may not add due to rounding.

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Reasonably Available Revenues

There are several new funding sources that will increase the revenues available for the 2008 RTP. The region also expects to leverage innovative financing strategies.

Table 4.2 presents twelve categories of funding sources and financing techniques that were evaluated for the RTP. They were selected as a result of their use in other areas of the state, the burgeoning potential, historical precedence and likelihood of implementation within the time frame of the 2008 RTP. These funding sources are reasonably available and are included in the financially constrained plan. For each funding source, SCAG has examined the policy and legal context of implementation and has prepared an estimate of the revenue potential.

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TABLE 4.2 NEW REVENUE SOURCES AND INNOVATIVE FINANCING STRATEGIES (IN NOMINAL DOLLARS, BILLIONS)

Revenue Source	Description	Amount	Actions to Ensure Availability	Responsible Party
Value Capture Strategies	Various techniques assumed: formation of special districts, including Benefit Assessment Districts, Mello-Roos Community Facility Districts, as well as tax increment financing and joint development to provide gap financing for specific transit investments (Gold Line extension, Purple Line extension, and the HSRT system). SCAG also assumes one-time proceeds from the sale of Caltrans-owned property within the SR-710 tunnel vicinity.	$3.7	Pursue necessary approvals for special districts by 2012 (Benefit Assessment Districts require majority approval by property owners; Mello-Roos tax requires two-thirds approval); work with private entities for joint development opportunities; also, work with Caltrans to utilize proceeds from real estate sales to partially fill funding gap for the SR-710 tunnel; pursue legislation to enable sales and to establish escrow account for the proceeds	MPO, transit operators, local jurisdictions, property owners along project corridors, developers, Caltrans
Local Option Sales Tax Extension	Half-cent sales tax measure extension for Imperial County—existing Measure D expires in 2010	$0.8	Local sales tax measure to be placed on ballot by 2010	Imperial County
Highway Tolls (includes toll revenue bond proceeds)	Toll revenues generated from the SR-710 tunnel, I-710 dedicated truck lanes, High Desert Corridor, and CETAP Corridor	$22.0	Region was granted authority under AB 1467 (2006) to impose tolls and work with private entities for the financing of goods movement related facilities including the I-710 dedicated truck lanes; additional state legislative approval needed for the SR-710 tunnel	MPO, local county transportation commissions (LACMTA, SANBAG, RCTC), State Legislature
State and Federal Gas Excise Tax Adjustment to Maintain Historical Purchasing Power	Estimate equivalent to additional ten cent per gallon gasoline tax imposed by the state and federal government starting in 2012—extrapolation of historical trend	$17.0	Congressional and state legislative approval	MPO, State Legislature, Congress
Container Fees (includes container fee bond proceeds)	Charge imposed on containerized cargo moving through the Ports of LA/LB (includes railroad user-fees for rail capacity improvement program); fees are directly linked to specific goods movement projects	$41.5	Negotiated by ports, shipping community, regional stakeholders or state legislative approval (upon passage of SB 974 or other legislative effort)	Ports, shippers, goods movement stakeholders (MPO, railroads, local county transportation commissions), State Legislature
Private Equity Participation	Public Private Partnership arrangement whereby a private entity designs, finances, builds, operates, and maintains a facility under a lease arrangement for a fixed period of time	$4.4	Region was granted authority under AB 1467 (2006) to work with private entities for the financing of freight-related projects; additional state legislative approval needed for the SR-710 tunnel	MPO, local county transportation commissions, private consortium, State Legislature

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Revenue Source	Description	Amount	Actions to Ensure Availability	Responsible Party
Private Activity Bonds (PAB)	Interest savings from the issuance of tax-exempt private activity bonds	$0.4 (included in container fees)	Work with railroads and other regional stakeholders to receive federal PAB allocation	MPO, freight railroads, local county transportation commissions, US DOT
U.S. Environmental Protection Agency (EPA) funding for clean freight rail technology	EPA subsidies to help mitigate locomotive emissions per the 2007 State Implementation Plan (SIP)	$1.9	Work with railroads, AQMD, ARB and US EPA for federal clean technology funding allocation	MPO, freight railroads, AQMD, ARB, US EPA
Interest Earnings	Interest earnings from toll bond proceeds (High Desert Corridor, CETAP, SR-710 tunnel, and I-710 truck lanes)	$0.4	See Highway Tolls	See Highway Tolls
Riverside County Measure A (Bond Anticipation Notes)	Short-term debt to help fund the CETAP Corridor in anticipation of the sale of Measure A revenue bonds	$1.5	Issuance of debt subject to RCTC Board policy	RCTC
Transportation Infrastructure Finance and Innovation Act (TIFIA) Loan	The TIFIA loan program provides credit assistance for transportation investments of national/regional significance; TIFIA loan assumed for the CETAP Corridor	$0.9	Work with US DOT and RCTC to evaluate applicability of the TIFIA loan program for the CETAP Corridor; further feasibility work necessary to assess traffic and revenue potential on CETAP Corridor	MPO, RCTC, US DOT TIFIA Office
HSRT Passenger System (Private Contribution & User Fee)	User fee-supported initiative for HSRT system. Assumes private-sector development: design, finance, build, operate and maintain. See HSRT Report for further details	$26.2	For the IOS: form JPA, finalize development of a comprehensive business plan; work with private entity to ensure commitment	MPO, private consortium, local/regional stakeholders

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Summary of Revenue Sources and Expenditures

TABLE 4.3.1 CORE AND REASONABLY AVAILABLE REVENUE PROJECTIONS (IN NOMINAL DOLLARS, BILLIONS)

Revenue Source	Revenue Projection Assumptions	Revenue Estimate
LOCAL REVENUE SOURCES		
Local Option Sales Tax Measures	**Description:** Locally imposed ½ percent sales taxes in four counties (Imperial, Orange, Riverside, and San Bernardino). Permanent 1 percent (combination of two ½ cent sales taxes) in Los Angeles. **Assumptions:** Sales taxes grow consistent with county transportation commission forecasts and historical trends.	$145.6
Transportation Development Act (TDA) – Local Transportation Fund	**Description:** Local Transportation Funds (LTF) are derived from a ¼ cent sales tax on retail sales statewide. Funds are returned to the county of generation and used mostly for transit operations and transit capital expenses. **Assumptions:** Same sales tax growth rate as used for local option sales tax measures	$52.7
Gas Excise Tax Subventions (to Cities and Counties)	**Description:** Subventions to counties and local jurisdictions in region from the California state gas tax. Revenues for the forecast are proportionate to the percentage of streets and roads that are regionally significant. **Assumptions:** Fuel consumption does not grow except in Los Angeles and Orange counties where growth is less than historical trends and consistent with forecasts by local transportation commissions. Regionally significant streets and roads (37 to 50 percent of roads) are classified as either arterials or collectors.	$8.0
Transit Farebox Revenue	**Description:** Transit fares collected by transit operators in the SCAG region. **Assumptions:** Farebox revenues increase consistent with historic trends, planned system expansions, and operator forecasts.	$41.2
Highway Tolls (in core revenue forecast)	**Description:** Revenues generated from toll roads operated by the Transportation Corridor Agencies (TCA). **Assumptions:** Traffic does not grow (compared to historical growth of about 3.8 percent) in core revenue forecast scenario.	$3.0
Mitigation Fees	**Description:** Revenues generated from development impact fees. The revenue forecast includes fees from the Transportation Corridor Agency (TCA) development impact fee program; the Riverside County's Transportation Uniform Mitigation Fee (TUMF) for both the Coachella Valley and Western Riverside County; and the San Bernardino County's Development Impact Fee (DIF) program. **Assumptions:** The financial forecast is consistent with revenue forecasts from Riverside County Transportation Commission (RCTC), and San Bernardino Associated Governments (SANBAG).	$15.9
Local Agency Funds	**Description:** Includes committed local revenue sources, such as transit advertising and auxiliary revenues, lease revenues, and interest and investment earnings from reserve funds. **Assumptions:** Revenues are based on financial data from transit operators and local county transportation commissions.	$20.0
LOCAL SUBTOTAL		**$286.5**

Note: Numbers may not add due to rounding

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TABLE 4.3.2 CORE AND REASONABLY AVAILABLE REVENUE PROJECTIONS (IN NOMINAL DOLLARS, BILLIONS)

Revenue Source	Revenue Projection Assumptions	Revenue Estimate
STATE REVENUE SOURCES		
State Transportation Improvement Program (STIP)	**Description:** The STIP is a five-year capital improvement program that provides funding from the State Highway Account (SHA) for projects that increase the capacity of the transportation system. The SHA is funded through a combination of state gas excise tax, the Federal Highway Trust Fund, and truck weight fees. The STIP may include projects on state highways, local roads, intercity rail, or public transit systems. The Regional Transportation Planning Agencies (RTPAs) propose 75 percent of STIP funding for regional transportation projects in Regional Transportation Improvement Programs (RTIPs). Caltrans proposes 25 percent of STIP funding for interregional transportation projects in the Interregional Transportation Improvement Program (ITIP). **Assumptions:** Funds are based upon the 2006 STIP program of projects. Long-term forecasts assume no growth in fuel consumption..	$15.9
State Highway Operation and Protection Plan (SHOPP)	**Description:** Funds state highway maintenance and operations projects. **Assumptions:** Short-term revenues are based on overlapping 2004, 2006 and 2008 SHOPP programs. Long-term forecasts are consistent with STIP forecasts and assume no growth in the fuel consumption.	$33.3
State Gasoline Sales Tax	**Description:** The state gasoline sales tax funds discretionary projects through the former Traffic Congestion Relief Program (TCRP). Proposition 42, recently restored by Proposition 1A, transfers future revenues to the Transportation Investment Fund, which distributes revenues to the STIP, local streets and roads, and transit. **Assumptions:** The financial forecast assumes that each county receives its fair share of state gasoline sales tax based upon county population. Future revenues are not expected to grow, with the exception of Orange County, which is expected to grow by a modest one percent.	$14.3
State Transit Assistance Fund (STA)	**Description:** STA is funded with 50 percent of State Public Transit Account (PTA) revenues, which come from diesel sales tax and "spillover" in the gasoline sales tax. Funding is distributed 50 percent by population share and 50 percent by revenue share of the transit operators. **Assumptions:** The forecast is based on current funding levels reported by the State Controller., except in Los Angeles and Orange counties, where growth is less than historical trends and consistent with forecasts by local transportation commissions.	$9.1
Highway Safety, Traffic, Air Quality, and Port Security Bond Act of 2006 (Proposition 1B)	**Description:** Proposition 1B authorizes $19.9 billion to be spent statewide over the next several years on existing and new statewide transportation-related infrastructure programs and projects. Several programs are included under Proposition 1B. The California Transportation Commission has not yet established priorities and funding formulas for all categories. **Assumptions:** The forecast assumes that the SCAG region receives its fair share of funding under the categories with established funding formulas. Other categories are assumed to be allocated according to population.	$10.1
Other State Sources	**Description:** Other state sources include Service Authority for Freeways and Expressways (SAFE), Freeway Service Patrol, Air Quality Vehicle Registration Fee (AB 2766), Environmental Enhancement and Mitigation, and other miscellaneous state grants. The Clean Air and Transportation Improvement Act added Proposition 116 to use state general obligation bonds to finance rail infrastructure. **Assumptions:** The RTP uses forecasts provided by LACMTA for Los Angeles County for consistency with the LACMTA long-range transportation plan. These revenues are not estimated for other counties.	$0.7
STATE SUBTOTAL (State STIP funds include FHWA IM and NHS funding categories)		**$83.4**

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TABLE 4.3.3 CORE AND REASONABLY AVAILABLE REVENUE PROJECTIONS (IN NOMINAL DOLLARS, BILLIONS)

Revenue Source	Revenue Projection Assumptions	Revenue Estimate
FEDERAL REVENUE SOURCES		
FHWA Non-Discretionary Congestion Mitigation and Air Quality (CMAQ) Program	**Description:** Program to reduce traffic congestion and improve air quality in non-attainment areas. **Assumptions:** Short-term revenues are based upon the Caltrans apportionment estimates. Long-term revenues assume that the Federal Highway Trust Fund stays solvent, but revenues do not grow. CMAQ funding is assumed to be halved starting in 2020 due to improved air quality.	$9.5
FHWA Non-Discretionary Regional Surface Transportation Program (RSTP)	**Description:** Projects eligible for RSTP funds include rehabilitation and new construction on any highways included in the National Highway System (NHS) and Interstate Highways (including bridges). Also, transit capital projects, as well as intracity and intercity bus terminals and facilities, are eligible. **Assumptions:** Short-term revenues are based upon the Caltrans apportionment estimates. Long-term revenues assume that the Federal Highway Trust Fund stays solvent, but revenues do not grow.	$10.6
FTA Formula Programs 5307 Urbanized Area Formula (Capital), 5310 Elderly and Persons with Disabilities Formula, 5311 Non-Urbanized Area Formula, 5309 Fixed Guideway Program	**Description:** This includes a number of FTA programs that are distributed by formula. 5307 is distributed annually to state urbanized areas with a formula based on population, population density and transit revenue miles of service. Program funds capital projects (and operations expenses in areas under 200,000 in population), preventative maintenance and planning activities. 5310 funds are allocated by formula to states for capital costs of providing services to the elderly and disabled. The 5311 program provides capital and operating expenses for rural and small urban public transportation systems. Section 5309 Fixed Guideway (FG) funds are also distributed to regions on an urbanized area formula. **Assumptions:** Formula funds are assumed to increase in proportion with the Federal Highway Trust Fund. As with the FHWA sources, the Trust Fund is expected to stay solvent, but not grow. For Los Angeles and Orange Counties, the local transportation commissions have estimated formula allocations based on future increases in service and past allocations that yield results consistent with a no-growth assumption.	$15.8
FTA Non-Formula Program 5309 New and Small Starts, 5309 Bus & Bus-Related Grants	**Description:** Capital projects include preliminary engineering, acquisition of real property, final design and construction, initial acquisition of rolling stock for new fixed guideway systems or extensions, including bus rapid transit, light rail, heavy rail, and commuter rail systems. Capital investment grants of less than $75 million are considered "small starts." "Small starts" will have a separate funding category beginning in FY07. Program funds bus acquisition and other rolling stock, ancillary equipment and the construction of bus facilities. Also includes bus rehabilitation and leasing, park-and-ride facilities, parking lots associated with transit facilities and bus passenger shelters. **Assumptions:** Operators are assumed to receive FTA discretionary funds in rough proportion to what they have received historically. The Federal Highway Trust Fund is expected to stay solvent, but not grow. For Los Angeles and Orange counties, the local transportation commissions have estimated discretionary allocations based on future increases in service and past allocations. Los Angeles expects discretionary allocations to remain constant in nominal terms, while Orange County expects discretionary allocations to grow slower than inflation.	$3.1
Other Federal Funds	**Description:** Includes other federal programs, such as Regional Transportation Enhancements, Highway Bridge Replacement and Rehabilitation, Homeland Security Grants, Bus Preferential Signal Systems, Highway Earmarks, Hazard Elimination Safety, and Railroad/Highway Grade Crossing Protection (Section 130). **Assumptions:** LACMTA provided forecasted revenues for these programs, which have been adopted in the RTP for Los Angeles County. For other counties, Highway Bridge Program revenues are estimated in the short term using program allocations provided by the California Department of Transportation through FY2010. Longer-term estimates are based upon the no-growth assumption used for other federal funding sources.	$2.5
FEDERAL SUBTOTAL		**$41.6**

Note: Numbers may not add due to rounding

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TABLE 4.3.4 CORE AND REASONABLY AVAILABLE REVENUE PROJECTIONS (IN NOMINAL DOLLARS, BILLIONS)

Revenue Source	Revenue Projection Assumptions	Revenue Estimate
INNOVATIVE FINANCING & NEW REVENUE SOURCES		
Value Capture Strategies	**Description:** This strategy refers to capturing the incremental value generated by transportation investments through formation of special districts, joint development, and tax increment financing. Also includes sale of Caltrans-owned property. **Assumptions:** SCAG assumes the formation of special districts, including Benefit Assessment Districts, Mello-Roos Community Facilities Districts, as well as use of tax increment financing and joint development to provide gap financing for specific transit investments: Gold Line extension, Purple Line extension, and passenger HSRT system. SCAG also assumes one-time proceeds from the sale of Caltrans-owned property within the SR-710 tunnel vicinity.	$3.7
Local Option Sales Tax Extension	**Description:** Locally imposed ½ percent sales tax measure extension for Imperial County—existing Measure D expires in 2010. **Assumptions:** Sales tax grows consistent with historical trends in county retail sales.	$0.8
Highway Tolls	**Description:** Toll revenues generated from SR-710 tunnel. Also, tolls assumed for the I-710 dedicated truck lanes, High Desert Corridor, and CETAP Corridor as well as SR-91. **Assumptions:** Toll revenues based on recent feasibility studies for applicable corridors. Also includes toll revenue bond proceeds.	$22.0
State and Federal Gas Excise Tax Adjustment to Maintain Historical Purchasing Power	**Description:** Equivalent to additional ten cent per gallon gasoline tax imposed by the state and federal government starting in 2012 - based on historical extrapolation. **Assumptions:** Forecast consistent with historical adjustments for both state and federal gas taxes.	$17.0
Container Fees	**Description:** Charge imposed on containerized cargo moving through the Ports of LA/LB and region (includes railroad user fees for rail capacity improvement program) and directly linked to specific goods movement projects. **Assumptions:** Container fees at $30 per Twenty-foot Equivalent Unit (TEU). Revenue total also includes railroad user fees assessed on a TEU basis for the rail capacity improvement program; revenue total includes bond proceeds.	$41.5
Private Equity Participation	**Description:** Public Private Partnership arrangement whereby a private entity designs, finances, builds, operates, and maintains a facility under a lease arrangement for a fixed period of time. **Assumptions:** Private capital is assumed for the financing of a number of projects including the SR-710 tunnel, CETAP Corridor and the HSRT system (freight only component assumed in this total). See separate line-item for passenger HSRT.	$4.4
Private Activity Bonds	**Description:** Title XI Section 11142 of SAFETEA-LU amends Section 142(a) of the IRS Code to allow the issuance of tax exempt private activity bonds for highway and freight transfer facilities. States and local governments are allowed to issue tax-exempt bonds to finance highway and freight transfer facility projects sponsored by the private sector. **Assumptions:** Partial interest savings from the issuance of tax-exempt private activity bonds for freight rail investment package are assumed to offset some of the grade separation costs.	$0.4 (included in container fees)
Federal (EPA) funding for clean freight rail technology	**Description:** Federal funding to mitigate locomotive emissions. **Assumptions:** In accordance with the proposed 2007 State Implementation Plan (SIP), it is assumed that the federal government (US EPA) will provide subsidies to mitigate locomotive emissions; the severity of the region's PM2.5 problem and the attainment deadline make it necessary to mitigate locomotive emissions	$1.9
Interest Earnings	**Description:** Interest earnings from toll bond proceeds. **Assumptions:** Interest earnings are assumed from toll bond proceeds (High Desert Corridor, CETAP, SR-710 tunnel, and I-710 truck lanes.	$0.4

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Revenue Source	Revenue Projection Assumptions	Revenue Estimate
Riverside County Measure A (Bond Anticipation Notes)	**Description:** BANs are short-term debt financing strategies often used by local governments. The proceeds of a future issue are expected to cover anticipation notes. **Assumptions:** Short-term debt is assumed in the latter years of the RTP to help fund the CETAP Corridor in anticipation of the sale of Measure A revenue bonds.	$1.5
TIFIA Loan	**Description:** TIFIA loan program provides credit assistance under flexible terms for transportation investments of national or regional significance. **Assumptions:** A TIFIA loan is assumed to facilitate financing of the CETAP Corridor; a direct loan is assumed to be repaid by project generated toll revenue.	$0.9
HSRT Passenger System (Private Contribution & User Fee	**Description:** User-fee supported initiative for HSRT system. **Assumptions:** Assumes private sector development including design, finance, build, operate, and maintain. See HSRT report for further details.	$26.2
NEW REVENUE SOURCE SUBTOTAL		**$120.1**
GRAND TOTAL		**$531.5**

Note: Numbers may not add due to rounding

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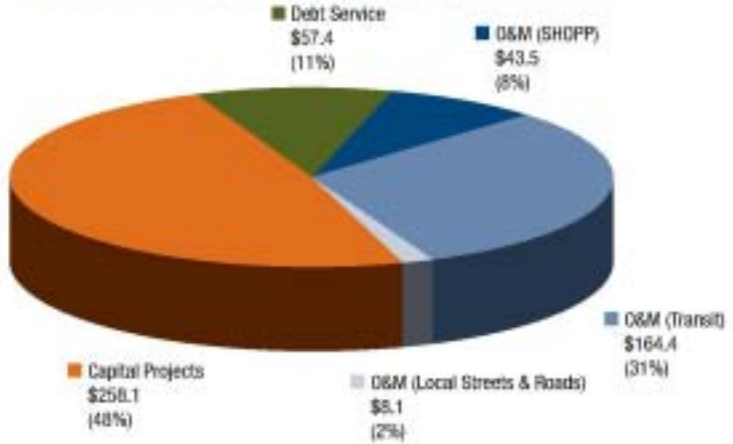
The SCAG region's financially constrained RTP includes revenues from both the core and reasonably available revenue sources. A summary of these forecasted revenues and expenditures is presented in Figures 4.12 and 4.13. As shown in these figures, the SCAG region's budget over the next 30 years totals an estimated $531.5 billion.

FIGURE 4.12 2008 RTP REVENUE SUMMARY
$531.5 BILLION (IN NOMINAL DOLLARS) FY2007-FY2036

Note: Numbers may not add due to rounding.

FIGURE 4.13 2008 RTP EXPENDITURE SUMMARY
$531.5 BILLION (IN NOMINAL DOLLARS) FY2007-2036



As shown in Figure 4.14, transit and highway expenditures are roughly comparable at 41 and 36 percent, respectively, of the RTP costs for each category. About 12 percent of costs are attributable to an "other" category, reflecting proposed investments in HSRT systems as well as freight rail capacity and grade separation improvements. Consistent with historical practice, agencies in the region are expected to bond against future revenues to provide additional funding in the early years of the plan. As a result, debt service equal to historical payments and future bonding needs has been included as part of the RTP. Anticipated debt service payments make up 11 percent of total costs.

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FIGURE 4.14 REVENUES COMPARED TO COSTS BY MODE

Note: Numbers may not add due to rounding

The following Table 4.4 provides details of the SCAG region's 2008 revenue forecast by source in five-year increments. This is followed by Table 4.5, which provides details of the region's expenditures by category in five-year increments.

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TABLE 4.4 2008 REGIONAL TRANSPORTATION PLAN REVENUES (IN NOMINAL DOLLARS, BILLIONS)

	REVENUE SOURCES	FY2007-11	FY2012-16	FY2017-21	FY2022-26	FY2027-31	FY2032-36	TOTAL
LOCAL	Sales Tax	$14.3	$19.4	$26.0	$34.1	$44.8	$59.7	$198.3
	– County	10.7	14.4	19.3	25.1	32.8	43.3	145.6
	– Transportation Development Act	3.6	5.0	6.7	9.0	12.0	16.4	52.7
	Gas Tax (Subvention to Cities & Counties)	1.1	1.2	1.3	1.4	1.5	1.6	8.0
	Other Local Funds	2.5	4.5	3.2	4.6	3.5	1.6	20.0
	Transit Fares	3.1	4.5	5.7	7.3	9.3	11.3	41.2
	Tolls	0.3	0.4	0.4	0.5	0.6	0.8	3.0
	Mitigation Fees	1.3	1.7	2.3	2.3	3.4	5.0	15.9
	LOCAL TOTAL	$22.6	$31.7	$39.0	$50.3	$63.0	$79.8	$290.5
STATE	State Highway Operations and Protection Program (SHOPP)	5.3	5.3	5.7	5.7	5.7	5.7	33.3
	State Transportation Improvement Program (STIP)	2.9	2.2	2.4	2.5	2.7	3.1	15.9
	– Regional - RTIP	2.2	1.7	1.8	1.9	2.1	2.3	11.9
	– Interregional - ITIP	0.7	0.6	0.6	0.6	0.7	0.8	4.0
	Traffic Congestion Relief Program, Propositions 42 and 1A	2.0	1.8	2.0	2.3	2.8	3.4	14.3
	State Transit Assistance (STA)	0.8	1.0	1.3	1.6	2.0	2.4	9.1
	Proposition 1B	7.2	2.9	0.0	0.0	0.0	0.0	10.1
	Other (1)	0.1	0.1	0.1	0.1	0.1	0.2	0.7
	STATE TOTAL	$18.3	$13.3	$11.4	$12.2	$13.3	$14.7	$83.4
FEDERAL	Federal Transit	$2.9	$2.5	$2.9	$3.2	$3.3	$4.2	$19.0
	– Federal Transit Formula	1.9	2.0	2.3	2.7	3.1	3.8	15.8
	– Federal Transit Non-Formula	1.0	0.4	0.6	0.5	0.2	0.5	3.1
	Federal Highway & Other	$3.0	$3.1	$3.6	$3.5	$4.2	$5.1	$22.6
	– Congestion Mitigation and Air Quality	1.3	1.6	1.8	1.3	1.6	1.9	9.5
	– Surface Transportation Program (Regional)	1.1	1.3	1.5	1.9	2.2	2.7	10.6
	– Other (2)	0.7	0.2	0.3	0.3	0.4	0.6	2.5
	FEDERAL TOTAL	$5.9	$5.6	$6.5	$6.7	$7.5	$9.3	$41.6
INNOVATIVE FINANCING & NEW REVENUE SOURCES	Private Equity Participation	1.1	1.5	1.8	0.0	0.0	0.0	4.4
	TIFIA Loans	0.0	0.0	0.0	0.0	0.0	0.9	0.9
	Value Capture Strategies	1.0	1.4	1.4	0.0	0.0	0.0	3.7
	Highway Tolls (including bond proceeds)	0.1	2.3	4.8	3.1	3.8	7.8	22.0
	Port Container Fee (including railroad fee and bond proceeds)	4.0	9.4	7.8	6.3	6.3	7.7	41.5
	Riverside Co. Measure A - BANs	0.0	0.0	0.0	0.0	0.0	1.5	1.5
	Federal EPA Funding for clean freight rail technology	0.0	0.8	1.1	0.0	0.0	0.0	1.9
	Interest Earnings	0.0	0.3	0.1	0.0	0.0	0.0	0.4
	HSRT passenger user fee & private contribution	8.7	8.7	8.7	0.0	0.0	0.0	26.2
	Private Activity Bonds (included in container fee estimate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	State and Federal Gas Excise Tax Adjustment	0.0	3.4	3.4	3.4	3.4	3.4	17.0
	Local Option Sales Tax Extension (Imperial County)	0.0	0.1	0.1	0.1	0.2	0.3	0.8
	Innovative Financing Total	$14.9	$27.9	$29.2	$13.0	$13.7	$21.5	$120.1
	REVENUE TOTAL	$61.7	$78.6	$86.1	$82.2	$97.5	$125.4	$531.5

Notes:
(1) Service Authority for Freeways and Expressways (SAFE), Freeway Service Patrol, Air Quality Vehicle Registration Fee (AB 2766), Environmental Enhancement and Mitigation.
(2) Includes other federal programs, such as Regional Transportation Enhancements, Highway Bridge Replacement and Rehabilitation, Homeland Security Grants, Bus Preferential Signal Systems, Highway Earmarks, local assistance, Hazard Elimination Safety, and Railroad/Highway Grade Crossing Protection (Section 130).
Numbers may not add due to rounding.

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TABLE 4.5 2008 REGIONAL TRANSPORTATION PLAN EXPENDITURES (IN NOMINAL DOLLARS, BILLIONS)

RTP COSTS	FY2007-11	FY2012-16	FY2017-21	FY2022-26	FY2027-31	FY2032-36	TOTAL
Capital Projects:	**$42.5**	**$51.6**	**$52.5**	**$32.2**	**$38.4**	**$41.0**	**$256.1**
Arterials	3.9	3.8	3.3	3.6	3.7	6.5	24.8
Grade Separation	2.6	4.5	0.2	0.1	0.7	2.1	10.2
HOV	2.3	2.2	3.3	1.3	1.5	0.9	11.5
Mixed Flow	6.7	8.0	8.0	7.8	11.1	2.7	44.3
Toll Facilities	1.5	7.5	13.7	4.8	2.8	8.5	38.7
ITS	0.4	0.3	0.4	0.6	1.2	0.1	3.0
Transit	9.6	8.8	8.1	8.6	11.1	8.2	54.5
High Speed Regional Transport - Passenger	9.7	9.7	9.7	0.0	0.0	0.0	29.1
High Speed Regional Transport - Freight	2.0	2.3	2.4	3.2	3.6	4.4	17.9
Other (1)	4.0	4.4	3.4	2.1	2.7	7.5	24.1
Operations and Maintenance:	**$19.7**	**$24.8**	**$30.7**	**$37.5**	**$46.0**	**$57.2**	**$216.0**
Highway	5.5	6.4	7.3	7.6	8.1	8.5	43.5
Transit	13.1	17.2	22.1	28.5	36.5	47.1	164.4
Local Streets and Roads	1.2	1.2	1.3	1.4	1.5	1.6	8.1
Debt Service	**$2.7**	**$5.3**	**$8.4**	**$10.8**	**$12.6**	**$17.6**	**$57.4**
COST TOTAL	**$65.0**	**$81.7**	**$91.5**	**$80.5**	**$97.1**	**$115.7**	**$531.5**

Note: (1) Includes: Rail Capacity Expansion, Truck Climbing, Non-Motorized, TDM and contingencies.
Numbers may not add due to rounding.

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V. PLAN PERFORMANCE

This chapter summarizes how well the 2008 RTP performs in meeting its adopted goals and satisfying state and federal requirements. Table 5.1 summarizes goals and their related performance outcomes. One or more performance measures were developed for each of these outcomes to quantify the Plan's performance. These goals and outcomes were used successfully to develop the update to the 2004 RTP.

TABLE 5.1 2008 RTP GOALS AND RELATED PERFORMANCE OUTCOMES

RTP Goals	Mobility	Accessibility	Reliability	Productivity	Safety	Sustainability	Preservation	Cost-Effectiveness	Environmental	Environmental Justice
Maximize mobility and accessibility for all people and goods in the region	✓	✓						✓		✓
Ensure travel safety and reliability for all people and goods in the region	✓		✓		✓					
Preserve and ensure a sustainable regional transportation system						✓	✓			
Maximize the productivity of our transportation system	✓			✓						
Protect the environment, improve air quality and promote energy efficiency									✓	✓
Encourage land use and growth patterns that complement our transportation investments	✓	✓							✓	
Maximize the security of our transportation system through improved system monitoring, rapid recovery planning, and coordination with other security agencies*										

* SCAG does not yet have an agreed-upon security performance measure; therefore it is not included in this table.

PLAN INVESTMENT PERFORMANCE

This section provides detailed information on each of the performance outcomes and related measures approved by the Regional Council in 2002. The basic concept for each criterion is to compare the performance of the Plan (2035) to both the Base Year (2003) and the Baseline scenario for 2035. The Plan is the selected strategy to guide the region's transportation planning over the next few decades. The Baseline represents "business as usual" and a future condition in which the Plan is not implemented. It assumes only the completion of projects currently under construction or right-of-way acquisition, projects that have completed the National Environmental Policy Act (NEPA) process, or projects that come from the first year of the previous RTP/RTIP. The data for the analysis is based on the SCAG Regional travel demand model results.

MOBILITY

The mobility performance outcome relies on two commonly used measures: speed and delay. Speed and delay were computed using SCAG's regional travel demand model. They are defined as follows:

- Speed is the average speed experienced by travelers regardless of mode in miles per hour (mph).
- Delay is the difference between the actual travel time and travel time that would be experienced if a person traveled at the legal speed limit. This measure is reported as person-hours of delay, which is presented here as a total delay and as delay per capita. The latter measure balances the results with the expected population growth during the Plan period (i.e., through 2035).

Figure 5.1 compares the speeds of the three scenarios. It shows that the Plan improves average daily speeds by eight percent compared to the 2035 Baseline and represents a less than 4-mile-per-hour decline over 2003 Base Year results.

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FIGURE 5.1 AVERAGE DAILY SPEED

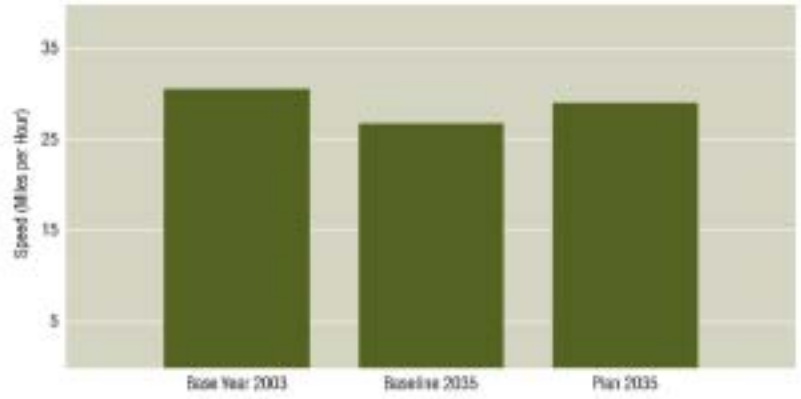

Figure 5.2 compares delay results and shows that the Plan reduces total daily person-hours of delay by 16 percent compared to the Baseline, but also represents an increase of 76 percent over Base Year conditions. This increase reflects the growth in the region and the resulting incremental travel.

FIGURE 5.2 DAILY PERSON-HOURS OF DELAY

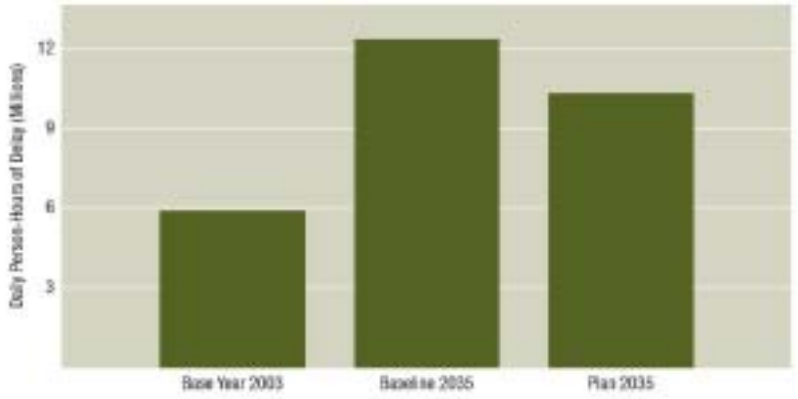

Figure 5.3 compares average daily delay per capita, which is a measure that takes into account that there will be more people traveling on the Region's transportation system by 2035. The results tell a different story. Whereas total person delay for the Plan increases by 76 percent over Base Year conditions, each person in the region experiences only a 29 percent increase - less than six minutes per day on a per-capita basis.

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FIGURE 5.3 AVERAGE DAILY DELAY PER CAPITA

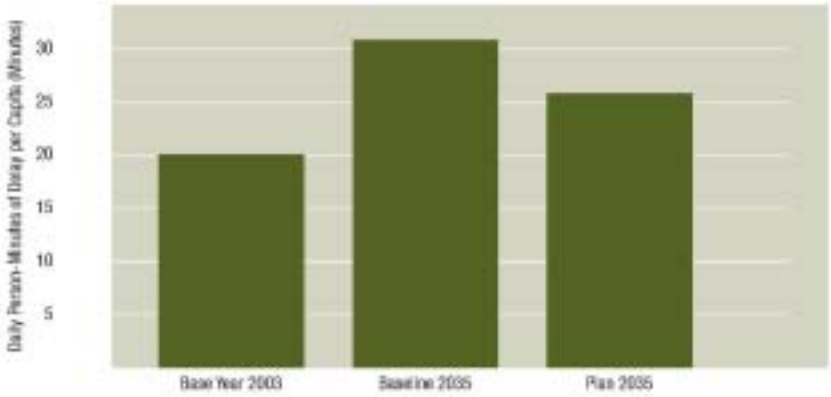
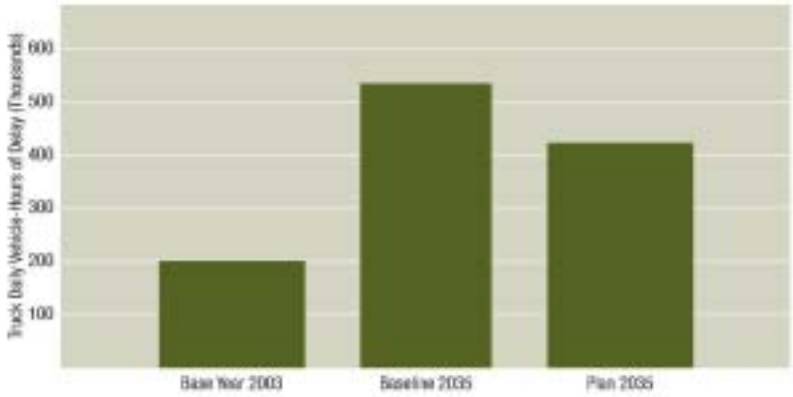


FIGURE 5.4 AVERAGE DAILY HEAVY-DUTY TRUCK DELAY



Finally, Figure 5.4 compares average daily Heavy Duty Truck delays, which shows an improvement of nearly 21 percent compared to the Baseline. This is an important statistic given the Plan's emphasis on the logistics industry and its importance to the regional economy.

Exhibits 5.1, 5.2, and 5.3 depict regional PM peak (3 p.m. to 7 p.m.) freeway speeds for Base Year 2003, Baseline in 2035, and Plan in 2035, respectively.

ACCESSIBILITY

Accessibility measures how well the transportation system provides people access to opportunities. Opportunities can include jobs, education, medical care, recreation, shopping, or other activities that help improve people's lives. For the 2008 RTP, accessibility is defined as the percentage of the population who can travel between work and home within 45 minutes during the peak period. Access to employment is used as a reasonable proxy for access to all opportunities, since work trips make up a large percentage of total trips during commute periods. For people traveling by automobiles, this is defined as those who travel during the afternoon commute period, and for transit users, both the AM and PM commute periods are included to facilitate the modeling of transit trips.

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EXHIBIT 5.1 BASE YEAR 2003 FREEWAY SPEED | PM PEAK

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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EXHIBIT 5.2 BASELINE 2035 FREEWAY SPEED | PM PEAK

Source: Southern California Association of Governments, ESRI StreetMap USA, Tele Atlas

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EXHIBIT 5.3 PLAN 2035 FREEWAY SPEED | PM PEAK

Source: Southern California Association of Governments, ESRI StreetMap USA, Teleatlas

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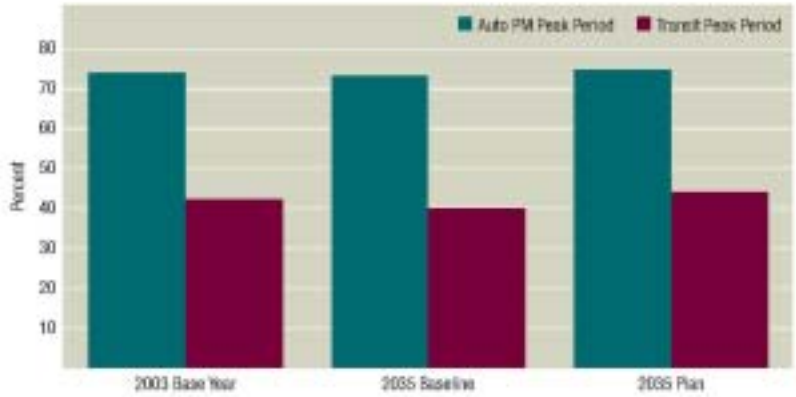
Figure 5.5 compares the Plan to Base Year and Baseline, and presents the percent of work trips completed within 45 minutes for both automobiles and transit. The figure shows that automobile accessibility stays relatively constant over the 2035 Baseline period at around 77 percent, but the Plan improves automobile accessibility slightly to 79 percent. Transit accessibility is projected to decline from 43 percent currently to around 42 percent under the 2035 Baseline scenario. However, it will improve to 45 percent under the Plan.

FIGURE 5.5 AUTO AND TRANSIT ACCESSIBILITY



RELIABILITY

The reliability outcome reflects the degree to which travelers experience variations in their trip times from day to day. As such, it captures the relative predictability of the public's travel time. Unlike mobility (which measures how quickly the transportation system is moving people) and accessibility (which addresses how well the system provides access to opportunities, primarily jobs), reliability focuses on how much mobility and accessibility vary from day to day.

The reliability measure is calculated by using the statistical concept of standard deviation. The indicator is computed by dividing the standard deviation of travel time for a given trip by the average travel time of that trip, measured over many days and weeks. Table 5.2 shows how a traveler can use this indicator depending on the importance of arriving on time. For example, if a person's morning commute takes on average 26 minutes, but varies 15 percent from day to day, then he or she must plan the trip to account for additional time. Table 5.2 also shows that if this person wants to be 99 percent confident that he or she arrives on time, he or she must plan for 38 minutes of travel instead of 26.

TABLE 5.2 VARIABILITY OF TRAVEL TIME: HYPOTHETICAL ILLUSTRATION

Trip	Time Period	Average Travel Time	Variability of Travel Time	Travel Time Based on Level of Confidence of Arriving on Time		
				70%	95%	99%
Hypothetical Commute Trip	AM Peak	26 min.	15%	30 min.	34 min.	38 min.
	PM Peak	32 min.	25%	40 min.	48 min.	56 min.
	Off Peak	20 min.	10%	22 min.	24 min.	26 min.

This indicator is relatively new in transportation planning and operations, and exact models to compute and forecast it are not available. However, by using existing travel time data and research results, it is possible to estimate the Plan's impact on reliability. Table 5.3 presents these results, which reflect the benefits derived from the investments that help respond more quickly and effectively to traffic accidents or provide traveler information. These improvements are conservatively projected in the 10 percent range. However, it is critical to continue to monitor this measure and improve the tools to forecast the impacts of such investments in future SCAG planning cycles.

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TABLE 5.3 ESTIMATED IMPROVEMENTS IN TRAVEL TIME RELIABILITY

Peak Period	Hour	Base Year 2005 Average Percent Variability of Travel Time	Plan 2035 Average Percent Variability of Travel Time
Morning Peak Period (6 am to 9 am)	6 am to 7 am	16%	14%
	7 am to 8 am	22%	20%
	8 am to 9 am	23%	21%
Afternoon Peak Period (3 pm to 7 pm)	3 pm to 4 pm	25%	23%
	4 pm to 5 pm	26%	23%
	5 pm to 6 pm	28%	25%
	6 pm to 7 pm	25%	23%

Source: Caltrans

PRODUCTIVITY

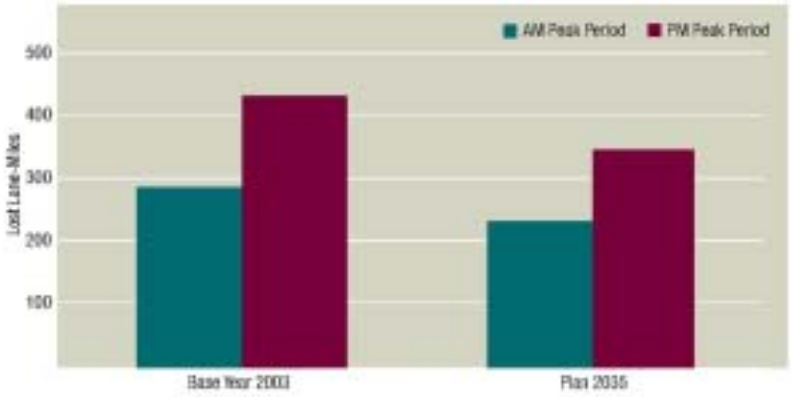
The productivity outcome reflects the degree to which the transportation system performs during peak demand conditions. It is a system efficiency measure. The productivity indicator is defined as the percent utilization during peak demand conditions.

As an example, freeways are typically designed to carry 2,000 vehicles per lane per hour. However, in many locations on the region's freeway system, vehicles weaving and merging in and out of traffic cause bottlenecks, which lead to significant reductions in capacity utilization. Again, using freeways as an example, the carrying capacity of a freeway lane can drop by as much as 50 percent, allowing only 1,000 vehicles per hour to pass. In effect, the system "loses" capacity, which can be estimated in terms of lost lane-miles.

Figure 5.6 summarizes the current estimate for productivity losses on the region's freeway system and the expected improvements due to Plan investments. Maximizing the system's productivity is a critical goal of this RTP, and the overall system management approach aims to recapture lost productivity. The incremental investment of over $2 billion to implement advanced operational strategies on our freeways and arterials is projected to recapture 20 percent of the lost productivity. These projections are based on recent studies indicating that investments in ramp metering, arterial signal coordination, traveler information, and incident management can achieve such improvements.

The Plan improves productivity by committing to investments in state highway operations discussed in Chapter IV. Transit productivity will also improve through increased ridership, which maximizes the number of seats occupied during peak demand conditions.

FIGURE 5.6 HIGHWAY SYSTEM PRODUCTIVITY (LOST LANE-MILES)



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SAFETY

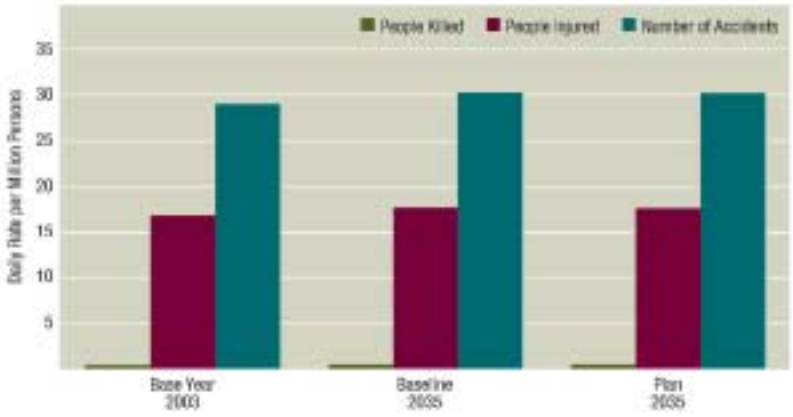
Improving safety by minimizing accidents is a critical outcome of the RTP. The safety indicators used to measure and track safety-related performance are:

- Fatalities per million persons
- Injuries per million persons
- Property damage accidents per million persons

State and regional transportation agencies dedicate funds to projects that specifically address safety deficiencies. However, it is not possible to predict the reduction in accident rates resulting from these investments. Hence, the safety results presented here are estimated based on current accident rate trends for the different modes applied to projected levels of system use by mode. They represent a conservative estimate for safety benefits.

Figure 5.7 compares safety indicators for the Base Year, Baseline, and Plan scenarios. The overall improvement is estimated based on overall accident rates by mode (e.g., auto, bus, and rail) and facility (e.g., freeways and principal arterials).

FIGURE 5.7 ACCIDENT RATES



SUSTAINABILITY

A transportation system is sustainable if it maintains its overall performance over time with the same costs for its users. Sustainability, therefore, reflects how our decisions today affect future generations. The indicator for sustainability is the total inflation-adjusted cost per capita to maintain overall system performance at current conditions.

The performance measures presented in this chapter show that the planned transportation system in 2035 will perform better in some cases (e.g., safety, preservation) and worse in others (e.g., delay per capita) compared to today. Moreover, the overall cost of the Plan represents a significant increase in nominal costs based on increased taxes to fund additional regional projects discussed in Chapter III as well as incremental preservation and operations investments.

PRESERVATION

The preservation outcome reflects how well the region is taking care of its multimodal transportation infrastructure. As discussed in Chapter II of this document, deferred maintenance investments end up costing much more in the future as the conditions of our assets (e.g., pavement) deteriorate.

Figure 5.8 shows the benefits of the additional expenditures dedicated in this RTP over and beyond the historical trends. As of 2005, 28 and 11 percent of the SCAG Region's roadways and bridges required rehabilitation, which are more intensive and expensive projects. As a result of the incremental investments, these percentages are projected to fall to 24 percent for roadways and 6 percent for bridges. Similar improvements are expected for regional arterials as well.

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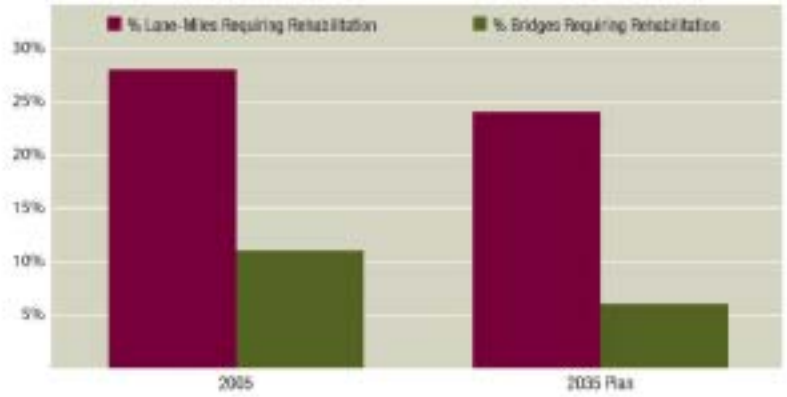
FIGURE 5.8 PRESERVATION IMPROVEMENTS



COST-EFFECTIVENESS

Cost-effectiveness reflects the degree to which transportation expenditures in the Plan yield benefits that the transportation users experience. It attempts to measure how much "bang for the buck" is received from the Plan. The indicator for cost-effectiveness is the benefit-cost ratio. Benefits are divided into several categories as follows:

- Delay savings
- Safety improvements
- Air quality improvements
- Reductions in vehicle operating costs

For each of these categories, models are used to estimate the benefits of the Plan compared to Baseline. The benefits are converted into dollars, added together, and divided by the total incremental costs of the Plan's transportation improvements. Table 5.4 summarizes the results of the benefit-cost analysis.

TABLE 5.4 SCAG REGIONAL PERFORMANCE ANALYSIS BENEFIT/COST RESULTS

Project	Value of $1 Invested
2008 RTP	$2.21

SCAG's 2008 RTP provides a $2.21 return for every dollar invested. For this analysis, all benefits and costs are expressed in year 2007 dollars. Benefits are estimated through the year 2035. The user benefits are estimated using methodologies consistent with the Cal B/C model adjusted to incorporate SCAG's regional travel demand model output. Costs include incremental public expenditures over the RTP time period.

While $2.21 return on every dollar invested is an excellent return on investment, it is lower than the $3.08 reported in the 2004 RTP. Several factors influence this outcome. First, project costs have skyrocketed over the past several years, negatively impacting the rate of return. Second, this Plan proposes significant investment increases in strategies that do not easily translate into readily quantifiable benefits based on currently available tools, namely SCAG's transportation demand model. Such investment categories include system preservation, system operation and management, and investments that are not captured in SCAG's demand model, such as rail improvements associated with goods movement.

Transportation Conformity Analysis

Transportation conformity is required under the federal Clean Air Act (CAA) to ensure that federally supported highway and transit project activities conform to the purpose of the State Implementation Plan (SIP).[1] Conformity to the purpose of the SIP means that transportation activities will not cause new

[1] To comply with the CAA in achieving the NAAQS, the ARB develops SIPs for federal nonattainment and maintenance areas. In California, SIP development is a joint effort of the local air agencies and ARB working with federal, state, and local agencies (including the MPOs). Local Air Quality Management Plans (AQMPs) are prepared in response to federal and state requirements.

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air quality violations, worsen existing violations, or delay timely attainment of the relevant National Ambient Air Quality Standards (NAAQS). Conformity applies to areas that are designated non-attainment, and those re-designated to attainment after 1990 ("maintenance areas") for the following transportation-related criteria pollutants: ozone, particulate matter (PM2.5 and PM10), carbon monoxide (CO), and nitrogen dioxide (NO2).

NON-ATTAINMENT/MAINTENANCE AREAS

The boundaries of the federal non-attainment/maintenance areas in the SCAG Region are:

- Ventura County portion of the South Central Coast Air Basin (SCCAB) — The entire county is a non-attainment area for ozone.
- South Coast Air Basin (SCAB) — The entire basin is a non-attainment or maintenance area for NO2, CO, PM10, PM2.5, and ozone.
- Western MDAB (Antelope Valley portion of Los Angeles County and San Bernardino County portion of MDAB excluding Searles Valley) — This is a non-attainment area for ozone.
- San Bernardino County portion of MDAB.
  - Searles Valley (situated in the NW part of the county) is a non-attainment area for PM10.
  - San Bernardino County (excluding the Searles Valley area) portion of MDAB is a non-attainment area for PM10.
- Riverside County portion of Salton Sea Air Basin (SSAB) — The entire Riverside County portion of SSAB (Coachella Valley) is a non-attainment area for PM10 and ozone.
- Imperial County portion of SSAB - The entire Imperial County portion of SSAB is designated as a non-attainment area for ozone and PM10.

CONFORMITY TESTS

The 2008 RTP must pass the following tests and analyses to meet the requirements for a positive conformity finding:

- Regional Emission Analysis
- Timely Implementation of Transportation Control Measures (TCMs) Analysis
- Financial Constraint Analysis
- Interagency Consultation and Public Involvement Analysis

REGIONAL EMISSIONS ANALYSIS

Regional emissions analyses, by non-attainment area and by pollutant, compare on-road emissions to the applicable on-road emissions budgets in the SIPs for the SCAG Region. The applicable emissions budgets are those found to be adequate for conformity determination by the U.S. EPA. In the absence of applicable emissions budgets, the regional emission tests for conformity finding are based on either a build/no-build or less-than-Base-Year scenario.

Due to recent litigation relative to U.S. EPA's Eight-Hour Ozone Phase 2 Rule, EPA has instructed ARB to revise the established method of demonstrating Reasonable Further Progress (RFP) in ozone non-attainment areas that utilize reductions from other areas to demonstrate attainment (e.g., upwind areas). In the SCAG Region, these areas are the Ventura County portion of the SCCAB, the Western MDAB, and the Coachella Valley portion of the SSAB. Therefore, at this time, there are no AQMPs or SIPs and, thus, no 8-hour ozone transportation emission budgets for these areas. SCAG has worked closely with the ARB and EPA to resolve this issue. As agreed upon by ARB and EPA, ARB has adopted Early Progress Plans (i.e., emissions inventories and transportation emission budgets) for areas that need upwind reductions to show RFP. The Early Progress Plans establish the transportation emission budgets while EPA decides how to respond to the RFP issue raised by the litigation. EPA found these emission budgets adequate in April 2008.

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In addition, EPA's review of the South Coast ozone and PM2.5 emission budgets raised concerns such that the ARB was required to revise and resubmit the emission budgets to EPA. This requirement dictated that SCAG make appropriate revisions to the conformity analysis to reflect the new emission budgets and rerelease the Draft Conformity Report. SCAG staff worked closely with the federal reviewing agencies regarding the emission budget adequacy and conformity approval review process timeline. From these efforts, all agencies confirmed they will expedite their respective reviews to allow for approval of SCAG's conformity finding before the current (2004) RTP conformity finding expires on June 7, 2008.

TIMELY IMPLEMENTATION OF TCMS ANALYSIS

This conformity test requires Transportation Control Measures (TCM) projects subject to reporting be fully funded and on schedule. In the SCAG Region, there are two areas for which SIPs contain TCMs: the ozone AQMPs/SIPs for the SCAB, and for the Ventura County portion of SCCAB. SCAG works with the CTCs to ensure TCMs are on schedule or that steps are being taken to overcome obstacles.

FINANCIAL CONSTRAINT ANALYSIS

The 2008 RTP is financially constrained and is financed by federal, state, local and private sources. Detailed information on the financial analysis is included in Chapter IV.

INTERAGENCY CONSULTATION AND PUBLIC INVOLVEMENT

Throughout its development, the 2008 RTP has been discussed at meetings of various policy committees, working groups (including the Transportation Conformity Working Group), task forces, and technical advisory committees. SCAG's Transportation Conformity Working Group has served as a forum for interagency consultation, and additionally, there were many ad hoc meetings held between the involved agencies for this purpose. SCAG's RTP public outreach effort is documented in a separate Public Participation report. Continued interagency consultation and public involvement will occur throughout the public review process.

CONFORMITY FINDING

The conformity analysis indicates a positive conformity finding for the 2008 RTP. The detailed transportation conformity analyses for the 2008 RTP are included in the 2008 RTP Conformity Report.

Environmental Justice

The environmental justice movement stems from Title VI of the Civil Rights Act of 1964. This title declares it to be the policy of the United States that discrimination on the grounds of race, color, or national origin shall not occur in connection with programs and activities receiving federal financial assistance,

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and authorizes and directs the appropriate federal departments and agencies to take action to carry out this policy. Title VI of the Civil Rights Act of 1964 provides a significant means by which the public can seek greater accountability from transportation agencies. Title VI bars intentional discrimination, but also unjustified disparate impact discrimination.[2]

SCAG'S ENVIRONMENTAL JUSTICE POLICY & PROGRAM

Environmental Justice is an integral part of the planning process, which must be considered in all phases of planning. SCAG's environmental justice program includes two main elements: public outreach and technical analysis.

ENVIRONMENTAL JUSTICE PUBLIC OUTREACH

Public outreach efforts are intended to ensure that all members of the public have an opportunity to participate meaningfully in the planning process. SCAG's public outreach efforts include the following:

- Compliance Procedure for Environmental Justice in the Transportation Planning Process — In October 2000, SCAG released the Compliance Procedure for Environmental Justice in the Transportation Planning Process, which provided a detailed description of SCAG's public outreach activities. Since its publication, SCAG staff has utilized this guidance document to ensure that it 1) includes traditionally unrepresented groups early and throughout the planning process; 2) carefully examines performance measures to determine any inequities of the RTP on any group; 3) and follows the self-evaluation procedure for public outreach and environmental justice analysis programs.
- Public Workshops — SCAG holds workshops throughout the planning process and targets minority and low-income communities throughout the region. Follow-up workshops are held with groups that want to stay involved throughout the planning cycle.
- Presentations — SCAG conducts presentations upon request to a variety of groups. These include Chambers of Commerce, community-based organizations, nonprofit groups, etc. Generally, these presentations provide an overview of SCAG and its function as an MPO.
- Website Dissemination — SCAG utilizes its website to provide information on the RTP. SCAG works to ensure that the information available is timely, easy to understand and accessible, and that the website is compliant with the 1990 Americans with Disabilities Act. SCAG's RTP and the EJ program have individual webpages dedicated to each.[3]
- Documentation — Following each contact with the public, every comment and concern is recorded in writing regardless of source. Each comment is logged, categorized, and submitted to SCAG planning staff for review and consideration.

TECHNICAL ANALYSIS

The goal of the 2008 RTP environmental justice analysis is to ensure that when transportation decisions are made, low-income and minority communities have ample opportunity to participate in the decision-making process and receive an equitable distribution of benefits and not a disproportionate share of burdens.[4]

Identifying Demographic Groups

Executive Order 12898 and the DOT and FHWA Orders on Environmental Justice define "minority" as persons belonging to any of the following groups, as well as "other" categories that are based on self-identification of individuals in the U.S. Census[5]: Black, Hispanic, Asian, American Indian and Alaskan Native, and Native Hawaiian or Other Pacific Islander. SCAG bases its analyses on the latest census data for ethnic/racial groups in the SCAG Region, by census tract and by transportation analysis zone (TAZ).

[2] CommunityLink 21, Regional Transportation Plan: Equity and Accessibility Performance Indicators http://www.fhwa.dot.gov/environment/ejustice/case/case4.htm

[3] RTP Website:http://scag.ca.gov/rtp2008/
EJ Website: http://scag.ca.gov/environment/ej.htm

[4] Caltrans. Desktop Guide: Environmental Justice in Transportation Planning Investments. January 2003.

[5] http://www.fhwa.dot.gov/environment/ej2000.htm

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Identifying low-income and minority populations is necessary both for conducting effective public participation and for assessing the distribution of benefits and burdens of transportation plans and projects. For the purposes of this analysis, SCAG focused on all low-income groups and minority populations. The minority population in the SCAG Region comprises over 70 percent of the population. The predominant minority groups are Hispanics and Asian/Pacific Islanders, which combine to account for 66 percent of the total minority population within the SCAG Region. Poverty level is a federally established income guideline used to define persons who are economically disadvantaged, as defined by the U.S. Department of Health & Human Services guidelines.* The poverty level applicable to the SCAG Region is chosen on the basis of regional average household size for the census year. For example, for a regional mean of 2.98 persons—rounded to 3—per household, the threshold would consist of the sum of the value for the first person plus two additional people. The household counts in each income range are then used to determine the number and percentage of households in each census tract below the poverty level. In 2007, a family of three earning less than $17,170 was classified as living in poverty.

In addition to complying with federal guidance, SCAG also conducts income equity analyses based on five income quintiles. A quintile, by definition, is a category into which 20 percent of the ranked population falls. For each new analysis, SCAG defines regional income quintiles based on the most recent census data on household income. Once the income quintiles are established, the incidence of benefits and costs can be estimated and compared across these income categories. Table 5.5 lists the demographic categories used in SCAG's EJ analysis.

TABLE 5.5 DEMOGRAPHIC CATEGORIES USED IN SCAG ENVIRONMENTAL JUSTICE ANALYSIS

Ethnic/Racial/Other Categories (persons)	Income Categories (households)
White (Non-Hispanic)	Below Poverty Level
African-American	100%–150% of Poverty Level
American Indian	150%–200% of Poverty Level
Asian/Pacific Islander	Income Quintile 1 (lowest)
Hispanic (Latino)	Income Quintile 2
Other	Income Quintile 3
Disabled/Mobility Limited	Income Quintile 4
Age 65 and Above	Income Quintile 5

The 2008 RTP Plan versus Baseline

The comparison of the Plan versus Baseline is the primary focus of the environmental justice analysis for the 2008 Regional Transportation Plan. The basic concept is to compare the performance of the Plan (2035) to the Baseline scenario for 2035. For the purposes of this analysis, the Plan represents the selected strategy to guide the Region's transportation planning over the next three decades and Baseline is defined as the set of all projects and investments currently underway or for which funds are already committed. Baseline represents "business as usual" and assumes current land use trends and the completion of projects currently under construction or with funding available for construction over the next few years. The data for the analysis is based on the SCAG Regional travel demand model results.

* White House Council on Environmental Quality (CEQ). Environmental Justice Guidance Under the National Environmental Policy Act, December 1997.

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Performance Measures

In the development of the Plan, SCAG utilized a number of performance measures designed to assess the overall equity.

- Accessibility (Employment Services and Parks)
- Distribution of Plan Expenditures (Investments)
- Taxes Paid
- Auto Travel Time Savings
- Auto Travel Distance Reductions
- Environmental Impact Analyses (Air Emissions and Noise)

These performance measures were intended to evaluate how low-income and minority communities fared under RTP investments. The performance measures and the results of the analysis are described in detail below.

ACCESSIBILITY TO EMPLOYMENT SERVICES

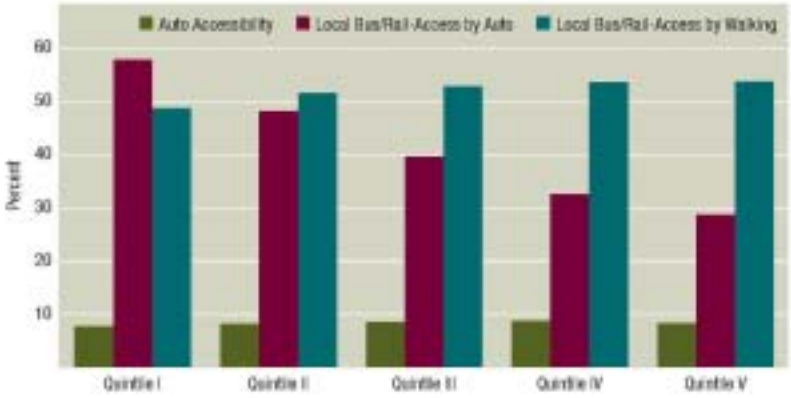
Accessibility is a foundation for social and economic interactions. As an indicator, accessibility is measured by the spatial distribution of potential destinations; the ease of reaching each destination; and the magnitude, quality and character of the activities at the destination sites. Travel costs are central: The lower the costs of travel, in terms of time and money, the more places that can be reached within a certain budget and, thus, the greater the accessibility. Destination choice is equally crucial: The more destinations and the more varied the destinations, the higher the level of accessibility.[7]

Employment accessibility evaluates how well the transportation system is providing access to jobs for underrepresented populations. In this analysis, employment accessibility is defined as the percentage of total employment opportunities that can be reached within 30 minutes during the PM peak period.

[7] CommunityLink 21, Regional Transportation Plan: Equity and Accessibility Performance Indicators: http://www.fhwa.dot.gov/environment/ejustice/case/case4.htm

Figure 5.9: Comparison of Employment Accessibility Improvements by Travel Mode and Income Category shows the percentage improvement between the Plan versus Baseline. It is projected that low-income communities in the region will have better access to employment via local bus and rail compared to higher-income groups. This can be attributed to the number of system expansion projects proposed in the 2008 RTP, which includes a number of commuter/light/heavy rail improvements and bus rapid transit expansion projects. Additionally, improvements in accessibility via automobile are expected to be lower than improvements via transit for any quintile group. The results indicate that on a regional scale, no disproportionate impacts are anticipated between income groups as a result of the Plan.

FIGURE 5.9 COMPARISON OF EMPLOYMENT ACCESSIBILITY IMPROVEMENTS BY TRAVEL MODE AND INCOME CATEGORY (PLAN VS. BASELINE, 2035)



ACCESSIBILITY TO PARKS

Numerous national parks, state parks, and local parks are all found within the SCAG Region. However, not all neighborhoods and people have equal access to these public resources. For the purposes of this analysis, three types of

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parks were considered: 1) local parks; 2) state parks; and 3) national parks. The acreage of each park type in all TAZs was identified. Similar to the method in measuring job accessibility, park accessibility is defined as the percentage of park acreage reachable within a 30-minute off-peak travel time period via 1) automobile; 2) local bus/urban rail via automobile; and 3) local bus/urban rail via walking. Without a weekend regional transportation model system, the existing typical weekday model was utilized for the analysis. Because visits to parks are, by nature, leisure trips, off-peak travel time is used instead of peak travel time. For transit travel time, both the waiting time and the on-board time are included.

FIGURE 5.10 PARK ACCESSIBILITY BY TRAVEL MODE AND INCOME CATEGORY (BASELINE 2035)

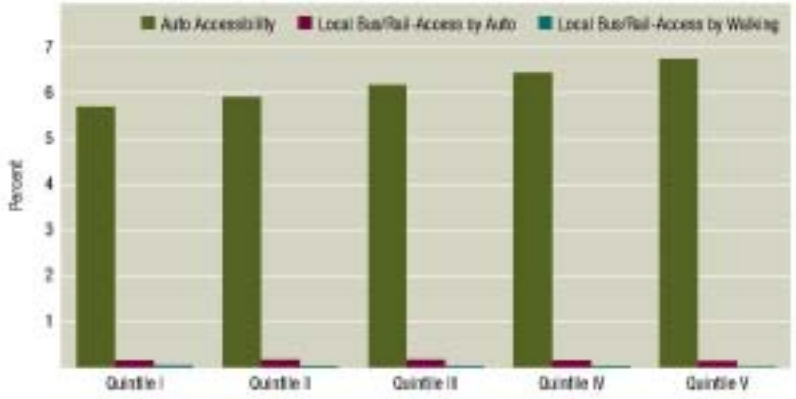


Figure 5.10: Park Accessibility by Travel Mode and Income Category shows the access to parks in the Baseline scenario. Park accessibility by transit is much lower than that by automobile for all income groups. However, Quintiles IV and V will have moderately higher access to parks in the region via automobile.

FIGURE 5.11 NATIONAL PARK ACCESSIBILITY BY TRAVEL MODE AND INCOME CATEGORY (BASELINE 2035)

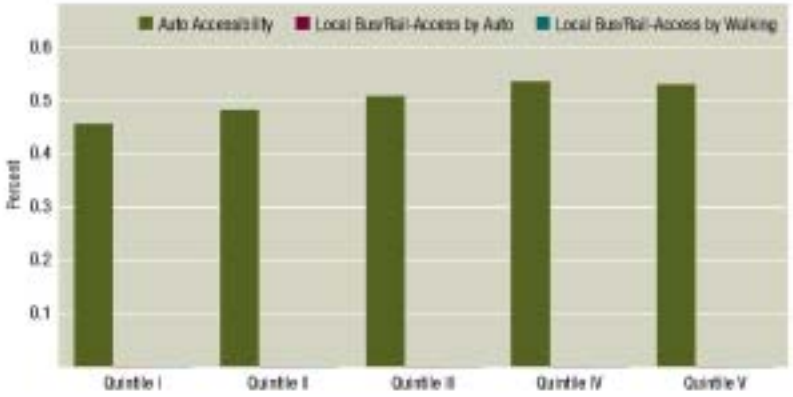
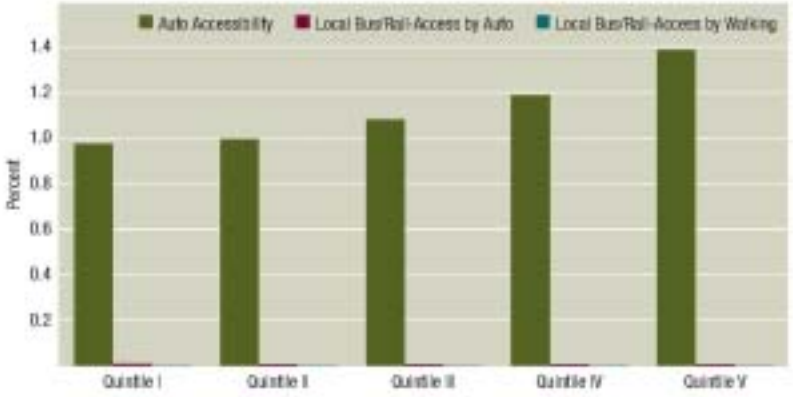


FIGURE 5.12 STATE PARK ACCESSIBILITY BY TRAVEL MODE AND INCOME CATEGORY (BASELINE 2035)



Research has found a complete lack of public transportation services into national parks,[8] but this also appears true for state parks. There is almost no

[8] Frescas, Ron, Chris Martin, and Christine Steenken. Public Transportation to Local National Forests. April 15, 2004.

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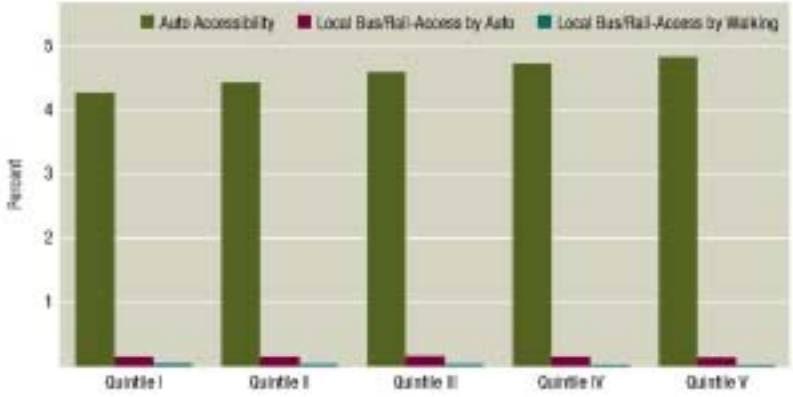
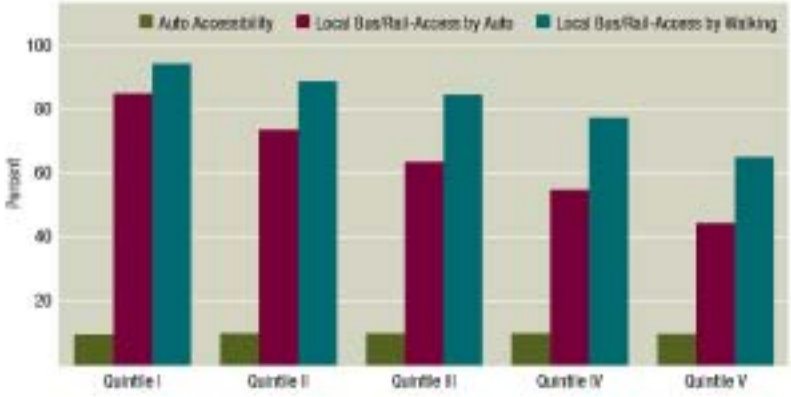
access to national parks and very limited access to state parks by transit across all income groups in the Baseline scenario (see Figure 5.11: National Park Accessibility by Travel Mode and Income Category, and Figure 5.12: State Park Accessibility by Travel Mode and Income Category).

FIGURE 5.13 LOCAL PARK ACCESSIBILITY BY TRAVEL MODE AND INCOME CATEGORY (BASELINE 2035)



The analysis also concluded that local parks are mostly accessible via the automobile. Figure 5.13: Local Park Accessibility by Travel Mode and Income Category reveals that there is limited transit service that accommodates local parks and, regionwide, there is a marginal difference in accessibility between all income groups.

FIGURE 5.14 COMPARISON OF PARK ACCESSIBILITY IMPROVEMENTS BY TRAVEL MODE AND INCOME CATEGORY (PLAN VS. BASELINE, 2035)



As shown in Figure 5.14: Comparison of Park Accessibility Improvements by Travel Mode and Income Category, park accessibility for all income groups by three travel modes is expected to improve under the Plan scenario.

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FIGURE 5.15 COMPARISON OF PARK ACCESSIBILITY IMPROVEMENTS BY PARK TYPE AND TRAVEL MODE (PLAN VS. BASELINE, 2035)

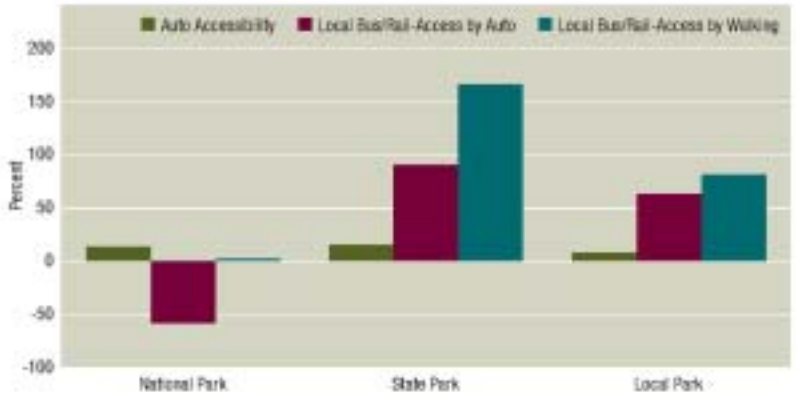

Figure 5.15: Comparison of Park Accessibility Improvements by Park Type and Travel Mode displays the improvement of park accessibility by park type: national park, state park and local parks. The results reveal that there will be significant improvements in accessibility to both state and local parks by all three travel modes. However, the accessibility to the national parks shows minor improvement, and even decreases for the mode of local bus/rail-access by auto.

PLAN EXPENDITURES/INVESTMENTS

SCAG reports expenditure distribution in several ways. First, SCAG estimates the share of total RTP expenditures allocated to each category of household income. This is done by totaling expenditures on each type of mode (bus, HOV lanes, commuter/high-speed rail, highways/arterials, and light/heavy rail). These expenditures are then allocated to income categories based on each income group's tendency to use these modes.[9]

[9] Caltrans. Desktop Guide: Environmental Justice in Transportation Planning Investments. January 2003.

SCAG analyzed the distribution of Plan expenditures based on mode usage information by income quintile. As illustrated in Figure 5.16: Distribution of Plan Expenditures by Income Category, approximately 28 percent of Plan investments will be invested in modes predominantly used by the lowest quintile group, while 16 percent will be invested in modes used by the highest-income category (Quintile V). A total of 68 percent of transportation investments would go to modes likeliest to be used by the lower-three-income households in the 2008 RTP.

FIGURE 5.16 DISTRIBUTION OF PLAN EXPENDITURES BY INCOME CATEGORY

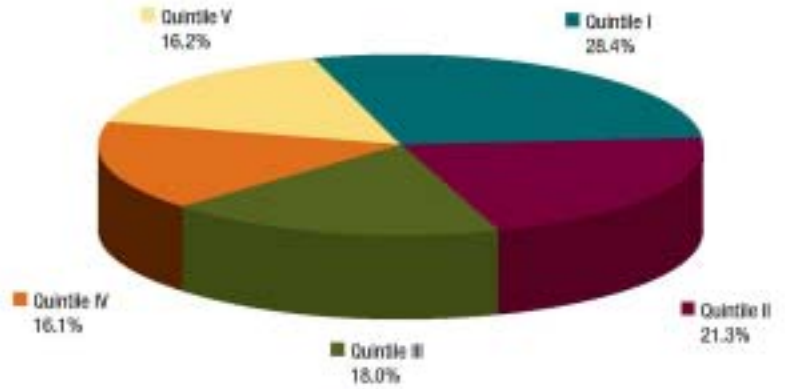

Figure 5.17: Distribution of Plan Expenditures by Ethnic/Racial Category evaluates the allocation of transportation investments in modes used by various ethnic/racial categories. The current analysis reveals that under the 2008 RTP, Plan investments will be distributed more equitably on the basis of system usage by ethnic/racial groups.

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FIGURE 5.17 DISTRIBUTION OF PLAN EXPENDITURES BY ETHNIC/RACIAL CATEGORY

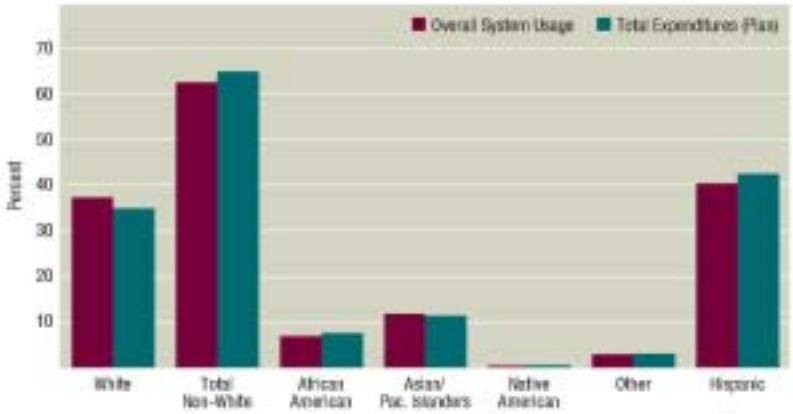
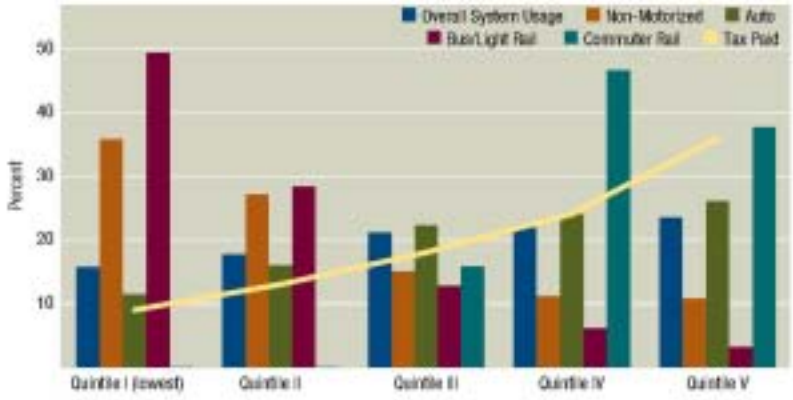


FIGURE 5.18 SHARE OF TAXES PAID BY INCOME CATEGORY*



* The contents in this chart use both work and non-work trips; rail capacity uses only work trip data.
* Share of Tax Paid includes sales and gasoline taxes.

TAXES PAID

The 2008 RTP environmental justice analysis performed a comparative analysis of the amount of taxes (sales, gasoline, and income) paid by five income groups. Figure 5.18: Share of Taxes Paid by Income Category, indicates that tax burdens are expected to fall heavily on higher-income groups. The lower-income groups (Quintile I and Quintile II), which use bus and light rail as their primary modes of travel, are anticipated to pay 22 percent of taxes.

DISTRIBUTION OF TRAVEL TIME SAVINGS

This analysis involved measuring the average travel time for both work trips and non-work trips. SCAG assesses the distribution of travel time savings that are expected to result from the Plan's implementation. SCAG conducted this analysis for transit (i.e. bus and light rail) and automobile. These travel time savings were reported as a proportion of the total travel time savings for each mode.

Figure 5.19: Share of Transit System Usage, Transit Travel Time Savings, and Taxes Paid, shows the results for low-cost transit modes, such as local bus and light rail, for the five income groups. According to the 2008 RTP analysis, the two lowest-income quintiles will pay just over 20 percent of total taxes collected in the region, but will enjoy 65 percent of the transit time savings. The two highest-income quintiles share of taxes (60 percent) will exceed the benefits they receive in local transit time savings (16 percent) and account for only 9 percent of total bus and light rail usage. The findings indicate that

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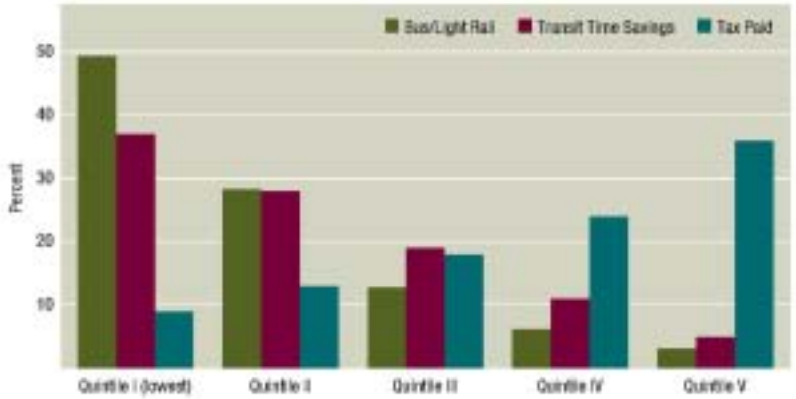
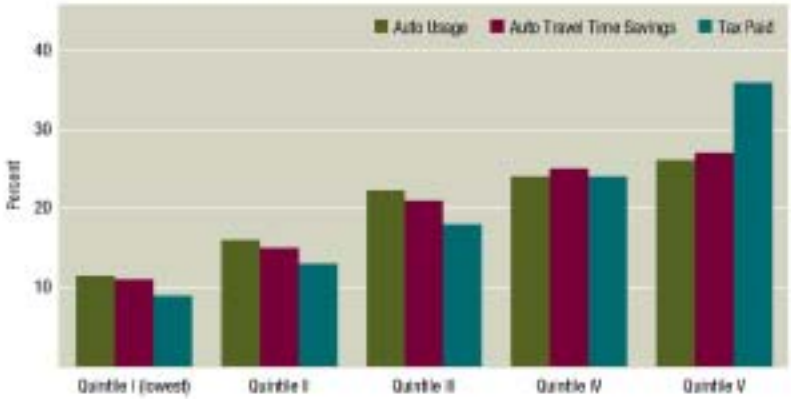
transit travel times for lower-income groups for both work and non-work trips are expected to decrease due to the number of new bus and rail improvements proposed in the 2008 RTP.

FIGURE 5.19 SHARE OF TRANSIT SYSTEM USAGE, TRANSIT TRAVEL TIME SAVINGS, AND TAXES PAID



Results are also shown for trips made by automobile. Figure 5.20: Share of Auto Usage, Auto Travel Time Savings, and Taxes Paid, illustrates that the share of benefits is proportionate to the share of taxes paid. Higher-income groups are anticipated to have the most benefit in auto travel time savings, but will also incur the highest taxes. This can be attributed to the fact that higher-income groups (Quintiles IV and V) have higher access to private automobiles and will use this as their primary mode of travel. However, that benefit comes at a steep price, as the two highest-income quintiles pay for 60 percent of total taxes.

FIGURE 5.20 SHARE OF AUTO USAGE, AUTO TRAVEL TIME SAVINGS, AND TAXES PAID



TRAVEL DISTANCE REDUCTIONS

Another way of estimating benefits is to calculate savings in terms of person-miles traveled (PMT). These results indicate that the share of auto travel distance savings, like that for time savings, generally resembles the share of usage and taxes paid.

The underlying assumption for Figure 5.21: Share of Auto Usage, Auto Travel Distance Savings and Taxes Paid, is that the share of auto travel distance savings is generally proportionate to the share of taxes paid and transportation system usage between all income groups. The taxes paid by the highest,income group (36 percent) are anticipated to exceed their share of benefits (27 percent). The lowest,quintile group is expected to have the least amount of benefits, accounting for 12 percent of auto usage and travel distance savings. They will also pay the least amount of taxes at 9 percent. Higher,income groups are anticipated to have the most benefits because their primary mode of travel will be the automobile.

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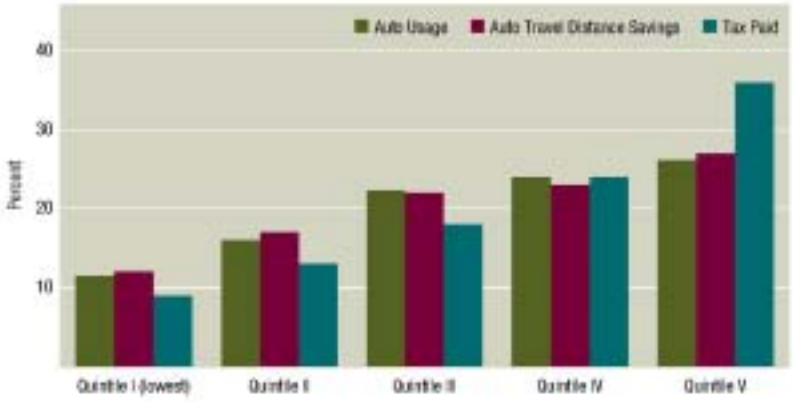
FIGURE 5.21 SHARE OF AUTO USAGE, AUTO TRAVEL DISTANCE SAVINGS AND TAXES PAID



ENVIRONMENTAL IMPACTS

Transportation projects can have both a positive or negative impact on the environment. On the one hand, investments can cause travelers to shift to less-polluting modes (e.g., bus, train, carpooling, or commuter rail). On the other hand, investments that increase traffic on a particular facility usually degrade air quality in the immediate vicinity of that facility.[10]

Air Pollutant Emissions

Minorities and low-income groups may be particularly vulnerable to the effects of air pollution. SCAG's analysis is based on emissions estimates for pollutants that have localized health effects: carbon monoxide (CO) and particulate matter (PM). Analysis was also conducted for PM exhaust emissions from heavy-duty vehicles, an indicator for diesel toxic air contaminants. The results were computed based on the average emissions at the TAZ level and weighted according to the population of each ethnic or income group in that TAZ. This analysis focuses on air emissions and noise impacts generated from aviation and highway activity.

It is important to note that total emissions of all pollutants in the region will decrease compared to existing conditions with or without the Plan, due to the combination of measures being taken to meet air quality standards. Since the Plan must demonstrate conformity with regional air quality management plans that call for reductions in emissions of air pollutants, the Plan itself will likewise result in reductions of pollutant emissions. This is generally because the Plan investments will alleviate roadway congestion and provide a greater range of alternatives to the use of a car. The following analysis, however, is based on a comparison of Plan to Baseline conditions, rather than a comparison of Plan to current conditions.

Since ambient pollutant concentration levels that are directly linked to localized emissions could not be easily estimated, the geographic emissions distribution analysis presented here focuses on pollutants that tend to have localized effects which are generally proportionate to emissions—carbon monoxide (CO) and fine particulate matter (PM10). The analysis does not cover pollutants that do not have localized effects proportionate to emissions, but are regionally distributed as a result of chemical interactions, photochemical reactions and meteorology (VOC, NOx, and SOx).

In addition, this methodology assumes that all residents in a given TAZ are equally exposed. Generally, both CO and PM10 tend to impact those located closest to the source of emissions. Thus, in a TAZ containing a roadway, those closest to the roadway would experience greater emissions and potential health impacts than those located further away. This differential as it might exist within TAZs is not addressed by this analysis; only differences between the aggregate demographic totals of different TAZs are addressed. Notwithstanding these assumptions, the methodology presents a reasonable gross measure of air quality impacts of mobile sources in the region.

[10] Caltrans. Desktop Guide: Environmental Justice in Transportation Planning Investments. January 2003.

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FIGURE 5.22 DECREASE IN AIR POLLUTANT EMISSIONS BY INCOME CATEGORY (PLAN VS. BASELINE, 2035)

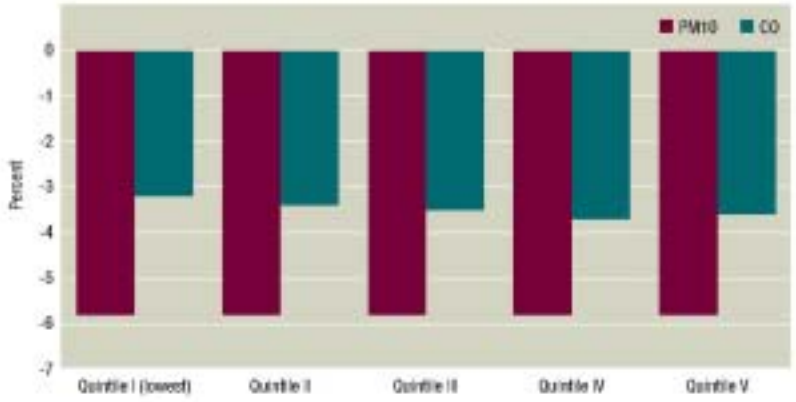
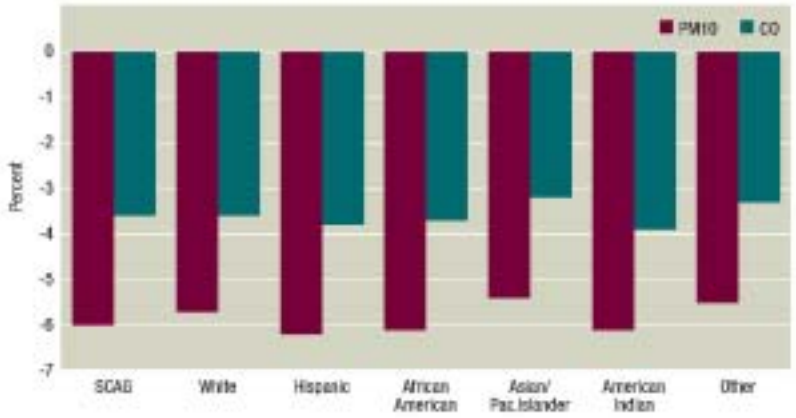


FIGURE 5.23 DECREASE IN AIR POLLUTANT EMISSIONS BY ETHNIC/ RACIAL CATEGORY (PLAN VS. BASELINE, 2035)



Overall, the region as a whole will generally experience an improvement in air quality via reductions in transportation-related emissions. As illustrated by Figure 5.22: Decrease in Air Pollutant Emissions by Income Category, and Figure 5.23: Decrease in Air Pollutant Emissions by Ethnic/Racial Category, on a regional scale, all income and ethnic groups will experience reductions in PM10 and CO under the Plan.

Aviation Noise Impacts

The SCAG Region supports the nation's largest regional airport system in terms of number of airports and aircraft operations, operating in a very complex airspace environment. One significant challenge is striking a balance between aviation capacity needs of Southern California with local quality-of-life constraints for the affected populations.

Projected noise impacts from aircraft operations at the region's airports in 2035 were modeled for inclusion in the PEIR for the RTP. For each airport, modeling produced a contour or isoline for the 65 dB Community Noise Equivalent Level (CNEL), a measure of noise that takes into account both the number and the timing of flights, as well as the mix of aircraft types. The Federal Aviation Administration (FAA) considers residences to be an "incompatible land use" with noise at or above 65dB this CNEL level.

To identify potentially impacted populations, the anticipated population within the 65 dB CNEL contour was calculated by the following steps:

1. Calculating the percentage of TAZs that would lie within a 65 dB CNEL contour
2. Assigning the SCAG projected population to the TAZ
3. Applying the demographic breakdown of the TAZ as a whole to the population within the 65 dB CNEL contour

For the purposes of this study, Aviation Noise Areas are defined as areas that are adversely affected by aircraft and airport noise. Figure 5.24: Distribution of Households in Aviation Noise Areas by Income Category, demonstrates that there is a marginal disproportionate impact between each income group in the 2008 RTP, which is similar to the findings in the 2004 RTP. The disparity between the lowest and highest quintile groups is approximately 7 percent. Each income quintile (by definition) contains 20 percent of the region's

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households in 2035. Under the 2008 RTP, the lowest-income group (Quintile 1) will represent 23 percent of the households impacted by noise above the 65 dB CNEL.

FIGURE 5.24 DISTRIBUTION OF HOUSEHOLDS IN AVIATION NOISE AREAS BY INCOME CATEGORY (PLAN VS. BASELINE, 2035)

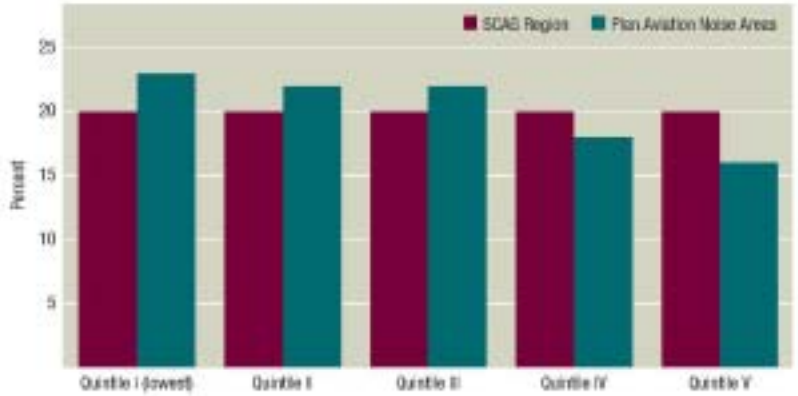

FIGURE 5.25 DISTRIBUTION OF HOUSEHOLDS IN AVIATION NOISE AREAS BY ETHNIC/RACIAL CATEGORY (PLAN VS. BASELINE, 2035)

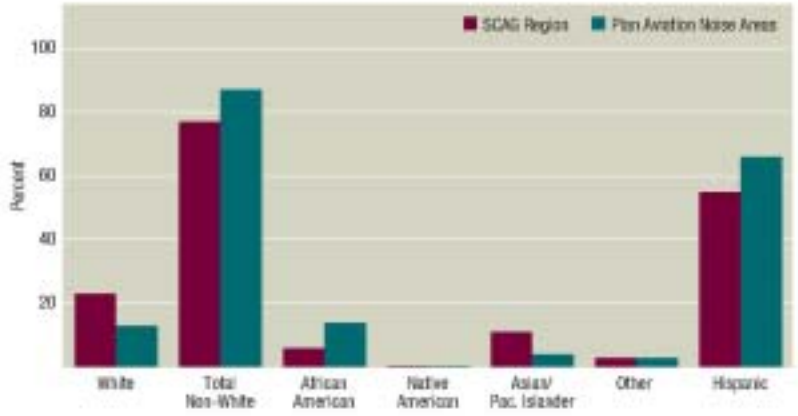

Figure 5.25: Distribution of Households in Aviation Noise Areas by Ethnic/Racial Category, indicates that the 2008 RTP is projected to have a disproportionate aviation noise impact on minority groups. Although non-whites will comprise 77 percent of the region's population in 2035, they will make up 87 percent of those affected by the 65 dB CNEL contour. In particular, 66 percent of the impacted population will be Hispanics, which is a 20 percent increase from the 2004 RTP.

Although the gap between the income groups is projected to be a marginal difference, the environmental justice analysis results demonstrate that lower-income and minority residents still bear a disproportionate burden from aviation noise pollution with the 2008 RTP.

Highway Noise Impacts

Noise associated with highway traffic depends on a number of factors that include traffic volumes, vehicle speed, vehicle fleet mix (cars, trucks), as well as the location of the highway with respect to sensitive receptors. According to Federal Highway Administration (FHWA) guidance, noise impacts occur when noise levels increase substantially when compared to existing noise levels. For the purposes of this analysis, noise increases of 3 dB along highways, where noise levels are currently, or would be in the future above 66 dB, are considered to be significant, regardless of adjacent land use.

The demographic characteristics of each impacted TAZ portion were aggregated and compared with the regional demographics to determine if there would be any disproportionate impacts to any of the demographic groups identified. This approach identified a marginal disproportionate impact between each income group (see Figure 5.26: Distribution of Households in Highway Noise Areas by Income Category). The lowest-income group will account for 22 percent of the affected population in 2035. There is a 6 percent difference between the lowest- and the highest-income quintiles.

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FIGURE 5.26 DISTRIBUTION OF HOUSEHOLDS IN HIGHWAY NOISE AREAS BY INCOME CATEGORY (PLAN VS. BASELINE, 2035)

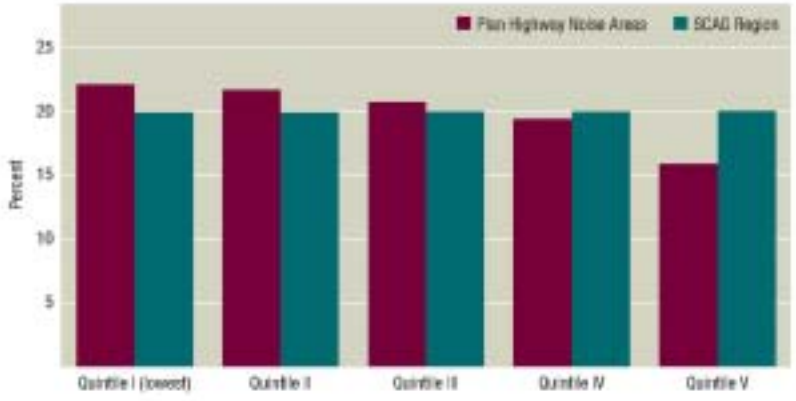
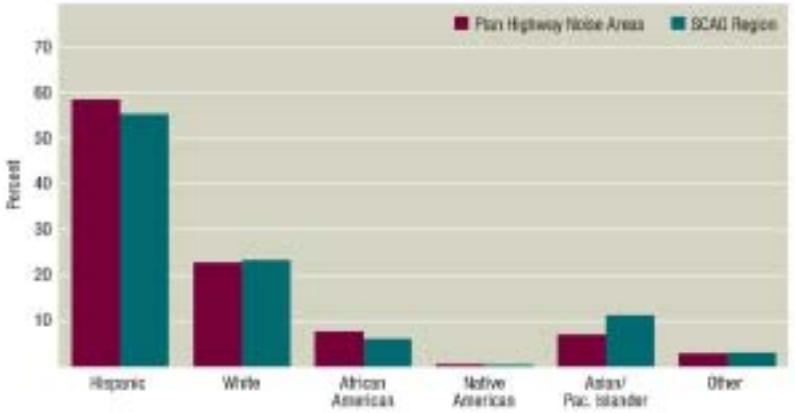


FIGURE 5.27 DISTRIBUTION OF HOUSEHOLDS IN HIGHWAY NOISE AREAS BY ETHNIC/RACIAL CATEGORY (PLAN VS. BASELINE, 2035)



The 2008 RTP also found that minority populations were primarily affected by highway noise impacts. Figure 5.27: Distribution of Households in Highway Noise Areas by Ethnic/Racial Category, indicates that minority populations, specifically Hispanics, would be disproportionately impacted by highway noise. Approximately 59 percent of Hispanics would be residing in highway noise areas by 2035.

The identification of these disparate highway noise impacts at the regional level can be attributed to the issue of incompatible land use, where high-polluting transportation projects, such as freeway construction, airport expansions, or rail extension projects, are located in minority-populated neighborhoods. Corridor-level analysis should be conducted for proposed projects in areas where burdens are concentrated. In addition, the 2008 RTP proposes mitigating these impacts to the extent possible, for example, by requiring new soundwalls where freeway expansions are proposed. Furthermore, the RTP also proposes grade crossings, new technologies, and other clean technologies for goods movement corridors.

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NEW SOCIAL EQUITY ELEMENTS

In addition to the performance measures analyzed above, the 2008 RTP environmental justice analysis has undertaken new components. Summarized below are the new initiatives that have either directly or indirectly resulted from the previous environmental justice discussions and comments received.

- Accessibility: In the 2004 RTP environmental justice analysis, SCAG analyzed the percentage of jobs accessible within 45 minutes. The 2008 RTP analysis instead used 30 minutes to calculate accessibility. SCAG determined that the 30-minute travel-time criterion was more indicative of accessibility to the locations of employment services.
- Trips: In the 2008 RTP, both work and non-work trips were analyzed. Previous RTP environmental justice analysis included only work trips. In this analysis, both work and non-work trips were calculated for each TAZ. Incorporating non-work trips into the analysis provides a more accurate determination of allocation of benefits and burdens for each of the performance measures.
- Access to Parks: In response to the comments on the draft 2008 RTP Environmental Justice analysis, SCAG conducted additional and new analysis on accessibility to parks from the perspective of the long-range regional transportation plan.
- County Data: In response to the comments received on the draft 2008 RTP Environmental Justice analysis, SCAG prepared additional and new analysis on a countywide level. This information is included as supplementary information. (See Environmental Justice Report, pages 26 through 28.)

CONCLUSION

The 2008 RTP seeks to identify and address Title VI of the Civil Rights Act and any environmental justice implications of the planning processes and investment decisions. It is critical for SCAG and policy-makers alike to ensure that their transportation programs, policies, and activities serve all segments of the region without generating disproportionately strong and adverse effects.

Economic Impact Analysis

DECLINE IN EMPLOYMENT GROWTH RATE

As revealed in current and previous RTP growth forecasts, the region's employment growth will slow down considerably after 2010, compared with historical trends. This sharp and unprecedented decline in job growth as well as underlying changes in the makeup of the labor force in the region are due primarily to a large number of "Baby Boomers" starting to reach the age of retirement. The share of total population and households of elderly and retired persons in the region is projected to double from today. These households are more likely to be headed by minorities (i.e., non-Hispanic White householders).

Unlike the 1960–2000 period, the region will not have a large labor force to support a relatively small retired population. Instead, the region will experience a situation in which a smaller labor force made up of minority households will be supporting a relatively large retired population made up of non-minority households. Increased by immigration, these minority households will be larger, consist of multiple generations, and be headed by younger individuals in the workforce. The size of our labor force as well as employment growth will be sensitive to these changes in demographics.

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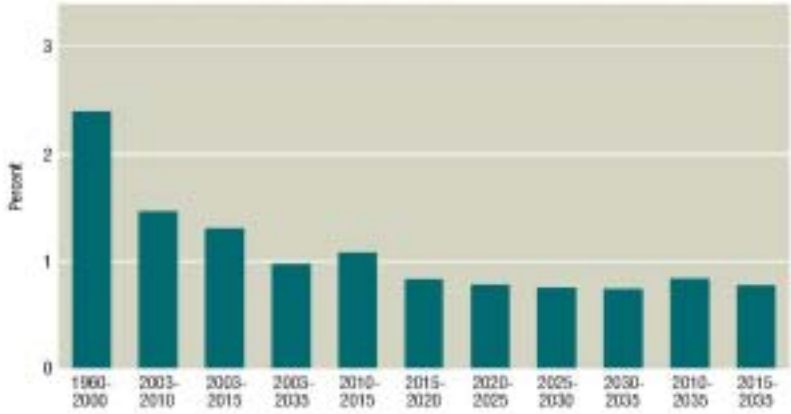
During the 2003–2035 forecast period, employment growth will be constrained by the size of the anticipated labor force. A major challenge for the region will be to prepare and match younger workers with future jobs. Matching needed skills and education levels with new and especially better-paying future jobs will affect migration trends and immigration levels. These impacts will be felt the most after 2010. During the last 40 years (1960–2000), while the region expanded its job base at an annual compound growth rate of 2.4 percent, the region's job growth rate is now projected to be only 0.84 percent during the 25-year period between 2010 and 2035 (Figure 5.28).

This is about one-third of what was achieved in prior decades. The projected employment growth trends after 2010 suggest an imbalance between the size of the labor force, the retired population that employed workers must support, and the amount of job growth that can be achieved. As a result, the regional economy is expected to face tremendous downward pressure and may not be able to produce the jobs, wealth, and prosperity that it did in prior decades. The economic health of the region is tied to job growth, particularly the creation of high-paying jobs that match the skills and education level of the region's future workforce made up primarily of households headed by minority populations.

FIGURE 5.28 HISTORICAL AND PROJECTED SCAG REGION EMPLOYMENT GROWTH RATES



PUBLIC- AND PRIVATE-SECTOR INVESTMENTS

The 2008 RTP proposes investing $234 billion in 2007 constant dollars (or $412 billion) from public funding sources between 2007 and 2035. In addition, consistent with strategies laid out in previous SCAG RTPs, the 2008 RTP continues to emphasize using innovative financing tools, such as user-based fees and direct investment from the private sector to address challenges limiting transportation revenue growth, constraining transportation investments, and enlarging gaps in unmet transportation demand. The innovative funding revenues which are deemed reasonably available for the 2008 RTP planning horizon are projected to be around $75.6 billion in 2007 constant dollars (or $125 billion in nominal dollars)[11] between 2007 and 2035.

The economic impacts from private-sector-funded projects are different from those funded by tax dollars. Since transportation projects funded by retail sales and gasoline tax revenues are simply extensions of past economic trends, most of their economic impacts are reflected either in the existing employ-

[11] Including additional gas tax and sales tax of $12 billion in 2007 constant dollars

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ment base, or in the baseline employment growth forecast. However, enabling private sector engagement in transportation investments through innovative financial arrangements will generate and create new economic activities not experienced before and not captured by past historical trends. As a result, private-sector investments in transportation infrastructure will work to boost regional economic and job growth above the Baseline growth forecast (Economic Impact Analyses for the 1998, 2001, and 2004 RTPs).

The impacts of the RTP expenditures were estimated using the economic input/output model (IMPLAN) and are presented in Table 5.6. The implementation of public-sector-funded infrastructure projects recommended in the 2008 RTP is projected to account for almost 120,000 jobs annually, while projects proposed in the RTP funded through innovative financing would create a net additional 32,800 jobs annually during the planning period.

TABLE 5.6 AVERAGE ANNUAL ECONOMIC IMPACTS FOR 2008 RTP (DIRECT, INDIRECT AND INDUCED IMPACTS)

	Average Annual Investment (Millions $2007)	Employment (No. of Jobs)	Output (Millions $2007)	Income (Millions $2007)
Public Sector	$8,540	119,600	$15,300	$4,200
Private Sector	$2,700	32,800	$4,890	$1,220

Source: Draft 2008 RTP & SCAG Input-Output Model

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VI. IMPLEMENTATION AND MONITORING

This section discusses how SCAG, as the MPO for the six-county region, monitors the implementation of the 2008 RTP and monitors its progress in achieving its stated goals and system performance.

As discussed in Chapter II, the 2008 RTP comes at a time of great challenges. SCAG and its partners believe they have addressed these challenges from a planning perspective. However, as with any plan, its success or failure depends on the execution.

SCAG intends to continue its longstanding role as the monitoring agency for Plan implementation in all its facets.

Implementing the RTP

REGIONAL TRANSPORTATION IMPROVEMENT PROGRAM (RTIP)

The RTIP is the tool for the Metropolitan Planning Organizations (MPOs) to monitor and implement their RTP. The RTIP is updated every two years, the most recent being in 2006.

The RTIP provides a listing of projects proposed for implementation in the Region during the six-year period covered by the document. The RTIP projects are described in detail, including the funding amounts allocated by source and fiscal year. RTIP projects are categorized according to the transportation system to which they apply: state highways, local highways, or transit.

The passage of SAFETEA-LU in 2005 has created additional requirements for the RTP and RTIP, including an expanded public participation plan with expanded consultation requirements, the use of visualization techniques, publication of an annual list of obligated projects and the requirement that all regionally significant projects be listed individually.

One of the first steps in RTP implementation is that during each RTIP development cycle, SCAG provides the county transportation commissions (CTCs) and Imperial Valley Association of Governments (IVAG) with RTIP Guidelines. The RTIP Guidelines are used by the counties in the development of their county transportation improvement programs (TIPs). These Guidelines are consistent with SAFETEA-LU and the Metropolitan Transportation Programming final rule: 23 CFR Parts 450 and 500, and 49 CFR Part 613.

The RTP non-motorized, rideshare, ITS, and TDM investments were developed in consultation with the county transportation commissions and the IVAG. These investments are annualized in the RTIP Guidelines in order to provide the county transportation commissions and IVAG with average yearly investments. The investments are reflected in the RTIP Guidelines by category in order to facilitate monitoring and ensure RTP implementation.

The RTIP Guidelines also contain the RTP constrained project listing. The counties need to program these projects for initiation within an appropriate time frame to ensure that they become operational during the time frame indicated in the RTP.

The projects identified within the RTP and RTIP must be financially constrained. The RTIP Guidelines provide the RTP funding forecasts for the programming years associated with the RTIP cycle under development. The CTCs and IVAG should program within the RTP forecasts. If a county programs more in project costs than can be accommodated by the RTP financial forecasts, then appropriate justification must accompany the county TIP documentation and be accepted by SCAG prior to TIP approval.

CONGESTION MANAGEMENT PROCESS

The Congestion Management Process as implemented in the SCAG region provides for a comprehensive and integrated transportation planning process that links together the RTP, RTIP, and county-level Congestion Management Programs.

BACKGROUND

The United States Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) requires the development, establish-

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ment and implementation of a Congestion Management Process which is fully integrated into the regional planning process.

The Federal Highway Administration defines the congestion management process as a "systematic approach required in transportation management areas (TMAs) that provides for effective management and operation, based on a cooperatively developed and implemented metropolitan-wide strategy, of new and existing transportation facilities eligible for funding under Title 23 U.S.C. and Title 49 U.S.C., through the use of operational management strategies."

SCAG's Congestion Management Process is a comprehensive strategy designed to relieve traffic congestion and maintain high levels of service on roadways within the Southern California region. SCAG has facilitated efforts by counties and subregions to develop County-level Congestion Management Programs (CMPs) in cooperation with regional and subregional transportation providers, local governments, Caltrans, and the South Coast Air Quality Management District.

In the SCAG region, Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties are contained within Transportation Management Areas (TMAs). The Federal Highway Administration (FHWA) defines TMAs as the following:

1. All urbanized areas over 200,000 in population, and any other area that requests such designation
2. An urbanized area with a population over 200,000 (as determined by the latest decennial census) or other area when TMA designation is requested by the governor and the MPO (or affected local officials), and officially designated by the administrators of the FHWA and the FTA. The TMA designation applies to the entire metropolitan planning area(s) (23CFR500)

The County Transportation Commission in each county also functions as a Congestion Management Agency (CMA) under California regulations. To meet the federal Congestion Management Process requirements, SCAG and the county CMAs have come together to develop a Congestion Management Process for the region. Under California law, the Congestion Management Programs (CMPs) are prepared and maintained by the respective CMAs:

- The Los Angeles County Metropolitan Transportation Authority (LACMTA)
- The Orange County Transportation Authority (OCTA)
- The Riverside County Transportation Commission (RCTC)
- The San Bernardino Associated Governments (SANBAG)
- The Ventura County Transportation Commission (VCTC)

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With the exception of small portions of Riverside and San Bernardino Counties, all counties within the TMA are designated as ozone non-attainment areas. SCAB covers the urbanized portions of Los Angeles, Orange, Riverside, and San Bernardino Counties.

Federal funds may not be programmed in the carbon monoxide and ozone non-attainment areas of the Transportation Management Areas (TMAs) for any project that will result in a significant increase in single-occupant vehicle (SOV) capacity unless that project is addressed through a CMP.

The CMPs work in collaboration with the AQMP in several areas, but most significantly through the TCMs. Most TCM projects identified in the RTIP are designed to help relieve congestion at the local level. Thus, implementation of the AQMP helps local governments tackle congestion, which, in turn, reduces emissions from idling vehicles or the number of vehicles traveling on congested roadways, and also helps maintain service level standards. At the same time, the CMP process provides local governments with a mechanism to contribute to the regional effort toward attaining the NAAQS.

REGIONAL CONGESTION MANAGEMENT ELEMENTS

In compliance with the sections of the Metropolitan Planning Regulations [23 U.S.C. 134 and 49 U.S.C. 5303- 5305], SCAG's Congestion Management Process comprises the following Regional Congestion Management Elements:

- The Regional Transportation Plan (RTP)
- The counties' Congestion Management Programs (CMPs)
- The Regional Transportation Improvement Program (RTIP)

The functionality of each element is described in the following sections.

Regional Transportation Plan (RTP)

SCAG's RTP establishes overall long-term mobility policies for the movement of people and goods, including congestion relief strategies for all regionally significant facilities and activities (projects and programs).

Congestion Management Program (CMP)

There are five CMAs in the SCAG region and each develops a CMP for their respective county. The degree of urbanization varies from one county to another and consequently the magnitude of congestion will also vary. The CMPs' efforts have been brought together on a regionwide basis and integrated into the SCAG regional planning process.

SCAG's Regional Council and the Regional Transportation Agencies Coalition ensure consistency between the county CMPs and SCAG's RTP and RTIP, through project implementation.

In 1995, SCAG and the CMAs developed the following criteria to ensure consistency and compatibility between the regional transportation planning process and the county congestion management process:

- CMP consistency with the current RTP
- Interregional (inter-county) coordination between the CMPs' goals and objectives
- Consistency between countywide model/database and SCAG's model/database
- All regionally significant CMP projects are to be modeled and incorporated into SCAG's Regional Transportation Modeling System (network)

The purpose of these criteria is to hold each county CMP responsible for the goals and objectives of SCAG's RTP. Compliance with the above criteria is essential, particularly for CMP projects that are going to be programmed into the SCAG RTIP.

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TABLE 6.1 CMPS IN THE SCAG REGION

County	Congestion Management Agency (CMA)	Congestion Management Program
Los Angeles	Los Angeles County Metropolitan Transportation Authority (LACMTA)	2004 Congestion Management Program for Los Angeles County (Updated Statement of Conformity issued in 2007)
Orange	Orange County Transportation Authority (OCTA)	2007 Orange County Congestion Management Program (November 2007)
Riverside	Riverside County Transportation Commission (RCTC)	2006 Riverside County Congestion Management Program
San Bernardino	San Bernardino Associated Governments (SANBAG)	2005 Congestion Management Program for San Bernardino County
Ventura	Ventura County Transportation Commission (VCTC)	2005 Ventura County Congestion Management Program

All county CMPs share the same goal of reducing congestion and applying congestion relief strategies. However, there are different priorities in the selection of related strategies based on the needs of each county. Therefore, each county CMP differs in form and local procedure. By state statute, all CMPs must perform the same functions outlined below and must be consistent with the federal requirements.

Highway Performance - Each CMA monitors the performance of an identified highway system. This allows each county to track how their systems, and their individual components, are performing in comparison to established standards, and how performance changes take place over time.

MultiModal Performance - In addition to highway performance, each CMP contains an element to evaluate the performance of other transportation modes, including transit.

Transportation Demand Management (TDM) - Each CMP contains a TDM component geared to reducing travel demand and promoting alternative transportation methods.

Land-Use Programs and Analysis - Each CMP incorporates a program to analyze the impacts of local land-use decisions on the regional transportation system.

Capital Improvement Program (CIP) - Using data and performance measures developed through the activities identified above, each CMP develops a CIP. This becomes the first step in developing the County TIP. Under state law, projects funded through the Regional Transportation Improvement Program (RTIP) must first be contained in the CMP.

Deficiency Plan – Despite the above-stated efforts, when unacceptable levels of congestion occur, the respective CMP contains a set of "deficiency plan"

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provisions to address the problems. Deficiency plans may be developed for specific problem areas or on a countywide-system basis. Projects implemented through the deficiency plan must, by statute, include both mobility and air quality benefits. In many cases, the deficiency plan captures the benefits of the transportation projects beyond the SCAG RTIP such as non-federally funded/non-regionally significant projects.

Information on the CMP activities and resulting data are updated on a biennial basis by each CMA and supplied to SCAG and the respective air quality management district.

Regional Transportation Improvement Program (RTIP)

All federally funded congestion relief strategies (projects and programs) are programmed into the RTIP in the SCAG region. Under state law, the CMP projects must be incorporated into the RTIP in order to receive federal and state funds. Under federal law, the RTIP must be updated every four years for funding. Note that the CMP documents list additional projects which are 100% locally funded and not regionally significant, such as the transportation demand management (TDM) and bike lane projects, as these also cumulatively help mitigate congestion.

In non-attainment and maintenance areas, the RTIP projects as a whole, including congestion relief projects, must fulfill the Transportation Conformity requirements. In project-level analysis, the projects requiring federal action (funding or approval) are subject to Environmental Impact Study (EIS) through the National Environmental Policy Act (NEPA). This is an evaluation and analysis of the alternatives. The selected alternative will then be incorporated into the RTP and RTIP for implementation.

Regionally Significant Transportation Investment Studies

Within the context of regional transportation planning, the first step toward strategy or program development is the Regionally Significant Transportation

Investment Study (RSTIS), or a corridor feasibility study of alternatives including a National Environmental Policy Act (NEPA) "purpose and need" statement and preliminary environmental documentation.

SCAG, in cooperation with other stakeholders, will approve the initiation and scope of an RSTIS. Before a project may be included in the RTIP for construction, the project must be one of the alternatives in a completed RSTIS, and must have a completed project initiation document and cleared environmental documents.

Regionally significant alternatives must be evaluated by the RTP performance measures in order to be considered for incorporation in the RTP. RSTIS analyses are currently being performed for corridors in the region, including the South Orange County Major Investment Study and the Orange County/Los Angeles Intercounty Transportation Study. The 2008 RTP includes alternative modes and technologies (intelligent transportation vehicle and highway systems), general alignment, number of lanes, the degree of demand manage-

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ment and operating characteristics. Furthermore, an RSTIS is required to evaluate the effectiveness and cost-effectiveness of alternatives in attaining local, regional, state and national goals and objectives. This analysis considers the direct and indirect costs (of capital, operating and maintenance, and rights-of-way) of alternatives; benefits or impacts of mobility improvements; air quality requirements; social, economic and environmental impacts, including environmental justice; safety, operating efficiencies; financing (federal, state and private sources); energy consumption; and public outreach. The results of the RSTIS help shape decisions by SCAG, in cooperation with participating public and private organizations, on the design and scope of the investment for the RTP. The preferred alternative of an RSTIS must meet the performance and financial criteria established by the RTP, and it must be approved by the Regional Council before being included in the RTP and RTIP.

An RSTIS is eligible for funds authorized under Sections 8, 9 and 26 of the Federal Transit Act, state planning funds, as well as planning and capital funds appropriated under Title 23, United States Code.

RSTIS or other analyses are appropriate when regionally significant investments in the RTP have not developed sufficient environmental analysis, design concept and scope (mode and alignment not fully determined). In cases requiring further analysis, the RTP may stipulate either a set of assumptions concerning the proposed improvement or a no-build condition pending the completion of a corridor or sub-area analysis. In either case, the RTP provides enough detail to provide a plan conformity determination.

Monitoring Our Progress

As the designated MPO for the six-county region, SCAG monitors transportation plans, projects and programs for consistency with regional plans. SCAG also monitors the performance of the transportation system. This performance monitoring is especially important to the planning process for future RTPs. It is impossible to solve our regional transportation problems unless we are able to identify and measure them effectively.

SCAG prepares the RTP using performance-based measures that help public officials to better analyze transportation options and trade-offs and make informed decisions. By examining the performance of existing systems over time, SCAG monitors trends and identifies regional transportation needs that may be considered in the RTP. Performance measurements help clarify the link between transportation decisions and eventual outcomes, thereby improving the discussion of planning options and communication with the public. This also helps determine which improvements provide the best opportunities for maximizing the system's performance within the defined constraints.

SCAG has developed performance measures (see Chapters I and V) for the regional transportation system. New tools are also being developed that will help SCAG monitor system performance over time. The Freeway Performance Measurement System (PeMS), developed by UC Berkeley, Caltrans, and the California Partners for Advanced Transit and Highways (PATH), has the ability to measure freeway speeds, delay, and reliability for the regional freeway system. SCAG monitors a number of performance measures through a benchmarking process in the annual State of the Region report.

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Transportation planning for the region requires continually improved information on the condition and utilization of the transportation system. Special reports are required periodically from SCAG to show the condition of the highway infrastructure and to monitor the region's overall traffic. The Highway Performance Monitoring System (HPMS) is a federally mandated program designed by the Federal Highway Administration (FHWA) to assess the performance of the nation's highway system. Under the Clean Air Act, SCAG is also required to report periodically on vehicle miles traveled in each air basin to determine whether traffic growth is consistent with the projections on which the State Implementation Plans (SIPs) are based.

The HPMS is one of the components of an Internet-based transportation system currently under development, the Regional Transportation Monitoring Information System (RTMIS). RTMIS is the source for real-time and historical transportation data collected from different local and regional transportation agencies as well as from private data sources. Based on a GIS mapping system, RTMS will be the main monitoring system for collection and distribution of highway and transit data, local and regional traffic information and activities, as well as hosting the subregional transportation monitoring programs.

The following sections outline several of the significant tools used by SCAG to monitor regional progress in advancing the 2008 RTP.

RTIP DATABASE MANAGEMENT

To manage the RTIP process efficiently, SCAG has developed a web-based RTIP database. The new RTIP database serves as a listing for projects in the RTIP, as well as a mechanism for monitoring implementation of these projects. The new database includes a mapping component that allows the CTCs to view all the RTIP projects that have been modeled. The new database will play a pivotal role in the creation of an audit trail for programmed projects. Moreover, it will also make it easier to submit the draft and final RTIP lists to Caltrans and the California Transportation Commission for their review and approval. The CTCs, Imperial Valley Association of Governments and SCAG staff are responsible for inputting this data into the RTIP database. Once the SCAG Regional Council has approved the RTIP, the data is then transmitted to Caltrans for incorporation into the statewide database, or California Transportation Improvement Program System (CTIPS).

CONFORMITY

In federally designated non-attainment or maintenance areas, specific monitoring procedures and tests for conformity are required under the federal Transportation Conformity Rule. At the time of conformity determination, the RTIP must be consistent with the RTP. At any given time, there is only one federally approved and conforming RTP and RTIP in place as the operating documents. During project implementation, sponsor agencies must implement only those projects that are consistent with the conforming RTIP and RTP. The project design concept and scope also must be consistent with those reflected in the conforming RTIP.

SCAG must be informed of any projects that are regionally significant and modeled, regardless of their funding sources. Project sponsors must also inform SCAG (as the region's MPO) of any delay in implementing any TCM projects that are included in an approved SIP. In association with the CTCs and the TCWG, SCAG must report on the timely implementation of TCMs. The Timely Implementation Report is provided in the 2008 RTP Conformity Report. If a project cannot be implemented, the sponsor agency must officially substitute or replace the affected TCM project.

Additionally, SCAG monitors legal, legislative, and election processes that may impact the transportation conformity requirements, the implementation of any TCM or regionally significant projects. SCAG informs the sponsor agency of required actions to address any changes that may have been made.

SCAG's TCWG and Modeling Task Force are two official forums used for interagency consultation. There may be additional ad hoc forums, if needed, to facilitate the required course of action.

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HIGHWAY PERFORMANCE MONITORING SYSTEM (HPMS)

HPMS is used as a transportation monitoring and management tool to determine the allocation of federal aid funds, to assist in setting policies and to forecast future transportation needs as it analyzes the transportation systems' length, condition and performance. Additionally, HPMS is used to provide data to the Environmental Protection Agency (EPA) to assist in monitoring air quality conformity, and its data is used in support of the Biennial Report to Congress on the Status of the Nation's Highways. In California, Caltrans implements the program annually. SCAG's responsibility is to assist Caltrans in collecting data from local jurisdictions, and in the distribution, collection and administration of all HPMS survey packages in the six-county region.

VMT, EMISSION AND CONGESTION REPORT

Six years after the enactment of the Clean Air Act Amendments of 1990, any state that contains serious and worse ozone non-attainment areas, or moderate and/or serious carbon monoxide non-attainment areas, is required to demonstrate whether current aggregate VMT, aggregate vehicle emissions, congestion levels and other relevant parameters are consistent with those used for the area's demonstration of attainment. As the region's MPO, SCAG is responsible for forecasting and tracking VMT, emissions and congestion, and submitting these reports to the ARB. VMT reports for ozone non-attainment areas are submitted every three years.

TRANSIT SYSTEM PERFORMANCE ASSESSMENT

Implementation of the RTP requires changes in the operating practices of transit agencies and the integration of the three tiers of transit into a single functioning system. The process of integration is the responsibility of the operators. SCAG will be evaluating the performance of selected operators to provide feedback and to transfer applicable lessons to other operators in the region. The application of advanced transportation technologies applied to the scheduling and routing of transit will be evaluated.

INTERGOVERNMENTAL REVIEW

Under federal law, SCAG is designated as the Regional Clearinghouse for review of all submitted plans, plan changes, projects and programs for consistency with adopted regional plans and policies. Regionally significant transportation projects reviewed for consistency with regional plans are defined as: construction or expansion of freeways; state highways; principal arterials; routes that provide primary access to major activity centers, such as amusement parks, regional shopping centers, military bases, airports and ports; goods movement routes, including both truck routes and rail lines; intermodal transfer facilities, such as transit centers, rail stations, airports and ports; and fixed transit routes, such as light and heavy rail and commuter rail. Any project involving transportation improvements is reviewed to determine whether such improvements are included in the RTIP.

THE STATE OF THE REGION

SCAG develops and publishes the annual State of the Region Report, which monitors the primary economic and transportation trends in Southern California and compares them to other major metropolitan regions in the country. The report helps to set goals for future RTP updates and provides indicators of regional progress from previous RTPs.

Each report presents the major socioeconomic trends in the region, including population, employment, wages, and ethnic composition. It then presents a Report Card for a number of critical indicators, including air quality, modal share, transit ridership, congestion, and income based upon the actual trend and comparison results. The latest update of the Report will be released by the Regional Council in December 2007 and can be accessed via the SCAG website.

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OTHER RELATED EFFORTS

There are other efforts that SCAG partner agencies undertake that provide assistance with the overall monitoring of the RTP implementation. Data collected through these efforts can be used by agencies to make more informed decisions. These efforts include:

Caltrans Highway Congestion Monitoring Program (HICOMP) – Caltrans compiles congestion information in an annual report that illustrates the trends in congestion in each Caltrans District. The report includes congestion magnitude, extent, and duration for the peak travel periods.

Caltrans State Highway Operations and Protection Program (SHOPP) 10-Year Plan – Caltrans updates their 10-year SHOPP Plan periodically, focusing on pavement conditions, safety, and operations. The Plan includes the programmed portion of the SHOPP as well as planned investments over a ten-year horizon.

County-Level Congestion Management Program (CMP) Monitoring – County Transportation Commissions monitor cities' performances regarding service levels on CMP systems and opportunities to mitigate the impacts of new development on the transportation system.

County Long-Range Plans – Several County Transportation Commissions have developed 20-year Long-Range Plans that serve as input to the subsequent RTP update. These plans are the blueprints for investments and expected performance for the county.

Transit Operator Short-Range Transit Plans – Transit operators also develop and publish short-range transit plans that define strategies and actions over the short term.

Transit Operators' Performance Reports – Transit operators compile various performance data and submit their reports to the Federal Transit Administration (FTA) annually. The FTA then compiles all the data provided by transit operators and stores them in the National Transit Database (NTD). The NTD provides a wealth of data that can be used to compare trends over time and among operators throughout the United States.

Transit Operators' Triennial Audits – Transit operators undergo an audit every three years to ensure that they comply with state and federal regulations. The audit findings and recommendations are published and reviewed by Caltrans and other agencies.

Regionally Significant Transportation Improvement Studies (RSTIS) (formerly Major Investment Studies) Project sponsors develop these studies. SCAG monitors and assists the projects to ensure communication between the sponsors and SCAG, and to assure compliance with the RTP.

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VII. FUTURE CONNECTIONS: THE STRATEGIC PLAN

The RTP strategies discussed in Chapter III represent the region's collective vision for addressing our transportation needs within the constraints of committed, available, or reasonably available revenue sources. Despite the substantial commitments contained in the RTP, this level of investment does not meet the overall needs identified through the RTP development process. If we truly want to address the needs set forth in this RTP, then we must look toward additional strategies and investments to get us there. Often this will entail controversial and difficult choices that will push the envelope and test the boundaries of what is politically acceptable. For now, these elements are contained in the Strategic Plan with the recognition that they merit further study and that, over time and with further consensus building, these programs and policies may move forward into the constrained RTP.

This chapter provides a brief illustrative overview of the additional strategies and investments that the region would pursue if additional funding were to become available, and after further consensus building to solidify commitment around specific projects and policies. It is envisioned that future updates or amendments to the RTP would draw from the projects contained in the Strategic Plan; exceptions would be handled on a case-by-case basis. While there is no funding strategy attached to the Strategic Plan, this chapter discusses additional potential funding sources that merit further study and evaluation.

Unfunded System Preservation and Operations Needs

Beyond the investments proposed in the 2008 RTP, there is a shortfall of $24 billion in highway system preservation, and a shortfall of $8 billion in arterial and transit system preservation, through 2035. With the recognition that the costs of deferred maintenance could grow exponentially over time, investment in preservation should be given priority for new funding sources beyond those identified in the 2008 RTP.

Additionally, SCAG identified a shortfall of approximately $6.7 billion in highway operations needs, and $1.3 billion in regionally significant arterial and transit operations needs, through 2035. SCAG, Caltrans, and our transportation planning partners will continue to evaluate corridor-level performance, develop corridor system management plans, and incorporate the resulting recommendations into future Plans and Programs.

Unfunded Capital Improvements

There are approximately $273 billion in additional capital investment needs above what are identified in the financially constrained RTP. These projects address important transportation corridor needs in the region, but still face significant challenges in terms of local consensus on a preferred strategy, funding priority, or both, before potential inclusion in the RTP. For example, the proposed Orangeline project faces significant challenges in terms of right-of-way availability, funding commitment, and stakeholder consensus. In recognition of the regional benefits the project may provide, it is being included in the Strategic Plan until such issues have been resolved.

Regionally significant major corridor improvements in the Strategic Plan are identified in Table 7.1. A more complete list is contained in the RTP Project List report available at www.scag.ca.gov/rtp2008.

Strategic Finance

Recognizing that new sources of revenue over and above those already identified in the RTP are required to help fund these unmet needs, SCAG will initiate a comprehensive study of congestion pricing strategies over the next year. A regionwide congestion pricing strategy can be structured to help the region meet its transportation demand management and air quality goals while providing a reliable and dedicated revenue source. The pricing mechanism could allow users of the transportation system to know the true cost of their travel, resulting in informed decision-making and more efficient use of the system. Potential pricing strategies can include a regional vehicle-miles-traveled fee

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and/or a regional high-occupancy toll lane network. While promising, these strategies still face a number of significant hurdles—there is currently no legislative authority to implement such strategies, and there is no regional entity that exists to administer or implement such a comprehensive program. SCAG's study will attempt to address some of these hurdles by evaluating the feasibility of these strategies and coalescing regional consensus for potential input into the next update of the RTP.

In addition to SCAG's regional congestion pricing initiative, a number of local efforts to study additional transportation revenues are underway or may be in the near future. The Los Angeles County Metropolitan Transportation Authority (MTA) is evaluating the feasibility of a Congestion Mitigation Fee as part of a proposed restructuring of its Congestion Management Program (CMP). If enacted, the fee would be imposed on new development and would generate new revenue to assist MTA in addressing congestion caused by growth. In 2004, the voters in Ventura County were asked to approve a local sales tax measure for transportation. While the voters did not approve the sales tax increase, it remains a popular option for the region's counties to generate a significant amount of revenues dedicated to transportation. All of the other counties in the SCAG region have a local sales tax measure dedicated to transportation.

TABLE 7.1 MAJOR STRATEGIC PLAN PROJECTS

Strategic Plan Project Description
• Dedicated Lanes for Clean-Technology Trucks on an East-West Corridor connecting the Ports of LA/LB to and through the Inland Empire (I-710 to I-15)
• Dedicated Lanes for Clean-Technology Trucks on I-15 (East-West Corridor to Barstow)
• US-101 HOT Lanes (SR-23 to SR-134/SR-170)
• CETAP Riverside County to Orange County (Corridor B from I-15/Mid-County Pkwy to SR-133/SR-241)
• Purple Line Extension to Century City and Santa Monica
• Gold Line Extension to Ontario Airport
• Metrolink and LOSSAN Strategic Plans
• Santa Paula Branch Line
• High-Speed Regional Transport - system extensions to Palmdale, Victorville, Coachella Valley, Imperial, Orange County, San Diego
• High-Speed Regional Transport - California High-Speed Rail Authority (serving the SCAG region beyond the Union Station-Anaheim segment in the financially constrained RTP)
• High-Speed Regional Transport - California-Nevada Maglev - Ontario Airport to Nevada State Line
• Orangeline High-Speed Transit (Orange County - Union Station - Santa Clarita - Palmdale)

Corridor Preservation

For those corridor projects identified in the Strategic Plan, right-of-way preservation should be undertaken to begin laying the groundwork for advancing these long-range improvements. The SCAG Region is pursuing an innovative, environmentally sensitive approach to considering future development and transportation projects. This approach envisions that transportation options

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will be developed with consideration for environmentally sensitive land uses and habitat issues as part of the planning and design criteria. It would involve early and active involvement by all stakeholders at the local, state, and federal levels.

This approach draws on the Community and Environmental Transportation Acceptability Process (CETAP) undertaken in Riverside County, which serves as a template for other agencies and jurisdictions seeking to preserve rights-of-way for long-range transportation needs. The four CETAP corridors, two intra-county corridors—the Mid-County Parkway and the Winchester-Temecula Corridor—and two inter-county corridors—the Riverside County-Orange County Corridor (Corridor A) and the Moreno Valley-San Bernardino Corridor—are included in the financially constrained RTP.

As Riverside County has shown, it is important to identify and preserve transportation corridors needed to expand or enhance transportation for future generations. Local governments will find it difficult to obtain optimal locations for these corridors unless efforts to preserve them are made early. The American Association of State Highway and Transportation Officials (AASHTO) Report on Corridor Preservation states that early efforts provide the following benefits:

- prevent inconsistent development
- minimize or avoid environmental, social and economic impacts
- prevent the loss of desirable corridor locations
- allow for the orderly assessment of impacts
- permit orderly project development, and
- reduce costs

Planners and policy-makers should start preparing strategies for preserving corridors now to prevent losing rights-of-way needed for transportation beyond the year 2035. Rights-of-way preservation is a reasonable concern, particularly in areas where development may block a long-range corridor. More opportunities to capitalize on preservation are available in less-urban areas,

where local governments have an opportunity to obtain available land for new transportation facilities.

The first step in this kind of planning is to identify potential long-range corridors and determine if there is a need to preserve them. This will require intergovernmental coordination and should include a funding component. Next, criteria to evaluate and prioritize the selected corridors must be developed. Once a corridor is selected, environmental studies will be needed. Traditional preservation techniques include purchasing land or using government statutes to place a corridor alignment on a general plan land-use map. Other state and federal funds can be used to assist in acquiring land for long-range corridors.

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AASHTO American Association of State Highway and Transportation Officials – A nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia and Puerto Rico.

AB 32 Assembly Bill 32 – Signed into law on September 26, 2006, it requires that the state's global warming emissions be reduced to 1990 levels by 2020. This reduction will be accomplished through an enforceable statewide cap on global warming emissions that will be phased in starting in 2012. In order to effectively implement the cap, AB 32 directs the California Air Resources Board (CARB) to develop appropriate regulations and establish a mandatory reporting system to track and monitor global warming emissions levels.

AB 169 Assembly Bill 169 – Provides for the sixteen federally recognized tribes in the SCAG Region to join the SCAG Joint Powers Authority (JPA) to participate in the Southern California Association of Governments by voting at the SCAG General Assembly.

ACE Alameda Corridor East – A 35-mile corridor extending through the San Gabriel Valley between East Los Angeles and Pomona and connecting the Alameda Corridor to the transcontinental railroad network.

ADA Americans with Disabilities Act of 1990 – Guarantees equal opportunity for individuals with disabilities in public accommodations, employment, transportation, state and local government services, and telecommunications. It prescribes federal transportation requirements for transportation providers.

AJR Assembly Joint Resolution No. 40 – Introduced on August 23, 2007, the Resolution calls upon the governor to declare a state of emergency in respect to the air quality health crisis in the South Coast Air Quality Basin related to emissions of PM2.5, and to direct steps necessary to address the emergency.

ANCA Federal Airport Noise and Capacity Act of 1990 – Establishes a national aviation noise policy that reviews airport noise and access restrictions on operations for Stage 2 and Stage 3 aircraft.

Antelope Valley AQMD Antelope Valley Air Quality Management District – The air pollution control agency for the portion of Los Angeles County north of the San Gabriel Mountains.

AQMP Air Quality Management Plan – Regional plan for air quality improvement in compliance with federal and state requirements.

ARB Air Resources Board – Refer to CARB, California Air Resources Board.

ATIS Advanced Traveler Information Systems – Technology used to provide travelers with information, both pre-trip and in-vehicle, so they can better utilize the transportation system.

ATMS Advanced Transportation Management Systems – Technology used to improve the operations of the transportation network.

AVO Average Vehicle Occupancy – Calculated by dividing the total number of travelers by the total number of vehicles.

Base Year The year 2003, used in the RTP performance analysis as a reference point for current conditions.

Baseline Future scenario which includes only those projects that are: existing, undergoing right-of-way acquisition or construction, come from the first year of the previous RTP or RTIP, or have completed the NEPA process. The Baseline is based upon the adopted 2006 RTIP. The Baseline functions as the "No Project" alternative used in the RTP Program EIR.

BLS Bureau of Labor Statistics – The principal fact-finding agency for the federal government in the broad field of labor economics and statistics.

BNSF Burlington Northern and Santa Fe Railway Company.

BRT Bus Rapid Transit – Bus transit service that seeks to reduce travel time through measures such as traffic signal priority, automatic vehicle location, dedicated bus lanes, limited-stop service, and faster fare collection policies.

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BTA Bicycle Transportation Account – Provides state funds for city and county projects that improve safety and convenience for bicycle commuters.

CAA Clean Air Act (CAA) – 1970 federal act that authorized EPA to establish air quality standards to limit levels of pollutants in the air. EPA has promulgated such standards (or NAAQS) for six criteria pollutants: sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), ozone, lead, and particulate matter (PM10). All areas of the United States must maintain ambient levels of these pollutants below the ceilings established by the NAAQS; any area that does not meet these standards is a "non-attainment" area. States must develop SIPs to explain how they will comply with the CAA. The act was amended in 1977 and again in 1990.

CAFR Comprehensive Annual Financial Report – Official annual financial report that encompasses all funds and financial components associated with any given organization.

Cal B/C Model California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) – Was developed for the California Department of Transportation (Caltrans) as a tool for benefit-cost analysis of highway and transit projects. It is an Excel (spreadsheet) application structured to analyze several types of transportation improvement projects in a corridor where there already exists a highway facility or a transit service (the base case).

Caltrans California Department of Transportation – State agency responsible for the design, construction, maintenance, and operation of the California State Highway System, as well as that portion of the Interstate Highway System within the state's boundaries.

CARB California Air Resources Board – State agency responsible for attaining and maintaining healthy air quality through setting and enforcing emissions standards, conducting research, monitoring air quality, providing education and outreach, and overseeing/assisting local air quality districts.

Catalytic Demand Additional aviation demand that is created by companies that locate in the proximity of expanding airports with developable land around them, to reduce airport ground access time and costs for their employees and clients. Catalytic demand is greatest for large hub airports, particularly international airports.

CEHD Community, Economic and Human Development Committee – A SCAG committee that studies the problems, programs and other matters which pertain to the regional issues of community, economic and human development and growth. This committee reviews projects, plans and programs of regional significance for consistency and conformity with applicable regional plans.

CEQA California Environmental Quality Act – State law providing certain environmental protections that apply to all transportation projects funded with state funds.

CETAP Community Environmental and Transportation Acceptability Process – Part of the Riverside County Integrated Project that is examining where to locate possible major new multimodal transportation facilities to serve the current and future transportation needs of Western Riverside County, while minimizing impacts on communities and the environment.

CHSR California High-Speed Rail Authority – Agency responsible for planning, designing, constructing and operating a state-of-the-art high-speed train system in California.

CIP Capital Improvement Program – Long-range strategic plan that identifies capital projects; provides a planning schedule and financing options.

CMAQ Congestion Mitigation and Air Quality Program – Federal program initiated by ISTEA to provide funding for surface transportation and other related projects that contribute to air quality improvements and reduce congestion.

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CMIA Corridor Mobility Improvement Account – These funds would be allocated by the California Transportation Commission to highly congested travel corridors in the state. Projects in this category must be a high priority; be able to start construction by 2012; improve mobility in a highly congested corridor by improving travel times and reducing vehicle hours of delay; connect the State Highway System; and improve access to jobs, housing, markets and commerce.

CMP Congestion Management Program – Established by Proposition 111 in 1990, requires each county to develop and adopt a CMP that includes highway and roadway system monitoring, multimodal system performance analysis, transportation demand management program, land-use analysis program and local conformance.

CNSSTC California-Nevada Super Speed Train Commission – Public-private Partnership developed to promote a high-speed link between California and Nevada.

CO Carbon monoxide – A colorless, odorless, poisonous gas formed when carbon in fuels is not burned completely. It is a byproduct of highway vehicle exhaust, which contributes about 60 percent of all CO emissions nationwide.

COG Council of Governments – Under state law, a single or multicounty council created by a joint powers agreement.

COMPASS/Growth Visioning A planning process guided by input from the public and initiated by SCAG to develop a regional strategy for addressing future growth in Southern California.

Congestion Management Process Congestion Management Process – Systematic approach required in transportation management areas (TMAs) that provides for effective management and operation, based on a cooperatively developed and implemented metropolitan-wide strategy, of new and existing transportation facilities eligible for funding under title 23 U.S.C. and title 49 U.S.C., through the use of operational management strategies.

Congestion Pricing User fee imposed on vehicles during peak demand periods on congested roadways.

Constant Dollars Dollars expended/received in a specific year adjusted for inflation/deflation relative to another time period.

Corridor In planning, a broad geographical band that follows a general directional flow or connects major sources of trips. It may contain a number of streets and highways, and transit lines and routes.

CTC California Transportation Commission – A nine-member board appointed by the governor to oversee and administer state and federal transportation funds and provide oversight on project delivery.

CTIPS California Transportation Improvement Program System – A project programming database system used to efficiently and effectively develop and manage various transportation programming documents as required under state and federal law.

CTP California Transportation Plan – A statewide, long-range transportation policy plan that provides for the movement of people, goods, services, and information. The CTP offers a blueprint to guide future transportation decisions and investments that will ensure California's ability to compete globally, provide safe and effective mobility for all persons, better link transportation and land-use decisions, improve air quality, and reduce petroleum energy consumption.

CVO Commercial Vehicle Operations – Management of commercial vehicle activities through ITS.

Deficiency Plan Set of provisions contained in a Congestion Management Plan to address congestion, when unacceptable levels of congestion occur. Projects implemented through the Deficiency Plan must, by statute, have both mobility and air quality benefits.

DTIM Direct Travel Impact Model – A vehicle emissions forecasting model.

EDF Environmental Defense Fund – A national nonprofit organization that seeks to protect the environmental rights of all people, including future generations.

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EIR Environmental Impact Report – An informational document, required under CEQA, which will inform public agency decision-makers and the public generally of the significant environmental effects of a project, possible ways to minimize significant effects, and reasonable alternatives to the project.

EIS Environmental Impact Statement (federal) – National Environmental Policy Act (NEPA) requirement for assessing the environmental impacts of federal actions that may have a significant impact on the human environment.

EMFAC Emission Factor – Model that estimates on-road motor vehicle emission rates for current year as well as backcasted and forecasted inventories.

EPA Environmental Protection Agency – Federal agency established to develop and enforce regulations that implement environmental laws enacted by Congress to protect human health and safeguard the natural environment.

FAA Federal Aviation Administration – Federal agency responsible for issuing and enforcing safety regulations and minimum standards, managing air space and air traffic, and building and maintaining air navigation facilities.

FHWA Federal Highway Administration – Federal agency responsible for administering the Federal-Aid Highway Program, which provides federal financial assistance to the states to construct and improve the National Highway System, urban and rural roads, and bridges.

Financially Constrained Expenditures are said to be financially constrained if they are within limits of anticipated revenues.

FRA Federal Railroad Administration – Federal agency created to promulgate and enforce rail safety regulations, administer railroad assistance programs, conduct research and development in support of improved railroad safety and national rail transportation policy, and consolidate government support of rail transportation activities.

FTA Federal Transit Administration – The federal agency responsible for administering federal transit funds and assisting in the planning and establishment of areawide urban mass transportation systems. As opposed to FHWA funding, most FTA funds are allocated directly to local agencies, rather than Caltrans.

FTIP Federal Transportation Improvement Program – A three-year list of all transportation projects proposed for federal transportation funding within the planning area of an MPO. (Note: The FTIP is locally referred to as the 2006 RTIP.)

FY Fiscal Year – The twelve-month period on which the budget is planned. The state fiscal year begins July 1 and ends June 30 of the following year. The federal fiscal year begins October 1 and ends September 30 of the following year.

GAO Government Accountability Office – Congressional agency responsible for examining matters related to the receipt and payment of public funds.

GARVEE Grant Anticipation Revenue Vehicles – A debt financing instrument authorized to receive federal reimbursement of debt service and related financing costs under Section 122 of Title 23, United States Code. GARVEEs can be issued by a state, a political subdivision of a state, or a public authority.

GHG Greenhouse Gases – Components of the atmosphere that contribute to the greenhouse effect. The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

GIS Geographic Information System – Powerful mapping software that links information about where things are with information about what things are like. GIS allows users to examine relationships between features distributed unevenly over space, seeking patterns that may not be apparent without using advanced techniques of query, selection, analysis, and display.

GNP Gross National Product – An estimate of the total value of goods and services produced in any specified country in a given year. GNP can be measured as a total amount or an amount per capita.

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Grade Crossing A crossing or intersection of highways, railroad tracks, other guideways, or pedestrian walks, or combinations of these at the same level or grade.

HCP Habitat Conservation Plan – Established under Section 10 of the Endangered Species Act to allow development to proceed while protecting endangered species.

HDT Heavy-Duty Truck – Truck with a gross vehicle weight of 8,500 pounds or more.

HICOMP Highway Congestion Monitoring Program (Caltrans) – A report that measures the congestion that occurs on urban area freeways in California.

Home-based work trips Trips that go between home and work, either directly or with an intermediate stop. Home-based work trips include telecommuting, working at home and non-motorized transportation work trips.

HOT Lane High-Occupancy Toll Lane – An HOV lane that single-occupant drivers can pay to drive in.

HOV Lane High-Occupancy Vehicle Lane – A lane restricted to vehicles with two (and in some cases three) or more occupants to encourage carpooling. Vehicles include automobiles, vans, buses and taxis.

HPMS Highway Performance Monitoring System – A federally mandated program designed by FHWA to assess the performance of the nation's highway system.

HSRT High-Speed Regional Transport – Transportation system that operates at very high speeds on an exclusive right-of-way.

HUD U.S. Department of Housing and Urban Development – Federal agency charged with increasing homeownership, supporting community development, and increasing access to affordable housing free from discrimination.

ICAPCD Imperial County Air Pollution Control District – Local air pollution control agency mandated by state and federal regulations to implement and enforce air pollution rules and regulations.

IGR Intergovernmental Review Process – The review of documents by several governmental agencies to ensure consistency of regionally significant local plans, projects, and programs with SCAG's adopted regional plans.

Infrastructure The basic facilities, equipment, services and installations needed for the growth and functioning of a community.

IOS Initial Operating Segment.

ISTEA Intermodal Surface Transportation Efficiency Act – Signed into federal law on December 18, 1991, it provided authorization for highways, highway safety and mass transportation for FYs 1991–1997 and served as the legislative vehicle for defining federal surface transportation policy.

ITIP Interregional Transportation Improvement Program – The portion of the STIP that includes projects selected by Caltrans (25 percent of STIP funds).

ITS Intelligent Transportation Systems – Systems that use modern detection, communications and computing technology to collect data on system operations and performance, communicate that information to system managers and users, and use that information to manage and adjust the transportation system to respond to changing operating conditions, congestion or accidents. ITS technology can be applied to arterials, freeways, transit, trucks and private vehicles. ITS include Advanced Traveler Information Systems (ATIS), Advanced Public Transit Systems (APTS), Advanced Traffic Management Systems (ATMS), Advanced Vehicle Control Systems (AVCS) and Commercial Vehicle Operations (CVO).

IVAG Imperial Valley Association of Governments – Council of Governments for Imperial County. IVAG is responsible for short-range transportation planning, including all projects utilizing federal and state highway and transit funds.

JPA Joint Powers Authority – Two or more agencies that enter into a cooperative agreement to jointly wield powers that are common to them. JPAs are a vehicle for the cooperative use of existing governmental powers to finance and provide infrastructure and/or services in a cost-efficient manner.

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LACMTA Los Angeles County Metropolitan Transportation Authority, more commonly referred to as the MTA – Agency responsible for planning and funding countywide transportation improvements, administering the county's transportation sales tax revenues, and operating bus and rail transit service.

LAUPT Los Angeles Union Passenger Terminal, also known as Union Station.

LAWA Los Angeles World Airports – Aviation authority of the City of Los Angeles. LAWA owns and operates Los Angeles International (LAX), Ontario International, Van Nuys, and Palmdale Airports.

LCVs Longer-Combination Vehicles – Includes tractor-trailer combinations with two or more trailers that weigh more than 80,000 pounds.

LEM Location Efficient Mortgage – Allows people to qualify for larger loan amounts if they choose a home in a densely populated community that is well served by public transit, and where destinations are located close together so that they can also walk and bike instead of driving everywhere.

Livable Communities Any location in which people choose may be viewed as "livable." However, communities that contain a healthy mix of homes, shops, work places, schools, parks, and civic institutions coupled with a variety of transportation choices, give residents greater access to life's daily essentials and offer higher quality of life to a wider range of residents.

LRT Light Rail Transit – A mode of transit that operates on steel rails and obtains its power from overhead electrical wires. LRT may operate in single or multiple cars on separate rights-of-way or in mixed traffic.

LTF Local Transportation Fund – A fund which receives TDA revenues.

MAGLEV Magnetic Levitation high-speed transportation system.

MAP Million Annual Passengers – Used to quantify airport activity.

Market Incentives Measures designed to encourage certain actions or behaviors. These include inducements for the use of carpools, buses and other HOVs in place of single-occupant automobile travel. Examples include HOV lanes, preferential parking, and financial incentives.

MDAB Mojave Desert Air Basin – Area defined by state law as comprising the desert portions of Los Angeles, Kern, Riverside, and San Bernardino Counties.

MDAQMD Mojave Desert Air Quality Management District – Local air agency mandated by state and federal regulations to implement and enforce air pollution rules and regulations; encompasses the desert portion of San Bernardino County from the summit of the Cajon Pass north to the Inyo County line, as well as the Palo Verde Valley portion of Riverside County.

Measure A Revenues generated from Riverside County's local half-cent sales tax.

Measure I Revenues generated from San Bernardino County's local half-cent sales tax.

Metrolink Regional commuter rail system connecting Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties and operated by SCRRA.

MIS Major Investment Study – The preliminary study, including preliminary environmental documentation, for choosing alternative transportation projects for federal transportation funding. An MIS is a requirement, which is conducted cooperatively by the study sponsor and the MPO.

Mixed Flow Traffic movement having autos, trucks, buses and motorcycles sharing traffic lanes.

Mode A particular form of travel (e.g., walking, traveling by automobile, traveling by bus or traveling by train).

Mode Split The proportion of total person trips using various specified modes of transportation.

Model A mathematical description of a real-life situation that uses data on past and present conditions to make a projection.

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MPO Metropolitan Planning Organization – A federally required planning body responsible for transportation planning and project selection in a region.

MTS Metropolitan Transportation System – Regional network of roadways and transit corridors.

Multimodal A mixture of the several modes of transportation, such as transit, highways, non-motorized, etc.

NAAQS National Ambient Air Quality Standards – Targets established by the U.S. Environmental Protection Agency (EPA) for the maximum contribution of a specific pollutant in the air.

NAFTA North American Free Trade Agreement – An agreement between the governments of Canada, Mexico, and the United States to eliminate barriers to trade and facilitate the cross-border movement of goods and services.

NCCP Natural Communities Conservation Plan – Program under the Department of Fish and Game that uses a broad-based ecosystem approach toward planning for the protection of plants, animals and their habitats, while allowing compatible and appropriate economic activity.

NEPA National Environmental Protection Act – Federal environmental law that applies to all projects funded with federal funds or requiring review by a federal agency.

NIMS National Incident Management System – Nationwide template that enables all government, private-sector and non-governmental organizations to work together during a domestic incident.

Nominal dollars Actual dollars expended/received in a specific year without adjustments for inflation/deflation.

NOx Nitrogen oxides – A group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. NOx are a major component of ozone and smog, and they are one of six principal air pollutants tracked by the EPA.

NTD National Transit Database – The Federal Transit Administration's (FTA) national database for transit statistics.

O&M Operations and Maintenance – The range of activities and services provided by the transportation system and the upkeep and preservation of the existing system.

OCTA Orange County Transportation Authority – Agency responsible for planning and funding countywide transportation improvements, administering the county's transportation sales tax revenues, and operating bus transit service.

OLDA Orangeline Development Authority – Joint exercise of powers authority developed by the cities located along the Orangeline corridor.

OnTrac Orange-North America Trade Rail Access Corridor – Formed in April of 2000 to build and support the Orangethorpe Avenue Grade Separation and Trade Corridor project, a 5-mile-long railroad-lowering project that will completely grade separate 11 rail crossings in the cities of Placentia and Anaheim.

OWP Overall Work Program – SCAG develops an OWP annually, describing proposed transportation planning activities for the upcoming fiscal year, including those required by federal and state law.

PATH Partners for Advanced Transit and Highways – Joint venture of Caltrans which includes the University of California, and other public and private academic institutions and industries.

PEIR Program Environmental Impact Report – Environmental review process used to evaluate the potential environmental effects of large-scale plans or programs.

PeMS Freeway Performance Measurement System – A service provided by the University of California, Berkeley, to collect historical and real-time freeway data from freeways in the state of California in order to compute freeway performance measures.

Person Trip A trip made by a person by any mode or combination of modes for any purpose.

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PM10 Particulate Matter – A mixture of solid particles and liquid droplets found in the air, 10 micrometers or less in size (a micrometer is one-millionth of a meter). These coarse particles are generally emitted from sources such as vehicles traveling on unpaved roads, materials handling, and crushing and grinding operations, as well as windblown dust.

PM2.5 Particulate Matter – A mixture of solid particles and liquid droplets found in the air, 2.5 micrometers or less in size (a micrometer is one-millionth of a meter). These fine particles result from fuel combustion from motor vehicles, power generation, and industrial facilities, as well as from residential fireplaces and wood stoves.

PMD LA/Palmdale Regional Airport – Regional airport located in Palmdale.

PPP Public-Private Partnership – Contractual agreements formed between a public agency and private sector entity that allow for greater private sector participation in the delivery of transportation projects.

PRC Peer Review Committee – An "informal" committee of technical experts usually organized and invited to review and comment on various technical issues and processes used in the planning process.

Proposition 1A Passed by voters in 2006, Proposition 1A protects transportation funding for traffic congestion relief projects, safety improvements, and local streets and roads. It also prohibits the state sales tax on motor vehicle fuels from being used for any purpose other than transportation improvements, and authorizes loans of these funds only in the case of severe state fiscal hardship.

Proposition 1B Highway Safety, Traffic Reduction, Air Quality, and Port Security State of California – Passed in November 2006, Proposition 1B provides $19.9 billion to fund state and local transportation improvement projects to relieve congestion, improve movement of goods, improve air quality, and enhance safety and security of the transportation system.

Proposition 42 As of March 2002, placed in the State Constitution those provisions of current law requiring the use of state gasoline sales tax revenues for state and local transportation purposes.

Proposition A Revenues generated from Los Angeles County's local half-cent sales tax. Los Angeles County has two permanent local sales taxes (Propositions C and A).

Proposition C Revenues generated from Los Angeles County's local half-cent sales tax. Los Angeles County has two permanent local sales taxes (Propositions C and A).

PSR Project Study Report – Defines and justifies the project's scope, cost, and schedule. PSRs are prepared for state highway projects and PSR equivalents are prepared for projects not on the State Highway System. Under state law, a PSR or PSR equivalent is required for STIP programming.

PTA Public Transportation Account – The major state transportation account for mass transportation purposes. Revenues include a portion of the sales tax on gasoline and diesel fuels.

PUC Public Utilities Commission – Regulates privately owned telecommunications, electric, natural gas, water, railroad, rail transit, and passenger transportation companies.

Railroad Siding A short stretch of railroad track used to store rolling stock or enable trains on the same line to pass; also called sidetrack.

RC Regional Council – Conducts the affairs of SCAG; implements the General Assembly's policy decisions; acts upon policy recommendations from SCAG policy committees and external agencies; appoints committees to study specific problems; and amends, decreases or increases the proposed budget to be reported to the General Assembly.

RCP Regional Comprehensive Plan (RCP) – Developed by SCAG, the RCP is a vision of how Southern California can balance resource conservation, economic vitality, and quality of life. It will serve as a blueprint to approach growth and infrastructure challenges in an integrated and comprehensive way.

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RCTC Riverside County Transportation Commission – Agency responsible for planning and funding countywide transportation improvements and administering the county's transportation sales tax revenues.

RHNA Regional Housing Needs Assessment – Quantifies the need for housing within each jurisdiction of the SCAG Region based on population growth projections. Communities then address this need through the process of completing the housing elements of their general plans.

Robust Flight Portfolio Providing a range of flight offerings in different haul length categories including short-haul, medium-haul, long-haul and international flights.

ROG Reactive organic gas – Organic compounds assumed to be reactive at urban/regional scales. Those organic compounds that are regulated because they lead to ozone formation.

RSTIS Regionally Significant Transportation Investment Study – Involves identifying all reasonable transportation options, their costs, and their environmental impacts. RSTIS projects are generally highway or transit improvements that have a significant impact on the capacity, traffic flow, level of service or mode share at the transportation corridor or sub-area level.

RSTP Regional Surface Transportation Program – Established by the California state statute utilizing federal Surface Transportation Program funds. Approximately 76 percent of the state's RSTP funds must be obligated on projects located within the 11 urbanized areas of California with populations of 200,000 or more.

RTIP Regional Transportation Improvement Program – Refers to the share of capital outlay improvement funds controlled by regional agencies (75 percent of STIP funds). (Note: The FTIP is locally referred to as the 2006 RTIP.)

RTMS Regional Transportation Monitoring System – Internet-based transportation monitoring system. The RTMS will be the source for real-time and historical transportation data collected from local, regional and private data sources.

RTP Regional Transportation Plan (RTP) – Federally required 20-year plan prepared by metropolitan planning organizations and updated every four years. Includes projections of population growth and travel demand, along with a specific list of proposed projects to be funded.

RTSS Regional Transit Security Strategy – Strategy for the region with specific goals and objectives related to the prevention, detection, response and recovery of transit security issues.

SAFETEA-LU Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users – Signed into law by President Bush on August 10, 2005, it authorized the federal surface transportation programs for highways, highway safety, and transit for the 5-year period of 2005-2009.

SANBAG San Bernardino Associated Governments – The council of governments and transportation planning agency for San Bernardino County. SANBAG is responsible for cooperative regional planning and developing an efficient multimodal transportation system countywide.

SANDAG San Diego Association of Governments.

SB 45 Senate Bill 45 (Chapter 622, Statutes of 1997, Kopp) – Established the current STIP process and shifted control of decision-making from the state to the regional level.

SB 79 Senate Bill 79 Transportation Trailer Bill – Provides transportation funds on an ongoing basis to help the General Fund beyond Fiscal Year 2008

SB 974 Senate Bill 974 – Introduced by Senator Alan Lowenthal, SB 974 would impose a $30 fee on each shipping container processed at the Ports of Los Angeles, Long Beach, and Oakland for congestion management and air quality improvements related to ports.

SBD San Bernardino International Airport – International airport located in San Bernardino.

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SCAB South Coast Air Basin – Comprises the non–Antelope Valley portion of Los Angeles County, Orange County, Riverside County, and the non-desert portion of San Bernardino County.

SCAG Southern California Association of Governments – The metropolitan planning organization (MPO) for six counties including Los Angeles, Orange, San Bernardino, Riverside, Ventura, and Imperial.

SCAQMD South Coast Air Quality Management District – The air pollution control agency for Orange County and major portions of Los Angeles, San Bernardino and Riverside Counties in Southern California.

SCCAB South Central Coast Air Basin – Comprises San Luis Obispo, Santa Barbara, and Ventura Counties.

SCRIFA Southern California Railroad Infrastructure Financing Authority.

SED Socioeconomic Data – Population, employment and housing forecast.

SHA State Highway Account – The major state transportation account for highway purposes. Revenues include the state excise taxes on gasoline and diesel fuel and truck weight fees.

SHOPP State Highway Operation and Protection Program – A four-year capital improvement program for rehabilitation, safety, and operational improvements on state highways.

SIP State Implementation Plan – State air quality plan to ensure compliance with state and federal air quality standards. In order to be eligible for federal funding, projects must demonstrate conformity with the SIP.

SOV Single–Occupant Vehicle – Privately operated vehicle that contains only one driver or occupant.

SOX Sulfur oxide – Any of several compounds of sulfur and oxygen, formed from burning fuels such as coal and oil.

SSAB Salton Sea Air Basin – Comprises the Coachella Valley portion of Riverside County and all of Imperial County.

STA State Transit Assistance – State funding program for mass transit operations and capital projects. Current law requires that STA receive 50 percent of PTA revenues.

STIP State Transportation Improvement Program – A four-year capital outlay plan that includes the cost and schedule estimates for all transportation projects funded with any amount of state funds. The STIP is approved and adopted by the CTC and is the combined result of the ITIP and the RTIP.

STP Surface Transportation Program – Provides flexible funding that may be used by states and localities for projects on any federal-aid highway, bridge projects on any public road, transit capital projects, and intracity and intercity bus terminals and facilities. A portion of funds reserved for rural areas may be spent on rural minor collectors.

TAC Technical Advisory Committee – A SCAG committee that provides ideas and feedback on the technical integrity of the Regional Transportation Plan.

TANN Traveler Advisory News Network – Provides real-time traffic and transportation information content to communications service providers and consumer media channels both nationally and internationally.

TAZ Traffic Analysis Zone – Zone system used in travel demand forecasting.

TCC Transportation and Communications Committee (SCAG) – Committee used to study problems, programs and other matters related to regional issues of mobility, air quality, transportation control measures and communications.

TCM Transportation Control Measure – A project or program that is designed to reduce emissions or concentrations of air pollutants from transportation sources. TCMs are referenced in the state Implementation Plan (SIP) for the applicable air basin and have priority for programming and implementation ahead of non-TCMs.

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TCRP Traffic Congestion Relief Program – Enacted by state legislation in 2000 to provide additional funding for transportation over a six-year period (later extended to eight years). The program is funded by a combination of General Fund revenues (one-time) and ongoing revenues from the state sales tax on gasoline. In March 2002 voters passed Proposition 42, which permanently dedicated gasoline sales tax revenues to transportation purposes.

TCWG Transportation Conformity Working Group – Forum used to support interagency coordination to help improve air quality and maintain transportation conformity.

TDA Transportation Development Act – State law enacted in 1971 that provided a 0.25 percent sales tax on all retail sales in each county for transit, bicycle, and pedestrian purposes. In non-urban areas, funds may be used for streets and roads under certain conditions.

TDM Transportation Demand Management – Strategies that result in more efficient use of transportation resources, such as ridesharing, telecommuting, park-and-ride programs, pedestrian improvements, and alternative work schedules.

TEA-21 Transportation Equity Act for the 21st Century – The predecessor to SAFETEA-LU, it was signed into federal law on June 9, 1998. TEA-21 authorized the federal surface transportation programs for highways, highway safety, and transit for the six-year period 1998–2003. TEA-21 builds upon the initiatives established in ISTEA.

TEU Twenty-foot Equivalent Unit, a measure of shipping container capacity.

TIFIA Transportation Infrastructure Finance and Innovation Act of 1998 – Established a new federal credit program under which the US DOT may provide three forms of credit assistance—secured (direct) loans, loan guarantees, and standby lines of credit—for surface transportation projects of national or regional significance. The program's fundamental goal is to leverage federal funds by attracting substantial private and other non-federal co-investment in critical improvements to the nation's surface transportation system. Sponsors may include state departments of transportation, transit operators, special authorities, local governments, and private entities.

TOD Transit-Oriented Development – A planning strategy that explicitly links land-use and transportation by focusing mixed housing, employment and commercial growth around bus and rail stations (usually within ½ mile). TODs can reduce the number and length of vehicle trips by encouraging more bicycle/pedestrian and transit use, and can support transit investments by creating the density around stations to boost ridership.

TP&D Transportation Planning and Development Account – A state transit trust fund that is the funding source for the STA program.

Trantrak RTIP database management system.

TSWG Transportation Security Working Group – Advises the operating organizations on transportation safety matters associated with the transfer or shipment of hazardous materials.

TUMF Transportation Uniform Mitigation Fee – Ordinance enacted by the Riverside County Board of Supervisors and cities to impose a fee on new development to fund related transportation improvements.

UP Union Pacific Railroad.

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US DOT U.S. Department of Transportation – Federal agency responsible for the development of transportation policies and programs that contribute to providing fast, safe, efficient, and convenient transportation at the lowest cost consistent with those and other national objectives, including the efficient use and conservation of the resources of the United States. US DOT is comprised of ten operating administrations, including FHWA, FTA, FAA, and FRA.

VCTC Ventura County Transportation Commission – Agency responsible for planning and funding countywide transportation improvements.

Vehicle Hours of Delay The travel time spent on the highway due to congestion. Delay is estimated as the difference between vehicle hours traveled at a specified free-flow speed and vehicle hours traveled at a congested speed.

VHDD Vehicle Hours of Daily Delay – Hours of delay attributed to congestion for vehicles each day.

VMT Vehicle Miles Traveled – On highways, a measurement of the total miles traveled by all vehicles in the area for a specified time period. It is calculated by the number of vehicles times the miles traveled in a given area or on a given highway during the time period. In transit, the number of vehicle miles operated on a given route or line or network during a specified time period.

VOC Volatile Organic Compounds – Organic gases emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and other industrial sources. Ozone, the main component of smog, is formed from the reaction of VOCs and NOx in the presence of heat and sunlight.

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SCAG Management

Executive Director: Hasan Ikhrata

Director of Planning (Acting): Rich Macias

Chief Counsel & Director of Legal Services: Joe Burton

Chief Financial Officer: Wayne Moore

Director of Administrative Services & Human Resources (Acting): Debbie Dillon

Director of Regional Services & Public Affairs: Brian Williams

Planning and Policy Department

TRANSPORTATION PLANNING DIVISION

Naresh Amatya, Manager (Acting) • Mike Ainsworth • Sungbin Cho • Guoxiong Huang • Hsi-hwa Hu • Ryan Kuo • Philip Law • Deng Bang Lee • Jessica Meaney • Sreedharan Nambisan • Mingxuan Wang • Teresa Wang • Julie Zhu

TRANSPORTATION FINANCE & GOODS MOVEMENT DIVISION

Annie Nam, Manager (Acting) • Mervin Acebo • Joseph Alcock • Mike Armstrong • John Asuncion • Rosemary Ayala • Pablo Gutierrez • Wesley Hong • Mike Jones • Betty Mann • David Rubinow • Akiko Yamagami

COMMUNITY DEVELOPMENT DIVISION

Mark Butala, Manager (Acting) • Peter Brandenburg • Joseph Carreras • Simon Choi • Elizabeth Delgado • Lynn Harris • Pria Hidisyan • Matthew Horton • Lingqian Hu • Ma'Ayn Johnson • Rongsheng Luo • SungHo Ryu • Frank Wen • Ying Zhou

ENVIRONMENTAL PLANNING DIVISION

Sylvia Patsaouras, Manager • Sheryll Del Rosario • Christine Fernandez • Laverne Jones • Jessica Kirchner • Jacob Lieb • Sofia Lo • Jonathan Nadler • Jennifer Sarnecki • Justus Stewart

PROGRAM DEVELOPMENT & EVALUATION DIVISION

Huasha Liu, Manager • Ping Chang • Andre Darmanin • Dan Griset • Robert Huddy • Richard Marcus • Llewellyn Miller • Javier Minjares • Dimitris Poulakidas • Alan Thompson • Ping Wang • Elizabeth Wojdak • Ming Yin

Other Departments

EXECUTIVE MANAGEMENT

Adriana Madrigal-Munoz • Judy Owens • Deby Salcido • Shelia Stewart • Lisa Taylor

LEGAL SERVICES

Joann Africa • Justine Block

CHIEF FINANCIAL OFFICER

Laura Aguilar • Jacqueline Bobo • Debbie Chen • Ted Dorjee • Lori Grebbien • Norma Hernandez • Richard Howard • Judith Kim • Andrew Lee • Leyton Morgan • Mari Munoz • Ricardo Olivarez • Basil Panas • Audrey Roa • Carmen Summers • Joan Tsao • Bernice Villanueva • Susan Youngs • Ranjini Zucker

ADMINISTRATIVE SERVICES & HUMAN RESOURCES

Cathy Alvarado • Patricia Camacho • Catherine Chavez • Cheryl De Salvo • Rhonda Lawrence • Cheryl Leising • Sam Liang • Corine Milner • David Milner • Mariana Pulido • Catherine Rachal • Jon Raymond • Victor Ryden • Chris Serrano • Jianhong Sun • Royalan Swanson • Nina Tozzi • Bonnie Verdin • Kurt Walker • Alex Yu

REGIONAL SERVICES & PUBLIC AFFAIRS

Ludlow Brown • Juan Camacho • Angie Chen • Darin Chidsey • Cheryl Collier • Barbara Dove • Jane Embry • Welma Fu • Jeremy Goldman • Scott Harrell • Carolyn Hart • Reese Healey • Christine Jerian • Linda Jones • Sean Murphy • Bev Perry • Arnold San Miguel • Mamie Tenden

LEGISLATION

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SOUTHERN CALIFORNIA COMPASS

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Southern California
Charting the course for a sustainable southland

SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

GROWTH VISION REPORT

- JUNE, 2004 -

AR0072624

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A Growth Vision for Southern California

Southern California is a diverse region in a variety of ways – including in its physical, cultural and economic landscapes. The region boasts an enviable setting: a moderate climate with varied terrain that ranges from sandy beaches to rolling hills, to snow-capped mountains to captivating deserts. Its diverse cultural mix offers residents and visitors alike a haven for community, entertainment and enrichment. As the 12th most productive economy in the world and one of the largest concentrations of employment, income, business, industry and finance, Southern California offers the potential for prosperity to everyone.

Because of these, and many other reasons, millions of people continue to recognize Southern California as a very desirable place to live.

As the region continues to grow, it's important to move forward in preserving and enhancing the area's land, culture and economy.

The Southern California Association of Governments (SCAG) has taken the first steps in that stewardship. SCAG has embarked on a process that will create a vision of the future for the Southern California region. In an effort to maintain the region's prosperity, continue to expand its economy, house its residents affordably, and protect its environmental setting as a whole, SCAG has brought together the ideas, hopes and dreams of interdependent sub-regions, counties, cities, communities and neighborhoods.

This process is called Southern California Compass, and the result is a shared Growth Vision for Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura Counties. SCAG began Compass in 2002, spearheaded by the Growth Visioning Subcommittee, which consists of civic leaders from throughout the region. Creating a shared regional vision is an effective way to begin addressing issues, such as congestion and housing availability, which may threaten the region's livability.

By definition, a successful Growth Vision must be driven by a wide array of input from the public and from various stakeholder groups. Such a process involves gathering a broad range of participants and stakeholders to gradually sculpt a consensus vision for the region. This includes administering a region-wide citizen survey, developing and refining a series of principles to guide the vision and the process, crafting growth scenarios based on the principles and on detailed public input, evaluating each scenario based on objective benchmarks, developing a preferred growth scenario, and gaining acceptance and endorsement of the preferred growth vision.

In the short term, SCAG's growth visioning process has found common ground in a preferred vision for growth and has incorporated it into immediate housing allocation and transportation planning decisions. In the long term, the Growth Vision is a framework that will help local jurisdictions address growth management cooperatively and will help coordinate regional land use and transportation planning.

A Growth Vision is important to preserve the quality of life for future generations.

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The Role of This Report

This Growth Vision Report presents the comprehensive Growth Vision for the six-county SCAG region as well as the achievements of the Compass process. It details the evolution of the draft vision, from the study of emerging growth trends to the effects of different growth patterns on transportation systems, land consumption and other factors.

This report begins with a general discussion of the challenges facing Southern California as it prepares to accommodate an estimated 6.3 million additional people by 2030. It studies historical trends in demographics, housing, jobs and other key aspects essential to understanding how the region will evolve and grow. Looking forward, the report explores how emerging trends and conditions will affect future growth in the region. It also discusses the challenges of continuously developing and refining the Growth Vision.

The Growth Vision report then turns to the public and to the stakeholders within each sub-region. This section emphasizes the close connection between the Growth Vision and the public input that shaped it. The results of a comprehensive regional survey and focus groups also are presented. A detailed discussion of the Compass regional visioning workshops follows, including the major themes gleaned from the public workshops held throughout the region. Descriptions and findings of the ensuing sub-regional review sessions and policy dialogues then summarize how the Compass public process continued to refine the elements of the Growth Vision.

In the next step, the report outlines the PILUT (Planning for Integrated Land Use and Transportation) test scenarios and the Growth Vision scenario. The PILUT scenarios, along with other regional development scenarios in SCAG's Regional Transportation Plan (RTP) process, present essential lessons and challenges for coordinating development and transportation in the final Growth Vision. The major themes and organizing principles of the Growth Vision are then presented. The section concludes with an analysis of the Growth Vision scenario and discusses the modeled impacts and effects the Growth Vision scenario is likely to have on Southern California.

The Growth Vision report concludes with a series of implementation steps – including tools for each guiding principle as well as overarching implementation strategies – that will guide Southern California toward its envisioned future.

It should be noted that this report concentrates on the physical aspects of regional growth – where people and jobs locate, the type and quantity of buildings that may be constructed, and how people and goods move in the region. To truly address all of the Growth Visioning principles, SCAG, sub-regions and cities should continue to refine the social, economic and other components that are also crucial to the Vision's success, including: workforce housing, job training and education, prosperity that reaches everyone, and protection of key open spaces.

A vision is not static but is constantly evolving. One goal of this report is that it will foster additional progress toward a vision of truly shared values – a vision that will evolve through well informed and wide debate about the direction the Southern California region should take as it embarks on a new era of challenges, growth and prosperity.

DEVELOPING A VISION

The Compass project develops a vision for the future of the region using the following components:

Public Participation– receive input from residents and community leaders through region-wide surveys, innovative workshops, and forums.

Scenarios – build and evaluate scenarios to understand future possibilities and the strategies that seem to work best in them.

Testing & Evaluation – apply innovative modeling techniques to evaluate each scenario on objective benchmarks of success.

The Growth Vision – describe an attainable vision of the future that is the best achievable based on the shared values of the region.

Strategies – outline the strategies that are key in attaining the vision, and build an implementation strategy around those main strategies.

Benchmarks – establish key benchmarks, and develop a monitoring system so progress can be measured and adjustments made.

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The Need for a Regional Vision

The Southern California region is the second largest metropolis in the country and one of the most diverse. While it contains one of the world's most dynamic economies, it also "boasts" some dubious titles, such as the most congested region in the country. At times it is also the national leader for air pollution. In addition, the SCAG region is challenged by both a high growth rate and substantial physical constraints. Part of the reason the region is so appealing is the proximity of beaches and mountains, yet the Los Angeles Basin is also confined by these same geographical barriers. What is not already developed is often regarded as a precious and scarce open space resource. Examples include the agricultural lands of Ventura County, the foothills that surround the Coastal Plain, and the unique habitats areas in the High Desert.

Nevertheless, the region will grow and change during the next 30 years, facing daunting challenges due to its physical land constraints. Some of these challenges can be solved by community action – the people of this region acting together in their own enlightened self-interest. When a country or a state faces these kinds of challenges, there is a democratic government through which these solutions can be debated and implemented. But regions have no common forum or process for debating and implementing these types of issues; instead, they rely on a patchwork of local and regional governments. This approach can work when issues are fundamentally local in their impact and solution, or when a specific regional problem is addressed by an entity with the necessary skills and authority.

Increasingly, however, most regional challenges are complex, with causes and solutions intertwined across political authorities and jurisdictions. Cooperation and coordination on a much wider scale than has been practiced in the past is required to address this complexity.

The solution is for Southern Californians to debate solutions, propose ideas and cooperate on important initiatives at both regional and sub-regional scales. Compass was begun for this reason – to develop a vision for the future that embodies the shared values of the Southland and details the actions necessary to preserve the livability of this region.

The SCAG region incorporates six diverse counties and covers 38,000 square miles.

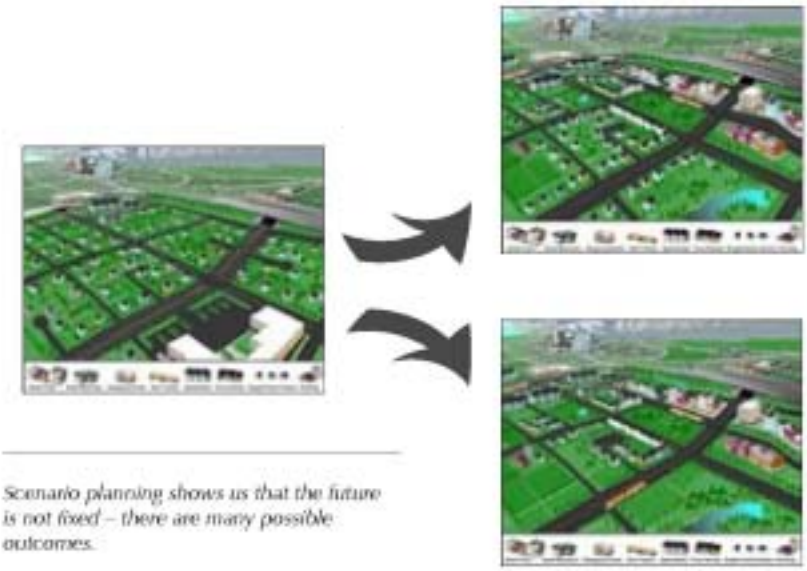
AR0072630

The Purpose of a Regional Vision

The word vision conjures up some ethereal images – of saints and mystics but not practical people. However, the word also represents the ability of people to imagine a reality that is not apparent in the immediate present. It refers to explorers of distant lands and of inventors who can envision how their new machines will work. In fact, the presence of this kind of vision is essential for most creative and innovative work – if visions did not exist, nothing new or untried would ever be pursued, except by fortuitous accident.

A regional vision is a special kind of practical vision – it is a shared vision. This is when a future is defined and agreed upon by a group of people. This kind of vision led the original colonists to fight for the independent democracy that became the United States. Their vision was described by authors such as Thomas Paine in the Common Sense pamphlets and Thomas Jefferson in The Declaration of Independence. These documents pointed the way and set out key guiding principles. The future did not turn out precisely as envisioned, but the principles were used to adjust to new realities as they came to pass. The documents had the ability to inspire large numbers of people to work toward the same cause, to adhere to the same principles, and to express the purpose of their struggle.

The regional Growth Vision is an attempt to develop the same kind of vision – one that expresses the common interests of multiple stakeholders as well as the desired end point: a sustainable Southern California with a high quality of life for everyone.



Scenario planning shows us that the future is not fixed – there are many possible outcomes.

Scenario Planning: A New Approach

The way governments have converted visions into reality in the past has been through a fairly simple planning process. In part because city planning has its roots in architecture, landscape architecture, and engineering, the concept of laying out a plan for a city or town was an easy leap – if one can build a building or bridge, why not a town? This model often works well at the small scale, where there is a fair degree of control over key variables. However, regions, especially regions as large as Southern California, have millions of actors and countless variables that interact to produce the resulting metropolis. A better approach in this type of situation is to use a model called scenario planning

Scenario planning is widely used in business and military settings. Given the complexity of issues faced in today's environment, the number of variables that have to be considered, and the 20 or 30-year time frame, it's apparent that getting the right prediction isn't really possible or even necessary. The better approach is to develop a method for outlining possible future scenarios.

Scenarios are really stories about what might be. They are not forecasts, and they are not predictions. They are possible futures that are based on what already exists, on trends that are evident, and on the values and preferences of a region and on decisions that might shape future outcomes. Scenarios are fed by input received from the combination of public workshops, surveys and stakeholder meetings. The essential requirement of any scenario is that it be plausible – within the realm of what exists and what is now known. Usually three or four scenarios are built as a way to compare outcomes and learn about the forces that are shaping the future. The point of this is to find out which strategies work in which scenarios. If a strategy works in any scenario, it's deemed robust – or a safe bet. If a strategy works in only one scenario, it is fragile and should be approached cautiously, with a good knowledge of the possible downsides.

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The scenarios for the SCAG region were developed from several sources, but they are all feasible. The purpose of this growth visioning process is to find out how to achieve our shared regional vision with strategies that are as robust as possible.

Models

Models were used extensively in developing these scenarios. Models are representations of reality that are used to learn, teach and explore new possibilities. Architects build scale models of their projects to see how it might look before the real thing is built. A scale model of an airline cockpit, outfitted with a computer model of different flight scenarios, can be used to teach pilots how to fly.

For Compass, three sophisticated computer models were used in preparing and evaluating the scenarios.

The first is the SCAG forecasting model. This develops future demographic and economic projections based on national and international inputs and factors such as birth rates. It gives an internally consistent total for each scenario.

The second is a land use model, developed at a very fine level of detail for the 38,000- square-mile area of the SCAG region. This model not only maps existing conditions but also allocates future growth using various assumptions. The land use model keeps a running inventory of how land resources are used and where people live and work.

Modeling is more than processing numbers in an equation. It is an iterative process with many feedback loops and complex cause-and-effect relationships.

The third model is SCAG's transportation model, which is used to design future transportation systems and evaluate the consequences of these systems in terms of traffic congestion, pollution, time spent in traffic, trade-offs between cars and public transportation, and much more. The transportation model used by SCAG is one of the most progressive in the country – sensitive to the impacts land use changes have on transportation and capable of considering separately the effect freight movement has on congestion.

These models were used to evaluate the scenarios created for the SCAG region, allowing the use of objective measurements to understand the scenarios and determine which would be best for the region.

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Growth Visioning Principles

The underlying goal of the growth visioning effort is to make the SCAG region a better place to live, work, and play for all residents regardless of race, ethnicity or income. To organize the strategies for improving the quality of life in the SCAG region, a series of principles was established by the Growth Vision Subcommittee. The four principles are intended to promote and maximize regional mobility, livability, prosperity and sustainability. Decisions regarding growth, transportation, land use and economic development should support and be guided by these principles. Specific policy and planning strategies also are provided as a way to achieve each of the principles.

PRINCIPLE #1

*Improve **mobility** for all residents*

- Encourage transportation investments and land use decisions that are mutually supportive
- Locate new housing near existing jobs and new jobs near existing housing
- Encourage transit-oriented development
- Promote a variety of travel choices

Providing transit options is a way to improve mobility for residents within the region.

PRINCIPLE #2

*Foster **livability** in all communities*

Walkable communities help improve livability and promote a mix of uses.

- Promote infill development and redevelopment to revitalize existing communities
- Promote developments that provide a mix of uses
- Promote "people-scaled," pedestrian-friendly communities
- Support the preservation of stable, single-family neighborhoods

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PRINCIPLE #3

*Enable **prosperity** for all people*

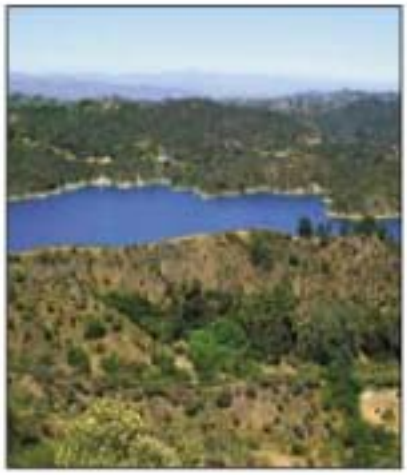
A variety of housing types enables prosperity for all people.

- Provide a variety of housing types in each community to meet the housing needs of all income levels
- Support educational opportunities that promote balanced growth
- Ensure environmental justice regardless of race, ethnicity or income class
- Support local and state fiscal policies that encourage balanced growth
- Encourage civic engagement

PRINCIPLE #4

*Promote **sustainability** for future generations*

- Preserve rural, agricultural, recreational and environmentally sensitive areas
- Focus development in urban centers and existing cities
- Develop strategies to accommodate growth that use resources efficiently, eliminate pollution, and significantly reduce waste
- Utilize "green" development techniques



Open space is integral to the health of communities.

GROWTH VISIONING SUBCOMMITTEE

SCAG's Growth Visioning Subcommittee consists of elected officials from around the region. It serves as the regional leadership body and is charged with leading the visioning process. The interaction between the regional leadership and SCAG's sub-regions form the foundation of the visioning process. Local jurisdictions and other local stakeholders provide input into the process at the sub-regional level. Regional stakeholders and the Compass Advisory Committee – which consists of participants from varied disciplines who generously donate their time and viewpoints – provide input into the process through the Growth Visioning Subcommittee. All results from surveys and focus groups are presented to the Subcommittee for review and feedback.

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Regional Challenges

To develop a common vision for the future, it's important to understand the challenges facing the Southern California region. Because the past often provides an indication of what is to come, this section summarizes the recent trends of the Southern California region – those issues that historically have been a struggle for the region. Then the section looks forward to 2030 to paint a picture of the challenges the region will encounter in the coming decades. It is precisely these challenges that a successful regional vision must address.

California's biggest challenge is the extraordinary growth that it has experienced and will continue to experience. In recent years, Southern California has faced some of the most dramatic growth seen anywhere in the world for decades. The U.S. Census reports that between 1980 and 2000 the overall population in the region grew by 5 million people, from 11.5 million to 16.5 million. Projections indicate that 6.3 million more people will be added to the region between 2000 and 2030, bringing the total population to 22.9 million.

The dynamic interplay between immigration, out-migration, and natural increase (births minus deaths) accounts for the complexity of the population change. Immigrants – from around the world, but dominantly from Mexico, Central America and Asia – will continue to come to the region. But although immigration will continue to play a major role in the population change, the greatest portion of new growth is expected to come from natural increase – the children of people who are already here. At the same time, out-migration of various segments of the population will continue to rearrange the make-up of the region. The future will require planning and preparation for a more culturally diverse and varied population.

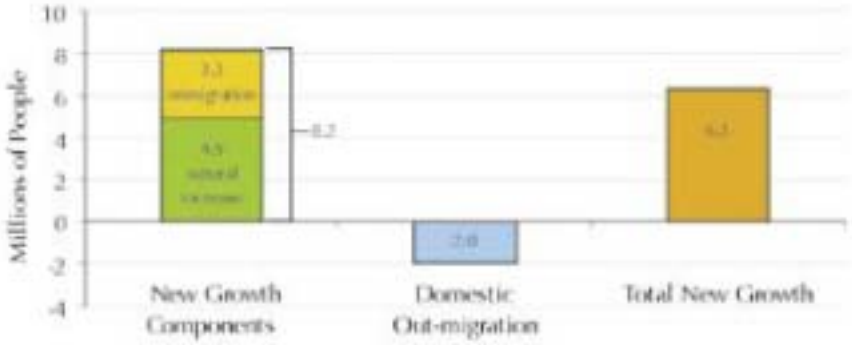
Looking Back

Demographics

The SCAG region has experienced dynamic population change in the last decade. Primarily due to the recession that struck the SCAG region from 1990-1993, 1.5 million people moved out of the region during the 1990s. Most of the population loss was in Los Angeles County. However, this loss was part of a bigger picture of turnover. During the same period, many people were born or moved into the region, resulting in a net population increase of nearly 1.9 million people. Most of the population increase was attributable to natural increase (more births than deaths in the existing population). A higher rate of births among the foreign-born population in the region is a contributing factor.

The population remains relatively young. The average age of the population in the SCAG region, between 1990 and 2000, increased at a slower rate than that of the state of California or the U.S. Overall, the region has a younger population than the state. The distribution, however, is varied. In San Bernardino County, the median age is 30, while in Ventura it is 34. All counties in the region have a younger median age than the nation; only Ventura has an older median age than the state. Compared to the nine largest metropolitan regions in the country, Southern California is the second youngest in terms of median age.

Components of Forecasted Population Growth in the SCAG Region, 2000-2030



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From 1990 to 2000, the region's senior population (aged 65 years or over) increased slightly to 10 percent, which is below the national rate but slightly higher than that of the state. In 2000, a total of 1.7 million seniors were counted in the region, up by nearly 220,000 from 1990. Only Riverside County had a higher senior population than the rest of the nation in 2000, while San Bernardino County had the lowest number of seniors in the region.

The ethnic makeup of the population also changed significantly during the last decade. The region continues to be a magnet for immigrants. Between 1980 and 2000, the region's foreign-born population increased by 3 million, from 2.1 million to 5.1 million. In 2000, one out of every three Southern Californians (31 percent) was born in a foreign country. In this regard it is now comparable to other immigrant destinations such as New York; Vancouver, B.C.; and Toronto, Ontario.

The age and ethnic diversity of citizens in the SCAG region drives the demand for critical public services such as schools, job training, public transportation and senior housing. Consequently, the study of current and future trends in demographics is important to any long-range planning effort.

Percent Hispanic Population

1990

2000

Red and dark purple represent a higher percent of Hispanic population in the census tract.

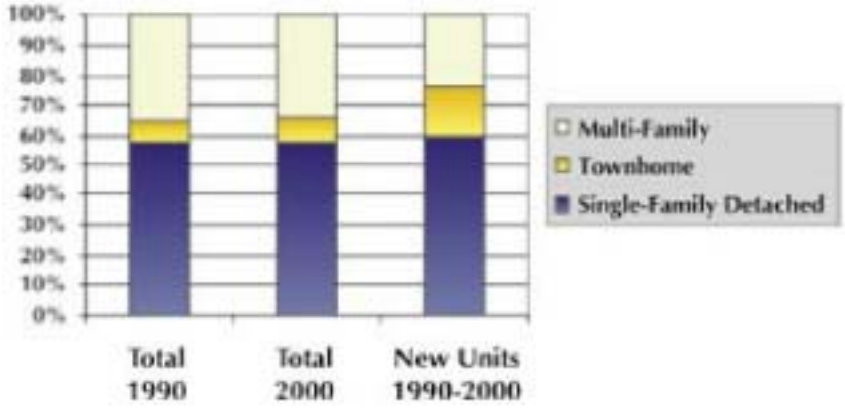
Housing

Recent trends and existing housing conditions point to an unmet demand for a greater diversity of housing throughout the six-county region. During the 1990s, the overall supply of housing did not match increasing demand in the SCAG region. Even as the population continued to grow, home construction lagged behind. The number of annual building permits decreased by 20 percent between 1990 and 2000. Further, those units built were out of sync with the demand for a broader array of housing choices from an increasingly diverse Southern California.

Single-family detached homes account for about 60 percent of housing in the region, according to the U.S. Census Bureau, mirroring the proportion of single-family units constructed during the last decade. And while multi-family units account for a significant proportion of the overall supply at about 40 percent, there were fewer multi-family building permits issued in 2000 than in 1990.

As a result, as populations in need of multi-family housing increase the demand for such housing is outpacing production. Immigrant populations and the 20-29 year-old and senior populations – those most likely to want multi-family housing – are increasing faster than the multi-family housing supply.

Housing Split



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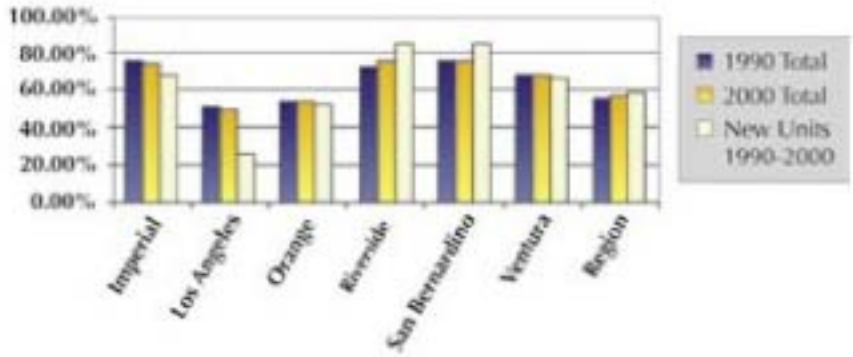
The cost of living has soared across the region, causing an affordability crisis for low-income households and increasingly for middle-income families wanting single-family homes. This is especially true in the coastal and jobs-rich areas of the region where vacancy rates are low, housing costs are high, and new housing typically consists of single-family homes for people in upper-income brackets. Earning the median household income no longer qualifies families for the median mortgage payment. Households earning the Area Median Income (AMI) in Los Angeles, Orange, and Ventura Counties, for example, spend more than 50 percent of their income on housing.

The increase in construction of townhomes also suggests that there are housing types that are becoming more in demand. While townhomes account for only 18 percent of the region's multi-family units, they accounted for more than 40 percent of the growth in multi-family housing built from 1990 and 2000.

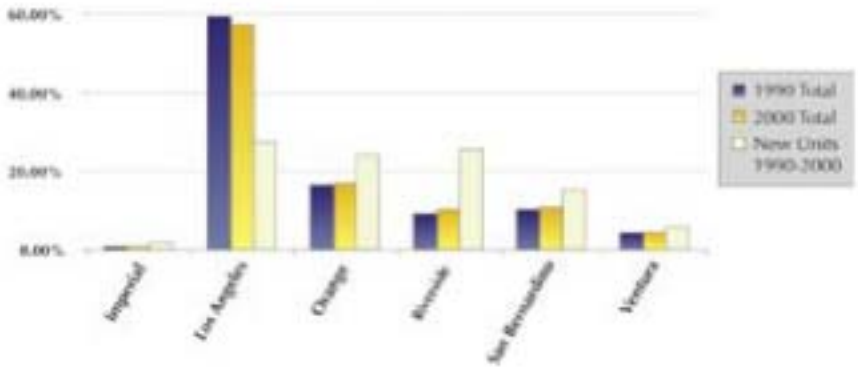
Although Los Angeles County still retains the bulk of the region's housing (approximately 60 percent), Census data show that the new housing is being constructed in equal proportions across Los Angeles, Orange and Riverside Counties. Between 1990 and 2000, about 25 percent of housing in the region was built in each of these counties, with another 15 percent of the new housing in San Bernardino County. And while multi-family housing construction has increased in Los Angeles and Orange Counties in the last couple of years, it still has not kept up with population growth, a situation exacerbated by the slump in multi-family housing construction in the 1990s. At the same time, Riverside and San Bernardino Counties are building single-family homes in greater proportion (85 percent are single-family) than what currently exists (75 percent). This shift in population away from existing job centers can compound the lack of housing near jobs in the counties that already have the longest commutes in the region.

The gap in unmet demand for greater housing diversity will continue to grow without a regional long-term planning effort. In particular, the housing need for new employees entering the workforce and senior housing must be addressed if the region is going to sustain economically viable and healthy communities.

Single-Family Housing Split



Share of Regional Housing



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CURRENT TRENDS IN INFILL

When housing is built on land that is already developed, or on scattered small sites of undeveloped land, the process is called infill. The images to the right show where redevelopment and infill occurred in the 1990s. The fuchsia represents Census tracts in which all the development in the 1990s was through infill and redevelopment, while the lavender shows tracts in which some of the development in the 1990s occurred through infill and redevelopment. In the 1990s, 35 percent of the new housing developed in the region was built on already developed land. Most of the redevelopment occurred in the Los Angeles basin. This high redevelopment rate is a testament to the limited land supply and continuing strong demand for housing in the basin.

Jobs

The recession in the early 1990s hit the Southland hard. The employment growth rate in the SCAG region between 1990 and 2000 was only 8 percent, about half of the 16 percent job growth experienced in California, and well below the national rate of 20 percent. During the second half of the decade, however, the region's employment grew faster than the nation, at 14 percent. During the 1990s, certain counties fared better than others. The Inland Empire experienced an explosive growth rate of 37 percent, followed by Ventura and Orange Counties at 19 percent and 18 percent respectively. Los Angeles County had a net loss of 67,000 jobs during the 1990s.

In the 1980s the manufacturing sector accounted for nearly one-quarter of the jobs in the region, but during the past two decades manufacturing jobs have declined and now represent only 14 percent of the employment mix. Service sector jobs, on the other hand, have skyrocketed from 22 percent in 1980 to 31 percent. Jobs were also added in government, trade, transportation and public utilities, and construction and mining between 1990 and 2000.

Most of the manufacturing decline occurred in Los Angeles County and was defense or aerospace related. While Orange County also experienced a net loss of manufacturing jobs from 1990 to 2000, Riverside and San Bernardino gained about 39,000 manufacturing jobs.

Since a healthy economy is the driving force behind a healthy community, it's important to plan for an equitable dispersion of employment opportunities throughout the region. Job location affects public services such as transportation, education and housing, making a regional coordinated planning effort key.

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Transportation

In the 1990s, the region experienced an infusion of transit infrastructure investment. Most notably, the Los Angeles County Metropolitan Transportation Authority (MTA) embarked on an ambitious process to improve existing systems, while also developing new light, heavy and commuter rail systems. The improved system has helped spawn development around major transit stations, contributing to increased ridership along the lines.

The Wilshire Boulevard rapid transit bus has improved service along this busy corridor.

The region still depends heavily on the freeways to move people and goods.

The MTA has also recently introduced "Metro Rapid" – a form of bus rapid transit – along two major transit corridors. Additionally, many municipalities in the region have upgraded bus service. Worth mentioning is the Santa Monica Big Blue Bus, one of the most successful transit systems in the country. In the year 1998-1999, according to the Center for Neighborhood Technology, the Big Blue Bus moved more than 20 million passengers.

Other transit agencies made big strides in the 1990s as well. Orange County Transportation Authority increased ridership by nearly 10 million trips between 1990 and 1999. In the seven-year period from 1992 to 1999, 100 percent more transit trips were taken on Foothill Transit, while ridership in Antelope Valley increased by more than 200 percent in the 1990s.

During the 1990s, transit use in Southern California increased more than vehicle miles traveled.

The Santa Monica Big Blue Bus moved over 20 million passengers from 1998-1999.

Across the Southern California region as a whole, transit use increased by 20 percent in 2000 – outpacing both the 13 percent growth in population and the 15 percent growth in the Vehicle Miles Traveled (VMT).

In 2000, total unlinked transit trips in the region increased by more than 40 million, or 7 percent since 1999. However, even in a time of increasingly improved transit access, the region is still encountering a number of transportation-related challenges.

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The mode choice to work in the region remained essentially unchanged in the 1990s, contrary to the national trend. In 2000 the area had the highest share of workers that carpooled among the nine largest metropolitan regions and maintained a higher level of carpooling than the rest of the nation.

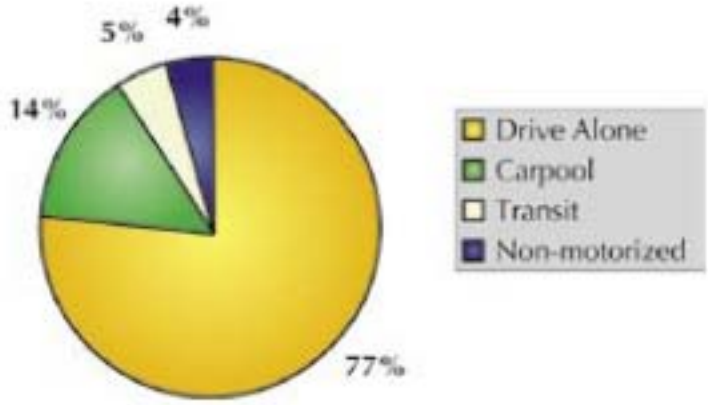
Despite the fact that in 2000 23 percent of commuters found alternatives to driving alone to work, congestion continues to be a problem in the Southern California region. In 2000, the Los Angeles metropolitan area (Los Angeles and Orange Counties) remained the most congested metropolitan area in the country in terms of hours of delay and congestion cost per person.

From 1980 to 2000, VMT nearly doubled. The good news, though, is that VMT growth has slowed down considerably. Whereas between 1980 and 1990 VMT increased three times faster than population growth, in the 1990s persistent congestion played a factor in slowing VMT growth to nearly the same rate as the region's population growth.

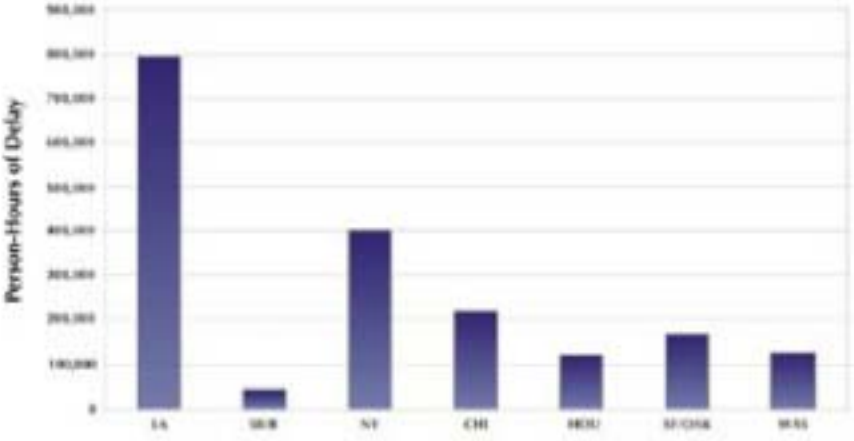
Between 1990 and 2000, the average time it took to commute to work increased in every county in the region. The region's average travel time to work increased from about 26 to 29 minutes and continued to be higher than the state and national averages but significantly lower than other large regions.

Transportation behavior is greatly affected by household, employment and service location. An aging population will change transportation mode choice, travel time and location. These changes affect future transportation decisions.

Home to Work Mode Split
Southern California Region, 2000

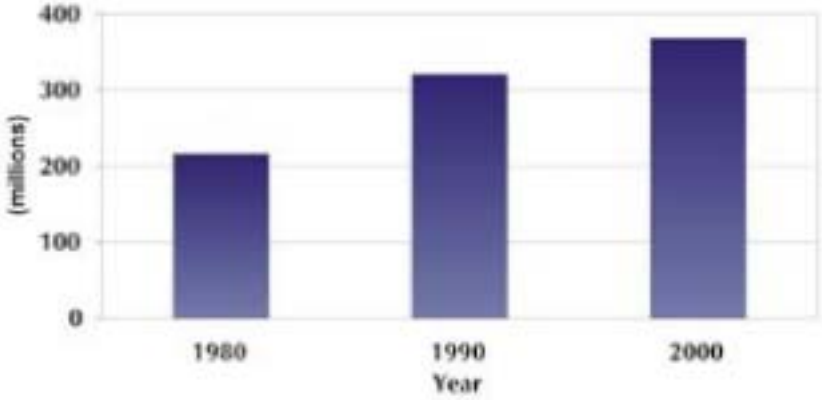


Annual Person-Hours of Delay



Source: Texas Transportation Institute, 2000

Daily Vehicle Miles of Travel



Source: SCAG State of the Region 2002

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The dynamic interplay between past and current challenges will shape any vision for the Southland's future. A shared vision must anticipate the needs of a population that is simultaneously younger, older and more diverse.

Reduction in the wage-earning population will affect revenue for public services, yet more public services will be demanded. The growing senior population will require more housing options close to shopping and health care services, as well as alternatives to getting around by automobile.

In addition, the limited land supply in the basin will require new strategies for accommodating housing and employment.

The knowledge gained through observing these trends will enable the region to respond to these challenges and provide a range of options for accommodating the housing, transportation and employment changes that will help the region grow and prosper.

Looking Forward

Changing Ethnicity

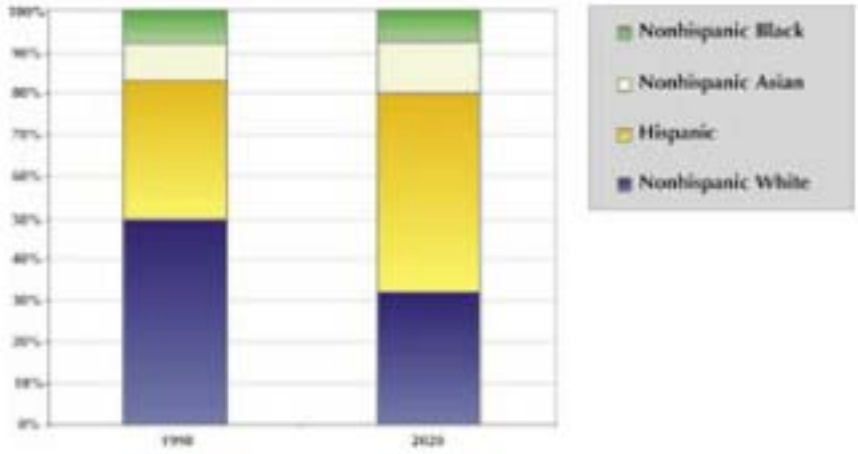
In the next several decades, recent trends will persist, and the Southland will continue to become more diverse. While all ethnicities and races will experience an increase in numbers, the most dramatic gains will be among the Hispanic and Asian populations. By 2030 there will no longer be one race or ethnicity in the majority; the region will be truly international.

These changing demographics will provide the driving force for much of how the region will evolve. New housing markets will be opened as families look for cost-effective housing near jobs. Many people in the region will place a greater value on living close to family members and on proximity and quality of schools. These preferences will encourage the creation of a wide variety of housing products aimed toward the different needs and wishes that occur throughout this diverse region.

The increase in diversity also will fuel the natural progression of the "international city." With a broad range of customs, languages and international ties, Southern California will serve as the gateway for the majority of the country's commerce with Asia and Latin America. The ability to have a base in the prosperous and stable United States – but also tap into a workforce that is fluent in Spanish, Mandarin, Cantonese, Korean and other languages – will be a tremendous advantage in a global marketplace.

The future population will demand more entry-level and mid-priced housing. It will place a premium on location and good access to work opportunities, services and family. It will be important to place a high priority on locating new housing and job opportunities in areas that meet these criteria. Reinvesting in the region's corridors as mixed-use areas and opening up housing opportunities through infill and redevelopment will provide needed options in communities that are well served by transportation infrastructure and ripe with urban amenities.

SCAG Region Projections of Population Distribution by Ethnicity



Source: SCAG, 2000

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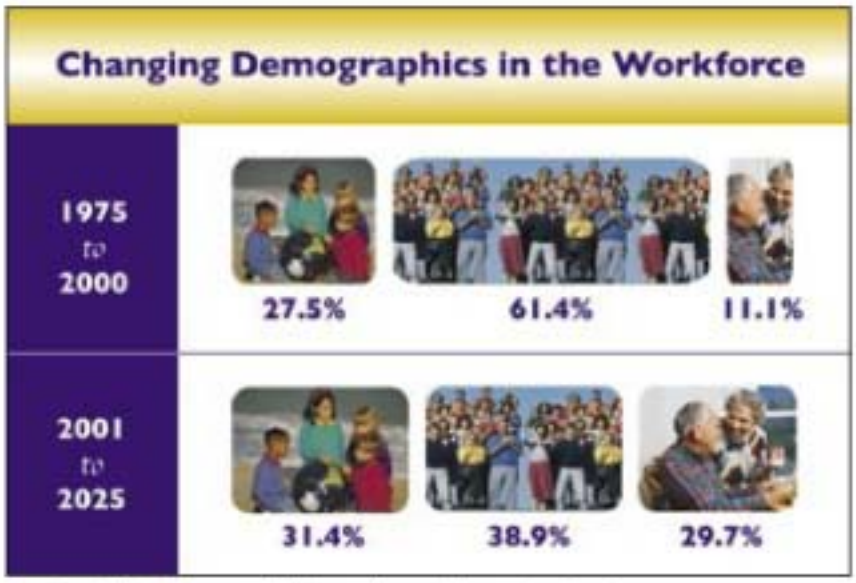
Changing Workforce

One of the greatest scientific achievements in the last several decades is the dramatic increase in an individual's lifespan. Many news segments, however, have depicted some of the worrisome aspects of an aging population – namely a growing number of people who are cared for through programs such as Medicare and Social Security. The Southland faces another daunting challenge. As our population ages and leaves the workforce, there will be a delay in filling their jobs until enough younger people become of working age. Currently, roughly two-thirds of the population in Southern California is of working age – the demographic generating the tax revenue that pays for public services that everyone uses. During the next 25 years, it is expected that the number of people over age 55 will increase by six times, while the number of children will also increase modestly. These two factors will interact to produce a situation in which the non-working population will increase from a mere 11 percent today to nearly one-third of the population. In 25 years, it is projected that less than 40 percent of the population will be in the wage-earning workforce.



Southern California faces a shrinking workforce in the coming decades.

Change in Job Types

The region, as well as the nation, has seen a general decline in the manufacturing sector in recent years, resulting in the loss of a large number of living wage jobs. At the same time, the region is increasingly becoming dependent on the service sector. Service jobs are not as lucrative as union manufacturing jobs of past generations and often do not require a highly educated workforce. In many cases service jobs are located within communities whose home prices exclude service workers from living close to their workplaces. The shift to a service economy therefore intensifies the need for workforce housing close to jobs. To create prosperity for everyone and to diminish the impacts of long commutes, housing diversity and affordability will become increasingly important.

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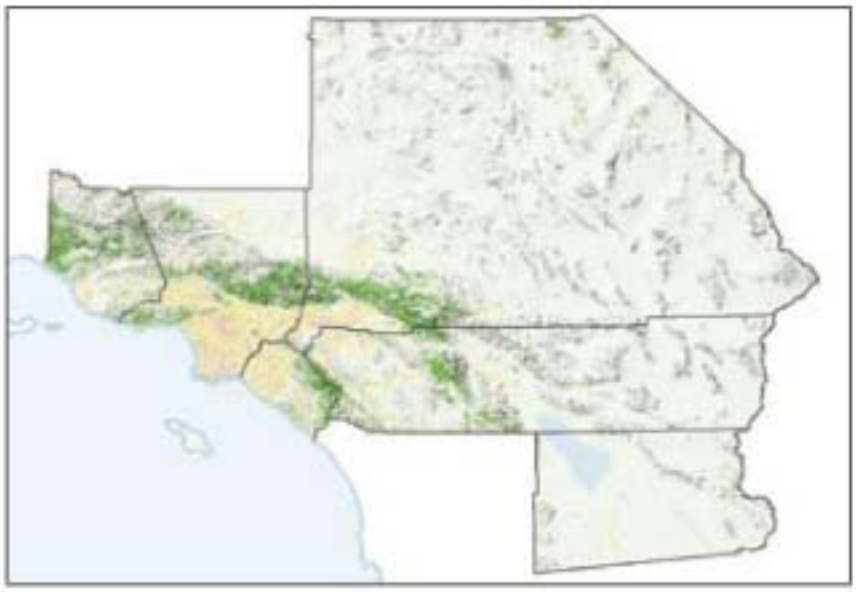
Land Supply

Since the SCAG region covers more than 38,000 square miles, few would imagine the area could be short of undeveloped land. But the region does in fact face a severe limit on the amount of undeveloped land suitable for development, which hinders its ability to accommodate new housing and jobs. The Coastal Basin of Los Angeles and Orange Counties, along with the San Fernando Valley, is home to 77 percent of the region's jobs and 71 percent of its population. Under current general plans, capacity on vacant land accommodates only 238,000 new households. That means that only 29 percent of the SCAG 2030 growth projection for this area could be accommodated through new development on vacant land.



Geography and the highly urbanized Coastal Basin constrain development opportunities.

Accommodating growth through infill housing is one way of dealing with the limited land supply in the Coastal Basin.

With limited undeveloped land, developed land will become increasingly important in accommodating growth. Infill, or new development in already developed areas, will be the method used to construct nearly half of the new housing region wide. In the city of Los Angeles, infill development could accommodate up to 80 percent of the projection for this area.

Another factor adding to the issue of a constrained land supply is the cost in time, money, and community building that is incurred by long commutes between the region's job centers and areas with plentiful land.

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Provision Of Open Space

While some communities in the Southland provide an exceptional amount and quality of open space, other areas provide few opportunities for experiencing the outdoors. As the hillsides, once considered too steep for development, are now sprouting houses, there is a growing concern about natural areas that are not preserved by public or protective ownership. As the population grows, the pressure to develop environmental assets will only increase. Likewise, with a growing population there will be more demand to save these areas and to create more recreational opportunities. All the region's general plans address open space in some fashion. Additionally, several innovative and progressive projects are currently under way. Some of these programs, such as the Coachella Valley Habitat Conservation Plan, are taking place at the sub-regional level. Other notable efforts, such as the Ventura County SOAR initiative (Save Open Space and Agricultural Resources) and the Riverside County Integrated Project (RCIP), are being implemented through general plans at the county level. Too numerous to list are the varied efforts taking place among the many cities of the Southland.

These green hills of Ventura County are a natural feature worth preserving.

Congestion

Congestion will continue to pose a problem for the Southland. The increasing population in the region will cause vehicle miles of travel to rise. Without significant changes in the way land uses are integrated with transportation, congestion is predicted to worsen. If current trends continue, estimates are that congestion, in terms of regional daily vehicle hours of delay, will more than double from 1.6 million to 3.6 million in 2030. In Riverside County alone, vehicle hours of delay could more than triple.

In a survey conducted by Compass, residents rated congestion as one of their top concerns.

AR0072645

Pollution

Despite significant air quality improvements in the region in the last 30 years, the Southern California region is still, and will continue to be, challenged with air pollution. Maximum pollutant concentrations in the region still exceed the federal standards for ozone, carbon monoxide and particulate matter (PM10 and PM2.5) significantly. In the last several years the downward trend of pollution production has reversed. Despite improved emission standards for passenger automobiles, big trucks and sport utility vehicles, which are exempt from fuel efficiency standards, have increasingly become the vehicle of choice.

Daily vehicle miles of travel also are still very high, despite a slower rate of increase in recent years. Additionally, emissions from ships, locomotives, buses, trucks, other large vehicles, as well as many household chemical products, remain unregulated. Thus, the combination of increased emissions, the regional geography, and the hot climate encourages ideal conditions (temperature inversions) for increased pollutant buildup and reaction. As a result of these factors, the air quality in the region could continue to worsen unless measures are taken and policy is introduced to reduce pollution production.

Managing freight efficiently is a crucial part of maintaining a healthy Southern California economy.

Although technological advances have helped curb pollution in Southern California, it is still a big challenge for the region.

Freight Management

Freight operation in the Los Angeles region originated next to the Port of Los Angeles at Long Beach in the early 20th Century, when these ports were separate from other development in the region. Subsequent growth has surrounded the original industrial lands and is currently constraining the expansion of operations needed to keep pace with increases in freight volume. Truck access directly to the ports contributes to severe congestion on the freeway system and to poor air quality in the region. The Alameda Corridor was built to alleviate some of the problems associated with truck access to the port.

In addition to rail and truck freight, the Southern California region is experiencing astonishing increases in air freight volume. During the next 30 years, conservative projections indicate that this market of high value shipments will triple in volume, despite the dramatic growth anticipated in other freight sectors.

And because air freight shipments intended for the local market must be transferred to trucks for delivery, air freight relies upon the surface transportation network, in the same way that other types of freight do.

Even when air or rail networks are used for freight, trucks are still needed for collection and distribution.

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Public Input & Involvement

The Compass process has defined a shared vision that can guide regional and local land use decisions, transportation improvements and housing development for the next 30 years. The Growth Vision creates a goal toward which objectives and implementation strategies can strive. Arriving at the goal consisted of an extensive public outreach and input process. The Growth Vision was formed and refined through public surveys, focus groups, public workshops, sub-regional review sessions and policy dialogues held throughout Southern California. This section summarizes the process and findings of each of these components of public involvement and discusses how the results are incorporated into the Growth Vision.

Survey Findings

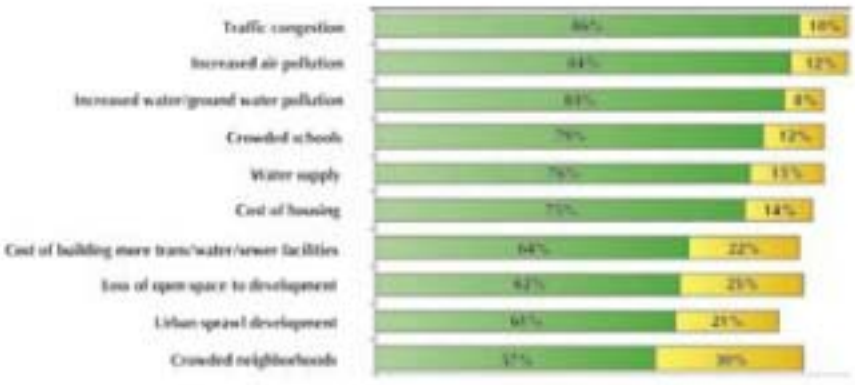
At the beginning of the Compass process, SCAG conducted a survey that asked Southern Californians them about the region's "biggest problems," perceived impacts of population growth, and transportation priorities.

Overall, the survey shows that while the results are diverse, Southern Californians hold collective concerns and hopes for growth in their region. The respondents want a balanced approach to managing growth. Respondents support allocating tax money to a variety of transportation improvements, from freeways to transit to bike paths. They were receptive to higher density development and redevelopment as long as it is coupled with preserving open space. And they believe that environmental protection must be balanced with economic growth. The summaries below provide a better understanding of why respondents are concerned with growth and their openness to solutions to growth-related challenges.

The Role of Planning

The survey results indicate that the respondents are very concerned that growth and its impacts will erode quality of life. In fact, 46 percent of respondents in the region agree that "my local government should try to slow growth down." When respondents prioritized their top four growth-related concerns, overcrowding of schools, at 46 percent, was of greatest concern. Traffic congestion was second, with 38 percent of respondents identifying it as their first or second most significant concern. Housing costs and increased air pollution were next on respondents' list of concerns.

Despite the concern about growth, wide support for planning solutions to growth exists throughout the region: 78 percent of the survey participants believe planning is necessary to maintain livability. The strongest support for planning exists among the most active voting population of citizens 55 and older. These survey results validate findings from previous focus groups. Balanced approaches to managing growth are also important. Respondents supported both transit and freeway expansion, allocating tax money to a variety of infrastructure (from freeways to bike paths), and they believe that environmental protection must balance economic growth. This search for balance and varied solutions means that any strategic policy or funding initiative is not likely to be widely supported if it focuses on just a single answer. Respondents also thought that it was both likely (78 percent) and desirable (61 percent) that Southern California will become more ethnically diverse.



The green bars show the proportion of survey respondents who were Somewhat or Very Concerned with each topic.

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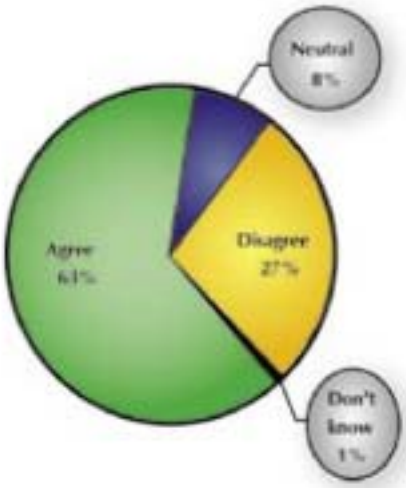
Transportation

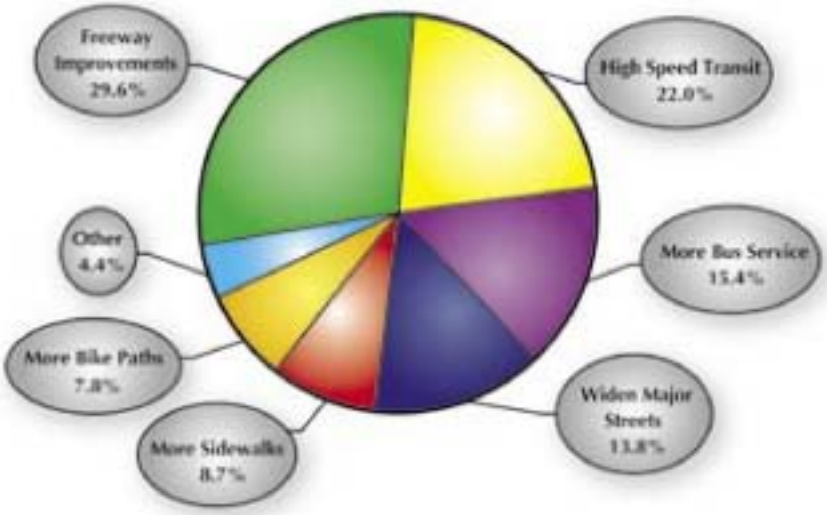
The survey, as well as web surveys and earlier focus groups, reflected a strong desire among residents for balanced approaches to managing transportation. The results indicated that citizens view freeways as an integral part of the region's future and dislike the current congested state of these roads. When asked how future tax money should be spent on the transportation system in the Southern California region, nearly 30 percent of respondents mentioned freeway improvements.

Yet more than two-thirds of the survey respondents believe transit is part of the solution to traffic congestion. Nearly 3 out of 5 found it desirable that transit trips would replace more and more automobile trips, and a large minority (34 percent) thought that it was likely as well. Survey respondents would allocate 37 percent of transportation funds to public transit (high-speed and bus) on average. They would allocate 30 percent to freeway improvements and 14 percent to surface streets. In total, respondents would allocate 54 percent of transportation funding to non-automobile modes of travel. These allocations hold true across all the counties in the region, with the exception of San Bernardino and Riverside, where residents allocated more funds to street-widening than bus service. Imperial County, despite its distance from the major employers of the Coastal Basin, gave highest priority to transit.

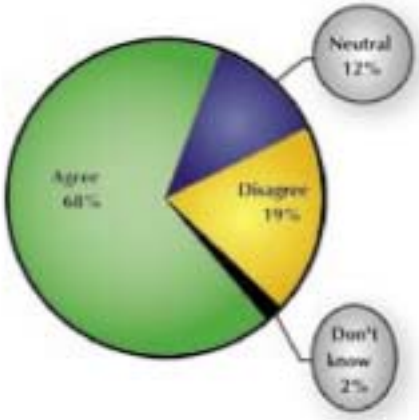
"We should widen congested freeways and build new ones."



Survey respondents' mean allocation of tax funds to transportation projects



"Building more high quality, high speed transit is part of the solution to the traffic congestion problem."



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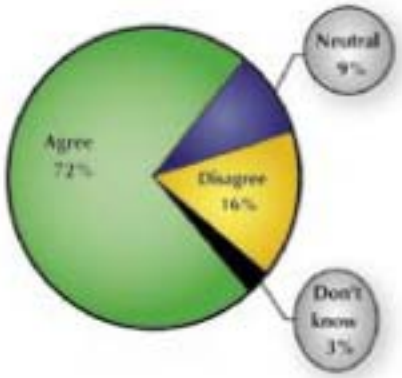
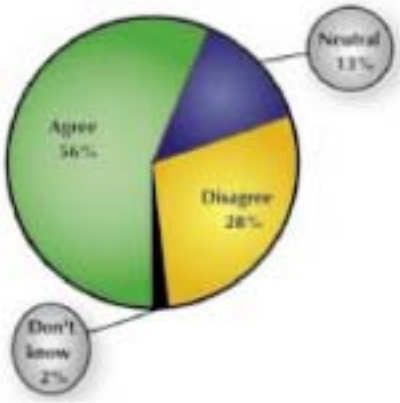
Land Use

Survey respondents showed a general concern for open space. More than 60 percent of respondents were somewhat or very concerned with urban sprawl and the loss of open space. And 56 percent of the respondents found it somewhat or very desirable that environmental protection will become more important than economic growth. Almost half (49 percent) of those surveyed believe this is likely to occur. The public was also receptive to the ideas of higher density development and redevelopment as long as they were combined with preserving open space. However, the same respondents were less amenable to higher density development or to new residents in their own neighborhoods. Overall, there was a general awareness of land use issues and little willingness "to not plan" or "to believe that somehow there is enough space to accommodate unfettered development." On the issue of infill, only 25 percent thought that growth will be concentrated in existing cities in the future, while 43 percent thought that this concentration would be positive.

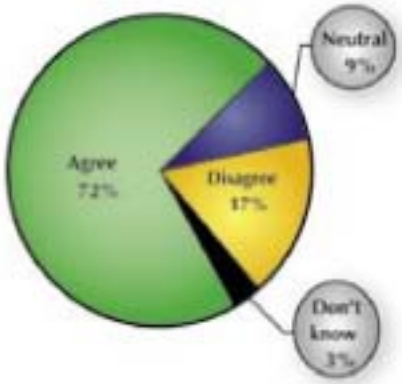
"New neighborhoods with higher density development are OK if they are carefully designed and provide open space."



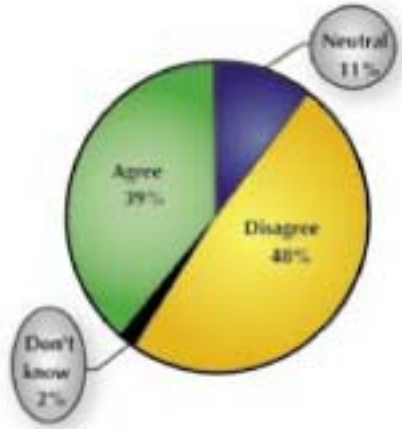
"Higher density development in my neighborhood is OK if it is carefully designed and provides open spaces."



"Areas of existing neighborhoods/business districts should be redeveloped instead of using up farm land or open space for development."



"I am willing to have more people live in my neighborhood so that less open space will have to be developed."



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SOUTHERN CALIFORNIANS ARE MORE ALIKE THAN DIFFERENT

Southern Californians in different Counties showed that they are more alike than different. For example, between 84 and 90 percent of respondents in each of the Counties except Imperial were very or somewhat concerned with traffic congestion. Each County's survey respondents would allocate 18 - 24 percent of transportation funds to high-speed transit, while the proportion for freeway improvements was 28 - 36 percent. Their prioritization of transportation fund allocations was the same across all Counties, with one small exception in Riverside and San Bernardino Counties. Respondents from Los Angeles, Orange, and Ventura Counties put greater priority on bus service than on widening major streets, while residents in Riverside and San Bernardino Counties preferred the reverse. The overall distribution of funds fell into three categories in the following order of priority: (1) freeway and high-speed transit, (2) increased bus service and wider streets, and (3) more sidewalks and bike paths.

Respondents showed similarities toward general land use and planning issues as well. At least 70 percent of respondents in all Counties strongly or somewhat agreed that planning is necessary to keep the region livable. Nearly 80 percent agreed in five of the six Counties (70 percent agreed in Orange County). At least 70 percent of all Counties also agreed with the idea of higher density neighborhoods that are carefully designed and provide open space.

While it is often said that the sub-regions of Southern California are very different – and in many respects they are – this survey reveals that when it comes to picking strategies and investments, people across the region are remarkably consistent in their preferences. This similarity is a key asset to building a shared regional vision and to implementing positive long-range strategies.

Participants placed "chips" representing growth on this regional base map.

WORKSHOPS

The Compass workshops allowed Southern Californians to explore ideas about what the region will look like in the next 25 to 30 years. The workshops specifically asked the public how and where to accommodate the region's next 6 million people and 3 million jobs. Nearly 1,300 members of the public attended 13 Compass workshops. Using maps of the entire region, Southern Californians experienced firsthand the interdependence of regional land use, transportation, economics, and environmental issues across political boundaries.

The workshop participants came up with countless ideas, solutions, and plans, as well as more than 100 maps – each a unique vision of the future. While land use, transportation, and development issues are often approached at a local level, each Compass workshop map created solutions to these regional challenges. The workshop results support both the survey findings and the Growth Vision principles. They reflect the need for balance and planning, with consistent concern for environmental protection as well as economic growth, for multi-family and single-family housing types, and for mixed-use centers as well as single-use districts.

Workshop participants assess growth options.

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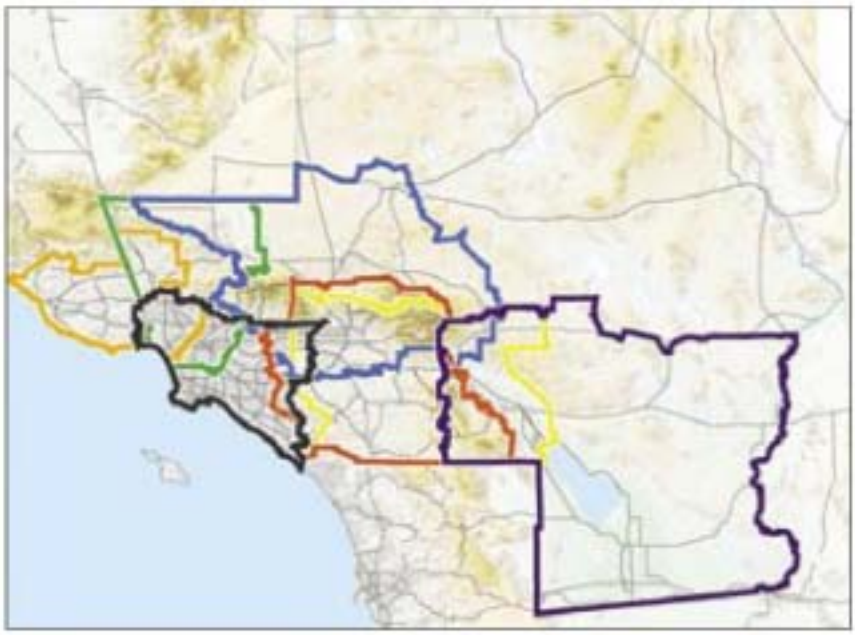
Workshop Process

Compass used workshop maps of three different scales to gather the greatest diversity of citizen input. At the kickoff workshop Southern Californians from around the region worked on the entire six-county SCAG region. The majority of workshops were conducted at the sub-area scale – smaller than the entire region but incorporating multiple counties. Different sub-areas overlapped so participants had a choice of workshops. They were also formed based on commuting patterns, urbanized land and other geographic factors – not jurisdictional boundaries. Sub-area workshop participants were given the opportunity to work at the regional scale as well. The final two workshops allowed participants to work at an even finer level of detail in the South Bay/Gateway Cities and the Four Corners/Inland Empire Focus Areas. Also, as a result of public input the latter workshops allowed participants to select from a menu of transportation improvement options – allowing them to coordinate regional land use and transportation while considering the costs of transportation infrastructure.

Workshop participants sat at tables of eight to 12 people with people from diverse backgrounds. The diversity of each table allowed the participants to experience alternative points of view. Environmentalists and developers, students and seniors, immigrants and California natives often sat at the same table. They frequently found that they agreed more often than they disagreed – despite their different backgrounds. Other times, they negotiated trade-offs and developed successful compromises.



So that participants could work on a more meaningful scale, the entire region was broken into seven overlapping subareas.

Each workshop group was given a base map that included existing land uses, existing and planned highways and transit lines, and environmental constraints (steep slopes, floodplains, and wetlands). The participants were also given regional transportation, topographical, and endangered habitat maps – vital information that showed a regional context and with more detail than feasible on a workshop base map.

Participants first identified areas where they felt growth should not occur. These areas included stream and trail corridors, environmentally sensitive areas, and other significant natural features they thought should be preserved. The participants were then challenged to accommodate the base map area's projected growth in housing and jobs using various combinations of development-type game pieces, or chips. The development types represent a range of ways in which jobs and housing could be accommodated. Each development type has a unique development pattern (from auto-oriented to pedestrian-friendly), number of households and jobs, density, and combination of retail, office, and residential space. They were modeled after communities and places in Southern California (See Appendix I: Workshop Development Types).

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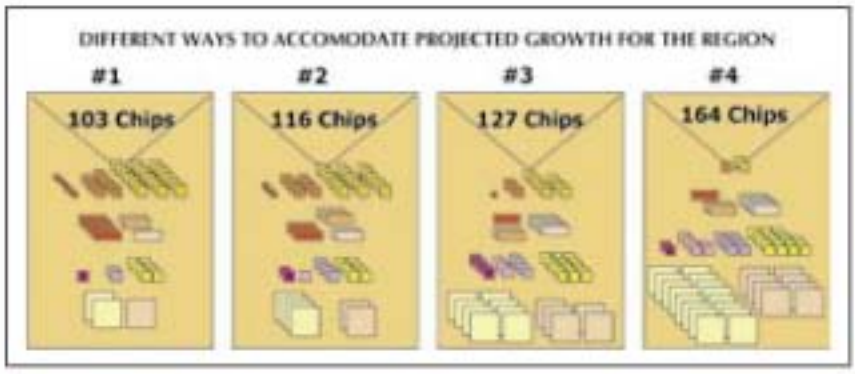

The workshop groups were given three to four "starter" sets of chips. Each chip set consisted of a different combination of 14 development types. The development types were either separate-use, auto-oriented or they were mixed-use, pedestrian-oriented. They also included different levels of redevelopment. By choosing a starter chip set, groups indicated the quality of development (auto-oriented vs. pedestrian-oriented) and the general quantity of redevelopment they wanted on their map.

To accommodate the same growth increment, a chip set consisting solely of low-density, auto-oriented chips would consume more land than a set consisting of mixed-use, pedestrian-friendly chips. The workshops allowed participants to grapple with these tradeoffs. Each workshop group had to reach consensus on tradeoffs of low-density versus compact growth, redevelopment versus greenfield development, and other important development issues facing the region. As the exercise progressed, groups were allowed to trade chips if their preferences changed. In order to accommodate the region's projected growth, however, the final number of households and jobs had to remain constant after trading.

In conjunction with land use decisions made by placing chips, workshop groups marked ideal improvements and additions to the regional transportation system. This task serves as one example of how the workshops responded to the demands of its participants. As more and more workshop groups were eager to plan transportation improvements and modes, the final workshops provided participants with various colors of tape to delineate planned transportation improvements. Since the transportation options were described in detail *(see Appendix I)*, participants could then coordinate development with appropriate transportation service and even calculate the costs of the transportation improvements.

At the end of each workshop, the groups had the opportunity to present their own visions and ideas about growth. This exchange proved valuable, informative and enjoyable for the participants.

A woman presents the results of her group's work to the rest of the workshop participants.

Workshop Results

The workshop maps were compiled into a Geographic Information System (GIS) database that identified and analyzed the location, type and number of chips placed on each workshop map. Composite maps also were made of the transportation networks and open space corridors envisioned by each workshop group. The composite maps then formed the basis of the draft Growth Vision scenario – an alternative for future regional growth shaped by the visions and wishes of Southern California residents. The following summaries outline the common land use and transportation characteristics among workshop maps, as well as key differences between the various workshops.

Land Use

Whether or not the criticism of Southern California as an area of sprawl is true, there is a limited amount of easily developable land left in the region. That means there will be little opportunity to sprawl in the future. With this truth in mind, most of the workshop groups opted for higher degrees of infill development.

The workshop participants showed a strong preference for development in mixed-use centers and corridors. A surprising majority of workshop participants chose the most intense, mixed-use starter chip set (Chip Set 1). Chip Set 4 often approximated development trends from the 1990s or was slightly more compact. In most sub-areas, this chip set consumed all remaining undeveloped land. Of all the sub-area workshop groups, not one chose Chip Set 4.

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The vast majority chose either Chip Set 1 or 2, both of which contained a majority of mixed-use, pedestrian-oriented development types. Through their chip selection, workshop participants indicated that they do not prefer one style of development over another. Instead, they seek choices and a wider array of options in building their future.

In nearly every workshop, participants demonstrated the importance of the region's transportation corridors. Through the placement of high intensity land uses and improved transit and auto service, participants assured a place in any scenario for these important corridors.

Conservation of existing parks and mountains was a high priority for many workshop groups. These groups sought to enhance networks of green corridors through mountain ranges and along rivers, particularly the Los Angeles and San Gabriel rivers, and worked to incorporate wildlife habitat corridors in their plans.

Tranportation

Consistent with the surveys, the workshops illustrate that transportation networks are indeed on the public' mind. Workshop groups often complained of congested freeways and routes, but they also proposed many solutions to the problem. While many participants advocated expanded capacity or new alignments, the majority used land use decisions and alternative means of transportation in addition to the more conventional manners of addressing congestion. This again illustrates that people want a wider range of options in their quest to achieve better mobility.

Workshop maps and comments also called for better access to transit and more comprehensive transit systems that approximate commute flows rather than remaining within political boundaries – most often with connections between Orange and Los Angeles Counties. Even residents who do not use transit supported upgrading transit networks. Many called for greater access to local bus routes for students and seniors.

Compilation map representing the sum of all land set aside for conservation by the more than 100 workshop groups.

Workshop Variation

The development types that participants typically chose to accommodate growth were heavily influenced by where they lived. For example, participants in the Downey workshop were much more likely to emphasize corridor reinvestment and intense, mixed-use centers than were participants in Palmdale, or even in built-out areas such as Garden Grove and the San Fernando Valley.

While many of the workshop groups opted for redevelopment over greenfield development, the workshop exercise exposed the difficulty of redevelopment in accommodating projected growth in nearly built-out areas such as the Los Angeles Basin and San Fernando Valley. While a strong desire to reinvest in the historic downtowns of San Bernardino and Orange Counties remained, interest in redevelopment was generally low in these counties compared to Los Angeles County. The High Desert cities incorporated more single-use development and fewer mixed-use centers than most other parts of the region. However, workshop participants continued to locate mixed-use development in High Desert city and town centers.

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Residents in the Coachella Valley, the High Desert and other, more remote communities created more roads than other places. This is most likely due to the available land, recent growth, and the prevalence of automobile travel in these areas. While new roads mean more travel options, they also hamper conservation measures envisioned by many participants. Imperial County generally prioritized transportation connections to San Diego over connections to Riverside or Orange Counties.

The workshop participants encountered challenges in thinking regionally. Many were concerned with the effect of a regional scheme on other cities or neighborhoods on their maps. Similarly, others focused growth and improvements in areas they knew best – their own cities or neighborhoods – and did not attempt to change other areas. This stands in contrast to experience in other similar exercises where locals shun the idea of growth in their own neighborhoods and place disproportionate amounts of development in other communities.

Web-based Outreach

Compass also has used the world-wide web extensively to maximize outreach to Southern Californians. The award-winning Compass website offers a range of valuable resources, including news articles and reports related to regional planning and growth. It also offered several ways to get involved in the Compass process. Since not everyone could attend a workshop, web-based access to workshop information was made available. A web-based survey also was conducted so that people could respond to the issues of regional growth at a convenient time and place for them. The web survey was consistent with the phone survey. The Southern California Compass website was the recipient of an American Planning Association award of excellence.

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Coordinating Land Use With the Regional Transportion Plan

As a metropolitan planning organization, SCAG is required by federal law to create a Regional Transportation Plan (RTP) that determines the needs of the transportation system and prioritizes proposed transportation projects. The RTP is also necessary to obtain and allocate federal funding for regional transportation projects. The RTP must be updated every three years to ensure that the plan adequately addresses future travel needs and is consistent with the federal Clean Air Act. While the Compass workshops were taking place, SCAG staff was working to update the 2004 RTP.

In keeping with the philosophy of scenario planning, a research project was undertaken in partnership with the SCAG RTP team to examine the effects of land use on regional transportation performance. Various regional development scenarios – alternative snapshots of land use 30 years into the future – were created to measure the various impacts of land use on congestion, vehicle trips, transit use and air pollution. The research was undertaken with the understanding that the scenario analysis would inform both the RTP and the Growth Vision. Incorporating land use into a regional transportation model is nothing short of a paradigm shift in the way regions plan transportation. The outcome of this scenario analysis will have tremendous implications for future RTP cycles in Southern California and regions nationwide.

To study the effect of alternative land use designs on regional transportation performance, multiple regional development scenarios were created through SCAG's Planning for Integrated Land Use and Transportation (PILUT). Two "bookend" PILUT land-use scenarios were developed to compare variations on regional trend scenarios and the draft Growth Vision scenario. One bookend, PILUT 1, focused on infill development in existing cities while the PILUT 2 distributed growth over a broader area in newer cities. Comparing these two extremes to the Trend Scenario provided valuable lessons for the Growth Vision principles and the Growth Vision scenario. Below is a summary of the PILUT scenario analysis process and its findings.

PILUT Scenario Analysis

How the Scenarios Were Modeled

A detailed land use model can help create scenarios that more fully test the integration of land use and transportation than regional transportation models can alone. Through the use of robust computer planning tools, development types were combined to create the two PILUT scenarios. These scenarios were designed to test two possible future outcomes. The PILUT scenarios were engineered not as draft visions but as studies that could help create a draft vision. Measures of the effects of the PILUT scenarios were then compared to the same measures of various baseline or trend-based scenarios.

Both the PILUT 1 and 2 scenarios consist of the same population as the total projected by SCAG for the trend scenarios and approximately the same distribution among the counties. In defining the scenarios, SCAG provided a mix of housing and jobs for each of the seven modeling zones within the region. This allocation was broken down to include population, households and three categories of employment.

The PILUT methodology incorporated many datasets from a variety of sources. The primary reference layers were from SCAG (regional land use 1993), satellite data (1992 and 2001), and Census data (1990 and 2000). Additional data included general plans for each of the counties, environmental layers, and derived layers from a digital elevation model. These layers were combined to create a database that could be queried to provide the most accurate land use information available.

The overall strategy in developing the map layers was to identify developed, environmentally constrained, and committed (publicly owned or tax exempt) land. The model assumes that publicly owned land is not available for either development or redevelopment, and removes it from developed and vacant inventories. Environmentally constrained land was also removed from the vacant land inventories in order to leave it in its natural state as much as possible. The resulting inventories of vacant and developed land are assessed for suitability for development and redevelopment, taking into account the land's proposed density and connection to infrastructure.

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In addition to the detailed land use models that are used to both establish scenarios and monitor crucial themes (such as types of jobs and housing and the amount of vacant land versus infill development), SCAG maintains transportation models that use these scenarios as inputs. These models are capable of measuring the changes in land use, and in conjunction with current and planned infrastructure, of determining how the region's travel will be affected by the future growth.

The Trend Projection

As part of the RTP update, SCAG performed a detailed analysis of the region's existing conditions. This inventory counted the location and variety of the region's jobs, households and people. The modelers at SCAG then integrated this inventory with the transportation system and behavioral patterns to understand impacts on travel. Finally, the modelers developed a series of alternative land use scenarios.

One scenario, known as the Baseline alternative, represents what is likely to happen given the continuation of existing trends. Scenario planning relies on the idea of a Baseline alternative because it serves as a point of comparison for other alternatives. The Baseline is a prediction of where the future jobs and people will locate within the region if policies remain the same. It represents the continuation of current development trends, with adjustments made based on local input. The Baseline scenario for the Compass project is known as the 2030 No Project scenario. In the RTP process, several trend-based scenarios were created.

The Trend Projection

The process used to create the PILUT scenarios is very similar to the process participants in the workshops used to create their plans for the region's future. The scenarios were built by placing development types, representing a mix of land uses, throughout the region. The 17 development types (See Appendix II: Scenario Allocation Development Types.) used to create the scenarios are more detailed and refined than the ones used in the workshops, but they are similar in that they are based on places experienced by residents and workers alike.

The components of the development types are "building types," which were established based on real world examples found within the Southland. The building types represent a wealth of data – from jobs and housing types to the mix of land uses to building height and parking requirements – applied at the smallest level of geography available (about five acres). Each development type represents a unique grouping of building types.

At their most basic level, development types represent households and employees for a given amount of land. In addition to this simple representation of density, information can be associated with these development types indicating many factors, such as the amount of impervious surface, percentage of rental units, single-family and multi-family mix, infrastructure costs, and other derived assumptions. Scenarios were populated using development types, allowing for direct comparisons between them via evaluation criteria such as land consumption, comparative infrastructure costs, and housing and job profiles.

The scenarios themselves also are host to a wealth of data that can be used for further modeling or analysis. The following is a description of the two PILUT scenarios and the results of the scenario analysis.

Developed Land

Vacant Land

Environmental Constraints

In order to develop a land use model, developed and vacant land must be identified and environmental constraints removed.

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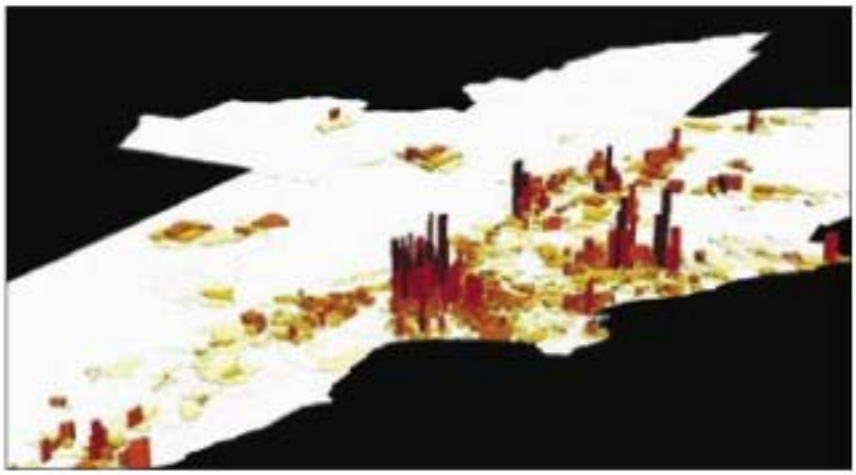
PILOT Scenario Analysis Results

PILUT 1

This alternative is often referred to as the "infill" scenario. It's based on an intense realization of the growth potential of the Coastal Basin of Los Angeles and Orange Counties and the San Fernando Valley. In PILUT 1, both jobs and housing growth would be focused on existing centers and corridors throughout the region. The majority of the workshop maps used similar strategies for accommodating growth.

In this scenario the city of Los Angeles, building upon its growing multi-ethnic population, will be transformed into an international city rivaling any in the world. Los Angeles would be home to significant amounts of growth, with most of it occurring through infill development. The intensive network of transportation corridors would be the target of significant reinvestment, creating highly desirable places to live and work in the central city that are near excellent transit service.

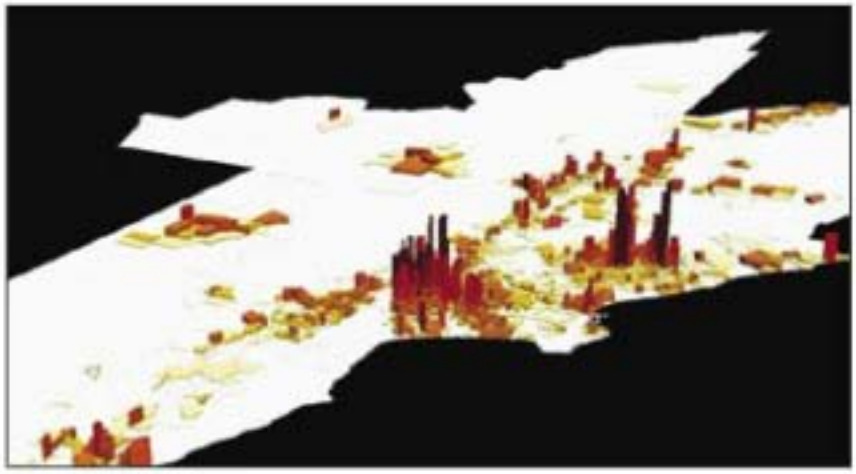
Beyond the Coastal Basin, cities would experience a significant amount of investment. To reduce trips and make transit more widely available, development that might currently locate along interchanges instead would be focused on the combination of existing well-connected road networks, transit access and services. This development would be mixed use, with close proximity to goods and services for new households.



A geographic representation of PILUT 1 shows intensity of development by TAZ.

PILUT 2

This alternative is often referred to as the "Fifth Ring" scenario. It is based on a broad distribution of future growth in the region. While the basin is still popular, an increasing share of growth will locate in newer cities. Places such as Palmdale and Ontario would become regional centers, with growth similar to that experienced by Orange County in the 1960s and 70s. Because most of the development occurs at the edge of what is current development, many towns and cities that today are separate from one another will grow together. The growth of the outer ring cities will transform the region, bringing economic growth to areas that have seen mostly housing development over the last decade. The region will become even more polycentric, with Palmdale, San Bernardino/Riverside, and Los Angeles operating as the three large centers from which growth extends.



In PILUT 2, outlying areas are a focus for growth.

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With the outward expansion in business growth, Los Angeles will not see the extent of growth seen in PILUT 1. With job growth focused around the Ontario airport, San Bernardino and Riverside will merge to become one unified job destination. Palmdale will grow at a rate and density similar to Las Vegas during the last decade – minus the casinos.

There will be a significant number of new jobs coming to these emerging areas as manufacturing finds its place among the new investments in airports and centers. Accompanying all of these jobs are thousands of new homes, ensuring a balanced mix of jobs and housing that will allow the transportation system to work most efficiently.

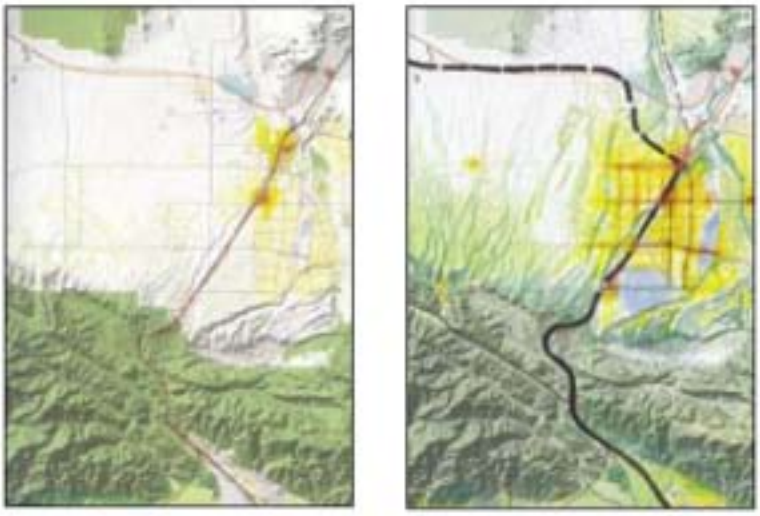
Within the centers themselves, housing will play a smaller role, since commerce is more predominant. These areas will, however, be home to a significant number of homes, primarily multi-family with some small-lot, single-family housing at the edge. Redevelopment and infill will continue to play a role in the development of new housing, likely continuing at about the same pace as today.

PILUT Performance

The two PILUT scenarios, using land use integrated with transportation, modeled significantly better than the conventionally created scenarios, the projected trend, and the composite of local plans. Specifically, with the same amount of investment, there was significantly less congestion and slightly more transit and walking than unaided. When the results are taken in whole, it is clear that either of the PILUT land use scenarios would be superior to the trend scenarios – and that they would achieve benefits equivalent to billions of dollars of transportation investments. Clearly, smart land use choices are one of the best potential strategies that can be used today. It is interesting to note that while PILUT 1 and 2 have very different distributions, they have similar development patterns that were developed by SCAG's Growth Visioning Subcommittee. When these principles are implemented, transportation improves to some extent, regardless of the specific location of development in the region. This is a robust strategy – it works well in many scenarios.

Toward the Growth Vision

Both PILUT 1 and PILUT 2 are plausible scenarios in the long term. But because they are "bookends," neither scenario represents a story about growth that is readily feasible in the short term. Both require significant and immediate policy changes. PILUT 1 requires policy changes at the local level to focus infill in existing centers, in transportation corridors, and around areas with high quality transit service. While PILUT 2 also would require significant policy changes to achieve its compact form, it also requires intensive investment in transportation facilities to spur the employment growth required in the High Desert. Based on results of the PILUT scenario modeling and the workshops, the team began to create the Growth Vision alternative.



PILUT 2 (right) places more growth in high desert areas such as Victorville compared with PILUT 1 (left).

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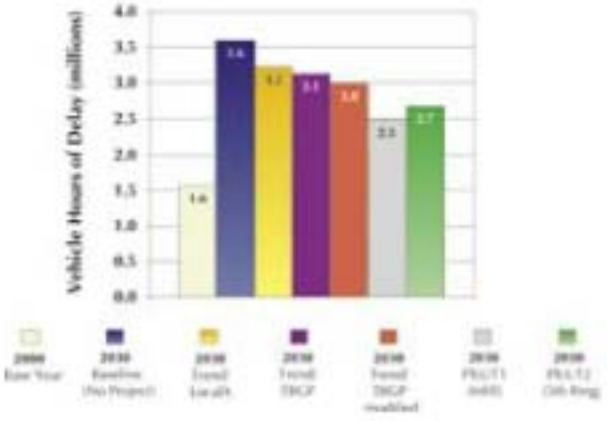
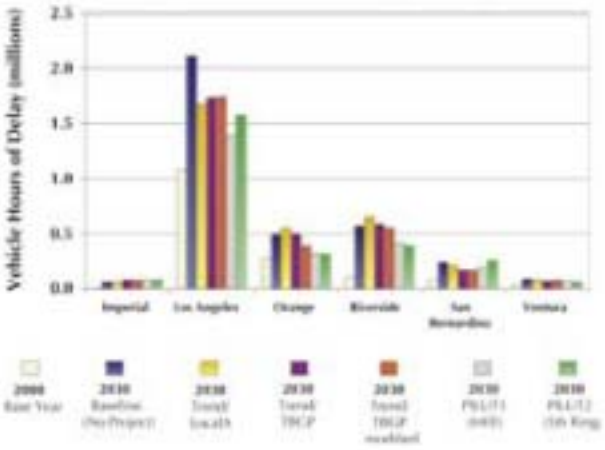
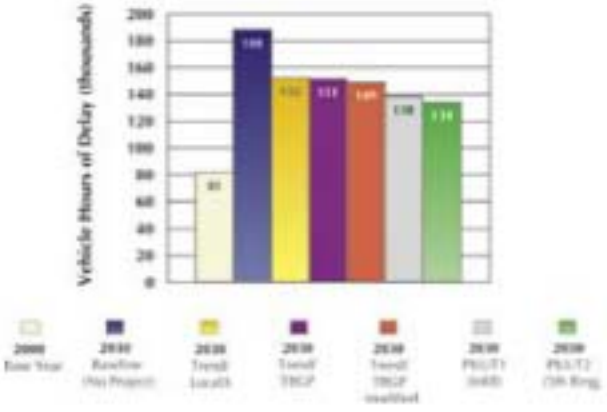
Regional Daily Vehicle Hours of Delay



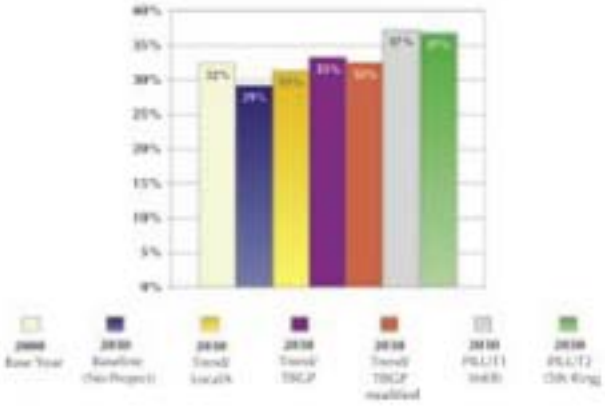
Daily Vehicle Hours of Delay By County



Heavy Duty Truck
Regional Daily Vehicle Hours of Delay



Transit Accessibility
(PM Commute Trips Within 45 Minutes)



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Putting it Together: The Growth Vision

The foundation of the Growth Vision is built on lessons learned from surveys, workshops, scenario modeling sub-regional review sessions and policy dialogues.

Fundamental among the "lessons learned" from the PILUT scenarios is that the physical limits on developable land, from mountains and streams to existing development, will require finding new ways for the region to grow. Unable to rely on a never-ending supply of usable vacant land, cities and developers will need to focus on mixed-use development and on locating new jobs and houses in developed areas that are capable of supporting additional growth.

The network of transportation corridors provides a strong backbone for future land use in the Growth Vision alternative.

The region is rich with efficient and well-connected centers and corridors. These are prime areas where investment in infrastructure can act as a catalyst to focus growth. Development in these areas provides residents with many options for travel – from foot to bus to car – and minimizes reliance on scarce vacant land. Modeling has shown that more intense development, along with a mix of uses in these areas, has a great effect on reducing regional congestion.

Residents of the Southland can be open to higher-density development, especially when it brings investment to areas in need or preserves the region's open space. There is increasing evidence that new forms of higher density housing, when combined with the proper amenities and urban environment, are successful in the marketplace.

The amount of land that the region might consume does not depend on differing policy choices as much as it depends on the many smaller regions surrounded by rural land. Because there is such a limited supply of available land near infrastructure, the amount of land consumed in the future is less important than how the land is used.

The strategy of combining compact, mixed-use development with housing and jobs near major transportation infrastructure proved to be of enormous benefit in accommodating future growth. There is much evidence that a reduction in vehicle driving occurs in areas where land use and transportation are integrated and densities are higher. In a congested region such as the Southland, integration of land use and transportation has an even greater effect.

Higher density housing along the Wilshire Boulevard corridor.

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Foundation of a Vision

The lessons outlined in the last section provide the basis for crafting a vision that uses the four Growth Visioning principles.

Again, the foundational principles for developing the Vision are:

- ✔ Improve ***mobility*** for all residents
- ✔ Foster ***livability*** in all communities
- ✔ Enable ***prosperity*** for all people
- ✔ Promote ***sustainability*** for future generations

The Growth Vision is based on a combination of inputs, namely:

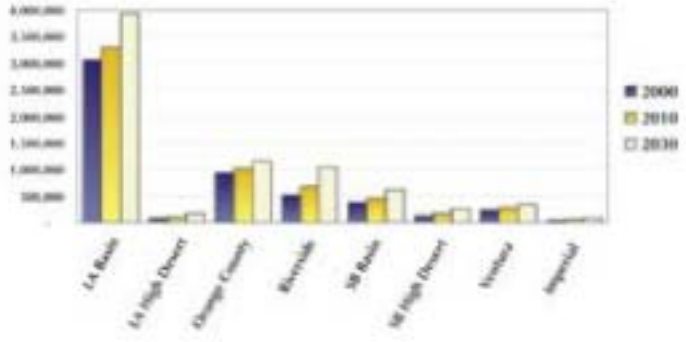
- The Growth Visioning principles
- Composite of local government general plans and input to SCAG
- Pojected demand for jobs and households
- Compass workshops and survey results
- Lessons learned from the PILUT research
- Sub-regional review sessions
- Policy dialogues

Creating the Growth Vision alternative is one way to combine these principles into a viable and realistic alternative. It is important to note that there are many ways to configure the Growth Vision alternative and still achieve the same (or better) results. The important decisions are the principles, strategies and performance of the results. In crafting a practical Growth Vision for the region, the goal should be to achieve high performance and beneficial results – while tailoring the land use and investments to local needs and wishes.

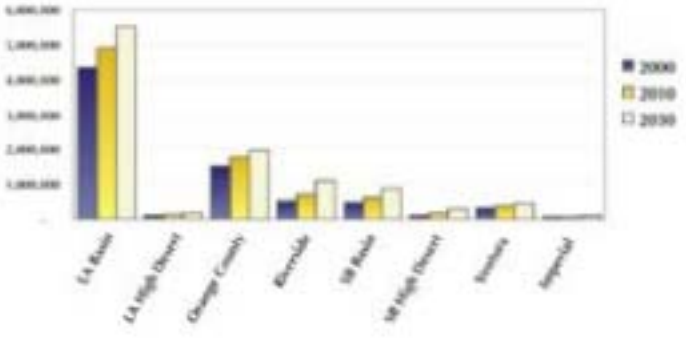
Short-term Issues

It was important to include SCAG's projections for 2010 into the Growth Vision process so that the two projects can be folded into each effectively. While many of the policy changes depicted by the Growth Vision scenarios were positive, it may take some time to incorporate them into local ordinances and local development practices. By building the Growth Vision alternative on top of the 2010 projections, a full six years is incorporated for "ramp-up," or adoption of new policies and acceptance of new building styles. Further, the alternative was designed to recognize the local input received by SCAG during the RTP process. While the locations of jobs and housing are significantly different than in the conventional models, for the most part the total projection is very close to that requested by the member jurisdictions of SCAG.

Households by Year



Employment by Year



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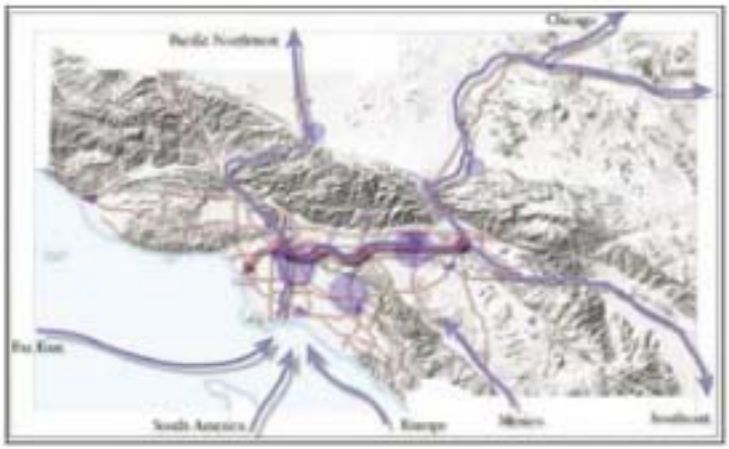
Prosperity: Economic Drivers

Southern California is an international center for freight, manufacturing, services and artistic production. These traditional sources of job growth will be reinforced in the regional vision through investments and strategies that bolster the local economy.

Southern California will continue to be both the cultural and financial center of the western United States, with major markets in Asia and Latin America. With increased opportunities for work and significant reinvestment, the motto will surely be "place matters." Major employers and corporate headquarters, along with start-up and creative-class businesses, all will be drawn to the region's core.

In addition to a commercial and cultural core, the region depends on the free flow of goods from its ports to maintain a healthy economy. The Growth Vision will help ensure the movement of freight flows efficiently through the region. Its aim is to reinvigorate the economy in the short term with road and rail improvements and to carry on long-term prosperity via the free flow of goods. The Growth Vision calls for upgrading much of the region's freight movement infrastructure. Dedicated truckways would be built along many sections of busy freeways to improve the movement of freight truck traffic. Railway improvements along specific corridors would move freight more efficiently. A MAGLEV train would offer an alternative mode for regional travel, to reinforce the larger business centers, and to improve the connections between the region's airports.



Prosperity will depend on efficient movement of goods into, through, and out of the region.

The success of the Alameda Corridor has spawned numerous proposals for improvements that will benefit freight movement. An inland port in San Bernardino County, which capitalizes on the regional interface between trucking, rail, and air is key among these enhancements. The ultimate vision is to provide direct rail access between the port and this major intermodal facility that will intercept through-region shipments for repackaging before distribution. Shipments for local markets still will be distributed from Long Beach but will cause less congestion.

The inland port intermodal facility will become a regionally significant employer, cementing the area's role as both a job and distribution center. In the process, a large number of currently underutilized industrial sites in the City of Los Angeles will become available for new uses.

The Growth Vision will improve freight distribution from the port of Los Angeles.

Air Cargo Demand
(Thousands of tons of Air Cargo)

Airport	2002 Tons x 000	2002 Percent of total	2030 Tons x 000	2030 Percent of total
Burbank	41	1.6%	87	1.0%
John Wayne	11	0.4%	41	0.5%
Los Angeles	1,950	74.7%	2,340	26.8%
Long Beach	58	2.2%	137	1.6%
March	0	0.0%	1,117	12.8%
Ontario	547	20.9%	2,252	25.8%
Palm Springs	0.8	0.0%	128	1.5%
Palmdale	0	0.0%	1,024	11.7%
San Bernardino	0	0.0%	1,092	12.5%
Victorville	0	0.0%	504	5.8%
Total	2,622	100%	8,724	100%

Air freight plays a significant role in the region's economy. While Los Angeles International Airport (LAX) currently handles the majority of air freight in the region, the Growth Vision proposes shifting more cargo movement to Ontario International Airport to free LAX for passenger travel. Ontario International Airport has already become a major facility for United Parcel Service, handling most shipments arriving or departing from the West Coast. With the acceleration of Internet commerce, special delivery services can be expected to increase at a higher rate than traditional shipping. Ontario Airport is planning an additional runway to increase capacity.

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Employment in proximity to Ontario Airport.

These strategies carry the potential to increase the hum of the region's economy. Investing in freight movement infrastructure will keep the region's ports healthy. Ports – the beginning points for trade and commerce – are at the heart of this region's economy. Ensuring free-flowing movement of goods is imperative to the region's economic prosperity.

The Growth Vision depicts a region of many centers. The centers, in conjunction with the high intensity corridors that contain a significant amount of the region's commerce, will be filled with the vibrancy that comes from investment and additional people and jobs. While growth will be shared, variety will be intensified. These centers and corridors will continue to specialize, providing a home to unique business and cultural elements. The critical mass that can be attained through clustering of these uses will help cement the identities of places such as Burbank with the film industry, Los Angeles as a cultural center, and job centers such as the harbor or inland port as centers of industry.

Beyond the Coastal Plain, the shape of new development will undergo change. Auto-oriented commercial uses, from stores to offices, will find vacant land with good auto access difficult to obtain. While there will continue to be areas that are dominated by auto-oriented business, redevelopment and its higher densities will become more common. Existing city centers and the remarkable network of corridors will become the choice location for new jobs, combining with existing employment to strengthen the centers. These areas are locations with well-connected street systems, a pedestrian-friendly street environment, efficient freeway access and many transit options.

The cities and towns of the High Desert will make a name for themselves as they grow into unique new places. With a large supply of available raw land and a rapid rate of growth, these areas will have the unique opportunity to go from the planning stage to realization of a vision quickly.

Ventura County will continue to embrace the value placed on agriculture and open space. The SOAR boundaries, drawn for preservation, will demonstrate their power in bringing land uses together and lessening the impact on the transportation system. As long as Ventura County can accommodate sufficient workforce housing to match its employment growth, the SOAR boundaries will have a beneficial impact on transportation – if the boundaries cause long commutes because of a lack of housing, they could exacerbate congestion. Communities in this area will grow in popularity, capitalizing on the scenic beauty and quality of life.

Farthest from the Coastal Basin, Imperial County also will retain its strong agricultural heritage. Existing towns such as El Centro will evolve as even more important commercial and cultural centers. Strong preservation of agricultural land will keep the cities from unnecessarily growing outward. Building on a compact urban form, residents will have ready access to jobs, goods, services, and cultural activities within a very short distance of their front doors.

Livable Communities

Along with the Basin's increase in employment, Los Angeles and Orange Counties will become significant magnets for housing growth. Long commutes to outlying areas will be discouraged by rising congestion and the availability of nearby jobs and services. With many new residents from areas with high urban densities, the new population will be more adapted to urban living. The new availability of old industrial sites within the Basin will provide a much needed increase in land available for housing. These areas will be transformed into new neighborhoods, complete with a range of housing options and excellent accessibility to the Basin's

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Open space protected by general plans, government ownership, or other conservation management efforts.

jobs, entertainment, and cultural opportunities. New housing will sprout at a rapid rate along the transportation corridors that define the area. This resurgence will provide housing for thousands of people through infill and redevelopment.

Throughout the region, existing centers also will become the focus for new housing. Like the Basin, but on a smaller scale, these areas will to some extent replace the demand for today's subdivisions. People will choose to live closer to work, shopping and transit. Local businesses will prosper as people enjoy shopping close to home. For areas such as Ventura and El Centro, as well as much of the region, this will mean a plethora of fresh local foods and quality local products. People living in the bustling urban core will find daily needs and cultural opportunities easily accessible. With a great variety of transportation choices as well, people living in commuter suburbs will also reap the rewards of a livable region.

Suitable housing will be available to everyone, regardless of where they live in the region. There will be a wide variety of housing choices – from public housing to multi-family housing and single-family homes – that are within the means of the majority of the labor force. Although many affordable housing units will be built through infill development, a fair share of workforce units will be located throughout the region, not just in the inner urban areas.

The same growth strategy that helps the Growth Vision perform so well on transportation models also makes the Growth Vision more equitable. The Growth Vision's focus on balanced development – ensuring that workforce housing is built near job rich areas, and that both are served by good transit services – shortens commute trips and makes jobs and housing more accessible to people without cars.

The Growth Vision also depends on investment in important regional infrastructure and transit services that satisfy the transportation needs of the labor force throughout the region. Transit services that serve low-income residents are enhanced and upgraded in the Growth Vision.

Sustainability

Sustainable cities pay close attention to their environment – recognizing correctly that it contributes significantly to an area's quality of life and that it creates a sense of place and character. Humankind has always modified the environment to meet its needs, but throughout most of history these changes have been, by modern standards, relatively modest adjustments to the landscape. It is only recently that such monumental attempts to control the landscape, as are commonly seen in American cities, have been made to develop land. Steep slopes, flood plains and wetlands are persistent features in the environment that have historically shaped development. Disregarding the risks involved in urbanizing them is potentially an enormous community liability, both financially and in terms of predictable community disruption.

The Growth Vision seeks to accommodate growth while avoiding the development of sensitive open space resources. In developing the scenario, development was avoided on steep hillsides, areas designated as open space in local plans, protected agriculture, and areas identified as potential future open space. Actually, the avoidance of these areas increased the beneficial transportation results by concentrating new housing and jobs closer together, and by providing access and views of the natural areas of the region to its urban inhabitants.

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A depiction of the transportation network for the Growth Vision with Imperial subarea as the inset.

Mobility

The vast network of transportation corridors that help to define the Los Angeles Basin will undergo a transformation. Fueled by demand from new residents, the boulevards, with their high quality transit, will play a dominant role in people's daily lives. They will shine as a signature to the health and vitality of the Basin. Transit will play an even greater role in serving people's daily needs.

A combination of increased separate lane – or fixed guideway – bus and rail transit, along with growth in traditional buses, will enable quick and easy travel throughout the Basin. Los Angeles and Orange Counties will become part of a seamless transit network. For longer distances, high-speed trains and MAGLEV (trains that can go more than 240 miles per hour because they use magnets to hover over the guideway) will fill a role of ever increasing importance. This high-speed system will easily serve center-to-center regional travel as well as longer in-state trips.

The Ontario Airport will experience a unique type of growth as it is developed to an international standard. And by largely eliminating short distance flights, Los Angeles International Airport can shift to become more of a national and international airport without expanding the number of planes using it as a destination. These two airports will ensure Southern California's connection to the world and will further cement the region's position in the global marketplace.

Smaller airports around the region will absorb the demand for some of the flights from the rest of California and other nearby states, while the majority of the short-haul trips will occur by rail.

One of the keys to this strategy is promoting the use of freeways for long trips and local streets for short trips. The Southern California region has a good system of arterial streets that can replace the need to use freeways for short trips. In the Vision, many arterials are converted to boulevards, which are laid out in a web-like network or grid so that convenient access is provided to the greatest number of locations and multiple routes are available in times of congestion. The arterials will emphasize capacity and good design rather than speed, somewhat redefining the goals of mobility and accessibility. Only a small fraction of total daily trips in the region are longer than 15 miles, so the arterials are designed to serve trips of moderate length (up to 30 minutes) at moderate speeds (30 mph). The Growth Vision emphasizes good transportation facilities closer in, connecting our existing communities with an arterial network and planning future growth areas near existing transportation infrastructure.

Bus Rapid Transit

Ontario Airport

Maglev

AR0072667

Arterials Strategy

To reduce congestion on key streets and make them a viable alternative to freeways for medium distance travel, the Growth Vision proposes community-friendly arterials. They are designed to be safe and convenient for pedestrians as well as cars, to promote a pedestrian-friendly pattern of land uses, and to encourage alternative modes of travel.

Open spaces, landscaping, and sidewalks help make a safe walking environment.

The Purpose of A Street

Conventional highway and road planning and design has focused on efficient car movement, often at the expense of the adjacent business environment, community interaction, pedestrians, bicyclists, and others not in cars. Because of this, the word "arterial" often conjures up an image of wide roads, grit, traffic signals, and ugly roadside development. They are generally designed to have uniform speeds throughout their length, resulting in places that tend to look the same.

Multimodal streets focus on moving people, not just automobiles.

Streets for Multiple Modes

The Growth Vision views most roadways, from local streets to intra-regional arterials, as places that add to the quality of life of adjacent neighborhoods. Roads are not simply routes to move people and goods from place to place but have the potential to be quality places themselves. The focus of a roadway should be the people using it, not the cars and trucks moving through it. Roads have the potential to be many things and to accommodate a variety of travel modes. Seen in this light, a road can accommodate pedestrians as well as bikes and cars, while simultaneously serving as a community gathering place.

Arterials should be multi-modal, or multi-purpose, balancing the needs of all types of travel, including walking, bicycling, and transit, so that people have choices in how they get from one place to another. This is important for at least two reasons. To start with, a roadway with a fixed width can move more people and goods – which will improve regional mobility – if forms of travel such as walking, bicycling, and transit are used in addition to automotive vehicles. These means of travel simply take up less space per person.

An additional advantage is that walking, bicycling, and transit produce many positive qualities – they produce less pollution and noise, promote exercise and physical fitness, and spur development that is geared toward pedestrians.

Consider Streets And Buildings Together

The characteristics of each type of road suit some forms of development better than others. To take advantage of pedestrian-oriented land uses envisioned in the SCAG Growth Vision, a new circulation pattern to match these land uses must be developed – one that accommodates the car and transit and that reinforces pedestrian locations rather than isolating them. Instead of designing roads to be most convenient for cars and drivers, without regard to the resulting land use implications, it is important to consider the type of communities desired and to design roads to fit in and foster these communities.

Strong arterial design also focuses on how the adjacent buildings are designed and used. Arterial streets should not be considered by themselves, because they are defined in part by the adjacent buildings and land uses. Streets are made up of the area where vehicles move, the area where pedestrians move, and the areas where buildings interface with the rest of the street. The Growth Vision calls for street design that considers the entire right of way – travel lanes, parking, bike lanes, medians, sidewalks, and street trees – and ensures it is appropriate for and complements the adjacent buildings.

Since every trip begins and ends with walking, the pedestrian system is the primary transportation element that connects all travel modes. An arterial's pedestrian environment should move people and provide them access to adjacent land uses. A safe, comfortable and attractive environment includes a continuous system of sidewalks, wider sidewalks at congested locations, visible crosswalks, pedestrian signals, landscape buffers between sidewalks and streets, and a variety of public open spaces.

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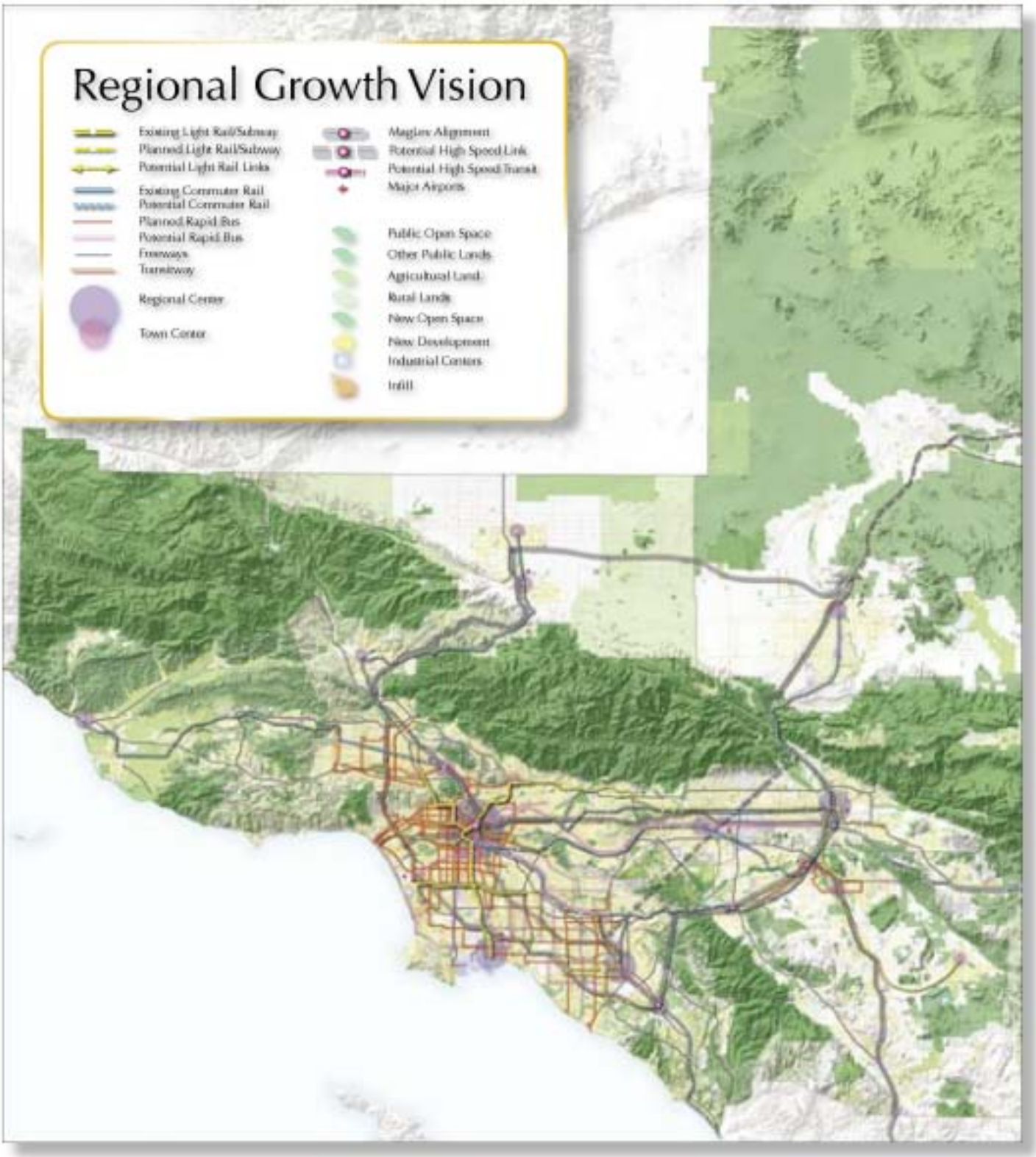
Regional Growth Vision
Existing Light Rail/Subway
Planned Light Rail/Subway
Potential Light Rail Links
Existing Commuter Rail
Potential Commuter Rail
Planned Rapid Bus
Potential Rapid Bus
Freeways
Transitway
Regional Center
Town Center
Maglev Alignment
Potential High Speed Link
Potential High Speed Transit
Major Airports
Public Open Space
Other Public Lands
Agricultural Land
Rural Lands
New Open Space
New Development
Industrial Centers
Infill

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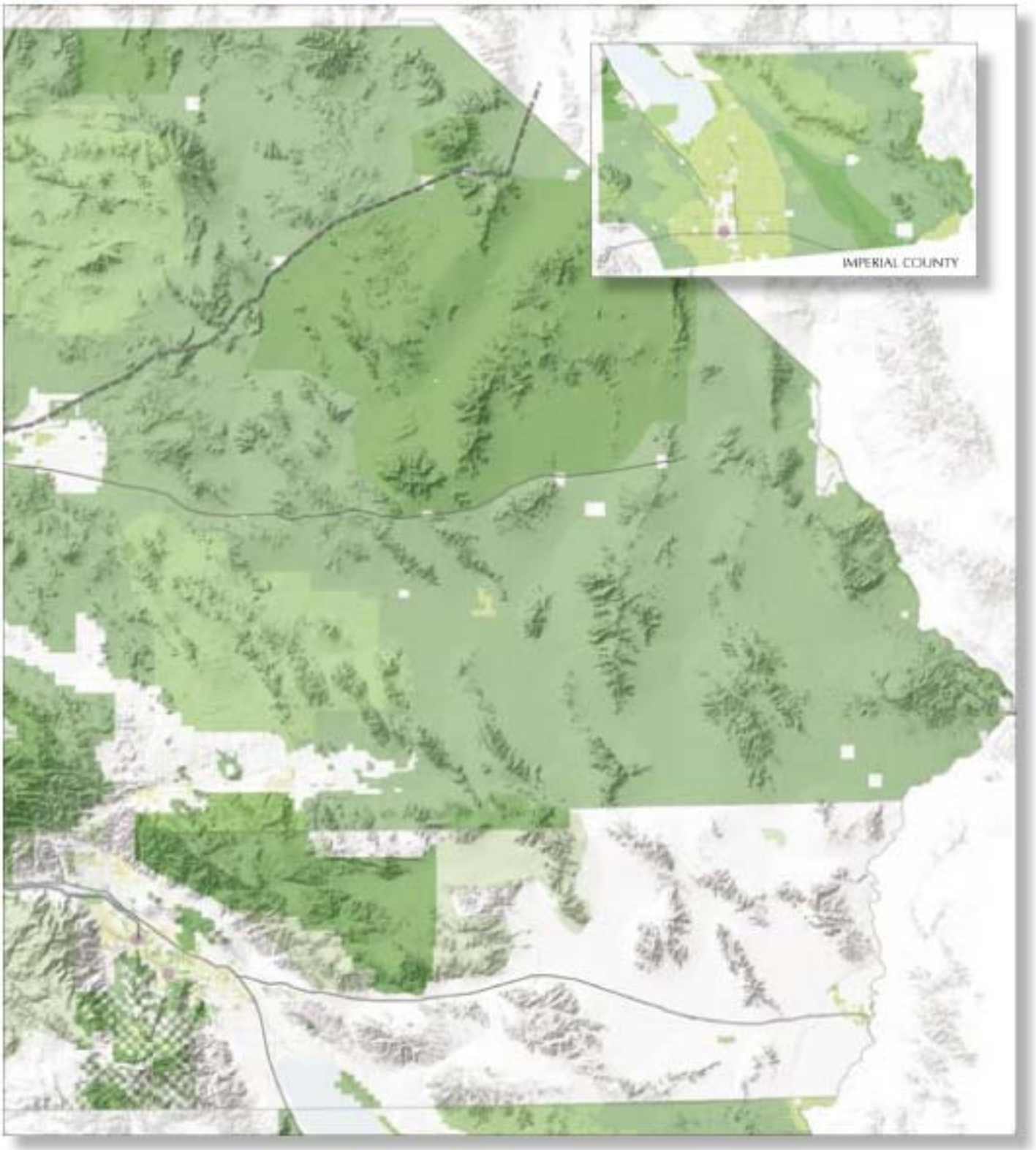

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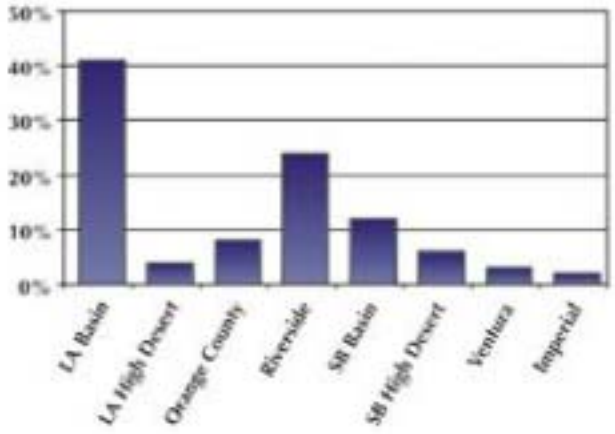
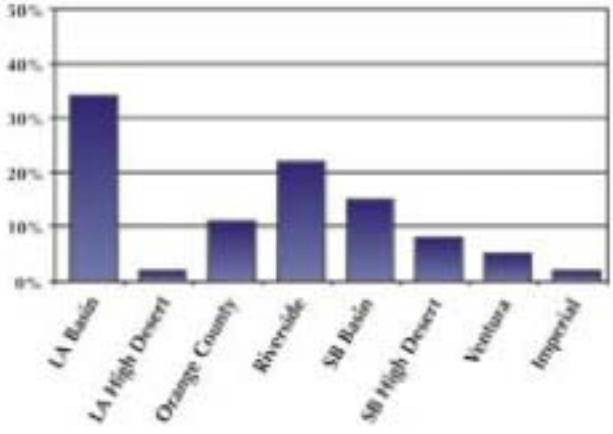
Results

The Growth Vision alternative places most growth in the Los Angeles Basin, Riverside County, and the San Bernardino Basin. These modeling zones have existing infrastructure, particularly transportation related, that allows growth to be absorbed with minimum adverse effects.

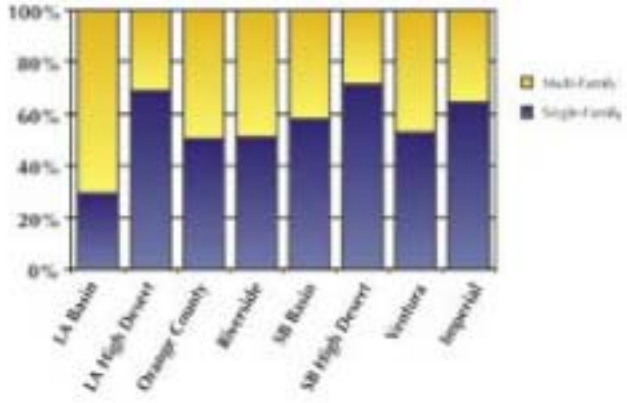
Incremental Household Distribution



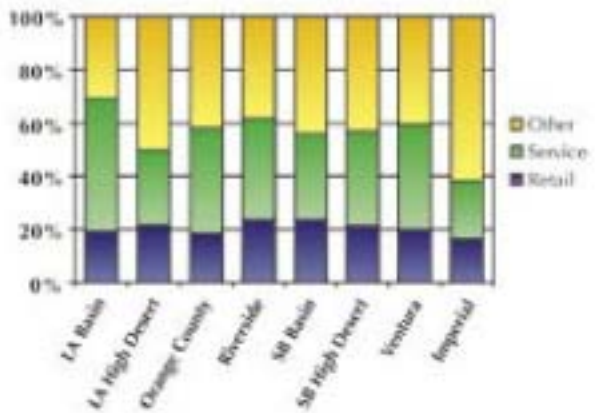
Incremental Employment Distribution



Incremental Households by Type



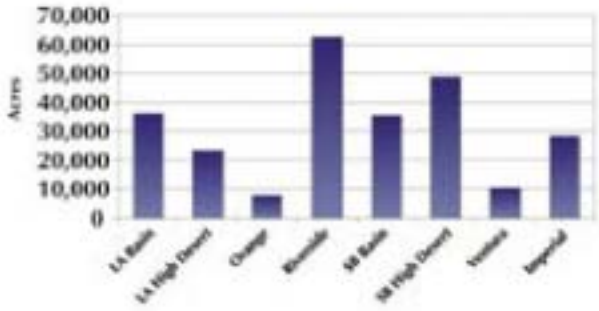
Incremental Employment by Type



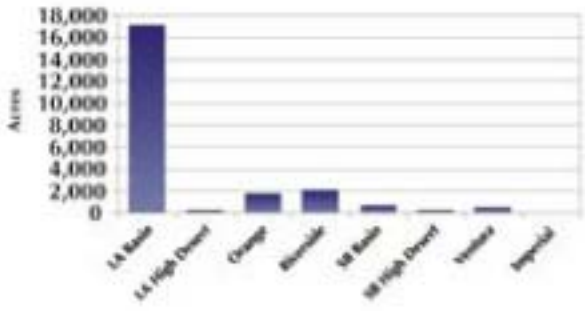
In the Growth Vision alternative, the Riverside and San Bernardino High Desert modeling zones absorb the most greenfield development – new development on vacant land. Ventura and Orange Counties have the least development on vacant land. Los Angeles Basin absorbs the most growth – both in households and employees – through infill, far more than any other modeling zone. Orange County also absorbs almost half of its households through infill.

The eight transportation modeling zones.

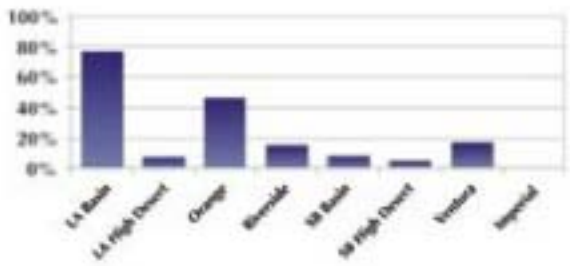
New Development on Vacant Land



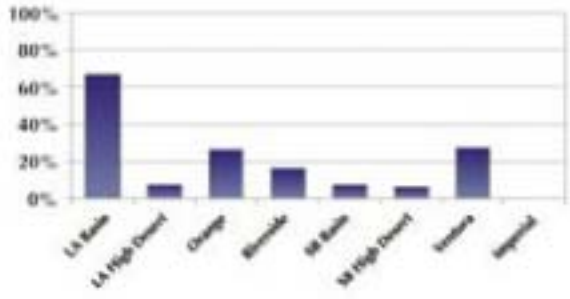
New Development through Infill



Percent of New Households through Infill



Percent of New Jobs through Infill



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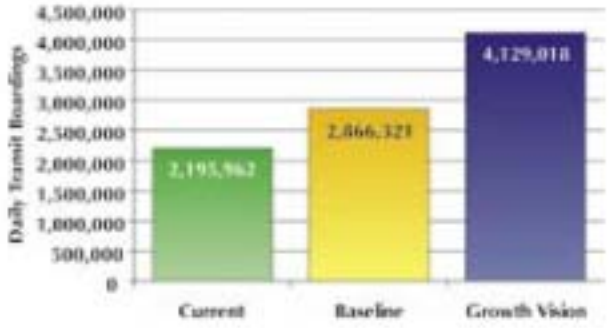
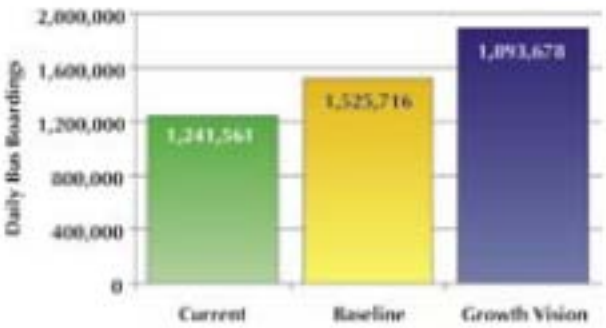
The Growth Vision alternative has much higher transit ridership than the Baseline alternative. Total daily transit boardings increase 44 percent in the Growth Vision alternative over the Baseline. MTA bus boardings increase 24 percent over the Baseline and 53 percent over the current level. The Baseline increases only 23 percent over the current level.

Total Daily Transit Boardings, 2030

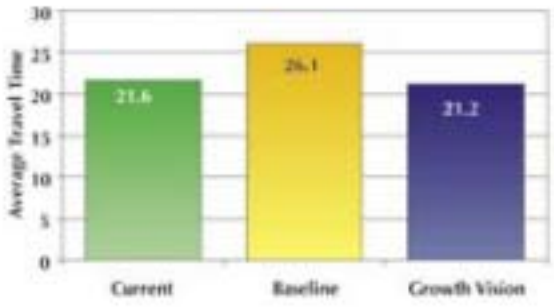


MTA Bus Daily Transit Boardings, 2030

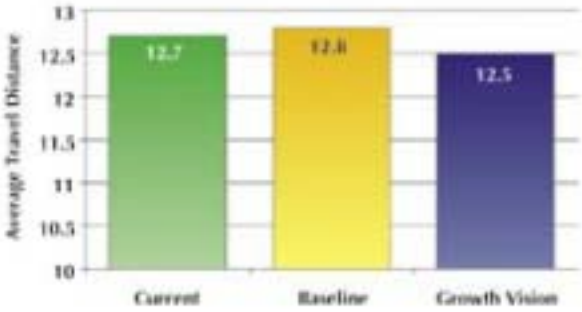


While the Baseline increases the current average travel time to work by 21 percent, the Growth Vision alternative actually decreases the average travel time by 2 percent. The Growth Vision alternative also decreases the average travel distance to work, while the Baseline increases average travel distance. The Growth Vision alternative decreases average travel distance to work by 2 percent as compared to the Baseline.

Home to Work Trips –Daily Travel Time per Person, 2030



Home to Work Trips –Daily Travel Distance per Person, 2030



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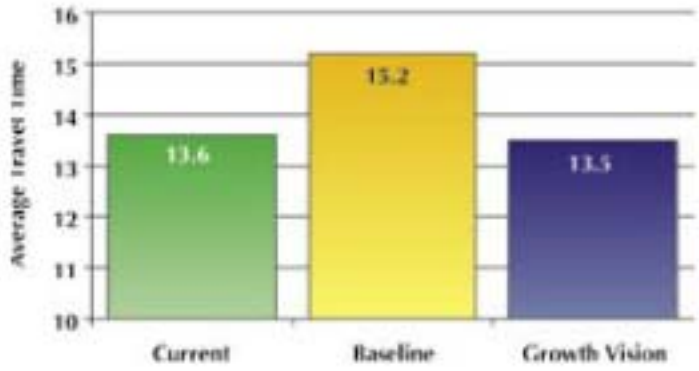
The Growth Vision alternative decreases the average travel time for all trips by 7.5 percent, while the Baseline increases the average travel time by 12 percent, from 13.6 minutes to 15.2 minutes. The Growth Vision alternative decreases average travel time by 11 percent over the Baseline.

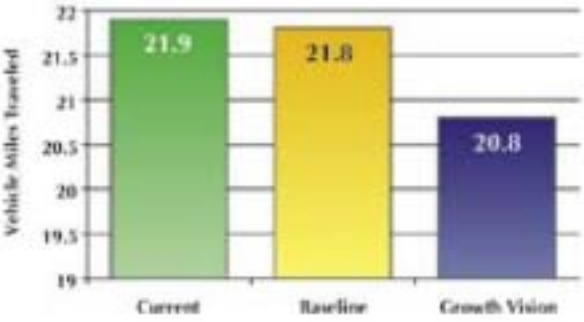
All Trips –Daily Travel Time per Person, 2030



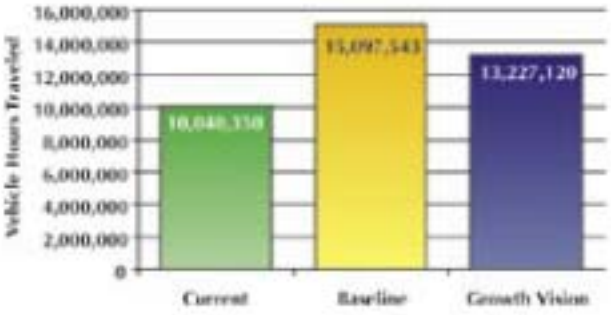
In both the Baseline as well as the Growth Vision alternatives, vehicle miles traveled per capita in the region decrease from the current level. However, the Growth Vision alternative represents a much greater decline – a 5 percent decrease compared to the decrease of less than 1 percent seen in the Baseline.

The Growth Vision alternative performs even better when considering total vehicle hours of travel. While the Baseline increases hours of travel by 50 percent compared to the current level, the Growth Vision alternative only increases the hours of travel by 32 percent compared to the current level – reducing the hours of travel by 12 percent compared to the Baseline.

Daily Vehicle Miles of Travel per Person, 2030



Total Daily Vehicle Hours of Travel, 2030



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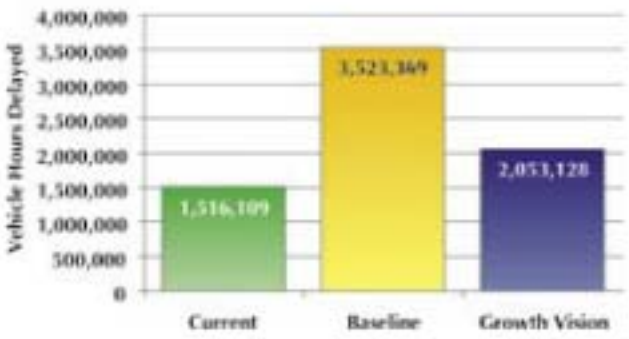
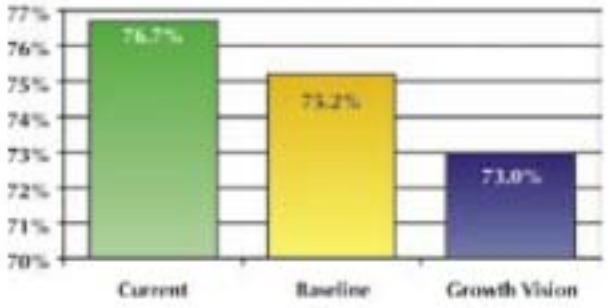
Vehicle hours of delay increase by 132 percent from the current level in the Baseline alternative. The Growth Vision alternative represents a reduction of 42 percent from the Baseline, limiting the increase from the current to 35 percent.

Total Daily Vehicle Hours of Delay, 2030

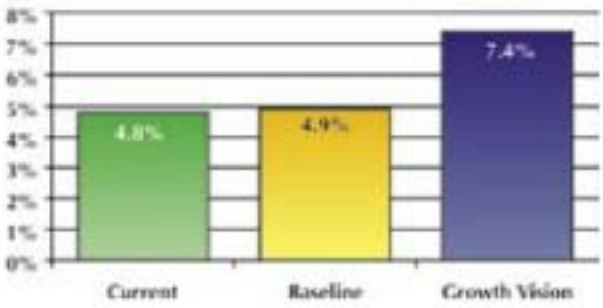


While the rate of people driving alone decreases significantly in both the Baseline and the Growth Vision alternatives, the Growth Vision alternative shows a greater increase in the transit mode split. The percentage of people using transit to get from home to work or school increases from less than 5 percent currently and in the Baseline to 7.4 percent in the Growth Vision alternative. This represents an increase of 54 percent.

Home to Work/University Trips – Drive Alone Mode Choice, 2030



Home to Work/University Trips – Transit Mode Choice, 2030



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Strategies & Performance

The transportation model results of the previous section indicate that the Growth Vision performed better than any other scenario. Transit mode split is increased while travel distance and time, vehicle miles of travel, and vehicle hours of delay all decrease. The obvious question is why: What makes the Growth Vision perform better than the Baseline scenario? What strategies contributed to the superior performance of the Growth Vision?

The Growth Vision alternative was created by thoughtfully locating a mix of land uses around the region, while taking into account current development, vacant land, the current and proposed road and transit network, and environmentally constrained areas. In this way, certain guidelines could be followed:

- Locate growth in areas with robust existing transportation infrastructure (plenty of streets)
- Locate growth in centers and along transportation corridors
- Locate growth near transit corridors/stations
- Locate jobs near housing and vice versa
- Locate heavy trip-generating development in areas with robust existing transportation infrastructure
- Avoid sensitive environmental features such as steep slopes, wetlands and stream corridors

DEVELOPMENT PATTERNS MAKE THE DIFFERENCE

Adhering to the guidelines listed to the left resulted in the following development patterns, which the Compass team believes to be the reason for the excellent performance of the Growth Vision:

Compact, Corridors- and Centers-Focused Development

The Growth Vision is much more compact than the Baseline Scenario. In the Growth Vision alternative, growth was located, as much as possible, in centers and along corridors. Growth was primarily located in existing centers and corridors, but if none existed, new centers and corridors were created.

Locating growth in centers improves transportation performance in several ways. First, the centers themselves usually have a good street network. There are many streets, options, and routes for getting where you want to go, so that not everyone will need to use the same road at the same time. Secondly, centers usually are easy to access. They are usually near freeway exits or at the intersection of other important roadways. Finally, centers are usually accessible by transit, and transit may provide mobility within the center as well. These factors allow centers to absorb growth without as much strain on the transportation system.

In addition, when employment and housing are located in centers and along corridors, trips become shorter. Housing, shopping, errands, recreation, entertainment and employment are more likely to be nearby. Even if housing or employment is elsewhere, the center or corridor encourages trip chaining for other needs such as shopping and errands.

Mixed use development

The Growth Vision employs mixed-use development, which ensures a mix of jobs and housing. Similar to the centers-focused strategy, mixed-use development brings daily errands within reach, shortening the two-thirds of trips that are non-commute trips.

Transit-oriented development

The Growth Vision located as much growth as possible near transit corridors and stations. In some cases, transit stations grow into mixed use, pedestrian-oriented centers, designed so that people can access them via transit and then walk to all other destinations.

Centers-based, transit-oriented development is particularly important for employment. Dispersed employment is almost impossible to serve via transit, because it is too expensive and takes too long. For commuting by transit to be feasible, employment density is even more important than housing density. Dispersed housing can be served by park-and-ride facilities, but dispersed employment cannot. Destinations (employment) must be close to transit stations. In the Growth Vision, employment density near transit corridors/stations was very high, in order to locate as many jobs as possible near transit and to make transit a viable commute option.

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Sub-Regional Review

Southern California Compass conducted review sessions with city planners, public officials and local experts in an effort to refine the Growth Vision scenario that arose from the PILUT scenarios and workshop results. The SCAG region consists of 14 sub-regions, each of which operate as councils of governments in their own right. In an unprecedented effort to include sub-regional input and refine the draft Growth Vision based on local commentary, SCAG hosted review sessions in nearly every sub-region – often more than once. Through reviewing the Growth Vision scenario maps with SCAG, with neighboring jurisdictions and with sub-regional coordinators, local planners, officials and experts refined the public's ideas in finer detail and shaped the draft Growth Vision scenario to make it more consistent with sub-regional growth visioning efforts. In most cases the sub-regional review sessions confirmed the concepts behind the vision and tailored the scenario to a level of detail that only local knowledge and experience could provide.

The sessions showed consistencies and differences between sub-regions and the draft Growth Vision scenario. Open space provisions were consistent between the Growth Vision and much of the local planning initiatives in the region. Yet they also showed differing expectations concerning future housing, jobs and development. Local planners were concerned that entitled and recently constructed projects were sometimes not shown in the Growth Vision scenario. Since the draft Growth Vision scenario was based on public and regional input at the time of the review, local representatives were aware of new and pipeline projects that may not have been known by others. Other comments sought to better coordinate mixed-use centers with existing commercial developments.

The sub-regional review sessions shed light on existing growth visions and opportunities for future collaborative visioning efforts. Just looking at the maps of the Growth Vision and local plans made apparent the local competition for commercial development and opportunities for better land use and transportation coordination between cities. At the same time, the sessions created the opportunity to coordinate the Compass Growth Vision with sub-regional visions already under way. Such visioning efforts have been a great success and, as shown later in the implementation section, local officials and Compass agree that sub-regional visioning is key to achieving the goals of the Growth Vision and a sustainable Southland. *(Individual subregional review sessions are summarized in Appendix.)* The Growth Vision and sub-regional review sessions also serve as valuable input to the Regional Transportation Plan (RTP) and are further discussed in the Coordination With the Regional Transportation Plan section below.

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Next Steps: Implementation

Southland Policy Dialogues

After the ideas from the public workshops were refined into the Growth Vision and the Growth Vision scenario was vetted in the sub-regional review sessions, Compass returned to the sub-areas where the map-based workshops were held to conduct five Southland policy dialogues in March 2004. By exploring the tools to make the vision a future reality, the dialogues represented an opportunity to "close the circle" from the map-based workshops. The dialogues aimed to achieve the following:

- Familiarize leaders across the region with the draft Growth Vision
- Help leaders to understand its implications for growth-related decisions within Southern California's sub-regions
- Identify barriers (regional and local) to effective implementation of the Growth Vision
- Develop priorities on key implementation strategies for SCAG, local governments and other decision-makers

At the dialogues, a diverse array of public and private sector community leaders explored implementation strategies, with a particular emphasis on the programs and policies needed to achieve the Growth Vision. Attendees at the dialogues included local civic leaders, government officials, business owners, developers and representatives of state agencies. Nearly 200 local community leaders participated in the five dialogue sessions.

The dialogue participants were asked a series of questions within each of the Growth Vision's four categories of guiding principles: mobility, livability, prosperity and sustainability. The questions were:

1.) What changes in local, regional and state decisions will need to be made in order to achieve the Vision?

2.) What are the barriers to those changes taking place?

3.) What policy and program strategies would help overcome those barriers?

4.) Given the near-term state budget crisis and its implication for transportation and conservation funding (as well as local government services) what needs to be defended to ensure that the longer-term policy and program strategies are not impeded by near-term policy and funding decisions?

Leadership Southern California Class XIV (a diverse group of 48 leaders from across the region) assisted in organizing and executing the dialogues. In addition to the five dialogues held throughout Southern California, a "pilot" Southland policy dialogue was convened with the participation of the 48-member Leadership Southern California (LSC) Class XIV. This group provided invaluable feedback about the Dialogue presentation and discussion format. In addition, many LSC Class members and alumni attended the dialogue sessions.

Policy Dialogue Findings

Key themes emerged from the dialogues in all sub-regions. *(Summaries of the policy dialogues can be found in Appendix IV.)*

Dialogue participants agreed that the region is likely to reach the population growth projected by SCAG for the Compass project (6 million additional people), though when that will occur was debated. To achieve the goals of the Growth Vision in accommodating such growth, policy dialogue participants came to some conclusions, disagreed on other issues, and asked more questions. While each of the policy dialogues produced unique ideas, three broad categories of ideas encompass the majority of the input. The first is the need for better collaboration and coordination of planning. The second theme is recognizing the importance of, and creating incentives for, the private sector and local decision-makers. Finally, there was significant call for sustained education and consensus building.

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Better Collaboration and Coordination of Planning:

A primary theme of policy dialogue comments and ideas was better collaboration and coordination. Participants felt that SCAG and sub-regional agencies need to foster better coordination and collaboration among different levels of government, among the various agencies that affect land use, and between land use and transportation planning.

The idea that "sub-regions matter" was a resounding message at the dialogues. Participants emphasized the importance of planning that is tailored to the particular needs of a sub-region. Through the collaboration of sub-regional visioning efforts and the Growth Vision, Compass has acknowledged this need and taken the first step to making the vision a reality at the sub-regional scale. The diversity of the Growth Vision Subcommittee and the multiple public workshops have also helped Compass address the diversity of issues inherent to such a large and variegated region.

To continue along this path, better collaboration of the multiple scales of government and land use planning entities is necessary, according to dialogue participants. The principles need to be acknowledged and acted upon at the state, regional, sub-regional, local and community levels. For example, state agencies and regional agencies have tremendous impact on transportation infrastructure, while local entities have greater control over land use. With this understanding, participants expressed a desire for greater partnership with state agencies. At the same time, SCAG sub-regions are increasingly creating their own visions of growth to coordinate between their cities. Community planning initiatives also shape the design of open space, main streets and local districts. Participants recognized that these various jurisdictions exist and each has a unique role in land use and transportation planning. Achieving the Growth Vision therefore means relying upon and coordinating between each of these entities and levels of government.

The policy dialogue participants also stressed the need for collaboration among the many local public agencies that make land-use decisions. Transportation agencies, school districts, utility districts, redevelopment authorities and others agencies all have an impact on land use and, consequently, transportation. Coordinating decisions between these public bodies is another essential step in the direction of the Growth Vision.

As the Growth Vision principles are recognized locally and regionally, better coordination of land use and transportation planning is necessary. The Growth Vision analyses showed the benefits the coordination of land use and transportation will have on congestion, air pollution and commute times. To ensure these benefits, dialogue participants called for linking land use plans and project approval with transportation investments.

The Importance of the Private Sector

The policy dialogue participants recognize the importance of business location decisions in achieving a better jobs-housing balance and making jobs more accessible to employees. However, many questions remain about how to influence such private sector decisions. Beyond the traditional strategies of shaping infrastructure and using the project-approval process to influence business development and location decisions, participants could not agree on how to best influence private sector decisions. However, acknowledging these "traditional strategies" while increasing collaboration between public entities will guide business location decisions while removing impediments to market forces – market forces such as the trend toward transit-oriented development or pedestrian-friendly main streets. In the end, local and regional agencies need to maximize choice through incentives for the private sector. By creating development incentives and making them clear to the private sector, Southern California can achieve the Growth Vision by enabling businesses to make their own decisions and by increasing choice in the marketplace.

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Sustained Education and Consensus Building

The final theme that emerged from the policy dialogues is the need for sustained efforts in public education and consensus-building related to the Growth Vision.

The participants agreed that a major step is to encourage local and regional officials to approve the Growth Vision principles and use them as guidance for local development and planning. Through this Growth Visioning process, Compass has taken the first step to listen, acknowledge and act upon the diverse ideas of elected officials, planners and citizens from throughout the region.

At the same time, participants recognized the need to acknowledge differing opinions. Not everyone agrees on redevelopment, on solutions to congestion, and on what to create as incentives and how. Achieving the Growth Vision will require broad public understanding and the alignment of thousands of individual decisions made in both the public and private sectors over many years. Thus, participants said, achieving the Growth Vision is as much a "cultural" shift as it is a technical or policy challenge.

In this sense, participants agreed it is necessary to sustain extensive public outreach and education campaigns to achieve the Growth Vision. Education curricula and worker training can encourage new and local ways to achieve vision goals. SCAG and sub-regions should promote exemplary projects and innovative policies that support and complement the Growth Vision. With examples, discussion and popular support, the communities, developers and businesses that make land use decisions will be enabled to set the region on track toward the Growth Vision.

Implementing the Vision

As a result of the policy dialogues, sub-regional input, and a look at best practices around the country, Compass compiled the following implementation framework to turn the Growth Vision into a reality for Southern California. While Compass has succeeded in garnering citizens, planners and officials to create a shared regional vision, its true success will be measured over the time. Southern California can achieve maximum mobility, livability, prosperity and sustainability through a series of agreed upon and feasible implementation tools. What follows, therefore, is a framework for implementing the Compass Growth Vision at the regional, sub-regional and local levels.

The Compass Growth Vision relies primarily on the four principles for a more livable future -- mobility, livability, prosperity and sustainability -- that were adopted by the Growth Visioning Subcommittee. These principles serve as the foundation for both the vision itself and for the strategies that will implement that vision and make it a reality. There are a number of implementation strategies that could be used, including some that are broad and overarching, thus applying to all the principles. Other implementation strategies are narrower and apply specifically to an individual principle.

General Strategies

Develop a monitoring system to gauge local and regional success of the elements within the Growth Vision

What gets measured gets done. One of the key advantages of a scenario planning approach is the reliance on monitoring, evaluation and adjustment of strategies based on success or failure. Without quality monitoring systems in place it can be difficult, even impossible, to accurately gauge the success of planning efforts. The RTP and Growth Vision both lend themselves well to detailed monitoring. The statements and policies about the future that will result from actions made today, tomorrow and the next few years can only be ensured if we can continually verify that we are on track. It is vital to measure our actions objectively to determine the level of performance being reached. This monitoring can provide an early warning system if things are not going according to plan. On the other hand, it can also alert us to early successes that provide valuable lessons and that further the plan's goals.

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Of utmost importance in developing a monitoring system for the Growth Vision is that the measures and techniques to be used are developed through a collaborative process where all participating jurisdictions can agree on both the purpose and the method of monitoring. Once developed, this monitoring system should be used on a regular basis, resulting in a report that is shared with all member jurisdictions, which will help everyone understand how their policies and actions affect the collective goals of the vision.

SCAG should begin by incorporating the Growth Visioning monitoring system into the annual *State of the Region Report*. The report should include benchmarks and indicators, which evaluate progress toward quantifiable goals derived from the Vision. This monitoring system also should be used to compare the differences between the 2001 and 2004 Regional Transportation Plans to learn more about the effects of land use on transportation measures, such as reductions in congestion and emissions

Develop a legislative agenda to aid in the realization of the Vision

Coordinate this agenda with the other regional governments in the state, such as ABAG/MTC, SACOG, and SANDAG, to change state law that hinders the a common regional approach. State policy affects a wide variety of issues including transportation policy, housing and even labor laws that may weaken the Southland's potential to attract manufacturing firms.

Issues to be addressed at the state level include:

- Establishing priorities based on the Vision that can leverage funds for local governments.
- Using housing allocation funds and discretional decisions at the state and federal level to reinforce and support the Vision.
- Complying with a regional vision of tangible benefit, such as shifting the burden of proof for EIR compliance from the city and developer to the plaintiff, once compliance with objective measures of a growth management strategy are attained.

Use the Regional Comprehensive Plan as a tool to coordinate local plans and embrace the Southland's many unique local identities

Experience suggests that SCAG, the sub-regions, and local jurisdictions can more easily achieve their collective goals by actively encouraging and empowering sub-regional planning and coordination within the context of a regional comprehensive plan. The Vision should be built on this type of cooperative partnership. The Vision will be implemented through everyday decisions made at the local level and will therefore only succeed if it helps to accomplish local desires. The effort required to implement the Vision will not fall on any one jurisdiction. Cities, counties, transportation authorities and SCAG are partners, sharing the responsibility for making the Vision a reality for the residents of the Southland.

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Create a targeted public relations strategy that emphasizes regional leadership and builds a sense of common interests among Southern Californians. Begin to develop a deeper respect for SCAG by the sub-regions and local jurisdictions

Sub-regional groups have discussed the critical importance and lasting potential of a good public relations strategy. This outreach should take a variety of forms. Publicizing the regional planning activities under way with SCAG's partners and the public is the primary goal of a regional PR strategy. This could involve a speaker's bureaus, planning assistance, and various mediastrategies. Other regions have also found great success by preparing handbooks or tools to assist their member cities in achieving a shared vision.

Education also is a key component of this outreach strategy. Education opportunities exist both in and out of the classroom. Conferences or symposia are an excellent way to bring important regional lessons to groups of elected officials, planners, and even students – our future leaders. Introducing regional planning into the schools themselves has also been a successful strategy. A first strategy might involve university-level course work through some of the many planning schools in the Southland. Further down the road, a program could be developed to educate high-school age students. For years Chicago had a mandatory class that taught children about their famed Burnham Plan of 1909. Getting children involved in the importance and quality-of-life benefits of planning at an early age helps to ensure that it will remain a topic of interest and concern as they become adults.

Establish a method to convene representatives from government, civic leaders and members of the development community to work together on issues and challenges that are shared by communities within the Southland

Setting up periodic forums to bring these groups together can be extremely valuable in helping everyone understand different perspectives and goals. Solutions are more easily derived from a common understanding. This coordination will allow the private sector to build the type of products that jurisdictions and their citizens want.

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Implementation Tools by Principle

PRINCIPLE #1

*Improve **mobility** for all residents*

- Encourage transportation investments and land use decisions that are mutually supportive
- Locate new housing near existing jobs and new jobs near existing housing
- Encourage transit-oriented development
- Promote a variety of travel choices

Providing transit options is a way to improve mobility for residents within the region.

The 2004 RTP benefited from the land use element that came out of the Compass process. SCAG should begin each RTP process with scenarios based on land use to inform projections and transportation modeling

The 2004 RTP benefited from the land use element that evolved from the Compass process. This "bottom-up" approach has met with success during the Compass process. This includes incorporating input received locally from the sub-region and city review of the Growth Vision into a "starter Compass scenario" for the 2007 model runs, informed by the monitoring of key indicators in the interim.

There is no reason to wait to model these virtual futures. Iterative scenario modeling coupled with a detailed monitoring system will allow SCAG and local jurisdictions to stay continually informed regarding the benefits of the various growth strategies they are employing.

The Regional Transportation Plan is now aligned with the principles of the Growth Vision. SCAG should prioritize transportation improvements so that they parallel goals within the Vision

Projects funded by the RTP could be evaluated using the Vision, and the Vision could provide incentives for implementation of key policies in the RTP. The corridors described in the Vision and on the map are one of several items to explore. Corridors are the easiest places to make a case for using federal and state dollars to help cities with planning. Fully using the corridors will help focus the necessary land use changes into areas where change is both wanted and needed, protecting stable neighborhoods from significant impact. Increasing the housing and jobs in these corridors was one of the leading components of the Vision and led to many of the modeled transportation efficiencies of the 2004 RTP.

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Develop a diverse set of pilot corridor projects that show the Growth Vision in action

Successful pilot projects can demonstrate progress in implementing some of the key principles of the Vision. These studies can help in understanding market and regulatory barriers that inhibit both economic growth and the provision of needed housing. Further, they can act as a catalyst, showing other developers, lenders, and jurisdictions the potential that can be achieved.

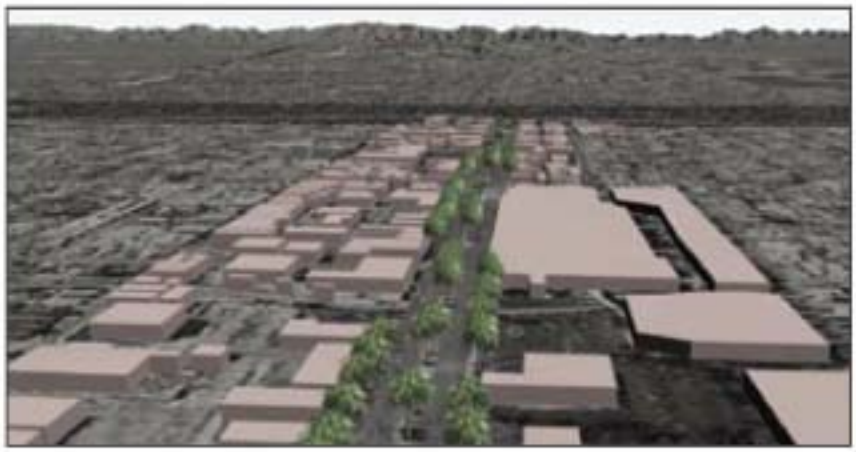
POSSIBLE PILOT PROJECTS

Below is an initial list of possible pilot projects for implementing the vision.

- Gold Line Extension
- Exposition Line
- Valley Bus Way
- Maglev IOS
- San Jacinto Line
- Highway 30
- 101 Corridor HOT lanes
- CenterLine
- North Los Angeles County to the High Desert
- Other corridors with significant transportation and land use interaction

For each of the corridor pilot projects, the parties involved should engage in a full land use and transportation study. Strategies would include

- Combining land use and transportation strategies, rather than holding land use constant and changing transportation investments on a case-by-case basis.
- Using scenario planning to investigate options and develop feasible strategies that allow the region to "plan without boundaries."
- Using a wide-ranging public awareness program, including workshops or charrettes to engage the public in developing scenarios and strategies.
- Developing a set of measurable criteria to evaluate different scenarios and using a consistent set of criteria to select a final strategy.
- Using this process to help define options for developing the Environmental Impact Review.



Work with county transportation commissions to help coordinate inter-regional transit travel

A recurring theme at the many Compass workshops was the difficulty many people face in using transit to travel across the region. Concerns ranged from varying fares, to headways, and most importantly gaps in service that seem to correspond to jurisdictional boundaries. The needs of residents of the Southland transcend city and county borders. These boundaries must be removed from the thought process in planning for seamless travel.

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PRINCIPLE #2

*Foster **livability** in all communities*

Walkable communities help improve livability and promote a mix of uses.

- Promote infill development and redevelopment to revitalize existing communities
- Promote developments that provide a mix of uses
- Promote "people-scaled," pedestrian-friendly communities
- Support the preservation of stable, single-family neighborhoods

The Regional Housing Needs Assessment process should be coordinated with visioning and planning at the regional level to identify areas of common interest and mutual benefit

The Compass process should be used as a means of collaboration and compromise to revise the RHNA process to one that is less adversarial and more creative. As creator of the RTP, SCAG has the ability to bring about this change by facilitating a common understanding among local jurisdictions – one based on the demographic needs of the region. Building the process on top of a commonly held vision of the future can help focus the discussions on both regional and local needs while bringing consistency to the regional planning effort.

Endow the sub-regions with greater responsibility in conducting their own visioning

Use sub-regional efforts to guide the shape of regional plans and recognize that sub-regional, county and local collaboration is the cornerstone of implementation. SCAG's role would be to facilitate sub-regional efforts and help coordinate inter-jurisdictional planning projects. Building the Growth Vision from local planning efforts resonated well with the sub-regions and local jurisdictions that participated in Compass workshops, policy dialogues and scenario review sessions.

Establish elements of the Growth Vision scenario, such as centers and corridors and a well-defined open space system, with clear objectives for development, preservation and social equity

Agencies may use these objectives in providing assistance to developers who want to further city goals with their projects. SCAG can work to ensure that the Vision and its concept map evolve to recognize the local implementation efforts and priorities that are discovered during the process.

Offer planning assistance and cooperatively develop recommended model ordinances for those who wish to implement specific parts of the regional Vision

Model ordinances can make development that supports the vision the rule, rather than the exception. Through pilot projects, handbooks and partnerships, cities in the region have many resources at their fingertips to assist in planning and achieving the Vision. Research of pilot projects during the Compass project alone has shown that policies such as allowing for flexible building height standards and reductions in parking requirements for pedestrian-friendly areas can reduce costs by as much as 30 percent. Continued exploration and ongoing projects will provide the region with the tools necessary to properly use land use, specifically infill to enhance the transportation corridor efficiency.

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PRINCIPLE #3

*Enable **prosperity** for all people*

A variety of housing types enables prosperity for all people.

- Provide a variety of housing types in each community to meet the housing needs of all income levels
- Support educational opportunities that promote balanced growth
- Ensure environmental justice regardless of race, ethnicity or income class
- Support local and state fiscal policies that encourage balanced growth
- Encourage civic engagement

Create a rich, comprehensive regional database for planning and economic development

SCAG should assemble and keep current a quality GIS inventory of: vacant and reuse opportunity sites, local and regional open space plans and information that will help companies find locations within the Southland near their desired employees. This data should be shared with jurisdictions and the development community. Such data sharing promotes jobs-housing balance, open space preservation and infill development and investment in areas that are largely developed.

Foster greater cooperation between business, government and community organizations through training in public-private partnerships

This effort opens the door to the creation of important partnerships with the development community, learning from them how policies and practices both help and hinder the creation of products that support the vision. These developers will benefit as they work with the cities and counties and will be able to act as ambassadors to their colleagues.

Accelerate employment balance throughout the region

The natural progression of growth in the Southland during the past several decades has been to initially develop an area as a place for people to live who have either been priced out of the market where they work or are willing to commute farther in exchange for other housing or neighborhood amenities. This of course leads to an imbalance of too many households versus available jobs in the area. In the years that follow, manufacturing and professional jobs often move to these areas in response to both land price and the availability of workers.

During the next 25 years freight coming into the Southland is expected to nearly triple – threatening further congestion. A goods movement strategy that addresses this tremendous growth can play a vital role in enabling employers to locate in these housing rich areas. It is therefore important when planning for the region's transit and highway corridors to also focus on logistics and goods movement. Southern California is multi-centric. Creating efficient access and goods movement allows these centers to develop in a balanced fashion. Being locations for people to live, they also have the basic elements for prosperous job centers.

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Implement the techniques outlined in the 2004 Regional Transportation Plan's privately funded projects

Jobs for people in the middle class are not as available as they should be. State policies and changing demands on infrastructure from the increases in distribution are hindering the region's competitive advantage for manufacturing jobs. Addressing the infrastructure and location needs of the manufacturing and distribution sectors would allow more people to have access to these jobs. This would enable people in that cohort to more readily afford homes.

Discussion has been initiated at the state level about a manufacturing tax credit. SCAG could help increase economic security by using the Vision to create empowerment zones where employers would reap benefits for providing family wage jobs to people living locally. This can also be an assistance tool for areas that historically have been overlooked by new investment.

Engage a study to look at how public investment such as transit facilities increase land value and what options may exist to use newly created wealth to increase opportunities for others and create more transit-oriented developments

The increased value that comes with reinvestment in a specific area can often mean existing families are priced out of housing, or that it is not feasible for the market to produce the needed affordable housing. Cities are further trapped in that funds provided by the developers for city creation of affordable housing have diminishing purchase power with the success of the nearby developments. There may be avenues to explore in which the public could benefit from land value increases that occur because of new publicly-funded projects related to transit.

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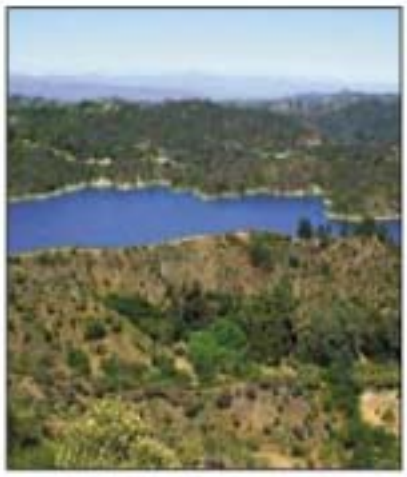
PRINCIPLE #4

Promote ***sustainability*** *for future generations*

- Preserve rural, agricultural, recreational and environmentally sensitive areas
- Focus development in urban centers and existing cities
- Develop strategies to accommodate growth that use resources efficiently, eliminate pollution, and significantly reduce waste
- Utilize "green" development techniques



Open space is integral to the health of communities.

Integrate the many open space and habitat plans under way throughout the region into an open space element for the Growth Vision

Much significant work in this arena has been completed or is under way throughout the region. The open space component of the Vision should be considered as important as urban centers and infrastructure. Through collaboration, SCAG should assemble the many planning efforts into a standardized inventory that can both inform the Vision and provide lessons to other jurisdictions interested in performing similar analysis. This green infrastructure should in no way hinder a jurisdiction's ability to accommodate needed housing or jobs. Instead, they should be rewarded for the extra effort of ensuring sustainability for the Southland. This inventory should be used to monitor sustainability and livability goals and help neighbor cities plan for open spaces in a coordinated fashion.

Offer training for elected leaders, planning officials, and the development community in green planning and design

As with planning for infill, handbooks, symposiums, and other education tools should be used to enable cities and counties to embrace the sustainable practices of green building. SCAG should act as a coordinating body to help the region determine a standard set of approaches. With SCAG helping to create these standards, the region's cities may face much less uncertainty at the state level as they work to implement the various techniques.

Identify or adopt a conflict resolution mechanism to assist with open space protection agreements already in place and work to enhance additional open space needs

SCAG can use its position as a regional leader to bring together the many interests that have a stake in protection or enhancement of open space. During regional planning activities, SCAG should factor in the need for preservation of open space and natural areas when determining growth projections and housing needs.

AR0072688

Cities and counties with a well-defined open space system or urban limit lines have a reputation for becoming desirable and expensive. Offer planning assistance and model ordinances that will help preserve the environment and enable inclusionary housing practices and housing choice

Cities throughout the region grapple with deciding how to appropriately address growth for their community while preserving their cherished open space and productive agricultural areas. Some cities and counties, for example, have adopted urban limit lines or growth boundaries. These tools can be very successful; however, they can also lead to unintended consequences. As a coordinating body, SCAG can help to share the best practices and lessons learned by cities that have employed these sprawl preventive measures. These tools can help ensure that the jurisdiction's goals are met and reduce the likelihood of problems arising. Cities across the country that have employed these preservation techniques have had to learn a few hard lessons before finally tuning the regulations to work as intended. By helping with these lessons learned, SCAG can help jurisdictions achieve their goals without facing the pitfalls that invariably come from trying something for the first time.

Calculate demand for water based on the Growth Vision projections and distribution

SCAG can bring the cities, counties and water providers together to better coordinate the availability of water with projections and capacity calculations for housing and jobs throughout the region.

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SCAG Compass Regional Vision: Within Our Reach

Public spaces will continue to be enjoyed by future generations.

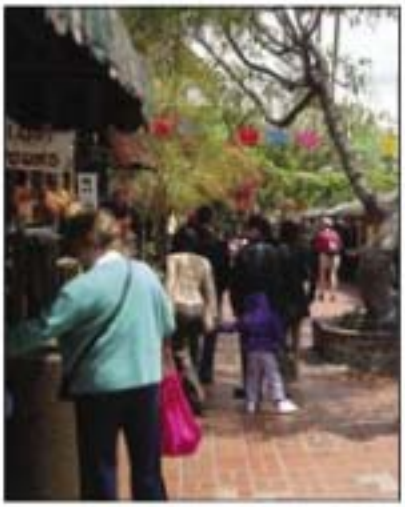
Fifty years ago, Southern California had a common vision of its future. The vision was based on a common set of values as well as the strategies to achieve that vision. In today's world, the problems and their solutions are much more complex. However, there are many efforts under way in the Southland to craft a viable solution that matches the values of the region today. Compass is only one such effort. All are working to identify solutions that will help the Southern California region move into the future with confidence and optimism.

While the solutions remain elusive, it is clear that there are common values in this region that can form the basis of a common vision. Most people want a plan for the future that adheres to the principles adopted as the SCAG Growth Visioning principles.

SCAG cannot implement this Growth Vision alone. It will require the efforts and collaboration of hundreds of groups and thousands of leaders. However, SCAG brings a unique, region-wide perspective, as well as the energy and the vision needed to solve regional problems that require a large-scale view. Conversations with residents of the region reveal what many other groups have found – some anxiety and some dissatisfaction, but more importantly, a common core of support for ideas that will actually work.

The sense of place in many areas will strengthened.

The key to success now is the most difficult – discovering the specific actions Southern Californians can agree on to make the region of their dreams come true. To this end, SCAG, its member governments, and the hundreds of other organizations must contribute and work together in a true regional partnership. SCAG stands ready to contribute to this important effort.



Southern Californians will maintain a high quality of life.

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Appendix I: Workshop Development Types

URBAN CENTER

The Urban Center development type incorporates households, offices, retail, and civic uses into a walkable and mixed-use environment. This type is modeled on downtown Los Angeles and serves as a commercial destination and employment center. The Urban Center development type also contains a diverse array of multi-family homes and townhouses. The building types range from mid-rise residential buildings to mixed residential towers and commercial high-rise buildings. Interconnected street networks and a variety of amenities within walking distance make Urban Centers accessible by automobile, transit, bicycle and foot. Civic and open spaces lend to the walkability and diversity of uses in Urban Centers, they are lively throughout the day and evening. This development type is especially apt for infill in downtown Los Angeles.

Urban Center	
Acres per Chip	160
Households per Acre	110
Employees per Acre	320

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CITY

The City development type incorporates a diverse mix of residential and employment uses, though at a lower density than the Urban Center. The City still serves as a significant source of employment. Like Pasadena or Santa Monica, this development type has a walkable center at its core. It may require structured parking and is accessible via multiple modes of transportation. Cities include a greater proportion and diversity of housing than downtowns, including multi-family homes, single-family homes and townhouses.

City	
Acres per Chip	640
Households per Acre	35
Employees per Acre	70

AR0072693

TOWN

As with the Urban Center and City, Towns are also walkable because of their mix of uses and interconnected street network, but at a lower density. Towns primarily function as service destinations with a central Main Street rather than centers of employment. Surface parking lots provide parking in Towns. Buildings on the Main Street typically stand two to four stories tall and include townhouses or apartments above storefronts. Most homes in a Town are detached single-family residences that are oriented towards the street, commercial areas and open space.

Town	
Acres per Chip	640
Households per Acre	20
Employees per Acre	20

AR0072694

High Intensity Corridor

HIGH-INTENSITY CORRIDOR

Similar to an Urban Center, High Intensity Corridors incorporate households, offices, and retail uses at a high density. However, High Intensity Corridors are stretched along one central Boulevard without the street connectivity and accessibility experienced in Urban Cores. Considered a high employment area, building types range from mid-rise residential to office high-rise tower, with less mixed-use than in other high-density development types. Wilshire Boulevard is considered a High Intensity Corridor.

High Intensity Corridor	
Acres per Chip	480
Households per Acre	65
Employees per Acre	95

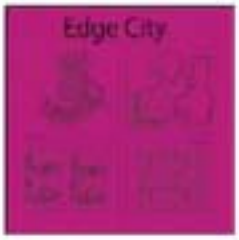
Medium
Intensity Corridor

MEDIUM-INTENSITY CORRIDOR

Like a High-Intensity Corridor, Medium-Intensity Corridors are also stretched along one single Boulevard but experience less dense building types. Households, offices and retail uses are accommodated with a few high-rise towers but are primarily comprised of mid-rise building types. Pedestrian access is limited with transit generally only available along the Boulevard. The Medium-Intensity development type is patterned after Ventura and Sepulveda Boulevard.

Medium Intensity Corridor	
Acres per Chip	480
Households per Acre	25
Employees per Acre	30

AR0072696



EDGE CITY

An Edge City, such as Warner Center, is a central location for offices, retail uses and multi-family housing. Building types range from high-rise office towers to low to mid-rise residential. As an auto-oriented environment, surface parking lots are plentiful and transit options limited. Retail centers are located in strip malls with minimal walkability. Multi-family residential units are located on streets that lack connectivity and promote auto usage.

Edge City	
Acres per Chip	640
Households per Acre	30
Employees per Acre	100

AR0072697

ACTIVITY CENTER

An Activity Center is an agglomeration of large-scale retail buildings, offices and multi-family housing such as South Coast Plaza and Ontario Mills. The Activity Center development type contains a relatively dense mix of uses, comparable to a City. But, unlike the City, it is not pedestrian-friendly. Land uses are separated from each other by parking areas, freeways or arterials. Activity Centers are usually positioned at intersections of highways or arterials, sometimes along major transit corridors.

Activity Center	
Acres per Chip	640
Households per Acre	15
Employees per Acre	15

AR0072698

Highway Commercial

HIGHWAY COMMERCIAL

This type is modeled after highway-oriented development. Like the Activity Center, it contains many residential units. But rather than being agglomerated at a highway intersection, Highway Commercial development takes a linear form along both sides of the highway. Connections in this development type consist mostly of highways and frontage roads. Housing is either in the form of multi-family apartments or residential subdivisions; both are typically auto-oriented.

Highway Commercial	
Acres per Chip	480
Households per Acre	10
Employees per Acre	10

AR0072699

EMPLOYMENT DISTRICT

Often considered to be an Office Park, Employment Districts are comprised of low to medium density office buildings surrounding by surface parking. Generally located near highways for easy auto-access, transit and walking options are limited. Employment districts lack residential or retail uses, thus increasing the number of auto trips needed.

Employment District	
Acres per Chip	640
Households per Acre	0
Employees per Acre	40

AR0072700

INDUSTRIAL

The Industrial development type is made up of a mix of low and medium density industrial buildings. They often consist of industrial yards and campuses separate from other uses due to the nature of industrial use. This development type is often near highways and accessed via automobiles with large surface parking for autos and trucks. Walking and transit options are severely limited.

Industrial	
Acres per Chip	640
Households per Acre	0
Employees per Acre	20

AR0072701

CITY NEIGHBORHOOD

City Neighborhoods are comprised of mid to low-rise multi-family, townhouses and small lot single-family dwellings. With the same number of residential units per acre as the Town development type, City Neighborhoods are medium-high density residential areas with a small number of service or office jobs. Street connectivity is favorable, allowing for a high degree of walkabililty and transit options.

City Neighborhood	
Acres per Chip	640
Households per Acre	20
Employees per Acre	6

AR0072702

RESIDENTIAL SUBDIVISION

Residential Subdivisions are comprised of single-family, detached homes and duplexes. Street networks are typical of post -World War II suburbs. Residential Subdivisions are designed for automobile travel. Due to the extensive use of cul-de-sacs, street connectivity and walkability are generally low. Examples include Santa Clarita and parts of San Bernardino and Riverside Counties.

Residential Subdivision	
Acres per Chip	640
Households per Acre	10
Employees per Acre	0

AR0072703

LARGE-LOT SUBDIVISION

Large-Lot Subdivisions consist entirely of single-family, detached homes. This development type can be found in Orange and Ventura Counties as well as outlining areas. Large-Lot Subdivisions are typically isolated or far from employment and retail services. Averaging two units per acre, this development type is characterized by very large residences without sidewalks. Street connectivity is low and travel to and from the Large-Lot Subdivision development type is usually by automobile.

Large-Lot Subdivision	
Acres per Chip	5,760
Households per Acre	2
Employees per Acre	0

AR0072704

RURAL HOUSING

The Rural Housing development type consists of estate lots that amount to one unit per five acres. Rural Housing development provides residents with access to rural areas while being within reach of urban amenities. This development type consumes greater amounts of open space and tends to be farther from employment than Large-Lot Subdivisions. Street connectivity is also generally low among estate lots.

Rural Housing	
Acres per Chip	5,760
Households per Acre	0.2
Employees per Acre	0

AR0072705

Appendix II: Scenario Allocation Development Types

Place3s methodology

Planning for Community Energy, Economic and Environmental Sustainability (Place3s) is a GIS ArcView3.2 extension used to simulate land-use patterns for scenarios. A geographic representation of each scenario is created in Place3s by locating different development types on vacant and developed land while limiting development in environmentally constrained areas. The geographic representation of development types for each scenario is the foundation for calculating benchmarks. The benchmarks are then used to evaluate the viability of each growth scenario.

Similar to the workshop development type chip sets, the series of development types for Place3s are created from a set of building types that represent residential, employment and mixed-use alternatives. Each building type has an associated employee and household density. The households and employees per acre for each building type is multiplied by the percentage each building type represents within the development type to determine the employees and households per acre for each development type.

Because the development type densities are based on vacant land, a set of standards is used to calculate the propensity of a certain development type to redevelop. Areas such as Downtown are more likely to redevelop than Towns, while Centers are more likely to redevelop than Residential land. The redevelopment percent is then multiplied by the employees and households per acre for vacant land to obtain a redevelopment density.

	Vacant Land		Redevelopment		
	Emp/acre	HH/acre	Emp/acre	HH/acre	Redev %
Downtown Center	367.88	30.64	91.97	7.66	25%
Downtown Residential	46.03	119.19	9.21	23.84	20%
City Center	54.67	15.63	10.93	3.13	20%
City Residential	8.95	31.98	1.34	4.80	15%
Town Center	17.14	11.24	2.57	1.69	15%
Town Residential	3.53	13.79	0.35	1.38	10%
City Neighborhood	0.53	9.07	0.03	0.45	5%
Residential Suburb	0.22	1.25	-	-	0%
Large Lot Residential	-	0.25	-	-	0%
Rural Cluster	-	0.41	-	-	0%
Activity Center	12.66	10.27	-	-	0%
Transit Station	12.70	20.29	3.81	6.09	30%
Transit Corridor	7.06	16.91	1.41	3.38	20%
Main Street	8.24	12.99	1.65	2.60	20%
Office Park	39.69	-	-	-	0%
Industrial	14.86	-	-	-	0%
Highway Commercial	6.62	5.85	-	-	0%

AR0072706

Building Type Proportions

Development Types	Mixed-Use				Residential									
	DT Mixed	DT Residential Tower	City Center Mixed Use	Town Center Mixed Use	Apartment / Condo High	Apartment / Condo Med	Apartment / Condo Low	Townhouse	Residential Small Lot	Residential Medium Lot	Residential Medium Lot	Residential Large Lot	Rural Housing	Rural Cluster
Downtown Center	10%	15%												
Downtown Residential	5%	65%	10%		10%	10%								
City Center			50%	25%		10%	10%							
City Residential		10%	5%	5%	10%	5%	15%	15%	35%					
Town Center				50%			30%	20%						
Town Residential				10%		10%	15%	45%	20%					
City Neighborhood							10%	25%	35%	25%	0%			
Residential Suburb											38%	60%		
Large Lot Residential												10%	90%	
Rural Cluster												30%	0%	70%
Activity Center						20%	25%							
Transit Station			10%	15%	10%	15%	20%	25%	5%					
Transit Corridor			5%	10%	5%	15%	20%	30%	10%	5%				
Main Street				15%		10%	25%	35%	5%					
Office Park														
Industrial														
Highway Commercial							15%	10%	20%					

Development Types	Employment						
	DT Office+HI	Office Park-Towers	Regional Mall	Office Park	Light Industrial	Heavy Industrial	Strip Commercial
Downtown Center	40%	35%					
Downtown Residential							
City Center		5%					
City Residential							
Town Center							
Town Residential							
City Neighborhood							5%
Residential Suburb							2%
Large Lot Residential							
Rural Cluster							
Activity Center			30%	25%			
Transit Station							
Transit Corridor							
Main Street				10%			
Office Park		5%		95%			
Industrial					60%	40%	
Highway Commercial							55%

APPENDIX III: BENCHMARKS

AVERAGE TRAVEL DISTANCE

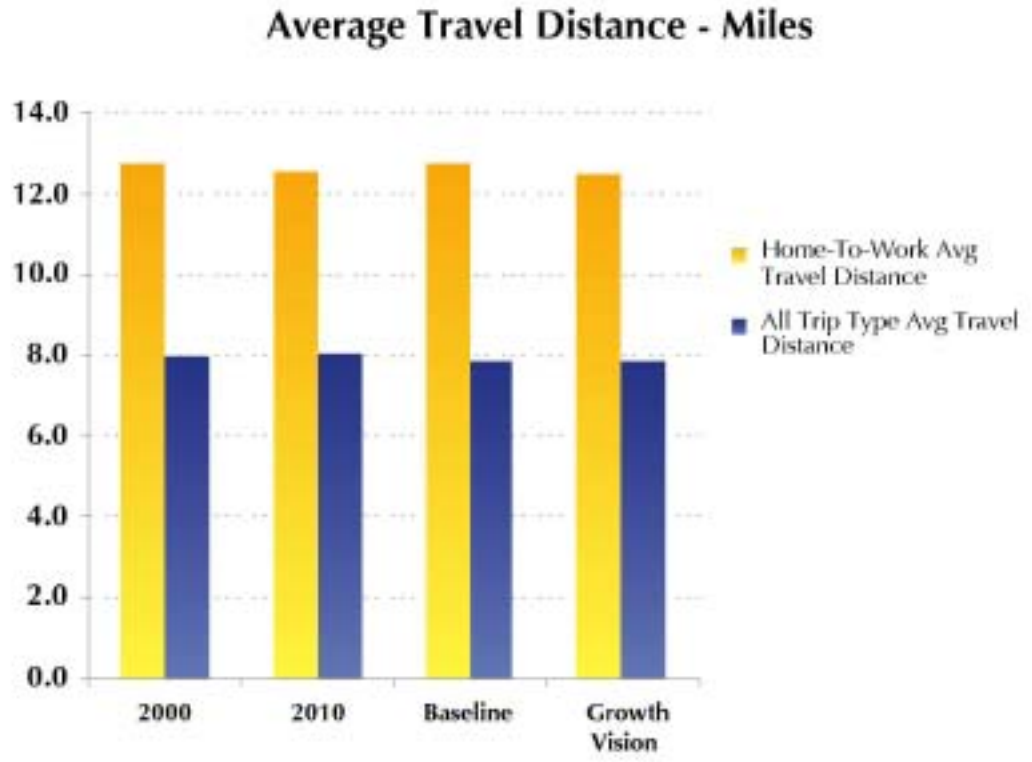
What does it mean?

The average travel distance is a measure of how well the transportation network in each scenario is performing in conjunction with the placement of land uses. Travel distance is dependent on the locations of jobs, housing and services, which in turn influence the total distance traveled. If the jobs and housing balance is not favorable, distance traveled for each alternative increases. However, if jobs and housing are within close proximity, then the home-to-work average distance decreases.

How was it measured?

The demographic, travel behavior, and transport infrastructure data for each scenario are used as model input to calculate the travel distance for each type of trip based on the transportation network. The trip types are summed to determine average distance traveled by category.

Average Travel Distance - Miles				
	2000	2010	Baseline	Growth Vision
Home-To-Work Avg Travel Distance	12.72	12.57	12.77	12.50
All Trip Type Avg Travel Distance	8.00	8.04	7.85	7.88



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AVERAGE TRAVEL TIME

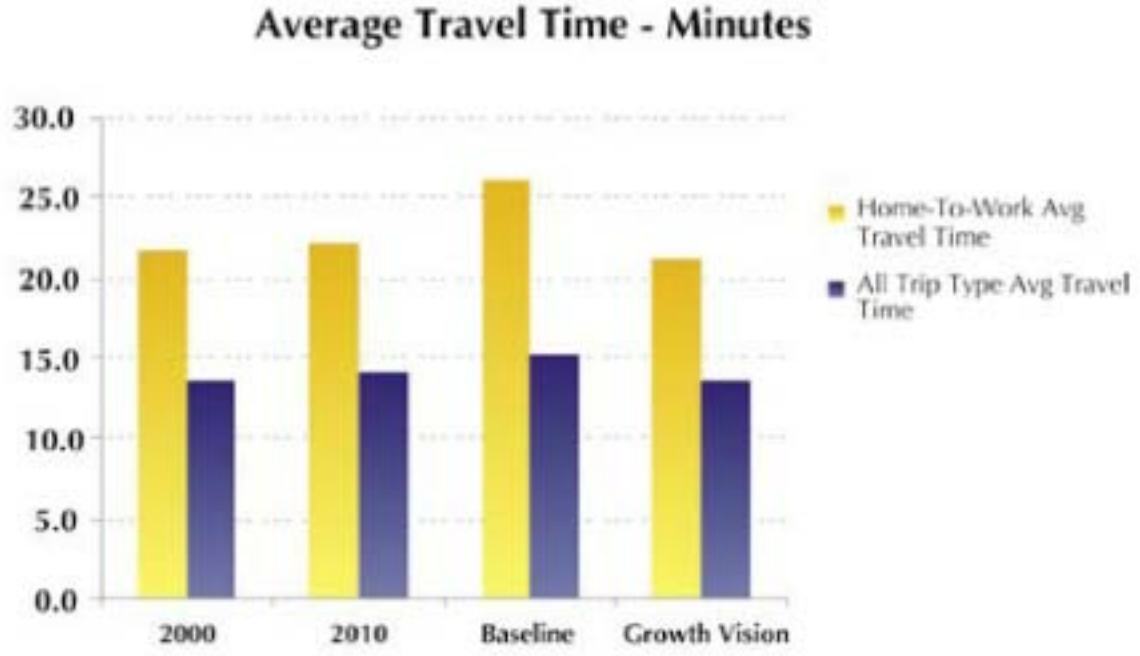
What does it mean?

The average travel time is a measure of how well the transportation network in each scenario is performing as well as a measure of the effectiveness of designated land uses for each scenario. Travel time is dependent on the locations of jobs, housing, and services that influence the total distance traveled; shorter distances require less time spent for each trip.

How was it measured?

For each link in the transportation network, the model generates the amount of time it takes to travel that link given the average road conditions in each scenario. The demographic, travel behavior, and transport infrastructure data for each scenario are used as model input to calculate the travel time based on the transportation network.

Average Travel Time - Minutes				
	2000	2010	Baseline	Growth Vision
Home-To-Work Avg Travel Time	21.6	22.1	26.1	21.2
All Trip Type Avg Travel Time	13.6	14.0	15.2	13.5



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DAILY TRANSIT BOARDINGS

What does it mean?

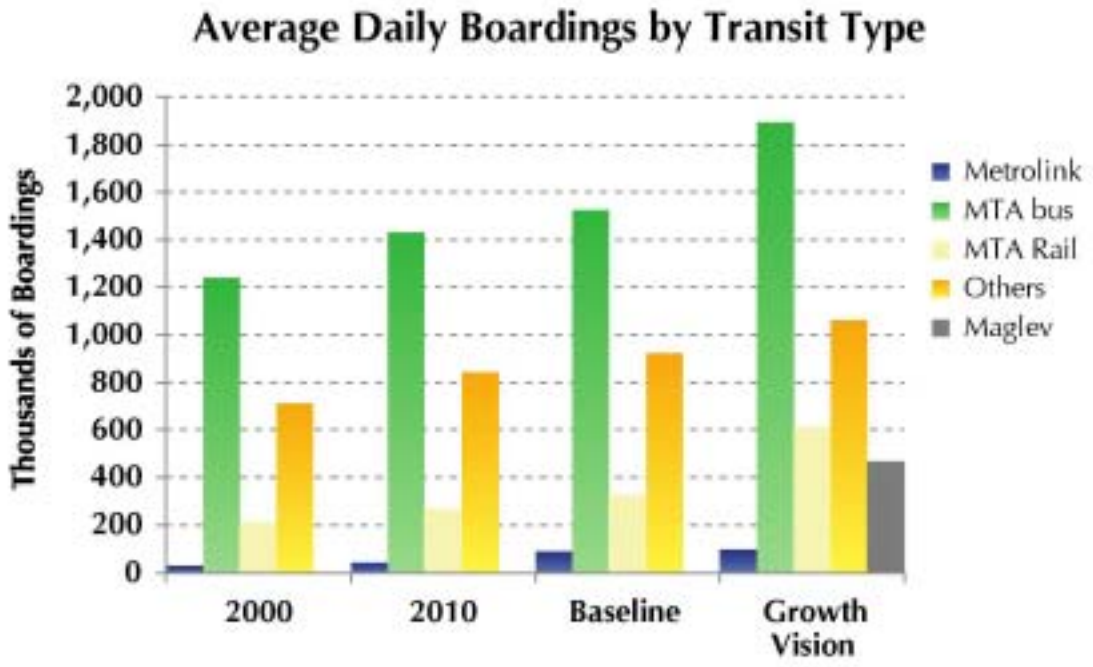
Daily transit boardings is a measure of the number of trips made on an average day by each type of transit service. The higher the transit ridership, the more capacity the roads will have to carry people and goods. Transit trips consolidate many travelers to a single vehicle with specific capacities depending on each transit mode.

How was it measured?

The demographic, travel behavior, and transport infrastructure data for each scenario are used as model input. The travel demand model uses these inputs, including the service characteristics of each mode, to calculate a probability of a trip choosing each type of transit. Choices are summed to determine the total probability of use by mode.

Average Daily Transit Boardings

	2000	2010	Baseline	Growth Vision
Metrolink	32,615	45,315	92,904	98,258
MTA Bus	1,241,561	1,429,990	1,525,716	1,893,678
MTA Rail	211,327	266,275	325,698	608,896
Others	710,459	844,675	922,003	1,062,540
Maglev	n/a	n/a	n/a	465,646
TOTAL	2,195,962	2,586,255	2,866,321	4,129,018



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EMPLOYMENT MIX & DISTRIBUTION

What does it mean?

The mix and distribution of employment types—retail, service, and other—is an indicator of the land use pattern of an area, and can have great effect on the efficiency of the transportation system. For example, an area with high service and retail employment may serve shopping, entertainment, and recreational trips, while an area with a concentration of other type employment may only serve commute trips. Transit use as well as trip-chaining—the term for combining many trips needs into one outing—work best when there is a mix of employment types concentrated in one area.

How was it measured?

The forecasting department at SCAG provided control totals for the number of retail, service, and other employees in each subregion. For the Growth Vision alternative, these employment numbers were then distributed across each modeling zone by association with development types.

	Retail Employees		Service Employees		Other Employees		Total Employees
2000	1,256,917	17%	2,751,322	37%	3,456,683	46%	7,464,922
2010	1,487,324	17%	3,492,229	40%	3,773,413	43%	8,752,966
Baseline	1,781,332	18%	4,057,286	40%	4,295,510	42%	10,134,128
Growth Vision	1,856,491	18%	4,203,640	40%	4,442,696	42%	10,502,827
2000-2010	230,407	18%	740,907	58%	316,731	25%	1,288,045
Baseline Increment	294,008	21%	565,057	41%	522,097	38%	1,381,162
Growth Vision Inc.	369,167	21%	711,411	41%	669,283	38%	1,749,861

AR0072711

HOUSING MIX

What does it mean?

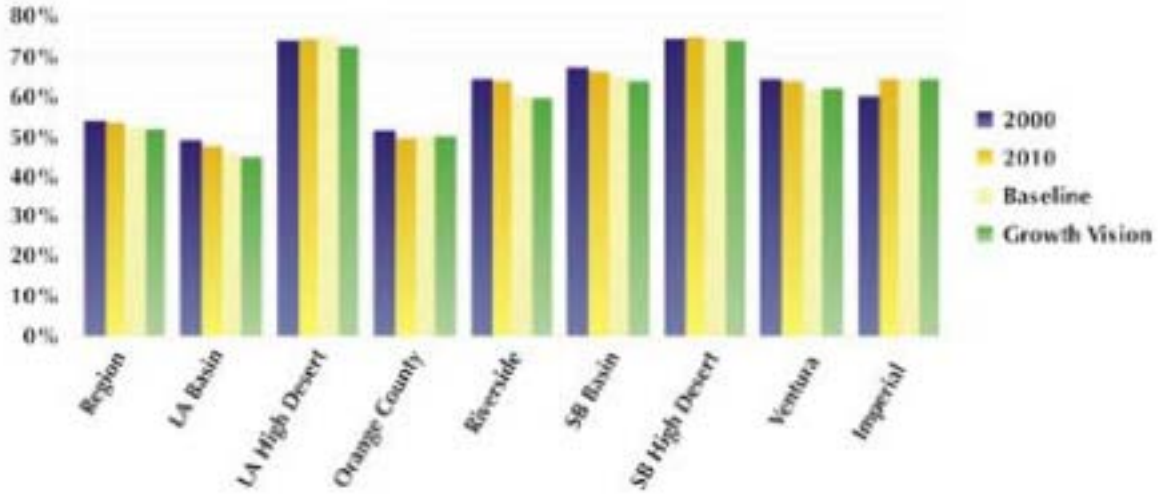
Housing mix indicates whether the housing in an area is single-family or multi-family. This measures the variety of housing types provided, as well as the density typical of new housing types. The 2000 and 2010 projection data allow for comparison.

How was it measured?

Each scenario contains a different mix of development types. Each development type is defined as a certain mix of building types. Therefore, each development type contains a certain mix of single-family homes and multi-family homes. The number of acres of each development type in each scenario were multiplied by the single-family and multi-family percentages in each development type to come up with the number of single-family and multi-family households in each scenario.

Scenario	Single-family Households		Multi-family Households	
2000	2,898,175	54%	2,487,372	46%
2010	3,219,676	53%	2,836,204	47%
Baseline	3,895,169	52%	3,558,562	48%
Growth Vision	3,935,985	52%	3,701,470	48%
2000-2010	369,101	51%	348,831	49%
Baseline Increment	675,493	48%	722,358	52%
Growth Vision Increment	716,309	45%	865,266	55%

Percent Single-family Household by Modeling Zones



AR0072712

NEW DEVELOPMENT OCCURRING THROUGH INFILL DEVELOPMENT OR REDEVELOPMENT

What does it mean?

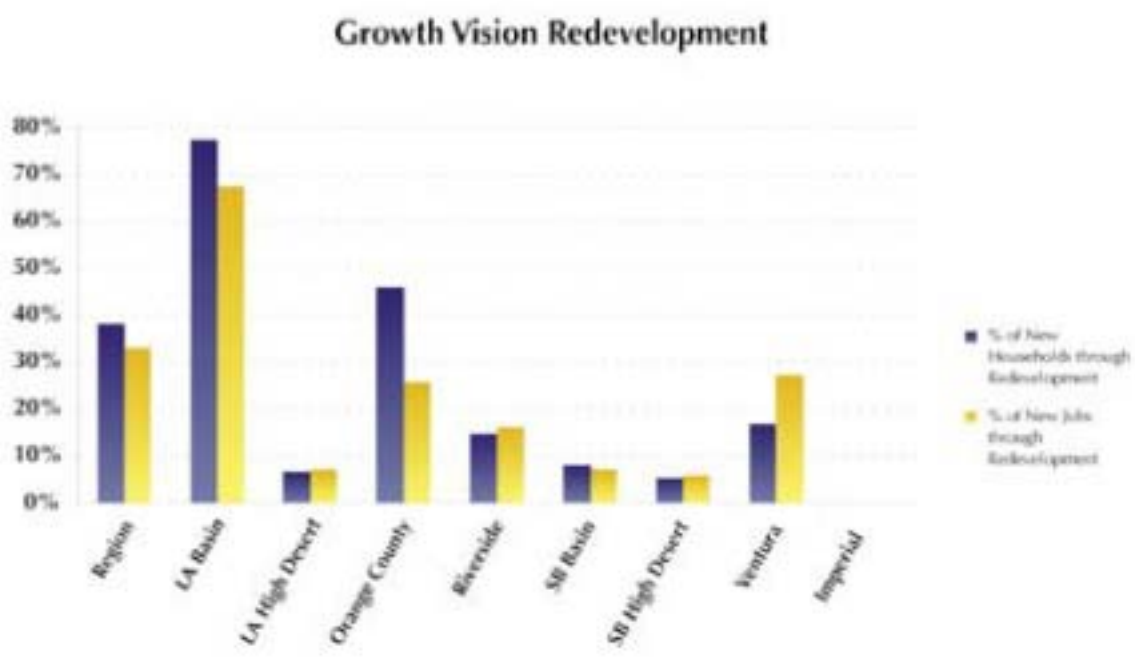
Infill development or redevelopment indicates the extent to which a city is renewed on an ongoing basis. It indicates that older parts of the city are attracting new housing and investment. High percentages of infill development indicate that a larger proportion of growth is occurring where development has already occurred before, through recycling of older buildings.

How was it measured?

For each scenario, a raster format map is made showing new development by development type. A raster map with the location of vacant land and one with developed land are also made, and the grid cells of each development type that fall on the vacant land can be summarized separately from those that fall on developed land. The number of redeveloped acres of each development type is multiplied by the number of households and employees per redeveloped acre to get new households and employees on developed land.

Growth Vision Redevelopment

	% of New Households through Redevelopment	% of New Jobs through Redevelopment
Region	38%	33%
LA Basin	77%	67%
LA High Desert	7%	7%
Orange County	46%	26%
Riverside	15%	16%
SB Basin	8%	7%
SB High Desert	5%	6%
Ventura	17%	27%
Imperial	0%	0%



AR0072713

JOBS-HOUSING BALANCE

What does it mean?

The ratio of jobs to households in each modeling zone can be an important indicator of the health of a region. If there exists a large mismatch between employment and housing in one or more modeling zones, then significant incommuting and outcommuting will occur, putting pressure on the transportation system.

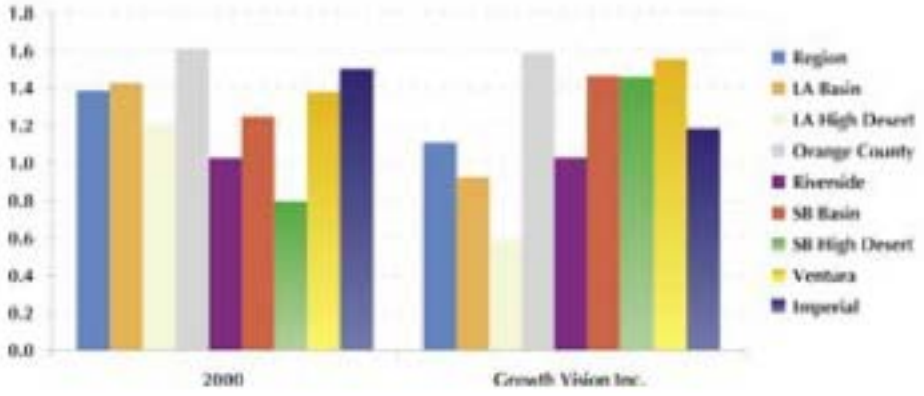
How was it measured?

For the Growth Vision alternative, a raster format map is created that shows the location of the various development types that comprise the scenario. Each development type represents a certain number of households and employees per grid cell. From the number of grid cells of each development type, the number of households and employees can be calculated for each modeling zone. The number of employees are divided by households to get jobs-housing balance. The 2000, 2010, and Baseline data are obtained at the TAZ level from the forecasters at SCAG and then summarized to the model zone level.

Jobs-Housing Balance

	Region	LA Basin	LA High Desert	Orange County	Riverside	SB Basin	SB High Desert	Ventura	Imperial
2000	1.39	1.42	1.21	1.61	1.02	1.25	0.80	1.38	1.50
2010	1.45	1.49	1.05	1.74	1.05	1.38	0.91	1.36	1.40
Baseline	1.36	1.39	0.80	1.75	1.09	1.40	1.00	1.39	1.31
Growth Vision	1.38	1.40	0.86	1.71	1.04	1.41	1.11	1.39	1.33
2000-2010	1.92	2.36	0.58	3.13	1.14	2.29	1.42	1.25	1.01
Baseline Increment	0.99	0.83	0.42	1.84	0.90	1.45	1.17	1.52	1.18
Growth Vision Inc.	1.11	0.92	0.58	1.59	1.03	1.47	1.46	1.56	1.18

Total Jobs-Housing Balance



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MODE SHARE

What does it mean?

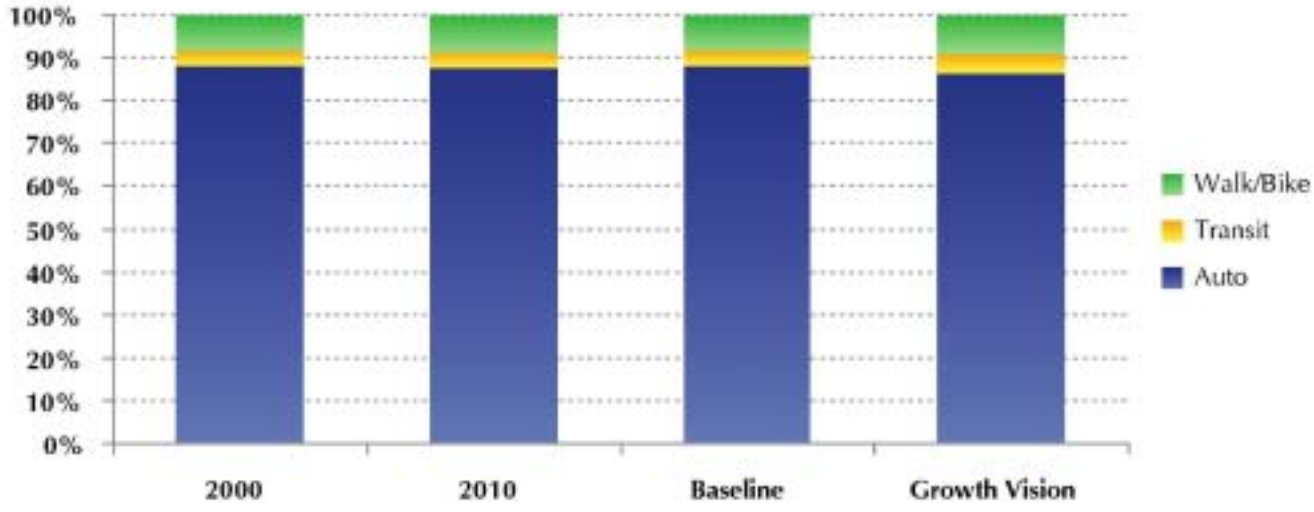
The mode share is a measure of the percent of trips made on an average day that are made by the various modes—walking, transit, and auto. Trips may originate from home, work, university, school or other. Even small changes in the share of trips made by automobile can make a big difference in congestion levels for those who are driving, especially in areas of congested corridors.

How was it measured?

The demographic, travel behavior, and transport infrastructure data for each scenario are used as model input. The travel demand model uses these inputs, including the service characteristics of each mode, to calculate a probability of a trip choosing each mode. Choices are summed to determine the total probability of use by mode as well as categorized by the home base and trip destination.

TOTAL Person Trips Mode Choice				
	2000	2010	Baseline	Growth Vision
Drive Alone	26,461,571	29,464,117	35,710,642	35,406,343
% Person Trips	48.0	47.3	47.7	46.7
Carpool	22,206,444	25,265,296	30,550,236	30,227,403
% Person Trips	40.2	40.5	40.8	39.9
Transit	1,185,606	1,509,972	1,507,345	2,301,119
% Person Trips	2.1	2.4	2.0	3.0
School Bus	736,367	732,267	899,170	876,214
% Person Trips	1.3	1.2	1.2	1.2
Non Motorized	4,591,408	5,386,262	6,255,318	6,940,129
% Person Trips	8.3	8.6	8.3	9.2

Mode Choice Distribution



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VEHICLE HOURS DELAYED

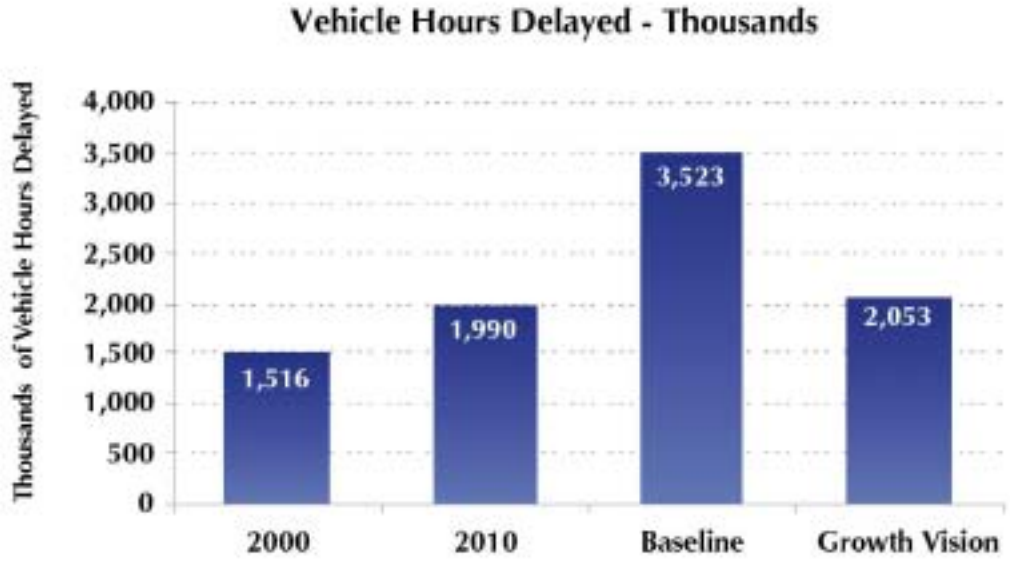
What does it mean?

The vehicle hours delayed is the amount of time travelers spend in congestion getting to their destinations over and above the amount of time it would take traveling in uncongested conditions. This measure reflects spatial relationships between residence and employment or other destinations as well as the efficiency of the road and transit network. The more hours in delay, the less time is allowed for work, recreation and other activities. Lower vehicle hours of delay reflects more efficient transportation networks and transit alternatives.

How was it measured?

The traffic speeds on each road network link are calculated using travel demand modeling software. The demographic, travel behavior, and transport infrastructure data for each scenario are used as model input. Congested link speed values are divided by link length to determine the link travel time. Subtract the uncongested link travel time to determine the amount of time per link caused by delays. The sum of these links is the total vehicle hours of delay for the region.

Vehicle Hours Delayed	
2000	1,516,109
2010	1,989,824
Baseline	3,523,369
Growth Vision	2,053,128



AR0072716

VEHICLE HOURS TRAVELED

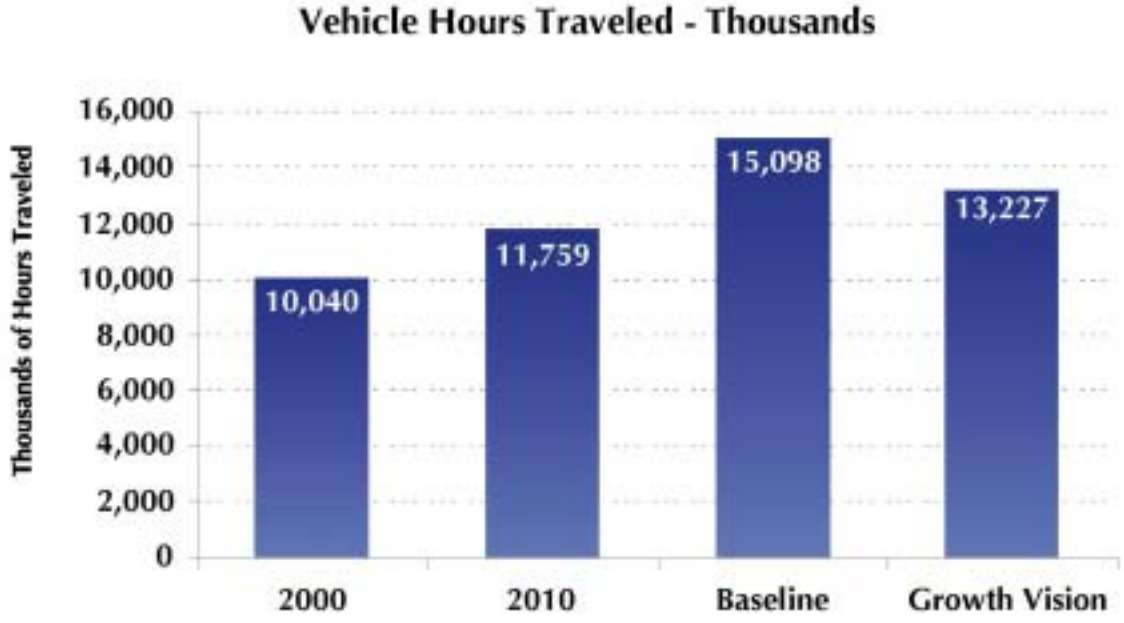
What does it mean?

Vehicle Hours Traveled (VHT) is the total hours of travel for cars or trucks per year for the total region. This measure reflects spatial relationships between residences and employment or other destinations as well as the efficiency of the transportation network and resulting air quality. The more hours spent traveling, the less time is allowed for work, recreation and other activities, and the higher the environmental impacts. Lower vehicle hours traveled reflects additional trips by non-auto modes as well as trips eliminated due to jobs, residences, and services within close proximity.

How was it measured?

The traffic speeds on each road network link are calculated using travel demand modeling software. The demographic, travel behavior, and transport infrastructure data for each scenario are used as model input. The link speed and length are used to determine the link travel time. The link travel time is multiplied by the number of vehicles per link to obtain the vehicle hours traveled.

Total Vehicle Hours Traveled	
2000	10,040,350
2010	11,759,250
Baseline	15,097,543
Growth Vision	13,227,120



AR0072717

VEHICLE MILES OF TRAVEL PER CAPITA

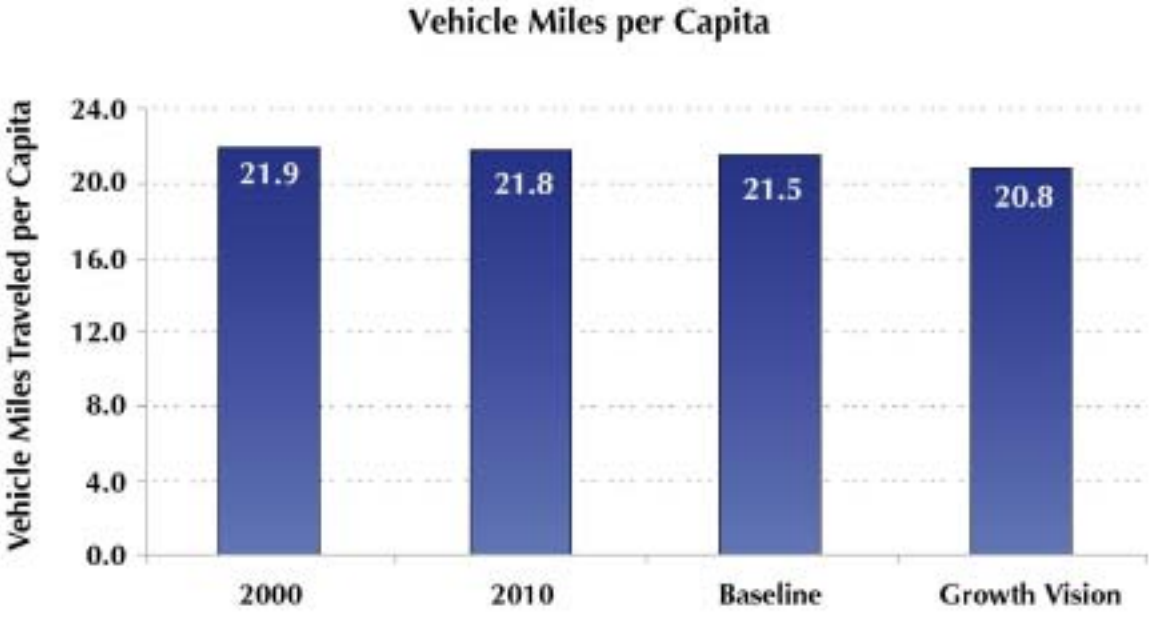
What does it mean?

Vehicle Miles Traveled (VMT) per person per day is the average distance traveled by a single person in a 24 hour period. This can reflect the spatial relationship between residence and employment or other destinations. Lower average VMT often reflects a better spatial match between residence and employment, while higher average VMT can indicate a spatial mismatch between place of residence and place of employment. VMT per person per day also will be lower when non-auto mode share (walk and transit) increases.

How was it measured?

The traffic volumes on each road network link are calculated using travel demand modeling software. The demographic, travel behavior, and transport infrastructure data for each scenario are used as model input. Each link volume is multiplied by the average vehicle occupancy rate in the region. This value is multiplied by the length of each link to determine the person-miles traveled on each network link. All these values are added and then divided by the total regional population to determine the average VMT per person per day.

Vehicle Miles of Travel per Capita	
2000	21.9
2010	21.8
Baseline	21.5
Growth Vision	20.8



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APPENDIX IV: SOUTHLAND POLICY DIALOGUES

Report on the Southern California Compass Project

by

The California Center for Regional Leadership

May 2004

I. WHY SOUTHLAND POLICY DIALOGUES?

The Southern California Compass Project is a collaborative regional planning process designed to develop a shared regional vision that will enable residents, local governments, developers, and other decision-makers to wisely manage projected growth across the region over the next twenty-five years. The Southern California Association of Governments and its Compass consultant team have produced a draft Growth Vision for the Southern California region through a variety of processes: development of growth principles, a survey of public opinion, development of growth "scenarios" through technical analysis, and public input through map-based workshops.

The Compass Project organized the Southland Policy Dialogues to enable local civic leaders to review and develop ideas for implementing the draft Growth Vision. The sessions aimed to achieve the following:

- Familiarize leaders across the region with the draft Growth Vision
- Help leaders to understand its implications for growth-related decisions within the Southland's "sub-regions"
- Identify barriers (regional and local) to effective implementation of the draft Growth Vision
- Develop and set priorities on key implementation strategies for SCAG, local governments, and other decision-makers

This report presents the key themes emerging from the Dialogues. Notes of the discussions were taken and revised by CCRL staff, and are available on the Compass website. They were sent to all participants, as was an online survey (results presented below).

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II. What Did We Do?

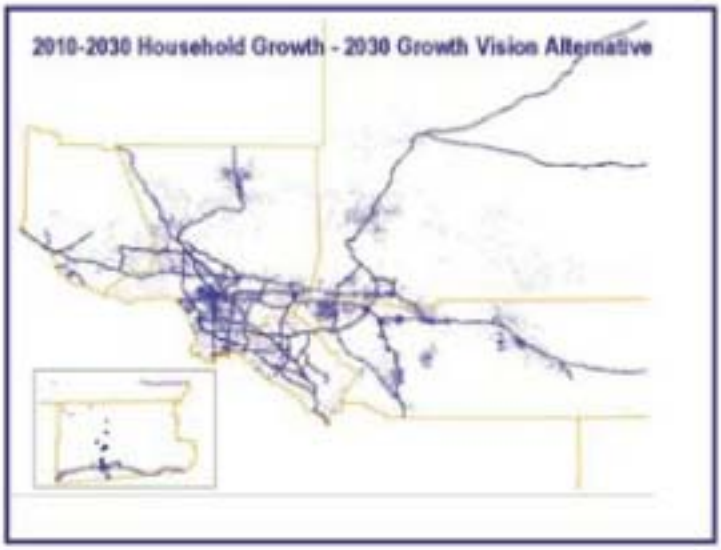
The California Center for Regional Leadership organized the Southland Policy Dialogues in five locations around the SCAG region, each focused on the unique issues of different sub-regions:

- Inland Empire – *March 10, 2004*
- San Fernando Valley, Ventura County, Arroyo Verdugo, North Los Angeles County (held in Van Nuys) – *March 11, 2004*
- South Bay Cities and Gateway Cities – *March 17, 2004*
- Orange County – *March 25, 2004*
- Downtown and Westside Los Angeles – *March 26, 2004*

The Compass Team also coordinated two sessions focused on the Latino community in Los Angeles and Orange County during April 2004.

In addition to the Dialogues noted above, a "pilot" Southland Policy Dialogue was convened on February 27, 2004, with the participation of the 48-member Leadership Southern California (LSC) Class XIV. This group provided invaluable feedback about the Dialogue presentation and discussion format. In addition, many LSC Class members and alumni attended the March Dialogue sessions.

Dialogue participants included local civic leaders, government officials, business owners, developers, neighborhood activists, and representatives of state agencies. In total, nearly 200 local community leaders participated in the five Dialogue sessions. Major sub-regional organizations, such as Councils of Government and other regional entities, were recruited to help plan and host these events. Summary reports and participant lists of each the sessions are attached to this report.



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III. What Did We Learn?

1. About the Growth Vision and its Implementation

The attached Summaries provide detail about responses to the draft Growth Vision and ideas for implementation. However, certain key themes emerged from Dialogue participants across the sub-regions, especially the following actions and issues:

- Encourage local and regional officials to approve, and then use as guidance, the basic principles and directions of the Growth Vision, such as preserving stable, existing single-family neighborhoods; directing new development, whenever possible, to existing employment or housing centers and to robust transportation corridors; promoting development around transit stations; protecting or expanding park and recreation facilities and open space; using land more efficiently wherever development occurs.

- Understand that there are differing opinions on: 1) where further development can be accommodated in existing communities ("it's a good idea, just not here -- we're built out"); 2) which highways or arterials could accommodate additional traffic; and 3) what level of incentives it would take for more people to use transit over automobiles.
- Plan from the bottom up, and recognize and value the particular needs of sub-regions and localities. The Southland is composed of connected but profoundly diverse places, and planning should advance different models of development that fit these differences.
- For more integrated and cost-effective results, link regional and local land use planning and project approvals with transportation planning and investment.
- Foster collaborative planning across and among all public sector agencies making land-use and infrastructure investment decisions, including local governments but also transit agencies, school districts, and water districts.
- Promote "choice" (particularly housing and transportation options) through consumer and governmental incentives rather than top-down mandates.
- Appreciate that achievement of the Growth Vision will require broad public understanding and the alignment of thousands of individual decisions made in both the public and private sectors over many years. In that sense, achieving the Growth Vision is as much a "cultural" shift as it is a technical or policy challenge, and will require sustained public education and involvement.

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"Local governments and regional agencies are not the only decision-makers that we have to take into account. Thousands of decision-makers will have to align with each other to achieve the Vision: consumers, developers, investors, business executives, employees, and countless others."

-- Nick Boltman, Dialogue Moderator

- Make the state government a full partner in achieving the Growth Vision, through major reforms in fiscal policy, state agency planning decisions, and infrastructure investments.
- Protect the environment. The commitment to this value runs deeply and broadly across the region and among all kinds of groups.
- Create more effective means of influencing business-location decisions to achieve a better "jobs-housing balance."
- Understand the differences of opinion on the economics benefits and challenges of mixed-use development.
- Acknowledge that, on the critical issue of whether or not the projected population growth in the region (6 million additional people) will actually occur, there was common agreement that it is likely to happen (often expressed with expressions of resignation rather than anticipation). On the other hand, long-term questions about the "carrying capacity" of the region, particularly with respect to water supply, remain unresolved.
- Bring the education sector into the collaboration. It is crucial to align K-12 education and worker training, as well as school siting, with community needs.
- Promote viable infill development projects by removing the regulatory barriers and supporting local public officials who make tough decisions.

2. About the Compass Project and the Southland Policy Dialogues

- Participation in the Dialogues was somewhat diverse, but did not mirror the population, let alone the future demography of the SCAG region and its sub-regions. Two additional Dialogues, with Latino leaders, were organized to ensure an opportunity for feedback and participation from that community.
- Participants were earnest about becoming engaged in discussion about the future of the entire SCAG region. They do not entirely believe that the Growth Vision will have a large enough impact on growth patterns, but there was general appreciation of SCAG's efforts to reach out to their communities.
- The Dialogues were a largely a conversation about possible futures and not necessarily the technical aspects of planning and growth management, even among local elected officials.
- The Dialogues represented an opportunity to "close the circle" from the map-based workshops, though the overlap in participants between the two was minimal.
- The opportunities for oral presentation directly to the Growth Visioning Subcommittee of first, the design, and then the results, of the Dialogues ensured a strong linkage between the Committee process and the Dialogue outcomes.

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3. Of interest to the Southern California Association of Governments

> "If we are to accommodate the addition of a third more people in the state, water supply, quality, and systems will become an enormous problem."
>
> – Participant in the March 11 Southland Policy Dialogue

- Sub-regions matter, and local leaders were pleased that SCAG acknowledged them as important "building blocks" and valued their opinions.
- There was deep interest (especially among local elected officials and planners) about how the kind of Vision discussion engendered by the project can be continued, and expanded to the scale necessary to actually result in effective, sustained change.
- Participants expressed a desire for partnership and greater alignment of goals and decisions with the state government, but little knowledge or willingness to get directly involved in making that happen ("Let SCAG do it.").
- Very few participants (even many of the local elected officials) understand what leverage SCAG itself has (and does not have) to advance the Growth Vision.

IV. Evaluation results

1. Who participated in the Southland Policy Dialogues?

Dialogue participants were surveyed electronically two weeks following the events in an effort to help us better understand the sessions. Approximately 200 people attended the five Southland Policy Dialogues and were representative of a wide range of sectors, with business/building developers and regional/local government making up the greatest numbers of participants.

Participants in Southland Policy Dialogues by Sector
(according to survey responses)

Sector	%
Civic Group	20%
Building/Development	16%
Local/Regional Government	15%
Regional Council of Government	11%
State Government	8%
Manufacturing	8%
Other Business	8%
Other	8%
Labor	3%
Academic	3%
Finance	0%

2. Selected survey results

- In all five subregions, over 90% of survey respondents agreed that "the Dialogue increased my knowledge and understanding of the Growth Vision."
- By contrast, Downtown/Westside Los Angeles session data indicates that 50% of survey respondents were "dissatisfied" with the dialogue overall.
- In four of the five subregions, 75% of survey respondents agreed that "the Dialogue generated solutions to the successful implementation of the Growth Vision."

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3. Written feedback

Below is a sampling of the written comments provided by respondents to the survey:

…These are fundamentally regional issues that can only be addressed regionally.

There are some good elements in the Vision, but there is no clear road to implementation, and especially no identification where the funding will come from.

…Mobility will be key. Alternatives to the auto must be provided and linked in the region…Maybe this is a start to really address the great challenges ahead to maintain and improve the quality of life in the region.

Although the concepts are terrific and very important to the future of our region, the Vision must include practical/doable/locally supportable implementations for it to make a difference in the real world. This next step in SCAG's vision effort (implementation) is so very critical.

Livability is a key ingredient often overlooked when visioning.

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4. Ranking of barriers

Survey respondents ranked a series of statements regarding barriers to successfully implementing the Growth Vision:

- The highest-ranking barrier in all five regions was an "under-informed general public, media and other key institutions."
- The second-highest-ranking barrier in the five regions was the recognition that "local control over land use decisions and competition between municipalities drives land use decisions."
- There was some variation among the remaining barriers, with "big, diverse, multiple jurisdictions in the region" and "state government historically slow to respond to changing land use needs at the regional level" ranking as third in the South Bay and Downtown/Westside L.A, but fourth in the remaining subregions.

5. Ranking of policy recommendations

Survey respondents ranked a series of policy recommendations regarding the successful implementation of the Growth Vision. The following three strategies were rated as high priorities by participants at all of the Dialogues:

- *First priority*: Create a targeted public education campaign to increase awareness of the issues outlined in the Growth Vision
- *Second priority*: Develop a best practices database that shows progress towards implementation of the key principles outlined in the Growth Vision
- *Third priority*: Foster greater cooperation between business and government through public-private partnerships

The policy recommendations that received the most varied response, with no more than 30% of survey respondents supporting the strategy, were:

- Develop a legislative agenda for the region, supported by a range of local governments, to aid in the realization of the Growth Vision
- Work to make the regional economy of the Southland a place where businesses are supported by government policies

AR0072726

V. Questions for the Future

A. Would this project add value to the work of COGs and MPOs? How?

B. Is it possible to reach agreement on 5-10 statewide goals and 35-40 indicators that would measure progress against these goals?

C. Is it possible/valuable to present a few goals and measures unique to each sub-region?

D. Is the timeframe practical and are there sufficient resources to develop a quality product?

E. Who are the audiences for this report?

- Governor & Cabinet
- California Performance Review
- Legislature
- Regional leaders
- Media
- General Public
- Who else?

AR0072727

CEQA

air quality handbook

Prepared by:

South
Coast
Air
Quality
Management
District

April, 1993

AR0072728

South Coast
AIR QUALITY MANAGEMENT DISTRICT
21865 E. Copley Drive, Diamond Bar, CA 91765-4182 (909) 396-2000

MESSAGE FROM THE CHAIRMAN

April, 1993

The federal Clean Air Act, the California Clean Air Act, and the 1991 AQMP revision have set forth an attainment program for this region to achieve the federal and state ambient air quality standards. Success in achieving our goal lies in the cooperative efforts of all levels of government as well as public support. Together, we have made the last three years the cleanest on record. But we have a long way to go to regain healthful air in this region. Our efforts will be challenged along the way by increases in population growth, the need to obtain emission reductions from more and smaller sources, and the need for technological breakthroughs.

However, there are actions that local government planners and project proponents can take to be proactive members of the clean air team. One of those actions involves the California Environmental Quality Act (CEQA) process. Only local governments have the ability to assess and mitigate the air quality impacts of land development or redevelopment. This fifth edition of the District's CEQA Air Quality Handbook is intended to assist you in carrying out this objective.

Without this extra effort by local government, new development could account for 43% of reactive organic compounds and oxides of nitrogen generated by mobile sources in the year 2010. It is critical that we reduce these pollutants, as they are precursors to the smoggy haze we see so frequently in our region.

If past experience is any indication of our potential to solve this problem, then I am confident that our continued partnership will succeed and the residents of this region will breathe healthful air by the year 2010.

Henry W. Wedaa

Henry W. Wedaa, Chairman
SCAQMD

AR0072729

PREFACE

The South Coast Air Quality Management District (District) has prepared this CEQA Air Quality Handbook which replaces the District's 1987 Environmental Impact Report Handbook. This Handbook is intended to provide local governments, project proponents, and consultants who prepare environmental documents with guidance for analyzing and mitigating air quality impacts of projects. This Handbook also describes the criteria the District uses when reviewing and commenting on the adequacy of environmental documents. Projects that are categorically or statutorily exempt from CEQA are not subject to these guidelines. This guidance document does not, nor does it intend to, supercede local jurisdictions' CEQA procedures.

This Handbook is an advisory tool and it is hoped that, over time, voluntary use will lead to a standardized format for the preparation of air quality analysis in environmental documents for new development and a proactive procedure for mitigating potential air quality impacts from new projects. This Handbook is intended to address the identification, analysis and mitigation of air quality impacts. Other resources which may be impacted, such as water quality, hazardous materials and light and glare are not addressed in this guidance.

The District staff will initiate a training program aimed at providing technical assistance to those persons responsible for the preparation or review of an air quality analysis. Please contact the District Local Government - CEQA Review Section for information on the training schedule.

The District will update sections of the CEQA Air Quality Handbook as new information and analysis methods become available. Purchasers of the Handbook will automatically be notified about annual subscriptions for these updates. (Subscription rates will cover costs of printing and distribution only.)

The District recognizes that the CEQA Air Quality Handbook may affect environmental documents which are currently being prepared or undergoing revisions prior to release as a final document. It is not our intent that the release of the District's CEQA Air Quality Handbook impede the progress of these documents. The CEQA Air Quality Handbook should, however, be utilized as a guide to preparing any newly initiated environmental documents.

AR0072730

NOTICE TO SUBSCRIBERS

If you purchased this copy of the 1993 CEQA Air Quality Handbook directly from the SCAQMD, you have automatically been recorded as a subscriber for all updates distributed in 1993. Thereafter, subscriptions for Handbook updates will be offered on an annual basis (rates cover costs of printing and distribution only).

AR0072731

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Supervisor, County of Riverside

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JAMES M. LENTS, Ph.D

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SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Office of Planning and Technology Advancement

ALAN C. LLOYD, Ph.D.
Chief Scientist

BARRY R. WALLERSTEIN, D.Env.
Assistant Deputy Executive Officer

CINDY GREENWALD
Planning Manager

AUTHORS

Alane Taber, AICP
Connie Day
Gary Bill
Shalini George
Douglas Kim
Von Loveland
Steve Smith, Ph.D.

ADVISORY/TECHNICAL CONSULTATION

Andy Abele
Barbara Baird
Jack Broadbent
Dave Coel
Mark Coleman
Margaret Hoggan
Henry Hogo
Hasan Ichrara, Ph.D.
Robert Kwong
Mo Lakhany
Mike Laybourn
Jon Leonard
Pat Leyden, AICP
Danny Luong, P.E.
Chris Marlia
Mohsen Nazami
Robert Pease, P.E.
Ed Pupka
John Reimers
Doug Ronaldson
Mark Saperstein, D.Env.
Tara Sheehy
Cindy Sullivan
Ditas Shikiya
Alex Vardakis
Karen Weir-Brown
Robert Wu
Mel Zeldin

Richard L. Perrine, Ph.D.
Alan Jonsich, Ph.D.
Aspen Environmental Group

EDITORIAL AND TECHNICAL ASSISTANCE

Patricia Whiting

F. Miriam Reed, Ph.D.
SAGE Resources

PUBLICATION SERVICES

Royetta Campbell
Lori Inga
Duke Quach
Liz Salazar
Penny Shaw
Donna Vernon
SCAQMD Print Shop
SCAQMD Creative Services

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SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Technical Assistance

Special Topic Numbers

Local Government-CEQA Review (909) 396-3109	Information and assistance in the preparation and review of environmental documents for which the District is a responsible/commenting agency, and questions regarding the Handbook and the MAAQI model
Transportation/Indirect Source (909) 396-3269	Local government technical assistance on transportation issues (i.e., model ordinances) and rule development relating to transportation sources
PM10/Global Warming/ Ozone Depletion/Toxics (909) 396-3109	Technical assistance relating to the control of fugitive dust/PM10, and the District's global warming/ozone depletion and toxics policies
Environmental Analysis (909) 396-3109	Information and inquiries regarding Environmental Assessments performed for District rules and regulations
Toxics (909) 396-3108	Information on health risk assessments and toxics permits and compliance
Transportation Program (909) 396-3273	Information on facility-specific Regulation XV trip reduction plans
Intergovernmental Affairs LA/Orange Counties (909) 396-3232 Inland Empire (909) 396-3231	Information for elected local government officials and general local government assistance
Library (909) 396-2600	Information on obtaining publications
Speakers Bureau (909) 396-3202	Requests for public presentations and speakers
Air Quality Evaluation (909) 396-3147	Information on current air quality from monitoring stations
Modeling (909) 396-3179	Information and assistance on air quality modeling

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SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

General Telephone Numbers

SCAQMD Headquarters
21865 East Copley Drive
Diamond Bar, California 91765
(909) 396-2001

Anaheim Office
2100 E. Katella Avenue, Suite 200
Anaheim, CA 92806
(909) 740-6734

Long Beach Office
145 W. Victoria Avenue
Long Beach, CA 90805
(310) 885-6816

Colton Office
851 S. Mt. Vernon Avenue
Colton, CA 92324
(909) 420-7100
(909) 420-7000

Pasadena Office
(Small Business Asst.)
297 N. Marengo Avenue
Suite 101
Pasadena, CA 91101
(818) 585-6400

Cerritos Office
17215 Studebaker Road
Cerritos, CA 90701
(310) 403-6000

Air Pollution Complaints
(800) 572-6306

Public Information Center
General Inquiries, Referrals, Literature - (909) 396-3600

Daily Air Quality Information Recordings
Los Angeles and Orange Counties - (800) 242-4022
San Bernardino and Riverside Counties - (800) 367-4710

Service Station Nozzle Complaints
(800) 242-4020

CUT SMOG PROGRAM
(To Report Smoking Vehicles)
(800) 288-7664
(800) CUT-SMOG

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INTRODUCTION TO THE CEQA AIR QUALITY HANDBOOK

CHAPTER 1

This California Environmental Quality Act (CEQA) Air Quality Handbook has been prepared by the South Coast Air Quality Management District (SCAQMD, or District) as guidance to assist local government agencies and consultants in developing the environmental documents required by CEQA. With the help of the Handbook, local land use planners will be able to analyze and document how proposed and existing projects affect air quality and should be able to fulfill the requirements of the CEQA review process.

It is within this framework of the CEQA review process that the air quality effects of proposed projects can be identified, analyzed, and mitigated. The CEQA review process is structured to: 1) identify significant adverse environmental impacts of the project, and 2) identify ways that environmental damage can be avoided or significantly reduced, by requiring changes in a project through alternatives or mitigation measures that are found to be reasonable and feasible.

1.1 Categories of Projects Reviewed by CEQA

Any project that has the potential to emit air pollutants should undergo some form of CEQA review. Generally, there are two categories of projects: (1) public, and (2) private. Public projects include those projects initiated by a local agency in support of its responsibilities. For instance, a water district may install water lines to provide customers with a water supply, a city or county may construct new roads, buildings, or other public infrastructure facilities; a local government may prepare a General Plan; or a school district may construct a new school. In each case, the project will have air pollutant emissions during its construction and operation that should be evaluated under CEQA to determine the potential for significant adverse impacts.

Private projects include private sector projects for which the local agency exercises its discretion in issuing a permit before each project can proceed. The most obvious examples of such projects include discretionary land use permits, (i.e., tentative maps, conditional use permits, Specific Plans, and other types of private development).

1.2 Categories of Emissions

In referring to sources of air pollutant emissions, the District categorizes them as:

- Stationary (area and point) sources
- Mobile (on-road and off-road) sources

Most sources produce emissions in each of these categories. These categories of emissions, illustrated in Figure 1-1, are defined and discussed below:

Stationary sources can be divided into two major subcategories: **point** and **area sources**. **Point sources** consist of one or more emission sources at a facility with an identified location and are usually associated with manufacturing and industrial projects. Examples are refinery boilers or combustion equipment that produces electricity or processes heat. **Area sources** are widely distributed and produce many small emissions. Examples of such sources are residential water heaters, painting operations, lawn mowers, agricultural fields, landfills, and consumer products such as barbecue lighter fluid or hair spray.

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Mobile sources refer to emissions from motor vehicles, including tailpipe and evaporative emissions, and are classified as either **on-road or off-road**.

- **On-road sources** are considered to be a combination of emissions from automobiles, trucks and **indirect sources**:

  Indirect sources are defined as sources that by themselves may not emit air contaminants; however, they indirectly cause the generation of air pollutants by attracting vehicle trips or by consuming energy. Examples of indirect sources include an office complex or commercial center that generates commuter trips and consumes energy resources through the use of electricity for lighting and space heating. Indirect sources include actions proposed by local government, such as redevelopment districts and private projects involving either large buildings or tract developments. Indirect sources also include those emissions created by the distances vehicles travel.

- **Off-road sources** include aircraft, ships, trains, and self-propelled construction equipment.

Some people are more likely to be affected by air pollution emissions as such, and are considered to be "sensitive." These include children, the elderly, persons with pre-existing respiratory and/or cardiovascular illness, and athletes and others who engage in frequent exercise. Because these groups of people are sensitive to air pollution, their environment is given special consideration. Thus, residences, schools, playgrounds, child-care centers, convalescent centers, retirement homes, and athletic fields are defined as **sensitive receptors**, as shown in Figure 1-2.

1.3 Handbook Organization and CEQA Review Process

The organization of this Handbook follows the steps of the local government project review process. The flow chart in Figure 1-3 sets out the organization of the Handbook and gives a simplified overview of the steps in the CEQA review process. Concurrently, the flow chart summarizes the different air quality impact categories and where each category is discussed in this Handbook. A brief description of each step in the CEQA review process is described below.

BACKGROUND INFORMATION (Chapters 2 and 3)

Chapters 2 and 3 give planners background information on air quality. Chapter 2 introduces the District and explains how the District manages air quality. Chapter 3 discusses why the region has smog and the effects of air pollution on quality of life.

INITIAL CONSULTATION (Chapters 4 and 5)

The first step in the project review process is the initial consultation between local governments and project proponents. The purpose of the initial consultation is to identify projects that may have problems with (1) land use compatibility and (2) site design and planning. The Handbook provides planners with suggestions for creating a local initial consultation process related to air quality. Finally, the Handbook discusses consultation between the District and the lead agency.

INITIAL STUDY AND DETERMINATION OF SIGNIFICANCE (Chapter 6)

The next step in the process is the preparation of the Initial Study and determination by the local government as to the project's significance. Projects with emissions found to be environmentally insignificant are granted a Negative Declaration (ND). Projects with emissions that are determined significant because one or more thresholds are exceeded will require a more in-depth environmental analysis, and the preparation of either a Mitigated Negative Declaration (MND) (when impacts can be

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made insignificant due to the imposition of mitigation measures) or an Environmental Impact Report (EIR).

DOCUMENT PREPARATION (Chapters 7 through 13)

Pre-Screening Review/Preparation of Environmental Analysis Components. This Handbook provides guidance on preparing the MND and EIR, with sections on establishing baseline, emissions calculations, tables, mitigation, and consistency. The Handbook also gives instructions for using the Mobile Assessment for Air Quality Impacts (MAAQI) model to analyze air quality (mobile sources and energy) for all types of environmental documents. Prior to completion of the EIR CEQA requires lead agencies to consult with responsible agencies and provides for consultation with any persons or agencies with special expertise (PRC Section 21153).

The District as a Responsible Agency. The Handbook provides guidance in assessing the potential multi-media impacts for those cases when the environmental documentation will address both air quality and other environmental impacts (e.g., water, waste disposal, etc.).

PROJECT REVIEW (Chapter 14)

District Review and Commenting Process. The District reviews and comments on the air quality analysis in environmental documents for projects exceeding the thresholds of significance. The Handbook describes the review process when the District is a responsible and/or commenting agency.

MONITORING AND REPORTING (Chapters 15 and 16)

Implementing and Monitoring Mitigation. State law requires that mitigation be monitored after the EIR or MND is approved by the local government. The Handbook provides planners with suggestions for monitoring and enforcing air quality mitigation measures.

Reporting on Project Disposition. Each year, it is necessary for the District to report to the California Air Resources Board (ARB) and the Federal Environmental Protection Agency (EPA) on the progress made to date in reducing emissions. In order to credit local government actions, local governments are requested to voluntarily report information regarding CEQA documents to the District. Additional monitoring information may be requested by the Southern California Association of Governments (SCAG). The Handbook provides reporting forms.

APPENDICES

The Handbook appendices provide more detailed guidance information, including calculation procedures, quantification formulas, screening tables, and background material, to assist in the preparation of CEQA-required environmental documents.

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Figure 1-1. Major Categories of Emissions

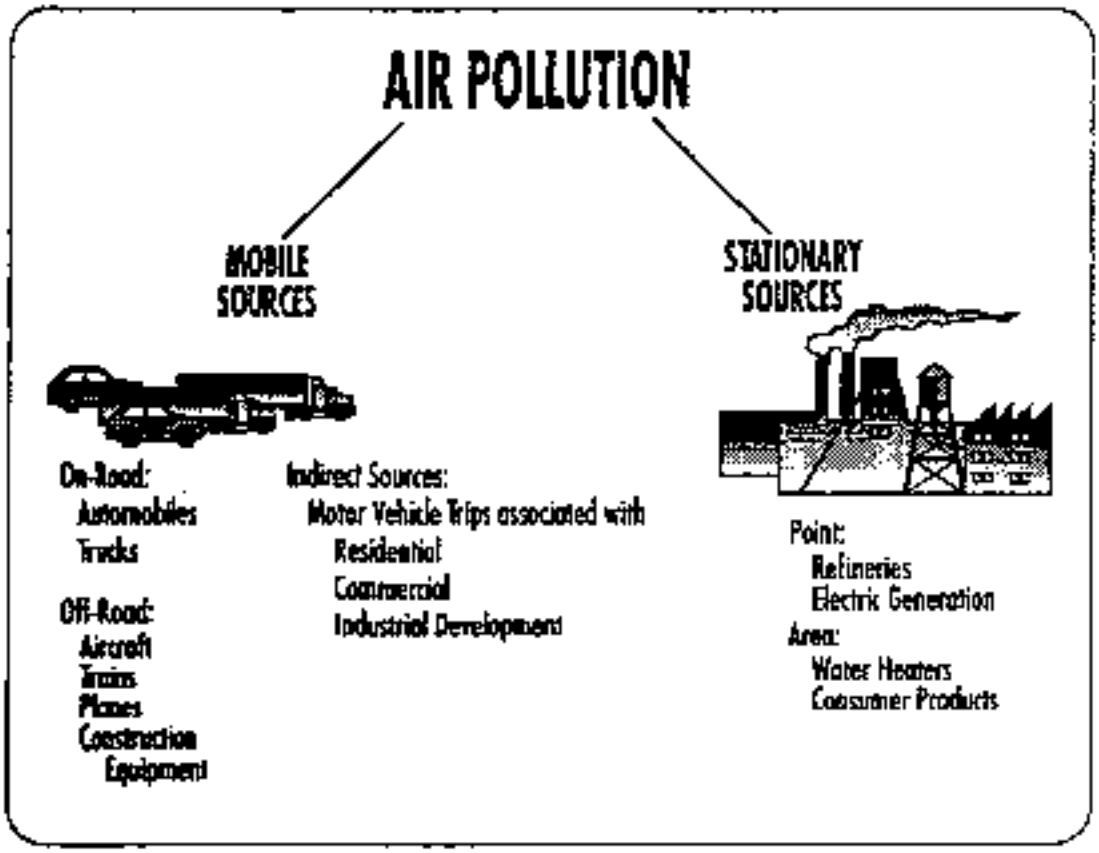

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Figure 1-2. Typical Sensitive Receptors

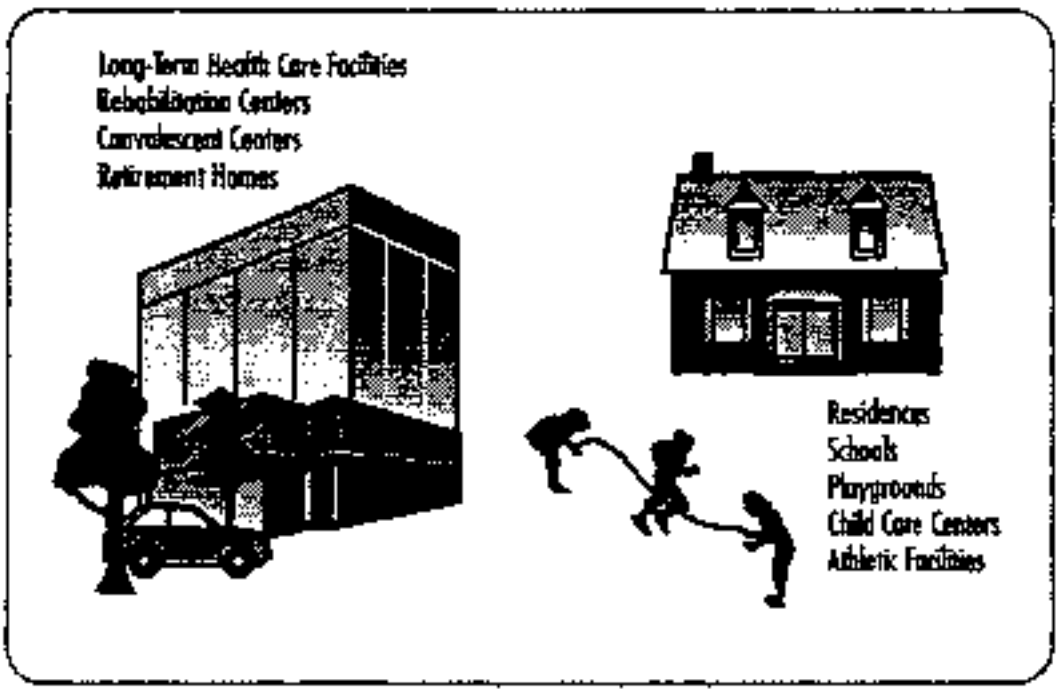

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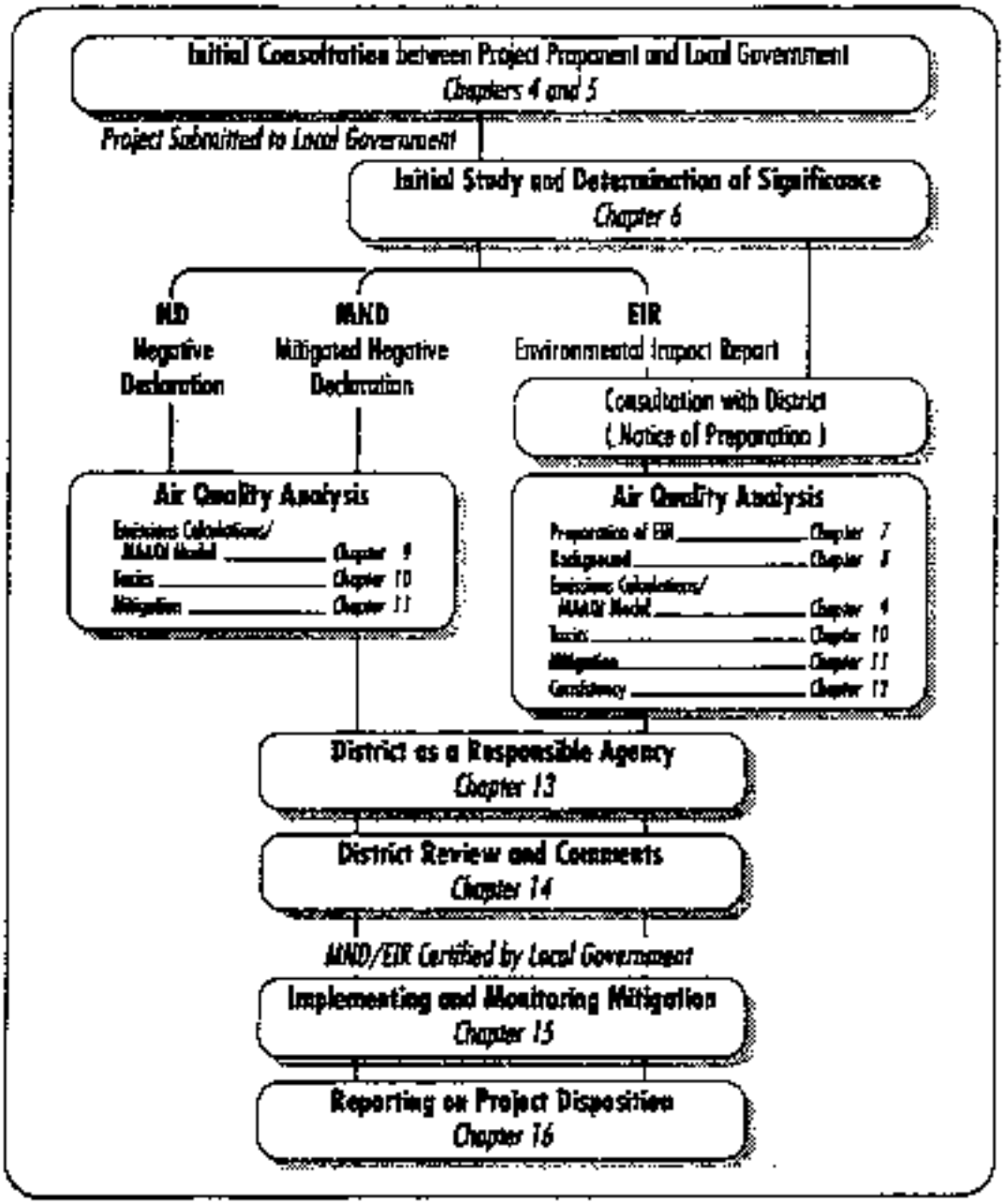
Figure 1-3. Steps in the CEQA Review Process



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AIR QUALITY MANAGEMENT AND THE DISTRICT'S ROLE

CHAPTER 2

The South Coast Air Quality Management District (SCAQMD, or District) was created by the 1977 Lewis-Presley Air Quality Management Act, which merged four county air pollution control bodies into one regional district. Under the Act, the District is responsible for bringing air quality in the areas under its jurisdiction into conformity with federal and state air quality standards. To that end, the District is working systematically to:

(1) Reduce present emissions to levels that will meet state and federal air quality standards, and

(2) Ensure that future emissions will be within state and federal standards.

The area managed by the District includes Los Angeles, Orange, and Riverside Counties, and the non-desert portion of San Bernardino County. The four counties lie within two air basins: the South Coast Air Basin (SCAB), which comprises Orange County and the non-desert portions of Los Angeles, San Bernardino, and Riverside Counties, and the Southeast Desert Air Basin (SEDAB), which covers a large area of the desert portion of Riverside and Los Angeles County and includes the Coachella Valley. Figure 2-1 shows the relative orientation and size of the two air basins.

Both Basins are named because their geographical formation is that of a basin, with the surrounding mountains containing the air and its pollutants in the valleys or "basins" below. In addition, each Basin has separate air quality problems. The SCAB must deal primarily with the pollutants created by dense population centers, heavy vehicular traffic, and industry; while in the Coachella Valley and Antelope Valley portions of the SEDAB, pollution results primarily from dust raised by heavy construction, and travel on unpaved roads and paved roads with silty debris. Unfortunately, as its population increases, the Coachella Valley may also begin to have smog problems similar to those in the SCAB.

2.1 Government Agencies and Air Quality Management

Air quality problems in the SCAB and SEDAB are addressed through the efforts of federal, state, local, and regional government agencies, as seen in Figure 2-2. These agencies work jointly as well as individually to clean up the air through legislation, regulations, policy making, education, and a variety of programs. These agencies include:

- Environmental Protection Agency (EPA)
- California Environmental Protection Agency (Cal EPA) and California Air Resources Board (ARB) which is a part of Cal EPA.
- Local governments
- Southern California Association of Governments (SCAG)
- Coachella Valley Association of Governments (CVAG)
- South Coast Air Quality Management District (SCAQMD)

In the following paragraphs, these agencies are further identified and their individual responsibilities summarized.

o Environmental Protection Agency

The federal Environmental Protection Agency (EPA) is responsible for setting and enforcing the national standards for atmospheric pollutants. The EPA enforces these national standards and also regulates emission sources that are under the exclusive authority of the federal government, such as aircraft and certain locomotives. The EPA has jurisdiction over emission sources outside state waters (outer continental shelf), and establishes various emission standards, including those

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for vehicles sold in states other than California. Automobiles sold in California must meet the stricter emission standards established by the ARB.

o **California Air Resources Board**

The State of California Air Resources Board (ARB), which became part of the California Environmental Protection Agency (Cal EPA) in 1991, is responsible for ensuring implementation of the California Clean Air Act (CCAA), responding to the federal Clean Air Act (CAA), and for regulating emissions from motor vehicles and consumer products. The ARB has established emission standards for vehicles sold in California and for various types of equipment available commercially. The ARB also sets fuel specifications to further reduce vehicular emissions.

o **Southern California Association of Governments**

The Southern California Association of Governments (SCAG) is a council of governments for the following six southern California counties: Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura. SCAG is a regional planning agency and serves as a forum for regional issues relating to transportation, the economy and community development, and the environment. SCAG also serves as the regional clearinghouse for projects requiring environmental documentation under federal and state law. In this role, SCAG reviews proposed projects to analyze their impacts on SCAG's regional plans.

As the largest metropolitan planning organization (MPO) in the United States, SCAG is primarily responsible for preparing the Regional Mobility Plan (RMP), and Growth Management Plan (GMP). The RMP and GMP form the basis for the land use and transportation control portions of the Air Quality Management Plan. SCAG is the region's state-designated transportation planning agency and the federally designated MPO. As such, SCAG is responsible for developing the Regional Transportation Plan and the Regional Transportation Improvement Program and performing the conformity analysis for transportation plans and programs.

o **Coachella Valley Association of Governments**

The Coachella Valley Association of Governments (CVAG) is a council of governments composed of cities in the Coachella Valley. The CVAG plays a key role in the implementation of the Coachella Valley PM10 Plan, wherein it is responsible for coordinating and monitoring local government efforts to reduce PM10 emissions.

o **Local Governments**

Local governments have the authority and responsibility to reduce air pollution through their police power and land use decision-making authority. Specifically, local governments are responsible for the mitigation of emissions resulting from land use decisions and for the implementation of transportation control measures as outlined in the Air Quality Management Plan (AQMP).

The AQMP assigns local governments certain responsibilities to assist the air basin in meeting air quality goals and policies. In general, a first step towards implementation of a local government's responsibilities will be accomplished through development of an enforceable local air quality implementation plan, or by amending a city's or county's General Plan, or by preparing a free-standing Air Quality Element to its General Plan. Air quality policies need to be subsequently codified into zoning ordinances (or other legally enforceable mechanisms) that will implement the AQMP. Such ordinances can encourage trip reduction, and be incorporated as design standards that may require bicycle racks, landscaping, etc.

Through capital improvement programs, local governments can fund infrastructure that contributes to improved air quality, by requiring such improvements as bus turnouts, energy-efficient street lights, and synchronized traffic signals. Local governments can also take administrative actions that reduce air pollution, such as creating a telecommunication program for local government employees that will enable them to work at home.

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In accordance with CEQA requirements and the CEQA review process, local governments assess air quality impacts, require mitigation of potential air quality impacts by conditioning discretionary permits, and monitoring and enforcing implementation of such mitigation.

2.2 South Coast Air Quality Management District

The California Clean Air Act (H & S Section 40412) designates the South Coast Air Quality Management District as the agency principally responsible for comprehensive air pollution control in the South Coast Air Basin (SCAB) and certain areas of the Southeast Desert Air Basin (SEDAB). To that end, the District, a regional agency, works directly with SCAG, CVAG, county transportation commissions, local governments, and cooperates actively with all state and federal government agencies. The District develops rules and regulations, establishes permitting requirements, inspects emission sources, and enforces such measures through educational programs or fines, when necessary.

The District is responsible for reducing emissions from stationary (area and point), mobile, and indirect sources. The District works closely with the ARB, which regulates mobile sources, and is in the process of developing programs such as limits on bus or truck idling and requirements for low-emission vehicle fleets. The District works to reduce indirect sources through such measures as the "Carpooling Rule," Regulation XV. Finally, the District develops regulations and programs for reducing emissions from consumer products such as barbecue lighter fluid.

Organization of the District. The District operates and is organized in a manner similar to local governments, as outlined in Figure 2-3. The Governing Board is the decision-making body that adopts District rules and the Air Quality Management Plan much as a City Council approves its General Plan, ordinances, and specific projects. The twelve-member Governing Board is comprised of three state appointees and nine elected officials who represent local governments.

There are several special committees that review and recommend actions to the Governing Board. The Interagency Air Quality Management Plan Implementation Committee is made up of local government officials, transportation commissioners, and wastewater agency representatives. This committee offers local governmental agencies the opportunity to comment directly on the District's rulemaking and planning processes.

The Role of SCAQMD in the CEQA Review Process

The District takes an active part and a variety of roles in the CEQA review process. Pursuant to CEQA requirements, the District may act as a lead agency, a responsible agency, or a commenting agency in the process.

Lead Agency: A lead agency is the public agency with the principle responsibility for carrying out or approving a project; in general a local government agency with jurisdiction over land use serves as lead agency. However, the District may serve as lead agency for its own projects, such as its own new rules and regulations. As a lead agency, the District is responsible for deciding if an EIR or other environmental document must be prepared for these projects, and for causing the document to be prepared. In certain limited circumstances (CEQA Guidelines Section 15052), the District may also assume the lead agency role or prepare a subsequent Environmental Impact Report for impacts of permitted equipment for projects requiring a District permit, when prior environmental documentation is not adequate for the District to take action.

Responsible Agency: A responsible agency is a public agency that proposes to carry out or approve an aspect of a proposed project for which a lead agency is preparing an environmental document. The District serves as a responsible agency for those portions of a development project that require a District permit, or where the District has any other approval power over the project. If the development project does not require a District permit or approval, the District would be neither a lead nor responsible agency. In its responsible agency capacity, the District provides comments to the lead agency on the project's impact on air quality and recommended feasible mitigation measures.

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Commenting Agency: In accordance with Health and Safety Code Section 40412, the District is the sole and exclusive local agency within the South Coast Air Basin with the responsibility for comprehensive air pollution control, and it shall have the duty to represent the citizens of the Basin in influencing the decisions of other public and private agencies whose actions might have an adverse impact on air quality in the Basin. As such, the District may comment on projects that have the potential to adversely affect air quality in the Basin and over which the District has no discretionary permit authority. As when the District is a responsible agency, the District's comments are advisory to the lead agency, similar to those provided by other limited-purpose agencies such as flood control districts. District comments are focused on identifying a project's impact on air quality and recommending potential mitigations for the lead agency's consideration.

Combined Responsible/Commenting Agency Role: The District can simultaneously serve as both a responsible and a commenting agency for a proposed project. For example, the District would be a responsible agency for the aspects of a hospital development which require a District permit or approval. The District would be a commenting agency for all other aspects of the project affecting air quality.

2.3 The Air Quality Management Plan

Both federal and state Clean Air Acts require that each nonattainment area prepare a plan to reduce air pollution to healthful levels. The 1989 AQMP was the first AQMP to define a comprehensive control strategy, achievable attainment dates, and an aggressive rulemaking schedule for implementation of the Plan.

Even as the 1989 AQMP was being developed, unprecedented population growth and concurrent environmental pollution precipitated passage of the 1988 California Clean Air Act (CCAA), and 1990 amendments to the federal Clean Air Act (CAA). Both of these laws require stricter controls on pollutants and attainment of the air quality standards within specified time frames. A revised AQMP, which reflected these new requirements from the federal and state government, was adopted on July 12, 1991.

In response to the 1988 CCAA, the 1991 AQMP proposed stricter control over emissions from industrial plants; extended the scope of District air pollution regulations to include the categories of air toxics, and global warming and ozone-depleting gases; and established an attainment schedule to approach the state requirement of a five percent per year reduction of emissions. Details regarding the policies and strategies of the AQMP and their implementation are given in Chapter 3.

The 1991 AQMP also responds to some of the 1990 CAA amendments by setting requirements for clean motor fuels; tightening controls on industrial plants; identifying a wide variety of air toxics to be restricted; and in recognition of the threat of global warming and ozone depletion, limiting chlorofluorocarbon (CFC) and halon use.

The updated AQMP establishes a blueprint to achieve the federal and state health-based air quality standards within twenty years. Finally, the 1991 AQMP is the nation's most advanced air pollution control program, providing a framework for future air pollution control efforts that will assure clean air for the South Coast and Southeast Desert Air Basins into the twenty-first century.

2.4 Other Air Quality Plans

In accordance with federal CAA requirements, the State of California must submit State Implementation Plans (SIPs) which demonstrate how nonattainment areas will meet a number of federal health-based standards by specific deadlines. The District has submitted specific attainment plans for carbon monoxide, nitrogen dioxide, and PM10 containing control measures derived from the 1991 AQMP, which are then incorporated into the state plans; each individual plan represents the current formal attainment strategy for that criteria pollutant. As part of CCAA requirements, the air quality status of each of these criteria pollutants will be reviewed in the 1994 AQMP submitted to the state.

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References

1991 *Air Quality Management Plan*. Available from the District Public Information Center.

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Figure 2-1. Location and Boundaries of SCAB and SCAQMD Jurisdiction

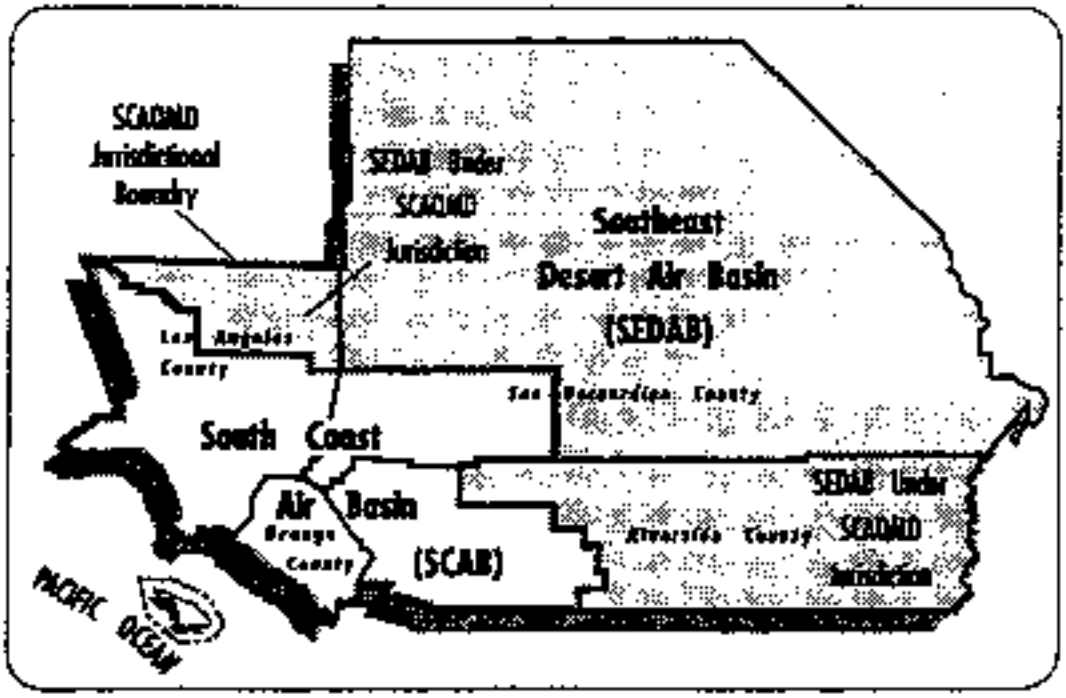

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Figure 2-2. Air Quality Legislation and Responsible Agencies

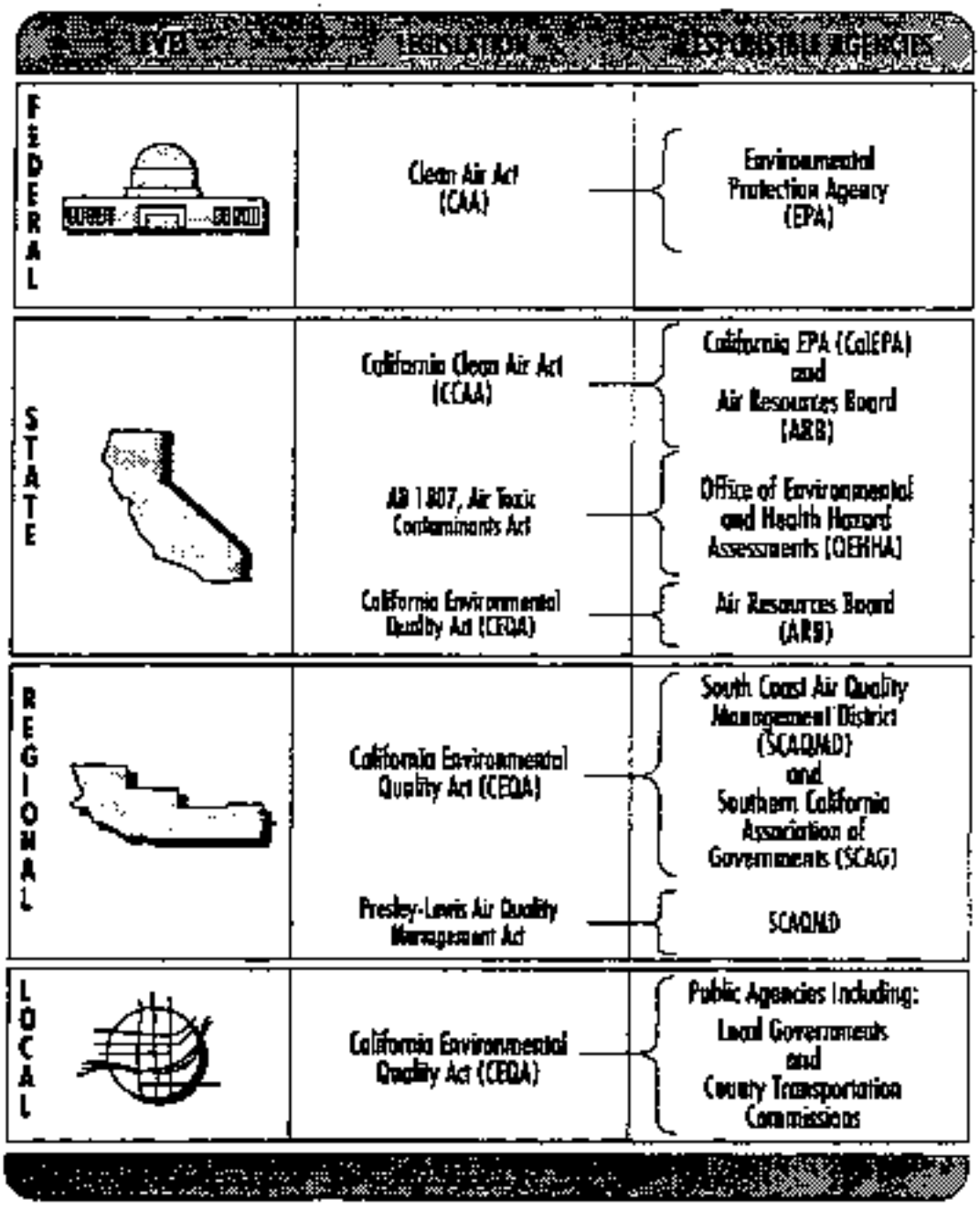

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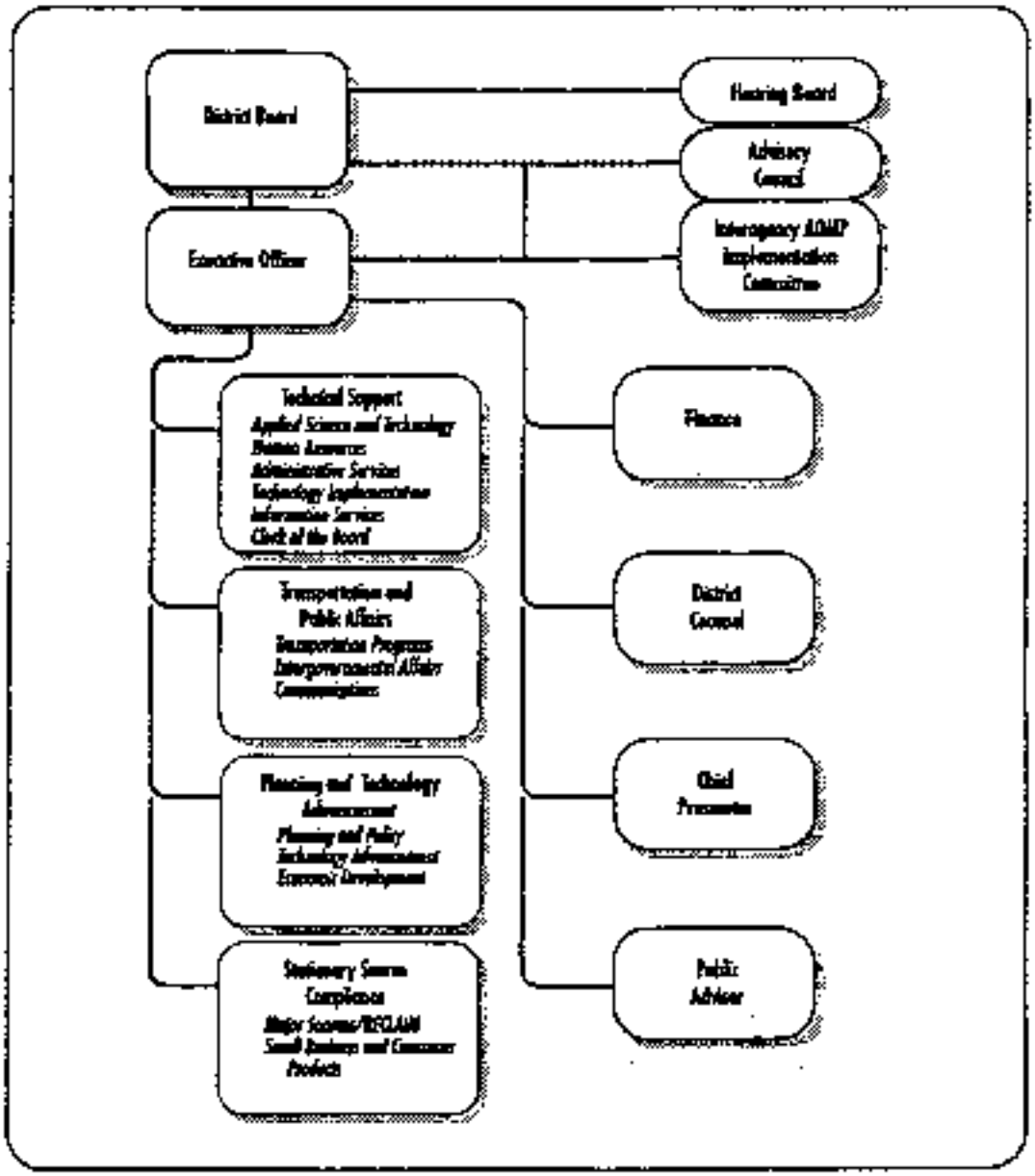
Figure 2-3. SCAQMD Organization



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BASIC AIR QUALITY INFORMATION

CHAPTER 3

Effects of Polluted Air on Health

The residents of Southern California pay for breathing polluted ambient air with:

- o Increased episodes of respiratory infections and other illnesses
- o Increased number of days of discomfort and missed days from work and school
- o Increased use of medications to relieve eye and throat irritation, headache, nausea, and aggravated asthma
- o Increased mortality.

Polluted air also damages agriculture, our natural environment and man-made materials, and decreases visibility. Cleaning up the air will result in improved public health and economic benefits that will offset, in whole or in part, the costs of attaining clean air.

A conservative estimate of the benefits derived from improved air quality in the District's four-county region, when expressed in economic terms, is approximately $6.2 billion per year. This estimate takes into account the economic benefits that will accrue from: (1) the improved health that will accompany reduced ozone emissions, (2) fewer deaths from high fine-particulate concentrations, and (3) fewer restricted activity days. There are many more health factors which have not been quantified (refer to Figure 3-1).

3.1 Regulated Pollutants

The pollutants regulated by the Clean Air Acts and state law fall under three categories:

- o Criteria air pollutants
- o Toxic air pollutants
- o Global warming and ozone-depleting gases

Each of these categories is monitored and dealt with differently. Criteria air pollutant levels are based on the measurement of their presence in the general atmosphere; toxic pollutant emissions are measured at their individual sources and general atmosphere; and global warming and ozone-depleting gases are subject to federal and regional policies that call for their reduction and eventual phase-out.

o Criteria Air Pollutants

Criteria air pollutants are defined as those pollutants for which the federal and state governments have established ambient air quality standards, or criteria, for outdoor concentrations in order to protect public health. The federal and state standards have been set at levels above which concentrations could be generally harmful to human health and welfare. Table 3-1 compares existing regional levels of criteria pollutants with those levels set by federal and state standards. These standards are designed to protect the most sensitive persons from illness or discomfort with a margin of safety. However, a 1986 review of health information by EPA's Office of Air Quality Planning and Standards concluded that the existing one-hour ozone standard may not provide an adequate margin of safety. The criteria pollutants listed in Table 3-1 contribute to the smoggy haze visible in the SCAB (also referred to as "Basin" hereafter). The state standard for visibility is also given in Table 3-1.

Criteria air pollutant concentrations are higher in the Basin than any other area of the country. This regional problem exists because of local emission sources which are the principal cause of elevated levels (e.g., heavy industry, concentrated population, and dense vehicle traffic) within the SCAB. Table

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3-2 lists the primary emission sources of these criteria pollutants and some of their harmful effects. These pollutants are known to damage property, impair visibility, and cause damage to plants. Adverse effects upon human health, however, are of greatest concern.

At the present time, six ambient air pollutants are of special concern: sulfur dioxide (SO_2), lead (Pb), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and fine particulate matter (PM10). Although federal and state standards for sulfur dioxide are met within the SCAB, emissions of SO_2 contribute to violations of the state sulfate standards. Atmospheric concentrations of the other five pollutants exceed both the state and federal standard. The SCAB also exceeds the state visibility standards.

The following paragraphs describe briefly the adverse health effects of the five criteria pollutants that exceed the air quality standards in the SCAB. The District publication entitled "Where Does It Hurt?" provides additional health-related information on these pollutants.

Lead in the atmosphere occurs as particulate matter. The combustion of leaded gasoline is the primary source of lead emissions in the Basin. Other sources of lead include the manufacturing of batteries, paint, ink, ceramics, and ammunition and secondary lead smelters. With the phase-out of leaded gasoline, secondary lead smelters and battery recycling and manufacturing facilities are becoming lead-emission sources of greater concern.

Prolonged exposure to atmospheric lead poses a serious threat to human health. Health effects associated with exposure to lead include gastrointestinal disturbances, anemia, kidney disease, and in severe cases, neuromuscular and neurologic dysfunction. Of particular concern are low-level lead exposures during infancy and childhood. Such exposures are associated with decrements in neurobehavioral performance (including IQ performance, psychomotor performance and reaction time) and growth. Lead is currently classified as a probable human carcinogen with an EPA weight-of-evidence classification of B2.

Carbon Monoxide (CO). The automobile and other types of motor vehicle are the main source of this pollutant in the SCAB. This gas is colorless and odorless, which adds to its danger. In high concentrations, CO can cause physiological and pathological changes, and ultimately death, by incapacitating the red blood cells and interfering with their ability to carry oxygen to body tissues.

Nitrogen Dioxide (NO_2) is a by-product of fuel combustion. The principal form of nitrogen oxide produced by combustion is nitric oxide (NO), but NO reacts quickly to form NO_2, creating the mixture of NO and NO_2 commonly called NOx. Nitrogen dioxide acts as an acute irritant and, in equal concentrations, is more injurious than NO. At atmospheric concentrations, however, NO_2 is only potentially irritating. There is some indication of a relationship between NO_2 and chronic pulmonary fibrosis. Some increase in bronchitis in children (two to three years old) has also been observed at concentrations below 0.3 parts per million (ppm). Nitrogen dioxide absorbs blue light; the result is a brownish-red cast to the atmosphere and reduced visibility. NO_2 also contributes to the formation of PM10.

Ozone (O_3) is one of a number of substances called photochemical oxidants that are formed when reactive organic compounds (ROC)[1] and nitrogen oxides, both byproducts of the internal combustion engine, react in the presence of ultraviolet sunlight. Ozone is present in relatively high concentrations in this Basin, and the damaging effects of photochemical smog are generally related to the concentrations of ozone. Ozone may pose its worst health threat to those who already suffer from respiratory diseases. Ozone also hurts healthy people. In the past, those effects were thought to be limited to more difficult breathing during work and exercise. However, research indicates that children in the SCAB experience a 10-15% loss in lung function. Figure 3-2 shows how often the ozone standard is exceeded compared to other areas of the U.S. The SCAB has peak ozone levels two and a half times higher than the federal health standard, and three times higher than the more stringent state standard.

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1 In District documents, the inclusive term "reactive organic compounds" (ROC) is gradually replacing the separate terms reactive organic gases (ROG), volatile organic compounds (VOCs), and hydrocarbons (HC), except in cases where such separation is useful.

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Fine Particulate Matter (PM10) consists of extremely small suspended particles or droplets 10 microns or smaller in diameter that can lodge in the lungs contributing to respiratory problems. PM10 arises from such sources as road dust, diesel soot, combustion products, abrasion of tires and brakes, construction operations, and wind storms. It is also formed in the atmosphere from NO_2 and SO_2 reactions with ammonia. PM10 scatters light and significantly reduces visibility.

Fine particulates pose a serious health hazard, alone or in combination with other pollutants. More than half of the smallest particles inhaled will be deposited in the lungs and can cause permanent lung damage. Fine particulates can also have a damaging effect on health by interfering with the body's mechanism for clearing the respiratory tract or by acting as a carrier of an absorbed toxic substance.

Since 1987, when EPA established air quality standards for PM10, efforts to reduce fugitive dust levels have focused more specifically on PM10 emissions. While prior fugitive dust emission factors were developed for total suspended particulates (TSP), both EPA and ARB have developed "conversion" factors to convert TSP to PM10 emission factors. Accordingly, the CEQA Handbook uses PM10 emission factors.

- **Toxic Air Contaminants**

Toxic air pollutants are often termed "non-criteria" because ambient air standards have not been established for them. This is so, not because they are fundamentally different from criteria pollutants, but because they are diverse, and because their effects on health tend to be local rather than regional. There are hundreds of air toxics, and exposure to these pollutants can cause or contribute to cancer, birth defects, genetic damage, and other adverse health effects.

The regulatory approach used in controlling toxic air pollutant levels relies on a quantitative risk assessment process to determine allowable emissions from the source, rather than on ambient air concentrations. In addition, for carcinogenic air pollutants, there is no safe concentration in the atmosphere. Local concentrations can pose a significant health risk and are termed "toxic hot spots."

The state has implemented a long-term program to identify, assess, and control ambient levels of air toxics. Toxic air contaminants have been identified as carcinogens by ARB in conjunction with Cal EPA Office of Environmental and Health Hazard Assessments (OEHHA, formally DHS). After identification, ARB may adopt an air toxics control measure to reduce ambient concentrations below a specified threshold based on health effects, or to the lowest concentration achievable through the use of best available control technology (BACT). Based on a 1987 District report, the two toxics which appear to offer the greatest risk for the Basin's population are hexavalent chromium and benzene.

Toxic air contaminants have their sources in many aspects of our high-tech lifestyle. Studies have shown that the concentrations of many toxic air contaminants could be two to four times higher inside commuter vehicles than they are generally found outdoors. High concentrations may also be found in enclosed parking garages, office buildings, and gasoline stations.

Toxic air pollutants may have both chronic effects (i.e., of long duration), and acute effects (i.e., severe but of short duration) on human health. Acute health effects are due to sudden exposure to high quantities of air toxics. These effects include nausea, skin irritation, respiratory illness, and in some cases, death. Chronic health effects result from low-dose, long-term exposure from routine releases of air toxics. The effect of major concern for this type of exposure is cancer, which requires a period of 10 to 30 years after exposure to develop.

- **Global Warming and Ozone-Depleting Gases**

Stratospheric ozone depletion refers to the slow destruction of naturally occurring ozone, which lies in the upper atmosphere (called the stratosphere), and which protects the earth from the damaging effects of solar ultraviolet radiation. Figure 3-3 illustrates these reactions. Certain gases in the atmosphere affect the Earth's heat balance by absorbing infrared radiation. This layer of gases in the atmosphere functions much the same as glass in a greenhouse (i.e., both prevent the escape of heat).

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This is why global warming is also known as the "greenhouse effect." The gases responsible for global warming, and their relative contribution to the overall warming effect are: carbon dioxide (55%), chlorofluorocarbons (CFCs) (24%), methane (15%), and nitrous oxide (6%). It is widely accepted that continued increases in greenhouse gases will cause global warming, although there is uncertainty concerning the magnitude and timing of the warming trend.

Certain compounds, including CFCs, halons, carbon tetrachloride, methyl chloroform, and other halogenated compounds accumulate in the lower atmosphere and then gradually migrate into the stratosphere. In the stratosphere, these compounds participate in complex chemical reactions to destroy the upper ozone layer. The role of these compounds in the depletion of stratospheric ozone was delineated by Molina and Roland in 1974 (Molina et al., 1974). Destruction of the ozone layer increases the penetration of ultraviolet radiation to earth's surface, a known risk factor that can increase the incidence of skin cancers and cataracts, contribute to crop and fish damage, and further degrade air quality.

Global warming gases and ozone-depleting gases include, but are not limited to, the following (Source; Piccot, et al., 1991):

> **Carbon Dioxide** - caused by fossil fuel combustion in stationary and mobile sources. Carbon dioxide contributes to the greenhouse effect, but not to stratospheric ozone depletion. In the Basin, approximately 48% of carbon dioxide emissions come from transportation, residential and utility sources contribute approximately 13% each, 20% come from industry, and the remainder comes from a variety of other sources.
>
> **CFCs** (Chlorofluorocarbons) - emitted from blowing agents used in producing foam insulation. They are also used in air conditioners and refrigerators, and as solvents to clean electronic microcircuits. CFCs are primary contributors to stratospheric ozone depletion and also to global warming. Based on a 1987 AQMD report, 63% of CFC emissions in the South Coast Air Basin come from the industrial sector.
>
> **Halons** - used in fire extinguishers, and behave as both ozone-depleting and greenhouse gases.
>
> **HCFCs** (Hydro-chlorofluorocarbons) - solvents, similar in use and chemical composition to CFCs. The hydrogen component makes HCFCs more chemically reactive than CFCs, allowing them to break down more quickly in the atmosphere.
>
> **Methane** - emitted from biogenic sources, incomplete combustion in forest fires, landfills, and leaks in natural gas pipelines. Methane is a greenhouse gas and traps heat 40 to 70 times more effectively than carbon dioxide. In the Basin, over 50% of human-induced methane emissions come from natural gas pipelines, while landfills contribute 24%.
>
> **TCA** (1,1,1,-Trichloroethane or Methyl Chloroform) - a solvent and cleaning agent commonly used by manufacturers. It is less destructive of the environment than CFCs or HCFCs, but its continued use will contribute to global warming and ozone depletion.

3.2 Causes of Smog

In the SCAB, two factors produce the region's high pollution concentrations and smog:

- Emissions
- Meteorology

Emissions. Emission sources may be as small as individual residential water heaters and as large as electrical power plants. Figure 3-4 illustrates typical emission sources found in the SCAB. Appendix 3 gives the percentages of emissions from these sources. ROC and NOx are the primary precursors of smog. In 1987, the base analysis year for the 1991 AQMP, emissions into the atmosphere of the SCAB from stationary, mobile, and indirect sources including consumer products added up to an average of 10,000 tons of pollutants per day.

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Vehicular sources account for over 95% of the carbon monoxide emissions, approximately two-thirds of the oxides of sulfur emissions, three-fourths of the oxides of nitrogen emissions, and one-half of ROC. NOx (including NO and NO_2), ROC, and the ultraviolet energy from the sun are involved in the complex chemical reactions that form ozone, the primary constituent of smog. In 1990, the maximum ozone concentration was two and one-half times, and the maximum carbon monoxide was nearly twice the national standards set to protect public health.

Stationary source emissions made up almost 95% of the particulate emissions in 1987; however, two-thirds of the stationary source particulate emissions consisted of road dust, which is categorized as a stationary source emission. Approximately half of this road dust qualified as fine particulates or PM10, the basis of the particulate air quality standards.

Meteorology. Compared with other urban areas in the U.S., metropolitan Los Angeles, which lies in the central SCAB, has a low average wind speed. Sea breezes carry pollutants inland, but the mountains act as a barrier restricting the horizontal dispersion of the pollution.

An inversion layer is a layer of warm air that lies over cooler, ocean-modified air. Over the SCAB, this layer acts as a lid, preventing air pollutants from escaping upward. In the summer, these temperature inversions are stronger than in winter and prevent ozone and other pollutants from escaping upward. In the winter, a ground-level or surface inversion commonly forms during the night and traps carbon monoxide emitted by vehicles during the morning rush hours.

Figure 3-5 illustrates the combination of these smog-producing factors.

Episode Levels of Ozone Pollution. To protect the public health, the District has initiated a system to warn the public of severe pollution levels in the air. At times, meteorological conditions are so adverse to pollutant dispersion that concentrations of ozone exceed the state air quality standard by as much as a factor of three. The California Air Resources Board (ARB) has defined Episode Levels of ozone air pollution as follows:

> **Health Advisory Levels** occur when hourly ozone concentrations equal or exceed 0.15 ppm. At this level, residents are advised to avoid prolonged, vigorous outdoor exercise, and persons with respiratory or coronary disease should avoid exercise.
>
> **Stage 1 Episodes** occur when hourly ozone concentrations equal or exceed 0.20 ppm. At these times, persons with respiratory or coronary artery disease should be notified to take precautions against exposure and should stay indoors as much as possible. Schools are also notified to advise against strenuous physical activity for their students. To this end, schools are in regular communication with the District.
>
> **Stage 2 Episodes** occur when hourly ozone concentrations equal or exceed 0.35 ppm. The District requires industry to take prompt actions to reduce emissions at those times. Stage 1 and 2 episodes are less frequent in the SCAB today than a decade ago. In fact, no Stage 2 episodes occurred from 1989 through 1992.
>
> **Stage 3 Episodes** occur when hourly ozone concentrations equal or exceed 0.50 ppm. The last Stage 3 episode occurred in the Basin in 1974; the total lack of Stage 3 episodes in nearly two decades points to improved air quality and significant progress made in the SCAB attainment effort.

The District reports air quality in terms of a Pollutant Standards Index (PSI). The PSI is a simplified method of forecasting and reporting air quality conditions on a numerical scale averaging from 0 to 500. Good air quality is 0 to 50, while 400-500 PSI is a hazardous Third Stage Episode. Refer to Figure 3-6, which describes the PSI ganging.

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3.3 SCAQMD Strategy and Control Measures

On July 12, 1991, the SCAQMD Governing Board adopted a revision to the Air Quality Management Plan (AQMP), which responded to new demands and tightened controls of pollutants specified by both the federal and California state governments.

As discussed in Chapter 2, the 1988 California Clean Air Act (CCAA) requires the District to adopt a plan that seeks to attain the California Ambient Air Quality Standards and that will also meet a variety of state performance standards; these include a five-percent annual reduction in emissions, and achievement of a 1.5-person average vehicle occupancy (AVO) during commute periods by 1999. In addition, the District must comply with the performance standards set by the 1990 Amendments to the federal Clean Air Act (CAA). The District seeks to do all of the above through the 1991 AQMP, which includes a variety of strategies and control measures. The 1991 AQMP was designed to comply with state and federal requirements, reduce the high level of pollutant emissions in the SCAB, and return clean air to the region by 2010.

To accomplish its task, the AQMP relies on a multi-level partnership of governmental agencies at the federal, state, regional, and local level. These agencies (EPA, ARB, local governments, SCAG, and the District) are the cornerstones that implement the AQMP programs.

The control measures in the 1991 AQMP are categorized into three tiers:

> **Tier I** includes measures that propose currently available technological applications and management practices than can be adopted within the next five years.
>
> **Tier II** measures are based on significant advancement of today's technological applications within the next ten to fifteen years.
>
> **Tier III** requires the development of new technologies that are currently in the research stage and that will be implemented within the next twenty years.

The AQMP provides an attainment planning framework that sets specific dates by which the SCAB will achieve the federal and state air quality standards.

- **Control of Criteria Pollutants**

The District has determined a schedule under which emissions of criteria pollutants must be reduced in order to attain state and federal standards. Under the present attainment schedule, the Plan calls for attaining federal standards by the years 2010 for ozone and 2006 for PM10. The deadlines for attaining federal and state standards for NO_2 and CO are earlier, as seen in Figure 3-7.

- **Control of Toxic Air Contaminants and Acutely Hazardous Emissions**

Control of toxic air pollutants is set out in Section 112 of the federal Clean Air Act, which established the National Emissions Standards for Hazardous Air Pollutants (NESHAPs), and under which the EPA established emission standards for toxic air contaminants.

The state also regulates toxic air pollutants through its air toxics program (AB 1807). In addition, the state legislature has passed several related legislative programs (AB 2588, AB 3205, and AB 3374). Finally, for the control of air toxics, there are several District rules being adopted and implemented by the District under authority based on Section 41700 of the California Health and Safety Code and by ARB. These are discussed below.

Tanner Air Toxics Act (AB 1807) established the California toxic air contaminant control program wherein ARB, working in conjunction with the OEHHA, identifies toxic air contaminants. Air Toxic Control Measures (ATCMs) may then be adopted to reduce ambient concentrations of the identified toxic below a specific threshold based on its effects on health, or to the lowest concentration achievable through use of best available control technology (BACT). The program is administered by ARB. The District must incorporate ATCMs into its regulatory program or adopt equally stringent control measures as rules. Currently, the District has adopted seven rules related to control of AB 1807 substances.

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Air Toxics "Hot Spots" Information and Assessment Act (AB 2588) requires operators of specified facilities to submit to the District comprehensive emissions inventory plans and reports by specified dates. The District reviews the reports and then places the facilities into high, intermediate, and low priority categories, based upon the potency, toxicity, quantity and volume of hazardous emissions, and the proximity of potential sensitive receptors to the facility. Facilities designated as high priority (category A) must prepare a health risk assessment. Those found to pose a significant risk are required to notify the surrounding population. The emissions inventory data are to be updated every two years. This process is intended to achieve the following goals:

- To collect emission inventories from facilities that use any of the 300 toxic substances currently listed by CARB.
- To develop health risk assessments for designated facilities that have emissions which may result in adverse public health impacts.
- To make information available to the public on the health risks from air toxic emissions.

Toxic Emissions Near Schools (AB 3205) requires new or modified sources of air contaminants located within 1,000 feet from the outer boundary of a school to give public notice to the parents of school children before an air pollution permit is granted. The District conducts field and data base surveys to identify all existing sources of air contaminants located within a quarter mile of a proposed school site.

Air Monitoring of Disposal Sites (AB 3374) requires owners of solid waste disposal sites to submit to the District a solid waste air quality assessment test report for evaluation. If the District determines that levels of specified air contaminants pose a health risk, remedial action must be taken.

District Rule 1401 (New Source Review of Carcinogenic Air Contaminants) assesses and manages risk from new or modified sources of air toxics through the District's permitting program. Rule 1401 also describes the risk assessment procedures to use in evaluating risks from sources that emit cancer-causing substances. Further, it specifies the allowable risks for new and modified stationary sources.

Acutely Hazardous Emissions. Any facility that handles, uses, or transports acutely hazardous materials is required to develop a Risk Management and Prevention Plan (RMPP). In most jurisdictions, the Fire Department is responsible for overseeing the preparation of the RMPPs.

- **Control of Global Warming and Ozone-Depleting Gases**

The South Coast Air Quality Management District adopted a policy on global warming and stratospheric ozone depletion on April 6, 1990, that commits the District to consider global impacts in its rulemaking and in drafting revisions to the Air Quality Management Plan. The policy was updated in April 1992, and includes the following directives:

- Phase out the use of chlorofluorocarbons (CFCs), methyl chloroform (1,1,1-trichloroethane or TCA), carbon tetrachloride, and halons by December 1995.
- Phase out the large-quantity use of hydrochlorofluorocarbons (HCFCs) by the year 2000.
- Develop recycling regulations for HCFCs.
- Include strategies in the 1991 AQMP to reduce carbon dioxide and methane emissions.
- Develop an emissions inventory of ozone-depleting and global warming gases.
- Support research funding and seek alternative technologies to control pollutant emissions contributing to global environmental change.

Since adopting the policy, the District has developed and adopted recycling rules to reduce CFC and halon emissions as well as developed 1991 AQMP control strategies to reduce emissions of carbon dioxide and methane.

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3.4 Control of PM10 in the Coachella Valley

The latest AQMP revision also provides data on emission sources in that portion of the Southeast Desert Air Basin (SEDAB) under District jurisdiction. Figure 2-1 in Chapter 2 shows the relationship between the two air basins under the jurisdiction of the District.

In much of the SEDAB, ozone and PM10 standards are regularly exceeded. Much of the ozone problem is the result of ozone transport from the South Coast Air Basin. The geographic characteristics of the Coachella Valley nevertheless make it a prime candidate for a locally generated ozone problem in the future. Therefore, it is important at this time to mitigate emissions that lead to the formation of ozone and contribute to the local violations of ambient air quality standards. High PM10 concentrations, on the other hand, are strictly a localized problem resulting mainly from fugitive dust emissions.

In December 1989, the District Governing Board adopted the **State Implementation Plan for PM10** for the portion of the SEDAB known as the Coachella Valley. Typical control measures adopted include:

- Using soil stabilizers to treat areas adjacent to roadways
- Erecting snow-fence windbreaks
- Planting vegetative and tree windbreaks
- Removing accumulated dirt from streets
- Treating unpaved roads with chemical stabilizers
- Covering loaded trucks
- Prohibiting construction grading on windy days

Implementation of the control measures contained in this Plan by local governments, the District, and the Coachella Valley Association of Governments is expected to bring the Coachella Valley into compliance with the federal ambient air quality standards for PM10 by the year 1995.

Eighteen months after EPA classifies the area as non-attainment for PM10, a similar plan will be developed for the Antelope Valley.

References

Final Socio-Economic Report for the 1991 AQMP. Available from the District's Public Information Center.

Where Does It Hurt? Pamphlet available from the District's Public Information Center.

Coachella Valley PM10 Plan. Available from the District's Office of Planning and Technology Advancement, PM10/Global Warming/Ozone Depletion/Toxics Section.

Summary of Air Quality in California's South Coast and Southeast Desert Air Basins, 1987-1990. Available from the District's Public Information Center

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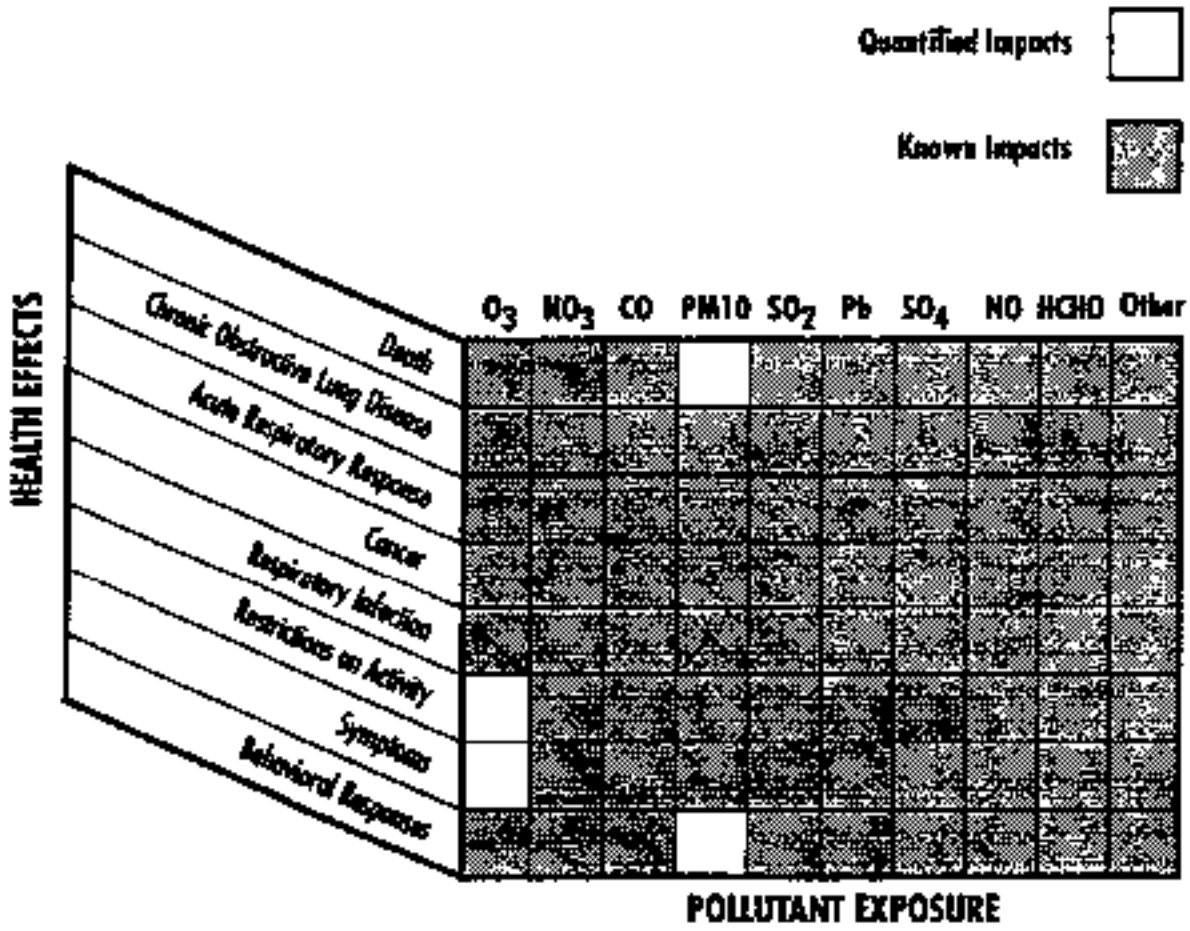
Figure 3-1. Health Responses to Criteria and Non-Criteria Pollutant Exposures



Source: Socio-Economic Report for 1991 AQMP, July 1991

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Figure 3-2. Ozone Standard Exceedances in the U.S.

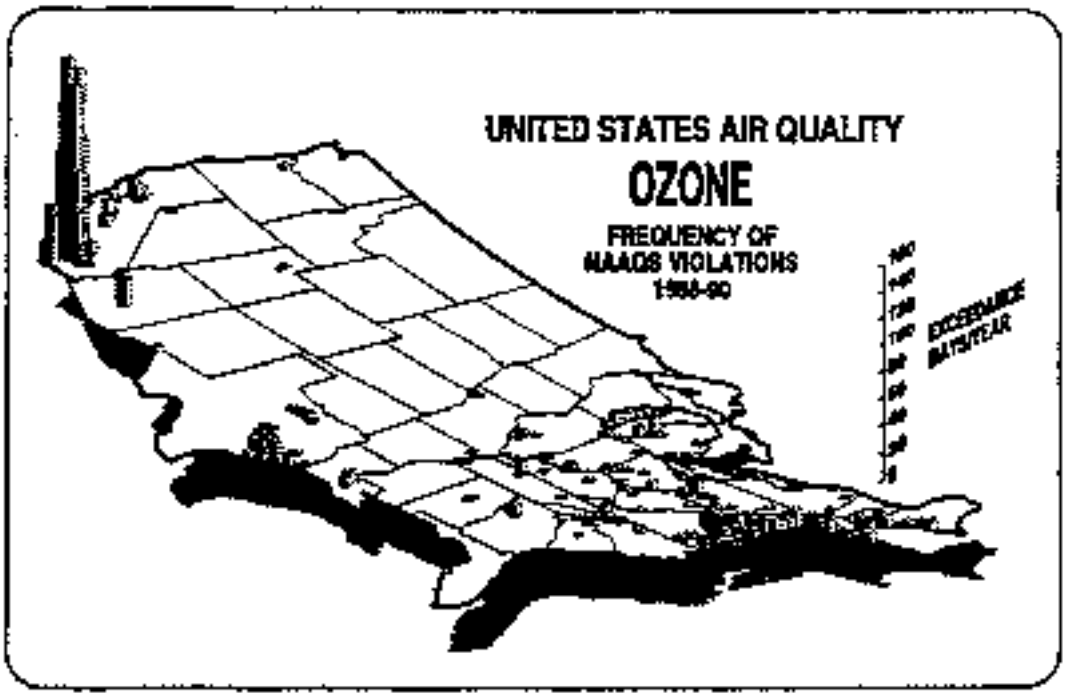

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Figure 3-3. Stratospheric Ozone Depletion and Global Warming

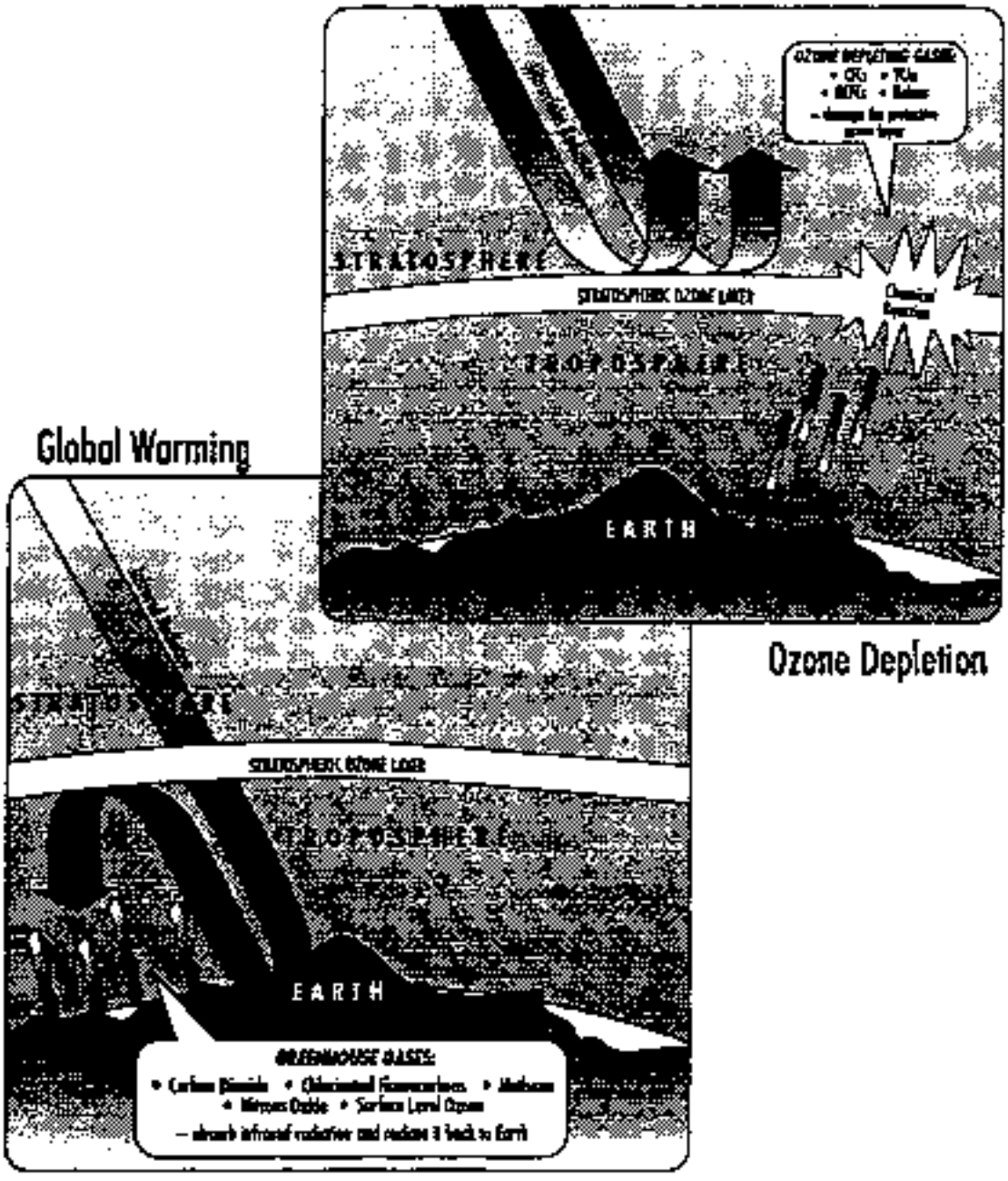

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Figure 3-4. Typical Emission Sources

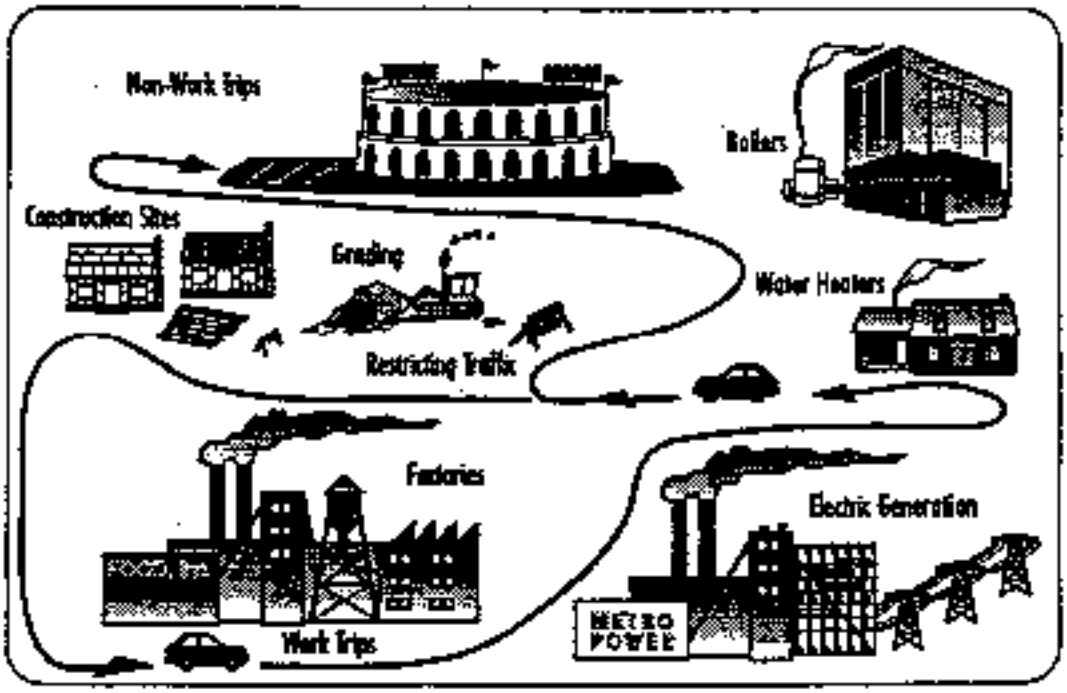

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Figure 3-5. Formation of Smog from Emissions Plus Meteorology

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Figure 3-6. Smog Episodes and PSI Grading

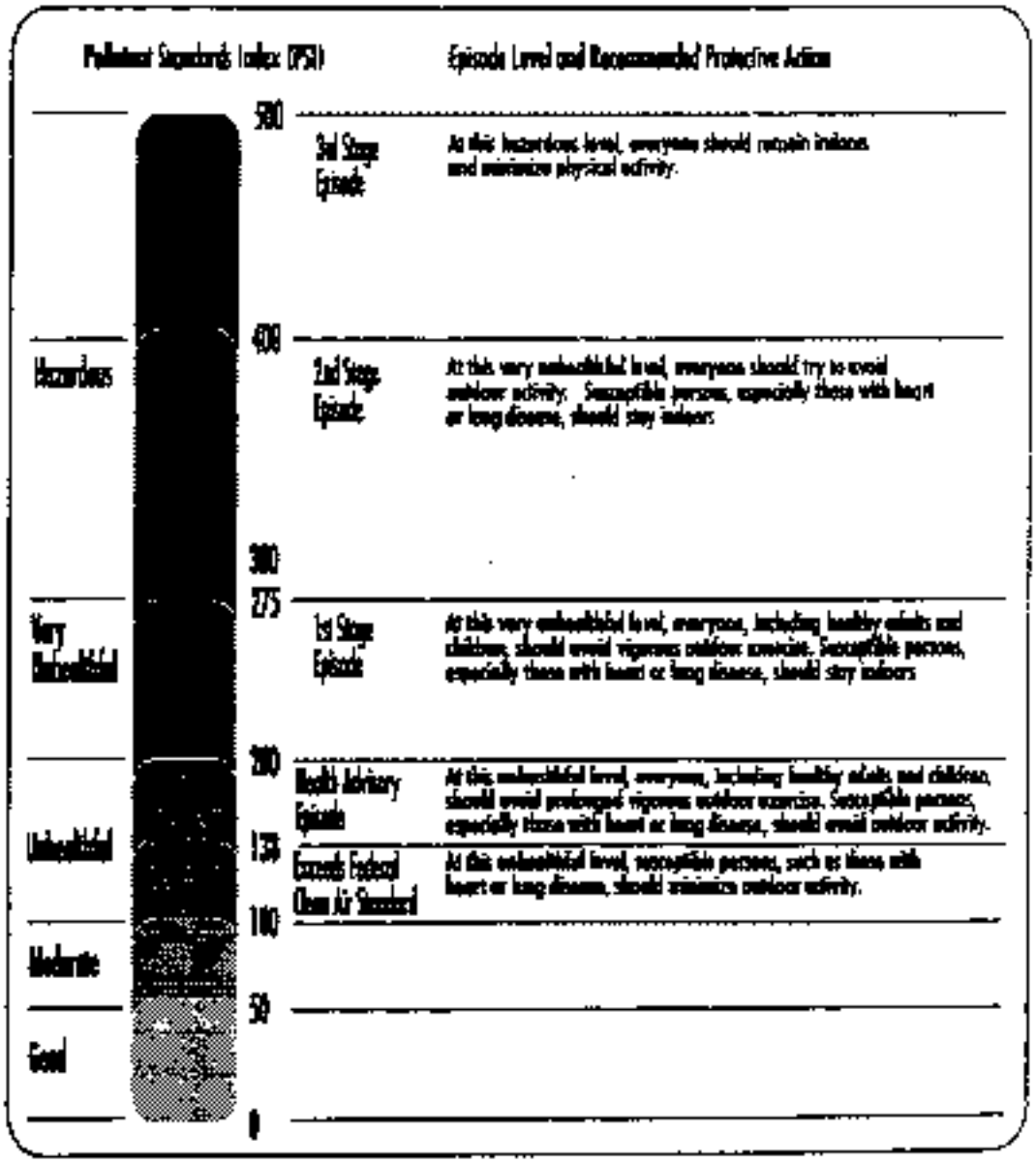

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Figure 3-7. Attainment Schedule for Criteria Pollutants

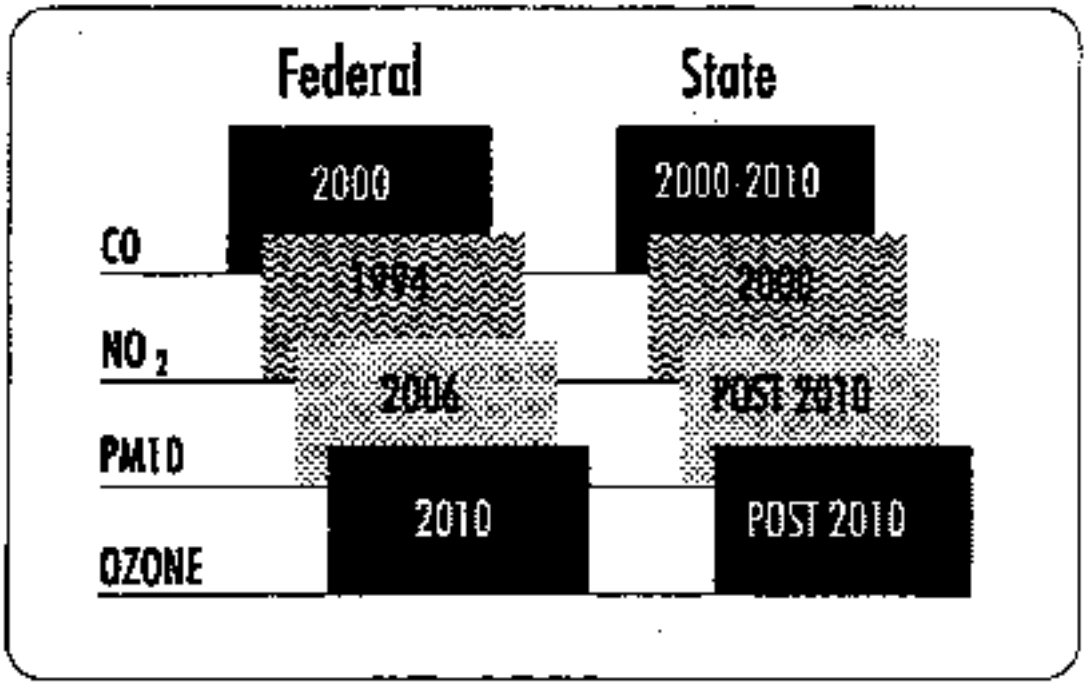

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Table 3-1. 1992 Maximum Concentrations of Criteria Pollutants in SCAB and Coachella Valley

Pollutants	National Standards	State Standards	Regional SCAB Levels and Exceedances	Coachella Valley Levels and Exceedances
Lead (Pb)	1.5 ug/m³ (calendar quarter)	1.5 ug/m³ (30-day average)	0.11 ug/m³ (quarterly avg.) 0.16 ug/m³ (monthly avg.)	No monitoring
Sulfur Dioxide (SO_2)	0.14 ppm (24-hour)	0.25 ppm (1-hour) 0.05 ppm (24-hour)	.035 ppm (24-hour) (no days exceeded) 0.15 ppm (1-hour) (no days exceeded)	No monitoring
Carbon Monoxide (CO)	9.0 ppm (8 hours) 35 ppm (1-hour)	9.0 ppm (8 hours) 20.0 ppm (1-hour)	18.8 ppm (8 hours) 31 days/federal 36 days/state 28 ppm (1-hour) (5 days/state)	2.4 ppm* (8 hours) (no days exceeded) 5.0 ppm* (1-hour) (no days exceeded)
Nitrogen Dioxide (NO_2)	0.053 ppm (annual average)	0.25 ppm (1-hour)	0.0507 ppm (annual average) 0.30 ppm (1-hour) 1 day/state	0.0210* ppm (annual average) 0.09* ppm (1-hour) (no days exceeded)
Ozone (O_3)	0.12 ppm (1-hour)	0.09 ppm (1-hour)	0.30 ppm (118 days/federal 164 days/state)	0.15 ppm 21 days/federal 69 days/state
Fine Particulate Matter (PM10)	150 ug/m³ (24-hour)	50 ug/m³ (24-hour)	649 ug/m³ (24-hour) 3% days/federal 66% days/state	175 ug/m³ 2% days/federal 31% days/state
Sulfate	None	25 ug/m³ (24-hour)	22.6 ug/m³ (no days exceeded)	No monitoring
Visual Range	None	10 miles (8 hour) w/humidity < 70%	39% days*	No monitoring

* Longest Travis Field data 12 full months of data.
Days/federal = Number of days that federal standard was exceeded
Days/state = Number of days that State of California standard was exceeded

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Table 3-2. Primary Sources and Effects of Criteria Pollutants

Lead (Pb)	Contaminated soil	Impairment of blood function and nerve construction Behavioral and learning problems in children
Sulfur Dioxide (SO_2)	Combustion of sulfur-containing fossil fuels Smelting of sulfur-bearing metal ores Industrial processes	Aggravation of respiratory diseases (asthma, emphysema) Reduced lung function Irritation of eyes Reduced visibility Plant injury Deterioration of metals, textiles, leather, finishes, coatings, etc.
Carbon Monoxide (CO)	Incomplete combustion of fuels and other carbon-containing substances, such as motor vehicle exhaust Natural events, such as decomposition of organic matter	Reduced tolerance for exercise Impairment of mental function Impairment of fetal development Death at high levels of exposure Aggravation of some heart diseases (angina)
Nitrogen Dioxide (NO_2)	Motor vehicle exhaust High-temperature stationary combustion Atmospheric reactions	Aggravation of respiratory illness Reduced visibility Reduced plant growth Formation of acid rain
Ozone (O_3)	Atmospheric reaction of organic gases with nitrogen oxides in sunlight	Aggravation of respiratory and cardiovascular diseases Irritation of eyes Impairment of cardiopulmonary function Plant leaf injury
Fine Particulate Matter (PM10)	Stationary combustion of solid fuels Construction activities Industrial processes Atmospheric chemical reactions	Reduced lung function Aggravation of the effects of gaseous pollutants Aggravation of respiratory and cardio-respiratory diseases Increased cough and chest discomfort Soiling Reduced visibility

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[redacted]

[redacted]

INITIAL CONSULTATION

CHAPTER 4

Local governments are encouraged to establish a formal consultation process for projects at the earliest planning stages. The purpose of this consultation is to identify construction procedures, air quality design standards, and reasonable mitigation measures that should be considered for incorporation into the project from the onset, as well as to discuss environmental documentation requirements.

Project proponents who begin the planning process with an understanding of environmental and air quality regulations will find it much easier to avoid or to mitigate air quality impacts as well as costly and unnecessary litigation. To make fundamental changes to a site plan, or to address land use compatibility issues or impacts on infrastructure after the CEQA review process has begun, is time consuming and expensive for both local government and the project proponent.

For this reason, early contact and initial consultation between local government planners and project proponents is vital, while the project is still in its conceptual phase.

Early consultation or informal review will not replace thorough environmental analysis of a project, but can assist the project proponent in anticipating and preparing for the requirements of CEQA. The initial consultation is intended to assist local government planners in identifying air quality impacts before the formal CEQA review process begins, thereby allowing the project proponent to make the appropriate changes during the initial design phase.

4.1 Consultation at the Planning Counter

An initial consultation can be as simple as a discussion of air quality issues at the planning counter with a project proponent, who is making inquiries about zoning and permits concerning a particular piece of property. Typically, the inquiries are focused on the zoning of the property, the land uses the zoning allows, and the discretionary permits that are needed to develop the property. This type of initial consultation can become more effective if government agencies and planners are well informed and are able to provide project proponents with up-to-date information on environmental issues and on local and regional air quality policies.

Effective initial consultation is largely dependent on local government planners familiar with air quality policies and an ability to identify land use compatibility issues and suggest mitigation measures. To that end, the District holds workshops and training sessions to assist planners in staying current with air quality issues. The District also plans to hold periodic meetings of the region's planning directors to discuss implementation of the Air Quality Management Plan (AQMP). Finally, technical assistance is always available from the District through the telephone contacts listed in the Introduction to this Handbook.

Local government can better communicate current information on air quality issues at the planning counter through the use of:

- Handouts
- Land use/zoning maps

Handouts. Handouts on local government land use policies and development standards can be expanded to include air quality issues. Handouts can include basic information on:

- Compatible land use - Higher densities in transit corridors; supportive services in commercial districts
- Incompatible land use - Location of sensitive receptors
- Preparing the Initial Study - Determining significance of air quality impacts

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Handouts can also explain how specific measures improve air quality, such as:

- Landscaping requirements that reduce electrical energy use
- Development standards such as those that require commercial developments to provide bicycle racks, designate carpool parking spaces, and place interior bus turnouts
- Air quality mitigation measures (refer to Tables 11-2, 11-3, 11-4, 11-6, and 11-7 in Chapter 11)

Land Use/Zoning Maps. The location of industries that are significant sources of toxic air pollutants (defined as facilities producing emissions that exceed the maximum individual cancer risk of 10 in 1 million either individually or cumulatively) as well as properties that are adjacent to congested freeways can be identified on counter land use/zoning maps, so that issues of land use compatibility can be readily identified. As discussed in Chapter 5, the District will be providing planners with a database identifying known sources in their jurisdiction. Bicycle pathways and transit bus stops where land dedications are needed can also be identified on counter maps, along with transit corridors, which are important when considering density and land uses necessary to support ridership. Issues regarding air toxics and land use compatibility need to be fully addressed in the environmental documentation.

4.2 Establishing a Formal Initial Consultation Process

An initial consultation can be a formal, scheduled interview, requested by the planner or the project proponent. The District encourages local governments to incorporate a formal initial consultation as part of the project review, especially for significant projects (refer to Table 6-2 in Chapter 6), so that air quality issues and mitigation measures may be investigated early in the process. Upon request by the local government, the District will participate in the initial consultation for significant projects. Contact the District's Local Government - CEQA Section to request the District's assistance.

When establishing a procedure for a formal initial consultation, the local jurisdiction may need to consider the following:

- Is there an existing process that can be expanded to encompass this initial consultation, or does a new process need to be created?
- Should the consultation be mandatory or voluntary?
- Which projects should require an initial consultation?
- Should a fee be charged to cover the cost of the consultation?

To streamline the initial consultation and focus on the key issues of development, a checklist of items to look for when reviewing a project for air quality impacts is important. An example of such a checklist is given in Figure 4-1.

4.3 Air Quality Issues for Formal Consultation

Of particular interest to the project proponent are those policies that:

- Could significantly alter the project's design or scope
- Require an in-depth air quality analysis during CEQA review
- Require coordination with the District and other agencies

When a project is within a quarter mile of an existing land use that emits toxic pollutants, these issues should be discussed more fully.

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The initial consultation, therefore, should identify those areas where air pollution mitigation might require redesigning the project; or where a finding is probable that the project could have a significant effect on air quality, and feasible alternatives and mitigation are not available; or where a responsible agency needs to be consulted. Major emphasis and consideration of potential air quality impacts should be given to the following issues during the initial consultation:

- Land use/densities, site plan design, and building design
- Land use incompatibility involving proximity to sensitive receptors of a (1) toxic air emission source, (2) objectionable odors, or (3) localized CO hot spots
- Intergovernmental coordination for major stationary sources and impacts on infrastructure that affect air quality

4.4 Land Use, Densities, Site Plan, Building Design

Land use, densities, site plan design, and building design are fundamental to the project's function. Together these factors affect the number of vehicle trips that the project may generate and, in turn, its transportation needs. According to the ARB document, *Guidance for the Development of Indirect Source Control Programs*, a design incorporating mixed uses can potentially reduce trips by 20% to 50% if certain design strategies are followed. A site plan with a design sensitive to air quality that incorporates facilities such as bicycle racks, pedestrian paths, etc., can be expected to reduce vehicle trips by 1% to 10% of the ARB estimate. Refer to Chapter 9 for specific quantification estimates.

Other design-related issues that are fundamental to reducing air pollution include densities and land uses in transit corridors, along with building orientation to maximize passive solar heating and cooling benefits.

The key items to look for in considering the site plan and building design at the initial consultation are the following:

Do the designs of public right-of-way and pedestrian walkways within the site encourage pedestrian traffic?

Is on-site traffic circulation designed to reduce vehicle queuing?

Are dedications needed for transit/bike pathways, in compliance with the Circulation Element of the General Plan?

Are links between the project and bike/pedestrian pathways adequate and will walking and bicycling, rather than driving, be facilitated?

Are supportive land uses such as restaurants, banks, and a post office included in office and industrial parks?

Do residential Specific Plans incorporate mixed uses?

Is the building or subdivision oriented to take advantage of natural heating and cooling patterns?

Are landscaped treatments designed to reduce the energy needs of the building?

Is the project accessible to transit facilities?

Do developments in transit corridors provide sustainable densities to support transit ridership? (Refer to the SCAG Transportation Corridors map in Figure 4-2 and Chapter 5 for information on sustainable densities.)

Could the project impact the levels of service on the Congestion Management Program (CMP) transportation system?

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These questions complement the list of specific site-design mitigation measures, found in Chapter 5, that project proponents should employ to reduce emissions. At the conclusion of the initial consultation, the project proponent should have an understanding of the design features that will reduce emissions and that need to be incorporated into the site plan and building design.

4.5 Incompatible Land Uses

- **CO Hot Spots, Toxic Sources, and Sensitive Receptors**

An initial consultation can be particularly important when considering the siting of sensitive receptors, such as nursery schools or long-term health care facilities. Placement of sensitive receptors near localized concentrations of the criteria pollutant carbon monoxide (CO) is of concern. Since the automobile is the primary source of carbon monoxide, high levels of CO are associated with congested roadways, such as freeways and major intersections. Toxics are also of concern. For example, if a project wants to build a long-term health care facility next to a chrome plating shop, the initial consultation should alert the developer to the potential public health risk issues associated with this proposed siting. The project proponent should be made aware of any environmental documentation, including a public health risk assessment that is necessary to assess the public health impacts of the project. The project proponent should analyze publicly available information on public health risks posed by nearby sources of toxic emissions. The District serves as a clearinghouse for publicly available information on toxic emissions and associated public health risks. This information is compiled from documentation required of toxic emitters by Rule 1401 and the AB 2588 Air Toxics Hot Spots Program. The applicant should also make a reasonable attempt to obtain toxic information from any known sources that could potentially affect the project site which is not covered by Rule 1401 and AB 2588. Pursuant to CEQA Guidelines Section 15151, if the information is not available, the sufficiency of the air toxics analysis should be determined in light of what is reasonably available. Additionally, the project proponent should understand that, depending on the risk levels identified through the environmental process, the local government may determine that such a site is not an appropriate location for a particular sensitive receptor, e.g., in this example, a long-term health care facility.

These are the key items to look for when considering land use compatibility:

- Are there any sensitive receptors (defined in Chapter 1) that would be affected by the proposed siting of this facility?
- Does a sensitive receptor want to locate next to a congested roadway, which is a source of carbon monoxide? (Figure 5-4)
- Are high CO levels projected to decrease at the project site to acceptable levels in the future?
- Can the sensitive receptors be moved out of range of a CO hotspot on the same parcel?
- Will a sensitive receptor be located within a quarter mile of an existing facility that emits toxic pollutants? (The quarter mile distance is for screening only)

The initial consultation should determine if existing facilities that emit toxic emissions will affect the sensitive receptor and whether or not further analysis is needed. Refer to Chapter 5 for information on the initial screening for land use compatibility and District-recommended criteria for determining when a public health risk assessment is necessary.

- **Odor Issues**

Almost any source may emit objectionable odors, but some land uses will be more likely to produce objectionable odors because of the nature of their operation. The initial consultation should identify both new projects that have a high probability of emitting objectionable odors and new developments that may be affected because of their location downwind. (Refer to Chapter 8 for methods to identify downwind sources.)

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In most cases, odor issues can be resolved with additional control equipment, a change in siting of the operation that is generating the odor, or process change. The initial consultation can be particularly useful in determining the appropriate location for equipment that produces odors, thereby lessening the potential impacts on surrounding properties. The initial consultation can also identify existing sources of odors and assess their impact on projects proposing to locate downwind. Refer to Chapter 5 for procedures to assess and mitigate potential odors.

4.6 Intergovernmental Coordination for Major Sources and Impacts on Infrastructure

During the initial consultation, planners have the opportunity to identify projects whose conditional use or building permits might require intergovernmental coordination. One example of a project requiring intergovernmental coordination on a project's permits is the construction of a major stationary source such as a cogeneration facility, which would be considered significant by both the local government and the District. At the initial consultation, the planner can also identify projects that could have an air quality impact due to increased demand on, or expansion of, the infrastructure. In this example, the transportation and wastewater treatment infrastructure are likely to be affected. Modifications to these systems involve coordination among the county transportation commissions, congestion management plan agencies, and wastewater treatment districts.

- **Major Stationary Sources**

In addition to obtaining local government discretionary permits, new or modified stationary emission sources will need to obtain permits from the District to construct and operate. Through the District's permitting process, factors such as the availability of emission offsets and their ability to reduce emissions are addressed. Some District permits, like local government permits that involve discretionary approval, are subject to a CEQA analysis. The District is a responsible agency for those permits considered to be projects under CEQA that are not exempt or ministerial. As soon as the lead agency has determined that an Initial Study will be required for the project, the lead agency should consult informally with all responsible agencies to obtain recommendations as to whether an EIR or Negative Declaration should be prepared (CEQA Guidelines Section 15063 (g)). In addition, there are a number of land use projects that could considerably impact air quality. For these projects, the District is a commenting agency. The District should be consulted to ensure that potential impacts are adequately identified.

Refer to Table 4-1 for a list of sources requiring intergovernmental coordination during the initial consultation. This list is based on the emission threshold criteria defined in Chapters 6 and 14, and is used by the District to determine if a project could have a significant impact, and if the District is to be consulted as a responsible agency under CEQA. The projects in this table either have the potential to significantly affect the air quality or require technical expertise to adequately assess impacts such as toxic sources.

Through intergovernmental coordination, the District and local government can ensure that the environmental documentation addresses both the local government land use permits as well as District permits to construct and operate equipment. Through closer coordination, the District can ensure that it does not issue permits for facilities that do not have land use approval from local governments; likewise, local governments can identify additional mitigation needed for a project that they might have otherwise missed.

Chapter 13 discusses additional required contents for environmental documents when the District is a responsible agency. Any environmental document that the project proponent intends to use to comply with CEQA for a District permit and local government permit should follow Chapter 13 for analyzing the potential secondary impacts of control technologies proposed for use.

Coordination between the District and local governments will enable local governments to obtain information about the facility's previous operation. The local government will then be able to evaluate the requests of facilities to relocate or expand. The local government can contact the District Office of Stationary Source Rules and Compliance at the numbers indicated in the Introduction. Table 4-2 provides planners with information sources on specific types of permits.

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In addition, this type of intergovernmental coordination can be important to those local governments that have major stationary sources operating under outdated discretionary permits or with grandfathered uses. In those cases, intergovernmental coordination can provide local governments with an additional opportunity to comment and recommend mitigation on established projects to protect public health.

- **Transportation Infrastructure Impacts and Congestion Management Program (CMP)**

Projects affecting the regional transportation system will also affect air quality. Development that brings additional traffic to already congested roadways will increase localized carbon monoxide emissions. Traffic delayed by congestion will further degrade regional air quality, since vehicles produce more emissions when traveling at lower speeds. (It is interesting to note that recent research indicates that vehicles also produce substantial emissions at speeds greater than 55 mph.)

The requirements of CEQA and the Congestion Management Program (CMP) are closely linked. Under the CMP legislation, local governments are required to adopt and implement a program to analyze the impacts of land use decisions on their portion of the CMP transportation system. As such, CEQA may be used to facilitate the land use and transportation components of the CMP.

The initial consultation can identify local areas where a project or series of projects may bring increased congestion to a segment of roadway identified in the CMP. If the project would cause service to deteriorate below level of service (LOS) E (considerable congestion) or the level established in the CMP, the resulting congestion should be addressed by improvements, programs, or actions which either mitigate the deficiency or measurably improve the level of service of the system and contribute to significant improvements in air quality. In fact, the CMP legislation requires that the impact be mitigated through the development of a deficiency plan. Chapter 11 provides further guidance on preparing site-specific mitigation measures than can be used in deficiency plans. It is important to note that if a roadway deteriorates to a lower LOS, causing a CO hot spot, the resulting localized CO hot spot(s) should be mitigated under CEQA. (Refer to Chapter 5.)

In addition, as part of the CMP land use analysis element, most local governments will require project proponents to prepare a traffic impact analysis when, according to the initial study, the project is likely to impact the transportation system. The traffic impact analysis can also become the starting point for the analysis of congestion and air quality impacts by providing project-specific transportation inputs (assumptions) for calculating pollutant emissions.

Mitigation measures that reduce traffic and circulation also contribute to improved air quality. Therefore, planners should use the initial consultation process to determine where coordination of the CMP and air quality CEQA analysis is needed.

- **Wastewater Treatment Impacts**

Developments that significantly increase demands on the wastewater treatment system of an area can create a situation where service demand would be in excess of the system's capacity. Population projections in the Regional Growth Management Plan serve as the basis for determining the capacity of a wastewater treatment system. These projections also form the basis for the air quality estimates in the Air Quality Management Plan (AQMP). Figure 4-3 lists projects that produce a substantial amount of wastewater, or that have the potential for toxic discharges. Project proponents of these projects should consult the local wastewater treatment agency to determine if the project could affect overall wastewater treatment capacity and increase toxic emissions (e.g. since treating toxic wastewater could increase toxic air emissions).

Any development that would exceed wastewater treatment capacity would thereby exceed the geographic area's population projections in the AQMP. Subsequently, the future emissions forecast in the AQMP would be understated, and without additional mitigation, the region would not achieve the federal and state air quality standards. Therefore, if the wastewater treatment facility needed to expand to provide services beyond the growth projections, the AQMP would need to be amended and additional sources would have to be regulated to offset the increases in emissions due to population growth.

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References

SCAG 1989 Regional Mobility Plan: Information on Transportation Corridors. Available from SCAG at (213) 236-1800.

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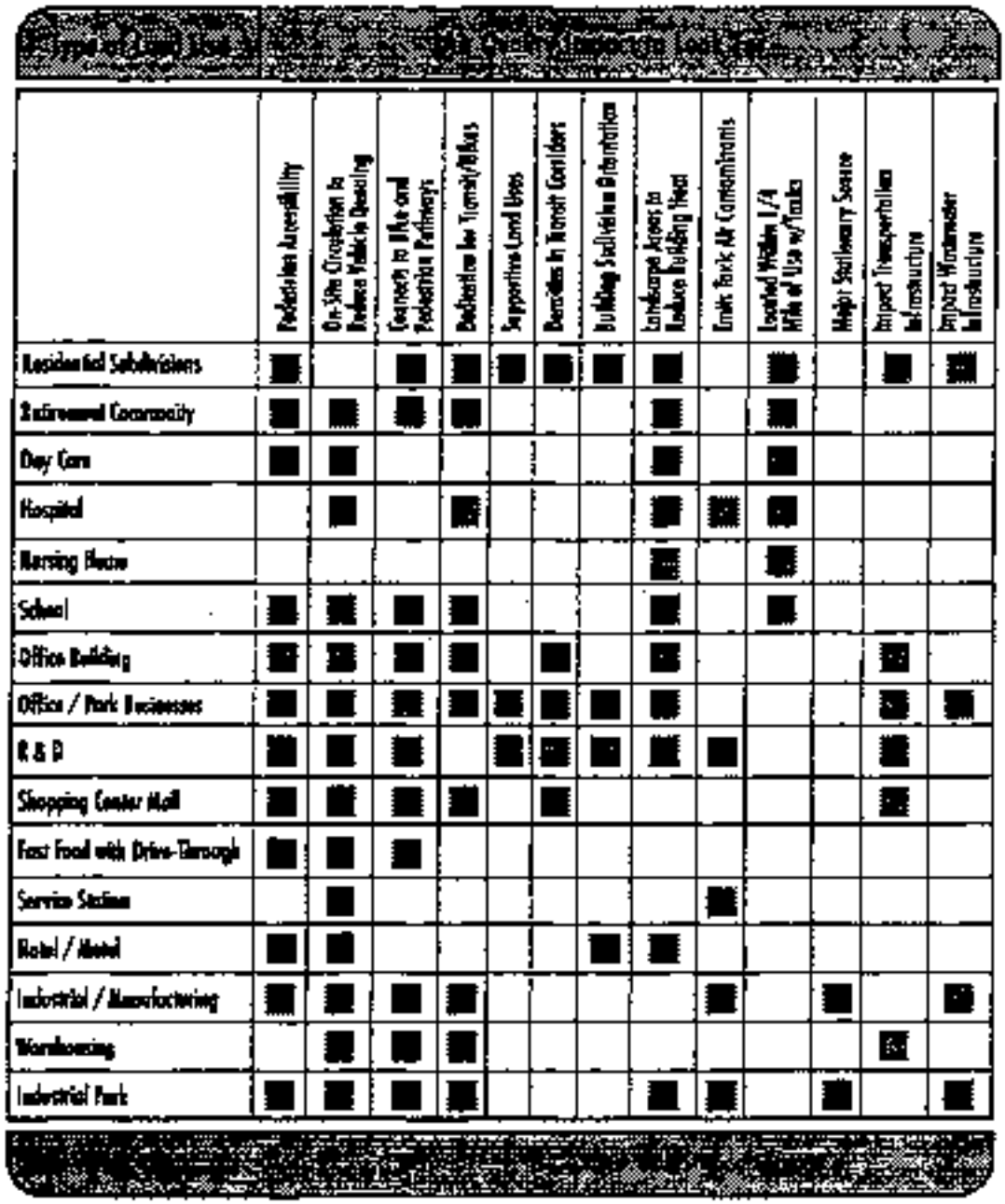
Figure 4-1. Formal Pre-Screen Review Checklist



Type of Land Use	Pedestrian Accessibility	On-Site Circulation to Reduce Vehicle Dependency	Connects to Bike and Pedestrian Pathways	Pedestrian Low Transit/Bus	Supportive Land Uses	Densities in Transit Corridors	Building Solid/Void Orientation	Landscape Areas to Reduce Building Heat	Emits Toxic Air Contaminants	Located Within 1/4 Mile of Use w/Tanks	Major Stationary Source	Impact Transportation Infrastructure	Impact Wastewater Infrastructure
Residential Subdivisions	■		■	■	■	■	■	■		■		■	■
Retirement Community	■	■	■	■				■		■			
Day Care	■	■						■		■			
Hospital		■		■				■	■	■			
Nursing Home								■		■			
School	■	■	■	■				■		■			
Office Building	■	■	■	■		■		■				■	
Office / Park Businesses	■	■	■	■	■	■	■	■				■	■
R & D	■	■	■		■	■	■	■	■			■	
Shopping Center Mall	■	■	■	■		■						■	
Fast Food with Drive-Through	■	■	■										
Service Station		■							■				
Hotel / Motel	■	■					■	■					
Industrial / Manufacturing	■	■	■	■					■		■		■
Warehousing		■	■	■								■	
Industrial Park	■	■	■	■				■	■		■		■

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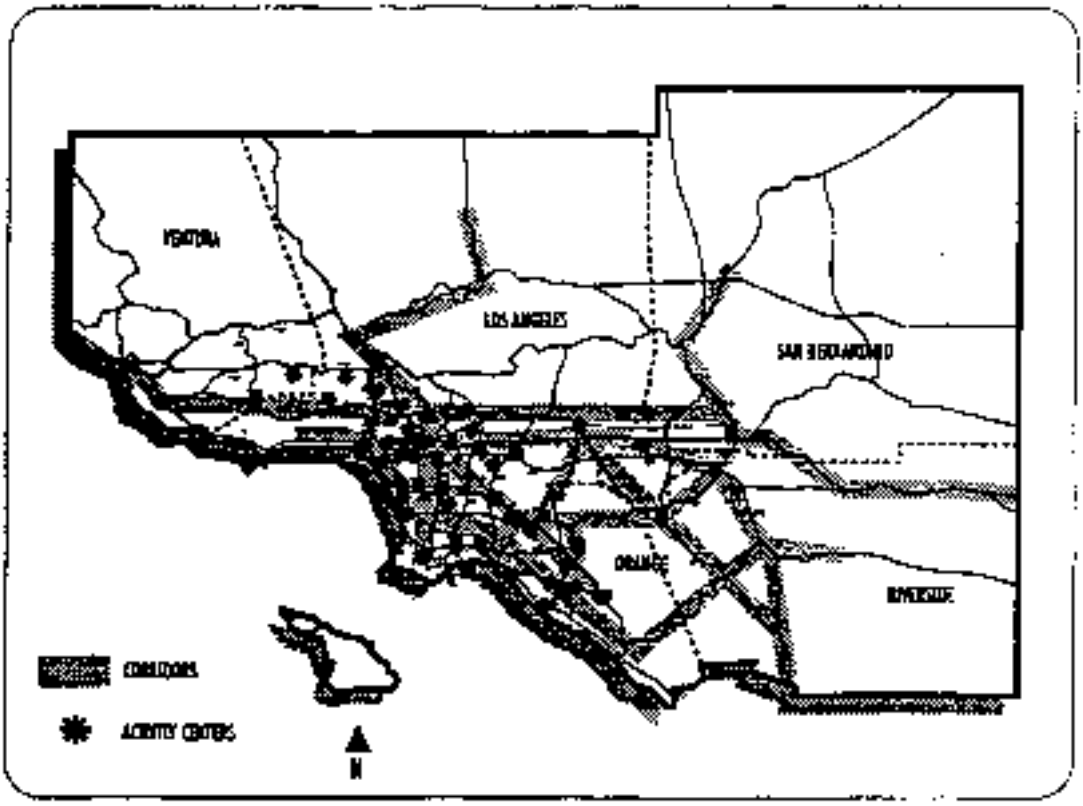
Figure 4-2. SCAG Transportation Corridors Map



Refer to SCAG's Regional Mobility Plan (RMP) for further detail

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Figure 4-3. Projects Potentially Producing Substantial Amounts of Water or Toxic Wastewater

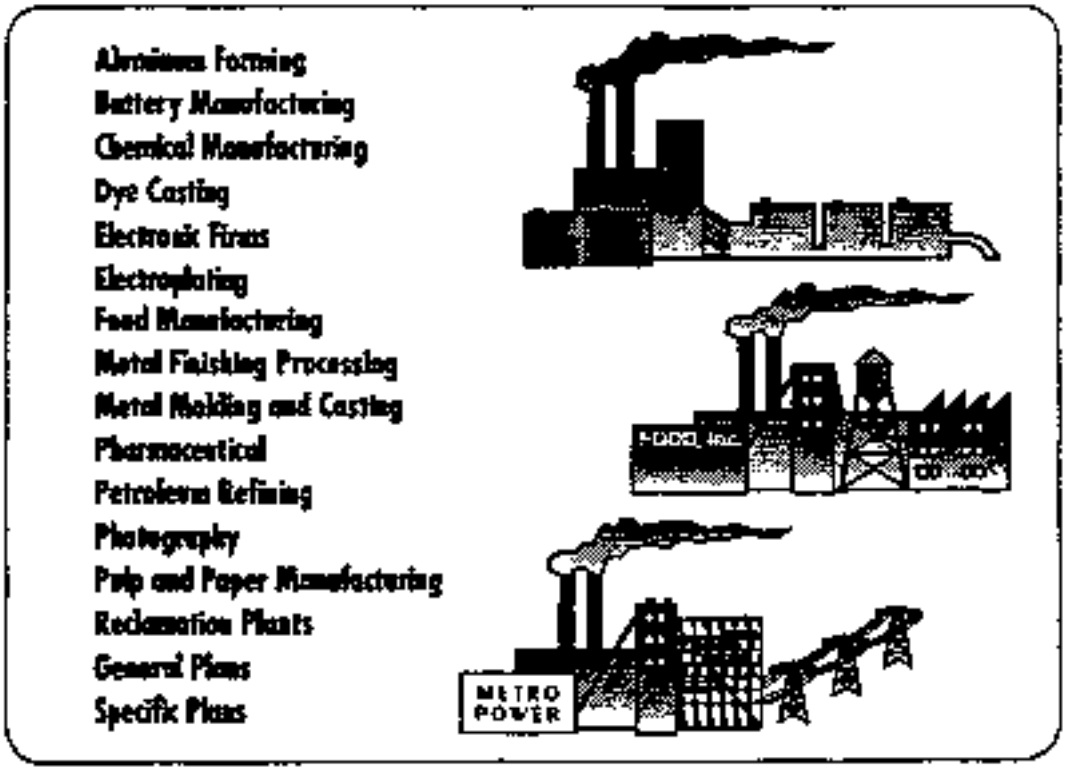

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Table 4-1. Major Sources Requiring Intergovernmental Coordination with the District

- Aerospace Projects
  - Aircraft Manufacturing
  - Airport Expansions
- Aggregate Mining
- Base Closings
- Bulk Terminal Construction
- Cement Plant
- Chemical Plant
- Chemical Waste Treatment Facilities
  - For Organic Solvents and Acids
- Cogeneration Projects
  - Usually Greater Than 1 Megawatt
- Food Manufacturing Plants
- Hazardous Waste Treatment, Storage, Disposal and Incineration
- Infectious Waste Incineration
- Landfill
- Military Bases
- Oil and Gas Production
- Power Generating Facilities
- Pulp/Paper Mills
- Refinery Construction/Modernization Projects
  - Crude Oil Distillation Units
  - Catalytic Cracking Units
  - Gasoline Blending Units
- Sewage Treatment Plants
- Transportation Facilities (Rail, Highway, etc.)
- Waste To Energy
- Waterport Projects, Expansions, Shiploading and Unloading Operations

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Table 4-2. Operating Permits Guidance for Local Government

Chemical Plants, Aerospace, Rubber Products Manufacturing, Electronics	Chemical, Rubber, Electronics, and Aerospace Operations	(909) 396-2538
Small Printing and Coating Businesses	Automotive Services, Small Coating and Printing	(909) 396-3393
Public Facilities, Landfills, POTWs, Medical Waste Disposal, Hospitals, Schools, & Military Bases	Public Facilities	(909) 396-3387
Mechanical Processing, Raw Materials	Mechanical Processing and Raw Materials	(909) 396-3122
Refinery Operations	Refinery and OCS Operations	(909) 396-3392
Printing Operations, Furniture, Plastics Manufacturing, Other Coatings	Automotive Services, Small Coating, and Printing	(909) 396-3393
Gas and Electric Utilities, Pipelines and Oilfields	Gas and Electric Utilities, and Pipelines and Oil Fields	(909) 396-3394
Dry Cleaners, Charbroilers, and Other Local Commercial Businesses	Neighborhood Commercial Operations	(909) 396-2391
CFC and Vapor Recovery	Neighborhood Commercial Operations	(909) 396-2391
Toxics, Ozone Depletors and Greenhouse Gases	Air Toxics Program and Global Climate Changes	(909) 396-2740

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[redacted]

SENSITIVE RECEPTOR SITING CRITERIA and DESIGN MITIGATION MEASURES

CHAPTER 5

Prior to the formal submittal of the project to the local government, there are two issues that planners need to communicate and which project proponents need to address:

- Potential air quality impacts on sensitive receptors
- Integration of site design features that will reduce emissions

Any project evaluation undertaken by local government planners should include these issues.

5.1 Evaluating Impacts on Sensitive Receptors

Sensitive populations are more susceptible to the effects of air pollution than are the population at large. Sensitive populations (sensitive receptors) who are in proximity to localized sources of toxics and carbon monoxide (CO) are of particular concern. (Refer to Figure 5-1 for a list of land uses considered to be sensitive receptors and to Table 5-1 for a list of land uses associated with toxic air emissions.)

Local governments have a responsibility for determining land use compatibility in the case of sensitive receptors. They also determine the type of land uses (sensitive receptors) and densities of use within their jurisdiction. The District has established standards through its rulemaking authority for carcinogenic and toxic air contaminants that are emitted by stationary sources which are designed to protect public health. These standards are identified in Section 5.2. Local governments can use the District standards to assist in making their land use decisions.

State law currently requires school districts to consider the impact of siting a new facility within close proximity to existing facilities that emit toxics. This principle should be applied in siting other sensitive receptors such as rehabilitation centers. Furthermore, local governments should be aware of the potential effects on the health of sensitive populations when a sensitive receptor is proposed to be situated adjacent to a significant source of CO, such as a freeway or a major intersection. High levels of CO are associated with traffic congestion and with idling or slow-moving vehicles. Depending on existing background concentrations of CO, roadways have the potential to be CO hot spots. Therefore, projects with sensitive receptors or projects that could negatively impact levels of service (LOS) should utilize the screening procedures in this chapter to determine the potential to create a CO hotspot. The responsibility for properly siting sensitive receptors rests with local governments.

Another land use compatibility issue involves sources that emit odors. The District's compliance officers may receive a number of odor complaints from residents surrounding a source. Many of these complaints could have been avoided if equipment had not been located upwind of a sensitive receptor, or if the facility employed add-on control equipment to reduce odorous emissions.

Ideally, as suggested in Chapter 4, these types of land use compatibility issues would have been raised at an initial consultation. Otherwise, these siting issues need to be identified early in the project review process, preferably before projects are formally submitted to the jurisdiction. The three key air quality questions that affect land use compatibility and that should be considered for each sensitive receptor project are:

- Is the proposed sensitive receptor located within a quarter mile of an existing facility that emits toxic pollutants?
- Is the proposed sensitive receptor adjacent to a congested roadway or in an area with high background concentrations of CO?
- Is the proposed sensitive receptor downwind of an existing source of odorous emissions, or is a proposed use associated with odorous emissions upwind of an existing sensitive receptor?

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In addition, proposed projects that could negatively impact the adjacent roadway's LOS, and as such subject an existing sensitive receptor to high levels of CO, should also undergo the screening procedures in this chapter.

These questions should be used to identify projects where additional review is needed.

5.2 Evaluating Sensitive Receptors for Toxic Impacts

The steps for evaluating toxic impacts on sensitive receptors are summarized in Figure 5-2. First, development plans for sensitive receptor projects should be accompanied by a radius map. An example of the information contained in the radius map is illustrated in Figure 5-3. The planner can compare the uses identified in the map with the list of land uses associated with toxic air emissions in Table 5-1.

If the map shows that there is an existing industrial source that emits toxic or carcinogenic air pollutants which may create a potential human health hazard within a quarter mile of the proposed sensitive receptor, planners should confirm with the District that this facility emits the pollutants indicated. The District is preparing a database of facilities that emit toxic emissions, and planners can contact the Toxics Unit at 909 396-3108. If the District confirms the location and type of emissions, then the local government should include a public health risk screening assessment as part of the environmental analysis. It is the responsibility of the local government to determine if the risk is significant and/or acceptable. The District uses the standard of 1 in 1 million as the maximum individual cancer risk and 10 in 1 million if the source of the toxic emissions uses best available control technology for toxics (T-BACT) when approving permits for new or modified stationary sources.

If the site is to be pursued as a potential location, then the toxic emissions from the existing nearby sources need to be identified (quantified to the extent that such data is reasonably available, Section 4.5) and a risk assessment performed. Chapter 10 discusses procedures for quantifying toxic emissions and making risk assessments. These assessments can be reviewed by the District prior to local government action to ensure that the assessment is adequate and that the risk is identified accurately.

There are no mitigation measures that sensitive receptors can employ to lessen the impact of siting next to a toxic source.

Additional Resources for Toxics Information

Sometimes additional information is needed to understand the extent and type of toxic emissions or to verify that a business does or does not emit toxic compounds. Several additional information sources are available to the planner including:

(1) State of California Health and Safety Code Section 25510(k) and (q) requires businesses that use hazardous materials or that involve a potential threatened release of acutely hazardous materials to submit a business plan for emergency response as set forth in Health and Safety Code Section 25503.5.

In most jurisdictions, the local or county fire department is charged with overseeing compilation of a **Hazardous Material Business Plan** for businesses that store or use hazardous materials in reportable quantities. The fire department will have a documentation package that can be used to provide the necessary information.

(2) Planners can contact the District's Toxic Source Unit to determine if a facility is operating under District permits and to learn the types of pollutants emitted by the facility.

(3) In 1987, the California legislature passed the **Air Toxics "Hot Spots" Information and Assessment Act of 1987** (AB 2588), which requires a statewide emissions inventory of toxic air pollutants. The Act further requires that the District first prioritize facilities and then require risk assessments of facilities that represent significant sources of toxic emissions. Facilities began entering this program on August 1, 1989, according

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to the schedule set forth in the Act. After entering the program, facilities must submit updated air toxics emissions inventories every two years.

Based on (1) quantity and volume of emissions, (2) toxicity and potency of substances, and (3) proximity to receptors, facilities are placed into one of three categories. The categories are:

Category A: Facilities that are required to submit risk assessments within 150 days of being placed in this category.

Category B: Facilities that may be required to submit risk assessments in a later year.

Category C: Facilities that are not likely to be required to submit health risk assessments.

In addition, the District is developing "industry-wide" inventories and assessing risks of small business facilities with emissions that are easily characterized. Some of the facilities in the industry-wide program include gas stations, small auto body shops, small dry cleaners, plating shops, and fiberglass product manufacturers.

Currently planners and project proponents can request through a public records request to the District health risk assessments performed pursuant to AB 2588. The assessments identify impacts on nearby receptors, including existing sensitive receptors. That information can then be used as an initial screening tool to determine if a particular site is advisable for siting a sensitive receptor.

Ultimately, this program will yield a database that will be made available to local planners in 1993. The database will:

(1) Provide information necessary to assess health impacts from cumulative sources of toxic emissions.

(2) Provide information to planners on the amount and type of toxic emissions from a particular business and/or toxic hot spots that can then be identified on land use/zoning maps for future reference.

Planners can contact the District's Toxics Unit to determine if a business has already submitted a risk assessment that analyzes impacts on sensitive uses. If so, the risk assessment can be used to determine if the siting of a sensitive receptor within the impact area is appropriate. A public health risk assessment, however, may only be available for District 1401 permits (since June 1990) and AB 2855 facilities at this time.

5.3 Evaluating Projects for CO Impacts

In order to evaluate a project and assess the localized CO impacts on sensitive receptors that are sited adjacent to congested roadways, the following screening procedures should be followed, and the roadway level of service (LOS) should be identified during the initial consultation, as described in Chapter 4.

(1) Determine the "no project" ambient background CO concentrations based on information from the air quality monitoring station located in the same source receptor area (SRA) as the project. If CO is not monitored at the station in the same SRA as the project, the nearest or most representative air monitoring station data should be used. Contact the District for assistance in identifying the most representative station. Tables 5-2 (1-hour) and 5-3 (8-hour) may be used to determine project future year CO ambient concentrations.

(2) Estimate the projected 1-hour and 8-hour CO concentration levels at the site. CO concentrations may be determined based on roadway type and LOS. Table 5-4 provides estimates of roadway and intersection emissions. To establish the projected 8-hour concentration, the 1-hour concentration should be multiplied by the persistence factor (see Section 9.4).

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(3) Add the "No Project" ambient concentration level to those generated by the project (i.e., total project impact).

(4) Compare the total project impact to the 1-hour and 8-hour state ambient CO standards (Chapter 3).

(5) If a CO hot spot is anticipated, determine the extent of area impacted. This can be accomplished by plotting the queuing distance from the intersection stopline (Q) as the X axis, and the distance from edge of roadway (A) as the Y axis. The area which falls within the XY coordinates is most likely impacted with CO concentration levels which exceed the state standard (refer to Figure 5-4). Identify and determine CO concentration levels for each sensitive receptor.

(6) Compare the concentration levels of CO at the proposed site locations for sensitive receptors to the 1-hour and 8-hour CO standards.

(7) Determine project significance.

This analysis should be performed for each development phase of the project and project build-out.

There may be cases where the background concentration already exceeds the state 1-hour and 8-hour CO standards. In these cases, the analysis should determine if there will be a measurable increase at the project site. A measurable increase is defined as one part per million (ppm) for the 1-hour CO standard and 0.45 ppm for the 8-hour standard (consistent with District Regulation XIII definition of a significant impact).

If it is determined that the project could be significant, there are a number of dispersion models that are available for site specific analysis. The District recommends the use of CALINE4 or CAL3QHC to estimate the potential for CO hot spots. These models are based on continuous line source emissions and therefore, can estimate roadway impacts. Both models are described in Section 9.7.

Unlike toxic land use compatibility issues, CO excesses can be mitigated to some extent by increasing traffic speeds through methods such as traffic light synchronization, improved intersection channelization, inclusion of left turn lanes, demand management strategies or through site design measures which can considerably reduce the impacts of proximate CO due to dispersion. Expansion of the roadway by adding additional lanes may not be a preferable mitigation measure because increased traffic volume may wipe out any reductions in CO gained from increasing speeds. If the analysis demonstrates that the sensitive receptor will be affected and the state 1-hour or 8-hour CO standards are exceeded, mitigation measures such as those given in Table 5-5 should be employed if the local government intends to approve the proposed project. However, the District does not recommend siting sensitive receptors on those portions of a project site where the state 1-hour or 8-hour CO standard could be violated.

5.4 Evaluating Projects for Odor Impacts

Because both the District and local government are receiving an increasing number of formal complaints about offensive odors, potential sources of odors need to be identified from the standpoints of both the emitter and of the downwind receptor. Preferably, this will be done while the project is still in its initial design phase. If potential odor issues can be identified and mitigated before construction, later problems with enforcement will be avoided.

Assessing odor impacts depends upon such variables as wind speed, wind direction, and the sensitivities of receptors to different odors. By contacting either the District's Office of Stationary Source Rules and Compliance or the jurisdiction's code enforcement department, a planner can learn if any complaints about odors have been filed by property owners/occupants in the general vicinity of the proposed project site and thereby determine if a sensitive receptor could be affected by odors. Additionally, if the proposed project is in close proximity to a use identified in Figure 5-5 or is one of these uses, then potential odor impacts should be addressed.

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For sensitive receptors, mitigation measures are limited. In fact, in some instances the only mitigation available to sensitive receptors is to relocate upwind or further downwind from the source. The facility that is, or will be, producing the odor can also relocate equipment so that fumes can be emitted at locations to take the best advantage of wind patterns. Projects that may cause odors can also change stack heights and add additional control technology. In some cases, a project proponent for development of a sensitive receptor may be able to mitigate potential impacts by paying for mitigation at the source.

When odors are an issue, the air quality analysis should include a quantitative assessment of potential odors and meteorological conditions. A method of quantitatively assessing odors has been devised by the American Society of Testing Materials (ASTM, Standard Method D 1391), which considers how many times an air sample must be diluted with "clean" air before the odor is no longer detectable to an average adult with average odor sensitivity. The number of dilutions needed to reach this threshold level is referred to as a "dilution to threshold" (D/T) factor. An odor with a D/T of 2 (2 parts of fresh air to one part of odorous air) becomes faintly detectable to almost all receptors. At 5 D/T, people become consciously aware of the presence of an odor, and at 5 to 10 D/T, the odor is strong enough to evoke registered complaints. The standard to utilize in assessing off-site odor exposure is preferably below 5 D/T and acceptable below 10 D/T.

In addition, ASTM, standard method E679-79 can be used to analyze odors. This method relies on the sensory responses of a selected group of individuals called panelists. The threshold used in this method ranges from only detection that a very small amount of added substance is present but not necessarily recognized to recognition of the nature of the added substance.

Determining which properties will be subject to odors requires meteorological data, including a wind rose. A wind rose illustrates the different speeds and directions taken by the wind at different times during the day. With the information from the wind rose, measurements using the ASTM methods are to be taken from surrounding properties to assess the impact. Refer to Chapter 8 for information on developing meteorological information.

5.5 Site Plan Design and Building Design Mitigation Measures

All projects should integrate mitigation measures that facilitate trip reduction, reduce energy use, and reduce PM10 by modifying the following project factors:

- Site plan design
- Building design
- Land use/densities
- Landscape design

This Handbook provides a listing of mitigation measures that planners should make project proponents aware of before projects are designed. Ideally, these mitigation measures are discussed during an initial consultation between planners and the project proponents, as outlined in Chapter 4. Table 5-5 identifies the site plan/building design mitigation measures by type of land use. The District recommends that these mitigation measures be employed by all projects to the extent feasible and consistent with local land use policies.

The mitigation measures relating to site plan design and building design can be divided into four categories:

Support Facilities. Support facilities encourage modes of transportation other than the automobile, such as walking and bicycling. Support facilities include pedestrian pathways, showers and lockers for employees in office buildings, and bicycle racks.

Trip Reduction Through Land Use. Land uses, such as mixed uses, can reduce the number and/or length of vehicle trips by ensuring that supportive land uses are within walking distance of

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one another. An example would be locating neighborhood retail services, such as food markets and a post office, within walking distance of a residential subdivision. In addition, increased densities in transit corridors (particularly within a quarter of a mile of a transit station, see Table 5-6 for distances) can support transit and carpooling levels.

Reduction in Vehicle Idling Through Design. Idling and slow-moving vehicles produce more emissions, particularly carbon monoxide (CO), than those that are moving more quickly. Enclosed parking facilities can also have high levels of carbon monoxide. Consideration should be given to vehicle speeds and idling when designing parking lots, egress/ingress areas, and drive-through facilities, such as fast-food restaurants.

Reduction in Energy Use. The amount of energy required to maintain a building depends upon such design factors as building orientation, window treatments, and type of indoor lighting. Through careful site planning, wise choice of building materials, and shade-producing landscaping, energy requirements are greatly reduced; this in turn places less demand on power-generating facilities.

Reduction in PM10. PM10 emissions can be reduced by requiring adequately maintained landscaping, inclusion of snow fences or trees as wind breaks in areas prone to dust storms, and ensuring all vehicle parking and maneuvering areas are paved.

In addition, the Local Government Commission (based in Sacramento) recently prepared a handbook, *Land Use Strategies for More Liveable Places*, that identifies site plan and building designs that are effective in mitigating air quality impacts.

References

Land Use Strategies for More Liveable Places, June 1992.
The Local Government Commission, 909-12th Street, Suite 205, Sacramento, CA 95814.

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Figure 5-1. Land Uses Considered To Be Sensitive Receptors

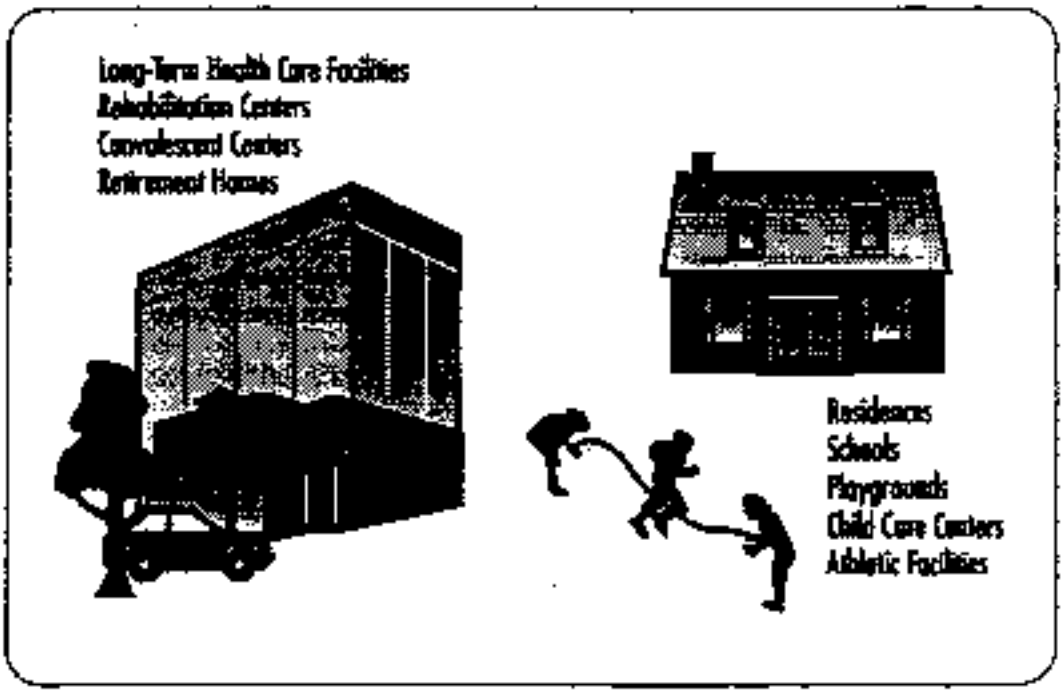

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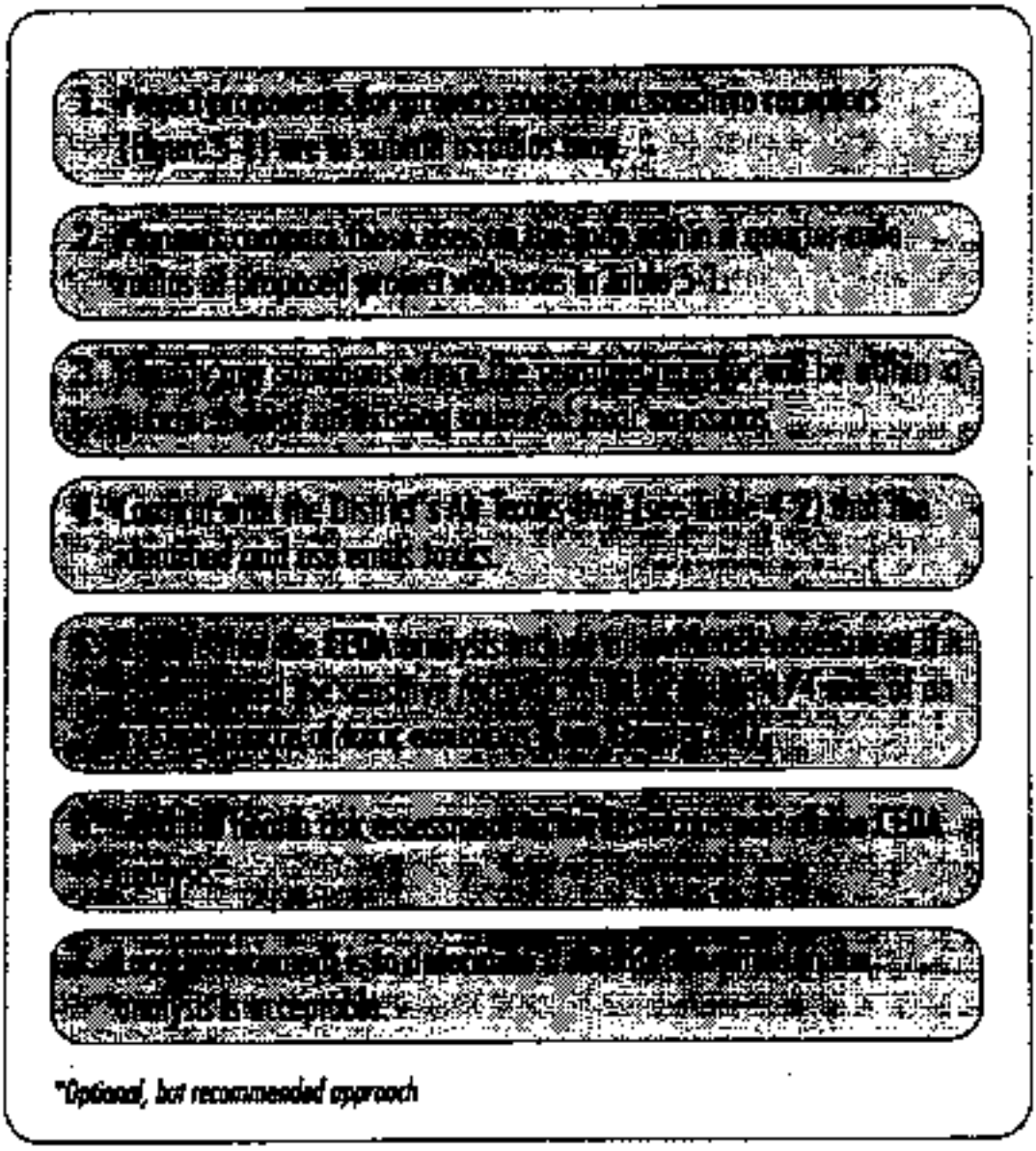
Figure 5-2. Steps to Evaluate Toxic Impact on Sensitive Receptors*



*Optional, but recommended approach

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Figure 5-1. Radius Map

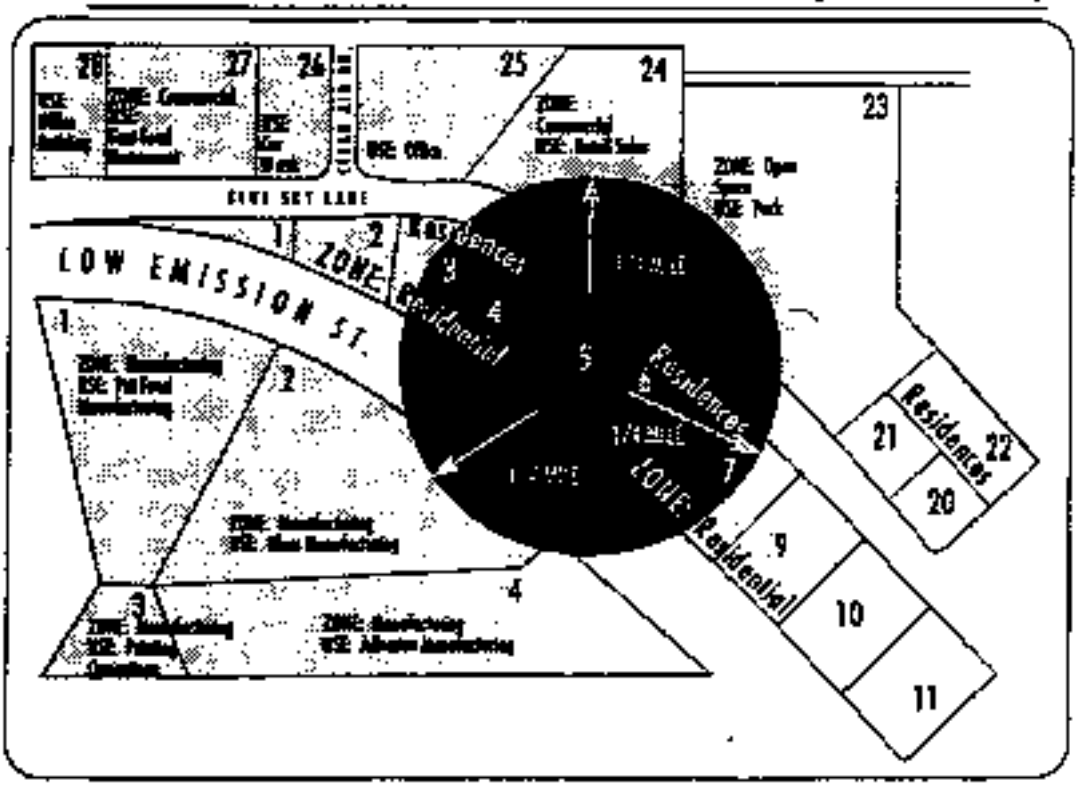

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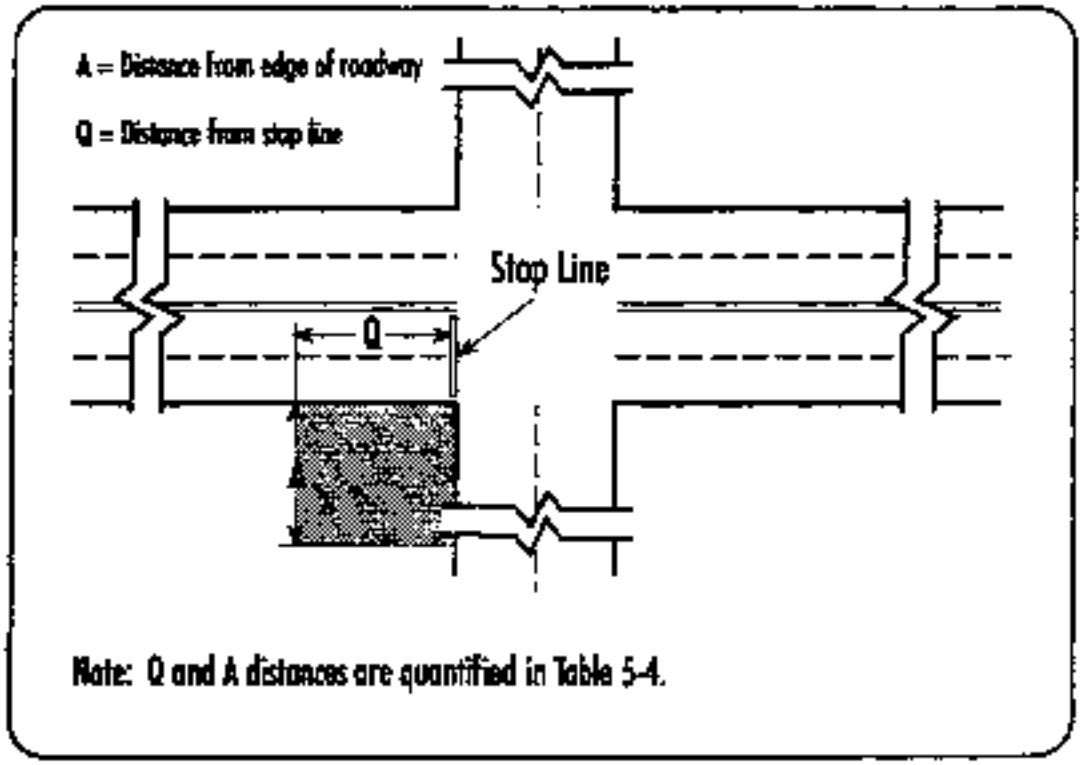
Figure 5-4. Example of Screening Analysis for Sensitive Receptors



Note: Q and A distances are quantified in Table 5-4.

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Figure 5-5. Land Uses Associated with Odor Complaints

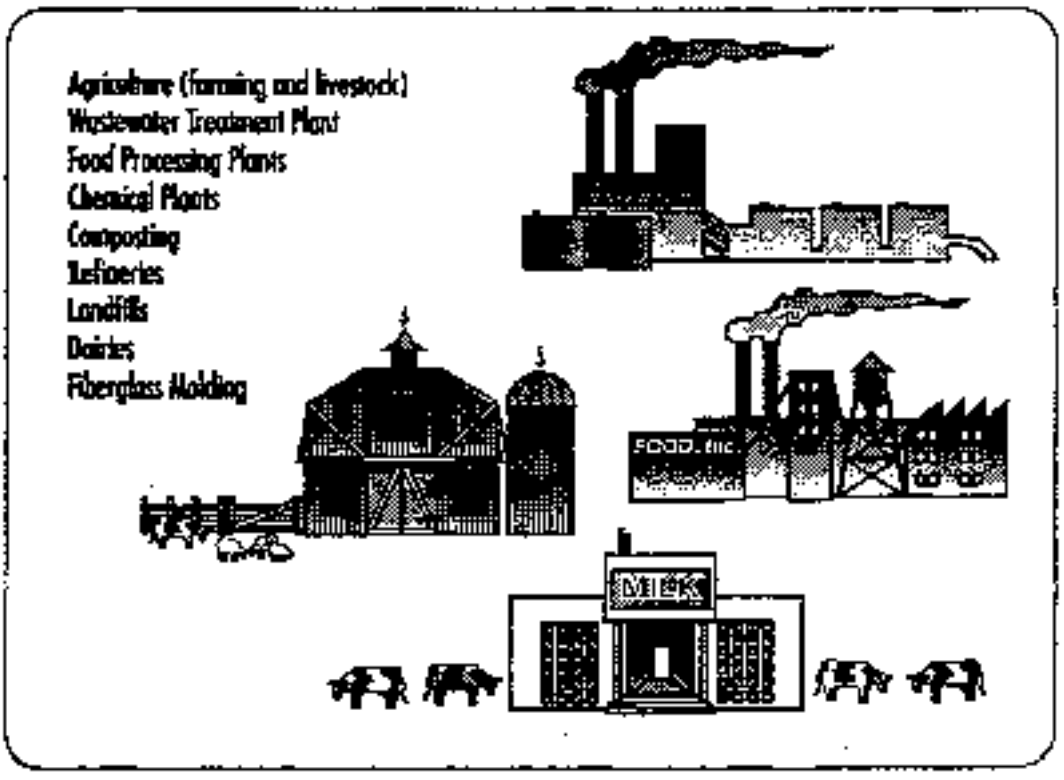

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Table 5-1. Examples of Toxic Emissions, By Land Use

Land Use	Source Type	Air Toxic Emissions
INDUSTRIAL Acoustic Ceiling, Asbestos Product, Caulk, and Gasket Manufacturing	Blending Tank with Baghouse	Asbestos
Aerospace Manufacturing	Chrome Plating Shop, Spray Booth, Aircraft Parts	Hexavalent Chromium
Asphalt Batch Plant, Asphalt and Paving Contractors, Asphalt and Asphalt Products Mfg.	Mixing Tank, Asphalt Manufacturing with Baghouse	Asbestos
Brake Manufacturing Facility	Arc Grinders	Asbestos
Brake Shoe Rebuilders and Recyclers	Brake Debonder with Afterburner	Asbestos
Chemical Manufacturing	Reaction Tank Wastewater Treatment Mixing Tank, High-Temperature Adhesive Mfg., Chlorinated Wax Manufacturing, Feedstock Refrigerants Mfg.	Ethylene Dichloride, Asbestos Carbon Tetrachloride
Chemical Plants Hazardous Waste Incinerator	Hazardous Waste Rotary Kiln Incinerator	Beryllium, Hexavalent Chromium, Benzene, Carbon Tetrachloride, Dioxins, Dibenzofurans, Ethylene Dichloride, PAHs, PCBs
Chrome Plating Facility	Chrome Plating Shop, Evaporation System Chromic Acid Solution, Chrome Plating Shop and Tank	Hexavalent Chromium, Cadmium
Electrical Manufacturing	Transformer, Plating	PCBs, Cadmium, Chromium, Nickel, Trichloroethylene, 1,4-Dioxane
Electronic Manufacturing	Plating, Etching	Cadmium, Chromium, 1,4-Dioxane, Nickel, Trichloroethylene

Note: This table does not include all types of land uses with non-toxic emissions, nor all source types and toxic air emissions for listed components.

(continued on next page)

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Table 5-1. Examples of Toxic Emissions, By Land Use (continued)

Commercial Medical Equipment Sterilization Facility	Ethylene Oxide Sterilization Chamber	Ethylene Oxide
Fiberglass Manufacturing	Machine Operation with Baghouse	Styrene
Glass Container Manufacturing		
Graphite Manufacturing	Polycarbon Graphitization	Dioxins, Dibenzofurans
Industrial with Heating or Steam Needs	Fuel Oil Steam Generator Boiler Unit	Cadmium, Hexavalent Chromium
Petroleum Refinery Modification/Expansion	Petroleum Product Storage Tank Fuel Oil Steam Generator	Benzene Benzene, Cadmium
Storage Tank Farm	Storage Tank	Benzene
COMMERCIAL Auto Machine Shop Brake Realignment Shop Gas Station Medical Clinic and Laboratory Dry Cleaners Auto Body Shop	 Arc Grinders Arc Grinders Typical Gas Station Ethylene Oxide Medical Sterilizer	 Asbestos Asbestos Benzene Ethylene Oxide Perchloroethylene
INSTITUTIONAL/PUBLIC College/University	Fuel Oil Boiler Unit Ethylene Oxide Medical Sterilizer	Cadmium, Hexavalent Chromium, Ethylene Oxide
Groundwater Clean-Up Wastewater Treatment	Aeration Tower	Benzene, Perchloroethylene, Trichloroethylene
Hospital	Refuse Incinerator, Medical Sterilizer Sterilization Chamber, Boiler Unit	Dioxins, Dibenzofurans, Cadmium, Ethylene Oxide
Landfill	Landfill Gas Flare	Benzene, Vinyl Chloride
Biomedical Laboratory	Fugitive Emissions and Fume Hood Exhaust	Benzene, Carbon Tetrachloride, Chloroform, Formaldehyde, Methylene Chloride

(continued on next page)

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Table 5-1. Examples of Toxic Emissions, By Land Use (continued)

[illegible]	[illegible]	[illegible]
Municipal Solid Waste Incinerator	Mass Burn Incinerator	Dioxins, Dibenzofurans, Cadmium, Hexavalent Chromium, PAHs, PCBs, Mercury
Wastewater Treatment Facility (POTW)	Digester Gas-Fired Reciprocating Engines	Hexavalent Chromium, Others
Wastewater Treatment Plant	Wastewater Treatment	Benzene, Carbon Tetrachloride, Ethylene Dichloride, Ethylene Dibromide, Chloroform

[illegible]

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Table 5-2. Projected Future Year 1-Hour CO Concentrations (ppm)

Location	Year							
	1982	1985	1987	1990	1993	1995	1997	2000
1 – Los Angeles	11.0	10.2	9.5	8.7	8.0	7.2	6.4	5.7
2 – West L.A.	11.9	11.1	10.3	9.5	8.7	7.9	7.1	6.3
3 – Hawthorne	17.9	16.6	15.3	14.0	12.8	11.5	10.2	8.9
4 – Long Beach	10.9	10.2	9.4	8.6	7.9	7.1	6.3	5.5
5 – Pico Rivera	10.2	9.4	8.7	8.0	7.3	6.6	5.9	5.2
6 – Reseda	14.8	13.8	12.7	11.7	10.6	9.6	8.5	7.5
7 – Burbank	15.6	14.5	13.4	12.3	11.1	10.0	8.9	7.8
8 – Pasadena	12.6	11.7	10.9	10.0	9.2	8.3	7.5	6.6
9 – Azusa	6.4	6.0	5.6	5.3	4.9	4.5	4.1	3.7
10 – Pomona	10.9	10.4	9.9	9.4	8.8	8.3	7.8	7.3
11 – Whittier	10.3	9.6	8.9	8.2	7.6	6.9	6.2	5.5
12 – Lynwood	24.7	23.1	21.5	20.0	18.4	16.8	15.2	13.6
13 – Santa Clarita	10.1	9.7	9.2	8.8	8.3	7.8	7.4	6.9
14 – Lancaster	10.6	10.0	9.5	8.9	8.3	7.7	7.1	6.5
16 – La Habra	20.0	19.0	18.1	17.1	16.1	15.1	14.1	13.1
17 – Anaheim	16.8	15.8	14.7	13.7	12.7	11.6	10.6	9.5
18 – Costa Mesa	12.9	12.1	11.3	10.5	9.7	8.9	8.1	7.3
19 – El Toro	8.5	8.4	8.3	8.2	8.0	7.9	7.8	7.7
23 – Rubidoux	10.2	9.8	9.3	8.9	8.4	8.0	7.6	7.1
– Riverside Mag.	12.8	12.2	11.7	11.1	10.6	10.0	9.5	8.9
33 – Upland	7.8	7.5	7.3	7.0	6.7	6.4	6.1	5.8
34 – Fontana	5.7	5.4	5.0	4.7	4.4	4.0	3.7	3.4
– San Bernardino	8.9	8.4	7.9	7.4	6.9	6.4	5.8	5.3

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Table 5-3. Projected Future Year 8-Hour CO Concentrations (ppm)

Location	1990	1991	1992	1993	1994	1995	1996	2000
1 – Los Angeles	7.8	7.2	6.7	6.2	5.6	5.1	4.6	4.0
2 – West L.A.	6.3	5.9	5.5	5.1	4.6	4.2	3.8	3.4
3 – Hawthorne	12.8	11.8	10.9	10.0	9.1	8.2	7.3	6.4
4 – Long Beach	7.9	7.3	6.8	6.2	5.7	5.1	4.6	4.0
5 – Pico Rivera	8.4	7.8	7.2	6.6	6.0	5.4	4.9	4.3
6 – Reseda	11.6	10.8	10.0	9.1	8.3	7.5	6.7	5.9
7 – Burbank	10.8	10.1	9.3	8.5	7.7	7.0	6.2	5.4
8 – Pasadena	7.9	7.3	6.8	6.3	5.7	5.2	4.7	4.1
9 – Azusa	4.7	4.5	4.2	3.9	3.6	3.3	3.0	2.7
10 – Pomona	6.3	6.0	5.7	5.4	5.1	4.8	4.5	4.2
11 – Whittier	7.1	6.6	6.2	5.7	5.2	4.8	4.3	3.8
12 – Lynwood	17.4	16.3	15.1	14.0	12.9	11.8	10.7	9.6
13 – Santa Clarita	4.6	4.4	4.1	3.9	3.7	3.5	3.3	3.1
14 – Lancaster	6.8	6.4	6.0	5.7	5.3	4.9	4.5	4.2
16 – La Habra	8.9	8.5	8.0	7.6	7.2	6.7	6.3	5.8
17 – Anaheim	9.7	9.1	8.5	7.9	7.3	6.7	6.1	5.5
18 – Costa Mesa	10.2	9.6	9.0	8.3	7.7	7.1	6.5	5.8
19 – El Toro	5.3	5.2	5.1	5.1	5.0	4.9	4.8	4.8
23 – Rubidoux	8.8	8.4	8.0	7.6	7.3	6.9	6.5	6.1
– Riverside Mag.	7.2	6.9	6.6	6.3	6.0	5.7	5.4	5.0
33 – Upland	5.7	5.5	5.3	5.1	4.9	4.7	4.5	4.2
34 – Fontana	4.7	4.4	4.2	3.9	3.6	3.3	3.1	2.8
– San Bernardino	6.6	6.2	5.8	5.4	5.1	4.7	4.3	3.9

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Table 5-4. Screening Table to Estimate CO Concentrations from Roadways

Roadway Type	Level of Service	Capacity (veh)/Speed (mph)	Wind Angle (degrees)	Receptor Distance (meters)	1-hour CO Concentration (ppm)	8-hour CO Concentration (ppm)	
						30 m (98 ft.)	60 m (197 ft.)
Freeway	C	20,400/50	12	0.0	4.0	3.1	2.2
	D	21,600/40	12	0.0	4.3	3.3	2.4
	E	24,000/35	12	0.0	4.8	3.7	2.7
	F0	27,120/30	12	0.0	5.7	4.4	3.2
	F1	31,440/25	12	0.0	7.2	5.6	4.0
	F2	33,840/21	12	0.0	8.5	6.6	4.8
	F3	36,000/18	12	0.0	9.1	7.0	5.1
	C	13,200/50	8	0.0	3.2	2.4	1.8
	D	14,400/40	8	0.0	3.5	2.7	1.9
	E	16,000/35	8	0.0	3.7	2.8	2.0
	F0	18,080/30	8	0.0	4.3	3.3	2.4
	F1	20,960/25	8	0.0	5.4	4.1	2.9
	F2	22,560/21	8	0.0	6.4	4.9	3.5
	F3	24,000/18	8	0.0	6.8	5.2	3.7
Arterial	C	6,375/20		879.25	10.8	7.1	4.4
	D	6,750/15		931.75	12.5	8.3	5.3
	E	7,125/10		980.96	17.5	11.7	7.6
	F0	8,051/10		1108.91	23.2	15.4	10.0
Local	C	255/25		36.09	1.2	0.9	0.7
	D	270/15		36.09	0.8	0.7	0.5
	E	285/10		39.37	0.9	0.7	0.5
	F0	322/10		45.93	1.2	0.9	0.7

Notes: 1. Highway CO concentrations multiplied by appropriate urban persistence factors.
2. Wind angles parallel to roadway and perpendicular to roadway.
3. Capacity refers to traffic volume per hour.

* A = Distance from edge of roadway. Q = Distance from stop line.

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Table 5-5. Site Plan/Building Design Mitigation Measures

Residential	Mixed uses (supportive neighborhood uses) in subdivisions Solar water heaters Centralized water heating systems Energy efficient appliance when built-in units are provided Site design to reduce proximate CO emissions
Residential/Commercial	Increased land use densities in transit corridors (see Table 5-6) Pedestrian facilities and access Building and subdivision orientation to the north for natural cooling Shade trees to reduce building's heat Energy-efficient and automated controls for air conditioners Window treatments (double-paned glass) Increased insulation beyond Title 24 (attic and walls) Snowfences and/or plant trees as wind barriers
Commercial	Bicycle facilities; showers and lockers Bus shelters On-site bus turnaround On-site circulation in parking lots to reduce vehicle queuing* Pedestrian kiosks for pay parking rather than paying from vehicle* Energy-efficient parking lot lights Improve traffic flow at drive-throughs* Light-colored roof materials to reflect heat Park 'n ride lots in vacant parking lots Video-conference facility Ventilation system for enclosed parking facilities*
Commercial/Industrial	Reserved and preferentially located carpool/vanpool parking spaces Use of building materials that do not require use of paints/solvents Supportive land uses in office/industrial parks Lighting controls and energy-efficient lighting in buildings Reduction in the number of employee parking spaces consistent with Regulation XV: 25% of employee spaces in San Bernardino 25% of employee spaces in Riverside County 33% of employee spaces in LA/Orange County 43% of employee spaces in Downtown LA

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Table 5-6. Land Use Densities for Supporting Transit Service in Corridors

Type of Transit Service	Residential Densities	Commercial Densities
Minimum level of local bus service (20 daily trips in each direction or 1 bus per hour)	4–5 du/acre (or 3,000–4,000 people/sq. mile)	5–8 million sq. ft. of floor area
Intermediate level of local bus service (40 daily trips in each direction or 30-minute headways)	7 du/acre (or 5,000–6,000 people/sq. mile)	8–20 million sq. ft. of floor area
Frequent level of bus service (120 daily trips in each direction or 10-minute headways)	15 du/acre (or 8,000–12,000 people/sq. mile)	20–50 million sq. ft. of floor area
Light rail transit (medium-capacity of 2,000–20,000 travelers/hour)	9–12 du/acre	35–50 million sq. ft. of floor area
Commuter rail transit (between suburban and Central Business District (CBD) areas)	1–2 du/acre	100 million sq. ft. of floor area

Source: *TDM, A Toolbox for Alleviating Traffic Congestion*

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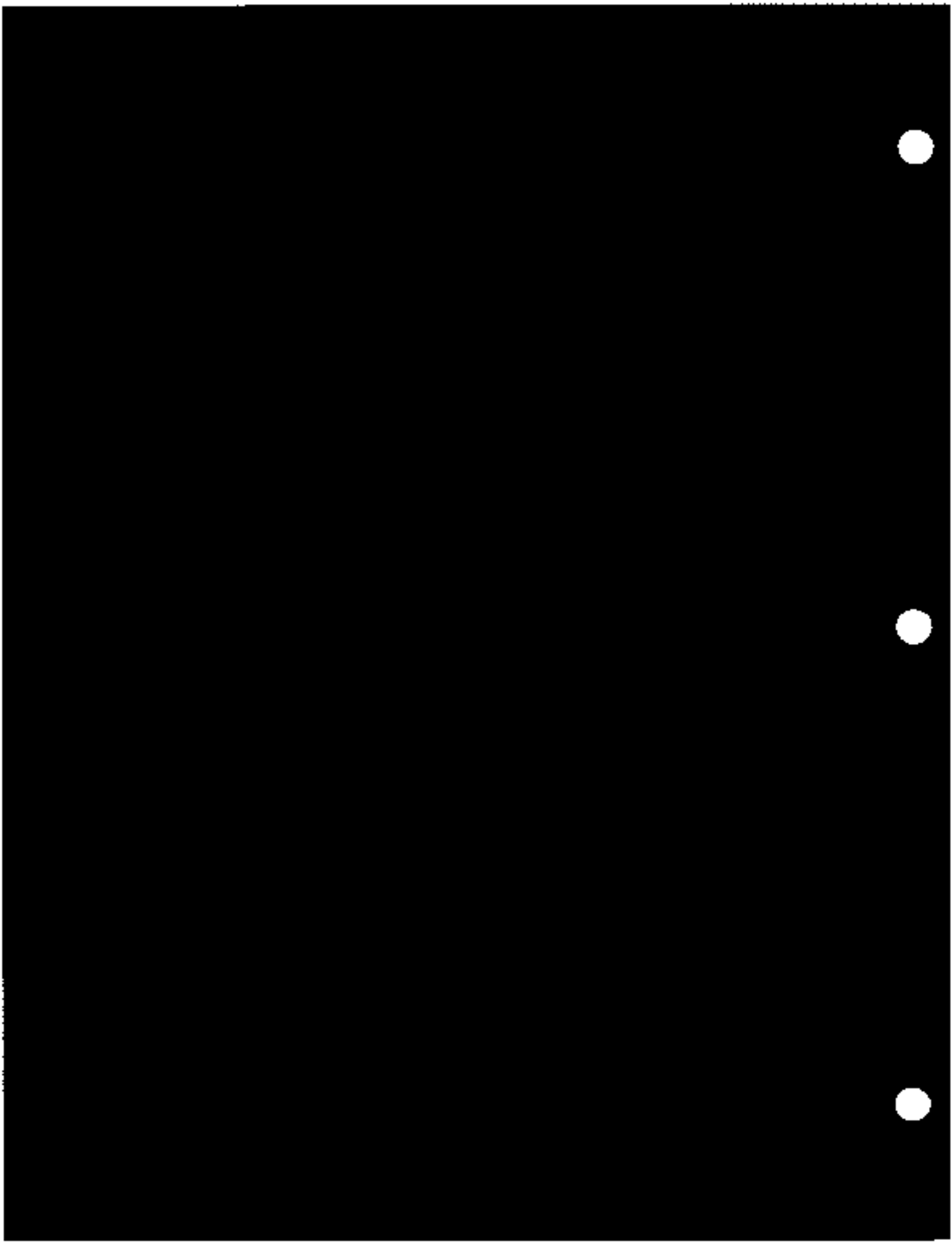

DETERMINING THE AIR QUALITY SIGNIFICANCE OF A PROJECT

CHAPTER 6

Section 15002(g) of the state CEQA Guidelines defines a significant effect on the environment as "a substantial adverse change in the physical condition which exists in the area affected by the proposed project." Further, the project is considered to be of statewide, regional, or area-wide significance if it, for example, interferes with attaining the federal or state air quality standards (CEQA Guidelines Section 15206(b)(2)). To determine the significance of a project, CEQA requires the preparation of an Initial Study by the project proponent or lead agency. The Initial Study will evaluate the impact of the proposed project upon the environment, including air quality. From an air quality perspective, the impact of the project is determined by examining the types and levels of emissions generated by the project and its impact on factors that affect air quality. As such, projects should be evaluated in terms of air pollution thresholds established by the District. The thresholds of significance differ for the SCAB and the Coachella Valley. The scope of the evaluation and the extent of the required CEQA review will depend upon the estimated extent of the impact as determined by the lead agency in the Initial Study.

6.1 Preparing the Initial Study

To assist local planners and project proponents in answering the questions in the Initial Study, and thereby determining the air quality significance of a project, the key air quality issues to consider in each Initial Study category are summarized in Table 6-1.

Beyond the obvious primary impact of specific emissions arising from the operation and construction of a project, there is the potential for secondary effects. Secondary effects include such things as: impacts on the earth, water, population, transportation/circulation, energy/utilities, human health, and public services, that affect air quality indirectly. Among these secondary effects are, for example, high CO emissions from degradation in roadway level of service and NOx from power plants producing energy. All of those emissions contribute to air pollution, and need to be included in the project's emissions calculations. CEQA requires that in evaluating the significance of the environmental effect of a project, the lead agency shall consider both primary or direct and secondary or indirect consequences (CEQA Guidelines Section 15064 (d)). The impact of a project needs to be evaluated in terms of emisstion thresholds and other indicators of potential air quality impacts.

6.2 SCAB Air Pollution Thresholds for Operations

As seen above, new and modified projects will affect regional air quality both directly and indirectly. To determine the extent of a proposed project's environmental impact and the significance of such impact the project should be compared to established levels of significance. The District has established two types of air pollution thresholds to assist lead agencies in determining whether or not the operation phase of a project is significant. These can be found in the following sections under: 1) emission thresholds; and 2) additional indicators. If the lead agency finds that the operational phase of a project has the potential to exceed either of the air pollution thresholds, the project should be considered significant.

- **Emission Significance Thresholds (Primary Effects)**

The District has established these thresholds, in part, based on Section 182 (e) of the federal Clean Air Act which identifies ten tons a year of volatile organic gases as the significance level for stationary sources of emissions in extreme non-attainment areas for ozone. The South Coast Air Basin is the only extreme non-attainment area in the United States. This emission threshold has been converted to a pounds per day threshold for the operational phase of a project. The District staff also evaluated the thresholds established by other air quality management agencies in California and has taken into account the effect the thresholds would have on local governments' work load.

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While Section 15064 (b) of CEQA Guidelines states that an ironclad definition of a significant effect is not possible because the significance of an activity may vary with the setting, the District believes that the setting as referred to in CEQA can be defined in this case. Under California state law (Health and Safety Code Section 40402), the South Coast Air Basin is defined as a distinct geographic area with a critical air pollution problem for which ambient air quality standards have been promulgated to protect public health. As such, the District believes that significance thresholds can be established based on scientific and factual data that is contained in the federal and state Clean Air Acts. Therefore, the District recommends that these thresholds be used by lead agencies in making a determination of significance. However, the final determination of whether or not a project is significant is within the purview of the lead agency pursuant to Section 15064 (b) of the CEQA Guidelines.

Both direct and indirect emissions should be included when determining whether the project exceeds these thresholds. The following significance thresholds for air quality have been established by the District for project operations:

55 pounds per day of ROC

55 pounds per day of NOx

550 pounds per day of CO

150 pounds per day of PM10

150 pounds per day of SOx

Ca. state 1-hour or 8-hour CO standard

Projects in the South Coast Air Basin (SCAB) with daily operation-related emissions that exceed any of the above emission thresholds should be considered to be significant.

Planners and project proponents may determine if a project is likely to be significant by screening the project using Table 6-2. The land uses listed therein are based on the mobile source emissions from projects that have the potential to exceed the emission thresholds. Table 6-2 does not cover all proposed projects or situations. If site-specific information is available, the MAAQI model or emission calculation procedures discussed in Chapter 9 of this Handbook can be used to estimate emissions totals to determine significance. Any emission reductions resulting from existing rules and ordinances should be calculated as the project's non-mitigated emissions and discussed in the project description.

In addition, level of service can be used as a screening method for determining when vehicle trips will impact a roadway, thus violating the state 1-hour or 8-hour standard, and creating a CO hotspot. Refer to Section 9.4.

- **Additional Indicators of Potential Air Quality Impacts (Secondary Effects)**

Additional indicators should be used as screening criteria indicating the need for further analysis with respect to air quality. Whenever possible, the project should be evaluated in a quantitative analysis; otherwise a qualitative analysis is appropriate. The additional indicators are as follows:

- Project could interfere with the attainment of the federal or state ambient air quality standards by either violating or contributing to an existing or projected air quality violation (refer to Chapter 12 and Appendix G, Significant Effects, State CEQA Guidelines);
- Project could result in population increases within the regional statistical area which would be in excess of that projected in the AQMP and in other than planned locations for the project's build-out year (refer to Chapter 12);
- Project could generate vehicle trips that cause a CO hot spot (refer to Section 9.4);

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- Project will have the potential to create or be subjected to an objectionable odor over 10 dilution to thresholds (D/T) (refer to Chapter 5) that could impact sensitive receptors;
- Project will have hazardous materials on site (Table 10-4 and 10-5) and could result in an accidental release of air toxic emissions or acutely hazardous materials posing a threat to public health and safety (refer to Chapter 10);
- Project could emit an air toxic contaminant regulated by District rules or that is on a federal or state air toxic list (refer to Appendix 10);
- Projects could involve burning of hazardous, medical, or municipal waste as waste-to-energy facilities (refer to Chapters 10 and 13);
- Projects could be occupied by sensitive receptors within a quarter mile of an existing facility that emits air toxics identified in District Rule 1401 (New Source Review of carcinogenic air contaminants) or near CO hot spots (refer to Chapters 5 and 10);
- Project could emit carcinogenic or toxic air contaminants that individually or cumulatively exceed the maximum individual cancer risk of 10 in 1 million.

If the project has significant air quality impacts, an EIR should be prepared. If the impact of the project can be reduced below significant by the application of mitigation measures, then a Mitigated Negative Declaration (MND) can be prepared. The MND or EIR should quantify the level of emissions using the standards in this Handbook, and identify mitigation measures to lessen the project's impact to the greatest extent possible. The District recommends that all projects apply feasible mitigation measures to reduce individually and cumulatively significant air quality impacts to less than significant. Refer to Chapter 11 for an identification of mitigation measures, and the potential for emission reductions.

6.3 SEDAB (Under District Jurisdiction) Air Pollution Thresholds for Operations

The Coachella Valley and Antelope Valley, which are under the jurisdiction of the District, are in the SEDAB which has a distinctly different air pollution problem than the SCAB. The SEDAB is not classified as an extreme non-attainment area for ozone and therefore, the District has not changed the significance thresholds for the Coachella Valley and Antelope Valley from the 1987 version of this Handbook. In determining whether or not a project exceeds these thresholds, the project emissions should be calculated in the same manner as that for the SCAB (e.g. utilizing the highest daily emissions). These thresholds are as follows:

75 pounds per day of ROC

100 pounds per day of NOx

550 pounds per day of CO

150 pounds per day of PM10

150 pounds per day of SOx

Ca. state 1-hour and 8-hour CO standard

Projects in the Coachella Valley and Antelope Valley portion of the SEDAB with peak operation-related emissions that exceed any of the above emission thresholds should be considered significant.

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As with the significance thresholds defined for the SCAB, planners and project proponents may determine if a project is significant by screening the project using Table 6-2 or the alternatives mentioned in Section 6.2. Level of service can also be used for determining a likely violation of the state 1-hour or 8-hour CO standard for the Coachella Valley and Antelope Valley.

The additional indicators of potential air quality impacts identified in Section 6.2 should also be used in determining if a project is significant in the Coachella Valley and Antelope Valley.

6.4 Construction Emission Thresholds for SCAB and Coachella Valley

Both the SCAB and SEDAB (that portion under the jurisdiction of the District) exceed the federal and state PM10 standards. The problem in these areas results from fugitive dust distributed during construction, from transport of disturbed dust on roadways by vehicles and wind. However, since a project's impact is limited to the construction phase, and level of mitigation, the procedure for determining significance is different than that for a project's operational impacts. When estimating a project's construction-related emissions, the emissions can be averaged over a 3-month period to include only actual working days.

The following significance thresholds for air quality have been established by the District on a quarterly basis:

2.5 tons per quarter of ROC

2.5 tons per quarter of NO_x

24.75 tons per quarter of CO

6.75 tons per quarter of PM10

6.75 tons per quarter of SO_x

However, if emissions on an individual day exceed 75 lbs a day for ROC, or 100 lbs a day for NOx, or 550 lbs a day for CO, or 150 lbs a day for PM10 , the project should be considered significant.

Projects in the SCAB or SEDAB with construction-related emissions in a quarterly period that exceed any of the emission thresholds should be considered to be significant.

Table 6-3 provides a screening table for determining when a project's construction emissions could exceed the threshold of significance.

6.5 Selecting the Appropriate Document

Upon completion of the Initial Study, the lead agency in consultation with responsible agencies determines the most appropriate type of environmental documentation, (i.e., a Negative Declaration (ND), a Mitigated Negative Declaration (MND), or an Environmental Impact Report (EIR)). Specific criteria for determining the appropriate environmental document with respect to air quality are described below. Table 6-4 provides a quick reference for planners to determine the appropriate environmental documents for particular types of land use projects.

- **Negative Declarations**

A Negative Declaration (ND) is prepared if the Initial Study identifies no significant environmental impacts from the project. Before the release of the ND for the project, the lead agency must determine that there is no substantial evidence that the project without mitigation may have a significant adverse effect on the environment. Article 6 of the State CEQA Guidelines contains the requirements for the ND process and the contents of an ND.

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The District recommends that a ND be prepared for any project if it meets all of the below criteria:

(a) The construction or operation of the project will not exceed the emission thresholds of significance as established by the District.

(b) The project will not cause a CO hot spot.

(c) The project will not be occupied primarily by sensitive individuals within a quarter mile of any facility that emits air toxic contaminants which could result in a health risk for pollutants identified in District Rule 1401 or exposure to a CO hot spot.

(d) The project could not result in the accidental release of air toxic emissions or acutely hazardous materials, posing a threat to the public (Table 10-4 and 10-5).

(e) The project will not emit an air contaminant regulated by the District, or found on a federal or state air toxic list, and which causes a significant health risk (see section 6.2).

(f) The project does not involve the burning of municipal, hospital, or hazardous waste.

(g) The project will not violate any ambient air quality standard, contribute substantially to an existing or projected violation or expose sensitive receptors to substantial pollution concentrations (Refer to Appendix G, Significant Effects, State CEQA Guidelines).

(h) The project will not have a significant effect on the environment from a cumulative standpoint (Chapter 9).

- **Mitigated Negative Declarations**

Although the State CEQA Guidelines do not explicitly identify a document called a Mitigated Negative Declaration (MND), this term has come into use to refer to a specific type of environmental document. If an Initial Study is prepared for a project and significant adverse environmental impacts are identified, an MND may be prepared for that project if all potential impacts can be eliminated or mitigated to a level of insignificance. An MND is only appropriate for those projects that have been revised or modified by the application of mitigation measures that reduce the impact below the level of significance. Those mitigation measures then become part of the project description so that the project no longer has a significant impact and, therefore, may be addressed through a ND. The MND is subject to the same requirements as is an ND (see Article 6 of the state CEQA Guidelines).

In order to determine if all impacts are mitigated, all emissions associated with the project as well as the mitigation measures should be quantified through use of either the screening table (Table 6-2), the emission calculation procedures described in Chapter 9, or the MAAQI model. In order to determine the net air quality impact after mitigation is applied, mitigation measures efficiency may be derived by using the data in Tables 11-2, 11-3, 11-4, 11-6, and 11-7; the calculation procedures described in Chapter 11; or the MAAQI model. The District recommends that all projects employ all feasible mitigation measures to reduce individually and cumulatively significant air quality impacts caused by the project to less than significant. Refer to Chapter 11 for an identification of mitigation measures, and the potential for emission reductions.

Agencies certifying MND must take affirmative steps to determine that approved mitigation measures are implemented subsequent to project approval. Specifically, a mitigation monitoring and reporting plan must be prepared pursuant to Public Resources Code 21081.6 for any mitigation measures incorporated into the project or imposed as a condition of approval.

The District recommends that an MND be prepared for any project if it meets all of the following criteria:

(a) The construction or operation of the project may result in the threshold emissions being exceeded; however, quantifiable mitigation measures have been prescribed that reduce the emissions to below the significance thresholds.

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(b) The project may cause a CO hot spot, however, quantifiable mitigation measures have been prescribed to prevent it.

(c) The project will not violate any ambient standard, contribute substantially to an existing or projected violation after mitigation or expose sensitive receptors to substantial pollutant concentrations. (Refer to Appendix G, Significant Effects, State CEQA Guidelines).

(d) The project could result in the accidental release of air toxic emissions or acutely hazardous materials, posing a threat to the public (Tables 10-4 and 10-5); however mitigation measures (e.g. safety engineering practices) have been prescribed that reduce the risk of a release to insignificance.

(e) The project could emit an air toxic contaminant that is regulated by the District, or is found on a federal or state air toxic list, and which causes a significant health risk (see Section 6.2); however, mitigation measures are employed which reduce the impact to insignificant.

(f) The project does not involve the burning of municipal, hospital, or hazardous waste.

(g) The project may have a significant effect on the environment from a cumulative standpoint (Chapter 9); however, mitigation measures have been prescribed that make the project's cumulative impacts insignificant.

- **Environmental Impact Reports**

If the Initial Study identifies potential significant adverse impacts from the project that cannot be mitigated below the significance thresholds, then the lead agency should prepare an Environmental Impact Report for the project rather than a Mitigated Negative Declaration. A lead agency may also elect to prepare an EIR if there is serious public controversy over the environmental effects of the project. (Refer to CEQA Guidelines Section 15064(h)(1).)

As with a Mitigated Negative Declaration, all potential impacts should be quantified using the emission calculations procedures described in Chapter 9 for mitigation measures quantified pursuant to Chapter 11.

The District recommends that an Environmental Impact Report be prepared for any project that can be characterized by any of the criteria listed below.

(a) The construction or operation of the project may result in the emission thresholds being exceeded even with application of all possible mitigation measures.

(b) The project will be occupied primarily by sensitive individuals within a quarter mile of a facility that emits an air toxic contaminant(s) which could result in a health risk for pollutants identified in District Rule 1401 or exposure to a CO hot spot.

(c) The project would create a a CO hot spot.

(d) The project could result in the accidental release of air toxic emissions or an acutely hazardous material (Tables 10-4 and 10-5) posing a threat to the public health and safety.

(e) The project will emit an air toxic contaminant that is regulated by the District, or found on a federal or state air toxic list, and which causes a significant health risk (see Section 6.2).

(f) The project involves the burning of municipal, or hospital, or hazardous waste.

(g) The project will violate any ambient air quality standard, contribute substantially to an existing or projected violation or expose sensitive receptors to substantial pollutant concentrations. (Refer to Appendix G, Significant Effects, State CEQA Guidelines.)

(h) The project may have a significant effect on the environment from a cumulative standpoint (Chapter 9).

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CEQA requires that immediately after deciding an EIR is required for the project, the lead agency shall send to each responsible agency a Notice of Preparation (NOP). (Refer to CEQA Guidelines Section 15082.) The District will respond to NOPs and provide lead agencies with guidance in preparing the EIR.

6.6 Use of Another EIR for Air Quality Analysis

Prior to adopting the 1991 AQMP, the District prepared a comprehensive program EIR to evaluate any adverse environmental impacts that could be generated by implementing the control measures and strategies contained in the 1991 AQMP. A program EIR was prepared because the AQMP is composed of strategies related to the "issuance of rules, regulations, plans, or general criteria to govern the conduct of a continuing program." (Refer to CEQA Guidelines Section 15168(a)(3).)

The 1991 AQMP is a blueprint outlining the strategies identified for achieving clean air. Therefore, environmental impacts were analyzed in broad, general terms. The level of detailed analysis in the 1991 AQMP EIR is commensurate with the degree of specificity of the strategies contained therein. This degree of specificity is consistent with requirements in the CEQA Guidelines which recognize that the level of detail of an environmental analysis is directly related to the level of detail of the project.

The AQMP provides valuable information for the preparation of the air quality sections of EIRs, as well as information that can be extracted or referenced. The AQMP EIR provides an in-depth analysis of potential control measures. Using the AQMP EIR as a program EIR and tiering other environmental documents after the AQMP EIR is appropriate for programs or projects which implement AQMP control measures; this includes District rules, local government Air Quality Elements, and ordinances that implement control measures.

Although CEQA allows an EIR from a previous project to be used for a later project (refer to CEQA Guidelines Section 15153), this can only occur if "such projects are essentially the same in terms of environmental impact." Consequently, the 1991 AQMP EIR should not be used as the EIR for a specific land use project because the level of detail of the analysis between the AQMP and a land use project is substantially different. Furthermore, the 1991 AQMP EIR did not analyze impacts from specific land use projects, therefore, it is unlikely that impacts resulting from the 1991 AQMP are essentially the same as impacts generated by land use projects. The AQMP EIR is only appropriate for land use projects as a reference on regional air quality issues and source for pollutant baseline emission levels.

The program EIR or MND should identify impacts that are different than those identified at the regional level in the AQMP EIR, as well as any local impacts. The program EIR or MND should also include any appropriate mitigation measures identified in the AQMP EIR, and any additional mitigation measures necessary to mitigate local impacts that were not identified in the AQMP. (Refer to Table 6-4 for a list of mitigation measures identified in the AQMP EIR for local government implementation.) These EIRs or MNDs should also be sent to the District for review and comments.

References

1991 AQMP EIR. Available from the District's Environmental Analysis Unit, (909) 396-3109.

California ARB, Transportation Performance Standards of the CCAA, May 1991. Available from ARB Transportation Strategies Group.

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Table 6-1. Preparing the Initial Study

Earth	Fugitive dust emissions from movement of soil Emissions from heavy duty diesel and gasoline-powered construction equipment Changes in topography that could affect wind patterns and cause emissions from the project to impact surrounding residential areas Alterations or expansions of landfills affecting public health as the result of moving toxic materials and contaminated soil Demolition of buildings containing asbestos Movement of contaminated soils
Air Quality	Emissions from construction (equipment and fugitive dust) or operation (vehicle trips and energy consumption) of the project will exceed the thresholds (refer to table 6-2 for land uses that could exceed the thresholds) Projects that could create or be subjected to objectionable odors
Water	Projects that involve the disposal of toxic or hazardous compounds into wastewater or groundwater that produces air emissions when the compounds are removed
Risk of Upset	Projects that are located on or near an active earthquake fault (Alquist-Priolo zone) and which could release acutely hazardous emissions due to an act of God or human error Projects using hazardous materials
Population	Projects resulting in population increases in excess of those projected in the Regional Growth Management Plan or projects locating population in areas other than those projected in the GMP, causing the region to fail to meet the federal and state air quality standards
Transportation/ Circulation	Emissions from vehicle trips (passenger vehicles and trucks) that are attached to or generated by the project (including transportation projects) Projects generating significant trips that could create a CO hot spot Emissions from ships, aircraft and locomotive engines
Energy/ Utilities	Projects demanding significant energy use, that produce emissions through the development of additional sources of energy Emissions from the development of power-generating facilities and waste-to-energy plans

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Table 6-1. Preparing the Initial Study (continued)

Human Health	Projects occupied primarily by sensitive receptors within 1/4 mile of an existing source emitting toxic emissions Projects occupied by sensitive receptors located near an existing landfill or waste-to-energy project or waste disposal facility that could emit toxic/hazardous emissions
Public Services	Projects generating significant waste (solid, wastewater, hazardous) that increases demand for disposal facilities whose disposal methods (landfill/incineration) impact air quality Projects generating a significant amount of hazardous waste that could produce emissions through accidental release

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Table 6-2. Screening Table for Operation – Daily Thresholds of Potential Significance for Air Quality

PRIMARY LAND USE		POTENTIALLY SIGNIFICANT AIR QUALITY IMPACT
RESIDENTIAL	Single Family Housing	166 units
	Apartments	261 units
	Condominiums	297 units
	Mobile Homes	340 units
	Retirement Community	612 units
EDUCATION	Elementary School	220,000 sq. ft.
	High School	177,000 sq. ft.
	Community College	150,000 sq. ft.
	* University	813 students
COMMERCIAL	* Airport	15 Daily Commercial Flights
	Business Park	136,000 sq. ft.
	Day Care	26,000 sq. ft.
	* Discount Store	32,000 sq. ft.
	Fast Food w/o Drive-Thru	3,500 sq. ft.
	Fast Food with Drive-Thru	2,800 sq. ft.
	* Hardware Store	28,000 sq. ft.
	Hotel	213 rooms
	Medical Office	61,000 sq. ft.
	Motel	220 rooms
	* Movie Theatre	30,000 sq. ft.
	* Car Sales	43,000 sq. ft.
	Office (small, 10–100)	96,221 sq. ft.
	Office (medium, 100–200)	139,222 sq. ft.
	Office (large, 200–>)	201,000 sq. ft.
	Office Park	171,000 sq. ft.
	Racquet Club	98,000 sq. ft.
	Research Center	245,000 sq. ft.
	Resort Hotel	199 rooms
	Restaurant	23,000 sq. ft.
	* Restaurant (high-turnover)	9,000 sq. ft.
	Shopping Center (small, 10–500)	22,000 sq. ft.
	Shopping Center (medium, 500–1,000)	50,000 sq. ft.
	Shopping Center (large, 1,000-1,600)	64,000 sq. ft.

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Refer to Appendix B for methodologies and assumptions used in preparing this table.

NOTES:

* Trip generation rates from the 5th Edition ITE Manual were based upon small sample sizes.

These size construction projects have the potential to exceed the daily emissions significance thresholds. Local governments should use these thresholds as screening tools when a project proponent first approaches the lead agency for a permit, to determine whether or not the proposed project will be significant. Moreover, using these thresholds, a project proponent should be advised to include feasible mitigation measures at the project design level rather than in the later stages of the project.

DEFINITIONS:

"Manufacturing" means to make goods and articles by hand or by machinery, often on a large scale and with division of labor.

"Industry" means any large-scale business activity or manufacturing productive enterprises collectively, especially as distinguished from agriculture.

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Table 6-2. Screening Table for Operation – Daily Thresholds of Potential Significance for Air Quality (continued)

PRIMARY LAND USE		POTENTIALLY SIGNIFICANT AIR QUALITY IMPACT
COMMERCIAL (continued)	*Special Activity Centers (Stadiums and Amusement Parks)	87 Employees
	Supermarket	12,500 sq. ft.
INDUSTRIAL/ MINING	Light Industrial	276,000 sq. ft.
	* Heavy Industrial	1,284,000 sq. ft.
	Industrial Park	276,000 sq. ft.
	Aircraft Manufacturing & Repairs	**
	Bulk Terminals	**
	Cement Plant	**
	Chemical Plant	**
	Hazardous Waste Treatment & Storage	**
	Manufacturing	500,000 sq. ft.
	Mining	**
	Pulp/Paper Mills	**
	Refinery	**
INSTITUTIONAL/ GOVERNMENTAL	* Clinic	94,000 sq. ft.
	* Government Center	83,000 sq. ft.
	* Hospital	176 Beds
	Library	51,000 sq. ft.
	Nursing Home	741 Beds
	U.S. Post Office	26,000 sq. ft.
	Freeway Lane Addition	All
	Designation of a New Transportation Corridor	All
	New Freeway/Highway	All
	Auxiliary Lanes	Beyond One Ramp
	Waterport	**
	Sewage Treatment Plant	**
	Rail	All
	Cogeneration Project	**
	Landfill	**
	Incineration	Hazardous, Medical or Municipal Waste
	Power Generating Facility	**
	Waste-To-Energy Plant	**

Use of the Appendix B for methodologies and assumptions used in preparing this table.

NOTES:

* Trip generation rates from the 5th Edition ITE Manual were based upon small sample sizes.

** New facilities, expansions or other change that could result in emissions exceeding the significance thresholds.

These size construction projects have the potential to exceed the daily emissions significance thresholds. Local governments should use these thresholds as screening tools when a project proponent first approaches the local agency for a permit, to determine whether or not the proposed project will be significant. Moreover, using these thresholds, a project proponent should be advised to include feasible mitigation measures at the project design level rather than in the later stages of the project.

DEFINITIONS:

"Manufacturing" means to make goods and articles by hand or by machinery, often on a large scale and with division of labor.

"Industry" means any large-scale business activity or manufacturing productive enterprises collectively, especially as distinguished from agriculture.

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Table 6-3. Screening Table for Construction - Quarterly Thresholds of Potential Significance for Air Quality

RESIDENTIAL	Single Family Housing	1,309,000 sq. ft. GFA*
	Apartments	1,410,000 sq. ft. GFA
	Condominiums	1,455,000 sq. ft. GFA
	Mobile Homes	1,455,000 sq. ft. GFA
EDUCATION	Schools	660,000 sq. ft. GFA
COMMERCIAL	Business Park	559,000 sq. ft. GFA
	Day Care Center	975,000 sq. ft. GFA
	Discount Store	975,000 sq. ft. GFA
	Fast Food	975,000 sq. ft. GFA
	Government Office Complex	559,000 sq. ft. GFA
	Hardware Store	975,000 sq. ft. GFA
	Hotel	745,000 sq. ft. GFA
	Medical Office	559,000 sq. ft. GFA
	Motel	745,000 sq. ft. GFA
	Movie Theatre	975,000 sq. ft. GFA
	Office	559,000 sq. ft. GFA
	Resort Hotel	745,000 sq. ft. GFA
	Restaurant	975,000 sq. ft. GFA
	Shopping Center	975,000 sq. ft. GFA
	Supermarket	975,000 sq. ft. GFA
INDUSTRIAL		1,102,520 sq. ft. GFA
UNPAVED ROADS	Passenger Vehicle	1,750 Vehicle Miles Traveled (1)
	Loaded Truck	430 Vehicle Miles Traveled (1)
PAVED ROADS	Local Road	24,000 Vehicle Miles Traveled (1)
	Construction Road	5,000 Vehicle Miles Traveled (1)
DEMOLITION		23,214,000 Cubic Feet of Building
GRADING		177.00 Acres

NOTES:

(1) VMT is a function of linear road length and average daily trips.

These size construction projects have the potential to exceed the quarterly emissions thresholds of significance. Local governments should use these thresholds as screening tools when a project proponent first approaches the lead agency for a permit, to determine whether or not the proposed project will be significant. Moreover, using these thresholds, a project proponent should be advised to include feasible mitigation measures at the project design level rather than in the later stages of the project.

For daily thresholds, divide thresholds by 65, not 91.

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Table 6-4. 1991 AQMP EIR Mitigation Measures Identified for Local Government Implementation

Earth	Building/expanding transportation corridors, rail systems transmission lines, could affect topography or soils.	Use discretionary permit authority, place conditions on projects to control erosion, set landscape standards, etc.
Air Quality	Positive air quality impacts.	Implement indirect source control measures; recycling programs; promote energy efficiency for home appliances.
Water (Demand)	Increased demand for water as a fugitive dust suppressant during construction.	Use reclaimed water, non-toxic soil binders, pave dirt roads, etc.
Plant and Animal Life	Reduction in plant habitats and animal populations as a result of changes in land use designation or population relocations. (Primarily the result of factors other than AQMP.)	Establish project setting procedures to preserve sensitive habitat, protect animal populations, and preserve agricultural land.
Noise	Increased noise from construction of transit lines, freeways, etc.	Regulate hours of construction.
Light and Glare	Glare from solar panels for water heaters; increased density of industrial parks.	Establish building stands to screen panels and to minimize glare to adjoining residents.
Land Use	Shift in land uses; population relocation. (Primarily the result of factors other than the AQMP.)	Zoning changes; mixed land uses.
Natural Resources	Increased demand for natural resources, e.g. minerals, timber, etc., that will accompany infrastructure development and changes in land uses.	Establish recycling programs; promote conservation measures.
Population	Growth management and mode shifts resulting in population relocation.	Careful designation of transit routes; incorporate Regional Housing Needs Assessment into General Plan housing elements; use zoning and land use plans.

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Table 4-4. 1991 AQMP EIR Mitigation Measures Identified for Local Government Implementation (continued)

Housing	Growth management policies may affect cost and distribution of housing.	Obtain VMT reduction through ISR measures; provide affordable housing through fee waivers or subsidies.
Transportation/ Circulation	Positive effect. Transportation congestion reduction.	VMT reductions through ISR measures; implement transportation management strategies; increase or expand urban transit systems.
Public Service Impacts	May require new and/or expanded services.	Work with the District to obtain technical and implementation support; secure new sources.
Energy	Shift away from petroleum-based liquid fuels to clean energy such as electricity or natural gas.	Improved standards for thermal integrity of building; high energy efficiency standards for major appliances and equipment; conservation programs; promote recycling.
Utilities-Solid Waste	AQMP has limited effect on solid waste disposal.	Promote recycling and waste minimization; establish conservation programs.
Aesthetics	Windbreaks to minimize fugitive dust could obstruct scenic vista; electrification of transit systems may produce visual impacts from overhead wires.	Establish architectural standards for windbreaks, e.g. height standards, use vegetation as windbreak; use underground electrical cables where possible.
Recreation	AQMP has limited effect, if any, on recreation resources.	Prepare/update local open space plans; establish development fees for new recreation facilities or maintain existing ones.
Cultural Resources	AQMP has limited effect, if any, on cultural resources.	Establish historical overlay zone status or equivalent for culturally significant sites.

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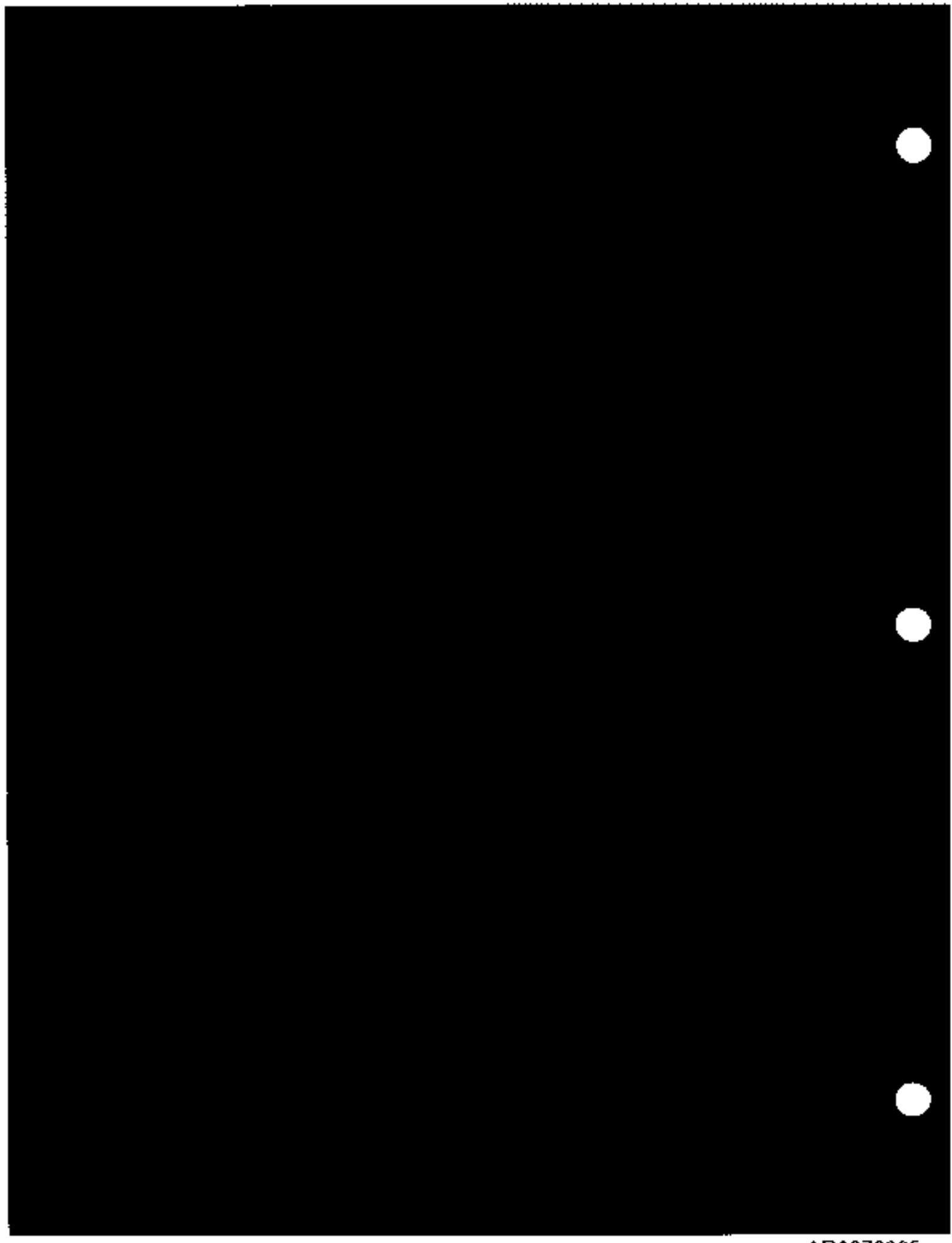

COMPONENTS OF THE AIR QUALITY ANALYSIS FOR EIRs AND MNDs

CHAPTER 7

Any project that contributes emissions during construction or operation affects air quality. Therefore, the extent to which a project impacts air quality should be examined. If, during the preparation of an Initial Study, the impact of the project upon air quality is determined to be significant (see Chapter 6) and the emissions cannot be mitigated below the level of significance, then an EIR with an air quality analysis section should be prepared. The depth of the analysis will be in proportion to the level and significance of the emissions.

This chapter and Figure 1-3 (Chapter 1) are road maps to assist the planner in the preparation of the air quality analysis for an EIR or other CEQA documentation. Table 7-1 summarizes the steps for evaluating air quality impacts. At the end of this chapter is a comprehensive checklist (Table 7-2) that provides the basis for preparing the required components of the air quality analysis.

7.1 Baseline Air Quality Information

CEQA requires an EIR to include "a description of the environment in the vicinity of the project, as it exists before the commencement of the project, from both a local and regional perspective." (Refer to CEQA, Section 15125.) The background, or baseline air quality information, should include a discussion of the following points:

- Project setting and description
- Climate and meteorological conditions
- Existing regional and local air quality
- Existing sensitive receptors
- Existing toxics emission sources
- Extent of air basin affected, and applicable Plan (AQMP or PM10 Plan)
- Transportation system as it relates to air quality

The air quality analysis of each EIR and MND should provide a description of the existing regional and local environment. Such information is referred to as baseline information (see Appendix 3). Baseline information can consist of a summary of air quality and references to readily available documents which contain detailed information for regional analysis.

Baseline information for the local air quality analysis should include information obtained from the nearest or most appropriate District air quality monitoring station and any site-specific characteristics caused by such factors as congested roadways or existing facilities that emit toxics. Generally, the most appropriate air quality monitoring station is the one located within the same source receptor area as the proposed project (refer to Source Receptor Map, Figure 8-3). Section 8.1 contains specific information regarding selecting appropriate air quality monitoring data.

The baseline air quality data should be tailored to support the evaluation of the air quality impacts. For example, if odors are an issue, the baseline information should include a wind rose, which is necessary for evaluating air quality impacts on surrounding properties. All pertinent data should be included, or at least summarized, if the detailed baseline data necessary to corroborate the analysis are provided only through readily available reference documents.

Data should be concise. Detailed data unnecessary for assessing the impact should be omitted, so that the discussion of impacts can be readily identified by decision makers and the public. Chapter 8 provides more specific information on developing baseline air quality information.

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7.2 Emission Sources: Construction and Operational

Emissions that can adversely affect air quality will originate from various activities. A project generates emissions both during the period of its construction and through ongoing daily operations. Emissions from both of these sources should be quantified in the EIR. In addition, the EIR should analyze the impact of emissions during each identified phase of project development and build-out year. As part of the impact analysis, emissions need to be compared to the thresholds of significance. The existing level of background emissions and local air quality need also be taken into account.

In the case of an MND, the analysis need not be as extensive as that prepared for an EIR. If the Initial Study identified emissions from construction and/or operation as a potentially significant effect, then the MND should quantify those sources of emissions and perform an analysis similar to an EIR.

Construction Emissions. The EIR and MND should identify all emissions associated with construction activities, including site preparation, construction of new facilities, or modification of an existing facility or site. Demolition, clearing, grading, excavating, using heavy equipment or trucks on unpaved surfaces and loading/unloading of trucks creates large quantities of fugitive dust, and thus PM10. Heavy equipment required for demolition, grading, and construction generates and emits exhaust emissions. The vehicles of commuting construction workers and trucks hauling equipment or materials (mobile source emissions) are another source of emissions which should be quantified. The emissions from electric power generators, architectural coatings, traffic impacts, and stationary construction equipment must be quantified. In addition, any asbestos removal should also be quantified. Procedures for calculating these various types of emissions are provided in Chapters 9 and Appendix 9. It is appropriate for an MND to utilize the screening tables in Chapter 9 as opposed to the detailed analysis recommended for an EIR.

Operational Emissions. After construction is completed, the project becomes operational. Operational emissions are produced by the occupancy of a facility or residential development and by both mobile and stationary sources connected therewith. Stationary emissions result from natural gas combustion and the use of electricity and equipment for manufacturing processes. Mobile emissions result from motor vehicles, airplanes, trains, ships, and construction equipment. A project may be an "indirect source" of mobile emissions by the nature of its operation; for example, vehicles operating within a project, such as warehouse forklifts or tour trains. However, the most significant indirect source emissions result from vehicles attracted to the project, such as shoppers visiting a mall or employees commuting to the work site. Procedures for calculating all of these emission sources are provided in Chapter 9 and Appendix 9. It is appropriate for a MND to utilize the screening tables in Chapter 9 if applicable as opposed to the detailed analysis recommended for an EIR.

If the District is a responsible agency and the stationary source has the potential to have significant environmental impacts, the calculation procedures in Appendix 13 should be utilized.

7.3 Analysis of Toxic Emissions and Risk of Upset

If a project may emit toxic emissions that could have an impact on sensitive receptors or risk of an on- or off-site upset or spillage, then a quantitative analysis should be performed using the guidelines provided in Chapter 10 and Appendix 10. In these cases, the District may be a responsible agency if a District permit is required. In order for the environmental document to be used for the permitting process, it must be found satisfactory by the District.

The District recommends that if a project is a sensitive receptor within a quarter mile of a source of toxic emissions, then a public health risk screening assessment should be performed as part of the environmental documentation. Refer to Chapters 5 and 10 for information on performing this type of analysis.

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7.4 Cumulative Air Quality Impacts

While one insignificant project may not affect air quality, the cumulative effect of numerous smaller projects may. In order to reduce cumulative impacts, the District recommends that all projects should, to the greatest extent possible, employ feasible mitigation measures. CEQA requires that a proposed project be examined within the scope of the existing setting and that the examination take into account new and planned similar and nearby projects.

7.5 Project Alternatives

Analysis of Alternative Emissions. CEQA for EIRs requires that feasible alternatives are to be evaluated for environmental impacts. The analysis for the project alternatives does not need to be as extensive as those for the preferred alternative. Analyses may be developed for each alternative using either the MAAQI model or screening tables and default assumptions. The results should be presented in comparative tables. The comparative analysis more clearly defines the environmental implications and benefits of each proposal. In order to perform such an analysis, the air quality impacts of each alternative should be quantified, to the extent possible. (See section 9.6.)

Beneficial Air Quality Alternatives. The selection of feasible project alternatives should take air quality into account when it is identified as a key environmental issue by either the lead agency or the District. Varying degrees or densities of site development, and the corresponding emission differences, are often considered as project alternatives. Significant mitigation measures can at times be offered as project alternatives. An example is the inclusion of commercial or residential land uses within office complexes to reduce vehicular trips and emissions. Energy cogeneration is in some instances an alternative where introduction of an on-site emission source can result in an overall reduction of emissions (waste heat produced during electrical generation is used for heating and cooling near the power plant). Industrial projects should consider all feasible alternative processes and their resulting emissions. The analysis of beneficial air quality alternatives should be in addition to the "No Project" alternative. The procedures for calculating emissions are in Chapter 9 and Appendix 9.

7.6 Determining Significance with Emission Thresholds

The EIR and MND should compare total project emissions both before and after the application of mitigation measures to the existing regional and local air quality setting and the emission thresholds in Chapter 6. If the project is to be built out over a series of years, then the project emissions should be compared to the projected future baseline (without mitigation) for the years corresponding to project phasing and/or build-out year. In addition, Chapter 6 identifies other indicators of potential air quality impacts based on a project's secondary impacts. An analysis of the project should be performed for those indicators that relate to the project. These comparisons will provide the basis for a determination of significance. If it is determined that the project will have significant impacts on air quality, it is up to the lead agency to determine if the merits of the project outweigh the adverse environmental effects such that it chooses to approve the project. If such a project is approved by the lead agency, then the project should be mitigated to the greatest extent possible and a Statement of Overriding Considerations should be prepared.

7.7 Mitigation Measures

Mitigation is crucial to reducing a project's environmental impact. The question addressed in the analysis is not whether mitigation is necessary, but rather how much mitigation is required. Mitigation must be sufficient to reduce adverse impacts below the level of significance to the greatest extent possible.

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A lead agency has the authority to require changes in any or all activities involved in the project to lessen or avoid significant impacts. A responsible agency, such as the District, can also require changes in that part of the project the responsible agency will be called on to carry out or approve. (Refer to CEQA Guidelines Section 15041.) Further, it is the policy of the State of California that agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen the significant environmental effects of such projects (PRC Section 21002). This Handbook identifies feasible mitigation measures that should be employed to reduce a project's impact on air quality.

Quantifying Effectiveness. The EIR and MND should quantify the extent to which mitigation measures can be effective and can reduce a given impact. Chapter 11 provides a menu of mitigation measures and their effectiveness in reducing emissions. Chapter 11 also includes calculation procedures for those cases in which site-specific quantification is desirable. It is appropriate for an MND to utilize the mitigation efficiency tables in Chapter 11 if applicable as opposed to the more detailed analysis recommended for EIRs. Projects should employ enough measures to reduce the impact to a level of insignificance.

In some cases, not all air quality impacts can be mitigated below a level of significance. In such cases, the District recommends that all feasible mitigation measures be applied to the project to reduce the impact to the greatest extent possible.

7.8 Consistency with Regional Plans

It is essential that the EIR analyze a project's consistency with regional plans that deal with large-scale environmental problems such as air quality as required by CEQA Guidelines Section 15125. The EIR should consider consistency of the project with all applicable plans, including:

- Air Quality Management Plan or Coachella Valley PM10 Plan
- Regional Growth Management Plan (population projections)
- Regional Mobility Plan (transportation projects)
- Locally adopted Congestion Management Plan (impacts on established levels of service and CO hot spots)
- Air Quality Element of the local General Plan (if adopted) or Air Quality Policies integrated into several General Plan Elements
- Any other plans that are applicable to the project

Refer to Chapter 12 for additional information on determining consistency/conformity of a project with the appropriate regional plans.

7.9 The District as a Responsible Agency

During the preparation of the Initial Study and throughout the preparation and approval of the EIR, CEQA requires that the lead agency consult with responsible agencies regarding the scope and content of the analysis in the EIR. The responsible agency should in turn review and comment on the notice of preparation of the EIR and the draft EIR, MND, or Negative Declaration (ND). If the responsible agency believes that the final EIR, MND, or ND is adequate for subsequent permit actions, the responsible agency may use that environmental documentation for its purposes. If the responsible agency does not believe the final document is adequate, CEQA requires a responsible agency to take one of four actions (CEQA Guidelines Section 15096(e)):

- Waive its objections.
- Prepare a subsequent EIR if permissible under CEQA Guidelines Section 15162.

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- Assume the lead agency role if authorized pursuant to CEQA Guidelines Section 15052.

- Take the issue to court to seek a remedy.

Under CEQA, the District is a responsible agency for those portions of a project subject to a District permit. Chapters 13 and 14, and Appendix 13 provide a summary of the steps for coordinating with the responsible agency. Those same sections contain information on the additional emissions analysis the EIR should contain.

The thresholds of significance for District permits are identified in Chapter 13. Where District rules reduce project impacts below the level of significance, the analysis should concentrate on secondary impacts and their mitigation. Secondary impacts are those which result from the application of control technology. (Refer to Section 6.1.)

7.10 Findings

CEQA requires the decision-maker to balance the benefits of a proposed project against its unavoidable environmental impacts in determining whether to approve the project. If the lead agency determines that the benefits of the project outweigh the potential unavoidable adverse environmental impacts, the project may be approved (CEQA Guidelines Section 15093(a)). In these types of cases where the environmental impacts of the project identified in the EIR are not mitigated to a level of insignificance, the agency must state in writing specific reasons that support its action (Statement of Overriding Considerations). In approving such a project, the lead agency must make written findings, supported by substantial evidence in the record. Additionally, the lead agency may not make findings, if the agency making the findings has concurrent jurisdiction with another agency to deal with identified feasible mitigation measures or alternatives (CEQA Guidelines Section 15091).

One example of a case where a local government might consider approving a project with overriding considerations is the siting of high-density housing in a transit corridor which is likely to adversely impact the adjacent roadway system's level of service. In this case, the local government should consider orientation of the project to the roadway and other applicable mitigation to minimize impacts of CO on a sensitive receptor. If the project is still considered significant after application of the mitigation, then the local government should consider the benefit the project would have in supporting transit services in determining whether the benefits outweigh the environmental impact.

7.11 Mitigation Monitoring

As of January 1, 1989, lead agencies are required to prepare a mitigation monitoring plan to ensure implementation of mitigation measures in an EIR or Mitigated Negative Declaration. The Plan is to contain a list of all mitigation measures and to identify the agency responsible to ensure that the mitigation is carried out. In this way, proper follow-up is made, and all conditions applying to the project are fulfilled. Typically, a mitigation monitoring plan is completed after the draft EIR has been circulated for review and before the project is approved.

Mitigation Monitoring and the Need for District Review. The District requests that the draft portions of the mitigation monitoring plan pertaining to air quality be submitted for review. A copy of the response to comments, and a list of conditions of approval or other documentation indicating the mitigation measures included in the final approved EIR should also be forwarded to the District. It is recommended that these documents be submitted to the District within 60 days of approval of the project by the lead agency. All mitigation measures should identify the party responsible for implementation and monitoring. Refer to Chapter 15 for a detailed discussion on monitoring of air quality mitigation measures.

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7.12 Program EIRs and EIRs for General Plans

Section 15168 of the CEQA Guidelines states that a program EIR can be prepared on a series of actions that can be characterized as one large project and are related either:

- o geographically;
- o as individual parts of contemplated actions;
- o in connection with the issuance of rules, regulations, plans, or other general criteria; or,
- o as individual activities carried out under the same authorizing statutory or regulatory authority and having generally similar environmental effects which can be mitigated in similar ways.

At a programmatic level, the air quality assessment should be as comprehensive as possible. There are some cases, such as construction impacts of a General Plan, where specific information may not be available. A best-effort approach to disclose all reasonably available information should be used. If the program EIR was not sufficiently detailed so that all significant effects were evaluated, then such evaluation should be performed when subsequent activities involving site-specific operations are contemplated. Additional analysis is also necessary whenever the project could result in significant impacts not analyzed in or changed from the program EIR.

The environmental analysis for a General Plan EIR provides an opportunity for a more exhaustive consideration of effects and alternatives than would be practical for an EIR on a more specific action. Additionally, the program EIR for a General Plan can ensure consideration of cumulative impacts that might be slighted when development projects are considered on a case-by-case basis. A program EIR also allows the lead agency to consider broad policy alternatives and program-wide mitigation measures at an early time when the agency has greatest flexibility to deal with basic problems or cumulative impacts.

Inclusion of air-quality-related goals, policies, and programs may act as mitigation for the overall General Plan build-out scenario, provided that specific objectives and actions are included and implemented within the time frame specified in the General Plan.

7.13 EIR Format Issues

During the preparation of an EIR, many questions regarding the preparation of the air quality analysis arise. Among the most prevalent are:

- o What level of detail is necessary in the analysis?
- o How must assumptions be documented?
- o What format should be used for reporting emissions information?

The air quality analysis should contain sufficient detail to support the conclusions reached in the analysis. If background information pertaining to the analysis is readily available in separate documents, reference to those documents is adequate. The EIR should document all assumptions for quantifying emissions (or other impacts) and mitigation measures. To document assumptions and as a format for reporting emissions, the calculation tables in Appendix 9 may be used. At the option of the preparer these tables may be inserted into the air quality section or placed in a technical appendix to the EIR. All impacts and mitigation measures related to the project should also be summarized as part of the conclusion to the air quality sections.

A practical format for documenting the project's impact is a tabular listing of estimated project emissions, effectiveness of mitigation measures, and net total project impact for the proposed project and each alternative analyzed in the EIR. Concisely summarizing the conclusions of the air quality analysis will permit decision makers to base their decisions on the final results of all calculations and analysis.

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Table 7-1. Steps for Evaluating Air Quality Impacts

STEPS	EIR	MND
1. **Baseline information:** Describe existing regional climate and air quality and cite specific ambient air quality from the District monitoring station located in project source receptor area.		
2. Identify and quantify all project **emission sources** (construction and operational).		
3. Identify and assess **toxic source emissions** and risk of upset if applicable.		
4. Assess **cumulative air quality impacts** from potentially related projects.		
5. Identify and quantify **project alternatives** that may attain the goals of the project with substantially fewer or less significant impacts.		
6. Compare anticipated project emissions with **thresholds of significance** and existing regional and site-specific air quality.		
7. Identify **mitigation measures** necessary to substantially reduce air quality impacts.		
8. Assess **consistency** of project with the AQMP.		
9. Integrate air quality analysis requirements for those projects where the District is a **responsible agency.**		
10. Make findings.		
11. Develop a **mitigation monitoring plan.**		

The MND can use screening tables to quantify emissions and mitigation measures, and may not need the same level of detail as an EIR.

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Table 7-2. Checklist for an Air Quality Analysis Section

[illegible]	Key Questions and Issues	Ref.*	Page No.	Page No.
1. Baseline Air Quality Information (Chapter 8 and Appendix 8)				
Project Setting and Description	Has the local setting surrounding the project been identified, including any unique geographic elements? Has the total project area, square footage, and use of building been identified?	8.1		
Regional Climate and Meteorological Conditions	Has either a description or reference to regional climate and meteorological data been included? In cases where odors or toxics are an issue, have wind direction and speed been identified?	8.1 5.4 5.2 12.4		
Existing Climate and Local Air Quality	Have the most current data (i.e., background concentrations and numbers of days that exceed federal and state standards) from the nearest District monitoring station in the same source receptor areas as the project been identified?	8.1 A3		
Sensitive Receptors	Are there toxic emitters within 1/4 mile of a sensitive receptor?	5.2		
Air Basin & AQMP	Is the project located in the SCAB or Coachella Valley?	2.2 F2-1		
Transportation System	Have the segments and existing LOS of the transportation system on which the project will generate trips been identified? Will the project generate trips on CMP system? How does the project relate to existing and planned transit network? How does the project relate to regional HOV network?	9.1 4.6		
2. Project-Related Emissions (Chapter 9 and Appendix 9)				
A. Determine Construction-Related Emissions	Have all construction-related emissions been identified and quantified?	9.1		
Grading	Have the amount of soil and number of acres to be disturbed and number of days required for grading been identified? Will grading take place during the windy season for that area?	A9-9		
Demolition	Will any buildings containing asbestos be demolished?	A9-10		
Excavation	Has the amount of soil (cubic feet) to be excavated been identified?	A9-9		

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*The reference column of this table refers to the following portions of this Handbook:
Reference Column Key: A = Appendix F = Figure T = Table 8.1, etc. = Chapter location

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Table 7-2. Checklist for an Air Quality Analysis Section (continued)

Determine Construction-Related Emissions (continued)				
Heavy Duty Equipment	Have the number and type (weight and wheels) of heavy-duty equipment and trucks on unpaved roads that are expected to operate on site been identified and PM10 emissions quantified?	9.3 AP		
Off-Road Mobile Source Emissions (construction equipment)	Have the number and type (i.e., fuel) of construction equipment been identified and tailpipe emissions quantified?	9.1		
On-Road Mobile Source Emissions (including work trips by construction employees, non-work trips to lunch, etc., and truck trips)	Are all construction-related trips (i.e., hauling, deliveries of materials, trips, and non-work trips) quantified?	9.1		
Power Usage	Has total power usage (i.e., electrical generation, natural gas consumption) been estimated?	9.2		
B. Determine Operation-Related Emissions	Have all operation-related emissions been quantified?	5.2		
Stationary Area Sources (incl. water heaters, energy generators)	Have emissions from area sources (pool heaters, water heaters, boilers) been identified and quantified?	9.2		
Stationary Point Sources (incl. those subject to District permits)	Have emissions from point sources (smoke stacks, paint booths, etc.) been identified and quantified?	9.2		

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*The reference column of this table refers to the following portions of this Handbook:

Reference Column Key: A = Appendix F = Figure T = Table 8.3, etc. = Chapter location

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Table 7-2. Checklist for an Air Quality Analysis Section (continued)

		Ref*		
Determine Operation-Related Emissions (continued)				
On-Road Mobile Source Emissions (including work, non-work, truck trips, etc.)	Have the number and length for all trip types (i.e., work, non-work, truck) been identified for each land use?	9.2		
Off-Road Mobile Source Emissions (including ships, trains, etc.)	Will the project generate any emissions from sources such as ships, trains, airplanes, or ancillary operations? If so, have the emissions been quantified?	9.2		
Fugitive Dust (including mining operations, unpaved roads, etc.)	Will the project generate any fugitive dust emissions from mining or unpaved roads? If so, have the emissions been quantified?	9.2		
3. Toxic Emissions and Risk of Upset (Chapter 10 and Appendix 10)				
Sensitive Receptors	Has analysis been prepared to determine the risk of siting a sensitive receptor within 1/4 mile of a toxic source?	5.2		
Effects on Future Land Use	Has an analysis been included describing the implications of siting a sensitive receptor on land near future businesses handling toxic sources or vice versa?	5.2		
Risk of Facilities Emitting Toxics to Population of Jurisdiction	If the project is a toxic source, has the general risk to the population been identified? If risk of upset is an issue, either due to the nature of the toxic or due to proximity to an earthquake fault (Alquist-Priolo zones), has an analysis been included?	10.2 10.4 10.5		
4. Cumulative Air Quality Impacts (Chapter 9)				
Related Projects (under construction, or proposed future projects)	Have emissions from related projects (i.e., recently permitted, similar type, size, or next phase) either under construction or proposed, been identified?	9.5		

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*The reference column of this table refers to the following portions of this Handbook:
Reference Column Key: A = Appendix F = Figure T = Table 8.1, etc. = Chapter location

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Table 7-2. Checklist for an Air Quality Analysis Section (continued)

Comments	Item	Ref.*	Page of EIR No.
Cumulative Air Quality Impacts (Chapter 9) (continued)			
Analysis Consistent with CEQA Section 15130	Has the following information been provided? • A list of all past, present and reasonably anticipated future projects; • A summary of expected environmental effects; • A reasonable analysis of relevant projects including mitigation.	9.5	
Optional Cumulative Impact Analysis	Does the documentation provide: • An analysis comparing the project with mitigation to determine if emissions will be reduced by 1% per year or 18% to the year 2010? • An analysis comparing the project with mitigation to determine if it will achieve a 1.5 AVR (or AVO for transportation projects)? • An analysis comparing the project with mitigation to determine if it will reduce the rate of growth in VMT and trips?	9.5	
5. Project Alternatives (Chapter 9)			
Quantify Air Quality Impacts of Alternatives	Have the air quality impacts of the alternatives been determined utilizing the Handbook's emission calculation procedures?	9.6	
Select Alternatives to Reduce Air Quality Impacts When Such is a Key Issue	If air quality is a key environmental issue, have alternatives been selected that reduce air quality impacts?	9.6	
6. Analyzing Other Indicators of Potential Air Quality Impacts			
Compare Project to Secondary Effects	Has the project been compared to the secondary effects to determine whether the project will need further analysis?	6.2	

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*The reference column of this table refers to the following portions of this Handbook:
Reference Column Key: A = Appendix F = Figure T = Table 8.1, etc. = Chapter location

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Table 7-2. Checklist for an Air Quality Analysis Section (continued)

7. Determining Significance (Chapter 6)				
Compare Total Project Emissions to Significance Thresholds	Have the total project emissions been compared to the significance thresholds to determine whether the project will have a significant impact on air quality?	6.2		
Compare Changes from the Project Baseline Air Quality Information	Does the project have the potential to cause a CO hot spot? Will the project impact sensitive receptors? Will the project result in a measurable change in number or severity of ambient air quality standards?	9.4		
Analysis of Other Appropriate Impacts (i.e., odor, etc.)	Will the project generate odors? Will the project impact the level of service on the CMP system?	5.4 4.6		
8. Mitigation Measures (Chapter 11 and Appendix 11)				
Identify Mitigation Measures to Reduce Impact from Construction and Operation	Have all applicable mitigation measures been identified to reduce air quality impacts resulting from construction and operation of the project?	11.3 11.4		
Quantify Reductions from Application of Mitigation Measures	Have the emission reduction benefits from the application of the mitigation measures been quantified?	11.8		
Determine Level of Impact after Mitigation	Will the project still result in a significant impact after mitigation?	T11-5		

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*The reference column of this table refers to the following portions of this Handbook:

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Table 7-2. Checklist for an Air Quality Analysis Section (continued)

9. Consistency with Regional Plans (Chapter 12)				
Determine the Project's Consistency with AQMP and/or PM10 Plan	Is the project consistent with AQMP and/or Coachella Valley PM10 Plan?	12.2		
Determine the Project's Consistency with GMP	If the project will result in increased jobs, housing, or population, are these increases consistent with the targets in the GMP?	12.2		
Determine the Project's Consistency with RMP	If the project is a transportation project, is it consistent (use location and lane miles) with the RMP?	12.2		
Determine the Project's Consistency with CMP	If the project will generate trips that affect the CMP system, has a Traffic Impact Assessment been completed and mitigation described?	12.2 4.6		
Determine the Project's Consistency with Air Quality Element of a General Plan	If the local government has an Air Quality Element, is the project consistent with its goals and objectives?	12.2		
10. Requirements with the District as a Responsible Agency (Chapter 13)				
Determine If the District Is a Responsible Agency	Is this project subject to District permitting requirements?	13		

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*The reference column of this table refers to the following portions of this Handbook:
Reference Column Key: A = Appendix F = Figure T = Table 8.1, etc. = Chapter location

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Table 7-2. Checklist for an Air Quality Analysis Section (continued)

Requirements with the District as a Responsible Agency (Chapter 13) (continued)				
Determining Significance	Does an assessment indicate if the project exceeds significance standards for District permits?	13.1		
Assessing Cross-Media Impacts	If it is a significant project, is an assessment of the cross-media impacts included?	13.2 A13		
11. Mitigation Monitoring Plan (Chapter 15)				
Develop a Mitigation Monitoring Program	Has the mitigation monitoring program for air quality measures that responds to each of the components been identified?	15.1		
Initiate Monitoring and Reporting	Have the entities responsible for implementation of the mitigation measures and monitoring been notified?	15.2		

*The reference column of this table refers to the following portions of this Handbook:

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DEVELOPING EIR BASELINE INFORMATION

CHAPTER 8

When an environmental document is required, the preparer should begin to develop the baseline, or background information necessary for the environmental setting and the air quality assessment. Baseline information for the environmental setting should identify and describe the following:

- Project description
- Project setting
- Regional and local climate and meteorological conditions
- Existing air quality at the site-specific location of the project, including anticipated toxic emissions
- Sensitive receptors
- Identification of the appropriate air basin and air quality management plan (AQMP or PM10 Plan)
- Regional and local transportation system supporting the project

8.1 Background Air Quality Information

Prior to determining the air quality impacts of a proposed project, it is necessary to prepare a detailed description of the existing regional climate and site-specific air quality conditions. This will establish a basis for comparing the project's subsequent air quality impacts with the existing air quality setting.

Project Description. To the extent that the information is available, the description of the project should be specific as to total project area, square footage, and use of buildings and structures. The amount of development projected for each phase, approximate completion date for each phase, and build-out should also be defined. In addition, the project description should include a listing and expected emission reductions from District-required permits, as well as any existing local government ordinances that will result in quantifiable emission reductions.

Project Setting. The EIR should contain a description of the local setting surrounding the project, including identification of any unique geographic elements. The project setting description should identify any elements that may cause or generate air pollutant emissions (such as working construction equipment or the number of acres disturbed). The transportation system which will support the project and existing levels of service (LOS) should also be identified in the EIR. Figure 8-1 explains the LOS categories for freeways. In addition, any earthquake faults (i.e., Alquist/Priola zones) that could result in a threatened release of air toxics should be identified.

Regional Climate. Detailed descriptions of the regional climate are contained in Appendix 8. To streamline the environmental document, a summary of the information contained in Appendix 8 may be used to satisfy the regional climate description. The EIR may also incorporate Appendix 8 in full by reference. A wind rose, illustrated in Figure 8-2, should be provided if toxic emissions or odors are issues. The District maintains a historical archive of wind roses. This information is available upon written request to the District's Meteorological Section at the District's Diamond Bar Headquarters. Identify in the correspondence that this information is for an environmental analysis and it will be given priority.

Existing Air Quality. To characterize the site-specific air quality setting, the environmental document should contain a summary of the most current air quality data. The data must be derived from the nearest District monitoring station located in the same source/receptor area(s) (SRA) as the project (see map in Figure 8-3). Some stations do not monitor all pollutants. In that instance, information on the remaining pollutants should be drawn from the nearest upwind station which monitors the pollutants. Air quality data are prepared for each District air monitoring station in table format (see

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Appendix 3). These tables are updated annually, generally in March of each year. Monitoring station data should be used to provide background concentration levels of criteria pollutants and the number of days in which the criteria pollutants exceeded state and federal standards. For trend information, refer to Appendix II-B of the 1991 AQMP dated July 1991.

For projects located in more than one SRA, use the SRA most representative of the on-site conditions; or for transportation projects, analyze the project links in each SRA. In some unique cases, the air quality monitoring station within the SRA may not be representative of project site characteristics. Project proponents may contact the District for a recommendation which monitoring stations would be most characteristic of the project site.

As an alternative, a project proponent may perform on-site monitoring based on approved methodologies and monitoring procedures. Contact the District's Air Quality Monitoring Section for assistance in developing an adequate background concentration.

Information on existing air quality is also needed to perform air quality modeling analyses required for environmental documents or for District permit applications. If the project is expected to generate toxic air contaminants, the lead agency should contact the District to obtain information on the specific toxic air contaminant of concern for use in future land use decision-making.

Sensitive Receptors. Special attention should be given to the effect of CO, toxic, and odor emissions on sensitive receptors including:

- Residences
- Schools (children)
- Playgrounds
- Child care centers
- Convalescent homes (senior citizens)
- Retirement homes
- Rehabilitation centers
- Athletic facilities (athletes)

When evaluating air quality impacts on sensitive receptors, planners should use the background data described in this chapter to:

(1) Map the source of elevated CO, toxic, or odor emissions in relation to existing sensitive receptor areas.

(2) Identify wind patterns, direction, and speed using nearby wind rose information.

Air Quality Management Plan. The federal and state Clean Air Acts require that non-attainment basins that do not meet federal or state clean air standards must prepare a plan for bringing the area into compliance. The 1991 AQMP is the appropriate plan for that portion of the SEDAB under District jurisdiction. Refer to Figure 2-1 in Chapter 2 to determine in which air basin the project is located.

Transportation System. The regional and local transportation system that will serve the project should be identified. In particular, the EIR should identify existing and proposed transportation infrastructure (i.e., freeways, major arteries, rail and bus transit, etc.), that could in any way be used by vehicle traffic generated by or attracted to the project. SCAG's Regional Mobility Plan should be consulted to determine location and mode of future transportation systems. Any significant roadways that serve the project should be identified, along with their levels of service (LOS). The general information on determining LOS for freeways is provided in Figure 8-1. The county transportation commission, Caltrans, and local governments should also be consulted when determining LOS for freeways and

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other roadways. The Congestion Management Plan (CMP) identifies LOS for roads on the regional network. Local public works or traffic engineering offices should have information available on the LOS for local streets. See screening Tables 5-2 and 5-4 to determine if the state one-hour CO standard may be exceeded locally. In addition, some CMPs include methods for determining LOS. The CMP of each county should be consulted to determine which roadways are part of the CMP transportation system.

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Figure 8-1. LOS Categories for Freeways

A	Highest quality of service. Free traffic flow, low volumes and densities. Little or no restriction on maneuverability or speed.	55+	None	Good
B	Stable traffic flow, speed becoming slightly restricted. Low restrictions on maneuverability.	50	None	Good
C	Stable traffic flow, but less freedom to select speed, change lanes, or pass. Density increasing.	45	Minimal	Adequate
D	Approaching unstable flow. Speeds tolerable but subject to sudden and considerable variation. Less maneuverability and driver comfort.	40	Minimal	Adequate
E	Unstable traffic flow with rapidly fluctuating speeds and flow rates. Short headways, low maneuverability and low driver comfort.	35	Significant	Poor
F	Forced traffic flow. Speed and flow may drop to zero with high densities.	<25	Considerable	Poor

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Figure 8-2. Wind Rose

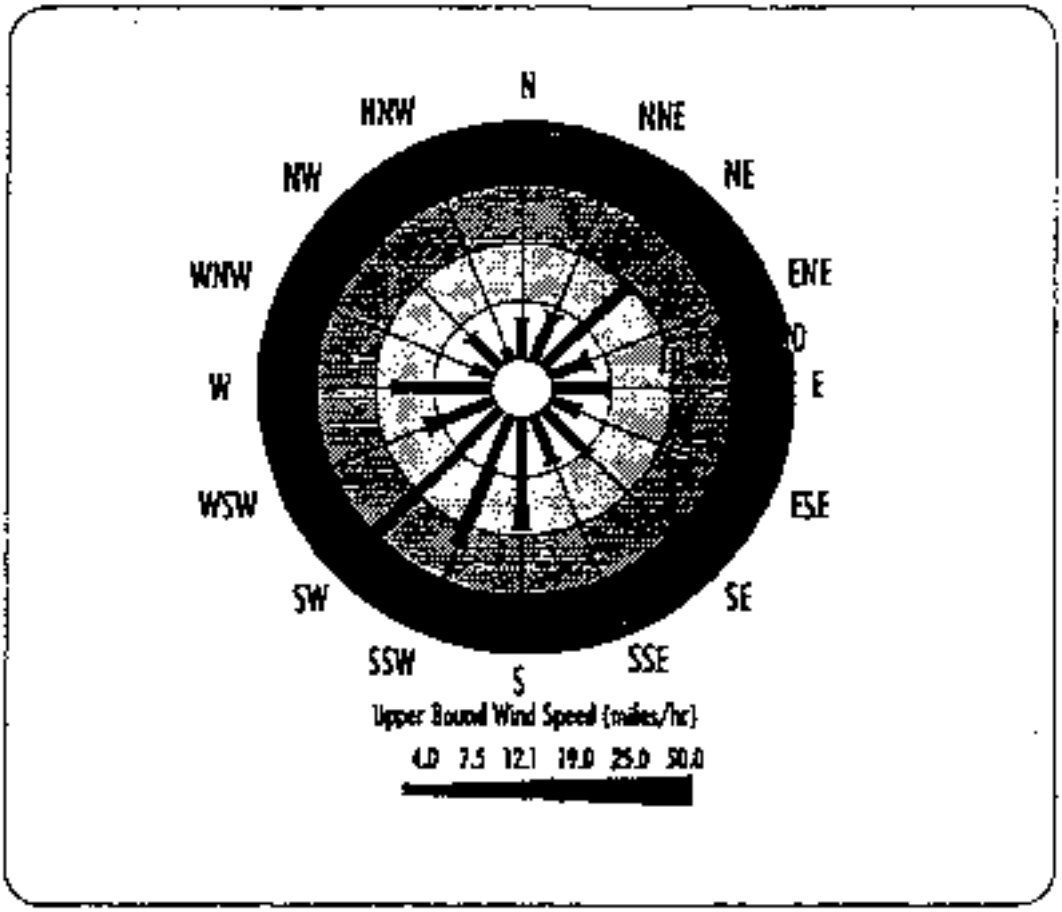

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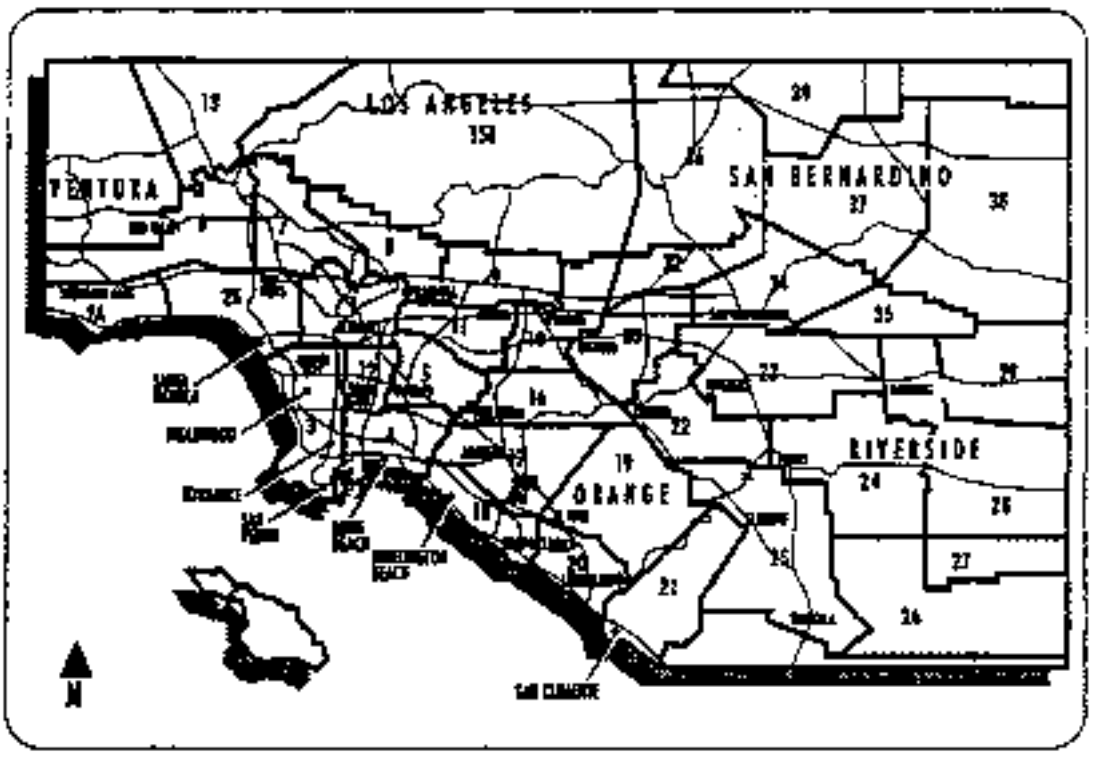
Figure 8-3. Source Receptor Areas



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CHAPTER 9

This chapter outlines District-recommended procedures for calculating emissions that may be generated during project construction and operation. Drafting an EIR or preparing a Negative Declaration necessarily involves some degree of forecasting. While foreseeing the unforeseeable is not possible, an agency must use its best efforts to find out and disclose all that it reasonably can (CEQA Guidelines Section 15144). The District recognizes that in all cases the information necessary for estimating emissions may not be available. However, in preparing the emission calculations, the lead agency should take a best-effort approach. If quantification is not possible, then a qualitative evaluation of project emissions may be acceptable to identify probable or likely emissions from construction and operational sources.

The air quality impact of the project is determined by estimating the total emissions from the construction and operation of the project. Emissions estimates are also necessary for assessing cumulative impacts and for evaluating the air quality impact of the project alternatives.

This chapter identifies the data needed to calculate the emissions estimates, describes the various methods of calculating estimates, and advises on the calculation method appropriate for each type of environmental document. If other methodologies and/or data are used, the source should be documented so that all parties can reasonably evaluate and determine the adequacy of the procedures and data used in assessing air quality impacts.

9.1 Construction Emissions

Emissions are a cause for concern beginning with the very first phase of project development. The first phase may include site preparation, construction of new facilities, modification of an existing facility or site, as well as demolition, renovation, and asbestos removal. These construction activities are responsible for the emissions of ROC and NOx produced by vehicular traffic, asbestos emissions associated with demolition work, and PM10 in the form of fugitive dust raised by earth-moving equipment.

Emissions from construction, renovation, and demolition may be estimated by one of two methods: (1) screening tables, or (2) using the methodology and emission factors shown in Appendix 9. The screening table is appropriate for estimating emissions for a Negative Declaration (ND) and Mitigated Negative Declaration (MND), but should not be used for preparing an EIR. The emissions estimates in screening Tables 9-1 (total construction emissions) and 9-2 (PM10) are based on regional averages. To further break down construction emission sources, Tables 9-3 and 9-4 call out emission factors for construction workers' travel and materials handling, which are a subset of total construction emissions. This information will be useful when quantifying the effectiveness of mitigation measures, as discussed in Chapter 11. To estimate emissions with these tables:

(1) Estimate daily emissions for each source category (i.e., on-road, off-road, and PM10) separately. (Mitigation efficiencies are subtracted from the applicable source categories.)

(2) For each source category, determine the total area for each activity (in units specified in the screening tables).

(3) Multiply those totals by the emissions estimates provided in the screening tables.

(4) Add the emissions from each category to determine total construction impacts.

Other sources of emissions should be identified as appropriate for the project using the information in Appendix 9 and added to the final total of unmitigated project emissions. An example of how to account for emissions by pollutant and source category is provided in Table 9-5.

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Figure 9-1 illustrates the process used to identify a project's unmitigated emissions using the screening tables. As is shown in the shaded portion of the figure, once a project's unmitigated emissions have been calculated, quantified mitigation measures can be applied to reduce the potential air quality impact. This process is described in Chapter 11. Step-by-step instructions for using the screening tables to determine unmitigated emissions are described in Table 9-6. These instructions correspond with the unshaded portion of Figure 9-1.

Emissions estimates for an EIR should be made following the methods and emission factors provided in Appendix 9 of this Handbook. All sources of emissions should be identified (*refer* to Figure 9-2) and reasonably foreseeable significant environmental consequences considered for all emissions forecasting. Emissions estimates should be developed for each phase of development where construction, renovation, and/or demolition will occur. The emissions estimates can be averaged over a 3-month period (for actual working days) when determining tons per quarter. Those estimates should then be reported for each applicable pollutant in pounds per quarter for each year of construction. Where construction is scheduled to occur over several years, emissions estimates should be provided for the base year (initial year of construction), each development phase, and build-out. Any emission reductions resulting from existing rules or ordinances should be calculated as part of the project's non-mitigated emissions and included as part of the project description.

Sources of construction-related emissions, data needs, and emissions factors are discussed below. The emission calculation methodology, emission factors, and assumptions are provided in Appendix 9. The Appendix also provides worksheets for estimating emissions and emissions summary sheets.

In order to estimate emissions, specific information about construction activity is needed. When specific information is not available such as in long range planning documents, reasonable estimates based on past experience may be used. All of the basic assumptions for some of the other factors have also been formulated for this purpose and are provided in Appendix 9. All of the basic assumptions used to estimate construction emissions should be documented in the EIR. Prior to the issuance of a building permit or grading permit, the assumptions used in the EIR should be compared to the construction plan. If the comparison shows that emissions will be greater, additional environmental analysis may be necessary.

Emissions From Construction Equipment. Fugitive dust is generated not only by moving the earth, but by the heavy equipment that does the moving. The exhaust fumes of this equipment are a direct source of PM10, NOx, and ROC. To estimate emissions from heavy-duty construction equipment, the following should be considered:

- Emission factors for each piece of equipment
- Types and number of pieces of each kind of equipment
- Volume of material to be moved
- Number of hours of operation per average day
- Number of days of operation in a 3-month period
- Duration of each activity for each phase of the project

This information can be calculated using the tables provided in Appendix 9.

PM10 and Asbestos. When fugitive dust enters the atmosphere, the larger particles of dust quickly fall to the ground. The smaller particles, however, may remain suspended for long periods and are referred to as total suspended particulates (TSP). Within TSP are those dust particles that are less than ten microns in diameter and which are referred to as PM10. Because PM10 is respirable and can seriously damage the lungs, fugitive dust is a matter of concern. Therefore, sources of fugitive dust which can generate PM10 need to be quantified by identifying the amount of soil that will be disturbed by the following activities:

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- Grading
- Excavation
- Demolition
- Heavy-duty equipment on unpaved roads
- Loading and unloading trucks of sand, dirt, etc.

The EPA has developed various emission factors which are provided in Appendix 9 for estimating PM10 emissions. When using these factors to estimate emissions, the following data are needed:

- **Grading and Excavation**
  - Amount of soil to be disturbed
  - Emissions factors for disturbed soil (26.4 pounds of PM10 per day per acre)
  - Duration of grading or excavation
  - Number of days of grading in a 3-month period
- **Demolition**
  - Cubic feet of buildings
  - Emission factors for demolition (.00042 per cubic foot)
  - Duration of demolition in a 3-month period
- **Heavy-Duty Equipment on Unpaved Roads**
  - Length of the road
  - Type of soil
  - Type and number of pieces of equipment
  - Average weight and number of wheels on the trucks
  - Duration of activity in a 3-month period
- **Loading/Unloading Trucks**
  - Volume of material
  - Approximate number of truck loads during a 3-month period
  - Type of material
  - Vehicle speed

In addition, any demolition or renovation work involving asbestos-containing material must be identified. An estimate of potential asbestos emissions should be determined using the procedures in Appendix 9. District Rule 1403 (Asbestos Emissions From Demolition/Renovation Activities) should be identified as a required permit in the EIR. (Compliance with Rule 1403 is considered to mitigate the emissions to a level of insignificance).

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Energy Use. Temporary power is often utilized at the construction site to operate equipment. Power usage from temporary generators, natural gas hookups, existing power sources, and other sources should all be identified for the EIR. Such calculations should be based on the following factors:

- Type of power source
- Fuel used if power is provided by a generator
- Duration of power usage
- Estimated power demand over a 3-month period

Architectural Coatings. Architectural coatings applied to a building either during or just after construction are a source of emissions that need to be quantified. In some cases specific information on architectural coatings may not be available, and a good faith effort based on generalized factors would be appropriate. Examples of architectural coatings include painting the exterior walls, or coatings applied to windows and window casings at the construction site. To estimate these emissions, the following should be considered:

- Total area to be covered by the architectural coating
- Estimated amount of material (architectural coating) needed to cover the area
- ROC (reactive organic compounds) emitted by the coating material

Vehicle Trips. Construction and development activities also contribute to mobile emissions generated by commute trips to and from the site, non-work trips associated with lunch or other errands, and trucks hauling soil or construction materials. To quantify these emissions, the following should be considered:

- Number of employee-related work trips and non-work trips and average vehicle miles traveled (VMT), for each type of trip
- Estimated total vehicle emissions based on number of trips, average speed (lowest speeds should be used for assessing CO and higher speeds for NOx and ROC), and VMT (use worksheets in Appendix 9)
- Number of construction trucks in fleet, number of trips, and VMT averaged over a 3-month period
- Estimated total vehicle emissions based on number of trips, average speed (lowest speeds should be used for assessing CO and higher speeds for NOx and ROC), and VMT (use worksheets in Appendix 9)
- Estimated total mobile heavy-duty (gasoline- or diesel-powered) truck emissions based on number of trips, average speed, and VMT (use worksheet, Appendix 9)
- Calculated emissions from the above sources using the most recent ARB emission factors.

In some cases, construction vehicle trips are difficult to accurately quantify at the time environmental documents are prepared. In all cases, a good faith effort should be made to quantify emissions from these sources to the degree practicable.

Traffic Impacts. Other construction impacts include potential construction-related traffic impacts. Such impacts are caused by congestion and the resulting reduction in level of service (LOS) on nearby streets due to such construction activities as lane closures and parking for construction personnel and/or equipment. These impacts should be identified in the Initial Study. The subsequent environmental document should estimate the impacts by considering the following:

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- Existing local street level of service (LOS) based on existing volume
- Implications of lane closures and detours on local street LOS
- Average length of delays at strategic points on local streets within the construction areas
- Determination of level of pollutant concentrations within construction areas

9.2 Operational Emissions

During the life of the project, a variety of emissions are produced by its day-to-day operations. On-site equipment may emit reactive organic compounds (ROC) and nitrogen oxides (NOx). In addition, vehicle trips to and from the project produce ROC, CO and NOx.

There are three methods available for estimating emissions from the operation of a facility:

- Screening data through Tables 9-7 and 9-8
- Employing the Mobile Assessment for Air Quality Impacts (MAAQI) model for mobile emissions
- Using the methodology and emission factors given in Appendix 9

Tables 9-4 and 9-5 are adequate for estimating emissions when preparing a ND or a MND, but it should not be depended upon for estimates for an EIR. The emissions estimates shown in screening Tables 9-4 and 9-5 are based on regional averages, and focus on emissions from vehicle trips and energy consumption. To estimate emissions with these screening tables:

1) Estimate emissions for each source category (i.e., on-road and area) separately. (Mitigation efficiencies are subtracted from the applicable source categories);
2) Determine total square footage (or other appropriate unit and land use);
3) Multiply those totals by the emissions estimates provided in the tables;
4) Add the emissions from each category to determine total operation impacts;

The District has developed a version of the Urban Air Shed model specific to the South Coast Air Basin (SCAB) called MAAQI. The MAAQI model will estimate emissions associated with vehicle trips, and energy use for residential areas. Planners can estimate emissions with relatively little site-specific information by using the county-wide defaults in the MAAQI model or by entering site-specific information if available.

The MAAQI Model can be used to estimate emissions for the ND or MND; however, site-specific information should be developed to the fullest extent possible for the EIR. Also, emissions from other sources need to be identified in the EIR. (Appendix 9 provides calculation procedures for estimating emissions from these other sources.) The MAAQI model can only be used as a substitute for analyzing the motor vehicle emissions.

If through the Initial Study it is determined that a significant amount of emissions will come from stationary sources, emissions estimates should be developed using the references provided in Appendix 9. These should be added to the total emissions from the project.

Emissions estimates for the EIR should follow the methodology and emissions factors provided in this Handbook. All sources of emissions should be identified (refer to Figure 9-3), with reasonably foreseeable significant environmental consequences addressed. Emissions estimates should be developed for each phase of development and reported in pounds per day for each applicable pollutant. The daily emissions estimate should be based on the highest day (including weekdays and weekends).

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This is because travel characteristics are different for weekdays and weekends. In addition, emissions estimates should be provided for the base year (initial year of operation), each development phase, and build-out, based on information available in the traffic impact study. Any emissions reductions resulting from existing ordinances and rules should be calculated as part of the project's non-mitigated emissions.

Sources of operation-related emissions, data needs, and emission factors are discussed below. The emission calculation methodology, emission factors, and assumptions are provided in Appendix 9. The Appendix also provides emissions summary sheets. In order to estimate emissions, specific information about the operation of the facility is needed. When specific information is not available, reasonable estimates based on past experience may be used. Assumptions for some of the factors have also been formulated for this purpose and are provided in the Appendix. All of the basic assumptions used to estimate operation emissions should be documented in the EIR.

Stationary Sources. There are two types of stationary sources: point and area. Point sources refer to a site that has one or more emission sources at a facility with an identified location (e.g., power plants, refinery boilers). Area sources comprise many small emissions sources for which locations are not specifically identified, but for which emissions over a given area may be calculated using socioeconomic data (e.g., water heaters, painting and coatings, and fuel use and consumption).

Emissions from new, modified, or relocated stationary source equipment are regulated extensively through the following:

- o District's Regulation XIII: New Source Review Program
- o District's Permitting Program
- o Compliance with the District's source-specific regulations

Stationary source emissions can be calculated by determining the following:

- o Types and number of pieces of equipment
- o Rate and quantity of fuel consumption
- o Number of hours of operation per day
- o Phases and duration of operation
- o Estimated emissions assuming implementation of SCAQMD-adopted Rules and Regulations (which should be identified in the environmental documentation)

If the number and types of equipment, or other necessary data, are not available when the environmental document is prepared, stationary source emissions may be estimated by using other indicators, such as emission rates per square foot of development. Refer to Appendix 9 for calculation tables. In addition, ARB source classification codes and EPA emission factors should be consulted.

Energy Use. The generation of electric energy and use of natural gas by facilities to power lights, appliances, equipment, etc. should be calculated. Usage factors for natural gas and electric generation are included in Appendix 9, and should be based on the highest daily usage.

Vehicle Trips. Motor vehicles are the primary source of emissions associated with residential, commercial, professional, institutional, and some industrial land uses. Typically, these land uses do not directly emit significant amounts of air pollutants from on-site activities. Motor vehicle trips to and from these facilities do however, emit pollutants adversely affecting air quality.

Development projects and public infrastructure projects are classified as "indirect sources" of vehicle emissions because of trips made to and from them. Quantifying and mitigating emissions from indirect sources poses difficult theoretical and methodological issues.

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When quantifying the emissions from indirect sources the issue of assignment and generation of vehicle trips should be considered. When assigning trips to a development there may be some circumstances where a proposed project might divert trips, decrease vehicle trips and/or vehicle miles, or not result in an increase to the extent assumed when using standardized trip generation figures.

For example, the issue of diverted trips arises when a city rejects a proposal to develop a new grocery store. The trips to and from the grocery store do not simply disappear from the region. Customers are likely to travel to another grocery store. Depending on the location of the grocery store's distance from the customer or possible location on a more congested road, VMT and emissions could increase or decrease. Schools are another example of a situation where the construction of a neighborhood school designed to accommodate existing student demand could reduce the number of vehicle miles that students generate by commuting to school outside the neighborhood.

Developers, occupants, and local governments have different abilities to reduce indirect source emissions. Each of these parties can influence trip making, but not fully control trip making through their own actions. The District recommends that project proponents and approving jurisdictions adopt mitigation measures to discourage mobile source emissions which, in the circumstances of the specific project as identified in the CEQA process, are feasible and effective.

Finally, land uses naturally evolve and shift with economic and demographic trends in ways that are difficult to predict and model. These dynamics can completely change commute patterns and related emissions. For example, in the last twenty years, Orange County evolved from a residential county to one with a substantial employment base. Employment centers that once had primarily industrial or manufacturing firms now have mainly commercial and service firms, which have different residential needs and trip-making patterns.

The major technical issue is the difficulty in correlating indirect source emissions from an individual development or infrastructure project with the projections of regional emissions used to develop the AQMP. The Building Industry believes that development and infrastructure projects typically accommodate economic and demographic trends assumed in the AQMP, although they acknowledge that the projects also add to the cumulative impact that greater economic activity has by "inducing" additional trip-making and higher emissions. District staff believes that projects may stimulate as well as respond to growth.

This Handbook recommends the use of the 5th edition of the ITE Trip Generation Manual. The ITE Manual recognizes that the issues of multi-use developments and quantifying capture rates for developments are limited by the specificity of the information provided. Additionally, the ITE Manual discusses primary trips, pass-by trips and diverted linked trips and provides guidance, in the form of technical methodologies, on estimating percentages of each type of trip by land use type. The methodologies contained in the ITE Manual are based on actual data. Just as the CEQA Handbook provides default values for emissions calculations based on county averages, the ITE Manual provides traffic averages based on actual data. Additionally, both the CEQA Handbook and the ITE Manual recommend the utilization of the best available data to calculate impacts. Therefore, if project specific data is available it should be used to adjust the factors for calculating both the traffic reports as recommended by the ITE Manual, and the project emissions. The District is committed to working cooperatively with other public agencies and private groups to improve both the theory and methodologies for quantifying indirect source emissions.

Mobile source emissions include vehicle emissions from work trips, non-work trips, and truck trips to and from the project site. Therefore, when estimating indirect source emissions the following should be considered:

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- Types of land uses (i.e., commercial, industrial, residential, and/or institutional)
- Size of land use project (i.e., square footage, number of units, and capacity)
- Modes of transportation and fleet mix of trips associated with each land use category
- Number of employees per land use category
- Average number of daily trips associated with each type of trip (work, non-work, truck trips)
- Vehicle speed (linked to roadway volume) and ambient temperature
- Average vehicle miles traveled for each trip type

Calculation of project-related trips should be based on the Trip Generation Manual (Fifth edition, 1991) published by the Institute of Transportation Engineers (ITE). Trip generation should be based on the highest day (either weekday or weekend) trips for each land use category. Trip generation data from other sources (i.e., traffic impact analysis) may be used if determined to be more appropriate for a given project. In performing a traffic impact analysis, the procedures specified in the county CMP within which the project is located should be followed. It is presumed that all trips attributed to project development are new trips unless it can be reasonably demonstrated that such trips are derived from elsewhere. There may be some circumstances where a proposed project might decrease vehicle trips and/or vehicle miles, or not result in an increase to the extent assumed when using standardized trip generation figures. Schools are one example of a situation where the addition of an on-site dormitory design to accommodate existing student capacity could reduce the number of vehicle miles that students would generate by commuting to school. Any such analysis in an environmental document should not be based on speculative information. Substantive data based on information from sources such as site-specific and market studies needs to be available to agencies reviewing the environmental documentation to substantiate that trips attributed to the project are either not new trips or that the number or length of trips are less than that expected when using standardized trip information. The air quality analysis should utilize ARB emission factors. Contact the District regarding the current version of the EMFAC program.

In addition, to identify mobile source emissions from trip generation, the impact of additional trips to and from the project site on the transportation system must be assessed. In order to do this, the trips on the transportation network and the impact on level of service must be identified. In particular, the analysis should calculate change in vehicle speed and resulting emissions. Hot spots at intersections should also be assessed and the ARB CALINE4 model or EPA CAL3QHC model should be employed.

PM10. Although fugitive dust is associated primarily with initial construction activity, many operational aspects of a facility can contribute to PM10 emissions. These include vehicles traveling on unpaved roads, tire wear based on vehicle miles traveled, as well as land use specific impacts from mining operations, outdoor storage of building materials such as sand and dirt, and landfills. In order to estimate emissions, the following factors will need to be determined:

- Amount of material or soil
- Type of material or soil
- Emission factors for materials or disturbed soil
- Duration of disturbance of material or soil averaged over 3 months
- Length of road (for unpaved roads)
- Average vehicle weight and number of wheels per vehicle (unpaved road)

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9.3 Assessing Other Indicators of Potential Air Quality Impacts (Secondary Impacts)

In addition to primary emission thresholds of significance, Chapter 6 also identifies other indicators of potential air quality impacts. The analysis of a project's impact should include an evaluation of these indicators as appropriate for the project. For example, only projects that involve sensitive receptors need to evaluate surrounding land uses within a quarter mile to determine if there are any sources of toxic emissions.

The type of analysis to perform for each indicator is discussed in the Handbook as follows:

Chapter 5: Potential to create or be subjected to an objectionable odor over 10 dilution to threshold that could impact sensitive receptors;

Chapter 5, 9: Generation of vehicle trips causing a roadway to be reclassified and create a CO hot spot;

Chapter 5, 10: Emitting air toxic contaminants that are regulated by District rules or on a federal or state air toxic list;

Chapter 5, 10: Sensitive receptors within a quarter mile of an existing facility that emits air toxics identified in District Rule 1401;

Chapter 10: Emitting carcinogenic or toxic air contaminants that individually or cumulatively exceed the maximum individual cancer risk of 10 in 1 million;

Chapter 10, 13: Burning of hazardous, medical, or municipal waste in waste to energy facilities;

Chapter 12: Interference with the attainment of the federal or state ambient air quality standards by violating or contributing to an existing or projected air quality violation;.

Chapter 12: Population increases in excess of that projected in the AQMP and in other than planned locations for the project's build-out year.

9.4 Guidance for Assessing Carbon Monoxide Emissions

Carbon monoxide (CO) is a localized problem requiring additional analysis when a project is likely to impact a roadway's level of service (LOS), subject sensitive receptors to CO hot spots, or the project itself is the development of transportation infrastructure. For CEQA purposes, a CO analysis should be performed when air quality has been identified as having a significant impact.

Whenever a land use project could have a significant impact on air quality as a result of vehicle trips, even after mitigation is included, a CO analysis should be performed. Transportation projects that should be analyzed for localized CO problems include: park-and-ride lots, high-occupancy vehicle (HOV) lanes, mixed-flow lanes, designation of new transportation corridor, transportation plan or program, rail and bus transit projects, etc. The methodologies contained in SCAG's Carbon Monoxide Transportation Project Protocol, Technical Addendum Sections 1 through 14 (see Appendix 9) would be appropriate for use in a CEQA CO analysis. CEQA, however, requires additional information beyond the discussion contained in the CO Protocol. The methodology discussed below is intended to assist in preparing a complete and adequate CEQA analysis for air quality. To assist planners in preparing a CO analysis and adequately evaluating the potential impacts, the following guidelines were developed.

Methodology. To assess CO emissions and evaluate the impacts, the following steps should be employed:

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1. Determine "No Project" ambient concentration of CO emissions. Utilize Tables 5-2 and 5-3 for future year ambient concentrations, or use Table 9-9 to adjust on-site monitoring data to reflect future year emissions.

2. Estimate the CO emissions from the project by modeling.

3. Add the "No Project" ambient concentration level of CO emissions to those generated by the project (i.e., total project impact).

4. Compare the total project impact to the state 1-hour and 8-hour CO standards.

5. If modeling indicates a CO hot spot could occur, determine the area impacted and determine if sensitive receptors are located in that area. Identify and determine the level of CO emissions at sensitive receptors. (Refer to Section 5.3(5) for methodology.)

6. Compare the levels of CO emissions at sensitive receptors to the state 1-hour and 8-hour CO standards.

7. Determine project significance.

The analysis should be performed for the following years: each development phase and project build-out.

If the project causes the state 1-hour and 8-hour CO standards to be exceeded, then a "CO hot spot" is created. As such, it is considered that the project is likely to cause or contribute to a CO exceedance of a state air quality standard. There may be cases where the background concentration already exceeds the state 1-hour and 8-hour CO standards. In these cases, the analysis should determine whether there will be a measurable increase at the project site. A measurable increase is defined as one part per million (ppm) for the 1-hour CO standard and 0.45 ppm for the 8-hour standard (consistent with District Regulation XIII definition of a significant impact). A measurable increase is considered likely to increase the frequency or severity of an existing CO violation.

There are a number of dispersion models that are available to estimate potential CO hot spots. Two such models, CAL3QHC and CALINE4, have been developed to estimate potential CO hot spots. The models are based on continuous line source emissions and therefore, can estimate roadway impacts. The CAL3QHC model has been enhanced to analyze idling and queuing from congestion and impacts on sensitive receptors. CALINE4 is the model used by ARB and CalTrans. The District recommends CALINE4. Both models are described in Section 9.7 of this Chapter.

Establishing the "No Project" Ambient Concentration. Two options are available for establishing CO 1-hour ambient background concentrations. Table 5-2 provides projected future year 1-hour CO concentrations based on adopted rules or regulations. These projections may be utilized as the future year ambient concentrations. These numbers will be revised as better modeling techniques are developed and as necessary due to the results of the District's ongoing monitoring.

Planners or the project proponent may wish to utilize the second option and perform more site specific monitoring to determine the CO "No Project" ambient concentrations. On-site monitoring requires a minimum of 4 months of continuous sampling during the winter CO season, November through February. Sampling and receptor siting for this option should be in accordance with 40 CFR 58 microscale criteria and achieve a minimum of 90% data completeness. The monitored data may be adjusted for future years utilizing the factors in Table 9-8. These adjustment factors are also based on implemented rules and regulations.

The 8-hour CO concentration levels may be established in two ways. Table 5-3 provides projected future year 8-hour ambient CO concentrations, adjusted to take into account adopted rules and regulations. For the second option the 8-hour CO concentrations are calculated from the 1-hour levels directly by a factor termed the Persistence Factor. This factor is the ratio over the most recent three years between the highest annual maximum 1-hour and 8-hour CO concentrations as measured at the

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nearest representative permanent monitoring station. If no nearby monitoring station data is available, the following factors are suggested:

Factor	Setting
0.6	Attainment
0.7	Non-attainment
0.8	Urban areas with persistent stagnation and/or congestion

If a project is located in more than one source receptor area, the background concentration from the air monitoring station which is most representative of the conditions at the project site should be used, or each source receptor area should be modeled separately. It is necessary to evaluate CO impacts based on the highest concentrations, or actual concentrations if they can be determined, because the state law mandates that violation of the CO standards at any location during the year results in the area being classified as non-attainment for that pollutant.

Relocation of CO Hot Spots. Occasionally, project development will cause emission patterns to shift or move, possibly resulting in the reduction or elimination of a hot spot at one location, and the initiation of a new hot spot at another location. For example, if an extra lane for traffic flow is added to a roadway link which has a hot spot, the hot spot may shift to the portion of the roadway link where the extra lane ends. The hot spot is then caused by congestion from vehicles merging into a fewer number of lanes. It is acceptable in some instances to move a hot spot without it being considered as creating a new hot spot when the following criteria are met:

- The relocated hot spot will not be within a quarter mile of sensitive receptors or it is demonstrated that a hot spot will not be created that will impact sensitive receptors;
- The CO emissions will be equal to or less than the emissions at the original hot spot within the project impact area; and
- The relocated hot spot will not result in a new CO violation.

9.5 Cumulative Impact Evaluation

CEQA defines cumulative impact as follows:

- Two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts (refer to CEQA Guidelines Section 15355), and
- The change in the environment which results from the incremental impact of the project when added to other closely related past, present, or reasonably foreseeable future projects, and can result from individually minor, but collectively significant, projects taking place over a period of time (refer to CEQA Guidelines Section 15355(b)

Section 15130 of the CEQA Guidelines specifies that cumulative impacts shall be discussed when significant. The discussion of cumulative impacts should reflect the severity of the impacts and the likelihood of occurrence, but need not provide as great detail as needed to assess the effects of the project itself. CEQA requires that the following elements be discussed when assessing cumulative impacts:

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- A list of past, present and reasonably anticipated future projects producing related or cumulative impacts, including those outside the control of the Agency or a summary of projections contained in an adopted General Plan or related planning document which is designated to evaluate regional or areawide conditions. The discussion should be guided by the standards of practicality and reasonableness; and

- A summary of the expected environmental effects to be produced by those projects; and

- A reasonable analysis of the cumulative impacts of relevant projects including the examination of reasonable options for mitigating or avoiding any significant cumulative effect of the proposed project.

The following approach has been developed by District staff as a possible means to determine the cumulative significance of a land use project. This approach is consistent with the AQMP which contains performance standards and emission reduction targets necessary to attain the federal and state air quality standards. This approach is not mandatory under CEQA, and District staff is available to consult on the preparation of a cumulative impact analysis.

The environmental documentation could analyze the project according to the following assumptions (as applicable to the project):

- *1% per year (or 18% over 18 years to the year 2010) reduction in project emission (ROC, NOx, CO, PM10, SOx)*

  The analysis can be performed by calculating the total project unmitigated emissions using the procedures in Chapter 9, and then dividing by the reductions from the application of mitigation measures. This will provide the percent reduction in project emissions. (Refer to Appendix 9 for methodology.)

- *1.5 average vehicle ridership (AVR), or average vehicle occupancy (AVO) if a transportation project*

  The calculation procedures in the District's Regulation XV should be used for commercial and industrial land use projects in determining AVR. The AVO for transportation projects should be determined based on ARB's guidance document for complying with the CCAA transportation performance standards. (Refer to Appendix 9 for methodology.)

- *Reduce the rate of growth in vehicle miles traveled (VMT) and trips*

  According to ARB's transportation performance standards, the rate of growth in vehicle miles traveled (VMT) and trips should be held to the rate of population or household growth. Compliance with this performance standard for residential projects, General Plan amendments, and Specific Plans is assessed by determining the population for the projected build-out year of the project. Planners should use population, VT, and VMT projections disaggregated to the local jurisdiction by SCAG that were contained in the AQMP. The population increase from the project should then be divided by the population projection for the build-out year. This gives the acceptable rate of growth in VMT and trips. To determine the number of VMTs a project can generate, determine VMT and trips projection for the build-out year for the local jurisdiction (after consultation with SCAG), and divide by the acceptable rate of VMT and trip growth percentage. (Refer to Appendix 9 for methodology.)

If the analysis shows that the project complies with the above assumptions, the project's cumulative impact could be considered insignificant. If the analysis shows that the project does not comply with the above assumptions, then cumulative impacts are considered to be significant, unless there is other pertinent information to the contrary.

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9.6 Analyzing Project Alternatives

CEQA requires that the project be compared to feasible alternatives, including a no-project alternative. CEQA Guidelines Section 15126(A)(d)(3) states that the discussion of alternatives shall focus on alternatives capable of eliminating any significant adverse environmental effects (such as air quality) or reducing them to a level of insignificance even if these alternatives would impede to some degree the attainment of the project objectives, or would be more costly.

The EIR should include an air quality impact analysis of all the project alternatives. For this type of assessment, it is appropriate to estimate emissions only for the build-out year and consider emissions associated only with operations. CEQA does not require the same level of analysis for alternatives as it does for the project-specific analysis. This Handbook suggests that project alternatives should be quantified so that decision makers have the ability to determine which alternative is environmentally superior from an air quality perspective. Quantification may be done to a lesser degree, and does not need to be as extensive as that performed for the preferred alternative. For instance, if a project is reduced in size, emissions can be proportionally reduced. If however an alternative site is considered, it may not be feasible to do a quantified air quality analysis. In addition, since there may not be project specific information developed for each of the alternatives, the MAAQI model with the county-wide default assumptions or the screening table may be used to quantify the alternatives.

All of the alternatives, including the proposed project, should use the same basic assumptions, except where a change in assumptions is necessary due to the nature of the alternative. For example, a project alternative might involve electric vehicles rather than gas-fueled vehicles so that the vehicle emission factors would be different. It is important that all appropriate assumptions be held constant so that it is possible to ascertain the difference in emissions as a result of the alternatives. The use of default assumptions from Appendix 9 is acceptable for the alternatives (including the preferred project alternative) in this analysis. This means that the emissions estimates used in the analyses for the alternatives will be different than those used in estimating the impacts of the proposed project (e.g., preferred alternative).

The emissions estimates for the proposed project and alternatives should be reported in the EIR along with the basic underlying assumptions used in assessing all of the alternatives. Also to be reported is an identification of differences in assumptions among the alternatives, for those cases where a change in assumptions is necessary due to the nature of the alternate. An example of a reporting format for the emissions estimates of the project alternatives is provided in Table 9-10.

9.7 Air Quality Modeling Tools

There are a number of air quality modeling tools available to assess air quality impacts of projects. A few of the models that are available to planners and project consultants are described below. Planners and project consultants are not limited to these models and can use other models, as appropriate, to perform the analysis.

The accuracy from any model is directly dependent on the accuracy of the input variables or assumptions. Meteorology, trip generation rates, and emission factors can vary widely, and in many situations there is a degree of uncertainty in their selection. The user should be confident with the input assumptions before they are used in the model. Preferably, the inputs are based on research or case studies. It is recommended that the user contact the District's Modeling staff prior to selecting meteorological parameters and estimating composite running and idling emission factors. For recommendations on other types of input assumptions, contact the District's Local Government-CEQA Section.

Mobile Assessment for Air Quality Impacts (MAAQI). The MAAQI model is used to estimate CO, ROC, NOx, SOx, and PM10 emissions from the motor vehicles associated with new or modified land uses (e.g., shopping centers, residential development, commercial mini-malls, etc). The District has developed MAAQI to include county default assumptions (for trip length, speeds, temperature, etc.), energy use in residential developments, and quantification of mitigation measures.

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The District's MAAQI model has been designed for planners wanting to assess the indirect vehicular emissions associated with various projects, such as residential developments, shopping centers, and offices. The program uses the emission factors generated by the EMFAC7E.P model for on-road motor vehicles as input. The data needed to run the MAAQI model for a new or modified land use project can be as simple as the following:

- Type of land use
- Size of the project
- Year of project operation

The MAAQI model contains a number of built-in default values (values automatically inserted by the program when project-specific data are unavailable). Unless project-specific information is available and documented, the default values for each of the four counties under the District's jurisdiction are recommended for the following model inputs:

- Trip rate
- Percent cold starts
- Vehicle fleet mix types
- Trip speed
- Trip lengths

Input values other than those recommended in MAAQI may be used for calculating commercial and industrial emissions. Likewise, modified trip generation rates and percent work trips may also be used. However, if different values are used, full documentation and justification for the different inputs should be provided. If the MAAQI model is used to estimate emissions associated with land uses, the following non-vehicular emissions must be added to the estimate.

- Emissions from stationary sources
- Emissions from other mobile sources (planes, trains, etc.)
- PM10 emissions
- Emissions from traffic impacts

CALINE4. The CALINE4 is a computer model used to predict CO, nitrogen dioxide (NO2), and particulate concentrations near a roadway. CALINE4 is an effective tool for forecasting free-flowing mobile source emissions resulting from a proposed project and can be used to determine if a CO hot spot will be created. The information obtained from CALINE4 projections can also be used to determine the project's effect on ambient air quality in localized areas. (Contact the CalTrans Technical Support Division for further information about the CALINE4 model.)

CAL3QHC. The CAL3QHC is another computer model for predicting the level of carbon monoxide or other criteria pollutant concentrations from motor vehicles near a roadway. The model is based on the assumption that vehicles near an intersection are either in motion or idling. Therefore, CAL3QHC is effective at estimating mobile source emissions which are either free-flowing or idling. Details of the modeling application can be found in "User's Guide to CAL3QHC" (EPA, Contract No. 68-02-4394, 1990).

EMFAC7E.P. These emission factors use the most current assumptions for estimating and projecting emissions from motor vehicles. The model can be used to quickly estimate pollutant emission factors given a vehicle fleet size, year, temperature and operating speed. The output can be used as input to the CALINE4 model. The vehicle types programmed into this model include light-duty auto, light-duty truck, medium-duty truck, heavy-duty truck and motorcycles.

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The EMFAC7E.P model takes into account all ARB regulations adopted up to January 1, 1991. The District recommends that this version be used for all emissions estimates. These emissions factors or the most recent factors can be obtained by contacting the ARB Technical Support Division or the District's Local Government/CEQA unit. The emission factors contained in Appendix 9 for on-road mobile sources are generated from EMFAC7E.P.

9.8 Analyzing and Reporting Emissions

Once the emissions from construction and operation of the project have been estimated, the effect of District rules and local ordinances should be taken into account. Any reductions should be documented in the EIR and calculated as part of the project's emissions prior to the inclusion of mitigation. This is because mitigation refers to actions beyond those required by rules or ordinances. Then a quantitative assessment should be completed comparing the project emissions to the thresholds in Chapter 6. In addition, qualitative assessments that compare the project with the existing setting described in Chapter 8 and with any potential impacts identified during the Initial Study need to be made.

The environmental documentation should demonstrate clearly that the amount of emissions generated by the project have been compared to the thresholds of significance. (In this step, construction and operation related emissions should be considered separately). While the analysis for the ND and MND may analyze emissions impacts based on the screening tables, the EIR must include a project specific analysis.

The impacts of the project on the existing setting should be analyzed (e.g., changes to current traffic LOS, etc.) and any other changes from current conditions noted. In addition, an analysis of any impacts relating to air quality identified during the Initial Study should also be included (e.g., changes in population projections, etc.).

All of the assumptions used in estimating future emissions must be documented in the EIR. Emissions estimates for each source related to construction and operation activities along with total emissions from each applicable pollutant (e.g., tons or pounds of pollutant a day) should be reported. Emissions estimates should be reported for each phase of build-out and project completion.

AR0072874

Figure 9-1. Flow Chart for Estimating Emissions from Projects

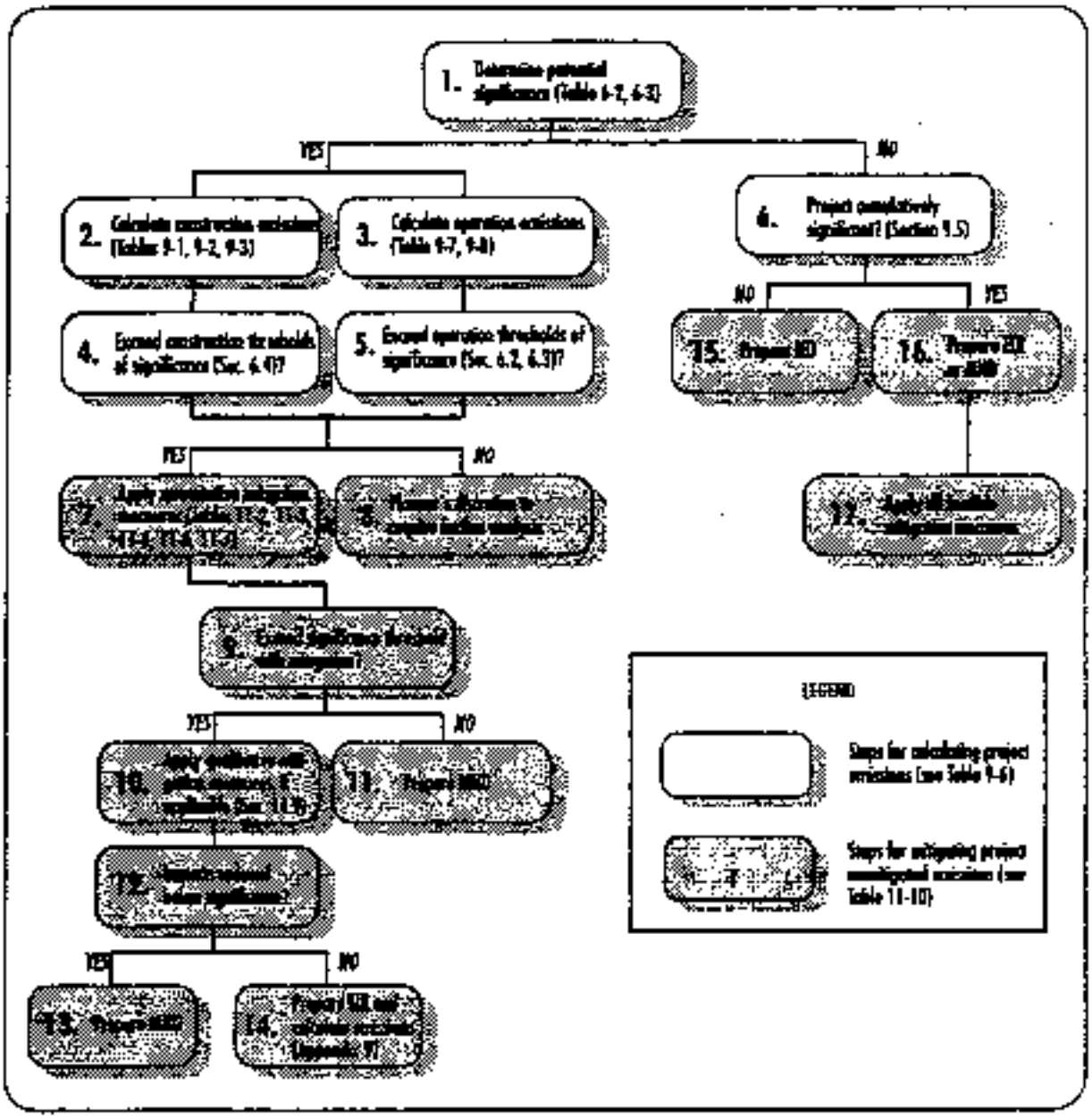

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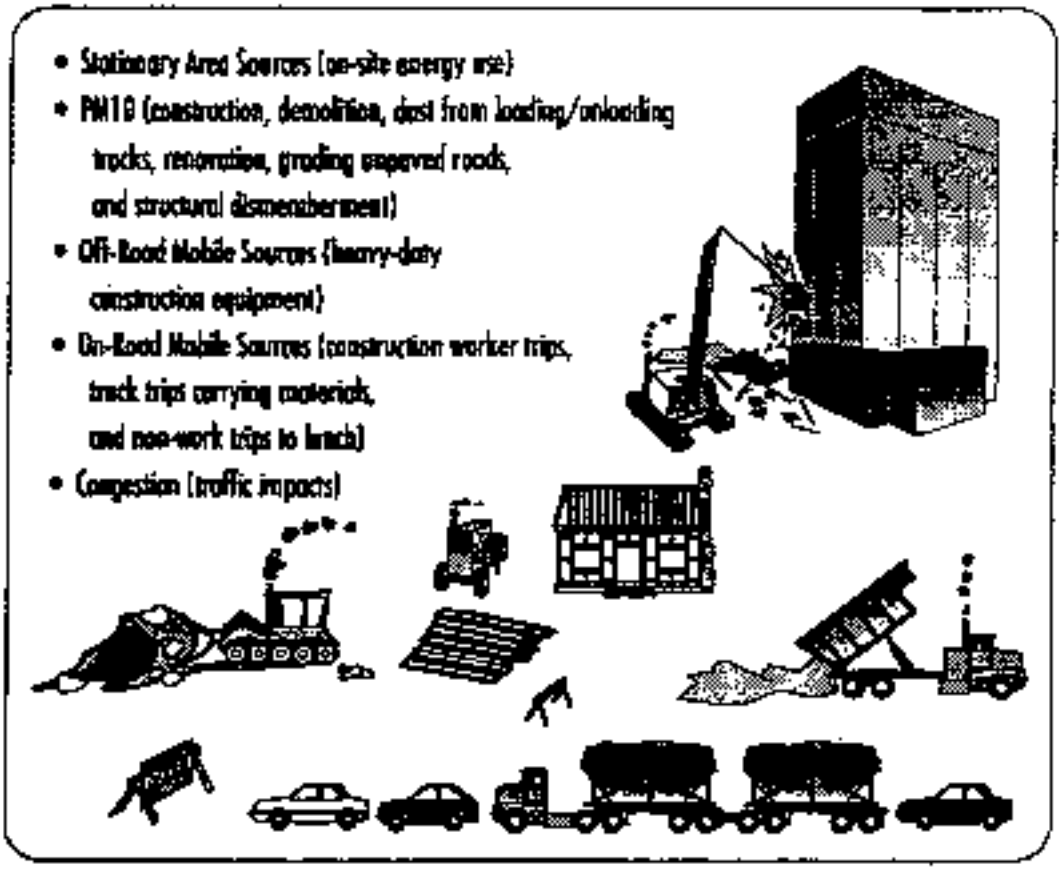
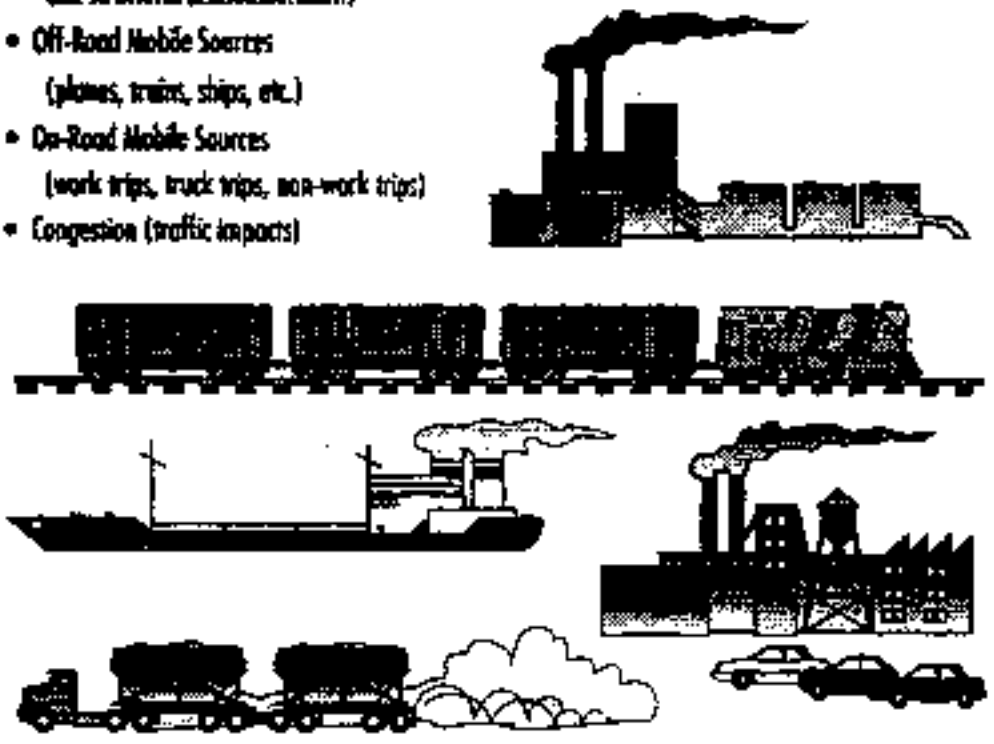
Figure 9-2. Emission Sources Associated with Construction



AR0072876

Figure 9-3. Emission Sources Associated with Operation of a Facility

- Stationary Point Sources (large boilers, etc.)
- Stationary Area Sources (on-site energy use)
- PM10 (unpaved roads, and structural dismemberment)
- Off-Road Mobile Sources (planes, trains, ships, etc.)
- On-Road Mobile Sources (work trips, truck trips, non-work trips)
- Congestion (traffic impacts)



AR0072877

Table 9-1. Screening Table for Estimating Total Construction Emissions**

LAND USE	UNIT OF MEASURE	EMISSION FACTORS* (lbs/CONSTRUCTION PERIOD)			
		SO_x	NO_x	CO	PM10
RESIDENTIAL					
Single Family Housing	1,000 sq. ft. GFA*	23.66	347.74	75.62	24.69
Apartments	1,000 sq. ft. GFA	21.97	322.90	70.22	22.93
Condominiums	1,000 sq. ft. GFA	21.30	312.97	68.06	22.22
Mobile Homes	1,000 sq. ft. GFA	21.30	312.97	68.06	22.22
EDUCATION					
Schools	1,000 sq. ft. GFA	46.99	690.52	150.16	49.03
COMMERCIAL					
Business Park	1,000 sq. ft. GFA	55.44	814.72	177.17	57.85
Day Care Center	1,000 sq. ft. GFA	31.87	466.97	101.55	33.16
Discount Store	1,000 sq. ft. GFA	31.78	466.97	101.55	33.16
Fast Food	1,000 sq. ft. GFA	31.78	466.97	101.55	33.16
Government Office Complex	1,000 sq. ft. GFA	55.44	814.72	177.17	57.85
Hardware Store	1,000 sq. ft. GFA	31.78	466.97	101.55	33.16
Hotel	1,000 sq. ft. GFA	41.58	611.04	132.87	43.39
Medical Office	1,000 sq. ft. GFA	55.44	814.72	177.17	57.85
Motel	1,000 sq. ft. GFA	41.58	611.04	132.87	43.39
Movie Theatre	1,000 sq. ft. GFA	31.78	466.97	101.55	33.16
Office	1,000 sq. ft. GFA	55.44	814.72	177.17	57.85
Resort Hotel	1,000 sq. ft. GFA	41.58	611.04	132.87	43.39
Restaurant	1,000 sq. ft. GFA	31.78	466.97	101.55	33.16
Shopping Center	1,000 sq. ft. GFA	31.78	466.97	101.55	33.16
Supermarket	1,000 sq. ft. GFA	31.78	466.97	101.55	33.16
INDUSTRIAL	1,000 sq. ft. GFA	32.79	481.88	104.79	34.22

* GFA = GROSS FLOOR AREA

**Construction emissions include on-site construction equipment and workers' travel.

E = (((Project square footage/1,000) × (Table 9-1 emission factor))/(Number of days to construct)
E = Daily construction emissions

For on-site construction equipment and material handling construction emissions, subtract emissions obtained by using screening Table 9-3.

For on-site construction equipment emissions, subtract emissions obtained by using screening Tables 9-3 and 9-4.

Refer to Appendix 9 for methodologies and assumptions used in preparing this table.

These emissions were estimated using energy consumption values provided in Energy and Labor in the Construction Sector, B. Hannon, R. Steitz, and D. Serbst, Science, 1978, 202:837–847.

AR0072878

Table 9-2. Screening Table for Estimating Construction PM10 Emissions – Fugitive Dust

LAND USE	UNIT OF MEASURE	EMISSION FACTOR (LBS/DAY)
UNPAVED ROADS		
Passenger Vehicle	Vehicle Miles Traveled (1)	5.56
Loaded Truck	Vehicle Miles Traveled (1)	23.00
PAVED ROADS		
Local Road	Vehicle Miles Traveled (1)	0.33
Construction Road	Vehicle Miles Traveled (1)	2.00
DEMOLITION	Cubic Foot	0.00042
GRADING	Acres/Day	55.00
ASBESTOS	Cubic Foot	0.00006

Refer to Appendix A, page A-38 for methodologies and assumptions used in preparing this table.

NOTES:

(1) VMT is a function of linear road length and average daily trips. Any combination that equals or exceeds the daily and quarterly thresholds could be significant.

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Table 9-3. Screening Table for Estimating Emissions from Construction Workers' Travel

LAND USE	UNIT OF MEASURE	EMISSION FACTORS LBS/DAY			
		ROG	NO_x	CO_2	PM10
RESIDENTIAL					
Single Family Housing	1,000 sq. ft. GFA*	0.008	0.007	0.096	0.0007
Apartments	1,000 sq. ft. GFA	0.008	0.007	0.101	0.0007
Condominiums	1,000 sq. ft. GFA	0.008	0.007	0.101	0.0007
Mobile Homes	1,000 sq. ft. GFA	0.008	0.007	0.096	0.0007
EDUCATION					
Schools	1,000 sq. ft. GFA	0.007	0.006	0.086	0.0006
COMMERCIAL					
Business Park	1,000 sq. ft. GFA	0.007	0.005	0.080	0.0006
Day Care Center	1,000 sq. ft. GFA	0.005	0.004	0.060	0.0004
Discount Store	1,000 sq. ft. GFA	0.005	0.004	0.060	0.0004
Fast Food	1,000 sq. ft. GFA	0.007	0.006	0.090	0.0007
Government Office Complex	1,000 sq. ft. GFA	0.009	0.007	0.104	0.0008
Hardware Store	1,000 sq. ft. GFA	0.005	0.004	0.060	0.0004
Hotel	1,000 sq. ft. GFA	0.007	0.006	0.089	0.0006
Medical Office	1,000 sq. ft. GFA	0.008	0.007	0.099	0.0007
Motel	1,000 sq. ft. GFA	0.007	0.006	0.089	0.0006
Movie Theatre	1,000 sq. ft. GFA	0.007	0.006	0.085	0.0006
Office	1,000 sq. ft. GFA	0.007	0.005	0.080	0.0006
Resort Hotel	1,000 sq. ft. GFA	0.007	0.006	0.089	0.0006
Restaurant	1,000 sq. ft. GFA	0.007	0.006	0.090	0.0007
Shopping Center	1,000 sq. ft. GFA	0.005	0.004	0.060	0.0004
Supermarket	1,000 sq. ft. GFA	0.005	0.004	0.060	0.0004
INDUSTRIAL	1,000 sq. ft. GFA	0.003	0.003	0.042	0.0003

[1] Refer to Appendix 9 for methodologies and assumptions used in preparing this table.

[2] Use these emissions to determine post-mitigation emissions after applying percent mitigation efficiencies applicable towards construction workers' travel emissions.

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Table 9-4. Screening Table for Estimating Construction Materials Handling Emissions

CONSTRUCTION EQUIPMENT EMISSIONS		EMISSION FACTORS			
		LBS / CONSTRUCTION PERIOD			
LAND USE	UNIT OF MEASURE	ROG	NO_x	CO	PM10
RESIDENTIAL					
Single Family	1000 sq. ft. GFA*	3.38	49.63	10.79	3.52
Apartments	1000 sq. ft. GFA	3.14	46.08	10.02	3.27
Condominiums	1000 sq. ft. GFA	3.04	44.67	9.71	3.17
Mobile Homes	1000 sq. ft. GFA	3.04	44.67	9.71	3.17
EDUCATION					
Schools	1,000 sq. ft. GFA	6.71	98.55	21.43	7.00
COMMERCIAL					
Business Park	1,000 sq. ft. GFA	7.91	116.28	25.28	8.26
Day Care Center	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
Discount Store	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
Fast Food	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
Government Office Complex	1,000 sq. ft. GFA	7.91	116.28	25.28	8.26
Hardware Store	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
Hotel	1,000 sq. ft. GFA	5.93	87.20	18.96	6.19
Medical Office	1,000 sq. ft. GFA	7.91	116.28	25.28	8.26
Motel	1,000 sq. ft. GFA	5.93	87.20	18.96	6.19
Movie Theatre	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
Office	1,000 sq. ft. GFA	7.91	116.28	25.28	8.26
Resort Hotel	1,000 sq. ft. GFA	5.93	87.20	18.96	6.19
Restaurant	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
Shopping Center	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
Supermarket	1,000 sq. ft. GFA	4.53	66.64	14.49	4.73
INDUSTRIAL	1,000 sq. ft. GFA	4.68	68.77	14.96	4.88

*GFA = Gross Floor Area

E = Daily Construction Emissions (construction emissions include material handling)

E = (((project square footage/1000)×(Table 9-4 emission factor))/(Number of days to construct))

These emissions were estimated using energy consumption values provided in Energy and Labor in the Construction Sector, B. Hannon, R. Stein, and D. Serber, Science, 1978, 202:837–847

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Table 9-5. Examples of Calculating Project Emissions

Project: 210 SINGLE-FAMILY DWELLING UNITS	(Lbs/Day)			
	ROC	NOx	CO	PM10
Unmitigated Daily Construction Emissions				
Exhaust Emissions*	6.66	97.93	21.30	7.01
• Construction Workers' Travel	0.0028	0.0025	0.270	0.0002
• Construction Material Hauling	0.95	13.98	3.04	0.99
• Construction Equipment	5.71	83.95	18.23	6.02
Fugitive Dust Emissions**	37.93	N/A	N/A	N/A
Total Construction Emissions	**6.66**	**97.93**	**21.30**	**44.94**
Construction Significance Thresholds	75.00	100.00	550.00	150.00
Significant?	No	No	No	No
Unmitigated Daily Operation Emissions				
Exhaust Emissions	56.70	48.30	697.20	4.20
Energy	0.04	4.02	0.70	0.14
Total Operation Emissions	**56.74**	**52.32**	**697.90**	**4.34**
Construction Significance Thresholds	75.00	100.00	550.00	150.00
Significant?	No	Yes	No	No

* Assumes 1,250 dwelling units are built [illegible] 261 days per year is assumed.
** Assumes 83 acres of grading in first 65 days of construction.

Project: 199,000 sq. ft. Multi-Tenant Office Building	(Lbs/Day)			
	ROC	NOx	CO	PM10
Unmitigated Daily Construction Emissions				
Exhaust Emissions*	40.36	593.09	128.97	42.11
• Construction Workers' Travel	0.0510	0.0364	0.5824	0.0044
• Construction Material Hauling	5.23	84.65	18.40	6.01
• Construction Equipment	35.07	508.41	109.99	36.10
Fugitive Dust Emissions**	N/A	N/A	N/A	7.74
Total Construction Emissions	**40.36**	**593.09**	**128.97**	**49.85**
Construction Significance Thresholds	75.00	100.00	550.00	150.00
Significant?	No	Yes	No	No
Unmitigated Daily Operation Emissions				
Exhaust Emissions	57.00	32.30	560.50	5.70
Energy	0.05	5.27	0.92	0.18
Total Operation Emissions	**57.05**	**37.57**	**561.42**	**5.88**
Construction Significance Thresholds	55.00	55.00	550.00	150.00
Significant?	Yes	No	Yes	No

* Assumes 1 year with 261 days per year is construed.
** Assumes 8.36 acres of grading in first 31 days of construction.

AR0072882

Table 9-6. Steps for Calculating Project Emissions (Screening Analysis)

(The following steps correspond to the extended portion of the flow chart in Figure 9-3.)

1. Determine if the project could be significant by comparing the project to the thresholds in Tables 6-2 and 6-3.
2. Calculate construction emissions using screening Tables 9-1 (Total Construction), 9-2 (Construction PM10), and 9-3 (Construction Workers' Travel) to determine total construction emissions.
3. Calculate operation emissions using screening Tables 9-7 (Mobile Source) and 9-8 (Stationary Source) to determine total operation emissions.
4. Compare project construction emissions to thresholds in Section 6.4 to determine significance.
5. Compare project operation emissions to the thresholds in Section 6.2 or 6.3 to determine significance.
6. Determine if the project could be cumulatively significant (Section 9.5).

AR0072883

Table 9-7. Screening Table for Estimating Mobile Source Operation Emissions

Land Use	Unit of Measure	Emission Factors lbs/day			
		ROG	NOx	CO	PM10
RESIDENTIAL					
Single Family Housing	Dwelling Unit	0.27	0.23	3.32	0.02
Apartments	Dwelling Unit	0.17	0.14	2.11	0.02
Condominiums	Dwelling Unit	0.16	0.13	1.91	0.01
Mobile Homes	Dwelling Unit	0.13	0.11	1.62	0.01
Retirement Community	Dwelling Unit	0.07	0.06	0.90	0.01
EDUCATION					
Elementary School	1,000 sq. ft. GFA*	0.25	0.03	1.84	0.03
High School	1,000 sq. ft. GFA	0.31	0.18	3.08	0.03
Community College	1,000 sq. ft. GFA	0.37	0.22	3.64	0.03
University	Student	0.07	0.04	0.67	0.01
COMMERCIAL					
Airport	Commercial Flight	3.66	1.58	33.06	0.32
Business Park	1,000 sq. ft. GFA	0.40	0.23	3.94	0.03
Day Care Center	1,000 sq. ft. GFA	2.10	0.91	19.03	0.19
Discount Store	1,000 sq. ft. GFA	1.69	0.35	13.24	0.17
Fast Food w/Drive-Thru	1,000 sq. ft. GFA	16.02	1.91	117.77	1.62
Fast Food w/o Drive-Thru	1,000 sq. ft. GFA	19.21	2.29	141.26	1.94
Government Office Complex	1,000 sq. ft. GFA	0.72	0.45	7.29	0.06
Hardware Store	1,000 sq. ft. GFA	1.99	0.41	15.58	0.19
Hotel	Occupied Room	0.26	0.06	2.07	0.02
Medical Office	1,000 sq. ft. GFA	0.91	0.39	8.20	0.08
Motel	Occupied Room	0.25	0.06	2.01	0.02
Movie Theatre	1,000 sq. ft. GFA	1.88	0.39	14.68	0.18
Car Sales	1,000 sq. ft. GFA	1.27	0.55	11.50	0.11
Office (small)	1,000 sq. ft. GFA	0.42	0.24	4.07	0.03
Office (medium)	1,000 sq. ft. GFA	0.30	0.17	2.95	0.03
Office (large)	1,000 sq. ft. GFA	0.25	0.14	2.48	0.02
Office Park	1,000 sq. ft. GFA	0.32	0.18	3.13	0.03
Racquet Club	1,000 sq. ft. GFA	0.56	0.04	4.00	0.06
Research Center	1,000 sq. ft. GFA	0.22	0.14	2.24	0.02
Resort Hotel	Occupied Room	0.28	0.07	2.22	0.03
Restaurant	1,000 sq. ft. GFA	2.56	1.11	23.17	0.23
Restaurant (high-turnover)	1,000 sq. ft. GFA	6.09	2.64	55.06	0.54
Shopping Center (small)	1,000 sq. ft. GFA	1.32	0.27	10.31	0.13
Shopping Center (medium)	1,000 sq. ft. GFA	1.02	0.21	7.97	0.10
Shopping Center (large)	1,000 sq. ft. GFA	0.79	0.16	6.16	0.08
Supermarket	1,000 sq. ft. GFA	4.43	1.27	36.56	0.42

*GFA = GROSS FLOOR AREA

Refer to Appendix E for methodologies and assumptions used in preparing this table.

(continued on next page)

AR0072884

Table 9-7. Screening Table for Estimating Mobile Source Operation Emissions (continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
INDUSTRIAL					
Light Industrial	1,000 sq. ft. GFA *	0.20	0.12	1.97	0.020
Heavy Industrial	1,000 sq. ft. GFA	0.04	0.03	0.42	0.004
Industrial Park	1,000 sq. ft. GFA	0.20	0.12	1.97	0.020
Manufacturing	1,000 sq. ft. GFA	0.11	0.07	1.09	0.010
INSTITUTIONAL/GOVERNMENTAL					
Clinic	1,000 sq. ft. GFA	0.58	0.14	4.69	0.06
Government Center	1,000 sq. ft. GFA	0.66	0.29	6.00	0.06
Hospital	Beds	0.31	0.14	2.83	0.03
Library	1,000 sq. ft. GFA	1.08	0.18	8.20	0.11
Nursing Home	Beds	0.07	0.04	0.74	0.01
U.S. Post Office	1,000 sq. ft. GFA	2.14	0.53	17.19	0.21

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Table 9-8. Screening Table for Estimating Area Source Operation Emissions – Energy Consumption

LAND USE	UNIT OF MEASURE	EMISSION FACTORS (lbs/unit)			
		VOC*	NOx*	CO*	PM10
RESIDENTIAL					
Single Family Housing	Dwelling Unit	0.00017	0.01916	0.00333	0.00067
Apartments	Dwelling Unit	0.00017	0.02203	0.00333	0.00067
Condominiums	Dwelling Unit	0.00017	0.01916	0.00333	0.00067
Mobile Homes	Dwelling Unit	0.00017	0.01916	0.00333	0.00067
Retirement Community	Dwelling Unit	0.00017	0.01916	0.00333	0.00067
EDUCATION					
Elementary School	1,000 sq. ft. GFA*	0.00017	0.01985	0.00345	0.00069
High School	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Community College	1,000 sq. ft. GFA	0.00032	0.03655	0.00636	0.00127
University	Student	N/A	N/A	N/A	N/A
COMMERCIAL					
Airport	Commercial Flight	N/A	N/A	N/A	N/A
Business Park	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Day Care Center	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Discount Store	1,000 sq. ft. GFA	0.00032	0.03718	0.00647	0.00129
Fast Food	1,000 sq. ft. GFA	0.00130	0.14903	0.02592	0.00518
Government Office Complex	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Hardware Store	1,000 sq. ft. GFA	0.00032	0.03718	0.00647	0.00129
Hotel	Occupied Room	0.00019	0.02142	0.00373	0.00075
Medical Office	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Motel	Occupied Room	0.00019	0.02142	0.00373	0.00075
Car Sales	1,000 sq. ft. GFA	0.00032	0.03718	0.00647	0.00129
Office	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Racquet Club	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Research Center	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096
Resort Hotel	Occupied Room	0.00006	0.00643	0.00112	0.00022
Restaurant	1,000 sq. ft. GFA	0.00130	0.14903	0.02592	0.00518
Shopping Center	1,000 sq. ft. GFA	0.00032	0.03718	0.00647	0.00129
Supermarket	1,000 sq. ft. GFA	0.00141	0.16195	0.02816	0.00563
INDUSTRIAL	1,000 sq. ft. GFA	0.00024	0.02773	0.00482	0.00096

*GFA = GROSS FLOOR AREA

Refer to Appendix C for methodologies and assumptions used in preparing this table.

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Table 9-9. Future Year CO Adjustment Factors

LOCATION	YEAR							
	1994	1995	1996	1997	1998	1999	2000
1 – Los Angeles	0.78	0.73	0.68	0.62	0.57	0.51	0.46	0.41
2 – West L.A.	0.79	0.74	0.69	0.63	0.58	0.53	0.48	0.42
3 – Hawthorne	0.78	0.72	0.67	0.61	0.56	0.50	0.44	0.39
4 – Long Beach	0.78	0.73	0.67	0.62	0.56	0.51	0.45	0.40
5 – Pico Rivera	0.78	0.73	0.67	0.62	0.56	0.51	0.45	0.40
6 – Reseda	0.78	0.72	0.67	0.61	0.56	0.50	0.45	0.39
7 – Burbank	0.78	0.72	0.67	0.61	0.56	0.50	0.45	0.39
8 – Pasadena	0.79	0.73	0.68	0.63	0.57	0.52	0.47	0.41
9 – Azusa	0.80	0.75	0.71	0.66	0.61	0.56	0.51	0.46
10 – Pomona	0.84	0.80	0.76	0.72	0.68	0.64	0.60	0.56
11 – Whittier	0.79	0.74	0.69	0.63	0.58	0.53	0.48	0.43
12 – Lynwood	0.80	0.75	0.69	0.64	0.59	0.54	0.49	0.44
13 – Santa Clarita	0.85	0.81	0.77	0.73	0.69	0.65	0.61	0.58
14 – Lancaster	0.82	0.77	0.73	0.68	0.64	0.59	0.55	0.50
15 – San Gabriel Mountains	0.80	0.75	0.70	0.65	0.60	0.56	0.51	0.46
16 – La Habra	0.83	0.79	0.75	0.71	0.67	0.63	0.59	0.55
17 – Anaheim	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45
18 – Costa Mesa	0.80	0.75	0.71	0.66	0.61	0.56	0.51	0.46
19 – El Toro	0.95	0.93	0.92	0.91	0.89	0.88	0.87	0.85
20 – Central Coastal	0.84	0.80	0.76	0.71	0.67	0.63	0.59	0.55
21 – Capistrano Valley	0.87	0.84	0.81	0.78	0.74	0.71	0.68	0.65
22 – Norco	0.88	0.85	0.82	0.79	0.76	0.73	0.70	0.67
23 – Rubidoux	0.85	0.82	0.78	0.74	0.70	0.67	0.63	0.59
– Riverside Mag.	1.86	2.08	2.29	2.51	2.72	2.94	3.16	3.37
24 – Perris	0.96	0.95	0.95	0.94	0.93	0.92	0.91	0.90
25 – Lake Elsinore	1.17	1.21	1.25	1.30	1.34	1.38	1.42	1.47
26 – Temecula	3.87	4.58	5.30	6.02	6.74	7.45	8.17	8.89
27 – Anza	0.64	0.55	0.46	0.37	0.28	0.19	0.10	0.01
28 – Hemet	1.03	1.03	1.04	1.05	1.06	1.06	1.07	1.08
29 – Banning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30 – Palm Springs	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
31 – East Riverside County	0.64	0.55	0.45	0.36	0.27	0.18	0.09	0.00
32 – Northwest San Bernardino Valley	0.75	0.69	0.62	0.56	0.50	0.43	0.37	0.31
33 – Upland	0.79	0.74	0.68	0.63	0.58	0.52	0.47	0.42
34 – Fontana	1.32	1.41	1.49	1.57	1.65	1.73	1.81	1.89
– San Bernardino	3.34	3.93	4.51	5.10	5.68	6.27	6.85	7.44
35 – Redlands	0.96	0.95	0.95	0.94	0.93	0.92	0.91	0.90
36 – West San Bernardino Mountains	0.77	0.71	0.66	0.60	0.54	0.48	0.43	0.37
37 – Crestline	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91
38 – East San Bernardino Mountains	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89

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Table 9-10. Air Quality Analysis for Assessing Project Alternatives - Format Example

Proposed Project: CO ROC NO_x SO_x PM10					
Alternative A: CO ROC NO_x SO_x PM10					
Alternative B: CO ROC NO_x SO_x PM10					
Alternative C: CO ROC NO_x SO_x PM10					

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ASSESSING TOXIC AIR POLLUTANTS

CHAPTER 10

During the past decade, concern has grown over certain air pollutants (other than the criteria pollutants) that may cause cancer or otherwise harm human health and the environment. Public interest and hence public policy clearly demand that air toxics and acutely hazardous materials be taken into account. Chapter 3 provides background information on air toxics, defining and explaining their origins. Chapter 5 discusses the siting of sensitive receptors within a close proximity to toxic emission sources. This chapter discusses three primary issues: 1) the analysis necessary for sources of air toxics, 2) the analysis necessary to assess the siting of sensitive receptors within a quarter mile of a toxic source, and 3) the analysis necessary to assess risks from acutely hazardous materials. Figure 10-1 illustrates the sequential flow of these analyses.

Projects emitting significant levels of air toxics must be carefully evaluated, since air toxics may cause harmful effects. Because of their known expected harmful effects, regulations adopted by the federal and state governments and limited purpose districts restrict the levels of air toxics that may be emitted from stationary sources (refer to Chapter 3 for background information.

Concern about toxics introduces a new dimension into the environmental planning process. Planners must now be aware of air toxics and what is required to prevent their release. Historically, environmental planning for air quality has focused on criteria pollutants, about which a great deal is known and on which information can be built into the planning process. "Safe" limits are established for criteria pollutants (ambient air quality standards), and thresholds for significant levels of emissions can be established relative to the air quality standards threshold levels. Release of criteria pollutants at levels exceeding the standards can cause reversible effects, such as eye irritation and coughing, as well as irreversible health effects including deterioration of lung function. When emissions are kept at or below the accepted threshold levels, no adverse health effects are expected to occur.

There are different types of toxics analysis depending on the type of toxic air pollutant and conditions of release (i.e., routine and accidental releases). Table 10-1 provides an overview of the compounds that should be analyzed depending on whether there is a routine or accidental release.

The state is required to compile and maintain a list of substances recognized by the state ARB as presenting a chronic or acute threat to health when present in the ambient air, including, but not limited to, any neurotoxins, or chronic respiratory toxins. Table 10-2 provides a list of current state and federal designated toxic contaminants (AB 1807 and federal NESHAPs) that should be analyzed for chronic health hazards. Table 10-3 lists District-recommended air dispersion models for risk assessment use. Table 10-4 provides a list of acutely hazardous materials that should be analyzed where there is a risk of accidental release. Table 10-5 provides a list of air contaminants that should be analyzed for acute health hazards during routine short-term releases.

As California is part of a belt of earthquakes and volcanic activity that circles the Pacific, there is concern in the Basin regarding the siting of facilities that use acutely hazardous materials and their proximity to active earthquake faults. The San Andreas fault, which extends almost the entire length of the state, is an area of high seismic activity.

The U.S. Geological Survey (USGS) evaluates California earthquake probabilities. Its evaluations are based on a probability model that assumes increased probability with elapsed time since the previous major earthquake on a fault system. A report by FEMA (Federal Emergency Management Agency), 1980) stated that a major earthquake in Southern California comparable to the great earthquake of 1857 (L.A., 7.9 Richter) has a probability of occurrence greater that 50% in the next 30 years. The Working Group of the USGS found that the earthquake hazard on the South San Andreas fault is at least as high as that reported by FEMA. Planners should consult the Alquist/Priolo maps to determine if a project proposes to locate near an earthquake zone.

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10.1 Roles of the District and Local Governments

Both the District and local governments issue permits to sources that could emit toxic air or acutely hazardous contaminants. The District regulates air toxics and acutely hazardous materials by issuing operating permits which limit the amount of emissions. Local governments control the impact of air toxics on sensitive receptors through land use decisions. The District has adopted Rule 1401 which specifies limits for maximum individual cancer cases from new or modified stationary sources which emit carcinogenic air toxics. Local governments grant discretionary permits for land uses emitting air toxics and issue building permits for the construction of such facilities. In some cases, the local government permit is for equipment that is directly related to a land use, such as a permit for a gas station. Other times the equipment is an accessory to the primary land use, as would be the case with the extensive consumption of gasoline fuels by internal combustion engines at a special activity center.

The local government is the lead agency with respect to the land use decision and any discretionary permits that are required. The District is the lead agency for the District permit to construct and operate. In both cases, the local governments and the District are the respective responsible agencies. The lead agency must consult with responsible agencies. Refer to the front matter of this Handbook to identify the appropriate District number to contact regarding environmental documentation.

10.2 Local Government Land Use Permits (for Stationary Sources Emitting Toxic Emissions)

Most likely, planners will only see those projects that fall into one of two categories: (1) those that involve a use new to the local government, or (2) those for an expanding use that is subject to a discretionary permit. The local government's involvement for most existing uses, is often limited to issuing business licenses, and building permits for minor alterations and equipment. When evaluating permits for new uses, planners have the opportunity to focus on the land use implications of the proposed project. In considering air toxics, planners may use Table 5-1 which identifies land uses and equipment commonly associated with significant toxic emissions, to determine when public health risk assessment should be performed. Refer to Appendix 3 to obtain a full listing of toxic air contaminants under District Rule 1401, ARB (AB 1807), and EPA (NESHAPs).

Planners can use the information in Table 5-1 to identify projects prior to consulting with District staff and prior to the completion of the Initial Study and the preparation of the draft EIR. If the planner determines that the project could have carcinogenic air toxics emissions, based on the District's information, the EIR should thoroughly analyze the air toxics emissions and include a discussion of land use compatibility issues.

In reviewing the EIR, local governments should consider the potential for carcinogenic toxic emissions and threat of release of acutely hazardous materials due to earthquakes from a land use perspective. Local governments should focus the analysis primarily on land use siting issues. As with toxics, the District adopts rules to regulate emissions from these sources. In granting a land use permit that involves carcinogenic toxic emissions or acutely hazardous materials, local government decision makers should ask the following:

- What is the health risk to the population surrounding the facility?
- If a discretionary permit is granted to a significant source of toxic emissions, how will this affect land use in the future?
- What are the health risks associated with siting a sensitive receptor within a quarter mile of a source of toxic emissions?
- What is the risk of upset from siting a facility using acutely hazardous materials near an earthquake zone? (i.e., Alquist/Priola zone).

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The EIR should provide technical information that will assist local governments in addressing these issues. The District staff is available to review any air toxic analysis. The EIR does not need to address District permitting requirements for stationary sources, since the District is responsible for ensuring that emissions from both small and large sources are kept at acceptable levels. The District permitting process does not address land use compatibility or siting issues, which are the responsibility of local governments.

Land use compatibility issues need only be addressed for: (1) projects that emit toxic air contaminants as identified in District Rule 1401, AB 1807, and NESHAPs (2) the siting of sensitive receptors that could be impacted by existing sources of toxic emissions, and (3) projects that have a risk of releasing (either routinely or accidentally) acutely hazardous materials. Refer to Table 5-1 for an example of land uses that could meet this criteria. In addition, if an existing source emitting toxic air contaminants has not obtained a Rule 1401 permit and if a sensitive receptor is to be located within a quarter mile of the existing source, the issue of land use compatibility should be considered.

10.3 District Permits

The District regulates levels of air toxics through a permitting process that covers both construction and operation. Both new and existing industries routinely use materials classified as air toxics. For both new and modified sources, the District has adopted Rule 1401, with which the project proponent must comply before the project can be constructed and put into operation. A permit, when issued, will allow the facility to operate and will specify the conditions, if any, that might limit its operation. The District permit is granted on the basis of an independent environmental analysis conducted according to CEQA Guidelines.

The District's CEQA Guidelines for permit processing consider the following types of projects significant:

- Any project involving the emission or threatened emission of a carcinogenic or toxic air contaminant identified in District Rule 1401 that exceeds the maximum individual cancer risk of one in one million or 10 in one million if the project is constructed with best available control technology for toxics (T-BACT) using the procedures in District Rule 1401
- Any project that could accidentally release an acutely hazardous material (Table 10-4) or routinely release a toxic air contaminant posing an acute health hazard (Table 10-5)
- Any project that could emit an air contaminant that is not currently regulated by District rule, but that is on the federal or state air toxics list (see Appendix 3 and Table 10-2)

Under CEQA, the District is the lead agency for District permits involving projects meeting these criteria. The District will prepare a Negative Declaration when it is determined that the project does not have a significant adverse impact on the environment pursuant to Article 6 of the District CEQA Guidelines. The District will prepare a Mitigated Negative Declaration (MND) when it is determined that the project may have significant adverse impacts on the environment, but that the permit applicant can modify the project so as to eliminate all identified significant impacts or reduce them to a level of insignificance. The District will prepare an EIR when it is determined through substantial evidence that the project might produce significant adverse environmental impacts pursuant to Articles 7 and 9 of the District CEQA Guidelines.

The local government within whose jurisdiction the proposed project is located will be considered the responsible agency. When the District prepares an EIR for its permit, the District will circulate both the Notice of Preparation and draft EIR to the appropriate local government. The District provides the local government, as responsible agency, the opportunity to review and comment on the EIR.

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10.4 Assessing Toxics/Acutely Hazardous Materials

Whenever a proposed project will likely entail the use of chemical compounds that: have been identified in District Rule 1401; have been placed on the ARB air toxics list pursuant to AB 1807 or EPA's National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (Table 10-2) and air toxic air contaminants of concern for acute exposure (Table 10-5); or will entail a facility using an acutely hazardous material (Table 10-4), the project proponent should anticipate that some level of risk assessment will be required. In addition, if a facility is using acutely hazardous materials near an earthquake zone or sensitive receptor, a risk assessment should also be performed. The quantities involved for some projects, and the actual release, may result in insignificant levels of risk. In such cases, a very simple "worst case" screening assessment may make that case clear and allow permitting to move ahead. In others, the situation may be uncertain or potentially result in unacceptable risks. At that point, a refined risk assessment may be required. Additional information is available on how to prepare a risk assessment by referring to the SCAQMD document, *"Procedures for Preparing Risk Assessments to Comply with the Air Toxics Rules of the SCAQMD,"* at the Public Information Center.

As required in the EIR, assessing toxics and acutely hazardous materials can be complex and time consuming. It is important at the start to distinguish between those cases where some lesser level of analysis may be sufficient and where nothing less than the most thorough assessment will serve the public interest. Even with limited information, a screening procedure may define a "worst-case" estimate of risk. Simple screening procedures may also give the basis for a more detailed assessment. Contact the District local governments/CEQA unit if the Planner is unsure about the level of analysis necessary.

A useful first step in the screening procedure is to find out whether or not a risk assessment for the facility has been required and performed under AB 2588. A facility will only have an AB 2588 assessment if it is an existing facility. Such an assessment will have brought together most though not necessarily all of the information required for analysis. Information in all cases will include an estimate of the quantities of materials that might be released based on: (1) data from emissions testing, (2) a mass balance calculation, or (3) emission factors for types of processes.

When the District's screening procedure as detailed in the District's procedures for preparing risk assessments is used, some simplified assumptions are made: flat terrain in an urban area, uniform emissions throughout the operation schedule, a source close to the property line. If the project is at substantial variance from these conditions, the simple screening procedure may not be accurate. Exposures to an urban population in a residential area are assumed to extend over the standard reference lifetime of 70 years. Exposures in commercial or industrial areas, presumably limited to working hours, can be adjusted downward.

The District's air toxics compliance guide, listed in the references at the end of this chapter, will help an applicant or consultant work through the required screening procedure, leading to an estimated maximum cancer risk for each carcinogenic air contaminant. Although the District does not currently regulate non-carcinogens, the risks associated with exposure to these air toxics may be assessed following the guidelines established by the California Air Pollution Control Officers Association (CAPCOA) for use in preparing risk assessments for the AB 2588 program.

In those cases where substantial potential risk may be involved, or where the simpler screening approach leads to a determination of significance, a more extensive refined risk assessment will be necessary. At that point, more detailed information will be required, such as:

Stack Height
Stack Diameter
Exhaust Gas Exit Velocity
Exhaust Gas Exit Temperature
Exhaust Gas Volume
Dimensions of Building Structures Near the Source
Dimensions of Area Sources
Land Use and Geographical Features Surrounding the Facility

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It can be particularly important to have information available on land uses in the surrounding area, and information such as: population distribution in general and population distribution by time of day; locations of potentially sensitive receptors; location and availability of emergency services and their relative sophistication; and similar data.

EIRs for land uses that have the potential to emit toxics must address and identify potential risks associated with siting, including identifying risks to surrounding land uses. The potential for risk and impact on future land uses as well as impact on projects already in place should be considered. The EIR should assist local government in making the land use decision that specifically will:

(1) Identify the risk to the population from the facility

(2) Evaluate future land use implications

(3) Incorporate mitigation measures when appropriate

Sometimes facilities that emit toxics can apply mitigation measures such as: adjusting the location of equipment emitting toxics so that it is not upwind of sensitive receptors, and designating surrounding properties for industrial uses.

The CEQA air toxic analysis is not a substitute for complying with District toxic regulations. The project will still need to undergo an in-depth risk assessment prior to issuance of a District permit. Appendix 10 summarizes the procedures to be followed in complying with Rule 1401 and is a useful guide for preparation of a toxic emission analysis for the EIR.

10.5 Siting of Sensitive Receptors

The local government will need to analyze the land use implications when siting a toxic source within its jurisdiction, particularly when sensitive receptors will be involved (refer to Chapter 5 for discussion on sensitive receptors). Such an analysis is not a substitute for the subsequent District permitting action over the source of the toxic emissions which requires a health risk assessment to be performed pursuant to Rule 1401. Local government analysis of the land use implications should only be based on an accurate health risk assessment, and the District staff is available to review such assessments.

Screening procedures identified in Chapter 5 will determine if further toxic emissions analysis is necessary when siting a sensitive receptor in proximity to a project that releases air toxics. If the initial screening indicates that the toxic emissions could exceed significance thresholds, the planners should require a thorough analysis as part of the CEQA documentation.

Specifically, planners can require that a public health risk assessment be performed and reviewed by the District. This type of assessment would involve summing risks from facilities within a quarter mile radius to the proposed sensitive receptor. Local governments then need to determine if the risk is acceptable in their community. The District uses the following standards for protecting existing receptors from new sources of toxic emissions: exceedance of the maximum individual cancer risk of 1 in 1 million, or 10 in 1 million if the project has best available control technology for toxics (T-BACT).

The health risk assessment for sensitive receptors should be performed using the same methodologies and inputs as those performed for a direct source of toxic emissions on the AB 1807 and NESHAPs lists. Each facility that does not have a Rule 1401 permit should be included in the analysis to the extent feasible. The toxic emissions should be quantified for each source using the District's procedures for Rule 1401 and an individual cancer risk identified for the sensitive receptor in Chapter 5. Risk assessments that have been previously performed pursuant to AB 2588 and Rule 1401 can be used in lieu of a new assessment. The analysis should include AB 2588 data, District Rule 1401 data, AB 1807, EPA NESHAPs toxic compounds and toxic air contaminants of concern for acute exposure. The project proponent should analyze publicly available information on health risks posed by nearby sources of toxic emissions. The District serves as a clearinghouse for publicly available information on toxic emissions and associated public health risks. This information is compiled from documentation

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required of toxic emitters by Rule 1401 and the AB 2588 Air Toxics Hot Spot Program. The applicant should also make a reasonable attempt to obtain toxic information from any sources that could potentially affect the project site which is not covered by Rule 1401 and AB 2588. Pursuant to CEQA Guidelines Section 15151, if the information is not available, the sufficiency of the air toxics analysis should be reviewed in light of what is reasonably feasible.

The EIR, at a minimum, should:

- Identify all potential land uses emitting toxics within a quarter mile surrounding the proposed project
- List types of pollutants most commonly associated with these uses
- Check the AB 2588 database and identify any risk levels that have been reported
- Perform a health risk assessment for those pollutants listed on the AB 1807 and EPA NESHAPs lists (Table 10-2), toxic air contaminants of concern for acute exposure (Table 10-5), and data from District Rule 1401 and the AB 2588 program

10.6 Air Quality Modeling Tools

Table 10-3 lists the air dispersion models recommended by the District for use in performing risk assessments. This list is consistent with the CAPCOA-recommended models. The most recent version of these models should be used. The CAPCOA *Air Toxics Hot Spot Program Risk Assessment Guidelines* should be consulted prior to performing any dispersion modeling.

References

Procedures for Preparing Risk Assessments to Comply with Air Toxics Rules of the South Coast Air Quality Management District. Available from the District's Public Information Center.

Air Toxics "Hot Spots" Information and Assessment Act of 1987. California Health and Safety Code Section 44300 *et seq.*

Air Toxics "Hot Spots" Program Risk Assessment Guidelines. California Air Pollution Control Officers Association (CAPCOA); updated yearly. Available from CAPCOA for fee, (916) 676-4323.

Air Toxics Assessment Manual. California Air Pollution Control Officers Association (CAPCOA); 1987.

Toxic Air Contaminants (Chapter 3.5). California Health and Safety Code Section 39650 *et seq.*

Guideline on Air Quality Models (Revised). U.S. Environmental Protection Agency; 1986. EPA-450/2-78-027R.

District Regulation 14. Rules and Regulations. Available from the District's Public Information Center.

California Air Resources Board prepares documents for each specific AB 1807 toxic air contaminant which is identified. These documents are available from ARB. Contact the ARB's Public Information Office at (916) 322-2990.

User guides for each particular air dispersion model are available and should be used with the appropriate model. These manuals are available from U.S. EPA.

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Figure 10-1. Toxic Air Quality Analysis Flow Chart

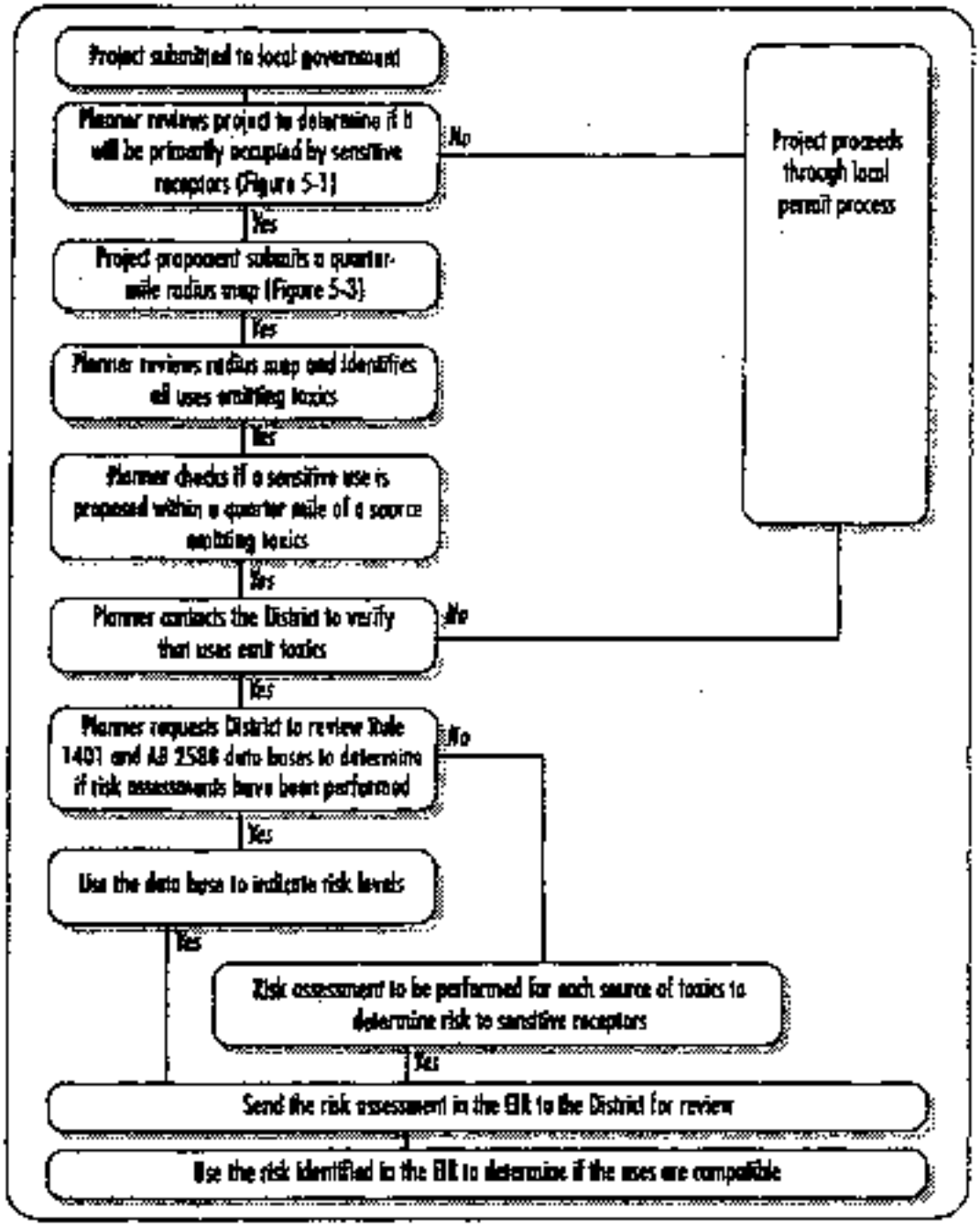

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Table 10-1. Toxics Analysis Overview

Routine Releases of Toxic Air Contaminants	Accidental Releases
• Carcinogenic compounds • Compounds of concern for non-cancer health effects from chronic exposure • Compounds of concern for acute exposure	• Compounds of concern for acute exposure from accidental release

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Table 10-2. Toxic Air Contaminants Identified Under AB 1807 and Federal NESHAPs

Acetaldehyde	Combustion of fuel from mobile sources, agricultural burning, wildfires
Asbestos	Manufacturing of brakes, acoustic ceiling tiles, gaskets, brake shoe rebuilders and recyclers
Benzene	Constituent of gasoline; used in organic chemical manufacturing, pharmaceuticals, food processing
1,3-Butadiene	Incomplete combustion of petroleum-derived fuels, petroleum refining, certain fumigant production and styrene-butadiene copolymer production
Cadmium	Secondary smelters; cement manufacturing plants; cadmium electroplating facilities; oil or coal burning; sewage sludge incinerators
Carbon Tetrachloride	Use of pesticides; production of fluorocarbon, chlorinated paraffin wax, and carbon tetrachloride
Chlorinated Dioxins and Dibenzofurans	Manufacture of chemicals such as pesticides and wood preservatives; manufacture of PCBs, solid waste incinerators
Chloroform	Manufacture of fluorocarbon 22 refrigerants and fluoropolymers; manufacture of pharmaceuticals, laboratory use; water chlorination (POTWs); air stripping towers, chemical manufacturing cooling towers; pulp bleaching in paper manufacturing
Chromium VI	Chrome plating, combustion of oil, coal, municipal waste and sewage sludge, used in production of chromium chemicals and paints
Ethylene Dibromide	Pesticide and solvent use; chemical feed stock for dye; manufacturing of pharmaceuticals
Ethylene Dichloride	Manufacture of vinyl chloride, solvents, paints, varnish, and finish removers; metal degreasing, soaps and scouring compound

(Continued on next page)

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Table 10-2. Toxic Air Contaminants Identified Under AB 1807 and Federal NESHAPs (continued)

Ethylene Oxide	Sterilization; fumigation; surfactant manufacturing; ethylene oxide distribution
Formaldehyde	Manufacture of resins, rubber and paper products, dyes, plastics and cosmetics; chemical sterilant, leather tanner, plating, preservative, embalming fluid and fumigant; fuel combustion
Inorganic Arsenic	Pesticide use; herbicide use, arsenic mining; cement, glass, and chemical manufacturing; agricultural burning; waste incineration; secondary lead smelting
Methylene Chloride	Food processing; manufacturing of paint removers, aerosols, degreasers, polyurethane foam, electronics, chemical, and pharmaceuticals
Trichloroethylene	Polyvinylchloride production; adhesive, painting, and coating operation; refrigerant and heat exchange operations; solvent applications; land POTWs; ground aeration; air strippers
Nickel	Production of polyvinylchloride for plastic products, fabrication facilities; landfills; POTWs
Perchloroethylene	Dry cleaning; degreasing, paint, coatings, adhesives, aerosols and chemical production; printing operations
Vinyl Chloride	Asbestos mining and milling; secondary smelting; solid waste and sewage sludge incineration; electroplating and electrical equipment manufacturing; cement manufacturing

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Table 10-3. District-Recommended Models for Risk Assessments

Application	Source (Type)	Land Use	Model
Flat	Point, Area[2]	Rural, Urban	ISC2
Complex	Point	Rural	COMPLEX1, RTDM
		Urban	COMPLEX1, SHORTZ
	Area[2]	Rural, Urban	ISC2

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Table 10-4. Acutely Hazardous Materials

Acetone cyanohydrin	Trans-1,4-dichlorobutene	Nickel carbonyl
Acrolein	Dichloroethyl ether	Nitric acid
Acrylonitrile	Dimethyldichlorosilane	Nitric oxide
Acryloyl chloride	Dimethylhydrazine	Nitrobenzene
Allyl alcohol	Dimethyl phosphorochloridothioate	Parathion
Allylamine	Epichlorohydrin	Peracetic acid
Ammonia (anhydrous)	Ethylenediamine	Perchloromethylmercaptan
Ammonia (aqueous solution, conc. ≥20%)	Ethylenimine	Phenol (liquid)
Aniline	Ethylene oxide	Phosgene
Antimony pentafluoride	Fluorine	Phosphine
Arsenous trichloride	Formaldehyde	Phosphorous oxychloride
Arsine	Formaldehyde cyanohydrin	Phosphorous trichloride
Benzal chloride	Furan	Piperidine
Benzenamine, 3-(trifluoromethyl)-	Hydrazine	Propionitrile
Benzotrichloride	Hydrochloric acid (solution, conc. ≥20%)	Propyl chloroformate
Benzyl chloride	Hydrocyanic acid	Propyleneimine
Benzyl cyanide	Hydrogen chloride (anhydrous)	Propylene oxide
Benzyl trichloride	Hydrogen fluoride	Pyridine, 2-methyl-5-vinyl-
Boron trifluoride	Hydrogen peroxide (conc. ≥52%)	Sulfur dioxide
Boron trifluoride compound with methyl ether (1:1)	Hydrogen selenide	Sulfuric acid
Bromine	Hydrogen sulfide	Sulfur tetrafluoride
Carbon disulfide	Iron, pentacarbonyl-	Sulfur trioxide
Chlorine	Isobutyronitrile	Tetramethyllead
Chlorine dioxide	Isopropyl chloroformate	Tetranitromethane
Chloroethanol	Lactonitrile	Thiophenol
Chloroform	Methacrylonitrile	Titanium tetrachloride
Chloromethyl ether	Methyl bromide	Toluene 2,4-diisocyanate
Chloromethyl methyl ether	Methylene chloride	Toluene 2,6-diisocyanate
Crotonaldehyde	Methylene chloroformate	Toluene diisocyanate (unspecified isomer)
Crotonaldehyde (E)-	Methyl hydrazine	Trichloroethylsilane
Cyanogen chloride	Methyl isocyanate	Trimethylchlorosilane
Cyclohexylamine	Methyl mercaptan	Vinyl acetate monomer
Diborane	Methyl thiocyanate	Vinyl chloride
	Methyltrichlorosilane	

Acutely hazardous substances are substances which pose a risk of causing death, injury, or serious adverse effects to human health or the environment if released short-term as accidental releases. Listed in the table are substances commonly in use within the Army which may pose a serious health hazard during a short-term or accidental release.

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Table 10-5. Toxic Air Contaminants of Concern for Acute Exposure

Ammonia	Hydrogen Sulfide
Acrolein	Lead
Arsine	Maleic Anhydride
Benzyl Chloride	Inorganic Mercury
Carbon Tetrachloride	Methyl Chloroform
Chlorine	Methylene Chloride
Copper and Compounds	Nickel Compounds
1,4-Dioxane	Nitrogen Dioxide
Ethylene Glycol Methyl Ether	Ozone
Ethylene Glycol Ethyl Ether	Perchloroethylene (Tetrachloroethylene)
Ethylene Glycol Monoethyl Ether Acetate	Phosgene
Ethylene Glycol Monobutyl Ether	Propylene Oxide
Formaldehyde	Selenium
Hydrochloric Acid	Sodium Hydroxide
Hydrogen Cyanide	Sulfates
Hydrogen Fluoride	Sulfur Dioxide
	Xylenes

Listed in this table are substances commonly found within the Basin which may pose an acute health hazard during reported short-term releases.

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[redacted]

[redacted]

MITIGATING THE IMPACT OF A PROJECT

CHAPTER 11

CEQA requires public agencies to take responsibility for protecting the environment. In regulating public or private projects, agencies are expected to avoid or minimize environmental damage. The purpose of an EIR is to identify the significant effects of a project on the environment, identify alternatives to the project, and indicate the manner in which significant impacts can be mitigated or avoided (PRC Section 21002.1). CEQA further states that a public agency should not approve a project as proposed, if there are feasible alternatives or mitigation measures that would substantially lessen any significant effects on the environment (unless all feasible mitigation has been applied and overriding considerations are made pursuant to CEQA Guidelines Section 15093).

If the impacts cannot be mitigated below the significance threshold, they must nevertheless be reduced. CEQA describes various types of mitigation as follows:

(a) Avoiding the impact altogether by not taking a certain action or part of an action

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation

(c) Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action

(e) Compensating for the impact by replacing or providing substitute resources or environments

Section 15041 (a) of the State CEQA Guidelines states that the lead agency has the authority to require changes in any or all activities involved in a project in order to lessen or avoid significant effects on the environment. With regard to any aspects of a project over which the District acts as a responsible agency, the District has the authority to also require that changes be made to those aspects of the project over which the responsible agency has authority. The District as a commenting agency has a duty to recommend mitigation to lessen air quality impacts as the local agency responsible for air quality.

Mobile source emissions in the SCAB and construction-related PM10 emissions in the Coachella Valley are of particular concern to the District. In addition to CEQA requirements, mitigation of impacts are necessary to achieve the federal and state ambient air quality standards. Specifically, all future sources of emissions, including those associated with land development, must be mitigated to the greatest extent possible to expeditiously achieve ambient air quality standards.

11.1 Overview of Mitigation Measures

This chapter contains a menu of mitigation measures that project proponents and local governments can use to select those measures that are feasible to mitigate the project's impact. According to CEQA Guidelines Section 15364, feasible means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors. Lead agencies are responsible for determining the feasibility of mitigation measures. In instances where a project has a significant impact, CEQA requires that feasible mitigation measures be applied to the project in order to reduce cumulative impacts and to reduce individually significant impacts (Section 9.5, Chapter 9). The District considers a project to be mitigated to a level of insignificance if its impact is mitigated below the thresholds in Chapter 6. Refer to Chapter 6 to determine when an impact is significant.

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A project which incorporates all feasible mitigation measures and/or CEQA options for mitigation (refer to CEQA Guidelines Section 15370 (a)(e)) is considered to have substantially mitigated air quality impacts pursuant to CEQA Guidelines Section 15093 (b). However, if the project's emissions are still over the significance level and the agency decides to approve the project, the lead agency must prepare a Statement of Overriding Considerations pursuant to CEQA.

The Handbook establishes mitigation measures for reducing emissions associated with the construction and operation of a project. These lists are not exhaustive. Both lead agencies and project proponents are encouraged to identify and quantify additional mitigation measures appropriate to individual projects.

11.2 Criteria for Mitigation Measures

The project's net emissions will determine the impact that the project will have after mitigation measures are applied. Net project emissions are determined by subtracting the emission reductions due to mitigation measures from the total project emissions. The District recommends that only mitigation measures which meet the following criteria (which are summarized in Table 11-1) can be used in calculating a project's emission reductions to determine if the project could have a significant air quality impact.

1. **The effect of the mitigation measures should coincide with the cause of the impact.**

Mitigation measures should be linked to the phase of construction or operation that is generating the impact to be mitigated. Project proponents should implement the mitigation measure in concert with the activity that will generate the impact. For example, if the emissions caused by idling vehicles exiting a congested parking lot are mitigated by the institution of a staggered work schedule, that work schedule should commence when the project is initially occupied. In some cases, interim mitigation measures will need to be implemented until the final mitigation is in place (i.e., transit line to be built at a later date, serving as mitigation).

Large projects that have several construction and operational phases should be linked to the particular phase that creates the impact that the measures are mitigating. In addition, if the project is to be developed in phases and it is determined that mitigation measures need to become progressively more stringent in order to reduce emissions, standards that act as triggers should be identified. For example, a predetermined number of trips generated by the project could serve as a trigger for requiring the implementation of a shuttle service at a shopping center.

2. **The agency responsible for implementing the mitigation measures should have the resources to carry out the mitigation.**

When ensuring that the mitigation measures will be implemented, it is imperative that the financial resources be available to carry out the mitigation measures. It is particularly important to demonstrate the availability of funding where the mitigation involves capital expenditures. In most cases, the project proponent can demonstrate financial resources for capital improvements by, for example, posting a bond or entering into an enforceable development agreement with the local government.

3. **To ensure implementation and enforcement, the mitigation should be enforceable by a legally binding commitment.**

Mitigation measures should meet the test of enforceability. Agencies can utilize mechanisms such as recording the conditions of approval (including the mitigation measures) on the property title, including conditions in developer agreements, posting bonds, adopting a local ordinance, drawing up a legal agreement between the project proponent and the jurisdiction to implement the measures or by placing phasing requirements on projects to assure a measure is in place before the next stage of a project proceeds. It is the responsibility of the lead agency to determine the appropriate mechanism. For public projects, lead agencies should request a verification by the responsible public agency that the public improvement will be constructed in time to reduce the impact.

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4. The mitigation measures should define the basis for their monitoring and enforcement.

Assumptions used to quantify the effectiveness of the mitigation measure should be used as the basis to determine implementation. For example, if a telecommunications program is used as a mitigation measure to reduce ROC emissions from work trips, the assumptions (e.g., that one percent of the work force will work at home each day) used in quantifying its effectiveness should become the basis for determining whether or not a mitigation measure is being implemented.

Quantitative standards should be used whenever possible. If it is not possible to quantify the mitigation measure, qualitative standards are appropriate. Only when all quantitative mitigation measures reasonably available to the project have been applied should qualitative measures be used. More details on use of qualitative analyses are provided in Section 11.9.

5. The mitigation measure can be reasonably accomplished within a reasonable time frame by the project proponent.

The lead agency should determine that the mitigation measures selected are reasonable, that targets can be met within the stated time frame, and that the measures to be taken are within the project proponent's legal authority. Interim targets should be established for mitigation measures that have a long lead time (more than five years).

6. Public agencies should verify the effectiveness assumed for any public improvements or permitting requirements that are used as mitigation measures.

If mitigation measures are to be implemented by an agency other than the lead agency or the project proponent, the responsible agency should verify the ability of the measure to reduce the project emissions. The following questions should be asked to ascertain the validity and effectiveness of the measure:

(1) What is the effectiveness of the improvement or permitting requirement in reducing the impact?

(2) During what time frame will the measure be implemented?

(3) Is constrained funding available for public improvements (i.e., federal, state, or local commitment to provide the funds)?

(4) Is the project proponent seeking a permit subject to the permitting requirements?

For example, if a project will generate fewer vehicle trips and therefore less emissions after the development of a rail transit line, then before the reductions can be credited, the county transportation commission should be consulted through the CEQA review process. The effectiveness of the rail line for reducing trips should also be ascertained: Are trips being reduced within the same time frame assumed for the project? Have federal, state, or local funds been set aside for the improvement?

For most transportation improvements, planners can consult with the county transportation commission. If a transportation improvement is not in the biennial element of the Regional Transportation Improvement Program (RTIP) or identified in the Regional Mobility Plan as having funding, it should not be used as a quantifiable mitigation measure, unless the transportation improvement will be privately funded through a development agreement enforceable against the project proponent.

11.3 Mitigation Measures Related to Construction

In many cases, the largest impact on air quality by land use projects is from emissions produced by construction. Construction emissions are often dismissed as short term impacts and not examined as thoroughly as are emissions associated with the long term operation of the project. Emissions from construction, however, can be significant. Because widespread growth is anticipated in the SCAB along with corresponding increases in construction activity, mitigating the impact of construction on air quality should be emphasized. For example, grading one acre of land without implementation of

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mitigation measures can contribute 55 pounds of PM10 a day. The PM10 problem in the Coachella Valley is largely caused by wind-blown dust in the desert areas. However, the second largest source of PM10 is from construction activities.

The District's Rule 403 governs construction projects and other fugitive dust-generating activities. Rule 403 is primarily based on emission standards and does not contain project-specific mitigation measures. As such, Rule 403 should be considered as a performance standard to any specific mitigation measures required for any proposed project. Copies of Rule 403 and its Implementation Handbook can be obtained from the District's Public Information Center at (909) 396-3600.

The mitigation measures to reduce air quality impacts of construction, demolition, or renovation activities are identified in Tables 11-2, 11-3, and 11-4. Mitigation measures are categorized by the source of emissions to be reduced. The percentage of emission reductions that can be expected from implementation of mitigation measures is identified as that measure's control efficiency. The estimated efficiencies represent the percent reduction in emissions anticipated from one of three source categories from a project's construction activities (on-road mobile sources, off-road mobile sources, and PM10 emissions). Efficiencies may differ for each pollutant depending on the mitigation measure, emission source, and specific process affected. Wherever possible, a range of likely efficiencies are provided. Using any efficiencies within this range should be supported by reviewing: a) the favorable factors listed for each mitigation measure in Appendix 11, and b) the packaging guidance in Section 11.10. Additional justification can also be presented by the air quality analysis. The assumptions that were used to determine these efficiencies are in Appendix 11. The assumptions (i.e., actions and/or setting) used in determining the control efficiency of the mitigation measure should become the basis for determining whether or not a mitigation measure is implemented. Where there are no control efficiencies identified, a qualitative evaluation is appropriate. See Section 11.9 for more details on performing a qualitative analysis.

The efficiencies listed in Tables 11-2, 11-3, and 11-4 along with the assumptions in Appendix 11, represent data from case studies and reports, sources of which are referenced at the end of this Chapter. In some cases, data for particular mitigation measures was unavailable. As such, these measures may be quantified in the future as more programs are implemented and monitored for results. Other quantified data are subject to change as new information becomes available. In addition, these anticipated reductions are representative of conditions in the South Coast Air Basin and portions of SEDAB under the jurisdiction of the District and as such may not be applicable to other air basins.

Planners may use one of two methods to quantify construction mitigation measures: (1) the control efficiencies provided in screening Tables 11-2, 11-3, and 11-4; or (2) quantification calculation procedures described in Appendix 11. The control efficiencies in the screening tables are based on region-wide data and assumptions, and should be applied to the appropriate source category of unmitigated emissions (refer to Chapter 9) to determine net emissions. Other sources of emissions should be identified as appropriate for the project using the information in Appendix 11 and added to the final total of unmitigated project emissions. An example of how to account for emissions by pollutant and source category is provided in Table 11-9.

Figure 11-1 provides a graphic illustration of the process used to identify a project's unmitigated emissions using the screening tables. As is shown in the shaded portion of the figure, once a project's unmitigated emissions have been calculated, quantified mitigation measures can be applied to reduce the potential air quality impact. Step-by-step instructions for using the screening tables to determine unmitigated emissions are described in Table 11-1. These instructions correspond with the unshaded portion of Figure 11-1. Appendix 11 identifies calculation procedures, emission factors, and assumptions necessary to determine the effectiveness of various mitigation measures and thus to determine project specific reductions in emissions.

An example of a summary table that can be used to determine net project emissions is provided in Table 11-5. Information provided in a similar format should be included in the EIR.

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11.4 Mitigation Measures Related to Operation

Emissions resulting from operation of a project are critical because these impacts continue throughout the life of the project. It is important to remember that even in those cases where the emissions related to operation are less than construction-related impacts, the operational emissions create long-term impacts on air quality.

District-recommended mitigation measures to reduce air quality impacts of operational activities are identified in Tables 11-6 and 11-7, in addition to the design-related mitigation measures which were identified in Table 5-5. The mitigation measures are categorized by land use and by the emission sources within each land use category. The percentage of emission reductions that can be expected from implementation of mitigation measures is identified as that measure's control efficiency. The estimated efficiencies represent the percent of reduction in emissions anticipated from one of two source categories associated with the project's operations activities (on-road mobile sources or stationary sources). Efficiencies may differ for each pollutant depending on the mitigation measure, emission source, and specific process affected. Wherever possible, a range of likely results is provided. Using any efficiencies within this range should be supported by reviewing: a) the favorable factors listed for each mitigation measure in Appendix 11, and b) the packaging guidance in Section 11.10. Additional justification can also be presented by the air quality analysis. The assumptions used in determining these efficiencies are in Appendix 11. The assumptions (i.e., actions and/or setting) used in determining the control efficiency of the mitigation measure should become the basis for determining if a mitigation measure is implemented. Where there are no control efficiencies identified, a qualitative evaluation is appropriate. See Section 11.9 for more details on performing a qualitative analysis.

The efficiencies listed in Table 11-6 and 11-7, along with the assumptions in Appendix 11, represent data from case studies and reports, sources of which are referenced at the end of this Chapter. In some cases, data for particular mitigation measures was unavailable. As such, these measures may be quantified in the future as more programs are implemented and monitored for results. Other quantified data are subject to change as new information becomes available. In addition, these anticipated reductions are representative of conditions in the South Coast Air Basin and portions of the SEDAB under the District's jurisdiction and as such may not be applicable to other air basins.

Furthermore, any site plan design and building design mitigation measures identified in Section 5.5 that are already incorporated into the project should be quantified if possible or should be qualitatively discussed. See Section 5.5 for further discussion of design-related mitigation measures and Section 11.8 for caveats in using such measures as quantifiable mitigations.

There are three methods planners can employ to quantify operation mitigation measures: (1) the control efficiencies provided in screening Tables 11-5 and 11-6; (2) the quantification calculation procedures described in Appendix 11; or (3) the MAAQI model. The control efficiencies in the screening tables are based on region-wide data and assumptions and should be applied to the appropriate source category of unmitigated emissions (refer to Chapter 9) to determine net emissions. Examples of how to use the screening tables are discussed in Section 11.3. Appendix 11 identifies calculation procedures, emission factors, and assumptions necessary to determine the effectiveness of various mitigation measures to determine project specific reductions in emissions. The MAAQI model can also be used to quantify mitigation measures. This model can determine net emissions either based on pre-set mitigation measures that rely on county averages, or planners can input project specific data to determine efficiency. Chapter 9 provides additional discussion on the MAAQI model. In addition, the District's MAAQI model manual may be consulted.

In addition, many models and studies have identified procedures for analyzing transportation control measures, and estimating travel and emission effects of implementing transportation control measures. These resources provide more complex methodologies for determining a mitigation measure's effectiveness and can be used in lieu of the simplified approaches in this Handbook.

A summary table that can be used to determine net project emissions is provided in Table 11-8. Information provided in a similar format should be included in the EIR.

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11.5 Other Mitigation Measures

Project proponents and local planners are also encouraged to identify other types of mitigation not suggested in this Handbook or in the 1991 AQMP. Local governments and project proponents are often in the best position to identify unique mitigation measures. For example, in an urban area, a community may have designated an extensive network of bicycling paths. This community could require access, dedications for future bicycle pathways and support facilities (e.g., showers, lockers, and storage areas) to encourage travel by bicycles rather than by automobile. Such specific mitigation for the community is best developed at the local level.

As with the other mitigation measures, the EIR should quantify the effectiveness of unique mitigation measures whenever possible. In those instances where quantification is not possible, a qualitative analysis should be provided. Lastly, the assumptions used to determine the effectiveness and the source from which estimates were obtained should be identified and the guidelines for preparing such an analysis in Section 11.9 consulted.

11.6 Mitigation for Cumulative Impacts

The District recommends that all cumulatively significant projects apply feasible mitigation measures to a project's contribution to reduce region-wide cumulative impacts. Refer to Chapter 11 for an identification of mitigation measures and the potential for emissions reductions.

11.7 Off-Site Mitigation

A project with a significant air quality impact may be able to mitigate the impact below the threshold of significance by reducing emissions off-site through off-site improvements. Off-site emissions reductions can come either from stationary or mobile sources. For example, NOx emissions from vehicle trips could be reduced by installing solar water heaters in a residential development. The off-site mitigation measures should meet the same standards as on-site mitigation, and be enforceable and quantifiable. The emission reductions resulting from off-site mitigation can only be credited within the same pollutant. Reducing emissions for one pollutant and crediting it to another is not permissible.

Off-site improvements can include the following:

Park-and-ride lots
HOV bypass lane
Class 1 bike path
Transit shelters and benches
Contributions to transit
HOV capital improvements
Clean fuel dispensing station
Contributions to a local shuttle service
Purchase of clean fuel vehicle for another facility
Purchase of clean fuel transit buses
Purchase of CNG school buses

11.8 Quantification Issues

There are four key issues relating to quantifying emission reductions that planners need to consider. These involve adding the emission reductions for different mitigation measures to determine net emissions associated with the project; selecting efficiencies for mitigation measures; determining whether the assumptions used to determine the effectiveness of the mitigation measures are reasonable; and determining emission reduction credits for site plan and building design mitigation measures.

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Adding Emission Reductions. In order to determine net emissions for a project, the emission reductions attributed to each mitigation measure applied to the project need to be subtracted from the project's unmitigated emissions. The screening tables in Chapters 9 and 11 have been developed in such a way that planners can apply the efficiencies from mitigation measures identified in the tables in Chapter 11 to the project's emissions that are derived by using the tables in Chapter 9. Mitigation measures have been divided into five source categories to correspond with the five source categories listed in the Chapter 9 screening tables. These include three source categories for construction mitigation:

- o On-road mobile emissions associated with construction work trips (Table 11-2)
- o Off-road mobile emissions associated with construction equipment (Table 11-3), and
- o PM10 emissions from grading, etc. (Table 11-4);

and two source categories for operation mitigation:

- o On-road mobile emissions associated with vehicle trips (Table 11-6)
- o Area source emissions associated with energy consumption (Table 11-7).

The percentage efficiency for any mitigation measure in Tables 11-2 through 11-7 should be applied to the corresponding source category table in Chapter 9 (Tables 9-1 through 9-4 and 9-7, 9-8). The resulting emission reductions should be subtracted from the unmitigated emissions derived in Chapter 9.

The efficiencies in each of the five tables are generally additive, with the following exceptions:

1) Table 11-3 (Mitigation for Off-Road Mobile Source - Construction) assumes that only one of the four mitigation measures can be applied to any construction site;

2) Table 11-4 (Mitigation for PM10 Emissions - Construction) efficiencies apply when only one measure within a source category (e.g., grading, paved roads, or unpaved roads) is applied. If more than one mitigation measure within a source category is applied, the efficiency of the second measure must be adjusted to account for the reduction in unmitigated PM10 emissions from the first measure. To quantify this impact, see Table A11-9 of the Appendix to Chapter 11 for specific direction.

The same procedures can be used when quantifying unmitigated emissions using the methodologies in the Appendix to Chapter 9 and in quantifying emission reductions using the methodologies in the Appendix to Chapter 11.

Selecting Efficiencies. The screening tables that identify efficiencies for mitigation measures often provide a range of efficiencies. Planners should select efficiencies that best coincide with the on-site characteristics for the project as well as the community the project is located in. The low and high numbers represent the range of efficiencies planners can select from. Unless justified, the low end of the range should be used. Planners can use the favorable factors identified in Appendix 11 to justify a higher rate of efficiency. In addition, planners can use the guidance in Section 11.10 to select the higher end of the range when there may be synergistic effects between packages of mitigation measures and the low end when there may be neutral or conflicting effects. Finally, a third criterion should be considered when applying mobile source mitigation measures in Table 11-6, where the ranges of effectiveness also reflect how much of a project's daily trip generation is due to the type of trip being mitigated. For example, a restaurant generates a significant number of daily vehicle trips, most of which are non-work (e.g., customer) trips. Consequently, a mitigation measure that reduces employee work trips is likely to reduce few trips relative to the facility's total daily trips. In such a case, the low

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end of the efficiency range is appropriate. On the other hand, a commercial office project's daily trips are largely work-related.

The two previous criteria noted above should be used to select a value within the efficiency range for all mitigation measures. For mitigation measures in Table 11-6, the trip generation criteria should also be considered as the primary criterion for selecting a value.

Assumptions. Another of the key quantification issues that planners face is determining whether or not the reduction in emissions assumed through the implementation of mitigation measures is "reasonable." The test of reasonableness depends on two primary factors: (1) the assumptions used in determining the reduction, and (2) the emission factors used to calculate the emissions. For mitigation measures identified in this Handbook, planners can refer to the mitigation measure effectiveness numbers in Tables 11-2, 11-3, 11-4, 11-6, and 11-7 to assess whether or not the percentage of reduction is reasonable.

In situations where planners are unsure of the reasonableness of assumptions, planners can confer with the District and/or make the assumptions enforceable. This can be accomplished by requiring that the assumptions used in determining the effectiveness, and thus the net impact of the project on air quality, are also used as the measurement of whether or not a mitigation measure has been implemented. For example, if it is assumed that five percent of the work trips to the site will be reduced through telecommuting, then the mitigation monitoring program should use the five percent participation rate as the indicator of whether a measure has been implemented pursuant to AB 3180.

Vehicle trips are generally the greatest source of emissions from the operation of a project. As such, the assumptions about trip reduction are critical to assessing the overall impact of a project on air quality. In particular, the use of transit as mitigation and assignment of future trips to transit and other modes of travel should be reviewed. It is important that projects depending on transit or other modes of travel to reduce vehicle trips use appropriate trip assignment percentages. A trip assignment percentage refers to that percentage of future trips projected to be made by a single occupant vehicle, carpool/vanpool, transit, walking, bicycling, etc. Transit agencies should verify that service is available and passenger capacity exists to support the assumptions. In addition, the number of trips to be mitigated through measures such as carpooling programs needs to be "reasonable."

Emission reductions for site plan and building design mitigation measures. While mitigation measures can be added to a proposed project, some mitigation may have already been incorporated into the site plan and/or building design (Section 5.5), and have become a part of the project's description.

These design measures can be credited for quantified emission reductions only if energy or mobile source credits were not already included in the project's non-mitigated analysis of impacts. For example, a development that will include bicycle shower and locker facilities may take credit for reducing vehicle trips in the traffic study of the environmental analysis. In turn, the calculation of the project's non-mitigated emissions may reflect such a design measure. However, additional credit may not be taken in the project's mitigation measure analysis, as the vehicle trip and emissions reductions would be double-counted.

11.9 Qualitative Analysis

In mitigating the air quality impacts of a development proposal, quantitative mitigation measures should be used to the extent possible to demonstrate reduction of emissions below thresholds of significance. However, not all effective mitigation measures can reasonably be quantified. Once all reasonably available mitigation measures have been applied to a project, it is appropriate to apply qualitative measures whose specific emission reductions are not known. Such a qualitative analysis can be used to further reduce air quality impacts of a project.

Qualitative mitigation measures can also be used to mitigate significant impacts to below the thresholds of significance identified in Chapter 6. In making such a finding, the air quality analysis should identify the rationale used to arrive at such a determination. Use of non-quantified mitigation measures to

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reduce significant amounts of emissions should be used with discretion, however, as many non-quantified measures are unlikely to produce substantial reductions.

An air quality analysis that describes the effectiveness of implementing non-quantified mitigation measures should address, but not be limited to, the following issues:

1. What is the source category (e.g., Work Trips, Energy Use, Congestion Relief) being affected and how significant are emissions from that category? For example, work commute trips constitute the majority of vehicular trips to office worksites. Mobile source emissions may in turn constitute the majority of total emissions from these land uses. Consequently, a mitigation measure that would reduce work commute trips to an office park has the potential to reduce a significant amount of vehicle trips and the corresponding emissions. Conversely, a mitigation measure that reduces energy use from swimming pools is likely to have a much smaller emissions reduction potential.

2. What are the pollutants affected by the emission source category? For each source category, measures reduce ROC, CO, NOx, PM10, and SOx to varying degrees. For example, energy use primarily generates NOx emissions while construction grading and demolition creates significant levels of PM10. Consequently, a mitigation measure that reduces emissions from demolition and grading activities during the construction phase may reduce substantial amounts of PM10 but is unlikely to reduce substantial levels of ROC, CO, NOx, or SOx. The qualitative analysis should identify the pollutants associated with the emission source category and draw conclusions accordingly.

3. Are there favorable factors associated with a mitigation measure? As with the quantified mitigation measures, the success of any mitigation measure is largely dependent on the project setting. This can include site-specific conditions and/or characteristics in the local vicinity. Favorable factors can improve the effectiveness of a mitigation measure and facilitate greater emission reductions. The analysis should identify all those factors which are likely to produce more favorable results.

4. Are any of these measures, when combined with other proposed mitigation, likely to complement or impact the effectiveness of any other measures? Some combinations of measures can produce synergistic or non-complementary reactions that increase or decrease the effectiveness of the actions. The analysis should identify whether the qualitative mitigation measures are likely to produce such reactions with other measures and identify potential impacts (See Section 11.10 below).

11.10 Packaging of Mitigation Measures

In many cases the most effective way to reduce a project's impact is to package mitigation measures. In selecting a package of mitigation measures, a lead agency and/or project proponent takes into account several criteria, including the nature of the significant impact requiring mitigation, those measures that are most reasonable and cost-effective, and the applicability of the measures to the project.

Another important criterion for packaging should be to combine mitigation measures that will improve and maximize their aggregate effectiveness. While Tables 11-2, 11-3, 11-4, 11-6, and 11-7 attempt to quantify the effectiveness of isolated mitigation measures, the actual effectiveness of many measures is affected by other measures within the same source category that are implemented as part of a package. Mitigation measures can complement one another or detract from their individual effectiveness depending on upon site-specific and local conditions. The ways in which mitigation measures interact can be divided into three basic groups: Neutral, Synergistic, and Non-Complementary.

Neutral measures. These measures exhibit no change in effects when combined. Neutral actions generally fall into two categories: combinations that address different sources of emissions and combinations that affect different targets within a source of emissions. For example, mitigation measure from one source of emissions such as energy reduction are most likely to have a neutral affect on another source that reduces vehicle trips to the site. In addition, two neutral measures can target different markets within the same source of emissions without affecting the effectiveness of each such as when some mitigation measures target work trips and other measures target non-work trips.

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Synergistic measures. These measures are complementary to the extent that the combined effects are greater than the sum of the effects if the two measures were implemented separately. For example, incorporating a mitigation measure that provides an on-site transit stop is more effective when discounted transit passes are provided to employees. These measures should be the primary focus of packaging efforts. At the present time, there are no procedures for providing extra emission reductions for these types of packages, however by packaging measures that have synergistic effects the likelihood of the measures successfully mitigating the impact is increased.

Non-complementary measures. These measures reduce the effectiveness of one another when combined. When implemented together, the combined efficiency in reducing emissions is less than the sum of the benefit in implementing each measure individually. For example, measures that address the same target market as in the case of seeking to reduce the number of work trips to a site by encouraging telecommuting and compressed work schedules (e.g. working 40 hours in 4 days) could result in less emission reductions than if the telecommuting measure was packaged with ridesharing incentives.

Steps for Developing Effective Packages of Mitigation Measures. In selecting and evaluating a package of mitigation measures, planners and/or project proponents should consider the following steps:

1. Identify those mitigation measures that will have neutral effects on the remainder of measures in the proposed package. For these measures, estimate the emission reduction efficiency assuming that the packaging will not affect the effectiveness of these mitigation measures.

2. Identify whether the package includes combinations of measures that are potentially non-complementary. Determine if this package of mitigation measures is likely to result in less emission reductions due to the conflict. If so, revise the package to reduce the conflict.

3. Identify whether the package includes combinations of measures that are potentially synergistic. For synergistic mitigation measures, it may be appropriate to base the effectiveness on the higher end of the range if the project site and community are consistent with the favorable factors identified for each measure in Appendix 11.

References

Transportation Control Measure Analysis Procedures, Final Report, Systems Applications International for ARB, November 25, 1991.

Estimating Travel and Emission Effects of TCMs, System Applications International for EPA, September 30, 1991.

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Figure 11-1. Flow Chart for Applying Mitigation Measures

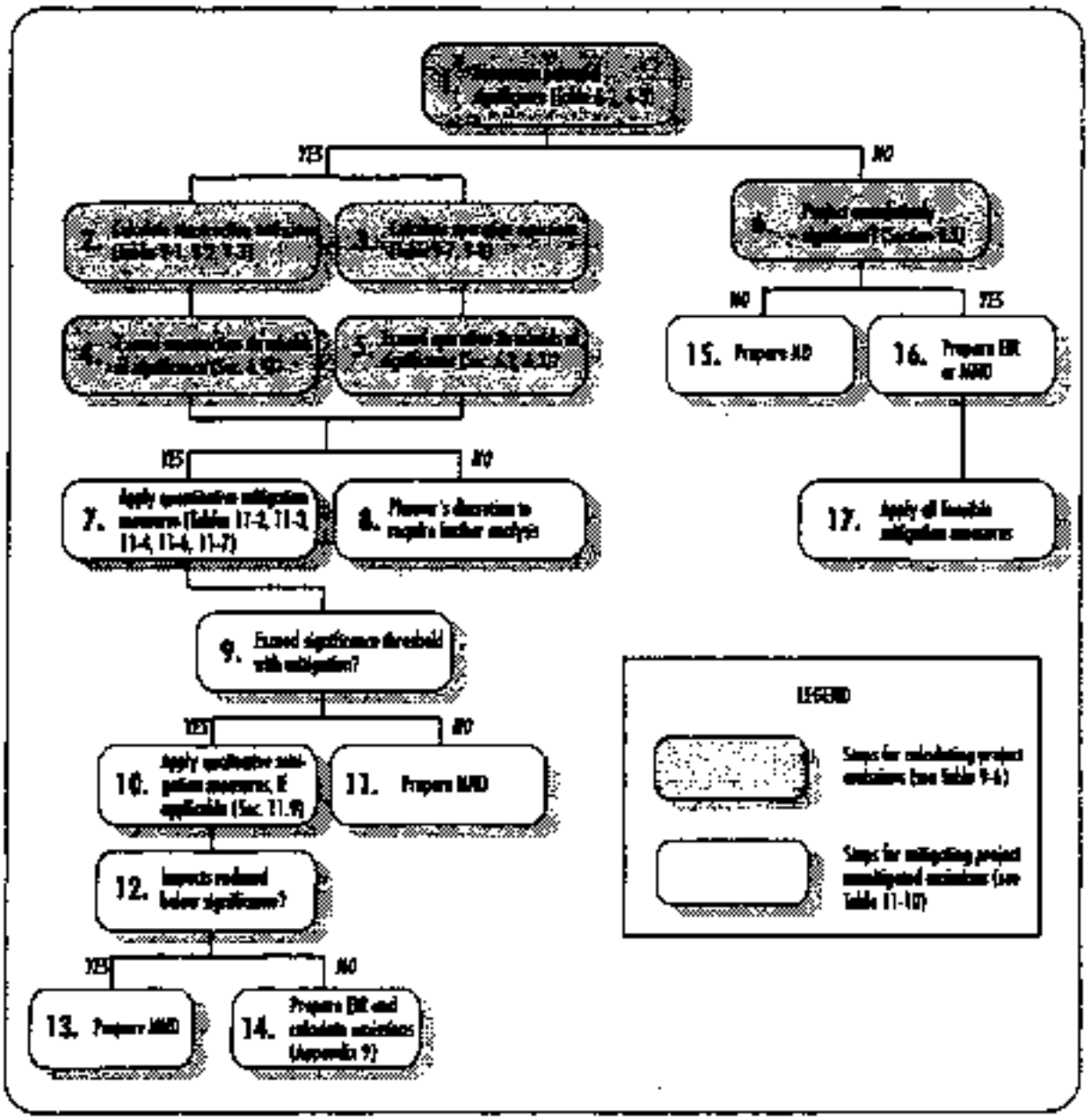

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Table 11-1. Criteria for Mitigation Measures

1. Implementation of mitigation should coincide with environmental impact.
2. Adequate resources should be available to ensure implementation of mitigation.
3. Mitigation should be enforceable by a legally binding commitment.
4. Standards should be defined for monitoring and enforcing mitigation.
5. Mitigation should be able to be reasonably accomplished within a reasonable timeframe.
6. Public projects and other agencies' permit conditions should be verified when identified as mitigation.

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Table 11-2. Mitigation for On-Road Mobile Source Emissions - Construction

• Configure construction parking to minimize traffic interference	NQ			
• Provide temporary traffic control during all phases of construction activities to improve traffic flow (e.g., flag person)	NQ			
• Schedule construction activities that affect traffic flow to off-peak hours (e.g., between 7:00 p.m. and 6:00 a.m. and between 10:00 a.m. and 3:00 p.m.)	NQ			
• Develop a trip reduction plan to achieve a 1.5 AVR for construction employees	0.1-2.2%	0.1-2.9%	0.1-2.9%	0.1-2.9%
• Implement a shuttle service to and from retail services and food establishments during lunch hours	0.1-1.0%	0.1-1.3%	0.1-1.3%	0.1-1.3%
• Develop a construction traffic management plan that includes, but is not limited to:	NQ			
- Rerouting construction trucks off congested streets				
- Consolidating truck deliveries				
- Providing dedicated turn lanes for movement of construction trucks and equipment on- and off-site				
• Prohibit truck idling in excess of two minutes	NQ			

* These efficiencies represent additive reductions from unmitigated on-road mobile source construction emissions (Table 9-3). The resulting emission reductions can be subtracted from the unmitigated totals. These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

Where efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-3. Mitigation for Off-Road Mobile Source Emissions - Construction

• Methanol-fueled pile drivers	54%	+29%	25%	95%
• Suspend use of all construction equipment operations during second stage smog alerts. For daily forecast, call (800) 242-4022 (L.A. and Orange counties) or (800) 367-4710 (San Bernardino and Riverside counties)	NQ			
• Prevent trucks from idling longer than two minutes	NQ			
• Use electricity from power poles rather than temporary diesel power generators	99%	97%	98%	98%
• Use electricity from power poles rather than temporary gasoline power generators	99%	96%	99%	98%
• Use of methanol or natural gas on-site mobile equipment instead of diesel	54%	+29%	25%	95%
• Use of propane- or butane-powered on-site mobile equipment instead of gasoline	53%	+53%	96%	18%

* These efficiencies represent additive reductions from unmitigated on-road mobile source construction emissions (Table 9-1). The resulting emission reductions can be subtracted from the unmitigated totals. These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix H.

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Table 11-4. Mitigation for PM10 Emissions - Construction

GRADING				
• Apply non-toxic soil stabilizers according to manufacturers' specification to all inactive construction areas (previously graded areas inactive for ten days or more)				30-65%
• Replace ground cover in disturbed areas as quickly as possible				15-49%
• Enclose, cover, water twice daily or apply non-toxic soil binders according to manufacturers' specifications, to exposed piles (i.e., gravel, sand, dirt) with 5% or greater silt content				30-74%
• Water active sites at least twice daily				34-68%
• Suspend all excavating and grading operations when wind speeds (as instantaneous gusts) exceed 25 mph				NQ
• Monitor for particulate emissions according to District-specified procedures. For information, call (714) 396-3600.				NQ
• All trucks hauling dirt, sand, soil, or other loose materials are to be covered or should maintain at least two feet of freeboard (i.e., minimum vertical distance between top of the load and the top of the trailer) in accordance with the requirements of CVC Section 23114				7-14%
PAVED ROADS				
• Sweep streets at the end of the day if visible soil material is carried onto adjacent public paved roads (recommend water sweepers with reclaimed water)				25-60%
• Install wheel washers where vehicles enter and exit unpaved roads onto paved roads, or wash off trucks and any equipment leaving the site each trip				40-70%

NQ = Not Quantified

* These efficiencies represent additive reductions from unmitigated PM10 construction emissions (Table 9-3). The resulting emission reductions can be subtracted from the unmitigated subtotals (Unpaved Road, Paved Road, Demolition, Grading, Asbestos). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

** Additive reductions: Reductions in emissions obtained from one source category, then added to that from another source category.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-4. Mitigation for PM10 Emissions - Construction (continued)

UNPAVED ROADS				
• Apply water three times daily, or non-toxic soil stabilizers according to manufacturers' specifications, to all unpaved parking or staging areas or unpaved road surfaces				45-85%
• Traffic speeds on all unpaved roads to be reduced to 15 mph or less				40-70%
• Pave construction roads that have a traffic volume of more than 50 daily trips by construction equipment, 150 total daily trips for all vehicles				92.5%
• Pave all construction access roads at least 100 feet on to the site from the main road				92.5%
• Pave construction roads that have a daily traffic volume of less than 50 vehicular trips				92.5%

* These efficiencies represent additive reductions from unmitigated PM10 construction emissions (Table 9-2). The resulting emission reductions can be subtracted from the unmitigated subtotals (Unpaved Road, Paved Road, Demolition, Grading, Asbestos). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

– Additive reductions: Reductions in emissions obtained from one source category, then added to that from another source category.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-5. Identifying Net Construction Emissions

Grading/ Demolition Fugitive Dust							
Fugitive Dust from Roads							
Construction Equipment							
Work Trips							
Non-Work Trips							
Truck Trips							
Energy Usage							
Traffic Impacts							
Unmitigated Emissions:							
Total Net Project Emissions:							

Key: Unmitigated Emissions / Mitigated Emissions

AR0072924

Table 11-6a. Mitigation for On-Road Mobile Source Emissions - Operation (Residential)

• Include satellite telecommunications centers in residential subdivisions	0.1-0.7%	0.1-0.9%	0.1-0.9%	0.1-0.9%
• Establish a shuttle service from residential subdivisions to commercial core areas	0.1-0.2%	0.1-0.3%	0.1-0.3%	0.1-0.3%
• Construct on-site or off-site bus turnouts, passenger benches, and shelters	0.2-1.9%	0.2-2.5%	0.2-2.5%	0.2-2.5%
• Construct off-site pedestrian facility improvements, such as overpasses and wider sidewalks	0.1-0.3%	0.1-0.4%	0.1-0.4%	0.1-0.4%
• Include retail services within or adjacent to residential subdivisions	1.0-4.0%	1.3-6.0%	1.3-6.0%	1.3-6.0%
• Provide shuttles to major rail transit centers or multi-modal stations	0.1-0.3%	0.1-0.5%	0.1-0.5%	0.1-0.5%
• Contribute to regional transit systems (e.g., right-of-way, capital improvements, etc.)	NQ			
• Synchronize traffic lights on streets impacted by development	4.0-8.0%	4.0-8.0%	4.0-8.0%	4.0-8.0%
• Construct, contribute, or dedicate land for the provision of off-site bicycle trails linking the facility to designated bicycle commuting routes	0.1-0.6%	0.1-0.8%	0.1-0.8%	0.1-0.8%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

Where efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

AR0072925

Table 11-6h. Mitigation for On-Road Mobile Source Emissions - Operation (Commerical)

• Provide preferential parking spaces for carpools and vanpools and provide 7'2" minimum vertical clearance in parking facilities for vanpool access	0.1-1.0%	0.1-1.3%	0.1-1.3%	0.1-1.3%
• Implement on-site circulation plan in parking lots to reduce vehicle queuing	NQ			
• Improve traffic flow at drive-throughs by designing separate windows for different functions and by providing temporary parking for orders not immediately ready for pickup	NQ			
• Provide video-conference facilities	NQ			
• Set up resident worker training programs to improve job/housing balance	NQ			
• Implement home dispatching system where employees receive routing schedule by phone instead of driving to work	Negl.	0.1%	0.1%	0.1%
• Develop a program to minimize the use of fleet vehicles during smog alerts (for businesses not subject to Regulation XV or XII)	NQ			
• Use low-emission fleet vehicles - TLEV - ULEV - LEV - ZEV	NQ			
• Reduce employee parking spaces for those businesses subject to Regulation XV	0.1-2.2%	0.1-2.9%	0.1-2.9%	0.1-2.9%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix H.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-6b. Mitigation for On-Road Mobile Source Emissions - Operation (Commerical) (continue

• Implement a lunch shuttle service from a worksite(s) to food establishments	0.4-1.5%	0.5-1.8%	0.5-1.8%	0.5-1.8%
• Implement compressed work-week schedules where weekly work hours are compressed into fewer than five days				
- 9/80	0.8-7.6%	1.0-10.0%	1.0-10.0%	1.0-10.0%
- 4/40	1.5-15.3%	2.0-20.0%	2.0-20.0%	2.0-20.0%
- 3/36	3.1-40.0%	4.0-40.0%	4.0-40.0%	4.0-40.0%
• Develop a trip reduction plan to achieve 1.5 AVR for businesses with less than 100 employees or multi-tenant worksites	0.1-2.2%	0.1-2.9%	0.1-2.9%	0.1-2.9%
• Utilize satellite offices rather than regular worksite to reduce VMT	0.1%	0.1-0.2%	0.1-0.2%	0.1-0.2%
• Establish a home-based telecommuting program	0.1-1.6%	0.1-2.1%	0.1-2.1%	0.1-2.1%
• Provide on-site child care and after-school facilities or contribute to off-site development within walking distance	0.1%	0.1-0.2%	0.1-0.2%	0.1-0.2%
• Require retail facilities or special event centers to offer travel incentives such as discounts on purchases for transit riders	ND			
• Provide on-site employee services such as cafeterias, banks, etc.	0.2-3.4%	0.3-4.5%	0.3-4.5%	0.3-4.5%
• Establish a shuttle service from residential care areas to the worksite	0.1-0.3%	0.1-0.5%	0.1-0.5%	0.1-0.5%
• Construct on-site or off-site bus turnouts, passenger benches, or shelters	0.1-1.0%	0.1-1.3%	0.1-1.3%	0.1-1.3%

- These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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AR0072927

Table 11-6b. Mitigation for On-Road Mobile Source Emissions - Operation (Commerical) (continued)

• Implement a pricing structure for single-occupancy employee parking and/or provide discounts to rideshorers	1.5-11.0%	2.0-15.5%	2.0-15.5%	2.0-15.5%
• Include residential units within a commercial project	3.1-13.7%	4.0-18.0%	4.0-18.0%	4.0-18.0%
• Utilize parking in excess of code requirements as on-site park-n-ride lots or contribute to construction of off-site lots	0.1%	0.1-0.2%	0.1-0.2%	0.1-0.2%
• Any two of the following:				
– Construct off-site bicycle facility improvements, such as bicycle trails linking the facility to designated bicycle commuting routes, or on-site improvements, such as bicycle paths	0.2-2.4%	0.3-3.2%	0.3-3.2%	0.3-3.2%
– Include bicycle parking facilities, such as bicycle lockers and racks	See Above			
– Include showers for bicycling employees' use	See Above			
• Any two of the following:				
– Construct off-site pedestrian facility improvements, such as overpasses, wider sidewalks	0.2-1.2%	0.2-1.6%	0.2-1.6%	0.2-1.6%
– Construct on-site pedestrian facility improvements, such as building access which is physically separated from street and parking lot traffic and walk paths	See Above			
– Include showers for pedestrian employees' use	See Above			
• Provide shuttles to major rail transit stations and multi-model centers	0.1-0.3%	0.1-0.5%	0.1-0.5%	0.1-0.5%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix H.

Where efficiency is provided as a range:
if project-specific efficiency is unknown, use the lowest number given;
if project-specific efficiency is utilized, provide supporting analysis and documentation.

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AR0072928

Table 11-6b. Mitigation for On-Road Mobile Source Emissions - Operation (Commercial) (continued)

• Contribute to regional transit systems (e.g., right-of-way, capital improvements)	NQ			
• Charge visitors to park	1.5-11.0%	2.0-15.5%	2.0-15.5%	2.0-15.5%
• Synchronize traffic lights on streets impacted by development	4.0-8.0%	4.0-8.0%	4.0-8.0%	4.0-8.0%
• Reschedule truck deliveries and pickups for off-peak hours	NQ			
• Set up paid parking systems where drivers pay on walkup kiosk and exit via a stamped ticket to reduce emissions from queuing vehicles	NQ			
• Require on-site truck loading zones	NQ			
• Implement or contribute to public outreach programs	NQ			
• Require employers not subject to Regulation XV to provide commuter information areas	0.1-0.4%	0.1-0.5%	0.1-0.5%	0.1-0.5%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix H.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-6c. Mitigation for On-Road Mobile Source Emissions - Operation (Industrial)

• Provide preferential parking spaces for carpools and vanpools and provide 7'2" minimum vertical clearance in parking facilities for vanpool access	0.1-1.0%	0.1-0.3%	0.1-0.3%	0.1-0.3%
• Implement on-site circulation plans in parking lots to reduce vehicle queuing	NQ			
• Set up resident worker training programs to improve job/housing balance	NQ			
• Implement home dispatching system where employees receive routing schedule by phone instead of driving to work	Negl.	0.1%	0.1%	0.1%
• Develop a program to minimize the use of fleet vehicles during smog alerts (for businesses not subject to Regulation XV or XII)	NQ			
• Use low-emission fleet vehicles - TLEV - ULEV - LEV - ZEV	NQ			
• Require employers not subject to Regulation XV to provide commuter information areas	Negl.-0.6%	Negl.-0.8%	Negl.-0.8%	Negl.-0.8%
• Reduce employee parking spaces for those businesses subject to Regulation XV	0.1-2.2%	0.1-2.9%	0.1-2.9%	0.1-2.9%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-6c. Mitigation for On-Road Mobile Source Emissions - Operation (Industrial) (continued)

• Implement compressed work-week schedules where weekly work hours are compressed into fewer than five days - 9/80 - 4/40 - 3/36	 0.8-7.6% 1.5-15.3% 3.1-40.0%	 1.0-10.0% 2.0-20.0% 4.0-40.0%	 1.0-10.0% 2.0-20.0% 4.0-40.0%	 1.0-10.0% 2.0-20.0% 4.0-40.0%
• Offer first right of refusal, low-interest loans, or other incentives to employees who purchase or rent local residences	NQ			
• Develop a trip reduction plan to achieve 1.5 AVR for businesses with less than 100 employees or multi-tenant worksites	0.1-2.2%%	0.1-2.9%	0.1-2.9%	0.1-2.9%
• Provide on-site child care and after-school facilities or contribute to development within walking distance	0.1%	0.1-0.2%	0.1-0.2%	0.1-0.2%
• Provide on-site employee services such as cafeterias, banks, etc.	0.2-3.4%	0.3-4.5%	0.3-4.5%	0.3-4.5%
• Establish a shuttle service from residential core areas to the worksite	0.1-0.3%	0.1-0.5%	0.1-0.5%	0.1-0.5%
• Construct on-site or off-site bus turnouts, passenger benches, or shelters	0.1-1.0%	0.1-1.3%	0.1-1.3%	0.1-1.3%
• Implement a pricing structure for single-occupancy employee parking and/or provide discounts to rideshareers	1.5-11.0%	2.0-15.5%	2.0-15.5%	2.0-15.5%
• Utilize parking in access of code requirements as on-site park-a-ride lots or contribute to construction of off-site lots	0.1%	0.1-0.2%	0.1-0.2%	0.1-0.2%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-6c. Mitigation for On-Road Mobile Source Emissions - Operation (Industrial) (continued)

• Any two of the following:				
– Construct off-site bicycle facility improvements, such as bicycle trails linking the facility to designated bicycle commuting routes, or on-site improvements, such as bicycle paths	0.2-2.4%	0.3-3.2%	0.3-3.2%	0.3-3.2%
– Include bicycle parking facilities, such as bicycle lockers and racks	See Above			
– Include showers for bicycling employees' use	See Above			
• Any two of the following:				
– Construct off-site pedestrian facility improvements, such as overpasses, wider sidewalks	0.2-1.2%	0.2-1.6%	0.2-1.6%	0.2-1.6%
– Construct on-site pedestrian facility improvements, such as building access which is physically separated from street and parking lot traffic and walk paths	See Above			
– Include showers for pedestrian employees' use	See Above			
• Provide shuttles to major rail transit stations and multi-modal centers	0.1-0.3%	0.1-0.5%	0.1-0.5%	0.1-0.5%
• Contribute to regional transit systems (e.g., right-of-way, capital improvements)	NQ			
• Synchronize traffic lights on streets impacted by development	4.0-8.0%	4.0-8.0%	4.0-8.0%	4.0-8.0%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix 11.

Where efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

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Table 11-6c. Mitigation for On-Road Mobile Source Emissions- Operation (Industrial) (continued)

• Reschedule truck deliveries and pickups for off-peak hours	NQ			
• Implement a lunch shuttle from a worksite(s) to food establishments	0.4-1.5%	0.5-1.8%	0.5-1.8%	0.5-1.8%
• Require on-site truck loading zones	NQ			
• Install aerodynamic add-on devices to heavy-duty trucks	NQ			
• Implement or contribute to public outreach programs	NQ			
• Reduce ship cruising speeds in the inner harbor	NQ			
• Use low-emission fuels or electrify airport ground service vehicles	NQ			
• Engine tuning for marine vessels (e.g., injection timing retard)	NQ			
• Reduce number of aircraft engines used during idling	NQ			
• Install monitoring system to control airport shuttles	NQ			
• Use centralized ground power systems for airport service vehicles	NQ			

[redacted] These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from On-Road Mobile Sources (i.e., Work Trips, Non-Work Trips, Congestion Relief, Truck Trips, Off-Road Vehicles). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-7). These data will be updated as more information becomes available. More detailed descriptions of mitigation measures are included in Appendix F1.

When efficiency is provided as a range:
If project-specific efficiency is unknown, use the lowest number given;
If project-specific efficiency is utilized, provide supporting analysis and documentation.

AR0072933

Table 11-7a. Mitigation for Stationary Source Emissions - Operation (Residential)

• Use solar or low-emission water heaters	11%	9.5%	10%	4.5%
• Use central water heating systems	9%	8%	8.5%	4%
• Use built-in energy-efficient appliances	2.5%	3%	3%	6.5%
• Provide shade trees to reduce building heating/cooling needs	Negl.	Negl.	Negl.	0.5%
• Use energy-efficient and automated controls for air conditioners	–	Negl.	–	0.5%
• Use double-glass-paned windows	4.5%	4%	4.5%	2.5%
• Use energy-efficient low-sodium parking lot lights	–	–	–	0.5%
• Provide adequate ventilation systems for enclosed parking facilities	–	Negl.	Negl.	Negl.
• Use lighting controls and energy-efficient lighting	Negl.	Negl.	Negl.	0.5%
• Use fuel cells in residential subdivisions to produce heat and electricity	Negl.	1.5%	1%	7%
• Orient buildings to the north for natural cooling and include passive solar design (e.g., daylighting)	14%	13%	13.5%	10.5%
• Use light-colored roof materials to reflect heat	1.5%	1.5%	1.5%	1.5%
• Increase walls and attic insulation beyond Title 24 requirements	14%	13%	13%	7.5%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from Stationary Sources (i.e., Energy Use, Area Sources, Stationary Sources). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-8). These data will be updated as more information becomes available.
More detailed descriptions of mitigation measures are included in Appendix 11.

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Table 11-7b. Mitigation for Stationary Source Emissions - Operation (Commerical)

• Use solar or low-emission water heaters	0.5%	0.5%	0.5%	0.5%
• Use central water heating systems	0.5%	0.5%	0.5%	0.5%
• Provide shade trees to reduce building heating/cooling needs	0.5%	0.5%	0.5%	1%
• Use energy-efficient and automated controls for air conditioners	1%	1%	1%	1.5%
• Use double-glass-paned windows	3.5%	3%	3%	2.5%
• Use energy-efficient low-sodium parking lot lights	Negl.	Negl.	Negl.	Negl.
• Provide adequate ventilation systems for enclosed parking facilities	–	–	–	0.5%
• Use lighting controls and energy-efficient lighting	3%	8.5%	7%	19.5%
• Use light-colored roof materials to reflect heat	1%	1%	1%	0.5%
• Increase walls and attic insulation beyond Title 24 requirements	10%	9%	9.5%	7%
• Orient buildings to the north for natural cooling and include passive solar design (e.g., daylighting)	11%	13.5%	12.5%	17.5%

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from Stationary Sources (i.e., Energy Use, Area Sources, Stationary Sources). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-8). These data will be updated as more information becomes available.
More detailed descriptions of mitigation measures are included in Appendix 11.

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Table 11-7c. Mitigation for Stationary Source Emissions - Operation (Industrial)

• Provide shade trees to reduce building heating/cooling needs	Negl.	Negl.	Negl.	0.5%
• Use energy-efficient and automated controls for air conditioning	Negl.	Negl.	Negl.	1%
• Use double-glass-paned windows	Negl.	0.5%	Negl.	1%
• Use energy efficient low-sodium parking lot lights	Negl.	0.5%	Negl.	1%
• Provide adequate ventilation systems for enclosed parking facilities	Negl.	Negl.	Negl.	Negl.
• Use lighting controls and energy-efficient lighting	Negl.	1%	0.5%	2.5%
• Use light-colored roof materials to reflect heat	Negl.	Negl.	Negl.	0.5%
• Orient buildings to the north for natural cooling and include passive solar design (e.g., daylighting)	2%	3%	2.5%	5.5%
• Increase walls and attic insulation beyond Title 24 requirements	Negl.	1%	0.5%	3%
• Improved storage and handling of source materials	NQ	NQ	NQ	NQ
• Materials substitution (e.g., use water-based paints, life-cycle analysis)	NQ	NQ	NQ	NQ
• Modify manufacturing processes (e.g., reduce process stages, closed-loop systems, materials' recycling)	0.5%	2%	1.5%	6%
• Resource recovery systems that redirect chemicals to new production processes	3.5%	3%	3%	1.5%

NQ = Not Quantified Negl. = Negligible (less than 0.05%)

* These efficiencies represent additive reductions from facility operations, specifically unmitigated emissions from Stationary Sources (i.e., Energy Use, Area Sources, Stationary Sources). These efficiencies can be subtracted from the corresponding unmitigated emissions from this category (Table 9-8). These data will be updated as more information becomes available.
More detailed descriptions of mitigation measures are included in Appendix 11.

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Table 11-4. Identifying Net Operation Emissions

Fugitive Dust from Roads							
Work Trips							
Non-Work Trips							
Truck Trips							
Congestion							
Off-Road Vehicles (i.e., forklifts, ships, trains, etc.)							
Energy Usage							
Stationary Equipment							
Unmitigated Emissions:							
Total Net Project Emissions:							

Key: Unmitigated Emissions
Mitigated Emissions

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Table 11-9. Examples of Calculating Reductions from Mitigation Measures

Project: 210 Single-Family Dwelling Units	(lbs/day)			
	ROC	NOx	CO	PM10
Unmitigated Operation Emissions	56.74	52.32	697.00	4.34
Significance Thresholds	55.00	55.00	550.00	150.00
Significant?	Yes	No	Yes	No
Amount Needed to Reduce Emissions Below Level of Significance	-1.74	0.00	-147.00	0.00
Mitigation Measures				
1. Include Satellite Telecommunications Center	-0.11	-0.10	-1.39	-0.01
2. Include Retail Services in or within 1/4 mile	-1.42	-1.31	-17.43	-0.11
3. Establish/Contribute to Shuttle Service	-0.11	-0.10	-1.39	-0.01
4. Construct On-Site Bus Turnouts	-0.17	-0.16	-2.09	-0.01
Total Reduction	-1.82	-1.67	-22.30	-0.14
Total Mitigated Emissions	54.92	50.65	674.70	4.20
Significant?	No	No	Yes	No

Project: 190,000 Sq. Ft. Multi-Tenant Office Building	(lbs/day)			
	ROC	NOx	CO	PM10
Unmitigated Operation Emissions	57.05	37.57	561.42	5.88
Significance Thresholds	55.00	55.00	550.00	150.00
Significant?	Yes	No	Yes	No
Amount Needed to Reduce Emissions Below Level of Significance	-2.05	0.00	-11.42	0.00
Mitigation Measures				
1. Establish Telecommuting Program	-0.11	-0.08	-1.12	-0.01
2. Implement Parking Pricing	-1.71	-1.13	-16.84	-0.18
3. Provide On-Site Employee Services	-0.17	-0.15	-2.25	-0.02
4. Provide Child Care Center	-0.06	-0.04	-0.56	-0.01
Total Reduction	-2.05	-1.39	-20.77	-0.22
Total Mitigated Emissions	55.00	36.18	540.65	5.66
Significant?	No	No	No	No

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Table 11-10. Steps for Mitigating Project Unmitigated Emissions (Screening Analysis)

(The following steps correspond to the unshaded portion of the flow chart in Figure 11-1.)

7. If a project is significant, apply all feasible mitigation for construction and/or operation. To calculate emission reductions, multiply the percent efficiency by the unmitigated emissions from the same source category, then subtract the result from unmitigated emissions. The following lists unmitigated emission sources and corresponding mitigation measures: 9-1 and 11-3 (Total Construction); 9-2 and 11-4 (Construction PM10); Table 9-3 and 11-2 (Construction Workers' Travel); 9-7 and 11-6 (Operation Mobile); and 9-8 and 11-7 (Operation Stationary).

8. If the project's construction and operation impacts are not significant, the lead agency has the discretion to require further analysis of impacts if the project has other potential air quality impacts (Section 6.2).

9. Compare construction and operation emissions to the thresholds of significance (Section 6.2).

10. If the project's construction AND/OR operation emissions remain above significance thresholds, apply qualitative mitigation measures that have not been quantified (Section 11.9). These can be found in Tables 11-2, 11-3, 11-4, 11-6, or 11-7, or can represent unlisted measures.

11. If the project's construction AND operation impacts are reduced below the thresholds of significance, an MND is appropriate.

12. Determine if the project's construction AND/OR operation emissions still exceed the thresholds of significance.

13. If construction AND operation emissions fall below thresholds of significance, an MND is appropriate.

14. If construction AND operation emissions remain above the significance thresholds, an EIR should be prepared. Appendices 9 and 11 should be used to calculate specific emissions.

15. If a project is not cumulatively significant, an ND is appropriate.

16. If a project is cumulatively significant, an EIR or MND is appropriate. Appendices 9 and 11 should be used to calculate project-specific emissions.

17. Apply all feasible mitigation measures.

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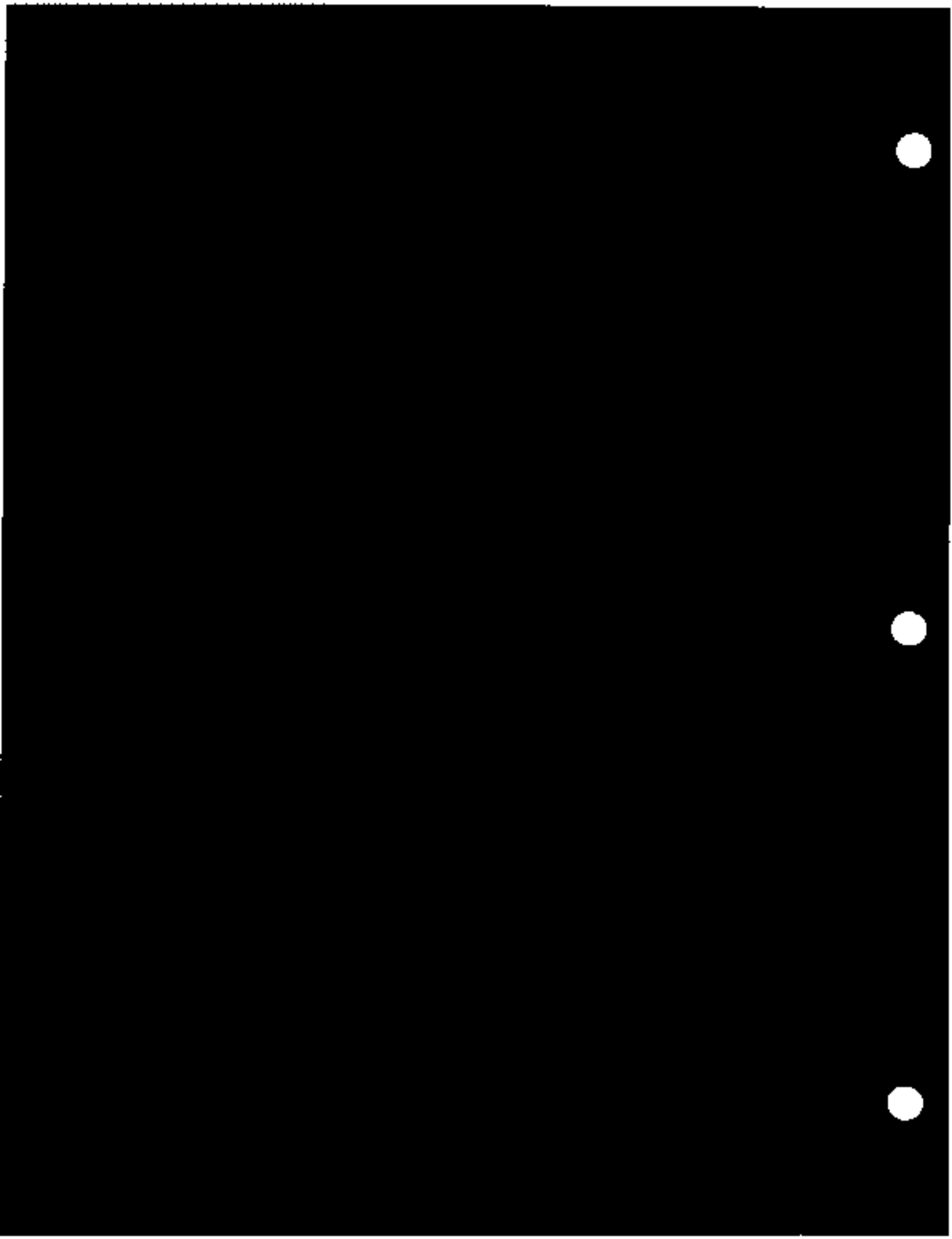

ASSESSING CONSISTENCY WITH APPLICABLE REGIONAL PLANS

CHAPTER 12

Information should be provided in the EIR to determine consistency of a project with the AQMP and other applicable regional plans. Consistency is different from conformity. Consistency is a CEQA requirement. Conformity is a federal Clean Air Act requirement. Specifically, the federal Clean Air Act prohibits federal departments, agencies, or other agencies acting on behalf of the federal government, and the Metropolitan Planning Organization (MPO) which is SCAG from engaging in, supporting in any way, providing financial assistance for, licensing or permitting, or approving any activity that does not conform to the AQMP. For projects involving federal approval, the federal agency is the lead agency for making the conformity finding. In the case of transportation plans and programs, the MPO, SCAG, is responsible for conformity of its actions. The EPA is developing guidance for determining conformity of non-transportation related projects and actions, and transportation projects, plans, and programs. Refer to this guidance when preparing a conformity analysis.

Use the guidelines provided in this chapter for assessing consistency with regional plans relating to air quality as required under CEQA.

12.1 Overview of Consistency with Regional Plans

Section 15125 of the State CEQA Guidelines requires that EIRs analyze and discuss any inconsistencies between the proposed project and applicable General Plans and regional plans. As such, the EIR should address the General Plans and regional plans in the SCAB, Coachella Valley, and Antelope Valley that are applicable to the project.

Specifically, the EIR should discuss the project's consistency with the current AQMP or Coachella Valley PM10 State Implementation Plan (if the project is located in the Coachella Valley). In addition, several of the underlying key assumptions for both the air quality plans should be included in the analysis as well:

- Assumptions such as the number and location of population, housing units, and employment from the SCAG Growth Management Plan (GMP).
- Assumptions concerning type, size, and location of transportation infrastructure from SCAG's Regional Mobility Plan (RMP).
- Consistency with a local government's Air Quality Element or air quality related policies in other General Plan Elements, if the local government has adopted such policies.

The purpose of the consistency finding is to determine if a project is inconsistent with the assumptions and objectives of the regional air quality plans, and thus if it would interfere with the region's ability to comply with federal and state air quality standards. If the project is inconsistent, local governments should consider project modifications or inclusion of mitigation to eliminate the inconsistency. It is important to note that even if a project is found consistent it could still have a significant impact on air quality under CEQA. For example, if the analysis demonstrates a project is consistent with the regional air quality plans and local Air Quality Element, that does not mean that the project could not also have a significant effect on air quality by exceeding the significance thresholds.

12.2 Consistency with AQMP/PM10 Plan

The consistency determination at the environmental review stage in the planning process plays an essential role in local agency project review by linking local planning (e.g. General Plan and Specific Plans) to the AQMP and PM10 Plan in the following ways. It fulfills the CEQA goal of fully informing local agency decision makers of the environmental costs of projects under consideration and does so at a stage early enough to ensure that air quality concerns are fully addressed. It provides the local agency with ongoing information assuring local decision makers that they are making real contributions to the

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clean air goals contained in the 1991 AQMP and PM10 Plan. Only new or amended General Plan Elements, Specific Plans, and significant projects need to undergo a consistency review. This is because the AQMP control strategy is based on projections from local General Plans. As such, projects consistent with local General Plans are considered consistent with the air quality related regional plans.

Consistency with the AQMP and PM10 Plan means that a project is consistent with the goals, objectives, and assumptions in the respective plan to achieve the federal and state air quality standards. As part of assessing consistency with the AQMP, consistency should also be assessed with the following regional plans:

- **AQMP/PM10 Plan**

If the project is in the SCAB or SEDAB (under District's jurisdiction), consistency with the AQMP (and PM10 plan for the Coachella Valley) should be assessed. Section 12.3 provides guidance in performing a consistency analysis. In addition to assessing consistency with the AQMP, a project should also be assessed with two of the regional planning documents prepared by SCAG that relate to air quality: the Growth Management Plan, and the Regional Mobility Plan.

Growth Management Plan (GMP). The growth projections and location of population should be compared to the growth the project will generate. That is important because the GMP was used to determine the control strategy needed to attain the federal and state clean air standards, while accommodating future growth. This can be accomplished by comparing the project's density, location, and land use pattern with the adopted local General Plan and associated zoning ordinance and maps that were in place in 1989 when the GMP was adopted. If the project will result in a significant change in the density, location, and land use pattern, then it is considered to be inconsistent with the GMP. For General Plan amendments and projects involving a significant change to the General Plan, a comparison to the growth projections in the appropriate regional statistic area (RSA) for the build-out year should be performed to determine consistency.

Regional Mobility Plan (RMP). If the project is a transportation project, it should be compared to the assumptions in the RMP concerning the type, size, and location of the project. The comparison is necessary because many of these transportation projects are relied upon in the AQMP to reduce emissions.

- **Congestion Management Plan (CMP)**

Projects should be compared to the CMP goals to retain and obtain certain levels of service on roadways. When the impact of a project will be reduced by transit use, the trip assignment that the project assumes must be consistent with the transit provider's assumptions. The local CMP should be consulted when assessing consistency. Consistency with the CMP is important to air quality because vehicles traveling at slower speeds generate more pollution than those traveling at higher speeds (up to 55 mph).

- **Consistency With General Plans**

Both CEQA and the California planning, zoning and development laws require projects to be consistent with the jurisdiction's General Plan. The EIR should identify if the local government has an Air Quality Element or has incorporated air quality goals and objectives into another element of the General Plan. This project should be evaluated for consistency with the appropriate element. Examples of air quality related goals that can be included in a General Plan are identified in Table 12-1.

12.3 AQMP Consistency

New or amended General Plan Elements (including land use zoning and density amendments), Specific Plans, and significant projects must be analyzed for consistency with the AQMP. There are two key indicators of consistency:

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(1) Whether the project will not result in an increase in the frequency or severity of existing air quality violations or cause or contribute to new violations, or delay timely attainment of air quality standards or the interim emission reductions specified in the AQMP (except as provided for CO in Section 9.4 for relocating CO hot spots).

(2) Whether the project will exceed the assumptions in the AQMP in 2010 or increments based on the year of project build-out and phase (Table 12-2).

In order to address the first criterion, an air quality modeling analysis that identified the projects impact on air quality will need to be performed. As with the CO analysis, the "No Project" ambient concentration should be determined using information from District monitoring stations (refer to Chapter 9). In order to be found consistent, the analysis will need to demonstrate that the project's emissions will not increase the frequency or the severity of existing violations, or contribute to a new violation at the project. The violations that are referred to are the state and federal criteria pollutant ambient air quality standards (refer to Chapter 3). The analysis must look at each phase and build-out, and include a no-project and project alternatives analysis.

Consistency with the AQMP assumptions is determined by performing an analysis of the project with the assumptions in the AQMP for the year 2010. Table 12-2 identifies the types of projects and assumptions they should be compared with. Additionally, those types of land uses identified need to undergo an emissions analysis. The information regarding specific assumptions can be obtained from the District or SCAG. When specific information for a build-out year is not available, data that is available between the two nearest dates can be interpolated to estimate the assumptions for the interim years.

If the air quality modeling demonstrates that the project is inconsistent with the AQMP, the project can be modified and mitigation measures applied. However, before a determination of consistency can be made, the project must quantitatively demonstrate that such modifications or mitigation measures fully offset the negative impact on air quality, such that the project can be found consistent with the applicable regional plan; otherwise the project is considered significant. Any mitigation applied to reduce the impact must meet the test of having adequate funding, a legally binding commitment to ensure implementation, and a showing that it will be implemented simultaneous with the impact.

12.4 Consistency Findings

CEQA states that an agency has the authority to approve projects with the potential to cause significant adverse environmental impacts (California Public Resource Code 21002 and State CEQA Guidelines 15092 and 15093). Thus, even if a project is found inconsistent with the AQMP and a net degradation of Basin air quality could occur, a local agency may approve a discretionary land use project or a government project that results in unmitigated air pollutant emissions.

On the other hand, some state and federal statutes affect local agency discretion to trade off social, economic, or other benefits for significant impacts on air quality. The federal Clean Air Act establishes requirements to prevent air quality degradation beyond established standards. The SCAB exceeds federal standards for five pollutants at this time. The AQMP represents the regional plan for attaining both the federal and state clean air goals. Therefore, any findings of overriding considerations for projects that are not consistent with the AQMP should consider the potential ramifications. Specifically, that the region will not be able to achieve the air quality standards within the time frame specified in law, potential restrictions on federal funding, imposition of a federal plan and regulations, federal sanctions and/or the need for regulation of additional sources in order to make up the emission reductions lost.

References

Federal Clean Air Act, Section 176 (c).

Guidance for Determining Conformity of Transportation Plans, Programs, and Projects with Clean Air Act Implementation Plans During Phase 1 of the Interim Period, EPA, June 1991.

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Table 12-1. Examples of Air Quality Policies for General Plan Elements

Land Use	Ensure land use compatibility for sensitive uses Integrate land uses and densities that support transit corridors
Circulation	Integrate Congestion Management Program requirements Provide local shuttle services
Conservation	Plant trees to reduce carbon dioxide Integrate solid waste requirements from AB 939 Incorporate city-wide energy reduction goals
Open Space	Encourage urban infill to reduce trip lengths
Housing	Provide for housing development to support type of job growth
Noise	Facilitate off-peak period truck operations in areas not adjacent to residential developments
Safety	Protect sensitive uses from exposure to air toxics Prepare contingency plans for emergencies
Redevelopment	Provide resident working training programs to improve jobs/housing balance Use tax increment financing for air quality beneficial to infrastructure improvements
Air Quality	Reduce energy use in public buildings Change local government administrative practices (e.g. phone-in registration for city programs, etc.) Make transportation demand management a priority Implement 1991 AQMP and CO Plan control measures

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Table 12-2. Key Assumptions

Airports	Number of Flights, Million Air Passengers (MAP)
Electrical Generating Facilities	Electrical Demand (KWG hours)
Petroleum or Gas Refineries	Fuel Refined
Designation of Drilling District	Fuel Refined
Water Ports	Cargo Tons, Ship Berths
Solid Waste Disposal Sites	Tons of Solid Waste
General Plans, Specific Plans, Residential Projects, Wastewater Facilities/Interceptors	Population Number and Location, Regional Housing Needs Assessment
Off-Shore Oil Facilities	OCS Emissions

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THE DISTRICT AS A RESPONSIBLE AGENCY

CHAPTER 13

According to the State CEQA Guidelines, a responsible agency is a public agency that proposes to carry out or approve an aspect of the project for which a lead agency is preparing environmental documentation. The District is a responsible agency for aspects of projects requiring District permits. The District is a commenting agency for those portions of a project not subject to a District permit. As a responsible agency, the District will review, comment, and establish mitigation whenever necessary to reduce air quality impacts for those aspects of the project relating to the District's permit. For example, a hospital would probably require permits from the District (boilers, sterilization apparatus, etc.), and as such, the District would be a responsible agency under CEQA for those aspects of the project relating to the permit. For the other aspects of the project that could impact air quality such as non-work vehicle trips, the District would recommend mitigation measures for reducing these environmental impacts as a commenting agency.

Most of the District permits are considered to be either ministerial or exempt (statutorily or categorically), or to have a non-significant effect on air quality. (Refer to District CEQA Guidelines, Articles 18, 19, 20 and 21.) As such, the environmental documentation prepared by the lead agency should in most cases be sufficient to cover the District's subsequent permit action. In those cases, where the District action is not considered to be ministerial or exempt, the environmental documentation prepared by the lead agency should include an environmental analysis description and recommended mitigation for any impacts resulting from the District permit, if that document is intended to suffice for the District permit.

13.1 Thresholds for District Permits

Currently, the District uses the thresholds for significance specified in this Handbook for determining which projects requiring District permits could have a significant effect on the environment. When the District's CEQA Guidelines are revised, these thresholds may be revised. A number of qualitative thresholds have also been identified.

Projects requiring District permits may significantly affect the environment when any of the following is involved:

- Criteria emissions that are not regulated under a District rule with an established emissions limitation over the following thresholds--
  - 55 pounds per day for ROC
  - 55 pounds per day for NOx
  - 150 pounds per day for PM10
  - 550 pounds per day for CO
  - 150 pounds per day for SOx
- Carcinogenic or toxic air contaminants identified in Rule 1401 are emitted from the project that exceed the maximum individual cancer risk of one in one million or 10 in one million if the project is constructed with best available control technology for toxics (T-BACT).
- The project may result in the accidental release of an acutely hazardous air pollutant.
- The project could emit an air contaminant not regulated by District Rules, but that is on the federal or state air toxics list (Appendix 3).

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Refer to Table 4-1 in Chapter 4 which provides a list of land uses likely to involve equipment that will meet these criteria. For these projects, the District assesses the environmental documentation already prepared for the land use approval by the local government. If that analysis is sufficient, the District will not require additional environmental documentation. If the analysis is not sufficient, the District will assume a lead agency role for the District permits, if authorized pursuant to CEQA Guidelines Section 15052, or prepare a subsequent EIR, if appropriate, pursuant to CEQA Guidelines Section 15162, since the project could have potentially significant air quality impacts.

13.2 Environmental Analysis

The District has determined that in some situations various air pollution control equipment may generate cross-media environmental impacts, or in some cases the reduction of one air pollutant may result in an increase in another air pollutant. A cross-media impact refers to the removal of a contaminant from one medium, such as air, and release to another medium, such as water. Cross-media impacts should be identified and discussed as part of the environmental documentation for the project. These impacts may require analysis in a CEQA document to determine the significance of the impact. If necessary, suitable mitigation measures will be required.

Cross-media impacts should be investigated during the Initial Study for all significant projects where the District is a responsible agency to determine whether there is the potential for a significant impact. When an EIR is prepared for the project, the environmental documentation should include an analysis of cross-media impacts, and based on that analysis, incorporate a finding that the cross-media impact is either significant or insignificant.

The environmental analysis should identify the control technology to be used and any potential cross-media impacts. The purpose of the analysis is to identify multi-media impacts as a result of the permitting action. Since these potential environmental impacts are within the responsibility of agencies other than the District, these other agencies should be consulted through the CEQA review process to determine if the impact is significant and what recommendations for mitigation should be made. Often the responsible agency will be a water supply agency, Regional Water Quality Control Board, wastewater treatment agency, and agency responsible for solid waste disposal. The analysis of the potential cross-media impacts should be performed whenever the District has a subsequent permitting responsibility and an EIR is being prepared.

The significance of a cross-media impact should be determined by the thresholds established by the responsible agency (e.g., sanitation district, water quality control board, etc.). To date, only the Solid Waste Management Boards have established a threshold of significance, which is a ten percent increase in the capacity utilization of a solid waste disposal facility.

There will be some cases where the District will not be able to use another agency's environmental documentation. An example would be environmental documents considered by the District to have insufficient analysis of the potential environmental impacts. Projects with significant emissions, involving toxic emissions, or threatened releases of acutely hazardous materials most likely will fall in this category. In other instances, the project proponent may not know which specific control technology will be used in the project, and in that case, the environmental analysis will need to wait until the applicant applies for the permit.

Appendix 13 describes the specific control technologies, potential cross-media impacts of the different control technologies, and identification of agencies that should be consulted as responsible or commenting agencies. The analysis described in Appendix 13 must be followed for EIRs where the District will be taking a subsequent permit action.

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DISTRICT REVIEW AND COMMENTING PROCESS

CHAPTER 14

The air quality analysis in an EIR (or other environmental documentation) is often so technical that only a specialist in air quality can ensure that it is adequate. This is particularly true as evaluation of impacts becomes more complex and concern over toxic emissions grows. Given the severity of air quality problems already plaguing the region and the certainty of continued population growth, it is imperative that air quality analyses be adequate in relation to CEQA standards. In addition, CEQA Guidelines Section 15086 requires lead agencies to consult responsible agencies, other agencies which exercise authority over resources which may be affected by the project, and any person who has special expertise with respect to any environmental impact involved. The District, therefore, has established a program for reviewing and commenting on the air quality analyses in environmental documents submitted to the District pursuant to CEQA Guidelines Sections 15086, 15087, and 15096.

This chapter should be consulted prior to the public review period of an EIR (or other environmental documentation) for any project deemed to have a significant impact on air quality. Refer to Chapter 6 for a listing of the types of projects and emission thresholds that determine which projects are significant.

14.1 Purpose of the District's CEQA Program

The District, as commenting or responsible agency for air quality issues, evaluates the air quality analysis in environmental documents to ensure impacts are accurately identified and mitigation applied to lessen the impact. Lead agencies can be confident that the environmental documents that meet the District's standards for performing an air quality analysis are adequate for decision making.

The District's CEQA program is also intended to provide the framework within which the District will fulfill its role, under CEQA and the Health and Safety Code, as the agency responsible for protecting air quality. Thus, the District is responsible for commenting on any project that may have an adverse impact on air quality within its jurisdictional boundaries (Health and Safety Code, Section 40412). The District is considered to be a responsible agency for any project for which a subsequent District permit is required (refer to Chapter 3) and also has authority over projects that could affect air quality. CEQA (Section 15086) requires the lead agency to consult with and request comments on the draft EIR (or other environmental documentation) from responsible agencies and other involved agencies.

14.2 Role of the District

The District, acting as a commenting and/or responsible agency under CEQA, will review the EIR (or other environmental documentation) and comment on the adequacy of the air quality analysis, as well as recommend mitigation measures. The District will review the air quality analysis according to its uniform standards (refer to Section 14.4). While the Handbook provides general guidance, the District's comment letter is the project-specific review for adequacy under CEQA.

This does not mean, however, that the District's CEQA program moves the District into the role of lead agency with respect to the air quality portion of an EIR (or other environmental documentation).

14.3 District's CEQA Program

The District will review and comment on the air quality analysis in an environmental document during the public review period. The lead agency should send all significant projects with air quality impacts to the District.

In order to determine which projects are considered significant from an air quality perspective, refer to Chapter 6. In order to facilitate the District's review, the following items should be submitted to the District:

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- Draft EIR or other environmental documentation
- Any technical appendices that relate to air quality (including traffic impact analysis, growth forecasts, etc.)
- Name and address of the person to whom the District should submit comments
- Date public comments are due
- Mitigation Monitoring Program, if available

This information should be sent to:

CEQA Coordinator
Office of Planning and Technology Advancement
21865 East Copley Drive
P.O. Box 4939
Diamond Bar, CA 91765-0939

Early consultation with the District can ensure that the EIR adequately addresses air quality issues. The District recommends that project proponents and/or local governments consult with the District if the project is an extremely large project encompassing several hundred acres or attracts a large number of trips (such as a stadium, new town, etc.), or if regardless of size the project has the potential to emit substantial amounts of air pollutants, or if project proponents would like to explore innovative mitigation measures for the project (such as energy fuel cells). A planner or project proponent can consult with the District prior to the completion of the EIR or even earlier during the project design phase by contacting the CEQA Coordinator through the District's Local Government/CEQA Unit.

The District will review each portion of the EIR that could have an impact on air quality. In addition to the section entitled "Air Quality," for example, sections that describe impacts on mobility, and hence determine vehicle miles traveled must be considered because transportation contributes substantial emissions. Consideration of air quality relates to such concerns as the levels of congestion experienced at roadway intersections. Waste management issues may also involve air toxics, as can advanced technology and new processes with new materials.

The District will carefully review the air quality analysis and the mitigation measures. At the conclusion of the District's review, local governments will receive a letter identifying any deficiencies in the air quality analysis and recommending mitigation measures.

The flow chart in Figure 14-1 illustrates District involvement in the CEQA process.

14.4 Criteria for the Performance of an Air Quality Analysis

To determine if an air quality analysis is adequate to assess and mitigate a project's impact, a series of criteria has been developed. The District will use these criteria when reviewing the adequacy of an air quality analysis and in recommending mitigation measures. As such, the Districts comments will be based on the following:

(1) Air Quality Analysis

- All emission sources from construction and operation are quantified according to Chapter 9 and Appendix 9 of the CEQA Handbook.
- Most current emission factors are used in calculations.
- Assumptions used in calculating emissions are reasonable.
- Project employs the appropriate environmental document.
- Cumulative impact analysis is performed pursuant to Chapter 9.

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- All alternatives are quantified, at a minimum using the screening tables in Chapter 9.
- The baseline information identified in Chapter 8 is included in the EIR.
- A consistency analysis has been performed consistent with Chapter 12.

(2) Mitigation Measures

- Assumptions used in quantifying mitigation are reasonable.
- Mitigation measures are included to reduce cumulative impact projects.
- Mitigation measures are included as appropriate to use.
- Mitigation measures are enforceable as described in Chapter 11.

(3) Mitigation Monitoring

- The lead agency commits to including standards for measuring whether or not air quality mitigation measures have been implemented.
- The lead agency commits to remedial action if air quality mitigation is not implemented.

(4) Toxics

- An impact screening assessment is performed when sensitive receptors are to be sited within a quarter mile of a known source of toxic air pollutants.
- The potential of an accidental release of an acutely hazardous material into the air has been analyzed.

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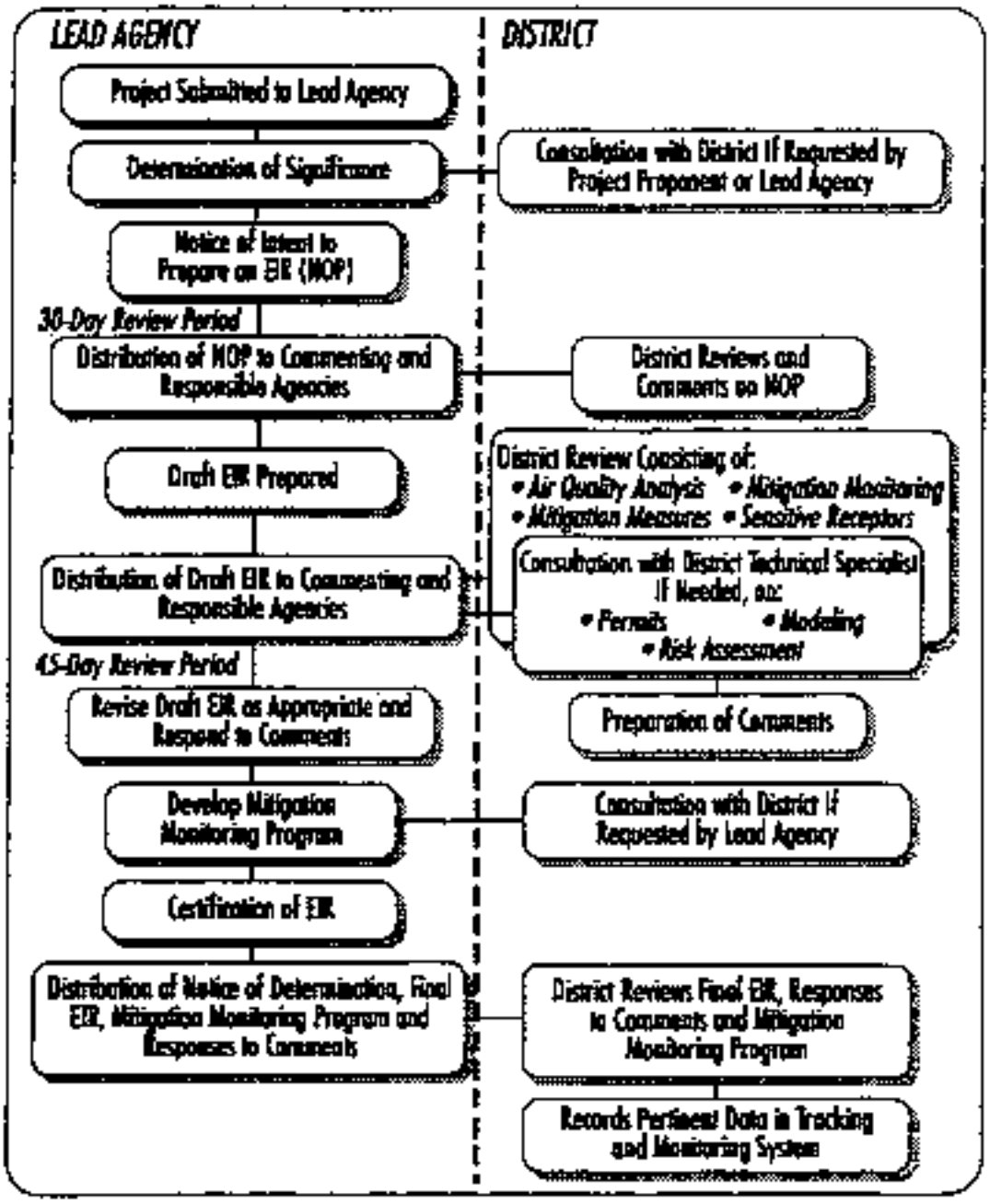
Figure 14-1. District Review of Environmental Documents



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IMPLEMENTING AND MONITORING MITIGATION

CHAPTER 15

Pursuant to AB 3180 (California Public Resources Code), CEQA requires public agencies to monitor and to report on any mitigation required on an approved project. This ensures that the mitigation will be implemented and the environment protected. Mitigation measures, once implemented, should be judged for their effectiveness. Refer to Chapter 11 for further information on developing appropriate mitigation measures. A mitigation monitoring program includes several key components. A checklist is provided in Table 15-1 to assist planners in preparing the mitigation plan.

15.1 Mitigation Monitoring Plan Components

The District recommends that mitigation monitoring plans contain the components described below. The District believes these components are important to fulfilling the monitoring and reporting requirements of CEQA. They will also assist in ensuring that mitigation measures reduce air quality impacts.

Communicating Mitigation Measures and Reporting Requirements. Frequently, the requirements for mitigating impacts and reporting are not properly explained to those responsible. For example, mitigation measures related to construction, such as street sweeping, should be explained to the construction site manager and to contractors. Business owners need to be aware of mitigation measures related to operation, such as transit passes for shoppers at malls. One method of ensuring that those responsible are properly informed is to have contractors and business owners certify, at the time they are issued a business license, that they are aware of and will commit to employing the mitigation measures identified for that project. Mitigation measures could also be recorded on the title of properties, thereby informing future owners of the requirements.

Identification of Agency Responsible for Monitoring. The governmental body responsible for monitoring each mitigation measure should be clearly identified. The lead agency is responsible for the majority of the mitigation measures (including those recommended by commenting agencies).

Identification of Implementation Time Frame. The time frame for implementing the mitigation measures should be identified for each measure. Identification could consist of pinpointing a step in the project approval process when the measure should be implemented, setting a trigger such as when a project produces a certain number of vehicle trips, identifying a project phase, or simply selecting a date.

Establishment of Specific Compliance Criteria. In order to adequately monitor a mitigation measure, it is imperative that the measure have a quantifiable standard or a specific set of actions identified for determining whether or not it has been implemented. Compliance criteria can be the assumptions used in quantifying the mitigation measures, the standard established as a trigger for additional mitigation measures, or criteria based on a qualitative assessment such as odors. (Refer to Chapter 11.)

Identification of Remedial Actions. The program should identify remedial actions that the local government can take, including such measures as fines or court orders. Lead Agencies may also wish to consider having the program provide for the substitution of a more effective mitigation measure by the responsible agency if the current measure proves ineffective. This latter suggestion is not required by CEQA, but could provide an insurance policy for assumed mitigation effects.

Reporting Mechanism and Requirements. The program should state the method of reporting and its requirements. Further it should specify the frequency of monitoring, designate the monitoring party (i.e., building department, planning department, fire department), and identify any agency that should receive periodic activity reports.

An outline of the key components is provided in Table 15-1. This outline can be used as a checklist for determining if the appropriate components are included in the mitigation monitoring program.

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15.2 Monitoring and Reporting of Mitigation Measures

In order to determine if measures are being implemented and if the measures are effectively reducing the impact, CEQA requires that a monitoring and reporting system be established. Local governments need to establish a monitoring and reporting system for projects for which they are the lead agency. The District also has a role in local government monitoring and reporting systems when it is a responsible agency for the project.

- **Local Government Monitoring and Reporting Programs**

The key issues in monitoring are: frequency of monitoring, and at what stage in the project permit/construction process mitigation should be monitored. The frequency of monitoring mitigation measures should be based on the duration of implementation of the measures and the amount of monitoring necessary to ensure that measures are implemented. For construction mitigation measures, monitoring during both scheduled building inspections and at a pre-established frequency (such as once a week) is desirable. If the construction phase is extremely long, or if emissions exceed the PM10 standard, or the project is very complex, the local government may want to require continual on-site monitoring.

Operational mitigation measures should be monitored at least once a year, or more frequently if:

- The project is to be developed in phases
- Land uses other than those anticipated during project approval are present
- The project's impacts are extremely significant
- The mitigation measures protect sensitive receptors

Monitoring may be linked to a specific step in the planning process that requires local government approval or inspections. Examples of such steps include:

- Final subdivision map approval
- Grading permit
- Land use clearance permit
- Building permit
- Construction inspections
- Occupancy permit
- Business license
- Discretionary permit annual review

The flow chart in Figure 15-1 identifies types of mitigation measures that can be monitored in each development phase. This is intended to be a general list. Since local government planning processes vary, other steps in the planning process may also exist that can be used to monitor implementation. Table 15-1 provides a sample checklist for monitoring and reporting air quality mitigation measures. Figure 15-2 provides a sample outline of a mitigation monitoring program that contains all the components recommended in Section 15.1. Figure 15-3 provides a sample reporting form to assist local governments in tracking and determining effectiveness of mitigation measures.

Local governments have the authority to levy charges, fees, or assessments to pay for the monitoring and reporting program. Local governments have an opportunity to use the information gathered through the monitoring program to determine if a mitigation measure is effective. The January/February 1989 issue of California Planner suggested that if the measures are not as effective

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as intended and the impact remains substantial, the local government may substitute a more effective measure. While not specifically required by CEQA, Lead Agencies can exercise this approach at their option.

- **District and Monitoring and Reporting Programs**

The District is involved in local government monitoring and reporting programs as both a responsible agency and technical resource to local governments. The AB 3180 also requires the District to adopt a mitigation monitoring program for mitigation measures imposed on projects for which the District is the lead agency. As a responsible agency, the District can only impose mitigation measures that are related to the District's permitting authority. For example, the District would be responsible for monitoring mitigation measures relating to the permitting process imposed on projects where the District is a responsible agency under CEQA; however, the District is not responsible for monitoring mitigation measures that it has recommended in the role of a commenting agency. The District can be both a responsible agency for aspects of a project relating to District permitting and a commenting agency relating to other aspects of the project.

The District will, if necessary, recommend mitigation measures when it reviews and comments on a project. In addition, the District may specify required mitigation measures relating to the District's subsequent permitting action and submit monitoring and reporting requirements for these measures. The District will work with local governments to coordinate monitoring of District permit-related mitigation measures when applicable.

The District can assist local governments in monitoring certain mitigation measures by providing its technical expertise or by using District permitting and enforcement activities, particularly when measures relate to District permits; by evaluating air quality monitoring samples; and by making District inspections. In those cases in which local governments identify the District as a responsible monitoring agency for air quality mitigation measures, both the EIR and mitigation monitoring program must be submitted for District review and comments.

15.3 Enforcement

Measures that are critical to mitigating the impact should be legally enforceable. Enforcement depends largely on the implementation mechanism and specificity of the measures. The easiest measures to enforce are those that clearly identify who is going to do what by when. When mitigation fees are involved, it is important to identify when in the planning process the fee should be paid, how much the fee is (or the mechanism for determining the fee), and what the fee is to be used for (identification of the particular program or improvement).

AB 3180 (Cortese), which codified mitigation monitoring requirements, does not provide additional sanctions for local governments to impose if monitoring reveals that the mitigation measures or changes to the project have not been implemented. Local governments can, however, use existing sanctions available to them, such as stop work orders, fines, and restitutions. In addition, a variety of enforceable mechanisms are available to local planners to ensure that the air quality mitigation measures are implemented.

- **Examples of the Enforceable Mechanisms for Mitigation Measures**

Conditions of Approval on Discretionary Permits. Air quality mitigation measures can become conditions of approval on discretionary permits (e.g., conditional use permits, variances, design review permits, subdivision maps, etc.). Local governments have the authority to condition projects as long as the conditions are reasonably related to the discretionary permit. Mitigation measures are related to the project in the sense that through the environmental process these measures have been deemed necessary to reduce the potential environmental impact of the project.

Most mitigation measures are tied to conditions of approval as they relate to a particular step in the planning process. For example, if a mitigation measure that required the planting of shade trees to reduce electrical energy usage had been included in an EIR, a requirement could be made that such trees be planted prior to the issuance of an occupancy permit.

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Impact, Mitigation, or Improvement Fees. Local governments are empowered to exact impact, mitigation, or improvement fees from developments as long as the fee meets the nexus test. In most cases, the environmental documentation can establish a nexus by showing that the fee will be used to offset the impact and fund its amelioration.

Impact or mitigation fees support mitigation measures such as transportation demand management (TDM) programs where the program will benefit properties in addition to the project site. Improvement fees are best suited for mitigation measures that involve capital improvements, such as traffic light synchronization, where the improvement involves expenditure of funds beyond the funding that can be reasonably exacted from the project.

Conditions, Covenants, and Restrictions. Through the discretionary permitting process, local governments can require that certain mitigation measures be recorded on a property's conditions, covenants, and restrictions (CC&Rs). CC&Rs can govern aspects of a project including land uses, development standards, responsibilities of property owners and associations, and any other requirements unique to the area covered under the CC&Rs.

Mitigation measures included in CC&Rs may be recorded on the title of the property and made available to future owners and concerned citizens through the county recorder's office. In that way, CC&Rs are effective implementation mechanisms for long-term operational mitigation measures (such as ridesharing requirements) and measures that are expected to be carried out by an association of the owners of individual lots (such as maintaining low-energy lights in the common parking area of a planned unit development). CC&Rs are also effective in ensuring mitigation of projects that are to be built out over a series of several years, such as Specific Plans that will serve as the guide for all future development of the project.

Improvement Securities. Through local ordinances, local government can require project proponents to furnish a security for the performance of any act, agreement, or work. Improvement securities include bonds, deposits with a local agency, a trust account, instrument or letter of credit, or lien. Local governments commonly use improvement securities for items such as construction of capital improvements. Improvement securities can also be used to assure implementation of air quality mitigation measures. Improvement securities would permit a local government to carry out the work if the project proponent failed to implement the measure. Examples include: traffic light synchronization, bus turnouts and passenger benches, and recycling collection service.

Development Agreements. Local governments have the authority to enter into development agreements with any property owner. Development agreements can specify the permitted uses on the property, the density or intensity of use, the maximum height and size of proposed buildings, provisions for reservation or dedication of land for public purposes, and terms and conditions relating to financing public facilities and subsequent reimbursement. The development agreement may include conditions, terms, restrictions, and requirements for subsequent discretionary actions. While development agreements are not specifically entered into to implement mitigation measures, development agreements, if instituted, should incorporate such measures.

The most appropriate measures for inclusion in a development agreement are design and land use related, such as support services in business parks, operational mitigation measures such as participation in a transportation management association, dedications for uses such as bicycle lanes and public transit, and financing of public facilities such as rail transit line extensions. In addition, development agreements are beneficial in establishing trigger mechanisms and requirements for additional mitigation measures, if the existing measures do not prove adequate.

Memorandum of Understanding. Local governments are empowered to enter into memoranda of understanding (MOUs) with other public agencies, private developers, etc., to facilitate a public interest or cause. Mitigating environmental impacts, including those on air quality, fall within these parameters. MOUs are most useful in implementing measures that require a long term commitment on behalf of the project proponent, a partnership between the local government and project proponent, or an enforceable mechanism. For example, an MOU would be appropriate where the commitment calls for the operation of a shuttle service between residences and a commercial district, requiring a long-term enforceable agreement to ensure appropriate implementation.

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Figure 15-1. Monitoring Mitigation Measures

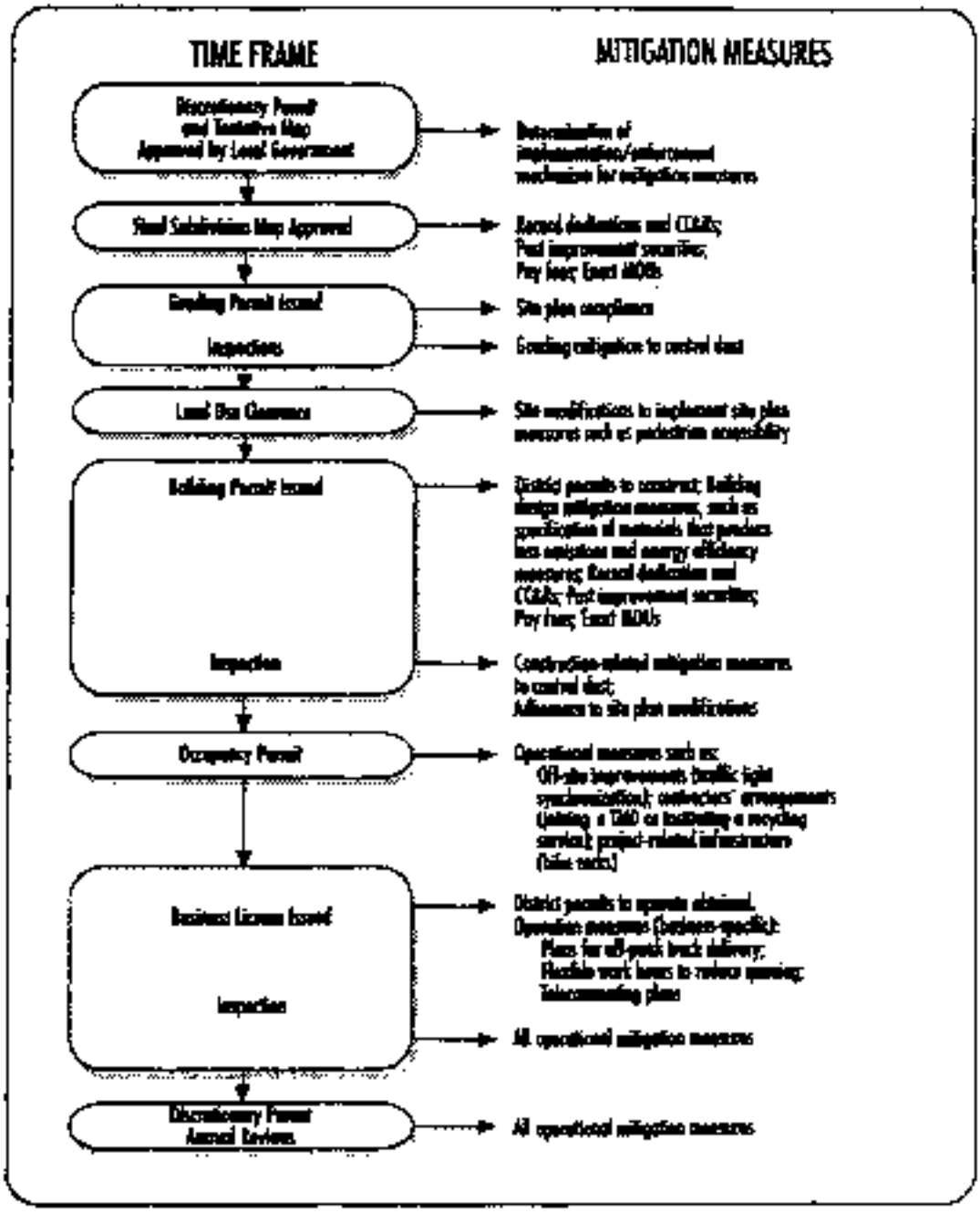

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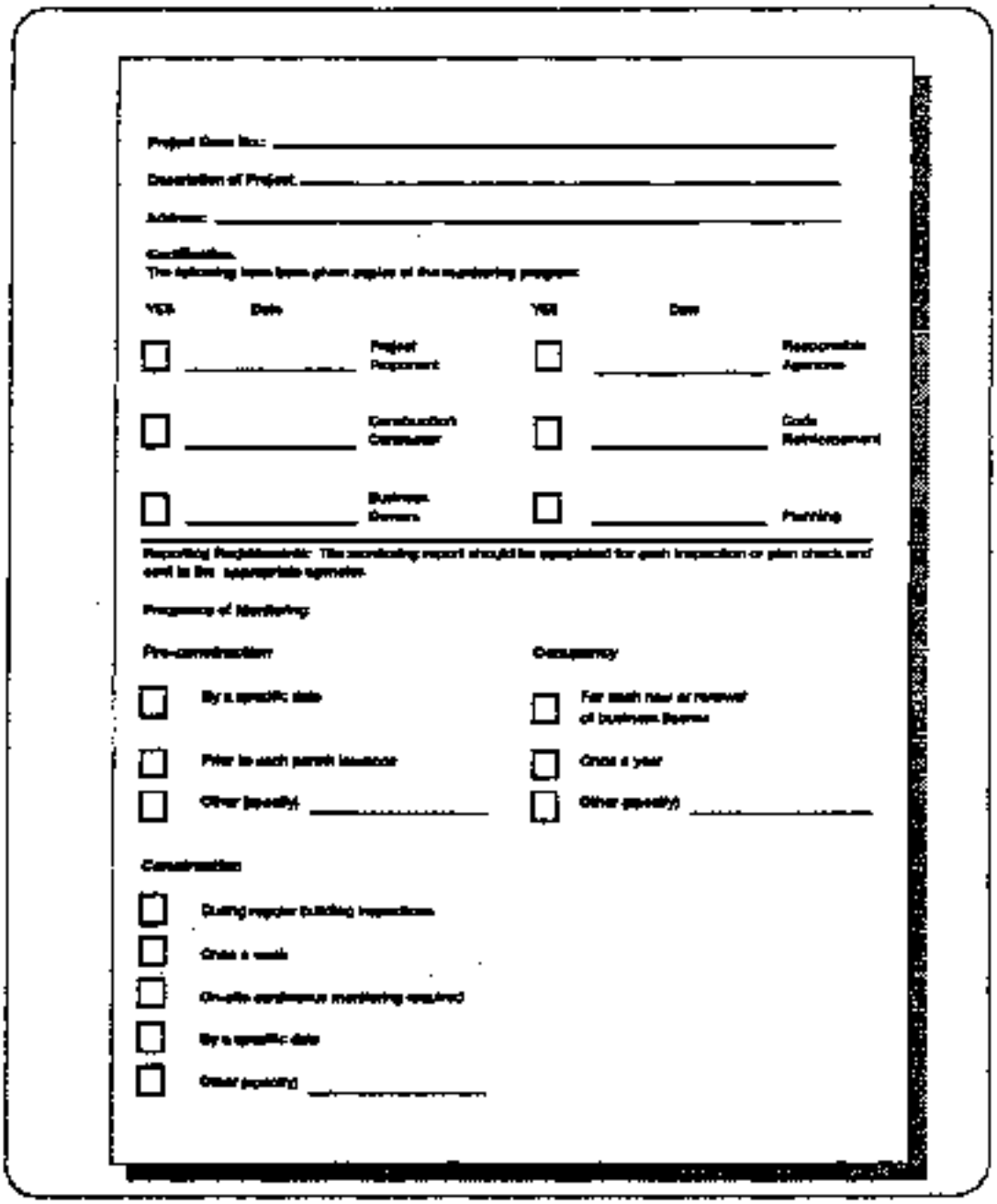
Figure 15-2. Monitoring Program Outline



Project Name No.: _____

Description of Project: _____

Address: _____

Certification.
The following items have been given copies of the monitoring program:

Yes	Date		Yes	Date	
☐	_____	Project Proponent	☐	_____	Responsible Agencies
☐	_____	Construction Contractor	☐	_____	Code Enforcement
☐	_____	Business Owners	☐	_____	Planning

Reporting Requirements: The monitoring report should be completed for each inspection or plan check and sent to the appropriate agencies.

Frequency of Monitoring:

Pre-construction:

- ☐ By a specific date
- ☐ Prior to each permit issuance
- ☐ Other (specify) _____

Occupancy:

- ☐ For each new or renewed of business license
- ☐ Once a year
- ☐ Other (specify) _____

Construction:

- ☐ During regular building inspections
- ☐ Once a week
- ☐ On-site continuous monitoring required
- ☐ By a specific date
- ☐ Other (specify) _____

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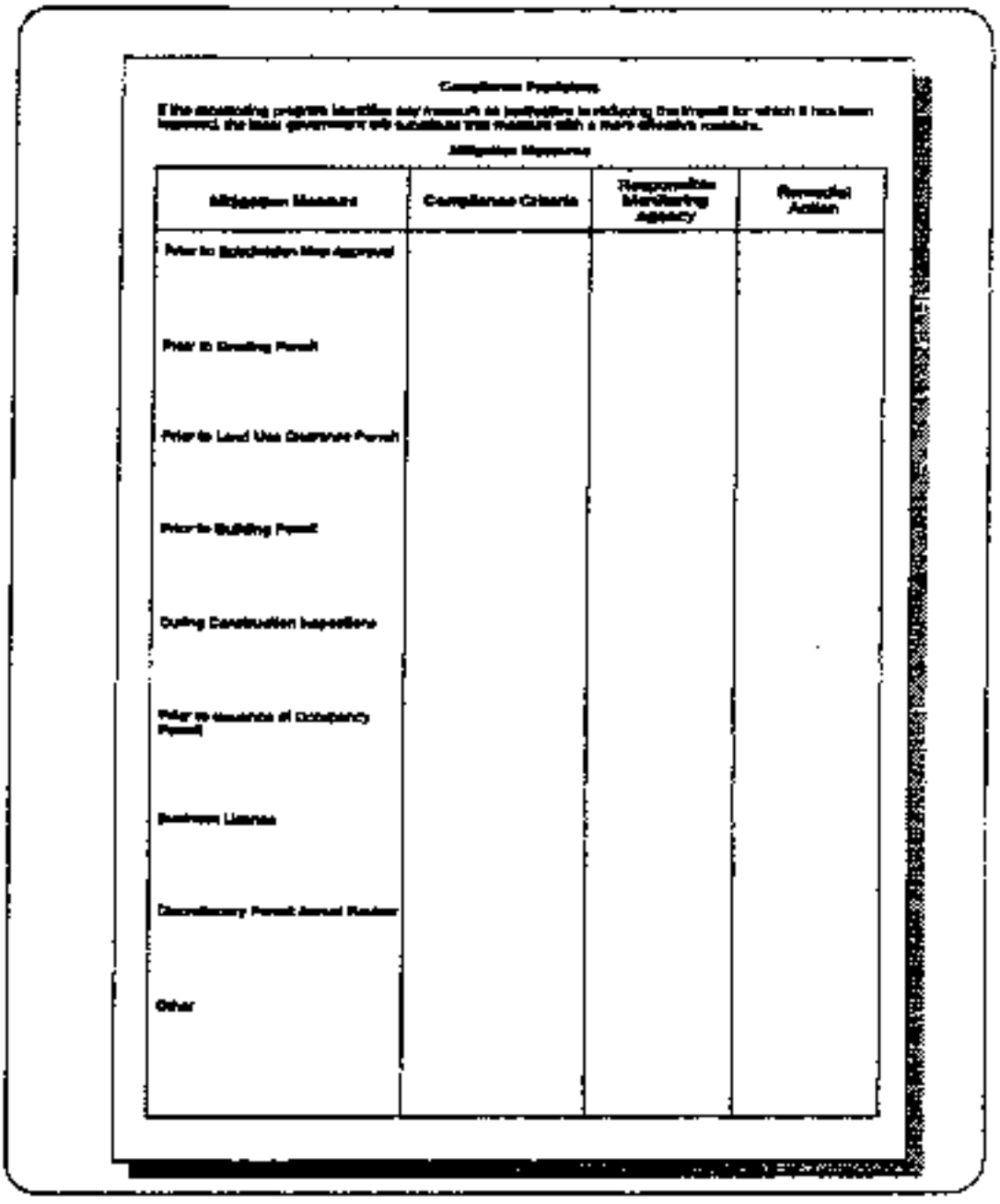
Figure 15-2. Monitoring Program Outline (continued)



Mitigation Measure	Compliance Criteria	Responsible Monitoring Agency	Remedial Action
Prior to Subdivision Map Approval			
Prior to Grading Permit			
Prior to Land Use Clearance Permit			
Prior to Building Permit			
During Construction Inspections			
Prior to Issuance of Occupancy Permit			
Business Licenses			
Discretionary Permit Annual Review			
Other			

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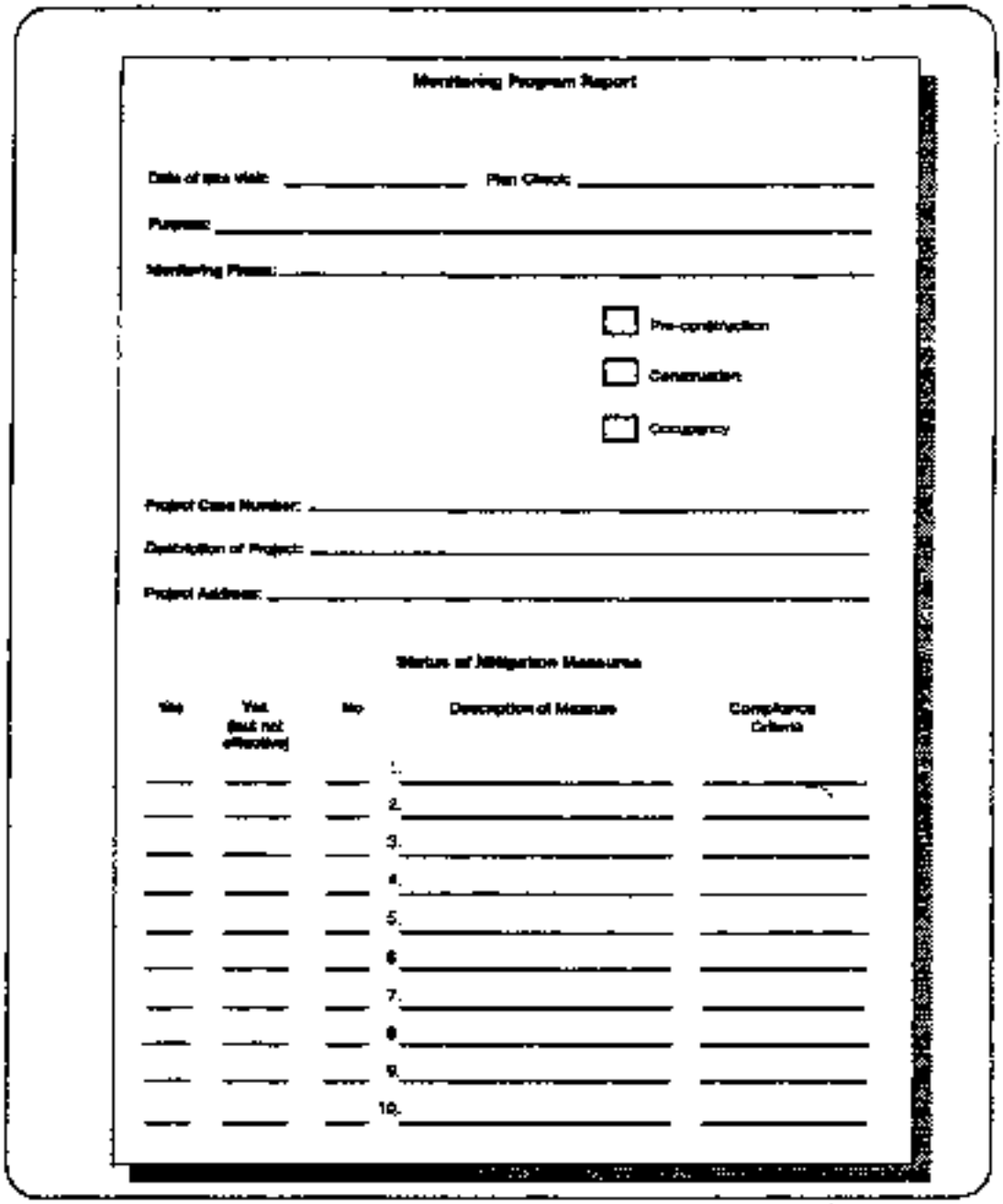
Figure 15-3. Monitoring Program Report



Monitoring Program Report

Date of site visit: _____ Plan Check: _____

Purpose: _____

Monitoring Phase: _____

☐ Pre-construction

☐ Construction

☐ Occupancy

Project Case Number: _____

Description of Project: _____

Project Address: _____

Status of Mitigation Measures

Yes	Yes (but not effective)	No	Description of Measure	Compliance Criteria
			1.	
			2.	
			3.	
			4.	
			5.	
			6.	
			7.	
			8.	
			9.	
			10.	

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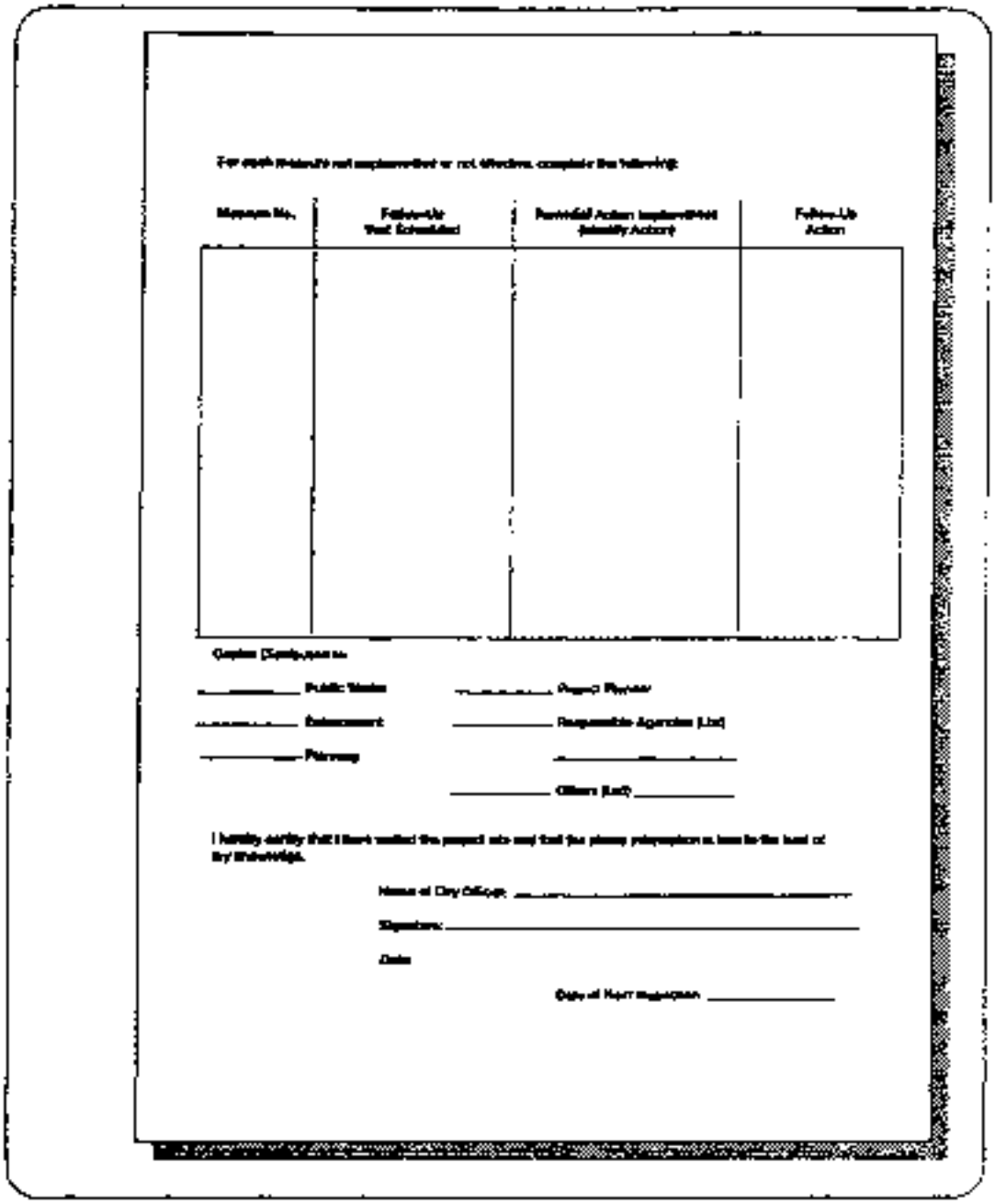
Figure 15-2. Monitoring Program Report (continued)



For each measure not implemented or not effective, complete the following:

Measure No.	Follow-Up Visit Scheduled	Remedial Action Implemented (Identify Action)	Follow-Up Action

Copies (Specify name):

_____ Public Works _____ Project Planner

_____ Enforcement _____ Responsible Agencies (List)

_____ Planning _____

_____ Others (List) _____

I hereby certify that I have visited the project site and that the above information is true to the best of my knowledge.

Name of City Official: _____

Signature: _____

Date

Date of Next Inspection: _____

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Table 15-1. Mitigation Monitoring Checklist

Requirement	Yes	No
1. Have the mitigation measures and reporting requirements been communicated?		
2. Have entities responsible for monitoring each measure been identified?		
3. Has a time frame for implementation of each mitigation measure been identified?		
4. Have specific compliance criteria been identified for each measure?		
5. Have remedial actions been identified?		
6. Does the program identify the method of reporting and reporting requirements?		

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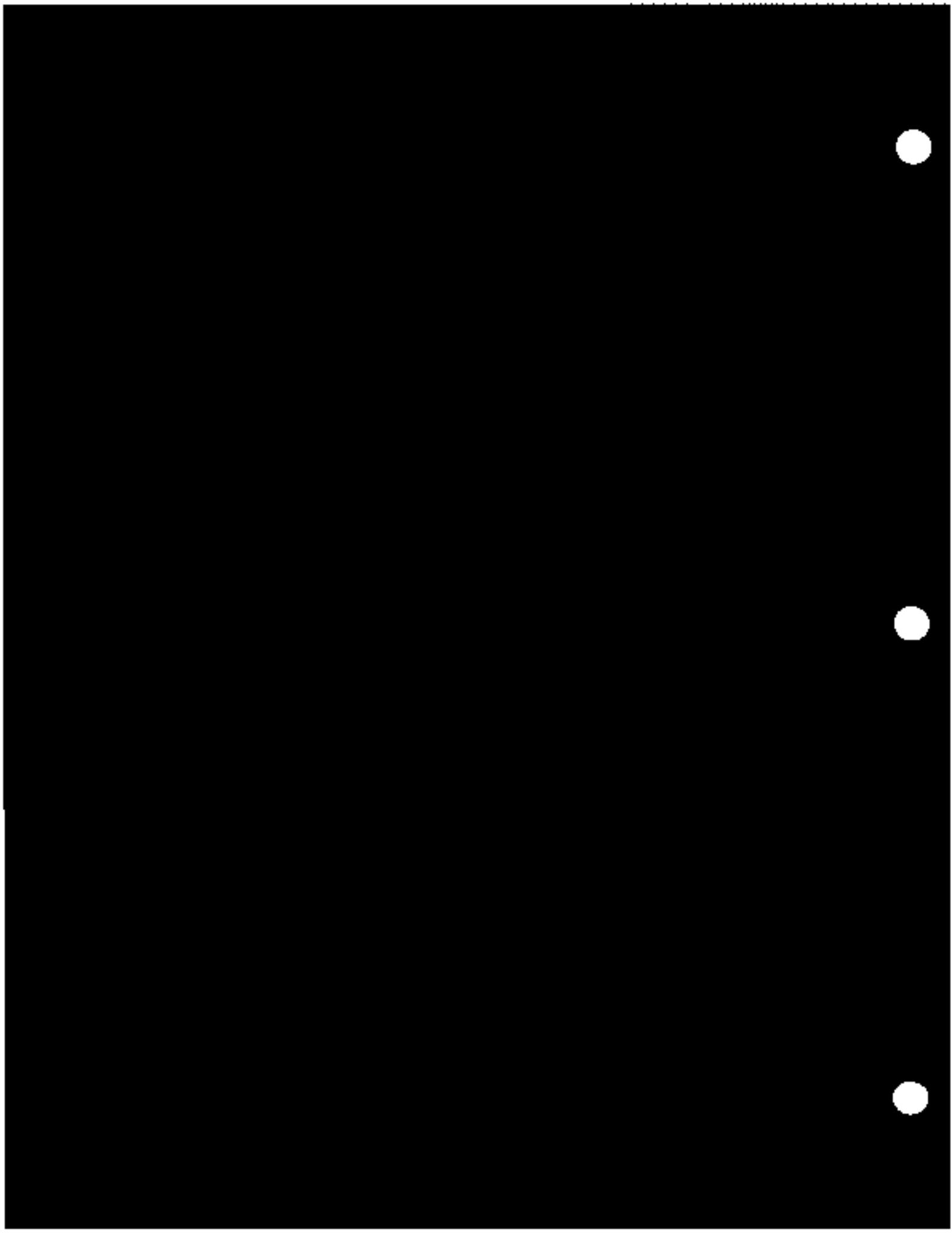

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REPORTING ON PROJECT DISPOSITION

CHAPTER 16

The need for local governments to report to the District on environmental analysis is important for a number of reasons:

- to take credit for actions local governments take to reduce emissions under the AQMP (i.e., reductions from mitigation measures applied to projects)
- to reassess the key assumptions that were used in determining the appropriate attainment strategy that was included in the AQMP (i.e., population projections, etc.)
- to assess cumulative impacts of insignificant projects
- To comply with CEQA

Credit for Local Government Actions. The District is responsible for demonstrating that the SCAB, Coachella Valley and Antelope Valley are making sufficient progress in attaining the federal and state ambient air quality standards. Therefore, the District must show that emissions within its jurisdiction are being reduced and must substantiate its progress through quantitative reporting. In the past, the District has not been able to quantitatively demonstrate reductions in emissions from local government actions, despite the mitigation measures now in force. Therefore, the District is requesting that local governments voluntarily participate in monitoring programs.

When the lead agencies report on the disposition of environmental documents for projects, the District is able to document emission reductions. These reports will also document the progress of local governments in implementing the 1991 AQMP since a heightened CEQA involvement process was included as a control measure (M-H-1) in the Plan. Documenting the contributions of local governments in implementing the AQMP is critical. Without the cooperation of local governments, the region could face a situation in which emission reductions would need to be made up through the application of more stringent regulations and the regulation of smaller sources, and contingency measures would need to be implemented. Additionally, federal funds for transportation and wastewater treatment facilities could be restricted.

Most importantly, recent gains toward cleaning up the air could be set back, and the region would not be able to meet the federal and state ambient air quality standards within the 20-year time frame set out in the 1991 AQMP.

Assessing AQMP Assumptions. The AQMP must set out a comprehensive emissions reduction strategy that demonstrates attainment of National Ambient Air Quality Standards by the deadlines established in the federal Clean Air Act for each type of pollutant. In addition, the AQMP strategy must also achieve federal and state targets for interim emissions reductions. The AQMP strategy forecasts emission levels, based in part on SCAG's forecasts of future employment, population, and travel in the region. SCAG's forecasts reflect trends in the many complex forces which determine regional growth: births, deaths, immigration, emigration, shifts in regional, state, national and international economic factors; and changes in local land use plans and policies. It is important to monitor and regularly update forecasts of future emissions, employment, population, and travel. It is also important that new and existing development implement the measures which the AQMP assumes they will perform.

Cumulative Impacts. Individually, projects may not have a significant impact on air quality, however when considered together the impact may be significant. Annual reporting will assist the District in assessing the impacts that the unmitigated emissions from projects are having on the attainment strategy contained in the AQMP.

CEQA Reporting. CEQA Guidelines Section 15095 requires that lead agencies provide a final certified EIR to responsible agencies. The District requests a copy of the final certified EIR whenever it is a responsible or commenting agency under CEQA. In addition, CEQA Guidelines Section 21092.5

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requires lead agencies to provide written responses to public agencies on comments made by that agency at least ten days prior to certifying the final EIR for the project.

Ten days prior to certifying the final EIR, the lead agency should provide the District with written responses to comments made by the District.

Project environmental documentation which the District has commented on should be sent to the District. Specifically, the lead agency should transmit the final environmental documentation and the mitigation monitoring program, along with a District reporting form (see Figure 16-1). The District will use the information on the reporting form relating to unmitigated and mitigated emissions to document local government efforts in implementing the AQMP. In addition, if the project proponent will be applying for a District permit which is covered by the environmental document, it should be submitted to Engineering when the permit is applied for. At that time, the District will make a determination as to whether the environmental documentation is sufficient to cover the District's permitting activity. In addition, the District will request annual reporting of all projects to document region-wide cumulative impacts. SCAG monitors local government actions to assess the key assumptions, such as population forecasts, that went into the AQMP.

16.1 Reporting on Environmental Documents

Local governments are requested to report on the disposition of all significant projects. Refer to Chapter 6 for a list of projects deemed to be significant.

The report should be made to the District within 60 days of approval of the project by the lead agency. The information submitted to the District should include the following:

- Final certified EIR or Mitigated Negative Declaration (MND)
- Mitigation monitoring program
- Completed reporting form

The project disposition reporting form is divided into three sections. Section I requests information on the lead agency, project location, and State Clearinghouse and District project identification numbers (the District assigns identification numbers only to those projects that it has reviewed and commented upon). It is imperative that information on the estimated year of construction and build-out be included on the reporting form.

Section II requests specific information regarding the type and size of the project. The District needs a definitive description of the project in order to quantitatively determine the emission reduction benefits of the CEQA program. It is preferable that planners provide the number of units or square feet of facilities whenever possible. Use acres only when estimates of square footage are not available.

In Section III, planners should identify the emissions produced by the project prior to mitigation (unmitigated emissions), the emissions reductions from mitigation (mitigated emissions), and the emissions that the project will produce with mitigation being applied (net emissions). If the EIR or MND was prepared in accordance with the CEQA Handbook, these emissions estimates should be readily available.

The completed reporting form, along with the final certified EIR or MND, mitigation monitoring program, and response to District comments should be sent to:

CEQA Coordinator
South Coast Air Quality Management District
21865 East Copley Drive
P.O. Box 4939
Diamond Bar, CA 91765-0939

If you have any questions about reporting or completing the reporting form, contact the CEQA Coordinator at (909) 396-3109.

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Figure 16-1. Reporting Form

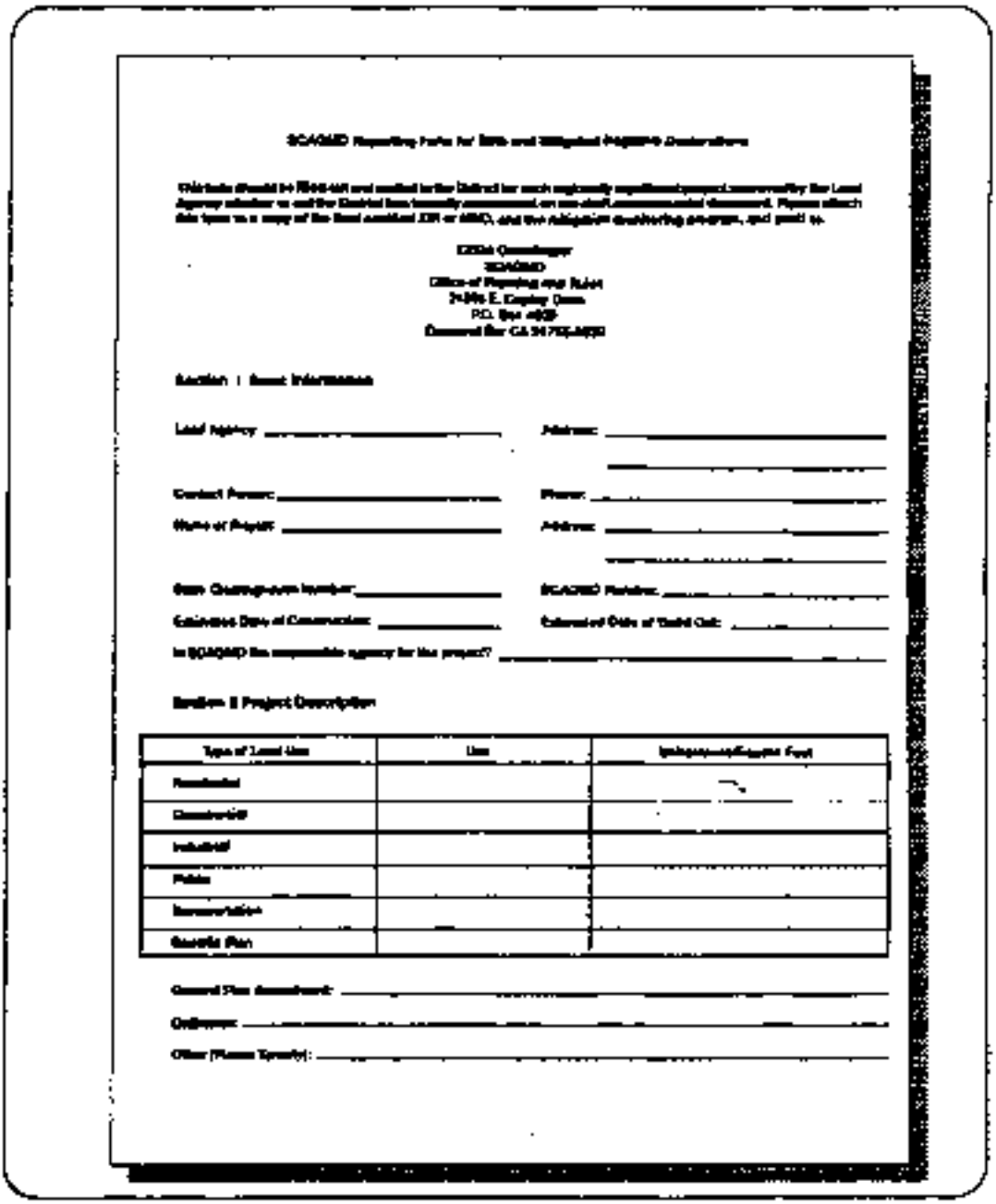

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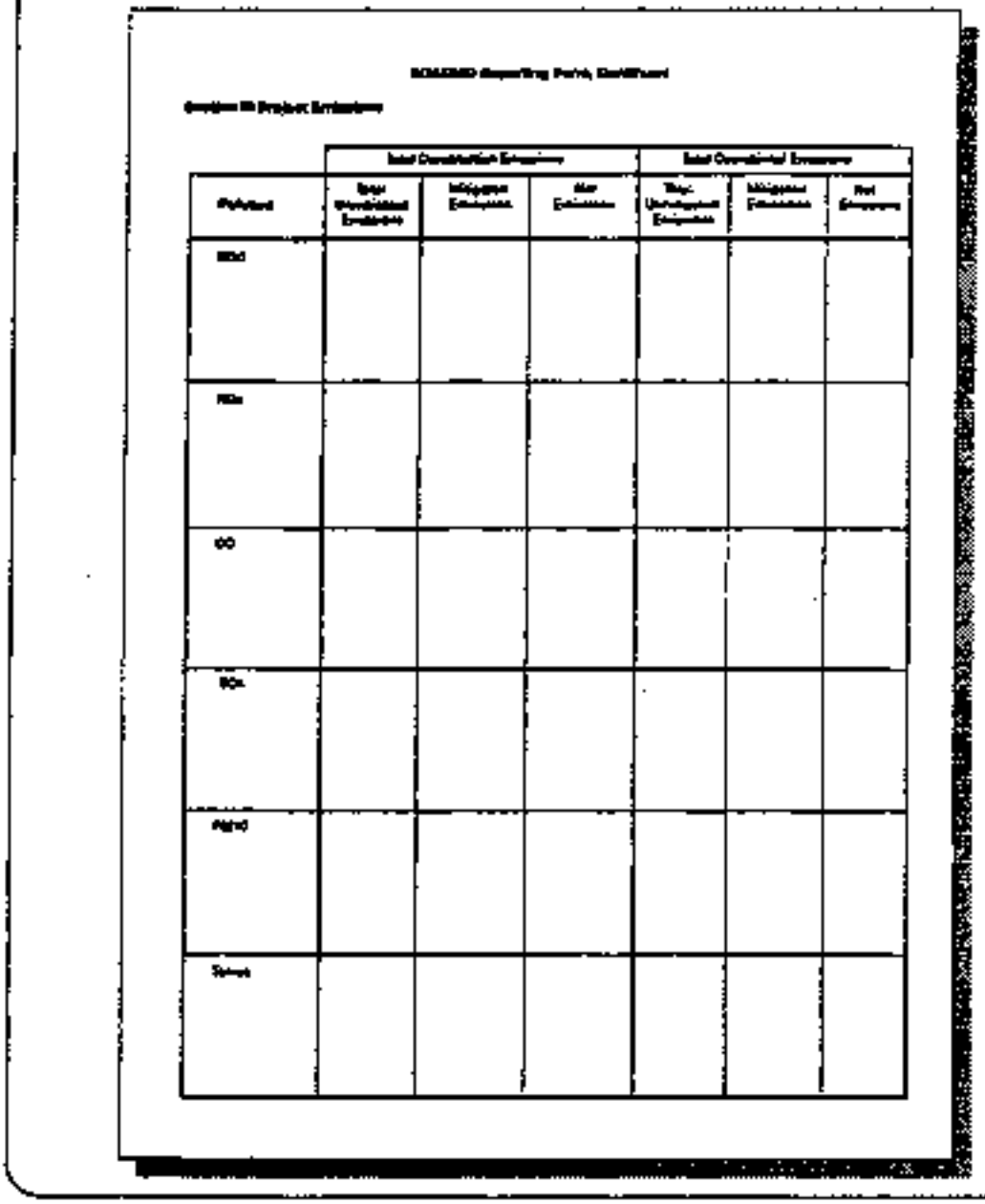
Figure 16-1. Reporting Form (continued)



Pollutant	Total Construction Emissions			Total Operational Emissions		

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CIVIC CENTER PARKING
[illegible] LOS ANGELES ST [illegible]
LOS ANGELES, CA. 90012
213-978-2777

Merchant ID: 8013418599
Term ID: 001[illegible]

Sale

xxxxxxxxxxxx0952
DISCOVER Entry Method: Swiped

Total: $ 16.00

08/29/13 12:11:04
Inv #: 000024 Appr Code: 000720
Approval: Online

Customer Copy

Thank You

Los Angeles Mall
City of Los Angeles

TRANSACTION ID: 20045
TICKET NO. 12772

OPERATOR: MARIA GUILLEN(MARIG-1)

[illegible]

[illegible]	$[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
TOTAL AMOUNT DUE	$[illegible]
CASH	$[illegible]
CHANGE DUE	$[illegible]

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INFORMATION
FOR
TEMPERATURES, AREAS, AND EMISSION FACTORS

AR0072977

TABLE A9 - 5 - I

ESTIMATING TEMPERATURES NEEDED TO CHOOSE COMPOSITE EMISSION FACTORS

The air quality analysis in environmental documents (EIR, NDs, MNDs, etc.) should include emission estimates using average speed, vehicle miles traveled (VMT), average daily trips (ADT) and number of vehicles (NOVs). Composite emission factors are provided in Table A9 - 5 - I, A9 - 5 - K, A9 - 5 - L and A9 - 5 - N of the Appendix 9.

COMPOSITE EMISSION FACTORS

Emission factors associated with gasoline vehicles equipped with and without catalytic converters were combined. These combined factors were added to the diesel-fueled vehicles emission factors to estimate a weighted average between three fuels. For passenger vehicles, the weighted average was for light-duty automobiles and light-duty trucks, and for materials hauling vehicles, the weighted average was for medium-duty, light-heavy-duty, medium-heavy-duty, and heavy-heavy-duty trucks as defined by the California Air Resources Board.

TEMPERATURES FOR EACH POLLUTANT TYPE AND AREA TYPE

Table A9 - 5 - I, A9 - 5 - K, A9 - 5 - L and A9 - 5 - N provide emissions factors for the Areas 1-3.

Area 1	Orange County
Area 2	Los Angeles County
Area 3	Riverside County and San Bernardino County

Temperatures for each area were selected using worst-case scenarios. The ten highest exceedance days experienced, in the counties and subcounties within the District, were examined to determine the worst-case temperatures. Each exceedance day had six two-hour time periods in which high levels were observed. Temperature readings between four time periods were selected. Morning temperatures were averaged for time periods between 6 a.m to 8 a.m., and 9 a.m. to 11 a.m. for each County. For the remainder of the exceedance day, the temperatures between 12 p.m. to 2 p.m., and 3 p.m. to 5 p.m. were averaged for each County.

The lowest temperatures were selected for carbon monoxide (CO) and oxides of nitrogen (NOx), because at lower temperatures incomplete combustion occurs that leads to high CO and NOx emissions. CO emission factors for all areas were adjusted to 60°F. For Area 1, NOx emission factors were adjusted to 70°F, for Area 2 to 75°F, and for Area 3 to 80°F. Temperature correction factors for PM10, sulfur and lead are not currently available. The enclosed emission factors are based on room temperatures (i.e., 75°F) for these three pollutants.

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The District takes limited measurements of reactive organic compounds (ROCs). Temperature estimates are based on the 10 worst ozone exceedance days. Ozone is formed from reactions between ROC and NOx in the presence of sunlight. Greater levels of ozone are formed at higher temperatures. ROC emission increases are high during high temperatures due to evaporative and combustive emissions, with minimal evaporative emissions during cooler weather. For Areas 1 and 2, ROC emission factors were adjusted to 85°F, while for Area 3, these were adjusted to 100°F. (0.92 factor was used to convert Total Organic Compounds to Reactive Organic Gases.) Following are the pollutant concentrations exceedance day temperatures and selected temperatures for the composite emission factors:

Time of the Day	Exceedance Temperature			Temperatures For Each Area (°F)
	6-11	12-14	15-17	
Carbon Monoxide (CO)				
Orange (Area 1)	69	71	66	60
Los Angeles Coastal (Area 2)	57.5	70	65	60
Los Angeles Inland (Area 2)	60.5	73	64	60
Riverside (Area 3)	64	75	68	60
San Bernardino (Area 4)	62.5	79	73	60
Oxides of Nitrogen (NOx)				
Orange (Area 1)	71	82	77	70
Los Angeles Coastal (Area 2)	67.5	76	72	75
Los Angeles Inland (Area 2)	82.5	91	83	75
Riverside (Area 3)	77	87	81	80
San Bernardino (Area 4)	82.5	93	86	80
Reactive Organic Compounds (ROC)				
Orange (Area 1)	75	83	80	85
Los Angeles Coastal (Area 2)	71	78	75	85
Los Angeles Inland (Area 2)	83.5	93.5	88	85
Riverside (Area 3)	88.25	99.5	96	100
San Bernardino (Area 4)	86.0	99.5	97	100

Tables A9 - 5 - J - 1 thru 10, and Table A9 - 5 - L
Emission factors for passenger vehicles

Tables A9 - 5 - K - 1 thru 10, and Table A9 - 5 - L
Emission factors for trucks

Tables A9 - 5 - N - 1 thru 3
Emission factors for motorcycles

Tables A11 - 5 - H - 1 thru 10
Emission factors for buses

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TABLE A9 - 5 - J

EMISSION FACTORS FOR ESTIMATING PASSENGER VEHICLE EMISSIONS

USE

TABLE A9 - 5 - L

FOR ESTIMATING OXIDES OF SULFUR AND LEAD EMISSIONS FROM PASSENGER VEHICLES

USE

TABLE A9 - 14 - A

FOR PASSENGER VEHICLE-RELATED
VEHICLE MILES TRAVELED (VMT)
AVERAGE DAILY TRIPS (ADT) AND NUMBER OF VEHICLES (NOV)
IN COUNTYWIDE AND REGIONWIDE FLEET MIX
AND

TABLE A9 - 5 - G*

FOR THEIR PERCENTAGES

USE

TABLE A9 - 5 - P - 1 AND 2

FOR DETERMINING COMPOSITE EMISSION FACTOR BETWEEN
FOUR DIFFERENT TYPES OF VEHICLES TOGETHER, SUCH AS,
PASSENGER VEHICLES, MOTORCYCLES AND BUSES
INCLUDING MATERIAL HAULING VEHICLES
AND
BETWEEN RUNNING, HOT AND COLD START EMISSION FACTORS FOR
THE PASSENGER VEHICLES

(* IF PROJECT-SPECIFIC FLEET MIX DATA IS NOT AVAILABLE,
USE TABLE A9 - 5 - G TO DETERMINE PROJECT-RELATED
FLEET MIX DATA)

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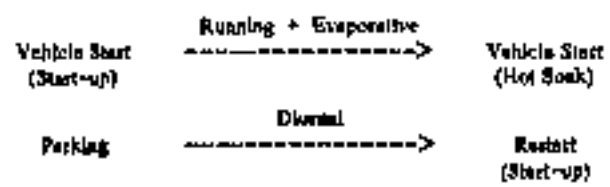
TABLE A9 – 5 – J – 1
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 1991

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	40.70	40.76	41.51	3.51	3.51	4.73	1.22	1.22	1.20	0.01	0.10
10	21.07	21.10	21.47	1.97	1.97	2.90	1.10	1.10	1.08	0.01	0.10
15	14.55	14.57	14.81	1.42	1.42	2.19	1.00	1.01	0.98	0.01	0.10
20	11.05	11.06	11.24	1.11	1.12	1.75	0.93	0.93	0.91	0.01	0.10
25	8.86	8.87	9.02	0.91	0.91	1.43	0.88	0.88	0.86	0.01	0.10
30	7.37	7.38	7.50	0.75	0.76	1.16	0.85	0.85	0.83	0.01	0.10
35	6.30	6.31	6.41	0.62	0.23	0.91	0.83	0.83	0.81	0.01	0.10
40	5.51	5.52	5.61	0.50	0.19	0.69	0.82	0.82	0.80	0.01	0.10
45	4.93	4.94	5.02	0.40	0.15	0.49	0.83	0.83	0.81	0.01	0.10
50	4.49	4.49	4.57	0.35	0.13	0.39	0.96	0.96	0.93	0.01	0.10
55	4.09	4.09	4.16	0.32	0.12	0.35	1.25	1.25	1.22	0.01	0.10
60	7.67	7.68	8.02	0.41	0.15	0.45	1.55	1.55	1.51	0.01	0.10
65	17.98	18.00	18.30	0.70	0.26	0.77	1.85	1.86	1.81	0.01	0.10
COLD START* (Grams/Trip)	93.50	93.49	93.38	5.20	5.21	5.38	2.89	2.90	2.85		
HOT START* (Grams/Trip)	12.72	12.74	13.02	1.37	1.38	1.55	1.68	1.68	1.66		
HOT SOAK* (Grams/Trip)	---	---	---	2.11	2.11	2.13	---	---	---		
DIURNAL** (Grams/Vehicle/Day)	---	---	---	5.01	5.01	5.01	---	---	---		

Example of one daily trip:



* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT)-weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (2.25%), gasoline-fueled vehicles equipped with catalyst (93.58%), and gasoline-fueled vehicles not equipped with catalyst (4.18%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (2.40%), gasoline-fueled vehicles equipped with catalyst (89.51%), and gasoline-fueled vehicles not equipped with catalyst (8.1%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 trucks.

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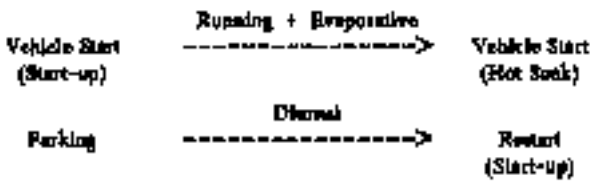
TABLE A9 - 5 - J - 2
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 1993

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	73.49	71.92	65.84	6.49	6.39	6.95	7.97	7.64	9.43	0.47	0.19
10	46.95	45.75	42.01	4.23	4.11	4.61	6.97	6.69	8.11	0.47	0.19
15	33.39	32.56	29.96	3.04	2.96	3.38	6.30	6.04	7.21	0.47	0.19
20	25.08	24.48	22.54	2.32	2.27	2.62	5.86	5.62	6.61	0.47	0.19
25	19.83	19.36	17.84	1.85	1.80	2.10	5.60	5.37	6.25	0.47	0.19
30	16.46	16.07	14.80	1.52	1.48	1.74	5.48	5.25	6.06	0.47	0.19
35	14.31	13.97	12.86	1.29	1.26	1.47	5.48	5.26	6.05	0.47	0.19
40	13.05	12.73	11.70	1.11	1.09	1.27	5.62	5.38	6.19	0.47	0.19
45	12.49	12.16	11.15	1.00	0.97	1.13	5.87	5.62	6.50	0.47	0.19
50	12.54	12.18	11.15	0.92	0.90	1.04	6.37	6.09	7.09	0.47	0.19
55	13.16	12.76	11.63	0.87	0.85	0.98	7.17	6.88	8.04	0.47	0.19
60	16.74	16.39	14.88	0.91	0.90	1.03	8.23	7.90	9.32	0.47	0.19
65	24.75	24.61	22.26	1.11	1.10	1.23	9.66	9.27	11.10	0.47	0.19
COLD START* (Grams/Trip)	46.17	44.77	45.50	2.76	2.68	2.93	2.02	1.96	1.97		
HOT START* (Grams/Trip)	4.42	4.27	4.36	0.72	0.69	0.81	0.95	0.92	0.88		
HOT SOAK* (Grams/Trip)	—	—	—	0.90	1.02	1.04	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	3.64	3.64	3.64	—	—	—		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy vehicles, e.g.; construction and demolition materials hauling trucks.

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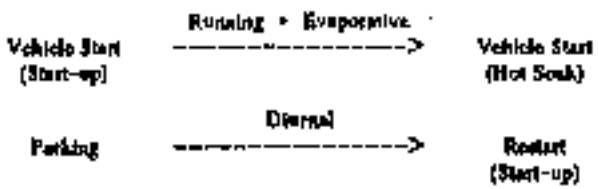
TABLE A9 - 5 - J - 3
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 1995

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	25.53	25.57	26.00	1.91	1.91	2.67	0.94	0.94	0.93	0.01	0.10
10	14.21	14.23	14.45	1.03	1.03	1.54	0.84	0.84	0.83	0.01	0.30
15	10.44	10.46	10.61	0.72	0.72	1.12	0.77	0.77	0.75	0.01	0.10
20	8.00	8.01	8.13	0.56	0.56	0.89	0.70	0.70	0.69	0.01	0.10
25	6.40	6.41	6.50	0.45	0.45	0.71	0.66	0.66	0.65	0.01	0.10
30	5.32	5.32	5.40	0.37	0.37	0.58	0.61	0.61	0.60	0.01	0.10
35	4.54	4.54	4.61	0.31	0.31	0.45	0.59	0.59	0.58	0.01	0.10
40	3.97	3.97	4.03	0.26	0.26	0.36	0.57	0.57	0.56	0.01	0.10
45	3.54	3.54	3.60	0.22	0.22	0.28	0.56	0.56	0.55	0.01	0.10
50	3.20	3.21	3.25	0.19	0.19	0.23	0.64	0.64	0.63	0.01	0.10
55	2.90	2.91	2.95	0.18	0.18	0.22	0.85	0.85	0.83	0.01	0.10
60	5.60	5.61	5.70	0.23	0.23	0.27	1.05	1.05	1.03	0.01	0.10
65	12.81	12.83	13.02	0.38	0.38	0.46	1.25	1.25	1.22	0.01	0.10
COLD START* (Grams/Trip)	81.98	82.00	82.10	4.36	4.37	4.34	2.52	2.52	2.50		
HOT START* (Grams/Trip)	10.90	10.92	11.12	0.96	0.96	1.45	1.30	1.31	1.24		
HOT SOAK* (Grams/Trip)	----	----	----	1.11	1.11	1.11	-----	-----	-----		
DIURNAL** (Grams/Vehicle/Day)	-----	----	----	2.90	2.90	2.91	-----	-----	-----		

Example of one daily trip.



* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (1.11%), gasoline-fueled vehicles equipped with catalyst (97.32%), and gasoline-fueled vehicles not equipped with catalyst (1.57%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (1.54%), gasoline-fueled vehicles equipped with catalyst (95.06%), and gasoline-fueled vehicles not equipped with catalyst (3.40%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 trucks.

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TABLE A9 - 5 - 1 - 4
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 1997

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	19.92	19.97	20.26	1.65	1.65	2.17	0.84	0.85	0.84	0.005	0.10
10	11.60	11.63	11.79	0.88	0.88	1.25	0.75	0.75	0.75	0.005	0.10
15	8.84	8.86	8.98	0.61	0.61	0.90	0.68	0.68	0.68	0.005	0.10
20	6.81	6.83	6.92	0.47	0.47	0.71	0.62	0.62	0.62	0.005	0.10
25	5.45	5.46	5.54	0.38	0.38	0.57	0.58	0.58	0.58	0.005	0.10
30	4.53	4.54	4.61	0.31	0.31	0.45	0.54	0.54	0.53	0.005	0.10
35	3.88	3.89	3.94	0.25	0.25	0.36	0.51	0.51	0.51	0.005	0.10
40	3.39	3.40	3.44	0.21	0.21	0.32	0.49	0.49	0.49	0.005	0.10
45	3.03	3.03	3.08	0.17	0.17	0.21	0.48	0.48	0.48	0.005	0.10
50	2.74	2.74	2.78	0.16	0.16	0.18	0.55	0.55	0.54	0.005	0.10
55	2.48	2.49	2.52	0.15	0.15	0.17	0.72	0.72	0.71	0.005	0.10
60	4.60	4.61	4.88	0.18	0.18	0.21	0.88	0.88	0.97	0.005	0.10
65	10.97	10.99	11.14	0.31	0.32	0.36	1.05	1.05	1.04	0.005	0.10
COLD START* (Grams/Trip)	74.78	74.82	74.98	4.10	4.11	4.02	2.39	2.40	2.38		
HOT START (Grams/Trip)	9.47	9.49	9.64	0.91	0.92	1.07	1.26	1.26	1.16		
HOT SOAK* (Grams/Trip)	—	—	—	0.94	0.94	0.95	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	2.63	2.63	2.64	—	—	—		

Example of one daily trip:

Vehicle Start (Start-up) —Running + Evaporative—> Vehicle Start (Hot Soak)

Parking —Diurnal—> Restart (Start-up)

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (0.68%), gasoline-fueled vehicles equipped with catalyst (98.45%), and gasoline-fueled vehicles not equipped with catalyst (0.87%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (1.04%), gasoline-fueled vehicles equipped with catalyst (97.03%), and gasoline-fueled vehicles not equipped with catalyst (1.93%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 trucks

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TABLE A9 - 5 - J - 5
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 1999

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	15.61	15.65	15.87	1.33	1.33	1.75	0.73	0.73	0.76	0.005	0.10
10	9.48	9.51	9.64	0.69	0.69	0.99	0.65	0.66	0.68	0.005	0.10
15	7.45	7.47	7.57	0.48	0.48	0.72	0.59	0.59	0.61	0.005	0.10
20	5.76	5.77	5.85	0.37	0.37	0.56	0.53	0.54	0.55	0.005	0.10
25	4.60	4.62	4.68	0.29	0.29	0.44	0.49	0.49	0.51	0.005	0.10
30	3.83	3.85	3.90	0.23	0.23	0.35	0.46	0.46	0.48	0.005	0.10
35	3.29	3.30	3.34	0.20	0.20	0.28	0.44	0.44	0.45	0.005	0.10
40	2.88	2.89	2.92	0.16	0.16	0.21	0.42	0.42	0.43	0.005	0.10
45	2.55	2.56	2.59	0.13	0.13	0.16	0.40	0.41	0.42	0.005	0.10
50	2.30	2.31	2.34	0.12	0.12	0.14	0.46	0.46	0.47	0.005	0.10
55	2.09	2.10	2.13	0.11	0.11	0.13	0.60	0.60	0.62	0.005	0.10
60	4.08	4.09	4.15	0.14	0.14	0.16	0.74	0.74	0.77	0.005	0.10
65	9.34	9.36	9.49	0.24	0.24	0.28	0.89	0.90	0.92	0.005	0.10
COLD START* (Grams/Trip)	68.40	68.45	68.61	3.63	3.63	3.55	2.20	2.21	2.20		
HOT START* (Grams/Trip)	7.96	7.99	8.12	0.71	0.71	0.83	1.11	1.12	0.89		
HOT SOAK* (Grams/Trip)	—	—	—	0.76	0.76	0.76	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	2.21	2.21	2.21	—	—	—		

Example of one daily trip:

Vehicle Start (Start-up) —— Running + Evaporative ——> Vehicle Start (Hot Soak)

Parking —— Diurnal ——> Restart (Start-up)

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (0.39%), gasoline-fueled vehicles equipped with catalyst (99.38%), and gasoline-fueled vehicles not equipped with catalyst (0.23%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (0.68%), gasoline-fueled vehicles equipped with catalyst (98.78%), and gasoline-fueled vehicles not equipped with catalyst (0.54%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 trucks.

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TABLE A9 – 5 – J – 6
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 2001

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	12.23	12.28	12.44	2.49	2.50	1.38	0.66	0.67	0.67	0.005	0.10
10	7.76	7.79	7.90	1.81	1.82	0.78	0.59	0.59	0.60	0.005	0.10
15	6.27	6.30	6.38	1.47	1.48	0.56	0.53	0.54	0.54	0.005	0.10
20	4.87	4.89	4.96	1.21	1.21	0.43	0.49	0.49	0.49	0.005	0.10
25	3.90	3.91	3.96	0.98	0.99	0.34	0.44	0.45	0.45	0.005	0.10
30	3.24	3.25	3.30	0.77	0.77	0.27	0.42	0.42	0.42	0.005	0.10
35	2.78	2.79	2.83	0.57	0.57	0.22	0.39	0.39	0.39	0.005	0.10
40	2.43	2.44	2.47	0.37	0.37	0.16	0.37	0.38	0.38	0.005	0.10
45	2.17	2.18	2.20	0.18	0.18	0.13	0.36	0.36	0.37	0.005	0.10
50	1.95	1.96	1.98	0.10	0.10	0.11	0.41	0.41	0.41	0.005	0.10
55	1.78	1.78	1.81	0.09	0.09	0.10	0.53	0.54	0.54	0.005	0.10
60	3.46	3.47	3.52	0.12	0.12	0.14	0.66	0.66	0.67	0.005	0.10
65	7.90	7.93	8.04	0.19	0.19	0.22	0.79	0.80	0.80	0.005	0.10
COLD START* (Grams/Trip)	62.48	62.55	62.71	3.01	3.02	2.98	1.94	1.95	1.95		
HOT START* (Grams/Trip)	6.67	6.70	6.83	0.57	0.58	0.67	0.97	0.98	0.72		
HOT SOAK* (Grams/Trip)	—	—	—	0.61	0.61	0.61	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	1.77	1.77	1.79	—	—	—		

Example of one daily trip:

Vehicle Start (Start-up) —— Running + Evaporative ——> Vehicle Start (Hot Soak)

Parking —— Diurnal ——> Restart (Start-up)

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT)-weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (0.22%), gasoline-fueled vehicles equipped with catalyst (99.68%), and gasoline-fueled vehicles not equipped with catalyst (0.1%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (0.43%), gasoline-fueled vehicles equipped with catalyst (99.36%), and gasoline-fueled vehicles not equipped with catalyst (0.21%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4

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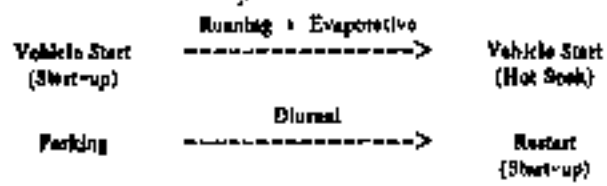
TABLE A9 - 5 - 3 - 7

EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 2003

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	11.37	11.42	11.55	0.85	0.85	1.09	0.57	0.58	0.59	0.005	0.10
10	7.48	7.51	7.60	0.44	0.45	0.61	0.51	0.51	0.52	0.005	0.10
15	6.19	6.22	6.29	0.30	0.30	0.43	0.46	0.46	0.47	0.005	0.10
20	4.62	4.64	4.90	0.23	0.23	0.33	0.41	0.42	0.42	0.005	0.10
25	3.86	3.87	3.92	0.19	0.19	0.27	0.38	0.38	0.39	0.005	0.10
30	3.21	3.22	3.26	0.15	0.15	0.21	0.36	0.36	0.37	0.005	0.10
35	2.76	2.77	2.80	0.12	0.12	0.16	0.33	0.34	0.34	0.005	0.10
40	2.41	2.42	2.45	0.10	0.10	0.13	0.32	0.32	0.33	0.005	0.10
45	2.14	2.15	2.17	0.09	0.09	0.10	0.31	0.31	0.32	0.005	0.10
50	1.93	1.94	1.96	0.08	0.08	0.09	0.35	0.35	0.35	0.005	0.10
55	1.75	1.76	1.78	0.07	0.07	0.09	0.46	0.46	0.47	0.005	0.10
60	3.42	3.44	3.47	0.10	0.10	0.11	0.56	0.57	0.57	0.005	0.10
65	7.83	7.87	7.96	0.16	0.16	0.18	0.68	0.68	0.69	0.005	0.10
COLD START+ (Grams/Trip)	57.53	57.60	57.72	2.47	2.47	2.44	1.70	1.72	1.71		
HOT START+ (Grams/Trip)	5.58	5.62	5.74	0.57	0.59	0.66	0.84	0.84	0.69		
HOT SOAK+ (Grams/Trip)	----	----	----	0.48	0.48	0.49	----	----	----		
DIURNAL++ (Grams/Vehicle/Day)	----	----	----	1.37	1.37	1.38	----	----	----		

Example of one daily trip:



\+ Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weigted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (0.13%), gasoline-fueled vehicles equipped with catalyst (99.83%), and gasoline-fueled vehicles not equipped with catalyst (0.04%).

++ Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (0.29%), gasoline-fueled vehicles equipped with catalyst (99.62%), and gasoline-fueled vehicles not equipped with catalyst (0.09%).

+++ Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 trucks.

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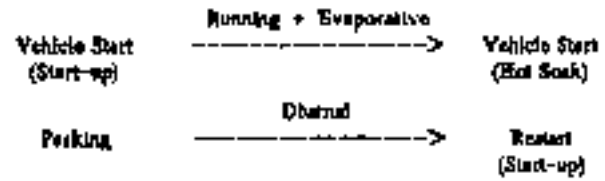
TABLE A9 - 5 - J - 8
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 2005

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	7.89	7.93	8.03	0.92	0.92	0.84	0.50	0.51	0.51	0.005	0.10
10	5.34	5.37	5.44	0.33	0.34	0.46	0.44	0.45	0.46	0.005	0.10
15	4.50	4.53	4.58	0.23	0.23	0.33	0.39	0.40	0.41	0.005	0.10
20	3.51	3.53	3.57	0.17	0.17	0.25	0.36	0.37	0.37	0.005	0.10
25	2.81	2.83	2.86	0.13	0.14	0.20	0.33	0.33	0.34	0.005	0.10
30	2.34	2.35	2.38	0.11	0.11	0.16	0.30	0.31	0.31	0.005	0.10
35	2.00	2.02	2.04	0.09	0.09	0.12	0.29	0.29	0.30	0.005	0.10
40	1.76	1.77	1.79	0.08	0.08	0.10	0.27	0.27	0.28	0.005	0.10
45	1.56	1.57	1.59	0.07	0.07	0.08	0.26	0.27	0.27	0.005	0.10
50	1.41	1.41	1.43	0.06	0.06	0.07	0.29	0.30	0.30	0.005	0.10
55	1.28	1.28	1.30	0.05	0.05	0.06	0.38	0.39	0.40	0.005	0.10
60	2.50	2.51	2.54	0.08	0.08	0.09	0.48	0.48	0.49	0.005	0.10
65	5.71	5.74	5.81	0.12	0.12	0.14	0.57	0.58	0.59	0.005	0.10
COLD START* (Grams/Trip)	53.27	53.37	53.48	1.99	1.99	1.97	1.48	1.50	1.50		
HOT START* (Grams/Trip)	4.73	4.77	4.89	0.35	0.35	0.41	0.72	0.73	0.44		
HOT SOAK* (Grams/Trip)	—	—	—	0.40	0.40	0.40	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	1.04	1.04	1.04	—	—	—		

Example of one daily trip:



* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (0.09%), gasoline-fueled vehicles equipped with catalyst (99.91%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (0.21%), gasoline-fueled vehicles equipped with catalyst (99.79%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 tr

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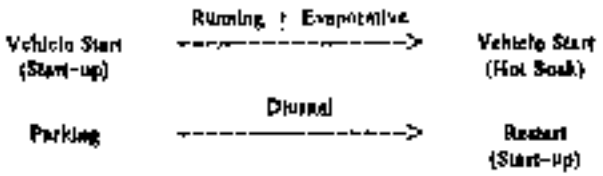
TABLE A9 - 5 - J - 9
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 2007

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	6.61	6.65	6.74	0.50	0.51	0.64	0.43	0.44	0.45	0.005	0.10
10	4.57	4.60	4.66	0.26	0.26	0.35	0.38	0.39	0.40	0.005	0.10
15	3.89	3.92	3.97	0.18	0.18	0.25	0.35	0.35	0.36	0.005	0.10
20	3.05	3.07	3.11	0.13	0.14	0.19	0.31	0.32	0.32	0.005	0.10
25	2.44	2.45	2.48	0.11	0.11	0.15	0.29	0.30	0.30	0.005	0.10
30	2.03	2.04	2.06	0.08	0.09	0.13	0.27	0.27	0.27	0.005	0.10
35	1.74	1.75	1.77	0.07	0.07	0.10	0.25	0.26	0.26	0.005	0.10
40	1.52	1.53	1.55	0.06	0.06	0.07	0.23	0.24	0.24	0.005	0.10
45	1.36	1.36	1.38	0.05	0.05	0.06	0.22	0.23	0.23	0.005	0.10
50	1.22	1.23	1.24	0.04	0.04	0.05	0.25	0.26	0.26	0.005	0.10
55	1.10	1.11	1.13	0.04	0.04	0.05	0.34	0.34	0.35	0.005	0.10
60	2.17	2.18	2.21	0.05	0.05	0.06	0.42	0.42	0.43	0.005	0.10
65	4.94	4.98	5.04	0.10	0.10	0.11	0.49	0.50	0.51	0.005	0.10
COLD START* (Grams/Trip)	49.96	50.07	50.18	1.60	1.60	1.58	1.32	1.33	1.33		
HOT START* (Grams/Trip)	4.13	4.18	4.31	0.28	0.28	0.32	0.64	0.65	0.35		
HOT SOAK* (Grams/Trip)	----	----	----	0.33	0.33	0.34	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	0.75	0.75	0.75	----	----	----		

Example of one daily trip:



* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (0.05%), gasoline-fueled vehicles equipped with catalyst (99.95%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)- weighted emission factors:
Includes NOV from diesel-fueled vehicles (0.11%), gasoline-fueled vehicles equipped with catalyst (99.89%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 trucks.

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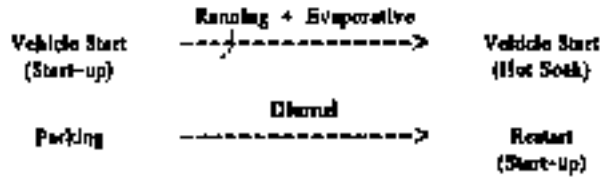
TABLE A9 – 5 – J – 10
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,000 Pounds and less***
Calendar Year 2009

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	5.73	5.78	5.86	0.39	0.39	0.50	0.38	0.39	0.40	0.005	0.10
10	4.04	4.08	4.13	0.20	0.20	0.27	0.34	0.35	0.35	0.005	0.10
15	3.48	3.51	3.56	0.13	0.14	0.19	0.30	0.31	0.32	0.005	0.10
20	2.73	2.75	2.79	0.11	0.11	0.15	0.28	0.29	0.29	0.005	0.10
25	2.18	2.20	2.23	0.09	0.09	0.12	0.26	0.26	0.26	0.005	0.10
30	1.82	1.83	1.86	0.07	0.07	0.10	0.23	0.24	0.24	0.005	0.10
35	1.56	1.57	1.59	0.06	0.06	0.08	0.22	0.23	0.23	0.005	0.10
40	1.36	1.37	1.39	0.05	0.05	0.06	0.21	0.21	0.22	0.005	0.10
45	1.22	1.23	1.24	0.04	0.04	0.05	0.20	0.20	0.21	0.005	0.10
50	1.10	1.11	1.12	0.03	0.03	0.04	0.22	0.23	0.23	0.005	0.10
55	0.99	1.00	1.01	0.03	0.03	0.04	0.29	0.30	0.30	0.005	0.10
60	1.93	1.95	1.98	0.04	0.04	0.05	0.36	0.37	0.38	0.005	0.10
65	4.43	4.47	4.53	0.08	0.08	0.09	0.43	0.44	0.45	0.005	0.10
COLD START* (Grams/Trip)	47.53	47.65	47.75	1.30	1.30	1.28	1.19	1.21	1.20		
HOT START* (Grams/Trip)	3.71	3.76	3.89	0.22	0.23	0.26	0.57	0.58	0.28		
HOT SOAK* (Grams/Trip)	——	——	——	0.29	0.29	0.29	——	——	——		
DIURNAL** (Grams/Vehicle/Day)	——	——	——	0.53	0.54	0.54	——	——	——		

Example of one daily trip:



* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (0.03%), gasoline-fueled vehicles equipped with catalyst (99.97%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (0.07%), gasoline-fueled vehicles equipped with catalyst (99.93%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Vehicles with gross vehicle weight 6,000 pounds and less:
Includes ARB's light automobiles, light-duty trucks, vans, station wagons and 4x4 [illegible]

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TABLE A9 - 5 - K

EMISSION FACTORS FOR ESTIMATING MATERIAL HAULING VEHICLE EMISSIONS

USE

TABLE A9 - 5 - L

FOR ESTIMATING OXIDES OF SULFUR AND LEAD EMISSIONS FROM MATERIAL HAULING VEHICLES

USE

TABLE A9 - 14 - A

FOR MATERIAL HAULING VEHICLE-RELATED
VEHICLE MILES TRAVELED (VMT)
AVERAGE DAILY TRIPS (ADT) AND NUMBER OF VEHICLES (NOV)
IN COUNTYWIDE AND REGIONWIDE FLEET MIX
AND

TABLE A9 - 5 - G*

FOR THEIR PERCENTAGES

USE

TABLE A9 - 5 - F - 1 AND 2

FOR DETERMINING COMPOSITE EMISSION FACTOR BETWEEN
FOUR DIFFERENT TYPES OF VEHICLES TOGETHER, SUCH AS,
PASSENGER VEHICLES, MOTORCYCLES AND BUSES
INCLUDING MATERIAL HAULING VEHICLES
AND
BETWEEN RUNNING, HOT AND COLD START EMISSION FACTORS FOR
THE MATERIAL HAULING VEHICLES

(* IF PROJECT-SPECIFIC FLEET MIX DATA IS NOT AVAILABLE,
USE TABLE A9 - 5 - G TO DETERMINE PROJECT-RELATED
FLEET MIX DATA)

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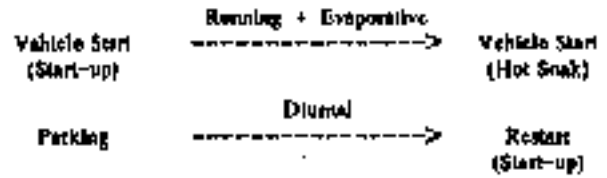
TABLE A9 – 5 – K – 1
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 1991

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	84.49	82.50	74.48	7.75	7.62	8.19	8.60	8.25	10.20	0.565	0.175
10	53.78	52.33	47.33	5.00	4.90	5.41	7.31	7.20	8.76	0.565	0.175
15	38.02	37.01	33.53	3.60	3.52	3.98	6.76	6.49	7.77	0.565	0.175
20	28.52	27.78	25.20	2.75	2.70	3.09	6.28	6.04	7.12	0.565	0.175
25	22.54	21.97	19.94	2.19	2.15	2.49	6.00	5.76	6.72	0.565	0.175
30	18.70	18.23	16.54	1.79	1.76	2.05	5.87	5.63	6.53	0.565	0.175
35	16.28	15.86	14.38	1.51	1.48	1.72	5.88	5.64	6.51	0.565	0.175
40	14.87	14.48	13.11	1.31	1.28	1.47	6.02	5.77	6.66	0.565	0.175
45	14.28	13.88	12.54	1.16	1.14	1.29	6.30	6.04	7.00	0.565	0.175
50	14.40	13.97	12.59	1.07	1.04	1.18	6.84	6.56	7.64	0.565	0.175
55	15.19	14.71	13.20	1.01	0.99	1.11	7.71	7.41	8.68	0.565	0.175
60	19.07	18.62	16.66	1.07	1.05	1.18	8.87	8.52	10.08	0.565	0.35
65	27.63	27.37	24.53	1.31	1.30	1.43	10.43	10.02	12.02	0.565	0.35
COLD START* (Grams/Trip)	48.49	47.11	47.20	2.99	2.91	3.29	2.00	1.94	1.93		
HOT START* (Grams/Trip)	4.37	4.22	4.32	0.76	0.74	0.85	0.92	0.89	0.85		
HOT SOAK* (Grams/Trip)	----	----	----	1.43	1.60	1.63	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	5.75	5.75	5.75	----	----	----		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy-duty vehicles, e.g.; construction and demolition materials hauling trucks.

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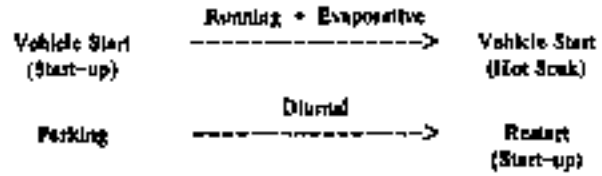
TABLE A9 - 5 - K - 2
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 1993

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	73.49	71.92	65.84	6.49	6.39	6.98	7.97	7.64	9.43	0.47	0.19
10	46.95	45.75	42.01	4.21	4.11	4.61	6.97	6.69	8.11	0.47	0.19
15	33.39	32.56	29.96	3.04	2.96	3.38	6.30	6.04	7.21	0.47	0.19
20	25.08	24.48	22.54	2.32	2.27	2.62	5.86	5.62	6.61	0.47	0.19
25	19.83	19.36	17.84	1.85	1.80	2.10	5.60	5.37	6.25	0.47	0.19
30	16.46	16.07	14.80	1.52	1.48	1.74	5.48	5.25	6.06	0.47	0.19
35	14.31	13.97	12.86	1.29	1.26	1.47	5.48	5.26	6.05	0.47	0.19
40	13.05	12.73	11.70	1.11	1.09	1.27	5.62	5.38	6.19	0.47	0.19
45	12.49	12.16	11.15	1.00	0.97	1.13	5.87	5.62	6.50	0.47	0.19
50	12.54	12.18	11.15	0.92	0.90	1.04	6.37	6.09	7.09	0.47	0.19
55	13.16	12.76	11.63	0.87	0.85	0.98	7.17	6.88	8.04	0.47	0.19
60	14.74	14.39	14.08	0.91	0.90	1.03	8.23	7.90	9.32	0.47	0.19
65	24.75	24.61	22.26	1.11	1.10	1.23	9.66	9.27	11.10	0.47	0.19
COLD START* (Grams/Trip)	46.17	44.77	45.50	2.76	2.68	2.90	2.02	1.96	1.97		
HOT START* (Grams/Trip)	4.42	4.27	4.36	0.72	0.69	0.81	0.95	0.92	0.88		
HOT SOAK* (Grams/Trip)	----	----	----	0.90	1.02	1.04	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	3.64	3.64	3.64	----	----	----		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy-duty vehicles, e.g.; construction and demolition materials hauling trucks

(SCHDL3.WK1)

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TABLE A9 - 5 - K - 3
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 1995

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	58.79	57.23	53.35	5.79	5.68	6.33	7.48	7.16	8.87	0.385	0.19
10	38.11	36.98	34.61	3.77	3.67	4.20	6.55	6.28	7.64	0.385	0.19
15	27.27	26.49	24.84	2.72	2.65	3.09	5.92	5.67	6.79	0.385	0.19
20	20.49	19.92	18.69	2.09	2.03	2.39	5.50	5.28	6.23	0.385	0.19
25	16.18	15.73	14.77	1.66	1.61	1.92	5.26	5.04	5.89	0.385	0.19
30	13.41	13.05	12.25	1.36	1.33	1.58	5.15	4.93	5.72	0.385	0.19
35	11.66	11.34	10.63	1.15	1.12	1.34	5.16	4.94	5.71	0.385	0.19
40	10.63	10.33	9.67	1.00	0.97	1.16	5.27	5.04	5.84	0.385	0.19
45	10.18	9.87	9.23	0.90	0.87	1.03	5.51	5.26	6.12	0.385	0.19
50	10.22	9.89	9.22	0.83	0.80	0.95	5.97	5.71	6.67	0.385	0.19
55	10.74	10.37	9.64	0.78	0.76	0.91	6.72	6.44	7.56	0.385	0.19
60	13.48	13.14	12.13	0.82	0.80	0.94	7.71	7.39	8.77	0.385	0.19
65	19.54	19.33	17.70	0.99	0.98	1.11	9.04	8.67	10.43	0.385	0.19
COLD START* (Grams/Trip)	43.33	41.93	43.23	2.64	2.55	2.72	2.03	1.97	2.01		
HOT START* (Grams/Trip)	4.31	4.16	4.25	0.68	0.66	0.78	0.95	0.91	0.90		
HOT SOAK* (Grams/Trip)	———	———	———	0.77	0.87	0.88	———	———	———		
DIURNAL** (Grams/Vehicle/Day)	———	———	———	3.12	3.12	3.12	———	———	———		

Example of one daily trip:

Vehicle Start (Start-up) ---- Running + Evaporative ----> Vehicle Start (Hot Soak)

Parking ---- Diurnal ----> Restart (Start-up)

* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Incl ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy- vehicles, e.g.; construction and demolition materials hauling trucks.

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TABLE A9 – 5 – K – 4

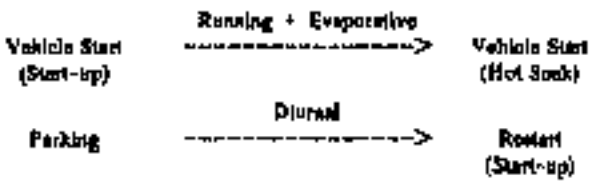
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***

Calendar Year 1997

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	48.53	47.06	44.86	5.16	5.05	5.73	6.96	6.65	8.31	0.32	0.19
10	31.77	30.73	29.43	3.37	3.27	3.82	6.08	5.81	7.14	0.32	0.19
15	22.90	22.19	21.27	2.45	2.37	2.81	5.49	5.24	6.34	0.32	0.19
20	17.23	16.71	16.03	1.87	1.81	2.18	5.10	4.87	5.81	0.32	0.19
25	13.60	13.19	12.66	1.49	1.45	1.75	4.87	4.65	5.49	0.32	0.19
30	11.27	10.93	10.49	1.23	1.19	1.45	4.76	4.54	5.32	0.32	0.19
35	9.79	9.49	9.10	1.04	1.01	1.22	4.76	4.54	5.30	0.32	0.19
40	8.91	8.63	8.27	0.90	0.87	1.06	4.86	4.63	5.42	0.32	0.19
45	8.51	8.23	7.87	0.81	0.78	0.94	5.09	4.84	5.69	0.32	0.19
50	8.53	8.23	7.85	0.75	0.72	0.87	5.52	5.25	6.21	0.32	0.19
55	8.94	8.60	8.19	0.71	0.69	0.83	6.21	5.93	7.04	0.32	0.19
60	10.19	10.87	10.26	0.74	0.72	0.85	7.34	6.82	8.17	0.32	0.19
65	16.20	16.01	14.87	0.87	0.86	1.00	8.31	7.93	9.66	0.32	0.19
COLD START* (Grams/Trip)	38.61	37.50	39.03	2.63	2.55	2.56	2.05	1.99	2.05		
HOT START* (Grams/Trip)	4.24	4.11	4.18	0.82	0.80	0.95	1.03	1.00	0.99		
HOT SOAK* (Grams/Trip)	----	----	----	0.66	0.74	0.75	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	2.66	2.66	2.66	----	----	----		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy-duty vehicles, e.g.; construction and demolition materials hauling trucks.

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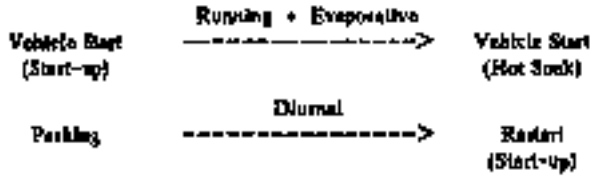
TABLE A9 - 5 - K - 5
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 1999

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	40.65	39.28	38.33	5.18	5.06	5.21	6.59	6.27	7.89	0.275	0.19
10	26.83	25.87	25.39	3.37	3.26	3.48	5.74	5.47	6.77	0.275	0.19
15	19.44	18.79	18.44	2.43	2.35	2.57	5.17	4.93	6.00	0.275	0.19
20	14.64	14.16	13.90	1.86	1.80	2.00	4.79	4.57	5.49	0.275	0.19
25	11.56	11.19	10.99	1.48	1.43	1.60	4.57	4.35	5.18	0.275	0.19
30	9.58	9.27	9.10	1.21	1.17	1.33	4.45	4.24	5.02	0.275	0.19
35	8.32	8.05	7.90	1.02	0.99	1.12	4.45	4.23	5.00	0.275	0.19
40	7.57	7.32	7.18	0.90	0.86	0.98	4.55	4.32	5.11	0.275	0.19
45	7.22	6.96	6.82	0.80	0.77	0.87	4.75	4.51	5.36	0.275	0.19
50	7.22	6.94	6.79	0.74	0.71	0.81	5.16	4.89	5.85	0.275	0.19
55	7.56	7.25	7.07	0.70	0.67	0.76	5.82	5.53	6.64	0.275	0.19
60	9.47	9.19	8.83	0.73	0.71	0.79	6.69	6.37	7.71	0.275	0.19
65	13.74	13.58	12.80	0.86	0.85	0.91	7.87	7.49	9.19	0.275	0.19
COLD START* (Grams/Trip)	34.16	33.18	34.95	2.43	2.36	2.39	2.03	1.97	2.05		
HOT START* (Grams/Trip)	3.79	3.69	3.73	0.70	0.68	0.81	1.00	0.97	0.97		
HOT SOAK* (Grams/Trip)	----	----	----	0.54	0.62	0.63	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	2.32	2.32	2.32	----	----	----		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy-duty vehicles, e.g.: construction and demolition materials hauling trucks.

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TABLE A9 - 5 - K - 6

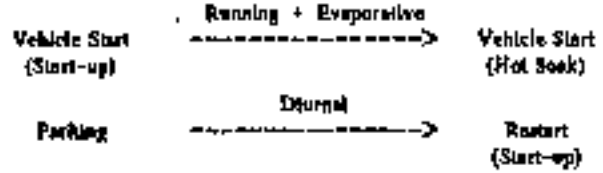
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***

Calendar Year 2001

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	37.85	36.33	35.86	3.81	3.70	3.97	6.29	5.97	7.61	0.24	0.19
10	25.20	24.16	23.96	2.53	2.44	2.73	5.47	5.20	6.51	0.24	0.19
15	18.29	17.58	17.43	1.86	1.79	2.05	4.91	4.67	5.77	0.24	0.19
20	13.76	13.24	13.13	1.44	1.38	1.61	4.55	4.32	5.28	0.24	0.19
25	10.86	10.46	10.38	1.15	1.11	1.30	4.32	4.10	4.97	0.24	0.19
30	9.00	8.67	8.60	0.96	0.92	1.09	4.21	4.00	4.81	0.24	0.19
35	7.82	7.53	7.46	0.81	0.78	0.93	4.21	3.99	4.79	0.24	0.19
40	7.13	6.86	6.79	0.71	0.68	0.81	4.30	4.07	4.89	0.24	0.19
45	6.80	6.53	6.46	0.64	0.61	0.73	4.49	4.24	5.14	0.24	0.19
50	6.81	6.51	6.44	0.59	0.57	0.68	4.87	4.61	5.60	0.24	0.19
55	7.15	6.82	6.72	0.56	0.53	0.64	5.50	5.22	6.36	0.24	0.19
60	8.90	8.59	8.34	0.58	0.56	0.65	6.34	6.02	7.40	0.24	0.19
65	12.72	12.51	11.87	0.66	0.65	0.73	7.48	7.10	8.83	0.24	0.39
COLD START+ (Grams/Trip)	31.31	30.63	32.35	2.14	2.09	2.12	2.02	1.94	2.07		
HOT START+ (Grams/Trip)	3.46	3.38	3.40	0.56	0.55	0.66	0.97	0.95	0.96		
HOT SOAK+ (Grams/Trip)	——	——	------	0.46	0.53	0.53	——	——	——		
DIURNAL++ (Grams/Vehicle/Day)	——	-----	.....	1.96	1.96	1.96	——	——	——		

Example of one daily trip:



\+ Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

++ Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy-duty vehicles, e.g.; construction and demolition materials hauling trucks.

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TABLE A9 – 5 – K – 7
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 2003

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	30.32	29.06	29.74	3.60	3.57	4.24	6.15	5.83	7.42	0.22	0.19
10	20.35	19.49	20.04	2.46	2.36	2.88	5.35	5.07	6.36	0.22	0.19
15	14.88	14.30	14.67	1.80	1.72	2.14	4.80	4.55	5.62	0.22	0.19
20	11.21	10.79	11.07	1.39	1.33	1.67	4.41	4.20	5.13	0.22	0.19
25	8.86	8.53	8.75	1.12	1.07	1.35	4.21	3.99	4.83	0.22	0.19
30	7.35	7.07	7.26	0.92	0.88	1.12	4.11	3.89	4.68	0.22	0.19
35	6.39	6.15	6.30	0.79	0.75	0.96	4.09	3.87	4.65	0.22	0.19
40	5.80	5.58	5.71	0.69	0.66	0.84	4.18	3.95	4.75	0.22	0.19
45	5.52	5.29	5.42	0.62	0.59	0.75	4.37	4.12	4.98	0.22	0.19
50	5.49	5.25	5.38	0.57	0.54	0.69	4.78	4.47	5.44	0.22	0.19
55	5.73	5.46	5.59	0.54	0.52	0.66	5.36	5.07	6.18	0.22	0.19
60	7.20	6.93	6.93	0.56	0.53	0.67	6.18	5.86	7.20	0.22	0.19
65	10.43	10.29	9.06	0.64	0.62	0.76	7.29	6.91	8.60	0.22	0.19
COLD START* (Grams/Trip)	28.91	28.65	30.09	1.84	1.82	1.83	1.99	1.98	2.05		
HOT START* (Grams/Trip)	3.25	3.12	3.12	0.47	0.45	0.54	0.97	0.93	0.94		
HOT SOAK* (Grams/Trip)	——	——	——	0.39	0.46	0.46	——	——	——		
DIURNAL** (Grams/Vehicle/Day)	——	——	——	1.67	1.67	1.67	——	——	——		

Example of one daily trip:

Vehicle Start (Start-up) —— Running + Evaporative ——> Vehicle Start (Hot Soak)

Parking —— Diurnal ——> Restart (Start-up)

* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy duty and heavy/heavy-duty vehicles, e.g.; construction and demolition materials hauling trucks.

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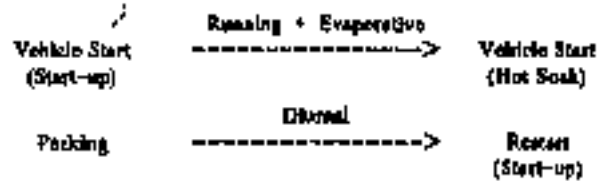
TABLE A9 - 5 - K - 8
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 2005

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	28.32	26.99	28.02	3.37	3.24	3.91	6.03	5.70	7.30	0.205	0.19
10	19.11	18.22	18.98	2.26	2.16	2.68	5.24	4.95	6.24	0.205	0.19
15	13.99	13.40	13.91	1.67	1.59	2.00	4.69	4.44	5.52	0.205	0.19
20	10.55	10.12	10.51	1.30	1.23	1.57	4.33	4.10	5.04	0.205	0.19
25	8.33	7.99	8.30	1.04	0.99	1.26	4.11	3.89	4.74	0.205	0.19
30	6.91	6.63	6.88	0.86	0.82	1.05	4.01	3.78	4.58	0.205	0.19
35	6.00	5.75	5.97	0.73	0.70	0.90	3.99	3.76	4.55	0.205	0.19
40	5.46	5.23	5.42	0.65	0.62	0.79	4.07	3.84	4.65	0.205	0.19
45	5.19	4.96	5.15	0.58	0.55	0.71	4.26	4.00	4.88	0.205	0.19
50	5.17	4.93	5.11	0.54	0.51	0.66	4.62	4.35	5.33	0.205	0.19
55	5.41	5.18	5.32	0.51	0.49	0.63	5.23	4.94	6.06	0.205	0.19
60	6.74	6.49	6.57	0.52	0.50	0.64	6.04	5.70	7.06	0.205	0.19
65	9.68	9.52	9.32	0.59	0.57	0.71	7.13	6.73	8.44	0.205	0.19
COLD START* (Grams/Trip)	26.74	26.31	28.01	1.60	1.57	1.59	1.96	1.93	2.04		
HOT START* (Grams/Trip)	3.00	2.94	2.93	0.39	0.39	0.47	0.93	0.92	0.93		
HOT SOAK* (Grams/Trip)	----	----	----	0.36	0.42	0.42	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	1.46	1.47	1.47	----	----	----		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy-duty vehicles, e.g.: construction and demolition materials hauling trucks.

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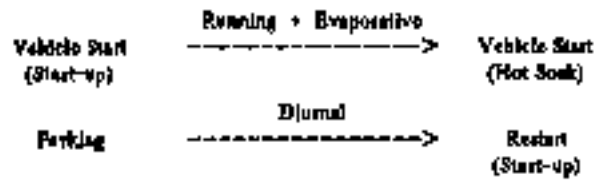
TABLE A9 - 5 - K - 9

EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 2007

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	25.05	23.97	25.48	2.90	2.77	3.13	5.92	5.58	7.22	0.195	0.195
10	16.99	16.26	17.34	1.98	1.88	2.21	5.13	4.83	6.17	0.195	0.195
15	12.57	12.10	12.83	1.48	1.39	1.68	4.59	4.33	5.43	0.195	0.195
20	9.81	9.46	9.71	1.15	1.09	1.33	4.23	3.99	4.97	0.195	0.195
25	7.92	7.25	7.68	0.93	0.88	1.09	4.01	3.78	4.67	0.195	0.195
30	6.23	6.01	6.37	0.77	0.73	0.91	3.90	3.67	4.52	0.195	0.195
35	5.41	5.21	5.52	0.67	0.63	0.79	3.89	3.66	4.49	0.195	0.195
40	4.90	4.72	4.99	0.59	0.55	0.69	3.97	3.73	4.59	0.195	0.195
45	4.64	4.45	4.72	0.53	0.50	0.62	4.15	3.89	4.81	0.195	0.195
50	4.58	4.39	4.65	0.49	0.46	0.58	4.50	4.22	5.25	0.195	0.195
55	4.76	4.53	4.81	0.46	0.44	0.55	5.10	4.79	5.97	0.195	0.195
60	5.05	5.86	5.04	0.47	0.45	0.56	5.89	5.55	6.96	0.195	0.195
65	9.00	8.93	8.83	0.53	0.50	0.60	6.97	6.56	8.33	0.195	0.195
COLD START* (Grams/Trip)	25.59	25.24	26.97	1.41	1.39	1.42	1.94	1.92	2.03		
HOT START* (Grams/Trip)	2.85	2.81	2.79	0.35	0.34	0.42	0.91	0.90	0.92		
HOT SOAK* (Grams/Trip)	—	—	—	0.34	0.40	0.39	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	1.30	1.30	1.30	—	—	—		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy duty vehicles, e.g.; construction and demolition materials hauling trucks.

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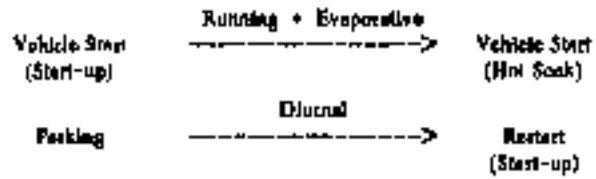
AR007300

TABLE A9 - 5 - K - 10
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Vehicles with Gross Vehicle Weight 6,001 Pounds and Up***
Calendar Year 2009

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
(Miles per Hour)	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	23.21	22.03	22.98	2.93	2.80	3.34	5.90	5.55	6.80	0.17	0.185
10	15.80	15.01	15.69	2.01	1.90	2.30	5.11	4.81	5.86	0.17	0.185
15	11.65	11.13	11.61	1.49	1.40	1.72	4.58	4.31	5.22	0.17	0.185
20	8.81	8.43	8.79	1.16	1.09	1.34	4.22	3.97	4.80	0.17	0.185
25	6.96	6.66	6.94	0.94	0.88	1.09	3.99	3.75	4.53	0.17	0.185
30	5.77	5.52	5.76	0.78	0.74	0.91	3.89	3.65	4.40	0.17	0.185
35	5.01	4.79	4.99	0.67	0.63	0.78	3.87	3.63	4.38	0.17	0.185
40	4.55	4.34	4.52	0.59	0.55	0.68	3.95	3.70	4.48	0.17	0.185
45	4.31	4.11	4.28	0.53	0.50	0.61	4.13	3.86	4.69	0.17	0.185
50	4.28	4.07	4.23	0.49	0.46	0.57	4.49	4.20	5.10	0.17	0.185
55	4.45	4.21	4.38	0.47	0.44	0.55	5.08	4.77	5.78	0.17	0.185
60	5.57	5.35	5.47	0.47	0.45	0.55	5.87	5.51	6.69	0.17	0.185
65	8.07	7.96	7.94	0.53	0.51	0.61	6.94	6.52	7.95	0.17	0.185
COLD START* (Grams/Trip)	24.44	24.16	25.00	1.28	1.27	1.30	1.94	1.92	2.02		
HOT START* (Grams/Trip)	2.73	2.70	2.66	0.31	0.31	0.38	0.90	0.89	0.92		
HOT SOAK* (Grams/Trip)	----	----	----	0.33	0.38	0.37	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	1.18	1.18	1.18	----	----	----		

Example of one daily trip:



* Vehicle Miles Traveled (VMT) or Average Daily Trips (ADT)-weighted emission factors:
Includes VMT or ADT from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (46.02%), and gasoline-fueled vehicles not equipped with catalyst (20.65%)

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (33.33%), gasoline-fueled vehicles equipped with catalyst (37.74%), and gasoline-fueled vehicles not equipped with catalyst (28.93%).

*** Vehicles with gross vehicle weight 6,001 pounds and up:
Includes ARB's medium-duty and light/heavy-duty, medium/heavy-duty and heavy/heavy-duty vehicles, e.g.; construction and demolition materials hauling trucks.

AR007300

TABLE A9 - 3 - L

EMFAC EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Oxides of Sulfur and Lead Emissions

Year	Vehicles with Gross Vehicle Weight up to 6,000 Pounds*** (grams per mile)						Vehicles with Gross Vehicle Weight 6,000 Pounds and Greater*** (grams per mile)					
	OXIDES of SULFUR			LEAD			OXIDES of SULFUR			LEAD		
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3
1991												
1993	0.07	0.07	0.07	0.00016	0.00016	0.00017	0.44	0.44	0.44	0.0017	0.0017	0.0017
1995	0.06	0.06	0.06	0.00011	0.00012	0.00012	0.33	0.33	0.33	0.0011	0.0011	0.0011
1997	0.06	0.06	0.06	N/A	N/A	N/A	0.32	0.32	0.32	0.0010	0.0010	0.0010
1999	0.06	0.06	0.06	N/A	N/A	N/A	0.31	0.31	0.31	0.0007	0.0007	0.0007
2001	0.05	0.05	0.05	N/A	N/A	N/A	0.30	0.30	0.30	0.0007	0.0007	0.0007
2003	0.05	0.05	0.05	N/A	N/A	N/A	0.30	0.30	0.30	0.0007	0.0007	0.0007
2005	0.05	0.05	0.05	N/A	N/A	N/A	0.30	0.30	0.30	0.0004	0.0004	0.0004
2007	0.05	0.05	0.05	N/A	N/A	N/A	0.29	0.29	0.29	0.0004	0.0004	0.0004
2009	0.05	0.05	0.05	N/A	N/A	N/A	0.28	0.28	0.28	0.0004	0.0004	0.0004

Emissions (pounds per day) = (*VMT x EMISSION FACTOR)/454

*VMT = Vehicle Miles Traveled per Day

AR0073002

INFORMATION
FOR
PERCENT HOT STARTS
AND PERCENT COLD STARTS

AR0073003

TABLE A9 - 5 - M

INPUT ASSUMPTIONS FOR PERCENT HOT START TRIPS AND COLD START TRIPS, BY LAND USE TYPE

Project Type	Percent Of Average Daily Trips	
	% Hot Start Trips	% Cold Start Trips
Residential		
Single Family Detached Housing	- -	100
Apartment	- -	100
Residential Condominium	- -	100
Mobile Home Park	- -	100
Retirement Community	- -	100
Congregate Care Facilities	- -	100
Commercial		
Hotel	75	25
General Office Building	30	70
Office Park	30	70
Retail General Merchandise	80	20
Nursery/Garden Center	75	25
Shopping Centers	20	80
Quality Restaurant	50	50
Fast Food/With Drive Through	90	10
New Car Sales	50	50
Service Station	90	10
Car Wash	95	5
Supermarket	70	30
Convenience Market	95	5
Furniture Store	85	15
Video Arcade	50	90
Walk-in Bank	85	15
Industrial		
Truck Terminal	95	5
Industrial Park	30	70
Mini-warehouse	10	90
Government/Institutions		
Utilities	75	25
Military Base	15	85
Elementary School	90	10
High School	25	75
University/College	25	75
Church/Synagogue	50	50
Day Care Center	50	50
Library	85	15
Hospital	50	50
Nursing Homes	25	75
Clinics	75	25

AR0073004

TABLE A9 - 5 - M (Cont.)

INPUT ASSUMPTIONS FOR PERCENT HOT START TRIPS AND COLD START TRIPS

Project Type	Percent Of Average Daily Trips	
	% Hot Start Trips	% Cold Start Trips
Recreation		
City Park	100	--
Water Slide Park	100	--
Marina	80	20
Golf Course	50	50
Movie Theatre with Matinee	95	5
Stadium	95	5
Racquet Club	95	5
Unique Sources		
Waterports	50	50
Commercial Airports	50	50
Bus Park-n-Ride Station	5	95
Cemetery	25	75

Source:

Cold and hot start percentages provided in Table A9 - 5 - M are District assumptions based on ITE manual. For each land-use type (except for a few such as mail delivery, UPS delivery, etc.), all employee-related trips were assumed to be with cold start. Visitors and other short trips were assumed to be with hot starts. Both assumptions were combined to determine above reported hot and cold start percentages. The District recommends use of these percentages only when project-specific data is not available.

Cold start trips result when car is started after one sitting for one hour or more. An example would be cars used to commute to work then not being used until lunch hour trips. In this case both work-trips and lunch trips will be with cold starts. Hot start trips are those trips when car is re-started before one hour of non-use. An example would be a mini-market or gas station where visitors' cars are turned off for less than one hour before they are re-started.

AR0073005

TABLE A9 - 5 - M - 1

INPUT ASSUMPTIONS FOR PERCENT HOT AND COLD START TRIPS
(Expressed in Percent of Vehicles On Roadways)

Travel Period of the Day / Area Types / Road-Types	Percent Hot (H) and Cold (C) Starts by Road-type and Period of the Day: AM Peak*		OFF Peak*		PM Peak*		Daily	
*Recommended Defaults	(CO, and NOx)		(ROC)					
	H	C	H	C	H	C	H	C
Inside the County Business District								
Regional Average Cold Starts	10 and 20		20 and 30		40 and 70		25 and 55	
Regional Average Cold Starts	5 and 15		15 and 45		30 and 50		20 and 40	
Regional Average Cold Starts	1 and 6		5 and 20		25 and 40		15 and 25	
Fringe Areas (non-urban) **	10 and 20		25 and 60		40 and 65		25 and 50	
Fringe Areas (non-urban) ***	5 and 15		20 and 25		30 and 45		20 and 35	
Fringe Areas (non-urban) ****	1 and 15		10 and 20		15 and 40		10 and 30	
Outer Arterials **	15 and 25		30 and 50		30 and 60		30 and 60	
Outer Arterials ***	10 and 20		15 and 25		20 and 45		20 and 30	
Outer Arterials ****	5 and 15		10 and 15		15 and 30		15 and 20	
Local & Collector Streets **	10 and 20		35 and 50		35 and 55		30 and 40	
Outer Arterials ***	5 and 20		15 and 35		25 and 40		25 and 30	
Outer Arterials ****	5 and 15		10 and 15		15 and 25		15 and 25	
Within Urban And Its Fringe Areas (Non-urban Areas Closer and Urban Areas)								
Inbound Expressways **	3 and 5		15 and 20		20 and 30		15 and 20	
Inbound Expressways ***	2 and 4		10 and 20		15 and 25		10 and 20	
Inbound Expressways ****	1 and 3		10 and 15		15 and 25		10 and 25	
Outbound Expressways **	1 and 3		15 and 20		15 and 20		10 and 15	
Outbound Expressways ***	1 and 3		10 and 20		10 and 20		10 and 15	
Outbound Expressways ****	1 and 3		10 and 15		10 and 15		10 and 15	
Outer Portion of Urban Area								
Inbound Expressways **	3 and 5		2 and 4		2 and 4		3 and 5	
Inbound Expressways ***	2 and 4		2 and 4		2 and 4		3 and 5	
Inbound Expressways ****	1 and 3		1 and 3		1 and 3		2 and 4	
Outbound Expressways **	3 and 5		2 and 4		15 and 20		10 and 15	
Outbound Expressways ***	2 and 4		2 and 4		10 and 20		10 and 15	
Outbound Expressways ****	1 and 3		1 and 3		10 and 15		10 and 15	
Outside the County Business District								
Special Generators	25 and 40		30 and 50		45 and 60		20 and 30	
Special Generators	15 and 25		20 and 25		30 and 35		25 and 55	
Special Generators	15 and 20		10 and 20		20 and 30		20 and 30	

AR0073006

- Use *AM Peak Speeds* to select hot and cold starts emission factors for CO, and NOx; *and,* use *Off Peak Speeds* to select hot and cold start emissions factors.

Table A9 - 5 - M - 1 includes the percent of hot and cold starts on various types of roadways. These percentages may be used for analysis of pollutants in Table A9 - 5 - P and Q as well as to determine project related emission estimates. After determining the number of vehicles on a road, use Table A9 - 5 - M - 1 to determine % cold start and hot start. Remaining vehicles will be at stabilized levels. Then use Table A9 - 5 - M - 3 to determine % passenger vehicles and Trucks for each of the hot and cold start vehicles on that road. Use Table A9 - 5 - G to determine % passenger vehicles and trucks for stabilized vehicles on that road.

The information provided on Table A9 - 5 - M - 1 is from federal EPA Table 26, entitled, <u>For Suggested Ranges of Values of the Percentages of Vehicles Operating in the Cold Mode for Various Conditions of Time and Location</u>. The table includes information for three different cases as follows:

**	Case 1:	No access time added
***	Case 2:	1-minute additional access time
****	Case 3:	2.5-minute additional access time

These cases are identified in Table A9 - 5 - M - 1 by an asterisk.

AR0073007

TABLE A9 - 5 - M - 2

INPUT ASSUMPTIONS FOR PERCENT COLD AND HOT START TRIPS
(Expressed in Percent of Vehicle Type for Each County in the District)

Year	Passenger		Trucks		All Vehicle Types*	
	Cold Starts % PV	Hot Starts % PV	Cold Starts % Trucks	Hot Starts % Trucks	Cold Starts % All Vehicles	Hot Starts % All Vehicles
ORANGE COUNTY						
1991	52.23	47.77	46.70	53.30	51.50	48.50
1993	52.54	47.46	48.25	51.75	51.95	48.05
1995	52.72	47.28	49.36	50.64	52.22	47.78
1997	52.85	47.15	50.13	49.87	52.42	47.58
1999	52.97	47.03	50.66	49.34	52.58	47.42
2001	52.98	47.02	51.05	48.95	52.64	47.36
2003	52.99	47.01	51.32	48.68	52.67	47.32
2005	53.00	47.00	51.50	48.50	52.70	47.30
2007	53.00	47.00	51.62	48.38	52.71	47.29
2009	53.00	47.00	51.73	48.27	52.72	47.28
LOS ANGELES COUNTY						
1991	52.23	47.77	46.58	53.42	51.47	48.54
1993	52.54	47.46	48.15	51.85	51.92	48.08
1995	52.72	47.28	49.28	50.72	52.20	47.80
1997	52.85	47.15	50.07	49.93	52.35	47.65
1999	53.00	47.00	50.91	49.09	52.55	47.45
2001	53.00	47.00	51.22	48.78	52.74	47.26
2003	53.00	47.00	51.45	48.55	52.75	47.25
2005	53.00	47.00	51.60	48.40	52.76	47.24
2007	53.00	47.00	51.69	48.31	52.77	47.23
2009	53.00	47.00	51.72	48.28	52.78	47.22
SAN BERNARDINO COUNTY						
1991	52.23	47.77	46.67	53.33	51.38	48.62
1993	52.54	47.46	48.22	51.78	51.86	48.14
1995	52.71	47.29	49.33	50.67	52.15	47.85
1997	52.85	47.15	50.10	49.90	52.37	47.63
1999	52.97	46.33	50.64	49.36	52.54	47.46
2001	52.98	47.01	51.03	48.97	52.61	47.39
2003	52.99	47.01	51.30	48.70	51.66	47.34
2005	53.00	47.00	51.48	48.52	52.68	47.32
2007	53.00	47.00	51.60	48.40	52.70	47.30
2009	53.00	47.00	51.71	48.29	52.71	47.29
RIVERSIDE COUNTY						
1991	52.23	47.77	46.59	53.41	51.41	48.59
1993	52.54	47.46	48.21	51.89	51.90	48.10
1995	52.72	47.28	49.35	50.65	52.21	47.78
1997	52.85	47.15	50.15	49.85	52.43	47.57
1999	52.97	47.03	50.70	49.30	52.61	47.39
2001	52.98	47.01	51.10	48.90	52.68	47.32
2003	52.99	47.01	51.38	48.62	52.73	47.27
2005	53.00	47.00	51.55	48.45	52.75	47.25
2007	53.00	47.00	51.68	48.32	52.77	47.23
2009	53.00	47.00	51.79	48.21	52.79	47.21

* For all counties and for all years buses have 0.0 % cold starts and 0.0 % hot starts (Source: ARB)
* For all counties and for all years motorcycles have 34.30 % cold starts and 65.70 % hot starts

Source: ARB Computer outputs, "Predicted California Vehicle Emissions".

AR0073008

TABLE A9 - 5 - M - 3

INPUT ASSUMPTIONS FOR PERCENT COLD AND HOT START TRIPS
(% Associated with Type of Vehicle in Total (Ttl) Cold and Hot Starts and % Cold and Hot Starts Associated with Each Type of Vehicle in Total (Ttl) Average Daily Trips)

Year	V % of Ttl Cold			V % of Ttl Hot			% Cold of ADTs			% Hot of ADTs		
	PVs	Trucks	Mtrcycls	PVs	Trucks	Mtrcycls	PVs	Trucks	Mtrcycls	PVs	Trucks	Mtrcycls
ORANGE COUNTY												
1991	89.61	9.94	00.45	88.36	10.96	0.67	98.50	0.75	0.75	10.39	90.06	99.55
1993	89.33	10.21	00.45	88.32	10.99	0.69	98.76	0.62	0.62	10.66	89.78	99.55
1995	89.12	10.42	00.46	88.28	11.02	0.70	98.96	0.52	0.52	10.88	89.58	99.54
1997	88.98	10.56	00.46	88.25	11.04	0.70	99.09	0.45	0.45	11.02	89.44	99.54
1999	88.88	10.66	00.46	88.25	11.06	0.71	99.18	0.41	0.41	11.12	89.34	99.54
2001	88.79	10.74	00.47	88.21	11.08	0.71	99.27	0.37	0.36	11.21	89.26	99.54
2003	88.72	10.81	00.47	88.18	11.09	0.72	99.32	0.34	0.34	11.28	89.19	99.53
2005	88.69	10.86	00.47	88.16	11.11	0.73	99.36	0.32	0.32	11.33	89.14	99.53
2007	88.63	10.90	00.47	88.14	11.13	0.73	99.38	0.31	0.31	11.37	89.10	99.53
2009	88.60	10.93	00.48	88.12	11.15	0.73	99.40	0.30	0.30	11.41	89.06	99.53
LOS ANGELES COUNTY												
1991	89.23	10.33	00.44	87.93	11.42	0.66	98.43	0.78	0.78	10.77	89.66	99.56
1993	88.89	10.67	00.44	87.83	11.50	0.66	98.70	0.65	0.65	11.11	89.33	99.56
1995	88.61	10.94	00.44	87.74	11.59	0.67	98.92	0.54	0.54	11.39	89.05	99.56
1997	88.39	11.16	00.45	87.56	11.67	0.68	98.96	0.52	0.52	11.61	88.84	99.55
1999	88.17	11.38	00.45	86.34	11.75	0.66	97.65	1.18	1.18	11.83	88.61	99.55
2001	87.79	11.45	00.44	97.39	11.78	0.67	99.48	0.26	0.26	12.20	88.55	99.56
2003	87.80	11.62	00.45	87.34	11.86	0.68	97.60	1.20	1.20	10.71	89.11	99.55
2005	87.81	11.72	00.46	87.20	11.94	0.69	99.22	0.39	0.39	12.18	88.28	99.54
2007	87.71	11.82	00.46	87.22	12.07	0.71	99.36	0.32	0.32	12.28	88.18	99.54
2009	87.62	11.92	00.47	87.14	12.04	0.72	99.39	0.30	0.30	12.38	88.08	99.53
SAN BERNARDINO COUNTY												
1991	87.46	12.19	00.35	86.04	13.42	0.53	98.46	0.77	0.77	12.54	87.81	99.65
1993	87.06	12.58	00.35	85.93	13.53	0.53	98.58	0.65	0.65	12.94	87.42	99.65
1995	86.75	12.90	00.35	85.83	13.64	0.54	98.83	0.53	0.53	13.25	87.10	99.65
1997	86.51	13.14	00.35	85.73	13.73	0.54	99.00	0.50	0.50	13.49	86.86	99.65
1999	86.34	13.32	00.35	85.64	13.83	0.54	99.11	0.44	0.44	13.67	86.67	99.65
2001	86.14	13.51	00.35	85.53	13.93	0.54	99.21	0.39	0.39	13.86	86.49	99.65
2003	85.96	13.68	00.35	85.41	14.05	0.54	99.28	0.36	0.36	14.03	86.32	99.65
2005	85.83	13.82	00.35	85.31	14.14	0.54	99.33	0.32	0.32	14.17	86.18	99.65
2007	85.71	13.94	00.35	85.22	14.24	0.55	99.36	0.32	0.32	14.29	86.06	99.65
2009	85.59	14.06	00.35	85.10	14.33	0.55	99.39	0.30	0.30	14.41	85.94	99.64
RIVERSIDE COUNTY												
1991	87.76	11.96	00.28	86.39	13.04	0.42	98.32	0.84	0.84	12.24	88.04	99.72
1993	87.64	12.09	00.27	86.58	13.02	0.41	98.67	0.67	0.67	12.36	87.91	99.73
1995	87.59	12.15	00.26	86.75	12.85	0.40	98.94	0.53	0.53	12.41	87.85	99.74
1997	87.61	12.13	00.25	86.92	12.69	0.39	99.13	0.44	0.44	12.39	87.86	99.75
1999	87.66	12.09	00.25	87.07	12.54	0.38	99.25	0.38	0.38	12.34	87.91	99.75
2001	87.71	12.05	00.24	87.20	12.42	0.37	99.36	0.32	0.32	12.29	87.95	99.76
2003	87.75	12.01	00.24	87.30	12.33	0.37	99.43	0.29	0.29	12.25	87.98	99.76
2005	87.79	11.97	00.24	87.39	12.25	0.36	99.48	0.26	0.26	12.21	88.03	99.76
2007	87.85	11.92	00.23	87.47	12.17	0.36	99.52	0.24	0.24	12.15	88.08	99.77
2009	87.89	11.87	00.23	87.54	12.10	0.36	99.55	0.23	0.23	12.10	88.13	99.77

First six columns: for percentages associated with each vehicle type from total cold starts or hot starts. Last six columns: for hot and cold start percentages associated with each vehicle type from total average daily trips. Bus ADTs, cold starts & hot starts are not included in the totals used to create above data. (Source: ARB)

AR0073009

TABLE A9 - 5 - N

EMISSION FACTORS FOR ESTIMATING MOTORCYCLE EMISSIONS

USE

TABLE A9 - 14 - A

FOR MOTORCYCLE-RELATED
VEHICLE MILES TRAVELED (VMT)
AVERAGE DAILY TRIPS (ADT) AND NUMBER OF VEHICLES (NOV)
IN COUNTYWIDE AND REGIONWIDE FLEET MIX
AND

TABLE A9 - 5 - G*

FOR THEIR PERCENTAGES

USE

TABLE A9 - 5 - P - 1 AND 2

FOR DETERMINING COMPOSITE EMISSION FACTOR BETWEEN
FOUR DIFFERENT TYPES OF VEHICLES TOGETHER, SUCH AS,
PASSENGER VEHICLES, MATERIAL HAULING VEHICLES AND BUSES
INCLUDING MOTORCYCLES
AND
BETWEEN RUNNING, HOT AND COLD START EMISSION FACTORS FOR
MOTORCYCLES

(* IF PROJECT-SPECIFIC FLEET MIX DATA IS NOT AVAILABLE,
USE TABLE A9 - 5 - G TO DETERMINE PROJECT-RELATED
FLEET MIX DATA)

AR0073010

TABLE A9 - 5 - N - 1

EMISSION FACTORS FOR MOTORCYCLES AT 75°F
(Grams per Mile)
Reactive Organic Compounds

Speed	YEARS 1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
	Running Exhaust Emission Factors at 75°F Total Organic Compound (TOC)									
5	10.73	9.9	9.82	9.92	10.07	10.18	10.24	10.27	10.28	10.28
10	5.66	5.22	5.18	5.23	5.31	5.36	5.40	5.41	5.42	5.42
15	3.99	3.68	3.65	3.68	3.74	3.78	3.80	3.81	3.82	3.82
20	3.23	2.98	2.96	2.99	3.03	3.06	3.08	3.09	3.10	3.10
25	2.77	2.55	2.53	2.56	2.60	2.62	2.64	2.65	2.65	2.65
30	2.41	2.23	2.21	2.23	2.26	2.29	2.30	2.31	2.31	2.31
35	2.13	1.97	1.95	1.97	2.00	2.02	2.03	2.04	2.04	2.04
40	1.93	1.78	1.77	1.79	1.81	1.83	1.84	1.85	1.85	1.85
45	1.82	1.68	1.66	1.68	1.71	1.72	1.73	1.74	1.74	1.74
50	1.77	1.63	1.62	1.63	1.66	1.67	1.68	1.69	1.69	1.69
55	1.70	1.57	1.56	1.57	1.60	1.62	1.62	1.63	1.63	1.63
60	1.50	1.38	1.37	1.38	1.40	1.42	1.43	1.43	1.43	1.43
65	1.03	0.95	0.94	0.95	0.96	0.98	0.98	0.98	0.98	0.99
(To Obtain Temperature Corrected Emission Factor, Multiply Above Emission Factors with the Following Temperature Correction Factors For the Appropriate Area)										
	Running Exhaust Temperature Correction Factors									
Area 1 and 2	1.00	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Area 3	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
(To Convert TOCs to ROCs, Multiply Above Temperature Corrected Emission Factor With 0.92)										
	Cold Start TOC at 75°F									
	11.21	10.36	10.28	10.39	10.55	10.66	10.72	10.75	10.76	10.77
(To Obtain Temperature Corrected Emission Factor, Multiply Above Emission Factors with the Following Temperature Correction Factors For the Appropriate Area)										
	Cold Start Temperature Correction Factor									
Area 1 and 2	0.85	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Area 3	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
(To Convert TOCs to ROCs, Multiply the Above Emission Factor With 0.92 After Temperature Correction)										
	Hot Start at 75°F									
	3.95	3.68	3.66	3.70	3.76	3.80	3.82	3.83	3.83	3.83
(To Obtain Temperature Corrected Emission Factor, Multiply Above Emission Factors with the Following Temperature Correction Factors For the Appropriate Area)										
	Hot Start Temperature Correction Factors									
Area 1 and 2	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Area 3	2.06	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07
(To Convert TOCs to ROCs, Multiply the Above Emission Factor With 0.92 After Temperature Correction)										
	Hot Soak Emission Factors									
All Areas	1.60	0.92	0.81	0.76	0.76	0.76	0.76	0.76	0.76	0.76
	Diurnal Emission Factors									
All Areas	4.74	2.99	2.74	2.63	2.62	2.62	2.62	2.62	2.62	2.62

Note: See Tables A9 - 5 - N - 1- a and A9 - 5 - N - 1 - b for temperature corrected ROC emissions factors.

AR0073011

Table A9 – 5 – N –1 – a

AREA 1 and AREA 2

TEMPERATURE CORRECTED EMISSION FACTORS FOR MOTORCYCLES

(Grams Per Mile)

REACTIVE ORGANIC COMPOUNDS (ROC)

SPEED	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
5	9.87	9.38	9.31	9.40	9.54	9.65	9.70	9.73	9.74	9.74
10	5.21	4.95	4.91	4.96	5.03	5.08	5.12	5.13	5.14	5.14
15	3.67	3.49	3.46	3.49	3.54	3.58	3.60	3.61	3.62	3.62
20	2.97	2.82	2.80	2.83	2.87	2.90	2.92	2.93	2.94	2.94
25	2.55	2.42	2.40	2.43	2.46	2.48	2.50	2.51	2.51	2.51
30	2.22	2.11	2.09	2.11	2.24	2.17	2.18	2.19	2.19	2.19
35	1.96	1.87	1.85	1.87	1.90	1.91	1.92	1.93	1.93	1.93
40	1.78	1.69	1.68	1.70	1.72	1.73	1.74	1.75	1.75	1.75
45	1.67	1.59	1.57	1.59	1.62	1.63	1.64	1.65	1.65	1.65
50	1.63	1.54	1.54	1.54	1.57	1.58	1.59	1.60	1.60	1.60
55	1.56	1.49	1.48	1.49	1.52	1.54	1.54	1.54	1.54	1.54
60	1.38	1.31	1.30	1.31	1.33	1.35	1.36	1.36	1.36	1.36
65	0.95	0.90	0.89	0.90	0.91	0.93	0.93	0.93	0.93	0.94
Cold start	8.77	8.20	8.13	8.22	8.35	8.43	8.48	8.51	8.51	8.52
Hot start	2.36	2.23	2.22	2.25	2.28	2.31	2.32	2.33	2.33	2.33

Table A9 – 5 – N –1 – b

AREA 3

TEMPERATURE CORRECTED EMISSION FACTORS FOR MOTORCYCLES

(Grams Per Mile)

REACTIVE ORGANIC COMPOUNDS (ROC)

SPEED	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
5	10.25	9.45	9.38	9.47	9.62	9.72	9.78	9.81	9.82	9.82
10	5.41	4.99	4.95	4.99	5.07	5.12	5.16	5.17	5.18	5.18
15	3.81	3.51	3.49	3.51	3.57	3.61	3.63	3.64	3.65	3.65
20	3.08	2.85	2.83	2.86	2.89	2.92	2.94	2.95	2.96	2.96
25	2.65	2.44	2.42	2.44	2.48	2.50	2.52	2.53	2.53	2.53
30	2.30	2.13	2.11	2.13	2.25	2.19	2.20	2.21	2.21	2.21
35	2.03	1.88	1.86	1.88	1.91	1.93	1.94	1.95	1.95	1.95
40	1.84	1.70	1.69	1.71	1.73	1.75	1.76	1.77	1.77	1.77
45	1.74	1.60	1.59	1.60	1.63	1.64	1.65	1.66	1.66	1.66
50	1.69	1.56	1.55	1.56	1.59	1.59	1.60	1.61	1.61	1.61
55	1.62	1.50	1.49	1.50	1.53	1.55	1.55	1.56	1.56	1.56
60	1.43	1.32	1.31	1.32	1.34	1.36	1.37	1.37	1.37	1.37
65	0.98	0.91	0.90	0.91	0.92	0.94	0.94	0.94	0.94	0.95
Cold start	14.23	13.15	13.05	13.19	13.39	13.53	13.61	13.65	13.66	13.67
Hot start	7.49	6.97	6.94	7.01	7.13	7.20	7.24	7.26	7.26	7.26

AR0073012

Table A9 - 5 - N - 2

EMISSION FACTORS FOR MOTORCYCLES at 75°F
(Grams per Mile)
Carbon Monoxide and Oxides of Sulfur

Speed	YEARS 1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
Running Exhaust Emission Factors at 75°F										
Carbon Monoxide (CO)										
5	62.71	62.59	61.89	61.83	61.82	61.81	Same Factors As Year 2001			
10	30.13	29.83	29.76	29.73	29.72	29.72				
15	19.77	19.59	19.54	19.52	19.52	19.51				
20	15.15	15.02	14.99	14.97	14.97	14.97				
25	12.39	12.29	12.27	12.26	12.25	12.25				
30	10.40	10.32	10.30	10.29	10.29	10.29				
35	8.89	8.83	8.81	8.81	8.80	8.80				
40	7.84	7.79	7.78	7.77	7.77	7.77				
45	7.23	7.18	7.18	7.17	7.17	7.17				
50	6.94	6.90	6.89	6.89	6.88	6.88				
55	6.70	6.67	6.67	6.66	6.66	6.66				
60	6.00	5.98	5.98	5.97	5.97	5.97				
65	4.30	4.29	4.29	4.29	4.29	4.29				

(To Obtain Temperature Corrected Emission Factor, Multiply Above Emission Factors with the Following Temperature Correction Factors For the Appropriate Area)

					Running Exhaust Temperature Correction Factors					
All Areas	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Cold Start at 75°F										
All Areas	65.98	65.29	65.08	65.02	65.01		65.00	65.00	Same as Year 2001	

(To Obtain Temperature Corrected Emission Factor, Multiply Above Emission Factors with the Following Temperature Correction Factors For the Appropriate Area)

					Cold Start Temperature Correction Factor					
All Areas	1.54	Same as Year 1991			Same as Year 1991			Same as Year 1991		
Hot Start at 75°F										
All Areas	9.51	9.44	9.43	9.42	Same as Year 1997					

(To Obtain Temperature Corrected Emission Factor, Multiply Above Emission Factors with the Following Temperature Correction Factors For the Appropriate Area)

					Hot Start Temperature Correction Factors					
All Areas	0.51	Same as Year 1991			Same as Year 1991			Same as Year 1991		
Oxides of Sulfur (SOx)										
(Tons/District Total Vehicle Miles Traveled (VMT) by Motorcycles/Day)										
All Areas	0.08				0.09			0.10		
Years	(1991 and 1993)				(1995 to 2001)			(2003 to 2009)		
VMT		278,570,000		304,232,000		329,894,000		355,555,000		381220000
Years		*(1993)*		*(1997)*		*(2001)*		*(2005)*		*(2009)*
VMT	N/A		291,401,000		317,065,900		342,727,000		368,388,000	
Years			*(1995)*		*(1999)*		*(2003)*		*(2007)*	

Emissions in Grams per Mile = [(Tons/Day) x (907.18) x (1,000.0)]/[VMT For That Year]
Project Related Emissions = (Emissions in Grams Per Mile) x (Project Related VMT)

Note: See Table A-9-5-N-2a for temperature corrected CO emission factors.
See Table A-9-5-N-2-b for temperature corrected SOx emission factors.
See Table A-9-5-N-3 for PM10 and Lead emission factors.

AR0073013

Table A9 – 5 – N –2 – a

AREA 1, AREA 2 and AREA 3

TEMPERATURE CORRECTED EMISSION FACTORS FOR MOTORCYCLES

(Grams Per Mile)

CARBON MONOXIDE (CO)

SPEED	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
5	63.34	63.22	62.51	62.45	62.44	62.43	62.43	62.43	62.43	62.43
10	30.63	30.13	30.06	30.03	30.02	30.02	30.02	30.02	30.02	30.02
15	19.97	19.79	19.74	19.72	19.72	19.71	19.71	19.71	19.71	19.71
20	15.30	15.17	15.14	15.12	15.12	15.12	15.12	15.12	15.12	15.12
25	12.51	12.41	12.39	12.38	12.37	12.37	12.37	12.37	12.37	12.37
30	10.50	10.42	10.40	10.39	10.39	10.39	10.39	10.39	10.39	10.39
35	8.98	8.92	8.90	8.90	8.89	8.89	8.89	8.89	8.89	8.89
40	7.92	7.87	7.86	7.85	7.85	7.85	7.85	7.85	7.85	7.85
45	7.30	7.25	7.25	7.24	7.24	7.24	7.24	7.24	7.24	7.24
50	7.01	6.97	6.96	6.96	6.95	6.95	6.95	6.95	6.95	6.95
55	6.77	6.74	6.74	6.73	6.73	6.73	6.73	6.73	6.73	6.73
60	6.06	6.04	6.04	6.03	6.03	6.03	6.03	6.03	6.03	6.03
65	4.34	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
Cold start	101.61	100.55	100.22	100.13	100.12	100.10	100.10	100.10	100.10	100.10
Hot start	4.85	4.81	4.81	4.80	4.80	4.80	4.80	4.80	4.80	4.80

Table A9 – 5 – N –2 – b

AREA 1, AREA 2 and AREA 3

TEMPERATURE CORRECTED EMISSION FACTORS FOR MOTORCYCLES

(Grams Per Mile)

OXIDES OF SULFUR (SOx)

SPEED	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
N/A	N/A	0.0003	0.0003	0.0003	0.0003	0.0002	0.0003	0.0003	0.0002	0.0002

AR0073014

Table A9 - 5 - N - 3

EMISSION FACTORS FOR MOTORCYCLES AT 75°F
(Grams per Mile)
Oxides of Nitrogen (NOx), Combustion PM10, Tire Wear PM10 and Lead

Speed	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
		YEARS								
		Running Exhaust Emission Factors at 75°F								
		Oxides of Nitrogen (NOx)								
5	0.69	Same Factors As Year 1991					Same Factors As Year 1991			
10	0.62									
15	0.64									
20	0.69									
25	0.77									
30	0.85									
35	0.91									
40	0.96									
45	1.00									
50	1.05									
55	1.16									
60	1.44									
65	2.11									
		Running Exhaust Temperature Correction Factors								
Area 1 and 2	1.03	Same Factors As Year 1991					Same Factors As Year 1991			
Area 3	0.955	Same Factors As Year 1991					Same Factors As Year 1991			
		Cold Start at 75°F								
	0.68	0.69	Same Factor as Year 1993							
		Cold Start Temperature Correction Factor								
Area 1 and 2	0.88	Same as Year 1991				Same as Year 1991			Same as Year 1991	
Area 3	1.155	Same as Year 1991				Same as Year 1991			Same as Year 1991	
		Hot Start at 75°F								
	0.86	Same as Year 1991				Same as Year 1991			Same as Year 1991	
		Hot Start Temperature Correction Factors								
Area 1 and 2	1.04	Same as Year 1991				Same as Year 1991			Same as Year 1991	
Area 3	0.94	Same as Year 1991				Same as Year 1991			Same as Year 1991	
		Combustion PM10, Tire Wear PM10 and Lead								
		(For all Years and Speeds For All Areas)								
Tire Wear PM10	0.05	Grams per Mile				Lead		0.0 tons per day		
Exhaust PM10	0.01	Grams Per mile								

Note: See Table A9 - 5 - N - 3 - a and A9 - 5 - N - 3 - b for temperature corrected NOx emission factors.

AR0073015

Table A9 – 5 – N –3 – a

AREA 1 and AREA 2

TEMPERATURE CORRECTED EMISSION FACTORS FOR MOTORCYCLES

(Grams Per Mile)

OXIDES OF NITROGEN (NOx)

SPEED	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
5	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
10	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
15	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
20	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
25	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
30	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
35	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
40	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
45	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
50	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
55	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
60	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
65	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17
Cold start	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Hot start	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89

Table A9 – 5 – N –3 – b

AREA 3

TEMPERATURE CORRECTED EMISSION FACTORS FOR MOTORCYCLES

(Grams Per Mile)

OXIDES OF NITROGEN (NOx)

SPEED	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009
5	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
10	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
15	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
20	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
25	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
30	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
35	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
40	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
45	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
55	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
60	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
65	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
Cold start	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Hot start	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81

AR0073016

INFORMATION
FOR
FUEL CONSUMPTION IN VEHICULAR SOURCES

AR0073017

TABLE A9 - 5 - O
FORECASTED FUEL CONSUMPTION SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Fuel Consumption by Fuel Type And Vehicle Type
(Gallons Per VMT)

Year	Vehicles with Gross Vehicle Weight up to 6,000 Pounds						Vehicles with Gross Vehicle Weight 6,000 Pounds and Greater***					
	AUTOMOBILES			LIGHT DUTY TRUCKS			MEDIUM-DUTY			HEAVY-DUTY		
	NCAT	CAT	DIESEL	NCAT	CAT	DIESEL	NCAT	CAT	DIESEL	NCAT	CAT	DIESEL
1991												
1993	0.08	0.04	0.03	0.09	0.05	0.04	0.10	0.09	N/A	0.18	0.18	0.18
1995	0.08	0.04	0.03	0.09	0.05	0.04	0.10	0.09	N/A	0.18	0.18	0.17
1997	0.08	0.04	0.03	0.09	0.05	0.04	0.10	0.09	N/A	0.18	0.18	0.17
1999	0.07	0.04	0.03	0.08	0.05	0.04	0.10	0.09	N/A	0.18	0.18	0.16
2001	0.06	0.04	0.03	0.07	0.05	0.04	0.10	0.09	N/A	0.18	0.18	0.16
2003	0.06	0.04	0.03	0.07	0.05	0.04	0.10	0.09	N/A	0.18	0.18	0.16
2005	0.00	0.04	0.03	0.00	0.05	0.04	0.00	0.08	N/A	0.18	0.18	0.15
2007	0.00	0.03	0.03	0.00	0.05	0.04	0.00	0.08	N/A	0.18	0.18	0.15
2009	0.00	0.03	0.03	0.00	0.05	0.04	0.00	0.08	N/A	0.18	0.18	0.15

Fuel Consumption (Gallons per day or per quarter) = (*Daily or quarterly project related VMT x Gallons per VMT)

*VMT = Vehicle Miles Traveled per Day or per Quarter

For total VMT in the county please see Table A - 9 - 14 - A

NCAT = Gasoline-fueled vehicles without catalyst

CAT = Gasoline-fueled vehicles with catalyst

Diesel = Diesel-fueled vehicles

AR0073018

INFORMATION
FOR
ESTIMATING ROLLBACK 8-HOUR AND 1-HOUR PPM LEVELS OF POLLUTANTS

AR0073019

TABLE A9 - 5 - P

ESTIMATING ROLLBACK 8-HOUR PPM LEVELS FOR FUTURE YEARS

(Note: Values used in examples were created, therefore, may not match with values in referenced tables. When performing project-specific analysis always use values from referenced tables and project-specific data. Do not use values from our example in your analysis. For future year CO adjustment factors use Table A9 - 9.)

$E = (\{F \times G\} + \{[G \times H] + [(I \times G \times H) \times (J/K)]\})$ *(See Table A9 - 5 - Q for 1-Hour Levels)*

Where,

- E = Rollback 8-hour PPM levels for the future year.
- F = Percent contribution of that pollutant to ambient levels by stationary (direct) sources. *(District's reports for Air Quality Management Plan or see Table A3 - 1.)*
- G = The highest 8-hour concentration in PPM for the previous three years *(Use the last 3 years of air quality monitoring data.)*
- H = Percent contribution of that pollutant to ambient levels by mobile (indirect) sources. *(District's reports for Air Quality Management Plan or see Table A3 - 1.)*
- I = Percent VMT Growth for that future year

  = [100 x (Future Year VMT - Current Year VMT)]/[Current Year VMT]

  To determine percent increase in VMT, use Table A9 - 14 - A of this Handbook.
- J = Composite (between all autos, trucks, motorcycles, buses, etc.) on-road vehicle emission factor for the future year in grams per mile. See Table A9 - 5 - P - 1
- K = Composite (between passenger vehicles, trucks and other on-road vehicles) emission factor for the current year in grams per mile. See Table A9 - 5 - P - 1

NOTE: Even though the following methodologies in Table A9 - 5 - P - 1 and 2 are included under a methodology that estimates background levels in ppm, these can also be used to estimate composite grams per mile emissions for Caline 4 ppm levels needed to determine CO, NOx and PM10 hot spots, and mass emissions needed to establish project significance.

- *Table A9 - 5 - P - 1 to determine composite emission factor expressed in grams per mile; and,*
- *Table A9 - 5 - P - 2 to determine composite emission factor expressed in grams per minute.*

AR0073020

TABLE A9 - 5 - P - 1

ESTIMATING COMPOSITE EMISSION FACTORS IN GRAMS PER MILE (FOR CALINE 4, BACKGROUND LEVELS OR MASS EMISSIONS)

$$(J) \text{ or } (K) = [(B \times B_{CHS}) + (M \times M_{CHS}) + (P \times P_{CHS}) + (T \times T_{CHS})]/(B + M + P + T)$$

Where,

J = Composite emission factor for future year in **Grams per Mile**

K = Composite emission factor for current year in **Grams per Mile**

B = Bus percent ADT from Table A9 - 5 - G. (If 0.5 %, use 0.5, not 0.005)

B_{CHS} = Bus related composite emission factor between hot start, cold start and stabilized mode

$$= (\{B_C \times [(C_C/A_B) + (D_{RE})]\} + \{B_H \times [(C_H/A_B) + (D_{RE})]\} + \{B_S \times D_{RE}\})/(B_C + B_H + B_S)$$

Where,

B_C = Bus percent cold start estimates from Table A9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)
(If Table A9 - 5 - M - 1 is used to determine hot and cold start percentages by the road type, use Table A9 - 5 - M - 3 percentages to determine hot and cold start related fleet mix and Table A9 - 5 - G percentages to determine stabilized vehicles related fleet mix)

C_C = Bus cold start emission factor in **grams per trip** from Table A11 - 5 - H

A_B = Bus travel related trip length in miles. If unknown, use 3.59 miles.

D_{RE} = Bus running emission factor in **grams per mile** from Table A11 - 5 - H

B_H = Bus percent hot start estimates from Table A9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)

C_H = Bus hot start emission factor in **grams per trip** from Table A11 - 5 - H

B_S = Bus percent stabilized estimates, if Table A9 - 5 - M - 1 is used for hot and cold start %
$= [100 - (B_C + B_H)]$

M = Motorcycle percent ADT from Table A9 - 5 - G. (If 0.6 %, use 0.6, not 0.006)

M_{CHS} = Motorcycle related composite emission factor between hot start, cold start and stabilized mode

$$= (\{M_C \times [(N_C/A_M) + (O_{RE})]\} + \{M_H \times [(N_H/A_M) + (O_{RE})]\} + \{M_S \times O_{RE}\})/(M_C + M_H + M_S)$$

Where,

M_C = Motorcycle percent cold start estimates from Table A9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)
(If Table A9 - 5 - M - 1 is used to determine hot and cold start percentages for the road type, use Table A9 - 5 - M - 3 percentages to determine hot and cold start related fleet mix and Table A9 - 5 - G percentages to determine stabilized vehicles related fleet mix)

N_C = Motorcycle cold start emission factor in grams per trip from Table A9 - 5 - N (1, 2 or 3)

A_M = Motorcycle travel related trip length in miles. If unknown, use 3.59 miles.

O_{RE} = Motorcycle running emission factor in grams per mile from Table A9 - 5 - N (1, 2, or 3)

M_H = Motorcycle percent hot start estimates from Table A9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)

N_H = Motorcycle hot start emission factor in grams per trip from Table A9 - 5 - N (1, 2, or 3)

M_S = Motorcycle percent stabilized estimates, if Table A9 - 5 - M - 1 is used for hot and cold start %
$= [100 - (M_C + M_H)]$

P = Passenger vehicle ADT from Table A9 - 5 - G. (If 85.0 %, use 85.0, not 0.85)

P_{CHS} = Passenger vehicle related composite emission factor between hot start, cold start and stabilized mode

$$= (\{P_C \times [(Q_C/A_P) + (R_{RE})]\} + \{P_H \times [(Q_H/A_P) + (R_{RE})]\} + \{P_S \times R_{RE}\})/(P_C + P_H + P_S)$$

AR0073021

Where,

P_C = Passenger vehicle percent cold start estimates from Table A9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)
(If Table A9 - 5 - M - 1 is used to determine hot and cold start percentages for the road type, use Table A9 - 5 - M - 3 percentages to determine hot and cold start related fleet mix and Table A9 - 5 - G percentages to determine stabilized vehicles related fleet mix)

Q_C = Passenger vehicle cold start emission factor in grams per trip from Table A9 - 5 - J

A_P = Passenger vehicle travel related trip length in miles. If unknown, use 3.59 miles.

R_{RE} = Passenger Vehicle running emission factor in grams per mile from Table A9 - 5 - J

P_H = Passenger vehicle percent hot start estimates from Table A9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)

Q_H = Passenger vehicle hot start emission factor in grams per trip from Table A9 - 5 - J

P_S = Passenger vehicle percent stabilized estimates, if Table A9 - 5 - M - 1 is used for hot and cold start %
$= [100 - (P_C + P_H)]$

T = Trucks or material hauling vehicle ADT from Table A9 - 5 - G. (If 10.0 %, use 10.0, not 0.10)

T_{CHS} = Truck related composite emission factor between hot start, cold start and stabilized mode
$= (\{T_C \times [(U_C/A_T) + (V_{RE})]\} + \{T_H \times [(U_H/A_T) + (V_{RE})]\} + \{T_S \times V_{RE}\})/(T_C + T_H + T_S)$

Where,

T_C = Truck percent cold start estimates from Table A - 9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)
(If Table A9 - 5 - M - 1 is used to determine hot and cold start percentages for the road type, use Table A9 - 5 - M - 3 percentages to determine hot and cold start related fleet mix and Table A9 - 5 - G percentages to determine stabilized vehicles related fleet mix)

U_C = Truck cold start emission factor in grams per trip from Table A9 - 5 - K

A_T = Truck travel related trip length in miles. If unknown, use 3.59 miles.

V_{RE} = Truck running emission factor in grams per mile from Table A9 - 5 - K

T_H = Truck percent hot start estimates from Table A9 - 5 - M - 1 (Caline 4) or 2 (Background or Mass)

U_H = Truck hot start emission factor in grams per trip from Table A9 - 5 - K

T_S = Truck percent stabilized estimates, if Table A9 - 5 - M - 1 is used for hot and cold start %
$= [100 - (T_C + T_H)]$

TABLE A9 - 5 - P - 2

ESTIMATING COMPOSITE EMISSION FACTORS IN GRAMS PER MINUTE

J^* or $K^* = \{[W \times Y]/60$

Where,

J^* = Composite emission factor for future year in grams per minute

K^* = Composite emission factor for current year in grams per minute

W = Freeflow (5 mph or higher) or congested (Lower than 5 mph) travel speed expressed in miles per hour *(see Table A9 - 5 - F for freeflow speeds)*

Y = Composite emission factor expressed in gms per mile at W mph
(Use Table A9 - 5 - P - 1 methodology to estimate grams per mile composite emission factors)

Use the following methodologies to estimate project emissions:

If the distance traveled is in meters (as required in CALINE 4 model)

$E^* = (L \times Y)/(1609.3)$, where,

E^* = Emissions in gms for distance traveled at W mph speed

L^* = Actual distance traveled in meters at W mph speed

If the distance traveled is in miles (as required in the mass-emission estimating model, Table A9 - 5)

$E^* = (L^* \times Y)$, where,

L^* = Actual distance traveled in miles at W mph speed

AR0073022

TABLE A9 - 5- Q

ESTIMATING ROLLBACK 1-HOUR PPM LEVELS FOR FUTURE YEARS
(Parts Per Million or PPM)

(Note: Values used in examples were created, therefore, may not match with values in referenced tables. When performing project-specific analysis always use values from referenced tables and project-specific data. Do not use values from our example in your analysis.)

E = (F)/(G)

Where,

E = Rollback 1-hour PPM levels for the future year.
F = Rollback 8-hour PPM levels for the future year.
(Use Table A9 - 5 - P to determine the value for F.)
G = The highest persistent factor among previous three years.
(To determine 1- to 8-hour persistent factor, use the last 3 years of air quality monitoring data.)
= (H)/(I)

where,

H = 8-hour concentrations for each of the previous three years
I = 1-hour concentrations for each of the previous three years

AR0073023

TABLES FOR ESTIMATING GASOLINE AND DIESEL FUELING EMISSIONS

AR0073024

TABLE A9 - 6

ESTIMATING EMISSIONS FROM GASOLINE AND DIESEL FUELING ACTIVITY
(Pounds Per Day)

$E = [(F/365) \times ((G1, G2 \text{ or } J)/H)] \times I$

Where,

E = Emissions of Reactive Organic Compounds (ROC) or Benzene* From Gasoline Station During Fueling and Storage

F = Amount of Gasoline Dispensed in Gallons per Year (If Unknown, Use 248,000,000 Gallons Per Year For Stations with both controls, Phase I and Phase II; 12,900,000 per year for stations without any Control and 20,900,000 per year for stations with only Phase I Control)

G1, G2 or J = Emission Factor per 1,000 gallons Dispensed

H = 1000; Because the emission factor is used for 1000 gallons

I = 0.92; Use only to convert Total Organic Compounds (TOC) Emissions to ROC emissions. (Do not use "I" for Benzene)

TABLE A9 - 6 - A

EMISSION FACTORS (G1) FOR EACH CRITERIA POLLUTANT FOR INDIVIDUAL ACTIVITIES ASSOCIATED WITH ORIGINAL (REMOVED) EQUIPMENT

(For composite activities emission factor (G2) please see third column of Table A - 9 - 6 - B)

(Pounds Per 1000 Gallons)

Pollutant Type	CO	TOC	NOx	SOx	PM10
Stage I (Storage Tank Loading and Storing)					
Storage					
Breath-Underground Tank	N/A	1.0	N/A	N/A	N/A
Loading					
Splash Filling	N/A	11.50	N/A	N/A	N/A
Sub-Fill No Control	N/A	7.30	N/A	N/A	N/A
Unloading	N/A	1.00	N/A	N/A	N/A
Sub-Fill Balanced	N/A	0.30	N/A	N/A	N/A
Stage II (Motor Vehicle Fueling)					
No Vapor Control	N/A	11.00	N/A	N/A	N/A
No Liquid Control	N/A	0.67	N/A	N/A	N/A
Vapor Controlled	N/A	0.90	N/A	N/A	N/A

N/A = Not Applicable

TABLE A9 - 6 - B

EMISSION FACTORS (J) FOR BENZENE* AND EQUIVALENT EMISSION FACTORS (G2) FOR TOC IN VEHICULAR FUELING AND STORING COMPOSITE ACTIVITIES
(Pounds per 1000 Gallons)

(NOTE: Benzene is identified as a carcinogenic air contaminant, which should be quantified using above methodology)

	Benzene Emissions (J)	TOC Emissions (G2)
Phase I and II Control	0.0138 lbs. / 1000 gallons	1.725 lbs. / 1000 gallons
Phase I Only	0.0974 lbs. / 1000 gallons	12.175 lbs. / 1000 gallons
No Control	0.1696 lbs. / 1000 gallons	21.200 lbs. / 1000 gallons

* **If ROC (E) is estimated using "G2" emission factors, benzene emissions can be estimated by the following methodology: $[(E_{ROC}) \times (J)]/[(G2 \times (0.92)]$**

SOURCE: Proposed Airborne Toxic Control Measure for Emissions of Benzene from Retail Service Stations, July 9, 1997

AR0073025

INFORMATION
FOR
AVERAGE VEHICLE RIDERSHIP DETERMINATION

AR0073026

TABLE A9 - 7

ESTIMATING PROJECT-RELATED EXISTING OR CURRENT AVERAGE VEHICLE RIDERSHIP OR OCCUPANCY
(Based on the District's Regulation XV)

CAVR = [F]/[G]; *OR*
CAVR = [{A x B} + {C x D}]/[{(A/E)xB*} + {(C/E)xD*}]

Where,

CAVR = Current or Pre-Mitigation Average Vehicle Ridership

To improve AVR, the number of cars associated with the following should be eliminated or reduced;

- F = Average Persons Arriving in Vehicles at the Project Site; and,
- G = Average Cars Arriving at the Project Site; *OR*
- A = Total Number of 1-Way or 2-Way Trips made with Automobiles, trucks, etc. by 1 Person in 1 Vehicle per Week;
- B = Number of Days Trips made with Automobiles, trucks, etc. by 1 Person in 1 Vehicle per Week;
- C = Total Number of 1-Way or 2-Way Trips made with Motorcycles by 1 Person on 1 Motorcycle per Week;
- D = Number of Days Trips made with Motorcycles by 1 Person on 1 Motorcycle per Week;
- E* = 1.0 or 2.0; *(Used to Determine Number of Cars Arriving at the Project Site).*
- * If A and C were One-Way Trips, then A and C will be divided by 1.0 To obtain Number of Cars.
- * If A and C were Two-Way Trips, then A and C will be divided by 2.0 to obtain Number of Cars.

To improve AVR, the number of cars arriving at the project site must be reduced.
Use Table 11-5 methodologies from Appendix 11 for emission reductions after implementation of each mitigation measure that reduces number of cars arriving at the project site.

AVR for the Vehicles Staying Home but Used for Other Trips = 1/1 = 1:00

Even though the following information is not needed to estimate the work-related AVR, this information should be provided in an environmental document as Non-work Related AVR. Use the following information for Appendix 11 methodologies to estimate emissions from Non-work trips. *The 1991 AQMP states that 5% of the following trips were for Home to Other trips:*

Non-work 1-Way Project Trips = [{(J+K+L+M+N+O+P+Q+R+U) x 0.05} + {(S+T) x V}]; Where,

- J = Number of Persons Walked 1-way
- K = Number of Persons Traveled 1-way by Bicycle
- M = Number of Persons did not travel to the project site due to days off from 3/36 work week
- N = Number of Persons did not travel to the project site due to days off from 4/40 work week
- O = Number of persons did not travel to the project site due to days off from 9/80 work week
- P = Number of persons did not travel to the project site due to vacation
- Q = Number of persons did not travel to the project site due to sick leave
- R = Number of persons did not travel to the project site because they were absent for reasons other than vacation and sick leaves
- S = Number of persons did not travel to the project site because it was Saturday
- T = Number of persons did not travel to the project site because it was Sunday
- V = Percent Weekend Trips to other

Note: 1-way trip is trip to work.

AR0073027

INFORMATION
FOR
MOBILE EQUIPMENT EMISSIONS

AR0073028

TABLE A9 - 8

ESTIMATING EMISSIONS FROM MOBILE *** EQUIPMENT (EXHAUST AND EVAPORATIVE TYPE) (Pounds Per Day)

$E^{*} = (F \times G) \times H$; or

$E^{**} = (F \times G) \times (K \times L \times M)$

Use Table A9 - 3 of this Handbook with information provided in Tables A9 - 8 - C and A9 - 8 - D

Where,

E* = Time specific exhaust emissions of criteria pollutants in pounds per day or pounds per quarter

F = Source population or number of equipment with the same characteristic information****
(Please see Tables A9 - 8 - A, B, C, D and E for the types of equipment for which this formula can be used)

G = Daily hours or quarterly hours of operation per day per F type equipment
(If unknown, use 8, 16 or 24 hours depending on the number of shifts in a day; use 65 to 91 days per quarter depending on the number of work days in a quarter, and use 261 to 365 days per year depending on the number of work days in a year.)

H = Time specific emission factors in pounds per hour per F type equipment
(Please see Table A9 - 8 - A for time specific emission factors)

E** = Mechanical energy output specific exhaust emissions of criteria pollutants in pounds per day

K = Average rated mechanical energy output for F type equipment in horsepower
(Please see Table A9 - 8 - C for average rated horsepower)

L = Mechanical energy output specific emission factors at 100 % load in pounds per horsepower-hour

M = Fraction for typical load factor *(If unknown, use value from Table A9 - 8 - D divided by 100)*

* Use this formula only when hours of operation of each equipment is available

** Use this formula only when mechanical energy output in horsepower and hours of operation is known.

*** Contact California Air Resources Board (El Monte, California Branch) to obtain the copy of the most recent version of regulations on exhaust emission standards and performance specifications for mobile (off-road) equipment.

**** For an initial study, use Table A9 - 8 - E to estimate number of equipments that can be operated in a day without exceeding construction thresholds.

TABLE A9 - 8 - A

EXHAUST EMISSION FACTORS (H) FOR EACH CRITERIA POLLUTANT
(Pounds Per Hour)

Note: As much as possible use the following emission factors from Table A9 - 8 - A. If these emission factors cannot be applied to your project then only use emission factors provided in Table A9 - 8 - B.

Equipment Type	CO		ROC		NOx		SOx		PM10	
***	G	D	G	D	G	D	G	D	G	D
Fork Lift - 50 Hp	14.0	0.18	0.5	0.053	0.016	0.441	-	-	0.003	0.031
Fork Lift - 175 Hp	43.97	0.52	1.53	0.17	0.92	1.54	-	-	0.123	0.093
Trucks: Off-Highway	-	1.8	-	0.19	-	4.17	-	0.45	-	0.26
Tracked Loader	-	0.201	-	0.095	-	0.83	-	0.076	-	0.059
Tracked Tractor	-	0.35	-	0.12	-	1.26	-	0.14	-	0.112
Scraper	-	1.25	-	0.27	-	3.84	-	0.46	-	0.41
Wheeled Dozer	-	-	-	-	-	-	-	0.35	-	0.165
Wheeled Loader	15.57	0.572	0.515	0.23	0.518	1.9	0.023	0.182	0.03	0.17
Wheeled Tractor	9.53	3.58	0.351	0.18	0.43	1.27	0.015	0.09	0.024	0.14
Roller	13.41	0.30	0.59	0.065	0.362	0.87	0.0185	0.067	0.026	0.05
Motor Grader	12.10	0.151	0.40	0.039	0.32	0.713	0.017	0.086	0.021	0.061
Miscellaneous	17.02	0.675	0.543	0.15	0.412	1.7	0.023	0.143	0.026	0.14

*** Fuel types: G = Gasoline-Powered; and D = Diesel-Powered

Source: AP-42 Report, September 1985, Federal Environmental Protection Agency

AR0073029

TABLE A9 - 8 - B

EXHAUST EMISSION FACTORS (L) AT 100% LOAD FOR EACH CRITERIA POLLUTANT

(4-stroke and 2-stroke description applies only to gasoline-powered equipment)

(Pounds Per Horsepower-Hour)

As much as possible use emission factors provided in Table A9 - 8 - A. The following emission factors should be used only if emission factors from previous Table cannot be used. As a last source to estimate construction related exhaust emissions use Tables A9 - 5 - G and A9 - 5 - H. These tables provide methodology to estimate construction related BTU values for a project. Convert daily BTU consumption to daily horsepower-hour (multiply BTUs by 0.000393) consumption and then use the following emission factors.

Equipment Type ***	CO		ROC		NOx		SOx		PM10	
	Diesel	Gasl.	Diesel	Gasl.	Diesel	Gasl.	Diesel	Gasl.	Diesel	Gasl.
Paving Equp (4-strk)	0.010	0.83	0.002	0.042	0.024	0.004	0.002	0.0005	0.001	0.00025
Paving Equip (2-strk)	0.010	2.04	0.002	0.896	0.024	0.0006	0.002	0.0005	0.001	0.00845
Plate Compctr (4-strk)	0.007	0.83	0.002	0.043	0.020	0.004	0.002	0.0005	0.001	0.00025
Plate Compctr (2-Strk)	0.007	2.04	0.002	0.897	0.020	0.0006	0.002	0.0005	0.001	0.00845
Bore/Drill Rig (4-strk)	0.020	0.57	0.003	0.025	0.024	0.011	0.002	0.0005	0.0015	0.00005
Bore/Drill Rig (2-strk)	0.020	2.04	0.003	0.897	0.024	0.0006	0.002	0.0005	0.0015	0.00845
ChainSaws >4HP(2-Strk)	--	2.15	--	0.684	--	0.0021	--	0.0008	--	0.00143
Tmpr/Rammr (2-Strk)	--	2.04	--	0.897	--	0.0006	--	0.0005	--	0.00845
Tampers/Rammers	--	0.83	--	0.043	--	0.004	--	0.0005	--	0.00025
Skid-Steer Loader	0.020	0.44	0.004	0.018	0.021	0.44	0.002	0.0005	0.0015	0.00005
Rubber Tired Loaders	0.011	0.47	0.002	0.021	0.023	0.012	0.002	0.0005	0.0015	0.00005
Tretr/Ldr/Bckhe	0.015	0.57	0.003	0.025	0.022	0.011	0.002	0.0005	0.001	0.00005
Terminal Tractors	0.013	0.026	0.003	0.57	0.031	0.011	0.002	0.0006	0.0015	0.00005
Excavators	0.011	0.57	0.001	0.025	0.024	0.011	0.002	0.0005	0.0015	0.00005
Trenchers	0.020	0.57	0.003	0.026	0.022	0.011	0.002	0.0005	0.0015	0.00005
Rollers	0.007	0.85	0.002	0.049	0.020	0.005	0.002	0.0006	0.001	0.00025
Other Concrete Equip	0.020	0.57	0.003	0.025	0.024	0.011	0.002	0.0005	0.0015	0.00005
Cement/Mortar Mix	0.010	0.83	0.002	0.040	0.024	0.004	0.002	0.0006	0.001	0.00025
Asphalt Pavers	0.007	0.57	0.001	0.025	0.023	0.011	0.002	0.0005	0.001	0.00005
Concrete Saws	0.020	0.003	0.024	0.043	0.002	0.004	0.003	0.0005	0.001	0.00025
Crushing Equipment	0.020	0.57	0.003	0.025	0.024	0.011	0.002	0.0005	0.0015	0.00005
Aerial Lifts	0.013	0.57	0.003	0.025	0.031	0.011	0.002	0.0006	0.0015	0.00005
Rough Terrain Fork Lifts	0.022	0.57	0.003	0.025	0.018	0.011	0.002	0.0005	0.0015	0.00005
Crushing Equipment	0.020	0.57	0.003	0.025	0.024	0.011	0.002	0.0005	0.0015	0.00005
Fork Lifts	0.013	0.57	0.003	0.025	0.031	0.011	0.002	0.0006	0.0015	0.00005
Cranes	0.009	0.57	0.003	0.025	0.023	0.011	0.002	0.0005	0.0015	0.00005
Sprayers	0.008	0.62	0.005	0.029	0.017	0.011	0.002	0.0006	0.0015	0.00025
Dumpers/Tenders	0.006	0.83	0.002	0.043	0.021	0.004	0.002	0.0005	0.0015	0.00025
Signal Boards	0.011	0.83	0.002	0.043	0.018	0.004	0.002	0.0005	0.001	0.00025
Sweepers/Scrubbers	0.013	0.57	0.003	0.025	0.031	0.011	0.002	0.0006	0.0015	0.00005
Sweepers/Scrubbers	0.013	0.57	0.003	0.025	0.031	0.011	0.002	0.0006	0.0015	0.00005
Generator sets <50 HP	0.011	1.479	0.002	0.054	0.018	0.002	0.002	0.0006	0.001	0.00025
Genr <50 HP (2-stroke)	0.011	2.036	0.002	0.893	0.018	0.0006	0.002	0.0006	0.001	0.00845
Pressur Washer <50 HP	0.011	1.479	0.002	0.054	0.018	0.002	0.002	0.0006	0.001	0.00025
Hydro Power Units	0.008	0.913	0.005	0.038	0.017	0.006	0.002	0.0006	0.0015	0.00025
Welders <50 HP	0.011	1.479	0.002	0.054	0.018	0.002	0.002	0.0006	0.001	0.00025
Pumps <50 HP	0.011	1.479	0.002	0.054	0.018	0.002	0.002	0.0006	0.001	0.00025
Air Compressor <50 HP	0.011	1.479	0.002	0.054	0.018	0.002	0.002	0.0006	0.001	0.00025
Surfacing Equipment	--	0.83	--	0.043	--	0.004	--	0.0005	--	0.00025
2-Wheeled Tractors	--	0.600	--	0.032	--	0.0058	--	0.0005	--	0.00025
Shredder >5 HP	--	1.479	--	0.056	--	0.0018	--	0.0004	--	0.0004
Concrete Pavers	0.01	--	0.002	--	0.022	--	0.002	--	0.001	--
Rubber Tired Dozers	0.01	--	0.002	--	0.021	--	0.002	--	0.0005	--
Off-Highway Tractors	0.052	--	0.005	--	0.026	--	0.002	--	0.002	--
Skidder	0.011	--	0.002	--	0.025	--	0.002	--	0.0015	--
Crawler Tractors	0.011	--	0.002	--	0.023	--	0.002	--	0.001	--
Grader	0.008	--	0.003	--	0.021	--	0.002	--	0.001	--
Scraper	0.011	--	0.001	--	0.019	--	0.002	--	0.0015	--

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TABLE A9 - 8 - C

FUEL CONSUMPTION AND NUMBER OF HOURS OF OPERATION FOR AVERAGE-RATED HORSEPOWER CAPACITY AT 100 % LOAD

(All values are taken from November 1991 Nonroad Engine and Vehicle Emission Study and averaged)
(NTIS PB92 - 126960, EPA 460/3-91-02, or EPA 21A - 2001)

The following information should be used only if Table A9 - 8 - A and Table A9 - 8 - B emission factors and related methodology cannot be used, or to estimate approximate fuel consumption in gallons if horsepower rating and hours of operation are known.

	DIESEL (0.066 Gals/Hp-Hr)			GASOLINE (0.16 Gals/Hp-Hr)		
Equipment Type	Horsepower	Gallons	Hrs at 100 % Load	Horsepower	Gallons	Hrs at 100 % Load
Skid-Steer Loader	39.0	16.72	6	31.0	10.0	2
Wheel or Rubber Tired Loader	147	59.5	6	77.0	34.2	3
Tractors/Loaders	77	39.27	8	63.0	32.1	3
Airport Terminal Tractors	96	5.7	1	82.0	5.71	0.4
Excavators	56	28.56	8	80.0	40.8	3
Trenchers	60	30.60	8	27.0	2.6	1
Rollers	99	50.49	8	17.0	3.00	1
Other Construction Equipment	161	82.11	8	150.0	76.5	3
Cement and Mortar Mix	11	3.0	4	7.0	1.2	1
Paving Equipment	99	50.49	8	7.0	1.0	1
Asphalt Pavers	91	46.41	8	31.0	15.8	3
Plate Compactors	8	2.00	4	5.0	0.94	1
Concrete Saws (Cutting Concrete)	56	28.56	8	13.0	1.4	1
Crushing Equipment	127	64.77	8	60.0	30.6	3
Aerial Lifts	43	21.93	8	36.0	18.36	3
Rough Terrain Fork Lifts	93	47.43	8	88.0	44.8	3
Fork Lifts	83	42.33	8	62.0	18.0	2
Cranes	194	96.94	8	55.0	28.05	3
Sprayers	92	46.92	8	24.0	1.5	4
Dumpers/Tenders	23	11.73	8	9.0	3.0	2
Signal Boards (Routing Boards)	11.22	6.0	8	8.0	1.1	1
Bore/Drill Rigs (Groundwater)	209	106.59	8	54.0	27.5	3
Sweepers/Scrubbers	97	49.47	8	39.0	19.8	3
Generator sets < 50 HP	22	11.22	8	11.0	1.0	1
Pressure Washers <50 HP	21	10.71	8	7.0	0.75	1
Hydro Power Units	35	17.85	8	14.0	5.0	2
Welders <50 HP	35	17.85	8	19.0	3.25	1
Pumps <50 HP	23	11.73	8	7.0	0.7	1
Air Compressors <50 HP	37	18.87	8	9.0	1.13	1
Landscape Loader	55	23.00	6	-.-	-.-	-.-
Backhoe Loader	79	21.0	3.5	-.-	-.-	-.-
Log Loader	116	50.8	7	-.-	-.-	-.-
Excavator (Utility)	34.2	28.23-	13	-.-	-.-	-.-
Excavator (Construction)	151.7	94.61	9	-.-	-.-	-.-
Surfacing Equipment (All Gasoline)	-.-	-.-	-.-	8.0	1.0	1
Tampers/Rammers (All Gasoline)	-.-	-.-	-.-	4.0	0.94	1
2-Wheeled Tractors (All Gasoline)	-.-	-.-	-.-	7.0	2.67	2
Shredder >5 HP (All Gasoline)	-.-	-.-	-.-	8.0	1.0	1
Chain Saws >4 HP (All Gasoline)	-.-	-.-	-.-	6.0	0.2	2

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TABLE A9 - 8 - C (Cont.)

DIESEL (0.066 Gallons/Hp-Hr)				GASOLINE (0.16 Gallons/Hp-Hr)		
Equipment Type	Horsepower	Gallons	Hrs at 100 % Load	Horsepower	Gallons	Hrs at 100 % Load
Crawler Dozer (All Diesel)	102.9	54.25	8	-.-	-.-	-.-
Rubber Tired Dozers (All Diesel)	356	181.56	8	-.-	-.-	-.-
Crawler Tractors (All Diesel)	157	80.07	8	-.-	-.-	-.-
Tractor (Utility Compact)	29.4	7.53	4	-.-	-.-	-.-
Tractor (Utility General Purpose)	69	21.53	5	-.-	-.-	-.-
Fellers/Bunchers (All Diesel)	183	144.0	12	-	-.-	
Concrete Pavers (All Diesel)	130	66.3	8	-.-	-.-	-.-
Skidder (All Diesel)	134	63.95	7	-.-	-.-	-.-
Off-Highway Trucks (All Diesel)	489	249.39	8	-.-	-.-	-.-
Grader (All Diesel)	156.6	81.36	8	-.-	-.-	-.-
Scraper (All Diesel)	266.76	124.5	7	-.-	-.-	-.-

TABLE A9 - 8 - D

TYPICAL LOAD FACTORS FOR MOBILE (OFF-ROAD) EQUIPMENT

(*All values are taken from November 1991 Nonroad Engine and Vehicle Emission Study and averaged*)
(NTIS PB92 - 126960, EPA 460/3-91-02, or EPA 21A - 2001)

The following information should be used only if emission factors from Table A9 - 8 - B and related emission estimating methodology is used.

DIESEL		GASOLINE
Equipment Type	Load Factor (Percent or %)	Load Factor (Percent or %)
Crawler Dozer (All Diesel)	59	-.-
Rubber Tired Dozers (All Diesel)	59	-.-
Crawler Tractors (All Diesel)	57.5	-.-
Tractor (Utility Compact)	46.5	-.-
Tractor (Utility General Purpose)	46.5	-.-
Fellers/Bunchers (All Diesel)	71	-.-
Concrete Pavers (All Diesel)	62	-.-
Skidder (All Diesel)	61.5	-.-
Off-Highway Trucks (All Diesel)	41	-.-
Grader (All Diesel)	57.5	-.-
Scraper (All Diesel)	66	-.-

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TABLE A9 - 8 - D (Cont.)

DIESEL		GASOLINE
Equipment Type	Load Factor (Percent or %)	Load Factor (Percent or %)
Skid-Steer Loader	51.5	58
Wheel Loader	46.5	-.-
Rubber Tired Loaders	54	54
Tractors/Loaders/Backhoes	46.5	48
Airport Terminal Tractors	82	78
Excavators	58	78
Trenchers	69.5	66
Rollers	57.5	62
Other Construction Equipment	62	48
Cement and Mortar Mixer	56	59
Paving Equipment	53	59
Asphalt Pavers	59	66
Plate Compactors	43	55
Concrete Saws (Cutting Concrete)	73	78
Crushing Equipment	78	85
Aerial Lifts	50.5	46
Rough Terrain Fork Lifts	47.5	63
Fork Lifts	30	30
Cranes	43	47
Sprayers	50	50
Dumpers/Tenders	38	41
Signal Boards (Routing Boards)	82	76
Bore/Drill Rigs (Groundwater)	75	79
Sweepers/Scrubbers	68	71
Generator sets < 50 HP	74	68
Pressure Washers < 50 HP	30	30
Hydro Power Units	48	55
Welders <50 HP	45	51
Pumps < 50 HP	74	69
Air Compressors < 50 HP	48	56
Landscape Loader	46.5	-.-
Backhoe Loader	46.5	-.-
Log Loader	46.5	-.-
Excavator (Utility)	58	-.-
Excavator (Construction)	58	-.-
Surfacing Equipment (All Gasoline)	-.-	49
Tampers/Rammers (All Gasoline)	-.-	56
2-Wheeled Tractors (All Gasoline)	-.-	62
Shredder >5 HP (All Gasoline)	-.-	36
Chain Saws > 4 HP (All Gasoline)	-.-	50

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TABLE A9 - 8 - E

NUMBER OF CONSTRUCTION EQUIPMENT THAT WILL EXCEED SCAQMD DAILY THRESHOLDS AT 100 PERCENT LOAD
(Based on Emission Factors from Table A9 - 8 - A)

(The following table provides pieces of equipment that can be operated for each category and emissions for that equipment category which will still remain within daily thresholds during 8-hour construction activity.)

EQUIPMENT TYPE	GASOLINE-OPERATED	DIESEL-OPERATED
DETERMINING FACTOR	CARBON MONOXIDE THRESHOLDS (550 Pounds/Day)	OXIDES OF NITROGEN THRESHOLDS (100 Pounds Per Day)
Wheeled Loader	4	6+
Wheeled Tractor	7	9+
Roller	5	14+
Fork Lift - 50 HP	4	28
Fork Lift - 175 HP	4+	8
Trucks: Off-Highway	--	3
Tracked Loader	--	15
Tracked Tractor	--	9+
Scraper	--	3+
Motor Grader	5+	17
Miscellaneous	4	7

\+ *An Additional Equipment in this Category may be Operated for 4 or Less Hours Per Day, and Remain Below the District New Threshold Levels for That Equipment Category*

Note: Table A9 - 8 - E shall only be used as a reference in selecting the amount of potential equipment that may be needed for the project. It shall not be used for estimating emissions. Manufacturers' emission data should be used to determine emission estimates. If manufacturers' data is not available, use applicable tables from appendices. If manufacturers' data is used, make sure that the data is developed using EPA, ARB and SCAQMD approved test protocols.

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INFORMATION
FOR
PM10 EMISSIONS
FROM
FUGITIVE DUST CREATED DURING
CONSTRUCTION AND OPERATION OF THE PROJECT

AR0073035

TABLE A9 - 9

ESTIMATING PM10 EMISSIONS FROM FUGITIVE DUST
(CONSTRUCTION SITES, AND OPERATION OF COMMERCIAL, RESIDENTIAL FACILITIES AND INDUSTRIES SUCH AS QUARRIES, ROCK-CRUSHING, ETC.)
(POUNDS PER DAY)

SOURCE TYPE	SOURCE-RELATED ESTIMATIONS	MULTIPLY BY	EMISSION FACTORS (F)	REFERENCE TO TABLES*****	EMISSIONS (Pounds/Day) (E)
Passenger Vehicle/ On Paved Roadways (without street cleaning)	_____ VMT per DAY (Use Table A9 - 9 - A)	X	_____, or (0.33 lbs/mile)*	Table A9 - 9 - B	_____
Passenger Vehicle/ On Paved Roadways (with street cleaning)	_____ VMT per DAY (Use Table A9 - 9 - A)	X	_____, or (0.018 lbs/mile)*	Table A9 - 9 - B	_____
Passenger Vehicle/ On Unpaved Roads	_____ VMT per DAY (Use Table A9 - 9 - A)	X	_____, or (5.56 lbs/mile)*	Table A9 - 9 - D	_____
Trucks on Paved Roadways (without street cleaning)	_____ VMT per DAY (Use Table A9 - 9 - A)	X	_____, or (2.00 lbs/mile)*	Table A9 - 9 - C	_____
Trucks on Paved Roadways (with street cleaning)	_____ VMT per DAY (Use Table A9 - 9 - A)	X	_____, or (0.40 lbs/mile)*	Table A9 - 9 - D	_____
Trucks On Unpaved Roads	_____ VMT per DAY (Use Table A9 - 9 - A)	X	_____, or (23.0 lbs/mile)*	Table A9 - 9 - D	_____

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TABLE A9 - 9 (Cont.)

ESTIMATING PM10 EMISSIONS FROM FUGITIVE DUST
(POUNDS PER DAY)

SOURCE TYPE	SOURCE-RELATED ESTIMATIONS	MULTIPLY BY	EMISSION FACTORS (F)	REFERENCE TO TABLES*****	EMISSIONS (Pounds/Day) (E)
Passenger Vehicle/ Paved Parking Lots (without street cleaning)	_____ # of Vehicles per Day	X	____ x (L** + W***); or (0.003 gms/vehicle*) x(L + W)	EPA MRI Report	_____
Passenger Vehicle/ Paved Parking Lots (with street cleaning)	_____ # of Vehicles per Day	X	____ x (L** + W***); or (0.00015 gms/vehicle*) x(L + W)	EPA MRI Report	_____
Passenger Vehicle/ Unpaved Parking Lots	_____ # of Vehicles per Day	X	____ x (L** + W***); or (0.08 gms/vehicle*) x(L + W)	EPA MRI Report	_____
Trucks/Paved Parking Lots (without street cleaning)	_____ # of Vehicles per Day	X	____ x (L** + W***); or (0.015 gms/vehicle*) x(L + W)	EPA MRI Report	_____
Trucks/Paved Parking Lots (with street cleaning)	_____ # of Vehicles per Day	X	____ x (L** + W***); or (0.003 gms/vehicle*) x(L + W)	EPA MRI Report	_____
Trucks Vehicles/ Unpaved Parking Lots	_____ # of Vehicles per Day	X	____ x (L** + W***); or (0.2 gms/vehicle*) x(L + W)	EPA MRI Report	_____

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TABLE A9 - 9 (Cont.)

ESTIMATING PM10 EMISSIONS FROM FUGITIVE DUST (POUNDS PER DAY)

SOURCE TYPE	SOURCE-RELATED ESTIMATIONS	MULTIPLY BY	EMISSION FACTORS (F)	REFERENCE TO TABLES*****	EMISSIONS (Pounds/Day) (E)
Open Storage Piles	____ Acres of Area Covered by Storage Piles per Day	X	_____, or (85.6 lbs/Day/Acre)*	Table A9 - 9 - E	_____
	- OR -				
	____ Square Feet of Area Covered by Storage Piles per Day	X	_____, or (1.97 lbs per Day per 1000 Square Feet)*	Table A9 - 9 - E	_____
Dirt/Debris Pushing Operations	___ # of Bulldozers x ___ Hours of Operation per Day	X	_____, or (21.8 lbs/hour)*	Table A9 - 9 - F	_____
Storage Pile Filling or Truck Dumping	____ Tons of Material Handled per Day	X	_____, or (0.009075 lbs/ton)*	Table A9 - 9 - G	_____
Truck Filling or Storage Pile Emptying	____ Tons of Materials Handled per Day	X	_____, or (0.02205 lbs/ton)*	EPA MRI Report	_____
Demolition	____ Cubic Feet of building volume Demolished	X	_____, or (0.00042 lbs/PM10 per cubic feet of building volume)*	Table A9 - 9 - H	_____

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TABLE A9 - 9 (Cont.)

ESTIMATING PM10 EMISSIONS FROM FUGITIVE DUST
(POUNDS PER DAY)

SOURCE TYPE	SOURCE-RELATED ESTIMATIONS	MULTIPLY BY	EMISSION FACTORS (F)	REFERENCE TO TABLES*****	EMISSIONS (Pounds/Day) (E)
Graded Surface	_____ Acres of Area Graded	X	N/A or, (26.4 lbs/Day/Acre)*	EPA MRI Report	_____
Top Soil Removal (15 Cubic Meter Pan Scraper)	_____ VMT per DAY (Table A9 - 9 - A)	X	N/A or, (20.0 lbs/mile)*	EPA MRI Report	_____
Earthmoving (Cut and Fill Operation) (15 Cubic Meter Pan Scraper)	_____ VMT per DAY (Table A9 - 9 - A)	X	N/A or, (4.3 lbs/mile)*	EPA MRI Report	_____
Dirt Hauling w/Truck	_____ VMT per DAY (Table A9 - 9 - A)	X	N/A or, (10.0 lbs/mile)*	EPA MRI Report	_____

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* Default value

** L = Length in feet of the Parking Lot

*** W = Width in feet of the Parking Lot

Note *If value of (L + W) is unknown, use the following methodology to best estimate that value: Multiply the width of a carspace by 3.0 and add it to the length of that carspace. Multiply the addition by number of cars estimated for that parking lot or a project. For a normal size passenger carspace, width is 10 ft and length is 20 ft; for a compact size passenger carspace, width is 7 ft and length is 15 ft.*

***** Tables with examples to estimate emissions and project specific emission factors

AR007303

TABLE A9 - 9 - A

ESTIMATING VEHICLE MILES TRAVELED FOR DUST EMISSIONS

$V = W \times (X/Y) \times Z$

This formula can also be used for estimating vehicle miles traveled (VMT) for Table A9 - 5 of this Handbook

Where,

- V = Vehicle Miles Traveled or VMT (*Use this VMT to estimate fugitive dust and PM10 from fugitive on roads in Table A9 - 9*).
- W = Traveled Distance or Trip Length in miles (*For unpaved haul road, please see Example - 1 for unpaved country road, see Example - 2.*)
- X = Number of vehicles (*See environmental document or analysis for Tables 9 - 5 and 9 - 17*).
- Y = One Hour
- Z = Travel times in hours (*See environmental document or analysis for Tables 9 - 5 and 9 - 17*)

EXAMPLE - 1

EXAMPLE FOR AN UNPAVED HAUL ROAD
(Estimated VMT = 9,000 with the following input assumptions)
(Please do not copy these assumptions, use the project specific data)

	Input Example	Input Examples
W =	Distance	5 miles
X =	Number of Vehicles per hour	150
Z =	Hours of Dust-Causing Activity	12

EXAMPLE - 2

EXAMPLE FOR AN UNPAVED COUNTRY ROAD
(Estimated VMT = 13,500 with the following input assumptions)
(Please do not copy these assumptions, use the project specific data)

	Input Example	Input Examples
W =	Distance	5 miles
X =	Number of Vehicles per hour	150
Z =	Hours of Dust-Causing Activity	18

Note: In above two examples hours of dust-causing activities was changed; therefore, VMT was changed from 9,000 to 13,500 miles. Use project specific estimates.

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TABLE A9 - 9 - B

ESTIMATING EMISSIONS FROM PASSENGER VEHICLE TRAVEL ON PAVED ROADS

$E^* = V \times F$ (without street cleaning); or,
$E^{**} = V \times G$ (with street cleaning and is dependent on type of road); or,

Where,

- E^* = Emissions for passenger vehicles on paved roads and paved parking lots without street cleaning,
- V = Vehicle miles Traveled *(See Table A9 - 9 - A to estimate VMT associated with passenger vehicles.)*
- F = Default Emission Factor *(without street cleaning)* of 0.33 Pounds per Mile Traveled
- E^{**} = Emissions for passenger vehicles on paved roads and paved parking lots with street cleaning,
- G = Emission factors *(with street cleaning and is dependent on type of road)* from Sierra Research *(See Table A9 - 9 - B - 1)*

TABLE A9 - 9 - B - 1

PAVED ROAD EMISSION FACTORS - PASSENGERS CARS WITH STREET CLEANING

(Pounds of PM10/Mile Traveled)

Road Type	G
Local Streets	0.018
Collector Streets	0.013
Major Streets/Highways	0.0064
Freeways	0.00065

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TABLE A9 - 9 - C

ESTIMATING EMISSIONS FROM TRUCK TRAVEL ON PAVED ROADS

$E = V \times F$

Where,

E = Emissions for Truck Travel on paved roads and paved parking lots without street cleaning.

V = Vehicle miles Traveled (*See Table A9 - 9 - A to eminate VMT associated with trucks.*)

F = Emission Factor for Truck Travel on paved roads and paved parking lots without street cleaning.

$0.77 \times (G \times 0.35])^{0.3}$ in pounds per miles traveled

Where,

G = Surface silt loading in grams/square meter (*Please see Table A9 - 9 - C - 1 for the type of roads and the silt loading*)

TABLE A9 - 9 - C - 1

PAVED ROAD SILT LOADING (G) AND ROAD TYPE - TRUCK TRAVEL

(G = Grams per square meter of the road)

Road Type	G
Construction sites (without cleaning)	300.0
Construction sites (with cleaning)	1.4
Industrial Sites (in operation)	100.0
Local Streets	1.4
Collector Streets	0.9
Major Streets/Highways	0.4
Freeway	0.022

EXAMPLES

Examples of Estimating Emission Factor (F) for Truck on Local Road

(F = pounds per vehicle miles traveled)

Truck on	F
Example 1 Local Road	$F = 0.77 \times ([(G = 1.4) \times 0.35]^{0.3})$ = 0.62
Example 2 Construction Site (without cleaning)	$F = 0.77 \times ([(G = 300) \times 0.35]^{0.3})$ = 3.11

AR0073042

TABLE A9 - 9 - D

ESTIMATING EMISSIONS FROM VEHICLE TRAVEL ON UNPAVED ROADS

$E = V \times F$

Where,

E^* = Emissions for Vehicle Travel on unpaved roads and unpaved parking lots.

V = Vehicle Miles Traveled *(See Table A9 - 9 - A to estimate VMT associated with passenger vehicles.)*

F = Emission Factor for Vehicle Travel on unpaved roads and unpaved parking lots.

$2.1 \times (G/12) \times (H/30) \times \{(I/3)^{0.7}\} \times \{(J/4)^{0.5}\} \times \{(365 - K)/365\}$ in pounds per miles traveled

Where,

G = Surface silt loading in percent *(Please see Table A9 - 9 - D - 1 for the type of road and the silt loading for that road)*

H = Mean vehicle speed in miles per hour *(Please see Table A9 - 9 - D - 2 for the speed assumptions)*

I = Mean vehicle weight in tons *(Please see Table A9 - 9 - D - 3 for mean vehicle weight corresponding to the mean number of wheels)*

J = Mean Number of wheels on vehicles *(Please see Table A9 - 9 - D - 3 for number of wheels corresponding to the mean vehicle weight)*

K = Mean number of days per year with at least 0.01 inches of precipitation *(Please see Table A9 - 9 - D - 4 for number of days of precipitation for the project area)*

TABLE A9 - 9 - D - 1

UNPAVED ROAD SILT LOADING AND ROAD TYPE (G = Percent)

Road Type	G
Gravel Road	4.0
Sand/Gravel Plant Road	6.0
Mining Haul Road	8.0
Crushed Limestone Road	10.0
Mountain Roads	12.0
Stone Quarrying Plant Roads	14.0
Farm Road	16.0
Copper Smelting Plant	18.0
Coal Mine Haul Road (freshly Scraped)	24.0
City and County Road	28.0

TABLE A9 - 9 - D - 2

MEAN VEHICLE SPEEDS (H = Miles per Hour)

Scenario Description	H
Recommended Maximum	15.0
Maximum Allowable	25.0
Worst-case	35.0

AR0073043

TABLE A9 - 9 - D - 3

MEAN NUMBER OF WHEELS (I) AND MEAN NUMBER WEIGHT (J) OF THE VEHICLE

Vehicle Type	Weight of the Vehicle (I)	Number of Wheels (J)
Autos, Light Duty Pick-up Trucks, & Vans	2,000 to 6,000	4
Light Duty Vans and Utility Vehicles	6,001 to 10,000	4 to 6
Motor Homes, Medium Duty Flat-bed Trucks and Multi-stop Trucks	10,001 to 16,000	6 to 8
Heavy-Duty Flat-bed Trucks and Delivery Vans	16,001 to 19,500	6 to 10
Light/Heavy duty garbage dump and ready mix Concrete Trucks, Heavy/Heavy duty fuel and Waste Dump Trucks	19,501 to 33,000	10
Tractor Trailer Trucks	33,001 or More	18 to 30

TABLE A9 - 9 - D - 4

PRECIPITATION CONDITIONS AND NUMBER OF DAYS
(K = Number of Days)

Number of Days	K
Worst-case desert/drought	2.0
Worst-case SCAB/drought	10.0
Average year for desert	18.0
Average year for SCAB	34.0
Average year for mountains	40.0

EXAMPLES

Examples of Estimating Emission Factor (F) for Truck on Local Road
(F = pounds per vehicle miles traveled)

Example 1 **Truck to Pick-up Goods in Drought Conditions**

(F = 2.1 x [(G=28)/12] x [(H=35)/30] x [(I=(10,000 lbs/2,000))/3)^0.7] x [(J=6/4)^0.5] x [(365 - (K=10)}/365]) = 9.73

Example 2 **Truck on Haul Road in Drought Conditions**

(F = 2.1 x [(G=28)/12] x [(H=12)/30] x [(I=(70,000 lbs/2,000))/3)^0.7] x [(J=18/4)^0.5] x [{365-(K=2)}/365]) = 23.08

AR0073044

TABLE A9 - 9 - E

ESTIMATING EMISSIONS FROM WIND EROSION OF STORAGE PILES
(Pounds/Day/Acre)

$E = (1.7 \times [G/1.5] \times [365-H]/235] \times [I/15]) \times J$

Where,

- E = PM10 Emissions from wind erosion of storage piles in pounds per day per acre
- G = Silt content of aggregate in percent (*Please see Table A9 - 9 - E - 1 for the type of aggregate in storage pile and silt content.*)
- H = Number of Days with $\geq$ 0.25 mm (0.01 inch) of precipitation per year (*Please see Table A9 - 9 - E - 2 for number of days in the project area.*)
- I = Percentage of time that the unobstructed wind speed exceeds 12 miles per hour or 5.4 meters/second at mean pile height.
- J = Fraction of Total Suspended Particulates which is estimated at 0.5.

TABLE A9 - 9 - E - 1

SILT CONTENT AND TYPES OF AGGREGATES IN ACTIVE STORAGE PILES
(G = Silt Content of Aggregate in Percent)

Types of Aggregates	G
Limestones	0.5
Sinter	0.7
Crushed Limestones	1.5
Slag and Coke	5.0
Coal	6.0
Overburden	7.5
Blended Ore and Dirt	15.0
Fine Dust	18.0

TABLE A9 - 9 - E - 2

PRECIPITATION CONDITIONS AND NUMBER OF DAYS
(H = Number of Days)

Number of Days	H
Worst-case desert/drought	2.0
Worst-case SCAB/drought	10.0
Average year for desert	18.0
Average year for SCAB	34.0
Average year for mountains	40.0

EXAMPLE

Examples of Estimating Emissions (E) from a Storage Pile
(E = pounds per day per acre)

(E = {1.7 x [(G = 15% = 0.15)/1.5] x [(365 - (H = 10)]/235]) x [(I = 100 % = 100.0)/15]} x [J = 0.5] = 0.86)

AR0073045

TABLE A9 - 9 - F

ESTIMATING EMISSIONS FROM DIRT PUSHING OR BULLDOZING OPERATIONS
(Pounds/Day)

$E = \{[0.45 \times (\{[G]^{1.5}\}/\{[H]^{1.4}\})] \times I\} \times J$

Where,

- E = PM10 Emissions from Dirt Pushing (Bulldozer Type Operations)
- G = Silt content of aggregate in percent (*Please see Table A9 - 9 - F - 1 for the type of aggregate in storage pile and the silt content.*)
- H = Moisture Content of the surface material (*Please see Table A9 - 9 - F - 2 for the moisture content and soil condition.*)
- I = 2.2046; a conversion Factor to convert kilograms per hour to pounds per hour.
- J = Hours of Pushing Operation (*User provides the value for J; See environmental documents.*)

TABLE A9 - 9 - F - 1

SILT CONTENT AND TYPES OF AGGREGATES IN ACTIVE STORAGE PILES
(G = Percent)

Types of Dirt	G
Limestones	0.5
Sinter	0.7
Crushed Limestones	1.5
Slag and Coke	5.0
Coal	6.0
Overburden	7.5
Blended Ore and Dirt	15.0
Fine Dust	18.0

TABLE A9 - 9 - F - 2

DIRT CONDITIONS AND MOISTURE CONTENT
(H = Percent)

Dirt Conditions	H
Dry	2.0
Moist	15.0
Wet	50.0

EXAMPLE

Examples of Estimating Emissions (E) for Dirt Pushing Operations
(E = pounds per day)

$(E = [(\{0.45 \times [(G = 15\ \% = 15.0)^{1.5}]\}/\{[(H = 2.0\ \% = 2.0)^{1.4}]\}) \times I = 2.2046] \times [J = 4\ hours] = 87.36)$

AR0073046

TABLE 9 - 9 - G

ESTIMATING EMISSIONS FROM DIRT PILING OR MATERIAL HANDLING
(Pounds/Day)

$E = [0.00112 \times (([G/5]^{1.3})/([H/2]^{1.4}))] \times [I/J]$

Where,

- E = PM10 Emissions from dirt piling or material handling to form a storage pile on ground
- G = Mean Wind speed in miles per hour (*user should provide this information in environmental documents, or use 12 miles per hour for daily maximum and 25 miles per hour for worst-case scenario.*)
- H = Moisture Content of the surface material (*Please see Table 9 - 9 - G - 1 for the moisture content and soil condition.*)
- I = Pounds of dirt handled or stocked in a storage pile per day (*for truck piling please see Table 9 - 9 - G - 2 for guidelines.*)
- J = 2,000; a conversion factor to convert pounds of dirt to tons of dirt

TABLE 9 - 9 - G - 1

DIRT CONDITIONS AND MOISTURE CONTENT
(H = Percent)

Dirt Conditions	H
Dry	2.0
Moist	15.0
Wet	50.0

TABLE 9 - 9 - G - 2

MAXIMUM DIRT WEIGHT (I) THAT CAN BE STORED IN A TRUCK
(User should provide the value for H. For truck piling use the following for guidelines)

Vehicle Type	Maximum Weight of the Dirt (I)
Light Duty Pick-up Trucks	(2,000 to 6,000) -* (Wt.** of Empty Truck)
Utility Vehicles	(6,001 to 10,000) - (Wt. of Empty Truck)
Medium Duty Flat-bed Trucks and Multi-stop Trucks	(10,001 to 16,000) - (Wt. of Empty Truck)
Heavy-Duty Flat-bed Trucks	(16,001 to 19,500) - (Wt. of Empty Truck)
Light/Heavy duty garbage dump and ready mix Concrete Trucks	(19,5001 to 33,000) - (Wt. of Empty Truck)
Heavy/Heavy duty waste dump trucks, Tractor Trailer Trucks	(33,001 or More) - (Wt. of Empty Truck)

* "-" = Minus sign or subtraction sign ** "Wt." = Weight

EXAMPLE

Example of Estimating Emissions (E) for Dirt Pushing Operations
(E = pounds per day)

$(E = 0.00112 \times (([(G=25\ mph)/5]^{1.3})/([(H=2.0\ \% \div 0.02)/2]^{1.4})) \times (I=[10,000\ lbs/J = 2,000]\ tons) = 28.63)$

AR0073047

TABLE A9 - 9 - H

ESTIMATING EMISSIONS FROM BUILDING WRECKING
(Pounds/Day)

$E = 0.00042^{*} \times J$

Where,
J = Building volume handled per day (*Use environmental documents for the following information*); or
$J = (N \times O \times P)/Q$

where,

N = Width of building in feet
O = Length of building in feet
*P = Height of building in feet
Q = Number of days required to demolish a building

* = Pounds of PM10 Per Cubic Feet

AR0073048

INFORMATION
FOR
ASBESTOS EMISSIONS DURING
DEMOLITION AND RENOVATION OF PROJECT

AR0073049

TABLE A9 - 10

ESTIMATING ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION ACTIVITIES
(POUNDS PER DAY)

SOURCE TYPE	SOURCE-RELATED ESTIMATIONS	MULTIPLY BY	EMISSION FACTORS (F)	REFERENCE TO TABLES**	EMISSIONS (E) (Pounds/Day)
Asbestos Removal or Asbestos in Structural Debris	_____ Ft^3 of Building Disturbed/Day	X	_____, or (0.00006 lbs/ft^3)*	Table 9 - 10 - A	_____

* Default value

Example: Estimated Value _____, or Estimate Emission Factors Using Project Specific Data and Appropriate Tables

Default Value — Use this value instead of estimating project specific emission factor

** Tables with examples to estimate emissions and project specific emission factors

AR0073050

TABLE A9 - 10 - A

ESTIMATING EMISSIONS FROM DRY REMOVAL OF ASBESTOS

(Emissions associated with wet removal of asbestos should be included as emissions after implementation of mitigation measure. See Table 11 - 10 Appendix 11.)

(Pounds/Day)

$$E = \{[(F/G) \times (H/I) \times (J/K) \times (L/M) \times (N/O) \times (P)]/[(Q) \times (R) \times (S/T) \times (N/O)]\}$$

Where,

E = Asbestos emissions during the dry asbestos removal activities

Ft^3 = Cubic feet

F = Typical number of fibers counted per cubic meter of work area
(5×10^5 to 80×10^5 fibers per cubic meter is the range of asbestos concentration in a typical work area.)

G = 35.315 cubic feet, a conversion factor to convert 1 cubic meter into cubic feet

H = 1.0 nanograms, a weight of 30 asbestos fibers

I = 30.0, number of fibers weigh equivalent to 1 nanogram

J = 2.2046 pounds, a conversion factor to convert 1 kilogram into pounds

K = 10^{12} nanograms, a conversion factor to convert 1 kilogram into nanograms

L = Volume of air released during M hours to the atmosphere during air changes
Usually, equals to = U x V x W x X

Where,

U = Width of a room from which air escapes or is released

V = Length of a room from which air escapes or is released

W = Height of a room from which air escapes or is released

X = number of rooms from which air escapes or is released

M = Rate in Hours by which (L) amount of air is released to the atmosphere

N = 0.0283 cubic meters, a conversion factor to convert 1 cubic foot to cubic meters

O = 1 cubic foot

P = Total number of hours the air is released to the atmosphere

Q = V/r, where,

V = Volume of asbestos bearing surfaces, i.e.,

For Ceiling a x b x c x r

For Pipelines $\{(a \times c \times pi \times [(OD)^2/4]) - (a \times c \times pi \times [(ID)^2/4])\}$

For rectangular or square object — For circular surface

a = Width of the asbestos bearing object — = Length of asbestos bearing object

b = Length of the asbestos bearing object — = Square of outer and/or inner diameter

c = Number of asbestos bearing objects — = Number of asbestos bearing objects

r = Thickness of in-place asbestos in same unit (Foot) as a, b, OD and ID

pi = 3.14159265

R = Thickness of in-place asbestos in inches; — OD = Outer diameter of the pipeline

S = 0.083 feet, a conversion factor to convert 1 inch — ID = Inner diameter of the pipeline = [OD-(2r)]

T = 1.0 inch

AR0073051

EXAMPLE

Example of Estimating Emissions from Dry Removal of Asbestos From a Ceiling

Source: SCAQMD's Rule 1403 staff report

F = 1.5×10^6 fibers per cubic meter of work area
(5×10^6 to 80×10^6 fibers per cubic meter is the range of asbestos concentration in a typical work area.

L = 2,250 Ft^3 of air released during M hours to the atmosphere (U = 15 feet, V = 15 feet, W = 10 feet, & X = 1)

M = 1 Hour (rate of one change per hour)

P = 8 Hours (for 8 hour shift with the rate of one change per hour)

O = 225 square feet of asbestos bearing surface (a = 15, b = 15, c = 1) for rectangular objects; or *[For pipelines (a x c) x (pi x {[(b = outer diameter)^2]/4.0}) - (pi x {[(b = inner diameter)^2]/4.0})]*

R = 0.5 inches [For Pipelines *(a x c) x (pi x {[(b = outer diameter at the asbestos thickness)^2]/4.0}) - (pi x {[(b = inner diameter at the asbestos thickness)^2]/4.0})*]

E = {{[1.5x10^6/35.315]x(1/30)x(2.2046/10^{12})x(2250/1)x(0.0283/1)x(8)}/{(225)x(0.5)x(0.083/1) x (0.0283/1)}}

= 0.00006 pounds of asbestos per cubic feet of structure demolished or renovated

AR0073052

TABLE A9 - 10 - A - 1

INPUT ASSUMPTIONS TO DETERMINE ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION ACTIVITIES AT SINGLE-UNIT DWELLING

BLDG	LOCATION OF ASBESTOS	ASBESTOS CONTENT			
		In Place Amount	Thickness	ASBESTOS REMOVED Demolition	Renovation
Model A	**Furnace**	**72 Ft²**	**3.0 inch/T**	**18.0 Ft³**	**18.0 Ft³**
	Ducts 5.0 inch	60 Ft	2.0 inch/P	18.0 Ft³	- -
	Waste Generated	4.0 Yard³	3 Yard³		
Model B	Furnace	**72 Ft²**	**3.0 inch/T**	**18.0 Ft³**	**18.0 Ft³**
	Ducts 5.0 inch	60 Ft	2.0 inch/P	18.0 Ft³	18.0 Ft³
	Walls (Interior)	112 Ft²	0.6 inch/B	6.0 Ft³	- -
	Waste Generated		5.0 Yard³	4 Yard³	
Model C	Furnace	**72 Ft²**	**3.0 inch/T**	**18.0 Ft³**	- -
	Ducts 5.0 inch	60 Ft	2.0 inch/P	18.0 Ft³	- -
	Walls (Exterior)	1,184 Ft²	0.3 inch/A-C Shingles	25.0 Ft³	- -
	Ceiling	1,288 Ft²	0.5 Inch/S	54.0 Ft³	54.0 Ft³
	Waste Generated			12.0 Yard³	5 Yard³

TABLE A9 - 10 - A - 2

INPUT ASSUMPTIONS TO DETERMINE ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION ACTIVITIES AT THESE STRUCTURES

BLDG	LOCATION OF ASBESTOS	ASBESTOS CONTENT			
		In Place Amount	Thickness	ASBESTOS REMOVED Demolition	Renovation
Small School	**Boiler**	**100 Ft²**	**2.5 inch/T**	**21.0 Ft³**	- -
Size	Steam Piping	30.7 Ft³	- -	- -	- -
43,200 Ft²	Exposed 2.5 inch	100 Ft	3.0 inch/P	- -	- -
	Concealed 0.75 inch	1500 Ft	1.0 inch/P	- -	- -
	Hot Water Piping			30.7 Ft³	
	Concealed 2.0 inch	200 Ft	0.25 inch/C	- -	- -
	Concealed 1.0 inch	350 Ft	0.25 inch/C	- -	- -
	Ceiling	43,200 Ft²	0.5 inch/S	1,800 Ft³	1,800 Ft³
	Waste Generated			207 Yard³	200 Yard³

Ft	Feet
Ft²	Square Feet
Ft³	Cubic Feet
T	Troweled-on Asbestos Material
P	Premolded Asbestos Material
B	Wallboard Asbestos Material
C	Corrugated Paper Asbestos Material
A-C	A/C, i.e., Asbestos/Cement Material
S	Sprayed-on Asbestos Material

AR0073053

TABLE A9 - 10 - A - 2 (Cont.)

INPUT ASSUMPTIONS TO DETERMINE ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION ACTIVITIES AT VARIOUS STRUCTURES

BLDG	LOCATION OF ASBESTOS		ASBESTOS CONTENT		
		In Place Amount	Thickness	ASBESTOS REMOVED Demolition	Renovation
Medium School	Boiler	450 Ft^2	2.0 inch/P	98.0 Ft^3	- -
Size	Steam Piping			63.0 Ft^3	- -
122,800 Ft^2	Exposed 3.0 inch	65 Ft	1.0 inch/P	- -	- -
	Concealed 2.0 inch	165 Ft	2.5 inch/P	- -	- -
	Concealed 3.0 inch	1,800 Ft	2.5 inch/P	- -	- -
	Hot Water Piping				- -
	Concealed 2.0 inch	360 Ft	0.25 inch/C	- -	- -
	Concealed 1.0 inch	45 Ft	0.25 inch/C	- -	- -
	Structural Steel			8,295 Ft^3	- -
	Columns 10.0 inch	1,600 Ft	2.5 inch/S	- -	- -
	Beams 6.0 inch	22,500 Ft	1.5 inch/S	- -	
	Ceiling	103,000 Ft^2	0.5 inch/S	4,629 Ft^3	4,631 Ft^3
Cafeteria	Boiler	45 Ft^2	2.0 inch/P	- -	
	Steam Piping				- -
	Exposed 2.5 inch	36 Ft	1.0 inch/P	- -	- -
	Concealed 0.75 inch	135 Ft	1.0 inch/P	- -	- -
	Ceiling	8,100 Ft^2	0.5 inch/S		
Gymnasium					
	Furnace	90 Ft^2	2.0 inch/T		- -
	Hot Water Pipes 2.0 inch		135 Ft	0.25 inch/C	- -
	Airducts	495 Ft^2	0.25 inch/C	- -	
	Beams 18.0 inch	630 Ft	1.5 inch/S	- -	
	Waste Generated			1,457 $Yard^3$	514 $Yard^3$
Large School	Boiler (2)	1,000 Ft^2	3.0 inch/T	312.0 Ft^3	- -
Size	Steam Piping			320.0 Ft^3	- -
271,000 Ft^2	Exposed 3.0 inch	140 Ft	1.0 inch/P	- -	- -
	Concealed 2.0 inch	1,200 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	4,000 Ft	1.0 inch/P	- -	- -
	Hot Water Piping- -				
	Concealed 2.0 inch	800 Ft	0.25 inch/C	- -	- -
	Concealed 1.0 inch	100 Ft	0.25 inch/C	- -	- -
	Structural Steel			18,482 Ft^3	- -
	Columns 10.0 inch	3,500 Ft	2.5 inch/S	- -	- -
	Beams 6.0 inch	50,000 Ft	1.5 inch/S	- -	- -
	Ceiling	227,0000 Ft^2	0.5 inch/S	10,208 Ft^3	10,206 Ft^3
Cafeteria	Boiler	100 Ft^2	2.5 inch/P		- -
	Steam Piping				- -
	Exposed 2.0 inch	80 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	300 Ft	1.0 inch/P	- -	- -
	Ceiling	18,000 Ft^2	0.5 inch/S		
Gymnasium					
	Furnace	200 Ft^2	2.5 inch/T		- -
	Hot Water Pipes 2.0 inch		300 Ft	0.25 inch/C	- -
	Airducts	1,100 Ft^2	0.25 inch/C		- -
	Beams 18.0 inch	1,400 Ft	1.5 inch/S		- -
	Waste Generated			3,259 $Yard^3$	1,135 $Yard^3$

AR0073054

TABLE A9 - 10 - A - 2 (Cont.)

INPUT ASSUMPTIONS TO DETERMINE ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION ACTIVITIES AT VARIOUS STRUCTURES

BLDG	LOCATION OF ASBESTOS	ASBESTOS CONTENT			
		In Place Amount	Thickness	ASBESTOS REMOVED Demolition	Renovation
Small Office Building	**Boiler**	**100 Ft²**	**3.0 inch/T**	**25.0 Ft³**	--
	Boiler Stack	40 Ft²	1.5 inch/P	5.0 Ft³	--
Size	Steam Piping			15.3 Ft³	--
7,200 Ft²	Exposed 2.0 inch	70 Ft	1.0 inch/P	--	--
	Concealed 1.0 inch	250 Ft	1.0 inch/P	--	--
	Hot Water Piping				--
	Concealed 1.0 inch	100 Ft	1.0 inch/C	--	--
	Ceiling	7,200 Ft²	0.5 inch/S	300.0 Ft³	300.0 Ft³
	Waste Generated			38.0 Yard³	34.0 Yard³
Medium Office Building	**Boiler**	350 Ft²	3.0 inch/T	75.0 Ft³	--
Size	Steam Piping			66.2 Ft³	--
36,000 Ft²	Exposed 3.0 inch	120.0 Ft	1.0 inch/P	--	--
	Concealed 2.0 inch	100 Ft	1.0 inch/P	--	--
	Concealed 1.0 inch	450 Ft	1.0 inch/P	--	--
	Hot Water Piping				--
	Concealed 2.0 inch	150 Ft	1.0 inch/C	--	--
	Concealed 1.0 inch	450 Ft	1.0 inch/C	0.0	--
	Ceiling	36,000 Ft²	1.0 inch/S	3000.0 Ft³	3000.0 Ft³
	Waste Generated			349 Yard³	334 Yard³
Large Office Building	**Boilers (2)**	**800 Ft²**	**3.0 inch/T**	**200.0 Ft³**	
	Steam Piping			434 Ft³	
Size	Exposed 3.0 inch	360 Ft	1.0 inch/P	--	--
288,000 Ft²	Concealed 2.0 inch	650 Ft	1.0 inch/P	--	--
	Concealed 1.0 inch	3,300 Ft	1.0 inch/P	--	--
	Hot Water Piping				--
	Exposed 2.0 inch	1,100 Ft	1.0 inch/P	--	--
	Concealed 1.0 inch	3,300 Ft	1.0 inch/P	--	--
	Ceiling	38,000 Ft²	0.5 inch/S	24,000 Ft³	24,000 Ft³
	Structural Steel	--	--	21,500 Ft³	--
	Columns 12.0 inch	3,900 Ft	3.0 inch/S	--	--
	Beams 6.0 inch	58,000 Ft	1.5 inch/S	--	--
	Ceiling	288,000 Ft²	1.0 inch/S	24,000 Ft³	24,000 Ft³
	Waste Generated			5,128 Yard³	2,666 Yard³

AR0073055

TABLE A9 - 10 - A - 2 (Cont.)

INPUT ASSUMPTIONS TO DETERMINE ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION ACTIVITIES AT VARIOUS STRUCTURES

BLDG	LOCATION OF ASBESTOS	ASBESTOS CONTENT			
		In Place Amount	Thickness	ASBESTOS REMOVED Demolition	Renovation
Small Hotel	**Boiler**	**440 Ft²**	**3.0 inch/T**	**110 Ft³**	- -
Size:	Steam Piping			185.0 Ft³	10 Ft³
69,320 Ft²	Exposed 3.0 inch	120 Ft	1.0 inch/P	- -	- -
	Concealed 2.0 inch	170 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	900 Ft	1.0 inch/P	- -	- -
	Hot Water Piping				- -
	Concealed 2.0 inch	290 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	900 Ft	1.0 inch/P	- -	- -
	Structural Steel	- -	- -	5,542 Ft³	- -
	Columns 10.0 inch	- -	- -	- -	- -
	Beams 6.0 inch	- -	- -	- -	- -
	Ceiling	2,400 Ft²	1.0 inch/S	200.0 Ft³	200 Ft³
	Waste Generated			671 Yard³	24 Yard³
Large Hotel	**Boilers (2)**	**860 Ft²**	**3.0 inch/T**	**215.0 Ft³**	- -
Size	Steam Piping			348.0 Ft³	30.0 Ft³
221,184 Ft²	Exposed 3.0 inch	360 Ft	1.0 inch/P	- -	- -
	Concealed 2.0 inch	500 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	2,600 Ft	1.0 inch/P	- -	- -
	Hot Water Piping				- -
	Concealed 2.0 inch	860 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	2,600 Ft	1.0 inch/P	- -	- -
	Structural Steel			16,625 Ft³	- -
	Columns 12.0 inch	3,000 Ft	3.0 inch/T	- -	- -
	Beams 6.0 inch	45,000 Ft	1.5 inch/T	- -	- -
	Ceiling	3,750 Ft²	1.0 inch/S	308.0 Ft³	313 Ft³
	Waste Generated			1,487 Yard³	39 Yard³
Small Store	**Boiler**	**100 Ft²**	**3.0 inch/T**	**25 Ft³**	**25 Ft³**
Size	Boiler Stack	40 Ft²	1.5 inch/P	5 Ft³	3 Ft³
	Steam Piping			11.0 Ft³	3 Ft³
2,800 Ft²	Exposed 2.0 inch	70 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	100 Ft	1.0 inch/P	- -	- -
	Hot Water Piping				- -
	Concealed 1.0 inch	40 Ft	1.0 inch/P	- -	- -
	Waste Generated			4.0 Yard³	4 Yard³
Medicin Store	**Boiler**	**100 Ft²**	**3.0 inch/T**	**25 Ft³**	**25 Ft³**
Size	Boiler Stack	60 Ft²	1.5 inch/P	7.5 Ft³	- -
	Steam Piping			36.0 Ft³	10.6 Ft³
65,700m Ft²	Exposed 2.0 inch	190 Ft	2.0 inch/P	- -	- -
	Concealed 3.0 inch	600 Ft	2.0 inch/P	- -	- -
	Waste Generated			8.0 Yard³	4 Yard³

AR0073056

TABLE A9 - 10 - A - 2 (Cont.)

INPUT ASSUMPTIONS TO DETERMINE ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION ACTIVITIES AT VARIOUS STRUCTURES

BLDG	LOCATION OF ASBESTOS	ASBESTOS CONTENT			
		In Place Amount	Thickness	ASBESTOS REMOVED Demolition	Renovation
Small Hospital	**Boiler**	**100 Ft^2**	**3.0 inch/T**	**25.0 Ft^3**	**25.0 Ft^3**
	Boiler Stack	40 Ft^2	1.5 inch/P	5.0 Ft^3	5.0 Ft^3
Size	Steam Piping			63.0 Ft^3	- -
14,400 Ft^2	Exposed 2.0 inch	70 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	420 Ft	1.0 inch/P	- -	- -
	Hot Water Piping				- -
	Concealed 1.0 inch	600 Ft	1.0 inch/C	49.1 Ft^3	3.0 Ft^3
	Ceiling	800 Ft^2	0.5 inch/S	33.3 Ft^3	
	Waste Generated			207 Yard^3	200 Yard^3
Medium Hospital	**Boiler (2)**	**450 Ft^2**	**3.0 inch/T**	**112.0 Ft^3**	**112.0 Ft^3**
	Stacks (2)	100 Ft^2	3.0 inch/P	8.3 Ft^3	8.3 Ft^3
Size	Steam Piping			419.0 Ft^3	419.0 Ft^3
60,000 Ft^2	Exposed 3.0 inch	60 Ft	3.0 inch/P	- -	- -
	Concealed 2.0 inch	1,500 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	2,500 Ft	1.0 inch/P	- -	- -
	Hot Water Piping				- -
	Concealed 2.0 inch	1,500 Ft	1.0 inch/C	- -	- -
	Concealed 1.0 inch	2,500 Ft	1.0 inch/C	- -	- -
	Structural Steel			11,380 Ft^3	- -
	Columns 10.0 inch	9,400 Ft	2.5 inch/S	- -	- -
	Beams 6.0 inch	14,400 Ft	1.5 inch/S	- -	
	Waste Generated			1,324 Yard^3	14 Yard^3
Large Hospital	**Boilers (2)**	**900 Ft^2**	**3.0 inch/T**	**225.0 Ft^3**	**225.0 Ft^3**
	Stacks (2)	225 Ft^2	1.0 inch/P	18.8 Ft^3	18.8 Ft^3
Size	Steam Piping			3,015 Ft^3	26.2 Ft^3
316,000 Ft^2	Exposed 3.0 inch	400 Ft	1.0 inch/P	- -	- -
	Concealed 2.0 inch	6,580 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	24,000 Ft	1.0 inch/P	- -	- -
	Hot Water Piping				- -
	Exposed 3.0 inch	400 Ft	1.0 inch/P	- -	- -
	Concealed 2.0 inch	6,580 Ft	1.0 inch/P	- -	- -
	Concealed 1.0 inch	24,00 Ft	1.0 inch/P	- -	- -
	Ceiling	38,000 Ft^2	0.5 inch/S	1,583 Ft^3	
	Waste Generated			538 Yard^3	30 Yard^3
Small Industry	**Boiler**	**1500 Ft^2**	**2.5.0 inch/T**	**312 Ft^3**	**312 Ft^3**
Size	Steam Piping	500 ft	1.2 inch/P	78.5 Ft^3	1.9 Ft^3
	Boiler Exhaust Duct	214 ft^2	0.5 inch/T	44 Yard^3	8.9 Ft
	Waste Generated			44 Yard^3	37 Yard^3
Medium Industry	**Boilers**	**10,000 Ft^2**	**2.5 inch/T**	**215.0 Ft^3**	**2,083 Ft^2**
Size	12 inch Steam Piping	1,500 Ft	1.2 inch/P	471.2 Ft^3	6.9 Ft^3
	Boiler Exhaust Duct	680 Ft^2	0.5 inch/T	28.3 Ft^3	28.3 Ft^3
	Waste Generated			287.0 Yard^3	236.0 Yard^3

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Table A9 - 10 - A - 3

EXAMPLES OF INDUSTRIES WHERE ASBESTOS IS FOUND IN MANUFACTURING PROCESSES

Paper Manufacturing
(Table 5-64, Page 5-55)*

Friction Material Manufacturing
(Table 5-65, Page 5-56)*

Vinyl/Asbestos Floor Tile Manufacturing
(Table 5-67, Page 5-60)*

Asbestos-Reinforced Plastics
(Table 5-68, Page 5-61)*

Phenolic Modeling Compounds Manufacturing
(Table 5-68, Page 5-61)*

Asbestos/Cement Products Manufacturing
(Table 5-66, Page 5-58)*

Brake-Shoe Rebuilding Plant
(Table 5-74, Page 5-66)*

Shotgun Shell Manufacturing
Asbestos Board Fabrication
(Table 5-76, Page 5-68)*

Coatings And Sealants Manufacturing
(Table 5-69, Page 5-63)*

Gaskets and Packing Manufacturing
(Table 5-70, Page 5-63)*

Chlorine Manufacturing
(Table 5-72, Page 5-64)*

Asphalt Concrete Manufacturing
(Table 5-73, Page 5-66)*

Asbestos Milling
(Table 5-63, Page 5-52)*

Asbestos Textiles Manufacturing
(Table 5-71, Page 5-64)*

Prefabricator of A/C Building Products
(Table 5-75, Page 5-68)*

Asbestos Drilling Fluids (Petroleum Industry)

* Use These Tables For Model Parameters. These Tables are provided in EPA Report Titled, National Emission Standards For Asbestos -- Background Information For Proposed Standards, 1987

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INFORMATION
FOR
ENERGY CONSUMPTION IN VARIOUS STRUCTURES

AR0073059

TABLE A9 - 11

EMISSIONS FROM ELECTRICITY CONSUMPTION BY LAND USES
(Pounds Per Day)

$E = (\{F \times G\}/365)/1000) \times H$

Where,

E = Emissions of criteria pollutants in pounds per day due to electricity consumption by land uses

F = Gross square foot (*see Environmental Document*) of each type of land use except for residential uses; *or*
= Number of units for residential land use (*see Environmental Document*)

G = Electricity usage rate to determine annual usage (*see Table A9 - 11 - A*)
Varies according to the type of land use (*see Environmental Document*)

H = Emission factors in pounds per megawatt-hours (*see Table A9 - 11 - B*)
Varies according to the type of criteria pollutant

TABLE A9 - 11 - A

ELECTRICITY USAGE RATE (G)
(To Determine Annual Consumption, Kilowatt-hours)

Land Use Type	Unit Type	Usage Rate Average for Southern California Edison and Los Angeles Dept. of Water and Power
Residential	Kilowatt-hour/Unit/Year	5,626.50
Food Store	Kilowatt-hour/Square feet/Year	53.30
Restaurant	Kilowatt-hour/Square feet/Year	47.45
Hospitals	Kilowatt-hour/Square feet/Year	21.70
Retail	Kilowatt-hour/Square feet/Year	13.55
College/University	Kilowatt-hour/Square feet/Year	11.55
High School	Kilowatt-hour/Square feet/Year	10.50
Elementary School	Kilowatt-hour/Square feet/Year	5.90
Office	Kilowatt-hour/Square feet/Year	12.95
Hotel/Motel	Kilowatt-hour/Square feet/Year	9.95
Warehouse	Kilowatt-hour/Square feet/Year	4.35
Miscellaneous	Kilowatt-hour/Square feet/Year	10.50

TABLE A9 - 11 - B

EMISSION FACTORS (H) FOR EACH CRITERIA POLLUTANT FROM CONSUMPTION OF ELECTRICITY
(Pounds Per Megawatt-Hours)

Pollutant Type	CO	ROC	NOx	SOx	PM10
	0.20	0.01	1.15	0.12	0.04

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TABLE A9 - 11 - C

ESTIMATING REMAINING EMISSIONS OF EACH POLLUTANT AFTER REMOVING CONTRIBUTED FRACTIONS BY EACH SOURCE CATEGORY

$N = [(E - (O_1 + O_2 + O_3 + \ldots\ldots O_n)$

Where,

N = Remaining Non-mitigated Electricity consumption emissions after the removal of all source categories for which mitigation measures are included.

E = Total Non-mitigated Electricity Consumption Emissions of a Criteria Pollutant. (*See above methodology*)

$O_1, O_2, O_3, \ldots\ldots O_n$ = Emissions of a Criteria Pollutant Associated with Each Source Category for which mitigation measures are included. (See Table A9 - 11 - D)

TABLE A9 - 11 - D

ESTIMATING PRE-MITIGATION EMISSIONS OF EACH POLLUTANT FOR EACH SOURCE CATEGORY

$O_1, O_2, O_3 \ldots O_n = [(E_R \times I_1)]$, *OR* $[(E_R \times I_2)]$, *OR* $[(E_R \times I_3)]$, *OR*$\ldots\ldots$ $[(E_R \times I_n)]$

Where,

$O_1, O_2, O_3 \ldots O_n$ = Source Category's Market Segment of Total Non-mitigated Emissions
(See Table A9 - 11 - D to determine which source category the mitigation measure is going to impact to obtain emission reductions. Use respective percent value to extract the fraction of non-mitigated emissions associated with that source category.)

E = Total Non-mitigated Electricity Consumption Emissions of Each Pollutant.
(Utilizing Table A9 - 11 - A and Table A9 - 11 - B methodologies)

$I_1, I_2, I_3 \ldots I_n$ = Percent of Total Non-mitigated Emissions For Each Source Category
(See Table A9 - 11 - E to determine which source category the mitigation measure is going to impact to obtain emission reductions. Use respective percent value (fraction) for I to extract the fraction of non-mitigated emissions associated with that source category.)

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TABLE A9 - 11 - E

SOURCE CATEGORIES (I) OF PRE-MITIGATION ENERGY USE IN RESIDENTIAL, COMMERCIAL AND INDUSTRIAL SECTORS

(Committee Draft Energy Efficiency Report, 1990, California Energy Commission)

(Percent of the Total Pre-mitigation Energy Use Per Project)

Source Category	Electricity (Percent)	Source Category	Electricity (Percent)
Residential		**Commercial**	
Lighting	13.70	Indoor lighting	38.24
Cooking	4.50	Outdoor lighting	4.55
Refrigeration	20.40	Refrigeration	11.36
Freezer	3.90	Cooking	1.04
Dishwasher:		Ventilation	9.92
Hot water wash	0.80	Space heating	2.52
Dishwshr Motor	2.40	Space cooling	19.19
Furnace fan	1.60	Water heating	0.87
Clothes Dryer	6.80	Office Equipment	1.86
Clothes Washer:		Miscellaneous	10.57
Hot water wash	1.30	**Industrial**	
Motor	0.90	Services including:	15.90
Space Heating	7.60	(Transport, Communication & Utilities)	
Space Cooling	7.00	Unclassified industries	1.96
Water heating:		Other industries	10.87
Non-solar	3.20	Process Industries	22.20
Solar	0.04	Pollution Control	3.30
Pump	0.20	Motors	16.19
Swimming pool heating:		Space cooling/Ventilation	12.03
Non-solar	0.060	Refrigeration	1.53
Solar	0.90	Street lighting	2.23
Pump	3.40	Lighting	7.54
Water Bed	2.80	Process heat	5.49
Color TV	4.80	Process Electric	0.59
Miscellaneous	0.180	Miscellaneous	13.70

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TABLE A9 - 12

ESTIMATING EMISSIONS FROM NATURAL GAS CONSUMPTION BY LAND USE
(Pounds Per Day)

$E = (\{[F \times G]/30\}/1000000) \times H$

Where,

E = Emissions of criteria pollutants due to natural gas consumption land uses

F = Gross square foot of each type of land use (*see Environmental Document*) except for residential and industrial uses; or
= Number of units for residential land use (*see Environmental Document*); or
= Number of meters (per business) as to an industrial park (*see Environmental Document*)

G = Natural gas usage rate to determine daily usage (*see Table A9 - 12 - A*)
Varies according to the type of land use

H = Emission factors in pounds per million cubic feet (*see Table A9 - 12 - B*)
Varies according to the type of criteria pollutant

TABLE A9 - 12 - A

NATURAL GAS USAGE RATE (G)
(To Determine Daily Consumption)

Land Use Type	Unit Type	Usage Factor
Residential		
Single Family Units	Cubic Feet/Unit/Month	6,665.0
Multi-Family Units	Cubic Feet/Unit/Month	4,011.5
Nonresidential		
Industrial	Cubic Feet/Parcel/Month	2,939.6 x 1,000
Hotel/Motel	Cubic Feet/Square Feet/Month	4.8
Retail/Shopping Centers	Cubic Feet/Square Feet/Month	2.9
Office	Cubic Feet/Square Feet/Month	2.0

TABLE A9 - 12 - B

EMISSION FACTORS (H) FOR EACH CRITERIA POLLUTANT From Consumption of Natural Gas
(Pounds Per Million Cubic Feet)

CO	ROC	NOx	SOx	PM10
20.0	5.3	80.0 (*for Residential Use*); or 120.0 (*for Nonresidential Use*)	Negligible	0.2

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TABLE A9 - 12 - C

ESTIMATING REMAINING EMISSIONS OF EACH POLLUTANT AFTER REMOVING CONTRIBUTED FRACTIONS BY EACH SOURCE CATEGORY

$N = [E - (O_1 + O_2 + O_3 + \ldots\ldots O_n)]$

Where,

N = Remaining Non-mitigated Natural Gas consumption emissions after the removal of all source categories for which mitigation measures are included.

E = Total Non-mitigated Natural Gas Consumption Emissions of a Criteria Pollutant. (*See above methodology*)

$O_1, O_2, O_3, \ldots\ldots O_n$ = Emissions of a Criteria Pollutant Associated with Each Source Category for which mitigation measures are included. (See Table A9 - 12 - D)

TABLE A9 - 12 - D

ESTIMATING PRE-MITIGATION EMISSIONS OF EACH POLLUTANT FOR EACH SOURCE CATEGORY

$O_1, O_2, O_3 \ldots O_n = [(E_R \times I_1)]$, *OR* $[(E_R \times I_2)]$, *OR* $[(E_R \times I_3)]$, *OR* $\ldots\ldots [(E_R \times I_n)]$

Where,

$O_1, O_2, O_3 \ldots O_n$ = Source Category's Market Segment of Total Non-mitigated Emissions
(*See Table A9 - 12 - D to determine which source category the mitigation measure is going to impact to obtain emission reductions. Use respective percent value to extract the fraction of non-mitigated emissions associated with that source category.*)

E = Total Non-mitigated Natural Gas Consumption Emissions of Each Pollutant.
(*Utilizing Table A9 - 12 - A and Table A9 - 12 - B* methodologies)

$I_1, I_2, I_3 \ldots I_n$ = Percent of Total Non-mitigated Emissions For Each Source Category
(*See Table A9 - 12 - E to determine which source category the mitigation measure is going to impact to obtain emission reductions. Use respective percent value (fraction) for I to extract the fraction of non-mitigated emissions associated with that source category.*)

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TABLE A9 - 12 - E

SOURCE CATEGORIES (I) OF PRE-MITIGATION ENERGY USE IN RESIDENTIAL, COMMERCIAL AND INDUSTRIAL SECTORS
(Committee Draft Energy Efficiency Report, 1990, California Energy Commission)

(Percent of the Total Pre-mitigation Energy Use Per Project)

Source Category	Natural Gas (Percent)	Source Category	Natural Gas (Percent)
Residential		**Commercial**	
Lighting	0.0	Indoor lighting	0.00
Cooking	5.50	Outdoor lighting	0.00
Refrigeration	0.0	Refrigeration	0.46
Freezer	0.0	Cooking	6.32
Dishwasher:		Ventilation	0.00
Hot water wash	8.9	Space heating	27.10
Dshwshr Motor	0.0	Space cooling	7.87
Furnace fan	0.0	Water heating	9.92
Clothes Dryer	2.10	Office Equipment	0.00
Clothes Washer:		Miscellaneous	48.33
Hot water wash	8.90	**Industrial**	
Motor	0.00	Services including:	3.99
Space Heating	45.70	(Transport, Communication & Utilities)	
Space Cooling	1.00	Unclassified industries	0.89
Water heating:		Other industries	0.00
Non-solar	22.20	Process Industries	37.39
Solar	0.10	Pollution Control	0.77
Pump	0.00	Motors	0.00
Swimming pool heating:		Space cooling/Ventilation	0.00
Non-solar	6.60	Refrigeration	0.00
Solar	1.00	Street lighting	0.00
Pump	0.00	Lighting	0.00
Water Bed	0.00	Process heat	0.00
Color TV	0.00	Process Electric	25.04
Miscellaneous	1.6	Miscellaneous	0.00

AR0073065

INFORMATION
FOR
ARCHITECTURAL COATINGS AND OTHER COATING MATERIALS

AR0073066

TABLE A9 - 13

ESTIMATING EVAPORATIVE EMISSIONS FROM ARCHITECTURAL COATINGS AND BUILDING MATERIALS
(Pounds Per Day)

$E = [(F \times G)/(H)] \times [I]$

Where,

E = Non-mitigated emissions of Reactive Organic Compounds (ROCs) from architectural coatings.
(These emissions will be during exterior finish and interior finish phases of the project construction. If these phases are overlapping with other phases of the construction, these emissions should be combined with ROC emissions from other phases. These combined emissions should be used to determine project significance.)

F = Pounds of ROC emissions. (If unknown, use Table A9 - 13 - C for this value. These values are expressed for 1000 square feet area to be coated 1 mil thick .)

G = One mil (0.001 inch) thick total exterior and/or interior area to be coated
(If unknown, use Table A9 - 13 - D methodology to determine this value. Thickness should always be expressed in "mils" for this methodology to work.)
(See Table A9 - 5 - 13 - C for percent transfer efficiency default values.)

H = One thousand (1,000) square feet. *(This value is needed because value for F is for a 1,000 square foot surface area one mil thick.)*

I = Required "mils" of coating thickness for the project. *(If unknown, use 17.5 mils for exterior and interior walls, and 3 mils for wood and metal surfaces. Also, use Table A9 - 13 - A for mil thickness default values for coatings on various surfaces.)*

TABLE A9 - 13 - A

DRY FILM THICKNESS
(Mils)

Surface Type	Thickness
Wood/Metal	1 < 4
Concrete/Masonry	5 < 30

TABLE A9 - 13 - B

TRANSFER EFFICIENCY FRACTIONS
(Percent)

Coating Equipment Type	Transfer Efficiency
Air Atomized Spray	25
HVLP Spray[2]	65
Hand Application[3]	100

1 Architectural coating emissions are currently expressed in terms of Volatile Organic Compounds (VOC), however, the term VOC has been incorporated under the larger category of Reactive Organic Compounds (ROC). *(See Chapter 3, Section 3.1, Ozone, of this Handbook for clarification)*

2 High Volume Low Pressure spray is a coating application system which is operated at air pressure between 0.1 and 10 pounds per square inch gauge (Psig)

3 Application of coatings by manual methods such as paint brush, hand roller, trowel, spatula, dauber, rag or sponge.

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TABLE A9 - 13 - C

ESTIMATING NON-MITIGATED EMISSIONS OF REACTIVE ORGANIC COMPOUNDS (ROCs) FROM ARCHITECTURAL COATINGS

(Value for "F" in Pounds for 25 % Transfer Efficiency of Air Atomized Spray Equipment.)

(This table provides VOC[1] (ROC) emissions for 1 mil thick 1000 square feet area for all VOC limits included in Rule 1113. Rule 1113 should be consulted for corresponding coating types.)

Rule 1113 limits (Grams/Liter)	Rule 1113 limits (Pounds/Gallon)	Coatings (Gallons/1000 SF)	Clean-up Solvents Percent	VOCs Lbs
Conventional Coatings				
*(Conventional coatings assumed to have 66.26 percent by weight solids, and 10.45 pounds per gallon density.)***				
780	6.49	20.67	10.0	149.34
730	6.07	13.78	10.0	93.77
680	5.66	10.78	10.0	68.97
650	5.41	9.54	10.0	58.62
600	4.99	7.75	10.0	44.38
580	4.83	7.29	10.0	40.60
550	4.58	6.53	10.0	34.69
500	4.16	5.77	10.0	28.24
High Solid Coatings				
*(High solids coatings assumed to have 77.35 percent by weight solids, and 11.33 pounds per gallon density.)***				
420	3.49	16.64	15.0	21.91
400	3.33	15.58	15.0	20.75
350	2.91	11.28	20.0	16.98
346	2.88	11.16	20.0	16.86
304	2.53	9.65	20.0	15.27
234	1.95	7.22	20.0	12.67
Water Based Coatings				
*(Water-based coatings assumed to have 47.67 percent by weight solids, and 10.54 pounds per gallon density.)***				
340	2.58	20.00	5.0	22.85
262	2.18	16.47	5.0	19.25
258	2.15	16.25	5.0	19.03
253	2.10	15.87	5.0	18.65
250*	**2.08**	**15.72**	**5.0**	**18.50**
244	2.03	14.89	5.0	17.59
217	1.81	13.28	5.0	15.97
152	1.26	8.98	5.0	11.6
148	1.23	8.76	5.0	11.39
103	0.86	5.96	5.0	8.51
75	0.62	4.18	5.0	6.66

* If unknown use 2.08 pounds/gallon VOC coatings for exterior walls.

** ARB's test results in 1988 report for Rule 1113 sales survey.

1. Architectural coating emissions are currently expressed in terms of Volatile Organic Compounds (VOC), however, the term VOC has been incorporated under the larger category of Reactive Organic Compounds (ROC). *(See Chapter 3, Section 3.1, Ozone, of this Handbook for clarification.)*

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ASSUMPTIONS:

1. The use of solvents in the cleaning and painting of the structures will generate Volatile Organic Compound emissions.
2. Non-mitigated VOCs are those which should not exceed Rule 1113 limits as coating is applied to the surface.
3. After removing % volume of VOC (non-exempt solvent), water and exempt solvents, what remains is the % volume of solids.
4. Non-exempt solvent density is 7.36 pounds per gallon of solvent.
5. Exempt solvent (1, 1, 1 -TCA) density is 11.06 pounds per gallon of solvent.
6. Water density is 8.337 pounds per gallon.
7. Water percent by weight is assumed to be 3.5 times higher than that of exempt solvent in the coating. (ARB's test results in 1988 report for Rule 1113 sales survey.)
8. For non-mitigated emissions, transfer efficiency is 25 percent of solids applied to the surface.
9. Mathematical formulation indicates that 1 gallon of solids will cover 1 mil (0.001 inch) thick a 1604 square foot area. For the same amount of coating if thickness is increased, the size of the area that can be coated with that amount of paint will be proportionally decreased. For the same size of the area if thickness is increased, the amount of coating will be proportionally increased.

TABLE A9 - 13 - D

ESTIMATING SURFACE AREA TO BE COATED

Estimate interior and exterior area to be covered by using the following methodologies:

Residential Structures:

Method 1.

It was estimated that every square foot of floor space would require the coating equivalent of 2.7 square feet of surface area. This may actually be an underestimate, but allows for non-coated surfaces such as windows, fireplaces, cabinets, overhead recessed ceiling lighting, etc.

For single family units consider 1/7 acre of floor surface or lot size per unit (ARB Report March 1990).
For multi-family units 1/20 acre lot size per unit (ARB Report March 1990).

Method 2.

Exterior Wall

1,280 square feet of exterior wall per single-family unit; or,
1,800 square feet of exterior wall on average for other than single-family units.
(Energy and Labor in the Construction Sector, Hannon, et.al.).

Interior Wall

The exterior wall amount can be tripled to consider interior walls, ceiling coatings, trim, etc.

Non-residential Structures:

For nonresidential structures (schools, shopping malls, etc.) rooms will be larger in size, ceilings will be acoustic panels type. In this case, each of the floor areas can be multiplied by 2.0 to obtain the total area to be coated.

Emissions from exterior and interior walls should be estimated and reported separately. These emissions should be combined with emissions from other construction activities.

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TABLES TO ESTIMATE CUMULATIVE IMPACTS

AR0073070

TABLE A9 - 14

OPTIONAL CUMULATIVE IMPACT ANALYSIS BASED ON ARB PERFORMANCE STANDARDS

STANDARDS

Rate Of Growth In Vehicle Miles Traveled Must Not Exceed The Rate Of Growth In Population During The Life-span Of The General Plan, Specific Plan, Redevelopment Plan And Project Developments

If A/B > C/D The project is cumulatively significant for population related activities; and, the additional vehicle miles traveled (VMT), average daily trips (ADT) and/or number of vehicles (NOVs) has to be mitigated to the extent feasible before writing the Overriding Consideration.

And/Or

If E/F > G/H The project is cumulatively significant for employment related activities; and, the additional vehicle miles traveled (VMT), average daily trips (ADT) and/or number of vehicles (NOVs) has to be mitigated to the extent feasible before writing the Statement of Overriding Consideration.

Where,

Utilize growth in population to estimate impact on cumulative population related VMT, ADT, or NOV

- A = Calculated or estimated population related VMT, ADT or NOV due to the project development for the build-out year;
- B = Anticipated cumulative population related VMT, ADT or NOV for each county; see Table A9 14 - A;
- C = Calculated or estimated project related population due to the project development for the build-out year
- D = Expected or Anticipated cumulative population for the City or County in the Growth Management Plan and/or by SCAG for the build-out year;

Utilize growth in employment to estimate impact on cumulative employment related VMT, ADT, or NOV

- E = Calculated or estimated employment related VMT, ADT or NOV for each County please see Table A9 - 14 - A;
- G = Calculated or estimated project related employment due to the project development for the build-out year
- H = Expected or anticipated cumulative employment for the City or County in the Growth Management Plan and/or by SCAG for the build-out year.

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TABLE A9 – 14 – A (Cont.)
VEHICLES MILES TRAVELED (VMT), AVERAGE DAILY TRIPS (ADT) AND NUMBER OF VEHICLES (NOV)
Anticipated values for (B) or (F) by California Air Resources Board

		PASSENGER			TRUCKS		
COUNTY	YEAR	VMT	ADT	NOV	VMT	ADT	NOV
Los Angeles							
	1991	146,985,000	17,439,537	4,675,939	16,968,000	2,264,666	453,677
	1993	151,751,395	17,764,296	4,744,948	17,606,802	2,327,741	465,623
	1995	156,512,871	18,088,461	4,818,539	18,251,492	2,389,348	476,877
	1997	161,264,510	18,411,738	4,883,763	18,902,069	2,449,486	488,401
	1999	166,015,164	18,696,482	4,948,814	19,555,591	2,511,120	499,895
	2001	170,768,770	19,059,188	5,014,073	20,213,037	2,574,251	511,520
	2003	175,521,393	19,383,357	5,079,540	20,875,389	2,642,163	523,116
	2005	180,270,080	19,707,319	5,144,838	21,537,742	2,707,247	535,239
	2007	185,016,799	20,031,364	5,210,009	22,204,019	2,770,836	546,813
	2009	189,762,535	20,355,046	5,275,098	22,873,241	2,834,176	558,382
Orange							
	1991	50,188,320	5,993,388	1,508,130	6,052,630	741,585	145,137
	1993	53,229,172	6,225,234	1,556,423	6,437,085	772,840	150,854
	1995	56,276,911	6,458,209	1,608,722	6,813,890	803,837	156,887
	1997	59,336,454	6,692,321	1,676,519	7,180,883	834,536	163,235
	1999	62,395,998	6,926,428	1,744,314	7,547,875	865,286	169,585
	2001	65,450,622	7,160,065	1,810,504	7,917,811	896,132	175,822
	2003	68,505,247	7,393,707	1,875,085	8,288,729	926,974	182,058
	2005	71,558,888	7,627,342	1,939,667	8,660,627	957,819	188,297
	2007	74,615,480	7,860,972	2,004,263	9,029,582	988,689	194,541
	2009	77,670,105	8,094,597	2,068,858	9,401,481	1,019,581	200,791
Riverside							
	1991	18,698,632	1,600,795	414,270	2,685,717	241,612	47,976
	1993	20,360,230	1,719,243	433,136	2,953,602	255,391	50,065
	1995	22,025,763	1,837,944	451,209	3,217,561	269,119	52,229
	1997	23,693,263	1,956,923	472,309	3,481,521	282,385	54,327
	1999	25,361,747	2,075,910	493,215	3,742,537	295,792	56,476
	2001	27,030,232	2,194,850	514,773	4,003,553	309,925	58,883
	2003	28,697,732	2,313,877	537,831	4,263,588	324,049	61,290
	2005	30,365,232	2,432,778	560,895	4,524,604	338,174	63,698
	2007	32,034,700	2,551,722	583,963	4,786,601	352,257	66,107
	2009	33,702,201	2,670,690	607,043	5,047,617	366,417	68,519
San Bernardino							
	1991	20,824,572	2,325,791	589,758	3,340,219	362,967	71,531
	1993	22,342,539	2,448,366	620,030	3,611,048	385,701	75,913
	1995	23,861,489	2,571,719	650,417	3,879,914	408,663	80,520
	1997	25,387,325	2,695,277	686,712	4,141,911	431,571	85,250
	1999	26,912,178	2,818,821	723,986	4,407,833	454,819	90,105
	2001	28,428,177	2,941,645	760,404	4,678,662	479,138	95,073
	2003	29,945,160	3,064,458	796,807	4,950,472	503,793	100,166
	2005	31,462,143	3,187,291	832,285	5,222,282	528,129	105,146
	2007	32,978,142	3,310,107	867,778	5,494,092	552,860	110,264
	2009	34,495,124	3,432,942	904,395	5,765,901	577,251	115,262

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TABLE A9 – 14 – A (Cont.)
VEHICLES MILES TRAVELED (VMT), AVERAGE DAILY TRIPS (ADT) AND NUMBER OF VEHICLES (NOV)
Anticipated values for (B) or (F) by California Air Resources Board

		MOTORCYCLES			BUSES		
COUNTY	YEAR	VMT	ADT	NOV	VMT	ADT	NOV
Los Angeles							
	1991	999,000	130,005	175,683	310,000	4,460	2,230
	1993	1,032,000	134,270	181,446	314,000	4,524	2,262
	1995	1,065,000	138,535	187,376	319,000	4,588	2,294
	1997	1,101,000	142,800	194,081	323,000	4,652	2,326
	1999	1,141,000	147,065	200,773	328,000	4,716	2,358
	2001	1,174,000	152,921	206,586	331,000	4,768	2,384
	2003	1,202,000	156,551	211,524	334,000	4,810	2,405
	2005	1,230,000	160,181	216,449	337,000	4,850	2,425
	2007	1,258,000	163,811	221,366	340,000	4,892	2,446
	2009	1,286,000	167,441	226,271	343,000	4,934	2,467
Orange							
	1991	340,000	45,320	68,666	58,000	842	421
	1993	359,000	47,884	72,551	60,000	870	435
	1995	378,000	50,448	76,436	62,000	898	449
	1997	396,000	52,826	80,040	64,000	926	463
	1999	414,000	55,205	83,644	66,000	956	478
	2001	432,000	57,627	87,313	68,000	982	491
	2003	451,000	60,090	91,046	70,000	1,006	503
	2005	469,000	62,555	94,781	72,000	1,030	515
	2007	488,000	65,019	98,514	73,000	1,052	526
	2009	506,000	67,484	102,248	75,000	1,076	538
Riverside							
	1991	72,000	7,473	19,162	13,000	188	94
	1993	75,000	7,854	20,139	15,000	206	103
	1995	79,000	8,220	21,078	16,000	224	112
	1997	82,000	8,560	21,948	17,000	242	121
	1999	85,000	8,896	22,811	18,000	260	130
	2001	89,000	9,248	23,713	20,000	278	139
	2003	92,000	9,632	24,697	21,000	296	148
	2005	96,000	10,015	25,679	22,000	312	156
	2007	100,000	10,398	26,661	23,000	330	165
	2009	104,000	10,782	27,645	24,000	346	173
San Bernardino							
	1991	114,000	14,143	30,746	9,000	126	63
	1993	121,000	14,979	32,562	9,000	134	67
	1995	127,000	15,818	34,387	10,000	142	71
	1997	134,000	16,619	36,128	11,000	152	76
	1999	140,000	17,443	37,920	11,000	160	80
	2001	147,000	18,293	39,768	12,000	168	84
	2003	155,000	19,190	41,718	12,000	176	88
	2005	162,000	20,065	43,620	13,000	184	92
	2007	169,000	20,940	45,521	13,000	192	96
	2009	176,000	21,841	47,481	14,000	200	100

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TABLE A9 - 15

OPTIONAL CUMULATIVE IMPACT ANALYSIS BASED ON THE 1991 AQMP PERFORMANCE STANDARDS

STANDARD

One Percent Per Year Reduction In Project Emissions
During The Life-span Of The General Plan

$A = \{B\} - \{[(C)^{-(D)}] \times [B]\}$

Where,

- A = Emission reduction in pounds for given year
- B = Starting cumulative emissions
- C = 0.99, a fraction for remaining emissions (The fraction assumes that 100 pounds are unmitigated cumulative emissions. Using the procedures outlined in Chapter 9, 1 percent or 1 pound of this 100 pounds of unmitigated emissions must be eliminated for given year)
- D = Number of years

EXAMPLE

B = 500 pounds of Unmitigated cumulative emissions in 1993 beginning of the project development
C = 0.99

For first year A = 500 - (500 x 0.99) = 5.0 per year from 1993 onward should be reduced (approximately)

Year	Starting Emissions		Remaining Emissions	= Cumulative Emission Reduction
1993	500.00	-	N.A.	= 0 Project Starts to Operate
1994	500.00	-	495.00	= 5.00 pounds of reduction in cumulative emissions
1995	495.00	-	490.05	= 4.95 pounds of reduction in cumulative emissions
1996	490.05	-	485.15	= 4.90 pounds of reduction in cumulative emissions
1997	485.15	-	480.30	= 4.85 pounds of reduction in cumulative emissions
1998	480.30	-	475.50	= 4.80 pounds of reduction in cumulative emissions
1999	475.50	-	470.74	= 4.75 pounds of reduction in cumulative emissions
2000	470.74	-	466.03	= 4.71 pounds of reduction in cumulative emissions
2001	466.03	-	461.37	= 4.66 pounds of reduction in cumulative emissions
2002	461.37	-	456.76	= 4.61 pounds of reduction in cumulative emissions
2003	456.76	-	452.19	= 4.57 pounds of reduction in cumulative emissions
2004	452.19	-	447.69	= 4.52 pounds of reduction in cumulative emissions
2005	447.69	-	443.19	= 4.48 pounds of reduction in cumulative emissions
2006	443.19	-	438.76	= 4.43 pounds of reduction in cumulative emissions
2007	438.76	-	434.37	= 4.39 pounds of reduction in cumulative emissions
2008	434.37	-	430.03	= 4.34 pounds of reduction in cumulative emissions
2009	430.03	-	425.73	= 4.30 pounds of reduction in cumulative emissions
2010	425.73	-	421.47	= 4.26 pounds of reduction in cumulative emissions
2011	421.47	-	417.26	= 4.21 pounds of reduction in cumulative emissions
Total				= 82.74 pounds of reduction in 17 years

A reduction in cumulative impacts should continue at the rate of approximately 5 pounds per year
N.A. = Not applicable in start year.

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TABLE A9 - 16

OPTIONAL CUMULATIVE IMPACT ANALYSIS BASED ON THE CALIFORNIA CLEAN AIR ACT PERFORMANCE STANDARDS 1.5 AVERAGE VEHICLE RIDERSHIP (AVR)

G = H - C

where,

G = Needed Reduction in Number of Vehicles to Achieve Targeted AVR

H = Current Number of Vehicles = D/E

where,

D = Average Daily (Weighted using weekday and weekend Travel data) Number of Persons Traveling in vehicles for the buildout year = A + B + L1

Where,

To improve the AVR, trips associated with the following should be eliminated or reduced.

A = Number of Persons Traveled in 4+ Person vehicles 1-way Alone

B = Number of Persons Traveled in 2 Person Motorcycles 1-way Alone

L1 = Number of Persons Traveled 1-way but No Survey Response (If Not Applicable, Use 0.0) *(Treat these as A, i.e., traveling Alone in 4+ Person Vehicles)*

E = Estimated AVR for the City or County without implementation of TCM mitigation measures *(To Estimate buildout year AVR, Use Table 9-7 methodology)*

C = Number of Allowed Vehicles = D/P, Where,

D = Average Daily (Weighted using weekday and weekend travel data) Number of Persons Traveling in buildout year

P = Targeted AVR for the City or County for the buildout year *(If unknown, Use 1.5, the California Clean Air Act requirement)*

Examples of Cumulative Work Trips AVR

Cumulative AVR for 1 Person Traveled to Work 1-Way by One vehicle	= 1/1 = 1.0
Cumulative AVR for 2 Persons Traveled to Work 1-way by One vehicle	= 2/1 = 2.0
Cumulative AVR for 3 Persons Traveled to Work 1-way by One vehicle	= 3/1 = 3.0
Cumulative AVR for 4 Persons Traveled to Work 1-way by One vehicle	= 4/4 = 4.0
Cumulative AVR for 7 Persons Traveled to Work 1 way by One Van	= 7/1 = 7.0
Cumulative AVR for 15 Persons Traveled to Work 1-way by One Subscription or planned bus	= 15/1 = 15.0
Cumulative AVR for 15 Persons Traveled to Work 1-way by One Public transit (rail/buses)	= 15/1 = 15.0
Cumulative AVR for 1 Person Traveled to Work 1-way to Report to Another Site *(1991 AQMP states that 5% of following trips were for Home to other)*	= 1/1 = 1.0

Example of Non-Work Trip AVR for the Vehicles Not Used for Work trips but Used for Other Trips=1/1

Non-work 1-Way Cumulative Trips = [{(J+K+L+M+N+O+P+Q+R+U) x 0.05} + {(S+T)xV)]; Where,

L = Number of Persons Travel did not travel due to Telecommuting at home

J = Number of Persons Traveled 1-way by Walk V = Percent Weekend Trips to other

K = Number of Persons Traveled 1-way by Bicycle

M = Number of Persons did not travel to the project site due to days off from 3/36 work week

N = Number of Persons did not travel to the project site due to days off from 4/40 work week

O = Number of persons did not travel to the project site due to days off from 9/80 work week

P = Number of persons did not travel to the project site due to vacation

Q = Number of persons did not travel to the project site due to sick leave

R = Number of persons did not travel to the project site because they were absent for reasons other than vacation and sick leaves

S = Number of persons did not travel to the project site because it was Saturday (Weekend)

T = Number of persons did not travel to the project site because it was Sunday (Weekend)

U = Number of persons did not use cars due the mitigations described to estimate various AVRs above

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AR0073075

INFORMATION
FOR
ESTIMATING
NUMBER OF CONSTRUCTION EMPLOYEES

AR0073076

TABLE A9 - 17
ESTIMATING THE NUMBER OF ON-SITE CONSTRUCTION EMPLOYEES
(Number of Employees Per Project)

E* = ((F x G x H)/1,000,000) x I; or, ***
E** = (G x H)/1,000,000) x I; ***

Where,

E = Number of Construction Employees
F = Gross square footage of that type of construction for which the value for (G) will be selected (*Refer to project description of environmental documents*)
G = Construction Value
(*If unknown, use cost values from Table A9 - 17 - C*)
H = Full time employment rate for construction related on-site[1] and off-site[2] activities.
(*If unknown, see Table A9 - 17 - A*)
I = Rate of on-site construction employment
(*If unknown, see Table A9 - 17 - B*)

1. 'on-site' means at the construction site and does not include employees needed to move goods; and
2. 'off-site' means employees needed at the goods (cement, walls, nails, etc.) manufacturing sites and goods transportation*** activities. For CEQA there is no need to estimate impact associated with employees needed at the goods manufacturing sites, however, impact associated with employees*** needed to transport goods to the project site should be estimated and included in the environmental documents.
3. In order to estimate employees needed to transport goods use the methodology suggested in Energy and Labor in the Construction Sector, B. Hannon, R. Stein, and D. Serber, Science, 1978, 202: 837-847.

* *For E* use information from column labelled as dollars/gross square foot.*

** *For E** use the methodology suggested in footnote of the Table A9 - 17 - C and historical values provided in the third column of this table (New Valuation) or estimate current values by applying seasonal and annual rate changes provided in the Composite Index Example column of this table to the historical values provided in the New Valuation column of this table.*

*** To determine employee related Average Daily Trips, use Tables A9 - 5 - A - 1 or A9 - 5 - A - 2.

TABLE A9 - 17 - A

FULL TIME EMPLOYMENT FACTORS (H) ASSOCIATED WITH THE CONSTRUCTION INDUSTRY****

Land Use Type	FTE Factor (H)
o Building Construction (Construction of New Residential, and Non-Residential)	9.2
o Non-building Construction (Construction of parking lots roadways, etc.)	8.78
o Demolition/Renovation/Repairs	9.15

TABLE A9 - 17 - B

PERCENT RATE (I) OF ON-SITE CONSTRUCTION JOBS****

Land Use Type	Percent Values/100 (I)
o Building Construction (Construction of New Residential, and Non-Residential Structures)	0.392
o Non-building Construction (Construction of parking lots roadways, etc.)	0.458
o Demolition/Renovation/Repairs	0.602

**** *Use the values as provided in Tables A9 - 17 - A and A9 - 17 - B*

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TABLE A9 - 17 - C

LAND USE TYPES (F) AND CONSTRUCTION COST (G) (DOLLARS PER SQUARE FOOT, PREVIOUS COSTS, AND SEASONAL AND ANNUAL % CHANGE RATES)

Land Use Type	Derived Cost Rate Dollars/Gross Square Foot	New Valuation* Year 1988	Composite Index Example Dec '88	Jan '88	Year 1978
Renovation, Repairs and Demolition					
Building- Residential		119,758.00	-11.6	-11.2	+9.0
Non-building - Residential		237,648,000.00	-18.7	-5.6	+5.8
Nonbuilding/Heavy Construction Activities					
Streets and Highways		59,612,000.00	-22.1	+0.4	+0.3
Bridges (inc. elev. hwys)		9,805,000.00	+212.3	-20.0	+10.8
Sewerage and Waste Systems		29,175,000.00	+117.9	+11.9	-33.1
Electric Power and Heating Systems		22,372,000.00	-57.7	-33.3	-49.0
River, Harbor, and Flood Control Systems		17,265,000.00	-67.2	-15.7	-11.1
Water Supply Systems		38,590,000.00	-4.2	+15.6	+41.4
Dams and Reservoirs		836,000.00	-82.3	-83.3	+7.7
Other Nonbuilding		70,546,000.00	+9.2	+56.3	+23.6
Building - Residential					
2-4 Unit Structures		40,774,000.00	-51.1	-58.2	-20.3
Single family dwelling units	55.70	978,406,000.00	+6.2	+6.9	+2.9
5-More Units (Apartments)	58.73	165,351,000.00	-40.6	-64.0	-25.4
Nonbuilding - Nonresidential					
Service Stations		3,145,000.00	-29.3	-23.7	+23.1
Amusements and Recreation		8,822,000.00	-16.8	+0.3	+48.0
Other Non-residential Buildings		81,964,000.00	-2.9	-26.2	-11.3
Hospital	112.46	78,472,000.00	+19.3	+109.8	-3.1
Industrial Buildings	31.75	136,763,000.00	+1.8	+6.7	-13.2
Office Buildings	59.98	105,434,000.00	-50.7	-44.6	-17.2
Public Garages	28.16	113,350,000.00	+572.4	n/a	+2.7
Stores and Mercantiles	45.15	132,401,000.00	-8.6	+18.1	+22.0
Hotel and motel	67.34	23,711,000.00	-32.2	-40.4	-43.5
Schools	64.91				
Churches	60.71				
Convalescent Hospitals	86.83				
Medical Offices	74.70				
Banks	91.12				
Public Buildings	78.24				
Warehouses	27.32				
Theaters	63.88				
Auditorium	61.65				
Restaurants	67.85				
Bowling Alleys	39.74				

For quick computation of present replacement costs from dependable historical costs, use Cooperative Cost Index subject of Section 98 reflecting the latest quarters. These are published by Marshall Valuation Service (Marshall and Swift - printed in U.S.A.) January, April, July and October of each year. The index values are developed by taking into consideration seasonal and annual changes. In order to estimate current (Yr 1989) cost divide current index value by former (Yr 1988) index value, multiply the answer with known cost (yr 1988 cost).

Source: Residential building cost data are from the U.S. Department of Commerce, Bureau of the Census, and Construction Industry Research Board. Nonresidential building cost data are from the U.S. Department of Commerce, Bureau of the Census, Security Pacific National Bank, and Construction Industry Research Board. Nonbuilding costs are from Dodge Division of McGraw-Hill and compiled by Construction Industry Research Board.

Note: Commercial Construction usually assumes 3-7 acres/$1,000,000 and built in 11 months.

AR0073078

ASSUMPTIONS FOR THE SCREENING TABLES IN CHAPTERS 6 AND 9

AR0073079

TABLE A9 – 18
ASSUMPTIONS FOR THE SCREENING TABLES IN CHAPTERS 6 AND 9

The following is a list of methodologies and defaults used in the preparation of the screening tables used in Chapters 6 and 9.

TABLE 6-2 *PROJECTS OF POTENTIAL SIGNIFICANCE FOR AIR QUALITY – OPERATION*
TABLE 9-4 *ESTIMATING MOBILE SOURCE OPERATION EMISSIONS*

METHODOLOGY	Table A9 – 5
DEFAULTS	
REGIONAL TRIP LENGTH	10.7
TRIPS	ITE TRIP GENERATION MANUAL
PERCENT HOT AND COLD STARTS	Table A9 – 5 – M
EMFAC7EP	Table A9 – 5 – J – 2
	35 MPH
	AREA 2

TABLE 9-1 *ESTIMATING ON-ROAD CONSTRUCTION EMISSIONS*

METHODOLOGY	Table A9 – 5, A9 – 6
DEFAULTS	
REGIONAL TRIP LENGTH	10.7
TRIPS	ITE TRIP GENERATION MANUAL
PERCENT HOT AND COLD STARTS	Table A9 – 5 – M
EMFAC7EP	Table A9 – 5 – J – 2
	35 MPH
	AREA 2
FULL-TIME CONSTRUCTION RATE	Table A9 – 6 – A
RATE OF ONSITE CONSTRUCTION JOBS	Table A9 – 6 – B
LAND USE CONSTRUCTION VALUE	Table A9 – 6 – C
WORKER TRIP RATE	Table A9 – 5 – A

TABLE 6-3 *PROJECTS OF POTENTIAL SIGNIFICANCE FOR AIR QUALITY – CONSTRUCTION*
TABLE 9-2 *ESTIMATING OFF-ROAD CONSTRUCTION EMISSIONS*

METHODOLOGY	Table A9 – 3
DEFAULTS	
ENERGY CONSUMPTION FOR CONSTRUCTION EXHAUST EMISSIONS	Table A9 – 3 – M
EMISSION FACTORS FOR EACH CRITERIA POLLUTANT	Table A9 – 3 – A

TABLE 6-3 *PM10 PROJECT SIGNIFICANCE*
TABLE 9-3 *ESTIMATING CONSTRUCTION PM10 EMISSIONS*

METHODOLOGY	
UNPAVED ROADS	Table A9 – 9 – D
PAVED ROADS	Table A9 – 9 – C
DEMOLITION	Table A9 – 9
DEFAULTS	
UNPAVED ROAD SILT LOADING AND ROAD TYPE	Table A9 – 9 – D – 1
MEAN VEHICLE SPEED	Table A9 – 9 – D – 2
MEAN NUMBER OF WHEELS AND WEIGHT	Table A9 – 9 – D – 3
PRECIPITATION CONDITIONS AND NUMBER OF DAYS	Table A9 – 9 – D – 4

TABLE 9-5 *ESTIMATING AREA SOURCE OPERATION EMISSIONS*

METHODOLOGY	Table A9 – 11
DEFAULTS	
ANNUAL CONSUMPTION OF KILOWATT HOURS	Table A9 – 11 – A
EMISSION FACTOR FOR EACH CRITERIA POLLUTANT	Table A9 – 11 – B

AR0073080

TECHNICAL ADDENDUM

CARBON MONOXIDE TRANSPORTATION PROJECT PROTOCOL

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AR0073081

TECHNICAL ADDENDUM

1. General

A Gaussian based line source model is to be used, as appropriate, to assess the effects of specific projects on local CO concentrations. An example of such a model is the Caltrans supported CALINE4 model.

The CALINE4 model is the most commonly used line source model in California. The technical assumptions contained in this Addendum are for use with this model. The use of CAL3QHC or TEXIN II models may require modification of these assumptions.

Use of alternative line source models, while not discouraged, must be agreeable to the local air district.

2. Background CO Levels

An important element in a microscale analysis of the CO concentrations expected as a result of particular projects, is the "background" concentration levels of CO upon which to add the estimated CO concentrations expected from the proposed project.

The model analysis must be carefully designed so as to minimize duplication of CO concentrations resulting from traffic otherwise accounted for in "background" CO levels.

The objective of the model analysis is to determine the incremental change in the CO concentration level between the "no project" alternative, and the CO concentration level resulting if the proposed project is constructed. The resultant incremental CO concentration levels are to be added to the background CO level and compared to the CO standards.

The appropriate "background" CO level shall be the estimated ambient levels determined either by using the CO concentration levels as measured by a nearby permanent monitoring station, or by the use of project-specific monitoring.

Unless otherwise agreed to by the sponsors and the local air district, a project-specific monitoring program shall consist of 4 months of continuous sampling during the winter CO season (November thru February). The sampling shall be in accordance with 40 CFR 58; Appendices A, D and E; and shall achieve a 90% data completeness. Sampling shall be at location(s) so as to both minimize duplication of CO concentrations resulting from traffic otherwise accounted for in the model analysis, and appropriately account for CO concentration levels from other major sources.

AR0073082

The "background" or ambient CO levels used in the analysis must be reflective of the same time of day as the traffic volumes used in the project analysis.

In the CO nonattainment area of the South Coast Air Basin, "background" levels for future years shall be estimated by application of factors to the base year "background" levels. The factors are directly proportional to the estimated future year total CO emissions, within each air quality analysis zone, as estimated by the South Coast AQMD in a manner consistent with SCAG's most recent transportation plan or program conformity analysis. The current estimated future year total CO emissions are attached.

3. Receptor Sites

A key element in the CALINE analysis is the location used to calculate the expected CO concentrations for comparison to the standards. These location(s) are termed the critical receptor sites. The critical receptor site(s) shall be at location(s) which are estimated to be representative of the highest CO concentrations expected in the area potentially effected by the proposed project.

Generally, receptor sites shall be representative of locations where there is a reasonable expectation of continuous human exposure during the time period(s) coinciding with peak CO concentrations. Receptor site(s) shall be located in a manner consistent with EPA's "microscale" criteria contained in 40 CFR 58. The location(s) shall be representative of existing and reasonably expected future land development projects.

Additionally, the receptor site(s) are to be selected reflective of meteorology, background CO levels, and the traffic/operational characteristics of the nearby existing and proposed transportation facilities.

Frequently, it is necessary to analyze multiple receptor sites in order to identify the critical site(s) with the highest CO concentrations with and/or without the proposed project. Once identified, the CO concentrations at the critical receptor site(s) will be used to judge the acceptability of the proposed project under the applicable laws.

If the project is unusually complex, or if the CO analysis appears potentially a deciding issue as to whether the project is allowed to proceed, sponsors should consult with the local air district regarding selection of the critical receptor site(s). This should be accomplished as early as possible in the process.

AR0073083

4. Calculation of 8-hour CO Concentrations - Persistence Factors

Estimated 8-hour CO concentrations expected to occur in the area are calculated by use of the persistence factor from the 1-hour levels estimated to occur at the 8-hour receptor sites. This factor is the ratio between the 1-hour and 8-hour CO concentrations as measured at the nearest representative permanent monitoring station.

Because the persistence factor really represents a combination of both the traffic persistence and the meteorological persistence, the preferred method is to use monitoring data to calculate the 1-hour to 8-hour ratio, as it would inherently include both traffic and meteorological conditions.

The persistence factor should be based on values obtained using the 10-highest non-overlapping 8-hour concentrations obtained from the latest three CO seasons of monitoring data. The ratio of the 8-hour concentration to the highest 1-hour concentration in each of the non-overlapping 8-hour periods is determined, and the average of the 10 values is used as the persistence factor.

Optimally the use of three seasons of CO monitoring data should be utilized to establish the 8-hour concentrations at the project site. However, two seasons of CO monitoring performed subject to 40CFR58 would be acceptable. If less than two years of information is available then the persistence factor values from the table below should be utilized.

Factor	Setting
0.6	Attainment areas
0.7	Nonattainment areas
0.8	Urban area with persistent stagnation and/or congestion

5. Ambient Air Temperature

For purposes of initial estimating, the lowest winter (November thru February) mean minimum temperature over a representative three-year period may be used. Temperature Adjustments for the time of day analyzed are noted on Table 3120.1 of the Caltrans "Air Quality Technical Analysis Notes" - AQTAN - (1988).
A more accurate estimation is achieved by using the temperatures associated with the actual time periods during which the historic high CO events in the area have occurred.

AR0073084

6. Vehicle Mix

The vehicle type distribution must be compatible with the version of EMFAC utilized in the analysis, and representative of the facility analyzed.

Heavy duty gas trucks are the most critical classification. The "Annual Truck Traffic Reports," available from Caltrans, contain the average daily percentage of trucks on State Highways. Time period adjustment factors must be applied to these percentages to more accurately reflect the targeted time period of the air quality analysis. (See Table 3130.2 of the AQTAN, 1988).

7. Percent Cold & Hot Starts

Vehicle emissions are especially sensitive to the percentages of cold starts within the vehicle mix. To a much lesser extent, emissions are also sensitive to hot starts.

The start-up phase is defined as the first 505 seconds or 3.59 miles. A cold start is defined as occurring after 1 hour of off time for a catalytic equipped vehicle, or 4 hours for a non-catalytic equipped vehicle.

For initial estimating purposes on urban freeways, these percentages are able to be estimated with Equation 2 from Section 3140 of the AQTAN (1988). Further, AQTAN Sections 3140, 6134, and 6221 (1988) contain simplified methods for making approximate estimates.

For initial estimating on non-freeways, cold and hot starts should be estimated at 95% and 5%, respectively.

In non-freeway situations, the range of the percent of cold starts can vary widely. More accurate estimates are able to be achieved through a project specific analysis, and may be utilized with appropriate documentation.

8. Speed

The vehicle operating conditions (speeds, accelerations, etc.) should represent the average conditions on the route, or element thereof, during the hour(s) analyzed. The present and projected conditions should be obtained from speed profiles or appropriate traffic models.

AR0073085

9. Surface Roughness

Surface Roughness affects the mechanical turbulence, thus the dispersion of the pollutants near the ground. Surface roughness is to be 15% of the average canopy height, and should be limited between 3 and 400 cm. As the calculations are not very sensitive to changes in surface roughness; generally, a rough order of magnitude estimate, based on the predominate land use, is sufficient.

10. Mixing Height

A mixing height of 1000 meters should be used, bypassing the mixing height algorithm, unless the local air district indicates otherwise.

11. Wind Speed

Unless the local air district indicates otherwise, the wind speeds in Table 4127.1 from the AQTAN (1988) may be assumed for estimating purposes.

12. Wind Direction

For estimating purposes, the "worst" wind angle is to be used. In order to determine the "worst" wind angle, it is necessary to calculate CO levels at the receptor site for a range of alternative angles at 10 degree increments. The "worst" wind angle, is the angle, within 1 degree, which results in the highest CO concentration at the receptor site.

13. Stability Class

Stability class describes the potential of atmospheric conditions to disperse pollutants through the process of turbulent diffusion. The line source model is not very sensitive to changes in the stability class. Unless the local air district indicates otherwise, the stability classes in Table 4127.1 from the AQTAN (1988) may be assumed for estimating purposes.

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14. Sigma Theta

Sigma theta is the standard deviation of the wind direction. With receptors close to the roadway and parallel winds (a typical worst case scenario), changes in sigma theta can have a very dramatic effect on predicted concentrations. Unless the local air district indicates otherwise, the sigma thetas in Table 4127.1 from the AQTAN (1988) may be assumed for estimating purposes.

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APPENDIX 10 SUMMARY OF GUIDELINES FOR LAND USE ANALYSIS WITH AIR TOXICS

The EIR that considers air toxics as well as criteria pollutants will differ in a few respects from the conventional EIR, *but the differences are critical*. The additional analyses will determine what kinds and level of mitigation are required and what residual impact cannot be eliminated if the project is pursued.

Substantial technical complexity may be involved in assessing air toxics. Publications prepared by the District and the ARB can be helpful. Assistance with understanding technical aspects may be obtained from the District. Of necessity, analysis involving air toxics will follow the basic approach used in preparing a risk assessment.

An outline listing elements needed for such an approach follows.

A. Description of the Facility and the Area of Planning Concern

- o The usual content provided under the project's 'Setting'
- o Focused description of each operation which may release air toxics including actual facility operating hours and release characteristics

B. Emissions Sources—a flow diagram of all process flows for a toxics-emitting facility, identifying:

- o Specific processes with a potential for emissions
- o Devices associated with emitting processes
- o Estimate of number of possible accidental release sites
  - valves
  - flanges
  - locations, devices sensitive to seismic events
- o All locations of possible exhaust release locations

C. Substances Emitted:

- o Quantities expected to be released, from all emission points
  - routine releases
  - accidental releases, with probability for the causative event
- o How releases take place (source data for modeling)
- o Emission control equipment and its efficiency

D. Possible Modeling Approaches and Requirements:

- o Available and suitable modeling approaches
- o Information requirements for modeling
  - Terrain: Flat, or complex topography
  - Degree of urbanization
  - Meteorological data available

E. Receptor Data:

- o Particularly sensitive receptor points
- o Commercial receptors
- o Zone of potential impact defined as an area with a 1 in 2 million risk
- o Exposed population: size, character (census tracts)
- o Type of exposure: inhalation, non-inhalation

F. Estimation of Health Risk:

- o Cancer risk analysis
  - Individual excess cancer risk for sensitive receptors
  - Individual excess cancer risk for commercial receptor

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- Population excess cancer burden including both sensitive and commercial receptors

o Estimation of non-cancer health effects (if identifiable) and description of non-cancer effects (both chronic and acute) for each air toxic emitted

Planning for air toxics must first establish what emissions may result if the project is carried out, together with where, how, and when they may be released. The District Engineering staff will need to be consulted for data estimates. The District Modeling staff can be consulted for emissions estimates used in modeling. Data must be site- and facility- specific. As noted in Chapter 5, risk assessments prepared under AB 2588, when available, are a useful starting point for the planning analysis. Source and surrounding receptor locations must be characterized with a particular view toward the kind and extent of risk which may result from the project. Conventional features such as terrain, building characteristics of surroundings, and population distribution and character are also essential.

(APPND_10)

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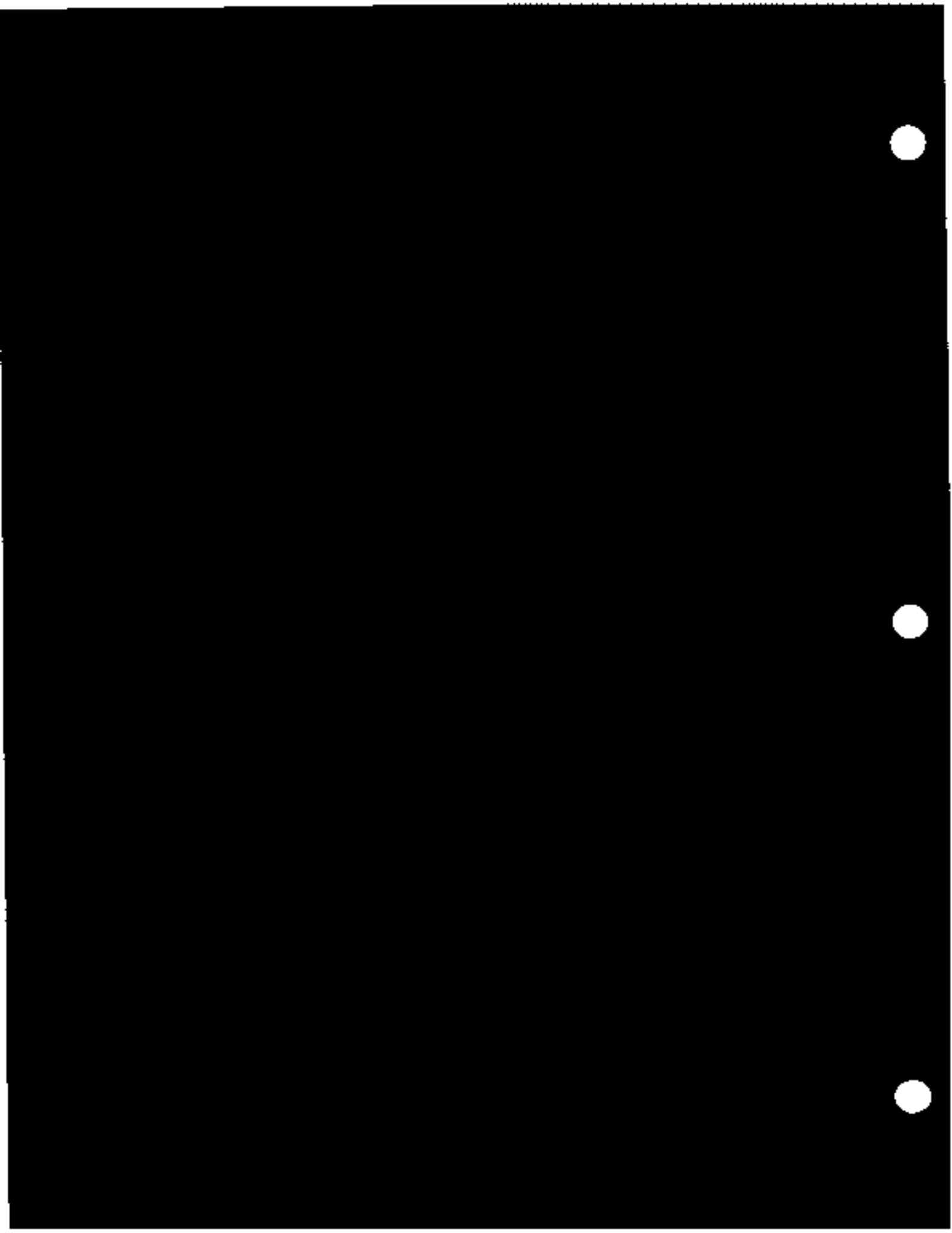

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ESTIMATING EMISSIONS FROM COATINGS AND SPRAY EQUIPMENT AFTER IMPLEMENTATION OF MITIGATION MEASURES A11-93

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TABLE A11 - 1
SUMMARY OF ESTIMATED DAILY EMISSIONS
FOR CONSTRUCTION, DEMOLITION & RENOVATION AFTER MITIGATION

PROJECT NAME:

PREPARED BY: DATE:

Source	Emissions in Pounds per Day					
	Reference	CO	ROC	NOx	SOx	PM10
STATIONARY CONSTRUCTION EQUIPMENT						
Gasoline Engines	Table A11 - 3					
Diesel Engines	Table A11 - 3					
VEHICULAR						
Work Trips	Table A11 - 5					
Non-Work Trips	Table A11 - 5					
Truck Trips	Table A11 - 5					
Traffic Impacts	Table A11 - 6					
MOBILE CONSTRUCTION EQUIPMENT						
Diesel-Powered	Table A11 - 8					
Gasoline-Powered	Table A11 - 8					
DUST/PM10						
Paved Roads	Table A11 - 9					
Unpaved Roads	Table A11 - 9					
Storage Piles	Table A11 - 9					
Paved Parking Lots	Table A11 - 9					
Unpaved Parking Lots	Table A11 - 9					
Storage Piles	Table A11 - 9					
Earthmoving Storage Pile Filling	Table A11 - 9					
Demolition	Table A11 - 9					
ENERGY USE						
SCE	Table A11 - 11					
LADWP	Table A11 - 11					
Natural Gas	Table A11 - 12					
ASBESTOS	Table A11 - 10					
BUILDING MATERIALS	Table A11 - 13					
OTHER						
TOTALS						
Emissions (lbs/day)						
SCAQMD Thresholds (lbs/day)						
Project's Significance (Yes or No)						

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TABLE A11 - 2
SUMMARY OF ESTIMATED DAILY
OPERATION-RELATED EMISSIONS AFTER MITIGATION

PROJECT NAME:

PREPARED BY: DATE:

Source	Emissions in Pounds per Day					
	Reference	CO	ROC	NOx	SOx	PM10
STATIONARY						
(List Sources Qualified)	Table A11 - 4					
VEHICULAR						
Work Trip	Table A11 - 5					
Non-Work Trip	Table A11 - 5					
Truck Trip	Table A11 - 5					
Traffic Impacts	Table A11 - 5					
OFF-ROAD MOBILE:						
(List Sources Qualified)						
DUST/PM10						
Paved Roads	Table A11 - 9					
Unpaved Roads	Table A11 - 9					
Storage Piles	Table A11 - 9					
Paved Parking Lots	Table A11 - 9					
Unpaved Parking Lots	Table A11 - 9					
ENERGY USE						
SCE	Table A11 - 11					
LADWP	Table A11 - 11					
Natural Gas	Table A11 - 12					
OTHER						
TOTALS						
Emissions (lbs/day)						
SCAQMD Thresholds (lbs/day)						
Project's Significance (Yes or No)						

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TABLES FOR ESTIMATING STATIONARY EQUIPMENT EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES

Mitigation Measures That Reduce Emissions Associated With Gasoline- and Diesel- Powered Stationary Equipment

- Replace Gasoline- and Diesel-Powered Stationary Equipment With Natural-Gas-Powered Stationary Equipment;
- Replace Gasoline- and Diesel)-Powered Stationary Equipment With LPG (Propane and Butane)-Gas-Powered Stationary Equipment; or,
- Replace Gasoline- and Diesel-Powered Stationary Equipment With Battery-Powered Stationary Equipment; and/or
- Replace Reciprocating Stationary Engines with Turbine Stationary Engines.

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TABLE A11 - 3

ESTIMATING EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE EMISSIONS FROM STATIONARY OR HEAVY-DUTY ENGINES
(Pounds Per Day)

M = R + N

Where,

M = Mitigated Stationary Equipment Emissions After Implementation of Mitigation Measures *(Use Table A9 - 3 to Estimate Non-mitigated Emissions from Original Stationary Equipment)*

R = Remaining or Residual Non-mitigated Emissions From Remaining Original Equipment
= {[E x (1 - {F/G})]; Where,

E = Non-Mitigated Emissions from Table A9 - 3

F = Number of Removed Original (and Replaced with New) Stationary Equipment

G = Number of Original Stationary Equipment
(Used to Estimate Non-Mitigated Emissions (E) in Table A9 - 3 of Appendix 9)

N = New Emissions per Million BTUs From Replacement Equipment
= {V x (H/I)}; Where,

V = Emissions from Removed Original Equipment
= {(E x {F/G)]

H = New Emission Factor Per Million BTUs** For New (*or Replaced*) Equipment *(Please see Table A11 - 3 - A or C)*;

I = Emission Factor per Million BTUS For Original Equipment *(Please see Table A11 - 3 - B or D)*

** *BTUs = British Thermal Units*

TABLE A11 - 3 - A

Emission Factors (H) for Each Criteria Pollutant for New Equipment (Pounds Per Million BTUs)

Pollutant Type / Fuel Type *****	CO R	CO T	ROC R	ROC T	NOx R	NOx T	SOx R	SOx T	PM10 R	PM10 T
(Industrial/Commercial Type)										
Propane	1.267	- -	0.815	- -	1.365	- -	0.003	- -	0.025	- -
Butane	1.267	- -	0.815	- -	1.365	- -	0.003	- -	0.025	- -
(Cogeneration Type)										
Natural Gas (Methane)	0.4095	0.1095	0.079	0.012	3.23$1	0.3933	0.0006	0.0006	0.0048	0.0067
(Turbine Aircraft Type Engine Testing)										
Natural Gas (Methane)	- -	0.1143	- -	0.0066	- -	0.2857		0.0006		0.0067

***** Electricity generation engine type; R = Reciprocating; and T = Turbine
If unknown, use emission factors for reciprocating engines

TABLE A11 - 3 - B

Emission Factors (I) for Each Criteria Pollutant for Original (Removed) Equipment (Pounds Per Million [1,000,000] BTUs)

Pollutant Type / Fuel Type *****	CO R	CO T	ROC R	ROC T	NOx R	NOx T	SOx R	SOx T	PM10 R	PM10 T
Distilled Oil, or Diesel	0.735	0.11	0.23	0.034	3.38	0.49	0.225	1.01	0.12	0.018
Gasoline	34.26	- -	1.28	- -	0.89	- -	0.046	- -	0.028	- -

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TABLE A11 - 3 - C

Emission Factors for (H) Each Criteria Pollutant for New Equipment
(The following emission factors should be converted to emissions per million BTUs))

Pollutant Type / Fuel Type *****	CO R	CO T	ROC R	ROC T	NOx R	NOx T	SOx R	SOx T	PM10 R	PM10 T
(Pounds/Megawatt-Hours [1] and [2])										
Electricity	0.2	--	0.01	--	1.15	--	0.12	--	0.04	--
Dual Fuel (Oil/Gas)	7.9	--	2.0	--	24.14	--	0.94	--	1.48	--
(Pounds/One Thousand [1,000] Gallons)										
Propane	129.0	--	83.0	--	139.0	--	0.35	--	2.5	--
Butane	129.0	--	83.0	--	139.0	--	0.35	--	2.5	--
(Pounds/Million [1,000,000] Cubic Feet)										
Process Gas*	--	--	83.0	--	--	--	--	--	--	--
Landfill Gas	--	--	--	--	--	--	--	--	--	--
(Cogeneration Type)										
Natural Gas (Methane)	430.0	115.0	82.9	12.6	3,400.0	413.0	0.6	0.6	5.0	7.0
(Turbine Aircraft Engine Testing)										
Natural Gas (Methane)	--	120.0	--	6.9	--	300.0	--	0.6	--	7.0

[1] When using emissions factors expressed in megawatt-hour, they should be adjusted using efficiency factors "S" from Table A9-3-C.

[2] For generators, when using emissions factors expressed in megawatt-hour, they should be further adjusted using efficiency factor "U" from Table A9-3-C.

* 525 BTUs per cubic feet of process gas

TABLE A11 - 3 - D

Emission Factors for (I) Each Criteria Pollutant for Original (Removed) Equipment
(The following emission factors should be converted to emissions per million BTUs)

Pollutant Type / Fuel Type *****	CO R	CO T	ROC R	ROC T	NOx R	NOx T	SOx R	SOx T	PM10 R	PM10 T
(Pounds/Megawatt-Hours [1] and [2])										
Diesel	2.51	--	0.79	--	11.55	--	0.77	--	0.41	--
Gasoline	117.0	--	4.39	--	3.03	--	0.16	--	0.10	--
(Pounds/1,000 Gallons)										
Diesel	102.0	15.4	32.1	4.77	469.0	67.8	31.2	140.0[s]	16.75	2.5
Gasoline	3,940.0	--	147.7	--	102.0	--	5.31	--	3.235	--
Residual Crude Oil	102.0	--	32.10	--	469.0	--	155.0	--	16.75	--
Kerosaptha Jet Fuel	102.0	15.4	32.1	4.77	469.0	67.8	6.2	6.2	16.75	2.5
(Diesel/Kerosene Mixture)										
(Pounds/Ton)										
Jet Fuel (Turbine)	--	150.0	--	1.7	--	1.0	--	0.5	--	2.5

[1] and [2] See explanation given under Table A11 - 3 - C

[s] Percent sulfur content of the fuel. *(Please see Rule 431.2 for the applicable project related fuel sulfur content factor, and multiply 140.0 with [s] to obtain project related SOx emission factor.)*

***** Electricity generation engine type: R = Reciprocating; and T = Turbine
If unknown, use emission factors for reciprocating engines

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TABLES FOR ESTIMATING EMISSION REDUCTIONS FROM MITIGATION MEASURES FOR WHICH A METHODOLOGY IS NOT INCLUDED

AR0073107

TABLE A11 - 4

SOURCES OF EMISSION FACTORS FOR QUANTIFYING STATIONARY SOURCE* EMISSIONS

SCAQMD's Best Available Control Technologies Guidelines should be Consulted for Mitigating Emissions from Stationary Equipment.

1. California Air Resources Board, 1988, Instructions for the Emission Data System Review and Update Report, January 1988.

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11. SCAQMD's Rules and Regulations

12. SCAQMD's staff reports (the most recent) for applicable source specific rules.

* Many of these sources also include emission factors for mobile equipment utilized at stationary sources

Note: These sources are available at the District library located at 21865 Copley Drive in Diamond Bar, California 91765.

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TABLE A11 - 4 - A

GENERAL METHODOLOGY TO DETERMINE EMISSION REDUCTIONS

(Table for estimating emissions from mitigation measures for which a methodology is not included in Appendix 11)

REMAINING ORIGINAL EMISSIONS
AFTER
THE IMPLEMENTATION OF MITIGATION MEASURE
= {[Nonmitigated Emissions] x [1 - ({# of Source Removed}/{# of Original Source})]}
or
= {[Nonmitigated Emissions] x [(# of Remaining Source)/(# of Original Source)]}

EMISSIONS REDUCTION FROM THE IMPLEMENTATION
OF
MITIGATION MEASURE
= {[Nonmitigated Emissions] - [Post-Mitigation Remaining Original Emissions]}

PERCENT REDUCTION FROM THE IMPLEMENTATION
OF
MITIGATION MEASURE
{[100 x (Emissions Reduction After Mitigation)]/[Nonmitigated Emissions]}

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TABLE A11 - 5

METHODOLOGIES TO ESTIMATE EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE VEHICULAR EMISSIONS

Implementation of mitigation measures will have direct impacts on emissions from on-road mobile sources. These direct impacts may be expressed as increases in average vehicle ridership (AVR), reductions in average daily trips, trip lengths, or congestion. It is assumed that indirect impacts may include a slight increase in nonwork trips and increased work trips by substitute traveling modes and activities. For example the 1991 AQMP projects that employer trip reduction programs, may result in an approximate 5% increase in nonwork trips. Nevertheless, there will be an overall benefit from these strategies. In addition, whenever a methodology for calculating reactive organic gases includes removal of diurnal emissions, they are also added back, as a vehicle still emits ROC emissions when not in use. Separate methodologies are provided in this table to estimate net emissions after implementation of a mitigation measure.

MITIGATION MEASURES THAT REDUCE TRIPS

Tables A11 - 5 - A and A11 - 5 - B identify mitigation measures that reduce vehicle trips to or from a facility.

Table A11 - 5 - A includes measures that reduce vehicle trips by shifting the mode of transportation from a single occupancy vehicle to a high occupancy vehicle. While emissions are reduced from eliminating a trip, new emissions are created by utilizing a motorized vehicle for the substitute trip. Therefore, the entire range of emissions associated with the replacement mode must be factored added back in. Examples include measures that increase carpooling, transit ridership, or shuttle services.

Table A11 - 5 - B includes mitigation measures that reduce vehicle trips by eliminating the need to travel altogether or shifting the mode of transportation from a single occupancy vehicle to a non-motorized mode. These mitigation measures eliminate emissions from a vehicle trip with no trip (i.e., telecommuting, alternative work weeks), or a non-emitting mode (i.e., bicycling, walking).

NON-MITIGATED EMISSIONS

To determine net emissions after implementation of mitigation measure, all methodologies will begin with non-mitigated emissions. Non-mitigated emissions are obtained by using Table A9 - 5 of Appendix 9. The following summarizes how these emissions were estimated.

A = Total Non-mitigated Vehicular Emissions = W + X + Y + Z;

where,

W = Non-mitigated Average Daily One-way Trips x Multiplier (Use 2.0 to obtain two-way or round trips, otherwise multiply by 1.0) x Original Trip length x Running Emission Factors

X = Non-mitigated Average Daily One-way Trips x Multiplier (Use 2.0 to obtain two-way or round trips, otherwise multiply by 1.0) x Start-up Emission Factors

Y = Non-mitigated Average Daily One-way Trips x Multiplier (Use 2.0 to obtain two-way or round trips, otherwise multiply by 1.0) x Hot-Soak Emission Factors. (only ROC)

Z = Non-mitigated Average Daily Trips/Divider (Use 2.0 only for two-way or round trips, otherwise divide by 1.0) x Diurnal Emission Factors. (only ROC)

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TABLES FOR ESTIMATING VEHICULAR EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE TRIPS BY UTILIZING SUBSTITUTE MOTORIZED VEHICLES

Mitigation Measures That Reduce Emissions Associated With Reduction in Average Daily Trips With an Increase in Vehicle Miles Traveled by Substitute Vehicles

- Establish or Contribute to Shuttle Service from Residential Subdivisions to or Non-Residential Developments to Rail or Multi-Modal Transit Stations
- Establish or Contribute to Shuttle Service from Residential Subdivision to Commercial Core Areas
- Require Retail and Special Event Centers to Offer Consumers Travel Incentives (Discounted or Free Transit Passes to Clients, Discounts on Purchases for Transit Riders, and Other Promotional Events)
- Provide On-Site Bus and Shuttle Turnouts, Passenger Benches, and Shelters or Contribute to Off-Site Improvements
- Provide Preferential Parking Spaces for Carpools and Vanpools
- Develop a Trip Reduction Plan to Achieve a 1.5 AVR or Higher for Multi-Tenant Buildings or Businesses with Fewer than 100 Employees
- Include Residential Units Within Commercial Developments or Contribute Towards its Development Off-Site
- Require Retail Facilities and Special Event Centers to Offer Transit Incentives (e.g., Discounted or Free Transit Rides, Discounts on Purchases or Admission for Transit Riders)
- Implement or Contribute to Public Outreach and Ridesharing Education Programs
- Employers Provide Employees Incentives for Ridesharing or Charge for Single Occupant Vehicles to Encourage Ridesharing
- Charge to Park for Non-Employees or Provide Discounts to High Occupancy Vehicles
- Require Future Employers Not Subject to Regulation XV to Provide Centrally Located Commuter Area Offering Information on Transportation Alternatives
- Reduce Employee Parking Spaces for Those Employers Subject to Regulation XV
- Contribute to Regional Transit Systems (e.g., Funding for Capital Improvements, Dedication of Right-of-Way)
- Implement a Trip Reduction Plan to Achieve a 1.5 AVR or Higher for Construction Employees (Construction Activities)
- Establish or Contribute to Shuttle Service to and From Construction Sites to Retail and Food Establishments During Lunch Hours (Construction)

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TABLE A11 - 5 - A

METHODOLOGY FOR VEHICLE TRIP REDUCTION BY UTILIZING SUBSTITUTE MOTORIZED VEHICLES

This methodology calculates net emissions after implementation of mitigation measures that reduce vehicle trips, however substitute vehicle trips cause an increase in vehicle miles traveled. While a vehicle trip is eliminated, the mode shift to a high occupancy vehicles i.e., buses, carpools, shuttles, result in an incremental increase in VMT and emissions. Diurnal emissions need to be added because a vehicle still emits emissions sitting in a carport or garage.

$$N = \{[(A \times \{1-[C/B]\})] + [(\{C/D\} \times Q) + \{R + S\} + \{X\}]/[454]\} + \{I\}$$

Where,

- N = Net Emissions In Pounds Per Day After Implementation of Average Daily Trip (ADT) Reduction Measures
- A = Total Non-mitigated Vehicular Emissions
  (Resulted from Table A9 - 5 or Appendix 9 Methodologies); or,
  = (A x {1-[C/B]}) of the above calculations; Residual Emissions of the above calculations, if emission reductions caused by other mitigation measures are reduced.
  (Resulted from Table A11 - 5 or Appendix 11 Methodologies).
- B = Total Original Number of Average Vehicle Trips Generated By the Project
  (Trips used to estimate value for "A" in Table A9 - 5 from Appendix 9 Methodologies)
  To estimate ADT reduced due to the participation in Trip Reduction program, Use Table A9 - 5 Methodologies from Appendix 9, and the Needed Data from Table A11 - 5 - A - 1.
- C = Number of Trips Reduced from the Original Work Site after Implementation of the Mitigation Measure
  (See Table A11 - 5 - A - 4 for methodologies to calculate "C" that are specific to individual mitigation measures
  To estimate diurnal emissions associated with trip reduction
- D = 2.0, if non-mitigated vehicular emissions were for 2-way or round trips; or
  = 1.0, if non-mitigated vehicular emissions were for 1-way trips
- Q = EMFAC7EP Diurnal Emission Factors *(Applicable only to ROG)* in grams per NOV.
  Please estimate running exhaust, running evaporative, start-up, and hot soak emissions for the following modes. (Also estimate diurnal emissions for all replacement modes i.e., R, S and X.)
  To Estimate Emissions Associated with the Following Travel Modes, Use Table A9 - 5 Methodologies from Appendix 9 and the Needed Data from Table A11 - 5 - A - 3.
- R = Replacement or Additional Emissions in grams per day Associated with Employees Traveling in Personal Cars (reduced from original work trips) to other work sites with shorter traveling distance, or to original work sites work with improved AVR. (If not applicable to your project, enter 0.0); and/or
- S = Replacement or Additional Emissions in grams per day Associated with Employees Traveling in Buses to other work sites with shorter traveling distance, or to original work sites with improved AVR. (If not applicable to your project, enter 0.0); and/or Any other traveling mode
  To Estimate Emissions Associated with Replacement Trips to Other Work Sites with Shorter Traveling Distance or to Original Work Sites with Improved AVR, Use Table A9 - 5 Methodologies from Appendix 9 and the Appropriate Data from Table A11 - 5 - A - 2.

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X = Replacement or Additional Emissions in grams per day Associated with Employees Traveling in Personal Cars to other work sites with shorter traveling distance. Please estimate all (running exhaust and evaporative, start-up, and hot soak emissions and do not estimate diurnal emissions associated with these trips (If not applicable to your project, enter 0.0).
To Estimate Emissions Associated with Nonwork Trips Made by the Personal Vehicles of Home-based employees, Use Table A9 - 5 Methodologies from Appendix 9 and the Needed Data from TABLE A11 - 1 - B.

I = Non-Work Related Emissions in pounds per day Associated with use of Reduced Cars for personal trips; (If not applicable to your project, enter 0.0);
= [(B x D x E x F x H)/(454)];

where,

B = Number of Vehicles Reduced After Implementation of Mitigation Measure = (L - O)

D = 0.05; Five percent of cars reduced and used for personal travel such as home to other or shop travel

E = Number of Trips per Vehicle per Day (*For Round-trip Use 2, and One-way Trip Use 1*)

F = Trip Length for Home to Shop or Home to Other

H = Running Emission Factors In Grams Per Mile At New Speed (based on New Speed for the Non-work Trip).

TABLE A11 - 5 - A - 1

DATA NEED FOR DETERMINING DIRECT IMPACTS

Impacts	Data Need	At Home	Other Work Site
Reduced Work Trips			
	# of Employees Participating Per Day	_____	_____
	# of Days of the Week	_____	_____
	Average Daily Trip Rate/Employee	_____	_____

TABLE A11 - 5 - A - 2

DATA NEED FOR DETERMINING INDIRECT IMPACTS (ADDITION OF NEW AVERAGE DAILY NONWORK TRIPS)

Impacts	Data Need	At Home	Other Work Site
Added Nonwork Trips			
	# of Employees Participating Per Day	_____	_____
	# of Days of the Week	_____	_____
	Average Daily Trip Rate/Employee	_____	_____

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TABLE A11 - 5 - A - 3

DATA NEED FOR DETERMINING INDIRECT IMPACT (ADDITION OF NEW AVERAGE DAILY WORK TRIPS)

Impacts	Travel Modes	Data Need	At Home	Other Work Sites
Added Work Trips By Vehicle Type				
	o Cars or Motorcycles (See Table A9 - 5 - J, L and N for Emission Factors)			
		# of Employees Participating per Day	_____	_____
		# of Days of the Week	_____	_____
		Average Daily Trip Rate/Employee	_____	_____
		Average Trip Length	_____	_____
		Average Speed	_____	_____
	o Buses (See Table A11 - 5 - H for Emission Factors)			
		# of Employees Participating per Day	_____	_____
		# of Days of the Week	_____	_____
		Average Daily Trip Rate per Employee	_____	_____
		Average Trip Length	_____	_____
		Average Speed	_____	_____
	o Shuttles			
		# of Employees Participating per Day	_____	_____
		# of Days of the Week	_____	_____
		Average Daily Trip Rate Per Employee	_____	_____
		Average Trip Length	_____	_____
		Average Speed	_____	_____

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TABLE A11 - 5 - A - 4

TRIP DEPENDENT INPUT ASSUMPTIONS MEASURES FOR VEHICLE TRIP REDUCTION BY UTILIZING SUBSTITUTE MOTORIZED VEHICLES

Mitigation measures for which,

$$C = K \times (L/M) \times O \times 2$$

Where,

- C = Number of Trips Reduced from the Original Work Site after Implementation of the Mitigation Measure
  (*See Table A11 - 5 - A methodology to use "C"*)
- K = Number of employees anticipated to Participate in Trip Reduction mitigation measure per day
- L = Number of Days per Week Employees will Participate in the Mitigation Measure (*Based on 5-day work week assumption*)
- M = Number of Days per Week for which Work Trips are Estimated in Appendix 9
- O = Number of Daily Trips per Worker
  (*Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.26 trips/worker*)

Mitigation Measure	Emission Source	Range of Input Assumptions K	L	Favorable Factors
Trip reduction plan to achieve a 1.5 AVR for construction employees	Work Trips Construction	1-5%	1-2	Large construction site with a substantial pool of workers with long construction phases and limited parking in staging area or vicinity
Preferential parking spaces for carpools and vanpools and provide a minimum vertical clearance of 72" in parking facilities to permit access to vanpools	Work Trips	1-5%	1-2.5	Large employers that must draw from regional employment base that results in significant commutes. Employers of 1,000+ best for vanpool results. Worksites in dense, urban CBDs where parking demand exceeds supply and transit alternatives are not readily available. Parking pricing that provides discounts to HOVs, bus stop location no more than 1,000 feet from employee entrance. Free or reduced transit fare passes.
Provide on-site bus transit stops with turnouts, passenger shelters, or benches to encourage use or contribute to off-site development	Work Trips	1-5%	1-2.5	

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Mitigation measures for which,

$$C = K \times E \times (L / M) \times 2$$

Where,

C= Number of Trips Reduced from the Original Work Site after Implementation of the Mitigation Measure
(See Table A11 - 5 - A methodology to use "C")

K = Number of construction workers anticipated to Participate in Trip Reduction mitigation measure per day

or

K1 = Number of workers anticipated to Participate in Trip Reduction mitigation measure per day.

E = Average Non-Work Lunch Trip Rate per Day per Worker
(Use TIA Report or assume 2)

L = Number of Days per Week Construction Workers will Participate in the Mitigation Measure
(Assume 1 to 2.5, based on 5-day work week)

M = Number of Days per Week for which Work Trips are Estimated in Appendix 9

Mitigation Measures	Emission Source	Range of Input Assumptions K	Favorable Factors
Establish or contribute to shuttle service from construction site to retail and food services during lunch hours	Non-Work Trips Construction	1-5%	Large construction site with substantial pool of workers. Areas with significant lunch and food services. Remote construction where mobile food service is difficult or prohibited

Mitigation Measures	Emission Source	Range of Input Assumptions K1	Favorable Factors
Establish or contribute to shuttle service from general worksites to retail and food services during lunch hours	Non-Work Trips	5-50%	Large employers in office park settings more than 1/4 mile from lunchtime destinations. Any worksites without on-site food services.

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Mitigation measures for which,

$$C = G \times (H + I) \times F \times O \times 2$$

Where,

- C = Number of Trips Reduced from the Original Work Site after Implementation of the Mitigation Measure
  (See Table A11 - 5 - A methodology to use "C")
- G = Estimated Trip Reduction from Mitigation Measure
- H = Average Daily Work Trip Generation from a Residence
  (See Table A9 - 5 - A - 2 or assume 1.62)
- I = Average Daily Non-Work Trip Generation from a Residence
  (See Table A9 - 5 - A - 2 or assume 7.39)
- F = Units of Size of Affected Existing or New Land Use(s) for Trip Geacration per Attraction Rate
- O = Number of Daily Trips per Worker
  (Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.26 trips/worker)

Mitigation Measures	Emission Source	Range of Input Assumptions G	Favorable Factors
Include residential units within commercial development or contribute towards its development to reduce VT and/or VMT	Work Trips Non-Work Trips	4-18%	Land use mixes, sizes, numbers of employees, proximity and length of bike/walking lanes/paths Pedestrian-friendly urban design. Comparable match between employment & resident job skills. Most effective when housing to jobs ratio exceeds 1:3

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Mitigation measures for which,

$C = J \times K \times L \times O \times W \times 2$

Where,

- C = Number of Trips Reduced from the Original Work Site after Implementation of the Mitigation Measure
  (See Table A11 - 5 - A methodology to use "C")
- J = Percentage Required Trip Reduction
  ([Target AVR - Baseline AVR]/[Baseline AVR])
- K = Number of employees anticipated to Participate in Trip Reduction mitigation measure per day
- L = Percentage of single occupant vehicles arriving per day at worksite *(default, 70%)*
- O = Number of Daily Trips per Worker
  (Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.26 trips/worker)
- W = Worksite's long-term ability to meet the Required Trip Reduction AVR target (percentage)
  (For example, 10% for a worksite that is able to reduce 10% of its necessary 27% target (1.5-1.1)/1.5)

Mitigation Measures	Emission Source	Range of Input Assumptions for K	Favorable Factors
Develop a trip reduction plan to achieve a 1.5 AVR for multi-tenant worksites with businesses not subject to Regulation XV or with fewer than 100 employees	Work Trips Commute Trips	1-25%	Worksites with common parking facilities and nearby transit alternatives within 1,000 ft of employee entrance. Multi-tenant worksites where aggregate total exceeds 200 and where business operating hours are standard for most employers

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Mitigation measures for which,

$$C = G \times K \times L \times O \times 2$$

Where,

- C = Number of Trips Reduced from the Original Work Site after Implementation of the Mitigation Measure
  (See Table A11 - 5 - A methodology to use "C")
- G = Estimated Trip Reduction from Mitigation Measure
- K = Number of employees anticipated to Participate in Trip Reduction mitigation measure per day
- L = Percentage of single occupant vehicles arriving per day at worksite
  (Default, 70%)
- O = Number of Daily Trips per Worker
  (Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.26 trips/worker)

Mitigation Measure	Emission Source	Range of Input Assumptions G	K	Favorable Factors
Require future employers not subject to Regulation XV to provide centrally located commuter area offering information on transportation alternatives	Work Trips	1-20%	2-3%	Worksites in jurisdictions that require trip reduction plans from non-Regulation XV employers. Those with standard business hours. Worksites in dense urban areas where transit alternatives, parking deficits, large local employee base, and congestion increase ridesharing mode split. Worksites where TMOs planned or required with at least 1 coordinator per 4,000 employees

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Mitigation measures for which,

$$C = (K \times P \times O \times 2) + (K1 \times P1 \times O1 \times 2)^*$$

Where,

- C = Number of Trips Reduced from the Original Work Site after Implementation of the Mitigation Measure
  (See Table A11 - 5 - A methodology to use "C")
- K = Number of employees anticipated to Participate in Trip Reduction mitigation measure per day
- P = Average Percent Increase in Daily Employee Work Trips on Transit Expected With Shuttle
- O = Number of Daily Work Trips per Dwelling Unit
  (Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.62 trips/DU)
- K1 = Number of residents anticipated to Participate in Trip Reduction mitigation measure per day
- P1 = Average Percent Increase in Daily Resident Non-Work Trips on Transit Expected With Shuttle
- O1 = Number of Daily Non-Work Trips per Dwelling Unit
  (Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 7.39 trips/DU)

* This two-part formula accounts for potential vehicle trip reductions from both work and non-work trips from a new residential development to a transit station or worksite. If work trips /ffrom home only will be reduced, use the first half of the formula; if non-work trips are to be reduced, use the second half.

Mitigation Measures	Emission Source	Range of Input Assumptions K/K1	P/P1	Favorable Factors
Establish or contribute to shuttle service from residential subdivisions to rail or multi-modal transit stations	Work Trips Non-Work Trips	1-5%	1-5%	Large projects located in major or housing employment centers where access to rail station within 5 miles can increase commuter rail ridership
Establish or contribute to a shuttle service from residential subdivision to commercial core areas	Work Trips Non-Work Trips	1-5%		Dense subdivision or area with significant adjoining housing core within 5 miles of significant work centers

Quantification was based on previous case studies.
(Including estimates of "C," or percentage reduction in unmitigated vehicle trips)

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QUANTIFIED MITIGATION MEASURES

Mitigation Measures	Emission Source	Range of Input Assumptions C	Favorable Factors
Reduce employee parking spaces for those employers subject to Regulation XV	Work Trips		Worksites in dense CBDs where parking demand exceeds supply, employees are charged to park, significant transit alternatives exist, and on-street parking on nearby residential streets is restricted
Implement or contribute to public outreach and ridesharing education programs	Work Trips Non-Work Trips	1 2.5%	Extent of ridesharing program and promotions.
Employers provide employees incentives for ridesharing or charge for single occupant vehicles to encourage ridesharing	Work Trips	2.5-15%0	For vanpool or carpool subsidy programs, trip reduction is dependent on extent of the incentive. Programs that don't charge HOVs, large employers of 500+, employers that draw on regional labor pool, resulting in longer average commutes of over 15 miles.
Charge to park for non-employees or provide discounts to high occupancy vehicles	Non-Work Trips	2.5 - 15%	Project sites in dense, CBDs where parking options are limited and parking charges exceed $6.0.

UNQUANTIFIED MITIGATION MEASURES

Mitigation Measures	Emission Source	Range of Input Assumptions C	Favorable Factors
Require retail facilities or special event centers to offer transit incentives (e.g., discounted or free transit rides, discounts on purchases or admissions for transit riders)	Non-Work Trips		
Contribute to regional transit systems (e.g., funding for capital improvements, dedication of right-of-way)	Work Trips Non-Work Trips		

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TABLES FOR ESTIMATING VEHICULAR EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE TRIPS BY ELIMINATING A TRIP ALTOGETHER OR UTILIZING A SUBSTITUTE NON-MOTORIZED MODE

Mitigation Measures That Reduce Emissions Associated With Reduction in Average Daily Trips Without an Increase in Vehicle Miles Traveled

- Include Neighborhood Telecommunication Centers in Residential Subdivisions.
- Provide On-Site Child Care Facilities and/or After-School Care Facilities or Contribute to Development Within 1/4 Mile of the Worksite to Reduce VT and/or VMT
- Include Retail Services within or Adjacent to Residential Subdivisions such as Grocery Markets, Copy Centers, Restaurants, Banks, and Day-care, or Contribute to Its Development Within 1/4 Mile to Allow Residents to Walk or Bicycle
- Include Residential Development Within Commercial Core Areas, or Business Districts.
- Provide On-site Employee Services such as Cafeterias, Banks, Grocery Stores, and Other Common Services.
- Implement Compressed Work Week Schedules in Which Weekly Full-Time Hours are Compressed into Fewer than the Normal Five Days (4/40, 9/80, 3/36).
- Establish a Home-Based Telecommuting Program for Employees.
- Construct Off-site Pedestrian Facilities, such as, Overpasses, Wider Sidewalks, Safe Lighting, and Access to Buildings that are Physically Separated From Street and Parking Lot Traffic.
- Construct, Contribute, or Dedicate Land for the Provision of Off-site Bicycle Trails Linking the Facility to Designated Bicycle Commuting Routes.
- Provide Bicycle Parking Facilities, Some of Which are Secured Lockers
- Provide Shower Facilities in Non-Residential Development to Support Bicycle or Pedestrian Travel Modes
- Provide Video Conferencing Facilities

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TABLE A11 - 5 - B

METHODOLOGY FOR VEHICLE TRIP REDUCTION BY ELIMINATING A TRIP ALTOGETHER OR UTILIZING A SUBSTITUTE NON-MOTORIZED MODE

This methodology calculates net emissions after implementation of mitigation measures that cause a reduction in vehicle trips only and does not add vehicle miles traveled by replacement trips. Implementation of these mitigation measures will have direct impacts on emissions from on-road mobile sources, including a reduction in average daily trips, trip lengths, or congestion. It is assumed that indirect impacts may include a slight increase in nonwork trips. It is assumed that indirect impacts may include a slight increase in nonwork trips and increased work trips by substitute traveling modes and activities. In addition, whenever calculating reactive organic compound emissions, removal of diurnal emissions are always added back, as a vehicle still emits ROC emissions when not in use. Separate methodologies are provided in this table to estimate net emissions after implementation of a mitigation measure.

$$N = \{[(A \times \{1-[C/B]\})] + [(\{C/D\} \times Q)]/[454]\} + \{I\}$$

N = Net Emissions In Pounds Per Day After Implementation of Average Daily Trip (ADT) Reduction Measures

A = Total Non-mitigated Vehicular Emissions In Pounds Per Day
(From Table A9 - 5 or Appendix 9 Methodologies);

or,

= (A x {1-[C/B]}) of previous calculations; Residual Emissions of previous calculations, if emission reductions caused by other mitigation measures are eliminated in Table A11- 5 - A from Appendix 11 Methodologies.

B = Total Number of Original Average Vehicle Trips Generated By the Project
(Trips Used to Estimate value for "A" in Table A9 - 5 from Appendix 9 Methodologies)
To Estimate ADT Eliminated due to the Participation in Trip Reduction Programs, Use Table A9 - 5 Methodologies from Appendix 9, and the Needed Data from Table A11 - 5 - B - 1.

C = Number of Trips Eliminated from the Original Work Site after Implementation of the Mitigation Measure
(To calculate "C", see Table A11 - 5 - B - 2 for methodologies specific to individual mitigation measures
To estimate diurnal emissions associated with eliminated trips use

D = 2.0, if non-mitigated vehicular emissions were for 2-way or round trips; or
= 1.0, if non-mitigated vehicular emissions were for 1-way trips.

Q = EMFAC7EP Diurnal Emission Factors (*Applicable only to ROC*) In grams per NOV
To Estimate Emissions Associated with Nonwork Trips Made by the Personal Vehicles of Home-based employees, Use Table A9 - 5 Methodologies from Appendix 9 and the Needed Data from Table A11 - B - 1

I = Non-Work Related Emissions In Pounds Per Day Associated with use of Eliminated Cars for personal trips; (If not applicable to your project, enter 0.0);
= {(B x D x E x F x H)/(454)};

Where,

B = Eliminated Vehicles After Implementation of Mitigation Measure
= (L - O)

D = 0.05; Five percent of eliminated cars used for personal travel such as home to other or shop travel.

E = Number of Trips per Vehicle per Day
(For Round-trip Use 2, and One-way Trip Use 1)

F = Trip Length for Home to Shop or Home to Other (*1-way*)

H = Running Emission Factors In Grams Per Mile With New Speed for New Non-Work Trip

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TABLE A11 - 5 - B - 1

DATA NEED FOR DETERMINING DIRECT IMPACTS

Impacts	Data Need	At Home	Other Work Site
Reduced Work Trips			
	# of Employees Participating Per Day	_____	_____
	# of Days of the Week	_____	_____
	Average Daily Trip Rate per Employee	_____	_____

TABLE A11 - 5 - B - 2

TRIP DEPENDENT INPUT ASSUMPTIONS MEASURES FOR VEHICLE TRIP REDUCTION BY ELIMINATING A TRIP ALTOGETHER OR UTILIZING A SUBSTITUTE NON-MOTORIZED MODE

Mitigation measures for which,

$C = K \times (L / M) \times O \times 2$

Where

C = Number of Trips Eliminated from the Original Work Site after Implementation of the Mitigation Measure
(To use the value of "C", see Table A11 - 5 - B methodology)

K = Number of employees anticipated to Participate in Trip Reduction mitigation measure per day

L = Number of Days per Week Employees will Participate in the Mitigation Measure

M = Number of Days per Week for which Work Trips are Estimated in Appendix 9

O = Number of Daily Trips per Worker.
(Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.26 trips/worker)

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Mitigation Measures	Emission Source	Range of Input Assumptions K	L	Favorable Factors
ANY TWO OF THE FOLLOWING:				
Develop or contribute to off-lighted site bicycle improvements (e.g., development of bicycle route system, bicycle trails linking the facility to designated bicycle routes) or on-site bicycle paths = = & = = Provide bicycle parking facilities, some of which are secured lockers = = & = = Provide shower facilities in non-residential development to support bicycling or pedestrian travel modes	Work Trips	3-10%	1-3	Worksites with existing, bike paths nearby. Nearby residential areas within 5 of worksite with local street miles on thoroughfares with low speed access limits (35 mph and below). Comfortable climate and reasonable air quality in vicinity, and bicycle paths which logically connect neighborhoods and destinations. 1 shower and 8 lockers per 200 employees
BOTH OF THE FOLLOWING:				
Develop or contribute to off-site pedestrian improvements (e.g., overpasses, wider sidewalks) or on-site pedestrian improvements (e.g., exclusive walkway, building access physically separated from street and parking lot traffic = = & = = Shower facilities in non-residential development to support bicycling or pedestrian travel modes	Work Trips Non-Work Trips	2-5%	1-3	Worksites with existing, lighted pedestrian paths nearby. Residential areas within 1/4 mile of worksite with local street access on thoroughfares with low speed limits (35 mph and below). Comfortable climate and reasonable air quality in vicinity, walkable streets and pedestrian-friendly amenities. Areas with grid street system that maximizes access to destination while minimizing walking distance
Require a telecommuting program that allows employees to work at home	Work Trips	1-10%	1-2	Worksites with general office and information industries that accommodate work-at- home strategies where computers, telephones, faxes, etc. can link employees to the workplace. Large employers that attract workers from a regional base, necessitating long commutes for many

AR0073125

Mitigation measures for which,

$C = K \times (L / M) \times O \times 2$

Where,

- C = Number of Trips Eliminated from the Original Work Site after Implementation of the Mitigation Measure
  (To use the value of "C", see Table A11 - 5 - B methodology)
- K = Number of employees anticipated to Participate in Trip Reduction mitigation measure per day
- L = Number of Days per Week Employees will Participate in the Mitigation Measure
- M = Number of Days per Week for which Work Trips are Estimated in Appendix 9
- O = Number of Daily Trips per Worker
  (Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.26 trips/worker)

Mitigation Measures	Emission Source	Range of Input Assumptions K	L	M	Favorable Factors
Implement compressed work week schedules where weekly full-time hours are compressed into fewer working days (e.g., 4/40, 9/80, or 3/36)	Work Trips (9/80 schedule)	10-100%	1	10	Worksites with employers on flexible work schedules where a business can either close for an entire day or operate with a smaller employee pool each day. Maximum VT reductions occur only when the worksite is closed to allow all employees to have same day off
	(4/40 schedule)	10-100%	1	5	
	(3/36 schedule)	10-100%	2	5	

AR0073126

Mitigation measures for which,

$$C = (R / S) \times (L / M) \times O \times 2$$

Where,

- C = Number of Trips Eliminated from the Original Work Site after Implementation of the Mitigation Measure
  (To use the value of "C", see Table A11 - 5 - B methodology)
- R = Number of Residents who Are New Telecommuters
- S = Average vehicle occupancy for work trips
  (Before implementation, default = 1.13)
- L = Number of Days per Week Residents will Participate in the Mitigation Measure
- M = Number of Days per Week for which Work Trips are Estimated in Appendix 9
- O = Number of Daily Trips per Dwelling Unit
  (Use TIA Report or ITE Manual 5th Edition or Table A9 - 5 - A - 2 or assume 1.62 trips/DU)

Mitigation Measures	Emission Source	Range of Input Assumptions R	L	Favorable Factors
Include neighborhood telecommunications center in residential subdivision or contribute to development within 1/4 mile to allow local residents to walk/bike to center	Work Trips	1-5%	1-2	Comparable match between resident job skills and white-collar, information-based employers likely to use such a center. Large subdivision

AR0073127

Mitigation measures for which,

$C = (G \times H \times F \times (L/M) \times 2) + (G1 \times H1 \times F \times (L/M) \times 2)^*$

Where,

C = Number of Trips Eliminated from the Original Work Site after Implementation of the Mitigation Measure
(To use the value of "C", see Table A11 - 5 - B methodology)

G = Estimated Work Trip Reduction from Mitigation Measure

H = Average Daily Work Trip Generation per Dwelling Unit
(See Table A9 - 5 - A - 2 or assume 1.62)

F = Units of Size of Affected Existing or New Land Use(s) for Trip Generation Rate
(i.e., Dwelling Units)

L = Number of Days per Week Residents will Participate in the Mitigation Measure
(Assume 5 days for work trips and 1-2 days for non-work trips)

M = Number of Days per Week for which Work or Non-Work Trips are Estimated in Appendix 9

G1 = Estimated Non-Work Trip Reduction from Mitigation Measure

H1 = Average Daily Non-Work Trip Generation per Dwelling Unit
(See Table A9 - 5 - A - 2 or assume 7.39)

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* This two-part formula estimates the reduction in daily vehicle trips assuming the inclusion of commercial uses in a residential subdivision will attract both work (new employment) and non-work trips. If work or non-work trips are not expected to decrease from this measure, enter "0" for G or G1.

Mitigation Measures	Emission Source	Range of Input Assumptions G/G1	Favorable Factors
Include retail services within or adjacent (1/4 mile) of residential subdivisions such as grocery markets, copy centers, restaurants, banks, etc.	Work Trips Non-Work Trips	4-13%	Projects which include commercial uses likely to be used everyday or on frequent basis, & which are centrally located to increase the appeal of walking/bicycling to the use. Also dependent on match of new jobs to the job skills of potential residents

AR0073128

Measures measures for which,

$C = G \times H \times K \times H2 \times (L/M) \times 2$

Where,

- C = Number of Trips Eliminated from the Original Work Site after Implementation of the Mitigation Measure
  (To use the value of "C", see Table A11 - 5 - B methodology)
- G = Estimated Trip Reduction from Mitigation Measure
- H = Average Daily Non-Work Trip Generation per Worker
  (See Table A9 - 5 - A - 2 or assume 5.72)
- K = Number of employees anticipated to Participate in Trip Reduction mitigation measure/day
- L = Number of Days per Week Workers will Participate in the Mitigation Measure
  (Default assumption: 3-5 days)
- M = Number of Days per Week for which Non-Work Trips are Estimated in Appendix 9
- H2 = Percent of Daily Non-Work Trips Performed During Work Day e.g., Lunch, breaks
  (Default assumption, 35%)

QUANTIFIED MITIGATION MEASURES

Mitigation Measures	Emission Source	Range of Input Assumptions G	K	Favorable Factors
Provide on-site employee services such as cafeterias, banks, grocery stores, and other common services	Non-Work Trips	10-50%	25-50%	On-site services needed by employees on a regular basis. Extent of services, size of cafeteria, lack of similar services within 5 mile radius of worksite
Provide on-site child care facilities and/or after school care facilities or contribute to such development within 1/4 mile of worksite to reduce VT and/or VMT	Non-Work Trips	1-10%	1-10	Worksites with large employers, locations in office parks where pooling of resources to create common child care facility. Employers who rely on regional labor force, necessitating longer commutes for some employees. Proximity to pre- or elementary schools. Pleasant environment and amenities at the center

AR0073129

UNQUANTIFIED MITIGATION MEASURES

Mitigation Measures	Emission Source	Range of Input Assumptions G	K	Favorable Factors
Provide video conference facilities or contribute to development in office parks or multi-tenant worksites	Work Trips	29%*		* Up to 29% reduction in work trips from meeting participants has been documented

AR0073130

TABLES FOR ESTIMATING VEHICULAR EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE VEHICLE MILES TRAVELED

Mitigation Measures That Reduce Emissions Associated With Reduction in Average Daily Vehicle Miles Traveled with No Decrease in Average Daily Trips

- Implement Home Dispatching Systems Where Employees Receive Routing Schedule by Phone Instead of Driving to Work.
- Utilize Satellite Offices Rather than Regular Worksite for Multi-Sited Employers to Reduce Employee VMT.
- Construct or Contribute to Development of Off-Site Park-n-Ride Lots or Designate Parking Spaces in Excess of Code Requirements for Park-n-Ride.

AR0073131

TABLE A11 - 5 - C

METHODOLOGY FOR VEHICLE MILES TRAVELED REDUCTION (VMT REDUCTION)

This methodology calculates net emissions after implementation of mitigation measures that reduce vehicle miles traveled (VMT) without reducing vehicle trips. As these measures do not affect the number of vehicles and employees, average daily trips will be the same as those used to estimate non-mitigated emissions, though new and weighted average trip lengths will be less. Emission reductions are due to reductions in trip length, running exhaust, and evaporative emissions. Diurnal emissions do not need to be added, having been estimated in the non-mitigated emissions. Since the travel mode remains the same, there are no additional or substitute emissions from increased nonwork trips.

$N = [A - \{Y \times (E / F)\}]$

- N = Net Emissions In Pounds Per Day After Implementation of Vehicle Miles Traveled (VMT) Reduction Measures
- A = Total Non-mitigated Vehicular Emissions *(From Table A9 - 5 or Appendix 9 Methodologies)* In Pounds Per Day;
- Y = Total Non-mitigated Vehicular Running Exhaust and Evaporative Emissions In Pounds Per Day; *(From Table A9 - 5 or Appendix 9 Methodologies)*
- F = Original Trip Length *(Used to determine VMT in Table A9 - 5 of Appendix 9 to estimate non-mitigated running exhaust and running evaporative emissions in "A.")*.
- E = Average (Shorter or Reduced) Daily Trip Length or Traveling Distance After Implementation of Mitigation Measure *(See Table A11 - 5 - C - 1 and A11 - 5 - C - 2 for more variables specific to particular mitigation measures)*
  $= P1 \times [F - (H \times I/G)]$ *(Weighted Average Daily Trip Length)*

  Where,
  - P1 = Number of Employees Participating in VMT Reduction Measures
  - F = Original Trip Length *(Used to determine VMT in Table A9 - 5 of Appendix 9 to estimate non-mitigated running exhaust and running evaporative emissions in "A.")*.
  - G = Number of Days Traveled with Original Trip Length or the Distance to the project site.
  - H = New Trip Length or New Traveling Distance *(Associated with the mitigation measure)*
  - I = Number of Days Traveled with New Trip Length or New Distance to Other Work Sites.
    (I and G should equal to Number of Days [Maximum 7.0] used to Determine Non-mitigated Vehicular Emissions Using Original Trip Length in Table A9 - 5 of Appendix 9.)

TABLE A11 - 5 - C - 1

DATA NEED FOR DETERMINING DIRECT IMPACTS (REDUCTION IN AVERAGE TRIP LENGTH)

Impacts	Data Need	Other Work Sites	Project Site
	Non-mitigated Vehicular Emissions (A)	_____	_____
	Non-mitigated Running Vehicular Emissions (Y)	_____	_____
	% of Employees Participating (P1)	_____	_____
	New Trip Length (H)	_____	_____
	# of Days of the Week with New Trip Length (I)	_____	_____
	Original Trip Length (F)	_____	_____
	# of Days of the Week with Original Trip Length (G)	_____	_____

AR0073132

TABLE A11 - 5 - C - 2

TRIP DEPENDENT INPUT ASSUMPTIONS (E)
MEASURES THAT REDUCE VEHICLE MILES TRAVELED WITHOUT A DECREASE IN VEHICLE TRIPS

Mitigation Measures	Emission Source	Range of Input Assumptions P1	J	H	Favorable Factors
Implement home dispatching system where employees receive routing schedule by phone instead of driving to work ** Assume anywhere from 1/10 to 1/4 of "F"	Work Trips	1-25%	1-3	**	Worksites where construction and sales employers expected. Employers in urbanizing areas, commercial/industrial areas that rely on workers to commute from outlying residential areas

Mitigation Measures	Emission Source	Range of Input Assumptions P1	J	H	Favorable Factors
Require use of satellite offices rather than regular worksite for multi-sited employers to reduce VMT by allowing them to report to the nearest worksite ** Assume anywhere from 1/10 to 1/4 of "F"	Work Trips	1-5%	1-5	**	Worksites where large employers of 1000+ & multiple branch offices throughout the region are anticipated. Work-geared to information-based industries that can reassign worksite destinations for its employees or permit occasional use of other satellite offices

AR0073133

Mitigation Measures for which

$$E = [(0.5 \times V \times I) + \{(1 - 0.5) \times F \times G\}]/(1 + G)$$

where

V = Number of Parking Spaces Set Aside for Park-N-Ride Spaces (Project-specific Input)

Mitigation Measures	Emission Source	Range of Input Assumptions G	I	H	Favorable Factors
Construct or contribute to development of off-site park-n-ride lots or designate parking in excess of code requirements for park-n-ride	Work Trips Non-Work Trips	1-3	**		Park-n-ride location near transit station or freeway w/convenient access/proximity to residential concentrations w/i 5 mi. HOV lanes on freeways enhance use of park-n-rides, larger lots of 300+ spaces

** Assume 1/6 of "F"

AR0073134

TABLES FOR ESTIMATING VEHICULAR EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES THAT IMPROVE AVERAGE VEHICLE RIDERSHIP

Mitigation Measures
That Reduce Emissions Associated With Increased
Average Vehicle Ridership

- Establish or Contribute to Shuttle Service from Residential Subdivision to Commercial Core Areas.
- Construct On-site or Off-site Bus Turn-outs, Passenger Benches and Shelters or Contribute to Off-Site Development.
- Require Retail and Special Event Facilities to Offer Customers Travel Incentives such as Discounted or Free Transit to Clients, or Discounts on Purchases or Admission for Transit Riders and Other Promotional Type Events.
- Reduce Employee Parking Spaces for Those Employers Subject to Regulation XV.
- Require Future Employers Not Subject to Regulation XV to Provide Centrally Located Commuter Information Area Offering Information on Transportation Alternatives.
- Develop a Trip Reduction Plan to Achieve 1.5 AVR or Higher, for Multi Tenant Worksites or Businesses with Less than 100 Employees.
- Provide or Contribute to Shuttle Service from Residential Subdivisions to Major Transit Centers.
- Contribute to Regional Transit Systems (i.e., Right of Way, Capital Improvements, etc.).
- Provide Preferential Parking Spaces for Carpools and Vanpools.
- Provide Minimum Vertical Clearance of 72" in Parking Facilities to Permit Access for Vanpools
- Develop a Trip Reduction Plan to Achieve a 1.5 AVR or Higher for Construction Employees (CONSTRUCTION)

AR0073135

TABLE A11 -5 - D

METHODOLOGY FOR AVERAGE VEHICLE RIDERSHIP IMPROVEMENT (INCREASED AVR)

This methodology calculates net emissions after implementation of mitigation measures that improve Average Vehicle Ridership (AVR). AVR is defined as the number of employees arriving at a site divided by the number of cars arriving at the project site. Even after implementation of mitigation measures, the number of employees arriving at the project site will be the same as that assumed for non-mitigated emissions. However, the average number of cars arriving at the project site will be less, resulting in emission reductions. Since this methodology removes all emissions associated with eliminated trips, diurnal emissions associated with these eliminated vehicles must be added back. Net emission reductions will be affected if vehicle trips are eliminated, as increased availability of vehicles at home may increase non-work trips by up to 5%.

It must be noted that while these measures reduce the number of cars arriving to the worksite, the reduction in vehicle trip emissions will be largely negated if ridesharers drive individually to carpool meeting points or park-n-ride lots, as there are additional emissions from these travel modes. All mitigation measures that a) reduce Vehicle Trips with an Increase in VMT and b) reduce VMT result in secondary impacts, namely an increase in Average Vehicle Ridership. Consequently, mitigation measures that increase AVR will have the same direct impacts as indicated in either Table A11 - 5 - A or A11 - 5 - C.

$N = [A \times (J/M)] + [V] + [W] + [X] + [Y] + [Z] + [I]$, or
$N = [A \times (O/L)] + [V] + [W] + [X] + [Y] + [Z] + [I]$, if K is equal to N; or
$N = [A \times (J/M) \times (N/K)] + [V] + [W] + [X] + [Y] + [Z] + [I]$, if K is not equal to N.
(*For Mitigation Measure to Work Effectively, the Value for K Should be Equal or Greater than the Value for N*)

- N = Net Emissions After Implementation of Mitigation Measures That Improve Average Vehicle Ridership
- A = Total Non-mitigated Vehicular Emissions (*Resulted from Table A9 - 5 or Appendix 9 Methodologies*);
- J = Original Average Vehicle Ridership
  - = K/L; Where,
    - K = Original Number of Persons Arriving at the Project Site Before Implementation of Mitigation. (*Used to Estimate Non-mitigated Emissions, "A," using Table A9 - 5 of Appendix 9*).
    - L = Original Number of Cars Arriving at the Project Site Before Implementation of Mitigation. (*Used to Estimate Non-mitigated Emissions in Appendix 9*)
- M = New Improved Average Vehicle Ridership After Implementation of Mitigation Measure
  - = N/O; Where,
    - N = Weighted Average Daily Number of Persons Arriving at the Project Site
      - = $\{[P \times Q] + [K \times R]\}/\{Q + R\}$
      - P = New (Reduced) Number of Persons Arriving at the Project Site After Implementation of Mitigation Measure.
      - Q = Number of Days New (Reduced) Number of Persons Traveled to the Project Site After Implementation of Mitigation Measure.
      - R = Number of Days Original (Appendix 9) Number of Persons Traveled to the Project Site After Implementation of Mitigation Measure.
    - O = Weighted Average Daily Number of Cars Arriving at the Project Site
      - = $\{[S \times T] + [L \times U]\}/\{T + U\}$
      - S = Reduced No. of Cars Arriving at the Site After Implementation of Mitigation Measure.

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T = Number of Days New (Reduced) Number of Cars Traveled to the Project Site After Implementation of Mitigation Measure.

U = Number of Days Original (Appendix 9) Number of Cars Traveled to the Project Site After Implementation of Mitigation Measure.
(The Total of Q and R, and T and U Should be Equal to Number of Days [Maximum Would be 7.0] Used to Determine Non-mitigated Vehicular Emissions Using Original Number of Cars in Table A9 - 5 of Appendix 9.)

V = Diurnal ROC Emissions Pounds Per Day Associated with Removed Cars
(This Addition is Only for ROC)
= (B x C)/454; where,
B = Removed Vehicles After Implementation of Mitigation Measure = (L - O)
C = Diurnal ROC Emission Factor In Grams Per NOV
(This Emission Factor is Only for ROC)

Please estimate running exhaust, running evaporative, start-up, and hot soak emissions with the following modes. Also estimate diurnal emissions for all other modes except for R and X mode of transport, i.e., removed vehicles reused with shorter trip lengths.

To estimate emissions associated with the following (various) Travel Modes, Use Table A9 - 5 Methodologies from Appendix 9 and the Needed Data from TABLE A11 - 1 - C.

W = Additional Emissions In Pounds Per Day After Implementation of Mitigation Measure or with Improved AVR Associated with Certain Number of Employees Traveling in Personal Cars (Removed) to Other Work Sites with Shorter Traveling Distance
(If not applicable to the project, enter 0.0); and/or

X = Additional Emissions In Pounds Per Day After Implementation of Mitigation Measure or with Improved AVR Associated with Certain Number of Employees Traveling in Buses (Removed) to Other Work Sites with Shorter Traveling Distance
(If not applicable to the project, enter 0.0); and/or

Y = Additional Emissions In Pounds Per Day After Implementation of Mitigation Measure or with Improved AVR Associated with Certain Number of Employees Traveling in Shuttles (Removed) to Other Work Sites with Shorter Traveling Distance
(If not applicable to the project, enter 0.0); and/or

Z = Additional Emissions In Pounds Per Day Associated with Certain Number of Employees Traveling in Personal Cars to to Pick Up Employees At Their Houses
(If not applicable to the project, enter 0.0); and/or

To estimate emissions associated with Nonwork Trips made by the Personal Vehicles of Home-based employees, Use Table A9 - 5 Methodologies from Appendix 9 and the Needed Data from TABLE A11 - 1 - B.

I = Non-Work Related Emissions Associated with Use of Removed Cars for Personal Trips;
(If not applicable to the project, enter 0.0);
= (B x D x E x F x H)/454; where,
B = Removed Vehicles After Implementation of Mitigation Measure = (L - O)
D = 0.05; Five Percent of Removed Cars Used for Personal Travel Such as Home to Other or Shop Travel
E = Number of Trips per Vehicle per Day
(For Round-Trip Use 2, and One-way Trip Use 1)
F = Trip Length for Home to Shop or Home to Other
G = New Speed For this Short Travel
H = Emission Factors In Grams Per Mile With New Speed

AR0073137

TABLE A11 -5 - D - 1

AVERAGE VEHICLE RIDERSHIP DEPENDENT DATA NEEDED TO DETERMINE DIRECT IMPACTS (REDUCTION IN CARS ARRIVING AT THE PROJECT SITE)

(AVR = Number of Persons Arriving At a Site/Number of Cars Arriving at That Site)

Mitigation Measures	Participation	Current or Original Impact		Estimated Impact	
		# Cars Arriving	Current AVR	# Cars Ariving	New AVR
e.g., Shuttle Service from Home to Work	15 out of 100	100	100/100+1.0	(100-30)=70	100/70=1.4

TABLES FOR ESTIMATING VEHICULAR EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES THAT RELY ON PRICING STRATEGIES

Mitigation Measures
That Rely on Pricing Strategies
Reduce Emissions Associated With
Average Daily Trips and Vehicle Miles Traveled

- Provide Employees with Cash Allowances for Ridesharing
- Charge Employees or Visitors to Park, or Provide Discounts to High Occupancy Vehicles
- Pay or Provide Employer Incentives Not to Drive Once a Week

AR0073139

TABLE A11 - 5 - E

METHODOLOGY TO DETERMINE IMPACT OF PRICING STRUCTURES

Mitigation measures with pricing structures will have the same direct impacts as indicated for those same measures in Tables A11 - 5 - A, B, C or D of Appendix 11 (i.e., increase in Average Vehicle Ridership (AVR), and/or reduction in Average Daily Trips (ADT) with increase in VMT by substitute travel modes, Average Daily Trips (ADT) without an increase in VMT or Vehicle Miles Traveled (VMT) with no reduction in ADT). Methodologies and data needed should be the same as described in those four tables. Because the variables that determine vehicle trips and/or VMT reductions from a pricing standpoint are dependent on a myriad of influences, methodologies based on pricing are not provided. For example, the efficiency of a mitigation measure in reducing vehicle trips may be dependent on the allowance paid to employee by the employer or vice versa. If an employer increases the allowance for parking by 50 cents, it may linearly increase AVR by 0.1 or remove 10 average daily trips and 5 cars, or reduce average trip length by 2 miles. These results are largely based on demand elasticities. Consequently, any data that follows is based on published studies that compared pricing strategies with travel demand.

TABLE A11 - 5 - E - 1

DATA NEEDED FOR DETERMINING DIRECT IMPACTS (REMOVED AVERAGE DAILY TRIPS FROM ORIGINAL AVERAGE DAILY TRIPS)

Impacts	Data Need	At Home	Other Site	Project Site
Reduced Work Trips	Type of Mitigation Measure: e.g. Cash Allowance for Ridesharing $5.00/Day of Participation (Pre-Parking Charges) Cash Allowance For That Mitigation Measure			
	# of Employees Participating Per Day	N/A		
	# of Days of the Week	N/A		
	Average Daily Trip Rate/Employee	N/A		

TABLE A11 - 5 - E - 2

DATA NEEDED FOR DETERMINING INDIRECT IMPACTS (ADDITION OF NEW AVERAGE DAILY NONWORK TRIPS)

Impacts	Data Need	At Home	Other Site	Project Site
Added Nonwork Trips	Type of Mitigation Measure: e.g. Cash Allowance for Ridesharing Cash Allowance For That Mitigation Measure $5.00/Day of Participation (Pre-Parking Charges)			
	# of Employees Participating Per Day	N/A		
	# of Days of the Week	N/A		
	Average Daily Trip Rate/Employee	N/A		
	Average Trip Length	N/A		
	Average Speed	N/A		

AR0073140

TABLE A11 - 5 - E - 3

DATA NEED FOR DETERMINING INDIRECT IMPACT (ADDITION OF NEW AVERAGE DAILY WORK TRIPS)

Impacts	Travel Modes	Data Need	At Home	Other Site	Project Site
Added Work Trips By Vehicles From Homes to Work or Work Centers	Type of Mitigation Measure: e.g. Cash Allowance for Ridesharing Cash Allowance for That Mitigation Measure $ 5.00/Day of Participation (Pre-Parking Charges)				
	o Cars				
	# of Employees Participating Per Day	N/A			
	# of Days of the Week	N/A			
	Average Daily Trip Rate/Employee	N/A			
	Average Trip Length	N/A			
	Average Speed	N/A			
	o Buses				
	# of Employees Participating Per Day	N/A			
	# of Days of the Week	N/A			
	Average Daily Trip Rate/Employee	N/A			
	Average Trip Length	N/A			
	Average Speed	N/A			
	o Shuttles				
	# of Employees Participating Per Day	N/A			
	# of Days of the Week	N/A			
	Average Daily Trip Rate/Employee	N/A			
	Average Trip Length	N/A			
	Average Speed	N/A			

AR0073141

TABLE A11 - 5 - E - 4

DATA NEED FOR DETERMINING DIRECT IMPACTS (REMOVED TRIP LENGTH FROM ORIGINAL TRIP LENGTH) (CAUSING REDUCTION IN VMT)

Impacts	Data Need	Other Work Site	Project Site
Reduced VMT	Type of Mitigation Measure: e.g. Cash Allowance for Ridesharing Cash Allowance For That Mitigation Measure $5.00/Day of Participation (Pre-Parking Charges) New Trip Length (G) # of Days of the Week with New Trip Length (H) Original Trip Length (I) # of Days of the Week with Original Trip Length (F)	____ ____ ____ ____	____ ____ ____ ____

TABLE A11 - 5 - E - 5

PRICE DEPENDENT INPUT ASSUMPTIONS TO DETERMINE DIRECT IMPACTS (REDUCTION IN ADT)

Mitigation Measure	Cash Amount Per Day $	Percent Reduction in Average Daily Trips
Cash Allowances for Ridesharing (Pre-Parking Charges)	Less Than 1.0	**
	1.0	**
	2.0	**
	3.0	**
	4.0	**
	5.0	**
	10.0	**
	Other	**
Charge to Park (After Any Subsidies)	Less Than 1.0	**
	1.0	4.0%
	2.0	9.0%
	3.0	1.8%-15.0%
	4.0	20.0%
	5.0	25.0%
	6.0	31.0%
	Other	**
Pay or Provide Employer Incentives to Not Drive	**	

** Input assumptions to be included as information becomes available

AR0073142

TABLES FOR ESTIMATING VEHICULAR EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE CONGESTION AND IMPROVE SPEED WITH INCREASED NUMBER OF VEHICLES

Mitigation Measures That Reduce Emissions Associated With On- and Off-Road Congestion

OPERATION

- Implement On-Site Circulation Plan in Parking Lots to Reduce Emissions From Queuing Vehicles
- Improve Traffic Flow at Drive-Throughs by Designing Separate Windows for Different Functions and Providing Temporary Parking for Orders That Are Not Immediately Ready for Pickup
- Construct On- or Off-Site Bus Turnouts, Passenger Benches, and Shelters
- Synchronize Traffic Lights on Streets Impacted by Development
- Reschedule Truck Deliveries and Pickups for Off-Peak Hours
- Implement Staggered Work Hours So That Employees Arrive and Depart From Work Stations at Different Times and Reduce Vehicle Queuing
- Set Up Paid Parking System Where Drivers Pay at a Walkup Kiosk and Exit Via a Stamped Ticket to Reduce Vehicle Queuing
- Require On-Site Truck Loading Zones

CONSTRUCTION

- Configure Construction Parking to Minimize Traffic Interference
- Provide Temporary Traffic Control During All Phases of Construction Activities to Improve Traffic Flow, Such as Providing a Flag Person to Direct Traffic and Ensure Safe Movements Off the Site
- Schedule Off-Site Cut-and-Fill Transport and Other Construction Activities to Off-Peak Hours (i.e., Between 7:00 p.m. and 6:00 a.m. and Between 10:00 a.m. and 3:00 p.m.)
- Develop a Construction Traffic Management Plan That Includes, But Is Not Limited to: a) Rescheduling Goods Movements for Off-Peak Hours; b) Rerouting Construction Trucks Off Congested Streets; c) Consolidating Truck Deliveries; d) Providing Dedicated Turn Lanes for Movement of Construction Trucks and Equipment On- and Off-Site

AR0073143

TABLE A11 - 5 - F

METHODOLOGY FOR REDUCED CONGESTION (INCREASED NUMBER OF VEHICLES WITH IMPROVED SPEED)

This methodology calculates the net emissions after implementation of mitigation measures that cause a reduction only in traffic congestion. The number of vehicles traveling on roadways over a given period of time will increase due to improved speeds and improved circulation. Improved speed will improve the corresponding emission factor for the traveling vehicle, causing a reduction in emissions.

$$N = [A \times (E/F) \times (G/H)]$$

- N = Net Emissions After Implementation of Average Daily Trip (ADT) Reduction Measures
- A = Total Non-mitigated Vehicular Emissions *(Resulting from Table A9 - 5 of Appendix 9 Methodologies)*
- E = New Number of Vehicles on the Same Road After Implementation of Mitigation Measure *(Traffic Study)*
- F = Original Number of Vehicles on That Road Used for Original LOS *(Traffic Study Input)*
- E = New Number of Vehicles on the Same Road After Implementation of Mitigation Measure *(Traffic Study)*
- G = New Speed-Dependent Emission Factors
- H = Original Speed-Dependent Emission Factor *(Table A9-5 of Appendix 9)*

TABLE A11 - 5 - F - 1

RELATIONSHIP BETWEEN TRIP SPEED AND NUMBER OF VEHICLES (ROAD CAPACITY) PASSING A CERTAIN POINT IN ONE HOUR, BY ROAD TYPE (MPH AND NUMBER OF VEHICLES PER HOUR)

Traffic impact analysis should provide number of vehicles on nearby roads. To determine fleet mix (passenger and trucks) on the following road types please use EPA report Contract Number A2-155-32 on Assessment of Heavy-Duty Gasoline and Diesel Vehicles in California: Population and Use Patterns, Prepared in July 1985 by Yuji Horie, Richard Rapoport of Pacific Environmental Services, Inc. Passenger vehicles include all autos and light-duty trucks; trucks include all medium-duty, light-heavy, medium-heavy, and heavy-heavy-duty trucks.

Traveling Speed/Number of Vehicles Crossing an Intersection Per Hour

County		Los Angeles		Orange		Riverside		San Bernardino	
Road Type	Year	1987	2010	1987	2010	1987	2010	1987	2010
Freeways									
Speed/One Hour		55	55	60	60	60	60	60	60
Vehicle Capacity		/1650	/1650	/1750	/1750	/1750	/1750	/1750	/1750
Non-Freeway									
Speed/One Hour		20	20	28.3	28.3	33.33	33.33	36.33	38.33
Vehicle Capacity		/550	/550	/575	/575	/600	/600	/800	/800
Major Arterial									
Speed/One Hour		20	20	30	30	35	35	40	40
Vehicle Capacity		/600	/600	/625	/625	/650	/650	/800	/800
Primary Arterial									
Speed/One Hour		20	20	30	30	35	35	40	40
Vehicle Capacity		/550	/550	/575	/575	/600	/600	/800	/800
Secondary Arterial									
Speed/One Hour		20	20	25	25	30	30	35	35
Vehicle Capacity		/500	/500	/525	/525	/550	/550	/800	/800

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TABLES FOR ESTIMATING VEHICULAR EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE THE USE OF GASOLINE- AND DIESEL-FUELED VEHICLES

Mitigation Measures That Reduce Emissions Associated With Gasoline- and Diesel-Fueled Vehicles By Utilizing Alternate Fuel-Fueled Vehicles

- Use Low-Emission Vehicles (LEVs) (Scheduled Penetration Between 1998 and 2004)
- Use Ultra Low Emission Vehicles (ULEVs) (Scheduled Penetration Between 1998 and 2010)
- Use Zero Emission Vehicles (ZEVs) (Scheduled Penetration Between 1998 and 2010)
  (*For Percent Penetration See Attached Table*)

SOURCE: ARB's Staff Report for Proposed Regulations for Low-Emission Vehicles and Clean Fuel

AR0073145

TABLE A11 - 5 - G

METHODOLOGY FOR REDUCED NUMBER OF GASOLINE-FUELED AND DIESEL-FUELED VEHICLES WITH INCREASED NUMBER OF ALTERNATE FUEL-FUELED VEHICLES

This methodology is for net emissions after implementation of mitigation measures that cause a reduction only in the number of gasoline- and diesel-fueled vehicles.

N = [A x (1 - L)] + [((F x L) x (ADT Rate*) x (Trip Length**) x (New Running Exhaust and Evaporative Emission Factor***)] + {(F x L) x (ADT Rate*) x (New Start-Up Emission Factor***)} + {(F x L) x (ADT Rate*) x (New Hot-Soak Emission Factor***)} + {(F x L) x (New Diurnal Emission Factor***)}; Where,

N = Net Emissions After Implementation of Measures that Reduce Diesel- and Gasoline-fueled Vehicles.

A = Total Nonmitigated Vehicular Emissions
(*Resulting from Table A9 - 5 or Appendix 9 Methodologies* for the First Mitigation Measure);
Please repeat the same formula for each type of alternatively fueled vehicle. When repeating the formula use net emissions from previous calculations as nonmitigated emissions.

(Note: Please note all vehicle categories (LEVs, ULEVs and ZEVs) fueled with varieties of fuels will have the same emissions factor, i.e., emission factor will be dependent on vehicle category and not fuel category. The emission factor is not fuel dependent.)

F = Original Number of Project-Related Gasoline-and Diesel-Fueled Vehicles (*Traffic Study Input*)

L = Fraction or Percent Vehicles Replaced With Alternate Fuel-Fueled Vehicles
(Mitigations should at least utilize the same percent substitutions for that build-out year as indicated in Table A11 - 5 - G - 1. If a lower percent is utilized, please provide reasons for not utilizing available percent penetration rate.)

(F x L) = New (Reduced) Number of Alternatively Fueled Vehicles
After Implementation of Mitigation Measure (*Traffic Study*)

* For ADT Rates, Please See Table A9 - 5 of Appendix 9 or Traffic Analysis Used to Estimate Nonmitigated Emissions (A)

** For Trip Length, Please See Table A9 - 5 of Appendix 9 or Traffic Analysis Used to Estimate Nonmitigated Emissions (A).

*** For Emission Factors Contact California Air Resources Board or Manufacturers of the New Vehicles.

(If Emission Factors are not available, please indicate potential emission reduction by using Fractions provided in ARB's Staff Report on Clean Fuel Regulation, and make a statement to indicate that additional emissions from substitute vehicles will be estimated when emission factors are available for substitute vehicles.)

Note: ADT and Trip Length data should be weighted for the average of seven days, i.e., five days for workdays and two days for weekends.

TABLE A11 - 5 - G - 1

ALTERNATE FUEL-FUELED VEHICLE PENETRATION SCHEDULE
Passenger Vehicles or Vehicles Gross Vehicle Weight of 6,000 Pounds or Less
(Percent)

	LEV	ULEV	ZEV	Year	LEV	ULEV	ZEV
1998	48	2	2	2005	- -	80	20
1999	73	2	2	2006	- -	80	20
2000	96	2	2	2007	- -	65	35
2001	90	5	5	2008	- -	65	35
2002	85	10	5	2009	- -	50	50
2003	75	15	10	2010	- -	50	50
2004	50	40	10	2011(Unknown)	U	U	U

* LEV = Low-Emission Vehicles; ULEV = Ultra-Low-Emission Vehicles; ZEV = Zero-Emission Vehicles

AR0073146

TABLE A11 - 5 - G - 2

ALTERNATE FUEL-FUELED VEHICLE PENETRATION SCHEDULE
(Grams Per Mile)

Reactive Organic Gases	TLEV	LEV	ULEV	ZEV
Up to 50,000 Miles				
Low-Emission Vehicles	0.115	0.069	0.057	0.0
Gasoline Standards For Flexible and Dual-Fuel Low-Emission Vehicles	0.23	0.115	0.069	0.0
Up to 100,000 Miles				
Low-Emission Vehicles	0.143	0.083	0.051	0.0
Gasoline Standards For Flexible and Dual-Fuel Low-Emission Vehicles	0.28	0.143	0.083	0.0

Carbon Monoxide	TLEV	LEV	ULEV	ZEV
Up to 50,000 Miles				
Low-Emission Vehicles	3.4	3.4	1.7	0.0
Gasoline Standards For Flexible and Dual-Fuel Low-Emission Vehicles	3.4	3.4	1.7	0.0
Up to 100,000 Miles				
Low-Emission Vehicles	4.2	4.2	2.1	0.0
Gasoline Standards For Flexible and Dual-Fuel Low-Emission Vehicles	4.2	4.2	2.1	0.0

Oxides of Nitrogen	TLEV	LEV	ULEV	ZEV
Up to 50,000 Miles				
Low-Emission Vehicles	0.4	0.2	0.2	0.0
Gasoline Standards For Flexible and Dual-Fuel Low-Emission Vehicles	0.4	0.2	0.2	0.0
Up to 100,000 Miles				
Low-Emission Vehicles	0.6	0.3	0.3	0.0
Gasoline Standards For Flexible and Dual-Fuel Low-Emission Vehicles	0.6	0.3	0.3	0.0

TABLE A11 - 5 - G - 3

1993 - 1998 ALTERNATE FUEL-FUELED VEHICLE EMISSION FACTORS
(Grams Per Mile)

YEARS	DISTANCE TRAVELED (Miles)	ROC	CO	NOx	Notes
		(Grams per Miles)			
1993 - 1994					
Primary	Up to 50,000 Miles	0.23	3.4	0.4	- -
	50,00 to 100, 000	0.23	3.4	0.7	- -
	100,00	0.29	4.2	- -	1993 Option Only
Secondary	Up to 50,000 Miles	0.36	7.0	0.4	- -
	50,00 to 100, 000	0.36	7.0	0.7	Optional
	100,00	0.42	8.3	1.0	Diesel Option

AR0073147

TABLE A11 - 5 - H

EMISSION FACTORS FOR ESTIMATING BUS EMISSIONS

USE

TABLE A9 - 34 - A

FOR BUS RELATED
VEHICLE MILES TRAVELED (VMT)
AVERAGE DAILY TRIPS (ADT) AND NUMBER OF VEHICLES (NOV)
IN
COUNTYWIDE AND REGIONWIDE FLEET MIX
AND

TABLE A9 - 5 - G*

FOR THEIR PERCENTAGES

USE

TABLE A9 - 5 - P - 1 AND 2

FOR DETERMINING COMPOSITE EMISSION FACTOR BETWEEN
FOUR DIFFERENT TYPES OF VEHICLES TOGETHER, SUCH AS,
PASSENGER VEHICLES, MATERIAL HAULING VEHICLES AND
MOTORCYCLES
INCLUDING BUSES
AND
BETWEEN RUNNING, HOT AND COLD START EMISSION FACTORS FOR
THE BUSES

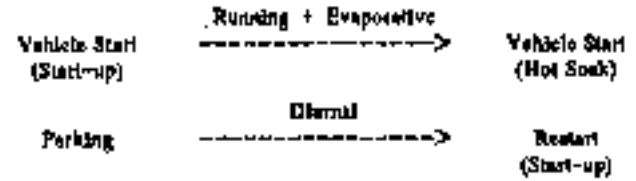
(* IF PROJECT-SPECIFIC FLEET MIX DATA IS NOT AVAILABLE,
USE TABLE A9 - 5 - G TO DETERMINE PROJECT RELATED
FLEET MIX DATA)

AR0073148

Table A11 - 5 - H - 1
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 1991

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	63.73	63.73	63.73	9.83	9.83	9.83	37.15	37.15	37.15	2.31	0.66
10	43.95	43.95	43.95	7.72	7.72	7.72	30.82	30.82	30.82	2.31	0.66
15	31.71	31.71	31.71	6.19	6.19	6.19	26.49	26.49	26.49	2.31	0.66
20	23.95	23.95	23.95	5.08	5.08	5.08	23.60	23.60	23.60	2.31	0.66
25	18.93	18.93	18.93	4.26	4.26	4.26	21.78	21.78	21.78	2.31	0.66
30	15.66	15.66	15.66	3.65	3.65	3.65	20.83	20.83	20.83	2.31	0.66
35	13.55	13.55	13.55	3.20	3.20	3.20	20.63	20.63	20.63	2.31	0.66
40	12.28	12.28	12.28	2.87	2.87	2.87	21.18	21.18	21.18	2.31	0.66
45	11.64	11.64	11.64	2.62	2.62	2.62	22.53	22.53	22.53	2.31	0.66
50	11.55	11.55	11.55	2.46	2.46	2.46	24.83	24.83	24.83	2.31	0.66
55	12.00	12.00	12.00	2.36	2.36	2.36	28.36	28.36	28.36	2.31	0.66
60	13.04	13.04	13.04	2.30	2.30	2.30	33.56	33.56	33.56	2.31	0.66
65	14.83	14.83	14.83	2.30	2.30	2.30	41.14	41.14	41.14	2.31	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	---	---	---	N/A	N/A	N/A	---	---	---		
DIURNAL** (Grams/Vehicle/Day)	---	---	---	N/A	N/A	N/A	---	---	---		

Example of one daily trip:



Please see Table A9 - 5 - 1 for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

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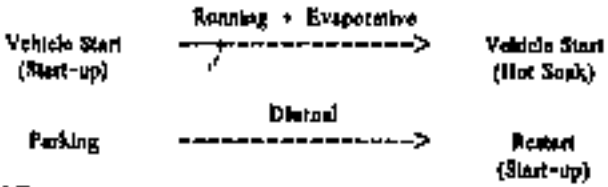
Table A11 – 5 – H – 2
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 1993

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed (Miles per Hour)	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	64.95	64.95	64.95	9.73	9.73	9.73	35.61	35.61	35.61	2.16	0.66
10	44.78	44.78	44.78	7.65	7.65	7.65	29.54	29.54	29.54	2.16	0.66
15	32.32	32.32	32.32	6.14	6.14	6.14	25.40	25.40	25.40	2.16	0.66
20	24.41	24.41	24.41	5.03	5.03	5.03	22.62	22.62	22.62	2.16	0.66
25	19.29	19.29	19.29	4.22	4.22	4.22	20.88	20.88	20.88	2.16	0.66
30	15.96	15.96	15.96	3.62	3.62	3.62	19.96	19.96	19.96	2.16	0.66
35	13.81	13.81	13.81	3.17	3.17	3.17	19.78	19.78	19.78	2.16	0.66
40	12.51	12.51	12.51	2.84	2.84	2.84	20.30	20.30	20.30	2.16	0.66
45	11.86	11.86	11.86	2.60	2.60	2.60	21.60	21.60	21.60	2.16	0.66
50	11.77	11.77	11.77	2.44	2.44	2.44	23.80	23.80	23.80	2.16	0.66
55	12.23	12.23	12.23	2.33	2.33	2.33	27.18	27.18	27.18	2.16	0.66
60	13.29	13.29	13.29	2.28	2.28	2.28	32.16	32.16	32.16	2.16	0.66
65	15.11	15.11	15.11	2.28	2.28	2.28	39.43	39.43	39.43	2.16	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	—	—	—	N/A	N/A	N/A	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	N/A	N/A	N/A	—	—	—		

Example of one daily trip:



Please see Table A9 – 5 – I for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%)

** Number of Vehicles (NOV) -weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

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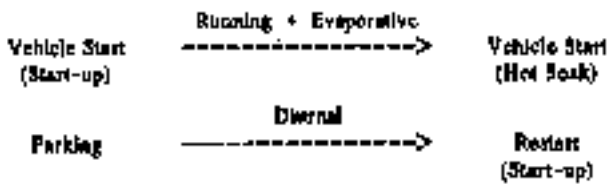
Table A11 – 5 – H – 3
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 1995

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	66.00	66.00	66.00	9.74	9.74	9.74	34.66	34.66	34.66	2.03	0.66
10	45.51	45.51	45.51	7.65	7.65	7.65	28.76	28.76	28.76	2.03	0.66
15	32.84	32.84	32.84	6.14	6.14	6.14	24.72	24.72	24.72	2.03	0.66
20	24.80	24.80	24.80	5.03	5.03	5.03	22.02	22.02	22.02	2.03	0.66
25	19.60	19.60	19.60	4.22	4.22	4.22	20.32	20.32	20.32	2.03	0.66
30	16.21	16.21	16.21	3.62	3.62	3.62	19.43	19.43	19.43	2.03	0.66
35	14.04	14.04	14.04	3.14	3.14	3.14	19.25	19.25	19.25	2.03	0.66
40	12.72	12.72	12.72	2.80	2.80	2.80	19.76	19.76	19.76	2.03	0.66
45	12.06	12.06	12.06	2.44	2.44	2.44	21.02	21.02	21.02	2.03	0.66
50	11.96	11.96	11.96	2.33	2.33	2.33	23.17	23.17	23.17	2.03	0.66
55	12.42	12.42	12.42	2.28	2.28	2.28	26.46	26.46	26.46	2.03	0.66
60	15.36	15.36	15.36	2.28	2.28	2.28	31.31	31.31	31.31	2.03	0.66
65	15.11	15.11	15.11	2.28	2.28	2.28	38.38	38.38	38.38	2.03	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	---	---	---	N/A	N/A	N/A	---	---	---		
DIURNAL** (Grams/Vehicle/Day)	---	---	---	N/A	N/A	N/A	---	---	---		

Example of one daily trip:



Please see Table A9 – 5 – I for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

AR007315

Table A11 – 5 – H – 4
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 1997

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed (Miles per Hour)	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	66.63	66.63	66.63	9.84	9.84	9.84	32.08	32.08	32.08	1.64	0.66
10	45.94	45.94	45.94	7.73	7.73	7.73	26.62	26.62	26.62	1.64	0.66
15	33.15	33.15	33.15	6.20	6.20	6.20	22.88	22.88	22.88	1.64	0.66
20	25.04	25.04	25.04	5.09	5.09	5.09	20.38	20.38	20.38	1.64	0.66
25	19.79	19.79	19.79	4.27	4.27	4.27	18.81	18.81	18.81	1.64	0.66
30	16.37	16.37	16.37	3.65	3.65	3.65	17.98	17.98	17.98	1.64	0.66
35	14.17	14.17	14.17	3.20	3.20	3.20	17.82	17.82	17.82	1.64	0.66
40	12.84	12.84	12.84	2.87	2.87	2.87	18.29	18.29	18.29	1.64	0.66
45	12.17	12.17	12.17	2.63	2.63	2.63	19.46	19.46	19.46	1.64	0.66
50	12.08	12.08	12.08	2.47	2.47	2.47	21.45	21.45	21.45	1.64	0.66
55	12.54	12.54	12.54	2.36	2.36	2.36	24.00	24.00	24.00	1.64	0.66
60	13.63	13.63	13.63	2.30	2.30	2.30	28.00	28.00	28.00	1.64	0.66
65	15.50	15.50	15.50	2.30	2.30	2.30	35.00	35.00	35.00	1.64	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	—	—	—	N/A	N/A	N/A	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	N/A	N/A	N/A	—	—	—		

Example of one daily trip:

Vehicle Start (Start-up) —— Running + Evaporative ——> Vehicle Start (Hot Soak)

Parking —— Diurnal ——> Restart (Start-up)

Please see Table A9 – 5 – I for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) - weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

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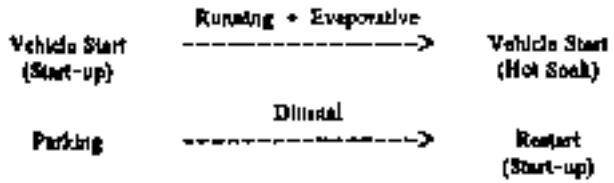
Table A11 – 5 – H – 5
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 1999

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed (Miles per Hour)	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	67.23	67.23	67.23	9.92	9.92	9.92	31.49	31.49	31.49	1.51	0.66
10	46.36	46.36	46.36	7.78	7.78	7.78	26.12	26.12	26.12	1.51	0.66
15	33.45	33.45	33.45	6.25	6.25	6.25	22.46	22.46	22.46	1.51	0.66
20	25.26	25.26	25.26	5.12	5.12	5.12	20.00	20.00	20.00	1.51	0.66
25	19.97	19.97	19.97	4.30	4.30	4.30	18.46	18.46	18.46	1.51	0.66
30	16.52	16.52	16.52	3.68	3.68	3.68	17.65	17.65	17.65	1.51	0.66
35	14.30	14.30	14.30	3.23	3.23	3.23	17.49	17.49	17.49	1.51	0.66
40	12.95	12.95	12.95	2.89	2.89	2.89	17.96	17.96	17.96	1.51	0.66
45	12.28	12.28	12.28	2.65	2.65	2.65	19.10	19.10	19.10	1.51	0.66
50	12.19	12.19	12.19	2.48	2.48	2.48	21.05	21.05	21.05	1.51	0.66
55	12.66	12.66	12.66	2.37	2.37	2.37	24.04	24.04	24.04	1.51	0.66
60	13.75	13.75	13.75	2.32	2.32	2.32	28.44	28.44	28.44	1.51	0.66
65	15.64	15.64	15.64	2.32	2.32	2.32	34.87	34.87	34.87	1.51	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	—	—	—	N/A	N/A	N/A	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	N/A	N/A	N/A	—	—	—		

Example of one daily trip:



Please see Table A9 – 5 – 1 for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

(SC10BS19.WK1)

AR007315

Table A11 - 5 - H - 6

EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Buses or Multi-Person Vehicles***

Calendar Year 2001

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	67.64	67.64	67.64	9.92	9.92	9.92	31.48	31.48	31.48	1.42	0.66
10	46.64	46.64	46.64	7.79	7.79	7.79	26.12	26.12	26.12	1.42	0.66
15	33.65	33.65	33.65	6.25	6.25	6.25	22.45	22.45	22.45	1.42	0.66
20	25.42	25.42	25.42	5.12	5.12	5.12	20.00	20.00	20.00	1.42	0.66
25	20.09	20.09	20.09	4.30	4.30	4.30	18.45	18.45	18.45	1.42	0.66
30	16.62	16.62	16.62	3.69	3.69	3.69	17.65	17.65	17.65	1.42	0.66
35	14.38	14.38	14.38	3.23	3.23	3.23	17.48	17.48	17.48	1.42	0.66
40	13.03	13.03	13.03	2.90	2.90	2.90	17.95	17.95	17.95	1.42	0.66
45	12.36	12.36	12.36	2.65	2.65	2.65	19.09	19.09	19.09	1.42	0.66
50	12.26	12.26	12.26	2.48	2.48	2.48	21.04	21.04	21.04	1.42	0.66
55	12.73	12.73	12.73	2.37	2.37	2.37	24.03	24.03	24.03	1.42	0.66
60	13.84	13.84	13.84	2.32	2.32	2.32	28.43	28.43	28.43	1.42	0.66
65	15.74	15.74	15.74	2.32	2.32	2.32	34.86	34.86	34.86	1.42	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	----	----	----	N/A	N/A	N/A	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	N/A	N/A	N/A	----	----	----		

Example of one daily trip:

Vehicle Start (Start-up) --- Running + Evaporative ---> Vehicle Start (Hot Soak)

Parking --- Diurnal ---> Restart (Start-up)

Please see Table A9 - 5 - I for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors-
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

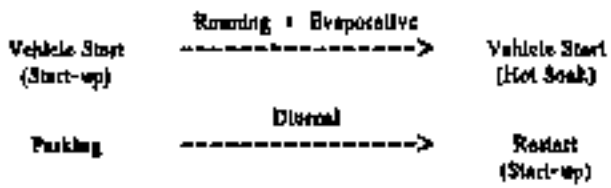
*** Buses or Multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

AR007315

Table A9 - 5 - H - 7
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 2003

	Running Exhaust and Evaporative (Grams per Mile)*										
Vehicle Speed (Miles per Hour)	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	67.80	67.80	67.80	10.01	10.01	10.01	31.26	31.26	31.26	1.23	0.66
10	46.75	46.75	46.75	7.86	7.86	7.86	25.94	25.94	25.94	1.23	0.66
15	33.73	33.73	33.73	6.30	6.30	6.30	22.30	22.30	22.30	1.23	0.66
20	25.48	25.48	25.48	5.17	5.17	5.17	19.86	19.86	19.86	1.23	0.66
25	20.14	20.14	20.14	4.33	4.33	4.33	18.33	18.33	18.33	1.23	0.66
30	16.66	16.66	16.66	3.72	3.72	3.72	17.53	17.53	17.53	1.23	0.66
35	14.42	14.42	14.42	3.26	3.26	3.26	17.36	17.36	17.36	1.23	0.66
40	13.06	13.06	13.06	2.92	2.92	2.92	17.83	17.83	17.83	1.23	0.66
45	12.39	12.39	12.39	2.68	2.68	2.68	18.96	18.96	18.96	1.23	0.66
50	12.29	12.29	12.29	2.50	2.50	2.50	20.90	20.90	20.90	1.23	0.66
55	12.76	12.76	12.76	2.39	2.39	2.39	23.86	23.86	23.86	1.23	0.66
60	13.87	13.87	13.87	2.35	2.35	2.35	28.24	28.24	28.24	1.23	0.66
65	15.78	15.78	15.78	2.35	2.35	2.35	34.62	34.62	34.62	1.23	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	---	---	---	N/A	N/A	N/A	---	---	---		
DIURNAL** (Grams/Vehicle/Day)	---	---	---	N/A	N/A	N/A	---	---	---		

Example of one daily trip:



Please see Table A9 - 5 - I for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) -weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

(SC10BS23.WK1)

AR007315S

TABLE A11 – 5 – H – 8

EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 2005

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	67.93	67.93	67.93	10.06	10.06	10.06	31.17	31.17	31.17	1.12	0.66
10	46.84	46.84	46.84	7.89	7.89	7.89	25.86	25.86	25.86	1.12	0.66
15	33.80	33.80	33.80	6.33	6.33	6.33	22.23	22.23	22.23	1.12	0.66
20	25.53	25.53	25.53	5.20	5.20	5.20	19.80	19.80	19.80	1.12	0.66
25	20.17	20.17	20.17	4.36	4.36	4.36	18.27	18.27	18.27	1.12	0.66
30	16.69	16.69	16.69	3.74	3.74	3.74	17.47	17.47	17.47	1.12	0.66
35	14.45	14.45	14.45	3.28	3.28	3.28	17.31	17.31	17.31	1.12	0.66
40	13.09	13.09	13.09	2.93	2.93	2.93	17.77	17.77	17.77	1.12	0.66
45	12.41	12.41	12.41	2.69	2.69	2.69	18.91	18.91	18.91	1.12	0.66
50	12.31	12.31	12.31	2.51	2.51	2.51	20.84	20.84	20.84	1.12	0.66
55	12.79	12.79	12.79	2.40	2.40	2.40	23.80	23.80	23.80	1.12	0.66
60	13.90	13.90	13.90	2.36	2.36	2.36	28.16	28.16	28.16	1.12	0.66
65	15.81	15.81	15.81	2.36	2.36	2.36	34.52	34.52	34.52	1.12	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	—	—	—	N/A	N/A	N/A	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	N/A	N/A	N/A	—	—	—		

Example of one daily trip:

Vehicle Start (Start-up) —— Running + Evaporative ——> Vehicle Start (Hot Soak)

Parking —— Diurnal ——> Restart (Start-up)

Please see Table A9 – 5 – 1 for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) –weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)-weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

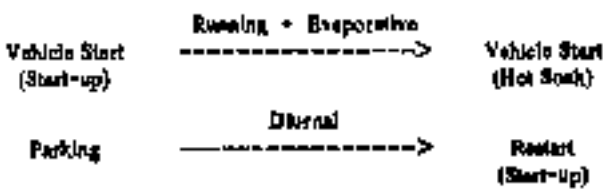
*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

AR007315

Table A11 – 5 – H – 9
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi–Person Vehicles***
Calendar Year 2007

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	68.01	68.01	68.01	10.08	10.08	10.08	31.14	31.14	31.14	1.075	0.66
10	46.89	46.89	46.89	7.91	7.91	7.91	25.84	25.84	25.84	1.075	0.66
15	33.84	33.84	33.84	6.36	6.36	6.36	22.21	22.21	22.21	1.075	0.66
20	25.56	25.56	25.56	5.21	5.21	5.21	19.78	19.78	19.78	1.075	0.66
25	20.20	20.20	20.20	4.37	4.37	4.37	18.26	18.26	18.26	1.075	0.66
30	16.71	16.71	16.71	3.74	3.74	3.74	17.46	17.46	17.46	1.075	0.66
35	14.46	14.46	14.46	3.28	3.28	3.28	17.30	17.30	17.30	1.075	0.66
40	13.10	13.10	13.10	2.94	2.94	2.94	17.76	17.76	17.76	1.075	0.66
45	12.42	12.42	12.42	2.70	2.70	2.70	18.89	18.89	18.89	1.075	0.66
50	12.33	12.33	12.33	2.52	2.52	2.52	20.82	20.82	20.82	1.075	0.66
55	12.80	12.80	12.80	2.41	2.41	2.41	23.77	23.77	23.77	1.075	0.66
60	13.91	13.91	13.91	2.36	2.36	2.36	28.13	28.13	28.13	1.075	0.66
65	15.83	15.83	15.83	2.36	2.36	2.36	34.49	34.49	34.49	1.075	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	—	—	—	N/A	N/A	N/A	—	—	—		
DIURNAL** (Grams/Vehicle/Day)	—	—	—	N/A	N/A	N/A	—	—	—		

Example of one daily trip:



Please see Table A9 – 5 – 1 for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) –weighted emission factors:
Includes VMT/ADT from diesel–fueled vehicles (100%), gasoline–fueled vehicles equipped with catalyst (0.0%), and gasoline–fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)–weighted emission factors:
Includes NOV from diesel–fueled vehicles (100%), gasoline–fueled vehicles equipped with catalyst (0.0%), and gasoline–fueled vehicles not equipped with catalyst (0.0%).

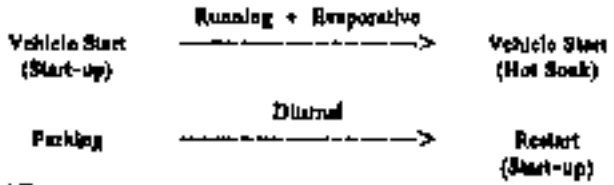
*** Buses or multi–person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

AR0073157

Table A11 – 5 – H – 10
EMFAC7EP EMISSION FACTORS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
Buses or Multi-Person Vehicles***
Calendar Year 2009

Vehicle Speed (Miles per Hour)	Running Exhaust and Evaporative (Grams per Mile)*										
	Carbon Monoxide			Reactive Organic Compounds			Oxides of Nitrogen			PM10 Exhaust	PM10 Tire Wear
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	FOR ALL AREA	FOR ALL AREA
5	68.05	68.05	68.05	10.10	10.10	10.10	31.12	31.12	31.12	1.05	0.66
10	46.92	46.92	46.92	7.93	7.93	7.93	25.82	25.82	25.82	1.05	0.66
15	33.86	33.86	33.86	6.37	6.37	6.37	22.19	22.19	22.19	1.05	0.66
20	25.57	25.57	25.57	5.22	5.22	5.22	19.77	19.77	19.77	1.05	0.66
25	20.21	20.21	20.21	4.38	4.38	4.38	18.24	18.24	18.24	1.05	0.66
30	16.72	16.72	16.72	3.75	3.75	3.75	17.45	17.45	17.45	1.05	0.66
35	14.47	14.47	14.47	3.29	3.29	3.29	17.29	17.29	17.29	1.05	0.66
40	13.11	13.11	13.11	2.94	2.94	2.94	17.74	17.74	17.74	1.05	0.66
45	12.43	12.43	12.43	2.70	2.70	2.70	18.88	18.88	18.88	1.05	0.66
50	12.33	12.33	12.33	2.53	2.53	2.53	20.80	20.80	20.80	1.05	0.66
55	12.81	12.81	12.81	2.42	2.42	2.42	23.76	23.76	23.76	1.05	0.66
60	13.92	13.92	13.92	2.36	2.36	2.36	28.11	28.11	28.11	1.05	0.66
65	15.83	15.83	15.83	2.36	2.36	2.36	34.46	34.46	34.46	1.05	0.66
COLD START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT START* (Grams/Trip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
HOT SOAK* (Grams/Trip)	----	----	----	N/A	N/A	N/A	----	----	----		
DIURNAL** (Grams/Vehicle/Day)	----	----	----	N/A	N/A	N/A	----	----	----		

Example of one daily trip:



Please see Table A9 – 5 – 1 for Areas and Associated Temperatures.

* Vehicle Miles Traveled (VMT)/Average Daily Trips (ADT) –weighted emission factors:
Includes VMT/ADT from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

** Number of Vehicles (NOV)–weighted emission factors:
Includes NOV from diesel-fueled vehicles (100%), gasoline-fueled vehicles equipped with catalyst (0.0%), and gasoline-fueled vehicles not equipped with catalyst (0.0%).

*** Buses or multi-person vehicles (Vehicles with 20 person per vehicle)
Does not include trains or airplanes.

(SCIO I)

AR007315

EXAMPLES OF EMPLOYERS WHO HAVE IMPLEMENTED SUCCESSFUL MITIGATION PROGRAMS THAT INVOLVE PACKAGES OF TRANSPORTATION DEMAND MANAGEMENT INCENTIVES

AR0073160

TABLE A11 - 5 - I

ESTIMATING EMISSIONS FROM THE TCM PACKAGES

Tables A11 - 5 - A through A11 - 5 - F attempt to quantify the effectiveness of a variety of individual, transportation-based mitigation measures. These measures, defined by the California Clean Air Act as "transportation control measures (TCMs)," involve strategies to reduce vehicle trips, vehicle use, vehicle miles traveled, vehicle idling, and traffic congestion for the purposes of reducing motor vehicle emissions. Many TCMs are effective when implemented without supporting measures. However, most are ineffective or less effective when implemented in isolation. This helps to explain the difficulty in quantifying the impact of a particular, isolated mitigation measure, as measures are usually effected as part of a transportation program. Therefore disaggregating the impacts of a multi-pronged TCM program is difficult.

To address this issue, the following table summarizes a variety of employers who have implemented and monitored the results of successful programs which utilized a package of transportation-based mitigation measures. The success of each program is attributed to a specific menu of related measures. Based on monitored results, the impacts of each case study are characterized in terms of reductions in vehicle trip (VT), vehicle miles traveled (VMT) and/or improvements in average vehicle ridership (AVR).

The purpose of this table is to supplement Tables A11 - 5 - A through A11 - 5 - F and assist local government decision-makers, air quality analysts, employers, and other private entities to determine the best package of transportation-based mitigation measures for their needs. To this end, the summary reflects a variety of circumstances, based on the following criteria:

- Type of land use or employer,
- Size of employer,
- Local conditions surrounding the employer, based on the following definitions:

  Urban: Jurisdiction characterized by moderate to dense population and development intensity.

  Urbanizing: Jurisdiction characterized by low to moderate population and development density, with significant growth projected over the next 20 years.

  Rural: Characterized by low population and development intensity, with significant growth projected by the year 2010.

- Accessibility to rail or bus transit facilities.

AR0073161

TABLE A11 - 5 - I

Land Use Site Description	Mitigation Measures (TDM Package)	Factors	Impacts/ Results
o Industrial office o 13,000 employees o Urban community	o Subscription bus Program o "Ride-Guide" carpooling program o Vanpool program o Staggered work hours	o Employer flextime policy - min 8 hr. o contract with transit operator - pick-up at home, three fare options max. ridership 250 employees o Avg round trip of van 50 miles - monthly charge $ 46 vanpool.	o 1,124 VTs reduced or 9.7% reduction in vehicle trips; AVR 1.21
o Office o 400 employees o Urban (CBD) o Transit accessible	o Transportation allowance program o Restricted on-site parking (limitation in parking capacity) o HOV subsidies	o Parking facility is limited o Parking is priced - $ 40 per month; Transit users $ 15 monthly pass discount, carpoolers park free	o AVR 1.40
o Office o 980 employees o Urbanizing community o Transit accessible	o Direct subsidy to employees using commute alternatives (coupon system) o Preferential parking o Vanpool o Marketing through posters, memos, brochures	o Monthly reimbursement = $ 30, depending on mix modes used by employees; o Subsidized van service; o Avg round trip of van ranges between 60-80 miles- o Passengers charged $40 a month	o AVR 1.55; o Reduction of vehicle trip rate from 82.4 daily one-way trips per employee to 63.4, a 22% reduction.
o Office o Urban community (CBD) o Transit accessible o 1,100 employees	o Constrained on-site parking o Parking charge o Transit subsidies o Vanpool subsidy o Good marketing and promotion by management - corporate-supported plan.	o Additional offsite parking available through lease - $ 30 a month per employee; o On site spaces = $110 per month per employee; 36% of all employees use transit to work o Constrained parking - 223 spaces - 5 employees per space = 1.05 spaces per 1,000 Sq. Ft. o Parking charge: 2-person carpool = $ 75 per month 3-person = $ 40 per month 4-person or more = $ 10 per month o Transit subsidies: $15 - $30 per month o Vanpool subsidies $10 - $30 per month	o Removal of 7.8 ADTs per 100 employees = 86 ADTs reduced per day; o 13.6% VT reduction

AR0073162

TABLE A11 - 5 - I (CONT.)

Land Use Site Description	Mitigation Measures (TDM Package)	Factors	Impacts/ Results
o Manufacturing o 125 employees o Urban community	o Preferential parking spaces o Promotional commuter fairs, bulletin boards, newsletter o Guaranteed ride home o Rideshare subsidy o Transit subsidy	o On-site transportation coordinator o Rideshare subsidy $15 monthly o Transit subsidy $15 monthly o 200 parking spaces o Limited rail and bus service opportunities o 15 preferential parking spaces	o 1.09 AVR increased to 1.23 AVR
o Office o 321 employees o Urbanizing community o Transit accessible	o ETC on-site o Direct ridesharing/vanpooling subsidy o Free passes to special activities o Discounted transit and train passes o Preferential parking	o Drawings and promotional support o $20 per month to employees for ridesharing o $25 per month to employees for vanpooling 20 parking spaces reserved for ridesharers o Computerized rideshare matching o 438 parking spaces o Bicycle paths and wide sidewalks to site o Transit, signalized intersections, and light rail available	o 1.03 AVR increased to 1.24 AVR o 40 daily trips reduced
o Municipal Government o Urban community o 166 employees	o ETC on-site o Raffles and giveaways o Preferential parking spaces o Transit discounts o Guaranteed ride home o Commuter shuttle service o Flextime	o Ride matching service o Daily raffle tickets o Awarded for ridesharing o 124 parking spaces	o 1.09 AVR increased to 1.15 AVR o 8 daily one-way trips o 5% VT reduction
o Utility company o 134 employees o Urban community	o Preferential parking spaces o Guaranteed ride home o Transit subsidy o Flextime o On-site cafeteria o Vanpool program	o $63 a month per employee for transit o Commuter hot-line 24 - hour telephone line (trip reduction plan) o Free pick-up and delivery service to light rail transit o 97 parking spaces o On-street parking	o AVR 1.28

AR0073163

TABLE A11 - 5 - I (CONT.)

Land Use Site Description	Mitigation Measures (TDM Package)	Factors	Impacts/ Results
o Insurance office o 249 employees o Urban community	o Compressed work week o Vanpool/carpool subsidies o Quarterly drawings for prizes	o Subsidize carpool participants - $5 per month drivers - $20 per month o Management support o News bulletin, flyers, active promotion of program o Sidewalks, signalization and crosswalks	o 1.19 AVR
o New car dealership o 228 employees o Urban community	o Preferential parking o Flextime o Guaranteed ride home	o Employee recognition o Prize drawings o Rideshare matching services o 140 parking spaces o Freeway accessibility o Transit accessible o Special driving privileges for management personnel that rideshare	o 1.03 AVR increase to 1.38 AVR o 56 one-way trips reduced o 25% VT reduction
o Industrial/Manufacturing o 217 employees o Urban community	o Vanpool/carpool subsidies o Compressed work week o Preferential parking o Guaranteed ride home o ETC on-site	o Rideshare subsidy of $15 a month o Quarterly prizes for ridesharing o Ridesharing match service o Brochures, posters, announcements to promote ridesharing o Freeway accessibility o 144 parking spaces	o 1.03 AVR increase to 1.18 o 27 one-way trips reduced; o 13% VT reduction
o Industrial/Manufacturing o Urbanizing community o 171 employees	o Preferential parking o Compressed work week o Guaranteed ride home	o 48 preferential parking spaces o Quarterly drawing for prizes	o 1.09 AVR increase to 1.33 AVR o 28 one-way trips reduced; o 17% VT reduction

AR0073164

TABLE A11 - 5 - I (CONT.)

Land Use Site Description	Mitigation Measures (TDM Package)	Factors	Impacts/ Results
o Retail discount store o Urban community o 200 employees o Transit accessible	o Preferential parking o Transit pass subsidy o Flextime o ETC on-site	o 11 preferential parking spaces o Monthly transportation contest o Transportation center for employees o Education in new-hire orientation o Transit subsidy - $15 per month o Transit pass drawing o 900 parking spaces o "User friendly" pedestrian site	o AVR 1.16 increased to 1.39 AVR; o 29 one-way trips reduced; o 17% VT
o Manufacturing/Industrial o Urbanizing community o 192 employees	o Guaranteed ride home o Compressed work week o Telecommuting	o Carpooling information o 162 parking spaces	o AVR 1.37 increased to 1.97 AVR o 40 one-way trips reduced o 30% VT reduction
o Medical supplies o Manufacturing o Urbanizing o Transit oriented o Employees	o Transit subsidy o Carpooling subsidy o Preferential parking o Flextime o Guaranteed ride home o Vanpooling pilot program o Bike racks, lockers, showers	o $1 per day for ridesharing o Matchlist services o Displays, posters, and newsletter promoting ridesharing o Drawings for cash o 50% transit subsidy - $10 per month o 712 parking spaces	o AVR 1.05 increased to 1.22 AVR o 62 one-way trips reduced o 13% VT reduction

AR0073165

TABLES FOR ESTIMATING EMISSIONS FROM REDUCTION IN PETROLEUM PRODUCTS PUMPED AT SERVICE STATIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES

Mitigation Measures That Reduce Emissions Associated With Petroleum Product Fueling Activities (SCAQMD Rule 461 Emissions)

- Provide Electric Outlets for Electric Vehicles in Garages
- Provide Electric Outlets at Service Stations
- Provide Service Stations that Supply Alternate Fuels

AR0073166

TABLE A 11 - 6

ESTIMATING EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE EMISSIONS FROM PETROLEUM PRODUCTS FUELING ACTIVITIES
(Pounds Per Day)

This methodology is for net emissions after implementation of mitigation measures that cause a reduction in emissions associated with the amount of gasoline and diesel dispensed due to a reduction in the number of gasoline- and diesel-fueled vehicles.

$N = [A \times \{1 - [O/F]\}] + [\{A \times [O/F]\} \times ((E \underline{OR} M)/(G \underline{OR} D))]$, OR
$N = [A \times \{(1 - L)\}] + [\{A \times L\}] \times ((E \text{ OR } M)/(G \underline{OR} D))$

Where,

- A = Total Non-Mitigated Diesel or Gasoline Fuel Dispensing Fugitive Emissions.
  (*Use Rule 461 Staff Reports* or See Table A9 - 17 in Appendix 9)
  (*Resulting from Table A9 - 5 or Appendix 9 Methodologies* for the First Mitigation Measure);
  Please repeat the same formula for each type of alternate fuel-fueled vehicle penetration. when repeating the formula, use net emissions from previous calculations as non-mitigated emissions.
- D = Original Diesel Emission Factor in Pounds per Million BTUs
- E = New or Electricity Consumption Emission Factor in Pounds per Million BTUs
- F = Original Number of Project-Related Gasoline- or Diesel-Fueled Vehicles (*Traffic Study Input*)
- G = Original Gasoline or Diesel Emission Factor in Pounds per Million BTUs
- O = Removed from Original Number of Project-Related Gasoline- or Diesel-Fueled Vehicles
- L = Percent Vehicles Replaced With Alternate Fuel-Fueled Vehicles:
  (F x L) = Alternate Fuel-Fueled Vehicles (contact ARB to obtain fueling emission factors for altern fuels, i.e., natural gas, methanol, Phase 2 fuel, LPG, etc.).
  (Mitigations should at least utilize the same percent substitutions for that build-out year as indicated in Table A11 - 5 - G - L. If lower percent is utilized, please provide reasons for not utilizing available percent penetration rate.)
- M = New or Alternate Fuel Emission Factor in Pounds per Million BTUs (contact ARB for fueling emission factors)
- N = Net Emissions After Implementation of Measures that Reduce Diesel and Gasoline Fuel Dispensing Fugitive Emissions.

Note: Dispensing data should be weighted for the average of seven days, i.e., five days for workdays and two days for weekends.

TABLE A11 - 6 - A

DISPENSING EMISSION FACTORS FOR VARIOUS FUELS
(Pounds Per Million BTUs)

Fuel Type	CO	ROC	NOx	SOx	PM10
Gasoline (G) (Vapor Control Transfer)	N/A	0.008	N/A	N/A	N/A
Diesel (D) (No Vapor Control Transfer)	N/A	0.079	N/A	N/A	N/A
Electricity (E) (Battery Charging)	0.059	0.0029	0.34	0.035	0.012
Alternate Fuel (M) (Phase 2 Gasoline, Alcohol, CNG (Natural Gas) or LPG (Propane or Butane))*					

* Use California Air Resources Board Staff Report for the Proposed Regulations for Low-Emission Vehicles and Clean Fuels, August 13, 1990.

AR0073167

TABLES FOR ESTIMATING AVERAGE VEHICLE RIDERSHIP AFTER THE IMPLEMENTATION OF MITIGATION MEASURES
(After Reduction in Number of Vehicles Traveled)

- Walk to work or destination
- Bicycle to work or destination
- Telecommute
- Report to another site for work
- Implementation of:
  - 3/36 work week
  - 4/40 work week
  - 9/80 work week
- Use of LPG powered vehicles
- Use of methanol-powered vehicles
- Use of natural gas-powered vehicles
- Use of electricity-powered vehicles
- Travel in 2 to 40 persons per vehicle format

AR0073168

TABLE A11 - 7

ESTIMATING PROJECT-RELATED AVERAGE VEHICLE RIDERSHIP OR OCCUPANCY AFTER THE IMPLEMENTATION OF VARIOUS MITIGATION MEASURES (Based on District Regulation XV)

AVR = Number of Persons Traveled/Number of Cars or Vehicles
(The Lower the Number of Vehicles, the Greater the AVR)

AVR = [A + B + C + D + E + F + M + G + H + L1]/[(A/1 + B/1 + C/2 + D/3 + E/4 + F/4 + M/7 + G/12 + H/40 + L1/1)

Where,

AVR	=	Average Vehicle Ridership after implementation of mitigation measures. To improve the AVR, trips associated with the following should be eliminated or reduced.
A	=	Remaining Number of 1-Way Trips in 1-Person 1-Vehicle Format
B	=	Remaining Number of 1-Way Trips in 1-Person 1-Motorcycle Format
L1	=	No survey response 1-Way Trips (Report these trips as "A"; If not applicable, use 0.0) To improve the AVR, more trips associated with the following combination of mitigation measures are needed. If not applicable, use 0 for the following, and use Appendix 11 methodologies for emission reduction
C	=	Number of 1-Way Trips in 2-Person 1-Vehicle Format
D	=	Number of 1-Way Trips in 3-Person 1-Vehicle Format
E	=	Number of 1-Way Trips in 4-Person 1-Vehicle Format
F	=	Number of 1-wAY Trips in More Than 4-Person 1-Vehicle Format
M	=	Number of 1-Way Trips in More Than 7-Person 1-Vehicle Format
G	=	Number of 1-Way Trips in More Than 12-Person 1-Vehicle Format
H	=	Number of 1-Way Trips in More Than 40-Person 1-Vehicle Format

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The following mitigation measures should be used to determine emission reductions and should not be used to determine post-mitigation AVR.

I	=	Walk 1-way trips
J	=	Bicycle 1-way trips
K	=	Telecommute 1-way trips
L	=	Report to another site 1-way trips
M	=	1-way trips for persons with days off due to a 3/36 work week
N	=	1-way work trips for persons with days off due to a 4/40 work week
O	=	1-way trips for persons with days off due to a 9/80 work week
S	=	Total # of clean fuel vehicles used for commuting from home to work per day of the week
T	=	Number of workdays of the week on which "clean fuel vehicles" are used for commuting from home to work *(if unknown, use 5.0)*
U	=	Total liquid petroleum gas (LPG) vehicles
V	=	Total methanol vehicles
W	=	Total compressed natural gas (CNG) vehicles
Y	=	Total electricity powered vehicles
Z	=	Number of workdays in a week chosen to determine AVR *(if unknown, use 5.0)*
P	=	*1-way trips for persons on vacation*
Q	=	*1-way trips for persons who are on sick leave*
R	=	*1-way trips for persons who are absent for other than vacation and sick leaves*

AR0073169

TABLES FOR ESTIMATING MOBILE EQUIPMENT EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES

Mitigation Measures That Reduce Emissions Associated With Gasoline- and Diesel- Powered Mobile Equipment

- Replace Gasoline- and Diesel-Powered Mobile Equipment With Natural-Gas-Powered Mobile Equipment;
- Replace Gasoline- and Diesel-Powered Mobile Equipment With LPG (Propane and Butane)-Gas-Powered Mobile Equipment; or,
- Replace Gasoline- and Diesel-Powered Mobile Equipment With Battery-Powered Mobile Equipment (*Electricity usage from existing power outlets supplied by SCE, LADWP, etc. to recharge batteries*)

AR0073170

TABLE A11 - 8

ESTIMATING EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE EMISSIONS FROM MOBILE EQUIPMENT
(Pounds Per Day)

M = R + N

Where,

M = Mitigated Mobile Equipment Emissions After Implementation of Mitigation Measures *(Use Table A9 - 8 to Estimate Non-Mitigated Emissions from Original Mobile Equipment)*

R = Remaining or Residual Non-Mitigated Emissions From Unreplaced Original Mobile Equipment

= {[E x {1 - (F/G)}]; Where,

E = Non-Mitigated Emissions from Table A9-8 of Appendix 9 *(The District Prefers F Being Equal to G)*

F = Number of Removed Original (and Replaced with New) Mobile Equipment

G = Number of Original Mobile Equipment *(Used to Estimate Non-Mitigated Emissions (E) in Table 9-8 of Appendix 9)*

N = New Emissions From Replaced Equipment *(Replacing Removed Original Equipment)*

= (V x (H OR J/I OR K)); Where,

V = Removed Emissions *(Emissions of Removed Original Equipment)*

= [E x {F/G}]

H = New Emission Factor per Million BTU** for New *(For Replaced)* Equipment *(See Table A11 - 8 - A)*;

J = New Emission Factor (EF) per "Converted" unit to EF "Unit" of Original Equipment; Converted unit is in the same unit as that for Original Emission Factor; for example, if original EF is in lbs per 1000 gals the new EF should be also in lbs/1000 gals *(See Table A11 - 8 - C)*

I = Original Emission Factor per Million BTU for Original (for Removed) Equipment*, OR Use Table A11 - 8 - B***

K = Original Emission Factor per Unit for Original (for Removed) Equipment*, OR Use Table A11 - 8 - D***

* *Use emission factors from Table A9 - 8 - A or Table A9 - 8 - B and/or their conversions into per million BTUs per hour*

** *BTU = British Thermal Unit*

*** *Use stationary equipment emission factors found in Table A11-8-B and Table A11 - 8 - D only if emissions for mobile equipment cannot be derived from Tables A9 - 8 - A and A9 - 8 - B*

AR0073171

TABLE A11 - 8 - A

Emission Factors (H) for Each Criteria Pollutant for New Mobile Equipment (Pounds Per Million BTUs)

Pollutant Type / Fuel Type	CO	ROC	NOx	SOx	PM10
	(Industrial/Commercial Type)				
Propane	1.267	0.815	1.365	0.003	0.025
Butane	1.267	0.815	1.365	0.003	0.025
	(Cogeneration or Non-cogeneration Type)				
Natural Gas (Methane)	0.4095	0.079	3.2381	0.0006	0.0048

TABLE A11 - 8 - B

Emission Factors (I) for Each Criteria Pollutant for Original (Removed) Equipment (Pounds Per Million BTUs)

Pollutant Type / Fuel Type	CO	ROC	NOx	SOx	PM10
Distilled Oil, or Diesel	0.735	0.23	3.38	0.225	0.12
Gasoline	34.26	1.28	0.89	0.046	0.028

TABLE A11 - 8 - C

Emission Factors (J) for Each Criteria Pollutant for New Mobile Equipment (The following emission factors should be converted to emissions per million BTUs)

Pollutant Type / Fuel Type	CO	ROC	NOx	SOx	PM10
	(Pounds/Megawatt-Hours [1] and [2]*)*				
Electricity	0.2	0.01	1.15	0.12	0.04
Dual Fuel (Oil/Gas)	7.9	2.0	24.14	0.94	1.48
	(Pounds/One Thousand [1,000] Gallons)				
Propane	129.0	83.0	139.0	0.35	2.5
Butane	129.0	83.0	139.0	0.35	2.5
	(Pounds/Million [1,000,000] Cubic Feet)				
Process Gas*	--	83.0	--	--	--
Landfill Gas	--	--	--	--	--
	(Cogeneration and noncogeneration Type)				
Natural Gas (Methane)	430.0	82.9	3,400.0	0.6	5.0

[1] When using emissions factors expressed in megawatt-hour, they should be adjusted using efficiency factors "S" from Table A9-3-C.

[2] For generators, when using emissions factors expressed in megawatt-hour, they should be further adjusted using efficiency factor "U" from Table A9-3-C.

* 525 BTUs per cubic feet of process gas

AR0073172

TABLE A11 - 8 - D

Emission Factors (K) for Each Criteria Pollutant for Original (Removed) Mobile Equipment
(The following emission factors should be converted to emissions per million BTUs)

Pollutant Type / Fuel Type	CO	ROC	NOx	SOx	PM10
	(*Pounds/Megawatt-Hours* [1] and [2])				
(Reciprocating)					
Diesel	2.51	0.79	11.55	0.77	0.41
Gasoline	117.0	4.39	3.03	0.16	0.10
	(*Pounds/1,000 Gallons*)				
(Reciprocating)					
Diesel	102.0	32.1	469.0	31.2	16.75
Gasoline	3,940.0	147.7	102.0	5.31	3.235
Residual Crude Oil	102.0	32.10	469.0	155.0	16.75
Keronaptha Jet Fuel (Diesel/Kerosene Mixture)	102.0	32.1	469.0	6.2	16.75
	(*Pounds/Ton*)				
(Turbine)					
Jet Fuel	150.0	1.7	1.0	0.5	2.5

[1] When using emissions factors expressed in megawatt-hour, they should be adjusted using efficiency factors "S" from Table A9-3-C.

[2] For generators, when using emissions factors expressed in megawatt-hour, they should be further adjusted using efficiency factor "U" from Table A9-3-C.

[s] Percent sulfur content of the fuel. (*Please see Rule 431.2 for the applicable project related fuel sulfur content factor, and multiply 140.0 by [s] to obtain project-related SOx emission factor.*)

AR0073173

TABLE A11 - 8 - E

TYPICAL LOAD FACTORS, ETC FOR MOBILE (OFF-ROAD) EQUIPMENT

(All values are taken from November 1991 Nonroad Engine and Vehicle Emission Study and averaged)

(NTIS PB92 - 126960, EPA 460/3-91-02, or EPA 21A - 2001)

The following information should be used only if emission factors expressed in megawatt-hours are used. Content of this table will be updated as each equipment is made capable of utilizing LPG (Propane and Butane) and CNG (Natural Gas or Methanol).

LPG/CNG		LPG/CNG
Equipment Type	**Load Factor (Percent or %)**	**Load Factor (Percent or %)**
Skid-Steer Loader Wheel/Rubber-Tired Loader Tractors/Loaders Airport Terminal Tractors Excavators Trenchers Rollers Other Construction Equipment Cement and Mortar Mixer Paving Equipment Asphalt Pavers Plate Compactors Concrete Saws (Cutting Concrete) Crushing Equipment	78	
Aerial Lifts	46	
Rough Terrain Fork Lifts Fork Lifts Cranes Sprayers Dumpers/Tenders Signal Boards (Rotating Boards) Bore/Drill Rigs (Groundwater)	30	
Sweepers/Scrubbers Generator sets <50 HP Pressure Washers <50 HP Hydro Power Units Welders <50 HP	71	
Pumps <50 HP Air Compressors <50 HP Landscape Loader Backhoe Loader Log Loader Excavator (Utility) Excavator (Construction) Surfacing Equipment Tampers/Rammers 2-Wheeled Tractors Shredder >5 HP Chain Saws >4 HP	69	

AR0073174

TABLE A11 - 9

ESTIMATING EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE PM10 EMISSIONS FROM CONSTRUCTION ACTIVITIES

(This methodology also estimates emissions from one source category if more than one mitigation measure is implemented towards that same source category.)

$M^* = E \times C$

$M^{**} = E \times C \times (1-(D \times L)$

M^*	=	Mitigated PM10 Emissions from Source After Implementation of One Mitigation Measure Affecting the Source
M^{**}	=	Mitigated PM10 Emissions from Source After Implementation of Two Mitigation Measures Affecting the Same Source. Assume that Three or More Mitigation Measures Affecting the Same Source Will Not Increase the Efficacy Beyond the First Two Measures
E	=	Unmitigated PM10 Emissions from One Source *(from Passenger Vehicles on Paved Surfaces, Table A9 - 9 - C; from Trucks on Paved Surfaces, Table A9 - 9 - C; from Passenger Vehicles on Unpaved Surfaces, Table A9 - 9 - D; and from Bulldozing or Dirt Piling, Tables A9 - 9 - F and A9 - 9 - G)*
C	=	Control Efficiency of First Mitigation Measure Applied to Emission Source *(For more mitigation measures please see Table A11 - 9 - A)*
D	=	Control Efficiency of Second Mitigation Measure Applied to Emission Source *(For more mitigation measures please see Table A11 - 9 - A)*
L	=	Percent of Unmitigated PM10 affected by the Second Mitigation Measure That Was Not Affected by the First Measure Applied to the Same Source Category (If second mitigation measure is not used, "L" should be 0.0%)

AR0073175

TABLE A11 - 9 - A

CONTROL EFFICIENCY OF PM10 MITIGATION MEASURES
Percentage Efficiencies Within the Emission Source Category (C)

Emission Source	Mitigation Measure	Reduction Efficiency	Favorable Factors
Fugitive Dust/ Construction	Apply non-toxic chemical soil stabilizers according to manufacturers' specifications, to all inactive construction areas (previously graded areas inactive for ten days or more)	30% - 65%*	Stabilizers applied in sufficient concentration to provide erosion protection for at least one year
Fugitive Dust/ Construction	Replace ground cover in disturbed areas as quickly as possible	15% - 49%*	Small, densely planted ground cover
Fugitive Dust/ Construction	Enclose, cover, water twice daily, or apply non-toxic soil binders, according to manufacturers' specifications, to exposed stock piles (i.e., gravel, sand, dirt) with 5% or greater silt content	30% - 74%*	Automatic water mist or sprinkler systems should be installed in areas with stock piles
Fugitive Dust/ Construction	Water active sites at least twice daily	34% - 68%*	Water at sufficient frequency to keep soil moist enough so visible plumes are eliminated
Fugitive Dust/ Construction	Suspend all excavating and grading operations when wind speeds (as instantaneous gusts) exceed 25 mph	NQ	
Fugitive Dust/ Construction	Monitor for particulate emissions according to District-specified procedures	NQ	
Fugitive Dust from Roads	All trucks hauling, dirt, sand, soil, or other loose materials are to be covered, or should maintain at least two feet of freeboard in accordance with the requirements of CVC section 23114, (freeboard means vertical space between the top of the load and top of the trailer)	7% - 14%*	Tightly secured covering to truck
Fugitive Dust from Roads	Sweep streets once a day if visible soil materials are carried to adjacent streets (recommend water sweepers with reclaimed water)	25% - 60%*	Sweep streets immediately after period of heaviest vehicular track-out activity

AR0073176

TABLE A11 - 9 - A
(continued)

Emission Source	Mitigation Measure	Reduction Efficiency	Favorable Factors
Fugitive Dust from Roads	Install wheel washers where vehicles enter and exit unpaved roads onto paved roads, or wash off trucks and any equipment leaving the site each trip.	40 - 70%*	Set up truck washing area on paved access road area so subsequent truck travel on unpaved roads can be eliminated
Fugitive Dust from Roads	Pave construction roads that have a traffic volume of more than 50 daily trips by construction equipment, or 150 total daily trips for all vehicles	92.5% (91% for trucks) 94% for Passenger Vehicles)	
Fugitive Dust from Roads	Pave construction access roads at least 100 feet onto the site from main road	92.5% (91% for trucks) (94% for Passenger Vehicles)	
Fugitive Dust from Roads	Pave construction roads that have a daily traffic volume of less than 50 vehicular trips.	92.5% (91% for trucks) (94% for Passenger Vehicles)	
Fugitive Dust stabilizers from Roads use on	Apply water three times daily, or non-toxic soil stabilizers according to manufacturers' specifications to all unpaved parking or staging areas or unpaved road surfaces	45%-85%*	Use non-toxic chemical that are formulated for unpaved road surfaces
Fugitive Dust or signage from Roads	Traffic speeds on all unpaved roads to be reduced to 15 mph or less	40%-70%*	Effective traffic control

* Use the lowest value if better information is not known. If higher than lowest value is used, please provide the supporting analysis and data in the environmental documentation.

AR0073177

EXAMPLE 1

Sample Calculation: PM10 Emissions After Implementation of One Mitigation Measure:

E = 10 lbs of PM10 from unpaved roads
C = 50% reduction from trucks on unpaved roads

$M^* = E \times C$
$M^* = 10 \times 0.5$
$M^* = 5$ lbs of mitigated PM10 emissions

EXAMPLE 2

Sample Calculation: PM10 Emissions After Implementation of Two Mitigation Measures:

E = 10 lbs of PM10 from unpaved roads
C = Measure 1 reduces 50% from trucks on unpaved roads
D = Measure 2 reduces 40% from trucks on unpaved roads
L = Measure 2 will affect 10% of the unmitigated PM10 after implementing Measure 1

$M^{**} = E \times C \times (1 - (D \times L))$
$M^{**} = 10 \times 0.5 \times (1 - (0.4 \times 0.1))$
$M^{**} = 4.8$ lbs of unmitigated PM10 emissions

AR0073178

AR0073179

TABLES FOR ESTIMATING ASBESTOS EMISSIONS AFTER THE IMPLEMENTATION OF MITIGATION MEASURES
(During Physical Removal of Asbestos-Containing Objects in Sections, or Units, or by Scrapping or Chipping Prior to Demolition or Renovation)

- To Prevent the Release of Fibers, Wet the Asbestos Sufficiently with a Wetting Agent or Other Liquid Such as a Removal Encapsulant with a Fine Spray for Several Hours Before Removal Begins. Use Low-Pressure or Airless Spray Equipment. Cut the Impermeable Outer Jacket or Coating Prior to Wetting. Add Surfactant or Wetting Agent to Water (use 1 ounce of polyoxyethylene ester in 5 gallons of water, or use ethylene glycol).
- Use LEV and a Collection System at Or Near the Point of Asbestos Generation; Use Portable or Mobile Vacuum System or Transportable Pneumatic Conveying Systems.
- Use Manometers to Indicate the Need for Cleaning Main Filter.
- Use Space Exhaust Ventilation and Air Cleaning System with Enclosure of the Asbestos Removal Area.
- Use Portable or Designed Exhaust Ventilation Systems.
- Use Transparent Containment Barriers.
- Use Glove Box or Glove Bag Techniques.
- Use Power Grinding, Sanding, Cutting and Drilling Tools with LEV Systems Connected to a Vacuum Source.
- Use Field Cutting Tools Especially Designed for Cutting Asbestos-Containing Materials Pipes, Sheets, etc.
- Wet Cutting Methods Should Be Used During Construction.
- Use EPA-Recommended Substitute for Asbestos and Asbestos Products.
- Spray Asbestos-Containing Material in Which the Asbestos Is Encapsulated With a Bituminous or Resinous Binder.
- Encapsulate Asbestos-Containing Materials by Spraying a Sealant Onto the Material.

AR0073180

TABLE A11 - 10

ESTIMATING ASBESTOS EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES

(Based on the EPA Report, National Emission Standards For Asbestos -- Background Information For Proposed Standards, 1987)

M = E x [J/H]; If Wetting or Polyethylene Barriers Are Used
M = E x [(100 - F)/100]; If Control Device is Used

During Demolition, Renovation and Construction Activities

Where,

M = Mitigated Emissions (Tons Per Year)
E = Non-Mitigated Emissions from Table A9 -10 of Appendix 9, or,
E = Non-Mitigated Emissions; if Control Device is Used
= (G x H)/1 - I; If Control Device is Used;
(For Input Assumptions, Use Table 3-3 of Above-Mentioned Report.)
where,
G = Waste Collected in Control Device in Pounds/Year
H = Asbestos Content of G, i.e., Control Device Waste in Decimal Fraction (if 10%, use 0.10 rather than 10.0)
I = Control Device Efficiency (in Decimal Fraction) (if 15%, Use 0.15 rather than 15.0)
F = Time-Weighted-Average Efficiency by Gas Volumes in Percent *(If 85%, use 85 rather than 0.85)*
J = New Fiber Count After Implementation of Mitigation Measure *(Use Table A11 - 10 - A)*
H = Original Fiber Count Before Implementation of Mitigation Measure *(Use Table A11 - 10 - A)*

TABLE A11 - 10 - A

INPUT ASSUMPTIONS FOR FIBER COUNTS
(Use the Following Information to Determine Percent Reduction of Impacts)

Source	Asbestos Handling Method	Fibers per Cubic Centimeters
8 x 12 Foot Ceiling	Dry Removal (H)	82.2
8 x 12 Foot Ceiling	Untreated Water (J)	23.1
8 x 12 Foot Ceiling	Treated Water (J)	8.1
Inner Room	Dry with Polyethylene Barriers (H or J)	74.4
Middle Room (Entry)	Dry with Polyethylene Barriers (H or J)	6.4
Outer Room (Staging)	Dry with Polyethylene Barriers (H or J)	2.0
Inner Room	Wet with Treated Water & Polyethylene Barriers (H or J)	8.2
Middle Room (Entry)	Wet with Treated Water & Polyethylene Barriers (H or J)	2.0
Outer Room (Staging)	Wet with Treated Water & Polyethylene Barriers (H or J)	0.0

AR0073181

TABLE A11 - 10 - B

ENVIRONMENTAL IMPACTS
NATIONWIDE ASBESTOS EMISSIONS FROM DEMOLITION AND RENOVATION
(Use the Following Information to Determine Percent Reduction of Impacts)
(Kilograms per Year)

Control Method	Asbestos Removal		Waste Disposal	
	Demolition	Renovation	Demolition	Renovation
No Regulation (1987 NESHAP)	1,713	13	509,800	1,400
Anticipated Reduction (Full Compliance with 1987 NESHAP)	700	9	380	2.0
Actual Reduction (Current Practices of Compliance)	1,300	13	226,000	1,000
Negative Pressure & High-Particulate Air (HEPA) With Freezing Weather	400	8	380	2.0
Negative Pressure & HEPA All Removals	0.2	0.003	380	2.0

TABLE A11 - 10 - C

ENVIRONMENTAL IMPACTS
NATIONWIDE ASBESTOS EMISSIONS FROM
MILLING MANUFACTURING AND FABRICATION
(Use the Following Information to Determine Percent Reduction of Impacts)
(Kilograms per Year)

Control Method	Emissions After Implementation of Controls in Year 1987		
	Current Regulation (1987 NESHAP) Best Estimates (Range)	HEPA Filter Best Estimates (Range)	Waste Disposal Estimates
Milling	2,390 (2,220 to 16,420)	0.7 (0.7 to 4.9)	160.0
Fabrication	7,410 (380 to 1,590)	2.2 (0.1 to 0.05)	3.0
	(Manufacturing)		
Friction	3,590 (3,390 to 19,280)	1.1 (0.2 to 5.0)	54.0
A/C Pipe	260 (240 to 1,790)	0.08 (0.07 to 0.5)	5.0
A/C Sheet	190 (190 to 1,130)	0.06 (0.06 to 0.3)	4.0
Paper	60 (60 to 620)	0.02 (0.02 to 0.2)	0.5
Coatings/Sealant	120 (120 to 170)	0.04 (0.04 to 0.05)	0.7
Plastics	250 (200 to 850)	0.07 (0.06 to 0.3)	3.0
Textiles	20 (20 to 480)	0.01 (0.01 to 0.1)	0.4
Packings, Gaskets	10 (10 to 290)	0.01 (0.01 to 0.1)	0.2
V/A Tile	60 (50 to 180)	0.02 (0.01 to 0.05)	0.5
Other Manufacturing			0.1

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TABLES FOR ESTIMATING EMISSIONS FROM HOUSEHOLD ELECTRICITY CONSUMPTION AFTER IMPLEMENTATION OF MITIGATION MEASURES

Mitigation Measures That Reduce Emissions Associated With Electricity Consumption

- Use Compact Fluorescent Lighting
- Use R-30 Ceiling and R-19 Walls with Central H/C Pump System
- Use Refrigerator with Vacuum Powet Insulation
- Heat Water with Combined Space/Water Heater Unit
- Install High-Efficiency Air Conditioners
- Improve Evapotranspiration by Planting Three Trees to Provide Shade and Shadow on Building
  (*If Planting of Three Trees Does Not Provide Shade or Shadow on Building, this Mitigation Measure Does Not Apply. See Next Mitigation Measure*)
- Improve House Albedo by Choosing Light Colors for Exterior of Buildings
- Improve Overall Albedo Effect by:
  - Improving House Albedo or by Choosing Light Colors for Exterior of Buildings
  - Planting Trees to Provide Shade and Shadow on Buildings
  - Using Soil and Building Materials that Reduce the Roughness of Exterior of Buildings
  - Planting Trees in Surrounding Areas, and
  - Avoiding the Use of Dark-Colored Asphalt on Roofs or Surrounding Streets
- Install Fuel Cell For Residential Subdivisions or Office Buildings to Generate Electricity
- Recover Heat Produced in the Fuel Cell and Recycle it for Space Heating
- Recover and Condense the Steam Generated in the Fuel Cell and Recycle it as Hot Water
- Utilize Window Treatment (Reflective Window Film and High-Performance Glazing)

AR0073183

TABLE A11 - 11

ESTIMATING EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE EMISSIONS FROM ELECTRICITY USAGE

(Note: Reduction efficiencies [in percents or in decimal fractions] are not needed for the formula to estimate remaining emissions from remaining Electricity consumption, but reduction efficiencies can be included in environmental documents for additional information)

(Pounds Per Day)

$M = \{[N] + [(O) \times (P)]\}$

(If Mitigation Measures Are Included In The Environmental Documents To Reduce Emissions From Only One Source Category)

$M = \{[N] + [(O_1) \times (P_1)] + [(O_2) \times (P_2)] + [(O_3) \times (P_3)] + \ldots\ldots\ldots + [(O_n) \times (P_n)]\}$

(If Mitigation Measures Are Included In The Environmental Documents To Reduce Emissions From Multiple Source Categories)

Where,

M = Total Mitigated Emissions from New Electricity Consumption After Implementation of Mitigation Measures and Non-Mitigated Portion of Original Electricity Consumption

N = Remaining Non-Mitigated Emissions from Original Electricity Consumption After the Removal of All Source Categories for Which Mitigation Measures Are Included in the Environmental Documents
(From the Use of Table A9 - 11 - C in Appendix 9)

O = Non-mitigated Emissions for Each Source Category From Table A9 - 11 - D in Appendix 9
(Use non-mitigated emissions from Table A9 - 11 - D for each source category O_1, O_2, O_3, ...O_n for which mitigation measures included in the environmental documents)

P = Combined Remaining Emissions Fraction or Remaining Electricity Consumption Fraction for That Source Category for which Mitigation Measure Are Included in the Environmental Document
(Use remaining Electricity consumption fractions from Table A11 - 11 - A for each mitigation measure P_1, P_2, P_3, ...P_n)
$= Q_1 \times Q_2 \times Q_3 \times \ldots \times Q_n$

Where,

Q_1 = Remaining Emission Fraction or Remaining Electricity Consumption Fraction for the First Mitigation Measure for That Source Category

Q_2 = Remaining Emission Fraction or Remaining Electricity Consumption Fraction for the Second Mitigation Measure for That Source Category

Q_n = Remaining Emission Fraction or Remaining Electricity Consumption Fraction for the Last Mitigation Measure for That Source Category

Example: For Source Category, Space Cooling:

	P_1 Remaining E.	O_1 # of Measures
Reorient Buildings Facing North (Q_1)	0.65	1
Double Paned Windows (Q_2)	x 0.90	1
Window Glazing Treatment (Q_3)	x 0.90	1
White-washing of Buildings (Q_4)	x 0.998	1
Total Remaining Emissions Fraction	0.525	4

Thus, for this example, since Value for P_1 = 0.525,

- Combined Remaining Emissions would be 52.5 percent; and,
- Combined Emission Reduction Efficiency from Implementation of 4 different mitigation measures would be
  {[100] - [52.5]} = 47.5 Percent (%).
  (See note below the Table Title)

Similarly, continue to determine value for P_1, P_2, P_3, ...P_n, for all source categories O_1, O_2, O_3, ...O_n for which mitigation measures are included in the environmental document.

AR0073184

TABLE A11 - II - A

REMAINING (NEW) ELECTRICITY CONSUMPTION IN RESIDENTIAL, COMMERCIAL AND INDUSTRIAL SECTORS

(Committee Draft Electricity Efficiency Report, 1990, California Energy Commission)

(Percent of the pre-mitigation Electricity use for that source category)

Note: **The following percentages are provided to determine remaining emissions after the implementation of mitigation measures. These are not percent reductions**

(One hundred minus the following values will provide percent reductions)

Source Category/ Mitigation Measures	Electricity Use (Percent)	Source Category/ Mitigation Measures	Electricity Use (Percent)
Space Cooling		**Space Heating**	
Face buildings to north	65.0	Face buildings to north	45.0
Insulation beyond Title 24	70.0	Insulation beyond Title 24	70.0
Double-paned windows	90.0	Double-paned windows	90.0
Fuel cell	93.0	Fuel cell	92.4
Window glazing treatment	90.0	**Water Heating**	
Efficient air-conditioners	94.0	Solar water heaters	50.0
Three trees per structure	95.0	Central & low-flow showerheads	56.4
White-washing of buildings	99.8	Fuel cell	96.8
Improved overall albedo	99.4	Light-colored roofs	97.0
Refrigeration		**Cooking**	
Efficient appliances	73.0	Efficient appliances	89.0
Fuel cell	79.6	Fuel cell	95.5
Freezing		**Clothes Dryer**	
Efficient appliances	84.0	Efficient appliances	89.0
Fuel cell	96.1	Fuel cell	93.2
Dishwashers w/Hot-Water Cycle		**Clothes Washer w/Hot-Water wash**	
Efficient appliances	89.0	Efficient appliances	89.0
Fuel cell	99.2	Fuel cell	98.7
Dishwasher Motor		**Clothes Washer Motor**	
Efficient appliances	89.0	Efficient appliances	89.0
Fuel cell	97.6	Fuel cell	99.1
Lighting		**Miscellaneous**	
Face buildings to north	69	Ventilation in parking lots	99.31 (R)
Lighting controls	96.0(R)	Fuel cell	86.3
Low-sodium parking lights	98.0 (R & C)	Ventilation in parking lots	99.5 (C)
Fuel cell	86.3	Ventilation in parking lots	99.5 (I)
Low-sodium lighting	87.5 (I)	**Lighting**	
Lighting controls	61.5 (I)	Lighting controls	50.0 (C)
		Use of Fuel cell	
For Swimming Pool Heating:		**For Solar Water Heating:**	
Solar	99.1	Water heating	99.8
Pump	96.6	Water heater's pump	99.96
Water Bed (fuel cell)	97.2	**Color TV**	95.2
Furnace Fan	98.4	**Other**	99.9
		Industrial	
Process Motors		**Process Heat**	
Modify processes	56.0	Use heat recovery systems	85.0

(R) = Residential (C) = Commercial (I) = Industrial

Bolded words describe source categories and remaining describe potential mitigation measures for those source categories. Impact should be analyzed for each source category separately. To determine remaining emissions from a source category, efficiencies of several mitigation measures for that source category can be combined.

AR0073185

TABLES FOR ESTIMATING EMISSIONS FROM HOUSEHOLD NATURAL GAS CONSUMPTION AFTER IMPLEMENTATION OF MITIGATION MEASURES

Mitigation Measures That Reduce Emissions Associated With Natural Gas Consumption

- Use R-30 Ceiling and R-19 Walls with Central H/C Pump System
- Heat Water with Combined Space/Water Heater Unit
- Improve Evapotranspiration by Planting Three Trees to Provide Shade and Shadow on Building
  (If Planting of Three Trees Does Not Provide Shade or Shadow on Building, this Mitigation Measure Does Not Apply. See Next Mitigation Measure)
- Improve House Albedo by Choosing Light Colors for Exterior of Buildings
- Improve Overall Albedo Effect by:
  - Improving House Albedo or by Choosing Light Colors for Exterior of Buildings
  - Planting Trees to Provide Shade and Shadow on Buildings
  - Using Soil and Building Materials that Reduce the Roughness of Exterior of Buildings
  - Planting Trees in Surrounding Areas, and
  - Avoiding the Use of Dark-Colored Asphalt on Roofs or Surrounding Streets
- Recover Heat Produced in the Fuel Cell and Recycle it for Space Heating
- Recover and Condense the Steam Generated in the Fuel Cell and Recycle it as Hot Water
- Utilize Window Treatment (Reflective Window Film and High-Performance Glazing)

AR0073186

TABLE A11 - 12

ESTIMATING EMISSIONS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE EMISSIONS FROM NATURAL GAS USAGE

(Reduction efficiencies either in percents or in decimal fractions are not needed for the formula to estimate remaining emissions from remaining Natural Gas consumption, but reduction efficiencies can be included in environmental documents for additional information)

(Pounds Per Day)

$M = ([N] + [(O) \times (P)])$

(If Mitigation Measures Are Included In The Environmental Documents To Reduce Emissions From Only One Source Category)

$M = \{[N] + [(O_1) \times (P_1)] + [(O_2) \times (P_2)] + [(O_3) \times (P_3)] + \_\_\_\_\_ + [(O_n) \times (P_n)]\}$

(If Mitigation Measures Are Included In The Environmental Documents To Reduce Emissions From Multiple Source Categories)

Where,

- M = Total Mitigated Emissions from New Electricity Consumption After Implementation of Mitigation Measures and Non-Mitigated Portion of Original Electricity Consumption
- N = Remaining Non-Mitigated Emissions from Original Electricity Consumption After the Removal of All Source Categories for Which Mitigation Measures Are Included in the Environmental Documents
  (From the Use of Table A9 - 11 - C in Appendix 9)
- O = Non-mitigated Emissions for Each Source Category From Table A9 - 11 - D in Appendix 9
  (Use non-mitigated emissions from Table A9 - 11 - D for each source category O_1, O_2, O_3, $\_\_O_n$ for which mitigation measures included in the environmental documents)
- P = Combined Remaining Emissions Fraction or Remaining Electricity Consumption Fraction for That Source Category for which Mitigation Measure Are Included in the Environmental Document
  (Use remaining Natural Gas consumption fractions from Table A11 - 11 - A for each mitigation measure P_1, P_2, P_3, $\_\_P_n$)
  $= Q_1 \times Q_2 \times Q_3 \times \ldots\ldots \times Q_n$
  Where,
  - Q_1 = Remaining Emission Fraction or Remaining Natural Gas Consumption Fraction for the First Mitigation Measure for That Source Category
  - Q_2 = Remaining Emission Fraction or Remaining Natural Gas Consumption Fraction for the Second Mitigation Measure for That Source Category
  - Q_n = Remaining Emission Fraction or Remaining Natural Gas Consumption Fraction for the Last Mitigation Measure for That Source Category

Example:

For Source Category, Space Cooling:	P_1 Remaining E.	O_1 # of Measures
Reorient Buildings Facing North (Q_1)	0.65	1
Double Paned Windows (Q_2)	x 0.90	1
Window Glazing Treatment (Q_3)	x 0.90	1
White-washing of Buildings (Q_4)	x 0.998	1
Total Remaining Emissions Fraction	0.525	4

Thus, for this example, since Value for P_1 = 0.525,

- Combined Remaining Emissions would be 52.5 percent; and,
- Combined Emission Reduction Efficiency from Implementation of 4 different mitigation measures would be
  $\{[100] - [52.5]\}$ = 47.5 Percent (%).
  (See note provided under Table Title)

Similarly, continue to determine value for $P_1, P_2, P_3, \_\_P_n$, for all source categories O_1, O_2, O_3, $\_\_O_n$ for which mitigation measures are included in the environmental document.

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TABLE A11 - 12 - A

SOURCE CATEGORIES (P) OF POST-MITIGATION (NEW) NATURAL GAS USE IN RESIDENTIAL, COMMERCIAL AND INDUSTRIAL SECTORS
(Committee Draft Natural Gas Efficiency Report, 1990, California Energy Commission)
(Percent of the pre-mitigation Natural Gas use for that source category)

Note: The following percentages are provided to determine remaining emissions after the implementation of mitigation measures. These are not percent reductions
(One hundred minus the following values will provide percent reductions)

Source Category/ Mitigation Measures	Electricity Use (Percent)	Source Category/ Mitigation Measures	Electricity Use (Percent)
Space Cooling		**Space Heating**	
Face buildings to north	65.0	Face buildings to north	40.0
Insulation beyond Title 24	70.0	Insulation beyond Title 24	70.0
Double-paned windows	90.0	Double-paned windows	90.0
Window glazing treatment	90.0	**Water Heating**	
Efficient air-conditioners	94.0	Solar water heaters	50.0
Three trees per structure	95.0	Central & low-flow showerheads	58.4
White-washing of buildings	99.8	Light-colored roofs	97.0
Improved overall albedo	99.4		
Refrigeration		**Cooking**	
Efficient appliances	N/A	Efficient appliances	89.0
Freezing		**Clothes Dryer**	
Efficient appliances	N/A	Efficient appliances	89.0
Dishwashers w/Hot-Water Cycle		**Clothes Washer w/Hot Water Wash**	
Efficient appliances	89.0	Efficient appliances	89.0
Dishwasher Motor		**Clothes Washer Motor**	
Efficient appliances	89.0	Efficient appliances	89.0
Lighting		**Miscellaneous**	
Face buildings to north	69	Ventilation in parking lots	99.02 (R)
Lighting controls	N/A (R)	Ventilation in parking lots	N/A (C)
Low-sodium parking lights	N/A (R & C)	Ventilation in parking lots	N/A (I)
Low-sodium lighting	N/A (I)		
Lighting controls	N/A (I)	**Lighting**	
		Lighting controls	N/A (C)

(R) = Residential (C) = Commercial (I) = Industrial N/A Not Available

Bolded words describe source categories and remaining describe potential mitigation measures for those source categories. Impact should be analyzed for each source category separately. To determine remaining emissions from a source category, efficiencies of several mitigation measures for that source category can be combined.

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TABLES FOR ESTIMATING EMISSIONS FROM COATINGS AND SPRAY EQUIPMENT AFTER IMPLEMENTATION OF MITIGATION MEASURES

Mitigation Measures That Reduce Emissions Associated With Coatings and Spray Equipment

- Eliminate the Use of Paints and Solvents By Utilizing Precoated Building Materials
- Eliminate the Use of Paints and Solvents By Utilizing Naturally Colored Building Materials
- Use Water-Based or Low-VOC Coatings
- Use Coating Transfer or Spray Equipment with High Transfer Efficiency
- Employ Skilled Operators Who Are Well-Versed in Rule 1113 Requirement (Not Quantifiable, However, the Anticipated Emission Reductions Are from Improved Transfer Efficiency and from Less Paint and Solvent Spills)

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TABLE A11 - 13

ESTIMATING EVAPORATIVE EMISSIONS FROM ARCHITECTURAL COATINGS AND BUILDING MATERIALS AFTER IMPLEMENTATION OF MITIGATION MEASURES THAT REDUCE EMISSIONS FROM COATINGS AND SPRAY EQUIPMENT

(These emissions occur during exterior finish and interior finish phases of project construction. If these phases overlap other phases of the construction, these emissions should be combined with ROC emissions from the other phases. These combined emissions should be used to determine project significance.)

(Pounds Per Day)

$$M1 = [E \times \{1 - (G + H + I + J)\}] + [F \times \{(G \times K) + (H \times L) + (I \times N) + (J \times O)\}]$$

(Use this formula if non-mitigated emissions are estimated first)

$$M2 = [(P \times Q)/(R)] \times [S]$$

(Use this formula if mitigated emissions are estimated without estimating non-mitigated emissions, or to estimate new coating and spray equipment-specific emissions. Convert these emissions per 1000 square foot with project-specific thickness in mils for value of K, L, N, and O for estimating M1 in above formula)

Where,

- M1 = Mitigated Coatings Emissions After Implementation of Mitigation Measures
- M2 = Mitigated emissions of Volatile Reactive Organic Compounds (ROC) from architectural coatings
- E = Non-Mitigated Emissions Before Implementation of Mitigation Measure
  (From Table A9 - 13)
- F = Original Total Area (in Square Feet) To Be Coated with Original Coating Material Per Project Before the Implementation of that Mitigation Measure
  (The area used for estimating non-mitigated emissions (E) in Table A9 - 13 of Appendix 9. If unknown, use Table A11 - 13 - E methodologies for estimating this area)
- G = Decimal Fraction of Original Amount of Area Not Coated with Original Coating Material due to the Use of Pre-coated Building Materials or Natural-Colored Building Materials
  (If the percent is expressed as 19.0, use 0.19 for G, and not 19.0. Natural-colored materials should not have additional emissions. Also, there is no need to add off-site emissions associated with the pre-coated building materials. However, vehicular emissions associated with hauling of these materials should be estimated using Table A9 - 5 of Appendix 9 and these vehicular emissions should be mitigated and mitigated emissions should be estimated using Table A11 - 5 of Appendix 11)
- K = 0.0, natural-colored or pre-coated materials' emission rate
- H = Decimal Fraction of Original Amount of Area Not Coated with Original Coating Material due to the Use of Water Based or Low VOC Coating Materials
  (If the percent is expressed as 21.0, use 0.21 for H, and not 21.0)
- L = Emission Rate of Water-Based or Low-VOC Coating Materials
  (Use value of M2 converted into per 1000 square feet or see Table A9 - 13 - C, A11 - 13 - D, and A11 - 13 - E)
- I = Decimal Fraction of Original Amount of Area Not Coated with Original Spraying Equipment due to the Use of High Transfer Efficiency Equipment
  (If the Percent is Expressed as 21.0, Use 0.21 for I, and not 21.0)
- N = Emission Rate of Original Coating with Greater or Improved-Transfer-Efficiency Spray Equipment
  (Use value of M2 converted into per 1000 square feet or see Table A9 - 13 - C, A11 - 13 - D, and A11 - 13 - E)

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TABLE A11 - 13 (Continued-)

J = Decimal Fraction of Original Amount of Area not Coated with Original Coating Materials and Spray Equipment due to the Use of Water-Based or Low-VOC Coating Materials Along With the Use of High Transfer Efficiency Equipment For the Same Area
(If the percent is expressed as 21.0, use 0.21 for J, and not 21.0)

O = Emission Rate of New Water-Based or Low-VOC Coating with Greater or Improved-Transfer-Efficiency Spray Equipment
(Use value of M2 converted into per 1000 square feet or see Table A9 - 13 - C, A11 - 13 - D, and A11 - 13 - E)

P = Pounds of ROC emissions
(If unknown, use Table A11 - 13 - C and Table A11 - 13 - D for this value. These values are expressed for 1 mil thick 1000 square feet area to be coated.)

O = One mil (0.001 inch) thick total exterior and/or interior area to be coated
(If unknown, use Table A11 - 13 - F methodology to determine this value. Also, thickness should always be expressed in "mils" of thickness for this methodology to work. Also, see Table A11 - 13 - B for percent transfer efficiency default values.)

R = One thousand (1,000) square feet
(This value is needed because value for P is for one mil thick 1,000 square feet surface area.)

S = Required "mils" of coating thickness for the project
(If unknown, use 17.5 mils for exterior and interior walls, and 3 mils for wood and metal surfaces. Also, use Table A11 - 13 - A for mil thickness default values for coatings on various surfaces.)

TABLE A11 - 13 - A

Dry Film Thickness (Mils)

Surface Type	Thickness
Wood/Metal	1 < 4
Concrete/Masonry	5 < 30

TABLE A11 - 13 - B

Transfer Efficiency Fractions (Percent)

Coating Equipment Type	Transfer Efficiency
Air Atomized Gun	25
HVLP	65
Brush/Roller	100

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TABLE A11 - 13 - C

EMISSIONS OF VOLATILE REACTIVE ORGANIC COMPOUNDS (ROC) FROM ARCHITECTURAL COATINGS

(Value for "F" in Pounds for 65 % Transfer Efficiency For Spray Equipment Similar to HVLP.)

(This table provides VOC (ROC) emissions for 1 mil thick 1000 square feet area for all VOC limits included in Rule 1113. Rule 1113 should be consulted for corresponding coating types.)

(Pounds Per One Mil Thick 1000 Square foot Area)

Rule 1113 Limits (Grams/Liter)	Rule 1113 Limits (Pounds/Gallon)	Coatings (Gallons/1000 SF)	Clean-Up Solvents Percent	VOCs Lbs
Conventional Coatings				
*(Conventional coatings assumed to have 66.26 percent by weight solids, and 10.45 pounds per gallon density.)***				
780	6.49	7.92	10.0	57.21
730	6.07	5.28	10.0	35.92
680	5.66	4.13	10.0	26.42
650	5.41	3.65	10.0	22.46
600	4.99	2.97	10.0	17.00
580	4.83	2.79	10.0	15.55
550	4.58	2.50	10.0	13.29
500	4.16	2.21	10.0	10.82
420	3.49	6.38	15.0	8.39
400	3.33	5.97	15.0	7.95
High-Solid Coatings				
*(High-solid coatings assumed to have 77.35 percent by weight solids, and 11.33 pounds per gallon density.)***				
350	2.91	4.32	20.0	6.50
346	2.88	4.28	20.0	6.46
304	2.53	3.70	20.0	5.85
234	1.95	2.76	20.0	4.85
Water-Based Coatings				
*(Water-based coatings assumed to have 47.67 percent by weight solids, and 10.54 pounds per gallon density.)***				
310	2.58	7.73	5.0	8.84
262	2.18	6.34	5.0	7.41
258	2.15	6.25	5.0	7.32
253	2.10	6.10	5.0	7.17
250*	**2.08**	**6.05**	**5.0**	7.12
244	2.03	5.73	5.0	6.76
217	1.81	5.11	5.0	6.14
152	1.26	3.45	5.0	4.46
148	1.23	3.37	5.0	4.38
103	0.86	2.29	5.0	3.27
75	0.62	1.61	5.0	2.56

* If unknown use, 2.08 pounds/gallon VOC coatings for exterior walls.

** ARB's test results in 1988 report for Rule 1113 sales survey.

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TABLE A11 - 13 - D

EMISSIONS OF VOLATILE REACTIVE ORGANIC COMPOUNDS (ROC) FROM ARCHITECTURAL COATINGS

(Value for "P" in Pounds for 100 % Transfer Efficiency for Brushes, Electrostatic Spray Guns)

(This table provides VOC (ROC) emissions for 1 mil thick 1000 square feet area for all VOC limits included in Rule 1113. Rule 1113 should be consulted for corresponding coating types.)

(Pounds Per One Mil Thick 1000 Square foot Area)

Rule 1113 Limits (Grams/Liter)	Rule 1113 Limits (Pounds/Gallon)	Coatings (Gallons/1000 SF)	Clean-Up Solvents Percent	VOCs Lbs
Conventional Coatings				
*(Conventional coatings assumed to have 66.26 percent by weight solids, and 10.45 pounds per gallon density.)***				
780	6.49	5.17	10.0	37.33
730	6.07	3.44	10.0	23.44
680	5.66	2.70	10.0	17.24
650	5.41	2.38	10.0	14.66
600	4.99	1.94	10.0	11.09
580	4.83	1.82	10.0	10.15
550	4.58	1.63	10.0	8.67
500	4.16	1.44	10.0	7.06
420	3.49	4.16	15.0	5.48
400	3.33	3.90	15.0	5.19
High Solid Coatings				
*(High solids coatings assumed to have 77.35 percent by weight solids, and 11.33 pounds per gallon density.)***				
350	2.91	2.82	20.0	4.25
346	2.88	2.79	20.0	4.22
304	2.53	2.41	20.0	3.82
234	1.95	1.80	20.0	3.17
Water Based Coatings				
*(Water-based coatings assumed to have 47.67 percent by weight solids, and 10.54 pounds per gallon density.)***				
310	2.58	5.05	5.0	5.74
262	2.18	4.12	5.0	4.81
258	2.15	4.06	5.0	4.76
253	2.10	3.97	5.0	4.66
250*	2.08	3.93	5.0	4.62
244	2.03	3.72	5.0	4.40
217	1.81	3.32	5.0	3.99
152	1.26	2.24	5.0	3.90
148	1.23	2.19	5.0	2.90
103	0.86	1.49	5.0	2.13
75	0.62	1.04	5.0	1.66

* If unknown use, 2.08 pounds/gallon VOC coatings for exterior walls.

** ARB's test results in 1988 report for Rule 1113 sales survey.

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TABLE A11 - 13 - C and D (Continued-)

ASSUMPTIONS:

1. The use of solvents in the cleaning and painting of the structures will generate Volatile Organic Compound (VOC) or Reactive Organic Compound (ROC) emissions.
2. Non-mitigated VOCs are those which should not exceed Rule 1113 limits as coating is applied to the surface.
3. After removing % volume of VOC (non-exempt solvent), water and exempt solvents, what remains is the % volume of solids.
4. Non-exempt solvent density is 7.36 pounds per gallon of solvent.
5. Exempt solvent (1, 1, 1 -TCA) density is 11.06 pounds per gallon of solvent.
6. Water density is 8.337 pounds per gallon.
7. Water percent by weight is assumed to be 3.5 times higher than that of exempt solvent in the coating. (ARB's test results in 1988 report for Rule 1113 sales survey.)
8. For non-mitigated emissions, transfer efficiency is 25 % of solids applied to the surface.
9. Mathematical formulation indicates that 1 gallon of solids will cover 1 mil (0.001 inch) thick a 1604 square foot area. For the same amount of coating, if thickness is increased, the size of the area that can be coated with that amount of paint will be proportionally decreased. For the same size area if thickness is increased, the amount of coating will be proportionally increased.

TABLE A11 - 13 - E

ESTIMATING SURFACE AREA TO BE COATED

Estimate interior and exterior area to be covered by using the following methodologies:

Residential Structures:

Method 1.

It was estimated that every square foot of floor space would require the coating equivalent to that of 2.7 square feet of surface area. This may actually be an underestimate, but allows for non-coated surfaces such as windows, fireplaces, cabinets, overhead recessed ceiling lighting, etc.

For single family units consider 1/7 acre of floor surface or lot size per unit (ARB Report March 1990).

For multi-family units 1/20 acre lot size per unit (ARB Report March 1990).

Method 2.

Exterior Wall

1,280 square feet of exterior wall per single-family unit; or,
1,800 square feet of exterior wall on average for other than single-family units.
(Energy and Labor in the Construction Sector, Hannon, et al).

Interior Wall

The exterior wall amount can be tripled to consider interior walls, ceiling coatings, trim, etc.

Non-residential Structures:

For nonresidential structures (schools, shopping malls, etc.) rooms will be larger in size, ceilings will be acoustic panels type. In this case, each of the floor area can be multiplied by 2.0 to obtain the total area to be coated.

Emissions from exterior and interior walls should be estimated and reported separately. These emissions should be combined with emissions from other construction activities.

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Control Technologies. Some projects that may be encountered by local planners may include point sources requiring permits from the District, as well as air pollution control equipment. A point source has one or more permitted pieces of equipment in a fixed identifiable location. Pursuant to the District's Regulation XIII, all major new or modified emission sources in the Basin must install best available control technology (BACT) to reduce emissions to the lowest achievable emission rate (LAER). BACT consists of a variety of air pollution control technologies, including process changes and substitution of high-polluting materials with low-polluting materials. BACT can also consist of air pollution control equipment that captures or oxidizes criteria pollutants to reduce air pollution emissions. The District periodically publishes a BACT Guideline document (available from the District's Public Information Center) for commonly encountered industrial processes or equipment categories. The purpose of the BACT Guideline is to provide the public with an up-to-date listing of current BACT requirements.

The District has determined that in some situations various air pollution control technologies may generate cross-media or indirect environmental impacts that may require analysis in a CEQA document to determine the significance of the impact and, if necessary, identify mitigation measures to minimize these cross-media impacts to the greatest extent feasible. For the purposes of this discussion, a cross-media impact is the removal of a contaminant or hazardous substance from one medium, e.g., air, and transferring it to another medium, e.g., water, which is typically released to a public sewer system. The purpose of this appendix, therefore, is to identify some common types of air pollution control equipment, or BACT equipment, and to summarize potential cross-media or other indirect adverse environmental impacts they may create, which may warrant a CEQA analysis.

A.13.1 Volatile Organic Compound (VOC) Control Technologies Add-On Control Technologies

For facilities unable to use reformulated materials or with operations that do not use coatings, two basic types of add-on control technologies are available, carbon adsorption and incineration. Many of the VOC control technologies can also be used to control air toxics. These technologies are briefly described in the following subsections.

Carbon Adsorption

Carbon adsorption is a control process typically used for organic contaminants (an organic compound is a chemical compound containing carbon and, typically, hydrogen). This control technology operates by collecting air containing VOCs and venting them to a carbon bed where the organic contaminants in the air stream are separated from the remaining effluent and adsorbed onto the surface of the carbon particles. Depending on the application, carbon adsorbers can achieve a removal efficiency of essentially 100% until breakthrough occurs (a situation where the carbon particles are completely saturated with organic contaminants and are no longer able to remove these contaminants from the exhaust air). Carbon adsorption is commercially available and is used in a wide variety of industrial applications. Although carbon adsorption devices for most applications have a similar design, two general categories of applications have been identified that differ significantly in their potential to create adverse environmental impacts. The two categories are:

(1) Vapor solvent recovery, and

(2) Liquid solvent recovery

Gaseous phase vapor recovery systems use a carbonized organic material (carbonized coconut shell, for example) as an activated carbon source to remove organic substances from gas streams. When the activated carbon of vapor solvent recovery becomes saturated with organic material, it is removed and regenerated (usually off-site) typically using a rotary kiln to oxidize (destroy by combustion) the organic material. Once the organic material is oxidized, the activated carbon can be reused. During the regeneration process, approximately five percent of the activated carbon is lost. This loss is replaced with new activated carbon and the entire amount is then reused. Vapor solvent recovery carbon can be continuously regenerated and replenished.

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Liquid solvent recovery uses a moderately hard type of coal as a source of activated carbon to capture solvents. When carbon is saturated with solvent it is regenerated by heating the carbon and injecting either steam or hot gas into the carbon bed. The resulting hot solvent mixture is vented to a condenser, which cools the hot gases to a liquid/solvent mixture (known as regenerant). The solvent is then separated from the regenerant by gravity or distillation. The recovered solvent is then recycled or can be used in another application.

Carbon adsorption solvent recovery systems are most effective when only a single solvent is involved and the solvent does not break down during the heating process. For a system in which VOC compounds have a molecular weight less than or equal to eight carbon atoms, no polymer formers, or excessive particulates, a carbon life of 5-10 years is possible.

Depending on the type of carbon adsorption system used, several types of secondary impacts may occur. Carbon adsorption systems used for liquid solvent recovery have the potential to generate water quality impacts because water is often used to clean the spent carbon. Water contaminated with organic compounds could then be released to a public sewer system, not only affecting water quality, but water treatment utilities (often called Publicly Owned Treatment Works or POTWs).

Regenerating spent carbon for each type of carbon adsorption system has the potential to create air quality impacts because the regeneration process requires a combustion source which can generate criteria pollutant emissions or emissions of other products of incomplete combustion. For example, liquid and aqueous phase vapor recovery systems require a combustion source to heat water to steam which is then used to purge adsorbed organics from the carbon. Gaseous phase vapor recovery uses a combustion device to directly oxidize the organic compounds adsorbed to the carbon.

Liquid solvent carbon adsorption systems also have the potential to generate solid waste impacts because the coal eventually loses its effectiveness at capturing organic compounds and must then be disposed of. As previously indicated, carbon used in the liquid and aqueous phase can be regenerated and reused for approximately 5-10 years depending upon specific operating parameters, the components of the waste stream, control requirements, etc. Since spent carbon is typically considered a hazardous waste, it would most likely be disposed of in a Class 1 landfill. Therefore, hazardous waste disposal utilities could be adversely affected.

Solid waste impacts are, typically, not a problem with vapor recovery systems because the activated carbon can be used continuously until it is incinerated in the rotary kiln in the regeneration process.

Any incinerated carbon ash is generally produced in small quantities and, therefore, is typically not a significant solid waste impact.

Risks of upset impacts could occur during handling and transport of spent carbon because in many cases the organic compound may be flammable, thus creating risks of fire or explosion.

Incineration

Incineration is the most universally applied control method for organics because it is a "destructive" control technique in which the pollutants are destroyed, i.e., oxidized (burned) to carbon dioxide, water vapor and other products of combustion. Given the proper conditions, any organic compound will oxidize. Two of the most common types of incinerator technologies are identified here.

Thermal Incineration

Thermal incineration has a wide range of applications and is frequently used to oxidize organic compounds emitted from process industries. The organic compounds are collected and vented to a combustion chamber where the compound is oxidized. Supplemental fuel, generally natural gas, may be added to the combustion chamber to maintain the combustion process. The rate at which the compound is oxidized is greatly affected by the temperature within the combustion device. Thermal incineration destroys most organic compounds at temperatures between 1,100°F and 1,500°F. At these temperatures, efficiency levels of up to 99% are possible.

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Catalytic Incineration

A catalytic incinerator is essentially identical to a thermal incinerator except that combustion of the exhaust gas takes place in the presence of a catalyst (a catalyst is a substance that promotes/accelerates a chemical reaction without being changed in the reaction itself). The presence of the catalyst allows the incinerator to operate at a lower temperature range (500°F-900°F compared to 1,100°F-1,500°F for thermal incinerators), consequently reducing supplemental fuel consumption and associated operating costs. Reduction efficiencies of up to 99% are also possible with catalytic incinerators.

Both types of incinerators have the potential to create air quality impacts because both generate criteria pollutant and reactive organic pollutant products. Because catalytic incinerators operate at lower combustion temperatures, they typically produce lower oxides of nitrogen emissions, which contribute to NO2 and ozone concentrations. Although newer incinerators burn natural gas very efficiently (thus producing fewer emissions) emissions should be calculated and compared with the District's emissions threshold of significance (Refer to Chapter 6 of this Handbook).

A drawback of catalytic incinerators is that the catalyst becomes less effective over time. Eventually the catalyst must be replaced and the spent catalyst must be disposed of, thus creating the potential for solid waste impacts.

Coating Solvent Reformulation

Methods of reducing VOC emissions from operations using coatings (paints) and cleaning solvents include reducing the VOC content and/or increasing the solids content of coating and cleanup solvent materials. Reformulating coatings or solvents with new or alternative compounds is another method that can be used to comply with District emission reduction requirements.

Product reformulation may result in adverse environmental impacts depending on the characteristics and chemical composition of the reformulated materials. For example, compounds such as 1,1,1-trichloroethane (TCA), methylene chloride (dichloromethane), and other chlorofluorocarbons (CFCs) could produce environmental impacts, including adverse human health effects. Worker safety and human health could be affected because some reformulated compounds may be toxic, carcinogenic, or have other adverse effects on human health. In addition, both TCA and CFCs are considered ozone depleting substances and CFCs contribute to global warming. Some reformulated compounds may be flammable, thus, increasing the risk of fire or explosions. Other risk of upset impacts could occur if any hazardous reformulated compounds are accidentally released during transport, which may also adversely affect public health.

A.13.2 NOx Control Technologies

NOx is formed by the oxidation of atmospheric nitrogen during combustion and from the oxidation of bound nitrogen in organic fuels. Thermal NOx formation is negligible below a peak flame temperature of approximately 2800°F, but rises exponentially above this temperature. Fuel NOx formation is typically a function of the type of fuel used for combustion.

Therefore, the actual amount of NOx formed depends, in part, upon the amount of available air supply, the type of fuel used, and the combustion temperature. Two major categories of NOx control options are currently available: (1) combustion modification and (2) flue gas treatment systems.

Combustion Modification

Combustion modification methods reduce NOx emissions, either by lowering the combustion temperature or by reducing the amount of oxygen available for combustion. The actual NOx reduction achieved is case-specific and depends upon the technology employed. In general, combustion modification reduces NOx emissions approximately 10-70% from baseline emission values. Combustion modification technologies have found widespread industrial applications. An overview of six widely used combustion modification technologies and one experimental technology is briefly described below.

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Low Excess Air Burners

Low-excess air (LEA) burners require less oxygen for combustion because air and fuel are thoroughly mixed prior to combustion, thus requiring less excess air. Although fuel is more completely burned in this process, reducing excess oxygen tends to reduce combustion efficiency while increasing CO and particulate emissions. LEA burners have a maximum NOx emission reduction efficiency of approximately 25%.

Staged Air Burners

Staged air (SA) burners divide the combustion fuel mixture into two or more streams before combustion. The first stream flows into a fuel-rich zone where the fuel is partially burned. At this stage, thermal NOx formation is reduced because of the lack of excess oxygen. The remainder of the combustion air is mixed with the partially burned combustion air downstream of the fuel-rich zone where combustion is then completed. At this stage, NOx formation is reduced because of a lower flame temperature. SA burners have a maximum NOx reduction efficiency of about 30%.

Flue Gas Recirculation

Flue Gas Recirculation (also called exhaust gas recirculation when applied to internal combustion engines) is a control technique in which the flue gas is mixed with incoming combustion air. This process limits the oxygen level, resulting in a lower flame temperature and a lower peak combustion temperature, thus reducing thermal NOx formation. This method alone reduces NOx formation approximately 50% for gaseous fuel firing. In some circumstances, flue gas recirculation in conjunction with other control techniques, SA for example, can achieve a NOx reduction efficiency approaching 70%.

Water/Steam Injection

NOx formation rates can be lowered by the instantaneous cooling of the combustion temperatures. This cooling can be accomplished through the injection of water or steam into the combustion zone. The injected water acts as the inert mass and results in lower NOx production through lower peak combustion temperatures. Water injection, when used alone, can reduce NOx emissions 33-67%, but there is a slight increase in CO emissions due to the lowered combustion temperatures. Steam injection has an even higher NOx reduction efficiency. The primary impact associated with this type of control technology is increased water demand as substantial volumes of water may be necessary to achieve the desired NOx control efficiency. No other direct or indirect impacts are associated with this NOx control technology.

Stratified Combustion

Stratified combustion modification, used primarily for NOx control in internal combustion engines (ICEs), involves layering the fuel such that one layer is fuel-rich and the other layer is fuel-lean during and just after the combustion process. The fuel-rich layer is situated near the spark plug so that the elements burned as the flame moves out from the spark are subject to low-NOx formation rates because of the lower temperature and lack of oxygen. The stratified combustion process must be monitored frequently because improper stratification can actually cause NOx emissions to increase. No adverse environmental impacts, either direct or indirect, are associated with this type of control technology.

Lean Combustion

Air/fuel adjustments are applicable primarily to spark-ignited engines. Lean combustion requires increasing the air mass relative to the fuel concentration, thus creating a lean fuel mixture. One method of increasing the air/fuel ratio is through the application of turbocharging. Turbocharging involves recovering the energy of the exhaust gas stream by passing it through a turbine mechanically coupled to a compressor. The energy extracted from the exhaust is used to increase the pressure of the incoming air, increasing the quantity of air in the cylinder. Turbocharging is often used in conjunction

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with an intercooler to offset the temperature rise associated with increasing the compression. Turbocharging reduces NOx emissions by reducing the brake specific emission rate. As with stratified combustion, no direct or indirect adverse environmental impacts are associated with this type of control technology.

Low NOx Burners

Low NOx burners use a combination of fuel rich mixtures and staged combustion to control combustion and reduce NOx flue gas concentrations. This method reduces NOx formation approximately 50%. This technology can be used in conjunction with flue gas recirculation to achieve additional NOx reductions.

Oxygen Trim. Mechanical equipment can be used to reduce the excess oxygen by using oxygen trim. This method involves combustion at a low air to fuel ratio, still allowing for complete fuel combustion. Oxygen trim can increase boiler fuel combustion efficiency, which can result in a fuel savings of 1-2%. This method has a NOx emission reduction efficiency of 10-25%.

Staged Fuel Burners. Staged fuel (SF) burners divide the fuel into two or more streams. One fuel stream flows into, and is burned in a lean primary combustion zone. The remainder of the fuel is then mixed with the partially burned fuel downstream of the lean primary combustion zone. This process lowers the peak flame temperature, which reduces thermal NOx formation. SF burners have a maximum NOx emission reduction efficiency of approximately 55%.

Ceramic Fiber Burner. An emerging NOx control technology that requires additional retrofit demonstration on boiler equipment is a new ceramic fiber burner. Low NOx levels are achieved due to the slow kinetics of thermal NOx formation. The largest unit tested so far is a 10 million Btu burner. Test results indicate NOx emission levels of 50 ppm. Impacts. Few adverse environmental impacts have been identified for combustion modification technologies. The only exception is possibly for ceramic fiber burners. Ceramic fiber burners may pose worker health concerns because they contain ceramic fibers that could be released into the work place at a rate that may adversely affect worker health. Ceramic fibers are a health concern because of their structural similarity to asbestos, a carcinogen. However, there have been no human studies investigating the carcinogenicity of ceramic fibers. Furthermore, tests of ceramic fiber burners indicated that releases of ceramic fibers from radiant burners were typically 2-4 orders of magnitude less than the two fibers per cubic centimeter of air threshold limit value (TLV) established for ceramic fibers and recommended by the American Conference of Governmental Industrial Hygienists. This result should be periodically re-evaluated in case the conclusions regarding ceramic fibers are modified in the future.

Post-Combustion Flue Gas Treatment

Post-combustion flue gas treatment systems use a reducing agent, usually ammonia (NH_3), to react with NOx, reducing it to molecular nitrogen (N_2) and water (H_2O). There are two basic types of post-combustion flue gas treatment technologies: selective catalytic reduction and selective noncatalytic reduction. Both technologies, discussed below, involve injecting a reducing agent, such as ammonia or urea, directly into the flue gas stream.

Selective Catalytic Reduction (SCR). This technology reduces NOx in the flue gas by using either anhydrous ammonia (a gaseous form free of water or moisture) or aqueous ammonia (a liquid mixture of ammonia and water) as a reducing agent. The reduction reaction occurs in the presence of a proprietary catalyst. In general, ammonia vapor, often diluted with air or steam, is injected into the flue gas in an approximately equimolar[1] ratio, depending upon the NOx removal requirements. To ensure maximum efficiency, the flue gas and ammonia should be thoroughly mixed to ensure uniform gas distribution prior to entering the catalyst grid system. For optimum results, this reaction must occur in a relatively narrow temperature window of between 200°C to 450°C. NOx emissions are reduced by the ammonia to molecular nitrogen (N_2) and water vapor over the catalyst surface. NOx reduction efficiencies up to 95% have been obtained in some practical applications.

Impacts. Anhydrous ammonia is considered an acutely hazardous material according to state law. Therefore, technologies using this substance may have a number of adverse impacts associated with them. For example, an accidental release of ammonia during transport, storage, or handling may

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create significant risk of upset impacts because the released ammonia could form a dense gas that is passively transported close to the ground by wind. In addition, significant human health impacts could occur if anyone is exposed to released ammonia gas clouds. A site-specific analysis may be necessary to evaluate these potential impacts.

The catalyst of SCR systems typically contains small amounts of vanadium pentoxide, which is also classified as an acutely hazardous material. The District has assessed the possibility of risk of upset impacts and human health impacts from catalyst materials and has determined that they are not significant. However, the catalyst generally loses its effectiveness over time and must be replaced and properly disposed of, thus creating solid waste impacts. It may be necessary to determine the volume of spent catalyst generated each year to assess whether or not this exceeds any solid waste utility's significance threshold.

Selective Non-Catalytic Reduction - Ammonia Injection. Selective non-catalytic reduction (SNCR) reduces NOx emissions by injecting a reducing agent, such as ammonia, directly into the flue gas stream, usually at a temperature greater than 500°C. There is no catalyst, but the high temperature acts as a "catalyst" to reduce the NOx to molecular nitrogen and water. This technique is often used in situations where there are "dirty" flue gases which may plug or poison an SCR catalyst. NOx flue gas concentrations are reduced approximately 50% to possibly 80%.

Technologies that use ammonia as a NOx reducing agent may also create air quality impacts. For example, to ensure the efficiency of the NOx reduction reaction, small quantities of extra ammonia are injected into the exhaust gas. As a result, not all ammonia reacts with the NOx molecules and, therefore, is released into the atmosphere. This is known as an ammonia slip. Generally, the ammonia slip can be maintained at 5-10 ppm or slightly greater, which is not expected to adversely affect air quality. Ammonia slip, however, should be calculated for any project using ammonia.

High ammonia slip levels that could cause adversely affect human health or, at the very least, could create an odor nuisance. The District has determined that, because exhaust gases are typically very hot and buoyant, ground-level concentrations would not be expected to adversely affect human health or create an odor nuisance. Ground-level concentrations of ammonia from ammonia slip may need to be estimated to ensure that adverse impacts do not occur.

Selective Non-Catalytic Reduction - Urea Injection. Urea injection involves injecting a reducing agent, aqueous urea (an ammonia-based chemical compound) in this case, into the flue gas where it reacts with NOx, reducing it to molecular nitrogen, water, and carbon dioxide. The reduction reaction is maximized when the urea is thoroughly mixed in the flue gas and the temperature range is between 1,400°F-1,800°F. This process has a NOx reduction efficiency range of 50% to as high as 80% in some specific cases.

Urea itself is not considered to be a hazardous substance under state or federal law. In addition, it is typically transported in solid pellet form so, if an accidental release occurs, it is relatively easily cleaned up and does not pose a significant public health problem. One of the by-products of urea injection technologies, similar to SCR, is the production of ammonia slip. Typically, the amount of ammonia slip generated by urea injection is in the 10-20 ppm range and because of the buoyancy of the exhaust does not present an adverse air quality impact or a human health hazard at these low levels. However, a site-specific assessment may be necessary to ensure that ammonia slip levels do not pose a significant human health impact.

A.13.2 Particulate Control.

Filters, scrubbers, and mist eliminators are used primarily to reduce particulate emissions, as well as other criteria pollutant and toxic air contaminants. Particulate control devices can also be used to control air toxics. Each device is discussed briefly in the following paragraphs.

Baghouse Filters

Suspended dust and fumes may be removed from an air stream by a number of different devices. When high collection efficiency on small particles size is required, the most widely used method consists of separating the dust from the air by means of a fabric filter. Fibrous or fabric filter media formed into

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cylindrical sleeves or bags are the most widely used type of dry-particle collector for air cleaning. Baghouses (the structure supporting the filter) remove solid particulate contaminants from gas streams by filtering them through a fabric media which is generally a woven or felted material. Several different types of filters may be used within a baghouse depending on the particular source and composition of the particulates or gases to be controlled.

Baghouse filters collect dry particulates that must ultimately be disposed of as a solid waste. If care is not exercised during disposal of the waste particles, they could be blown from the trucks during transport to a waste disposal facility, creating secondary environmental impacts, e.g., re-entrainment to the atmosphere. In addition, depending upon the type of pollutant being collected, the resulting solid waste may be considered a hazardous waste, requiring disposal in a Class I landfill. If the amount of solid waste generated exceeds any threshold levels of significance established by any waste management agencies, solid waste impacts may be considered significant and, therefore, may warrant further investigation.

Scrubbers

Scrubbers have a number of advantages over other types of air pollution control devices: they do not create a secondary dust problem when disposing of the contaminant; they can handle high-temperature or moisture-laden air; and they can handle corrosive gases or aerosols. Scrubbers commonly used to control particulate emissions include spray towers, packed bed and venturi (high energy) scrubbers. These devices work by pumping a reagent such as sodium or calcium compounds into the device which condenses the air contaminant. Wet scrubbers use water "sprays" to collect and remove particulates. However, wet scrubbers are not well suited to control very fine particulates. Packed-bed scrubbers are generally used to remove pollutant gases. The packed-bed scrubber, or column, is generally a vertical column that has been filled with packing or materials with large surface areas. The gas stream that contains the pollutant moves upward through the packed bed against an absorbing or reacting liquid that is injected at the top of the packed column.

Installation of scrubbers as control equipment may require the use of caustic alkali solutions such as sodium hydroxide, calcium hydroxide, or magnesium hydroxide for removing dioxin compounds from incinerator exhausts. These alkali solutions are inorganic alkali compounds that are primary irritants to the skin. The alkali liquid can be recycled and reused until the pH exceeds a specified level or it becomes too concentrated. The liquid, called blowdown, is either shipped off-site as a hazardous waste or treated on-site to neutralize it, and is then reused in the system or released to a public sewage system. Disposal of the wastewater or its clarification for reuse may be difficult or expensive. Use of wet scrubbers may, therefore, pose a water quality impact, a solid waste impact, or a risk of upset impact if the alkali waste is accidentally released during transport to a disposal facility.

Mist Eliminators

Mist eliminators are "impaction" collectors that place barriers in the path of the mist particulates in the flowing gas. These barriers intercept the particulates and remove them from the gas stream. A demister is often used as part of a packed scrubbing device to increase its efficiency in removing fine particulate matter.

Impacts for mist eliminators will be similar to those described for scrubbers except that they do not use alkali materials.

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[1] In this case, equimolar means that the number of moles of ammonia needed is equal to the number of moles of NOx to be reduced. One mole of a substance contains 6.023×10^{23} molecules.

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[redacted]

ACRONYMS
AS USED IN THE
CEQA AIR QUALITY HANDBOOK

AQMP	Air Quality Management Plan
AQTAN	(CalTrans) Air Quality Technical Analysis Notes
ARB	Air Resources Board
ASTM	American Society of Testing Materials
ATCM	Air Toxics Control Measure
AVO	average vehicle occupancy
AVR	average vehicle ridership
BACT	best available control technology
CAAA	Clean Air Act Amendments (federal law)
CCAA	California Clean Air Act (state law)
CAPCOA	California Air Pollution Control Officers Association
CEQA	California Environmental Quality Act
CFC	chlorofluorocarbon
CMP	Congestion Management Program
CNG	compressed natural gas
CO	carbon monoxide
CVAG	Coachella Valley Association of Governments
DU	dwelling unit
EPA	Environmental Protection Agency
ERC	emission reduction credits
GMP	Growth Management Plan
HOV	high-occupancy vehicle lane
ISR	indirect source rule
LAER	lowest achievable emission rate
LOS	level of service

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MAAQI	Mobile Assessment for Air Quality Impacts
MND	Mitigated Negative Declaration
MOU	Memorandum of Understanding
MPO	metropolitan planning organization
ND	Negative Declaration
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES Permit	National Pollutant Discharge Elimination System
NOP	Notice of Preparation
NO_2	nitrogen dioxide
NOx	nitric oxide and nitrogen dioxide
OEHHA	Office of Environmental & Health Hazard Assessments
Pb	lead
POTW	publicly owned treatment works
PM10	Particulate matter less than 10 micrometers in diameter
PRC	Public Resource Code
PSI	Pollutant Standards Index
RECLAIM	Regional Clean Air Incentives Market
RMP	Regional Mobility Plan
RMPP	Risk Management and Prevention Program
ROC	reactive organic compounds
RU	residential unit
SCAB	South Coast Air Basin
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SEDAB	Southeast Desert Air Basin
SO_2	sulfur dioxide
SOx	sulfur oxides

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TBACT	best available control technology for toxics
TCA	trichloroethane
TDM	transportation demand management
TIP	Transportation Improvement Program
TLV	threshold limit value
VMT	vehicle miles traveled
VOC	volatile organic compounds
VT	vehicle trips

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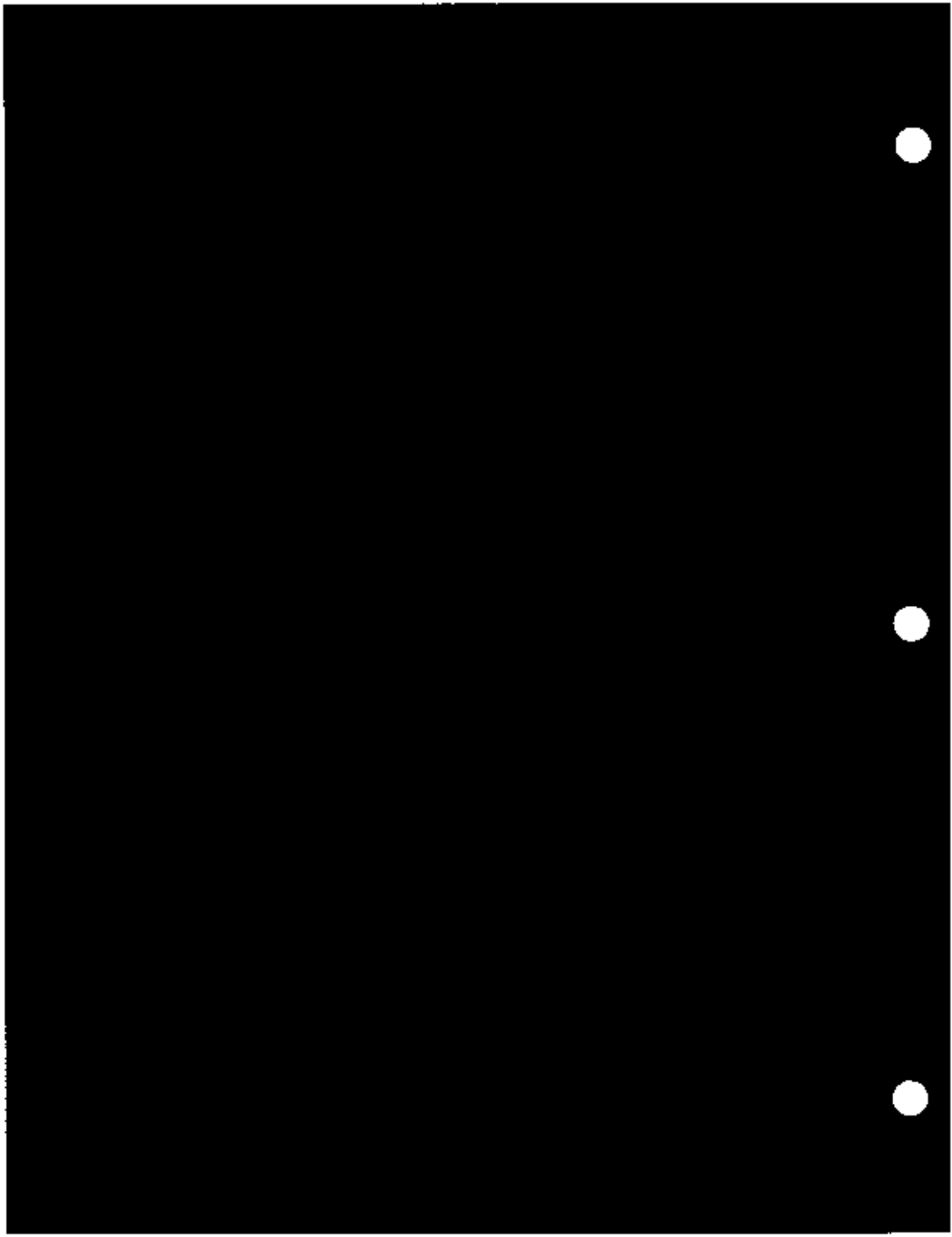
[redacted]



GLOSSARY OF TERMS
AS USED IN THE
CEQA AIR QUALITY HANDBOOK

ADVISORY COUNCIL -
A group of technical and scientific specialists who advise the District on long- and short-term matters affecting Clean Air programs.

AIR BASIN - An area designated by the Air Resources Board for air quality planning purposes.

AIR MONITORING - Sampling for and measuring of air pollutants present in the ambient air.

AIR POLLUTANT - A material in the ambient air that produces air pollution. Common air pollutants are ozone (O_3), nitrogen dioxide (NO_2), particulate matter (PM10), sulfur dioxide (SO_2), and carbon monoxide (CO). Air pollution is defined in the California Health and Safety Code as any discharge, release, or other propagation into the atmosphere, and includes, but is not limited to, smoke, charred paper, dust, soot, grime, carbon, fumes, gases, odors, particulate matter, acids or any combination thereof.

AIR QUALITY MANAGEMENT PLAN (AQMP) -
A document describing how the SCAQMD plans to achieve federal and state air quality standards by the year 2010, as required by the CAAA and CCAA. The complete AQMP consists of more than 30 documents, including the plan itself, appendices and technical reports. Portions of the Plan are contributed by other agencies (e.g., SCAG produces the transportation and land use portions; ARB produces the mobile source regulations.) State law requires that the Plan be updated every three years.

AIR QUALITY STANDARD -
The specified average concentration of an air pollutant in ambient air during a specified time period at or above which undesirable effects may be produced. The two sets of air quality standards with which the District is concerned are the National Ambient Air Quality Standards and the California State Air Quality Standards.

AIR RESOURCES BOARD (ARB) -
Was subsumed into the California Environmental Protectiona Agency (Cal EPA) in 1991 and is responsible for setting state ambient air quality standards and allowable emission levels from new motor vehicles in California. The ARB is responsible for overseeing the efforts of local air pollution control districts and air quality management districts in regulating emissions from non-vehicular sources of air pollution. Also known as the California Air Resources Board (CARB), and State Air Resources Board (ARB), the Air Resources Board is the agency responsible for developing the State Implementation Plan and transmitting it to the federal Environmental Protection Agency for approval.

AMBIENT AIR - Any unconfined portion of the atmosphere; the outside air.

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AREA-WIDE SOURCES -

Those sources that individually emit relatively small quantities of air pollutants. This includes small items such as home heaters and consumer products.

AUXILIARY LANES - Traffic lanes that provide egress and ingress for vehicles entering or leaving a roadway.

AVERAGE VEHICLE RIDERSHIP -

The number of employees who report to a worksite or another work-related activity divided by the number of vehicles driven by those employees, typically averaged over an established time period. This calculation typically includes crediting vehicle trip reductions from telecommuting, compressed work weeks, and non-motorized transportation.

AVERAGE VEHICLE OCCUPANCY -

The average number of persons occupying a passenger vehicle along a roadway segment intersection, or area, as typically monitored during a specified time period. For the purpose of the California Clean Air Act, passenger vehicles includes autos, light duty trucks, passenger vans, buses, passenger rail vehicles, and motorcycles.

BASELINE INFORMATION -

Information regarding the project's existing setting such as current air quality, transportation system serving the project, etc.

BEST AVAILABLE CONTROL TECHNOLOGY (BACT) -

Under District rules, BACT is defined as the most stringent emissionscontrol which, for a given class of source, has been: 1) achieved in practice; 2) identified in a state implementation plan; or 3) found by the District to be technologically achievable and cost-effective. This definition is more closely aligned to the federal Lowest Achievable Emission Rate (LAER) definition and is far more stringent than the federal BACT definition.

BUILD-OUT YEAR - The year in which the project construction has been completed and the project is ready to be occupied.

CAL3QHC - An evolution of the CALINE 3 model enhanced by the EPA to incorporate vehicle traffic queuing emissions (at intersections) using recommended procedures as described in the Highway Capacity Manual.

CALIFORNIA CLEAN AIR ACT -

A law setting forth a comprehensive program to assure that all areas within the State of California will attain federal and state ambient air quality standards by the earliest practicable date. Also known as the Sher Bill or AB-2595, the law mandates comprehensive planning and implementation efforts, and empowers local districts to adopt transportation control measures and indirect source control measures to achieve and maintain ambient air quality standards. The law provides annual emission reduction targets and regular review and evaluation of local programs by the Air Resources Board. The Act added and amended various sections in Division 26 of the Health and Safety Code.

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CALINE MODEL - A model developed by Caltrans which calculates ambient concentrations of carbon monoxide from vehicular traffic on a roadway segment, intersection, or parking lot.

CARBON DIOXIDE - A colorless gas whose chemical formula is CO_2. It enters the atmosphere as the result of natural and artificial combustion processes and is also a normal part of the ambient air.

CARBON MONOXIDE - An invisible, odorless, tasteless, and toxic gas; its chemical formula is CO. It is primarily generated by motor vehicles but is found in trace quantities in the natural atmosphere.

CARCINOGENIC - Cancer producing.

CHLOROFLUOROCARBON (CFC) - A gas which when released into the troposphere, gradually migrates upward into the stratosphere. The CFCs participate and react with other complex chemicals (e.g., chlorinated compounds, nitrous oxide, etc.) and lead to the destruction of upper level ozone.

CLEAN AIR ACT - The federal statute which mandates a program to attain and maintain federal ambient air quality standards in all areas of the country. The Act establishes several programs. With respect to controlling emissions from non-vehicular sources, states are given primary authority to develop plans and regulations to attain federal ambient air quality standards by a specific date. These plans are called "state implementation plans" or "SIPs." With respect to emissions of motor vehicles, EPA sets emission standards for all states except California, which can adopt stricter standards. The Act also sets forth minimum standards for large new pollution sources by requiring EPA to adopt New Source Performance Standards or "NSPS." In addition, EPA is mandated to adopt regulations governing toxic air pollutants (National Emission Standards for Hazardous Air Pollutants, or NESHAPS). This Act is found beginning at 42 U.S.C. 7401.

CO HOT SPOTS - An area, usually an intersection or congested segment of a highway that exceeds the federal or state carbon monoxide standard.

CONFORMITY - A requirement in the federal Clean Air Act that no department, agency, or instrumentality of the federal government shall engage in, support in any way or provide financial assistance for, license or permit or approve any activity which does not conform with the State Implementation Plan (SIP) by causing or contributing to an increase in air pollutant emissions, or violation of an air pollutant standard, or frequency of violating that standard.

CONGESTION MANAGEMENT PROGRAM (CMP) - A state mandated program that requires each county to prepare a plan to relieve congestion and air pollution.

CONSISTENCY - A term used in CEQA to determine if a project is consistent by furthering the goals and objectives, and will not interfere with the implementation of, applicable regional plans.

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CRITERIA POLLUTANTS -
Air pollutants for which the federal or state governments have established ambient air quality standards, or criteria, for outdoor concentration in order to protect public health.

DISAGGREGATE - Separate into component parts.

EMISSION STANDARD -
The maximum amount of an emittant legally permitted to be discharged from a single source.

EMISSION THRESHOLDS -
An amount of emissions established by the District, for use by local government planners, to compare with the emissions that could be emitted from a particular project to determine if that project could have a significant impact on air quality.

EMISSIONS - The mass of a specific material released to the atmosphere.

EMISSIONS INVENTORY -
A tabular listing, by source category, of all emissions within a specified political jurisdiction for an average annual day within a specified year.

ENVIRONMENTAL PROTECTION AGENCY (EPA) -
The federal agency responsible for coordinating pollution control activities at the federal level and for carrying out the terms of the federal Clean Air Act, Clean Water Act, and Superfund laws, among others. The EPA operates through regional offices located throughout the country. California is the responsibility of Region IX, which is headquartered in San Francisco.

EVAPORATIVE EMISSIONS -
Release of hydrocarbon (or reactive organic gas) emissions which occurs when fuel is exposed to the air, based on a variety of processes: when fuel entering a fuel tank displaces vapors into the air; when diurnal temperature variations on the fuel and fuel vapors in the fuel tank release hydrocarbons; or in the hot stabilized mode, after the engine and catalytic converter have warmed up to normal operating temperature (e.g., "blow-by" and crankcase emissions).

GLOBAL WARMING - The gradual buildup of "greenhouse" gases that absorb energy, and preventing it from passing into space. As a result, more solar energy is retained near the earth's surface than is lost into space, and there is a general warming of the earth's atmosphere.

GROWTH MANAGEMENT PLAN (GMP) -
A plan developed by SCAG that contains demographic projections (i.e., housing units, employment, and population) through the year 2010 for a six county region (i.e., L.A. County, Orange County, Riverside County, San Bernardino County, Ventura County, and Imperial County). The plan also provides recommendations for local governments to better accommodate the growth projected to occur and reduce environmental impacts.

HALONS - A family of compounds containing bromine used in fire extinguishers; and are both ozone depleting and greenhouse gases.

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HAZARDOUS AIR POLLUTANT -
Defined by the Clear Air Act as an air pollutant to which no ambient air quality standard is applicable and which, in the judgement of the administrator of the Environmental Protections Agency, may result in an increased in mortality, serious irreversible illness, or incapacitating reversible illness.

HEAT ISLAND - An area, generally around a center of urban buildup, in which the average temperature is higher than that of the surrounding area.

HOT SPOT - A localized concentration of an air pollutant associated with restricted dispersion conditions, often occurring in such places as street canyons or close to sources of emissions.

INDIRECT SOURCE - Defined by the Clean Air Act as a facility, building, structure, installation, real property, road, or highway that attracts, or may attract, mobile sources of pollution. Examples of indirect sources are major highways and airports, large regional shopping center, major sports complexes and stadiums, large amusement and recreational facilities, and major parking facilities. Also known as a complex source.

INVERSION - A condition of the atmosphere in which the temperature increases with altitude.

INVERSION LAYER - A layer in the atmosphere through which the temperature remains constant or increases with altitude.

ITE TRIP GENERATION MANUAL -
A document produced by the Institute Of Transportation Engineers (ITE) that provides trip generation numbers by land use based on trip generation studies conducted nationwide.

LEVEL OF SERVICE (LOS) -
A scale that is used to rate the service (i.e., speed and maneuverability) on roadways. An LOS of "A" means that traffic is free flowing, while "F" refers to severely congested conditions.

LEWIS-PRESLEY AIR QUALITY MANAGEMENT ACT -
The legislation which established the South Coast Air Quality Management District in 1977, and which sets forth those powers, authorities, and responsibilities of the District which may be different from those possessed by other air pollution control districts in California. It has been amended from time to time, most notably by legislation introduced by Senator Robert Priestly to expand the authorities of the District. The Act is found in Chapter 5.5 of Part 3 of Division 26 of the Health and Safety Code, beginning with Section 40400.

MITIGATE - Reduce the air quality impact on the environment through the application of programs and other mechanisms. Alleviate, ease, reduce, lighten, minimize.

MOBILE SOURCES - Those sources that emit pollution from vehicles. There are two types of mobile source emissions, those from on-road sources (e.g., passenger automobiles, trucks, busses, etc.) and off-road sources (e.g., airplanes, trains, construction equipment, etc.)

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OZONE - A highly reactive, bluish-colored gas with a pungent odor. Its chemical formula is O_3. Ozone is a major constituent of photochemical oxidants. Ozone is formed in the atmosphere by a complex series of photo-chemical reactions involving oxides of nitrogen and reactive organic gases in the presence of sunlight. A National Ambient Air Quality Standard has been established for ozone.

OZONE DEPLETING GASES - Gases released into the ambient air which are considered as global-warming and stratospheric ozone-depleting. These gases include chlorofluorocarbon, halons, methyl chloroform, and carbon tetrachloride.

OZONE LAYER - Located in the stratosphere, approximately 10-30 miles above the earth's surface, is the ozone layer. This layer prevents most of the solar ultraviolet radiation (in the 290 to 320 nm wavelength range (UV-B)) from reaching the earth's surface. Increased exposure to UV-B could have serious public health and environmental effects.

PERMIT - Written authorization from the District for the construction or operation of equipment which controls or may cause regulated emissions.

PHOTOCHEMICAL OXIDANTS (OX) - A collective term for a group of oxidizing gases produced by photochemical reactions involving reactive organic compounds and oxides of nitrogen, also referred to as an oxidant. Photochemical oxidants include ozone and other more complex compounds such as organic peroxides and peroxyacyl nitrates. A California State Air Quality Standard has been established for photochemical oxidants.

POINT SOURCE - A term used to designate a sizeable stationary emission source at a specific location.

POLLUTANT STANDARDS INDEX (PSI) - A scale ranging between 0 and 500 that is used to indicate the air quality at a given time and location relative to National Ambient Air Quality Standards. A PSI of 100 for any air pollutant represents a concentration equal to its respective air quality standard.

QUANTIFIABLE - The expression of air emissions either generated or mitigated from a project in numerical terms.

REACTIVE ORGANIC COMPOUNDS (ROC) - Species of organic compounds that undergo photochemical reactions.

REASONABLE FURTHER PROGRESS (RFP) - Defined in the Clean Air Act as annual incremental reductions in emissions of an air pollutant that are sufficient to provide attainment of the applicable National Ambient Air Quality Standard by a specified date.

REGIONAL MOBILITY PLAN (RMP) - A plan developed by SCAG that contains a listing of infrastructure improvements, travel forecasts, and other programs to regain mobility for a six county region (i.e., L.A. County, Orange County, Riverside County, San Bernardino County, Ventura County, and Imperial County).

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SENSITIVE RECEPTORS -

Refers to sensitive populations such as children, athletes, elderly, and sick, that are more susceptible to the effects of air pollution than the population at large.

SMOG - A general term used to describe dense, visible air pollution. In the South Coast Air Basin, smog is formed when combustion products and gaseous emissions such as nitrogen oxides, sulphur oxides, and various hydrocarbons undergo photochemical reactions. Particles such as soil, dust, and various exhaust particles may mix with the ozone, carbon monoxide, and other compounds that are produced, creating a brownish, irritating haze. Smog poses health risks and damages crops, rubber, and other materials.

SMOG EPISODE LEVELS -

An occurrence of high concentration of air pollutants that could endanger or cause significant harm to the public. Alerts are classified by severity: Stage 1 is described a "Unhealthful," Stage 2 is "Very Unhealthful," and Stage 3 is classified as "Hazardous." Stationary Source Curtailment Plans and Traffic Abatement Plans are required to be implemented to reduce the severity of air pollution levels whenever episodes of high pollution are forecast.

SOIL STABLIZERS -

Chemical or other agents which are applied to soil surfaces to stabilize and mitigate PM10 fugitive dust emissions by creating a wind-resistant crust. Typically applied to disturbed surface areas next to roadways, bare ground areas, dirt parking lots and roadway shoulders, and exposed construction areas.

SOURCE - Any particular individual or group of organisms, mechanisms, devices, structures, installations, operations, facilities, or processes that emit air pollutants.

SOURCE CATEGORIES -

There are two primary source categories relating to projects; construction and operation. Refer to Figure 9-1 for an identification of source categories associated with construction and Figure 9-2 for source categories associated with operation.

SOUTH COAST AIR BASIN (SCAB) -

A geographic area defined by the San Jacinto Mountains to the east, the San Bernardino Mountains to the north, and the Pacific Ocean to the west and south. The entire SCAB is under the jurisdiction of the South Coast Air Quality Management District.

SOUTHEAST DESERT AIR BASIN (SEDAB) -

The air basin containing Imperial County and specific desert portions of Los Angeles, Kern, Riverside, and San Bernardino Counties. The full description is contained in the California Administrative Code.

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS (SCAG) -

The organization, known in federal law as a Council of Governments, representing Los Angeles, Ventura, San Bernardino, Riverside, Orange, and Imperial Counties and the cities of the six counties.

AR0073226

STATE IMPLEMENTATION PLAN (SIP) -
A state's plan to attain the federal air quality standards for all non-attainment areas within the state. The 1991 AQMP is integrated into the SIP once it is approved by the EPA and becomes the SIP for the South Coast Air Basin.

STATEMENT OF OVERRIDING CONSIDERATIONS -
Written statement by lead agency giving reasons for its approval of a project having environmental impacts which have not been mitigated to a level of insignificance.

STATIONARY SOURCES -
Those sources that emit pollution from equipment, or industrial or commercial processes. There are two types of stationary source emissions, those from area sources (e.g., water heaters, consumer products, architectural coatings, etc.) and point sources (e.g., boilers, refinery flairs, etc.)

SULFATES (SO_4) - The chemical designation for compounds containing sulfur and oxygen found in the atmosphere in the form of particulate matter. A California State Air Quality Standard has been established for sulfates. Sulfates are formed mainly by the oxidation of sulfur dioxide in the atmosphere.

SULFUR DIOXIDE - A colorless, extremely irritating gas or liquid; its chemical formula is SO_2. Sulfur dioxide enters the atmosphere as a pollutant mainly as a result of burning high sulfur-content fuel oils and coal and from chemical processes occurring at chemical plants and refineries. National Ambient Air Quality Standards and California State Air Quality Standards have been established for sulfur dioxide.

TELECOMMUTE - A work mode where individuals perform job requirements for part or all of the work week at off-site facilities, such as private residences or satellite centers (rather than commuting to the primary work site), thereby reducing vehicle trips or vehicle miles traveled, respectively.

TOXICS - Air pollutants that are carcinogens or produce acute effects. Toxic air pollutant thresholds are based on a quantative risk assessment rather than ambient air standards as with criteria pollutants.

TRANSPORTATION CONTROL MEASURES (TCM) -
Control measures in the AQMP that are directed at reducing emissions by reducing vehicle travel. Both the federal and state law specify requirements for TCMs.

VISIBILITY - The distance that atmospheric conditions permit a person to see at a given time and location. The visibility reduction from air pollutions is due to the presence of sulfates, nitrates, and particulate matter in the atmosphere.

WIND ROSE - A graphic depiction of the direction and speed of wind in a given area. Wind roses are particularly important when assessing toxic emissions and odor problems.

(GLOSS_3)

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[redacted]

[redacted]

INDEX
FORTHCOMING

An index to the Handbook is being compiled as part of the ongoing update process.

Individuals who purchased this 1993 Handbook directly from the SCAQMD will automatically be sent the index as part of an update package later in 1993.

(jadxtbc)

SECOR

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www.secor.com
200 Conejo Ridge Avenue
Thousand Oaks, CA 91361
805 230-1260 tel
805 230-1277 fax

August 10, 2006

Mr. Daniel Pirotton
California Regional Water Quality Control Board
Los Angeles Region
320 West 4th Street, Suite 200
Los Angeles, CA 90013

RE: **Transmittal of Second Quarter 2006 Groundwater Monitoring Report**
ARCO Service Station No. 1057
6100 Franklin Avenue
North Hollywood, CA
LARWQCB ID No. 900280034

Dear Mr. Piroton:

SECOR International Incorporated (SECOR), on behalf of Atlantic Richfield Company (Atlantic Richfield), is pleased to submit the Second Quarter 2006 Groundwater Monitoring Report for the above referenced site (Attachment A). On June 29, 2006, SECOR sent an electronic correspondence discussing the issues with the first set of data from the laboratory analysis of groundwater on and off-Site. These issues included the following:

- MS&MSD for the samples were spiked with only ½ the correct amount; and
- Samples were analyzed past the hold times due to instrument failure. The purge and trap had to be refurbished and a new column was installed.

Due to the importance of the groundwater data necessary for the closure of the adjacent parcel, SECOR rescheduled and re-sampled the groundwater wells on and off-Site on July 6, and 7, 2006. The Second Quarter Groundwater Monitoring Report is included at Attachment A. SECOR will complete the Third Quarter Report and submit the report as directed by October 15, 2006.

SECOR and Atlantic Richfield look forward to continuing working with the LARWQCB toward the successful closure of the adjacent parcel to ARCO Station No. 1057. If you have any questions regarding this letter or the attached Second Quarter 2006 Groundwater Monitoring Report, please do not hesitate to contact Mr. Kelly Brown at (714) 230-0321.

Respectfully Submitted,

SECOR International Incorporated

Andrew J. Modugno, R.G. #7036
Senior Geologist

Attachments:

Attachment A - Second Quarter 2006 Groundwater Monitoring Report

cc: Mr. Darrell Fah – Atlantic Richfield Company
Mr. Kelly Brown – SECOR
Mr. John Bollier – SECOR

ATTACHMENT A

Second Quarter 2006 Groundwater Monitoring and Remediation Report

SECOR

SECOR INTERNATIONAL INCORPORATED

ATLANTIC RICHFIELD COMPANY QUARTERLY REPORT
Quarter 2, 2006 (July 15, 2006)

Station No.: 1057 Address: 6100 Franklin Avenue, Hollywood, CA
Atlantic Richfield Company Environmental Engineer/Phone No.: Mr. Darrell Fah / (714) 378-6105
Consulting Co./Contact Person/Phone No.: SECOR/ Kelly Brown (714) 379-3366
SECOR Project No.: 37BP.01057.06
Primary Agency/Regulatory ID No.: LARWQCB/ Mr. Dan Flotton/ 900280034
Other Agencies to Receive Copies: None

WORK PERFORMED THIS QUARTER [Second - 2006]:
1. Completed quarterly groundwater sampling and prepared Quarterly Status Report.
2. Submitted Well Destruction and System Decommissioning Work Plan on 7/24/06.
3. Submitted a Work Plan for Soil and Soil Gas Investigations on 7/28/06.
4. Completed System Shutdown

WORK PROPOSED FOR NEXT QUARTER [Third- 2006]:
1. Conduct quarterly groundwater sampling and prepare Quarterly Status Report.
2. Remove AS/SVE System and Compound.
3. Remove all Groundwater and AS/SVE wells from adjacent property.
4. Site re-assigned Priority B Status by the LARWQCB

REGISTERED GEOLOGIST ANDREW JAMES MORGAN No. 7036 STATE OF CALIFORNIA

Current Phase of Project:	Soil and GW Remediation	(Assmn., Remed. etc)
Frequency of Sampling:	GW-Quarterly	(Quarterly, etc.)
Frequency of Monitoring:	GW-Quarterly	(Monthly, etc.)
Liquid Phase Hydrocarbon Present On-Site	No	(Yes/No)
Cumulative LPH Recovered to Date:	0.15	(gallons)
LPH Recovered This Quarter:	0.00	(gallons)
Bulk Soil Removed to Date:	76.2	(cubic yards)
Bulk Soil Removed This Quarter:	None	(cubic yards)
Water Wells or Surface Waters (4000-ft radius)	Hollywood Reservoir	
Radius & Their Respective Directions:	~5,000 feet north-northwest	(Distance and Direction)
Current Remediation Techniques:	Post-SVE/AS	(SVFS, LPH Removal, etc.)
Permits for Discharge:	N/A	(NPDES, POTW, etc.)
Approximate Depth to Groundwater:	Range: 32.38 to 41.44	(Measured Feet)
Groundwater Gradient:	Southeast	(Direction)
	0.015 feet/foot	(Magnitude)
Agency Directive Requirements:	Complete Quarterly GW monitoring and sampling.	

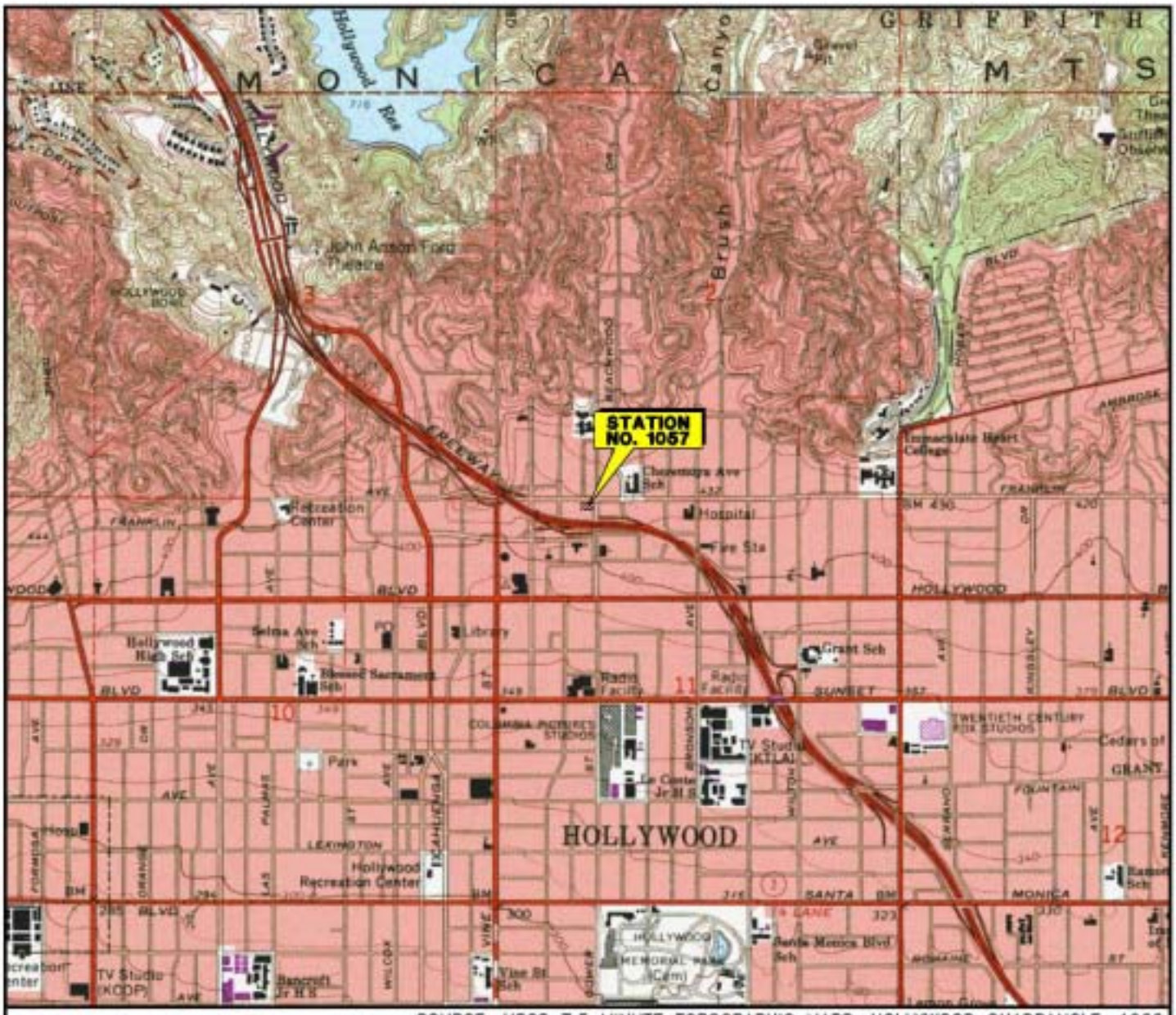
ATTACHED:

Figure 1 - Site Location Map Showing Municipal Wells within A One Mile Radius
Figure 2 - Site Map
Figure 3 - Site Map Showing Groundwater Contour and Hydrocarbon Concentrations
Figure 4 - GRO Isoconcentration Map
Figure 5 - Benzene Isoconcentration Map
Figure 6 - MTBE Isoconcentration Map
Figure 7 - TBA Isoconcentration Map

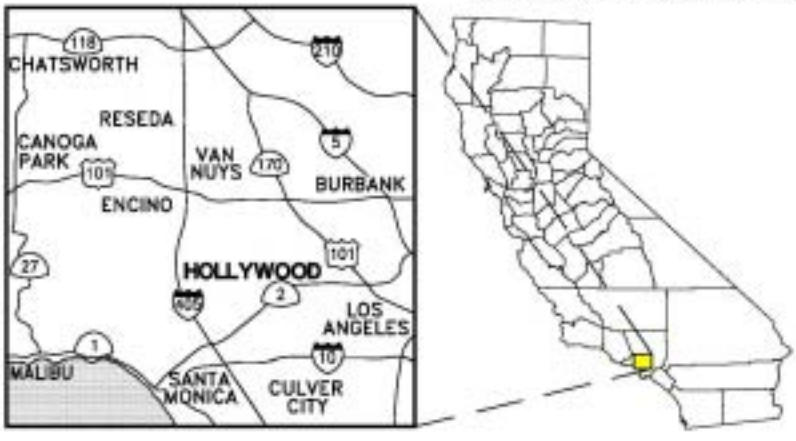
Table 1 - Summary of Groundwater Analytical and Elevation Results

Appendix A - Laboratory Report and Chain-of-Custody
Appendix B - Groundwater Sampling Data Sheets
Appendix C - Waste Disposal Documents

Figures



SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAPS, HOLLYWOOD QUADRANGLE, 1966
PHOTOREVISED 1981



APPROXIMATE SCALE (FEET)

SECOR
290 Conejo Ridge Avenue, Suite 200
Thousand Oaks, CA 91361
(805) 230-1266/230-1277 (Fax)

FOR:
ATLANTIC RICHFIELD COMPANY
STATION NO. 1057
6100 Franklin Avenuns
Hollywood, California

SITE LOCATION MAP

FIGURE: **1**

JOB NUMBER:	DRAWN BY:	CHECKED BY:	APPROVED BY:	DATE:
37BP.01057.06.0336	R. Roman	A. Modugno	A. Modugno	06/23/06

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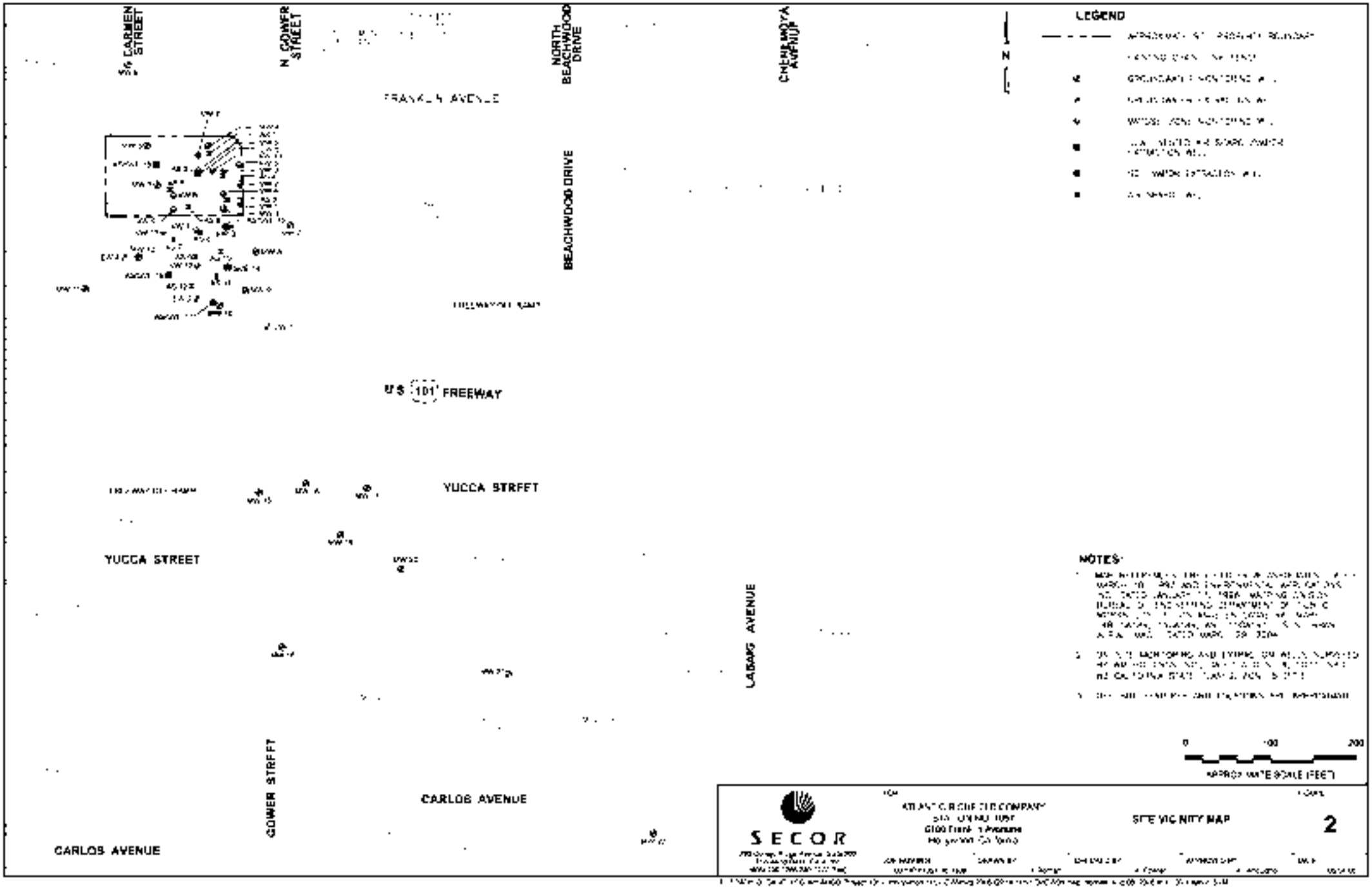
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N GOWER STREET
NORTH BEACHWOOD DRIVE
CHEROKEE AVENUE
FRANKLIN AVENUE
BEACHWOOD DRIVE
HOLLYWOOD FREEWAY
US 101 FREEWAY
YUCCA STREET
YUCCA STREET
LADAGE AVENUE
GOWER STREET
CARLOS AVENUE
CARLOS AVENUE
LEGEND
NOTES:
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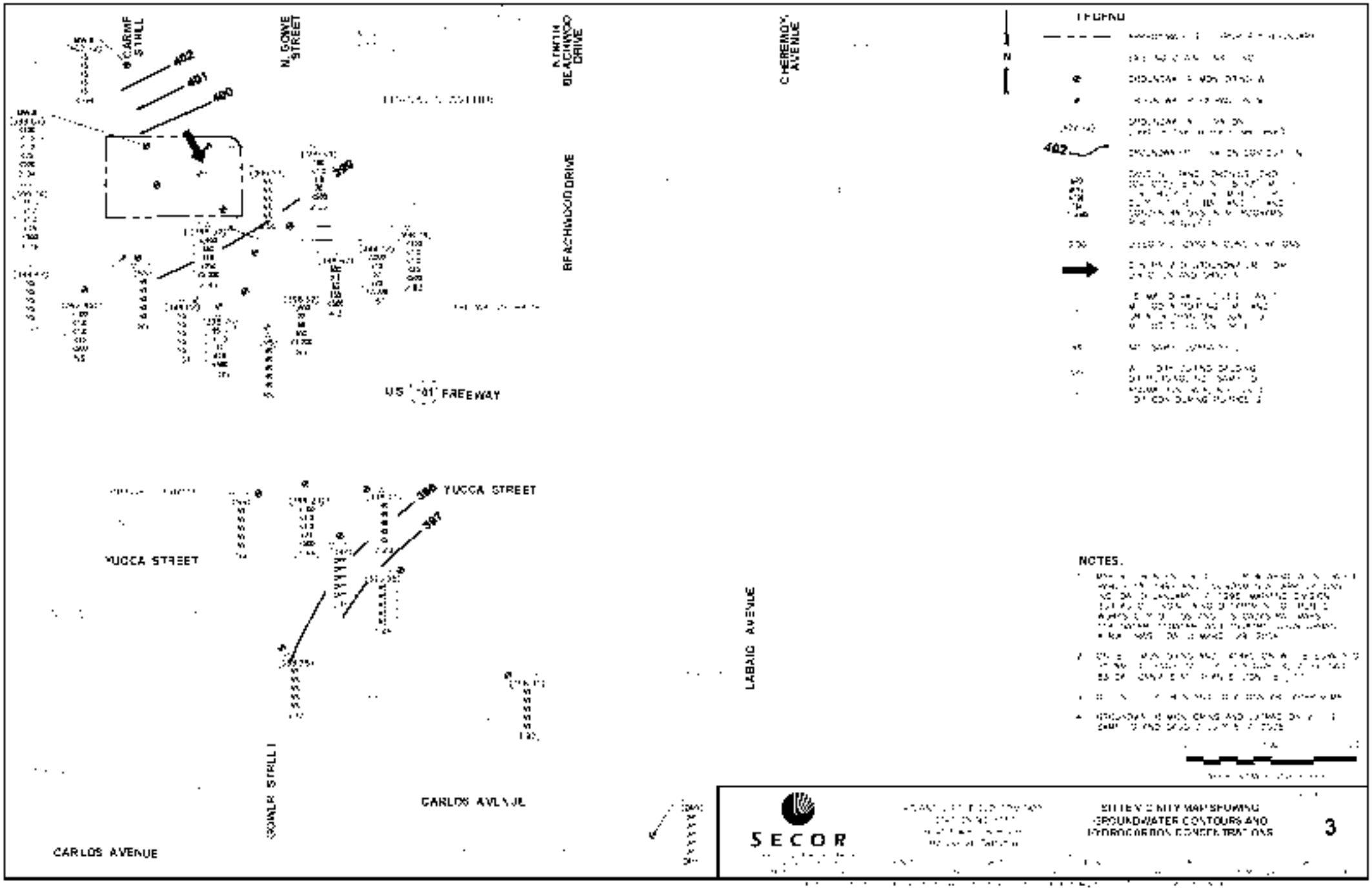
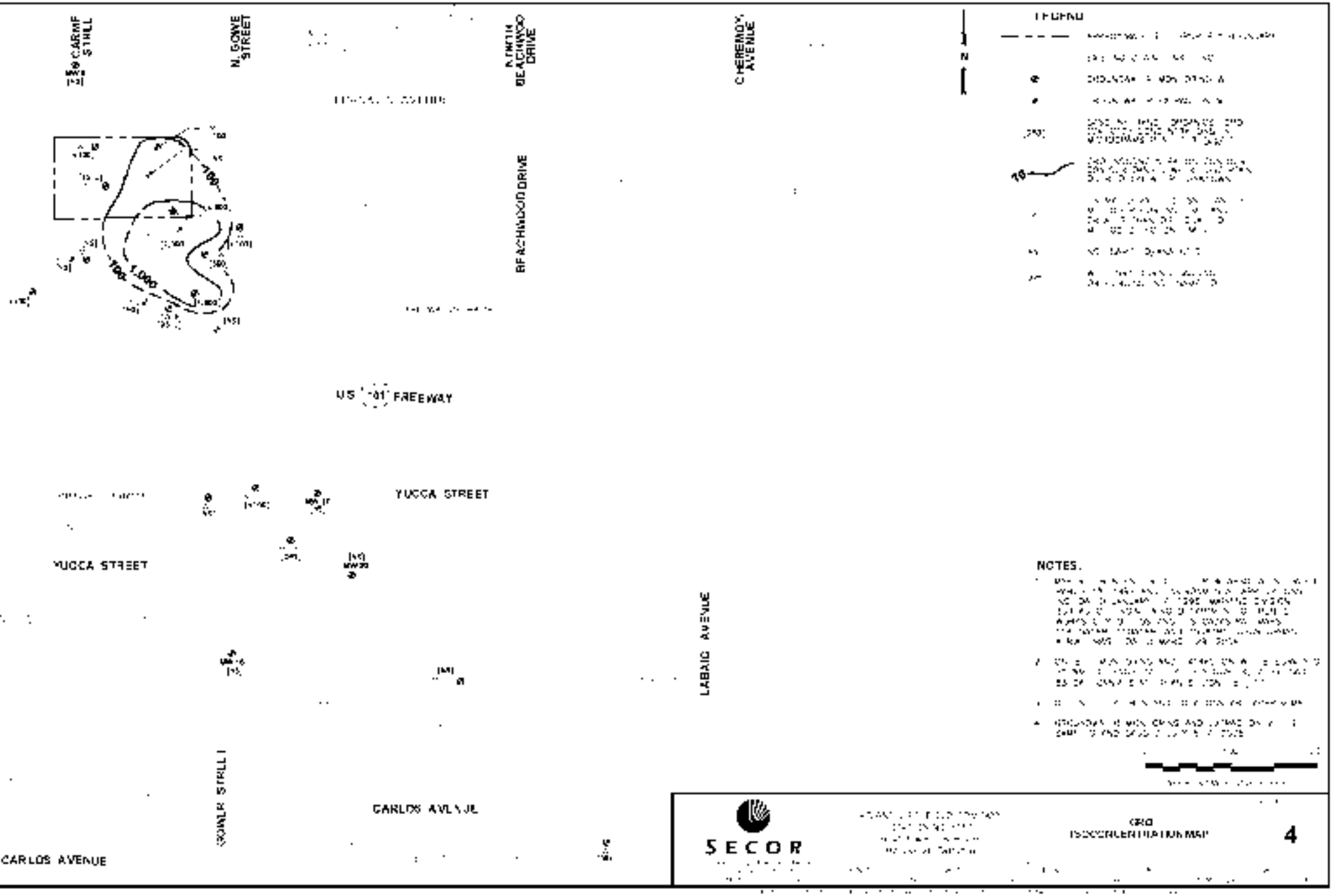
100
200
APPROX. IMAGE SCALE (FEET)
SECOR
ATLANTIC RICHFIELD COMPANY
SITE VICINITY MAP
2

AR0073240


N. GOWE STREET
N. FIFTH BEACHWOOD DRIVE
CHEREMOYA AVENUE
BEACHWOOD DRIVE
US 101 FREEWAY
YUCCA STREET
YUCCA STREET
LABAIG AVENUE
CARLOS AVENUE
CARLOS AVENUE
LEGEND
NOTES:
SECOR
SITE VICINITY MAP SHOWING GROUNDWATER CONTOURS AND HYDROCARBON CONCENTRATIONS
3

AR307324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N. GONVE STREET
N. FIFTH BEACHWOOD DRIVE
CHEREMOYA AVENUE
BEACHWOOD DRIVE
US 101 FREEWAY
YUCCA STREET
YUCCA STREET
LABAIG AVENUE
CRAWLER STREET
CARLOS AVENUE
CARLOS AVENUE
LEGEND
NOTES.
SECOR
GRID
IDENTIFICATION MAP
4

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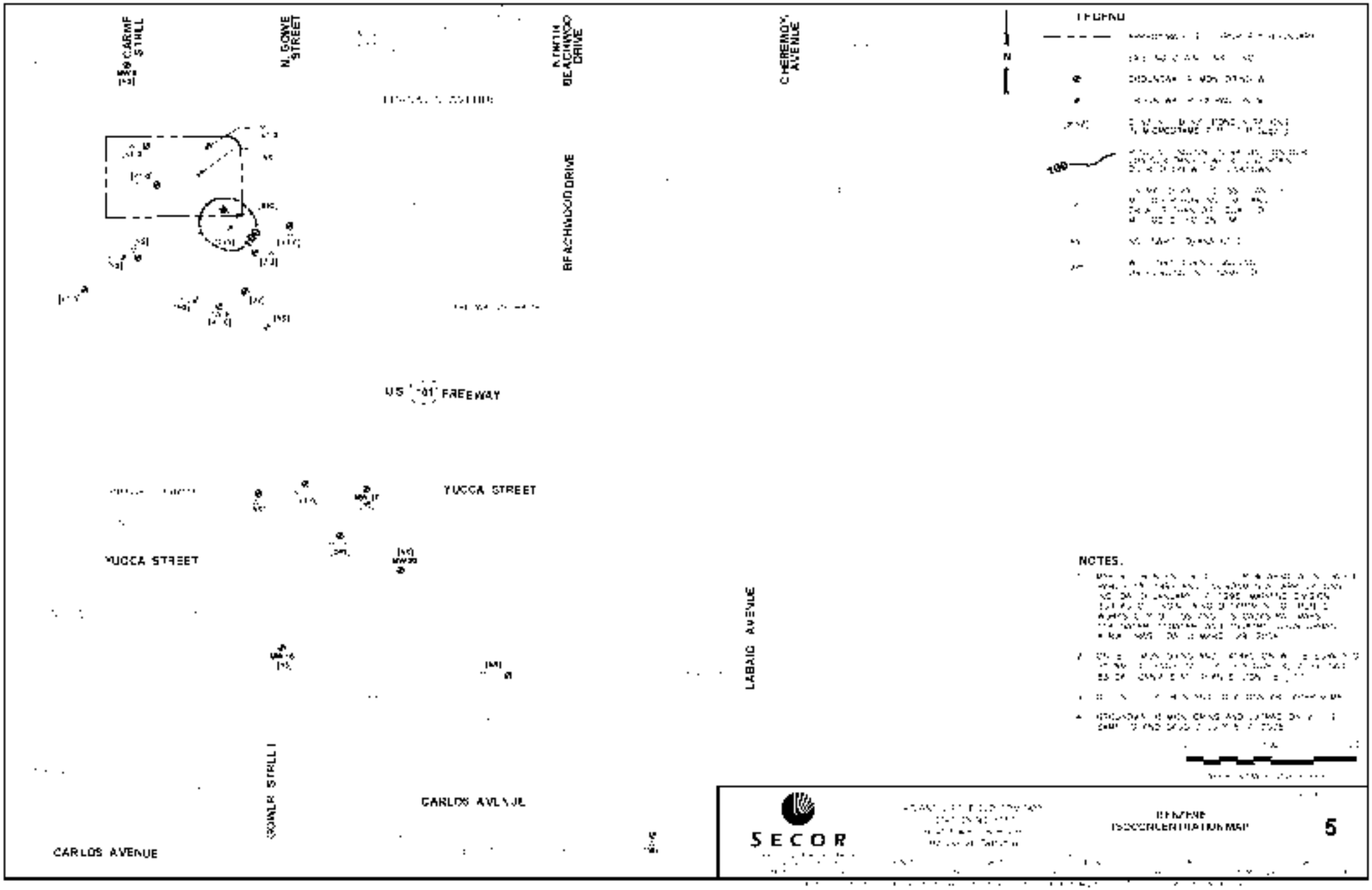
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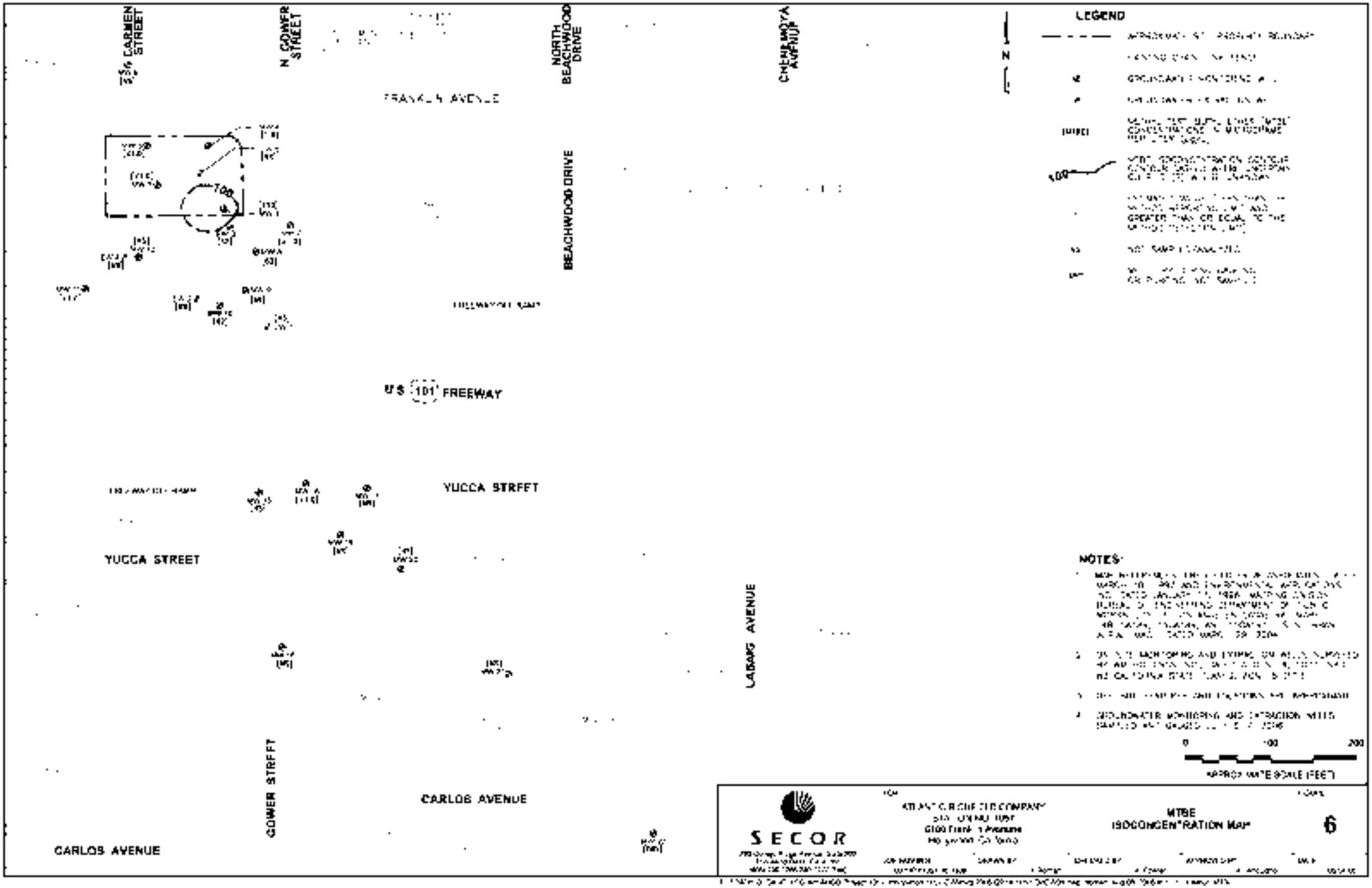
BEACHWOOD DRIVE
CHEREMOYA AVENUE
US 101 FREEWAY
YUCCA STREET
YUCCA STREET
LABAIG AVENUE
CARLOS AVENUE
CARLOS AVENUE
NOTES:
SECOR
5

AR3073243


CARMEN STREET
N GOWER STREET
NORTH BEACHWOOD DRIVE
CHEMEMOYA AVENUE
FRANKLIN AVENUE
BEACHWOOD DRIVE
US (101) FREEWAY
YUCCA STREET
YUCCA STREET
LADAGE AVENUE
GOWER STREET
CARLOS AVENUE
CARLOS AVENUE
LEGEND
NOTES:
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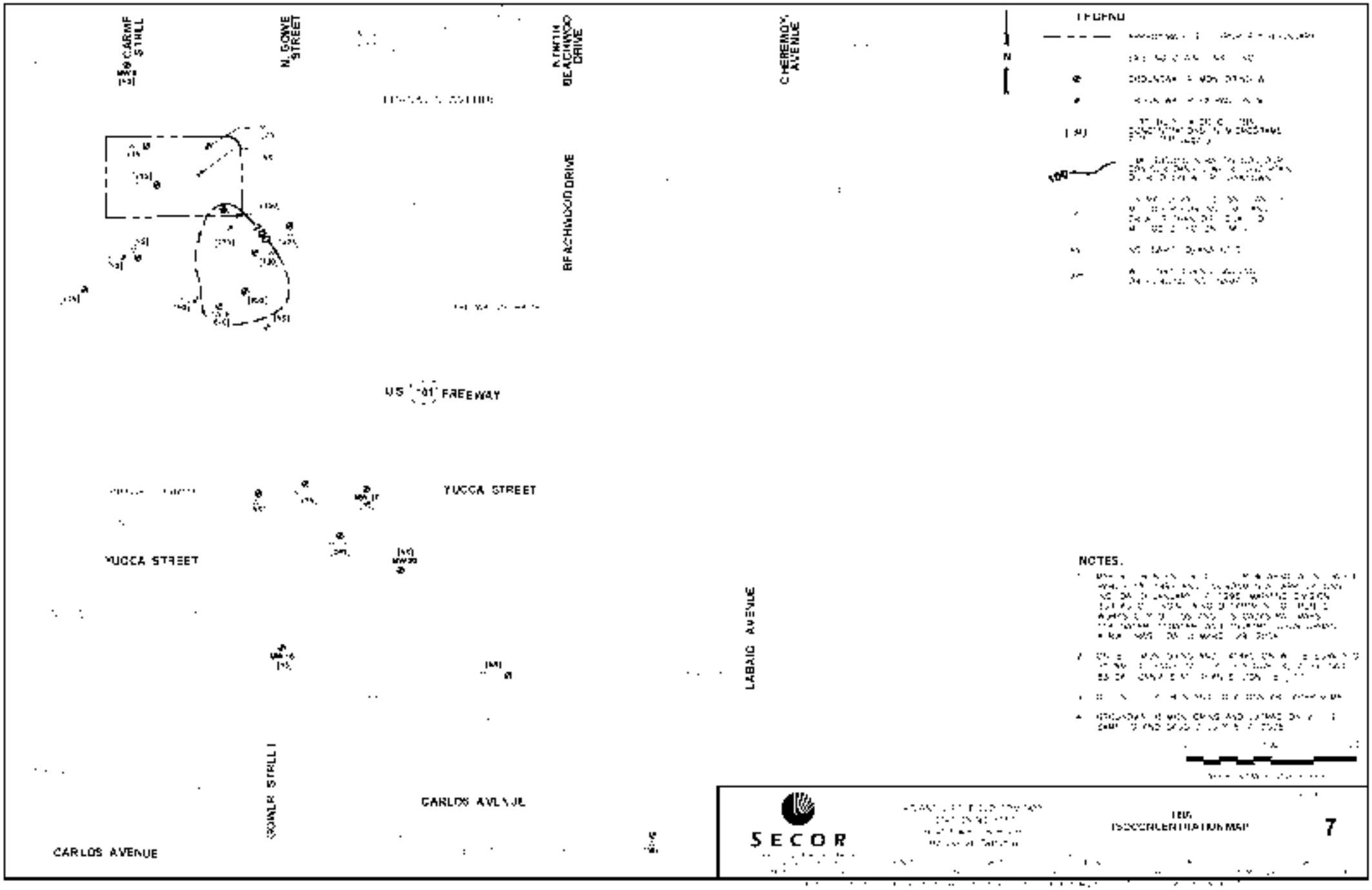
APPROX. MAP SCALE (FEET)
SECOR
ATLANTIC RICHFIELD COMPANY
6100 Franklin Avenue
Hollywood, California
MTBE
ISOCONCENTRATION Map
6

AR0073244


CARMEL STILL
N. GOWE STREET
N. PINE TREE BEACHWOOD DRIVE
CHEREMOYA AVENUE
BEACHWOOD DRIVE
US 101 FREEWAY
YUCCA STREET
YUCCA STREET
LABAIG AVENUE
CRANLEY STREET
CARLOS AVENUE
CARLOS AVENUE
LEGEND
NOTES.
SECOR
7

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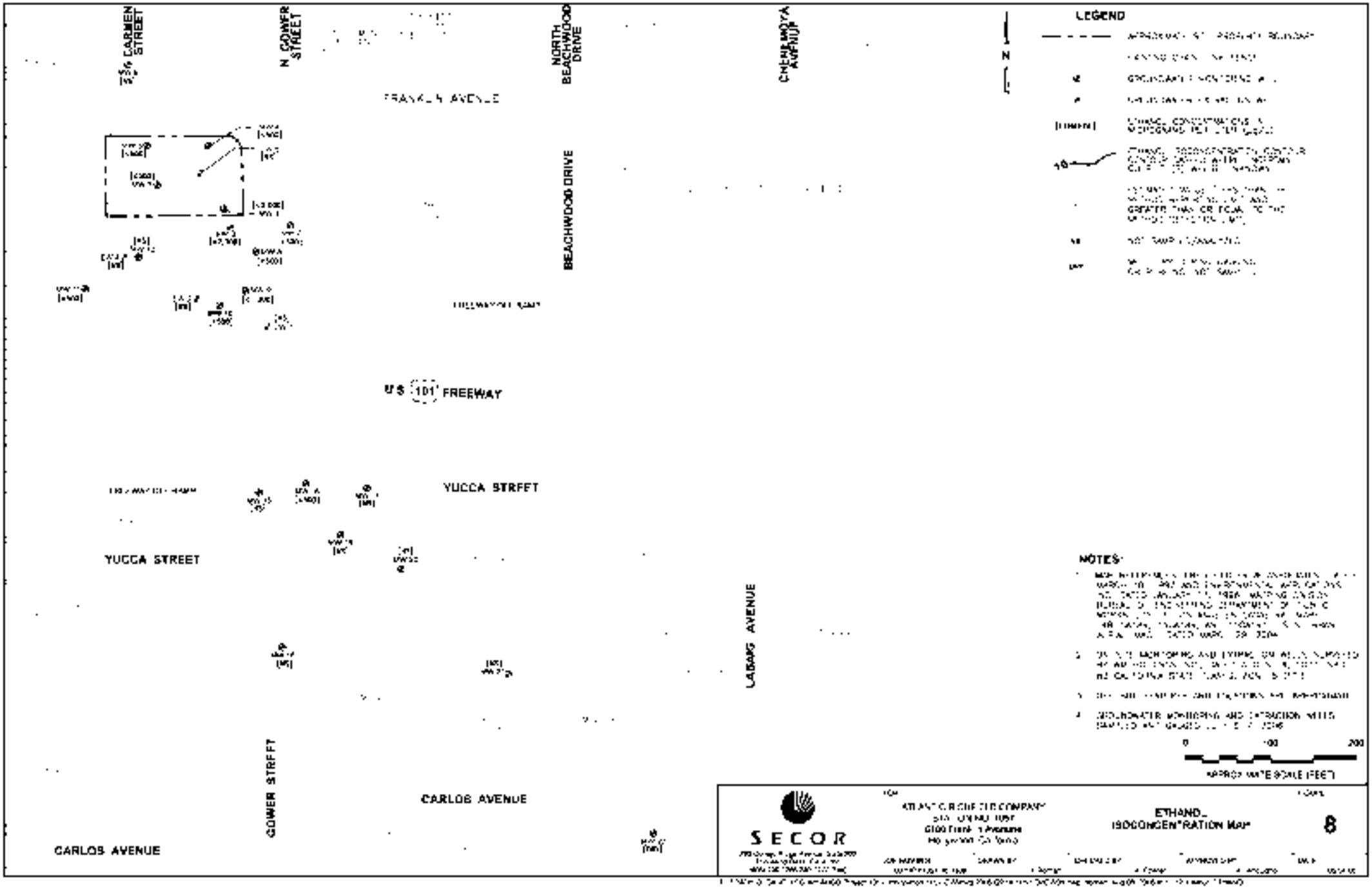
CARMEN STREET
N GOWER STREET
NORTH BEACHWOOD DRIVE
CHEMEHUEVA AVENUE
FRANKLIN AVENUE
BEACHWOOD DRIVE
US 101 FREEWAY
YUCCA STREET
YUCCA STREET
LADAKG AVENUE
GOWER STREET
CARLOS AVENUE
CARLOS AVENUE
LEGEND
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APPROX. MILE SCALE (FEET)
NOTES:
SECOR
ATLANTIC RICHFIELD COMPANY
ETHANOL
ISOCONCENTRATION Map
8

Table

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-1	09/22/93		-	-	-	-	500	29	7.0	16	52	-	-	-	-	-	-	-	
	12/01/93			-	-	-	800	52	5.0	24	70	-	-	-	-	-	-	-	
	04/04/94			-	-	-	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	05/26/94			-	-	-	220	32	1.0	6.0	26	-	-	-	-	-	-	-	
	08/26/94			33.64	0.00	-	350	43	1.0	10	32	-	-	-	-	-	-	-	
	11/23/94			34.42	0.00	-	110	16	<0.5	3.0	10	-	-	-	-	-	-	-	
	02/22/95			33.48	0.00	-	86	1.2	<0.30	0.60	3.6	-	-	-	-	-	-	-	
	04/21/95			31.16	0.00	-	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			29.97	0.00	-	250	19	0.84	8.4	30	-	-	-	-	-	-	-	
	11/03/95			30.25	0.00	-	260	22	0.48	10	28	-	-	-	-	-	-	-	
	02/01/96			33.60	0.00	-	290	81	<0.60	25	<1.2	-	-	-	-	-	-	-	
	05/02/96			31.42	0.00	-	120	25	<0.30	6.3	19	-	-	-	-	-	-	-	
	07/24/96			32.02	0.00	-	110	20	<0.30	3.9	12	230	-	-	-	-	-	-	
	12/12/96			33.14	0.00	-	1,100	110	<1.2	110	48	1,400	-	-	-	-	-	-	
	03/18/97			32.42	0.00	-	<50	1.8	<0.30	<0.30	<0.60	3,400	-	-	-	-	-	-	
	06/12/97			32.50	0.00	-	140	5.1	0.32	5.4	2.2	16,000	-	-	-	-	-	-	
	07/31/97			32.85	0.00	-	63	2.0	<0.38	<0.38	<0.75	16,000	-	-	-	-	-	-	
	10/15/97			33.33	0.00	-	<500	<3.0	<3.0	<3.0	<6.0	13,000	-	-	-	-	-	-	
	03/25/98			24.08	0.00	-	<50	<0.30	<0.30	<0.30	<0.60	31	-	-	-	-	-	-	
	06/11/98			29.48	0.00	-	<50	1.9	<0.30	0.51	<0.60	700	-	-	-	-	-	-	
	08/27/98			29.37	0.00	-	110	5.6	<0.30	0.77	<0.60	1,600	-	-	-	-	-	-	
	12/01/98			30.14	0.00	-	<500	3.8	<3.0	<3.0	<6.0	9,500	-	-	-	-	-	-	
	03/03/99			30.71	0.00	-	<5,000	<30	<30	<30	<60	39,000	-	-	-	-	-	-	
	05/24/99			32.22	0.00	-	110	<0.60	<0.60	<0.60	<1.2	16,000	-	-	-	-	-	-	
	08/10/99			32.78	0.00	-	55	0.35	<0.30	0.80	0.79	120	-	-	-	-	-	-	
	10/25/99			33.35	0.00	-	75	6.2	<0.30	5.7	1.6	150	-	-	-	-	-	-	
	02/17/00			34.12	0.00	-	<50	<80	<80	<80	<160	5,900	<200	<200	<200	22,000	-	-	
	05/18/00			33.18	0.00	-	<500	<200	<200	<200	<400	6,800	<500	<500	<500	13,000	-	-	
	05/18/00	DUP		33.18	0.00	-	<500	<100	<100	<100	<200	6,900	<250	<250	<250	22,000	-		
	08/15/00			32.98	0.00	-	<50	2.6 J	<20	<20	<40	8,200	<50	<50	9.2 J	16,000	-	-	
	12/11/00			33.20	0.00	-	3,600	7.1	<0.30	1.4	1.9	11,000	<200	<200	<200	25,000	-	-	
	02/20/01			32.98	0.00	-	76 J	1.2 J	<3.0	<3.0	<6.0	6,500	<500	<500	<500	26,000	-	-	
	05/08/01			32.73	0.00	-	50	3.8	<0.30	<0.30	0.62	3,200	<100	<100	<100	22,000	-	-	
	08/11/01			31.76	0.00	-	43 J	3.5	0.28 J	0.24 J	<0.60	1,000	<25	<25	<25	18,000	-	-	
	11/06/01			31.89	0.00	-	320	1.7 J	<5.0	<5.0	<5.0	510	<5.0	3.1 J	<5.0	18,000	-	-	
	02/25/02			32.97	0.00	-	250	2.5 J	<5.0	<5.0	1.4 J	280	<5.0	2.9 J	<5.0	23,000	-	-	
	05/08/02			33.55	0.00	-	290	2.4 J	<40	<40	<80	150	<100	<100	<100	28,000	-	-	
	07/15/02			34.18	0.00	-	160	<20	<20	<20	<40	36 J	<50	<50	<50	32,000	-	-	
	10/15/02			34.64	0.00	-	380	1.7 J	<20	1.5 J	<40	11 J	<50	<50	<50	28,000	-	-	
	02/13/03			34.73	0.00	-	820	<50	<50	<50	<100	12 J	<120	<120	<120	24,000	<3,800	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-1	04/22/03		-	34.99	0.00	-	170	3.1 J	<20	<20	<40	25 J	<50	<50	<50	26,000	<1,500	-	
	07/30/03		428.29	33.28	0.00	395.01	250	<100	<100	<100	<200	16 J	<250	<250	<250	25,000	<7,500	-	
	12/10/03			33.46	0.00	394.83	260	<100	<100	<100	<200	<250	<250	<250	<250	23,000	<7,500	-	
	02/18/04			33.87	0.00	394.42	200	<100	<100	<100	<200	<250	<250	<250	<250	25,000	<7,500	-	
	05/12/04			33.57	0.00	394.72	170	<40	<40	<40	<80	8.8 J	<100	<100	<100	16,000	<3,000	-	
	08/16/04			33.50	0.00	394.79	210	6.8 J	<40	<40	<80	6.6 J	<100	<100	<100	19,000	<3,000	-	
	11/29/04			33.32	0.00	394.97	180	<40	<40	<40	<80	<100	<100	<100	<100	14,000	<3,000	-	
	03/08/05			27.66	0.00	400.63	110	<20	<20	5.5 J	<20	<20	<40	<40	<40	9,400	<10,000	-	
	06/06/05	NS		24.54	0.00	403.75	-	-	-	-	-	-	-	-	-	-	-	-	
	08/04/05	NS		25.18	0.00	403.11	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/05			23.63	0.00	404.66	<100	<2.0	<2.0	1.9 J	<2.0	55	<4.0	<4.0	<4.0	1,400	<1,000	-	
	02/16/06	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
EW-2	09/23/93		-	-	-	-	15,000	4,600	830	550	1,200	-	-	-	-	-	-	-	
	12/02/93			-	-	-	16,000	4,200	590	410	900	-	-	-	-	-	-	-	
	04/05/94			-	-	-	19,000	4,900	1,100	660	1,700	-	-	-	-	-	-	-	
	05/27/94			-	-	-	12,000	4,300	850	530	1,300	-	-	-	-	-	-	-	
	08/26/94			35.34	-	-	22,000	5,800	1,200	780	2,300	-	-	-	-	-	-	-	
	11/23/94			36.20	0.00	-	250	50	3.0	4.0	52	-	-	-	-	-	-	-	
	02/22/95			35.15	0.00	-	16,000	5,200	410	370	1,000	-	-	-	-	-	-	-	
	04/21/95			32.72	0.00	-	3,300	190	33	560	430	-	-	-	-	-	-	-	
	08/09/95			31.50	0.00	-	13,000	4,500	630	480	990	-	-	-	-	-	-	-	
	11/06/95			31.83	0.00	-	18,000	5,300	1,200	640	2,000	-	-	-	-	-	-	-	
	02/02/96			35.20	0.00	-	13,000	4,600	85	710	630	-	-	-	-	-	-	-	
	05/02/96			33.07	0.00	-	9,700	3,800	94	620	710	-	-	-	-	-	-	-	
	07/24/96			33.67	0.00	-	3,800	940	25	180	98	110	-	-	-	-	-	-	
	12/13/96			34.82	0.00	-	5,000	1,900	51	190	570	<10	-	-	-	-	-	-	
	03/20/97			34.05	0.00	-	2,700	990	7.7	110	170	52	-	-	-	-	-	-	
	06/12/97			34.22	0.00	-	320	150	1.3	5.2	5.2	39	-	-	-	-	-	-	
	07/31/97			34.52	0.00	-	4,000	2,000	<9.9	170	53	<130	-	-	-	-	-	-	
	10/15/97			35.06	0.00	-	3,600	1,800	18	190	31	180	-	-	-	-	-	-	
	03/25/98			33.36	0.00	-	1,800	910	8.2	<6.0	52	200	-	-	-	-	-	-	
	06/11/98			31.02	0.00	-	<50	11	<0.30	<0.30	<0.60	26	-	-	-	-	-	-	
	08/27/98			30.91	0.00	-	1,400	570	<3.0	<3.0	<6.0	180	-	-	-	-	-	-	
	12/01/98			31.74	0.00	-	400	57	2.0	3.6	1.4	160	-	-	-	-	-	-	
	03/03/99			33.04	0.00	-	1,700	750	18	120	150	250	-	-	-	-	-	-	
	05/24/99			33.93	0.00	-	2,500	1,000	18	48	<12	410	-	-	-	-	-	-	
	08/11/99			34.53	0.00	-	430	25	2.3	12	2.1	360	-	-	-	-	-	-	
	10/25/99			35.05	0.00	-	710	170	3.8	<1.2	<2.4	490	-	-	-	-	-	-	
	02/18/00			35.94	0.00	-	1,000	220	<5.0	41	26	260	<13	<13	<13	<130	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-2	05/17/00		-	34.91	0.00	-	6,600	2300	<40	380	230	1300	<100	<100	<100	<1,000	-	-	
	08/16/00			34.76	0.00	-	700	300	2.7	50	27 J	320	0.58 J	<5.0	<5.0	100	-	-	
	08/16/00	DUP		34.76	0.00	-	830	280	2.7	49	26 J	290	0.60 J	<5.0	<5.0	100	-		
	12/12/00			34.89	0.00	-	1,300	380	4.3	54	20	460	1.1 J	<10	<10	190	-	-	
	12/12/00	DUP		34.89	0.00	-	1,400	500	4.1 J	64	17	470	1.5 J	<5.0	<5.0	200	-		
	02/22/01			35.02	0.00	-	800	310	2.5 J	45	16	330	<25	<25	<25	270	-	-	
	02/22/01	DUP		35.02	0.00	-	640	250	2.2 J	37	13	310	<13	<13	<13	230	-		
	05/08/01			34.43	0.00	-	500	160	5.1	28	15	360	<5.0	<5.0	<5.0	95	-	-	
	05/08/01	DUP		34.43	0.00	-	370	120	3.7	21	11	220	<5.0	<5.0	<5.0	90	-		
	08/12/01			33.38	0.00	-	1,500	590	10	87	85	640	0.84 J	<5.0	<5.0	160	-	-	
	11/07/01			33.55	0.00	-	1,500	670	<100	98 J	69 J	390	<5.0	<5.0	<5.0	200	-	-	
	11/07/01	DUP		33.55	0.00	-	1,900	580	10 J	89	63	540	<10	<10	<10	160	-		
	02/26/02			34.71	0.00	-	1,700	720	11 J	81	42	360	<5.0	<5.0	<5.0	110	-	-	
	05/08/02			35.30	0.00	-	2,300	830	12	66	<16	530	<20	<20	<20	150 J	-	-	
	05/08/02	DUP		35.30	0.00	-	1,700	1,100	13	67	34	470	<20	<20	<20	170 J	-		
	07/16/02			35.95	0.00	-	1,000	820	7.2	63	19	430	<10	<10	<10	250	-	-	
	10/14/02			36.42	0.00	-	860	640	5.2	44	11	200	<5.0	<5.0	<5.0	170	-	-	
	10/14/02	DUP		36.42	0.00	-	780	520	3.8	33	8.4	180	<5.0	<5.0	<5.0	160	-		
	02/13/03			36.53	0.00	-	720	320	2.8 J	27	8.8 J	63	<25	<25	<25	160 J	<750	-	
	02/13/03	DUP		36.53	0.00	-	750	270	2.4 J	22	6.8 J	45	<25	<25	<25	120 J	<750		
	04/22/03			35.65	0.00	-	1,100	500	4.6 J	32	14 J	130	<20	<20	<20	400	<600	-	
	04/22/03	DUP		35.65	0.00	-	1,100	510	4.4	31	13	120	0.79 J	<5.0	<5.0	400	<150		
	07/30/03		430.40	35.05	0.00	395.35	98	24	<2.0	1.2 J	<4.0	10	0.44 J	<5.0	<5.0	190	<150	-	
	07/30/03	DUP		35.05	0.00	395.35	130	28	<2.0	1.2 J	<4.0	13	0.49 J	<5.0	<5.0	230	<150		
	12/10/03			35.14	0.00	395.26	330	110	0.88 J	21	1.1 J	99	0.38 J	<5.0	<5.0	460	<150	-	
	12/10/03	DUP		35.14	0.00	395.26	430	170	1.3 J	30	1.7 J	160	0.57 J	<5.0	<5.0	630	<150		
	02/18/04			35.65	0.00	394.75	47 J	0.34 J	<2.0	0.29 J	<4.0	6.9	0.34 J	<5.0	<5.0	170	<150	-	
	02/18/04	DUP		35.65	0.00	394.75	34 J	0.29 J	<2.0	0.29 J	<4.0	6.3	0.32 J	<5.0	<5.0	150	<150		
	05/12/04			35.19	0.00	395.21	290	130	3.5 J	4.1	32	19	<10	<10	<10	220	<300	-	
	05/12/04	DUP		35.19	0.00	395.21	310	130	3.4 J	4.3	35	10	<10	<10	<10	240	<300		
	08/16/04			35.20	0.00	395.20	42 J	1.1 J	<2.0	<2.0	<4.0	3.0 J	<5.0	<5.0	<5.0	100	<150	-	
	08/16/04	DUP		35.20	0.00	395.20	44 J	1.7 J	<2.0	0.33 J	<4.0	6.0	0.28 J	<5.0	<5.0	130	<150		
	11/30/04			35.05	0.00	395.35	1,200	550	3.2 J	82	18 J	65	<25	<25	<25	720	<750	-	
	11/30/04	DUP		35.05	0.00	395.35	970	100	0.61 J	15	3.3 J	18	<5.0	<5.0	<5.0	130	<150		
	03/09/05			29.14	0.00	401.26	760	380	4.5 J	65	13	30	<10	<10	<10	490	<2,500	-	
	03/09/05			29.14	0.00	401.26	690	440	4.8 J	81	13	33	<10	<10	<10	<120	<2,500	-	
	06/06/05	NS		27.29	0.00	403.11	-	-	-	-	-	-	-	-	-	-	-	-	
	08/04/05	NS		26.08	0.00	404.32	-	-	-	-	-	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-2	10/25/05	NS	430.40	27.67	0.00	402.73	-	-	-	-	-	-	-	-	-	-	-	-	
	02/16/06	NS		27.79	0.00	402.61	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06	NS		31.58	0.00	398.82	-	-	-	-	-	-	-	-	-	-	-	-	
EW-3	09/25/93		-	-	-	-	13,000	3,500	1,300	430	1,200	-	-	-	-	-	-	-	
	12/02/93			-	-	-	37,000	8,800	2,400	1,000	2,100	-	-	-	-	-	-	-	
	04/05/94			-	-	-	29,000	7,100	2,300	980	3,200	-	-	-	-	-	-	-	
	05/27/94			-	-	-	20,000	6,500	1,700	820	2,300	-	-	-	-	-	-	-	
	08/26/94			38.48	0.00	-	21,000	5,100	1,200	620	1,800	-	-	-	-	-	-	-	
	11/23/94			39.34	0.00	-	680	96	7.0	8.0	110	-	-	-	-	-	-	-	
	02/22/95			38.26	0.00	-	40,000	10,000	1,400	1,000	4,000	-	-	-	-	-	-	-	
	04/21/95			35.79	0.00	-	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/09/95			34.48	0.00	-	27,000	4,100	1,400	950	2,900	-	-	-	-	-	-	-	
	11/06/95			34.86	0.00	-	15,000	4,900	1,100	730	2,200	-	-	-	-	-	-	-	
	02/02/96			38.27	0.00	-	25,000	6,900	1,100	850	2,500	-	-	-	-	-	-	-	
	05/02/96			36.12	0.00	-	17,000	5,900	560	690	1,800	-	-	-	-	-	-	-	
	07/24/96			36.75	0.00	-	4,700	2,100	82	130	180	2,900	-	-	-	-	-	-	
	12/13/96			37.96	0.00	-	9,600	3,400	300	410	1,600	9400	-	-	-	-	-	-	
	03/20/97			37.14	0.00	-	12,000	3,200	410	500	1,400	20000	-	-	-	-	-	-	
	06/12/97			37.33	0.00	-	11,000	4,300	510	630	1,800	29000	-	-	-	-	-	-	
	07/31/97			37.63	0.00	-	11,000	3,600	280	410	1,200	32000	-	-	-	-	-	-	
	10/15/97			38.15	0.00	-	1,100	370	4.3	22	84	7,800	-	-	-	-	-	-	
	03/25/98			36.38	0.00	-	13,000	3,800	410	690	2,300	22,000	-	-	-	-	-	-	
	06/21/98			33.98	0.00	-	540	90	2.3	3.0	42	8,700	-	-	-	-	-	-	
	06/21/98	DUP		33.98	0.00	-	510	75	1.9	2.1	33	8,700	-	-	-	-	-		
	08/27/98			33.95	0.00	-	1,400	450	41	100	240	13,000	-	-	-	-	-	-	
	08/27/98	DUP		33.95	0.00	-	1,500	470	21	90	160	12,000	-	-	-	-	-		
	12/01/98			34.48	0.00	-	16,000	3,200	590	580	2,500	61,000	-	-	-	-	-	-	
	12/01/98	DUP		34.48	0.00	-	15,000	3,600	640	610	2,300	61,000	-	-	-	-	-		
	03/04/99			36.12	0.00	-	14,000	4,300	630	850	2,800	65,000	-	-	-	-	-	-	
	03/04/99	DUP		36.12	0.00	-	13,000	3,500	520	650	2,200	50,000	-	-	-	-	-		
	05/24/99			37.01	0.00	-	19,000	4,400	480	1,100	2,600	53,000	-	-	-	-	-	-	
	05/24/99	DUP		37.01	0.00	-	25,000	5,000	520	1,300	2,800	63,000	-	-	-	-	-		
	08/10/99			37.57	0.00	-	19,000	5,200	410	1,000	2,400	47,000	-	-	-	-	-	-	
	08/10/99	DUP		37.57	0.00	-	18,000	4,500	400	970	2,400	46,000	-	-	-	-	-		
	10/25/99			38.15	0.00	-	12,000	2,500	200	430	380	29,000	-	-	-	-	-	-	
	10/25/99	DUP		38.15	0.00	-	11,000	2,900	230	500	1,600	29,000	-	-	-	-	-		
	02/18/00			39.07	0.00	-	2,000	3,100	<400	<400	1,800	16,000	<1,000	<1,000	<1,000	<10,000	-	-	
	02/18/00	DUP		39.07	0.00	-	9,300	2,800	<200	350	1,600	17,000	<500	<500	<500	8,000	-		
	05/17/00			38.04	0.00	-	18,000	5,800	<400	950	2,200	28,000	<1,000	<1,000	<1,000	15,000	-	-	
	08/16/00			37.85	0.00	-	15,000	3700	250	900	1900	34000	<200	<200	32 J	24,000	-	-	

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ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-3	12/12/00		-	38.00	0.00	-	2,500	290	8	120	120	7800	<130	<130	<130	20,000	-	-	
	02/22/01			38.12	0.00	-	6,200	2,100	29	370	680	10,000	<500	<500	<500	9,700	-	-	
	05/08/01			37.47	0.00	-	11,000	3,800	320	540	1,100	22,000	<200	<200	<200	16,000	-	-	
	09/12/01			36.45	0.00	-	23,000	5,600	590	890	2,000	35,000	<20	<20	39 J	14,000	-	-	
	11/07/01			36.65	0.00	-	19,000	3,800	380 J	640	1,800	38,000	<500	<500	<500	16,000	-	-	
	02/26/02			37.81	0.00	-	20,000	3,700	220 J	660	1,700	27,000	<200	<200	<200	12,000	-	-	
	05/08/02			38.40	0.00	-	6,000	1,100	120	230	640	12,000	<100	<100	17 J	4,600	-	-	
	07/16/02			39.03	0.00	-	3,300	540	78	160	350	7,800	<100	<100	11 J	5,900	-	-	
	10/14/02			39.54	0.00	-	3,300	290	20	110	150	5,200	<50	<50	7.0 J	4,900	-	-	
	02/13/03			39.60	0.00	-	3,200	290	<20	100	57	1,800	<50	<50	3.5 J	6,900	<1,500	-	
	04/22/03			38.85	0.00	-	5,100	1,300	7.5 J	260	300	7,900	<50	<50	15 J	16,000	<1,500	-	
	07/30/03		433.71	38.11	0.00	395.60	2,100	450	<20	94	51	2,000	<50	<50	<50	3,200	<1,500	-	
	12/10/03			38.81	0.00	394.90	1,200	170	<20	60	35 J	700	<50	<50	<50	5,400	<1,500	-	
	02/18/04			38.81	0.00	394.90	1,200	270	<20	75	39 J	1,100	<50	<50	<50	4,200	<1,500	-	
	05/12/04			38.21	0.00	395.50	1,000	230	<20	68	25 J	190	<50	<50	<50	4,900	<1,500	-	
	08/16/04			38.31	0.00	395.40	930	140	<20	48	15 J	130	<50	<50	<50	2,100	<1,500	-	
	11/30/04			38.14	0.00	395.57	630	50	<8.0	24	8.0 J	27	<20	<20	<20	2,900	<600	-	
	03/09/05			32.02	0.00	401.69	<100	0.66 J	<1.0	<1.0	<1.0	2.7	<2.0	<2.0	<2.0	<25	<500	-	
	06/07/05			30.45	0.00	403.26	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	08/04/05			31.06	0.00	402.65	270	6.6	1.5 J	11	12	300	<8.0	<8.0	<8.0	200	<2,000	-	
	10/25/05			30.65	0.00	403.06	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/16/06			30.92	0.00	402.79	1,200	63	8.1 J	60	34	870	<29	<29	<29	1,500	<7,100	-	
	07/06/06	NS		34.59	0.00	399.12	-	-	-	-	-	-	-	-	-	-	-	-	
	07/07/06			-	-	-	2,000	210	9.8	150	42	52	220	<8.0	<8.0	<8.0	<2,000	EW-3	
EW-4	09/25/93		-	-	-	-	41,000	510	2,000	2,400	9,600	-	-	-	-	-	-	-	
	12/02/93			-	-	-	35,000	200	920	1,400	7,100	-	-	-	-	-	-	-	
	04/05/94			-	-	-	30,000	150	510	1,100	4,700	-	-	-	-	-	-	-	
	05/27/94			-	-	-	26,000	49	530	1,300	4,300	-	-	-	-	-	-	-	
	08/26/94			37.14	0.00	-	27,000	150	360	940	3,100	-	-	-	-	-	-	-	
	11/23/94			38.03	0.00	-	<50	3.0	4.0	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			36.91	0.00	-	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	04/21/95			34.32	0.00	-	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/09/95			33.10	0.00	-	32,000	180	280	1,100	5,000	-	-	-	-	-	-	-	
	11/03/95	NS		33.45	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	02/02/96			36.90	0.00	-	9,500	61	32	980	2,800	-	-	-	-	-	-	-	
	05/02/96	NS		34.74	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/24/96	NS		35.34	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/12/96	NS		36.58	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	03/20/97			35.82	0.00	-	9,400	32	4.1	320	600	<10	-	-	-	-	-	-	
	06/12/97	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

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ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-4	07/31/97	NS	-	36.25	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	10/15/97	NS		36.81	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	03/25/98			35.00	0.00	-	9,500	80	12	270	290	<20	-	-	-	-	-	-	
	06/21/98	NS		32.56	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/27/98	NS		32.48	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/98	NS		33.33	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	03/03/99			34.72	0.00	-	7,100	15	<3.0	93	83	<100	-	-	-	-	-	-	
	05/24/99	NS		35.67	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/10/99	NS		36.22	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/99	NS		36.79	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	02/18/00			37.76	0.00	-	4,800	3.2	<2.0	53	69	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	05/17/00	NS		36.70	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/15/00	NS		36.53	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/11/00	NS		37.01	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	02/22/01			37.16	0.00	-	410	2.5	1.0	6.6	6.5	0.38 J	<5.0	<5.0	<5.0	<10	-	-	
	05/09/01			36.19	0.00	-	6,500	28	<3.0	140	95	<20	<20	<20	<20	<200	-	-	
	09/12/01			35.07	0.00	-	5,700	<3.0	4.7	73	43	<20	<20	<20	<20	<200	-	-	
	11/07/01			35.24	0.00	-	5,700	<25	15 J	68	38	<20	<20	<20	<20	<200	-	-	
	02/26/02			36.41	0.00	-	5,100	<5.0	2.1 J	7.1	5.4	<5.0	<5.0	<5.0	<5.0	<25	-	-	
	05/08/02			37.06	0.00	-	3,900	0.68 J	0.26 J	28	26	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	07/16/02			37.74	0.00	-	2,200	0.14 J	<2.0	22	20	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	10/14/02			38.21	0.00	-	2,100	<2.0	<2.0	13	11	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			38.28	0.00	-	1,600	<2.0	<2.0	8.6	6.3	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			37.54	0.00	-	1,600	<2.0	<2.0	19	11	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03		432.58	36.84	0.00	395.74	1,500	<2.0	<2.0	7.3	2.8 J	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	12/10/03			36.94	0.00	395.64	2,500	<2.0	<2.0	8.2	4.4	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	02/18/04			37.44	0.00	395.14	1,900	<2.0	<2.0	10	6.1	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			36.93	0.00	395.65	1,600	<2.0	<2.0	5.6	1.8 J	<5.0	<5.0	<5.0	<5.0	7.3 J	<150	-	
	08/16/04			37.02	0.00	395.56	2,500	<2.0	<2.0	10	3.4 J	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/30/04			36.79	0.00	395.79	1,600	<2.0	<2.0	4.2	1.1 J	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/09/05			30.39	0.00	402.19	380	<1.0	<1.0	0.31 J	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	06/06/05	NS		28.62	0.00	403.96	-	-	-	-	-	-	-	-	-	-	-	-	
	08/04/05	NS		27.91	0.00	404.67	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/05	NS		29.14	0.00	403.44	-	-	-	-	-	-	-	-	-	-	-	-	
	02/16/06	NS		29.63	0.00	402.95	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06	NS		33.16	0.00	399.42	-	-	-	-	-	-	-	-	-	-	-	-	
EW-5	09/23/93	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/05/93			-	-	-	1,400	87	41	5.0	15	-	-	-	-	-	-	-	
	04/05/94			-	-	-	2,600	580	280	18	140	-	-	-	-	-	-	-	
	05/27/94			-	-	-	2,500	960	520	33	220	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-5	08/26/94		-	43.93	0.00	-	2,300	760	210	9	130	-	-	-	-	-	-	-	
	11/23/94			45.14	0.00	-	<50	1.0	2.0	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			43.96	0.00	-	12,000	1,600	300	35	610	-	-	-	-	-	-	-	
	04/21/95			41.44	0.00	-	550	25	3.6	75	66	-	-	-	-	-	-	-	
	08/09/95			40.14	0.00	-	6,900	510	55	8.8	130	-	-	-	-	-	-	-	
	11/03/95	NS		40.31	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	02/02/96			43.92	0.00	-	12,000	94	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	05/02/96	NS		41.81	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/24/96	NS		42.43	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/12/96	NS		43.70	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	03/19/97	NS		42.88	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	06/12/97	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/31/97	NS		43.42	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	10/15/97	NS		43.88	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	03/25/98			42.02	0.00	-	140	33	0.99	0.77	12	5,700	-	-	-	-	-	-	
	03/25/98	DUP		42.02	0.00	-	500	100	3.6	3.2	33	4,900	-	-	-	-	-	-	
	06/11/98	NS		39.51	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/27/98	NS		39.40	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/98	NS		40.18	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	03/04/99			41.81	0.00	-	<1,000	130	<6.0	21	21	8,900	-	-	-	-	-	-	
	05/24/99	NS		42.73	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/11/99	NS		43.32	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/99	NS		43.67	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	02/18/00			44.83	0.00	-	130	<400	<400	<400	<800	9,700	<1,000	<1,000	<1,000	<10,000	-	-	
	05/17/00	NS		40.43	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/15/00	NS		43.92	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/11/00	NS		44.01	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	02/21/01			43.55	0.00	-	48 J	1.8	<0.30	0.14 J	0.80	4,100	<500	<500	<500	2,300	-	-	
	05/08/01			43.05	0.00	-	<50	0.78	<0.30	<0.30	<0.60	1,200	<10	<10	<10	210	-	-	
	09/11/01			42.17	0.00	-	60	2.2	<0.30	0.36	<0.60	730	<10	1.3 J	2.6 J	170	-	-	
	11/06/01			42.31	0.00	-	220	5.2	<5.0	<5.0	<5.0	320	<5.0	<5.0	<5.0	210	-	-	
	02/25/02			43.49	0.00	-	<100	4.5 J	<5.0	<5.0	<5.0	200	<5.0	<5.0	<5.0	160	-	-	
	05/08/02			44.15	0.00	-	110	2.4	0.16 J	0.38 J	<4.0	220	<5.0	0.98 J	0.86 J	200	-	-	
	07/15/02			44.80	0.00	-	19 J	<2.0	0.63 J	0.78 J	4.2	3.5 J	<5.0	<5.0	<5.0	27 J	-	-	
	10/15/02			45.30	0.00	-	13 J	<2.0	<2.0	<2.0	<4.0	1.4 J	<5.0	<5.0	<5.0	11 J	-	-	
	02/13/03			45.42	0.00	-	8.8 J	<2.0	<2.0	<2.0	<4.0	8.0	<5.0	<5.0	<5.0	24 J	<150	-	
	04/22/03			44.61	0.00	-	13 J	0.47 J	<2.0	<2.0	<4.0	12	<5.0	<5.0	<5.0	9.9 J	<150	-	
	07/30/03		439.74	43.91	0.00	395.83	<50	<2.0	<2.0	<2.0	<4.0	14	<5.0	<5.0	<5.0	26 J	<150	-	
	12/10/03			44.09	0.00	395.65	44 J	<2.0	<2.0	<2.0	<4.0	41	<5.0	<5.0	<5.0	15 J	<150	-	
	02/18/04			44.58	0.00	395.16	43 J	<2.0	<2.0	<2.0	<4.0	110	<5.0	<5.0	<5.0	49 J	<150	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
EW-5	05/12/04		439.74	44.13	0.00	395.61	66	<4.0	<4.0	<4.0	<8.0	180	<10	<10	<10	94 J	<300	-	
	08/16/04			44.05	0.00	395.69	40 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/29/04			43.85	0.00	395.89	30 J	<2.0	<2.0	<2.0	<4.0	28	<5.0	<5.0	<5.0	38 J	<150	-	
	03/09/05			37.46	0.00	402.28	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	06/07/05			36.87	0.00	402.87	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	08/04/05			34.91	0.00	404.83	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	10/26/05			36.13	0.00	403.61	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/17/06			36.69	0.00	403.05	120	<3.6	<3.6	<3.6	<3.6	300	<7.1	<7.1	2.7 J	<69	<1,800	-	
	07/06/06	NS		40.21	0.00	399.53	-	-	-	-	-	-	-	-	-	-	-	-	
MW-1	09/22/93	NS	438.29	33.66	Sheen	404.63	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/93	NS		39.68	Sheen	398.61	-	-	-	-	-	-	-	-	-	-	-	-	
	04/05/94			41.58	0.00	396.71	49,000	6,000	5,600	1,400	6,100	-	-	-	-	-	-	-	
	05/27/94			42.18	0.00	396.11	35,000	6,400	4,900	1,400	5,500	-	-	-	-	-	-	-	
	08/26/94			43.05	0.00	395.24	48,000	7,300	5,200	1,500	6,600	-	-	-	-	-	-	-	
	11/23/94			44.20	0.00	394.09	<50	7.0	15	2.0	5.0	-	-	-	-	-	-	-	
	02/22/95			43.08	0.00	395.21	42,000	8,000	5,200	1,100	5,700	-	-	-	-	-	-	-	
	04/21/95			40.83	0.00	397.66	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			39.28	0.00	399.01	38,000	5,600	2,100	900	3,800	-	-	-	-	-	-	-	
	11/03/95			39.63	0.00	398.66	32,000	5,600	2,000	890	3,400	-	-	-	-	-	-	-	
	02/02/96			43.08	0.00	395.21	38,000	8,000	3,300	1,100	5,200	-	-	-	-	-	-	-	
	05/02/96			40.93	0.00	397.36	21,000	5,300	1,000	770	2,500	-	-	-	-	-	-	-	
	07/24/96			41.54	0.00	396.75	27,000	5,500	1,400	620	2,700	3,000	-	-	-	-	-	-	
	12/13/96			42.79	0.00	395.50	19,000	3,400	940	410	1,600	2,400	-	-	-	-	-	-	
	03/20/97			41.98	0.00	396.31	19,000	4,900	800	520	1,700	4,300	-	-	-	-	-	-	
	06/12/97			42.15	0.00	396.14	1,700	580	45	58	69	1,200	-	-	-	-	-	-	
	07/31/97			42.44	0.00	395.85	13,000	3,200	360	350	1,400	3,500	-	-	-	-	-	-	
	10/15/97			42.98	0.00	395.31	11,000	4,000	210	360	660	2,700	-	-	-	-	-	-	
	03/25/98	NS		40.42	0.00	397.87	-	-	-	-	-	-	-	-	-	-	-	-	
	06/21/98	NS		38.02	0.00	400.27	-	-	-	-	-	-	-	-	-	-	-	-	
	08/27/98			37.93	0.00	400.36	25,000	9,600	93	280	2,100	6,800	-	-	-	-	-	-	
	12/01/98			39.55	0.00	398.74	16,000	4,300	170	720	530	5,300	-	-	-	-	-	-	
	03/04/99			41.01	0.00	397.28	12,000	3,200	150	560	750	4,600	-	-	-	-	-	-	
	05/24/99			41.85	0.00	396.44	19,000	5,000	240	700	1,900	8,300	-	-	-	-	-	-	
	08/10/99			42.41	0.00	395.88	14,000	2,900	170	460	1,100	4,500	-	-	-	-	-	-	
	10/25/99			42.96	0.00	395.33	19,000	3,600	200	540	1,200	4,700	-	-	-	-	-	-	
	02/17/00			43.94	0.00	394.35	19,000	3,400	330	730	1,900	4,600	<250	<250	<250	<2,500	-	-	
	05/17/00			42.38	0.00	395.91	13,000	2,900	170	590	1,200	4,500	<200	<200	<200	<2,000	-	-	
	08/16/00			42.67	0.00	395.62	14,000	3,300	150	660	910	6,900	<250	<250	<250	310 J	-	-	
	12/11/00			42.87	0.00	395.42	4,100	870	28	120	160	1,500	<25	<25	<25	130 J	-	-	
	02/20/01			42.62	0.00	395.67	3,700	960	45	140	220	2000	<50	<50	<50	1,300	-	-	

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Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-1	05/08/01		438.29	41.05	0.00	397.24	7,400	1900	64	180	440	3600	<50	<50	<50	<500	-	-	
	09/11/01			41.27	0.00	397.02	7,600	1,900	51	250	300	2,900	<50	<50	<50	230 J	-	-	
	11/06/01			41.46	0.00	396.83	13,000	2,500	<500	350 J	720	3,700	<5.0	<5.0	6.2	580	-	-	
	02/25/02			41.77	0.00	396.52	17,000	3,500	120 J	590	1,000	5,300	<50	<50	<50	1,200	-	-	
	05/08/02			43.24	0.00	395.05	20,000	4,200	180	540	870	5,600	<50	<50	<50	700	-	-	
	07/15/02			43.81	0.00	394.48	21,000	1,300	800	830	3,600	5,100	<50	<50	15 J	330 J	-	-	
	10/15/02			44.37	0.00	393.92	20,000	2,000	190	600	950	1,900	<50	<50	<50	560	-	-	
	02/13/03			44.29	0.00	394.00	25,000	2,100	230	780	1,300	1,300	<500	<500	<500	790 J	<15,000	-	
	04/22/03			43.67	0.00	394.62	14,000	1,800	150	520	710	2,300	<50	<50	<50	1,200	<1,500	-	
	07/30/03			42.99	0.00	395.30	7,000	1,100	71	450	310	1,500	<100	<100	<100	580 J	<3,000	-	
	12/10/03			43.11	0.00	395.18	12,000	1,200	130 J	430	490	1,600	<500	<500	<500	520 J	83,000	-	
	02/18/04			43.57	0.00	394.72	23,000	930	180	510	830	1,500	<100	<100	<100	900 J	<3,000	-	
	05/12/04			43.12	0.00	395.17	16,000	1,700	230	480	740	2,500	<250	<250	<250	910 J	<7,500	-	
	08/16/04			43.17	0.00	395.12	20,000	2,000	230	770	1,000	3,000	<250	<250	<250	2,100 J	<7,500	-	
	11/29/04			42.97	0.00	395.32	13,000	1,200	160	470	680	1,300	<250	<250	<250	580 J	20,000	-	
	03/09/05			36.79	0.00	401.50	2,700	540	45	150	240	1,100	<40	<40	<40	280 J	<10,000	-	
	06/07/05			33.81	0.00	404.48	4,300	420	40	230	340	500	<80	<80	<80	360 J	34,000	-	
	08/04/05			34.17	0.00	404.12	1,300	37	3.1 J	48	37	250	<6.7	<6.7	<6.7	150	<1,700	-	
	10/25/05			35.41	0.00	402.88	1,900	87	2.6	190	11	130	<5.0	<5.0	<5.0	<62	<1,200	-	
	02/17/06			35.96	0.00	402.33	4,600	800	20	320	78	190	<20	<20	<20	<250	<5,000	-	
	07/06/06	NS		39.37	0.00	398.92	-	-	-	-	-	-	-	-	-	-	-	-	
	07/07/06			-	-	-	4,900	660	15	130	79	110	<250	<20	<20	<20	<5,000	MW-1	
MW-3	09/23/93	NS	440.58	40.30	0.00	400.28	-	-	-	-	-	-	-	-	-	-	-	-	
	12/05/93			41.35	0.00	399.23	2,400	140	13	30	120	-	-	-	-	-	-	-	
	04/05/94			43.30	0.00	397.28	4,500	200	76	50	200	-	-	-	-	-	-	-	
	05/27/94			43.91	0.00	396.67	3,500	210	76	54	180	-	-	-	-	-	-	-	
	08/26/94			44.83	0.00	395.75	11,000	2,700	1,400	280	1,000	-	-	-	-	-	-	-	
	11/23/94			45.98	0.00	394.60	130	4.0	12	4.0	23	-	-	-	-	-	-	-	
	02/22/95			44.85	0.00	395.73	8,300	500	79	30	240	-	-	-	-	-	-	-	
	04/21/95			42.24	0.00	398.34	4,800	36	21	630	180	-	-	-	-	-	-	-	
	08/08/95			40.84	0.00	399.74	10,000	2,300	360	330	1,200	-	-	-	-	-	-	-	
	11/06/95			41.33	0.00	399.25	3,900	470	6.4	21	57	-	-	-	-	-	-	-	
	02/02/96			44.78	0.00	395.80	6,000	1,000	9.7	36	120	-	-	-	-	-	-	-	
	05/02/96			42.67	0.00	397.91	5,000	1,800	<15	60	170	-	-	-	-	-	-	-	
	07/24/96			43.28	0.00	397.30	3,400	520	<3.0	26	43	450	-	-	-	-	-	-	-	
	12/13/96			44.53	0.00	396.05	2,400	480	9.7	30	100	240	-	-	-	-	-	-	-	
	03/20/97			43.75	0.00	396.83	1,100	74	<1.5	3.3	11	120	-	-	-	-	-	-	-	
	06/12/97			43.91	0.00	396.67	4,000	790	35	74	99	1,200	-	-	-	-	-	-	-	
	07/31/97			44.21	0.00	396.37	1,500	520	12	33	33	1,100	-	-	-	-	-	-	-	
	10/15/97			44.77	0.00	395.81	320	140	6	9	18	210	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-3	03/25/98		440.58	42.71	0.00	397.87	1,700	510	31	52	210	830	-	-	-	-	-	-	
	06/21/98			39.40	0.00	401.18	12,000	3,800	<38	520	860	14,000	-	-	-	-	-	-	
	08/27/98			40.39	0.00	400.19	4,900	1,900	<12	360	270	6,600	-	-	-	-	-	-	
	12/01/98			41.25	0.00	399.33	810	290	<1.5	66	14	2,100	-	-	-	-	-	-	
	03/04/99			43.64	0.00	396.94	2,500	590	19	33	32	2,800	-	-	-	-	-	-	
	05/24/99			43.60	0.00	396.98	3,200	1,200	36	190	170	7,100	-	-	-	-	-	-	
	08/11/99			44.17	0.00	396.41	1,100	280	18	16	79	6,600	-	-	-	-	-	-	
	10/25/99			44.75	0.00	395.83	280	88	12	4.7	45	1,700	-	-	-	-	-	-	
	02/17/00			45.73	0.00	394.85	670	200	25	<10	120	990	<25	<25	<25	<250	-	-	
	05/17/00			44.64	0.00	395.94	2,200	490	46	36	100	1,200	<50	<50	<50	<500	-	-	
	08/15/00			44.47	0.00	396.11	860	110	14	16	43	2,100	<5.0	<5.0	2.3 J	55	-	-	
	12/11/00			44.65	0.00	395.93	560	49	3.1	11	14	520	<10	<10	<10	63 J	-	-	
	02/22/01			44.40	0.00	396.18	18	1.6	0.38	0.56	0.75	75	<20	<20	<20	46	-	-	
	05/08/01			43.15	0.00	397.43	510	40	0.66	5.5	6.0	200	<5.0	<5.0	<5.0	57	-	-	
	08/12/01			43.35	0.00	397.23	660	34	5.0	6.4	9.3	150	<5.0	<5.0	<5.0	550	-	-	
	08/12/01	DUP		43.35	0.00	397.23	370	26	3.0	4.9	6.7	170	<5.0	<5.0	<5.0	550	-		
	11/07/01			43.54	0.00	397.04	500	43	4.3 J	9.7	3.2 J	220	<5.0	<5.0	<5.0	530	-	-	
	02/25/02			44.78	0.00	395.80	720	3.8 J	3.2 J	<5.0	9.6	1,400	<5.0	<5.0	<5.0	1,600	-	-	
	05/08/02			45.44	0.00	395.14	390	27	3.1	3.2	19	170	<5.0	<5.0	<5.0	320	-	-	
	07/15/02			46.06	0.00	394.52	150	0.18 J	<2.0	<2.0	<4.0	6.0	<5.0	<5.0	<5.0	13 J	-	-	
	10/15/02			46.58	0.00	394.00	98	<2.0	<2.0	<2.0	<4.0	0.38 J	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			46.74	0.00	393.84	400	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			45.90	0.00	394.68	370	22	<2.0	0.86 J	7.6	46	<5.0	<5.0	<5.0	15 J	<150	-	
	07/30/03			46.21	0.00	394.37	98	<2.0	<2.0	0.27 J	<4.0	0.47 J	<5.0	<5.0	<5.0	<50	290	-	
	12/10/03			46.38	0.00	394.20	130	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	8.3 J	<150	-	
	02/18/04			46.80	0.00	393.78	80	<2.0	<2.0	<2.0	<4.0	0.66 J	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			46.28	0.00	394.30	210	<2.0	<2.0	<2.0	<4.0	0.62 J	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			46.34	0.00	394.24	170	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/29/04			46.13	0.00	394.45	210	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/09/05			38.64	0.00	401.94	87 J	2.3	<1.0	16	1.2	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	06/07/05			37.02	0.00	403.56	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	08/04/05			36.05	0.00	404.53	<100	<1.0	<1.0	0.27 J	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	10/26/05			37.26	0.00	403.32	<100	<1.0	<1.0	1.8	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/17/06			37.87	0.00	402.71	<100	<1.0	<1.0	9.8	0.91 J	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	07/06/06	NS		41.44	0.00	399.14	-	-	-	-	-	-	-	-	-	-	-	-	
	07/07/06			-	-	-	75 J	<1.0	<1.0	1.2	1.4	<1.0	<25	<2.0	<2.0	<2.0	<500	MW-3	
MW-4	09/25/93		439.53	39.28	0.00	400.25	23,000	670	1,300	490	2,500	-	-	-	-	-	-	-	
	12/05/93			40.33	0.00	399.20	14,000	1,000	2,300	650	2,000	-	-	-	-	-	-	-	
	04/05/94			42.31	0.00	397.22	22,000	1,100	1,100	520	2,700	-	-	-	-	-	-	-	
	05/27/94			42.93	0.00	396.60	16,000	1100	960	480	2100	-	-	-	-	-	-	-	

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ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-4	08/26/94		439.53	43.81	0.00	395.72	230,000	10000	7400	2900	15000	-	-	-	-	-	-	-	
	11/23/94	NS		45.12	0.13	394.51	-	-	-	-	-	-	-	-	-	-	-	-	
	04/20/95	NS		41.37	0.04	398.19	-	-	-	-	-	-	-	-	-	-	-	-	
	08/08/95	NS		39.89	0.01	399.65	-	-	-	-	-	-	-	-	-	-	-	-	
	11/06/95			40.34	0.00	399.19	25,000	5,300	970	670	3,200	-	-	-	-	-	-	-	
	02/02/96			53.52	0.00	386.01	13,000	2,000	390	220	1,400	-	-	-	-	-	-	-	
	05/02/96			41.68	0.00	397.85	33,000	8,400	2,300	1,200	5,600	-	-	-	-	-	-	-	
	07/24/96			42.30	0.00	397.23	10,000	1,800	570	200	1,200	3100	-	-	-	-	-	-	
	12/13/96			43.60	0.00	395.93	3,200	260	69	70	430	360	-	-	-	-	-	-	
	03/20/97			42.72	0.00	396.81	9,500	980	310	240	1,200	2,100	-	-	-	-	-	-	
	06/12/97			42.92	0.00	396.61	21,000	3,600	1,200	720	3,800	19,000	-	-	-	-	-	-	
	07/31/97			43.25	0.00	396.28	16,000	1,900	620	480	2,200	11,000	-	-	-	-	-	-	
	10/15/97			43.77	0.00	395.76	21,000	3,100	1,100	800	3,400	17000	-	-	-	-	-	-	
	03/25/98			41.86	0.00	397.67	4,600	730	69	26	660	2,100	-	-	-	-	-	-	
	03/25/98	DUP		41.86	0.00	397.67	5,300	1,100	71	38	890	2,700	-	-	-	-	-	-	
	06/21/98			39.32	0.00	400.21	13,000	850	82	80	460	<250	-	-	-	-	-	-	
	08/27/98			39.39	0.00	400.14	13,000	2,300	210	530	1,900	13,000	-	-	-	-	-	-	
	08/27/98	DUP		39.39	0.00	400.14	13,000	2,200	210	490	1,800	11,000	-	-	-	-	-	-	
	12/01/98			40.22	0.00	399.31	16,000	1,800	260	500	1,900	9,700	-	-	-	-	-	-	
	12/01/98	DUP		40.22	0.00	399.31	13,000	1,800	290	490	1,800	9,200	-	-	-	-	-	-	
	03/04/99			41.67	0.00	397.86	20,000	3,200	520	810	3,200	14,000	-	-	-	-	-	-	
	05/24/99			42.60	0.00	396.93	17,000	1,500	310	610	2,400	6,400	-	-	-	-	-	-	
	08/10/99			43.20	0.00	396.33	24,000	2,100	500	850	3,900	15,000	-	-	-	-	-	-	
	10/25/99			43.78	0.00	395.75	12,000	1,500	260	600	2,600	6,700	-	-	-	-	-	-	
	02/17/00			44.73	0.00	394.80	20,000	760	420	390	2,900	2,500	<100	<100	<100	<1,000	-	-	
	05/17/00			43.65	0.00	395.88	16,000	1,300	430	530	2,800	4,600	<200	<200	<200	<2,000	-	-	
	08/16/00			43.46	0.00	396.07	21,000	1,800	830	880	3,900	11,000	<100	<100	21 J	380 J	-	-	
	12/11/00			43.65	0.00	395.88	2,700	150	44	70	310	730	<13	<13	1.8 J	46 J	-	-	
	02/21/01			42.79	0.00	396.74	5,600	540	150	32	980	2,300	<25	1.2 J	5.9 J	1,900	-	-	
	05/08/01			42.97	0.00	396.56	15,000	1,000	320	410	2,300	3,600	<50	<50	<50	600	-	-	
	09/11/01			41.97	0.00	397.56	15,000	1,000	220	260	1,700	13,000	<50	<50	25 J	1,300	-	-	
	11/06/01			42.21	0.00	397.32	19,000	1,500	420	410	2,200	12,000	<5.0	9.4	41	1,300	-	-	
	02/25/02			43.38	0.00	396.15	14,000	560	190 J	330	1,500	3,500	<50	<50	<50	610	-	-	
	05/08/02			44.07	0.00	395.46	22,000	1,200	710	650	3,100	6,900	<100	<100	23 J	460 J	-	-	
	07/15/02			44.69	0.00	394.84	5,400	1,500	100	300	450	1,700	<20	<20	3.2 J	310	-	-	
	10/15/02			45.24	0.00	394.29	19,000	740	550	600	2,200	3,400	<50	<50	11 J	310 J	-	-	
	02/13/03			45.35	0.00	394.18	740	5.5	9.4	12	56	1.6 J	<5.0	<5.0	<5.0	<50	56 J	-	
	04/22/03			44.51	0.00	395.02	9,500	210	140	310	1,500	9.7	<5.0	<5.0	0.50 J	11 J	<150	-	
	07/30/03			43.79	0.00	395.74	13,000	410	260	730	1,800	20 J	<50	<50	<50	<500	<1,500	-	
	12/10/03			43.98	0.00	395.55	6,800	160	68	330	740	10 J	<50	<50	<50	<500	<1,500	-	

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6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-4	02/18/04		439.53	44.46	0.00	395.07	7,200	110	75	230	640	4.1 J	<25	<25	<25	<250	<750	-	
	05/12/04			43.99	0.00	395.54	8,100	210	210	460	1,300	5.0 J	<50	<50	<50	<500	<1,500	-	
	08/16/04			43.94	0.00	395.59	12,000	130	150	500	1,300	7.9 J	<50	<50	<50	<500	<1,500	-	
	11/29/04			43.75	0.00	395.78	6,900	78	96	210	630	1.5 J	<10	<10	<10	<100	<300	-	
	03/08/05			37.29	0.00	402.24	85 J	<1.0	0.55 J	1.6	10	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	06/07/05			35.84	0.00	403.69	<100	0.64 J	0.42 J	0.42 J	2.3	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	08/04/05			34.66	0.00	404.87	60 J	1.0	0.46 J	1.1	3.6	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	10/26/05			35.93	0.00	403.60	<100	<1.0	<1.0	0.36 J	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/17/06			36.42	0.00	403.11	170	<1.0	<1.0	1.4	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	07/06/06	NS		40.04	0.00	399.49	-	-	-	-	-	-	-	-	-	-	-	-	
	07/07/06			-	-	-	100	<1.0	<1.0	1.4	2.9	1.8	70	<2.0	<2.0	<2.0	<500	MW-4	
MW-5	09/25/93		440.17	39.70	0.00	400.47	200	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	12/05/93			40.82	0.00	399.35	400	4.0	<0.5	<0.5	0.80	-	-	-	-	-	-	-	
	04/05/94			42.77	0.00	397.40	380	3.0	<0.5	<0.5	1.0	-	-	-	-	-	-	-	
	05/27/94			43.38	0.00	396.79	340	25	<0.5	4.0	1.0	-	-	-	-	-	-	-	
	08/26/94			44.27	0.00	395.90	1,500	110	4.0	20	6.0	-	-	-	-	-	-	-	
	11/23/94			45.51	0.00	394.66	<50	3.0	<0.5	0.50	1.0	-	-	-	-	-	-	-	
	02/22/95			44.32	0.00	395.85	1,500	27	1.3	1.7	2.4	-	-	-	-	-	-	-	
	04/21/95			41.69	0.00	398.48	320	3.1	0.70	53	16	-	-	-	-	-	-	-	
	08/08/95			40.32	0.00	399.85	350	53	0.31	1.4	1.3	-	-	-	-	-	-	-	
	11/06/95			40.76	0.00	399.41	98	3.9	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	02/02/96			44.23	0.00	395.94	60	7.3	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	05/02/96			42.13	0.00	398.04	170	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	07/24/96			42.76	0.00	397.41	100	5.1	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	12/13/96			44.04	0.00	396.13	53	2.8	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	03/20/97			43.22	0.00	396.95	68	2.9	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/12/97			43.38	0.00	396.79	65	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	07/31/97			43.70	0.00	396.47	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	10/15/97			44.26	0.00	395.91	53	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	03/25/98			42.35	0.00	397.82	380	3.8	0.30	0.70	1.4	430	-	-	-	-	-	-	
	06/21/98			39.81	0.00	400.36	160	2.6	<0.30	<0.30	<0.60	630	-	-	-	-	-	-	
	08/27/98			39.79	0.00	400.38	150	3.1	<0.30	<0.30	<0.60	560	-	-	-	-	-	-	
	12/01/98			40.64	0.00	399.53	100	<0.60	4.7	<0.60	<1.2	670	-	-	-	-	-	-	
	03/04/99			42.11	0.00	398.06	<50	<0.30	2.7	<0.30	<0.60	44	-	-	-	-	-	-	
	03/04/99	DUP		42.11	0.00	398.06	85	14	2.3	3.2	13	72	-	-	-	-	-		
	05/24/99			43.07	0.00	397.10	76	<0.30	<0.30	<0.30	<0.60	510	-	-	-	-	-	-	
	05/24/99	DUP		43.07	0.00	397.10	78	2.2	<0.30	<0.30	<0.60	610	-	-	-	-	-		
	08/11/99			43.66	0.00	396.51	<50	1.0	1.7	<0.30	<0.60	160	-	-	-	-	-	-	
	08/11/99	DUP		43.66	0.00	396.51	<50	<0.30	1.2	<0.30	<0.60	<10	-	-	-	-	-		
	10/25/99			44.22	0.00	395.95	<50	<0.30	<0.30	<0.30	<0.60	150	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-5	10/25/99	DUP	440.17	44.22	0.00	395.95	<50	1	<0.30	<0.30	<0.60	190	-	-	-	-	-		
	02/17/00			45.25	0.00	394.92	64	<2.0	<2.0	<2.0	<4.0	140	<5.0	<5.0	<5.0	51	-	-	
	02/17/00	DUP		45.25	0.00	394.92	77	<2.0	<2.0	<2.0	<4.0	120	<5.0	<5.0	<5.0	<50	-		
	05/17/00			44.18	0.00	395.99	83	<2.0	<2.0	<2.0	<4.0	53	<5.0	<5.0	<5.0	<50	-	-	
	08/15/00			43.96	0.00	396.21	<50	<2.0	<2.0	<2.0	<4.0	35	<5.0	<5.0	<5.0	7.8 J	-	-	
	12/11/00			44.13	0.00	396.04	94	0.18 J	<0.30	<0.30	<0.60	59	<5.0	<5.0	<5.0	14 J	-	-	
	02/21/01			43.90	0.00	396.27	43 J	0.40	0.18 J	<0.30	0.42 J	41	<5.0	<5.0	<5.0	38	-	-	
	05/08/01			42.20	0.00	397.97	<50	0.62	<0.30	<0.30	0.60	40	<5.0	<5.0	<5.0	<50	-	-	
	08/12/01			42.43	0.00	397.74	31 J	<0.30	<0.30	<0.30	<0.60	85	<5.0	<5.0	<5.0	10 J	-	-	
	11/07/01			42.66	0.00	397.51	53 J	<5.0	2.7 J	<5.0	<5.0	110	<5.0	<5.0	<5.0	13 J	-	-	
	02/25/02			43.87	0.00	396.30	51 J	<5.0	2.7 J	<5.0	<5.0	34	<5.0	<5.0	<5.0	27	-	-	
	05/08/02			44.58	0.00	395.59	43 J	<2.0	<2.0	<2.0	<4.0	21	<5.0	<5.0	<5.0	14 J	-	-	
	07/16/02			45.21	0.00	394.96	9.3 J	<2.0	<2.0	<2.0	<4.0	4.7 J	<5.0	<5.0	<5.0	<50	-	-	
	10/15/02			45.69	0.00	394.48	<50	<2.0	<2.0	<2.0	<4.0	0.44 J	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			45.85	0.00	394.32	13 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			45.03	0.00	395.14	16 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			44.32	0.00	395.85	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	12/10/03			44.49	0.00	395.68	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	02/18/04			44.94	0.00	395.23	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			44.45	0.00	395.72	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			44.43	0.00	395.74	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/30/04			44.24	0.00	395.93	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/09/05			37.58	0.00	402.59	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	06/07/05			36.02	0.00	404.15	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	08/04/05			35.02	0.00	405.15	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	10/25/05			36.26	0.00	403.91	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/17/06			36.87	0.00	403.30	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	07/06/06	NS		40.50	0.00	399.67	-	-	-	-	-	-	-	-	-	-	-	-	
	07/07/06			-	-	-	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<25	<2.0	<2.0	<2.0	<500	MW-5	
MW-6	09/23/93		440.70	39.85	0.00	400.85	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	12/02/93			40.90	0.00	399.80	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	04/05/94			42.94	0.00	397.76	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	05/27/94			43.58	0.00	397.12	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	08/26/94			44.42	0.00	396.28	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	11/23/94			45.72	0.00	394.98	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			44.57	0.00	396.13	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	04/21/95			43.73	0.00	396.97	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			40.45	0.00	400.25	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	11/03/95			40.89	0.00	399.81	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	02/01/96			44.40	0.00	396.30	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-6	05/02/96		440.70	42.29	0.00	398.41	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	07/24/96			42.94	0.00	397.76	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	12/12/96			44.28	0.00	396.42	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	03/19/97			43.43	0.00	397.27	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/12/97			43.60	0.00	397.10	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	07/31/97			43.92	0.00	396.78	<51	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	10/15/97			44.50	0.00	396.20	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	03/25/98			42.45	0.00	398.25	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/21/98			39.91	0.00	400.79	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	09/27/98			39.90	0.00	400.80	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	12/01/98			40.78	0.00	399.92	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	03/03/99			42.22	0.00	398.48	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	05/24/99			43.26	0.00	397.44	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	08/10/99			43.88	0.00	396.82	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	10/25/99			44.48	0.00	396.22	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	02/17/00			45.51	0.00	395.19	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	05/18/00			44.36	0.00	396.34	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	08/15/00			44.17	0.00	396.53	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	12/11/00			44.37	0.00	396.33	<50	<0.30	<0.30	<0.30	<0.60	0.34 J	<5.0	<5.0	<5.0	<50	-	-	
	02/20/01			44.10	0.00	396.60	<50	<0.30	<0.30	<0.30	<0.60	0.26 J	<5.0	<5.0	<5.0	<10	-	-	
	05/08/01			43.65	0.00	397.05	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	08/11/01			42.57	0.00	398.13	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	11/06/01			42.79	0.00	397.91	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/25/02			44.05	0.00	396.65	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-	-	
	05/08/02			44.78	0.00	395.92	9.8 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	07/15/02			45.43	0.00	395.27	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	10/15/02			46.00	0.00	394.70	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			46.12	0.00	394.58	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			45.26	0.00	395.44	9.2 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			44.58	0.00	396.12	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	12/10/03			44.72	0.00	395.98	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	5.8 J	<150	-	
	02/18/04			45.15	0.00	395.55	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			44.77	0.00	395.93	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			44.64	0.00	396.06	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/29/04			44.43	0.00	396.27	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/08/05			37.42	0.00	403.28	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	06/06/05	NS		34.19	0.00	406.51	-	-	-	-	-	-	-	-	-	-	-	-	

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MW-6	08/04/06	NS	440.70	33.21	0.00	407.49	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/06	NS		36.29	0.00	404.41	-	-	-	-	-	-	-	-	-	-	-	-	
	02/16/06	NS	443.41	38.79	0.00	406.62	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06	NS		40.69	0.00	402.72	-	-	-	-	-	-	-	-	-	-	-	-	
MW-7	09/23/93		433.99	34.55	0.00	399.44	200	24	<0.5	3.0	2.0	-	-	-	-	-	-	-	
	12/02/93			35.49	0.00	398.50	200	4.0	0.70	1.0	1.0	-	-	-	-	-	-	-	
	04/04/94			37.35	0.00	396.64	78	10	<0.5	1.0	1.0	-	-	-	-	-	-	-	
	05/26/94			37.94	0.00	396.05	84	8.0	<0.5	0.50	1.0	-	-	-	-	-	-	-	
	08/26/94			38.81	0.00	395.18	130	6.0	<0.5	<0.5	1.0	-	-	-	-	-	-	-	
	11/23/94			39.91	0.00	394.08	130	7.0	<0.5	<0.5	2.0	-	-	-	-	-	-	-	
	02/22/95			38.86	0.00	395.13	130	2.2	0.38	0.32	0.72	-	-	-	-	-	-	-	
	04/21/95			36.43	0.00	397.56	<50	1.6	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			35.10	0.00	398.89	52	1.6	<0.30	<0.30	0.64	-	-	-	-	-	-	-	
	11/03/95			35.49	0.00	398.50	91	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	02/01/96			38.84	0.00	395.15	700	4.2	2.2	1.9	3.7	-	-	-	-	-	-	-	
	05/02/96			36.72	0.00	397.27	460	4.4	<0.30	1.0	1.8	-	-	-	-	-	-	-	
	07/24/96			37.37	0.00	396.62	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	12/12/96			38.55	0.00	395.44	480	5.5	1.5	2.8	1.6	<10	-	-	-	-	-	-	
	03/19/97			37.76	0.00	396.23	65	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/12/97			37.90	0.00	396.09	<50	0.94	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	07/31/97			38.20	0.00	395.79	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	10/15/97			38.72	0.00	395.27	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	03/25/98			34.00	0.00	399.99	230	1.4	<0.30	<0.30	1.3	<10	-	-	-	-	-	-	
	06/21/98			34.61	0.00	399.38	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	08/27/98			34.58	0.00	399.41	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	12/01/98			35.44	0.00	398.55	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	03/03/99			36.71	0.00	397.28	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	05/24/99			37.61	0.00	396.38	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	08/10/99			38.17	0.00	395.82	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	10/25/99			38.72	0.00	395.27	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	02/17/00			39.61	0.00	394.38	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	05/18/00			38.59	0.00	395.40	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	08/15/00			38.38	0.00	395.61	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	12/11/00			38.56	0.00	395.43	<50	0.15 J	<0.30	0.11 J	<0.60	0.38 J	<5.0	<5.0	<5.0	<50	-	-	
	02/20/01			38.94	0.00	395.05	17 J	<0.30	<0.30	<0.30	<0.60	0.36 J	<5.0	<5.0	<5.0	5.5 J	-	-	
	05/08/01			38.15	0.00	395.84	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	08/11/01			37.02	0.00	396.97	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	11/06/01			37.10	0.00	396.89	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/25/02			38.37	0.00	395.62	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-	-	
	05/08/02			38.95	0.00	395.04	8.6 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-7	07/15/02		433.99	39.60	0.00	394.39	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	10/15/02			40.08	0.00	393.91	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			40.18	0.00	393.81	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			39.38	0.00	394.61	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			38.71	0.00	395.28	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	12/10/03			38.83	0.00	395.16	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	02/18/04			39.28	0.00	394.71	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			38.87	0.00	395.12	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			38.90	0.00	395.09	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/29/04			38.70	0.00	395.29	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/08/05			32.74	0.00	401.25	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	06/06/05			29.44	0.00	404.55	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	08/04/05			30.11	0.00	403.88	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	10/26/05			31.29	0.00	402.70	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/16/06			31.76	0.00	402.23	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	07/06/06			35.20	0.00	398.79	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<25	<2.0	<2.0	<2.0	<500	MW-7	
MW-8	09/23/93	NS	432.44	33.11	0.00	399.33	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/93	NS		34.07	0.00	398.37	-	-	-	-	-	-	-	-	-	-	-	-	
	04/05/94	NS		35.89	0.00	396.55	-	-	-	-	-	-	-	-	-	-	-	-	
	05/26/94	NS		36.51	0.00	395.93	-	-	-	-	-	-	-	-	-	-	-	-	
	08/26/94	NS		37.57	0.00	394.87	-	-	-	-	-	-	-	-	-	-	-	-	
	11/23/94	NS		38.39	0.00	394.05	-	-	-	-	-	-	-	-	-	-	-	-	
	02/22/95	NS		37.38	0.00	395.06	-	-	-	-	-	-	-	-	-	-	-	-	
	04/21/95	NS		34.98	0.00	397.46	-	-	-	-	-	-	-	-	-	-	-	-	
	08/08/95	NS		33.68	0.00	398.76	-	-	-	-	-	-	-	-	-	-	-	-	
	11/03/95			34.05	0.00	398.39	17,000	600	210	580	1,500	-	-	-	-	-	-	-	
	02/01/96			37.41	0.00	395.03	7,600	320	76	130	1,000	-	-	-	-	-	-	-	
	05/02/96			35.28	0.00	397.16	20,000	900	760	1,100	5,200	-	-	-	-	-	-	-	
	07/24/96			35.88	0.00	396.56	11,000	710	280	730	2,200	370	-	-	-	-	-	-	
	12/12/96			37.06	0.00	395.38	12,000	260	190	330	1,900	580	-	-	-	-	-	-	
	03/19/97			36.31	0.00	396.13	9,700	330	220	490	1,900	3,200	-	-	-	-	-	-	
	06/12/97			36.50	0.00	395.94	18,000	660	410	980	4,000	5,500	-	-	-	-	-	-	
	07/31/97			36.75	0.00	395.69	17,000	520	330	690	2,700	6,800	-	-	-	-	-	-	
	10/15/97			37.25	0.00	395.19	17,000	550	260	650	2,900	5,700	-	-	-	-	-	-	
	03/25/98			35.62	0.00	396.82	5,000	11	23	66	240	160	-	-	-	-	-	-	
	06/21/98			33.19	0.00	399.25	6,800	7.2	28	100	420	330	-	-	-	-	-	-	
	08/27/98			33.16	0.00	399.28	5,000	26	6.2	70	260	840	-	-	-	-	-	-	
	12/01/98			33.95	0.00	398.49	9,800	61	28	240	640	2,800	-	-	-	-	-	-	
	03/03/99			35.27	0.00	397.17	5,600	63	46	160	520	2,300	-	-	-	-	-	-	
	06/24/99			36.13	0.00	396.31	15,000	130	47	360	1200	5500	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-8	08/10/99		432.44	36.71	0.00	395.73	16,000	220	47	330	1200	13000	-	-	-	-	-	-	
	10/25/99			37.25	0.00	395.19	11,000	230	59	330	1,400	14,000	-	-	-	-	-	-	
	02/17/00			38.13	0.00	394.31	15,000	<1,000	<1,000	<1,000	<2,000	23,000	<2,500	<2,500	<2,500	<25,000	-	-	
	05/18/00			37.13	0.00	395.31	9,700	<250	<250	610	1,400	17,000	<630	<630	<630	<6,300	-	-	
	08/15/00			36.95	0.00	395.49	14,000	41 J	23 J	260	530	13,000	<250	<250	<250	1,900 J	-	-	
	12/11/00			37.11	0.00	395.33	13,000	150	55	450	1,200	20,000	<250	<250	<250	2,400 J	-	-	
	02/21/01			36.89	0.00	395.55	8,500	160	74	460	1,500	14,000	<1,300	<1,300	<1,300	18,000	-	-	
	05/08/01			36.59	0.00	395.85	13,000	340	61	590	1,900	12,000	<130	<130	<130	15,000	-	-	
	08/11/01			35.62	0.00	396.82	15,000	770	100	610	1,800	3,700	<25	4.0 J	10 J	23,000	-	-	
	11/06/01			35.77	0.00	396.67	14,000	460	50 J	560	1,600	3,900	<5.0	2.7 J	8.9	16,000	-	-	
	02/25/02			36.88	0.00	395.56	16,000	480	52 J	670	2,000	1,900	<50	<50	<50	21,000	-	-	
	05/08/02			37.50	0.00	394.94	16,000	530	63	710	2,300	850	<50	<50	<50	27,000	-	-	
	07/15/02			38.13	0.00	394.31	14,000	420	55	630	2,100	250	<50	<50	<50	23,000	-	-	
	10/15/02			38.64	0.00	393.80	17,000	360	51	700	2,500	200	<50	<50	<50	21,000	-	-	
	02/13/03			38.70	0.00	393.74	22,000	310	54	740	2,400	150	<100	<100	<100	14,000	<3,000	-	
	04/22/03	NS		37.95	0.00	394.49	-	-	-	-	-	-	-	-	-	-	-	-	
	07/30/03	NS		37.24	0.00	395.20	-	-	-	-	-	-	-	-	-	-	-	-	
	12/10/03	NS		37.40	0.00	395.04	-	-	-	-	-	-	-	-	-	-	-	-	
	02/18/04			37.67	0.00	394.77	610	4.2 J	<20	55	<40	16 J	<50	<50	<50	2,800	<1,500	-	
	05/12/04			37.42	0.00	395.02	820	15	<10	90	<20	10 J	<25	<25	<25	2,200	<750	-	
	08/16/04			37.47	0.00	394.97	570	3.3 J	<10	35	<20	9.9 J	<25	<25	<25	3,300	<750	-	
	11/29/04			37.26	0.00	395.18	1,000	5.6 J	<10	130	<20	4.9 J	<25	<25	<25	2,800	<750	-	
	03/08/05			31.33	0.00	401.11	640	27	3.2	100	2.5	6.7	<4.0	<4.0	<4.0	350	<1,000	-	
	06/06/05			28.07	0.00	404.37	94 J	11	0.76 J	22	3.8	35	<2.0	<2.0	<2.0	210	<500	-	
	06/06/05	DUP		28.07	0.00	404.37	86 J	12	0.83 J	26	4.2	38	<2.0	<2.0	<2.0	260	<500	DUP-1057-20050606	
	08/04/05			28.82	0.00	403.62	66 J	8.4	0.38 J	2.8	3.4	43	<2.0	<2.0	<2.0	66	<500	-	
	08/04/05	DUP		28.82	0.00	403.62	64 J	8.0	0.34 J	3.2	3.0	44	<2.0	<2.0	<2.0	60	<500	DUP-1057-20050804	
	10/26/05			29.94	0.00	402.50	<100	1.2	<1.0	0.76 J	<1.0	21	<2.0	<2.0	<2.0	<25	<500	-	
	10/26/05	DUP		29.94	0.00	402.50	<100	1.3	0.31 J	1.2	<1.0	29	<2.0	<2.0	<2.0	25	<500	DUP-1057-20051026	
	02/16/06			30.42	0.00	402.02	240	1.9	0.61 J	17	7.8	48	<2.0	<2.0	<2.0	52	<500	-	
	02/16/06	DUP		30.42	0.00	402.02	220	2.4	0.64 J	16	7.0	64	<2.0	<2.0	<2.0	61	<500	DUP-1057-20060216	
	07/06/06			33.77	0.00	398.67	300	2.3	0.39 J	5.8	1.5	63	130	<2.0	<2.0	<2.0	<500	MW-8	
	07/06/06	DUP		-	-	-	470	6.5	1.3	19	3.0	58	150	<2.0	<2.0	<2.0	<500	DUP-1057-20060706	
MW-9	09/22/93	NS	429.83	32.71	sheen	397.12	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/93	NS		31.63	sheen	398.20	-	-	-	-	-	-	-	-	-	-	-	-	
	04/04/94	NS		33.46	0.01	396.38	-	-	-	-	-	-	-	-	-	-	-	-	
	05/26/94	NS		33.50	0.03	396.35	-	-	-	-	-	-	-	-	-	-	-	-	
	08/26/94	NS		35.19	0.03	394.66	-	-	-	-	-	-	-	-	-	-	-	-	
	11/23/94	NS		35.94	0.04	393.92	-	-	-	-	-	-	-	-	-	-	-	-	
	04/20/95	NS		32.52	0.01	397.32	-	-	-	-	-	-	-	-	-	-	-	-	

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Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-9	08/08/95	NS	429.83	31.25	0.01	398.59	-	-	-	-	-	-	-	-	-	-	-	-	
	11/03/95			31.63	0.00	398.20	17,000	600	210	580	1,500	-	-	-	-	-	-	-	
	02/01/96			34.93	0.00	394.90	7,600	320	76	130	1,000	-	-	-	-	-	-	-	
	05/02/96			32.83	0.00	397.00	20,000	900	760	1,100	5,200	-	-	-	-	-	-	-	
	07/24/96			33.42	0.00	396.41	11,000	710	280	730	2,200	370	-	-	-	-	-	-	
	12/12/96			34.60	0.00	395.23	12,000	260	190	330	1,900	580	-	-	-	-	-	-	
	03/19/97			33.87	0.00	395.96	9,700	330	220	490	1,900	3,200	-	-	-	-	-	-	
	06/12/97			34.00	0.00	395.83	18,000	660	410	980	4,000	5,500	-	-	-	-	-	-	
	07/31/97			34.30	0.00	395.53	17,000	520	330	690	2,700	6,800	-	-	-	-	-	-	
	10/15/97			34.80	0.00	395.03	17,000	550	260	650	2,900	5,700	-	-	-	-	-	-	
	03/25/98			33.11	0.00	396.72	5,000	11	23	66	240	160	-	-	-	-	-	-	
	06/21/98			30.79	0.00	399.04	6,800	7.2	28	100	420	330	-	-	-	-	-	-	
	08/27/98			30.75	0.00	399.08	5,000	26	6.2	70	260	840	-	-	-	-	-	-	
	12/01/98			31.53	0.00	398.30	9,800	61	28	240	640	2,800	-	-	-	-	-	-	
	03/03/99			32.86	0.00	396.97	5,600	63	46	160	520	2,300	-	-	-	-	-	-	
	05/24/99			33.71	0.00	396.12	15,000	130	47	360	1,200	5,500	-	-	-	-	-	-	
	08/10/99			34.25	0.00	395.58	16,000	220	47	330	1,200	13,000	-	-	-	-	-	-	
	10/25/99			34.78	0.00	395.05	11,000	230	59	330	1,400	14,000	-	-	-	-	-	-	
	02/17/00			35.67	0.00	394.16	15,000	<1,000	<1,000	<1,000	<2,000	23,000	<2,500	<2,500	<2,500	<25,000	-	-	
	05/18/00			34.73	0.00	395.10	9,700	<250	<250	610	1,400	17,000	<630	<630	<630	<6,300	-	-	
	08/15/00			34.53	0.00	395.30	14,000	41 J	23 J	260	530	13,000	<250	<250	<250	1,900 J	-	-	
	12/11/00			34.70	0.00	395.13	13,000	150	55	450	1,200	20,000	<250	<250	<250	2,400 J	-	-	
	02/20/01			34.51	0.00	395.32	8,500	160	74	460	1,500	14,000	<1,300	<1,300	<1,300	18,000	-	-	
	05/08/01			34.25	0.00	395.58	13,000	340	61	590	1,900	12,000	<130	<130	<130	15,000	-	-	
	08/11/01			33.19	0.00	396.64	15,000	770	100	610	1,800	3,700	<25	4.0 J	10 J	23,000	-	-	
	11/06/01			33.35	0.00	396.48	14,000	460	50 J	560	1,600	3,900	<5.0	2.7 J	8.9	16,000	-	-	
	02/25/02			34.46	0.00	395.37	16,000	480	52 J	670	2,000	1,900	<50	<50	<50	21,000	-	-	
	05/08/02			35.02	0.00	394.81	16,000	530	63	710	2,300	850	<50	<50	<50	27,000	-	-	
	07/15/02			35.70	0.00	394.13	14,000	420	55	630	2,100	250	<50	<50	<50	23,000	-	-	
	10/15/02			36.20	0.00	393.63	17,000	360	51	700	2,500	200	<50	<50	<50	21,000	-	-	
	02/13/03			36.12	0.00	393.71	22,000	310	54	740	2,400	150	<100	<100	<100	14,000	<3,000	-	
	04/22/03	NS		35.48	sheen	394.35	-	-	-	-	-	-	-	-	-	-	-	-	
	07/30/03	NS		34.87	sheen	394.96	-	-	-	-	-	-	-	-	-	-	-	-	
	12/10/03	NS		34.87	sheen	394.96	-	-	-	-	-	-	-	-	-	-	-	-	
	02/18/04	NS		35.37	0.01	394.47	-	-	-	-	-	-	-	-	-	-	-	-	
	05/12/04	NS		34.97	sheen	394.86	-	-	-	-	-	-	-	-	-	-	-	-	
	08/16/04			34.95	sheen	394.88	18,000	380	90	970	3,500	200	<100	<100	<100	5,200	<3,000	-	
	11/29/04			34.82	0.00	395.01	21,000	280	270	800	2,700	120	<100	<100	<100	5,600	<3,000	-	
	03/08/05			29.15	0.00	400.68	890	15	8.9	30	75	3.5	<2.0	<2.0	<2.0	210	<500	-	
	06/06/05			25.74	0.00	404.09	680	20	13	83	180	14	<2.0	<2.0	<2.0	520	<500	-	

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Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-9	08/04/06		429.83	26.45	0.00	403.38	210	2	1	9	20	10	<2.0	<2.0	<2.0	160	<500	-	
	10/26/06			27.58	0.00	402.25	480	6.6	2.3	24	30	13	<2.0	<2.0	<2.0	470	<500	-	
	02/16/06			28.07	0.00	401.76	380	8.0	0.62 J	33	2.0	21	<2.0	<2.0	<2.0	<25	<500	-	
	07/06/06			31.21	0.00	398.62	1,800	22	3.0	150	93	66	950	<5.0	<5.0	<5.0	<1,200	MW-9	
MW-10	11/23/94		-	36.12	0.00	-	<50	8.0	<0.5	<0.5	2.0	-	-	-	-	-	-	-	
	02/22/95			34.98	0.00	-	160	16	26	0.45	2.2	-	-	-	-	-	-	-	
	04/21/95			32.63	0.00	-	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/09/95			31.36	0.00	-	5,100	1,000	37	350	1,000	-	-	-	-	-	-	-	
	11/06/95			31.79	0.00	-	4,600	1,100	18	350	690	-	-	-	-	-	-	-	
	02/02/96			35.13	0.00	-	2,500	540	4.5	250	370	-	-	-	-	-	-	-	
	05/02/96			32.98	0.00	-	3,500	1,100	<6.0	310	510	-	-	-	-	-	-	-	
	07/24/96			33.58	0.00	-	2,000	370	<3.0	200	65	21	-	-	-	-	-	-	
	12/13/96			34.73	0.00	-	640	150	3.4	71	59	130	-	-	-	-	-	-	
	03/20/97			33.95	0.00	-	330	35	<0.30	25	10	65	-	-	-	-	-	-	
	06/12/97			34.14	0.00	-	1,900	460	<3.9	190	170	320	-	-	-	-	-	-	
	07/31/97			34.44	0.00	-	870	240	<2.0	49	15	320	-	-	-	-	-	-	
	10/15/97			34.93	0.00	-	600	56	<0.60	65	4.9	260	-	-	-	-	-	-	
	03/25/98			33.24	0.00	-	340	74	<0.99	18	10	40	-	-	-	-	-	-	
	06/21/98			30.91	0.00	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	08/27/98			30.68	0.00	-	82	11	<0.30	8.7	<0.60	38	-	-	-	-	-	-	
	12/01/98			31.67	0.00	-	170	39	<0.30	24	7.1	130	-	-	-	-	-	-	
	03/04/99			33.09	0.00	-	280	57	<0.60	32	34	140	-	-	-	-	-	-	
	05/24/99			33.84	0.00	-	130	36	<0.30	13	5.4	12	-	-	-	-	-	-	
	08/11/99			34.41	0.00	-	2,200	540	<6.0	260	110	<200	-	-	-	-	-	-	
	10/25/99			34.94	0.00	-	2,900	660	<6.0	350	29	200	-	-	-	-	-	-	
	02/18/00			35.79	0.00	-	650	140	<10	110	<20	680	<25	<25	<25	1,200	-	-	
	05/17/00			34.83	0.00	-	540	69	<20	60	<40	1,000	<50	<50	<50	1,100	-	-	
	08/16/00			34.51	0.00	-	690	100	<2.0	130	9.6 J	350	1.4 J	<5.0	<5.0	1,700	-	-	
	12/12/00			34.76	0.00	-	170	21	<0.30	17	4.3	35	<5.0	<5.0	<5.0	540	-	-	
	02/22/01			34.90	0.00	-	58	4.0	<0.30	4.3	0.90	13	<5.0	<5.0	<5.0	350	-	-	
	05/09/01			34.17	0.00	-	180	23	<0.60	24	6.7	11	<5.0	<5.0	<5.0	300	-	-	
	09/12/01			33.31	0.00	-	290	20	0.44	21	2.5	24	0.92 J	<5.0	<5.0	740	-	-	
	11/07/01			33.47	0.00	-	360	16	1.3 J	37	4.2 J	51	<5.0	<5.0	<5.0	1,200	-	-	
	02/26/02			34.57	0.00	-	550	18	1.4 J	7.4	1.7 J	180	<5.0	<5.0	<5.0	2,100	-	-	
	05/08/02			35.16	0.00	-	470	8.0	0.74 J	1.5 J	1.2 J	290	1.4 J	<5.0	<5.0	3,100	-	-	
	07/16/02			35.83	0.00	-	300	1.6 J	0.53 J	0.71 J	0.29 J	120	1.4 J	<5.0	<5.0	2,800	-	-	
	10/14/02			36.29	0.00	-	230	0.71 J	0.40 J	0.28 J	0.38 J	13	1.1 J	<5.0	<5.0	2,600	-	-	
	02/13/03			36.36	0.00	-	91	<4.0	<4.0	<4.0	<8.0	4.5 J	<10	<10	<10	1,800	<300	-	
	04/22/03			35.80	0.00	-	45 J	0.30 J	<2.0	0.75 J	1.0 J	5.1	<5.0	<5.0	<5.0	730	<150	-	
	07/30/03		430.16	34.94	0.00	395.22	72	<4.0	<4.0	<4.0	<8.0	120	<10	<10	<10	1,300	210 J	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-10	12/10/03		430.16	35.04	0.00	395.12	63	<4.0	<4.0	<4.0	<8.0	2.3 J	0.54 J	<10	<10	1,500	<300	-	
	02/18/04			35.51	0.00	394.65	31 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	22 J	210	-	
	05/12/04			35.14	0.00	395.02	39 J	<2.0	<2.0	0.31 J	<4.0	1.8 J	<5.0	<5.0	<5.0	48 J	<150	-	
	08/16/04			35.10	0.00	395.06	57	<2.0	<2.0	<2.0	<4.0	2.2 J	<5.0	<5.0	<5.0	170	<150	-	
	11/30/04			34.94	0.00	395.22	47	<2.0	<2.0	<2.0	<4.0	0.60 J	<5.0	<5.0	<5.0	250	<150	-	
	03/09/05	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	06/07/05			25.94	0.00	404.22	<100	<1.0	<1.0	0.43 J	<1.0	1.3	<2.0	<2.0	<2.0	160	<500	-	
	08/04/05			26.58	0.00	403.58	<100	<1.0	<1.0	<1.0	<1.0	0.84 J	<2.0	<2.0	<2.0	92	<500	-	
	10/26/05			27.74	0.00	402.42	<100	<1.0	<1.0	<1.0	<1.0	4.3	<2.0	<2.0	<2.0	<25	<500	-	
	02/16/06			28.26	0.00	401.90	<100	<1.0	<1.0	<1.0	<1.0	36	<2.0	<2.0	<2.0	53	<500	-	
	07/06/06			31.41	0.00	398.75	95 J	<1.0	<1.0	<1.0	<1.0	62	670	<2.0	<2.0	<2.0	<500	MW-10	
MW-11	09/23/93		432.51	32.52	0.00	399.99	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	12/02/93			33.53	0.00	398.98	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	04/04/94			35.36	0.00	397.15	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	05/26/94			36.02	0.00	396.49	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	08/26/94			37.13	0.00	395.38	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	11/23/94			38.04	0.00	394.47	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			36.90	0.00	395.61	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	04/21/95			34.37	0.00	398.14	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			33.09	0.00	399.42	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	11/03/95	NS		33.47	0.00	399.04	-	-	-	-	-	-	-	-	-	-	-	-	
	02/02/96			36.90	0.00	395.61	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	05/02/96	NS		34.75	0.00	397.76	-	-	-	-	-	-	-	-	-	-	-	-	
	07/24/96	NS		35.36	0.00	397.15	-	-	-	-	-	-	-	-	-	-	-	-	
	12/12/96	NS		36.46	0.00	396.05	-	-	-	-	-	-	-	-	-	-	-	-	
	03/20/97			35.76	0.00	396.75	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/12/97	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/31/97	NS		36.13	0.00	396.38	-	-	-	-	-	-	-	-	-	-	-	-	
	10/15/97	NS		36.80	0.00	395.71	-	-	-	-	-	-	-	-	-	-	-	-	
	03/25/98			40.30	0.00	392.21	<50	0.33	<0.30	<0.30	<0.30	<10	-	-	-	-	-	-	
	06/21/98	NS		32.53	0.00	399.98	-	-	-	-	-	-	-	-	-	-	-	-	
	08/27/98	NS		32.51	0.00	400.00	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/98	NS		33.35	0.00	399.16	-	-	-	-	-	-	-	-	-	-	-	-	
	03/04/99			34.75	0.00	397.76	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	05/24/99	NS		35.66	0.00	396.85	-	-	-	-	-	-	-	-	-	-	-	-	
	08/11/99	NS		36.25	0.00	396.26	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/99	NS		36.81	0.00	395.70	-	-	-	-	-	-	-	-	-	-	-	-	
	02/18/00			37.75	0.00	394.76	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	05/17/00	NS		36.74	0.00	395.77	-	-	-	-	-	-	-	-	-	-	-	-	
	08/15/00	NS		35.55	0.00	396.96	-	-	-	-	-	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-11	12/11/00	NS	432.51	36.01	0.00	396.50	-	-	-	-	-	-	-	-	-	-	-	-	
	02/22/01			35.71	0.00	396.80	<50	<0.30	<0.30	<0.30	<0.60	0.38 J	<5.0	<5.0	<5.0	<10	-	-	
	05/08/01			36.29	0.00	396.22	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	09/12/01			35.08	0.00	397.43	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	12 J	-	-	
	11/07/01			35.19	0.00	397.32	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/26/02			36.45	0.00	396.06	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-	-	
	05/08/02			37.07	0.00	395.44	14 J	<2.0	0.40 J	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	07/16/02			37.74	0.00	394.77	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	10/14/02			38.21	0.00	394.30	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			38.51	0.00	394.00	10 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			37.60	0.00	394.91	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			36.90	0.00	395.61	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	12/10/03			36.99	0.00	395.52	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	02/18/04			37.35	0.00	395.16	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			36.94	0.00	395.57	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			37.08	0.00	395.45	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/30/04			36.81	0.00	395.70	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/09/05	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	06/06/05			27.29	0.00	405.22	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	08/04/05			27.99	0.00	404.52	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	10/26/05			29.24	0.00	403.27	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/16/06	NS		29.73	0.00	402.78	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06			39.65	0.00	392.86	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<25	<2.0	<2.0	<2.0	<500	MW-11	
MW-12	09/22/93	NS	432.93	33.91	sheen	399.02	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/93	NS		33.86	sheen	399.07	-	-	-	-	-	-	-	-	-	-	-	-	
	04/04/94	NS		35.76	0.01	397.18	-	-	-	-	-	-	-	-	-	-	-	-	
	05/27/94			36.37	0.00	396.56	22,000	2,800	1,900	310	4,900	-	-	-	-	-	-	-	
	08/26/94			37.24	0.00	395.69	34,000	3,800	1,800	300	4,900	-	-	-	-	-	-	-	
	11/23/94			38.28	0.00	394.65	72	3.0	9.0	2.0	15	-	-	-	-	-	-	-	
	02/22/95			37.30	0.00	395.63	25,000	260	150	640	2,200	-	-	-	-	-	-	-	
	04/21/95			34.76	0.00	398.17	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/09/95			33.45	0.00	399.48	31,000	1,600	600	130	3,600	-	-	-	-	-	-	-	
	11/06/95			33.86	0.00	399.07	22,000	1,500	510	150	2,600	-	-	-	-	-	-	-	
	02/02/96			35.63	0.00	397.30	23,000	2,800	1,100	310	3,100	-	-	-	-	-	-	-	
	05/02/96			35.15	0.00	397.78	12,000	1,100	540	160	1,600	-	-	-	-	-	-	-	
	07/24/96			35.77	0.00	397.16	22,000	1,500	340	120	2,400	<10	-	-	-	-	-	-	
	12/13/96			36.37	0.00	396.56	6,600	850	920	180	730	<10	-	-	-	-	-	-	
	03/20/97			36.21	0.00	396.72	18,000	1,300	900	210	1,800	<10	-	-	-	-	-	-	
	06/12/97			36.37	0.00	396.56	16,000	2,800	1,800	420	1,800	<130	-	-	-	-	-	-	
	07/31/97			36.62	0.00	396.31	16,000	2400	1700	410	1500	550	-	-	-	-	-	-	

AR0073268

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6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-12	10/15/97		432.93	37.19	0.00	395.74	14,000	1400	110	91	650	<100	-	-	-	-	-	-	
	03/25/98			35.39	0.00	397.54	25,000	1,100	300	170	1,200	<80	-	-	-	-	-	-	
	06/21/98			32.95	0.00	399.98	13,000	920	78	70	440	<250	-	-	-	-	-	-	
	08/27/98			32.91	0.00	400.02	14,000	1,400	130	140	400	<20	-	-	-	-	-	-	
	12/01/98			33.76	0.00	399.17	14,000	1,600	100	200	530	<400	-	-	-	-	-	-	
	03/04/99			35.15	0.00	397.78	14,000	2,000	130	510	590	<400	-	-	-	-	-	-	
	05/24/99			35.95	0.00	396.98	13,000	1,300	110	310	570	<500	-	-	-	-	-	-	
	08/10/99			36.61	0.00	396.32	17,000	2,600	260	560	1,200	<400	-	-	-	-	-	-	
	10/25/99			36.02	0.00	396.91	19,000	2,600	350	860	1,800	440	-	-	-	-	-	-	
	02/18/00			38.11	0.00	394.82	19,000	2,600	360	920	1,700	<250	<250	<250	<250	<2,500	-	-	
	05/17/00			37.09	0.00	395.84	14,000	2,100	250	690	1,200	<100	<100	<100	<100	<1,000	-	-	
	08/16/00			36.91	0.00	396.02	12,000	1,900	160	620	710	20 J	<25	<25	<25	<250	-	-	
	12/12/00			37.61	0.00	395.32	16,000	2,100	240	640	1,100	20 J	<25	<25	<25	<250	-	-	
	02/22/01			36.59	0.00	396.34	11,000	1,400	170	550	790	14	<13	<13	<13	<25	-	-	
	05/09/01			36.45	0.00	396.48	11,000	1,300	140	560	670	<25	<25	<25	<25	<250	-	-	
	09/12/01			35.48	0.00	397.45	9,600	930	100	460	490	5.0 J	<10	<10	<10	17 J	-	-	
	11/07/01			35.67	0.00	397.26	9,900	970	89 J	380	390	8.6	<5.0	<5.0	<5.0	<50	-	-	
	02/26/02			36.82	0.00	396.11	12,000	1,800	110 J	570	390	20 J	<25	<25	<25	<120	-	-	
	05/08/02			36.09	0.00	396.84	1,700	81	11	69	81	0.76 J	<5.0	<5.0	<5.0	30 J	-	-	
	07/16/02			38.12	0.00	394.81	11,000	1,500	130	640	760	19	1.7 J	<5.0	<5.0	23 J	-	-	
	10/14/02			38.61	0.00	394.32	14,000	1,100	96	720	410	<200	<20	<20	<20	<20	-	-	
	02/13/03			38.42	0.00	394.51	11,000	980	270	730	480	<100	<100	<100	<100	<1,000	<3,000	-	
	04/22/03			37.94	0.00	394.99	2,600	310	16	240	79	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			37.13	0.00	395.80	4,600	540	68	460	280	<50	<50	<50	<50	<500	<1,500	-	
	12/10/03			37.34	0.00	395.59	5,900	390	52	470	130	<50	<50	<50	<50	<500	<1,500	-	
	02/18/04			37.65	0.00	395.28	5,300	350	36	410	77	<50	<50	<50	<50	<500	<1,500	-	
	05/12/04			37.20	0.00	395.73	3,300	240	23	220	60	<20	<20	<20	<20	<200	<600	-	
	08/16/04			37.21	0.00	395.72	5,700	300	44	260	120	<20	<20	<20	<20	<200	<600	-	
	11/30/04			37.22	0.00	395.71	4,900	350	38	240	150	<25	<25	<25	<25	<250	<750	-	
	03/09/05			30.94	0.00	401.99	1,800	310	7.7	84	8.3	<5.0	<10	<10	<10	<120	<2,500	-	
	06/06/05			27.73	0.00	405.20	2,100	330	17	170	44	<4.0	<8.0	<8.0	<8.0	<100	<2,000	-	
	08/04/05			28.41	0.00	404.52	350	15	6.5	30	25	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	10/26/05			29.65	0.00	403.28	3,500	240	82	170	100	<2.5	<5.0	<5.0	<5.0	<62	<1,200	-	
	02/16/06			30.12	0.00	402.81	2,600	150	73	160	140	<2.5	<5.0	<5.0	<5.0	<62	<1,200	-	
	07/06/06	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MW-15	09/22/93		419.89	22.57	0.00	397.32	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	12/01/93			23.47	0.00	396.42	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	04/04/94			24.88	0.00	395.01	110	8.0	<0.5	<0.5	4.0	-	-	-	-	-	-	-	
	05/26/94			25.39	0.00	394.50	<50	0.90	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	08/26/94			26.34	0.00	393.55	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-15	11/23/94		419.89	27.01	0.00	392.88	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			26.05	0.00	393.84	<50	0.68	<0.30	<0.30	1.9	-	-	-	-	-	-	-	
	04/21/95			24.11	0.00	395.78	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			23.03	0.00	396.86	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	11/03/95	NS		23.32	0.00	396.57	-	-	-	-	-	-	-	-	-	-	-	-	
	02/01/96			26.55	0.00	393.34	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	05/02/96	NS		24.37	0.00	395.52	-	-	-	-	-	-	-	-	-	-	-	-	
	07/24/96	NS		24.88	0.00	395.01	-	-	-	-	-	-	-	-	-	-	-	-	
	12/12/96	NS		25.83	0.00	394.06	-	-	-	-	-	-	-	-	-	-	-	-	
	03/19/97			25.20	0.00	394.69	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/12/97	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/31/97	NS		25.61	0.00	394.28	-	-	-	-	-	-	-	-	-	-	-	-	
	10/15/97	NS		26.02	0.00	393.87	-	-	-	-	-	-	-	-	-	-	-	-	
	03/25/98			24.57	0.00	395.32	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/11/98	NS		22.58	0.00	397.31	-	-	-	-	-	-	-	-	-	-	-	-	
	08/27/98	NS		22.55	0.00	397.34	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/98	NS		22.88	0.00	397.23	-	-	-	-	-	-	-	-	-	-	-	-	
	03/03/99			24.32	0.00	395.57	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	05/24/99	NS		25.04	0.00	394.85	-	-	-	-	-	-	-	-	-	-	-	-	
	08/10/99	NS		25.51	0.00	394.38	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/99	NS		25.96	0.00	393.93	-	-	-	-	-	-	-	-	-	-	-	-	
	02/17/00			26.76	0.00	393.13	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	05/18/00	NS		25.86	0.00	394.03	-	-	-	-	-	-	-	-	-	-	-	-	
	08/15/00	NS		25.70	0.00	394.19	-	-	-	-	-	-	-	-	-	-	-	-	
	12/11/00	NS		25.97	0.00	393.92	-	-	-	-	-	-	-	-	-	-	-	-	
	02/21/01			25.61	0.00	394.28	<50	0.12 J	<0.30	<0.30	<0.60	1.0 J	<5.0	<5.0	<5.0	<10	-	-	
	05/08/01			24.45	0.00	395.44	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	08/11/01			24.62	0.00	395.27	<50	<0.30	<0.30	<0.30	<0.60	1.1 J	<5.0	<5.0	<5.0	<50	-	-	
	11/06/01			24.71	0.00	395.18	<100	<5.0	<5.0	<5.0	<5.0	2.0 J	<5.0	<5.0	<5.0	6.1 J	-	-	
	02/26/02			25.62	0.00	394.27	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-	-	
	05/08/02			26.15	0.00	393.74	14 J	<2.0	<2.0	<2.0	<4.0	1.4 J	<5.0	<5.0	<5.0	<50	-	-	
	07/15/02			26.72	0.00	393.17	<50	<2.0	<2.0	<2.0	<4.0	0.72 J	<5.0	<5.0	<5.0	<50	-	-	
	10/15/02			27.11	0.00	392.78	14 J	<2.0	<2.0	<2.0	<4.0	0.69 J	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			27.22	0.00	392.67	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			26.55	0.00	393.34	9.0 J	<2.0	<2.0	<2.0	<4.0	0.57 J	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			25.99	0.00	393.90	<50	<2.0	<2.0	<2.0	<4.0	0.62 J	<5.0	<5.0	<5.0	<50	<150	-	
	12/10/03			26.06	0.00	393.83	<50	<2.0	<2.0	<2.0	<4.0	1.1 J	<5.0	<5.0	<5.0	<50	<150	-	
	02/18/04			26.39	0.00	393.50	<50	<2.0	<2.0	<2.0	<4.0	0.78 J	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			25.89	0.00	394.00	<50	<2.0	<2.0	<2.0	<4.0	0.98 J	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			26.10	0.00	393.79	<50	<2.0	<2.0	<2.0	<4.0	1.6 J	<5.0	<5.0	<5.0	<50	<150	-	

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Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-15	11/29/04		419.89	25.95	0.00	393.94	<50	<2.0	<2.0	<2.0	<4.0	0.73 J	<5.0	<5.0	<5.0	<50	<150	-	
	03/08/05			21.06	0.00	398.83	<100	<1.0	<1.0	<1.0	<1.0	1.2	<2.0	<2.0	<2.0	<25	<500	-	
	06/06/05	NS		19.81	0.00	400.08	-	-	-	-	-	-	-	-	-	-	-	-	
	08/04/05	NS		19.11	0.00	400.78	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/05	NS		20.02	0.00	399.87	-	-	-	-	-	-	-	-	-	-	-	-	
	02/16/06	NS	422.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MW-16	09/23/93		419.46	22.44	0.00	397.02	100	2.0	<0.5	8.0	1.0	-	-	-	-	-	-	-	
	12/01/93			23.15	0.00	396.31	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	04/04/94			24.68	0.00	394.78	<50	<0.5	<0.5	<0.5	0.90	-	-	-	-	-	-	-	
	05/26/94			25.29	0.00	394.17	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	08/26/94			26.16	0.00	393.30	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	11/23/94			26.84	0.00	392.62	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			25.92	0.00	393.54	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	04/21/95			24.00	0.00	395.46	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			22.92	0.00	396.54	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	11/03/95			23.14	0.00	396.32	<50	0.74	<0.30	1.5	0.62	-	-	-	-	-	-	-	
	02/01/96			26.42	0.00	393.04	<50	1.4	<0.30	1.2	<0.60	-	-	-	-	-	-	-	
	05/02/96			24.22	0.00	395.24	<50	1.1	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	07/24/96			24.71	0.00	394.75	<50	<0.30	<0.30	<0.30	<0.60	13	-	-	-	-	-	-	
	12/12/96			25.67	0.00	393.79	<50	<0.30	<0.30	<0.30	<0.60	70	-	-	-	-	-	-	
	03/19/97			25.08	0.00	394.38	<50	<0.30	<0.30	<0.30	<0.60	92	-	-	-	-	-	-	
	06/12/97			25.20	0.00	394.26	110	<0.30	<0.30	<0.30	<0.60	710	-	-	-	-	-	-	
	07/31/97			25.43	0.00	394.03	<50	<0.30	<0.30	<0.30	<0.60	310	-	-	-	-	-	-	
	10/15/97			25.88	0.00	393.58	<50	<0.30	<0.30	<0.30	<0.60	120	-	-	-	-	-	-	
	03/25/98			24.32	0.00	395.14	<50	<0.30	<0.30	<0.30	<0.60	560	-	-	-	-	-	-	
	06/21/98			22.40	0.00	397.06	<50	<0.30	<0.30	<0.30	<0.60	11,000	-	-	-	-	-	-	
	08/27/98			22.43	0.00	397.03	66	1.4	<0.30	<0.30	<0.60	6,700	-	-	-	-	-	-	
	12/01/98			23.10	0.00	396.36	<500	<3.0	<3.0	<3.0	<6.0	5,900	-	-	-	-	-	-	
	03/03/99			24.12	0.00	395.34	<500	5.1	<3.0	<3.0	<6.0	6,500	-	-	-	-	-	-	
	05/24/99			24.86	0.00	394.60	<100	<0.60	<0.60	<0.60	1.5	3,600	-	-	-	-	-	-	
	08/11/99			25.31	0.00	394.15	<100	<0.60	<0.60	<0.60	<1.2	1,700	-	-	-	-	-	-	
	10/25/99			25.77	0.00	393.69	<50	<0.30	<0.30	<0.30	<0.60	280	-	-	-	-	-	-	
	02/18/00			26.52	0.00	392.94	<50	<4.0	<4.0	<4.0	<8.0	230	<10	<10	<10	<100	-	-	
	05/18/00			25.71	0.00	393.75	<50	<2.5	<2.5	<2.5	<5.0	150	<6.3	<6.3	<6.3	<63	-	-	
	08/15/00			25.50	0.00	393.96	<50	<2.0	<2.0	<2.0	<4.0	250	<5.0	<5.0	<5.0	9.4 J	-	-	
	12/11/00			25.67	0.00	393.79	290	<0.30	<0.30	<0.30	<0.60	1,000	<13	<13	<13	52 J	-	-	
	02/21/01			25.41	0.00	394.05	7.1 J	<0.30	<0.30	<0.30	<0.60	330	<50	<50	<50	230	-	-	
	05/09/01			24.25	0.00	395.21	<50	<0.30	<0.30	0.84	<0.60	1,700	<20	<20	<20	1,800	-	-	
	08/12/01			24.39	0.00	395.07	34 J	<0.30	<0.30	1	<0.60	760	<10	<10	<10	2,700	-	-	

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Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-16	11/07/01		419.46	24.53	0.00	394.93	120	<5.0	<5.0	<5.0	<5.0	560	<5.0	<5.0	<5.0	2,000	-	-	
	02/26/02			25.48	0.00	393.98	98 J	<5.0	<5.0	<5.0	<5.0	180	<5.0	<5.0	<5.0	1,100	-	-	
	05/08/02			25.96	0.00	393.50	35 J	0.11 J	0.23 J	<2.0	<4.0	99	<5.0	<5.0	<5.0	630	-	-	
	07/16/02			26.58	0.00	392.88	24 J	<2.0	<2.0	<2.0	<4.0	48	<5.0	<5.0	<5.0	250	-	-	
	10/14/02			26.91	0.00	392.55	16 J	<2.0	<2.0	<2.0	<4.0	13	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			27.00	0.00	392.46	8.9 J	<2.0	<2.0	<2.0	<4.0	5.3	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			26.38	0.00	393.08	10 J	<2.0	<2.0	<2.0	<4.0	1.5 J	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			25.70	0.00	393.76	<50	0.34 J	<2.0	<2.0	<4.0	1.1 J	<5.0	<5.0	<5.0	7.5 J	<150	-	
	12/10/03			25.90	0.00	393.56	<50	<2.0	<2.0	<2.0	<4.0	0.61 J	<5.0	<5.0	<5.0	6.1 J	<150	-	
	02/18/04			26.24	0.00	393.22	<50	<2.0	<2.0	<2.0	<4.0	0.62 J	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			25.82	0.00	393.64	<50	<2.0	<2.0	<2.0	<4.0	0.38 J	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			25.96	0.00	393.50	<50	<2.0	<2.0	<2.0	<4.0	0.35 J	<5.0	<5.0	<5.0	<50	<150	-	
	11/30/04			25.77	0.00	393.69	<50	<2.0	<2.0	<2.0	<4.0	0.38 J	<5.0	<5.0	<5.0	<50	<150	-	
	03/08/05			20.96	0.00	398.50	<100	<1.0	<1.0	0.22 J	<1.0	2.2	<2.0	<2.0	<2.0	<25	<500	-	
	06/06/05			18.55	0.00	400.91	<100	<1.0	<1.0	<1.0	<1.0	1.3	<2.0	<2.0	<2.0	43	<500	-	
	08/04/05			19.08	0.00	400.38	<100	<1.0	<1.0	<1.0	<1.0	0.85 J	<2.0	<2.0	<2.0	58	<500	-	
	10/25/05			19.89	0.00	399.57	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	02/16/06		422.17	20.33	0.00	401.84	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	-	
	07/06/06			22.94	0.00	399.23	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<25	<2.0	<2.0	<2.0	<500	MW-16	
MW-17	09/23/93		419.56	23.37	0.00	396.19	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	12/01/93			24.10	0.00	395.46	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	04/05/94			25.54	0.00	394.02	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	05/26/94			26.09	0.00	393.47	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	08/26/94			26.91	0.00	392.65	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	11/23/94			27.54	0.00	392.02	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			26.78	0.00	392.78	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	04/21/95			24.86	0.00	394.70	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			23.83	0.00	395.73	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	11/03/95	NS		24.10	0.00	395.46	-	-	-	-	-	-	-	-	-	-	-	-	
	02/01/96			27.32	0.00	392.24	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	05/02/96	NS		25.07	0.00	394.49	-	-	-	-	-	-	-	-	-	-	-	-	
	07/24/96	NS		25.53	0.00	394.03	-	-	-	-	-	-	-	-	-	-	-	-	
	12/12/96	NS		26.45	0.00	393.11	-	-	-	-	-	-	-	-	-	-	-	-	
	03/19/97			25.85	0.00	393.71	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/12/97	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/31/97	NS		26.23	0.00	393.33	-	-	-	-	-	-	-	-	-	-	-	-	
	10/15/97	NS		26.62	0.00	392.94	-	-	-	-	-	-	-	-	-	-	-	-	
	03/25/98			24.26	0.00	395.30	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/21/98	NS		23.37	0.00	396.19	-	-	-	-	-	-	-	-	-	-	-	-	
	08/27/98	NS		23.35	0.00	396.21	-	-	-	-	-	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-17	12/01/98	NS	419.56	23.97	0.00	395.59	-	-	-	-	-	-	-	-	-	-	-	-	
	03/03/99			25.02	0.00	394.54	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	05/24/99	NS		25.72	0.00	393.84	-	-	-	-	-	-	-	-	-	-	-	-	
	08/10/99	NS		26.15	0.00	393.41	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/99	NS		27.59	0.00	391.97	-	-	-	-	-	-	-	-	-	-	-	-	
	02/18/00			27.31	0.00	392.25	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	05/18/00	NS		26.47	0.00	393.09	-	-	-	-	-	-	-	-	-	-	-	-	
	08/15/00	NS		26.31	0.00	393.25	-	-	-	-	-	-	-	-	-	-	-	-	
	12/11/00	NS		27.03	0.00	392.53	-	-	-	-	-	-	-	-	-	-	-	-	
	02/21/01			26.24	0.00	393.32	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<10	-	-	
	05/09/01			25.71	0.00	393.85	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	08/12/01			25.30	0.00	394.26	32 J	<0.30	0.52	<0.30	0.61	<5.0	<5.0	<5.0	<5.0	8.1 J	-	-	
	11/07/01			25.40	0.00	394.16	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/26/02			26.27	0.00	393.29	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-	-	
	05/08/02			26.75	0.00	392.81	13 J	<2.0	0.54 J	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	07/16/02			27.28	0.00	392.28	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	10/14/02			27.65	0.00	391.91	<50	<2.0	<2.0	0.11 J	0.28 J	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/13/03			27.75	0.00	391.81	<50	0.55 J	0.98 J	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	04/22/03			27.12	0.00	392.44	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	07/30/03			26.48	0.00	393.08	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	12/10/03			26.68	0.00	392.88	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	02/18/04			27.02	0.00	392.54	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	05/12/04			26.65	0.00	392.91	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	08/16/04			26.70	0.00	392.86	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	11/30/04			26.56	0.00	393.00	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/09/05	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	06/06/05	NS		19.64	0.00	399.92	-	-	-	-	-	-	-	-	-	-	-	-	
	08/04/05	NS		20.24	0.00	399.32	-	-	-	-	-	-	-	-	-	-	-	-	
	10/25/05	NS		21.01	0.00	398.55	-	-	-	-	-	-	-	-	-	-	-	-	
	02/16/06	NS	422.26	21.31	0.00	400.95	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06	NS		23.85	0.00	398.41	-	-	-	-	-	-	-	-	-	-	-	-	
MW-18	09/23/93		413.92	18.00	0.00	395.92	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	12/02/93			18.70	0.00	395.22	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	04/04/94			20.08	0.00	393.84	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	05/26/94			20.53	0.00	393.39	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	08/26/94			21.45	0.00	392.47	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	11/23/94			21.88	0.00	392.04	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	
	02/22/95			21.04	0.00	392.88	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	04/21/95			19.27	0.00	394.65	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	08/08/95			18.40	0.00	395.52	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-18	11/03/95	NS	413.92	18.66	0.00	395.26	-	-	-	-	-	-	-	-	-	-	-	-	
	02/02/96			21.82	0.00	392.10	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-	-	
	05/02/96	NS		19.55	0.00	394.37	-	-	-	-	-	-	-	-	-	-	-	-	
	07/24/96	NS		20.03	0.00	393.89	-	-	-	-	-	-	-	-	-	-	-	-	
	12/12/96	NS		20.80	0.00	393.12	-	-	-	-	-	-	-	-	-	-	-	-	
	03/19/97			20.25	0.00	393.67	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/12/97	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/31/97	NS		20.60	0.00	393.32	-	-	-	-	-	-	-	-	-	-	-	-	
	10/15/97	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	03/25/98			19.64	0.00	394.28	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	06/21/98	NS		18.92	0.00	395.00	-	-	-	-	-	-	-	-	-	-	-	-	
	08/27/98	NS		17.92	0.00	396.00	-	-	-	-	-	-	-	-	-	-	-	-	
	12/01/98	NS		17.51	0.00	396.41	-	-	-	-	-	-	-	-	-	-	-	-	
	03/03/99	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	05/24/99			20.09	0.00	393.83	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	08/10/99			20.51	0.00	393.41	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-	-	
	10/25/99	NS		20.93	0.00	392.99	-	-	-	-	-	-	-	-	-	-	-	-	
	02/18/00			21.60	0.00	392.32	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	05/18/00	NS		20.80	0.00	393.12	-	-	-	-	-	-	-	-	-	-	-	-	
	08/15/00	NS		20.63	0.00	393.29	-	-	-	-	-	-	-	-	-	-	-	-	
	12/11/00	NS		20.92	0.00	393.00	-	-	-	-	-	-	-	-	-	-	-	-	
	02/21/01	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	05/08/01			19.53	0.00	394.39	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	09/12/01			19.70	0.00	394.22	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	11/07/01			19.80	0.00	394.12	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	02/26/02			20.61	0.00	393.31	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-	-	
	05/08/02			21.07	0.00	392.85	10 J	<2.0	0.39 J	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	07/16/02			21.60	0.00	392.32	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-	-	
	10/14/02	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	02/13/03	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	04/22/03	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/30/03	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12/10/03			20.97	0.00	392.95	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	02/18/04	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	05/12/04	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/16/04	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	11/30/04			20.86	0.00	393.06	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	-	
	03/09/05	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	06/06/05	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	08/04/05	NS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

AR0073274

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-18	10/25/05	NS	413.92	21.32	0.00	392.60	-	-	-	-	-	-	-	-	-	-	-	-	
	02/16/06	NS	416.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	07/06/06	NS		18.37	0.00	398.28	-	-	-	-	-	-	-	-	-	-	-	-	
MW-19	09/23/93	Dry	417.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/01/93	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	04/04/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/26/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/26/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/23/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/22/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	04/20/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/08/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/03/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/01/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/02/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/24/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/12/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/19/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/31/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/15/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/25/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	06/11/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/27/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/01/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/03/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/24/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/11/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/25/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/18/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/18/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/15/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/11/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/20/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/08/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/11/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/06/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/25/02	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/08/02	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/15/02	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/14/02	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-19	02/13/03	Dry	417.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	04/22/03	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/30/03	Dry	417.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/10/03	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/18/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/12/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/16/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/30/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/09/05	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	06/06/05	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/04/05	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/25/05	NS		11.56	0.00	406.19	-	-	-	-	-	-	-	-	-	-	-		
	02/16/06	NS		11.87	0.00	405.88	-	-	-	-	-	-	-	-	-	-	-		
	07/06/06	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MW-20	09/23/93		414.06	20.61	0.00	393.45	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	12/01/93			21.20	0.00	392.86	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	04/05/94			22.65	0.00	391.41	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	05/27/94			22.93	0.00	391.13	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	08/26/94			23.81	0.00	390.25	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	11/23/94			23.13	0.00	390.93	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	02/22/95			23.39	0.00	390.67	95	7.2	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	04/21/95			21.63	0.00	392.43	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	08/08/95			20.84	0.00	393.22	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	11/03/95	NS		21.20	0.00	392.86	-	-	-	-	-	-	-	-	-	-	-		
	02/01/96			24.20	0.00	389.86	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	05/02/96	NS		21.95	0.00	392.11	-	-	-	-	-	-	-	-	-	-	-		
	07/24/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/12/96	NS		22.86	0.00	391.20	-	-	-	-	-	-	-	-	-	-	-		
	03/19/97			22.35	0.00	391.71	<50	<0.30	<0.30	<0.30	<0.60	670	-	-	-	-	-		
	06/12/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/31/97	NS		22.54	0.00	391.52	-	-	-	-	-	-	-	-	-	-	-		
	10/15/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/25/98			21.90	0.00	392.16	<50	0.76	<0.30	<0.30	0.67	5,500	-	-	-	-	-		
	06/21/98	NS		20.38	0.00	393.68	-	-	-	-	-	-	-	-	-	-	-		
	08/27/98	NS		20.43	0.00	393.63	-	-	-	-	-	-	-	-	-	-	-		
	12/01/98	NS		20.91	0.00	393.15	-	-	-	-	-	-	-	-	-	-	-		
	03/03/99	NS		21.80	0.00	392.26	-	-	-	-	-	-	-	-	-	-	-		
	05/24/99			22.32	0.00	391.74	<500	<3.0	<3.0	<3.0	<6.0	2,900	-	-	-	-	-		
	08/11/99			22.68	0.00	391.38	<500	<3.0	<3.0	<3.0	<6.0	7,100	-	-	-	-	-		
	10/25/99			22.83	0.00	391.23	<500	<3.0	<3.0	<3.0	<6.0	5400	-	-	-	-	-		

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-20	02/18/00		414.06	23.68	0.00	390.38	<50	<80	<80	<80	<160	3600	<200	<200	<200	<2,000	-		
	05/18/00			22.61	0.00	391.45	<500	<100	<100	<100	<200	5,200	<250	<250	<250	<2,500	-		
	08/16/00			22.61	0.00	391.45	<50	<10	<10	<10	<20	1,500	<25	<25	<25	3,400	-		
	08/16/00	DUP		22.61	0.00	391.45	<50	<10	<10	<10	<20	1,500	<25	<25	<25	3,300	-		
	12/12/00			22.73	0.00	391.33	320	<0.30	<0.30	<0.30	<0.60	920	<13	<13	<13	4,100	-		
	12/12/00	DUP		22.73	0.00	391.33	310	<0.30	<0.30	<0.30	<0.60	960	0.71 J	0.62 J	1.3 J	3,800	-		
	02/22/01			22.17	0.00	391.89	9.3 J	<0.30	<0.30	<0.30	<0.60	1,100	<100	<100	<100	5,200	-		
	02/22/01	DUP		22.17	0.00	391.89	14 J	<0.30	<0.30	<0.30	<0.60	1,000	<50	<50	<50	4,200	-		
	05/09/01			21.67	0.00	392.39	<50	<0.30	<0.30	<0.30	<0.60	170	<5.0	<5.0	<5.0	3,200	-		
	05/09/01	DUP		21.67	0.00	392.39	<50	<0.30	<0.30	<0.30	<0.60	160	<5.0	<5.0	<5.0	3,400	-		
	08/12/01			21.87	0.00	392.19	<50	<0.30	<0.30	<0.30	<0.60	12	<5.0	<5.0	<5.0	940	-		
	08/12/01	DUP		21.87	0.00	392.19	<50	<0.30	<0.30	<0.30	<0.60	17	<5.0	<5.0	<5.0	1,100	-		
	11/07/01			21.95	0.00	392.11	<100	<5.0	<5.0	<5.0	<5.0	30	<5.0	<5.0	<5.0	2,000	-		
	11/07/01	DUP		21.95	0.00	392.11	52 J	<5.0	<5.0	<5.0	<5.0	31	<5.0	<5.0	<5.0	2,800	-		
	02/26/02			22.62	0.00	391.44	170	<5.0	<5.0	<5.0	<5.0	280	<5.0	<5.0	<5.0	5,400	-		
	02/26/02	DUP		22.62	0.00	391.44	160	<5.0	<5.0	<5.0	<5.0	180	<5.0	<5.0	<5.0	4,800	-		
	05/08/02			23.01	0.00	391.05	160	<4.0	0.58 J	<4.0	<8.0	450	<10	1.3 J	0.76 J	4,700	-		
	07/16/02			23.48	0.00	390.58	180	<4.0	<4.0	<4.0	<8.0	290	<10	1.2 J	<10	4,600	-		
	07/16/02	DUP		23.48	0.00	390.58	74	<4.0	<4.0	<4.0	<8.0	270	<10	<10	<10	3,900	-		
	10/14/02			23.75	0.00	390.31	86	<10	<10	<10	<20	100	<25	<25	<25	2,000	-		
	02/13/03			23.85	0.00	390.21	23 J	<2.0	<2.0	<2.0	<4.0	25	<5.0	<5.0	<5.0	82	<150		
	04/22/03			23.33	0.00	390.73	19 J	<2.0	<2.0	<2.0	<4.0	14	<5.0	<5.0	<5.0	29 J	<150		
	07/30/03			22.81	0.00	391.25	30 J	<8.0	<8.0	<8.0	<16	16 J	<20	<20	<20	1,900	<600		
	12/10/03			22.90	0.00	391.16	32 J	<8.0	<8.0	<8.0	<16	5.0 J	<20	<20	<20	2,300	<600		
	02/18/04			23.21	0.00	390.85	79	<2.0	<2.0	<2.0	<4.0	3.0 J	<5.0	0.43 J	<5.0	490	<150		
	05/12/04			22.92	0.00	391.14	<50	<2.0	<2.0	<2.0	<4.0	2.4 J	<5.0	0.47 J	<5.0	320	<150		
	08/16/04			22.94	0.00	391.12	<50	<2.0	<2.0	<2.0	<4.0	1.2 J	<5.0	0.34 J	<5.0	74	<150		
	11/30/04			22.81	0.00	391.25	<50	<2.0	<2.0	<2.0	<4.0	0.65 J	<5.0	<5.0	<5.0	<50	<150		
	03/09/05			19.41	0.00	394.65	<100	<1.0	<1.0	<1.0	<1.0	0.61 J	<2.0	<2.0	<2.0	400	<500		
	06/06/05	NS		18.86	0.00	395.20	-	-	-	-	-	-	-	-	-	-	-		
	08/04/05	NS		18.73	0.00	395.33	-	-	-	-	-	-	-	-	-	-	-		
	10/25/05	NS		18.82	0.00	395.24	-	-	-	-	-	-	-	-	-	-	-		
	02/16/06	NS	416.76	18.95	0.00	397.81	-	-	-	-	-	-	-	-	-	-	-		
	07/06/06	NS		20.81	0.00	395.95	-	-	-	-	-	-	-	-	-	-	-	-	
MW-21	09/23/93		405.99	11.85	0.00	394.14	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	12/02/93			12.56	0.00	393.43	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	04/05/94			14.02	0.00	391.97	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	05/27/94			14.53	0.00	391.46	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	08/26/94			15.41	0.00	390.58	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		
	11/23/94			15.27	0.00	390.72	<50	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-		

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MW-21	02/22/95		405.99	14.96	0.00	391.03	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	04/21/95			13.24	0.00	392.75	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	08/08/95			12.33	0.00	393.66	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	11/03/95	NS		12.57	0.00	393.42	-	-	-	-	-	-	-	-	-	-	-		
	02/01/96			16.62	0.00	389.37	<50	<0.30	<0.30	<0.30	<0.60	-	-	-	-	-	-		
	05/02/96	NS		13.48	0.00	392.51	-	-	-	-	-	-	-	-	-	-	-		
	07/24/96	NS		13.87	0.00	392.12	-	-	-	-	-	-	-	-	-	-	-		
	12/12/96	NS		14.71	0.00	391.28	-	-	-	-	-	-	-	-	-	-	-		
	03/19/97			14.11	0.00	391.88	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	06/12/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/31/97	NS		14.52	0.00	391.47	-	-	-	-	-	-	-	-	-	-	-		
	10/15/97	NS		14.88	0.00	391.11	-	-	-	-	-	-	-	-	-	-	-		
	03/25/98			13.74	0.00	392.25	<50	<0.30	<0.30	<0.30	<0.60	23	-	-	-	-	-		
	06/21/98	NS		11.91	0.00	394.08	-	-	-	-	-	-	-	-	-	-	-		
	08/27/98	NS		11.87	0.00	394.12	-	-	-	-	-	-	-	-	-	-	-		
	12/01/98	NS		12.46	0.00	393.53	-	-	-	-	-	-	-	-	-	-	-		
	03/03/99			13.39	0.00	392.60	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	05/24/99	NS		14.05	0.00	391.94	-	-	-	-	-	-	-	-	-	-	-		
	08/11/99			14.45	0.00	391.54	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	10/25/99			14.85	0.00	391.14	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	02/18/00			15.47	0.00	390.52	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	05/18/00			14.72	0.00	391.27	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	08/16/00			14.56	0.00	391.43	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	12/12/00			14.59	0.00	391.40	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-		
	02/22/01			15.07	0.00	390.92	<50	<0.30	<0.30	<0.30	<0.60	0.24 J	<5.0	<5.0	<5.0	<10	-		
	05/09/01			13.55	0.00	392.44	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-		
	08/12/01			13.68	0.00	392.31	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	22 J	-		
	11/06/01	NS		13.76	0.00	392.23	-	-	-	-	-	-	-	-	-	-	-		
	02/26/02			14.52	0.00	391.47	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-		
	05/08/02			14.98	0.00	391.01	8.9 J	<2.0	0.31 J	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	07/16/02			15.48	0.00	390.51	15 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	10/14/02			15.87	0.00	390.12	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	02/13/03			15.90	0.00	390.09	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	04/22/03			15.31	0.00	390.68	8.9 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	07/30/03			14.80	0.00	391.19	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	12/10/03			14.95	0.00	391.04	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	02/18/04			15.28	0.00	390.71	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	05/12/04			14.93	0.00	391.06	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	08/16/04			14.99	0.00	391.00	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	11/30/04			14.77	0.00	391.22	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		

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Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-21	03/09/05		405.99	10.66	0.00	395.33	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500		
	06/06/05	NS		10.27	0.00	395.72	-	-	-	-	-	-	-	-	-	-	-		
	08/04/05	NS		8.59	0.00	397.40	-	-	-	-	-	-	-	-	-	-	-		
	10/25/05	NS		9.67	0.00	396.32	-	-	-	-	-	-	-	-	-	-	-		
	02/16/06	NS	408.69	9.82	0.00	398.87	-	-	-	-	-	-	-	-	-	-	-		
	07/06/06	NS		12.38	0.00	396.31	-	-	-	-	-	-	-	-	-	-	-		
MW-22	09/23/93	Dry	402.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/01/93	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	04/04/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/26/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/26/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/23/94	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/22/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	04/20/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/08/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/03/95	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/01/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/02/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/24/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/12/96	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/19/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	06/12/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/31/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/15/97	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/25/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	06/11/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/27/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/01/98	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/03/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/24/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/11/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/25/99	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/18/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/18/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/15/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/11/00	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/20/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/08/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	09/11/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/06/01	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
MW-22	02/25/02	Dry	402.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/08/02	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/16/02	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/14/02	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/13/03	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	04/22/03	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/30/03	Dry	402.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	12/10/03	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/18/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	05/12/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/16/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	11/30/04	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	03/08/05	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	06/06/05	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	08/04/05	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	10/25/05	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	02/16/06	Dry		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	07/06/06	DRY		-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Trip Blank	03/25/98		-	-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	06/21/98			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	08/27/98			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	12/01/98			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	03/03/99			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	05/24/99			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	08/10/99			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	10/25/99			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<10	-	-	-	-	-		
	02/18/00			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<54.0	<5.0	<50	-		
	05/18/00			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<54.0	<5.0	<50	-		
	08/15/00			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	12/12/00			-	-	-	<50	<0.30	0.22 J	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<50	-		
	02/22/01			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<10	-		
	05/08/01			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<5.0	-		
	08/12/01			-	-	-	<50	<0.30	<0.30	<0.30	<0.60	<5.0	<5.0	<5.0	<5.0	<5.0	-		
	11/07/01			-	-	-	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	02/26/02			-	-	-	<100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<25	-		
	05/08/02			-	-	-	14 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	-		
	07/15/02			-	-	-	<50	<2.0	0.55 J	0.18 J	0.94 J	<5.0	<5.0	<5.0	<5.0	<50	-		
	10/15/02			-	-	-	12 J	0.39 J	3.0	0.42 J	2.7 J	<5.0	<5.0	<5.0	<5.0	<50	-		
	02/13/03			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	04/22/03			-	-	-	10 J	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		

AR0073280

Table 1
Summary of Groundwater Analytical & Elevation Results
ARCO Station No. 1057
6100 Franklin Avenue, Hollywood, CA

Well No.	Date	Notes	TOC Elevation (ft-MSL)	Depth to Water (feet)	Measured SPH Thickness (feet)	Calc. GW Elev. (ft-MSL)	GRO (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	TBA (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	Ethanol (µg/L)	Sample ID	Comments
Trip Blank	07/30/03		-	-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	12/09/03			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	05/12/04			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150		
	08/16/04			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	TB-1057-20040816	
	11/29/04			-	-	-	<50	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0	<5.0	<5.0	<50	<150	TB-1057-20041129	
	03/09/05			-	-	-	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	TB-1057-20050309	
	06/06/05			-	-	-	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	TB-1057-20050606	
	08/04/05			-	-	-	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	TB-1057-20050804	
	10/25/05			-	-	-	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	<25	<500	TB-1057-20051025	
	02/16/06			-	-	-	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<2.0	18 J	<500	TB-1057-20060216	
	07/06/06			-	-	-	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<25	<2.0	<2.0	<2.0	<500	TB-1057-20060706	

Notes:

DRO = Diesel range organics

GRO = Gasoline range organics

B = Benzene

T = Toluene

E = Ethylbenzene

X = Total xylenes

MTBE = Methyl tert-butyl ether

TBA = Tert-butyl alcohol

DIPE = Di-isopropyl ether

ETBE = Ethyl tert-butyl ether

TAME = Tert-amyl methyl ether

SPH = Separate phase hydrocarbons

TOC = Top of casing (surveyed)

Calc. GW Elev. = Calculated groundwater elevation = TOC - Depth to Water + 0.75*(Measured SPH Thickness); assuming a specific gravity of 0.75 for SPH

ft-MSL = feet above mean sea level

µg/L = Micrograms per liter

< = Analyte was not detected above the specified method detection limit (MDL); except after 2006 Quarter 2 where reporting limits are used.

- = Not measured or analyzed

J = Estimated value (less than the method reporting limit and greater than or equal to the method detection limit)

Refer to the reports in which data was first presented for more information on historical data.

DRO analyzed by EPA Method 8015 Modified.

GRO analyzed by EPA Method 8015 Modified. The carbon chain range used for analysis since 2000 Quarter 2 is C4-C12.

BTEX and oxygenates analyzed by EPA Method 8260B since 2000 Quarter 2.

DRY = Well dry during gauging or purging; not sampled

DUP = Duplicate sample

NS = Well not sampled

APPENDIX A

Laboratory Report and Chain-of-Custody

STL Los Angeles
1721 South Grand Avenue
Santa Ana, CA 92705

p: 714 258-8610 Fax: 714 258 5921
www.stl-inc.com

July 20, 2006

STL LOT NUMBER: **E6G100133**
PO/CONTRACT: GEM-6-21909

Andrew Modugno
SECOR International Inc
290 Conejo Ridge Ave
Suite 200
Thousand Oaks, CA 91361

Dear Andrew Modugno,

This report contains the analytical results for the 13 samples received under chain of custody by STL Los Angeles on July 8, 2006. These samples are associated with your ARCO #1057 project.

STL Los Angeles certifies that the test results provided in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in the case narrative. The case narrative is an integral part of the report. NELAP Certification Number for STL Los Angeles is 01118CA / E87652.

Any matrix related anomaly is footnoted within the report. A cooler receipt temperature between 2-6 degrees Celsius is within EPA acceptance criteria. The temperature(s) of the cooler received for this project can be found on the Project Receipt Checklist. Historical control limits for the LCS are used to define the estimate of uncertainty for a method. All applicable quality control procedures met method-specified acceptance criteria.

Preliminary results were sent via facsimile on Thursday, July 20, 2006.
This report shall not be reproduced except in full, without the written approval of the laboratory.

000037

This report contains [illegible] pages.

If you have any questions, please feel free to call me at (714) 258-8610.

Sincerely,

Beth Riley
Project Manager

cc: Project File

CASE NARRATIVE

STL LOT NUMBER: **E6G100**138

The relative response factor (RRF) for Ethanol does not meet the GCLN criteria for either the initial calibration (ICAL) or the continuing calibration verification (CCV). Even though this criteria was not met, the RRF's for Ethanol were greater than 0.05; which, is consistent with the USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review and the data is suitable for use.

EDG 100:350

Chain of Custody Record

Page 1 of 1

Project Name: 03-2006 GROUNDWATER
BP BU/AR Region/Entos Segment: RETAIL (West LA)
State or Load Regulatory Agency:
Requested Due Date (July 19, 2006) Standard TAT

On site Time:		Temp	
Off site Time		Temp	
Sky Conditions			
Meteorological Events			
Wind Speed:		Direction:	

Lab Name: STL L.A.		BP/AR Facility No: 1057	
Address: 1220 S. Grand Ave. Santa Ana, CA 92705		BP/AR Facility Address: 6100 Franklin Ave Hollywood, CA	
Lab PM:		Site Lat/Long:	
Tele/Fax:		California Global ID No.: T0600735992	
BP/AR PM Contact:	Ray Vose	Enfos Project No: 03 FPM	
Address:	4 Centerpointe Dr. La Palma, CA	Project for MCAS: (circle one)	
Tele/Fax:		Phase/WBS:	
		Sub Phase/Task: Analytical	
		Total Number of Containers: Sub Contractor Cost	

Consultant/Contractor:	SECOR International Inc.		
Address:	290 Conejo Ridge Ave Suite 200 Thousand Oaks, CA 91361		
Consultant/Contractor Project No:	3710F 01561		
Consultant/Contractor PM:	Andy Mongini		
Tele/Fax:	805-230-1266 207		
Report Type & QC Level:	Standard		
E-mail EDD To:	bpaulsen@secor.com		
Invoice to: (Consultant or BP or Atlantic Richfield Co)	(circle one)		

Lab Bottle Order No:

Item No.	Sample Description	Time	Date	Matrix: Soil/Sed	Water/Liquid	Air	Laboratory No.	No. of Containers	Preservative: Unpreserved	H_2SO_4	HNO_3	HCl	Methanol	Requested Analysis: GRO C4-C12 (8015)	BTEX/MTBE (8260)	Sample Point Identification and Comments
1	MW-1	0950	7/7/06		X			6				X		X	X	
2	MW-3	0900	7/7/06		X			6				X		X	X	
3	MW-4	0940	7/7/06		X			6				X		X	X	
4	MW-5	0910	7/7/06		X			6				X		X	X	
5	MW-7	1210	7/6/06		X			6				X		X	X	
6	MW-8	0855	7/6/06		X			6				X		X	X	
7	MW-9	1035	7/6/06		X			6				X		X	X	
8	MW-10	1045	7/6/06		X			6				X		X	X	
9	MW-11	1015	7/6/06		X			6				X		X	X	
10	MW-12				X			6				X		X	X	
10	MW-16	1105	7/6/06		X			6				X		X	X	
10	EW-1				X			6				X		X	X	
10	EW-3	1115	7/6/06		X			6				X		X	X	
13	DUP-1057-070606		7/6/06					6				X		X	X	
14	TB-1057-070606		7/6/06					2				X		X	X	

	Relinquished By / Affiliation	Date	Time	Accepted By / Affiliation	Date	Time
Sampler's Name: A. Fowler						
Sampler's Company: SECOR		7/7/06	0900	FedEx	7/7/06	1600
Shipment Date: 7/7/06					7/8/06	1015
Shipment Method: FedEx						
Shipment Tracking No:						

Special Instructions:

Copy Distribution: White Copy - Laboratory / Yellow Copy - Temp Blank Yes No Cooler Temperature on Receipt °F/C Trip Blank Yes No

BP COC Rev. 4 10/1/04

AR0073285

STL LOS ANGELES - PROJECT RECEIPT CHECKLIST Date: 7/18/06

Single Cooler Only

IMS Lot #: E6G180138 Quote #: 62668

Client Name: Secor Project: Q3-GW

Received by: CA Date/Time Received: 7/18/06 1015

Delivered by: ☐ Client ☐ STL ☐ DHL ☒ Fed Ex ☐ UPS ☐ Other

	Initial / Date
Custody Seal Status Cooler: ☐ Intact ☐ Broken ☒ None	CA 7/18/06
Custody Seal Status Samples: ☐ Intact ☐ Broken ☒ None	
Custody Seal #(s): ☒ No Seal #	
Sampler Signature on COC: ☐ Yes ☐ No ☒ N/A	
IR Gun # A Correction Factor -0.3 °C IR passed daily verification: ☒ Yes ☐ No	
Temperature - BLANK 6.3 °C - .3 °C = 6.0 °C Cooler #1 ID N/A	
Temperature – COOLER: °C °C °C °C = avg °C 43 °F °C	
Samples outside temperature criteria but received within 8 hours of first sampling: ☐ Yes ☒ N/A	
Sample Container(s): ☒ STL-LA ☐ Client	
pH measured: ☐ Yes ☐ Anomaly (If checked, notify lab and file NCM) ☒ N/A	
Aromatics: ☒ No ☐ Yes – complete COR and Create NCM	
Complete shipment received in good condition with correct temperatures, containers, labels, volumes preservatives and within method specified holding times ☒ Yes ☐ No	
Labeled by: CA	
Turn Around Time: ☐ RUSH 24HR ☐ RUSH 48HR ☐ RUSH 72HR ☒ NORMAL	

LEAVE NO BLANK SPACES - USE N/A

Headspace Anomaly ☐ YES ☒ N/A CA 7/18/06

Lab ID	Container(s) #	Headspace	Lab ID	Container(s) #	Headspace
		☐ > 6mm			☐ > 6mm
		☐ > 6mm			☐ > 6mm
		☐ > 6mm			☐ > 6mm
		☐ > 6mm			☐ > 6mm
		☐ > 6mm			☐ > 6mm
		☐ > 6mm			☐ > 6mm
		☐ > 6mm			☐ > 6mm

LIMS Lot # 260009396

PROJECT RECEIPT CHECKLIST Cont'd

Fraction															
VOAH	6	3													

CA 7/8/16

B: EDT, S: H2SO4, N: HNO3, V: VOA, SL: Sleeve, E: Encore, PR: Perchlorate Bottle, CB: Clear Glass Bottle, AGB: Amber Glass Jar, T: Tedlar Bag, ABG: Amber Glass Bottle, ZnAc: Zinc Acetate/Sodium Hydroxide, $Na_2S_2O_3$: sodium thiosulfate

Condition Upon Receipt Anomaly Form

Anomalies ☐ Yes ☒ No CA 7/8/16

- COOLERS
  - 1 Not Received (received COC only)
  - 2 Leaking
  - 3 Other:
- CUSTODY SEALS (COOLER(S))
  - 1 None
  - 2 Not Intact
  - 3 Other
- CONTAINER(S)
  - 1 None
  - 2 Not Intact
  - 3 Other
- TEMPERATURE (SPECS 4 ± 2°C)
  - 1 Cooler Temp(s)
  - 2 Temperature Blank(s)
- CHAIN OF CUSTODY (COC)
  - 1 Not relinquished by Client; No date/time relinquished
  - 2 Incomplete information provided
  - 3 Other 4 COC not received – told by PM
- CONTAINERS
  - 1 Leaking 2 Voa Vials with Bubbles > 6mm
  - 3 Broken
  - 4 Extra
  - 5 Without Labels
  - 6 Other:
- LABELS
  - 1 Not the same ID/info as in COC
  - 2 Incomplete Information
  - 3 Markings/Info Illegible
  - 4 Torn
- SAMPLES
  - 1 Samples NOT RECEIVED but listed on COC
  - 2 Samples received but NOT LISTED on COC
  - 3 Logged based on Label Information
  - 4 Logged based on info from other samples on COC
  - 5 Logged according to Work Plan
  - 6 Logged on HOLD UNTIL FURTHER NOTICE
  - 7 Will be noted on COC. Client to send samples with new COC
  - 8 Mislabeled as to tests, preservatives, etc
  - 9 Holding time expired – see sample ID and test
  - 10 Improper container used
  - 11 Not preserved/Improper preservative used
  - 12 Improper pH _____ Lab to preserve sample and document
  - 13 Insufficient quantities for analysis 14 Other

Comments:

1 Corrective Action Implemented:

2 Client Informed: 1 Verbally on By: 2 In writing on By:

3 Sample(s) on hold until: 4 Sample(s) processed "as is."

Logged by/Date: CA 7/8/16 1 Logged in by other STL. ☐

PM Review/Date: 7/8/16

ORCOR Informational Inc

Client Sample ID: MW 1

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		DL/RDL		
Analyte	Result	Factor	Units	MDL
Benzene	660	10	ug/L	5.0
Ethanol	ND	5000	ug/L	[illegible]
Ethylbenzene	130	10	ug/L	5.0
Tert-Butyl alcohol	ND	200	ug/L	[illegible]
Toluene	15	10	ug/L	5.0
o Xylene	47	10	ug/L	5.0
Xylenes (total)	89	10	ug/L	5.0
m Xylene & p Xylene	42	10	ug/L	5.0
Methyl tert butyl ether (MTBE)	110	10	ug/L	5.0
Diisopropyl Ether (DIPE)	ND	10	ug/L	5.0
Ethyl tert-Butyl Ether (ETBE)	ND	10	ug/L	5.0
Tert-Amyl Methyl Ether (TAME)	ND	10	ug/L	5.0

	Result	Surrogate
Analyte	[illegible]	Limits
Dibromofluoromethane	94	75 - 124
1,2-Dichloroethane-d4	95	65 - 131
Toluene-d8	101	81 - 117

NOTES:

Out of range [illegible]

ORCOR International Inc

Client Sample ID: MW 1

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		DL/RL		
Parameter	Result	DL	Units	MDL
CRO (C4 - C12)	4900	100	ug/L	40

Surrogate	Result	Limits		
4-Bromofluorobenzene (FID)	120	70 - 130		

ORCOR Informational Inc

Client Sample ID: MW 3

GC/MS Volatiles

Lot Sample #:	[illegible]	Work Order #:	[illegible]
Date Sampled...:	[illegible]	Date Received...:	[illegible]
Prep Date.....:	[illegible]	Analysis Date..:	[illegible]
Prep Batch #...:	[illegible]	Analysis Time..:	[illegible]
Dilution Factor:	1		
Analyst ID.....:	[illegible]	Instrument ID...:	[illegible]
		Method.....:	[illegible]
Matrix:	W		
MS Run #.....:	[illegible]		

		DL/RDL		
Analyte	Result	Factor	Units	MDL
n-Butanol	ND	1.0	ug/L	0.61
Isobutanol	ND [1]	5.0	ug/L	1.5
Ethylbenzene	1.2	1.0	ug/L	0.30
tert-Butyl alcohol	ND	2.0	ug/L	0.62
Toluene	ND	1.0	ug/L	0.37
o-Xylene	1.4	1.0	ug/L	0.20
Xylenes (total)	1.4	1.0	ug/L	0.60
m-Xylene & p-Xylene	ND	1.0	ug/L	0.52
Methyl tert-butyl ether (MTBE)	ND	1.0	ug/L	0.35
Diisopropyl Ether (DIPE)	ND	1.0	ug/L	0.52
Ethyl tert-butyl ether (ETBE)	ND	1.0	ug/L	0.35
Tert-amyl methyl ether (TAME)	ND	1.0	ug/L	0.61

Surrogate	%Rec	Recovery Limits
1,2-Dichloroethane-d4	101	70 - 121
Toluene-d8	97	85 - 113
4-Bromofluorobenzene	101	74 - 121

NOTES:

Not analyzed - Flow rate out of range

CHCOR International Inc

Client Sample ID: MW 3

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		SURROGATE		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CRD (C4 - C12)	70-130	100	ug/L	40

		[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]		
4,5,6 Trifluorotoluene (TFT)	70	130		

NOTES(S):

[illegible]

ORCOR International Inc

Client Sample ID: MW 4

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		DL/RDL		
Analyte	Result	Factor	Units	MDL
Acetone	ND	1.0	ug/L	0.50
Benzene	ND [illegible]	5.0	ug/L	1.0
Ethylbenzene	1.4	1.0	ug/L	0.30
Tert Butyl alcohol	20	25	ug/L	6.0
Toluene	ND	1.0	ug/L	0.50
o Xylene	2.1	1.0	ug/L	0.20
Xylenes (total)	2.9	1.0	ug/L	0.60
m Xylene & p Xylene	0.88 JDX	1.0	ug/L	0.50
Methyl tert butyl ether (MTBE)	1.8	1.0	ug/L	0.50
Diisopropyl Ether (DIPE)	ND	1.0	ug/L	0.50
Ethyl tert butyl ether (ETBE)	ND	1.0	ug/L	0.50
Tert amyl methyl ether (TAME)	ND	1.0	ug/L	0.50

	Result	Recovery
Surrogate	Recovery	Limits
Dibromofluoromethane	92	75 - 125
Toluene-d8	100	85 - 115
4-Bromofluorobenzene	100	85 - 115

NOTES:

B Also detected in the blank

JDX - EPA Eq. Estimated. DX = Diln. Confirmed NC. --> ND.

CHCOR International Inc

Client Sample ID: MW 4

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		DILUTION		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CRD (C4 - C12)	100	100	ug/L	40

	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
4,4,4 Trifluorobutanol (TFB)	82	40 - 154	

ERCOR International Inc

Client Sample ID: MW 5

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		BASIS: W		
Analyte	Result	RL	Units	MDL
Benzene	ND	1.0	ug/L	0.14
Ethanol	ND [2]	500	ug/L	96
Ethylbenzene	ND	1.0	ug/L	0.16
Methyl tert-butyl ether	ND	2.0	ug/L	0.22
Toluene	ND	1.0	ug/L	0.17
o-Xylene	ND	1.0	ug/L	0.21
Xylenes, Total	ND	1.0	ug/L	0.41
m,p-Xylene	ND	1.0	ug/L	0.32
Methyl tert-butyl ether (MTBE) [2C]	ND	1.0	ug/L	0.22
Diisopropyl Ether (DIPE)	ND	2.0	ug/L	0.32
Ethyl tert-butyl ether (ETBE)	ND	2.0	ug/L	0.23
Tert-amyl methyl ether (TAME)	ND	2.0	ug/L	0.14

	Result	Acceptance
Surrogate	Recovery	Limits
Dibromofluoromethane	89	78 - 124
1,2-Dichloroethane-d4	84	65 - 133
Toluene-d8	100	81 - 117

NOTES:

Not analyzed - Client request

OMCOR International Inc

Client Sample ID: MW 5

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled...:	[illegible]	Date Received...:	[illegible]	MS Run #.....:	[illegible]
Prep Date.....:	[illegible]	Analysis Date..:	[illegible]		
Prep Batch #...:	[illegible]	Analysis Time..:	[illegible]		
Dilution Factor:	1				
Analyst ID.....:	[illegible]	Instrument ID...:	[illegible]		
		Method.....:	[illegible]		

		SURROGATE		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	

ERCOR International Inc

Client Sample ID: MW 7

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		BASIS:		
Analyte	Result	PQL	Units	MDL
Benzene	ND	1.0	ug/L	[illegible]
Ethanol	ND [illegible]	500	ug/L	[illegible]
Ethylbenzene	[illegible]	[illegible]	ug/L	[illegible]
Iso-Butyl alcohol	ND	20	ug/L	[illegible]
Toluene	ND	1.0	ug/L	[illegible]
o-Xylene	[illegible]	[illegible]	ug/L	[illegible]
Xylenes, total	[illegible]	[illegible]	ug/L	[illegible]
m-Xylene & p-Xylene	ND	1.0	ug/L	[illegible]
Methyl tert-butyl ether (MTBE)	[illegible]	[illegible]	ug/L	[illegible]
Diisopropyl Ether (DIPE)	ND	1.0	ug/L	[illegible]
Ethyl tert-butyl ether (ETBE)	[illegible]	[illegible]	ug/L	[illegible]
Tert-amyl methyl ether (TAME)	ND	1.0	ug/L	[illegible]

	%Rec/Qual	Acceptance
4-Bromofluorobenzene	[illegible]	[illegible]
1,2-Dichloroethane-d4	[illegible]	[illegible]
Toluene-d8	[illegible]	[illegible]

NOTES:

Out of [illegible] - [illegible]

ORCOR Informational Inc

Client Sample ID: MW 7

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		SURROGATE		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	

AR0073297

ERCOR International Inc

Client Sample ID: MW 8

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		DL/RDL		
Analyte	Result	Factor	Units	MDL
Benzene	2.4	1.0	ug/L	0.40
Ethanol	ND [illegible]	500	ug/L	[illegible]
Ethylbenzene	5.8	1.0	ug/L	0.30
Tert Butyl alcohol	140	25	ug/L	6.0
Toluene	0.30 JDX	1.0	ug/L	0.30
o Xylene	1.5	1.0	ug/L	0.20
Xylenes (total)	1.5	1.0	ug/L	0.50
m Xylene & p Xylene	ND	1.0	ug/L	0.30
Methyl tert butyl ether (MTBE)	63	1.0	ug/L	0.50
Diisopropyl Ether (DIPE)	ND	1.0	ug/L	0.50
Ethyl tert butyl ether (ETBE)	ND	1.0	ug/L	0.50
Tert amyl methyl ether (TAME)	ND	1.0	ug/L	0.50

	Result	Recovery
Surrogate	Recovery	Limits
Dibromofluoromethane	98	85 - 124
Toluene-d8	94	85 - 113
4-Bromofluorobenzene	101	84 - 115

NOTES:

B Also detected in the associated method blank

DX - EPA Fig. Estimated. DX = Diln. Confirmed NC. = Not Det.

ERCOR International Inc

Client Sample ID: MW 8

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled...:	[illegible]	Date Received...:	[illegible]	MS Run #.....:	[illegible]
Prep Date.....:	[illegible]	Analysis Date..:	[illegible]		
Prep Batch #...:	[illegible]	Analysis Time..:	[illegible]		
Dilution Factor:	1				
Analyst ID.....:	[illegible]	Instrument ID...:	[illegible]		
		Method.....:	[illegible]		

		SURROGATE		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CRD (C4 - C12)	400	100	ug/L	40

		[illegible]	
[illegible]	[illegible]	[illegible]	
4,5,6 Trifluorotoluene (TFT)	80	70 - 130	

ORCOR Informational Inc

Client Sample ID: MW 9

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1.0			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		DILUTION		
Analyte	Result	Factor	Units	MDL
Benzene	22	2.5	ug/L	0.75
Ethanol	ND [illegible]	1200	ug/L	[illegible]
Ethylbenzene	150	2.5	ug/L	0.75
Tert-Butyl alcohol	960	62	ug/L	3.5
Toluene	3.0	2.5	ug/L	0.75
o-Xylene	52	2.5	ug/L	0.50
Xylenes (total)	94	2.5	ug/L	1.2
m-Xylene & p-Xylene	42	2.5	ug/L	1.2
Methyl tert-butyl ether (MTBE)	66	2.5	ug/L	1.2
Diisopropyl Ether (DIPE)	ND	1.0	ug/L	1.0
Ethyl tert-butyl ether (ETBE)	ND	1.0	ug/L	1.0
Tert-amyl methyl ether (TAME)	ND	1.0	ug/L	1.0

	%REC	Limits
4-Bromofluorobenzene	94	75 - 124
Dibromofluoromethane	98	85 - 115
Toluene-d8	102	87 - 113

NOTES:

Not within limits - Flow rate error

ERCOR International Inc

Client Sample ID: MW 9

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		DL/RDL		
Parameter	Result	RDL	Units	MDL
CRO (C4 - C12)	1400	100	ug/L	40

Surrogate	Recovery	Control Limits		
4,5,6 Trifluorotoluene (TFT)	113	70	130	

ERCOR International Inc

Client Sample ID: MW 10

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		BASIS:		
Analyte	Result	PQL	Units	MDL
Benzene	ND	1.0	ug/L	0.34
Ethanol	ND [2]	5.0	ug/L	3
Ethylbenzene	ND	1.0	ug/L	0.36
Tert Butyl alcohol	6.0	2.5	ug/L	0.80
Toluene	ND	1.0	ug/L	0.37
o Xylene	ND	1.0	ug/L	0.41
Xylenes, total	ND	1	ug/L	0.41
m Xylene & p Xylene	ND	1.0	ug/L	0.72
Methyl tert butyl ether (MTBE)	62	1.0	ug/L	0.50
Diisopropyl Ether (DIPE)	ND	1.0	ug/L	0.32
Ethyl tert butyl ether (ETBE)	ND	1.0	ug/L	0.43
Tert amyl methyl ether (TAME)	ND	1.0	ug/L	0.41

	Result	Acceptance
Dibromofluoromethane	92	75 - 124
Toluene-d8	94	85 - 113
4-Bromofluorobenzene	97	77 - 123

NOTES:

Out of acceptance limits

ORCOR Informational Inc

Client Sample ID: MW 10

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		DL/RDL		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CRD (C4 - C12)	96 ppm	100	ug/L	40

	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		
4,4,5 Trifluorotoluene (FID)	85	70 - 130		

NOTES(S):

[illegible]

ERCOR International Inc

Client Sample ID: MW 11

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		BASIS: W		
Analyte	Result	RL	Units	MDL
Benzene	ND	[illegible]	ug/L	[illegible]
Ethanol	ND [illegible]	500	ug/L	[illegible]
Ethylbenzene	ND	[illegible]	ug/L	[illegible]
Iso-Butyl alcohol	ND	[illegible]	ug/L	[illegible]
Toluene	ND	[illegible]	ug/L	[illegible]
o-Xylene	ND	[illegible]	ug/L	[illegible]
Xylenes, total	ND	[illegible]	ug/L	[illegible]
m-Xylene & p-Xylene	ND	[illegible]	ug/L	[illegible]
Methyl tert-butyl ether (MTBE)	ND	[illegible]	ug/L	[illegible]
Diisopropyl Ether (DIPE)	ND	[illegible]	ug/L	[illegible]
Ethyl tert-butyl ether (ETBE)	ND	[illegible]	ug/L	[illegible]
Tert-amyl methyl ether (TAME)	ND	[illegible]	ug/L	[illegible]

		Acceptance
Surrogate	%Rec	Limits
Dibromofluoromethane	89	72-124
1,2-Dichloroethane-d4	101	65-133
Toluene-d8	104	71-126

NOTES:

Outside acceptance limits

OMCOR International Inc

Client Sample ID: MW 11

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		BASIS		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	

ERCOR International Inc

Client Sample ID: MW 1G

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		BASIS: W		
Analyte	Result	RL	Units	MDL
Benzene	ND	1.0	ug/L	0.14
Ethanol	ND [2]	500	ug/L	96
Ethylbenzene	ND	1.0	ug/L	0.16
Methyl tert-butyl ether	ND	2.0	ug/L	0.22
Toluene	ND	1.0	ug/L	0.17
o-Xylene	ND	1.0	ug/L	0.21
Xylenes, Total	ND	1.0	ug/L	0.41
m,p-Xylene	ND	1.0	ug/L	0.32
Methyl tert-butyl ether (MTBE) [2C]	ND	1.0	ug/L	0.22
Diisopropyl Ether (DIPE)	ND	2.0	ug/L	0.32
Ethyl tert-butyl ether (ETBE)	ND	2.0	ug/L	0.23
Tert-amyl methyl ether (TAME)	ND	2.0	ug/L	0.14

	Result	Acceptance
4-Bromofluorobenzene	89	75 - 124
1,2-Dichloroethane-d4	110	65 - 131
Toluene-d8	101	84 - 120

NOTES:

Not analyzed - Client request

ERCOR International Inc

Client Sample ID: MW 1G

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		BASIS:		
Analyte	Result	MDL	Limit	Q
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	Surrogate	Recovery	Limits
[illegible]	[illegible]	[illegible]	[illegible]

ORCOR International Inc

Client Sample ID: MW 3

GC/MS Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: 23:58		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID..: MS3		
	Method.....: SW846 8260B		

		BASIS:		
Analyte	Result	RL	Units	%R
Benzene	210	4.0	ug/L	112
Ethanol	NC [illegible]	[illegible]	ug/L	[illegible]
Ethylbenzene	150	4.0	ug/L	112
Tert Butyl alcohol	220	100	ug/L	94
Toluene	9.8	4.0	ug/L	112
o Xylene	19	4.0	ug/L	0.80
Xylenes (total)	40	4.0	ug/L	2.0
m Xylene & p Xylene	21	4.0	ug/L	2.0
Methyl tert butyl ether (MTBE)	57	4.0	ug/L	2.0
Diisopropyl Ether (DIPE)	ND	4.0	ug/L	[illegible]
Ethyl t Butyl Ether (ETBE)	ND	4.0	ug/L	[illegible]
Tert amyl methyl ether (TAME)	ND	4.0	ug/L	[illegible]

Surrogate	%R/Qual	Control Limits	
Dibromofluoromethane	97	85 - 124	
1,2 Dichloroethane-d4	96	85 - 118	
Toluene-d8	100	94 - 108	

NOTES:

Outside control limits

ORCOR International Inc

Client Sample ID: MW 3

GC Volatiles

Lab Sample #:	[illegible]	Work Order #:	[illegible]	Matrix:	W
Date Sampled:	[illegible]	Date Received:	[illegible]	MS Run #:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]		
Prep Batch #:	[illegible]	Analysis Time:	[illegible]		
Dilution Factor:	1				
Analyst ID:	[illegible]	Instrument ID:	[illegible]		
		Method:	[illegible]		

		DL		
Analyte	Result	(MDL)	Units	RL
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CRO (C4 - C12)	2000	100	ug/L	40

[illegible]	[illegible]	[illegible]	
4-Bromofluorobenzene (FID)	104	70 - 130	

ORCOR International Inc

Client Sample ID: DUP 105/ 20063706

GC/MS Volatiles

Lot Sample #:	[illegible]	Work Order #:	[illegible]
Date Sampled:	[illegible]	Date Received:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]
Prep Batch #:	[illegible]	Analysis Time:	[illegible]
Dilution Factor:	1		
Analyst ID:	[illegible]	Instrument ID:	[illegible]
		Method:	[illegible]
Matrix:	W		
MS Run #:	[illegible]		

		BASIS		
Analyte	Result	RL	Units	MDL
Benzene	6.5	1.0	ug/L	0.40
Ethanol	ND [illegible]	500	ug/L	N/A
Ethylbenzene	1.9	1.0	ug/L	0.30
Tert Butyl alcohol	150	25	ug/L	6.0
Toluene	1.3	1.0	ug/L	0.30
o Xylene	1.6	1.0	ug/L	0.20
Xylenes (total)	4.0	1.0	ug/L	0.50
m Xylene & p Xylene	1.4	1.0	ug/L	0.50
Methyl tert butyl ether (MTBE)	58	1.0	ug/L	0.50
Diisopropyl Ether (DIPE)	ND	1.0	ug/L	0.50
Ethyl tert butyl ether (ETBE)	ND	1.0	ug/L	0.50
Tert amyl methyl ether (TAME)	ND	1.0	ug/L	0.50

Surrogate	%Rec/Qual	Limits	
1,2-Dichloroethane-d4	108	75 - 124	
Toluene-d8	94	85 - 113	
Bromofluorobenzene	101	84 - 115	

NOTES:

Out of range - Flow rate

CHCOR International Inc

Client Sample ID: DUP 105/ 20060706

GC Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		SURROGATE		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CRD (D4 - D12)	470	100	ug/L	40

[illegible]	[illegible]	[illegible]	
1,2,4-Trichlorobenzene (TCB)	.6	1.0	1.0

ORCOR International Inc

Client Sample ID: TB 1057 20060706

GC/MS Volatiles

Lot Sample #:	[illegible]	Work Order #:	[illegible]
Date Sampled:	[illegible]	Date Received:	[illegible]
Prep Date:	[illegible]	Analysis Date:	[illegible]
Prep Batch #:	[illegible]	Analysis Time:	[illegible]
Dilution Factor:	1		
Analyst ID:	[illegible]	Instrument ID:	[illegible]
		Method:	[illegible]
Matrix:	[illegible]		
MS Run #:	[illegible]		

		BASIS: [illegible]		
Analyte	Result	RL	Units	DF
[illegible]	ND	[illegible]	ug/l	[illegible]
Ethanol	ND [illegible]	500	ug/l	1
Ethylbenzene	[illegible]	[illegible]	ug/l	[illegible]
[illegible] butyl alcohol	ND	25	ug/l	[illegible]
Toluene	ND	1.0	ug/l	[illegible]
o-Xylene	[illegible]	[illegible]	ug/l	[illegible]
Xylenes, total	[illegible]	[illegible]	ug/l	[illegible]
m-Xylene & p-Xylene	ND	2.0	ug/l	[illegible]
Methyl tert-butyl ether (MTBE)	[illegible]	[illegible]	ug/l	[illegible]
Dibromofluoromethane	ND	2.0	ug/l	1
Ethyl tert-butyl ether (ETBE)	ND	2.0	ug/l	1
Tert-amyl methyl ether (TAME)	ND	2.0	ug/l	1

	Result	Acceptance Limits
[illegible]	[illegible]	[illegible]
Dibromofluoromethane	89	72-124
Toluene-d8	100	85-113
4-Bromofluorobenzene	94	75-120

NOTES:

Not [illegible] [illegible]

ERCOR International Inc

Client Sample ID: TB 1057 20060706

GC Volatiles

Lab Sample #: [illegible]	Work Order #: [illegible]	Matrix: W	
Date Sampled...: [illegible]	Date Received...: [illegible]	MS Run #.....: [illegible]	
Prep Date.....: [illegible]	Analysis Date..: [illegible]		
Prep Batch #...: [illegible]	Analysis Time..: [illegible]		
Dilution Factor: 1			
Analyst ID.....: [illegible]	Instrument ID...: [illegible]		
	Method.....: [illegible]		

		SURROGATE		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

METHOD BLANK REPORT

GC/MS Volatiles

Client Lot #... : [illegible] Work Order #... : [illegible] Matrix... : WATER
MB Lot-Sample #: [illegible]

Prep Date..... : [illegible] Analysis Time... : [illegible]
Analysis Date... : [illegible] Prep Batch #... : [illegible] Instrument ID... : VOA
Dilution Factor: 1

Analyst ID..... : [illegible]

		Blank		
Compound	Status	Result	Units	Qualifiers
Benzene	ND	1.0	ug/l	SW846 8260B
Ethanol	ND	500	ug/L	SW846 8015B
Ethylbenzene	ND	1.0	ug/l	SW846 8260B
Methyl-t-butyl ether	ND	5.0	ug/l	SW846 8260B
Toluene	ND	1.0	ug/L	SW846 8015B
o-Xylene	ND	1.0	ug/l	SW846 8260B
Xylenes, total	ND	1.0	ug/l	SW846 8260B
m-Xylene & p-Xylene	ND	1.0	ug/l	SW846 8260B
Diethyl ether (ethyl ether)	ND	1.0	ug/l	SW846 8260B
Diisopropyl ether (DIPE)	ND	1.0	ug/l	SW846 8260B
Ethyl t-butyl ether (ETBE)	ND	1.0	ug/l	SW846 8260B
Tert-amyl methyl ether (TAME)	ND	1.0	ug/l	SW846 8260B

	Recovery	Recovery
Surrogate	Qualifiers	Limits
Dibromofluoromethane	97	[illegible]
1,2-Dichloroethane-d4	91	[illegible]
Toluene-d8	98	[illegible]

NOTE(S):

[illegible]

METHOD BLANK REPORT

GC Volatiles

Client Lot #... : [illegible] Work Order #... : [illegible] Matrix... : WATER

MB Lot Sample #: [illegible]

Prep Date..... : [illegible] Analysis Time... : [illegible]

Analysis Date... : [illegible] Prep Batch #... : [illegible] Instrument ID... : [illegible]

Dilution Factor: 1

Analyst ID..... : [illegible]

		Blank		
[illegible]	Result	Limit	Units	Qualifier
[illegible]	ND	1.0	ug/L	[illegible]

		Percent	Acceptance
Surrogate	Recovery	Limits	
[illegible]	93	70 - 130	

NOTES(S):

[illegible]

LABORATORY CONTROL SAMPLE DATA REPORT

GC/MS Volatiles

Client Lot #: [illegible] Work Order #: [illegible] Matrix: WATER
LCS Lot Sample#: [illegible]
Prep Date: [illegible] Analysis Date: [illegible]
Prep Batch #: [illegible] Analysis Time: [illegible]
Dilution Factor: 1 Instrument ID: [illegible]
Analyst ID: [illegible]

Parameter	Spike Amount	Measured Amount	Units	Percent Recovery	Method
Benzene	10.0	11.1	ug/L	111	SW846 8260B
tert Butyl alcohol	50.0	69.5	ug/L	139	SW846 8260B
MEthanol	2000	2050	ug/L	102	SW846 8260B
Tert amyl methyl ether (T	10.0	10.8	ug/L	108	SW846 8260B
Ethyl t Butyl Ether (ETBE	10.0	9.44	ug/L	94	SW846 8260B
MEthylbenzene	10.0	10.3	ug/L	103	SW846 8260B
Diisopropyl Ether (DIPE)	10.0	9.85	ug/L	98	SW846 8260B
Methyl tert butyl ether (MTBE)	10.0	9.60	ug/L	96	SW846 8260B
Toluene	10.0	10.3	ug/L	103	SW846 8260B
m Xylene & p Xylene	20.0	20.3	ug/L	101	SW846 8260B
o Xylene	10.0	10.2	ug/L	102	SW846 8260B

Surrogate	Percent Recovery	Control Limits
Dibromofluoromethane	113	[illegible]
1,2-Dichloroethane-d4	96	[illegible]
Toluene-d8	99	[illegible]

NOTE(S):

[illegible]

[illegible]

LABORATORY CONTROL SAMPLE DATA REPORT

GC Volatiles

Client Lot #... : [illegible] Work Order #... : [illegible] Matrix... : WATER
LCS Lot Sample#: [illegible]
Prep Date..... : [illegible] Analysis Date... : [illegible]
Prep Batch #.... : [illegible] Analysis Time... : 12:0[illegible]
Dilution Factor: 1 Instrument ID... : [illegible]
Analyst ID..... : [illegible]

	Spike	Measured		Recovery	
Analyte	Added	Concn	Units	%Rec	Limits
GRO (C4 - C12)	1000	936 TN	ug/L	94	SW846 8015B

	Duplicate	Relative
Analyte	Result	%Diff
[illegible]	[illegible]	[illegible]

NOTES(S):

[illegible]

[illegible]

[illegible]

MATRIX SPIKE SAMPLE DATA REPORT

GC/MS Volatiles

Client Lot # : [illegible] Work Order # : [illegible] Matrix : W
MS Lot Sample #: [illegible] [illegible]
Date Sampled...: [illegible] Date Received...: [illegible] MS Run #.....: [illegible]
Prep Date.....: [illegible] Analysis Date...: [illegible]
Prep Batch #....: [illegible] Analysis Time...: [illegible]
Dilution Factor: 1 Analyst ID.....: [illegible] Instrument ID...: MAC

Parameter	Result	RL	Spike Amount	Units	Percent Recovery	RPD	Qualifiers	
Ethanol	ND	2000	2550	ug/L	128		SW846	8260B
	ND	2000	2440	ug/L	122	0.35	SW846	8260B
Tert amyl methyl ether (T	ND	10.0	10.5	ug/L	105		SW846	8260B
	ND	10.0	10.6	ug/L	106	1.1	SW846	8260B
Ethyl t Butyl Ether (ETBE	ND	10.0	8.98	ug/L	90		SW846	8260B
	ND	10.0	9.10	ug/L	91	1.3	SW846	8260B
Ethylbenzene	ND	10.0	11.1	ug/L	111		SW846	8260B
	ND	10.0	10.9	ug/L	109	1.4	SW846	8260B
Diisopropyl Ether (DIPE)	ND	10.0	8.63	ug/L	86		SW846	8260B
	ND	10.0	8.68	ug/L	87	0.57	SW846	8260B
Methyl tert butyl ether (MTBE)	ND	10.0	9.41	ug/L	94		SW846	8260B
	ND	10.0	9.47	ug/L	95	1.7	SW846	8260B
Toluene	ND	10.0	10.7	ug/L	107		SW846	8260B
	ND	10.0	10.7	ug/L	107	0.28	SW846	8260B
m Xylene & p Xylene	ND	20.0	21.2	ug/L	106		SW846	8260B
	ND	20.0	21.1	ug/L	106	0.37	SW846	8260B
o Xylene	ND	10.0	10.6	ug/L	106		SW846	8260B
	ND	10.0	10.5	ug/L	105	0.94	SW846	8260B
Benzene	ND	10.0	10.2	ug/L	102		SW846	8260B
	ND	10.0	10.1	ug/L	101	0.39	SW846	8260B
tert Butyl alcohol	ND	50.0	224	ug/L	447 JM		SW846	8260B
	ND	50.0	214	ug/L	428 JM	4.3	SW846	8260B

Surrogate	Acceptance	Qualifiers
Dibromofluoromethane	86	105 [illegible]
	88	104 [illegible]
1,2-Dichloroethane-d4	105	105 [illegible]
	107	105 [illegible]
Toluene-d8	97	99% [illegible]
	100	100 [illegible]

NOTES(S):

[illegible]

[illegible]

[illegible]

JM Matrix MSD recoveries [illegible]

MATRIX SPIKE SAMPLE DATA REPORT

GC Volatiles

Client Lot #	- [illegible]	Work Order #	- [illegible] Matrix - W
MS Lab Sample #:	[illegible]	[illegible]	
Date Sampled....	[illegible]	Date Received...	[illegible] MS Run #..... [illegible]
Prep Date.....	[illegible]	Analysis Date...	[illegible]
Prep Batch #....	[illegible]	Analysis Time...	[illegible]
Dilution Factor:	1	Analyst ID.....	[illegible] Instrument ID... [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GRO (C4 - C12)	ND	1000	972	ug/L	97 LW	SW846 8015B
	ND	1000	959	ug/L	96 LW 1.4	SW846 8015B

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible] "P"	[illegible]	[illegible]
	[illegible]	[illegible]

NOTE(S):

[illegible]

[illegible]

[illegible]

Subjective and Well-Head Evaluation Form

Project No.: Q3-2006 Groundwater Location: Hollywood Date: 7/6/2006

Station No.: 1057 Field Technician: Shaun Dickinson Day of Week: THURSDAY

DTW ORDER	WELL ID	SURFICIAL SEAL	CONCRETE SEAL	LID SECURE	GASKET	LOCK	EXPANDING CAP	TOTAL DEPTH (feet)	DEPTH TO WATER (feet)	FLOATING PRODUCT THICKNESS (feet)	DISSOLVED OXYGEN READING (mg/L)	COMMENTS
	MW-1	Y	Y	Y	Y	Y	Y	70.28	39.37	Ø	2.85	
	MW-3	Y	Y	Y	Y	Y	Y	68.45	41.44	Ø	4.16	
	MW-4	Y	Y	Y	Y	Y	Y	69.86	40.04	Ø	2.02	
	MW-5	Y	Y	Y	Y	Y	Y	50.45	40.50	Ø	2.04	
	MW-6	Y	Y	Y	Y	Y	Y	70.11	40.69	Ø	4.98	Gauge only
	MW-7	Y	Y	Y	Y	Y	Y	67.00	35.20	Ø	2.83	
	MW-8	Y	Y	Y	Y	Y	Y	63.42	33.77	Ø	4.30	Duplicate Sample
	MW-9	Y	Y	Y	Y	Y	Y	56.25	31.21	Ø		
	MW-10	Y	Y	Y	Y	Y	Y	58.10	31.41	Ø	1.05	Please see next pg. A-6
	MW-11	NS	—	—	—	—	—	59.95	[illegible]	Ø	→	[illegible]
	MW-12	NS	—	—	—	—	—	55.51	[illegible]	Ø	→	[illegible]
	MW-15	NS	—	—	—	—	—	43.90	[illegible]	[illegible]	→	No Buildings Gauge only PERMIT
	MW-16	Y	Y	Y	Y	Y	Y	44.50	22.94	Ø	1.44	
	MW-17	Y	Y	Y	Y	Y	Y	44.45	23.85	Ø	2.26	Gauge only
	MW-18	Y	Y	Y	Y	Y	Y	42.50	18.37	Ø	3.73	Gauge only
	MW-19	Y	Y	Y	Y	Y	Y	22.62	#21.25	NAA	NM	Gauge only

at depth to obstruction/dry

Note: Use G=Good and P=poor for well condition

Subjective and Well-Head Evaluation Form

Project No.: Q3 2006 Groundwater Location: Hollywood Date: 7/6/2006

Station No.: 1057 Field Technician: Shaun Dickinson Day of Week: THURSDAY

DTW ORDER	WELL ID	SURFICIAL SEAL	CONCRETE SEAL	LID SECURE	GASKET	LOCK	EXPANDING CAP	TOTAL DEPTH (feet)	DEPTH TO WATER (feet)	FLOATING PRODUCT THICKNESS (feet)	DISSOLVED OXYGEN READING (mg/L)	COMMENTS
	MW-20	Y	Y	Y	Y	Y	Y	37.45	20.81	0	1.98	Gauge only
	MW-21	Y	Y	Y	Y	Y	Y	39.15	17.38	0	1.92	Gauge only
	MW-22	Y	Y	N	Y	Y	Y	39.25	DRY	NM	NM	Missing bolt Gauge only
	EW-1	NS	—	—	—	—	→	49.15	—	—	→	No well head permit
	EW-2	Y	Y	Y	Y	N	N	55.45	31.58	0	1.31	Gauge only
	EW-3	Y	Y	Y	Y	N	N	56.32	34.59	0	1.61	
	EW-4	Y	Y	Y	Y	N	N	51.55	33.16	0	1.57	Gauge only
	EW-5	Y	Y	Y	Y	N	N	49.89	40.21	0	2.05	
	MW-11							59.95	39.67			

Note: Use G=Good and P=poor for well condition

APPENDIX B

Groundwater Sampling Data Sheets

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-1
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches): 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): ~~70.75~~ 70.18	CALCULATED PURGE (gal): 61.62
DEPTH TO WATER (feet): ~~45.54~~ 29.37	ACTUAL PURGE VOL (gal): 62.00

Standing Water in Casing (feet) 30.81 x 0.20= 6.18 + DTW 45.52 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet) 30.71	x 2.0= 61.62	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/6/06 Start (2400 Hr.): 0850 End (2400 Hr.): 943

Date Sampled: 7/6/06 Time (2400 Hr.): 0950 DTW @ Samp. Time: 44.80

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
906	20	21.3	1.18	8.04	Clear	Light	
920	41	21.4	1.18	8.11	"	"	
943	62	21.4	1.21	8.17	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, id, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCL: 6 Liter amber, none: 4 16 oz poly, HNO3: 0

WATER LEVEL ONLY NO SAMPLE COLLECTED.

REVIEWED BY: Bruce Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-3
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 68.45	CALCULATED PURGE (gal): 54.02
DEPTH TO WATER (feet): 41.44	ACTUAL PURGE VOL (gal): 55.00

Standing Water in Casing (feet) 27.01 x 0.20= 5.40 + DTW 46.64 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet) 27.01	x 2.0= 54.02	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/7/06 Start (2400 Hr.): 0712 End (2400 Hr.): 0749

Date Sampled: 7/7/06 Time (2400 Hr.): 0800 DTW @ Samp Time: 46.67

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
0725	18	21.6	1.15 mS	8.02	Clear	Light	
0737	36	21.0	1.14	8.10	"	"	
0749	55	21.1	1.16	7.98	"	V	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	~~Bailer (Teflon)~~
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	~~Dedicated~~
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA HCL: 6 1 liter amber, none: 0 15 oz poly, HNO3: 0

WATER LEVEL ONLY, NO SAMPLE COLLECTED: REVIEWED BY: Russ Cameron DATE: 7/26/06

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-4
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 69.86	CALCULATED PURGE (gal):
DEPTH TO WATER (feet): 40.04	ACTUAL PURGE VOL (gal): 60.00

Standing Water in Casing (feet) 29.82 x 0.20= 5.96 + DTW 40.00 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet) 29.82	x 2.0= 59.64	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/7/06 Start (2400 Hr.): 0805 End (2400 Hr.):

Date Sampled: 7/7/06 Time (2400 Hr.): 0845 DTW @ Samp. Time: 45.33

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) X 1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
815	20	20.9	1.09	8.08	Clear	Light	
0825	40	20.6	1.10	8.12	"	"	
0838	60	21.2	1.10	8.02	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCL: 6 1 liter amber, none: 2 16 oz poly, HNO3: 2

WATER LEVEL ONLY NO SAMPLE COLLECTED

REVIEWED BY: Bruce Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073325

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-5
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07706/2006 7/7/06	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 50.45	CALCULATED PURGE (gal): 19.90
DEPTH TO WATER (feet): 40.50	ACTUAL PURGE VOL (gal): 20.00
Standing Water in Casing (feet) 9.95 x 0.20= 1.99	= DTW 42.49 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0= 19.90	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/7/06 Start (2400 Hr.): 646 End (2400 Hr.): 658

Date Sampled: 7/7/06 Time (2400 Hr.): 0710 DTW @ Samp. Time: 42.03

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
0650	7	19.4	0.81 mS	8.82	Cloudy	Light	
0655	14	20.2	0.79	8.52	Cloud	Hvy	
0658	20	20.7	0.79	8.24	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet) Color: Padlock Number:

COMMENTS:

40 ml VOA, HCl: 6 1 liter amber, none: 0 26 oz poly, HNO3: 0

WATER LEVEL ONLY NO SAMPLE COLLECTED: REVIEWED BY: Bruce Cameron DATE: 7/7/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-6
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):		CALCULATED PURGE (gal):	
DEPTH TO WATER (feet):		ACTUAL PURGE VOL (gal):	
Standing Water in Casing (feet)	x 0.20=	+ DTW	=80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Red-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS: Gauge Only

40 ml VOA, HCL: _____ Liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED: _____ REVIEWED BY: Bruce Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073327

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-7
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 102.00	CALCULATED PURGE (gal): 53.60
DEPTH TO WATER (feet): 55.20	ACTUAL PURGE VOL (gal): 54
Standing Water in Casing (feet) 46.80 x 0.20= 9.36	+DTW 0.70 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/6/06 Start (2400 Hr.): 1100 End (2400 Hr.): 1152

Date Sampled: 7/6/06 Time (2400 Hr.): 1210 DTW @ Samp. Time: 55.20

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE. FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
1135	18	71.6	8.04	6.52	clear	slight	
1143	36	72.0	7.81	6.41	"	"	
1152	54	72.2	8.02	6.47	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCL: 6 1 liter amber, none: 0 16 oz poly, HNO3: 0

WATER LEVEL ONLY, NO SAMPLE COLLECTED: REVIEWED BY: Jane Cameron DATE: 7/26/06

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-8
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 63.41	CALCULATED PURGE (gal): 59.30
DEPTH TO WATER (feet): 33.77	ACTUAL PURGE VOL (gal): 60.00
Standing Water in Casing (feet) 29.65 x 0.20= 5.93	+ DTW 39.70 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet) 29.65	x 2.0= 59.30	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/6/06 Start (2400 Hr.): 0920 End (2400 Hr.): 0941
Date Sampled: 7/6/06 Time (2400 Hr.): 0935 DTW @ Samp. Time: 33.77

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): Dup-1057-20060706

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	EC (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)
0928	20	73.0	1926	6.11	Clear	Light	
0934	40	73.3	1274	7.04	"	"	
0941	60	74.0	1282	7.59	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):
Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCL: 6 1 liter amber, unpres: 2 16 oz poly, HNO3:

WATER LEVEL ONLY, NO SAMPLE COLLECTED

REVIEWED BY: Bruce Cameron DATE: 7/20/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-9
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 46.25	CALCULATED PURGE (gal): 20.04
DEPTH TO WATER (feet): 31.24	ACTUAL PURGE VOL (gal): 21
Standing Water in Casing (feet): 15.01 x 0.20= 7.002 + DTW 38.24	=80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/6/06 Start (2400 Hr): 0948 End (2400 Hr.): 1019
Date Sampled: 7/6/06 Time (2400 Hr.): 1035 DTW @ Samp. Time: 37.94

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
0955	24	75.0	1059	7.81	clear	Light	
1007	42	75.1	1091	7.89	"	"	
1019	21	76.0	1103	7.93	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	~~Bailer (Teflon)~~
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable-Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, lockT, padlock, screws, lid, etc.):

Flooring Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCl: 6 Liter amber, none: 4 16 oz poly, HNO3: 2

WATER LEVEL ONLY, NO SAMPLE COLLECTED: REVIEWED BY: Bruce Cameron DATE: 7/20/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3 2006 Groundwater	SAMPLE ID: MW-10
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 55.67	CALCULATED PURGE (gal): 13.88
DEPTH TO WATER (feet): 31.41	ACTUAL PURGE VOL (gal): 54

Standing Water in Casing (feet) 24.26 x 0.20= 4.85 + DTW 36.74 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/6/06 Start (2400 Hr.): 1212 End (2400 Hr.): 1254

Date Sampled: 7/6/06 Time (2400 Hr.): 1245 DTW @ Samp. Time: 31.91

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
1222	18	71.0	1.145	8.08	Clear	Light	
1230	36	70.3	1.097	8.12	"	"	
1254	54	71.2	1.153	7.97	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCL 6 Other (specify, note): 0 250 ml poly, HNO3: 0

WATER LEVEL ONLY NO SAMPLE COLLECTED

REVIEWED BY: Brian Cameron DATE: 7/28/06

Atlantic Richfield Company No. # 1057

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-11
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 57.57	CALCULATED PURGE (gal): 42.06
DEPTH TO WATER (feet): 35.67	ACTUAL PURGE VOL (gal): 41
Standing Water in Casing (feet) 20.27 x 0.20= 4.05	+DTW 42.71 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/6/2006 Start (2400 Hr.): 1243 End (2400 Hr.): 1257

Date Sampled: 7/6/06 Time (2400 Hr.): 1315 DTW @ Samp. Time: 42.17

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP. (degrees F)	E.C. (uS/cm) x100	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)
1250	14	75.5	1392	7.59	Clear	Trace	
1253	28	74.1	1438	7.91	"	"	
1257	41	77.1	1494	7.91	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	~~Bailer (Teflon)~~
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	~~Dedicated~~
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, ~~cement~~, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCL: 6 Liter amber, none: 2 1L w/ poly, HNO3: 2

WATER LEVEL ONLY, NO SAMPLE COLLECTED: REVIEWED BY: Bruce Cameron DATE: 7/24/06

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: ~~MW-12~~ -
SAMPLER: Shaun Dickmson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal):
DEPTH TO WATER (feet): 51.60	ACTUAL PURGE VOL (gal):
Standing Water in Casing (feet) x 0.20=	+ DTW =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
5 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS

NS

40 ml VOA, HCL: _____ 1 liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY NO SAMPLE COLLECTED: _____

REVIEWED BY: Bruce Conner DATE: 7/25/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-15
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal):
DEPTH TO WATER (feet):	ACTUAL PURGE VOL (gal):

Standing Water in Casing (feet) x 0.20= + DTW =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy, Yellow, Brown. ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated

OTHER: VAC TRUCK OTHER:

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS: NS No Cal Trans Permit

40 ml VOA, HCl: _____ Liter amber, none: _____ 1 liter poly, HNO3: _____

WATER LEVEL ONLY NO SAMPLE COLLECTED: _____

REVIEWED BY Bruce Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-36
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 (4) 6 8 12 OTHER:

DEPTH OF WELL (feet): 49.50	CALCULATED PURGE (gal): 43.12
DEPTH TO WATER (feet): 22.94	ACTUAL PURGE VOL (gal): 44
Standing Water in Casing (feet) 21.56 x 0.20= 4.312	+ DTW 27.25 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (Feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/6/06 Start (2400 Hr.): 1037 End (2400 Hr.): 1053
Date Sampled: 7/6/06 Time (2400 Hr.): 1105 DTW @ Samp. Time: 22.94

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)
1041	15	74.4	1053	8.08	Clear	Light	
1045	30	73.7	1048	8.02	"	"	
1050	45	72.3	1030	8.00	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):
Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCl; Liter amber, none; 16 oz poly, HNO3

WATER LEVEL ONLY, NO SAMPLE COLLECTED:

REVIEWED BY Bill Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-17
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal):
DEPTH TO WATER (feet):	ACTUAL PURGE VOL (gal):
Standing Water in Casing (feet) x 0.20=	+ DTW =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS: GAUGE ONLY

40 ml VOA, HCl: _____ Liter amber, none: _____ 16 oz poly, HNO3 _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED: _____ REVIEWED BY: Bruce Carson DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073336

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-19
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):		CALCULATED PURGE (gal):	
DEPTH TO WATER (feet):		ACTUAL PURGE VOL (gal):	
Standing Water in Casing (feet)	x 0.20=	+ DTW	=80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP 1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated

OTHER: VAC TRUCK	OTHER:

Well Condition (cap, cement, padlock, screws, lid, etc.):		
Floating Product Thickness (feet):	Color:	Padlock Number:

COMMENTS: GAUGE ONLY

40 ml VOA, HCl: _____ 1 liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED

REVIEWED BY: Billie Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073337

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-19
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):		CALCULATED PURGE (gal):	
DEPTH TO WATER (feet):		ACTUAL PURGE VOL (gal):	
Standing Water in Casing (feet)	x 0.20=	+ DTW	=80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Reci-Flo2	Dedicated	Well Wizard	Dedicated

OTHER: VAC TRUCK	OTHER:

Well Condition (cap, cement, padlock, screws, lid, etc.):		
Floating Product Thickness (feet):	Color:	Padlock Number:

COMMENTS: GAUGE ONLY

40 ml VOA, HCL: _____ Liter amber, none: _____ 35 oz poly, HNO3: _____

WATER LEVEL ONLY - NO SAMPLE COLLECTED: _____ REVIEWED BY: Allie Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY		
	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-20
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal):
DEPTH TO WATER (feet):	ACTUAL PURGE VOL (gal):
Standing Water in Casing (feet) x 0.20=	+ DTW =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated

OTHER: VAC TRUCK	OTHER:

Well Condition (cap, cement, padlock, screws, lid, etc.):
Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS: GAUGE ONLY

40 ml VOA, HCL: _____ 1 liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED.

REVIEWED BY: Bruce Conaway DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073339

GROUNDWATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3 2006 Groundwater	SAMPLE ID: MW-21
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):		CALCULATED PURGE (gal):	
DEPTH TO WATER (feet):		ACTUAL PURGE VOL. (gal):	
Standing Water in Casing (feet)	x 0.20=	+ DTW	=80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS: GAUGE ONLY

40 ml VOA, HCl: _____ 1 liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED

REVIEWED BY: Brad Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: MW-22
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal):
DEPTH TO WATER (feet):	ACTUAL PURGE VOL (gal):
Standing Water in Casing (feet) x 0.20=	+ DTW =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, pad ock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS: GAUGE ONLY

40 ml VOA HCL: _____ 1 liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY NO SAMPLE COLLECTED: _____ REVIEWED BY: Bruce Cameron DATE: 7/24/06

*Atlantic Richfield Company No. # 1057

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: EW-1
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal):
DEPTH TO WATER (feet):	ACTUAL PURGE VOL (gal):
Standing Water in Casing (feet) x 0.20=	+ DTW =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):		
Floating Product Thickness (feet):	Color:	Padlock Number:

COMMENTS:

40ml VOA, HCL: _____ Liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED: _____ REVIEWED BY: Steve Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073342

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: EW-2
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal):
DEPTH TO WATER (feet):	ACTUAL PURGE VOL (gal):
Standing Water in Casing (feet) x 0.20=	+ DTW =80% Recharge Water Level

2	(inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4	(inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6	(inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8	(inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): DUP: EW-99

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) xxxx	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, None

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS: GAUGE ONLY

40 ml VOA, HCL: _____ Filter order, name: _____ 1 liter poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED: _____ REVIEWED BY: Brian Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

GROUND ATER SAMPLE FIELD DAT SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: EW-3
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: ~~07/06/2006~~ 7/7/06	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 (6) 8 12 OTHER:

DEPTH OF WELL (feet): 51.55	CALCULATED PURGE (gal): 80.72
DEPTH TO WATER (feet): 33.16	ACTUAL PURGE VOL (gal): 87.00

Standing Water in Casing (feet) 18.39 x 0.20= 3.67 + DTW 36.83 =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4= 80.92	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: 7/7/06 Start (2400 Hr.): 1015 End (2400 Hr.): 1103

Date Sampled: 7/7/06 Time (2400 Hr.): 1115 DTW @ Samp. Time: 36.56

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP. (degrees F)	C.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)
1031	27	24.6	1.10	8.90	Clear	Light	
1099	54	24.6	1.11	7.99	"	"	
1103	81	24.9	1.10	8.02	"	"	

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	(Bailer (Disposable Teflon))
Reci-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: (VAC TRUCK)		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCl: 6 Liter amber, none: 2 16 oz poly, HNO3: 2

WATER LEVEL ONLY, NO SAMPLE COLLECTED: REVIEWED BY: Brian Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073344

GROUND WATER SAMPLE FIELD DATA SHEET

ATLANTIC RICHFIELD COMPANY

PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: EW-4
SAMPLER: Shaun Dickinson	FACILITY NO: 1057
DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches): 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):		CALCULATED PURGE (gal):	
DEPTH TO WATER (feet):		ACTUAL PURGE VOL (gal):	
Standing Water in Casing (feet)	x 0.20=	+ DTW	=80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Samp Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1): _____

TIME (2400 Hr.)	VOLUME (gallons)	TEMP (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZE (gallons)

* (Color) Clear, Cloudy, Yellow, Brown ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated

OTHER: VAC TRUCK	OTHER:

Well Condition (cap, cement, pad ock, screws, l d, etc.):		
Floating Product Thickness (feet):	Color:	Padlock Number:

COMMENTS: GAUGES ONLY

40 ml VOA, HCL: _____ 1 liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED: _____ REVIEWED BY: Bruce Cameron DATE: 7/26/06

Atlantic Richfield Company No. # 3057

GROUNDWATER SAMPLE FIELD DATA SHEET

RICHFIELD COMPANY	PROJECT NO: Q3-2006 Groundwater	SAMPLE ID: EW-5
	SAMPLER: Shaun Dickinson	FACILITY NO: 1057
	DATE: 07/06/2006	LOCATION: Hollywood

CASING DIAMETER (inches) 2 3 4 6 8 12 OTHER:

DEPTH OF WELL (feet):	CALCULATED PURGE (gal.):
DEPTH TO WATER (feet):	ACTUAL PURGE VOL (gal):
Standing Water in Casing (feet) x 0.20=	+ DTW =80% Recharge Water Level

2 (inches)	Standing Water in Casing (feet)	x 0.5=	3 Casing Volumes (gal.)
4 (inches)	Standing Water in Casing (feet)	x 2.0=	3 Casing Volumes (gal.)
6 (inches)	Standing Water in Casing (feet)	x 4.4=	3 Casing Volumes (gal.)
8 (inches)	Standing Water in Casing (feet)	x 7.8=	3 Casing Volumes (gal.)

Date Purged: _____ Start (2400 Hr.): _____ End (2400 Hr.): _____

Date Sampled: _____ Time (2400 Hr.): _____ DTW @ Sump. Time: _____

FIELD QC SAMPLES COLLECTED AT THIS WELL (IE: FB-1, X-DUP-1):

TIME (2400 Hr.)	VOLUME (gallons)	TEMP. (degrees F)	E.C. (uS/cm) x1000	pH (units)	COLOR (visual)*	TURBIDITY (visual)**	TOTALIZER (gallons)

* (Color) Clear, Cloudy, Yellow, Brown. ** (Turbidity) Heavy, Moderate, Light, Trace

PURGING EQUIPMENT		SAMPLING EQUIPMENT	
2" Bladder Pump	Bailer (Teflon)	2" Bladder Pump	Bailer (Stainless Steel)
Centrifugal Pump	Bailer (PVC)	Submersible Pump	Bailer (Teflon)
Submersible Pump	Bailer (Stainless Steel)	Dipper	Bailer (Disposable Teflon)
Redi-Flo2	Dedicated	Well Wizard	Dedicated
OTHER: VAC TRUCK		OTHER:	

Well Condition (cap, cement, padlock, screws, lid, etc.):

Floating Product Thickness (feet): Color: Padlock Number:

COMMENTS:

40 ml VOA, HCl: _____ 1 liter amber, none: _____ 16 oz poly, HNO3: _____

WATER LEVEL ONLY, NO SAMPLE COLLECTED: _____ REVIEWED BY: Paul Cameron DATE: 7/24/06

Atlantic Richfield Company No. # 1057

AR0073346

APPENDIX C

Waste Disposal Documents

Not Available

South Central Coastal Information Center
California State University, Fullerton
Department of Anthropology MH-426
800 North State College Boulevard
Fullerton, CA 92834-6846
714.278.5395 / FAX 714.278.5542
arthro.fullerton.edu/sccic.html - sccic@fullerton.edu
California Historical Resources Information System
Orange, Los Angeles, and Ventura Counties

August 19, 2008 SCCIC #8609.5647

Ms. Carol Rosskam
Christopher A. Joseph & Associates
11849 Olympic Blvd., Suite 101
Los Angeles, CA 90064
310.473.1600

RE: Record Search for the Millennium Hollywood Towers Project

Dear Ms. Rosskam,

As per your request received on June 2, 2008, a records search was conducted for the above referenced project. The search includes a review of all recorded archaeological sites within a ½-mile radius of the project site as well as a review of cultural resource reports on file. In addition, the California Points of Historical Interest (PHI), the California Historical Landmarks (CHL), the California Register of Historical Resources (CR), the National Register of Historic Places (NR), the California State Historic Resources Inventory (HRI), and the City of Los Angeles Historic-Cultural Monuments (LAHCM) listings were reviewed for the above referenced project site. The following is a discussion of the findings.

Due to the sensitive nature of cultural resources, archaeological site locations are not released.

Hollywood, CA. USGS 7.5' Quadrangle

ARCHAEOLOGICAL RESOURCES:

One archaeological site (19-003543) has been identified within a ½-mile radius of the project site. It is not located within the project site. It is not listed on the Archaeological Determinations of Eligibility (DOE) list. No isolates have been identified within a ½-mile radius of the project site. No isolates are located within the project site.

HISTORIC RESOURCES:

Sixty-seven additional cultural resources (19-169074, 19-168085, 19-168086, 19-168087, 19-168088, 19-168089, 19-168090, 19-168091, 19-169092, 19-168093, 19-168094, 19-168095, 19-168096, 19-168097, 19-168098, 19-168099, 19-168100, 19-168101, 19-168102, 19-168103, 19-168104, 19-168105, 19-168106, 19-168107, 19-168108, 19-168109, 19-168110, 19-168111, 19-168112, 19-168113, 19-168114, 19-

168115, 19-168116, 19-168117, 19-168268, 19-168269, 19-168270, 19-168271, 19-168272, 19 168273, 19-168274, 19-168275, 19-168276, 19-168277, 19-168278, 19-168279. 19-168280, 19-168281, 19-168282, 19-168283, 19-168284, 19-168285, 19-168286, 19-168287, 19-168288, 19-168289, 19-168290, 19-168291, 19-168292, 19-168378. 19-168437, 19-168773, 19-168774, 19-168775, 19-168776, 19-169323, 19-174178*, and 19-187897) have been identified within the a ½-mile radius of the project site. One cultural resource is located within the project site.
(= Located within the project site)*

A review of the historic maps – Santa Monica (1902, and 1921) 15' USGS - indicated that in 1902, a network of improved roads and many structures were present. Two intermittent streams ran north of the project site. The Hollywood & Cahuenga Valley Railroad ran through the project radius. Place names included Hollywood and Colegrove. In 1921, there was marked increase in development of the area. All features mentioned above were still present.

The California Point of Historical Interest (2008) of the Office of Historic Preservation, Department of Parks and Recreation, lists no properties within a ½-mile radius of the project site.

The California Historical Landmarks (2008) of the Office of Historic Preservation, Department of Parks and Recreation, lists no properties within a ½-mile radius of the project site.

The California Register of Historical Resources lists 365 properties within a ½-mile radius of the project site (see enclosed HRI list for properties marked with a +). These are properties determined to have a National Register of Historic Places Status of 1 or 2, a California Historical Landmark numbering 770 and higher, or a Point of Historical Interest listed after 1/1/1998.

The National Register of Historic Places lists 222 properties within a ½-mile radius of the project site (see enclosed HRI list for properties marked with an *).

The City of Los Angeles Historic-Cultural Monuments lists 50 properties within a ½-mile radius of the project site (see below).

No. 165 Fire Station No. 27
When built in 1930, it was considered the largest fire station west of the Mississippi (27,00 square feet); designed by Peter K. Schabarum.
Located at 1355 North Cahuenga Blvd. Declared: 10/20/76.
19-169280

No. 180 (Site of) The filming of the first talking feature film
Currently KTLA-TV, this is the site of the filming, in October, 1927, of "The Jazz Singer," the first feature film with synchronized dialogue.
Located at 5800 Sunset Blvd. Declared: 9/21/77.
5858: 19 169360

No. 193 Pantages Theatre
An exceptional example of Art Deco architecture of the 1920's and 1930's, it was designed in 1929 by architect B. Marcus Priteca and interior decorator Anthony Heinsbergen. Opened on June 4, 1930 as the last and

:argest of a chain of theaters operated by vaudeville magnate Alexander Pantages, its interior is considered by many to be the most magnificent example of theater architecture in Los Angeles. Located at 6233 Hollywood Boulevard. Declared: 7/5/78.
19-167073

No. 194 Hollywood Walk of Fame
Conceived by the Hollywood Chamber of Commerce in the late 1950's the "walk" is a tribute to the artists who have made significant contributions to the film, radio, television and recording industries. It contains over 2,500 bronze stars embedded in charcoal terrazzo squares, each with its distinctive emblem identifying the category in which the recipient is being honored. Located on Hollywood Boulevard between Gower Street and Sycamore Avenue and on Vine Street between Yucca Street and Sunset Boulevard. Declared: 7/5/78.
19-167544

No. 227 Janes House
Designed by Oliver Dennis and Lyman Farwell, the Queen Anne-style house was built in 1902 and purchased by the Janes family in 1903. The Janes sisters, Carrie, Mabel, and Grace, for many years operated the Misses Janes Kindergarten in their home. The school was attended by children of the Hollywood community including those of Cecil B. DeMille and Charles Chaplin. Located at 6541 Hollywood Boulevard, Hollywood. Declared: 4/3/80.
19-167559

No. 315 Villa Carlotta
Designed by architect Arthur E. Harvey, the four-story brick structure was constructed in 1926. The structure is designed in Spanish Churrigueresque style. Incorporated in the construction is an elaborate system of sound-proofing, a system of water filtration, a central refrigeration system and a ventilation system which changes air in each apartment every five minutes. Located at 5959 Franklin Avenue. Declared: 10/28/86.
19-169316

No. 316 William Stromberg Clock
The William Stromberg Clock, a landmark on Hollywood Boulevard since 1927, is a boulevard street clock. It is associated with of the street's oldest retailers. Located at 6439 Hollywood Boulevard. Declared: 1/7/87.
19-167555

No. 329 Chateau Elysee
The Chateau Elysee was built as a residential hotel in 1928 by Mrs. Eleanor Ince. Arthur E. Harvey designed the building in the Chateau Revival architectural style. Located at 5930 Franklin Avenue. Declared: 9/23/87.
19-169315

No. 334 Security Trust & Savings Building
One of the first high-rise (seven stories) buildings on Hollywood Boulevard, it was designed by the architectural firm of Parkinson & Parkinson in 1921 in the beaux Art and Italian Renaissance Revival styles. Located at 6381-6385 Hollywood Boulevard. Declared: 12/18/87.
6381: 19-171016

No. 448 Whitley Court
This court, designed by Dennis & Farwell, consists of a grouping of four Dutch Colonial Revival duplexes, built in 1919, along each side of a central garden, with a Craftsman house, circa 1903, in the rear. This court's two-story bungalow style is now unique in the Hollywood area. Located at 1720-1728 Whitley Avenue. Declared: 12/13/88.

No. 453 Artisan's Patio Complex
Built in 1914 and designed by Morgan, Walls & Clements it is the only historic courtyard on Hollywood Blvd. and has been used as an art gallery and art studio. Located at 6727-6733 Hollywood Boulevard. Declared: 10/17/89.
6727: 19-174201

No. 463 Afton Arms Apartments
This Mission Revival-style building was designed in 1921 by the prominent local architect Leland A. Bryant. Located at 6141 Afton Place. Declared: 11/3/89.
19-159291

No. 557 Little Country Church of Hollywood
Built in 1934 in the Classical Revival style from plans drawn by architect Paul Kingsbury. It is a physical record of a pre-World War II radio ministry church. Located at 1750 North Argyle Avenue. Declared: 10/2/92

No. 572 Warner Brothers Hollywood Theatre
A four-story, Italianate/Beaux Arts retail/office/theater building completed in 1928 from a design by prominent theater architect G. Albert Lansburgh. Located at 6433 Hollywood Boulevard. Declared: 2/9/93
6423/6433: 19-167554

No. 584 Egyptian Theatre
Built in 1922 from a design by Mayer & Holler, one of the most respected architectural firms in Los Angeles during that era. Located at 6706-6712 Hollywood Boulevard. Declared: 9/21/93
19-167076

No. 597 Raymond Chandler Square
Cahuenga Avenue and Hollywood Boulevard Intersection, Los Angeles, CA
(No further description is available)

No. 603 Villa Vallambrosa
2074 Watsonia Terrace

No. 659 Pacifics Cinerama Dome Theatre and Marquee
6360 Sunset Boulevard, Los Angeles, CA
(No further description is available)

No. 664 Broadway Department Store and Neon Sign
6300 West Hollywood Boulevard, Los Angeles, CA
(No further description is available)

No. 665 Hollywood Plaza Hotel and Neon Sign
1633 Vine Street, Los Angeles, CA
(No further description is available)

No. 666 Taft Building and Neon Sign
6280 West Hollywood Boulevard, Los Angeles, CA
(No further description is available)

No. 687 Tornberg House
1918 North Tamarind Avenue, Los Angeles, CA
(No further description is available)

No. 1030 Hollywood Paladium
6201 – 6229 West Sunset Boulevard, Los Angeles, CA
(No further description is available)

No. 2196 Whitley Heights Historic District
1900-2121 N. Las Palmas Avenue
1900-2150 Whitley Avenue (Both sides of street)
2001-2037 Holly Hill Terrace (Both sides of street)
2058-2075 Wataonia Terrace
2133-2145 Fairfield Avenue
6510-6532 Cerritos Place
6538-6542 Bella Vista Way
6603-6689 Emmet Terrace (Both sides of street)
6607-6621 Padre Terrace (Both sides of street)
6733-6767 Wedgewood Place
Bonair Place
Whitley Terrace
Los Angeles, CA
(No further description is available)

No. 2258 Montecito Apartment
6650 Franklin Avenue, Los Angeles, CA
(No further description is available)

No. 2303 Hollywood Station (U.S. Post Office)
1615 Wilcox Avenue, Los Angeles, CA
(No further description is available)

No. 2308 Hollywood Boulevard Commercial and Entertainment District
1708 Cahuenga Boulevard
1709-1715 Argyle Avenue
6200-7000 Hollywood Boulevard

6225-6249 Hollywood Boulevard
6233 Hollywood Boulevard
6253 Hollywood Boulevard
6264 Hollywood Boulevard
6300 Hollywood Boulevard
6324 Hollywood Boulevard
6331 Hollywood Boulevard
6336-6340 Hollywood Boulevard and 1560-1660 N. Ivar Avenue
6349-6353 Hollywood Boulevard
6352 Hollywood Boulevard
6367-6385 Hollywood Boulevard
6380 Hollywood Boulevard
6381 Hollywood Boulevard
6400 Hollywood Boulevard
6423 Hollywood Boulevard
6423-6445 Hollywood Boulevard and 1700-1718 Wilcox Avenue
6436 Hollywood Boulevard
6439 Hollywood Boulevard
6523 Hollywood Boulevard
6531 Hollywood Boulevard
6541 Hollywood Boulevard
6542 Hollywood Boulevard
6549-6551 Hollywood Boulevard
6553 Hollywood Boulevard
6554 Hollywood Boulevard
6600 Hollywood Boulevard
6601 Hollywood Boulevard
6606 Hollywood Boulevard
6626 Hollywood Boulevard
6630 Hollywood Boulevard
6652 Hollywood Boulevard
6663 Hollywood Boulevard
6679 Hollywood Boulevard
6701 Hollywood Boulevard
6706-6712 Hollywood Boulevard and 1650-1654 McCadden Place
6708 Hollywood Boulevard
6718 Hollywood Boulevard
6724 Hollywood Boulevard
6727-6733 Hollywood Boulevard
6740 Hollywood Boulevard
6743 Hollywood Boulevard
6755 Hollywood Boulevard
6765 Hollywood Boulevard
6766 Hollywood Boulevard
6777 Hollywood Boulevard
6780 Hollywood Boulevard
6800 Hollywood Boulevard
6806 Hollywood Boulevard
6834-6838 Hollywood Boulevard
6840 Hollywood Boulevard
6904 Hollywood Boulevard
6915-6927 Hollywood Boulevard

7000-7034 Hollywood Boulevard
7001-7039 Hawthorn Avenue
Hollywood Boulevard and Cahuenga Intersection
Ivar Street
N. Highland Avenue
N. Vine Street
Los Angeles, CA
(No further description is available)

No. 2382 La Belle Tour
6200 Franklin Avenue, Los Angeles, CA
(No further description is available)

No. 2400 6000 Carlton Way, Los Angeles, CA
(No further description is available)

No. 2401 6004 Carlton Way, Los Angeles, CA
(No further description is available)

No. 2402 6008 Carlton Way, Los Angeles, CA
(No further description is available)

No. 2403 6012 Carlton Way, Los Angeles, CA
(No further description is available)

No. 2404 6016 – 6018 Carlton Way, Los Angeles, CA
(No further description is available)

No. 2405 6082 Selma Avenue, Los Angeles, CA
(No further description is available)

No. 2406 6070 – 6072 ½ Selma Avenue, Los Angeles, CA
(No further description is available)

No. 2407 6088 – 6088 ½ Selma Avenue, Los Angeles, CA
(No further description is available)

No. 2409 6128-6134 ½ Carlos Avenue, Los Angeles, CA
(No further description is available)

No. 2413 6063 – 6065 ½ Harold Way, Los Angeles, CA
(No further description is available)

No. 2417 6046 – 6048 Carlton Way, Los Angeles, CA
(No further description is available)

No. 2418 6118 Carlos Avenue, Los Angeles, CA
(No further description is available)

No. 2419 6136 – 6136 ½ Carlos Avenue, Los Angeles, CA
(No further description is available)

No. 2421 6100 De Longpre Ave, Los Angeles, CA
(No further description is available)

No. 2422 6117 De Longpre Ave, Los Angeles, CA
(No further description is available)

No. 2423 6122 De Longpre Ave, Los Angeles, CA
(No further description is available)

No. 2424 6220 De Longpre Ave, Los Angeles, CA
(No further description is available)

No. 2430 6160 – 6168 Hollywood Boulevard, Los Angeles, CA
(No further description is available)

No. 2431 6549 – 6551 Hollywood Boulevard, Los Angeles, CA
(No further description is available)

No. 2441 6074 – 6074 ½ Selma Avenue, Los Angeles, CA
(No further description is available)

No. 2464 Hollywood YMCA
1541-1553 N. Hudson Ave/6550 6600 Selma Ave, Hollywood, CA
(No further description is available)

No. 2465 I. Magnin & Company (Platos Retreat West)
1560 – 1560 North Ivar Avenue/6336 – 6340 Hollywood Boulevard
Los Angeles, CA
(No further description is available)

The California Historic Resources Inventory lists 752 properties that have been evaluated for historical significance within a ½-mile radius of the project site (see enclosed HRI properties list).

PREVIOUS CULTURAL RESOURCES INVESTIGATIONS:

Fifteen studies (LA447, LA1578, LA3496, LA3510, LA3682, LA4345, LA4580, LA4909, LA5095, LA5332, LA5348, LA6811, LA7992, LA8020, and LA8251) have been conducted within a ½-mile radius of the project site. Of these, none are located within the project site. There are 32 additional investigations located on the Hollywood, CA. 7.5' USGS Quadrangle that are potentially within a ½-mile radius of the project site. The reports are not mapped due to insufficient locational information.

RECOMMENDATIONS

Based on the results of the records search, cultural resources at the project site (the Capitol Records Tower is on the California Register) and in the area of potential effect may be affected by this project. While current surface conditions do not appear to allow for an adequate survey of potential surface or sub-surface cultural artifacts, a Phase I survey that also includes additional archival research could be useful in

determining the history of the project site and the likelihood of encountering cultural resources during project activities. Therefore, a Phase-I survey is recommended for the project, prior to the approval of project plans. It is also recommended that any historic properties (45 years and older) in the area of potential effect be identified, recorded, and evaluated for local, state, or national significance prior to the approval of project plans. It is also recommended that the Native American Heritage Commission should be consulted to identify if any additional traditional cultural properties or other sacred sites are known to be in the area.

The professional consultant you retain may request the records search map, archaeological site records, and bibliography from the Information Center referencing the SCCIC number listed above for a fee (per the fee schedule). Any resulting reports by the qualified consultant should be submitted to the South Central Coastal Information Center as soon as possible.

If you have any questions regarding the results presented herein, please contact the office at 714.278.5395 Monday through Thursday 9:00 am to 3:30 pm.

Should you require any additional information for the above referenced project, reference the SCCIC number listed above when making inquiries. Requests made after initial invoicing will result in the preparation of a separate invoice.

Sincerely,
SCCIC

Michelle Galaz
Staff Researcher

Enclosures:

(X) HRI – 70 pages
(X) National Register Status Codes – 3 pages
(X) Invoice #8609.5647

ADDRESS-NUMBER	PREFIX	STREET NAME	...	NAME ...	CITY NAME ...	QUA	YR-C	DOC CODE	FOR-RECORDED-NUMBER	STRUCTURE	GRADE	QUALITY
0814		49th W [illegible]	ST		[illegible]-Circle	U	1925	PROT.REVOK.	M0397[illegible]	5/15/03	GY	
0814		49th W [illegible]	ST		[illegible]-Circle	U	1911	OTHR.REVOK.	M03e9[illegible]	10/15/01	GY	
0814		49th W [illegible]	ST		[illegible]-Circle	U	1925	PROT REVOK	M1057[illegible]	11/30/99	GY	
2[illegible]		[illegible] W [illegible]	ST		[illegible]-Circle	U	1941	MORT.REL	[illegible]-99 [illegible]	30/04/99	GY	
								PROT.REVOK	M0399[illegible]	06/16/99	GY	
1[illegible]		[illegible] W [illegible]	St		[illegible]-Circle	P	1946	M.DT.REL.	[illegible]-99 [illegible]	01/14/02	GY	
								PROT REVOK	M1[illegible]	01/14/02	GY	
1951		[illegible] W [illegible]	ST		[illegible]-Circle	P	1946	MORT REL	[illegible]-02 0011 [illegible]	01/16/02	GY	
								PROT REVOK	M[illegible]	01/16/02	GY	
1947		30th PLACE NW		[illegible] FOR [illegible] [illegible]	[illegible] HEIGHTS	F		PROT.REVOK.	M0[illegible]	06/15/01	GY	
1[illegible]		[illegible] PLACE NW		[illegible] [illegible] [illegible]	[illegible] HEIGHTS	V	1911	PROT REVOK	M[illegible]	11/14/01	GY	
								M.DT REL	[illegible]-02 [illegible]	11/30/02	GY	
								PROT.REVOK	M[illegible]	12/18/02	GY	
09[illegible]		[illegible] VALLEY DR		[illegible] [illegible]	[illegible] [illegible]	W	1917	MORT REL	DOC 19 94 0401 0020	06/19/94	GY	A
								PROT REVOK	M[illegible]	06 10/94	GY	A
2[illegible]		[illegible] [illegible]	N		[illegible] [illegible]	P	1924	MORT REL	[illegible] 19-04 0179-0211	05/10/04	GY	
								PROT REVOK	[illegible]	07/10/04	GY	
[illegible]		[illegible] ANDY H AVE		[illegible] [illegible] [illegible] [illegible]	[illegible]	P	1914	MORT REL	[illegible]-19 [illegible]	03/07/95	GY	
								PROT.REVOK.	[illegible]	08/07/97	GY	
2[illegible]		[illegible] [illegible] [illegible]		[illegible] [illegible] THEATER	[illegible]	U	1930	PROT REVOK	M[illegible]	11/19/99	GY	ADT
1[illegible]		[illegible] [illegible] ST		[illegible] [illegible] [illegible]	[illegible]	P	1930	MORT REL	DOC-19-94-[illegible] $[illegible]	02/08/94	GY	
								PROT REVOK	[illegible]	03/09/94	GY	
1[illegible]		[illegible] [illegible] ST		[illegible] [illegible] [illegible]	[illegible]	P	1921	MORT.REL	DOC-19-94-[illegible] [illegible]	03/03/94	GY	
								PROT REVOK.	M[illegible]	03/03/94	GY	
1[illegible]		[illegible] [illegible] ST		[illegible] [illegible] [illegible]	[illegible]	P	[illegible]	MORT REL	DOC 19 94 0401 [illegible]	03/30/94	GY	
								PROT REVOK	M[illegible]	04/08/94	GY	
1[illegible]		[illegible] [illegible] ST		[illegible] [illegible] [illegible]	[illegible]	P		MORT REL	DOC 19 94 0413 [illegible]	04/08/94	GY	
								PROT.REVOK.	M[illegible]	7/08/96	GY	
1[illegible]		[illegible] [illegible] ST		[illegible] [illegible] [illegible]	[illegible]	P	1926	MORT.REL.	DOC-19-94-[illegible] [illegible]	03/09/94	GY	
								PROT REVOK.	M[illegible]	03/09/94	GY	
1[illegible]		[illegible] [illegible] ST		[illegible] [illegible] [illegible]	[illegible]	P	1911	MORT REL	DOC 19 94-0413 [illegible]	04/08-94	GY	
								PROT.REVOK.	M[illegible]	7/08/96	GY	
[illegible]	[illegible]	[illegible] [illegible] AVE		[illegible] AVE. [illegible] [illegible]	[illegible]	P	1911	MORT.REL.	[illegible]		GY	
1[illegible]		15th PLACE NW		THE [illegible] [illegible]	[illegible]	P	1915	MORT REL	DOC 19 92 0[illegible]	09/22/92	GY	
								PROT PROT	M[illegible]	10/22/92	GY	
1[illegible]		[illegible] N [illegible]	ST		[illegible]	P	1913	MORT.REVOK.	M[illegible]	1/22/91	GY	
1[illegible]		[illegible] N [illegible]	AVE		[illegible]	P	1911	MORT.REL.	DOC-19-90 [illegible]	10/07/90	GY	
								PROT REVOK	M[illegible]	10/07/90	GY	
1[illegible]		[illegible] N [illegible]	St		[illegible]		1915	MORT.REL	DOC 19 91 0120 [illegible]	01/31/91	GY	
								PROT REVOK.	M[illegible]	11/15/91	GY	
1[illegible]		[illegible] N [illegible]	ST		[illegible]		1917	MORT REL	[illegible]- 19 [illegible] [illegible]	11/1/91	GY	
								PROT.REVOK.	M[illegible]	11/1/91	GY	
[illegible]		[illegible] [illegible] AVE			[illegible]	P	1916	MORT REVOK.	M[illegible]	11/22/91	GY	
[illegible]	[illegible]	[illegible] [illegible] ST		[illegible] [illegible]	[illegible]	P	1921	MORT REL.	[illegible]-99 [illegible] [illegible]	11/1/99	222	AL
								LOA LIEN	[illegible] 19-0198	10/1,98	-3	
								REV. REVK	M[illegible]	12/11/95	222	AL
								MORT [illegible]	9911 2445 [illegible]		9k	
[illegible]				[illegible] [illegible] [illegible] [illegible]	[illegible] [illegible] PARK	U		[illegible]	DOC-[illegible] [illegible]	01/16/01	222	C
								PROT.REVOK	M[illegible]	10/16/96	222	C
06-[illegible]		D		[illegible] [illegible] PARK [illegible] [illegible]	[illegible] [illegible] PARK	U		PROT [illegible]	M[illegible]	07/18/89	01	

AR0073358

AR0073359

AR0073360

AR0073361

PROPERTY NUMBER	...	STREET ADDRESS	NAME	CITY	...	ZIP	...	...	...
84000...	...	6253 ATOLL PL	...	LOS ANGELES	...	9...	...	...	...
92000...	...	6264 ATOLL PL	...	LOS ANGELES	...	9...	...	...	...
84000...	...	6250 ATOLL PL	...	LOS ANGELES	...	9...	...	...	...
84000...	...	6260 ATOLL PL	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5816 ALABAMA ST	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5830 ALABAMA ST	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5910 ALABAMA AVE	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5926 ALABAMA AVE	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5940 ALABAMA AVE	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5952 ALABAMA AVE	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5946 ALABAMA AVE	...	LOS ANGELES	...	9...	...	...	...
84000...	...	ALAMEDA ST	6 ST CROSSES ARROYO SECO. USE BOTH	LOS ANGELES	...	9...	...	...	...
84000...	...	ALAMEDA ST	PUBLIC TRUST RESTORATION SITE - FL	LOS ANGELES	...	9...	...	...	...
84000...	...	941 ALAMEDA ST	EL PUEBLO ENN	LOS ANGELES	...	9...	...	...	...
84000...	...	909 ALAMEDA ST	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5400 ALCOVE AVE	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5010 ALEGRIA PL	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5116 ALEGRIA ST	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5130 ALEGRIA ST	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5140 ALEGRIA ST	...	LOS ANGELES	...	9...	...	...	...
84000...	...	5146 ALEGRIA ST	...	LOS ANGELES	...	9...	...	...	...
84000...	...	ALEGRIA ST	1000-1050 ALCORA ST/5400 SUNSET	LOS ANGELES	...	9...	...	...	...
84000...	...	4910 ALHAMBRA AVE	RESIDENT TOWER/ST & 49 TOWER	LOS ANGELES	...	9...	...	...	...
84000...	...	4924 ALHAMBRA AVE	EDITED BY PRESERVATION	LOS ANGELES	...	9...	...	...	...
84000...	...	4938 ALHAMBRA AVE	BUILDING NAME ASSISTANCE	LOS ANGELES	...	9...	...	...	...
84000...	...	4946 ALHAMBRA AVE	EDITED BY PRESERVATION	LOS ANGELES	...	9...	...	...	...
84000...	...	4949 ALHAMBRA AVE	SOLARIA PETTILLO	LOS ANGELES	...	9...	...	...	...
84000...	...	2006 ALICE ST	2006-2008 ALICE ST	LOS ANGELES	...	9...	...	...	...

AR0073362

ASSESSOR PARCEL NO	PRIMARY M	SECONDARY ASSESSE...	... ...	LEGAL...	CITY.NAME.	CAT	ZONE	OWNER/PROP	PRIOR REFERENCE NUMBER	SPECIAL DATE	TAX	CODE
								PROP.REFER.	20[illegible]776	02/17/76	187	
								OTHER OWNER.	0018 0781 0116		187	
7[illegible]300	19-[illegible]	0131 DEASON ST			[illegible] PASADENA		1[illegible]	OTHER OWNER.	1069 1255 0117		18	
	19-[illegible]											
6[illegible]871	19-[illegible]	0134 DEASON ST			[illegible] PASADENA	P	1914	OTHER OWNER.	0759-0761 0110		18	
	19-[illegible]											
7[illegible]092	19-[illegible]	1401 DEASON ST			[illegible] ARCADIA	P	1915	OTHER OWNER.	0053-1255 0010		18	
	19-[illegible]											
1[illegible]8[illegible]	19-[illegible]	4567 PEARL ST			[illegible] ARCADIA	P	1921	OTHER OWNER.	0051-1259 0170		1	
	19-[illegible]											
7[illegible]404	19-[illegible]	0111 DEASON ST			[illegible] ARCADIA	P	1912	OTHER OWNER.	0051 [illegible]469 0010		19	
	19-[illegible]											
1[illegible]2047		0511 PEARL ST			[illegible] ARCADIA		1920	OTHER REFER	1[illegible]08-19 [illegible]1,47 1[illegible]02	11/[illegible]/84	6Y	
								PREVIOUS REFER.	20[illegible]0766	11/[illegible]/76	6Y	
5[illegible]4[illegible]	19-[illegible]	0131 DEASON ST			[illegible] ARCADIA	P	1941	OTHER OWNER.	0051 [illegible]461-0001		19	
	19-[illegible]											
6[illegible]218	19-[illegible]	BEAUTIFICATION TR		1[illegible]07-1[illegible]07 BLK 6[illegible] BENCHMARK DRIVE	[illegible] ARCADIA	P	1[illegible]04	OTHER OWNER.	0051-0699 5999		502	
6[illegible]179	19-[illegible]	BEAUTIFICATION LO			[illegible] ARCADIA	P	1[illegible]07	OTHER OWNER.	0051-0698 6001		502	
6[illegible]282	19-[illegible]	BEAUTIFICATION LO			[illegible] ARCADIA	P	1[illegible]04	OTHER OWNER.	0051 0698 5999		502	
6[illegible]4[illegible]	19- 6[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1[illegible]03	OTHER OWNER.	0051 0699 6[illegible]5		502	
6[illegible]291	19-[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1[illegible]10	OTHER OWNER.	0051-0695 6[illegible]5		502	
6[illegible]206	19-[illegible]	BEAUTIFICATION LO			[illegible] ARCADIA	P	1[illegible]24	OTHER OWNER.	0051 0699-6[illegible]6		502	
6[illegible]96	19-[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1[illegible]10	OTHER OWNER.	0051-0695 [illegible]001		502	
6[illegible]297	19-[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1[illegible]04	OTHER OWNER.	0051-0698-0002		502	
6[illegible]298	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695 [illegible]004		502	
6[illegible]299	19-[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1926	OTHER OWNER.	0051 0698-0004		502	
6[illegible]30	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1919	OTHER OWNER.	0051 0698-0010		502	
6[illegible]3[illegible]	19-[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1[illegible]21	OTHER OWNER.	0051 0698 0011		502	
6[illegible]32	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1913	OTHER OWNER.	0051-0695-0010		502	
6[illegible]151	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1921	OTHER OWNER.	0051-0696-0015		502	
6[illegible]4	19- 6[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1917	OTHER OWNER.	0051 0696 0014		502	
6[illegible]105	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1914	OTHER OWNER.	0051 0698 6019		502	
6[illegible]106	19-[illegible]	BEAUTIFICATION DR		KNOLL ACTIVISTS	[illegible] ARCADIA	P	1930	OTHER OWNER.	0051-0695 0014		502	
6[illegible]107	19- 6[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	I	1[illegible]0	OTHER OWNER.	0051 0696 0017		701	
6[illegible]10[illegible]	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1909	OTHER OWNER.	0051 0695 6018		502	
6[illegible]109	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695 [illegible]019		502	
6[illegible]110	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1922	OTHER OWNER.	0051-0696 6[illegible]3		502	
6[illegible]1	9- 6[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051 0696-6021		502	
6[illegible]112	19-[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1916	OTHER OWNER.	0051-0697 6019		502	
6[illegible]11[illegible]	19-[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1920	OTHER OWNER.	0051 0698 6[illegible].		502	
6[illegible]1	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1909	OTHER OWNER.	0051-0696 6021		502	
6[illegible]116	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1913	OTHER OWNER.	0051-0695-6020		502	
6[illegible]1	9- 6[illegible]	BEAUTIFICATION TR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051 0696-6021		502	
6[illegible]118	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]119	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]120	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]121	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]122	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]123	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]124	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]125	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]126	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]127	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]128	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]129	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]130	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]131	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]132	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]133	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]134	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]135	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]136	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]137	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]138	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]139	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]140	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]141	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]142	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]143	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]144	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]145	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]146	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]147	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]148	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]149	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]150	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]151	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]152	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]153	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]154	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]155	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]156	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]157	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]158	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]159	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]160	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]161	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]162	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]163	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]164	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]165	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]166	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]167	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]168	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]169	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]170	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]171	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]172	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]173	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]174	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]175	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]176	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]177	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]178	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]179	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]180	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]181	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]182	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]183	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]184	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]185	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]186	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]187	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]188	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]189	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]190	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]191	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]192	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]193	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]194	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]195	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]196	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]197	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]198	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]199	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]200	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]201	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]202	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]203	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]204	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]205	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]206	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]207	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]208	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]209	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]210	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]211	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]212	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]213	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]214	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]215	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]216	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]217	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]218	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]219	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]220	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]221	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]222	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]223	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]224	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]225	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]226	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]227	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]228	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]229	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]230	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]231	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]232	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]233	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]234	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]235	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]236	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]237	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]238	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]239	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]240	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]241	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]242	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]243	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]244	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]245	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]246	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]247	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]248	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]249	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]250	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]251	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]4		502	
6[illegible]252	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]5		502	
6[illegible]253	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]6		502	
6[illegible]254	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]7		502	
6[illegible]255	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]8		502	
6[illegible]256	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]9		502	
6[illegible]257	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]0		502	
6[illegible]258	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]1		502	
6[illegible]259	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]2		502	
6[illegible]260	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OWNER.	0051-0695-6[illegible]3		502	
6[illegible]261	19-[illegible]	BEAUTIFICATION DR			[illegible] ARCADIA	P	1911	OTHER OW

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PROPERTY NUMBER	OPERATOR NUMBER	STREET ADDRESS	CITY NAME	ZIP	SEC	TWP	RNG	API NUMBER	STATUS	TYPE	CLASS
020042	10-190741	415 [illegible] ST	SAMUEL H STOCKER RESIDENCE	LOS ANGELES		F	1455	4TH16	15-151225	10/06/21	1	
									[illegible]	[illegible]	[illegible]	
									[illegible]	[illegible]	[illegible]	
									[illegible]	[illegible]	[illegible]	
024011	19 170911	16 W [illegible] CT	[illegible] PIKE [illegible]	LOS ANGELES		F	1800	[illegible]	[illegible]	[illegible]	[illegible]	
									[illegible]	[illegible]	[illegible]	
									[illegible]	[illegible]	[illegible]	
1[illegible]		6710 BEVERLY AVE		LOS ANGELES		D	1914	[illegible]	[illegible]	09/30/71	OY	
1[illegible]		6711 BEVERLY AVE		LOS ANGELES		D	1923	[illegible]	[illegible]	06/30/71	OY	
04[illegible]	19 [illegible]	8387 [illegible]	[illegible] [illegible]	LOS ANGELES		N	1971	[illegible]	[illegible]	08/31/74	OY	
								[illegible]	[illegible]	[illegible]	[illegible]	
02[illegible]	19-[illegible]	6010 BEVERLY BLVD		LOS ANGELES		P	1911	[illegible]	[illegible]	[illegible]	[illegible]	
	19-[illegible]											
1[illegible]		[illegible] BEVERLY BLVD	[illegible] [illegible] [illegible]	LOS ANGELES		P	50[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1[illegible]	19 [illegible]	[illegible] BEVERLY BLVD	[illegible] [illegible] [illegible]	LOS ANGELES		D	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
05[illegible]	19 [illegible]	8[illegible] BEVERLY BLVD		LOS ANGELES		P	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
								[illegible]	[illegible]	[illegible]	[illegible]	
1[illegible]		1911 BEVERLY BLVD		LOS ANGELES		P	1947	[illegible]	[illegible]	[illegible]	[illegible]	
14[illegible]		2419 BEVERLY BLVD		LOS ANGELES		L	1924	[illegible]	[illegible]	06/21/01	333	T
								[illegible]	[illegible]	12/17/21	333	T
008119	19 [illegible]	1393 BEVERLY BLVD	[illegible] [illegible]	LOS ANGELES		D	1924	[illegible]	[illegible]	[illegible]	OIL	
0[illegible]	19 [illegible]	7410 BEVERLY BLVD	[illegible] [illegible] [illegible] [illegible]	LOS ANGELES		P	19[illegible]	[illegible]	[illegible]	04/10/91	11	
	19 [illegible]								[illegible]	11/01/94	15	
	19-[illegible]											
1[illegible]		7311 BEVERLY BLVD		LOS ANGELES		P		[illegible]	[illegible]	[illegible]	OY	
12[illegible]	19 [illegible]	[illegible] BEVERLY BLVD	[illegible] [illegible] [illegible]	LOS ANGELES		D	1911	[illegible]	[illegible]	[illegible]	OY	
	19-[illegible]								[illegible]	[illegible]	[illegible]	
10[illegible]	19-[illegible]	7411 BEVERLY BLVD	[illegible] [illegible] [illegible]	LOS ANGELES		P	1911	[illegible]	[illegible]	[illegible]	[illegible]	
	19 [illegible]								[illegible]	[illegible]	[illegible]	
	19-[illegible]											
04[illegible]	19 [illegible]	6[illegible] B[illegible] V[illegible]		LOS ANGELES		N		[illegible]	[illegible]	11/29/94	OY	
								[illegible]	[illegible]	[illegible]	[illegible]	
11[illegible]	19 [illegible]	BEVERLY GLEN WATER CO#	BEVERLY GLEN WATER CO#	LOS ANGELES		N	1955	[illegible]	[illegible]	11/29/95	WY	
								[illegible]	[illegible]	11/26/96	OY	
02[illegible]	19 [illegible]	4441 BIG [illegible] CANYON RD	LOT #1, TR[illegible] TRACT	LOS ANGELES		P	1931	[illegible]	[illegible]	[illegible]	OI	
0[illegible]	0 [illegible]	1[illegible] BIG K 01	[illegible] [illegible]	LOS ANGELES		P		[illegible]	[illegible]	06/01/94	OL	
								[illegible]	[illegible]	[illegible]	GS	
1[illegible]		2[illegible] BIGKEY[illegible] 01		LOS ANGELES			1931	[illegible]	[illegible]	[illegible]	OY	
								[illegible]	[illegible]	[illegible]	OY	
1[illegible]	19 [illegible]	[illegible] BIGGER ST	[illegible]ENNAL HIGH SCHOOL	LOS ANGELES		P		[illegible]	[illegible]	[illegible]	2[illegible]	
								[illegible]	[illegible]	[illegible]	2[illegible]	
2[illegible]	19 1[illegible]	14[illegible] [illegible] ST	[illegible]PARTMENT REVABILITATION	LOS ANGELES		O		[illegible]	[illegible]	12/01/87	OY	
1[illegible]		2[illegible] BLANCHARD ST		LOS ANGELES		P	1907	[illegible]	[illegible]	[illegible]	OY	
17[illegible]	19 1[illegible]	3[illegible] BLANCHARD ST		LOS ANGELES		O	1930	[illegible]	[illegible]	[illegible]	SY	
0[illegible]	1 [illegible]	1[illegible] BLANCHARD ST		LOS ANGELES		O		[illegible]	[illegible]	[illegible]	SY	
35[illegible]	19 [illegible]	1[illegible] BLUEGRASS LN		LOS ANGELES		O	1927	[illegible]	[illegible]	[illegible]	SY	
0[illegible]	19-[illegible]	100 BOYCE ST[illegible] AV	[illegible] OF FLORAL - [illegible] [illegible]	LOS ANGELES		C	1960	[illegible]	[illegible]	[illegible]	[illegible]	
1[illegible]	19 [illegible]	5[illegible] BOW AIR TR		LOS ANGELES		P	1940	[illegible]	[illegible]	[illegible]	OI	GS
02[illegible]	19 [illegible]	2[illegible] BOW AIR [illegible]		LOS ANGELES		P	1940	[illegible]	[illegible]	[illegible]	OI	GS
02[illegible]	19 [illegible]	5[illegible] BOW AIR [illegible]		LOS ANGELES		P	1[illegible]	[illegible]	[illegible]	[illegible]	OI	GS
06[illegible]		1[illegible] BOWDITCH BEACH TR		LOS ANGELES		O	1911	[illegible]	[illegible]	12/22/03	OY	
01[illegible]	19 [illegible]	8[illegible] BOWDITCH BEACH RD		LOS ANGELES		O		[illegible]	[illegible]	[illegible]	OY	
1 [illegible]		1[illegible] BOWDITCH BEACH RD		LOS ANGELES			1920	[illegible]	[illegible]	10/05/80	GS	

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PROPERTY NAME	PRIMARY #	STREET ADDRESS	NAME	CITY/ZIP	CODE	ST	DATE	DOE-TYPE	NR REFERENCE-NUMBER	START-DATE	DOE	OFF
								PROJ REVW	PUE0133015	03/01/00	SV	
		2140 [illegible] ST		LOS ANGELES		U	1901	HIST PRO	DOE-10 5-0124-1006	07/01/99	SV	
								PROJ REVW	PUE9902015	03/01/99	SV	
[illegible]	LA [illegible]	[illegible] SUNSET BLVD		LOS ANGELES		P	1928	PROJ.REVW.	7000[illegible]0	11/19/96	SV	
[illegible]		[illegible] [illegible] ST		LOS ANGELES		U	1924	HIST.RES.	DOE-10-87 0047 1100	02/01/00	SV	
								PROJ REVW.	9700000015	03/01/97	SV	
[illegible]		[illegible] [illegible] ST		LOS ANGELES			1945	EligD SES	DOE 10-84 0167 0700	09/30/97	SV	
								PROJ REVW.	4700110102	03/10/97	SV	
[illegible]	LA [illegible]	[illegible] [illegible] DR	[illegible] WATER TOWER WATER TANK	LOS ANGELES		H	1924	HIST.REG	DOE-10 5s 0170 0141	12/04/95	SV	
								PROJ.REVW	9801402037	07/01/98	SV	
[illegible]	LA [illegible]	[illegible] [illegible] AVE		LOS ANGELES		P		HIST SURV	1983 0819 0000		SV	
[illegible]	LA [illegible]	[illegible] SUNSET AVE		LOS ANGELES		P		HIST SURV.	1983 0819 0000		SV	
[illegible]	LA [illegible]	[illegible] HOLLYWOOD BLVD	MASONIC & MASONIC BUILDINGS	LOS ANGELES		P	1908	HIST.SURV	1983 0811 0000		SV	
[illegible]	LA [illegible]	[illegible] [illegible] AVE		LOS ANGELES		P		HIST SURV	1983-0831-0000		SV	
[illegible]	LA [illegible]	[illegible] [illegible] AVE		LOS ANGELES		P		HIST SURV	1983 0401-0000		SV	
[illegible]	LA [illegible]	[illegible] [illegible] AVE		LOS ANGELES		P	1921	PROJ REVW	9609111109	12/24/96	SV	
[illegible]		[illegible] [illegible] Blvd		LOS ANGELES			1921	PROJ REVW.	9707010101	11/04/97	SV	
[illegible]		[illegible] [illegible] Blvd		LOS ANGELES			1926	HIST.REG.	DOE-10 1s 1.50 0100	12/05/97	SV	
								PROJ.REVW.	9807210009	11/09/98	SV	
[illegible]		[illegible] [illegible] ST	[illegible][illegible][illegible][illegible]	LOS ANGELES		P	1961	PROJ.REVW.	9709190026	10/07/97	SV	
[illegible]		[illegible] [illegible] ST		LOS ANGELES				HIST.REG.	DOE 10-01 0148 1100	11/02/99	SV	
								PROJ.REVW.	9812210019	04/04/99	SV	
[illegible]	LA [illegible]	[illegible] [illegible] ST		LOS ANGELES		P		PROJ.REVW	9808190218	04/14/98	SV	
[illegible]	LA [illegible]	[illegible] [illegible] AVE		LOS ANGELES		P	1921	PROJ REVW	9802150243	03/13/98	SV	
[illegible]		[illegible] [illegible] AVE		LOS ANGELES			1929	HIST REG	DOE 10 01 0147-0700	12/11/98	SV	
								PROJ.REVW	9809190103	07/13/98	SV	
[illegible]		[illegible] [illegible] AVE		LOS ANGELES		P	1927	HIST.REG.	DOE-10 97-0231 0700	09/10/98	SV	
								PROJ REVW	9809190112	09/09/98	SV	
[illegible]	LA [illegible]	[illegible] [illegible] ST		LOS ANGELES		P	1913	HIST SURV.	1983-0719 0000		SV	
[illegible]		[illegible] [illegible] AVE	[illegible][illegible] & DEPOT BLDG	LOS ANGELES		H	1924	HIST.REG.	DOE 10-89 0219 [illegible]	01/07/97	SV	
								PROJ REVW	9701[illegible]7	01/07/97	SV	
[illegible]		[illegible] [illegible] AVE		LOS ANGELES		P	1922	HIST NPS	DOE 10 [illegible]-0247-0000	0 /0 /97	SV	
								PROJ REVW	9708[illegible]2	01/07/98	SV	
[illegible]	LA [illegible]	[illegible] BROADWAY	[illegible] BLDG CO [illegible] ST	LOS ANGELES		P	1907	HIST.SURV.	1983-0719 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY	BROADWAY Street Bridge	LOS ANGELES		P	1.0	HIST.SURV.	1981-0702 0700		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY	[illegible] LOS ANGELES [illegible]ROAD CO.	LOS ANGELES		N	1871	HIST.REG.	DOE2 LAND-0[illegible]	03/07/96	SV	
[illegible]		[illegible] [illegible] BROADWAY	VICTOR CLOTHING COMPANY	LOS ANGELES			1914	NRS CERT.	9[illegible]7 9-19 0000	11/07/97	SV	
[illegible]	LA [illegible]	[illegible] BROADWAY	BROADWAY DEPARTMENT STORE, BROADWAY	LOS ANGELES		P	1917	HIST.SURV.	1981 0704 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1911	HIST SURV	1984-1107-0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1907	HIST SURV	1984-1077-0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1911	HIST STRV	1983 1011-0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1911	HIST STRV	1984 1011 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1911	HIST SURV.	1983 1067 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1913	HIST SURV.	1983 1067 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1925	HIST SURV	1983 1042 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1906	HIST STRV	1983 1063 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		C	1907	HIST SURV	0975-1063 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1914	HIST SURV	0975 1063 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1912	HIST.SURV.	1983-1063 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1909	HIST SURV.	1983 1067-0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	0	PRS DEMO	9[illegible]7 9-19 0000	11/22/13	SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1900	HIST SURV	1983 1063 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1906	HIST SURV.	1983-1063 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY		LOS ANGELES		P	1906	HIST SURV.	1983 1101-0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY	STREET [illegible]	LOS ANGELES		H	1926	HIST SURV	1983 1011 0000		SV	
[illegible]	LA [illegible]	[illegible] BROADWAY	STREET [illegible]	LOS ANGELES		P	1921	HIST.SURV.	1983 1067 0000		SV	

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PROPERTY NAME	ADDRESS	CITY NAME	CODE	YR BUILT	ORG-PROP	PROPERTY NUMBER	STATUS	NPS	CITY
[illegible]	[illegible] BROADWAY AVE	[illegible]	LOS ANGELES	P	1909	DIST.HISTV.	0051 0065-0999		582	
[illegible]	[illegible] BROADWAY AVE		LOS ANGELES	P	1901	DIST.HISTV.	0051 0023-0013		39	
[illegible]	[illegible] [illegible] AVE	[illegible] BOOKS AND BAKERY	LOS ANGELES	P	1929	HIST.RES	DOF 10 94-0481-1700	06/10/94	6Y	
						PROJ.REVW.	PT#941062.A	08/10/94	6Y	
						PROJ.REVW.	IDF:920/295	01/21/93	6Y	
[illegible]	[illegible] BROADWAY AVE		LOS ANGELES	C	1949	PROJ.REVW.	IDF:830/2059	01/21/93	6Y	
[illegible]	[illegible] BROADWAY AVE	[illegible] VILLA VINCENZO	LOS ANTONIO	J	1927	DIST.HIS.	DOE:10 94-0651 6.09	09/30/94	6Y	
						PROJ.REVW.	PT#940796	04/07/95	5Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1921	PROJ.REVW.	HOL-4012-C	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1931	PROJ.REVW.	IDF:830/2059	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1923	PROJ.REVW.	IDF:830/2010	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1924	PROJ.REVW.	IDF:830/2011	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1924	PROJ.REVW.	IDF:830/2012	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1911	PROJ.REVW.	IDF:830/2013	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1921	PROJ.REVW.	IDF:830/2014	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1921	PROJ.REVW.	IDF:830/2015	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1921	PROJ.REVW.	IDF:830/2016	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1921	PROJ.REVW.	IDF:830/2017	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1924	PROJ.REVW.	IDF:830/2018	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1924	HIST.RES	DOF 10-94 0092 6.00	05/04/94	6Y	
						PROJ.REVW.	PT#940296	04/04/94	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1920	PROJ.REVW.	IDF:830/2019	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1920	HIST.RES	DOE 10 94-0631-0000	06/30/94	6Y	
						PROJ.REVW.	PT#940796	05/30/94	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1924	PROJ.REVW.	IDF:830/2020	01/21/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1921	HIST.RES.	DOE 10-94-0496 1.00	11/30/94	6Y	
						PROJ.REVW.	PT#940796	12/30/94	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1923	PROJ.REVW.	IDF:830/2021	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1919	PROJ.REVW.	IDF:830/2022	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1921	PROJ.REVW.	IDF:830/2023	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1921	PROJ.REVW.	IDF:830/2024	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1924	PROJ.REVW.	IDF:830/2025	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1920	PROJ.REVW.	IDF:830/2026	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1923	PROJ.REVW.	IDF:830/2027	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1923	PROJ.REVW.	IDF:830/2028	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1923	PROJ.REVW.	IDF:830/2029	01/06/93	6Y	
[illegible]	[illegible] AVE		LOS ANGELES	U	1924	PROJ.REVW.	IDF:830/2030	01/06/93	6Y	
[illegible]	[illegible] AVE	[illegible]	LOS ANGELES	J	1927	HIST.SURV.	0053 4425 0020		5Y	
[illegible]	[illegible] AVE	[illegible]	LOS ANGELES	C		PROJ.REVW.	NOM@706028	09/15/93	1Z	
[illegible]	[illegible] AVE	J. A. [illegible]	LOS ANGELES	P	1911	HIST.SURV.	0053 1044 0100		5Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1911	HIST.SURV.	0051-1043 0010		5Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1913	HIST.SURV.	0051-1037-0010		582	
[illegible]	[illegible] AVE		LOS ANGELES	P	1913	HIST.SURV.	0051 1043-0010		582	
[illegible]	[illegible] AVE		LOS ANGELES	P	1920	HIST.SURV.	0051 1052-0010		5Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1911	HIST.SURV.	0051 1051 0010		582	
[illegible]	[illegible] AVE		LOS ANGELES	P	1905	HIST.SURV.	0051 1051 0011		5Y	
[illegible]	[illegible] AVE	[illegible] THE [illegible] CHURCH	LOS ANGELES	P	1911	HIST.SURV.	0053 1055 0010		5Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1911	HIST.SURV.	0051-1054 0021		1Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1911	HIST.SURV.	0051-1051 0010		1Y	
[illegible]	[illegible] AVE		LOS ANGELES	P	1909	HIST.SURV.	0051 1054 0011		582	
[illegible]	[illegible]		LOS ANGELES	P	1923	HIST.RES	DOF 10 94 0231 6.00	05/05/94	6J	
						PROJ.REVW.	PT#940302	04/05/94	6J	
[illegible]	[illegible] AVE	[illegible] FOX WILSHIRE THEATRE	LOS ANGELES	P	1930	HIST.RES	DOE 10 89 0025 0.00	03/20/90	4B2	C
[illegible]	[illegible] AVE	FOX ARGYLWOOD VILLAGE [illegible]	LOS ANGELES	P	193-	PROJ.REVW.	PT#890816	11/ 9/89	4B2	C
[illegible]	[illegible] AVE	FOX ARGYLWOOD VILLAGE THEATRE	LOS ANGELES	P	193-	DPOS.REVW.	UNTA1089396	11/29/89	4B2	C
						HIST.SURV.	1051 0119 0010		1Y	
						HIST.SURV.	1051-4510 1010		1Y	
[illegible]	[illegible] AVE		LOS ANGELES		1923	HIST.RES	DOE 10 94-0431 6.00	07/11/94	6Y	
						PROJ.REVW.	PT#940816	06/10/94	6Y	
[illegible]	[illegible] AVE		LOS ANGELES		1913	HIST.RES	DOE 10 91 0233 6.00	01/31/91	6Y	

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PROPERTY#	PRIMARY#	HRI#	STREET.ADDRESS	NAMES	CITY.NAME	OWN	YR-C	OHP-PROG	PRG-REFERENCE-NUMBER	STAT	DAT	NRS	CRIT
								PROJ.REVW	HUD010161S	0/11/01	6Z		
134774			5415 BRENTHURST AVE		LOS ANGELES		1926	HIST.RES.	DOE-19-01-2921-0000	0/11/01	6Y		
								PROJ.REVW	HUD010111DU	0/11/01	6Y		
003210	19 1674		5001 BUCHANAN ST	BUCHANAN STREET SCHOOL	LOS ANGELES	B	1937	HIST.RES.	DOE-19-94-0047-0000	10/05/94	2S2		
	19 1670							PROJ.REVW	HUD940920A	10/05/94	2S2		
								HIST.SURV	7033 2688 1996		5S2		
114034			2446 BUCKINGHAM RD		LOS ANGELES	P		HIST.RES.	DOE-19-95-1150-0000	09/21/95	6Y		
								PROJ.REVW	HUD950922A	09/21/95	6Y		
112235			1709 BUCKINGHAM RD		LOS ANGELES	P		HIST.RES.	DOE-19-95-1157-0000	09/21/95	6Y		
								PROJ.REVW	HUD950922A	09/21/95	6Y		
119136			1511 BUCKINGHAM RD		LOS ANGELES	P		HIST.RES.	DOE-19-95-1139-0000	09/21/95	6Y		
								PROJ.REVW	HUD950921B	09/21/95	6Y		
119337			2417 BUCKINGHAM RD		LOS ANGELES	P		HIST.RES.	DOE-19-95-0245-0000	09/21/95	6Y		
								PROJ.REVW	HUD950921B	09/21/95	6Y		
111277			3421 BUCKINGHAM RD		LOS ANGELES	P		HIST.RES.	DOE-19-95-2945-0000	05/21/95	6Y		
								PROJ.REVW	HUD950921A	05/21/95	6Y		
094480	19 174881		3924 BUCKINGHAM RD		LOS ANGELES	P	1928	PROJ.REVW	HUD910924A	06/12/91	6Y		
104473			4929 BUCKINGHAM RD		LOS ANGELES		1935	HIST.RES.	DOE-19-01-2469-0000	07/11/01	6Y		
								PROJ.REVW	HUD010628A	07/11/01	6Y		
085721	19 173014		2414 BUDAU AVE		LOS ANGELES	P	1919	PROJ.REVW	HUD901117C	11/12/90	6Y		
070275	19 170147		2527 BUDAU AVE		LOS ANGELES	P	1920	PROJ.REVW	HUD910528A	07/20/91	6Y		
087248	19 174807		2102 BUDAU AVE		LOS ANGELES	P	1927	PROJ.REVW	HUD910418C	04/29/91	6Y		
151775			BUDLONG AVE	BROADACRES SLAUSON AVENUE AREA, REAR	LOS ANGELES			HIST.RES.	DOE-19-00-0011-0000	12/11/01	2D4		
								PROJ.REVW	HUD001114A	12/11/01	2D4		
097156	19 174214		1701 BUDLONG AVE	SISTERS STATION / COMMUNITY CENTER	LOS ANGELES	P	1917	HIST.RES.	DOE-19-94-0554-0000	06/15/94	6Y		
								PROJ.REVW	HUD940520A	06/15/94	6Y		
061147	19 1 635		1114 BUENA AVE		LOS ANGELES	P	1926	PROJ.REVW	HUD871027C	03/23/88	6Y		
112679			10515 BUFORD AVE		LOS ANGELES	P		HIST.RES.	DOE-19-98-0281-0000	01/13/98	6Y		
								PROJ.REVW	HUD980109A	01/13/98	6Y		
141322			1601 BURBY DR		LOS ANGELES		1924	HIST.RES.	DOE-19-01-0011-0000	01/11/01	6Y		
								PROJ.REVW	HUD001220A	01/11/01	6Y		
024040	19 170471		814 BUNKER HILL AVE	GEORGE W. BURTON-PERSIS HOUSE	LOS ANGELES	P	1887	HIST.SURV	0655 2451 2900		7J		
024045	19 170462		818 BUNKER HILL AVE	HARRY W ALEXANDER RESIDENCE	LOS ANGELES	P	1887	HIST.SURV	0655 2452 2900		7J		
024053	19 170411		811 BUNKER HILL AVE		LOS ANGELES	P	1892	HIST.SURV	0655 2453 2900		7J		
127469			11141 BURBANK ST		LOS ANGELES		1921	HIST.RES.	DOE-19-01-1036-0000	01/11/01	6Y		
								PROJ.REVW	HUD001228A	01/11/01	6Y		
094164	19 175210		3215 BURBANK BLVD	BURBANK BAY CARNEGIE LIBRARY	LOS ANGELES	P	1922	HIST.RES.	DOE-19-94-1575-0000	09/15/94	6Y		
								PROJ.REVW	HUD940820A	10/21/94	6Y		
092252	19 174921		1660 BUTTE ST	REDONDO JUNCTION SUBSTATION / OFFICE	LOS ANGELES	P	1929	HIST.RES.	DOE-19-94-0245-0000	10/27/94	2D2	AC	
								PROJ.REVW	FHWA940927A	10/27/94	2D2	AC	
092255	19 174922		1660 BUTTE ST	REDONDO JUNCTION ROUNDHOUSE TOWER	LOS ANGELES	P	1924	HIST.RES.	DOE-19-94-0247-0000	10/27/94	2D2	AC	
								PROJ.REVW	FHWA940927A	10/27/94	2D2	AC	
092254	19 174920		2687 BUTTE ST	REDONDO JUNCTION ROUNDHOUSE	LOS ANGELES	P	1911	HIST.RES.	DOE-19-94-0246-0000	10/27/94	2D2	AC	
								PROJ.REVW	FHWA940927A	10/27/94	2D2	AC	
092257	19 174919		2657 BUTTE ST	ATCHISON, TOPEKA & SANTA FE RAILWAY	LOS ANGELES	P	1911	HIST.RES.	DOE-19-94-0249-0000	10/27/94	2D2	AC	
								PROJ.REVW	FHWA940927A	10/27/94	2D2	AC	
121166			1227 CABRILLO AVE	VENICE OF AMERICA HOUSE	LOS ANGELES	P	1906	HIST.RES.	NPS-00001427-0000	10/13/00	1S	AC	
								NAT.REG.	00 1427	10/13/00	1S	AC	
128505			CAHUENGA BLVD	HOLLYWOOD BOULEVARD COMMERCIAL AND ENTERTAINMENT	LOS ANGELES	P		HIST.RES.	DOE-19-00-0724-0000	05/22/01	2D2		
								PROJ.REVW	FTA000522A	05/22/01	2D2		
070038	19 171101		1601 CAHUENGA BLVD	MARION BUILDING	LOS ANGELES	P	1915	HIST.SURV	0655 2121 0000		5S		
070029	19 171100		1615 CAHUENGA BLVD	DEPARTMENT OF WATER & POWER BUILDING	LOS ANGELES	P	1925	HIST.SURV	0655 2122 0000		5S		
087550	19 174717		1731 CAHUENGA BLVD		LOS ANGELES	P	1935	HIST.RES.	DOE-19-94-0101-0000	02/22/94	6Y		
								PROJ.REVW	HUD940209A	02/22/94	6Y		
120611	19 172106		1825 CAHUENGA BLVD	AVONDALE APARTMENTS	LOS ANGELES	P	1924	HIST.SURV	0655 2480 0000		5S		

OFFICE OF HISTORIC PRESERVATION * * * Directory of Properties in the Historic Property Data File for LOS ANGELES County. Page [illegible] 12-05-[illegible]

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PROPERTY-NUMBER	PRIMARY-#	STREET.ADDRESS	NAMES	CITY.NAME	OWN	YR-C	OHP-PROG..	PRG.-REFERENCE-NUMBER	STAT-DAT	NRS	CRIT
[illegible]		1825 CAHUENGA BLVD	AVONDALE APARTMENTS, A T & T [illegible]	LOS ANGELES	P	1927	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	19-[illegible]	1834 CAHUENGA BLVD		LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]-4901-[illegible]		7N	
[illegible]		[illegible] CAHUENGA AVE		LOS ANGELES	Y	[illegible]	HIST.RES.	[illegible]	[illegible]	[illegible]	
							PROJ.REVW.	[illegible]	[illegible]	6U	
[illegible]	19-[illegible]	[illegible] CAJON ST		LOS ANGELES	S	1949	HIST.RES.	[illegible]	[illegible]	6Y	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]	19-[illegible]	[illegible]	VENICE BRANCH, LOS ANGELES PUBLIC [illegible]	LOS ANGELES	M	[illegible]	HIST.RES.	[illegible]	[illegible]	[illegible]	
							PROJ.REVW.	[illegible]	[illegible]	[illegible]	
							[illegible]	[illegible]	[illegible]	[illegible]	
							HIST.RES.	NPS [illegible]	[illegible]	1D	A[illegible]
[illegible]	19-[illegible]	[illegible] CALIFORNIA ST		LOS ANGELES	[illegible]	1919	PROJ.REVW.	[illegible]	[illegible]	6Z	
[illegible]	19-[illegible]	20[illegible] CALLAS [illegible]	SYLVIA PARK COUNTRY CLUB CLUBHOUSE	LOS ANGELES	[illegible]	1919	ST.PT.INT	[illegible] 0081	[illegible]	[illegible]	
[illegible]	19-[illegible]	1[illegible] CALUMET AVE	LOUIS [illegible] RESIDENCE	LOS ANGELES	[illegible]	1892	HIST.SURV.	[illegible] 2[illegible] [illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] CALUMET AVE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible] 2513 [illegible]		7N	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		7N	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		7N	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		7N	
[illegible]	19-[illegible]	[illegible] CALUMET AVE	MARTIN [illegible] RESIDENCE	LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		7N	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE	[illegible] RESIDENCE	LOS ANGELES	P	19[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE	[illegible] DE [illegible] RESIDENCE	LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE	BASIL [illegible] RESIDENCE	LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		7N	
[illegible]	19-[illegible]	[illegible] CALUMET AVE	GEORGE [illegible] RESIDENCE	LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible] 2642 [illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		PROJ.REVW.	[illegible]	[illegible]	6[illegible]	
							HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		7P	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		7P	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		7P	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		7R	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CALUMET AVE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]		[illegible] CALZONA ST		LOS ANGELES		1921	PROJ.REVW.	[illegible]	[illegible]	6U	
[illegible]		[illegible] CAMARILLO [illegible]		LOS ANGELES	P	19[illegible]	HIST.RES.	[illegible]	[illegible]	6Y	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]		[illegible] CAMARILLO		LOS ANGELES	P	1953	HIST.RES.	[illegible]	[illegible]	6Y	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]	19-[illegible]	[illegible] CAMINO PALMERO	[illegible] ESTATE	LOS ANGELES	P	1921	TAX.CERT.	[illegible]	[illegible]	[illegible]	
							HIST.RES.	NPS [illegible]	[illegible]	1S	[illegible]
[illegible]	19-[illegible]	[illegible] CAMPUS RD		LOS ANGELES	P	1911	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	[illegible] CAMPUS RD		LOS ANGELES	P	1911	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	1600 CAMPUS RD	OCCIDENTAL COLLEGE	LOS ANGELES	P	1911	HIST.SURV.	[illegible]		[illegible]	
	19-[illegible]										

PROPERTY NUMBER	DESCRIPTION	ADDRESS ACCESS...	...	...	OWNERS	CITY NAME	...	...	CODE	YR C	USE CODE	BOOK REFERENCE DATA	TRANSFER DATE	BOOK	PAGE
	19 147867														
	19 176758														
	19 176772														
	19 165879														
	19 165878														
	19-176777														
	19 176782														
	19 165 62														
	19 165 1														
	19 176781														
	19 176752														
	19 165 65														
	19 165 61														
	19 176 77														
	19 150192														
197691		1101 DAVID AV				LOS ANGELES			1110						
007114	19 171961	1109 THOMAS ST			RICHARD CHARLES WINSLOW ET	LOS ANGELES		C	1940						
011175	19 153145	1813 CAMBRIA ST			DAVID AND CAMPBELL STEPHEN JR	LOS ANGELES		F	1911						
009118	19-171154	436 FAIRLOS AV				LOS ANGELES		L	1925						
009119	19 171955	500 CARLOS AV				LOS ANGELES		P	1916						
010114	19 15941	829 CARLOS AV				LOS ANGELES		D	1926						
010116	19 171967	451 FAIRLOS AV				LOS ANGELES		D	1913						
010118	19 171962	475 FAIRLOS AV				LOS ANGELES		D	1911						
010121	19 171959	501 FAIRLOS AV				LOS ANGELES		D	1911						
010122	19 171956	1564 CARLOS AV			EA SMITH, ERIK LUTHERAN CHURCH	LOS ANGELES		P	1915						
010130	19 176617	946 FAIRVIEW AV				LOS ANGELES		J	1923						
010140	19 171951	FAIRFIELD ST			SUSMAN CALIFORNIA FIDELITY WILSHIRE ET	LOS ANGELES		M							
010119	19 171923	1124 CARLOS AV				LOS ANGELES		P	1941						
04,100	19 [illegible]	1121 CARLOS AV				LOS ANGELES		P	1927						
021357	19-147867	CARLOS AV			LION A IRON BLOCK OF FARMER PETER	LOS ANGELES		P	1903						
021 2	19-147861	1149 CARLOS AV				LOS ANGELES		P	1917						
021 71	19-147863	1145 CARLOS AV				LOS ANGELES		I	1913						
021077	19 147864	1101 FAIRFAX AV				LOS ANGELES		P	1919						
021078	19-147874	1011 FAIRFAX AV				LOS ANGELES		I	1911						
1151	19 15 [illegible]	1100 FAIRFAX AV				LOS ANGELES		P	1911						
021012	19 151863	1119 FAIRFAX AV				LOS ANGELES		P	19.1						
021013	19 1e-607	1125 CARLOS AV				LOS ANGELES		P	1911						
021040	19 171865	1134 FAIRFAX AV				LOS ANGELES		P	1911						
021041	19 17 [illegible]	1140 FAIRFAX AV				LOS ANGELES		P	1911						
021042	19 147811	1214 CARLOS AV				LOS ANGELES		P	1911						
021043	19 147811	1200 CARLOS AV				LOS ANGELES		P	1916						
021046	19-147814	1251 FAIRFAX AV				LOS ANGELES		P	1913						
021051	19 147812	1252 FAIRFAX AV				LOS ANGELES		P	1914						
021055	19 15 [illegible]	1254 CARLOS AV				LOS ANGELES		P	1911						
009104	19 171961	3101 DANIELS AVE			LOCUSTTY HOTEL	LOS ANGELES		P							
009104	19 1-0410	4110 DANIELS AVE			VISTA DEL MAR/CARLOS DISTRICT	LOS ANGELES		N	1911						
009104	19-176411	4102 DANIELS AVE			VISTA DEL MAR/CARLOS DISTRICT	LOS ANGELES		P							

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PROPERTY-NUMBER	PRIMARY-#	STREET-ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP PROG.	PRG REFERENCE-NUMBER	STAT DAT	NRS	CRIT
							PROJ REVW.	HRO94?12??	1?/01/94	2?2	
170896	19 176112	6128 CARLTON AVE	VISTA DEL MAR/CARLTON DISTRICT	LOS ANGELES	P	1911	HIST RES	30S 19 94 0144-2?0?	0?/01/94	2D2	
							PROJ.REVW.	HRO9402728	0?/01/94	2?2	
170697	19 176113	6136 CARLTON AVE	VISTA DEL MAR/CARLTON DISTRICT	LOS ANGELES	P	1911	HIST.RES.	30S-19 94-0444 2???	0?/01/94	2D2	
							PROJ.REVW.	HRO94028??	0?/01/94	2D2	
170???	19-176???	6142 CARLTON AVE	VISTA DEL MAR/CARLTON DISTRICT	LOS ANGELES	P	1914	HIST RES	30S 19 94-0444 ????	?/01/94	2D2	
							PROJ REVW	HRO9402??2	??/01/94	2?2	
2229?9	19 16????		CARLTON WY	LOS ANGELES	P	1921	HIST.RES.	3?? 19-94 0447 ????	??/01/94	2??	
							PROJ REVW.	HRO9402?22	??/01/94	2??	
??9873			CARLTON WY	[illegible] HISTORIC OF CARLTON 1950	LOS ANGELES	P		HIST SURV.	2051-0641-????		5S2	
2?1872	19 16????	5401 CARLTON WY		LOS ANGELES	P	1914	HIST SURV	0051 0641 ????		5S2	
221867	19 16????	5101 CARLTON WY		LOS ANGELES	P	1919	HIST.SURV	5031 0641 ????		5S2	
?2?491	19-177???	5??1 CARLTON WY		LOS ANGELES		1917	PROJ.REVW.	[illegible]	1?/1?/95	6?	
??82??		5441 CARLTON WY		LOS ANGELES	P	1911	HIST RES.	3?? 19 9? ???? ????.	??/??/96	6?	
							PROJ REVW	HRP?5090??	??/??/96	6?	
1?8958	19 1???75	5446 CARLTON WY		LOS ANGELES	M	1924	HIST.RES	30F-19 94 ????-????	??/01/94	6?	
							PROJ.REVW	HRO94026??	??/01/94	6?	
??02??		5449 CARLTON WY		LOS ANGELES	P	1910	HIST.RES.	30?-19 9? ?151 ????	??/??/96	6?	
							PROJ.REVW.	HRO??????	??/??/96	6?	
221???	19-167???	5?36 CARLTON WY		LOS ANGELES	P	1908	HIST.SURV.	2057 0591-????		7?	
?21???	19 167???	5?40 CARLTON WY		LOS ANGELES	P	1908	HIST.SURV.	2051 0591 ????		??	
??1???	19-17????	5?46 CARLTON WY		LOS ANGELES	P	1909	HIST.SURV.	2051 0591-????		7?	
221??9	19 1?????	5??2 CARLTON WY	[illegible]	LOS ANGELES	P	1908	HIST RES.	30? 19-94 0??? ????	??/0?/94	2??	?
							PROJ REVW.	HRO9402???	??/0?/94	2??	?
							HIST SURV	2051 0591-????		??	
221???	19 167?98	5??? CARLTON WY		LOS ANGELES	P	1918	HIST SURV.	2051-0591 ????		??	
221?4?	19 16????	5?0? CARLTON WY		LOS ANGELES	P	1923	HIST SURV.	2051-0591 ????		7?	
221?41	19 167???	5??? CARLTON WY		LOS ANGELES	P	1924	HIST SURV.	2051 0591 0022		??	
221??2	19 167???	5610 CARLTON WY		LOS ANGELES	P	1917	HIST SURV	2051 0591 ????		??	
?21?43	19 167??1	5627 CARLTON WY		LOS ANGELES	P	1922	HIST.SURV.	2051-0591 00??		??	
221?4?	19 16????	5632 CARLTON WY		LOS ANGELES	P	1915	HIST.SURV.	2051-0591-00??		??	
221?4?	19-167???	5??2 CARLTON WY		LOS ANGELES	P	1917	HIST SURV.	2051 0591-00??		??	
221?4?	19-167???	5??? CARLTON WY		LOS ANGELES	P	1916	HIST SURV	2051 0591-00??		??	
221?4?	19 16????	5??? CARLTON WY		LOS ANGELES	P	1916	HIST SURV	2053 0591 00??		??	
221?44	19 1?????	5??? CARLTON WY		LOS ANGELES	P	1914	HIST SURV	2051 0591-0??9		??	
221?4?	19 1?????	5?26 CARLTON WY		LOS ANGELES	P	1917	HIST SURV.	2051 0591-0???		??	
221?5?	19-16???8	5?10 CARLTON WY		LOS ANGELES	P	1917	HIST SURV	2053 0591 0???		??	
221?5?	19 16????	5??? CARLTON WY		LOS ANGELES	P	1916	HIST SURV	2053 0591 0???		??	
221?52	19 16??9?	5??1 CARLTON WY		LOS ANGELES	P	1911	HIST SURV	2053 0591-0???		??	
221?53	19 16????	5??? CARLTON WY		LOS ANGELES	P	1920	HIST SURV	2053 0591 0??4		??	
???7??	19 16????	5??? CARLTON WY		LOS ANGELES	P	1911	HIST SURV	2053-0591 0??5		??	
??1?9?	19 167???	5?2? CARLTON WY		LOS ANGELES	P	192?	PROJ REVW	?HP9?0?30?	??/??/9?	6?	
							HIST SURV	2051 0591 ????		??	
?21???	19 167???	5??? CARLTON WY		LOS ANGELES	P	1918	HIST SURV	2053-0592-????		??	
?29???	19 17????	5?10 CARLTON WY		LOS ANGELES	P	192?	PROJ REVW	?HP9???30?	??/2?/9?	??	
??0???	19 17????	5?4? CARLTON WY		LOS ANGELES	P	19??	PROJ REVW	?HP9??30?	??/2?/9?	??	
?21?4?	19 16????	5??? CARLTON WY		LOS ANGELES	P	19??	HIST SURV	2051 0641 000?		??	
?21?4?	19 16????	5??? CARLTON WY		LOS ANGELES	P	1922	HIST SURV	2051-0641 0002		??	
?21?4?	19 16????	5??? CARLTON WY		LOS ANGELES	P	192?	HIST.SURV.	2051-0641-000?		??	
?21?4?	19 167???	5??? CARLTON WY		LOS ANGELES	P	1917	HIST SURV.	2051 0641 00??		??	
?21?3?	19 167???	5??? CARLTON WY		LOS ANGELES	M	192?	HIST RES	30E 19 94 01?? ????	04/12/9?	??	
							PROJ REVW	HRO940?6??	04/12/9?	??	
							HIST SURV	2051 0641-00??		??	
?21???	19 167??8	5??? CARLTON WY		LOS ANGELES	P	1905	HIST SURV.	2053 0641 00??		??	
?21?72	19 167???	5??? CARLTON WY		LOS ANGELES	P	1915	TAX REG	?D ?????	??/??/??	??	
							HIST SURV	2053 0641 00??		??	

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Property Number	National Register Status	Street Address	Name	City/Vicinity	Owner	Year Built	Arch. Style	Area of Significance	Date Listed	Date Removed
100582	LS 12/31/80	5901 HOLLYWOOD BV		LOS ANGELES	P	1925	WEST RES.	POR 13-14 0691 0831	11/12/74	NR
							PROJ REVW	1407A02010	11/12/74	NR
071963	LS 12/27/78	6001 HOLLYWOOD BV		LOS ANGELES	P	1929	WEST RES	LOT 13-14 0447 0021	5/15/91	DEM
							PROJ REVW	1F0296L02A	5/15/91	NR
							WEST VERB	0713-0643 0003		NR
071964	LS 12/27/78	5921 HOLLYWOOD BV		LOS ANGELES	P	1929	WEST ARCH	0713-0643 0003		NR
071969	LS 12/27/78	6001 HOLLYWOOD BV		LOS ANGELES	P	1910	ARCH/ARCH.	DOE 13-14 0691 0131	05/01/91	DEM
							PROJ REVW	1C0296L02A	6/01/94	NR
							HIST SURV.	1953-0641-0010		NR
071966	LS 12/27/78	6017 HOLLYWOOD BV		LOS ANGELES	M	1926	HIST RES	DOE 13 14-0441-0 13	5/01/91	DEM
							PROJ REVW	1F0296L02A	5/01/91	NR
071967	LS 12/27/78	6027 HOLLYWOOD BV		LOS ANGELES	M	1926	HIST REG	DOE 13-14 0441 0134	5/01/94	DEM
							PROJ REVW	1C0296L02A	5/01/94	NR
							HIST SURV	1953 1441 0010		NR
021964	LS 12/27/78	6411 HOLLYWOOD BV		LOS ANGELES	M	1926	HIST RES	DOE 13 14 0641 0136	6/01/94	DEM
							PROJ REVW	1F096L02A	5/01/94	NR
							HIST SURV	0 0+7(43 001)		NR
021965	LS 12/27/78	6611 HOLLYWOOD BV		LOS ANGELES	M	1924	HIST RES	DOE 13 14-044+ 0136	05/01/94	DEM
							PROJ REVW	1C0296L02A	5/01/94	NR
							HIST SURV	1953 1441 0010		NR
071968	LS 12/27/78	6801 HOLLYWOOD BV		LOS ANGELES	M	1926	HIST RES	DOE 13-14 0441 0134	6/01/94	DEM
							PROJ REVW	1F096L02A	5/01/94	NR
							HIST SURV	0 0+7(43 001)		NR
071969	LS 12/27/78	6811 HOLLYWOOD BV		LOS ANGELES	M	1924	HIST RES	DOE 13 14-044+ 0136	05/01/94	DEM
							PROJ REVW	1C0296L02A	5/01/94	NR
							HIST SURV	1953 1441 0010		NR
071970	LS 12/27/78	6821 HOLLYWOOD BV		LOS ANGELES	M	1924	HIST RES	DOE 13 14-044+ 0136	05/01/94	DEM
							PROJ REVW	1C0296L02A	5/01/94	NR
							HIST SURV	1953 1441 0010		NR
071971	LS 12/27/78	6 29 HOLLYWOOD BV		LOS ANGELES	M	1926	HIST SURV	0053 0641 0016		NR
071981	LS 12/27/78	6136 SELMA AV		LOS ANGELES	P	1926	HIST REG	DOE 13-14 0441 0136	05/01/94	DEM
							PROJ REVW	1C0296L02A	5/01/94	NR
071983	LS 12/27/78	6 29 HOLLYWOOD BV	SELMA-LABRAIN DISTRICT	LOS ANGELES	P		HIST REG	DOE 13-14 0447 0131	05/01/94	DEM
							PROJ REVW	1C0296L02A	5/01/94	NR
071984	LS 12/27/78	6400 HOLLYWOOD BV		LOS ANGELES	M	1924	PROJ REVW.	1C0296L02A	05/01/94	DEM
							HIST RES	1953-44	05/01/94	NR
021987	LS 12/27/78	6641 CARLTON WY		LOS ANGELES	P	1928	HIST SURV	0053 0641 0016		NR
021988	LS 12/27/78	6643 CARLTON WY		LOS ANGELES	P	1922	HIST RES.	DOE 13-14 0447 0134	5/01/96	DEM
							PROJ REVW	1F096L02A	5/01/96	NR
021994	LS 12/27/78	6056 CAHUENGA		LOS ANGELES	P	1938	HIST RES	DOE 13 14 0641 0134	5/01/94	NR
							PROJ REVW	1B096L02A	5/01/94	NR
021995	LS 12/27/78	6065 CAHUENGA BV	C. PHILLIPPI APARTMENTS	LOS ANGELES	P	1925	HIST. SURV	0053-0641 0001		NR
142196		1401 CAHUENGA BV		LOS ANGELES	P	1924	PROJ REVW	1F096L02A	05/02/96	NR
153584		1424 LODGEPOLE AVE		LOS ANGELES	P	1929	WEST RES	DOE 13-14-1447-0134	09/23/96	NR
							PROJ REVW	1C0296L02A	09/23/96	NR
09 1000	LS 12/27/78	7021 CAHUENGA AVE		LOS ANGELES	P	1928	HIST.RES	DOE 13 14 0641 0134	5/01/94	NR
							PROJ REVW	1B096L02A	5/01/94	NR
021984	LS 12/27/78	611 CARDIFF AV #F		LOS ANGELES	P	1928	HIST SURV	0053 1341 0007		NR
021982	LS 12/27/78	621 CARDIFF AV		LOS ANGELES	P	1924	WEST SURV	0053 1341 0007		NR
021983	LS 12/27/78	6 1 CARLTON WY		LOS ANGELES	P	1926	HIST SURV	0053 1341 0007		NR
100376	LS 12/27/78	2900 CANYON DR	CARPENTER ELEMENTARY SCHOOL	LOS ANGELES	P	1926	WEST RES	DOE 13 14 0321 0134	12/29/93	NR
							PROJ REVW	1B096L02A	12/29/93	NR
100376	LS 12/27/78		CARPENTER SCHOOL	LOS ANGELES	P	1926	HIST.SURV	0053-0738 0001	12/27/78	NR
021986	LS 12/27/78	1401 CARPENTER AVE	SOUTH P. DIETRICH HOUSE	LOS ANGELES	P	1923	HIST.SURV.	0053-0736-0001	12/27/78	NR
							HIST.REG.	1C1-0960844F 0134	12/27/78	
							HIST SURV.	0053-0573-0130		NR
021987	LS 12/27/78	1412 CARPENTER AVE	CHARLES M BIGELOW HOUSE	LOS ANGELES	P	1887	HIST SURV	0134 1308-1902	12/27/78	NR
							HIST CHRO	0131-1570 1900		NR
044008	LS 12/27/78	1416 CHEMEKETA PL	RUSSELL CARRIAGE HOUSE	LOS ANGELES	P	1911	HIST SURV.	0131-1571 1900		NR
077128	LS 12/27/78	1421 CHEMEKETA AVE	FORTUNATO A. MEDEN HOUSE	LOS ANGELES	P	1924	ARCH/ENGR	537 0 13-0134	12/27/78	DEM
							HIST.SURV.	0053-1738-1301	12/27/78	NR
							HIST.SURV	001 1 2773-1301		NR
021988	LS 12/27/78	1425 CHEMEKETA PL	1425 CHEMEKETA PLACE HOUSE	LOS ANGELES	P	1931	HIST SURV	0053-0736 1304		NR
021989	LS 12/27/78	1428 CHEMEKETA PL	JOHN EDMISTON HOUSE	LOS ANGELES	P	1921	HIST.SURV.	1053-0738 1304	12/27/78	NR

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PROPERTY-NUMBER	PROPERTY-TYPE	STREET/LOCATION	NAME	CITY AREA	ORG	VER	CHG-PROT	REG-REFERENCE NUMBER	STAT DAT	DPS	CITY
							2NOJ.REVW.	00890C937A	10/27/93	3PD	AT
111114		6717 CENTINELA AVE	BUILDING 5	LOS ANGELES	P	1992	HIST 36B	LOS 19 89 0127 0011	12/22/93	3DD	AB
							PROJ.REVW	00890C937A	10/21/93	2DD	AT
111224		5715 CENTINELA AVE	BUILDING 16 (OBT STATION	LOS ANGELES	P	1992	HIST.BLDG.	DOE 19-89-0001-0015	10/22/97	3DD	AB
							2NOJ.REVW.	00890C937A	10/27/97	3DD	AT
111234		6717 CENTINELA AVE	BUILDING 15 ASSEMBLY BUILDING/STABLE	LOS ANGELES	P	1992	HIST.SES.	DOE 19 89 0122 0017	10/22/92	3DD	AB
							2NOJ.REVW	00890C937A	10/22/97	3DD	AB
111245		5715 CENTINELA AVE	BUILDING 1	LOS ANGELES	P	1991	HIST REC	DOE 19 89 0121 0011	10/22/91	3DD	AB
							2NOJ.REVW.	00890C937A	10/22/91	3DD	AB
111247		6715 CENTINELA AVE	BUILDING 14-INFIRMARY	LOS ANGELES	P	1991	HIST.BLDG.	DOE-19-89-0121 0011	10/22/91	3DD	AB
							2NOJ.REVW.	00890C937A	12/22/91	3DD	AT
111234		6717 CENTINELA AVE	BUILDING 13-PAINT SHOP/MAINTENANCE	LOS ANGELES	P	1991	HIST.BLDG.	DOE-19-89-0121 0011	10/22/91	3DD	AB
							2NOJ.REVW.	00890C937A	10/22/91	3DD	AB
111233		6717 CENTINELA AVE	BUILDING 12-WAREHOUSE/PLANT FACILI	LOS ANGELES	P	1991	HIST.BLDG.	DOE 19 89-0121-0013	10/22/91	3DD	AB
							2NOJ.REVW.	00890C937A	10/22/91	3DD	AB
111221		5715 CENTINELA AVE	BUILDING 14 CARPENTRY SHOP	LOS ANGELES	P	1991	HIST REG	DOE 19 89 0121-0003	10/22/91	3DD	AB
							2NOJ.REVW.	00890C937A	10/22/91	3DD	AB
111214		6717 CENTINELA AVE	BUILDING 14 ASSEMBLY BUILDING	LOS ANGELES	P	1991	HIST.BLDG.	DOE-19-89-0121 0011	12/22/91	3DD	AB
							2NOJ.REVW.	00890C937A	10/22/91	3DD	AB
02e700	19 176e2?	1012 CENTRAL AVE	BARN CASTERGALA ONE CIRCU	LOS ANGELES	P	1991	HIST SURV	0021-0134 0001		3B	
023503	19 166931	913 CENTER ST		LOS ANGELES	P	1979	HIST.SURV	0021 0156 0002		5B2	
023506	19-166529	915 CENTER ST		LOS ANGELES	P	1987	HIST.SURV.	0021-0155 0002		5B2	
023507	19 166527	921 CENTER ST		LOS ANGELES	P	1917	HIST.SURV.	0021 0156 0002		5B2	
023506	19 166932	925 CENTER ST		LOS ANGELES	P	1917	HIST SURV	0021 0151 0002		5B2	
023509	19 1 9611	931 CENTER ST		LOS ANGELES	P	1982	HIST.SURV	0021 0152 0002		7B	
023510	19-166931	935 CENTRE ST		LOS ANGELES	P	1911	HIST.SURV.	0021-0153 0002		5B2	
023511	19 166911	1011 CENTRE ST		LOS ANGELES	P	1902	HIST.SURV.	0021-0154 0002		5B	
023512	19 166931	1021 CENTRE ST		LOS ANGELES	P	1911	HIST.SURV.	0021-0155-0002		5B2	
023513	19 166944	1031 CENTRE ST		LOS ANGELES	I	1903	HIST.SURV.	0021 0156 0 00		5B2	
023514	19 166933	1041 CENTRE ST		LOS ANGELES	P	1903	HIST.SURV.	0021 0157-0002		5B2	
023515	19-166961	1051 CENTRE ST		LOS ANGELES	P	1903	HIST SURV	0021 0158 0002		5B2	
024516	19-166962	1061 CENTRE ST		LOS ANGELES	P	1907	HIST SURV	0021 0159 0002		5B2	
023517	19 166967	1071 CENTRE ST		LOS ANGELES	P	1902	HIST SURV.	0021 0160 0002		5B2	
023818		615 CENTRE AVE		LOS ANGELES	U		HIST.REV.	DOE 19-89 0150 0001	03/01/90	6Y	
							2NOJ.REVW.	00890C937A	03/01/90	2Y	
021618	19-177870	1910 CERRITOS PL		LOS ANGELES	P	1924	HIST REG.	021-6020185-0178	03/07/82	4B	4C
121648	19-177868	1920 CERRITOS PL		LOS ANGELES	P	1923	HIST DES.	021 6020185-0178	03/17/82	4B	6L
121121	19 177862	1932 CERRITOS PL		LOS ANGELES	P	1923	HIST REG	021 6020185 07 0	3/15/82	4B	6L
100350	19 1-9496	1107 CESAR E CHAVEZ AVE	SCHOOL (EAST)	LOS ANGELES	P	1931	HIST.REV	DOE-19 89 0114 0001	01/18/95	6Y	
							2NOJ.REVW.	00890C937A	01/17/95	6Y	
100144	19 1-9091	1 20 CESAR E CHAVEZ AVE	TENEMENT/ROOMING-BATTISTEPS SHOP	LOS ANGELES	P	1930	HIST.REV.	DOE-19-89-0124-0119	01/19/95	6Y	
							2NOJ.REVW.	00890C937A	01/19/95	6Y	
100344	19 1-9094	1120 CESAR E CHAVEZ AVE	OFFICE/ FACTORY	LOS ANGELES	P	1910	HIST REG	DOE 19 89 0124-0120	01/19/95	6Y	
							FPOC.REVW	00890C937A	01/19/95	6Y	
100375	19 17 9497	1130 CESAR E CHAVEZ AVE	ASSEMBLY BUILDING	LOS ANGELES	J	1931	HIST.REV.	DOE 19 89 0124-0120	01/19/95	6Y	
							2NOJ.REVW.	00890C937A	01/19/95	6Y	
114213		201 E CESAR E CHAVEZ AVE		LOS ANGELES	D	1912	HIST.REV.	DOE 19-89 0124 0120	02/20/96	6J	
							PROJ.REVW.	00890C937A	02/20/96	6J	
114542		4019 CESAR E CHAVEZ AVE		LOS ANGELES	D	1942	HIST REG	DOE-19 89 0124 0120	10/06/97	6J	
							PROJ.REVW.	00890C937A	10/06/97	6J	
148019		1731 CHAPIN PL	MONTE ST MARY'S COLLEGE HISTORIC D	LOS ANGELES	D	1911	HIST REG	DOE 19-89 0677-0009	10/20/77	3B2	C
							PROJ.REVW.	00890C937A	10/20/77	2B2	T
149193		12101 CHALON RD	MOUNT ST MARY'S COLLEGE LAUNDRY/AT	LOS ANGELES	P	1936	HIST REG	DOE 19 89 0681-0106	10/20/77	4DD	J
							PROJ.REVW.	00890C937A	10/20/77	2DD	J
149181		12101 CHALON RD	MOUNT ST MARY'S COLLEGE (BARLOW M	LOS ANGELES	P	1941	HIST.REG.	DOE 19 89 0681 0 00	10/20/77	3DD	T
							PROJ.REVW	00890C937A	10/20/77	4DD	J

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PROPERTY	NUMBER	DESCRIPTION	STREET ADDRESS	Boundary of ...	Properties in the Historic Property	CITY	ZONE	...	DWG	YR ...	DEP	PROG...	PRO	REGISTERED NUMBER	STAT-DAT	NR#	CRIT
												HIST	HIS	500 19-45-0159-0005	03/08/95	336	
												MISC	MISC	19810300010	07/08/95	337	
												PROJ	MISC	20001910010	04/20/00	1Y	
-|-	100219	19-1641-05	4215 DR 19497965	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1922	NRIS	NRS	JOE 19 ss 0241 0046	01/11/95	203	
												PROC	RSVR	8005500010	01/11/96	102	
												HIST	RES	500 19 ss 0159 0005	02/08/95	202	
												PROC	RSVR	9810100102	02/08/95	203	
												PROJ	RSVR	8001910010	01/20/01	5Y	
												MISC	SUBV	1951-0001 0007		302	
-|-	500010	19-1647-12	4219 DR 20482958	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1956	HIST	RES	JOE 19 19 0241 0041	09/11/95	202	
												PROC	RSVR	8005500010	09/11/95	204	
												MISC	RSRV	500-19 95 0 49-0047	03/--/00	2Y	
												PROJ	RSVR	8005910010	03/03/95	205	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 104		302	
-|-	500017	9 16th PL	4220 DR 20482958	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1915	HIST	RES	500 19-95-724, 201	09/11/95	206	
												PROC	RSVR	8005500010	09/11/95	207	
												MISC	RES	500 19-95 0146-0047	03/08/95	208	
												PROJ	RSVR	8005910010	03/03/95	209	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 0106		303	
-|-	100044	12-1739-01	4214 DR 20482958	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1921	HIST	RES	500 19 95 0241 0041	09/11/95	209	
												PROC	RSVR	8005500010	09/11/95	210	
												MISC	RES	500 19-95 0149-0047	03/08/95	211	
												PROJ	RSVR	8005910010	03/03/95	212	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 0106		304	
T	500044	1 16th PL	1334 DR 20482958	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1921	HIST	RES	500 19 95 0241 0041	09/11/95	210	
												PROC	RSVR	8005500010	09/11/95	211	
												MISC	RES	500-19-95-0241-0044	03/08/95	212	
												PROJ	RSVR	8005910010	03/03/95	213	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 000.		305	
-|-	500019	19 16th PL	4218 DR 20482958	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1924	HIST	RES	500-19 95 0241 0041	09/11/95	213	
												PROC	RSVR	8005500010	09/11/95	214	
												MISC	RES	500 19 95-0149 0047	03/08/95	214	
												PROJ	RSVR	8005910010	03/03/95	215	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 0106		306	
-|-	100047	15-1661-05	4214 DR 20482958	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1937	HIST	RES	500-19-95-0241 0046	09/11/95	215	
												PROC	RSVR	8005500010	09/11/95	216	
												MISC	RES	JOE 19-95 0149 0046	03/08/95	216	
												PROC	RSVR	8005910010	03/08/95	217	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 0106		307	
-|-	100044	11 16th PL	4217 DR 20482958	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P	1917	HIST	RES	500 19 95 0241 0047	09/11/95	217	
												PROC	RSVR	8005500010	09/11/95	218	
												MISC	RES	JOE 19-95 0149 0046	03/08/95	218	
												PROC	RSVR	8005910010	03/08/95	219	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 0106		308	
	AP-136	19-1743-1	4211 DR 19497965	AVE	ALTON SQUARE DISTRICT		103	ANGELES		P		HIST	RES	500-19-95 0241 0049	09/11/95	219	
												PROC	RSVR	8005500010	09/11/95	220	
												HIST	RES	500 19-95-0149-0047	03/08/95	220	
												PROJ	RSVR	8005910010	03/03/95	221	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 0106		309	
												HIST	RES	500 19 95 0241 0049	09/11/95	221	
												PROC	RSVR	8005500010	09/11/95	222	
												HIST	RES	500 19-95-0149-0047	03/08/95	222	
												PROC	RSVR	8005910010	03/08/95	223	
												PROJ	RSVR	8005910010	04/20/01	6Y	
												MISC	SUBV	0003 0102 0106		310	

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PROPERTY-NUMBER	PRIMARY-#	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP-PROG	PRG-REFERENCE-NUMBER	STAT-DAT	NRS	CRIT
026[illegible]	19-[illegible]	2[illegible] ELLENDALE PL		LOS ANGELES	P	1922	HIST.SURV.	0051-4[illegible]		5S	
	19-[illegible]										
[illegible]	19-[illegible]	[illegible] ELLENDALE PL		LOS ANGELES	P	[illegible]	HIST.SURV.	0051-4[illegible]-0[illegible]		5S	
	19-[illegible]										
[illegible]	19-[illegible]	[illegible] ELLENDALE PL		LOS ANGELES	P	1922	HIST.SURV.	0051-4[illegible]		5S	
	19-[illegible]										
[illegible]	19-[illegible]	2[illegible] ELLENDALE PL		LOS ANGELES	P	19[illegible]	HIST.SURV.	0051-4[illegible]		5S	
	19-[illegible]										
026[illegible]	19-[illegible]	2801 ELLENDALE PL		LOS ANGELES	P	19[illegible]	HIST.SURV.	0051-4[illegible]		5S	
	19-[illegible]										
026[illegible]	19-[illegible]	2802 ELLENDALE PL		LOS ANGELES	P	19[illegible]	HIST.SURV.	0051-4[illegible]		5S	
	19-[illegible]										
026[illegible]	19-[illegible]	2806 ELLENDALE PL		LOS ANGELES	P	190[illegible]	HIST.SURV.	0051-4[illegible]		5S	
	19-[illegible]										
02[illegible]	19-[illegible]	2[illegible] ELLENDALE PL		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-4[illegible]		5S	
	19-[illegible]										
02[illegible]	19-[illegible]	[illegible] ELLENDALE PL		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-4[illegible]		5S	
	19-[illegible]										
0[illegible]	19-[illegible]	2[illegible] ELLENDALE PL		LOS ANGELES	P	192[illegible]	HIST.SURV.	0[illegible]-4[illegible]		5S	
	19-[illegible]										
02[illegible]	19-[illegible]	2[illegible] ELLENDALE PL		LOS ANGELES	P	19[illegible]	HIST.SURV.	0051-4[illegible]		5S	
	19-[illegible]										
02[illegible]	19-[illegible]	[illegible] ELLENDALE PL		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-4[illegible]		5S	
	19-[illegible]										
[illegible]	19-[illegible]	[illegible] ELLENWOOD DR	[illegible] CHURCH OF CHRIST [illegible]	LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-4[illegible]		5S	
	19-[illegible]										
[illegible]	19-[illegible]	[illegible] ELLISON ST		LOS ANGELES	[illegible]		PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]	19-[illegible]	[illegible] ELLSMERE AVE		LOS ANGELES	[illegible]	19[illegible]	HIST.RES.	[illegible]	[illegible]	6L	
							PROJ.REVW.	[illegible]	[illegible]	6Z	
0[illegible]	19-[illegible]	1[illegible] ELMWOOD AVE		LOS ANGELES		19[illegible]	PROJ.REVW.	[illegible]	[illegible]	[illegible]	
0[illegible]	19-[illegible]	2119 ELSINORE ST		LOS ANGELES	[illegible]	19[illegible]	HIST.SURV.	0[illegible]-1566-0000		5S2	
02[illegible]	19-[illegible]	[illegible] ELSINORE ST		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-1566-0000		5S2	
02[illegible]	19-[illegible]	[illegible] ELSINORE ST		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-1566-0000		5S2	
02[illegible]	19-[illegible]	[illegible] ELSINORE ST		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-1[illegible]-0000		5S2	
02[illegible]	19-[illegible]	[illegible] ELSINORE ST		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-1678-0000		5S2	
02[illegible]	19-[illegible]	[illegible] ELSINORE ST		LOS ANGELES	[illegible]	19[illegible]	HIST.SURV.	0[illegible]-1678-0000		[illegible]	
02[illegible]	19-[illegible]	[illegible] ELYRIA DR		LOS ANGELES	[illegible]	[illegible]	HIST.SURV.	0[illegible]		[illegible]	
	19-[illegible]										
02[illegible]	19-[illegible]	1[illegible] ELYSIAN PARK AVE	CHAVEZ RAVINE [illegible] STATION	LOS ANGELES	[illegible]		HIST.SURV.	0[illegible]-4[illegible]		[illegible]	
021[illegible]	19-[illegible]	6601 EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6611 EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE	[illegible] HOME	LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE	PHYLLIS HAVER HOME	LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE	JEAN PARKER HOME	LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	1925	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	1920	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6[illegible] EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6658 EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6661 EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6669 EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	6665 EMMET TERRACE	BISHOPS EARLY/ROLAND [illegible] HOME	LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC
021[illegible]	19-[illegible]	66[illegible] EMMET TERRACE		LOS ANGELES	P	192[illegible]	HIST.RES.	[illegible]	[illegible]/19/82	1D	AC

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PARCEL NUMBER	PRIMARY #	STREET NUMBER	STREET NAME	BANK	CITY NAME	ZIP	YR-T	USE-DESC.	WAS-ESTABLISHED %/SIZE	SIZE-FAT	MFS	ZPIT
4446-5	12 16-182	4216	RAVOZ TERRACE		LOS ANGELES	5	1913	HIST.RES	RBT-020921541 7104	08/10/22	13	AT
5116-7	19 167481	4551	ARMA-T TERRACE		LOS ANGELES	9	1939	0357 RES.	RPS 83902.104-0107	02/14/22	13	52
4811-2	14 167511	4474	ARGYLE TERRACE	HEILIGH EYZOIZ/JAN MORLLEIOZB JUNI	LOS ANGELES	J	1147	4387 RES.	RPS 4291211V-0901	2307/2/2	13	52
4911-13	13- - 46.	111	ETCHARD DR		LOS ANGELES	V	1914	4387 RES	DOE 19-94 0122 0111	07/0.794	17	
								RPJT REVN	RRRRN.2.22	1./07/94	17	
2-1-13	9 1-4047	121	ESTRALA DR	STRYDN RITCH, CANYON ASSMEN AUV 2	LOS ANGELES	M	1994	0182 SURV.	1994-0711 0013		23	
11-132		2121	ERSTOT AVE		LOS ANGELES	7	1174	4182 RES	DOE 19 95-0244 1004	12/01/96	02	
								PROJ REVN	4/1/1/2/1	1./01/96	5.	
1110-6		9124	ERNEST AVE		LOS ANGELES		1941	5501.REVN.	0020402001	1./02/02	65	
2410-1	19 170412	5041	ERNEST AVE		LOS ANGELES	M	1994	4141 PLU.	DOE 19 94-11.3 0004	74/22/96	02	
								PROJ REVN	HP0.+102.22	1422/2/01	67	
1110-4	11-1 7111.3	14401	ERKLO CT		LOS ANGELES	M		4.87.RES.	D/0-15 44-7 11-0001	05/12/91	67	
								2502.0004.	0070402202	512.5/94	67	
12-863	15 170134	14417	ERKIN CT	VAN NUYS SECTION	LOS ANGELES	M		0151.0RS.	0001 10-94 0111 041	04/16/96	67	
								PROJ REVN	0100402/022	1402/2/94	67	
5401-4	15 171405	15117	ERWIN ST	VALLEY APPLIED/NAZION CENTER PART	LOS ANGELES	M		0.87 RES.	DOE 19 94 0111 0010	5./04/14	67	
								PROJ REVN	RR0402/002	10/20/94	67	
2-1-13	13-12.406	14417	ERWIN ST		LOS ANGELES	M	.021	4187 RES.	DOE-19 94 0111 0010	12/20/94	67	
								PROJ REVN	Rev'94.2022	6./20/14	67	
11-021		17111	ERWIN ST		LOS ANGELES	M	1973	4187 RES	DOE 19 96 0155 0020	02/11/96	02	
								PRJJ REVN	RP0.967.0011	02/11/96	57	
2710-6	14 170-11	4715	ESMERALDA ST		LOS ANGELES	L	1923	PROJ REVN.	1202510825E	66/10/71	57	
2241-1	19 170-11	1917	ESTHER AVE	VERTLOO ROAD DISTRICT OR RTAN SCHO	LOS ANGELES	P	1-50	4187 SURV	.063 2224 0010		58	
	9 166-17											
4111-1		10511	ESTHER AVE		LOS ANGELES	P	1946	1151.RES	DOE 19-95 0245-7100	09/17/96	53	
								PROJ.REVN.	9R0/702110	19/21/96	60	
1-1-13		9217	ESTRADA ST		LOS ANGELES	P	1941	1157 RES	DOE 19 94 0151 1006	14/09/96	582	0
								PROJ.REVN	9P/1402/016	1./09/14	592	0
1-1-13		1011	ESTRELLA AVE	1951 ESTRELLA AVENUE / 1957 RESIDE	LOS ANGELES	U	1911	0187.RES.	1004-19-09 0100 702	12/01/09	57	
								PROJ.REVN	1100402/016	1./01/09	57	
4211-7	11-121-15	1917	EUCALYPTUS AVE	200. 1/16 SELLER ARNOLD SUBDIVISION	LOS ANGELES	P	1984	0187.SURV.	1001 1981 0100		58	
	1.-164746							0182.RES.	DOE-19-86-03.2-7002	75/01/86	592	0
	19 164710							PROJ.REVN.	9L0.550.1258	22/01/86	592	1
1111-1		1119	EUCLID AVE		LOS ANGELES	Y		0121 RES.	DOE 19 05-2116-7006	1./01/06	67	
								PROJ REVN	2LL0.1/001	12./01/06	67	
1-1-13	12 11-1.6	1110	EUCLID AVE	TIPS BIRAN V PIERT PERSERVE	LOS ANGELES	P	1969	0157 0100	0007 2016 .000		58	
	12 1-1.47							4187 RES.	DOE 19-96 1015 000.	06/11.86	652	1
								PROJ REVN	1100960/016	1./01/86	652	1
3931-8	13-171.73	2119	EUCLID AVE	RICHARD D ALEXANDER /0011 RACE	LOS ANGELES	P	1913	0157 0100	07 1-2042 5007		58	
	13 164731							0151.RES.	DOE-11 96-0011-0012	07/21/96	592	0
								PROJ.REVN	1R0860/057	7/07/1..	592	1
0217-9	11 1.1.21	1.24	EUCALYPTUS AVE	CP2RGE A. RUTZLER APPTMENTS	LOS ANGELES	L	1.45	4181 0100	1 55-2048 5000		58	
	19 .5.16							4187 RES	DOE 19 96 1015 0110	10/11/96	622	1
								PROJ.REVN	1R0860/1201	08/01/46	622	0
1211-7		9161	ESCANDILLA AVE		LOS ANGELES	Y	1913	4181.RES.	DOE-19-90 1170 01 0	09/13/92	62	
								PROJ REVN	1R0790.0011	09/13/9.	62	
1.21-3		1.12	ETON AVE		LOS ANGELES	Y	1947	2151 RES	DOE 19-94-0141 0110	08/27/95	62	
								PROJ.REVN	1R2991.0017	08/27/95	62	
1911-2	19 174-11	613	EUCLID AVE		LOS ANGELES	P	1910	2R0J REVN.	1R0910.017	03/20/91	61	
4211-12	15 1.1 1.1	2107	EUCLID AVE	CASA DEL REDIDAS	LOS ANGELES	P	1910	1151.0007	0211-1195 1001		52	
4211-21	15 171033	2117	EUCLID AVE		LOS ANGELES	P	1913	4181 0001.	0111 1105 1010		58	
4211-1.	15-171.73	2121	EUCLID AVE		LOS ANGELES	P	1920	4187 0001.	0111 1107-1011		58	
4111-11	15-171.26	4421	EUCLID AVE		LOS ANGELES	U		RPCJ REVN	1.1.8e102.1	11/14/11	57	
4211-20	17 169-11	2401	EUCLID AVE		LOS ANGELES	P	1917	0187.0007	1.11-1211 0110		58	
	17 167-10											
1111-21		9011	EVERGLADE ST		LOS ANGELES	P	1911	1101 RES.	0001010011	12/ 1.07	62	

PROPERTY NUMBER	PRIMARY #	STATE/ALT #	NAME	ADDRESS	CITY NAME	DOM	TYP	ORG	PROC	DOCUMENTATION	STAT DATE	LAT	LONG
	19-111125								HIST.SURV.	1981-1983-0000			402
									HIST Rec.	801 1981-0000	12/27/60	41	
7168 E	11 111627	7 7	FORT BLISS		LOS ANGELES	U			PROC.REVW	PCL@1981	12/27/60	41	
134751	11 120177	0210	AMPEST TANK TX	PERSHING TANK CEMETERY	LOS ANGELES	P	1917	HIST	SURV.	1981-1984 0.10	12/19/88	51	
134913	19-106736		FORT MACARTHUR	CAMP NOAH TEAL STANLEY OSBORN BATTERY	LOS ANGELES	M	1858	CAL	REG.	19 0131			18
134914	19 106736		FORT MACARTHUR	ARTIFACT POINT NIKE MISSILE CANTONE	LOS ANGELES	P	1939	CAL.REG.		19 0131	02/12/70	34	
134914	19 106736		FORT MACARTHUR	ARTIFACT POINT NIKE MISSILE CANTONE	LOS ANGELES	P	1939	CAL.REG.		19 0131	10/12/7 P	47	
1.674	11 100497		FORT MACARTHUR	HELICOPTER POINT ORLEANSCOUSO NIKE MIS	LOS ANGELES	M	1944	CAL REG.		19-0131	02/12/70	33	
134915			FORT MACARTHUR	PAVEMENT PUMP HOUSE - HELICOPTER PO	LOS ANGELES	P	1942	CAL REG		19 0131	02/12/70	33	
134941	19-111-94		FORT MACARTHUR	GENERATOR BUILDING 1031	LOS ANGELES	M	1944	CAL REG		19-0131	02/12/70	33	
											02/12/70		
134913	19 101695		FORT MACARTHUR	NIKE BUILDING 1004	LOS ANGELES	M	1950	CAL REG		19-0131	02/12/70	33	
134735	19 111716		FORT MACARTHUR	BATTERY POINT SITE REMODELED CAISSON	LOS ANGELES	P	1942	CAL REG		19-0131	0 726-70	33	
134738	19 101705		FORT MACARTHUR	BATTERY POINT SITE EARTH ROOM, BLI	LOS ANGELES	M	1941	CAL REG		0 0126	02/12/70	33	
134734	19 101701		FORT MACARTHUR	BATTERY POINT SEARCH POINT ANT	LOS ANGELES	M	1941	CAL.REG		19-0131	02/12/70	33	
134736	19 101701		FORT MACARTHUR	BATTERY PT. NIKE PERIMETER ANTENN	LOS ANGELES	M	1941	CAL REG		19 0131	02/12/70	33	
134734	19 101701		FORT MACARTHUR	ANTIA'S POINT EXCLUSION AREA BOARD	LOS ANGELES	M	1942	CAL.REG		19 150	02/04/74	33	
134739	19-101701		FORT MACARTHUR	ARTILERY POINT OBSERVATORY GUN FORT	LOS ANGELES	M	1942	CAL REG		19-0131	02/04/70	33	
134737	19 101701		FORT MACARTHUR	BATTERY POINT DIRECTOR STATION SENTRY	LOS ANGELES	M	1941	CAL REG		19 0131	02/04/70	33	
134739	19 101701		FORT MACARTHUR	NIKE PIT POINT ANTENN ARES OBSD SI	LOS ANGELES	M	1941	CAL REG		19 0131	02/04/70	33	
134129	19 101701		FORT MACARTHUR	BELLEVUE LOOKOUT NIKE HORIZON STATION	LOS ANGELES	M	1941	CAL REG		19 0131	02/04/70	33	
134131	19 101701		FORT MACARTHUR	BATTERY POINT SITE AJAX TARGET FOU	LOS ANGELES	M	1941	CAL REG		19 0131	02/04/70	33	
134134	19-101701		FORT MACARTHUR	BATTERY POINT NIKE AJAX LAUNCHER C	LOS ANGELES	M	1941	CAL REG		19 0131	02/04/70	33	
134134	19-101701		FORT MACARTHUR	BATTERY POINT NIKE HERCULES MAGAZINE	LOS ANGELES	M	1942	CAL REG		19-0131	02/04/70	33	
002134	19 1444.1		POINTVIEW AVE	5500 AND 5600 BLOCKS POINTVIEW AVES	LOS ANGELES	P	1905	HIST SURV.		1981 0000-0000			401
002436	19-107844		POINTVIEW AVE	5600 6900 BLOCKS POINTVIEW AVENUE	LOS ANGELES	P	1907	HIST SURV		0000 0711 0000			300
002107	19-110413		POINTVIEW AVE	69.0 TO 7200 BLOCKS POINTVIEW AVENUE	LOS ANGELES	P	1911	DIST.SURV		0001-0714 0000			300
002842	19-115667		POINTVIEW AVE	5910 BLOCK POINTVIEW AVENUE	LOS ANGELES	P	1920	DIST.SURV.		0001-0711 0000			300
002134	19 115381	5911	POINTVIEW AVE		LOS ANGELES	P	1919	DIST.SURV.		0001-0705-0000			300
002107	19 115384	5913	POINTVIEW AVE		LOS ANGELES	P	1905	DIST.SURV		0001-0705 0000			300
002108	19 115383	5915	POINTVIEW AVE		LOS ANGELES	P	1918	HIST SURV.		1981-0705-0000			300
002109	19-115384	5917	POINTVIEW AVE		LOS ANGELES	P	1917	HIST SURV.		1981 0705 0000			300
002110	19-115385	5919	POINTVIEW AVE		LOS ANGELES	P	915	HIST.SURV.		0001-0705 0000			300
002111	19 115386	5921	POINTVIEW AVE		LOS ANGELES	P	1919	HIST SURV.		0001 0705 0000			300
002112	19-115387	5923	POINTVIEW AVE		LOS ANGELES	P	1920	HIST SURV.		0001 0705 0000			300
002113	19 115388	5925	POINTVIEW AVE		LOS ANGELES	P	1921	HIST SURV.		0001 0705 0000			300
002114	19 115389	5927	POINTVIEW AVE		LOS ANGELES	P	1922	HIST SURV		0001-0705 0000			300
002115	19 115390	5929	POINTVIEW AVE		LOS ANGELES	P	1923	HIST SURV		0001-0705-0000			300
002116	19 115391	5931	POINTVIEW AVE		LOS ANGELES	P	1924	HIST SURV		0001-0705-0000			300
002117	19 115392	5933	POINTVIEW AVE		LOS ANGELES	P	1925	HIST SURV		0001-0705-0000			300
002118	19 115393	5935	POINTVIEW AVE		LOS ANGELES	P	1926	HIST SURV		0001-0705-0000			300
002119	19-115394	5937	POINTVIEW AVE		LOS ANGELES	P	1927	HIST SURV		0001-0705-0000			300
002120	19 115395	5939	POINTVIEW AVE		LOS ANGELES	P	1928	HIST SURV		0001-0705-0000			300
002121	19 115396	5941	POINTVIEW AVE		LOS ANGELES	P	1929	HIST SURV		0001-0705-0000			300
002122	19 115397	5943	POINTVIEW AVE		LOS ANGELES	P	1930	HIST SURV		0001-0705-0000			300
002123	19 115398	5945	POINTVIEW AVE		LOS ANGELES	P	1931	HIST SURV		0001-0705-0000			300
002124	19 115399	5947	POINTVIEW AVE		LOS ANGELES	P	1932	HIST SURV		0001-0705-0000			300
002125	19 115400	5949	POINTVIEW AVE		LOS ANGELES	P	1933	HIST SURV		0001-0705-0000			300
002126	19 115401	5951	POINTVIEW AVE		LOS ANGELES	P	1934	HIST SURV		0001-0705-0000			300
002127	19 115402	5953	POINTVIEW AVE		LOS ANGELES	P	1935	HIST SURV		0001-0705-0000			300
002128	19 115403	5955	POINTVIEW AVE		LOS ANGELES	P	1936	HIST SURV		0001-0705-0000			300
002129	19 115404	5957	POINTVIEW AVE		LOS ANGELES	P	1937	HIST SURV		0001-0705-0000			300
002130	19 115405	5959	POINTVIEW AVE		LOS ANGELES	P	1938	HIST SURV		0001-0705-0000			300
002131	19 115406	5961	POINTVIEW AVE		LOS ANGELES	P	1939	HIST SURV		0001-0705-0000			300
002132	19 115407	5963	POINTVIEW AVE		LOS ANGELES	P	1940	HIST SURV		0001-0705-0000			300
002133	19 115408	5965	POINTVIEW AVE		LOS ANGELES	P	1941	HIST SURV		0001-0705-0000			300
002134	19 115409	5967	POINTVIEW AVE		LOS ANGELES	P	1942	HIST SURV		0001-0705-0000			300
002135	19 115410	5969	POINTVIEW AVE		LOS ANGELES	P	1943	HIST SURV		0001-0705-0000			300
002136	19 115411	5971	POINTVIEW AVE		LOS ANGELES	P	1944	HIST SURV		0001-0705-0000			300
002137	19 115412	5973	POINTVIEW AVE		LOS ANGELES	P	1945	HIST SURV		0001-0705-0000			300
002138	19 115413	5975	POINTVIEW AVE		LOS ANGELES	P	1946	HIST SURV		0001-0705-0000			300
002139	19 115414	5977	POINTVIEW AVE		LOS ANGELES	P	1947	HIST SURV		0001-0705-0000			300
002140	19 115415	5979	POINTVIEW AVE		LOS ANGELES	P	1948	HIST SURV		0001-0705-0000			300
002141	19 115416	5981	POINTVIEW AVE		LOS ANGELES	P	1949	HIST SURV		0001-0705-0000			300
002142	19 115417	5983	POINTVIEW AVE		LOS ANGELES	P	1950	HIST SURV		0001-0705-0000			300
002143	19 115418	5985	POINTVIEW AVE		LOS ANGELES	P	1951	HIST SURV		0001-0705-0000			300
002144	19 115419	5987	POINTVIEW AVE		LOS ANGELES	P	1952	HIST SURV		0001-0705-0000			300
002145	19 115420	5989	POINTVIEW AVE		LOS ANGELES	P	1953	HIST SURV		0001-0705-0000			300
002146	19 115421	5991	POINTVIEW AVE		LOS ANGELES	P	1954	HIST SURV		0001-0705-0000			300
002147	19 115422	5993	POINTVIEW AVE		LOS ANGELES	P	1955	HIST SURV		0001-0705-0000			300
002148	19 115423	5995	POINTVIEW AVE		LOS ANGELES	P	1956	HIST SURV		0001-0705-0000			300
002149	19 115424	5997	POINTVIEW AVE		LOS ANGELES	P	1957	HIST SURV		0001-0705-0000			300
002150	19 115425	5999	POINTVIEW AVE		LOS ANGELES	P	1958	HIST SURV		0001-0705-0000			300

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PROPERTY NUMBER	PRIMARY-#	STREET.ADDRESS	NAMES	CITY.NAME	OWN	YR-C	OHP PROG	PRG REFERENCE NUMBER	STAT DAT	NRS	CRIT
012425	19-165?61	4??? FOUNTAIN AVE		LOS ANGELES	P	1912	HIST.SURV.	0?5?-0??8-0??0		5S2	
012429	19-165?64	45?? FOUNTAIN AVE		LOS ANGELES	P	1921	HIST SURV	0???-0??1-0001		5S2	
012441	19-16???1	4?56 FOUNTAIN AVE		LOS ANGELES	P	1929	HIST SURV.	0??? ???1 ????		5S1	
0?2?5?	19-16????	4?66 FOUNTAIN AVE		LOS ANGELES	P	1927	HIST SURV	0??? ???1-????		5S2	
1?9??1	19-1??4??	1??7? F?? ??		LOS ANGELES	P	1925	HIST RES	??? 19 96 0??? ????	04/29/94	6Y	
							PROJ REVW	HRC96.?62?	04/29/94	6Y	
1?11?4		????? FRANKLIN AVE		LOS ANGELES		1911	HIST.RES	DOE-19-92-01?? ????	04/??/??	6Y	
							PROJ REVW	??????????	04/??/??	6Y	
0??250	19-1?18?	??? FRANKLIN AV	WATER & POWER SUBSTATION ??	LOS ANGELES	M	1922	HIST SURV	0??? 1516 ?000		5S	
?? ???	19-1????1		FRANKLIN AVE	??????? ?????? HISTORIC DIST	LOS ANGELES	P	1926	HIST RES	KPR-A?????59 ????	08/??/??	1D	AC
1??????	19-17?6??		FRANKLIN AVE	FRANKLIN AVE	LOS ANGELES	?	?	HIST SURV	???? ???? ????		5S2	
1??7?6			FRANKLIN AVE	??????? ??????? / SHAKESPEARE BRID	LOS ANGELES	M	1925	HIST RES	DOE 19-9? 0065 ????	??/19/??	5??	?
							PROJ REVW	??????????	??/19/??	5??	?
1?9??1	19-1???41	4??? FRANKLIN AVE		LOS ANGELES	P	1922	HIST RES	DOE 19-94 00?? 0???	04/29/94	6Y	
							PROJ REVW	???????????	04/29/94	6Y	
0??? ?	19-1?6?14	4?4? FRANKLIN AVE		LOS ANGELES	P	1920	HIST RES	DOE-19 94 0??6 0???	04/?9/?4	6Y	
							PROJ REVW	??????????	04/?9/?4	6Y	
0????0	19-1?77??	4??? FRANKLIN AVE		LOS ANGELES	P	1919	HIST SURV	0???-0??? 0??0		5S2	
0??1?6	19-1?7?0?	???? FRANKLIN AVE	??????? ?????, ??????	LOS ANGELES	P	1926	HIST RES	???-?????????? ????	??/??/??	1S	
							HIST SURV	0???-0??6-????	??/??/??	1S	
0????0	19-1?77??	???? FRANKLIN AVE		LOS ANGELES	P	1926	HIST SURV	0??0 0??? 0???		5S	
0?????	19-1?77??	???? FRANKLIN AVE		LOS ANGELES	P	19??	HIST SURV	0??? 0?7? 0???		5S	
0?????	19-1?7???	???? FRANKLIN AVE		LOS ANGELES	P	1926	HIST SURV	0???-0??? 0???		5S2	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1911	HIST SURV	0??? 0??? 0???		5S2	
0????4	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1917	HIST SURV	0??3 0575 0???		5S2	
0?????	19-16???4	???? FRANKLIN AVE		LOS ANGELES	P	1926	HIST SURV	0??? 0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1921	HIST SURV.	0??? 0??? 0???		5S	
0??1??	19-1?77??	???? FRANKLIN AVE		LOS ANGELES	P	1922	HIST SURV	0???-0??? 0???		5S	
0??1??	19-1?77??	???? FRANKLIN AVE		LOS ANGELES	P	1921	HIST SURV	0??? 0??? 0???		5S	
0??7??	19-1?77??	???? FRANKLIN AVE		LOS ANGELES	P	1921	HIST SURV	0??? 0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1924	HIST SURV	0??? 0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1921	HIST SURV	0??? 0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1925	HIST SURV.	0???-0??? 0???		5S	
0?????	19-16????	???? FRANKLIN AV		LOS ANGELES	P	1921	HIST SURV.	0???-0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1922	HIST SURV.	0???-0???-0???		5S	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1924	HIST SURV	0??? 0???-0???		5S	
0?????	19-1?????	???? FRANKLIN AVE	????? RESIDENCE	LOS ANGELES	P	1919	HIST SURV	0??? 0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE	????? RESIDENCE	LOS ANGELES	P	1905	HIST SURV	0??? 0??? 0???		5S	
0??1?4	19-1?7???	???? FRANKLIN AVE	FRANKLIN ??????????	LOS ANGELES	P	1926	PROJ REVW.	??????????	??/??/??	5??	AC
							TAX CERT	????-??-????	??/??/??	5??	
							HIST SURV	0???-0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1922	HIST SURV	0??? 0??? 0???		5S?	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1920	HIST SURV	0???-0???-0???		5S2	
0?????	19-1?????	???? FRANKLIN AVE		LOS ANGELES	P	1922	HIST SURV	0???-0???-0???		5S2	
0??150	19-1?7???	???? FRANKLIN AVE		LOS ANGELES	P	1922	HIST SURV	0???-0??? 0???		5S2	
0????1	19-1?0???	???? FRANKLIN AVE		LOS ANGELES	P	191?	HIST SURV	0??? 0??? 0???		5S2	
0?????	19-1?7???	???? FRANKLIN AVE		LOS ANGELES	P	1928	HIST SURV	0???-0???-0???		5S2	
0?????	19-1?7???	???? FRANKLIN AVE		LOS ANGELES	P	1927	HIST SURV	0??? 0??? 0???		5S	
0?????	19-1?77??	???? FRANKLIN AVE		LOS ANGELES	P	1926	HIST SURV	0??? 0??? 0???		5S2	
0?????	19-1?????	???? FRANKLIN AVE	??????? ??????, ??????? ?????, ???	LOS ANGELES	P	1925	HIST SURV	0??? 0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE	VILLA ???????? APARTMENTS	LOS ANGELES	P	1926	HIST SURV	0???-0??? 0???		5S	
0?????	19-1?????	???? FRANKLIN AVE	?????????? ?????? ?????????? ??????	LOS ANGELES	P		HIST.RES	???-??-?? ???? ????	01/?5/94	6Y	
							PROJ REVW	?????????	01/?5/94	6Y	
0?????	19-1?7???	???? FRANKLIN AVE	??????? ????? / ?? ????? ????	LOS ANGELES	P	1929	HIST RES	???-????????? ????	0?/??/??	1S	
							HIST SURV.	0???-0???-0? ?	??/??/??	1S	

											TAX CERT.	047 / 15-0075		10/21/16	101
	031051	11 169313	0350 FRANKLIN AVE	ALTO NIDO APARTMENTS		705 ANGELES		P	1991	HIST SURV	0092 0112 0500			10
	031065	14 169114	0726 FRANKLIN AVE	ORNAMENTAL IRON WORK		705 ANGELES		P	1921	HIST.SURV.	0093-0356 1/96			10
	031099	13 169114	0810 FRANKLIN AVE	TREE REMOVAL (IN IMPROVEMENTS		705 ANGELES		P	599	HIST REV.	YES 2000139?-0022		12/19/00	35
										HIST SURV	0051 0219 1751		1/13/87	10
										TAX CERT	037 / 15-0134		4/28/16	212
	031092	15 169171	0911 FRANKLIN AVE	ALTERATIONS REMODELING GARAGE		705 ANGELES		P	1924	HIST PRS	705 19 05 0211 0100		03/14/94	260	AL
										DOCC.REVW	HPT9407072		7/14/94	262	AC
										HIST.SURV.	0091 0807 0700			78	
	031179	19 169-065	0901 FRANKLIN AVE	ALTERATIONS TO EAST RESTAURANT, PATIO ADD		705 ANGELES		P	1909	HIST SURV	0051 0133 0700			78	
	030754	10-177744	0911 FRANKLIN AVE			705 ANGELES		P	1921	HIST PRS	705 19 15 0251 7700		12/29/95	282	J
										PROC.REVW	9505312?LJ		12/29/95	261	D
	002610	1 -19190	0430 FLORIDA AVE			005 ANGELES		U		PROC.REVW.	9809F80?SE		11/10/?1	17	
	046?.?	1 -19070	1017 FRANKLIN AVE			005 ANGELES		U		PROC REVW.	1?0207-1?16		12/19/?1	17	
	030716		14132 FRISA ST			005 ANGELES		P	1974	PROC.REVW.	9?? 19-16 0244 ?00		11/10/94	17	
										HIST PRS	705 19 26-0249-0006		11/30/??	5.	
	030717		14016 FRISA ST			705 ANGELES		P	1921	HIST REV.	4?0?702?17		11/30/??	5.	
										PROC REVW.			11/30/??	17	
	030032		1?? FLORIDAGE PL	NEW SINGLE FAMILY DWELLING		705 ANGELES			1944	PROC REVW	FPA-111-05		07/20/?1	5Y	
	030051		5111 FOLSOM AVE			705 ANGELES		P	1904	HIST.REV.	705-19 05 0?2. 0211		03/20/??	5Y	
										PROC.REVW	5?6010?716		01/20/??	5Y	
	034?97	14 170011	5434 FONTANA ST			705 ANGELES		P	1415	HIST SURV.	0051 0?75 0700			?50	
	030015	19 170181	1?11 FONTANA ST			705 ANGELES		P	1982	HIST PRS	705 19 34-0?51-?706		11/??/94	5Y	
										PROC.REVW.	0905?0?-?8		11/02/94	5Y	
	1?0?44		01/222 ST	BRIDGE #51-1?9?? / BATTERY STREET T		705 ANGELES		A	929	PROJ REVW.	PUB0?01?6?		12 ??/?5	282	*
	030?1.	9 169?47	1-?1 BATTERY PL			705 ANGELES		P	1?1?	HIST SURV.	0051 0?13 1?16			19	
	030?18	14 169?31	1?1. BATTERY ST	BRIDGE REHABILITATION/PORT HUENEME		705 ANGELES		M	1917	ST ENG.PRO	51N ? 0? 55 19 ?5?		12/07/?0	?	
										PRO PUB IN	??? ?.?5 ?v-?? ??		01/?1/??	?L	
										NPS? REV.	?NS-?4?0?50? 06 ?		12/12/?4	5?	
										HIST SURV.	0051 0?27 0?20		01/?1/?4	15	
	1?7?47		1?1F AVE			108 ANGELES			1910	PROC.REVW.	?U?5111?5?		.?2?5/?1	10	
	01?.?	19 ?7?467	11?9 OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		M		PROJ REVW.	?U?9?06100		11/12/??	5Y	
	01?1..	19 ?7?5?1	11?7 OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		C		PROJ REVW	M?0?.?5?1?		9?/1?/?1	?Y	
	00?2?1	19 ?7?5?1	11?4 OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		C		PROJ REVW	0?0?1?0?1??		?7?1/?1	?Y	
	041?51	19-171???	110 ? OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		C		PROJ REVW	?U?0?06?2?		?7?1/?1	?Y	
	040?81	19 171?0?	11?? OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		C		PROJ REVW	?U?0?06?1?		?7?1/?1	?Y	
	05?0??	19 171?67	1141 OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		C		PROJ REVW	?U?0?06?1?		07?2/?1	?Y	
	0?0?.	19 1?1?67	1124 OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		C		PROJ REVW	?U?0?06?1?		.?? ?/??	?Y	
	04?0??	19 17?567	1127 OAK AVE	LANDMARK RESIDENTIAL DISTRICT		705 ANGELES		C		PROJ REVW	?U?0?06?1?		??1?/??	?Y	
	030?05	19 1-?0?0	4?05 OANMIER ST			705 ANGELES		C	1?20	PROJ REVW	M?0?0?160A		??/?3/?1	?Y	
	1?0?01	19 ??1??1	<0-? OANMIER ?.			705 ANGELES		C	1?21	PROJ REVW	M?0?0?116?		12/?3/??	?Y	
	1?0?11	19-1?1???	4?2? OSTRICH ??			705 ANGELES		C	1?2?	PROJ REVW	M?0?0?113M		01?1/??	?Y	
	030?1.	1? 1?1?4?	1?50 OXNARD ST			705 ANGELES		C	1?25	PROJ REVW	?U?0?1?04A		02?6/?2	??	
	1?0?14	?? 17?1??	?1?1 OXNARD STATES AVE			705 ANGELES		C	1?26	PROJ REVW	0?0?1?1?3A		02?2/??	??	
	111?47		1?0? PARK ST	FRITZMAN BAT CO. ? STORAGE BUILDING		705 ANGELES			1?55	PROJ REVW	0?0?1?07?A		01?7/?4	?Y	
	1?1?71	11 1?1?2?	1?14 PARRISH PL			705 ANGELES		P	1?22	HIST SURV	0?05 1?1? 0?00			?03	
	031?42	19 1?11??	1?2? PARRISH PL	ADVANCE APPROVALS		705 ANGELES		P	1?24	HIST SURV	0?51 1?11-?00?			?.??	
	031?5?	17 1?1?04	1?4? PARRISH PL			705 ANGELES		P	1?26	HIST SURV	0?51 1?11-?00?			?.??	
	031?71	11 1?1?0?	1?5? PARRISH PL			705 ANGELES		P	1??8	HIST SURV	0?51 1?11-?00?			?.??	
	031?78	11 1?1?0?	1?11 PARRISH PL			705 ANGELES		P	1?27	HIST SURV	0?51 1?11-?00?			?.??	
	031?72	11 1?1?07	1?2? PARRISH PL			705 ANGELES		P	1?27	HIST SURV	0?51 1?11-?00?			?.??	
	031?8?	11 1?1?08	1?1? PARRISH PL			705 ANGELES		P	1?27	HIST SURV	0?51-1?16-?00?			10	
	031?8.	1. 1?1?09	1?0? PARRISH PL			705 ANGELES		?	1?2?	HIST SURV	0?51 1?11-?00?			?.??	
	1?1?62		?.1 PARSELL ST			705 ANGELES			1?42	HIST PRS	10E 19 06 0?1? 0?1?		04/30/?1	05	
										PROJ REVW	HPT?410?5?		01/?6/?4	?Y	
	1?1?05		21?.5 PARTRIDGE AVE			105 ANGELES			19??	HIST.REV.	DOE-19-?7-0?1? 0?1?		01/?1/?1	??	

AR0073385

PROPERTY NUMBER	OWNER	PRIMARY ADDRESS	CURRENT MAILING ADDRESS	NAME	CITY NAME	CVR	YR C	CHG-PROP	PRO REFERENCE-NUMBER	STAT DAT	NBG	UNIT
	129425		2229 GLENDALE BLVD	MEXICAN OFFICE ASSOCIATION	LOS ANGELES	P	1949	MISC RPS	NBG 1106706 3017	03/08/11	19	B
								MAT PER.	19-0145	09/16/00	19	A
	119997		2230 GLENDALE BVD	GLENDALE FEDERAL	LOS ANGELES	P	1969	MISC RPS	CS	11/13/00	20S	AU
								JUL PER	19-0264	07/21/98	02S	MF
	977753	19-178403	2400 GLENDALE AVE	LOMAS BRYANT BUILDING & LOAN ASSOC	LOS ANGELES	P	1924	MISC.MISC.	005 19 94 0154 3101	04/01/94	99	C
								MISC PERM.	JB0940211A	03/30/94	00	J
								MISC RES	9HD 1011 0411	10/14/91	10	
								ST MS CONV	19 0302	04/16/90	01	
								ST PMT PRO	019 0 2F 84 19-019	12/15/00	1	
								ST MS CONV	19-0313	10/26/88	01	
								PMT PMT PR	021 0-80-MPF 19 01	11/01/80	08	
								TAX CONV.	552 9-19-0097	12/12/77	77	
								MISC.MISC.	MPR 7107013A1 3200	11/19/71	10	C
								MISC SURV.	0062 0218 0214	12/14/71	15	I
	92114		1919 GRAYBURN AVE		LOS ANGELES	Y	1923	MISC RPS	20E-19-95 0134 3001	10/11/95	5Y	
								PROJ.REVW	MISCMISC01	02/07/95	07	
	0.0000	19 178617	1211 GLENWOOD AVE		LOS ANGELES	P	1948	MISC.SURV.	0051-2114 0201		0F	
		27 189421										
	241358	19- 17474	5851 GLENWOOD ST		LOS ANGELES	U	1925	PROJ REVW	NLD9710970	05/22/01	6Y	
	177146	19 178193	1734 GOLDEN GATE AVE		LOS ANGELES	P	1924	MISC.RES.	6GB 19 95 0109 0001	11/08/95	6L	
								PROJ.REVW.	MRB9607092	11/08/95	6Y	
	199410	19 178614	17922 GRACE ST		LOS ANGELES	M	1911	MISC.RES.	0030-19-96-0312-0100	04/29/96	6Z	
								ANAL.REVW.	JMB9602022	04/29/96	6Y	
	240819	19 178619	1508 TOWNE ST		LOS ANGELES	M		MISC.RES.	JGE 19 94 0015-0101	04/29/94	6Y	
								PROJ REVW.	MRB9410022	04/29/94	6Y	
	167994		75021 GOODWIN AVE		LOS ANGELES		1951	MISC.RES.	10B-19-97-0342 3001	01/31/03	6B	
								PROJ.REVW.	MISC0301197	01/31/03	0L	
	200802	19 178819	1745 TOWER ST	VISTA DEL VALLECARLOS DISTRICT	LOS ANGELES	P	1924	MISC.RES.	003 19-94 0444-3001	11/01/94	7F2	
								PROJ REVW	MRB9402022	09/01/94	7F2	
	239758	19-178921	3760 GOMER ST	MOZAMBIQUE PRESBYTERIAN CHURCH	LOS ANGELES	P	1923	MISC.SURV	0051 0401-1300		7G	
	051435	19-197447	1001 GRACE AVE		LOS ANGELES	P	1910	MISC.RES.	SPA-8270218A-0121	08/19/82	1D	AT
	041411	19 197445	2019 GRACE AVE		LOS ANGELES	P	1921	MISC.RES.	SPA-8209218A-0104	06/19/82	1L	AU
	041426	19 197438	2014 GRACE AVE		LOS ANGELES	P	1923	MISC RES.	MLS-8208218A 0102	06/19/82	1L	AQ
	041401	19-197419	2021 GRACE AVE	CHAPTER X BUDAPEST/HUNGARIAN REACH ORD	LOS ANGELES	P	1914	MISC RES	MLS 8210218A 011	08/19/82	1D	AV
	121401	19 19743-	2026 GRACE AVE		LOS ANGELES	P	1921	MISC RES	MLS 8210218A 0111	07/19/82	1F	AT
	041340	19 197422	2031 GRACE AVE		LOS ANGELES	P	1924	MISC RES	SPA-8210218A 0106	07/19/82	1F	AT
	121410	19 19 414	2041 GRACE AVE	MARTIN WILSON HOME (USUR VAL PROP	LOS ANGELES	P	1923	MISC.RES.	MRS-8210218A-0118	08/19/82	1D	AV
	021358	19 197423	2044 GRACE AVE		LOS ANGELES	P	1921	MISC.RES.	SPA-8209218A-0107	06/19/82	1D	AT
	021107	19-197431	2047 GRACE AVE		LOS ANGELES	P	1919	MISC.RES.	SPA 8209218A 0116	06/19/82	1D	AT
	041306	19 19741D	2054 GRACE AVE	MARY CAMPBELL HOME	LOS ANGELES	P	1921	MISC.RES.	MRS-8210218A-01 4	08/19/82	1D	AT
	021109	19-197121	2055 GRACE AVE		LOS ANGELES	P	1938	MISC.RES.	MRS-8210218A-0106	08/19/82	1J	AV
	121321	19 19742-	2101 GRACE AVE	PRADA SCULLY INC.	LOS ANGELES	P	1929	MISC RES.	MRS 8210218A 0113	08/19/82	1J	AV
	0239 +	19 190825	9515 GRAHAM ST		LOS ANGELES	P	1918	MISC SURV.	0062 1282 2300		7P	
	020817	19 190629	9518 GRAHAM ST		LOS ANGELES	P	1910	MISC SURV	0051-1215 0200		7P	
	021130	19-190618	9521 GRAHAM ST		LOS ANGELES	P	1901	STAT.SURV.	0051 1284 1200		7P	
	021219	19-190611	9704 GRAHAM ST		LOS ANGELES	P	1927	MISC.SURV.	0051 1044-1200		7K	
	020610	19 190817	9715 GRAHAM ST		LOS ANGELES	P	1916	MISC.SURV.	0051 1276 0300		7R	
	020411	19 190801	9724 GRANBERRY PL		LOS ANGELES	P	1913	MISC SURV.	0052 0115-0201		7S	
	1330 +	19 197601	1737 GRANBERRY PL		LOS ANGELES	P	1924	MISC.SURV	0031 0216 1300		5E	
	020965	19 197551	1741 GRANBERRY PL	CHA DRAMATICS	LOS ANGELES	P	1924	MISC.SURV	0051-0317 1300		7C	
	020482	19 197497	1745 GRANBERRY PL	KOREATOWN APARTMENT ASSOCIATES (DUTCH	LOS ANGELES	P	1930	MISC.SURV.	0051-0318 1200		7S	
	021108	19 197486	1801 GRANBERRY PL		LOS ANGELES	P	1907	MISC.SURV.	0051 0119 1000		6R	
	021109	19 197477	1805 GRANBERRY PL		LOS ANGELES	P	1908	MISC.SURV.	0051 0219 1000		6R	
	021110	19 197457	1811 GRANBERRY PL		LOS ANGELES	P	1910	MISC SURV	0053 0511 0900		5F	

ASSESSOR'S MAP BOOK

PROPERTY NUMBER	DETAIL REFERENCE	STATUS CODE	NAME	CITY NAME	CODE	OWNER	DATE	DATE
700012	12-000401		HARBOR BLVD	LOS ANGELES	037			
700013			HARBOR FREEWAY	LOS ANGELES	037			
700014	12-000402		HARBOR FREEWAY	LOS ANGELES	037			
700015	12-000403		HARBOR FREEWAY	LOS ANGELES	037			
700016	12-000404		HARBOR FREEWAY	LOS ANGELES	037			
700017	12-000405		HARBOR FREEWAY	LOS ANGELES	037			
700018	12-000406		HARBOR FREEWAY	LOS ANGELES	037			
700019	12-000407		HARBOR FREEWAY	LOS ANGELES	037			
700020	12-000408		HARBOR FREEWAY	LOS ANGELES	037			
700021	12-000409		HARBOR FREEWAY	LOS ANGELES	037			
700022	12-000410		HARBOR FREEWAY	LOS ANGELES	037			
700023	12-000411		HARBOR FREEWAY	LOS ANGELES	037			
700024	12-000412		HARBOR FREEWAY	LOS ANGELES	037			
700025	12-000413		HARBOR FREEWAY	LOS ANGELES	037			
700026	12-000414		HARBOR FREEWAY	LOS ANGELES	037			
700027	12-000415		HARBOR FREEWAY	LOS ANGELES	037			
700028	12-000416		HARBOR FREEWAY	LOS ANGELES	037			
700029	12-000417		HARBOR FREEWAY	LOS ANGELES	037			
700030	12-000418		HARBOR FREEWAY	LOS ANGELES	037			
700031	12-000419		HARBOR FREEWAY	LOS ANGELES	037			
700032	12-000420		HARBOR FREEWAY	LOS ANGELES	037			
700033	12-000421		HARBOR FREEWAY	LOS ANGELES	037			
700034	12-000422		HARBOR FREEWAY	LOS ANGELES	037			
700035	12-000423		HARBOR FREEWAY	LOS ANGELES	037			
700036	12-000424		HARBOR FREEWAY	LOS ANGELES	037			
700037	12-000425		HARBOR FREEWAY	LOS ANGELES	037			
700038	12-000426		HARBOR FREEWAY	LOS ANGELES	037			
700039	12-000427		HARBOR FREEWAY	LOS ANGELES	037			
700040	12-000428		HARBOR FREEWAY	LOS ANGELES	037			
700041	12-000429		HARBOR FREEWAY	LOS ANGELES	037			
700042	12-000430		HARBOR FREEWAY	LOS ANGELES	037			
700043	12-000431		HARBOR FREEWAY	LOS ANGELES	037			
700044	12-000432		HARBOR FREEWAY	LOS ANGELES	037			
700045	12-000433		HARBOR FREEWAY	LOS ANGELES	037			
700046	12-000434		HARBOR FREEWAY	LOS ANGELES	037			
700047	12-000435		HARBOR FREEWAY	LOS ANGELES	037			
700048	12-000436		HARBOR FREEWAY	LOS ANGELES	037			
700049	12-000437		HARBOR FREEWAY	LOS ANGELES	037			
700050	12-000438		HARBOR FREEWAY	LOS ANGELES	037			
700051	12-000439		HARBOR FREEWAY	LOS ANGELES	037			
700052	12-000440		HARBOR FREEWAY	LOS ANGELES	037			
700053	12-000441		HARBOR FREEWAY	LOS ANGELES	037			
700054	12-000442		HARBOR FREEWAY	LOS ANGELES	037			
700055	12-000443		HARBOR FREEWAY	LOS ANGELES	037			
700056	12-000444		HARBOR FREEWAY	LOS ANGELES	037			
700057	12-000445		HARBOR FREEWAY	LOS ANGELES	037			
700058	12-000446		HARBOR FREEWAY	LOS ANGELES	037			
700059	12-000447		HARBOR FREEWAY	LOS ANGELES	037			
700060	12-000448		HARBOR FREEWAY	LOS ANGELES	037			
700061	12-000449		HARBOR FREEWAY	LOS ANGELES	037			
700062	12-000450		HARBOR FREEWAY	LOS ANGELES	037			
700063	12-000451		HARBOR FREEWAY	LOS ANGELES	037			
700064	12-000452		HARBOR FREEWAY	LOS ANGELES	037			
700065	12-000453		HARBOR FREEWAY	LOS ANGELES	037			
700066	12-000454		HARBOR FREEWAY	LOS ANGELES	037			
700067	12-000455		HARBOR FREEWAY	LOS ANGELES	037			
700068	12-000456		HARBOR FREEWAY	LOS ANGELES	037			
700069	12-000457		HARBOR FREEWAY	LOS ANGELES	037			
700070	12-000458		HARBOR FREEWAY	LOS ANGELES	037			
700071	12-000459		HARBOR FREEWAY	LOS ANGELES	037			
700072	12-000460		HARBOR FREEWAY	LOS ANGELES	037			
700073	12-000461		HARBOR FREEWAY	LOS ANGELES	037			
700074	12-000462		HARBOR FREEWAY	LOS ANGELES	037			
700075	12-000463		HARBOR FREEWAY	LOS ANGELES	037			
700076	12-000464		HARBOR FREEWAY	LOS ANGELES	037			
700077	12-000465		HARBOR FREEWAY	LOS ANGELES	037			
700078	12-000466		HARBOR FREEWAY	LOS ANGELES	037			
700079	12-000467		HARBOR FREEWAY	LOS ANGELES	037			
700080	12-000468		HARBOR FREEWAY	LOS ANGELES	037			
700081	12-000469		HARBOR FREEWAY	LOS ANGELES	037			
700082	12-000470		HARBOR FREEWAY	LOS ANGELES	037			
700083	12-000471		HARBOR FREEWAY	LOS ANGELES	037			
700084	12-000472		HARBOR FREEWAY	LOS ANGELES	037			
700085	12-000473		HARBOR FREEWAY	LOS ANGELES	037			
700086	12-000474		HARBOR FREEWAY	LOS ANGELES	037			
700087	12-000475		HARBOR FREEWAY	LOS ANGELES	037			
700088	12-000476		HARBOR FREEWAY	LOS ANGELES	037			
700089	12-000477		HARBOR FREEWAY	LOS ANGELES	037			
700090	12-000478		HARBOR FREEWAY	LOS ANGELES	037			
700091	12-000479		HARBOR FREEWAY	LOS ANGELES	037			
700092	12-000480		HARBOR FREEWAY	LOS ANGELES	037			
700093	12-000481		HARBOR FREEWAY	LOS ANGELES	037			
700094	12-000482		HARBOR FREEWAY	LOS ANGELES	037			
700095	12-000483		HARBOR FREEWAY	LOS ANGELES	037			
700096	12-000484		HARBOR FREEWAY	LOS ANGELES	037			
700097	12-000485		HARBOR FREEWAY	LOS ANGELES	037			
700098	12-000486		HARBOR FREEWAY	LOS ANGELES	037			
700099	12-000487		HARBOR FREEWAY	LOS ANGELES	037			
700100	12-000488		HARBOR FREEWAY	LOS ANGELES	037			

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OFFICE OF HISTORIC PRESERVATION * * * Directory of Properties in the Historic Property Data File for LOS ANGELES County Page 126 12-03-07

PROPERTY#	PRIMARY-#	STREET.ADDRESS	NAMES	CITY.NAME	OWN	YR-C	OHP-PROG	PRG-REFERENCE-NUMBER	STAT-DAT	NRS	CRIT
021111	19-164185	5596 HAROLD WY		LOS ANGELES	P	1929	HIST.SURV.	0071-2591-9999		5S	
021162	19-164199	5604 HAROLD WY		LOS ANGELES	P	1924	HIST.SURV.	0071-2591-0071		5S	
021165	19-164114	5701 HAROLD WY		LOS ANGELES	P	1911	HIST.SURV.	0071-2591-0002		5S	
141542		5805 HAROLD WY		LOS ANGELES	P	1955	HIST.RES.	DOE-19-04-0101-0000	11/13/04	6Y	
							PROJ.REVW.	FHWA040305A	11/11/04	6Y	
021149	19-164211	5812 HAROLD WY		LOS ANGELES	P	1929	HIST.SURV.	0071-2591-0001		5S	
021151	19-164213	5816 HAROLD WY		LOS ANGELES	P	1909	HIST.SURV.	0071-2591-0002		5S	
021152	19-167309	5820 HAROLD WY		LOS ANGELES	P	1919	PROJ.REVW.	FHWA040305A	07/18/05	6Y	
							HIST.RES.	DOE-19-94-0447-0000	09/21/94	2S2	
							PROJ.REVW.	HUD940322	09/21/94	2S2	
							HIST.SURV.	0071-2591-0009		7N	
021700	19-167415	5820 HAROLD WY		LOS ANGELES	P	1911	HIST.SURV.	0071-0194-0002		5S	
021711	19-167410	5826 HAROLD WY		LOS ANGELES	P	1926	HIST.SURV.	0071-0194-0004		5S	
021153	19-167812	5831 HAROLD WY		LOS ANGELES	P	1913	HIST.SURV.	0071-2591-0007		5S	
021154	19-167811	5832 HAROLD WY		LOS ANGELES	P	1924	HIST.SURV.	0153-2591-0001		5S	
021155	19-167814	5902 HAROLD WY		LOS ANGELES	P	1924	HIST.SURV.	0153-2591-0002		5S	
021156	19-167813	5908 HAROLD WY		LOS ANGELES	P	1923	HIST.SURV.	0153-2591-0004		5S	
021157	19-169544	6023 HAROLD WY		LOS ANGELES	P	1925	HIST.SURV.	0153-2519-0003		5S	
020757	19-169540	6054 HAROLD WY		LOS ANGELES	P	1921	HIST.RES.	DOE-19-94-0447-0010	07/21/94	2S2	
							PROJ.REVW.	HUD940322	07/21/94	2S2	
							HIST.SURV.	0071-2519-0016		5D	
021124	19-169160	6057 HAROLD WY		LOS ANGELES	P	1913	HIST.RES.	DOE-19-94-0447-0011	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0017		5D	
021125	19-169161	6060 HAROLD WY		LOS ANGELES	P	1919	HIST.RES.	DOE-19-94-0447-0012	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0012		5D	
021227	19-175239	6061 HAROLD WY		LOS ANGELES	P		PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.RES.	HUD 0322	07/21/94	2D2	
021130	19-169157	6063 HAROLD WY		LOS ANGELES	P	1921	HIST.RES.	DOE-19-94-0447-0013	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0013		5D	
021131	19-169177	6066 HAROLD WY		LOS ANGELES	P	1919	HIST.RES.	DOE-19-94-0447-0014	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0014		5D	
021132	19-169176	6070 HAROLD WY		LOS ANGELES	P	1922	HIST.RES.	DOE-19-94-0447-0015	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0015		5D	
021133	19-169155	6071 HAROLD WY		LOS ANGELES	P	1919	HIST.RES.	DOE-19-94-0447-0017	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0017		5D	
021137	19-169155	6075 HAROLD WY		LOS ANGELES	P	1913	HIST.RES.	DOE-19-94-0447-0016	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0016		5D	
021134	19-169038	6076 HAROLD WY		LOS ANGELES	P	1919	HIST.SURV.	0071-2519-0018		5D	
021135	19-169157	6078 HAROLD WY		LOS ANGELES	P	1912	HIST.RES.	DOE-19-94-0447-0018	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0019		5D	
021710	19-169142	6081 HAROLD WY		LOS ANGELES	P	1917	HIST.SURV.	0071-2519-0001		5D	
021139	19-169143	6082 HAROLD WY		LOS ANGELES	P	1921	HIST.RES.	DOE-19-94-0447-0011	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0021		5D	
021136	19-169144	6084 HAROLD WY		LOS ANGELES	P	1919	HIST.SURV.	0071-2519-0021		5D	
021133	19-169145	6084 HAROLD WY		LOS ANGELES	P	1924	HIST.RES.	DOE-19-94-0447-0012	07/21/94	2D2	
							PROJ.REVW.	HUD940322	07/21/94	2D2	
							HIST.SURV.	0071-2519-0022		5D	

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ENTRY NUM	PROPERTY NAME	ADDRESS	RANGE	CITY NAME	CODE	YR C	OWNERSHIP	OWNER PERMANENT NUMBER	STAT DATE	REG	CERT
	CITRUS	15 10314	6038 HAROLD RD	LOS ANGELES	P	1915	DISTRICT	0011 0139-1706		5D	
4	070324	19 166312	6031 HAROLD RD	LOS ANGELES	P	1913	PRIVATE	2507 19-04 2447 3021	3/27/74	5D4	
							PRIVATE	RR0=102507	03/31/94	5D3	
							DISTRICT	0011-0139-1001		3D	
	031561	15 179138	615 HARRIS AVE	LOS ANGELES	M		DISTRICT	0002-19 94-0002 0013	3/31/91	6Y	
							PRIVATE	BR0=042922	12/03/94	6Y	
	026152	15 17743	4031 HARRISON AVE	LOS ANGELES	M	1907	DEPT REG	002 10-94 0121 0001	12/5/94	6Y	
							PRIVATE	RR0=012023	08/31/94	6Y	
	13374		734 HASTINGS AVE	LOS ANGELES	D	1925	DISTRICT	0006-19-95 1321 1011	12/31/95	6Y	
							TRUST	0D7=02010	3/31/94	6Y	
	120757		717 HASTINGS AVE	LOS ANGELES	D	1923	DEPT REG	002-19 99-0196-11	06/14/99	6Y	
							CHURCH	RR0=011023	12/31/97	6Y	
	07.002	17-167006	HAWKINS AVE	1750-1820 BLOCK OF HAWKINS AVENUE	LOS	ANGELES	P	1924	DISTRICT	0001-0140 2005		5N	
	04.043	13 16719	2511 HAWKINS AVE		LOS	ANGELES	P	1921	DISTRICT	001 0140 2041		5D2	
	04.007	13 167316	2521 HAWKINS AVE		LOS	ANGELES	P	1921	PRIVATE	001 0140 2043		5D4	
	021542	19 167121	1927 HAWKINS AVE		LOS	ANGELES	P	1913	DEPT SURV	0001-0142 2001		5D4	
	12547	15 161596	1555 HAWKINS AVE		LOS	ANGELES	P	1930	DEPT SURV	0001 0141 2006		5D4	
	12.07	15 161543	1737 HAWKINS AVE		LOS	ANGELES	P	1914	DEPT OTHR	0001-0140 2021		5D4	
	02.171	19 167.58	2141 HAWKINS AVE		LOS	ANGELES	P	1913	PRIVATE	0001 0140 2001		5D4	
	02.172	13 167796	1949 HAWKINS AVE		LOS	ANGELES	P	1916	PRIVATE	0001 0140 2001		5D4	
	02.173	19 16.096	1955 HAWKINS AVE		LOS	ANGELES	P	1926	DISTRICT	0001-0140 2001		5D4	
	021075	19- 07401	1913 HAWKINS AVE		LOS	ANGELES	P	1923	DEPT SURV	0001 0140 2003		5D4	
	021077	15 161981	1921 HAWKINS AVE		LOS	ANGELES	P	1924	DEPT OTHR	0001 0140 2011		5D4	
	021079	15 161982	1911 HAWKINS AVE		LOS	ANGELES	P	1924	DISTRICT	0001 0140 2011		5D4	
	021077	15 15-906	1913 HAWKINS AVE		LOS	ANGELES	P	1916	DEPT SURV	0001 0140 2001		5D4	
	021079	19 167906	1932 HAWKINS AVE		LOS	ANGELES	P	1924	DEPT SURV	0001 0140 2001		5D4	
	021079	19 167906	1916 HAWKINS AVE		LOS	ANGELES	P	1924	DEPT SURV	0001 0140 2001		5D4	
	021.88.	17-167907	1935 HAWKINS AVE		LOS	ANGELES	P	1916	DISTRICT	0001-0140 2011		5D4	
	021.81	17 167909	1939 HAWKINS AVE		LOS	ANGELES	P	1917	DISTRICT	0001-0140 2017		5D4	
	021.83	19 16-.72	1949 HAWKINS SELL	1 A TUBERMAN RESIDENCE	LOS	ANGELES	P	1917	DEPT SURV	0001 0003-0001		1D	
	021.15	19 161787	2015 HAWKINS BLVD	THE CIRCLE 2 RIDGE DRIVE	LOS	ANGELES	P	1972	DEPT RES	NAT REGISTER-7000	01/23/92	1D	
							PRIVATE	0701 0140 2001	01/23/92	1D	
	04.03.	15 17741	10311 HAWORTH AVE		LOS	ANGELES	M	1929	DISTRICT	0001 0E8 0N 1021 0019	12/30/94	6Y	
							PRIVATE	DRONA71020	04/09/94	6Y	
	0010.6	19 11-132	10970 HAWTHORNE AVE		LOS	ANGELES	V	1921	DEPT REG	002-19-94-0021 0119	02/01/21	6Y	
							PRIVATE	RR0=011023	09/31/21	6Y	
	010507	15 17411.4	4114 HAYDEN PL	LOS ANGELES	D	1941	DEPT PARK	5070110019	11/1/91	3S	
	110980		1015 HAYDEN ST	LOS ANGELES	Y	1941	DEPT REG	005 19 00 0183 0 21	01/31/05	4Y	
							PRIVATE	RR0=010.7	01/31/05	6Y	
	01.061	13 171046	HAYNES AVE	SUBDIVISION AREAS AND SETTLERS' DWELL	LOS	ANGELES	V	1870	DISTRICT	0011-4174 0001		1S	
	13.051		1451 HAYWARD DR	TRACT ANDALUSIA HEIGHTS 3	LOS	ANGELES	P	1926	DISTRICT	5D5-010007115 0001	10/11/01	1S	1
							CHURCH	ID 0420	11/11/02	1S	1
	144144		1111 HAYENHURST LN	TRACT ANDALUSIA HEIGHTS 3	LOS	ANGELES	D	1925	DISTRICT	RR5-0310071 0001	10/23/01	1D	0
	144127		1401 HAYENHURST LN	TRACT ANDALUSIA HEIGHTS 2	LOS	ANGELES	D	1925	DISTRICT	RR5-0310711 0001	10/23/01	1D	0
	14.011		1171 HAYENHURST TR	TRACT ANDALUSIA HEIGHTS 3	LOS	ANGELES	I	1926	DISTRICT	5D7-0501071 0001	11/21/01	1T	0
	021.21	11 164045	6716 HAZELHURST AVE	SUBDIVISION OF RANCH A TOWN STATION	LOS	ANGELES	N	1902	DEPT SURV	0011-0111-1000		5N	
	03.020	15 161.76	6631 HEATHERDALE AVE		LOS	ANGELES	P	1914	DEPT SURV	0001-0141 1000		5D2	
	021.21	19 171351	6731 HEATHERDALE AVE	SUBDIVISION OF RANCH A TOWN STATION	LOS	ANGELES	N	1913	DEPT SURV	0001 2401 0000		1S	
	03.025	17 171.26	6729 HEATHERDALE AVE		LOS	ANGELES	P	1913	DEPT SURV	0001 2411-0001		1S	
	03.01	19 171010	6715 HEATHERDALE AVE		LOS	ANGELES	P	1913	DEPT SURV	0001 2411-0001		1S	
	03.023	19 171007	6711 HEATHERDALE AVE		LOS	ANGELES	P	1917	DEPT SURV	0001 2412 0001		1S	
	03.021	19-171009	6709 HEATHERDALE AVE		LOS	ANGELES	P	1913	DEPT SURV	0001 2412 0001		1S	
	03.03	19-171001	724 HEIGHTS AVE		LOS	ANGELES	P	1914	DEPT SURV	0001-2414 1001		1S	
	07.03	19-171001	724 HEIGHTS AVE		LOS	ANGELES	D		PRIVATE	RR0=011010	11/19/84	6Y	

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VERIFY	NR REFNUM	CERTIFY	CURRENT ALLOCATION	NAME	CITY NEAR	CNTY	ZIP CODE	PROPERTY TYPE	STAT DATE	CRIT	CRIT
	99000...	12 07/1997	2,000 WILSHIRE BLVD	DOWNTOWN MOTOR INNS	LOS ANGELES	P	9001	HIST.RES.	5/19/82	A	A
	99000...	06/14/1999	2000 WILSHIRE BLVD		LOS ANGELES	P	9005	HIST.RES.	5/19/82	A	A
	99000...	05/12/1999	2000 WILSHIRE BLVD		LOS ANGELES	P	9005	HIST.RES.	5/19/82	A	A
	99000...	05/14/1999	2000 WILSHIRE BLVD		LOS ANGELES	P	9005	HIST.RES.	5/19/82	A	A
	99000...	12/16/1997	WILSHIRE BLVD	STREET LIGHTS	LOS ANGELES	N	9001	HIST CONV.	5/19/82		
	99000...	09/16/1999	WILSHIRE BLVD	STREET LIGHTS	LOS ANGELES	N	0	HIST CONV.			
	99000...	12/12/1997	WILSHIRE BLVD	HOLLYWOOD WALK OF FAME	LOS ANGELES	N		HIST RES.	11/15/00	A	
								PROP NAME	11/15/00	A	
								HIST.DIST.			
	99000...	12/12/1997	WILSHIRE BLVD		LOS ANGELES	P	9001	HIST.DIST.			
	97000...	12/12/1997	HOLLYWOOD BOULEVARD COMMERCIAL A	HOLLYWOOD BOULEVARD COMMERCIAL A	LOS ANGELES	P	9001	HIST.RES.	11/04/97	C	
								FIRST SUBM.	11/04/97	C	
	99000...	12/12/1997	HOLLYWOOD BLVD	EAST HOLLYWOOD BOULEVARD DISTRICT	LOS ANGELES	P	9001	HIST.RES.	11/04/97		
								PROP NAME	11/04/97		
								HIST.RES.	11/04/97		
								PROP NAME	11/04/97		
	00000...		1400 WILSHIRE BLVD	DAVIDSON BUILDING	LOS ANGELES	P	9001	HIST RES	12/11/02		
								PROP NAME	12/11/02		
	00000...	9 10/2001	4800 HOLLYWOOD BLVD	HOLLYWOOD HOTEL	LOS ANGELES	N	9001	HIST.RES.	11/27/99		
								PROP NAME	11/27/99		
								ADDT DOC	01/31/01		
								PROP NAME	01/31/01		
								ADDT DOC	11/26/01		
	00000...	10/ 1/2001	4800 HOLLYWOOD BLVD	HOLLYWOOD HOTEL	LOS ANGELES	N		PROP NAME	12/12/02		
								HIST.RES	09/30/04		
	00000...	10/ /2001	1500 WILSHIRE BLVD	WILSHIRE A	LOS ANGELES	N	1910	HIST.DIST.	11/15/84		
								PROP NAME	12/12/04		
	00000...	10/ 5/2001	4500 HOLLYWOOD BLVD	PARAMOUNT PARK	LOS ANGELES	P	1926	HIST.DIST.	09/20/01		
								PROP NAME	2/11/04		
								AT PRO APP	6/11/0 08:49 10-05	12/21/01	
								HIST.RES	8/5 /11.0167 1999	5/25/11	
	99000...	10 10/2001	1901 HOLLYWOOD BLVD	FRANK AMERICAN BUILDING / ARAIS P	LOS ANGELES	N	1910	HIST.RES	11/27/99		
								PROP NAME	12/01/01		
	00000...	10 10/2001	2201 HOLLYWOOD BLVD		LOS ANGELES	N	1922	HIST.DIST.	02/11/04		
								PROP NAME	02/01/04		
	00000...	10/ 1/2001	2354 HOLLYWOOD BLVD		LOS ANGELES	P		PROP.NAME	04/17/04		
	00000...	10 10/2001	7358 SUNSET BLVD		LOS ANGELES	N	1927	PROP NAME	4/10/04		
								PROP NAME	11/04/04		
								PROP NAME	11/01/04		
	00000...	10 10/2001	6900 HOLLYWOOD BLVD		LOS ANGELES	E		PROP NAME	11/15/04		
	00000...	10 10/2001	7000 HOLLYWOOD BLVD		LOS ANGELES	W		PROP.NAME	12/12/04		
	00000...	10 10/2001	7060 HOLLYWOOD BLVD		LOS ANGELES	E		PROP.NAME	12/12/04		
	00000...	10 10/2001	7080 HOLLYWOOD BLVD		LOS ANGELES	E		PROP NAME	12/12/04		
	00000...	10 10/2001	7100 HOLLYWOOD BLVD		LOS ANGELES	E	1927	HIST RES	2 /11/04		
								PROP NAME	12/12/04		
								HIST.RES	11/15/04		
	00000...	10/ 1/2001	1700 HOLLYWOOD BLVD		LOS ANGELES	P		HIST.RES	11/15/04		
	00000...	10/ 1/2001	1701 HOLLYWOOD BLVD		LOS ANGELES	P		PROP NAME	11/01/04		
	00000...	10/ 1/2001	1702 HOLLYWOOD BLVD		LOS ANGELES	P		PROP NAME	11/01/04		
	00000...	10/ 1/2001	6400 HOLLYWOOD BLVD	EAST HOLLYWOOD BOULEVARD DISTRICT	LOS ANGELES	E	1911	HIST.RES.	2 /11/04		
								PROP NAME	12/12/04		
								HIST.RES	11/15/04		
								PROP NAME	11/01/04		
	00000...	10/ 1/2001	6401 HOLLYWOOD BLVD	EAST HOLLYWOOD RESIDENTIAL DISTRICT	LOS ANGELES	E	1925	HIST.RES	11/15/04		
								PROP NAME	11/01/04		
								HIST.RES.	11/15/04		

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LIABILITY PAYMENT	SECURITY #	INTEREST ADDRESS	PROPERTY ...	CITY,STATE	CODE	LOT	DEED CODE	BOOK REFERENCE / APPEAL	CONSTRUCTION	BOOK	COST
							FIRST SURV	0169 0661 0001			71
	031/4	15 1075.6	9015 ROLLYWOOD BLVD	CALIFORNIA BANK/PROTECTION ATTY. DIST	LOS ANGELES	J	1944	DEED REC	BOOK 19 PG 003: 0021	04/15/32	383	0
								PROJ.ASSN	UNTRA-09118	09/11/41	201	C
								FIRST SURV	0.55 0107-0002		32	
	04.146	10 111.43	596 BOULEVARD BLVD		LOS ANGELES	K	1427	WEST PPR	106 LP 34 0761-0107	07/27/61	41	
								PROJ.ASSN	8806-72024	07/11/61	64	
	021.02	19 1.7419	641 BOULEVARD BLVD		LOS ANGELES	J	1954	DEED.FUND	0077-0108 /001		965	
	021.01	9 15.419	5701 BOULEVARD BLVD	ARTERITY PUBLIC BANK / ASSOC CORP	LOS ANGELES	P	1923	FIRST SURV	0141-0569-0002		38	
	1.191	1 15.841	5715 BOULEVARD BLVD	SYNCOPATED SPORTS CO.	LOS ANGELES	P	1931	WEST DEED.	BOOK 11-04 1643 0711	09/13/34	933	
								PROJ.ASSN	8806-72023	09/21/34	903	
								PLAT SURV	2251-0100 000		33	
+	17.877	19 1.0163	5941 BOULEVARD BLVD	SALVATION ARMY TABERNACLE	LOS ANGELES	P	1962	DEED ASSN.	BOOK 11-04 1401 0021	06/21/74	983	0
								PROJ ASSN	8806-72024	06/21/74	982	7
	1.0.1.2	14 176.04	7445 BOULEVARD BLVD		LOS ANGELES	I	1937	WEST SRS	BOOK 15 PG 0154 0117	05/14/59	12	
								PROJ ASSN	8806-72021	05/14/59	87	
	4.6.1.3	13 1.7.11	6421 BOULEVARD BLVD		LOS ANGELES	P	1930	ASSN ASN	BOOK 19-04 0961 0120	06/19/61	69	
								PROJ ASSN	8806-72027	14/15/31	67	
+	021.12	11 1.0.03	6311 BOULEVARD BLVD	HOLLYWOOD PARKWAYS TURNATION	LOS ANGELES	P	1938	TAX CERT.	81.3 .0 0111	14/10/02	71	
								WEST SRS	LOT 13 93-0604 0003	08/11/91	302	0
								PROJ.ASSN	8806-7202A	08/11/91	304	0
								MUSIC.CORP.	0051-4450-7001	04/04/81	10	0
								WEST SURV	0.15 0191 0007		79	
+	0.1.6	14 1.7.1	5251 BOULEVARD BLVD	HOLLYWOOD. BOULEVARD BUILDING	LOS ANGELES	J	1929	TAX.CERT	01. 9 11 2011	10/.0/92	211	
								WEST CORP	0211-4590 0101	04/14/87	13	0
								WEST.CORP	0211-0504 7501		44	
+	0.1.1.4	15 1.0.42	5364 BOULEVARD BLVD	WILSHIRE'S BOOK STORE	LOS ANGELES	P	1913	WEST CORP	0051 4160-7011	01/24/8	10	0
								WEST SUBL.	0051 0404 0001		10	
+	321.31	19 11.7.2	6.71 BOULEVARD BLVD	E. A. DELAS COMPANY. PARKWAY DEPOT	LOS ANGELES	P	1911	WEST SURV	0053 4150-0711	01/01/41	13	0
								WEST SURV	0755 0108 0120		14	
	17.1.3	19 174.35	1401 BOULEVARD BLVD	CARVAJAL PIOT	LOS ANGELES	C	1914	DEED CORP	0751 0580 .041	02/04/35	69	
	026.7	19 1.4.14	6213 BOULEVARD BLVD	GARAGE 1	LOS ANGELES	D	1921	WEST SURV	1211-0580 .062	04/21/89	68	
	004.5	19 174.04	4320 BOULEVARD BLVD		LOS ANGELES	M	1913	DEED.DEED	BOOK 15-04 .5 1.0	09/17/44	68	
								Proj.ASSN	8806-72027	09/11/04	68	
	024.71	19 1.4.14	6211 BOULEVARD BLVD	VINE ST TRIALSP	LOS ANGELES	L	1933	WEST SURV	0051 4110-7701	04/01/84	68	
+	09.1 19	14 167.76	5574 BOULEVARD BLVD	BRODERY BLDG / ORIGINAL STRUCTURE &	LOS ANGELES	P	1922	DEED.CORP.	0051-4450 1003	04/21/87	11	0
								PLAT.CORP.	0051-0434 1007		98	
	0.1.4.2	19 1.4.159	1121 BOULEVARD BLVD		LOS ANGELES	D	1919	WEST SURV	0051 4671-2004	04/01/81	68	
+ 1	07.177	19 15.7.1	5101 WILSHIRE BLVD	CHANGABLY TOLDS. ALTERATIVE STYLE BLDG	LOS ANGELES	D	1921	WEST.CORP	0051 4650 2004	04/11/85	12	0
								TAX.ASST.	511 9.19 0.05	11/21/82	76	
								SUBT.DEED.	0051-7501010 0110	09/14/79	19	0
								SUBT.SURV.	0051-0151 0.07	09/04/21	14	0
								FIRST.SURV.	0051-0410 0101		10	
	0.1.6.1	19 174.25	4134 BOULEVARD BLVD		LOS ANGELES	P	0	FIRST SURV.	0051-4050-0.00	12/04/81	68	
	07.1.9	19 174.21	61.4 BOULEVARD BLVD		LOS ANGELES	P	0	FIRST SURV	0051 4610 0151	11/04/85	82	
+	7.1.2.1	19 15.7.1.	6262 BOULEVARD BLVD	BEGAL SIDE SHOWS	LOS ANGELES	P	1911	WEST SURV	0051 4650-0106	01/09/89	12	7
								WEST SURV	.053 0611-0101		10	
+	02.1.3	19 1.0.3.	6252 BOULEVARD BLVD	Classic	LOS ANGELES	P	1911	WEST SURV	1051 4650 0.10	01/04/55	21	0
+	.04.21	19 174.23	6263 BOULEVARD BLVD	TOURIST HOTEL PLAZA	LOS ANGELES	P	1929	DEED.SURV	0051 4650 0501	14/01/89	12	0
	104.12	19 174.27	6316 BOULEVARD BLVD		LOS ANGELES	M	1921	DEED.SURV.	0051 4650 0201	14/04/89	68	
+	021.1.1	19 1.7.21	1303 BOULEVARD BLVD	GARNER BLDG	LOS ANGELES	P	1921	DEED.SURV.	0051 4650 0251	11/04/89	12	0
	11.2.2		1302 BOULEVARD BLVD		LOS ANGELES	P	1921	DEED.ASS.	BOOK 19 PG 0256 0107	1.1/1/00	61	
								PROJ.ASSN.	8806-72029	12/10/96	60	
	11.2.1.3		1301 BOULEVARD BLVD		LOS ANGELES	P	1924	DEED REC.	BOOK 19 PG 0154 1001	15/10/96	60	
								PROJ ASSN	8806-72030	14/11/96	60	
	0.1.1.2	19 174.20	6201 BOULEVARD BLVD		LOS ANGELES	P	1914	WEST.CORP	0051 4650 0101	11/01/89	68	

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NUMBER	ASSESSEE	TYPE	ADDRESS	PARCEL	CITY CODE	TAX CODE	USE	YEAR ACQ	PRIOR OWNER	PRIOR REFERENCE NUMBER	YEAR LOST	VAL	CHG
	074115	19 1-6227	5368 HOLLYWOOD BLVD	PALMER APTS II	LOS ANGELES	P	1931	MORT	RUSS	966 4586-0067	10/04/85	6X	
	074112	19 1-7221	5372 HOLLYWOOD BLVD		LOS ANGELES	P	1919	MORT	REA	DOC 19-84 1154 2000	02/07/96	6X	
								PROB	REVW	0000000000F	02/07/96	6X	
								MORT	SWAV	2054-1600-0035	10/04/85	6X	
	074107	19 1-7111	5371 HOLLYWOOD BLVD		LOS ANGELES	I	1924	MORT	SCAV	2053 4631 0054	01/04/85	6X	
	021722	19 15-7251	5340 HOLLYWOOD BLVD	UNI DOOR VI, JUDITH REDSTAR	LOS ANGELES	P	1974	DIST	SUBV	2051-4661-0023	04/06/85	1X	
								DIST	SUBV	2051-5611-0023		1X	
								DIST	SUBV	4051-2315-0210		1X	
	074110	19 1-6110	5381 HOLLYWOOD BLVD	PETOVITY TRUST & SAVINGS BANK 657	LOS ANGELES	P	1921	MORT	SUBV	2053 4683 0057	04/04/85	1X	
								DIST	PTS	002 8301/04 0001	11/18/85	1X	
								DIST	SUBV	2053 4684 0030	11/18/85	1X	
								DIST	REL	DOC 19 83 0172 .000	04/04/85	2X	NC
								PROB	REVW	0074A0307150	12/03/85	2X	NC
								DIST	SUBV	1051-2407 0050	01/01/85	2X	
								DIST	SUBV	2051-0417-0 50	01/01/85	2X	
								TAX	CERT	511.9-111-0060	12/10/85	2X	
	021707	19 1-7115	5403 HOLLYWOOD BLVD	THE J P MORGAN 0F1300150 HOLLYWOOD	LOS ANGELES	P	1912	DIST	SUBV	2051 4687 0049	01/04/85	1X	C
								DIST	SUBV	2051-0139-0100		1X	
								DIST	SUBV	0051 0416-0070		1X	
	014159	19 174130	6611 HOLLYWOOD BLVD		LOS ANGELES	P	1913	DIST	SUBV	2051 4685 0057	76/04/85	6X	
	074111	19-174330	6411 HOLLYWOOD BLVD	MOSLEY BOOK	LOS ANGELES	P	1921	DIST	SUBV	2051-4629 0135	01/04/85	6X	
	014461	19-174 91	6411 HOLLYWOOD BLVD		LOS ANGELES	P	1921	DIST	SUBV	1051-4689-0260	01/04/85	6X	
	014403	19-174136	6411 HOLLYWOOD BLVD		LOS ANGELES	P	1921	MORT	SUBV	1051 4689-0169	01/04/85	6X	
	074405	19 174339	6415 HOLLYWOOD BLVD		LOS ANGELES	P	1913	DIST	SUBV	2051 4689 0134	04/04/85	6X	
	021569	19 147 54	6421 HOLLYWOOD BLVD	ARONSP THEATRE BUILDING, SPECIFIC H	LOS ANGELES	P	1925	MINT	SUBV	2051-4683 0398	04/04/85	1D	C
								DIST	SUBV	2051 0415 0000		1X	
	074501	19 174218	6410 HOLLYWOOD BLVD		LOS ANGELES	P	1911	MORT	SUBV	0051 408. 0092	04/04/85	6X	
	021599	19 174126	6416 HOLLYWOOD BLVD	ATTIC BOOKSHOP	LOS ANGELES	P	1931	MORT	SUBV	2053 4682 0064	04/04/85	1D	C
	014107	19-167155	6417 HOLLYWOOD BLVD	SIMONSEN BLOCK	LOS ANGELES	P	1921	DIST	SUBV	0051-0416 0110		1X	
	074404	19-174196	6421 HOLLYWOOD BLVD		LOS ANGELES	P	1911	DIST	SUBV	2051-4724-0120	01/01/85	7X	
								DIST	SUBV	2051-4611-0710	01/04/85	7X	
	0 14ne	19-174196	6415 HOLLYWOOD BLVD	SUPERIOR BLDG	LOS ANGELES	P	1915	DIST	SUBV	1051 4796 0100	10/01/85	6X	
								DIST	SUBV	2051-4610-0121	04/04/85	1X	
	111.44		6415 HOLLYWOOD BLVD		LOS ANGELES	P	1916	MINT	PASS	DOC 19-86-0165 200	05/01/96	6X	
								CHGD	REVW	0LD0960918	05/01/96	6X	
	021618	19 147557	6421 HOLLYWOOD BLVD	BOSLEY GENEVA	LOS ANGELES	P	1927	DIST	SUBV	0051 4683 2064	04/01/85	1D	C
								MINT	SUBV	0051 0415 0200		1X	
	021629	19-167578	6431 HOLLYWOOD BLVD	SIMONSEN ARRANGEMENTS	LOS ANGELES	P	1927	TAX	CERT	511 9-19-0245	05/14/92	21-	
								DIST	SUBV	0051-0500 0201	10/04/85	1D	C
								DIST	SUBV	2051-4683-0714	01/04/85	1D	C
								DIST	SUBV	0051 0414 0220		1X	
	021631	19-167159	6441 HOLLYWOOD BLVD	CHARLES HOUSE	LOS ANGELES	P	1913	MINT	SUBV	0051 4680 1011	10/01/85	1D	C
								DIST	SUBV	2051-0420 0200		1X	
	021631	21 15-150	6411 HOLLYWOOD BLVD	CHRISTNER DRAPERIES SPIVA	LOS ANGELES	P	1925	DIST	SUBV	2051-4683-0743	04/04/85	1D	C
								MINT	SUBV	2051-5621-0730		1X	
	074401	19-174197	6441 HOLLYWOOD BLVD		LOS ANGELES	P	0	MINT	SUBV	0051 4683-0074	04/04/85	6X	
	014612	19 174150	6449 HOLLYWOOD BLVD		LOS ANGELES	P	1925	DIST	SUBV	0051 4687 0071	04/01/85	1X	
	021604	19-167111	6431 HOLLYWOOD BLVD	CORDOVA'S ATLAS/VOGUE	LOS ANGELES	M	1916	MINT	SUB	DOE 19 84 0115 106	05/31/96	2X2	NC
								PROC	REVW	MP0960210X	10/01/96	2X	
								DIST	SUBV	0051 4680 0012	04/01/85	1D	C
								DIST	SUBV	0051-0427 0.20		1X	
	021593	19 167157	6451 HOLLYWOOD BLVD	ARCHIBALD TOYS	LOS ANGELES	P	1913	DIST	SUBV	0051 4680 1046	04/04/85	1D	C
								MINT	SUBV	0051 0411 .000		1X	
	014403	19-174193	6445 HOLLYWOOD BLVD		LOS ANGELES	P	0	MINT	SUBV	0051 4684-0074	04/04/85	6X	
	021601	19-167161	6435 HOLLYWOOD BLVD	JJ NEWBERRYS	LOS ANGELES	P	1925	DIST	SUBV	0051 4680 1045	04/04/85	1D	C
								DIST	SUBV	0051-0424-1007		1X	

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PROPERTY NUMBER	PHONE #	ADDRESS	STREET NAME	CITY	ZIP	OWNER NAME	MAILING ADDRESS	ASSESSMENT	NOTES
021776	19 1170641	6701 HOLLYWOOD BLVD	THE CAPITOL RECORDING, INCORPORATED TRUS	LOS ANGELES	P	1956	HIGH SURV	1053 469. 7411	04/04/47
							HIGH SURV	7059 3424 0003	
03361	19-1107761	6236 HOLLYWOOD BLVD	S H KRESS & CO. PROPERTIES OF CALIF	LOS ANGELES	P	1935	ASSY SURV	2051-4795-0003	06/11/47
							HIGH SURV	0002 468. 0044	01/04/55
							HIGH SURV	0059 0420 0017	
276427	19 1743111	6514 HOLLYWOOD BLVD		LOS ANGELES	L	1939	JOHN SURV	2051 1686 0014	04/04/54
11535	19 117744	6526 HOLLYWOOD BLVD		LOS ANGELES	L	1947	4762 SURV	2051 4805 0010	05/11/55
							HIGH SURV	2051 4610-4031	11/04/54
276427	19-1174411	1821 HOLLYWOOD BLVD	ALEXANDERS	LOS ANGELES	P	1971	HIGH SURV	2051-4641-0030	01/04/55
276427	19-1174411	6526 HOLLYWOOD BLVD	LOS FELIZ BLVD	LOS ANGELES	P	1957	HIGH SURV	7051 1691 0011	04/04/55
176015		6727 HOLLYWOOD BLVD		LOS ANGELES	P	1917	HIGH PFS	70E 19 55 0215-0111	11/11/96
							PROJ REVW	0716-0703.	11/11/96
276428	19 1171201	6752 HOLLYWOOD BLVD	VOGUE THEATER	LOS ANGELES	P	1935	HIGH SURV	2051-4630-0731	04/04/54
							HIGH SURV	2051-7421-3716	
021334	19 1411061	6767 HOLLYWOOD BLVD	CROSSROAD BUILDING	LOS ANGELES	P	1937	HIGH SURV	2051 4680-0010	01/04/55
							HIGH SURV	2059 0429 0109	
021317	19-1179461	6769 HOLLYWOOD BLVD	KRAKE BUILDING	LOS ANGELES	P	1963	HIGH.SURV.	2051-4691-0011	03/04/64
							HIGH.SURV.	2051-0421 0000	
176439	19 1741211	7072 HOLLYWOOD BLVD		LOS ANGELES	P	1936	HIGH PFS	70E 19 55 0215-0111	03/11/96
							PROJ REVW	4059500028	03/11/96
276427	19 1742211	5660 HOLLYWOOD BLVD		LOS ANGELES	P	1926	HIGH SURV	2059 4681 0021	04/04/55
021319	19 1571319	6663 HOLLYWOOD BLVD	MYRON FRANK BUILDING	LOS ANGELES	P	1921	HIGH.SURV.	2051-4651-0750	04/04/55
							HIGH.SURV.	2051 4610 0714	04/04/54
							HIGH SURV	2051-0410-0070	
176745		7004 HOLLYWOOD BLVD		LOS ANGELES	P	1935	HIGH PFS	70E 19 95 0217-0710	03/30/96
							PROJ.REVW	4059500028	03/30/96
276455	19 1742211	6615 HOLLYWOOD BLVD		LOS ANGELES	P	1940	HIGH.SURV.	7051 0726 0151	04/04/54
02154	19 1170411	6677 HOLLYWOOD BLVD		LOS ANGELES	M	1929	HIGH REV.	20E 19 94 0162 2000	03/01/96
							PROJ REVW	4059500028	03/01/96
							HIGH SURV	2059 4682 0014	04/04/55
							HIGH.SURV	0002 063. 0200	11/04/54
276419	19 1742211	6733 HOLLYWOOD BLVD		LOS ANGELES	P	1940	HIGH.SURV.	2051 4681 0040	04/04/54
021662	19 1671-1	6731 HOLLYWOOD BLVD	OUTPOST BUILDING	LOS ANGELES	P	1924	HIGH SURV	2051 4681 0016	01/04/55
							HIGH SURV	2059 0012 0014	
021031	19-1170914	7051 HOLLYWOOD BLVD	CHAUNCEY'S EGYPTIAN THEATER	LOS ANGELES	M	1921	HIGH.REV.	20E 19 94 0110 2000	11/11/96
							PROJ REVW	4059500028	11/11/96
							HIGH SURV	2051 4610 0210	11/04/55
							HIGH SURV	2051 0125-0200	
021743	19 1670-1	5701 HOLLYWOOD BLVD	PIG N WHISTLE RESTAURANT, INCORPORATED	LOS ANGELES	P	1919	HIGH SURV	2051 4681 0019	01/04/55
							HIGH SLAV.	2051 7411 0709	
047046	19 1671711	6721 HOLLYWOOD BLVD	CHURCH OF SCIENTOLOGY INTER	LOS ANGELES	P	1957	HIGH.SLAV.	2051-4611-0710	04/04/55
							HIGH SLAV.	2051-2416 0210	
076164	19 1742211	6727 HOLLYWOOD BLVD	ARTISAN PATIO	LOS ANGELES	P	1	HIGH SURV	2051 4681-0210	04/04/55
076477	19 1742211	6749 HOLLYWOOD BLVD		LOS ANGELES	P	1	HIGH.SURV	0051 4681 0277	11/04/54
021402	19 1671-1	6741 HOLLYWOOD BLVD	MILLARD BROTHERS	LOS ANGELES	M	1923	HIGH.SURV.	2051-4691-0010	03/04/55
021301	19 1671711	6731 HOLLYWOOD BLVD	PICKWICK BOOKSHOP, A JANSON LICK	LOS ANGELES	P	1927	HIGH.SURV	2051 4647 0010	04/04/55
							HIGH.SURV.	2051-0415-0071	
021479	19 1741111	5771 HOLLYWOOD BLVD	VANDERBILT CENTER	LOS ANGELES	P	1926	HIGH SURV	7051 4681 0017	03/04/55
021403	19 1741211	6715 HOLLYWOOD BLVD		LOS ANGELES	P	1921	HIGH.SURV	7051 4681 0015	01/04/55
021662	19 1671711	6751 HOLLYWOOD BLVD	L.BRYAN DRYDAVY, BENEFICIAL BOOK P	LOS ANGELES	P	1922	HIGH.SURV	2051-0635 0110	
021309	19 1671311	1755 HOLLYWOOD BLVD	MONTMARTRE	LOS ANGELES	P	1922	HIGH.SURV.	2051-4651-0715	04/04/55
144451	19 1741751	6721 HOLLYWOOD BLVD		LOS ANGELES	P	1914	HIGH SURV	2051-4611-0214	01/04/55
021564	19 1671777	6741 HOLLYWOOD BLVD	HOLLYWOOD BOX SIGN CO	LOS ANGELES	P	1928	HIGH.SURV	2051-4681 0014	11/01/55
							HIGH.SURV	2051-0415 0200	
021647	19-1671776	6755 HOLLYWOOD BLVD	HOLLYWOOD THEATER	LOS ANGELES	P	1911	HIGH.SURV	2051 4630 0206	14/04/55
							HIGH.SURV	2051-0412-0-00	

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PROPERTY NUMBER	TELEPHONE #	ADDRESS	NAME	CITY NAME	...	TYPE	YR B	SQR FEET	POSTAGE/VALUE NUMBER	STAT EXT	NOT	CERT
376685	213-124301	6766 HOLLYWOOD BLVD		LOS ANGELES		F	1974	MIXT USE	0052 4000 0001	04/14/89	AR	
201512	213 157611	5777 HOLLYWOOD BLVD	YOU ANGELES FIRST FEDERAL SAVINGS	LOS ANGELES		F	1977	MIXT USE	0055 1600 0021	06/24/87	IR	C
								MIXT USE	0055 7439 0001		IR	
731011	213 14-537	6780 HOLLYWOOD BLVD	BANK OF AMERICA	LOS ANGELES		F	1974	MIXT USE	0055 4400 1001	04/24/81	IR	C
								MIXT USE	0251-0447-0001		IR	
02241	213 1771-3	6500 HOLLYWOOD BLVD	HOLLYWOOD CENTRAL PARK OFFICE	LOS ANGELES		S	1965	MIXT USE	0159-4687-0001	04/06/85	IR	C
								MIXT USE	0155-7611 0001		IR	
007053	213 14-628	1680 HOLLYWOOD BLVD		LOS ANGELES		S	1924	MIXT USE	0251 4680 0002	04/24/85	IR	I
001113	213 14-081	6614 HOLLYWOOD BLVD	ALL AMERICAN INDUSTRIAL DEVELOPMENT	LOS ANGELES		F	1914	TAX CERT	917 5-15-0.01	07/09/85	AIR	
								TAX CERT	917.5-15 0101	04/02/85	IRR	
								TAX CERT	917 5-15 0104	07/12/84	RRR	
								MIXT USE	1953 4681-0011	04/24/84	IR	C
								MIXT USE	1953 4682-0002		IR	
201/5	213 1079-2	7851 HOLLYWOOD BLVD	HOLLYWOOD TOWER	LOS ANGELES		F	1954	MIXT USE	0252 4680 0002	04/24/87	IR	I
								MIXT USE	0251 4681 0001	01/06/84	IR	I
								MIXT PKG	0251 2500 1155 0007	04/24/85	IR	
								MIXT USE	0159 0443-0010	01/28/86	IR	
376411	213-134374	7901 HOLLYWOOD BLVD	CHINESE ANNEX	LOS ANGELES		J	1950	MIXT USE	0253 4581 0010	04/24/85	RR	
001560	213 467 77	6901 HOLLYWOOD BLVD	IBSEN DEAD	LOS ANGELES		F	1940	MIXT USE	1953 1602 0029	04/24/85	IR	.
021486	213-134207	6921 HOLLYWOOD BLVD	MAX FACTOR BLDG	LOS ANGELES		F	1930	MIXT USE	1953-4680 0002	04/24/85	RR	
021116	213 134017	1927 HOLLYWOOD BLVD	GRAUMAN'S CHINESE THEATRE	LOS ANGELES		F	1927	MIXT USE	0253 4640 0021	04/24/85	IR	I
								MIXT PKG	0255 0194 0100		IR	
0.1561	213 397557	7021 HOLLYWOOD BLVD	HOLLYWOOD ROOSEVELT HOTEL	LOS ANGELES		P	1926	TAX CERT	737 5-15 0301	09/21/83	IR	
								MIXT USE	1953 1601 0025	04/24/85	IR	C
								MIXT USE	1953 0441 0017		IR	
1.16 A	213 14-1555	7901 HOLLYWOOD BLVD	HOLLYWOOD CAPITOL, INCORPORATED	LOS ANGELES		F	1929	MIXT PKG	0251-4685-0102	01/06/85	IR	I
								MIXT USE	0251-0445-0010		IR	
021-11	213 1071-4	7021 HOLLYWOOD BLVD	ARTHUR MURRAY DANCE STUDIO	LOS ANGELES		P	1924	MIXT USE	1251 0441 0017		IR	
021.12	213 1.2279	7021 HOLLYWOOD BLVD	ORPHEUM CLOSE APARTMENTS RECEIVERSHIP	LOS ANGELES		P	1920	MIXT USE	1953-4679 0101	04/24/85	IR	
								MIXT USE	1953 0441 0110		IR	
021-12	213 -0012	7021 HOLLYWOOD BLVD	HARTEN COURT APARTMENTS	LOS ANGELES		D		MIXT USE	1951-4684 0010	01/01/86	IRR	
004440	714-174-1	7021 HOLLYWOOD BLVD	ARTHUR MURRAY	LOS ANGELES		P	1911	MIXT USE	2044 4680 0017	04/24/85	IR	C
021405	213-134017	7021 HOLLYWOOD BLVD		LOS ANGELES		P	1924	MIXT USE	20E 10 95 0150-0100	04/12/86	IR	
								PROJ.ABOVE	XXX66480012	09/30/86	IR	
								MIXT USE	1953 1601 0101	04/24/85	IR	
7.1461	213 134/24	7021 HOLLYWOOD BLVD		LOS ANGELES		P	1924	MIXT USE	1951-4687 0110	01/04/84	IR	
021-12	213-134/011	7021 HOLLYWOOD BLVD	HOLLYWOOD ROOSEVELT HOTEL	LOS ANGELES		T	1924	TAX CERT	917 5-15-0301	01/21/84	IRR	
								MIXT USE	0251 4681 0016	04/24/85	IR	I
								MIXT USE	1951-0441-0150		IR	
021176	213 1.-134	7021 HOLLYWOOD BLVD	SECURITY TRUST/BUYERS	LOS ANGELES		P	1920	MIXT USE	1951-4679-0101	01/04/85	IR	C
								TAX CERT	737 5-15 0042			
								MIXT USE	0251 0441 1150		IR	
7214..	213 1710-1	7021 HOLLYWOOD BLVD		LOS ANGELES		P	1924	MIXT USE	1951-4687-0124	04/24/85	IR	C
7.1471	213 -7401	7021 HOLLYWOOD BLVD	LOS ANGELES CONVENTION/VISITORS BUREAU	LOS ANGELES		P	1920	TAX CERT	917.5 15 1001	01/16/90	RR	
								MIXT USE	1953 4691 0021	04/24/85	IR	I
03 .1	213 134-1.4	7021 HOLLYWOOD BLVD	ITOYOP HOUSE	LOS ANGELES		P	1924	MIXT USE	1951-4682-0010	01/28/85	IR	
								MIXT USE	0251-0441 0110	12/01/85	IR	
376719		7021 HOLLYWOOD BLVD	AUDREY LOVE'S BOUTIQUE	LOS ANGELES			1915	SNL ABOVE	19 7106	11/26/86	IR	
021408	213-134/21	6767 HOLLYWOOD AVE	FIRST BAPTIST CHURCH, WOMENS AUXILIARY	LOS ANGELES		M	1923	MIXT USE	1951 0119-0700		IR	
	213-134/31											
761179		6775 HOLLYWOOD AVE		LOS ANGELES				PROJ PKNG	XXE66.2150	12/10/86	RR	
376478		7031 HOLLYWOOD AVE		LOS ANGELES		L	1924	MIXT USE	20E 10 95-0111-0000	12/11/90	RR	
								PROJ ABOVE	XXX9-0111	12/11/90	RR	
045410	213 1731-2	6.01 HOLLYWOOD AVE		LOS ANGELES		C		PROJ.ABOVE	1000E00/2	12/21/86	RR	
077442	213 134/24	6111 HOLLYWOOD AVE		LOS ANGELES		C	1.31	PROJ ABOVE	1000E00293	01/ 1/91	RR	
								PROJ.ABOVE	1000E00216	01/12/90	RR	

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PROPERTY NUMBER	PARCEL #	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP-PROG	PRG-REFERENCE NUMBER	STAT DAT	NRS	CR
023524	19 168549	6561 HOMEWOOD AVE		LOS ANGELES	P	1920	HIST.SURV.	0051-0717-0017		5S2	
[illegible]	19 168570	6562 HOMEWOOD AVE		LOS ANGELES	P	1920	HIST.SURV.	0051-0717-0014		5S2	
033521	19 168712	6577 HOMEWOOD AVE		LOS ANGELES	P	1920	HIST.SURV.	0051-0718-0011		5S2	
013526	19 168[illegible]	[illegible] HOMEWOOD AVE		LOS ANGELES	P	1920	HIST.SURV.	0051-0718-0019		5S2	
023529	19 220551	6571 HOMEWOOD AVE		LOS ANGELES	P	1919	HIST.SURV.	0051-0718-0021		5S2	
[illegible]		[illegible] HOOPER AVE		LOS ANGELES		1911	HIST.RES.	DOE 19 [illegible]	[illegible]	6D	
							PROJ.REVW.	HUD[illegible]	[illegible]	6U	
[illegible]		11219 HOOPER AVE		LOS ANGELES		1947	PROJ.REVW.	HUD950424L	[illegible]/05	6Y	
[illegible]	19 170[illegible]	4415 HOOPER ST	VERNON CONSERVATION DISTRICT UNIT	LOS ANGELES	P	1875	HIST.SURV.	0051-4219-0001		3S	
[illegible]	19 170[illegible]	4416 HOOPER ST		LOS ANGELES	P	1898	HIST.SURV.	0051-4219-0017		7R	
	19 16[illegible]										
023747	19 1[illegible]	4405 HOOVER ST		LOS ANGELES	P	1909	HIST.SURV.	0051-4220-0000		7R	
	19-164636										
[illegible]	19 173404	8419 HOOVER ST		LOS ANGELES	N		PROJ.REVW.	HUD[illegible]	12/14/88	6Y	
021148	19 173512	8011 HOOVER ST		LOS ANGELES	P	1929	PROJ.REVW.	HUD[illegible]	[illegible]	6Y	
[illegible]	19-[illegible]	9042 HOOVER ST		LOS ANGELES	P	1907	PROJ.REVW.	HUD940125J	[illegible]/94	6Y	
130776		HOOVER ST	NORTH UNIVERSITY PARK HISTORIC DIS	LOS ANGELES	P	[illegible]	HIST.RES.	NPS-04000015-9999	[illegible]/94	1S	
							NAT REG	19-2420	[illegible]	1S	
[illegible]		[illegible] HOOVER ST		LOS ANGELES	P	1911	HIST.RES.	DOE 19-96 0169 [illegible]	[illegible]/96	6D	
							PROJ.REVW.	HUD[illegible]	[illegible]	6L	
[illegible]		[illegible] HOUSLEY ST		LOS ANGELES	[illegible]	1922	HIST.RES.	DOE 19-99-[illegible]	[illegible]	6Y	
							PROJ.REVW.	HUD990[illegible]	[illegible]/99	6Y	
[illegible]	19 167[illegible]		HOWLAND CANAL ST	HOWLAND CANAL	LOS ANGELES	M	1905	HIST.SURV.	0511-0147-0003	[illegible]/82	3D	PC
021[illegible]	19 170449	[illegible] HUB ST		LOS ANGELES	P	1924	HIST.SURV.	0051-2215-0000		5[illegible]	
	19-170[illegible]										
024[illegible]	19 1[illegible]	5650 HUB ST		LOS ANGELES	P	1924	HIST.SURV.	0051-2216-0000		4D	
	19 138[illegible]										
[illegible]	19 165[illegible]		HUDSON AVE	HUDSON AVE/HUDSON PL [illegible]	LOS ANGELES	P	1902	HIST.SURV.	0051 0116 [illegible]		5S2	
[illegible]	19-167[illegible]	2614 HUDSON AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	0051 0[illegible]		5S	
[illegible]	19 17[illegible]	4927 HUNTINGTON DR	EL SERENO MUNICIPAL AUDITORIUM	LOS ANGELES	M	1924	HIST.RES.	DOE-19 94 [illegible]	[illegible]/94	6Y	
	19 156[illegible]						PROJ.REVW.	[illegible]	[illegible]/94	6Y	
[illegible]		[illegible] HUNTINGTON DR S		LOS ANGELES	P	1922	HIST.RES.	DOE-19 [illegible]	[illegible]/95	6Y	
							PROJ.REVW.	FHWA[illegible]	[illegible]	6Y	
[illegible]		[illegible] HUNTINGTON DR S		LOS ANGELES	P	1947	HIST.RES.	DOE 19-[illegible]	[illegible]	6Y	
							PROJ.REVW.	FHWA[illegible]	[illegible]	6Y	
[illegible]		[illegible] [illegible] AVE		LOS ANGELES	P	1922	PROJ.REVW.	FHWA[illegible]	[illegible]	6Y	
[illegible]	19-[illegible]	[illegible] HURON ST		LOS ANGELES	P	1899	HIST.SURV.	0051-2217-0000		5S2	
	19 155[illegible]										
[illegible]	19 [illegible]	[illegible] HURON ST		LOS ANGELES	P	1905	HIST.SURV.	0051-2268-0000		5S2	
	19-[illegible]										
[illegible]	19-[illegible]	[illegible] HURON ST		LOS ANGELES	P	1912	HIST.SURV.	0051-2269-0000		[illegible]	
[illegible]	19 [illegible]	[illegible] HURON ST		LOS ANGELES	P	1908	HIST.SURV.	0051-2270-0000		[illegible]	
	19 [illegible]										
[illegible]	19 [illegible]	[illegible] HURON ST		LOS ANGELES	P	1918	HIST.SURV.	0051-2271-0000		5S2	
	19-[illegible]										
[illegible]	19 [illegible]	[illegible] HURON ST		LOS ANGELES	P	19[illegible]	HIST.SURV.	0051-2272-0000		5S2	
	19-[illegible]										
[illegible]	19 [illegible]	[illegible] HUTTON DR		LOS ANGELES	P	1948	HIST.RES.	DOE-19 94-0051 [illegible]	[illegible]/94	6Y	
							PROJ.REVW.	[illegible]	[illegible]/94	6Y	
[illegible]	19 [illegible]	[illegible] HYDE PARK BLVD	[illegible] PARK BOULEVARD ELEMENTARY SCH	LOS ANGELES	D		HIST.RES.	DOE 19-94-[illegible]	[illegible]/94	6Y	
							PROJ.REVW.	[illegible]	[illegible]/94	6Y	
106035	19-[illegible]	[illegible] HYPERION AVE		LOS ANGELES	M	[illegible]	HIST.RES.	DOE 19 94 [illegible]	[illegible]/94	6Y	
							PROJ.REVW.	[illegible]	[illegible]/94	6Y	
[illegible]	19-[illegible]	[illegible] IDELL ST		LOS ANGELES	P	1912	HIST.SURV.	0051-2273-0000		5S2	
	19 [illegible]										
[illegible]	19 [illegible]	[illegible] IDELL ST		LOS ANGELES	P	19[illegible]	HIST.SURV.	0051-2274-0000		5S[illegible]	

PROPERTY NUMBER	PRIMARY #	STREET ADDRESS	NAME	CITY NAME	QUAD	YR BUILT	CONFIDENCE	SURVEY TYPE	STATUS CODE	DATE	CHG
							HIST.SURV	0000-0000-0000			DN
—	019367	19 19601	1962 LARATC AVE	BELMA MANOR ELEMENTARY	LOS ANGELES	D	1911	ARCH.STYLE	CRAFTSMAN	07/01/94	2D1
							PROJ.REVW	NR0994120003		12/01/94	CDP
							HIST.SURV	0000-0000-0000			DN
⊥	000349	19 19627	1969 LARATC AVE	BELMA LARACH DISTRICT	LOS ANGELES	D		HIST.EVAL	DOE 10 91 0000 0000	07/01/94	3S2
							PROJ.REVW	NR0994120003		07/01/94	3S2
+	021988	19 19601 15	1961 LARATC AVE	BELMA LARACH DISTRICT	LOS ANGELES	D	1911	HIST.REG	DOE 10 91 0000 0000	07/01/94	3S2
							HIST.REVW	NR0994120003		07/01/94	3S2
							HIST.SURV.	0000-0000-0000			7S
+	021989	19 19601 15	1959 LARATC AVE	BELMA LARACH DISTRICT	LOS ANGELES	D	1911	HIST.REG	DOE 10 91 0000 0000	07/01/94	3S2
							PROJ.REVW	NR0994120003		07/01/94	3S2
							HIST.SURV.	0000-0000-0000			7S
	019681		1957 LARATC AVE		LOS ANGELES		1925	HIST.REG.	DOE-10 91-0000 0000	07/01/94	6Y
							PROJ.REVW.	NRD 0000/00		00/00/00	6Y
	019697	19 19616	1951 LARATC AVE	SITE - PETER & PAUL KOREAN CHURCH	LOS ANGELES	V	1924	ELIG.SURV	DOE: 4550-0000		7N
	019716	19 19628	1941 LARATC AVE	SITE - JESUS & PAUL KOREAN CHURCH	LOS ANGELES	D	1919	HIST.SURV	0000 4456 0001		7S
	019701	9 19720	1953 LARATC AVE	SACRED HEART & MARY FACTORY	LOS ANGELES	D	1915	HIST.SURV	0000-4465 0000		7S
	020206		LARA HOLLYWOOD DR	HOLLYWOOD ARSENAL/HOLLYWOOD ARMORY	LOS ANGELES	M		HIST.REG	DOE-10-00-0000 0000	11/00/00	DAA
							PROJ.REVW	1200000000A		01/00/00	3S3
	020246		1936 HOLLYWOOD DR	HOLLYWOOD RESIDENTIAL DISTRICT	LOS ANGELES	M		HIST.REG	DOE 10 00 0000 0000	01/01/00	3S3
							DETAT.REVW	SIM0100000A		01/01/00	3S3
	020240		LARA HOLLYWOOD DR	HOLLYWOOD RESIDENTIAL COMPLEX/ MULTI	LOS ANGELES	M	1931	HIST.REG	DOE-10-00-0000 0000	00/00/00	3S3
							PROJ.REVW.	SIM0100000A		01/00/00	3S3
	020302		1900 HOLLYWOOD DR	HOLLYWOOD RESIDENTIAL COMPLEX/ HOTEL	LOS ANGELES	M		HIST.REG.	DOE 10 00-0000-0000	01/00/00	6Y
							PROJ.REVW.	NR0990000A		11/00/00	6Y
	020444		1900 HOLLYWOOD DR	HOLLYWOOD APARTMENTS/ COMPLEX/ HOTEL	LOS ANGELES	M	1907	HIST.REG	DOE 10-00-0000-0000	01/00/00	6Y
							PROJ.REVW	NR0990000A		11/00/00	6Y
	020501		1900 HOLLYWOOD DR	HOLLYWOOD APARTMENTS/ COMPLEX/ HOTEL	LOS ANGELES	M		HIST.REG.	0000-00-00-0000-0000	00/00/00	6Y
							PROJ.REVW.	NR0990000A		00/00/00	6Y
	020567		1900 HOLLYWOOD DR	HOLLYWOOD APARTMENTS/ COMPLEX/ HOTEL	LOS ANGELES	M	1927	ELIG.REG.	0000-00-00-0000-0000	00/00/00	6Y
							PROJ.REVW.	NR0990000A		00/00/00	6Y
	020687		1900 HOLLYWOOD DR	HOLLYWOOD APARTMENTS/ COMPLEX/ HOTEL	LOS ANGELES	M		HIST.REG	DOE 10-00-0000-0000	01/00/00	6Y
							PROJ.REVW	NR0990000A		11/00/00	6Y
	020746	19 19626	921 TAYR ST		LOS ANGELES	D	1924	HIST.SURV	0000-1700-0000		7S2

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PROPERTY NUMBER	PRIMARY #	STREET ADDRESS	NAMES	CITY NAME	OWN	YR C	OHP-PROG	PRG REFERENCE NUMBER	STAT DAT	NRS	CRIT
[illegible]	19 158[illegible]	1117 LAS PALMAS AVE		LOS ANGELES	P	1905	HIST.SURV.	[illegible]		5S2	
[illegible]	19 [illegible]	1120 LAS PALMAS AVE		LOS ANGELES	P	1912	HIST.SURV.	[illegible]		5S2	
[illegible]	19 [illegible]	1124 LAS PALMAS AVE		LOS ANGELES	P	1917	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	1126 LAS PALMAS AVE		LOS ANGELES	P	1911	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	1127 LAS PALMAS AVE		LOS ANGELES	P	1921	HIST.SURV.	[illegible]		5S2	
[illegible]	19 [illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	1907	HIST.SURV.	[illegible]		5S2	
[illegible]	19 [illegible]	1132 LAS PALMAS AVE		LOS ANGELES	P	1912	HIST.SURV.	[illegible]		5D2	
[illegible]	19 158[illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	1912	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	1923	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	1921	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	1414 LAS PALMAS AVE		LOS ANGELES	P	1907	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	1921	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	1907	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		5D2	
[illegible]	19 158[illegible]	1129 LAS PALMAS AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	1131 LAS PALMAS AVE		LOS ANGELES	P	1921	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	[illegible] LAS PALMAS AVE		LOS ANGELES	P	1921	HIST.SURV.	[illegible]		5D2	
[illegible]		[illegible] LAS PALMAS AVE		LOS ANGELES		1923	HIST.RES.	[illegible]	[illegible]	[illegible]	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]	19 [illegible]	[illegible] LASSEN ST	CHATSWORTH COMMUNITY CHURCH	LOS ANGELES	P	1911	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	2100 LATHAM ST		LOS ANGELES	P	1925	HIST.SURV.	[illegible]		[illegible]	
	19 [illegible]										
[illegible]	19 [illegible]	[illegible] LATHAM ST		LOS ANGELES	P	1925	HIST.SURV.	[illegible]		[illegible]	
	19 [illegible]										
[illegible]	19 [illegible]	[illegible] LAUGHLIN ST		LOS ANGELES	U	1925	PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]	19 [illegible]	[illegible] LATIMER RD	[illegible]	LOS ANGELES	[illegible]	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]		[illegible] LAUREL AVE		LOS ANGELES		1930	PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]	19 [illegible]	[illegible] LAUREL CANYON BLVD		LOS ANGELES	P	1921	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	[illegible]		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LAVETA TERRACE		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]		[illegible] LEONARD AVE		LOS ANGELES	P	[illegible]	HIST.RES.	[illegible]	[illegible]	[illegible]	
							PROJ.REVW.	[illegible]	[illegible]	[illegible]	
[illegible]	19 [illegible]	[illegible] LEE MTN WY		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] LEE MTN WY		LOS ANGELES	P		HIST.SURV.	[illegible]		[illegible]	
[illegible]		[illegible] LEIGHTON AVE		LOS ANGELES	[illegible]	[illegible]	HIST.RES.	[illegible]	[illegible]	[illegible]	
							PROJ.REVW.	[illegible]	[illegible]	[illegible]	
[illegible]	19 [illegible]	[illegible] LEIGHTON AVE		LOS ANGELES	[illegible]	[illegible]	HIST.RES.	[illegible]	[illegible]	6Y	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]		[illegible] LEIGHTON AVE		LOS ANGELES	U	[illegible]	HIST.RES.	[illegible]	[illegible]	6Y	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]		LELAND WY	6400 BLOCK OF LELAND WAY	LOS ANGELES	P		HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	LELAND WY	6400 BLOCK OF LELAND WAY	LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	LELAND WY	[illegible] BLOCK OF LELAND WAY	LOS ANGELES	[illegible]	[illegible]	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	LELAND WY	6400 6500 BLOCK OF LELAND WAY	LOS ANGELES	P	1911	HIST.SURV.	[illegible]		5D2	
[illegible]	19 [illegible]	[illegible] LE ROY ST	[illegible] SQUARE DISTRICT	LOS ANGELES	P	1923	HIST.RES.	[illegible]	[illegible]	2D2	
							PROJ.REVW.	[illegible]	[illegible]	2D2	
							HIST.RES.	[illegible]	[illegible]	2D2	
							PROJ.REVW.	[illegible]	[illegible]	2D2	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
							HIST.SURV.	[illegible]		5D2	

NUMBER	ADDRESS	NAME	CITY/ZIP	CA	SQ FT	USE CODE	PREVIOUS OWNER	YEAR BUILT	RBS	CRIT
032469	19 168771	5211 LELAND WY								
032468	19 168772	5211 LELAND WY								
032467	19 168773	5211 LELAND WY								
032466	19 168774	5211 LELAND WY								
032465	19 168775	5211 LELAND WY								
032464	19 168776	5211 LELAND WY								
032463	19 168777	5211 LELAND WY								
032462	19 168778	5211 LELAND WY								
032461	19 168779	5211 LELAND WY								
032460	19 168780	5211 LELAND WY								
032459	19 168781	5211 LELAND WY								
032458	19 168782	5211 LELAND WY								
032457	19 168783	5211 LELAND WY								
032456	19 168784	5211 LELAND WY								
032455	19 168785	5211 LELAND WY								
032454	19 168786	5211 LELAND WY								
032453	19 168787	5211 LELAND WY								
032452	19 168788	5211 LELAND WY								
032451	19 168789	5211 LELAND WY								
032450	19 168790	5211 LELAND WY								
032449	19 168791	5211 LELAND WY								
032448	19 168792	5211 LELAND WY								
032447	19 168793	5211 LELAND WY								
032446	19 168794	5211 LELAND WY								
032445	19 168795	5211 LELAND WY								
032444	19 168796	5211 LELAND WY								
032443	19 168797	5211 LELAND WY								
032442	19 168798	5211 LELAND WY								
032441	19 168799	5211 LELAND WY								
032440	19 168800	5211 LELAND WY								
032439	19 168801	5211 LELAND WY								
032438	19 168802	5211 LELAND WY								
032437	19 168803	5211 LELAND WY								
032436	19 168804	5211 LELAND WY								
032435	19 168805	5211 LELAND WY								
032434	19 168806	5211 LELAND WY								
032433	19 168807	5211 LELAND WY								
032432	19 168808	5211 LELAND WY								
032431	19 168809	5211 LELAND WY								
032430	19 168810	5211 LELAND WY								
032429	19 168811	5211 LELAND WY								
032428	19 168812	5211 LELAND WY								
032427	19 168813	5211 LELAND WY								
032426	19 168814	5211 LELAND WY								
032425	19 168815	5211 LELAND WY								
032424	19 168816	5211 LELAND WY								
032423	19 168817	5211 LELAND WY								
032422	19 168818	5211 LELAND WY								

PROPERTY NUMBER	PRIMARY #	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	PRG-PROG	PRG REFERENCE NUMBER	STAT DAT	NRS	CRIT
022791	19-156017	5654 LELAND WY		LOS ANGELES	P	1911	HIST.SURV.	0[illegible]-0724 [illegible]		5D[illegible]	
022793	19-1559[illegible]	5711 LELAND WY		LOS ANGELES	P	1922	HIST.SURV.	0[illegible]-0725 0001		5D[illegible]	
022794	19-156615	5712 LELAND WY		LOS ANGELES	P	1920	HIST.SURV.	0[illegible] 0725 0002		5D[illegible]	
022795	19-157[illegible]	5716 LELAND WY		LOS ANGELES	P		HIST.SURV.	0[illegible] 0725 0003		5D[illegible]	
022796	19-158[illegible]	5720 LELAND WY		LOS ANGELES	P	1922	HIST.SURV.	0[illegible]-0725 0004		5D[illegible]	
022797	19-158221	5726 LELAND WY		LOS ANGELES	P	1922	HIST.SURV.	0[illegible]-0725 0005		5D[illegible]	
022798	19-15[illegible]21	5731 LELAND WY	[illegible] APARTMENTS	LOS ANGELES	P	1925	HIST.SURV.	0[illegible]-0725 0006		5D[illegible]	
022799	19-15[illegible]21	5732 LELAND WY		LOS ANGELES	P	1919	HIST.SURV.	0[illegible] 0725 0007		5D[illegible]	
022800	19-15[illegible]	[illegible] LELAND WY		LOS ANGELES	P	1912	HIST.SURV.	0[illegible]-0726 0001		5D[illegible]	
022803	19-158[illegible]	5812 LELAND WY		LOS ANGELES	P	1912	HIST.SURV.	0[illegible]-0726-0002		5D[illegible]	
022804	19-1588[illegible]	5817 LELAND WY		LOS ANGELES	P	1913	HIST.SURV.	0[illegible]-0726-0004		5D[illegible]	
022807	19-158[illegible]	5828 LELAND WY		LOS ANGELES	P	1929	HIST.SURV.	0[illegible] 0726 0007		5D[illegible]	
022808	19-158[illegible]	5826 LELAND WY		LOS ANGELES	P	1924	HIST.SURV.	0[illegible] 0726 0004		5D[illegible]	
022805	19-1580[illegible]	[illegible] LELAND WY		LOS ANGELES	P	1919	HIST.SURV.	0[illegible]-0726 000[illegible]		5D[illegible]	
022801	19-158011	[illegible] LELAND WY		LOS ANGELES	P	1921	HIST.SURV.	0[illegible]-0726-0001		5D[illegible]	
022802	19-1580[illegible]	58[illegible] LELAND WY		LOS ANGELES	P	1929	HIST.SURV.	0[illegible] 0726 000[illegible]		5D[illegible]	
[illegible]	19-17502[illegible]	[illegible] LEMARSH ST		LOS ANGELES	P	1917	PROJ REVW	HUD[illegible]	11/25/91	6Y	
[illegible]	19-175[illegible]	[illegible] LEMARSH ST	[illegible] COMMUNITY CENTER - PROJ	LOS ANGELES	X		HIST RES	DOE 19 94-[illegible]-0070	08/29/91	[illegible]	
							PROJ.REVW	HUD[illegible]	06/29/94	6Y	
129[illegible]		7[illegible] LEMON GROVE AVE		LOS ANGELES	Y	19[illegible]	HIST.RES.	DOE 19-88-[illegible] 0011	[illegible]	[illegible]	
							PROJ REVW	HUD[illegible]	[illegible]	[illegible]	
125[illegible]		5[illegible] LOOK AVE		LOS ANGELES	Y	1919	HIST RES	DOE 19-[illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]		4921 [illegible] BLVD		LOS ANGELES	L	1929	HIST RES	DOE-19-90-[illegible]	[illegible]	[illegible]	
							PROJ REVW	HUD[illegible]	[illegible]	[illegible]	
[illegible]		[illegible] LEOTA ST		LOS ANGELES			PROJ.REVW	HUD941[illegible]	12/1[illegible]	[illegible]	
02[illegible]24	19-1[illegible]	[illegible]05 LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	0[illegible] 4[illegible] [illegible]		7[illegible]	
022725	19-1[illegible]	901 LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	0[illegible] 4[illegible] 0000		7[illegible]	
022725	19-[illegible]	907 LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	[illegible] 1521-0002		[illegible]	
022726	19-1[illegible]	909 LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	0[illegible] 1522 000[illegible]		[illegible]	
022727	19-1[illegible]	911 LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	0[illegible] 4[illegible] [illegible]		7[illegible]	
022728	19-1[illegible]	917 LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	0[illegible] 4[illegible] 000[illegible]		7[illegible]	
022729	19-1[illegible]	921 LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	0[illegible] [illegible] 0000		[illegible]	
022730	19-1[illegible]	[illegible] LEXINGTON AVE		LOS ANGELES	P	1947	HIST.SURV.	0[illegible]-4[illegible]-000[illegible]		[illegible]	
[illegible]	19-156945	LEXINGTON AVE	[illegible] BLOCK OF LEXINGTON AVENU	LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-[illegible] 9999		[illegible]	
[illegible]	19-1568[illegible]	LEXINGTON AVE	[illegible] BLOCK OF LEXINGTON AVENU	LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible] 0727 9999		[illegible]	
[illegible]	19-158[illegible]	LEXINGTON AVE	5400-5500 BLOCK OF LEXINGTON AVENU	LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible] 07[illegible] 9999		5D[illegible]	
[illegible]	19-160[illegible]	LEXINGTON AVE	5600-5700 BLOCK OF LEXINGTON AVENU	LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible] 0728 99[illegible]		[illegible]	
[illegible]	19-160[illegible]	LEXINGTON AVE	5700 BLOCK OF LEXINGTON AVENUE	LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible] 0729-9999		[illegible]	
[illegible]	19-1[illegible]	5406 LEXINGTON AVE	APARTMENT REHABILITATION	LOS ANGELES	[illegible]		PROJ REVW.	HUD[illegible]	11/04/[illegible]	6Y	
022[illegible]	19-15[illegible]	[illegible] LEXINGTON AVE		LOS ANGELES	P	1924	HIST.SURV.	0[illegible]-0727-0001		5D[illegible]	
[illegible]	19-1588[illegible]	[illegible] LEXINGTON AVE		LOS ANGELES	P	1921	HIST.SURV.	[illegible]-0727 0002		5D[illegible]	
[illegible]	19-1[illegible]	5521 LEXINGTON AVE		LOS ANGELES	P	1926	HIST.REG.	DOE 19-95-[illegible] 00[illegible]	[illegible]	[illegible]	
							PROJ REVW	HUD94[illegible]	[illegible]	[illegible]	
022512	19-1608[illegible]	5524 LEXINGTON AVE		LOS ANGELES	P	1927	HIST.SURV.	0[illegible] 07[illegible]-0001		[illegible]	
022513	19-1608[illegible]7	552[illegible] LEXINGTON AVE		LOS ANGELES	P	1927	HIST.SURV.	0[illegible] 07[illegible]-0004		5D[illegible]	
022514	19-1[illegible]	5529 LEXINGTON AVE		LOS ANGELES	P	191[illegible]	HIST.SURV.	0[illegible] 07[illegible] 000[illegible]		5D[illegible]	
022515	19-15[illegible]	5531 LEXINGTON AVE		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible]-0727 000[illegible]		5D[illegible]	
022516	19-159[illegible]0	5535 LEXINGTON AVE		LOS ANGELES	P	1923	HIST.SURV.	0[illegible] 0727 000[illegible]		5D[illegible]	
022517	19-1[illegible]	5541 LEXINGTON AVE		LOS ANGELES	P	1920	HIST.SURV.	0[illegible]-0727 000[illegible]		5D[illegible]	
022518	19-15[illegible]	5575 LEXINGTON AVE		LOS ANGELES	P	19[illegible]	HIST.SURV.	0[illegible] 07[illegible] 000[illegible]		5D[illegible]	
022519	19-1[illegible]	5601 LEXINGTON AVE		LOS ANGELES	P	1921	HIST.SURV.	0[illegible]-0727 0010		5D[illegible]	
022520	19-1[illegible]	560[illegible] LEXINGTON AVE		LOS ANGELES	P	1927	HIST.SURV.	0[illegible] 0727 [illegible]		5D[illegible]	
022521	19-1[illegible]	5607 LEXINGTON AVE		LOS ANGELES	P	1920	HIST.SURV.	0[illegible] 0727-[illegible]		5D[illegible]	
022522	19-16[illegible]	5612 LEXINGTON AVE		LOS ANGELES	P	1920	HIST.SURV.	0[illegible]-0727-0011		5D[illegible]	
022523	19-1[illegible]	[illegible] LEXINGTON AVE		LOS ANGELES	P	1926	HIST.SURV.	[illegible]-[illegible]		5D[illegible]	

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PROPERTY NUMBER	PRIMARY #	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP PROG.	PRG REFERENCE NUMBER	STAT DAT	NRS	CHL
							PROJ.REVW.	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible] AVE		LOS ANGELES		1919	PROJ REVW	HUD[illegible]	[illegible]	[illegible]	
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	[illegible]	HIST.RES.	NPS [illegible]	[illegible]/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1920	HIST.RES.	NPS [illegible]	[illegible]	[illegible]	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1924	HIST RES	NPS [illegible]	[illegible]	[illegible]	AC
[illegible]	19 [illegible]	[illegible]	[illegible]	LOS ANGELES	P	1923	HIST RES	NPS [illegible]	[illegible]	[illegible]	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1925	TAX CERT	[illegible]	[illegible]	[illegible]	
							HIST.RES	NPS [illegible]	[illegible]/82	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1924	HIST RES	NPS [illegible]	08/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]	[illegible]	LOS ANGELES	P	1921	HIST RES	NPS [illegible]	[illegible]	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	[illegible]	HIST RES.	NPS [illegible]	[illegible]/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]	[illegible]	LOS ANGELES	P	1921	HIST.RES.	NPS [illegible]	[illegible]	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	[illegible]	HIST.RES	NPS [illegible]	[illegible]	[illegible]	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1921	HIST RES.	NPS [illegible]	[illegible]	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1923	HIST RES	NPS [illegible]	[illegible]/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	[illegible]	HIST RES.	NPS [illegible]	08/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	[illegible]	HIST.RES.	NPS [illegible]	08/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1921	HIST RES	NPS [illegible]	[illegible]/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]	[illegible]	LOS ANGELES	P	1922	HIST RES	NPS [illegible]	[illegible]/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	[illegible]	HIST RES	NPS [illegible]	[illegible]	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	[illegible]	HIST RES	NPS [illegible]	[illegible]/19/82	1D	AC
[illegible]	19 [illegible]	[illegible]		LOS ANGELES	P	1925	HIST RES	NPS [illegible]	[illegible]/19/82	1D	AC
[illegible]		[illegible]		LOS ANGELES		1925	PROJ REVW	HUD[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]		LOS ANGELES		1924	PROJ REVW	HUD[illegible]	[illegible]	[illegible]	
[illegible]	19 [illegible]	[illegible] ST	[illegible]	LOS ANGELES	P	1900	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible]	RESIDENCE	LOS ANGELES	L		PROJ REVW	[illegible]	[illegible]	6Y	
[illegible]	19 [illegible]	[illegible] RD	[illegible] RESEARCH CENTER / [illegible]	LOS ANGELES	[illegible]	1944	HIST RES	[illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]2022	[illegible]	[illegible]	
[illegible]	19 [illegible]	751 [illegible] AVE	RESIDENCE	LOS ANGELES	L		PROJ REVW	[illegible]	04/[illegible]	[illegible]	
[illegible]	19 [illegible]	1006 MOHAWK ST		LOS ANGELES	L	[illegible]	HIST.SURV	[illegible]		5S1	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		5S2	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	1912	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	1922	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST.SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	[illegible] MOHAWK ST		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	19 [illegible]	1505 MOHAWK ST		LOS ANGELES	P	1905	HIST SURV	[illegible]		[illegible]	

[illegible] OF HISTORIC PRESERVATION [illegible] Directory of Properties in the Historic Property Data File for LOS ANGELES County Page [illegible] [illegible]

PROPERTY-NUMBER	PRIMARY-#	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP-PROG..	PRG REFERENCE-NUMBER	STAT-DAT	NRS	CRIT
[illegible]	[illegible]	1226 N ALVARADO ST	ECHO PARK UNITED METHODIST CHURCH	LOS ANGELES	P	1924	HIST.SURV.	0653 [illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N ALVARADO ST		LOS ANGELES	P	[illegible]	HIST.SURV.	0653 [illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N ALVARADO ST		LOS ANGELES	P	1912	HIST.SURV.	0653-[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N ALVARADO ST		LOS ANGELES	P	[illegible]	HIST.SURV.	0653 [illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N ALVARADO ST		LOS ANGELES	P	1922	HIST.SURV.	0653 [illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N ARGYLE AVE		LOS ANGELES	P	[illegible]	PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N ARGYLE AVE	RESIDENCE	LOS ANGELES	[illegible]		PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N ARIZONA AVE	[illegible] BLOCK OF NORTH ARIZONA AVE	LOS ANGELES	[illegible]		PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N ARIZONA AVE		LOS ANGELES		[illegible]	PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible] N AVE [illegible]		LOS ANGELES		[illegible]	HIST RES	DOE [illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE [illegible]		LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]		[illegible] N AVE 50		LOS ANGELES	P	[illegible]	HIST.RES.	DOE [illegible]	[illegible]	[illegible]	
							PROJ REVW.	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible] N AVE 50		LOS ANGELES		[illegible]	PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 50		LOS ANGELES	[illegible]	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 50		LOS ANGELES	P	[illegible]	HIST.SURV.	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 50		LOS ANGELES	P	[illegible]	HIST.RES.	DOE [illegible]	[illegible]	[illegible]	
							PROJ.REVW	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible] N AVE 51		LOS ANGELES	[illegible]	[illegible]	HIST.RES.	DOE-[illegible]	[illegible]	[illegible]	
							PROJ REVW.	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 51		LOS ANGELES	[illegible]	[illegible]	HIST SURV.	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible] N AVE [illegible]		LOS ANGELES	U	[illegible]	HIST RES	DOE [illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE [illegible]		LOS ANGELES	[illegible]	[illegible]	HIST.SURV	[illegible]		[illegible]	
[illegible]		[illegible] N AVE [illegible]		LOS ANGELES	Y	[illegible]	HIST RES	DOE [illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 52		LOS ANGELES	P	[illegible]	HIST SURV.	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 52		LOS ANGELES	[illegible]	[illegible]	HIST SURV.	[illegible]		[illegible]	
[illegible]		[illegible] N AVE 52		LOS ANGELES	Y	[illegible]	HIST RES	DOE [illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 52		LOS ANGELES	P	[illegible]	PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 52		LOS ANGELES	P	[illegible]	PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 53	FAITH UNITED PRESBYTERIAN CH	LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 53		LOS ANGELES	[illegible]	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 53		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 53		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]		[illegible] N AVE 53		LOS ANGELES	[illegible]	[illegible]	HIST RES	DOE-[illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 54		LOS ANGELES	[illegible]	[illegible]	HIST. SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 54		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 54		LOS ANGELES	P	[illegible]	HIST SURV.	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 54		LOS ANGELES	P	[illegible]	HIST SURV.	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 54		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 54		LOS ANGELES	P	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 54		LOS ANGELES	P	[illegible]	PROJ REVW	[illegible]	[illegible]	[illegible]	
	[illegible]										
[illegible]	[illegible]	[illegible] N AVE 54	FRANKLIN HIGH SCHOOL	LOS ANGELES	[illegible]	[illegible]	HIST RES.	DOE [illegible]	[illegible]	[illegible]	
							PROJ REVW	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible] N AVE 56	HIGHLAND PARK MASONIC TEMPLE	LOS ANGELES	P	[illegible]	HIST RES	NPS [illegible]	[illegible]	[illegible]	[illegible]
							NAT.REG	[illegible]	[illegible]	[illegible]	
							TAX.CERT	[illegible]	[illegible]	[illegible]	
							HIST.SURV	[illegible]		[illegible]	
							HIST.SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 56	SECURITY TRUST AND SAVINGS BANK, [illegible]	LOS ANGELES	[illegible]	[illegible]	HIST SURV	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible] N AVE 56		LOS ANGELES	[illegible]	[illegible]	HIST SURV	[illegible]		[illegible]	

AR0073403

AR0073404

[illegible] OF [illegible] ASSESSMENTS					Directory of Properties in the Alphabetic Property Data File for [illegible]												
ASSESSMENT NUMBER	"SITUS" P	STREET ADDRESS			OWNER					TITLE NAME		SAN	YR-C	CURR-PROP	PROP-RECORDING NUMBER	SALE DAT	BKP	PRT
														CPOC	[illegible]				
45765	19 114575	446	D	DICKSON AVE						106 ANGELES		D	1911	PROP	[illegible]	10/18/51	6Y	
266735	19 119036	1267	N	DICKENS AVE						108 ANGELES		N		PROP	[illegible]	06/30/11	6Y	
108915	19 114134	1160	W	EASTERN AVE	GRAEN RES/ACC RESTRICTS					106 ANGELES		M	1911	RESTRICT	[illegible]	07/17/55	6Y	
														[illegible]	[illegible]	09/30/54	6Y	
1e2241	19 104326	1113	N	EASTERN AVE						105 ANGELES		D	1925	PROP	[illegible]	06/04/11	6Y	
16e2.1	19 1214 1	1179	N	EASTERN AVE	RESIDENCE					107 ANGELES		N		PROP	[illegible]	04/19/61	6Y	
2e/16		1196	N	EASTERN AVE						108 ANGELES		V	1910	RIGHT	DOR-19-66-3134 [illegible]	07/16/70	6Y	
														PROP	[illegible]	10/19/10	6Y	
46311	19-119543	1178	N	Eastern Ave						105 ANGELES		D	1911	PROP	[illegible]	12/12/7	6Y	
2699	19-1214 11	1432	N	EASTERN AVE						105 ANGELES		D	1910	PROP	[illegible]	11/17/61	6Y	
22711	19 11321	1219	N	EASTERN AVE	PARKING SCHOOL					108 ANGELES		M	1e1-	FIRST	0715 1370 1960		6Y	
1e411	19 119e13	1179	N	EASTERN AVE	RESIDENCE					108 ANGELES		M		PROP	[illegible]	11/24/06	6Y	
0e6510	19 19 611	1187	N	EASTMONT AVE						108 ANGELES		E		PROP	[illegible]	04/ 6/89	6Y	
P66.5A	19 11e632	1163	N	EASTMONT AVE						108 ANGELES		N		PROP	[illegible]	06/13/81	6Y	
44674		761	D	EATON PARK EASTMOUNT	DOCK PARK EASTMOUNT					108 ANGELES		V	1932	FIRST	DOR-19-81-3251-0000	11/18/81	2Y	A1
														PROP	[illegible]	11/11/81	2Y	A2
5/1026	19 111087	1156	N	EDGEMONT AVE	DOG ANGELES THEOSOPHICAL SOCIETY OF C					108 ANGELES		E	1925	FIRST	CON. 2100-2007		2Y	
0322e5	19-141 e06		N	EL CENTRO AVE	2 SA FLORES AVE, 2100 2110					108 ANGELES		E	1910	SECRT	CON. 1702 9001		6Y	
0142e0	19-111e65	1.1%	N	EL CENTRO AVE						108 ANGELES		E	1925	FIRST	0062 0702 9001		2Y	
0/0341	19 .68ve1	1111	N	EL CENTRO AVE						108 ANGELES		J	1911	SECT.SERV.	0063 0701 0011		5Y	
0/2146	19 .16867	1122	N	EL CENTRO AVE						106 ANGELES		J	1910	SECT. PROP.	0063 0701 0011		5Y	
0/2147	19 168049	1127	N	EL CENTRO AVE						106 ANGELES		J	1910	SECT SERV	0063 0701 0014		5Y	
022144	19-161.69	1131	N	EL CENTRO AVE						108 ANGELES		P	1e25	FIRST SERV	0063-0701-0103		5Y	
1/214.	19-116.72	1150	N	EL CENTRO AVE						108 ANGELES		P	1940	FIRST SERV	0063-0701 0014		5Y	
10/116	19 1/2e11	1141	N	EL CENTRO AVE						108 ANGELES		P	1931	FIRST SERV	0063 1701 0011		5Y	
022.13	19 1e1531	1144	N	E. CENTRO AVE						108 ANGELES		P	1941	FIRST SERV	0063 0701 01 4		5Y	
022113	19 116171	1134	N	EL CENTRO AVE						108 ANGELES		P	1931	FIRST SERV	0063-0701-0114		5Y	
0/3.6	19 116/71	1140	N	EL CENTRO AVE						108 ANGELES		P	1932	FIRST SERV.	0063 0701-0114		5Y	
1e3176	19-116e17	1152	N	EL CENTRO AVE						108 ANGELES		P	1916	FIRST SERV	0063-0701 0114		5Y	
2/1213	19 116171	1156	N	EL CENTRO AVE						108 ANGELES		P	1925	FIRST SERV	0063-0701-0114		5Y	
022.6.	19 116/71	1140	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV.	0063 0701-0114		5Y	
022.57	19 11e571	1156	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
0/2.13	19 116/71	1149	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.17	19 116/71	1156	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.16	19 116/71	1140	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.15	19 116/71	1144	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.14	19 116/71	1148	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.13	19 116/71	1152	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.12	19 116/71	1156	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.11	19 116/71	1140	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.10	19 116/71	1144	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.9	19 116/71	1148	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.8	19 116/71	1152	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.7	19 116/71	1156	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.6	19 116/71	1140	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.5	19 116/71	1144	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.4	19 116/71	1148	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.3	19 116/71	1152	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.2	19 116/71	1156	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.1	19 116/71	1140	N	EL CENTRO AVE						108 ANGELES		P	1910	FIRST SERV	0063-0701-0114		5Y	
022.0

PROPERTY-NUMBER	PRIMARY #	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP PROG	PRG-REFERENCE NUMBER	STAT DAT	NRS	CRIT
022455	19-156451	1240 N GORDON ST		LOS ANGELES	P	1920	HIST.SURV.	0051 0712 [illegible]		5S2	
022451	19-156491	1242 N GORDON ST		LOS ANGELES	P	1914	HIST.SURV.	0051 0712 [illegible]		5S2	
022474	19-156493	1243 N GORDON ST		LOS ANGELES	P	1912	HIST SURV	0051-0712-[illegible]		[illegible]	
022457	19-156494	1255 N GORDON ST		LOS ANGELES	P	1907	HIST.SURV	0051 0712 [illegible]		[illegible]	
[illegible]	19-156495	1256 N GORDON ST		LOS ANGELES	P	1912	HIST.SURV.	0051 0712 [illegible]		5S2	
[illegible]	19-156496	1262 N GORDON ST		LOS ANGELES	P	1921	HIST.SURV	0053 0712 [illegible]		5S2	
022412	19-142490	1336 N GORDON ST		LOS ANGELES	P	1914	HIST SURV	0051 0712-[illegible]		5S2	
[illegible]	19-156413	1358 N GORDON ST		LOS ANGELES	P	1913	HIST SURV	0055-0712-[illegible]		5S2	
022494	19-156495	1400 N GORDON ST		LOS ANGELES	P	1922	HIST.SURV	0153 0712 [illegible]		5S2	
022495	19-156571	1412 N GORDON ST		LOS ANGELES	P	1925	HIST.SURV	0153 0712 5011		5S2	
022476	19-166561	1426 N GORDON ST		LOS ANGELES	P	1911	HIST.SURV	0153 0712 [illegible]		5S2	
022477	19-148562	1432 N GORDON ST		LOS ANGELES	P	1921	HIST SURV	0153 0712 5029		5S2	
022441	19-148563	1436 N GORDON ST		LOS ANGELES	P	1926	HIST.SURV	0753 0712 [illegible]		7R	
022179	19-116564	1442 N GORDON ST		LOS ANGELES	[illegible]	1921	HIST SURV	0053-0712 0037		5S2	
022180	19-115565	1446 N GORDON ST		LOS ANGELES	P	1912	HIST SURV	0053 0712 [illegible]		5S2	
021965	19-127552	1502 N GORDON ST		LOS ANGELES	P	1921	HIST.SURV	0053-0541 1020		5S2	
021966	19-117551	1529 N GORDON ST		LOS ANGELES	P	1923	HIST.SURV	0053 0541 1021		5S2	
[illegible]	19-117554	1534 N GORDON ST		LOS ANGELES	P	1922	HIST SURV	0053 0513 [illegible]		5S2	
021595	19-147595	1542 N GORDON ST		LOS ANGELES	P	1912	HIST SURV	0053 0541 [illegible]		5S2	
[illegible]	19-147997	1523 N GORDON ST		LOS ANGELES	P	1921	PROJ REVW	HUD[illegible]	09/16/91	6Y	
							HIST REG	PaD [illegible]	09/30/94	6Y	
							HIST SURV.	0153-0641 0023		5S2	
021909	19-167996	1535 N GORDON ST		LOS ANGELES	P	1912	HIST SURV	0053-0641-0074		5S2	
021911	19-117998	1541 N GORDON ST		LOS ANGELES	P	1922	HIST SURV	0153-0641 0025		5S2	
021912	19-167999	1550 N GORDON ST		LOS ANGELES	P	1929	HIST SURV	0153-0641-0027		5S2	
[illegible]	19-161007	1555 N GORDON ST		LOS ANGELES	P	1927	HIST SURV.	0153 0641 0029		5S2	
[illegible]	19-116003	1556 N GORDON ST		LOS ANGELES	P	1923	HIST SURV	0153 0641 0025		5S2	
021975	19-166011	1558 N GORDON ST		LOS ANGELES	P	1925	HIST SURV.	1053-0641-0030		5S2	
021976	19-166013	1551 N GORDON ST		LOS ANGELES	P	1923	HIST SURV.	1053-0641 0031		5S2	
021977	19-166014	1560 N GORDON ST		LOS ANGELES	P	1913	HIST SURV	1053 0641-0032		5S2	
021978	19-165075	1568 N GORDON ST		LOS ANGELES	P	1915	HIST SURV.	1051-0641-0013		5S2	
022150	19-168521	N GOWER ST	N GOWER AVE. 1100 1200 BLOCKS	LOS ANGELES	P	1908	HIST SURV.	1054 0711-9999		5S1	
022452	19-158521	1111 N GOWER ST		LOS ANGELES	P	1916	HIST SURV	1053 0711 0011		5S2	
022453	19-148513	1118 N GOWER ST		LOS ANGELES	P	1921	HIST SURV	0053-0711 0012		5S2	
022164	19-156509	1122 N GOWER ST		LOS ANGELES	P	1916	HIST.SURV.	0051-0711 0021		5S2	
022465	19-159510	1160 N GOWER ST		LOS ANGELES	P	1919	PROJ REVW	HUD[illegible]	11/26/91	6Y	
							HIST SURV	0051-0711-0104		5S2	
022166	19-110511	1206 N GOWER ST		LOS ANGELES	P	1923	HIST SURV	0051-0711-0022		5S2	
022157	19-116512	1212 N GOWER ST		LOS ANGELES	P	1925	HIST SURV.	1051-0711-0025		5S2	
022468	19-155511	1232 N GOWER ST		LOS ANGELES	P	1911	HIST SURV.	1051 0711 0027		5S2	
022459	19-165514	1234 N GOWER ST		LOS ANGELES	P	1911	HIST SURV.	1053 0711 0025		5S2	
022191	19-168515	1234 N GOWER ST		LOS ANGELES	P	1908	HIST SURV.	0053 0711 0016		5S2	
[illegible]	19-168511	1235 N GOWER ST		LOS ANGELES	P	1921	HIST SURV	0053 0711 0012		5S2	
[illegible]	19-168517	1240 N GOWER ST		LOS ANGELES	P	1914	HIST SURV	0053-0711 0011		5S2	
[illegible]	19-178511	1243 N GOWER ST		LOS ANGELES	P	1929	HIST SURV	0053 0711-0012		5S2	
022451	19-168513	1244 N GOWER ST		LOS ANGELES	P	1921	HIST SURV	0051-0711-5013		5S2	
022457	19-168520	1249 N GOWER ST		LOS ANGELES	P	1921	HIST SURV	0151-0711-0014		5S2	
022477	19-168521	1255 N GOWER ST		LOS ANGELES	P	1926	HIST SURV.	1051 0711-0015		5S2	
022507	19-168527	1290 N GOWER ST		LOS ANGELES	P	1914	HIST SURV.	1053 0711-0016		5S2	
023510	19-168562	1570 N GOWER ST		LOS ANGELES	P	1917	HIST SURV	0053 0822 [illegible]		5S	
023577	19-167362	1551 N GOWER ST		LOS ANGELES	P	1926	HIST SURV	0050-1606-0212		5S2	
023299	19-167321	1550 N GRACE AVE	EL TABACILLO	LOS ANGELES	P	1921	HIST REG	NPS-[illegible] 9999	07/17/05	1S	C
							NAT.REG.	19-0445	09/14/04	2S	C
							HIST SURV	0053 0802 [illegible]	06/21/80	5S	
052965		1552 N GRACE AVE	EL TABACILLO FOUNTAIN	LOS ANGELES	P	1921	HIST REG	NPS [illegible]-0001	07/20/05	1D	C
052968		1552 N GRACE AVE	EL TABACILLO WALL	LOS ANGELES	P	1921	HIST.REG	NPS 05000211-0003	07/20/05	1D	C

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PROPERTY NUMBER	PRIMARY-#	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP-PROG	PRG-REFERENCE-NUMBER	STAT-DAT	NRS	CRIT
051590	19-173592	[illegible] N HOBART BLVD		LOS ANGELES	P	1929	PROJ.REVW.	HUD941[illegible]	12/28/91	6Y	
094275	19-176[illegible]	1242 N HOBART BLVD		LOS ANGELES	P		PROJ.REVW.	HUD950[illegible]	[illegible]	6Y	
098240	19-176[illegible]	1545 N HOBART BLVD		LOS ANGELES	M	1949	HIST.RES.	DOE-19-94-[illegible]	04/29/94	6Y	
							PROJ.REVW.	HUD940[illegible]	04/29/94	6Y	
[illegible]	19-156[illegible]	[illegible] N HOPE ST	[illegible]	LOS ANGELES	M	1905	[illegible]	[illegible]	[illegible]	[illegible]	
	19-158880						HIST.RES.	[illegible]	[illegible]	[illegible]	
	19-159[illegible]						HIST.SURV.	0153 0236 [illegible]	[illegible]	[illegible]	
	19-157725										
	19-[illegible]										
	19-[illegible]										
	19-[illegible]										
	19-[illegible]										
	19-[illegible]										
	19-[illegible]										
[illegible]		[illegible] N HOOVER ST		LOS ANGELES		1910	HIST.RES.	DOE-19-0[illegible]	10/29/02	6Y	
							PROJ.REVW.	HUD[illegible]	10/29/02	6Y	
[illegible]		[illegible] N HOOVER ST		LOS ANGELES		1917	HIST.RES.	DOE-19-02-[illegible]	10/29/02	6Y	
							PROJ.REVW.	HUD[illegible]	10/29/02	6Y	
[illegible]	19-168[illegible]	1121 N HUDSON AVE		LOS ANGELES	P	1923	HIST.SURV.	0153 0716-0002		5D2	
[illegible]	19-168[illegible]	1122 N HUDSON AVE		LOS ANGELES	P	1921	HIST.SURV.	0153 0716 0001		5D2	
[illegible]	19-168[illegible]	1124 N HUDSON AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	0153 0716 0003		5D2	
[illegible]	19-168[illegible]	1128 N HUDSON AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	0153-0716-0004		5D2	
[illegible]	19-168540	1132 N HUDSON AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	0153-0716-0005		5D2	
[illegible]	19-168[illegible]	11[illegible] N HUDSON AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	0153 0716-0006		5D2	
[illegible]	19-168[illegible]	1134 N HUDSON AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	0153 0716 0007		5D2	
[illegible]	19-168[illegible]	1135 N HUDSON AVE		LOS ANGELES	P	1923	HIST.SURV.	0153 0716-0008		5D2	
[illegible]	19-168[illegible]	1138 N HUDSON AVE		LOS ANGELES	P	1921	HIST.SURV.	0153-0716-0009		5D2	
[illegible]	19-168[illegible]	1141 N HUDSON AVE		LOS ANGELES	P	1921	HIST.SURV.	0153 0716 0010		5D2	
[illegible]	19-168[illegible]	1145 N HUDSON AVE		LOS ANGELES	P	1926	HIST.SURV.	0153 0716 0011		5D2	
[illegible]	19-168[illegible]	1146 N HUDSON AVE		LOS ANGELES	P	1925	HIST.SURV.	0153 0716 0012		5D2	
[illegible]	19-168[illegible]	1150 N HUDSON AVE		LOS ANGELES	P	1912	HIST.SURV.	0153-0716 0013		5D2	
[illegible]	19-168[illegible]	1151 N HUDSON AVE		LOS ANGELES	P	1923	HIST.SURV.	0153-0716 0014		5D2	
[illegible]	19-168[illegible]	1156 N HUDSON AVE		LOS ANGELES	P	1922	HIST.SURV.	0153 0716-0015		5D2	
[illegible]	19-168[illegible]	1157 N HUDSON AVE		LOS ANGELES	P	1921	HIST.SURV.	0153-0716-0016		5D2	
[illegible]	19-168[illegible]	1401 N HUDSON AVE		LOS ANGELES	P	1905	HIST.SURV.	0153 0701 0016		5D2	
[illegible]	19-168[illegible]	1402 N HUDSON AVE		LOS ANGELES	P	1905	HIST.SURV.	0153 0701 0017		5D2	
[illegible]	19-168[illegible]	1415 N HUDSON AVE		LOS ANGELES	P	1905	HIST.SURV.	0153 0701 0018		5D2	
[illegible]	19-168[illegible]	1421 N HUDSON AVE		LOS ANGELES	P	1921	HIST.SURV.	0153 0704 0019		5D2	
[illegible]	19-168[illegible]	1422 N HUDSON AVE		LOS ANGELES	P	1921	HIST.SURV.	0153-0704 0020		5D2	
[illegible]	19-168[illegible]	1425 N HUDSON AVE		LOS ANGELES	P	1927	HIST.SURV.	0153-0704-0021		5D2	
[illegible]	19-168[illegible]	1428 N HUDSON AVE		LOS ANGELES	P	1911	HIST.SURV.	0153 0704 0022		5D2	
[illegible]	19-168[illegible]	1432 N HUDSON AVE		LOS ANGELES	P	1924	HIST.SURV.	0153 0704 0023		5D2	
[illegible]	19-168[illegible]	1433 N HUDSON AVE		LOS ANGELES	P	[illegible]	HIST.SURV.	0153-0704-0024		5D2	
[illegible]	19-17[illegible]	1518 N HUDSON AVE		LOS ANGELES	M	[illegible]	PROJ.REVW.	HUD94[illegible]	[illegible]/15/94	6Y	
							HIST.RES.	FAD 51B	[illegible]/15/94	6Y	
[illegible]	19-[illegible]	1740 N HUDSON AVE		LOS ANGELES	U	1911	PROJ.REVW.	HUD9115226	06/13/91	6Y	
[illegible]	19-[illegible]	1752 N HUDSON AVE		LOS ANGELES	P	1911	PROJ.REVW.	HUD90[illegible]	[illegible]/90	6Y	
[illegible]	19-[illegible]	1[illegible] N HUDSON ST	SELBY HOTEL	LOS ANGELES	P	1910	HIST.RES.	DOE-19-94-0[illegible]	09/10/94	6Y	
							PROJ.REVW.	[illegible]	09/10/94	6Y	
							PROJ.REVW.	[illegible]	[illegible]	6Y	
[illegible]	19-[illegible]	1[illegible] N HUDSON ST	SELBY HOUSE	LOS ANGELES	P	1911	HIST.RES.	DOE-19-94-0[illegible]	09/10/94	6Y	
							PROJ.REVW.	[illegible]	09/10/94	6Y	
							PROJ.REVW.	[illegible]	[illegible]	7J	
[illegible]	19-17[illegible]	4551 S HUNTINGTON DR	SEASIDE GAS STATION, GORDONS SERVI	LOS ANGELES	P	1941	HIST.SURV.	[illegible]		[illegible]	
[illegible]	19-[illegible]	151 N INDIANA ST	HOUSING REHABILITATION	LOS ANGELES	C		PROJ.REVW.	HUD[illegible]	07/2?/98	6Y	
[illegible]		[illegible] N INDIANA ST		LOS ANGELES	P	1929	HIST.RES.	DOE-19-0[illegible]	11/0?/04	6Y	

PROPERTY-NUMBER	PRIMARY #	STREET ADDRESS	NAME	CITY NAME	OWN	YR-C	OWN-PROP	KEY-REFERENCE NUMBER	LAST UPD	NPS	DETT
							CROS.REVW.	PCC9410C1E	11/03/94	6Y	
1:0752		534 N JEFFERSON BLVD		LOS ANGELES	P	1913	HIST.RSRC	86-19 26 7126 0401	02/01/94	6U	
							PROP REVW	HHDD5A8D2CC	11/01/94	AU	
120789		401 N VINCENT AVE	ANDREW STEVE FLOAT	WEST HOLLYWOOD	M	1941	HIST.DIST.	1995 10 09 2:06 90.	01/03/95	5S3	6C
							LPAC.REVW.	P1C99E1231B	01/03/95	3L4	AC
910993	19 174439	1610 N JEAN AVE	JEAN TERRACE	LOS ANGELES	U	1937	PROP REVW	HHDD91C1C2	02/01/93	7R	
033011	19-184240	1621 N JEAN AVE	WILLIAM T. BOARDMAN PROPERTY	LOS ANGELES	M	1902	HIST.SURV	0011 0E8A 1000		5D3	
120019	19-182045	1641 N JEAN AVE	ORA HALL RESIDENCE	LOS ANGELES	P	1913	HIST.SURV	0153 0565 3007		7R	
123941	19-179163	1650 N JEAN AVE	J. MAGNIN & COMPANY, BUILDING NUMBER	LOS ANGELES	P	1923	HIST.SURV	0075-0521 5001		4S	
120103	19-179141	1714 N JEAN AVE	WILSHIRE BOULEVARD/TEMPLE HISTORIC	LOS ANGELES	P	1923	HIST.INDV	0053-4180-5005	10/09/95	1E	T
							HIST.SURV	0053 0810 1007		7R	
10320	9 114860	4410 N JEAN AVE	RESIDENCE	LOS ANGELES	J		ARCH.REVW.	91C8870102E	01/30/87	5Y	
120946	19 165613	N JEAN ST	N JEAN ST, 1300-1100 BLOCKS	LOS ANGELES	P	1911	HIST.SURV	0053 0107 5009		5D2	
164598	19 174081	710 N JEAN ST		LOS ANGELES	U		PROJ.REVW	90JUN01J1M7	12/13/90	7Z	
022564	19 115870	1000 N JEAN ST		LOS ANGELES	P	1926	HIST.SURV	0053 0417 0001		5D2	
070035	19 166581	1401 N JEAN ST		LOS ANGELES	P	1926	HIST.SURV	0053 0417.0002		5D2	
007314	19 166582	1407 E JEAN ST		LOS ANGELES	P	1900	HIST.SURV	0053 0717 0004		5D2	
070018	19 165593	1408 N JEAN ST		LOS ANGELES	P	1919	HIST.SURV	0053 0417 0005		5D2	
020015	19 165594	1414 N JEAN ST		LOS ANGELES	P	1915	HIST.SURV	0 053 0717 0006		5D2	
022013	19-181668	1414 N JEAN ST		LOS ANGELES	D	1911	HIST.SURV	0053-0717-0001		5D2	
022062	19 165597	1420 N JEAN ST		LOS ANGELES	P	1915	HIST.SURV	0053-0717-0008		5D2	
022764	19 165599	1426 N JEAN ST		LOS ANGELES	P	1914	HIST.SURV	0053-0717-0010		5D2	
022566	19 166601	1430 N JEAN ST		LOS ANGELES	P	1915	HIST.SURV	0053 0717-0012		5D2	
021167	19 165592	1436 N JEAN ST		LOS ANGELES	P	1916	HIST.SURV	.0053 0717 0014		5D2	
022768	19-179564	1510 N JEAN ST		LOS ANGELES	A	1915	HIST.SURV	0053-0717-0016		5D2	
022570	19-181736	1514 N JEAN ST		LOS ANGELES	P	1910	HIST.SURV	0053-0717-0017		5D2	
022571	19-166596	1516 N JEAN ST		LOS ANGELES	P	1914	HIST.SURV.	0053-0717 0018		5D2	
021572	19 160597	1524 N JEAN ST		LOS ANGELES	P	1909	HIST.SURV.	0053 0717 0019		5D2	
022574	19 6895-	1541 N JEAN ST		LOS ANGELES	P	1917	HIST.SURV.	0053 0717 0020		5D2	
022574	19 165599	1610 N JEAN ST		LOS ANGELES	P	1926	HIST.SURV	0053-0717 0021		5D2	
022575	19-166601	1614 N JEAN ST		LOS ANGELES	P	1926	HIST.SURV.	0053-0717-0022		5D2	
022576	19 166602	1620 N JEAN ST		LOS ANGELES	P	1925	HIST.SURV	0053-0717-0023		5D2	
022577	19 165603	1624 N JEAN ST		LOS ANGELES	P	1925	HIST.SURV	0053 0717 0024		5D2	
022578	19-166604	1630 N JEAN ST		LOS ANGELES	P	1925	HIST.SURV	0053-0717-0025		5D2	
022579	19 166605	1636 N JEAN ST		LOS ANGELES	P	1930	HIST.INDV.	0053-0717 0026		5D2	
022580	19 166606	1640 N JEAN ST		LOS ANGELES	P	1927	HIST.SURV.	0053 0717 0.19		5D2	
022582	19 166607	1646 N JEAN ST		LOS ANGELES	P	1924	HIST.SURV.	0053-0717 0.19		5D2	
022583	19-166608	1701 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV	0053-0717 0.20		5D2	
							HIST.INDV.	0053-0717-0010		5D2	
022584	19 166611	1714 N JEAN ST		LOS ANGELES	P	1927	HIST.SURV.	0053 0717 0012		5D2	
022586	19-166611	1716 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV.	0053 0717-0013		5D2	
022587	19 166613	1720 N JEAN ST		LOS ANGELES	P	1917	HIST.INDV.	0053-0717-0014		5D2	
022588	19 166614	1730 N JEAN ST		LOS ANGELES	P	1917	HIST.INDV.	0053-0717-0015		5D2	
022589	19 166615	1731 N JEAN ST		LOS ANGELES	P	1911	HIST.INDV.	0053 0717 0016		5D2	
022590	19 166615	1736 N JEAN ST		LOS ANGELES	P	1916	HIST.SURV	0053 0717 0017		5D2	
022591	19-166616	1744 N JEAN ST		LOS ANGELES	P	1925	HIST.SURV	0053 0717 0018		5D2	
022592	19-166617	1750 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV	0053 0717 0019		5D2	
022593	19-166618	1751 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV.	0053 0717 0020		5D2	
022594	19-166619	1754 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV	0053-0717 0021		5D2	
022595	19-166621	1756 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV	0053-0717 0022		5D2	
022596	19-166622	1764 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV	0053 0717 0023		5D2	
022597	19 166623	1770 N JEAN ST		LOS ANGELES	P	1921	HIST.SURV	0053 0717 0024		5D2	
964195	19-179603	219 W KENSINGTON AVE	RIVERMONT RESUBDIVISION	LOS ANGELES	U		PROJ.REVW.	90JUN01J1M5	11/04/90	5Y	
112567		317 N KENSINGTON AVE		LOS ANGELES	P	1923	HIST.SURV	DOE-19-86 0456-000.	4/01/95	5S3	J
							PROJ REVW	90JUN07J01J	07/31/90	3S7	J
101501	19 179011	3121 N KENMORE AVE		LOS ANGELES	U	1923	PROJ.REVW.	90JUN01J2E7	09/11/90	6Y	

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PROPERTY NUMBER	DATE LIST'D	STREET ADDRESS	CITY NAME	ZIP	OWN	STATUS CODE	NRHP REFERENCE NUMBER	STAT-DATE	ASS	CMT
691077	10-11847D	1726 N SYCAMORE AVE	LOS ANGELES	9	1921	PDST RSB.	5CS-10 84-1267 0010	09/02/84	RS	
						PROP REVW	IM8409020P	10/01/84	RS	
683116	10-11861	1101 N KEELER AVE	LOS ANGELES	9		DOES.REVW.	HCD8410110	09/01/84	RS	
651166	10-17505	919 N KINGS AVE	LOS ANGELES		1925	DOES.REVW.	HUD8401140	03/16/84	RS	
671100	10-18715	801 N KINGS RD	LOS ANGELES	9	1921	PDS PRO DR	029 0 10 PDF In C.	02/11/10	RS	
						PDST PDPV	0001 0244-0000	01/11/1.	RS	
621014	10-169035	1365 N LA BREA AVE	LOS ANGELES	9	1913	DIST.DIRV	0071-1141 0000		RS	
621045	10-169210	140. N LA BREA AVE	LOS ANGELES	9	1920	DIST.DIRV	0055-0742-0007		1S	
621021	10-169279	1414 N LA BREA AVE	LOS ANGELES	9	1917	DIST.DIRV	0055-0742-0007		1S	
						DIST.DIS.	SPDT-CAS 106	06/06/07	1S	
621011	10-169239	1411 N LA BREA AVE	LOS ANGELES	9	1916	DIST.DIRV.	0055-0741 0007		1S	
621009	10-169241	1421 N LA BREA AVE	LOS ANGELES	9	1917	DIST DIRV	0055-0146 0007		7S	
1000.7	10-1.15.7	1911 N LA BREA AVE	LOS ANGELES	9	1914	HIST NRS	DOE Ln 84 0003 0150	11/16/88	RY	
						PROT REVW	LM8708160P3R	11/15/88	RY	
769514	10-171814	2011 N LA BREA TERRACE	LOS ANGELES	9	1911	DIST.RES.	DOE-10-88-0003-0000	11/16/88	2S2	C
						DOES REVW	LM8708310P3R	11/16/88	2S2	C
615605	10-171815	2015 N LA BREA TERRACE	LOS ANGELES	9	1911	HIST x85	DOE 10 88 0004 0150	11/16/88	2S2	C
						PROJ PRDV	LM8708310P3R	11/15/88	2S2	C
647741	10-171121	121 E LAKE ST	LOS ANGELES	9	1927	DIST DIRV	0055-1661 0010		1S	
115635		939 N LAKE ST	LOS ANGELES		1919	DIST REG.	DOE-10-01 0077-0170	01/11/01	4S	
						PROJ REVW	5U0001010P3	01/11/01	RY	
724101	10-170121	121 N LAKE ST	LOS ANGELES	7	1916	HIST DURV.	0052 1562 0011		1S2	
115621		220 N LONGWOOD BLVD.	LOS ANGELES	9	1925	HIST PRS	DOE 10 01 0001 0000	01/17/01	RY	
						PROJ.REVW	PC701750AP	01/17/01	RY	
648042	10-17516	939 N LAS PALMAS AVE	LOS ANGELES	9	1929	DIST.RES.	DOE-10-84-0051 0010	08/15/84	RS	
						PROJ REVW.	LM8508200P3R	08/16/84	RY	
023258	10-169787	1121 N LAS PALMAS AVE	LOS ANGELES	9	1914	HIST DURV.	0154-0774 0003		1S	
021757	10-169317	1111 N LAS PALMAS AVE	LOS ANGELES	9	1929	HIST DURV	0154 0774 0003		7S	
021056	10-169210	1441 N LAS PALMAS AVE	LOS ANGELES	9	1930	HIST DURV	0153-1770-0003		1S2	
022108	10-168125	1611 N LAS PALMAS AVE	LOS ANGELES	9	1926	DIST.DIRV	0153 1650-0003		1S2	
021200	10-169074	1419 N LAS PALMAS AVE	LOS ANGELES	9	1916	DIST DIRV	0055-0607-0010		1S2	
023006	10-168015	1615 N LAS PALMAS AVE	LOS ANGELES	9	1921	HIST DURV	0055 0656-0003		7S	
110152		1714 N LAS PALMAS AVE	LOS ANGELES	9	1926	HIST PRS	DOE 10 90 0265-0150	03/11/90	4S	
						PROJ.REVW	M9003020P3	03/11/90	4S	
721142	10-167480	1614 N LAS PALMAS AVE	LOS ANGELES	9	1919	DIST.RES	NPS-82003186 0165	08/15/82	1S	AC
721311	10-167345	2000 N LAS PALMAS AVE	LOS ANGELES	9	1907	HIST RES	NPS 82002186 0039	08/19/82	1S	AC
721310	10-167319	2004 N LAS PALMAS AVE	LOS ANGELES	9	1920	HIST RES	NPS 82002189-0011	08/19/82	1S	AC
721313	10-167148	2006 N LAS PALMAS AVE	LOS ANGELES	9	1927	HIST RES	NPS 82002189 0010	08/19/82	1S	AC
721314	10-167319	2008 N LAS PALMAS AVE	LOS ANGELES	9	1921	HIST RES.	NPS-82002189-0011	08/19/82	1S	AC
721318	10-167352	2014 N LAS PALMAS AVE	LOS ANGELES	9	1921	HIST RES	NPS 82002189 0011	08/19/82	1S	AC
721319	10-167355	2016 N LAS PALMAS AVE	LOS ANGELES	9	1918	HIST RES	NPS 82002189 0011	08/19/82	1S	AC
721321	10-167359	2018 N LAS PALMAS AVE	LOS ANGELES	9	1924	HIST RES	NPS 82002189 0093	08/19/82	1S	AC
721325	10-167357	2012 N LAS PALMAS AVE	LOS ANGELES	9	1926	HIST RES.	NPS 82002189-0041	08/19/82	1S	AC
721322	10-167356	2014 N LAS PALMAS AVE	LOS ANGELES	9	1923	HIST RES	NPS 82002189 0042	08/19/82	1S	AC
721344	10-167359	2018 N LAS PALMAS AVE	LOS ANGELES	9	1924	HIST RES	NPS 82002189 0042	08/19/82	1S	AC
021329	10-167419	1901 N LAS PALMAS AVE	LOS ANGELES	1	1921	HIST RES	NPS 82002189 0042	08/19/82	1S	AC
021330	10-167403	1903 N LAS PALMAS AVE	LOS ANGELES	9	1921	HIST RES	NPS 82002189-0142	08/19/82	1S	AC
021326	10-167401	1905 N LAS PALMAS AVE	LOS ANGELES	9	1911	HIST RES.	NPS-82002189-0144	08/19/82	1S	AC
721329	10-167351	2010 N LAS PALMAS AVE	LOS ANGELES	9	1925	HIST RES.	NPS-82002189-0141	08/19/82	1S	AC
021327	10-167351	2005 N LAS PALMAS AVE	LOS ANGELES	9	1924	HIST RES	NPS 82002189-0045	08/19/82	1S	AC
021328	10-167342	2007 N LAS PALMAS AVE	LOS ANGELES	9	1929	DIST.RES.	NPS-82002189 0046	08/19/82	1S	AC
009108	10-171017	420 N LOS ANGELES ST	LOS ANGELES	9	1895	TAX.INPST	8401040P	12/19/84	6M	
						HIST RDPV	2153-1332-0002		7S	
019210	10-174100	631 N LOS ANGELES ST	LOS ANGELES	9	0	TAX.CERT	017 9 10 0126	09/19/76	6A	
021045	10-171164	515 N LOS ANGELES ST	LOS ANGELES	9	1915	HIST SURV	0109-0230-0003		3S	
021084	10-171145	515 N LOS ANGELES ST	LOS ANGELES	9		DIST SURV.	0041-1988-0002		7S	

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TYPE	ST	NUMBER	HISTORY #	STREET ADDRESS	AREA	CITY NAME	CAT	ZIP	OTHER INFO	PRI REFERENCE NUMBER	NEXT DAT	NRD	CRIT
									SPOT REVW.	HRI9402022	03/01/96	222	2
									HIST.REV	HDP 10-16 0170-0207	04/12/96	203	2
									PROJ.REVW.	UNIA8602110	05/17/96	182	1
		926114	19 172914	4406 W VERMONT AVE	PICTURESQUE / CABLECIVARZ	LOS ANGELES	M	1951	HIST.RES.	DOE 19 34-0451 0010	02/00/94	552	
									DRAC.REVW.	2B0a602010	04/00/94	552	
									HIST SURV	1951 4260 0010		552	
		216915	19 172813	3656 N VERMONT AVE		LOS ANGELES	P	1907	HIST SURV	1950 4261 0130		19	
		930216	19 172916	2003 N VERMONT AVE		LOS ANGELES	P	1900	HIST SURV.	0051 426. 0300		19	
		020317	19-172917	207. N VERMONT AVE		LOS ANGELES	P	1900	HIST.SURV.	0051-4261 0700		19	
		020318	19-172817	3674 N VERMONT AVE		LOS ANGELES	P	1900	HIST.SURV.	0051-4264 0130		19	
		007147	19-172023	959 N VINE ST	VINE STREET ELEMENTARY SCHOOL	LOS ANGELES	D	1922	HIST.RES.	DOE 19 34 0552-1999	03/16/94	252	
									PROJ REVW.	HRI9102028	08/15/94	252	
		106549	19-172817	957 N VINE ST	VINE STREET ELEMENTARY SCHOOL ADDI	LOS ANGELES	D	1922	HIST RES	DOE-19-91 0752-0302	08/15/94	252	
									PROJ.REVW.	HRI9402022	03/15/96	252	
		16.160	19 172869	951 N VINE ST	VINE STREET ELEMENTARY SCHOOL MAIN	LOS ANGELES	D	1922	HIST.RES.	DOE 19 34-0552 0001	04/12/94	252	
									PROJ REVW	HRI9402022	03/15/94	252	
		107415	19 172015	1051 N VINE ST	HOLLYWOOD STATION	LOS ANGELES	P	1910	HIST RES	DOE-19 85 0146 0000	01/16/95	6Y	
									PROJ.REVW.	HP95102072	01/15/95	6Y	
		921.50	19 172814	1016 N VINE ST		LOS ANGELES	P	1924	HIST.SURV.	0051-0747 0300		7H	
		921.51	19 172815	1007 N VINE ST	FIRST METHODIST CHURCH, SOUTH, HOL	LOS ANGELES	P	1924	HIST.SURV.	0051-0755-0300		3S	
		033753	19 169214	1234 N VINE ST	HARVARD NORTH, HOLLYWOOD PARCEL 4	LOS ANGELES	P	1924	HIST.SURV.	0051 0710-0300		7H	
		737053	19-169716	1511 N VINE ST	VISTA THEATRE	LOS ANGELES	P	1937	HIST RES.	DOE-19 95-0256 0001	09/21/95	6Y	
									PROJ.REVW.	HCP9505210	10/01/95	6Y	
									HIST.SURV.	0051-0749-0300		7S	
		737796	19 169119	1313 N VINE ST	HOTEL DOK FOR RESURRECTION STUDIO	LOS ANGELES	P	1924	HIST.SURV	0051 0711 0300		7H	
		021850	19-169219	1317 N VINE ST		LOS ANGELES	P	1931	HIST SURV	0051 0714 0300		7H	
		101416	19 176017	1611 N VINE ST	DOUBLEDOOR THEATER / VINE THEATER,	LOS ANGELES	P	1926	HIST REA	DOE-19-93 0149-0001	11/22/95	6Y	
									PROJ.REVW.	HRI9402022A	11/24/95	6Z	
									HIST.SURV	0051 0456-0700		3S	
★	←	034870	19 170031	1025 N VINE ST	HOLLYWOOD PALMS THEATRE	LOS ANGELES	P	1935	HIST SURV	0051 0610 1056	04/04/85	1E	C
★	←	021868	19 169831	1033 N VINE ST		LOS ANGELES	P	1923	HIST SURV	0051 0610 1057	04/04/85	1D	C
									HIST.SURV	0051-0754 0300		7SS	
★	←	013ee	19 167895	1031 N VINE ST	HOLLYWOOD PLAZA HOTEL	LOS ANGELES	P	1921	HIST.SURV.	0051-4750-0350	11/04/85	1C	*
									HIST.SURV.	0051-0475-0300		1S	
★	←	021917	19-167548	1610 N VINE ST	TAFT BUILDING	LOS ANGELES	P	1923	HIST.SURV.	0051-0478 0350	04/01/85	1D	C
									HIST.SURV.	0051 0457-0300		3S	
									PROJ REVW.	HRI	10/17/90	2D	C
									FIST RES.	DOE 19 89 1506 0000	10/17/90	2Y	C
		021966	19 167594	1717 N VINE ST	JAPAN CAFE(Bldg / GENERAL BLDG / GL	LOS ANGELES	P	1927	HIST.SURV.	0051-4659 1560	04/30/85	6X	
									HIST.SURV	0051-0436 7000		5S2	
★	←	021907	19-167595	1721 N VINE ST	HOLLYWOOD PLAYHOUSE, HOLLYWOOD VAR	LOS ANGELES	P	1925	HIST.SURV.	0051-4653-0301	01/30/89	1C	*
									FIST.SURV.	0051 0210-0300		3S	
		107441		1125 N VISTA, AVE.		LOS ANGELES		1900	PROT.REVW	HRI060211P	11/01/96	6Z	
		107021		979 N VISTA ST		LOS ANGELES		1922	HIST.RES	DOE-19 91 0170 2001	11/11/91	6Y	
									CHAC.REVW.	HRI0108310	11/11/91	5Y	
		015081	19 173511	411 N WATSON ST		LOS ANGELES	U		PROJ.REVW.	HRI9901130	12/29/99	5Y	
		034 16	19 170119	515 N WATSON ST		LOS ANGELES	P	1955	HIST.SURV.	0051 15-7-0720		7H	
		034117	19 170120	511 N WATSON ST		LOS ANGELES	P	1947	HIST SURV	0051 1510 0710		5S2	
		034113	19-170140	331 N WATSON ST		LOS ANGELES	P	1937	HIST SURV	0051 1470-0300		5S2	
		034115	19 170141	445 N WATSON ST		LOS ANGELES	P	1941	HIST SURV.	0051-1510 0300		5S2	
		034107	19 170131	811 N WATSON ST		LOS ANGELES	P	1924	HIST.SURV.	0051 1511 0300		5S2	
		021121	19 170141	100 N WALGROVE ST		LOS ANGELES	P	1911	HIST.SURV	0051-1511 0300		5S2	
		021122	19 170131	1126 N WALGROVE ST		LOS ANGELES	P	1911	HIST.SURV.	0051 1511 0300		5S2	
		121121	19-170134	1945 N WALGROVE ST		LOS ANGELES	P	1913	HIST.SURV.	0051-1511 0300		5S2	
		121121	19 170110	2451 N WATSON ST		LOS ANGELES	P	1912	HIST.SURV	0051-1515-0300		5S2	
		764559	19 173450	41 N WESTERN AVE	GALAXY APARTMENTS/SAN MARCOS HOTEL	LOS ANGELES	P	1925	PROJ REVW	CHA9510017Y	10/12/06	9J	

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PROPERTY NUMBER	NATIONAL REGISTER #	STREET ADDRESS	NAME	CITY NAME	ZIP	YR BLT	CHP CODE	REG REFERENCE NUMBER	STAT DATE	KEY	CNTY
014001	77-373453	401 W ALESSIO AVE	SECURITY PACIFIC NATIONAL BANK	LOS ANGELES	90	1923	HIST	REG	DOE LP 86 0043 0010	04/11/86	221	D
							PROJ	REVW	LMTN8403017 F	09/11/85	221	C
055573	77-373457	1100 W ALESSIO AVE		LOS ANGELES	90	1949	HIST	SURV	0255 4854-0001	06/01/87	6A	
055582	77-373457	1100 W ALESSIO AVE		LOS ANGELES	90	1949	HIST	SURV	0255 4855-0001	06/01/87	6J	
013667	77-373453	1101 W ALESSIO AVE	SECURITY PACIFIC NATIONAL BANK	LOS ANGELES	90	1923	HIST	ARC.	DOE 12-00-9113 #771	03/11/97	3A3	C
							PROJ	REVW	LMTN8403017 F	04/11/97	3A3	C
021530	76-167377	1521 W ALLESSIO AVE.	BINGER CHK FOUNDRY	LOS ANGELES	90	1921	HIST	SURV	0703 0515 000.		4A3	
109142	77-174096	1545 W ALESSIO AVE		LOS ANGELES	90	1927	HIST	REG	DOE-12 93-0125 7.00	12/08/95	6Y	
							PROJ	REVW.	LMTN9413003	02/09/95	6Y	
110263		1750 W ALESSIO AVE		LOS ANGELES	90	1916	HIST	REG	DOE-12-93-0131 0700	02/07/96	6J	
							PROJ	REVW	LMTN9413003	12/07/96	6J	
110442	77-174987	1550 W ALESSIO AVE		LOS ANGELES	90	1928	HIST	ARC.	DOE 12 95 0124-0000	03/30/95	6Z	
							PROJ	REVW	LMTN9413003A	03/04/95	6Y	
098202	77-173794	146 N ALESSIO AVE		LOS ANGELES	90	1919	HIST	REG	DOE LP 94 0124 0000	07/01/94	6Y	
							PROJ	REVW	LMTN9403003	07/01/94	6Y	
090713	76-174-192	1771 W ALESSIO AVE		LOS ANGELES	90	1921	TAX.	CRED	517 6-15-1981		6Y	
							PROJ	REVW	LMTN9403003A	03/03/94	6Y	
024034	77-173197	410 W ALESSIO AVE		LOS ANGELES	90	1910	HIST	SURV	0255-1545-0001		4B2	
024037	77-173197	501 W ALESSIO AVE		LOS ANGELES	90	1922	HIST	SURV	0255-1540-0001		4B2	
110410		1101 W ALESSIO AVE		LOS ANGELES	90	1916	HIST	ARC.	DOE 12-95-0124 0.00	03/13/96	6J	
							PROJ	REVW	LMTN9403003	02/13/95	6J	
110410		124 W ALESSIO AVE		LOS ANGELES	90	1926	HIST	REG	DOE 12 91 0145 1200	08/29/95	6J	
							PROJ	REVW	LMTN9403003	03/13/95	6J	
104549	77-173796	1154 N ALESSIO AVE	CHILDCARE - HIGH TECH/HP EXTENSION	LOS ANGELES	90	1920	HIST	REG	DOE-12 95-0329 1700	07/16/99	6Y	
							PROJ	REVW	2NNA-9901401	07/11/99	6J	
							HIST	REG	DOE 12 91 0145 1200	09/19/97	1A4	A
							PROJ	REVW	LMTN9403003	06/19/97	1A3	A
021034	77-174956	417 N ALLESSIO AVE	EGYPTIAN REVIVAL APARTMENTS	LOS ANGELES	90	1928	HIST	SURV	0255 2414-0001		4B	
023434	77-174961	1201 N ALLESSIO AVE		LOS ANGELES	90	1919	HIST	SURV	0255 2410-0019		4AL	
011017	77-173944	1901 N ALLESSIO AVE	HOTEL ROOSEVELT, ALLESSIO	LOS ANGELES	90	1926	HIST	SURV	0255 1501 0027		6B2	
021021	77-173962	1044 N ALLESSIO AVE		LOS ANGELES	90	1925	HIST	SURV	0255-0502 0001		4B2	
022023	77-173950	1515 N ALLESSIO AVE	HOLLYWOOD CITIZEN NEWS BUILDING	LOS ANGELES	90	1930	HIST	SURV	0255-1527-0001		4A	
013024	77-173951	1615 N ALLESSIO AVE	U. S. POST OFFICE, HOLLYWOOD STATI	LOS ANGELES	90	1935	SIGN	ARC.	REG-05300170-7000	01/11/95	4C	
							HIST	SURV	0255-0870 0001	01/11/95	4A	
023013	77-173953	1733 N ALLESSIO AVE	KNOX CRAIG HOTEL, LOVEL KNOX CRAIG	LOS ANGELES	90	1925	HIST	SURV	0255-0503-0003		4A	
110407		1104 N ALLESSIO AVE		LOS ANGELES	90	1939	SIGN	ARC.	DOE 12 96-0033-0000	07/11/96	6C	
							PROJ	REVW.	LMTN9403003	12/11/96	6C	
023014	77-173961	1947 N ALLESSIO AVE		LOS ANGELES	90	1929	HIST	SURV	0255 0504-0001		4A	
023015	77-173961	1801 N ALLESSIO AVE		LOS ANGELES	90	1923	HIST	SURV	0255 1518 0001		4C	
055.03	77-177196	1435 N ALLESSIO AVE	RESIDENCE	LOS ANGELES	90		PROJ	REVW	LMTN9403003	10/01/97	6Y	
021023	77-173962	1-00 N ALLESSIO PL		LOS ANGELES	90	2011	HIST	SURV	0255-0504 0001		4A	
021023	77-173977	1506 N ALLESSIO PL	TYNDALL APTS. AT LOS ANGELES HARBOR	LOS ANGELES	90	1923	HIST	SURV	0255-0505 0001		4A	
021.01	77-173962	417 N ALMANSOR BLVD		LOS ANGELES	90	1923	FIRE	REG.	209-17 94-0168 0001	07/01/94	6Y	
							PROJ	REVW	LMTN9403003	07/01/94	6Y	
107713	76-175135	1144 N ALMANSOR BLVD		LOS ANGELES	90	1921	SIGN	REVW.	LMTN9403003	03/31/95	6Y	
14.911		1105 PROPT AVE		LOS ANGELES	90	1926	HIST	REG.	209-19-03 1167 0001	12/13/95	6E	
111 37		1701 CAROT AVE		LOS ANGELES	90	1905	PROJ	REVW.	LMTN9403003	01/11/96	6Y	
							HIST	REG.	DOE 12 91-0104-0001	10/03/92	6Y	
021.11	77-173293	2110 MACRT ST	LA PORTLA CINEMA APARTMENTS HOTEL	LOS ANGELES	90	1925	PROJ	REVW	LMTN9403003	04/03/92	6Z	
	77-160777						HIST	REG	DOE 87-001013 0176	05/19/87	1B	AC
098.02	77-173193	10115 NORD ST		LOS ANGELES	90	1922	PROJ	REVW.	LMTN9403003	08/10/94	6Y	
							HIST	REG.	NRT 613	09/19/94	6Y	
133201		11941 ORCIDORAL BLVD		LOS ANGELES	90	1949	HIST	REG.	DOE 12-00-9048 0119	09/19/90	6Y	
							PROJ	REVW.	LMTN9403003	09/19/90	6Y	
774141	77-174-20	5033 VANALDO ST		LOS ANGELES	90	1911	PROJ	REVW	LMTN9411136	11/26/94	6Z	

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PROPERTY NUMBER	DATABASE #	STREET ADDRESS	NAME	CITY NAME	??	OWN	YR C	CAT CODE	STATUS REFERENCE NUMBER	HIST DATE	BOX	FOLDER
	056480	19-175011	3140 GRAPES ST	HOLLYWOOD	LOS ANGELES		H		PROJ REVW	HLD960124A2	05/27/96	254	C
									HIST REG	DOE 12 86 0090-0070	08/03/94	153	C
									PROJ REVW	HLD961-250	04/01/96	254	C
	027445	19-175257	3140 GRAPES ST	HOLLYWOOD	LOS ANGELES	W	1921	HIST.RES.	NRR-91001181, 0011	10/27/91	10	C
		19-154661						HIST.SURV	HCRS 3450 1990		78	
								HIST REG.	DOE-10-50-0001 0003	10/01/90	252	C
								PROJ.REVW	HLD960-050	10/02/96	254	C
	022127	19 154064	3141 GRAPES ST	ALHAMBRA-LI APARTMENTS	LOS ANGELES	P	1915	HIST REG	NPS 91001020-0419	09/27/91	LD	AAL
		19 154011										
	021127	19 [illegible]	2145 GLASS ST		LOS ANGELES	S	1920	HIST REG	DOE-91001.257 0001	10/31/91	HA	
	021111	19 154715	115 GLASS ST		LOS ANGELES	S	1925	HIST.RES	NPS 91001257-0111	09/27/91	HA	
	027118	19 [illegible]	1910 GLASS ST	COLUMBIA HOTEL	LOS ANGELES	S	1891	HIST REG	NPS-91001.257-0122	09/27/91	LD	I
		19 151471										
	027136	19 154778	2345 GLASS ST	FREEMAN G VEEH HOUSE	LOS ANGELES	S	1892	HIST.RES.	NPS-91001257 0003	09/27/91	LD	L
		19 154760										
	027138	19-154759	2317 GLASS ST	JAMES AYRES HOUSE	LOS ANGELES	S	1893	HIST.RES.	NPS-91001257-0004	09/27/91	LD	C
		19-154463										
	021110	19 [illegible]	2323 GLASS ST	EDITH C BOLTMAN HOUSE	LOS ANGELES	S	1909	HIST REG	NPS 91001257-0005	11/14/91	LD	C
		19 154171						HIST ARCH.	DOE 12-98 0001-0013	09/27/91	LD	C
	020315	19 [illegible]	2161 GLASS ST	WACHTEL / SEBASTA / JOSHUA HOUSE	LOS ANGELES	S		HIST SURV	DOE 12-98 0001-0013	09/27/91	LD	
		19 [illegible]						PROJ REVW	HLD960124A2	12/02/96	254	
		19 154491						HIST SURV	HCRS 0001 1990		78	
	023011	19 [illegible]	1911 GLENDALE BLVD		LOS ANGELES	L	1920	HIST REG	DOE 12-98 0001-0013	09/27/91	LD	
								PROJ REVW	HLD960124A2	12/02/96	254	
								HIST SURV	HCRS 0001 1990		78	
→	1220.0	19 151017	1701 GOTHARD ST	HOLLYWOOD SIGN	LOS ANGELES	P	1923	HIST.RES.	DOE 12 98 0001 0003	12/03/98	281	A2
								PROJ.REVW	HLD961250	12/01/98	282	A2
								HIST REG	DOE 12-92 0001 0007	11/27/91	252	A2
								PROJ REVW	HLD911196:	11/27/91	253	A2
								ARCH.INVEN.	0001-0000 0000		78	
	021.0	19 154019	1911 GLENDALE BLVD	The MANSION	LOS ANGELES	P	1921	HIST REG.	DOE 12 98-0004-0005	12/12/98	62	
								PROJ.REVW	HLD961250	12/01/98	62	
								HIST.SURV	0001 0000 1000		562	
	117020		1510 FOREMAN BLVD		LOS ANGELES	P		HIST.INFO.	0001-19 98 1265 0010	12/03/98	62	
								PROJ.REVW.	HLD961 252	12/03/98	62	
	1.5176		2119 GOTH AVE		LOS ANGELES	S	1905	HIST.ARCH.	0001-19 98 0260 0011	05/11/98	62	
								PROJ.REVW.	HLD980-052	05/11/98	62	
	024117	19 1-0162	2120 GOTH AVE		LOS ANGELES	S	1913	HIST.SURV.	0001-1478-5006		562	
	026.10	9-1-0770	4310 GEA VIEW LANE		LOS ANGELES	S	1924	HIST.SURV.	0001 2170 0001		78	
	026.11	19 [illegible]	4363 GEA VIEW LANE		LOS ANGELES	S	1910	HIST SURV.	0001 2170 0001		78	
	024112	19 [illegible]	1626 AFR VIEW LANE	WEST/DOE-SHAPE BOUNDARY	LOS ANGELES	P	1924	HIST.INFO	0001 2180 0000		78	
	024111	19 [illegible]	4260 GRA VIEW TERR		LOS ANGELES	P	1901	HIST.INFO	0001 2181 0000		78	
	024114	19 [illegible]	4261 GRA VIEW AVE		LOS ANGELES	P	1923	HIST.SURV.	0001-2182 1000		78	
	1212.5	19 154512	181 GRAYDON WAY	Yamashiro BOOKOL	LOS ANGELES	P	1924	HIST SURV.	0001 0149 1100		78	
	166.00		1040 GELDY AVE	[illegible] V VOLE STUDIO	LOS ANGELES	M	1940	HIST REG	DOE 12 94 0001 0101	12/15/94	282	T
								PROJ.REVW	PTRA951.65A	12/15/94	282	T
	110019	19-154727	901 HA AVE	4000 BLOCK YALVA AVENUE	LOS ANGELES	P	1913	HIST.SURV.	0001-0412 0109		65	
⊣	101511	19 154701	6741 GELMA AVE	SELMA-LABRIEA DISTRICT	LOS ANGELES	P	1919	HIST.REG.	DOE-19 91 0147 11 2	11/01/94	253	
								PROJ.REVW.	HD7960202	11/01/94	253	
⊣	001731	19 147035	6966 SELMA AVE	SELMA-LABRIEA DISTRICT	LOS ANGELES	P	1917	HIST REG.	DOE 12-96 7447-001,	07/31/96	201	
								PROJ REVW.	HD7960202	07/31/96	202	
								HIST SURV.	0001-0003 0004		78	
⊣	001728	19 147031	7047 SELMA AVE	SELMA-LABRIEA DISTRICT	LOS ANGELES	P	1920	HIST REG	DOE 12-96 7447 056	07/31/96	202	
								PROJ REVW	HD7960202	07/31/96	202	
								HIST SURV	0001 0001 0001		78	
⊣	001718	19 147017	6067 SELMA AVE	SELMA-LABRIEA DISTRICT	LOS ANGELES	P	1911	HIST.REG.	DOE-19 94 0001 0107	07/31/96	202	

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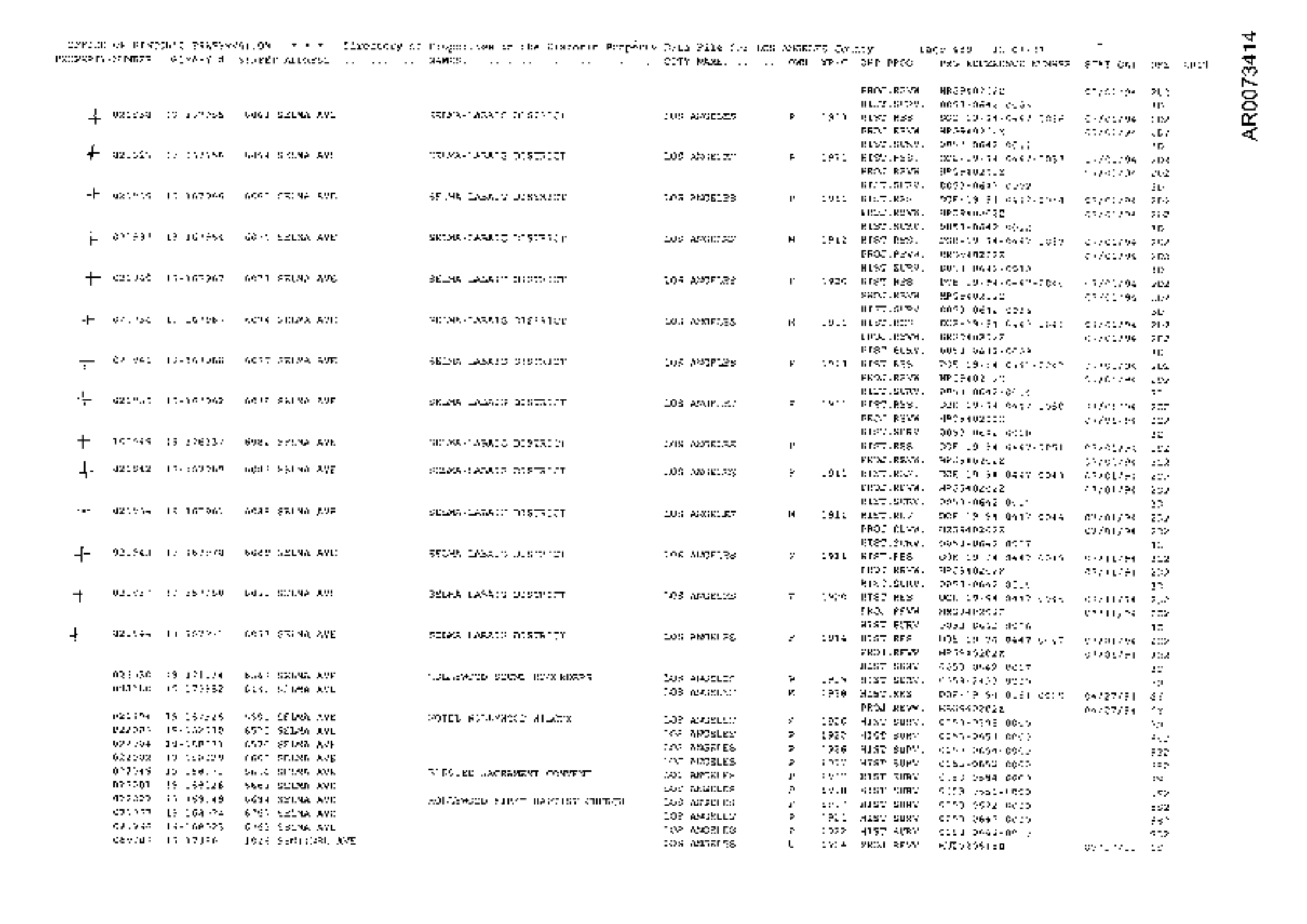

NR/SHL/OTH	NUMBER	DATE/ACTION	STREET & NUMBER	NAME	CITY	ZIP	CAT	OWNER	RES/PROP	REF NUMBER	STAT DATE	KEY	CERT
	970306	10 10/10/97	1487 SYCAMORE AVE		LOS ANGELES	90028						176	
	970307	10 10/07/97	115 SYCAMORE AVE		LOS ANGELES	90036						176	
	970308	10 10/07/97	1107 SYCAMORE AVE		LOS ANGELES	90036						176	
	921110	10 10/01/97	1615 SYCAMORE AVE		LOS ANGELES	90028						176	
	921111	10 10/01/97	1621 SYCAMORE AVE		LOS ANGELES	90028						176	
	921112	10 10/01/97	1641 SYCAMORE AVE		LOS ANGELES	90028						176	
	970113	10 10/07/97	1616 SYCAMORE AVE		LOS ANGELES	90028						176	
	970114	10 10/07/97	1636 SYCAMORE AVE		LOS ANGELES	90028						176	
	970137	10 10/10/97	1631 N HOPE AVE		LOS ANGELES	90042						176	
	970115		810 SOUTH TU	JEWISH COMMERCIAL YOUNG WOMENS CHR	LOS ANGELES								
	921217	10 10/10/97	1631 SOUTH ST		LOS ANTELES	90015						176	
	921218	10 10/10/97	1634 S OLIVE ST	CORDE ADAPTMENTS	LOS ANGELES	90015						176	
	970219	10 10/10/97	1621 S HILL ST		LOS ANGELES	90015						176	
	970110	10 10/10/97	1615 SOUTH ST		LOS ANGELES	90015						176	
	97011	10 10/10/97	1610 THIRD AVE	PIKE SLAUSON #61	LOS ANGELES	90062						176	
	921111	10 10/10/97	SUNSET BLVD	SUNSET JUNCTION	LOS ANGELES	90029						176	
	970113		13016 SHERMAN WAY		LOS ANGELES	91605							
	970114		21100 SHERMAN WY		LOS ANGELES	91303							
	980100	10 10/10/97	21122 SHERMAN WY		LOS ANGELES	91356						176	
	921117	10 10/10/97	21120 SHERMAN WY		LOS ANGELES	91356						176	
	970118		9110 SPRING MOUNTAIN RD		LAS VEGAS	89102							
	970119		2017 SYCAMORE ST		LOS ANGELES	90018							
	970120	10 10/10/97	2200 SYCAMORE ST	CHURCH OF THE SACRED HEART	LOS ANGELES	90018						176	
		10 10/10/97											
	970121	10 10/10/97	2210 SYCAMORE ST	SACRED HEART ROTTERY	LOS ANGELES	90018						176	
		10 10/10/97											
	970122	10 10/10/97	2210 SYCAMORE ST	LOS ANGELES CHURCH OF THE BLESSED S	LOS ANGELES	90018						176	
	970123		21000A PONTOA AVE	SICORA CHURCH ROMAN ATHOLIC DIOC	LOS ANGELES	90018						176	
	970124		9 10 SYCAMORE PONTOA AVE		LOS ANGELES	90018						176	
	970125		1210 SICORA MONTOA TER	CONGREGATION - SICORA DUNCIA AMERIC	LOS ANGELES	90006						176	
	970126		2111 CAROLA ST		LOS ANTELES	90006						176	
	970127	10 10/10/97	9107 SICORA VISTA AVE		LOS ANGELES	90029						176	
	970128		2016 SICORA LAKE BLVD		LOS ANGELES	90026						176	
	970129		2200 SICORA LAKE BLVD	PICARDS AND SONS MONTOA VOL REGULAR	LOS ANGELES	90026						176	
	980130	10 10/10/97	1910 SICORAKAKE BLVD	SICORALAKE REHABILITATION CENTER / CON	LOS ANGELES	90026						176	
	970131	10 10/10/97	4000 ASHLAND AVE	METCALFE	LOS ANGELES	90008						176	

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PROPERTY NUMBER	PRIMARY #	STREET ADDRESS	NAMES	CITY NAME	OWN	YR C	OHP PROG.	PRG REFERENCE NUMBER	STAT DAT	NRS	CRIT
[illegible]	19 1?4970	4532 SUNSET BLVD	LAS PALMAS CENTER	LOS ANGELES	P	19?5	HIST.RES	DOE-19-97-0??? [illegible]	??/2?/95	6Y	
							PROJ REVW.	HUD?950?? [illegible]	??/??/95	6Y	
021?27	19 16????	5115 SUNSET BLVD		LOS ANGELES	P	1930	HIST SURV	0050-0??4-0???		7??	
0219??	19 167902	5121 SUNSET BLVD		LOS ANGELES	P	1909	HIST SURV.	0050-0??2-0???		5??	
021911	19 167???	5127 SUNSET BLVD		LOS ANGELES	P	1921	HIST SURV	0050-0??? 0000		5??	
0219??	19 16????	5145 SUNSET BLVD		LOS ANGELES	P	[illegible]	HIST SURV	0050-0??? 0000		5??	
0219??	19 16?9??	5211 SUNSET BLVD		LOS ANGELES	P	[illegible]	HIST SURV	0050-0??? 0000		5??	
0?1021	19 16?9??	5212 SUNSET BLVD		LOS ANGELES	P	1952	HIST.SURV	0050 0003 0000		5??	
021???	19 16?002	5600 SUNSET BLVD	HOLLYWOOD MOVIE ARCADE	LOS ANGELES	P	1921	HIST.SURV.	0051-0001 0000		5S2	
021?36	19 1?????	5701 SUNSET BLVD		LOS ANGELES	P	1936	HIST.SURV.	0051-0002-0000		1S	
130620		5800 SUNSET BLVD	EXECUTIVE OFFICE BUILDING/OLD WARN	LOS ANGELES	P	1920	HIST.BLD.	NPS-0?00??-0002	??/??/??	1S	A
							NAT REG	19 ????	0?/??/??		A
0??11?	19 16?162	5858 SUNSET BLVD	WARNER BROTHERS WEST COAST STUDIOS	LOS ANGELES	P	1920	TAX CERT	5??.? 19-0049	01/2?/91	1S	
							HIST SURV.	0051-0022-0000		1S	
0??126	19 1?1109	5901 SUNSET BLVD	RADIATA BUILDINGS & GARAGE	LOS ANGELES	P	0	TAX CERT	5?? 9 19-0107	0?/??/90	6X	
021523	19 14?5??	5929 SUNSET BLVD		LOS ANGELES	P	1924	HIST.SURV.	0051-0??? 0000		5S3	
021?24	19 127???	6000 SUNSET BLVD	TOWER ... [illegible]	LOS ANGELES	P	1925	HIST.SURV	0051-0??? 0000		5S	
021507	19 1?5510	6001 SUNSET BLVD		LOS ANGELES	P	1922	HIST.SURV.	0051-0410 0001		5D2	
021506	19 127540	6007 SUNSET BLVD		LOS ANGELES	P	1949	HIST.SURV.	0051-0410-0000		5S2	
021110	19 1?1548	6011 SUNSET BLVD		LOS ANGELES	P	1921	HIST SURV.	0051 0411-0000		5S3	
021127	19 127754	6041 SUNSET BLVD		LOS ANGELES	P	1925	HIST.SURV	0051-0411 0000		7R	
021506	19 1?7751	6121 SUNSET BLVD	COLUMBIA SQUARE, CBS, KNXT	LOS ANGELES	P	1937	HIST.SURV.	0051-0440 0000		5?	
022152	19 156081	6215 SUNSET BLVD	HOLLYWOOD PALLADIUM	LOS ANGELES	P	1940	HIST SURV.	0051-0470-0000		1S	
022150	19 158091	6230 SUNSET BLVD	EARL CARROLL THEATRE, AQUARIUS THE	LOS ANGELES	P	1938	HIST.SURV	0051 0495 0000		5S3	
0220??	19 158042	6360 SUNSET BLVD	SUNSET VINE TOWER	LOS ANGELES	P	1962	HIST SURV	0051 0594 0000		5S3	
022014	19 151081	6360 SUNSET BLVD	PACIFIC CINERAMA	LOS ANGELES	P	1963	HIST.SURV.	0051-0595 0000		5S3	
022051	19 156001	6520 SUNSET BLVD	HOLLYWOOD CHAMBER OF COMMERCE, SUN	LOS ANGELES	P	1924	HIST.SURV.	0051-0592-0000		7R	
02206?	19 15507?	6525 SUNSET BLVD	HOLLYWOOD ATHLETIC CLUB, BERKELEY	LOS ANGELES	P	1923	HIST SURV	0051 0627 0000		1S	
022052	19 1560?9	6528 SUNSET BLVD		LOS ANGELES	P	1929	HIST.SURV	0051 0631 0000		7L	
0220?8	19 168015	6540 SUNSET BLVD	WESTERN RECORDS	LOS ANGELES	P	1921	HIST.SURV.	0051 0632 0000		5S3	
02207?	19 15601?	6599 SUNSET BLVD		LOS ANGELES	P	1925	HIST.SURV.	0051-0490-0000		7R	
022070	19 155037	6601 SUNSET BLVD		LOS ANGELES	P	1925	HIST.SURV.	0051 0490-0000		7R	
022047	19 155074	6624 SUNSET BLVD	ED ADAMS MEDICAL CENTER	LOS ANGELES	P	1921	HIST SURV.	0051-0490 0000		5S2	
022015	19 155071	6630 SUNSET BLVD		LOS ANGELES	P	1927	HIST.SURV.	0051-0497-0000		7R	
0220?2	19 1550?1	6641 SUNSET BLVD	HUBBARD ... SCHOOL [illegible]	LOS ANGELES	P	1925	HIST SURV.	0051-0052 0000		5S	
022144	19 1550?1	6657 SUNSET BLVD	HUBBARD ... [illegible]	LOS ANGELES	P	1927	HIST SURV.	0051 0051-0000		5S	
021228	19 120071	6671 SUNSET BLVD	CROSSROADS OF THE WORLD	LOS ANGELES	P	1936	HIST.RES	NPS-800?0?? 0000	0?/??/80	1S	
							HIST.SURV	0051 0917 0000	0?/??/80	1S	
							HIST.SURV	0051-0012 0000		7R	
022142	19 155067	6683 SUNSET BLVD		LOS ANGELES	P	1923	HIST.SURV.	0051 0011-0000		5S2	
022111	19 158068	6715 SUNSET BLVD	HOLLYWOOD REPORTER	LOS ANGELES	P	1936	HIST SURV.	0051 0011 0000		5S	
021140	19 15006?	6721 SUNSET BLVD		LOS ANGELES	P	1925	HIST SURV	0051 0070 0000		5S2	
022139	19 156069	6902 SUNSET BLVD		LOS ANGELES	P	1926	HIST.SURV	0051-0615 0000		5S2	
02?21R	19 156061	7?27 SUNSET BLVD	[illegible] SCHOOL	LOS ANGELES	P	1915	HIST.SURV.	0051-0017 0000		5S3	
022119	19 155561	8171 SUNSET BLVD	TONY ROMA'S	LOS ANGELES	P	1957	HIST.SURV.	0051 0027 0000		7R	
							HIST SURV.	0051 0197 0000		7R	
021511	19 1?6087	8221 SUNSET BLVD	CHATEAU MARMONT	LOS ANGELES	P	1929	HIST SURV	0051 0101-0000		1S	
026001	19 146984	9641 SUNSET BLVD	BEVERLY HILLS HOTEL	LOS ANGELES	P	1912	HIST.RES	DOE-19-01-0280 0000	1?/??/01	2S2	AC
							PROJ.REVW	FCC011??1??	1?/??/01	2S2	AC
							HIST.SURV	0051 0158 0000		5S	
							HIST.SURV.	0051 0154 0000		5S	
0??822	19 1?5?1?	11513 SUNSET BLVD	MARYMOUNT HIGH SCHOOL	LOS ANGELES	P	1932	HIST.RES.	DOE-19-94-0154 0000	??/04/94	2S2	C
							PROJ.REVW.	HUD?4?0?22	??/04/94	2S2	C
026130	19 173063	11725 SUNSET BLVD	EASTERN STAR HOME	LOS ANGELES	P		HIST.RES.	DOE-19-89-0??? 0000	??/??/89	2S2	?
							PROJ REVW	FEMA8?0?24R	??/??/89	2S2	?
021?37	19 167?00	14253 SUNSET BLVD	BUILDINGS, WELL, ... / ST ... [illegible]	LOS ANGELES	P	1926	HIST RES	NPS-?1000149-0000	??/??/??	1S	

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PROPERTY NUMBER	PRIMARY #	STREET ADDRESS	NAMES	CITY NAME	OWN	YR-C	OHP-PROG	PRG REFERENCE NUMBER	STAT DAT	NRS	CRIT
000010	19 175158	10444 TAMARACK AVE		LOS ANGELES	P	1921	PROJ.REVW.	HUD930601X	07/20/93	6Y	
021102	19-169246	TAMARIND AVE	1100 1400 BLOCK OF TAMARIND AVE	LOS ANGELES	P	1905	HIST.SURV.	0051 0719 9999		5S2	
021101	19 169229	1111 TAMARIND AVE		LOS ANGELES	P	1923	HIST.SURV.	0051 0719 0101		5S2	
021103	19 169222	1114 TAMARIND AVE		LOS ANGELES	P	1918	HIST.SURV.	0051 0719-0102		5S2	
021102	19-169226	1124 TAMARIND AVE		LOS ANGELES	P	1923	HIST.SURV.	0051 0719 0103		5S2	
021161	19 169225	1125 TAMARIND AVE		LOS ANGELES	P	1914	HIST.SURV.	0051 0719 0104		5S2	
021185	19 169229	1127 TAMARIND AVE		LOS ANGELES	P	1920	HIST.SURV.	0051 0719 0105		5S2	
021166	19 169219	1131 TAMARIND AVE		LOS ANGELES	P	1924	HIST.SURV.	0051 0719 0106		5S2	
021101	19 169221	1134 TAMARIND AVE		LOS ANGELES	P	1911	HIST.SURV.	0051 0719 0107		5S2	
021185	19 169212	1142 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0108		5S2	
021186	19 169212	1151 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051-0719-0109		5S2	
021141	19 169214	1154 TAMARIND AVE		LOS ANGELES	P	1920	HIST.SURV.	0051 0719-0110		5S2	
021191	19 169215	1202 TAMARIND AVE		LOS ANGELES	P	1915	HIST.SURV.	0051-0719-0111		5S2	
021152	19 159516	1201 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051-0719 0112		7N	
021193	19-169217	1204 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051-0719-0113		5S2	
021194	19 169218	1211 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0114		5S2	
021195	19 169219	1215 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719-0115		5S2	
021196	19 169220	1261 TAMARIND AVE		LOS ANGELES	P	1922	HIST.SURV.	0051 0719 0116		5S2	
021198	19 169213	1300 TAMARIND AVE		LOS ANGELES	P	1920	HIST.SURV.	0051 0719 0118		5S2	
021197	9 169221	11 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0117		5S2	
021200	9 169224	1316 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051-0719-0120		5S2	
021199	19 169225	1309 TAMARIND AVE		LOS ANGELES	P	922	HIST.SURV.	0051 0719 0119		5S2	
021201	19 169215	1317 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051-0719 0121		5S2	
021202	19 169226	1322 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0122		5S2	
021203	19 169227	1331 TAMARIND AVE		LOS ANGELES	P	1912	HIST.SURV.	0051-0719-0123		5S2	
021204	19 169228	1332 TAMARIND AVE		LOS ANGELES	P	1920	HIST.SURV.	0051-0719-0124		5S2	
021205	19 169229	1337 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0125		5S2	
021206	19 169215	1342 TAMARIND AVE		LOS ANGELES	P	1920	HIST.SURV.	0051 0719 0126		5S2	
021207	19 169231	1357 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051-0719 0127		5S2	
021208	19-169212	1405 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0128		5S2	
021209	19 169213	1412 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0129		5S2	
021210	19 169214	1411 TAMARIND AVE		LOS ANGELES	P	1912	HIST.SURV.	0051 0719 0130		5S2	
021211	19 169215	1415 TAMARIND AVE		LOS ANGELES	P	1915	HIST.SURV.	0051-0719 0131		5S2	
021212	19 169216	1421 TAMARIND AVE		LOS ANGELES	P	1920	HIST.SURV.	0051-0719-0132		5S2	
021213	19 169217	1428 TAMARIND AVE		LOS ANGELES	P	1914	HIST.SURV.	0051 0719-0133		5S2	
021214	19 169218	1431 TAMARIND AVE		LOS ANGELES	P	1912	HIST.SURV.	0051-0719-0134		5S2	
021215	19 169219	1437 TAMARIND AVE		LOS ANGELES	P	1907	HIST.SURV.	0051-0719-0135		5S2	
021216	19-169240	1438 TAMARIND AVE		LOS ANGELES	P	1911	HIST.SURV.	0051-0719-0136		5S2	
021217	19-169241	1441 TAMARIND AVE		LOS ANGELES	P	1904	HIST.SURV.	0051 0719 0137		5S2	
021219	9 169242	1444 TAMARIND AVE		LOS ANGELES	P	1921	HIST.SURV.	0051 0719 0138		5S2	
021219	19 169243	1446 TAMARIND AVE		LOS ANGELES	P	1912	HIST.SURV.	0051 0719 0139		5S2	
021220	19 169211	1453 TAMARIND AVE		LOS ANGELES	P	912	HIST.SURV.	0051-0719 0140		5S2	
021221	19-169715	1460 TAMARIND AVE		LOS ANGELES	P	1911	HIST.SURV.	0051-0719-0141		5S2	
004110	19 174674	1254 TAMARIND AVE		LOS ANGELES	P	1926	PROJ.REVW.	HUD910128L	03/19/94	6Y	
117158		2461 TAMPA AVE		LOS ANGELES		1969	HIST.RES.	DOE 19-91-0119-0007	03/21/77	6Y	
							PROJ.REVW.	TCN910920LA	07/31/91	6Y	
074173	19 174573	1815 TAMPICO AVE		LOS ANGELES	U	1914	PROJ.REVW.	COE910706F	07/01/91	6Y	
124775		4405 TAYLOR ST		LOS ANGELES	P	1914	HIST.RES.	DOE 19-01-0131 0159	04/30/01	6Y	
							PROJ.REVW.	FHWA010403K	04/30/01	6Y	
125507		5450 TEESDALE AVE		LOS ANGELES	P	1948	HIST.RES.	DOE 19 02-0443-0066	05/20/02	6Y	
							PROJ.REVW.	FEMA020604A	05/20/02	6Y	
125402		6561 TEESDALE AVE		LOS ANGELES	P	1940	HIST.RES.	DOE 19 02-0441 0040	01/28/02	6Y	
							PROJ.REVW.	FEMA020404S	03/20/02	6Y	
073898	19 176211	19435 TELFAIR AVE		LOS ANGELES	P	1966	HIST.RES.	DOE 19 94-0014-0000	12/20/94	6Y	
							PROJ.REVW.	FHWA940922B	12/20/94	6Y	
085501	19 173548	10551 TELLAIR AVE		LOS ANGELES	M	1994	HIST.RES.	DOE-19-94-0158-0000	12/27/94	6Y	

OFFICE OF HISTORIC PRESERVATION * * * Directory of Properties in the National Register Data File for Los Angeles County. Page 999 12/ 1/ 1

PROPERTY NUMBER	DATA KEY #	STREET ADDRESS	..	NAME	..	CITY,BORO	..	..	CAT	YR #	ARCH STYLE..	LOC RELEVANCE DATE/PA	STAT LOC	SYS	TRIT
790130	19-190550	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1996	WEST SURV	9999-9999-9999	04/01/93	13	A7
790131	19-179269	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST.SURV	0001-9999-9999	04/01/93	13	A7
790132	19-190469	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	194	WEST.SURV.	0001-9999-9999	04/01/93	13	A7
790133	19-190471	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST.SURV	0001-9999-9999	04/01/93	13	A7
790134	19-190464	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST.SURV	0001-9999-9999	04/01/93	13	A7
790135	19-190466	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790136	19-190467	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790137	19-190469	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790138	19-190467	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST.SURV	0001-9999-9999	04/01/93	13	A7
790139	19-190466	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790140	19-190465	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790141	19-190463	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790142	19-190462	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790143	19-190461	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790144	19-190460	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790146	19-190458	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790162	19-190442	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790173	19-190431	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790176	19-190428	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790177	19-190427	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790179	19-190425	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790181	19-190423	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790182	19-190422	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790183	19-190421	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790184	19-190420	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790185	19-190419	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790186	19-190418	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790187	19-190417	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790188	19-190416	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790189	19-190415	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790201	19-190403	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790204	19-190400	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790205	19-190399	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790206	19-190398	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790210	19-190394	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790222	19-190382	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790223	19-190381	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790239	19-190365	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
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790249	19-190355	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790250	19-190354	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790251	19-190353	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790252	19-190352	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790253	19-190351	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790254	19-190350	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790255	19-190349	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790256	19-190348	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790257	19-190347	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790258	19-190346	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790259	19-190345	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790260	19-190344	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790261	19-190343	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790262	19-190342	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790263	19-190341	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790264	19-190340	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790265	19-190339	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790266	19-190338	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790267	19-190337	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790268	19-190336	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790269	19-190335	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790270	19-190334	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790271	19-190333	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790272	19-190332	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790273	19-190331	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790274	19-190330	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790275	19-190329	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790276	19-190328	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790277	19-190327	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790278	19-190326	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790279	19-190325	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790280	19-190324	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790281	19-190323	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790282	19-190322	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790283	19-190321	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790284	19-190320	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790285	19-190319	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790286	19-190318	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790287	19-190317	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790288	19-190316	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790289	19-190315	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790290	19-190314	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790291	19-190313	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790292	19-190312	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790293	19-190311	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790294	19-190310	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790295	19-190309	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790296	19-190308	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790297	19-190307	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790298	19-190306	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790299	19-190305	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790300	19-190304	VILLAGE GREEN		BOUNDARY INCREASE		LOS ANGELES			P	1991	WEST SURV	0001-9999-9999	04/01/93	13	A7
790301	19-190303	VIL

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PROPERTY-LOCATION	PRIMARY #	STREET ADDRESS	MAKE	CITY NAME	USE	YR C	CHG ENGL	ENG REFERENCE NUMBER	STAT-DAT	BRD	TR T
							PROJ.REVW.	0000960501P	12/29/96	6C	
001387	19-187416	8731 NEDDFWOOD PL		LOS ANGELES	P	1921	SALT.DEED.	REV-02300119-0134	08/19/02	1D	AC
001386	19-187406	8736 NEDDGWOOD PL	DENNIS HOBERG/POTTER HOME HOME	LOS ANGELES	P	1922	SALT.DEED	NOR 02300119-0086	08/19/02	1D	AC
001681	19-187415	8731 N-DDLWOOD PL		LOS ANGELES	P	1921	NEST REV	NOR 02300119 0140	08/19/02	1D	AC
001685	19 187402	8738 NEDDLEWOOD PL	PAT CONNIHAN/ADRIENN BRIGHTLN/TYCHKR	LOS ANGELES	P	1923	NEST REV	NOR 02300119 0061	08/19/02	1D	AC
001691	19 187326	8742 NEDDLEWOOD PL		LOS ANGELES	P	1923	NEST.REV.	NOR-02300119 0103	08/19/02	1D	AC
001692	19 187406	8746 NEDDLEWOOD PL	M C FIELDS/MAY STERSEN HOME DENK	LOS ANGELES	P	1921	NEST.REV.	NOR-02300119 0130	08/19/02	1D	AC
001693	19-187407	8751 NEDDLEWOOD PL		LOS ANGELES	P	1923	NEST.REV.	NOR-02300119-0151	08/19/02	1D	AC
001697	19-187411	8754 NEDDLEWOOD PL	LLOYD NOLAN/HELEN IRVUBEL/B KEYES	LOS ANGELES	P	1929	NEST.REV.	NOR 02300119-0140	08/19/02	1D	AC
001698	19 187413	8755 NEDDLEWOOD PL		LOS ANGELES	P	1921	NEST.REV.	NOR-02300119-0137	08/19/02	1D	AC
001708	19 187414	8759 NEDDLEWOOD PL		LOS ANGELES	P	1926	NEST.REV.	NOR-02300119-0096	08/19/02	1D	AC
001.00	19 187416	8767 NEDDLEWOOD PL		LOS ANGELES	P	1926	NEST.REV.	NOR-02300119-0108	08/19/02	1D	AC
19		8981 NELLAIO AVE		LOS ANGELES		1934	PLAT.REV.	NOV 19 94-0302 0001	09/27/94	6C	
							PROT REVW	0007410361	09/27/94	6C	
20971	19-373319	3416 NELLINGTON RD		LOS ANGELES	U	1922	PROJ.REVW.	0000901130	12/26/90	6E	
21.13		4166 NEPTUNE CT RD		LOS ANGELES		1926	.191.REV.	DOE-19-92 0327 000.	10/12/92	6J	
19 375		10109 NEPTUNE ST	BOTTE ATHTOR XOOJONNY VOPTOLE CA	LOS ANGELES	P		PROJ.REVW	0000960501P	12/27/96	6C	
19							PROJ.REVW	FPVA0C1514D	09/27/96	6Z	
19		4217 NEST BLVD	DRIVE WEST 1900 / WEST POPLEVARI	LOS ANGELES	N	1911	PROJ.REVW	FPVA05102H9	12/31/95	2Y7	C
19 1721		1035 NEST BLVD		LOS ANGELES	P	1926	NEST.DEPO.	NOT 9715-0305		1E	
19 172		1036 NEST BLVD		LOS ANGELES	P	1926	NEST SUNV	NOT-9516 1001		1L	
		1101 NEST BLVD		LOS ANGELES	V	1911	PROJ REVW.	0000912000.	12/12/09	6E	
19 172176		1105 NEST BLVD	DOOR / SIDEIN	LOS ANGELES	P	1911	NEST.DEPO	0053 3117 0300		3E1	
19 172178		1111 NEST BLVD		LOS ANGELES	P	1911	NEST.SUBV	0071 9114- 009		7E	
19 172177		1121 NEST BLVD	HADDON & SILVER TRUSTEES.	LOS ANGELES	P	1926	NEST.REV.	DOE 19-92 1284-1001	11/21/92	2E2	"
							PROJ.REVW.	0000912000	11/21/92	2E2	"
							PLAT.SURV.	0051 9116-0300		2E	
19 1721		1129 NEST BLVD		LOS ANGELES	F	1915	NEST.PROV.	0033-9520 .90C		7E	
19 1721		1141 NEST BLVD		LOS ANGELES		1915	NEST.REV.	DOE 19 91 .107 0001	01/11/91	6L	
							PROC.REVW.	0000910111	03/11/91	6H	
19 197537		2025 NEST BLVD	DELUA SILVA TUSTA HOUSTON, TRUSTE	LOS ANGELES	M		NEST.REV.	DOE-19 94-0168 0001	03/28/96	6Y	
							PROC.REVW.	HH0940210X	12/18/96	6Y	
19 197537		2027 NEST BLVD		LOS ANGELES	P		PROT REVW.	HOU-950615A	04/21/95	7E	
19 ..598.		2031 NEST BLVD		LOS ANGELES	M		NEST.REV.	DOE-19 94 0189 0001	04/27/94	6Y	
							PROC.REVW.	0000940305	04/21/94	6Y	
		2979 WEST BLVD		LOS ANGELES	F		NEST.REV.	DOE 19 95-0297-0001	01/21/95	6H	
							PROC PROV.	NOT950910H	09/21/95	6J	
		3026 NEST BLVD		LOS ANGELES	P	1924	NEST REV	DOE 19 95 0214 0011	09/21/95	6J	
							PROC.REVW	NOT950921E	09/21/95	6J	
19 1798.4		3019 NEST. BLVD		LOS ANGELES	U	1929	NEST.REV	DOE-19-95 0228 0001	09/21/95	7H	
							PROC.REVW.	0000950910	09/21/95	7H	
							NEST.REV.	DOE-19-94 0198-1002	12/01/94	6Y	
							PROC REVW.	0000940210X	12/01/94	6Y	
19		3101 NEST BLVD		LOS ANGELES	U	1929	NEST REV	DOE 19 95-0210 1001	09/21/95	6J	
							PROC REVW	NOT950921E	09/21/95	6J	
							NEST.REV	DOE-19-95 0191 1001	07/01/94	6Y	
							PROC REVW.	0000910211	07/01/91	7Y	
19		3139 NEST BLVD		LOS ANGELES	P		NEST REV	DOE-19-91-0210-1700	09/21/95	7H	
							PROC.REVW.	NOV-950921R	10/21/95	6J	
19		3141 NEST BLVD		LOS ANGELES	U		NEST REV.	DOE 19 91-0211-1000	07/11/91	6H	
							PROC REVW	DOE-950921H	09/21/95	6J	
19		3143 NEST BLVD		LOS ANGELES	U		NEST.REV.	DOE 19-95 0211 1000	11/01/95	6J	
							PROC.REVW.	0000950921H	01/21/95	6J	
19		3535 NEST BLVD		LOS ANGELES	M		NEST REV	DOE 19-94 0192-0001	01/01/94	6Y	
							PROT.REVW	NHQ9410210X	11/01/94	6Y	

AR0073422

AR0073423

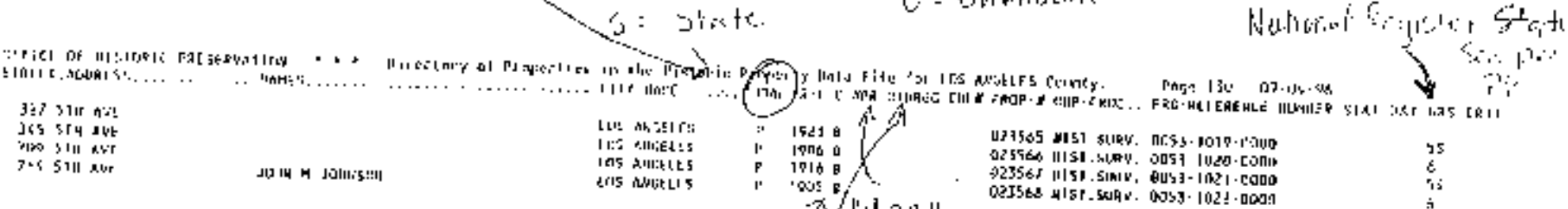
PROPERTY NUMBER	PRIMARY #	STREET ADDRESS	NAME	CITY NAME	OWN	YR C	ORG-PROG	PRS REFERENCE NUMBER	STAT DAT	NRS	CRIT
021563	19 169481	541 WESTMINSTER AVE		LOS ANGELES	P	1914	HIST.SURV.	2051-1124-0011		5S2	
021576	19 169492	546 WESTMINSTER AVE		LOS ANGELES	P	1914	HIST.SURV.	2051-1125-0170		5S2	
021721	19 169494	551 WESTMINSTER AVE		LOS ANGELES	P	1914	HIST.SURV.	2051-1125-0175		7R	
021578	19 169494	551 WESTMINSTER AVE	JAY F. HILLARD	LOS ANGELES	P	1914	HIST.SURV.	2051-1125-0170		7R	
021570	19 169495	564 WESTMINSTER AVE	DANIEL SIPPRELL	LOS ANGELES	P	1956	HIST.SURV.	2051-1125-0110		7R	
164025		1547 WESTMORELAND AVE		LOS ANGELES	P	1940	PROJ.REVW.	HUD971017I	11/10/97	6Y	
152539		1644 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0236	05/29/02	2D2	AC
151549		1645 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-[illegible]	05/29/02	2D2	AC
152541		1650 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0238	05/29/02	2D2	AC
152542		1651 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0239	05/29/02	2D2	AC
152543		1655 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0240	05/29/02	2D2	AC
152544		1656 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0241	05/29/02	2D2	AC
152545		1701 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0242	05/29/02	2D2	AC
152546		1702 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0243	05/29/02	2D2	AC
152547		1705 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0244	05/29/02	2D2	AC
152548		1711 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0245	05/29/02	6L	
152549		1717 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0246	05/29/02	2D2	AC
152550		1719 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0247	05/29/02	2D2	AC
152551		1720 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0248	05/29/02	2D2	AC
152552		1723 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0249	05/29/02	2D2	AC
152553		1724 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0250	05/29/02	2D2	AC
152554		1725 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0251	05/29/02	2D2	AC
152555		1730 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0252	05/29/02	2D2	AC
152556		1733 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0253	05/29/02	2D2	AC
152557		1736 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0254	05/29/02	2D2	AC
152558		1741 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0255	05/29/02	2D2	AC
152559		1742 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0256	05/29/02	2D2	AC
152560		1745 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0257	05/29/02	6L	
152561		1750 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0258	05/29/02	2D2	AC
152562		1804 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0259	05/29/02	6L	
152563		1809 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0260	05/29/02	2D2	AC
152564		1810 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0261	05/29/02	2D2	AC
152565		1811 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0262	05/29/02	2D2	AC
152566		1814 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0263	05/29/02	2D2	AC
152567		1820 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0264	05/29/02	2D2	AC
152568		1821 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0265	05/29/02	2D2	AC
152569		1825 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0266	05/29/02	2D2	AC
152570		1831 WESTMORELAND BLVD		LOS ANGELES			HIST.RES.	DOE-19-02-1201-0267	05/29/02	2D2	AC
112777	19-175246	2161 WESTVIEW ST		LOS ANGELES	P	1923	HIST.RES.	DOE-19-94-0454-0000	12/22/94	6Y	
							PROJ.REVW.	HUD940202[illegible]	12/22/94	6Y	
101381	19-175250	2611 WESTVIEW ST		LOS ANGELES	P	1922	PROJ.REVW.	HUD950207[illegible]	01/21/96	6Y	
164549		WESTWOOD BLVD	LOS ANGELES/VETERANS CAMPUS	LOS ANGELES			PROJ.REVW.	FEMA[illegible]	04/15/99	6Y	
043783	19 171770	1142 WESTWOOD BLVD	RALPHS GROCERY STORE	LOS ANGELES	P	1929	HIST.RES.	NPS-92000969-0000	07/16/92	1S	AC
							HIST.SURV.	0051-4716-0000	01/20/88	1S	AC
							NAT.REG.	19 0091	07/30/92	1S	AC
							TAX.CERT.	537-9-19-0023	08/21/90	2S1	
102751	19-171547	2201 WESTWOOD BLVD		LOS ANGELES	U	1927	HIST.RES.	DOE-19-94-0204-0000	07/08/94	6Y	
							PROJ.REVW.	DRE940207[illegible]	07/08/94	6Y	
148511		519 WHEELING WY		LOS ANGELES		1901	HIST.RES.	DOE-19-03-0188-0000	03/31/03	6U	
							PROJ.REVW.	HUD030103[illegible]	03/31/03	6U	
028118	19 164227	WHITE OAK AVE	THE DECKER BARRE	LOS ANGELES	P	1912	HIST.SURV.	0051-0215-0000		3S	
164727	19 177601	1630 WHITESIDE ST	RESIDENTIAL REHABILITATION	LOS ANGELES	P		PROJ.REVW.	HUD971116T	12/11/97	6Y	
157149		WHITLEY AVE	WHITLEY COURT / GARAGE	LOS ANGELES	P	1919	HIST.RES.	NPS-04000912-0005	11/29/04	1D	AC
022316	19 168394	1720 WHITLEY AVE	WHITLEY COURT / BUNGALOW COURT #1	LOS ANGELES	P	1919	HIST.RES.	NPS-04000912-0001	11/29/04	1D	AC

D - Special District

S : State.

U = Unknown

National Register Status Code



OFFICE OF HISTORIC PRESERVATION * * * Directory of Properties in the Historic Property Data File for LOS ANGELES County. Page 130 07-05-96

STREET ADDRESS	NAME	CITY	ZIP	C	NPR	DIIREG	DHP #	PROP #	COMP-CHOC	PRG-REFERENCE NUMBER	STAT DAT	GAS DATE
337 S1ST AVE		LOS ANGELES		P	1921	B				023565 MIST SURV.	0053-1019-0000	95
345 S14 AVE		LOS ANGELES		P	1906	B				023566 MISR.SURV.	0053 1020-0000	6
909 S1H AVE		LOS ANGELES		P	1916	B				023567 MISR.SURV.	0053-1021-0000	95
745 S1H Ave	JOHN M JOHNSON	LOS ANGELES		P	1905	B				023568 MISR.SURV.	0053-1022-0000	6

"NPR" : # of properties contributing to this resource.

"C" : Type of property

D = District

B = Building

C = Site.

S = Structure.

O = Object

"DIIREG" : Codes of legal designations other than National Register of Historic Preservation

H : HABS / HAER Record

N : National Historic Landmark.

S : State Historic Landmark.

C : CA Pt of Hist. Interest

P. State or Local Park.

L : Locally designated

O : Other type of Registration

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Old NR Status Code	DESCRIPTION of former NR Status Codes	NEW CHR STATUS CODE
4M2	May become elig. for NR as contrib. if restrd & more research on Dist.	7N1
4M3	May become elig. for NR as contrib. if restrd & context is expanded.	7N1
4M4	May become elig. NR as contrib. if restrd & approp. prop. type is defined	7N1
4M5	May become elig. NR as contrib. if restrd & prop. types are clarified.	7N1
4M6	May become elig. NR as contrib. if rstrd & Dist. eval. in diff. context.	7N1
4M7	May become elig. NR as contrib. if rstrd & integ.of Dist. is rstrd.	7N1
4M8	May become elig. NR as contrib. if rstrd & oth like Dist. are lost	7N
4R	May become a contributor to a listed/elig./appears. elig. dist.	7N
4S	May become elig. for NR as a separate property.	7N
4S*	May become elig. for NR as separate when it becomes old enough.	7N1
4S2	May become elig. for NR as separate with more research.	7N1
4S3	May become elig. for NR as separate if context info. is expanded.	7N1
4S4	May become elig. for NR as sep. if more approp. prop. type is def.	7N1
4S5	May become elig. for NR as sep. when regis requirements are clarified.	7N1
4S6	May become elig. for NR as separate when eval. in another context.	7N1
4S7	May become elig. for NR as sep. when its integrity is restored.	7N1
4S8	May become elig. for NR as sep. when other like prop. are lost.	7N
4X	May become elig. for NR as contrib. to District that has not been doc.	7N
5	Ineligible for the NR but still of local interest.	5D1, 5D2, 5S, 5S2
5B	Elig. for Loc List only - Both as separate property and as contrib.	5B
5B1	Eligible for Local Listing only - Both 5S1 and 5D1.	5B
5B2	Eligible for Local Listing only - Both 5S2 and 5D2.	5B
5B3	Not Elig. Loc List but for spec. consid. in Loc Plan - Both 5S3 and 5D3.	6L
5B4	Elig. for Loc List only - Both 5S1 and 5D2.	5B
5B5	Elig. for Loc List only - Both 5S1 and 5D3.	6L
5B6	Elig. for Loc List only - Both 5S2 and 5D1.	5B
5B7	Elig. for Loc List only - Both 5S2 and 5D2.	5B
5B8	Elig. for Loc List only - Both 5S3 and 5D1.	5B
5B9	Elig. for Loc List only - Both 5S3 and 5D2	5B
5D	Elig. for Local Listing as contributor only.	5D2
5D1	Elig. for Local Listing only-contributor to District listed or eligible under Local Ordinance	5D1
5D2	Elig. for Local Listing only-contributor to District listed or eligible under possible Local Ordinance	5D2
5D3	Not Elig. for Local Listing-contributor to District eligible for special consideration in Local Planning	6L
5N	Not Elig. for anything but Needs special consid. for other reasons.	6I
5S	Eligible for Local Listing only	5S2
5S1	Elig for Local Listing only-listed or elig separately under Local Ordinance	5S1
5S2	Eligible for Local Listing only- likely to become eligible under Local Ordinance	5S2
5S3	Not Elig for Local Listing is elig for special consid in Local Planning	6L
5X	Unknown	undefined 6T, 6U, 6X
6	Det. ineligible for National Register listing	6Y or 6Z
6DW	Removed from the Cal. Register by the SHRC	6C

AR0073425

California Historical Resource Status Codes

1 Properties listed in the National Register (NR) or the California Register (CR)

1D Contributor to a district or multiple resource property listed in NR by the Keeper. Listed in the CR.
1S Individual property listed in NR by the Keeper. Listed in the CR.

1CL Listed in the CR as a contributor to a district or multiple resource property by the SHRC.
1CS Listed in the CR as individual property by the SHRC.
1CT Automatically listed in the California Register – Includes State Historical Landmarks 770 and above and Points of Historical Interest nominated after December 1997 and recommended for listing by the SHRC.

2 Properties determined eligible for listing in the National Register (NR) or the California Register (CR)

2B Determined eligible for NR as an individual property and as a contributor to an eligible district in a federal regulatory process. Listed in the CR.
2D Contributor to a district determined eligible for NR by the Keeper. Listed in the CR
2D2 Contributor to a district determined eligible for NR by consensus through Section 106 process. Listed in the CR.
2D3 Contributor to a district determined eligible for NR by Part I Tax Certification. Listed in the CR.
2D4 Contributor to a district determined eligible for NR pursuant to Section 106 without review by SHPO. Listed in the CR.
2S Individual property determined eligible for NR by the Keeper. Listed in the CR.
2S2 Individual property determined eligible for NR by a consensus through Section 106 process. Listed in the CR.
2S3 Individual property determined eligible for NR by Part I Tax Certification. Listed in the CR.
2S4 Individual property determined eligible for NR pursuant to Section 106 without review by SHPO. Listed in the CR.

2CB Determined eligible for CR as an individual property and as a contributor to an eligible district by the SHRC.
2CD Contributor to a district determined eligible for listing in the CR by the SHRC.
2CS Individual property determined eligible for listing in the CR by the SHRC.

3 Appears eligible for National Register (NR) or California Register (CR) through Survey Evaluation

3B Appears eligible for NR both individually and as a contributor to a NR eligible district through survey evaluation.
3D Appears eligible for NR as a contributor to a NR eligible district through survey evaluation.
3S Appears eligible for NR as an individual property through survey evaluation.

3CB Appears eligible for CR both individually and as a contributor to a CR eligible district through a survey evaluation.
3CD Appears eligible for CR as a contributor to a CR eligible district through a survey evaluation.
3CS Appears eligible for CR as an individual property through survey evaluation.

4 Appears eligible for National Register (NR) or California Register (CR) through other evaluation

4CM Master List - State Owned Properties – PRC §5024.

5 Properties Recognized as Historically Significant by Local Government

5D1 Contributor to a district that is listed or designated locally.
5D2 Contributor to a district that is eligible for local listing or designation.
5D3 Appears to be a contributor to a district that appears eligible for local listing or designation through survey evaluation.

5S1 Individual property that is listed or designated locally.
5S2 Individual property that is eligible for local listing or designation.
5S3 Appears to be individually eligible for local listing or designation through survey evaluation.

5B Locally significant both individually (listed, eligible, or appears eligible) and as a contributor to a district that is locally listed, designated, determined eligible or appears eligible through survey evaluation.

6 Not Eligible for Listing or Designation as specified

6C Determined ineligible for or removed from California Register by SHRC.
6L Landmarks or Points of Interest found ineligible for designation by SHRC.
6L Determined ineligible for local listing or designation through local government review process; may warrant special consideration in local planning.
6T Determined ineligible for NR through Part I Tax Certification process.
6U Determined ineligible for NR pursuant to Section 106 without review by SHPO.
6W Removed from NR by the Keeper.
6X Determined ineligible for the NR by SHRC or Keeper.
6Y Determined ineligible for NR by consensus through Section 106 process – Not evaluated for CR or Local Listing.
6Z Found ineligible for NR, CR or Local designation through survey evaluation.

7 Not Evaluated for National Register (NR) or California Register (CR) or Needs Revaluation

7J Received by OHP for evaluation or action but not yet evaluated
7K Resubmitted to OHP for action but not reviewed
7L State Historical Landmarks 1-769 and Points of Historical Interest designated prior to January 1998 – Needs to be reevaluated using current standards
7M Submitted to OHP but not evaluated – referred to NPS
7N Needs to be reevaluated (formerly NP Status Code 4)
7N1 Needs to be reevaluated (formerly NP 5C4) – may become eligible for NR w/restoration or when meets other specific conditions
7R Identified in Reconnaissance Level Survey: Not evaluated.
7W Submitted to OHP for action - withdrawn

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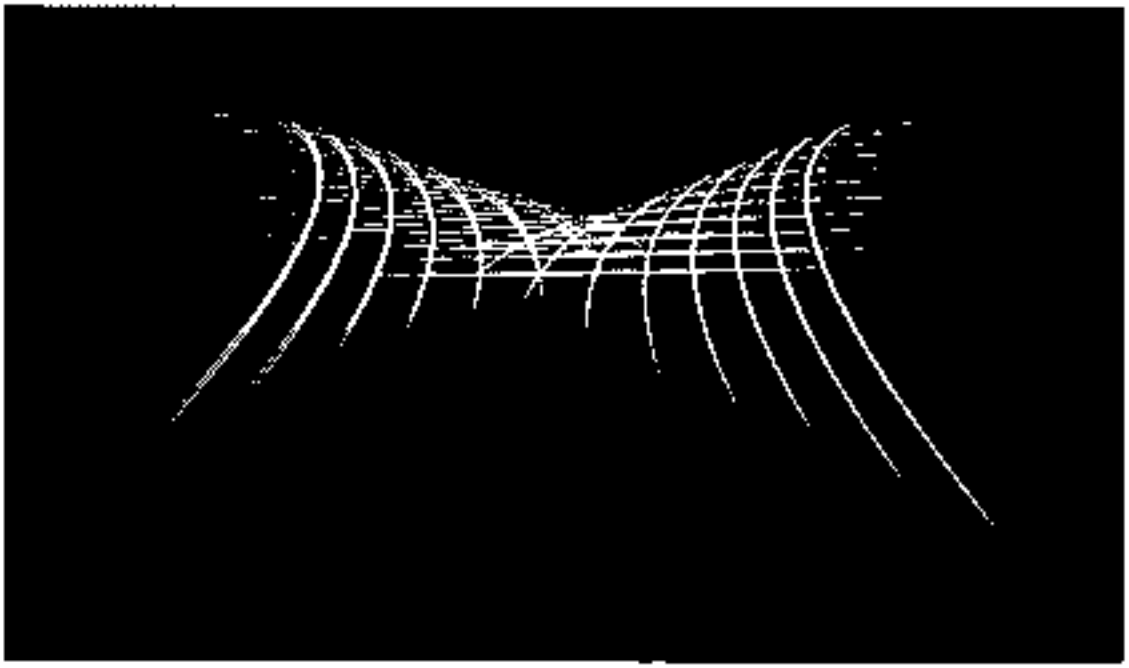
HCM2010

HIGHWAY CAPACITY MANUAL



VOLUME 2: UNINTERRUPTED FLOW

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VOLUME 2
UNINTERRUPTED FLOW

OVERVIEW

Volume 2 of the *Highway Capacity Manual* (HCM) contains six chapters that present analysis methods for uninterrupted-flow roadways—that is, roadways that have no fixed causes of delay or interruption external to the traffic stream. This volume addresses three types of uninterrupted-flow roadways:

- *Freeways*, defined as separated highways with full control of access and two or more lanes in each direction dedicated to the exclusive use of traffic;
- *Multilane highways*, defined as highways that do not have full control of access and that have two or more lanes in each direction, with traffic signals or roundabouts spaced at least 2 mi apart on average; and
- *Two-lane highways*, defined as roadways with one lane for traffic in each direction (except for occasional passing lanes or truck climbing lanes), with traffic signals, roundabouts, or stop-controlled intersections spaced at least 2 mi apart on average.

The HCM treats roadways that have traffic signals, roundabouts, or stop-controlled intersections spaced less than 2 mi apart on average as urban streets. Urban streets are discussed in Volume 3, Interrupted Flow.

VOLUME ORGANIZATION

Freeways

Traffic enters and exits a freeway via ramps. **Chapter 13, Freeway Merge and Diverge Segments,** focuses on locations where two or more traffic streams combine to form a single traffic stream (a *merge*) or where a single traffic stream divides to form two or more separate traffic streams (a *diverge*). These locations are most commonly ramp–freeway junctions but include points where mainline roadways join or separate. Chapter 13 can also be applied in an approximate way to ramp–highway junctions on multilane highways and collector–distributor roads. Ramp–street junctions are analyzed with the methods in the intersection and interchange chapters in Volume 3.

Sometimes freeway merges are closely followed by freeway diverges, or a one-lane off-ramp closely follows a one-lane on-ramp and the two are connected by a continuous auxiliary lane. In these cases, the traffic streams found from the ramps must cross each other over a significant length of freeway without the aid of traffic control devices (except for guide signs). The term "closely" implies that the distance between the merge and diverge segments is not sufficient for them to operate independently. Data on what is a short, **Chapter 12, Freeway Weaving Segments,** provides procedures for analyzing weaving operations on freeways.

VOLUME 2: UNINTERRUPTED FLOW
10. Freeway Facilities
11. Basic Freeway Segments
12. Freeway Weaving Segments
13. Freeway Merge and Diverge Segments
14. Multilane Highways
15. Two-Lane Highways

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It can be applied in an approximate way to weaves on multilane highways and collector–distributor roads, but not to weaves on arterial streets.

The remaining portions of the freeway mainline that are not merge, diverge, or weaving segments (except for toll plazas, drawbridges, or similar points where freeway traffic may be temporarily required to stop) are covered in **Chapter 11, Basic Freeway Segments.** This chapter also provides information on the base conditions and passenger car equivalents for heavy vehicles that are common to all of the freeway chapters.

Chapter 10, Freeway Facilities, provides a methodology for analyzing extended lengths of freeway composed of continuously connected basic freeway, weaving, merge, and diverge segments. Such extended lengths are referred to as a *freeway facility*. In this terminology, the term *facility* does not refer to an entire freeway from beginning to end; instead, it refers to a specific set of connected segments that have been identified for analysis. In addition, the term does not refer to a freeway system consisting of several interconnected freeways.

The methodologies of Chapters 11, 12, and 13 all focus on a single time period of interest, generally the peak 15 min within a peak hour. However, Chapter 10's methodology allows for the analysis of multiple and continuous 15 min periods and is capable of identifying breakdowns and the impact of such breakdowns over space and time.

Multilane Highways

Chapter 14, Multilane Highways, presents analysis methods for the portions of multilane highways away from the influence of signalized intersections or other forms of intersection traffic control that interrupt the flow of traffic on the highway. Many multilane highways will have periodic signalized intersections, even if the average signal spacing is well over 2 mi. In such cases, the multilane highway segments that are more than 2 mi away from any signalized intersections are analyzed with the Chapter 14 methodology. Isolated signalized intersections should be analyzed with the methodology of Chapter 18, Signalized Intersections.

Bicycles are typically permitted on multilane highways, and multilane highways often serve as primary routes for both commuter cyclists (on suburban highways) and recreational cyclists (on rural highways). Chapter 14 presents a method for estimating the bicycle level of service (LOS) on multilane highways.

Two-Lane Highways

Chapter 15, Two-Lane Highways, presents analysis methods for the portions of two-lane highways that are away from the influence of intersection traffic control that interrupts the flow of traffic. In general, any segment that is 2.0 to 3.0 mi from the nearest signalized intersection, roundabout, or intersection where the highway is STOP controlled would fit into this category. Where these interruptions in traffic are less than 2.0 mi apart, the facility should be classified as an urban street and analyzed with the methodologies of Chapter 16, Urban Street Facilities, and Chapter 17, Urban Street Segments, which are located in Volume 3.

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Chapter 15 can be used to analyze three classes of two-lane highways:

- *Class I* highways are ones where motorists expect to travel at relatively high speeds, such as major intercity routes, primary connectors of major traffic generators, daily commuter routes, or major links in state or national highway networks;
- *Class II* highways are ones where motorists do not necessarily expect to travel at high speeds, such as highways serving as access routes to Class I facilities, serving as scenic or recreational routes, or passing through rugged terrain; and
- *Class III* highways are ones serving moderately developed areas, such as portions of a Class I or Class II highway passing through small towns or developed recreational areas or longer segments passing through more spread-out recreational areas, with increased roadside densities.

Two-lane highways often serve as routes for recreational cyclists. Chapter 15 presents a method for estimating the bicycle LOS on these highways.

RELATED CHAPTERS

Volume 1

The chapters in Volume 2 assume that the reader is already familiar with the concepts presented in the Volume 1 chapters, in particular the following:

- *Chapter 2, Applications*—types of HCM analysis, types of roadway system elements, and traffic flow characteristics;
- *Chapter 3, Modal Characteristics*—evaluation of demand, peak and analysis hours, K and D factors, facility types by mode, and interactions between modes;
- *Chapter 4, Traffic Flow and Capacity Concepts*—traffic flow parameters and factors that influence capacity; and
- *Chapter 5, Quality and Level-of-Service Concepts*—performance measures, service measures, and LOS.

Volume 3

The intersection and interchange chapters (Chapters 18–22) are used to determine the operations of freeway ramp–street junctions and the operations of isolated traffic signals, roundabouts, and STOP-controlled intersections along multilane and two-lane highways. In the context of Volume 2, it is particularly important to examine the length of the queue extending back from a freeway off-ramp–street junction, since long queues may affect freeway operations, a situation that is not accounted for in the HCM techniques.

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VOLUME 4: APPLICATIONS GUIDE
Methodological Details
- 25: Freeway Facilities: Supplemental
- 26: Freeway and Highway Segments: Supplemental
- 27: Freeway Weaving: Supplemental
- 28: Freeway Ramps and Diverges: Supplemental
- 35: Active Traffic Management

Case Studies
Technical Reference Library

Volume 4

Five chapters in Volume 4 (accessible at www.HCM2010.org) provide additional information that supplements the material presented in Volume 2. These chapters are as follows:

- *Chapter 25, Freeway Facilities: Supplemental*—details of the computations used in the Chapter 10 methodology, and computational engine flowcharts and linkage lists.
- *Chapter 26, Freeway and Highway Segments: Supplemental*—examples of applying alternative tools to situations that are not addressed by the Chapter 11 method for basic freeway segments, and state-specific default values for heavy-vehicle percentage that apply to all Volume 2 chapters.
- *Chapter 27, Freeway Weaving: Supplemental*—examples of applying alternative tools to situations not addressed by the Chapter 12 method.
- *Chapter 28, Freeway Ramps and Diverges: Supplemental*—examples of applying alternative tools to situations not addressed by the Chapter 13 method, and
- *Chapter 35, Active Traffic Management*—descriptions of active traffic management strategies, a discussion of the mechanisms by which they affect demand, capacity, and performance, and general guidance on possible evaluation methods for active traffic management techniques.

Access Volume 4 at www.HCM2010.org

The *HCM Applications Guide* in Volume 4 provides three case studies on the analysis of uninterrupted-flow facilities:

- *Case Study No. 3* illustrates the process of applying HCM techniques to the analysis of a two-lane highway.
- *Case Study No. 4* illustrates the process of applying HCM techniques to the analysis of a freeway; and
- *Case Study No. 5* illustrates the application of alternative tools to a freeway facility in a situation where HCM techniques are unsuitable.

Case Studies No. 3 and No. 4 focus on the process of applying the HCM rather than on the details of performing calculations (which are addressed by the example problems in the Volume 2 chapters). These case studies' computational results were developed by using HCM2000 methodologies and therefore may not match the results obtained from applying the HCM 2010. However, the process of application is the focus, not the specific computational results.

The Technical Reference Library in Volume 4 contains copies of (or links to) many of the documents referenced in Volume 2 and its supplemental chapters. Because the Chapter 10 methodology is too complex to be implemented by manual pencil-and-paper techniques, the FRETEVAL-2010 spreadsheet has been developed to implement the methodology's calculations. The Technical Reference Library contains a copy of the spreadsheet along with a user's guide.

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LEVELS OF ANALYSIS AND ANALYSIS TOOLS

As discussed in Chapter 2, Applications, HCM methodologies can be applied to the operations, design, preliminary engineering, and planning levels of analysis. These levels differ both in the amount of field data used in the analysis (as opposed to default values) and in the way the HCM is applied (iteratively, to find a design that meets a desired set of criteria, or as a single application, to evaluate performance given a particular set of inputs). Each Volume 2 chapter provides a section that discusses how to apply the chapter to these different levels of analysis, along with a section with recommended default values for planning and preliminary engineering analyses.

Three Volume 2 chapters (10, 14, and 15) provide generalized service volume tables applicable to freeway facilities, multilane highways, and two-lane highways, respectively. These tables can be used for large-scale planning efforts when the goal is to analyze a large number of facilities to determine where problems might exist or arise or where improvements might be needed. Any facilities identified as likely to experience problems or need improvement should then be subjected to a more detailed analysis that takes into account the existing or likely future characteristics of the specific facility before any detailed decisions on implementing specific improvements are made. Because the service volumes provided in these tables are highly dependent on the default values assumed as inputs, it is recommended that users wishing to apply generalized service volume tables develop their own tables by using local default values, in accordance with the processes described in Appendix A and Appendix B of Chapter 6, HCM and Alternative Analysis Tools.

Chapter 6 also describes in general terms the conditions under which the use of alternative tools to supplement HCM capacity and quality-of-service procedures should be considered. Each Volume 2 chapter contains a section discussing the potential application of alternative tools to the specific system element addressed by the chapter, and Chapters 26–28 in Volume 4 provide example problems illustrating applications of alternative tools to address HCM limitations. Each chapter lists the specific limitations of its methodology. The major limitations are summarized as follows:

- Freeways
  - Operations of oversaturated freeway segments (but not necessarily oversaturated freeway facilities, as discussed later),
  - Multiple overlapping breakdowns or bottlenecks,
  - Conditions where off-ramp queues extend back onto the freeway or affect the operation of exiting vehicles,
  - Operation of separated high-occupancy vehicle (HOV) facilities and weaving movements between HOV and general-purpose lanes,
  - Toll plaza operations, and
  - Ramp-metering effects.

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- *Multilane highways*
  - Operations during oversaturated conditions
  - The impacts of shoulder parking activity, bus stops, or significant pedestrian activity
  - Possible queuing impacts when a multilane highway segment transitions to a two-lane highway segment
  - Differences between various types of median barriers, and the difference between the impact of a median barrier and a two-way left-turn lane

  The range of values used to develop the bicycle LOS model. Although the model has been successfully applied to rural multilane highways, users should be aware that conditions on many of these highways are outside the range of values used to develop the model.
- *Two-lane highways*
  - Operations during oversaturated conditions
  - Impact of intersection traffic control on the overall facility LOS
  - The range of values used to develop the bicycle LOS model. Although the model has been successfully applied to rural two-lane highways, users should be aware that conditions on many of these highways are outside the range of values used to develop the model.

If an analysis of an individual freeway segment reveals the segment to be oversaturated, then Chapter 10, Freeway Facilities, must be used to assess operation of the segment and its impacts on upstream and downstream sections. If the Chapter 10 analysis reveals that the oversaturation would extend beyond the geographic or temporal boundaries of the analysis, then the boundaries of the Chapter 10 analysis should be expanded to contain the oversaturation. If expanding the boundaries of the analysis is not practical, then no analytical tool, including the HCM, can give a complete answer in this situation.

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CHAPTER 10
FREEWAY FACILITIES

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1. INTRODUCTION

VOLUME 2: UNINTERRUPTED FLOW
10. Freeway Facilities
11. Basic Freeway Segments
12. Freeway Weaving Segments
13. Freeway Merge and Diverge Segments
14. Multilane Highways
15. Two-Lane Highways

A freeway is a separated highway with full control of access and two or more lanes in each direction dedicated to the exclusive use of traffic. Freeways are composed of various uniform segments that may be analyzed to determine capacity and level of service (LOS). Three types of segments are found on freeways.

- *Freeway merge and diverge segments*: Segments in which two or more traffic streams combine to form a single traffic stream (merge) or a single traffic stream divides to form two or more separate traffic streams (diverge).
- *Freeway weaving segments*: Segments in which two or more traffic streams traveling in the same general direction cross paths along a significant length of freeway without the aid of traffic control devices (except for guide signs). Weaving segments are formed when a diverge segment closely follows a merge segment or when a one-lane on-ramp closely follows a one-lane on-ramp and the two are connected by a continuous auxiliary lane.
- *Basic freeway segments*: All segments that are not merge, diverge, or weaving segments.

Analysis methodologies are detailed for basic freeway segments in Chapter 11, for weaving segments in Chapter 12, and for merge and diverge segments in Chapter 13.

Chapter 10, Freeway Facilities, provides a methodology for analyzing extended lengths of freeway composed of continuously connected basic freeway, weaving, merge, and diverge segments. Such extended lengths are referred to as *a freeway facility*. In this terminology, the term *facility* does not refer to an entire freeway from beginning to end; instead, it refers to a specific set of connected segments that have been identified for analysis. In addition, the term does not refer to a freeway system consisting of several interconnected freeways.

The methodologies of Chapters 11, 12, and 13 focus on a single time period of interest, generally the peak 15 min within a peak hour. This chapter's methodology allows for the analysis of multiple and continuous 15-min time periods and is capable of identifying breakdowns and the impact of such breakdowns over space and time.

The methodology is integral with the FREEVAL-2010 model, which implements the complex computations involved. This chapter discusses the basic principles of the methodology and its application. Chapter 25, Freeway Facilities Supplemental, provides a complete and detailed description of all the algorithms that define the methodology. The Technical Reference Library in Volume 4 contains a user's guide to FREEVAL-2010 and an executable spreadsheet that implements the methodology.

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SEGMENTS AND INFLUENCE AREAS

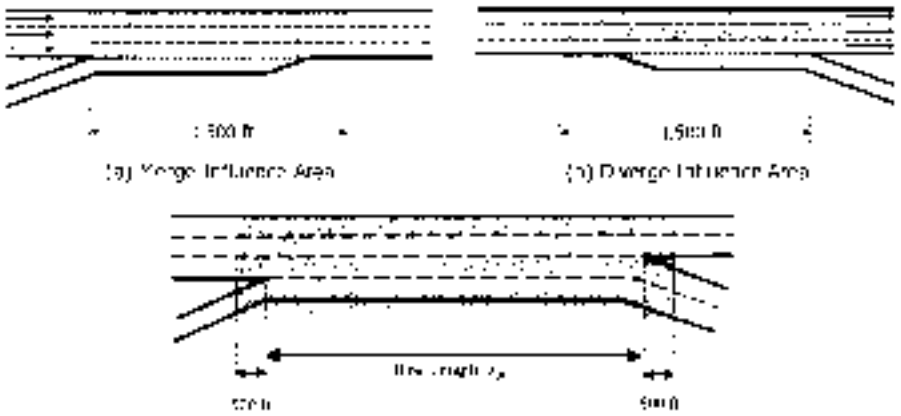
It is important that the definition of freeway segments and their influence areas be clearly understood. The influence areas of merge, diverge, and weaving segments are as follows:

- *Weaving segment*: The base length of the weaving segment plus 500 ft upstream of the entry point to the weaving segment and 500 ft downstream of the exit point from the weaving segment; entry and exit points are defined as the points where the appropriate edges of the merging and diverging lanes meet.
- *Merge segment*: From the point where the edges of the travel lanes of the merging roadways meet to a point 1,500 ft downstream of that point.
- *Diverge segment*: From the point where the edges of the travel lanes of the merging roadways meet to a point 1,500 ft upstream of that point.

Points where the "edges of travel lanes" meet are most often defined by pavement markings.

The influence areas of merge, diverge, and weaving segments are illustrated in Exhibit 10-1.

Exhibit 10-1
Influence Areas of Merge, Diverge, and Weaving Segments



Basic freeway segments are any other segments along the freeway that are not within those defined influence areas, which is not to say that basic freeway segments are not affected by the presence of adjacent and nearby merge, diverge, and weaving segments. Particularly when a segment breaks down, its effects will propagate to both upstream and downstream segments, regardless of type. Furthermore, the general impact of the frequency of merge, diverge, and weaving segments on the general operation of all segments is taken into account by the free-flow speed of the facility.

Basic freeway segments, therefore, do exist even on urban freeways where merge and diverge points (most often ramps) are closely spaced. Exhibit 10-2 illustrates this point. It shows a 9,100 ft (1.7 mi) length of freeway with four ramp terminals, two of which form a weaving segment. Even with an average ramp spacing of less than 0.5 mi, this length of freeway contains three basic freeway segments. The lengths of these segments are relatively short, but, in terms of

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analysis methodologies, they must be treated as basic freeway segments. Thus, while it is true that many urban freeways will be dominated by frequent merge, diverge, and weaving segments, there will still be segments classified and analyzed as basic freeway segments.

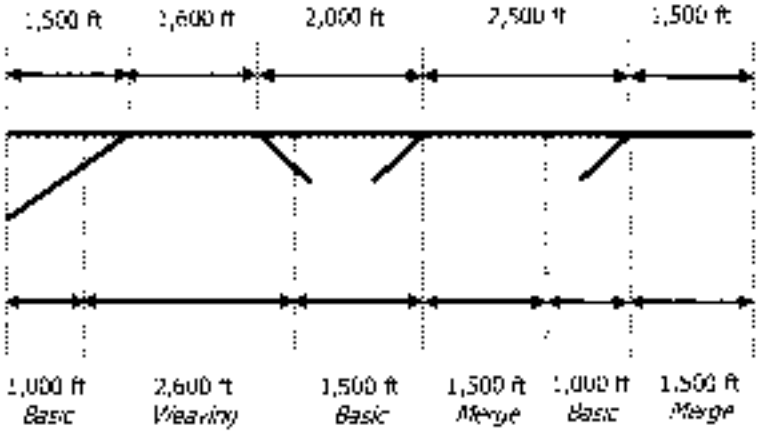

Exhibit 10-2
Basic Freeway Segments on an Urban Freeway

FREE-FLOW SPEED

Free-flow speed is strictly defined as the theoretical speed when the density and flow rate on the study segment are both zero. Chapter 11, Basic Freeway Segments, presents speed–flow curves that indicate that the free-flow speed on freeways is expected to prevail at flow rates between 0 and 1,000 passenger cars per hour per lane (pc/h/ln). In this broad range of flows, speed is insensitive to flow rates. This characteristic simplifies and allows for measurement of free-flow speeds in the field.

Chapter 11 also presents a methodology for estimating the free-flow speed of a basic freeway segment if it cannot be directly measured. The free-flow speed of a basic freeway segment is sensitive to three variables:

- Lane widths,
- Lateral clearances, and
- Total ramp density.

The most critical of these variables is total ramp density. *Total ramp density* is defined as the average number of on-ramp, off-ramp, major merge, and major diverge junctions per mile. It applies to a 6-mi segment of freeway facility, 3 mi upstream and 3 mi downstream of the midpoint of the study segment.

While the methodology for determining free-flow speed is provided in Chapter 11, Basic Freeway Segments, it is also applied in Chapter 12, Freeway Weaving Segments, and Chapter 13, Freeway Merge and Diverge Segments. Thus, free-flow speed affects the operation of all basic, weaving, merge, and diverge segments on a freeway facility.

The free-flow speed is an important characteristic, as the capacity, service flow rates (*SF*), service volumes (*SV*), and daily service volumes (*DSV*) all depend on it.

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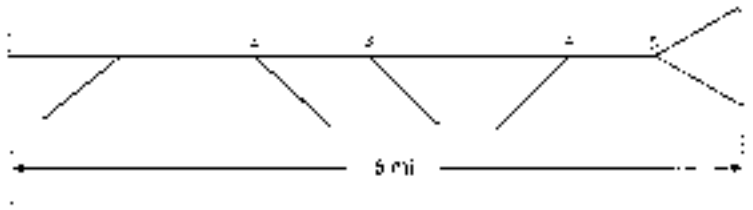
Exhibit 10-3 illustrates the determination of total ramp density on a 6-mi length of freeway facility.

Exhibit 10-3
Ramp Density Determination



As illustrated in Exhibit 10-3, there are four ramp terminals and one major diverge point in the 6-mi segment illustrated. The total ramp density is, therefore, 5/6 = 0.83 ramps/mi.

CAPACITY OF FREEWAY FACILITIES

Capacity traditionally has been defined for segments of uniform roadway, traffic, and control conditions. When facilities consisting of a series of connected segments are considered, the concept of capacity is more complicated.

The methodologies of Chapters 11, 12, and 13 allow the capacity of each basic freeway, freeway weaving, freeway merge, and freeway diverge segment to be estimated. It is highly unlikely that every segment of a facility will have the same roadway, traffic, and control conditions and even less likely that they will have the same capacity.

Conceptual Approach to the Capacity of a Freeway Facility

Consider the example shown in Exhibit 10-4. It illustrates five consecutive segments that are to be analyzed as one "freeway facility." Demand flow rates v_i, capacities c_i, and actual flow rates v_i are shown, as are the resulting v_i/c_i and v_i/c_i ratios. A lane is added in Segment 3 (even though this segment begins with an off-ramp), providing higher capacities for Segments 3, 4, and 5 than in Segments 1 and 2. The example analyzes three scenarios.

In Scenario 1, none of the demand flow rates exceeds the capacities of the segments that make up the facility. Thus, no breakdowns occur, and the actual flow rates are the same as the demand flow rates ($v_i = v_i$ for this scenario). None of the v_i/c_i or v_i/c_i ratios exceeds 1.00, although the highest ratios (0.979) occur in Segment 5.

Scenario 2 adds 200 vehicles per hour (veh/h) of demand to each segment (essentially another 200 veh/h of through freeway vehicles). In this case, Segment 5 will experience a breakdown—that is, the demand flow rate will exceed the capacity. In this segment, demand flow rate v_i differs from the actual flow rate v_i, as the actual flow rate v_i can never exceed the capacity c_i.

In Scenario 3, all demand flow rates are increased by 10%, which, in effect, keeps the relative values of the segment demand flow rates constant. In this case, demand flow rate will exceed capacity in Segments 1 and 5. Again, the demand flow rates and actual flow rates will differ in these segments.

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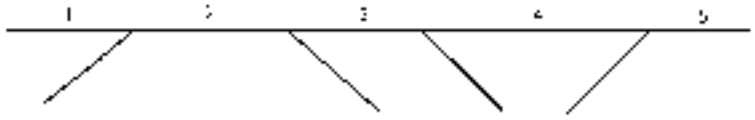

Exhibit 10-4
Example of the Effect of Segment Capacity on a Freeway Facility

Scenario	Performance Measures	Freeway Segment 1	2	3	4	5
Scenario 1 (stable flow)	Demand v_i, veh/h	3,400	3,500	3,400	4,200	4,400
	Capacity c_i, veh/h	4,000	4,000	4,500	4,500	4,500
	Volume v_i, veh/h	3,400	3,500	3,400	4,200	4,400
	v_i/c_i ratio	0.850	0.875	0.756	0.933	0.978
	v_i/c_i ratio	0.850	0.875	0.756	0.933	0.978
Scenario 2 (add 200 veh/h to each segment)	Demand v_i, veh/h	3,600	3,700	3,600	4,400	4,600
	Capacity c_i, veh/h	4,000	4,000	4,500	4,500	4,500
	Volume v_i, veh/h	3,600	3,700	3,600	4,400	4,500
	v_i/c_i ratio	0.900	0.925	0.800	0.978	1.022
	v_i/c_i ratio	0.900	0.925	0.800	0.978	1.000
Scenario 3 (increase demand by 10% in all segments)	Demand v_i, veh/h	3,740	3,850	3,740	4,840	5,060
	Capacity c_i, veh/h	4,000	4,000	4,500	4,500	4,500
	Volume v_i, veh/h	3,740	3,850	3,740	4,500	4,500
	v_i/c_i ratio	0.935	0.963	0.831	1.078	1.120
	v_i/c_i ratio	0.935	0.963	0.831	1.000	1.000

Note: Shaded cells indicate segments where demand exceeds capacity.

This example highlights a number of points that make the analysis of freeway facilities very complicated:

1. It is critical to the methodology that the difference between demand flow rate v_i and actual flow rate v_i be highlighted and that both values be clearly and appropriately labeled.
2. In Scenarios 2 and 3, the analysis of Exhibit 10-4 is inadequate and misleading. In Scenario 2, when Segment 5 breaks down, queues begin to form and to propagate upstream. Thus, even though the demands in Segments 1 through 4 are less than the capacity of those segments, the queues generated by Segment 5 over time will propagate through Segments 1 through 4 and significantly affect their operation. In Scenario 3, Segments 4 and 5 fail, and queues are generated, which also propagate upstream over time.
3. It might be argued that the analysis of Scenario 1 is sufficient to understand the facility operation as long as all segments are undersaturated (i.e., all segment v/c ratios are less than or equal to 1.00). However, when any segment v_i/c_i ratio exceeds 1.00, such a simple analysis ignores the spreading impact of breakdowns in space and time.
4. In Scenarios 2 and 3, the segments downstream of Segment 5 will also be affected, as demand flow is prevented from reaching those segments by the Segment 5 (and Segment 4 in Scenario 3) breakdowns and queues.
5. In this example, it is also important to note that the segment(s) that break down first do not have the lowest capacities. Segments 1 and 2, with lower capacities, do not break down in any of the scenarios. Breakdown occurs first in Segment 5, which has one of the higher capacities.

Considering all these complications, the capacity of a freeway facility is defined as follows:

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Freeway facility capacity is the capacity of the critical segment among those segments composing the freeway facility. This capacity must, for analysis purposes, be compared with the demand flow rate on the critical segment.

The critical segment is defined as the segment that will break down first, given that all traffic, roadway, and control conditions do not change, including the spatial distribution of demands on each component segment. This definition is not a simple one. It depends on the relative demand characteristics and can change over time as the demand pattern changes. Facility capacity may be more than the capacity of the component segment with the lowest capacity. Therefore, it is important that individual segment demands and capacities be evaluated. The fact that one of these segments will be the critical one and will define the facility capacity does not diminish the importance of the capacities of other segments in the defined facility.

Base Capacity of Freeway Facilities

In the methodologies of Chapters 11, 12, and 13, a base capacity is used. The base capacity represents the capacity of the facility, assuming that there are no heavy vehicles in the traffic stream and that all drivers are regular users of the segment. The base capacity for all freeway segments varies with the free-flow speed, as indicated in Exhibit 10-5.

Exhibit 10-5
Free-Flow Speed vs. Base Capacity for Freeways

Free-Flow Speed (mi/h)	Base Capacity (pc/h/ln)
75	2,400
70	2,400
65	2,350
60	2,300
55	2,250

The equation given in Chapter 11, Basic Freeway Segments, for estimating the free-flow speed of a segment is as shown in Equation 10-1:

Equation 10-1

$$FFS = 75.4 - f_{LW} - f_{LC} - 3.22\,TRD^{0.84}$$

where

FFS = free-flow speed (mi/h),

f_{LW} = adjustment for lane width (mi/h),

f_{LC} = adjustment for lateral clearance (mi/h), and

TRD = total ramp density (ramps/mi).

The process for determining the value of adjustment factors is described in Chapter 11.

Because the base capacity of a freeway segment is directly related to the free-flow speed, it is possible to construct a relationship between base capacity and the lane width, lateral clearance, and total ramp density of the segment. If the lane width and lateral clearance are taken to be their base values (12 and 6 ft, respectively), a relationship between base capacity and total ramp density emerges, as shown in Exhibit 10-6.

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Base capacity is expressed as a flow rate for a 15-min analysis period, not a full-hour volume. It also represents a flow rate in pcph, with no heavy vehicles, and a driver population familiar with the characteristics of the analysis segment.

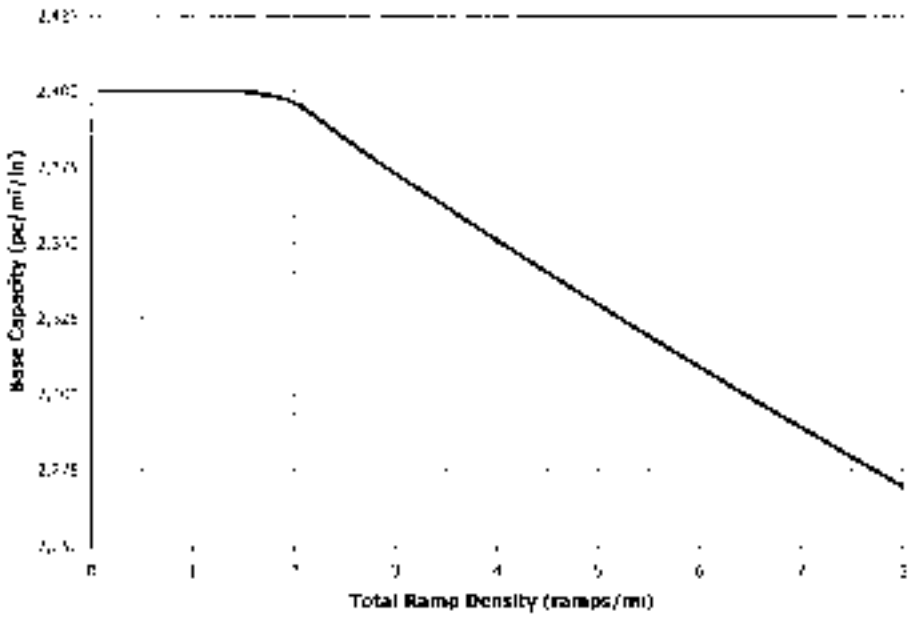

Exhibit 10-6
Base Capacity vs. Total Ramp Density

Segment Capacity vs. Facility Capacity

Free-flow speed is a characteristic of a length of freeway extending 3 mi upstream and 3 mi downstream of the center point of an analysis segment. The segment may be a basic freeway segment, a weaving segment, a merge segment, or a diverge segment. In essence, it is a measure of the impact of overall facility characteristics on the operation of the individual analysis segment centered in the defined 6-mi length.

This concept can be somewhat generalized where freeway facility analysis is involved. If conditions (particularly ramp density) are similar along a greater length of freeway, it is acceptable to compute the total ramp density for the greater length and apply it to all segments within the analysis length. This process assumes that moving the "center" of a 6-mi length for each component segment will not result in a significant change in the free-flow speed.

The capacity of a nearly homogeneous freeway facility is, for all practical purposes, the same as the capacity of a basic freeway segment with the same roadway and traffic characteristics. Consider the following:

- Merge and diverge segments have the same capacity as a similar basic freeway segment. As discussed in Chapter 11, the presence of merge and diverge segments on a freeway may affect operating characteristics, generally reducing speeds and increasing densities, but does not reduce capacity.
- Weaving segments often have per lane capacities that are less than those of the entering and leaving basic freeway segments. In almost all cases, however, weaving segments have more lanes than the entering and

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leaving basic freeway segments. Thus, the impact on the capacity of the mainline freeway most often is negligible.

This does not mean, however, that the capacity at each component segment of a facility is the same. Each segment has its own demand and demand characteristics. Demand flow rate can change at every entry and exit point along the freeway, and the percent of heavy vehicles can change too. Terrain also can change at various points along the freeway.

Changes in heavy vehicle presence can change the capacity of individual segments within a defined facility. Changes in the split of movements in a weaving segment can change its capacity. In the same way, changes in the relative demand flows at on- and off-ramps can change the location of the critical segment within a defined facility and its capacity.

As noted previously, the capacity of a freeway facility is defined as the capacity of its critical segment.

LOS: COMPONENT SEGMENTS AND THE FREEWAY FACILITY

LOS of Component Segments

Chapters 11, 12, and 13 provide methodologies to determine the LOS in basic, weaving, merge, and diverge segments. In all cases, LOS F is identified when v/c is greater than 1.00. Such breakdowns are easily identified, and users are referred to this chapter.

This chapter's methodology provides an analysis of breakdown conditions, including the spatial and time impacts of a breakdown. Thus, in the performance of a facility level analysis, LOS F in a component segment can be identified (a) when the segment v/c is greater than 1.00 and (b) when a queue from a downstream breakdown extends into an upstream segment. The latter cannot be done by using the individual segment analysis procedures of Chapters 11, 12, and 13.

Thus, when facility-level analysis is undertaken by using the methodology of this chapter, LOS F for a component segment will be identified in two different ways.

- When v/c is greater than 1.00, or
- When the density is greater than 45 pc/mi/ln for basic freeway segments or 43 pc/mi/ln for weaving, merge, or diverge segments.

The latter identifies segments in which queues have formed as a result of downstream breakdowns.

LOS for a Freeway Facility

Because LOS for basic, weaving, merge, and diverge segments on a freeway is defined in terms of density, LOS for a freeway facility is also defined on the basis of density.

A facility analysis will result in a density determination and LOS for each component segment. The facility LOS will be based on the weighted average density for all segments within the defined facility. Weighting is done on the

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basis of segment length and the number of lanes in each segment, as shown in Equation 10-2:

$$D_R = \frac{\sum_{i=1}^{n} D_i \times L_i \times N_i}{\sum_{i=1}^{n} L_i \times N_i}$$

Equation 10-2

where

D_R = average density for the facility (pc/mi/ln),

D_i = density for segment i (pc/mi/ln),

L_i = length of segment i (ft),

N_i = number of lanes in segment i, and

n = number of segments in the defined facility.

The LOS criteria for a freeway facility are shown in Exhibit 10-7. They are the same criteria used for basic freeway segments.

Exhibit 10-7
LOS Criteria for Freeway Facilities

Level of Service	Density (pc/mi/ln)
A	≤10
B	>10–18
C	>18–26
D	>26–35
E	>35–45
F	>45 or
	any component v/c ratio > 1.00

Use of a LOS descriptor for the overall freeway facility must be done with care. It is critical that the LOS for individual segments composing the facility also be reported. Because the overall LOS is an average, it may mask serious problems in individual segments of the facility.

This is particularly important if one or more of the component segments are operating at LOS F. As described in this chapter's methodology section, the freeway facility methodology applies models to estimate the propagation of the effects of a breakdown in time and space. When breakdowns exist in one or more segments of a facility, the average LOS is of limited use. The average LOS applies to a specific time period, usually 15 min.

While LOS A through D are defined by using the same densities that apply to basic freeway segments, LOS F for a facility is defined as a case in which any component segment of the freeway exceeds a v/c ratio of 1.00 or the average density over the defined facility exceeds 45 pc/mi/ln. In such a case, this chapter's methodology allows the analyst to map the impacts of this breakdown in time and space, and close attention to the individual LOS of component segments is necessary.

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SERVICE FLOW RATES, SERVICE VOLUMES, AND DAILY SERVICE VOLUMES FOR A FREEWAY FACILITY

Just as each segment of a freeway facility has its own capacity, each segment also has a set of service flow rates SF_i for each LOS. A service flow rate is the maximum directional rate of flow that can be sustained in a given segment without violating the criteria for LOS *i*. Service flow rates are stated in vehicles per hour under prevailing roadway, traffic, and control conditions. By definition, the service flow rate for LOS E is synonymous with capacity for all uninterrupted-flow facilities and their component segments.

Chapters 11, 12, and 13 provide complete discussions of how to determine service flow rates for basic, weaving, merge, and diverge freeway segments.

A service volume SV_i is the maximum hourly directional volume that can be sustained in a given segment without violating the criteria for LOS *i* during the worst 15 min of the hour (period with the highest density) under prevailing roadway, traffic, and control conditions. Once a set of service flow rates has been established for a segment, the service volume is found from Equation 10-3:

Equation 10-3

$$SV_i = SF_i \times PHF$$

where

SV_i = service volume for LOS *i* (veh/h),

SF_i = service flow rate for LOS *i* (veh/h), and

PHF = peak hour factor.

A daily service volume DSV_i is the maximum total daily volume in both directions that can be sustained in a given segment without violating the criteria for LOS *i* in the peak direction in the worst 15 min of the peak hour under prevailing roadway, traffic, and control conditions. Given a set of service volumes for a segment, the daily service volume is found from Equation 10-4:

Equation 10-4

$$DSV_i = \frac{SV_i}{K \times D}$$

where

DSV_i = daily service volume (veh/day),

K = proportion of daily traffic occurring in the peak hour of the day, and

D = proportion of traffic in the peak direction during the peak hour of the day.

The capacity of a freeway facility has been defined as the capacity under prevailing conditions of the critical segment. For consistency, therefore, other service flow rates must also be applied to the critical segment.

For an overall understanding of the freeway facility, the LOS and service flow rates (or service volumes or daily service volumes) of the individual component segments must be considered along with the overall average LOS for the defined facility and its service flow rate.

AR0073450

GENERALIZED DAILY SERVICE VOLUMES FOR FREEWAY FACILITIES

Generalized daily service volume tables provide a means to assess all freeways in a region or jurisdiction quickly to determine which segments need to be assessed more carefully using operational analysis to ameliorate existing or pending problems.

To generate a generalized daily service volume table for freeway facilities, several simplifying assumptions must be made. The assumptions made here include the following:

1. All segments of the freeway have the same basic number of lanes (two, three, or four in each direction).
2. Lane widths are 12 ft, and lateral clearances are 6 ft.
3. All on-ramps and off-ramps handle the same percentage of freeway traffic. This setup maintains a reasonably consistent demand flow rate on each segment of the facility.
4. The first ramp on the defined freeway facility is an off-ramp. This assumption is necessary to implement Item 3, below.
5. Given the demand characteristics of Items 2 and 3, all daily service volumes are stated in terms of the demand entering the defined freeway facility at its upstream boundary.
6. The terrain is the same in all segments of the facility.
7. The heavy vehicle percentage is the same in all segments of the facility.

On the basis of these assumptions, generalized daily service volume tables are shown in Exhibit 10-8 (for urban freeways) and Exhibit 10-9 (for rural freeways).

Generalized service volumes are provided for level and rolling terrain; for four lane, six lane, and eight lane freeways (both directions); and for a variety of combinations of the K factor and D-factor. To use the table, analysts must select a combination of K and D appropriate for their state or region. Additional assumptions made for urban and rural freeways are listed here.

Assumptions for urban freeways:

- Total ramp density = 3.00 ramps/mi (i.e., ½-mi average spacing between ramps);
- 5 % trucks, no recreational vehicles (RVs), and no buses;
- PHF = 0.95; and
- $f_p = 1.00$

Assumptions for rural freeways:

- Total ramp density = 0.20 ramp/mi (i.e., 5-mi average spacing between ramps);
- 12 % trucks, no RVs, and no buses;
- PHF = 0.88; and
- $f_p = 0.85$

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Generalized daily service volumes are based on the maximum service flow rate values for basic freeway segments. Exhibit 10-7 (Chapter 11) shows maximum service flow rates MSF_i for basic freeway segments. They are converted to service flow rates under prevailing conditions by multiplying by the number of lanes in one direction N, the heavy-vehicle adjustment factor f_{HV}, and the driver-population adjustment factor f_p. Equation 10-3 and Equation 10-4 are then used to convert the service flow rate SF_i to a service volume SV_i and a daily service volume DSV_i.

By combining these equations, the daily service volumes DSV_i of Exhibit 10-8 and Exhibit 10-9 are estimated from Equation 10-5:

Equation 10-5

$$DSV_i = \frac{MSF_i \times N \times f_{HV} \times f_p \times PHF}{K \times D}$$

where all variables are as previously defined.

In applying Equation 10-5, the values of MSF_i are selected from Exhibit 10-17 (Chapter 11), and values for the heavy-vehicle and driver-population adjustment factors are computed in accordance with the methodology of Chapter 11. The MSF_i for LOS E, which is capacity, may be taken directly from Exhibit 10-5, based on the total ramp density, as lane widths and lateral clearances are standard and have no effect on the DSV_i and thus no effect on the resulting capacities.

Exhibit 10-8 and Exhibit 10-9 are provided for general planning use and should not be used to analyze any specific freeway or to make final decisions on important design features. A full operational analysis using this chapter's methodology is required for such specific applications.

The exhibits are useful, however, in evaluating the overall performance of many freeways within a jurisdiction, as a first pass in determining where problems might exist or arise, and in deciding where improvements might be needed. Any freeways identified as likely to experience problems or to need improvement, however, should be subjected to a full operational analysis before any detailed decisions on implementing specific improvements are made.

Daily service volumes are heavily affected by the K and D factors chosen as typical for the analysis. It is important that the analyst use values that are reasonable for the facilities under study. Also, if any characteristic differs significantly from the typical values used to develop Exhibit 10-8 and Exhibit 10-9, the values taken from these exhibits will not be representative of the study facilities.

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Exhibit 10-8
Generalized Daily Service Volumes for Urban Freeway Facilities (1,000 veh/day)

K-Factor	D-Factor	Four-Lane Freeways LOS B	LOS C	LOS D	LOS E	Six-Lane Freeways LOS B	LOS C	LOS D	LOS E	Eight-Lane Freeways LOS B	LOS C	LOS D	LOS E
Level Terrain													
0.08	0.50	54.2	75.5	94.1	109.9	81.3	113.3	141.1	164.9	108.4	151.1	188.1	219.9
	0.55	49.4	68.7	85.5	99.9	73.9	103.0	128.3	149.9	98.6	137.3	171.0	199.9
	0.60	45.2	62.9	78.4	90.6	67.8	94.4	117.6	136.1	90.4	125.9	156.8	181.5
	0.65	41.7	58.1	72.4	83.6	62.6	87.2	108.5	125.7	83.4	116.3	144.7	167.5
0.09	0.50	48.2	67.1	83.6	96.8	72.3	100.7	125.4	145.2	96.4	134.3	167.2	193.6
	0.55	43.8	61.0	76.0	88.0	65.7	91.6	114.0	132.0	87.6	122.1	152.0	176.0
	0.60	40.2	56.0	69.7	80.7	60.2	83.9	104.5	121.0	80.2	111.9	139.4	161.3
	0.65	37.1	51.6	64.3	74.5	55.6	77.5	96.5	111.7	74.1	103.3	128.6	148.9
0.10	0.50	43.4	60.4	75.2	87.1	65.1	90.6	112.9	130.7	86.8	120.9	150.5	174.2
	0.55	39.4	54.9	68.4	79.2	59.1	82.4	102.6	118.8	78.9	109.9	136.8	158.4
	0.60	36.1	50.4	62.7	72.6	54.2	75.5	94.1	108.9	72.3	100.7	125.4	145.2
	0.65	33.4	46.5	57.9	67.0	50.0	69.7	86.8	100.5	66.7	93.0	115.8	134.0
0.11	0.50	39.4	54.9	68.4	79.2	59.1	82.4	102.6	118.8	78.9	109.9	136.8	158.4
	0.55	35.8	49.9	62.2	72.0	53.8	74.9	93.3	108.0	71.7	99.9	124.4	144.0
	0.60	32.9	45.8	57.0	66.0	49.4	68.7	85.5	99.0	65.7	91.6	114.0	132.0
	0.65	30.3	42.3	52.6	60.9	45.5	63.4	78.9	91.4	60.7	84.5	105.3	121.9
Rolling Terrain													
0.08	0.50	51.7	72.0	89.7	103.8	77.5	108.0	134.5	155.6	103.4	144.0	179.4	207.7
	0.55	47.0	65.5	81.5	94.4	70.5	98.2	122.3	141.6	94.0	131.0	163.1	188.8
	0.60	43.1	60.0	74.7	86.5	64.6	90.0	112.1	129.8	86.2	120.0	149.5	173.1
	0.65	39.8	55.4	69.0	79.9	59.7	83.1	103.5	119.8	79.5	110.8	138.0	159.7
0.09	0.50	46.0	64.0	79.7	92.3	68.9	96.0	119.6	138.4	91.9	128.0	159.5	184.5
	0.55	41.8	58.2	72.5	83.9	62.7	87.3	108.7	125.9	83.6	116.4	145.0	167.8
	0.60	38.5	53.4	66.4	76.9	57.4	80.0	99.7	115.4	76.6	106.7	132.9	153.9
	0.65	35.3	49.2	61.3	71.0	53.0	73.9	92.0	106.5	70.7	98.5	122.7	142.0
0.10	0.50	41.4	57.6	71.8	83.1	62.0	86.4	107.6	124.6	82.7	115.2	143.5	166.1
	0.55	37.6	52.4	65.2	75.5	56.4	78.6	97.9	113.3	75.2	104.8	130.5	151.1
	0.60	34.5	48.0	59.8	69.2	51.7	72.0	89.7	103.8	68.9	96.0	119.6	138.4
	0.65	31.8	44.3	55.2	63.9	47.7	66.5	82.8	95.8	63.6	88.6	110.4	127.8
0.11	0.50	37.6	52.4	65.2	75.5	56.4	78.6	97.9	113.3	75.2	104.8	130.5	151.1
	0.55	34.2	47.6	59.3	68.7	51.3	71.4	89.0	103.0	68.4	95.2	118.6	137.3
	0.60	31.3	43.7	54.4	62.9	47.0	65.5	81.5	94.4	62.7	87.3	108.7	125.9
	0.65	28.9	40.3	50.2	58.1	43.4	60.4	75.3	87.1	57.8	80.6	100.4	116.2

Note: Assumptions include the following: 5% trucks, 0% buses, 0% RVs, 0.90 PHF, 3 ramps/mi, f_HV = 1.00, 12 lanes, and 6-ft lateral clearance. Values do not represent specific segment characteristics.

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Exhibit 10-9
Generalized Daily Service Volumes for Rural Freeway Facilities (1,000 veh/day)

K-Factor	D-Factor	Four-Lane Freeways LOS B	LOS C	LOS D	LOS E	Six-Lane Freeways LOS B	LOS C	LOS D	LOS E	Eight-Lane Freeways LOS B	LOS C	LOS D	LOS E
Level Terrain													
0.09	0.50	41.1	51.9	66.2	75.3	61.6	62.3	99.4	112.9	82.2	109.8	132.4	150.5
	0.55	37.4	47.3	60.2	68.4	56.0	74.6	90.2	102.6	74.7	99.8	120.3	136.9
	0.60	34.2	43.2	55.1	62.7	51.4	68.6	82.7	94.1	68.5	91.5	110.3	125.5
	0.65	31.6	40.2	50.9	57.9	47.4	63.3	76.4	86.9	63.2	84.4	101.8	115.8
0.10	0.50	47.0	49.4	59.6	67.7	55.5	74.1	89.3	101.6	74.0	98.8	119.1	135.5
	0.55	33.6	44.9	54.1	61.6	50.4	67.4	81.2	92.4	67.3	89.8	108.3	123.2
	0.60	30.8	41.2	49.6	56.5	46.2	61.7	74.4	84.7	61.6	82.3	99.3	113.0
	0.65	28.4	38.0	45.8	52.1	42.7	57.0	68.7	78.2	56.9	76.0	91.6	104.2
0.11	0.50	43.6	44.9	54.1	61.6	50.4	67.4	81.2	92.4	67.2	89.8	108.3	123.2
	0.55	30.6	40.8	49.2	56.0	45.8	61.2	73.8	84.0	61.1	81.6	98.4	112.0
	0.60	28.0	37.4	45.1	51.3	42.0	56.1	67.7	77.0	56.0	74.8	90.2	102.6
	0.65	25.8	34.5	41.6	47.4	38.6	51.6	62.3	71.1	51.7	69.1	83.3	94.7
0.12	0.50	39.6	41.2	49.6	56.5	46.2	61.7	74.4	84.7	61.6	82.3	99.3	113.0
	0.55	28.0	37.4	45.1	51.3	42.0	56.1	67.7	77.0	56.0	74.8	90.2	102.6
	0.60	25.7	34.3	41.4	47.0	38.5	51.5	62.0	70.6	51.4	68.6	82.7	94.1
	0.65	23.7	31.7	38.2	43.4	35.6	47.5	57.3	65.1	47.4	63.3	76.4	86.9
Rolling Terrain													
0.09	0.50	36.9	49.3	59.4	67.6	55.4	74.0	89.2	101.4	73.8	98.6	118.9	135.2
	0.55	33.6	44.8	54.0	61.5	50.3	67.2	81.1	92.3	67.1	89.6	108.1	122.9
	0.60	30.8	41.1	49.5	56.3	46.1	61.6	74.3	84.5	61.5	82.2	99.1	112.7
	0.65	28.4	37.9	45.7	52.0	42.6	56.9	68.6	78.0	56.8	75.9	91.5	104.0
0.10	0.50	33.2	44.4	53.5	60.9	49.8	66.6	80.3	91.3	66.4	88.7	107.0	121.7
	0.55	30.2	40.4	48.6	55.4	45.3	60.5	73.0	83.0	60.4	80.7	97.3	110.6
	0.60	27.7	37.0	44.6	50.7	41.5	55.5	66.9	76.1	55.4	74.0	89.2	101.4
	0.65	25.6	34.1	41.2	46.8	38.3	51.2	61.7	70.2	51.1	68.3	82.3	93.6
0.11	0.50	30.2	40.3	48.6	55.3	45.4	60.5	73.0	83.0	60.4	80.7	97.3	110.6
	0.55	27.5	36.7	44.2	50.3	41.2	55.0	66.2	75.4	54.9	73.3	88.4	100.6
	0.60	25.2	33.6	40.5	46.1	37.7	50.4	60.6	69.2	50.3	67.2	81.1	92.2
	0.65	23.2	31.0	37.4	42.6	34.9	46.5	56.1	63.8	46.5	62.1	74.8	85.1
0.12	0.50	27.7	37.0	44.6	50.7	41.5	55.5	66.9	76.1	55.4	74.0	89.2	101.4
	0.55	25.2	33.6	40.5	46.1	37.7	50.4	60.6	69.2	50.3	67.2	81.1	92.2
	0.60	23.1	30.8	37.2	42.3	34.5	46.2	55.7	63.4	46.1	61.6	74.3	84.5
	0.65	21.3	28.4	34.3	39.0	31.3	42.7	51.4	58.5	42.6	56.9	68.6	78.0

Note: Assumptions include the following: 12ft lanes, 6ft sides, 0.92 PHF, 0.2 trucks, $f_G = 0.97$, 12-ft lanes, and 5-0 lanes. Operation values do not represent specific segments of service.

ACTIVE TRAFFIC MANAGEMENT AND OTHER MEASURES TO IMPROVE PERFORMANCE

Active traffic management (ATM) consists of the dynamic and continuous monitoring and control of traffic operations on a facility to improve its performance. Examples of ATM measures include congestion pricing, ramp metering, changeable message signs, incident response programs, and speed harmonization (variable speed limits).

ATM measures can influence both the nature of demand for the facility and the ability of the facility to deliver the capacity tailored to serve the demand. ATM measures can improve facility performance, sometimes significantly.

Other advanced design and management measures, not specifically included in the definition of ATM, can also significantly improve facility performance. These measures include auxiliary lanes, narrow lanes, high occupancy vehicle (HOV) lanes, temporary use of shoulders, and designated truck lanes and ramps.

This methodology does not reflect all these measures. However, ramp metering can be taken into account by altering on-ramp demands in accordance

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with metering rates. Auxiliary lanes and narrow lanes are taken into account in the segment methodologies for basic freeway segments and weaving segments.

Other measures are not accounted for in this methodology. Chapter 35 provides a more detailed discussion of ATM and other advanced design and management strategies and insight into how their impacts may be evaluated

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2. METHODOLOGY

The methodology presented in this chapter provides for the integrated analysis of a freeway facility composed of contiguous segments. The methodology builds on the models and procedures for individual segments, as described in Chapter 11, Basic Freeway Segments, Chapter 12, Freeway Weaving Segments, and Chapter 13, Freeway Merge and Diverge Segments.

SCOPE OF THE METHODOLOGY

Because the freeway facility methodology builds on the segment methodologies of Chapters 11, 12, and 13, it incorporates all aspects of those chapters' methodologies. This methodology adds the ability to consider a number of linked segments over a number of time periods and to determine some overall operational parameters that allow for the assessment of a facility LOS and capacity.

This methodology also adds the ability to analyze operations when LOS F exists on one or more segments of the defined facility. In Chapters 11, 12, and 13, the existence of a breakdown (LOS F) is identified for a given segment, as appropriate. The segment methodologies do not, however, provide tools for analyzing the impacts of such breakdowns over time and space.

The methodology analyzes a set of connected segments over a set of sequential 15-min periods. In deciding which segments and time periods to analyze, two principles should be observed.

1. The first and last segments of the defined facility should not operate at LOS F.
2. The first and last time periods of the analysis should not include any segments that operate at LOS F.

When the first segment operates at LOS F, there is a queue extending upstream that is not included in the facility definition and that therefore cannot be analyzed. When the last segment operates at LOS F, there may be a downstream bottleneck outside the facility definition. Again, the impacts of this congestion cannot be evaluated when it is not fully contained within the defined facility. LOS F in either the first or last time period creates similar problems with regard to time. If the first time period is at LOS F, then LOS F may exist in previous time periods as well. If the last time period is at LOS F, subsequent periods may be at LOS F as well. The impacts of a breakdown cannot be fully analyzed unless it is fully contained within the defined facility and defined total analysis period. The same problems would exist if the analysis were conducted by using simulation.

There is no limit to the number of time periods that can be analyzed. The length of the freeway should be less than the distance a vehicle traveling at the average speed can achieve in 15 min. This specification generally results in a maximum facility length between 9 and 12 mi.

This methodology is based on research sponsored by the Federal Highway Administration (1).

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LIMITATIONS OF THE METHODOLOGY

The methodology has the following limitations:

1. The methodology does not account for the delays caused by vehicles using alternative routes or vehicles leaving before or after the analysis period.
2. Multiple overlapping breakdowns or bottlenecks are difficult to analyze and cannot be fully evaluated by this methodology. Other tools may be more appropriate for specific applications beyond the capabilities of the methodology. Consult Chapter 6, HCM and Alternative Analysis Tools, for a discussion of simulation and other models.
3. Spatial, temporal, modal, and total demand responses to traffic management strategies are not automatically incorporated into the methodology. On viewing the facility traffic performance results, the analyst can modify the demand input manually to analyze the effect of user-demand responses and traffic growth. The accuracy of the results depends on the accuracy of the estimation of user-demand responses.
4. The methodology can address local oversaturated flow but cannot directly address systemwide oversaturation flow conditions.
5. The completeness of the analysis will be limited if freeway segments in the first time interval, the last time interval, and the first freeway segment (in all time periods) have demand to capacity ratios greater than 1.00. The rationale for these limitations is discussed in the section on demand-to-capacity ratio.
6. The existence of HOV lanes on freeways raises the issues of the operating characteristics of such lanes and their effect on operating characteristics on the remainder of the freeway. The methodology does not directly address separated HOV facilities and does not account for the interactions between HOV lanes and mixed-flow lanes and the weaving that may be produced.
7. The method does not address conditions in which off-ramp capacity limitations result in queues that extend onto the freeway or affect the behavior of off-ramp vehicles.
8. The method does not address toll plaza operations or their effect on freeway facility operations.

Given enough time, the analyst can analyze a completely undersaturated time–space domain manually, although it is very difficult and time consuming. It is not expected that analysts will ever manually analyze a time–space domain that includes oversaturation. FREEVAL-2010 is a computational engine that can be used to implement the methodology, regardless of whether the time–space domain contains oversaturated segments and time periods. It is available in the Technical Reference Library section of Volume 4 of the *Highway Capacity Manual* (HCM).

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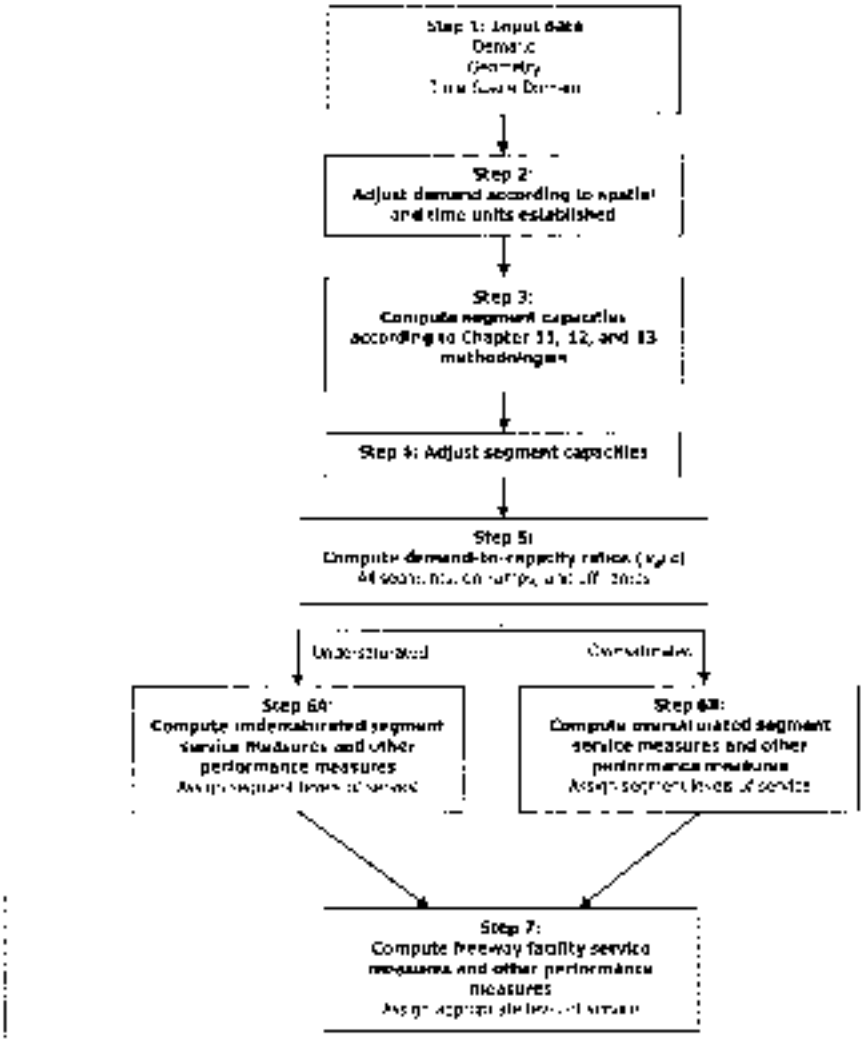
Because this chapter's methodology incorporates the methodologies for basic, weaving, merging, and diverging freeway segments, the limitations of those procedures also apply here.

The method does not include analysis of the street-side terminals of freeway on- and off-ramps. The methodologies of Chapters 18, 19, 20, and 21 should be used for intersections that are signalized, two-way STOP-controlled, all-way STOP-controlled, and roundabouts, respectively. Chapter 22, Interchange Ramp Terminals, provides a more comprehensive analysis of freeway interchanges where the street-side ramp terminals are signalized intersections or roundabouts.

OVERVIEW

Exhibit 10-10 summarizes the methodology for analyzing freeway facilities. The methodology adjusts vehicle speeds appropriately to account for the effects in adjacent segments. The methodology can analyze freeway traffic management strategies only in cases for which 15-min intervals are appropriate and for which reliable data for estimated capacity and demand exist.

Exhibit 10-10
Freeway Facility Methodology



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COMPUTATIONAL STEPS

The purpose of this section is to describe the methodology's computational modules. To simplify the presentation, the focus is on the functions of, and rationale for, each module. Chapter 25 presents an expanded version of this section, including all the supporting analytical models and equations.

Step 1: Input Data

Data concerning demand, geometry, and the time–space domain must be specified. As the methodology builds on segment analyses, all data for each segment and each time period must be provided, as indicated in Chapter 11 for basic freeway segments, Chapter 12 for weaving segments, and Chapter 13 for merge and diverge segments.

Demand

Demand flow rates must be specified for each segment and time period. Because analysis of multiple time periods is based on consecutive 15-min periods, the demand flow rates for each period must be provided. This condition is in addition to the requirements for isolated segment analyses.

Demand flow rates must be specified for the entering freeway mainline flow and for each on ramp and off-ramp within the defined facility. The following information is needed for each time period to determine the demand flow rate:

- Demand flow rate (veh/h),
- Percent trucks (%),
- Percent RVs (%), and
- Driver population factor (f_p).

For weaving segments, demand flow rates must be identified by component movement: freeway to freeway, ramp to freeway, freeway to ramp, and ramp to ramp. Where this level of detail is not available, the following procedure may be used to estimate the component flows. It is not recommended, however, as weaving segment performance is sensitive to the split of demand flows.

- *Ramp–ramp segments:* Assume that the ramp-to-ramp flow is 0. The ramp-to-freeway flow is then equal to the on ramp flow, the freeway-to-ramp flow is then equal to the off-ramp flow.
- *Major–major segments:* On-ramp flow is apportioned to the two exit legs (freeway and ramp) in the same proportion as the total flow on the exit legs (freeway and ramp).

The driver population factor is normally 1.00, unless the driver population is dominated by unfamiliar users, in which case a value between 0.85 and 1.00 is assigned, on the basis of local characteristics and knowledge.

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Geometry

All geometric features for each segment of the facility must be specified, including the following:

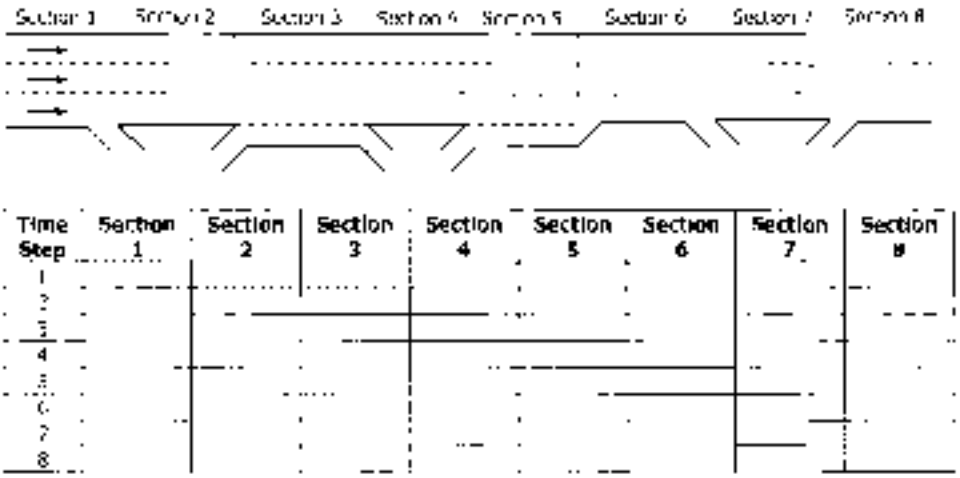
- Number of lanes;
- Average lane width;
- Right-side lateral clearance;
- Terrain;
- Free-flow speed; and
- Location of merge, diverge, and weaving segments, with all internal geometry specified, including the number of lanes on ramps and at ramp–freeway junctions or within weaving segments, lane widths, existence and length of acceleration or deceleration lanes, distances between merge and diverge points, and the details of lane configuration where relevant.

Geometry does not change by time period, so this information is given only once, regardless of the number of time periods under study.

Time–Space Domain

A time–space domain for the analysis may be established. The domain consists of a specification of the freeway sections included in the defined facility and an identification of the time intervals for which the analysis is to be conducted. A typical time–space domain is shown in Exhibit 10-11.

Exhibit 10-11
Example Time–Space Domain for Freeway Facility Analysis



The horizontal scale indicates the distance along the freeway facility. A freeway section boundary occurs where there is a change in demand—that is, at each on-ramp or off-ramp or where a lane is added or dropped. These areas are referred to as *sections*, but many adjustments will be made within the procedure to determine where *section* boundaries should be for analysis. This process relies on the influence areas of merge, diverge, and weaving segments, discussed earlier in this chapter, and on variable length limitations specified in Chapter 12 for weaving segments and in Chapter 13 for merge and diverge segments.

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The vertical scale indicates the study time duration. Time extends down the time–space domain, and the scale is divided into 15-min intervals. In the example shown, there are 8 sections and 8 time steps, yielding $8 \times 8 = 64$ time–space cells, each of which will be analyzed within the methodology.

The boundary conditions of the time–space domain are extremely important. The time–space domain will be analyzed as an independent freeway facility having no interaction with upstream or downstream portions of the freeway or any connecting facilities, including other freeways and surface facilities. Therefore, no congestion should occur along the four boundaries of the time–space domain. The cells located along the four boundaries should all have demands less than capacity and should contain undersaturated flow conditions. A proper analysis of congestion within the time–space domain can occur only if the congestion is limited to internal cells not along the time–space boundaries.

Converting the Horizontal Scale from Sections to Analysis Segments

The sections of the defined freeway facility are established by using points where demand changes or where lanes are added or subtracted. This, however, does not fully describe individual segments for analysis within the methodology. The conversion from sections to analysis segments can be done manually by applying the principles discussed here.

Chapter 13, Freeway Merge and Diverge Segments, indicates that each merge segment extends from the merge point to a point 1,500 ft downstream of it. Each diverge segment extends from the diverge point to a point 1,500 ft upstream of it. This allows for a number of scenarios affecting the definition of analysis segments within the defined freeway.

Consider the illustration of Exhibit 10-12. It shows a one-lane on-ramp followed by a one-lane off-ramp with no auxiliary lane between them. The illustration assumes that there are no upstream or downstream ramps or weaving segments that impinge on this section.

In Exhibit 10-12(a), there are 4,000 ft between the two ramps. Therefore, the merge segment extends 1,500 ft downstream, and the diverge segment extends 1,500 ft upstream, which leaves a 1,000-ft basic freeway segment between them.

In Exhibit 10-12(b), there are 3,000 ft between the two ramps. The two 1,500-ft ramp influence areas define the entire length. Therefore, there is no basic freeway segment between the merge and diverge segments.

In Exhibit 10-12(c), the situation is more complicated. With only 2,000 ft between the ramps, the merge and diverge influence areas overlap for a distance of 1,000 ft.

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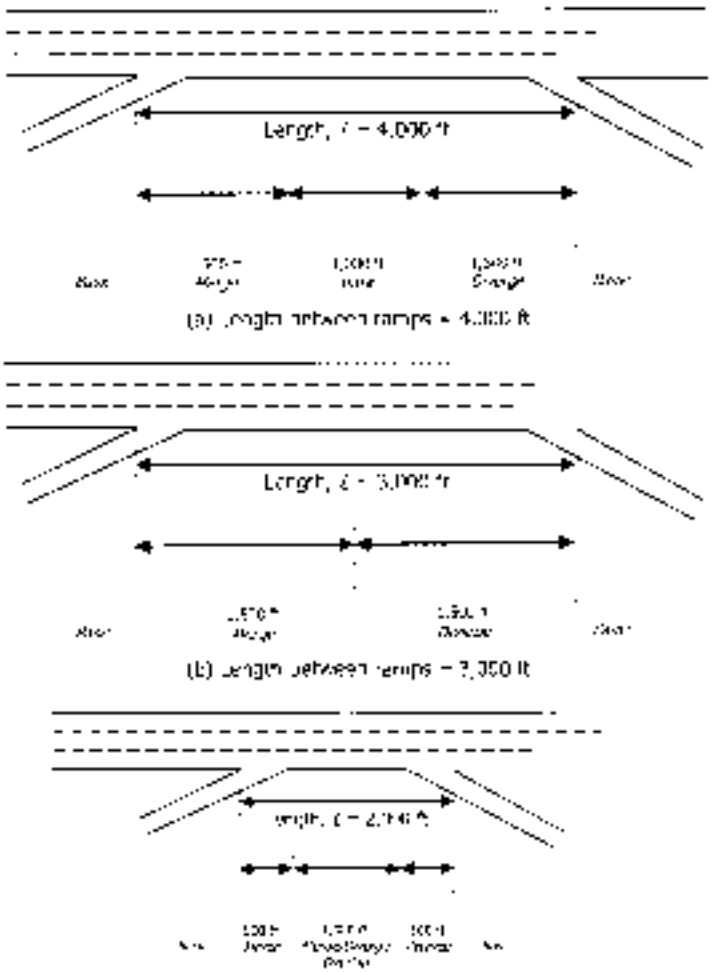
Exhibit 10-12
Defining Analysis Segments for a Ramp Configuration



Chapter 13, Freeway Merge and Diverge Segments, covers this situation where ramp influence areas overlap. The analysis is conducted for each ramp separately. The analysis producing the worst LOS (or service measure value if the LOS is equivalent) is used to define operations in the overlap area.

The facility methodology goes through the logic of distances and segment definitions to convert section boundaries to segment boundaries for analysis. If the distance between an on-ramp and off-ramp is less than the full influence area of 1,500 ft, the worst case is applied to the distance between the ramps, while basic segment criteria are applied to segments upstream of the on-ramp and downstream of the off-ramp.

A similar situation can arise where weaving configurations exist. Exhibit 10-13 illustrates a weaving configuration within a defined freeway facility. In this case, the distance between the merge and diverge ends of the configuration must be compared with the maximum length of a weaving segment, L_{max}. If the distance between the merge and diverge points is less than or equal to L_{max}, then the entire segment is analyzed as a weaving segment, as shown in Exhibit 10-13(a).

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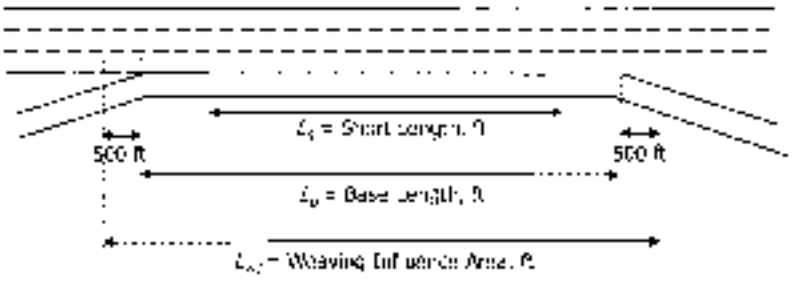
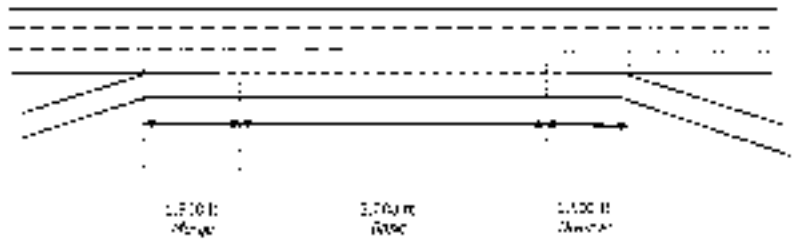


(a) Case I: $L_B \leq L_{W(1)}$ (weaving segment exists)



(b) Case II: $L_B > L_{W(1)}$ (isolated merge and diverge exists)

Exhibit 10-13
Defining Analysis Segments for a Weaving Configuration

Three lengths are involved in analyzing a weaving segment:

- The base length of the segment, measured from the points where the edges of the travel lanes of the merging and diverging roadways converge (L_B);
- The influence area of the weaving segment (L_W), which includes 500 ft upstream and downstream of L_B; and
- The short length of the segment, defined as the distance over which lane changing is not prohibited or discouraged by markings (L_S).

The latter is the length that is used in all the prediction models for weaving segment analysis. The results of these models, however, apply to a distance of L_S + 500 ft upstream and L_S + 500 ft downstream. For further discussion of the various lengths applied to weaving segments, consult Chapter 12.

If the distance between the merge and diverge points is greater than $L_{W(1)}$, then the merge and diverge segments are too far apart to form a weaving segment. As shown in Exhibit 10-13(b), the merge and diverge segments are treated separately, and any distance remaining between the merge and diverge influence areas is treated as a basic freeway segment.

In the Chapter 12 weaving methodology, the value of $L_{W(1)}$ depends on a number of factors, including the split of component flows, demand flows, and other traffic factors. A weaving configuration could therefore qualify as a weaving segment in some analysis periods and as separate merge, diverge, and possibly basic segments in others.

In segmenting the freeway facility for analysis, merge, diverge, and weaving segments are identified as illustrated in Exhibit 10-12 and Exhibit 10-13. All segments not qualifying as merge, diverge, or weaving segments are basic freeway segments.

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However, a long basic freeway section may have to be divided into multiple segments. This situation occurs when there's a sharp break in terrain within the section. For example, a 5-mi section may have a constant demand and a constant number of lanes. If there is a 2-mi level terrain portion followed by a 4% grade that is 3 mi long, then the level terrain portion and the specific grade portion would be established as two separate, consecutive basic freeway segments.

Step 2: Adjust Demand According to Spatial and Time Units Established

Traffic counts taken at each entrance to and exit from the defined freeway facility (including the mainline entrance and mainline exit) for each time interval serve as inputs to the methodology. While entrance counts are considered to represent the current entrance demands for the freeway facility (provided that there is not a queue on the freeway entrance), the exit counts may not represent the current exit demands for the freeway facility because of congestion within the defined facility.

For planning applications, estimated traffic demands for each entrance to and exit from the freeway facility for each time interval serve as input to the methodology. The sum of the input demands must equal the sum of the output demands in every time interval.

Once the entrance and exit demands are calculated, the demands for each cell in every time interval can be estimated. The segment demands can be thought of as filtering across the time–space domain and filling each cell of the time–space matrix.

Demand estimation is needed if the methodology uses actual freeway counts. If demand flows are known or can be projected, they are used directly without modification.

The methodology includes a demand estimation model that converts the input set of freeway exit 15-min counts to a set of vehicle flows that desire to exit the freeway in a given 15-min period. This demand may not be the same as the 15-min exit count because of upstream congestion within the defined freeway facility.

The procedure sums the freeway entrance demands along the entire directional freeway facility, including the entering mainline segment, and compares this sum with the sum of freeway exit counts along the direct-to-final freeway facility, including the departing mainline segment. This procedure is repeated for each time interval. The ratio of the total facility entrance counts to total facility exit counts is called the *time interval scale factor* and should approach 1.00 when the freeway exit counts are, in fact, freeway exit demands.

Scale factors greater than 1.00 indicate increasing levels of congestion within the freeway facility, with exit counts underestimating the actual freeway exit demands. To provide an estimate of freeway exit demand, each freeway exit count is multiplied by the time interval scale factor.

Equation 10-6 and Equation 10-7 summarize this process.

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$$f_{adj} = \frac{\sum V_{entry}}{\sum V_{exit}}$$

Equation 10-6

$$V_{adj,exit} = V_{exit} \times f_{adj}$$

Equation 10-7

where

f_{adj} = unit-interval scale factor for time period t,

V_{entry} = 15-min entering count for time period t and entering location j (veh),

V_{exit} = 15-min exit count for time period t and exiting location j (veh), and

$V_{adj,exit}$ = adjusted 15-min exit demand for time period t and exiting location j (veh).

Once the entrance and exit demands are determined, the traffic demands for each section and each time period can be calculated. On the time–space domain, section demands can be viewed as projecting horizontally across Exhibit 10-11, with each cell containing an estimate of its 15-min demand.

Because each time period is separately balanced, it is advisable to limit the total length of the defined facility to a distance that can be traversed within 15 min. In practical terms, this practice limits the length of the facility to 9 to 12 mi.

Step 3: Compute Segment Capacities According to Chapter 11, 12, and 13 Methodologies

Segment capacity estimates are determined by the methodologies of Chapter 11 for basic freeway segments, Chapter 12 for weaving segments, and Chapter 13 for merge and diverge segments. All estimates of segment capacity should be carefully reviewed and compared with local knowledge and available traffic information for the study site, particularly where known bottlenecks exist.

On-ramp and off-ramp roadway capacities are also determined in this step with the Chapter 13 methodology. On-ramp demands may exceed on-ramp capacities and limit the traffic demand entering the facility. Off-ramp demands may exceed off-ramp capacities and cause congestion on the freeway, although that impact is not accounted for in this methodology.

All capacity results are stated in vehicles per hour under prevailing roadway and traffic conditions.

The effect of a predetermined ramp-metering plan can be evaluated in this methodology by overriding the computed ramp roadway capacities. The capacity of each entrance ramp in each time interval is changed to reflect the specified ramp-metering rate. This feature not only allows for evaluating a prescribed ramp-metering plan but also permits the user to improve the ramp-metering plan through experimentation.

Freeway design improvements can be evaluated with this methodology by modifying the design features of any portion of the freeway facility. For example, the effects of adding auxiliary lanes at critical locations and full lanes over multiple segments can be assessed.

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Step 4: Adjust Segment Capacities

Segment capacities can be affected by a number of conditions not normally accounted for in the segment methodologies of Chapters 11, 12, and 13. These values may include the effects of short-term and long-term lane closures for construction or major maintenance operations, the effects of adverse weather conditions, and the effects of other environmental factors.

At lane drops, permanent reductions in capacity occur. They are included in the base methodology, which automatically accounts for the capacity of segments on the basis of the number of lanes in the segment and other prevailing conditions.

Capacity Reductions due to Construction and Major Maintenance Operations

Capacity reductions due to construction activities can be divided into short-term work zone lane closures, typically for maintenance, and long-term lane closures, typically for construction. A primary distinction between short-term work zones and long-term construction zones is the nature of the barriers used to demarcate the work area. Long-term construction zones generally use portable concrete barriers, while short term work zones use standard channelizing devices (e.g., traffic cones, drums) in accordance with the *Manual on Uniform Traffic Control Devices for Streets and Highways* (2). Capacity reductions due to long-term construction or major maintenance operations generally last several weeks, months, or even years, depending on the nature of the work. Short-term closures generally last a few hours.

Short-Term Work Zones

Research (3) suggests that a capacity of 1,600 pc/h/ln be used for short-term freeway work zones, regardless of the lane-closure configuration. However, for some types of closures, a higher value could be appropriate.

This base value should be adjusted for other conditions, as follows:

1. *Intensity of work activity*: The intensity of work activity refers to the number of workers on the site, the number and size of work vehicles in use, and the proximity of the work activity to the travel lanes. Several types of work also contribute to intensity in terms of rubbernecking by drivers passing through the site. Research (3) suggests that the base value of 1,600 pc/h/ln be adjusted by as much as ±10% for work activity that is more or less intensive than normal. It does not, however, define what constitutes "normal" intensity, so this factor should be applied on the basis of professional judgment and local experience.
2. *Effects of heavy vehicles*: Because the base value is given in terms of pc/h/ln, it is recommended that the heavy vehicle adjustment factor (f_{HV}) be applied. A complete discussion of the heavy vehicle adjustment factor and its determination are included in Chapter 12, Basic Freeway Segments. Equation 12-5 shows how the factor is determined.

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$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$ **Equation 10-8**

where

f_{HV} = heavy-vehicle adjustment factor,

P_T = proportion of trucks and buses in the traffic stream,

P_R = proportion of RVs in the traffic stream,

E_T = passenger-car equivalent for trucks and buses, and

E_R = passenger-car equivalent for RVs.

Passenger car equivalents for trucks and buses and for RVs may be found in Chapter 13, Basic Freeway Segments.

7. *Presence of ramps:* If there is an entrance ramp within the taper area approaching the lane closure or within 500 ft downstream of the beginning of the full lane closure, the ramp will have a noticeable effect on the capacity of the work zone for handling mainline traffic. This situation arises in two ways, (a) the ramp traffic generally forces its way in, so it directly reduces the amount of mainline traffic that can be handled, and (b) the added turbulence in the merge area may slightly reduce capacity (even though such turbulence does not reduce capacity on a normal freeway segment without lane closures). If at all possible, on-ramps should be located at least 1,500 ft upstream of the beginning of the full lane closure to maximize the total work zone throughput. If that cannot be done, then either the ramp volume should be added to the mainline volume to be served or the capacity of the work zone should be decreased by the ramp volume (up to a maximum of one-half of the capacity of one lane) on the assumption that, at very high volumes, mainline and ramp vehicles will alternate.

Equation 10-9 is used to estimate the resulting reduced capacity in vehicles per hour

$$c_a = \{[(1{,}600 - I) \times f_{HV}] \times N\} - R$$ **Equation 10-9**

where

c_a = adjusted mainline capacity (veh/h),

I = adjustment factor for type, intensity, and proximity of work activity, pc/h/ln (ranges between +150 pc/h/ln),

f_{HV} = heavy-vehicle adjustment factor,

N = number of lanes open through the work zone, and

R = manual adjustment for on-ramps (veh/h).

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Long-Term Construction Zones

There have been many studies of long-term construction zone capacities. They are summarized in Exhibit 10-14.

Exhibit 10-14
Capacity of Long-Term Construction Zones (veh/h/ln)

State	Normal Lanes to Reduced Lanes						Source
	2 to 1	3 to 2	3 to 1	4 to 3	4 to 2	4 to 1	
TX	1,310		1,170				[4]
NC	1,590		1,640				[5]
CT	1,500–1,850		1,500–1,800				[6]
MD	1,240	1,050	960	1,450	1,120		[7]
NE	1,635–1,670		1,635–1,700				[8]
OR	1,400–1,600		1,400–1,600				[9]
SC	950		950				[9]
WA	1,350		1,450				[9]
WI	1,550–1,700		1,700–2,000		1,800–2,100		[10, 11]
IL	1,800		1,800				[12]
VA	1,600	1,000	1,300	1,300	1,000	1,000	[13]
CA	1,400–1,600	1,400–1,600	1,400–1,600	1,400–1,600	1,400–1,600	1,400–1,600	[14]
MA	1,240	1,490	1,170	1,520	1,480	1,172	[15]
Default	**1,400**	**1,450**	**1,450**	**1,500**	**1,450**	**1,350**	

Source: Adapted from Dudek et al. (16).

It is easy to see from Exhibit 10-14 that capacities through long-term construction zones are highly variable and depend on many site-specific characteristics. Therefore, it is better to base this adjustment on local data and experience. If such data do not exist and cannot be reasonably acquired, the default values of Exhibit 10-14 may be used to provide an approximate estimate of construction zone capacity.

Lane-Width Consideration

The impact of lane width on general freeway operations is incorporated into the methodology of Chapter 11, Basic Freeway Segments, for determining free-flow speed. As free-flow speed affects capacity, it follows that restricted lane widths will negatively affect capacity.

As free-flow speeds are not estimated specifically for work or construction zones, it is appropriate to add an adjustment factor for the effect of lane widths narrower than 12 ft in a work or construction zone. The factor f_{ln} would be added to Equation 10-9, as shown in Equation 10-10:

Equation 10-10

$$c_w = c_i \times f_{ln}$$

where c_i is the adjusted capacity of the work or construction zone reflecting the impact of restricted lane width, in vehicles per hour, and all other variables are as previously defined.

The value of the adjustment factor f_{ln} is 1.01 for 12 ft lanes, 0.91 for lanes between 10.0 and 11.9 ft, and 0.85 for lanes between 9.0 and 9.9 ft. If lanes narrower than 9.0 ft are in use, local observations should be made to calibrate an appropriate adjustment.

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Capacity Reductions due to Weather and Environmental Conditions

A number of studies have attempted to address the impacts of adverse weather and environmental conditions on the capacity of freeways. Comprehensive results on a range of conditions in Iowa, summarized in Exhibit 10-15, are provided elsewhere (74).

Type of Condition	Intensity of Condition	Percent Reduction in Capacity	
		Average	Range
Rain	>0 ≤ 0.10 in/h	2.01	1.17–3.43
	>0.10 < 0.25 in/h	7.24	5.67–10.10
	>0.25 in/h	14.13	10.72–17.67
Snow	>0 ≤ 0.05 in/h	4.29	3.44–5.51
	>0.05 ≤ 0.10 in/h	8.06	5.48–11.53
	>0.10 ≤ 0.50 in/h	11.04	7.45–13.75
	>0.50 in/h	22.43	19.53–27.62
Temperature	<0°F ≥ -4°F	1.07	1.06–1.08
	<4°F ≥ -4°F	1.50	1.48–1.52
	<-4°F	8.45	6.62–10.27
Wind	>10 ≤ 20 mi/h	1.07	0.74–1.41
	>20 mi/h	1.47	0.74–2.19
Visibility	<1 > 0.50 mi	9.67	One site
	<0.50 < 0.25 mi	11.07	One site
	<0.25 mi	10.49	One site

Source: Adapted from Agarwal et al. (74).

Exhibit 10-15
Capacity Reductions due to Weather and Environmental Conditions in Iowa

Additional information is available in the literature. Additional data and information on the impacts of rain on freeway capacity are provided elsewhere (75, 76), as are information on the effects of snow (76) and insights and information on the effects of fog (77, 78).

A study of capacity on German autobahns provides data on the differences between daytime and nighttime conditions on wet or dry pavements (79). Exhibit 10-16 summarizes these results.

Freeway Lanes	Weekday or Weekend	Daylight Dry	Dark Dry	Daylight Wet	Dark Wet
6	Weekday (% change*)	1,489	1,299 (-14%)	1,310 (-12%)	923 (-38%)
6	Weekend (% change*)	1,480	1,099 (-21%)	1,014 (-27%)	—
4	Weekday (% change*)	1,739	1,415 (-19%)	1,421 (-18%)	913 (-47%)
4	Weekend (% change*)	1,551	1,158 (-25%)	1,104 (-29%)	—

Note: *Percent change from daylight, dry conditions for the same day of week.
Source: Adapted from Brilon and Ponzlet (79).

Exhibit 10-16
Capacities on German Autobahns Under Various Conditions (veh/h/ln)

This exhibit is interesting in that the daylight, dry capacities of German autobahns are somewhat less than might be expected on U.S. freeways. This situation could be due to the higher speeds that prevail on the autobahns and heavy-vehicle presence, which are not reflected in these vehicle/h/ln statistics.

The daylight wet versus dry capacity reductions are greater in Exhibit 10-16 than those shown in Exhibit 10-15, which may again be a reflection of different driver behavior characteristics in Germany and the United States. Darkness alone has a significant impact on autobahn capacities. Since winter peak hours occur

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when it is dark in many areas of the country, such reductions are important to incorporate.

The difference between weekday and weekend capacities is also interesting and is on the order of 7% to 10% in Exhibit 10-16. This impact is generally reflected in the use of a driver-population factor f_p (see Chapter 11). Weekend driving populations may not be as familiar with the facility as weekday commuters. Even familiar users may not drive as aggressively on weekend recreational or other trips when the pressure of a specific schedule may be less than is present during the week.

Capacity Reductions due to Traffic Accidents or Vehicular Breakdowns

Capacity reductions due to traffic accidents or other incidents are generally short-lived, ranging from less than 1 h before they can be cleared to as long as 2 h for an accident involving severe injuries, fatalities, hazardous materials cleanup, or cleanup of other materials from vehicles involved in accidents.

One study (*20*) reported the mean duration of a traffic incident to be 37 min, with more than half the incidents lasting 30 min or less and 82% lasting less than 1 h.

Exhibit 10-17 summarizes the results of two studies (*21, 22*) on the capacity impacts of lane blockages due to incidents, including accidents. An incident's effect on capacity depends on the proportion of the traveled roadway that is blocked and on the number of lanes on the freeway at that point.

Exhibit 10-17
Proportion of Freeway Segment Capacity Available Under Incident Conditions

Number of Lanes (One Direction)	Shoulder Disablement	Shoulder Accident	One Lane Blocked	Two Lanes Blocked	Three Lanes Blocked
2	0.95	0.81	0.35	0.00	N/A
3	0.99	0.83	0.49	0.17	0.00
4	0.99	0.85	0.58	0.25	0.13
5	0.99	0.87	0.65	0.40	0.20
6	0.99	0.89	0.71	0.50	0.26
7	0.99	0.91	0.75	0.57	0.36
8	0.99	0.93	0.78	0.63	0.41

In a blocked lane, the loss of capacity is likely to be greater than the proportion of the roadway that is blocked. A one-lane blockage on a two-lane directional freeway segment (50% of the roadway blocked) reduces capacity to 35% of the original value, not a sample. The added loss of capacity arises because drivers slow to look at the incident while they are aware of it and are slow to react to the possibility of squeezing up or move through the incident area.

The "rubbernecking" factor is also responsible for a reduction in capacity in the direction of travel opposite to that in which the accident or incident occurred. While no quantitative studies of this impact have been conducted, experience suggests that the severity of the accident or incident plays a significant role in the impact of rubbernecking. The reduction in capacity may range from 5% for a single-vehicle accident with no emergency vehicle present to as high as 27% for a multivehicle accident with several emergency vehicles.

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Applying Capacity Reductions

There are several ways to use the information on reduced capacities discussed in this section.

Quick approximations simply require that the capacity of each freeway facility segment be estimated by using the methodologies of Chapters 11, 12, and 13; be reduced by all the impacts of work zones, weather, environment, and accidents or incidents that are present, in accord with the information provided here. The methodology continues using these reduced capacities.

If speed information is available, then the free-flow speed through the restricted capacity area can be used to select an appropriate speed–flow curve for analysis (from Chapter 11). The reduced free-flow speed results in a reduced capacity. An example of this approach is illustrated in Exhibit 10-18, which is based on speed data presented elsewhere (16, 19).

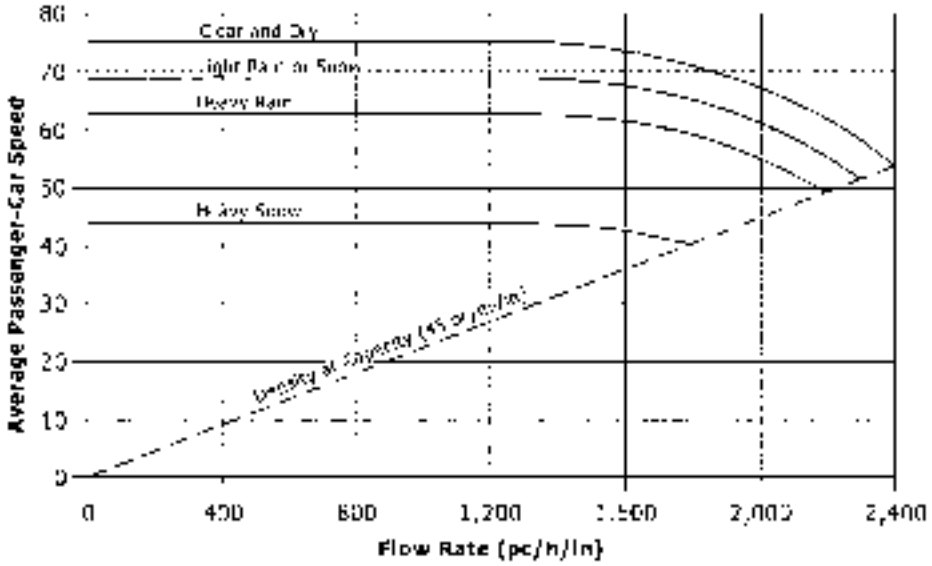

Exhibit 10-18
Illustration of Speed–Flow Curves for Different Weather Conditions

Note: Free-flow speed = 70 mi/h (base condition).

For most temporary capacity reductions, the only information available relates to capacity. In most of these cases, speed conditions can be reasonably estimated. For example, in construction zones, a reduced speed limit is usually posted, and lower speeds can be expected to occur, particularly when actual construction operations are taking place. Likewise, for incidents, traffic naturally slows as drivers pass the incident site where rubbernecking takes place. Exhibit 10-19 shows an example of modeling such cases on the basis of a downward-shifted speed–flow curve.

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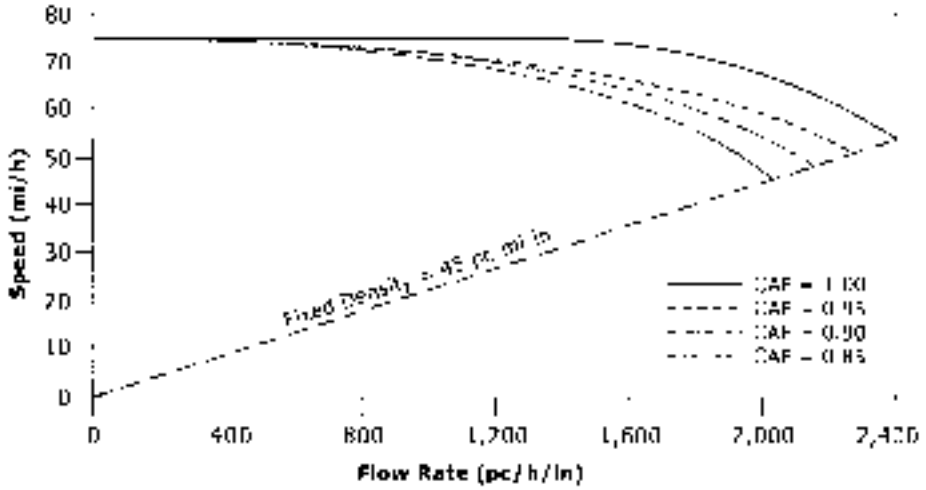
Exhibit 10-19
Illustration of Adjusted Speed–Flow Curves for Indicated Capacity Reductions



Note: Free-flow speed = 75 mi/h (base conditions); CAF = capacity adjustment factor (percent of nominal capacity).

If the analyst has no interest in speeds, the capacity reduction could be modeled by using a fractional number of lanes that would reflect the new capacity of the roadway rather than the actual number of lanes present. For example, in the case of a four-lane directional freeway segment with two lanes blocked, Exhibit 10-17 indicates that only 25% of capacity would be available. This segment could be modeled as if only one lane were available through the incident (even though two are actually in use).

Some of the performance measures that result from this methodology, however, rely on speed. A simple approach that does not deal with speed consequences would result in an incomplete analysis. Consequently, an approach that uses modified speed–flow curves, as illustrated here, is recommended.

Step 5: Compute Demand-to-Capacity Ratios

Each cell of the time–space domain now contains an estimate of demand and capacity. A demand-to-capacity ratio can be calculated for each cell. The cell values must be carefully reviewed to determine whether all boundary cells have v/c ratios of 1.00 or less and to determine whether any cells in the interior of the time–space domain have v/c values greater than 1.00.

If any boundary cells have a v/c ratio greater than 1.00, further analyses may be significantly flawed:

1. If any cell in the first time interval has a v/c ratio greater than 1.00, there may have been oversaturated conditions in earlier time intervals without transfer of unsatisfied demand into the time–space domain of the analysis.
2. If any cell in the last time interval has a v/c ratio greater than 1.00, the analysis will be incomplete because the unsatisfied demand in the last time interval cannot be transferred to later time intervals.
3. If any cell in the last downstream segment has a v/c ratio greater than 1.00, there may be downstream bottlenecks that should be checked before

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proceeding with the analysis. If any cell in the first segment has a v/c ratio greater than 1.00, then oversaturation will extend upstream of the defined freeway facility, but its effects will not be analyzed within the time–space domain.

These checks do not guarantee that the boundary cells will not show v/c ratios greater than 1.00 later in the analysis. If these initial checks reveal boundary cells with v/c ratios greater than 1.00, then the time–space domain of the analysis should be adjusted to eliminate the problem.

As the analysis of the time–space domain proceeds, subsequent demand shifts may cause some boundary cell v/c ratios to exceed 1.00. In these cases, the problem should be reformulated or alternative tools applied. Most alternative tools will have the same problem if the boundary conditions experience congestion.

Another important check is to observe whether any cell in the interior of the time–space domain has a v/c ratio greater than 1.00. There are two possible outcomes:

1. If all cells have v/c ratios of 1.00 or less, then the entire time–space domain contains undersaturated flow, and the analysis is greatly simplified.
2. If any cell in the time–space domain has a v/c ratio greater than 1.00, then the time–space domain will contain both undersaturated and oversaturated cells. Analysis of oversaturated conditions is much more complex because of the interactions between freeway segments and the shifting of demand in both time and space.

If Case 1 exists, the analysis moves to Step 6A. If Case 2 exists, the analysis moves to Step 6B.

The v/c ratio for all on-ramps and off-ramps should also be examined. If an on-ramp demand exceeds the on-ramp capacity, the ramp demand flow rate should be adjusted to reflect capacity. Off ramps generally fail because of deficiencies at the ramp–street junction. They may be analyzed by procedures in Chapters 18–22, depending on the type of traffic control used at the ramp–street junction. These checks are done manually, and inputs to this methodology must be revised accordingly.

Steps 6A and 6B: Compute Undersaturated (6A)/Oversaturated (6B) Service Measures and Other Performance Measures

The analysis begins in the first cell in the upper-left corner of the time–space domain (the first segment in the first time interval) and continues downstream along the freeway facility for each segment in the first time interval. The analysis then returns to the first upstream segment in the second time interval and continues downstream along the freeway for each segment in the second time interval. This process continues until all cells in the time–space domain have been analyzed.

As each cell is analyzed in turn, its v/c ratio is checked. If the v/c ratio is 1.00 or less, the cell is not a bottleneck and is able to handle all traffic demand that

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wishes to enter. The process is continued in the order noted in the previous paragraph until a cell with a v/c ratio greater than 1.00 is encountered. Such a cell is labeled as a bottleneck. Because it cannot handle a flow greater than its capacity, the following impacts will occur:

1. The v/c ratio of the bottleneck cell will be exactly 1.00, as the cell processes a flow rate equal to its capacity.
2. Flow rates for all cells downstream of the bottleneck must be adjusted downward to reflect the fact that not all the demand flow at the bottleneck gets through. Downstream cells are subject to demand starvation due to the bottleneck.
3. The unsatisfied demand at the bottleneck cell must be stored in the upstream segments. Flow conditions and performance measures in these upstream cells are affected. Shock wave analysis is applied to estimate these impacts.
4. The unsatisfied demand stored upstream of the bottleneck cell must be transferred to the next time interval. This transfer is accomplished by adding the unsatisfied demand by desired destination to the origin–destination table of the next time interval.

This four-step process is implemented for each bottleneck encountered, following the specified sequence of cell analyses. If no bottlenecks are identified, the entire domain is undersaturated, and the sequence of steps for oversaturated conditions is not applied.

If a bottleneck is severe, the storage of unsatisfied demand may extend beyond the upstream boundary of the freeway facility or beyond the last time interval of the time–space domain. In such cases, the analysis will be flawed, and the time–space domain should be reconstructed.

After all demand shifts (in the case of one or more oversaturated cells) are estimated, each cell is analyzed by the methodologies of Chapter 11, Basic Freeway Segments; Chapter 12, Freeway Weaving Segments; and Chapter 13, Freeway Merge and Diverge Segments. Facility service and performance measures may then be estimated.

Undersaturated Conditions

For undersaturated conditions, the process is straightforward. Because there are no cells with v_i/c_i ratios greater than 1.00, the flow rate in each cell, v_i, is equal to the demand flow rate, v_i. Each segment analysis using the methodologies of Chapters 11, 12, and 13 will result in estimating a density, D_i, and a space mean speed, S_i.

When the analysis moves from isolated segments to a system, additional constraints may be necessary. A maximum-achievable-speed constraint is imposed to limit the prediction of speeds on segments downstream of a segment experiencing low speeds. This constraint prevents large speed fluctuations from segment to segment when the segment methodologies are directly applied. This process results in some changes in the speeds and densities predicted by the segment methodologies.

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For each time interval, Equation 10-3 is used to estimate the average density for the defined freeway facility. This result is compared with the criteria of Exhibit 10-7 to determine the facility LOS for the time period. Each time period will have a separate LOS. Although LOS is not averaged over time intervals, if desired, density can be averaged over time intervals.

Oversaturated Conditions

Once oversaturation is encountered, the methodology changes its temporal and spatial units of analysis. The spatial units become nodes and segments, and the temporal unit moves from a time interval of 15 min to smaller time periods, as recommended in Chapter 25, Freeway Facilities Supplemental.

Exhibit 10-20 illustrates the node–segment concept. A node is defined as the junction of two segments. Given that there is a node at the beginning and end of the freeway facility, there will always be one more node than the number of segments on the facility.

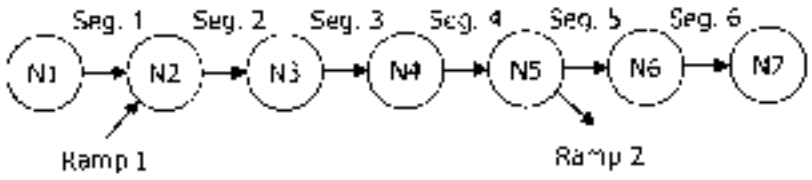
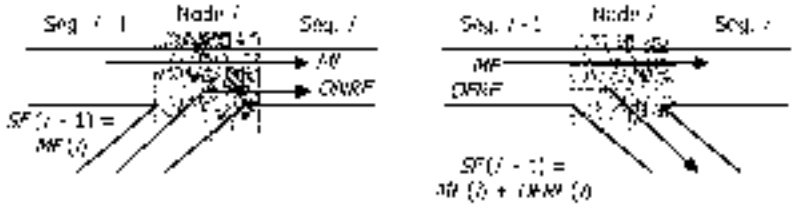


Exhibit 10-20
Node–Segment Representation of a Freeway Facility

The numbering of nodes and segments begins at the upstream end of the defined freeway facility and moves to the downstream end. The segment upstream of node i is numbered $i - 1$, and the downstream segment is numbered i, as shown in Exhibit 10-21.



Note: SF = segment flow, MF = mainline flow, ORRF = on-ramp flow, and OFRF = off-ramp flow.

Exhibit 10-21
Mainline and Segment Flow at On- and Off-Ramps

The oversaturated analysis moves from the first node to each downstream node for a time step. After the analysis for the first time step is complete, the same node analysis is performed for each subsequent time step.

When oversaturated conditions exist, many flow variables must be adjusted to reflect the upstream and downstream effects of bottlenecks. These adjustments are explained in general terms in the sections that follow and are fully detailed in Chapter 25.

Flow Fundamentals

As noted previously, segment flow rates must be calculated for each time step. They are used to estimate the number of vehicles on each segment at the

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end of every time step. The number of vehicles on each segment is used to track queue accumulation and discharge and to estimate the average segment density.

The conversion from standard 15-min time intervals to time steps (of lesser duration) occurs during the first oversaturated interval. Time steps are then used until the analysis is complete. This transition to time steps is critical because, at certain points in the methodology, future performance is estimated from past performance of an individual variable. Use of time steps also allows for a more accurate estimation of queues.

Service and other performance measures for oversaturated conditions use a simplified, linear flow–density relationship, as detailed in Chapter 25.

Segment Initialization

To estimate the number of vehicles on each segment for each time step under oversaturated conditions, it is necessary to begin the process with the appropriate number of vehicles in each segment. Determining this number is referred to as *segment initialization*.

A simplified queuing analysis is initially performed to account for the effects of upstream bottlenecks. The bottlenecks limit the number of vehicles that can proceed downstream.

To obtain the proper number of vehicles on each segment, the expected demand is calculated from the demands for and capacities of the segment, including the effects of all upstream segments. The expected demand represents the flow that would arrive at each segment if all queues were stacked vertically (i.e., if the queues had no upstream impacts). For all segments upstream of a bottleneck, the expected demand will equal the actual demand.

For the bottleneck segment and all further downstream segments, a capacity restraint is applied at the bottleneck when expected demand is computed. From the expected segment demand, the background density can be obtained for each segment by using the appropriate estimation algorithms from Chapters 11, 12, and 13.

Mainline Flow Calculation

Flows analyzed in oversaturated conditions are calculated for every time step and are expressed in vehicles per time step. They are analyzed separately on the basis of the origin and destination of the flow across the node. The following flows are defined:

1. The flow from the mainline upstream segment $i-1$ to the mainline downstream segment i is the mainline flow (MF_i).
2. The flow from the mainline to an off-ramp is the off-ramp flow (OFF_i).
3. The flow from an on-ramp to the mainline is the on-ramp flow (ONF_i).

Each of these flows is illustrated in Exhibit 10-21.

Mainline Input

The mainline input is the number of vehicles that wish to travel through a node during the time step. The calculation includes the effects of bottlenecks

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upstream of the subject node. The effects include the metering of traffic during queue accumulation and the presence of additional vehicles during queue discharge.

The mainline input is calculated by taking the number of vehicles entering the node upstream of the analysis node, adding on-ramp flows or subtracting off-ramp flows, and adding the number of unserved vehicles on the upstream segment. The result is the maximum number of vehicles that desire to enter a node during a time step.

Mainline Output

The mainline output is the maximum number of vehicles that can exit a node, constrained by downstream bottlenecks or by merging traffic. Different constraints on the output of a node result in three different types of mainline outputs (M01, M02, and M03).

- *Mainline output from ramp flow (M01):* M01 is the constraint caused by the flow of vehicles from an on-ramp. The capacity of an on-ramp flow is shared by two competing flows: flow from the on-ramp and flow from the mainline. The total flow that can pass the node is estimated as the minimum of the segment capacity and the mainline outputs (M02 and M03) calculated in the preceding time step.
- *Mainline output from segment density (M02):* The output of mainline flow through a node is also constrained by the growth of queues on the downstream segment. The presence of a queue limits the flow into the segment once the queue reaches its upstream end. The queue position is calculated by shock wave analysis. The M02 limitation is determined first by calculating the maximum number of vehicles allowed on a segment at a given queue density. The maximum flow that can enter a queued segment is the number of vehicles leaving the segment plus the difference between the maximum number of vehicles allowed on a segment and the number of vehicles already on the segment. The queue density is determined from the lower congested portion of the density–flow relationship shown in Chapter 25.
- *Mainline output from front clearing queue (M03):* The final limitation on exiting mainline flows at a node is caused by front clearing downstream queues. These queues typically occur when temporary incidents clear. Two conditions must be satisfied: (a) the segment capacity (minus the on-ramp demand, if present) for the current time interval must be greater than the segment capacity (minus on-ramp demand) in the preceding time interval, and (b) the segment capacity minus the ramp demand for the current time interval must be greater than the segment demand in the same time interval. Front-clearing queues do not affect the segment throughput (which is limited by queue throughput) until the recovery wave has reached the upstream end of the segment. The shock wave speed is estimated from the slope of the line connecting the bottleneck throughput and the segment capacity points.

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Mainline Flow

The mainline flow at node *i* is the minimum of the following variables:

- Node *i* mainline input,
- Node *i* MLI2,
- Node *i* MLI3,
- Segment *i* − 1 capacity, and
- Segment *i* capacity.

Determining On-Ramp Flow

The on-ramp flow is the minimum of the on-ramp input and output. Ramp input in a time step is the ramp demand plus any unserved ramp vehicles from a previous time step.

On-ramp output is limited by the ramp roadway capacity and the ramp-metering rate. It is also affected by the volumes on the mainline segments. The latter is a very complex process that depends on the various flow combinations on the segment, the segment capacity, and the ramp roadway volumes. Details of the calculations are presented in Chapter 25.

Determining Off-Ramp Flow

The off-ramp flow is determined by calculating a diverge percentage based on the segment and off-ramp demands. The diverge percentage varies only by time interval and remains constant for vehicles that are associated with a particular time interval. If there is an upstream queue, then traffic to the off-ramp may be metered. This will cause a decrease in the off-ramp flow. When vehicles that were metered arrive in the next time interval, they use the diverge percentage associated with the preceding time interval. This methodology ensures that all off-ramp vehicles prevented from exiting during the presence of a bottleneck are appropriately discharged in later time intervals.

Determining Segment Flow

Segment flow is the number of vehicles that flow out of a segment during the current time step. These vehicles enter the current segment either to the mainline or to an off-ramp at the current node as shown in Exhibit 10-20. The number of vehicles on each segment in the current time step is calculated with the following information:

- The number of vehicles that were in the segment in the previous time step,
- The number of vehicles that entered the segment in the current time step, and
- The number of vehicles that can leave the segment in the current time step.

Because the number of vehicles that leave a segment must be known, the number of vehicles on the current segment cannot be determined until the upstream segment is analyzed.

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The number of unserved vehicles stored on a segment is calculated as the difference between the number of vehicles on the segment and the number of vehicles that would be on the segment at the background density.

Determining Segment Service Measures

In the last time step of a time interval, the segment flows in each time step are averaged over the time interval, and the service measures for each segment are calculated. If there were no queues on a particular segment during the entire time interval, then the performance measures are calculated from Chapters 11, 12, and 13 as appropriate.

If there was a queue on the current segment during the time interval, then the performance measures are calculated in four steps:

1. The average number of vehicles over a time interval is calculated for each segment.
2. The average segment density is calculated by taking the average number of vehicles in all time steps (in the time interval) and dividing it by the segment length.
3. The average speed on the current segment during the current time interval is calculated as the ratio of segment flow to density.
4. The final segment performance measure is the length of the queue at the end of the time interval (if one exists), which is calculated by using shock wave theory.

On-ramp queue lengths can also be calculated. A queue will form on the on-ramp roadway only if the flow is limited by a meter or by freeway traffic in the gore area. If the flow is limited by the ramp roadway capacity, unserved vehicles will be stored on a facility upstream of the ramp roadway, most likely a surface street. The methodology does not account for this delay. If the queue is on a ramp roadway, its length is calculated by using the difference in background and queue densities.

Step 7: Compute Freeway Facility Service Measures and Other Performance Measures by Time Interval

The previously discussed traffic performance measures can be aggregated over the length of the defined freeway facility for each time interval. Aggregations over the entire time–space domain of the analysis are also mathematically possible, although LOS is defined only for 15-min time intervals.

Freeway facility LOS is defined for each time interval included in the analysis. An average density for each time interval, weighted by length of segments and numbers of lanes in segments, is calculated (with Equation 10-2) and used to compare with the criteria of Exhibit 10-7.

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3. APPLICATIONS

Specific computational steps for the freeway facility methodology were conceptually discussed and presented in this chapter's methodology section. Additional computational details are provided in Chapter 25, Freeway Facilities: Supplemental.

This chapter's methodology is sufficiently complex to require software for its application. Even for fully undersaturated analyses, the number and complexity of computations make it difficult and extremely time-consuming to analyze a case manually. Oversaturated analyses are considerably more complex, and manual solutions would be impractical. The computational engine for this methodology is FRESIM. A complete user's guide and executable spreadsheet are available in the Technical Reference Library in Volume 4.

OPERATIONAL ANALYSIS

The only mode in which the methodology can be directly implemented is operational analysis—that is, given a complete description of a freeway facility, its component segment geometrics, and all relevant demand flow rates, a complete analysis is conducted of each segment and of the freeway facility, by time interval. Outputs will include segment flow rates, densities, and average speeds as well as average facility density and speed for each time interval. By using the estimated facility density for each time interval, a facility LOS can be assigned.

Exhibit 10-22 shows the data inputs that are required for an operational analysis of a freeway facility.

Exhibit 10-22
Required Input Data for Freeway Facility Analysis

Geometric Data for Each Section
• Section length (ft)
• Mainline number of lanes
• Mainline average lane width (ft)
• Mainline lateral clearance (ft)
• Terrain (level, rolling, or mountainous), or specific grade (or grade length in mi)
• Ramp number of lanes
• Ramp acceleration or deceleration lane length (ft)
• Existence of independent HOV lane
Traffic Characteristic Data for Each Segment
• Mainline free-flow speed (mph), optional
• Vehicle occupancy (passengers/veh)
• Percent trucks and buses (%)
• Percent RVs (%)
• Driver population (commuter or recreational)
• Ramp free-flow speeds (mi/h)
Demand Data for Each Segment
• Mainline entry demand for each time interval (veh/h)
• On-ramp demands for each time interval (veh/h)
• Off-ramp demands for each time interval (veh/h)
• Weaving demands on weaving segments, by movement (veh/h)
• HOV lane demand (veh/h), if present

Where all data are not readily available or collectable, the analysis may be supplemented by using consistent default values for each segment. Lists and discussions of default values are found in Chapter 11, Basic Freeway Segments.

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Chapter 12, Freeway Weaving Segments, and Chapter 13, Freeway Merge and Diverge Segments.

Performance measures output by the methodology for individual segments and the facility (for a given time interval) include the following:

- Average speed (mi/h),
- Average density (pc/mi/ln),
- Vehicle miles of travel,
- Vehicle hours of travel, and
- Travel time (min/veh).

Chapter 23 details facility-wide performance measure calculations by time interval.

PLANNING, PRELIMINARY ENGINEERING, AND DESIGN ANALYSIS

This methodology cannot be directly used in planning, preliminary engineering, and design applications. However, for generalized planning, Exhibit 10-5 (urban freeways) and Exhibit 10-9 (rural freeways) provide daily service-volume tables for a variety of typical freeway conditions. These tables may be applied for general evaluations of a number of freeway facilities in a specified region. They should not be used for directly evaluating a specific freeway facility or for developing detailed facility improvement plans. A full operational analysis would normally be applied to any freeway facility identified as potentially needing improvement.

Preliminary engineering and design applications of the methodology are possible by using the segment procedures described in Chapters 11, 12, and 13. Various geometric scenarios can be evaluated and compared by using a travel demand matrix and the facility methodology on the basis of the segment results.

TRAFFIC MANAGEMENT STRATEGIES

The freeway facilities methodology has incorporated procedures for assessing a variety of traffic management strategies. The methodology permits modifying previously calculated demands or capacities (or both) within the time–space domain to assess a traffic management strategy or a combination of strategies.

1. A growth factor parameter has been incorporated to evaluate traffic performance when traffic demands are higher or lower than the demand calculated from the traffic counts. This parameter would be used to undertake a sensitivity analysis of the effect of demand on freeway performance and to evaluate future scenarios. In these cases, all cell demand estimates are multiplied by the growth factor parameter.
2. The effect of a predetermined ramp-metering plan can be evaluated by modifying the ramp roadway capacities. The capacity of each entrance ramp in each time interval is changed to the desired metering rate. This feature permits evaluating a predetermined ramp-metering plan and experimenting to obtain an improved ramp-metering plan.

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3. Freeway design improvements can be evaluated with this methodology by modifying the design features of any portion of the freeway facility. For example, the effect of adding an auxiliary lane at a critical location or adding merging or diverging lanes can be assessed.
4. Reduced-capacity situations can be investigated. The capacity in any cell or cells of the time–space domain can be reduced to represent situations such as construction and maintenance activities, adverse weather, and traffic accidents and vehicle breakdowns.
5. User demand responses such as spatial, temporal, modal, and total demand responses caused by a traffic management strategy are not automatically incorporated into the methodology. Or, viewing the new freeway traffic performance results, the user can modify the demand input manually to evaluate the effect of anticipated demand responses.

USE OF ALTERNATIVE TOOLS

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools. This section contains specific guidance for applying alternative tools to the analysis of freeway facilities. Additional information on this topic may be found in Chapter 25, Freeway Facilities: Supplemental.

Strengths of the HCM Procedure

This chapter's procedures were based on extensive research supported by a significant quantity of field data. They have evolved over a number of years and represent a consensus of experts. Specific strengths of the HCM freeway facilities procedures include the following:

- They provide more detailed algorithms for considering geometric elements of the facility (such as lane and shoulder width).
- They provide capacity estimates for each segment of the facility, which simulation tools do not provide directly (and in some cases may require as an input).
- The capacity can be explicitly adjusted to account for weather conditions, lighting conditions, work zone setup and activity, and incidents.
- The calculation of key performance measures, such as speed and density, is transparent. Simulation tools often use statistics accumulated over the simulation period to derive various link or time-period-specific results, and the derivation of these results may not be obvious. Thus, the user of a simulation tool must know exactly which measure is being reported (e.g., space mean speed versus time mean speed). Furthermore, simulation tools may apply these measures in ways different from the HCM to arrive at other measures.

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Limitations of the HCM Procedures That Might Be Addressed by Alternative Tools

Freeway facilities can be analyzed with a variety of stochastic and deterministic simulation tools. These tools can be useful in analyzing the extent of congestion when there are failures within the simulated facility range and when interaction with other freeway segments and other facilities is present.

Exhibit 10-23 provides a list of the limitations stated earlier in this chapter, along with their potential for improved treatment by alternative tools.

Exhibit 10-23
Limitations of the HCM Freeway Facilities Analysis Procedure

Limitation	Potential for Improved Treatment by Alternative Tools
Changes in travel time caused by vehicles using alternate routes	Modeled explicitly by dynamic traffic assignment tools
Multiple overlapping bottlenecks	Modeled explicitly by simulation tools
Just-demand responses (spatial, temporal, modal)	Modeled explicitly by dynamic traffic assignment tools
System-wide oversaturated flow conditions	Modeled explicitly by simulation tools
First/last time interval or first/last segment demand-to-capacity ratio > 1.0	Modeled explicitly by simulation tools, except that a simulation analysis may also be inaccurate if it does not fully account for a downstream bottleneck that causes congestion in the last segment during the last time period
Interaction between managed lanes and mixed-flow lanes	Modeled explicitly by some simulation tools

Additional Features and Performance Measures Available from Alternative Tools

This chapter provides a methodology for estimating a variety of performance measures for individual segments along a freeway facility, and for the entire facility, given each segment's traffic demand and characteristics. The following performance measures are reported by the freeway facilities procedure:

- Travel time,
- Free-flow travel time,
- Traffic delay,
- Vehicle miles of travel,
- Person miles of travel,
- Speed, and
- Density (segment only).

Alternative tools can offer additional performance measures, such as queue lengths, fuel consumption, vehicle emissions, and operating costs. As with most other procedural chapters in the HCM, simulation outputs—especially graphics-based presentations—may provide details on point problems that might go unnoticed with a macroscopic analysis.

Development of HCM-Compatible Performance Measures Using Alternative Tools

LOS for all types of freeway segments is estimated by the density of traffic (pc/mi/ln) on each segment. The guidance provided in Chapter 12, Basic Freeway

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segments, for developing compatible density estimates applies to freeway facilities as well.

With the exception of true flow travel time, the additional performance measures listed above that are produced by the procedure in this chapter are also produced by typical simulation tools. For the most part, the definitions are compatible, and, subject to the precautions and calibration requirements that follow, the performance measures from alternative tools may be considered equivalent to those that are produced by the procedures in this chapter.

Conceptual Differences Between the HCM and Simulation Modeling That Preclude Direct Comparison of Results

To better determine when a simulation of a freeway facility may be more appropriate than an HCM analysis, the fundamental differences between the two approaches must be understood. The HCM and simulation analysis approaches are reviewed in the following subsections.

HCM Approach

The HCM analysis procedure uses one of two approaches—one for undersaturated conditions and one for oversaturated conditions. For undersaturated conditions—that is, v/c less than 1.0 for all segments and time periods—the approach is generally disaggregate. In other words, the facility is subdivided into segments corresponding to basic freeway, weaving, and merge/diverge segments, and the LOS results are reported for individual segments on the basis of the analysis procedures of Chapters 11, 12, and 13, respectively. However, LOS results are not reported for the facility as a whole.

For oversaturated conditions, the facility is analyzed in a different manner. First, the facility is considered in its entirety rather than as the individual segment level. Second, the analysis time interval, typically 15 min, is subdivided into time steps of 15 to 60 s, depending on the length of the shortest segment. This approach is necessary so that flows can be reduced to capacity levels at bottleneck locations and queues can be tracked in space and time. For oversaturated segments, the average segment density is calculated by dividing the average number of vehicles for all time steps (in the time interval) by the segment length. The average segment speed is calculated by dividing the average segment flow rate by the average segment density. Facility/area performance measures are calculated by aggregating segment performance measures across space and time, as outlined in Chapter 25. A LOS for the facility is assigned on the basis of density for each time interval.

When the oversaturation analysis procedure is applied, if any segment is undersaturated for an entire time interval, its performance measures are calculated as occurring to the appropriate procedure in Chapters 11, 12, and 13.

Simulation Approach

Simulation tools model the facility in its entirety and from that perspective have some similarity to the oversaturated analysis approach of the HCM. Microscopic simulation tools operate similarly under both saturated and undersaturated conditions, tracking each vehicle through time and space and

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generally handling the accumulation and queuing of vehicles in saturated conditions in a realistic manner. Macroscopic simulation tools vary in their treatment of saturated conditions. Some tools do not handle oversaturated conditions at all, while others may queue vehicles in the vertical, rather than horizontal, dimension. These tools may still provide reasonably accurate results under slightly oversaturated conditions, but the results will clearly be invalid for heavily congested conditions.

The treatment of oversaturated conditions is a fundamental issue that must be understood when considering whether to apply simulation in lieu of the HCM for analysis of congested conditions. A review of simulation modeling approaches is beyond the scope of this document. More detailed information on the topic may be found in the Technical Reference Library in Volume 4.

Adjustment of Simulation Parameters to the HCM Results

Some calibration is generally required before an alternative tool can be used effectively to supplement or replace the HCM procedure. The following subsections discuss key variables that should be checked for consistency with the HCM procedure values.

Capacity

In the HCM, capacity is a function of the specified free-flow speed (which can be adjusted by lane width, shoulder width, and ramp density). In a simulation tool, capacity is typically a function of the specified minimum vehicle entry headway (into the system) and car-following parameters (assuming microscopic simulation).

While the determination of capacity for a basic freeway segment is clearly described in Chapter 12, this chapter does not offer specific guidance on determining the appropriate capacity for different segment types within a facility, other than to refer the reader to the individual chapters (basic segments, weaving segments, merge segments, diverge segments) for appropriate capacity values. The HCM specifies the capacity of a freeway facility in units of veh/h, rather than pc/h.

In macroscopic simulation tools, capacity is generally an input. Thus, for this situation, it is straightforward to match the simulation capacity to the HCM capacity. Microscopic simulation tools, however, do not have an explicit capacity input. Most microscopic tools provide an input that affects the minimum separation for the generation of vehicles into the system. Therefore, specifying a value of 1.5 s for this input will result in a maximum vehicle entry rate of 2,400 (3,600/1.5) veh/h/ln. Once vehicles enter the system, vehicle headways are governed by the car-following model. Thus, given other factors and car following model constraints, the maximum throughput on any one segment may not reach this value. Consequently, some experimenting is usually necessary to find the right minimum entry separation value to achieve a capacity value comparable with that in the HCM. Again, the analyst needs to be careful of the units being used for capacity in making comparisons.

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The other factor to be aware of is that, while geometric factors such as lane and shoulder width affect the free-flow speed (which in turn affects capacity) in the HCM procedure, some simulation tools do not account for these effects, or they may account for other factors, such as horizontal curvature, that the HCM procedure does not consider.

Lane Distribution

In the HCM procedure, there is an implicit assumption that, for any given vehicle demand, the vehicles are evenly distributed across all lanes of a basic freeway segment. For merge and diverge segments, the HCM procedure includes calculations to determine how vehicles are distributed across lanes as a result of merging or diverging movements. For weaving segments, there is not an explicit determination of flow rates in particular lanes, but consideration of weaving and nonweaving flows and the number of lanes available for each is an essential element of the analysis procedure.

In simulation tools, the distribution of vehicles across lanes is typically specified only for the entry point of the network. Once vehicles have entered the network, they are distributed across lanes according to car-following and lane-changing logic. The input value should reflect field data if they are available. If field data indicate an imbalance of flows across lanes, this situation may lead to a difference between the HCM and simulation results. If field data are not available, specifying an even distribution of traffic across all lanes is probably reasonable for networks that begin with a long basic segment. If there is a ramp junction within a short distance downstream of the entry point of the network, setting the lane distribution values to be consistent with those from Chapter 13 of the HCM will likely yield more consistent results.

Traffic Stream Composition

The HCM deals with the presence of non-passenger car vehicles in the traffic stream by applying passenger car equivalent values. These values are based on the percentage of trucks, buses, and RVs in the traffic stream as well as type of terrain (grade percent and its length). Thus, the traffic stream is converted into some equivalent number of passenger cars only, and the analysis results are based on flow rates in these units.

In the case of macroscopic-based simulators, the generated vehicle type percentages may also approximate the specified percentages.

Simulation tools deal with the traffic stream composition just as it is specified; that is, the specific percentages of each vehicle type are generated into and moved through the system according to their specific vehicle attributes (e.g., acceleration and deceleration capabilities). Thus, simulation, particularly microscopic simulation, results likely better reflect the effects of non-passenger car vehicles on the traffic stream. Although in some instances the passenger car equivalent values contained in the HCM were developed from simulation data, simplifying assumptions made to make them implementable in an analytical procedure result in some loss of fidelity in the treatment of different vehicle types.

Furthermore, it should be recognized that the HCM procedure does not explicitly account for differences in driver types. Microscopic simulation tools explicitly provide for a range of driver types and allow a number of factors

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relative to driver type to be modified (e.g., free flow speed, gap acceptance threshold). However, it should also be recognized that the empirical data some HCM procedures are based on include the effects of the various driver types present in traffic streams.

Free-Flow Speed

In the HCM, free flow speed is either measured in the field or estimated with calibrated predictive algorithms. In simulation, free-flow speed is almost always an input value. Where field measurements are not available, simulation users may wish to use the HCM predictive algorithms to estimate free-flow speed.

Step-by-Step Recommendations for Applying Alternative Tools

General guidance for applying alternative tools is provided in Chapter 6, HCM and Alternative Analysis Tools. The chapters that cover specific types of freeway segments offer more detailed step by step guidance specific to those segments. All the segment-specific guidance applies to freeway facilities, which are configured as combinations of different segments.

The first step is to determine whether the facility can be analyzed satisfactorily by the procedures described in this chapter. If the facility contains geometric or operational elements beyond the scope of these procedures, then an alternative tool should be selected. The steps involved in the application will depend on the reason(s) for choosing an alternative tool. In some cases, the step by step segment guidance will cover the situation adequately. In more complex cases (e.g., those not involving integrated analysis of a freeway corridor), more comprehensive guidance from one or more documents in the Technical Reference Library in Volume 4 may be needed.

Sample Calculations Illustrating Alternative Tool Applications

The limitations of this chapter's procedures are mainly related to the lack of a comprehensive treatment of the interaction between segments and facilities. Many of these limitations can be addressed by simulation tools, which generally take a more integrated approach to the analysis of complex networks of freeways, ramps, and surface street facilities. Supplemental examples illustrating interactions between segments are presented in Chapter 26, Freeway and Highway Segments: Supplemental, and Chapter 30, Interchange Ramp Terminals: Supplemental. A comprehensive example of the application of simulation tools to a major freeway reconstruction project is presented as Case Study 6 in the HCM Applications Guide located in Volume 4.

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4. EXAMPLE PROBLEMS

Exhibit 10-24
List of Example Problems

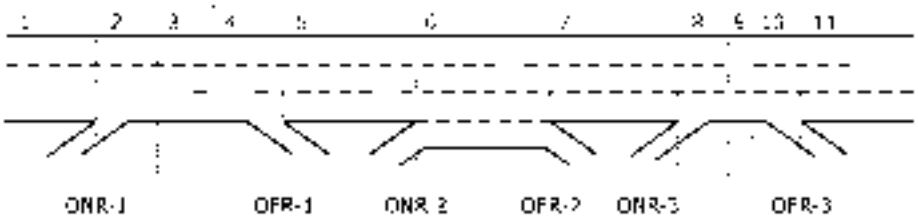
Example Problem	Description	Application
1	Evaluation of an undersaturated facility	Operational analysis
2	Evaluation of an oversaturated facility	Operational analysis
3	Capacity improvements to an oversaturated facility	Operational analysis

EXAMPLE PROBLEM 1: EVALUATION OF AN UNDERSATURATED FACILITY

The Facility

The subject of this operational analysis is an urban freeway facility in mid-city and composed of 11 individual analysis segments, as shown in Exhibit 10-25.

Exhibit 10-25
Freeway Facility in Example Problem 1



The facility has three on-ramps and three off-ramps. Geometric details are given in Exhibit 10-26.

Exhibit 10-26
Geometry of Directional Freeway Facility for Example Problem 1

Segment No.	1	2	3	4	5	6	7	8	9	10	11
Segment type	B	ONR	B	OFR	B	B or W	O	ONR	R	OFR	B
Segment length (ft)	5,280	1,500	2,200	1,500	5,280	2,640	5,280	1,140	360	1,140	5,280
No. of lanes	3	3	3	3	3	4	3	3	3	3	3

Note: B = basic freeway segment, W = weaving segment, ONR = on-ramp (merge) segment, OFR = off-ramp (diverge) segment, R = overlapping ramp segment.

The on- and off-ramps in Segment 5 are connected by an auxiliary lane and the segment may therefore operate as a weaving segment, depending on traffic patterns. The separation of the on-ramp in Segment 8 and the off-ramp in Segment 10 is less than 3,000 ft. Since the ramp influence area of on-ramps and off-ramps is 1,500 ft, according to Chapter 13, the segment affected by both ramps is analyzed as a separate overlapping ramp segment (Segment 9), labeled "R."

The analysis question at hand is the following: What is the operational performance and LOS of the directional freeway facility shown in Exhibit 10-25?

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The Facts

In addition to the information contained in Exhibit 10-25 and Exhibit 10-26, the following characteristics of the freeway facility are known:

Heavy vehicles – 5% trucks, 0% RVs (all movements);
Driver population – regular commuters;
FFS – 60 mi/h (all mainline segments);
Ramp *FFS* – 40 mi/h (all ramps);
Acceleration lane length – 500 ft (all ramps);
Deceleration lane length – 500 ft (all ramps);
$D_{1,4}$ – 191 pc/mi/ln;
$c_{h,1}$ – 2,300 pc/h/ln (for *FFS* = 60 mi/h);
L_1 – 1,940 ft (for Weaving Segment 6);
TRD – 10 ramp/mi;
Terrain – level; and
Analysis duration – 75 min (divided into five 15-min intervals).

Comments

The facility was segmented into analysis segments on the basis of the guidance given in this chapter. The facility shown in Exhibit 10-25 initially depicts seven freeway sections (measured between ramps) that are divided into 11 analysis segments. The facility contains each of the possible segment types for illustrative purposes, including basic segment (B), weaving segment (W), merge segment (ONR), diverge segment (OFR), and overlapping ramp segment (R). The input data contain the required information needed for each of the segment methodologies.

The classification of the weaving Segment 6 is preliminary until it is determined whether the segment operates as a weave. For this purpose, the short length must be compared with the maximum length for weaving analysis to determine whether the Chapter 12, Weaving Segments, methodology or the Chapter 13, Basic Freeway Segments, methodology is applicable. The short length of the weaving segment used for calculation is shorter than the weaving influence area over which the calculated speed and density measures are applied.

Chapter 7 must be consulted to find appropriate values for the heavy vehicle adjustment factor f_{HV} and the driver population adjustment factor f_p. FREEVAL-2010 automatically determines these adjustment factors for general terrain conditions, but user input is needed for specific upgrades and composite grades.

All input parameters have been specified, so default values are not needed. Fifteen-minute demand flow rates are given in vehicles per hour under prevailing conditions. These demands must be converted to passenger cars per

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hour under equivalent ideal conditions for use in the parts of the methodology related to segment LOS estimation.

Step 1: Input Data

Traffic demand inputs for all 11 segments and five analysis intervals are given in Exhibit 10-27.

Exhibit 10-27
Demand Inputs for Example Problem 1

Time Step (15 min)	Entering Flow Rate (veh/h)	Ramp Flow Rates by Time Period (veh/h)						Exiting Flow Rate (veh/h)
		ONR1	ONR2*	ONR3	OFR1	OFR2	OFR3	
1	4,200	410	590 (30)	490	270	360	270	5,040
2	4,955	540	720 (180)	540	360	360	270	5,765
3	5,735	630	810 (150)	630	270	360	450	6,715
4	4,585	360	360 (90)	450	270	360	270	4,965
5	3,785	180	270 (90)	270	270	180	180	3,875

* Numbers in parentheses indicate OFR 2 to OFR 2 demand flow rates passing Segment 6.

The volumes in Exhibit 10-27 represent the 15-min demand flow rates on the facility as determined from field observations or other sources. The actual volume served in each segment will be determined by the methodology. The demand flows are given for the extended time–space domain, consistent with this chapter's recommendations. Peaking occurs in the third 15-min period. Since inputs are in the form of 15-min flow rates, no peak hour factor adjustment is necessary. Additional geometric and traffic-related inputs are as specified in Exhibit 10-25 and the facts section of the problem statement.

Step 2: Demand Adjustments

The traffic flows in Exhibit 10-27 are already given in the form of actual demands. Therefore, no additional demand adjustment is necessary, since the flows represent true demand. Demand adjustment is necessary only if field-measured volumes are used that may be affected by upstream congestion (bottlenecks) on the facility. The methodology (and FREEVAL-2010) assumes that the user inputs true demand flows.

Step 3: Compute Segment Capacities

Segment capacities are determined by using the methodologies of Chapter 11 for basic freeway segments, Chapter 12 for weaving segments, and Chapter 13 for merge and diverge segments. The resulting capacities are shown in Exhibit 10-28. Since the capacity of a weaving segment depends on traffic patterns, including the weaving ratio, it varies by time period. The remaining segment capacities are constant in all five time intervals. The capacities for Segments 1–5 and 7–11 are the same, since the segments have the same basic cross-section. The units shown are in vehicles per hour.

Exhibit 10-28
Segment Capacities for Example Problem 1

Time Step	Capacities (veh/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1						8,252					
2						8,761					
3	8,712	8,712	8,712	8,712	8,712	8,303	8,712	8,712	8,712	8,712	8,712
4						8,362					
5						8,342					

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Step 4: Adjust Segment Capacities

This step typically allows the user to adjust capacities of specific segments or time periods to model the effects of short-term work zones, long-term construction, inclement weather conditions, or incidents. Since it's the base scenario in this sequence of example problems, no additional capacity adjustments are performed.

Step 5: Compute Demand-to-Capacity Ratios

The demand-to-capacity ratios are calculated from the demand flows in Exhibit 10-27 and from the segment capacities in Exhibit 10-28.

Exhibit 10-29
Segment Demand-to-Capacity Ratios for Example Problem 1

Time Step	Demand-to-Capacity Ratios by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	0.67	0.74	0.74	0.74	0.70	0.63	0.72	0.75	0.75	0.79	0.75
2	0.74	0.82	0.82	0.82	0.76	0.71	0.82	0.90	0.90	0.90	0.86
3	0.78	0.87	0.87	0.87	0.83	0.77	0.90	0.95	0.95	0.99	0.92
4	0.70	0.75	0.75	0.75	0.71	0.61	0.71	0.78	0.78	0.78	0.74
5	0.56	0.59	0.59	0.59	0.55	0.47	0.55	0.60	0.60	0.60	0.58

The computed demand-to-capacity ratio matrix in Exhibit 10-29 shows no segments with a v/c ratio greater than 1.0 in any time interval. Consequently, the facility is categorized as *globally undersaturated* and the analysis proceeds with computing the undersaturated service measures in Step 6a. Further, it is expected that no queuing will occur on the facility and that the volumes served in each segment is identical to the input demand flows. Consequently, the matrix of volume-to-capacity ratios would be identical to the demand-to-capacity ratios in Exhibit 10-29. The resulting matrix of volumes served by segment and time interval is shown in Exhibit 10-30.

Exhibit 10-30
Volume-Served Matrix for Example Problem 1

Time Step	Volumes Served (veh/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	4,930	4,995	4,995	4,995	4,685	5,275	4,865	5,315	5,315	5,315	5,045
2	4,995	5,495	5,495	5,495	5,135	5,855	5,495	6,035	6,035	6,035	5,765
3	5,225	5,855	5,855	5,855	5,585	6,395	6,035	6,665	6,665	6,665	6,215
4	4,685	5,045	5,045	5,045	4,775	5,135	4,775	5,225	5,225	5,225	4,955
5	3,795	3,965	3,965	3,965	3,695	3,965	3,785	4,055	4,055	4,055	3,875

Step 6a: Compute Undersaturated Segment Service Measures

Since the facility is globally undersaturated, the methodology proceeds to calculate service measures for each segment and each time period, starting with the first segment in Time Step 1. The computational details for each segment type are exactly as described in Chapters 11, 12, and 13. The weaving methodology in Chapter 13 checks whether the weaving short length L_S is less than or equal to the maximum weaving length $L_{W,MAX}$. It is assumed that, for any time interval, where L_S is longer than $L_{W,MAX}$, the weaving segment will operate as a basic freeway segment.

The key performance measures computed for each segment and each time step are the segment speed (Exhibit 10-31), density (Exhibit 10-32), and LOS (Exhibit 10-33).

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Exhibit 10-31
Speed Matrix for Example Problem 1

Time Step	Speed (mi/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	60.0	53.9	59.7	56.1	61.0	48.0	59.8	59.4	54.4	56.0	59.7
2	59.8	53.2	58.6	55.8	59.6	45.7	58.6	57.2	52.2	55.6	57.5
3	59.4	52.5	57.1	55.7	58.4	46.1	56.1	56.6	50.6	55.7	55.0
4	61.0	53.8	59.7	56.1	60.0	49.7	60.0	59.5	54.5	56.0	59.6
5	60.0	54.9	59.8	56.3	61.0	52.5	60.2	54.8	54.8	56.5	60.0

Exhibit 10-32
Density Matrix for Example Problem 1

Time Step	Density (veh/mi/ln) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	25.0	30.7	27.7	29.4	26.0	27.2	27.1	34.2	34.2	31.7	28.2
2	27.6	34.5	31.0	32.8	29.7	31.3	31.3	38.5	38.5	36.2	33.4
3	29.3	37.7	44.2	35.0	31.0	34.0	35.6	44.9	43.9	40.5	47.7
4	26.2	31.3	28.2	30.0	26.5	25.8	29.5	37.5	37.5	31.1	27.9
5	21.0	24.1	22.1	23.6	20.5	18.9	21.3	24.7	24.7	23.9	21.5

Exhibit 10-33
LOS Matrix for Example Problem 1

Time Step	LOS by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	C	C	D	C	D	C	D	D	D	D	D
2	D	D	D	D	D	D	D	D	D	D	D
3	D	D	D	D	D	E	E	E	E	E	E
4	D	C	D	D	D	C	D	D	D	D	D
5	C	C	C	C	C	B	C	C	C	C	C

Step 7: Compute Facility Service Measures and Determine LOS

In the final analysis step, facilitywide performance and service measures are calculated for each time step. Examples of calculations are provided for the first time step only; summary results are shown for all five time steps.

First, the facility space-mean speed S is calculated for time interval t from the n individual segment flows $SF(i,t)$, segment lengths $L(i)$, and space-mean speeds in each segment and time period $U(i,t)$:

$$S(t) = \frac{\sum_{i=1}^{n} SF(i,t) \times L(i)}{\sum_{i=1}^{n} SF(i,t) \times \frac{L(i)}{U(i,t)}}$$

$$\sum_{i=1}^{n} SF(i,t) \times L(i) = 4{,}707 \times 5{,}280 + 4{,}970 \times 5{,}280 + 4{,}955 \times 2{,}280 + 4{,}955 \times 1{,}500 + 4{,}687 \times 5{,}280 + 5{,}225 \times 2{,}640 + 4{,}567 \times 5{,}280 + 5{,}315 \times 1{,}140 + 5{,}315 \times 360 + 5{,}315 \times 1{,}320 + 5{,}015 \times 5{,}280 = 154{,}836{,}000 \text{ veh-ft}$$

$$\sum_{i=1}^{n} SF(i,t) \times \frac{L(i)}{U(i,t)} = (4{,}707 \times 5{,}280/60.00) + (4{,}970 \times 1{,}500/53.40) + (4{,}955 \times 2{,}280/59.70) + (4{,}955 \times 1{,}500/60.10) + (4{,}687 \times 5{,}280/60.00) + (5{,}225 \times 2{,}640/48.00) + (4{,}567 \times 5{,}280/59.90) + (5{,}315 \times 1{,}140/53.10) + (5{,}315 \times 360/53.40) + (5{,}315 \times 1{,}320/56.00) + (5{,}015 \times 5{,}280/59.70) = 2{,}688{,}024 \text{ veh-ft/mi/h}$$

$$S(t) = \frac{154{,}836{,}000}{2{,}688{,}024} = 57.6 \text{ mi/h}$$

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Second, the average facility density is calculated for Time Step 1 from the individual segment densities D, segment lengths L, and number of vehicles in each segment N:

$$D(t=1) = \frac{\sum_{i=1}^{11} D(i,1) \times L(i) \times N(i,1)}{\sum_{i=1}^{11} L(i) N(i,1)}$$

$$\sum_{i=1}^{11} D(i,1) \times L(i) \times N(i,1) = (25.0 \times 5,280 \times 3) + (30.7 \times 1,500 \times 3) + (27.7 \times 2,280 \times 3) + (29.4 \times 1,500 \times 3) + (26.0 \times 5,280 \times 3) + (27.2 \times 2,640 \times 4) + (27.1 \times 5,280 \times 3) + (33.2 \times 1,140 \times 3) + (35.2 \times 5,280 \times 3) + (31.7 \times 1,140 \times 3) + (28.2 \times 5,280 \times 3) = 2,687,957 \text{ (veh/mi/ln)(ln-ft)}$$

$$\sum_{i=1}^{11} L(i) N(i,1) = (5,280 \times 3) + (1,500 \times 3) + (2,280 \times 3) + (1,500 \times 3) + (5,280 \times 3) + (2,640 \times 4) + (5,280 \times 3) + (1,140 \times 3) + (5,280 \times 3) + (1,140 \times 3) + (5,280 \times 3) = 97,680 \text{ ln-ft}$$

$$D(t=1) = \frac{2,687,957}{97,680} = 27.5 \text{ veh/mi/ln}$$

These calculations are repeated for all five time steps. The overall space mean speed across all time intervals is calculated as follows:

$$S(p=5) = \frac{\sum_{p=1}^{5} \sum_{i=1}^{11} SF(i,p) L(i)}{\sum_{i=1}^{11} \sum_{p=1}^{5} SF(i,p) \frac{L(i)}{U(i,p)}}$$

The overall average density across all time intervals is calculated as follows:

$$D(p=5) = \frac{\sum_{p=1}^{5} \sum_{i=1}^{11} D(i,p) \times L(i) \times N(i,p)}{\sum_{p=1}^{5} \sum_{i=1}^{11} L(i) N(i,p)}$$

The resulting performance and service measures for Time Steps 1–5 and the facility totals are shown in Exhibit 10-34. The LOS for each time interval is determined directly from the average density for each time interval by using Exhibit 10-2. No LOS is defined for the average across all time intervals.

Exhibit 10-34
Facility Performance Measure Summary for Example Problem 1

Time Step	Performance Measures: Space Mean Speed (mi/h)	Performance Measures: Average Density (veh/mi/ln)	LOS
1	57.6	27.5	D
2	55.6	31.3	D
3	55.1	34.6	E
4	57.9	27.5	D
5	59.4	23.4	C
Total	**56.9**	**28.5**	—

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Discussion

This facility turned out to be globally undersaturated. Consequently, the facility aggregated performance measures could be calculated directly from the individual segment performance measures. An assessment of the segment service measures across the time–space domain can begin to highlight areas of potential congestion. Visually, this process can be facilitated by plotting the v/c, s/c, speed, or density matrices in contour plots.

EXAMPLE PROBLEM 2: EVALUATION OF AN OVERSATURATED FACILITY

The Facility

The facility used in Example Problem 2 is identical to the one in Example Problem 1, which is shown in Exhibit 10-25 and Exhibit 10-26.

The Facts

In addition to the information in Exhibit 10-25 and Exhibit 10-26, the following characteristics of the freeway facility are known.

Heavy vehicles	=	5% trucks, 0% RVs (all movements);
Driver population	=	regular commuters;
FFS		60 mi/h (all mainline segments);
Ramp FFS		40 mi/h (all ramps);
Acceleration lane length	=	500 ft (all ramps);
Deceleration lane length		500 ft (all ramps);
$c_{i,m}$	=	190 pc/min/ln;
$c_{i,o}$		2,300 pc/h/ln (for LOS = 60 mi/h);
L_i		1,640 ft (for Weaving Segment 6);
FRO		1.0 ramp/mi;
Terrain	=	level;
Analysis duration		2 h; and (divided into five 15-min time steps); and
Demand adjustment	=	11% increase in demand volumes across all segments and time steps compared with Example Problem 1

Comments

The facility and all geometric inputs are identical to Example Problem 1. The same general comments apply. The results of Example Problem 1 suggested a globally undersaturated facility, but some segments were close to their capacity (v/c ratio approaching 1.0). In the present example, a facilitywide demand increase of 11% is applied to all segments and all time periods. Consequently, it is expected that parts of the facility may become oversaturated and that queues may form on the facility.

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Step 1: Input Data

The freeway traffic demand inputs for all 11 segments and five analysis intervals are shown in Exhibit 10-35.

Time Step (15 min)	Entering Flow Rate (veh/h)	Ramp Flow Rates by Time Period (veh/h)						Exiting Flow Rate (veh/h)
		ONR1	ONR2[a]	ONR3	OFR1	OFR2	OFR3	
1	5,001	500	599 (56)	500	600	400	300	5,000
2	5,977	592	799 (111)	559	400	400	300	6,392
3	5,800	699	999 (107)	659	300	400	500	6,699
4	5,200	400	400 (90)	501	400	400	300	5,501
5	4,201	200	300 (56)	300	300	200	200	4,301

[a] Numbers in parentheses indicate ONR 2 to OFR 2 demand flows going to Freeway Segment 6.

Exhibit 10-35
Demand Inputs for Example Problem 2

The values in Exhibit 10-35 represent the adjusted demand flows on the facility as determined from field observations or demand projections. The actual volume served in each segment will be determined during application of the methodology and is expected to be less downstream of a congested segment. The demand flows are given for the extended time–space domain, consistent with this chapter's methodology. Peaking occurs in the third 15-min period. Since inputs are in the form of 15-min observations, no peak hour factor adjustment is necessary. Additional geometric and traffic-related inputs are as specified in Exhibit 10-23 and the facts section of the problem statement.

Step 2: Demand Adjustments

The traffic flows in Exhibit 10-35 have already been given in the form of actual demands and no further demand adjustments are necessary.

Step 3: Compute Segment Capacities

Since no changes to segment geometry were made, the segment capacities for basic and ramp segments are consistent with Example Problem 1 and Exhibit 10-25. Capacities for weaving segments are a function of weaving flow patterns, and the increased demand flows resulted in slight changes as shown in Exhibit 10-36.

Time Step	Capacities (veh/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1						8,753					
2						8,260					
3	6,737	6,732	6,732	6,732	6,732	8,304	6,732	6,732	6,732	6,732	6,732
4						8,382					
5						8,443					

Exhibit 10-36
Segment Capacities for Example Problem 2

Step 4: Adjust Segment Capacities

No capacity adjustments are made in this example.

Step 5: Compute Demand-to-Capacity Ratios

The demand-to-capacity ratios in Exhibit 10-37 are calculated from the demand flows in Exhibit 10-35 and from the segment capacities in Exhibit 10-36.

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Exhibit 10-37
Segment Demand-to-Capacity Ratios for Example Problem 2

Time Step	Demand-to-Capacity Ratios by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	0.74	0.82	0.82	0.82	0.77	0.70	0.80	0.88	0.88	0.88	0.83
2	0.82	0.91	0.91	0.91	0.85	0.78	0.91	1.00	1.00	1.00	0.91
3	0.86	0.97	0.97	0.97	0.92	0.85	1.00	**1.10**	**1.10**	**1.10**	**1.02**
4	0.77	0.83	0.83	0.83	0.75	0.68	0.79	0.86	0.86	0.86	0.82
5	0.62	0.69	0.69	0.69	0.61	0.57	0.67	0.67	0.67	0.67	0.61

The completed cycle matrix in Exhibit 10-37 shows that segments 8–11 now have cycle ratios greater than 1.0 (bold values). Consequently, the facility is categorized as *oversaturated* and the analysis proceeds with computing the oversaturated service measures in Step 6b. Further, it is expected that queuing will occur on the facility upstream of the congested segments and that the volume served in each segment downstream of the congested segments will be less than the demand. This residual demand will be served in later time intervals, provided that upstream demand drops and queues are cleared to clear.

Step 6b: Compute Oversaturated Segment Service Measures

The oversaturated computations apply to any segment with a cycle ratio greater than 1.0 as well as any segments upstream of those segments that experience queuing as a result of the bottleneck. All remaining segments are analyzed by using the individual segment methodologies of Chapters 11, 12, and 13, as applicable, with the caveat that volumes served may differ from demand flows.

Similar to Example Problem 1, the methodology calculates performance measures for each segment and each time period, starting with the first segment in Time Step 1. The computations are repeated for all segments for Time Steps 1 and 2 without encountering a segment with cycle > 1.0. Once the methodology enters Time Period 3 and Segment 8, the oversaturated computational module is invoked.

As the first active bottleneck, the cycle ratio for Segment 8 will be exactly 1.0 and will process traffic at its capacity. Consequently, demand for all downstream segments will be metered by that bottleneck. The unsatisfied demand is stored in upstream segments, which causes queuing in Segment 7 and perhaps further upstream segments, depending on the level of excess demand. The rate of growth of the vehicle queue (wave speed) is estimated from shock wave theory, as discussed in detail in Chapter 25, Freeway Facilities: Supplemental. The performance measures (speed and density) of any segment with queuing are recomputed as discussed in Chapter 25, and the newly calculated values override the results from the segment-specific procedures.

Any unserviced demand is serviced in later time periods. As a result, volumes served in later time periods may be higher than the period demand flows. The resulting matrix of volumes served for Example Problem 2 is shown in Exhibit 10-38. The table emphasizes cells where volumes served are less than demand flows (in **bold**) and where volumes served are greater than demand flows (*italicized*).

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Exhibit 10-38
Volume Served Matrix for Example Problem 2

Time Step	Volumes Served (veh/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	5,000	5,500	5,500	5,500	5,200	5,600	5,400	5,000	5,000	5,000	5,600
2	5,500	6,099	6,099	6,099	5,700	6,400	6,099	6,699	6,699	6,699	6,099
3	5,800	6,499	6,499	6,499	**6,115**	**6,625**	**6,037**	**6,737**	**6,737**	**6,737**	**6,777**
4	5,200	5,500	5,600	5,500	*5,369*	*6,173*	*5,967*	*6,466*	*6,466*	*6,466*	*6,122*
5	4,200	4,401	4,401	4,401	4,131	4,401	4,201	4,501	4,501	4,501	4,401

As a result of the bottleneck activation in Segment 8 in Time Period 3, queues form in upstream Segments 7, 6, and 5. The queuing is associated with reduced speeds and increased densities in those segments. Details on how those measures are calculated for oversaturated segments are given in Chapter 25. The results in this chapter were obtained from the FREEVAL-2010 engine. The resulting performance measures computed for each segment and time interval are the speed (Exhibit 10-39), density (Exhibit 10-40), and LOS (Exhibit 10-41).

Exhibit 10-39
Speed Matrix for Example Problem 2

Time Step	Speed (mi/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	59.0	58.1	58.0	58.0	59.4	46.0	58.9	52.5	52.5	55.7	58.2
2	58.6	57.1	55.7	55.5	57.8	45.4	55.7	50.5	50.5	55.4	57.8
3	57.4	51.0	51.0	55.4	55.6	38.2	44.9	50.2	50.2	55.1	54.6
4	59.4	58.0	58.0	55.8	49.9	39.0	53.9	51.2	51.2	56.3	56.6
5	60.0	58.5	59.7	56.2	60.0	51.7	60.0	54.4	54.4	56.3	60.0

Exhibit 10-40
Density Matrix for Example Problem 2

Time Step	Density (veh/mi/ln) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	29.0	34.5	31.0	32.8	29.7	31.3	30.6	37.5	37.5	40.3	42.1
2	31.5	38.0	36.5	36.7	32.9	45.9	36.5	44.2	44.2	40.4	39.7
3	33.7	42.5	40.9	39.1	38.0	**58.8**	**57.7**	44.7	44.7	40.7	38.3
4	26.2	35.2	32.1	33.4	36.0	36.1	36.9	42.1	42.1	38.9	36.7
5	23.5	26.3	24.6	26.1	22.8	21.3	23.3	27.6	27.6	25.6	23.9

Exhibit 10-41
Expanded LOS Matrix for Example Problem 2

Time Step	Density Based LOS by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	D	D	D	D	D	D	D	D	D	D	D
2	D	D	E	D	D	E	E	E	E	E	E
3	D	D	E	D	E	**F**	F	F	E	F	F
4	D	D	D	D	E	E	E	D	D	D	E
5	C	C	C	C	C	C	C	C	C	C	C
Time Step	**Demand-Based LOS by Segment**										
	1	2	3	4	5	6	7	8	9	10	11
1											
2											
3								F	F	F	F
4											
5											

The LOS table for oversaturated facilities (Exhibit 10-41) distinguishes between the conventional density-based LOS and a segment demand-based LOS. The density-based stratification strictly depends on the prevailing average density on each segment. Segments downstream of the bottleneck, whose capacities are greater than or equal to the bottleneck capacity, operate at LOS F (or better), even though their v/c ratios were greater than 1.0. The demand-based LOS identifies those segments with demand-to-capacity ratios exceeding 1.0 as if they had been evaluated in isolation (i.e., using methodologies of Chapters 11,

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12, and 13). By contrasting the two parts of the LOS Table, the analyst can develop an understanding of the governing driver of the bottleneck.

Step 7: Compute Facility Service Measures and Determine LOS

In the final analysis step, facilitywide performance and service measures are calculated for each time interval (Exhibit 10-42), consistent with Example Problem 1. Only summary results are shown in this case, since the computations have already been shown. The facility operates at LOS F in Time Period 3, since one or more individual segments have D/C ratios > 1.0, even though the average facility density is below the LOS F threshold.

Exhibit 10-42
Facility Performance Measure Summary for Example Problem 2

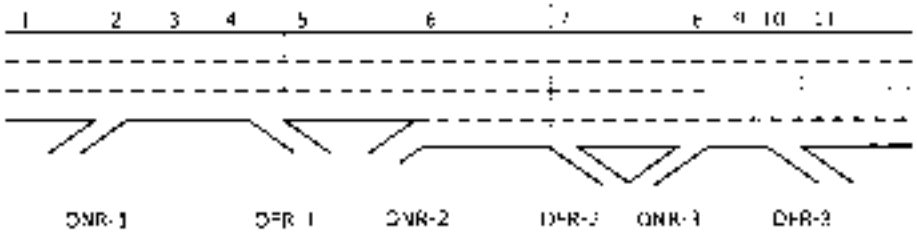
Time Interval	Performance Measure: Space Mean Speed (mi/h)	Performance Measure: Average Density (veh/mi/ln)	LOS
1	56.7	31.0	D
2	54.5	36.1	E
3	46.3	43.7	F
4	52.8	34.1	E
5	58.2	23.3	C
Total	**52.9**	**34.0**	—

EXAMPLE PROBLEM 3: CAPACITY IMPROVEMENTS TO AN OVERSATURATED FACILITY

The Facility

In this example, portions of the congested facility in Example Problem 2 are being improved in an attempt to alleviate the congestion resulting from the Segment 6 bottleneck. Exhibit 10-43 shows the upgraded facility geometry.

Exhibit 10-43
Freeway Facility in Example Problem 3



The modified geometry of the 6-mi directional freeway facility is reflected in Exhibit 10-44.

Exhibit 10-44
Geometry of Directional Freeway Facility in Example Problem 3

Segment No.	1	2	3	4	5	6	7	8	9	10	11
Segment type	B	ONR	B	OFR	B	B or W	B	ONR	R	OFR	B
Segment length (ft)	5,280	1,500	2,280	1,500	5,280	2,640	5,280	1,140	260	1,140	5,280
No. of lanes	3	3	3	3	3	4	4	4	4	4	4

Note: B = basic freeway segment; W = weaving segment; ONR = on-ramp (merge) segment; OFR = off-ramp (diverge) segment; R = ramp (only one lane); bold type indicates geometric changes from Example Problems 1 and 2.

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The facility improvements consisted of adding a lane to Segments 7–11 to give the facility a continuous four-lane cross section starting in Segment 6. While the active bottleneck in Example Problem 2 was in Segment 8, the prior analysis showed that other segments (Segments 9–11) showed similar demand to capacity ratios greater than 1.0. Consequently, any capacity improvements that are limited to Segment 8 would have merely moved the spatial location of the bottleneck to either downstream rather than improving the overall facility. Segments 9–11 may also be referred to as "hidden" or "latent" bottlenecks because their predicted congestion is mitigated by the upstream metering of traffic.

The Facts

In addition to the information contained in Exhibit 10-43 and Exhibit 10-44, the following characteristics of the freeway facility are known.

Heavy vehicles	= 5% trucks, 0% RVs (all movements),
Driver population	= regular commuters,
FFS	= 60 mi/h (all mainline segments),
Ramp *FFS*	= 40 mi/h (all ramps),
Acceleration lane length	= 500 ft (all ramps),
Deceleration lane length	= 500 ft (all ramps),
D_{cr}	= 130 pc/mi/ln,
c_{ad}	= 2,300 pc/h/ln (for *FFS* = 60 mi/h),
L_s	= 1,640 ft (for Weaving Segment 6),
TRD	= 1.0 ramp/mi,
Terrain	= level,
Analysis duration	= 75 min (divided into five 15-min intervals), and
Demand adjustment	= 11% (all segments and all time intervals).

Comments

The traffic demand flow inputs are identical to those in Example Problem 2, which reflected an 11% increase in traffic applied to all segments and all time periods. In an attempt to solve the congestion effect found in the earlier example, the facility was widened in Segments 7 and 11. This change directly affects the capacities of those segments.

In a more subtle way, the proposed modifications also change some of the defining parameters of Weaving Segment 6 as well. With the added continuous lane downstream of the segment, the required number of lane changes from the ramp to the freeway is reduced from one to zero, following the guidelines in Chapter 12. These changes need to be considered when the undersaturated performance of that segment is evaluated. The weaving segment's capacity is unchanged relative to Example Problem 2, since, even with the proposed improvements, the number of weaving lanes remains two.

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Step 1: Input Data

Traffic demand inputs for all 11 segments and five analysis intervals are coded in the same manner as in Example Problem 2 as shown in Exhibit 10-35. The values in Exhibit 10-35 represent the adjusted demand flows on the facility as determined from field observations or other sources. The actual volume served in each segment will be determined during the methodologies and is expected to be less downstream of a congested segment. Additional geometric and traffic-related inputs are as specified in Exhibit 10-44 and the facts section of the problem statement.

Step 2: Demand Adjustments

The traffic flows in Exhibit 10-35 have already been given in the form of actual demands and no further demand adjustments are necessary.

Step 3: Compute Segment Capacities

Segment capacities are determined by using the methodologies of Chapter 11 for basic freeway segments, Chapter 12 for weaving segments, and Chapter 13 for merge and diverge segments. The resulting capacities are shown in Exhibit 10-45. Since the capacity of a weaving segment depends on traffic patterns, it varies by time period. The remaining capacities are constant for all five time steps. The capacities for Segments 1–5 and for Segments 7–11 are the same, since the segments have the same basic cross section.

Exhibit 10-45
Segment Capacities for Example Problem 3

Time Step	Capacities (veh/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1						8,253					
2						8,700					
3	6,732	6,732	6,732	6,732	6,732	8,403	8,976	8,976	8,976	8,976	8,976
4						8,382					
5						8,418					

Step 4: Adjust Segment Capacities

No additional capacity adjustments are made in this example.

Step 5: Compute Demand-to-Capacity Ratios

The demand-to-capacity ratios are calculated from the demand flows in Exhibit 10-35 and segment capacities in Exhibit 10-45.

Exhibit 10-46
Segment Demand-to-Capacity Ratios for Example Problem 3

Time Step	Demand-to-Capacity Ratio by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	0.74	0.82	0.82	0.82	0.77	0.73	0.60	0.56	0.56	0.62	0.62
2	0.82	0.91	0.91	0.91	0.85	0.79	0.68	0.75	0.75	0.75	0.71
3	0.86	0.97	0.97	0.97	0.90	0.85	0.75	0.82	0.82	0.82	0.77
4	0.77	0.83	0.83	0.83	0.79	0.69	0.59	0.65	0.65	0.65	0.61
5	0.62	0.55	0.66	0.65	0.51	0.52	0.47	0.50	0.50	0.50	0.48

The demand-to-capacity ratio matrix for Example Problem 3 (Exhibit 10-46) shows that the capacity improvements successfully restored all the previously congested segments to $v/c < 1.00$. Therefore, it is expected that the facility will operate as originally understood and that all segment performance measures can

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be directly computed by using the methodologies in Chapters 11, 12, and 13 in Step 6a.

Step 6a: Compute Undersaturated Segment Service Measures

Since the facility is globally undersaturated, the methodology proceeds to calculate performance and service measures for each segment and each time step, starting with the first segment in Time Interval 1. The computational details for each segment type are exactly as described in Chapters 11, 12, and 13. The weaving methodology in Chapter 13 checks whether the weaving short length L_S is less than or equal to the maximum weaving length L_{max}. It is assumed that, for any time interval where L_S is longer than L_{max}, the weaving segment will operate as a basic freeway segment.

The basic performance service measures computed for each segment and each time interval include the segment speed (Exhibit 10-47), density (Exhibit 10-48), and LOS (Exhibit 10-49).

Time Step	Speed (mi/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	55.8	59.1	58.6	55.9	59.4	58.4	60.3	54.9	54.9	58.1	60.0
2	58.6	62.1	56.7	55.5	57.8	60.0	60.3	54.3	54.4	57.7	60.0
3	57.4	61.0	59.0	55.4	56.1	49.7	59.8	53.6	53.6	57.2	59.5
4	59.4	61.0	58.7	55.8	58.2	58.7	60.3	55.3	55.0	58.1	60.0
5	60.3	61.5	59.7	58.7	60.3	61.4	60.3	55.9	55.9	58.8	60.0

Exhibit 10-47
Speed Matrix for Example Problem 3

Time Step	Density (veh/mi/ln) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	27.9	34.5	31.3	32.8	29.2	26.8	22.5	25.9	26.9	25.4	22.3
2	41.4	49.0	46.5	46.7	42.9	33.5	25.4	38.9	38.9	36.0	30.7
3	33.7	42.5	40.9	41.9	37.5	45.7	29.3	34.5	34.5	43.4	29.3
4	25.2	25.2	22.1	21.4	23.8	26.1	22.1	26.4	26.4	24.9	22.5
5	23.3	26.9	20.6	20.1	22.8	20.6	17.5	22.1	20.1	19.1	17.5

Exhibit 10-48
Density Matrix for Example Problem 3

Time Step	LOS for Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	D	D	D	D	D	D	C	C	C	C	C
2	D	D	E	D	D	D	D	C	C	C	D
3	D	D	E	D	E	E	D	D	D	D	D
4	D	D	D	D	D	D	C	C	C	C	C
5	C	C	C	C	C	C	B	B	B	B	C

Exhibit 10-49
LOS Matrix for Example Problem 3

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Step 7: Compute Facility Service Measures and Determine LOS

In the final analysis step, facilitywide performance and service measures are calculated for each time step (Exhibit 10-50), consistent with Example Problem 2. Only summary results are shown in this case, since the computations have already been shown. The improvement has been able to restore the facility LOS to the values experienced in the original progression scenario shown in Exhibit 10-34.

Exhibit 10-50
Facility Performance Measure Summary for Example Problem 2

Time Step	Performance Measure: Space Mean Speed (mi/h)	Performance Measure: Average Density (veh/mi/ln)	LOS
1	57.9	26.8	D
2	57.1	30.4	D
3	56.0	33.5	D
4	57.8	26.9	D
5	58.6	20.8	C
Total	**57.3**	**27.7**	—

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CHAPTER 11
BASIC FREEWAY SEGMENTS

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1. INTRODUCTION

Basic freeway segments are defined as those freeway segments that are outside the influence of merging, diverging, or weaving maneuvers. In general, this means that lane-changing activity is not significantly influenced by the presence of ramps and weaving segments. Lane-changing activity primarily reflects the normal desire of drivers to optimize their efficiency through lane-changing and passing maneuvers.

A complete discussion of influence areas is included in Chapter 10, Freeway Facilities, with additional discussion in Chapters 12, Freeway Weaving Segments, and 13, Freeway Merge and Diverge Segments. In general terms, the influence area of merge (on-ramp) segments extends for 1,500 ft downstream of the merge point, the influence area of diverge (off-ramp) segments extends for 1,500 ft upstream of the diverge point, and the influence area of weaving segments extends 500 ft upstream and downstream of the segment itself. This description is not to suggest that the influence of these segments cannot extend over a broader range, particularly under breakdown conditions. Under stable operations, however, these distances define the areas most affected by merge, diverge, and weaving movements. The impact of breakdown on any type of freeway segment on adjacent segments can be addressed by using the methodology of Chapter 10, Freeway Facilities.

Chapter 11, Basic Freeway Segments, provides a methodology for analyzing the capacity and level of service (LOS) of existing or planned basic freeway segments. The methodology can also be used for design applications, where the number of lanes needed to provide a target LOS for an existing or projected demand flow rate can be found.

Analysis segments must have uniform geometric and traffic conditions, including demand flow rate.

Such analyses are applied to basic freeway segments with uniform characteristics. Uniform segments must have the same geometric and traffic characteristics, including a constant demand flow rate.

BASE CONDITIONS

Base conditions exclude good weather and visibility and no incidents or accidents. These conditions are always assumed to exist.

The base conditions under which the full capacity of a basic freeway segment is achieved include good weather, good visibility, no incidents or accidents, no work zone activity, and no pavement deterioration serious enough to affect operations. This chapter's methodology assumes that these conditions exist. If any of these conditions do not exist, the speed, LOS, and capacity of the freeway segment can be expected to be worse than those predicted by this methodology.

Base conditions also include the following conditions, which can be adjusted as the methodology is applied to address situations in which these conditions do not exist:

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Base conditions also include 0% heavy vehicles, a driver population composed of regular users of the roadway, and 12-ft lane widths and minimum 6-ft right-side clearances.

The methodology provides adjustments for situations when these conditions do not apply.

- No heavy vehicles (trucks, buses, recreational vehicles [RVs]) in the traffic stream,
- A driver population composed primarily of regular users who are familiar with the facility, and
- Minimum 12-ft lane widths and 6-ft right-side clearances.

FLOW CHARACTERISTICS UNDER BASE CONDITIONS

Traffic flow within basic freeway segments can be highly variable depending on the conditions constricting flow at upstream and downstream bottleneck locations. Such bottlenecks can be created by merging, diverging, or weaving traffic; lane drops; maintenance and construction activities; traffic accidents or incidents; objects in the roadway; or all of the foregoing. Bottlenecks can exist even when a lane is not fully blocked. Partial blockages will cause drivers to slow and divert their paths. In addition, the practice of rubbernecking near roadside incidents or accidents can cause additional bottlenecks.

Types of Flow

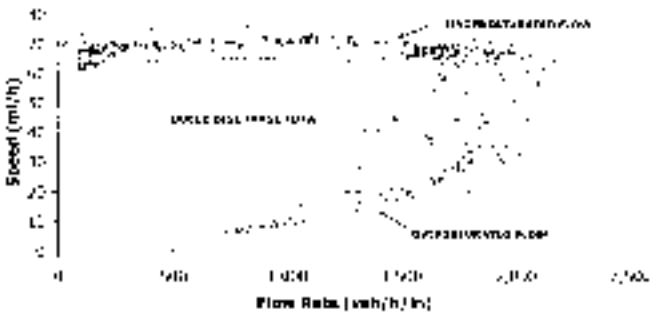
Chapter 3 describes in more detail the types of traffic flow on basic freeway segments.

As was discussed in more detail in Chapter 3, Applications, traffic flow within a basic freeway segment can be categorized as one of three general types: undersaturated, queue discharge, and oversaturated.

- *Undersaturated flow* represents conditions under which the traffic stream is unaffected by upstream or downstream bottlenecks.
- *Queue discharge flow* represents traffic flow that has just passed through a bottleneck and is accelerating back to drivers' desired speeds for the prevailing conditions. As long as another downstream bottleneck does not exist, queue discharge flow is relatively stable until the queue is fully discharged.
- *Oversaturated flow* represents the conditions within a queue that was backed up from a downstream bottleneck. These flow conditions do not reflect the prevailing conditions of the site itself but rather the consequences of a downstream problem. All oversaturated flow is considered to be congested.

An example of each of the three types of flow discussed is illustrated in Exhibit 11-1, using data from a freeway in California.

Exhibit 11-1
Three Types of Freeway Flow



Note: I-405, Los Angeles, Calif.
Source: California Department of Transportation, 2008.

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The analysis methodology for basic freeway segments is based entirely on calibrations of the speed–flow relationships under base conditions with undersaturated flow. The methodology identifies cases in which failure has occurred but does not attempt to describe operating conditions when a segment has failed. The methodology of Chapter 10, Freeway Facilities, should be used for oversaturated conditions.

The basic freeway segment methodology is based on undersaturated flow conditions

Speed–Flow Curves for Base Conditions

A set of speed–flow curves for basic freeway segments operating under base conditions is shown in Exhibit 11-2. There are five curves, one for each of five levels of free-flow speed (FFS): 75 mi/h, 70 mi/h, 65 mi/h, 60 mi/h, and 55 mi/h. Technically speaking, the FFS is the speed at the y-intercept of each curve. In practical terms, there are two ranges in the shape of the curves:

- For each curve, a range of flows exists from 0 pc/h/ln to a breakpoint in which speed remains constant at the FFS. The ranges vary for each of the curves as follows:
  - FFS = 75 mi/h: 0–1,300 pc/h/ln;
  - FFS = 70 mi/h: 0–1,200 pc/h/ln;
  - FFS = 65 mi/h: 0–1,400 pc/h/ln;
  - FFS = 60 mi/h: 0–1,600 pc/h/ln; and
  - FFS = 55 mi/h: 0–1,800 pc/h/ln.
- At flow rates above the breakpoint of each curve, speeds decline at an increasing rate until capacity is reached.

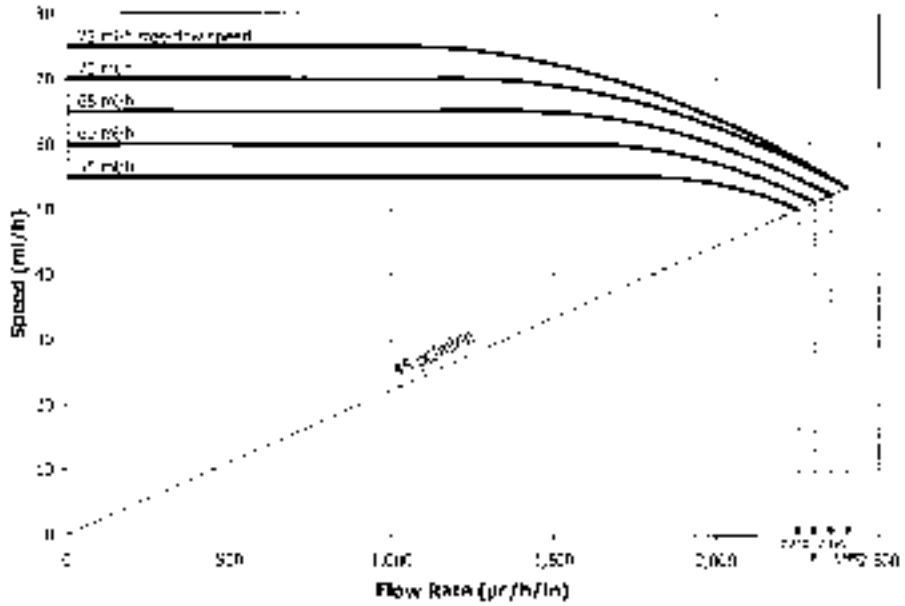

Exhibit 11-2
Speed–Flow Curves for Basic Freeway Segments Under Base Conditions

Exhibit 11-3 shows the equations that define each of the curves in Exhibit 11-2. Because estimating or measuring FFS is difficult, and there is considerable variation in observed and predicted values, no attempt should be made to

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FFS should be rounded to the nearest 5 mi/h.

interpolate between the basic curves. FFS should be rounded to the nearest 5 mi/h as follows:

- ≥72.5 mi/h < 77.5 mi/h: use FFS = 75 mi/h,
- ≥67.5 mi/h < 72.5 mi/h: use FFS = 70 mi/h,
- ≥62.5 mi/h < 67.5 mi/h: use FFS = 65 mi/h,
- ≥57.5 mi/h < 62.5 mi/h: use FFS = 60 mi/h,
- ≥52.5 mi/h < 57.5 mi/h: use FFS = 55 mi/h.

Exhibit 11-3
Equations Describing Speed–Flow Curves in Exhibit 11-2 (Speeds in mi/h)

FFS (mi/h)	Breakpoint (pc/h/ln)	Flow Rate Range: 0 ≤ Breakpoint	Flow Rate Range: >Breakpoint ≤ Capacity
75	1,000	75	$75 - 0.00001107 (v_p - 1,000)^2$
70	1,200	70	$70 - 0.00001160 (v_p - 1,200)^2$
65	1,400	65	$65 - 0.00001419 (v_p - 1,400)^2$
60	1,600	60	$60 - 0.00001826 (v_p - 1,600)^2$
55	1,800	55	$55 - 0.00002469 (v_p - 1,800)^2$

Notes: FFS = free-flow speed; v_p = demand flow rate (pc/h/ln) under equivalent base conditions.
Maximum flow rate for the equations is capacity: 2,400 pc/h/ln for 70- and 75-mi/h FFS; 2,350 pc/h/ln for 65-mi/h FFS; 2,300 pc/h/ln for 60-mi/h FFS; and 2,250 pc/h/ln for 55-mi/h FFS.

The research leading to these curves (*1, 2*) found that several factors affect the FFS of a basic freeway segment, including the lane width, right-shoulder clearance, and ramp density. Ramp density is the average number of on-ramps plus off-ramps in a 3-mi range, 3 mi upstream and 3 mi downstream of the midpoint of the study segment. Many other factors are likely to influence FFS, horizontal and vertical alignment, posted speed limits, level of speed enforcement, lighting conditions, and weather. Although these factors may affect FFS, little information is available that would allow their quantification.

CAPACITY UNDER BASE CONDITIONS

The capacity of a basic freeway segment under base conditions varies with the FFS. For 70- and 75-mi/h FFS, the capacity is 2,400 pc/h/ln. For lower levels of FFS, capacity diminishes slightly. For 65-mi/h FFS, the capacity is 2,350 pc/h/ln; for 60-mi/h FFS, 2,300 pc/h/ln; and for 55-mi/h FFS, 2,250 pc/h/ln.

Base capacity values refer to the average flow rate across all lanes. Individual lanes could have stable flows in excess of these values.

Chapter 10, Freeway Facilities, contains information that would allow these values to be reduced to reflect long- and short-term construction and maintenance activities, adverse weather conditions, and accidents or incidents.

Since freeways usually do not operate under base conditions, observed capacity values will typically be lower than the base capacity values.

These values represent national norms. It should be remembered that capacity varies stochastically and that any given location could have a larger or smaller value. It should also be remembered that capacity refers to the *average* flow rate across all lanes. Thus, a three-lane basic freeway segment with a 70-mi/h FFS would have an expected base capacity of 3 × 2,400 = 7,200 pc/h. This flow would not be uniformly distributed across all lanes. Thus, one or two lanes could have stable case flows in excess of 2,400 pc/h/ln.

As shown in Exhibit 11-2, it is believed that basic freeway segments reach capacity at a density of approximately 45 passenger cars per mile per lane (pc/mi/ln), which may vary slightly from location to location. At this density,

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vehicles are too closely spaced to dampen the impact of any perturbation in flow, such as a lane change or a vehicle entering the freeway, without causing a disruption that propagates upstream.

LOS FOR BASIC FREEWAY SEGMENTS

LOS for basic freeway segments is defined by density.

LOS on a basic freeway segment is defined by density. Although speed is a major concern of drivers as related to service quality, it would be difficult to describe LOS by using speed, since it remains constant up to flow rates of 1,000 to 1,800 pc/h/ln, depending on the FFS. Density describes the proximity to other vehicles and is related to the freedom to maneuver within the traffic stream. Unlike speed, however, density is sensitive to flow rates throughout the range of flows.

Exhibit 11-4 visually demonstrates the six LOS defined for basic freeway segments. LOS are defined to represent reasonable ranges in the three critical flow variables: speed, density, and flow rate.

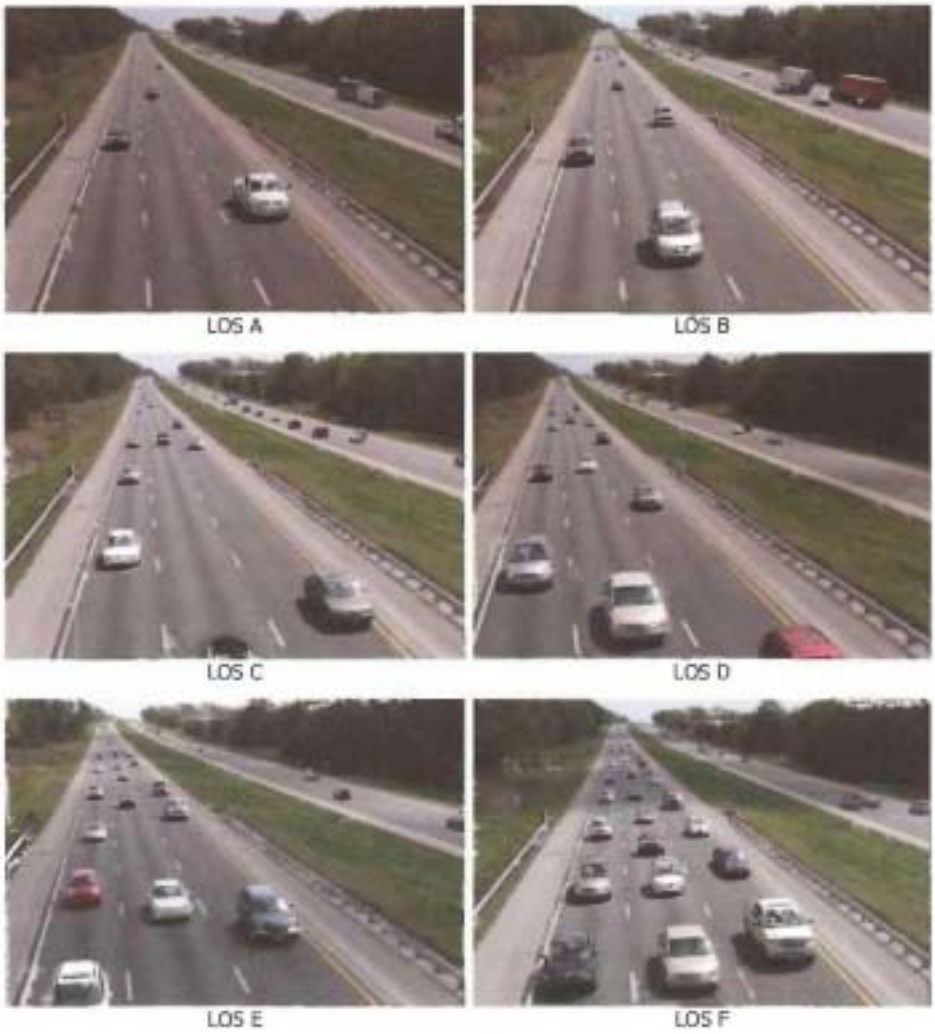

Exhibit 11-4
LOS Examples

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Freeway LOS Described

LOS A describes free-flow operations. FFS prevails on the freeway, and vehicles are almost completely unimpeded in their ability to maneuver within the traffic stream. The effects of incidents or point breakdowns are easily absorbed.

LOS B represents reasonably free-flow operations, and FFS on the freeway is maintained. The ability to maneuver within the traffic stream is only slightly restricted, and the general level of physical and psychological comfort provided to drivers is still high. The effects of minor incidents and point breakdowns are still easily absorbed.

LOS C provides for flow with speeds near the FFS of the freeway. Freedom to maneuver within the traffic stream is noticeably restricted, and lane changes require more care and vigilance on the part of the driver. Minor incidents may still be absorbed, but the local deterioration in service quality will be significant. Queues may be expected to form behind any significant blockages.

LOS D is the level at which speeds begin to decline with increasing flows, with density increasing more quickly. Freedom to maneuver within the traffic stream is seriously limited and drivers experience reduced physical and psychological comfort levels. Even minor incidents can be expected to create queuing, because the traffic stream has little space to absorb disruptions.

LOS E describes operation at capacity. Operations on the freeway at this level are highly volatile because there are virtually no usable gaps within the traffic stream, leaving little room to maneuver within the traffic stream. Any disruption to the traffic stream, such as vehicles entering from a ramp or a vehicle changing lanes, can establish a disruption wave that propagates throughout the upstream traffic flow. At capacity, the traffic stream has no ability to dissipate even the most minor disruption, and any incident can be expected to produce a serious breakdown and substantial queuing. The physical and psychological comfort afforded to drivers is poor.

LOS F describes breakdown, or unstable flow. Such conditions exist within queues forming behind bottlenecks. Breakdowns occur for a number of reasons:

- Traffic incidents can temporarily reduce the capacity of a short segment, so that the number of vehicles arriving at a point is greater than the number of vehicles that can move through it.
- Points of recurring congestion, such as merge or weaving segments and lane drops, experience very high demand in which the number of vehicles arriving is greater than the number of vehicles that can be discharged.
- In analyses using forecast volumes, the projected flow rate can exceed the estimated capacity of a given location.

Breakdown (LOS F) occurs whenever the demand-to-capacity ratio exceeds 1.00.

In all cases, breakdown occurs when the ratio of existing demand to actual capacity, or of forecast demand to estimated capacity, exceeds 1.00. Operations immediately downstream of, or even at, such a point, however, are generally at or near LOS E, and downstream operations improve (assuming that there are no additional downstream bottlenecks) as discharging vehicles move away from the bottleneck.

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LOS F operations within a queue are the result of a breakdown or bottleneck at a downstream point. In practical terms, the point of the breakdown has a *v/c* ratio greater than 1.00, and is also labeled LOS F, although actual operations at the breakdown point and immediately downstream may actually reflect LOS E conditions. Whenever queues due to a breakdown exist, they have the potential to extend upstream for considerable distances.

The effects of a breakdown can extend upstream for a considerable distance.

LOS Criteria

A basic freeway segment can be characterized by three performance measures: density in passenger cars per mile per lane (pc/mi/ln), space mean speed in miles per hour (mi/h), and the ratio of demand flow rate to capacity (*v/c*). Each of these measures is an indication of how well traffic is being accommodated by the basic freeway segment.

Because speed is constant through a broad range of flows and the *v/c* ratio is not directly discernible to road users (except at capacity), the service measure for basic freeway segments is density. Exhibit 11-5 shows the criteria.

Exhibit 11-5
LOS Criteria for Basic Freeway Segments

LOS	Density (pc/mi/ln)
A	≤11
B	>11–18
C	>18–26
D	>26–35
E	>35–45
F	Demand exceeds capacity >45

For all LOS, the density boundaries on basic freeway segments are the same as those for surface multilane highways, except at the LOS E/F boundary. Traffic characteristics are such that the maximum flow rates at any given LOS are lower on multilane highways than on similar basic freeway segments.

The specification of maximum densities for LOS A to D is based on the collective professional judgment of the members of the Transportation Research Board's Highway Capacity and Quality of Service Committee. The upper value shown for LOS E (45 pc/mi/ln) is the maximum density at which sustained flows at capacity are expected to occur. In effect, as indicated in the speed–flow curves of Exhibit 11-2, when a density of 45 pc/mi/ln is reached, flow is at capacity, and the *v/c* ratio is 1.00.

In the application of this chapter's methodology, however, LOS F is identified when demand exceeds capacity because the analytic methodology does not allow the determination of density when demand exceeds capacity. Although the density will be greater than 45 pc/mi/ln, the methodology of Chapter 10, Freeway Facilities, must be applied to determine a more precise density for such cases.

Exhibit 11-6 illustrates the defined LOS on the base speed–flow curves. On a speed–flow plot, density is a line of constant slope beginning at the origin. The LOS boundaries were defined to produce reasonable ranges within each LOS on these speed–flow relationships.

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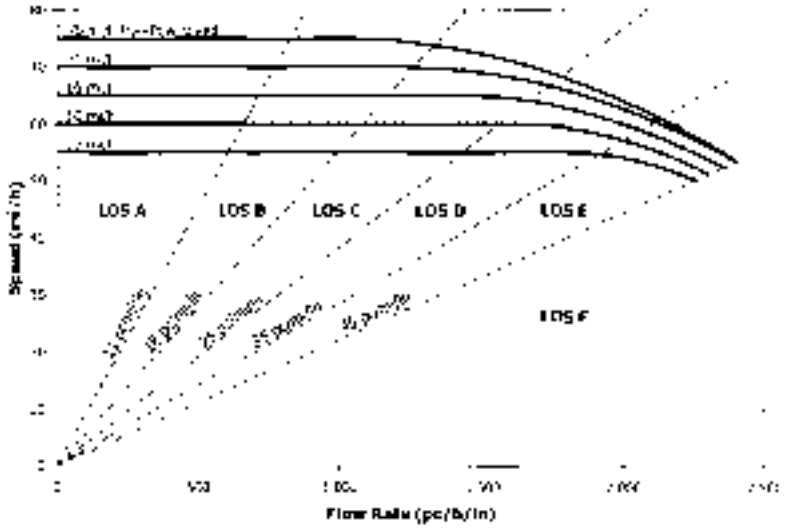
Exhibit 11-6
LOS for Basic Freeway Segments



REQUIRED INPUT DATA

The analysis of a basic freeway segment requires details concerning the geometric characteristics of the segment and the demand characteristics of the users of the segment. This section presents the required input data for the basic freeway segment methodology; specifics about individual parameters are given in the Methodology section.

Freeway Data

The following information on the segment's geometric features is needed to conduct an analysis (typical ranges for these parameters are shown):

1. FFS: 55 to 75 mi/h;
2. Number of mainline freeway lanes (one direction): at least two;
3. Lane width: 10 ft to 12 ft or more;
4. Right-side lateral clearance: 0 ft to more than 6 ft;
5. Total ramp density: 0 to 6 ramps/mi; and
6. Terrain: level, rolling, or mountainous; or specific length and percent grade.

Demand Data

The following information on the segment's users is required:

1. Demand during the analysis hour or daily demand and *K* and *D* factors;
2. Heavy-vehicle presence (proportion of trucks, buses, and RVs): 0 to 100% on general terrain, or 0 to 25% or more for specific grades;
3. Peak-hour factor (PHF): up to 1.00; and
4. Driver population factor: 0.85 to 1.00.

Length of Analysis Period

The analysis period for any freeway analysis is generally the peak 15-min period within the peak hour. Any 15-min period can be analyzed, however.

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2. METHODOLOGY

This chapter's methodology can be used to analyze the capacity, LOS, lane requirements, and effects of design features on the performance of basic freeway segments. The methodology is based on the results of an NCHRP study (1), which has been partially updated (2). A number of significant publications were also used in the development of the methodology (3–12).

LIMITATIONS OF METHODOLOGY

This chapter's methodology does not apply to or take into account (without modification by the analyst) the following:

- Special lanes reserved for a single vehicle type, such as high-occupancy-vehicle (HOV) lanes, truck lanes, and climbing lanes;
- Lane control (by restricted lane changing);
- Extended bridge and tunnel segments;
- Segments near a toll plaza;
- Facilities with FFS less than 55 mi/h or more than 75 mi/h;
- The influence of downstream queuing on a segment;
- Posted speed limit and enforcement practices;
- Presence of intelligent transportation systems (ITS) related to vehicle or driver guidance;
- Capacity enhancing effects of ramp metering;
- Operational effects of oversaturated conditions; and
- Operational effects of construction operations.

In most of the cases just cited, the analyst would have to utilize alternative tools or draw on other research information and develop special-purpose modifications of this methodology to incorporate the effects of any of the cited conditions. Operational effects of oversaturated conditions, incidents, work zones, and weather and lighting conditions can be evaluated with the methodology of Chapter 10, Freeway Facilities. Operational effects of active traffic management measures are discussed in Chapter 35.

Active traffic management measures for freeways discussed in Chapter 35 consist of:

- *Dynamic shoulder running,*
- *Congestion pricing,*
- *Traveler information systems,*
- *Dynamic lane and shoulder management,*
- *Speed harmonization,*
- *Incident management, and*
- *Work zone traffic management.*

OVERVIEW OF METHODOLOGY

The methodology of this chapter is for the analysis of basic freeway segments. A method for analysis of extended lengths of freeway composed of a concatenation of basic freeway segments, weaving segments, and merge or diverge segments is found in Chapter 10, Freeway Facilities.

Exhibit 11-9 illustrates the basic methodology used in operational analysis. The methodology can also be directly applied to determine the number of lanes required to provide a target LOS for a given demand volume.

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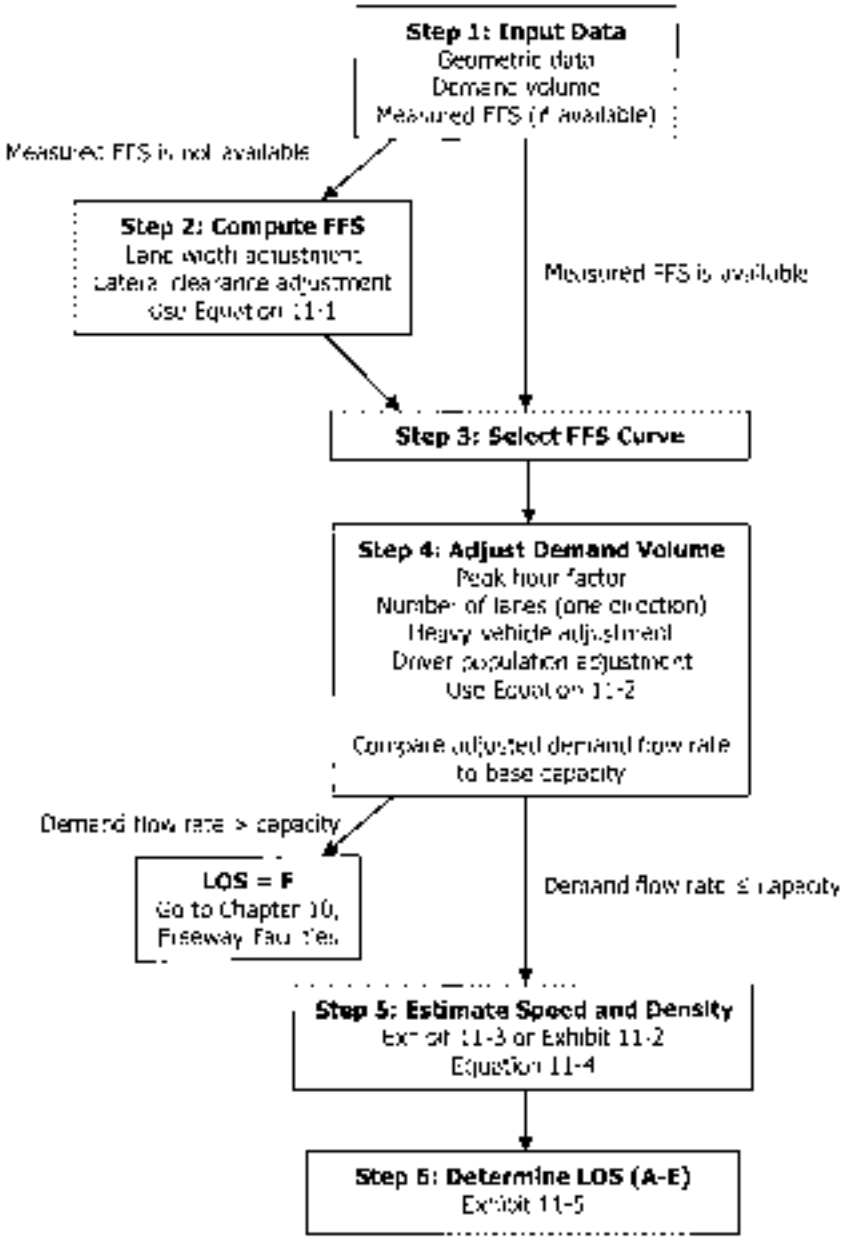
Exhibit 11-7
Overview of Operational Analysis Methodology for Base Freeway Segments

Exhibit 11-7 illustrates the methodology for operational analysis. Other types of analysis are described in the Applications section.



COMPUTATIONAL STEPS

Step 1: Input Data

For a typical operational analysis, as noted previously, the analyst would have to specify (with either site-specific or default values) demand volume, number and width of lanes, right-side lateral clearance, total ramp density, percent of heavy vehicles (trucks, buses, and RVs), PHF, terrain, and the driver population factor.

Step 2: Compute FFS

FFS can be determined directly from field measurements or can be estimated as described below.

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Field Measurement of FFS

FFS is the mean speed of passenger cars measured during periods of low to moderate flow (up to 1,000 pc/h/ln). For a specific freeway segment, average speeds are virtually constant at this range of flow rates. If the FFS can be field measured, this is the preferable way to make the determination. If the FFS is measured directly, no adjustments are applied to the measured value.

FFS is the mean speed of passenger cars during periods of low to moderate flow.

The speed study should be conducted at a location that is representative of the segment at a time when flow rates are less than 1,000 pc/h/ln. The speed study should measure the speeds of all passenger cars or use a systematic sample (e.g., every tenth car in each lane). A sample of at least 100 passenger-car speeds should be obtained. Any speed measurement technique that has been found acceptable for other types of traffic engineering applications may be used. Further guidance on the conduct of speed studies is provided in standard traffic engineering publications, such as the Institute of Transportation Engineers *Manual of Traffic Engineering Studies* (*11*).

Estimating FFS

It is not possible to make field measurements for future conditions, and field measurement may not be possible or practical in all existing cases. In such cases, the segment's FFS may be estimated by using Equation 11-1, which is based on the physical characteristics of the segment under study.

$$FFS = 75.4 \quad f_{LW} \quad f_{LC} \quad 3.22 TRD^{0.84} \qquad \text{Equation 11-1}$$

where

FFS = FFS of basic freeway segment (mi/h),

f_{LW} = adjustment for lane width (mi/h),

f_{LC} = adjustment for right-side lateral clearance (mi/h), and

TRD = total ramp density (ramps/mi).

Base FFS

This methodology covers basic freeway segments with FFSs ranging from 55 mi/h to 75 mi/h. Thus, the predictive algorithm must start with a base speed of 75 mi/h or higher. A value of 75.4 mi/h was chosen, since it resulted in the most accurate predictions versus data collected in 2008.

Adjustment for Lane Width

The base condition for lane width is 12 ft or greater. When the average lane width across all lanes is less than 12 ft, the FFS is negatively affected. Adjustments to reflect the effect of narrower average lane widths are shown in Exhibit 11-8.

Average Lane Width (ft)	Reduction in FFS, f_{LW} (mi/h)
≥12	0.0
11–12	1.9
<11–11	9.6

Exhibit 11-8
Adjustment to FFS for Average Lane Width

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Adjustment for Lateral Clearance

The base condition for right-side lateral clearance is 6 ft or greater. The lateral clearance is measured from the right edge of the travel lane to the nearest lateral obstruction. Care must be taken to identify a "lateral obstruction." Some obstructions may be continuous, such as retaining walls, concrete barriers, guardrails, or barrier curbs. Others may be periodic, such as light supports or bridge abutments. In some cases, drivers may become accustomed to certain types of obstructions, often making them influential on traffic negligible.

Exhibit 11-9 shows the adjustments to the base FFS due to the existence of obstructions closer than 6 ft to the right travel lane edge. Median clearances of 2 ft or more generally have little impact on traffic. No adjustments are available to reflect the presence of left-side lateral obstructions closer than 2 ft to the left travel lane edge. Such situations are, however, quite rare on modern freeways, except in constrained work zones.

Exhibit 11-9
Adjustment to FFS for Right-Side Lateral Clearance, f_{LC} (mi/h)

Right-Side Lateral Clearance (ft)	Lanes in One Direction			
	2	3	4	≥ 5
≥ 6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

The impact of a right-side lateral clearance restriction depends on both the distance to the obstruction and the number of lanes in one direction on the basic freeway segment. A lateral clearance restriction causes vehicles in the right lane to move somewhat to the left. This movement, in turn, affects vehicles in the next lane. As the number of lanes increases, the overall effect on freeway operations decreases.

Total Ramp Density

Equation 11-1 includes a term that accounts for the impact of total ramp density on FFS. Total ramp density is defined as the number of ramps (on and off, one direction) located between 3 mi upstream and 3 mi downstream of the midpoint of the basic freeway segment under study, divided by 6 mi. The total ramp density has been found to be a measure of the impact of merging and diverging vehicles on FFS.

Step 3: Select FFS Curve

As noted previously, once the FFS of the basic freeway segment is determined, one of the five base speed–flow curves (Exhibit 11-2) is selected for use in the analysis. Interpolation between curves is not recommended. Criteria for selecting an appropriate curve were given in the text following Exhibit 11-2.

Step 4: Adjust Demand Volume

Since the basis speed–flow curves of Exhibit 11-2 are based on flow rates in equivalent passenger cars per hour, with the driver population dominated by

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regular users of the basic freeway segment, demand volumes expressed as vehicles per hour under prevailing conditions must be converted to this basis. Equation 11-2 is used for this adjustment:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p} \quad \text{Equation 11-2}$$

where

v_p = demand flow rate under equivalent base conditions (pc/h/ln),
V = demand volume under prevailing conditions (veh/h),
PHF = peak hour factor,
N = number of lanes in analysis direction,
f_{HV} = adjustment factor for presence of heavy vehicles in traffic stream, and
f_p = adjustment factor for unfamiliar driver populations.

Peak Hour Factor

The PHF represents the variation in traffic flow within an hour. Observations of traffic flow consistently indicate that the flow rates found in the peak 15 min within an hour are not sustained throughout the entire hour. The application of the PHF in Equation 11-2 accounts for this phenomenon.

On freeways, typical PHFs range from 0.85 to 0.98 (15). Lower values within that range are typical of lower volume conditions. Higher values within that range are typical of urban and suburban peak hour conditions. Field data should be used if possible to develop PHFs that represent local conditions.

Adjustment for Heavy Vehicles

A heavy vehicle is defined as any vehicle with more than four wheels on the ground during normal operation. Such vehicles are generally categorized as trucks, buses, or RVs. Trucks cover a wide variety of vehicles, from single-unit trucks with double rear tires to triple-unit tractor–trailer combinations. Small panel or pickup trucks with only four wheels are, however, classified as passenger cars. Buses include intercity buses, public transit buses, and school buses. Because buses are in many ways similar to single-unit trucks, both types of vehicles are considered in one category. RVs include a wide variety of vehicles from self-contained motor homes to cars and small trucks with trailers (for boats, all-terrain vehicles, or other conveyances). It should be noted that most sport-utility vehicles have only four wheels and are thus categorized as passenger cars. The heavy vehicle adjustment factor f_{HV} is computed as follows:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \quad \text{Equation 11-3}$$

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where

f_{HV} = heavy-vehicle adjustment factor,

P_T = proportion of trucks and buses in traffic stream,

P_R = proportion of RVs in traffic stream,

E_T = passenger-car equivalent (PCE) of one truck or bus in traffic stream, and

E_R = PCE of one RV in traffic stream.

The adjustment factor is found in a two-step process. First, the PCE for each truck or bus and RV is found for the prevailing conditions under study. These equivalency values represent the number of passenger cars that would use the same amount of freeway capacity as one truck or bus or RV under the prevailing conditions. Second, Equation 11-3 is used to convert the PCE values to the adjustment factor.

In many cases, trucks will be the only heavy vehicle type present in the traffic stream. In others, the percentage of RVs will be small in comparison with trucks and buses. If the ratio of trucks and buses to RVs is 5:1 or greater, all heavy vehicles may be (but do not have to be) considered to be trucks.

The effect of heavy vehicles on traffic flow depends on terrain and grade conditions as well as traffic composition. PCEs can be selected for one of three conditions:

- Extended freeway segments in general terrain,
- Specific upgrades, or
- Specific downgrades.

Each of these conditions is more precisely defined and discussed next.

Equivalents for General Terrain Segments

General terrain refers to extended lengths of freeway containing a number of upgrades and downgrades where no one grade is long enough or steep enough to have a significant impact on the operation of the overall segment. As a guideline for this determination, extended segment analysis can be applied where grades are ≤2% and ≤0.25 mi long, or where grades between 2% and 3% are ≤0.50 mi long. For this determination, each upgrade and downgrade is considered to be a single grade, even if the grade is not uniform. The total length of the upgrade or downgrade is used with the steepest grade it contains. There are three categories of general terrain:

- *Level terrain*. Any combination of grades and horizontal or vertical alignment that permits heavy vehicles to maintain the same speed as passenger cars. This type of terrain typically contains short grades of no more than 2%.
- *Rolling terrain*. Any combination of grades and horizontal or vertical alignment that causes heavy vehicles to reduce their speed substantially below those of passenger cars but that does not cause heavy vehicles to operate at crawl speeds for any significant length

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of time or at frequent intervals. *Crawl speed* is the maximum sustained speed that trucks can maintain on an extended upgrade of a given percent. If the grade is long enough, trucks will be forced to decelerate to the crawl speed, which they can maintain for extended distances. Appendix A contains truck-performance curves illustrating crawl speed and length of grade.

- *Mountainous terrain*: Any combination of grades and horizontal and vertical alignment that causes heavy vehicles to operate at crawl speed for significant distances or at frequent intervals.

The mountainous terrain category is only used, because individual grades will typically be longer, steeper, or both, than the criteria for general terrain analysis.

Mountainous terrain is relatively rare. Generally, it segments severe enough to cause the type of operation described for mountainous terrain, individual grades will be longer or steeper, or both, than the criteria for general terrain analysis.

Exhibit 11-10 shows PCEs for trucks and buses and RVs in general terrain segments.

Exhibit 11-10
PCEs for Heavy Vehicles in General Terrain Segments

Vehicle	PCE by Type of Terrain		
	Level	Rolling	Mountainous
Trucks and buses, E_T	1.5	2.5	4.5
RVs, E_R	1.2	2.0	4.0

Equivalents for Specific Upgrades

Any freeway grade between 2% and 3% and longer than 0.5 mi or 3% or greater and longer than 0.25 mi should be considered a separate segment. The analysis of such segments must consider the upgrade conditions and the downgrade conditions separately, as well as whether the grade is a single, isolated grade of constant percentage or part of a series forming a composite grade. The analysis of composite grades is discussed in Appendix A.

Several studies have shown that freeway truck populations have an average weight-to-horsepower ratio between 125 and 150 lb/hp. This methodology adopts PCEs that are calibrated for a mix of trucks and buses in this range. RVs vary considerably in both type and characteristics and include everything from cars with trailers to self-contained mobile campers. In addition to the variability of vehicle characteristics, RV drivers are typically not professionals, and their degree of skill in handling such vehicles also varies widely. Typical RV weight-to-horsepower ratios range from 30 to 60 lb/hp.

Exhibit 11-11 and Exhibit 11-12 give values of E_T for trucks and buses and E_R for RVs, respectively. These factors vary with the percent of grade, length of grade, and the proportion of heavy vehicles in the traffic stream. Maximum values occur when there are only a few heavy vehicles in the traffic stream. The equivalents decrease as the number of heavy vehicles increases because these vehicles tend to form platoons. Because heavy vehicles have more uniform operating characteristics, fewer large gaps are created in the traffic stream when they platoon, and the impact of a single heavy vehicle in a platoon is less severe than that of a single heavy vehicle in a stream of primarily passenger cars. The aggregate impact of heavy vehicles on the traffic stream, however, increases as numbers and percentages of heavy vehicles increase.

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The grade length should include 25% of the length of the vertical curves at the start and end of the grade.

With two consecutive upgrades, 50% of the length of the vertical curve joining them should be included.

The point of interest is usually the point where heavy vehicles would have the greatest impact on operations: the top of a grade, the top of the steepest grade in a series, or a ramp junction, for example.

The length of the grade is generally taken from a highway profile. It typically includes the straight portion of the grade plus some portion of the vertical curves at the beginning and end of the grade. It is recommended that 25% of the length of the vertical curves at both ends of the grade be included in the length. Where two consecutive upgrades are present, 50% of the length of the vertical curve joining them is included in the length of each grade.

In the analysis of upgrades, the point of interest is generally at the end of the grade, where heavy vehicles would have the maximum effect on operations. However, if a ramp junction is being analyzed, for example, the length of the grade to the merge or diverge point would be used.

On composite grades, the relative steepness of segments is important. If a 3% upgrade is followed by a 2% upgrade, for example, the maximum speed of heavy vehicles is most likely at the end of the 3% segment. Heavy vehicles would be expected to accelerate after entering the 2% segment.

Exhibit 11-11
PCEs for Trucks and Buses (E_T) on Upgrades

Upgrade (%)	Length (mi)	Proportion of Trucks and Buses								
		2%	4%	5%	6%	8%	10%	15%	20%	≥25%
≤2	All	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
>2–3	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.50–0.75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.75–1.00	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	>1.00–1.50	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>1.50	3.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
>3–4	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	>0.50–0.75	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	>0.75–1.00	3.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	>1.00–1.50	3.5	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
	>1.50	4.0	4.0	3.0	3.0	3.0	3.0	2.5	2.5	2.5
>4–5	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>0.50–0.75	3.5	4.0	3.0	3.0	2.5	2.5	2.5	2.5	2.5
	>0.75–1.00	4.0	3.5	3.5	3.5	3.0	3.0	3.0	3.0	3.0
	>1.00	5.0	4.0	4.0	4.0	3.5	3.5	3.0	3.0	3.0
>5–6	0.00–0.25	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	4.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>0.50–0.75	4.5	4.0	3.5	4.0	3.5	3.5	3.5	3.5	3.5
	>0.75–1.00	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0
	>1.00	6.0	5.0	5.0	4.5	3.5	4.5	3.5	3.5	3.5
>6	0.00–0.25	4.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	>0.25–0.50	4.5	4.0	3.5	3.5	3.5	3.0	2.5	2.5	2.5
	>0.50–0.75	5.0	4.5	4.0	4.0	3.5	4.0	2.5	2.5	2.5
	>0.75–1.00	5.5	5.0	4.5	4.5	4.0	3.5	3.0	3.0	3.0
	>1.00	7.0	6.0	5.5	5.5	5.0	4.5	4.0	4.0	4.0

Note: Interpolation for percentages of trucks and buses not shown may be used.

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Upgrade (%)	Length (mi)	Proportion of RVs 2%	4%	5%	6%	8%	10%	15%	20%	≥25%
≤2	All	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
>2–3	0.00–0.50	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	>0.50	3.0	1.5	1.5	1.5	1.5	1.5	1.2	1.2	1.2
>3–4	0.00–0.25	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	>0.25–0.50	2.5	2.5	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	>0.50	3.0	2.5	2.5	2.5	2.0	2.0	2.0	1.5	1.5
>4–5	0.00–0.25	2.5	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	4.0	3.0	3.0	3.0	2.5	2.5	2.0	2.0	2.0
	>0.50	4.5	3.5	4.0	4.0	3.0	2.5	2.5	2.0	2.0
>5	0.00–0.25	4.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	1.5
	>0.25–0.50	5.0	4.0	4.0	3.5	3.0	3.0	2.5	2.5	2.0
	>0.50	5.0	4.5	4.0	4.0	3.5	3.0	3.0	2.5	2.0

Note: Interpolation for percentages of RVs is recommended to the nearest 0.1.

Exhibit 11-12
PCEs for RVs (E_R) on Upgrades

Equivalents for Specific Downgrades

Knowledge of specific impacts of heavy vehicles on operating conditions on downgrades is limited. In general, if the downgrade is not severe enough to cause trucks to shift into a lower gear (to engage engine braking), heavy vehicles may be treated as if they were on level terrain segments. Where a downgrade is severe, trucks must often use low gears to avoid gaining too much speed and running out of control. In such cases, their effect on operating conditions is more significant than on level terrain. Exhibit 11-13 gives values of E_T for this situation.

Downgrade (%)	Length of Grade (mi)	Proportion of Trucks and Buses 5%	10%	15%	≥20%
<4	All	1.5	1.5	1.5	1.5
4–5	≤4	1.5	1.5	1.5	1.5
	>4	2.0	2.0	2.0	1.5
>5–6	≤4	1.5	1.5	1.5	1.5
	>4	5.5	4.0	4.0	3.0
>6	≤4	1.5	1.5	1.5	1.5
	>4	7.5	6.0	5.5	4.5

Exhibit 11-13
PCEs for Trucks and Buses (E_T) on Specific Downgrades

On downgrades, RVs are always treated as if they were on level terrain; E_R is therefore always 1.2 on downgrades regardless of the length or severity of the downgrade or the percentage of RVs in the traffic stream.

E_R is always 1.2 on downgrades

Equivalents for Composite Grades

The vertical alignment of most freeways results in a continuous series of grades. It is often necessary to determine the effect of a series of grades in succession. The most straightforward technique is to compute the average grade from the beginning of the composite grade to the point of interest. The average grade is defined as the total rise from the beginning of the composite grade to the point in question divided by the length of the grade (to the point of interest).

The average grade can be used when all component grades are <4% or the total length of the grades is <4,000 ft

The average-grade technique is an acceptable approach for grades in which all subsections are less than 4% or the total length of the grade is less than 4,000 ft. For more severe composite grades, a detailed technique is presented in Appendix A. This technique uses vehicle performance curves and equivalent speeds to determine the equivalent sample grade for analysis.

Appendix A provides a method for addressing more severe composite grades

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Adjustment for Driver Population

The base traffic stream characteristics for basic freeway segments are representative of traffic streams composed primarily of commuters, or drivers who are familiar with the facility. It is generally accepted that traffic streams with different characteristics (e.g., recreational drivers) use freeways less efficiently. Although data are sparse and reported results vary substantially, significantly lower capacities have been reported on weekends, particularly in recreational areas. It may generally be assumed that the reduction in capacity (LOS E) extends to service flow rates and service volumes for other LOS as well.

An f$_p$ value of 1.00 should generally be used, unless it is known that drivers who are regular users of the freeway.

The adjustment factor f_p is used to reflect the effect of driver population. The values of f_p range from 0.85 to 1.00 in most cases, although lower values have been observed in isolated cases. In general, the analyst should use a value of 1.00, which reflects commuters or otherwise accustomed drivers, unless there is sufficient evidence that a lower value should be used. Where greater accuracy is needed, comparative field studies of commuter and recreational traffic flows and speeds are recommended.

Does LOS F Exist?

At this point, the demand volume has been converted to a demand flow rate in passenger cars per hour per lane under equivalent base conditions. This demand rate must be compared with the base capacity of the basic freeway segment (2,400 pc/h/ln for FFS = 75 mi/h and 70 mi/h; 2,350 pc/h/ln for FFS = 65 mi/h; 2,300 pc/h/ln for FFS = 60 mi/h; 2,250 pc/h/ln for FFS = 55 mi/h).

If the demand exceeds capacity, the LOS is F, and a breakdown has been identified. To analyze the impacts of such a breakdown, the methodology of Chapter 10, Freeway Facilities, must be used. No further analysis using the methodology of the current chapter is possible.

If the demand is less than or equal to capacity, the analysis continues to Step 5.

Step 5: Estimate Speed and Density

At this point in the methodology, the following have been determined: (a) the FFS and appropriate LOS curve for use in the analysis, and (b) the demand flow rate expressed in passenger cars per hour per lane under equivalent base conditions. With this information, the estimated speed and density of the traffic stream may be determined.

With the equations specified in Exhibit 11-3, the expected mean speed of the traffic stream can be computed. A graphical solution with Exhibit 11-2 can also be performed.

With the estimated speed determined, Equation 11-4 is used to estimate the density of the traffic stream:

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$$D = \frac{v_p}{S}$$

Equation 11-4

where

D = density (pc/mi/ln),

v_p = demand flow rate (pc/h/ln), and

S = mean speed of traffic stream under base conditions (mi/h).

As has been noted, Equation 11-4 is only used when the v/c is less than or equal to 1.00. All cases in which this ratio is greater than 1.00 are LOS F. In these cases, the speed S will be outside the range of Exhibit 11-3 and Exhibit 11-4, and no speed can be estimated.

Where LOS F exists, the analyst is urged to consult Chapter 10, Freeway Facilities, which addresses an analysis of the time and spatial impacts of a breakdown, including its effects on upstream and downstream segments.

Step 6: Determine LOS

Exhibit 11-3 is entered with the density obtained from Equation 11-4 to determine the expected prevailing LOS.

SENSITIVITY OF RESULTS

The freeway LOS is most sensitive to the total ramp density.

The FFS of basic freeway segments is most sensitive to the total ramp density. Exhibit 11-14 illustrates the resulting FFS when total ramp density varies from 0 ramps/mi to 6 ramps/mi. Standard lane widths and right-side clearances are assumed. A freeway with 0 ramps/mi represents a case in which there are no ramps within 3 mi on either side of the study location. This situation occurs primarily in rural areas, where interchanges may be 10 or more miles apart. In rare cases, ramp densities in excess of 6 ramps/mi may exist, particularly in dense urban areas.

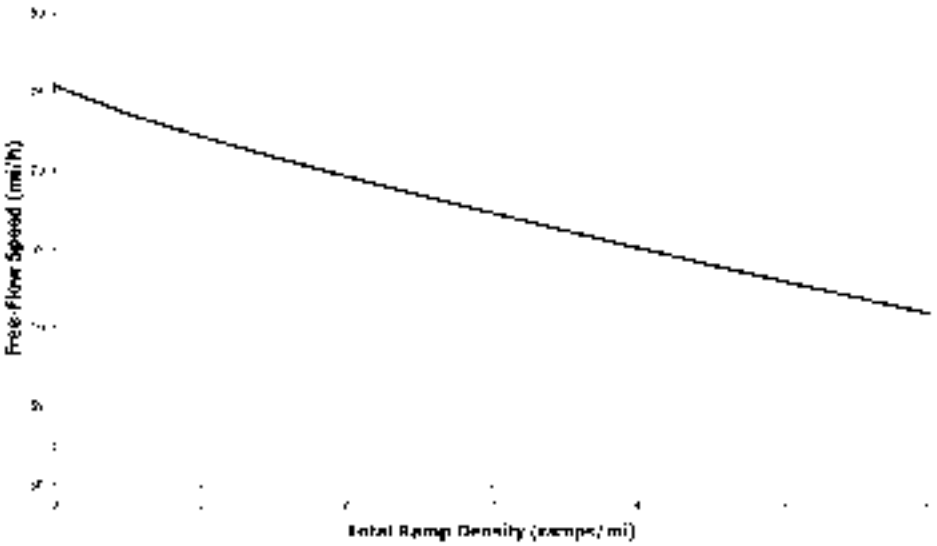

Exhibit 11-14
Sensitivity of FFS to Total Ramp Density

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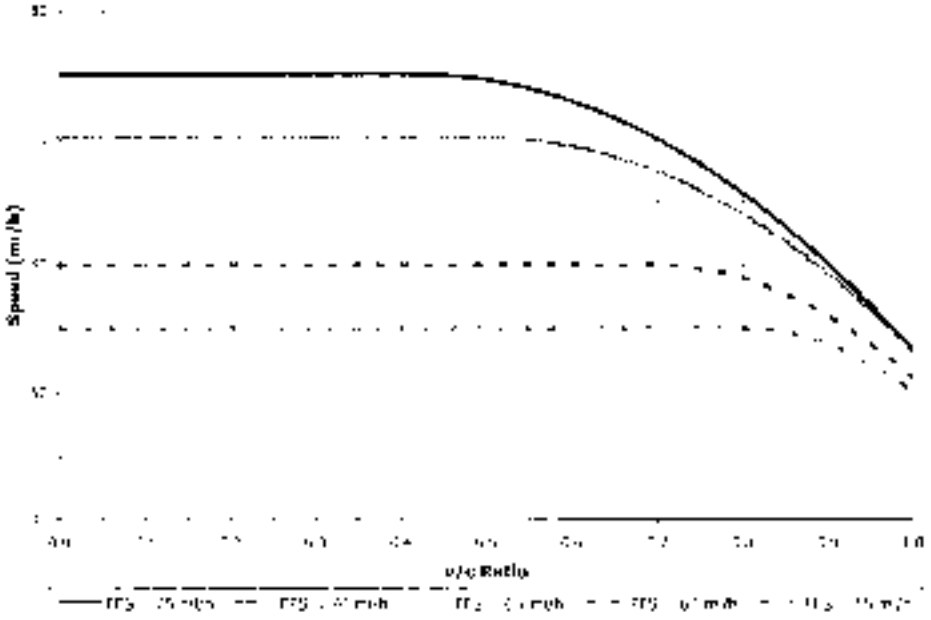
Each on- and off-ramp in the direction of travel is counted when total ramp density is determined.

Higher total ramp densities represent suburban and urban situations as well as the type of interchanges present. Most interchanges involve two to four ramps. A full cloverleaf, for example, has four ramps: two on-ramps and two off-ramps in each direction. A diamond interchange has two ramps in each direction, one on-ramp and one off-ramp. Thus, a freeway with two cloverleaf interchanges fully contained within 1 mi would have a total ramp density of 8 ramps/mi. A freeway with two diamond interchanges fully contained within 1 mi would have a total density of 4 ramps/mi. This finding suggests that in any given situation (with comparable demand flows), cloverleaf interchanges will have a greater negative impact on FFS than diamond interchanges.

Although Exhibit 11-14 is not a straight line, the slope is relatively constant. On average, an increase of 2 ramps/mi in total ramp density causes a drop in FFS of approximately 3 mi/h. A reduction in FFS, of course, implies reductions in capacity and service volumes.

Exhibit 11-15 shows the relationship between speed and v/c ratio. Not unexpectedly, the shapes of these curves are similar to the basic speed–flow curves of Exhibit 11-2. Speed does not begin to decline until a v/c ratio of 0.42 to 0.80 is reached, depending on the FFS.

Exhibit 11-15
Speed Versus v/c Ratio



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3. APPLICATIONS

The methodology in the chapter is relatively straightforward, so it can be directly used in any one of four applications:

1. *Operational analysis.* All traffic and roadway conditions are specified for an existing facility or a future facility with forecast conditions. The existing or expected LOS is determined.
2. *Design analysis.* A forecast demand volume is used, and key design parameters are specified (e.g., lane width and lateral clearance). The number of lanes required to deliver a target LOS is determined.
3. *Planning and preliminary engineering.* The basic scenario is the same as that for design analysis, except that the analysis is conducted at a much earlier stage of the development process. Inputs include default values, and the demand volume is usually stated as an annual average daily traffic (AADT) value.
4. *Service flow rates and service volumes.* The service flow rate, service volume, or daily service volume, or all three, are estimated for each LOS for an existing or future facility. All traffic and roadway conditions must be specified for this type of analysis.

Because the methodology and its algorithms are simple and do not involve iterations, all of the types of analysis cited can be done without the trial-and-error approach required by many other *Highway Capacity Manual* (HCM) methodologies.

DEFAULT VALUES

In using this chapter's methodology, a range of input data is needed. Most of these data should be field-measured or estimated values for the specific segment under consideration. When some of the data are not available, default values may be used. However, the use of default values will affect the accuracy of the output. Exhibit 11-16 shows the data that are required to conduct an operational analysis and the recommended default values when site-specific data are unavailable (*1*).

Exhibit 11-16
Required Input Data and Default Values for Basic Freeway Segments

Required Data	Default Values
Geometric Data	
Number of lanes in one direction	No default; must have site-specific value
Lane width (ft)	12 ft
Right-side lateral clearance (ft)	10 ft
Ramp density (ramps/mi)	No default; must have site-specific value
Terrain or specific grade (%, length)	No default; must have site-specific value
FFS (mi/h)	Urban, 70 mi/h; rural, 75 mi/h
Demand Data	
Length of analysis period (min)	15 min
PHF	0.94
Proportion of heavy vehicles (%)	Urban, 5%; rural, 12%*
Driver population factor	1.00

* Alternative state-specific default values for percentage of heavy vehicles are given in Chapter 26.

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The analyst may also replace the default values of Exhibit 11-16 with defaults that have been locally calibrated.

Research into the percentage of heavy vehicles on uninterrupted flow facilities (13) found a wide range of average values from state to state. Chapter 26 provides alternative default values for percentage of heavy vehicles by state and area population on the basis of data from the 2004 Highway Performance Monitoring System. Where states or local jurisdictions have developed their own values, these may be substituted. Analysts may also wish to develop their own default values based on more recent data.

ESTABLISH ANALYSIS BOUNDARIES

Determining capacity or LOS requires uniform traffic and roadway conditions on the analysis segment. Thus, any point where roadway or traffic conditions change must mark a boundary of the analysis segment.

Ramp junctions, grade changes of 2% or more, changes in the roadway geometric characteristics, and changes in speed limit are points where basic freeway segment boundaries should be established.

At every ramp–freeway junction, the demand volume changes (as some vehicles enter or leave the traffic stream). Thus, any ramp junction should mark a boundary between adjacent basic freeway segments.

In addition to ramp–freeway junctions, the following conditions generally dictate that a boundary should be established between basic freeway segments:

- Change in the number of lanes (cross section),
- Changes in lane width or lateral clearance,
- Grade change of 2% or more on a specific or composite grade,
- Change in terrain category (for general terrain segments), or
- Change in posted speed limit.

The last is not directly involved in the analysis of a basic freeway segment but would probably reflect changes in ramp density or other freeway features.

TYPES OF ANALYSIS

Operational Analysis

Operational analysis finds the expected LOS for specified roadway and traffic conditions.

The operational analysis application was fully specified in the Methodology section of this chapter. Operational analysis begins with all input parameters specified and is used to find the expected LOS that would result from the prevailing roadway and traffic conditions.

Design Analysis

Design analysis finds the number of lanes required for a target LOS, given a specified demand volume.

In design analysis, a known demand volume is used to determine the number of lanes needed to deliver a target LOS. Two modifications are required to the operational analysis methodology. First, since the number of lanes is to be determined, the demand volume is converted to a demand flow rate in passenger cars per hour, not per lane, using Equation 11-5 instead of Equation 11-2:

Equation 11-5

$$v_p = \frac{V}{PHF \times f_{HV} \times f_p}$$

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where v is the demand flow rate in passenger cars per hour and all other variables are as previously defined.

Second, a maximum service flow rate for the target LOS is then selected from Exhibit 11-17. These values are selected from the base speed–flow curves of Exhibit 11-6 for each LOS.

Exhibit 11-17
Maximum Service Flow Rates in Passenger Cars per Hour per Lane for Basic Freeway Segments Under Base Conditions

FFS (mi/h)	Target Level of Service A	B	C	D	E
75	820	1,310	1,750	2,110	2,400
70	770	1,250	1,680	2,090	2,400
65	710	1,170	1,630	2,050	2,350
60	660	1,080	1,560	2,010	2,300
55	600	990	1,430	1,900	2,250

Note: All values rounded to the nearest 10 pc/h/ln.

Next, the number of lanes required to deliver the target LOS can be found from Equation 11-6:

$$N = \frac{v}{MSF_i} \quad \text{Equation 11-6}$$

where N is the number of lanes required and MSF_i is the maximum service flow rate for LOS i from Exhibit 11-17. Equation 11-5 and Equation 11-6 can be conveniently combined as Equation 11-7.

$$N = \frac{V}{MSF_i \times PHF \times f_{HV} \times f_p} \quad \text{Equation 11-7}$$

where all variables are as previously defined.

All fractional values of N must be rounded up.

The value of N resulting from Equation 11-6 or Equation 11-7 will most likely be fractional. Since only integer numbers of lanes can be constructed, the result is always rounded to the next-higher value. Thus, if the result is 3.2 lanes, 4 must be provided. The 3.2 lanes is, in effect, the minimum number of lanes required to provide the target LOS. If the result were rounded to 3, a poorer LOS than the target value would result.

Because only whole lanes can be built, it may not be possible to achieve the target LOS for a given demand volume.

This rounding-up process will occasionally produce an interesting result: it is possible that a target LOS (for example, LOS C) cannot be achieved for a given demand volume. If 2 lanes are required to produce LOS C, providing 2 lanes would drop the LOS, most likely to D. However, if three lanes are provided, the LOS might actually improve to B. Thus, some judgment may be required to interpret the results. In this case, two lanes might be provided even though they would result in a lower-than-LOS C. Economic considerations might lead a decision maker to accept a slightly lower operating condition than that originally targeted.

Planning and Preliminary Engineering

Planning and preliminary engineering applications use both the number of lanes required to deliver a target LOS and prepare more generalized input values to the methodology.

The objective of planning or preliminary engineering is to get a general idea of the number of lanes that will be required to deliver a target LOS. The primary differences are that many default values will be used and the demand volume will be usually expressed as an AADT. Thus, a planning and preliminary engineering analysis starts by converting the demand expressed as an AADT to

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an estimate of the directional peak-hour demand volume (DDHV) with Equation 11-8:

Equation 11-8

$$V_{DDHV} = AADT \times K \times D$$

where K is the proportion of AADT occurring during the peak hour and D is the proportion of peak hour volume traveling in the peak direction; all other variables are as previously defined.

Chapter 3 provides additional guidance on K- and D-factors.

On urban freeways, the typical range of K-factors is from 0.08 to 0.10. On rural freeways, values typically range between 0.09 and 0.12. Directional distributions also vary, as was illustrated in Chapter 3, Modal Characteristics, but a typical value for both urban and rural freeways is 0.55. As with all default values, locally or regionally calibrated values are preferred and yield more accurate results. Both the K-factor and the D-factor have a significant impact on the estimated hourly demand volume.

Once the hourly demand volume is estimated, the methodology follows the same path as that for design analysis.

Service Flow Rates, Service Volumes, and Daily Service Volumes

This chapter's methodology can be easily manipulated to produce service flow rates, service volumes, and daily service volumes for a basic freeway segment.

Exhibit 11-17 gives values of the maximum service flow rates, MSF_i, for each LOS for freeways of various FFSs. These values are given in terms of passenger cars per hour per lane under equivalent base conditions. A service flow rate, SF_i, is the maximum rate of flow that can exist while LOS *i* is maintained during the 15-min analysis period under prevailing conditions. It can be computed from the maximum service flow rate by using Equation 11-9:

Equation 11-9

$$SF_i = MSF_i \times N \times f_{HV} \times f_p$$

where all variables are as previously defined.

A service flow rate can be converted to a service volume, SV_i, by applying a PHF as shown in Equation 11-10. A service volume is the maximum hourly volume that can exist while LOS *i* is maintained during the worst 15-min period of the analysis hour.

Equation 11-10

$$SV_i = SF_i \times PHF$$

where all variables are as previously defined.

A daily service volume, DSV_i, is the maximum AADT that can be accommodated by the facility under prevailing conditions while LOS *i* is maintained during the worst 15-min period of the analysis day. It is estimated from Equation 11-11:

Equation 11-11

$$DSV_i = \frac{SV_i}{K \times D}$$

where all variables are as previously defined.

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Service flow rates SF and service volumes SV are stated for a single direction of the freeway. Daily service volumes DSV are stated as total volumes in both directions of the freeway.

USE OF ALTERNATIVE TOOLS

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools. This section contains specific guidance for the application of alternative tools to the analysis of basic freeway segments. Additional information on this topic may be found in Chapter 26, Basic Freeway Segments: Supplemental.

Strengths of HCM Procedure

The HCM methodology provides FFS as an output. Simulators generate characteristics, calculate model capacity estimates, and produce a single deterministic estimate of traffic density.

This chapter's procedures were developed on the basis of extensive research supported by a significant quantity of field data. They have evolved over a number of years and represent a body of expert consensus.

Specific strengths of the HCM basic freeway segment methodology include the following:

- It provides a detailed methodology for obtaining FFS. This methodology is based on various geometric characteristics. In simulation packages, FFS (or an equivalent, such as desired speed) is an input.
- It accounts for geometric characteristics (such as lane width), which are rarely, if ever, incorporated into simulation algorithms.
- It provides explicit capacity estimates. Simulation packages do not provide capacity estimates directly. Capacity estimates can only be obtained from simulations through multiple runs with oversaturated conditions. The user can modify simulated capacities by supplying specific input values such as the minimum acceptable headway.
- It produces a single deterministic estimate of traffic density, which is important for some purposes such as development impact review.

Limitations of HCM Procedures That Might Be Addressed by Alternative Tools

Deterministic models yield the same results for the same inputs each time they are implemented; stochastic models incorporate statistical variability. For such inputs, different results in each run. For such models, an average result of X cycles is considered as output.

Basic freeway segments can be analyzed by using a variety of stochastic and deterministic simulation packages that include freeways. These packages can be very useful in analyzing the extent of congestion when there are features within the simulated facility range and when interaction with other freeway segments and other facilities is present.

Exhibit 11-18 tabulates the HCM limitations for basic freeway segments along with the potential for improved treatment by alternative tools.

Additional Features and Performance Measures Available from Alternative Tools

This chapter provides a methodology for estimating the capacity, speed, and density of a basic freeway segment, given the segment's traffic demand and characteristics. Alternative tools offer additional performance measures,

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including delay, stops, queue lengths, fuel consumption, pollution, and operating costs.

Exhibit 11-18
Limitations of HCM Basic Freeway Segments Procedure

Limitation	Potential for Improved Treatment by Alternative Tools
Special lanes reserved for a single vehicle type, such as HOV, truck, and climbing lanes	Modeled explicitly by simulation
Extended bridge and tunnel segments	Can be approximated by using assumptions related to desired speed and number of lanes along each segment
Segments near a toll plaza	Can be approximated by using assumptions related to discharge at toll plaza
Facilities with FFS less than 55 mi/h or more than 75 mi/h	Modeled explicitly by simulation
Oversaturated conditions (refer to Chapters 10 and 26 for further discussion)	Modeled explicitly by simulation
Influence of downstream blockages or queuing on a segment	Modeled explicitly by simulation
Posted speed limit and extent of police enforcement	Can be approximated by using assumptions related to desired speed along a given segment
Presence of ITS features related to vehicle or driver guidance	Several features modeled explicitly by simulation, others may be approximated by using assumptions (for example, by modifying origin–destination demands by time interval)

As with most other procedural chapters in the HCM, simulation outputs, especially graphics-based presentations, can provide details on point problems that might otherwise go unnoticed with a macroscopic analysis that yields only segment level measures. The effect of downstream conditions on lane utilization and backup beyond the segment boundary is a good example of a situation that can benefit from the increased insight offered by a microscopic model.

Development of HCM-Compatible Performance Measures Using Alternative Tools

The LOS for basic freeway segments is based on traffic density expressed in passenger cars per mile per lane. The HCM methodology estimates density by dividing the flow rate by the average passenger-car speed. Simulation models typically estimate density by dividing the average number of vehicles in the segment by the area of the segment (in lane miles). The result is vehicles per lane mile. This measurement corresponds to density based on space mean speed. The HCM-reported density is also based on space mean speed, but because there is no variability in the speeds, the space mean speed is equal to the time mean speed. Generally, increased speed variability in driver behavior (which simulators usually include) results in lower average space mean speed and higher density.

In obtaining density from alternative models, it is important to take into account the following:

- The vehicles included in the density estimation (for example, was that only the vehicles that have exited the link are considered);
- The manner in which auxiliary lanes are considered;

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- The units used for density, since a simulation package would typically provide density in units of vehicles rather than passenger cars; converting the simulation outputs to passenger cars with the HCM PCE values is typically not appropriate, given that the simulation should already account for the effects of heavy vehicles on a microscopic basis—with heavy vehicles operating at lower speeds and at longer headways—thus making any additional adjustments duplicative;
- The units used in the reporting of density (e.g., whether it is reported per lane only);
- The homogeneity of the analysis segment, since the HCM does not use the segment length as an input (unless it is a specific upgrade or downgrade segment, where the length is used to estimate the PCE values), and conditions are assumed to be homogeneous for the entire segment; and
- The driver variability assumed in the simulation package, since increased driver variability will generally increase the average density.

Regarding capacity, the HCM provides capacity estimates in passenger cars per hour per lane as a function of FFS. To compare the HCM's estimates with capacity estimates from a simulation package, the following should be considered:

- The manner in which a simulation package provides the number of vehicles exiting a segment; in some cases it may be necessary to provide virtual detectors at a specific point on the simulated segment so that the maximum throughput can be obtained;
- The units used to specify maximum throughput, since a simulation package would do this in units of vehicles rather than passenger cars, converting these to passenger cars by using the HCM PCE values is typically not appropriate, since differences between automobile and heavy-vehicle performance should already be accounted for microscopically within a simulation; and
- The incorporation of other simulation inputs, such as the "minimum separation of vehicles," that affect the capacity result.

Conceptual Differences Between HCM and Simulation Modeling That Preclude Direct Comparison of Results

The HCM's methodology is based on the relationship between speed and flow for various values of FFS. One fundamental potential difference between the HCM and other models is this relationship. For example, the HCM assumes a constant speed for a broad range of flows. However, this is not necessarily the case for any given simulation package, some of which assume a continuously decreasing speed with increasing flow. Furthermore, in some simulation packages, that relationship changes when certain parameters are modified. Therefore, if performance measures are compared between the HCM and an alternative model for a given set of flows, this will not necessarily be the case for all other sets of flows.

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Adjustment of Simulation Parameters to HCM Results

The most important elements to be adjusted when a basic freeway segment is analyzed are the speed–flow relationship or the capacity, or both. The speed–flow relationship should be examined as a function of the given FFS. That FFS should match the field- or HCM-estimated value. Some tools only accept integer values of FFS, whereas the HCM may provide a fractional value as an intermediate calculation result.

Step-by-Step Recommendations for Applying Alternative Tools

This section provides recommendations specifically for freeway segments (general guidance on selecting and applying simulation packages is provided in Chapter 6, HCM and Alternative Analysis Tools). To apply an alternative tool to the analysis of basic freeway segments, the following steps should be taken:

1. Determine whether the chosen tool can provide density and capacity for a basic freeway segment and the approach used to obtain those values. Once the analyst is satisfied that density and capacity can be obtained and that values compatible with those of the HCM can also be obtained, proceed with the analysis.
2. Determine the FFS of the study site either from field data or by estimating it according to this chapter's methodology.
3. Enter all available geometric and traffic characteristics into the simulator package and install virtual detectors along the study segment, if necessary, to obtain speeds and flows.
4. By loading the study network over capacity, obtain the maximum throughput and compare it with the HCM estimate. Calibrate the simulation package by modifying parameters related to the maximum flow headway, so that the capacity obtained by the simulator closely matches the HCM estimate. Estimate the required number of runs to be conducted so that the comparison is statistically valid.
5. If the analysis requires evaluating various different demand conditions for the segment, plot the simulator's speed–flow curve and compare it with the HCM relationship. Attempt to calibrate the simulation package by modifying parameters related to driver behavior, such as the distribution of driver types. It is possible that the simulator cannot be calibrated to match the HCM speed–flow relationship. In that case, the results should be viewed with caution in terms of their compatibility with the HCM methods.

Sample Calculations Illustrating Alternative Tool Applications

Chapter 26, in Volume 4 of the HCM, provides two supplemental problems that examine situations beyond the scope of this chapter's methodology by using a typical microsimulation-based tool. Both problems are based on Example Problem 3 (found in the next section of this chapter), which analyzes a six-lane freeway segment in a growing urban area. The first supplemental problem evaluates the facility when an HOV lane is added, and the second problem analyzes operations with an incident within the segment.

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4. EXAMPLE PROBLEMS

Exhibit 11-19
List of Example Problems

Example Problem	Description	Application
1	Four-lane freeway LOS	Operational analysis
2	Number of lanes required for target LOS	Design analysis
3	Six-lane freeway LOS and capacity	Operational and planning analysis
4	LOS on upgrades and downgrades	Operational analysis
5	Design hour volume and number of lanes	Planning analysis
6	Service flow rates and service volumes	Planning analysis

EXAMPLE PROBLEM 1: FOUR-LANE FREEWAY LOS

The Facts

- Four-lane freeway (two lanes in each direction);
- Lane width = 11 ft;
- Right-side lateral clearance = 2 ft;
- Commuter traffic (regular users);
- Peak hour, peak-direction demand volume = 2,000 veh/h;
- Traffic composition: 5% trucks, 0% RVs;
- PHF = 0.92;
- One cloverleaf interchange per mile; and
- Rolling terrain.

Comments

The task is to find the expected LOS for this freeway during the worst 15 min of the peak hour. With one cloverleaf interchange per mile, the total ramp density will be 4 ramps/mi.

Step 1: Input Data

All input data are specified above.

Step 2: Compute FFS

The FFS of the freeway is estimated as follows:

$$FFS = 75.4 - f_{LW} - f_{LC} - 3.22\,TRD^{0.84}$$

The adjustment for lane width is selected from Exhibit 11-8 for 11-ft lanes (1.9 mi/h). The adjustment for right-side lateral clearance is selected from Exhibit 11-9 for a 2-ft clearance on a freeway with two lanes in one direction (2.4 mi/h). The total ramp density is 4 ramps/mi. Then

$$FFS = 75.4 - 1.9 - 2.4 - 3.22\left(4^{0.84}\right) = 60.8 \text{ mi/h}$$

Step 3: Select FFS Curve

As the FFS calculated in Step 2 is greater than or equal to 57.5 and less than 62.5 mi/h, the 60-mi/h speed–flow curve will be used for this analysis.

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Step 4: Adjust Demand Volume

The demand volume must be adjusted to a flow rate that reflects passenger cars per hour per lane under equivalent base conditions by using Equation 11-7:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

The demand volume is given as 2,000 veh/h. The PHF is specified to be 0.92, and there are two lanes in each direction. The driver population factor is 1.00, since regular users (commuters) are also specified. Trucks make up 5% of the traffic stream, so a heavy-vehicle adjustment factor must be determined.

From Exhibit 11-10, the PCE for trucks is 2.5 for rolling terrain. The heavy-vehicle adjustment factor is then computed by using Equation 11-9:

$$f_{HV} = \frac{1}{1 + P_T (E_T - 1) + P_R (E_R - 1)}$$

$$f_{HV} = \frac{1}{1 + 0.05(2.5 - 1) + 0} = 0.930$$

Then,

$$v_p = \frac{2{,}000}{0.92 \times 2 \times 0.93 \times 1.00} = 1{,}169 \text{ pc/h/ln}$$

Since this value is less than the base capacity of 2,300 pc/h/ln for a freeway with FFS = 60 mi/h, LOS F does not exist, and the analysis continues to Step 5.

Step 5: Estimate Speed and Density

The FFS of the basic freeway segment is now estimated along with the demand flow rate in passenger cars per hour per lane under equivalent base conditions. From Exhibit 11-3, the equation for estimating the speed of the traffic stream is selected for a 60-mi/h FFS, with a flow rate less than 1,600 pc/h/ln. This is the constant-speed portion of the curve, or $S = 60$ mi/h. The density of the traffic stream may now be computed as:

$$D = \frac{v_p}{S} = \frac{1{,}169}{60} = 19.5 \text{ pc/mi/ln}$$

Step 6: Determine LOS

From Exhibit 11-5, a density of 19.5 pc/mi/ln corresponds to LOS C but is close to the boundary for LOS B, which is a maximum of 18 pc/mi/ln. This solution could also be calculated graphically by using Exhibit 11-6 as a base (Exhibit 11-20).

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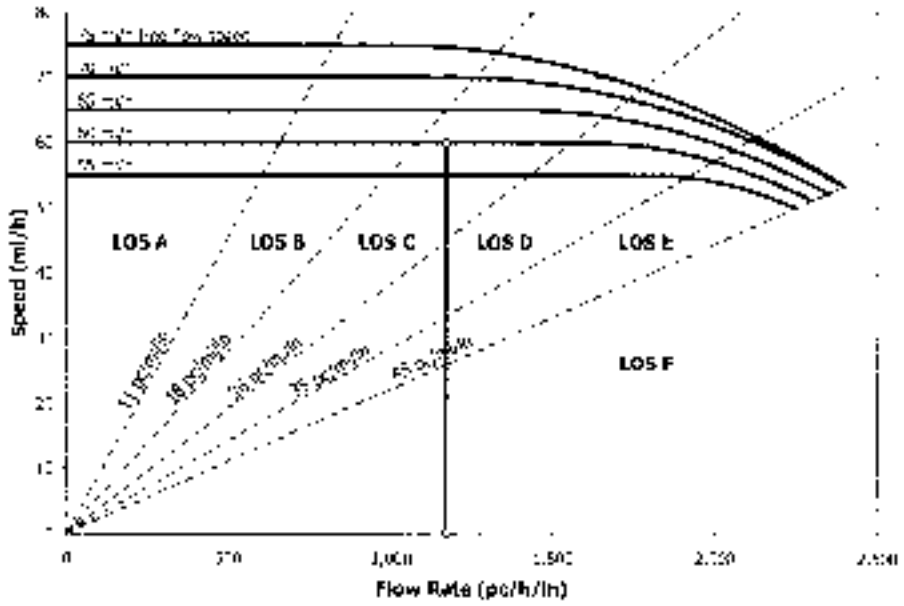

Exhibit 11-20
Graphical Solution for Example Problem 2

Discussion

The base freeway segment of a four-lane freeway is expected to operate at LOS C during the worst 15 min of the peak hour. It is important to note that the operation, although at LOS C, is close to the LOS B boundary. In most jurisdictions, this operation would be considered to be quite acceptable; therefore, no remediation would normally be required.

EXAMPLE PROBLEM 2: NUMBER OF LANES REQUIRED FOR TARGET LOS

The Facts

- Demand volume = 4,000 veh/h (one direction),
- Level terrain,
- Traffic composition: 15% trucks, 3% RVs,
- Provision of 12-ft lanes,
- Provision of 6-ft right-side lateral clearance,
- Commuter traffic (regular users),
- PHF = 0.85,
- Ramp density = 3 ramps/mi, and
- Target LOS = D.

Comments

This is a classic design application of the methodology. The number of lanes needed to provide LOS D during the worst 15 min of the peak hour is to be determined.

Step 1: Input Data

All input data were specified previously.

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Step 2: Compute FFS

The FFS is estimated by using Equation 11-1. Because the lane width and lateral clearance to be provided on the new freeway will be 12 ft and 6 ft, respectively, there are no adjustments for these features. The total ramp density is given as 3 ramps/mi. Then

$$FFS = 75.4 - f_{LW} - f_{LC} - 3.22TRD^{0.84}$$

$$FFS = 75.4 - 0.0 - 0.0 - 3.22(3^{0.84}) = 67.3 \text{ mi/h}$$

Step 3: Select FFS Curve

Since the FFS calculated in Step 2 is greater than or equal to 62.5 and less than 67.5 mi/h, the 65-mi/h speed–flow curve will be used for this analysis.

Step 4: Estimate Number of Lanes Needed

Because this is a design analysis, Step 4 of the operational analysis methodology is modified. Equation 11-7 may be used directly to determine the number of lanes needed to provide no at least LOS D.

$$N = \frac{V}{MSF_i \times PHF \times f_{HV} \times f_p}$$

A value of the maximum service flow rate must be selected from Table 11-17 for a FFS of 65 mi/h and LOS D. This value is 2,030 pc/h/ln. The PHF is given as 0.85. The driver population factor is 1.00, since commuters are involved. A heavy-vehicle factor for 15% trucks and 3% RVs must be determined by using Exhibit 11-10 for level terrain. The PCEs of trucks and RVs in level terrain are 1.5 and 1.2, respectively. Then

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{HV} = \frac{1}{1 + 0.15(1.5 - 1) + 0.03(1.2 - 1)} = 0.925$$

and

$$N = \frac{4{,}000}{2030 \times 0.85 \times 0.925 \times 1.00} = 2.51 \text{ lanes}$$

It is not possible to build 2.51 lanes. To provide a minimum of LOS D, it will be necessary to provide three lanes in each direction, or a six-lane freeway.

At this point, the design application ends. It is possible, however, to consider what speed, density, and LOS will prevail when three lanes are actually provided. Therefore, the example problem continues with Steps 5 and 6.

Step 5: Estimate Speed and Density

In pursuing additional information, the problem now reverts to an operational analysis of a three-lane basic freeway segment with a demand volume of 4,000 pc/h.

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Equation 12-2 is used to compute the actual demand flow rate per lane under equivalent base conditions:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

$$v_p = \frac{4,000}{0.85 \times 3 \times 0.925 \times 1.00} = 1,696 \text{ pc/h/ln}$$

The expected speed of the traffic stream may be estimated either by using Exhibit 11-6 (for a graphical solution) or by selecting the appropriate equation from Exhibit 11-3—in this case, using FFS = 65 mi/h and a demand flow rate over 1,400 pc/h/ln. With the latter approach,

$$S = 65 - 0.0000147(v_p - 1,400)^2$$

$$S = 65 - 0.0000147(1,696 - 1,400)^2 = 63.8 \text{ mi/h}$$

The density may now be computed:

$$D = \frac{v_p}{S} = \frac{1,696}{63.8} = 26.6 \text{ pc/mi/ln}$$

Step 6: Determine LOS

Entering Exhibit 11-5 with a density of 26.6 pc/mi/ln, the LOS is D but is very close to the boundary of LOS C, which is 26 pc/mi/ln.

Discussion

The resulting LOS is D, which was the target for the design. Although the minimum number of lanes needed was 2.51, which would have provided for a minimal 2.0 LOS, providing three lanes yields a density that is close to the LOS C boundary. In any event, the target LOS of the design will be met by providing a six-lane basic freeway segment.

EXAMPLE PROBLEM 3: SIX-LANE FREEWAY LOS AND CAPACITY

The Facts

- Volume of 5,000 veh/h (one direction, existing);
- Volume of 5,600 veh/h (one direction, in 3 years);
- Traffic composition: 10% trucks, no RVs;
- Level terrain;
- Three lanes in each direction;
- FFS = 70 mi/h (measured);
- PHF = 0.95;
- Commuter traffic (regular users); and
- Traffic growth after 3 years = 4% per year.

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Comments

This example consists of two operational analyses, one for the present demand volume of 5,030 pc/h and one for the demand volume of 5,600 pc/h expected in 3 years. In addition, a planning element is introduced. Assuming that traffic grows as expected, when will the capacity of the roadway be exceeded? This analysis requires that capacity be determined in addition to the normal output of operational analyses.

Step 1: Input Data

All input data were given previously.

Step 2: Compute FFS

Step 2 is not needed since a measured FFS is given (70 mi/h).

Step 3: Select FFS Curve

Step 3 is not needed. The FFS curve for 70 mi/h will be used, based on the measured value.

Step 4: Adjust Demand Volume

In this case, two demand volumes will be adjusted by using Equation 11-2:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

The PHF is given as 0.95, and there are three lanes in each direction. The driver population adjustment factor will be 1.00 for regular users. The heavy vehicle factor must reflect 10% trucks in level terrain. From exhibit 11-10, the PCE for trucks in level terrain is 1.5. Equation 11-3 then gives the following:

$$f_{HV} = \frac{1}{1 + P_T (E_T - 1) + P_R (E_R - 1)}$$

$$f_{HV} = \frac{1}{1 + 0.10(1.5 - 1) - 0} = 0.952$$

Two values of v_p will be computed, one for present conditions and one for conditions in 5 years:

$$v_p \text{ (present)} = \frac{5,030}{0.95 \times 3 \times 0.952 \times 1.00} = 1,843 \text{ pc/h}$$

$$v_p \text{ (future)} = \frac{5,600}{0.95 \times 3 \times 0.952 \times 1.00} = 2,064 \text{ pc/h}$$

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Step 5: Estimate Speed and Density

Two values of speed and density will be estimated, one each for the present and future conditions stated. The equations of Exhibit 11-3 will be used to estimate speeds. One equation applies to both cases, a 70-mi/h FFS with a flow rate of or 1,200 pc/h/ln:

$$S(\text{present}) = 70 - 0.00780(v_p - 1{,}200)^2$$

$$S(\text{present}) = 70 - 0.00780(1{,}843 - 1{,}200)^2 = 65.2 \text{ mi/h}$$

$$S(\text{future}) = 70 - 0.00780(v_p - 1{,}200)^2$$

$$S(\text{future}) = 70 - 0.00780(2{,}064 - 1{,}200)^2 = 61.3 \text{ mi/h}$$

The corresponding densities may now be estimated as follows:

$$D = \frac{v_p}{S}$$

$$D(\text{present}) = \frac{1{,}843}{65.2} = 28.3 \text{ pc/mi/ln}$$

$$D(\text{future}) = \frac{2{,}064}{61.3} = 33.7 \text{ pc/mi/ln}$$

Step 6: Determine LOS

From Exhibit 11-5, the LOS for the present situation is D, and the LOS for the future situation (in 5 years) is also D, despite the increase in density.

Step 7: When Will Capacity Be Reached?

Step 7 is an additional step for this problem. To answer the question, the capacity of the basic freeway segment must be estimated. From Exhibit 11-17, the maximum service flow rate for LOS E on a basic freeway segment with a 70 mi/h FFS is 2,400 pc/h/ln. This flow rate is synonymous with capacity.

The analyst must be sure that the capacity and demand flow rates compared in Step 7 are on the same basis. The 2,400 pc/h/ln is a flow rate under equivalent base conditions. The demand flow rate in 5 years was estimated to be 2,064 pc/h/ln on this basis. These two values, therefore, may be compared. As an alternative, the capacity could be computed for prevailing conditions:

$$SF_i = MSF_i \times N \times f_{HV} \times f_p$$

$$SF_i = 2{,}400 \times 3 \times 0.952 \times 1.00 = 6{,}854 \text{ veh/h}$$

This capacity, however, is stated as a *flow rate*. The demand volume is stated as an hourly volume. Thus, a service volume for LOS E is needed:

$$SV_i = SF_i \times PHF = 6{,}854 \times 0.95 = 6{,}511 \text{ veh/h}$$

The problem may be solved either by comparing the demand volume of 5,000 veh/h (in 5 years) with the hourly capacity of 6,511 veh/h or by comparing the demand flow rate under equivalent base conditions of 2,064 pc/h/ln with the

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base capacity of 2,400 pc/h/ln. With the hourly demand volume and hourly capacity,

$$6{,}511 = 5{,}600(1.04)^n$$

$$n = 3.85 \text{ years}$$

On the basis of the forecasts of traffic growth, the basic freeway segment described will reach capacity within 4 years (the demand of 5,600 veh/h occurs 3 years from the present).

Discussion

The LOS on this segment will remain D within 3 years despite the increase in density. The demand is expected to exceed capacity within 4 years. Given the normal lead times for planning, design, and approvals before the start of construction, it is probable that planning and preliminary design for an improvement should be started immediately.

EXAMPLE PROBLEM 4: LOS ON UPGRADES AND DOWNGRADES

The Facts

- Demand volume = 2,300 veh/h (one direction);
- Traffic composition: 15% trucks, no RVs;
- PHF = 0.90;
- FFS = 70 mi/h upgrade, 75 mi/h downgrade (measured);
- Unfamiliar drivers (f_p = 0.95); and
- Composite grade: 3,700 ft at 3%, followed by 2,600 ft at 5%.

Comments

This is a typical operational analysis. The expected outcome is an assessment of the LOS on both the upgrade and the downgrade. However, the problem deals with a specific grade and a composite grade. Because there is a segment of the grade that is greater than 4% and the total length of the composite grade exceeds 4,000 ft, the special procedure in Appendix A must be applied. That procedure will yield an equivalent constant percent grade of $(3{,}700 + 2{,}600 - 5{,}000)$ ft (1.08 mi), which has the same impact on heavy vehicles as the composite grade described.

Composite Grade

Exhibit 11-21 shows the conversion of the composite grade to a grade of constant percent 5,600 ft long. At the end of such a grade, the final speed of heavy vehicles is approximately the same as that on the composite grade.

A vertical line enters the truck performance curves at 3,000 ft corresponding to the 3% grade curve, indicating that the speed of trucks after 3,000 ft of 4.8% grade is approximately 42 mi/h. This is also the speed at which the truck enters the 5% grade; it corresponds to the same speed as that of a truck on a 4.8% grade after 1,300 ft. The truck travels another 2,600 ft (to 5,900 ft) on the 5% curve.

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where a final speed of 27 mi/h is reached. The intersection of a horizontal drawn at 27 mi/h and a vertical drawn at a total length of grade of 5,600 ft yields the equivalent of +5%. In effect, because trucks on this grade are at crawl speed, it does not matter how long the grade is; 27 mi/h can be maintained indefinitely.

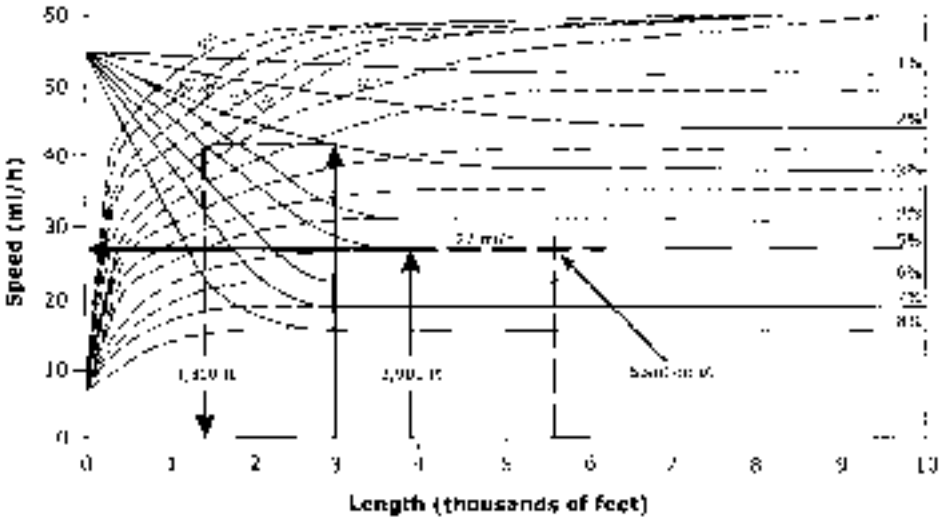

Exhibit 11-21
Determination of Composite Grade Equivalents for Example Problem 4

The equivalent grade is +5%, 5,600 ft. This equivalent should be applied to *both the upgrade and the downgrade*, even though it was developed specifically for the upgrade.

Although the truck acceleration curves of Appendix A could be used to develop a separate downgrade composite equivalent, it would be very misleading. The truck performance curves assume a maximum speed of 60 mi/h. On a long, steep downgrade, trucks will achieve much higher speeds.

It is highly likely that trucks will be forced to use a low gear to apply engine braking on the grade described. Thus, PCEs for the downgrade will be selected from Exhibit 11-18.

Step 1: Input Data

All input data were specified previously.

Step 2: Compute FFS

FFSs were measured in the field. The upgrade FFS is 70 mi/h; the downgrade FFS is 75 mi/h.

Step 3: Select FFS Curve

The 70-mi/h curve will be used for the upgrade; the 75-mi/h curve will be used for the downgrade.

Step 4: Adjust Demand Volume

The demand flow rates in passenger cars per hour per lane for the upgrade and downgrade are estimated by using Equation 11-2:

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$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

The PHF is 0.90, there are two lanes on the upgrade and two lanes on the downgrade, and f_p is specified as 0.95. Heavy-vehicle adjustment factors, however, must be determined separately for the upgrade and the downgrade.

The PCE for trucks (E_T) on the upgrade is selected from Exhibit 11-11 for a grade of 5%, >1.00 mi long, with 17% trucks: 3.0. The PCE for the trucks on the downgrade is selected from Exhibit 11-15 for a grade of 4% to 5%, ≤4 mi long: 1.5.

The heavy-vehicle adjustment factors, f_{HV} are computed by using Equation 11-8:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{HV}\text{ (upgrade)} = \frac{1}{1 + 0.15(3 - 1) + 0} = 0.769$$

$$f_{HV}\text{ (downgrade)} = \frac{1}{1 + 0.15(1.5 - 1) + 0} = 0.930$$

Then

$$v_p\text{ (upgrade)} = \frac{2{,}300}{0.90 \times 2 \times 0.769 \times 0.95} = 1{,}749\text{ pc/h/ln}$$

$$v_p\text{ (downgrade)} = \frac{2{,}300}{0.90 \times 2 \times 0.930 \times 0.95} = 1{,}446\text{ pc/h/ln}$$

Since neither of these values exceeds the base capacity of a freeway with FFS = 75 mi/h (downgrade) or FFS = 70 mi/h (upgrade), LOS F does not exist, and the analysis continues to Step 5.

Step 5: Estimate Speed and Density

With the FFS and the demand flow rates determined for both the upgrade and the downgrade, the expected speed and density on each may now be estimated. Speed is estimated by using the equations of Exhibit 11-3.

For the upgrade, the FFS is 70 mi/h, and the demand flow rate is greater than 1,200 pc/h/ln. Then

$$S = 70 - 0.00001160(v_p - 1{,}200)^2$$

$$S = 70 - 0.00001160(1{,}749 - 1{,}200)^2 = 66.5\text{ mi/h}$$

For the downgrade, the FFS is 75 mi/h, and the demand flow rate is greater than 1,000 pc/h/ln. Then

$$S = 75 - 0.00001107(v_p - 1{,}000)^2$$

$$S = 75 - 0.00001107(1{,}446 - 1{,}000)^2 = 72.8\text{ mi/h}$$

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Densities may now be estimated from the demand flow rates and estimated speeds:

$$D = \frac{v_p}{S}$$

$$D(\text{upgrade}) = \frac{1,749}{66.5} = 26.3 \text{ pc/mi/ln}$$

$$D(\text{downgrade}) = \frac{1,446}{72.8} = 19.9 \text{ pc/mi/ln}$$

Step 6: Determine LOS

As shown in Exhibit 11-5, the upgrade LOS is D; the downgrade LOS is C. Both levels, however, are close to the boundaries for better operations. The upgrade is close to the boundary for LOS C ($D = 26$ pc/mi/ln) and the downgrade is close to the boundary for LOS B ($D = 18$ pc/mi/ln).

Discussion

Both the upgrade and the downgrade are operating at what would generally be called acceptable levels. If traffic grows over time, the addition of a truck climbing lane on the upgrade might be considered.

EXAMPLE PROBLEM 5: DESIGN-HOUR VOLUME AND NUMBER OF LANES

The Facts

- Demand volume = 75,000 veh/day,
- Proportion of AADT in the peak hour: 0.09,
- Directional distribution: 56/44,
- Rolling terrain, and
- Target LOS = D.

Comments

In this planning and preliminary engineering application, several input variables are not specified, so default values will have to be used. With knowledge of local conditions and freeway design standards, the following default values will be used in the solution: PHF = 0.95; truck = 6% mid; 5% trucks, no RVs; FHV = 0.95; and $f_p = 1.00$.

Determining Opening-Day Directional Design-Hour Volume

Because the demand volume is given as an AADT, it must be converted to a directional design-hour volume (DDHV) by using Equation 11-8:

$$v = DDHV = AADT \times K \times D$$

$$v = DDHV = 75,000 \times 0.09 \times 0.55 = 3,713 \text{ veh/h}$$

Step 1: Input Data

All input data were specified.

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Step 2: Compute FFS

A default value of 65 mi/h will be used in this problem.

Step 3: Select FFS Curve

The 65-mi/h speed–flow curve will be used in this problem.

Step 4: Determine Number of Lanes Required

After estimating the demand volume on an hourly basis, the remainder of the solution follows the design application. The number of lanes needed is estimated by using Equation 11-7:

$$N = \frac{V}{MSF_i \times PHF \times f_{HV} \times f_p}$$

The maximum service flow rate is selected from Exhibit 11-17 for LOS D on a 65 mi/h basic freeway segment: 2,030 pc/h/ln. The PHF is a default value: 0.95. The driver population factor is also a default value: 1.00. The freeway is in rolling terrain and is expected to have 5% trucks (another default value). From Equation 11-10, for rolling terrain, $E_T = 2.5$. Then

$$f_{HV} = \frac{1}{1 + 0.05(2.5 - 1) + 0} = 0.930$$

$$N = \frac{3{,}713}{2{,}030 \times 0.95 \times 0.93 \times 1.00} = 2.07 \text{ lanes}$$

Because fractional lanes cannot be built, three lanes will have to be provided in each direction to ensure that LOS D is provided during the worst 15 min of the peak hour. Therefore, the resulting LOS may be better than the design target.

Step 5: Estimate Speed and Density

In order to determine the likely LOS resulting from a six-lane freeway, the speed and density should be estimated. Equation 11-2 is used to determine the actual demand flow rate for three lanes:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

$$v_p = \frac{3{,}713}{0.95 \times 3 \times 0.93 \times 1.00} = 1{,}401 \text{ pc/h/ln}$$

From Exhibit 11-3, for a 65-mi/h basic freeway segment with more than 1,400 pc/h/ln, the expected speed is

$$S = 65 - 0.0000141838(v_p - 1{,}400)^2$$

$$S = 65 - 0.0000141838(1{,}401 - 1{,}400)^2 = 65.0 \text{ mi/h}$$

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and the density is

$$D = \frac{v_p}{S} = \frac{1{,}401}{65.0} = 21.6 \text{ pc/mi/ln}$$

Step 6: Determine LOS

As shown in Exhibit 11-5, the expected LOS is C.

Discussion

This problem illustrates an interesting point: given the parameters of this example problem, the target LOS of D cannot be achieved on opening day. If a four-lane freeway (two lanes in each direction) is built, LOS E will result. If a six-lane freeway (three lanes in each direction) is built, LOS C will result.

EXAMPLE PROBLEM 6: SERVICE FLOW RATES AND SERVICE VOLUMES

The Facts

- Eight-lane freeway;
- FFS = 70 mi/h (measured);
- Traffic composition: 8% trucks, 1% RVs;
- Rolling terrain;
- PHF = 0.87;
- Driver population factor f_p = 1.00;
- Proportion of AADT in peak hour (*K*-factor): 10%; and
- Directional distribution (*D*-factor): 50/50.

Comments

In this problem, the service flow rate, service volume, and daily service volume for each LOS will be computed. These values could then be compared with any existing or forecast demand volumes to determine the LOS.

Step 1: Input Data

All input data were specified.

Step 2: Compute FFS

The FFS has been field-measured as 70 mi/h.

Step 3: Select FFS Curve

The curve for FFS = 70 mi/h will be used.

Step 4: Compute Service Flow Rates, *SF*

For a 70-mi/h basic freeway segment, maximum service flow rates, *MSF*, can be selected from Exhibit 11-17. These are the maximum service flow rates that can be maintained while a given LOS is maintained. They are stated as flow rates in passenger cars per hour per lane for equivalent base conditions. The values are

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- MSF_1 = 770 pc/h/ln,
- MSF_2 = 1,250 pc/h/ln,
- MSF_3 = 1,690 pc/h/ln,
- MSF_4 = 2,080 pc/h/ln, and
- MSF_5 = 2,400 pc/h/ln.

Service flow rates, SF_i are estimated by using Equation 11-9.

$$SF_i = MSF_i \times N \times f_{HV} \times f_p$$

where the maximum service flow rates are as cited, N = 4 lanes in each direction, and the driver population factor f_p is 1.00. The heavy vehicle adjustment factor must be determined for 8% trucks and 1% RVs in rolling terrain. From Exhibit 11-10, for rolling terrain, E_T = 2.5 and E_R = 2.0. Then

$$f_{HV} = \frac{1}{1 + 0.08(2.5 - 1) + 0.01(2.0 - 1)} = 0.885$$

Service flow rates may now be computed:

$$SF_1 = 770 \times 4 \times 0.885 \times 1.00 = 2,726 \text{ veh/h}$$

$$SF_2 = 1,250 \times 4 \times 0.885 \times 1.00 = 4,425 \text{ veh/h}$$

$$SF_3 = 1,690 \times 4 \times 0.885 \times 1.00 = 5,983 \text{ veh/h}$$

$$SF_4 = 2,080 \times 4 \times 0.885 \times 1.00 = 7,363 \text{ veh/h}$$

$$SF_5 = 2,400 \times 4 \times 0.885 \times 1.00 = 8,496 \text{ veh/h}$$

Service flow rates are the maximum rates of flow that may exist in the worst 15-min period of the peak hour while the stated LOS is maintained.

Step 5: Compute Service Volumes, *SV*

Equation 11-10 is used to convert service flow rates to service volumes. The conversion multiplies the service flow rates by the PHF to produce maximum hourly volumes that can be accommodated while the given LOS is maintained during the worst 15 min of the hour.

$$SV_i = SF_i \times PHF$$

$$SV_1 = 2,726 \times 0.87 = 2,372 \text{ veh/h}$$

$$SV_2 = 4,425 \times 0.87 = 3,850 \text{ veh/h}$$

$$SV_3 = 5,983 \times 0.87 = 5,205 \text{ veh/h}$$

$$SV_4 = 7,363 \times 0.87 = 6,406 \text{ veh/h}$$

$$SV_5 = 8,496 \times 0.87 = 7,392 \text{ veh/h}$$

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Step 6: Compute Daily Service Volumes, *DSV*

Equation 11-1 is used to convert service volumes to daily service volumes. Daily service volumes are the maximum AADTs that can be accommodated while the given LOS is maintained during the worst 15 min of the peak hour in the peak direction of flow.

$$DSV_i = \frac{SV_i}{K \times D}$$

$$DSV_A = \frac{2,372}{0.08 \times 0.60} = 49,417 \text{ veh/day}$$

$$DSV_B = \frac{3,850}{0.08 \times 0.60} = 80,208 \text{ veh/day}$$

$$DSV_C = \frac{5,205}{0.08 \times 0.60} = 108,438 \text{ veh/day}$$

$$DSV_D = \frac{6,406}{0.08 \times 0.60} = 133,458 \text{ veh/day}$$

$$DSV_E = \frac{7,392}{0.08 \times 0.60} = 154,000 \text{ veh/day}$$

Discussion

These results can be conveniently shown in the form of a table, as illustrated in Exhibit 11-22. Given the approximate nature of these computations and the default values used, it is appropriate to round the DSV values to the nearest 100 veh/day, and SF and SV values to the nearest 10 veh/h.

Exhibit 11-22
Service Flow Rates, Service Volumes, and Daily Service Volumes for Example Problem 6

LOS	*SF* (veh/h)	*SV* (veh/h)	*DSV* (veh/day)
A	2,730	2,370	49,400
B	4,430	3,850	80,200
C	5,990	5,210	108,400
D	7,360	6,410	133,500
E	8,500	7,390	154,000

Exhibit 11-22, of course, applies only to the basic freeway segment as described. Should any of the prevailing conditions change, the values in the exhibit would also change. However, for a given segment, forecast demand volumes, whether given as flow rates, hourly volumes, or AADTs, could be compared with the criteria in Exhibit 11-22 to determine the likely LOS immediately. For example, if the 10-year forecast AADT for this segment is 125,000 veh/day, the expected LOS would be D.

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Many of these references can be found in the Technical Reference Library in Volume 4

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APPENDIX A: COMPOSITE GRADES

The composite grade procedure should be used for a series of grades that are 4,000 ft in length and that have a portion of the grade steeper than 4%.

The procedure finds the equivalent single grade that results in the same final truck speed as the series of grades would.

In a basic freeway segment analysis, an overall average grade can be substituted for a series of grades if no single portion of the grade is steeper than 4% or the total length of the grade is less than 4,000 ft. For grades outside these limits (i.e., a portion of the grade is greater than 4% and the total length of the grade is greater than or equal to 4,000 ft), the composite grade procedure presented in this appendix is recommended. The composite grade procedure is used to determine an equivalent grade that will result in the same final speed of trucks as would the series of grades making up the composite.

The acceleration and deceleration curves presented here are for vehicles with an average weight-to-horsepower ratio of 200 lb/hp, heavier than typical trucks found on freeways, which range between 125 lb/hp and 150 lb/hp. This is done in recognition of the fact that heavier trucks will have more of an impact on the traffic stream than lighter trucks.

Exhibit 11-A1 shows typical acceleration (dashed lines) and deceleration (solid lines) performance for a truck with a ratio of 200 lb/hp. The curves are conservative in that they assume a maximum truck speed of 55 mi/h for trucks entering a grade and 60 mi/h for trucks accelerating on a grade.

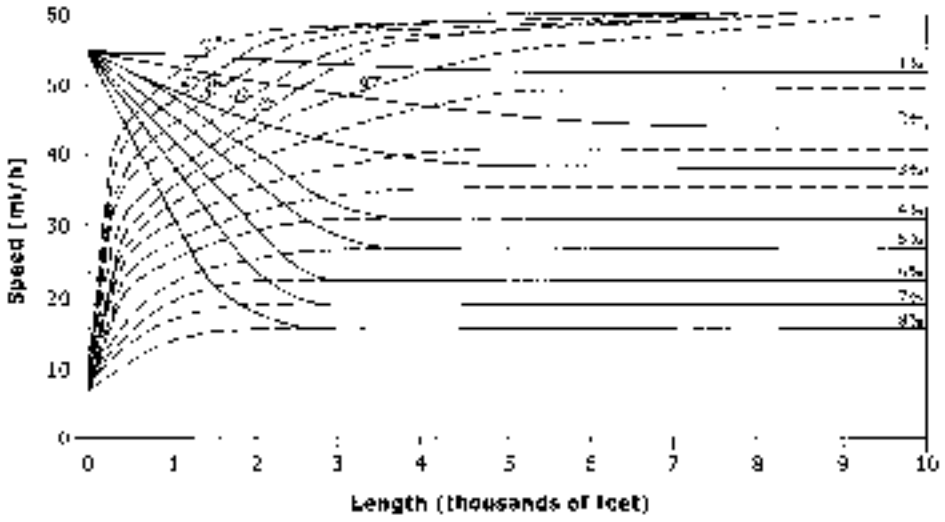

Exhibit 11-A1
Performance Curves for 200 lb/hp Truck

EXAMPLE PROBLEM

An example is provided to illustrate the process involved in determining an equivalent grade for a composite grade on a freeway. The example has two segments, but the procedure is valid for any number of segments. The composite grade is:

- Upgrade of 2% for 5,000 ft, followed by
- Upgrade of 6% for 5,000 ft.

This grade should not be analyzed with an average grade approach, because one portion of the grade is steeper than 4% and the total length of the grade is in

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excess of 4,000 ft. As a comparison, application of the average grade approach in this case would yield the following:

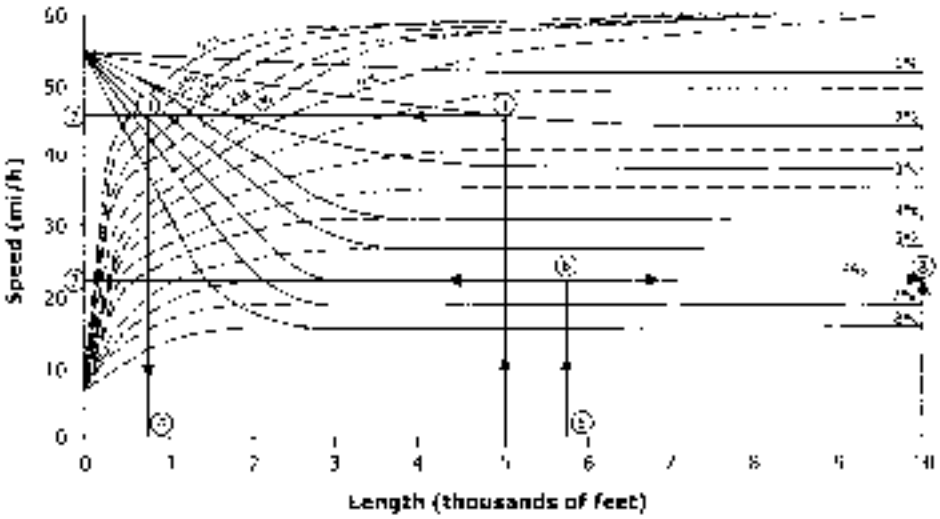
- Total rise along composite: (5,000 × 0.02) + (5,000 × 0.06) = 400 ft.
- Average grade: 400/10,000 = 0.04, or 4%.

With the average grade approach, the composite would be analyzed as if it were a single upgrade of 4%, 10,000 ft (1.89 mi) long.

Exhibit 11-A2 illustrates the recommended solution.

Exhibit 11-A2
Solution Using Composite Grade Procedure

The flat portions of the upgrade curves indicate the truck crawl speed on that grade.



A vertical line is drawn at 5,000 ft to the intersection with the curve for the +2% grade (Point 1). A horizontal line is drawn from the intersection point to the y-axis (Point 2). This procedure indicates that after 5,000 ft of +2% upgrade, trucks will be operating at a speed of approximately 48 mi/h.

This speed is also the speed at which trucks enter the +6% segment of the composite grade. The intersection of the 48 mi/h horizontal line with the curve for the +6% grade (Point 3) is found. A vertical line is dropped from this point to the x-axis (Point 4). This procedure indicates that trucks enter the +6% segment of the composite as if they had already been on the +6% grade for approximately 800 ft. Trucks will travel another 5,000 ft along the +6% grade, starting from Point 4. A vertical line is drawn at a distance of 800 + 5,000 = 5,800 ft (Point 5) to the intersection with the curve for the +6% grade (Point 6). A horizontal line drawn from this point to the y-axis (Point 7) indicates that the speed of trucks at the end of the two-segment composite grade will be approximately 23 mi/h.

The solution point is found as the intersection of a vertical line drawn at 10,000 ft (the total length of the composite grade) and a horizontal line drawn at 23 mi/h. The solution is read as the percent grade on which the solution point lies (Point 8). In this case, the point lies exactly on the curve for the 6% grade. Interpolations between curves are permissible.

In this case, the grade that is equivalent to the composite grade is a single grade of 6%, 10,000 ft (1.89 mi) long. This grade is 2% higher than the 4% average grade. The appropriate equivalent grade is the same percentage as the second

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segment of the composite grade because trucks have already reached crawl speed. Once trucks hit crawl speed, it does not matter how far from the beginning of the grade they are; their speed will remain constant.

PROCEDURAL STEPS

The general steps taken in solving for a composite-grade equivalent are summarized as follows:

1. Enter Exhibit 11-A1 with the length of the first segment of the composite grade.
2. Find the truck speed at the end of the first segment of the grade.
3. Find the length along the second segment of the grade that results in the same speed as that found in Step 2.
4. Add the length of the Segment 2 grade to the length determined in Step 3.
5. Repeat Steps 2 through 4 for each subsequent grade segment.
6. Find the intersection of a vertical line drawn at the total length of the composite grade and a horizontal line drawn at the final speed of trucks at the end of the composite grade.
7. Determine the percent of grade for the solution point of Step 6.

DISCUSSION

In the analysis of composite grades, the point of interest is not always at the end of the grade. It is important to identify the point at which the speed of trucks is the lowest because this is where trucks will have the maximum impact on operating conditions. This point may be an intermediate point. If a +3% grade of 1,000 ft is followed by a +4% grade of 2,000 ft, then by a +2% grade of 1,500 ft, the speed of trucks will be slowest at the end of the +4% grade segment. Thus, a composite grade solution would be sought for the first two segments of the grade, with a total grade length of 1,000 + 2,000 = 3,000 ft.

The composite grade procedure is not applicable in all cases, especially if the first segment is a downgrade and the segment length is long or if the segments are too short. In the use of performance curves, cases that cannot be solved with this procedure will become apparent to the analyst because the line will not intersect or the points will fall outside the limits of the curves. In such cases, field measurements of speeds should be used as inputs to the selection of appropriate truck equivalency values.

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CHAPTER 12
FREEWAY WEAVING SEGMENTS

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1. INTRODUCTION

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10. Freeway Facilities
11. Basic Freeway Segments
12 Freeway Weaving Segments
13. Freeway Merge and Diverge Segments
14. Multilane Highways
15. Two-Lane Highways

Weaving is generally defined as the crossing of two or more traffic streams traveling in the same direction along a significant length of highway without the aid of traffic control devices (except for guide signs). Thus, weaving segments are formed when merge segments are closely followed by diverge segments. "Closely" implies that there is not sufficient distance between the merge and diverge segments for them to operate independently.

Three geometric characteristics affect a weaving segment's operating characteristics: length, width, and configuration. All have an impact on the critical lane changing activity, which is the unique operating feature of a weaving segment. **Chapter 12, Freeway Weaving Segments,** provides a methodology for analyzing the operation of weaving segments based on these characteristics as well as a segment's free-flow speed (FFS) and the demand flow rates for each movement within a weaving segment (e.g., ramp to freeway or ramp to ramp). This chapter describes how the methodology can be applied to planning, operations, and design applications and provides examples of these applications.

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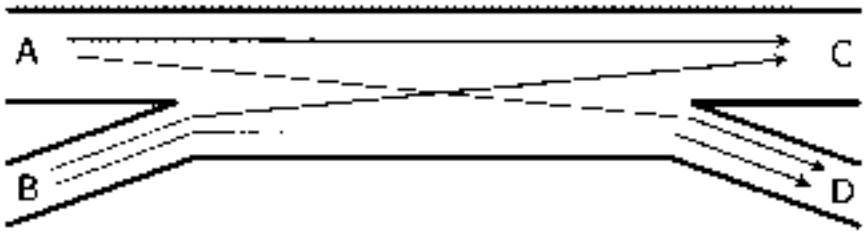
2. WEAVING SEGMENT CHARACTERISTICS

OVERVIEW

Exhibit 12-1 illustrates a freeway weaving segment. On entry and exit roadways, or legs, vehicles traveling from Leg A to Leg D must cross the path of vehicles traveling from Leg B to Leg C. Flows A–D and B–C are, therefore, referred to as *weaving movements*. Flows A–C and B–D may also exist, but as they are not required to cross the path of any other flow, they are referred to as *nonweaving movements*.

Exhibit 12-1
Formation of a Weaving Segment



Traffic in a weaving segment experiences more lane changing maneuvers as drivers must access lanes appropriate to their desired exit leg. Therefore, traffic in a weaving segment is subject to lane-changing turbulence in excess of that normally present on basic freeway segments.

Weaving segments require intense lane-changing maneuvers as drivers must access lanes appropriate to their desired exit leg. Therefore, traffic in a weaving segment is subject to lane-changing turbulence in excess of that normally present on basic freeway segments. This additional turbulence presents operational problems and design requirements, which are addressed by this chapter's methodology.

A weaving segment's geometry affects its operating characteristics.

Three geometric characteristics affect a weaving segment's operating characteristics:

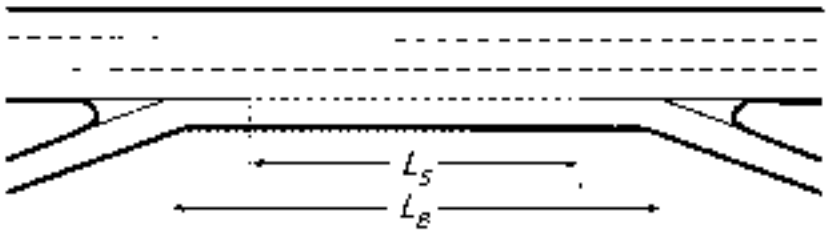
- Length,
- Width, and
- Configuration.

Length is the distance between the merge and diverge that form the weaving segment. *Width* refers to the number of lanes within the weaving segment. *Configuration* is defined by the way entry and exit lanes are aligned. All have an impact on the critical lane-changing activity, which is the unique operating feature of a weaving segment.

LENGTH OF A WEAVING SEGMENT

The two measures of weaving segment length that are relevant to this chapter's methodology are illustrated in Exhibit 12-2.

Exhibit 12-2
Measuring the Length of a Weaving Segment



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The lengths illustrated are defined as follows:

- L_s = short length, the distance in feet between the end points of any barrier markings (solid white lines) that prohibit or discourage lane changing.
- L_b = base length, the distance in feet between points at the respective gore areas where the left edge of the ramp-traveled way and the right edge of the freeway-traveled way meet.

Neither of these definitions is the same as those used in previous editions of the *Highway Capacity Manual* (HCM). The definitions used throughout the HCM2000 were historically tied to the specifics of the design of loop ramps in a cloverleaf interchange at a time when most weaving segments were part of such interchanges. Modern weaving segments occur in a wide range of situations and designs, and a more general definition of length is appropriate.

The weaving segment length used in the methodology is defined by the distance between barrier markings. Where no markings exist, the length is defined by the distance between where the far edge of the ramp gore area and the right edge of the freeway-traveled way meet.

This methodology includes several equations that include the length of the weaving segment. In all cases, these equations use the short length L_s. This is not to suggest that lane changing in a weaving segment is restricted to this length. Some lane changing takes place over solid white lines and even painted gore areas. Nevertheless, research has shown that the short length is a better predictor of operating characteristics within the weaving segment than either the base length or the length as defined in HCM2000 and previous editions.

For weaving segments in which no solid white lines are used, the two lengths illustrated in Exhibit 12-2 are the same, that is, $L_s = L_b$. In dealing with future designs in which the details of markings are unknown, a default value should be based on the general marking policy of the operating agency. At the time this methodology was developed, where solid white lines were provided, L_s was equal to 0.77 × L_b on average for the available data.

The estimated speeds and densities, however, apply over the base length L_b. Some evidence also indicates that these speeds and densities may apply to the 500 ft of freeway upstream of the merge and downstream of the diverge because of presegregation of movements in each case.

The weaving segment length strongly influences lane-changing intensity. For any given demand situation, longer segments allow weaving motorists more time and space to execute their lane changes. This reduces the density of lane changing and, therefore, turbulence. Lengthening a weaving segment both increases its capacity and improves its operation (assuming a constant demand).

Under constant demand conditions, making a weaving segment longer increases its capacity and improves its operation.

WIDTH OF A WEAVING SEGMENT

The width of a weaving segment is measured as the number of continuous lanes within the segment, that is, the number of continuous lanes between the entry and exit gore areas. Acceleration or deceleration lanes that extend partially into the weaving segment are not included in this count.

The number of continuous lanes between gore areas within a weaving segment defines its width.

While additional lanes provide more space for both weaving and nonweaving vehicles, they encourage additional optional lane changing activity. Thus, while reducing overall densities, additional lanes can increase lane changing activity and intensity. In most cases, however, the number of lanes in

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the weaving segment is controlled by the number of lanes on the entry and exit legs and the intended configuration.

CONFIGURATION OF A WEAVING SEGMENT

Configuration of a weaving segment refers to the way that entry and exit lanes are linked. The configuration determines how many lane changes a weaving driver must make to complete the weaving maneuver successfully. The following sections use a great deal of terminology to describe configurations; this terminology should be clearly understood.

One-Sided and Two-Sided Weaving Segments

One-sided weaving segments require no more than two lane changes to complete a weaving maneuver.

Most weaving segments are one-sided. In general, this means that the ramps defining the entry to and exit from the weaving segment are on the same side of the freeway—either both on the right (most common) or both on the left. The methodology of this chapter was developed for one-sided weaving segments; however, guidelines are given for applying the methodology to two-sided weaving segments.

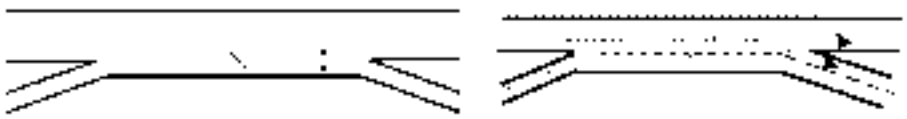
Two-sided weaving segments require three or more lane changes to complete a weaving maneuver or have a single-lane entry ramp closely followed by a single-lane off-ramp on the opposite side of the freeway.

One- and two-sided weaving segments are defined as follows:

- A *one-sided weaving segment* is one in which no weaving maneuvers require more than two lane changes to be completed successfully.
- A *two-sided weaving segment* is one in which at least one weaving maneuver requires three or more lane changes to be completed successfully or at which a single-lane on-ramp is closely followed by a single-lane off-ramp on the opposite side of the freeway.

Exhibit 12-3 illustrates two examples of one-sided weaving segments.

Exhibit 12-3
One-Sided Weaving Segments Illustrated



(a) One-Sided Ramp Weave (b) One-Sided Major Weave

Exhibit 12-3(a) shows a typical one-sided weaving segment formed by a one-lane, right-side on-ramp followed closely by a one-lane, right-side off-ramp. The two are connected by a continuous freeway auxiliary lane. Every weaving vehicle must make one lane change as illustrated, and the lane-changing turbulence caused is clearly focused on the right side of the freeway. Exhibit 12-3(b) shows another one-sided weaving segment in which the off ramp has two lanes. One weaving movement (ramp to freeway) requires one lane change. The other (freeway to ramp) can be made without making a lane change. Again, lane changing turbulence is focused on the right side of the freeway.

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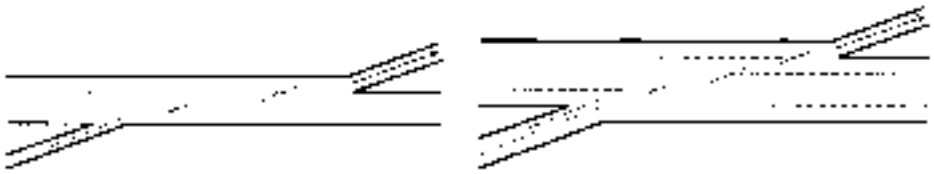
Exhibit 12-4 Illustrations of examples of two-sided weaving segments



(a) Two-Sided Weave Section with Single Lane Ramps

(b) Two-Sided Weaving Section with Three Lane Changes

Exhibit 12-4
Two-Sided Weaving Segments Illustration

Exhibit 12-4(a) is the most common form of a two-sided weave. A one-lane, right-side on-ramp is closely followed by a one-lane, left-side off-ramp (or vice versa). Although the ramp-to-ramp weaving movement requires only two lane changes, this movement is still classified as a two-sided weave because the geometry of the through movement on the freeway technically qualifies as a weaving flow.

Exhibit 12-4(b) is a less typical case in which one of the ramps has multiple lanes. Because the ramp-to-ramp weaving movement must execute three lane changes, it is also classified as a two-sided weaving segment.

Ramp-Weave Versus Major Weave Segments

Exhibit 12-3 can also be used to illustrate the difference between a ramp-weaving segment and a major weaving segment. Exhibit 12-3(a) shows a typical ramp-weaving segment, formed by a one-lane on ramp closely followed by a one-lane off-ramp, connected by a continuous freeway auxiliary lane. The unique feature of the ramp-weave configuration is that all weaving drivers must execute a lane change across the lane line separating the freeway auxiliary lane from the right lane of the freeway mainline.

One-sided configurations where a continuous auxiliary lane connecting an on ramp to a closely following off ramp are treated as isolated ramp junctions (Chapter 13) and not as weaving segments.

It is important to note that the case of a one-lane on ramp closely followed by a one-lane off-ramp (on the same side of the freeway), but not connected by a continuous freeway auxiliary lane, is not considered to be a weaving configuration. Such cases are treated as isolated merge and diverge segments by using the methodology described in Chapter 13. The distance between the on ramp and the off ramp is not a factor in this determination.

Exhibit 12-3(b) shows a typical major weaving segment. A major weaving segment is formed when three or more entry or exit legs have multiple lanes.

Numerical Measures of Configuration

Three numerical descriptors of a weaving segment characterize its configuration:

- LC_{RF} = minimum number of lane changes that a ramp-to-freeway weaving vehicle must make to complete the ramp-to-freeway movement successfully.
- LC_{FR} = minimum number of lane changes that a freeway-to-ramp weaving vehicle must make to complete the freeway-to-ramp movement successfully.

"Minimum number of lane changes" assumes drivers position themselves when entering the weaving segment to make the least number of lane changes possible.

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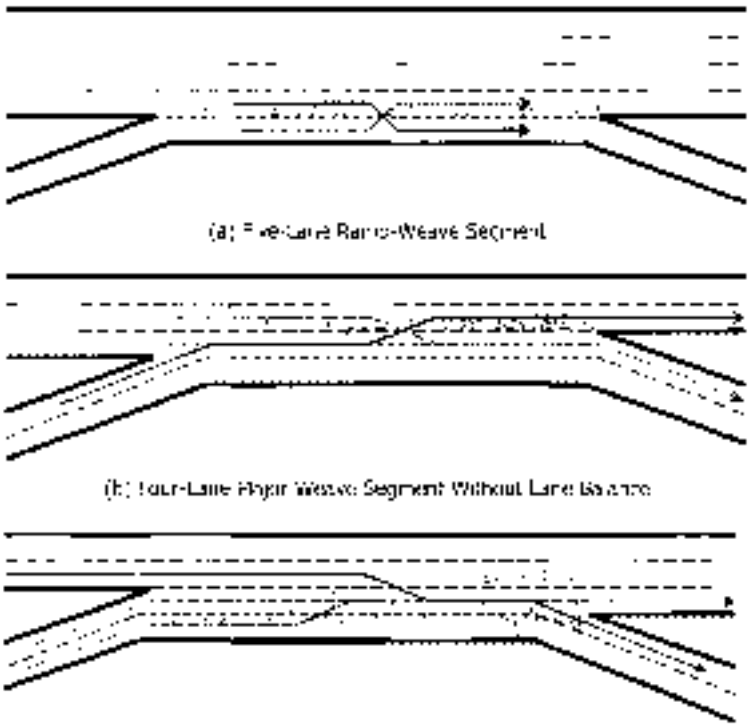
N_{w2} = number of lanes from which a weaving maneuver may be completed with one lane change or no lane changes.

These definitions apply directly to one-sided weaving segments in which the ramp-to-freeway and freeway-to-ramp elements are the weaving movements. Different definitions apply to two-sided weaving segments. Exhibit 12-5 illustrates how these values are determined for one-sided weaving segments.

The values of LC_{RF} and LC_{FR} are found by assuming that every weaving vehicle enters the segment in the lane closest to its desired exit leg and leaves the segment in the lane closest to its entry leg.

Exhibit 12-5
Configuration Parameters Illustrated



(a) Five-Lane Ramp-Weave Segment

(b) Four-Lane Major Weave Segment Without Lane Balance

(c) Four-Lane Major Weave Segment With Lane Balance

Exhibit 12-5(a) is a five-lane ramp-weave configuration. If a weaving driver wishes to exit on the off-ramp and enters the segment on the right-most freeway lane (the lane closest to the off-ramp), the driver must make a single lane change to enter the freeway auxiliary lane and leave via the off-ramp. Thus, for this case, $LC_{FR} = 1$. A weaving driver entering the freeway via the on-ramp has no choice but to enter on the freeway auxiliary lane. The driver must then make a single lane change from the freeway auxiliary lane to the right-most lane of the freeway (the lane closest to the entry leg). Thus, $LC_{RF} = 1$ as well.

Lane balance within a major weave segment provides operational flexibility.

Exhibit 12-5(b) and Exhibit 12-5(c) are both major weaving configurations consisting of four lanes. They differ only in the configuration of their entry and exit gore areas. One has lane balance, while the other does not. Lane balance exists when the number of lanes leaving a diverge segment is one more than the number of lanes entering it.

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Exhibit 12-5(b) is not typical. It is used here only to demonstrate the concept of lane balance on a major weaving segment. Five lanes approach the entry to the segment and four lanes leave it; four lanes approach the exit from the segment and four lanes leave it. Because of this configuration, vehicles approaching the exit gore must already be in an appropriate lane for their intended exit leg.

In Exhibit 12-5(b), the ramp-to-freeway weaving movement (right to left) requires at least one lane change. A vehicle can enter the segment on the leftmost ramp lane (the lane closest to the desired exit) and make a single lane change to exit on the rightmost lane of the continuing freeway. LC_{rf} for this case is 1. The freeway-to-ramp weaving movement can be made without any lane changes. A vehicle can enter on the rightmost lane of the freeway and leave on the leftmost lane of the ramp without executing a lane change. For this case, $LC_{fr} = 0$.

The exit junction in Exhibit 12-5(c) has lane balance: four lanes approach the exit from the segment and five lanes leave it. This is a desirable feature that provides some operational flexibility. One lane—in this case, the second lane from the right—splits at the exit. A vehicle approaching in this lane can take either exit leg without making a lane change. This is a useful configuration in cases in which the split of exiting traffic varies over a typical day. The capacity provided by the splitting lane can be used as needed by vehicles destined for either exit leg.

In Exhibit 12-5(c), the ramp-to-freeway movement can be made without a lane change, while the freeway-to-ramp movement requires a single lane change. For this case, $LC_{rf} = 0$ and $LC_{fr} = 1$.

In Exhibit 12-5(a), there are only two lanes from which a weaving movement may be made with no more than one lane change. Weaving vehicles may enter the segment in the freeway auxiliary lane (ramp-to-freeway vehicles) and in the rightmost freeway lane (freeway-to-ramp vehicles) and may execute a weaving maneuver with a single lane change. Although freeway-to-ramp vehicles may enter the segment on the outer freeway lanes, they would have to make more than one lane change to access the off-ramp. Thus, for this case, $N_{wL} = 2$.

In Exhibit 12-5(b), weaving vehicles entering the segment in the leftmost lane of the on-ramp or the rightmost lane of the freeway are forced to merge into a single lane. From this lane, the freeway-to-ramp movement can be made with no lane changes, while the ramp-to-freeway movement requires one lane change. Because the movement-base merges into a single lane, this counts as one lane from which weaving movements can be made with one or fewer lane changes. Freeway-to-ramp vehicles, however, may also enter the segment on the center lane of the freeway and make a single lane change (as shown) to execute their desired maneuver. Thus, for this case, N_{wL} is once again 2.

Lane balance creates more flexibility in Exhibit 12-5(c). Ramp-to-freeway vehicles may enter on either of the two lanes of the on-ramp and complete a weaving maneuver with either one or no lane changes. Freeway-to-ramp vehicles may enter on the rightmost freeway lane and also weave with a single lane change. In this case, $N_{wL} = 3$.

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In all one-sided weaving segments, the number of lanes from which weaving maneuvers may be made with one or no lane changes is either two or three. No other values are possible. Segments with $N_{w1} = 3$ generally exist in major weaving segments with lane balance at the exit gore.

Special Case: Two-Sided Weaving Segments

Only the ramp-to-ramp movement is considered to be a weaving flow in a two-sided weaving segment.

The parameters defining the impact of configuration apply only to one-sided weaving segments. In a two-sided weaving segment, neither the ramp-to-freeway nor the freeway-to-ramp movements weave. While the through freeway movement in a two-sided weaving segment might be functionally thought of as weaving, it is the dominant movement in the segment and does not behave as a weaving movement. Thus, in two-sided weaving segments, only the ramp-to-ramp movement is considered to be a weaving flow. This introduces two specific changes to the methodology:

1. Instead of LC_1 and LC_2 being needed to characterize weaving behavior, a value of LC_{12} (the minimum number of lane changes that must be made by a ramp-to-ramp vehicle) is needed. In Exhibit 12-4(a), $LC_{12} = 2$, while in Exhibit 12-4(b), $LC_{12} = 1$.
2. In all cases of two-sided weaving, the value of N_{w1} is set to 0 by definition.

With these two modifications, the methodology outlined for one-sided weaving segments may be applied to two-sided weaving segments as well.

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3. METHODOLOGY

The methodology presented in this chapter was developed as part of National Cooperative Highway Research Program (NCHRP) Project 3-77, *Analysis of Freeway Weaving Sections* (1). Elements of this methodology have also been adapted from earlier studies and earlier editions of this manual (2–9).

LIMITATIONS OF THE METHODOLOGY

The methodology of this chapter does not specifically address the following subjects (without modifications by the analyst).

- Special lanes, such as high-occupancy vehicle lanes, within the weaving segment,
- Ramp metering on entrance ramps forming part of the weaving segment,
- Specific operating conditions when oversaturated conditions exist,
- Effects of speed limit enforcement practices on weaving segment operations,
- Effects of intelligent transportation system technologies on weaving segment operations,
- Weaving segments on arterials or other urban streets, including one-way frontage roads,
- Effects of downstream congestion or upstream demand starvation on the analysis segment, or
- Multiple weaving segments.

Multiple weaving segments must be divided into merge, diverge, and simple weaving segments for analysis.

The last subject has been included in previous versions of this manual. Multiple weaving segments must now be divided into appropriate merge, diverge, and simple weaving segments for analysis.

OVERVIEW OF THE METHODOLOGY

Exhibit 12-6 is a flowchart illustrating the basic steps that define the methodology for analyzing freeway weaving segments. The methodology uses several types of predictive algorithms, all of which are based on a mix of theoretical and regression models. These models include the following:

- Models that predict the total rate of lane changing taking place in the weaving segment. This is a direct measure of turbulence in the traffic stream caused by the presence of weaving movements.
- Models to predict the average speed of weaving and nonweaving vehicles in a weaving segment under stable operating conditions, that is, not operating at Level of Service (LOS) F.
- Models to predict the capacity of a weaving segment under both ideal and prevailing conditions.
- A model to estimate the maximum length over which weaving operations can be said to exist.

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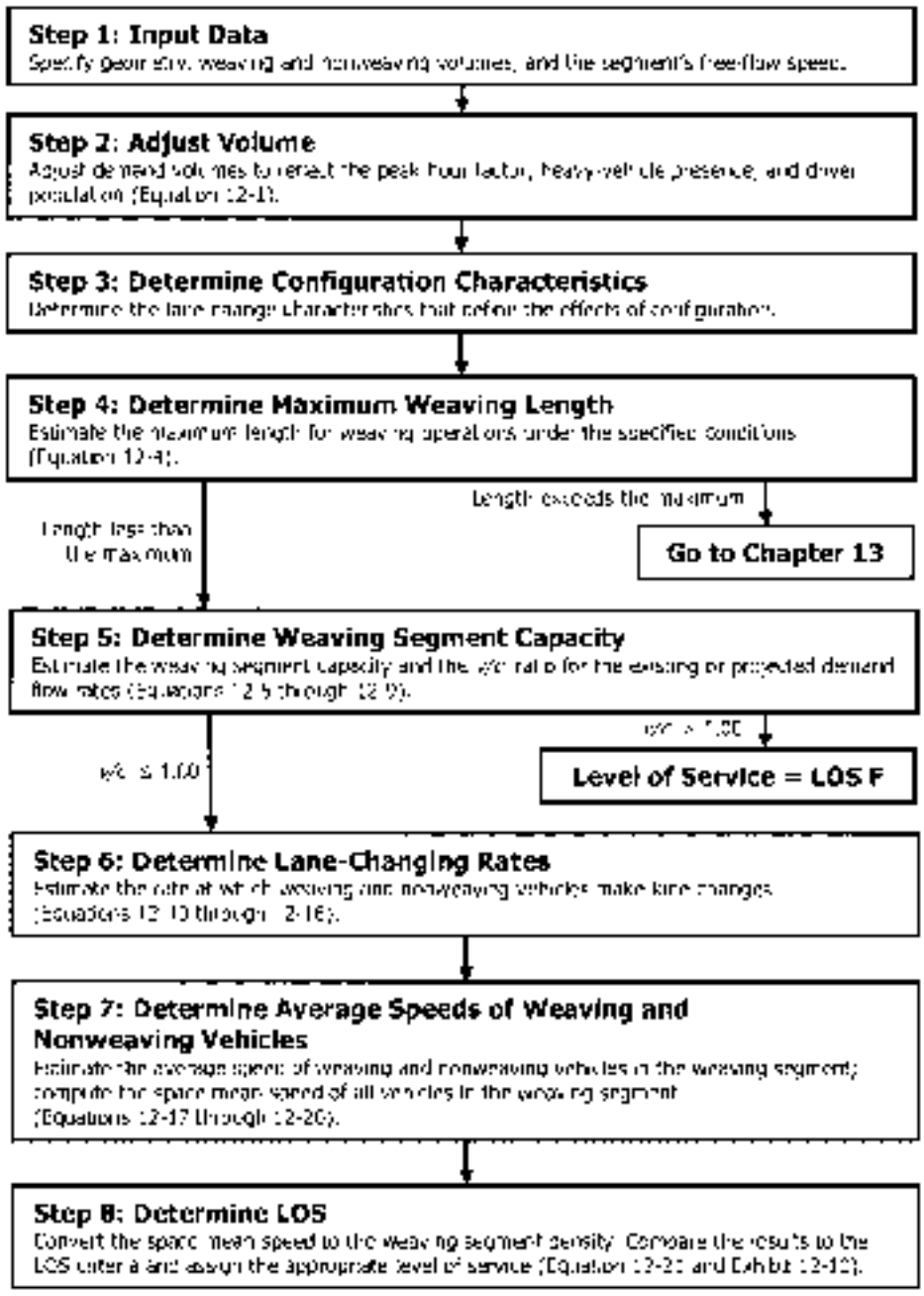
Exhibit 12-6
Weaving Methodology Flowchart



If the potential weaving segment is longer than the value given in Equation 12-4, it is treated as isolated merging and diverging ramp junctions by using the procedures of Chapter 13.

LOS F exists if a weaving segment's demand exceeds capacity.

PARAMETERS DESCRIBING A WEAVING SEGMENT

Several parameters describing weaving segments have already been introduced and defined. Exhibit 12-7 illustrates all variables that must be specified as input variables and defines those that will be used within or as outputs of the methodology. Some of these apply only to one-sided weaving segments. Exhibit 12-8 lists those variables that are different when applied to two-sided weaving segments.

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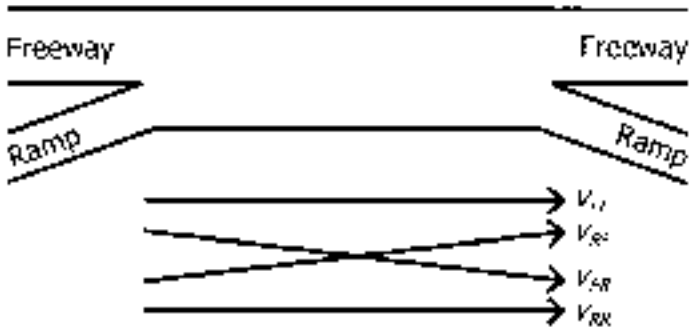

Exhibit 12-7
Weaving Variables for One-Sided Weaving Segments

v_{FF} = freeway-to-freeway demand flow rate in the weaving segment in passenger cars per hour (pc/h);
v_{RF} = ramp-to-freeway demand flow rate in the weaving segment (pc/h);
v_{FR} = freeway to ramp demand flow rate in the weaving segment (pc/h);
v_{RR} = ramp-to-ramp demand flow rate in the weaving segment (pc/h);
v_w = weaving demand flow rate in the weaving segment (pc/h): $v_w = v_{RF} + v_{FR}$
v_{NW} = nonweaving demand flow rate in the weaving segment (pc/h): $v_{NW} = v_{FF} + v_{RR}$
v = total demand flow rate in the weaving segment (pc/h): $v = v_{NW} + v_w$
VR = volume ratio: v_w/v;
N = number of lanes within the weaving section;
N_{wl} = number of lanes in which a weaving maneuver may be made with one or no lane changes (see Exhibit 12-5);
S_w = average speed of weaving vehicles within the weaving segment (mi/h);
S_{NW} = average speed of nonweaving vehicles within the weaving segment (mi/h);
S = average speed of all vehicles within the weaving segment (mi/h);
FFS = free flow speed of the weaving segment (mi/h);
D = average density of all vehicles within the weaving segment in passenger cars per mile per lane (pc/mi/ln);
W = weaving intensity factor;
L_S = length of the weaving segment (ft), based on the short length definition of Exhibit 12-2;
LC_{RF} = minimum number of lane changes that must be made by a single weaving vehicle moving from the on-ramp to the freeway (see Exhibit 12-5);
LC_{FR} = minimum number of lane changes that must be made by a single weaving vehicle moving from the freeway to the off-ramp;
LC_{MIN} = minimum rate of lane changing that must exist for all weaving vehicles to complete their weaving maneuvers successfully, in lane changes per hour (lc/h): $LC_{MIN} = 2.5(LC_{RF} + LC_{FR})$;
LC_w = total rate of lane changing by weaving vehicles within the weaving segment (lc/h);
LC_{NW} = total rate of lane changing by nonweaving vehicles within the weaving segment (lc/h);
LC_{ALL} = total rate of lane changing of all vehicles within the weaving segment (lc/h), $LC_{ALL} = LC_w + LC_{NW}$;
ID = interchange density, the number of interchanges within ±3 mi of the center of the subject weaving segment divided by 6, in interchanges per mile (int/mi); and
I_{LC} = lane-changing intensity: $I_{LC} = LC_{ALL}/6$, in lane changes per mile (lc/mi).

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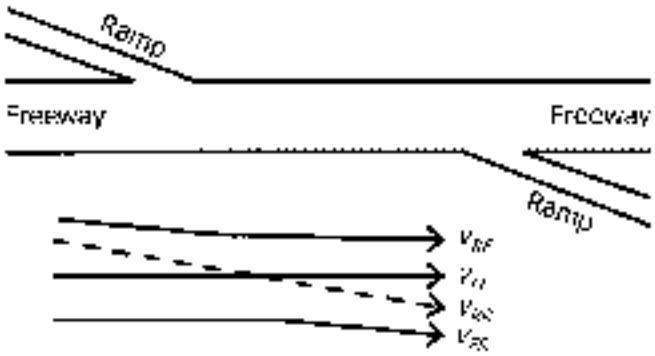
Exhibit 12-8
Weaving Variables for a Two-Sided Weaving Segment



The through freeway movement is not considered to be weaving in a two-sided weaving segment.

All variables are defined as in Exhibit 12-7, except for the following variables relating to flow designations and lane-changing variables:

v_w = total weaving demand flow rate within the weaving segment (pc/h), $v_w = v_{bf}$;

v_{nw} = total nonweaving demand flow rate within the weaving segment (pc/h), $v_{nw} = v_{ff} + v_{fr} + v_{rr}$;

LC_{rf} = minimum number of lane changes that must be made by one ramp-to-ramp vehicle to complete a weaving maneuver; and

LC_{av} = minimum rate of lane changing that must occur for all weaving vehicles to complete their weaving maneuvers successfully (pc/h), $LC_{av} = 1.0 \times v_{bf}$.

The principal difference between one-sided and two-sided weaving segments is the relative positioning of the movements within the segment. In a two-sided weaving segment, the ramp-to-freeway and freeway-to-ramp vehicles do not weave. In a one-sided segment, they execute the weaving movements. In a two-sided weaving segment, the ramp-to-ramp vehicles must cross the path of freeway-to-freeway vehicles. Both could be taken to be weaving movements. In reality, the through freeway movement is not weaving in that vehicles do not need to change lanes; nor generally can not shift lane position in response to a desired exit leg.

Thus, in two-sided weaving segments, only the ramp-to-ramp flow is considered to be weaving. The lane-changing parameters reflect this change in the way weaving flows are viewed. Thus, the minimum rate of lane changing that weaving vehicles must maintain to complete all desired weaving maneuvers successfully is also related only to the ramp-to-ramp movement.

The methodology uses demand flow rates for the peak 15 min of passenger cars per hour.

The definitions for flow all refer to *demand flow rate*. This means that for existing cases, the demand should be based on *metered flows*. For future cases, forecasting techniques will generally produce a *demand volume* or *demand flow rate*. All of the methodology's algorithms use demand expressed as flow rates in the peak 15 min of the design (or analysis) hour, in equivalent passenger cars per hour.

COMPUTATIONAL PROCEDURES

Each of the major procedural steps noted in Exhibit 12-6 is discussed in detail in the sections that follow.

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Step 1: Input Data

The methodology for weaving segments is structured for operational analysis usage, that is, given a known or specified geometric design and traffic demand characteristics, the methodology is used to estimate the LOS that is expected to exist.

Design and preliminary engineering are generally conducted in terms of comparative analyses of various design proposals. This is a good approach, given that the range of widths, lengths, and configurations in any given case is constrained by a number of factors. Length is constrained by the location of the weaving actions that determine the location of ramp ranges and ramps. Width is constrained by the number of lanes on entry and exit legs and usually involves no more than two choices. Configuration is also the result of the number of lanes on entry and exit legs as well as the number of lanes within the segment. Changing the configuration usually involves adding a lane to one of the entry or exit legs, or both, to create different linkages.

For analysis, the geometry of the weaving segment must be fully defined. This includes the number of lanes, lane widths, shoulder clearances, the details of entry and exit gore area designs (excluding markings), the existence and extent of barrier lines, and the length of the segment. A sketch of the weaving segment should be drawn with all appropriate dimensions shown.

Traffic demands are usually expressed as peak hour volumes under prevailing conditions. If flow rates have been directly observed in the field, the flow rates for the worst 15 min period in the peak hour may be substituted. In this case, the peak hour factor (PHF) is implicitly 1.00.

Step 2: Adjust Volume

All equations in this chapter use flow rates under equivalent ideal conditions as input variables. Thus, demand volumes and flow rates under prevailing conditions must be converted to their ideal equivalents by using Equation 12-1:

$$v_i = \frac{V_i}{PHF \times f_{HV} \times f_p} \qquad \text{Equation 12-1}$$

where

v_i = flow rate under ideal conditions (pc/h);

V_i = hourly volume for flow under prevailing conditions (veh/h);

PHF = peak hour factor;

f_{HV} = adjustment factor for heavy vehicle presence; and

f_p = adjustment factor for driver population (the subscript for the type of flow i can take on the following values:

- w = freeway to freeway,
- o = freeway to ramp,
- i = ramp to freeway,
- r = ramp to ramp).

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w = weaving; and

nw = nonweaving.

Factors f_{HV} and f_p are taken from Chapter 11, Basic Freeway Segments.

If flow rates for a 15-min period have been provided as inputs, the PHF is taken to be 1.00 in this computation. If hourly volumes are converted by using a PHF other than 1.00, there is an implicit assumption that all four component flows in the weaving segment peak during the same 15-min period of the hour. This is rarely true in the field, however, such an analysis represents a worst-case scenario.

Once demand flow rates have been established, it may be convenient to construct a weaving diagram similar to those illustrated in Exhibit 12-7 (for one-sided weaving segments) and Exhibit 12-8 (for two-sided weaving segments).

Step 3: Determine Configuration Characteristics

Several key parameters characterize the configuration of a weaving segment. These are descriptive of the segment and will be used as key variables in subsequent steps of the methodology:

LC_{min} = minimum rate at which weaving vehicles must change lanes to complete all weaving maneuvers successfully (veh/h); and

N_{ww} = number of lanes from which weaving maneuvers may be made with either one or no lane changes.

How these values are determined depends on whether the segment under study is a one-sided or two-sided weaving segment.

One-Sided Weaving Segments

The determination of key variables in one-sided weaving segments is illustrated in Exhibit 12-7. In one-sided segments, the two weaving movements are the ramp-to-freeway and freeway-to-ramp flows. As shown in Exhibit 12-7, the following values are established.

LC_{RF} = minimum number of lane changes that must be made by one ramp-to-freeway vehicle to execute the desired maneuver successfully; and

LC_{FR} = minimum number of lane changes that must be made by one freeway-to-ramp vehicle to execute the desired maneuver successfully.

LC_{min} for one-sided weaving segments is given by Equation 12-2:

Equation 12-2

$$LC_{min} = (LC_{RF} \times v_{RF}) + (LC_{FR} \times v_{FR})$$

For one-sided weaving segments, the value of N_{ww} is either 2 or 3. The determination is made by a review of the geometric design and the configuration of the segment, as illustrated in Exhibit 12-5.

Two-Sided Weaving Segments

The determination of key variables in two-sided weaving segments is illustrated in Exhibit 12-8. The unique feature of two-sided weaving segments is that only the ramp-to-ramp flow is functionally weaving. From Exhibit 12-8, the following value is established:

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LC_{es} minimum number of lane changes that must be made by one group to merge vehicle to execute the desired maneuver successfully.

LC_{es} for two-sided weaving segments is given by Equation 12-3:

$$LC_{es} = LC_{ef} \times C_{es} \quad \text{Equation 12-3}$$

For two-sided weaving segments, the value of N_{wl} is always 0 by definition.

Step 4: Determine Maximum Weaving Length

The maximum length of a weaving segment, L_{max}, is based on the distance beyond which additional length does not add to capacity.

The concept of maximum length of a weaving segment is critical to the methodology. Strictly defined, *maximum length* is the length at which weaving turbulence no longer has an impact on operations within the segment, or alternatively, on the capacity of the weaving segment.

Unfortunately, depending on the selected definition, these measures can be quite different. Weaving turbulence will have an impact on operations (i.e., weaving and nonweaving vehicle speeds) for distances far in excess of those defined by when the capacity of the segment is no longer affected by weaving.

This methodology uses the second definition (based on the equivalence of capacity). If the operational definition were used, the methodology would produce capacity estimates in excess of those for a similar basic freeway segment, which is illogical. The maximum length of a weaving segment (in feet) is computed from Equation 12-4:

$$L_{max} = \left[5{,}728(1 + VR)^{1.6}\right] - \left[1{,}566N_{ww}\right] \quad \text{Equation 12-4}$$

where L_{max} is the maximum weaving segment length (using the stated length definition) and other variables are as previously defined.

As VR increases, it is expected that the influence of weaving turbulence would extend for longer distances. All values of N_{ww} are either 0 (two-sided weaving segments) or 2 or 3 (one-sided weaving segments). Having more lanes from which easy weaving lane changes can be made reduces turbulence, which in turn reduces the distance over which such turbulence affects segment capacity.

Exhibit 12-9 illustrates the sensitivity of maximum length to both VR and N_{ww}. As expected, VR has a significant impact on maximum length, as does the configuration, as indicated by N_{ww}. While the maximum lengths shown can compute to very high numbers, the highest results are well outside the calibration range of the equation (limited to about 3,800 ft), and many of the situations are improbable. Values of VR on segments with $N_{ww} = 2$ or 3 lanes rarely rise above the range of 0.40 to 0.50. While values of VR above 0.70 are technically feasible on segments with $N_{ww} = 3.0$ lanes, they are rare.

While the extreme values in Exhibit 12-9 are not practical, it is clear that the maximum length of weaving segments can rise to 6,000 ft or more. Furthermore, the maximum length can vary over time, as VR is not a constant throughout every demand period of the day.

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Exhibit 12-9
Variation of Weaving Length Versus Weaving Ratio and Number of Weaving Lanes (4)

VR	Number of Weaving Lanes N_{w2} = 2	N_{w3} = 3
0.1	3,540	1,874
0.2	4,546	2,673
0.3	5,584	4,018
0.4	6,682	5,115
0.5	7,826	6,260
0.6	9,019	7,453
0.7	10,256	8,690
0.8	11,538	9,972

If the length of the segment is greater than L_{max}, it should be analyzed as separate merge and diverge components by using the methodology in Chapter 13. Any portion lying outside the influence of the merge and diverge segments is treated as a basic freeway segment.

The value of L_{max} is used to determine whether continued analysis of the configuration as a weaving segment is justified.

- If $L_s \leq L_{max}$, continue to Step 5, or
- If $L_s \geq L_{max}$, analyze the merge and diverge junctions as separate segments by using the methodology in Chapter 13.

If the segment is too long to be considered a weaving segment, then the merge and diverge areas are treated separately. Any distance between the two falling outside the influence areas of the merge and diverge segments would be considered to be a basic freeway segment and would be analyzed accordingly.

Step 5: Determine Weaving Segment Capacity

A weaving segment's capacity is controlled by either (a) the average vehicle density exceeding 43 pc/mi/ln or (b) the weaving demand flow rate exceeding a value that depends on the number of weaving lanes.

The capacity of a weaving segment is controlled by one of two conditions:

- Breakdown of a weaving segment is expected to occur when the average density of all vehicles in the segment reaches 43 pc/mi/ln; or
- Breakdown of a weaving segment is expected to occur when the total weaving demand flow rate exceeds
  - 2,400 pc/h for cases in which N_w = 2 lanes, or
  - 3,500 pc/h for cases in which N_w = 3 lanes.

The first criterion is based on the criteria listed in Chapter 11, Basic Freeway Segments, which state that freeway breakdowns occur at a density of 45 pc/mi/ln. Given the additional turbulence in a weaving segment, breakdown is expected to occur at slightly lower densities.

The second criterion recognizes that there is a practical limit to how many vehicles can mutually cross each other's path without causing serious operational failures. The existence of a third lane from which weaving maneuvers can be made with two or fewer lane changes in effect spreads the impacts of turbulence across segment lanes and allows for higher weaving flows.

For two-sided weaving segments (N_{ww} = 0 lanes), no limiting value on weaving flow rate is proposed. The analysis of two-sided weaving segments is approximate with this methodology, and a density sufficient to cause a breakdown is generally reached at relatively low weaving flow rates.

Weaving Segment Capacity Determined by Density

The capacity of a weaving segment, based on reaching a density of 43 pc/mi/ln, is estimated by using Equation 12-5:

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$$c_{ow} = c_{fo} - \left[438.2(1 + VR)^{1.3}\right] - \left[0.0765L_s\right] + \left[119.8N_{wl}\right]$$

Equation 12-5

where

c_{ow} = capacity of the weaving segment under equivalent ideal conditions, per lane (pc/h/ln), and

c_{fo} = capacity of a basic freeway segment with the same FFS as the weaving segment under equivalent ideal conditions, per lane (pc/h/ln).

All other variables are as previously defined.

The model describes the capacity of a weaving segment in terms of the difference between the capacity of a basic freeway segment and the capacity of a weaving segment with the same FFS. Capacity decreases with VR, which is logical. It increases as length and number of weaving lanes N_{wl} increase. These are also logical trends, as both increasing length and a larger number of weaving lanes reduce the intensity of turbulence.

Arithmetically, it is possible to get a result in which c_{ow} is greater than c_{fo}. In practical terms, this will never occur. The maximum length algorithm of Step 4 was found by setting the two values equal. Thus, weaving analyses would only be undertaken in cases in which c_{ow} is less than c_{fo}.

The value of c_{ow} must now be converted to total capacity under prevailing conditions by using Equation 12-6:

$$c_w = c_{ow} N f_{HV} f_p$$

Equation 12-6

where c_w is the capacity of the weaving segment under prevailing conditions in vehicles per hour. As with all capacities, it is stated as a flow rate for a 15-min analysis period.

Weaving Segment Capacity Determined by Weaving Demand Flows

The capacity of a weaving segment, as controlled by the maximum weaving flow rates noted previously, is found from Equation 12-7:

$$c_w = \frac{2{,}400}{VR} \quad \text{for } N_{wl} = 2 \text{ lanes}$$

$$c_w = \frac{3{,}500}{VR} \quad \text{for } N_{wl} = 3 \text{ lanes}$$

Equation 12-7

where c_w is the capacity of all lanes in the weaving segment under ideal conditions in passenger cars per hour, and all other variables are as previously defined. This value must be converted to prevailing conditions by using Equation 12-8:

$$c_w = c_w f_{HV} f_p$$

Equation 12-8

Final Determination of Capacity

The final capacity is the smaller of the two estimates of Equation 12-6 and Equation 12-8. With capacity determined, a v/c ratio for the weaving segment may be computed from Equation 12-9:

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Equation 12-9

$$v/c = \frac{v f_{HV} f_p}{c_{iw}}$$

Adjustment factors are used because the total demand flow rate, v, is stated for equivalent ideal conditions, while c_{iw} is stated for prevailing conditions.

Level of Service F

LOS F occurs when demand exceeds capacity

If v/c is greater than 1.00, demand exceeds capacity, and the segment is expected to fail, that is, have a LOS of F. If this occurs, the analysis is terminated, and LOS F is assigned. At LOS F, it is expected that queues will form within the segment, possibly extending upstream beyond the weaving segment itself. Queuing on the on-ramps that are part of the weaving segment would also be expected. Where LOS F is found to exist, the analyst is urged to use the methodology of Chapter 10, Freeway Facilities, to analyze the impacts of this on upstream and downstream segments during the analysis period and over time.

Step 6: Determine Lane-Changing Rates

The equivalent hourly rate at which weaving and nonweaving vehicles make lane changes within the weaving segment is a direct measure of turbulence. It is also a key determinant of speeds and densities within the segment, which ultimately determine the existing or anticipated LOS.

It should be noted that the lane-changing rates estimated are in terms of equivalent *passenger car lane changes*. It is assumed that heavy-vehicle lane changes create more turbulence than passenger-car lane changes.

Three types of lane changes can be made within a weaving segment:

- *Required lane changes made by weaving vehicles.* These lane changes must be made to complete a weaving maneuver and are restricted to the physical area of the weaving segment. In Step 3, the rate at which such lane changes are made by weaving vehicles, LC_{RW}, was determined.
- *Optional lane changes made by weaving vehicles.* These lane changes are not necessary to weave successfully. They involve weaving drivers who choose to enter the weaving segment in the outer lanes of either the freeway or ramp (assuming it has more than one lane), leave the weaving segment in an outer lane, or both. Such drivers make additional lane changes beyond those absolutely required by their weaving maneuver.
- *Optional lane changes made by nonweaving vehicles.* Nonweaving vehicles may also make lane changes within the weaving segment, but neither the configuration nor their desired origin and destination would require such lane changes. Lane changes by nonweaving vehicles are always made because the driver chooses that option.

While LC_{RW} can be computed from the weaving configuration and the demand flow rates, additional optional lane changes made by both weaving and nonweaving vehicles add to turbulence and must be estimated by using regression-based models.

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Estimating the Total Lane-Changing Rate for Weaving Vehicles

The model for predicting the total lane-changing rate for weaving vehicles is of the form MLC_{ex} plus an algorithm that predicts the additional optional lane-changing rate. These are combined so that the total lane-changing rate for weaving vehicles, including both required and optional lane changes, is as shown in Equation 12-10:

$$LC_w = LC_{MIN} - 0.39\left[(L_s - 300)^{1.3} N^{1.3} (1 - ID)^{1.3}\right] \quad \text{Equation 12-10}$$

where

LC_w = equivalent hourly rate at which weaving vehicles make lane changes within the weaving segment (l/h);

LC_{MIN} = minimum equivalent hourly rate at which weaving vehicles must make lane changes within the weaving segment to complete all weaving maneuvers successfully (l/h);

L_s = length of the weaving segment, using the short length definition (ft) (300 ft is the maximum value);

N = number of lanes within the weaving segment, and

ID = interchange density (int/mi).

Equation 12-10 has several interesting characteristics. The term $L_s - 300$ implies that for weaving segments of 300 ft (or shorter), weaving vehicles only make necessary lane changes, that is, $LC_w = LC_{MIN}$. While shorter weaving segments would be an aberration, they do occasionally occur. In using Equation 12-10, however, a length of 300 ft is used for all lengths less than or equal to 300 ft.

This model is also unique in that it is the first use of interchange density in a model not involving determination of the FFS. In this edition of the HCM, however, FFS is partially based on total ramp density rather than interchange density. The two measures are, of course, related to the type of interchange involved. A full cloverleaf interchange has four ramps, while a diamond interchange has two ramps. Care must be taken when determining the value of *total ramp density* and *interchange density*, as they are different numbers.

The algorithm uses the term $1 - ID$ because the value of ID may be either more than or less than 1.00, and the power term would not act consistently on the result. In determining interchange density for a weaving segment, a distance of 3 mi upstream and 3 mi downstream of the midpoint of the weaving segment is used. The number of interchanges within the 6-mi range defined above is counted and divided by 6 to determine the interchange density. The subject weaving segment should be counted as one interchange in this computation. For additional discussion of total ramp density, consult Chapter 11.

The basic sensitivities of this model are reasonable. Weaving-vehicle lane changing increases as the length and width of the weaving segment increase. A longer, wider weaving segment simply provides more opportunities for weaving vehicles to execute lane changes. Lane changing also increases as interchange density increases. Higher interchange densities mean that there are more reasons

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for drivers to make optional lane changes based upon their entry or exit at a nearby interchange.

Estimating the Lane-Changing Rate for Nonweaving Vehicles

No nonweaving driver must make a lane change within the confines of a weaving segment. All nonweaving vehicle lane changes are, therefore, optional. These are more difficult to predict than weaving lane changes, as the motivation for nonweaving lane changes varies widely and may not always be obvious. Such lane changes may be made to avoid turbulence, to be better positioned for a subsequent maneuver, or simply to achieve a higher average speed.

The research leading to this methodology (*20*) revealed several discontinuities in the lane-changing behavior of nonweaving vehicles within weaving segments. To identify the areas of discontinuity and to develop an estimation model for these areas, it was necessary to define a "nonweaving vehicle index," I_{nw}, as given in Equation 12-11:

Equation 12-11

$$I_{nw} = \frac{I_w \times (1) \times v_{nw}}{10{,}000}$$

This index is a measure of the tendency of conditions to induce unusually large nonweaving vehicle lane-changing rates. Large nonweaving flow rates, high interchange densities, and long weaving lengths seem to produce situations in which nonweaving lane-changing rates are unusually elevated.

Two models are used to predict the rate at which nonweaving vehicles change lanes in weaving segments. The first, Equation 12-12, covers the majority of cases, that is, cases for which normal lane-changing characteristics are expected. This is the case when I_{nw} is less than or equal to 1,300:

Equation 12-12

$$LC_{nw,1} = (0.2069 v_{nw}) - (0.5427 L_s) - (197.6N)$$

where $LC_{nw,1}$ is the rate of lane changing per hour. The equation shows logical trends in that nonweaving lane changes increase with both nonweaving flow rate and segment length. Less expected is that nonweaving lane changing *decreases* with increasing number of lanes. This trend is statistically very strong and likely indicates more propagation of flows in wider weaving segments. Arithmetically, Equation 12-12 can produce a negative result. Thus, the minimum value must be externally set at 0.

The second model applies to a small number of cases in which the combination of high nonweaving demand flow, high interchange density, and long segment length produce exceptionally high nonweaving lane changing rates. Equation 12-13 is used in cases for which I_{nw} is greater than or equal to 1,950.

Equation 12-13

$$LC_{nw,2} = 2{,}135 + 0.223(v_{nw} - 2{,}000)$$

where $LC_{nw,2}$ is the lane changing rate per hour, and all other variables are as previously defined.

Unfortunately, Equation 12-12 and Equation 12-13 are discontinuous and cover discontinuous ranges of I_{nw}. If the nonweaving index is between 1,301 and

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1,950, a straight interpolation between the values of LC_{12} and LC_{w2} is used as shown in Equation 12-14.

$$LC_{12a} = LC_{12} - (LC_{12} - LC_{w2})\left(\frac{I_{ww} - 1{,}300}{650}\right) \quad \text{Equation 12-14}$$

where LC_{ww} is the lane-changing rate per hour, and all other variables are as previously defined. Equation 12-14 only works for cases in which LC_{12a} is less than LC_{w2}. In the vast majority of cases, this will be true (unless the weaving length is longer than the maximum length estimated in Step 4). In the rare case when it is not true, LC_{w2} is used.

Equation 12-15 summarizes this in a more precise way:

$$\begin{aligned}
&\text{If } I_{ww} \le 1{,}300: && LC_{12a} = LC_{12} \\
&\text{If } I_{ww} \ge 1{,}950: && LC_{12a} = LC_{w2} \\
&\text{If } 1{,}300 < I_{ww} < 1{,}950: && LC_{12a} = LC_{12} - (LC_{12} - LC_{w2})\left(\frac{I_{ww} - 1{,}300}{650}\right) \\
&\text{If } LC_{12} > LC_{w2}: && LC_{12a} = LC_{w2}
\end{aligned} \quad \text{Equation 12-15}$$

Total Lane-Changing Rate

The total lane-changing rate (LC_{ALL}) of all vehicles in the weaving segment, in lane changes per hour, is computed from Equation 12-16:

$$LC_{ALL} = LC_{12a} + LC_{21} \quad \text{Equation 12-16}$$

Step 7: Determine Average Speeds of Weaving and Nonweaving Vehicles in Weaving Segment

The heart of this methodology is the estimation of the average speeds of weaving and nonweaving vehicles in the weaving segment. These speeds are estimated separately because they are affected by different factors, and they can be significantly different from each other.

The speeds of weaving and nonweaving vehicles will be combined to find a space mean speed of all vehicles in the segment. This will then be converted to a density, which will determine the LOS.

Average Speed of Weaving Vehicles

The algorithm for predicting the average speed of weaving vehicles in a weaving segment may be generally stated as shown in Equation 12-17:

$$S_w = S_{w(MIN)} + \left(\frac{S_{w(MAX)} - S_{w(MIN)}}{1 + W}\right) \quad \text{Equation 12-17}$$

where

S_w = average speed of weaving vehicles within the weaving segment (mi/h),

$S_{w(MIN)}$ = minimum average speed of weaving vehicles expected in a weaving segment (mi/h),

$S_{w(MAX)}$ = maximum average speed of weaving vehicles expected in a weaving segment (mi/h), and

W = weaving intensity factor.

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The form of the model is logical and constrains the result to a reasonable range, defined by the minimum and maximum speed expectations. The term $1 + W$ accommodates a weaving intensity factor that can be more or less than 1.0.

For this methodology, the minimum expected speed is taken to be 15 mi/h, and the maximum expected speed is the FFS. As with all analyses, the FFS is best observed in the field, either on the subject facility or a suitable facility. When measured, the FFS should be observed within the weaving segment.

In circumstances that require the FFS to be estimated, the model described in Chapter 11, Basic Freeway Segments, is used. The average speed of weaving vehicles within the weaving segment is estimated by using Equation 12-18 and Equation 12-19.

Equation 12-18

$$S_w = 15 + \frac{(FFS - 15)}{(1 + W)}$$

Equation 12-19

$$W = 0.226\left(\frac{VR \cdot LC_{all}}{L_S}\right)^{0.789}$$

Note that weaving intensity is based on the total lane-changing rate within the weaving segment. More specifically, it is based on the hourly rate of lane changes per foot of weaving length. This might be thought of as a measure of the density of lane changes. In addition, the lane-changing rate itself depends on many demand and physical factors related to the design of the segment.

Average Speed of Nonweaving Vehicles

The average speed of nonweaving vehicles in a weaving segment is estimated by using Equation 12-20:

Equation 12-20

$$S_{nw} = FFS - (0.0072 LC_{all}) - \left(0.0048 \frac{v_{nw}}{N}\right)$$

Equation 12-20 treats nonweaving speed as a reduction from FFS. As would be expected, the speed is reduced as v/N increases. More interesting is the appearance of LC_{all} in the equation. LC_{all} is a measure of minimal weaving turbulence, assuming that weaving vehicles make only necessary lane changes. It depends on both the configuration of the weaving segment and weaving demand flow rates. Thus, nonweaving speeds decrease as weaving turbulence increases.

Average Speed of All Vehicles

The space mean speed of all vehicles in the weaving segment is computed by using Equation 12-21:

Equation 12-21

$$S = \frac{v_w + v_{nw}}{\left(\frac{v_w}{S_w}\right) + \left(\frac{v_{nw}}{S_{nw}}\right)}$$

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Step 8: Determine LOS

The LOS in a weaving segment, as in all freeway analyses, is related to the density in the segment. Exhibit 12-10 provides LOS criteria for weaving segments on freeways, collector-distributor (C-D) roadways, and multilane highways. This methodology was developed for freeway weaving segments, although an isolated C-D roadway was included in its development. The methodology may be applied to weaving segments on uninterrupted segments of multilane surface facilities, although its use in such cases is approximate.

LOS can be determined for weaving segments on freeways, multilane highways, and C-D roadways.

Exhibit 12-10
LOS for Weaving Segments

LOS	Density (pc/mi/ln)	
	Freeway Weaving Segments	Weaving Segments on Multilane Highways or C-D Roadways
A	≤ 10	≤ 12
B	>10–20	>12–24
C	>20–28	>24–32
D	>28–35	>32–36
E	>35	>36
F	Demand exceeds capacity	

The boundary between stable and unstable flow—the boundary between levels of service E and F—occurs when the demand flow rate exceeds the capacity of the segment, as described in Step 3. The thresholds for other levels of service were set relative to the criteria for basic freeway segments (or multilane highways). In general, density thresholds in weaving segments are somewhat higher than those for similar basic freeway segments (or multilane highways). It is believed that drivers will tolerate higher densities in an area where lane-changing turbulence is expected than on basic segments.

To apply density criteria, the average speed of all vehicles, computed in Step 7, must be converted to density by using Equation 12-22.

$$D = \frac{\left(\frac{v}{N}\right)_i}{S} \qquad \text{Equation 12-22}$$

where D is density in passenger cars per mile per lane and all other variables are as previously defined.

SPECIAL CASES

Multiple Weaving Segments

When a series of closely spaced merge and diverge areas creates overlapping weaving movements (between different merge–diverge pairs) that share the same segment of a roadway, a multiple weaving segment is created. In earlier editions of the HCM, a specific application of the weaving methodology for two-segment multiple weaving segments was included. While it was a logical extension of the methodology, it did not address cases in which three or more sets of weaving movements overlapped, nor was it well-supported by field data.

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Multiple weaving segments should be analyzed as separate merge, diverge, and simple weaving segments, as appropriate.

Multiple weaving segments should be segregated into separate merge, diverge, and simple weaving segments, with each segment appropriately analyzed by using this chapter's methodology or that of Chapter 13, Freeway Merge and Diverge Segments. Chapter 11, Basic Freeway Segments, contains information relative to the process of identifying appropriate segments for analysis.

C-D Roadways

The methodology applies approximately to C-D roadways, but its use may produce an overly negative view of operations.

A common design practice often results in weaving movements that occur on C-D roadways that are part of a freeway interchange. The methodology of this chapter may be approximately applied to such segments. The FFS used must be appropriate to the C-D roadway. It would have to be measured on an existing or similar C-D roadway, as the predictive methodology of FFS given in Chapter 12 does not apply to such roadways. It is less clear that the LOS criteria of Exhibit 12-20 are appropriate. Many C-D roadways operate at lower speeds and higher densities than on basic segments, and the criteria of Exhibit 12-20 may produce an inappropriately negative view of operations on a C-D roadway.

If the measured FFS of a C-D roadway is high (greater than or equal to 50 mi/h), the results of analysis can be expected to be reasonably accurate. At lower FFS values, results would be more approximate.

Multilane Highways

Multilane highway weaving segments may be analyzed with the methodology, except in the words of unsignalized intersections.

Weaving segments may occur on surface multilane highways. As long as such segments are a sufficient distance away from signalized intersections—so that platoon movements are not an issue—the methodology of this chapter may be approximately applied.

Arterial Weaving

No generally accepted analysis methodologies currently exist for arterial weaving movements.

The methodology of this chapter does not apply to weaving segments on arterials. Arterial weaving is strongly affected by the proximity and timing of signals along the arterial. At the present time, there are no generally accepted analytic methodologies for analyzing weaving movements on arterials.

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4. APPLICATIONS

The methodology of this chapter is most often used to estimate the capacity and LOS of freeway weaving segments. The steps are most easily applied in the operational analysis mode, that is, all traffic and roadway conditions are specified, and a solution for the capacity (and v/c ratio) is found along with an expected LOS. Other types of analysis, however, are possible.

DEFAULT VALUES

An NCHRP report (10) provides a comprehensive presentation of potential default values for uninterrupted-flow facilities. Default values for freeways are summarized in Chapter 10, Freeway Facilities. These defaults cover the key characteristics of PHF and percentage of heavy vehicles. Recommendations are based on geographical region, population, and time of day. A general freeway default value may be applied to the analysis of weaving segments in the absence of field data or projected conditions.

There are many specific variables related to weaving segments. It is, therefore, virtually impossible to specify default values of such characteristics as length, width, configuration, and balance of weaving and nonweaving flows. Weaving segments are a detail of the freeway design and should therefore be treated only with the specific characteristics of the segment known or projected. Small changes in some of these variables can and do yield significant changes in the analysis results.

TYPES OF ANALYSIS

The methodology of this chapter can be used in three types of analyses: operational, design, and planning and preliminary engineering.

Operational Analysis

The methodology of this chapter is most easily applied in the operational analysis mode. In this application, all weaving demands and geometric characteristics are known, and the output of the analysis is the expected LOS and the capacity of the segment. Secondary outputs include the average speed of component flows, the overall density in the segment, and measures of lane-changing activity.

Design Analysis

Design analysis is best accomplished by iterative operational analyses on a small number of candidate designs.

In design applications, the desired output is the length, width, and configuration of a weaving segment that will sustain a target LOS for given demand flows. This application is best accomplished by iterative operational analyses on a small number of candidate designs.

Generally, there is not a great deal of flexibility in establishing the length and width of a segment, and only limited flexibility in potential configurations. The location of intersecting facilities places logical limitations on the length of the weaving segment. The number of entry and exit lanes on ramps and the freeway itself limits the number of lanes to, at most, two choices. The entry and exit

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design of ramps and the freeway facility also produces a configuration that can generally only be altered by adding or subtracting a lane from an entry or exit roadway. Thus, iterative analyses of candidate designs are relatively easy to perform, particularly with the use of LOM replicating software.

Planning and Preliminary Engineering

Planning and preliminary engineering applications generally have the same desired outputs as design applications: the geometric design of a weaving segment that can sustain a target LOS for specified demand flows.

In the planning and preliminary design phase, however, demand flows are generally stated as average annual daily traffic (AADT) that must be converted to directional design hour volumes. A number of variables may be unknown (e.g., PHF and percentage of heavy vehicles); these may be replaced by default values.

Service Flow Rates, Service Volumes, and Daily Service Volumes

This manual defines three sets of values that are related to LOS boundary conditions.

SF_i = service flow rate for LOS i (veh/h),

SV_i = service volume for LOS i (veh/h), and

DSV_i = daily service volume for LOS i (veh/day).

The service flow rate is the maximum rate of flow (for a 15-min interval) that can be accommodated on a segment while maintaining all operational criteria for LOS i under prevailing roadway and traffic conditions. The service volume is the maximum hourly volume that can be accommodated on a segment while maintaining all operational criteria for LOS i during the worst 15 min of the hour under prevailing roadway and traffic conditions. The *daily service volume* is the maximum AADT that can be accommodated on a segment while maintaining all operational criteria for LOS i during the worst 15 min of the peak hour under prevailing roadway and traffic conditions. The service flow rate and service volume are undirectional values, while the daily service volume is a total two-way volume. In the context of a weaving section, the daily service volume is highly approximate, as it is rare that both directions of a freeway have a weaving segment with similar geometry.

In general, service flow rates are initially computed for ideal conditions and are then converted to prevailing conditions by using Equation 12-23 and the appropriate adjustment factors from Chapter 11, Basic Freeway Segments:

Equation 12-23

$$SF = SF_i \times f_{HV} \times f_p$$

where

SF_i = service flow rate under ideal conditions (pc/h),

f_{HV} = adjustment factor for heavy-vehicle presence (Chapter 11), and

f_p = adjustment factor for driver population (Chapter 11).

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The methodology of this chapter is used to determine the values of ideal service flow rate (SF_i) for the specific weaving segment under study. The capacity of the segment is equivalent to the ideal service flow rate for LOS E. For other levels of service, the total flow rates required to produce threshold densities (Exhibit 12-10) are found. This is an iterative procedure in which all other characteristics are held constant. Iterative analyses are conducted until the defining densities are produced.

Once the ideal service flow rates are determined, service flow rates under prevailing conditions are computed by using Equation 12-23. These can be converted to hourly service volumes SV by using Equation 12-24. Service volumes can then be converted to daily service volumes DSV by using Equation 12-25.

$$SV_i = SF_i \times PHF \quad \text{Equation 12-24}$$

$$DSV_i = \frac{SV_i}{K \times D} \quad \text{Equation 12-25}$$

where

K = proportion of AADT occurring during the peak hour, and

D = proportion of traffic in the peak direction.

All other variables are as previously defined.

Example Problem 5 illustrates the computation of service flow rates, service volumes, and daily service volumes for a specific weaving segment.

USE OF ALTERNATIVE TOOLS

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools. This section contains specific guidance for the application of alternative tools to the analysis of freeway weaving segments. Additional information on this topic, including supplemental example problems, may be found in Chapter 27, Freeway Weaving, Supplemental, located in Volume 4.

Strengths of the HCM Procedure

The procedures in this chapter were developed from extensive research supported by a significant quantity of field data. They have evolved over a number of years and represent a body of expert consensus. Most alternative tools will not include the level of detail present in this methodology concerning the weaving configuration and balance of weaving demand flows.

Specific strengths of the HCM procedure include:

- Providing capacity estimates for specific weaving configurations as a function of various input parameters, which current simulators do not provide directly (and in some cases may require as an input);
- Considering geometric characteristics (such as lane widths) in more detail than most simulation algorithms;

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- Producing a single deterministic estimate of LOS, which is important for some purposes, such as development impact reviews, and
- Generating repeatable results with a small commitment of resources (including calibration) from a precisely documented methodology.

Limitations of the HCM Procedures That Might Be Addressed by Alternative Tools

Weaving segments can be analyzed by using a variety of stochastic and deterministic simulation tools that address freeways. These tools can be very useful in analyzing the extent of congestion when there are features within the simulated facility range and when interaction with other freeway segments and other facilities is present.

The limitations stated earlier in this chapter may be addressed by using available simulation tools. The following conditions, which are beyond the scope of this chapter, are treated explicitly by simulation tools:

- *Managed lanes within the weaving segment.* These lanes are typically modeled explicitly by simulation; for example, when one or more weaving movements are segregated by using pavement markings, signage, physical longitudinal barriers, or some combination of these.
- *Ramp metering on entrance ramps to/within part of the weaving segment.* These features are also modeled explicitly by many tools.
- *Specific operating conditions other than the analyzed conditions exist.* In this case, it is necessary to ensure that both the spatial and the temporal boundaries of the analysis extend beyond the congested operation.
- *Effects of Advanced Transportation System Initiatives on weaving segment operations.* Some intelligent transportation system features such as dynamic message signs are offered by a few simulation tools. Some features are modeled explicitly by simulation; others may be approximated by using assumptions (e.g., by modifying origin–destination demands by time interval).
- *Multiple weaving segments.* Multiple weaving segments were removed from this edition of the manual. They may be addressed to some extent by the procedures given in Chapter 10 for freeway facilities. Complex combinations of weaving segments may be analyzed more effectively by simulation tools, although such analyses might require extensive calibration of origin–destination characteristics.

Because of the interactions between adjacent freeway segments, alternative tools will find their principal application to freeways containing weaving segments at the facility level and not to isolated freeway weaving segments.

Additional Features and Performance Measures Available from Alternative Tools

This chapter provides a methodology for estimating the speed and density in a weaving segment given traffic demands from both the weaving and the nonweaving movements. Capacity estimates and maximum weaving lengths are

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also produced. Alternative tools offer additional performance measures including delay, stops, queue lengths, fuel consumption, pollution, and operating costs.

In addition to offering more performance measures, alternative tools can identify specific point problems that could be overlooked in a segment-level analysis.

As with most other procedural chapters in this manual, simulation outputs, especially graphics-based presentations, can provide details on point problems that might otherwise go unnoticed with a macroscopic analysis that yields only segment-level measures. The effect of queuing caused by capacity constraints on the exit ramp of a weaving segment, including difficulty in making the required lane changes, is a good example of a situation that can benefit from the increased insight offered by a microscopic model. An example of the effect of exit ramp queue backup is presented in Chapter 27, Freeway Weaving Supplemental.

Development of HCM-Compatible Performance Measures Using Alternative Tools

When using alternative tools, the analyst must be careful to note the definitions of simulation outputs. The principal measures involved in the performance analysis of weaving segments are speed and delay. These terms are generally defined in the same manner for alternative tools; however, there are subtle differences among tools that often make it difficult to apply HCM criteria directly to the outputs of other tools. Performance measure comparisons are discussed in more detail in Chapter 7, Interpreting HCM and Alternative Tool Results.

Conceptual Differences Between the HCM and Simulation Modeling That Preclude Direct Comparison of Results

Conceptual differences between the HCM and stochastic simulation models make direct comparison difficult for weaving segments. The HCM uses a set of deterministic equations developed and calibrated with field data. Simulation models treat each vehicle as a separate object to be propagated through the system. The physical and behavioral characteristics of drivers and vehicles in the HCM are represented in deterministic equations that compute passenger car equivalences, lane changing rates, maximum weaving lengths, capacity, speed, and density. Simulation models apply the characteristics to each driver and vehicle, and these characteristics produce interactions between vehicles, the sum total of which determines the performance measures for a weaving segment.

Direct comparison of the numerical outputs from the HCM and alternative tools can be misleading.

One good example of the difference between microscopic and macroscopic modeling is how trucks are entered into the models. The HCM uses a conversion factor that increases the demand volumes to reflect the proportion of trucks. Simulation models deal with trucks explicitly by assigning more sluggish characteristics to each of them. The result is that HCM capacities, density, and so forth are expressed in equivalent passenger car units, whereas the corresponding simulation values are represented by actual vehicles.

The HCM methodology estimates the speeds of weaving and nonweaving traffic streams, and on the basis of these estimates it determines the density within the weaving segment. Simulators that provide outputs on a link-by-link basis do not differentiate between weaving and nonweaving movements within

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a given line; thus, comparing these (intermediate) results to other tools would be somewhat difficult.

For a given set of inputs, simulation tools should produce answers that are similar to each other and to the HCM. Although most differences should be recognizable through calibration and identification of point problems within a segment, precise numerical agreement is not generally a reasonable expectation.

Sample Calculations Illustrating Alternative Tool Applications

Supplemental computational examples illustrating the use of alternative tools are included in Chapter 27 of Volume 4.

Chapter 27, Freeway Weaving Supplemental, contains three examples that illustrate the application of alternative tools to freeway weaving segments. All of the problems are based on Example Problem 3 presented later in this chapter. Three questions are addressed by using a typical simulation tool:

1. Can the weaving segment capacity be estimated realistically by simulation by varying the demand volumes up to and beyond capacity?
2. How does the demand affect the performance in terms of speed and density in the weaving segment when the default model parameters are used for vehicle and behavioral characteristics?
3. How would the queue backup from a signal at the end of the off-ramp affect the weaving operation?

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5. EXAMPLE PROBLEMS

Exhibit 12-11
List of Example Problems

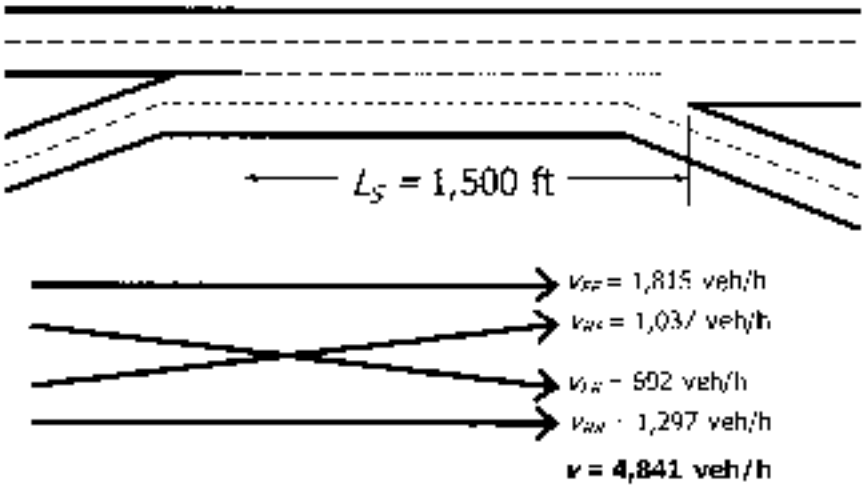
Example Problem	Description	Application
1	LOS of a major weaving segment	Operational Analysis
2	LOS of a ramp-weaving segment	Operational Analysis
3	LOS of a two-sided weaving segment	Operational Analysis
4	Design of a major weaving segment for a desired LOS	Design
5	Service volume table construction	Service Volumes

EXAMPLE PROBLEM 1: LOS OF A MAJOR WEAVING SEGMENT

The Weaving Segment

The subject of this operational analysis is a major weaving segment on an urban freeway, as shown in Exhibit 12-12.

Exhibit 12-12
Major Weaving Segment for Example Problem 1



What is the LOS and capacity of the weaving segment shown in Exhibit 12-12?

The Facts

In addition to the information contained in Exhibit 12-12, the following characteristics of the weaving segment are known:

PHF = 0.91 (for all movements),

Heavy vehicles = 10% trucks, 0% recreational vehicles (RV's) (all movements),

Driver population = regular commuters,

FFS = 65 mi/h,

c_{pl} = 2,350 pc/h/ln (for FFS = 65 mi/h),

f_N = 0.8 ln/mi; and

Terrain = level.

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Comments

Chapter 10, Basic Freeway Segments, must be consulted to find appropriate values for the heavy-vehicle adjustment factor f_{HV} and the driver population adjustment factor f_p.

All input parameters have been specified, so default values are not needed. Demand volumes are given in vehicles per hour under prevailing conditions. These must be converted to passenger cars per hour under equivalent ideal conditions for use in equations of the methodology. The length of the segment must be compared with the maximum length for weaving analysis to determine whether the methodology of this chapter is applicable. The capacity of the weaving segment is estimated and compared with the total demand flow to determine whether LOS F exists. Lane-changing rates are estimated to allow speed estimates to be made for weaving and nonweaving flows. An average overall speed and density are computed and compared with the criteria of Exhibit 12-10 to determine LOS.

Step 1: Input Data

All inputs have been specified in Exhibit 12-12 and the Facts section of the problem statement.

Step 2: Adjust Volume

Equation 12-1 is used to convert the four component demand volumes to flow rates under equivalent ideal conditions. Chapter 11 is consulted to obtain a value of E_T (1.5 for level terrain) and f_p (1.00 for regular commuters). The heavy-vehicle adjustment factor is computed as

$$f_{HV} = \frac{1}{1 - P_T(E_T - 1) - P_R(E_R - 1)} = \frac{1}{1 + 0.10(1.5 - 1)} = 0.952$$

Equation 12-1 is now used to convert all demand volumes:

$$v = \frac{V}{PHF \times f_{HV} \times f_p}$$

$$v_{FF} = \frac{1,815}{0.91 \times 0.952 \times 1} = 2,094 \text{ pc/h}$$

$$v_{FR} = \frac{692}{0.91 \times 0.952 \times 1} = 798 \text{ pc/h}$$

$$v_{RF} = \frac{1,037}{0.91 \times 0.952 \times 1} = 1,197 \text{ pc/h}$$

$$v_{RR} = \frac{1,297}{0.91 \times 0.952 \times 1} = 1,497 \text{ pc/h}$$

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Then

$$v_{ff} = 798 + 1{,}197 = 1{,}995 \text{ pc/h}$$

$$v_{nw} = 2{,}094 + 1{,}497 = 3{,}591 \text{ pc/h}$$

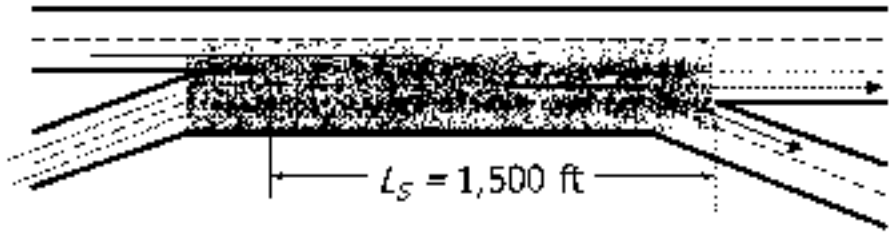
$$v = 1{,}995 + 3{,}591 = 5{,}586 \text{ pc/h}$$

$$VR = \frac{1{,}995}{5{,}586} = 0.357$$

Step 3: Determine Configuration Characteristics

The configuration is examined to determine the values of LC_{ff}, LC_{fr}, and N_{wl}. These determinations are illustrated in Exhibit 12-13. From these values, the minimum number of lane changes by weaving vehicles, LC_{all}, is then computed by using Equation 12-2.

Exhibit 12-13
Determination of Configuration Variables for Example Problem 1



From Exhibit 12-13, it can be seen that ramp-to-freeway vehicles can execute their weaving maneuver without making a lane change (if they so desire). Thus, $LC_{fr} = 0$. Freeway to ramp vehicles must make at least one lane change to complete their desired maneuver. Thus, $LC_{ff} = 1$. If optional lane changes are considered, weaving movements can be accomplished with one or no lane changes from both entering ramp lanes and from the rightmost freeway lane. Thus, $N_{wl} = 3$. Equation 12-2 can now be employed

$$LC_{all} = (LC_{ff} \times v_{ff}) + (LC_{fr} \times v_{fr}) = (0 \times 1197) + (1 \times 798) = 798 \text{ veh/h}$$

Step 4: Determine Maximum Weaving Length

The maximum length over which weaving movements may exist is determined by Equation 12-4. The determination is case specific, and the result is valid only for the case under consideration.

$$L_{max} = [5728(1 + VR)^{1.6}] - [1566 N_{wl}]$$

$$L_{max} = [5728(1 + 0.357)^{1.6}] - [1566 \times 3] = 4{,}639 \text{ ft}$$

As the maximum length is significantly greater than the actual segment length of 1,500 ft, weaving operations do exist, and the analysis may continue with the weaving analysis methodology.

Step 5: Determine Weaving Segment Capacity

Capacity may be controlled by one of two factors: operations reaching a maximum density of 43 pc/mi/ln or by the weaving demand flow rate reaching

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3,500 pc/h (for a weaving segment with $N_{wl} = 3$). Equation 12-5 through Equation 12-8 are used to make these determinations.

Capacity Controlled by Density

$$c_{wd} = c_{iq}\left[438.2(1+VR)^{1.3}\right] + \left[0.0765L_s\right] + \left[119.8N_{wl}\right]$$

$$c_{wd} = 2{,}350 - \left[438.2(1+0.357)^{1.3}\right] + \left[0.0765 \times 1{,}500\right] + \left[119.8 \times 3\right]$$

$$c_{wd} = 2{,}110 \text{ pc/h/ln}$$

$$c_w = c_{wd} N f_{HV} f_p = 2{,}110 \times 4 \times 0.952 \times 1 = 8{,}038 \text{ veh/h}$$

Capacity Controlled by Maximum Weaving Flow Rate

$$c_{ww} = \frac{3{,}500}{VR} = \frac{3{,}500}{0.357} = 9{,}800 \text{ pc/h}$$

$$c_w = c_{ww} f_{HV} f_p = 9{,}800 \times 0.952 \times 1 = 9{,}333 \text{ veh/h}$$

Note that the methodology computes the capacity controlled by density in passenger cars per hour per lane, while the capacity controlled by maximum weaving flow rate is computed in passenger cars per hour. After conversion, however, both are in units of vehicles per hour.

The controlling value is the smaller of these, or 8,038 veh/h. As the total demand flow rate is only 5,330 veh/h, the capacity is clearly sufficient, and the situation will not result in LOS F.

Step 6: Determine Lane-Changing Rates

Equation 12-10 through Equation 12-15 are used to estimate the lane-changing rates of weaving and nonweaving vehicles in the weaving segment. In turn, these will be used to estimate weaving and nonweaving vehicle speeds.

Weaving Vehicle Lane-Changing Rate

$$LC_w = LC_{w0} + 0.39\left[(1.\ - 300)^{.25}(N^2)(1+ID)^{.75}\right]$$

$$LC_w = 798 + 0.39\left[(1{,}500 - 300)^{.25}(4^2)(1+0.8)^{.75}\right] = 1{,}144 \text{ lc/h}$$

Nonweaving Vehicle Lane-Changing Rate

$$I_{nw} = \frac{L_s ID v_{nw}}{10{,}000} = \frac{1{,}500 \times 0.8 \times 3{,}591}{10{,}000} = 431 < 1{,}300$$

$$LC_{nw} = (0.206 v_{nw}) + (0.542 L_s) - (192.6N)$$

$$LC_{nw} = (0.206 \times 3{,}591) + (0.542 \times 1{,}500) - (192.6 \times 4) = 782 \text{ lc/h}$$

Total Lane-Changing Rate

$$LC_{all} = LC_w + LC_{nw} = 1{,}144 + 782 = 1{,}926 \text{ lc/h}$$

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Step 7: Determine Average Speeds of Weaving and Nonweaving Vehicles

The average speeds of weaving and nonweaving vehicles are computed from Equation 12-28 through Equation 12-30:

$$W = 0.226\left(\frac{LC_{RL}}{t_S}\right)^{0.789} = 0.226\left(\frac{1,926}{1,500}\right)^{0.789} = 0.275$$

Then

$$S_W = 15 - \left(\frac{FFS - 15}{1 + W}\right) = 15 + \left(\frac{65 - 15}{1 + 0.275}\right) = 54.2 \text{ mi/h}$$

and

$$S_{NW} = FFS - (0.0072 LC_{NW}) - \left(0.0048 \frac{v}{N}\right)$$

$$S_{NW} = 65 - (0.0072 \times 798) - \left(0.0048 \times \frac{5,586}{4}\right) = 52.5 \text{ mi/h}$$

Equation 12-31 is now used to compute the average speed of all vehicles in the segment:

$$S = \frac{v_{NW} + v_W}{\left(\frac{v_{NW}}{S_{NW}}\right) + \left(\frac{v_W}{S_W}\right)} = \frac{3,591 + 1,995}{\left(\frac{3,591}{52.5}\right) + \left(\frac{1,995}{54.2}\right)} = 53.1 \text{ mi/h}$$

Step 8: Determine LOS

Equation 12-32 is used to convert the average speed of all vehicles in the segment to an average density:

$$D = \frac{\left(\frac{v}{N}\right)}{S} = \frac{\left(\frac{5,586}{4}\right)}{53.1} = 26.3 \text{ pc/mi/ln}$$

The resulting density of 26.3 pc/mi/ln is compared with the LOS criteria in Exhibit 12-10. The LOS is C, as the density is within the specified range of 20 to 28 pc/h/ln for that level.

Discussion

As indicated by the results, this weaving segment operates at LOS C, with an average speed of 53.1 mi/h for all vehicles. Weaving vehicles travel a bit faster than nonweaving vehicles, primarily because the configuration favors weaving vehicles, allowing as any weaving maneuvers to be made without making a lane change. The demand flow rate of 4,861 veh/h is considerably less than the capacity of the segment, 8,038 veh/h. In other words, demand can grow significantly before reaching the capacity of the segment.

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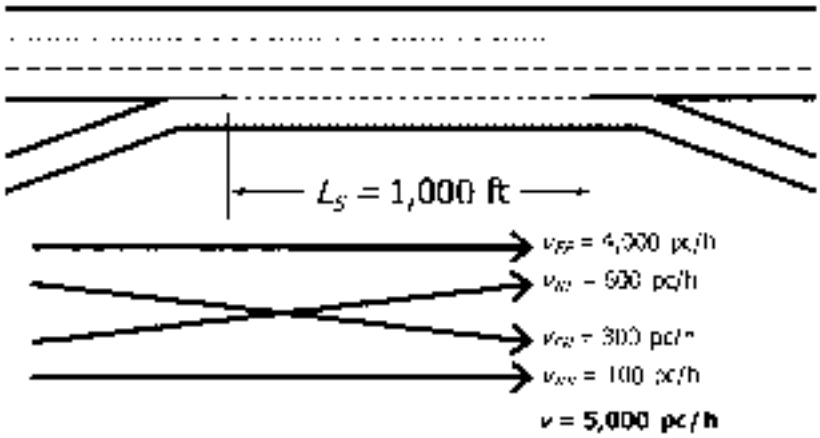
EXAMPLE PROBLEM 2: LOS OF A RAMP-WEAVING SEGMENT

The Weaving Segment

The weaving segment that is the subject of this operational analysis is shown in Exhibit 12-14. It is a typical ramp weave segment.

Exhibit 12-14
Ramp-Weave Segment for Example Problem 2



What is the capacity of the weaving segment of Exhibit 12-14, and at what LOS is it expected to operate with the demand flow rates as shown?

The Facts

In addition to the information given in Exhibit 12-14, the following facts are known about the subject weaving segment:

PHF = 1.00 (demands stated as flow rates);
Heavy vehicles = 6% trucks, 0% RVs (demands given as passenger car equivalents);
Driver population = regular commuters;
FFS = 55 mi/h;
c_{pi} = 2,400 pc/h/ln (for FFS = 75 mi/h);
N = 3 ln/dir; and
Terrain = level.

Comments

Because the demands have been specified as flow rates in passenger cars per hour under equivalent ideal conditions, Chapter 12 does not have to be consulted to obtain appropriate adjustment factors.

Several of the computational steps related to converting demand volumes to flow rates under equivalent ideal conditions are trivial, as demands are already specified in that form. Lane changing, the key issue, will be estimated. The maximum length for weaving operations in this case will be estimated and compared with the actual length of the segment. The capacity of the segment will be estimated and compared with the demand to determine whether LOS F exists. If it does not, exponent flow speeds will be estimated and averaged. A density

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will be estimated and compared with the criteria of Exhibit 12-10 to determine the expected LOS.

Step 1: Input Data

All input data are stated in Exhibit 12-14 and the Facts section.

Step 2: Adjust Volume

Because all demands are stated as flow rates in passenger cars per hour under equivalent ideal conditions, no further conversions are necessary. Key volume parameters are as follows:

$$v_{FF} = 4{,}000 \text{ pc/h}$$

$$v_{FR} = 600 \text{ pc/h}$$

$$v_{RF} = 300 \text{ pc/h}$$

$$v_{RR} = 100 \text{ pc/h}$$

$$v_{12} = 600 - 300 = 900 \text{ pc/h}$$

$$v_{34} = 4{,}000 - 100 = 3{,}900 \text{ pc/h}$$

$$v = 4{,}100 + 900 = 5{,}000 \text{ pc/h}$$

$$VR = \frac{900}{5{,}000} = 0.180$$

Step 3: Determine Configuration Characteristics

The configuration is examined to determine the values of LC_{RF}, LC_{FR}, and N_{WL}. These determinations are illustrated in Exhibit 12-15. From these values, the minimum number of lane changes by weaving vehicles (LC_{MIN}) is then computed by using Equation 12-2.

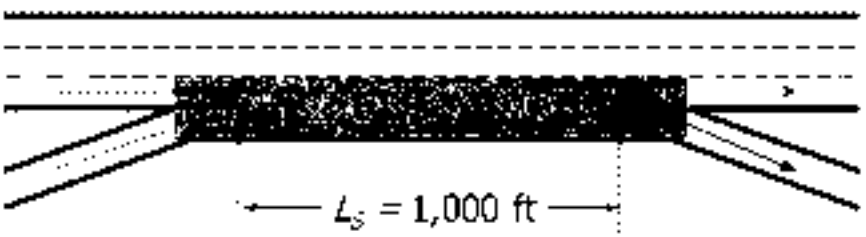

Exhibit 12-15
Configuration Characteristics for Example Problem 2

From Exhibit 12-15, it is clear that all ramp-to-freeway vehicles must make at least one lane change ($LC_{RF} = 1$), and all freeway-to-ramp vehicles must make at least one lane change ($LC_{FR} = 1$). It is also clear that a weaving maneuver can only be completed with a single lane change from the right lane of the freeway or the auxiliary lane ($N_{WL} = 2$). Then, by using Equation 12-2, LC_{MIN} is computed as

$$LC_{MIN} = (LC_{RF} \times v_{RF}) + (LC_{FR} \times v_{FR})$$

$$LC_{MIN} = (1 \times 600) + (1 \times 300) = 900 \text{ lc/h}$$

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Step 4: Determine Maximum Weaving Length

The maximum length over which weaving operations may exist for the segment described is found by using Equation 12-4.

$$L_{MAX} = [5{,}728(1 - VR)^{1.6}] - [1{,}566 N_{WL}]$$

$$L_{MAX} = [5{,}728(1 - 0.180)^{1.6}] - [1{,}566 \times 2] = 4{,}333 \text{ ft} > 1{,}000 \text{ ft}$$

As the maximum length for weaving operations significantly exceeds the actual length, this is a weaving segment, and the analysis continues.

Step 5: Determine Weaving Segment Capacity

The capacity of the weaving segment is controlled by one of two limiting factors: density reaches 43 pc/mi/ln or weaving demand reaches 2,400 pc/h for the configuration of Exhibit 12-15.

Capacity Limited by Density

The capacity limited by reaching a density of 43 pc/mi/ln is estimated by using Equation 12-5 and Equation 12-6.

$$c_{WL} = c_{IO} - [438.2(1 + VR)^{1.6}] + [0.0765 L_C] + [119.8 N_{WL}]$$

$$c_{WL} = 2{,}400 - [438.2(1 + 0.180)^{1.6}] + [0.0765 \times 1{,}000] + [119.8 \times 2]$$

$$c_{WL} = 2{,}145 \text{ pc/h/ln}$$

$$c_w = c_{wL} \times N \times f_{HV} \times f_p = 2{,}145 \times 4 \times 1 \times 1 = 8{,}581 \text{ pc/h}$$

Capacity Limited by Weaving Demand Flow

The capacity limited by the weaving demand flow is estimated by using Equation 12-7 and Equation 12-8.

$$c_{IO} = \frac{2{,}400}{VR} = \frac{2{,}400}{0.180} = 13{,}333 \text{ pc/h}$$

$$c_w = c_{IW} \times f_{HV} \times f_p = 13{,}333 \times 1 \times 1 = 13{,}333 \text{ pc/h}$$

The controlling capacity is the smaller value, or 8,581 pc/h. At this point, the value is usually stated as vehicles per hour. In this case, because inputs were already adjusted and were stated in passenger cars per hour, conversions back to vehicles per hour are not possible.

As the capacity is larger than the demand flow rate of 5,000 pc/h, LOS F does not exist, and the analysis continues.

Step 6: Determine Lane-Changing Rates

Equation 12-10 through Equation 12-15 are used to estimate the lane-changing rates of weaving and nonweaving vehicles in the weaving segment. In turn, these will be used to estimate weaving and nonweaving vehicle speeds.

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Weaving Vehicle Lane-Changing Rate

$$LC_w = LC_{w0} + 0.39\left[(L_s - 300)^{0.6}(N^{1.2})(1 + ID)^{0.5}\right]$$

$$LC_w = 900 + 0.39\left[(1{,}000 - 300)^{0.6}(4^{1.2})(1 + 1)^{0.5}\right] = 1{,}187 \text{ veh/h}$$

Nonweaving Vehicle Lane-Changing Rate

$$v_{nw} = \frac{(v_{12})(v_{w1})}{10{,}000} = \frac{1{,}000 \times 4{,}100}{10{,}000} = 410 < 1{,}300$$

$$LC_{nw} = (0.206 v_{w1}) + (0.542 L_s) - (192.6 N)$$

$$LC_{nw} = (0.206 \times 4{,}100) + (0.542 \times 1{,}000) - (192.6 \times 4) = 616 \text{ veh/h}$$

Total Lane-Changing Rate

$$LC_{all} = LC_w + LC_{nw} = 1{,}187 + 616 = 1{,}803 \text{ veh/h}$$

Step 7: Determine Average Speeds of Weaving and Nonweaving Vehicles

The average speeds of weaving and nonweaving vehicles are computed from Equation 12-18 through Equation 12-20:

$$W = 0.226\left(\frac{LC_{all}}{L_s}\right)^{0.789} + 0.226\left(\frac{1{,}803}{1{,}000}\right)^{0.789} = 0.360$$

Then

$$S_w = 15 + \frac{(FFS - 15)}{(1 + W)} = 15 + \left[\frac{(75 - 15)}{(1 + 0.360)}\right] = 59.1 \text{ mi/h}$$

and

$$S_{nw} = FFS - (0.0072 LC_{nw}) - \left(0.0048 \frac{v}{N}\right)$$

$$S_{nw} = 75 - (0.0072 \times 900) - \left(0.0048 \times \frac{5{,}000}{4}\right) = 62.5 \text{ mi/h}$$

Equation 12-21 is now used to compute the average speed of all vehicles in the segment:

$$S = \frac{v_{nw} + v_w}{\left(\frac{v_{nw}}{S_{nw}}\right) + \left(\frac{v_w}{S_w}\right)} = \frac{4{,}100 + 900}{\left(\frac{4{,}100}{62.5}\right) + \left(\frac{900}{59.1}\right)} = 61.9 \text{ mi/h}$$

Step 8: Determine LOS

The average density in the weaving segment is estimated by using Equation 12-22:

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$$D = \frac{\left(\frac{v}{N}\right)}{S} = \frac{\left(\frac{5{,}810}{4}\right)}{61.9} = 20.2 \text{ pc/mi/ln}$$

From Exhibit 12-10, this density is within the stated boundaries of LOS C (20 to 28 pc/mi/ln). It is, however, very close to the LOS B boundary condition.

Discussion

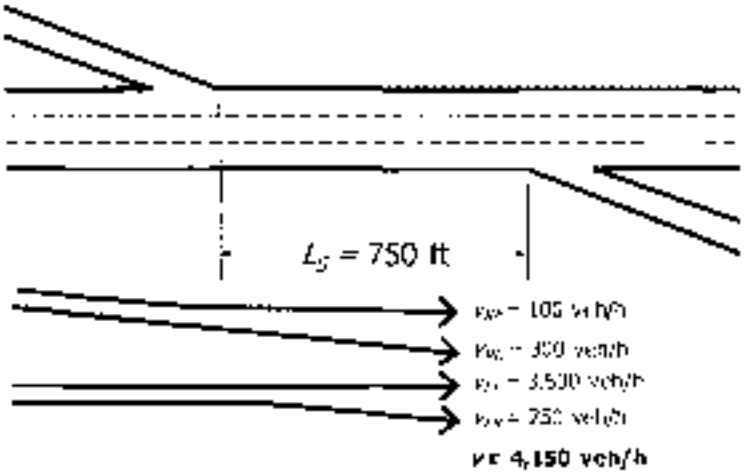
As noted, the segment is operating quite well (LOS C) and is very close to the LOS B boundary. Weaving and nonweaving speeds are relatively high, suggesting a stable flow. The demand flow rate of 5,000 pc/h is well below the capacity of the segment (8,590 pc/h). Weaving vehicles travel somewhat more slowly than nonweaving vehicles, which is typical of ramp-weave segments, where the vast majority of nonweaving vehicles are running from freeway to freeway.

EXAMPLE PROBLEM 3: LOS OF A TWO-SIDED WEAVING SEGMENT

The Weaving Segment

The weaving segment that is the subject of this example problem is shown in Exhibit 12-16.

Exhibit 12-16
Weaving Segment for Example Problem 3



What is the expected LOS and capacity for the weaving segment of Exhibit 12-16?

The Facts

In addition to the information contained in Exhibit 12-16, the following facts concerning the weaving segment are known.

PHF = 0.94 (all movements);
Heavy vehicles = 15% trucks, 0% RVs (all movements);
Driver population = regular commuters;
FFS = 60 mi/h;

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c_{fo} = 2,300 pc/h/ln (for FFS = 70 mi/h);

f_N = 2 ln/mi; and

Terrain = rolling.

Comments

Because this example illustrates the analysis of a two-sided weaving segment, several key parameters are redefined.

In a two-sided weaving segment, only the ramp-to-ramp flow is considered to be a weaving flow. While the freeway-to-freeway flow technically weaves with the ramp-to-ramp flow, the operation of freeway-to-freeway vehicles more closely resembles that of nonweaving vehicles. These vehicles generally make very few lane changes as they move through the segment in a freeway lane. The segment is in a busy urban corridor with a high interchange density and a relatively low FFS for the freeway.

Solution steps are the same as in the first two example problems. However, since the segment is a two-sided weaving segment, some of the key values will be computed differently as described in the methodology.

Component demand volumes will be converted to equivalent flow rates in passenger cars per hour under ideal conditions, and key demand parameters will be calculated. A maximum weaving length will be estimated to determine whether a weaving analysis is appropriate. The capacity of the weaving segment will be estimated to determine whether LOS F exists. If not, lane-changing parameters, speeds, density, and LOS will be estimated.

Step 1: Input Data

All information concerning this example problem is given in Exhibit 12-16 and the input section.

Step 2: Adjust Volume

To convert demand volumes to flow rates under equivalent ideal conditions, Chapter 11 must be consulted to obtain the following values:

P_T = 2.5 (for rolling terrain)

f_p = 1.0 (for regular commuters)

Then

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} = \frac{1}{1 + 0.15(2.5 - 1)} = 0.816$$

Component demand volumes may now be converted to flow rates under equivalent ideal conditions:

$$v_{FI} = \frac{3,500}{0.94 \times 0.816 \times 1} = 4,561 \text{ pc/h}$$

$$v_{IR} = \frac{250}{0.94 \times 0.816 \times 1} = 326 \text{ pc/h}$$

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$$v_{1,2} = \frac{100}{0.94 \times 0.816 \times 1} = 130 \text{ pc/h}$$

$$v_{1,3} = \frac{300}{0.94 \times 0.816 \times 1} = 391 \text{ pc/h}$$

Because this is a two-sided weaving segment, the only weaving flow is the ramp-to-ramp flow. All other flows are treated as nonweaving. Then

v_{nw} = 391 pc/h

v_{ww} = 4,561 + 521 + 130 = 5,017 pc/h

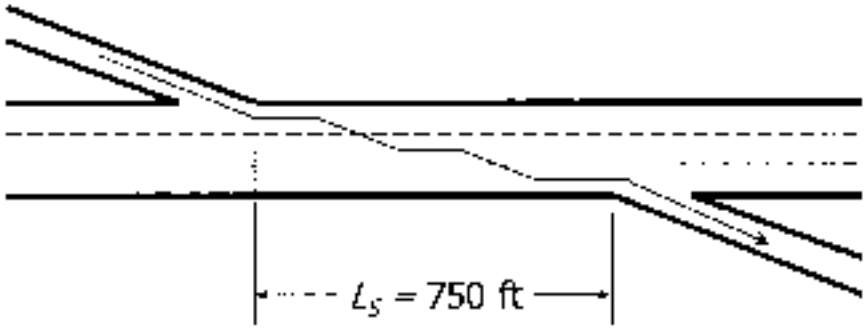
v = 5,017 + 391 = 5,408 pc/h

VR = 391/5,408 = 0.072

Step 3: Determine Configuration Characteristics

The determination of configuration characteristics is also affected by the existence of a two-sided weaving segment. Exhibit 12-17 illustrates the determination of LC_{RR}, the key variable for two-sided weaving segments. For such segments, $N_{WL} = 0$ by definition.

Exhibit 12-17
Configuration Characteristics for Example Problem 3



From Exhibit 12-17, ramp-to-ramp vehicles must make two lane changes to complete their desired weaving maneuver. Then

$$LC_{MIN} = LC_{RR} \times v_{RR} = 2 \times 391 = 782 \text{ lc/h}$$

Step 4: Determine Maximum Weaving Length

The maximum length of a weaving segment for this configuration and demand scenario is estimated by using Equation 12-4:

$$L_{MAX} = [5{,}728(1 + VR)^{1.6}] - [1{,}566 N_{WL}]$$

$$L_{MAX} = [5{,}728(1 + 0.072)^{1.6}] - [1{,}566 * 0] = 6{,}405 \text{ ft} > 750 \text{ ft}$$

In this two-sided configuration, the impacts of weaving on operations could be felt at lengths as long as 6,405 ft. As this is significantly greater than the actual length of 750 ft, this segment clearly operates as a weaving segment and, therefore, the methodology of this chapter should be applied.

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Step 5: Determine Weaving Segment Capacity

The capacity of a two-sided weaving segment can only be estimated when a density of 43 pc/h/ln is reached. This estimation is made by using Equation 12-5 and Equation 12-6:

$$c_{wl} = c_{ll} - \left[438.2(1 + VR)^{1.6}\right] - \left[0.0765 L_c\right] + \left[119.8 N_{wl}\right]$$

$$c_{wl} = 2{,}300 - \left[438.2(1 + 0.072)^{1.6}\right] + \left[0.0765 \times 750\right] + \left[119.8 \times 0\right]$$

$$c_{wl} = 1{,}867 \text{ pc/h/ln}$$

$$c_w = c_{wl} \times N \times f_{HV} \times f_p = 1{,}867 \times 3 \times 0.816 \times 1 = 4{,}573 \text{ veh/h} > 4{,}150 \text{ veh/h}$$

Because the capacity of the segment exceeds the demand volume (in vehicles per hour), LOS F is not expected, and the analysis may be continued.

Step 6: Determine Lane-Changing Rates

Equation 12-10 through Equation 12-15 are used to estimate the lane-changing rates of weaving and nonweaving vehicles in the weaving segment. In turn, these will be used to estimate weaving and nonweaving vehicle speeds.

Weaving Vehicle Lane-Changing Rate

$$LC_w = LC_{w0} - 0.39\left[(L_c - 300)^{0.4}(N_w)(1 - ID)^{0.8}\right]$$

$$LC_w = 782 - 0.39\left[(750 - 300)^{0.4}3^1(1 + 2)^{0.8}\right] = 961 \text{ lc/h}$$

Nonweaving Vehicle Lane-Changing Rate

$$L_{NW} = \frac{L_c ID v_{NW}}{10{,}000} = \frac{750 \times 2 \times 5{,}017}{10{,}000} = 753 < 1{,}300$$

$$LC_{NW} = (0.206 v_{w,w}) + (0.542 L_c) - (192.6 N)$$

$$LC_{NW} = (0.206 \times 5{,}017) + (0.542 \times 750) - (192.6 \times 3) = 862 \text{ lc/h}$$

Total Lane Changing Rate

$$LC_{all} = LC_w + LC_{NW} = 961 + 862 = 1{,}823 \text{ lc/h}$$

Step 7: Determine Average Speeds of Weaving and Nonweaving Vehicles

The average speeds of weaving and nonweaving vehicles are computed from Equation 12-18 through Equation 12-20:

$$W = 0.226\left(\frac{LC_{all}}{L_c}\right)^{0.789} - 0.226\left(\frac{1{,}823}{750}\right)^{0.789} + 0.456$$

Then

$$S_w = 15 + \left(\frac{FFS - 15}{1 + W}\right) = 15 + \left(\frac{60 - 15}{1 + 0.456}\right) = 45.9 \text{ mi/h}$$

and

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$$S_{ww} = FFS - (0.00726 v_{nonLC}) - \left(0.0048 \frac{v_{LC}}{N}\right)$$

$$S_{ww} = 75 - (0.00726 \times 782) - \left(0.0048 \times \frac{5{,}408}{3}\right) = 45.7 \text{ mi/h}$$

Equation 12-21 is now used to compute the average speed of all vehicles in the segment:

$$S = \frac{v_{nonLC} + v_{LC}}{\left(\frac{v_{nonLC}}{S_{nonLC}}\right) + \left(\frac{v_{LC}}{S_{LC}}\right)} = \frac{5{,}017 + 391}{\left(\frac{5{,}017}{45.7}\right) + \left(\frac{391}{45.9}\right)} = 45.7 \text{ mi/h}$$

Step 8: Determine LOS

The average density in this two-sided weaving segment is estimated by using Equation 12-22:

$$D = \frac{\left(\frac{v}{N}\right)}{S} = \frac{\left(\frac{5{,}408}{3}\right)}{45.7} = 39.4 \text{ pc/mi/ln}$$

From Exhibit 12-16, this density is clearly in LOS E. It is not far from the 43 pc/mi/ln that would likely cause a breakdown.

Discussion

This two-sided weaving segment operates at LOS E, not far from the LOS E/F boundary. The v/c ratio is 4,150/4,575 = 0.91. The major problem is that 948 veh/h crossing the freeway from ramp to ramp creates a great deal of turbulence in the traffic stream and limits capacity. Two-sided weaving segments do not operate well with such large numbers of ramp-to-ramp vehicles. If this were a basic freeway segment, the per lane flow rate of 5,408/3 = 1,803 pc/h/ln would not be considered excessive and would be well within a basic freeway segment's capacity of 2,300 pc/h/ln.

EXAMPLE PROBLEM 4: DESIGN OF A MAJOR WEAVING SEGMENT FOR A DESIRED LOS

The Weaving Segment

A weaving segment is to be designed between two major junctions at which two urban freeways join and then separate as shown in Exhibit 12-18. Entry and exit legs have the numbers of lanes shown. The maximum length of the weaving segment is 1,000 ft, based on the location of the junctions. The FFS of all entry and exit legs is 75 mi/h. All demands are shown as flow rates under equivalent ideal conditions.

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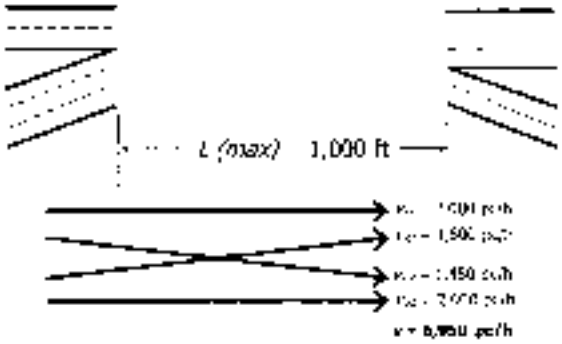

Exhibit 12-18
Weaving Segment for Example Problem 4

What design would be appropriate to deliver LOS C for the demand flow rates shown?

The Facts

In addition to the information contained in Exhibit 12-18, the following facts are known concerning this weaving segment:

PHF = 1.00 (all demands stated as flow rates);
Heavy vehicles = 0% trucks, 0% RVs (all demands in pc/h);
Driver population = regular commuters;
FFS = 75 mi/h;
c_{IL} = 2,400 pc/h/ln (for FFS = 75 mi/h);
f(N) = 1 interchange;
Terrain = level.

Comments

As is the case in any weaving segment design, there are considerable constraints imposed. The problem states that the maximum length is 1,000 ft, an length limited by locational issues for the merge and diverge junctions. It is probably not worth investigating shorter lengths, and the maximum should be executed for all trial designs. The simplest design merely connects entering lanes with exit lanes in a straightforward manner, producing a section of five lanes. A section with four lanes could be considered by merging two lanes into one at the entry gore and separating it into two again at the exit gore. In any event, the design is limited to a section of four or five lanes. No other widths would work without major additions to input and output legs. The configuration cannot be changed without adding a lane to at least one of the entry or exit legs. Thus, the initial trial will be at a length of 1,000 ft, with the five entry lanes connected directly to the five exit lanes, with no changes to the exit or entry lay designs. If this does not produce an acceptable operation, changes will be considered.

While the problem clearly states that all legs are freeways, no feasible configuration produces a two-sided weave section. Thus, to fit within the one-sided analysis methodology, the right-side entry and exit legs will be classified as ramps in the computational analysis.

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Step 1: Input Data – Trial 1

All input information is given in Exhibit 12-18 and in the accompanying Facts section for this example problem.

Step 2: Adjust Volume – Trial 1

All demands are already stated as flow rates in passenger cars per hour under equivalent ideal conditions. No further adjustments are needed. Critical demand values are as follows:

$$v_{FF} = 2{,}000 \text{ pc/h}$$

$$v_{14} = 1{,}450 \text{ pc/h}$$

$$v_{24} = 1{,}500 \text{ pc/h}$$

$$v_{12} = 2{,}000 \text{ pc/h}$$

$$v_{23} = 1{,}500 + 1{,}450 = 2{,}950 \text{ pc/h}$$

$$v_{4,34} = 2{,}000 + 2{,}000 = 4{,}000 \text{ pc/h}$$

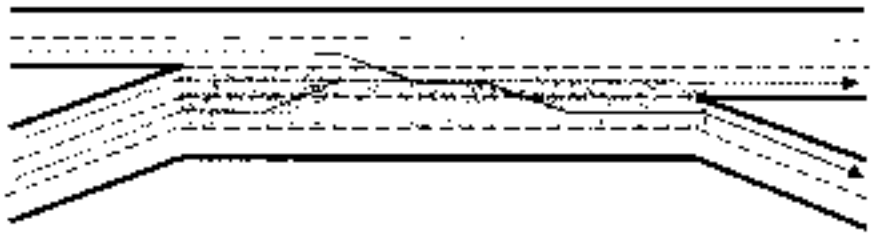
$$v = 2{,}950 + 4{,}000 = 6{,}950 \text{ pc/h}$$

$$VR = \frac{2{,}950}{6{,}950} = 0.424$$

Step 3: Determine Configuration Characteristics – Trial 1

Exhibit 12-19 illustrates the weaving segment formed under the assumed design discussed previously.

Exhibit 12-19
Trial Design 1
for Example Problem 4



The direct connection of entry and exit legs produces a weaving segment in which the ramp-to-freeway movement can be made without a lane change ($LC_{14} = 0$). Freeway-to-ramp vehicles, however, must make two lane changes ($LC_{23} = 2$). If the lane-changing pattern is considered, there are no lanes on the entering freeway leg from which a weaving maneuver can be made with one or no lane changes. Ramp drivers wishing to weave, however, can enter on either of the two left ramp lanes and weave with one or no lane changes. Thus, $N_{w4} = 2$.

By using Equation 12-2, LC_{av} is computed as

$$LC_{av} = (LC_{14} \times v_{14}) + (LC_{24} \times v_{24})$$

$$LC_{av} = (0 \times 1{,}500) + (2 \times 1{,}450) = 2{,}900 \text{ lc/h}$$

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Step 4: Determine Maximum Weaving Length – Trial 1

The maximum length of a weaving segment for this configuration and demand scenario is estimated by using Equation 12-6:

$$L_{MAX} = [5{,}728(1 + VR)^{-1}] - [1{,}566N_{ww}]$$

$$L_{MAX} = [5{,}728(1 + 0.424)^{-1}] - [1{,}566 \times 2] = 6{,}950 \text{ ft} > 1{,}000 \text{ ft}$$

As the maximum length is much greater than the actual length of 1,000 ft, it is appropriate to analyze the segment by using this chapter's methodology.

Step 5: Determine Weaving Segment Capacity – Trial 1

The capacity of the weaving segment is controlled by one of two limiting factors: density reaches 43 pc/mi/ln or weaving demand reaches 2,400 pc/h for the configuration of Exhibit 12-19.

Capacity Limited by Density

The capacity limited by reaching a density of 43 pc/mi/ln is estimated by using Equation 12-5 and Equation 12-6:

$$c_{pc,i} = c_{ri} = [438.2(1 + VR)^{1.6}] + [0.0765L_c] + [119.8N_{ww}]$$

$$c_{pc,i} = 2{,}400 = [438.2(1 + 0.424)^{1.6}] + [0.0765 \times 1{,}000] + [119.8 \times 2]$$

$$c_{i,ri} = 1{,}944 \text{ pc/h/ln}$$

$$c_{ri} = c_{i,ri} \times N \times f_{HV} \times f_p = 1{,}944 \times 5 \times 1 \times 1 = 9{,}721 \text{ pc/h}$$

Capacity Limited by Weaving Demand Flow

The capacity limited by the weaving demand flow is estimated by using Equation 12-7 and Equation 12-8:

$$c_{pc,i} = \frac{2{,}400}{VR} = \frac{2{,}400}{0.424} = 5{,}654 \text{ pc/h}$$

$$c_{ri} = c_{i,ri} \times f_{HV} \times f_p = 5{,}654 \times 1 \times 1 = 5{,}654 \text{ pc/h}$$

In this case, the capacity of the segment is limited by the maximum weaving flow rate of 5,654 pc/h, which is smaller than the total demand flow rate of 6,950 pc/h. Thus, this section is expected to operate at LOS F. No further analysis is possible with this methodology.

Discussion – Trial 1

This section would be expected to fail under the proposed design. The critical feature appears to be the configuration. Note that the capacity is limited by the maximum weaving flows that can be sustained, not by a density expected to produce queuing. This is primarily due to the freeway to ramp flow, which must make two lane changes. This number can be reduced to one by adding one lane to the "ramp" at the exit gore area. Not only does this reduce the number of lane changes made by 1,450 freeway-to-ramp vehicles, but it also increases the value of N_w from 2 to 3. In turn, this effectively increases the segment's capacity

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(as limited by weaving flow rate) is 3,500/VR = 3,500/0.424 = 8,255 pc/h, which is well in excess of the demand flow rate of 6,950 pc/h. Another analysis (Trial 2) will be conducted by using this approach.

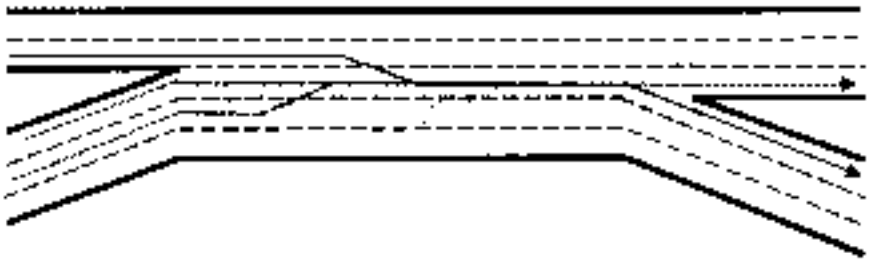
Steps 1 and 2: Input Data and Adjust Volume – Trial 2

Steps 1 and 2 are the same as for Trial 1. They are not repeated here. The new configuration affects the results beginning with Step 3.

Step 3: Determine Configuration Characteristics – Trial 2

Exhibit 12-20 illustrates the new configuration that will result from the changes discussed above. By adding a lane to the exit-ramp leg, the freeway-to-ramp movement can now be completed with only one lane change ($LC_{FR} = 1$). The value of LC_{RF} is not affected and remains 0. The right lane of the freeway-entry leg can also be used by freeway-to-ramp drivers to make a weaving maneuver with a single lane change, increasing N_{wR} to 3.

Exhibit 12-20
Trial Design 2
for Example Problem 4



Then

$$LC_{ALL} = (LC_{FF} \times v_{RF}) + (LC_{FR} \times v_{FF})$$

$$LC_{ALL} = (0 \times 2,580) + (1 \times 2,450) = 2,450 \text{ pc/h}$$

Step 4: Determine Maximum Weaving Length – Trial 2

The maximum length of a weaving segment for this configuration and demand scenario is estimated by using Equation 12-4.

$$L_{MAX} = \left[5,728(1+VR)^{1.6}\right] - \left[1,566N_{WL}\right]$$

$$L_{MAX} = \left[5,728(1+0.424)^{1.6}\right] - \left[1,566 \times 3\right] = 5,393 \text{ ft} > 1,000 \text{ ft}$$

As the maximum length is much greater than the actual length of 1,000 ft, analyzing the segment by using this chapter's methodology is appropriate.

Step 5: Determine Weaving Segment Capacity – Trial 2

The capacity of the weaving segment is controlled by one of two limiting factors: density reaches 43 pc/mi/ln or weaving demand reaches 3,500 pc/h for the configuration of Exhibit 12-20.

Capacity Limited by Density

The capacity limited by reaching a density of 43 pc/mi/ln is estimated by using Equation 12-5 and Equation 12-6.

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$$c_{pw} = c_{ir} \left[438.2(1 - VR)^{1.3}\right] + \left[0.0765L_{EL}\right] + \left[119.8N_{WL}\right]$$

$$c_{pw} = 2,400 \left[438.2(1 - 0.424)^{1.3}\right] + \left[0.0765 \times 1,000\right] + \left[119.8 \times 3\right]$$

$$c_{pw} = 2,064 \text{ pc/h/ln}$$

$$c_w = c_{pw} \times N \times f_{HV} \times f_p \quad 2,064 \times 5 \times 1 \times 1 = 10,320 \text{ pc/h}$$

Capacity Limited by Weaving Demand Flow

The capacity limited by the weaving demand flow is estimated by using Equation 12-7 and Equation 12-8:

$$c_{ov} \quad \begin{matrix} 3,500 & 3,500 \\ VR & 0.424 \end{matrix} \quad 8,255 \text{ pc/h}$$

$$c_w = c_{ov} \times f_{HV} \times f_p \quad 8,255 \times 1 \times 1 = 8,255 \text{ pc/h}$$

Once again, the capacity of the segment is limited by the maximum weaving flow rate; the difference is that now the capacity is 8,255 pc/h. This is larger than the total demand flow rate of 6,951 pc/h. Thus, this section is expected to operate without breakdown, and the analysis may continue.

Step 6: Determine Lane-Changing Rates – Trial 2

Equation 12-16 through Equation 12-18 are used to estimate the lane-changing rates of weaving and nonweaving vehicles in the weaving segment. In turn, these will be used to estimate weaving and nonweaving vehicle speeds.

Weaving Vehicle Lane-Changing Rate

$$LC_w = LC_{w0} + 0.39\left[(1 \quad 300)^{0.5}(N^{1})(1 + ID)^{0.5}\right]$$

$$LC_w = 1,450 + 0.39\left[(2,000 - 300)^{0.5}(1)(1 - 1)^{0.5}\right] = 1,899 \text{ lc/h}$$

Nonweaving Vehicle Lane-Changing Rate

$$L_{nw} \quad \frac{L_c ID v_{NW}}{10,000} \quad \frac{1.000 \times 1 \times 4,000}{10,000} \quad 400 < 1,300$$

$$LC_{nw} = (0.206v_{nw}) - (0.542L_c) - (192.6N)$$

$$LC_{nw} = (0.206 \times 4,000) - (0.542 \times 1,000) - (192.6 \times 5) \quad 403 \text{ lc/h}$$

Total Lane-Changing Rate

$$LC_{tot} = LC_w + LC_{nw} = 1,899 + 403 = 2,302 \text{ lc/h}$$

Step 7: Determine Average Speeds of Weaving and Nonweaving Vehicles – Trial 2

The average speeds of weaving and nonweaving vehicles are computed from Equation 12-18 through Equation 12-20.

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$$W = 0.226\left(\frac{LC_{ww}}{L_w}\right)^{0.536} = 0.226\left(\frac{2{,}302}{1{,}000}\right)^{0.536} = 0.436$$

Then

$$S_a = 15 - \left(\frac{FFS - 15}{1 + W}\right) = 75 - \left(\frac{75 - 15}{1 + 0.436}\right) = 56.8 \text{ mi/h}$$

and

$$S_{NW} = FFS - (0.0072 LC_{NW}) - \left(0.0048 \frac{v}{N}\right)$$

$$S_{NW} = 75 - (0.0072 \times 1{,}450) - \left(0.0048 \frac{6{,}950}{5}\right) = 57.9 \text{ mi/h}$$

Equation 12-21 is now used to compute the average speed of all vehicles in the segment.

$$S = \frac{v_{NW} + v_W}{\left(\frac{v_{NW}}{S_{NW}}\right) + \left(\frac{v_W}{S_W}\right)} = \frac{4{,}000 + 2{,}950}{\left(\frac{4{,}000}{57.9}\right) + \left(\frac{2{,}950}{56.8}\right)} = 57.4 \text{ mi/h}$$

Step 8: Determine the Level of Service – Trial 2

The average density in the weaving segment is estimated by using Equation 12-22.

$$D = \frac{v}{S} = \frac{6{,}950}{57.4} = 121.2 \text{ pc/mi/ln}$$

From Exhibit 12-10, this density is within the stated boundaries of LOS C (120 to 158 pc/mi/ln). As the design target was LOS C, the second trial design is acceptable.

Discussion – Trial 2

The relatively small change in the configuration makes all the difference in this design. LOS C can be achieved by adding a lane to the right-most leg, without it the section fails due to excessive weaving turbulence. If the extra lane is not needed on the departing freeway leg, it would be dropped somewhere downstream, perhaps as part of the next interchange. The extra lane would have to be carried for several thousand feet to be effective. An added lane generally will not be fully utilized by drivers if they are aware that it will be immediately dropped.

EXAMPLE PROBLEM 5: CONSTRUCTING A SERVICE VOLUME TABLE FOR A WEAVING SEGMENT

This example shows how a table of service flow rates or service volumes or both can be constructed for a weaving section with certain specified characteristics. The methodology of this chapter does not directly yield service

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flow rates or service volumes, but they can be developed by using spreadsheets or more sophisticated computer programs.

The key issue is the definition of the threshold values for the various levels of service. For weaving sections on freeways, levels of service are defined as limiting densities as follows:

LOS	Maximum Density (pc/mi/ln)
A	10
B	20
C	28
D	35

By definition, the service flow rate at LOS E is the capacity of the weaving section, which may or may not be keyed to a density.

Before the construction of such a table is illustrated, several key definitions should be reviewed.

- *Service flow rate (under ideal conditions):* The maximum rate of flow under equivalent ideal conditions that can be sustained while maintaining the designated LOS (*SFI*, passenger cars per hour).
- *Service flow rate under prevailing conditions:* The maximum rate of flow under prevailing conditions that can be sustained while maintaining the designated LOS (*SF*, vehicles per hour).
- *Service volume:* The maximum hourly volume under prevailing conditions that can be sustained while maintaining the designated LOS in the worst 15 min of the hour (*SV*, vehicles per hour).
- *Daily service volume:* The maximum AADT under prevailing conditions that can be sustained while maintaining the designated LOS in the worst 15 min of the peak hour (*DSV*, vehicles per day).

Note that flow rates are for a 15-min period, often a peak 15 min within the analysis hour, or the peak hour. These values are related as follows.

$$SF_i = SFI_i \times f_{HV} \times f_p$$

$$SV_i = SF_i \times PHF$$

$$DSV_i = \frac{SV_i}{K D}$$

This chapter's methodology estimates both the capacity and the density expected in a weaving segment of given geometric and demand characteristics. Consequently, the approach to generating values of *SFI* is straightforward: for any given situation, keep increasing the input flow rates until the boundary density for the LOS is reached; the input flow rate is the *SFI* for that situation and LOS. This obviously involves many iterations. A spreadsheet can be programmed to do this, either semiautomatically with manual input of demands, or fully automatically, with the spreadsheet automatically generating solutions until a density match is found. The latter method is not very efficient and involves a typical spreadsheet program running for several hours. A program could, of course, be written to automate the entire process.

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An Example

While all of the computations cannot be shown, demonstration results for a specific case can be illustrated. A service volume table is desired for a weaving section with the following characteristics:

- One-sided major weaving section
- Demand splits as follows:
  - v_1 = 65% of v
  - v_{12} = 15% of v
  - v_{21} = 12% of v
  - v_{22} = 8% of v
- Trucks = 10%, RVs = 0%
- Level terrain
- PHF = 0.93
- f_p = 1.00
- w = 12 ft/mi
- FFS = 65 mi/h

For these characteristics, a service volume table can be constructed for a range of lengths and widths and for configurations in which N_{wl} is 2 and 3. For illustrative purposes, lengths of 500, 1,000, 1,500, 2,000, and 2,500 ft and widths of three, four, or five lanes will be used. In a major weaving section, one weaving flow does not have to make a lane change. For the purposes of this example, it is assumed that the ramp-to-freeway movement has this characteristic. The freeway-to-ramp movement would require one or two lane changes, on the basis of the value of N_{wl}.

First Computations

Initial computations will be aimed at establishing values of SF_i for the situations described. A spreadsheet will be constructed in which the first column is the flow rate to be tested (in passenger cars per hour under ideal conditions), and the last column produces a density. Each line will be iterated manually (in this case) until each threshold density value is reached. Intermediate columns will be programmed to produce the intermediate results needed to get to this result. Because maximum length and capacity are decided at intermediate points, the applicable results will be manually entered before continuing. Such a procedure is less difficult than it seems once the basic computations are programmed. Manual iteration using the input flow rate is very efficient, as the operator will observe how fast the results are converging to the desired threshold and will change the inputs accordingly.

The results of a first computation are shown in Exhibit 12-21. They represent service flow rates under ideal conditions, SF_i. Consistent with the HCM's results presentation guidelines (Chapter 7, Interpreting HCM and Alternative Tool Results), all hourly service flow rates and volumes in the following exhibits have

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been rounded down to the nearest 100 passenger cars or vehicles for presentation.

Exhibit 12-21
Service Flow Rates Under Ideal Conditions (SF_I) for Example Problem 5 (pc/h)

LOS	Length of Weaving Section (ft)									
	500	1,000	1,500	2,000	2,500	500	1,000	1,500	2,000	2,500
	$N = 3$; $N_{wa} = 2$					$N = 3$; $N_{wa} = 3$				
A	1,700	1,700	1,700	1,700	1,700	1,900	1,900	1,900	1,800	1,800
B	3,200	3,200	3,200	3,200	3,200	3,300	3,300	3,400	3,400	3,400
C	4,300	4,300	4,300	4,300	4,300	4,400	4,500	4,500	4,500	4,500
D	5,000	5,100	5,100	5,100	5,100	5,300	5,400	5,400	5,500	5,500
E	5,900	6,000	6,100	6,100	6,100	6,300	6,400	6,500	6,600	6,700
	$N = 4$; $N_{wa} = 2$					$N = 4$; $N_{wa} = 3$				
A	2,200	2,200	2,200	2,200	2,200	2,300	2,300	2,300	2,300	2,300
B	4,200	4,200	4,200	4,200	4,200	4,300	4,400	4,400	4,400	4,400
C	5,400	5,500	5,500	5,500	5,600	5,900	5,900	5,900	5,900	5,900
D	6,300	6,500	6,500	6,600	6,600	6,900	7,000	7,000	7,100	7,100
E	7,900	8,000	8,200	8,400	8,500	8,400	8,500	8,700	8,800	9,000
	$N = 5$; $N_{wa} = 2$					$N = 5$; $N_{wa} = 3$				
A	2,800	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900
B	5,000	5,100	5,100	5,100	5,100	5,400	5,400	5,400	5,500	5,500
C	6,500	6,600	6,700	6,700	6,700	7,100	7,200	7,200	7,300	7,300
D	7,600	7,800	7,800	7,900	7,900	8,400	8,600	8,700	8,700	8,700
E	8,300	8,600	8,800	9,000	9,000	10,500	10,700	10,900	11,100	11,200

Exhibit 12-22 shows service flow rates under prevailing conditions, SF. Each value in Exhibit 12-21 (before rounding) is multiplied by

$$f_{HV} = \frac{1}{1 + 0.1(0)(1.5 \quad)} = 0.952$$

$$f_p \quad 1.00$$

Exhibit 12-22
Service Flow Rates Under Prevailing Conditions (SF) for Example Problem 5 (veh/h)

LOS	Length of Weaving Section (ft)									
	500	1,000	1,500	2,000	2,500	500	1,000	1,500	2,000	2,500
	$N = 3$; $N_{wa} = 2$					$N = 3$; $N_{wa} = 3$				
A	1,600	1,600	1,600	1,600	1,600	1,700	1,700	1,700	1,700	1,700
B	3,000	3,000	3,100	3,100	3,100	3,100	3,200	3,200	3,200	3,200
C	4,000	4,000	4,100	4,100	4,100	4,200	4,300	4,300	4,300	4,300
D	4,700	4,800	4,900	4,900	4,900	5,100	5,100	5,200	5,200	5,200
E	5,600	5,700	5,800	5,900	6,100	6,200	6,100	6,200	6,200	6,400
	$N = 4$; $N_{wa} = 2$					$N = 4$; $N_{wa} = 3$				
A	2,100	2,100	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
B	3,900	4,000	4,000	4,000	4,200	4,100	4,200	4,300	4,300	4,300
C	5,100	5,200	5,200	5,300	5,300	5,500	5,600	5,600	5,600	5,600
D	6,000	6,200	6,200	6,300	6,300	6,600	6,700	6,700	6,800	6,800
E	7,500	7,700	7,800	7,900	8,100	8,000	8,100	8,300	8,400	8,500
	$N = 5$; $N_{wa} = 2$					$N = 5$; $N_{wa} = 3$				
A	2,600	2,700	2,700	2,700	2,700	2,700	2,700	2,800	2,800	2,800
B	4,700	4,800	4,900	4,900	4,900	5,100	5,100	5,200	5,200	5,200
C	6,200	6,300	6,400	6,400	6,400	6,700	6,800	6,800	6,900	6,900
D	7,300	7,400	7,500	7,500	7,500	8,000	8,100	8,200	8,300	8,300
E	8,100	8,400	8,400	8,400	8,400	10,200	10,200	10,300	10,500	10,700

Exhibit 12-23 shows service volumes, SV. Each value in Exhibit 12-22 (before rounding) is multiplied by a PHF of 0.93.

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Exhibit 12-23
Service Volumes Under Prevailing Conditions (SV) for Example Problem 5 (veh/h)

LOS	Length of Weaving Section (ft) 500	1,000	1,500	2,000	2,500	500	1,000	1,500	2,000	2,500
	$N = 3$; $N_{wl} = 2$					$N = 3$; $N_{wl} = 3$				
A	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
B	2,800	2,800	2,800	2,800	2,900	2,900	2,900	3,000	3,000	3,000
C	3,700	3,700	3,800	3,900	3,900	3,900	4,000	4,000	4,000	4,000
D	4,400	4,500	4,500	4,500	4,500	4,700	4,800	4,800	4,900	4,800
E	5,200	5,200	5,400	5,500	5,500	5,500	5,600	5,700	5,800	5,900
	$N = 4$; $N_{wl} = 2$					$N = 4$; $N_{wl} = 3$				
A	2,000	2,000	2,000	2,000	2,000	2,000	2,100	2,100	2,100	2,100
B	3,600	3,700	3,700	3,700	3,700	3,800	3,900	3,900	3,900	3,900
C	4,700	4,800	4,900	4,900	4,900	5,100	5,200	5,200	5,200	5,200
D	5,500	5,700	5,900	5,800	5,800	6,100	6,200	6,400	6,400	6,300
E	7,000	7,100	7,200	7,400	7,500	7,400	7,500	7,700	7,800	7,900
	$N = 5$; $N_{wl} = 2$					$N = 5$; $N_{wl} = 3$				
A	2,400	2,500	2,500	2,500	2,500	2,500	2,500	2,600	2,600	2,600
B	4,400	4,500	4,500	4,500	4,500	4,700	4,800	4,800	4,800	4,800
C	5,700	5,800	5,900	5,900	5,900	6,200	6,400	6,400	6,400	6,400
D	6,800	6,900	7,000	7,000	7,000	7,500	7,600	7,700	7,700	7,700
E	7,800	7,800	7,800	7,800	7,800	9,300	9,400	9,600	9,800	9,900

Exhibit 12-24 shows daily service volumes, (DSV). An illustrative K-factor of 0.08 (typical of a large-town area) and an illustrative D-factor of 0.55 (typical of an urban route without strong peaking by direction) are used. Each (nonrounded) value used to generate Exhibit 12-23 was divided by both of these numbers.

Exhibit 12-24
Daily Service Volumes Under Prevailing Conditions (DSV) for Example Problem 5 (veh/day)

LOS	Length of Weaving Section (ft) 500	1,000	1,500	2,000	2,500	500	1,000	1,500	2,000	2,500
	$N = 3$; $N_{wl} = 2$					$N = 3$; $N_{wl} = 3$				
A	35,200	35,200	35,400	35,500	35,600	36,200	36,300	36,300	36,300	36,300
B	64,300	65,300	65,500	65,700	66,200	67,600	68,000	68,400	68,400	68,400
C	86,700	86,100	86,700	87,200	87,500	89,400	90,900	91,000	91,400	91,900
D	103,600	102,800	103,600	104,000	104,400	107,800	105,500	110,200	110,600	110,600
E	119,800	122,100	124,400	126,700	129,100	127,000	129,400	131,600	132,800	136,300
	$N = 4$; $N_{wl} = 2$					$N = 4$; $N_{wl} = 3$				
A	45,800	46,200	46,600	46,600	46,600	47,600	47,800	47,800	47,900	47,300
B	83,200	84,700	85,100	85,500	85,700	88,300	89,300	89,500	89,700	89,900
C	108,600	110,800	111,600	112,200	112,600	117,100	118,700	119,500	120,100	120,300
D	126,700	101,300	132,400	133,200	133,600	140,000	142,400	143,600	144,000	144,400
E	159,800	162,400	165,400	169,000	172,100	159,400	170,500	175,400	178,600	181,700
	$N = 5$; $N_{wl} = 2$					$N = 5$; $N_{wl} = 3$				
A	56,200	57,100	57,300	57,400	57,500	58,700	58,900	59,000	59,100	59,400
B	101,400	103,000	106,600	104,200	104,400	108,500	109,500	110,000	110,600	110,900
C	131,300	133,800	135,000	135,800	136,200	142,800	145,400	146,200	146,600	147,400
D	154,500	156,700	159,100	160,900	161,800	170,100	173,100	175,000	175,600	176,800
E	178,600	178,400	178,600	178,800	178,800	211,800	215,500	219,500	223,300	227,200

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CHAPTER 13
FREEWAY MERGE AND DIVERGE SEGMENTS

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1. INTRODUCTION

Freeway merge and diverge segments occur primarily at on-ramp and off-ramp junctions with the freeway mainline. They can also occur at major merge or diverge points where mainline roadways join or separate.

Freeway merge and diverge segments include ramp junctions and points where mainline roadways join or separate.

A ramp is a dedicated roadway providing a connection between two highway facilities. On freeways, all movements onto and off of the freeway are made at ramp junctions—designed to permit relatively high-speed merging and diverging maneuvers while limiting the disruption to the main traffic stream. Some ramps on freeways connect to collector–distributor (C-D) roadways, which in turn provide a junction with the freeway mainline. Ramps may appear on multilane highways, two-lane highways, arterials, and urban streets, but such facilities may also use signalized and unsignalized intersections at such junctions.

The procedures in Chapter 13, **Freeway Merge and Diverge Segments**, focus on ramp–freeway junctions, but guidance is also provided to allow approximate use of such procedures on multilane highways and on C-D roadways.

This chapter provides guidance for using the procedures on multilane highways and C-D roadways.

RAMP COMPONENTS

A ramp consists of three elements: the ramp roadway and two junctions. Junctions vary greatly in design and control features but generally fit into one of these categories:

- Ramp–freeway junctions (or a junction with a C-D roadway or multilane highway segment), or
- Ramp–street junctions.

When a ramp connects one freeway to another, the ramp consists of two ramp–freeway junctions and the ramp roadway. When a ramp connects a freeway to a surface facility, it generally consists of a ramp–freeway junction, the ramp roadway, and a ramp–street junction. When a ramp connection to a surface facility (such as a multilane highway) or a C-D roadway is designed for high-speed merging or diverging without control, it may be classified as a ramp–freeway junction for the purpose of analysis.

Ramps to multilane highways and C-D roadways that are designed for high-speed merging or diverging may be classified as ramp–freeway junctions for analysis purposes.

Ramp–street junctions may be uncontrolled, stop-controlled, yield-controlled, or signalized. Analysis of ramp–street junctions is not detailed in this chapter; rather, it is discussed in Chapter 22, Interchange Ramp Terminals. Note, however, that an off-ramp–street junction, particularly if signalized, can result in queuing on the ramp roadway that can influence operations at the ramp–freeway junction and even mainline freeway conditions. Mainline operations can also be affected by platoon gaps created by ramp–street intersection control.

See Chapter 22 for a discussion of ramp–street junctions.

Ramp queuing from a junction of an off-ramp and street can influence the operation of the ramp–freeway junction and the upstream freeway.

The geometric characteristics of ramp–freeway junctions vary. The length and type (parallel, taper) of acceleration or deceleration lane(s), the free-flow speed (FFS) of both the ramp and the freeway in the vicinity of the ramp, proximity of other ramps, and other elements all affect merging and diverging operations.

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CLASSIFICATION OF RAMPS

Ramps and ramp–freeway junctions may occur in a wide variety of configurations. Some of the key characteristics of ramps and ramp junctions are summarized below:

- Ramp–freeway junctions that accommodate merging maneuvers are classified as *on-ramps*. Those that accommodate diverging maneuvers are classified as *off-ramps*. Where the junctions accommodate the merging of two major facilities, they are classified as *major merge* junctions. Where they accommodate the divergence of two major roadways, they are classified as *major diverge* junctions.
- The majority of ramps are right-hand ramps. Some, however, join with the left lane(s) of the freeway and are classified as left-hand ramps.
- Ramp roadways may have one or two lanes. At on ramp freeway junctions, most two lane ramp roadways merge into a single lane before merging with the freeway. In this case, the junction is classified as a one-lane ramp–freeway junction on the basis of the methodology of this chapter. In other cases, a two-lane ramp–freeway merge exists, and a special analysis model is used (see this chapter's Special Cases section).
- For two-lane off-ramps, a single lane may exist at the ramp–freeway diverge, with the roadway widening to two lanes after the diverge. As with on-ramps, such cases are classified as one-lane ramp–freeway junctions on the basis of this chapter's methodology. Two lane off ramp roadways, however, often have two lanes at the diverge point as well. These are treated by using a special model (see this chapter's Special Cases section).
- Ramp–freeway merge and diverge operations are affected by the size of the freeway segment (or one direction).
- Ramp–freeway merge and diverge operations may be affected by the proximity of adjacent ramps and the flow rates on those ramps.

Left-hand ramps are considered as special cases later in the chapter.

Merge and diverge segments with two lanes at the point of merge or diverge are considered as special cases later in this chapter.

The number of combinations of these characteristics that can occur is very large. For any analyses, all of these (and other) characteristics must be specified if meaningful results are to be obtained.

RAMP AND RAMP JUNCTION ANALYSIS BOUNDARIES

Ramps and ramp junctions do not operate independently of the roadways they connect. Thus, operating conditions on the main roadways can affect operations on the ramp and ramp junctions, and vice versa. In particular, a breakdown (Level of Service (LOS) F) at a ramp–freeway junction may have serious effects on the freeway upstream or downstream of the junction. These effects can influence freeway operations for miles or the worst cases.

With understated conditions, the operational impacts of ramp–freeway junctions occur within a 1,500-ft-long influence area.

For most stable operations, however, studies (*1*) have shown that the operational impacts of ramp–freeway junctions are more localized. Thus, the methodology presented in this chapter predicts the operating characteristics within a defined ramp influence area. For right-hand on ramps, the ramp influence area includes the acceleration lane(s) and Lanes 1 and 2 of the freeway

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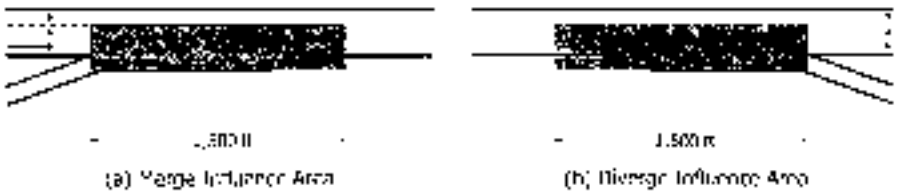
mainline (rightmost and second rightmost) for a distance of 1,500 ft downstream of the merge point. For right-hand off-ramps, the ramp influence area includes the deceleration lane(s) and Lanes 1 and 2 of the freeway for a distance of 1,500 ft upstream of the diverge point. Exhibit 13-1 illustrates the definition of ramp influence areas. For left-hand ramps, the two leftmost lanes of the freeway are affected.

The influence area includes the acceleration/deceleration lane and the right two lanes of the freeway (left two lanes for left-hand ramps).



(a) Merge Influence Area (b) Diverge Influence Area

Exhibit 13-1
Ramp Influence Areas Illustrated

RAMP–FREEWAY JUNCTION OPERATIONAL CONDITIONS

Ramp–freeway junctions create turbulence in the merging or diverging traffic stream. In general, the turbulence is the result of high lane-changing rates.

The action of individual merging vehicles entering the Lane 1 traffic stream creates turbulence in the vicinity of the ramp. Approaching freeway vehicles move toward the left to avoid the turbulence. Thus, the ramp influence area experiences a higher rate of lane changing than is normally present on ramp-free portions of freeway.

Ramp influence areas experience higher rates of lane changing than normally occur on basic freeway segments.

At off-ramps, the basic maneuver is a diverge—a single traffic stream separating into two streams. Exiting vehicles must occupy the lane(s) adjacent to the off-ramp (Lane 1 for a single-lane right-hand off-ramp). Thus, as the off-ramp is approached, vehicles leaving the freeway must move to the right. This causes other freeway vehicles to redistribute as they move left to avoid the turbulence of the immediate diverge area. Again, the ramp influence area has a higher rate of lane changing than is normally present on ramp-free portions of freeway.

Vehicle interactions are dynamic in ramp influence areas. Approaching freeway through vehicles will move left as long as there is capacity to do so. Whereas the intensity of ramp flow influences the behavior of through freeway vehicles, general freeway congestion can also act to limit ramp flow, causing diversion to other interchanges or routes.

Exhibit 13-1 and the accompanying discussion relate to single-lane right-hand ramps. For two-lane right-hand ramps, the characteristics are basically the same, except that two acceleration or deceleration lanes may be present. For left-hand ramps, merging and diverging obviously take place on the left side of the freeway. This chapter's methodology is based on right-hand ramps, but modifications allowing the application of the methodology to consider left-hand ramps are presented in the Special Cases section of this chapter.

BASE CONDITIONS

The base conditions for the methodology presented in this chapter are the same as for other types of freeway segments:

Base conditions for merge and diverge segments are the same as for other types of freeway segments.

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- No heavy vehicles,
- 12-ft lanes,
- Adequate lateral clearances (≥6 ft), and
- Road users familiar with the facility (i.e., $f_p = 1.00$).

LOS CRITERIA FOR MERGE AND DIVERGE SEGMENTS

LOS A–E is defined in terms of density. LOS F exists when demand exceeds capacity.

Merge/diverge segment LOS is defined in terms of density for all cases of stable operation (LOS A–E). LOS F exists when the freeway demand exceeds the capacity of the upstream (diverge) or downstream (merge) freeway segment, or when the off-ramp demand exceeds the off-ramp capacity.

At LOS A, unrestricted operations exist, and the density is low enough to permit smooth merging or diverging with very little turbulence in the traffic stream. At LOS B, merging and diverging maneuvers become noticeable to through drivers, and minimal turbulence occurs. At LOS C, speed within the ramp influence area begins to decline as turbulence levels become much more noticeable. Both ramp and freeway vehicles begin to adjust their speeds to accomplish smooth transitions. At LOS D, turbulence levels in the influence area become intrusive, and virtually all vehicles slow to accommodate merging or diverging maneuvers. Some ramp queues may exist at heavily used on-ramps, but freeway operation remains stable. LOS E represents operating conditions approaching or at capacity. Small changes in demand or disruptions within the traffic stream can cause extensive ramp and freeway queues to form.

LOS F defines operating conditions within queues that form on both the ramp and the freeway mainline when capacity is exceeded by demand. For on-ramps, LOS F exists when the total demand flow rate from the upstream freeway segment and the on-ramp exceeds the capacity of the downstream freeway segment. For off-ramps, LOS F exists when the total demand flow rate on the approaching upstream freeway segment exceeds the capacity of the upstream freeway segment. LOS F also occurs when the off-ramp demand exceeds the capacity of the off-ramp.

Exhibit 13-2 summarizes the LOS criteria for freeway merge and diverge segments. These criteria apply to all ramp–freeway junctions and may also be applied to auxiliary merges and diverges; high-speed, uncontrolled merge or diverge ramps on multilane highway sections; and merges and diverges on freeway C-D roadways. LOS is not defined for ramp roadways, while the LOS of a ramp–street junction is defined in Chapter 22, Interchange Ramp Terminals.

Exhibit 13-2
LOS Criteria for Freeway Merge and Diverge Segments

LOS	Density (pc/mi/ln)	Comments
A	≤10	Unrestricted operations
B	>10–20	Merging and diverging maneuvers noticeable to drivers
C	>20–28	Influence area speeds begin to decline
D	>28–35	Influence area turbulence becomes intrusive
E	>35	Turbulence felt by virtually all drivers
F	Demand exceeds capacity	Ramp and freeway queues form

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REQUIRED INPUT DATA

The analysis of a ramp–freeway junction requires details concerning the junction under analysis and adjacent upstream and downstream ramps, in addition to the data required for a typical freeway analysis.

Data Describing the Freeway

The following information concerning the freeway mainline is needed to conduct an analysis:

1. FFS: 55–75 mi/h;
2. Number of mainline freeway lanes: 2–5;
3. Terrain: level, rolling, or mountainous, or percent grade and length;
4. Heavy vehicle presence: percent trucks and buses, percent recreational vehicles (RVs);
5. Demand flow rate immediately upstream of the ramp–freeway junction;
6. Peak hour factor: up to 1.00; and
7. Driver population factor: 0.85–1.00.

FFS is best measured in the field but can be estimated by using the methodology for basic freeway segments or multilane highways, as applicable.

The freeway FFS is best measured in the field. If a field measurement is not available, one may be estimated by using the methodology for basic freeway segments presented in Chapter 12, Basic Freeway Segments. To use this methodology, information on lane widths, lateral clearances, number of lanes, and total ramp density is required. If the ramp junction is located on a multilane highway or C-D roadway, the FFS range is somewhat lower (45–60 mi/h) and can be estimated by using the methodology in Chapter 14, Multilane Highways, if no field measurements are available. The methodology can be applied to facilities with any FFS. Its use with multilane highways or C-D roadways must be considered approximate, however, since it was not calibrated with data from these types of facilities.

Where the ramp–freeway junction is on a specific grade, the length of the grade is measured from its beginning to the point of the ramp junction.

The driver population factor is generally 1.00, unless the demand consists primarily of drivers who are not regular users of the facility. In such cases, an appropriate value should be based on field observations at the location under study or at similar nearby locations.

Data Describing the Ramp–Freeway Junction

The following information concerning the ramp–freeway junction is needed to conduct an analysis:

1. Type of ramp: on-ramp, off-ramp, major merge, major diverge;
2. Side of junction: right-hand, left-hand;
3. Number of lanes on ramp roadway: 1 lane, 2 lanes;
4. Number of ramp lanes at ramp–freeway junction: 1 lane, 2 lanes;
5. Length of acceleration/deceleration lane(s);
6. FFS of the ramp roadway: 25–50 mi/h.

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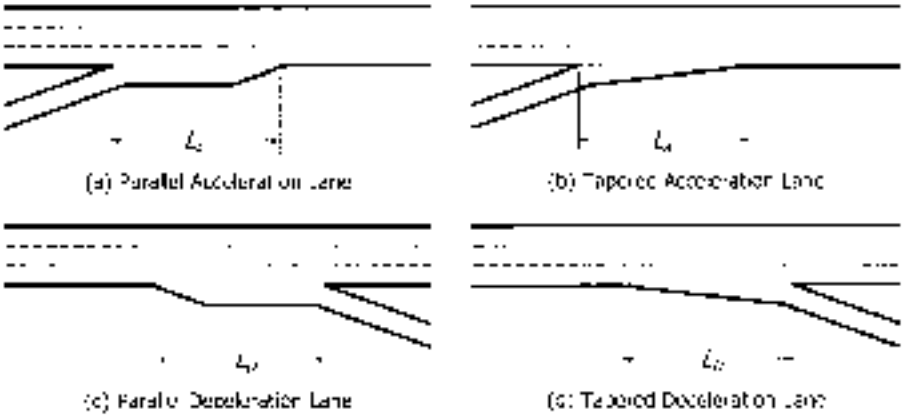
7. Ramp terrain: level, rolling, or mountainous, or percent grade, length;
8. Demand flow rate on ramp;
9. Heavy vehicle presence: percent trucks and buses, percent RVs;
10. Peak hour factor: up to 1.00;
11. Driver population factor: 0.85 - 1.00; and
12. For adjacent upstream or downstream ramps:
    a. Upstream or downstream distance to the merge/diverge under study,
    b. Demand flow rate on the upstream or downstream ramp, and
    c. Peak hour factor and heavy vehicle percentages for the upstream or downstream ramp.

The length of the acceleration or deceleration lane includes the tapered portion of the ramp.

The length of the acceleration or deceleration lane includes the tapered portion of the ramp. Exhibit 13-3 illustrates lengths for both parallel and tapered ramp designs.

Exhibit 13-3
Measuring the Length of Acceleration and Deceleration Lanes



Source: *Traffic Engineering*, 3rd edition [2].

Length of Analysis Period

The analysis period for any freeway analysis, including ramp junctions, is generally the peak 15-min period within the peak hour. Any 15-min period can be analyzed, however.

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2. METHODOLOGY

SCOPE OF THE METHODOLOGY

This chapter focuses on the operation of ramp–freeway junctions. The procedures may be applied in an approximate manner to completely uncontrolled ramp terminals on other types of facilities, such as multilane highways, two-lane highways, and freeway C–D roadways that are part of interchanges.

This chapter's procedures can be used to identify likely congestion at ramp–freeway junctions (LOS F) and to analyze undersaturated operations (LOS A–E) at ramp–freeway junctions. Chapter 10, Freeway Facilities, provides procedures for a more detailed analysis of oversaturated flow and congested conditions along a freeway section, including weaving, merge and diverge, and basic freeway segments.

The procedures in this chapter result primarily from studies conducted under National Cooperative Highway Research Program Project 3-33 (7, 8). Some special applications resulted from adaptations of procedures developed in the 1970's (3). American Association of State Highway and Transportation Officials policies (4) contain additional material on the geometric design and design criteria for ramps.

LIMITATIONS OF THE METHODOLOGY

The methodology in this chapter does not take into account, nor is it applicable to (without modification by the analyst), cases involving

- Special lanes, such as high-occupancy vehicle (HOV) lanes, as ramp entry lanes;
- Ramp metering; or
- Intelligent transportation system features.

The methodology does not explicitly take into account posted speed limits or level of police enforcement. In some cases, low speed limits and strict enforcement could result in lower speeds and higher densities than those anticipated by this methodology.

OVERVIEW

Exhibit 13-4 illustrates the computational methodology applied to the analysis of ramp–freeway junctions. The analysis is generally entered with known geometric and demand factors. The primary outputs of the analysis are LOS and capacity. The methodology estimates the density and speed in the ramp influence area.

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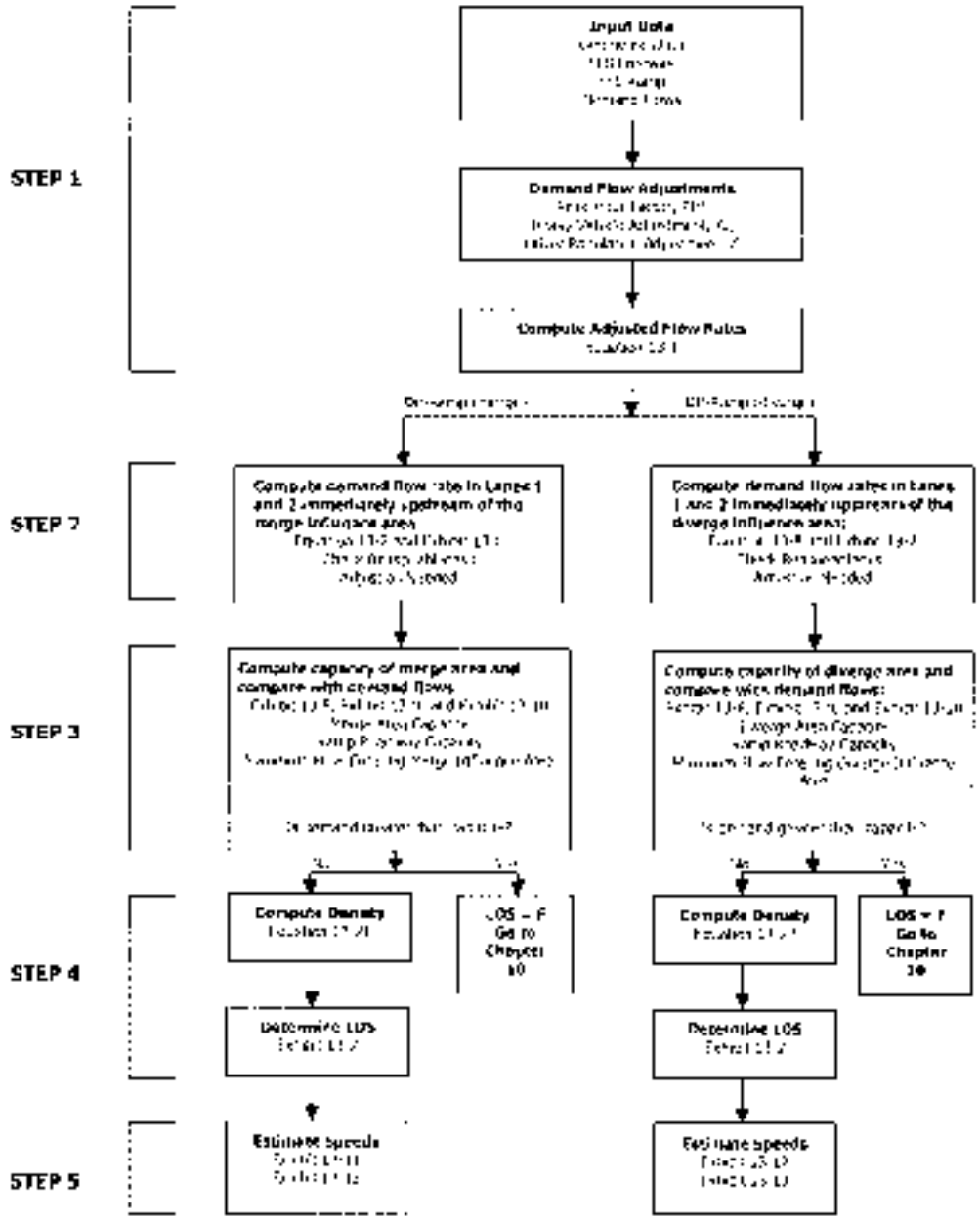
Exhibit 13-4
Flowchart for Analysis of Ramp–Freeway Junctions



As previously discussed, the methodology focuses on modeling the operating conditions within the ramp influence area, as defined in Exhibit 13-1. Because the ramp influence area includes only Lanes 1 and 2 of the freeway, an important part of the methodology involves predicting the number of approaching freeway vehicles that remain in these lanes immediately upstream of the ramp–freeway junction. While operations in other freeway lanes may be affected by merging and diverging maneuvers, particularly under heavy flow, the defined influence area experiences most of the operational impacts across all levels of service (except LOS F). All breakdown, queues, and operational impacts may extend well beyond the defined influence area. Exhibit 13-5 illustrates key variables involved in the methodology.

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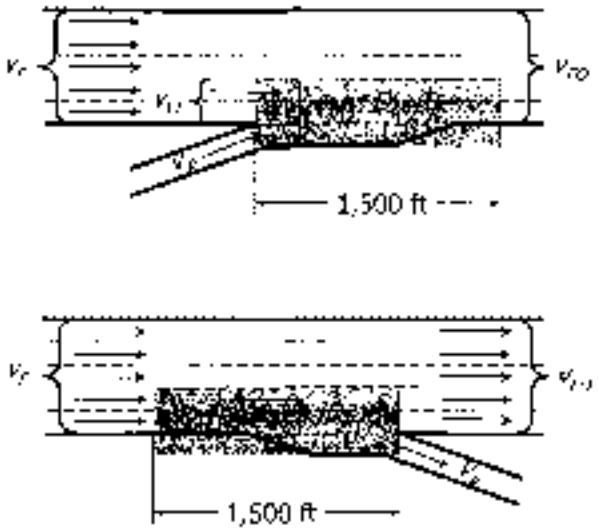

Exhibit 13-5
Key Ramp Junction Variables

The variables illustrated in Exhibit 13-5 are defined as follows:

- v_f = flow rate on freeway immediately upstream of the ramp influence area under study (pc/h),
- v_{12} = flow rate in freeway Lanes 1 and 2 immediately upstream of the ramp influence area (pc/h),
- v_{12} = flow rate on the freeway immediately downstream of the merge or diverge area (pc/h),
- v_R = flow rate on the on-ramp or off-ramp (pc/h),
- v_{12} = sum of the flow rates in Lanes 1 and 2 and the ramp flow rate (on ramps only) (pc/h),
- D_R = density in the ramp influence area (pc/mi/ln), and
- S_R = average speed in the ramp influence area (mi/h).

The computational process illustrated in Exhibit 13-4 may be broken into five primary steps:

1. Specify ramp input variables and convert ing demand volumes to demand flow rates in passenger cars per hour under equivalent base conditions;
2. Estimating the flow remaining in Lanes 1 and 2 at the freeway immediately up-stream of the merge or diverge influence area;
3. Estimating the capacity of the merge or diverge area and comparing the capacity with the converted demand flow rates,
4. For stable operations (i.e., demand is less than or equal to capacity), estimating the density within the ramp influence area and determining the expected LOS, and
5. When desired, estimating the average speed of vehicles within the ramp influence area.

Each step is discussed in detail in the sections that follow.

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COMPUTATIONAL STEPS

The methodology was calibrated for one-lane, right-side ramp freeway junctions. Other situations are addressed in the Special Cases section.

The methodology described in this section was calibrated for one-lane, right-side ramp freeway junctions. All other cases—two-lane ramp junctions, left-side ramps, and major merge and diverge configurations—are analyzed with the modified procedures detailed in the Special Cases section.

Step 1: Specify Inputs and Convert Demand Volumes to Demand Flow Rates

All geometric and traffic variables for the ramp–freeway junction should be specified as inputs to the methodology, as discussed previously. Flow rates on the approaching freeway, on the ramp, and on any existing upstream or downstream adjacent ramps must be converted from hourly volumes (in vehicles per hour) to peak 15-min flow rates (in passenger cars per hour) under equivalent ideal conditions:

Equation 13-1

$$v_i = \frac{V_i}{PHF \times f_{HV} \times f_p}$$

where

v_i = demand flow rate for movement i (pc/h),

V_i = demand volume for movement i (veh/h),

PHF = peak hour factor,

f_{HV} = adjustment factor for heavy vehicle presence, and

f_p = adjustment factor for driver population.

If demand data or forecasts are already stated as 15-min flow rates, PHF is set at 1.00. Adjustment factors are the same as those used in Chapter 11, Basic Freeway Segments. These can also be used when the primary facility is a multilane highway or a C-D roadway at a freeway interchange.

Step 2: Estimate the Approaching Flow Rate in Lanes 1 and 2 of the Freeway Immediately Upstream of the Ramp Influence Area

Because the ramp influence area includes Lanes 1 and 2 of the freeway (for a right-hand ramp), a critical step in the analysis is estimating the total flow rate in Lanes 1 and 2 immediately upstream of the ramp influence area.

The distribution of freeway vehicles approaching a ramp influence area is affected by a number of variables:

- Total freeway flow approaching the ramp influence area v_f (pc/h),
- Total on- or off-ramp flow v_R (pc/h),
- Total length of the acceleration lane L_A or deceleration lane L_D (ft), and
- FFS of the ramp at the junction point S_{FR} (mi/h).

The lane distribution of approaching freeway vehicles may also be affected by adjacent upstream or downstream ramps. Nearby ramps can influence lane distribution as drivers execute lane changes to position themselves for ramp movements at adjacent ramps. An on-ramp, for example, located only a few

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hundred feet upstream of a subject ramp may result in additional vehicles in Lanes 1 and 2 at the subject ramp. A downstream off-ramp near a subject ramp may contain additional vehicles in Lanes 1 and 2 destined for the downstream ramp.

Theoretically, the influence of adjacent upstream and downstream ramps does not depend on the size of the freeway. In practical terms, however, this methodology only accounts for such influences on six-lane freeways (three lanes in one direction). On four-lane freeways (two lanes in one direction), the determination of v_{12} is trivial, since only Lanes 1 and 2 exist; all approaching freeway vehicles are, by definition, in Lanes 1 and 2 regardless of the proximity of adjacent ramps. On eight-lane (four lanes in one direction) or larger freeways, the data are insufficient to determine the impact of adjacent ramps on lane distribution. In addition, two-lane ramps are never included as "adjacent" ramps under these procedures.

For six-lane freeways, the methodology includes a process for determining whether adjacent upstream and downstream ramps are close enough to influence lane distribution at a subject ramp junction. When such ramps are close enough, the following additional variables may be involved:

- Flow rate on the adjacent upstream ramp v_{r1} (pc/h),
- Distance between the subject ramp junction and the adjacent upstream ramp junction L_{up} (ft),
- Flow rate on the adjacent downstream ramp v_{r2} (pc/h), and
- Distance between the subject ramp junction and the adjacent downstream ramp junction L_{down} (ft).

The distance to adjacent ramps is measured between the points at which the left edge of the leftmost ramp lane meets the right-lane edge of the freeway.

In practical terms, the influence of adjacent ramps rarely extends more than approximately 8,000 ft. Nevertheless, whether an adjacent ramp on a six-lane freeway has influence should be determined by using the algorithms specified in this methodology.

Of all these variables, the total approaching freeway flow has the greatest impact on flow in Lanes 1 and 2. The models are structured to account for this phenomenon without distorting other relationships. Longer acceleration and deceleration lanes lessen turbulence as ramp vehicles enter or leave the freeway. This leads to lower densities and higher speeds in the ramp influence area. When the ramp has a higher FFS, vehicles can enter and leave the freeway at higher speeds, and approaching freeway vehicles tend to move left to avoid the possibility of high-speed turbulence. This produces greater passenger-car unit and smoother flow across all freeway lanes.

While the models are similarly structured, there are distinct differences between the lane distribution impacts of on ramps and off ramps. Separate models are presented for each case in the sections that follow.

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Estimating Flow in Lanes 1 and 2 for On Ramps (Merge Areas)

The general model for on-ramps operations that flow in Lanes 1 and 2 immediately upstream of the merge influence area is simply a proportion of the approaching freeway flow, as shown in Equation 13-2:

Equation 13-2

$$v_{12} = v_i \times P_{FM}$$

where

v_{12} = flow rate in Lanes 1 and 2 (pc/h),

v_i = total flow rate on freeway immediately upstream of the on-ramp (merge) influence area (pc/h), and

P_{FM} = proportion of freeway vehicles remaining in Lanes 1 and 2 immediately upstream of the on-ramp influence area.

Exhibit 13-6 shows the algorithms used to determine P_{FM} for on-ramps or merge areas. All variables in Exhibit 13-6 are as previously defined.

Three equations are provided for six-lane freeways. Equation 13-3 is the base case for isolated ramps and for cases in which adjacent ramps are not found to influence merging operations. Equation 13-4 addresses cases with an upstream adjacent off ramp, while Equation 13-5 addresses cases with a downstream adjacent on-ramp. Adjacent on-ramps (either upstream or downstream) have not been found to have a statistically significant impact on operations and are therefore ignored. Equation 13-3 is applied in such cases.

Adjacent upstream or downstream ramps do not affect the prediction of v_{12} for two-lane (one direction) freeway segments, since all vehicles are in Lanes 1 and 2. Data have been insufficient to determine whether adjacent ramps influence lane distribution on four-lane (one direction) freeway segments, and thus no such impact is used in this methodology.

Where an upstream or downstream adjacent off ramp exists on a six-lane freeway, a determination as to whether the ramp is close enough to the subject merge area to influence the area's operation is necessary. The determination is made by finding the equilibrium separation distance (L_{EQ}). If the actual distance is larger than or equal to L_{EQ}, Equation 13-3 should be used. If the actual distance is shorter than L_{EQ}, then Equation 13-4 or Equation 13-5 should be used as appropriate.

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No. of Freeway Lanes[a]	Model(s) for Determining P_{FM}
4	$P_{FM} = 1.000$
6	$P_{FM} = 0.8775 + 0.000028\,L_A$
	$P_{FM} = 0.5981 + 0.00013\,(v_{12} + v_R) + 0.0655\ln(S_{av}) + 0.0030\ln(L_A)$
	$P_{FM} = 0.5487 + 0.2856\,(v_{12}/S_{av})$
8	For $v_{12}/S_{av} \le 22$: $P_{FM} = 0.2778 + 0.000125\,v_{12} + 0.0115\ln(L_A + v_R)$
	For $v_{12}/S_{av} > 22$: $P_{FM} = 0.2778 + 0.000125\,v_{12}$

Exhibit 13-6
Models for Predicting P_{FM} at On-Ramps or Merge Areas

Equation 13-3
Equation 13-4
Equation 13-5

SELECTING EQUATIONS FOR P_{FM} FOR SIX-LANE FREEWAYS

Adjacent Upstream Ramp	Subject Ramp	Adjacent Downstream Ramp	Equation(s) Used
None	On	None	Equation 13-3
None	On	On	Equation 13-5
None	On	Off	Equation 13-5 or 13-3
On	On	None	Equation 13-3
Off	On	None	Equation 13-4 or 13-3
On	On	On	Equation 13-3
On	On	Off	Equation 13-5 or 13-3
Off	On	On	Equation 13-4 or 13-3
Off	On	Off	Equation 13-5 or 13-4 or 13-3

Note: [a] 4 lanes = two lanes in each direction, 6 lanes = three lanes in each direction, 8 lanes = four lanes in each direction.
[b] Except for a diverge on a six-lane freeway that has a one-lane, right-side off-ramp, see Equation 13-3.

The equilibrium distance is obtained by finding the distance at which Equation 13-3 would yield the same value of P_{FM} as Equation 13-4 or Equation 13-5, as appropriate. This results in the following:

For adjacent upstream off-ramps, use Equation 13-6:

$$L_{EQ} = 0.216(v_1 - v_2) - 0.444\,L_A + 52.32\,S_{av} - 2,403 \qquad \text{Equation 13-6}$$

For adjacent downstream off-ramps, use Equation 13-7:

$$L_{EQ} = \frac{v_1}{0.1096 + 0.000107\,L_A} \qquad \text{Equation 13-7}$$

where all terms are as previously defined.

When both adjacent upstream and downstream off-ramps are present, the larger resulting value of P_{FM} is used.

A special case exists when both an upstream and a downstream adjacent off-ramp are present. In such cases, two different values of P_{FM} could arise: one from consideration of the upstream ramp and the other from consideration of the downstream ramp. They cannot be considered simultaneously. In such cases, the analysis resulting in the larger value of P_{FM} is used.

When an adjacent off-ramp to a merge area on a six-lane freeway is not a one-lane, right-side off-ramp, apply Equation 13-3.

In addition, the algorithms used to calculate the impact of an upstream or downstream off-ramp on a six-lane freeway are only valid for single-lane, right-side adjacent ramps. Where adjacent off-ramps consist of two-lane junctions or major diverge configurations, or where they are on the left side of the freeway, Equation 13-3 is always applied.

Estimating Flow in Lanes 1 and 2 for Off-Ramps (Diverge Areas)

When approaching an off-ramp (diverge area), all off-ramp traffic must be in freeway Lanes 1 and 2 immediately upstream of the ramp to execute the desired

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maneuver. Thus, for off-ramps, the flow in Lanes 1 and 2 consists of all off-ramp vehicles and a proportion of freeway through vehicles, as in Equation 13-8:

Equation 13-8

$$v_{12} = v_R + (v_1 - v_R)P_{12}$$

where

v_1 = flow rate in Lanes 1 and 2 of the freeway immediately upstream of the deceleration lane (pc/h),

v_R = flow rate on the off-ramp (pc/h), and

P_{12} = proportion of diverging traffic remaining in Lanes 1 and 2 immediately upstream of the deceleration lane.

For off-ramps, the point at which flows are defined is the beginning of the deceleration lane(s), regardless of whether this point is within or outside the ramp influence area.

Exhibit 13-7 contains the equations used to estimate P_{12} at off-ramp diverge areas. As with the case for on-ramps (merge areas), the value of P_{12} for four-lane freeways is trivial, since only Lanes 1 and 2 exist.

Exhibit 13-7
Models for Predicting P_{12} at Off-Ramps or Diverge Areas

No. of Freeway Lanes[a]	Model(s) for Determining P_{12}
4	$P_{12} = 1.000$
6	Equation 13-9: $P_{12} = 0.760 - 0.000005v_1 - 0.000161v_R$
	Equation 13-10: $P_{12} = 0.717 - 0.000030v_1 + 0.001(v_R / (1 + v_{R,up}))$
	Equation 13-11: $P_{12} = 2.616 - 0.000021v_1 + 0.124(v_R / (1 + v_{R,up}))$
8	$P_{12} = 0.136$

SELECTING EQUATIONS FOR P_{12} FOR SIX-LANE FREEWAYS

Adjacent Upstream Ramp	Subject Ramp	Adjacent Downstream Ramp	Equation(s) Used
None	Off	None	Equation 13-9
None	Off	On	Equation 13-9
None	Off	Off	Equation 13-11 or 13-9
On	Off	None	Equation 13-10 or 13-9
Off	Off	None	Equation 13-9
On	Off	On	Equation 13-10 or 13-9
On	Off	Off	Equation 13-11, 13-10, or 13-9
Off	Off	On	Equation 13-9
Off	Off	Off	Equation 13-11 or 13-9

Note: Adjacent = two successive ramps in the same direction of travel along the freeway; Subject = the ramp under consideration.

a. If an adjacent ramp on a six-lane freeway is not a one-lane, right-side off-ramp, use Equation 13-9.

For six-lane freeways, three equations are presented. Equation 13-9 is the base case for isolated ramps or for cases in which the impact of adjacent ramps can be ignored. Equation 13-10 addresses cases in which there is an adjacent upstream on-ramp, while equation 13-11 addresses cases in which there is an adjacent downstream off-ramp. Adjacent upstream off-ramps and downstream on-ramps have not been found to have a statistically significant impact on diverge operations and may be ignored. All variables in Exhibit 13-7 are as previously defined.

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Insufficient information is available to establish an impact of adjacent ramps on eight-lane freeways (four lanes in each direction). This methodology does not include such an impact.

Where an adjacent upstream on-ramp or downstream off-ramp on a six-lane freeway exists, a determination as to whether the ramp is close enough to the subject off-ramp to affect its operation is necessary. As was the case for on-ramps, this is done by finding the equilibrium distance L_{EQ}. This distance is determined when Equation 13-9 yields the same value of P_{FD} as Equation 13-10 (for adjacent upstream on-ramps) in Equation 13-11 (adjacent downstream off-ramps). When the actual distance between ramps is greater than or equal to L_{EQ}, Equation 13-9 is used. When the actual distance between ramps is less than L_{EQ}, Equation 13-10 or Equation 13-11 is used as appropriate.

For adjacent upstream on-ramps, use Equation 13-12 to find the equilibrium distance:

$$L_{EQ} = \frac{v_R}{0.071 - 0.000023v_1 - 0.000076v_R}$$

Equation 13-12

For adjacent downstream off-ramps, use Equation 13-13:

$$L_{EQ} = \frac{v_D}{1.15 - 0.000032v_1 - 0.000369v_R}$$

Equation 13-13

where all terms are as previously defined.

A special case exists when both an adjacent upstream on-ramp and an adjacent downstream off-ramp are present. In such cases, two solutions for P_{FD} may arise, depending on which adjacent ramp is considered (both ramps cannot be considered simultaneously). In such cases, the larger value of P_{FD} is used.

When both an adjacent upstream on-ramp and an adjacent downstream off-ramp are present, the larger resulting value of P_{FD} is used.

As was the case for merge areas, the algorithms used to include the impact of an upstream or downstream ramp on a six-lane freeway are only valid for single-lane, right-side adjacent ramps. Where adjacent ramps consist of two-lane junctions or major diverge configurations, or where they are on the left side of the freeway, Equation 13-9 is always applied.

When an adjacent ramp is a diverge area on a six-lane freeway or has a two-lane, one-side ramp, apply Equation 13-9.

Checking the Reasonableness of the Lane Distribution Prediction

The algorithms of Exhibit 13-6 and Exhibit 13-7 were developed through regression analysis of a large database. Unfortunately, regression based models may yield unreasonable or unexpected results when applied outside the actual limits of the calibration database, and they may have inconsistencies at their boundaries.

Reasonableness checks on the value of v_{12}

Therefore, it is necessary to apply some limits to predicted values of flow in Lanes 1 and 2 (v_{12}). The following limitations apply to all such predictions:

1. The average flow per lane in the outer lanes of the freeway (lanes other than 1 and 2) should not be higher than 2,700 pc/h/ln.
2. The average flow per lane in outer lanes should not be higher than 1.5 times the average flow in Lanes 1 and 2.

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These limits guard against cases in which the predicted value of v_1 implies an unreasonably high flow rate in outer lanes of the freeway. When either of these limits is violated, an adjusted value of v_1 must be computed and used in the remainder of the methodology.

Application to Six-Lane Freeways

On a six-lane freeway (three lanes in one direction), there is only one outer lane to consider. The flow rate in this outer lane (Lane 3) is given by Equation 13-14:

Equation 13-14

$$v_3 = v_1 - v_2$$

where

v_3 = flow rate in Lane 3 of the freeway (pc/h/ln),

v_2 = flow rate on freeway immediately upstream of the ramp influence area (pc/h), and

v_1 = flow rate in Lanes 1 and 2 immediately upstream of the same influence area (pc/h).

Then, if v_3 is greater than 2,700 pc/h, use Equation 13-15.

Equation 13-15

$$v_{12a} = v_1 - 2{,}700$$

If v_3 is greater than $1.5 \times (v_1/2)$, use Equation 13-16.

Equation 13-16

$$v_{12a} = \left(\frac{v_1}{1.75}\right)$$

where v_{12a} equals the adjusted flow rate in Lanes 1 and 2 immediately upstream of the ramp influence area (pc/h) and all other variables are as previously defined.

In cases where both limitations on outer lane flow rate are violated, the result yielding the highest value of v_{12a} is used. The adjusted value replaces the original value of v_1, and the analysis continues.

Application to Eight-Lane Freeways

On eight-lane freeways, there are two outer lanes (Lanes 3 and 4). Thus, the limiting values cited previously apply to the average flow rate per lane in these lanes. The average flow in these lanes is computed from Equation 13-17:

Equation 13-17

$$v_{34} = \frac{v_3 + v_4}{2}$$

where v_{34} equals the flow rate in outer lanes (pc/h/ln) and all other variables are as previously defined.

Then, if v_{34} is greater than 2,700, use Equation 13-18:

Equation 13-18

$$v_{12a} = v_1 - 5{,}400$$

If v_{12a} is greater than $1.5 \times (v_1/2)$, use Equation 13-19.

Equation 13-19

$$v_{12a} = \left(\frac{v_1}{2.50}\right)$$

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where all terms are as previously defined.

In cases where both limitations on ramp flow rate are violated, the result yielding the highest value of v_{12} is used. The adjusted value replaces the original value of v_{12} and the analysis continues.

Summary of Step 2

At this point, an appropriate value of v_{12} has been computed and adjusted as necessary.

Step 3: Estimate the Capacity of the Ramp–Freeway Junction and Compare with Demand Flow Rates

There are three major checkpoints for the capacity of a ramp–freeway junction:

Locations for checking the capacity of a ramp–freeway junction

1. The capacity of the freeway immediately downstream of an on-ramp or immediately upstream of an off-ramp.
2. The capacity of the ramp roadway, and
3. The maximum flow rate entering the ramp influence area.

Freeway capacity immediately downstream of an on-ramp or upstream of an off-ramp is usually the controlling capacity value.

In most cases, the freeway capacity is the controlling factor. Studies (*1*) have shown that the turbulence in the vicinity of a ramp–freeway junction does not diminish the capacity of the freeway.

Failure of a merge maneuver is usually caused by a capacity deficiency at the ramp–street terminal or on the off-ramp roadway.

The capacity of the ramp roadway is rarely a factor at on-ramps, but it can play a major role at off-ramp (diverge) junctions. Failure of a diverge junction is most often caused by a capacity deficiency on the off-ramp roadway or at its ramp–street terminal.

While this methodology establishes a maximum desirable rate of flow entering the ramp influence area, exceeding this value does not cause a failure. Instead, it means that operations may be less desirable than indicated by the methodology. At off-ramps, the total flow rate entering the ramp influence area is merely the estimated value of v_{12}. At on-ramps, however, the on-ramp flow also enters the ramp influence area. Therefore, the total flow entering the ramp influence area at an on-ramp is given by Equation 13-20:

$$v_{r(o)} = v_{12} + v_o \quad \text{Equation 13-20}$$

where $v_{r(o)}$ is the total flow rate entering the ramp influence area at an on-ramp (pc/h) and all other variables are as previously defined.

Exhibit 13-8 shows capacity values for ramp–freeway junctions. Exhibit 13-9 shows similar values for high-speed ramps on multilane highways and C-D roadways within freeway interchanges. Exhibit 13-10 shows the capacity of ramp roadways.

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Exhibit 13-8
Capacity of Ramp–Freeway Junctions (pc/h)

FFS (mi/h)	Capacity of Upstream/Downstream Freeway Segment[a] No. of Lanes in One Direction 2	3	4	>4	Max. Desirable Flow Rate (v_{MAX}) Entering Merge Influence Area[b]	Max. Desirable Flow Rate (v_{MAX}) Entering Diverge Influence Area[b]
>70	4,900	7,200	9,800	2,400/ln	4,600	4,400
65	4,700	7,050	9,400	2,350/ln	4,600	4,400
60	4,600	6,900	9,200	2,300/ln	4,600	4,400
55	4,500	6,750	9,000	2,250/ln	4,600	4,400

Notes: [a] Demand in excess of these capacities results in LOS F.
[b] Demand in excess of these values but not in excess of capacity results in LOS F; operations may be worse than predicted by this methodology.

Exhibit 13-9
Capacity of High-Speed Ramp Junctions on Multilane Highways and C-D Roadways (pc/h)

FFS (mi/h)	Capacity of Upstream/Downstream Highway or C-D Segment[a] No. of Lanes in One Direction 2	3	>3	Max. Desirable Flow Rate (v_{MAX}) Entering Merge Influence Area[b]	Max. Desirable Flow Rate (v_{MAX}) Entering Diverge Influence Area[b]
>60	4,400	6,600	2,200/ln	4,600	4,400
55	4,200	6,300	2,100/ln	4,600	4,400
50	4,000	6,000	2,000/ln	4,600	4,400
45	3,800	5,700	1,900/ln	4,600	4,400

Notes: [a] Demand in excess of these capacities results in LOS F.
[b] Demand in excess of these values but not in excess of capacity results in LOS F; operations may be worse than predicted by this methodology.

Exhibit 13-10
Capacity of Ramp Roadways (pc/h)

Ramp FFS S_{FR} (mi/h)	Capacity of Ramp Roadway Single-Lane Ramps	Two-Lane Ramps
>50	2,200	4,400
>40–50	2,100	4,200
>30–40	2,000	4,000
≥20–30	1,900	3,800
<20	1,800	3,600

Note: Capacity of a ramp roadway does not ensure an equal capacity at a freeway or other high-speed junction. Junction capacity must be checked against criteria in Exhibit 13-8 and Exhibit 13-9.

Ramp–Freeway Junction Capacity Checkpoint

As noted previously, it is generally the capacity of the upstream or downstream freeway segment that limits flow through a merge or diverge area, assuming that the number of freeway lanes entering and leaving the ramp junction is the same. In such cases, the critical checkpoint for freeway capacity is

- Immediately downstream of an on-ramp influence area (v_{12}), or
- Immediately upstream of an off-ramp influence area (v_1).

These are logical checkpoints, since each represents the point at which maximum freeway flow exists.

When a ramp junction or major merge/diverge area involves lane additions or lane drops at the junction, freeway capacity must be checked both immediately upstream and downstream of the ramp influence area.

Failure of any ramp–freeway junction capacity check results in LOS F

Failure of any ramp–freeway junction capacity check (i.e., demand exceeds capacity, or v/c is greater than 1.0) results in LOS F.

Ramp Roadway Capacity Checkpoint

The capacity of the ramp roadway should always be checked against the demand flow rate on the ramp. For one-ramp on merge junctions, this is rarely a problem. Theoretically, cases could exist in which demand exceeds capacity. A

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failure due to insufficient on-ramp capacity does not, in itself, create problems on the freeway. Rather, it would result in queuing at the street-side terminal of the ramp (or in the case of a freeway-to-freeway ramp, on the entering freeway).

At off-ramps or diverge areas, the most frequent cause of failure is insufficient capacity on the off-ramp—due to either the ramp roadway or a failure at the ramp–street terminal. This methodology checks only for the off-ramp roadway capacity. The capacity of the ramp–street junction must be evaluated by using appropriate methodologies for unsignalized intersections (Chapter 19, 20, or 21) or signalized interchange ramp terminals (Chapter 22).

If the off-ramp demand flow rate v_R exceeds the capacity of the off-ramp, LOS F prevails. If appropriate analysis results in a finding that the ramp–street terminal is operating at a v/c ratio greater than 1.00 on the ramp approach leg, a queuing analysis should be conducted to evaluate (a) the extent of the queue that is likely to exist on the ramp roadway and (b) whether the queue is close enough to the ramp–freeway junction to affect its operation negatively.

Maximum Desirable Flow Entering the Ramp Influence Area

When a checkpoint for v_R (off-ramps) or v_{FO} (on-ramps) is conducted, failure does not result in assignment of LOS F, unless another failure occurs on a ramp roadway or freeway segment. Failing this checkpoint generally means that there will be more turbulence in the ramp junction influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely higher than those that will actually occur.

Failure of the check on flow entering the ramp influence area (v_{12}, Veh) does not automatically result in LOS F, but does indicate the need for additional analysis of the results.

Step 4: Estimate Density in the Ramp Influence Area and Determine the Prevailing LOS

Once the flow rate in Lanes 1 and 2 immediately upstream of the ramp influence area is determined, the expected density in the ramp influence area can be estimated.

Density in On-Ramp (Merge) Influence Areas

The density in on-ramp influence areas is estimated with Equation 13-21.

$$D_R = 5.475 + 0.00734 v_R + 0.0078 v_{12} - 0.00627 L_A \quad \text{Equation 13-21}$$

where D_R is the density in the ramp influence area (pc/mi/ln) and all other variables are as previously defined.

The equation is logical. As more on-ramp vehicles and freeway vehicles in Lanes 1 and 2 enter the ramp influence area, its density is expected to increase. As the length of the acceleration lane increases, there is more physical space in the ramp influence area, and operating speeds of merging vehicles are expected to increase—both tending to reduce densities.

Density in Off-Ramp (Diverge) Influence Areas

The density in off-ramp influence areas is estimated with Equation 13-22:

$$D_R = 4.252 + 0.0086 v_{12} - 0.009 L_A \quad \text{Equation 13-22}$$

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where all variables are as previously defined.

This equation also follows logical trends. There is no separate term for v_R because it is included in v_F for off-ramps. As the number of vehicles entering the ramp influence area increases, density increases. As the length of the deceleration lane increases, the additional space provided and the resulting higher speeds of merging vehicles both act to reduce density.

Determining LOS

LOS in ramp influence areas is directly related to the estimated density within the area, as given by Equation 13-21 or Equation 13-22. Exhibit 13-9, shown previously, contains the criteria for this determination. Note again that density definitions of LOS apply only to stable flow (i.e., LOS A–E). LOS F exists only when the capacity of the ramp junction is insufficient to accommodate the existing or projected demand flow rate.

If it is determined that a merge or diverge segment is operating (or expected to operate at) LOS F, the analyst should go to Chapter 10, Freeway Facilities, and conduct a facility analysis that will estimate the spatial and time impacts of queuing resulting from the breakdown.

Step 5: Estimate Speeds in the Vicinity of Ramp–Freeway Junctions

While an estimation of average vehicle speeds in and adjacent to ramp influence areas is not necessary, it is often a useful additional performance measure. Two types of speeds may be estimated:

- Average speed of vehicles within the ramp influence area (mi/h), and
- Average speed of vehicles across all lanes (including outer lanes) within the 1,500-ft length of the ramp influence area (mi/h).

Both types of speeds are needed when a freeway facility analysis is conducted (Chapter 10), while the first type of speed provides a useful companion measure to density within the ramp influence area in all cases.

Exhibit 13-11 and Exhibit 13-12 provide equations for estimating the average speed of vehicles (a) within the ramp influence area and (b) in outer lanes of the freeway adjacent to the 1,500-ft ramp influence area. For four-lane freeways (two lanes in each direction), there are no "outer lanes." For six-lane freeways (three lanes in each direction), there is one outer lane (Lane 3). For eight-lane freeways (four lanes in each direction), there are two outer lanes (Lanes 3 and 4). Exhibit 13-13 provides equations to determine the average speed of all vehicles (ramp plus all freeway vehicles) within the 1,500-ft length of the ramp influence area.

Exhibit 13-11
Estimating Speed at On-Ramp (Merge) Junctions

Average Speed in	Equation	
Ramp influence area	$S_R = FFS - 15$	
	$S_R = 0.321 + 0.0039/(v_F - v_{12})^{0.75} + 0.002(v_{12}/1{,}000)$	
Outer lanes of freeway	$S_O = FFS$	$v_{12} \leq 500$ pc/h
	$S_O = FFS - 0.0086(v_{12} - 500)$	500 pc/h $< v_{12} \leq$ 2,300 pc/h
	$S_O = FFS - 0.509 - 0.0034(v_{12} - 2{,}300)$	$v_{12} >$ 2,300 pc/h

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Average Speed in	Equation
Ramp influence area	$S_R = FFS - (FFS - 42)f_R$ $f_R = 0.883 + 0.000909v_R + 0.013S_{12}$
Outer lanes of freeway	$S_O = 1.0973S$ $v_{FO} = 1,650$ pc/h $S_O = 1.0973S - 0.0039(v_{12} - 1,800)$ $v_{12} > 1,650$ pc/h

Exhibit 13-12
Estimating Speed at Off-Ramp (Diverge) Junctions

Value	Equation
Average flow in outer lanes v_{12} (pc/h)	$v_{12} = \frac{v_F - v_{23}}{N_{12}}$
Average speed for on-ramp (merge) junctions (mi/h)	$S = \frac{v_R + S_{12}N_{12} + v_{23}\left(\frac{S_{12}}{S_{23}}\right)}{v_R + v_{12} + v_{23}\left(\frac{S_{12}}{S_{23}}\right)}$
Average speed for off-ramp (diverge) junctions (mi/h)	$S = \frac{v_{12} + v_{34}N_{34}}{v_{12} + v_{34}N_{34}\left(\frac{S_{12}}{S_{34}}\right)}$

Exhibit 13-13
Estimating Average Speed of All Vehicles at Ramp–Freeway Junctions

While many (but not all) of the variables in Exhibit 13-13, Exhibit 13-12, and Exhibit 13-14 have been defined previously, all are defined here for convenience:

S_R = average speed of vehicles within the ramp influence area (mi/h); for merge areas, this includes all ramp and freeway vehicles in Lanes 1 and 2; for diverge areas, this includes all vehicles in Lanes 1 and 2,

S_{12} = average speed of vehicles in outer lanes of the freeway, adjacent to the 1,500-ft ramp influence area (mi/h);

S = average speed of all vehicles in all lanes within the 1,500-ft length covered by the ramp influence area (mi/h),

FFS = free-flow speed of the freeway (mi/h),

S_R = free-flow speed of the ramp (mi/h);

L_A = length of acceleration lane (ft),

L_D = length of deceleration lane (ft);

v_R = demand flow rate on ramp (pc/h);

v_{12} = demand flow rate in Lanes 1 and 2 of the freeway immediately upstream of the ramp influence area (pc/h);

v_{FO} = total demand flow rate entering the ramp influence area, including v_R and v_{12} (pc/h);

v_{12} = average demand flow per lane in outer lanes adjacent to the ramp influence area (not including flow in Lanes 1 and 2) (pc/h/ln);

v_F = demand flow rate on freeway immediately upstream of the ramp influence area (pc/h),

N_O = number of outer lanes on the freeway (3 for a six-lane freeway; 2 for an eight-lane freeway);

MI_R = speed index for on-ramps (merge areas); this is simply an intermediate

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computation that simplifies the equations, and

(1) = speed index for off-ramps (diverge areas), this is simply an intermediate computation that simplifies the equations.

Exhibit 13-11, Exhibit 13-12, and Exhibit 13-13 only apply to Basic Ramp conditions. Consult Chapter 10 for analysis of oversaturated conditions.

The equations in Exhibit 13-11, Exhibit 13-12, and Exhibit 13-13 apply only to cases in which operation is stable (LOS A–E). Analysis of operational details for cases in which LOS F is present relies on deterministic queuing approaches, as presented in Chapter 10, Freeway Facilities.

Flow rates in outer lanes can be higher than the values cited for basic freeway segments. The basic freeway segment values represent averages across all freeway lanes, not flow rates in a single lane or a subset of lanes. The methodology herein allows flows in outer lanes to be as high as 2,700 pc/h/ln. The equations for average speed in outer lanes were based on a database that included average outer lane flows as high as 2,088 pc/h/ln while still maintaining stable flow. Values over 2,700 pc/h/ln, however, are unusual and cannot be expected in the majority of situations.

In addition, the equations of Exhibit 13-11 do not allow a predicted speed over the FFS for merge areas. For diverge areas at low flow rates, however, the average speed in outer lanes may marginally exceed the FFS. As with average lane flow rates, the FFS is stated as an average across all lanes, and speeds in individual lanes can exceed this value. Despite this, the average speed of all vehicles *S* should be limited to a maximum value equal to the FFS.

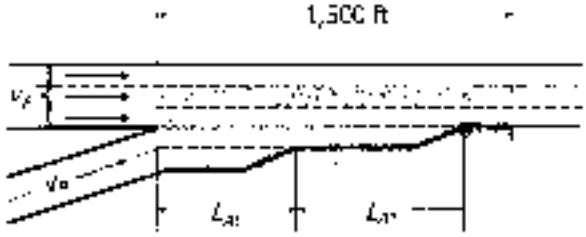
SPECIAL CASES

As noted previously, the computational procedure for ramp-freeway junctions was calibrated for single-lane, right-side ramps. Many other merge and diverge configurations may be encountered, however. In these cases, the general methodology is modified to account for special situations. These modifications are discussed in the sections that follow.

Two-Lane On-Ramps

Exhibit 13-14 illustrates the geometry of a typical two-lane ramp-freeway junction. It is characterized by two separate acceleration lanes, each successively forcing merging maneuvers to the left.

Exhibit 13-14
Typical Geometry of a Two-Lane Ramp-Freeway Junction



Two-lane on-ramps entail two modifications to the basic methodology: the flow remaining in Lanes 1 and 2 immediately upstream of the on-ramp influence area is generally somewhat higher than it is for one-lane on-ramps in similar situations, and densities in the merge influence area are lower than those for similar one-lane on-ramp situations. The lower density is primarily due to the

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existence of two acceleration lanes and the generally longer distance over which these lanes extend. Thus, two-lane on-ramps handle higher ramp flows more smoothly and at a better LOS than if the same flows were carried on a one-lane ramp–freeway junction.

Two-lane on-ramp–freeway junctions, however, do not enhance the capacity of the junction. The downstream freeway capacity still controls the total output capacity of the merge area, and the maximum desirable number of vehicles entering the ramp influence area is not changed.

There are three computational modifications to the general methodology for two-lane on-ramps.

First, while v_{12} is still estimated as $v_R \times P_{FM}$, the values of P_{FM} are modified as follows:

- For four-lane freeways: P_{FM} = 1.000;
- For six-lane freeways: P_{FM} = 0.555; and
- For eight-lane freeways: P_{FM} = 0.289.

Second, in all equations using the length of the acceleration lane L_A, this value is replaced by the effective length of both acceleration lanes L_{EA} from Equation 13-23:

$$L_{EA} = 2L_A + L_G \quad \text{Equation 13-23}$$

A two-lane ramp is always considered to be isolated (i.e., no adjacent ramp conditions affect the computation).

Component lengths are as illustrated in Exhibit 13-14.

Two-Lane Off-Ramps

Two common types of diverge geometries are in use with two-lane off-ramps, as shown in Exhibit 13-15. In the first, two successive deceleration lanes are introduced. In the second, a single deceleration lane is used. The left-hand ramp lane splits from Lane 1 of the freeway at the gore area, without a deceleration lane.

As is the case for two-lane on-ramps, there are three computational step modifications. While v_{12} is still computed as $v_{12} = (v_R + v_F) \times P_{FD}$, the values of P_{FD} are modified as follows:

- For four-lane freeways: P_{FD} = 1.000;
- For six-lane freeways: P_{FD} = 0.450; and
- For eight-lane freeways: P_{FD} = 0.260.

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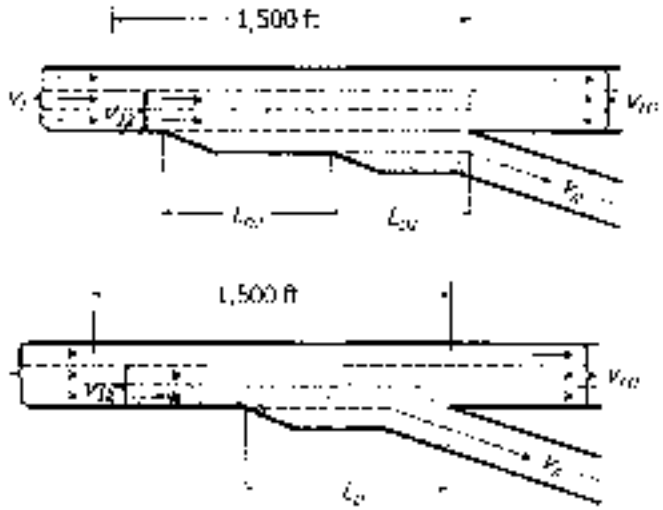
Exhibit 13-15
Common Geometries for Two-Lane Off-Ramp–Freeway Junctions



Where a single deceleration lane is used, there is no modification to the length of the deceleration lane L_d; where two deceleration lanes exist, the length is replaced by the effective length L_{ea} in all equations, obtained from Equation 13-24:

Equation 13-24

$$L_{ea} = 2L_d + L_{d2}$$

A two-lane ramp is always considered to be isolated (i.e., no adjacent ramp conditions affect the computation).

Component lengths are as illustrated in Exhibit 13-15.

The capacity of a two-lane off-ramp is essentially equal to that of a single two-lane off-ramp.

The capacity of a two-lane off-ramp freeway junction is essentially equal to that of a similar one-lane off-ramp; that is, the total flow capacity through the diverge is unchanged. It is limited by the upstream freeway, the downstream freeway, or the off-ramp capacity. While the capacity is not affected by the presence of two-lane junctions, the lane distribution of vehicles is more flexible than in a similar one-lane case. The two-lane junctions may also be able to accommodate a higher off-ramp flow than can a single-lane off-ramp.

Left-Hand On- and Off-Ramps

While they are not commonly accommodated, left-hand ramps (freeway continues to exist on same freeways, and they occur frequently on C-D roadways. The left-hand ramp influence area covers the same 1,500-ft length as that of right-hand ramps—upstream of off-ramps, downstream of on-ramps.

For right-hand ramps, the ramp influence area involves Lanes 1 and 2 of the freeway. For left-hand ramps, the ramp influence area involves the two leftmost lanes of the freeway. For four-lane freeways (two lanes in each direction), this does not involve any changes, since only Lanes 1 and 2 exist. For six-lane freeways (three lanes in each direction), the flow in Lanes 2 and 3 (v_{12}) is involved. For eight-lane freeways (four lanes in each direction), the flow in Lanes 3 and 4 (v_{34}) is involved.

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While there is no direct methodology for the analysis of left-hand ramps, some rational modifications can be applied to the right-hand ramp methodology to produce reasonable results (3).

It is suggested that analysts compute v_{12} as if the ramp were on the right. An estimate of the appropriate flow rate in the two leftmost lanes is then obtained by multiplying the result by the adjustment factors shown in Exhibit 13-16.

Freeway Size	Adjustment Factor for Left-Hand Ramps	
	On-Ramps	Off-Ramps
Four-lane	1.00	1.00
Six-lane	1.12	1.05
Eight-lane	1.20	1.10

Exhibit 13-16
Adjustment Factors for Left-Hand Ramp–Freeway Junctions

The remaining computations for density and speed determination by using the values of v_{12} (six-lane freeways) or v_{34} (eight-lane freeways) as appropriate. All capacity values remain unchanged.

Ramp–Freeway Junctions on 10-Lane Freeways (Five Lanes in Each Direction)

Freeway segments with five continuous lanes in a single direction are becoming more common in North America. A procedure is therefore needed to analyze a single-lane, right-hand on- or off-ramp on such a segment.

The approach taken is relatively simple: estimate the flow in Lane 5 of such a segment and deduct it from the approaching freeway flow v_f. With the Lane 5 flow deducted, the segment can now be treated as if it were an eight-lane freeway (4). Exhibit 13-17 shows the recommended values for flow rate in Lane 5 of these segments.

On-Ramps		Off-Ramps	
Approaching Freeway Flow v_f (pc/h)	Approaching Lane 5 Flow v_5 (pc/h)	Approaching Freeway Flow v_f (pc/h)	Approaching Lane 5 Flow v_5 (pc/h)
≥8,500	2,500	≥7,000	0.200 v_f
7,500–8,499	0.265 v_f	5,500–6,999	0.150 v_f
6,500–7,499	0.270 v_f	4,000–5,499	0.100 v_f
5,500–6,499	0.240 v_f	<4,000	0
<5,500	0.220 v_f		

Exhibit 13-17
Expected Flow in Lane 5 of a 10-Lane Freeway Immediately Upstream of a Ramp–Freeway Junction

Once the expected flow in Lane 5 is determined, the effective total freeway flow rate in the remaining four lanes is computed from Equation 13-25.

$$v_{f(4)} = v_f - v_5 \quad \text{Equation 13-25}$$

where

$v_{f(4)}$ = effective approaching freeway flow in four lanes (pc/h),

v_f = total approaching freeway flow in five lanes (pc/h), and

v_5 = estimated approaching freeway flow in Lane 5 (pc/h).

The remainder of the analysis uses the adjusted approaching freeway flow rate and treats the geometry as if it were a single-lane, right-hand ramp junction on an eight-lane freeway (four lanes in each direction).

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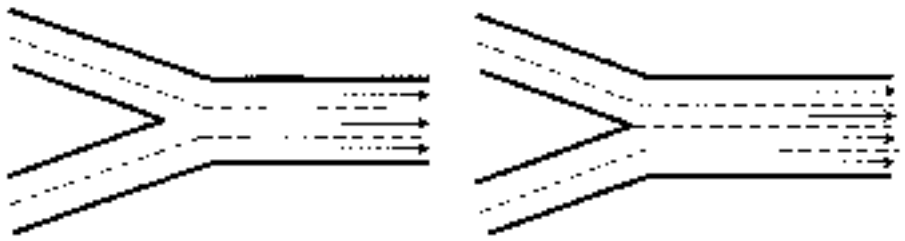
There is no calibrated procedure for adapting the methodology of this chapter to freeways with more than five lanes in one direction. The approach of Equation 13-25 is, however, conceptually adaptable to such situations. A local calibration of the amount of traffic using Lanes 5+ would be needed. The remaining flow could then be modeled as if it were taking place on a four-lane (one direction) segment.

Major Merge Areas

A major merge area is one in which two primary roadways, each having multiple lanes, merge to form a single freeway segment. Such junctions occur when two freeways join to form a single freeway or when a major multilane high-speed ramp joins with a freeway. Major merges are different from one- and two-lane on ramps in that each of the merging roadways is generally at or near freeway design standards and no clear ramp or acceleration lane is involved in the merge.

Such merge areas come in a variety of geometries, all of which fall into one of two categories. In one geometry, the number of lanes leaving the merge area is one less than the total number of lanes entering it. In the other, the number of lanes leaving the merge area is the same as that entering it. These geometries are illustrated in Exhibit 13-18.

Exhibit 13-18
Major Merge Areas Illustrated



(a) Major Merge with One Lane Dropped (b) Major Merge with No Lane Dropped

There are no effective models of performance for a major merge area. Therefore, analysis is limited to checking capacities on the approaching legs and the downstream freeway segment. A merge failure would be indicated by a v/c ratio in excess of 1.00. LOS cannot be determined for major merge areas. Problems in major merge areas usually result from insufficient capacity of the downstream freeway segment.

LOS cannot be determined for major merge areas.

Major Diverge Areas

The two common geometries for major diverge areas are illustrated in Exhibit 13-19. In the first case, the number of lanes leaving the diverge area is the same as the number entering it. In the second, the number of lanes leaving the diverge area is one more than the number entering it.

The principal analysis of a major diverge area involves checking the capacity of entering and departing roadways, all of which are generally built to mainline standards. A failure results when any of the demand flow rates exceeds the capacity of the segment.

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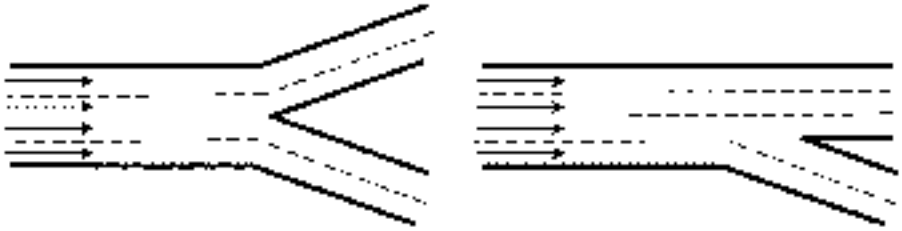

(a) Major Diverge Area with No Lane Addition (b) Major Diverge Area with Lane Addition

Exhibit 13-19
Major Diverge Areas Illustrated

For major diverge areas, a model exists for computing the average density across all approaching freeway lanes within 1,500 ft of the diverge, as given in Equation 13-26.

$$D_{MD} = 0.0175\left(\frac{v_f}{N}\right) \quad \text{Equation 13-26}$$

where

D_{MD} = density in the major diverge influence area (which includes all approaching freeway lanes) (pc/mi/ln),

v_f = demand flow rate immediately upstream of the major diverge influence area (pc/h), and

N = number of lanes approaching the major diverge.

The result can be compared with the criteria of Exhibit 13-2 to determine a LOS for the major diverge influence area. Note that the density and LOS estimates are only valid for stable cases (i.e., not in cases in which LOS F exists because of a capacity deficiency on the approaching or departing legs of the diverge).

Effect of Ramp Control at On-Ramps

For the purposes of this methodology, procedures are not modified in any way to account for the local effect of ramp control. Except for the limitation that the ramp meter may have on the ramp demand flow rate. Research (5) has found that the breakdown of a merge area may be a probabilistic event based on the platoon characteristics of the arriving ramp vehicles. Ramp meters can dictate uniform gaps between entering ramp vehicles and may reduce the probability of a breakdown on the associated freeway mainline.

OVERLAPPING RAMP INFLUENCE AREAS

Whenever a series of ramps on a freeway is analyzed, the 1,500-ft ramp influence areas could overlap. In such cases, the operation in the overlapping region is determined by the ramp influence area having the highest density.

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3. APPLICATIONS

The methodology of this chapter is most often used to estimate the capacity and LOS of ramp–freeway junctions. The steps are most easily applied in the operational analysis mode (i.e., all traffic and roadway conditions are specified), and the capacity (and v/c ratio) and expected LOS are found. Other types of analysis, however, are possible.

DEFAULT VALUES

A comprehensive presentation of potential default values for uninterrupted-flow facilities is provided elsewhere (6). Chapter 10, Freeway Facilities, provides a summary of the default values for freeways. These defaults cover the key characteristics of peak hour factor (PHF) and percent heavy vehicles (%HV) on freeways. Recommendations are based on geographical region, population, and time of day. All general freeway default values may be applied to the analysis of ramp–freeway junctions in the absence of field data or projections of conditions.

Because of the number of variables involved in the analysis of ramps, which have been discussed previously, it is difficult to base an analysis on too many default values. Clearly, all demand flow rates must be specified, even if they are projections.

Basic geometric characteristics cover a variety of conditions; default values should be avoided if possible.

Similarly, geometric characteristics of ramps cover a wide variety of conditions. If absolutely necessary, the following additional default values may be applied to a ramp junction analysis:

- Length of acceleration lane L_A = 800 ft.
- Length of deceleration lane L_D = 400 ft.
- FFS of ramp S_{FR} = Straight and
- Driver population factor f_P = 1.00.

Obviously, as the number of default values used in any analysis increases, the accuracy of the result becomes more approximate, and the result may be significantly different from the actual outcome (depending on local conditions). If locally calibrated default values are available, they may be substituted for the values above.

ESTABLISH ANALYSIS BOUNDARIES

No ramp–freeway junction is completely isolated. However, for the purposes of this methodology, many may operate as if they were. In the analyses of ramp–freeway junctions, it is important to establish the segment of freeway over which ramp–junctions are to be analyzed. Once this is done, each ramp may be analyzed in conjunction with the possible impacts of upstream and downstream adjacent ramps according to the methodology.

Analysis boundaries may also include different demand scenarios related to the time of the day or to different development scenarios that produce different demand flow rates.

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Any application of the methodology presented in this chapter can be made easier by carefully defining the spatial and time boundaries of the analysis.

TYPES OF ANALYSIS

The methodology of this chapter can be used in three types of analysis: operational analysis, design analysis, and planning and preliminary design analysis.

Operational Analysis

Operational analysis determines density, LOS, and speed within the merge influence area for a specified set of conditions.

The methodology is most easily applied in the operational analysis mode. In operational analysis, all traffic and geometric characteristics of the analysis segment must be specified, including:

- Analysis hour demand volumes for the subject ramp, adjacent ramps, and freeway (veh/h);
- Heavy vehicle percentages for all component demand volumes (ramps, adjacent ramps, freeway);
- PHF for all component demand volumes (ramp, adjacent ramps, freeway);
- Freeway terrain (level, rolling, mountainous, specific grade);
- FFS of the freeway and ramp (mi/h);
- Ramp geometrics: number of lanes, terrain, length of acceleration lane(s) or deceleration lane(s), and
- Distance to upstream and downstream adjacent ramps (ft).

The outputs of an operational analysis will be estimates of density, LOS, and speed for the ramp influence area. The capacity of the ramp–freeway junction will also be established.

The steps of the methodology, described in the Methodology section, are to be followed directly without modification.

Design Analysis

Design analysis is used to determine the geometric characteristics of the ramp that are needed to deliver a target LOS.

In design analysis, a target LOS is set and all relevant demand volumes are specified. The analysis seeks to determine the geometric characteristics of the ramp that are needed to deliver the target LOS. These characteristics include:

- FFS of the ramp S_R (mi/h),
- Length of acceleration L_A or deceleration lane L_D (ft), and
- Number of lanes on the ramp.

In some cases, variables such as the type of junction (e.g., major merge, two-lane) may also be under consideration.

There is no convenient way to compute directly the optimal value of any one variable without specifying all of the others. Even then, the computational methodology does not easily create the desired result.

Therefore, most design analysis becomes a trial and error application of the operational analysis procedure. Individual characteristics can be incrementally

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changed, as can groups of characteristics, to find scenarios that produce the desired LOS.

In many cases, some of the variables may be fixed by site-specific conditions. These can be set at their limiting values before attempting to optimize the others.

It is possible to program a spreadsheet to complete such an analysis, providing scenario results by simply changing some of the input variables under consideration. HCM-implementing software can also be used to simplify the computational process.

Planning and Preliminary Engineering Analysis

Planning and preliminary engineering analysis also seeks to determine the geometric characteristics of the ramp that are needed to achieve a target LOS, but it relies on more general input data.

The desired outputs of planning and preliminary engineering analysis are virtually the same as those for design analysis. The primary difference is that planning and preliminary engineering analysis occurs very early in the process of project consideration.

The first criterion that categorizes such applications is the need to use more general estimates of input data. Many of the default values specified for freeway facilities in Chapter 10 would be applied. Alternatively, local default values can be substituted. Demand volumes might be specified only as expected values of annual average daily traffic (AADT) for a target year. Directional design-hour volumes are based on AADTs, default (local or global) values are used for the K-factor (the proportion of AADT occurring in the peak hour) and the D-factor (the proportion of peak hour traffic traveling in the peak direction). Guidance on these values is given in Chapter 3, Modal Characteristics.

On the basis of these default and estimated values, the analysis is conducted in the same manner as a design analysis.

Service Volumes and Service Flow Rates

The method can be applied to determine service volumes for LOS A–E for a specified set of conditions.

Service volume is the maximum hourly volume that can be accommodated without exceeding the limits of the various levels of service during the worst 15 min of the analysis hour. Service volumes can be found for LOS A–E. LOS F, which represents unstable flow, does not have a service volume.

Service flow rates are the maximum rates of flow (within a 15-min period) that can be accommodated without exceeding the limits of the various levels of service. As is the case for service volumes, service flow rates can be found for LOS A–E, but none is defined for LOS F. The relationship between service volume and service flow rate is as follows:

Equation 13-27

$$SV_i = SF_i \times PHF$$

where

SV_i = service volume for LOS i (pc/h),

SF_i = service flow rate for LOS i (pc/h), and

PHF = peak hour factor.

For ramp–freeway junctions, service flow rate or service volume could be defined in several ways. It might be argued that since ramp–freeway junction capacities are usually limited by the upstream or downstream freeway segment,

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service flow rates and service volumes should be based on basic freeway criteria applied to the upstream or downstream freeway segments. This, however, would ignore the levels of service defined for the ramp influence area, which are the only unique service descriptors for ramps.

Levels of service for ramp–freeway junctions are defined in Exhibit 13-2 and relate to the density within the ramp influence area. The methodology estimates this density by using a series of algorithms affected by demand flows on the freeway, ramp, and adjacent ramps, ramp geometrics, and distances to adjacent ramps. The methodology uses demand volumes in vehicles per hour converted to demand flow rates in passenger cars per hour. Therefore, service flow rates and service volumes would originally be estimated in terms of flow rates in passenger cars per hour. They would then be converted back to demand volumes in vehicles per hour.

Because the balance of ramp and freeway demands has a significant impact on densities, there are a number of ways in which service flow rates and volumes can be considered:

- The limiting total upstream demand volume that produces a given LOS within the ramp influence area. The split between arriving freeway volume and ramp volume would have to be specified.
- The limiting volume entering the ramp influence area that produces a given LOS within the ramp influence area. Since this relies on the approaching freeway volume, the split between freeway and ramp demand would still have to be specified.
- The limiting ramp volume that produces a given LOS within the ramp influence area, based on a fixed upstream freeway demand.

Any of these are viable concepts for establishing a ramp service flow rate or service volume.

A number of factors influence the service volume to flow rate result, each of which must be individually considered.

In addition to different ways of interpreting a service volume or service flow rate, a large number of characteristics will influence the result, including the PHF, %HV, length of acceleration or deceleration lane(s), ramp FFS, and any relevant data for adjacent ramps. It is, therefore, virtually impossible to define a representative "typical" case with broadly applicable results. Each case must be individually considered.

The Example Problems section includes an example of how ramp junction service flow rates and service volumes can be computed.

USE OF ALTERNATIVE TOOLS

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools. This section contains specific guidance for applying alternative tools to the analysis of ramps and ramp junctions. Additional information on this topic may be found in the Volume 4 Technical Reference Library.

The HCM methodology for analyzing merge and diverge segments estimates the density of the ramp influence area (which includes the two rightmost lanes of the freeway and the acceleration or deceleration lane) and provides the

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respective LOS. As an intermediate step, the methodology estimates the capacity at various points through the section, and if the capacity is exceeded, the LOS is determined to be F without further calculation of density. The methodology is primarily based on the estimation of the demand onto the influence area.

Strengths of the HCM Procedure

This chapter's procedures were developed on the basis of extensive research supported by a significant quantity of field data. They have evolved over a number of years and represent a body of expert consensus. Most simulation packages will not include the level of detail present in this methodology concerning the ramp itself and its adjacent upstream and downstream ramps.

The HCM procedure's strengths are as follows:

- The methodology provides capacity estimates. Simulators do not provide capacity estimates directly; they can be obtained by developing a data collection scheme in the simulator. Furthermore, the user can modify those simulated capacities by modifying specific input values, such as the minimum acceptable headway.
- The methodology explicitly considers the impacts of the presence of and demands on the upstream and downstream ramps.
- It produces a single deterministic estimate of density, which is important for some purposes, such as development impact review.

Limitations of the HCM Procedures That Might Be Addressed by Alternative Tools

A list of the HCM's limitations for freeway merge and diverge segments is provided in Exhibit 13-20.

Exhibit 13-20
Limitations of the HCM Ramps and Ramp Junctions Procedure

Limitation	Potential for Improved Treatment by Alternative Tools
Managed lanes, such as HOV lanes, as ramp entrance lanes	Modeled explicitly by simulation
Ramp metering	Modeled explicitly by simulation
Oversaturated conditions *(Refer to Chapter 10 for further discussion)*	Modeled explicitly by simulation
Posted speed limit and amount of police enforcement	Can be approximated by using assumptions related to the desired speed along a given segment
Presence of intelligent transportation system features	Several features modeled explicitly by simulation; others may be approximated by using assumptions (for example, by modifying origin–destination demands by time interval)
Freeway operational analysis beyond the 1,500-ft area of influence	Modeled explicitly by simulation
Capacity-enhancing effects of ramp metering	Can be approximated by using assumptions related to car-following, lane-changing, and gap-acceptance behavior

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Ramp junctions can also be analyzed with a variety of stochastic and deterministic simulation packages that address freeways. These packages can be useful in analyzing the extent of congestion when there are failures either within or downstream of the simulated facility range.

Additional Features and Performance Measures Available From Alternative Tools

This chapter provides a methodology for estimating the capacity, speed, and density in the area of influence of on- and off-ramps, given traffic demands and segment characteristics. Alternative tools offer additional performance measures including delay, stops, queue lengths, fuel consumption, pollution, and operating costs.

As with most other HCM procedural chapters, simulation outputs, especially graphics-based presentations, can provide details on point problems that might otherwise go undetected with a macroscopic analysis that yields only segment-level measures. The effects of downstream conditions on lane utilization and backup beyond the segment boundary is a good example of a situation that can benefit from the increased insight offered by a microscopic model.

Development of HCM-Compatible Performance Measures Using Alternative Tools

The subject of performance-measure comparisons was discussed in more detail in Chapter 7, Interpreting HCM and Alternative Tool Results. This section deals with topics that apply specifically to ramps and ramp junctions.

When alternative tools are used, the analyst must be careful to note the definitions of simulation outputs. This chapter's measure of effectiveness for ramps and ramp junctions is the density of the ramp influence area. However, most simulators do not provide density estimates separately for the two right-most lanes within a link. This is a potentially significant obstacle in obtaining the service measures for ramp junctions from a simulator (unless the freeway has only two lanes per direction). Furthermore, at a simulator, there are lane changes along the entire segment. Therefore, it is not clear how a simulator should address the partial presence of vehicles in the link to ensure compatibility with the HCM. Also, as is generally the case for basic freeway segments, increased speed variability in driver behavior (which simulators usually include) results in lower average space mean speed and higher density.

Most simulation packages do not provide separate density estimates for the two right-most lanes within a link, which is a potentially significant obstacle in obtaining service measures.

In obtaining density from alternative models, it is important to consider the following:

- The ability of the simulator to provide density for the two rightmost lanes of the freeway;
- The vehicles included in the density estimation and how partial presence of vehicles on the link is considered;
- The manner in which the acceleration and deceleration lanes are considered in the density estimation;
- The units used by the simulator to measure density (most use vehicles rather than passenger cars); converting vehicles to passenger cars by using

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the HCM's passenger-car equivalence (PCE) values is typically not appropriate, given that simulator assumptions with regard to heavy vehicle performance vary widely].

- The units used in the reporting of density (i.e., whether density is reported per lane or not);
- The homogeneity of the analysis segment in the simulator, as the HCM assumes conditions to be homogeneous unless it is a specific upgrade or downgrade segment, in which case the segment length is used to estimate the PCE values); and
- The treatment of driver variability by the simulator, as increased driver variability in the simulator will generally increase the average density.

With regard to capacity, the HCM provides capacity estimates in units of passenger cars per hour per lane as a function of FFS for the locations approaching and departing the merge junction. In comparing the HCM estimates with capacity estimates from a simulator, the following should be considered:

- The manner in which a simulator provides the number of vehicles exiting a segment. In some cases it may be necessary to provide "virtual" detectors at specific points on the simulated segment so that the maximum throughput can be obtained.
- The simulator provides the maximum throughput at a particular location in units of vehicles, rather than passenger cars. Converting these units to passenger cars by using the HCM's PCE values is typically not appropriate, given that simulator assumptions with regard to heavy vehicle performance vary widely.
- A simulator will likely include inputs such as the "minimum separation of vehicles," which greatly affects the maximum throughput.

Conceptual Differences Between the HCM and Simulation Modeling That Preclude Direct Comparison of Results

Ramp junction density does not change with FFS in the HCM method, but density is a function of FFS on most simulation roadways.

In the HCM, the density at a ramp junction does not change with FFS, although density drops as a function of FFS on basic freeway segments. In simulators, the density typically changes as a function of FFS (or the desired speed). Therefore, calibration of a site using a specific FFS does not necessarily ensure that the site will be calibrated for a different FFS. Capacity, on the other hand, increases in the HCM with increasing FFS, which is typically the case with simulators.

The HCM method is based on the estimated demand approaching the ramp influence area. This demand is estimated as a function of the presence of and demands on the upstream and downstream ramps. Traffic simulators do not typically allow the user to input the specific percentages of traffic on each lane at the beginning of a link. Their internal rules relative to the lane chosen by a vehicle in a given link vary widely and can be modified by changing various default values within the simulator. In some simulators, virtual vehicles are "aware" of their ultimate destination; in others, the exit choice is made on a link-by-link basis. However, in comparing HCM results with those of a simulator, the

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analyst should, as an intermediate check, compare the flow approaching the two rightmost lanes of the junction.

Adjustment of Simulation Parameters to the HCM Results

The most important elements to be adjusted in analyzing a ramp junction are as follows:

- The flow approaching the two rightmost lanes (this is an intermediate step but would ensure that the influence of upstream and downstream ramps is considered in a manner compatible with the HCM), and
- The capacity of the junction at the critical locations indicated in the HCM (i.e., downstream of the junction and approaching the influence area).

Step-by-Step Recommendations for Applying Alternative Tools

The following steps are recommended when an alternative tool is applied to the analysis of ramps and ramp junctions.

1. Determine whether the chosen tool can provide density for the two rightmost lanes of the freeway and what approach is used to obtain it (including the treatment of the partial presence of vehicles on the link).
2. Determine the FFS of the study site, either from field data or by estimating it according to the Chapter 11 method for basic freeway segments.
3. Enter all available input characteristics (both geometric and traffic characteristics) into the simulator. The length of the segment or link to be simulated should be 1,500 ft, to correspond to the HCM-defined area of influence. Install virtual detectors within the area of influence and at the downstream end of the study segment to obtain density, speeds, and flows.
4. Load the study network above capacity to obtain the maximum throughput, and compare the result with the HCM estimate. Calibrate the simulator by modifying parameters related to the minimum time headway so that the simulated capacity matches the HCM estimate. Estimate the required number of simulation runs that will need to be conducted to produce a statistically valid comparison.
5. Compare the flow approaching the two rightmost lanes with the HCM's estimate. Adjust the simulation parameters related to driver awareness of upcoming lanes to match the HCM-predicted v_{12} value.

Example Problems Illustrating Alternative Tool Applications

Chapter 28, Freeway Merges and Diverges Supplemental, includes two example problems that examine situations beyond the scope of this chapter's methodology by using a typical microsimulation-based tool. Both problems are based on this chapter's Example Problem 3, which analyzes an eight-lane freeway segment with an entrance and an exit ramp. The first problem evaluates the effects of the addition of ramp metering, while the second evaluates the impacts of converting the leftmost lane of the mainline into an HOV lane.

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4. EXAMPLE PROBLEMS

Exhibit 13-21
List of Example Problems

Example Problem	Title	Type of Analysis
1	Isolated One-Lane, Right-Hand On-Ramp to a Four-Lane Freeway	Operational analysis
2	Two Adjacent Single-Lane, Right-Hand Off-Ramps on a Six-Lane Freeway	Operational analysis
3	One-Lane On-Ramp Followed by a One-Lane Off-Ramp on an Eight-Lane Freeway	Operational analysis
4	Single-Lane, Left-Hand On-Ramp on a Six-Lane Freeway	Special case
5	Service Flow Rates and Service Volumes for an Isolated On-Ramp on a Six-Lane Freeway	Service flow rates and service volumes

EXAMPLE PROBLEM 1: ISOLATED ONE-LANE, RIGHT-HAND ON-RAMP TO A FOUR-LANE FREEWAY

The Facts

The following data are available to describe the traffic and geometric characteristics of this location:

- Isolated location (no adjacent ramps to consider)
- One-lane ramp roadway and junction
- Four-lane freeway (two lanes in each direction)
- Upstream freeway demand volume = 2,610 veh/h
- Ramp demand volume = 550 veh/h
- 10% trucks, 0% RVs on the freeway
- 5% trucks, 0% RVs on the ramp
- Acceleration lane = 240 ft
- FFS, freeway = 60 mi/h
- FFS, ramp = 45 mi/h
- Level terrain for freeway and ramp
- Peak hour factor = 0.90
- Drivers are regular commuters

Comments

All input parameters are known, so no default values are needed or used. Adjustment factors for heavy vehicles and driver population are found in Chapter 11, Basic Freeway Segments.

Step 1: Convert Demand Volumes to Flow Rates Under Equivalent Ideal Conditions by Using Equation 13-1

$$v = \frac{V}{PHF \times f_{HV} \times f_p}$$

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Demand volumes are given for the freeway and the ramp. The PHF is specified. The driver population factor for commuters is 1.00 (Chapter 11), while the heavy vehicle adjustment factor is computed as follows:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) - P_R(E_R - 1)}$$

Truck and RV presence is given. The value of E_T for level terrain is 1.5 (Chapter 11). On the basis of these values, the freeway and ramp demand volumes are converted as follows:

For the freeway:

$$f_{HV} = \frac{1}{1 + 0.10\,(1.5 - 1)} = 0.952$$

$$v_i = \frac{2{,}500}{0.90 \times 0.952 \times 1.00} = 2{,}918 \text{ pc/h}$$

For the ramp:

$$f_{HV} = \frac{1}{1 + 0.05\,(1.5 - 1)} = 0.976$$

$$v_i = \frac{550}{0.90 \times 0.976 \times 1.00} = 626 \text{ pc/h}$$

Step 2: Compute Demand Flow in Lanes 1 and 2 Immediately Upstream of the Ramp Influence Area with Equation 13-2 and Exhibit 13-6

$$v_{12} = v_i \times P_{FM}$$

The freeway flow rate was computed in Step 1. The value of P_{FM} is found in Exhibit 13-6. For a four-lane freeway, the value is 1.00. Then:

$$v_{12} = 2{,}918 \times 1.00 = 2{,}918 \text{ pc/h}$$

Because there are no auxiliary lanes on a four-lane freeway, there is no need to check this result for reasonableness.

Step 3: Check Capacities by Using Exhibit 13-8 and Exhibit 13-10

The critical capacity checkpoint for a single-lane on-ramp is the downstream freeway segment:

$$v_{FO} = v_i + v_R = 2{,}918 + 626 = 3{,}544 \text{ pc/h}$$

The capacity of a four-lane freeway (two lanes in one direction) with an FFS of 60 mi/h is given in Exhibit 13-8. The capacity is 4,600 pc/h, which is more than the demand flow of 3,544 pc/h. The capacity of a one-lane ramp with an FFS of 45 mi/h is given in Exhibit 13-10 as 2,000 pc/h, which is well in excess of the ramp demand flow of 626 pc/h. The maximum desirable flow rate entering the ramp influence area is also 4,600 pc/h, again more than 3,544. Thus, the operation of the segment is expected to be stable. LOS F does not exist.

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Step 4: Compute Density and Find LOS by Using Equation 13-21 and Exhibit 13-2

The estimated density in the ramp–freeway junction is estimated by using Equation 13-21:

$$D_R = 5.475 + 0.00734v_{12} + 0.0078v_{34} - 0.00627L_A$$

$$D_R = 5.475 + (0.00734 \times 626) + (0.00078 \times 2{,}918) - (0.00627 \times 740) = 25.2 \text{ pc/mi/ln}$$

From Exhibit 13-2, this is LOS D, but the result is close to the LOS C boundary.

Step 5: Compute Merge Area Speed as Supplemental Information by Using Exhibit 13-11

Since there are no auxiliary lanes present on a four-lane freeway, only the speed within the ramp influence area should be computed:

$$S_R = FFS - (FFS - 42)M_s$$

$$M_s = 0.321 + 0.0039e^{-20.1(L_A S_{FR}/1{,}000)} - 0.002(L_A S_{FR}/1{,}000)$$

$$M_s = 0.321 + 0.0039e^{-20.1(740 \times 45/1{,}000)} - 0.002(740 \times 45/1{,}000) = 0.389$$

$$S_R = 60 - (60 - 42) \times 0.389 = 53.0 \text{ mi/h}$$

Discussion

The results indicate that the merge area operates in a stable fashion, with some deterioration in density and speed due to merging operations.

EXAMPLE PROBLEM 2: TWO ADJACENT SINGLE-LANE, RIGHT-HAND OFF-RAMPS ON A SIX-LANE FREEWAY

The Facts

The following information concerning demand volumes and geometrics is available for this problem:

- Two consecutive one-lane, right-hand off-ramps
- Six-lane freeway with FFS = 60 mi/h
- Rolling terrain for freeway and both ramps
- 5% trucks on freeway and both ramps; 0% RVs
- First ramp FFS = 40 mi/h
- Second ramp FFS = 25 mi/h
- Drivers are regular commuters
- Freeway demand volume = 4,500 veh/h (immediately upstream of the first off-ramp)
- First ramp demand volume = 300 veh/h
- Second ramp demand volume = 500 veh/h
- Distance between ramps = 750 ft
- First ramp deceleration lane length = 500 ft

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- Second ramp deceleration lane length = 300 ft
- Peak hour factor = 0.95

Comments

The solution will use adjustment factors for heavy vehicle presence and driver population selected from Chapter 11, Basic Freeway Segments. All input parameters are specified, so no default values are needed or used.

Step 1: Convert Demand Volumes to Flow Rates Under Equivalent Ideal Conditions by Using Equation 13-1

$$v = \frac{V}{PHF \times f_{HV} \times f_p}$$

In this case, three demand volumes must be converted: the freeway volume immediately upstream of the first ramp and the two ramp demand volumes. Since all demands include 5% trucks and no RVs, only a single heavy vehicle adjustment factor will be needed. From Chapter 11, the appropriate value of E_T for rolling terrain is 2.5. For drivers who are regular commuters, the appropriate value of f_p is 1.00.

Then

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{HV} = \frac{1}{1 + 0.05(2.5 - 1)} = 0.930$$

and

$$v = \frac{V}{PHF \times f_{HV} \times f_p}$$

$$v_1 = \frac{4,500}{0.95 \times 0.930 \times 1.00} = 5,093 \text{ pc/h}$$

$$v_{r1} = \frac{300}{0.95 \times 0.930 \times 1.00} = 340 \text{ pc/h}$$

$$v_{r2} = \frac{500}{0.95 \times 0.930 \times 1.00} = 566 \text{ pc/h}$$

Step 2: Compute Demand Flow in Lanes 1 and 2 Immediately Upstream of the Two Ramp Influence Areas by Using Equation 13-13 and Exhibit 13-7

Because there are two consecutive off-ramps under consideration, the first will have to consider the impact of the second on its operations, and the second will have to consider the impact of the first.

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First Off Ramp

From Exhibit 13-7, flow in Lanes 1 and 2 of the freeway is estimated by using Equation 13-11 or Equation 13-9, depending on whether the impact of the downstream off-ramp is significant. This is determined by comparing the equivalence distance by using Equation 13-13:

$$L_{EQ} = \frac{v_{12}}{1.15 + 0.000032v_3 - 0.000369v_R}$$

$$L_{EQ} = \frac{566}{1.15 - (0.000032 \times 5{,}093) - (0.000369 \times 340)} = 657 \text{ ft}$$

Since the actual distance between ramps, 750 ft, is greater than the equivalence distance of 657 ft, the ramp may be treated as if it were isolated, with Equation 13-9:

$$P_{FM} = 0.760 - 0.000025v_3 - 0.000046v_R$$

$$P_{FM} = 0.760 - (0.000025 \times 5093) - (0.000046 \times 340) = 0.617$$

Then

$$v_{12} = v_R + (v_3 - v_R)P_{FM}$$

$$v_{12} = 340 + (5{,}093 - 340) \times 0.617 = 3{,}273 \text{ pc/h}$$

Because a six-lane freeway includes one outer lane (Lane 6), the reasonableness of the predicted lane distribution of arriving freeway vehicles should be checked. The flow rate in Lane 3 is 5,093 – 3,273 = 1,820 pc/h. The average flow per lane in Lanes 1 and 2 is 3,273/2 = 1,637 pc/h (rounded to the nearest pc). Then:

Is $v_3 > 2{,}700$ pc/h/ln? **No**

Is $v_3 > 1.5 \times (1{,}637) = 2{,}456$ pc/h/ln? **No**

Since both checks for reasonable lane distribution are passed, the computed value of v_{12} for the first off-ramp is accepted as 3,273 pc/h.

Second Off-Ramp

From Exhibit 13-7, the second off-ramp should be analyzed by using Equation 13-9, which is for an isolated off-ramp. Adjacent upstream off-ramps do not affect the lane distribution of arriving vehicles at a downstream off-ramp.

The freeway flow approaching Ramp 2, however, includes the freeway flow approaching Ramp 1, less the flow rate of vehicles exiting the freeway at Ramp 1. Therefore, the freeway flow rate approaching Ramp 2 is as follows:

$$v_3 = 5{,}093 - 340 = 4{,}753 \text{ pc/h}$$

Then

$$P_{FM} = 0.760 - (0.000025 \times 4753) - (0.000046 \times 566) = 0.615$$

$$v_{12} = 566 + (4{,}753 - 566) \times 0.615 = 3{,}141 \text{ pc/h}$$

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Again, because there is an outer lane on a six-lane freeway, the reasonableness of this estimate must be checked. The flow rate in the outer lane (v_3) is 4,753 − 3,141 = 1,612 pc/h. The average flow rate in Lanes 1 and 2 is 3,141/2 = 1,571 pc/h/ln (rounded). Then

Is $v_3 > 2{,}700$ pc/h/ln?	No
Is $v_3 > 1.3 \times 1{,}571 = 2{,}357$ pc/h/ln?	No

Once again, the predicted lane distribution of arriving vehicles is reasonable, and v_{12} is taken to be 3,141 pc/h.

Step 3: Check Capacities by Using Exhibit 13-8 and Exhibit 13-10

Because two off-ramps are involved in this segment, there are several capacity checkpoints:

- Total freeway flow upstream of the first off-ramp (the point at which maximum freeway flow exists),
- Capacity of both off-ramps, and
- Maximum desirable flow rates entering each of the two off-ramp influence areas.

These comparisons are shown in Exhibit 13-22. Note that freeway capacity is based on a freeway with FFS = 60 mi/h. The first ramp capacity is based on a ramp FFS of 40 mi/h and the second on a ramp FFS of 25 mi/h.

Exhibit 13-22
Capacity Checks for Example Problem 2

Item	Capacity (pc/h) Exhibit 13-8, Exhibit 13-10	Demand Flow Rate (pc/h)	Problem?
Freeway flow rate	6,900	5,053	No
First off-ramp	2,000	340	No
Second off-ramp	1,900	586	No
Max. v, first ramp	4,400	3,377	No
Max. v, second ramp	4,400	3,141	No

None of the capacity values are exceeded, so operation of these ramp junctions will be stable, and LOS F does not occur.

Step 4: Compute Densities and Find Levels of Service by Using Equation 13-22 and Exhibit 13-2

Because there are two off-ramps, two ramp influence areas are involved, and two ramp influence area densities will be computed.

$$D_R = 4.252 + 0.0086 v_{12} - 0.009 L_a$$

$$D_{R1} = 4.252 + (0.0086 \times 3{,}273) - (0.009 \times 800) = 27.9 \text{ pc/mi/ln}$$

$$D_{R2} = 4.252 + (0.0086 \times 3{,}141) - (0.009 \times 300) = 28.6 \text{ pc/mi/ln}$$

From Exhibit 13-2, both of these ramp influence areas operate very close to the boundary between LOS C and LOS D (28.0 pc/mi/ln). Ramp 1 operates in LOS C, while Ramp 2 operates in LOS D.

While it makes virtually no difference in this case, note that the two ramp influence areas overlap. The influence area of the first off-ramp extends 1,500 ft upstream. The influence area of the second off-ramp also extends 1,500 ft

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upstream. Given that the ramps are only 750 ft apart, the second ramp influence area overlaps the first for 750 ft (immediately upstream of the first diverge point). Normally, the worse of the two levels of service would be applied to this 750 ft overlap. In this case, the levels of service are the same. Indeed, the predicted densities are virtually equal, so the impact of the overlap is minimal, and the predicted values are not really affected.

Step 5: Compute Diverge Area Speeds as Supplemental Information by Using Exhibit 13-12 and Exhibit 13-13

Because these ramps are on a six-lane freeway with an outer lane, it is possible to estimate the speed within each ramp influence area, the speed in the outer lane adjacent to each ramp influence area, and the weighted average of the two.

First Off-Ramp

The speed within the first ramp influence area is computed as follows:

$$D_R = 0.883 + 0.00309 v_p - 0.013 S_{FO}$$

$$D_R = 0.883 + (0.00309 \times 3{,}273) - (0.013 \times 40) = 0.894$$

$$S_R = FFS - (FFS - 42) D_R = 60 - (60 - 42) \times 0.894 = 52.9 \text{ mi/h}$$

The flow rate in the outer lane (v_{o1}) is 5,093 − 3,273 = 1,820 pc/h/ln. The average speed in this outer lane is computed as follows:

$$S_{o1} = 1.097 FFS - 0.0039 (v_{o1} - 1{,}000)$$

$$S_{o1} = (1.097 \times 60) - 0.0039 \times (1{,}820 - 1{,}000) = 62.6 \text{ mi/h}$$

The average speed in Lane 3 is predicted to be slightly higher than the FFS of the freeway. This is not uncommon, since through vehicles at higher speeds use Lane 3 to avoid congestion in the ramp influence area. The average speed across all lanes, however, should not be higher than the FFS. In this case, the average speed across all lanes is computed as follows:

$$S = \frac{3{,}273 + (1{,}820 \times 1)}{\left(\frac{3{,}273}{52.9}\right) + \left(\frac{1{,}820 \times 1}{62.0}\right)} = 56.0 \text{ mi/h}$$

This result is, as expected, less than the FFS of the freeway.

Second Off-Ramp

The speed in the second ramp influence area is computed as follows:

$$D_R = 0.883 + (0.00309 \times 566) - (0.013 \times 25) = 0.889$$

$$S_R = 60 - (60 - 42) \times 0.889 = 49.0 \text{ mi/h}$$

Lane 3 has a demand flow rate of 4,753 − 3,141 = 1,612 pc/h/ln. The average speed in the outer lane is computed as follows:

$$S_{o2} = (1.097 \times 60) - 0.0039 \times (1{,}612 - 1{,}000) = 63.4 \text{ mi/h}$$

The average speed across all freeway lanes is

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$$S = \frac{3{,}141 - (1{,}612 \times 1)}{\left(\frac{3{,}141}{49.0}\right) + \left(\frac{1{,}612 \times 1}{63.4}\right)} = 53.1 \text{ mi/h}$$

Discussion

The speed results in this case are interesting. While densities are similar for both ramps, the density is somewhat higher and the speed somewhat lower in the second influence area. This is primarily the result of a shorter deceleration lane and a lower ramp FFS (25 mi/h versus 40 mi/h). In both cases, the average speed in the outer lane is higher than the FFS, which applies as an average across all lanes.

Since the operation is stable, there is an special concern here, short of a significant increase in demand flows. LOS is technically D but falls just over the LOS C boundary. This is a case in which the step function LOS assigned may imply an operation poorer than actually exists. It emphasizes the importance of knowing not only the LOS but also the value of the service measure that predicates it.

EXAMPLE PROBLEM 3: ONE-LANE ON-RAMP FOLLOWED BY A ONE-LANE OFF-RAMP ON AN EIGHT-LANE FREEWAY

The Facts

The following information is available concerning this pair of ramps to be analyzed:

- Eight-lane freeway with an FFS of 65 mi/h
- One-lane, right-hand on ramp with an FFS of 40 mi/h
- One-lane, right-hand off ramp with an FFS of 25 mi/h
- Distance between ramps = 1,300 ft
- Acceleration lane on Ramp 1 = 260 ft
- Deceleration lane on Ramp 2 = 260 ft
- Level terrain on freeway and both ramps
- 10% trucks, no RVs on freeway and off ramp
- 5% trucks, no RVs on on ramp
- Freeway flow rate (upstream of first ramp) = 5,500 veh/h
- On-ramp flow rate = 400 veh/h
- Off-ramp flow rate = 400 veh/h
- PHF = 0.90
- Drivers are regular commuters

Comments

As with previous example problems, the conversion of demand volumes to flow rates requires adjustment factors selected from Chapter 11, Basic Freeway

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Segments. All pertinent information is given, and no default values will be applied.

Step 1: Convert Demand Volumes to Flow Rates Under Equivalent Ideal Conditions by Using Equation 13-1

$$v = \frac{V}{PHF \times f_{HV} \times f_p}$$

Three demand volumes must be converted to flow rates under equivalent ideal conditions: the freeway volume immediately upstream of the first ramp junction, the first ramp volume, and the second ramp volume. Because the freeway segment under study has level terrain, the value of E_T will be 1.5 for all volumes. Because the drivers are regular commuters, the driver population factor, f_p, is 1.00.

Then, for the freeway demand volume:

$$f_{HV} = \frac{1}{1 + 0.10(1.5 - 1)} = 0.952$$

$$v_F = \frac{5{,}500}{0.90 \times 0.952 \times 1.00} = 6{,}419 \text{ pc/h}$$

For the on-ramp demand volume:

$$f_{HV} = \frac{1}{1 + 0.05(1.5 - 1)} = 0.976$$

$$v_{ON} = \frac{400}{0.90 \times 0.976 \times 1.00} = 455 \text{ pc/h}$$

For the off-ramp demand volume:

$$f_{HV} = \frac{1}{1 + 0.10(1.5 - 1)} = 0.952$$

$$v_{OF} = \frac{600}{0.90 \times 0.952 \times 1.00} = 700 \text{ pc/h}$$

In the remaining computations, these converted demand flow rates are used as input values.

Step 2: Compute Demand Flow in Lanes 1 and 2 Immediately Upstream of the Two Ramp Influence Areas by Using Equation 13-2 and Exhibit 13-6 for the On-Ramp and Equation 13-8 and Exhibit 13-7 for the Off-Ramp

Once again, the situation involves a pair of adjacent ramps. Each ramp must consider the potential impact of the other on its operations. Because the ramps are on an eight-lane freeway (four lanes in each direction), Exhibit 13-6 and Exhibit 13-7 indicate that each ramp is considered as if it were isolated.

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First Ramp (On-Ramp)

Equation 13-2 and Exhibit 13-6 apply to on-ramps. Exhibit 13-6 presents two possible equations for use in estimating P_{FO} on the basis of the value of v_R/L_A. In this case, the value is 6,419/3,000 = 2,106 > 72. Therefore, Equation 13-3 is used, giving the following.

$$v_{12} = v_F \times P_{FO}$$

$$P_{FO} = 0.2178 - 0.000125 v_R$$

$$P_{FO} = 0.2178 - (0.000125 \times 455) = 0.161$$

$$v_{12} = 6,429 \times 0.161 = 2,033 \text{ pc/h}$$

Because the eight-lane freeway includes two outer lanes in each direction, the reasonableness of this prediction must be checked. The average flow per lane in Lanes 1 and 2 is 2,033/2 = 817 pc/h/ln (rounded). The flow in the two outer lanes, Lanes 3 and 4, is 6,419 − 2,033 = 5,486 pc/h. The average flow per lane in Lanes 3 and 4 is, therefore, 5,386/2 = 2,693 pc/h/ln. Then:

Is $v_{FO} > 2,700$ pc/h/ln? No

Is $v_{FO} > 1.5 \times 817 = 1,226$ pc/h/ln? Yes

The predicted lane distribution, therefore, is not reasonable. Too many vehicles are placed in the two outer lanes compared with Lanes 1 and 2. Equation 13-19 is used to produce a more reasonable distribution:

$$v_{12} = \begin{pmatrix} v_1 \\ 2,500 \end{pmatrix} = \begin{pmatrix} 6,419 \\ 2,500 \end{pmatrix} = 2,568 \text{ pc/h}$$

On the basis of this adjusted value, the number of vehicles now assigned to the two outer lanes is 6,419 − 2,568 = 3,851 pc/h.

Second Ramp (Off Ramp)

Equation 13-8 and Exhibit 13-7 apply to off-ramps. Exhibit 13-7 shows that the value of P_{FO} for off-ramps on eight-lane freeways is a constant: 0.436. As the methodology is based on regression analyses of a database, the recommendation of a constant reflects a small sample size in that database. Note also that the freeway flow approaching the second ramp is the sum of the freeway flow approaching the first ramp and the on-ramp flow that is now also on the freeway, or 6,419 + 455 = 6,874 pc/h. The flow rate in Lanes 1 and 2 is now easily computed by using Equation 13-8:

$$v_{12} = v_{ff} - (v_r - v_R) P_{FO}$$

$$v_{12} = 700 + (6,874 - 700) \times 0.436 = 3,392 \text{ pc/h}$$

Because there are two outer lanes on this eight-lane freeway, the reasonableness of this estimate must be checked. The average flow per lane in Lanes 1 and 2 is 3,392/2 = 1,696 pc/h/ln. The total flow in Lanes 3 and 4 of the freeway is 6,874 − 3,392 = 3,482 pc/h, or an average flow rate per lane of 3,482/2 = 1,741 pc/h/ln.

Is $v_{FO} > 2,700$ pc/h/ln? No

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Is $v_{12,EQ} > 1.5 \times 1,696 = 2,544$ pc/h/ln? No

Therefore, the estimated value of v_{12} is deemed reasonable and is carried forward in the computations.

Step 3: Check Capacities by Using Exhibit 13-8 and Exhibit 13-10

Because there are two ramps in this segment, there are five capacity checkpoints to consider:

- The freeway flow rate at its maximum point—which in this case is between the on- and off-ramp, since this is the only location where both on- and off-ramp vehicles are on the freeway.
- The capacity of the on-ramp.
- The capacity of the off-ramp.
- The maximum desirable flow entering the on-ramp influence area.
- The maximum desirable flow entering the off-ramp influence area.

These comparisons are shown in Exhibit 13-23. The capacity of the freeway is based on an eight-lane freeway with an FFS of 65 mi/h. The capacity of the on-ramp is based on an FFS of 50 mi/h, and the capacity of the off-ramp is based on an FFS of 55 mi/h.

Exhibit 13-23
Capacity Checks for Example Problem 3

Item	Capacity (pc/h) Exhibit 13-8, Exhibit 13-10	Demand Flow Rate (pc/h)	Problem?
Freeway flow rate	8,400	6,879	No
First on-ramp	1,900	345	No
Second off-ramp	1,900	700	No
Max. v_{12}, first ramp	4,600	2,568 + 455 = 3,023	No
Max. v_{12}, second ramp	4,400	3,392	No

There are no capacity concerns, since all demands are well below the associated capacities or maximum desirable values. LOS F is not present in any part of this segment, and operations are expected to be stable.

Step 4: Compute Densities and Find Levels of Service by Using Equation 13-21, Equation 13-22, and Exhibit 13-2

Equation 13-21 is used to find the density in the first on-ramp influence area.

$$D_R = 5.475 + 0.00734 v_R + 0.0078 v_{12} - 0.00627 L_A$$

$$D_R = 5.475 + (0.00734 \times 455) + (0.0078 \times 2,568) - (0.00627 \times 260) = 27.2 \text{ pc/mi/ln}$$

Equation 13-22 is used to find the density in the second off-ramp influence area.

$$D_R = 4.252 + 0.0086 v_{12} - 0.009 L_D$$

$$D_R = 4.252 + (0.0086 \times 3,391) - (0.009 \times 260) = 31.1 \text{ pc/mi/ln}$$

From Exhibit 13-2, both of these ramp influence areas operate very close to the boundary between LOS C and LOS D (28 pc/mi/ln). Ramp 1 operates in LOS C, while Ramp 2 operates in LOS D.

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Because the on-ramp influence area extends 1,500 ft downstream, the off-ramp influence area extends 1,500 ft upstream, and the two ramps are only 1,300 ft apart, the distance between the ramps is included in both. Therefore, the more pessimistic prediction of 1.026 for the off-ramp governs the operation. Oddly, the additional 200 ft of the off-ramp influence area is actually upstream of the on-ramp, and the additional 200 ft of the on-ramp influence area is downstream of the off-ramp.

Step 5: Compute Merge and Diverge Area Speeds as Supplemental Information by Using Exhibit 13-11 and Exhibit 13-12

Because of the eight-lane freeway, speeds should be estimated for the two ramp influence areas, for the outer lanes (Lanes 3 and 4) adjacent to the ramp influence area, and for all vehicles—the weighted average of the other two speeds.

First Ramp (On Ramp)

Equations for estimation of average speed in an on-ramp influence area and in outer lanes adjacent to it are taken from Exhibit 13-11.

$$M_s = 0.321 + 0.0039e^{(v_o + 1.3v_r)} - 0.002(L_a S_{pd} / 1{,}000)$$

$$M_s = 0.321 + 0.0039e^{(3{,}032 + 1{,}926)/1{,}000} - 0.002(260/30) = 0.385$$

$$S_o = FFS - (FFS - 42)M_s = 65 - (65 - 42) \times 0.385 = 56.2 \text{ mi/h}$$

Since the average outer lane demand flow rate is 3,651/3 = 1,926 pc/h/ln, which is greater than 500 pc/h/ln and less than 2,300 pc/h/ln, the outer speed is estimated as follows:

$$S_{12} = FFS - 0.0036(v_{12} - 500)$$

$$S_{12} = 65 - 0.0036(1{,}926 - 500) = 59.9 \text{ mi/h}$$

The weighted average speed of all vehicles is

$$S = \frac{3{,}032 + (1{,}926 \times 2)}{\left(\frac{3{,}032}{56.2}\right) + \left(\frac{1{,}926 \times 2}{59.9}\right)} = 58.2 \text{ mi/h}$$

Second Ramp (Off-Ramp)

For off-ramps, equations for estimation of average speed are drawn from Exhibit 13-12. At the second ramp, the flow in Lanes 1 and 2 has been computed as 3,392 pc/h or 1,696 pc/h/ln, while the flow in Lanes 3 and 4 is 3,482 pc/h or 1,741 pc/h/ln. Then

$$D_s = 0.883 - 0.00009v_o + 0.013S_{12}$$

$$D_s = 0.883 + (0.00009 \times 700) - (0.013 \times 25) = 0.621$$

$$S_o = FFS - (FFS - 42)D_s$$

$$S_o = 65 - (65 - 42) \times 0.621 = 50.7 \text{ mi/h}$$

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Because the average flow in the outer lanes is greater than 1,000 pc/h/ln, the average speed of vehicles in the outer lanes (Lanes 3 and 4) is as follows:

$$S_o = 1.097FFS - 0.0039(v_{p,o} - 1{,}000)$$

$$S_o = (1.097 \times 65) - 0.0039(1{,}741 - 1{,}000) = 68.4 \text{ mi/h}$$

The weighted average speed of all vehicles is

$$S = \frac{3{,}392 + (1{,}741 \times 2)}{\left(\frac{3{,}392}{50.7}\right) + \left(\frac{1{,}741 \times 2}{68.4}\right)} = 58.3 \text{ mi/h}$$

Discussion

As noted previously, between the ramps, the influence areas of both ramps fully overlap. Since a higher density is predicted for the off-ramp influence area, and LOS D results, this density would be applied to the entire area between the two ramps.

The speed results are also interesting. The slower speeds within the off-ramp influence area will also control the overlap area. On the other hand, the speed results indicate a higher average speed for all vehicles associated with the off-ramp than the speed associated with the on-ramp. This is primarily due to the much larger disparity between speeds within the ramp influence area and in outer lanes when the off-ramp is considered. The speed differential is more than 20 mi/h for the off-ramp, as opposed to a little more than 3 mi/h for the on-ramp. This is not entirely unexpected. At diverge junctions, vehicles in outer lanes tend to face less turbulence than those in outer lanes near merge junctions. All off-ramp vehicles must be in Lanes 3 and 4 for some distance before exiting the freeway. On-ramp vehicles, on the other hand, can execute as many lane changes as they wish—consistent with safety and sanity—and more of them may wind up in outer lanes within 1,500 ft of the junction point.

Thus, the total operation of this two-ramp segment is expected to be LOS D, with speeds of approximately 50 mi/h in Lanes 1 and 2 and approximately 70 mi/h in Lanes 3 and 4.

EXAMPLE PROBLEM 4: SINGLE-LANE, LEFT-HAND ON-RAMP ON A SIX-LANE FREEWAY

The Facts

- One-lane, left-side on-ramp on a six-lane freeway (three lanes in each direction)
- Freeway demand volume upstream of ramp = 4,600 veh/h
- On-ramp demand volume = 500 veh/h
- 25% trucks, no RVs on freeway
- 5% trucks, no RVs on ramp
- Freeway FFS = 65 mi/h
- Ramp FFS = 30 mi/h

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- Accelerations are 820 ft
- Level terrain on freeway and ramp
- Drivers are regular commuters

Comments

This is a special application of the ramp analysis methodology presented in this chapter. For left hand ramps, the flow rate in Lanes 1 and 2 (v_{12}) is initially computed as if it were a right hand ramp. Exhibit 13-16 is then used to convert this result to an estimate of the flow in Lanes 2 and 3 (v_{23}), since these are the two leftmost lanes that will be traversed in the merge. In effect, the ramp influence area is, in this case, Lanes 3 and 4 and the acceleration lane for a distance of 1,500 ft downstream of the merge point.

Step 1: Convert Demand Volumes to Flow Rates Under Equivalent Ideal Conditions by Using Equation 13-1

$$v = \frac{V}{PHF \times f_{HV} \times f_p}$$

From Chapter 11, Basic Freeway Segments, the passenger car equivalent E_T for trucks in level terrain is 1.5. The driver population adjustment factor f_p for regular commuters is 1.00.

For the freeway demand volume:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} = \frac{1}{1 + 0.15(1.5 - 1)}$$

$$f_{HV} = 0.930$$

$$v_F = \frac{4{,}089}{0.90 \times 0.93 \times 1.00} = 4{,}779 \text{ pc/h}$$

For the ramp demand volume:

$$f_{HV} = \frac{1}{1 + 0.05(1.5 - 1)} = 0.976$$

$$v_R = \frac{500}{0.90 \times 0.976 \times 1.00} = 569 \text{ pc/h}$$

Step 2: Compute Demand Flow in Lanes 2 and 3 Immediately Upstream of the Ramp Influence Area by Using Equation 13-2 and Exhibit 13-6

To estimate flow in the two left lanes, the flow normally expected in Lanes 1 and 2 for a similar right hand ramp must first be computed. From Exhibit 13-6, for an isolated on-ramp on a six-lane freeway, Equation 13-4 is used.

$$v_{12} = v_i \times P_{FM}$$

$$P_{FM} = 0.5775 + 0.000028L_A$$

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$$P_{FM} = 0.5775 + (0.000028 \times 820) = 0.601$$

$$v_{12} = 4,779 \times 0.601 = 2,867 \text{ pc/h}$$

From Exhibit 13-16, the adjustment factor applied to this result to find the estimated flow rate in Lanes 2 and 3 is 1.12. Therefore:

$$v_{23} = 2,867 \times 1.12 = 3,211 \text{ pc/h}$$

While, strictly speaking, the reasonableness criteria for lane distribution do not apply to left-hand ramps, they can be applied very approximately. In this case, the single "outer lane" (which is now Lane 1) would have a flow rate of $4,779 - 3,211 = 1,568$ pc/h. This is not greater than 2,700 pc/h/ln, nor is it greater than 1.5 times the average flow in Lanes 2 and 3 ($1.5 \times 3,211/2 = 2,408$ pc/h/ln). Thus, even if the reasonableness criteria were approximately applied in this case, no violation would exist.

The remaining computations proceed for the left-hand ramp, with the substitution of v_4 for v_3 in the algorithm used.

Step 3: Check Capacities by Using Exhibit 13-8 and Exhibit 13-10

For this case, there are three simple checkpoints:

- The principal capacity checkpoint is the total demand flow rate downstream of the merge, $4,779 + 569 = 5,348$ pc/h. From Exhibit 13-8, for a six-lane freeway with an FFS of 65 mi/h, the capacity is 7,050 pc/h, well over the demand flow rate.
- The ramp roadway capacity should also be checked by using Exhibit 13-10. For a single-lane ramp with an FFS of 30 mi/h, the capacity is 1,900 pc/h, which is much greater than the demand flow rate of 569 pc/h.
- Finally, the maximum flow entering the ramp influence area should be checked. In this case, a left-hand ramp, the total flow entering the ramp influence area is the freeway flow remaining in Lanes 2 and 3 plus the ramp flow rate. Thus, the total flow entering the ramp influence area is $3,211 + 569 = 3,780$ pc/h, which is lower than the maximum desirable flow rate of 4,600 pc/h, shown in Exhibit 13-8.

Thus, there are no capacity problems at this merge point, and stable operations are expected. LOS F will not result from the stated conditions.

Step 4: Compute Densities and Find Levels of Service by Using Equation 13-21 and Exhibit 13-2

The density in the ramp influence area is found by using Equation 13-21, except v_4 replaces v_R because of the left-hand ramp placement:

$$D_I = 5.475 + 0.00734\,v_4 - 0.00978\,v_{23} + 0.000627\,L_A$$

$$D_I = 5.475 + (0.00734 \times 569) - (0.00978 \times 3,211) + (0.000627 \times 820) = 29.6 \text{ pc/mi/ln}$$

From Exhibit 13-2, this is LOS D.

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Step 5: Compute Merge and Diverge Area Speeds as Supplemental Information by Using Exhibit 13-11 and Exhibit 13-13

The speed estimation algorithms were calibrated for right-hand ramps, and the estimation algorithms for "outer lane(s)" assume that these are the leftmost lanes. Thus, for a left-hand ramp, these computations must be considered approximate at best.

By using the equations in Exhibit 13-11 and Exhibit 13-13, the following results are obtained:

$$M1_o = 0.321 + 0.0039e^{(-0.0021 \times 1{,}000)} - 0.002(820 \times 30 / 1{,}000) = 0.443$$

$$S_o = 65 - (65 - 42) \times 0.443 = 54.8 \text{ mi/h}$$

$$S_i = 65 - 0.0036\,(1{,}568 - 500) = 61.2 \text{ mi/h}$$

$$S = \frac{3{,}780 + (1{,}568 \times 1)}{\left(\frac{3{,}780}{54.8}\right) + \left(\frac{1{,}568 \times 1}{61.2}\right)} = 56.5 \text{ mi/h}$$

While traffic in the outer lane is predicted to travel somewhat faster than traffic in the lanes in the ramp influence area (which includes the acceleration lane), the approximate nature of the speed result for left-hand ramps makes it difficult to draw any firm conclusions concerning speed behavior.

Discussion

This example problem is typical of the way the situations in the Special Cases section are treated. Modifications as specified are applied to the standard algorithms used for single-lane, right-hand ramp junctions. In this case, operations are acceptable, but in LOS D—though not far from the LOS C boundary. Because the left-hand lanes are expected to carry freeway traffic flowing faster than right-hand lanes, right-hand ramps are normally preferable to left-hand ramps when they can be provided without great difficulty.

EXAMPLE PROBLEM 5: SERVICE FLOW RATES AND SERVICE VOLUMES FOR AN ISOLATED ON-RAMP ON A SIX-LANE FREEWAY

The Facts

The following facts have been established for this situation:

- Single-lane, right-hand on-ramp with an FFS of 40 mi/h
- Six-lane freeway (three lanes in each direction) with an FFS of 70 mi/h
- Level terrain for freeway and ramp
- 12% trucks, 3% RVs on freeway
- 5% trucks, 2% RVs on ramp
- Peak hour factor = 0.97
- Drivers are regular users of the facility
- Acceleration lane = 1,000 ft

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Comments

This example illustrates the computation of service flow rates and service volumes for a ramp–freeway junction. The case selected is relatively straightforward to avoid cluttering the illustration with extraneous complications that have been addressed in other example problems.

Two approaches will be demonstrated:

1. The ramp demand flow rate will be stated as a fixed percentage of the arriving freeway flow rate. The service flow rates and service volumes are expressed as arriving freeway flow rates that result in the threshold densities within the ramp influence area that define the limits of the various levels of service. For this computation, the ramp flow is set at 10% of the approaching freeway flow rate.
2. A fixed freeway demand flow rate will be stated, with service flow rates and service volumes expressed as ramp demand flow rates that result in the threshold densities within the ramp influence area that define the limits of the various levels of service. For this computation, the approaching freeway flow rate is set at 4,000 veh/h.

For LOS E, density does not define the limiting value of service flow rate, which is analogous to capacity for ramp–freeway junctions. It is defined as the flow that results in capacity being reached on the downstream freeway segment or ramp roadway.

Since all algorithms in this methodology are calibrated for passenger cars per hour under equivalent ideal conditions, initial computations are made in those terms. Results are then converted to service flow rates by using the appropriate heavy vehicle and driver population adjustment factors. Service flow rates are then converted to service volumes by multiplying by the peak hour factor.

From Exhibit 13-2, the following densities define the limits of LOS A–D:

LOS A	10 pc/mi/ln
LOS B	20 pc/mi/ln
LOS C	28 pc/mi/ln
LOS D	35 pc/mi/ln

From Exhibit 13-8 and Exhibit 13-10, capacity (or the threshold for LOS E) occurs when the downstream freeway flow rate reaches 7,200 pc/h (FFS = 70 mi/h) or when the ramp flow rate reaches 2,000 pc/h (ramp FFS = 40 mi/h).

Case 1: Ramp Demand Flow Rate = 0.10 Freeway Demand Flow Rate

Equation 13-21 defines the density at an on-ramp influence area as follows:

$$D_R = 5.475 + 0.00734 v_R + 0.0078 v_{FD} - 0.00627 L_A$$

In this case:

$v_R = 0.10 v_F$

$L_A = 1.0$ mi

Equation 13-2 and Exhibit 13-6 give the following:

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$$v_{12} = v_f \times P_{FM}$$

$$P_{FM} = 0.5775 - 0.000028L_a$$

$$P_{FM} = 0.5775 - [0.000028 \times 1{,}000) \quad 0.6055$$

$$v_{12} \quad 0.6055v_f$$

Substitution of these values into Equation 13-21 gives:

$$D_R = 5.475 - [0.00734 \times 0.10v_r) + [0.00978 \times 0.6055v_f) - (0.00627 \times 1{,}000)$$

$$D_R = 5.475 + 0.000734v_r + 0.00592v_f - 6.27$$

$$D_R = 0.005454v_f \quad 0.795$$

$$v_f = \frac{D_R + 0.795}{0.005454}$$

This equation can now be solved for threshold values of v_f for LOS A through D by using the appropriate threshold values of density. The results will be in terms of service flow rates under equivalent ideal conditions:

$$v_f \text{ (LOS A)} = \frac{10 + 0.795}{0.005454} = 1{,}979 \text{ pc/h}$$

$$v_f \text{ (LOS B)} = \frac{20 + 0.795}{0.005454} = 3{,}813 \text{ pc/h}$$

$$v_f \text{ (LOS C)} = \frac{28 + 0.795}{0.005454} = 5{,}280 \text{ pc/h}$$

$$v_f \text{ (LOS D)} = \frac{35 + 0.795}{0.005454} = 6{,}563 \text{ pc/h}$$

At capacity, the limiting flow rate occurs when the downstream freeway segment is 7,200 pc/h. If the ramp flow rate is 0.10 of the approaching freeway flow rate, then

$$v_{12} = 7{,}200 = v_f + 0.10v_f \quad 1.10v_f$$

$$v_f \text{ (LOS E)} = \frac{7{,}200}{1.10} = 6{,}545 \text{ pc/h}$$

This must be checked to ensure that the ramp flow rate ($0.10 \times 6{,}545 = 655$ pc/h) does not exceed the ramp capacity of 2,000 pc/h. Since it does not, the computation stands.

Note, however, that the LOS E (capacity) threshold is lower than the LOS D threshold. This indicates that LOS D operation cannot be achieved at this location. Before densities reach the 35 pc/h/ln threshold for LOS D, the capacity of the merge junction has been reached. Thus, there is no service flow rate or service volume for LOS D.

The computed values, as noted, are in terms of passenger cars per hour under equivalent ideal conditions. To convert these to service flow rates in vehicles per hour under prevailing conditions, they must be multiplied by the

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heavy vehicle adjustment factor and the driver population factor. The approaching freeway flow rate includes 12% trucks and 3% RVs. For level terrain (Chapter 11, Basic Freeway Segments), $E_T = 1.5$ and $E_R = 1.2$. Then

$$f_{HV} = \frac{1}{1 + 0.12(1.5 - 1) + 0.03(1.2 - 1)} = 0.938$$

The driver population factor f_p for regular facility users is 1.00. Service volumes are obtained by multiplying service flow rates by the specified PHF, 0.87. These computations are illustrated in Exhibit 13-24.

Exhibit 13-24
Illustrative Service Flow Rates and Service Volumes Based on Approaching Freeway Demand

LOS	Service Flow Rate, Ideal Conditions (pc/h)	Service Flow Rate, Prevailing Conditions (SF) (veh/h)	Service Volume (SV) (veh/h)
A	1,970	1,970 × 0.938 × 1 = 1,848	1,848 × 0.87 = 1,608
B	3,813	3,813 × 0.938 × 1 = 3,577	3,577 × 0.87 = 3,112
C	5,288	5,288 × 0.938 × 1 = 4,960	4,960 × 0.87 = 4,315
D	NA	NA	NA
E	6,545	6,545 × 0.938 × 1 = 6,138	6,138 × 0.87 = 5,341

The service flow rates and service volumes shown in Exhibit 13-24 are stated in terms of the approaching freeway demand.

Case 2: Approaching Freeway Demand Volume = 4,000 veh/h

In this case, the approaching freeway demand will be held constant, and service flow rates and service volumes will be stated in terms of the ramp demand that can be accommodated at each LOS.

Since the freeway demand is stated in terms of an hourly volume in mixed vehicles per hour, it will be converted to passenger cars per hour under equivalent ideal conditions for use in the algorithms of this methodology.

$$v_f = \frac{V_f}{PHF \times f_{HV} \times f_p} = \frac{4,000}{0.87 \times 0.938 \times 1} = 4,902 \text{ pc/h}$$

The density is estimated by using Equation 13-20, and the variable P_{FM}, which is not dependent on v_R, remains 0.6055 as in Case 1. With a fixed value of freeway demand:

$$v_{12} = 0.6055 \times 4,902 = 2,968 \text{ pc/h}$$

Then, by using Equation 13-21:

$$D_R = 5.475 + 0.00734 v_{12} + (0.0078 \times 2,968) - (0.00627 \times 1,000)$$

$$D_R = 22.355 + 0.00734 v_R$$

$$v_R = \frac{D_R - 22.355}{0.00734}$$

It is apparent from this equation that neither LOS A ($D_R = 10$ pc/mi/ln) nor LOS B ($D_R = 20$ pc/mi/ln) can be achieved with a fixed freeway demand flow of 4,902 pc/h.

For LOS C and D:

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$$v_o(\text{LOS C}) = \frac{28 - 22.355}{0.00734} = 769 \text{ pc/h}$$

$$v_o(\text{LOS D}) = \frac{35 - 22.355}{0.00734} = 1{,}723 \text{ pc/h}$$

Capacity, the limit of LOS E, occurs when the downstream freeway flow reaches 7,200 pc/h. With a fixed freeway demand,

$$v_{fr} = 7{,}200 - 4{,}912 + v_o$$

$$v_o(\text{LOS E}) = 7{,}200 - 4{,}912 = 2{,}298 \text{ pc/h}$$

This, however, violates the capacity of the ramp roadway, which is 2,000 pc/h. Thus, the limiting ramp flow rate for LOS E is set at 2,000 pc/h.

As in Case 2, these values are all stated in terms of passenger cars per hour under equivalent ideal conditions. They are converted to service flow rates by multiplying by the appropriate heavy vehicle and driver population adjustment factors. Since the ramp has a composition different from that of the approaching freeway flow, its adjustment must be recomputed:

$$f_{HV} = \frac{1}{1 + 0.05(1.5 - 1) + 0.02(1.2 - 1)} = 0.972$$

Service flow rates are converted to service volumes by multiplying by the peak hour factor. These computations are illustrated in Exhibit 13-25.

LOS	Service Flow Rate, Ideal Conditions (pc/h)	Service Flow Rate, Prevailing Conditions (SF) (veh/h)	Service Volume (SV) (veh/h)
A	NA	NA	NA
B	NA	NA	NA
C	769	769 × 0.972 × 1 = 747	747 × 0.87 = 650
D	1,723	1,723 × 0.972 × 1 = 1,675	1,675 × 0.87 = 1,457
E	2,000	2,000 × 0.972 × 1 = 1,944	1,944 × 0.87 = 1,691

Exhibit 13-25
Illustrative Service Flow Rates and Service Volumes Based on a Fixed Freeway Demand

These service flow rates and service volumes are based on a constant upstream and ramp freeway demand and are stated in terms of limiting on-ramp demands for that condition.

Discussion

As this illustration shows, many considerations are involved in estimating service flow rates and service volumes for ramp–freeway junctions, not the least of which is specifying how such values should be defined. The concept of service flow rates and service volumes at specific ramp–freeway junctions is of limited utility. Since many of the details that affect the estimates will not be determined until final designs are prepared, operational analysis of the proposed design may be more appropriate.

Case 3 could have applications in considering ramp-to-ramp metering. Appropriate limiting ramp flows can be estimated by using the same approach as for service volumes and service flow rates.

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5. REFERENCES

Some of these references can be found in the Technical Reference Library in Volume 4.

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CHAPTER 14
MULTILANE HIGHWAYS

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1. INTRODUCTION

VOLUME 2: UNINTERRUPTED FLOW
10. Freeway Facilities
11. Basic Freeway Segments
12. Freeway Weaving Segments
13. Freeway Merge and Diverge Segments
14. Multilane Highways
15. Two-Lane Highways

Chapter 14, Multilane Highways, addresses capacity and level-of-service (LOS) analysis for uninterrupted-flow segments of surface multilane highways. In general, uninterrupted flow may exist on a multilane highway if there are 2 mi or more between traffic signals. Where signals are more closely spaced, the facility should be analyzed as an urban street.

Many multilane highways will have periodic signalized intersections, even if the average signal spacing is well over 2 mi. In such cases, the multilane highway segments that are more than 2 mi away from any signalized intersections are analyzed by using the methodology of this chapter. Isolated signalized intersections should be analyzed with the methodology of Chapter 18, Signalized Intersections.

LOS procedures are provided for both automobiles and bicycles. The automobile methodology is based on the results of NCHRP Project 3-33 (*1*), and bicycle LOS is based on research conducted for the Florida Department of Transportation (*2*). The same methodology for bicycle LOS is used for both multilane and two-lane highways; readers interested in details of the bicycle methodology should refer to Chapter 15, Two-Lane Highways.

TYPES OF MULTILANE HIGHWAYS

Multilane highways generally have four to six lanes (in both directions) and posted speed limits between 40 and 55 mi/h. In some states, speed limits of 60 or 65 mi/h are used on some multilane highways. These highways may be divided by one of various median types, may be undivided (with only a centerline separating the directions of flow), or may have a two-way left-turn lane (TWLTL). They are typically located in suburban areas, leading into central cities, or along high-volume rural corridors, connecting two cities or two activity centers that generate a substantial number of daily trips. Exhibit 14-1 illustrates common types of multilane highways.

Traffic volumes on multilane highways vary widely but often have demand in the range of 15,000 to 40,000 veh/day. In some cases, volumes as high as 100,000 veh/day have been observed when access across the median is restricted and when major crossings are grade-separated. Bicycles are typically permitted on multilane highways, and multilane highways often serve as primary routes for both commuter cyclists (on suburban highways) and recreational cyclists (on rural highways).

BASE CONDITIONS

The base conditions under which the full capacity of a multilane highway segment is achieved include good weather, good visibility, no incidents or accidents, no work zone activity, and no pavement defects that would affect operations. This chapter's methodology assumes that these conditions exist. If any of these conditions do not exist, the speed, LOS, and capacity of the multilane highway segment can be expected to be worse than the predictions by this methodology.

Base conditions include good weather, good visibility, and no incidents or accidents. These conditions are always assumed to exist.

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Exhibit 14-1
Multilane Highways

(a) Divided suburban multilane highway

(b) Undivided suburban multilane highway

(c) Suburban multilane highway with TWLTL

(d) Undivided rural multilane highway

Base conditions include 0% heavy vehicles and a driver population composed of regular users of the highway.

The methodology provides adjustments for situations in which these conditions do not apply.

Base conditions include the following conditions; the methodology can be adjusted to address situations in which these conditions do not exist:

- No heavy vehicles, such as trucks, buses, and recreational vehicles (RVs), in the traffic stream; and
- A driver population composed primarily of regular users who are familiar with the facility.

Characteristics such as lane width, total lateral clearance (TLC), median type, and access-point density will have an impact on the free-flow speed (FFS) of the facility. Curves describing operations under base conditions, however, account for differing FFSs.

FLOW CHARACTERISTICS UNDER BASE CONDITIONS

More severe geometric characteristics and the existence of access points are two key differences that result in lower multilane highway speeds and capacities than those of freeways with similar cross sections.

Uninterrupted flow on multilane highways is in most ways similar to that on basic freeway segments (Chapter 11). Several factors are different, however. Because side frictions are present in varying degrees from uncontrolled driveways and intersections as well as from opposing flows on undivided cross sections, speeds on multilane highways tend to be lower than those on similar basic freeway segments. The basic geometry of multilane highways also tends to be more severe than that of basic freeway segments because of the lower speed expectations. Last, isolated signalized intersections can exist along multilane highways. The overall result is that speeds and capacities on multilane highways are lower than those on basic freeway segments with similar cross sections.

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Exhibit 14-2 shows speed–flow characteristics of multilane highway segments for various FFSs. Equations describing these curves are shown in Exhibit 14-3.

Curves are shown for FFSs between 45 mi/h and 60 mi/h. Because FFSs can vary widely, it is recommended that the FFS of a multilane highway segment be estimated to the nearest 5 mi/h, as follows:

42.5 mi/h ≤ FFS < 47.5 mi/h: use FFS = 45 mi/h,

47.5 mi/h ≤ FFS < 52.5 mi/h: use FFS = 50 mi/h,

52.5 mi/h ≤ FFS < 57.5 mi/h: use FFS = 55 mi/h,

57.5 mi/h ≤ FFS < 62.5 mi/h: use FFS = 60 mi/h

The FFS of a multilane highway segment should be estimated to the nearest 5 mi/h.

For multilane highway segments, speeds remain constant until they reach 1,400 pc/h/ln, after which speeds decline with further increases in flow rate.

Flow rates over 1,400 pc/h/ln result in speeds below the highway's FFS.

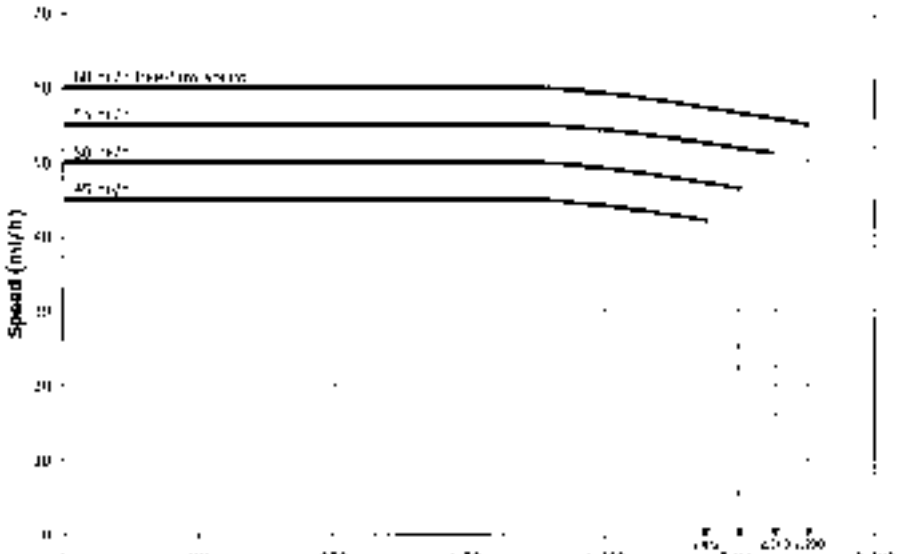

Exhibit 14-2
Speed–Flow Curves for Multilane Highways Under Base Conditions

Note: Max mum densities for LOS E occur at a flow rate of 1,400 pc/h/ln. These are 40, 41, 43, and 45 pc/mi/ln for FFSs of 60, 55, 50, and 45 mi/h, respectively.

FFS (mi/h)	For $v_p \leq 1{,}400$ pc/h/ln, S (mi/h)	For $v_p > 1{,}400$ pc/h/ln, S (mi/h)
60	60	$S = 60 - 1.76 \left[\frac{v_p - 1{,}400}{800} \right]^{2.7}$
55	55	$S = 55 - 3.76 \left[\frac{v_p - 1{,}400}{700} \right]^{2.7}$
50	50	$S = 50 - 3.48 \left[\frac{v_p - 1{,}400}{600} \right]^{2.7}$
45	45	$S = 45 - 2.76 \left[\frac{v_p - 1{,}400}{500} \right]^{2.7}$

Exhibit 14-3
Equations Describing Speed–Flow Curves in Exhibit 14-2

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CAPACITY OF MULTILANE HIGHWAY SEGMENTS

Multilane highways with higher FFSs can also have higher base capacities. As these highways do not operate under base conditions, observed capacities will usually be lower than the base capacity.

The capacity of a multilane highway segment under base conditions varies with the FFS. For 60-mi/h FFS, the capacity is 2,200 pc/h/ln. For lesser FFSs, capacity diminishes. For 55-mi/h FFS, the capacity is 2,100 pc/h/ln, for 50-mi/h FFS, 2,000 pc/h/ln, and for 45-mi/h FFS, 1,900 pc/h/ln.

Capacities represent an average flow rate across all lanes. Individual lanes could have higher stable flows.

These values represent national norms. Capacity varies stochastically, and any given location could have a larger or smaller value. In addition, capacity refers to the average flow rate across all lanes. Thus, a two-lane (in one direction) multilane highway segment with a 60-mi/h FFS would have an expected capacity of 2 × 2,200 = 4,400 pc/h. This flow would not be uniformly distributed in the two lanes. Thus, one lane could have stable flows in excess of 2,200 pc/h/ln.

LOS FOR MULTILANE HIGHWAY SEGMENTS

Automobile Mode

Automobile LOS is defined by density.

Automobile LOS for multilane highway segments are defined in Exhibit 14-4. Because speeds are constant through a broad range of flow rates, LOS are defined on the basis of density, which is a measure of the proximity of vehicles to each other in the traffic stream.

Exhibit 14-4
Automobile LOS for Multilane Highway Segments

LOS	FFS (mi/h)	Density (pc/mi/ln)
A	All	≤11
B	All	>11–18
C	All	>18–26
D	All	>26–35
E	60	>35–40
	55	>35–41
	50	>35–43
	45	>35–45
F	Demand Exceeds Capacity	
	60	>40
	55	>41
	50	>43
	45	>45

LOS thresholds for multilane highways are the same as those for freeways for LOS A–D. However, multilane highway capacity (the LOS E–F boundary) occurs at lower densities.

For LOS A through D, the criteria are the same as those for basic freeway segments. This classification is appropriate, since both represent multilane uninterrupted flow. The boundary between LOS E and F, however, represents capacity. For multilane highways, capacity occurs at varying densities, depending on the FFS. The density at capacity ranges from 40 pc/mi/ln for 60-mi/h FFS to 45 pc/mi/ln for 45-mi/h FFS.

LOS F is determined when the demand flow rate exceeds capacity. When this occurs, the methodology does not produce a density estimate. Thus, although density in such cases will be above the thresholds shown, specific values cannot be determined.

Exhibit 14-5 shows LOS thresholds in relation to the base speed–flow curves.

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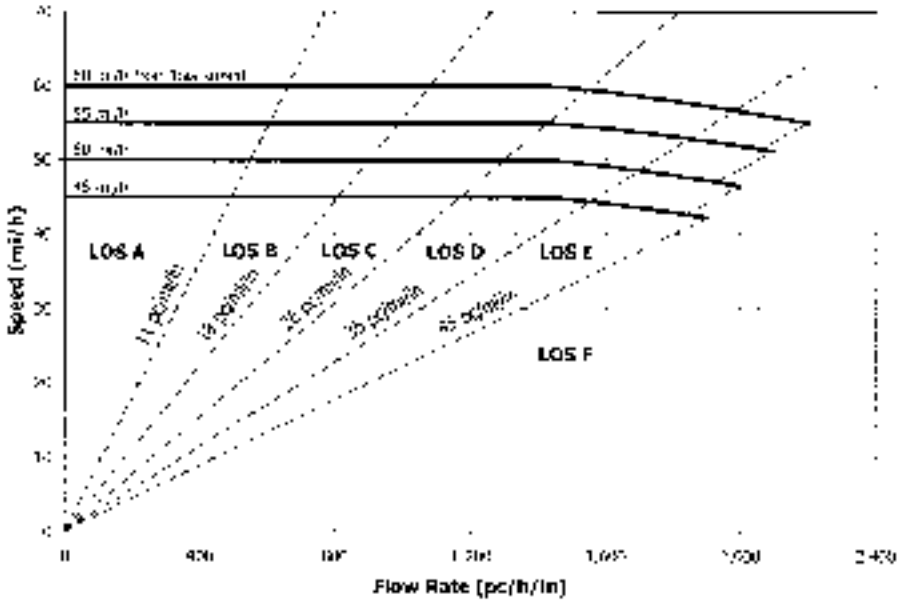

Exhibit 14-5
LOS for Base Speed Flow Curves

Automobile LOS Described

The descriptions of LOS for basic freeway segments given in Chapter 11 are also generally applicable to multilane highways. Vehicles entering the highway from a direct access point are an additional factor on multilane highways; these vehicles are not present on basic freeway segments and could result in a breakdown of flow at high flow rates.

The LOS thresholds for multilane highways reflect the collective professional judgment of the members of the Transportation Research Board's Highway Capacity and Quality of Service Committee. The upper values shown for LOS E (40 to 45 pc/mi/ln, depending on the FFS) represent the maximum density at which sustained flows at capacity are expected to occur. Breakdown (LOS F) conditions on multilane highways occur whenever the highway's demand exceeds its capacity.

Bicycle Mode

Bicycle LOS for multilane highway segments are based on a bicycle LOS score, which is in turn based on a traveler-perception index. Chapter 15, Two-Lane Highways, provides details about this index, which is identical for two-lane highways and multilane highways. The LOS ranges for bicycles on multilane highways are given in Exhibit 14-6.

Bicycle LOS is based on a traveler-perception index score. Details are given in Chapter 15.

LOS	Bicycle LOS Score
A	≤1.5
B	>1.5–2.5
C	>2.5–3.5
D	>3.5–4.5
E	>4.5–5.5
F	>5.5

Exhibit 14-6
Bicycle LOS on Multilane Highways

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REQUIRED INPUT DATA

Automobile Mode

Analysis of a multilane highway segment requires details concerning the geometric characteristics of the segment and the demand characteristics of the users of the segment. This section presents the required input data for the basic freeway segment methodology; specifics about individual parameters are given in Section 2, Methodology.

Data Describing Multilane Highway Segment

The following information concerning the geometric features of the multilane highway segment is needed to conduct an analysis:

- FFS: 45 to 60 mi/h;
- Number of lanes (one direction): two or three;
- Lane width: 10 ft to more than 12 ft;
- Right-side lateral clearance: 0 ft to more than 6 ft;
- Median- (left-) side lateral clearance: 0 ft to more than 6 ft;
- Access point density: 0 to 40 points/mi;
- Terrain: level, rolling, or mountainous, or length and percent grade of specific grades; and
- Type of median: divided, TWLTL, or undivided.

Data Describing Demand

The following information is required concerning the users of the multilane highway segment:

- Demand during the analysis hour, or daily demand, *K* factor, and *D* factor;
- Heavy-vehicle presence (percent trucks and buses, percent RV's): 0%–100% in general terrain or 0%–25% for specific grades;
- Peak hour factor (PHF): up to 1.00; and
- Driver-population factor: 0.85–1.00.

Length of Analysis Period

The period for any multilane-highway analysis is generally the critical 15-min period within the peak hour. The methodology can be applied to any 15-min period, however.

If demand volumes are used, demand flow rates are estimated through the use of the PHF. When 15-min volumes are directly measured, the worst analysis period within the hour is selected, and flow rates are the 15-min volumes multiplied by 4. For subsequent computations in the methodology, the PHF is set to 1.00.

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Bicycle Mode

The following data are required to evaluate bicycle LOS on a multilane highway; the ranges of values used in the development of the bicycle LOS model (3) are also shown:

- Width of the outside through lane: 10 to 16 ft,
- Shoulder width: 0 to 6 ft,
- Motorized vehicle volumes: up to 70,000 annual average daily traffic (AADT),
- Number of directional through lanes,
- Posted speed: 45 to 50 mi/h,
- Heavy-vehicle percentage: 0% to 2%, and
- Pavement condition: present serviceability rating of 1 to 5.

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2. METHODOLOGY

This methodology is used to analyze the capacity, LOS, lane requirements, and impacts of traffic and design features on uninterrupted-flow segments of rural and suburban multilane highways.

LIMITATIONS OF METHODOLOGY

Automobile Mode

The methodology of this chapter does not take into account the following conditions:

- The negative impacts of poor weather conditions, traffic accidents or incidents, railroad crossings, or construction operations,
- Interference caused by parking on the shoulders of the multilane highway;
- The effect of lane drops and lane additions at the beginning or end of multilane highway segments,
- Possible queuing impacts when a multilane highway segment transitions to a two-lane highway segment,
- Differences between various types of median barriers and the difference between the impacts of a median barrier and a TWLTL;
- FFS below 45 mi/h or higher than 60 mi/h;
- Significant presence of on-street parking,
- Presence of bus stops that have significant use, and
- Significant pedestrian activity.

The last three factors are more representative of an urban or suburban arterial, but they may also exist on facilities with more than 2 mi between traffic signals. When the factors are present on uninterrupted-flow segments of multilane highways, the methodology does not deal with their impact on flow. In addition, this methodology cannot be applied to highways with a total of three lanes in both directions, which should be analyzed as two-lane highways with periodic passing lanes.

Uninterrupted-flow facilities that allow access solely through a system of on-ramps and off-ramps from grade separations or service roads should be analyzed as freeways.

Bicycle Mode

Although the bicycle LOS model has been successfully applied to rural multilane highways, users should be aware that conditions on many of these highways are outside the range of values used to develop the model.

The bicycle methodology was developed with data collected on urban and suburban streets, including facilities that would be defined as suburban multilane highways. Although the methodology has been successfully applied to rural multilane highways in different parts of the United States, users should be aware that conditions on many rural multilane highways (i.e., posted speeds of 55 mi/h or higher or heavy-vehicle percentages over 2%) will be outside the range of values used to develop the bicycle LOS model.

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AUTOMOBILE MODE

Exhibit 14-7 provides an overview of this chapter's computational methodology for the automobile mode. It shows a typical operational analysis in which the LOS is determined for a specified set of geometric and traffic conditions. The methodology can also be used, as described in this chapter's Applications section, to determine the number of lanes needed to provide a target LOS, as well as to determine service flow rates, service volumes, and daily service volumes.

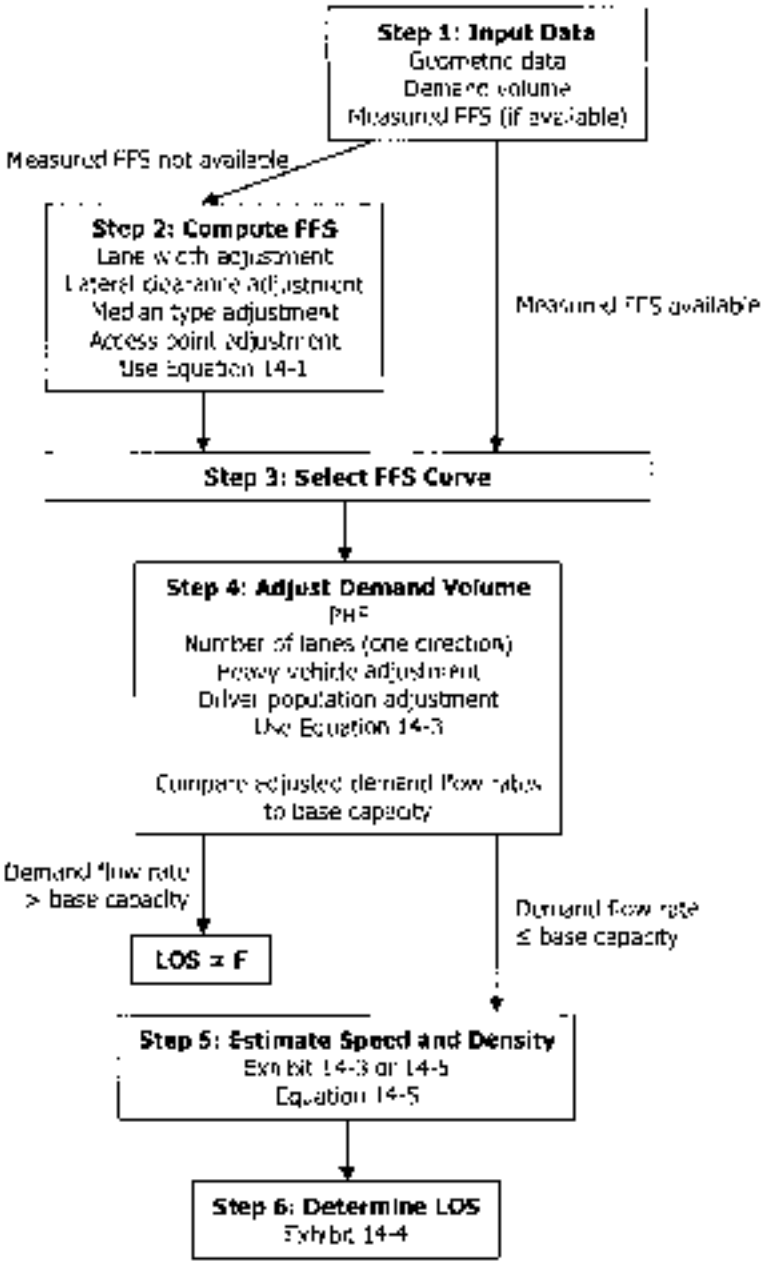

Exhibit 14-7
Overview of Multilane Highway Methodology for Automobile Mode

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Step 1: Input Data

For a typical operational analysis, the analyst must specify (with either site-specific or default values) demand volume, number and width of lanes, right-side and median lateral clearance, type of median, roadside access points per mile, percent of heavy vehicles, such as trucks, buses, and RVs, PHF, terrain, and driver population factor.

Step 2: Compute FFS

FFS can be determined directly from field measurements or can be estimated as described below.

Field Measurement

FFS is the mean speed of passenger cars during periods of low to moderate flow

FFS is the mean speed of passenger cars measured during periods of low to moderate flow (up to 1,400 pc/h/ln). For a specific multilane highway segment, speeds are virtually constant in this range of flow rates. If the FFS can be field measured, this determination is preferable. If the FFS is measured directly, no adjustments are applied to the measured value.

The speed study should be conducted at a location representative of the segment at a time when flow rates are less than 1,400 pc/h/ln. The speed study should measure the speeds of all passenger cars or use a systematic sample (e.g., every tenth car in each lane). A sample of at least 100 passenger-car speeds should be obtained. Any speed measurement technique that has been found acceptable for other types of traffic engineering applications may be used. Further guidance on the conduct of speed studies is provided in a standard traffic engineering publication (3).

Estimation

It is not possible to make field measurements for future facilities, and field measurement may not be possible or practical for all existing ones. In such cases, the segment's FFS may be estimated by using Equation 14-1, which is based on the physical characteristics of the segment under study:

Equation 14-1

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A$$

where

- $BFFS$ = base FFS for multilane highway segment (mi/h),
- FFS = FFS of basic freeway segment (mi/h),
- f_{LW} = adjustment for lane width, from Exhibit 14-8 (mi/h),
- f_{LC} = adjustment for TLC, from Exhibit 14-9 (mi/h),
- f_M = adjustment for median type, from Exhibit 14-10 (mi/h), and
- f_A = adjustment for access-point density, from Exhibit 14-11 (mi/h).

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Base FFS

This methodology covers multilane highway segments with FFS ranging from 45 mi/h to 60 mi/h. The most significant value in Equation 14-1 is the BFFS. There is not a great deal of information available to help establish a base value. In one sense, it is like the design speed—it represents the potential FFS based only on the horizontal and vertical alignment of the highway, not on the impacts of lane widths, lateral clearances, median type, or access points. The design speed may be used as the BFFS if it is available.

Although speed limits are not always uniformly set, the BFFS may be estimated, if necessary, as the posted or statutory speed limit plus 5 mi/h for speed limits 50 mi/h and higher and as the speed limit plus 7 mi/h for speed limits less than 50 mi/h.

Adjustment for Lane Width

Average lane widths less than 12 ft reduce the FFS.

The base condition for lane width is 12 ft or greater. When the average lane width across all lanes is less than 12 ft, the FFS is negatively affected. Adjustments to reflect the effect of narrow average lane widths are shown in Exhibit 14-8.

Exhibit 14-8
Adjustment to FFS for Average Lane Width

Lane Width (ft)	Reduction in FFS, f_{LW} (mi/h)
≥12	0.0
≥11–12	1.9
≥10–11	6.6

Adjustment for Lateral Clearance

Clearance restrictions on either the right or left side of the highway reduce the FFS.

The adjustment for lateral clearance on multilane highway segments is based on TLC at the roadside (right side) and at the median (left side). Fixed obstructions with lateral clearance effects include light standards, signs, trees, abutments, bridge rails, traffic barriers, and retaining walls. Standard raised curbs are not considered to be obstructions.

Right-side lateral clearance is measured from the right edge of the travel lanes to the nearest periodic or continuous roadside obstruction. If such obstructions are farther than 6 ft from the edge of the pavement, a value of 6 ft is used.

Left-side lateral clearance is measured from the left edge of the travel lanes to the nearest periodic or continuous obstruction in the median. If such obstructions are farther than 6 ft from the edge of the pavement, a value of 6 ft is used.

Use 6.0 as the left-side clearance for undivided highways and highways with TWTL.

Left-side lateral clearances are subject to some judgment. Many types of common median barriers do not affect driver behavior if they are no closer than 2 ft from the edge of the travel lane, including concrete and W-beam barriers. A value of 6 ft would be used in such cases. Also, when the multilane highway segment is undivided or has a TWTL, no left-side lateral clearance restriction is assumed, and a value of 6 ft is applied because there is a separate adjustment for the type of median that accounts for the impact of an undivided highway on FFS.

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Equation 14-2 is used to determine TLC:

Equation 14-2

$$TLC = LC_R + LC_L$$

where

TLC = total lateral clearance (ft) (maximum value 12 ft),

LC_R = right-side lateral clearance (ft) (maximum value 6 ft), and

LC_L = left-side lateral clearance (ft) (maximum value 6 ft).

Exhibit 14-9 shows the reduction in FFS due to lateral obstructions on the multilane highway.

Exhibit 14-9
Adjustment to FFS for Lateral Clearance

Four-Lane Highways		Six-Lane Highways	
TLC (ft)	Reduction in FFS (mi/h)	TLC (ft)	Reduction in FFS (mi/h)
12	0.0	12	0.0
10	0.4	10	0.4
8	0.9	8	0.8
6	1.3	6	1.2
4	1.8	4	1.7
2	3.6	2	2.6
0	5.4	0	3.9

Note: Interpolation to the nearest 0.1 is recommended.

Adjustment for Type of Median

The FFS is reduced on undivided highways.

The adjustment for type of median is given in Exhibit 14-10. Undivided multilane highways reduce the BFFS by 1.6 mi/h.

Exhibit 14-10
Adjustment to FFS for Median Type

Median Type	Reduction in FFS, f_M (mi/h)
Undivided	1.6
TWTL	0.0
Divided	0.0

Adjustment for Access-Point Density

FFS is reduced as the access point density increases.

Exhibit 14-11 presents the adjustment to FFS for various levels of access-point density. Studies indicate that for each access point per mile, the estimated FFS decreases by approximately 0.25 mi/h, regardless of the type of median.

The number of access points per mile is determined by dividing the total number of access points (i.e., driveways and unsignalized intersections) on the right side of the highway in the direction of travel by the length of the segment in miles. An intersection or driveway should only be included in the count if it influences traffic flow. Access points that go unnoticed by drivers, or with little activity, should not be used to determine access-point density.

Exhibit 14-11
Adjustment to FFS for Access-Point Density

Access-Point Density (access points/mi)	Reduction in FFS, f_A (mi/h)
0	0.0
10	2.5
20	5.0
30	7.5
≥40	10.0

Note: Interpolation to the nearest 0.1 is recommended.

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Although the calibration of this adjustment did not include one-way multilane highway segments, it might be appropriate to include intersection approaches and driveways on both sides of the facility in determining the access-point density on one-way segments.

Step 3: Select FFS Curve

As noted previously, once the multilane highway segment's FFS is determined, one of the four base speed–flow curves from Exhibit 14-2 is selected for use in the analysis. Interpolating between curves is not recommended. Criteria for selecting an appropriate curve were given in the text preceding Exhibit 14-2.

Step 4: Adjust Demand Volume

The basic speed–flow curves of Exhibit 14-2 are based on flow rates in equivalent passenger cars per hour, with the driver population dominated by regular users of the multilane highway segment. Demand volumes expressed as vehicles per hour under prevailing conditions must be converted to this basis. Equation 14-3 is used for this adjustment:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

Equation 14-3

where

v_p = demand flow rate under equivalent base conditions (pc/h/ln);
V = demand volume under prevailing conditions (veh/h);
PHF = peak hour factor;
N = number of lanes (one direction);
f_{HV} = adjustment factor for presence of heavy vehicles in traffic stream, from Equation 14-4; and
f_p = adjustment factor for atypical driver populations.

PHF

The PHF represents the variation in traffic flows within an hour. Observations of traffic flow consistently indicate that the flow rates found in the peak 15 min within an hour are not sustained throughout the entire hour. The application of the PHF in Equation 14-3 accounts for this phenomenon.

On multilane highways, typical PHFs range from 0.75 to 0.95. Lower values are typical of lower volume conditions. Higher values are typical of urban and suburban peak hour conditions. Field data should be used if possible to develop PHFs that represent local conditions.

Adjustment for Heavy Vehicles

A *heavy vehicle* is defined as any vehicle with more than four wheels on the ground during normal operation. Such vehicles are generally categorized as trucks, buses, or RVs. Trucks cover a wide variety of vehicles, from single-unit trucks with dual-rear tires to triple-unit tractor–trailer combinations. Small

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panel or pickup trucks with only four wheels are, however, classified as passenger cars. Buses include intercity buses, public transit buses, and school buses. Because buses are in many ways similar to single-unit trucks, both types of vehicles are considered in one category. RVs include a wide variety of vehicles from self-contained motor homes to cars and small trucks with trailers (for boats, all-terrain vehicles, or other items). The heavy vehicle adjustment factor f_{HV} is computed by using Equation 14-4:

Equation 14-4

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

where

f_{HV} = heavy-vehicle adjustment factor,

P_T = proportion of trucks and buses in traffic stream,

P_R = proportion of RVs in traffic stream,

E_T = passenger car equivalent (PCE) of one truck or bus in traffic stream, and

E_R = PCE of one RV in traffic stream.

The adjustment factor is found in a two-step process. First, the PCE for each truck, bus, and RV is found for the prevailing conditions under study. These equivalency values represent the number of passenger cars that would use the same amount of freeway capacity as one truck, bus, or RV under the prevailing conditions. Second, Equation 14-4 is used to convert the PCE values to the adjustment factor.

In many cases, trucks will be the only heavy vehicle present in the traffic stream. In others, the percentage of RVs will be small compared with trucks and buses. If the ratio of trucks and buses to RVs is 5:1 or greater, all heavy vehicles may be (but do not have to be) considered to be trucks.

The effect of heavy vehicles on traffic flow depends on terrain and grade conditions as well as traffic composition. PCEs can be selected for one of three conditions:

- Extended multilane highway segments in general terrain,
- Specific upgrades, or
- Specific downgrades.

Each of these conditions is more precisely defined and discussed below.

General terrain can be applied when:

Grades are <3%,

Grades are <5.2% for long, or

Grades are >3% and <5%, and are <0.50 mi long.

Equivalents for General Terrain Segments

General terrain refers to extended lengths of multilane highway containing a number of upgrades and downgrades where no single grade is long enough or steep enough to have a significant impact on the operation of the overall segment. As a guideline for this determination, extended segment analysis can be applied where no one grade of 3% or more is longer than 0.25 mi, or where no single grade between 2% and 3% is longer than 0.50 mi.

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There are three categories of *general terrain*:

- *Level terrain*: Any combination of grades and horizontal or vertical alignment that permits heavy vehicles to maintain the same speed as passenger cars. This type of terrain typically contains short grades of no more than 2%.
- *Rolling terrain*: Any combination of grades and horizontal or vertical alignment that causes heavy vehicles to reduce their speed substantially below that of passenger cars but that does not cause heavy vehicles to operate at crawl speeds for any significant length of time or at frequent intervals. *Crawl speed* is the maximum sustained speed that trucks can maintain on an extended upgrade of a given percent. If the grade is long enough, trucks will be forced to decelerate to the crawl speed, which they can maintain for extended distances. Appendix A of Chapter 11, Basic Freeway Segments, contains truck performance curves that provide truck speeds for various lengths and severities of grade. The same curves may be used for uninterrupted-flow segments on multilane highways.
- *Mountainous terrain*: Any combination of grades and horizontal and vertical alignment that causes heavy vehicles to operate at crawl speed for significant distances or at frequent intervals.

Mountainous terrain is relatively rare. Generally, in segments severe enough to cause the type of operation described for mountainous terrain, there will be individual grades that are longer and steeper than the criteria for general terrain analysis.

The mountainous terrain category is rarely used, because individual grades will typically be longer and steeper than the criteria for general terrain analysis.

Exhibit 14-12 shows PCEs for trucks and buses and RVs in general terrain segments.

Exhibit 14-12
PCEs for Heavy Vehicles in General Terrain Segments

Vehicle	PCE by Type of Terrain		
	Level	Rolling	Mountainous
Trucks and buses, E_T	1.5	2.5	4.5
RVs, E_R	1.2	2.0	4.0

Equivalents for Specific Upgrades

Any grade between 2% and 3% and longer than 0.5 mi, or 3% or greater and longer than 0.25 mi, should be considered to be a separate segment. The analysis of such segments must consider the upgrade conditions and the downgrade conditions separately, as well as whether the grade is a single, isolated grade of constant percentage or part of a series forming a composite grade. Appendix A of Chapter 11 discusses the analysis of composite grades.

Exhibit 14-13 and Exhibit 14-14 give values of I_D and I_R for trucks and buses and for RVs, respectively. These factors vary with the percent of grade, length of grade, and the proportion of heavy vehicles in the traffic stream. Maximum values occur when there are only a few heavy vehicles in the traffic stream. The equivalents decrease as the number of heavy vehicles increases because these vehicles tend to form platoons. Because heavy vehicles have more uniform operating characteristics, fewer large gaps are created in the traffic stream when they platoon, and the impact of a single heavy vehicle in a platoon is less severe than that of a single heavy vehicle in a stream primarily composed of passenger

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cars. The aggregate impact of heavy vehicles on the traffic stream, however, increases as the number and percentage of heavy vehicles increase.

Exhibit 14-13
PCEs for Trucks and Buses (E_T) on Upgrades

Percent Upgrade	Length (mi)	Proportion of Trucks and Buses 2%	4%	5%	6%	8%	10%	15%	20%	25%
≤2	All	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
>2 – 3	0.00 – 0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25 – 0.50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.50 – 0.75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.75 – 1.00	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	>1.00 – 1.50	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>1.50	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0
>3 – 4	0.00 – 0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25 – 0.50	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	>0.50 – 0.75	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	>0.75 – 1.00	3.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	>1.00 – 1.50	3.5	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
	>1.50	4.0	3.5	4.0	4.0	3.0	3.0	2.5	2.5	2.5
>4 – 5	0.00 – 0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25 – 0.50	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>0.50 – 0.75	4.5	4.0	4.0	4.0	2.5	2.5	2.5	2.5	2.5
	>0.75 – 1.00	4.0	3.5	3.5	3.5	3.0	3.0	3.0	3.0	3.0
	>1.00	5.0	4.0	4.0	4.0	3.5	3.5	3.0	3.0	3.0
>5 – 6	0.00 – 0.25	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25 – 0.50	4.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>0.50 – 0.75	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0
	>0.75 – 1.00	5.5	5.0	4.5	4.0	3.0	3.0	3.0	4.0	3.0
	>1.00	6.0	5.0	5.0	4.5	3.5	3.5	3.5	4.5	4.5
>6	0.00 – 0.25	4.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	1.0
	>0.25 – 0.50	4.5	4.0	3.5	3.5	3.5	3.0	2.5	2.5	2.5
	>0.50 – 0.75	5.0	4.5	4.0	4.0	3.5	3.0	2.5	2.5	2.5
	>0.75 – 1.00	5.5	5.0	4.5	4.5	4.0	3.5	3.0	3.0	3.0
	>1.00	6.0	5.5	5.0	5.0	4.5	4.0	3.5	4.5	3.5
	>1.00	7.0	6.0	5.5	5.5	5.0	4.5	4.0	4.0	4.0

Note: Interpolation for percentages of trucks and buses is recommended to the nearest 0.5.

Exhibit 14-14
PCEs for RVs (E_R) on Upgrades

Percent Upgrade	Length (mi)	Proportion of RVs 2%	4%	5%	6%	8%	10%	15%	20%	25%
≤2	All	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
>2 – 3	0.00 – 0.50	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	>0.50	3.0	1.5	1.5	1.5	1.5	1.5	1.2	1.2	1.2
>3 – 4	0.00 – 0.25	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	>0.25 – 0.50	2.5	2.5	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	>0.50	3.0	2.5	2.5	2.5	2.0	2.0	2.0	1.5	1.5
>4 – 5	0.00 – 0.25	2.5	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	>0.25 – 0.50	4.0	3.0	3.0	3.0	2.5	2.5	2.0	2.0	2.0
	>0.50	4.5	3.5	3.0	3.0	3.0	2.5	2.5	2.0	2.0
>5	0.00 – 0.25	4.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	1.5
	>0.25 – 0.50	5.0	4.0	4.0	4.0	3.5	3.0	3.0	2.5	2.0
	>0.50	6.0	4.5	4.0	4.0	3.5	3.0	3.0	2.5	2.0

Note: Interpolation for percentages of RVs is recommended to the nearest 0.1.

The grade length should include 25% of the length of the vertical curves at the start and end of the grade.

With two consecutive upgrades, 50% of the length of the vertical curve joining them should be included.

The length of the grade is generally taken from a highway profile. It typically includes the straight portion of the grade plus some portion of the vertical curves at the beginning and end of the grade. It is recommended that 25% of the length of the vertical curves at both ends of the grade be included in the length. Where two consecutive upgrades are present, 50% of the length of the vertical curve joining them is included in the length of each grade.

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In the analysis of upgrades, the point of interest is generally at the end of the grade, where heavy vehicles have the maximum effect on operations. However, if a segment ends midgrade (because of a major access point, for example), the length of the grade to the end of the segment would be used.

The point of interest in the analysis of upgrades is usually the spot where heavy vehicles would have the greatest impact on operations (for example, the top of a grade or the top of the steepest grade in a series).

On composite grades, the relative steepness of segments is important. If a 5% upgrade is followed by a 2% upgrade, for example, the maximum impact of heavy vehicles is most likely at the end of the 5% segment. Heavy vehicles would be expected to accelerate after entering the 2% segment.

Equivalents for Specific Downgrades

Knowledge of specific impacts of heavy vehicles on operating conditions on downgrades is limited. In general, if the downgrade is not severe enough to cause trucks to shift into a lower gear (to engage engine braking), heavy vehicles may be treated as if they were on level terrain segments. Where a downgrade is severe, trucks must often use low gears to avoid gaining too much speed and running out of control. In such cases, their effect on operating conditions is more significant than on level terrain. Exhibit 14-15 gives values of E_T for this situation.

Exhibit 14-15
PCEs for Trucks and Buses (E_T) on Specific Downgrades

Percent Downgrade	Length of Grade (mi)	Proportion of Trucks and Buses			
		5%	10%	15%	20%
≤4	All	1.5	1.5	1.5	1.5
>4 – 5	≤4	1.5	1.5	1.5	1.5
	>4	2.0	2.0	2.0	1.5
>5 – 6	≤4	1.5	1.5	1.5	1.5
	>4	5.5	4.0	4.0	3.0
>6	≤4	1.5	1.5	1.5	1.5
	>4	7.5	6.0	5.5	4.5

On downgrades, RVs are always treated as if they were on level terrain. E_R is therefore always 1.2 on downgrades regardless of the length or severity of the downgrade or the percentage of RVs in the traffic stream.

E_R is always 1.2 on downgrades.

Equivalents for Composite Grades

The vertical alignment of most multilane highways results in a continuous series of grades. It is often necessary to determine the effect of a series of grades in succession. The most straightforward technique is to compute the *average grade*, defined as the total rise from the beginning of the composite grade to the point of interest divided by the length of the grade (to the point of interest).

The average grade can be used when all component grades are <4% or the total length of the grade is <4,000 ft.

The average grade technique is an acceptable approach for grades in which all subsections are less than 4% or the total length of the grade is less than 4,000 ft. For more severe composite grades, a detailed technique is presented in Appendix A of Chapter 11, Basic Freeway Segments. This technique uses vehicle performance curves and equivalent speeds to determine the equivalent simple grade for analysis. It can be applied to composite grades on multilane highways.

Appendix A of Chapter 11 provides a method for addressing more severe composite grades.

Adjustment for Driver Population

The base traffic stream characteristics for multilane highway segments are representative of regular drivers in a traffic stream composed substantially of commuters, or drivers who are familiar with the facility. It is generally accepted

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that traffic streams composed of driver populations with different characteristics (e.g., recreational drivers) use freeways less efficiently. Although data are sparse and reported results vary substantially, significantly lower capacities have been reported on weekends, particularly in recreational areas. It may generally be assumed that the reduced capacity (1,650 pc/h/ln) extends to service flow rates and service volumes for other LOS as well.

A default value of 1.00 should generally be used, reflective of drivers who are typically users of the facility.

The adjustment factor f_p is used to reflect the effect of driver population. The values of f_p usually range from 0.85 to 1.00, although lower values have been observed in some cases. In general, the analyst should use a value of 1.00, which reflects commuters or otherwise familiar drivers, unless there is sufficient evidence that a lower value should be used. Where greater accuracy is needed, comparative field studies of commuter and recreational traffic flow and speeds are recommended.

Does LOS F Exist?

At this point, the demand flow rate has been computed and is stated in units of passenger cars per hour per lane under equivalent base conditions. This demand flow rate must be compared with the base capacity (in the same units). If demand exceeds capacity, LOS F is assigned, and the analysis ends. If demand is less than capacity, LOS F does not exist, and the analysis continues.

Step 5: Estimate Speed and Density

At this point in the methodology, the following have been determined: (a) the FFS and appropriate SFF curve for use in the analysis, and (b) the demand flow rate expressed in passenger cars per hour per lane under equivalent base conditions. With this information, the estimated speed and density of the traffic stream may be determined.

With the equations specified in Exhibit 14-3, the expected mean speed of the traffic stream can be computed. A graphical solution using Exhibit 14-2 can also be performed.

With the estimated speed determined, Equation 14-5 is used to estimate the density of the traffic stream.

Equation 14-5

$$D = \frac{v_p}{S}$$

where

D = density (pc/mi/ln),
v_p = demand flow rate (pc/h/ln), and
S = mean speed of traffic stream (mi/h).

Step 6: Determine LOS

Exhibit 14-4 is entered with the density obtained from Equation 14-5 to determine the expected prevailing LOS.

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BICYCLE MODE

The calculation of bicycle LOS on multilane and two-lane highways shares the same methodology, since multilane and two-lane highways operate in fundamentally the same manner for bicyclists and car drivers. Cyclists travel much more slowly than the prevailing traffic flow and stay as far to the right as possible, including using paved shoulders when available. This similarity indicates the need for only one model.

For bicycle LOS mode, for multilane highways uses a traveler perception index calibrated by using a linear regression model. The model fits independent variables associated with roadway characteristics to the results of a user survey that rates the comfort of various bicycle facilities. The resulting bicycle LOS index computes a numerical LOS score, generally ranging from 0.5 to 6.5, which is stratified to produce a LOS A to F result by using Exhibit 14-6.

Full details on the bicycle LOS methodology and calculation procedures are given in Chapter 15, Two-Lane Highways.

Follow the step-by-step description of the bicycle LOS method given in Chapter 15, Two-Lane Highways, when service LOS on multilane highways is calculated.

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3. APPLICATIONS

The analysis methodology for multilane highway segments is relatively straightforward. Thus, it can be directly used in any one of four applications:

1. *Operational analysis*. All traffic and roadway conditions are specified for an existing facility or a future facility with forecast conditions. The existing or expected LOS is determined.
2. *Design analysis*. A forecast demand volume is used, and key design parameters are specified (e.g., lane width and lateral clearance). The number of lanes required to deliver a target LOS is determined.
3. *Planning and preliminary engineering*. The basic scenario is the same as that for design analysis except that the analysis is conducted at a much earlier stage in the development process. Inputs include default values, and the demand volume is usually stated as an AADT.
4. *Service flow rate and service volume*. The service flow rate, service volume, daily service volume, or all three are estimated for each LOS for an existing or future facility. All traffic and roadway conditions must be specified for this type of analysis.

Because the methodology and its algorithms are simple and do not involve iterations, all of the types of analysis cited can be completed without the iterative approach required by many other HCM methodologies.

DEFAULT VALUES

For this chapter's methodology, a range of input data is needed. Most of these data should be field measured or estimated values for the specific segment under consideration. When some of the data are not available, default values may be used. However, use of default values will affect the accuracy of the output. Exhibit 14-16 shows the data that are required to conduct an operational analysis and the recommended default values when site-specific data are unavailable (1).

Exhibit 14-16
Required Input Data and Default Values for Multilane Highway Segments

Required Data	Default Values
Geometric Data	
Number of lanes in one direction	2 or 3 (in one direction); must have site-specific value
Lane width	12 ft
TLC	12 ft
Access-point density	8 access points/mi (rural) 16 access points/mi (low-density suburban) 25 access points/mi (high-density suburban)
Length of specific grade (%, length)	No default; must have site-specific value
Base FFS	65 mi/h [illegible]
Demand Data	
Length of analysis period	15 min
PHF	0.88, rural; 0.95, suburban
Percentage of heavy vehicles	10%, rural; 5%, urban*
Driver population factor	1.00

Note: *Refer to site-specific default values for percentage of heavy vehicles as given in Chapter 26, Freeway and Highway Segments: Supplemental.

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The analyst may also replace the default values in Exhibit 14-16 with defaults that have been locally calibrated.

ESTABLISHING ANALYSIS BOUNDARIES

The methodology of this chapter applies to an uninterrupted flow segment of multilane highway with uniform prevailing conditions. Thus, any point at which one or more of the prevailing conditions change should mark the beginning of a new analysis segment. The following conditions generally necessitate segmenting the highway:

- A change in the basic number of travel lanes on the highway;
- A change in the highway's median treatment;
- A change of grade of 2% or more on a constant upgrade longer than 1,000 ft;
- The presence of a traffic signal, stop sign, or roundabout along the multilane highway;
- A significant change in the cross-point density;
- A change in the speed limit;
- An access point at which a significant number or percentage of vehicles enters or leaves the highway; and
- The presence of a bottleneck condition.

Locate changes of 2% or more, changes in the highway's geometric characteristics, changes in speed limit, signalized intersections of the highway, and major access points are places where multilane highways should be segmented.

In general, when analysis boundaries are established, the minimum length of a study segment should be 2,500 ft. The boundary of a study segment should be no closer than 0.25 mi to a traffic signal.

TYPES OF ANALYSIS

Operational Analysis

The operational analysis application was fully specified in the Methodology section of this chapter. Operational analysis begins with all input parameters specified and is used to find the expected LOS that would result from the prevailing roadway and traffic conditions.

Operational analysis finds the expected LOS for specified roadway and traffic conditions.

Design Analysis

In design analysis, a known demand volume is used to determine the number of lanes needed to deliver a target LOS. Two modifications are required to the operational analysis methodology. First, since the number of lanes is to be determined, the demand volume is converted to a demand flow rate in passenger cars per hour, not passenger cars per hour per lane, by using Equation 14-6 instead of Equation 14-3.

Design analysis finds the number of lanes required for a target LOS given a specified demand volume.

$$v = \frac{V}{PHF \times f_{HV} \times f_p} \qquad \text{Equation 14-6}$$

where v is the demand flow rate in passenger cars per hour and all other variables are as previously defined.

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Second, a maximum service flow rate for the target LOS is then selected from Exhibit 14-17. These values are selected from the base speed–flow curves of Exhibit 14-5 for each LOS.

Exhibit 14-17
Maximum Service Flow Rates (pc/h/ln) for Multilane Highway Segments Under Base Conditions

FFS (mi/h)	Target LOS				
	A	B	C	D	E
60	660	1,080	1,550	1,980	2,200
55	600	990	1,420	1,810	2,100
50	550	900	1,300	1,710	2,000
45	290	810	1,170	1,550	1,900

Then the number of lanes required to deliver the target LOS can be found from Equation 14-7:

Equation 14-7

$$N = \frac{v}{MSF_i}$$

where N is the number of lanes required and MSF_i is the maximum service flow rate for LOS i from Exhibit 14-17. Equation 14-6 and Equation 14-7 can be conveniently combined as Equation 14-8:

Equation 14-8

$$N = \frac{V}{MSF_i \times PHF \times f_{HV} \times f_p}$$

where all variables are as previously defined.

All fractional values of N must be rounded up.

The value of N resulting from Equation 14-7 or Equation 14-8 will most likely be fractional. Because only integer numbers of lanes can be constructed, the result is always rounded to the next higher value. Thus, if the result is 2.1 lanes, 3 lanes must be provided. In effect, the minimum number of lanes needed to provide the target LOS is 2.1. If the result were rounded to 2, a poorer LOS than the target value would result.

Because only whole lanes can be built, it may not be possible to achieve the target LOS for a given demand volume.

This rounding-up process will occasionally produce an interesting result: it is possible that a target LOS (for example, LOS C) cannot be achieved for a given demand volume. If 2 lanes are required to produce LOS C, providing two lanes would drop the LOS, most likely to D. However, if three lanes are provided, the LOS might actually improve to B. Thus, some judgment may be required to interpret the results. In this case, two lanes might be provided even though they would result in a borderline LOS D. Economic considerations might lead a decision maker to accept a slightly lower operating condition than that originally targeted.

Planning and Preliminary Engineering

Planning and preliminary engineering applications also find the number of lanes required to deliver a target LOS but require more generalized input values to the methodology.

The objective of planning or preliminary engineering is to get a general idea of the number of lanes that will be required to deliver a target LOS. The primary differences are that many default values will be used, and the demand volume will be usually expressed as an AADT. Thus, a planning and preliminary engineering analysis starts by converting the demand expressed as an AADT to an estimate of the directional peak-hour demand volume (DDHV), as shown in Equation 14-9:

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$$V = DDHV = AADT \times K \times D$$

Equation 14-9

where K is the proportion of AADT occurring during the peak hour, D is the proportion of peak-hour volume traveling in the peak direction, and all other variables are as previously defined.

Chapter 2, Modal Characteristics, provides additional guidance on K- and D-factors.

Once the hourly demand volume is estimated, the methodology follows the same path as that for design analysis.

Service Flow Rates, Service Volumes, and Daily Service Volumes

This chapter's methodology can be easily manipulated to produce service flow rates, service volumes, or daily service volumes, or all three, for a multilane highway segment.

Exhibit 14-17 gives values of the maximum service flow rates MSF_i for each LOS for multilane highways of various FFSs. These values are given in terms of passenger cars per hour per lane under equivalent base conditions. A service flow rate SF_i is the maximum rate of flow that can exist while LOS i is maintained during the 15-min analysis period under prevailing conditions. It can be computed from the maximum service flow rate by using Equation 14-10:

$$SF_i = MSF_i \times N \times f_{HV} \times f_p$$

Equation 14-10

where all variables are as previously defined.

A service flow rate can be converted to a service volume SV_i by applying a PHF, as shown in Equation 14-11. A service volume is the maximum hourly volume that can exist while LOS i is maintained during the worst 15-min period of the analysis hour.

$$SV_i = SF_i \times PHF$$

Equation 14-11

where all variables are as previously defined.

A daily service volume DSV_i is the maximum AADT that can be accommodated by the facility under prevailing conditions while LOS i is maintained during the worst 15-min period of the analysis day. It is estimated from Equation 14-12:

$$MSV_i = \frac{SV_i}{K \times D}$$

Equation 14-12

where all variables are as previously defined.

GENERALIZED DAILY SERVICE VOLUMES

Exhibit 14-18 and Exhibit 14-19 are generalized daily service volume tables for multilane highway segments or facilities. They are based on a set of specified typical conditions for rural and urban multilane highways:

- Percent HV = 10% (rural), 5% (urban),
- FFS = 60 mi/h,
- PHF = 0.88 (rural), 0.95 (urban); and
- Driver population factor $f_p = 1.00$.

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Values of rural and urban daily service volumes are provided for four-lane and six-lane highways in level and rolling terrain. A range of K and D factors is provided. Users should enter Exhibit 14-18 and Exhibit 14-19 with local or regional values of these factors for the appropriate size of multilane highway in the appropriate terrain.

Exhibit 14-18
Generalized Daily Service Volumes for Rural Multilane Highways (1,000 veh/day)

K-Factor	D-Factor	Four-Lane Highways				Six-Lane Highways			
		LOS B	LOS C	LOS D	LOS E	LOS B	LOS C	LOS D	LOS E
Level Terrain									
0.09	0.50	33.2	48.0	63.1	73.8	49.8	71.9	94.6	110.7
	0.55	30.2	43.6	57.4	67.1	45.3	65.4	86.0	100.6
	0.60	27.7	40.0	52.6	61.5	41.5	60.0	78.9	92.2
	0.65	25.5	36.9	48.5	56.8	38.2	55.3	72.8	85.1
0.10	0.50	29.9	43.2	56.8	66.4	44.8	64.8	85.2	99.6
	0.55	27.2	39.2	51.6	60.4	40.8	58.9	77.4	90.6
	0.60	24.9	36.0	47.3	55.3	37.4	54.0	71.0	83.0
	0.65	23.0	33.2	43.7	51.1	34.5	49.8	65.5	76.6
0.11	0.50	27.2	39.2	51.6	60.4	40.8	58.9	77.4	90.6
	0.55	24.7	35.7	46.9	54.9	37.0	53.5	70.4	82.3
	0.60	22.6	32.7	43.0	50.3	34.0	49.1	64.5	75.5
	0.65	20.9	30.2	39.7	46.4	31.3	45.3	59.6	69.7
0.12	0.50	24.9	36.0	47.3	55.3	37.4	54.0	71.0	83.0
	0.55	22.6	32.7	43.0	50.3	34.0	49.1	64.5	75.5
	0.60	20.8	30.0	39.4	46.1	31.1	45.0	59.2	69.2
	0.65	19.2	27.7	36.4	42.6	28.7	41.5	54.6	63.9
Rolling Terrain									
0.09	0.50	28.8	43.1	58.7	68.3	44.7	64.6	88.0	102.4
	0.55	27.1	39.2	53.5	62.3	40.7	58.8	80.3	93.4
	0.60	24.9	35.9	49.2	57.2	37.3	53.9	73.8	85.9
	0.65	22.9	33.1	45.3	52.8	34.4	49.7	67.9	79.1
0.10	0.50	26.8	38.8	53.0	59.7	40.3	58.2	79.5	89.5
	0.55	24.4	35.3	48.4	54.2	36.6	52.9	72.6	81.4
	0.60	22.4	32.3	44.1	49.7	33.6	48.5	66.3	74.6
	0.65	20.7	29.8	40.8	45.9	31.0	44.7	61.2	68.8
0.11	0.50	24.4	35.3	48.4	54.2	36.6	52.9	72.6	81.4
	0.55	22.2	32.0	43.9	49.3	33.3	48.1	65.9	74.0
	0.60	20.3	29.4	40.2	45.2	30.5	44.1	60.4	67.8
	0.65	18.8	27.1	37.1	41.7	28.2	40.7	55.8	62.6
0.12	0.50	22.4	32.3	44.3	49.7	33.6	48.5	66.5	74.6
	0.55	20.3	29.4	40.3	45.2	30.5	44.1	60.4	67.8
	0.60	18.6	26.9	36.9	41.4	28.0	40.4	55.4	62.1
	0.65	17.2	24.9	34.1	38.2	25.8	37.4	51.2	57.4

Note: Key assumptions: 12% trucks, 0.98 PHF, 60 mi/h FFS, 0% access points/mi, 0

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Exhibit 14-19
Generalized Daily Service Volumes for Urban Multilane Highways (1,000 veh/day)

K-Factor	D-Factor	Four-Lane Highways LOS B	LOS C	LOS D	LOS E	Six-Lane Highways LOS B	LOS C	LOS D	LOS E
Level Terrain									
0.08	0.50	49.3	69.3	86.5	98.4	72.4	104.0	122.5	147.5
	0.55	43.9	63.0	80.5	89.4	65.8	94.5	120.7	134.1
	0.60	40.2	57.6	72.8	82.0	60.4	86.6	110.7	123.0
	0.65	37.1	52.2	66.1	75.7	55.7	80.0	102.1	113.5
0.09	0.50	42.9	61.6	76.7	87.4	64.4	92.4	116.0	131.2
	0.55	39.0	56.0	71.5	79.5	58.5	84.0	107.2	119.2
	0.60	35.9	51.3	65.6	72.9	53.7	77.0	98.4	109.3
	0.65	33.0	47.4	60.5	67.3	49.5	71.1	90.8	100.9
0.10	0.50	39.6	55.4	70.8	78.7	57.9	83.2	106.2	118.0
	0.55	35.1	50.4	64.4	71.5	52.7	75.6	96.6	107.3
	0.60	32.2	46.2	59.0	65.6	48.3	69.3	88.5	98.4
	0.65	29.7	42.6	54.5	60.5	44.6	64.0	81.7	90.8
0.12	0.50	36.1	50.4	64.4	71.5	52.7	75.6	96.6	107.3
	0.55	31.9	45.8	58.5	65.0	47.9	68.7	87.8	97.6
	0.60	28.3	42.0	53.7	59.6	42.9	63.0	80.5	89.4
	0.65	27.0	38.9	49.5	55.0	40.5	58.2	74.4	82.5
Rolling Terrain									
0.08	0.50	44.9	64.4	82.2	91.3	67.3	96.5	123.3	137.0
	0.55	40.8	58.5	74.7	83.0	61.1	87.9	112.1	124.6
	0.60	37.4	53.6	68.5	76.1	56.0	80.4	102.8	114.2
	0.65	34.5	49.5	63.2	70.1	51.7	74.3	94.9	105.4
0.09	0.50	39.9	57.2	73.1	81.2	59.8	85.8	109.6	121.8
	0.55	36.2	52.0	66.4	73.8	54.4	78.0	99.6	110.7
	0.60	33.2	47.7	60.9	67.7	49.8	71.5	91.3	101.5
	0.65	30.7	44.0	56.2	62.5	46.0	66.0	84.3	93.7
0.10	0.50	35.9	51.5	65.8	73.1	53.8	77.2	98.6	109.6
	0.55	32.6	46.8	59.8	66.4	48.9	70.2	89.7	99.6
	0.60	29.9	42.9	54.8	60.9	44.9	64.4	82.2	91.3
	0.65	27.6	39.6	50.6	56.3	41.4	59.4	75.9	84.3
0.12	0.50	32.6	46.8	59.8	66.4	48.9	77.2	89.7	99.6
	0.55	29.6	42.5	54.4	60.4	44.5	70.2	81.5	90.6
	0.60	27.2	39.0	49.8	55.4	40.8	64.4	74.7	83.0
	0.65	25.1	36.0	46.0	51.1	37.6	59.4	69.0	76.6

Note: Key assumptions: 8% trucks, 5% RVs, 67 mi/h FFS, drive population factor 1.0

Exhibit 14-18 and Exhibit 14-19 must be used with care. Because the characteristics of any given multilane highway may or may not be typical, the values should not be used in the analysis of a specific segment of multilane highway. The exhibits are intended to allow a general evaluation of many facilities within a given jurisdiction on a first-pass basis to identify those segments or facilities that might be in need of remediation. Any segments or facilities so identified should then be submitted to specific analysis by using this chapter's methodology and each segment's site-specific characteristics. Exhibit 14-18 and Exhibit 14-19 should not be used to make final decisions on which segments or facilities to upgrade or on the specific designs proposed for such upgrades.

Daily service volumes are computed with Equation 14-10 through Equation 14-12, which combined yield Equation 14-13:

$$DSV_{i,j} = \frac{MSF_i \times N \times f_{HV,i} \times f_{p,i} \times PHF}{K \times D} \quad \text{Equation 14-13}$$

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where all variables are as previously defined. Values of MSF are selected from Exhibit 24-18 or Exhibit 24-19 for the typical FFS of 60 mi/h. Exhibit 24-18 and Exhibit 24-19 do not show LOS A, since this level is rarely of interest in assessing improvement programs.

For multilane highways, daily service volume tables are quite easy to construct by using localized typical values and local defaults. Equation 24-13 is easily applied. All of the variables in the equation simply have to be defined for a given FFS. The heavy-vehicle adjustment depends on PCEs, which are easily obtained for each of the terrain categories.

USE OF ALTERNATIVE TOOLS

Except for the effects of interaction with other facilities, the limitations of the methodology that were stated earlier in the chapter have minimal potential to be addressed by alternative tools. There is thus insufficient experience with alternative tools to support the development of useful guidance for their application to multilane highways.

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4. EXAMPLE PROBLEMS

Exhibit 14-20
List of Example Problems

Problem Number	Description	Application
1	LOS on an undivided four-lane highway	Operational analysis
2	LOS on a five-lane highway with TWLTL	Operational analysis
3	Design cross-section required to provide target LOS	Design analysis
4	Multilane highway modernization	Planning analysis
5	Four-lane cross section required to provide target LOS	Planning analysis

EXAMPLE PROBLEM 1: LOS ON UNDIVIDED FOUR-LANE HIGHWAY

A 3.25-mi, undivided four-lane highway is primarily on level terrain. The highway does, however, contain one sustained grade of 2.5% that is 0,200 ft long. At what LOS is the highway expected to operate?

The Facts

- Level terrain; 0.200 ft, 2.5% grade in Cadiol;
- Base FFS = 65 mi/h;
- Lane width, 11 ft;
- Clearance at roadside 4 ft;
- Access points per mile: 20;
- Peak-hour volume: 1,900 veh/h;
- Traffic composition: 10% trucks, 2% RVs;
- PHF = 0.90, and
- Familiar facility users

Comments

Three solutions will be needed in this case: (a) for the level terrain portion of the highway, (b) for the 2.5% upgrade portion of the highway, and (c) for the 2.5% downgrade portion of the highway. The factor that will vary for each of these is the heavy-vehicle adjustment factor.

Step 1: Input Data

All input data are specified in the example problem statement.

Step 2: Compute FFS

The FFS is estimated with Equation 14-1. The BFFS is given as 65 mi/h. Adjustments are needed for

- Lane width (f_{LW} = 1.9 mi/h (Exhibit 14-8, with 11-ft lanes),
- Lateral clearance (f_{LC} = 0.4 mi/h (Exhibit 14-9, with TLC = 4 + 6 = 10 ft, four lanes),
- Median type (f_M = 1.6 mi/h (Exhibit 14-10, for undivided highways), and
- Access-point density (f_A = 5.0 mi/h (Exhibit 14-11, with 20 access points/mi).

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Then

$$FFS = BFFS - f_{LW} - f_{LC} - f_{M} - f_{A}$$

$$FFS = 65.0 - 1.9 - 0.4 - 1.6 - 5.0 = 56.1 \text{ mi/h}$$

Step 3: Select FFS Curve

FFSs are all rounded to the nearest 5 mi/h. Therefore, the FFS used in the calculations will be 55 mi/h.

Step 4: Adjust Demand Volume

The demand volume, stated in vehicles per hour under prevailing conditions, must be converted to a demand flow rate in passenger cars per hour under base conditions by using Equation 14-3:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

where

V = demand volume (veh/h) (3,900 veh/h, given),

PHF = peak hour factor (0.90, given), and

f_p = driver population factor (1.00, familiar users).

The heavy vehicle adjustment factor is computed by using Equation 14-4:

$$f_{HV} = \frac{1}{1 + P_T (E_T - 1) + P_R (E_R - 1)}$$

Three sets of PCEs have to be determined: for level terrain, for 2.5% upgrade, and for 2.5% downgrade.

- Level terrain: $E_T = 1.5$ (Exhibit 14-12); $E_R = 1.2$ (Exhibit 14-12);
- Upgrade $E_T = 1.5$ (Exhibit 14-13, with 13% trucks and a 2.5% grade: 3,200/5,280 = 0.61 mi); $E_R = 3.0$ (Exhibit 14-14 with 2% RVs and 2.5% grade for 0.61 mi); and
- Downgrade $E_T = 1.5$ (Exhibit 14-15 with less than 4% grade and 13% trucks); $E_R = 1.2$ (from the text following Exhibit 14-15)

In this case, the equivalents are the same for the level terrain segments and the 2.5% downgrade. Consequently, there are only two different heavy vehicle adjustment factors to work with.

$$f_{HV}(\text{level, down}) = \frac{1}{1 + 0.13(1.5 - 1) + 0.02(1.2 - 1)} = 0.935$$

$$f_{HV}(\text{up}) = \frac{1}{1 + 0.13(1.5 - 1) + 0.02(3.0 - 1)} = 0.905$$

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There are thus two values of flow rate in passenger cars per hour under base conditions.

$$v_p(\text{level, down}) = \frac{1{,}900}{0.90 \times 2 \times (0.905 \times 1)} = 1{,}129 \text{ pc/h}$$

$$v_p(\text{up}) = \frac{1{,}900}{0.90 \times 2 \times (0.905 \times 1)} = 1{,}166 \text{ pc/h}$$

Step 5: Estimate Speed and Density

Speed for the two demand levels can be estimated by using the equations in Exhibit 14-3 or graphically by using Exhibit 14-3. In this case, both demand flow rates, 1,129 pc/h and 1,166 pc/h, are less than 1,400 pc/h. From Exhibit 14-3, the speed for both of these situations is the FFS, or 55 mi/h.

The densities of the general-terrain and specific-grade segments are then computed with Equation 14-5:

$$D = \frac{v_p}{S}$$

$$D(\text{level, down}) = \frac{1{,}129}{55} = 20.5 \text{ pc/mi/ln}$$

$$D(\text{up}) = \frac{1{,}166}{55} = 21.2 \text{ pc/mi/ln}$$

Step 6: Determine LOS

As shown in Exhibit 14-4, the LOS for both densities is C.

Discussion

The multilane highway described here operates at LOS C throughout the entire study area, including the upgrade and the downgrade within it. In a sense, this problem involves a *facility* as opposed to a *segment*. The facility contains several component segments: level terrain segments on either side of the 2.3%, 3,200-ft grade and the uphill and downhill portions of the 2.3% grade itself.

This chapter's methodology applies to uniform multilane highway segments. In this example problem, there were three segments, which together formed a facility of more than 3 mi. LOS C on all segments is very likely acceptable and would not generally call for immediate remediation.

EXAMPLE PROBLEM 2: LOS ON FIVE-LANE HIGHWAY WITH TWLTL

An 11,000-ft segment of a five-lane highway (two travel lanes in each direction plus a TWLTL) includes a 4% grade of 6,000 ft followed by 5,000 ft of level terrain. At what LOS is the facility expected to operate?

The Facts

- Lane width: 12 ft;
- External clearance, both sides of the roadway: 12 ft;

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- Traffic composition: 6% trucks, 0% RVs;
- Access points per mile on the level segment: eastbound, 10; westbound, 13;
- Access points per mile on the specific grade segment: eastbound, 19; westbound, 0;
- PHF = 0.90;
- Familiar users of the facility;
- Peak-hour demand, 1,300 veh/h;
- The upgrade occurs in the westbound direction; and
- Posted speed limit = 45 mi/h.

Comments

This problem is similar to Example Problem 1 in that there are three segments in the facility as described, each of which must be analyzed. The upgrade and downgrade on the 4% grade must be separately analyzed, as well as the level terrain segment. This case is a bit more complex, since not all characteristics of the segments are the same, particularly access points. Because no BFFS is given, it will be estimated as the speed limit plus 7 mi/h, or 45 + 7 = 52 mi/h.

Step 1: Input Data

All input data are given in the example problem statement.

Step 2: Compute FFS

The FFS is estimated by using Equation 14-1:

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A$$

In this case, the BFFS is estimated to be 52 mi/h. The lane width is 12 ft, which is the base condition; therefore f_{LW} = 0.0 mi/h (Exhibit 14-8). The lateral clearance is 12 ft at each roadside, but a maximum value of 6 ft may be used. A TWLTL is considered to have a median lateral clearance of 6 ft. Thus, the TLC is 6 + 6 = 12 ft, which is also a base condition. Therefore, f_{LC} = 0.0 mi/h (Exhibit 14-9). The median type adjustment f_M is also 0.0 mi/h (Exhibit 14-10).

For this example problem, only the access point density produces a nonzero adjustment to the BFFS. Both eastbound (EB) segments (level terrain, 4% downgrade) have 10 access points/mi. From Exhibit 14-11, the corresponding adjustment factor is 2.5 mi/h. The westbound (WB) level terrain segment has 13 access points/mi, and an adjustment factor of 3.3 mi/h (by interpolation in Exhibit 14-11). The WB upgrade has 0 access points/mi and an adjustment factor of 0.0 mi/h. Therefore:

$$FFS_{(EB\ level,\ composite)} = 52.0 - 0.0 - 0.0 - 0.0 - 2.5 = 49.5\ \text{mi/h}$$

$$FFS_{(WB\ level)} = 52.0 - 0.0 - 0.0 - 0.0 - 3.3 = 48.7\ \text{mi/h}$$

$$FFS_{(WB\ upgrade)} = 52.0 - 0.0 - 0.0 - 0.0 - 0.0 = 52.0\ \text{mi/h}$$

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Step 3: Select FFS Curve

Despite the fact that slight differences in FFS exist, all three segment analyses will use the 50-mi/h speed–flow curve.

Step 4: Adjust Demand Volume

Demand volume is adjusted by using Equation 14-3:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

where

V = 1,500 veh/h (given),

PHF = 0.90 (given),

N = 2 lanes (given), and

f_p = 1.00 (familiar users, given).

To compute the heavy-vehicle adjustment factor (Equation 14-4), PCEs for trucks are needed for (a) level terrain, (b) a 4%, 6,500-ft upgrade, and (c) a 4%, 6,000-ft downgrade. The following values are obtained:

- Level terrain: 1.5 (Exhibit 14-12);
- Upgrade: 3.0 (Exhibit 14-13, with 6% trucks and a 4% grade, 0.00105,280 = 1.14 mi), and
- Downgrade: 1.5 (Exhibit 14-13 with a 4% grade less than 4 mi long).

As in Example Problem 1, the downgrade equivalent is the same as the equivalent for level terrain. Therefore, there are only two heavy-vehicle adjustment factors (Equation 14-4):

$$f_{HV}\text{ (level,down)} = \frac{1}{1 - 0.06(1.5 - 1)} = 0.971$$

$$f_{HV}\text{ (up)} = \frac{1}{1 - 0.06(3.0 - 1)} = 0.893$$

and

$$v_p\text{(level, down)} = \frac{1500}{0.90 \times 2 \times 0.971 \times 1.0} = 858\text{ pc/mi/ln}$$

$$v_p\text{ (up)} = \frac{1500}{0.90 \times 2 \times 0.893 \times 1.0} = 933\text{ pc/mi/ln}$$

Step 5: Estimate Speed and Density

Speed is estimated by using the equations of Exhibit 14-3 or the graph in Exhibit 14-3. With the equations of Exhibit 14-3, both demand flow rates are less than 1,400 pc/h/ln. Therefore, the speeds are equal to the FFSs, both of which are 50 mi/h.

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Density is computed by using Equation 14-5.

$$D\ (\text{level, down}) = \frac{858}{50} = 17.1\ \text{pc/mi/ln}$$

$$D\ (\text{up}) = \frac{933}{50} = 18.7\ \text{pc/mi/ln}$$

Step 6: Determine LOS

The LOS is found by comparing the densities of the segments with the criteria in Exhibit 14-4. The level terrain and downgrade segments operate at LOS B. The upgrade segment operates at LOS C.

Discussion

Even though the upgrade technically operates at LOS C, it is very close to the LOS B boundary (18.0 pc/mi/ln). All segments of the multilane highway facility described operate well. No remediation would likely be needed.

EXAMPLE PROBLEM 3: DESIGN CROSS SECTION REQUIRED TO PROVIDE TARGET LOS

A new 2-mi segment of multilane highway will be built within a 150-ft right-of-way. Sixty feet of right-of-way will be reserved for clear zones; therefore, 90 ft of width will be available for travel lanes, shoulders, and median. How many travel lanes are needed to provide LOS D during the peak hour?

The Facts

- AADT = 60,000 veh/day;
- D = 0.10; K = 0.55;
- 55-mi/h speed limit;
- Rolling terrain;
- Traffic composition: 5% trucks, no RVs;
- PHF = 0.90;
- Access-point density = 10.0 access points/mi; and
- Familiar facility users.

Comments

This problem is potentially iterative. The exact cross section is unknown—not only the number of lanes but also the lateral clearances and median treatment. Thus, assumptions will be made and will have to be checked when the final analysis is complete. To begin the solution, it will be assumed that 12-ft lanes will be provided and that 6-ft clearances at the roadside and median will also be provided (TLC = 6 + 6 = 12 ft). A divided highway will also be assumed for initial computations.

Step 1: Input Data

All input data are specified in the example problem statement.

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Step 2: Compute FFS

No BFFS is given. It will be assumed that the BFFS will be 5 mi/h more than the posted speed limit, or 50 + 5 = 55 mi/h. FFS is estimated by using Equation 14-1. Given that the lane width, lateral clearance, and median treatments assumed are all base conditions, there is no adjustment for these. The only adjustment is for access point density. On the basis of Exhibit 14-11 for 10 access points/mi, the adjustment is 2.5 mi/h. Therefore

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A$$

$$FFS = 55.0 - 0.0 - 0.0 - 0.0 - 2.5 = 52.5 \text{ mi/h}$$

Step 3: Select FFS Curve

Following this chapter's guidelines, for a FFS of 52.5 mi/h, the 55-mi/h base speed flow curve will be used in this analysis.

Step 4: Determine Number of Lanes Needed for LOS D

Step 4 has a number of intermediate computations. First, the demand volume is stated as an AADT. This volume must be converted to an estimated directional design-hour volume ($V = DDHV$) by using Equation 14-9.

$$V = DDHV = AADT \times K \times D$$

$$V = DDHV = 60{,}000 \times 0.10 \times 0.55 = 3{,}300 \text{ veh/h}$$

The number of lanes required to meet a target LOS is estimated with Equation 14-8.

$$N = \frac{V}{MSF \times PHF \times f_{HV} \times f_p}$$

where

MSF = 1,850 pc/h/ln (Exhibit 14-17, with LOS D and 55 mi/h),

PHF = 0.90 (given), and

f_p = 1.00 (familiar users).

The heavy-vehicle adjustment factor is estimated by using Equation 14-4 and the PCE for trucks on rolling terrain from Exhibit 14-12, which is 2.5. Thus

$$f_{HV} = \frac{1}{1 + 0.05(2.5 - 1)} = 0.930$$

and

$$N = \frac{3{,}300}{1{,}850 \times 0.90 \times 0.93 \times 1.00} = 2.13 \text{ lanes}$$

This result means that to meet the criteria for LOS D within the peak hour, three lanes in each direction will have to be provided and the facility will be a six-lane multilane highway.

It is necessary to consider whether the assumed cross section (now known to be six lanes) can fit in the 96 ft available width. Lane widths are 12 ft, which fit

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lateral clearances at both roadsides and in the median. If a 12-ft median is assumed, the total width becomes (6 × 12) + (6 × 2) = 12 + 72 + 12 + 12 = 96 ft, which is in excess of the 90-ft right-of-way.

The median treatment could be reconsidered. It is not necessary to have a 12-ft median with 6-ft clearances to the inside edges of the travel pavement to produce the desired operation. A concrete median barrier with 2-ft buffers on each side would occupy a total of only 4 ft and would not be expected to have any impact on driver behavior or the LOS. Then the total width required would be (6 × 12) + (6 × 2) + 4 = 88 ft. This is the design cross section. None of the calculations done to this point would be altered by this change.

It is likely that providing a six-lane highway will result in better operations than the minimum of LOS D. With three lanes shown, the demand flow rate under base conditions can be computed with Equation 14-3:

$$v_p = \frac{3{,}300}{0.90 \times 3 \times 0.93 \times 1.00} = 1{,}314 \text{ pc/h/ln}$$

Step 5: Estimate Speed and Density

The speed of the traffic stream can be determined by using the equations of Exhibit 14-2 or the graph in Exhibit 14-3. On the basis of the equations, because the demand flow rate is less than 1,400 pc/h/ln, the speed is the FFS, or 55 mi/h in this case.

The density may now be computed by using Equation 14-5:

$$D = \frac{1{,}314}{55} = 23.9 \text{ pc/mi/ln}$$

Step 6: Determine LOS

From the criteria of Exhibit 14-4, the LOS provided is C, one grade better than the design target of LOS D.

Discussion

The design method in a greenfield cross section on a divided multilane highway with no clearance obstructions. The LOS provided is better than the design target, since three lanes were provided in each direction while only 2.13 lanes were necessary.

EXAMPLE PROBLEM 4: MULTILANE HIGHWAY MODERNIZATION

A 2.5-mi segment of a substandard multilane highway is to be improved by providing wider shoulders, widening the lanes to 12 ft, improving the alignment on a few sharp curves, restricting the number of roadside access points, and adding a median. These improvements will increase the FFS of the facility from 50 mi/h to 60 mi/h. How much additional traffic can be accommodated while the post-improvement LOS is maintained?

The Facts

- Demand flow rate = 1,400 pc/h/ln under base conditions.

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Comments

This problem is relatively straightforward. Most of the steps in a standard analysis can be skipped, since the present and future FFS are given, and the demand flow rate has already been reduced to base conditions.

Step 1: Find Existing LOS

With the equations of Exhibit 14-3, the speed of vehicles in the existing configuration will be the FFS, or 50 mi/h. With Equation 14-5, the density is computed as

$$D = \frac{1{,}400}{50} = 28 \text{ pc/mi/ln}$$

From Exhibit 14-4, this is LOS D.

Step 2: Find Expected LOS After Improvement

With the equations of Exhibit 14-3, the speed of vehicles on the improved cross section will also be the FFS, or 60 mi/h. The density is computed with Equation 14-5.

$$D = \frac{1{,}400}{60} = 23.2 \text{ pc/mi/ln}$$

From Exhibit 14-4, this is LOS C.

Step 3: Find Additional Volume Under LOS C

From Exhibit 14-5, the maximum service flow rate for LOS C on a 60-mi/h multilane highway is 1,550 pc/h/ln. The existing demand flow rate is 1,400 pc/h/ln. The additional demand flow possible while LOS C is maintained is 1,550 − 1,400 = 150 pc/h/ln. Since there are three lanes in each direction, the demand flow rate can increase by 3 × 150 = 450 pc/h without slipping into LOS D.

Discussion

This example problem illustrates how the methodology can be adapted to different uses, in this case, evaluating the impact of a proposed improvement to a multilane highway. The LOS improves from D to C, and an additional peak-hour demand flow rate of 450 pc/h can be accommodated by the improved highway while LOS C is maintained.

EXAMPLE PROBLEM 5: FUTURE CROSS SECTION REQUIRED TO PROVIDE TARGET LOS

A new suburban multilane highway is being planned. The opening-day forecast AADT is 42,000 vehicles per day. How many lanes will be needed to provide for LOS C during the peak hour on opening day?

The Facts

Since this is a planning application, many details cannot be based on current information. As a result, some of the "facts" are forecasts, and default values based on regional data are used to complete the list of facts needed for the analysis.

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- Demand = 40,000 veh/day;
- K = 0.10; D = 0.60;
- Traffic composition: 10% trucks, no RVs;
- Rolling terrain;
- Base FFS = 55 mi/h;
- Lane width = 12 ft; roadside lateral clearance = 6 ft;
- Undivided highway;
- Access point density = 6 access points/mi;
- PHF = 0.90; and
- Commuter traffic.

Comments

The demand volume, given as an AADT, must be converted to a DDHV. Once this is done, the example becomes a design application to determine the number of lanes needed to deliver LOS C.

Step 1: Input Data

All input data for this problem are specified in the problem statement.

Step 2: Compute FFS

The FFS is computed by using Equation 14-1. The BFFS is given. Lane widths and lateral clearances conform to base conditions, and no adjustments will be necessary. Then

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A$$

where

$BFFS$ = 55 mi/h (given);

f_{LW} = 0.0 mi/h (Exhibit 14-8, with 12-ft lanes);

f_{LC} = 0.0 mi/h (Exhibit 14-9, with 6-ft clearances);

f_M = 1.6 mi/h (Exhibit 14-10, undivided);

f_A = 1.5 mi/h (Exhibit 14-11, with 6 access points/mi, interpolated);

and

$$FFS = 55.0 - 0.0 - 0.0 - 1.6 - 1.5 = 51.9 \text{ mi/h}$$

Step 3: Select FFS Curve

On the basis of criteria given in the methodology section, the 50-mi/h FFS curve will be used for this solution.

Step 4: Determine Number of Lanes Needed to Provide LOS C

The number of lanes needed to deliver LOS C on opening day is estimated with Equation 14-5.

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$$N = \frac{V}{MSF_i \times PHF \times f_{HV} \times f_p}$$

The demand volume must be converted to an hourly basis by using Equation 14-9:

$$V = DDHV = AADT \times K \times D$$

$$V = DDHV = 42{,}000 \times 0.10 \times 0.60 = 2{,}520 \text{ veh/h}$$

The value of MSF is selected from Exhibit 14-17 for a 50-mi/h highway and LOS C: 1,300 pc/h. The heavy-vehicle adjustment factor f_{HV} is computed by using Equation 14-4 with a PCE of 2.5 selected from Exhibit 14-12 for trucks on rolling terrain:

$$f_{HV} = \frac{1}{1 + 0.10(2.5 - 1)} = 0.870$$

Because the demand volume is composed primarily of commuters, the adjustment factor for driver population f_p is 1.00. The PHF was given as 0.90. Then

$$N = \frac{2{,}520}{1{,}300 \times 0.90 \times 0.87 \times 1.00} = 2.48 \text{ lanes}$$

This result implies that a six-lane cross section will have to be provided. Because this cross section is more than the minimum computed, the actual demand flow rate under base conditions should be computed by using Equation 14-3:

$$v_p = \frac{2{,}520}{0.90 \times 3 \times 0.87 \times 1.00} = 1{,}073 \text{ pc/mi/ln}$$

Step 5: Estimate Speed and Density

From the equations of Exhibit 14-5, the expected speed for the demand flow rate is the FFS of 50 mi/h. The density can now be computed with Equation 14-5:

$$D = \frac{1{,}073}{50} = 21.5 \text{ pc/mi/ln}$$

Step 6: Determine LOS

From Exhibit 14-4, the six-lane multilane highway will be expected to operate at LOS C, which was the design objective.

Discussion

In this case, the target LOS has been achieved with the six-lane cross section. The highway will, however, operate in the better portion of LOS C instead of at the boundary.

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5. REFERENCES

Some of these references can be found in the Technical Reference Library in Volume 4.

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CHAPTER 15
TWO-LANE HIGHWAYS

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1. INTRODUCTION

VOLUME 2: UNINTERRUPTED FLOW
10. Freeway Facilities
11. Basic Freeway Segments
13. Freeway Weaving Segments
14. Freeway Ramp and Diverge Segments
14. Multilane Highways
15. Two-Lane Highways

Two-lane highways have one lane for the use of traffic in each direction. The principal characteristic that separates minor vehicle traffic on two-lane highways from other uninterrupted-flow facilities is that passing maneuvers take place in the opposing lane of traffic. Passing maneuvers are limited by the availability of gaps in the opposing traffic stream and by the availability of sufficient sight distance for a driver to discern the approach of an opposing vehicle safely. As demand flows and geometric restrictions increase, opportunities to pass decrease. This creates platoons within the traffic stream, with trailing vehicles subject to additional delay because of the inability to pass the lead vehicles.

Two-lane highways have one lane for the use of traffic in each direction. Passing takes place in the opposing lane of traffic when sight distance is adequate and safe gaps in the opposing traffic stream are available.

Because passing capacity decreases as passing demand increases, two-lane highways exhibit a unique characteristic: operating quality often decreases precipitously as demand flow increases, and operations can become "unacceptable" at relatively low volume-to-capacity ratios. For this reason, few two-lane highways ever operate at flow rates approaching capacity; in most cases, poor operating quality has led to improvements or reconstruction long before capacity demand is reached.

The quality of service for bicyclists is primarily affected by the speed and volume of adjacent traffic flows and by the degree of separation between bicyclist and motor vehicle traffic allowed by the roadway geometry.

Chapter 15, Two-Lane Highways, presents methodologies for the analysis, design, and planning of two-lane highway facilities operating under uninterrupted flow, for both automobiles and bicycles. Uninterrupted flow exists when there are no traffic control devices that interrupt traffic and where no platoons are formed by upstream signals. In general, any segment that is 2.0 to 3.0 mi from the nearest signalized intersection would fit into this category. Where signalized intersections are less than 2.0 mi apart, the facility should be classified as an urban street and analyzed with the methodologies of Chapter 16, Urban Street Facilities, and Chapter 17, Urban Street Segments, which are located in Volume 3. It is assumed that no passing in the opposing lane occurs on urban streets.

Chapter 15 also includes a methodology for predicting the effect of passing and truck climbing lanes on two-lane highways.

CHARACTERISTICS OF TWO-LANE HIGHWAYS

Functions of Two-Lane Highways in Highway Systems

Two-lane highways are a key element in the highway systems of most states and counties. They are located in many different geographical areas and serve a wide variety of traffic functions. Two-lane highways also serve a number of bicycle trips, particularly recreational trips. Any consideration of operating quality criteria must account for these disparate functions.

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The functions of two-lane highways include efficient mobility, accessibility, scenic and recreational enjoyment, and service to small towns and communities.

Efficient mobility is the principal function of major two-lane highways that connect major trip generators or that serve as primary links in state and national highway networks. These routes tend to serve long-distance commercial and recreational travelers, and long sections may pass through rural areas without traffic control interruptions. Consistent high-speed operations and infrequent passing delays are desirable for these types of facilities.

Other paved, two-lane rural highways primarily provide accessibility to remote or sparsely populated areas. Such highways provide reliable all-weather access and often serve low traffic demands. Cost-effective access is a primary concern. Although high speed is beneficial, it is not the principal objective. Delay, as indicated by the formation of platoons, is a more relevant measure of service quality.

Two-lane roads also serve *scenic and recreational* areas in which the vista and environment are meant to be experienced and enjoyed without traffic interruption or delay. High-speed operation is neither expected nor desired. Passing delays, however, significantly distract from the scenic enjoyment of trips and should be minimized whenever possible.

Two-lane roads may also pass through and serve *small towns and communities*. Such areas have higher density development than would normally be expected along a rural highway, and speed limits in these areas are often lower. In these cases, drivers expect to be able to maintain speeds close to the posted limit. Since two-lane highway segments serving such developed areas are usually of limited length, passing delays are not a significant issue.

Two-lane highways serve a wide range of functions and serve a variety of rural areas, as well as more developed areas. Therefore, this chapter's methodology and level of service (LOS) criteria provide flexibility to encompass the resulting range of driver expectations.

Classification of Two-Lane Highways

Because of the wide range of functions served by two-lane highways, the automobile methodology establishes three classes of highways.

The first two classes address *rural two-lane highways*. The methodology for them was developed as part of National Cooperative Highway Research Program (NCHRP) Project 3-55(3) in 1999 (1) and revised as part of NCHRP Project 20-7(160) in 2008 (2).

The third class addresses two-lane highways in *developed areas*. The analysis approach for these highways is a modification of the rural highway method noted previously and was developed by the Florida Department of Transportation (FDOT) (3). This modification has not been subjected to a national calibration study and is based on the procedure developed and adopted by FDOT. It is presented here as an alternative procedure, since it is based entirely on information collected in Florida. For clarity, however, the material is integrated into the overall presentation and is not discussed separately as an alternative procedure.

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The three classes of two-lane highways are defined as follows:

- *Class I two-lane highways* are highways where motorists expect to travel at relatively high speeds. Two-lane highways that are major intercity routes, primary connectors of major traffic generators, daily commuter routes, or major links in state or national highway networks are generally assigned to Class I. These facilities serve mostly long-distance trips or provide the connections between facilities that serve long-distance trips.
- *Class II two-lane highways* are highways where motorists do not necessarily expect to travel at high speeds. Two-lane highways functioning as access routes to Class I facilities, serving as scenic or recreational routes (and not as primary arterials), or passing through rugged terrain (where high-speed operation would be impossible) are assigned to Class II. Class II facilities most often serve relatively short trips, the beginning or ending portions of longer trips, or trips for which sightseeing plays a significant role.
- *Class III two-lane highways* are highways serving moderately developed areas. They may be portions of a Class I or Class II highway that pass through small towns or developed recreational areas. On such segments, local traffic often mixes with through traffic, and the density of unsignalized roadside access points is noticeably higher than in a purely rural area. Class III highways may also be longer segments passing through more spread-out recreational areas, also with increased roadside densities. Such segments are often accompanied by reduced speed limits that reflect the higher activity level.

Exhibit 15-1 shows examples of the three classes of two-lane highway.

The definition of two-lane highway classes is based on their function. Most arterials or trunk roads are considered to be Class I highways, while most collectors and local roads are considered to be Class II or Class III highways. The primary determinant of a facility's classification is the motorist's expectation, which might not agree with the overall functional category of the route. For example, a major intercity route passing through a rugged mountainous area might be described as Class II if drivers recognize that high-speed operation is not feasible due to the terrain, but the route could still be considered to be in Class I.

Even Class III highways incorporate only uninterrupted-flow segments of two-lane highways. Occasional signalized or unsignalized intersections on any two-lane highway must be separately analyzed with the appropriate *Highway Capacity Manual* (HCM) methodologies in Chapter 18, Signalized Intersections, Chapter 20, All-Way STOP-Controlled Intersections, or Chapter 21, Roundabouts. The results must be carefully considered in conjunction with those of uninterrupted-flow portions of the facility to obtain a complete picture of probable operations.

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Exhibit 15-1
Two-Lane Highway
Classification Illustrated

(a) Examples of Class I Two-Lane Highways

(b) Examples of Class II Two-Lane Highways

(c) Examples of Class III Two-Lane Highways

Base Conditions

The base conditions for two-lane highways are the absence of restrictive geometric, traffic, or environmental factors. Base conditions are not the same as typical or default conditions, both of which may reflect common restrictions. Base conditions are closer to what may be considered as ideal conditions (i.e., the best conditions that can be expected given normal design and operational practice). The methodology of this chapter accounts for the effects of geometric, traffic, and environmental factors that are more restrictive than the base conditions. The base conditions for two-lane highways are as follows:

- Lane widths greater than or equal to 12 ft,
- Clear shoulders wider than or equal to 6 ft,
- No no-passing zones,
- All passenger cars in the traffic stream,

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- Level terrain, and
- No impediments to through traffic (e.g., traffic signals, turning vehicles).

Traffic can operate ideally only if lanes and shoulders are wide enough not to constrain speeds. Lanes narrower than 12 ft and shoulders narrower than 6 ft have been shown to reduce speeds, and they may increase percent time-spent-following (PTSF) as well.

The length and frequency of no-passing zones are a result of the roadway alignment. No-passing zones may be marked by barrier centerlines in one or both directions, but any segment with a passing sight distance of less than 1,000 ft should also be considered to be a no-passing zone.

On a two-lane highway, passing in the opposing lane of flow may be necessary. It is the only way to fill gaps forming in front of slower-moving vehicles in the traffic stream. Restrictions on the ability to pass significantly increase the rate at which platoons form in the traffic stream, since motorists are unable to pass slower vehicles in front of them.

Basic Relationships

Exhibit 15-2 shows the relationships among flow rate, average travel speed (ATS), and PTSF for an extended directional segment of two-lane highway under base conditions. While the two directions of flow interact on a two-lane highway (because of passing maneuvers), the methodology of this chapter analyzes each direction separately.

Exhibit 15-2(b) illustrates a critical characteristic that affects two-lane highways. Low directional volumes create high values of PTSF. With only 400 pc/h, PTSF ranges from 60% (with 200 pc/h opposing flow) to almost 80% (with 1,600 pc/h opposing flow).

In multilane uninterrupted flow, typically acceptable speeds can be maintained at relatively high proportions of capacity. On two-lane highways, service quality (as measured by PTSF) begins to deteriorate at relatively low demand flows.

CAPACITY AND LOS

Capacity

The capacity of a two-lane highway under base conditions is 1,700 pc/h in one direction, with a limit of 3,200 pc/h for the total of the two directions. Because of the interactions between directional flows, when a capacity of 1,700 pc/h is reached in one direction, the maximum opposing flow would be limited to 1,500 pc/h.

Capacity of a two-lane highway under base conditions is 1,700 pc/h in one direction, with a maximum of 3,200 pc/h in the two directions.

Capacity conditions, however, are rarely observed—except in short segments. Because service quality deteriorates at relatively low demand flow rates, most two-lane highways are upgraded before demand approaches capacity.

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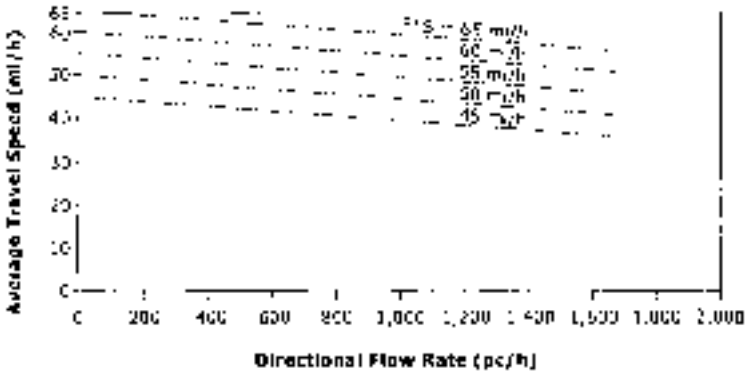
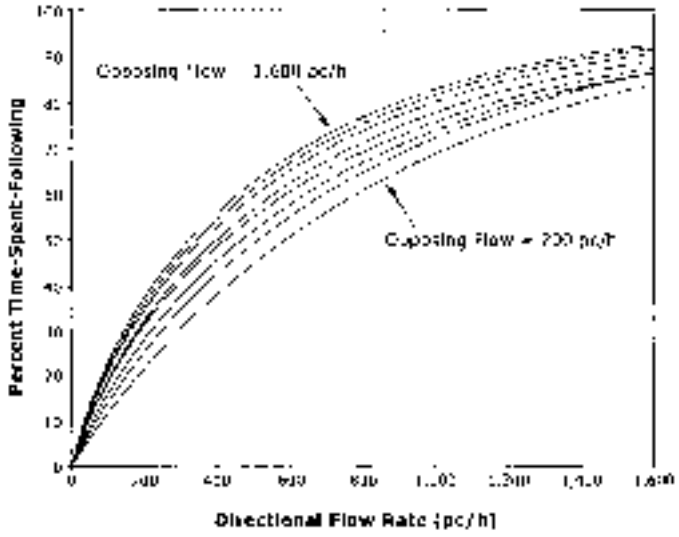
Exhibit 15-2
Speed, Flow, and PTSF Relationships for Directional Segments with Base Conditions



(a) ATS Versus Directional Flow Rate



(b) PTSF Versus Directional Flow Rate

Capacity is important for evacuation and special event planning

However, estimation of capacity conditions is important for evacuation planning, special event planning, and evaluation of the downstream impacts of incident bottlenecks once cleared.

Two-way flow rates as high as 3,200 pc/h can be observed for short segments fed by high demands from multiple or multilane facilities. This may occur at tunnels or bridges, for example, but such flow rates cannot be expected over extended segments.

Capacity is not defined for bicycles on two-lane highways because of lack of data. Bicycle volumes approaching capacity do not often occur on two-lane highways except during special bicycle events, and little information is available on which to base a definition.

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Levels of Service

Automobile Mode

Because of the wide range of situations in which two-lane highways are found, three measures of effectiveness are incorporated into the methodology of this chapter to determine automobile LOS.

1. *ATS* reflects mobility on a two-lane highway. It is defined as the highway segment length divided by the average travel time taken by vehicles to traverse it during a designated time interval.
2. *PTSF* represents the freedom to maneuver and the comfort and convenience of travel. It is the average percentage of time that vehicles must travel in platoons behind slower vehicles due to the inability to pass. Because this characteristic is difficult to measure in the field, a surrogate measure is the percentage of vehicles traveling at headways of less than 3.0 s at a representative location within the highway segment. PTSF also represents the approximate percentage of vehicles traveling in platoons.
3. *Percent of free-flow speed* (PFFS) represents the ability of vehicles to travel at or near the posted speed limit.

On Class I two-lane highways, speed and delay due to passing restrictions are both important to motorists. Therefore, on these highways, LOS is defined in terms of both ATS and PTSF. On Class II highways, travel speed is not a significant issue to drivers. Therefore, on these highways, LOS is defined in terms of PTSF only. On Class III highways, high speeds are not expected. Because the length of Class III segments is generally limited, passing restrictions are also not a major concern. In these cases, drivers would like to make steady progress at or near the speed limit. Therefore, on these highways, PFFS is used to define LOS. The LOS criteria for two-lane highways are given in Exhibit 15-3.

Exhibit 15-3
Automobile LOS for Two-Lane Highways

LOS	Class I Highways ATS (mi/h)	Class I Highways PTSF (%)	Class II Highways PTSF (%)	Class III Highways PFFS (%)
A	>55	≤35	≤40	>91.7
B	>50–55	>35–50	>40–55	>83.3–91.7
C	>45–50	>50–65	>55–70	>75.0–83.3
D	>40–45	>65–80	>70–85	>66.7–75.0
E	≤40	>80	>85	≤66.7

Because driver expectations and operating characteristics on the three categories of two-lane highways are quite different, it is difficult to provide a single definition of operating conditions at each LOS.

Two characteristics, however, have a significant impact on actual operations and driver perceptions of service.

- *Passing capacity*: Since passing maneuvers on two-lane highways are made in the opposing direction of flow, the ability to pass is limited by the opposing flow rate and by the distribution of gaps in the opposing flow.
- *Passing demand*: As passing and PTSF are related in a given direction, the demand for passing maneuvers increases. As more drivers are caught in a

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platoon behind a slow-moving vehicle, they will desire to make more passing maneuvers.

Both passing capacity and passing demand are related to flow rates. If flow in both directions increases, a difficult trend is established: as passing demand increases, passing capacity decreases.

At LOS A, motorists experience high operating speeds on Class I highways and little difficulty in passing. Platoons of three or more vehicles are rare. On Class II highways, speed would be controlled primarily by roadway conditions. A small amount of platooning would be expected. On Class III highways, drivers should be able to maintain operating speeds close or equal to the free-flow speed (FFS) of the facility.

At LOS B, passing demand and passing capacity are balanced. On both Class I and Class II highways, the degree of platooning becomes noticeable. Some speed reductions are present on Class I highways. On Class III highways, it becomes difficult to maintain FFS operation, but the speed reduction is still relatively small.

At LOS C, most vehicles are traveling in platoons. Speeds are noticeably curtailed on all three classes of highway.

At LOS D, platooning increases significantly. Passing demand is high on both Class I and II facilities, but passing capacity approaches zero. A high percentage vehicles are now traveling in platoons, and PTSF is quite noticeable. On Class III highways, the fall-off from FFS is now significant.

At LOS E, demand is approaching capacity. Passing on Class I and II highways is virtually impossible, and PTSF is more than 80%. Speeds are seriously curtailed. On Class III highways, speed is less than two-thirds the FFS. The lower limit of this LOS represents capacity.

LOS F occurs whenever demand flow in one or both directions exceeds the capacity of the segment. Operating conditions are unstable, and heavy congestion exists on all classes of two-lane highway.

Bicycle Mode

Bicycle LOS is based on a traveler-perception model.

Bicycle levels of service for two-lane highway segments are based on a bicycle LOS (BLOS) score, which is in turn based on a traveler-perception model. This score is based, in order of importance, on five variables:

- Average effective width of the outside through lane,
- Motorized vehicle volumes,
- Motorized vehicle speeds,
- Heavy vehicle (truck) volumes, and
- Pavement condition.

The LOS ranges for bicycles on two-lane highways are given in Exhibit 15-4. The same LOS score is used for multilane highways, as described in Chapter 14.

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LOS	BLOS Score
A	≤1.5
B	>1.5–2.5
C	>2.5–3.5
D	>3.5–4.5
E	>4.5–5.5
F	>5.5

Exhibit 15-4
Bicycle LOS for Two-Lane Highways

REQUIRED INPUT DATA AND DEFAULT VALUES

Exhibit 15-5 lists the information necessary to apply the methodology. It also contains suggested default values for use when segment-specific information is not available. The user is cautioned, however, that every use of a default value instead of a field-measured, segment-specific variable makes the analysis results more approximate and less related to the specific conditions that describe the study site. Defaults should be used only when field measurements cannot be collected.

Required Data	Recommended Default Value	Relevant Modes
Geometric Data		
Highway class	Must select as appropriate	Auto
Lane width	12 ft	Auto, bicycle
Shoulder width	6 ft	Auto, bicycle
Access-point density (one side)	Class I and II: 8/mi, Class III: 16/mi	Auto
Terrain	Level or rolling	Auto
Percent no-passing zone[a]	Level: 20%, rolling: 40%, mountainous: 80%	Auto
Speed limit	Speed limit	Bicycle
Base design speed	Speed limit + 10 mi/h	Auto
Length of passing lane (if present)	Must be site-specific	Auto
Pavement condition	1 on FHWA 5-point rating scale (good)	Bicycle
Demand Data		
Hourly automobile volume	Must be site-specific	Auto, bicycle
Length of analysis period	15 min (0.25 h)	Auto, bicycle
Peak hour factor	0.88	Auto, bicycle
Directional split	50/50	Auto, bicycle
Heavy vehicle percentage[b]	6% trucks	Auto, bicycle
Percent occupied on-highway parking	0%	Bicycle

Notes: [a] Percent no-passing zone may be different in each direction.
[b] See Chapter 25 in Volume 4 for more specific default values on vehicle percentages.

Exhibit 15-5
Required Input Data and Default Values for Two-Lane Highways

The use of some default values is less problematic than others. Lane and shoulder widths of 12 and 6 ft, respectively, are common, particularly on Class I highways. However, these variables have large impacts on bicycle LOS, increasing the importance of segment-specific data. A general assessment of terrain is usually straightforward and requires only general knowledge of the area through which the highway is built. Access-point densities are more difficult and tend to vary widely on a site-by-site basis. Estimating the percent no-passing zones on the basis of a generalized assessment of terrain is also challenging, since the details of vertical and horizontal alignment can have a significant impact on this factor.

FFS is best measured at the site or at a similar site. While adjustments to a base free-flow speed (BFFS) are provided as part of the methodology, no firm guidance on determining the BFFS is given. The default suggestions of Exhibit 15-5 are highly approximate.

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In terms of demand data, the length of the analysis period is a recommended HCM standard of 15 min (although longer periods can be examined). The peak hour factor (PHF) is typical but could vary significantly on the basis of localized trip generation characteristics. The directional split is best observed directly, since it can vary widely over time, even at the same location. The recommended default for heavy vehicle presence is also highly approximate. This factor varies widely with local conditions; Chapter 26, Freeway and Highway Segments: Supplemental, provides state-specific default values (6).

As is the case with all default values, these values should be used with care, and only when site-specific data cannot be acquired by any reasonable means.

DEMAND VOLUMES AND FLOW RATES

Demand volumes are generally stated in vehicles per hour under prevailing conditions. They are converted in the methodology to demand flow rates in passenger cars per hour under base conditions. The PHF, in particular, is used to convert hourly volumes to flow rates.

If demand volumes are measured in 15-min increments, use of the PHF to convert to flow rates is unnecessary. The worst 15 min period is selected, and flow rates are the 15-min volumes multiplied by 4. When this is done, the PHF is set at 1.00 for the rest of the application.

In measuring demand volumes or flow rates, flow may be restricted by upstream bottlenecks or even signals that are more than 2 mi away from the study site (if they are closer, this methodology is not applicable). Downstream congestion may also affect flows in a study segment. Insofar as is possible, demand volumes and flow rates should reflect the situation that would exist with no upstream or downstream limiting factors.

AR0073724

2. METHODOLOGY

This section presents the details of the methodology for two-lane highways and discusses its use in planning and operational analysis applications.

SCOPE OF THE METHODOLOGY

This chapter presents an operational analysis methodology for directional segments of two-lane highways for automobiles and bicyclists. Both directions may be analyzed separately on the facility as segments to obtain a full estimate of operating conditions.

This chapter's automobile methodology addresses the analysis of

- Directional segments in general terrain (level or rolling),
- Directional segments on specific grades, and
- Directional segments including passing and truck climbing lanes.

All segments in mountainous terrain, and all grades of 3% or more that cover a length of 0.6 mi or more, must be analyzed as specific grades.

The methodology is most directly used to determine the LOS on a uniform directional segment of two-lane highway by estimating the measures of effectiveness that define LOS (ATS, PTSF, PFFS). Such an analysis can also be used to determine the capacity of the directional segment or the service flow rate that can be accommodated at any given LOS.

This chapter includes an appendix that addresses specialized treatments for two-lane highways that cannot be evaluated with the basic methodology. Special procedures are also provided to determine the impact of passing lanes or truck climbing lanes on two-lane highway segments.

LIMITATIONS OF THE METHODOLOGY

The operational analysis methodologies in this chapter do not address two-lane highways with signalized intersections. Isolated signalized intersections on two-lane highways may be evaluated with the methodology of Chapter 18, Signalized Intersections. Two-lane highways in urban and suburban areas with multiple signalized intersections 2 mi or less apart should be analyzed as urban streets or arterials with the methodology of Chapter 17, Urban Street Segments.

The bicycle methodology was developed with data collected on urban and suburban streets, including facilities that would be defined as suburban two-lane highways. Although the methodology has been successfully applied to rural two-lane highways in different parts of the United States, users should be aware that conditions on many rural two-lane highways will be outside the range of values used to develop the bicycle LOS model. The ranges of values used in the development of the bicycle LOS model [7] are shown below:

- Width of the outside through lane: 10 to 16 ft;
- Shoulder width: 0 to 6 ft;

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- Motorized vehicle volumes: up to 36,000 annual average daily traffic (AADT);
- Posted speed: 45 to 50 mi/h;
- Heavy vehicle percentage: 0% to 2%; and
- Pavement condition: 1 to 5 on the Federal Highway Administration (FHWA) 5-point pavement rating scale.

The bicycle LOS methodology also does not take differences in prevalent driver behavior into consideration, although driver behavior may vary considerably both regionally and by facility. In particular, the likelihood of drivers slowing down or providing additional horizontal clearance while passing cyclists plays a significant role in the perceived quality of service of a facility.

AUTOMOBILE MODE

Overview

Exhibit 15-6 illustrates the basic steps in the methodology for two-lane highways. Because the three classes of highways use different service measures to determine LOS, not all steps are applied to each class of facility.

Note that the computational step for estimating ATS applies only to Class I and Class III highways, while the step for estimating PTSF applies only to Class I and Class II highways. The step for estimating PFFS applies only to Class III highways.

Segments for Analysis

The methodology of this chapter applies to uniform directional segments of two-lane highway. While the two directions of flow interact through passing maneuvers (and limitations on passing maneuvers), each direction must be analyzed separately.

Uniform segments have the same or similar traffic and roadway conditions. Segment boundaries should be established at points where a change occurs in any of the following: terrain, lane width, shoulder width, facility classification, or demand flow rate.

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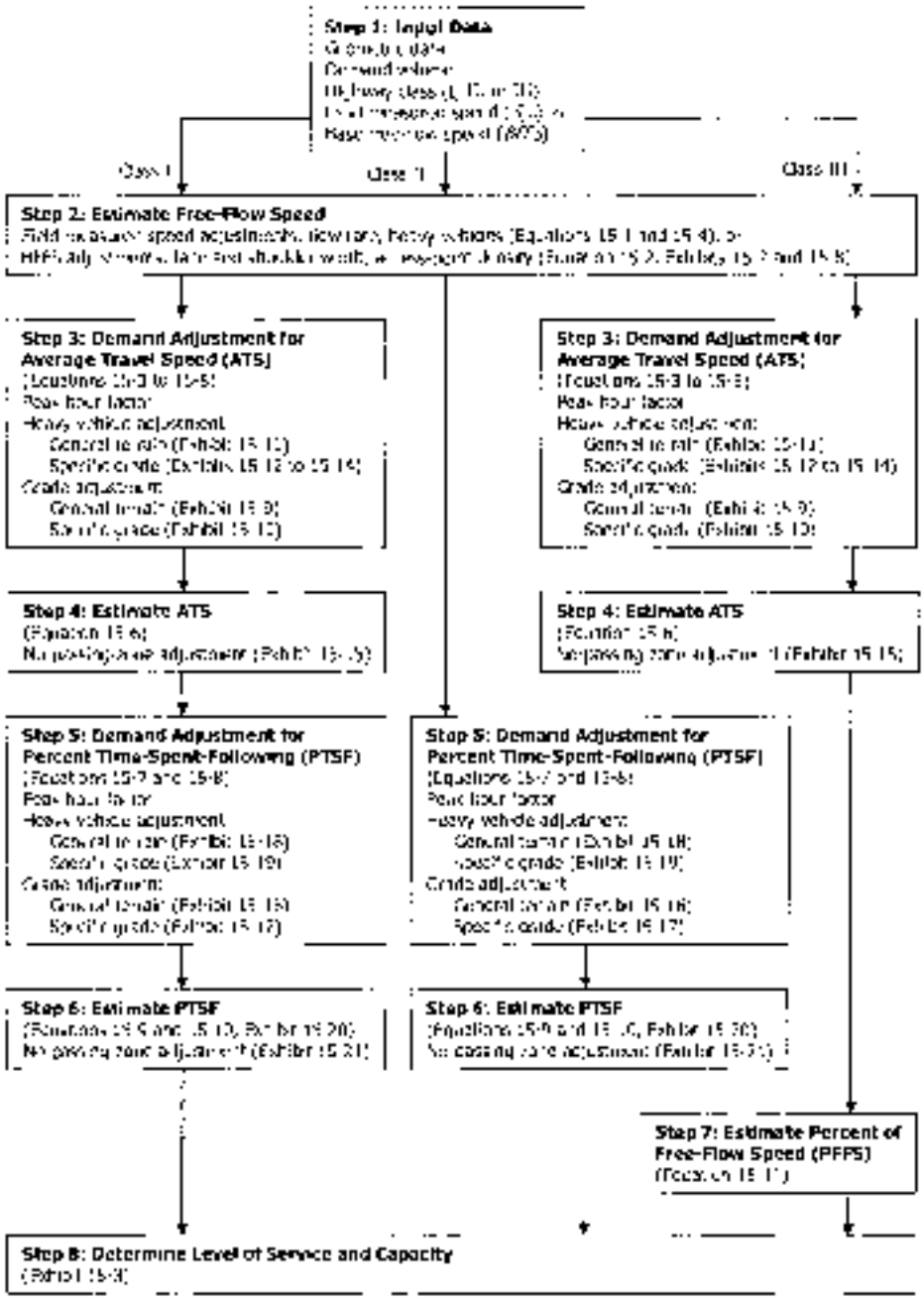

Exhibit 15-6
Flowchart of the Two-Lane Highway Methodology

Computational Steps

Step 1: Input Data

Exhibit 15-5 lists the information that must be available before a two-lane highway segment can be analyzed. The exhibit also lists default values suggested for use when site-specific data are not available.

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Step 3: Estimate the FFS

A key step in the analysis of a two-lane highway is the determination of the FFS for the segment. There are three ways to estimate FFS.

Direct Field Measurement

Direct field measurement on the subject highway segment is preferred. Measurements should be taken only in the direction under analysis; if both directions are to be analyzed, then separate measurements in each direction are made. Each directional measurement should be based on a random sample of at least 100 vehicle speeds. The FFS can be directly measured as the mean speed under low-demand conditions (i.e., the two-way flow rate is less than or equal to 200 veh/h).

If the analysis segment cannot be directly observed, then measurements from a similar facility (same highway class, same speed limit, similar environment, etc.) may be used.

Field Measurements at Higher Flow Rates

For some highways, it may be difficult or impossible to observe total flow rates less than 200 veh/h. In such cases, a speed sample may be taken at higher flow rates and adjusted accordingly. The same sampling approach is taken: each direction is separately observed, with each directional sample including at least 100 observed speeds. The measured mean speed is then adjusted with Equation 15-1.

Equation 15-1

$$FFS = S_{FM} + 0.00776\left(\frac{v}{f_{HV,ATS}}\right)$$

where

FFS = free-flow speed (mi/h);

S_{FM} = mean speed of sample in > 200 veh/h (mi/h);

v = total demand flow rate, both directions, during period of speed measurements (veh/h); and

$f_{HV,ATS}$ = heavy vehicle adjustment factor for ATS, from Equation 15-4 or Equation 15-5.

Estimating FFS

FFS on two-lane highways ranges from 45 mi/h to as high as 70 mi/h. BFFS reflects alignment of the facility and the nature of traffic.

The FFS can be estimated reliably if field data are not available. This is a greater challenge on two-lane highways than on other types of uninterrupted-flow facilities. FFS on two-lane highways covers a significant range, from as low as 45 mi/h to as high as 70 mi/h. To estimate the FFS, the analyst must characterize the operating conditions of the facility in terms of a BFFS that reflects the nature of the traffic and the alignment of the facility. Unfortunately, because of the broad range of speeds that occur and the importance of local and regional factors that influence driver-desired speeds, little guidance on estimating the BFFS can be given.

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Estimates of BFFS can be developed on the basis of speed data and local knowledge of operating conditions on similar facilities. As will be seen, once the BFFS is determined, adjustments for lane and shoulder widths and for the density of unsignalized access points are applied to estimate the FFS. In concept, the BFFS is the speed that would be expected on the basis of the facility's horizontal and vertical alignment, if standard lane and shoulder widths were present and there were no roadside access points. Thus, the *design speed* of the facility might be an acceptable estimator of BFFS, since it is based primarily on horizontal and vertical alignment. Posted speed limits may not reflect current conditions or driver desires. A rough estimate of BFFS might be taken as the posted speed limit plus 10 mi/h.

Once a BFFS is determined, the actual FFS may be estimated as follows:

$$FFS = BFFS - f_{LS} - f_A \quad \text{Equation 15-2}$$

where

FFS = free-flow speed (mi/h),

$BFFS$ = base free-flow speed (mi/h),

f_{LS} = adjustment for lane and shoulder width (mi/h), and

f_A = adjustment for access-point density (mi/h).

When field measurements are used to estimate FFS, standard approaches and sampling techniques should be applied. Guidance on field speed studies is provided in standard traffic engineering texts and elsewhere (3).

Adjustment factors for use in Equation 15-2 are found in Exhibit 15-7 (lane and shoulder width) and Exhibit 15-8 (access-point density).

Exhibit 15-7
Adjustment Factor for Lane and Shoulder Width (f_{LS})

Lane Width (ft)	Shoulder Width (ft)			
	≥0 ≤2	>2 ≤4	>4 ≤6	≥6
≥9 <10	6.4	4.8	3.5	2.2
≥10 <11	5.3	3.7	2.4	1.1
≥11 <12	4.7	3.0	1.7	0.4
≥12	4.2	2.6	1.3	0.0

Exhibit 15-8
Adjustment Factor for Access-Point Density (f_A)

Access Points per Mile (Two Directions)	Reduction in FFS (mi/h)
0	0.0
10	2.5
20	5.0
30	7.5
40	10.0

Note: Interpolation to the nearest 0.1 is recommended.

The access-point density is computed by dividing the total number of unsignalized intersections and driveways on both sides of the roadway segment by the length of the segment (in miles). Thus, in analyzing the two directions of the highway and estimating the FFS, the FFS will be the same in both directions. If the FFS is measured in the field, the value could be different in each direction.

If a highway contains sharp horizontal curves with design speeds substantially below those of the rest of the segment, it may be desirable to

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determine the PFS separately for curves and tangents and to compute a weighted-average PFS for the segment as a whole.

The data for PFS relationships in this chapter include both commuter and noncommuter traffic. There were no significant differences between the two. However, it is expected that commuters and other regular users will use a facility more efficiently than recreational and other occasional users. If the effect of driver population is a concern, the PFS should be measured in the field.

Step 3: Demand Adjustment for ATS

This computational step is applied only to cases of Class I and Class III two-lane highways. LOS on Class II highways is not based on ATS, and therefore this step is skipped for those highways.

Demand volumes on both directions (analysis direction and opposing direction) must be converted to flow rates under equivalent base conditions with Equation 15-3:

Equation 15-3

$$v_{d,ATS} = \frac{V_d}{PHF \times f_{g,ATS} \times f_{HV,ATS}}$$

where

$v_{d,ATS}$ = demand flow rate for ATS estimation (pc/h),

d = "d" (analysis direction) or "o" (opposing direction),

V_d = demand volume for direction d (veh/h),

$f_{g,ATS}$ = grade adjustment factor, from Exhibit 15-9 or Exhibit 15-10, and

$f_{HV,ATS}$ = heavy vehicle adjustment factor, from Equation 15-4 or Equation 15-5.

PHF

The PHF represents the variation in traffic flow within the hour. Two-lane highway analysis is based on the demand flow rates for a peak 15-min period within the analysis hour—usually (but not necessarily) the peak hour. If flow rates for the peak 15 min have been directly measured, the PHF used in Equation 15-3 is set equal to 1.00.

ATS Grade Adjustment Factor

The grade adjustment factor $f_{g,ATS}$ depends on the terrain. Factors are defined for:

- Extended segments (≥2 mi) of level terrain,
- Extended segments (≥2 mi) of rolling terrain,
- Specific upgrades, and
- Specific downgrades.

Any grade of 3% or steeper and 0.5 mi or longer will be analyzed as a specific upgrade or downgrade, depending on the analysis direction being considered. However, a grade of 3% or more may be analyzed as a specific grade if it is 0.25 mi or longer.

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Exhibit 15-9 shows grade adjustment factors for extended segments of level and rolling terrain, as well as for specific downgrades. Exhibit 15-9 is entered with the one-direction demand flow rate $v_{d,i}$, in vehicles per hour.

Exhibit 15-9
ATS Grade Adjustment Factor ($f_{g,ATS}$) for Level Terrain, Rolling Terrain, and Specific Downgrades

One-Direction Demand Flow Rate, $v_{d,i}$ (veh/h)	Adjustment Factor	
	Level Terrain and Specific Downgrades	Rolling Terrain
≤100	1.00	0.77
200	1.00	0.75
300	1.00	0.83
400	1.00	0.90
500	1.00	0.95
600	1.00	0.97
700	1.00	0.98
800	1.00	0.99
≥900	1.00	1.00

Note: Interpolation in the 4-level 0.01's recommended.

If demand is expressed as an hourly volume, it must be divided by the PHF ($v_{d,i} = V/PHF$) to obtain the appropriate factor. Other adjustment factor tables associated with Equation 15-3 are entered with this value as well.

Note that the adjustment factor for level terrain is 1.00, since level terrain is one of the base conditions. For the purposes of grade adjustment, specific downgrade segments are treated as level terrain.

Exhibit 15-10 shows grade adjustment factors for specific upgrades. The negative impact of upgrades on two-lane highway speeds increases as both the severity of the upgrade and its length increase. The impact, however, declines as demand flow rate increases. At higher demand flow rates, lower speeds would already result, and the additional impact of the upgrades is less severe.

ATS Heavy Vehicle Adjustment Factor

The base conditions for two-lane highways include 100% passenger cars in the traffic stream. This is a rare circumstance, and the presence of heavy vehicles in the traffic stream reduces the ATS.

In general, a heavy vehicle is defined as any vehicle (or vehicle-trailer unit) with more than four wheels on the ground during normal operation. Heavy vehicles are classified as trucks or recreational vehicles (RVs). Trucks cover a wide variety of vehicles from small pickup and panel trucks with more than four wheels to double and triple tractor–trailer units. Small pickup and panel trucks with only four wheels are classified as passenger cars. All school, transit, or intercity buses are classified as trucks. The RV classification also covers a wide range of vehicles, including motorized campers, motor homes, and cars or small trucks that are towing trailers.

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Exhibit 15-10
ATS Grade Adjustment Factor ($f_{g,ATS}$) for Specific Upgrades

Grade (%)	Grade Length (mi)	Directional Demand Flow Rate, $v_{pd,t}$ (veh/h)								
		<100	200	300	400	500	600	700	800	≥900
≤3 ≤3.5	0.25	0.78	0.84	0.87	0.91	1.00	1.00	1.00	1.00	1.00
	0.50	0.75	0.81	0.86	0.90	1.00	1.00	1.00	1.00	1.00
	0.75	0.73	0.81	0.85	0.89	1.00	1.00	1.00	1.00	1.00
	1.00	0.73	0.79	0.83	0.88	1.00	1.00	1.00	1.00	1.00
	1.50	0.73	0.79	0.83	0.87	0.96	0.99	1.00	1.00	1.00
	2.00	0.73	0.79	0.82	0.86	0.90	0.96	0.99	1.00	1.00
	3.00	0.73	0.78	0.82	0.85	0.90	0.90	0.96	0.97	0.98
	4.00	0.73	0.78	0.82	0.85	0.90	0.90	0.96	0.96	0.96
>3 ≤4.5	0.25	0.75	0.83	0.86	0.90	1.00	1.00	1.00	1.00	1.00
	0.50	0.72	0.80	0.84	0.88	1.00	1.00	1.00	1.00	1.00
	0.75	0.67	0.77	0.81	0.86	1.00	1.00	1.00	1.00	1.00
	1.00	0.66	0.73	0.77	0.81	0.91	0.95	0.97	1.00	1.00
	1.50	0.66	0.72	0.76	0.80	0.90	0.95	0.96	1.00	1.00
	2.00	0.62	0.70	0.74	0.79	0.90	0.94	0.96	1.00	1.00
	3.00	0.61	0.69	0.74	0.78	0.92	0.93	0.94	0.98	1.00
	4.00	0.61	0.69	0.73	0.78	0.91	0.91	0.92	0.96	1.00
>4.5 ≤5.5	0.25	0.71	0.79	0.83	0.88	1.00	1.00	1.00	1.00	1.00
	0.50	0.66	0.75	0.79	0.84	0.99	0.99	0.99	1.00	1.00
	0.75	0.55	0.65	0.70	0.75	0.90	0.90	0.95	1.00	1.00
	1.00	0.54	0.64	0.69	0.74	0.90	0.93	0.95	1.00	1.00
	1.50	0.52	0.62	0.67	0.72	0.86	0.90	0.95	1.00	1.00
	2.00	0.51	0.61	0.66	0.71	0.87	0.89	0.92	0.99	1.00
	3.00	0.51	0.61	0.65	0.70	0.86	0.88	0.91	0.98	0.99
	4.00	0.51	0.60	0.65	0.69	0.84	0.86	0.88	0.95	0.97
>5.5 ≤6.5	0.25	0.57	0.68	0.72	0.77	0.95	0.94	0.94	1.00	1.00
	0.50	0.52	0.62	0.66	0.71	0.87	0.90	0.92	1.00	1.00
	0.75	0.49	0.57	0.62	0.68	0.85	0.88	0.90	1.00	1.00
	1.00	0.46	0.56	0.60	0.65	0.82	0.86	0.88	1.00	1.00
	1.50	0.44	0.54	0.59	0.64	0.81	0.84	0.87	0.98	1.00
	2.00	0.43	0.53	0.58	0.63	0.81	0.83	0.86	0.97	0.99
	3.00	0.41	0.51	0.56	0.61	0.79	0.82	0.85	0.97	0.99
	4.00	0.40	0.50	0.55	0.61	0.79	0.82	0.85	0.97	0.99
>6.5	0.25	0.54	0.64	0.68	0.73	0.88	0.90	0.92	1.00	1.00
	0.50	0.49	0.59	0.63	0.68	0.84	0.87	0.89	0.96	1.00
	0.75	0.39	0.49	0.54	0.59	0.77	0.80	0.83	0.96	1.00
	1.00	0.37	0.48	0.53	0.58	0.74	0.77	0.81	0.96	1.00
	1.50	0.35	0.45	0.49	0.54	0.71	0.75	0.79	0.95	1.00
	2.00	0.34	0.44	0.48	0.53	0.71	0.74	0.78	0.94	0.99
	3.00	0.34	0.44	0.48	0.53	0.70	0.73	0.77	0.93	0.98
	4.00	0.33	0.43	0.47	0.52	0.70	0.73	0.77	0.91	0.95

Note: Straight line interpolation of $f_{g,ATS}$ for length of grade and demand flow permitted for any grade.

Exhibit 15-11
ATS Passenger Car Equivalents for Trucks (E_T) and RVs (E_R) for Level Terrain, Rolling Terrain, and Specific Downgrades

Vehicle Type	Directional Demand Flow Rate, $v_{pd,t}$ (veh/h)	Level Terrain and Specific Downgrades	Rolling Terrain
Trucks, E_T	<100	1.9	2.7
	200	1.5	2.3
	300	1.4	2.1
	400	1.3	2.0
	500	1.2	1.8
	600	1.1	1.7
	700	1.1	1.6
	800	1.1	1.4
	≥900	1.0	1.3
RVs, E_R	All flows	1.0	1.1

Note: Interpolation to the nearest 0.1 is recommended.

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Determining the heavy vehicle adjustment factor is a two-step process:

1. Passenger car equivalents are found for trucks (E_T) and RVs (E_R) under prevailing conditions.
2. A heavy vehicle adjustment factor is computed from the passenger car equivalents with Equation 15-4:

$$f_{HV,ATS} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \quad \text{Equation 15-4}$$

where

$f_{HV,ATS}$ = heavy vehicle adjustment factor for ATS estimation,

P_T = proportion of trucks in the traffic stream (decimal),

P_R = proportion of RVs in the traffic stream (decimal),

E_T = passenger car equivalent for trucks from Exhibit 15-11 or Exhibit 15-13, and

E_R = passenger car equivalent for RVs from Exhibit 15-11 or Exhibit 15-13.

The passenger car equivalent is the number of passenger cars displaced from the traffic stream by one truck or RV. Passenger car equivalents are defined for several situations.

- Extended sections of general level or rolling terrain,
- Specific upgrades, and
- Specific downgrades.

Exhibit 15-11 contains passenger car equivalents for trucks and RVs in general terrain segments and for specific downgrades, which are treated as level terrain in most cases. A special procedure is provided in the next section to evaluate specific downgrades on which significant numbers of trucks must reduce their speed to crawl speed to maintain control.

Exhibit 15-12 and Exhibit 15-13 show passenger car equivalents for trucks and RVs, respectively, on specific upgrades.

ATS Passenger Car Equivalents for Specific Downgrades Where Trucks Travel at Crawl Speed

As noted previously, any downgrade of 3% or more and 0.6 mi or longer must be analyzed as a specific downgrade. If the slope of the downgrade varies, it should be analyzed as a single composite by using an average grade computed by dividing the total change in elevation by the total length of grade and expressing the result as a percentage.

Most specific downgrades will be treated as level terrain for analysis purposes. Some downgrades, however, are severe enough to force some trucks into crawl speed. In such cases, the truck drivers are forced to operate in a low gear to apply engine braking, since the normal brake system would not be sufficient to slow or stop a heavy vehicle from gaining too much momentum as it travels down a steep downgrade. There are no general guidelines for identifying when or where these situations will occur, other than direct observation of heavy vehicle operations.

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Exhibit 15-12
ATS Passenger Car Equivalents for Trucks (E_T) on Specific Upgrades

Grade (%)	Grade Length (mi)	Directional Demand Flow Rate, v_{pd} (veh/h) <100	200	300	400	500	600	700	800	>900
	0.25	2.6	2.4	2.3	2.2	1.8	1.9	1.7	1.3	1.1
	0.50	3.7	3.4	3.2	3.1	2.7	2.5	2.6	2.3	2.0
	0.75	4.6	4.4	4.3	4.2	3.7	3.5	3.4	2.4	1.9
	1.00	5.2	5.0	4.9	4.9	4.4	4.2	4.1	3.8	3.6
>4 ≤4.5	1.50	5.2	5.0	5.0	5.0	5.0	5.0	4.6	4.6	2.9
	2.00	7.0	6.9	6.7	6.5	6.7	6.5	6.3	6.1	4.5
	3.00	8.1	8.0	7.7	7.5	6.5	6.2	6.0	6.5	3.9
	>4.00	9.4	8.6	8.6	8.3	7.2	6.9	6.6	4.0	3.7
	0.25	3.8	3.4	3.2	3.0	2.3	3.2	2.2	1.7	1.5
	0.50	5.5	5.2	5.1	5.0	4.4	4.3	4.0	2.8	2.2
	0.75	6.5	6.4	6.5	6.5	6.3	5.9	5.6	3.5	2.6
>4.5	1.00	7.9	7.8	7.9	7.2	6.7	6.6	6.4	5.4	4.7
≤5	1.50	9.5	9.2	9.0	8.9	8.1	7.9	7.7	6.5	5.6
	2.00	10.3	10.1	10.0	9.9	9.4	9.3	8.9	7.1	6.7
	3.00	11.4	11.3	11.2	11.2	10.7	10.3	10.0	8.0	7.8
	>4.00	12.1	12.2	12.2	12.1	11.6	11.3	10.8	8.6	7.6
	0.25	4.4	4.0	3.7	3.5	2.7	2.7	2.7	2.0	2.0
	0.50	6.0	6.0	5.9	5.9	5.8	5.7	5.0	4.6	4.2
	0.75	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
>5	1.00	9.2	9.2	9.1	9.1	9.0	9.0	9.0	8.9	8.8
≤5.5	1.50	10.6	10.6	10.6	10.6	10.5	10.4	10.4	10.2	10.1
	2.00	11.6	11.6	11.6	11.6	11.6	11.6	11.5	11.3	10.9
	3.00	13.7	13.7	13.6	13.6	13.6	13.1	13.0	11.9	11.3
	>4.00	15.3	15.2	15.2	15.2	14.6	14.2	14.8	11.3	10.0
	0.25	4.6	4.6	4.5	4.4	4.0	3.9	3.8	2.3	2.9
	0.50	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
	0.75	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
>5.5	1.00	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.2	10.1
≤6	1.50	11.9	11.9	11.9	11.9	11.8	11.8	11.8	11.7	11.6
	2.00	12.8	12.8	12.8	12.8	12.7	12.7	12.7	12.6	12.5
	3.00	14.4	14.4	14.4	14.4	14.3	14.3	14.3	14.2	14.1
	>4.00	15.4	15.4	15.4	15.3	15.2	15.1	15.1	14.9	14.8
	0.25	5.1	5.1	5.0	5.0	4.6	4.7	4.7	4.5	4.4
	0.50	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
	0.75	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
>6	1.00	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.3	10.2
≤6.5	1.50	12.0	12.0	12.0	12.0	11.9	11.9	11.9	11.8	11.7
	2.00	12.9	12.9	12.9	12.9	12.8	12.9	12.8	12.7	12.6
	3.00	14.5	14.5	14.5	14.5	14.4	14.4	14.4	14.3	14.2
	>4.00	15.4	15.4	15.4	15.4	15.3	15.3	15.3	15.2	15.1

Note: Interpolation for length of grade and demand flow rate is the preferred CLR recommended.

Exhibit 15-13
ATS Passenger Car Equivalents for RVs (E_R) on Specific Upgrades

Grade (%)	Grade Length (mi)	Directional Demand Flow Rate, v_{pd} (veh/h) ≤100	200	300	400	500	600	700	800	>900
	≤0.25	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
	>0.25 – 0.75	1.2	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1.0
>4 ≤4.5	>0.75 – 1.25	1.3	1.3	1.2	1.1	1.0	1.0	1.0	1.0	1.0
	>1.25 – 2.25	1.4	1.3	1.2	1.1	1.0	1.0	1.0	1.0	1.0
	>2.25	1.5	1.4	1.3	1.2	1.0	1.0	1.0	1.0	1.0
	≤0.25	1.4	1.2	1.2	1.1	1.0	1.0	1.0	1.0	1.0
>4.5 ≤5	>0.25 – 0.50	1.4	1.3	1.2	1.1	1.0	1.0	1.0	1.0	1.0
	>0.50	1.5	1.4	1.3	1.2	1.0	1.0	1.0	1.0	1.0
>5 ≤5.5	≤0.50	1.5	1.4	1.3	1.2	1.0	1.0	1.0	1.0	1.0
	>0.50	1.6	1.5	1.4	1.2	1.0	1.0	1.0	1.0	1.0
	≤0.75	1.5	1.4	1.3	1.1	1.0	1.0	1.0	1.0	1.0
>5.5 ≤6.5	0.75 – 2.50	1.6	1.6	1.4	1.2	1.0	1.0	1.0	1.0	1.0
	>2.50 – 3.50	1.6	1.5	1.4	1.3	1.2	1.1	1.0	1.0	1.0
	>3.50	1.6	1.6	1.6	1.5	1.5	1.4	1.3	1.2	1.1
	≤2.50	1.6	1.5	1.4	1.2	1.0	1.0	1.0	1.0	1.0
>6	>2.50 – 3.50	1.6	1.5	1.4	1.2	1.3	1.3	1.3	1.3	1.3
	>3.50	1.6	1.6	1.6	1.5	1.5	1.5	1.4	1.4	1.4

Note: Interpolation of this exhibit is not recommended.

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When this situation exists, the heavy vehicle adjustment factor $f_{HV,ATS}$ is found with Equation 15-5 instead of Equation 15-4:

$$f_{HV,ATS} = \frac{1}{1 + P_{t,ATS} \times P_T(E_T - 1) + (1 - P_{t,ATS}) \times P_R \times (E_R - 1) + P_B(E_B - 1)}$$

Equation 15-5

where

$P_{t,ATS}$ = proportion of trucks operating at crawl speed (decimal); and

E_T = passenger car equivalent for trucks operating at crawl speed, from Exhibit 15-14.

All other variables are as previously defined. Note that $P_{t,ATS}$ is the flow rate of trucks traveling at crawl speed divided by the flow rate of all trucks.

Exhibit 15-14
ATS Passenger Car Equivalents (E_T) for Trucks on Downgrades Traveling at Crawl Speed

Difference Between FFS and Truck Crawl Speed (mi/h)	Directional Demand Flow Rate, $v_{d,ATS}$ (veh/h)								
	≤100	200	300	400	500	600	700	800	>900
10	4.7	4.1	3.6	3.1	2.5	2.1	1.6	1.3	1.0
20	9.0	8.7	7.8	6.7	5.9	4.9	4.0	2.7	1.9
30	15.1	13.5	12.0	10.4	9.0	7.7	6.4	5.1	3.8
40	22.8	20.6	17.5	15.6	13.1	11.6	9.2	6.1	4.2
50	29.8	26.0	23.1	20.3	17.5	14.6	11.9	9.2	6.5
60	35.9	32.2	28.6	24.9	21.9	18.1	14.7	11.3	7.9

Note: Interpolation against both speed difference and demand flow rate to the nearest 0.1 is recommended.

Step 4: Estimate the ATS

As was the case with Step 3, this step applies only to Class I and Class III two-lane highways. Class II highways do not use ATS as a LOS measure.

The ATS is estimated from the FFS, the demand flow rate, the opposing flow rate, and the percentage of no-passing zones in the analysis direction. The ATS is computed from Equation 15-6:

$$ATS_d = FFS - 0.0077(v_{d,ATS} + v_{o,ATS}) \times f_{np,ATS}$$

Equation 15-6

where

ATS_d = average travel speed in the analysis direction (mi/h),

FFS = free-flow speed (mi/h),

$v_{d,ATS}$ = demand flow rate for ATS determination in the analysis direction (pc/h),

$v_{o,ATS}$ = demand flow rate for ATS determination in the opposing direction (pc/h), and

$f_{np,ATS}$ = adjustment factor for ATS determination for the percentage of no-passing zones in the analysis direction, from Exhibit 15-15.

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Exhibit 15-15
ATS Adjustment Factor for No-Passing Zones ($f_{np,ATS}$)

Opposing Demand Flow Rate, v_o (pc/h)	Percent No-Passing Zones				
	≤ 20	40	60	80	100
FFS ≥ 65 mi/h					
≤ 100	1.1	3.7	5.8	7.0	8.1
200	2.2	5.5	8.9	11.0	12.2
400	1.6	2.7	4.7	6.8	8.9
600	1.4	2.3	3.7	5.0	6.8
800	0.7	1.0	1.7	3.4	5.5
1,000	0.5	0.8	1.1	2.1	3.2
1,200	0.5	0.5	0.9	1.0	1.1
1,400	0.5	0.7	0.9	0.9	0.9
≥1,600	0.5	0.7	0.7	0.7	0.5
FFS = 60 mi/h					
≤ 100	0.7	3.7	5.5	6.9	8.9
200	1.9	3.9	5.7	7.9	9.3
400	1.3	2.6	3.5	5.7	7.9
600	1.1	1.3	1.6	3.1	5.0
800	0.5	0.5	1.1	1.3	1.4
1,000	0.5	0.7	0.9	1.1	1.2
1,200	0.5	0.7	0.9	0.9	1.1
1,400	0.5	0.6	0.8	0.8	0.9
≥1,600	0.5	0.6	0.7	0.7	0.7
FFS = 55 mi/h					
≤ 100	0.5	1.2	2.2	2.6	3.7
200	1.5	2.4	3.5	3.9	4.1
400	1.1	1.9	2.4	2.7	2.8
600	0.9	1.1	1.6	1.9	1.9
800	0.5	0.7	1.1	1.4	1.4
1,000	0.5	0.6	0.8	0.9	1.1
1,200	0.5	0.6	0.7	0.9	1.0
1,400	0.5	0.6	0.7	0.7	0.9
≥1,600	0.5	0.6	0.6	0.6	0.7
FFS = 50 mi/h					
≤ 100	0.7	0.7	1.1	2.4	3.5
200	1.3	2.0	3.3	3.9	4.0
400	1.1	1.9	2.2	2.5	2.7
600	0.6	0.9	1.4	1.7	1.9
800	0.4	0.6	0.9	1.2	1.3
1,000	0.4	0.4	0.7	0.9	1.1
1,200	0.4	0.4	0.7	0.8	1.0
1,400	0.4	0.4	0.5	0.7	0.8
≥1,600	0.4	0.4	0.5	0.5	0.5
FFS ≤ 45 mi/h					
≤ 100	0.5	0.4	1.2	2.2	3.4
200	0.9	1.5	3.1	3.4	4.0
400	0.9	0.5	2.0	2.5	2.7
600	0.4	0.3	1.3	1.7	1.8
800	0.3	0.3	0.5	1.1	1.2
1,000	0.3	0.3	0.6	0.8	1.1
1,200	0.3	0.2	0.5	0.7	1.0
1,400	0.3	0.3	0.5	0.6	0.7
≥1,600	0.3	0.3	0.4	0.4	0.6

Note: Interpolation of $f_{np,ATS}$ for percent no-passing zones, demand flow rate, and FFS to the nearest 1 is recommended.

Exhibit 15-15 is entered with v_o in passenger cars per hour, not v_{op} in vehicles per hour. At this point in the computational process, fully adjusted demand flow rates are available and are used in the determination of ATS. As shown in this exhibit, the effect of no passing zones is greatest when opposing flow rates are low. As opposing flow rates increase, the effect decreases to zero, since passing and no passing zones become irrelevant when the opposing flow rate allows no opportunities to pass.

Step 5: Demand Adjustment for PTSF

This computational step is applied only in cases of Class I and Class II two-lane highways. LOS on Class II highways is not based on PTSF, and therefore this step is skipped for those highways.

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The demand volume adjustment process for estimating PTSF is structurally similar to that for ATS. The general approach is the same, but different adjustment factors are used, and the resulting adjusted flow rates will be different from those used in estimating ATS. Therefore, a detailed discussion of the process is not included here, since it is the same as that described for ATS estimates.

Equation 15-7 and Equation 15-8 are used to determine demand flow rates for the estimation of PTSF:

$$v_{i,PTSF} = \frac{V_i}{PHF \times f_{g,PTSF} \times f_{HV,PTSF}} \quad \text{Equation 15-7}$$

$$f_{HV,PTSF} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \quad \text{Equation 15-8}$$

where

$v_{i,PTSF}$ = demand flow rate i for determination of PTSF (pc/h);

i = "d" (analysis direction) or "o" (opposing direction);

$f_{g,PTSF}$ = grade adjustment factor for PTSF determination, from Exhibit 15-16 or Exhibit 15-17; and

$f_{HV,PTSF}$ = heavy vehicle adjustment factor for PTSF determination, from Exhibit 15-18 or Exhibit 15-19.

All other variables are as previously defined.

PTSF Grade Adjustment Factor

As was the case for the ATS adjustment process, grade adjustment factors are defined for general terrain segments (level or rolling), specific upgrades, and specific downgrades. Exhibit 15-16 gives the adjustment factors for general terrain segments and specific downgrades (which are treated as level terrain). Exhibit 15-17 shows adjustment factors for specific upgrades. These adjustments are used to compute demand flow rates, and the exhibits are again entered with $v_{o,i} \cdot VDH$.

Exhibit 15-16
PTSF Grade Adjustment Factor ($f_{g,PTSF}$) for Level Terrain, Rolling Terrain, and Specific Downgrades

Directional Demand Flow Rate, $v_{o,i}$ (veh/h)	Level Terrain and Specific Downgrades	Rolling Terrain
≤ 100	1.00	0.73
200	1.00	0.80
300	1.00	0.85
400	1.00	0.90
500	1.00	0.94
600	1.00	0.97
700	1.00	0.99
800	1.00	1.00
≥ 900	1.00	1.00

Note: Interpolation to the nearest 0.01 is recommended.

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Exhibit 15-17
PTSF Grade Adjustment Factor ($f_{g,ATS}$) for Specific Upgrades

Grade (%)	Grade Length (mi)	Directional Demand Flow Rate, v_{pc} (veh/h)								
		≤100	200	300	400	500	600	700	800	≥900
3 <3.5	0.25	1.00	0.99	0.97	0.95	0.92	0.92	0.92	0.92	0.92
	0.50	1.00	0.99	0.98	0.97	0.93	0.93	0.93	0.93	0.93
	0.75	1.00	0.99	0.98	0.97	0.93	0.93	0.93	0.93	0.93
	1.00	1.00	0.99	0.98	0.97	0.95	0.95	0.95	0.94	0.94
	1.50	1.00	0.99	0.98	0.97	0.95	0.95	0.95	0.94	0.94
	2.00	1.00	0.99	0.98	0.98	0.95	0.95	0.95	0.95	0.95
	3.00	1.00	1.00	0.99	0.99	0.97	0.97	0.97	0.96	0.96
	≥4.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.97	0.97
3.5 <4.5	0.25	1.00	0.99	0.98	0.97	0.94	0.93	0.93	0.92	0.92
	0.50	1.00	1.00	0.99	0.99	0.97	0.97	0.97	0.96	0.96
	0.75	1.00	1.00	0.99	0.99	0.97	0.97	0.97	0.96	0.96
	1.00	1.00	1.00	0.99	0.99	0.97	0.97	0.97	0.97	0.97
	1.50	1.00	1.00	0.99	0.99	0.97	0.97	0.97	0.97	0.97
	2.00	1.00	1.00	0.99	0.99	0.98	0.98	0.98	0.98	0.98
	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	≥4.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
≥4.5 <5.5	0.25	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.97	0.97
	≥0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
≥5.5	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Interpolation for grades of a specific length is recommended.

PTSF Heavy Vehicle Adjustment Factor

The process for determining the heavy vehicle adjustment factor used in estimating PTSF (Equation 15-6) is similar to that used in estimating ATS. Passenger car equivalents must be found for trucks (E_T) and recreational vehicles (E_R). Equivalents for both trucks and RVs in general terrain segments (level, rolling) and on specific downgrades (which are treated as level terrain) are found in Exhibit 15-18. In estimating PTSF, there is no special procedure for trucks traveling at crawl speed on specific downgrades. Equivalents for trucks and RVs on specific upgrades are found in Exhibit 15-19.

Exhibit 15-18
PTSF Passenger Car Equivalents for Trucks (E_T) and RVs (E_R) for Level Terrain, Rolling Terrain, and Specific Downgrades

Vehicle Type	Directional Demand Flow Rate, v_{pc} (veh/h)	Level and Specific Downgrade	Rolling
Trucks, E_T	≤100	1.1	1.5
	200	1.1	1.6
	300	1.1	1.7
	400	1.1	1.6
	500	1.0	1.4
	600	1.0	1.2
	700	1.0	1.0
	800	1.0	1.0
	≥900	1.0	1.0
RVs, E_R	All	1.0	1.0

Note: Interpolation is not required but recommended.

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Exhibit 15-19
PTSF Passenger Car Equivalents for Trucks (E_T) and RVs (E_R) on Specific Upgrades

Grade (%)	Grade Length (mi)	Directional Demand Flow Rate, v_{pc} (veh/h) <100	200	300	400	500	600	700	800	>900
Passenger Car Equivalents for Trucks (E_T)										
≤2 ≤4.5	2.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	3.00	1.5	1.3	1.3	1.2	1.0	1.0	1.0	1.0	1.0
	≥4.00	2.6	1.4	1.3	1.2	1.0	1.0	1.0	1.0	1.0
>2 ≤4.5	1.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.50	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	2.00	1.6	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	3.00	1.8	1.4	1.1	1.2	1.2	1.2	1.2	1.2	1.2
	≥4.00	2.0	1.9	1.8	1.7	1.4	1.4	1.4	1.4	1.4
>4.5 ≤6.5	≤1.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.50	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2
	2.00	1.7	1.6	1.6	1.6	1.5	1.4	1.4	1.3	1.3
	3.00	2.4	2.2	2.2	2.1	1.9	1.8	1.8	1.7	1.7
	≥4.00	3.5	3.1	2.9	2.7	2.1	2.0	2.0	1.8	1.8
>6.5 ≤8.5	≤0.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.00	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.2
	1.50	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6
	2.00	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8
	3.00	3.1	3.2	3.0	2.9	2.4	2.3	2.3	1.9	1.9
	≥4.00	4.5	4.3	3.9	3.7	2.9	2.7	2.6	2.0	2.0
>8.5	≤0.50	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	0.75	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.0	1.0
	1.00	1.0	1.3	1.3	1.4	1.4	1.5	1.5	1.4	1.4
	1.50	2.1	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.0
	2.00	2.9	2.8	2.7	2.5	2.4	2.4	2.3	2.3	2.3
	3.00	4.2	3.9	3.7	3.6	3.0	2.8	2.7	2.2	2.2
	≥4.00	5.0	4.6	4.4	4.2	3.4	3.1	2.9	2.7	2.3
Passenger Car Equivalents for RVs (E_R)										
All	All	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Note: Interpolation is used to estimate passenger car equivalents for intermediate values of grade length.

Step 6: Estimate the PTSF

This step is only applied to Class I and Class II two-lane highways. Class III highways do not use PTSF to determine LOS.

Once the demand flows for estimating PTSF are computed, the PTSF is estimated with Equation 15-9:

$$PTSF_d = BPTSF_d + f_{np,PTSF}\left(\frac{v_{d,PTSF}}{v_{d,PTSF} + v_{o,PTSF}}\right)^x$$

Equation 15-9

where

$PTSF_d$ = percent time spent following in the analysis direction (decimal);

$BPTSF_d$ = base percent time spent following in the analysis direction, from Equation 15-10;

$f_{np,PTSF}$ = adjustment to PTSF for the percentage of no-passing zones in the analysis segment, from Exhibit 15-25;

$v_{d,PTSF}$ = demand flow rate in the analysis direction for estimation of PTSF (pc/h); and

$v_{o,PTSF}$ = demand flow rate in the opposing direction for estimation of PTSF (pc/h).

The base percent time spent following (BPTSF) applies to base conditions and is estimated by Equation 15-10:

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Equation 15-10

$$HPTSF_i = 100\left[1 - \exp\left(av_o^b\right)\right]$$

where a and b are constants drawn from Exhibit 15-20 and all other terms are as previously defined.

Exhibit 15-20 and Exhibit 15-21 are entered with demand flow rates fully converted to passenger cars per hour under base conditions (v_p and v_o).

Exhibit 15-20
PTSF Coefficients for Use in Equation 15-10 for Estimating BPTSF

Opposing Demand Flow Rate, v_o (pc/h)	Coefficient a	Coefficient b
≤200	-0.0014	0.973
400	-0.0022	0.928
600	-0.0033	0.870
800	-0.0045	0.813
1,000	-0.0049	0.829
1,200	-0.0034	0.925
1,400	-0.0018	0.991
≥1,600	-0.0062	0.917

Note: Straight-line interpolation of a to the nearest 0.0001 and b to the nearest 0.001 is recommended.

Exhibit 15-21
No-Passing-Zone Adjustment Factor ($f_{np,pt}$) for Determination of PTSF

Total Two-Way Flow Rate, $v = v_p + v_o$ (pc/h)	Percent No-Passing Zones					
	0	20	40	60	80	100
Directional Split = 50/50						
≤200	9.0	29.7	40.4	49.4	51.0	52.6
400	16.2	41.0	51.2	61.6	63.8	65.9
600	13.6	36.2	47.8	58.2	55.2	56.8
800	11.8	44.8	40.4	44.0	44.8	46.6
1,400	12.8	20.6	25.8	26.2	27.4	28.6
2,000	10.0	13.6	15.8	17.4	18.2	18.8
2,600	7.6	9.7	8.7	9.6	10.1	10.5
3,200	3.3	4.7	5.1	5.5	5.7	6.1
Directional Split = 60/40						
≤200	11.0	35.6	41.0	51.2	52.3	54.5
400	14.6	36.1	44.8	53.4	55.0	56.3
600	11.8	46.9	44.0	51.1	52.8	54.6
800	13.5	28.2	33.6	38.6	39.9	41.3
1,400	11.0	16.9	22.1	25.4	26.4	27.3
2,000	9.1	13.5	15.5	16.0	16.8	17.3
2,600	5.9	7.7	8.5	9.6	10.0	10.2
Directional Split = 70/30						
≤200	9.9	20.1	38.0	47.6	48.5	49.0
400	16.5	32.3	38.5	46.7	47.7	48.8
600	10.9	30.9	37.5	45.9	46.4	47.0
800	10.3	23.6	28.4	33.3	34.5	35.5
1,400	8.0	14.6	17.7	20.8	21.5	22.3
2,000	4.3	9.7	11.7	13.3	14.0	14.5
Directional Split = 80/20						
≤200	8.9	27.3	37.1	47.0	47.4	47.9
400	9.5	26.1	34.5	42.7	43.5	44.1
600	9.0	24.5	31.5	38.1	39.1	40.0
800	7.8	18.5	23.5	28.4	29.1	29.9
1,400	3.5	10.3	13.5	16.3	16.9	17.2
2,200	3.5	7.0	8.5	10.1	10.4	10.7
Directional Split = 90/10						
≤200	6.5	24.1	33.6	43.1	43.4	43.8
400	3.0	20.7	29.3	36.9	38.7	37.6
600	-3.1	16.8	23.5	30.1	30.6	31.1
800	-4.8	10.5	15.2	19.9	20.3	20.8
1,400	1.2	5.5	8.3	11.0	11.5	11.9

Note: Straight-line interpolation of $f_{np,pt}$ for percent no-passing zones, demand flow rate, and directional split is recommended to the nearest 0.1.

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Note that in Exhibit 15-21, the adjustment factor depends on the total two-way demand flow rate, even though the factor is applied to a single directional analysis. The factor reflects not only the percent of no-passing zones in the analysis segment but also the directional distribution of traffic. The directional distribution assumed is the same regardless of the direction being considered. Thus, for example, splits of 70/30 and 30/70 result in the same factor, all other variables being constant. Equation 15-9, however, adjusts the factor to reflect the balance of flows in the analysis and opposing directions.

Step 7: Estimate the PFFS

This step is included only in the analysis of Class III two-lane highways. PFFS is not used in the determination of LOS for Class I or Class II facilities. The computation is straightforward, since both the FFS and the ATS have already been determined in previous steps. PFFS is estimated from Equation 15-11:

$$PFFS = \frac{ATS_d}{FFS} \qquad \text{Equation 15-11}$$

where all terms are as previously defined.

Step 8: Determine LOS and Capacity

LOS Determination

At this point in the analysis, the values of any needed measure(s) have been determined. The LOS is found by comparing the appropriate measures with the criteria of Exhibit 15-3. The measure(s) used must be appropriate to the class of the facility being studied:

- Class I: ATS and PTSF;
- Class II: PTSF; and
- Class III: PFFS.

For Class I highways, two service measures are applied. When Exhibit 15-3 is entered, therefore, two LOS designations can be obtained. The worse of the two is the prevailing LOS. For example, if ATS results in a LOS C designation and PTSF results in a LOS D designation, LOS D is assigned.

Capacity Determination

Capacity, which exists at the boundary between LOS E and F, is not determined by a measure of effectiveness. Under base conditions, the capacity of a two-lane highway (in one direction) is 1,700 pc/h. To determine the capacity under prevailing conditions, relevant adjustment factors must be applied to Equation 15-3 and Equation 15-7. In this case, however, the demand flow rate of 1,700 pc/h under base conditions is known, and the demand flow rate under prevailing conditions is sought.

First, capacity is defined as a flow rate, so the PHF in Equation 15-3 and Equation 15-7 is set at 1.00. Then, Equation 15-12 or Equation 15-13 (or both) are applied, as described below.

AR0073741

Equation 15-12

$$c_{ATS} = 1{,}700 f_{g,ATS} f_{HV,ATS}$$

Equation 15-13

$$c_{PTSF} = 1{,}700 f_{g,PTSF} f_{HV,PTSF}$$

where

c_{ATS} = capacity in the analysis direction under prevailing conditions based on ATS (pc/h), and

c_{PTSF} = capacity in the analysis direction under prevailing conditions based on PTSF (pc/h).

For Class II highways, both capacities must be computed. The lower value represents capacity. For Class I highways, only the PTSF-based capacity is computed. For Class III highways, only the ATS-based capacity is computed.

One complication is that the adjustment factors depend on the demand flow rate (in vehicles per hour). Thus, adjustment factors for a base flow rate of 1,700 pc/h must be used. Technically, this value should be adjusted to reflect grade and heavy vehicle adjustments. This would create an iterative process in which a result is guessed and then checked.

In practical terms, this is unnecessary, since the highest flow group in all adjustment exhibits is greater than 900 veh/h. It is highly unlikely that any adjustments would reduce 1,700 pc/h to less than 900 veh/h. Therefore, in capacity determinations, all adjustment factors should be based on a flow rate greater than 900 veh/h.

Capacity must be limited by the directional distribution of traffic and the total two-way flow capacity of 3,200 pc/h.

Another characteristic of this methodology must be considered in computing capacity. Where the directional distribution is other than 50/50 (in level and rolling terrain), the two-way capacity implied by such directional capacity may be different. Moreover, the implied two-way capacity from either or both directions may be more than the limit of 3,200 pc/h. In such cases, the directional capacities estimated are not achievable with the stated directional distribution. If this is the case, then base capacity is restricted to 1,700 pc/h in the direction with the heaviest flow, and capacity in the opposing direction is found by using the opposing proportion of flow, with an upper limit of 3,200 pc/h.

Directional Segments with Passing Lanes

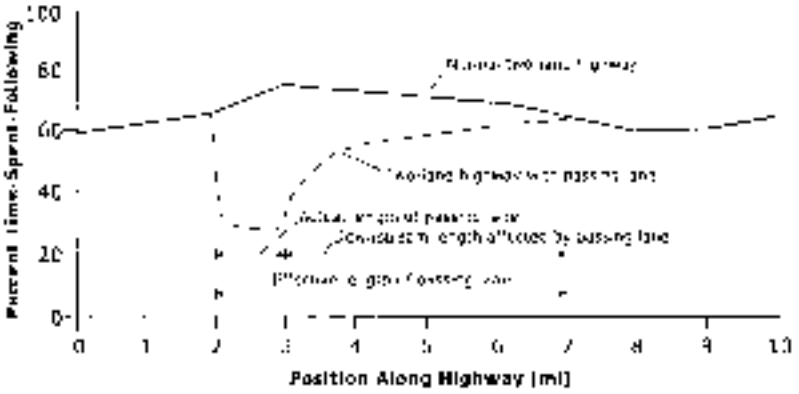
Providing a passing lane on a two-lane highway in level or rolling terrain improves operational performance and therefore may improve LOS. A procedure to estimate this effect is described in this section.

This procedure should be applied only in level and rolling terrain. On specific grades, added lanes are considered to be climbing lanes, which are addressed in the next section.

The effective length of a passing lane is longer than its actual length.

Exhibit 15-22 illustrates the operational effect of a passing lane on PTSF. It shows that the passing lane provides operational benefits for some distance downstream before PTSF returns to its former level (without a passing lane). Thus, a passing lane's effective length is greater than its actual length.

AR0073742



Source: Harwood and Hoban [9].

Exhibit 15-22
Operational Effect of a Passing Lane on PTSF

Exhibit 15-23 gives the length of the downstream segment affected by the passing lane for both ATS and PTSF. In the case of ATS, the effect is limited to 1.7 mi in all cases. Where PTSF is concerned, however, the effect can be far longer than the passing lane itself—up to 13 mi for low demand flow rates.

Directional Demand Flow Rate, v_d (pc/h)	Downstream Length of Roadway Affected, L_{ds} (mi)	
	PTSF	ATS
≤200	13.0	1.7
300	11.6	1.7
400	8.1	1.7
500	7.0	1.7
600	6.5	1.7
700	5.7	1.7
800	5.0	1.7
900	4.3	1.7
≥1,000	3.8	1.7

Note: Interpolation to the nearest 0.1 is recommended.

Exhibit 15-23
Downstream Length of Roadway Affected by Passing Lanes on Directional Segments in Level and Rolling Terrain

The procedure here is intended for the analysis of directional segments in level or rolling terrain that encompass the entire passing lane. Segments of the highway upstream and downstream of the passing lane may be included in the analysis. It is recommended that the analysis segment include the full length of the passing lane's downstream effect.

The analysis segment should include the entire length of the passing lane's downstream effect.

Because of the downstream effect on PTSF, the LOS of a two-lane highway segment that is determined by PTSF (Class I and Class II) may be significantly improved by the addition of a passing lane. Care must be taken, however, in considering the impact of a passing lane on service volumes or service flow rates. The result is highly dependent on the relative lengths of the analysis segment and the passing lane. If the analysis segment includes only the length of the passing lane and its downstream effective length (on PTSF), the passing lane may appear to increase service flow rates dramatically at LOS A–D (capacity and therefore LOS E, would not be affected). However, if additional lengths are included in the analysis segment, this impact is reduced, sometimes considerably. Thus, apparent increases in service volumes or service flow rates must be carefully considered in the context of how they were obtained.

Care should be taken in considering the effect of passing lanes on service flow rates. They are greatly affected by the length of the passing lane relative to the length of the analysis segment.

The steps of this special analysis procedure are as follows:

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Step 1: Conduct an Analysis Without the Passing Lane

The first step in the operational analyses of the impact of a passing lane is to conduct the basic analysis steps described previously. The remainder of the procedure essentially predicts the improvement caused by the passing lane compared with a similar segment without a passing lane.

Step 2: Divide the Segment into Regions

The analysis segment can be divided into four regions, as follows:

1. Length upstream of the passing lane L_u,
2. Length of the passing lane L_p,
3. Length downstream of the passing lane within its effective length L_d, and
4. Length downstream of the passing lane beyond its effective length L_o.

Some of these regions may not be involved in a particular analysis. Region 2, the passing lane, must be included in every analysis. In addition, it is strongly recommended, but not absolutely necessary, that Region 3 be included. Regions 1 and 4 are optional, and inclusion is at the discretion of the analyst.

The four lengths must add up to the total length of the analysis segment. The analysis regions and their lengths will differ for estimations of ATS and PTSF, as the downstream effects indicated in Exhibit 15-23 differ for each.

The length of the passing lane L_p is either the length of the passing lane as constructed or the planned length. It should include the length of the lane addition as well as the length of the entrance and exit tapers. The procedure is calibrated for passing lanes within the optimal lengths shown in Exhibit 15-24. Passing lanes that are substantially shorter or longer than the optimums shown may provide less operational benefit than predicted by this procedure.

Exhibit 15-24
Optimal Lengths of Passing Lanes on Two-Lane Highways

Directional Demand Flow Rate, v_d (pc/h)	Optimal Passing Lane Length (mi)
≤100	≥0.50
>100 ≤400	>0.50 ≤0.75
>400 ≤700	>0.75 ≤1.00
>700	>1.00 <2.00

The length of the conventional two-lane highway segment upstream of the passing lane L_u is determined by the actual or planned placement of the passing lane within the analysis segment. The length of the downstream highway segment within the effective length of the passing lane L_d is determined from Exhibit 15-23. Any remaining length of the analysis segment downstream of the passing lane is included in L_o, which is computed from Equation 15-14:

Equation 15-14

$$L_o = L_t - (L_u + L_p + L_d)$$

where L_t is the total length of the analysis segment in miles and all other terms are as previously defined.

Step 3: Determine the PTSF

PTSF within lengths L_u and L_d is assumed to be equal to the $PTSF_d$ as predicted by the normal analysis procedure (without a passing lane). Within the segment with the passing lane, L_p, PTSF is generally equal to 55% to 62% of its

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upstream value. This effect is a function of the directional demand flow rate. Within L_d, the PTSF is assumed to increase linearly from the passing lane value to the normal upstream value. This distribution is illustrated in Exhibit 15-25.

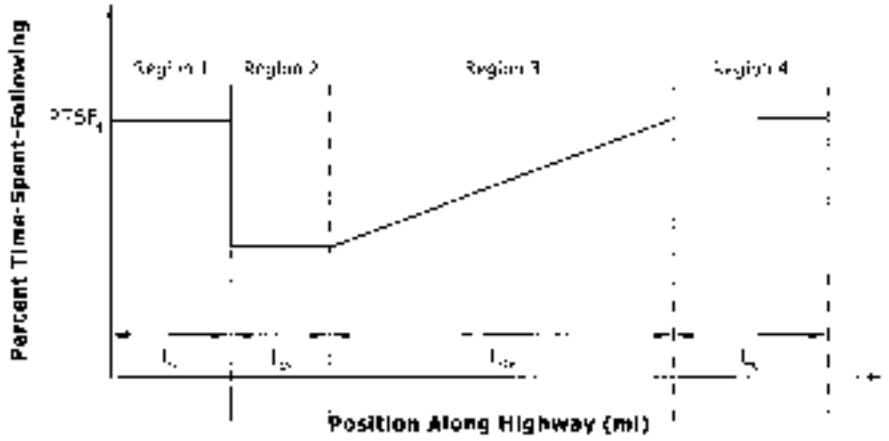

Exhibit 15-25
Effect of a Passing Lane on PTSF

On the basis of this model, the PTSF for the entire analysis segment, as affected by the passing lane, is given by Equation 15-15:

$$PTSF_{pl} = \frac{PTSF_1 \left[L_u + L_d + f_{pl,PTSF} L_{d2} \left(\frac{1 + f_{pl,PTSF}}{2} \right) \right]}{L_r} \quad \text{Equation 15-15}$$

where

$PTSF_{pl}$ = percent time spent-following for segment as affected by the presence of a passing lane (decimal); and

$f_{pl,PTSF}$ = adjustment factor for the impact of a passing lane on percent time spent following, from Exhibit 15-26.

All other variables are as previously defined.

Directional Demand Flow Rate, v_d (pc/h)	$f_{pl,PTSF}$
≤100	0.58
200	0.59
300	0.60
400	0.61
500	0.61
600	0.61
700	0.62
800	0.62
≥900	0.62

Note: Interpolation is not recommended; use next value.

Exhibit 15-26
Adjustment Factor for the Impact of a Passing Lane on PTSF ($f_{pl,PTSF}$)

If the analysis segment cannot encompass the entire length L_d because it is truncated by a town or major intersection within it, then distance L_r is not used. Therefore, the actual downstream length within the analysis segment, L_d, is less than the value of L_d tabulated in Exhibit 15-23. In this case, Equation 15-16 should be used instead of Equation 15-15:

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Equation 15-16

$$PTSF_d = \frac{PTSF_u L_u + f_{pe,ms} L_d + f_{pe,ms} L_{ds} \left[\left(1 - f_{pe,ms} \right) \left(\frac{L_d}{L_{ds}} \right) \right]}{L_t}$$

where all terms are as previously defined.

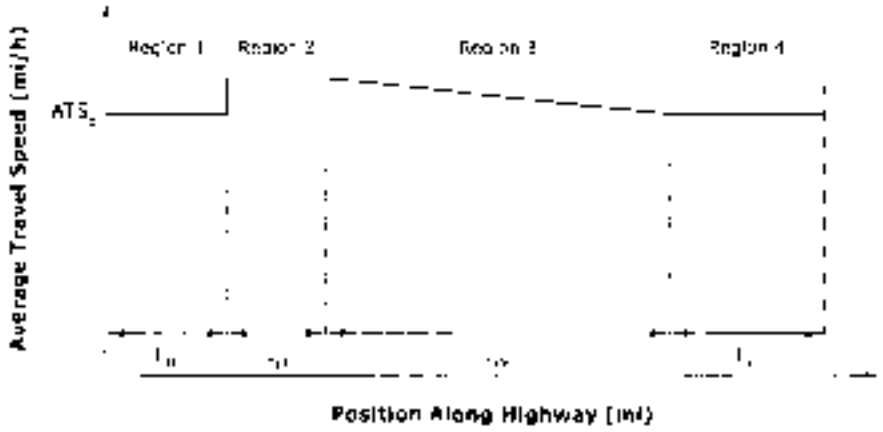
In general, the effective downstream distance of the passing lane should not be truncated. A downstream boundary short of the effective downstream distance should be considered at the point where any of the following occur:

- The environment of the highway radically changes, as in the case of entering a small town or developed area from a rural segment;
- A major unsignalized intersection is present, leading to a change in the demand flow rate;
- A proximate signalized intersection begins to affect the operation of the two-lane segment;
- The terrain changes significantly; and
- Lane or shoulder widths change significantly.

Step 4: Determine the ATS

The ATS within lengths L_u and L_d is assumed to be equal to ATS_o, the speed that would exist without the passing lane. Within the passing lane, the ATS is generally between 5% and 15% higher than its upstream value, depending on the directional demand flow rate. Within the effective downstream length, L_{ds}, ATS is assumed to decrease linearly with the distance from the passing lane, from the passing lane value to the normal value. Exhibit 15-27 illustrates the impact of a passing lane on ATS.

Exhibit 15-27
Impact of a Passing Lane on ATS



The ATS is computed with Equation 15-17.

Equation 15-17

$$ATS_d = \frac{ATS_o L_t}{L_u + L_d + \left(\frac{f_{pe,ATS}}{f_{pe,ATS}} \right) \left(\frac{2L_{ds}}{1 + f_{pe,ATS}} \right)}$$

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where

ATS_d = average travel speed in the analysis segment as affected by a passing lane (mi/h), and

$f_{pl,ATS}$ = adjustment factor for the effect of a passing lane on ATS, from Exhibit 15-28.

All other variables are as previously defined.

Directional Demand Flow Rate, v_d (pc/h)	$f_{pl,ATS}$
≤100	1.00
200	1.00
300	1.00
400	1.00
500	1.00
600	1.01
700	1.01
800	1.01
≥900	1.01

Note: Interpolation is not recommended; use nearest value.

Exhibit 15-28
Adjustment Factor for Estimating the Impact of a Passing Lane on ATS ($f_{pl,ATS}$)

In the case where the analysis segment cannot include all of the effective downstream distance, L_{ds}, because a town or major intersections cause the segment to be truncated, a value of L_d is less than the value of L_{ds}. In this case, Equation 15-38 is used instead of Equation 15-37 to compute ATS.

$$ATS_d = \frac{1}{\frac{L_d}{ATS_f + f_{pl,ATS}} + \left[1 - f_{pl,ATS} + \left(f_{pl,ATS} - 1\right)\left(\frac{L_{ds} - L_d}{L_{ds}}\right)\right]\frac{2.0}{ATS_f}}$$

Equation 15-38

where all terms are as previously defined.

Step 5: Determine the LOS

Determining the LOS for a segment with a passing lane is no different from determining the LOS for a normal segment, except that ATS_d and $PTSF_d$ are used as the service measures with the criteria of Exhibit 15-3.

As with a normal segment, LOS for Class I highways is based on both PTSF and ATS. LOS for Class II highways is based only on PTSF. Class III highways would not normally have passing lanes, but if such a situation arose, PFFS or AFSLOS would be used to determine LOS.

Directional Segments with Climbing Lanes on Upgrades

A climbing lane is, in effect, a passing lane added on an upgrade to allow traffic to pass heavy vehicles whose speeds are reduced. Generally, a lane is added to the right, and all slower-moving vehicles should move to this lane, allowing faster vehicles to pass in the normal lane.

The American Association of State Highway and Transportation Officials (7) indicates that climbing lanes on two-lane highways are warranted when

- The directional flow rate on the upgrade exceeds 200 veh/h,
- The directional flow rate for trucks on the upgrade exceeds 20 veh/h, and

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- Any of the following conditions apply:
  - A speed reduction of 10 mi/h or more exists for a typical truck,
  - LOS E or F exists on the upgrade without a climbing lane, or
  - Without a climbing lane, the LOS is two or more levels lower on the upgrade than on the approach segment to the grade.

An operational analysis of the impact of a climbing lane on a two-lane highway is performed with the same procedures as passing lanes in level or rolling terrain, with three major differences:

1. Adjustment factors for the existence of the climbing lane are taken from Exhibit 15-29,
2. The analysis without a climbing lane is conducted by using the specific grade procedures, and
3. Distances L_d and L_u are set to zero.

The effective downstream distance L_d is also generally set to zero unless the climbing lane ends before the grade does. In this case, a value less than the values typically used should be considered.

Exhibit 15-29
Adjustment Factors (f_G) for Estimating ATS and PTSF Within a Climbing Lane

Directional Demand Flow Rate, v_i (pc/h)	f_G	
	ATS	PTSF
0–420	1.02	0.20
>300–600	1.07	0.21
>600	1.14	0.22

LOS Assessment for Directional Two-Lane Facilities

Two-lane highway segments have uniform characteristics that provide a basis for their analysis. Several contiguous two-lane highway segments (in the same direction) may be combined to look at a longer section (with varying characteristics) as a facility. A separate operational analysis would have to be done for each uniform segment within the facility.

Weighted-average values of PTSF and ATS may be estimated for the facility. The weighting is on the basis of total travel time within the 15-min analysis period. The total travel time of all vehicles within the 15-min analysis period is estimated with Equation 15-19 and Equation 15-20.

Equation 15-19

$$VMT_{15} = 0.25\left(\frac{V_i}{PHF}\right)L_t$$

Equation 15-20

$$DT_i = \frac{VMT_{15i}}{ATS_i}$$

where

VMT_{15i} = total vehicle-miles traveled by all vehicles in directional segment i during the 15-min analysis period (veh-mi),

V_i = demand volume on directional segment i (veh/h),

PHF = peak hour factor,

L_t = total length of directional segment i (mi),

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TT_{di} = total travel time consumed by all vehicles traversing directional segment i during the 15-min analysis period (veh-h), and

ATS_i = average travel speed for directional segment i (mi/h).

Once the total travel time for all vehicles in each segment is computed, weighted-average values of PTSF and ATS can be obtained with Equation 15-21 and Equation 15-22:

$$ATS_f = \frac{VMT_1 + VMT_2 + VMT_3 + \ldots + VMT_i}{TT_1 + TT_2 + TT_3 + \ldots + TT_i} \quad \text{Equation 15-21}$$

$$PTSF_f = \frac{(TT_1 \times PTSF_1) + (TT_2 \times PTSF_2) + (TT_3 \times PTSF_3) + \ldots + (TT_i \times PTSF_i)}{TT_1 + TT_2 + TT_3 + \ldots + TT_i} \quad \text{Equation 15-22}$$

where

ATS_f = average travel speed for the facility (mi/h),

$PTSF_f$ = percent time-spent-following for the facility (decimal),

$PTSF_i$ = percent time-spent-following for segment i (decimal),

VMT_i = vehicle miles traveled for segment i (veh-mi), and

TT_i = total travel time of all vehicles in segment i (veh-h).

When a facility is put together, two-lane highway segments of different classes should not be combined. Levels of service for the facility are still based on the criteria of Exhibit 15-3. Class III two-lane highways generally only exist as short segments and would not be expected to cover a distance long enough to form a facility.

Other Performance Measures

This chapter provides detailed methodologies for estimating three measures of effectiveness that are used (depending on the highway class) to determine LOS:

- ATS (mi/h, Class I and Class III highways),
- PTSF (decimal, Class I and Class II highways), and
- PFFS (decimal, Class II highways).

In the previous section, two additional measures were introduced that can be considered as performance measures, even though they are not used to determine LOS. Equation 15-19 and Equation 15-20 can be used to estimate

- Total vehicle miles traveled by all vehicles in the analysis segment during the 15-min analysis period VMT_{15} (veh-mi), and
- Total travel time consumed by all vehicles traversing the analysis segment during the 15-min analysis period TT_{15} (veh-h).

These values may also be of interest in fully understanding the operational quality of the study segment.

A volume-to-capacity (v/c) ratio is also a common performance measure of interest in LOS and capacity analysis. It is most easily computed for two-lane highways with Equation 15-23:

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Equation 15-23

$$v/c = \frac{v_d}{1{,}700}$$

where v_d is the directional demand flow rate, converted to equivalent base conditions.

The difficulty in this is that there may be two values of v_d to use for estimating ATS and another for estimating PTSF (depending on the class of highway). For Class I highways, where both measures are used, the result yielding the highest v/c ratio would be used. For Class II highways, only PTSF is used, and only one value would exist. For Class III highways, only ATS is used, and only one value would exist.

BICYCLE MODE

The calculation of bicycle LOS on multilane and two-lane highways shares the same methodology, since multilane and two-lane highways operate in fundamentally the same manner for bicyclists. Cyclists travel much more slowly than the prevailing traffic flow, staying as far to the right as possible and using paved shoulders when available, indicating the need for only one model.

The bicycle LOS model for two-lane and multilane highways uses a travel-time perception model calibrated by using a linear regression (9). The model fits independent variables associated with roadway characteristics to the results of a user survey that rated the comfort of various bicycle facilities. The resulting bicycle LOS score generally ranges from 0.5 to 6.5 and is stratified to produce a LOS A–F result, on the basis of Exhibit 15-4.

Step 1: Gather Input Data

The methodology requires gathering the following input data for the facility in question:

1. Lane width (ft),
2. Shoulder width (ft),
3. Hourly directional motorized vehicle volume (veh/h),
4. Number of directional through lanes (needed for multilane highways),
5. Percentage of heavy vehicles (decimal),
6. Posted speed limit (mi/h),
7. Percentage of segment with occupied on-highway parking (decimal), and
8. Pavement rating.

Pavement rating is determined by using FHWA's 5-point present serviceability rating scale (0–1 [very poor], 2 [poor], 3 [fair], 4 [good], and 5 [very good]). Where data for specific variables are not available, default values may be used as shown in Exhibit 15-5.

Step 2: Calculate the Directional Flow Rate in the Outside Lane

On the basis of the hourly directional volume, the peak hour factor, and the number of directional lanes (one for basic two-lane highways, two or more for

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passing lanes on multilane highways), calculate the directional demand flow rate of motorized traffic in the outside lane with Equation 15-24.

$$v_o = \frac{V}{PHF \times N} \quad \text{Equation 15-24}$$

where

v_o = directional demand flow rate in the outside lane (veh/h),

V = hourly directional volume (veh/h),

PHF = peak hour factor, and

N = number of directional lanes (=1 for two-lane highways).

Step 3: Calculate the Effective Width

The effective width of the outside through lane depends on both the actual width of the outside through lane and the shoulder width, since cyclists will be able to travel in the shoulder where one is provided. Moreover, striped shoulders of 4 ft or greater provide more security to cyclists by giving cyclists a clear and place to ride outside of the motorized vehicle travelway. Thus, an 11-ft lane and adjacent 5-ft paved shoulder results in a larger effective width for cyclists than a 16-ft lane with no adjacent shoulder.

Parking occasionally exists along two-lane highways, particularly in developed areas (Class III highways) and near entrances to recreational areas (Class I and Class II highways) where a fee is charged for off-highway parking or where the off-highway parking is inadequate for the parking demand. On-highway parking reduces the effective width, because parked vehicles take up shoulder space and bicyclists leave some shy distance between themselves and the parked cars.

Equation 15-25 through Equation 15-29 are used to calculate the effective width, W_e, on the basis of the paved shoulder width, W_s, and the hourly directional volume, V.

If W_s is greater than or equal to 6 ft,

$$W_e = W_t + W_s - (\%OHP \times 10\text{ ft}) \quad \text{Equation 15-25}$$

If W_s is greater than or equal to 4 ft and less than 6 ft

$$W_e = W_t + W_s - 2 \times (\%OHP(2\text{ ft} - W_s)) \quad \text{Equation 15-26}$$

If W_s is less than 4 ft,

$$W_e = W_t + (\%OHP(2\text{ ft} - W_s)) \quad \text{Equation 15-27}$$

with, if V is greater than 100 veh/h:

$$W_t = W_{LT} - W_s \quad \text{Equation 15-28}$$

Otherwise,

$$W_t = (W_{LT} + W_s) \times (2 - 0.005V) \quad \text{Equation 15-29}$$

where

W_e = effective width as a function of traffic volume (ft).

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W_v = outside lane width (ft),

W_s = paved shoulder width (ft),

V = hourly directional volume (veh/h),

W_f = average effective width of the outside through lane (ft), and

P_{OSPF} = percentage of segment with occupied on-highway parking (decimal).

Step 4: Calculate the Effective Speed Factor

The effect of motor vehicle speed on bicycle quality of service is primarily related to the differential between motor vehicle and bicycle travel speeds. For instance, a typical cyclist may travel in the range of 15 mi/h. An increase in motor vehicle speeds from 20 to 25 mi/h is more readily perceived than a speed increase from 60 to 65 mi/h, since the speed differential increases by 33% in the first instance compared with only 11% in the latter. Equation 15-30 shows the calculation of the effective speed factor that accounts for this diminishing effect.

Equation 15-30

$$S_f = 1.1199 \ln(S_R - 20) + 0.8103$$

where

S_f = effective speed factor, and

S_R = posted speed limit (mi/h).

Step 5: Determine the LOS

With the results of Steps 1–4, the bicycle LOS score can be calculated from Equation 15-31:

Equation 15-31

$$BLOS = 0.507 \ln(v_{15}) + 0.199 SF_f (1 + 10.38 HV)^2 - 7.066 (1/P)^2 - 0.005 (W_e)^2 + 0.957$$

where

$BLOS$ = bicycle level of service score,

v_{15} = directional demand flow rate in the outside lane (veh/h),

HV = percentage of heavy vehicles (decimal); if $V < 200$ veh/h, then HV should be limited to a maximum of 50%,

P = FHWA's 5-point pavement surface condition rating, and

W_e = average effective width of the outside through lane (ft).

Finally, the BLOS score value is used in Exhibit 15-6 to determine the bicycle LOS for the segment.

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3. APPLICATIONS

This chapter provides methodologies for the analysis of two-lane highway uninterrupted flow segments that serve a wide variety of travel purposes. The procedures are most easily applied in the operational analysis mode to determine the capacity and LOS of a two-lane highway segment with known characteristics. Other applications are also possible.

DEFAULT VALUES

A detailed report on the use of default values in uninterrupted flow analyses, including the analysis of two-lane highways, is given elsewhere (*1*). Specific default values for use with the methodology of this chapter were given in Exhibit 15-5. Default values may also be based on local estimates developed from past observations of a specific site or similar sites in a given jurisdiction.

For operational analysis and design analysis, the use of default values should be minimized wherever possible. Every default value used to replace a field-measured or other site-specific value introduces additional uncertainty into the estimation process and into the accuracy of results. Nevertheless, where no site-specific values are available, default values allow at least an approximate analysis of the situation. For planning and preliminary design analyses, use of default values is generally required, since few details are available at this stage of consideration.

TYPES OF ANALYSIS

Operational Analysis

All geometric, development, and traffic demand characteristics are provided. The LOS that is expected to exist during the analysis period is estimated. A number of alternative performance measures may also be estimated. The methodology of this chapter is most easily used in this mode.

Design Analysis

In design analysis, demand characteristics are generally known. The analysis is intended to give insights into design parameters needed to provide a target LOS for the demand characteristics as stated. For two-lane highways, design decisions are relatively limited. Lane and shoulder widths have a moderate impact on operations but generally do not result in a markedly different LOS.

Typical design projects include horizontal or vertical curve realignments, which may affect percent no-passing zones and free-flow speeds.

The special procedures outlined in this chapter to consider the impacts of passing lanes and climbing lanes can be used to provide critical design insight. However, the comparisons are performed in the operational analysis mode, leading to a comparison of operations with or without the passing or climbing lane.

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This chapter's appendix deals with some special design issues related to two-lane highways. However, there is no methodology at this point for estimating the impact of these design treatments on operating quality.

Given the relatively few design parameters involved in a two-lane highway, most design analysis is conducted as an iterative series of operational analyses.

Planning and Preliminary Engineering Analysis

Planning and preliminary engineering analysis has the same objectives as design analysis, except that it occurs early in the process when few details of demand and other characteristics are known. Thus, design analysis is augmented by the use of default values for many inputs.

The other principal characteristic of planning and preliminary engineering analysis is that demands are generally described in terms of two-way AADT.

This chapter includes generalized daily service volume tables covering a specific range of default values. They can be used for a coarse and general evaluation of the likely LOS for a two-lane highway in various settings under an assumed AADT demand. These tables are useful only for the most preliminary of analyses. For example, all two-lane highway segments in a particular region can be considered by using these criteria. Any segments that appear to be operating at an undesirable LOS should be subjected to site-specific study with a more detailed operational analysis before any major design, reconstruction, or investment decisions are made.

SERVICE FLOW RATES, SERVICE VOLUMES, AND DAILY SERVICE VOLUMES

Service flow rates, service volumes, and daily service volumes are useful concepts that can be used in the analysis of many types of facilities, including two-lane highways. The three terms must be clearly understood, because they are very different:

1. Service flow rates (SF_i) represent the maximum directional rate of flow that can be accommodated by a segment while maintaining the designated LOS i.
2. Service volumes (SV_i) represent the maximum directional hourly volume that can be accommodated by a segment while maintaining the designated LOS i during the worst 15-min period of the hour.
3. Daily service volumes (DSV_i) represent the maximum AADT that can be accommodated by a segment while maintaining the designated LOS i during the worst 15 min of the peak hour of the day, in the higher-flow direction.

In general, service flow rates and service volumes are directional values, while the daily service volume is usually stated as total traffic in both directions (since that is how AADT is stated).

The service flow rate for a particular LOS is estimated by using the methodology for the segment type under study (two-lane highways in this

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chapter). Equation 15-32 is then used to estimate service volume for a segment, and Equation 15-33 is used to estimate daily service volume for a segment.

$$SV_i = SF_i \times PHF$$ Equation 15-32

$$DSV = \frac{SV_i}{K \times D}$$ Equation 15-33

where K is the proportion of traffic occurring in the peak hour for the study segment and D is the proportion of traffic occurring in the peak direction for the study segment.

For two-lane highways, several complications arise. While all analyses on two-lane highways are for one direction, the two directions interact. Thus, if a two-way daily service volume is estimated by using the service flow rate in one direction, and then again in the other direction, different results could easily be obtained.

As with all uninterrupted-flow segments, capacity is synonymous with the service flow rate for LOS E. Thus, Equation 15-12 and Equation 15-13, presented earlier, may be used to estimate service flow rates for LOS E. Even in this case, there are two equations, since the value will depend on whether ATS or PTSF is the determining LOS parameter.

For other levels of service, the process of determining a service flow rate is more complicated. It would be beneficial if the methodology of this chapter could be used in reverse—that is, start with a value of ATS or PTSF and work backwards to the demand flow rate that would create that value. Unfortunately, virtually all of the adjustment factors used in this process depend on the demand flow rate, which is what the analyst would be trying to find. Such computations would, therefore, be iterative. Finding appropriate service flow rates for each LOS requires an iterative process in which different flow rates are incrementally used until the threshold for a particular LOS is found.

Once service flow rates are found, Equation 15-32 and Equation 15-33 can be used to infer service volumes and daily service volumes.

GENERALIZED DAILY SERVICE VOLUMES

Exhibit 15-30 shows generalized daily service volumes for use in planning and preliminary design. The exhibit provides daily service volume values for three types of segments: (a) a Class I highway in level terrain, (b) a Class I highway in rolling terrain, and (c) a Class II highway in rolling terrain.

Typical conditions assumed for each are given below the table. Various values of K- and D-factors are given. Since these values vary greatly from region to region, the analyst must select the values most appropriate to the particular application. Interpolation may be used, if desired, to obtain intermediate values.

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Exhibit 15-30
Generalized Daily Service Volumes for Two-Lane Highways

The Class I—level example assumes higher speeds, with significant passing opportunities.

The Class I—rolling example assumes lower roadside speeds and restricted passing opportunities because of the terrain.

The Class II—rolling example is similar to a series of recreational highways with lower speeds and limited passing opportunities.

K-Factor	D-Factor	Class I—Level LOS B	LOS C	LOS D	LOS E	Class I—Rolling LOS B	LOS C	LOS D	LOS E	Class II—Rolling LOS B	LOS C	LOS D	LOS E
0.09	50%	5.5	9.3	16.5	31.7	4.7	8.4	15.7	30.1	5.0	9.5	16.2	31.7
	55%	4.9	8.7	14.9	30.2	3.7	7.9	14.0	29.2	4.1	8.7	15.0	30.2
	60%	4.4	8.1	13.9	27.6	3.7	6.7	12.8	26.8	3.7	7.9	14.6	27.5
	65%	4.1	7.6	13.0	25.1	3.4	6.0	11.4	24.7	3.3	6.6	13.3	25.5
0.10	50%	5.0	8.4	14.0	28.0	3.9	7.6	14.2	27.7	4.4	8.6	16.3	28.0
	55%	4.5	7.9	13.4	27.1	3.3	7.1	12.6	26.3	3.7	7.9	14.4	27.1
	60%	4.0	7.3	12.5	24.9	3.3	5.6	11.5	24.1	3.3	7.1	13.1	24.9
	65%	3.7	6.8	11.6	23.0	3.0	5.3	10.3	22.3	3.0	6.5	11.9	23.0
0.12	50%	4.1	7.0	12.4	23.4	3.1	6.3	11.8	23.1	3.7	7.4	13.6	23.4
	55%	3.7	6.5	11.2	22.6	2.8	5.9	10.5	21.9	3.1	6.5	12.0	22.6
	60%	3.3	6.1	10.4	20.7	2.7	4.7	9.6	20.1	2.7	5.9	10.9	20.7
	65%	3.1	5.7	9.6	19.1	2.5	4.4	8.5	18.5	2.4	5.4	9.9	19.1
0.14	50%	3.5	6.0	10.6	20.0	2.7	5.4	10.1	19.4	3.2	6.3	11.7	20.0
	55%	3.1	5.6	9.6	19.4	2.4	5.1	9.0	18.8	2.6	5.6	10.3	19.4
	60%	2.8	5.2	8.9	17.7	2.3	4.0	8.2	17.2	2.3	5.1	9.4	17.7
	65%	2.6	4.8	8.2	16.4	2.1	3.8	7.3	15.9	2.1	4.8	8.5	16.4

Notes: Volumes are thousands of vehicles per day.
Assumed values for all entries: 12% trucks, PHF = 0.88, 12.0 grades, 0% recreational vehicles, 0 access points/mi.
Assumed values for Class I—level: BFFS = 65 mi/h, 20% no passing zones.
Assumed values for Class I—rolling: BFFS = 60 mi/h, 40% no passing zones.
Assumed values for Class II—rolling: BFFS = 55 mi/h, 60% no passing zones.

A number of interesting characteristics are displayed in Exhibit 15-30:

1. LOS A is not shown. Even in level terrain, it is possible to achieve this level only at very low demand flow rates (almost always lower than 50 veh/h, directional).
2. The range of demand flows falling within LOS E is broad compared with other levels of service. This is because the quality of service on two-lane highways tends to become unacceptable at relatively low v/c ratios. Few two-lane highways are observed operating at or near capacity (except on short segments), because most will have been expanded before capacity demand flows develop.

Exhibit 15-30 should be used only in generalized planning and preliminary engineering analysis. It is best used to examine a number of two-lane highways within a given jurisdiction to determine which need closer scrutiny. If anticipated AADTs on a given segment or facility appear to put the segment or facility into an undesirable LOS, then more site-specific data should be obtained (or forecast) and a full operational analysis conducted before any firm commitments to reconstruct or improve the highway are made.

USE OF ALTERNATIVE TOOLS

No alternative deterministic tools are in common use for two-lane highway analysis. Two-lane highway simulation tools are in various stages of development, but user experience with these tools is insufficient to support the formulation of useful guidance for their application to extend the scope of the procedures described in this chapter.

One of the potentially useful features of two-lane highway simulation is the ability to model specific configurations of a series of no-passing zones, exclusive passing lanes, and access points, all of which are now described in general terms (e.g., percent no-passing zones) in this chapter. Network simulation tools can also use site-specific control devices at specific points.

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It is possible to obtain additional performance measures from simulation results. One example is *follower density*, which is defined in terms of the number of followers per mile per lane. This concept, which is discussed in more detail in Chapter 24, Concepts Supplemental, has attracted increasing international interest. Some examples that illustrate potential uses of two-lane highway simulation are presented elsewhere (9).

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4. EXAMPLE PROBLEMS

Exhibit 15-31
List of Example Problems

Problem Number	Description	Type of Analysis
1	Find the LOS of a Class I highway in rolling terrain	Operational analysis
2	Find the LOS of a Class II highway in rolling terrain	Operational analysis
3	Find the LOS of a Class III highway in level terrain	Operational analysis
4	Find the LOS of a Class I highway with a passing lane	Operational analysis
5	Find the future service LOS of a four-lane highway	Planning analysis

EXAMPLE PROBLEM 1: CLASS I HIGHWAY LOS

The Facts

A segment of Class I two-lane highway has the following known characteristics:

- Demand volume = 1,600 pc/h (total in both directions)
- Directional split (during analysis period) = 50/50
- PHF = 0.95
- 50% no-passing zones in the analysis segment (both directions)
- Rolling terrain
- 14% trucks, 4% RVs
- 11-ft lane widths
- 4-ft usable shoulders
- 20 access points/mi
- 60-mi/h BFFS
- 10-mi segment length

Find the expected LOS in each direction on the two-lane highway segment as described.

Comments

The problem statement calls for finding the LOS in each direction on a segment in rolling terrain. Because the directional split is 50/50, the solution in one direction will be the same as the solution in the other direction, so only one operational analysis needs to be conducted. The result will apply equally to each direction.

Because this is a Class I highway, both ATS and PTSF must be estimated to determine the expected LOS.

Step 1: Input Data

All input data were specified above.

Step 2: Estimate the FFS

FFS is estimated with Equation 15-2 and adjustment factors found in Exhibit 15-7 (for lane and shoulder width) and Exhibit 15-8 (for access points in both directions). For 12-ft lane widths and 4-ft usable shoulders, the adjustment factor

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for these features f_g is 1.7 mi/h for 20 access points/mi, the adjustment factor f_A is 5.0 mi/h. Then:

$$FFS = BFFS - f_g - f_A$$

$$FFS = 60.0 - 1.7 - 5.0 = 53.3 \text{ mi/h}$$

Step 3: Demand Adjustment for ATS

The demand volume must be adjusted to a flow rate in passenger cars per hour under equivalent base conditions. This is accomplished with Equation 15-3:

$$v_{i,ATS} = \frac{V}{PHF \times f_{g,ATS} \times f_{HV,ATS}}$$

Since the demand split is 50/50, both the analysis direction and opposing demand volumes are 1,600/2 = 800 veh/h.

The grade adjustment factor $f_{g,ATS}$ is selected from Exhibit 15-9 for rolling terrain. The table is entered with a demand flow rate $v_{d,i}$ in vehicles per hour, or 800/0.95 = 842 veh/h. By interpolation in Exhibit 15-9 between 800 and 900 veh/h, the factor is 0.99 to the nearest 0.01.

The passenger-car equivalent for trucks and RVs is obtained from Exhibit 15-11, again for a demand flow rate of 842 veh/h. Again, by interpolation between 800 and 900 veh/h, the values obtained are $E_T = 1.4$ and $E_R = 1.1$. The heavy vehicle adjustment is then computed with Equation 15-4:

$$f_{HV,ATS} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{HV,ATS} = \frac{1}{1 + 0.14(1.4 - 1) + 0.04(1.1 - 1)}$$

$$f_{HV,ATS} = 0.943$$

Then:

$$v_{i,ATS} = v_{i,ATS} = \frac{800}{0.95 \times 0.99 \times 0.943} = 902 \text{ pc/h}$$

Step 4: Estimate ATS

The ATS is estimated with Equation 15-6. The adjustment factor $I_{np,ATS}$ is found in Exhibit 15-13 for an FFS of 53.3 mi/h, 50% no-passing zones, and an opposing demand flow of 902 veh/h. This selection must use interpolation on all three scales. Note that interpolation is only to the nearest 0.1 for this adjustment factor. Exhibit 15-32 illustrates the interpolation.

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Exhibit 15-32
Interpolation for ATS Adjustment Factor

v_o (veh/h)	Factor for FFS = 55 mi/h			Factor for FFS = 50 mi/h		
	40% NPZ	50% NPZ	60% NPZ	40% NPZ	50% NPZ	60% NPZ
800	0.7	0.9	1.1	0.6	0.75	0.9
900		0.8			0.65	
1,000	0.6	0.7	0.8	0.4	0.55	0.7

Notes: $f_{g,ATS}$ = 0.65 + [(0.8 − 0.65)/(3.3 / 5.0)] × 0.749 = 0.7.
NPZ = no passing zone.

Then, Equation 15-6 gives the following:

$$ATS = FFS - 0.00776(v_o + v_o) \times f_{np,ATS}$$

$$ATS = 53.3 - 0.00776(902 + 902) \times 0.7$$

$$ATS = 53.3 - 14.0 \times 0.7 = 38.6 \text{ mi/h}$$

Step 5: Demand Adjustment for PTSF

The adjusted demand used to estimate PTSF is found with Equation 15-7 and Equation 15-8. The grade adjustment factor is taken from Exhibit 15-16 for rolling terrain and a demand flow rate of 800/0.95 = 842 pc/h. Passenger car equivalents for trucks and RVs are taken from Exhibit 15-18. In both exhibits, the demand flow rate of 842 pc/h is interpolated between 800 pc/h and 900 pc/h to obtain the correct values. The following values are obtained.

E_T = 1.00

E_R = 1.0

E_B = 1.0

Then, use of Equation 15-8 gives the following.

$$f_{HV,ATS} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{HV,ATS} = \frac{1}{1 + 0.14(1.0 - 1) + 0.04(1.0 - 1)} = 1.00$$

Equation 15-7 gives

$$v_{d,ATS} = \frac{V_o}{PHF \times f_{g,ATS} \times f_{HV,ATS}}$$

$$v_{d,ATS} = v_{p,ATS} = \frac{800}{0.95 \times 1.00 \times 1.00} = 842 \text{ pc/h}$$

Step 6: Estimate PTSF

PTSF is estimated with Equation 15-9 and Equation 15-10. Exhibit 15-20 is used to obtain exponents a and b for Equation 15-10, and Exhibit 15-21 is used to obtain the no-passing-zone adjustment for Equation 15-9. All three require interpolation.

Exponents a and b are based on the opposing flow rate of 842 pc/h, which is interpolated between tabulated values of 800 pc/h and 1,000 pc/h. This is illustrated in Exhibit 15-33.

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Opposing Flow Rate (pc/h)	a	b
800	-0.0045	0.833
842	**-0.0046**	**0.832**
1,200	0.0049	0.829

Exhibit 15-33
Interpolation for Exponents *a* and *b* for Equation 15-10

Then, use of Equation 15-10 gives

$$BPTSF = 100\left[1 - \exp\left(ax_3^b\right)\right]$$

$$BPTSF = 100\left[1 - \exp\left(-0.0046 \times 842^{0.832}\right)\right]$$

$$BPTSF = 71.3\%$$

The adjustment factor for no-passing zones must also be interpolated in two variables. Exhibit 15-21 is entered with 50% no-passing zones, a 50/50 directional split of traffic, and a total two-way demand flow rate of 842 + 842 = 1,684 pc/h. The interpolation is illustrated in Exhibit 15-34.

Total Flow Rate (pc/h)	Adjustment Factor for 40% NPZ	Adjustment Factor for 50% NPZ	Adjustment Factor for 60% NPZ
1,400	23.8	*25.0*	26.2
1,684		16.6 + (25.0 - 16.6) (136 / 600) = **21.0**	
2,000	15.0	*16.5*	17.4

Note: NPZ = no-passing zone.

Exhibit 15-34
Interpolation for $f_{np,ATS}$ for Equation 15-9

Then, use of Equation 15-9 gives

$$PTSF = BPTSF + f_{np,ATS}\left(\frac{v_{o,max}}{v_{o,max} + v_{o,adj}}\right)$$

$$PTSF = 71.3 - 21.0\left(\frac{842}{842 - 842}\right) = 81.8\%$$

Step 7: Estimate PFFS

This step is only used for Class III highways.

Step 8: Determine LOS and Capacity

LOS is determined by comparing the estimated values of ATS and PTSF with the criteria of Exhibit 15-3. An ATS of 38.0 mi/h suggests that LOS E will exist. A PTSF of 81.8% suggests that LOS E will exist. Thus, both criteria lead to the conclusion that the segment will operate at LOS E.

Capacity is determined by either Equation 15-12 or Equation 15-13, whichever produces the lower estimate. Note, however, that all adjustment factors for use in these equations are based on a directional flow rate greater than 900 pc/h. Thus, the grade factor will be 1.00 for both ATS and PTSF. The passenger car equivalent for trucks is 1.3 for ATS and 1.10 for PTSF; the passenger car equivalent for RVs is 1.1 for ATS and 1.00 for PTSF.

The adjustment factors for heavy vehicles are as follows:

$$f_{hv,ATS} = \frac{1}{1 - 0.14\,(1.3 - 1) + 0.04\,(1.1 - 1)} = 0.96$$

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$$f_{HV,pre} = \frac{1}{1 + 0.14\,(1.0 \quad) + 0.04\,(1.0 \quad 1)} = 1.00$$

and

$$c_{i,pre} = 1700 \times f_{g,pre} \times f_{HV,pre} = 1{,}700 \times 1.00 \times 0.960 = 1{,}632 \text{ veh/h}$$

$$c_{prac} = 1700 \times f_{g,pre} \times f_{HV,pre} = 1{,}700 \times 1.00 \times 1.00 = 1{,}700 \text{ veh/h}$$

Obviously, the first value holds, and the directional capacity of this facility is 1,632 veh/h. Given the 50/50 directional distribution, the two-way capacity of the segment is 1,632 + 1,632 = 3,264 veh/h. Because this exceeds the limiting capacity of 3,200 pc/h, the directional capacity cannot be achieved with a 50/50 directional distribution. A total two-way capacity of 3,200 pc/h would prevail. In terms of prevailing conditions, the capacity would be 3,200 × 1.00 × 0.960 = 3,072 veh/h. With a 50/50 directional split, this implies a directional capacity of 3,072/2 = 1,536 veh/h.

Discussion

The two-lane highway segment as described is expected to operate poorly, with LOS F. The operation is poor despite the fact that demand is only 842/1,536 = 0.55 of capacity. Both ATS and PTSF are at unacceptable levels (0.8 mi/h and 81.8%, respectively). This situation again highlights the characteristic of two-lane highways of having poor operations at relatively low *v/c* ratios. This segment should clearly be examined for potential improvements.

Given the 50/50 directional split of traffic, results for the second direction would be identical.

EXAMPLE PROBLEM 2: CLASS II HIGHWAY LOS

The Facts

A segment of Class II highway is part of a scenic and recreational route and has the following known characteristics:

- Class II highway
- 1,050 veh/h (both directions)
- 70/30 directional split
- 5% trucks, 3% RVs
- PHF = 0.85
- 10 ft lanes; 2 ft shoulders
- BFFS = 55.0 mi/h
- Rolling terrain
- 10 access points/mi
- 40% no-passing zones

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Comments

Computational steps 3 and 4, which relate to the estimation of average highway speed, will not be included. LOS for Class II highways depends solely on PTSF. The analysis will be conducted for both the 70% direction of flow and the 30% direction of flow. This is accomplished by merely reversing the analysis direction and opposing flows.

Step 1: Input Data

All input data have been summarized above.

Step 2: Estimate the FFS

FFS is estimated with Equation 15-2. Adjustment factors for lane and shoulder width (Exhibit 15-7) and access points per mile (Exhibit 15-8) are used.

Exhibit 15-7 is entered with 10-ft lanes and 2-ft shoulders. The resulting adjustment is 3.7 mi/h. Exhibit 15-8 is entered with 10 access points/mi. The resulting adjustment is 2.5 mi/h. The FFS is then estimated as follows.

$$FFS = 55.0 - 3.7 - 2.5 = 48.8 \text{ mi/h}$$

Steps 3 and 4

Steps 3 and 4 are not required for Class I highways.

Step 5: Demand Adjustment for PTSF

Equation 15-7 and Equation 15-8 are used to adjust analysis direction and opposing demands to flow rates under equivalent base conditions. With a 70/30 split of traffic, the two demands are as follows:

$$V_{o1} = V_1 = 1{,}050 \times 0.70 = 735 \text{ veh/h}$$

$$V_{o2} = V_2 = 1{,}050 \times 0.30 = 315 \text{ veh/h}$$

In this solution, directions will be referred to as 1 and 2. Since both directions are to be analyzed, their position as "analysis direction" and "opposing" will depend on which direction is under study.

Adjustment factors both for grades (Exhibit 15-16) and for heavy vehicles (Exhibit 15-18) are needed. Exhibit 15-16 and Exhibit 15-18 are entered with a directional flow rate of 735/0.85 = 865 veh/h (Direction 1) and 315/0.85 = 371 veh/h (Direction 2). Interpolation is required in both. The following values are obtained:

$f_{g,o1}$ = 1.00 (Direction 1); 0.89 (Direction 2)

E_T = 1.0 (Direction 1); 1.6 (Direction 2)

E_R = 1.0 (Direction 1); 3.0 (Direction 2)

The heavy vehicle adjustment factor for both directions is computed with Equation 15-8.

$$f_{HV,o1} = \frac{1}{1 + 0.05(1.00 - 1) + 0.07(1.00 - 1)} = 1.00$$

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$$f_{hv,pass} = \frac{1}{1 + 0.05(1.6 - 1) + 0.07(1.00 - 1)} = 0.97$$

The adjusted demand flow rates are computed with Equation 15-7.

$$v_{1,pass} = \frac{735}{0.85 \times 1.00 \times 1.00} = 865 \text{ pc/h}$$

$$v_{2,pass} = \frac{315}{0.85 \times 0.89 \times 0.97} = 429 \text{ pc/h}$$

Step 6: Estimate PTSF

PTSF is estimated with Equation 15-9 and Equation 15-10 with values a and b taken from Exhibit 15-20 and $f_{hv,pass}$ taken from Exhibit 15-21.

Exhibit 15-20 is entered with opposing flow rates of 429 pc/h (for Direction 1) and 865 pc/h (for Direction 2). Both values must be interpolated. The resulting values are as follows:

Direction 1: $a = -0.0024$; $b = 0.915$

Direction 2: $a = -0.0046$; $b = 0.852$

Exhibit 15-21 is entered with the total demand flow rate of 865 + 429 = 1,294 pc/h, a directional split of 70/30, and 60% no-passing zones. Interpolation is required. The factor is the same for both Directions 1 and 2.

$$f_{d/np} = 23.0\%$$

BPTSF is computed with Equation 15-10:

$$BPTSF_1 = 100\left[1 - \exp(-0.0024 \times 865^{0.915})\right] = 68.9\%$$

$$BPTSF_2 = 100\left[1 - \exp(-0.0046 \times 429^{0.852})\right] = 51.0\%$$

The PTSF for each direction is computed with Equation 15-9:

$$PTSF_1 = 68.9 + 23.0\left(\frac{865}{865 - 429}\right) = 84.3\%$$

$$PTSF_2 = 51.0 + 23.0\left(\frac{429}{429 + 865}\right) = 58.6\%$$

Step 7

Step 7 is only used for Class III highways.

Step 8: Determine LOS and Capacity

The LOS is determined by comparing the PTSF values obtained with the criteria of Exhibit 15-3. Applying these criteria reveals that Direction 1 operates at LOS D, while Direction 2 operates at LOS C.

By using the adjustment selected for 2900 veh/h, capacity is computed with Equation 15-13:

$$c_{1,2\%} = 1{,}700 \times 1.00 \times 1.00 = 1{,}700 \text{ veh/h}$$

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$$c_{3\,FSF} = 1{,}700 \times 1.00 \times 1.00 = 1{,}700 \text{ veh/h}$$

Discussion

The LOS is, at best, somewhat marginal on this two-lane highway segment, based solely on the PTSF.

The value of capacity must be carefully considered. If the directional capacities were expanded to two-way capacities based on the given demand split, the capacity in the 30% direction would imply a two-way capacity well in excess of the 3,200 pc/h limitation for both directions. Therefore, even though a capacity of 1,700 veh/h is possible in the 30% direction, it could not occur with a 70/30 demand split. In this case, the two-way capacity would be limited by the capacity in the 70% direction and would be 1,700/0.70 = 2,429 veh/h. The practical capacity for the 30% direction of flow is actually best estimated as 2,429 − 1,700 or 729 veh/h. Given that the 70/30 directional split holds, when the 30% direction reaches a demand flow rate of 729 veh/h, the opposing direction (the 70% side) would be at its capacity.

EXAMPLE PROBLEM 3: CLASS III HIGHWAY LOS

The Facts

A Class III two-lane highway runs through a rural community in level terrain. It has the following known characteristics:

- Class III highway
- Demand volume = 500 veh/h (both directions)
- 10% trucks; no RVs
- Measured FFS = 40 mi/h
- 12-ft lanes; 6-ft shoulders
- PHF = 0.88
- 80% no-passing zones
- 60/40 directional split
- 40 access points/mi
- Level terrain

Comments

Because this is a Class III highway, LOS will be based on PTSF. Thus, Steps 5 and 6, which relate to the estimation of PTSF, will not be used.

Step 1: Input Data

All input data are specified above.

Step 2: Estimate FFS

A measured FFS is specified: 40 mi/h.

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Step 3: Demand Adjustment for ATS

The total demand volume of 900 veh/h must be separated into two directional flows. Since both directions will be evaluated, directions are labeled 1 and 2.

$$V_1 = 900 \times 0.60 = 540 \text{ veh/h}$$

$$V_2 = 900 \times 0.40 = 360 \text{ veh/h}$$

The adjusted demand flow rate in passenger cars per hour under equivalent base conditions is estimated with Equation 15-3. A grade adjustment factor is selected from Exhibit 15-9, and passenger car equivalents for trucks are selected from Exhibit 15-11. Both exhibits are entered with a demand flow rate in vehicles per hour.

$$v_1 = 540/0.88 = 614 \text{ veh/h}$$

$$v_2 = 360/0.88 = 409 \text{ veh/h}$$

The following values are selected from Exhibit 15-9 and Exhibit 15-11. In all cases, interpolation is required:

Value	Direction 1	Direction 2
$f_{g,ATS}$	1.00	1.00
E_T	1.1	1.3

Then, use of Equation 15-4 gives

$$f_{HV,ATS1} = \frac{1}{1 + 0.10(1.1 - 1)} = 0.99$$

$$f_{HV,ATS2} = \frac{1}{1 + 0.10(1.3 - 1)} = 0.97$$

Use of Equation 15-3 gives

$$v_{1,ATS} = \frac{540}{0.88 \times 1.00 \times 0.99} = 620 \text{ pc/h}$$

$$v_{2,ATS} = \frac{360}{0.88 \times 1.00 \times 0.97} = 422 \text{ pc/h}$$

Step 4: Estimate ATS

ATS is estimated with Equation 15-6 with an adjustment factor for no-passing zones taken from Exhibit 15-15. The adjustment factor is based on a 40-mi/h free-flow speed, 60% no-passing zones, and 80% no-passing demand flow rate of 422 pc/h (Direction 1) and 620 pc/h (Direction 2) gives the following:

$$f_{np,ATS1} = 2.4 \text{ mi/h}$$

$$f_{np,ATS2} = 1.6 \text{ mi/h}$$

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Then, use of Equation 15-9 gives

$$ATS_1 = 40.0 - 0.00776(620 - 422) - 2.4 = 29.5 \text{ mi/h}$$

$$ATS_2 = 40.0 - 0.00776(422 + 620) - 1.6 = 30.3 \text{ mi/h}$$

Steps 5 and 6

Steps 5 and 6 are not used for Class III highways.

Step 7: Estimate PFFS

The LOS for Class III facilities is based on PFFS achieved, or ATS/FFS. For this segment, PFFS is as follows:

$$PFFS_1 = 29.5/40.0 = 73.8\%$$

$$PFFS_2 = 30.3/40.0 = 75.8\%$$

Step 8: Determine LOS and Capacity

From Exhibit 15-3, the LOS for Direction 1 is D, while the LOS for Direction 2 is C. The two values of PFFS are close, but the boundary condition between LOS C and D is 0.75. To be LOS C, PFFS must exceed 0.75, and it is just below the threshold in Direction 1 and just above the threshold in Direction 2.

Capacity is evaluated with adjustment factors for 2400 pc/h in level terrain. This makes all adjustment factors 1.00 (for ATS). Thus, the capacity in either direction is as follows:

$$c_{i,ATS} = c_{o,ATS} = 1{,}700 \times 1.00 \times 1.00 = 1{,}700 \text{ veh/h}$$

The two-way capacity values implied are 1,700/0.60 = 2,833 veh/h (Direction 1) and 1,700/0.40 = 4,250 veh/h (Direction 2). Obviously, the implied two-way capacity is the 2,833 veh/h. Moreover, this suggests that the directional capacity in Direction 2 cannot be achieved with a 60/40 demand split. Rather, the directional capacity in Direction 2 occurs when the capacity in Direction 1 occurs, or 2,833 × 0.40 = 1,133 veh/h.

Discussion

This segment of Class II two-lane highway operates just at the LOS C–D boundary. Depending on the length of the segment and local expectations, this may or may not be acceptable.

EXAMPLE PROBLEM 4: CLASS I HIGHWAY LOS WITH A PASSING LANE

The Facts

The 10-mi segment of the two-lane highway analyzed in Example Problem 1 will be improved with 2-mi passing lanes (one in each direction), both installed at 1.00 mi from the segment's beginning. The segment without a passing lane has already been analyzed, and the results of that analysis are listed below:

- Demand volume = 800 veh/h in each direction
- Demand flow rate (ATS) = 902 pc/h in each direction
- Demand flow rate (PTSF) = 842 pc/h in each direction

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- FFS = 53.5 mi/h
- ATS = 38.6 mi/h
- PTSF = 81.8%
- Rolling terrain
- PHF = 0.95

Comments

Both directions will involve the same computations, since the directional distribution is 50/50, and in both cases, the passing lane will start 1.00 mi after the beginning of the segment (of 10 mi) and will end 3.00 mi after the beginning of the segment.

Step 1: Conduct an Analysis Without the Passing Lane

Completed as Example Problem 1.

Step 2: Divide the Segment into Regions

Exhibit 15-35 shows the division of the 6-mi segment into regions. The effective downstream length of the passing lane is selected from Exhibit 15-23 (value is different for ATS and PTSF) for a demand flow rate of 800/0.95 = 842 veh/h.

Exhibit 15-35
Region Lengths for Use in Example Problem 4

To Determine	L_d (mi)	L_{up} (mi)	L_{ds} (mi) Exhibit 15-23	L_e (mi) Equation 15-14
ATS	1.00	2.00	1.7	5.3
PTSF	1.00	2.00	4.7	2.3

Step 3: Determine the PTSF

The PTSF, as affected by the presence of a passing lane, is estimated with Equation 15-15 and an adjustment factor selected from Exhibit 15-28. The adjustment factor $f_{p,ovtk}$ is 0.62. Then

$$PTSF_a = \frac{PTSF\left[L_u + L_d + f_{p,ovtk} L_{up} + \left(\frac{1 + f_{p,ovtk}}{2}\right) L_{ds}\right]}{L_t}$$

$$PTSF_{pl} = \frac{81.8\left[1.0 + 2.3 + (0.62 \times 2.00) + \left(\frac{1 + 0.62}{2}\right) 4.7\right]}{10}$$

$$PTSF_w = \frac{81.8(3.3 + 1.24 + 3.81)}{10} + \frac{81.8 \times 8.35}{10} = 68.3\%$$

Step 4: Determine the ATS

The ATS, as affected by the presence of a passing lane, is found with Equation 15-17 and an adjustment factor selected from Exhibit 15-28. The adjustment factor selected is 1.11. Then

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$$ATS_{pt} = \frac{ATSL_t}{L_s + L_a + \left(\frac{L_a}{f_{LA,ATS}}\right) \div \left(\frac{2L_a}{1 + f_{LA,ATS}}\right)}$$

$$ATS_{pt} = \frac{38.6 \times 2.0}{1.00 + 5.3 + \left(\frac{2.00}{1.12}\right) + \left(\frac{2 \times 11.7}{1 + 1.12}\right)}$$

$$ATS_{pt} = \frac{38.6 \times 11.0}{6.30 + 1.80 + 1.61} = \frac{38.6 \times 11.0}{9.71} = 39.7 \text{ mi/h}$$

Step 5: Determine the LOS

Exhibit 15-3 shows that the LOS, as determined by PTSF, has improved to D. The LOS determined by ATS remains E. Thus, while PTSF has improved significantly, the ATS has not improved enough to improve the overall LOS, which remains E.

Discussion

Adding a 2-mi passing lane to a 20-mi segment of Class I highway operating at LOS E was insufficient to improve the overall LOS, although the PTSF did improve from 61.8% to 68.0%. It is likely that a longer (or a second) passing lane would be needed to improve the ATS sufficiently to result in LOS C or LOS D.

EXAMPLE PROBLEM 5: TWO-LANE HIGHWAY BICYCLE LOS

A segment of two-lane highway (without passing lanes) is being evaluated for potential widening, resurfacing, and repaving. Analyze the impacts of the proposed project on the bicycle LOS in the peak direction.

The Facts

The roadway currently has the following characteristics:

- Lane width = 12 ft
- Shoulder width = 2 ft
- Pavement ramp = 3 (four)
- Posted speed limit = 50 mi/h
- Hourly directional volume = 500 veh/h (no growth is expected)
- Percentage of heavy vehicles = 5%
- PHF = 0.90
- No on-highway parking

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The proposed roadway design has the following characteristics:

- Lane width = 12 ft
- Shoulder width = 6 ft
- Pavement rating = 5 (very good)
- Posted speed limit = 55 mi/h
- No on-highway parking

Step 1: Gather Input Data

All data needed to perform the analysis are listed above.

Step 2: Calculate the Directional Flow Rate in the Outside Lane

By using the hourly directional volume and the PHF, calculate the directional demand flow rate with Equation 15-24. Because this is a two-lane highway segment without a passing lane, the number of directional lanes N is 1. Because traffic volumes are not expected to grow over the period of the analysis, v_d is the same for both current and future conditions.

$$v_{d,i} = \frac{V}{PHF \times N}$$

$$v_{d,i} = \frac{500}{0.90 \times 1} = 556 \text{ veh/h}$$

Step 3: Calculate the Effective Width

For current conditions, the hourly directional demand V is greater than 100 veh/h and the paved shoulder width is 2 ft; therefore, Equation 15-27 and Equation 15-28 are used to determine the effective width of the outside lane. Under future conditions, the paved shoulder width will increase to 6 ft; therefore, Equation 15-26 and Equation 15-28 are used.

For current conditions:

$$W_v = W_{v,i} + W = 12 \text{ ft} + 2 \text{ ft} = 14 \text{ ft}$$

$$W_s = W + (\%OHP(2 \text{ ft} - W_v))$$

$$W_s = 14 \text{ ft} + (0 \times (2 \text{ ft} + 2 \text{ ft})) = 14 \text{ ft}$$

Under the proposed design:

$$W_v = W_{v,i} + W = 12 \text{ ft} + 6 \text{ ft} = 18 \text{ ft}$$

$$W_s = W_v + W - 2 \times (\%OHP(2 \text{ ft} + W_v))$$

$$W_s = 18 \text{ ft} + 6 \text{ ft} - 2 \times (0 \times (2 \text{ ft} + 6 \text{ ft})) = 24 \text{ ft}$$

Step 4: Calculate the Effective Speed Factor

Equation 15-30 is used to calculate the effective speed factor. Under current conditions:

$$f_s = 1.1199 \ln(S_v - 20) + 0.8103$$

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$$S_a = 1.1199 \ln(50 - 20) + 0.8103 - 4.62$$

Under the proposed design:

$$S_a = 1.1199 \ln(55 - 20) + 0.8103 = 4.79$$

Step 5: Determine the LOS

Equation 15-31 is used to calculate the bicycle LOS score, which is then used in Exhibit 15-4 to determine the LOS. Under existing conditions:

$$BLOS = 0.507 \ln(v_{15,a}) + 0.1999 S_a (1 + 10.38 HV)^2 + 7.066(1/P)^2 - 0.005(W_v)^2 + 0.057$$

$$BLOS = 0.507 \ln(556) + 0.1999(4.62)(1 + 10.38 \times 0.05)^2 + 7.066(1/3)^2 - 0.005(14)^2 + 0.057$$

$$BLOS = 3.205 + 2.131 + 0.785 - 0.980 + 0.057 = 5.20$$

Therefore, the bicycle LOS for existing conditions is LOS F. Use of the same process for the proposed design results in the following:

$$BLOS = 0.507 \ln(556) + 0.1999(4.79)(1 + 10.38 \times 0.05)^2 + 7.066(1/5)^2 - 0.005(24)^2 + 0.057$$

$$BLOS = 3.205 + 2.209 + 0.283 - 2.880 + 0.057 = 2.87$$

The corresponding LOS for the proposed design is LOS C.

Discussion

Although the posted speed would increase as a result of the proposed design, this negative impact on bicyclists would be more than offset by the proposed shoulder widening, as indicated by the improvement from LOS F to LOS C.

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5. REFERENCES

Many of these references can be found in the Technical Reference Library in Volume 4.

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APPENDIX A: DESIGN AND OPERATIONAL TREATMENTS

Two-lane highways make up approximately 80% of all paved rural highways in the United States but carry only about 30% of all traffic. For the most part, two-lane highways carry light volumes and experience few operational problems. Some two-lane highways, however, periodically experience significant operational and safety problems brought about by a variety of traffic, geometric, and environmental causes. Such highways may require design or operational improvements to alleviate congestion.

When traffic operational problems occur on two-lane highways, many agencies consider widening to four lanes. Another effective method for alleviating operational problems is to provide passing lanes at intervals in each direction of travel or to provide climbing lanes on steep upgrades. Passing and climbing lanes cannot increase the capacity of a two-lane highway, but they can improve its LOS. Short sections of four-lane highway can function as a pair of passing lanes in opposite directions of travel. Operational analysis procedures for passing and climbing lanes are included in this chapter.

A number of other design and operational treatments are effective in alleviating operational congestion on two-lane highways, including:

- Turnouts,
- Shoulder use,
- Wide cross sections,
- Intersection turn lanes, and
- Two-way left-turn lanes.

No calculation methodologies are provided in this chapter for these treatments; however, the treatments are discussed below to indicate their potential for improving traffic operations on two-lane highways.

TURNOUTS

A turnout is a widened, unobstructed shoulder area on a two-lane highway that allows slow-moving vehicles to pull out of the through lane so that vehicles following may pass. Turnouts are relatively short, generally less than 625 ft. At a turnout, the driver of a slow-moving vehicle that is delaying one or more following vehicles is expected to pull out of the through lane, allowing the vehicles to pass. The driver of the slow-moving vehicle is expected to remain in the turnout only long enough to allow the following vehicle to pass before returning to the travel lane. When there are only one or two following vehicles, this maneuver can usually be completed smoothly, with no need for the vehicle to stop at the turnout. When there are three or more following vehicles, however, the vehicle in the turnout will generally have to stop to allow all vehicles to pass. In this case, the driver of the slower vehicle is expected to stop before the end of the turnout, so that the vehicle will develop some speed before reentering the lane. Signs inform drivers of the turnout's location and reinforce the legal requirements concerning turnout use.

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Turnouts have been used in several countries to provide additional passing opportunities on two-lane highways. In the United States, turnouts have been used extensively in western states. Exhibit 15-A1 illustrates a typical turnout.

Exhibit 15-A1
Typical Turnout Illustrated

Turnouts may be used on nearly any type of two-lane highway that offers limited passing opportunities. To avoid confusing drivers, turnouts and passing lanes should not be intermixed on the same highway.

A single well-designed and well-located turnout can be expected to accommodate 20% to 90% of the number of passes that would occur on a 1.6-km passing lane in level terrain (*A1, A2*). Turnouts have been found to operate safely, with experts (*A2, A4*) noting that turnout accidents occur at a rate of only 1 per 80,000 to 400,000 uses.

SHOULDER USE

The primary purpose of the shoulder on two-lane highways is to provide a stopping and recovery area for disabled or errant vehicles. However, paved shoulders also may be used to increase passing opportunities on two-lane highways.

In some parts of the United States and Canada, if the paved shoulders are adequate, there is a long-standing custom for slower vehicles to move to the shoulder when a vehicle approaches from the rear. The slower vehicle then returns to the travel lane once the passing vehicles has cleared. The custom is regarded as a courtesy and requires little or no restriction in speed by either motorist. A few highway agencies encourage drivers of slow-moving vehicles to use the shoulder in this way because it improves the LOS of two-lane highways without the expense of adding passing lanes or widening the highway. On the other hand, there are agencies that discourage this practice because their shoulders are not designed for frequent use by heavy vehicles.

One highway agency in the western United States generally does not permit shoulder use by slow-moving vehicles but designates specific sections on which the shoulder may be used for this purpose. These shoulder segments range in length from 0.2 to 3.0 mi and are identified by traffic signs.

Research (*A1, A2*) has shown that a shoulder-use segment is about 20% as effective in reducing platoons as a passing lane of comparable length.

WIDE CROSS SECTIONS

Two-lane highways with lanes about 50% wider than normal have been used in several European countries as a less expensive alternative to passing lanes. Sweden, for example, built approximately 500 mi of roadways with two 4.5-m travel lanes and relatively narrow (1.5-ft) shoulders. The wider lane permits faster vehicles to pass slower vehicles while encroaching only slightly on the opposing lane of traffic. Opposing vehicles must move toward the shoulder to permit such maneuvers. Roadway segments with wider lanes can be provided at

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intervals. The passing lanes do not increase passing opportunities on two-lane highways.

Research has shown that speeds at low traffic volumes tend to increase on wider lanes, but the effect on speeds at higher volumes varies (*A6*). More than 70% of drivers indicated that they appreciate the increased passing opportunities available on the wider lanes. No safety problems have been associated with the wider lanes.

Formal procedures have not yet been developed for evaluating the traffic operational effectiveness of wider lanes in increasing the passing opportunities on a two-lane highway. It is reasonable to estimate the traffic operational performance on a directional two-lane highway segment containing wider lanes as midway between the segment with and without a passing lane of comparable length.

INTERSECTION TURN LANES

Intersection turn lanes are desirable at selected locations on two-lane highways to reduce delays to through vehicles caused by turning vehicles and to reduce turning accidents. Separate right- and left-turn lanes may be provided, as appropriate, to remove turning vehicles from the through travel lanes. Left-turn lanes, in particular, provide a protected location for turning vehicles to wait for an acceptable gap in the opposing traffic stream. This reduces the potential for collisions from the rear and may encourage drivers of left-turning vehicles to wait for an adequate gap in opposing traffic before turning. Exhibit 15-A2 shows a typical two-lane highway with left-turn lanes at an intersection.

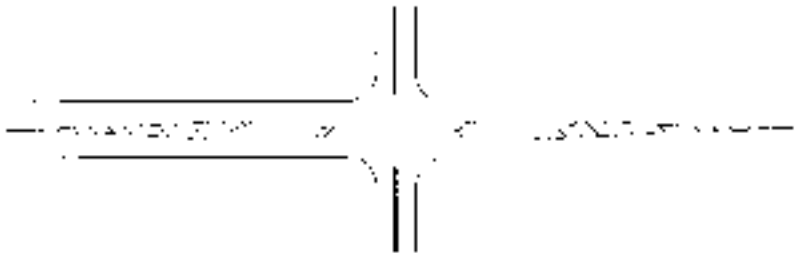

Exhibit 15-A2
Typical Two-Lane Highway
Intersection with Left-Turn Lane

Research has recommended specific operational warrants for left-turn lanes at intersections on two-lane highways based on the directional volumes and the percentage of left turns (*A6*). The HCM's intersection analysis methodologies can be used to quantify the effects of intersection turn lanes on signalized and unsignalized intersections. There is no methodology, however, for estimating the effect of turn lanes on average highway speed. Modeling of intersection delays shows the relative magnitude of likely effects of turning delays on PTSF (*A7*); the results are shown in Exhibit 15-A3. The top line in the exhibit shows that turning vehicles can increase PTSF substantially over a short road segment. However, when these effects are averaged over a longer road segment, the increase in PTSF is greatly reduced, as indicated by the dashed line in the exhibit. The provision of intersection turn lanes has the potential to minimize these effects.

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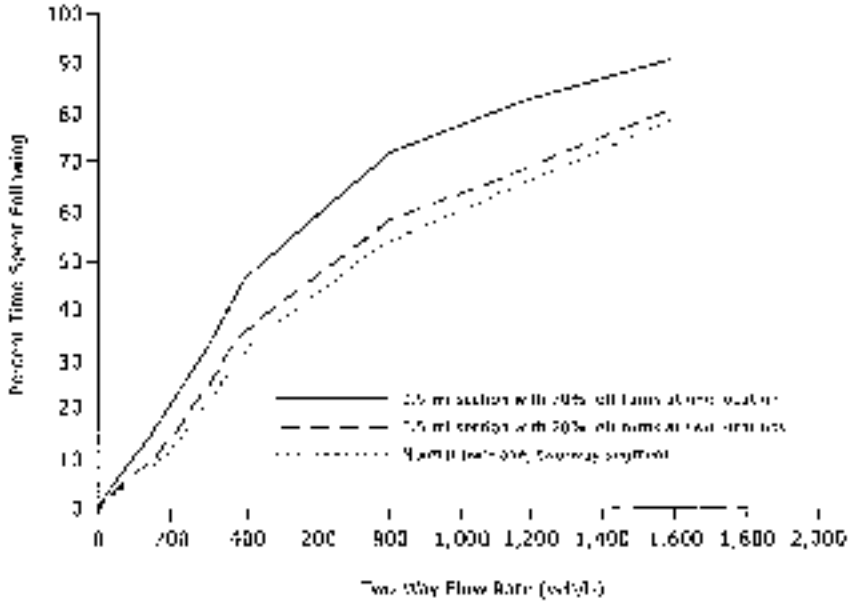
Exhibit 15-A3
Effect of Turning Delays at Intersections on FTSF

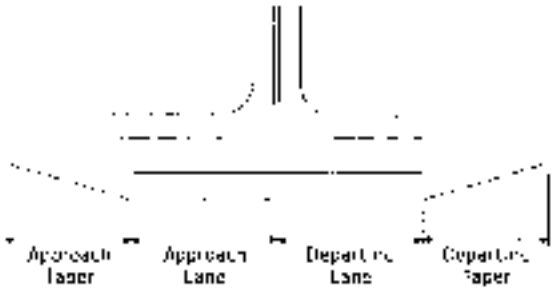


Source: Hoban (44).

Several agencies in the United States provide shoulder bypass lanes at three-leg intersections as a low-cost alternative to a left-turn lane. As shown in Exhibit 15-A4, a portion of the paved shoulder may be marked as a lane for through traffic to bypass vehicles that are slowing or stopped to make a left turn. Bypass lanes may be appropriate for intersections that do not have volumes high enough to warrant a left-turn lane.

The delay benefits of shoulder bypass lanes have not been quantified, but field studies have indicated that 97% of drivers who need to avoid delay will make use of an available shoulder bypass lane. One state has reported a marked decrease in rear-end collisions at intersections where shoulder bypass lanes were provided (*78*).

Exhibit 15-A4
Typical Shoulder Bypass Lane at a Three-Leg Intersection on a Two-Lane Highway



TWO-WAY LEFT-TURN LANES

A two-way left-turn lane (TWLTL) is a paved area in the highway median that extends continuously along a roadway segment and is marked to provide a deceleration and storage area for vehicles traveling in either direction that are making left turns at intersections and driveways.

TWLTLs have been used for many years on urban and suburban streets with high driveway densities and turning demands to improve safety and reduce

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delays to through vehicles. TWLTLs can be used on two-lane highways in rural and urban fringe areas to obtain the same types of operational and safety benefits—particularly on Class III two-lane highways. Exhibit 15-A5 illustrates a typical TWLTL.

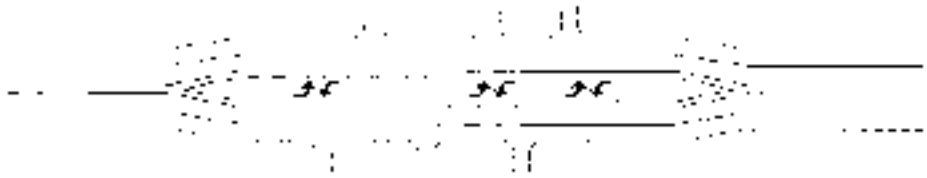

Exhibit 15-A5
Typical TWLTL on a Two-Lane Highway

There is no formal methodology for evaluating the traffic operational effectiveness of a TWLTL on a two-lane highway. Research has found that delay reduction provided by a TWLTL depends on both the left-turn demand and the opposing traffic volume (*A2*). Without a TWLTL or other left-turn treatment, vehicles that are slowing or stopped to make a left turn may create delays for following through vehicles. A TWLTL minimizes these delays and makes the roadway segment operate more like two-way and directional segments with 100% no-passing zones. These research results apply to sites that do not have paved shoulders available for following vehicles to bypass turning vehicles. Paved shoulders may alleviate as much of the delay as a TWLTL.

Research has found little delay reduction at rural TWLTL segments with traffic volumes below 300 vph in one direction (*A2*). At several low-volume sites, no reduction was observed. The highest delay reduction observed was 3.4 s per left-turning vehicle. Therefore, at low-volume rural sites, TWLTLs should be considered for reducing accidents but should not be expected to improve the operational performance of the highway.

At higher-volume urban fringe sites, greater delay reduction was found with TWLTLs on a two-lane highway. Exhibit 15-A6 shows the expected delay reduction per left-turning vehicle as a function of opposing volume. As the delay reduction increases, a TWLTL can be justified for improving both safety and operations.

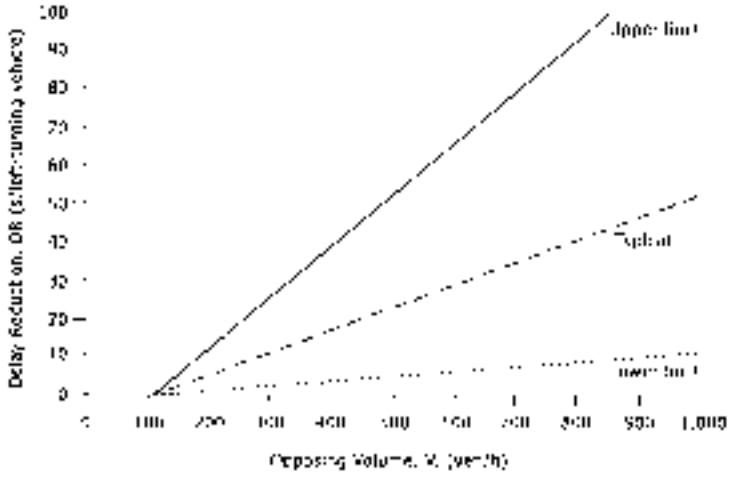

Exhibit 15-A6
Estimated Delay Reduction with a TWLTL on a Two-Lane Highway Without Paved Shoulders

Source: Harwood and St. John (*A2*).

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REFERENCES

Some of these references can be found in the Technical Reference Library in Volume 4

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A8. Sebastian, O. L., and R. S. Pusey. *Paved-Shoulder Left-Turn Bypass Lanes: A Report on the Delaware Experience*. Delaware Department of Transportation, Oct. 1983.

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VOLUME 2 INDEX

The index to Volume 2 lists the text citations of the terms defined in the Glossary (Volume 1, Chapter 9). Volumes 1, 2, and 3 are separately indexed. In the index listings, the first number in each hyphenated pair of numbers indicates the chapter, and the number after the hyphen indicates the page within the chapter.

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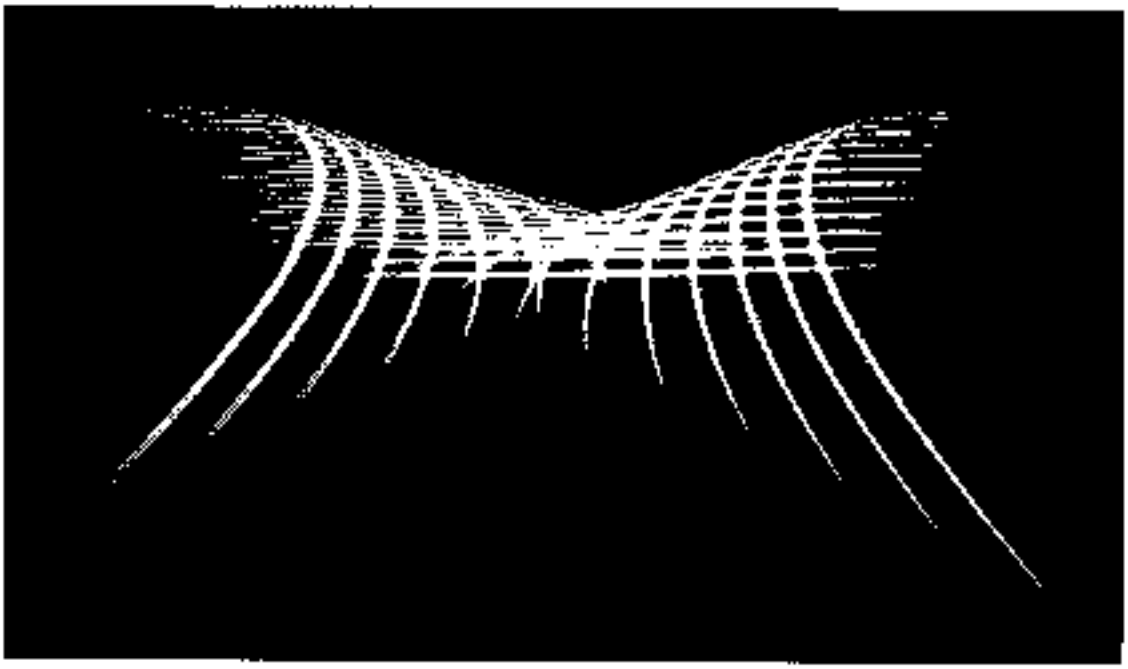

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FOREWORD

This fifth edition of the *Highway Capacity Manual* breaks a great deal of new ground.

- It is the first *Highway Capacity Manual* to provide an **integrated multimodal approach** to the analysis and evaluation of urban streets from the points of view of automobile drivers, transit passengers, bicyclists, and pedestrians. This is the first manual to take into account the effects of cars on bicyclists and pedestrians.
- It is the first to address the proper **application of microsimulation analysis** and the evaluation of those results.
- It is the first to discuss **active traffic management** in relation to both demand and capacity.
- It is the first to include **example applications of its procedures implemented in software code and executables** to assist users and software developers in understanding the subtleties of the methodologies.
- It is also the first to provide tools, **generalized service volume tables**, to assist planners in quickly sizing future facilities.

While this edition of the *Highway Capacity Manual* has many firsts, it also builds on more than 60 years of work by many dedicated experts in the field.[1]

The *First Highway Capacity Manual* was published in 1950 as a joint venture between the Highway Research Board's Committee on Highway Capacity and the Bureau of Public Roads. That effort was led by O. K. Normann, committee chair, and William Walker, committee secretary. The manual was the first international document on the broad subject of capacity and provided definitions of key terms, a compilation of maximum observed flows, and the initial fundamentals of capacity.

The second edition was published in 1965 by the Highway Research Board and authored by the Committee on Highway Capacity. O. K. Normann led much of this effort until his untimely death in 1964. Carl C. Saal continued the work as the new committee chair with Arthur A. Carter, Jr., as secretary. The Bureau of Public Roads was again a significant contributor to the project. The 1965 manual was a significant extension of the 1950 edition and introduced the concept of level of service.

The third edition of the manual was published in 1985 by the Transportation Research Board (TRB) and authored by the Committee on Highway Capacity and Quality of Service, chaired by Carlton C. Robinson, with Charles W. Dale as secretary. Credit is also due to Robert C. Blumenthal and James H. Kell, who served as committee chairs between the publication of the 1965 and 1985 editions. The 1985 edition extended capacity analysis to additional facility types,

[1] Thanks are extended to Alan M. May for this short history of the *Highway Capacity Manual*, which was first provided in his Foreword to the 1994 edition.

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incorporated driver perceptions into level of service and was the first to have the analysis procedures implemented on computer software.

An update to the third edition of the manual was published in 1994 with Adolf D. May as chair of the committee and Wayne K. Kittelson as secretary. The 1994 edition of the manual is noted for new procedures for the analysis of freeway ramp junctions, all-way and two-way stop-controlled intersections, and two-lane rural highways.

The fourth edition of the manual was published in 2000 with John D. Zegeer as chair of the committee and Richard C. Dowling as secretary. That manual was the first to go to a multivolume format (with one volume dedicated to concepts for policy makers) and was the first to test novel electronic formats for the manual using hypertext and narrated self-guided tutorials for some of the example problems.

The *Highway Capacity Manual* has grown over the decades, and it has long since ceased to be the product of a few highly competent experts or even that of a single committee. This edition of the *Highway Capacity Manual* has benefited from the most extensive involvement of the professional community—far surpassing that of all the previous editions. More than 200 professionals, many of them entirely new to TRB, the Committee on Highway Capacity and Quality of Service, and the manual development process itself, contributed to the year-long chapter review process, which has culminated in the publication of this fifth edition.

This edition is the first to involve other TRB committees in its development. The following committees from the Operations Section (AHB00) of the Technical Activities Council of TRB provided reviewers or comments directly on the drafts of the manual:

- AHB20, Freeway Operations;
- AHB25, Traffic Signal Systems;
- AHB35, Committee on High-Occupancy Vehicle, High Occupancy Toll, and Managed Lanes; and
- AHB45, Traffic Flow Theory and Characteristics.

The members of the Committee on Highway Capacity and Quality of Service thank these committees for their assistance and thank the chairs of the Operations Section, Daniel S. Turner and Ivan Peter M. Briglia, Jr., for their support and encouragement of the multicommittee involvement in the development of the *Highway Capacity Manual*.

We are also grateful for the support we have received from the members and staff of the Institute of Transportation Engineers (ITE). Our joint summer meetings with local ITE sections throughout the manual development process were particularly informative and productive.

Throughout this effort, the advice and support of Richard Cunard, Engineer of Traffic and Operations of TRB, was extremely valuable in helping the committee anticipate, address, and overcome the obstacles that arise every time a major new document is published.

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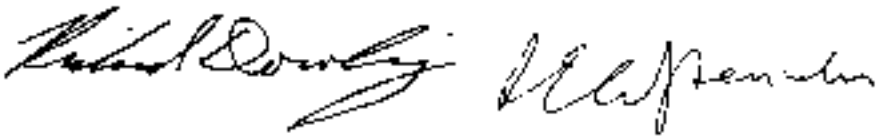
The *Highway Capacity Manual 2010* would never have become a reality without the hard work of the National Cooperative Highway Research Program (NCHRP) 3-92 panel, chaired by Barbara Ostrom, with Ray Derr as Senior Program Officer for the project. The committee thanks the NCHRP 3-92 panel, its staff, and its contractor, Kittelson & Associates, Inc. for delivering a high-quality manual that will greatly improve transportation engineering and planning practice in the years to come.

The committee invites those interested in improving the profession's understanding of capacity and quality of service analysis to contact us at www.AHB40.org and become involved.

For the Committee on Highway Capacity and Quality of Service (AHB40),



Richard G. Dowling
Committee Chair
October 1, 2010

Lily Elefteriadou
Committee Secretary

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CONTRIBUTORS AND ACKNOWLEDGMENTS

The *Highway Capacity Manual 2010* is the result of the coordinated efforts of many individuals, groups, research organizations, and government agencies. The TRB Committee on Highway Capacity and Quality of Service is responsible for the content of the *Highway Capacity Manual*; preparation of the manual was accomplished through the efforts of the following groups and individuals:

TRB COMMITTEE ON HIGHWAY CAPACITY AND QUALITY OF SERVICE

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Nagui Rouphail, *ITRE at North Carolina State University*

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Paul Ryus, *Kittelson & Associates, Inc.*
Mohsen Jafari Saleh, *Georgia Institute of Technology*
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NCHRP PROJECT 3-92 PANEL

Barbara Osborn, *MACTEC Engineering and Consulting, Inc.* — *Chair*
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David Gibson, *Federal Highway Administration*
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E. Andrew Wolfe, *State University of New York, Utica*
Richard Cunard, *Transportation Research Board liaison representative*
B. Ray Derr, *Transportation Research Board staff representative*

NCHRP PROJECT 3-92 RESEARCH TEAM

Mark Vandehey, *Kittelson & Associates, Inc.* — *Principal Investigator*
Wayne Kittelson, *Kittelson & Associates, Inc.*
Kyle Moyer, *Kittelson & Associates, Inc.*
Jamar Parks, *Kittelson & Associates, Inc.*
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Joe Bonneson, *Texas Transportation Institute*

Ken Courage, *University of Florida*

ADDITIONAL CHAPTER DEVELOPMENT

The projects listed below developed *Highway Capacity Manual* chapters outside the main NCHRP 3-92 production project. Chapter 1, HCM User's Guide, lists other NCHRP and Federal Highway Administration projects that also contributed significantly to this edition.

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NCHRP Projects 3-60 and 3-60A

Lily Elefteriadou, *University of Florida — Principal Investigator*
Xiao Cai, *University of Florida*
Aaron Elias, *University of Florida*
Alexandre Kondyli, *University of Florida*
Cong Liu, *University of Florida*
Dimitra Michalaka, *University of Florida*
Jiyeon Yeon, *University of Florida*
Clara Fang, *University of Durham*
Elena Prassas, *Polytechnic University*
Roger Roess, *Polytechnic University*
Baiyuan Wang, *Cornell University*
John Masiero, *Pennsylvania State University*

NCHRP Project 3-85

Ken Courage, *University of Florida — Principal Investigator*
Lily Elefteriadou, *University of Florida*
Scott Washburn, *University of Florida*
Dan Nam, *TY Concepts Corp.*

Federal Highway Administration Project DTFH61-06-D-00004

Richard Dowling, *Dowling Associates, Inc. — Principal Investigator*

PHOTO CREDITS

Peyton McCrank: Exhibit 3-17a
Minnesota Department of Transportation: Exhibit 35-2
Jamie Parks: Exhibit 3-14a,c,d
PB Farradyne: Exhibit 35-1
Theo Petritsch: Exhibit 3-17d
Lee Rodegerdts: Exhibits 3-14e,g, 3-17b, 15-1a,b (1)
Paul Ryus: Exhibits 3-14b, 3-17c,e, 3-20, 4-19, 15-1a(2), 23-18
Hermanus Steyn: Exhibit 14-3d
Yolanda Takefara: Exhibit 14-1a,b,c
Texas Transportation Institute: Exhibit 35-4
Scott Washburn: Exhibit 21-4
Jesse Yung, Exhibit 35-3

TRB PRODUCTION STAFF

Norman Solomon, Senior Editor (retired) edited HCM 2010 with the assistance of Cay Butler, Elaine Eldridge, Naomi C. Kassabian, and Luanne Crayton; Mary McLaughlin proofread the volumes; Juanita L. Green managed the production; and Melanie Wilkins designed the cover, under the supervision of Javy Awan, Director of Publications.

AR0073801

CHAPTER 1
HCM USER'S GUIDE

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1. INTRODUCTION

VOLUME 1: CONCEPTS
1. HCM User's Guide
2. Applications
3. Modal Chapters (Bike, Ped, Transit)
4. Traffic Flow and Capacity Concepts
5. Quality and Level-of-Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

The *Highway Capacity Manual 2010* (HCM) is the fifth edition of this fundamental reference document. Like its predecessors, the HCM 2010 has been significantly revised to incorporate the latest research on highway capacity and quality of service. It has also been substantially reorganized. These changes continue the HCM's evolution, keeping the manual in step with its users' needs and present times.

The 1950 HCM (1) was the first document to quantify the concept of capacity for transportation facilities and focused almost entirely on that subject. This focus was in response to the rapid expansion of the U.S. roadway system after World War II and the need to determine lane requirements for the Interstate highway system and the roads that provided access to it. The manual was designed to be "a practical guide by which the engineer, having determined the essential facts, can design a new highway or revamp an old one with assurance that the resulting capacity will be as calculated."

The focus on design continued in the 1965 HCM (2), but the level-of-service (LOS) concept was also introduced with this edition, along with a chapter on bus transit. The HCM permitted the "determination of the capacity, service volume, or level of service which will be provided by either a new highway design, or an existing highway under specified conditions."

The 1985 HCM (3) was another significant step in the evolution of the HCM. It further refined the concept of LOS and incorporated the results of several major research projects performed since the publication of the 1965 HCM. The target audience was broadened through the addition of chapters on pedestrians and bicycles and an expansion of the transit chapter.

A substantial increase in the volume and breadth of material occurred with the publication of the HCM2000 (4). The intent of the manual was "to provide a systematic and consistent basis for assessing the capacity and level of service for elements of the surface transportation system and also for systems that involve a series or a combination of individual facilities."

The HCM 2010 has updated much new material from research projects completed since the publication of HCM2000 and has been reorganized to make its contents more accessible and understandable. The reorganization is also intended to encourage analysts and decision makers to consider all roadway users, as well as a broader range of performance measures, when they assess transportation facility performance.

Chapter 1, HCM User's Guide, is the starting point for learning how to use this edition of the HCM. This chapter presents the purpose, objectives, intended use, and target users of the HCM 2010; describes the contents of each of the four volumes that make up the HCM; summarizes the major changes that have been made to HCM2000 methodologies; and mentions some of the important companion documents to the HCM. The remainder of Volume 1 presents the fundamental information with which users should be familiar before starting to apply the manual.

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2. HCM PURPOSE AND SCOPE

PURPOSE AND OBJECTIVES

Quality of service describes how well a transportation facility or service operates from the traveler's perspective.

The purpose of the HCM is to provide a set of methodologies and associated application procedures for evaluating the multimodal performance of highway and street facilities in terms of operational measures and two or more quality-of-service dimensions.

The objectives of the HCM are to

1. Define performance measures and their primary methods for key traffic characteristics,
2. Provide methodologies for estimating and predicting performance measures, and
3. Explain methodologies at a level of detail that allows readers to understand the factors affecting multimodal operation.

Level of service is the A–F stratification of quality of service.

The HCM 2010 presents the best available techniques at the time of publishing for determining capacity and LOS. However, it does not establish a legal standard for highway design or construction.

INTENDED USE

The HCM is intended to be used primarily for the analysis areas listed below, to the extent that they are supported by the individual analysis methodologies.

- *Levels of analysis*: operations, design, preliminary engineering, and planning.
- *Travel modes*: automobile (and other motorized vehicles), pedestrian, and bicycle, plus transit when it is part of a multimodal urban street facility.
- *Spatial coverage*: points, segments, and facilities.
- *Temporal coverage*: under undersaturated and oversaturated conditions.

TARGET USERS

The HCM is prepared for use by (a) engineers who work in the field of traffic operations or highway geometric design and (b) transportation planners who work in the field of transportation system management. To use the manual effectively and to apply its methodologies, some technical background is demanded—typically university-level training or technical work in a public agency or consulting firm.

The HCM is also useful to management personnel, educators, air quality specialists, noise specialists, elected officials, regional land use planners, and interest groups representing special users.

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3. STRUCTURE

OVERVIEW

Since 2000, more than $5 million in funded National Cooperative Highway Research Program (NCHRP) research has partially or entirely focused on HCM methodologies. To keep the HCM at a manageable size and yet incorporate the results of this research, the HCM 2010 has been divided into four volumes.

1. Concepts,
2. Uninterrupted Flow,
3. Interrupted Flow, and
4. Applications Guide.

When the HCM2000 (4) was being developed, U.S. states were moving toward compliance with federal requirements to use metric units in the design of roadways. As a result, the HCM2000 was published in "U.S. customary" and "metric" versions. Because the federal metrication requirements were later dropped and most states returned to U.S. customary units, this edition only uses U.S. customary units. A metric conversion guide is provided later in this chapter.

The following sections describe the contents of each HCM 2010 volume.

VOLUME 1: CONCEPTS

Volume 1 covers the basic information that an analyst should be familiar with before performing capacity or quality-of-service analyses. Its chapters cover the organization of the HCM; the kinds of applications that can be performed with the HCM; modal characteristics; traffic flow, capacity, and quality of service concepts; the range of tools available to perform an analysis; guidance on interpreting and presenting analysis results; and the terms and symbols used in the HCM. Chapter 8, HCM Primer, provides an executive summary of the HCM for decision makers.

Users familiar with the HCM2000 will find that Volume 1 incorporates Part I of the HCM2000; conceptual material from HCM2000 Parts II, IV, and V; and new material developed for the 2010 edition. Volume 1 is provided in three-ring binder and electronic formats, to facilitate the addition of new conceptual materials as new research is incorporated into the HCM between major updates.

VOLUME 1: CONCEPTS
1. HCM Users Guide
2. Applications
3. Modal Characteristics
4. Traffic Flow and Capacity Concepts
5. Quality and Level of Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

Chapter 8 serves as an executive summary of the HCM for decision makers.

VOLUME 2: UNINTERRUPTED FLOW

Volume 2 contains the methodological chapters relating to uninterrupted-flow system elements. All of the material necessary in performing an analysis of one of these elements appears here: a description of the process (enough to allow an analyst to understand the steps involved (although not necessarily replicate them by hand), the scope and limitations of the methodology, specific default values, LOS thresholds, and guidance on special cases and the use of alternative tools.

The freeway chapters are presented first, arranged from the facility level down to the segment level; the chapters for multilane and two-lane highways

VOLUME 2: UNINTERRUPTED FLOW
10. Freeway Facilities
11. Basic Freeway Segments
12. Freeway Weaving Segments
13. Freeway Merge and Diverge Segments
14. Multilane Highways
15. Two-Lane Highways

Uninterrupted-flow system elements, such as freeways, have no fixed causes of delay or interruption external to the traffic stream.

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follow. Users familiar with the HCM2000 will find that Volume 2 incorporates the Part III uninterrupted-flow chapters, along with the material from the corresponding Part II chapters (e.g., specific default values and LOS thresholds) used directly in an analysis. The Interchange Ramp Terminals chapter, which appeared with the uninterrupted-flow chapters in the HCM2000, appears with the interrupted-flow chapters (Volume 3) in the HCM 2010.

Volume 2 is provided in both three-ring binder and electronic formats to facilitate interim HCM updates as new research is performed.

VOLUME 3: INTERRUPTED FLOW
15. Urban Street Facilities
17. Urban Street Segments
18. Signalized Intersections
19. TWSC Intersections
20. AWSC Intersections
21. Roundabouts
22. Interchange Ramp Terminals
23. Off-Street Pedestrian and Bicycle Facilities

Interrupted-flow system elements, such as urban streets, have traffic control devices such as traffic signals and stop signs that periodically interrupt the traffic stream.

VOLUME 3: INTERRUPTED FLOW

Volume 3 contains all of the methodological chapters relating to interrupted-flow system elements. Its content is similar to that of the Volume 2 chapters. The facility chapter is presented first, followed by the segment chapter, the point chapters, and a chapter on off-street pedestrian and bicycle facilities.

Volume 3 incorporates the interrupted-flow chapters from the HCM2000's Part III, along with the corresponding detailed Part II material. Where applicable, pedestrian and bicycle material has been integrated throughout the Volume 3 chapters, along with public transit material specific to multimodal analyses. Users are referred to the *Transit Capacity and Quality of Service Manual* (TCQSM) (3) for transit-specific analysis procedures. The HCM2000 Unsignalized Intersections chapter has been split into three chapters in the 2010 edition, which individually cover two-way STOP-controlled intersections, all-way STOP-controlled intersections, and roundabouts. Finally, the Interchange Ramp Terminals chapter is now included with the interrupted-flow chapters.

Volume 3 is provided in both three-ring-binder and electronic formats to facilitate interim HCM updates as new research is performed.

VOLUME 4: APPLICATIONS GUIDE
Methodological Detail:
24. Concepts: Supplemental
25. Freeway Facilities: Supplemental
26. Freeway and Highway Segments: Supplemental
27. Freeway Weaving: Supplemental
28. Freeway Merges and Diverges: Supplemental
29. Urban Street Facilities: Supplemental
30. Urban Street Segments: Supplemental
31. Signalized Intersections: Supplemental
32. Stop-Controlled Intersections: Supplemental
33. Roundabouts: Supplemental
34. Interchange Ramp Terminals: Supplemental
35. Active Traffic Management
Interpretation
Case Studies
Technical Reference Library

VOLUME 4: APPLICATIONS GUIDE

Volume 4 is an electronic-only volume (www.HCM2010.org) that includes four types of content: supplemental chapters, methodological interpretations, comprehensive case studies, and a technical reference library.

The supplemental chapters include the following:

- More detailed descriptions of certain computational methodologies, written for users who seek a greater depth of understanding or plan to develop HCM implementation software;
- Example applications of alternative tools to situations not addressed by the Volume 2 or 3 chapter's methodology;
- Additional example problems and calculation results; and
- A new chapter on the impact of active traffic management techniques on freeway operations.

The methodological interpretations section will develop over time, as users apply the HCM 2010 and pose questions about particular methodologies to the Transportation Research Board (TRB) Committee on Highway Capacity and Quality of Service (AHB40). Clarifications of, interpretations of, and corrections

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to the HCM that have been officially approved by the committee will be posted in the interpretations section of Volume 4.

Access Volume 4 at www.HCM2010.org

The comprehensive case studies illustrate how to use the HCM to perform common types of analyses. The case studies are focused on the process of applying the HCM, rather than on the details of performing calculations (which are addressed by the example problems). Case Studies 1 through 5 are derived from the web-based *HCM Applications Guidebook* (6) that was developed after the HCM2000 was published, while Case Study 6 was developed by the NCHRP 3-85 project (7).

The Technical Reference Library contains a selection of papers, technical reports, and computer documents that provide background information about the development of HCM methodologies.

COMPUTATIONAL ENGINES

Historically, all HCM methodologies have been fully documented within the manual through text, figures, and worksheets (the Freeway Facilities chapter in the HCM2000 represents the first departure from this pattern). However, in response to practitioner needs and identified HCM limitations, methodologies have continued to grow in complexity, and some have reached the point where they can no longer be feasibly documented in such a manner (for example, methodologies that require multiple iterations to reach a solution). In those cases, computational engines become an important means by which details of some of the more complex calculations can be fully described. For the most complex methodologies, the Volume 2 or 3 chapter, the Volume 4 supplemental chapter, and the computational engine together provide the most efficient and effective way of fully documenting the methodology.

HCM chapters describe, at a minimum, the process used by a given methodology. For simpler methodologies, the chapters fully describe the computational steps involved.

Supplemental chapters to Volume 4 provide calculation details for the more computationally complex methods.

Computational engines document all the calculation steps for the most complex methods, such as those requiring iterative calculations.

The TRB Committee on Highway Capacity and Quality of Service maintains computational engines for most HCM methodologies for the purposes of evaluating methodologies as they are developed, developing new example problems, identifying needed improvements, and judging the impact of proposed changes. These engines are tools for developing and documenting HCM methodologies and do not have or need the sophisticated interfaces and input data manipulation techniques that would make them suitable for use in an engineering or planning office. The engines are not generally publicly distributed but are made available on request to researchers, practitioners, software developers, students, and others who are interested in understanding the inner workings of a particular HCM methodology.

COMMERCIAL SOFTWARE

To assist users in implementing the methodologies in the manual, commercial software is available (and has been since the publication of the 1985 HCM) to perform the numerical calculations for the more computationally intensive methods. A variety of commercial software products are available that implement HCM techniques and provide sophisticated user interfaces and data manipulation tools. It is the policy of TRB not to review or endorse commercial products.

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4. INTERNATIONAL USE

APPLICATIONS

Capacity and quality-of-service analysis have generated interest on an international scale. The HCM has been translated into several languages, and research conducted in numerous countries outside of North America has contributed to the development of HCM methodologies. HCM users are cautioned, however, that the majority of the research base, the default values, and the typical applications are from North America, particularly from the United States. Although there is considerable value in the general methods presented, their use outside of North America requires additional emphasis on calibrating the equations and the procedures to local conditions, as well as recognizing major differences in the composition of traffic in driver, pedestrian, and bicycle characteristics; and in typical geometric and control measures.

METRIC CONVERSION GUIDE

The HCM2000 (4) was produced as two editions, one using U.S. customary units and the other using metric units. Variables in the HCM2000 were subject to *hard conversion*, meaning that figures were rounded where this was reasonable. For example, a lane width of 12 ft was converted to a rounded value of 3.6 m. In comparison, a soft conversion would multiply 12 ft by a conversion factor of 0.305 m/ft, resulting in a value of 3.66 m.

As described in this chapter's Scenario section, there is no metric edition of the HCM 2010. Therefore, a soft conversion is required from U.S. customary units to metric units, so that computational engines produce the same result regardless of the measurement system used. However, in comparisons of the metric results of methodologies that have not changed from 2000 to 2010, such as multilane highways, small discrepancies may appear. The results produced by the HCM 2010 with soft conversion may be slightly different from those produced by the metric version of the HCM2000.

Exhibit 1-1 provides approximate conversion factors from U.S. customary to metric units.

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Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in.^{2}	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or metric ton)	Mg (or t)
		TEMPERATURE (exact conversion)		
°F	Fahrenheit	(°F − 32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/square meter	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	pound force	4.45	newtons	N
lbf/in.^{2}	pound force per square inch	6.89	kilopascals	kPa

Source: Federal Highway Administration (3).

Exhibit 1-1
Metric Conversion Tools

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5. WHAT'S NEW IN THE HCM 2010

OVERVIEW

Although the page layout of the HCM 2010 is similar to that of the HCM2000, a number of changes have been made to the manual—a result of both the extensive research that has been conducted since the HCM2000 and the feedback received from HCM2000 users.

Research Basis for the HCM 2010

Exhibit 1-2 lists the major research projects that have contributed to the HCM 2010. The impacts of these and other projects on individual HCM chapters are described later in this section.

Exhibit 1-2
Major Research Projects Contributing to the HCM 2010

Project	Project Title	Project Objective(s)
NCHRP 3-60	Capacity and Quality of Service of Interchange Ramp Terminals	Develop improved methods for capacity and quality-of-service analysis of interchange ramp terminals, for a full range of interchange types
NCHRP 3-64	*Highway Capacity Manual* Applications Guide	Develop an HCM Applications Guide that shows how to apply HCM methodologies to real-world problems and indicate when other methods may be more appropriate
NCHRP 3-65	Applying Roundabouts in the United States	Develop methods of estimating the safety and operational impacts of U.S. roundabouts and refine the design criteria used for them.
NCHRP 3-70	Multimodal Level of Service Analysis for Urban Streets	Develop a framework and enhanced methods for determining levels of service for automobile, transit, bicycle, and pedestrian modes on urban streets, in particular with respect to the interaction among the modes.
NCHRP 3-75	Analysis of Freeway Weaving Sections	Develop improved methods for capacity and LOS analysis of freeway weaving sections
NCHRP 3-79	Measuring and Predicting the Performance of Automobile Traffic on Urban Streets	Develop techniques to measure the performance of automobile traffic on urban streets for real-time applications, develop procedures to predict the performance of automobile traffic on urban streets.
NCHRP 3-80	Default Values for Capacity and Quality of Service Analyses	Determine appropriate default values for inputs to HCM analyses; develop a guide to select default values for various applications.
NCHRP 3-89	Guidance for the Use of Alternative Traffic Analysis Tools in Highway Capacity Analyses	Enhance the guidance in the HCM for the selection and use of alternative traffic analysis tools.
NCHRP 3-97	Production of the Year 2010 *Highway Capacity Manual*	Develop the 2010 edition of the HCM.
Federal Highway Administration	Evaluation of Safety, Design, and Operation of Shared-Use Paths (DTFH61-00-R-00070)	Develop an LOS estimation method for shared-use paths to assist path designers and operators in determining how wide to make new or retrofit paths and whether to separate the different types of users
Federal Highway Administration	Active Traffic Management Measures for Increasing Capacity and Improving Performance (DTFH61-05-D-00004)	Describe active traffic management techniques and available information and analysis methods for evaluating their effectiveness in increasing highway facility capacity and improving operational performance

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Focus Groups

After the publication of the HCM2000, the TRB Committee on Highway Capacity and Quality of Service sponsored a series of focus groups at various locations around the United States to obtain feedback and to identify desired improvements for the next edition. Committee and subcommittee members also prepared an audit of the HCM in the areas of planning, design and operations, and educational needs (9). After the HCM 2010 was finished, the Institute of Transportation Engineers sponsored a web-based survey on HCM usage and desired improvements, and the NCHRP 3-92 project organized several focus groups on these topics. The feedback from these and other sources was considered when decisions were made on the format, content, and organization of the HCM 2010.

Reorganization from the HCM2000

As described in detail in this chapter's Structure section, the HCM 2010 consists of four volumes: (a) Volume 1: Concepts, (b) Volume 2: Uninterrupted Flow, (c) Volume 3: Interrupted Flow, and (d) Volume 4: Applications Guide. Material from Parts I to V of the HCM2000 has been distributed to Volumes 1 to 4 of the HCM 2010 as follows:

- *Part I: Overview* material appears in Volume 1.
- *Part II: Concepts* material appears in Volumes 2 and 3 if used directly in an analysis (e.g., default values and LOS tables) and in Volume 1 otherwise.
- *Part III: Methodologies* material appears in Volume 2 for uninterrupted-flow chapters and Volume 3 for interrupted-flow chapters. Worksheets and highly detailed descriptions of methodological steps appear in the Volume 4 chapters.
- *Part IV: Corridor and Network* material that is conceptual in nature appears in Volume 1. More detailed analytical material has been removed in favor of guidance on the use of alternative tools for corridor and areawide analyses.
- *Part V: Simulation and Other Models* material has been distributed throughout the HCM 2010. Volume 1 contains an overview of alternative tools (Chapter 6) and general guidance on comparing HCM and alternative results (Chapter 7). Specific guidance on when to consider alternative tools is presented in each chapter in Volumes 2 and 3. Selected Volume 4 chapters provide examples of applying alternative tools to situations that cannot be addressed by HCM methodologies.

Multimodal Approach

To encourage HCM users to consider all travelers on a facility when they perform analyses and make decisions, the HCM 2010 integrates material on nonmotorized and motorized modes. Thus, there are no stand-alone Pedestrian, Bicycle, and Transit chapters in this edition. Instead, users should refer to the Urban Streets chapter for analysis procedures for pedestrians, bicyclists, and transit users on urban streets, to the Signalized Intersections chapter for procedures relating to signalized intersections, and so on.

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In recognition of the companion TCQSM (9) and of the difficulty in keeping the two manuals in synch, users are referred to the TCQSM for transit-specific capacity and quality-of-service procedures. However, transit quality of service in a multimodal context continues to be addressed in the HCM.

Traveler-Perception Models

Since the 1985 HCM, LOS has been defined in terms of measures of operational conditions within a traffic stream (1, 2). HCM methodologies have generally presented a single LOS measure per system element that can be (a) directly measured in the field, (b) perceived by travelers, and (c) affected by facility owners. However, since the publication of the HCM2000, a number of research projects have studied whether a single operational factor is sufficient to describe LOS, as well as whether nonoperational factors should also be used (10). These projects have proposed models that (a) incorporate multiple factors of traveler satisfaction and (b) set LOS thresholds based on traveler perceptions of service quality. Traveler perception models from two of these studies (11, 12) have been incorporated into the Multilane Highways, Two-Lane Highways, Urban Street Facilities, Urban Street Segments, and On-Street Pedestrian and Bicycle Facilities chapters.

Generalized Service Volume Tables

The HCM2000 provided "example service volume tables" for 10 system elements. The service volume tables were developed by using a single set of default values and were accompanied by cautionary notes that they were illustrative only. The HCM 2010 provides "generalized service volume tables" for facilities that incorporate a range of national default values. These tables can be considered for such applications as statewide performance reporting, areawide (i.e., regional) modeling, and future-year analyses as part of a long-range transportation planning process.

METHODOLOGICAL CHANGES BY SYSTEM ELEMENT

Freeway Facilities

The basic methodology is similar to the one given in the HCM2000 but incorporates the new weaving-segment analysis procedure. A significant change is the addition of LOS thresholds for freeway facilities based on density. Other changes include updates to the material on the impact of weather and work zones on freeway facility capacity, along with new information on the impact of active traffic management measures on freeway operations.

Basic Freeway Segments

The basic methodology is similar to the one given in the HCM2000. The free-flow speed prediction model has been improved, and a speed–flow curve for segments with 75 mi/h free-flow speeds has been added.

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Freeway Weaving Segments

This chapter has been completely updated and incorporates the methodology developed by the NCHRP 3-75 project. Although the general process for analyzing weaving segments is similar to that given in the HCM2000, the HCM 2010 models are based on an up-to-date set of weaving data. The following are the two major differences in how the methodology is applied: (a) there is now a single algorithm for predicting weaving speeds and a single algorithm for predicting nonweaving speeds regardless of the weaving configuration, and (b) the LOS F threshold was changed.

Ramps and Ramp Junctions

The following revisions have been made to the HCM2000 methodology:

- Procedures have been added to check for unreasonable lane distributions that overload the left or right lane(s) (or both) of the freeway.
- A revision has been made to correct an illogical trend involving on-ramps on right-lane freeways in which density increases as the length of the acceleration lane increases.

Multilane Highways

The multilane highways automobile methodology is essentially the same as that given in the HCM2000. A methodology for calculating bicycle LOS for multilane highways has been added.

Two-Lane Highways

The following revisions have been made to the HCM2000 automobile methodology:

- The two-direction analysis has been dropped; the one-direction methodology is the only one used, with two-direction results obtained by appropriate weighted averaging of the one-direction results.
- Several key curves and tables used in one-direction analysis have been adjusted and incorporated into the chapter.

A bicycle LOS methodology for two-lane highways has been added.

Urban Street Facilities

This is a new chapter that contains guidance to help analysts determine the scope of their analysis (i.e., isolated intersection versus coordinated signal system) and the relevant travel modes (i.e., automobile, pedestrian, bicycle, transit, or a combination). The methodology section describes how to aggregate results from the segment and point levels of analysis into an overall facility assessment. Information on the impact of active traffic management measures on urban street performance has been added.

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Urban Street Segments

This chapter has been completely rewritten. The work of the NCHRP 3-79 project has been incorporated into the chapter, providing improved methods for estimating urban street free-flow speeds and running times, along with a new method for estimating the stop rate along an urban street. In addition, the work of the NCHRP 3-70 project has been incorporated, providing a multimodal LOS methodology that can be used to evaluate trade-offs in how urban street right-of-way is allocated among the modes using the street.

Signalized Intersections

The following revisions have been made to the HCM2000 methodology:

- A new incremental queue accumulation method has been added to calculate the d_3 delay term and the Q_3 length term. It is equivalent to the HCM2000 method for the isolated case but is more flexible to accommodate nonideal cases, including coordinated arrivals and multiple green periods with differing saturation flow rates (i.e., protected-plus-permitted left turns and shoulders).
- An actuated controller operation modeling procedure has been added.
- A left-turn lane overflow check procedure has been added.
- Pedestrian and bicycle LOS methodologies relating to signalized intersections have been moved into this chapter.

Unsignalized Intersections

The HCM2000's Unsignalized Intersections chapter has been split into three chapters: two-way STOP-controlled intersections, all-way STOP-controlled intersections, and roundabouts.

Two-Way Stop-Controlled Intersections

The two-way STOP-controlled intersection methodology for the automobile mode is essentially the same as the one given in the HCM2000, except gap-acceptance parameters for six-lane streets have been added. In addition, pedestrian and bicycle LOS methodologies relating to two-way STOP-controlled intersections have been moved into this chapter.

All-Way Stop-Controlled Intersections

The all-way STOP-controlled intersection methodology is essentially the same as the one given in the HCM2000. A queue-estimation model has been added.

Roundabouts

This chapter replaces the HCM2000 roundabout content. It is based on the work of the NCHRP 3-65 project, which developed a comprehensive database of U.S. roundabout operations and new methodologies for evaluating roundabout performance. A LOS table for roundabouts has been added.

Interchange Ramp Terminals

This chapter is completely updated on the basis of the NCHRP 3-60 project.

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Off-Street Pedestrian and Bicycle Facilities

The pedestrian path procedures are essentially the same as those of the HCM2000, but guidance is provided on how to apply the procedures to a wider variety of facility types. The bicycle path procedures, which were based on Dutch research in the HCM2000, have been updated on the basis of results of a Federal Highway Administration (FHWA) study to calibrate the Dutch model for U.S. conditions and increase the number of path user groups (e.g., inline skaters and runners) addressed by the procedures.

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6. COMPANION DOCUMENTS

Throughout its 60 year history, the HCM has been one of the fundamental reference works used by transportation engineers and planners. However, it is but one of a number of documents that play a role in the planning, design, and operation of transportation facilities and services. The HCM's scope is to provide tools to evaluate the performance of highway and street facilities in terms of operational and quality-of-service measures. This section describes companion documents to the HCM that cover important topics outside the HCM's scope.

HIGHWAY SAFETY MANUAL

The *Highway Safety Manual* (HSM) (4) provides analytical tools and techniques for quantifying the safety effects of decisions related to planning, design, operations, and maintenance. The information in the HSM is provided to assist agencies as they integrate safety into their decision making processes. It is a nationally used resource document intended to help transportation professionals conduct safety analyses in a technically sound and consistent manner, thereby improving decisions made on the basis of safety performance.

A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS

The American Association of State Highway and Transportation Officials' *A Policy on Geometric Design of Highways and Streets* ("Green Book") (14) provides design guidelines for roadways ranging from local streets to freeways, in both urban and rural locations. The guidelines "are intended to provide operational efficiency, comfort, safety, and convenience for the motorist" and to emphasize the need to consider other modal users of roadway facilities.

MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

FHWA's *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) (15) is the national standard for traffic control devices for any street, highway, or bicycle trail open to public travel. Of particular interest to HCM users are the sections of the MUTCD pertaining to warrants for all-way stop control and traffic signal control, signing and markings to designate lanes at intersections, and associated considerations of adequate roadway capacity and less restrictive intersection treatments.

TRANSIT CAPACITY AND QUALITY OF SERVICE MANUAL

The TCQSM (6) is the transit counterpart to the HCM. The manual contains background, statistics, and graphics on the various types of public transportation, and it provides a framework for measuring transit availability, comfort, and convenience from the passenger point of view. The manual contains quantitative techniques for calculating the capacity of bus, rail, and ferry transit services and transit stops, stations, and terminals.

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Some of these references can be found in the Technical Reference Library in Volume 4.

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CHAPTER 2
APPLICATIONS

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1. INTRODUCTION

VOLUME 1: CONCEPTS
1. HCM User's Guide
2. Applications
3. Modal Characteristics
4. Traffic Flow and Capacity Concepts
5. Quality and Level-of-Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

Types of HCM analyses users.

The Highway Capacity Manual (HCM) can be applied to transportation applications that range from the highly detailed to the highly generalized, to roadway system elements that range from individual points to an entire transportation system, to four travel modes that can be considered separately or in combination, and to several types of roadway and facility operating conditions. **Chapter 2, Applications,** introduces the wide range of potential HCM applications, all of which can be applied as stand-alone analyses or as an input to or support of a broader process.

The HCM can be applied at the *operational*, *design*, *preliminary engineering*, and *planning* analysis levels. The required input data typically remain the same at each analysis level, but the degree to which analysis inputs use default values instead of actual measured or forecast values differs. In addition, operational analysis and planning and preliminary engineering analyses final ly evaluate the level of service (LOS) that will result from a given set of inputs, whereas design analyses typically determine which facility characteristics will be needed to achieve a desired LOS.

Travel modes and roadway system elements addressed by the HCM.

The travel modes covered by the HCM are the *automobile* (including other motorized vehicles such as trucks, recreational vehicles (RVs), intercity buses, and motorcycles), *pedestrian*, and *bicycle* modes, as well as *public transit* vehicles that operate on urban streets. All of these modes operate on a variety of roadway system elements, including *points* (e.g., intersections), *segments* (e.g., lengths of roadways between intersections), *facilities* (an aggregation of points and segments into longer lengths), or *systems* (parallel freeway and arterial facilities), and at the largest geographic scales, *areas* and *systems*.

Individual methodological chapters discuss the extent to which the HCM can be used for oversaturated analyses. Chapter 6 describes alternative analysis tools that may be applied in situations in which the HCM cannot be used.

HCM methodologies are provided both for *uninterrupted-flow* facilities, which have no fixed causes of delay or interruption external to the traffic stream, and for *interrupted-flow* facilities, on which traffic control devices such as traffic signals and stop signs periodically interrupt the traffic stream. HCM analyses are applicable to *undersaturated* conditions (when demand is less than a roadway system element's capacity) and, in certain situations, to *oversaturated* conditions (when demand exceeds capacity).

Finally, measures generated by HCM methodologies can be used for more than just stand-alone traffic analyses. This chapter describes potential applications of HCM methodologies to noise, air quality, economic, and multimodal planning analyses.

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2. LEVELS OF ANALYSIS

OVERVIEW

Any given HCM application can be analyzed at different levels of detail, depending on the purpose of the analysis and the amount of information available. The HCM defines three primary levels of analysis:

- *Operational analysis*, typically focusing on current or near-term conditions, involving detailed inputs to HCM procedures, with no or minimal use of default values;
- *Design analysis*, typically using HCM procedures to identify the required characteristics of a transportation facility that will allow it to operate at a desired LOS, with some use of default values; and
- *Planning and preliminary engineering analysis*, typically focusing on future conditions, where it is desired to evaluate a series of alternatives quickly or when specific input values to procedures are not known, requiring the extensive use of default values.

The following sections describe these analysis levels further.

OPERATIONAL ANALYSIS

Operational analyses are applications of the HCM that are generally oriented toward current or near-term conditions. They aim at providing information for decisions on whether there is a need for improvements to an existing point, segment, or facility. Occasionally, an analysis is made to determine whether a more extensive planning study is needed. Sometimes the focus is on a network, or part of one, that is approaching oversaturation or an undesirable LOS. Where, in the near term, is the facility likely to fail (or fail to meet a desired LOS threshold)? To answer this question, an estimate of the service flow rate allowable under a specified LOS is required.

For concept of LOS as described in Chapter 3, Quality and Level-of-Service Concepts

HCM analyses also help practitioners make decisions about operating conditions. Typical alternatives often involve the analysis of appropriate lane configurations, alternative traffic control devices, signal timing and phasing, spacing and location of bus stops, frequency of bus service, and addition of a managed (e.g., high-occupancy vehicle) lane or a bicycle lane. The analysis produces operational measures for a comparison of the alternatives.

Because of the immediate, short-term focus of operational analyses, it is possible to provide detailed inputs to the models. Many of the inputs may be based on field measurements of traffic, physical features, and control parameters. Generally, it is inappropriate to use default values at this level of analysis.

DESIGN ANALYSIS

Design analyses primarily apply the HCM to establish the detailed physical features that will allow a new or modified facility to operate at a desired LOS. Design projects are usually targeted for mid- to long-term implementation. Not all the physical features that a designer must determine are reflected in the HCM models. Typically, analysts using the HCM seek to determine such elements as

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the basic number of lanes required and the need for auxiliary or turning lanes. However, an analyst can also use the HCM to establish values for elements such as lane width, steepness of grade, length of added lanes, size of pedestrian queuing areas, widths of sidewalks and walkways, and presence of bus turnouts.

The data required for design analyses are fairly detailed and are based substantially on proposed design attributes. However, the intermediate to long-term focus of the work will require use of some default values. This simplification is justified in part by the limits on the accuracy and precision of the traffic predictions with which the analyst is working.

PLANNING AND PRELIMINARY ENGINEERING ANALYSIS

Planning analyses are applications of the HCM generally directed toward broad issues such as initial problem identification (e.g., screening a large number of locations for potential operations deficiencies), long-range analyses, and statewide performance monitoring. An analyst often must estimate the future times at which the operation of the current and committed systems will fall below a desired LOS. Preliminary engineering analyses are often conducted to support planning decisions related to roadway design concept and scope, and when alternatives analyses are performed. These studies can also assess proposed systemic policies, such as lane-use control for heavy vehicles, systemwide freeway ramp metering and other intelligent transportation system applications, and the use of demand-management techniques (e.g., congestion pricing) (*1*).

Planning and preliminary engineering analyses typically involve situations in which not all of the data needed for the analysis are available. Therefore, both types of analyses frequently rely on default values for many analysis inputs. Planning analyses may default nearly all inputs—for example, through the use of generalized service volume tables. Preliminary engineering analyses will typically fall between planning and design analyses in the use of default values.

RELATIONSHIP BETWEEN ANALYSIS LEVELS AND OBJECTIVES

Each methodological chapter in Volumes 2 and 3 has one basic method adapted to facilitate each of the levels of analysis. Analysis objectives include identifying a future problem, selecting an appropriate countermeasure to an identified problem, or evaluating the postimplementation success of an action. The HCM is particularly useful when a current situation is being studied in the context of future conditions or when an entirely new element of the system is being considered for implementation. Analysts studying current conditions should make direct field measurements of the performance attributes; these direct measurements can then be applied in the same manner as predicted values to determine performance measures of interest.

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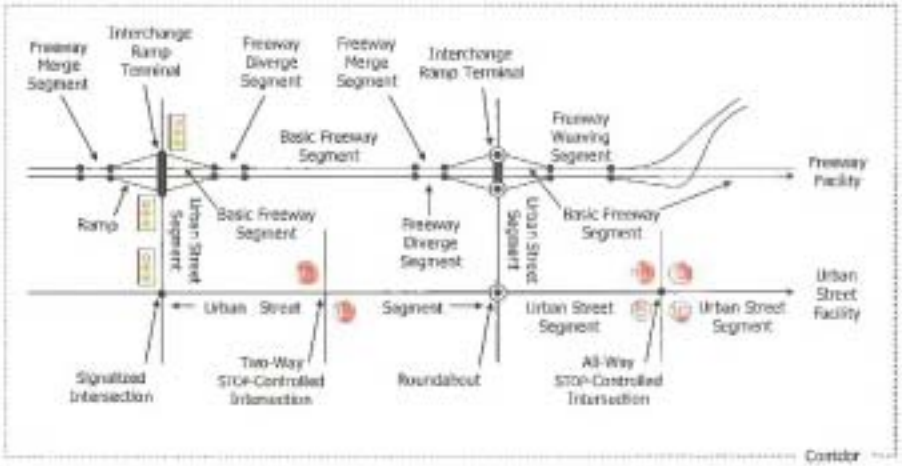
3. ROADWAY SYSTEM ELEMENTS

TYPES OF ROADWAY SYSTEM ELEMENTS

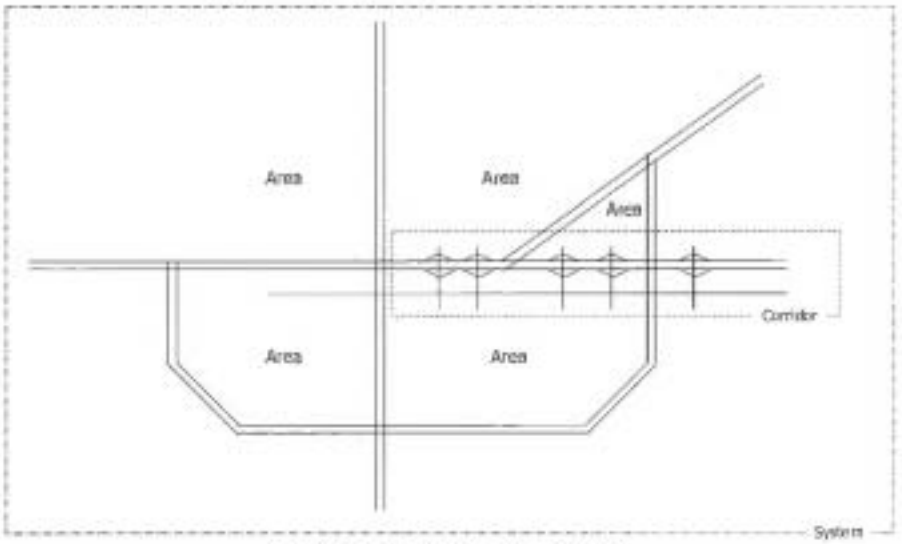
The HCM defines six main types of roadway system elements. From smallest to largest, these are points, segments, facilities, corridors, areas, and systems. The focus of the HCM is on the first three types of elements: points, segments, and facilities. Exhibit 2-1 illustrates the spatial relationships of these elements, and the following sections provide details about each system element type.

Exhibit 2-1
Illustrative Roadway System Elements

Note that a two-way STOP-controlled intersection does not normally divide the uncontrolled urban street into two segments.



(a) Points, Segments, Facilities, and Corridors



(b) Corridors, Areas, and Systems

Points

Points are places along a facility where (*a*) conflicting traffic streams cross, merge, or diverge; (*b*) a single traffic stream is regulated by a traffic control device; or (*c*) there is a significant change in the segment capacity (e.g., lane drop, lane addition, narrow bridge, significant upgrade, start or end of a ramp influence area).

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Some points, such as interchange ramp terminals, may actually have a significant physical length associated with them, as suggested by Exhibit 2-1(a). For urban street facility analysis, points are treated as having zero length. All of the delay occurs at the point. For freeway facility analysis, points are used to define the endpoints of segments, but they have no associated performance measures or capacity, as these are calculated at the segment level.

Urban street points have a physical length but are treated as having zero length for facility analysis purposes.

Freeway points are used only to define the endpoints of segments—performance measures and capacity are not defined for them.

Segments

A segment is the length of roadway between two points. Traffic volumes and physical characteristics generally remain the same over the length of a segment, although small variations may occur (e.g., changes in traffic volumes on a segment resulting from a few volume driveways). Segments may or may not be directional. The HCM defines basic freeway segments, freeway weaving segments, freeway merge and diverge segments, and urban street segments.

Facilities

Facilities are lengths of roadways, bicycle paths, and pedestrian walkways composed of a connected series of points and segments. Facilities may or may not be directional and are defined by two endpoints. The HCM defines freeway facilities, multilane highway facilities, two-lane highway facilities, urban street facilities, and pedestrian and bicycle facilities.

The types of facilities addressed by the HCM are described in Chapter 3, Modal Characteristics.

Corridors

Corridors are generally a set of parallel transportation facilities designed to move people between two locations. For example, a corridor may consist of a freeway facility and one or more parallel urban street facilities. There may also be rail or bus transit service on the freeway, the urban streets, or both, and transit service could be provided within a separate, parallel right-of-way. Pedestrian or bicycle facilities may also be present within the corridor, as designated portions of roadways and as exclusive, parallel facilities.

Areas

Areas consist of an interconnected set of transportation facilities serving movements within a specified geographic space, as well as movements to and from adjoining areas. The primary factor distinguishing areas from corridors is that the facilities within an area need not be parallel to each other. Area boundaries can be set by significant transportation facilities, political boundaries, or topographic features such as ridgelines or major bodies of water.

Systems

Systems are composed of all the transportation facilities and modes within a particular region. A large metropolitan area typically has multiple corridors passing through it, which divide the system into a number of smaller areas. Each area contains a number of facilities, which, in turn, are composed of a series of points and segments. Systems can also be divided into modal subsystems (e.g., the roadway subsystem, the transit subsystem) as well as subsystems composed of specific roadway elements (e.g., the freeway subsystem, the urban street subsystem).

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ANALYSIS OF INDIVIDUAL SYSTEM ELEMENTS

The HCM provides tools to help analysts estimate performance measures for individual elements of a multimodal transportation system, as well as guidance on combining those elements to evaluate larger portions of the system. Exhibit 2-2 tabulates the various system elements for which the HCM provides analysis methodologies in Volumes 2 and 3, the service measure(s) used to determine LOS for each mode operating on each system element, and the HCM performance measure that can be used to aggregate results to a system level. Some combinations of system elements and travel modes combine several performance measures into a single traveler perception model that is used to generate a LOS score. The components of each model are listed in Exhibit 2-3.

Exhibit 2-2
HCM Service Measures by System Element and Mode

System Element	HCM Chapter	Service Measure(s)				Systems Analysis Measure
		Automobile	Pedestrian	Bicycle	Transit	
Freeway facility	10	Density	--	--		Speed
Basic freeway segment	11	Density	--	--	--	Speed
Freeway weaving segment	12	Density	--	--	--	Speed
Freeway merge and diverge segments	13	Density		--		Speed
Multilane highway	14	Density	--	LOS score[1]	--	Speed
Two-lane highway	15	Percent time-spent-following, speed		LOS score[1]		Speed
Urban street facility	16	Speed	LOS score[1]	LOS score[1]	LOS score[1]	Speed
Urban street segment	17	Speed	LOS score[1]	LOS score[1]	LOS score[1]	Speed
Signalized intersection	18	Delay	LOS score[1]	LOS score[1]	--	Delay
Two-way stop	19	Delay	Delay	--	--	Delay
All-way stop	20	Delay				Delay
Roundabout	21	Delay	--	--	--	Delay
Interchange ramp terminal	22	Delay	--	--	--	Delay
Off-street pedestrian–bicycle facility	23	--	Space, events[2]	LOS score[1]	--	Speed

Notes: [1] See Exhibit 2-3 for the LOS score components.
[2] Events are counts of pedestrians and bicyclists.

Exhibit 2-3
Components of Traveler Perception Models Used in the HCM

The automobile traveler perception model for urban street segments and facilities is not used to determine LOS, but it is included to facilitate multimodal analysis.

System Element	HCM Chapter	Mode	Model Components
Multilane and two-lane highways	14, 15	Bicycle	Pavement quality, perceived separation from motor vehicles, motor vehicle volume and speed
Urban street facility	16	Automobile	Weighted average of segment automobile LOS scores
		Pedestrian	Urban street segment and signalized intersection pedestrian LOS scores, midblock crossing difficulty
		Bicycle	Urban street segment and signalized intersection bicycle LOS scores, driveway conflicts
		Transit	Weighted average of segment transit LOS scores
Urban street segment	17	Automobile	Stops per mile, effective green time per cycle
		Pedestrian	Pedestrian density, sidewalk width, perceived separation from motor vehicles, motor vehicle volume and speed
		Bicycle	Perceived separation from motor vehicles, pavement quality, motor vehicle volume and speed
		Transit	Service frequency, perceived speed, pedestrian LOS
Signalized intersection	18	Pedestrian	Street crossing delay, pedestrian exposure to turning vehicle conflicts, crossing distance
		Bicycle	Perceived separation from motor vehicles, crossing distance
Off-street pedestrian–bicycle facility	23	Bicycle	Average meetings/minute, active passing route, path width, centerline presence, delayed passing

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ASSESSMENT OF MULTIPLE FACILITIES

The analysis of a transportation system starts with estimates of delay at the point and segment level. Point delays arise from the effects of traffic control devices such as traffic signals and stop signs. Segment delays combine the point delay incurred at the end of the segment with other delays incurred within the segment. Examples of the latter include delays caused by midblock turning activity into driveways, parking activity, and midblock pedestrian crossings. The HCM estimates segment speed instead of segment delay; however, segment speed can be converted into segment delay by using Equation 2-1.

$$D_i = AVO_i \times d_i \left(\frac{L_i}{S_i} - \frac{L_i}{S_{fi}} \right) \qquad \text{Equation 2-1}$$

where

D_i = person-hours of delay on segment i,

AVO_i = average vehicle occupancy on segment i (passengers/vehicle),

d_i = vehicle demand on segment i (vehicles),

L_i = length of segment i (mi),

S_i = average vehicle speed on segment i (mi/h), and

S_{fi} = free-flow speed of segment i (mi/h).

Segment delays are added together to obtain facility estimates, and the sum of the facility estimates yields subsystem estimates. Mean delays for each subsystem are then computed by dividing the total person-hours of delay by the total number of trips on the subsystem. Subsystem estimates of delay can be combined into total system estimates, but typically the results for each subsystem are reported separately.

Normally, only the segments that constitute the collector and arterial system are used to estimate system delay.

SYSTEM PERFORMANCE MEASUREMENT

System performance must be measured in more than one dimension. When a single intersection is analyzed, it may suffice to compute only the peak period delay; however, when a system is analyzed, the geographic extent, the duration of delay, and any shifts in demand among facilities and modes must also be considered (2).

An increase in congestion on one system element may result in a shift of demand to other system elements. Therefore, estimating system delay or an alternative process, such as bridging, can be used to estimate the delay resulting from a given demand, but not the demand resulting from a given delay.

System performance can be measured in the following dimensions:

Dimensions of system performance

- *Quantity of service*—the number of person-miles and person-hours provided by the system;
- *Intensity of congestion*—the amount of congestion experienced by users of the system;
- *Duration of congestion*—the number of hours that congestion persists;
- *Extent of congestion*—the physical length of the congested system;
- *Variability*—the day-to-day variation in congestion; and
- *Accessibility*—the percentage of the populace able to complete a selected trip within a specified time.

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Quantity of Service

Quantity of service measures the utilization of the transportation system in terms of the number of people using the system, the distance they travel (person-miles of travel, PMT), and the time they require to travel (person-hours of travel, PHT). Dividing the PMT by the PHT gives the mean trip speed in the system.

Intensity of Congestion

The intensity of congestion can be measured by using total person-hours of delay and mean trip speed. Other metrics, such as mean delay per person-trip, can also be used. In planning and preliminary engineering applications, intensity of congestion is sometimes measured in terms of volume-to-capacity ratio or demand-to-capacity ratio.

Duration of Congestion

A segment is congested if the demand exceeds the segment's discharge capacity

The duration of congestion is measured in terms of the maximum amount of time that congestion occurs anywhere in the system. A segment is congested if the demand exceeds the segment's discharge capacity. Transit subsystem congestion can occur either when the passenger demand exceeds the capacity of the transit vehicles or when the need to move transit vehicles exceeds the vehicular capacity of the transit facility.

Extent of Congestion

The extent of congestion may be expressed in terms of the directional miles of facilities congested or—more meaningfully for the public—in terms of the maximum percentage of system miles congested at any one time.

Variability

Ideally, variability should be measured in terms of either (a) the probability of occurrence of, or (b) a confidence interval for, other aspects of congestion (intensity, duration, and extent). However, the state of the practice does not yet facilitate such a calculation. Instead, a measure of the sensitivity of the results to changes in the demand can be substituted until better methods for estimating variability become available. Various levels of demand are tested (such as a 5% increase or a 5% decrease), and the resulting effects on the intensity, duration, and extent of congestion are noted in terms of a percentage increase or decrease in their values. The sensitivity can be expressed in terms of elasticity by dividing the percentage change in output by the percentage change in demand. An elasticity greater than 1.0 means that the estimated congestion measure is highly sensitive to changes in demand.

Accessibility

Accessibility examines the effectiveness of the system from a perspective other than mobility. Accessibility can be expressed in terms of the percentage of trips (or persons) able to accomplish a certain goal—such as going from home to work—within a targeted travel time. Accessibility can also be defined in terms of a traveler's ability to get to and use a particular modal subsystem, such as transit. This definition is closer to the Americans with Disabilities Act's use of the term.

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4. TRAVEL MODES

This section introduces the four major travel modes addressed by the HCM: automobile, pedestrian, bicycle, and transit. Chapter 3 provides details about the characteristics of each mode that are important for HCM analyses.

AUTOMOBILE

The automobile mode includes all motorized vehicles except transit vehicles.

The automobile mode includes all motor vehicle traffic using a roadway except transit vehicles. Thus, trucks, RVs, motorcycles, and tour buses are all considered members of the automobile mode for HCM analyses purposes. Certain vehicle types (e.g., trucks and RVs) have operating characteristics different from those of private automobiles; these characteristics are taken into account by HCM methodologies where needed. The HCM's LOS thresholds for the automobile mode are based on the perspective of automobile drivers and passengers. Therefore, the automobile LOS measures may not necessarily reflect the perspective of drivers of other types of motorized vehicles, especially trucks.

PEDESTRIAN

The pedestrian mode consists of travelers along a roadway or pedestrian facility making a journey (or at least part of their journey) on foot. Pedestrians walk at different speeds, depending on their age, their ability, and environmental characteristics (e.g., grades and climate); HCM procedures generally account for this variability. Sidewalks and pathways may be used by more than just foot-based traffic—for example, inline skaters and persons in wheelchairs—but the HCM's LOS thresholds reflect the perspective of persons making a walking journey.

BICYCLE

The bicycle mode consists of travelers on a roadway or pathway who are using a nonmotorized bicycle for their trip. Bicycle LOS thresholds reflect their perspective. Mopeds and motorized scooters are not considered bicycles for HCM analysis purposes.

TRANSIT

The only-vehicle (OVISM) passenger capacity and speed estimation procedures for transit vehicles are additional LOS measures for transit passengers.

Urban roadways are often shared with public transit buses and, occasionally, with rail transit vehicles such as streetcars and light rail vehicles. Previous editions of the HCM have provided relatively extensive coverage of the transit mode. However, now that two editions of a companion, *Transit Capacity and Quality of Service Manual* (TCQSM) (3) have been published, the HCM now addresses the transit mode only with respect to multimodal analyses of urban streets. The HCM's LOS measure for transit on urban streets reflects the perspective of transit users—both those already on transit vehicles operating on the street and those waiting for transit vehicles at stops or stations along the street.

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5. OPERATING CONDITIONS

UNINTERRUPTED FLOW

Uninterrupted-flow facilities have no fixed causes of delay or interruption external to the traffic stream. Volume 2 of the HCM provides analysis methodologies for uninterrupted-flow facilities.

Freeways and their components operate under the purest form of uninterrupted flow. Not only are there no fixed interruptions to traffic flow, but access is controlled and limited to ramp locations. Multilane highways and two-lane highways can also operate under uninterrupted flow in long segments between points of fixed interruption. On multilane and two-lane highways, it is often necessary to examine points of fixed interruption (e.g., traffic signals) as well as uninterrupted-flow segments.

The traffic stream on uninterrupted-flow facilities is the result of individual vehicles interacting with each other and the facility's geometric characteristics. The pattern of flow is generally controlled only by the characteristics of the land uses that generate traffic that use the facility, although freeway management and operations strategies—such as ramp metering, freeway auxiliary lanes, truck lane restrictions, variable speed limits, and incident detection and clearance—can also influence traffic flow. Operations can also be affected by environmental conditions, such as weather or lighting, by pavement conditions, and by the occurrence of traffic incidents (*4*, *5*).

"Uninterrupted flow" describes the type of facility, not the quality of the traffic flow at any given time. A freeway experiencing extreme congestion, for example, is still an uninterrupted-flow facility because the causes of congestion are internal.

INTERRUPTED FLOW

Interrupted-flow facilities have fixed causes of periodic delay or interruption to the traffic stream, such as traffic signals and STOP signs. Urban streets are the most common form of this kind of facility. Exclusive pedestrian and bicycle facilities are also treated as interrupted flow, since they may occasionally intersect other streets at locations where pedestrians and bicyclists do not automatically receive the right-of-way. Volume 3 of the HCM provides analysis methodologies for interrupted-flow facilities.

The traffic flow patterns on an interrupted-flow facility are the result not only of vehicle interactions and the facility's geometric characteristics but also of the traffic control used at intersections and the frequency of access points to the facility. Traffic signals, for example, allow designated movements to occur only during certain portions of the signal cycle (and, therefore, only during certain portions of an hour). This control creates two significant outcomes. First, time becomes a factor affecting flow and capacity because the facility is not available for continuous use. Second, the traffic flow pattern is dictated by the type of control used. For instance, traffic signals create platoons of vehicles that travel along the facility as a group, with significant gaps between one platoon and the

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next. In contrast, all-way stop-controlled intersections and roundabouts discharge vehicles more randomly, creating small (but not necessarily usable) gaps in traffic at downstream locations (4, 6).

Platoons created by a traffic signal tend to disperse as they become more distant from the intersection. Many factors influence how quickly a platoon disperses, including the running speed and the amount of traffic that enters and leaves the facility between signalized intersections. In general, traffic signal spacing greater than 2 mi is thought to be sufficient for allowing uninterrupted flow to exist at some point between the signals. In contrast, on two-lane roadways downstream of a stop-controlled intersection or roundabout, platoons may redevelop as faster vehicles catch up to slower-moving vehicles, although this effect is again dependent on the amount of driveway traffic entering and leaving the roadway (4, 5).

UNDERSATURATED FLOW

Traffic flow during the analysis period is specified as "undersaturated" when the following conditions are satisfied: (*a*) the arrival flow rate is lower than the capacity of a point or segment, (*b*) no residual queue remains from a prior breakdown of the facility, and (*c*) traffic flow is unaffected by downstream conditions.

free-flow speed: the average speed of traffic on a segment at volume and density approach zero.

Uninterrupted-flow facilities operating in a state of undersaturated flow will typically have travel speeds within 10% to 20% of the facility's free-flow speed, even at high flow rates, assuming base conditions (e.g., level grades, standard lane widths). Furthermore, no queues would be expected to develop on the facility.

On interrupted-flow facilities, queues form as a natural consequence of the interruptions to traffic flow created by traffic signals and stop and yield signs. Therefore, travel speeds are typically 30% to 60% below the facility's free-flow speed in undersaturated conditions. Incremental cycle failures—where a vehicle has to wait through more than one green phase to be served—may occur at traffic signals under moderate- to high-volume conditions as a result of natural variations in the cycle-to-cycle arrival and service rate. Similarly, stop- and yield-controlled approaches may experience short periods of significant queue buildup. However, as long as all of the demand on an intersection approach is served within a 15-min analysis period, including any residual demand from the prior period, the approach is considered to be undersaturated.

OVERSATURATED FLOW

Traffic flow during an analysis period is characterized as "oversaturated" when any of the following conditions is satisfied: (*a*) the arrival flow rate exceeds the capacity of a point or segment, (*b*) a queue created from a prior breakdown at a facility has not yet dissipated, or (*c*) traffic flow is affected by downstream conditions.

On uninterrupted-flow facilities, oversaturated conditions result from a bottleneck on the facility. During periods of oversaturation, queues form and extend backward from the bottleneck point. Traffic speeds and flows drop

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significantly as a result of turbulence, and they can vary considerably, depending on the severity of the bottleneck. Freeway queues differ from queues at undersaturated signalized intersections in that they are not static or "standing." On freeways, vehicles move slowly through a queue, with periods of stopping and movement. Even after the demand at the back of the queue drops, it takes some time for the queue to dissipate because vehicles discharge from the queue at a slower rate than they do under free-flow conditions. Oversaturated conditions persist within the queue until the queue dissipates after a period of time during which demand flows are less than the capacity of the bottleneck, allowing the queue to discharge completely.

On uninterrupted-flow facilities, oversaturated conditions generate a queue that grows backward from the intersection at a rate faster than can be processed by the intersection over the analysis period. Oversaturated conditions persist after demand drops below capacity until the residual queue (i.e., the queue over and above what would be created by the intersection's traffic control) has dissipated. A queue generated by an oversaturated unsignalized intersection dissipates more gradually than is typically possible at a signalized intersection.

If an intersection approach or ramp meter cannot accommodate all of its demand, queues may back into upstream intersections, adversely affecting their performance. Similarly, if an interchange ramp terminal cannot accommodate all of its demand, queues may back onto the freeway, adversely affecting its performance.

QUEUE DISCHARGE FLOW

A third type of flow, queue discharge flow, is particularly relevant for uninterrupted-flow facilities. Queue discharge flow represents traffic flow that has just passed through a bottleneck and, in the absence of another bottleneck downstream, is accelerating back to the facility's free-flow speed. Queue discharge flow is characterized by relatively stable flow as long as the effects of another bottleneck downstream are not present.

On freeways, this flow type is generally defined within a narrow range of 2,200 to 2,300 passenger cars per hour per lane, with speeds typically ranging from 35 mi/h up to the free flow speed of the freeway segment. Lower speeds are typically observed just downstream of the bottleneck. Depending on horizontal and vertical alignments, queue discharge flow usually accelerates back to the facility's free-flow speed within 0.5 to 1 mi downstream of the bottleneck. Studies suggest that the queue discharge flow rate from the bottleneck is lower than the maximum flows observed before breakdown.

Because uninterrupted-flow facilities naturally operate from queue-discharge conditions, the queue discharge flow on these facilities is equal to the saturation flow rate.

Chapter 5, Traffic Flow and Capacity Concepts, provides details about the characteristics of traffic flow during undersaturated, oversaturated, and queue discharge conditions.

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6. HCM ANALYSIS AS PART OF A BROADER PROCESS

Since its first edition in 1950, the HCM has provided transportation analysts with the tools to estimate traffic operational measures such as speed, density, and delay. It also has provided insights and specific tools for estimating the effects of various traffic, roadway, and other conditions on the capacity of facilities. Over time, the calculated values from the HCM have increasingly been used in other transportation work. The practice of using estimated or calculated values from HCM work as the foundation for estimating user costs and benefits in terms of monetary value and environmental changes (especially air and noise) is particularly pronounced in transportation priority programs and in the justification of projects. This section provides examples of how HCM outputs can be used as inputs to other types of analyses.

NOISE ANALYSIS

At the time this chapter was written, federal regulations specifying noise abatement criteria stated that "in predicting noise levels and assessing noise impacts, traffic characteristics which will yield the worst hourly traffic noise impact on a regular basis for the design year shall be used" [23 CFR 772.17(b)]. The "worst hour" is usually taken to mean the busiest hour, which does not necessarily coincide with the busiest hour, since vehicular noise levels are directly related to speed. Traffic conditions in which large trucks are a high duty peak and in which LOS E conditions exist typically represent the busiest hour (7).

AIR QUALITY ANALYSIS

The 1990 Clean Air Act Amendments required state and local agencies to develop accurate emission inventories as an integral part of their air quality management and transportation planning responsibilities. Vehicular emissions are a significant contributor to poor air quality; therefore, the U.S. Environmental Protection Agency (EPA) has developed analysis procedures and tools for estimating emissions from mobile sources such as motorized vehicles. One input into the emissions model is average vehicle speed, which can be entered at the link (i.e., length between successive ramps) level, if desired. EPA's model has been found to be sensitive to average vehicle speed (i.e., a 20% change in average vehicle speed resulted in a greater than 20% change in the emissions estimates), implying that accurate speed inputs are a requirement for accurate emissions estimates. The HCM is a tool recommended by EPA for generating speed estimates on freeways and arterials and collectors (8, 9).

ECONOMIC ANALYSIS

The economic analysis of transportation improvements also lends itself to a large extent on information generated from the HCM. Road user benefits are directly related to reductions in travel time and delay, which results determined from construction of roadway improvements (e.g., addition of lanes, installation

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of traffic signals) and increases in travel time and delay. The following excerpt (11, p. 3-2) indicates the degree to which such analyses depend on the HCM.

> *The HCM provides many tools and procedures to assist in the calculation of system levels of performance and the determination of system deficiencies, evaluation of effects of roadway modifications on the operational level of a highway or street system, evaluation of the benefits and costs of highways and transit using the HCM. The most accurate rendering of the effects of mobility and access on quality of service is through the use of the HCM's calculation procedures.*

MULTIMODAL PLANNING ANALYSIS

An increasing number of jurisdictions are taking an integrated approach to multimodal transportation planning. That is, rather than simply developing plans for the automobile, transit, and pedestrian and bicycle modes in isolation, these jurisdictions are evaluating trade-offs among the modes as part of their transportation planning and decision making. This edition of the HCM is designed to support those efforts. For example, Chapter 16, Urban Street Facilities, presents an integrated, multimodal set of LOS measures for urban streets. The other uninterrupted-flow chapters in Volume 3 also integrate pedestrian and bicycle measures, to the extent that research is available to support those measures.

SYSTEM PERFORMANCE MEASUREMENT

State and federal governments use HCM procedures in reporting transportation system performance. For example, the Federal Highway Administration's Highway Performance Monitoring System uses HCM procedures to estimate the capacity of highway sections and to determine volumes to service flow rates (12). Florida uses HCM procedures to estimate speeds on the state highway system as part of its mobility performance measures reporting.

SUMMARY

In summary, almost all economic analyses and all air and noise environmental analyses rely directly on one or more measures estimated or produced with HCM calculations. Exhibit 2-4 lists the automobile-based performance measures from this manual that are applicable to environmental or economic analyses.

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Exhibit 2-4
HCM Automobile Performance Measures for Environmental and Economic Analysis

Chapter	Automobile Performance Measure	Analysis Types Appropriate for Use: Air	Noise	Economic
10. Freeway Facilities	Density*			
	Vehicle hours of delay			√
	Speed	√	√	√
	Travel time			√
11. Basic Freeway Segments	Density*			
	Speed	√	√	√
	v/c ratio	√		√
12. Freeway Weaving Segments	Density*			
	Weaving speed	√	√	√
	Nonweaving speed	√	√	√
13. Freeway Merge and Diverge Segments	Density*			
	Speed	√	√	√
14. Multilane Highways	Density*			
	Speed	√	√	√
	v/c ratio	√		√
15. Two-Lane Highways	Percent time-spent-following*			
	Speed*	√	√	√
16. Urban Street Facilities	Speed*			
	Stop rate	√	√	√
17. Urban Street Segments	Running time	√		√
	Intersection control delay	√		√
18. Signalized Intersections	Control delay*	√		√
19. TWSC Intersections				
20. AWSC Intersections				
21. Roundabouts	v/c ratio	√		√
22. Interchange Ramp Terminals				

Notes: * Chapter service measure.
TWSC = two-way stop controlled; AWSC = all-way stop controlled; v/c = volume-to-capacity.

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CHAPTER 3
MODAL CHARACTERISTICS

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1. INTRODUCTION

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1 HCM User's Guide
2 Applications
3. Modal Characteristics
4 Traffic Flow and Capacity Concepts
5 Quality and Level of Service Concepts
6 HCM and Alternative Analysis Tools
7 Interpreting HCM and Alternative Tool Results
8 HCM Primer
9 Glossary and Symbols

Roadways serve users of many different modes including pedestrians, bicyclists, and transit passengers. The roadway right of way is allocated among the modes through the provision of facilities that ideally serve each mode's needs. However, in many urban situations, the right-of-way is constrained by adjacent land development, causing transportation engineers and planners to consider trade-offs in how to allocate the right-of-way. Interactions among the modes that result from different right-of-way allocations are important to consider in analyzing a roadway, and the *Highway Capacity Manual* (HCM) provides tools for assessing these interactions. Local policies and design standards relating to roadway functional classifications are other sources of guidance on the allocation of right-of-way, safety and operational concerns should also be addressed.

Chapter 3. Modal Characteristics, introduces some basic characteristics of the four major modes addressed by the HCM. The following characteristics are considered in this chapter for each mode:

- Factors that contribute to a traveler's experience during a trip,
- Observed seasonal and daily variations in travel demand,
- Types of transportation facilities employed by a given mode,
- Notable capacity and volume observations, and
- Descriptions of the interactions that occur between modes.

Chapters 4 and 5 continue the discussion of multimodal performance. Chapter 4 discusses flow and capacity concepts and provides operational performance measures for each mode. Chapter 5 discusses quality and level of service (LOS) concepts and introduces the measures of effectiveness for each mode that the HCM uses to assess transportation facilities from a traveler point of view.

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2. AUTOMOBILE MODE

VEHICLE AND HUMAN FACTORS

Three major elements affect driving: the vehicle, the roadway environment, and the driver. This section identifies vehicle and driver characteristics and how they are affected by the roadway's environment and physical properties.

Motor Vehicle Characteristics

Characteristics of various motorized roadway users

This section provides a summary of the operating characteristics of motor vehicles that should be considered when a facility is analyzed. The major considerations are vehicle types and dimensions, turning radii and off-tracking, resistance to motion, power requirements, acceleration performance, and deceleration performance. Motor vehicles include passenger cars, trucks, vans, buses, recreational vehicles, and motorcycles. All of these vehicles have unique weight, length, size, and operational characteristics.

Vehicle acceleration and deceleration rates are factors that must be considered in designing traffic signal timing, computing sight distance and travel time, and estimating how normal traffic flow resumes after a breakdown. Passenger cars accelerate after a stop at a rate ranging between 7.5 and 9 ft/s². Trucks, however, accelerate from a stop at rates ranging from 0.7 to 3 ft/s². Maximum passenger car deceleration rates range between 10 and 25 ft/s², depending on road surface and tire conditions, with deceleration rates of 10 ft/s² or less considered reasonably comfortable for passenger car occupants (1). Typical truck deceleration rates are 6.5 ft/s² or lower (2).

Driver Characteristics

Driving is a complex task involving a variety of skills. The most important skills are taking in and processing information and making quick decisions on the basis of this information. Driver tasks are grouped into three main categories: control, guidance, and navigation. Control involves the driver's interaction with the vehicle in terms of speed and direction (accelerating, braking, and steering). Guidance refers to maintaining a safe path and keeping the vehicle in the proper lane. Navigation means planning and executing a trip.

The way in which drivers perceive and process information is important. About 90% of information is presented to drivers visually. The speed at which drivers process information is a significant component affecting their successful use of the information. One parameter used to quantify the speed at which drivers process information is perception–reaction time, which represents how quickly drivers can respond to an emergency situation. Another parameter—sight distance—is directly associated with reaction time. There are three types of sight distance: stopping, passing, and decision. Sight distance is a parameter that helps determine appropriate geometric features of transportation facilities. Acceptance of gaps in traffic streams is associated with driver perception and influences the capacity and delay of movements at unsignalized intersections.

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factors such as nighttime driving, fatigue, driving under the influence of alcohol and drugs, the age and health of drivers, and police enforcement also contribute to driver behavior on a transportation facility. All these factors can affect the operational parameters of speed, delay, and density. However, unless otherwise specified, the HCM assumes base conditions of daylight, dry pavement, typical drivers, and so forth.

Base conditions are discussed generally in Chapter 4 and specifically in chapters on volumes 2 and 3.

VARIATIONS IN DEMAND

The traffic volume counted at a given location on a given day is not necessarily reflective of the amount of traffic (a) that would be counted on another day or (b) that would be counted if an upstream bottleneck was removed. Traffic demand varies seasonally, by day of the week (e.g., weekdays versus weekends), and by hour of the day, as trip purposes and the number of persons desiring to travel varies. Bottlenecks—locations where the capacity provided is insufficient to meet the demand during a 15-min or hourly period—constrain the observed volume to the portion of the demand that can be served by the bottleneck. Because traffic counts only provide the portion of the demand that was served, the actual demand can be difficult to identify.

Demand relates to the number of vehicles that would like to be served by a roadway element, while volume relates to the number that can actually be served.

The following sections discuss monthly, daily, and hourly variations in traffic demand. Analysts need to account for these types of variations to ensure that the peak hour demand volumes used in an HCM analysis are reflective of conditions on peak days of the year. Failure to account for these variations can result in an analysis that reflects peak conditions on the days counts were made, but not peak conditions over the course of the year. For example, a highway serving a beach resort area may be virtually unused during much of the year but become oversaturated during the peak summer periods.

Selective peaks in traffic demand must also be considered, particularly on recreational corridors.

Chapter 4, Traffic Flow and Capacity Concepts, discusses subhourly variations in demand. It is possible for a roadway's capacity to be greater than its hourly demand, yet traffic flow may still break down if the flow rate within the hour exceeds the roadway's capacity. The effects of a breakdown can extend far beyond the time during which demand exceeded capacity and may take several hours to dissipate.

A highway that is rarely able to handle a peak hour demand may be subject to breakdown if flow rates within the peak hour exceed capacity—a topic of Chapter 4.

The data shown in the exhibits in this section represent typical observations that can be made. The patterns illustrated, however, vary in response to local travel habits and environments, and these examples should not be used as a substitute for locally obtained data.

Data shown in these graphs represent typical observations but should not be used as a substitute for local data.

Seasonal and Monthly Variations

Seasonal fluctuations in traffic demand reflect the social and economic activity of the area served by the highway. Exhibit 3-1 shows monthly patterns observed in Oregon and Washington. The highway depicted in Exhibit 3-1(a) serves national forestland with both winter and summer recreational activity. The highway depicted in Exhibit 3-1(b) is a rural route serving intercity traffic. Two significant characteristics are apparent from this data set:

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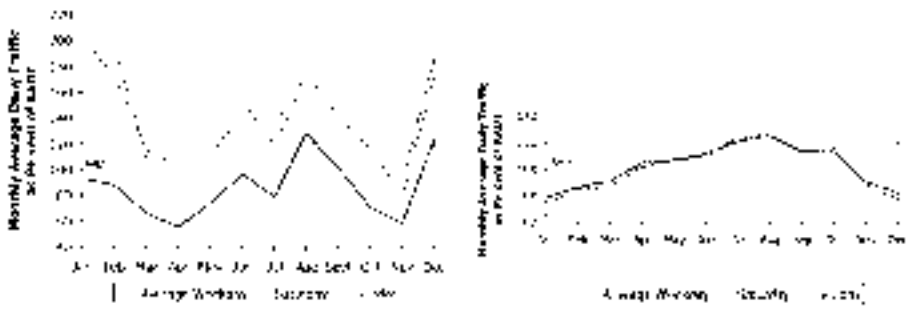
- The range of variation in traffic demand over the course of a year is more severe on rural routes primarily serving recreational traffic than on rural routes primarily serving intercity traffic; and
- Traffic patterns vary more severely by month on recreational routes.

Exhibit 3-1
Examples of Monthly Traffic Volume Variations for a Highway

Monthly volume variations for routes with recreational traffic show much higher seasonal peaking than do routes with predominantly intercity traffic.

The average daily traffic, averaged over a full year is referred to as the annual average daily traffic, or AADT, and is often used in forecasting and planning.



(a) Routes with Significant Recreational Traffic (b) Routes with Significant Intercity Traffic

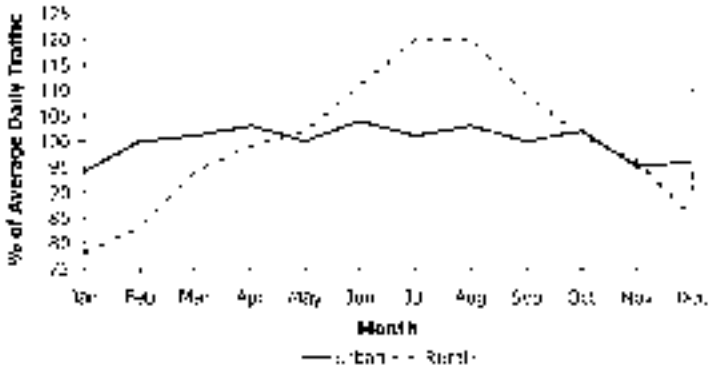
Note: (a) Highway 35 north of Parkdale, Oregon; (b) US-97 north of Merrill, Oregon, used in for
Source: (a) Oregon DOT, 2006; (b) Washington State DOT, 2007.

These and other similar observations lead to the conclusion that recreational- and business-oriented travel generally follow fairly uniform patterns, while recreational traffic creates the greatest variation in demand patterns.

The data for Exhibit 3-2 were collected on the same Interstate route. One segment is within 1 mi of the central business district of a large metropolitan area. The other segment is within 75 mi of the first but serves a combination of recreational and intercity travel. This exhibit illustrates that monthly variations in volume are more severe on rural routes than on urban routes. The wide variation in seasonal patterns for the two segments underscores the effect of trip purpose and may also reflect capacity restrictions on the urban section.

Exhibit 3-2
Examples of Monthly Traffic Volume Variations for the Same Interstate Highway (Rural and Urban Segments)

Monthly volume variations for rural segments of Interstate highways show much higher seasonal peaking than for urban segments of the same highway. This may reflect both recreational and agricultural traffic impacts.



Note: Urban, I-84 west of I-5 in Portland, rural, I-84 in Boardman
Source: Oregon DOT, 2006.

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Daily Variations

Time of peak demand will vary according to highway type.

Demand variations by day of the week are also related to the type of highway. Exhibit 3-3 shows that weekend volumes are lower than weekday volumes for highways serving predominantly business travel, such as urban freeways. In comparison, peak traffic occurs on weekends on main rural and recreational highways. Furthermore, the magnitude of daily variation is highest for recreational access routes and lowest for urban commuter routes.

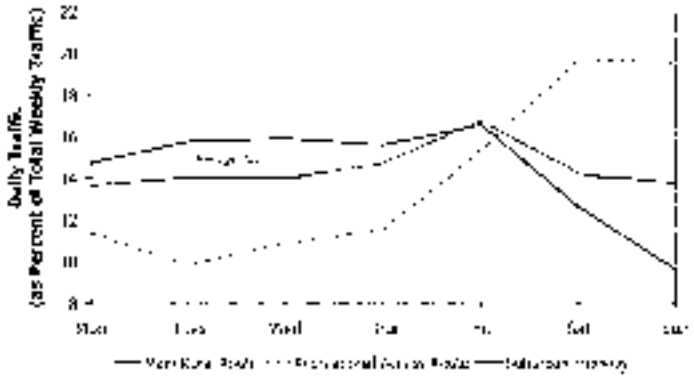

Exhibit 3-3
Examples of Daily Traffic Variation by Type of Route

Daily volume variations through the week show higher weekday volumes and lower weekend volumes for routes primarily serving commuter and business trips, but the opposite for segments serving recreational traffic. Fridays are typically the peak weekday.

Notes: Suburban Freeway, I-132 in Portland, Washington; Mountain Route, US 12 Southeast of Yakima, Washington; Intermediate Access Route, Highway 35 south of Parkdale, Oregon.
Source: Washington State DOT, 2007; and Oregon DOT, 2007.

Exhibit 3-4 shows the variation in traffic by vehicle type for the shoulder lane of an urban freeway. Although the values shown in Exhibit 3-3 and Exhibit 3-4 are typical of patterns that may be observed, they should not be used as a substitute for local studies and analyses.

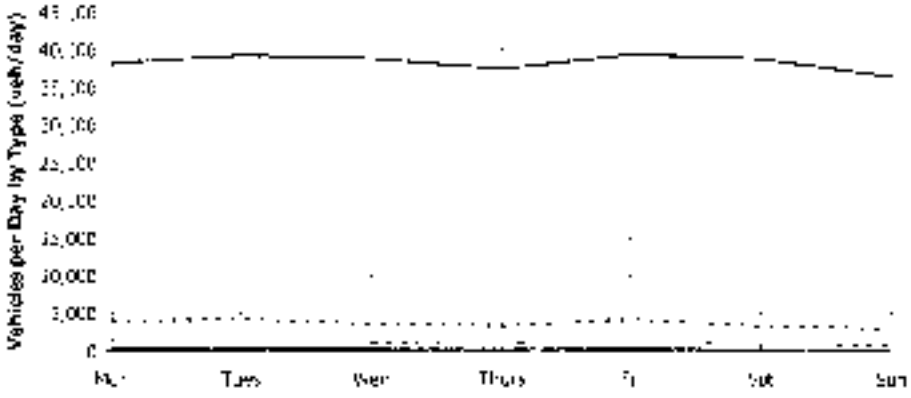

Exhibit 3-4
Daily Variation in Traffic by Vehicle Type for the Right Lane of an Urban Freeway

Daily volume variations by vehicle type through the week show higher weekday volumes and lower weekend volumes for truck traffic, with much smaller drops on the weekend for heavy truck traffic than for single-unit trucks. Car and pickup traffic peaks on Fridays and declines much more subtly on weekends on this urban freeway.

Note: Northbound Highway 26 north of I-5, Tacoma, Washington.
Source: Washington State DOT, 2007.

Hourly Variations

Typical hourly variation patterns for rural routes are shown in Exhibit 3-5, where the patterns are related to highway type and day of the week. Unlike urban routes, rural routes tend to have a single peak that occurs in the afternoon. A small morning peak is visible on weekdays that is much lower than the afternoon peak. The proportion of daily traffic occurring in the peak hour is much higher for recreational access routes than for intercity or local rural routes.

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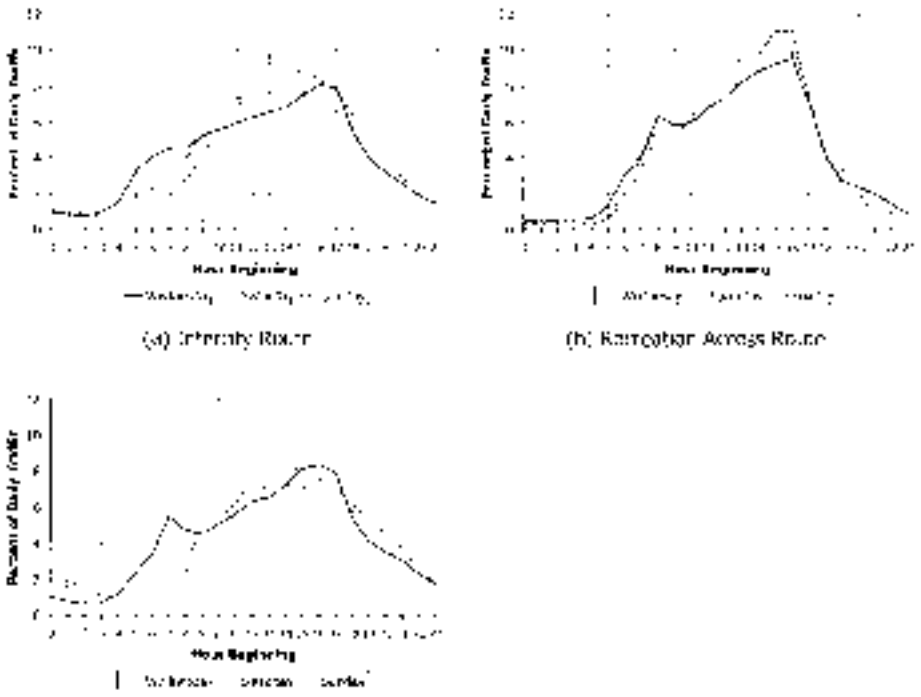
The weekend pattern for recreational routes is similar to the weekday pattern, as travelers tend to go to their recreation destination in the morning and return in the later afternoon. Weekend morning travel is considerably lower than weekday morning travel for most other types of rural routes.

Exhibit 3-5
Examples of Hourly Traffic Variations for Rural Routes



(a) Intercity Route

(b) Recreation Access Route

(c) Local Route

Traffic variations during the day by day of week for rural routes.

Notes: (a) US-395 south of Kennewick, Washington; (b) Highway 35 south of Parkdale, Oregon; (c) US 97 near Wasco, Wasco County.

Sources: Washington State DOT, 2007, and Oregon DOT, 2007.

The repeatability of hourly variations is of great importance. The stability of peak-hour demand affects the feasibility of using such values in design and operational analyses of highways and other transportation facilities. Exhibit 3-6 shows data obtained for single directions of urban streets in metropolitan Toronto. The data were obtained from detectors measuring traffic in one direction only, as evidenced by the single peak period shown for either morning or afternoon. The area between the dotted lines indicates the range within which one can expect 95% of the observations to fall. Whereas the variations by hour of the day are typical for urban areas, the relatively narrow and parallel fluctuations among the days of the study indicate the repeatability of the basic pattern.

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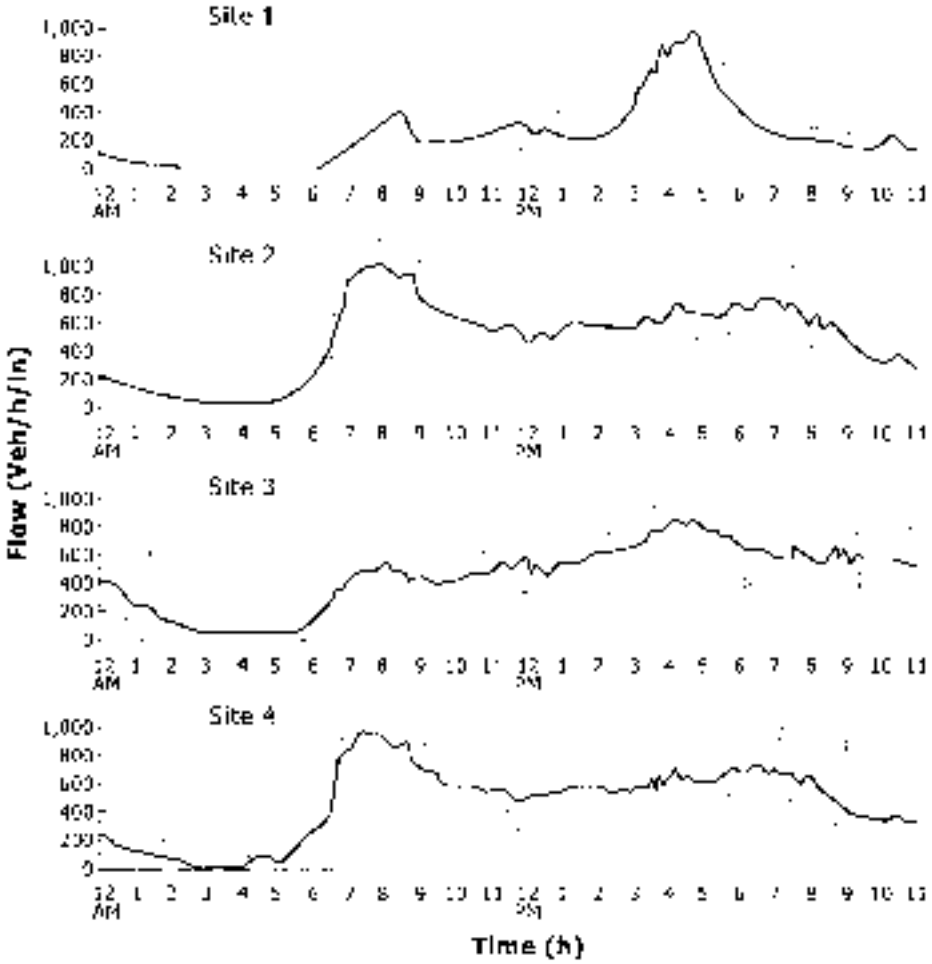

Notes: Sites 3 and 4 are one block apart on the same street in the same direction. All sites are two moving lanes in one direction.
Source: McShane and Crowley (2).

Exhibit 3-6
Repeatability of Hourly Traffic Variations for Urban Streets

Repeatability of hourly patterns

Peak Hour and Analysis Hour

Capacity and urban traffic analysis usually focus on the peak-hour traffic volume because it represents the most critical period for operations and has the highest capacity requirements. However, as shown in the previous sections, the peak hour volume is not a constant value from day to day or from season to season.

If the highest hourly volumes for a given location were listed in descending order, the data would vary greatly, depending on the type of facility. Rural and recreational routes often show a wide variation in peak-hour volumes. Several extremely high volumes occur on a few select weekends or in other peak periods, and traffic during the rest of the year flows at much lower volumes, even during the peak hour. Urban streets, on the other hand, show less variation in peak-hour traffic. Most users are daily commuters or frequent users, and occasional and special event traffic is minimal. Furthermore, many urban routes are filled to capacity during each peak hour, and variation is therefore severely constrained—an issue that will be revisited later in this section.

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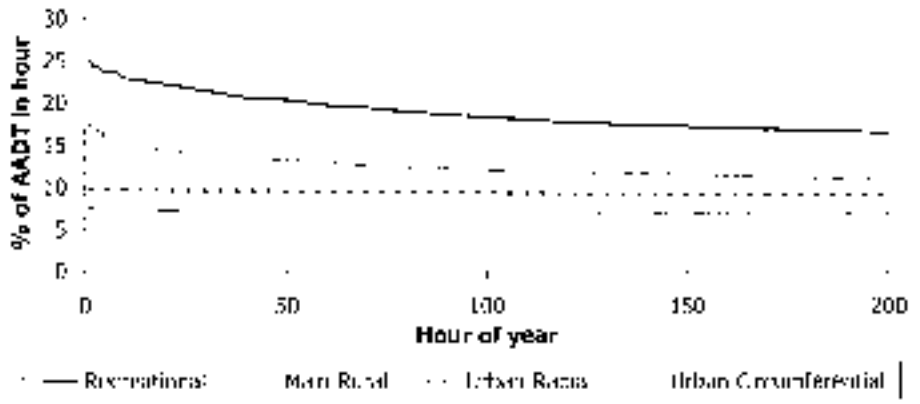
Exhibit 3-7 shows hourly volume relationships measured on four highway types in Washington. The recreational highway shows the widest variation in peak hour traffic. Its values range from 25% of AADT in the busiest hour of the year to about 10.5% in the 200th busiest hour of the year. The main rural freeway also varies widely, with 17.0% of the AADT in the highest hour, decreasing to 10.5% in the 200th-highest hour. The urban freeways show far less variation. The range in percent of AADT covers a narrow band, from approximately 9.7% (radial freeway) and 7.3% (circumferential freeway) for the highest hour to 8.9% and 6.9%, respectively, for the 200th-highest hour. Exhibit 3-7 is based on all hours of the year, not just peak hours of each day, and shows only the highest 200 hours of the year.

Exhibit 3-7
Ranked Hourly Volumes



Notes: Recreational, Two-Lane Mixed Pass (AADT = 7,000); Main Rural, Four-Lane Mixed Pass (AADT = 20,000); Urban Radial, Eight-Lane Freeway (AADT = 128,170); Urban Circumferential, Eight-Lane Freeway (AADT = 241,550).
Source: Washington State DOT, 2006.

Selection of an analysis hour usually implies that a small portion of the demand during a year will not be adequately served.

The selection of an appropriate hour for planning, design, and operational purposes is a compromise between providing an adequate LOS for every (or almost every) hour of the year and providing economic efficiency. Customary practice in the United States is to base rural highway design on the 30th-highest hour of the year. There are few hours with higher volumes than this hour, while there are many hours with volumes not much lower. In urban areas, there is usually little difference between the 30th- and 200th-highest hours of the year, because of the recurring morning and afternoon commute patterns (4).

The selection of the analysis hour should consider the impact on the design and operations of higher-volume hours that are not accommodated. The recreational access route curve of Exhibit 3-7 shows that the highest hours of the year have one-third more volume than the 100th-highest hour, whereas the highest hours of an urban radial route were only about 6% higher than the volume at the 100th-highest hour. Use of a design criterion set at the 100th-highest hour would create substantial congestion on a recreational access route during the highest-volume hours but would have less effect on an urban facility. Another consideration is the LOS objective. A route designed to operate at LOS C can absorb larger amounts of additional traffic than a route designed to operate at LOS D or E during the hours of the year operating with higher volumes than the design hour. As a general guide, the most frequently occurring peak volumes

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may be considered in the design of new or upgraded facilities. The LOS during higher-volume periods should be tested to determine the acceptability of the resulting traffic conditions.

Narrower traffic volume patterns may not reflect actual demand patterns

On roadways where oversaturation occurs during peak periods, analysts should be particularly careful in selecting a design hour, since measured traffic volumes may not reflect the changes in demand that occur once a bottleneck is removed. Exhibit 3-8 shows hourly variations in traffic on an urban freeway before and after the freeway was widened. In the before condition, the freeway's observed volumes were constrained by a bottleneck between 6 and 10 a.m., as indicated by the flat volume line. After the freeway widening, a more typical a.m. peak occurred, since travel patterns more closely reflected when travelers desired to travel rather than when the freeway could accommodate their travel.

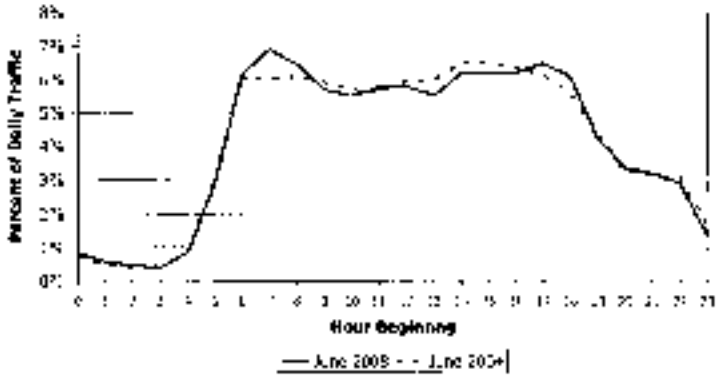

Exhibit 3-8
Example of a Change in Travel Patterns Following Removal of a Capacity Constraint

Note: I-25 south of US 6, Denver.
Source: Colorado DOT.

As used in the HCM, the *K*-factor is the proportion of AADT that occurs during the peak hour. For many rural and urban highways, this factor falls between 0.08 and 0.10. For highway sections with high peak periods and relatively low off-peak flows, the *K*-factor may exceed 0.10. Conversely, for highways that demonstrate consistent and heavy flows for many hours of the day, the *K*-factor is likely to be lower than 0.08. In general,

- The *K*-factor decreases as the AADT on a highway increases;
- The *K*-factor decreases as development density increases; and
- The highest *K*-factors occur on recreational facilities, followed by rural, suburban, and urban facilities, in descending order.

The *K*-factor should be determined, if possible, from local data for similar facilities with similar demand characteristics.

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Exhibit 3-9 demonstrates how K-factors decrease as AADT increases, on the basis of average data from Washington State.

Exhibit 3-9
Example *K* Factors by AADT

AADT	Average K-Factor	Number of Sites Included in Average K-Factor: Urban	Recreational	Other Rural
0–2,500	0.153	0	6	7
2,500–5,000	0.136	1	6	8
5,000–10,000	0.118	2	2	14
10,000–20,000	0.116	1	2	15
20,000–50,000	0.107	11	5	10
50,000–100,000	0.091	14	3	4
100,000–200,000	0.082	11	3	3
>200,000	0.087	2	3	3

Note: *K*-factors are for the 30th-highest traffic volume hour of the year.
Source: Washington State DOT (3).

Spatial Distributions

Traffic volume varies in space as well as time. The two critical spatial characteristics used to analyze capacity are directional distribution and volume distribution by lane. Volume may also vary longitudinally along various segments of a facility, but this does not explicitly affect HCM analyses because each facility segment that serves a different traffic demand is analyzed separately.

D-Factor

Concept of D-factor or directional distribution

The *D*-factor is the proportion of traffic moving in the peak direction of travel on a given roadway during the peak hours. A radial route serving strong directional demands into a city in the morning and out at night may display a 2:1 imbalance in directional flows. Recreational and rural routes may also be subject to significant directional imbalances, which must be considered in analyses. Circumferential routes and routes connecting two major cities within a metropolitan area may have very balanced flows during peak hours. Exhibit 3-10 provides examples of directional distributions from selected California freeways.

Exhibit 3-10
Example Directional Distribution Characteristics

Freeway Type	*D*-Factor
Rural–intercity	0.56
Rural–recreational and intercity	0.54
Suburban circumferential	0.52
Suburban radial	0.60
Urban radial	0.70
Intraurban	0.51

Notes: Rural–intercity, I-5 at Willows; rural–recreational and intercity, I-80 west of Donner Summit; suburban circumferential, I-680 in Danville; suburban radial, I-80 in Emeryville; urban radial, Highway 94 at I-5, San Diego; intraurban, I-880 in Hayward.
Source: Cothron, 2007.

Directional distribution is an important factor in highway capacity analysis. This is particularly true for two-lane rural highways. Capacity and level of service vary substantially with directional distribution because of the interactive nature of directional flows on such facilities—the flow in one direction of travel influences flow in the other direction by affecting the number of passing opportunities. Procedures for two-lane highway analyses include explicit consideration of directional distribution.

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While the consideration of directional distribution is not mandated in the analysis of multilane facilities, the distribution has a dramatic effect on both design and LOS. As indicated in Exhibit 3-10, up to two-thirds of the peak-hour traffic on urban radial routes has been observed as moving in one direction. Unfortunately, the peak occurs in one direction in the morning and in the opposite direction in the evening. Thus, both directions of the facility must have adequate capacity for the peak directional flow. This characteristic has led to the use of reversible lanes on some urban streets and highways.

Directional distribution is not a static characteristic. It changes annually, hourly, daily, and seasonally. Development in the vicinity of highway facilities often changes the directional distribution.

The D-factor is used with the K-factor to estimate the peak-hour traffic volume in the peak direction, as shown by Equation 3-1.

$$DDHV = AADT \times K \times D$$

Equation 3-1

where

$DDHV$ = directional design hour volume (veh/h),

$AADT$ = annual average daily traffic (veh/day),

K = proportion of $AADT$ occurring in the peak hour (decimal), and

D = proportion of peak hour traffic in the peak direction (decimal).

Lane Distribution

Concept of lane distribution.

When two or more lanes are available for traffic in a single direction, the lane use distribution varies widely. The volume distribution by lane depends on traffic regulations, traffic composition, speed and volume, the number and location of access points, the origin–destination patterns of drivers, the development environment, and local driver habits.

Because of these factors, there are no typical lane distributions. Data indicate that the peak lane on a six-lane freeway, for example, may be the shoulder, middle, or median lane, depending on local conditions.

Exhibit 3-11 gives daily lane distribution data for various vehicle types on three selected freeways. These data are illustrative and are not intended to represent typical values.

Exhibit 3-11
Lane Distribution by Vehicle Type

Highway	Vehicle Type	Percent Distribution by Lane[a]		
		Lane 3	Lane 2	Lane 1
Lodge Freeway, Detroit	Light[b]	32.4	38.4	29.2
	Single unit trucks	7.7	61.5	40.8
	Combinations	6.6	2.9	38.5
	All vehicles	31.3	37.8	30.9
I-95, Connecticut Turnpike	Light[b]	24.5	40.9	34.6
	All vehicles	22.5	40.4	37.1
I-4, Orange, Florida	All vehicles	36.4	33.7	29.9

Notes: [a] Lane 1 = shoulder lane; lanes numbered from right to left.
[b] Passenger cars, panel trucks, and pickup trucks.
Source: Hulbert and Tracy (5), Florida DOT, 1993.

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The trend indicated in Exhibit 3-11 is reasonably consistent throughout North America. However, vehicles tend to use the right-hand lanes, partially because they operate at lower speeds than other vehicles and partially because regulations may prohibit them from using the leftmost lanes.

Lane distribution must also be considered at intersections, since it affects how efficiently the demand for a particular movement can be served, as well as lane-by-lane queue lengths. Uneven lane distributions can be a result of upstream or downstream changes in the number of lanes available and the pre-positioning of traffic for downstream turning movements.

TRAVEL TIME VARIABILITY

Travelers using the same set of roadways notice that the time required to make their trip may vary from one day to the next. Depending on the importance of reaching one's destination by a given time (e.g., to start work, to pick up a child at day care, to deliver a shipment), one may budget extra time for the trip to allow for the possibility of a longer-than-usual travel time. This variability in travel times has several sources (7).

- *Traffic incidents* such as crashes, stalled cars, and debris in the roadway block travel lanes, reducing the roadway's capacity. Even when lanes are not physically blocked, activity on the shoulder (e.g., police activity) or in the opposite direction of travel (e.g., a crash scene being cleared) can lead to changes in driver behavior that result in congestion.
- *Work zones* may provide a reduced number of lanes or reduced clearances between vehicles (e.g., due to narrower lanes) and roadside objects (e.g., due to reduced or eliminated shoulders), which affect capacity. Speed limits may also be reduced in work zones. Temporary road closures may result in a diversion of traffic to other roadways, increasing traffic volumes on those roads above typical levels.
- *Environmental conditions* such as adverse weather, bright sunlight directly in drivers' eyes, and abrupt transitions from light to dark (such as at a tunnel entrance on a sunny day) may cause drivers to slow down and increase their spacing, resulting in a drop in a roadway's capacity.
- *Fluctuations in demand* occur both in longer-term patterns (by day of the week and by month of the year, as shown in Exhibit 3-1 through Exhibit 3-3) and more randomly from day to day, as shown in Exhibit 3-4. Variable traffic demand on a roadway with fixed capacity results in variable travel times.
- *Special events* are a special case of demand fluctuation occurring at known times relatively infrequently, resulting in traffic flow patterns that vary substantially from the typical situation.
- *Traffic control devices* that intermittently disrupt traffic flow (e.g., railroad crossings and drawbridges), as well as poorly timed traffic signals, contribute to travel time variability.
- *Inadequate base capacity*, interacting with the other six factors listed above, also influences travel time variability. Depending on how close a facility

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is to operating at its capacity, relatively small changes in demand can result in disproportionately large changes in travel time. Facilities with a greater base capacity are less vulnerable to disruptions: a freeway with three lanes per direction that experiences an incident blocking one lane loses at least one-third of its directional capacity, while a freeway with two lanes per direction would lose at least one-half of its directional capacity.

AUTOMOBILE FACILITY TYPES

Exhibit 3-12 illustrates the kinds of automobile facilities addressed in the HCM. They are divided into two main categories: *uninterrupted-flow facilities*, where traffic has no fixed causes of delay or interruption beyond the traffic stream, and *interrupted-flow facilities*, where traffic control such as traffic signals and STOP signs introduce delay into the traffic stream.

(a) Freeway (b) Multilane Highway

(c) Two-Lane Highway (d) Urban Street

Exhibit 3-12
Automobile Facility Types

Uninterrupted Flow

Freeways are fully access-controlled, divided highways with a minimum of two lanes (and frequently more) in each direction. Certain lanes on freeways may be reserved for designated types of vehicles, such as high-occupancy vehicles or trucks. Some freeway facilities charge tolls, and their toll-collection facilities can create interrupted-flow conditions, such as on facilities where tolls are paid manually at toll plazas located on the freeway mainline. *Ramps* provide access to, from, and between freeways; some ramps have meters that control the flow of traffic onto a freeway segment.

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Multilane highways are divided highways with a minimum of two lanes in each direction. They have zero or partial control of access. Traffic signals or roundabouts may create periodic interruptions to flow along an otherwise uninterrupted facility, but such interruptions are spaced at least 2 mi apart.

As the name implies, *two-lane highways* generally have a two-lane cross section, although passing and climbing lanes may be provided periodically. Within the two-lane sections, passing maneuvers must be made in the opposing lane. Traffic signals, STOP-controlled intersections, or roundabouts may occasionally interrupt flow, but at intervals longer than 2 mi.

Interrupted Flow

Urban streets are streets with relatively high densities of driveway and cross-street access, located within urban areas. The traffic flow of urban streets is interrupted (i.e., traffic signals, all-way stops, or roundabouts) at intervals of 2 mi or less. HCM procedures are applicable to arterial and collector urban streets, including those in downtown areas, but these procedures are not designed to address local streets.

MEASURED AND OBSERVED VOLUMES AND FLOW RATES

The direct observation of capacity is difficult to achieve for several reasons. The recording of a high, or even a maximum, volume or flow rate for a given facility does not ensure that a higher flow could not be accommodated at another time. Furthermore, capacity is sometimes an unstable operating condition. Depending on environmental factors, the mix of familiar and unfamiliar drivers in the traffic stream, and other considerations, the capacity achieved at a given location—or sets of otherwise similar locations—may vary from day to day.

HCM methodologies are based on calibrated national-average traffic characteristics observed over a range of facilities. Observations of these characteristics at specific locations will vary somewhat from national averages because of unique features of the local driving environment.

Freeways

HCM freeway capacity analysis procedures use a flow rate of 2,400 passenger cars per hour per lane (pc/h/ln) for basic freeway segments with free-flow speeds of 70 to 75 mi/h and 2,300 pc/h/ln for basic freeway segments with free-flow speeds of 65 mi/h as the capacity under base conditions.

Multilane Highways

The observation of multilane rural highways operating under capacity conditions is difficult, because such operations rarely occur. The HCM uses a flow rate of 2,200 pc/h/ln for multilane highways with free-flow speeds of 60 mi/h and 2,100 pc/h/ln for multilane highways with free-flow speeds of 55 mi/h as the capacity under base conditions.

Rural Two-Way, Two-Lane Highways

Two-way, two-lane rural highways in the United States and Canada rarely operate at volumes near capacity, and thus the observation of capacity

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operations for such highways in the field is difficult. The HCM methodology reports *single-direction* capacities, with a flow rate of 1,700 pc/h/ln used as the capacity under base conditions.

Urban Streets

Since flow on urban streets is uninterrupted only on segments between intersections, the interpretation of high-volume observations on urban streets is not as straightforward as for uninterrupted-flow facilities. Signal timing significantly alters the capacity of such facilities by limiting the time that is available for movement along the urban street at critical intersections. The prevailing conditions on urban streets may vary greatly, and such factors as curb parking, transit buses, lane widths, and upstream intersections may substantially affect operations and observed volumes.

INTERACTIONS WITH OTHER MODES

Each mode that uses a roadway interacts with the other modal users of that roadway. This section examines the effects of other modes on the automobile mode; the effects of the automobile mode on other modes are discussed later in the portions of the chapter addressing those modes.

Pedestrians

Pedestrians interact with the automobile mode on interrupted-flow elements of the roadway system. At signalized intersections, the minimum green time provided for an intersection approach is influenced by the need to provide adequate time for pedestrians using the parallel crosswalk to cross the roadway safely. In turn, the green time allocated to a particular vehicular movement affects the capacity of and the delay experienced by that movement. At signalized and unsignalized intersections, turning vehicles must yield to pedestrians in crosswalks, which reduces the capacity of and increases the delay to those turning movements, compared with a situation in which pedestrians are not present. The increased delays at intersections and midblock pedestrian crossings along urban streets that result from higher pedestrian crossing volumes lower vehicular speeds along the urban street.

Bicycles

At intersections, automobile capacity and delay are affected by bicycle volumes, particularly where turning vehicles conflict with through bicycle movements. However, HCM methodologies only account for these effects at signalized intersections. Bicycles may also delay automobiles on two-lane roadways, in cases where bicycles use the travel lane, causing vehicles to wait for a safe opportunity to pass. This kind of delay is not currently accounted for in the HCM two-lane roadway methodology, which only addresses delays associated with waiting to pass other automobiles.

Transit

Transit vehicles are longer than automobiles and have different performance characteristics; thus, they are treated as heavy vehicles for all types of roadway

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elements. At intersections, buses or streetcars that stop in the vehicular travel lane to serve passengers delay other vehicles in the lane and reduce the lane's capacity; however, this effect is only incorporated into the signalized intersection methodology. Special transit phases or bus signal priority measures at signalized intersections affect the allocation of green time to the various traffic movements, with accompanying effects on vehicular capacity and delay.

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3. PEDESTRIAN MODE

OVERVIEW

Approximately 9% of all trips in the United States are accomplished by walking (2001 National Household Travel Survey). Moreover, many automobile trips and most transit trips include at least one section of the trip where the traveler is a pedestrian. Given the presence of a network of safe and convenient pedestrian facilities, as well as the availability of potential destinations within walking distance of one's trip origin, walking can be the mode of choice for a variety of shorter trips, including going to school, running errands, and recreational and exercise trips.

HUMAN FACTORS

A pedestrian is considerably more exposed than is a motorist, in both good and bad ways. A pedestrian travels much more slowly than other modal users and can therefore pay more attention to his or her surroundings. The ability to take in one's surroundings and get exercise while doing so can be part of the enjoyment of the trip. At the same time, a pedestrian interacts closely with other modal users, including other pedestrians, with potential safety, comfort, travel hindrance, and other implications. In addition, a pedestrian is exposed to the elements. As a result, a number of environmental and perceived safety factors significantly influence pedestrian quality of service. In locations with large numbers of pedestrians, pedestrian flow quality is also a consideration.

Some pedestrian flow measures are similar to those used for vehicular flow, such as the freedom to choose desired speeds and to bypass others. Others are related specifically to pedestrian flow, such as (a) the ability to cross a pedestrian traffic stream, to walk in the reverse direction of a major pedestrian flow, and to maneuver without conflicts or changes in walking speed and (b) the delay experienced by pedestrians at signalized and unsignalized intersections.

Environmental factors also contribute to the walking experience and, therefore, to the quality of service perceived by pedestrians. These factors include the comfort, convenience, safety, security, and economics of the walkway system. Comfort factors include weather protection, proximity, volume, and speed of motor vehicle traffic, pathway surface and pedestrian amenities. Convenience factors include walking distances, intersection delays, pathway directness, grades, sidewalk curbs, wayfinding signage and maps, and many features making pedestrian travel easy and uncomplicated.

Safety is provided by separating pedestrians from vehicular traffic both horizontally, by using pedestrian zones and other vehicle free areas, and vertically, by using overpasses and underpasses. Traffic control devices such as pedestrian signals can provide time separation of pedestrian and vehicular traffic, which improves pedestrian safety. Security features include lighting, open lines of sight, and the degree and type of street activity.

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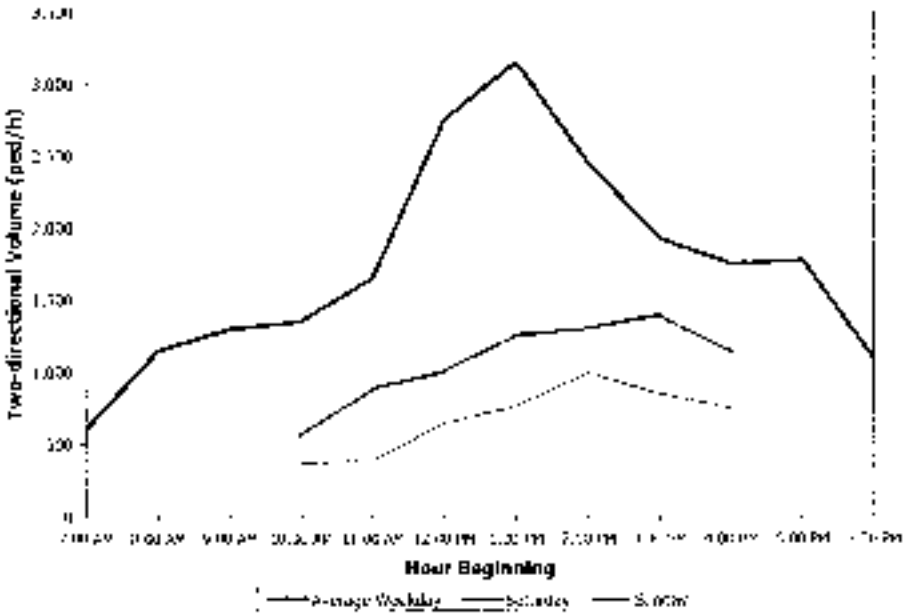
The economics of pedestrian facilities relate to user costs brought about by travel delays and inconvenience and to commercial values and retail development influenced by pedestrian accessibility.

Chapter 4, Traffic Flow and Capacity Concepts, discusses pedestrian flow measures, such as speed, space, and delay, while Chapter 5, Quality and Level-of-Service Concepts, covers the environmental factors that influence pedestrian quality of service.

VARIATIONS IN DEMAND

Pedestrian demand differs from the other modes addressed in the HCM in that the peak pedestrian demand often occurs at midday or during the early afternoon. Depending on the location, secondary peaks or plateaus in demand may also occur during the weekday a.m. and p.m. peak hours. Exhibit 3-13 shows two directional pedestrian volume data collected in May 2010 on a sidewalk in Lower Manhattan, for an average of five weekdays in a week, Saturday, and Sunday. Although weekday demand was considerably higher than weekend demand, a single peak can be seen clearly in all three counts. Work-related trips made up the majority of the peak period pedestrian trips, while non-work-related and tourist trips made up the majority of the midday and early afternoon pedestrian trips (8).

Exhibit 3-13
Temporal Variation in Pedestrian Demand



Source: Adapted from New York City Department of City Planning (8).

PEDESTRIAN FACILITY TYPES

Exhibit 3-14 illustrates the types of pedestrian facilities addressed in the HCM. The following sections define each type of facility.

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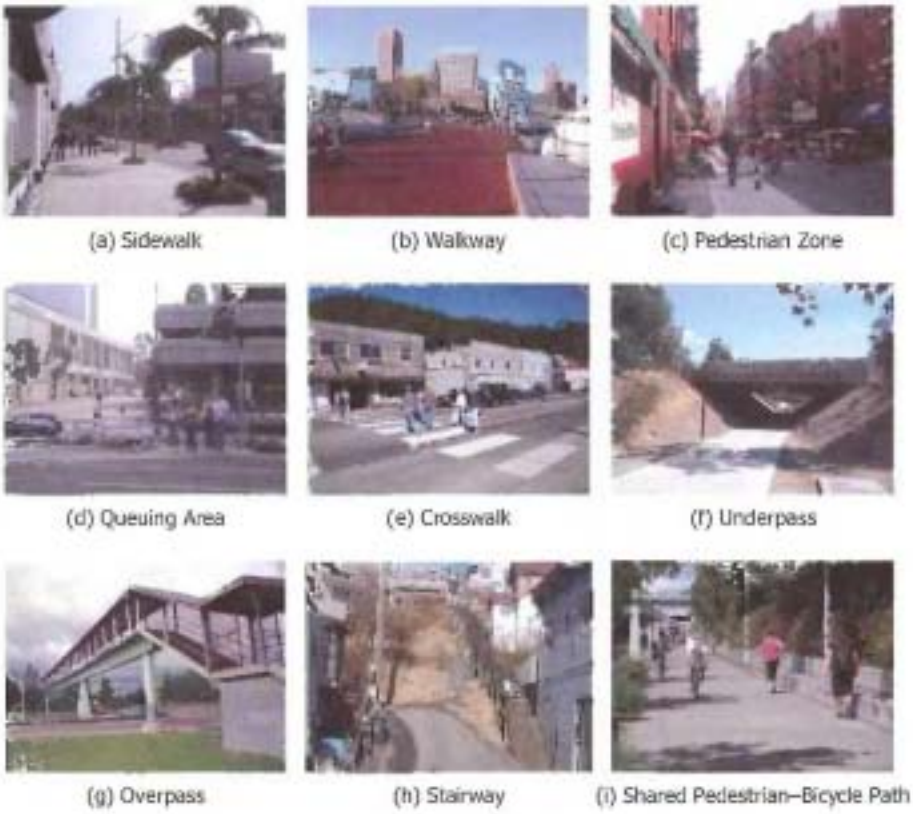

(a) Sidewalk (b) Walkway (c) Pedestrian Zone

(d) Queuing Area (e) Crosswalk (f) Underpass

(g) Overpass (h) Stairway (i) Shared Pedestrian–Bicycle Path

Exhibit 3-14
Pedestrian Facility Types

Sidewalks, Walkways, and Pedestrian Zones

These three facility types are separated from motor vehicle traffic and typically are not designed for bicycles or other nonpedestrian users, other than persons in wheelchairs. They accommodate the highest volumes of pedestrians and provide the best levels of service, because pedestrians do not share the facility with other modes traveling at higher speeds.

Sidewalks are located parallel and in proximity to roadways. Pedestrian walkways are similar to sidewalks in construction and may be used to connect sidewalks, but they are located well away from the influence of automobile traffic. Pedestrian zones are streets that are dedicated to pedestrian use on a full- or part-time basis.

Pedestrian walkways are also used to connect portions of transit stations and terminals. Pedestrian expectations about speed and density in a transit context are different from those in a sidewalk context; the *Transit Capacity and Quality of Service Manual* (TCQSM) (9) provides more information on this topic.

Queuing Areas

Queuing areas are places where pedestrians stand temporarily while waiting to be served, such as at the corner of a signalized intersection. In dense standing crowds, there is little room to move, and circulation opportunities are limited as the average space per pedestrian decreases.

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Pedestrian Crosswalks

Pedestrian crosswalks, whether marked or unmarked, provide connections between pedestrian facilities across sections of roadway used by automobiles, bicycles, and transit vehicles. Depending on the type of control used for the crosswalk, local laws, and driver observance of those laws, pedestrians will experience varying levels of delay, safety, and comfort while waiting to use the crosswalk.

Stairways

Stairways are sometimes used to help provide pedestrian connectivity in areas with steep hills, employing the public right-of-way that would otherwise contain a roadway. Today they are often also used in conjunction with a ramp or elevator to provide shorter access routes to overpasses, underpasses, or walkways located at a different elevation. Even a small number of pedestrians moving in the opposite direction of the primary flow can significantly decrease a stairway's capacity to serve the primary flow.

Overpasses and Underpasses

Overpasses and underpasses provide a grade-separated route for pedestrians to cross wide or high-speed roadways, railroad tracks, busways, and topographic features. Access is typically provided by a ramp or, occasionally, an elevator, which is often supplemented with stairs. Procedures exist to assess the quality of pedestrian flow on these facilities, but not the quality of the pedestrian environment.

Shared Pedestrian–Bicycle Paths

Shared pedestrian paths typically are open to use by nonmotorized modes such as bicycles, skateboards, and inline skaters. Shared-use paths often are constructed to serve areas without city streets and to provide recreational opportunities for the public. These paths are common on university campuses, where motor vehicle traffic and parking are often restricted. In the United States, there are few paths exclusively for pedestrians; most off-street paths, therefore, are for shared use.

On shared facilities, bicycles—because of their markedly higher speeds—can have a negative effect on pedestrian capacity and quality of service. However, it is difficult to establish a bicycle–pedestrian equivalent because the relationship between the two depends on the characteristics of the cycling population and the modes' respective flows, directional splits, and other factors.

INTERACTIONS WITH OTHER MODES

Automobiles

At signalized intersections, the delay experienced by pedestrians is influenced in part by the amount of green time allocated to serve vehicular volumes on the street being crossed. The volume of cars making turns across a crosswalk at an intersection also affects a pedestrian's delay and perception of the intersection's quality of service.

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At unsignalized intersections, increased major-street traffic volumes affect pedestrian crossing delay by reducing the number of opportunities for pedestrians to cross. The effect of motor vehicle volumes on pedestrian delay at unsignalized intersections also depends on local laws specifying yielding requirements to pedestrians in crosswalks and driver observation of those laws.

Automobile and heavy vehicle traffic volumes, and the extent to which pedestrians are separated from vehicular traffic, influence pedestrians' perceptions or quality of service while using a sidewalk.

Bicycles

Bicycle interaction with pedestrians is greatest on pathways shared by the two modes. Bicycles—because of their markedly higher speeds—can have a negative effect on pedestrian capacity and quality of service on such pathways.

Transit

The interaction of transit vehicles with pedestrians is similar to that of automobiles. However, because transit vehicles are larger than automobiles, the effect of a single transit vehicle is proportionately greater than that of a single automobile. The lack of pedestrian facilities in the vicinity of transit stops can be a barrier to transit access, and transit quality of service is influenced by the quality of the pedestrian environment along streets with transit service. Although it is not addressed by the HCM procedures, the pedestrian environment along the streets used to get to and from the streets with transit service also influences transit quality of service. Passengers waiting for buses at a bus stop can reduce the effective width of a sidewalk, while passengers getting off buses may create cross-flows that interact with the flow of pedestrians along a sidewalk.

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4. BICYCLE MODE

OVERVIEW

Bicycles are used to make a variety of trips, including trips for recreation and exercise, commutes to work and school, and trips for errands and visiting friends. Bicycles help extend the market area of transit service, since bicyclists can travel about five times as far as an average person can walk in the same amount of time. Although bicycle trip-making in North America is lower than in the rest of the world, several large North American cities that have invested in bicycle infrastructure and programs (e.g., Portland, Oregon; Minneapolis, Minnesota; and Vancouver, Canada) have bicycle commute mode splits around 4 % (2005–2007 census and local data). Some college towns like Eugene, Oregon, and Boulder, Colorado, have commute mode splits exceeding 8% (2007 census data), and Davis, California, achieved a 14% mode split (2005–2007 census data).

HUMAN FACTORS

Many of the measures of vehicular effectiveness can also describe bicycling conditions, whether on exclusive or shared facilities. As with motor vehicles, bicycle speeds remain relatively insensitive to flow rates over a wide range of flows. Delays due to traffic control affect bicycle speeds along a facility, and the additional effort required to accelerate from a stop is particularly noticeable to bicyclists. Grades, bicycle gearing, and the bicyclist's fitness level also affect bicycle speed and the level of effort required to maintain a particular speed.

Some vehicular measures are less applicable to the bicycle mode. For example, bicycle density is difficult to assess, particularly with regard to facilities shared with pedestrians and others. Because of the severe deterioration of service quality at flow levels well below capacity (e.g., freedom to maneuver around other bicyclists), the concept of capacity has little utility in the design and analysis of bicycle paths and other facilities. Capacity is rarely observed on bicycle facilities; rather, cyclists typically dismount and walk their bicycles before a facility reaches capacity. Values for capacity therefore reflect sparse data, generally from European studies or traffic simulation.

Bicycle as a pedestrian enabler.

Other measures of bicycle quality of service have no vehicular counterpart. For example, the concept of bicycle delay relates directly to bicyclists' comfort and convenience (*10*). During travel on a bicycle facility, two significant parameters can be easily observed and identified: (*a*) the number of users (other bicyclists, pedestrians, etc.) moving in the same direction and passed by the bicyclist and (*b*) the number of users moving in the opposing direction encountered by the bicyclist. Each event causes some discomfort and inconvenience to the bicyclist.

As is the case with pedestrians, environmental factors contribute significantly to the bicycling experience and, therefore, to quality of service. These factors include the volume and speed of adjacent vehicles, heavy vehicle presence, the presence of on-street parking, and the quality of the pavement. Chapter 5, Quality and Level-of-Service Concepts, discusses environmental and disturbance factors, while Chapter 4, Traffic Flow and Capacity Concepts, presents bicycle flow measures.

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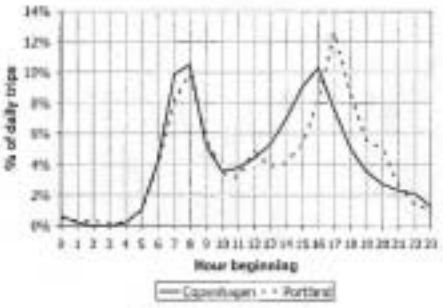
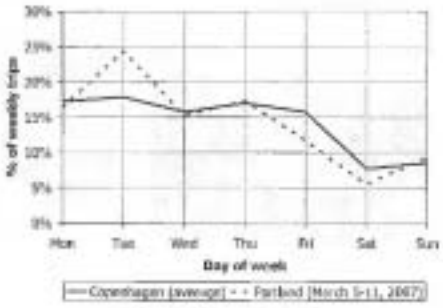
VARIATIONS IN DEMAND

Bicycle travel demand varies by time of day, day of the week, and month of the year. All of these variations in demand are related to trip-making demands in general (e.g., bicycle demand is highest during weekday a.m. and p.m. peak periods, just as with motor vehicles). Bicyclists are more exposed than motorists to the elements and other roadway users. Dutch research has shown that weather explains up to 80% of annual variation in bicycle travel, with higher rainfall and lower temperatures resulting in lower rates of bicycling (*11*).

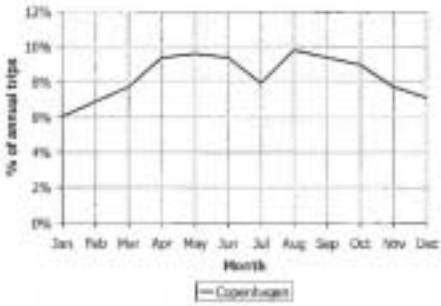
Therefore, monthly variations in bicycle demands are also weather- and daylight-related. Exhibit 3-15 shows variations in bicycle demand hourly, daily, and monthly, on the basis of data from Copenhagen, Denmark, and Portland, Oregon. Exhibit 3-16 shows observations of bicycle demand compared with variations in daily high temperature along a bicycle path in Boulder, Colorado.



(a) Hourly Variations



(b) Weekly Variations



(c) Monthly Variations

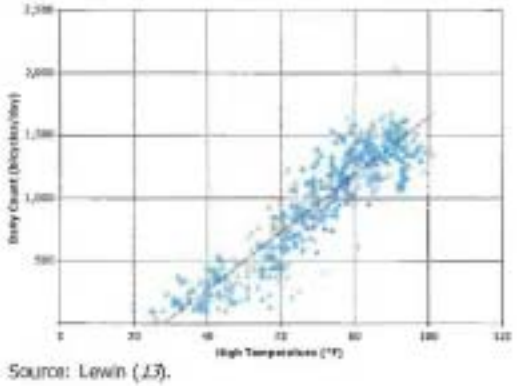
Source: Municipality of Copenhagen (*12*); Portland Office of Transportation, 2007.

Exhibit 3-15
Temporal Variations in Bicycle Demand

Copenhagen and Portland hourly demand patterns are nearly identical through noon. In the afternoon, Copenhagen peaks an hour earlier (due to a shorter workday length). The Portland p.m. peak is noticeably higher than the a.m. peak, unlike Copenhagen.

Bicycle volumes can fluctuate significantly from day to day, as suggested by the Portland line on the weekly variation chart. The Portland volumes may reflect the effects of rain on Wednesday, Friday, Saturday, and Sunday of that week.

Automobile volumes also drop in July in Copenhagen, when many people go on vacation. Except for July, months with higher temperatures and more daylight have higher bicycle volumes in Copenhagen.



Source: Lewin (*13*).

Exhibit 3-16
Example Variations in Bicycle Demand due to Temperature

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BICYCLE FACILITY TYPES

Exhibit 3-17 illustrates the types of bicycle facilities addressed in the HCM. The facilities are divided into two types, on-street and off-street, and include situations where a facility is shared with users of another mode (e.g., a lane shared by bicyclists and motor vehicle traffic or a pathway shared by bicyclists and pedestrians).

Exhibit 3-17
Bicycle Facility Types

(a) Shared Lane (b) Bicycle Lane (c) Shoulder Bikeway

(d) Sidepath (e) Bicycle Track (f) Exclusive Pathway

On-Street Bicycle Facilities

On-street bicycle facilities include roadways on which bicycles share a travel lane with motorized vehicular traffic, dedicated on-street bicycle lanes, paved roadway shoulders available for use by bicyclists, and bicycle tracks—mainly seen in Europe—located between the roadway and the sidewalk and separated from each by low curbs. For each facility type, bicycle flow is one-way. The quality of bicycle flow, safety, and the bicycling environment are all considerations for these types of facilities.

Off-Street Bicycle Facilities

Off-street bicycle facilities consist of pathways dedicated to the exclusive use of bicyclists and pathways shared with pedestrians and other types of users. These types of facilities may be located parallel and in proximity to roadways (*sidepaths*), or they may be completely independent facilities, such as recreational trails along former railroad rights-of-way and off-street pathways of the kind found in city parks and on college campuses. Bicycle flow along these types of facilities is typically two-way and is often shared with users of other modes. The number of meeting and passing events between cyclists and other path users affects the quality of service for bicyclists using these facility types. The presence and design of driveways and intersections may affect the quality of service of bicyclists on side paths but is not addressed by HCM procedures.

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MEASURED AND OBSERVED VOLUMES

Exhibit 3-18 provides daily two-directional bicycle volumes on selected U.S. roadways and bicycle facilities. Data were collected on weekdays, generally in late spring or summer, so these volumes represent peak conditions for the year. In comparison, the highest-volume roadways in Copenhagen, Denmark, have two-directional daily bicycle volumes exceeding 30,000 on spring and fall weekdays with good weather (12).

Exhibit 3-18
Daily Weekday Bicycle Volumes on Selected U.S. Bicycle Facilities (2006–2008)

Facility	Location	Facility Type	Daily Bicycle Volume
Hawthorne Bridge	Portland, OR	Shared pedestrian–bicycle path	7,400
Russell Boulevard	Davis, CA	Shared pedestrian–bicycle path	6,700
Broadway Bridge	Portland, OR	Shared pedestrian–bicycle path	4,300
North Vancouver Street	Portland, OR	Bicycle lane	3,500
Hudson River Greenway	New York, NY	Shared pedestrian–bicycle path	3,500
Steel Bridge	Portland, OR	Shared pedestrian–bicycle path	3,000
Waterfront Park	Portland, OR	Shared pedestrian–bicycle path	3,000
Williamsburg Bridge	New York, NY	Shared pedestrian–bicycle path	3,000
Springwater Trail	Portland, OR	Shared pedestrian–bicycle path	2,800

Source: City of Davis, Portland Office of Transportation, New York City DOT.

INTERACTIONS WITH OTHER MODES

Automobiles

Vehicular and heavy vehicle traffic volumes and speeds, the presence of on-street parking (which presents the potential for bicyclists to hit or be hit by car doors), and the degree to which bicyclists are separated from automobile traffic all influence bicyclists' perceptions of the quality of service received while using an on-street bicycle facility. Turning vehicles, particularly right-turning vehicles that cross the path of bicyclists, also affect quality of service.

Pedestrians

The effect of pedestrians on bicycles is greatest on pathways shared by the two modes. Pedestrians—because of their markedly lower speeds and tendency to travel in groups several abreast—can have a negative effect on bicycle quality of service on such pathways. Similar to pedestrian impacts on motor vehicles, bicyclists must yield to crossing pedestrians, and the signal timing at intersections reflects, in part, the time required for pedestrians to cross the street.

Transit

Transit vehicles interact with bicycles in much the same way as automobiles. However, because transit vehicles are heavy vehicles, the effect of a single transit vehicle is proportionately greater than that of a single automobile. Buses can also affect bicyclists when they pull over into a bicycle lane or paved shoulder to serve a bus stop; however, this impact is not accounted for in HCM procedures. Although not addressed by HCM procedures, the availability of good bicycle access extends the capture shed of a transit stop or station, and when bicycles can be transported by transit vehicles, transit service can greatly extend the range of a bicycle trip.

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5. TRANSIT MODE

OVERVIEW

Transit plays two major roles in North America. First, it accommodates choice riders—those who choose transit for their mode of travel even though they have other means available. These riders choose transit to avoid congestion, save money on fuel and parking, use their travel time productively for other activities, and reduce the impact of automobile driving on the environment, among other reasons. Transit is essential for mobility in the central business districts (CBDs) of some major cities, which could not survive without it.

The other major role of transit is to provide basic mobility for segments of the population that are unable to drive for age, physical, mental, or financial reasons. About 11% of the adult population in the United States does not have a driver's license (*14*) and must depend on others to transport them in automobiles, on transit, or via other modes, including walking, bicycling, and taxis. These transit users have been termed captive riders.

Exhibit 3-19 provides examples of peak-hour trips by transit to the downtowns of selected U.S. cities. The variations in transit use reflect differences in population, CBD employment, extent of bus and rail transit services, and geographic characteristics.

Exhibit 3-19
Transit Commuting to Downtowns (2000)

Area	Transit Share of Downtown Commuters	Area	Transit Share of Downtown Commuters
New York	76.5%	Los Angeles	20.3%
Chicago	61.7%	Houston	16.7%
Boston	50.9%	Dallas	13.6%
San Francisco	49.0%	Sacramento	12.3%
Philadelphia	45.7%	San Diego	11.4%
Washington, DC	37.8%	San Antonio	7.2%
Seattle	36.8%	Austin	3.8%
Portland	27.5%		

Source: *Commuting in America III* (*15*), adapted from "Commuting to Downtown in America: Census 2000," report to the Transportation Research Board Subcommittee on Census Data for Transportation Planning, Jan. 10, 2005.

HUMAN FACTORS

Transit passengers frequently rely on other modes to gain access to transit. Transit use is greater where population densities are higher and pedestrian access is good. Typical transit users do not have transit service available at the door and must walk, bicycle, or drive to a transit stop and walk or bicycle from the transit discharge point to their destination. In contrast, suburban areas are mainly automobile-oriented, with employment and residences dispersed, often without sidewalks or direct access to transit lines. If potential passengers cannot access service at both ends of their trip, transit is not an option for that trip.

Unlike the other modes addressed in the HCM, transit is primarily focused on a service rather than a facility. Roadways, bicycle lanes, and sidewalks, once constructed, are generally available at all times to users. Transit service, in contrast, is only available at designated times and places. Another important difference is that transit users are passengers, rather than drivers, and not in

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direct control of their travel. Thus, the frequency and reliability of service are important quality-of-service factors for transit users. Travel speed and comfort while making a trip are also important to transit users.

Transit is about moving people rather than vehicles. Transit operations at their most efficient level involve relatively few vehicles, each carrying a large number of passengers. In contrast, roadway capacity analysis typically involves relatively large numbers of vehicles, most carrying only a single occupant. In evaluating priority measures for transit and automobile users, the number of people affected is often more relevant than the number of vehicles.

ON-STREET TRANSIT CHARACTERISTICS

The TCQSM comprehensively addresses transit modes.

The HCM addresses only those major transit modes (in terms of passengers carried) that operate on streets and interact with other users of streets and highways. These modes are buses, streetcars, and light rail, illustrated in Exhibit 3-20 and described briefly in the following sections.

(a) Bus (b) Streetcar (c) Light Rail

Exhibit 3-20
Transit Modes Addressed in the HCM

Bus

Demand-responsive transit (with flexible schedules or routes, or both) is not addressed by the HCM but is addressed in the TCQSM.

The bus mode is operated by rubber-tired vehicles that follow fixed routes and schedules along roadways. Although the electric trolleybus (a bus receiving its power from overhead wires) is classified as a separate mode by the Federal Transit Administration (FTA), for the purposes of the HCM, it is also considered a bus. In 2007, more than 53% of all transit passenger boardings in the United States occurred on buses (*16*).

The bus mode offers considerable operational flexibility. Service can range from local buses stopping every two to three blocks along a street, to limited-stop service stopping every ½ to 1 mi, to express service that travels along a roadway without stopping. Buses may stop in the travel lane (*on-line*) or in a parking lane or pullout (*off-line*). On-line stops reduce bus delay but may increase vehicle and bicycle delay. Because buses frequently carry more people than the vehicles stopped behind them, on-line stops may help reduce overall person delay.

Streetcar

The streetcar mode is operated by vehicles that receive power from overhead wires and run on tracks. For FTA reporting purposes, streetcars are considered to be a form of light rail. For HCM purposes, the following operating and physical characteristics distinguish streetcars from light rail:

- Generally shorter (typically one-car) trains, with slightly narrower cars;
- Greater potential for onboard fare payment, which may affect dwell times;

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- Greater prevalence of mixed-traffic operation; and
- More frequent stops.

Streetcars make on-line stops, which minimizes their delay leaving a station, but may increase delay to vehicles and bicycles stopped behind the streetcar.

Light Rail

As is streetcar, light rail is a mode operated by vehicles that receive power from overhead wires and that run on tracks. Trains typically consist of multiple cars; fares are typically paid to a machine on the station platform (thus allowing passengers to board through all doors, reducing dwell time); station spacing tends to be relatively long, particularly outside downtown areas; and traffic signal preemption or priority is frequently employed.

The HCM only addresses light rail operations along roadways. Consult the TCQSM for a more comprehensive treatment of light rail.

When light rail operates along a roadway, it typically does so in an exclusive lane or in a segregated right-of-way in the street median or along the side of the street. Most light rail routes include lengthy sections where tracks are located in a separate, potentially grade-separated right-of-way and any interaction with traffic occurs at gate-controlled grade crossings.

TRAVEL TIME VARIABILITY

As do motorists, transit riders often allow extra time for time-sensitive trips. Sources of bus travel time variability include all of the factors listed in the automobile section of this chapter, plus bus-specific factors such as variations in passenger demands (day-to-day and bus-to-bus), traffic signal delays after stopping to serve passengers, wheelchair lift and bicycle rack usage, differences in bus operator experience, route length, and the number of stops (9).

ON-STREET TRANSIT FACILITY TYPES

Mixed Traffic

More than 99% of the bus route miles in the United States are operated in mixed traffic. In contrast, most rail route miles—other than portions of streetcar lines—operate in some form of segregated right-of-way. In mixed traffic, transit vehicles are subject to the same causes of delay as are automobiles, and they need to stop periodically to serve passengers. These stops can cause transit vehicles to fall out of any traffic signal progression that might be provided along the street, causing them to incur greater amounts of signal delay than other vehicles.

Exclusive Lanes

Exclusive lanes are on-street lanes dedicated for use by transit vehicles, on either a full-time or part-time basis. They are generally separated from other lanes by just a stripe, and buses may be able to leave the exclusive lane to pass buses or obstructions such as delivery trucks. Right-turning traffic, bicycles, carpools, and taxis are sometimes allowed in exclusive bus lanes. Generally, no other traffic, with the possible exception of transit buses, is allowed in exclusive lanes provided for rail transit vehicles. Exclusive lanes allow transit vehicles to bypass queues of vehicles in the general traffic lanes and reduce or eliminate

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delays to transit vehicles caused by right-turning traffic. Therefore, these lanes can provide faster, more reliable transit operations.

On-Street Transitways

Buses and trams sometimes operate within a portion of the street right-of-way that is physically segregated from other traffic in the median or adjacent to one side of the street. No other traffic is allowed in the transitway. The amount of green time allocated to transit vehicles may be different from the amount of time allocated to the parallel through movements—for example, it might be reduced to provide time to serve conflicting vehicular turning movements.

MEASURED AND OBSERVED VOLUMES

Exhibit 3-21 provides examples of observed peak-direction, peak-hour bus and passenger flows along selected roadways in the United States and Canada. Higher bus volumes have been observed on busways in South America; they require a combination of passing lanes at stations for express services and multiple-platform stations at major transfer points and downtown terminals.

Exhibit 3-21
Observed On-Street, Peak-Direction, Peak Hour Bus and Passenger Volumes (1995–2000)

Location	Facility	Peak-Hour Peak-Direction Buses	Peak-Hour Peak-Direction Passengers
Ottawa	Albert St./Slater St.	100	10,000
New York City	Madison Ave.	160	10,000
Portland	5th Ave./6th Ave.	175	9,300
Newark	Broad St.	150	6,000
Denver	Broadway/Lincoln St.	90	2,300
Boston	Tours St./High St.	90	2,000
Vancouver	Granville Mall	70	1,300

Source: Hoorweg (17), TCRP Report 90, Volume 2 (18), TCQSM (4).

INTERACTIONS WITH OTHER MODES

Automobiles

Higher automobile volumes result in greater delays for all motorized traffic, including buses. In locations where buses pull out of the travel lane to serve bus stops and yield-to-bus laws are not in place (or generally observed), buses experience delay waiting for a gap to pull back into traffic after serving a stop. Day-to-day variations in roadway congestion and trip-to-trip variations in making or missing green phases at signalized intersections affect bus schedule reliability, although no HCM techniques exist to predict this impact.

Pedestrians

Transit users are typically pedestrians immediately before and after their trip aboard a transit vehicle, so the quality of the pedestrian environment along access routes to transit stops also affects the quality of the transit trip. Pedestrians can also delay buses in the same way that they delay automobiles, as described earlier in this chapter.

Bicycles

In locations where buses pull out of the travel lane to serve bus stops, bicycles may delay buses waiting for a gap to pull back into traffic, similar to

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automobiles. Transit users may be bicyclists before or after their trip, so the quality of the bicycling environment along access routes to transit stops also influences the quality of the transit trip.

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CHAPTER 4
TRAFFIC FLOW AND CAPACITY CONCEPTS

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1. INTRODUCTION

VOLUME 1: CONCEPTS
1. HCM User's Guide
2. Applications
3. Mode Characteristics
4. **Traffic Flow and Capacity Concepts**
5. Quality and Level-of-Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

The relationships between volume (flow rate), speed, and density are among the most fundamental in transportation engineering. Chapter 4, **Traffic Flow and Capacity Concepts**, describes how these basic relationships apply to the four modes covered by the *Highway Capacity Manual* (HCM): automobiles, pedestrians, bicycles, and on-street transit. Details of these relationships specific to automobiles operating on a particular system element (for example, speed–flow curves for freeways) are provided in the appropriate methodological chapters of Volumes 2 and 3.

Capacity represents the maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, environmental, traffic, and control conditions. Reasonable expectancy is the basis for defining capacity. The stated capacity for a given system element is a flow rate that can be achieved repeatedly for peak periods of sufficient demand, as opposed to being the maximum flow rate that might ever be observed. System elements that have different prevailing conditions will have different capacities, and the maximum flow rate observed for a given system element may vary from day to day.

Several of the operational performance measures presented in Chapter 4 (speed, delay, and density, in particular) are used in Chapter 5 to describe the quality of service provided by a roadway, or—in the case of the volume to capacity (demand-to-capacity) ratio—are used to define the threshold between Levels of Service (LOS) E and F.

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2. AUTOMOBILE MODE

A few basic variables—volume, flow rate, speed, and density—can be used to describe traffic flow on any roadway. In the HCM, volume, flow rate, and speed are parameters common to both uninterrupted- and interrupted-flow facilities, but density applies primarily to uninterrupted flow. Some parameters related to flow rate, such as spacing and headway, are also used for both types of facilities. Other parameters, such as saturation flow and gap, are specific to interrupted flow.

BASIC AUTOMOBILE FLOW PARAMETERS

Volume and Flow Rate

Volume and flow rate are two measures that quantify the number of vehicles passing a point on a lane or roadway during a given time interval. These terms are defined as follows:

- *Volume*—the total number of vehicles that pass over a given point or section of a lane or roadway during a given time interval; any time interval can be used, but volumes are typically expressed in terms of annual, daily, hourly, or subhourly periods.
- *Flow rate*—the equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval of less than 1 h, usually 15 min. This chapter focuses on flow rate and the variations in flow that can occur over the course of an hour.

Flow rate is the equivalent hourly volume that would occur if a subhourly time was observed for an entire hour.

There is a distinction between volume and flow rate. Volume is the number of vehicles observed or predicted to pass a point during a time interval. Flow rate represents the number of vehicles passing a point during a time interval less than 1 h, but expressed as an equivalent hourly rate. A flow rate is the number of vehicles observed in a subhourly period, divided by the time (in hours) of the observation. For example, a volume of 100 veh observed in a 15-min period implies a flow rate of 100 veh divided by 0.25 h, or 400 veh/h.

Observed volumes may reflect capacity constraints rather than true demand. Demand is usually the desired input to HCM analyses, although it is not always easy to determine.

Volume and flow rate are variables that help quantify *demand*, that is, the number of vehicle occupants or drivers (usually expressed as the number of vehicles) who desire to use a given system element during a specific time period, typically 1 h or 15 min. As discussed in Chapter 3, Modal Characteristics, observed volumes may reflect upstream capacity constraints rather than the true demand that would exist without the presence of a bottleneck.

In many cases, demand volumes are the desired input to HCM analyses. (An exception would be, for example, when one is interested in analyzing traffic conditions downstream of a bottleneck that is not planned to be removed.) When conditions are undersaturated and no upstream bottlenecks exist, demand volume at a location can be assumed to be equivalent to the measured volume at that location. Otherwise, ascertaining demand requires a count of undersaturated traffic upstream of a bottleneck (i.e., a count of arrival volume rather than departure volume) (1). When the queue from a bottleneck extends past the

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previous intersection or interchange, it may not be easy to determine how much of the traffic approaching the end of the queue is actually destined for the bottleneck location. Furthermore, as illustrated in Chapter 3, demand patterns may change after a bottleneck is removed. Nevertheless, where bottlenecks exist, neglecting to use demand volumes as inputs to HCM methodologies will produce results that underestimate the presence and extent of congestion. In other words, using observed volumes instead of demand volumes will likely result in inaccurate HCM results.

Where bottlenecks exist, not accounting for demand will result in underestimating the extent of congestion

Subhourly Variations in Flow

Flow rates typically vary over the course of an hour. Exhibit 4-1 shows the substantial short-term fluctuation in flow rate that can occur within an hour, on the basis of data from the approaches to an all-way STOP-controlled intersection. In this data set, the 5-min flow rate ranges from a low of 1,248 veh/h to a high of 1,764 veh/h, compared with a total peak hour entering volume of 1,516 veh. Designing the intersection to accommodate the peak hour volume would result in oversaturated conditions for a substantial portion of the hour.

Flow rates rarely remain for less than a system element's capacity, flow rates within an hour may exceed capacity, creating oversaturated conditions

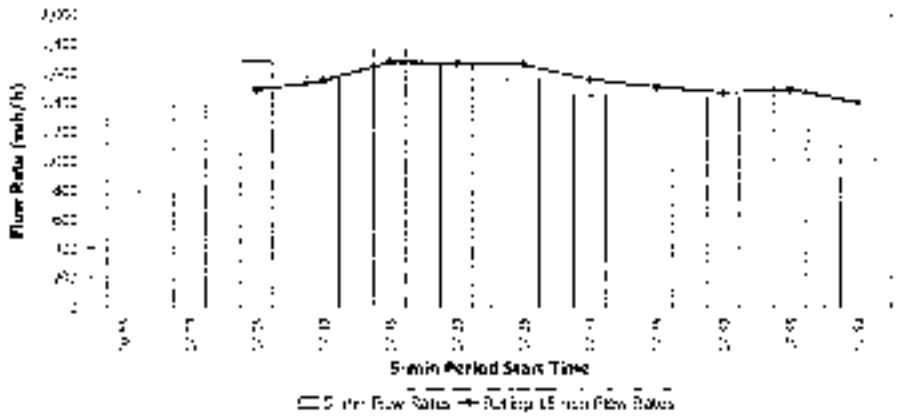

Exhibit 4-1
Relationship Between Short-Term and Hourly Flows

Source: SW 53rd Avenue at Dartmouth Street, Tigard, Oregon, 2008.

HCM analyses typically consider the peak 15 min of flow during the analysis hour. As illustrated in Exhibit 4-1, the use of a peak 15-min flow rate accommodates nearly all the variations in flow during the hour and therefore provides a good middle ground between designing for hourly volumes and designing for the most extreme 5-min flow rate.

Since inputs to HCM procedures are typically expressed in terms of hourly demands, the HCM uses the *peak hour factor* (PHF) to convert an hourly volume into a peak 15-min flow rate. Although traditionally called a "peak hour" factor, a PHF is applicable to any analysis hour, peak or off-peak. The PHF is the ratio of total hourly volume to the peak flow rate within the hour and is computed by Equation 4-1:

Peak hour factor (PHF) defined.

$$PHF = \frac{\text{Hourly volume}}{\text{Peak flow rate (within the hour)}}$$

Equation 4-1

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If 15-min periods are used, the PHF may be computed by Equation 4-2:

Equation 4-2

$$PHF = \frac{V}{4 \times V_{15}}$$

where

PHF = peak hour factor,

V = hourly volume (veh/h), and

V_{15} = volume during the peak 15 min of the analysis hour (veh/15 min).

When the PHF is known, it can convert a peak hour volume to a peak flow rate, as in Equation 4-3:

Equation 4-3

$$v = \frac{V}{PHF}$$

where v is the flow rate for a peak 15-min period, expressed in vehicles per hour, and the other variables are as defined previously.

Equation 4-3 does not need to be used to estimate peak flow rates if traffic counts are available; however, the chosen count interval must identify the maximum 15-min flow period. Then the rate can be computed directly as 4 times the maximum 15-min count and the PHF would take the value 1.00.

Lower PHF values signify greater variability of flow, while higher values signify less flow variation within the hour. When hourly counts are used, the PHF can range from 1.00, indicating that the same demand occurs during each 15-min period of the hour, to a theoretical minimum of 0.25, indicating that the entire hourly demand occurs during the peak 15 min. PHFs in urban areas generally range between 0.80 and 0.98. PHFs over 0.95 are often indicative of high traffic volumes, sometimes with capacity constraints on flow during the peak hour. PHFs under 0.80 occur in locations with highly peaked demand, such as festivals, factories with shift changes, and venues with scheduled events.

Speed

Although traffic volumes provide a method of quantifying capacity values, speed (or its reciprocal, *travel time rate*) is an important measure of the quality of the traffic service provided to the motorist. It defines LOS for two-lane highways and urban streets.

Speed parameters.

Speed is defined as a rate of motion expressed as distance per unit of time, generally as miles per hour (mi/h). To characterize the speed of a traffic stream, a representative value must be used, because a broad distribution of individual speeds is observed in the traffic stream. Several speed parameters can be applied to a traffic stream. Among them are the following:

Average travel speed.

- *Average travel speed.* A traffic stream measure based on travel time observed on a known length of highway. It is the length of the segment divided by the average travel time of vehicles traversing the segment, including all stopped delay times. It is also equal to the space mean speed.

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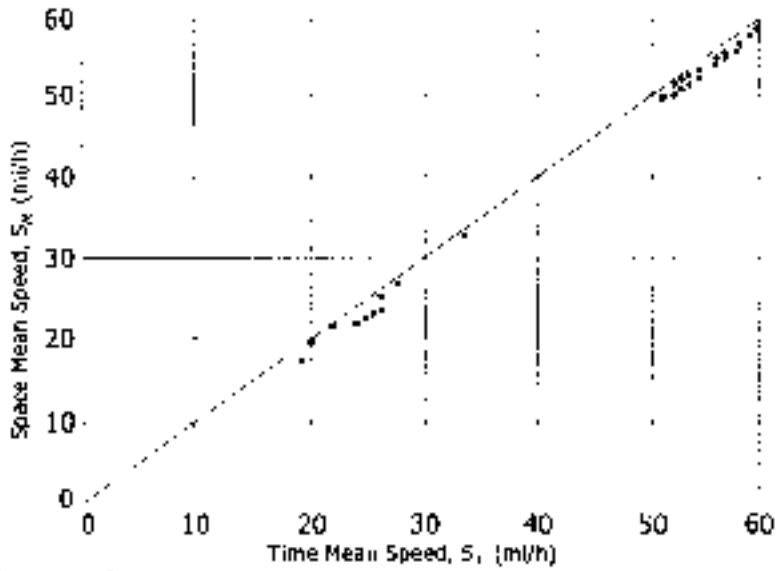
- *Space mean speed.* A statistical term denoting an average speed based on the average travel time of vehicles to traverse a length of roadway. It is called a space-mean speed because the average travel time weights the average by the time each vehicle spends on the defined roadway segment or space. *Space mean speed*
- *Time mean speed.* The arithmetic average of speeds of vehicles observed passing a point on a highway, also referred to as the *average spot speed*. The individual speeds of vehicles passing a point are recorded and averaged arithmetically. *Time mean speed*
- *Free-flow speed.* The average speed of vehicles on a given segment, measured under low-volume conditions, when drivers are free to drive at their desired speed and are not constrained by the presence of other vehicles or downstream traffic control devices (i.e., traffic signals, roundabouts, or STOP signs). *Free-flow speed*
- *Average running speed.* A traffic stream measure based on the observations of travel times of vehicles traversing a section of highway of known length. It is the length of the segment divided by the average running time of vehicles that traverse the segment. Running time includes only time during which vehicles are in motion. *Average running speed*

For most of the HCM procedures using speed as a service measure, average travel speed (or its equivalent, space-mean speed) is the defining parameter. On uninterrupted-flow facilities operating with undersaturated flow, the average travel speed is equal to the average running speed.

Exhibit 4-2 shows a typical relationship between time mean and space mean speeds. Space mean speed is always less than or equal to time mean speed, but the difference decreases as the absolute value of speed increases. Based on the statistical analysis of observed data, this relationship is useful because time mean speeds are typically easier to measure in the field than are space mean speeds.



Source: Drake et al. (2)

Exhibit 4-2
Typical Relationship Between Time Mean and Space Mean Speeds

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It is possible to calculate both time mean speed and space mean speed from a sample of individual vehicle speeds. For example, three vehicles are recorded with speeds of 30, 40, and 50 mi/h. The times to traverse 1 mi are 2.0 min, 1.5 min, and 1.2 min, respectively. The time mean speed is 40 mi/h, calculated as (30 + 40 + 50)/3. The space mean speed is 38.3 mi/h, calculated as 3/[(2.0 + 1.5 + 1.2)/60].

Space mean speed is recommended for HCM analyses. Speeds are best measured by observing travel times over a known length of highway. For uninterrupted-flow facilities operating in the range of stable flow, the length may be as short as several hundred feet for ease of observation.

Density

Density is the number of vehicles occupying a given length of a lane or roadway at a particular instant. For the computations in this manual, density is averaged over time and is usually expressed as vehicles per mile (veh/mi) or passenger cars per mile (pc/mi).

Computing density

Measuring density directly in the field is difficult; it requires a vantage point for photographing, videotaping, or observing significant lengths of highway. Density can be computed, however, from the average travel speed and flow rate, which are measured more easily. Equation 4-4 is used for uncongested traffic conditions.

Equation 4-4

$$D = \frac{v}{S}$$

where

v = flow rate (veh/h),

S = average travel speed (mi/h), and

D = density (veh/mi).

A highway segment with a flow rate of 1,000 veh/h and an average travel speed of 50 mi/h would have a density of

$$D = \frac{1{,}000 \text{ veh/h}}{50 \text{ mi/h}} = 20 \text{ veh/mi}$$

Density is a critical parameter for uninterrupted-flow facilities because it characterizes the quality of traffic operations. It describes the proximity of vehicles to one another and reflects the freedom to maneuver within the traffic stream.

Roadway occupancy is frequently used as a surrogate for density in control systems because it is easier to measure (most of the through equipment such as loop detectors). Occupancy in space is the proportion of roadway length covered by vehicles, and occupancy in time identifies the proportion of time a roadway cross section is occupied by vehicles. However, unless the length of vehicles is known precisely, the conversion from occupancy to density involves some error.

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Headway and Spacing

Spacing is the distance between successive vehicles in a traffic stream, measured from the same point on each vehicle (e.g., front bumper, front axle). Headway is the time between successive vehicles as they pass a point on a lane or roadway, also measured from the same point on each vehicle.

These characteristics are microscopic, because they relate to individual pairs of vehicles within the traffic stream. Within any traffic stream, both the spacing and the headway of individual vehicles are distributed over a range of values, generally related to the speed of the traffic stream and prevailing conditions. In the aggregate, these microscopic parameters relate to the macroscopic flow parameters of density and flow rate.

Spacing is a distance, measured in feet. It can be determined directly by measuring the distance between common points on successive vehicles at a particular instant. This generally requires costly aerial photographic techniques, so that spacing usually derives from other direct measurements. Headway, in contrast, can be measured with stopwatch observations as vehicles pass a point on the roadway.

References among density, speed and flow rate, and headway and spacing

The average vehicle spacing in a traffic stream is directly related to the density of the traffic stream, as determined by Equation 4-5:

$$\text{Density (veh/mi)} = \frac{5{,}280 \text{ ft/mi}}{\text{spacing (ft/veh)}} \quad \text{Equation 4-5}$$

The relationship between average spacing and average headway in a traffic stream depends on speed, as indicated in Equation 4-6.

$$\text{Headway (s/veh)} = \frac{\text{spacing (ft/veh)}}{\text{speed (ft/s)}} \quad \text{Equation 4-6}$$

This relationship also holds for individual headways and spacings between pairs of vehicles. The speed used is that of the second vehicle in a pair. The flow rate is related to the average headway of the traffic stream by Equation 4-7:

$$\text{Flow rate (veh/h)} = \frac{3{,}600 \text{ s/h}}{\text{headway (s/veh)}} \quad \text{Equation 4-7}$$

Relationships Among Basic Parameters

Equation 4-4 cites the basic relationship among the three parameters describing an uninterrupted traffic stream. Although the equation $v = S \times D$ algebraically allows for a given flow rate to occur in an infinite number of combinations of speed and density, there are additional relationships that restrict the variety of flow conditions that can occur in practice.

Exhibit 4-3 shows a generalized, theoretical representation of these relationships, which are the basis for the capacity analysis of uninterrupted-flow facilities. The flow–density function is placed directly below the speed–density relationship because of their common horizontal scales, and the speed–flow function is placed next to the speed–density relationship because of their common vertical scales. The speed in all cases is *space mean speed*.

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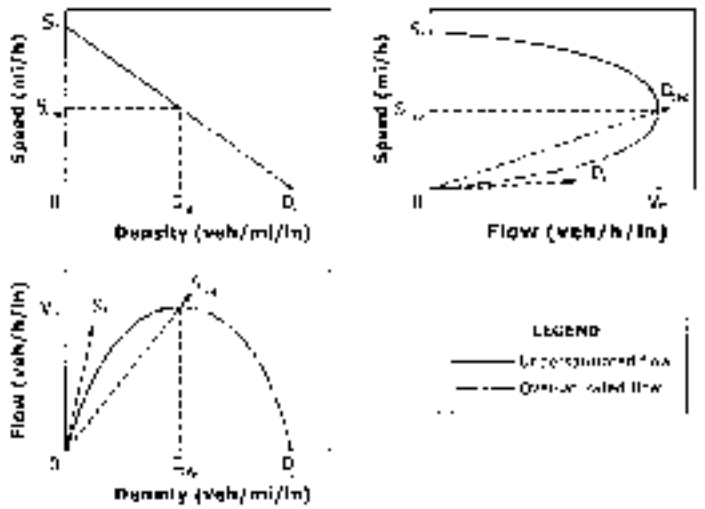
The form of these functions depends on the prevailing traffic and roadway conditions on the segment under study and on the segment length. Although the diagrams in Exhibit 4-3 show continuous curves, it is unlikely that the full range of the functions would appear at any particular location. Real-world data usually show discontinuities, with parts of the curves not present (3). Exhibit 4-4 shows that the real-world relationship between speed and undersaturated flow consists of a section of constant speed, followed by a section of declining speed until capacity is reached, unlike the idealized parabola shown in the speed–flow curve in Exhibit 4-3. Exhibit 4-4(a) shows a relatively complete curve, while Exhibit 4-4(b) has discontinuities.

Exhibit 4-3
Generalized Relationships Among Speed, Density, and Flow Rate on Uninterrupted Flow Facilities



Source: Adapted from Ref. (3).

Exhibit 4-4
Example Freeway Speed–Flow Data

Note that the real-world speed–flow curves in Exhibit 4-4 are not the idealized parabolas indicated in Exhibit 4-3. The other relationships in Exhibit 4-3 therefore also have somewhat different shapes in the real world.

(a) I 405, Los Angeles, California (b) I 805, San Diego, California

Source: California Department of Transportation, 2008.

The curves of Exhibit 4-3 illustrate several significant points. A zero flow rate occurs under two different conditions. The first is when there are no vehicles on the segment—density is zero, and flow rate is zero. Speed is theoretical for this condition and would be selected by the first driver (presumably at a high value). This speed is represented by S_f in the graphs.

The second is when density becomes so high that all vehicles must stop—the speed and flow rate are zero because there is no movement and vehicles cannot pass a point on the roadway. The density at which all movement stops is called *jam density*, denoted by D_j in the diagrams.

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Between these two extreme points, the dynamics of traffic flow produce a maximizing effect. As flow increases from zero, density also increases because more vehicles are on the roadway. When this happens, speed declines because of the interaction of vehicles. This decline is negligible at low and medium densities and flow rates. As density increases, the generalized curves suggest that speed decreases significantly before capacity is achieved. Capacity is reached when the product of density and speed results in the maximum flow rate. This condition is shown as the speed at capacity S_c (often called *critical speed*), density at capacity D_c (sometimes referred to as *critical density*), and maximum flow v_p.

The slope of any ray drawn from the origin of the speed–flow curve represents the inverse of density, on the basis of Equation 4-4. Similarly, a ray in the flow–density graph represents speed. As examples, Exhibit 4-3 shows the average free-flow speed and speed at capacity, as well as optimum and jam densities. The three diagrams are redundant—if any one relationship is known, the other two are uniquely defined. The speed–density function is used mostly for theoretical work; the other two are used in this manual to define LOS for freeways and multilane highways.

Exhibit 4-3 shows that any flow rate other than capacity can occur under two conditions, one low density and high speed and the other high density and low speed. The high-density, low-speed side of the curves represents oversaturated flow. Sudden changes can occur in the state of traffic (i.e., in speed, density, and flow rate). LOS A through E are drawn on the low-density, high-speed side of the curves, with the maximum-flow boundary of LOS E placed at capacity; in contrast, LOS F, which describes oversaturated and queue-discharge traffic, is represented by the high-density, low-speed part of the curves.

ADDITIONAL UNINTERRUPTED-FLOW PARAMETERS

The average headway in a lane is the reciprocal of the flow rate. Thus, at a flow of 2,400 veh/h/ln, the average headway is 3,600 s/h divided by 2,400 veh/h/ln, or 1.5 s/veh. Vehicles do not, however, travel at constant headways. Vehicles tend to travel in groups, or platoons, with varying headways between successive vehicles.

An example of the distribution of headways observed on the Long Island Expressway is shown in Exhibit 4-5. The headway distribution of Lane 3 is the most nearly uniform, as evidenced by the range of values and the high frequency of the modal value, which is the peak or the distribution curve. The distribution of Lane 2 is similar to that of Lane 3, with slightly greater scatter (range from 0.5 to 9.0 s). Lane 1 shows a much different pattern; it is more dispersed, with headways ranging from 0.5 to 12.0 s, and the frequency of the modal value is only about one-third of that for the other lanes. This indicates that the flow rate in the shoulder lane is usually lower than the flow rates in the adjacent lanes when the total flows on this segment are moderate to high.

Exhibit 4-5 shows relatively few headways smaller than 1.0 s. A vehicle traveling at 60 mi/h (88 ft/s) would have a spacing of 88 ft with a 1.0-s headway, and only 44 ft with a 0.5-s headway. This effectively reduces the space between

***Headway** is the time between the vehicle fronts, while **gap** is the space between vehicles.*

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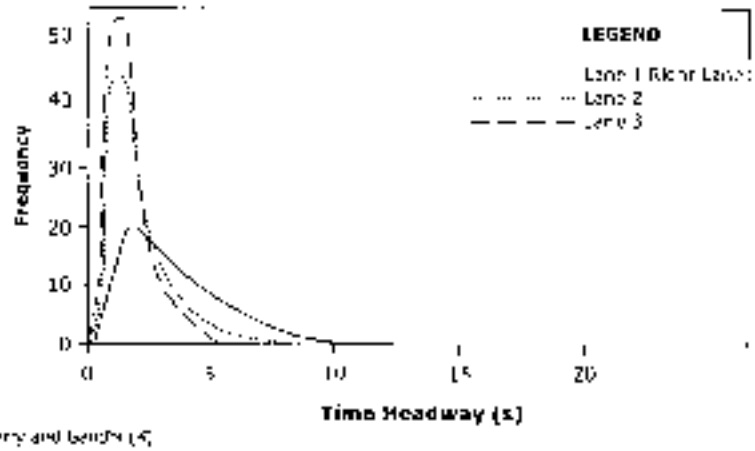
vehicles (rear bumper to front bumper) to only 25 to 30 ft. This spacing (also called gap) would be extremely difficult to maintain.

Exhibit 4-5
Time Headway Distribution for Long Island Expressway



Source: Derzko and Sangster (4).

Drivers react to this intervehicle spacing, which they perceive directly, rather than to headway. Headway includes the length of the vehicle, which became smaller for passenger cars in the vehicle mix of the 1980s. In the 1990s and 2000s, because of the popularity of sport utility vehicles, typical vehicle lengths increased. If drivers maintain the same intervehicle spacing and car lengths continue to increase, conceivably, some decreases in capacity could result.

If traffic flow were truly random, small headways (less than 1 s) could theoretically occur. Several mathematical models have been developed that recognize the absence of small headways in most traffic streams (5).

ADDITIONAL INTERRUPTED-FLOW PARAMETERS

Basic concepts for interrupted-flow facilities, intersection control, saturation flow rate, lost time, and delay.

Interrupted flow can be more complex to analyze than uninterrupted flow because of the time dimension involved in allocating space to conflicting traffic streams. On an interrupted-flow facility, flow usually is dominated by points of fixed operation, such as traffic signals and STOP signs. These controls have different impacts on overall flow.

The operational state of traffic on an interrupted-flow facility is defined by the following measures:

- Volume and flow rate (discussed earlier in the chapter),
- Saturation flow and departure headways,
- Control variables (e.g., for signal control),
- Gaps available in the conflicting traffic streams, and
- Control delay.

Signalized Intersection Flow

The most significant source of fixed interruptions on an interrupted-flow facility is traffic signals. A traffic signal periodically halts flow for each movement or set of movements. Movement on a given set of lanes is possible only for a portion of the total time, because the signal prohibits movement

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during some periods. Only the time during which the signal is effectively green is available for movement. For example, if one set of lanes at a signalized intersection receives a 30-s effective green time out of a 90-s total cycle, only 30/90 or 1/3 of total time is available for movement on the subject lanes. Thus, flow on the lanes can occur only for 20 min of each hour. If the lanes can accommodate a maximum flow rate of 1,500 veh/h with the signal green for a full hour, they can actually accommodate a total rate of flow of only 500 veh/h, since only one-third of each hour is available as green.

Impact of traffic signal control on maximum flow rate.

When the signal turns green, the dynamics of starting a stopped queue of vehicles must be considered. Exhibit 4-6 shows a queue of vehicles stopped at a signal. When the signal turns green, the queue begins to move. The headway between vehicles can be observed as the vehicles cross the stop line of the intersection. The first headway would be the elapsed time, in seconds, between the initiation of the green and the front wheels of the first vehicle crossing over the stop line. The second headway would be the elapsed time between the front bumpers (or wheels) of the first and second vehicles crossing over the stop line. Subsequent headways are measured similarly.

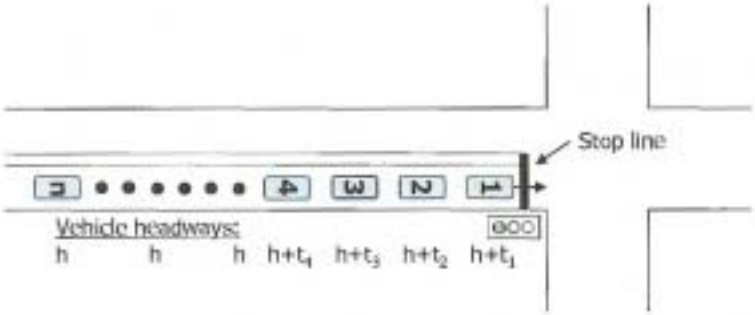

Exhibit 4-6
Acceleration Headways at a Signalized Intersection

The driver of the first vehicle in the queue must observe the signal change to green and react to the change by releasing the brake and accelerating through the intersection. As a result, the first headway will be comparatively long. The second vehicle in the queue follows a similar process, except that the reaction and acceleration period can occur while the first vehicle is beginning to move. The second vehicle will be moving faster than the first as it crosses the stop line, because it has a greater distance over which to accelerate. Its headway will generally be less than that of the first vehicle. The third and fourth vehicles follow a similar procedure, each achieving a slightly lower headway than the preceding vehicle. After four vehicles, the effect of the start-up reaction and acceleration has typically dissipated. Successive vehicles then move past the stop line at a more constant headway until the last vehicle in the original queue has passed the stop line.

In Exhibit 4-6, this constant average headway, denoted as h, is achieved after four vehicles. The acceleration headways for the first four vehicles are, on the average, greater than h and are expressed as $h + t_i$, where t_i is the incremental headway for the ith vehicle due to the start-up reaction and acceleration. As i increases from 1 to 4, t_i decreases.

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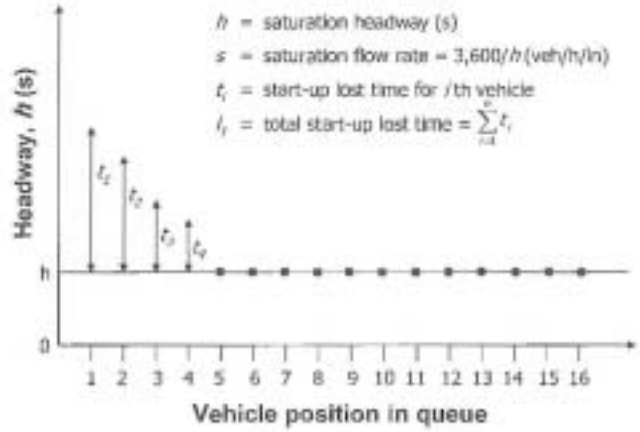
Exhibit 4-7 shows a conceptual plot of headways. The HCM recommends using the fifth vehicle following the beginning of a green as the starting point for saturation flow measurements.

Exhibit 4-7
Concept of Saturation Flow Rate and Lost Time



The value h represents the *saturation headway*, estimated as the constant average headway between vehicles after the fourth vehicle in the queue and continuing until the last vehicle that was in the queue at the beginning of the green has cleared the intersection.

Saturation flow rate.

The reference point on the vehicle used to measure headways is typically the front bumper, although front axles are sometimes used in studies that utilize tube counters to obtain the data.

Saturation flow rate is defined as the flow rate per lane at which vehicles can pass through a signalized intersection. It is computed by Equation 4-8:

Equation 4-8

$$s = \frac{3{,}600}{h}$$

where

s = saturation flow rate (veh/h), and

h = saturation headway (s).

The saturation flow rate represents the number of vehicles per hour per lane that could pass through a signalized intersection if a green signal was displayed for the full hour, the flow of vehicles never stopped, and there were no large headways. Chapter 24, Concepts: Supplemental, includes a summary of various studies of saturation flow at signalized intersections over a 25-year period.

Each time a flow is stopped, it must start again, with the first four vehicles experiencing the start-up reaction and acceleration headways shown in Exhibit 4-6. In this exhibit, the first four vehicles in the queue encounter headways longer than the saturation headway, h. The increments, t_i, are called start-up lost times.

Total start-up lost time.

The *total start-up lost time* for the vehicles is the sum of the increments, as computed by using Equation 4-9.

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$$l_1 = \sum_{i=1}^{n} t_i$$

Equation 4-9

where

l_1 = total start-up lost time (s),

t_i = lost time for ith vehicle in queue (s), and

n = last vehicle in queue.

Each stop of a stream of vehicles is another source of lost time. When one stream of vehicles stops, safety requires some clearance time before a conflicting stream of traffic is allowed to enter the intersection. The interval when no vehicles use the intersection is called *clearance lost time*, l_2. In practice, signal cycles provide for this clearance through change intervals, which can include yellow or red-clearance indications, or both. Drivers generally cannot observe this entire interval but use the intersection during some portion of it.

Clearance lost time.

The relationship between saturation flow rate and lost times is critical. For any given lane or movement, vehicles use the intersection at the saturation flow rate for a period equal to the available green time plus the change interval minus the start-up and clearance lost times. Because lost time is experienced with each start and stop of a movement, the total amount of time lost over an hour is related to the signal timing. For instance, if a signal has a 60-s cycle length, it will start and stop each movement 60 times per hour, and the total lost time per movement will be $60(l_1 + l_2)$.

Lost time affects capacity and delay. As indicated by the relationship of cycle length to lost time, the capacity of an intersection increases as cycle length increases. However, the capacity increase can be offset somewhat by the observation that the saturation headway, h, can increase if the length of a continuous green indication increases. Capacity increases due to longer cycles are also often offset by the increase in delay that typically results from longer cycles, as discussed below. Other intersection features, such as turning lanes, can also offset the reduced capacity that results from short cycles. Longer cycles increase the number of vehicles in the queues and can cause the left-turn lane to overflow, reducing capacity by blocking the through lanes.

As indicated in Exhibit 4-8, there is a strong relationship between delay and cycle length. For every intersection there is a small range of cycle lengths that will result in the lowest average delay for motorists. Delay, however, is a complex variable affected by many variables besides cycle length.

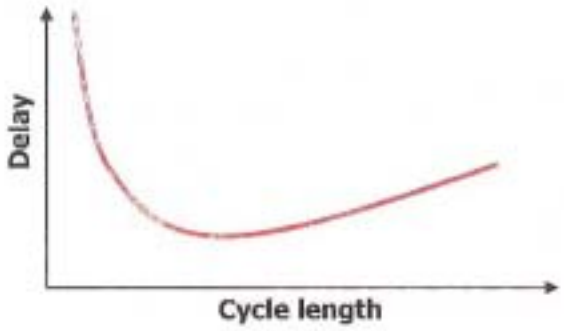

Exhibit 4-8
Generalized Cycle Length and Delay Relationship

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STOP- and YIELD-Controlled Intersection Flow

The driver on the minor street or the driver turning left from the major street at a two-way STOP-controlled intersection faces a specific task: selecting a gap in traffic through which to execute the desired movement. The term *gap* refers to the time interval (*time gap*) and corresponding distance for a given speed (*space gap*) between the major-street vehicles entering an unsignalized intersection, measured from back bumper to front bumper. The term *gap acceptance* describes the completion of a vehicle's movement into a gap.

The capacity of a minor street approach depends on two factors:

- The distribution of available gaps in the major-street traffic stream, and
- The gap sizes required by drivers in other traffic streams to execute their desired movements.

Gap acceptance.

The distribution of available gaps in the major-street traffic stream depends on the total volume on the street, its directional distribution, the number of lanes on the major street, and the degree and type of platooning in the traffic stream. The gap sizes required by the minor-movement drivers depend on the type of maneuver (left, through, right), the number of lanes on the major street, the speed of major-street traffic, sight distances, the length of time the minor-movement vehicle has been waiting, and driver characteristics (eyesight, reaction time, age, etc.).

Critical headway.

For ease of data collection, headways (e.g., front bumper to front bumper) are usually measured instead of gaps, since only half as much data are required (i.e., only front bumper positions need to be recorded, rather than both front and back bumper positions). The *critical headway* is the minimum time interval between the front bumpers of two successive vehicles in the major traffic stream that will allow the entry of one minor-street vehicle. When more than one minor-street vehicle uses one major-street gap, the time headway between the two minor-street vehicles is called *follow-up headway*. In general, the follow-up headway is shorter than the critical headway.

The operation of roundabouts is similar to that of two-way STOP-controlled intersections. In roundabouts, however, entering drivers scan only one stream of traffic—the circulating stream—for an acceptable gap.

At an all-way STOP-controlled intersection, all drivers must come to a complete stop. The decision to proceed is based in part on the rules of the road, which suggest that the driver on the right has the right-of-way, but it is also a function of the traffic condition on the other approaches. The departure headway for the subject approach is defined as the time between the departure of one vehicle and that of the next behind it. A departure headway is considered a saturation headway if the second vehicle stops behind the first at the stop line. If there is traffic on one approach only, vehicles can depart as rapidly as the drivers can safely accelerate into and clear the intersection. If traffic is present on other approaches, the saturation headway on the subject approach will increase, depending on the degree of conflict between vehicles.

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Delay

Control delay.

Delay is an important performance measure for interrupted-flow system elements. There are several types of delay, but *control delay*—the delay brought about by the presence of a traffic control device—is the principal service measure in the HCM for evaluating LOS at signalized and unsignalized intersections. Control delay includes delay associated with vehicles slowing in advance of an intersection, the time spent stopped on an intersection approach, the time spent as vehicles move up in the queue, and the time needed for vehicles to accelerate to their desired speed.

Other types of delay.

Other types of delay sometimes used are the following:

- *Geometric delay*. Delay caused by geometric features causing vehicles to reduce their speed in negotiating a system element (e.g., delay experienced where an arterial street makes a sharp turn, causing vehicles to slow, or the delay caused by the indirect route that through vehicles must take through a roundabout).
- *Incident delay*. The additional travel time experienced as a result of an incident, compared with the no-incident condition.
- *Traffic delay*. Delay resulting from the interaction of vehicles, causing drivers to reduce their speed below the free-flow speed.
- *Total delay*. The sum of control, geometric, incident, and traffic delay.

Number of Stops

Traffic control devices separate vehicles on conflicting paths by requiring one vehicle to stop or yield to the other. The stop causes delay and has an associated cost in terms of fuel consumption and wear on the vehicle. For this reason, information about stops incurred is useful in evaluating performance and calculating road user costs. This measure is typically expressed in terms of *stop rate*, which represents the count of stops divided by the number of vehicles served. Stop rate has units of stops per vehicle.

Stops are generally expected by motorists arriving at an intersection as a minor movement (e.g., a turn movement or a through movement on the minor street). However, through drivers do not expect to stop when they travel along a major street. Their expectation is that the signals will be coordinated to some degree such that they can arrive at each signal in succession while it is displaying a green indication for the through movement. For this reason, stop rate is a useful performance measure for evaluating coordinated signal systems.

Queuing

When demand exceeds capacity for a period of time or when an arrival headway is less than the service time (at the microscopic level) at a specific location, a queue forms (3). Queuing is both an important operational measure and a design consideration for an intersection and its vicinity. Queues that are longer than the available storage length can create several types of operational problems. A through-lane queue that extends past the entrance to a turn lane blocks access to the turn lane, keeping it from being used effectively. Similarly, a turn-lane queue overflow into a through lane interferes with the movement of

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through vehicles. Queues that extend upstream from an intersection can block access into and out of driveways and—in a worst case—can spill back into and block upstream intersections, causing side streets to begin to queue back.

Several queuing measures can be calculated, including the average queue length, the maximum back of queue, and the maximum probable queue (e.g., a 95th percentile queue).

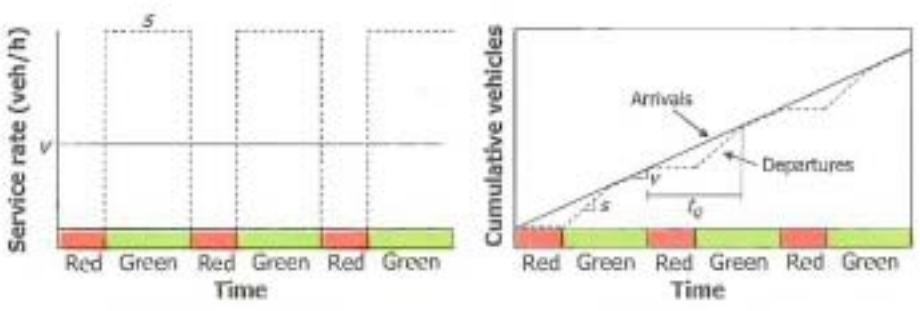
To predict the characteristics of a queuing system mathematically, it is necessary to specify the following system characteristics and parameters (4):

- Arrival pattern characteristics, including the average rate of arrival and the statistical distribution of time between arrivals;
- Service facility characteristics, including service-time average rates and the distribution and number of customers that can be served simultaneously or the number of channels available; and
- Queue discipline characteristics, such as the means of selecting which customer is next.

In oversaturated queues, the arrival rate is higher than the service rate; in undersaturated queues, the arrival rate is less than the service rate. The length of an undersaturated queue can vary but will reach a steady state with the arrival of vehicles. In contrast, the length of an oversaturated queue will never reach a steady state; it will increase with the arrival of vehicles until the arrival demand decreases.

An idealized undersaturated queue at a signalized intersection is shown in Exhibit 4-9 (3). The exhibit assumes queuing on one approach at an intersection with two signal phases. In each cycle, the arrival demand (assumed to be constant in this ideal example) is less than the capacity of the approach, no vehicles wait longer than one cycle, and there is no overflow from one cycle to the next. Exhibit 4-9(a) specifies the arrival rate, v, in vehicles per hour and is constant for the study period. The service rate, s, has two states: zero when the signal is effectively red, and up to saturation flow rate when the signal is effectively green. Note that the service rate is equal to the saturation flow rate only when there is a queue.

Exhibit 4-9
Idealized Queuing Diagram for a Two-Phase Signalized Intersection



(a) Arrival and Service Rates (b) Queue Lengths

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Exhibit 4-9(b) diagrams cumulative vehicles over time. The horizontal line, r, in Exhibit 4-9(a) becomes a solid sloping line in Exhibit 4-9(b), with the slope equal to the flow rate. Thus, the arrival rate goes through the origin and slopes up to the right with a slope equal to the arrival rate. Transferring the service rate from Exhibit 4-9(a) to Exhibit 4-9(b) creates a different graph. During the red period, the service rate is zero, so the service is shown as a horizontal dashed line in Exhibit 4-9(b). At the start of the green period, a queue is present, and the service rate is equal to the saturation flow rate. This forms a series of triangles, with the cumulative arrival line as the top side of each triangle and the cumulative service line forming the other two sides.

Each triangle represents one cycle length and can be analyzed to calculate the time duration of the queue. It starts at the beginning of the red period and continues until the queue dissipates. Its value varies between the effective red time and the cycle length, and it is computed by using Equation 4-10:

$$t_Q = s(t_Q - r) \text{ or } t_Q = \frac{sr}{s - v} \quad \text{Equation 4-10}$$

where

t_Q = time duration of queue (s),

v = mean arrival rate (veh/h),

s = mean service rate (veh/h), and

r = effective red time (s).

The queue length (i.e., the number of vehicles in the queue, as opposed to the location of the back of the queue) is represented by the vertical distance through the triangle. At the beginning of red, the queue length is zero. It increases to its maximum value at the end of the red period. Then the queue length decreases until the arrival line intersects the service line and the queue length equals zero.

The queuing characteristics can be modeled by varying the arrival rate, the service rate, and the timing plan. In real-life situations, arrival rates and service rates are continuously changing. These variations complicate the model, but the basic relationships do not change.

CAPACITY CONCEPTS

Definition of Capacity

The *capacity* of a system element is the maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, environmental, traffic, and control conditions.

Vehicle capacity is the maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic, and control conditions. This assumes that there is no influence from downstream traffic operation, such as queues backing into the analysis point.

Person capacity is the maximum number of persons that can pass a given point during a specified period under prevailing conditions. Person capacity is

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commonly used to evaluate public transit services, high-occupancy-vehicle lanes, and pedestrian facilities.

Prevailing roadway, traffic, and control conditions define capacity; these conditions should be reasonably uniform for any segment of a facility that is analyzed. Any change in the prevailing conditions changes a facility's capacity.

Capacity analyses examine roadway elements under uniform traffic, roadway, and control conditions. These conditions determine capacity; therefore, segments with different prevailing conditions will have different capacities.

Capacity is defined on the basis of reasonable expectancy.

Reasonable expectancy is the basis for defining capacity. That is, the stated capacity for a given system element is a flow rate that can be achieved repeatedly for peak periods of sufficient demand. Stated capacity values can be achieved on system elements with similar characteristics throughout North America. Capacity is not the absolute maximum flow rate observed on such a system element. The absolute maximum flow rate can vary from day to day and from location to location.

Persons per hour, passenger cars per hour, and vehicles per hour are measures that can define capacity, depending on the type of system element and the type of analysis. The concept of person flow is important in making strategic decisions about transportation modes in heavily traveled corridors and in defining the role of transit and high-occupancy vehicle priority treatments. Person capacity and person flow weight each type of vehicle in the traffic stream by the number of occupants carried.

Base Conditions

Base conditions defined.

Many of the procedures in this manual provide a formula or simple tabular or graphic presentations for a set of specified standard conditions, which must be adjusted to account for prevailing conditions that do not match. These standard conditions are termed *base conditions*.

Base conditions assume good weather, good and dry pavement conditions, users who are familiar with the system element, and no impediments to traffic flow. Other more specific base conditions are identified in each methodological chapter in Volumes 2 and 3.

Prevailing conditions almost always differ from the base conditions.

In most capacity analyses, prevailing conditions differ from the base conditions (e.g., there are trucks in the traffic stream, lanes are narrow). As a result, computations of capacity, service flow rate, and LOS must include adjustments. Prevailing conditions are generally categorized as roadway, traffic, or control.

Roadway Conditions

Impact of roadway conditions.

Roadway conditions include geometric and other elements. In some cases, they influence the capacity of a system element; in others, they can affect a performance measure such as speed, but not the roadway's capacity or maximum flow rate.

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Roadway factors include the following:

- Number of lanes,
- The type of system element and its development environment,
- Lane widths,
- Shoulder widths and lateral clearances,
- Design speed,
- Horizontal and vertical alignments, and
- Availability of exclusive turn lanes at intersections.

The horizontal and vertical alignments of a highway depend on the design speed and the topography of the land on which it is constructed.

In general, as the severity of the terrain increases, capacity and service flow rates are reduced. This is significant for two-lane rural highways, where the severity of terrain can affect the operating capabilities of individual vehicles in the traffic stream and restrict opportunities for passing slow-moving vehicles.

Traffic Conditions

Traffic conditions that influence capacities and service levels include vehicle type and lane or directional distribution.

Vehicle Type

The entry of heavy vehicles—that is, vehicles other than passenger cars (a category that includes small trucks and vans)—into the traffic stream affects the number of vehicles that can be served. Heavy vehicles are vehicles that have more than four tires touching the pavement.

Trucks, buses, and recreational vehicles (RVs) are the three groups of heavy vehicles addressed by the methods in this manual. Heavy vehicles adversely affect traffic in two ways.

- They are larger than passenger cars and occupy more roadway space and
- They have poorer operating capabilities than passenger cars, particularly with respect to acceleration, deceleration, and the ability to maintain speed on upgrades.

The second impact is more critical. The inability of heavy vehicles to keep pace with passenger cars in many situations creates large gaps in the traffic stream, which are difficult to fill by passing maneuvers. Queues may also develop behind a slow-moving heavy vehicle. The resulting inefficiencies in the use of roadway space cannot be completely overcome. This effect is particularly harmful on sustained, steep upgrades, where the difference in operating capabilities is most pronounced, and on two-lane highways, where passing requires use of the opposing travel lane.

Heavy vehicles also can affect downgrade operations, particularly when downgrades are steep enough to require operation in a low gear. In these cases, heavy vehicles may operate at speeds slower than passenger cars, again forming gaps ahead and queues behind in the traffic stream.

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Trucks cover a wide range of vehicles, from lightly loaded vans and panel trucks to the most heavily loaded coal, timber, and gravel haulers. An individual truck's operational characteristics vary on the basis of the weight of its load and its engine performance.

RVs also include a broad range campers (both self-propelled and towed), motor homes, and passenger cars or small trucks towing a variety of recreational equipment such as boats, snowmobiles, and motorcycle trailers. Although these vehicles might operate considerably better than trucks, their drivers are not professionals, which accentuates the negative impact of RVs on the traffic stream.

Intercity buses are relatively uniform in performance. Generally, urban transit buses are not as powerful as intercity buses, however. Their most severe impact on traffic results from the discharge and pickup of passengers on the roadway. For the methods in this manual, the performance characteristics of buses are considered to be similar to those of trucks.

Directional and Lane Distribution

Two traffic characteristics in addition to the distribution of vehicle types affect capacity, service flow rates, and LOS: directional distribution and lane distribution. Directional distribution has a dramatic impact on two-lane rural highway operation, where optimal conditions are achieved when the amount of traffic is roughly equal in each direction. Capacity analyses for multilane highways focus on a single direction of flow. Nevertheless, each direction of the highway is usually designed to accommodate the peak flow rate in the peak direction. Typically, morning peak traffic occurs in one direction and evening peak traffic occurs in the opposite direction. Lane distribution is another factor on multilane facilities. Typically, the right lane carries less traffic than other lanes.

Driver Population

Studies have noted that noncommuter driver populations do not display the same characteristics as do regular commuters. For example, for recreational traffic on a freeway segment, capacities have been observed to be as much as 10% to 15% lower than for commuter traffic traveling on the same segment. HCM methods include an adjustment for driver population, for system elements where driver population has made a difference in the observed capacity.

Control Conditions

For interrupted-flow facilities, the control of the time that specific traffic flows are allowed to move is critical to capacity, service flow rates, and level of service. The most critical type of control is the traffic signal. The type of control in use, signal phasing, allocation of green time, cycle length, and the relationship with adjacent control measures all affect operations.

STOP and YIELD signs also affect capacity, but in a less deterministic way. A traffic signal designates times when each movement is permitted; however, a STOP sign at a two-way stop-controlled intersection only designates the right-of-way to the major street. Motorists traveling on the minor street must stop to find gaps in the major traffic flow. The capacity of minor approaches, therefore,

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depends on traffic conditions on the major street. An all-way STOP control requires drivers to stop and enter the intersection in rotation. Capacity and operational characteristics can vary widely, depending on the traffic demands on the various approaches.

Other types of controls and regulations can significantly affect capacity, service flow rates, and LOS. Restricted curb parking can increase the number of lanes available on a street or highway. Turn restrictions can eliminate conflicts at intersections, increasing capacity. Lane use controls can allocate roadway space to component movements and can create reversible lanes. One-way street routings can eliminate conflicts between left turns and opposing traffic.

Technology

Intelligent transportation systems.

Intelligent transportation systems (ITS) strategies aim to increase the safety and performance of roadway facilities. For this discussion, ITS includes any technology that allows drivers and traffic control system operators to gather and use real-time information to improve vehicle navigation, roadway system control, or both. Research on ITS has grown significantly but cannot be considered comprehensive in terms of evaluating ITS impacts on roadway capacity and quality of service.

Arterial ITS strategies that have been shown to improve vehicular throughput or reduce vehicular delay are adaptive signal control and traffic signal interconnection. A freeway ITS strategy, ramp metering, has demonstrated improved mainline throughput and speed, while incident management techniques have reduced the time required to identify and clear incidents, thus minimizing the time during which capacity is reduced as well as the associated delay. Variable freeway speed limits, combined with automated speed limit enforcement, also show promise but require additional study (*6*).

Other ITS strategies seek to shift demand to alternate routes or times, thus making better use of available system capacity and reducing delay on individual facilities. Techniques include parking availability signs at the entrances to downtown areas, value pricing, variable message signs, highway advisory radio, real-time travel time and incident information provided to computers and mobile phones, and real-time in-vehicle navigation systems (*6*).

Specific impacts of ITS strategies on roadway capacity and performance are discussed in Chapter 35, Active Traffic Management, where research is available to document those impacts.

ESTIMATION OF TRAFFIC FLOW PARAMETERS

Analyzing a roadway's performance involves assigning estimated values to traffic flow parameters as a function of either time or distance. There are three common approaches to estimating traffic flow parameters:

1. Deterministic models, such as those presented in the HCM;
2. Simulation models, which take a microscopic and stochastic approach to the representation of traffic flow; and

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3. Field data observations, which attempt to measure the parameters directly by data collection and analysis.

All of these approaches can only produce estimates of the parameters of interest. Each approach involves assumptions and approximations. The three approaches are bound together by the common goal of representing field conditions accurately.

On the surface, it appears that field observations should produce the most accurate representation of traffic flow. It is difficult, however, to produce quantitative observations of some traffic phenomena in a consistent manner that avoids subjective interpretation. There are limits to the accuracy of human observation, and instrumentation of traffic flow data collection is not practical for routine field studies, except for very simple parameters such as flow rate. Field data observations require a level of effort that often exceeds the available resources. Modeling techniques have therefore been introduced as a practical, but also approximate, method of estimating required parameters. It is important that modeling techniques be based on definitions and computations that are as consistent as possible with field observations and with each other.

Vehicle trajectories are the lowest common denominator for estimating traffic flow parameters.

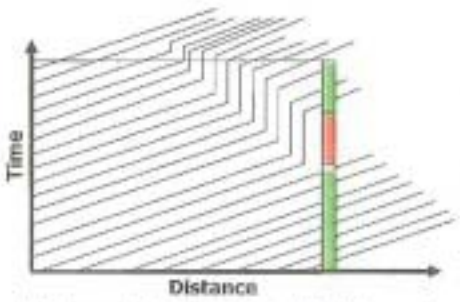
Vehicle trajectories have come to be recognized in the literature as the "lowest common denominator" for this purpose (7). Vehicle trajectories represent the "ground truth" that all measurement and analysis techniques attempt to represent. Microscopic simulation models create trajectories explicitly through algorithms that apply principles of traffic flow theory to the propagation of vehicles along a highway segment. Macroscopic deterministic models do not deal with trajectories at the same level of detail, but they attempt to produce an approximation of the results that would be obtained from trajectory analyses.

Field observations typically establish critical points along individual trajectories rather than complete trajectories.

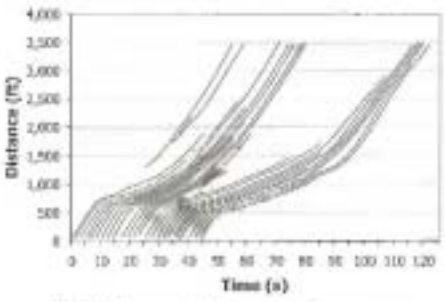
With a few exceptions involving a significant research effort, field observations are not able to create complete trajectories. Instead, they attempt to establish critical points along individual trajectories. Because of its ability to create complete trajectories, simulation modeling may be viewed as a surrogate for field data collection through which the critical points on the trajectory may be established. It is important for this purpose that the critical points be defined in a manner that promotes compatibility between the analysis techniques.

Vehicle trajectories may be represented graphically or mathematically. The graphical representation shows the position of each vehicle in time and space as it traverses a length of the highway. Typical examples of vehicle trajectory plots are shown in Exhibit 4-10.

Exhibit 4-10
Typical Examples of Vehicle Trajectory Plots



(a) Interrupted Flow on a Signalized Approach



(b) Uninterrupted Flow on a Freeway

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Exhibit 4-10(a) depicts a classical queue accumulation and release at a signalized stop line. Exhibit 4-10(b) shows a typical freeway situation in which queuing and shock waves are caused entirely by vehicle interactions and not by traffic control devices.

There are three characteristics shown in Exhibit 4-10 that are not necessarily common to all time–space representations of vehicle trajectories:

1. Time may be shown on either the vertical or horizontal axis. Note that Exhibit 4-10(a) shows time on the vertical axis, while Exhibit 4-10(b) shows time on the horizontal axis.
2. The angular shape of the interrupted-flow trajectory curves does not represent the acceleration and deceleration in their true forms. This shape displays an approximation of the trajectory that is appropriate for some interpretations and inappropriate for others.
3. Both plots represent a single lane of operation in which each vehicle follows its leader according to established rules. Multiple-lane trajectory plots differ from single-lane plots in two ways. First, the first in, first out queue discipline can be violated in multilane situations because of overtaking. In other words, a vehicle entering a link later than its leader could leave the link earlier. Graphically, this situation is represented by trajectory lines crossing each other. Second, some vehicles might change lanes. Lane changes cannot be represented in the Exhibit 4-10 plots because distance is shown as a one-dimensional scalar quantity. Because of these complexities, multiple-lane trajectories are much harder to analyze.

While the two plots shown in Exhibit 4-10 provide good visual insights into vehicle operations, they do not support any quantitative assessments. To develop performance measures from vehicle trajectories, it is necessary to represent them mathematically, rather than visually. A mathematical representation requires the development of a set of properties that are associated with each vehicle at specific points in time and space. Because of the time-step formulation of most simulation models, it is preferable to choose time as the reference point instead of distance.

The key to producing performance measures that are comparable among different estimation techniques is the development of a set of definitions that enforce a consistent interpretation of the vehicle trajectories. The subject of trajectory-based definitions is treated in more detail in Chapter 7, Interpreting HCM and Alternative Tool Results, with additional material presented in Chapter 24, Freeway Supplemental.

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3. PEDESTRIAN MODE

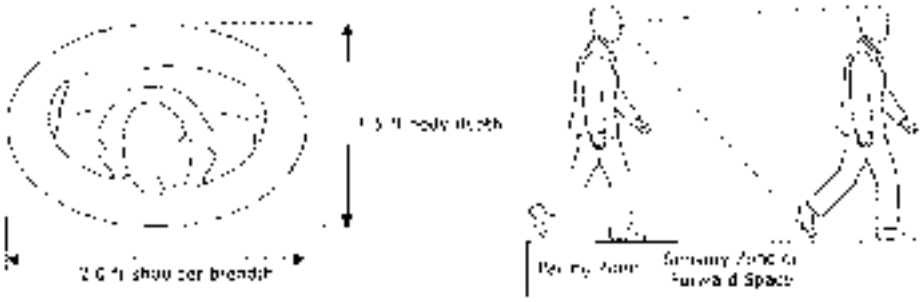
PEDESTRIAN CHARACTERISTICS

Pedestrian Space Requirements

Pedestrian facility designers use body depth and shoulder breadth for minimum space standards, at least implicitly. A simplified body ellipse of 1.5 ft by 2 ft, with a total area of 3 ft², is used as the basic space for a single pedestrian, as shown in Exhibit 4-11(a). This represents the practical minimum for standing pedestrians. In evaluating a pedestrian facility, an area of 6 ft² is used as the buffer zone for each pedestrian.

A walking pedestrian requires a certain amount of forward space. This forward space is a critical dimension, since it determines the speed of the trip and the number of pedestrians able to pass a point in a given time period. The forward space in Exhibit 4-11(b) is categorized into a personal zone and a sensory zone (8).

Exhibit 4-11
Pedestrian Body Ellipse for Standing Areas and Pedestrian Walking Space Requirement



(a) Pedestrian Body Ellipse (b) Pedestrian Walking Space Requirement

Source: Adapted from Fruin (8)

Walking Speed

Factors affecting walking speed.

Pedestrian walking speed is highly dependent on the characteristics of the walking population. The proportion of elderly pedestrians (65 years old or more) and children in the population, as well as trip purpose, affect walking speed. In a national study (9), the average walking speed of younger (age 13–60) pedestrians crossing streets was found to be significantly different from that of older pedestrians (4.74 ft/s versus 4.25 ft/s, respectively). The 15th percentile speed, the speed used in the *Manual on Uniform Traffic Control Devices (10)* for timing the pedestrian clearance interval at traffic signals, was 3.83 ft/s for older pedestrians and 4.77 ft/s for younger pedestrians. Exhibit 4-12 shows these relationships.

For flow analyses, a default free-flow speed (i.e., an average pedestrian's speed on an otherwise empty sidewalk) of 5.0 ft/s (11) is appropriate for sidewalks and walkways, on the basis of average walking speeds. In calculating pedestrian crossing rates, the 15th percentile crossing speed should be used. If no more than 20% of pedestrians are elderly, a crossing speed of 3.5 ft/s should be used (11). If elderly people constitute more than 20% of the total pedestrians, a crossing speed of 3.0 ft/s should be used. Several other factors may reduce

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average pedestrian speed, such as grades over 5% or a high percentage of slow-walking children, and should be taken into consideration.

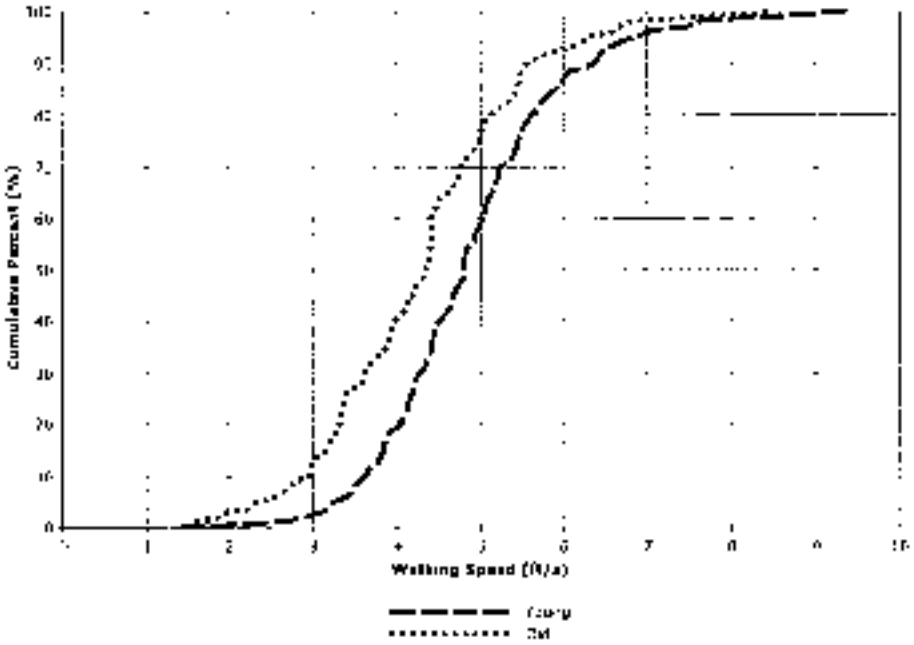

Exhibit 4-12
Observed Older and Younger Pedestrian Walking Speed Distribution at Unsignalized Intersections

Source: Adapted from *TCRP Report 112/NCHRP Report 562* (9).

Pedestrian Start-Up Time

At crosswalks located at signalized intersections, pedestrians may not step off the curb immediately when the walk indication appears, in part because of perception–reaction time and in part to make sure that no vehicles have, or are about to, move into the crosswalk's area. A pedestrian start-up time of 3 s is a reasonable midrange value to use for evaluating crosswalks at traffic signals.

PEDESTRIAN FLOW PARAMETERS

Speed, Flow, and Density Relationships

Speed–Density Relationships

The fundamental relationship between speed, density, and volume for directional pedestrian flow on facilities with no cross-flows, where pedestrians are constrained to a fixed walkway width (because of walls or other barriers), is analogous to that for vehicular flow. As volume and density increase, pedestrian speed declines. As density increases and pedestrian space decreases, the degree of mobility afforded to the individual pedestrian declines, as does the average speed of the pedestrian stream.

Exhibit 4-13 shows the relationship between speed and density for three pedestrian classes.

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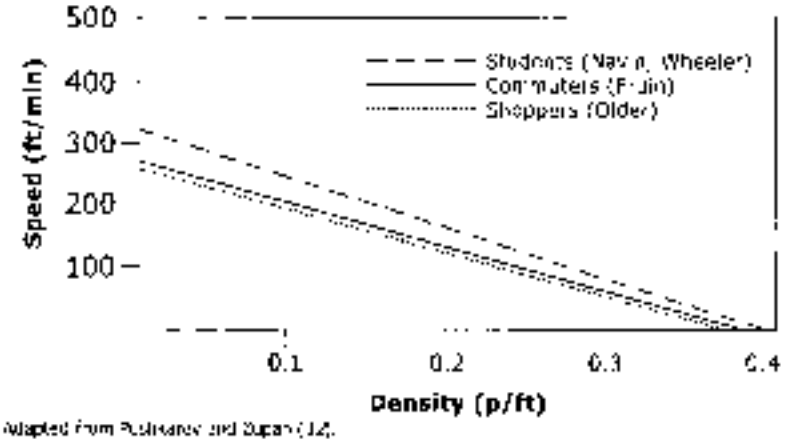
Exhibit 4-13
Relationships Between Pedestrian Speed and Density



Source: Adapted from Pushkarev and Zupan (12).

Similarities of pedestrian movement to vehicular traffic

Flow–Density Relationships

The relationship among density, speed, and directional flow for pedestrians is similar to that for vehicular traffic streams and is expressed in Equation 4-11:

Equation 4-11

$$v_{pd} = S_{ped} \times D_{ped}$$

where

v_{pd} = unit flow rate (p/min/ft),

S_{ped} = pedestrian speed (ft/min), and

D_{ped} = pedestrian density (p/ft²).

The flow variable in Equation 4-11 is the unit width flow, defined earlier. An alternative, more useful, expression uses the reciprocal of density, or space:

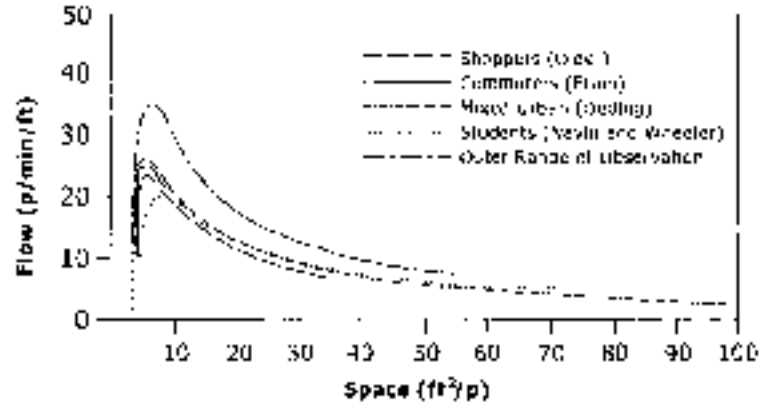
Equation 4-12

$$v_{ped} = \frac{S_{ped}}{M}$$

where M = pedestrian space (ft²/p).

The basic relationship between flow and space recorded by several researchers, as illustrated in Exhibit 4-14:

Exhibit 4-14
Relationships Between Pedestrian Flow and Space



Source: Adapted from Pushkarev and Zupan (12).

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The conditions at maximum flow represent the capacity of the walkway facility. From Exhibit 4-14, it is apparent that all observations of maximum unit flow fall within a narrow range of density, with the average space per pedestrian varying between 5 and 9 ft²/p. Even the outer range of these observations indicates that maximum flow occurs at this density, although the actual flow in this study is considerably higher than in the others. As space is reduced to less than 5 ft²/p, the flow rate declines precipitously. All movement effectively stops at the minimum space allocation of 2 to 4 ft²/p.

These relationships show that pedestrian traffic can be evaluated qualitatively by using basic concepts similar to those of vehicular traffic analysis. At flows near capacity, an average of 5 to 9 ft²/p is required for each moving pedestrian. However, at this level of flow, the limited area available restricts pedestrian speed and freedom to maneuver.

Speed–Flow Relationships

Exhibit 4-15 illustrates the relationship between pedestrian speed and flow. These curves, similar to vehicle flow curves, show that when there are few pedestrians on a walkway (i.e., low flow levels), there is space available to choose higher walking speeds. As flow increases, speeds decline because of closer interactions among pedestrians. When a critical level of crowding occurs, movement becomes more difficult, and both flow and speed decline.

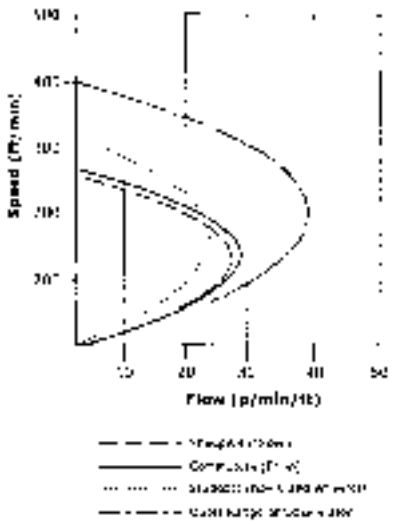

Exhibit 4-15
Relationships Between Pedestrian Speed and Flow

Source: Adapted from Pushkarev and Zupan (12).

Speed–Space Relationships

Exhibit 4-16 also confirms the relationships of walking speed and available space. The outer range of observations shown in Exhibit 4-16 indicates that at an average space of less than 15 ft²/p, even the slowest pedestrians cannot achieve their desired walking speeds. Faster pedestrians, who walk at speeds of up to 350 ft/min, are not able to achieve that speed unless the average space is 40 ft²/p or more.

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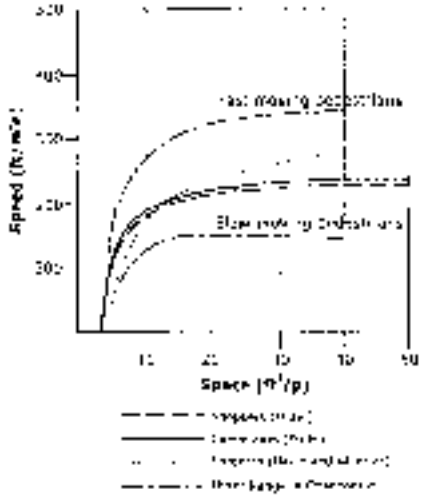
Exhibit 4-16
Relationships Between Pedestrian Speed and Space



Source: Adapted from Pushkarev and Zupan (15)

Flow on Urban Sidewalks and Walkways

While the fundamental relationships described above hold for pedestrians on constrained facilities with linear flow (e.g., bridges and underground passageways), they are complicated on urban sidewalks and walkways by other factors. In particular, cross-flows, stationary pedestrians, and the potential for spillover outside of the walkway affect pedestrian flows on these facilities. Quantitative research describing the effects of these factors on pedestrian flow is limited, but the effects are described qualitatively here.

Cross-flows of pedestrians entering or exiting adjacent businesses, getting on or off buses at bus stops, or accessing street furniture are typical on most urban pedestrian facilities. Where pedestrian volumes are high, these cross-flows will disrupt the speed–flow relationships described above, resulting in lower pedestrian speeds at equivalent flow rates. In addition to cross-flows, stationary pedestrians will be present on most urban pedestrian facilities, as pedestrians stop to talk, look in store windows, or pick up a newspaper from a vending machine. Stationary pedestrians reduce pedestrian flow by requiring pedestrians to maneuver around them and decreasing the available width of the walkway.

Finally, in situations where pedestrians are not physically confined within the walkway, pedestrians will often choose to walk outside of the prescribed walking area (e.g., walk in the furniture zone or street) when high densities are reached. Thus, in practice, facilities will often break down, with pedestrians spilling over into the street, before the maximum flow rate shown in Exhibit 4-14 is reached. Therefore, typical practice is to design pedestrian facilities for LOS C or D densities (13).

The result of the combination of factors described above is that many pedestrian facilities will reach effective failure at densities far less than the facility's capacity. Analysis of pedestrian facilities should take into consideration local conditions, including the presence of obstructions along the facility that contribute to cross-flows and stationary pedestrians, as well as opportunities for pedestrians to spill over onto adjacent facilities.

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Pedestrian Type and Trip Purpose

The analysis of pedestrian flow is generally based on the mean, or average, walking speeds of groups of pedestrians. Within any group, or among groups, there can be considerable differences in flow characteristics due to trip purpose, adjacent land use, type of group, age, mobility, cognitive ability, and other factors.

Pedestrians going to and from work and using the same facilities day after day walk at higher speeds than do shoppers, as was shown in Exhibit 4-13. Older or very young persons tend to walk more slowly than do other groups. Shoppers not only tend to walk more slowly than do commuters but also can decrease the effective walkway width by stopping to window-shop and by carrying shopping bags. The analyst should adjust for pedestrian behavior that deviates from the regular patterns represented in the basic speed, volume, and density curves.

Influences of Pedestrians on Each Other

Photographic studies show that pedestrian movement on sidewalks is affected by other pedestrians, even when space is more than 40 ft²/p. At 60 ft²/p, pedestrians have been observed walking in a checkerboard pattern, rather than directly behind or alongside each other. The same observations suggest the necessity of up to 100 ft²/p before completely free movement occurs without conflicts, and that at 130 ft²/p, individual pedestrians are no longer influenced by others (*14*). Bunching or platooning does not disappear until space is about 500 ft²/p or higher.

Maintaining flow in the minor (opposing) direction.

Another issue is the ability to maintain flow in the minor direction on a sidewalk when opposed by a major pedestrian flow. For pedestrian streams of roughly equal flow in each direction, there is little reduction in the capacity of the walkway compared with one-way flow, because the directional streams tend to separate and occupy a proportional share of the walkway. However, if the directional split is 90% versus 10% and space is 10 ft²/p, capacity reductions of about 15% have been observed. This reduction results from the minor flow using more than its proportionate share of the walkway.

Opposing flows on stairways.

Similar, but more severe, effects are seen with stairways. In contrast to their behavior on a level surface, people tend to walk in lines or lanes in traversing stairs. A small reverse flow occupies one pedestrian lane (30 in.) of the stair's width. For a stair 60 in. (5 ft) wide, a small reverse flow could consume half its capacity (*13*).

Cross-flows.

A pedestrian's ability to cross a pedestrian stream is impaired at space values less than 35 to 40 ft²/p, as shown in Exhibit 4-17 (*8*). Above that level, the probability of stopping or breaking the normal walking gait is reduced to zero. Below 15 ft²/p, virtually every crossing movement encounters a conflict. Similarly, the ability to pass slower pedestrians is unimpaired above 35 ft²/p, but it becomes progressively more difficult as space allocations drop to 18 ft²/p, the point at which passing becomes virtually impossible.

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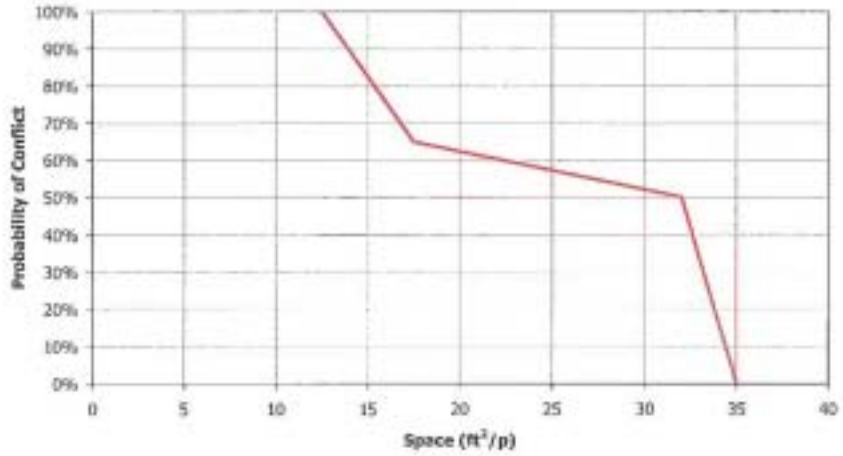
Exhibit 4-17
Probability of Conflict Within Pedestrian Cross-Flows



Source: Adapted from Fruin (*8*).

Pedestrian Facility Characteristics

Effective Walkway Width

The lane concept used for highway analysis is frequently not applicable to pedestrian analysis, because studies have shown that pedestrians normally do not walk in organized lanes. The concept is meaningful, however, in the following situations:

- Determining how many pedestrians can walk abreast in a given walkway width—for example, in establishing the minimum sidewalk width that will permit two pedestrians to pass each other conveniently; and
- Determining the capacity of a stairway, since pedestrians will tend to organize into lanes on stairways.

In other situations, the capacity of a pedestrian facility is directly related to the width of the facility. However, not all of the facility's width may be usable, because of obstructions and pedestrians' tendencies to shy away from curbs and building walls. The portion of a pedestrian facility's width that is used for pedestrian circulation is called the *effective width*. The degree to which single obstructions, such as poles, signs, and hydrants, influence pedestrian movement and reduce effective walkway width is not extensively documented. Although a single point of obstruction would not reduce the effective width of an entire walkway, it would affect its immediate vicinity.

To avoid interference when two pedestrians pass each other, each should have at least 2.5 ft of walkway width (*12*). When pedestrians who know each other walk close together, each occupies an average width of 26 in., allowing considerable likelihood of contact due to body sway. Lateral spacing less than this occurs only in the most crowded situations.

Pedestrian Platoons

Average pedestrian flow rates are of limited usefulness unless reasonable time intervals are specified. Exhibit 4-18 illustrates that average flow rates can be misleading. The data shown are for two locations in New York City, but the pattern is generally characteristic of concentrated central business districts. Flows

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during a 1-min interval can be more than double the rate in another, particularly at relatively low flows. Even during the peak 15-min periods, the peak 1-min flow exceeded the average flow by at least 20% and sometimes up to 75%.

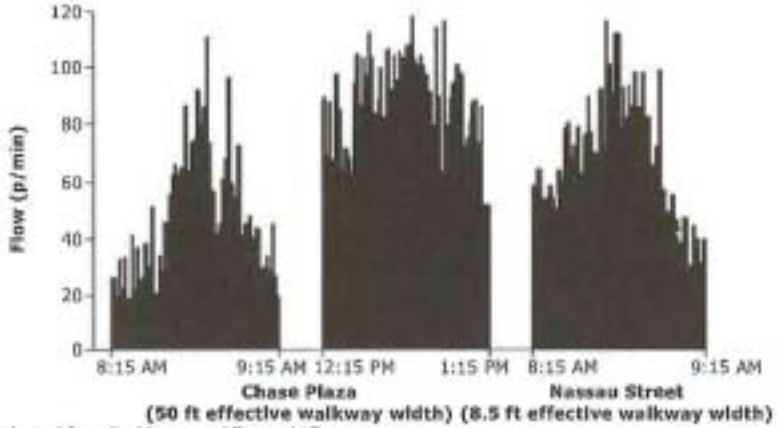

Exhibit 4-18
Minute-by-Minute Variations in Pedestrian Flow

Source: Adapted from Pushkarev and Zupan (*12*).

Depending on traffic patterns, a facility designed for average flow can afford a lower quality of flow for a portion of its pedestrian traffic. However, it is not prudent to design for extreme peak 1-min flows that occur only 1% or 2% of the time. A relevant time period should be determined through closer evaluation of the short-term fluctuations of pedestrian flow.

Short-term fluctuations are present in most unregulated pedestrian traffic flows because of the random arrivals of pedestrians. On sidewalks, these random fluctuations are exaggerated by the interruption of flow and queue formation caused by traffic signals. Transit facilities can create added surges in demand by releasing large groups of pedestrians in short time intervals, followed by intervals during which no flow occurs. Until they disperse, pedestrians in these types of groups move together as a platoon (Exhibit 4-19). Platoons can also form when passing is impeded because of insufficient space and faster pedestrians must slow down behind slower-moving ones.

Exhibit 4-19
Platoon Flow on a Sidewalk

The scatter diagram shown in Exhibit 4-20 compares the platoon flow rate (i.e., the rate of flow within platoons of pedestrians) with the average flow rate for durations of 5 to 6 min. The dashed line approximates the upper limit of platoon flow observations.

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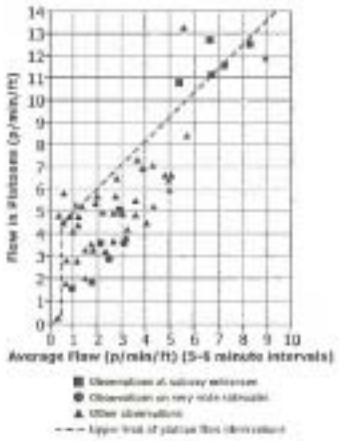
Exhibit 4-20
Relationship Between Platoon Flow and Average Flow



Source: Adapted from Pushkarev and Zupan (*12*).

CAPACITY CONCEPTS

Pedestrian Circulation Facilities

Pedestrian capacity on facilities designed for pedestrian circulation is typically expressed in terms of *space* (square feet per pedestrian) or *unit flow* (pedestrians per minute per foot of walkway width). The relationship between space and flow was illustrated in Exhibit 4-14. Capacity occurs when the maximum flow rate is achieved. Typical values for pedestrian circulation facilities are as follows:

- Walkways with random flow, 23 p/min/ft;
- Walkways with platoon flow (average over 5 min), 18 p/min/ft;
- Cross-flow areas, 23 p/min/ft (sum of both flows); and
- Stairways (up direction), 15 p/min/ft.

As shown in Exhibit 4-15, average pedestrian speeds at capacity are about half the average speed obtained under less congested conditions. As a result, pedestrian circulation facilities are typically not designed for capacity but rather for a less congested condition that achieves lower pedestrian throughput but that provides pedestrians with greater opportunity to travel at their desired speed with minimal conflicts with other pedestrians. Moreover, as described above under "Flow on Urban Sidewalks and Walkways," pedestrian facilities often break down before maximum flow rates are achieved, as a result of pedestrian spillover outside of the walkway into the furniture zone or roadway.

Pedestrian Queuing Facilities

Pedestrian capacity on facilities designed for pedestrian queuing is expressed in terms of space (square feet per pedestrian). In a queuing area, the pedestrian stands temporarily while waiting to be served. In dense, standing crowds, there is little room to move, but limited circulation is possible as the average space per pedestrian increases. Queuing at or near capacity (2 to 3 ft^2/p) typically occurs only in the most crowded elevators or transit vehicles. Queuing on sidewalks, waiting to cross at street corners, is more typically in the 3 to 6 ft^2/p range, which is still crowded but provides some internal maneuverability.

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4. BICYCLE MODE

BICYCLE FLOW PARAMETERS

Although bicyclists are not as regimented as vehicles, they tend to operate in distinct lanes of varying widths when space is available. The capacity of a bicycle facility depends on the number of effective lanes used by bicycles. Shared-lane facilities typically have only one effective lane, but segregated facilities such as bicycle lanes, shoulder bikeways, pathways, and cycle tracks may have more than one effective lane, depending on their width. When possible, an analysis of a facility should include a field evaluation of the number of effective lanes in use. When this is not possible, or when future facilities are planned, a standard width for an effective bicycle lane is approximately 4 ft (15). The American Association of State Highway and Transportation Officials recommends that off-street bicycle paths be 10 ft wide (15).

Research demonstrates that three-lane bicycle facilities operate more efficiently than two-lane bicycle facilities, affording considerably better quality of service to users (16). The improved efficiency is due primarily to increased opportunities for passing and for maneuvering around other bicyclists and pedestrians. This reinforces the value of determining the number of effective lanes as the principal input for analyzing a bicycle facility.

A study that compared mean bicycle speeds with bicycle flow rates over 5-min periods found at most a minor effect of flow rates on speed, for flow rates ranging from 50 to 1,500 bicycles/h. When the analysis focused on platoons of bicycles with headways less than 5 s, bicycle speeds trended slightly lower as flow rates increased (17).

Most bicyclists travel on facilities that are shared with automobiles. In these circumstances, bicycle flow is significantly affected by the characteristics of surrounding automobile flow. Bicyclists often must wait behind queues of automobiles. Even where bicyclists may pass such queues, they are often forced to slow because the available space in which to pass is too constrained to allow free-flow speeds to occur.

Data collected for more than 400 adult bicyclists riding on uninterrupted multiuse segments showed an average speed of 12.8 mi/h (16). However, the speed of an individual bicyclist varies considerably from this average on the basis of trail conditions, age, fitness level, and other factors. Exhibit 4-21 shows how bicyclist speed varies with age, on the basis of Danish data. Data are for typical bicycles on flat terrain.

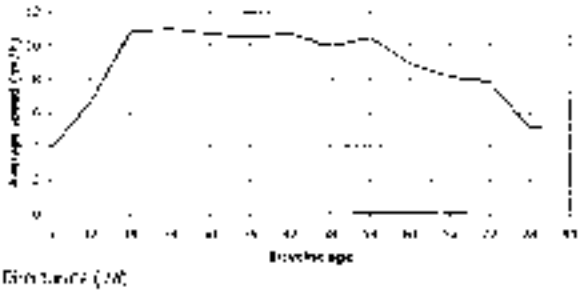

Exhibit 4-21
Age Effects on Bicyclist Speed

Source: Danish Road Directorate (18).

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Flow rates of bicyclists typically vary over the course of an hour. As described above for automobiles, HCM analyses typically consider the peak 15 min of flow during the analysis hour. Because inputs to HCM procedures are typically expressed in terms of hourly demands, the HCM uses the PHF, shown by Equation 4-1, to convert an hourly volume into a peak 15 min flow rate. Data for bicycles on eight trails, recorded over three separate time periods for each trail, showed PHFs ranging from 0.70 to 0.99, with an average of 0.85 (*18*).

CAPACITY CONCEPTS

Because service quality deteriorates at flow levels well below capacity, the concept of capacity has little utility in the design and analysis of bicycle paths and other facilities. Capacity is rarely observed on bicycle facilities. Values for capacity, therefore, reflect sparse data, generally from Europe and generally extrapolated from flow rates over time periods substantially less than 1 h.

One study reported capacity values of 1,600 bicycles/h/lane for two-way bicycle facilities and 3,200 bicycles/h/ln for one-way facilities. Both values were for exclusive bicycle facilities operating under uninterrupted-flow conditions (*19*). Other studies have reported values in the range of 1,500 to 5,000 bicycles/h/ln for one-way uninterrupted-flow facilities (*76*).

Danish guidelines suggest that bicycle capacity is normally only relevant at signalized intersections in cities and that a rule of thumb for the capacity of a two-lane cycle track is 2,000 bicycles/h under interrupted-flow conditions (i.e., 1,000 bicycles/h/ln) (*20*). The HCM recommends a saturation flow rate of 2,000 bicycles/h/ln for a one-direction bicycle lane under interrupted-flow conditions, which is equivalent to a capacity of 2,000 bicycles/h/ln when the bicycle lane receives a green indication during 50% of the signal cycle.

DELAY

Delay is an important performance measure for bicyclists on interrupted-flow system elements. This is true because delay increases travel time and because the physical exertion required to accelerate a bicycle makes stopping or slowing undesirable and tiring. The difficulty involved in stopping and starting a bicycle often makes it appropriate to assess not only the control delay incurred by bicyclists but also the number of stops that bicyclists are required to make to traverse a facility. For instance, a facility with stop signs every several hundred feet will require bicyclists to stop frequently and thus will provide lower capacity and quality of service to users.

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5. TRANSIT MODE

BUS SPEED PARAMETERS

Material in this section generally refers to buses but is also applicable to streetcars and light rail vehicles operating on urban streets, except where specifically stated otherwise.

Bus speeds on urban streets are influenced by the same factors that influence automobile speeds, particularly the delay caused by traffic signals and other forms of intersection control. As heavy vehicles, buses accelerate and decelerate more slowly than passenger cars. In addition, there are many bus-specific factors that influence speed, involving operations, vehicle, roadway, and passenger characteristics. These factors are described below.

Operations Characteristics

Stop Spacing

Unlike other urban street users, most transit vehicles (except for express buses) stop periodically so that passengers may board and alight. Each stop introduces up to four forms of delay:

- *Acceleration and deceleration delay*, as a bus slows down approaching a stop and returns to its running speed after departing the stop;
- *Passenger service time*, while the bus is stopped and passengers are actively boarding and alighting;
- *Traffic signal delay*, when a bus arrives at a curb-side stop (i.e., a bus stop immediately prior to an intersection) during the green interval, serves its passengers, and then experiences delay while waiting for the traffic signal to turn green again before proceeding; and
- *Reentry time*, when a bus stops out of the curb travel lane and then must wait for a gap in traffic before it can reenter the lane.

Increasing the stop spacing reduces the number of occurrences of these types of delay, which results in a net increase in speeds. (Passenger service times may increase, though, as passengers activity is concentrated at fewer stops.) For example, five bus rapid transit routes in Los Angeles that have stop spacings ranging from 2/3 to 1 mi and no other contributing factors (e.g., transit signal priority) achieved travel time reductions of 17% to 29% compared with the previous local bus service (*21*).

The ability to increase stop spacing depends on many factors, including the surrounding pedestrian environment, the locations of transit trip generators and transfer opportunities, and driveway and curb parking locations (*15*).

Fare Payment

The time required for passengers to pay a fare affects the passenger service rate at stops. The average base amount of time needed to board a high-floor bus with no or prepaid (e.g., bus pass or free transfer) fare payment is 2.5 s/passenger. The various types of fare payment methods (e.g., cash, tickets, tokens, magnetic-stripe cards, smart cards) have service times associated with them that increase the service time by up to 1.8 s/passenger, on average, above the base level. (*13*)

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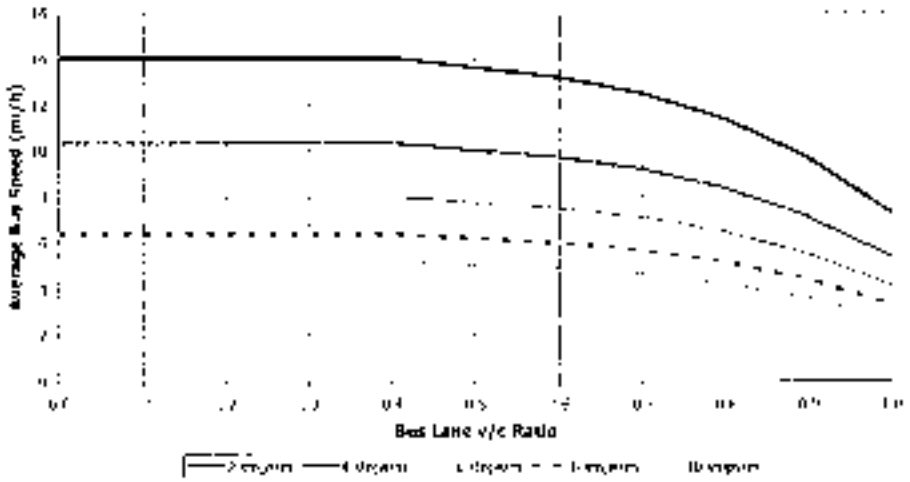
Service Planning and Scheduling

Bus speeds along an urban street decline when 50% or more of a bus lane's hourly capacity is utilized, as illustrated in Exhibit 4-22. As the number of buses using a bus lane increases, there is a greater probability that one bus will delay another bus, either by using all available space at a bus stop or by requiring bus passing and weaving maneuvers. At a volume-to-capacity (v/c) ratio of 1.0, bus speeds are approximately half of what can be achieved at v/c ratios under 0.5 (13).

Exhibit 4-22
Illustrative Bus Speed Relationship to Bus Lane v/c Ratio



Notes: Assumes 30 s cycle times, downtown bus lane with right-turn lanes, and typical signal timing.
Source: *TCRP Report 100: Transit Capacity and Quality of Service Manual (13).*

On buses where demand exceeds seating capacity, causing some passengers to stand, more passenger service time is required at stops, because standing passengers must push toward the back of the bus to allow other passengers to board and because alighting passengers take longer to get to a door.

Vehicle Characteristics

Low-floor buses can reduce passenger service time by eliminating the need to ascend and descend steps. These buses are particularly useful for routes frequently used by the elderly, persons with disabilities, or persons with strollers or bulky carry-on items. Wide bus doors also allow more passengers to board and alight simultaneously (13).

Roadway Characteristics

Transit Preferential Treatments

Refer to TCRP Report 118 (22) for illustrations and guidance on appropriate locations for transit preferential treatments.

Transit preferential treatments, both geometric and operational, give transit vehicles a travel time advantage over other roadway users. Common types of treatments include the following.

- *Exclusive bus lanes.* One or more lanes on a street that are reserved on a full- or part-time basis for the exclusive use of buses. Exclusive bus lanes partially or entirely eliminate interactions with automobiles and other roadway users that can slow down a bus. With typical signal timing, bus

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lanes typically provide a 10- to 15-min/mi speed advantage over mixed-traffic operations (13).

- *Queue jumps.* A short bus lane section (often shared with a right-turn lane), in combination with an advance green indication for the lane, that allows buses to move past a queue of cars at a signal. These typically reduce bus delay at a signalized intersection by 5% to 15% (22).
- *Curb extensions.* An extension of the sidewalk to the edge of the travel or bicycle lane (e.g., by removing on-street parking). Curb extensions allow buses to stop in the travel lane and thus to avoid delay when they leave the stop. At the range of curb volumes appropriate for curb extensions (under 500 veh/h), they can save buses up to 5 s of delay per stop on average (22).
- *Traffic signal priority.* Changes to traffic signal timing to favor bus operations. These include *passive* (pretimed) changes—for example, to set a street's signal progression to favor buses rather than cars (as is done at downtown Ottawa). *Active* strategies adjust signal timing in real time to the arrival of a bus—for example, to extend a green interval to accommodate a bus arriving late in the interval or to shorten the red interval to get a stopped bus under way sooner. *Real-time* strategies consider both automobile and bus arrivals at a single intersection or a network of intersections. *Traffic signal priority* is rarely used for buses because of signal system operations and safety issues but is a feature of some light rail routes. Systems of intersections equipped with traffic signal priority have typically reduced transit travel times by 5% to 15%, with a range of reported values of 0% to 40% (13, 22).
- *Turn restriction exemption.* Buses are allowed to make turns at locations where other vehicles are not allowed to. This treatment allows buses to travel more direct routes; the time saved depends on the length of and the delay associated with the alternate route (13).

Bus Stop Location

Buses can stop in the travel lane (*on line*) or out of the travel lane (*off line*), for example, in a bus pullout. Off-line stops require buses to find a gap in traffic when they reenter the travel lane, which generates reentry delay that can average 1 to 15 s with random vehicle arrivals, depending on the traffic volume in the curb lane. Some jurisdictions have passed yield-to-bus laws that require motorists to allow a bus back into traffic. These laws can reduce or eliminate reentry delay, depending on the degree of motorist compliance (13).

Bus stops can be located before an intersection (*near side*), after an intersection (*far side*), or between intersections (*midblock*). The interaction of right-turning vehicles and buses at near side stops can create delays. Buses are also more likely to get caught by a red signal after serving passengers at a near-side stop than at a far-side stop. On the other hand, buses using off-line far-side stops may cause traffic to back up behind the bus into the intersection. Refer to the *Transit Capacity and Quality of Service Manual* (13) for a full list of the advantages and disadvantages of each type of stop location.

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Passenger Characteristics

Passenger Distribution

The distribution of boarding passengers among bus stops affects the passenger service time of each stop. If passenger boardings are concentrated at one stop along a street, that street's bus capacity will be lower than if boardings were more evenly distributed. Bus stop capacity decreases as average passenger service time increases, and the bus capacity of a street is constrained by the lowest bus stop capacity along the street. With a lower capacity, it takes fewer scheduled buses in an hour for interactions between buses to begin to affect bus speeds. However, if boardings are concentrated because of a consolidation of bus stops, the net effect will be improved speed and a reduced number of stops, which will offset the increased passenger service time at the remaining stops.

Strollers, Wheelchairs, and Bicycles

Passenger service times are longer for passengers with strollers or using wheelchairs, particularly with high-floor buses when a lift must be deployed. A passenger using a bicycle rack mounted to the bus will also cause service time to increase, except when other passengers are still being served after the bicycle has been secured. In many cases, these events are sufficiently infrequent to be indistinguishable from the normal variation in passenger demands and service times at a bus stop.

CAPACITY CONCEPTS

Differences Between Transit and Automobile Capacity

Transit capacity is different from highway capacity: it deals with the movement of both people and vehicles, it depends on the size of the transit vehicles and how often they operate, and it reflects the interaction of passenger traffic and vehicle flow. Transit capacity depends on the operating policy of the transit agency, which specifies service frequencies and allowable passenger loadings. Accordingly, the traditional concepts applied to highway capacity must be adapted and broadened.

Two key characteristics differentiate transit from the automobile in terms of availability and capacity. Although the automobile has widespread access to roadway facilities, transit service is available only in certain locations and during certain times. Roadway capacity is available 24 h/day once constructed, but transit passenger capacity is limited by the number of transit vehicles operated at a given time.

Throughout the transit sections of the HCM, a distinction is made between vehicle and person capacity. *Vehicle capacity* reflects the number of transit units (buses or trains) that pass a given location during a given time period. Thus, bus vehicle capacity is most closely analogous to automobile capacity. *Person capacity* reflects the number of people that can be carried past a given location during a given time period under specified operating conditions, without unreasonable delay, hazard, or restriction, and with reasonable certainty.

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On-street bus capacity has a two-dimensional nature. It is possible to operate many buses, each carrying only a few passengers. Whether the buses are full or empty, a larger number of buses can have a negative impact on LOS in terms of highway capacity. Alternatively, only a few buses could operate, each overcrowded. This represents a poor quality of service from the passenger perspective, and long waiting times would detract from user convenience.

Vehicle Capacity

Vehicle (bus) capacity is commonly determined for three locations along an urban street: individual loading areas (berths) at bus stops, individual bus stops, and an urban street facility, as illustrated in Exhibit 4-23. Each location directly influences the next. The vehicle capacity of a bus stop is controlled by the vehicle capacities of the loading areas, and the vehicle capacity of the urban street facility is controlled by the vehicle capacity of the critical stop within the facility.

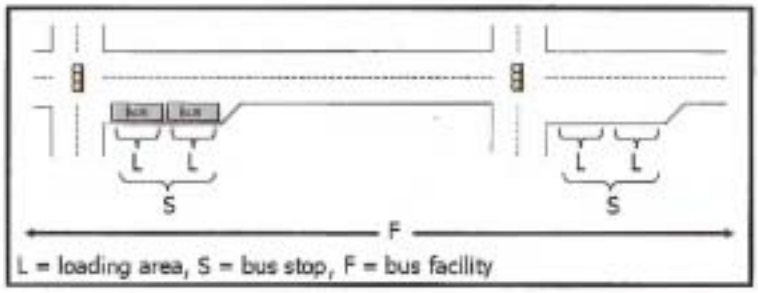

Exhibit 4-23
Bus Loading Areas, Stops, and Facilities

Source: *TCRP Report 100: Transit Capacity and Quality of Service Manual (13).*

Loading Area Capacity

The main elements that determine loading area capacity are dwell time, dwell time variability, traffic signal timing, failure rate, and clearance time (*13*):

- *Dwell time* is the sum of passenger service time and the time to open and close the bus doors.
- *Dwell time variability* accounts for the fact that buses do not stop for the same amount of time at a stop because of fluctuations in passenger demand for buses and routes.
- *Traffic signal timing* affects the time available in an hour for buses to enter and exit a bus stop. In addition, the length of red in relation to the dwell time of a bus affects vehicle capacity: if passenger movements have finished but the vehicle must wait for the traffic signal to turn green, vehicle capacity will be less than if the bus can leave immediately so that another bus can use the loading area.
- *Failure rate* is a design input and is the probability that one bus will arrive at a bus stop only to find all loading areas already occupied.
- *Clearance time* is an interval after a bus is ready to depart during which the loading area is not available for use by a following bus. Part of this time is fixed, consisting of the time for a bus to start up and travel its own length, clearing the stop. For off-line stops, a second component of clearance time is the reentry time discussed previously.

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Bus Stop Capacity

Bus stops consist of one or more loading areas. When a bus stop consists of a single loading area, its capacity is equivalent to the loading area capacity. However, when a bus stop consists of multiple loading areas, the number of loading areas and the design of the loading areas also influence its capacity.

Effective loading areas.

The vast majority of on-street bus stops are *linear* bus stops, where the first bus to arrive occupies the first loading area, the second bus occupies the second loading area, and so on. Each additional linear loading area at a bus stop is less efficient than the one before it for three reasons:

1. The rear loading areas will be used less often than the first loading area;
2. Not knowing which loading area their bus will stop at, passengers may have to walk down the line of buses to get to their bus, increasing its passenger service time; and
3. Depending on how closely buses stop behind the bus in front and the buses' ability to pass one another, a bus may not be able to leave its loading area until the bus in front of it departs.

Efficiency drops significantly above three loading areas. Efficiency is also affected by whether the bus stop is on-line or off-line and by whether buses arrive irregularly (the usual situation) or are operated in groups of two or three buses (*platoons*) that act like cars of a train (*13*).

Bus Facility Capacity

Bus facility capacity is constrained by the capacity of the critical bus stop along the facility. The critical bus stop is usually the bus stop with the longest dwell time; however, high vehicular traffic volumes (particularly turning volumes) along with conflicting pedestrian volumes can combine to make a particular bus stop the critical stop. The impact of vehicular traffic on capacity also depends on the location of a particular bus stop, with near-side stops being affected more than far-side stops, and on whether buses operate in mixed traffic or in a bus lane (*13*).

Exhibit 4-24 summarizes the elements that determine bus facility capacity.

Person Capacity

For HCM analysis purposes, person capacity is typically calculated only at the facility level.

Person capacity is determined by three main factors (*13*):

1. *Vehicle capacity,* which determines the maximum number of buses that can be scheduled to use the bus facility over the course of an hour;
2. *Agency policy,* which sets loading standards for buses and determines how frequently buses operate (which is usually less than the maximum possible frequency); and
3. *Passenger demand characteristics,* reflected by a PHF.

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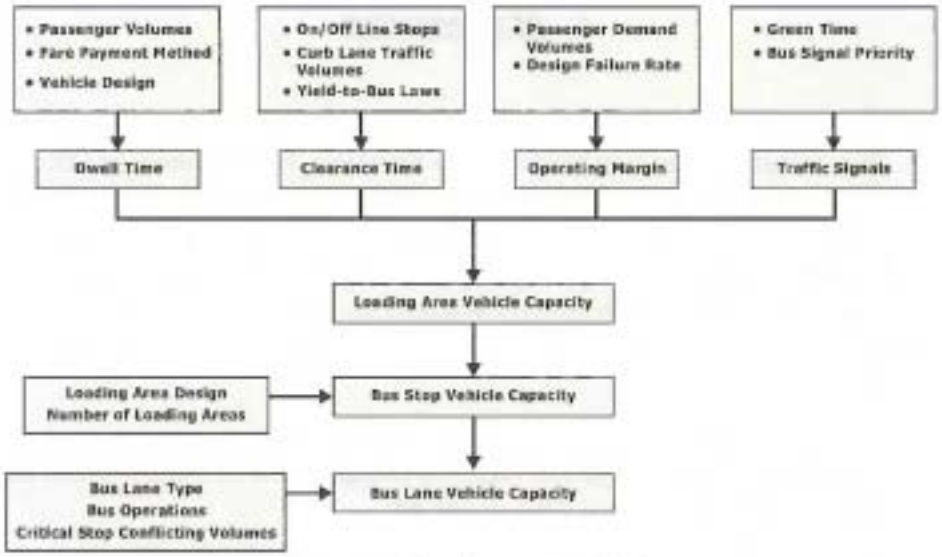

Exhibit 4-24
Capacity Factors for Bus Facilities

Source: *TCRP Report 100: Transit Capacity and Quality of Service Manual (13).*

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CHAPTER 5
QUALITY AND LEVEL-OF-SERVICE CONCEPTS

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Exhibit 5-1 Example of the Step Function Nature of LOS 5-4

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There are many ways to measure the performance of a transportation facility or service—and many points of view that can be considered in deciding which measurements to make. The agency operating a roadway, automobile drivers, pedestrians, bicyclists, bus passengers, decision makers, and the community at large all have their own perspectives on how a roadway or service should perform and what constitutes "good" performance. As a result, there is no one right way to measure and interpret performance. **Chapter 5, Quality and Level-of-Service Concepts,** presents the concepts that the *Highway Capacity Manual* (HCM) uses to describe performance from the traveler point of view in a way that is designed to be useful to roadway operators, decision makers, and members of the community.

Quality of service describes how well a transportation facility or service operates from the traveler's perspective. *Level of service* (LOS) is a qualitative stratification of a performance measure or measures that represent quality of service. The LOS concept facilitates the presentation of results through the use of a familiar A (best) to F (worst) scale. LOS is defined by one or more service measures that both reflect the traveler perspective and are useful to operating agencies.

Three overarching concepts—quality of service, LOS, and service measures—are the subjects of this chapter.

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2. QUALITY OF SERVICE

Quality of service defined.

Quality of service describes how well a transportation facility or service operates from a traveler's perspective. Quality of service can be assessed in a number of ways. Among them are directly observing factors measurable by and important to travelers (e.g., speed or delay), surveying travelers, tracking complaints and compliments about roadway conditions, forecasting traveler satisfaction by using models derived from past traveler surveys, and observing services not directly perceived by travelers (e.g., average time to clear an incident) that affect measures they can perceive (e.g., speed or arrival time at work).

Factors that influence traveler perceived quality of service have been found to include

- Travel time, speed, and delay,
- Number of stops incurred,
- Travel time reliability,
- Maneuverability (e.g., ease of lane changing, percent time-spent-following other vehicles),
- Comfort (e.g., bicycle and pedestrian interaction with and separation from traffic; transit vehicle crowding; ride comfort);
- Convenience (e.g., directness of route, frequency of transit service);
- Safety (actual or perceived);
- User cost;
- Availability of facilities and services;
- Facility aesthetics; and
- Information readability (e.g., highway wayfinding signage, transit route and schedule information).

The HCM provides tools to measure the multimodal operational aspects of quality of service.

The HCM's scope, measuring the multimodal performance of highway and street facilities, is narrower than the list of quality of service aspects listed above. As discussed in Chapter 1, HCM User's Guide, companion documents to the HCM address highway safety, roadway design, and wayfinding signage, among other topics. The HCM focuses particularly on the travel time, speed, delay, maneuverability, and comfort aspects of quality of service, although a limited number of the HCM's performance measures address some of the other aspects listed above. Federal Strategic Highway Research Program 2 research that was programmed at the time this manual was written may add measures of travel time reliability to the HCM in the future.

LOS is an important tool used by the HCM to define quality of service.

The HCM provides a variety of performance measures in Volumes 2 and 3 to assess the quality of service of transportation system elements. These measures can be directly observed in the field or estimated from things observable in the field. LOS is the stratification of quality of service and is further described in the next part of this chapter.

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3. LEVEL OF SERVICE

DEFINITION

LOS defined

LOS is a quantitative stratification of a performance measure or measures that represent quality of service. The measures used to determine LOS for transportation system elements are called *service measures*. The HCM defines six levels of service, ranging from A to F, for each service measure, or for the output from a mathematical model based on multiple performance measures. LOS A represents the best operating conditions from the traveler's perspective and LOS F the worst. For cost, environmental impact, and other reasons, roadways are not typically designed to provide LOS A conditions during peak periods, but rather some lower LOS that reflects a balance between individual travelers' desires and society's desires and financial resources. Nevertheless, during low-volume periods of the day, a system element may operate at LOS A.

LOS is analyzed on an A–F scale. LOS A represents the best conditions from a traveler's perspective.

USAGE

LOS is used to translate complex numerical performance results into a simple A–F system representative of travelers' perceptions of the quality of service provided by a facility or service. The LOS letter result hides much of the complexity of facility performance. This feature is intended to simplify decision making on whether facility performance is generally acceptable and whether a future change in performance is likely to be perceived as significant by the general public. The language of LOS provides a common set of definitions that transportation engineers and planners can use to describe operating conditions; however, it is up to local policymakers to decide the appropriate LOS for a given system element in their community. One reason for the widespread adoption of the LOS concept by agencies is the concept's ability to communicate roadway performance to nontechnical decision makers. However, LOS has other strengths and weaknesses, described below, that both analysts and decision makers need to be mindful of.

LOS is a useful and widely adopted tool for communicating roadway performance to laypersons and decision makers. However, one should also be mindful of its weaknesses.

Step Function Nature of LOS

LOS is a step function. An increase in average control delay of 12 s at a traffic signal, for example, may result in no change in LOS, a drop of one level, or even a drop of two levels, depending on the starting value of delay, as illustrated in Exhibit 3-1.

From a traveler perception standpoint, the condition shown in Exhibit 3-1 is not necessarily inconsistent. A change of LOS indicates that roadway performance has transitioned from one given range of traveler-perceivable conditions to another range, while no change in LOS indicates that conditions have remained within the same performance range as before. Service measure values indicate where conditions lie within a particular performance range. However, because a small change in a service measure, or the output from a mathematical model based on multiple performance measures, can sometimes result in a change from one LOS to another, the LOS result could imply a more significant effect than actually occurred.

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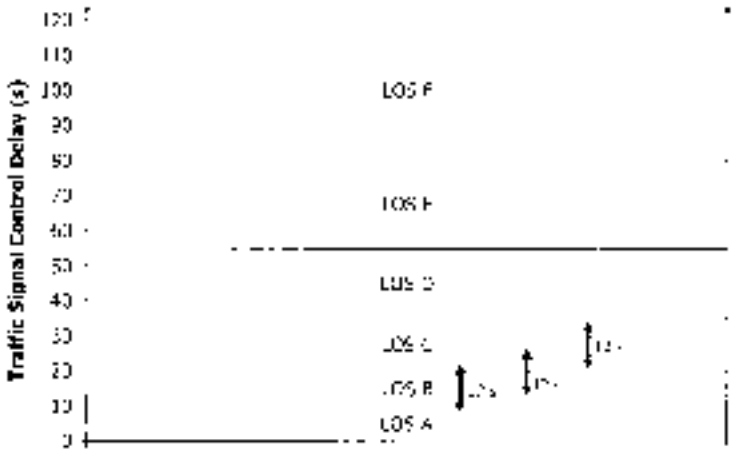
Exhibit 5-1
Example of the Step Function Nature of LOS



Identical changes in the service measure value may result in no change in LOS or a change of one or more levels of service, depending on how close the starting value is to a LOS threshold.

Use of LOS can be a particularly sensitive issue when agencies define their operational performance standards solely by using LOS. However, the definition of a level standard, whether numerically or as a LOS letter, always brings the possibility that a small change in performance can trigger the need for potentially costly improvements.

Defining performance standards on the basis of LOS for any facet (numerical value) means that even changes in performance can sometimes result in the standard being exceeded, when a facility is already operating close to the standard.

Variability of the Inputs to LOS

Although computer software that implements HCM methodologies can sometimes report results to many decimal places, three major sources of uncertainty influence service measure values and, thus, the LOS result:

1. The models used to estimate service measure values have confidence intervals associated with their outputs;
2. These models, in turn, rely on the output of other models that have their own associated confidence intervals; and
3. The accuracy of input variables, such as demand flow rate, is taken to be absolute when, in fact, there is a substantial stochastic variation around the measured values.

Chapter 7, Interpreting HCM and Alternative Tool Results, discusses sources of uncertainty and their impacts on analysis results in more detail.

Thus, any reported service measure value, whether resulting from an HCM methodology, an alternative tool, or even field measurement, potentially has a fairly wide range associated with it in which the "true" value actually lies. The LOS concept helps to downplay the implied accuracy of a numeric result by presenting a range of service measure results as being reasonably equivalent from a traveler's point of view. Nevertheless, the same variability issues also mean that the "true" LOS value may be different from the one predicted by a methodology. In addition, for any given set of conditions, different travelers may perceive their LOS to be different from one another, as well as different from the LOS estimated by an HCM method. One way of thinking about reported service measure values and the corresponding LOS result is that they are the statistical "best estimates" of conditions and aggregate traveler perceptions.

Models provide a best estimate of service measure values, but the "true" value may lie within a confidence interval range above or below the estimated value.

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Beyond LOS F

The HCM does not subdivide LOS F, but several measures are available to describe the severity of a LOS F condition.

The HCM uses LOS F to define operations that have either broken down (i.e., demand exceeds capacity) or have exceeded a specified service measure value (or combination of service measure values) that most users would consider unsatisfactory. However, particularly for planning applications where different alternatives may be compared, analysts may be interested in knowing just how bad the LOS F condition is. Several measures are available to describe numerically, or in combination, the severity of a LOS F condition:

- *Demand to capacity ratio* describes the extent to which capacity is exceeded during the analysis period (e.g., by 1%, 15%, etc.).
- *Duration of LOS F* describes how long the condition persists (e.g., 15 min, 1 h, 3 h).
- *Spatial extent* measures describe the areas affected by LOS F conditions. These include measures such as the back of queue and the identification of the specific intersection approaches or system elements experiencing LOS F conditions.

Separate LOS Reporting by Mode and System Element

LOS is reported separately by mode for a given system element.

LOS is reported separately for each mode operating on a given system element (although some other modes, such as large trucks, recreational vehicles (RVs), and motorcycles are currently considered members of the automobile mode for HCM analysis purposes). Each mode's travelers have different perspectives and potentially experience very different conditions while traveling along a particular roadway. Using a blended LOS risks overlooking quality of service deficiencies for nonautomobile travelers that discourage the use of those modes, particularly if the blended LOS is weighted by the number of modal travelers. Other measures, such as person delay, can be used when an analysis requires a combined measure.

Identical values of some service measures (e.g., delay) can produce different LOS results, depending on the system element to which the service measure is applied. The TRB Committee on Highway Capacity and Quality of Service (HCQS Committee) believes that travelers' expectation of performance varies at different system elements (e.g., unsignalized intersections versus signalized intersections), but realizes that further research is needed to understand fully the variation in traveler perceptions of LOS across facility types.

LOS as Part of a Bigger Picture

No single performance measure tells the full story of roadway performance.

Neither LOS nor any other single performance measure tells the full story of roadway performance. Depending on the particulars of a given analysis, queue lengths, demand-to-capacity ratios, average travel speeds, indicators of safety, quantities of persons and vehicles served, and other performance measures may prove as or even more important to consider, whether or not they are specifically called out in an agency standard. For this reason, the HCM provides methods for estimating a variety of useful roadway operations performance measures, and not just methods for determining LOS. Chapter 7, Interpreting

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HCM and Alternative Tool Results, lists the major performance measures available from each chapter of Volumes 2 and 3.

Duration of an operating condition can be important to know, since it helps describe the severity of the condition (e.g., the duration of a LOS F condition). In cases where demand exceeds capacity, duration must be known in order to set the analysis period long enough so that all demand is served and all relevant performance measures can be calculated properly. Frequency and probability of a particular condition occurring (e.g., likelihood or frequency of queue storage being exceeded during an analysis period) are also useful descriptors.

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4. SERVICE MEASURES

DEFINITION AND CHARACTERISTICS

Service measures reflect traveler perceptions and can be influenced by agency actions.

Service measures are performance measures used to define LOS for transportation system elements.

Ideally, service measures should exhibit the following characteristics:

- Service measures should reflect travelers' perceptions (i.e., measures should reflect things travelers can perceive during their journey);
- Service measures should be useful to operating agencies (e.g., agency actions should be able to influence future LOS);
- Service measures should be directly measurable in the field (e.g., an analyst wishing to determine LOS for a two-lane highway used for recreational access can go to the field and directly measure average travel speed); and
- Service measures should be estimable given a set of known or forecast conditions (e.g., a method is provided in Chapter 15 to estimate the average travel speed for a two-lane highway, given inputs for roadway and traffic conditions).

SERVICE MEASURE SELECTION

Service measure selection.

Historically, the selection of a service measure or measures for an analysis methodology has been based on the collective opinion and judgment of TRB's HCQS Committee. The service measure threshold values that identify the breakpoints between each level of service have also been determined by the HCQS Committee. This approach was necessary, because until recently little information was available on the subject of how travelers evaluate operating conditions. However, it has been the intent of the committee to select service measures that it felt would be highly correlated with travelers' personal assessments of the operating conditions. Since 1993, there has been considerable more research focused on determining appropriate service measures based directly on traveler input. While this area of research was still immature at the time of publication of this edition of the HCM, the HCQS Committee intends to monitor and evaluate future research in this area for potential inclusion in subsequent editions of the HCM.

Studies that seek to determine service measures and thresholds based on traveler perceptions obviously use research approaches that directly involve a sample of travelers. Some of the methods used to obtain this direct traveler input include in-field experiments (e.g., driving or riding courses), simulated in-field experiments (such as through the use of video presentations), focus groups, and surveys. The study participants are typically asked to rate the conditions they are presented with on a scale of "very good" to "very poor," or something similar. The qualitative ratings are later converted to numeric values for analysis purposes. Some challenges to these types of studies include designing the instrument (field experiment, focus group, etc.) to capture all of the roadway, traffic, and control factors that might affect travelers' perceptions of operating

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conditions; including factors that may not be relevant but could distract study subjects; recruiting an adequate sample of study participants from both a quantity and a diversity perspective; replicating desired conditions (for in-field experiments) for repeated observations; and accounting for the distribution of LOS responses that will result from each test scenario on the analysis methodology.

The advantage of this type of research approach is that, with application of an appropriate analysis methodology, multiple variables can be considered simultaneously, consistent with the high likelihood that travelers consider multiple factors when they evaluate the operating conditions. Including multiple factors also gives agencies more options in seeking to achieve a desired LOS for a given mode or in balancing the needs of various modes. All variables found to be statistically significant are incorporated into a mathematical function (more often referred to as a model). In the model, the coefficients (i.e., weighting factors) associated with each of the variables are determined directly through the statistical analysis. The output from such a model is a value often referred to as a LOS score. The LOS score value generally represents the average score that travelers would give a facility or service. Furthermore, some of the methodologies can directly estimate the threshold values that are used to distinguish between the LOS categories, again, on the basis of traveler input. To determine the LOS, the LOS score value is compared with the statistically estimated threshold values.

While variables representing any number of things can be included in this type of model, for models to be useful from a practical perspective, only variables representing operational or design conditions are usually included. Operational conditions refer to variables such as delay and speed (i.e., performance measures), while design conditions refer to variables such as median type and sidewalk presence. Traveler characteristics (e.g., age, gender, income) can certainly affect LOS perceptions; however, these data are difficult to collect in a transportation engineering situation. Thus, their study in a LOS model is limited.

Several methodological approaches have been applied to relate traveler perceptions directly to LOS, including regression-based methods (2–4), ordered probit models (5, 6), and fuzzy clustering (7). These studies have addressed facilities such as urban and rural freeways, arterial streets, and signalized intersections. LOS methods resulting from some of these studies have been included in the HCM 2010, while others have been studied by the HCQS Committee to improve the understanding of techniques used in estimating traveler-based LOS.

This edition of the HCM is the first to incorporate LOS methodologies that are based directly on results from traveler perceptions of LOS. As the field of traveler perception of LOS research continues to mature and results from regional studies are validated nationally, the HCQS Committee expects to continue to include these new LOS methodologies in future editions of the HCM. When research is not available to support traveler-perceived LOS methodologies,

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HCQS Committee–selected service measures and thresholds continue to be used in this edition of the HCM.

DETERMINATION OF LOS F

The threshold between LOS E and LOS F is based on the judgment of the HCQS Committee in some instances and is determined directly from research on traveler perceptions of LOS in others. One example of where the service measure and LOS thresholds were determined by the HCQS Committee is basic freeway segments; density was selected as the service measure and the LOS E–F density threshold value was selected as the density at which traffic flow transitions from uncongested to congested. Bicycling on urban streets is an example of where the service measures were determined from traveler perception of LOS research; the LOS E–F threshold was chosen as a value that represents the transition to a totally unacceptable condition (i.e., an average rider will not ride under these conditions). Thresholds between LOS A and F may be based on ranges of values that define particular operating conditions or may simply provide an even gradation of values from LOS A to F. As mentioned previously, in some studies on traveler perceptions of LOS, the methodological approach explicitly yields the model variables (e.g., speed, median presence) as well as the specific LOS thresholds. However, these thresholds are still a function of the total number of LOS categories originally included in the study.

The volume-to-capacity (v/c) ratio (or, more correctly, the demand-to-capacity, d/c, ratio) is a special-case service measure. It cannot be directly measured in the field, nor is it a measure of traveler perceptions. Until capacity is reached (i.e., when flow breaks down on uninterrupted-flow facilities and when queues build on interrupted- or uninterrupted-flow facilities), the v/c ratio is not perceivable by travelers. Therefore, the HCM often uses the v/c ratio to define the LOS E–F threshold, but not to define other LOS thresholds.

The v/c ratio is often used to define the LOS E–F threshold, but not other LOS thresholds

SERVICE MEASURES FOR SPECIFIC SYSTEM ELEMENTS

Cross-Cutting Issues

Automobile Mode

A facility's capacity to serve the automobile mode reflects the effects of all motorized vehicles using the facility, including trucks, RVs, motorcycles, and intercity buses. In contrast, LOS for the automobile mode reflects the perspective of automobile drivers and passengers, but not necessarily the perspectives of other motorized vehicle users. Although automobiles are usually the dominant motorized vehicle type on roadways, analysts should use care in interpreting LOS results at special cases, such as intermodal-terminal access routes, where trucks may dominate.

LOS for the automobile mode is reflective of automobile driver and passenger perspectives, but not necessarily those of other motorized vehicle users

Pedestrian and Bicycle Modes

Depending on local regulations, pedestrians and bicycles may be allowed on all types of uninterrupted-flow facilities, including sections of freeways. However, research is only available to support LOS estimation methods for bicyclists traveling on two-lane and multilane highways. Pathways that are

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Pathways parallel to freeways and multilane highways are analyzed by using the off-street facility procedures

parallel to freeways and multilane highways use the service measures for off-street pedestrian and bicycle facilities. Of the various types of interrupted-flow system elements, pedestrian and bicycle service measures are provided for urban street facilities, urban street segments, signalized intersections, and off-street pedestrian and bicycle facilities. Pedestrian LOS can also be calculated for two-way stop-controlled intersections and roundabouts.

Transit Mode

Bus service on uninterrupted-flow facilities typically serves longer distance trips, with few (if any) stops. The transit service measures provided in the *Transit Capacity and Quality of Service Manual* (TCQSM) (*8*) can be used to evaluate bus service along uninterrupted-flow facilities, as well as rail service operating within an uninterrupted-flow facility's right-of-way.

Transit service measures are provided only for urban streets. Consult the TCQSM for service measures for other situations.

The HCM provides transit service measures for urban street facilities and segments to facilitate multimodal comparisons of urban-street LOS. The TCQSM's service measures can be used to evaluate transit LOS at specific bus stops, for specific routes, for specific origin–destination pairs, and for specific areas. Some of the HCM's performance measures, such as delay, may also be useful in multimodal comparisons—for example, in comparing person-delay at an intersection with and without a transit preferential treatment, such as a queue jump lane.

Freeways and Multilane Highways

Automobile Mode

Density is the automobile service measure for all freeway and multilane highway system elements

Although travel speed is a major concern of drivers that relates to service quality, freedom to maneuver within the traffic stream and proximity to other vehicles are equally noticeable concerns. These qualities are related to the *density* of the traffic stream. Unlike speed, density increases as flow increases up to capacity, resulting in a service measure that is both perceivable by motorists and is sensitive to a broad range of flows. Density is used as the service measure for freeway facilities: basic freeway segments, ramp junctions, weaving segments, and multilane highways.

Bicycle Mode

Bicycle LOS for multilane highways is based on a bicycle LOS score model. The model uses variables determined from research that relate to bicyclists' comfort and perceived exposure while riding on multilane highways, such as separation from traffic, motorized traffic volumes and speeds, heavy-vehicle percentage, and pavement quality.

Higher vehicle volumes, a greater proportion of trucks and buses, and higher vehicle speeds all act to decrease a bicyclist's perceived comfort and traffic exposure. Striped bicycle lanes or roadway shoulders add to the perceived sense of traffic separation and improve the LOS. Pavement quality affects bicyclists' ride comfort: the better the pavement quality, the better the LOS.

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Two-Lane-Highway Measures

Automobile Mode

Density expectations for and travel conditions on basic freeway and different from those for other uninterrupted-flow facilities.

Traffic operations on two-lane, two-way highways differ from those on other uninterrupted-flow facilities. Lane changing and passing are possible only in the face of oncoming traffic. Passing demand increases rapidly as traffic volumes increase, and passing capacity in the opposing lane declines as volumes increase. Therefore, on two-lane highways, unlike other types of uninterrupted flow facilities, normal traffic flow in one direction influences flow in the other direction. Motorists must adjust their travel speeds as volume increases and the ability to pass declines.

Efficient mobility is the principal function of major two-lane highways that connect major traffic generators or that serve as primary links in state and national highway networks. These routes tend to serve long-distance commercial and recreational travelers, and long sections may pass through rural areas without traffic control interruptions. Consistent high-speed operations and infrequent passing delays are desirable for these facilities.

Other paved, two-lane rural highways are intended to serve primarily an accessibility function. Although beneficial, high speed is not the principal concern. Delay—as indicated by the formation of platoons—is more relevant as a measure of service quality.

Two-lane roads also serve scenic and recreational areas in which the vista and environment are meant to be experienced and enjoyed without traffic interruption or delay. A safe roadway is desired, but high-speed operation is neither expected nor desired. For these reasons, three service measures are used for two-lane highways: *percent time spent following*, *average travel speed*, and *percent free-flow speed*.

Percent time spent following defined.

Percent time-spent-following represents the freedom to maneuver and the comfort and convenience of travel. It is the average percentage of travel time that vehicles must travel in platoons behind slower vehicles because of the inability to pass. Percent time spent following is difficult to measure in the field. However, the percentage of vehicles traveling with headways of less than 3 s at a representative location can be used as a surrogate measure.

Average travel speed defined.

Average travel speed reflects the mobility on a two-lane highway. It is the length of the highway segment divided by the average travel time of all vehicles traversing the segment in both directions during a designated interval.

Percent of free-flow speed defined.

Percent of free-flow speed represents the ability of vehicles to travel at or near the posted speed limit.

LOS criteria use one or two of these measures. On major two-lane highways, for which efficient mobility is paramount, both percent time-spent-following and average travel speed define LOS. However, roadway alignments with reduced design speeds will limit the LOS that can be achieved. On highways for which accessibility is paramount and mobility less critical, LOS is defined only in terms of percent time spent following, without consideration of average travel speed. On two-lane highways in developed rural areas, LOS is defined in terms of percent of free-flow speed.

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Bicycle Mode

Bicycle LOS for two-lane highways is determined by a *bicycle* LOS score model in the same manner as described above for multilane highways, with the addition of on-highway parking as a factor that may exist on two-lane highways. The presence of on-highway parking negatively affects bicycle LOS because bicyclists tend to leave a buffer between themselves and parked vehicles, resulting in less separation between themselves and moving vehicles.

Urban Street Facility and Segment Measures

Automobile Mode

The service measure for the automobile mode on an urban street is the percent of base free-flow speed. Motorists traveling along arterial streets expect to be able to travel at or near the posted speed limit between intersections and to have to stop only infrequently. As delay due to traffic control devices and to other roadway users (e.g., vehicles stopped in a travel lane waiting to turn, buses stopping to serve passengers, or pedestrian crossings) increases, the lower the average speed and the lower the perceived LOS.

Research on automobile travelers' perceptions of LOS, as part of the National Cooperative Highway Research Program (NCHRP) 3-70 project, revealed that a combination of stops per mile and left-turn lane presence at signalized intersections had the highest statistical significance for predicting automobile LOS. However, the HCQS Committee elected to retain usage of a time-based service measure to analyze automobile LOS on urban streets for this edition of the HCM. The alternative NCHRP 3-70 methodology is also presented in Chapter 17, Urban Street Segments, since it is well suited for applications with a focus on determining multimodal LOS trade-offs and designing complete streets.

Urban street pedestrian LOS considers the quality of walking along a street, crossing at signalized intersections, and crossing the street between traffic signals.

Pedestrian Mode

Pedestrian LOS for urban streets is based on a *pedestrian* LOS score model that includes variables determined from research on pedestrians' perceptions of LOS. These variables relate to pedestrians' experiences walking along street segments between signalized intersections, crossing side streets at signalized intersections, and crossing the street between signalized intersections.

The segment component relates to both the density of pedestrians along the street and to pedestrian comfort and perceived exposure to traffic. The pedestrian-density indicator is a function of pedestrian volumes and sidewalk width, while the nondensity indicator is a function of separation from traffic due to distance and physical objects, sidewalk presence and width, and motorized traffic volumes and speeds. The worse of the two indicators is used to determine pedestrian-perceived segment LOS. The nondensity indicator is predominately used in suburban and rural settings.

The signalized-intersection component relates to pedestrian delay and perceived exposure to or interaction with traffic. The exposure elements of the calculation include potentially conflicting traffic volumes, parallel traffic volumes, parallel traffic speed, crossing width, and channelizing-island presence.

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The roadway-crossing component is a function of the lesser of the delay in waiting for a gap to cross the street and the delay involved in diverting to the nearest signalized intersection. It also incorporates the segment and signalized-intersection components, which relate to the quality of the pedestrian environment experienced when pedestrians divert to a signal, either because of lower delay or a prohibition on crossings between signalized intersections.

Overall, pedestrian LOS is improved by the provision of sidewalks, wider sidewalks, a greater degree of separation from traffic, and reduced delays crossing the street at both signalized and unsignalized locations. Higher traffic volumes, higher traffic speeds, and wider streets all tend to reduce pedestrian LOS.

Bicycle Mode

Bicycle LOS for urban streets is based on a bicycle LOS score model that includes variables determined from research on bicycle riders' perceptions of LOS. These variables relate to bicyclists' experiences at signalized intersections and their experiences on street segments between signalized intersections. The intersection component relates to bicyclist comfort and perceived exposure to traffic and is a function of separation from traffic, cross-street width, and motorized traffic volumes. The segment component similarly relates to comfort and perceived exposure. It is a function of separation from traffic, motorized traffic volumes, traffic speeds, heavy vehicle percentage, presence of parking, and pavement quality. The frequency of unsignalized intersections and driveways between traffic signals is also a factor in the LOS score value.

Urban street bicycle LOS considers the quality of bicycling along the street between traffic signals and the quality of passage through signalized intersections.

Higher vehicle volumes, a greater proportion of trucks and buses, higher vehicle speeds, and presence of parking all act to decrease a bicyclist's perceived comfort and traffic exposure. Striped bicycle lanes or roadway shoulders add to the perceived sense of traffic separation and improve the LOS. Pavement quality affects bicyclists' ride comfort: the better the pavement quality, the better the LOS.

Transit Mode

Transit LOS for urban streets is based on a transit LOS score model that includes variables determined from research on transit riders' perceptions of LOS. These variables relate to passengers' experiences walking to a transit stop on the street, waiting for the transit vehicle, and riding on the transit vehicle. The walking to the stop component is based on the street's pedestrian LOS score. Transit passengers are usually pedestrians before and after their transit trip, and improvements to the pedestrian environment along streets with transit service contribute to a better LOS. The waiting component is a function of the transit vehicle frequency (relating to wait time and trip-making convenience), service reliability (unplanned passenger waiting time at the stop), and the presence of shelters and benches (which make waiting more comfortable). Finally, the riding-on-the-vehicle satisfaction is a function of average travel speed (a convenience factor) and passenger loads (a comfort factor).

The transit service measure applies to bus, streetcar, and at-grade light rail services that make stops along an urban street.

The service measure combines traveler perceptions relative to a transit stop, waiting for a transit vehicle, and riding on the vehicle.

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Urban Street Intersections

Control delay is the automobile service measure for urban street intersections.

Automobile Mode

The service measure for the automobile mode at all urban-street intersections—including signalized intersections, all-way stop-controlled intersections, two-way stop-controlled intersections, roundabouts, and interchange ramp terminals—is *control delay*.

Control delay, which was defined in Chapter 4, Traffic Flow and Capacity Concepts, is a measure of driver discomfort, frustration, fuel consumption, and increased travel time. It depends on a number of variables, which are different depending on whether the intersection is signalized or unsignalized. As control delay increases, LOS worsens. The maximum control delay allowed for a given LOS at unsignalized intersections is lower than for signalized intersections due to differing driver expectations. In the HCQS Committee's opinion, the expectation of drivers is that a signalized intersection is designed to carry higher traffic volumes and experience greater delay than an unsignalized intersection.

Pedestrian, Bicycle, and Transit Modes

At the time of publication, there was insufficient research to be able to provide pedestrian and bicycle LOS for urban street intersections, except for signalized intersections and for pedestrians only—two-way stop-controlled intersections. The HCM provides transit LOS measures only at the urban street segment and facility levels.

Signalized Intersections

Pedestrian LOS at signalized intersections is based on a pedestrian LOS score model that incorporates conflicting motorized vehicle volumes and speeds, crosswalk length, average pedestrian delay, and the presence of right-turn channelizing islands. Pedestrian LOS improves with lower motorized vehicle volumes and speeds, shorter crosswalk lengths, lower delay, and the provision of right-turn channelizing islands.

Bicycle LOS at signalized intersections is based on a *bicycle LOS score* model that incorporates perceived separation from motorized vehicle traffic, motorized vehicle volumes, cross-street width, and presence and utilization of on-street parking. Bicycle LOS improves with greater perceived separation from motorized vehicle traffic, lower motorized vehicle volumes, shorter cross-street widths, and reduced on-street parking conflicts.

Two-Way Stop-Controlled Intersections

Pedestrian LOS at two-way stop-controlled intersections is based on average pedestrian *control delay* crossing the major street. Lower vehicle volumes, presence of a median, and provision of pedestrian crossing treatments that improve motorist yielding rates all help to improve pedestrian LOS.

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Off-Street Pedestrian and Bicycle Facilities

Pedestrian Mode

The service measure for off-street exclusive pedestrian facilities is pedestrian space.

Off-street facilities used exclusively by pedestrians (e.g., pedestrian pathways, plazas, and concourses) use pedestrian space as the service measure. As the space available to pedestrians increases, the ability to move at one's desired speed along one's desired line of travel increases. Therefore, as the space available to a pedestrian on an off-street facility increases, so does the LOS.

The pedestrian service measure for shared off-street facilities is the number of times per hour a pedestrian avoids or is passed by bicycles.

When an off-street facility is shared by pedestrians and bicycles, pedestrian quality of service is much more affected by the bicyclists using the facility than by other pedestrians because of the speed differential between the two types of travelers. Therefore, the pedestrian service measure for shared off-street facilities is based on avoids—the number of times per hour that a pedestrian is met by or passed by bicyclists. The greater the number of bicyclists on a shared facility, the lower the pedestrian LOS.

Bicycle Mode

The bicycle service measure for all off-street facilities is a bicycle LOS score.

Bicycle LOS for off-street bicycle facilities, both exclusive and shared, is based on a bicycle LOS score model that includes variables determined from research on bicyclists' perceptions of LOS. These variables consist of the number of times a bicyclist passes other path users per minute, the number of times per minute on average that a bicyclist passes or is delayed in passing other path users, the presence of a centerline, and the path width. As the number of other path users (including bicyclists) increases, the LOS declines. Wider paths and the presence of a centerline contribute to better LOS.

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CHAPTER 6
HCM AND ALTERNATIVE ANALYSIS TOOLS

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1. INTRODUCTION

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1. HCM User's Guide
2. Applications
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4. Traffic Flow and Capacity Concepts
5. Quality and Level-of-Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

It is well recognized that the models of the *Highway Capacity Manual* (HCM) are part of a continuum available to the analyst for highway capacity and quality-of-service analyses. For example, transportation planners and engineers have different needs in scope and level of detail. Planners focus on network performance in broad, general terms to understand supply–demand interactions between network capacity and flows. Of primary interest are the interactions of land uses and the transportation system. Engineers, in contrast, need to know how changes in the design of a specific system element or changes in the way it operates will affect its performance in terms of capacity, delays, queuing characteristics, and other measures. As a result, different traffic analysis tools are available to serve different analysis needs.

Chapter 6, HCM and Alternative Analysis Tools, begins by describing the HCM-based tools available to the analyst. In an *operations level analysis*, which is one such tool, HCM methodologies are applied directly and the user supplies all required inputs to the procedure. Many planning, preliminary engineering, and design applications do not require the level of accuracy provided by an operations analysis and substitute *default values* for some (or nearly all) of a methodology's inputs. *Generalized service volume tables* are sketch-planning tools that provide an estimate of the maximum volume a system element can carry at a given level of service (LOS), given a default set of assumptions about the system element. The use of local default values and local generalized service volume tables helps reduce the uncertainty in the results of analyses that use these tools, compared with using the HCM's national default values and tables. The chapter's two appendices provide guidance on developing local default values (Appendix A) and generating local generalized service volume tables (Appendix B).

Analysts might consider alternative tools as a supplement to HCM methods for a variety of reasons. Alternative tools might be considered in the following analyses, among others: those outside the range covered by an HCM methodology, those requiring performance measures not produced by the HCM, and those where the quantity of data required makes HCM methods impractical. To assist analysts in evaluating and applying alternative tools, this chapter describes traffic modeling concepts and terminology, identifies conceptual differences between analytical and simulation tools, provides a framework for applying alternative tools, and lists criteria to consider in the selection of a traffic analysis tool.

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2. HCM-BASED TOOLS

GENERALIZED SERVICE VOLUME TABLES

Service volume tables provide estimates of the maximum number of vehicles a system element can carry at a particular LOS, given a set of assumed conditions.

A service volume table provides an analyst with an estimate of the maximum number of vehicles that a system element can carry at a given LOS. The use of a service volume table is most appropriate in certain planning applications in which evaluation of every segment or node within a study area is not feasible. Examples of these applications are city, county, or statewide planning studies where the size of the study area makes a capacity or LOS analysis for every system element infeasible. For these types of planning applications, the focus of the effort is to highlight potential problem areas (for example, locations where demand may exceed capacity or where a desired LOS threshold may be exceeded). For such applications, a service volume table can be a useful sketch planning tool, provided the analyst understands the limitations of this method. Once potential problem areas have been identified, other tools (HCM-based or alternative) can be used to perform more detailed analyses on locations of interest.

As described in more detail in Appendix 3, generalized service volume tables are developed by holding constant all input values to a particular HCM methodology—except demand volume. Demand volume is increased until the measure of effectiveness (MOE) for the methodology reaches the threshold for a given LOS (e.g., the threshold between LOS B and C). That demand volume then becomes the service volume for the given LOS (in the example above, for LOS B). The service volume represents the maximum number of vehicles that the system element can carry at the given LOS, given the assumed inputs.

Service volume results should be applied with care. Since actual conditions will have ways in some way from the assumptions used to develop the table.

The characteristics of any given system element will likely vary in some way from the assumed input values used to develop a service volume table. Therefore, the results from a service volume table should be treated as rough approximations. Service volume tables should not be used as a substitute for other tools when a final determination of the operational adequacy of a particular roadway is made.

The assumptions built into a table may be average (or typical) values or conservative values. The given affects how results from the table are interpreted.

For ease of use, generalized service volume tables require a minimum of user inputs—typically, key design parameters that have the greatest influence on a facility's capacity and LOS, such as the number of lanes. Given these inputs, a user can then read the service volume for a given LOS directly from the table and compare it with the actual or forecast volume for a system element. A volume greater than the service volume for the desired LOS indicates the need for further analysis. Depending on the assumptions used to develop the table (i.e., average or typical values versus conservative values) and the sensitivity of the service volumes to the default values used, volumes somewhat less than the identified service volume (as much as 25% below the service volume in some cases) could also suggest the need for further analysis.

Service volumes can be sensitive to the choice of input values, depending on the particular methodology and input parameters.

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APPLICATION OF DEFAULT VALUES TO HCM METHODOLOGIES

Many planning, preliminary engineering, and design analyses apply HCM methodologies directly but use default values for some to many of the input parameters.

In most planning, preliminary engineering, and design applications of the HCM, an analyst applies an HCM methodology taken directly from one or more of the chapters in Volumes 2 and 3 but uses default values for some (or many) of the input parameters. These types of analyses are frequently used to evaluate or design for future operations. Therefore, not all of the input parameters required by an HCM methodology (e.g., heavy-vehicle percentage or peak hour factor) may be available or readily forecast. Default values can also be applied when current operations are evaluated as part of a screening effort, similar to the way service volume tables are applied. Because users have control over which input parameters are defaulted, the uncertainty of the analysis results is reduced compared with the application of a service volume table, which potentially reduces the number of problem areas flagged for further analysis.

Although the HCM provides default values for a number of methodologies, the analyst should be mindful that these values represent typical national values and that typical conditions within a state, region, or community may be different. When default values occur frequently in analyses, the use of local default values can help further reduce the uncertainty in the analysis results. Appendix A provides guidance on developing local default values.

OPERATIONS-LEVEL HCM ANALYSIS

Operations-level HCM analyses apply the HCM methodology directly and use no or minimal default values.

In an operations-level analysis, an analyst applies an HCM methodology directly from one or more of the chapters in Volumes 2 and 3 and supplies a full set of required input parameters from measured or forecast values. No or minimal default values are used. Therefore, compared with the generalized service volume tables and the application of default values, operations-level analyses provide the highest level of accuracy. However, as discussed in Chapter 7, Interpreting HCM and Alternative Tool Results, analysts must still account for variability, uncertainty, and measurement errors in input data, and their impact on the analysis outputs, in the interpretation of analysis results.

The chapters in Volumes 2 and 3 identify methodological limitations and special cases where analysts may wish to consider alternative tools.

An operations-level analysis is applicable to any situation covered by an HCM methodology. Analysts should refer to the Limitations of the Methodology and Special Cases sections of the HCM chapter that covers the system element being evaluated to ensure that the HCM methodology is appropriate for the specifics of the situation being studied. A situation that is outside the range of conditions covered by the methodology would be one reason for considering an alternative tool. Other cases when alternative tools might be considered are discussed in the next section.

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3. ALTERNATIVE TOOLS

OVERVIEW

Alternative tools include all non-HCM procedures that may be used to evaluate highway system performance.

Alternative tools include all analysis procedures outside of the HCM that may be used to compute measures of transportation system performance for analysis and decision support. Most alternative tools take the form of software products, and there is an abundance of literature describing alternative tools and their applications. The purpose of this section is to categorize the most commonly used tools, to identify the conditions under which they might be used to supplement the HCM procedures, and to suggest a framework and guidelines for their application that will maximize their compatibility with the HCM deterministic procedures. The intent is not to identify or compare specific tools or to duplicate the wealth of literature that exists on the general subject of traffic performance analysis.

This section describes the types of available tools (which are generally software products) but does not identify or compare specific tools.

Clearly, readers should use the material presented here in conjunction with other documents that also address analysis, modeling, and simulation of transportation systems. A considerable volume of authoritative information on this subject is available in the Federal Highway Administration's *Traffic Analysis Toolbox*. Four volumes of the *Toolbox* provide general guidance on the use of traffic analysis tools, including the HCM.

A useful reference on traffic operations modeling is the Federal Highway Administration's Traffic Analysis Toolbox.

- *Volume I: Traffic Analysis Tools Primer* (1) presents a high-level overview of the different types of traffic analysis tools and their role in transportation analyses.
- *Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools* (2) identifies key criteria and circumstances to consider in selecting the most appropriate type of traffic analysis tool for the analysis at hand.
- *Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software* (3) provides a recommended process for using traffic microsimulation software in traffic analyses.
- *Volume IV: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness* (4) describes the appropriate definition, interpretation, and computation of MOEs for traffic operations and capacity improvements. This report provides information and guidance on which MOEs should be produced, how they should be interpreted, and how they are defined and calculated in traffic analysis tools. The document recommends a basic set of MOEs that can help rapidly assess the current problems and the benefits of alternative improvements at the system level, in a form readily understandable by the decision maker.

Other volumes of the *Toolbox* deal with the application of alternative tools for specific application scenarios.

The material in this section focuses primarily on the automobile mode. The importance of other modes - particularly bicycles, pedestrians, and transit—is recognized, however, experience with the use of alternative tools to address these modes is limited. Some alternative tools address nonautomobile modes

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explicitly and some do not. The *Traffic Analysis Toolbox* (*1–3*) mentions the inability to deal with "interferences that can occur between bicycles, pedestrians, and vehicles sharing the same roadway" as a limitation of most simulation tools. Where appropriate, specific guidance is presented on the treatment of bicycles, pedestrians, and buses in the chapters of Volumes 2 and 3. The best source of guidance for the use of alternative tools for other modes is the detailed documentation and user's guide provided with tools that offer these features.

TRAFFIC MODELING CONCEPTS AND TERMINOLOGY

Hierarchy of Modeling Terminology

Modeling terminology has not been applied consistently throughout the realm of traffic analysis tools. For purposes of the HCM, the following terminology will be used to distinguish between different objects and processes that have been referred to in the literature simply as a "model."

- An *algorithm* is, by dictionary definition (*4*), "a set of rules for solving a problem in a finite number of steps." This definition suits the HCM's purposes.
- A *model* is, by dictionary definition (*5*), "a hypothetical description of a complex entity or process." Here is the root of the inconsistent usage. By this definition the word can be, and has been, applied to many different objects. A more focused definition is required. One definition in common use is that a model is "a representation of a system that allows for investigation of the properties of the system and, in some cases, prediction of future outcomes" (*6*). For HCM purposes, the term will be used in this sense but will be more precisely defined as "a procedure that uses one or more algorithms to produce a set of numerical outputs describing the operation of a highway segment or system, given a set of numerical inputs." By this definition, each of the performance analysis procedures specified in Volumes 2 and 3 constitutes a model. This term will generally be used with an adjective to denote its purpose (e.g., *delay model*).
- A *computational engine* is the software implementation of one or more models that produces specific outputs given a set of input data.
- A *traffic analysis tool*, often abbreviated in the HCM as a "tool," is a software product that includes, at a minimum, a computational engine and a user interface. The purpose of the user interface is to facilitate the process of entering the input data and interpreting the results.
- A *model application*, sometimes referred to as a *scenario*, specifies the physical configuration and operational conditions to which a traffic analysis tool is applied.

Inconsistency in terminology arises because each of these five objects has been characterized as a model in the literature, since each one satisfies the dictionary definition. The distinction between the five terms is made here in the hope of promoting more consistent usage.

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Additional Modeling Definitions

Another set of terminology that requires more precise definitions deals with the process by which the analyst ensures that the modeling results provide a realistic representation of the real world. The following terms are defined elsewhere (3):

- *Verification*. The process by which the software developer and other researchers check the accuracy of the software implementation of traffic operations theory. The extent to which a given tool has been verified is listed as an important tool selection criterion in this chapter.
- *Calibration*: The process by which the analyst selects the model parameters that cause the model to best reproduce field-measured local traffic conditions.
- *Validation*: The process by which the analyst checks the overall model-predicted traffic performance for a street–road system against field measurements of traffic performance, such as traffic volumes, travel times, average speeds, and average delays. Model validation is performed on the basis of field data not used in the calibration process.

Traffic Analysis Tool and Model Categories

The *Traffic Analysis Toolbox* identifies the following categories of traffic analysis models:

- *Sketch-planning tools* produce general order-of-magnitude estimates of travel demand and transportation system performance under different transportation system improvement alternatives.
- *Travel demand models* forecast long-term future travel demand on the basis of current conditions and projections of socioeconomic characteristics and changes in transportation system design.
- *HCM-based analytical deterministic tools* quickly predict capacity, density, speed, delay, and queuing on a variety of transportation facilities.
- *Traffic signal optimization tools* are primarily designed to develop optimal signal phasing and timing plans for isolated signalized intersections, arterial streets, or signal networks.
- *Macroscopic simulation models* are based on the deterministic relationships of the flow, speed, and density of the traffic stream.
- *Microscopic simulation models* simulate the movement of individual vehicles on the basis of car following and lane changing theories.
- *Mesoscopic models* combine the properties of microscopic and macroscopic simulation models.
- *Hybrid models* employ macroscopic and mesoscopic models simultaneously. These tools are intended to be applied to very large networks containing critical subnetworks connected by several miles of essentially local facilities. Microscopic modeling is applied to the critical subnetworks, while the connecting facilities are modeled at the

Hybrid models, used with very large networks, apply macroscopic modeling to critical subnetworks and mesoscopic or macroscopic modeling to the connecting facilities.

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meso-analytic or macroscopic level. Regional evaluation models are a typical example of hybrid model application.

Stochastic and Deterministic Models

A *deterministic* model is not subject to randomness. Each model run will produce the same outcome. If these statements are not true and some attribute of the model is not known with certainty, the model is *stochastic*. Random variables will be used to represent those attributes of the model not known with certainty. Descriptions of how these random numbers are selected to obtain sample values of the parameter of interest (i.e., from its cumulative distribution function) can be found in various texts (e.g., 7–10). Different random number sequences will produce different model results; therefore, the outcome from a simulation tool based on a stochastic model cannot be predicted with certainty before analysis begins. Stochastic models and the user in interpreting variability and uncertainty into the analysis.

The HCM's methodologies are deterministic: given the same set of inputs, the methods will produce the same result each time.

Most simulation models are stochastic: given identical inputs but a different random number seed, model runs will produce different results.

Static Flow and Time-Varying Flow Models

The terms *static flow* and *time-varying flow* relate to the temporal characteristics of the traffic flows in the simulation model. Basically, the terms differentiate between a model that uses constant traffic flow rates from one time period to another and a model that does not. This differentiation is not to be confused with whether the model can represent internally time-varying flows that occur because of simulated events (e.g., incidents, signal cycling, ramp metering, high occupancy vehicle lane closures). The difference is in the type of input flows that can be specified.

In static flow models, users provide a single set of flow rates. The model may vary headways, but the O-D matrix is fixed and does not change throughout the duration of the analysis.

Time-varying models allow flow rates to change with time. Users supply more than one set of flow rates so that the O-D matrix can vary over time. Most models change flows once an hour, but some allow more frequent changes.

In the static flow case, traffic flows are provided just once as a set of constants. A tool may vary the individual headways stochastically, but the flow rates are fixed. Put another way, the origin-destination (O-D) matrix is fixed and does not change throughout the duration of the analysis.

In the time-varying case, flow rates can change with time. More than one set of flow rates must be specified so that the O-D matrix can vary over time. The flexibility of specifying more than one set of flow rates is particularly useful when major surges in traffic need to be examined, such as the unloading of a special event or peak periods when a pronounced variation in traffic flows exists.

Descriptive and Normative Models

The terms *descriptive* and *normative* refer to the objective of performing the analysis with a simulation models. If the objective of the model is to describe how traffic will behave in a given situation, the model is most likely to be descriptive. It will not try to identify a preferred set of parameters that provide the best system performance but rather will show how events will unfold given a logic that describes how the objects involved will behave. For example, a simulation model could predict how drivers will behave in response to traffic flow conditions. A model attempting to shape that behavior by trying to force drivers to maintain specific headways would not be a descriptive model.

Descriptive models show how events unfold given a logic that describes how the objects involved will behave.

Normative models try to identify a set of parameters that provide the best system performance.

Normative models try to identify a set of parameters that provide the best system performance. An external influence (most often referred to as an objective

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functionality to force the system to behave in some optimal way. A good example is a model that tries to optimize signal timings. Another illustration is a freeway network model that requires drivers to alter their path choices to optimize some measure of system performance. In both cases, the behavior of the system is modified through an external influence, probably on an iterative basis, to create a sequence of realizations in which the objective function value is improved, as in minimizing total travel time or total system delay.

The distinction can be restated this way: if the model has an objective and seeks to optimize that objective, it is a normative model. Conversely, if it has an objective but does not seek to optimize that objective by changing the design or operational parameters (e.g., signal timing), it is a descriptive model.

Traffic assignment models are a special case, because they are based on an objective that is gradually improved over a sequence of iterations. In this case, the objective is for each driver to minimize either the travel time for the trip or some other quantitative measure of the general cost or disutility associated with the trip. Traffic assignment models are characterized as either static or dynamic, depending on whether the O-D characteristics are constant or time-varying. Most simulation tools have some form of dynamic traffic assignment (DTA). Because of its demands on computer resources, DTA is often implemented at the mesoscopic level. DTA models are often embedded in traffic microsimulation tools.

DTA models are a special case of descriptive models that are based on an objective (minimize the travel time or disutility associated with a trip) that is gradually improved over a sequence of iterations until the network reaches a state of equilibrium.

The optimization process may be characterized as either *system-optimal* or *user-optimal*. A user-optimal solution does not necessarily produce an optimal result for the system as a whole and vice versa. With user-optimal models, the objective being applied reflects a behavioral assumption, and therefore the model is primarily descriptive. System-optimal models enforce some changes in driver behavior and are therefore normative. The formulation of the generalized cost (disutility) function can be expanded to reflect actual driving behavior more accurately—for example, by taking into account the number of stops or the driver's familiarity with typical traffic conditions.

The important point is that the analyst needs to know which type of model is being used and how that type influences the model's predictions. For example, assume that the analyst is dealing with a scenario in which the signal timings are fixed and drivers can alter their path choices in response to those signal timings (in a way that replicates how they would actually behave). This is a descriptive model, and is a common application of a DTA model as mentioned above. Even though the analyst can change the signal timings and see how the drivers respond (and how the system performance changes), the model is still describing how the system would behave for a given set of conditions. On the other hand, if the analyst alters the scenario so that it seeks a better set of signal timings, a normative model has been created.

A descriptive model is implied if the analyst introduces a new demand–supply paradigm, such as congestion pricing, based on a field study. A new demand-side routine could be developed to predict how drivers alter path choices in response to congestion prices, and a supply-side routine could be developed that seeks to set those prices in some responsive and responsible way.

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in an effort to produce a desirable flow pattern. Even though two competing optimization schemes are at work, each describes how a portion of the system is behaving in response to inputs received. There is an explicit intent to optimize the system performance in a specific manner.

CONCEPTUAL DIFFERENCES BETWEEN DETERMINISTIC AND SIMULATION TOOLS

There are some conceptual differences between the HCM's analytical modeling and simulation modeling. It is useful to examine these differences before addressing alternative tool applications. Most of the differences may be described in terms of the way analytical and simulation tools deal with various traffic flow phenomena. Examples of the significant differences are identified in general terms in Exhibit 6-1.

APPROPRIATE USE OF ALTERNATIVE TOOLS

Situations where alternative tools might supplement HCM procedures.

Using alternative tools to supplement HCM capacity and quality-of-service procedures should be considered when one or more of these conditions apply:

- The configuration of the facility has elements that are beyond the scope of the HCM procedures. Each procedural chapter identifies the specific limitations of its own methodology.
- Viable alternatives being considered in the study require the application of an alternative tool to make a more informed decision.
- The measures produced by alternative tools are compatible with corresponding HCM measures and are arguably more credible than the HCM measures.
- The measures are compatible with corresponding HCM measures and are a by-product of another task, such as optimization of a network traffic control system.
- The measures are compatible with corresponding HCM measures and the decision process requires additional performance measures, such as fuel consumption and emissions, which are beyond the scope of the HCM.
- The system under study involves a group of different facilities on travel routes with mutual interactions invoking several procedural chapters of the HCM. Alternative tools are able to analyze these facilities as a single system.
- Routing is an essential part of the problem being addressed.
- The quantity of input or output data required presents an intractable problem for the HCM procedures.
- The HCM procedures predict oversaturated conditions that last throughout a substantial part of a peak period or queues that overflow the available storage space, or both.

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Exhibit 6–1
Comparison of Methods for Addressing Traffic Phenomena by the HCM and Typical Microsimulation Tools

Traffic Phenomenon	Deterministic (HCM) Treatment	Typical Microsimulation Treatment
Right-turn on red	Subtract right-turn-on-red volume from demand	Microscopic model of gap acceptance and follow-up time
Permitted left turns	Empirical model of capacity versus opposing volume, with minimum capacity determined by an assumption of two sneakers per cycle	Microscopic model of gap acceptance and follow-up time
STOP sign entry	Macroscopic model of gap acceptance and follow-up time	Microscopic model of gap acceptance and follow-up time
Channelized right turns	Subtract right-turning volume from demand	Microscopic model of gap acceptance and follow-up time, implicit effects of right-turn queues
Ramp merging	Empirical model of merge capacity versus freeway volume in the two outside lanes	Microscopic model of gap acceptance and follow-up time (some tools incorporate cooperative merging features)
Merging during congested conditions	Not addressed	Microscopic model of gap acceptance
Lane-changing behavior	Macroscopic model based on demand volumes and geometrics	Microscopic model of lane changing behavior
Queue start-up or green	Fixed start-up lost time subtracted from the displayed green time	Stochastic lost time applied to the first few vehicles in the departing queue
Response to change interval	Fixed extension of green time added to the displayed green time	Kinematic model of stopping probability
Actuated signal operation	Deterministic model for computing green times as a function of demand and operating parameters	Embedded logic emulates pretimed/actuated control logic, tools vary in the level of emulation detail
Delay accumulation	Analytical formulation for uniform delay based on the assumption of uniform arrivals over the cycle and uniform departures over the effective green	These three effects are combined implicitly in the accumulation and discharge of individual vehicles over the analysis period
Progression quality	Adjustment factor applied to the uniform delay term	
Random arrivals	Analytical formulation for incremental delay	
Generation of vehicles	Incremental delay formulation assumes Poisson arrivals (mean = variance) at the stop line; the variance-to-mean ratio is reduced for traffic-actuated control as a function of the unit extension	Individual vehicles are introduced into entry links randomly, on the basis of a specified distribution
Effect of oversaturation	A third analytical formulation, d_3, is introduced to cover the additional delay due to an initial queue	Oversaturated operation and residual queues are accounted for implicitly in the accumulation and discharge of individual vehicles
Residual queue at the end of analysis period	Analytical formulation computes the residual queue when $d/C > 1.0$; the residual queue from one period becomes the initial queue for the next period	

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In addition, when a specific HCM procedure has been developed by using simulation results as a surrogate for field data collection, it might be appropriate to use the underlying simulation tool directly to deal with complex configurations that are not covered in the HCM.

The following are factors to consider in the decision to use an alternative tool:

- Is the use of the alternative tool acceptable to the agency responsible for approving the decisions that result from its use?
- Are the necessary resources, time, and expertise available to apply the alternative tool?
- Does the application rely on a traceable and reproducible methodology?
- Have assumptions used to apply the tool been sufficiently documented?
- Is sufficient time available for calibration to promote a robust reliance on the model output?
- Are sufficient and appropriate data available to capitalize on or leverage the strength of the alternative tool?
- Are the alternative tool's performance measures (output) defined and computed in a manner consistent with the specifications given in Chapter 7, Interpreting HCM and Alternative Tool Results?

Exhibit 6-2 provides examples of typical alternative tool applications for various situations that occur with both interrupted and uninterrupted flow conditions. Corridor and areawide analyses are also addressed. In this exhibit HCM procedures, which focus on points on the roadway and on linear roadway systems, tend to have limitations that are best addressed by tools that explicitly model corridors and areawide transportation systems.

For corridor and areawide analysis, aggregation of the results from Volume 2 and Volume 3 procedures requires an intractable amount of data and effort. The interaction between individual facilities cannot be accounted for by HCM procedures. DTA might be required to balance flows among facilities and to model congestion propagation through the network due to oversaturation. Examples of promising alternative tool applications include active traffic management (ATM), congestion pricing, and freight corridors.

Alternative tool applications may be most appropriate for the evaluation of ATM measures that address operating conditions not explicitly addressed by HCM procedures. ATM consists of the dynamic and continuous monitoring and control of traffic operations on a facility. Examples of ATM measures include congestion pricing, managed lanes, ramp metering, changeable message signs, incident response, and speed harmonization (variable speed limits).

More information on ATM strategies and their evaluation can be found in Chapter 35, Active Traffic Management.

ATM measures, because of their dynamic nature, cannot be adequately modeled with HCM procedures. HCM procedures assume steady-state demand and control conditions within the typical minimum 15 min analysis period. Alternative tool applications that model traffic operations and interactions with traffic controls at the minute-by-minute level will be more accurate than HCM procedures that model operations at the higher level of temporal aggregation.

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Exhibit 6-2
Typical Applications for Alternative Traffic Analysis Tools

HCM Chapter	Typical Alternative Tool Application
Typical Applications in Volume 2: Uninterrupted Flow	
Applicable to all uninterrupted flow procedures	Bottlenecks Oversaturated flow analysis Time-varying demands Unbalanced lane use Special lane restrictions Surveillance, work zones
10. Freeway Facilities	Managed lanes Surface street traffic control and ramp metering
11. Basic Freeway Segments	See uninterrupted-flow situations above
12. Freeway Weaving Segments	Complex weaving areas
13. Freeway Merge and Diverge Segments	Ramp metering High-occupancy vehicle ramp lanes
14. Multilane Highways	See uninterrupted flow situations above
15. Two-Lane Highways	Combination of terrain and traffic characteristics such as presence of passing lanes or coefficient of variation of desired speeds
Typical Applications in Volume 3: Interrupted Flow	
Applicable to all interrupted-flow procedures	Oversaturated flow analysis (except for signalized intersections) Bus activity On-street parking Special lane use Queue spillback Pedestrian–bicycle interactions
16. Urban Street Facilities	Multimodal system analysis
17. Urban Street Segments	Mix of signals and no signals (stop and yield) Effects of midblock bottlenecks Signal timing plan development Turn bay overflow
18. Signalized Intersections	Geometrically offset intersections Alternative arrival characteristics Phase skips Pedestrian actuation Timing plan development
19. Two-Way STOP-Controlled Intersections	Two-way left turns Yield-controlled intersection delay TWSC intersection on a signalized arterial
20. All-Way Stop-Controlled Intersections	AWSC intersection on a signalized arterial
21. Roundabouts	Roundabout on a signalized arterial Multilane roundabouts Effect of geometrics Mixed-mode traffic
22. Interchange Ramp Terminals	Full cloverleaf interchange Back up from freeway segments Long-term (i.e., multicycle) blockage of approaches
23. Off-Street Pedestrian and Bicycle Facilities	Limit of modeling of pedestrian crossing activity

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APPLICATION FRAMEWORK FOR ALTERNATIVE TOOLS

A wide range of tools is available for application to most highway capacity and performance analysis situations. Each tool has certain inputs and outputs, some of which can support a productive flow of information between tools. This section discusses the classes of tools that are available to address different types of system elements and suggests a framework for their application. Since the application framework differs among system elements, each element will be discussed separately. In developing input data for all these elements, it is important to reflect local default values.

Freeways

The modeling framework for freeways is presented in Exhibit 6-3. Each of the tools and procedures can be used in a stand-alone fashion; the potential flow of information between them indicates how they might fit into an overall analysis structure.

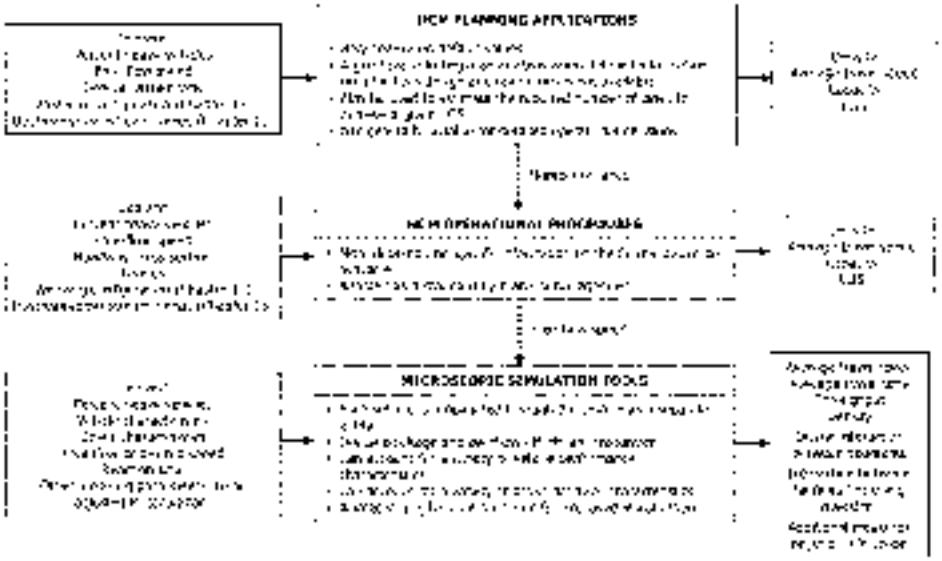

Exhibit 6-3
Freeway Modeling Framework for the HCM and Alternative Tools

The principal classes of tools are

- The HCM planning applications, which rely heavily on default values for parameters;
- The HCM operational applications that require more detailed inputs in place of the default parameter values; and
- Microscopic simulation tools, as described previously in this chapter.

Tools available for modeling freeways include HCM planning procedures, HCM operational procedures, and microscopic simulation.

Alternative tools find a much stronger application to freeway facilities than to individual freeway segments.

Most HCM freeway analysis limitations are apparent when the freeway is analyzed as a facility consisting of multiple segments or different types (basic segments, ramps, weaving segments, etc.) by using the procedures given in Chapter 10, Freeway Facilities. Alternative tools, especially microsimulation tools, find a much stronger application to freeway facilities than to individual segments.

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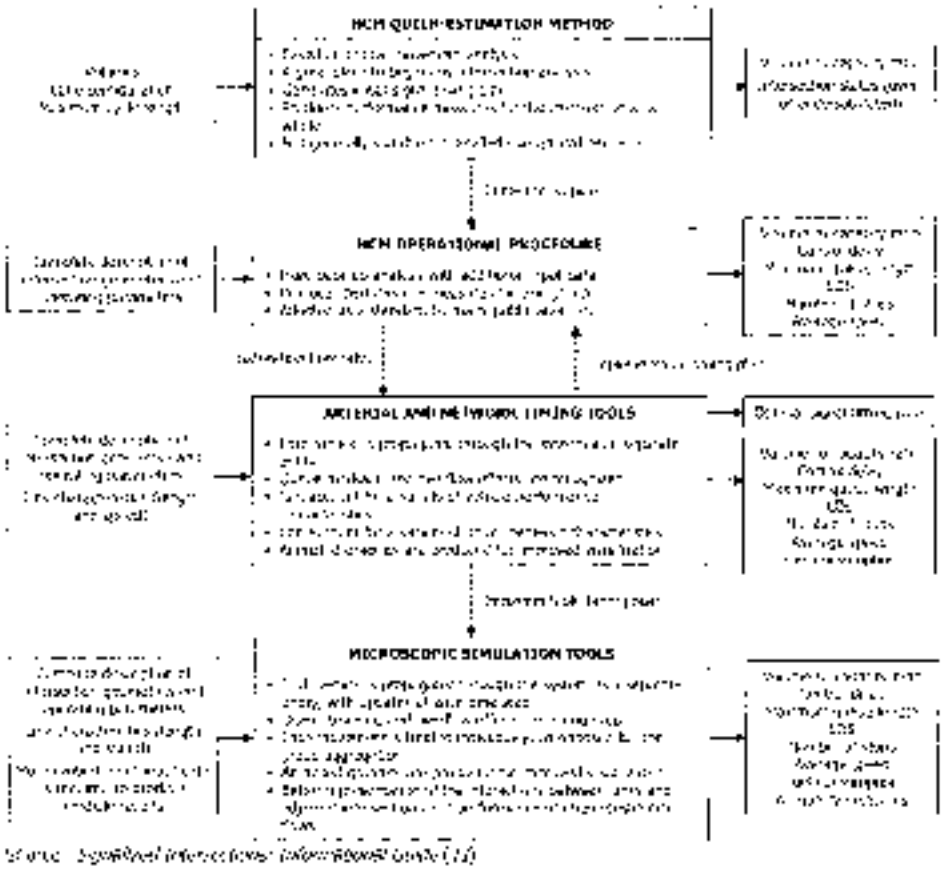
Urban Streets

Tools available for modeling urban streets include the HCM quick-estimation method for signalized intersections, HCM operational methods, arterial and network signal-timing tools, and microscopic simulation.

The modeling framework for urban streets, including their intersections, is presented in Exhibit 6-4. Each of the tools and procedures can be used in a stand-alone fashion; the potential flow of information between them indicates how they might fit into an overall analysis structure. The principal classes of tools are

- The HCM quick-estimation method for signalized intersections, which is based primarily on critical movement analysis and default values;
- The HCM operational methods for urban streets, including all types of intersections, which require more detailed traffic inputs and operating parameters;
- Arterial and network signal-timing tools, which produce recommended signal-timing plans based on measures that are generally similar to those produced by the HCM procedures; and
- Microscopic simulation tools, as described previously in this chapter.

Exhibit 6-4
Urban Street Modeling Frameworks for the HCM and Alternative Tools



Source: *Signalized Intersections: Informational Guide* (1)

Signal-timing tools generate signal-timing plans that can be used as inputs to HCM operational methods or to microsimulation tools.

Signal-timing tools are mostly based on macroscopic analytical models of traffic flow. Because they are the only class of urban street analysis tool that generates a signal timing plan as output, they are frequently used as an alternative tool for this purpose. The signal timing plan may be fed into the HCM operational analysis or used as input to a microsimulation tool.

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Microsimulation tools are used in urban street analysis, mainly to deal with complex intersection phenomena beyond the limitations of the HCM. These tools evaluate interactions between arterial segments, including the effect of various types of unsignalized intersections. They are also applied in evaluating networks and corridors with parallel facilities with the use of DTA routines.

Microsimulation tools are used to deal with complex intersection interactions beyond the limitations of the HCM.

Two-Lane and Multilane Highways

At this point, there is minimal application of alternative tools for the analysis of either type of highway. The HCM is the only macroscopic deterministic tool in common use, although some states such as Florida have developed their own analysis tools that implement derivatives of HCM procedures (12). At the time of writing, microsimulation models were in various stages of development. Some two-lane highway simulation tools were beginning to emerge, but there was insufficient experience to provide guidance for their use as an alternative to the methodology provided here.

At the time of writing, the HCM was the only deterministic tool in common use for two-lane and multilane highways.

Corridor and Areawide Analysis

Corridor and areawide analysis is an important application for alternative tools. The HCM procedures deal mainly with points and segments and are limited in their ability to recognize the interaction between segments and facilities. The overall modeling framework for corridor and areawide analysis is presented in Exhibit 6-5, which shows the relationship of the HCM to the broad field of corridor and areawide analysis models.

Corridor and areawide analysis is probably the most important application for alternative tools.

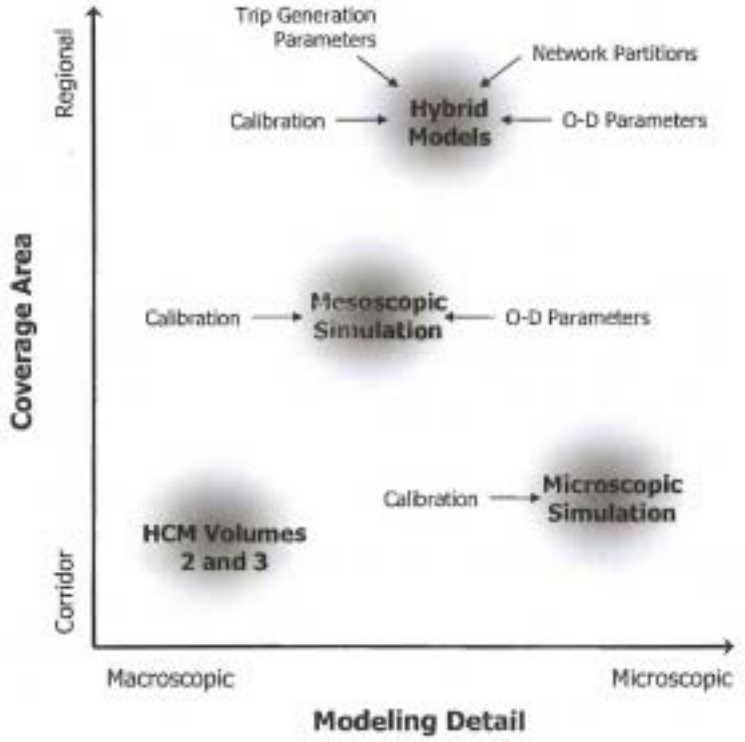

Exhibit 6-5
Corridor and Areawide Analysis Modeling Framework for the HCM and Alternative Tools

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An excellent reference for corridor and areawide simulation (13) is emerging from a U.S. Department of Transportation research initiative on integrated corridor modeling, providing detailed guidance on the conduct of large-scale simulation projects. This section presents an overview of corridor and areawide simulation from the perspective of HCM users, but considerably more detailed information is presented in the report (13), including a more detailed analysis framework.

The framework for corridor and areawide analysis differs from the framework presented for freeways and urban streets in three ways:

1. The HCM procedures account for a much smaller part of the modeling framework.
2. Different levels of simulation modeling are represented here. Simulation of urban streets and freeways is typically performed only at the microscopic level.
3. The framework is two-dimensional, with the coverage area as one dimension and the modeling detail as the other.

The selection of a model class (microscopic, mesoscopic, or hybrid) reflects a trade-off between coverage area and modeling detail.

The various model classes shown in Exhibit 6-5 depict the trade-off between these characteristics. The trade-off between coverage area and modeling detail is evident:

- Microscopic simulation provides more detail and more coverage than the HCM procedures. The additional detail comes from the microscopic nature of the model structure. The additional coverage comes from the ability to accommodate multiple links and nodes.
- Mesoscopic simulation provides more coverage with less modeling detail than microscopic simulation. In addition to accommodating larger areas, mesoscopic models are computationally faster than microscopic models and are thus well suited to the iterative simulations required for DTA, which can be time-consuming.
- Hybrid modeling uses network partitioning to treat more critical parts of the system microscopically and less critical parts mesoscopically—or even macroscopically. In this way, the regional coverage may be expanded without losing essential detail. A typical application for hybrid modeling might be interurban evacuation analysis, which must accommodate a very large geographical area without loss of detail at critical intersections and interchanges.

Some examples of corridor modeling are presented in Volume 4 of the HCM.

PERFORMANCE MEASURES FROM ALTERNATIVE TOOLS

The tool selected for a given analysis needs to provide performance measures that realistically reflect the attributes of the problem being studied.

Before the analyst can select the appropriate tool, the performance measures that realistically reflect attributes of the problem under study must be identified. For example, when oversaturated conditions are studied, it is necessary to use a tool that quantifies the effects of queuing as well as stops and delay. If the methodologies presented in Volumes 2 and 3 do not provide a particular performance measure of interest to the analyst (e.g., fuel consumption and emissions), an alternative tool might be required. Exhibit 6-6 provides a

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summary of important performance measures for the procedures discussed in Volumes 2 and 3. The applicability of the HCM procedures and alternative tools is indicated for each chapter in this exhibit.

Exhibit G-6
Principal Performance Measures from the HCM and Alternative Tools

Uninterrupted-Flow Chapters (Volume 2)								
HCM Chapter	Speed	Delay	Through-put	Density	% Time Spent Following	Passing/ Overtaking	Environ-mental	Demand/ Capacity
10. Freeway Facilities	H, A	H, A	H, A	H, A	X	X	H	X
11. Basic Freeway Segments	H, A	A	H, A	H, A	X	X	A	–
12. Freeway Weaving Segments	H, A	A	H, A	H, A	X	X	A	–
13. Freeway Merge and Diverge Segments	H, A	A	H, A	H, A	X	X	A	H
14. Multilane Highways	H, A	A	H, A	H, A	X	X	A	–
15. Two-Lane Highways	H, A	–	A	A	H	H, A	A	–

Interrupted-Flow Chapters (Volume 3)								
HCM Chapter	Delay	Stops	Through-put	Queue Length	Cycle Failure	Environ-mental	Speed	Demand/ Capacity
16. Urban Street Facilities	H, A	A	H, A	H, A	A	A	H, A	H
17. Urban Street Segments	H, A	A	H, A	H, A	A	A	H, A	H
18. Signalized Intersections	H, A	A	–, A	H, A	A	A	X	–
19. TWSC Intersections	H, A	A	–, A	H, A	X	A	A	–
20. AWSC Intersections	H, A	A	H, A	H, A	•	A	A	H
21. Roundabouts	H, A	A	H, A	H, A	•	A	A	–
22. Interchange Ramp Terminals	H, A	A	H, A	H, A	A	A	X	H
23. Off-Street Pedestrian and Bicycle Facilities	X	X	X	X	X	•	H	H (pedestrian)

Notes: Applicability codes:
- H: Performance measures computed by the HCM methodology (HCM methodology is the most appropriate for these performance measures).
- A: Performance measure computed by alternative tools (mostly simulation-based).
- X: Performance measures do not apply to this chapter.

TWSC: Two-way stop-controlled. AWSC: All-way stop-controlled.

Source: Adapted from Dowling et al. [5].

When an alternative tool is used to analyze highway capacity and quality of service, its performance measures should ideally be compatible with those prescribed by the HCM. Chapter 7 provides general guidance on this topic, while selected chapters in Volumes 2 and 3 provide specific guidance for certain system elements.

If an alternative tool is used to analyze highway capacity and quality of service, then the performance measures generated by the tool should, to the extent possible, be compatible with those prescribed by the HCM. Alternative tools frequently apply the same terminology to performance measures as the HCM, but divergent results are often obtained from different tools because of differences in definitions and computational methods. General guidance on reconciling performance measures is given in Chapter 7, Interpreting HCM and Alternative Tool Results. More specific guidance on dealing with performance measures from alternative tools is given in several of the procedural chapters in Volumes 2 and 3.

TRAFFIC ANALYSIS TOOL SELECTION CRITERIA

The success of a traffic analysis project depends on the selection of the best tool or tools for the purpose, followed by the proper application of the selected tools. Both of these issues are addressed in detail in the *Traffic Analysis Toolbox*, and the guidance provided in the *Toolbox* should be studied thoroughly before a major traffic analysis project is undertaken.

Determining Project Scope

Questions to ask during the scoping of a traffic analysis project.

A properly defined problem and project scope are essential prerequisites to the correct selection of tools or procedures for the project. Answers to the following questions will assist in scoping the project:

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1. What is the operational performance problem or goal of the study?
2. Does the network being studied include urban streets, freeways, rural highways, or any combination of them?
3. Are multiple routes available to drivers?
4. What are the size and topology (isolated junctions, linear arterial, grid) of the network?
5. What types of roadway users (cars, carpools, public transit vehicles, trucks, bicycles, pedestrians) should be considered?
6. What traffic control methods (regulatory signs, pretimed signals, actuated signals, real-time traffic-adaptive signals, and ramp metering signals) should be considered?
7. Should oversaturated traffic conditions be considered?
8. Does the network involve specialized traffic control or intelligent transportation system (ITS) features that are not covered by the HCM?
9. What is the duration of the analysis period?
10. Do the geometric conditions of the roadway facility change during the analysis period?
11. Does the traffic demand fluctuate significantly during the analysis period?
12. Does the traffic control change during the analysis period?
13. What output and level of detail are anticipated from the tool?
14. What information is available for model input, model calibration, and validation?
15. Are multiple methods available for consideration in the analysis?

Assessing HCM Methodologies

Use the Limitations of the Methodology and Special Cases sections of volume 2 and 3 chapters to assess the appropriateness of the HCM methodology for a given analysis

Another essential step in the analysis tool selection process is to assess the capability of the existing HCM methodologies and to determine whether these methodologies can be applied (in whole or in part) to the issues that were raised in the scoped-scoping step. In addressing these issues, two main questions should be answered: What are the limitations of the HCM methodologies? Can the limitations be overcome? Limitations of the existing HCM methodologies for each facility type are identified in the procedural chapters of Volumes 2 and 4 of this manual. If it is determined that an alternative tool is needed or advisable, then the most appropriate tool must be selected.

Selecting a Traffic Analysis Tool

Every traffic analysis tool, depending on the application, has its own strengths and weaknesses

Each analytical or simulation model, depending on the application, has its own strengths and weaknesses. It is important to relate relevant model features to the needs of the analysis and determine which tool satisfies those needs to the greatest extent. Both deterministic and simulation-based tools could be candidates for overcoming HCM limitations. In most cases, however, deterministic tools will exhibit limitations similar to the HCM procedures, which

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are also deterministic. Deterministic tools also tend to work at the same macroscopic level as the HCM. The main applications for alternative deterministic tools fall into the following categories.

- Signal-timing plan design and optimization,
- Proprietary deterministic models that offer features not found in the HCM,
- Proprietary tools that exchange data with other traffic analysis software, and
- Roundabout analysis tools that deal with geometric and operational parameters beyond the scope of the HCM.

Simulation tools will generally be chosen to deal with situations that are too complex to model as a deterministic process. The balance of this discussion deals primarily with microscopic simulation tools.

Model Development Environment and Process

The manner in which the modeling logic was developed is an important consideration in the selection of a traffic analysis tool. The credibility of results from a simulation model depends on the process by which it was designed, implemented, and tested. A comprehensive document [14] describes "a formal process used to verify the model's reproducibility of traffic conditions in the development of a traffic flow simulation model." The intent is to prescribe a set of requirements to which all tools should conform. There is no attempt to compare the merits of different tools.

The proper simulation model development process is described in terms of the following steps. The desirable attributes of each of these steps are described:

- Determination of model specifications,
- Conformance of the model operation principles,
- Programming and debugging,
- Verification using virtual data, and
- Verification using actual data.

The traffic phenomena to be modeled through simulation are identified, and the theoretical basis for dealing with each one in a traffic model is described:

- Generation of vehicles,
- Bottleneck capacity or saturation flow rate at a link's downstream end,
- Driving and elimination of breakdown and shock wave propagation speed,
- Capacity of the merge/diverge area and the merge/diverge ratio,
- Decrease in the left-turn capacity due to opposing traffic in a signalized intersection, and
- Route selector behavior.

Users who are unfamiliar with the operation of their candidate simulation tools may wish to consult this document for informational purposes.

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Key model features to consider

Model Capabilities

A review of modeling capabilities is probably the most important aspect of selecting a simulation tool. Simulation model results may be of no value if the model is not capable of addressing the project-scoping issues raised in the initial step. Some key features can be used to evaluate a model's capabilities, such as size of network, network representation, traffic representation, traffic composition, traffic operations, traffic control, and model output.

- *Size of network.* Most tools limit the size of network that can be analyzed and the number of vehicles that can be accommodated. The key network parameters limited by the tool include number of nodes, number of links, number of lanes per link, and number of signalized or signal-controlled intersections.
- *Network representation.* Network representation refers to the tool's ability to represent the network geometrics for urban streets, freeways, rural highways, or any combination, ranging from simple intersections to grid networks. For urban streets, major geometric elements include lane channelization at intersections, turning pockets, and bus bays and stops. For freeways, major geometric elements are acceleration lanes, deceleration lanes, auxiliary lanes, on-ramps, off-ramps, lane additions, lane drops, horizontal curvature, and grade. Elements for rural highways include grade, curvature, passing and no-passing zones, and sight distance for overtaking and passing.
- *Traffic representation.* The representation of lane traffic flows in the model, especially the level of aggregation, is an important consideration. Because of their microscopic and stochastic nature, microscopic models can simulate sophisticated vehicle movements, allowing analysts to perform complex traffic analyses such as those for weaving areas. In contrast, mesoscopic and macroscopic models are generally not appropriate for evaluating complex traffic conditions, since they use aggregate measures of flow or density to describe vehicle movements.
- *Traffic composition.* Traffic composition represents the mix of cars, buses, trucks, carpools, and bicycles in the network and is used to incorporate the differences in performance characteristics among types of vehicles and modes. Special attention needs to be given to the selection of the analysis tool when networks with dedicated accommodation for nonautomobile modes are involved.
- *Traffic operations.* The model should be capable of representing real-world traffic operations such as ramp merging, diverging, and weaving maneuvers at interchanges, high occupancy-vehicle lanes, bus transit operations, lane channelization at intersections, lane restrictions, lane blockages, and parking activities.
- *Traffic control.* For street intersections, control methods include yield signs, two-way STOP signs, all-way STOP signs, pretimed signals, actuated signals, real-time traffic-adaptive control signals, and traffic-responsive control systems. Those commonly used for freeway on-ramps include pretimed control, demand and capacity control, occupancy control, speed

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control, high occupancy vehicle priority at ramps, integrated (network) ramp control, ramp-metering optimization, and dynamic real-time ramp-metering control with flow prediction capabilities. Signal coordination between traffic signals or between on-ramp signals and traffic signals on adjacent streets may also need to be considered.

- *DTA features.* When a network involves multiple routes that present a choice to the driver, the model must employ dynamic assignment logic to distribute the vehicles over the available paths in a realistic way. Simulation models offer varying degrees of DTA formulation and may allow for various influencing factors to be included in the decision process to reflect driver behavior. DTA models are discussed in more detail later in this chapter.
- *Other ITS devices.* In addition to the ITS elements in the traffic control category, tools may be able to model the effects of other ITS devices, such as in-vehicle navigation systems, dynamic message signs, incident management, small work zones, or intervehicle communication technologies.
- *Real-time process control features.* Many tools offer the ability to communicate directly with other processes invoked in either hardware or software. Examples include intersection signal controllers and large-scale network traffic management systems. Most highway capacity analysis projects will not require features of this type. However, when complex networks with ITS elements are involved, the ability of a simulation tool to communicate directly with the outside world might become a significant factor in the selection of the proper tool.

Above all, the analyst should review the user's guide for the selected tool to get a more detailed description of its characteristics.

User Interface

User interface considerations

The user interface includes all of the features of a tool that supply input data from the user to the model and output data from the model to the user. Simulation tools vary in the nature of their user interface. To some extent, the suitability of the user interface is a matter of individual preference. However, a highly developed user interface can offer a better level of productivity for larger and more repetitive tasks. Selection criteria related to the user interface include

- The amount of training needed to master its operation,
- The extent to which it contributes to productive model runs,
- The extent to which it is able to import and export data between other processes and databases, and
- Special computational features that promote improved productivity.

The following are the principal elements associated with the user interface:

- *Inputs.* Most of the inputs required by the model will be in the form of data. In most cases, the input data will be entered manually. Most tools offer some level of graphic user interface to facilitate data entry. Some tools also offer features that import data directly from other sources.

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- *Outputs.* Two types of outputs are available from simulation tools: graphics files and static performance measures. Graphics files provide graphics output, including animation, so that users can visually examine the simulation model results. Static performance measures provide output for numerical analysis. Both types of outputs may be presented directly to the user or stored in files or databases for postprocessing by other programs.
- *Multiple-run support.* The stochastic nature of simulation models requires multiple runs to obtain representative values of the performance measures. Chapter 7, Interpreting HCM and Alternative Tool Results, provides guidance on the number of runs required under specific conditions. The ability of a tool to support multiple runs is an important selection criterion. Multiple-run support includes processing functions that perform a specified number of runs automatically and postprocessing functions that accumulate the results from individual runs to provide average values and confidence intervals.

Consider the kind of data required and the availability of the data in selecting a tool.

Data Availability

The next criterion identifies data requirements and potential data sources so that the disparity between data needs and data availability can be identified. In general, microscopic models require more intensive and more detailed data than do mesoscopic and macroscopic models. Three different types of data are required to make the application of the traffic simulation model successful: data for model input, data for model calibration, and data for model validation.

Data for Model Input

The basic data items required to describe the network and the traffic conditions to be studied can be categorized into four major groups:

1. *Transportation network data.* Simulation tools incorporate their network's representation into the user interface, and some differences are observed among different tools. Most simulation models use a link-based scheme in which links represent roadway segments that are connected in some manner. The required link data include endpoint coordinates, link length, number of lanes per link, lane additions, lane drops, turning pockets, lane channelization at intersections, grade, and horizontal curvature. The connector data describe the manner in which the links are connected, including the permissible traffic movements, type of control, and lane alignment.
2. *Traffic control and ITS data.* Detailed control data should be provided for all control points, such as street intersections or freeway on- and off-ramps. Sign controls include YIELD signs, two-way STOP signs, and all-way STOP signs. Signal controls include pretimed signals, actuated signals, or real-time traffic-adaptive signals. Ramp-metering control methods include all of the modes described earlier. Timing data are required for all signal controls. Detector data such as type and location of the detector are required for actuated and traffic-adaptive signals. Any special ITS

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features involved in a project will create a need for additional data describing their parameters.

3. *Traffic operations data.* To represent the real-world traffic environment, most simulation tools take link-specific operations data as input, such as parameters that determine roadway capacity, lane use, lane restriction, desired free-flow speed, high-occupancy-vehicle lanes, parking activities, lane blockages, and bus travel operations.
4. *Traffic demand data.* Different tools may require traffic demand data in different formats. The most commonly used demand data are traffic demand at the network boundary or within the network, traffic turning percentages at intersections or freeway junctions, O-D trip tables, path-based trips between origins and destinations, and traffic composition.

Data for Model Calibration

Calibration adjusts a model's vehicle, driver, and other characteristics so that the model can reasonably represent the traffic environment being analyzed.

Calibration was defined previously as the process by which the analyst selects the model parameters that cause the model to best reproduce field-measured local traffic operations conditions. Vehicle and driver characteristics, which may be site-specific and require calibration, are the key parameters. These data take the form of scalar elements and statistical distributions that are represented by the model. In general, simulation models are developed and calibrated on the basis of limited site-specific data. The development data may not be transferable and therefore may not accurately represent the local situation. In that case, the model results should be interpreted with caution, and the default parameters that must be overridden to better reflect local conditions should be identified. Most simulation tools allow the analyst to override the default driver behavior data and vehicle data to better match local conditions, thereby allowing for model calibration. The calibration process should be documented, traceable, and reproducible to promote a robust analysis.

1. *Driver behavior data.* Driver behavior is not homogeneous, and thus different drivers may behave differently in the same traffic conditions. Most microscopic models represent stochastic or random driver behavior (from passive to aggressive drivers) by taking statistical distributions of behavior-related parameters such as desired free-flow speed, queue-discharge headway, modeling parameters for lane changing and car following, and driver response to advance information and warning signs.
2. *Vehicle data.* Vehicle data represent the characteristics and performance of the types of vehicles in the network. Different vehicle types (e.g., cars, buses, single-unit trucks, semitrailers) have different characteristics and performance attributes. They vary in terms of vehicle length, maximum acceleration, maximum deceleration, emissions rate, and fuel consumption rate. All traffic simulation tools provide default vehicle characteristics and performance data. These data need to be overridden only when the local vehicle data are known to be different from the default data provided by the tool or when the default values do not provide reasonable results.

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Data Sources

Data collection is costly. Analysts should explore all possibilities to leverage previously collected data. The analyst should identify which data are currently available and which data need to be collected in the field. Most static network, traffic, and control data can be collected from local agencies. Such data include design drawings for geometrics, signal timing plans, actuated controller settings, traffic volume and pattern, traffic composition, and transit schedules.

Ease of Use

Simulation models use assumptions and complex theories to represent the real-world dynamic traffic environment. Therefore, an input–output graphical display and debugging tools that are easily understandable are important criteria to consider in selecting a tool. Although ease of use is important in a simulation tool, the fact that a particular tool is easy to use does not necessarily imply that it is the correct choice. The following five criteria can be considered in assessing the ease of use of a simulation tool:

- *Preprocessor*: input data handling (user-friendly preprocessor);
- *Postprocessor*: output file generation for subsequent analysis;
- *Graphic displays*: graphic output capabilities, both animated and static;
- *Online help*: quality of online help support; and
- *Calibration and validation*: ability to provide guidelines and data sets for calibration and validation.

Required Resources

The following issues with regard to resources should be addressed in selecting a traffic analysis tool:

- *Costs of the tool*: Examples are costs for data collection and input preparation, hardware and software acquisition, and model use and maintenance.
- *Staff expertise*: Intelligent use of the tool is the key to success. The analyst should understand the theory behind the model to eliminate improper use and avoid unnecessary questions or problems during the course of the project.
- *Technical support*: Quality and timely support are important in the acquisition of a tool.

User Applications and Past Performance

Credibility and user acceptance of a tool are built on the tool's past applications and experiences. No tool is error-free when first released, and all require continuous maintenance as well as periodic enhancements.

Verification and Validation

It is important to assess how extensively a given model has been verified. In many cases, but not all, simulation models are also validated as part of the formulation and development process. Certainly those that have been validated

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are nominally better to use than those that have not been validated. Generally, models that have been in use for some time are likely to have been assessed and validated by various researchers or practitioners who are using them. It is useful to look for evidence of validation in professional journals and periodicals.

APPLICATION GUIDELINES FOR SIMULATION TOOLS

This section presents general guidance for the use of simulation-based traffic analysis tools for capacity and performance analysis. More detailed guidance for the application of these tools to specific facilities is presented in the procedural chapters of Volumes 2 and 3. Additional information, including sample applications, may be found in Volume 4 and in the *Traffic Analysis Toolbox* (*5*) mentioned earlier in this chapter.

After the project scope has been determined and the tool has been selected, several steps are involved in applying the tool to produce useful results.

Assembling Data

Data assembly involves collecting the data required (but not already available) for the selected tool. Data collection is costly. Analysts should capitalize on previous modeling efforts and identify data available through local agencies. When existing data are assembled, users should develop a comprehensive plan for collecting data that are missing. In some cases, a pilot data collection effort may be needed to ensure that the developed data collection plan is workable before a full-scale effort is conducted.

An important part of the data assembly process is a critical review of all data items to ensure the integrity of the input data set. Of special concern are the continuity of traffic volumes from segment to segment and the distribution of turning movements at intersections and ramp junctions. Each data item should be checked to ensure that its value lies within reasonable bounds.

Entering Data

Once all required data are in hand, the next step is to create the input files in a format required by the selected tool. The following are the most commonly used methods for creating input files.

- *Importing from a traffic database.* Many analysts have large amounts of data in a variety of formats for the general purpose of traffic analysis. Such databases can be used to create input files.
- *Converting from the existing data of other tools.* Many traffic models use the same or similar data for modeling purposes so that these data may be shared. Some traffic simulation tools are accompanied by utility programs that allow the user to convert data into input files required by other tools.
- *Entering the data from scratch.* Many traffic analysis tools have their own specific input data preprocessors, which aid the analyst with input data entry and review. These advanced features of the input data preprocessor eliminate cumbersome coding efforts. In addition, some input preprocessors include online help features.

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Calibrating and Validating Models

The model should be run with the data set describing the existing network and traffic scenarios (i.e., the baseline case), and the simulation results should then be compared with the observed data collected in the field." The primary objective of this activity is to adjust the parameters in the model so that simulation results correspond to real-world situations.

Several critical issues must be addressed when an initial simulation model run is constructed for the baseline case. First, the model should be able to represent the initial state of the traffic environment before any statistics can be collected for analysis. Second, the model should be long enough to cover the entire analysis period. Third, if the model can handle time-varying input, the analyst should specify, to the extent possible, the dynamic input conditions that describe the traffic environment. For example, if 1 h of traffic is to be simulated, the analyst should always specify the variation in demand volumes over that hour at an appropriate level of detail rather than specifying average, constant values of volume.

Finally, the analyst should know how to interpret the simulation model results, draw inferences from them, and determine whether they constitute a reasonable and valid representation of the traffic environment. Given the complex processes taking place in the real-world traffic environment, the user must be alert to the possibility that the model's features may be deficient in adequately representing some important process; that the specified input data, calibration, or both are inaccurate or inadequate; that the results provide a level of insufficient detail to meet the project objectives; that the statistical analysis of the results is flawed (as discussed in the following section); or that the model has bugs or that some of its algorithms are incorrect, thereby necessitating revision. If animation displays are provided by the model, this option should always be exercised to identify any anomalies.

If the simulation model results do not reasonably match the observed data collected in the field, the user should identify the cause-and-effect relationships between the observed and simulated data and the calibration parameters and perform calibration and validation of the model. Information on calibration and validation of models may be found in the *Freeway Analysis* Section (F-3) and in the references listed in Volume 4.

Special Considerations for DTA

The term "traffic assignment" traditionally refers to the process of computing path demands, or path input flows, given a network and an O-D demand matrix (trip table). In macroscopic simulation models, this process is implemented as a route-choice model that is executed independently for each driver (vehicle) in the simulation. Using explicit routes to move vehicles through the simulation obviates the use of turning proportions at nodes. Routes and route flows may also be implicitly represented in a model by splitting rates, which are turning proportions at nodes by destination. Route flows can have a significant impact on model outputs such as LOS, since they play a key role in determining the local traffic demand on any given section of road.

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Regardless of the implementation, traffic assignment is the way in which travel demand is defined in the form of an OD matrix (static or time-varying) and multiple routes are available for some OD pairs. It is particularly relevant when congestion affects the travel times on some of these routes. DTA produces time-varying path flows (or splitting rates) by using a dynamic traffic model that is either mesoscopic or microscopic. DTA models normally permit the demand matrix to be time-varying as well. The assignment model (routing decision) is based on a specific objective, which is predominantly the minimization of travel time, but will also take other factors such as travel cost (e.g., tolls or congestion pricing) and travel distance into consideration.

A fundamental issue concerning the role of travel time in route choice is that the actual travel time from origin to destination cannot be known in advance; it results from the collective route choices of all the drivers. Thus, the input to the routing decision (travel time) depends on the decision itself (route choice), forming a logical cycle. This type of problem can be solved with an iterative algorithm that repeats the simulation several (or many) times over, imitating the day-to-day learning process of drivers in the real world. At each iteration (or "day") the assignment is adjusted until the route-choice decisions are consistent with the experienced travel times; this is referred to as the user-optimal solution. In practice, an approximation to the user-optimal route flows is often determined by using a "one-pass" (noniterative) assignment in which drivers repeatedly reevaluate their routes during a single simulation run. The choice of method depends on network characteristics and modeling judgment.

The assignment (routing) component of a DTA model may be deterministic or stochastic in nature, independent of whether the traffic model is deterministic or stochastic. In general, both approaches can produce good results as long as they produce route choices that are consistent with the routing objective, for example, the minimization of generalized travel cost. The generalized cost is determined from the combination of a range of factors, such as travel time, travel distance, and direct costs (e.g., tolls), by applying relative weights to each of these factors, which typically differ by user class.

DTA applications are not trivial. Whereas single-route applications are typically implemented by one analyst, DTA applications to large-scale systems are more likely to involve a team of analysts with a broader range of skills and experience. A comprehensive reference on DTA has been created by the Transportation Research Board's Committee on Network Modeling [15].

Analyzing Output

Proper output analysis is one of the most important aspects of any study using a simulation model. A variety of techniques are used, particularly for stochastic models, to arrive at inferences that are supportable by the output.

When the model is calibrated and validated, the user can conduct a statistical analysis of the simulation model results for the baseline case with calibration parameters. If the selected simulation model is stochastic in nature, simulation model results produced by a single run of the model represent only point estimates of the sample population. Typical goals of data analysis using output

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from stochastic-model experiments are to present point estimates of the performance measures and to form confidence intervals around these estimates. Point estimates and confidence intervals for the performance measures can be obtained from a set of replications of the system by using independent random number streams. The analyst should refer to previous studies for details on the design and analysis of stochastic simulation models in the *Traffic Analysis Toolbox* (*7*, *8*) and in Volume 4 of the HCM.

Analyzing Alternatives

When satisfactory simulation model results are obtained from the baseline case, the user can prepare data sets for alternative cases by varying geometry, controls, and traffic demand. If the model is calibrated and validated on the basis of the observed data, values of the calibrated parameters should also be used in the alternatives analysis, assuming that driver behavior and vehicle characteristics in the baseline case are the same as those in the alternative cases.

Traffic simulation models produce a variety of performance measures for alternatives analysis. As discussed previously, the user should identify what model performance measures and level of detail are anticipated. These performance measures, such as travel time, delay, speed, and throughput, should be quantifiable for alternatives analysis. Some tools provide utility programs or postprocessors, which allow users to perform the analysis easily. If animation is provided by the tool, the user can gain insight into how each alternative performs and can conduct a side-by-side comparison graphically.

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APPENDIX A: DEVELOPING LOCAL DEFAULT VALUES

Default values are generally used for HCM applications that do not require the accuracy provided by a detailed operational evaluation.

A default value is a constant to be used in an equation as a substitute for a field-measured (or estimated) value. Default values can be used for input parameters or calibration factors. The value selected should represent a typical value for the conditions being analyzed. Default values are generally used for planning, preliminary engineering, or other applications of the HCM that do not require the accuracy provided by a detailed operational evaluation (*A-1*). They can be applied to any of the modes addressed by the HCM.

Default values should not be applied for input variables that can significantly influence the analysis results.

Local default values can be developed by conducting measurements of "raw data" in the geographic area where the values are to be applied. Typically, default values are developed for roadway or traffic characteristics to identify typical conditions of input variables for planning or preliminary engineering analysis. Default values should not be applied for input variables that can significantly influence the analysis results. For interrupted-flow facilities, these sensitive input variables include peak hour factor, traffic signal density, and percent heavy vehicles. For uninterrupted-flow facilities, these sensitive input parameters include free-flow speed, peak hour factor, and specific grade. In developing generalized service volume tables for daily service volumes, the *K*- and D factors selected must be consistent with measured local values.

When local default values are developed, the raw data should be collected during the same time periods that will be used for analysis—typically during weekday peak periods. In some cases, the peak 15 min period is recommended as the basis for computation of default values because this time period is most commonly used for capacity and LOS analysis.

Input parameters that describe the facility type, area type, terrain type, and geometric configuration (such as lane width, segment length, and interchange spacing) are usually available to the analyst. Default values for these parameters should not be used.

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This reference can be found in the Technical Reference Library in Volume 4.

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APPENDIX B: DEVELOPING LOCAL SERVICE VOLUME TABLES

INTRODUCTION

This appendix focuses on the automobile mode. To the extent that modal analysis is an input to nonautomobile mode LOS procedures, the material could also be applied to nonautomobile modes.

As discussed in the body of this chapter, service volume tables can provide an analyst with an estimate of the maximum number of vehicles a system element can carry at a given LOS. The use of a service volume table is most appropriate for certain planning applications in which evaluation of every segment or node within a study area is not feasible. Once potential problem areas have been identified, other HCM tools can be used to perform more detailed analyses for just those locations of interest.

To develop a service volume table, the analyst needs to develop a default value for each of the input parameters. The choice of default value can have a significant impact on the resulting service volume for a given LOS. For this reason, great care should be used to develop default values that the analyst believes are most appropriate for the local condition. When results are particularly sensitive to a particular input parameter, a range of default values should be considered for that parameter. The application of sensitivity analyses is discussed in more detail in Chapter 7, Interpreting HCM and Alternative Tool Results.

A specific roadway's characteristics are unlikely to match exactly the default values used to generate a service volume table. Therefore, conclusions drawn from such tables should be considered to be rough approximations.

When the service volume table is applied, it is important to recognize that not all of the input parameters for the various roadway segments being evaluated are likely to match the default inputs. Accordingly, conclusions drawn from the application of service volume tables should be considered to be, and presented as, rough approximations.

TABLE CONSTRUCTION PROCESS

Service volume tables can be generated for a given system element by selecting appropriate input parameter values and applying software to back-solve for the maximum volume associated with a particular LOS. The procedure is as follows (Ref. 7):

1. Determine all of the nonvolume default values to be used in developing the service volume table (e.g., number of lanes, peak hour factor, percentage of heavy vehicles, area type, *K*- and *D*-factors), in accordance with the guidance in Appendix A. Repeat the following steps for each system element and area category.
2. Identify the threshold value associated with the system element's MOE for LOS A by using the LOS exhibit in the Volume 2 or Volume 3 chapter that covers that system element. For example, a density of 11 pc/mi/ln is the maximum density for LOS A for a basic freeway segment.
3. Compute the MOE for a volume of 10 veh/h for an hourly volume table, or 100 veh/h for a daily volume table. If the result exceeds the LOS A threshold value, then LOS A is unachievable. Repeat Steps 2 and 3 for the next LOS (e.g., LOS B) until an achievable LOS is found, then continue with Step 4.

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4. Adjust the input volume until the highest volume that achieves the LOS is found. Test volumes should be a multiple of at least 10 for hourly volume tables and a multiple of at least 100 for daily volume tables. If the table is being constructed by manually applying software, the analyst can observe how closely the MOE result is converging toward the LOS threshold value and can select a test volume for the next iteration accordingly. If the table generation function is being added to software, the automated method described below can be used to converge on the service volume progressively.
5. Identify the threshold value for the next LOS and repeat Steps 4 and 5 until threshold volumes (or unachievability) have been determined for each LOS.
6. If a daily volume table is being created, divide the identified hourly threshold volumes by the selected *K*- and *D*-factors and round down to a multiple of at least 100.
7. If desired, change the input value used for one of the input parameters (e.g., number of lanes) and repeat Steps 2 through 5 as many times as needed to develop service volumes for all desired combinations of input values.

The following is an automated method for finding threshold values:

1. Let the first achievable test volume be labeled Vol 1.
2. Select a second iteration volume (label this Vol 2) by doubling Vol 1.
3. Compute the MOE value for Vol 2.
4. If the resulting MOE value is lower than the LOS threshold, replace Vol 1 with Vol 2 and select a new Vol 2 with double the current Vol 2 value. Repeat Steps 3 and 4 until the MOE result is greater than the desired LOS threshold.
5. Use the bisection method described below (*B-1*) or another more efficient numerical method to converge on the service volume.
6. Compute the volume halfway between Vol 1 and Vol 2. Label this volume Vol 3.
7. Compute the MOE value for Vol 3.
8. If the MOE result for Vol 3 is greater than the desired LOS threshold, replace Vol 2 with Vol 3.
9. If the LOS result for Vol 3 is lower than the desired LOS threshold, replace Vol 1 with Vol 3.
10. Is the range between Vol 1 and Vol 2 acceptable? If yes, stop and use the average of Vol 1 and Vol 2. If not, repeat Steps 6 through 9.
11. If an hourly volume table is being generated, round down the result of Step 10 to a multiple of at least 10. If a daily volume table is being generated, divide the result of Step 10 by the selected *K*- and *D*-factors and round the result down to a multiple of at least 100.

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This reference can be found in the Technical Reference Library in Volume 4

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CHAPTER 7
INTERPRETING HCM AND ALTERNATIVE TOOL RESULTS

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1. INTRODUCTION

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2. Applications
3. Modal Characteristics
4. Traffic Flow and Capacity Concepts
5. Quality and Level-of-Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Errata
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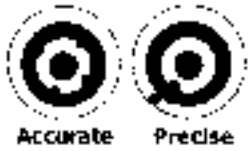
Uncertainty, sensitivity, accuracy, and precision are related concepts that need to be considered when interpreting and presenting model results



The evolution of computer software, with an ever-increasing variety of tools available, makes it easy for analysts to conduct transportation analyses and to consider a wide variety of factors in doing so. One thing that has not changed, however, is the analyst's responsibility to have a full understanding of the methodologies used by the selected analysis tools—including the level of uncertainty in the tools' results—in order to make well-informed recommendations based on the analysis results and to communicate those results to others. As tools become more complex and sophisticated, the analyst's challenge increases.

Chapter 7, Interpreting HCM and Alternative Tool Results, begins with a discussion of the uncertainty in model outputs that results from (a) uncertainty in a model's inputs, (b) uncertainty in the performance measure estimate produced by a model, and (c) imperfect model specification, as which a model may not fully account for all the factors that influence its output. Uncertainty in model inputs can result from the *variability* of field-measured values, from the uncertainty inherent in forecasts of future volumes, and from the use of default values. The *accuracy* of a model's results is directly related to its uncertainty. A model that incorporates more factors may appear on the surface to be more accurate, but if the inputs relating to the added factors are highly uncertain, accuracy may actually be decreased. Analysts should also carefully consider the *precision* used in presenting model results to avoid implying more accuracy than is warranted.

Alternative tools often provide performance measures that have the same, or similar, names as HCM measures but that are defined differently

When both HCM-based and alternative tools are used in an analysis or when a performance measure produced by an alternative tool is being used to determine level of service (LOS), analysts should take care to ensure that the measures produced by the alternative tool are defined in the same way as the HCM measure. Different tools use different definitions for similarly named measures, which may lead to inaccurate conclusions if the differences are not accounted for properly. Chapter 7 provides guidance on defining, measuring, and comparing key outputs of alternative tools when such outputs are intended to be used with or compared with those of the HCM.

Chapter 7 concludes with guidance on the number of significant digits to use in displaying HCM results and on ways to present HCM results to facilitate their interpretation by technicians, decision makers, and the general public.

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2. UNCERTAINTY AND VARIABILITY

UNCERTAINTY AND VARIABILITY CONCEPTS

Model outputs—whether from the HCM or alternative tools—are estimates of the "true" values that would be observed in the field. Actual values will be within some range of the estimated value.

The performance measure results produced by traffic models—both HCM-based and alternative tools—are estimates of the "true" values that would be observed in the field. These estimates are not exact, however—they are subject to statistical *uncertainty*, in which the true value of a given measure lies within some range of the estimated value.

Sources of variability in correctly measured values used as model inputs. Measurement error is yet another form of uncertainty.

To illustrate the lack of exactness, consider the *variability* in measured values, such as traffic volume inputs. There are several types of variability:

- *Temporal variability*, in which measured values, such as hourly traffic volumes, vary from day to day or month to month at a given location;
- *Spatial variability*, in which measured values, such as the percentage of trucks in the traffic stream, vary from one location to another within a state or vary from one state to another; and
- *User perception variability*, in which different users experiencing identical conditions may perceive those conditions differently—for example, when asked to rate their satisfaction with those conditions.

Sources of uncertainty in model outputs

Chapter 5, Quality and Level-of-Service Concepts, noted that model outputs are subject to three main sources of uncertainty (1):

1. Uncertainty in model inputs, such as variability in measured values, measurement error, uncertainty inherent in future volume forecasts, and uncertainty arising from the use of default values;
2. The uncertainty of the performance measure estimate produced by a model, which in turn may rely on the output of another model that has its own uncertainty; and
3. Imperfect model specification—a model may not fully account for all the factors that influence the model output.

Uncertainty cannot be eliminated, but its effects can be reduced through a variety of techniques.

Although uncertainty cannot be eliminated, its effects can be reduced to some extent. For example, the HCM's concept helps to dampen the effects of uncertainty by presenting a range of service-measure results as being reasonably equivalent from a traveler's point of view. The use of a design hour, such as the 30th-highest hour of the year, also reduces uncertainty, as the variability of the design hour volume is much lower than the variability of individual hourly volumes throughout the year (1). Measured values will have more certainty than default values will, and multiple observations of a model input will have more certainty than a single observation. Sensitivity analyses—described later in this section—and other statistical techniques (2) can be used to test the impact of changes in model inputs on model outputs.

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SOURCES OF UNCERTAINTY

Input Variables

HCM procedures and alternative tools typically require a variety of input data. Depending on the situation, there are up to three ways an analyst can provide these inputs. Listed in order of increasing uncertainty, they are (a) direct measurement, (b) locally generated default values, and (c) national default values suggested by the HCM or built into an alternative tool. Default values may not reflect spatial and temporal variability—national defaults to a greater extent than local defaults—because the mix of users and vehicles varies by facility and by time of day and because drivers' behavior varies depending on their familiarity with a facility and prevailing conditions. Direct measurements are subject only to temporal variability, as the measurement location's site-specific differences will be reflected in the observed values.

Traffic volume variability from day to day and unknowns associated with future year traffic volume forecasts are among the primary sources of uncertainty.

Day-to-day variability in traffic volume is a primary source of uncertainty in traffic analyses (1, 3). Future-year volumes are subject to higher degrees of uncertainty as one forecasts farther into the future because of unknowns about developmental patterns and timing, the timing of changes or additions to other parts of the transportation system, and changes in use of particular travel modes. Other input variables whose uncertainty has been studied in the literature are saturation flow rates (4), critical headways, and follow-up time (5).

Model Accuracy

Model Development

Many HCM models are based on theoretically derived relationships, which include assumptions and contain parameters that must be calibrated on the basis of field data. Other HCM models are primarily statistical. The accuracy of these models can be described in terms of standard deviations, coefficients of determination of linear regression (R^2), and other statistical measures.

Only some of the older HCM models (i.e., those first appearing in the HCM2000 or earlier editions) have well-documented measures of uncertainty. On occasion, the Transportation Research Board's Committee on Highway Capacity and Quality of Service has exercised its judgment in modifying models to address illogical results (e.g., at boundary conditions) or to fill in gaps in small databases. In such cases, the "true" uncertainty of the entire model is virtually impossible to quantify. In contrast, most models developed for the HCM 2010 have documented measures of uncertainty. This information is provided in the original research reports for the HCM methodologies, which can be found in the Technical Reference Library in Volume 4.

Documentation of the uncertainty inherent in HCM models can be found in the models' original research reports, located in the Technical Reference Library in Volume 4.

Nested Algorithms

In many methodologies, the algorithm used to predict the final service measure relies on the output of another algorithm, which has its own uncertainty. Thus, the uncertainty of the final algorithm is compounded by the uncertainty in an input value derived from another algorithm.

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In Chapter 12, Freeway Weaving Segments, for example, the prediction of weaving and nonweaving speeds depends on the free-flow speed and the total number of lane changes made by weaving and nonweaving vehicles. Each of these inputs is a prediction, based on other algorithms, each having its own uncertainty. As additional examples, the urban street facility and freeway facility procedures are built on the results of underlying segment and (for urban streets) point models, the outputs of which have their own associated uncertainties.

Traveler Perception

The HCM 2010 introduces several traveler perception-based models for estimating LOS for the bicycle, pedestrian, and transit modes. In addition, Chapter 17, Urban Street Segments, provides an alternative traveler-perception model for the automobile mode to help support multimodal analyses. These models produce estimates of the average LOS travelers would state for a particular system element and mode. However, people perceive conditions differently, which results in a range of responses to be covering the full LOS A to F range) for a given situation. As with other models, statistical measures can be used to describe the variation in the responses as well as the most likely response (6).

Different people will have different levels of satisfaction for identical conditions.

Additional Documentation

In addition to the uncertainty values given in the original research for HCM methods, the uncertainty of a number of current HCM models has been studied in the literature. These studies include unsignalized intersections (6, 7, 8), two-lane highways (9), and other uninterrupted-flow facilities (10).

Model Specification

A final potential source of uncertainty is an incomplete model specification, in which not all the factors that influence a model's result are reflected in the model's parameters. (An inaccurate specification, in which the wrong parameters are included in the model, also falls into this category.) The significant increase in the size of the HCM with each new edition, along with the complexity of its procedures, is due in part to users' desire for HCM models to account more fully for factors that influence the HCM's performance measures.

A more complex model is not necessarily a more accurate model.

However, a diminishing-returns principle also applies to model complexity. Each new variable added to a model brings with it uncertainty related to both the model's parameters and its input values. This additional complexity may not be warranted if the model's final output becomes more uncertain than it was before, even if the model appears to be more accurate by taking additional factors into account. Model complexity that leads to better decision making is justified; complexity that does not is best avoided (11).

SENSITIVITY ANALYSIS

One way to address the uncertainty inherent in a performance measurement estimate is to conduct a sensitivity analysis, in which key model inputs are individually varied over a range of reasonable values and the change in model outputs is observed. It is important for analysts to have a good understanding of

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the sensitivity of model inputs, and special care should be taken in selecting appropriate values for particularly sensitive parameters. It is also important for analysts and decision makers to understand the sensitivity of model outputs (numerical values or the LOS letter grade) to changes in inputs, particularly volume forecasts, when they interpret the results of an analysis.

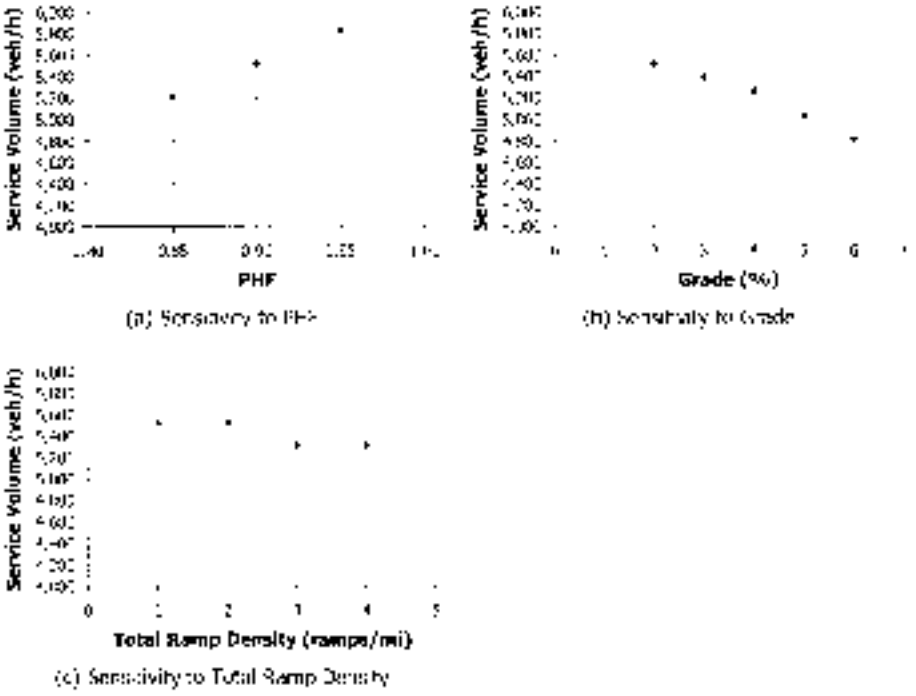
Sensitivity analysis is a useful technique for observing how model outputs change in response to changes in model inputs.

Exhibit 7-1 illustrates a sensitivity analysis for selected inputs to the basic freeway segment method. A typical application would be a planning study for a future freeway, where not all the inputs are known exactly. The output being tested is the service volume (in vehicles per hour, veh/h) for LOS D (i.e., the highest volume that results in LOS D, given the other model inputs). The following inputs were held constant in all three examples.

- Lane width: 12 ft
- Percent trucks: 3%
- Driver population factor: 1.00
- Number of lanes per direction: 3
- Shoulder width: 6 ft
- Grade length: 1 mi

In each example, one of the following inputs was varied, while the other two were held constant. The varied input differs in each example.

- Peak hour factor (PHF): 0.90, varied from 0.80 to 0.95 in Exhibit 7-1(a)
- Grade: 2%, varied from 1% to 6% in Exhibit 7-1(b)
- Total ramp density: 2 ramps/mi, varied from 1 to 4 ramps/mi in Exhibit 7-1(c)



(a) Sensitivity to PHF

(b) Sensitivity to Grade

(c) Sensitivity to Total Ramp Density

Exhibit 7-1
Example Sensitivity Analysis for Selected Basic Freeway Segment Model Inputs

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If varying a single input parameter within its reasonable range results in a 0% to 10% change in the service measure estimate, the model can be considered to have a low degree of sensitivity to that parameter. If a 10% to 20% change in the service-measure estimate results, the model can be considered moderately sensitive to that parameter, while if a change greater than 20% results, the model can be considered highly sensitive (12).

As shown in Exhibit 7-1(a) and Exhibit 7-1(b), LOS D service volumes for basic freeway segments are moderately sensitive to both PHF and grade across the reasonable ranges of values for those inputs, with the highest service volumes 12% and 14% higher than the lowest service volumes, respectively. Consequently, particular care should be taken to select appropriate values for those inputs.

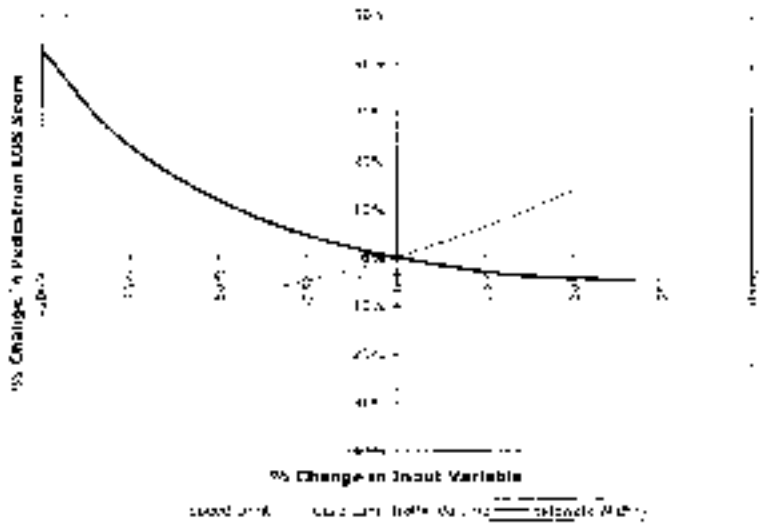
When changing the total ramp density results in a two-line speed estimate, while the same 5-mi/h range used in a particular speed–flow curve, no change in the service volume result will be seen.

Exhibit 7-1(c) shows that LOS D service volumes have a low sensitivity to total ramp density, with just a 4% range in the output volumes. Therefore, it is not essential for the assumed average ramp density value to match the future condition closely.

Exhibit 7-2 shows an alternative way to display sensitivity information, based on the pedestrian link LOS score from Chapter 17, Urban Street Segments. In this example, the number of directional lanes (1), each lane width (12 ft), and PHF (0.90) are held fixed, and it is assumed there is no bicycle lane, parking lane, or buffer between the sidewalk and the curb lane. The following inputs are varied one at time:

- Speed limit: 30 mi/h, varied from 20 to 60 mi/h;
- Curb lane traffic volume: 500 veh/h, varied from 50 to 1,000 veh/h; and
- Sidewalk width: 6 ft, varied from 0 to 10 ft.

Exhibit 7-2
Example Sensitivity Analysis of Urban Street Link Pedestrian LOS Score



The pedestrian LOS score is relatively insensitive to speed limit, moderately sensitive to sidewalk width (except when a sidewalk is not present), and highly sensitive to curb lane traffic volume. This kind of presentation works best when

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typical values for the input variables to be tested. For near the middle of their range rather than at or near one of the extremes.

Exhibit 7-3 shows an example of testing the sensitivity of control delay, and the corresponding LOS result, at an all-way stop-controlled intersection, by varying the demand volumes used in the analysis. In the exhibit, the base volume entering the intersection on all approaches is varied within a ±15% range in 5% increments. This kind of sensitivity analysis is particularly useful in working with forecasts of volume that have a relatively high degree of uncertainty associated with them.

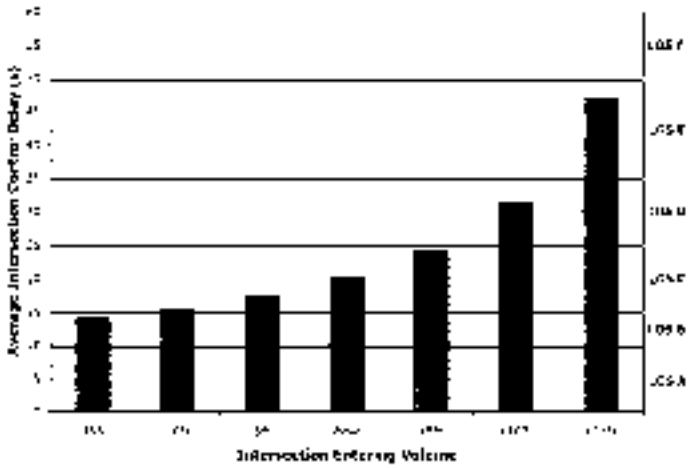

Exhibit 7-3
Example Sensitivity Analysis of All-Way Stop-Control Node Outputs Based on Varying Volume Inputs

Note: Values used in the calculations are for signalized intersections with one lane on each approach, PHF = 0.92, and 2% heavy vehicles. Base volumes are 200 through vehicles, 35 left-turning vehicles, and 35 right-turning vehicles on each approach.

As shown in Exhibit 7-3, under the base volume forecast, the intersection is forecast to operate at LOS C. If future traffic volumes are lower than forecast or as much as 5% higher than forecast, the intersection will still operate at LOS C or better. If future traffic volumes are 10% higher than forecast, the intersection will operate at LOS D. If traffic volumes are 15% higher than forecast, the intersection will operate at LOS E. If the jurisdiction's operations standard for the intersection is LOS E or better, it could be reasonably concluded that the intersection would still operate acceptably even if higher volumes than forecast were to occur. However, if the standard was LOS D or better, a closer look at the conservativeness of the volume forecasts might be needed to conclude that the intersection would operate acceptably.

Depending on the model and the specifics of the scenario being modeled, relatively small changes in model inputs can have relatively large impacts on model outputs.

ACCURACY AND PRECISION

Overview

Accuracy and precision are independent but complementary concepts. Accuracy relates to achieving a correct answer, while precision relates to the size of the estimation range of the parameter in question. As an example of accuracy, consider a method that is applied to estimate a performance measure. If the performance measure is delay, an accurate method would provide an estimate closely approximating the actual delay that occurs under field conditions. The

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precision of such an estimate is the range that would be acceptable from an analyst's perspective in providing an accurate estimate. Such a range might be expressed as the central value for the estimated delay plus or minus several seconds.

In general, the inputs used by HCM methodologies come from field data or estimates of future conditions. In either case, these inputs can be expected to be accurate to only within 5% or 10% of the true value. Thus, the computations performed with these inputs cannot be expected to be extremely accurate, and the final results must be considered as estimates that are accurate and precise only within the limits of the inputs used.

HCM users should be aware of the limitations of the accuracy and precision of the methodologies in the manual. Such awareness will help users interpret the results of an analysis and use the results to make a decision about the design or operation of a transportation facility.

Calculation Precision Versus Display Precision

Precision in calculation allows more precision in presenting final results.

The extensive use of personal computers has allowed calculations of capacity and LOS to be carried to a large number of digits to the right of the decimal point. Because of this ease of calculation, there is a need to state clearly that the final result of calculations done manually and carried to the suggested number of significant figures might be slightly different from the result of calculations performed on a computer.

Implied Precision of Results

The typical interpretation given to a value such as 2.0 is that the value is in a precision range of two significant figures and that results from calculations should be rounded to this level of precision. The actual computational result would have been in the range of 1.95 to 2.04 by standard rounding conventions. Occasionally, particularly in the running text of the HCM, editorial flexibility allows a zero to be dropped from the number of digits. In most cases, however, the number of the digits to the right of the decimal point does imply that a factor or numerical value has been calculated to that level of precision.

AVERAGE VALUES

Unless specifically noted otherwise, HCM performance measure estimates are average (mean) values.

Unless otherwise noted or defined, numerical values are mean values for the given parameter. Thus, a measure of speed or delay is the mean value for the population of vehicles (or persons) being analyzed. Similarly, a lane width for two or more lanes is the mean (average) width of the lanes. The word "average" or "mean" is only occasionally carried along in the text or exhibits to reinforce this otherwise implicit fact. LOS threshold values, adjustment factors used in computations, and calculated values of performance measures are assumed to represent conditions that have a reasonable expectation of being observed regularly in North America as opposed to the most extreme condition that might be encountered.

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3. DEFINING AND COMPUTING UNIFORM PERFORMANCE MEASURES

The exact definition of performance measures poses an important question, particularly when a comparison of performance measures produced by different tools is to be made. Definitions and computational methods are especially important when the LOS must be inferred from another performance measure obtained by alternative methods and applied to the thresholds presented in the HCM's procedural chapters. Often, a performance measure is given the same name in various tools, but its definition and interpretation differ.

This section identifies the performance measures commonly reported by the procedures given in Volumes 2 and 3. The concept of developing those measures from an analysis of the individual vehicle trajectories produced by microsimulation tools is introduced. The most important measures are discussed in terms of uniform definitions and methods of computation that will promote comparability among different tools. More detailed procedures for developing performance measures from individual vehicle trajectories are presented in Chapter 24, Concepts Supplemental.

PERFORMANCE MEASURES REPORTED BY HCM PROCEDURES

The key performance measures associated with each of the procedural chapters in Volumes 2 and 3 were summarized in Chapter 6, HCM and Alternative Analysis Tools. The applicability of these procedures and alternative tools was indicated for each type of facility. Exhibit 7-4 includes all the performance measures identified in Chapter 6. The service measures that determine LOS for each system element are also identified. In this section, the key performance measures are presented in terms of their definitions and computational procedures. The potential for the development of uniform performance measures from alternative tools is presented in a later section.

Exhibit 7-4
Performance Measures Reported by HCM Procedures

Chapter	Density	Speed	v/c Ratio[a]	Travel Time	Control Delay	Queue	Other Measures
10. Freeway Facilities	Yes	Yes	Yes	Yes		Yes	[b]
11. Basic Freeway Segments	Yes	Yes	Yes				
12. Freeway Weaving Segments	Yes	Yes	Yes				[c]
13. Freeway Merge and Diverge Segments	Yes	Yes	Yes				
14. Multilane Highways	Yes	Yes	Yes				
15. Two-Lane Highways		Yes	Yes				[d]
16. Urban Street Facilities		Yes		Yes	Yes		[e]
17. Urban Street Segments		Yes		Yes	Yes		[f]
18. Signalized Intersections			Yes		Yes	Yes	
19. TWSC Intersections			Yes		Yes	Yes	
20. AWSC Intersections			Yes		Yes	Yes	
21. Roundabouts			Yes		Yes	Yes	
22. Interchange Ramp Terminals			Yes		Yes	Yes	
23. Off-Street Pedestrian/Bicycle Facilities							[g]

Notes: v/c, volume to capacity ratio; TWSC, two-way stop-controlled; AWSC, all-way stop-controlled; **bold** text indicates key measures.
[a] A v/c ratio greater than 1.00 is often used to define LOS F conditions.
[b] Vehicle miles, vehicle hours.
[c] Weaving speed, non-weaving speed.
[d] Percent time spent following.
[e] Stop rate, running time.
[f] Meeting and passing events.

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Speed-Related Measures

Speeds are reported in several chapters of this manual:

- *Chapter 10, Freeway Facilities*, uses the average speeds computed by the other freeway procedural chapters when all segments are undersaturated. When demand exceeds capacity, the speeds on the affected segments are modified to account for the effects of slower-moving queues.
- *Chapter 11, Basic Freeway Segments*, estimates the average speed on the basis of the free-flow speed and demand volume by using empirically derived relationships.
- *Chapter 12, Freeway Weaving Segments*, estimates the average speed as a composite of the speeds of weaving and nonweaving vehicles on the basis of free-flow speed, demand volumes, and geometric characteristics. The computational procedures for estimating the actual speeds are based on the nature of the weaving segment and the origin–destination matrix of traffic entering and leaving the segment. The speed estimation processes are substantially more complex in weaving segments than in basic freeway segments.
- *Chapter 13, Freeway Merge and Diverge Segments*, estimates the average speed of vehicles across all lanes as well as the average speeds in the lanes adjacent to the ramp. The computations are based on empirical relationships specifically derived for merge and diverge segments.
- *Chapter 15, Two-Lane Highways*, treats the average travel speed (ATS) on certain classes of highways as one determinant of LOS. The ATS is determined as an empirical function of free-flow speed, demand flow rate, proportion of heavy vehicles, and grades.
- *Chapter 16, Urban Street Facilities*, uses "travel speed as a percentage of base free-flow speed" to determine LOS.
- *Chapter 17, Urban Street Segments*, also uses speed to determine LOS. The average speed is computed by dividing the segment length by the average travel time. The average travel time is determined as the sum of three components:
  1. Time to traverse the link at the running speed, which is computed as a function of the free-flow speed, demand flow rate, and geometric factors;
  2. Control delay due to the traffic control device at the end of the segment; and
  3. Midblock delay due to access points.

  The average speed applies only to arterial through vehicles and not to the traffic stream as a whole.

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Queue-Related Measures

Queue measures are defined and computed for both interrupted- and uninterrupted-flow facilities. Queues may be defined in terms of the number of vehicles contained in the queue or the distance of the last vehicle in the queue from the end of the segment (i.e., back of queue or BOQ). The probability of the BOQ reaching a specified point where it will cause problems is of most interest to the analyst. For most purposes, the BOQ is therefore a more useful measure than the number of vehicles in the queue.

Queue measures are reported by the following procedures in this manual.

- *Chapter 10, Freeway Facilities:* Queuing on freeway facilities is generally the result of oversaturation caused by excessive demand or by bottlenecks. As such, it is treated deterministically in Chapter 10 by an input–output model that tracks demand volumes and actual volume served through the bottleneck. The propagation and dissipation of freeway queues are estimated from a three-deterministic queuing model. The shock wave speed at which queues grow and shrink is calculated from the jam density and the flow and density at capacity. Residual demand is processed in subsequent time intervals as demand levels drop or the bottleneck capacity increases. Generally, a drop in demand results in a queue that closes from the back, while an increase in bottleneck capacity results in a forward-leaning queue. The spatial extent of the queue is calculated from the number of queued vehicles and the storage space on the facility (i.e., the length and number of lanes). The temporal duration of the queue is a function of demand patterns and bottleneck capacity. The presence of a queue on a given segment also affects the rate at which vehicles can flow into the next segment. The volume arriving in downstream segments may therefore be less than the demand volume. Downstream segments with demand volumes greater than capacity may turn out to be hidden bottlenecks if a more severe upstream bottleneck meters the volume served.
- *Chapter 18, Signalized Intersections:* The cyclical maximum BOQ is computed on the basis of a queue accumulation and discharge model with a correction applied to account for acceleration and deceleration. Random arrivals and over-saturated conditions are accommodated by correction terms in the model. The computational details are provided in Chapter 31, Signalized Intersections: Supplemental. The maximum number of vehicles in the queue occurs at the end of the red phase in each cycle. The maximum BOQ extends into the subsequent green phase because vehicles continue to join the BOQ until it is fully dissipated. The measure reported for signalized approaches is the average BOQ. Percentile values are also reported.
- *Chapters 19 to 21, Unsignalized Intersections:* The 95th percentile BOQ is computed by deterministic equations as a function of demand volume, capacity, and analysis period length.

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Stop-Related Measures

Stop-related measures are of interest to analysts because of their comfort, convenience, cost, and safety implications. An estimate of the number of stops on a signalized approach is reported by the signalized intersection analysis procedure described in Chapter 18, with details given in Chapter 31. Chapter 17, Urban Street Segments, incorporates the stops at the signal into a "stops per miles" rate for each segment. Other chapters do not report the number of stops. Most alternative tools based on both deterministic and simulation models produce an estimate of the number of stops for a variety of system elements by using the tools' own definitions, and most tools allow user-specified values for the parameters that define when a vehicle is stopped.

The Chapter 18 procedure defines a "partial" stop as one in which a vehicle slows as it approaches the BOQ but does not come to a full stop. Some alternative tools, both deterministic and simulation based, consider a partial stop to be a later stop after the first full stop.

Delay-Related Measures

The definition and computation of delay vary widely among tools.

Because of multiple definitions and thresholds, delay is one of the most difficult measures to compare among traffic analysis tools. Delay measures are reported by the same chapters in this manual that report queue measures:

- *Chapter 10, Freeway Facilities:* Delay on a freeway facility that is globally undersaturated is calculated from the sum of the delay on all individual segments. The segment delays are calculated from the travel time difference between the segment at free-flow speed and the segment at the calculated operational space mean speed. For undersaturated flow conditions, the segment space mean speed is calculated from the segment-type specific methodologies in Chapters 11 to 13. For oversaturated flow, the segment speed is estimated from the prevailing density on the segment. The travel time difference is multiplied by the number of vehicles in a segment during each time period to obtain the total vehicle hours of delay per segment and per time period. The total vehicle hours of delay on the facility for each time period and for the entire analysis are obtained by summation.
- *Chapter 18, Signalized Intersections:* The LOS estimation is based on control delay. Control delay is computed on the basis of an incremental queue analysis technique by using a queue accumulation and discharge model. Random arrivals and oversaturated conditions are accommodated by correction terms in the model. A separate correction is applied to account for an initial queue left from a previous interval. The details of the computation are provided in Chapter 31, Signalized Intersections: Supplemental.
- *Chapters 19 to 21, Unsignalized Intersections:* The LOS estimation is based on control delay. The control delay is computed by deterministic equations as a function of demand volume, capacity, and analysis period length. The LOS thresholds for unsignalized intersections are different from those for signalized intersections.

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Density-Related Measures

Density is expressed in terms of vehicles per mile per lane and is generally recognized as an unambiguous indicator of congestion. Density is used as the determinant of LOS A through F for freeway and multilane highway segments. It is conceptually easy to define and estimate, but the question is how to apply density to the right section of roadway over the right period of time.

The procedures for different types of freeway segments follow a density estimation process that is specific to each segment type:

- *Chapter 10, Freeway Facilities*, determines density for undersaturated conditions by applying the procedures given in Chapters 11 to 13. When queuing occurs as a result of oversaturation caused by excessive demand or by bottlenecks, the density is determined by the queue-tracking procedures described previously for freeway facilities.
- *Chapter 11, Basic Freeway Segments*, determines speeds and demand flow rates that are adjusted for a variety of geometric and operational conditions. The segment density is computed by dividing the adjusted flow rate by the estimated speed. Empirical relationships are used throughout the chapter for computations and adjustments.
- *Chapter 12, Freeway Weaving Segments*, also determines density by dividing the adjusted demand flow rate by the estimated speed. The speed estimation process was described previously.
- *Chapter 13, Freeway Merge and Diverge Segments*, bases the LOS assessment on the density in the two lanes adjacent to the ramp lanes. The density is estimated directly by using empirically derived relationships that depend on the ramp and freeway (Lanes 1 and 2) volumes and the length of the acceleration or deceleration lane. Several operational and geometric factors affect the computations.

USE OF VEHICLE TRAJECTORY ANALYSIS IN COMPARING PERFORMANCE MEASURES

This section explores the use of vehicle trajectory analysis to define and estimate consistent performance measures. It first introduces the mathematical properties of trajectories as an extension of the visual properties. It identifies the types of analyses that can be performed and provides examples that illustrate how trajectory analysis can be applied. A later section identifies the performance measures that can be computed from individual vehicle trajectories and explores their compatibility with the performance measures estimated by the HCM's computational procedures. Specific trajectory analysis procedures by which consistent performance measures can be estimated are presented in Chapter 24, Concepts, Supplemental.

The concept of individual vehicle trajectory analysis was introduced in Chapter 4, Traffic Flow and Capacity Concepts. The chapter indicated that a growing school of thought suggests that a comparison of results between traffic analysis tools and methods is possible only through an analysis of vehicle trajectories as the "lowest common denominator." Trajectory-based performance measures can be made consistent with HCM definitions, with field measurement

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techniques, and with each other. Examples of vehicle trajectory plots were shown in Chapter 4 to illustrate the visual properties of vehicle trajectories.

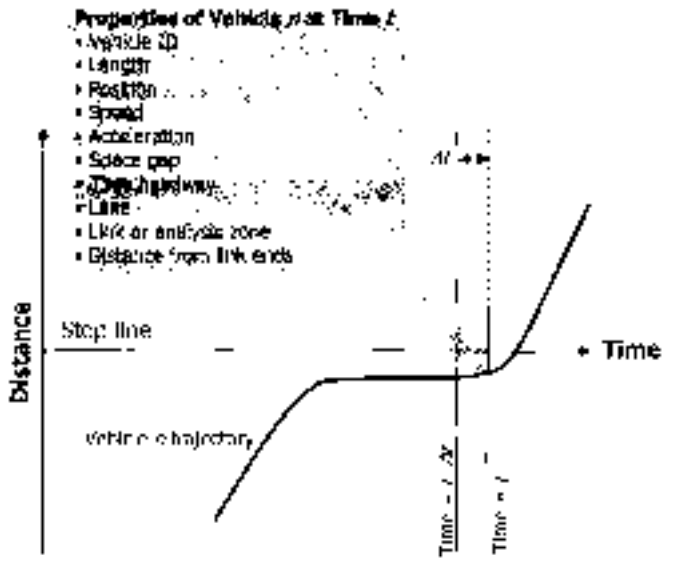
Mathematical Properties of Vehicle Trajectory

While the trajectory plots presented in Chapter 4 provide a good visual insight into operations, they do not support any quantitative assessments. To develop performance measures from vehicle trajectories, it is necessary to represent them mathematically and not just visually. A mathematical representation requires developing a set of properties that are associated with each vehicle at specific points in time and space.

Exhibit 7-5 shows the trajectory of a single vehicle through a signal. At each point in time, a number of properties may be determined. The trajectory for the vehicle is quantified through a list of the properties of vehicle *i* at each point in time. One important parameter in the quantification of trajectories is the time increment between sampling points, represented in Exhibit 7-5 as Δt. Time increments in typical simulation tools currently range from 0.1 to 1.0 s. Smaller values are gaining acceptance within the simulation modeling community because of their ability to represent traffic flow with greater fidelity.

Many properties can be associated with a specific vehicle at a point in time. Some properties are required for the accurate determination of performance measures from trajectories. Others are used for different purposes such as safety analysis. The important properties for estimating consistent performance measures are indicated in Exhibit 7-5.

Exhibit 7-5
Mathematical Properties of Vehicle Trajectories



Longitudinal and Spatial Analysis

It is necessary at the outset to distinguish between longitudinal and spatial analysis of vehicle trajectories. Longitudinal analysis involves following the presence of vehicles as they traverse a segment. The measures determined by this type of analysis include delay related measures or various types and stop-related

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measures. Driver comfort and safety measures may also be determined by longitudinal analyses, but these measures are beyond the scope of the HCM.

Spatial analysis, on the other hand, involves considering all the vehicles on a segment at a specific time step. The two principal spatial measures include density and queue lengths. Both types of analyses are examined here.

Limitations of Vehicle Trajectory Analysis

The procedures described here and in Chapter 24 are intended to produce performance measures from vehicle trajectories that are based on the definitions of traffic parameters given in this manual to promote uniformity of reporting among different simulation tools. The results should improve the acceptance of simulation tools for highway capacity and LOS analysis. However, the term "HCM compatible" does not suggest that the numerical values of measures produced by a simulation tool will be identical to those from the HCM or to those from other simulation tools. Several factors must be considered.

Traffic Modeling Differences

The trajectory information is produced by the simulation model. Each simulation tool has its own models of driver behavior that differ from those used by other tools. It is not practical or desirable to prescribe simulation modeling details in this document. Developers continually strive to improve the realism of their products to gain a competitive advantage in the market. The Next Generation Simulation Program (13) has had some success in developing core algorithms to be shared by simulation developers, but the notion of a universal simulation model is not a practical objective.

Approximations in Trajectory Analysis

It was pointed out in Chapter 4 that all performance measures reported by deterministic models, simulation models, and field observations represent an approximate assessment of field conditions. The need for approximations in trajectory analysis to promote uniform reporting is explored in more detail in Chapter 24. One problem is that the procedures presented in this manual introduce approximations that cannot be replicated in simulation because of conceptual differences and model structure.

Differences That Are Unrelated to Trajectory Analysis

The use of vehicle trajectories addresses some, but not all, of the sources of difference in the definition of performance measures. For example, the temporal and spatial boundaries of an analysis tend to be defined differently by different tools. It is important to HCM compatibility that the definitions and guidelines presented in this manual be used in conducting simulation analyses.

Examples of Vehicle Trajectory Data

Simulation tools propagate vehicles through a roadway segment by periodically updating and keeping track of the trajectory properties that are maintained internally within the traffic flow model. Several examples of the analysis of vehicle trajectories for both interrupted- and uninterrupted-flow

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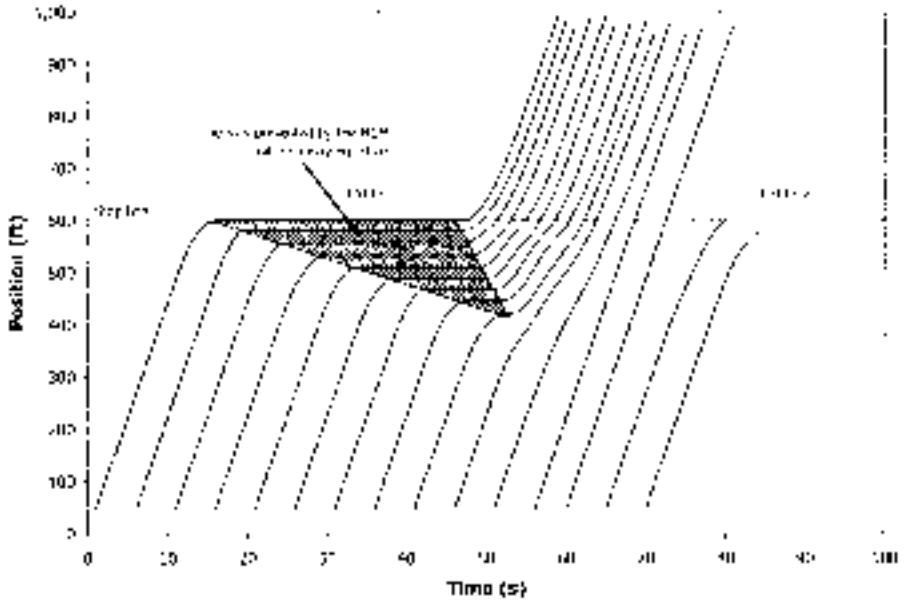
facilities are provided in Chapter 24. The examples demonstrate the complexities that can arise in certain situations, especially when demand exceeds capacity.

Two examples are cited in Chapter 24 are presented here to illustrate how vehicle trajectories can be obtained from simulation tools. The first is shown in Exhibit 7-6, which presents the simplest possible case, involving an approach with only one lane. The simulation parameters were constrained to remove all randomness in the arrival and departure characteristics. While this situation might appear to be somewhat trivial, it is the basis of the signalized intersection delay analysis procedure summarized in Chapter 18 and described in more detail in Chapter 31.

Exhibit 7-6
Trajectory Plot for Uniform Arrivals and Departures



The trajectories may be analyzed longitudinally to produce estimates of delays and stops. They may also be analyzed spatially to produce instantaneous queue length estimates.

A more complex situation is depicted in Exhibit 7-7, which illustrates the vehicle trajectories associated with queue backup from a downstream signal. The randomness of arrivals and departures was restored to this case.

The important difference from the simple case presented in Exhibit 7-6 is that backup into a specific segment from a downstream segment is not covered by the signalized intersection analysis procedures in Chapters 18 and 31. The performance measures may be estimated by trajectory analysis. The purpose of the procedures described in Chapter 24 is to promote definitions and computational algorithms that can be made consistent among different simulation tools.

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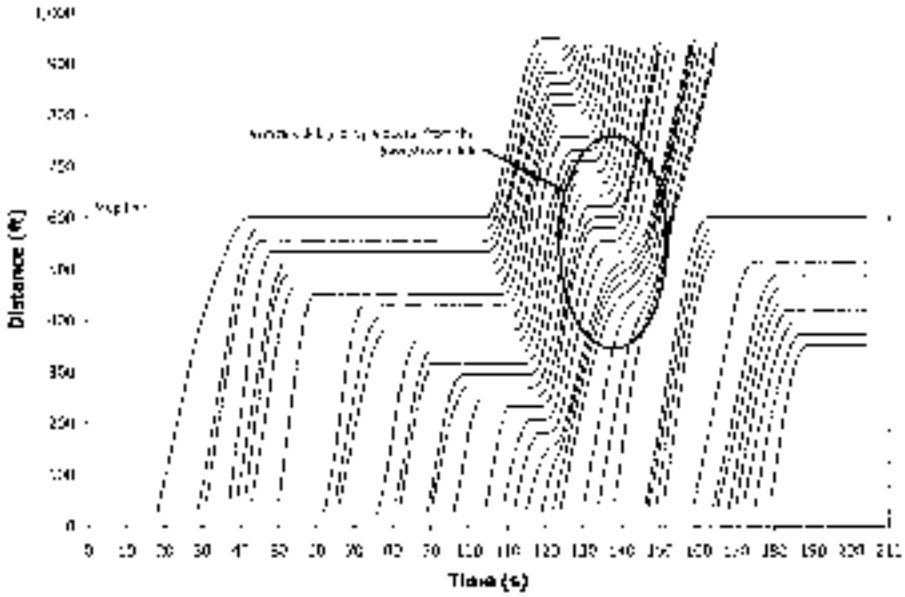

Exhibit 7-7
Queue Backup from a Downstream Signal

REQUIREMENTS FOR COMPUTING PERFORMANCE MEASURES BY VEHICLE TRAJECTORY ANALYSIS

Most performance measures reported by the procedures in this manual are also reported by simulation tools. This section identifies the general requirements for computing measures from simulation by using individual vehicle trajectories to achieve comparability between traffic analysis tools. More detailed procedures are presented in Chapter 24.

General Trajectory Analysis Guidelines

The following general guidelines apply to trajectory analysis procedures.

1. The trajectory analysis procedures are limited to the analysis of trajectories produced by the traffic flow model of each simulation tool. The nature of the procedures does not suggest the need for developers to change their driver behavior or traffic flow modeling logic.
2. If the procedures for estimating a particular measure cannot be satisfactorily defined to permit a valid comparison between the HCM and other modeling approaches, then such comparisons should not be made.
3. All performance measures that accrue over time and space shall be assigned to the link and time interval in which they occur. Subtle complexities make it impractical to do otherwise. For example, the root cause of a specific delay might not be within the link or the immediate downstream link. In fact, the delay might be secondary to a problem at some distant location in the network and in a different time interval.
4. The analyst must understand that the spatial and temporal boundaries of the analysis domain must include a period that is free of congestion on all sides. This principle is also stated in Chapter 10 for analyses of freeway facilities and in Chapter 18 for multiperiod signalized intersection analyses. To ensure that delays to vehicles that are denied entry to the

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system during a given period are properly recognized, it might be necessary to create fictitious links outside of the physical network to hold such vehicles. A more detailed discussion of spatial and temporal boundaries is provided later in this chapter.

5. It is important to ensure that the network has been properly initialized or "seeded" before trajectory analysis is performed. When setting and applying the warm-up periods, simulation tools typically start with an empty network and introduce vehicles until the vehicular content of the network stabilizes. Trajectory analysis should not begin until stability has been achieved. If the simulation period begins with oversaturated conditions, stability may never be achieved. See the discussion later in this chapter on temporal and spatial boundaries.

Speed- and Travel Time–Related Measures

Speed and travel time are treated together because, at least for segment values, they are closely related. The average speed of a vehicle traversing a segment may be determined by dividing the segment length by the travel time.

Macroscopic segment travel time estimation does not require a detailed trajectory analysis. The travel time for an individual vehicle may be computed for a given segment by subtracting the time when the vehicle entered the segment from the time when it left the segment. The average travel time may be computed as the mean of the individual travel times; however, this technique is valid only for complete trips (i.e., those that have entered and left the segment).

The space-mean speed for all vehicles within the segment during the time period may be estimated by dividing the number of vehicle miles of travel by the number of vehicle hours of travel time. The total vehicle miles and vehicle hours may be accumulated by including all the vehicles and time steps in the analysis domain. See the discussion later in this chapter on spatial and temporal boundaries.

Queue-Related Measures

Because of their microscopic nature, simulation tools have the potential to produce useful measures of queuing that are beyond the limits of those described in the procedural chapters of this manual. However, the queue-related performance measures are difficult to compare with those derived from HCM procedures. No such comparisons should be attempted without a detailed knowledge of the queue definitions and computations of a specific tool. With consistent definitions, more uniform queue measures could be obtained from simulation tools.

Queued State

What defines the entry to and exit from a queue? Several definitions are applied by different tools for this purpose. The definition given in Chapter 31 for purposes of field observations states the following.

> *A vehicle is considered as having joined the queue when it approaches within one car length of a stopped vehicle and is itself about to stop. This definition is*

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and because of the difficulty of keeping precise track of the moment when a vehicle comes to a stop.

The Chapter 31 definition of the exit from a queue, also intended for application to field studies, is more complex and offers some interesting challenges for implementation in both deterministic and simulation models. As a practical approximation, a vehicle should be considered to have left the queue when it has left the link on which it entered the queue. When a queue extends the full length of a link, a vehicle should be considered to enter the queue at the time it enters the link. Other conditions, such as a lane change to escape a queue, might also signal the exit from a queue. These conditions are discussed in Chapter 24.

Queue Length

The estimation of queue length is generally required to determine whether a queue has reached the point where it will interfere with other traffic movements. Queue length computations are applied at a macroscopic level by the procedures described in this manual. Simulation models, on the other hand, are able to establish the instantaneous BOQ at each point in time. The question is how to process the instantaneous values in a manner that will produce meaningful results.

Queue length analysis by simulation must be treated differently for different conditions. There are three cases to consider:

1. *Undersaturated noncyclical operation*, typical of the operation with isolated two-way stop control. In this case, the queue accumulation and discharge follow a more or less random pattern. The Chapter 19 procedure estimates the 95th percentile queue length on the basis of a deterministic average queue length modified by a term that accounts for random arrivals. This process could be approximated in trajectory analysis by establishing a distribution of instantaneous queue lengths by time step. The 95th percentile queue length could be determined from that distribution.
2. *Undersaturated cyclical operation*, typical of the operation at a traffic signal. In this case, a maximum BOQ is associated with each cycle. The maximum BOQ in each cycle represents one observation for statistical analysis purposes. The use of a distribution of instantaneous values is not appropriate here because the queue accumulation and discharge are much more systematic than random. Including instantaneous queue lengths that occur when the queue is expected to be zero (i.e., at the end of the green) would underestimate the measure of interest, which is the peak queue length. With a sufficient number of cycles, a distribution of peak queue lengths with a mean value and a standard deviation could be established. The probability of queue backup to any point could then be estimated from this distribution.
3. *Oversaturated operation*, either cyclical or noncyclical: When demand exceeds the capacity of an approach or system element, the queue will grow indefinitely. For purposes of simulation, the measure of interest is

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the residual RQ at the end of the simulated interval and the effect of the queue on upstream segments. These considerations are especially important in multiperiod analyses.

The undersaturated condition might include brief periods of queue buildup and discharge as long as continuous buildup and residual queues do not occur.

Stop-Related Measures

Most alternative tools based on both deterministic and simulation models produce an estimate of the number of stops by their own definition, and most allow user-specified values for the parameters that establish the beginning and end of a stop. Stop-related measures are of interest in analysis because of their comfort, convenience, cost, and safety implications.

Definition of the Stopped State

The definition of when a vehicle is stopped has the same two elements as the definition of when it is queued—that is, when does the stop begin and when does it end? Speed thresholds are often used to determine when a vehicle is stopped. The only nonarbitrary threshold for this purpose is zero. Practical considerations suggest, however, that simulation modeling algorithms that deal with stopping would be more stable if a near-zero speed were used instead. A speed of 5 mi/h was applied in other chapters for determining when a vehicle has stopped.

There are two different modeling purposes for releasing a vehicle from the stopped state:

- To terminate the accumulation of stopped delay, and
- To enable the accumulation of subsequent stops.

The first condition is easier to deal with in the trajectory analysis. When the vehicle is no longer stopped, it should no longer accumulate stopped delay. The logical speed threshold for this condition is the same speed threshold that established the beginning of the stop.

Estimating the Number of Stops

The accumulation of multiple stops poses more problems and generally relies on arbitrary thresholds that vary among different tools. The main problem with multiple stops is that, after the first stop, later stops take place from a lower speed and therefore have a less adverse effect on driver comfort, operating costs, and safety. For signalized approaches, some tools apply a "probability of stopping" model in which the maximum probability is 100% and, therefore, the maximum number of stops is 1.0 on any approach. Other tools model subsequent stops based on the release from the stopped state when the vehicle reaches an arbitrary threshold speed, often around 15 mi/h.

While the number of stops is an important performance measure, it is difficult to compare the values produced by different tools. Such comparisons should not be attempted without adequate knowledge of the definitions and parameters that are used by a specific tool.

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Delay-Related Measures

Practically all traffic analysis tools produce a performance measure called "delay," but tools vary widely in the definition and computation of delay. This discussion attempts to establish consistent definitions for delay.

Delay Definitions

Delay is generally defined as the excess time spent on a road segment compared with the time at a target speed that represents a zero-delay condition. The target speed is the speed at which a specific driver prefers to drive. Different tools have different definitions of target speed. Some are driver and vehicle specific, taking into account driver aggressiveness and roadway characteristics. Because target speed is a function of individual driver behavior, there will be some differences in the method of computation, especially if the target speed is different for each vehicle. For tools that require a user-specified free-flow speed as an input, the methodology presented in the procedural chapters of this manual should be used to determine the free-flow speed.

The time a vehicle actually spends on a segment is easy to determine from its trajectory. On the other hand, the target time is subject to a number of definitions.

- *Travel time at ideal speed*, usually the free-flow speed.
- *Travel time at the individual vehicle's target speed*: a function of the free-flow speed, prevailing roadway and traffic conditions, and the driver's characteristics.
- *Travel time at 10 mi/h below speed limit*: used by some agencies to determine whether a trip is "on time" for travel time reliability reporting. This measure defines "extreme delay."
- *Travel time at a specified travel time index*: The travel time index is the ratio of actual travel time to ideal travel time. It is used primarily for reporting congestion in nationwide mobility monitoring. A travel time index of 1.5 is sometimes taken as an indication of congestion. This measure defines congestion delay. It is intended to be an indicator of the need for roadway improvements.
- *Travel time without traffic control*: This measure defines control delay. Unlike the previous measures, which are applied to an entire segment, control delay is applied only to the portion of the segment where a queue is present. Control delay is a subset of segment delay because it does not include the delays caused by traffic interactions upstream of the queue. The definition applies uniformly to all types of control, including signals, stop signs, and roundabouts.

In all cases, a lower limit of zero must be imposed when the actual travel time is shorter than the reference time.

Aggregated Delay Versus Unit Delay

It is important to note the difference between aggregated delay, usually expressed in vehicle hours, and unit delay, usually expressed in seconds per

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vehicle. Aggregate delay is generally used to assess the operating costs associated with a candidate treatment, because an economic value can be assigned to a vehicle's hour of delay. Unit delays are associated with driver perception of the LOS on a facility. For these two definitions to be dimensionally consistent, the unit delays must actually be expressed in vehicle seconds per vehicle. It is common practice, however, to shorten the definition to seconds per vehicle to promote public understanding.

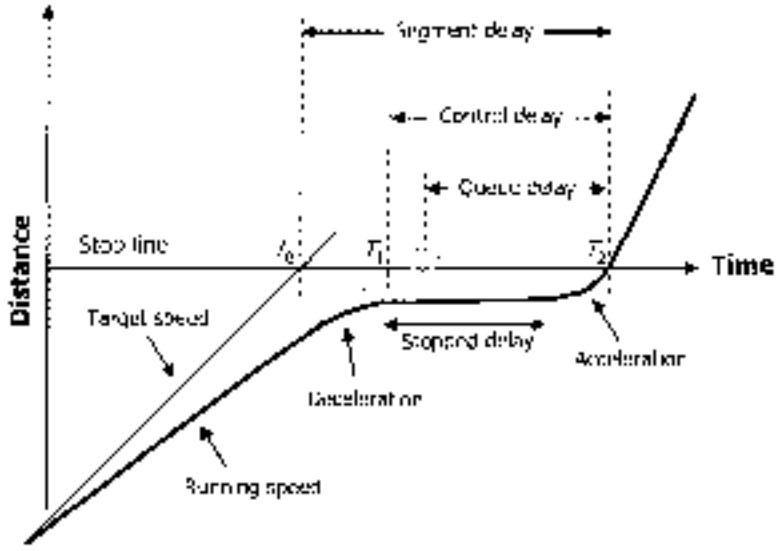
Representation of Delay by Vehicle Trajectories

Several delay definitions were presented previously. These definitions may be interpreted in terms of vehicle trajectories based on longitudinal trajectory analysis. In all cases, the delay is determined for each time step and accumulated over the entire time the vehicle was in a specified segment.

Exhibit 7-8 illustrates the various ways delay may be defined. These points are entered in this figure.

- T_A, the time at which a vehicle would have arrived at the stop line if it had been traveling at the target speed;
- T_t, the time at which a vehicle would have arrived at the stop line if it had been traveling at the running speed, which is generally less than the target speed because of traffic interactions; and
- T_D, the time at which a vehicle is discharged at the stop line.

Exhibit 7-8
Definition of Delay Terms in Time and Space



The delay measures defined in terms of the time differences shown in Exhibit 7-8 include the following.

- Control delay, defined as $T_D - T_t$. This delay definition is the one used by the procedure for assessing LOS at control-type intersections and roundabouts.

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- *Segment delay*, defined as $T_2 - T_1$. This definition is more commonly used by simulation tools. It reflects the delay experienced by each vehicle since it left the upstream node (usually another signal). Segment delay includes control delay plus all other delay due to traffic interactions.

In addition to these two precisely defined delay terms, two other delay definitions are shown in Exhibit 7-8 that are based on more complex properties of the vehicle trajectories:

- *Stopped delay*, which reflects the amount of time a vehicle was actually stopped. The beginning and end of a stop are generally based on speed thresholds, which may differ among tools. In some cases, the threshold speeds are user definable.
- *Queue delay*, which reflects the amount of time a vehicle spends in a queued state. The properties of the trajectory that define a queued state in different tools include speed, acceleration, spacing, and number of vehicles sharing these properties. For trajectory analysis purposes, the queued state was defined previously in this chapter, and this definition is reflected in Exhibit 7-8.

For simulation tools that report total segment delay but do not report control delay explicitly, it is possible to produce approximate estimates of control delay by performing simulation runs with and without the control device(s) in place. The segment delay reported with no control is the delay due to geometrics and interaction between vehicles. The additional delay reported in the run with the control in place is, by definition, the control delay. For short segments with low to medium volumes, the segment delay usually serves as an approximation of the control delay.

The development of control delay estimates by a multiple-run procedure is primarily of academic interest because of the amount of effort involved. The objective at this point is to develop a specification for estimating control delay from vehicle trajectories that may be intermalized by simulation model developers to produce HCM-compatible results.

Computational Procedures for Delay-Related Measures

The procedures for computing delay from vehicle trajectories involve aggregating all delay measures over each time step. Therefore, the results take the form of aggregated delay and per unit delay, as defined earlier. To determine unit delays, the aggregated delays must be divided by the number of vehicles involved in the aggregation. Partial trips made over a segment during the time period add some complexity to unit delay computations.

The following procedures should be used to compute delay-related measures from vehicle trajectories:

- *Time step delay*. The delay on any time step is, by definition, the length of the time step minus the time it would have taken the vehicle to cover the distance traveled in the step at the target speed. This value is easily determined and is the basis for the remainder of the delay computations.

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- *Segment delay.* Segment delay is represented by the time taken to traverse a segment minus the time it would have taken to traverse the segment at the target speed. The segment delay on any step is equal to the time step delay. Segment delays accumulated over all time steps in which a vehicle is present on the segment represent the segment delay for that vehicle.
- *Queue delay.* The queue delay is equal to the time step delay on any step in which the vehicle is in a queued state; otherwise, it is zero. Queue delays are accumulated over all time steps while the vehicle is in a queue.
- *Stopped delay.* The stopped delay is equal to the time step delay on any step in which the vehicle is in a stopped state; otherwise, it is zero. Since a vehicle is considered to be stopped if it is traveling at less than a threshold speed, a consistent definition of stopped delay requires that the travel time at the target speed be subtracted. Time step delays accumulated over all time steps in which the vehicle was in the stopped state represent the stopped delay. Earlier versions of this manual defined stopped delay as 90% of the control delay, on the basis of empirical data.

Queue delay computed from trajectory analysis provides the most appropriate representation of control delay.

- *Control delay.* Control delay is the additional travel time caused by operation of a traffic control device. The queue delay computed from vehicle trajectories provides a reasonable approximation of control delay when the following conditions are met:
  1. Queue delay is caused by a traffic control device, and
  2. Identification of the queued state is consistent with the definitions provided in the HCM.

Special Delay Estimation Issues

It is not possible to compute control delay from individual vehicle trajectory analysis in a manner consistent with the procedures in this manual that report control delay. It was demonstrated earlier in this chapter (see Exhibit 7-6) that the uniform delay term d_1 described in Chapter 18 is derived from trajectory analysis. The problem is that the delay adjustment terms d_2 and d_3 are macroscopic observations that have been derived analytically. As such, they cannot be represented by vehicle trajectories. When demand volumes approach and exceed capacity, the correction terms become very large.

Exhibit 7-8 showed the trajectory of a single vehicle in an undersaturated situation. From this figure, it is observed that the control delay will be the same as the queue delay when their travel times projected to the stop line at the running speed (i.e., the broken lines) follow the same path. The problem is that the additional delays from the d_2 and d_3 adjustment terms are not represented in the figure. The adjustment terms are represented implicitly in the queue delays produced by trajectory analysis. As such, they remain a valid estimator of control delay at all levels of saturation.

While the queue delay from trajectory analysis generally provides a reasonable estimate of the delay on a controlled link, it is important to recognize certain phenomena that raise interpretation issues. The first is geometric delay, which is not included in the Chapter 18 procedure. For example, a large truck

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turning right can cause additional delay to vehicles in a queue behind it. The additional delay, which would be ignored by the Chapter 18 control delay calculations, would be interpreted by trajectory analysis as control delay. This situation would cause problems in comparing the control delay estimates from the two methods.

Another problem arises with oversaturated conditions. The conceptual differences between the analytical delay model of Chapter 18 and the microscopic simulation approach make it difficult to compare their results. The comparison becomes even more complicated when queues extend into upstream links.

Density-Related Measures

Density is one of the easiest measures to compute from vehicle trajectories because it involves simply counting the vehicles in a section of roadway at a specific time. Density is therefore a product of spatial analysis as opposed to longitudinal analysis. The question is how to apply the proper definition of density to the right section of roadway over the right period of time. For example, a main obstacle in comparing densities reported by the procedural chapters in this manual with those reported by simulation tools is that different definitions. The procedures in this manual report density in terms of passenger cars per mile. Simulation tools report this measure in terms of actual vehicles per mile. The simulated densities must be converted to passenger cars per mile to produce comparable results. Procedures for conversion are discussed in Chapter 24, Concepts: Supplemental.

Because of the importance of density as a determinant of LOS, it is desirable to establish trajectory analysis procedures that are compatible with the HCM so that simulated densities can be used for LOS estimation. Microscopic simulation models establish the position of all vehicles in the system at all points in time, making it easy to define and compute density measures that are uniform among different tools by simply counting the number of vehicles on a specified part of a roadway.

Computational Procedures

The equivalent density at a point can be determined by simulation by using a simple equation that relates density to the spacing of vehicles:

$$\text{Density (veh/mi)} = \frac{5{,}280 \text{ ft/mi}}{\text{Vehicle spacing (ft/veh)}} \qquad \text{Equation 7-1}$$

Density can also be computed macroscopically at the segment level by simply counting the number of vehicles present on the segment during a particular time step. The density by time step may be aggregated over an analysis period by computing the arithmetic mean of the time step densities. This method of measurement and aggregation should produce density values that are compatible with the HCM in both definition and computation, provided that the demand (v) does not exceed the capacity (c). For v/c ratios greater than 1.0, the density at the end of the analysis period may be of more interest than the average density.

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Density is computed on a per lane basis in the examples given in Chapter 24. The combined density for the ramp influence area (the two freeway lanes adjacent to the ramp plus auxiliary lanes, if any, within 1,500 ft of the ramp junction) is also computed because of its application to freeway merge and diverge ramp functions. To compute the average density for a series of segments in a freeway facility, the procedure outlined in Chapter 10 should be used.

Follower Density

This measure is derived in terms of the number of followers per mile on a two-lane highway. Follower density is not reported in this manual. Instead, percent time spent following is used as a determinant of LOS for two-lane highways in Chapter 15. The definition of the following state is given in Chapter 15 as a condition in which a vehicle is following its leader by no more than 3 s. The concept of follower density has attracted increasing international interest. It is a measure that could be easily derived from a typical analysis.

STOCHASTIC ASPECTS OF SIMULATION ANALYSIS

Two HCM's deterministic procedures give a unique result for a given set of inputs, while stochastic tools may give a distribution of results for a given set of inputs over a series of runs.

The deterministic procedures in the HCM give a unique value for all performance measures based on the specifics of the input data. Stochastic analysis tools apply a randomization process that might give different values for performance measures each time the process is repeated. In other words, simulation tools produce a distribution of values for each performance measure, much as would be expected from a series of repeated field studies. It is essential in supporting decision making to represent the distribution of values in terms of a single representative value.

A comprehensive tutorial on the stochastic aspects of simulation is presented elsewhere (14). Topics covered include confidence intervals, the number of runs required to achieve a specified level of confidence, and hypothesis testing for comparing alternative configurations and strategies. The tutorial material is not repeated here, but it should be understood by analysts who are using simulation to produce performance measures that are comparable with those described in this manual.

Simulation modeling is based on internally generated random numbers that are controlled by specifying an initial random number or "seed" to start the generation process. In some cases, multiple seeds are used to control different aspects of the randomization. For example, driver characteristics and vehicle characteristics might be seeded differently. Multiple runs using a simulation tool with the same input data and random number seed(s) will produce the same answers. To establish a range of answers, repetitions must be created by running a simulation tool with the same input data with different random number seed(s). Most simulation tools provide guidance on selecting random number seeds.

Number of Required Repetitions

The result of a set of simulation runs is normally represented by a summary of the average values of the performance measures of interest. Confidence in the results is influenced by the number of runs included in the set. The question

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raised here is "How many runs are needed?" The answer depends on three parameters:

1. The maximum error that can be tolerated in the results. The tolerable error may be expressed in terms of an absolute value (e.g., 5 s of delay) or as a percentage of deviation from the true mean value. Greater acceptable maximum error (tolerance) suggests the need for fewer runs.
2. The degree of confidence that the true mean falls within the specified error limits. A greater degree of confidence (i.e., 99% as opposed to 95%) suggests a need for more runs.
3. The variability across simulation runs given by the standard deviation. A greater variability (higher standard deviation) suggests a need for more runs, if the other two parameters stay fixed.

In accordance with a basic statistical approach, the standard error of the mean may be estimated from the simple relationship in Equation 7-3:

$$E = \frac{s}{\sqrt{n}} \qquad \text{Equation 7-2}$$

where

E = standard error of the mean,

s = standard deviation of the set of runs for a particular performance measure, and

n = number of runs included in the set.

The confidence limits are expressed in terms of the number of standard errors from the mean value. A target of 95% confidence is often used for this purpose. The 95% confidence interval is represented by the mean value ±1.96 standard errors.

From the above relationship, it is possible, given the sample standard deviation s, to calculate the required sample size to produce 95% confidence of achieving a maximum tolerable error E_t by using Equation 7-3:

$$n = (1.96s)^2 / (E_t)^2 \qquad \text{Equation 7-3}$$

A few statistically oriented sites on the Internet offer online calculators for determining required sample sizes.

Expected Variation Between Runs

It is difficult to anticipate the amount of variation that will result from a set of runs given the input data. The standard deviation of a given performance measure is best determined by making a set of test runs and applying the sample size calculations. One factor that influences the variability of signalized intersections is the degree of saturation on each approach. This influence is illustrated in Exhibit 7-5, which shows the coefficient of variation (standard deviation/mean) on a simple signalized approach as a function of the approach volume. The data for this example included 30 runs for a 15-min period.

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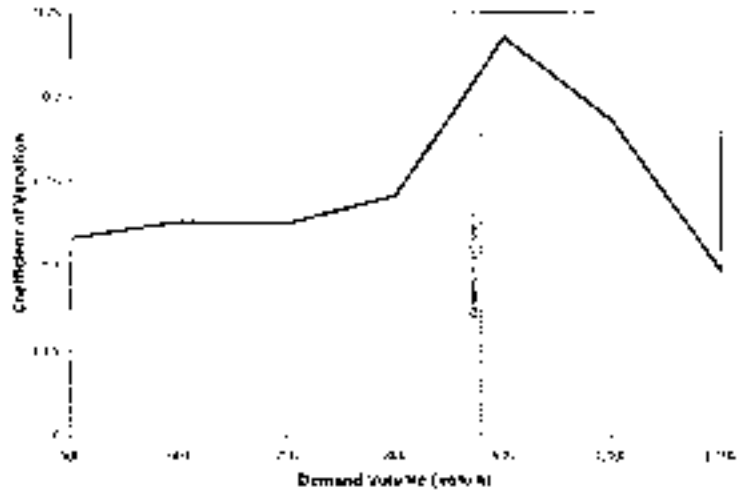
Exhibit 7-9
Effect of Demand Volume on Variability of Simulated Delay on an Approach to a Signalized Intersection



At low volumes, the variability is low, with the standard deviations approaching 10% of the mean value. The variability peaks at the capacity of the approach at a value near 25%. The variability is highest at capacity because some runs will see more undersaturated cycles in the operation, while others will see more oversaturated cycles. As demand volume increases well beyond approach capacity, the variability decreases significantly as deterministic phenomena begin to govern the operation.

Exhibit 7-9 shows the relationship for a single approach to an intersection. Variability may also be expected to decrease in larger systems, as illustrated in Exhibit 7-10. This example shows a very large system with 472 links, obtained from the sample data distributed with one simulation tool. The data set included 20 runs covering a 15 min period. The performance measures cover the entire system, and the resulting variation is substantially lower than would be expected on a single approach.

Exhibit 7-10
Variability of Overall Performance Measures for a Large Urban Network

Statistic	Vehicle Miles Traveled	Vehicle Hours Delay	Vehicle Hours Total	Minutes per Mile Delay	Minutes per Mile Total	Average Speed (Mi/h)
Mean	19,467	738	761	0.731	2.347	25.571
Standard deviation	140	7	9	0.019	0.021	0.213
CV	0.007	0.009	0.012	0.026	0.009	0.008
Standard error	31	1.49	1.96	0.00	0.00	0.05
Upper 95%	19,579	748.497	765.197	0.747	2.356	25.667
Lower 95%	19,496	234.661	757.508	0.725	2.337	25.475

Note: CV = coefficient of variation.

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COMPARING HCM ANALYSIS RESULTS WITH ALTERNATIVE TOOLS

At the start, it must be recognized that alternative traffic analysis tools have been used for many years and that not all their applications have a strong requirement for HCM compatibility. The guidance presented in this chapter and in the procedural chapters of Volumes 2 and 3 is addressed specifically to analysts who are seeking some degree of compatibility with the HCM procedures through the use of alternative tools. It is not the intent of the HCM to duplicate the tutorials and other authoritative documents in the literature dealing with the general application of traffic analysis tools.

Full numerical compatibility between the HCM and alternative tools is often unavoidable because of differences in defining, modeling assumptions, and computational methodologies.

Full numerical compatibility between the HCM and simulation-based analysis is seldom attainable because of differences in definitions, modeling approaches, and computational methodologies. An earlier section of this chapter dealt with the use of vehicle trajectory analysis to promote consistent definitions and computational procedures for the most important performance measures. The guidance in this section covers the following areas:

- Recognizing situations in which alternative tools should be applied,
- Recognizing situations in which basic incompatibilities preclude direct comparisons between the HCM and simulation results, and
- Achieving maximum compatibility between the HCM procedures and those of alternative tools.

Conceptual Differences Between Modeling Approaches

The analysis procedures described in this manual are based on deterministic models that are well founded in theory. They are implemented in the form of equations that describe the behavior of traffic. Most of the equations include empirical calibration factors derived from research. Simulation modeling, on the other hand, is based on the propagation of fictitious vehicles along a roadway segment in accordance with principles of physics, rules of the road, and driver behavior. While both modeling approaches attempt to replicate phenomena that can be observed and quantified in the field, it is sometimes difficult to obtain results that are mutually comparable. The conceptual differences that preclude comparison are discussed in the procedural chapters. A summary of key differences is presented here:

- Delays reported by the HCM interrupted-flow analysis procedures apply to all the vehicles that arrive during the analysis period. When demand volumes exceed capacity, the delay to vehicles entering the system during a given period and leaving during a subsequent period are excluded. Delays reported by simulation are those experienced within the analysis period regardless of when vehicles entered or left the system. This concept is explored in more detail later in this chapter in the discussion of multiperiod operation.
- Densities reported by the uninterrupted-flow chapters in terms of passenger cars per mile. Passenger car equivalency (PCE) factors are used to convert heavy vehicles to passenger cars. PCEs are applied before the density computations. Densities reported by simulation are generally expressed in actual vehicles per mile. The effect of heavy vehicles is an

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implicit result of their different characteristics. Because of this difference, it is difficult to apply PCE factors in reverse to the results of the computations.

- The procedures in this manual deal with peak 15-min-period demand flow rates, sometimes determined by applying a PHF to hourly volumes. Simulation models do not normally apply a PHF to input volumes. Therefore, some care must be taken to ensure that the demand and time periods are represented appropriately to promote the development of comparable results.
- The procedures for analysis of urban street operations focus on performance measures for arterial through vehicles. Simulation tools generally consider all vehicles, including turning movements on a street segment. To obtain comparable results from simulation, it is necessary to isolate the through movements.
- The procedures for analysis of ramp merge and diverge segments focus on traffic density within the influence of the merge area (usually the ramp and the two adjacent lanes). To obtain comparable results from simulation, it is necessary to define the merge area as a separate segment for analysis and to isolate the movements in the adjacent lanes.
- HCM procedures typically do not consider the effect of self-aggravating phenomena on the performance of a segment. For example, when traffic in a left-turn bay spills over into the adjacent through lane, the effect on the through lane performance is not considered. The inability of drivers to access their desired lane when queues back up from a downstream facility is not taken into consideration.
- Random arrivals in the traffic stream are also treated differently by the two modeling approaches. The HCM's interrupted-flow procedures apply analytical correction factors to account for this effect, while simulation modeling treats randomness explicitly by generating vehicle arrivals from statistical distributions. The difference between the two treatments affects the comparability of results.
- Some simulation tools either require or have the option of entering the origin–destination matrix instead of link and turning movement volumes. In these cases, the link and turning movement volumes are outputs from the dynamic traffic assignment models implemented as parts of the tools. HCM procedures require the link or turning movement counts as inputs.

Framework for Comparison of Performance Measures

The application framework for alternative tools is presented in the form of a flowchart in Exhibit 7-11. This framework applies to all the procedural chapters in Volumes 2 and 3.

The first steps in this flowchart deal with identifying whether the situation will support analyses in which some degree of compatibility between the HCM and alternative tools may be achieved. If it is determined that, because of conceptual differences in definitions and modeling, no potential for comparability

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exists, then the use of alternative tools should be limited to feasibility assessment and comparison of candidate solutions. It is anticipated that, in most cases, there will be potential areas of incompatibility.

The next steps cover the conduct of simulation analysis to achieve the desired level of compatibility with the HCM. Four steps are involved:

1. Calibrate the simulation parameters to the HCM, usually by seeking equal capacities from both processes.
2. Perform a statistically appropriate number of simulation runs.
3. Interpret the results.
4. Make iterative adjustments to calibration parameters to reconcile differences.

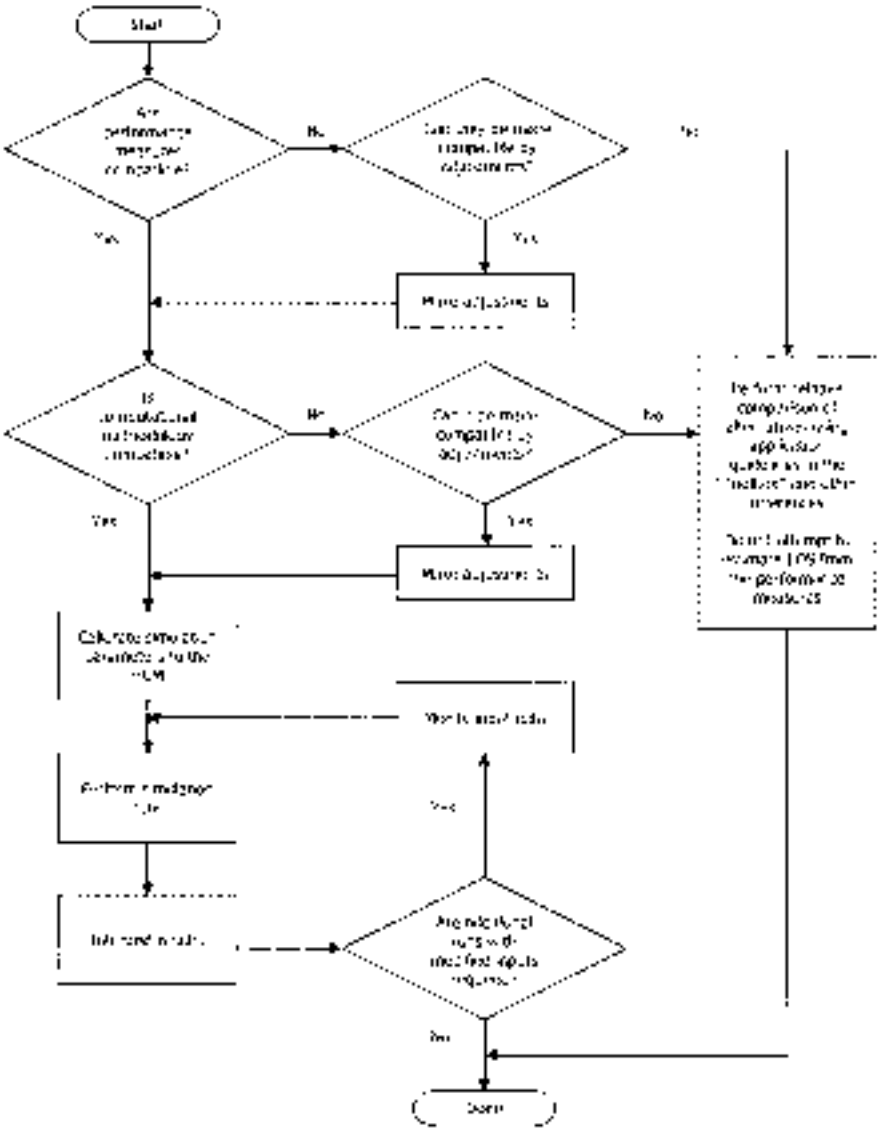

Exhibit 7-11
Application Framework for Alternative Tools

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Alternative tools that report a performance measure with the same name as an HCM service measure, but with a different method of computation, should not be used to estimate LOS for purposes of the HCM.

LOS Comparisons

LOS estimates are determined by applying thresholds to specified performance measures (i.e., service measures). When LOS is estimated from performance measures obtained from an alternative tool, it is essential that the performance measure be determined in the same way the HCM determines the same measure. Alternative methods may be used to estimate and compare performance measures as long as they are both trying to estimate the same fundamental measurement. Alternative tools that report a performance measure with the same name as an HCM measure, but with a different method of computation, should not be used to estimate the LOS for purposes of the HCM.

At this point, simulation tools do not generally report performance measures by using the definitions and trajectory-based method of estimation suggested in this chapter and in Chapter 24. Some refinement in the alternative tool definitions and methods of estimation based on vehicle trajectory analysis is required before valid comparisons can be made. The value of simulation modeling as a useful decision support tool is recognized, but the validity of direct comparison with performance measures defined by this manual is questionable unless the definitional and computational procedures conform to those prescribed in this chapter.

HCM LOS thresholds are often based on service measures representing the peak 15 min of demand (arriving vehicles) rather than the 15-min period when the measure reached its maximum value.

It is also important to note that the HCM applies LOS thresholds to performance measures that represent the peak 15 min of demand (i.e., arriving vehicles) and not necessarily the 15-min period when the performance measure produced its maximum value.

The presence of significant queues at the end of an analysis period can often be taken as an indicator that LOS F has been reached.

One consideration that makes simulation more compatible with the HCM in reporting LOS is the criterion that, for most roadway segments, LOS F is assigned to any segment that operates above its capacity. Therefore, without the need for a detailed trajectory analysis, the presence of significant queues at the end of the analysis period can be taken as an indicator that LOS F has been reached in the segment. When queues extend into a given segment from a downstream bottleneck, it is important to use the analysis procedures for freeway facilities described in Chapter 10 of this manual instead of the procedures for individual segments described in Chapters 11 to 15. On the other hand, when the purpose of the analysis is to develop a facility design that will produce a LOS better than F, the analyst must ensure that the performance measure on which LOS is based is estimated in a manner compatible with the HCM.

Estimation of Capacity by Simulation

It is commonly accepted that the capacity of an approach or segment may be estimated by overloading it and observing the maximum throughput. This technique is valid in some cases, but it must be used with caution when congestion could become a self-aggravating phenomenon. For example, when lane selection is important (as in the case of a turning bay) and congestion keeps vehicles from their desired lane, the throughput can drop below its theoretical maximum. This phenomenon is not recognized by most of the HCM's deterministic analysis procedures. Therefore, if the objective is to seek HCM compatible capacity levels, the approach or segment should not be overloaded.

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by more than a few percent. In this case, the process of determining capacity might require iteration. On the other hand, if the objective is to evaluate the operation under an anticipated heavy overload, then simulation modeling might provide some insight into the nature of the resulting congestion. In that case, the analysis could require development of the relationship between demand and throughput. Examples of the adverse effects of heavy overloading are presented in Chapter 27, Freeway Weaving: Supplemental, and Chapter 34, Interchange Ramp Terminals: Supplemental.

Temporal and Spatial Boundaries

The LOS reported by the HCM procedures applies to the 15-min period with the maximum number of arrivals (i.e., entering vehicles). This period might not be the same one that reports the maximum delay because of residual queues. In a discussion of the limitations of performance measure estimation and use (*15*), there is frequent reference to the issues that arise in the treatment of incomplete trips within the analysis period, including those that entered the spatial domain of the analysis but did not exit during the analysis period and those that were unable to enter the spatial domain because of queue backup. The main problem lies in differences in treatment among different modes.

Definition of incomplete trips within the temporal and spatial boundaries of an analysis

Complete Versus Incomplete Trips

Five categories are proposed with respect to incomplete trips (*15*).

1. Vehicles that were present at the start of the analysis period and were able to exit the system successfully before the end of the analysis period;
2. Vehicles that were present at the start of the analysis period but were unable to exit the system successfully before the end of the analysis period;
3. Vehicles that were able to enter the system during the analysis period but were unable to exit the system successfully before the end of the analysis period;
4. Vehicles that tried to enter the system during the analysis period but were unsuccessful; and
5. Vehicles that entered during the analysis period and were able to exit the system successfully before the end of the analysis period.

All categories except the fifth represent incomplete trips. It is suggested elsewhere (*15*) that, if a specific analysis contains more than 5% incomplete trips, the period length should be increased.

It is important to recognize that the objectives of the Federal Highway Administration's *Traffic Analysis Toolbox* (*16*) differ somewhat from those of the HCM. The purpose of the *Toolbox* is to provide general guidance on applying traffic analysis tools. The guidance on simulation included in this chapter is more focused on developing HCM-compatible performance measures so that those measures can be used in conjunction with the HCM procedures. Therefore, this discussion must examine temporal and spatial boundaries from the same perspective as the HCM procedures.

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When oversaturated operation is being studied, the definition of the facility in time and space is much less important. The operation tends to be more homogeneous when *v*/*c* ratios are less than 1.00. Extending the analysis period will give a larger sample of vehicles for most performance measures but will not affect the measures significantly.

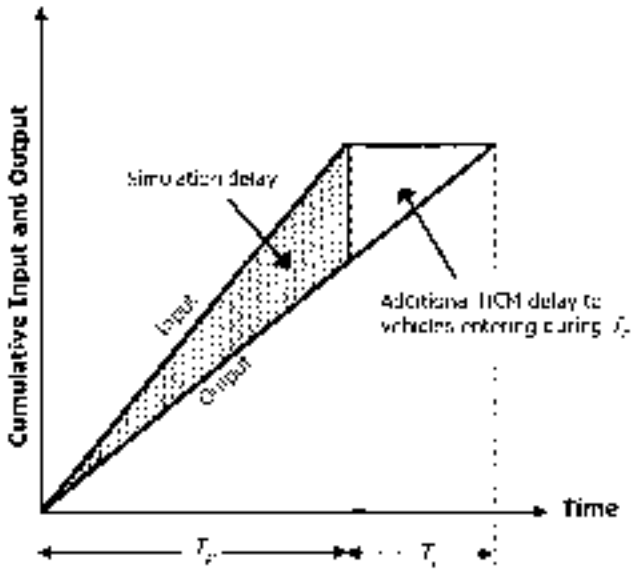
The issues are more complicated when the *v*/*c* ratio is greater than 1.00 for short periods. In this case, queues build up and the analysis (either HCM or simulation) must define temporal boundaries that begin and end without congestion. It is also desirable, but not essential, that the spatial boundaries encompass uncongested operation. Failure to define a spatially adequate system will result in vehicles being denied entry, but those vehicles will eventually be processed if the analysis period is long enough.

Delay on Oversaturated Signalized Approaches

LOS for interrupted flow is defined by the HCM in terms of the delay to all vehicles entering the facility during the analysis period. All vehicles wishing to enter are assumed to enter. Those unable to exit from a signalized intersection are accumulated in a residual queue and are assumed to exit later. The incremental (d_2) term of the delay model accounts for delay to vehicles that exit in a later period. The d_3 term accounts for the additional delay caused by an initial queue.

The formulation illustrated in Exhibit 7-12 recognizes that delay accrues when the vehicular input to a system exceeds the output for a period of time. The HCM uses this formulation to estimate delay that accrues at a signalized intersection when volume exceeds capacity over the analysis time period, T_f. The HCM delay in Exhibit 7-12 is represented by the area of the two triangles sunwen in the figure. The area within the two triangles is referred to as the deterministic queue delay (DQD). The DQD may be determined as $0.5 \times T_f \times (X - 1)$, where X is the *v*/*c* ratio.

Exhibit 7-12
Oversaturated Delay Representation by the HCM and Simulation Modeling



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When demand exceeds capacity, some vehicles that arrive during T_p will depart during the next period. The time required to clear all vehicles arriving during T_p is shown above as T_c. Because the HCM defines delay in terms of the delay experienced by *all vehicles that arrive* during the analysis period, the delay computations must include the delay to those vehicles that arrive during T_p and depart during T_c.

The HCM defines delay in terms of the delay experienced by all vehicles arriving during an analysis period (e.g., 15 min), including delay accumulated after the end of the analysis period.

This definition differs from the delay definition used by most simulation tools, which address the delay experienced *during* the analysis period. The HCM definition includes the area within both triangles of Exhibit 7-12. The simulation definition includes only that portion of the area within the interval T_p.

Most simulation tools define delay in terms of the delay experienced by all vehicles during a specified analysis period and do not include delay from later time periods.

Compatibility with the HCM definition dictates that a control delay measure should be based on all entering vehicles, without regard to completed trips. An adequate initialization period should be used to load the facility. When the *d/c* ratio is less than 1.00, some vehicles that entered before the start of the analysis (i.e., during the initialization period) will exit the system. There will also be vehicles that enter the system late in the period and do not exit. Including these incomplete trips will not bias the delay results.

When demand exceeds capacity for a single period, the HCM delay formulation shown in Exhibit 7-12 will include the delay to vehicles that exit in the next period. The simulation results will not. To produce a simulation run that replicates the HCM single-period calculations, a second period with zero demand must be added to the simulation run. Only the vehicles that were unable to exit during the first period will be accommodated during the second period. The sum of the delays for both periods will be equivalent to the HCM delay shown in Exhibit 7-12.

Delay for Multiperiod Oversaturation

When operations are oversaturated beyond a single analysis period, a multiperiod analysis is necessary.

When the operation is oversaturated beyond a single period, it is necessary to perform a multiperiod analysis, ensuring that the duration is sufficient to encompass uncongestion conditions at both ends.

As an example, HCM and simulation delay formulations are illustrated in Exhibit 7-13, which depicts the analysis of four oversaturated periods that begin and end without congestion. The analysis is performed sequentially, with the residual queues from one period applied as initial queues to the next period. The first two periods have demand in excess of capacity. In the last two periods, the demand drops sufficiently below capacity to allow the queues to clear. Delay polygons are shown for the HCM and simulation definitions for all periods. The shape of the delay polygons differs in the two formulations, so the delay values are not the same for any period. The important thing is that the sum of the areas for the four polygons is the same for each definition.

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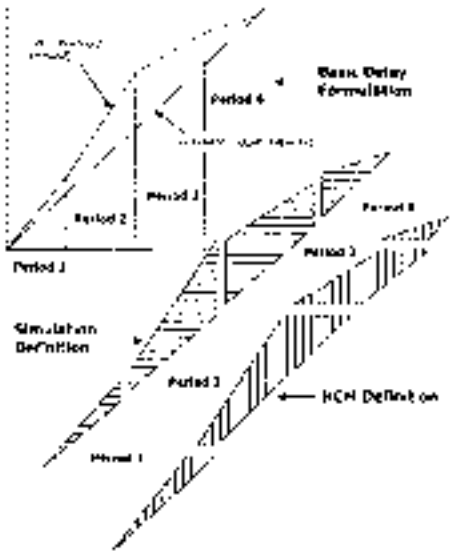
Exhibit 7-13
Comparison of HCM and Simulation Delay Definitions for Four Oversaturated Periods



Therefore, to promote compatibility between the HCM and simulation delay definitions for a multiperiod analysis involving oversaturated signalized approaches, the simulation results should be obtained as follows.

- Ensure that the analysis period is long enough to encompass a period of congestion-free operation at both ends.
- Perform an adequate initialization to load the system.
- Perform the analysis on all vehicles entering the system during each period.
- Do not ignore any entering or exiting vehicle in any period; otherwise, the results could be biased.
- If a measure of delay per vehicle is desired, develop the total delay by summing the delays for the individual periods and divide that delay by the total entering volume.

Delay is not reported explicitly in the freeway segment chapters (Chapters 11 to 13). However, delay may be inferred from each chapter's free-flow and average speed computations. This step is performed in Chapter 10 for analysis of freeway facilities involving a combination of different segment types. The delay due to queues forming from bottlenecks is added to the individual segment delays. While the delay computations are conceptually simpler for freeways, the same guidance for developing compatible simulation results applies to other system elements.

Density is defined only in the uninterrupted-flow chapters. Unlike delay measures, which apply to individual vehicles, the density measure applies to the facility. Therefore, the issue of how to treat incomplete trips does not apply. Instantaneous densities should be determined from simulation by time step and should be aggregated over suitable intervals. The average density over a long period will be of less interest for most purposes than the variation of density that takes place in time and space. Typical aggregation intervals for that purpose will range from 5 to 15 min.

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4. PRESENTATION OF RESULTS

GUIDANCE ON THE DISPLAY OF HCM RESULTS

Conventions for the display of results in the HCM.

Tabular values and calculated results are displayed in a consistent manner throughout the HCM. It is suggested that analysts adhere to these conventions. A key objective is to use the number of significant digits that is reasonable, to indicate to users, decision makers, and other viewers that the results are not extremely precise but take on the precision and accuracy associated with the input variables used. This guidance applies primarily to inputs and final outputs; intermediate results in a series of calculations should not be rounded unless specifically indicated by a particular methodology.

Input Values

Following is a list of representative (not exhaustive) input variables and the suggested number of digits for each:

- Volume (whole number);
- Grade (whole number);
- Lane width (one decimal place);
- Percentage of heavy vehicles (whole number);
- PHF (two decimal places);
- Pedestrian volume (whole number);
- Bicycle volume (whole number);
- Parking maneuvers (whole number);
- Bus stopping (whole number);
- Green, yellow, all-red, and cycle times (one decimal place);
- Lost time/phase (whole number); and
- Minimum pedestrian time (one decimal place).

Adjustment Factors

Factors interpolated from tabular material can use one more decimal place than is presented in the table. Factors generated from equations can be taken to three decimal places.

Service Volume Tables

When rounding volumes for service volume tables, a precision no greater than the nearest 10 vehicles or passenger cars should be used for hourly tables and the nearest 100 vehicles or passenger cars for daily tables.

Free-Flow Speed

For base free-flow speeds, show the value to the nearest 1 mi/h. For free-flow speeds that have been adjusted for various conditions and that are considered intermediate calculations, show speed to the nearest 0.1 mi/h.

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Speeds

For threshold values that define LOS, show speed to the nearest 1 mi/h. For intermediate calculations of speed, use one decimal place.

Volume-to-Capacity and Demand-to-Capacity Ratios

Show v/c and d/c ratios with two decimal places.

Delay

In computing delay, show results with one decimal place. In presenting delay as a threshold value in LOS tables, show a whole number.

Density

Show density results with one decimal place.

Pedestrian Space

Show pedestrian space values with one decimal place.

Occurrences and Events

For all event-based items, use values to a whole number. These items include parking maneuvers, bus stops, events along a pedestrian or bicycle path, and number of cycles in a given time period.

General Factors

In performing all calculations on a computer, the full precision available should be used. Intermediate calculation outputs should be displayed to more significant digits throughout. For the measure that defines LOS, the number of significant digits presented should exceed by one the number of significant digits shown in the LOS table.

PRESENTING RESULTS TO FACILITATE INTERPRETATION

Performance measures selected should be related to the problem being addressed.

Several performance measures can result from HCM analyses. Determining the most appropriate measures to use for a decision depends on the particular case. However, decision-making situations generally can be divided into those involving the public (e.g., city councils and community groups) and those involving technicians (e.g., state and local engineering and planning staff).

The HCM is highly technical and complex. The results of the analyses can be difficult for people to interpret for decision making, unless the data are carefully organized and presented. In general, the results should be presented as simply as possible. This presentation might use a small set of performance measures and provide the data in an aggregate form without losing the ability to relate to the underlying variations and factors that generated the results.

The LOS concept was created, in part, to make presentation of results easier than if numerical values of service measures were reported directly. In many cases, analysts and decision makers prefer to see one service measure rather than multiple performance measures. At the same time, relying solely on LOS results in making recommendations or decisions can result in important information available from other performance measures being overlooked. Nevertheless,

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although there are limitations to its usefulness, the LOS concept remains a part of the HCM because of its acceptance by the public and decision makers.

Decision makers who represent the public usually prefer measures that their constituents can understand; the public can relate to LOS results. Unit delay (e.g., seconds per vehicle) and travel speed are also readily understood. However, volume-to-capacity ratio, density, percent time spent following, and vehicle hours of travel are not measures to which the public easily relates. When the measures to present are selected, it is important for the analyst to recognize the orientation of the decision maker and the context in which the decision will be made. In general, these measures can be differentiated as system-user or system-manager oriented.

GRAPHIC REPRESENTATION OF RESULTS

Historically, data and analysis results have been presented primarily in tables. However, results may be best presented as pictures and supplemented only as necessary with the underlying numbers in some situations. Graphs and charts should not be used to decorate data or to make dull data entertaining; they should be conceived and fashioned to aid in interpretation of the meaning behind the numbers (17).

Present results to make them very plain (obvious) to the audience.

Most performance measures in the HCM are quantitative, continuous variables. LOS values, however, result from step functions and do not lend themselves to graphing. When placed on a scale, LOS results must be given an equivalent numeric value, as shown in Exhibit 7-14, which presents the LOS for a group of intersections. The LOS letter is indicated, and shaded (or colored) areas indicate intersections that are below, at, or above the analysis objective of LOS D. The size of the indicator at each intersection shows the relative control delay value for the indicated LOS.

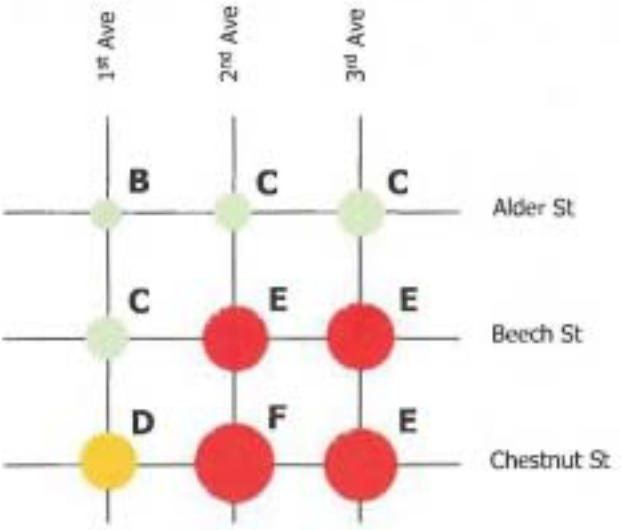

Exhibit 7-14
Example of a Graphic Display of LOS

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The issue is whether the change in value between successive LOS values (i.e., the interval) should be equal. For instance, is it appropriate for LOS A to F to be converted to a scale of 0 through 5? Should the numerical equivalent assigned to the difference of the thresholds between LOS A and B be the same as the difference between LOS E and F? These questions have not been addressed in research, except in the area of traveler-perception models. Furthermore, LOS F is not given an upper bound. Therefore, a graph of LOS should be considered ordinal, not interval, because the numeric differences between the levels would not appear significant.

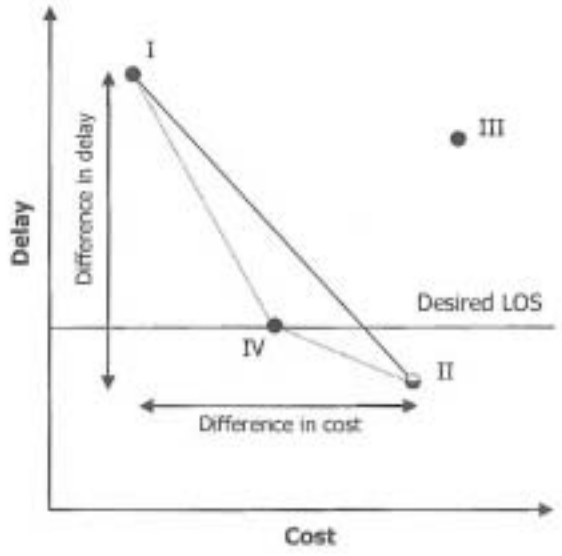
However, it is difficult to refrain from comparing the differences. A scale representing the relative values of the LOS letters would have to incorporate the judgment of the analyst and the opinions of the public or decision makers—a difficult task. A thematic graphic presentation, however, avoids this issue. In Exhibit 7-15, for example, shading is used to highlight time periods and basic freeway segments that do not meet the objective LOS (in this case, D).

Exhibit 7-15
Example of a Thematic Graphic Display of LOS

Start Time	Segment 1	Segment 2	Segment 3	Segment 4
5:00 p.m.	A	B	B	A
5:15 p.m.	B	B	D	A
5:30 p.m.	B	B	F	A
5:45 p.m.	B	D	F	A
6:00 p.m.	B	F	F	A
6:15 p.m.	D	F	E	A
6:30 p.m.	D	E	C	A
6:45 p.m.	B	B	B	A

Simple graphics often can facilitate decision making among available alternatives. For example, in the cost-effectiveness graph in Exhibit 7-16, the estimated delays resulting from alternative treatments are plotted against their associated cost. The graph shows more clearly than a tabulation of the numbers that Alternative III is more costly and creates higher delay than Alternative II. This result eliminates Alternative III.

Exhibit 7-16
Example of a Cost-Effectiveness Graph



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Whether Alternative I or II should be chosen, however, is a matter for the decision maker's judgment. Alternative II is more expensive than Alternative I but is predicted to deliver a significantly lower delay. A useful measure for decision makers is provided by the slope of the line between the alternatives, which shows the seconds of delay saved per dollar of cost.

For this example, assume that Alternative IV provides the minimum acceptable LOS at significantly less cost than Alternative III. The dotted lines in Exhibit 7-7 indicate the relative cost effectiveness of moving from Alternative I to IV or Alternative IV to II. The steepest slope—I to IV—signifies a high level of cost effectiveness. The two alternatives that just exceed the LOS objective are Alternatives II and IV. The most appropriate alternative, therefore, is Alternative IV.

The HCM provides valuable assistance in making transportation management decisions in a wide range of situations. It offers the user a selection of performance measures to meet a variety of needs. The analyst should recognize that using the HCM involves mixing a bit of art along with the science. Sound judgment is needed not only for interpreting the values produced but also for summarizing and presenting the results.

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CHAPTER 8
HCM PRIMER

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1. INTRODUCTION

VOLUME 1: CONCEPTS
1 HCM User's Guide
2 Applications
3 Modal Characteristics
4 Traffic Flow and Capacity Concepts
5 Quality and Level of Service Concepts
6 HCM and Alternative Analysis Tools
7 Interpreting HCM and Alternative Tool Results
8 HCM Primer
9 Glossary and Symbols

The 2010 *Highway Capacity Manual* (HCM) is the fifth edition of this fundamental reference document. Its objectives are threefold:

1. To define performance measures and describe various methods for key traffic characteristics,
2. To provide methodologies to estimate and predict facility-related performance measures, and
3. To explain methodologies in a manner that allows readers to understand the factors that affect multimodal roadway operations.

The travel modes covered by the HCM consist of the *automobile*, *pedestrian*, and *bicycle* modes, as well as *public transit* vehicles that operate on urban streets. The automobile mode includes other motorized roadway users, such as trucks, recreational vehicles, intercity buses, and motorcycles.

HCM methodologies can be applied both to *uninterrupted-flow* roadways, such as freeways, multilane rural highways, and two-lane rural highways, and to *interrupted-flow* roadways, primarily urban streets and the intersections located along those streets. Methodologies are also provided for evaluating off-street pedestrian and bicycle facilities. The HCM can be applied to *under-saturated* conditions (where traffic demand is less than a roadway's capacity) and, in certain situations, to *over-saturated* conditions (where demand exceeds capacity).

The HCM 2010 presents the best available techniques at the time of publication for determining roadway capacity and level of service (LOS), proven to work in the United States and validated by a group of experienced experts. However, the HCM does not endeavor to establish a legal standard for highway design or construction.

Chapter 8, HCM Primer, is written for a nontechnical audience and is a synopsis of Volume 1 of the HCM. An example of a potential audience for this chapter is decision makers who may be presented with the results of HCM analyses for the purpose of establishing policy or public interest findings. The chapter covers basic traffic operations terminology, capacity and quality-of-service concepts, and guidance on applying the results of analyses produced by the HCM and alternative traffic operations tools.

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2. HIGHWAY CAPACITY CONCEPTS

DEFINITION OF CAPACITY

Capacity is the maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, environmental, traffic, and control conditions. This one-sentence definition covers a variety of diverse topics, each discussed below:

- *Roadway conditions* include such factors as the number of lanes, the width of the lanes and shoulders, and the roadway's horizontal and vertical alignment. The addition of a lane to a freeway, for example, increases the freeway's capacity, while substandard lane and shoulder widths may result in a lower capacity than would standard widths.
- *Environmental conditions* include weather and lighting. The base conditions assumed in the HCM are good weather and lighting; however, depending on the needs of a given analysis (e.g., an analysis of travel time variability), roadway capacities under less than ideal conditions may be of interest. The HCM provides guidance for those situations as well.
- *Traffic conditions* include the proportion of heavy vehicles (i.e., trucks, buses, and recreational vehicles) in the traffic stream, the proportion of roadway users who are regular users, turning-movement patterns at intersections, and the distribution of vehicles between lanes and directions of a roadway. Heavy vehicles adversely affect traffic in two ways: (a) they occupy more roadway space than passenger cars and (b) they have poorer operating capabilities than passenger cars, particularly with respect to acceleration, deceleration, and the ability to maintain speed on upgrades.
- *Control conditions* include the types of traffic control used at intersections (i.e., traffic signals, stop signs, or YIELD signs), the amount of green time allocated to a particular movement at a traffic signal, and restrictions on the use of certain lanes (e.g., part-time restrictions on parking, or truck prohibitions on the left lane of a freeway).
- *Reasonable expectancy* is the basis for defining capacity. That is, the stated capacity for a given roadway element is one that can be achieved repeatedly during peak periods, rather than the absolute maximum flow rate that could be observed on such a roadway. Driver characteristics vary from region to region, and the absolute maximum flow rate can vary from day to day and from location to location.
- Finally, the *time period* used for analysis is typically the peak 15 min of the analysis hour. Traffic demands typically fluctuate over the course of an hour, so a roadway designed to accommodate hourly traffic demands may experience shorter-term peaks in demand that cause the roadway to break down. Once a roadway has broken down, it may take some time to recover. A 15-min analysis period accommodates most variations in flow without producing an excessively conservative estimate of capacity.

Traffic demands used in HCM analyses are typically expressed as flow rates that represent four times the peak 15-min traffic demand.

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Persons per hour, passenger-car equivalents per hour, and vehicles per hour are measures that can define capacity, depending on the type of roadway element and the type of analysis being conducted. The concept of person flow is important (a) in making strategic decisions about transportation modes in heavily traveled corridors and (b) in detecting the role of transit and high occupancy-vehicle priority treatments. Person-capacity and person-flow weight each type of vehicle in the traffic stream by the number of occupants carried.

UNINTERRUPTED-FLOW ROADWAYS

Characteristics

Uninterrupted-flow roadways have no fixed causes of delay or interruptions to the traffic stream such as traffic signals. Freeways and their components operate under the purest form of uninterrupted flow. There are no fixed interruptions to traffic flow, and access is controlled and limited to ramp locations. Multilane highways and two-lane highways can also operate under uninterrupted flow in long segments; however, it may also be necessary to examine points along these highways where traffic may need to slow or stop (e.g., traffic signals, roundabouts, and STOP signs).

The traffic stream on uninterrupted-flow facilities is the result of individual vehicles interacting with each other and the facility's geometric characteristics. The pattern of flow is generally controlled only by the characteristics of the land uses that generate the traffic using the facility, although freeway management and operations strategies—such as ramp metering, freeway auxiliary lanes, truck lane restrictions, variable speed limits, and incident detection and clearance—can also influence traffic flow. Operations can also be affected by environmental conditions, such as weather or lighting, by pavement conditions, and by the occurrence of traffic incidents (1, 2).

"Uninterrupted flow" describes the type of facility, not the quality of the traffic flow at any given time. A freeway experiencing stop-and-go congestion, for example, is still an uninterrupted-flow facility, despite the congestion.

HCM Methodologies

The HCM provides methodologies for the following uninterrupted-flow system elements:

- *Freeway facilities*. An extended length of a single freeway composed of a set of connected basic freeway, weaving, and merge and diverge segments.
- *Basic freeway segments*. The portions of a freeway outside the influence area of any on- or off-ramps.
- *Freeway weaving segments*. The portions of a freeway where an on-ramp is closely followed by an off-ramp and entering or exiting traffic must make at least one lane change to enter or exit the freeway.
- *Freeway merge and diverge segments*. The portions of a freeway where traffic enters or exits without having to change lanes to enter or leave a through traffic lane.

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- *Multilane highways.* Higher-speed facilities, with two or more lanes in each direction, without full access control (i.e., traffic enters and exits by means of at-grade intersections, which may or may not be signal controlled).
- *Two-lane highways.* Facilities with mostly one lane of travel per direction, with motorists using passing lanes, turnouts, or the opposing lane (where allowed by regulation and opposing traffic) to pass slower vehicles.

Performance Measures

The following are key performance measures used to evaluate the operation of uninterrupted-flow roadways:

- *Density* is typically defined by the average number of vehicles (or passenger car equivalents) per lane mile of roadway. The denser the traffic conditions, the closer vehicles are to each other and the harder it is for vehicles to change lanes or maintain a constant speed. Density is frequently used to evaluate freeways and multilane highways.
- *Speed* reflects how fast motorists can travel along a roadway. The speed that a motorist would travel along an uninterrupted-flow roadway under low-volume conditions is known as the *free-flow speed*. Drivers experience delay when their travel speed is less than the free-flow speed, which is a result of traffic demands approaching or exceeding the roadway's capacity. Speed is used to evaluate all kinds of uninterrupted-flow roadways.
- *Percent time spent following* is a measure specific to two-lane highways. It represents the freedom to maneuver and the comfort and convenience of travel. It is the average percentage of travel time that vehicles must travel in platoons behind slower vehicles because of the inability to pass.
- *Volume-to-capacity (v/c) ratio* reflects how close a roadway is operating to its capacity. By definition, the volume of traffic using a roadway cannot exceed the roadway's capacity. Therefore, the v/c ratio is actually a *demand-to-capacity (d/c) ratio*. However, v/c ratio is the historically used term. A v/c ratio that exceeds 1.00 indicates that more vehicles demand to use a roadway than can be accommodated. Observed volumes represent only the number of vehicles that are able to pass through a portion of roadway under existing conditions; these volumes may be constrained by bottlenecks elsewhere along the roadway. In contrast, *demand volumes* represent the number of vehicles that would be observed in the absence of any bottlenecks. Analyses that fail to account for demand volumes may result in a forecast of better future conditions than would actually occur.

INTERRUPTED-FLOW ROADWAYS

Characteristics

Interrupted-flow facilities have fixed causes of periodic delay or traffic stream interruption, such as traffic signals, roundabouts, and stop signs. Urban streets are the most common form of this kind of facility. Exclusive pedestrian and bicycle facilities are also treated as interrupted flow, since they may

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occasionally intersect other streets at locations where pedestrians and bicyclists do not automatically receive the right-of-way.

The traffic flow patterns on an interrupted-flow facility are the result of vehicle interactions, the facility's geometric characteristics, the traffic control used at intersections, and the frequency of access points to the facility. Traffic signals, for example, allow designated movements to occur only during certain portions of the signal cycle (and, therefore, only during certain portions of an hour). This control creates two significant outcomes. First, time affects flow and capacity, since the facility is not available for continuous use. Second, the traffic flow pattern is dictated by the type of control used. For instance, traffic signals create platoons of vehicles that travel along the facility as a group, with significant gaps between one platoon and the next. In contrast, all-way STOP-controlled intersections and roundabouts discharge vehicles more randomly, creating small (but not necessarily usable) gaps in traffic at downstream locations (1, 3).

HCM Methodologies

The HCM provides methodologies for the following interrupted-flow system elements:

- *Urban street facilities*, which are extended sections of collector or arterial streets, and which include the impacts of traffic signals or other traffic control along the street. Urban street facilities are formed by two or more *urban street segments*, which are typically street sections extending from one traffic signal to the next, including the impact of the traffic signal at the far ("downstream") end of the segment. Roundabouts and STOP sign control on the major street can also define the end of an urban street segment. Segments are the basic analysis unit for multimodal analyses.
- *Signalized intersections*.
- *Interchange ramp terminals*, which are two closely spaced intersections of freeway ramps and surface streets. The HCM can be used to analyze interchange ramp terminals consisting of a pair of signalized intersections or a pair of roundabouts.
- *Unsignalized intersections*, including two-way STOP-controlled intersections (i.e., intersections where only the side street approaches are required to stop), all-way STOP-controlled intersections, and roundabouts.
- *On-street pedestrian and bicycle facilities*, such as bicycle paths or multiuse trails. On-street pedestrian and bicycle facilities are addressed by the methodologies for urban streets and intersections, although not every system element has an associated pedestrian or bicycle methodology.

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Performance Measures

The following are key performance measures used in evaluating the operation of motorized vehicles on interrupted-flow roadways:

- *Control delay* is the delay incurred because of the presence of a traffic control device. It includes delay associated with vehicles slowing in advance of an intersection, the time spent stopped at intersection approach, the time spent as vehicles move through a queue, and the time needed for vehicles to accelerate to their desired speed once through the intersection.
- *Speed* reflects how fast motorists can traverse a roadway section, including the effects of traffic control devices, delays due to turning vehicles at intersections and driveways, and traffic demands on the roadway.
- *Number of stops* reflects how frequently motorists must come to a stop while traveling along an urban street because of traffic control, turning vehicles, midblock pedestrian crossings, and similar factors.
- *Queue length* reflects how far traffic backs up as a result of traffic control (e.g., a queue from a traffic signal) or a vehicle stopped in the travel lane while waiting to make a turn. Queuing is both an important operational measure and a design consideration. Queues that use storage from the available storage length can create several types of operational problems. A through-lane queue that extends past the entrance to a turn lane blocks access to the turn lane, keeping it from being used effectively. Similarly, a turn-lane queue overflow into a through lane interferes with the movement of through vehicles. Queues that extend upstream from an intersection can block access into and out of driveways and—in a worst case—can spill back into and block upstream intersections, causing side streets to begin to queue back.
- *Volume to capacity (demand to capacity) ratio*, which are defined and used similarly to those of uninterrupted-flow roadways.
- The performance measures produced by *traveler perception models* describe how travelers would perceive conditions. These models use a variety of inputs to generate a single performance measure. The measure value predicts the average perception rating that all users of a given mode would give a particular system element. Traveler perception models are frequently applied to pedestrian, bicycle, and transit analyses and are discussed further in Section 3, Quality and Level of Service Concepts.
- *Pedestrian space*, *bicycle speed*, and *number of meeting/passing events* on off-street pedestrian and bicycle facilities can also be of interest to analyses involving the pedestrian and bicycle modes.

MODAL INTERACTIONS

Roadways serve users of many different modes—in particular, motorists, pedestrians, bicyclists, and transit passengers. The roadway right-of-way is allocated among the modes through the provision of facilities that ideally serve each mode's needs. However, in many urban situations, the right-of-way is

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constrained by adjacent land development, existing transportation networks and planners to consider trade-offs in how to allocate the right-of-way. Interactions among the modes that result from different right-of-way allocations are important to consider in analyzing a roadway and the HCM provides tools for assessing these interactions. Local policies and design standards relating to roadway functional classifications also provide guidance on the allocation of right-of-way; safety and operational concerns should also be addressed. Exhibit 8-1 summarizes some of the key interactions that occur between modes.

Exhibit 8-1
Mode Interaction Summary

Mode Creating the Interaction	Mode Affected by the Interaction			
	Automobile	**Pedestrian**	**Bicycle**	**Transit**
Automobile	Turning automobiles can delay other automobiles, heavy vehicles, bicycles, pedestrians, and transit vehicles. Traffic signal timing is influenced by relative traffic volumes on intersection approaches. Intersection delay tends to increase as automobile volume increases.	Cross-street automobile volumes influence traffic signal timing (and, therefore, delay), further increasing conflicts between vehicles and pedestrians. Automobile and heavy vehicle volumes and their associated separation from pedestrians create a sense	Automobile and heavy vehicle volumes and speeds, presence of crosstown parking, and the degree to which bicyclists are separated from vehicular traffic influence bicyclists' perception of comfort during interactions with automobiles at intersections.	Impacts similar to those of automobiles or automobiles; however, may be delayed waiting for a gap in traffic when they cross a bus stop. Higher volumes of traffic, volumes and transit operations in making or missing green lights affect schedule reliability.
Pedestrian	Minimum green times at traffic signals may be dictated by crosswalk lengths for automobiles and for crossing pedestrians.	Congestion when pedestrian flows intersect cause pedestrians to adjust their routes and travel speed; pedestrian space and comfort decrease as pedestrian volumes increase.	Pedestrians being met and passed by bicycles on multiuse paths affect overall comfort because of pedestrians' slower speeds and tendency to walk abreast on streets, effect on bicycles' view is that of automobiles.	Impacts similar to those of pedestrians on automobiles; transit riders are often pedestrians before and after their transit trip, so the quality of the pedestrian environment affects the perceived quality of the transit trip.
Bicycle	Turning automobiles yield to bicycles; automobiles may be delayed waiting to pass bicyclists in standard lane situations.	Bicycles meeting and passing pedestrians on multiuse paths affect pedestrians' comfort because of the bicycles' relatively higher speeds.	Bicyclists may be delayed when they need caution when overtaking, meeting, and passing events on cross-street roadways affect bicyclist comfort.	Impacts similar to those of automobiles on bicycles, but a bicycle's ability to travel at greater speeds than transit vehicles between stops affects the reach of a bicycle trip and allows a bike to be considered in the event of a flat tire or a
Transit	Stopping heavy vehicles, buses stopping in the travel lane to serve passengers can delay other vehicles. Transit signal priority measures affect the allocation of green time.	Impacts similar to those of automobiles on pedestrians, but produce a relatively greater effect due to transit vehicles' greater size.	Impacts similar to those of automobiles on bicycles, but a bicycle's ability to travel at greater speeds than transit vehicles between stops affects the reach of a bicycle trip and allows a bike to be considered in the event of a flat tire or a	Bus speeds decrease as bus volumes increase; in urban headways of more passenger cars on some buses and increase wait times for buses.

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3. QUALITY AND LEVEL-OF-SERVICE CONCEPTS

OVERVIEW

There are many ways to measure the performance of a transportation facility or service, and many points of view that can be considered in making that measurement. The agency operating a roadway, automobile drivers, pedestrians, bicyclists, bus passengers, decision makers, and the community at large all have their own perspectives on how a roadway or service should perform and what constitutes "good" performance. As a result, there is not one right way to measure and interpret performance. The HCM provides a number of tools for describing how well a transportation facility or service operates from a traveler's perspective, a concept termed *quality of service*. One important tool for describing quality of service is the concept of LOS, which facilitates the presentation of results through the use of a familiar A (best) to F (worst) scale. A variety of specific performance measures, termed *service measures*, are used to determine LOS. These three concepts—quality of service, LOS, and service measures—are the topics of this section.

QUALITY OF SERVICE

Quality of service describes how well a transportation facility or service operates from a traveler's perspective.

Quality of service describes how well a transportation facility or service operates from a traveler's perspective. Quality of service can be assessed in a number of ways, including directly observing factors perceivable by and important to travelers (e.g., speed or delay), surveying travelers, tracking complaints and compliments about roadway conditions, forecasting traveler satisfaction by using models derived from past traveler surveys, and observing things not directly perceived by travelers (e.g., average time to clear a crash) that affect things they can perceive (e.g., speed or arrival time at work).

The HCM's focus is on the travel time, speed, delay, ability to maneuver, and comfort aspects of quality of service. Travel time reliability is expected to be added in the future, as a result of funded research. Other aspects of quality of service covered to a lesser degree by the HCM, or covered more thoroughly by its companion documents, include convenience of travel, safety, user cost, availability of facilities and services, roadway aesthetics, and information availability.

Dimensions of system performance and mobility.

Quality of service is one dimension of mobility and overall transportation system performance. Other dimensions to consider are the following (*6, 7*):

- *Quantity of service*—such as the number of person miles and person-hours provided by the system;
- *Capacity utilization*—including the amount of congestion experienced by users of the system, the physical length of the congested system, and the number of hours that congestion exists; and
- *Accessibility*—for example, the percentage of the population able to complete a selected trip within a specified time.

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LEVEL OF SERVICE

LOS is the stratification of quality of service.

The HCM defines LOS for most combinations of travel mode (i.e., automobile, pedestrian, bicycle, and transit) and roadway system element (e.g., freeway, urban street, intersection) addressed by HCM methodologies. Six levels are defined, ranging from A to F. LOS A represents the best operating conditions from the traveler's perspective and LOS F the worst. For cost, environmental impact, and other reasons, roadways and transit services are not typically designed to provide LOS A conditions during peak periods. Rather, a lower LOS that reflects a balance between individual travelers' desires and society's desires and financial resources is typically the goal. Nevertheless, during low-volume periods of the day, a system element may operate at LOS A.

LOS is used to translate complex numerical performance results into a simple A–F system representative of the travelers' perceptions of the quality of service provided by a facility or service. The LOS letter result hides much of the complexity of facility performance to simplify decision making about whether facility performance is generally acceptable and whether a change in this performance is likely to be perceived as significant by the general public. One of the strengths of the LOS system, and a reason for its widespread adoption by agencies, is its ability to communicate roadway performance to laypersons. However, LOS has other strengths and weaknesses, described below, that both analysts and decision makers need to be mindful of.

Step Function Nature of LOS

Setting performance standards on the basis of LOS for any facet (average delay, for example) means that small changes in performance can sometimes result in the demand being exceeded, when a facility is already operating close to the standard.

The measure of effectiveness for automobiles at traffic signals is the average delay experienced by motorists. As traffic volumes on certain critical approaches increase, so does the average delay. The added delay may or may not result in a change in LOS. An increase of delay of 12 s may result in no change in LOS, a drop of one LOS level, or a drop of two LOS levels, depending on the starting value of delay. Because there are only six possible LOS letters, each covering a range of possible values, the reported LOS does not change until the service measure increases past the threshold value for a given LOS. A change of LOS indicates that roadway performance has transitioned from one given range of traveler-perceivable conditions to another range, while no change in LOS indicates that conditions are in the same performance range as before. The service measure value—in this case, average delay—indicates more specifically where conditions lie within a particular performance range.

Because a small change in a service measure can sometimes result in a letter change in the LOS result, the LOS result may imply a more significant effect than actually occurred. This aspect of LOS can be a particularly sensitive issue when agencies define their performance standards on the basis of LOS, since a small change in performance can trigger the need for potentially costly improvements. However, this issue exists whenever a fixed standard is used, whether or not LOS is the basis of that standard.

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Uncertainty and False Precision

Computer software is frequently used to perform traffic operations analyses, and software can report results to many decimal places. However, such precision is often unjustified for four reasons:

1. In contrast to the force of gravity or the flow of water through a pipe, the actions of motorists driving on a roadway can vary. Traffic operations models predict average values of performance measures; the actual value for a measure on a given day may be somewhat higher or lower. Thus, the result reported by every traffic operations model has some uncertainty associated with it.
2. A given traffic operations model may rely on the output of other models that have their own associated result uncertainties.
3. Some model inputs, such as traffic volumes, are taken to be absolute, when there is actually variation in the inputs from month to month, day to day, or even within an hour. Traffic volumes, for example, may vary by 5% to 10% from one weekday to the next.
4. Some HCM models predict traveler perceptions. Two travelers who experience identical conditions may perceive those conditions differently. When many travelers are surveyed, a distribution of responses from "very satisfied" to "very dissatisfied" (or some similar scale) results. The traveler-perception models predict the average of those responses.
5. Some alternative tools involve the use of simulation, in which results will vary as inputs are randomly varied within a set distribution and average. Therefore, reporting only one result from simulation simplifies the actual results produced.

Therefore, any reported traffic operations performance measure value, whether resulting from an HCM methodology, an alternative tool (e.g., simulation), or even field measurement, potentially has a fairly wide range associated with it in which the "true" value actually lies. The LOS concept helps to downplay the implied accuracy of a numeric result by presenting a range of measure results as being reasonably equivalent from a traveler's point of view. However, the same variability issues also mean that the "true" LOS value may be different from the one predicted by a methodology. One way of thinking about a reported value and its corresponding LOS result is that they are the statistical "best estimators" of conditions.

LOS Reported Separately by Mode

In an effort to provide a single top-level measure of conditions, some HCM users may be tempted to blend the LOS reported for each mode into a single LOS value for a roadway element. However, each mode's travelers have different perspectives and could experience different conditions while traveling along a particular roadway. The use of a blended LOS carries the risk of overlooking quality-of-service deficiencies for nonautomobile travelers that discourage the use of those modes, particularly if the blended LOS is weighted by the number of auto travelers. Other measures, such as person delay, can be used when an

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analysis requires a combined measure. The HCM recommends reporting modal LOS results individually.

Reporting the Big Picture

Neither LOS nor any other single performance measure tells the full story of roadway performance.

Analysts and decision makers should always be mindful that neither LOS nor any other single performance measure tells the full story of roadway performance. Depending on the particulars of a given location and analysis, queue lengths, demand-to-capacity ratios, average travel speeds, indicators of safety, and other performance measures may be equally or even more important to consider, regardless of whether they are specifically called out in an agency standard. For this reason, the HCM provides methods for estimating a variety of typical roadway operations performance measures, and not just methods for determining LOS.

SERVICE MEASURES

Service measures are the performance measures that define LOS.

As introduced earlier, service measures are specific performance measures that are used to determine LOS. Exhibit 8-2 summarizes the service measures used by the HCM for different combinations of transportation system elements and travel modes. Some service measures are based on a traveler-perception model; the components of each model are given in Exhibit 8-3.

Exhibit 8-2
Service Measures by Individual System Element

System Element	Service Measures			
	Automobile	Pedestrian	Bicycle	Transit
Freeway facility	Density	--	--	--
Basic freeway segment	Density	--	--	--
Freeway weaving segment	Density	--	--	--
Ramp junction	Density	--	--	--
Multilane highway	Density	--	LOS score[a]	--
Two-lane highway	Percent time spent following, speed	--	LOS score[a]	--
Urban street facility	Speed	LOS score[a]	LOS score[a]	LOS score[a]
Urban street segment	Speed	LOS score[a]	LOS score[a]	LOS score[a]
Signalized intersection	Delay	LOS score[a]	LOS score[a]	--
Two-way stop	Delay	Delay	--	--
All-way stop	Delay		--	
Roundabout	Delay	--	--	--
Interchange ramp terminal	Delay	--	--	--
Off-street pedestrian bicycle facility		Space, speed[b]	LOS score[a]	--

Notes: [a] See Exhibit 8-3 for the LOS score components.
[b] Events on, speed on shared-use paths where pedestrians meet bicycles.

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Exhibit 8-3
Components of Traveler-Perception Models Used to Generate Service Measures

System Element	Mode	Model Components
Multilane highway and freeway	Bicycle	Perceived separation between bicycles and motor vehicles, pavement quality, automobile and heavy vehicle volume and speed
Urban street facility	Automobile	Weighted average of segment and intersection LOS scores
	Pedestrian	Driveway per segment and signalized intersection pedestrian LOS scores, midblock crossing difficulty
	Bicycle	Urban street segment and signalized intersection bicycle LOS scores, driveway density
	Transit	Weighted average of segment (transit) LOS scores
Urban street segment	Automobile	Stops per mile, delay, lane presence
	Pedestrian	Pedestrian density, sidewalk width, perceived separation between pedestrians and motor vehicles, motor vehicle volume and speed
	Bicycle	Perceived separation between bicycles and motor vehicles, pavement quality, automobile and heavy vehicle volume and speed
	Transit	Service frequency, perceived speed, pedestrian LOS
Signalized intersection	Pedestrian	Street crossing delay, pedestrian exposure to turning vehicle conflicts, crossing distance
	Bicycle	Perceived separation between bicycles and motor vehicles, crossing distance
Off-street pedestrian/bicycle facility	Bicycle	Average meetings/minute, active passings/minute, path width, centerline presence, delayed passings

Note: The automobile mode has prior models for urban street segments and facilities that used to determine LOS; however, it is provided as a performance measure for multimodal analyses.

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4. ANALYSIS PROCESS

LEVELS OF HCM ANALYSIS

The HCM can be applied at the *operational, planning and preliminary engineering,* and *design* analysis levels. The required input data typically remain the same at each analysis level, but the degree to which default values are used instead of measured or forecast values differs. In addition, operational and planning and preliminary engineering analyses frequently evaluate the LOS that will result from a given set of inputs, while design analyses evaluate the facility characteristics that will be needed to achieve a desired LOS.

Operational Analysis

In an operational analysis, an analyst applies an HCM methodology directly and supplies all of the required input parameters from measured or forecast values. No, or minimal, default values are used. Of the available ways to apply HCM methodologies, operational analyses provide the highest level of accuracy but, as a result, also require the most detailed data collection, which has time and cost implications.

An operational analysis helps in making decisions about operating conditions. Typical alternatives consider, for example, changes in traffic signal timing and phasing, changes in lane configurations, spacing, and location of bus stops, the frequency of bus service, or the addition of a bicycle lane. The analysis produces operational measures that can be used to compare the alternatives.

As discussed earlier in this chapter, even though a model's results may be highly accurate, any variability associated with the model's inputs can affect the model's results.

Planning and Preliminary Engineering Analysis

In planning and preliminary engineering analyses, an analyst applies an HCM methodology by using default values for some to nearly all of the model inputs—for example, through the use of generalized service volume tables. The results are less accurate than in an operations analysis, but the use of default values reduces the amount of data collection and the time required to perform an analysis. In a large-scale planning study, where a large number of roadways may be evaluated, this level of analysis may be the best practical, given time and budget constraints. For future-focused studies, not all of the model inputs may be known or forecastable, which suggests the need for a planning analysis with the use of default values for the unknown model inputs.

Planning analyses are applications of the HCM generally directed toward broad issues such as initial problem identification (e.g., screening a large number of locations for potential operations deficiencies), long-range analyses, and statewide performance monitoring. An analyst often must estimate the future times at which the transportation system will fall below a desired LOS. Preliminary engineering analyses are often conducted to support planning decisions related to a roadway design concept and scope and to perform alternatives analyses. These studies can also assess proposed system policies.

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such as lane-use control for heavy vehicles, systemwide freeway ramp metering and other intelligent transportation systems applications, and the use of demand management techniques, such as congestion pricing (5).

Generalized Service-Volume Tables

Generalized service-volume tables are sometimes used in planning analyses. These tables are constructed by applying default values to an HCM methodology and then incrementally determining the maximum number of vehicles that a roadway could carry at a given LOS, given the assumed conditions.

Service-volume results should be applied with care, since actual conditions will likely vary in some way from the assumptions used to develop the table.

The use of a service volume table is most appropriate in situations in which it is not practical to evaluate every roadway or intersection within a study area. Examples of these applications would be city, county, or statewide planning studies, where the size of the study area makes it infeasible to conduct a capacity or LOS analysis for every roadway segment. For these types of planning applications, the focus of the effort is simply to highlight potential problem areas (for example, locations where demand may exceed capacity or where a desired LOS may be exceeded). For such applications, a service-volume table can be a useful screening tool. Once potential problem areas have been identified, more detailed analyses can be performed for those locations.

The HCM provides generalized service-volume tables for
- *Freeway facilities*
- *Multilane highways*
- *Two-lane highways*
- *Urban street facilities*

The characteristics of any given roadway will likely vary in some way from the assumed input values used to develop a service volume table. Therefore, the results from a service volume table should be treated as rough approximations. Service volume tables should not be substituted for other tools to make a final determination of the operational adequacy of a particular roadway.

Design Analysis

Design analyses typically apply the HCM to establish the detailed physical features that will allow a new or modified roadway to operate at a desired LOS. Design projects are usually targeted for mid- to long-term implementation. Not all the physical features that a designer must determine are reflected in the HCM models. Typically, analysts using the HCM are seeking to determine such elements as the basic number of lanes required and the need for auxiliary or turning lanes. However, an analyst can also use the HCM to establish values for elements such as lane width, steepness of grade, the length of added lanes, the size of pedestrian queuing areas, the widths of sidewalks and walkways, and the presence of bus pullouts.

The data required for design analyses are detailed and are based substantially on proposed design attributes. However, the intermediate- to long-term focus of the work will require the use of some default values. This simplification is justified in part by the limits on the accuracy and precision of the traffic forecasts with which the analyst will be working.

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ANALYSIS TOOL SELECTION

Types of Tools

Each analytical or simulation tool, depending on the application, has its own strengths and weaknesses. It is important to relate relevant modeling features to the needs of the analyses and to determine which tool satisfies those needs to the greatest extent.

HCM methodologies are deterministic and macroscopic. A deterministic model will always produce the same result for a given set of inputs. A macroscopic model considers average conditions experienced by vehicles over a period of time (typically 15 min or 1 h). In comparison, microsimulation models are stochastic and microscopic. In a stochastic model, a different random number seed will produce a different modeling result; therefore, the outcome from a simulation run based on a stochastic model cannot be predicted with certainty before the analysis begins. Microscopic models simulate the movement of individual vehicles on the basis of car-following and lane-changing theories.

Situations When Alternative Tools Might Be Considered

The HCM is the product of a large number of peer-reviewed research projects and reflects the best available techniques (at the time of publication) for determining capacity and LOS. However, the research behind the HCM has not addressed every possible situation that can arise in the real world. Therefore, the HCM documents the limitations of its procedures and highlights situations when alternative analysis tools should be considered to supplement or substitute for the HCM. The following are examples of these situations:

- The configuration of the facility has elements that are beyond the scope of the HCM procedures. Each HCM procedural chapter identifies the specific limitations of its own methodology.
- Viable alternatives being considered in the study require the application of an alternative tool to make a more informed decision.
- The measures are incompatible with corresponding HCM measures and the decision process requires additional performance measures, such as fuel consumption and emissions, that are beyond the scope of the HCM.
- The system under study involves a group of different facilities with mutual interactions that require the use of more than one HCM chapter. Alternative tools are able to analyze these facilities as a single system.
- Routing is an essential part of the problem being addressed.
- The quantity of input or output data required presents an intractable problem for the HCM procedures.
- The HCM procedures predict oversaturated conditions that last throughout a substantial part of a peak period or queues that overflow the available storage space.

The Federal Highway Administration's Traffic Analysis Toolbox (6) provides general guidance on the use of traffic analysis tools, including the HCM. More detailed guidance for alternative tool application to specific system elements is

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presented in Volumes 2 and 3 of the HCM. Supplemental examples involving situations beyond the scope of the HCM procedures are presented in Volume 4.

INTERPRETING RESULTS

Uncertainty and Variability

Model outputs—whether from the HCM or alternative tools—are estimates of the "true" values that would be observed in the field. Actual values will fall within some range of the estimated value. The magnitude of the range, and therefore the degree of uncertainty, is a function of several variables, including the quality of the input data, the inherent variability of the model, and the degree to which the model accounts for all of the factors that govern the analysis. The uncertainty may be compounded to some extent by imperfect knowledge of the traveler perception aspects of quality of service.

When stochastic simulation tools are used, uncertainty is normally addressed through multiple runs with different random number seeding. Regardless of the modeling approach, a sensitivity analysis may be performed to assess the degree to which input data variation is likely to affect the range of performance measure outputs. Depending on the model and the specifics of the situation being modeled, small changes in model inputs can have large impacts on model outputs.

Accuracy and Precision

Accuracy and precision are independent but complementary concepts. *Accuracy* relates to achieving a correct answer, while *precision* relates to the size of the estimation range of the procedure in question. In most cases, the field data on which the analyses are based can only be expected to be accurate to within 5% or 10% of the true value. Thus, the computations performed with these inputs cannot be expected to be extremely accurate, and the final results must be considered as estimates that are accurate and precise only within the limits of the inputs used.

HCM users should be aware of the limitations of the accuracy and precision of the methodologies in the manual. Such awareness will help users interpret the results of an analysis and use the results to make a decision on the design or operation of a transportation facility.

Comparing HCM Results with Alternative Tools

The exact definitions of performance measures are an important issue, particularly when a comparison of performance measures produced by different tools is to be made. Many tools produce performance measures with the same name (e.g., "delay"), but the definitions and methods of computation can differ widely. Chapter 7, Interpreting HCM and Alternative Tool Results, presents general guidance on comparing results. The procedural chapters in Volumes 2 and 3 present guidance on this topic for specific system elements.

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Use of Vehicle Trajectory Analysis in Determining Performance Measures

It was pointed out in Chapter 6, Traffic Flow and Capacity Concepts, that the analysis of individual vehicle trajectories is becoming recognized as the most desirable method of producing performance measures that are consistent among different tools and comparable with the measures produced by the analysis procedures given in this manual. The HCM provides trajectory-based definitions and computational procedures for all of the commonly used performance measures. Alternative tool developers are encouraged to incorporate these definitions and computations into their products. Users of this manual are encouraged to consider the degree to which the performance measures comply with the HCM specifications in their traffic analysis tool selection process.

Temporal and Spatial Boundaries

Another source of difference in the performance measures obtained from different tools lies in their treatment of incomplete trips. Incomplete trips include those that enter a facility during a given analysis period and exit during a subsequent period and those that exit a facility after entering in a previous analysis period. To overcome differences among analysis tools, it is important that the analysis period cover enough time and space to include an uncongested interval at all boundaries.

When undersaturated operation is being studied, the definition of the facility in time and space is less important. The operation tends to be more homogeneous when the ratios are less than 1.00. For most performance measures, extending the analysis period will give a larger sample of vehicles, but it will not affect the performance measures significantly.

PRESENTING RESULTS

Tabular values and calculated results are displayed in a consistent manner throughout the HCM. It is suggested that analysts adhere to these conventions. A key objective is to use a number of significant digits indicating to users, decision makers, and other viewers that the results are not extremely precise but take on the precision and accuracy associated with the input variables used. This guidance applies primarily to inputs and final outputs; intermediate results in a series of calculations should not be rounded unless specifically indicated by a particular methodology.

Historically, data and analysis results have been presented primarily in tables. However, results may be best presented as pictures and only supplemented as necessary with the underlying numbers in some situations. Graphs and charts should not be used to decorate data or to make dull data entertaining; they should be conceived and fashioned to aid in the interpretation of the meaning behind the numbers.

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5. DECISION-MAKING CONSIDERATIONS

The HCM provides procedures for capacity and quality-of-service analyses and therefore serves as an analytical tool for transportation engineers and planners. The 2010 edition of the HCM presents the best available techniques at the time of publication for determining roadway capacity and LOS, proven to work in the United States and validated by a group of independent experts. However, the HCM is only a guidance document; it does not endeavor to establish a legal standard for highway design or construction. This section describes the role of other guidance and standards documents that complement the HCM, along with issues for decision makers to consider should they choose to adopt HCM service measures as standards.

ROLE OF HCM COMPANION DOCUMENTS

Throughout its 60 year history, the HCM has been a fundamental reference work for transportation engineers and planners. However, it is but one of a number of documents that play a role in the planning, design, and operation of transportation facilities and services. The HCM's scope is to provide tools to evaluate the performance of highway and street facilities in terms of operational and traveler-perception measures. This section describes companion documents to the HCM that cover important topics outside the HCM's scope.

Highway Safety Manual

The *Highway Safety Manual* (HSM) (7) provides analytical tools and techniques for quantifying the safety effects of decisions related to planning, design, operations, and maintenance. The information in the HSM is provided to assist agencies as they integrate safety into their decision making processes. It is a nationally used resource document intended to help transportation professionals conduct safety analyses in a technically sound and consistent manner, thereby improving decisions made on the basis of safety performance.

A Policy on Geometric Design of Highways and Streets

The American Association of State Highway and Transportation Officials' (AASHTO's) *A Policy on Geometric Design of Highways and Streets* ("Green Book") (8) provides design guidelines for roadways ranging from local streets to freeways, in both urban and rural locations. The guidelines "are intended to provide operational efficiency, comfort, safety, and convenience for the motorist," while also emphasizing the need to consider the use of roadway facilities by other modal users.

Manual on Uniform Traffic Control Devices

The Federal Highway Administration's *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) (9) is the national standard for traffic control devices for any street, highway, or bicycle trail open to public travel. Of particular interest to HCM users are the sections of the MUTCD pertaining to warrants for all-way stop control and traffic-signal control, signing and

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markings to designate lanes at intersections and associated considerations of adequate roadway capacity and less restrictive intersection treatments.

Transit Capacity and Quality of Service Manual

The *Transit Capacity and Quality of Service Manual* (TCQSM; 10) is the transit counterpart to the HCM. The TCQSM contains information on the various types of public transportation and provides a framework for measuring transit availability, comfort, and convenience from the passenger point of view. The manual contains quantitative techniques for calculating the capacity of bus, rail, and ferry transit services and of transit stops, stations, and terminals.

TOOLS VERSUS STANDARDS

Although the HCM does not set standards—for example, it does not specify a particular LOS that should be provided for a particular roadway type—it is referenced in the AASHTO Green Book (9), and numerous agencies and jurisdictions have adopted LOS standards based on the HCM. This section discusses issues that agencies and jurisdictions should consider when they adopt standards or guidance relating to LOS or default values used in HCM analyses.

Evolution of HCM Analysis Procedures

Each new edition of the HCM has incorporated new methodologies and—in some cases—new service measures for evaluating roadway system elements. This edition of the HCM is no different.

Changes in HCM methodologies are made to improve estimates of service and other performance measures. These types of changes do not directly affect an agency's adopted LOS standards, since the service measure for a particular roadway element and the threshold values for particular levels of service do not change. However, methodological changes frequently have indirect effects. For example, the estimated service measure value for a particular roadway might have met an agency's LOS standard under the previous methodology but might not meet the standard under the new methodology, and vice versa. Similarly, agencies that have adopted generalized service-volume tables may find that the service volumes associated with a given LOS have changed as a result of the methodological change. In this situation, the underlying estimate of the roadway's operation will not have changed, but the estimate of the traffic volume that produces that operation will have changed.

Even when the basic methodology for a roadway element does not change, the recommended default values for the methodology may have changed, which can also cause the issues described above with service volume tables and with old and new methodologies producing different results. Following the HCM's recommendations of using field-measured input values whenever possible and locally generated default values otherwise avoids this issue.

A service measure's LOS thresholds or the measure itself may change from one edition of the HCM to the next. In that case, it is recommended that an agency that has adopted an operations standard for that measure revisit the standard to ensure that it still accurately represents the quality of service the agency wishes to provide. These kinds of changes in the HCM may also have

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planning and project programming implications, as the need for or scale of a given project may change.

Incorporating HCM Analysis Results into Decision Making

Agencies and jurisdictions adopt roadway design and operations standards for a number of reasons, including consistency in roadway design across a jurisdiction and provision of an objective basis for making decisions on required improvements. As mentioned earlier, numerous agencies and jurisdictions have chosen to adopt LOS standards for their roadways. The existence of computerized tools that implement HCM procedures makes it easy for analysts to test a number of roadway improvements against an LOS standard. However, the analysis does not end once an LOS result has been determined.

The existence of a LOS F condition does not, by itself, indicate that action must be taken to correct the condition. Conversely, meeting a LOS standard does not necessarily mean that no problem exists or that an improvement that produces the desired LOS is a desirable solution. Other issues, including but not limited to safety, impacts on other modes, traffic signal warrants, turn-lane warrants, cost–benefit issues, and access management, may also need to be considered as part of the analysis, recommendations, and eventual decision. As always, engineering judgment should be applied to any recommendations resulting from HCM (or alternative tool) analyses.

Two examples of common situations where a LOS result considered by itself might lead to a decision different from one that would be reached if other factors were also considered are given below.

Traffic Signal Warrants

The MUTCD (9) provides a number of warrants that indicate when a traffic signal may be justified. It is possible to have a condition at a two-way stop intersection—particularly when a low-volume minor street intersects a very high-volume major street—where the minor street approach operates at LOS F but does not meet traffic signal warrants. Because the MUTCD is the standard for determining when a traffic signal is warranted, a LOS F condition by itself is not sufficient justification for installing a signal.

Turn-Lane Warrants

A number of agencies and jurisdictions have adopted warrants that indicate when the installation of turn lanes may be justified at an intersection. It is possible for an HCM analysis to indicate that the addition of a turn lane will result in an acceptable LOS but for the turn-lane warrant analysis to determine that the necessary conditions for installing a turn lane have not been satisfied. In this case, the potential for a satisfactory LOS in the future would not be sufficient justification by itself for installing the turn lane.

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6. REFERENCES

Many of these references are available in the Technical Reference Library in Volume 4

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CHAPTER 9
GLOSSARY AND SYMBOLS

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1. GLOSSARY

Chapter 9, Glossary and Symbols, defines the terms used in the *Highway Capacity Manual* (HCM) and presents the symbols and abbreviations used in the manual. Highway transportation terminology has evolved over time to create multiple definitions, and the confusion has been compounded by technical jargon. The definitions, abbreviations, and symbols presented here are intended to establish a consistent terminology for use in the HCM. It is recognized that other definitions and usage could exist.

VOLUME 1: CONCEPTS
1. HCM Users Guide
2. Applications
3. Modal Characteristics
4. Traffic Flow and Capacity Concepts
5. Quality and Level-of-Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

Acceleration lane – A speed-change lane including tapered areas, allowing vehicles to accelerate to the speed they enter the through traffic stream of the roadway.

Acceleration/deceleration delay – Delay experienced by vehicles slowing from and subsequently returning to their running speed.

Access point – An intersection, driveway, or opening onto the side of a roadway.

Access-point density – The total number of access points on both sides of the roadway, divided by the length of the segment.

Accessibility – The percentage of the population able to complete a selected trip within a specified time.

Accuracy – The degree of a measure's agreement with a standard or true value.

Active grass days – The number of days with more than 1 in. (25 mm) of rainfall during the growing season.

Average pace – The average speed of all bicyclists traveling at the average speed of all bicyclists traveling at the average speed of all bicyclists who are passed by that bicyclist.

Active priority – A form of traffic signal priority that adjusts signal timing in response to the arrival of a bus.

Active traffic management (ATM) – The dynamic and systematic monitoring and control of traffic conditions on a facility to improve its performance.

Actuated control – Control mode for which the green phase is in which the green time of each phase is dependent on whether the phase is on recall or the associated traffic movement has submitted a call for service through a detector.

Adjustment – An additive or multiplicative quantity that adjusts a parameter for a base condition to represent a prevailing condition.

Adjustment factor – A factor that adjusts a parameter for a base condition to represent prevailing condition.

Aggregate delay – The summed total of delays for multiple lanes or lane groups, usually aggregated for an approach, an intersection, or a arterial route.

Algorithm – A set of rules for solving a problem in a finite number of steps.

All-way stop-controlled (AWSC) intersection – An intersection with STOP signs on all approaches. The driver's decision to proceed is based on a consensus right-of-way governed by the traffic rules. Based on the other approaches and the rules of the road (e.g., the driver on the right has the right-of-way if two vehicles arrive simultaneously).

Alternative tool – Any analysis procedure outside of the HCM that may be used to evaluate measures of transportation system performance for analysis and decision support.

Analysis hour – A single hour for which a capacity analysis is performed for a system element.

Analysis period – A single time period (for example, the peak 15 min of the peak hour) during which a capacity analysis is performed for a system element.

Analytical model – A model based on traffic flow theory, combined with the use of field measures of driver behavior, resulting in an analytic formulation of the relationship between the field measures and performance measures such as capacity and delay.

Annual average daily traffic (AADT) – The total volume of traffic passing a point or segment of a highway facility in both directions for 1 year, divided by the number of days in the year.

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Approach – A set of lanes at an intersection that accommodates all of the turn, through, and right-turn movements from a given direction.

Approach delay – The control delay for a given approach.

Approach grade – The average grade along the approach, as measured from the stop line on a point 100 ft upstream of the stop line along a line parallel to the direction of travel. An uphill condition has a positive grade, and a downhill condition has a negative grade.

Area – An interconnected set of transportation facilities serving movements within a specified geographic space, as well as movements to and from adjoining areas.

Area type – A description of the environment in which a system element is located.

Arrival rate – The measure of the statistical distribution of vehicles arriving at a point or midblock segment of an urban street.

Arrival type – Six assigned categories for the quality of progression for a given approach to a signalized intersection.

Arterial street – A street primarily controlled by traffic control devices (e.g., signals, stop signs, or yield signs) that primarily serves through traffic and that secondarily provides access to abutting properties. It also may serve transit.

Automobile mode – A travel mode that includes all motor vehicle traffic using a roadway except for transit buses. It includes only vehicles such as trucks, recreational vehicles, motorcycles, and tour buses.

Auxiliary lane – See freeway auxiliary lane.

Available time-space – The product of available time and available space for pedestrian circulation on a crosswalk or a signalized intersection.

Average bus stop spacing – The average distance between bus stops along a street.

Average grade – The rise from the beginning of the composite grade to the point of interest, divided by the length of the grade (to the point of interest).

Average running speed – The length of a segment divided by the average running time of vehicles that traverse the segment.

Average spot speed – See time-mean speed.

Average travel speed – The length of the highway segment divided by the average travel time of all vehicles traversing the segment, including all stopped delay times. Equal to space-mean speed.

B

Back of queue – The maximum backward distance (in feet) from vehicles during a typical cycle, as measured from the stop line to the last queued vehicle.

Barrier – 1. A separation of intersecting movements in different rings to prevent operation of conflicting phases at the same time. 2. A physical object or pavement marking designed to prevent vehicles from crossing or departing a section of roadway.

Barrier pair – A pair of phases within the same ring and between which cannot be displayed concurrently.

Base conditions – A set of specified standard conditions (e.g., good weather, good and dry pavement conditions, no disturbances, no impediments to traffic flow) that must be observed to analyze or predict operations that do not match.

Base length – The distance between the points in a weaving segment where the edges of the travel lanes of the merging and diverging roadways converge.

Base saturation flow rate – The saturation flow rate for the base conditions.

Baseline uniform delay – The average uniform delay when there is no initial queue.

Basic freeway segment – A length of freeway facility whose characteristics and operations are unaffected by weaving, diverging, or merging.

Bicycle – A vehicle with two wheels or less, propelled by human power, and usually ridden by one person.

Bicycle facility – A road, path, or way specifically designated for bicycle travel, whether exclusively or with other vehicles or pedestrians.

Bicycle lane – A portion of a roadway designated by striping, signing, and pavement markings for the preferential or exclusive use of bicycles.

Bicycle mode – A travel mode in which a motorized bicycle is used on a roadway or pathway.

Bicycle path – A bikeway physically separated from motorized traffic by an open space or barrier, either within the highway right-of-way or within an independent right of way.

Bicycle speed – The riding speed of bicycles in miles per hour or feet per second.

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Bicycle track – A one-way bicycle facility separated from motor vehicle traffic and the sidewalk by low curbs.

Body ellipse – The practical minimum area for standing pedestrians.

Bottleneck – A system element on which demand exceeds capacity.

Boundary intersection – An intersection defining the endpoint of an urban street segment.

Breakdown – The transition from uncongested to congested conditions, typically observed as a speed drop accompanied by queue formation.

Breakdown flow – The flow at which operations transition from uncongested to congested.

Buffer width – The distance between the outside edge of the paved roadway (or face of curb, if present) and the inside edge of the sidewalk.

Bus – A self-propelled, rubber-tired, motor vehicle designed to carry a substantial number of passengers (at least 15) and commercially operated on streets and highways.

Bus lane – A highway or street lane reserved, primarily for buses during specified periods. It may be used by other traffic under certain circumstances, such as making a right or left turn, or by taxis, motorcycles, or carpools that meet the requirements of the jurisdiction's traffic laws.

Bus route – A fixed path or route operated by motor transit vehicles that follow fixed routes and schedules along roadways.

Bus shelter – A structure with a roof and (typically) three enclosed sides that protects waiting transit passengers from wind, rain, and sun.

Bus stop – A designated area along a street where one or more buses can simultaneously stop to load and unload passengers. It can be a curb lane (bus stop totally or partially in the travel lane) or off-line (bus stop out of the travel lane).

Busway – A right-of-way restricted to buses by a physical separation from other traffic lanes.

Bypass lane – A lane provided at a roundabout that allows a particular traffic movement to bypass the facility. Typically a one-way roadway.

Calibration – The process by which the analyst modifies model parameters so that the model estimates best reproduce field-measured local traffic conditions.

Call – A registration of a demand for right-of-way by vehicles or pedestrians to a controller.

Capacity – The maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, environmental, traffic and control conditions.

Case – See *Scenario*.

Central area pricing – An area-wide implementation of congestion pricing that imposes tolls for vehicles both entering and traveling within a central area's road network during certain hours of certain days.

Central business district (CBD) – An area with characteristics including many travel rights-of-way, frequent parking maneuvers (vehicle or pedestrian), taxi and bus activity, small-radius turns, inefficient use of curb lanes, high pedestrian activity, dense population, and multiblock curb cuts.

Change interval – See *yellow change interval*.

Circulating flow – The flow circulating with the entry flow on the subject approach to a roundabout (i.e., the flow passing to the left of the splitter island nose to the subject entry).

Circulation area – 1. The portion of a sidewalk intended to be used for pedestrian movement. 2. The average area available to each person using a pedestrian facility.

Circulation time-space – The total available time-space minus the time-space occupied by pedestrians waiting to cross a crosswalk.

Circulatory roadway – The curved one-lane section of a roundabout that requires other vehicles entering the roadway to yield.

Class I two-lane highways – Highways where motorists expect to travel at relatively high speeds, such as major intercity routes, primary connectors of major traffic generators, daily commuter routes, or major links in state or national highway networks.

Class II two-lane highways – Highways where motorists do not necessarily expect to travel at high speeds, such as access routes to Class I facilities, scenic or recreational routes, or routes passing through rugged terrain.

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Class III two-lane highways – Highways serving moderately developed areas or portions of a Class I or Class II highway that pass through small towns or developed recreational areas.

Clearance interval – See yellow change interval.

Clearance lost time – The time at the end of a signal phase during which the movements served by that phase are not used by any traffic because drivers decelerate and stop or respond to the presentation of a yellow indication.

Clearance time – 1. The interval when a lane is ready to depart during which a trailing vehicle is not available for service at a stop line, consisting of the sum of startup delay and the unit extension. 2. See clearance lost time and clearance interval.

Climbing lane – A passing lane added to an upgrade to allow traffic to pass heavy vehicles who are operating at reduced speeds.

Cloverleaf interchange – An interchange with four loop ramps and four diagonal ramps, with no traffic control on either crossing roadway.

Collector street – A urban street providing land access and traffic circulation within residential, commercial, and industrial areas.

Collector-distributor road (C-D road) – A continuous roadway without local access provided parallel to a freeway to provide one or more interchanges for the purpose of removing weaving, speed change, or other operational changes and delays from the mainline.

Common green time – The period of time when the phases at the two intersections of an arterial have the right-of-way to permit a given platoon to proceed from origin to destination movement.

Complete trip – A vehicle that enters the network during the analysis period; the analysis period is long enough that the vehicle can reach its destination before the end of the analysis period.

Composite grade – A series of adjacent grades along a highway that can approach, but not exceed, the critical length of grade for a single upgrade.

Compressed diamond interchange – A diamond interchange with a separation of 400 to 800 ft between the two intersections.

Computational engine – A software implementation of one or more models

Conflict – The crossing, merging, or diverging of two traffic streams at an intersection.

Conflicting approach – An approach whose vehicles in the intersection must yield to the left-turn or through movement of the subject approach.

Conflicting flow rate – The total flow rate in vehicles per hour of a specific movement that impedes the subject movement.

Conflicting movements – Vehicular, pedestrian, or bicycle streams that seek to occupy the same space at the same time.

Congestion – 1. Low-flow, high-occupancy traffic operations that arise when demand approaches or exceeds a system or element's capacity. 2. A difference between the highway system performance expected by users and how the system actually performs. For example, an observation that more vehicles were queued than normal, or that delay was greater than normal, on a freeway or in a large metropolitan area.

Congestion pricing – The practice of charging tolls for use of all or part of a facility at levels that vary according to the severity of congestion.

Continuous flow interchange – A diamond interchange that allows left-turning traffic from the arterial to be uncontrolled or crossed by the left side of the roadway in advance of the interchange, between the crossover and the ramp terminal. The left-turning traffic travels in its own roadway between the approaching through arterial traffic (on the right) and right-turning traffic from the arterial (on the left). Both left-turning traffic streams merge at the near ramp terminal and then left-turn to the off-ramp at the far ramp terminal, without conflicting with opposing through arterial traffic. Also known as displaced left-turn interchange.

Control condition – The traffic controls and regulations invoked for a sequence of adjacent highways, including the type, phasing, and timing of traffic signals and stops, interactive and fixed controls, and similar measures.

Control delay – Delay associated with vehicles slowing in the queue on an intersection approach, the time spent stopped on an intersection approach, the time spent accelerating to the desired speed.

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Controller – Hardware or software control device that interrupts traffic flow (e.g., a traffic signal, stop sign, or HOV ramp signal).

Conventional diamond interchange – A diamond interchange with a ramp terminal spacing of 300 ft or more between the two intersections.

Coordinated actuated control – A variation of semiactuated operation that uses the controller's force-off settings to establish the noncoordinated phases associated with the ring structure such that the coordinated phases are served at the start of green and progression for the major movements is maintained.

Corridor – A set of parallel transportation facilities, for example a freeway and an arterial street.

Crawl speed – The maximum sustained speed that can be maintained by a specified type of vehicle on a constant upgrade of a given percent.

Critical density – The density at which capacity occurs for a given facility.

Critical headway – The minimum headway in the stream of traffic or subset that will allow the entry of one additional vehicle.

Critical lane groups – The lane groups that have the highest flow ratio for a given signal group.

Critical phase – One (or more) of a set of phases that occur in sequence and whose combined flow ratios establish the longest cycle length.

Critical segment – The segment that will break down first, given that all other roadway and control conditions do not change, including the spatial configuration and demand on each component segment.

Critical speed – The speed at which capacity occurs on a segment.

Critical volume-to-capacity ratio – The proportion of available capacity required to move the vehicles in critical lane groups.

Cross flow – A pedestrian flow that is approximately perpendicular to and crosses another pedestrian flow or vehicular flow. The opposite of the cross-flow movement.

Crossing time – The curb-to-curb roadway distance divided by the pedestrian walking speed used in the Highway Capacity Manual. (Same as Walk.)

Crosswalk – A pedestrian facility.

Crosswalk occupancy time – The product of the pedestrian walking time and the number of pedestrians using a crosswalk during one signal cycle.

Curb extension – An extension of the sidewalk to the edge of the travel or parking lane.

Cycle – A complete sequence of signal indications.

Cycle failure – A condition where one or more queued vehicles are not able to depart due to insufficient capacity during the cycle in which they arrive.

Cycle length – The time elapsed between the initiation of two successive sequences of a given movement for coordinated signals; this is measured by using the coordinated phase given for a cycle.

Cyclic spillback – A queue for which the downstream boundary intersection is signalized and is operating such that the upstream intersection is blocked as a result of queue growth during the red indication.

D

D-Factor – The proportion of traffic traveling in the peak direction at a point or segment of roadway during the peak hour.

Daily service volume – The maximum total daily volume in both directions that can be sustained for a given segment without violating the criteria for LOS E in the peak direction for the worst 15 or 30 min of the peak hour under prevailing roadway, traffic, and control conditions.

Deceleration lane – A paved nonconventional lane, including paved area, allowing vehicles leaving the through traffic lane of the roadway to decelerate.

Default value – A representative value that can be used in the absence of site-specific data.

Degree of conflict case – For all-way stop-controlled intersections, a particular combination of vehicle presence in the approaches with respect to the subject approach.

Degree of saturation – See demand to capacity ratio.

Delay – Additional travel time experienced by a driver, passenger, bicyclist, or pedestrian beyond that required to make the desired speed.

Delayed passing maneuver – The total time of an average bicyclist to make a passing

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movement immediately downstream of the presence of bicycle or other path users ahead of the vehicle in the same direction and a path user in the opposite direction.

Demand – The number of vehicles or other roadway users desiring to move past a given point on a system element during a specified time period, typically 1 hour or 15 min.

Demand flow rate – The number of vehicles or other roadway users desiring to move past a given point on a system element during the analysis period, converted to an hourly rate. When expressed as a rate for 15 min, this flow rate is based on a traffic count between 15 and 30 min after the start of the analysis period. This distinction is important for events made during congested periods because the count of vehicles departing the system element will produce a demand flow rate that is lower than the true rate.

Demand starvation – A condition occurring when a signalized approach has adequate capacity but a significant portion of the traffic demand is held upstream and prevented from the capacity provided because of the signalization pattern.

Demand volume – The number of vehicles that desire to use a facility. Under nonoversaturated conditions demand volume is equal to the observed volume.

Demand-to-capacity ratio – The ratio of demand volume to capacity for a system element.

Density – The number of vehicles occupying a given length of a lane or roadway at a particular instant. See also *volume/density*.

Departure headway – The average time between departures of successive vehicles on a given approach at a signalized or stop-sign controlled intersection.

Descriptive model – A model that shows how events unfold given a time plot describes how the system being modeled will behave.

Design hour – An hour with a traffic volume that represents a reasonable value for designing the geometric and control elements of a facility.

Design hour factor – The proportion of the AADT that occurs during the design hour analysis hour. See also *K factor*.

Design-level analysis – Any application of the HCM to establish the detailed physical features that will be built or modified.

facility to operate at a desired LOS or performance value.

Design speed – A speed used to design the horizontal and vertical alignments of a highway.

Detection zone – The portion of a signalized intersection approach where a vehicle can be detected by the signal controller (loop detector, video camera, image or other technology), resulting in the display of the green indication for the approach being extended.

Deterministic model – A mathematical model that is not subject to random processes. For a given set of inputs, the result from the model is the same with every application.

Deterministic queue delay – The component of control delay, in excess of the delay to all vehicles arriving during the analysis period when the demand flow rate exceeds the capacity of an approach, computed by approximating the vehicular inputs and outputs under the assumption of uniform arrivals.

Diamond interchange – An arterial interchange with a single-point diamond ramp terminal configuration in each highway quadrant and with two connections per quadrant.

Directional design hour volume – The traffic volume for the design hour in the peak directional flow.

Directional distribution – A characteristic of traffic that indicates how the peak hour volume in the direction of the peak 15 min of the peak hour. See also *D factor*.

Directional flow rate – The flow rate in a highway in one direction.

Directional segment – A length of two-lane highway in one travel direction with homogeneous cross sections and relatively constant demand volume and vehicle mix.

Directional split – See *D factor*.

Diverge – A movement in which a single stream of traffic separates into two streams without the aid of traffic control devices.

Diverge segment – See *merge/diverge segment*.

Diverging diamond interchange – A diamond interchange in which traffic on the arterial switches sides of the street at both of the ramp terminals, allowing left turns to merge to or made directly from opposing through or similar traffic.

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Double-crossover interchange – See *diverging diamond interchange*.

Downstream – The direction of traffic flow.

Driver population factor – A parameter that accounts for driver characteristics that differ from base conditions and that influence traffic.

Dual entry – A right-of-way control (i.e., a roadway or ramp control) in which one pulse in each approach lane is served. Each pulse does not necessarily result in the vehicle being served; a pulse is served by the controller in a predetermined manner.

Duration of congestion – The amount of time that a congestion exists on the transportation system.

Dwell time – The time a bus or rail car is stopped to serve passengers. At a transit stop, dwell time includes time required to open and close doors while boarding and alighting passengers.

Dwell time variability – The distribution of dwell times at a stop because of fluctuations in passenger demand for boarding and alighting.

Dynamic traffic assignment model – A class of traffic assignment models that is based upon behavioral principles and that is designed to produce (e.g., maximize the level of service or desirability associated with a trip) that is precisely unproved over a sequence of time periods until the network reaches a state of equilibrium.

Effective available time-space – The available crosswalk time-space, adjusted to account for the effect of any pedestrians.

Effective green time – The time during which a given traffic movement or set of movements may proceed at the saturation flow rate. It is equal to the split time minus the lost time.

Effective red time – The time during which a given traffic movement or set of movements is not given the right-of-way. It is equal to the cycle length minus the effective green time.

Effective walk time – The time that a WALK indication is displayed to a crosswalk pedestrian. This time is the sum of the WALK indication time used by pedestrians to initiate their crossing.

Effective walkway width – The portion of a pedestrian facility's width that is usable for pedestrian circulation.

85th percentile speed – A speed value that is exceeded by 15% of the vehicles in a traffic stream.

Empirical model – A model that describes system performance and that is based on the statistical analysis of field data.

Entrance ramp – See *on ramp*.

Entry flow – The traffic flow entering a roundabout on the subject approach.

Environmental conditions – Conditions such as adverse weather, bright sunlight directly in drivers' eyes, and disruptions from traffic or pedestrians at a nearby driveway that may cause drivers to slow down and increase their spacing, resulting in a drop in a roadway's capacity.

Event – A specific occurrence of a vehicle or pedestrian arriving at a location.

Event-based model – A simulation model that advances from one event to the next, skipping over intervening points in time when no events occur.

Excess wait time – The average number of minutes that passengers must wait at a stop past the scheduled departure time.

Exclusive bus lane – A highway or street lane reserved for buses.

Exclusive off-street bicycle paths – Paths physically separated from highway traffic provided for the exclusive use of bicycles.

Exclusive turn lane – A designated left- or right-turn lane used only by vehicles making those turns.

Exit flow – The traffic flow leaving a roundabout to the subject leg.

Exit ramp – See *off ramp*.

Extent of congestion – The maximum physical length of the congestion on a transportation system at any one time.

Facility – A length of roadway, bicycle path, or pedestrian walkway composed of a connected series of points and sections.

Failure rate – The number of cycles in which all approaches and all available loading areas allocated to other buses.

Far-side stop – A transit stop where buses or other vehicles clear an intersection before stopping to serve passengers.

Fixed-object effective width – The sum of the physical width of a fixed object along a

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walkway or sidewalk may functionally substitute space associated with the object and the width given in the description.

Fixed obstruction – A nonmovable object in a roadway, including light poles, signs, trees, permanent bridge rails, traffic barriers, and retaining walls.

Flared approach – At a two-way stop-controlled intersection, a shared right-turn lane that allows right-turning vehicles to maneuver in a manner that avoids other vehicles and encourages free turns.

Flow rate – The equivalent hourly rate at which vehicles or other roadway users pass over a given point or section of a lane or roadway during a given time interval less than 1 h, usually 15 min.

Flow ratio – The ratio of the actual flow rate to the saturation flow rate for a lane group at an intersection.

Follow-up headway – The time between the departure of one vehicle from the stop line and the departure of the next vehicle using the same initial queue position, under a condition of continuous queuing at the intersection.

Follower density – The number of followers per mile per lane; the following state is determined by comparing the gap with the following vehicle to the driver's desired gap.

Force-off – A point within a cycle where the actuated phase runs end regardless of continued demand. This results in a coordinated cycle ensure that the coordinated phases receive their assigned amount of green time.

Four-phase pattern – A type of operation at a freeway-ramp controlled intersection with individual approaches, which allows traffic from a given approach to enter the intersection together, in right-of-way pairs, with the approach to the next ramp terminal in turn.

Free flow – A flow state unaffected by upstream or downstream conditions.

Free flow speed – 1. The theoretical speed when the density and flow rate on a study segment are both zero. 2. The prevailing speed on freeways at flow rates between 0 and 1,000 passenger cars per hour per lane (pc/h/ln).

Freeway – A fully access-controlled, divided highway with a minimum of two lanes and for one-way traffic in each direction.

Freeway auxiliary lane – An additional lane on a freeway to connect an on-ramp and an off-ramp.

Freeway diverge segment – A freeway segment in which a single traffic stream divides to head two or more separate traffic streams.

Freeway facility – An extended length of freeway composed of one or more directly connected basic freeway, weaving, merge, and diverge segments.

Freeway facility capacity – The capacity of the total set of basic segments comprising a defined freeway facility.

Freeway merge segment – A freeway segment in which two or more traffic streams combine to form a single traffic stream.

Freeway section – A portion of a freeway facility with a constant demand and a constant number of lanes.

Freeway weaving segment – Freeway segment in which two or more traffic streams traveling in the same general direction cross paths along a significant length of freeway without the aid of traffic control devices (except for guide signs).

Full stop – The stopping of a vehicle for less than 1 min.

Fully actuated control – A type of operation in which vehicle detectors at each approach to the intersection control the sequence and length of every phase.

Furniture zone – The buffer area between the sidewalk and the curb and the area reserved for pedestrian travel, it may be used for landscaping, utilities, or pedestrian amenities.

Gap – The space or time between two vehicles, measured from the rear bumper of the second vehicle to the front bumper of the second vehicle. See also headway.

Gap acceptance – The process by which a driver accepts an available gap in traffic to perform a maneuver.

Gap out – At the end of actuated operation for a given phase when the phase terminates because of a lack of vehicle calls within the passage time.

General terrain – An extended length of highway containing a number of upgrades and downgrades where neither grade is

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long enough to keep through traffic from significant impact on the operation of the exit ramp queue.

Generalized service volume table – A table containing for the base conditions estimates of the maximum volume a system element can carry at a specified level of service, given a default set of assumptions about the system element.

Geometric condition – The spatial characteristics of a facility, including approach grade, the number and width of lanes, turn bays, and parking lanes.

Geometric delay – Delay caused by the physical characteristics of the roadway, which force a driver to decrease speed below the desired cruise speed of the system element.

Gore area – The area located immediately between the lane edges of a ramp gore and the edge of the roadway at the theoretical point of ramp merge or diverge.

Green time – The duration of the green indication given movement at a signalized intersection.

Green time to cycle ratio – The ratio of the effective green time of a phase to the cycle length.

Growth factor – A percentage increase applied to current traffic demand to estimate future demands.

H

Hand conversion – The conversion of a vehicle from HCM customary units to metric units for international use through the application of rounding such as from 12 ft to 4 m. See also soft conversion.

Headway – The time between two successive vehicles as they pass a point on the roadway, measured from the same common feature of both vehicles (for example, the front axle or the front bumper).

Heavy vehicle – A vehicle with more than four tires touching the pavement during normal operation.

High-occupancy vehicle (HOV) – A vehicle with a defined minimum number of occupants (2+, 3+, etc., as determined by the agency), such as buses and carpools, which a lane is reserved for the use of.

Highway – A general term for denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.

Hindrance – Diversion and inconvenience to a bicyclist as a result of meeting, passing, or being overtaken by other pedestrians or users.

Holding area waiting time – The average time that pedestrians wait to cross the street in departure from the subject corner.

Hybrid models – Models that use both macro- and large network analysis that apply microscopic modeling to critical subsystems and the extension of macroscopic modeling to the remaining facilities.

I

Impedance – The reduction in the capacity of lower-rank movements caused by the presence of higher-rank movements at the two-way stop-controlled intersection.

Incident – Any occurrence on a roadway that impedes the natural flow of traffic.

Incident delay – The component of delay that results from an incident. Computed as the nonincident condition.

Incomplete trip – A vehicle trip that is unable to enter and exit successively the spatial domain of an analysis within the analysis period.

Incremental delay – Uniform delay plus any group control delay, accounting for delay due to the random arrival of vehicles, the fluctuations in queue and that occasionally exceed capacity (i.e., cycle failure) and delay due to perceived oversaturation during the analysis period.

Influence area – 1. The base length of a freeway weaving segment plus 500 ft upstream of the entry point to the weaving segment and 500 ft downstream of the exit point of the weaving segment. Entry and exit points are defined as the points where the appropriate edges of the merging and diverging lanes meet. 2. The acceleration lane(s) and Lanes 1 and 2 of the freeway mainline for a distance of 1,500 ft downstream of the merge point. 3. The deceleration lane(s) and Lanes 1 and 2 of the freeway for a distance of 1,500 ft upstream of the diverge point.

Initial queue – The internal demand at the beginning of an analysis period, either measured in the field or carried over from the computation of a previous analysis period.

Initial queue delay – The third term of the group control delay, accounting for delay due to residual queue ideal for the previous analysis period and present at the start of the current analysis period. This

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delay results from the additional time required to clear the initial queue.

Input – The data required by a model.

Instantaneous acceleration – Acceleration at a point, calculated from the initial and final speeds of a vehicle at the beginning and end of a time step, assuming a constant acceleration during Δt.

Instantaneous speed – A speed determined from data for a single point or a vehicle at a time interval Δt, assuming a constant acceleration during Δt.

Intelligent transportation system (ITS) – Transportation technology that allows drivers and traffic control system operators to gather and use real-time information to improve mobility, reliability, or system control, or both.

Intensity of congestion – The amount of congestion experienced by users of a system.

Interchange – A system of interconnecting roadways providing for traffic movement between two or more highways that do not intersect at grade.

Interchange density – The average number of interchanges per mile, measured over the entire extent of the downstream from the midpoint of the weaving segment.

Interchange ramp terminal – A junction of a ramp with a surface street that provides connecting or exiting driveway.

Internal link – The segment between two signalized intersections or other ramp terminals.

Interrupted flow – Traffic flow on facilities characterized by traffic signals, stop signs, or other fixed features that periodically cause delay or interruption to the traffic stream.

Intersection delay – The total additional travel time experienced by drivers, passengers, or pedestrians as a result of control measures and movements with other items of the facility, divided by the volume departing from the corresponding cross section of the facility.

Interval – A period of time for which all traffic signal indications remain constant.

Isolated intersection – An intersection experiencing negligible influences from upstream or downstream intersections, where flow is effectively random over the cycle and without a dynamic platoon pattern evident in the cycle profile of arrivals.

Jam density – The maximum density that can be achieved on a segment. It occurs when speed is zero (i.e., when there is no movement of persons or vehicles).

K factor – The proportion of AADT that occurs during the peak hour. Also called design hour factor.

Lane 1 – The highway lane adjacent to the outside shoulder.

Lane 2 – The highway lane adjacent to and left of Lane 1.

Lane balance – A condition when the number of lanes leaving a diverge point is equal to the number of lanes approaching it, plus one.

Lane distribution – A percentage used when two or more lanes are available for traffic in a single direction and the volume distribution across those lanes, depending on factors such as regulation, traffic composition, speed, and volume, the number and location of access points, the origin–destination patterns of drivers, the geometric characteristics, and local driver habits.

Lane group – A lane or set of lanes designated for separate analyses.

Lane group delay – The control delay for a given lane group.

Lane utilization – The distribution of vehicles among lanes when two or more lanes are available for a movement. See also proportion using.

Lane width – The lateral distance between stripes for a given lane.

Lateral clearance – 1. The sum of left- and right-side clearance from the outside edge of travel lanes to fixed objects on urban streets or multilane highways. 2. The right-side clearance is the distance from the edge of the travel lane to fixed objects on a freeway.

Leg – A section of an at-grade intersection accommodating all approaching movements associated with one of the roads entering the intersection.

Level of service (LOS) – A qualitative classification of a performance measure or measures that characterizes quality of service, measured on an A–F scale, with LOS A representing the best operating conditions

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from the traveler's perspective and LOS is the service.

Level of service score (LOS score) – A numerical output from a behavior perception model that typically indicates the average rating that travelers would give a transportation facility or service under a given set of conditions.

Level terrain – Any combination of grades and horizontal or vertical alignment that permits heavy vehicles to maintain the same speed as passenger cars. It usually contains short grades of no more than 2%.

Light rail mode – A transit mode operated by vehicles that receive power from overhead wires and that run on tracks that can be located at grade within street rights-of-way. See also *streetcar mode*.

Link – A length of roadway between two nodes or points.

Link length – The distance from the upstream boundary intersection to the downstream boundary intersection.

Load factor – The number of passengers occupying a transit vehicle divided by the number of seats on the vehicle.

Loading area – A curbside space where a single bus can stop to load and unload passengers. Bus stops include one or more loading areas.

Local street – A street that primarily serves as land-access treatment.

Local transit service – Transit service making regular stops along a street (typically every 0.2 mi or less).

Loop ramp – A ramp that a driving vehicle has to execute a left turn by turning a full circle. An example is a 360-degree left turn; training, a 270-degree left turn.

Lost time – The time during which the movement of a phase is not effectively using the approach or intersection. It is the sum of clearance lost time and start-up lost time.

M

Macroscopic model – A mathematical model that considers traffic conditions averaged over specified time intervals and specified segments of links without investigating individual vehicles in the traffic stream.

Mainline – The primary through roadway as distinct from ramps, auxiliary lanes, and collector–distributor roads.

Mainline output – The maximum number of vehicles that can serve a freeway mode, constrained by downstream bottlenecks or by merging traffic.

Major diverge area – A location where one freeway segment diverges to form two primary freeway segments with multiple lanes.

Major merge area – A location where two primary freeway segments, each with multiple lanes, merge to form a single freeway segment.

Major street – The street that is controlled by STOP signs at a two-way STOP-controlled intersection.

Major weaving segment – A weaving segment with at least three entry and exit legs, a total of two or more lanes.

Managed lanes – A limited number of lanes set aside within a freeway cross section where multiple operational strategies are utilized and in which vehicles are managed as needed for the purpose of achieving predefined performance objectives. Examples include priced lanes and special use lanes such as high-occupancy vehicle, express, freeway, or truck only lanes.

Max out – A type of actuated operation for a given phase where the phase terminates because it has reached the designated maximum green time for the phase.

Maximum green – The maximum amount of time that a green signal indication can be displayed in the presence of conflicting demand.

Maximum recall – A form of phase recall where the controller places a call on each phase for vehicle service on the phase. This results in the presence of the green indication for the maximum duration every cycle.

Maximum weaving length – The length at which weaving turbulence no longer has an impact on the capacity of the weaving segment.

Median – The area in the middle of a roadway separating opposing traffic flows.

Meeting – An encounter of bicycles or pedestrians moving in the opposite direction of the subject bicycle flow.

Merge – A maneuver in which two separate streams of traffic combine to form a single

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streets without the aid of traffic signals or other right-of-way controls.

Merge segment – See freeway merge segment.

Mesoscopic model – A mathematical model for the macroscopic analysis of platoons of vehicles that employs relationships to describe how the platoons interact.

Microscopic model – A mathematical model that captures the movements of individual vehicles and their car-following, lane-change, and gap-acceptance decisions at small time intervals, usually 1 s or smaller.

Midblock stop – A transit stop located at a point away from intersections.

Minimum green – The least amount of time that a green signal indication will be displayed when a signal phase is activated.

Minimum recall – A form of phase recall where the controller places a continuous call to service the phase and then services the phase at the minimum green duration each cycle.

Minor movement – A vehicular flow in a specific directional entity (also an aggregation of movements that must yield to other movements).

Minor street – The street controlled by stop or yield signs at a two-way or all-way controlled intersection.

Mixed-traffic operation – Operation of a transit mode in lanes shared with other roadway users.

Mobility – The ability of people and goods to travel from place to place.

Mode – See *transit mode*.

Model – A procedure that uses one or more algorithms to produce a set of numerical outputs describing the operation of a segment or system, given a set of numerical inputs.

Model application – The physical configuration and operational constraints to which a traffic analysis tool is applied.

Mountainous terrain – Any combination of grades and horizontal and vertical alignment that causes heavy vehicles to operate at crawl speed for significant distances or at frequent intervals.

Move-up time – The time it takes a vehicle to move from a service position to the next position in a queue at a stop-controlled intersection.

Movement capacity – The capacity of a specific traffic stream at a fully controlled intersection approach, assuming that the traffic has exclusive use of a separate lane.

Movement groups – A categorization of traffic movements at a signalized intersection by predominant geometry. A separate movement group is established for each lane that has movements with one or more exclusive turns. Through plus right-turn and through plus left-turn movements are also considered exclusive as any turn movements that share a lane.

Multilane highway – A highway with 2 or more lanes for the exclusive use of traffic in each direction, with no control or partial control of access. It may have periodic crossings at grade but should not have traffic signals within 3 mi of each other.

Multilane roundabout – A roundabout with more than one lane on at least one entry and at least part of the circulatory roadway.

Multimodal – Being used by more than one travel mode.

Multimodal analysis – A type of HCM analysis where the LOS for each travel mode on a facility is evaluated simultaneously.

Multiple weaving segment – A portion of a freeway where more than one pair of merge and diverge areas create overlapping weaving movements between adjacent merge–diverge pairs.

Near-side stop – A transit stop located on the approach side of an intersection. Transit vehicles stop to serve passengers before crossing the intersection.

No-passing zone – A segment of a two-lane, two-way highway along which passing maneuvers are prohibited in one or both directions.

Node – The end point of a link. See *centroid*.

Nonlocal transit service – Transit service on routes with an operating strategy (such as service type, limited-stop, express, or express-only) that is not local service.

Nonweaving flow – The total flow rate in that weaving segment that is not involved in weaving movements.

Nonweaving movement – A traffic flow within a weaving segment that does not need to cross paths with another traffic flow while traversing the segment.

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Normative model – A mathematical model that identifies a set of parameters providing the best system performance.

O

Off-line bus stop – See bus stop.

Off ramp – A ramp that accommodates diverging maneuvers.

Off-street path – See shared-use path; path.

Offset – The time that the reference phase begins (seconds) relative to the system master time zero.

On-line bus stop – See bus stop.

On-ramp – A ramp that accommodates merging maneuvers.

On-street transitway – A portion of a street right-of-way dedicated to one particular mode, physically separated from other traffic, and located in the median or adjacent to one side of the street.

One-sided weaving segment – A weaving segment in which all weaving maneuvers require more than two lane changes to be completed successfully.

Operations-level analysis – Any application of an analytical methodology where the user supplies all or nearly all required inputs to the procedure.

Opposing approach – At an all-way stop-controlled intersection, the approach approximately 180 degrees opposite the subject approach.

Opposing flow rate – The flow rate in the direction of travel opposite to the direction under analysis.

Outputs – The performance measures produced by a model.

Overflow queue – Queued vehicles left over from a given phase at a signalized intersection.

Oversaturated flow – Traffic flow where at the arrival flow rate exceeds the capacity at a point or segment, or a queue created from a prior breakdown of a facility has not yet dissipated, or traffic flow is affected by downstream conditions.

P

Partial cloverleaf interchange (parclo) – An interchange with ramps in fewer than four quadrants and two to four diagonal ramps with major turning movements less desirable (sometimes by signalization and crossings).

Partial diamond interchange – A diamond interchange with fewer than four ramps, so that not all of the freeway-street crossover movements are served.

Partial stop – A situation where a vehicle slows or approaches the back of a queue but does not come to a full stop.

Passage time – The maximum amount of time one vehicle actuation can extend the green interval beyond the point it is displayed. This is input for each actuated signal phase. Also referred to as vehicle interval, unit extension, interval extension, or unit extension.

Passenger-car equivalent – The number of passenger cars that will result in the same operational conditions as a single heavy vehicle of a particular type under specified roadway, traffic, and control conditions.

Passenger load factor – See *load factor*.

Passenger trip length – The average distance traveled by a passenger on board a transit vehicle.

Passing lane – A lane added to improve passing opportunities in one direction of travel on a two-lane, two-direction highway.

Passing sight distance – The length of highway required to complete normal passing maneuvers in which the passing driver can determine that he or she can pass a potentially conflicting vehicle ahead before regaining the normal lane.

Passive priority – A form of traffic signal priority that is retrieved, such as the setting of a street's signal progression to favor buses.

Pavement condition rating – A measure of the road surface in terms of ride quality and surface defects.

Peak hour – The hour of the day (usually the one hour with the highest volume) during the analysis hour divided by the peak 15-minute flow rate within the analysis hour; a measure of traffic demand fluctuation within the analysis hour.

Pedestrian – An individual traveling on foot.

Pedestrian clearance interval – Time provided for an inspection when departure from the curb during the WALK indication to reach the opposite curb for the next phase.

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Pedestrian crosswalk – A connection between pedestrian facilities across a roadway used by automobiles, bicycles, and buses (or rails). Crosswalks can be marked or unmarked.

Pedestrian density – The number of pedestrians per unit area within a walkway or queuing area.

Pedestrian flow rate – The number of pedestrians passing a point per unit of time during a sub-hourly time period.

Pedestrian mode – A travel mode under which a journey or part of a journey is made on foot along a roadway or pedestrian facility.

Pedestrian overpass – A grade separated pedestrian facility over roadways, railroad tracks, or other topographic features.

Pedestrian phase – A long green interval that serves multiple functions, including pedestrian circulation, special events, and parking.

Pedestrian queuing area – A place where pedestrians stand temporarily while waiting to cross a road, such as the corners of a signalized intersection.

Pedestrian recall – A type of phase control where the controller places continuous calls for pedestrian service at the beginning of each cycle. This services the phase for at least an amount of time equal to its walk and pedestrian clearance intervals (longer if vehicle detection is not covered).

Pedestrian service time – The elapsed time starting with the full pedestrian signal display from the curb or the last pedestrian's arrival at the far side of the roadway.

Pedestrian space – The average area provided for pedestrians in a moving pedestrian stream or pedestrian queue.

Pedestrian start-up time – The time for a platoon of pedestrians to get under way, following the beginning of the walk interval.

Pedestrian street – A street dedicated to pedestrian use with full or partial access.

Pedestrian underpass – A grade separated pedestrian facility under roadways, railroad tracks, high-speed roadways, or other topographic features.

Pedestrian walkway – A pedestrian facility similar to a sidewalk in concept but not adjacent to a road. Examples include the interiors of automobile malls.

Percent free-flow speed – The average travel speed under the free-flow speed.

Percent time-spent-following – The average percent of total travel time that vehicles must travel in platoons behind slower vehicles because of inability to pass on a two-lane highway.

Performance measure – A quantitative or qualitative characterization of some aspect of the service provided to a certain road user group.

Permitted plus protected – A separate left-turn protection that displays for permitted period before the protected phase.

Permitted turn – A left-turn operation at a signalized intersection that is made by a vehicle, usually during the cycle in which the vehicle does not have the right-of-way.

Person capacity – The maximum number of persons who can pass a given point during a specified period under prevailing conditions.

Phase – The part of the signal cycle allocated to any combination of traffic movements receiving the right-of-way, simultaneously, during one or more intervals. A phase includes the green, yellow change, and red clearance intervals.

Phase pair – See barrier pair.

Phase pattern – The combination of right-of-way assigned to traffic streams at a multiway STOP-controlled intersection.

Phase recall – A call made by the controller for a specified phase each time the controller is servicing a conflicting phase.

Phase sequence – 1. The sequence of service provided to each of the movements. 2. A description of the order in which the left-turn movements are served relative to the through movements.

Planning-level analysis – An application of the HCM generally directed toward broad policy questions, initial project identification, and assessing a large number of locations or corridors (typically less detailed than operations-level analysis and relative to before-and-after monitoring). Nearly all inputs to the analysis may be default values.

Platoon – A group of vehicles or pedestrians traveling together as a group, either voluntarily or involuntarily because of signal control, roadway features, or other factors.

Platoon ratio – A description of the quality of signal progression applied in the demand flow rate equation. Computed by dividing the average demand flow rate

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Point – A point along a facility where (a) conflicting traffic streams cross, merge, or diverge; (b) a single traffic stream is regulated by a traffic control device; or (c) there is a significant change in the segment capacity (e.g., number of lanes added or removed, or a significant upgrade start or end of a ramp influence area).

Potential capacity – The capacity of a specific movement at a STOP-controlled intersection approach, determined that it is unimpeded by pedestrians or higher-rank movements and not exclusive use of a separate lane.

Precision – The closeness of the interval surrounding a measured quantity.

Preliminary engineering, level analysis – An HCM application conducted to support planning-oriented or initial conceptual design concepts and scope when alternatives analyses are performed, or to assess proposed system-wide policies. Many of the inputs to the analysis will be simulated.

Prepositioning – A deliberate driver choice of lane or lane group at an intersection in anticipation of a turn or a downstream intersection.

Pretimed control – A signal control in which the cycle length, phase plan, and phase times are preset to repeat continuously.

Prevailing conditions – The geometric, traffic, control, and environmental conditions during the analysis period.

Progression – The act of vehicles controlled by successive green indications in accordance with a time–distance pattern to permit continuous operation of groups of vehicles at a designated speed at a series of signals.

Protected plus permitted – Compound left-turn operation at a signalized intersection that displays the protected phase before the opposing phase.

Protected turn – The left or right turns at a signalized intersection that are made by a vehicle during a time in the cycle when the vehicle has the right-of-way.

Q

Quality of service – A description of how well a transportation facility or service operates from a traveler's perspective.

Quantity of service – A measure of the utilization of a transportation system.

Queue – A line of vehicles, bicycles, or pedestrians waiting to be served due to traffic control, a bottleneck, or other causes.

Queue delay – 1. The amount of time that a vehicle spends in a queued state. 2. When computed from vehicle trajectories, it is the accumulated time-step delay over all time steps in which the vehicle is in a queue.

Queue discharge flow – A traffic flow that has passed through the downstream bottleneck, is moving at the maximum speed of the freeway.

Queue jump – A short median section often shared with a right-turn lane in combination with an advance green indication for the lane that allows buses to move past a queue of cars at a signal.

Queue length – The distance between the upstream and downstream ends of the queue.

Queue spillback – A condition where the back of a queue extends beyond the available storage length, resulting in potential interference with upstream traffic movements.

Queue storage ratio – The maximum back of queue as a proportion of the available storage on the subject lane or link.

Queued state – A condition when a vehicle is within one car length (20 ft) of a stopped vehicle and is itself in a stopped state (i.e., is slowing to less than 5 mi/h).

R

Ramp – A dedicated roadway providing a connection between two other roadways, at least one of the roadways a ramp connects is typically a high-speed facility such as a freeway, multilane highway, or C-D roadway.

Ramp–freeway junction – The point of connection between a ramp and a high-speed facility such as a freeway, multilane highway, or C-D roadway.

Ramp meter – A traffic signal that controls the entry of vehicles from a ramp onto a limited-access facility; the signal displays one or two of the following: red, green, or green flash.

Ramp roadway – See ramp.

Ramp–street junction – See ramp–surface street junction.

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Rank – The function by which all vehicles in conflicting traffic streams at a two-way STOP-controlled intersection.

Reasonable expectancy – The concept that the stated capacity for a given system element is one that can be achieved repeatedly during peak periods, rather than being the absolute maximum flow rate that could be observed.

Receiving lanes – Lanes departing an intersection.

Recreational vehicle – A motor vehicle, primarily operated by a private individual, for transporting recreational equipment or camping. Examples include campers, motor homes, and vehicles towing boat trailers.

Red clearance interval – A brief period of time following the yellow indication during which the signal heads associated with the ring, phase, and all conflicting phases display a red indication.

Red time – The period in the signal cycle during which, for a given phase or lane group, the signal is red.

Recovery delay – Delay experienced by a heavy vehicle or bus stop when they must wait for a gap in traffic before reentering the travel lane.

Reference phase – One of the two coordinated phases (see Phase Sets).

Regression model – A model that uses field or simulated data to develop statistically derived relationships between particular model inputs and performance measures, such as capacity and delay.

Residual queue – The number of vehicles at the end of the analysis period resulting from oversaturated conditions (i.e., demand exceeds capacity).

Rest-in-walk mode – A signal controller setting in which the phase will show the walk at only its first actuation. Once the walk is shown, it will not be shown again until a call is registered, the phase is shown, and the walk time has elapsed. Also known as rest-in-walk, no-pedestrian.

Restrictive median – A median (see median), raised or other physical device that prevents or discourages vehicles from crossing the opposing travel lanes.

Right-turn-on-red – The ability to make a right turn at a signalized intersection when a red indication is displayed, after stopping and only when no conflicting vehicular or pedestrian traffic is present.

Ring – A set of phases operating in sequence.

Roadside obstruction – An object or barrier along or adjacent to the roadside or median that affects traffic flow, whether vertical (e.g., curb, retaining wall, or bridge abutment), lateral (e.g., guardrail), or both (e.g., bridge pier).

Roadway – That portion of a highway improved, designed, or ordinarily used for vehicular travel and parking lanes but exclusive of the sidewalk, berm, or shoulder even though such sidewalk, berm, or shoulder is used by persons riding bicycles or other human-powered vehicles.

Roadway characteristic – A geometric characteristic of a street or highway, including the type of facility, number and width of lanes (by direction), shoulder width and lateral clearances, design speed and horizontal and vertical alignments.

Rolling terrain – Any combination of grades and horizontal or vertical alignment that occupy heavy vehicles to reduce their speed substantially below that of passenger cars but that does not cause heavy vehicles to operate at crawl speeds for any significant length of time or at frequent intervals.

Roundabout – An intersection with a perpendicularly circular shape, characterized by yield-at-entry and circulation around a central island.

Rubbernecking – The slowing of nonvehicle observers' traffic in close.

Running speed – See average running speed.

Running time – The time that a vehicle traverses a length of roadway excluding any delay related to traffic control devices.

Rural – An area with widely scattered development and a low density of housing and nonfarm businesses.

Saturation flow rate – The equivalent hourly rate at which persons or vehicles can traverse a point or uniform section of an approach during 60 minutes of green time, assuming that the green is never terminated and that there are always vehicles in queue. Also known as saturation flow.

Saturated flow – A traffic flow condition in which the number of vehicles approaching a point is greater than the number that can pass through the point during the green interval, so that some vehicles must wait through more than one cycle.

Saturated two-way – A signalized intersection approach where the average queue storage ratio (see queue storage ratio) for the left-turn lane(s) exceeds 1.0 and the left-turn lane(s) is not adequately protected.

Saturation headway – The average headway between vehicles crossing a stop line of a signalized approach, computed for the queued vehicles after the first four vehicles in the queue and ending with the last vehicle in the queue that exists before the intersection is cleared of all queued vehicles.

Saturation headway adjustment period – The time between the start of the green interval and the point at which the saturation headway is reached.

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pedestrian crosswalk or bicycle crossing.

Scenario – See *analysis scenario*.

Segment – 1. For interrupted-flow facilities: a length of lane and its boundary points. 2. For uninterrupted-flow facilities: a portion of a facility between two points.

Segment delay – 1. The delay experienced by a vehicle while traveling through a segment, usually including traffic delay, incident delay, control delay, and geometric delay. 2. When calculated from cubic flow rates, the time actually taken to traverse a segment minus the time it would take to traverse the segment at the target speed. The segment delay for any time step is equal to the total of the applicable delays accumulated over all time steps in which a vehicle is present on the segment minus the segment delay for that vehicle.

Segment initialization – The process of determining the appropriate number of vehicles on each segment. A precursor to estimating the number of vehicles on each freeway segment for each time step in a non-oversaturated condition.

Semiactuated control – A signal control in which some approaches (typically on the minor street) have detectors and some of the approaches (typically on the major street) have no detectors.

Sensitivity analysis – A technique for exploring how model output changes in response to changes in model inputs, implemented by varying one input at a time over its reasonable range while holding all other inputs constant.

Service flow rate – The maximum hourly rate of flow that can be maintained in a given segment under prevailing roadway, traffic, and control conditions without violating the criteria for LOS *x*.

Service measure – A performance measure used to define LOS for a transportation system element.

Service lane – A lateral way with controlled intersections. The departure roadway mirrors the arrival roadway.

Service volume – The maximum hourly directional flow rate that can be sustained in a given segment without violating the criteria for LOS *x* during the worst 15 min of the hour (peak) with the highest density under prevailing roadway, traffic, and control conditions.

Shared lane – 1. A lane shared by more than one movement. 2. A bicycle facility where bicyclists share a travel lane with motorized vehicular traffic.

Shared-lane capacity – The capacity of a lane at an intersection that is shared by two or more movements.

Shared pedestrian–bicycle path – A path physically separated from highway traffic for the use of pedestrians, bicyclists, runners, in-line skaters, and other nonmotorized users.

Shock wave – A change in the uniformity of traffic conditions. For example, a shock wave is generated when the signal turns green, and it moves upstream as vehicles accelerate out of the queue, slow down. A shock wave is also generated when the signal turns green, and it moves downstream as the first set of vehicles discharge from the signal.

Short length – The distance within a weaving segment over which lane changing is not prohibited or discouraged by markings.

Shoulder – A portion of the roadway or its vertical extensions with the traveled way for accommodation of stopped vehicles, emergency use, and lateral support of the subbase, base, and surface courses.

Shoulder bikeway – A bicycle facility where bicyclists ride on the paved shoulder, separated by striping from motor vehicle traffic, for travel along a roadway.

Shoulder bypass lane – A portion of the paved shoulder opposite the minor road at a three-leg intersection, marked as a lane for through traffic to bypass vehicles that are slowing or stopped to make a left turn.

Shy distance – The buffer that pedestrians give themselves to avoid the potentially stopping of the cars, bushes, against a building face, or getting too close to pedestrians standing under awnings or window shopping.

Side street – See *minor road*.

Sidepath – A shared pedestrian–bicycle path located parallel and in proximity to a roadway.

Sidewalk – A pedestrian facility located parallel and in proximity to a roadway.

Simple weaving segment – A weaving segment formed by a single merge point followed by a single diverge point.

Simultaneous gap out – A control feature of actuated control by which a phase is not terminated by a maximum green interval but is terminated only when adequate gaps in traffic flow are detected on all conflicting approaches.

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Single-entry – A movement (from a multilane approach) in which a portion of the vehicles in the lane(s) designated for the movement are required to enter a lane containing through traffic.

Single-point urban interchange – A diamond interchange for which all the ramp movements enter a single signalized intersection.

Single-stage gap acceptance – A condition where no more than one gap in the major-street traffic stream is available for minor-street drivers to enter, so that minor-street drivers must evaluate gaps in both major-street directions simultaneously.

Sketch planning tools – Tools that provide general order-of-magnitude estimates of travel demand and transportation system performance to help support high-level system improvement alternatives.

Soft conversion – The conversion of a value from U.S. customary units to metric units (or vice versa) through the application of a conversion factor, such as multiplying 12 ft by 0.305 m/ft, resulting in 3.65 m. See also *hard conversion*.

Spare – See *protected capacity*.

Space gap – See *gap*.

Space mean speed – An average speed based on the average travel time of vehicles to traverse a length of roadway.

Spacing – The distance between the same vehicle features (e.g., front axles) of two consecutive vehicles in a traffic lane, measured from the same common feature of the vehicles (e.g., rear axle, front bumper, or front bumper).

Spatial stop rate – The rate of stop rate per facility length.

Spatial variability – Variability in the observed values, such as the percentage of trucks in the traffic stream, from one location to another – within an area or from one area to another.

Special events – Unusual high-demand events that occur at known times and relatively infrequently, resulting in traffic flow patterns that vary substantially from the typical situation.

Specific grade – A single grade or a roadway segment or a complex roadway segment expressed as a percentage.

Speed – A rate of motion expressed as distance per unit of time.

Speed harmonization – A technique to reduce the shock waves that typically occur when traffic approaching a slowdown or a bottleneck is forced to decelerate, through the use of variable speed limits or advisory speed signs.

Split/Lack – See *queue spillback*.

Spillover – A condition occurring when a pedestrian queue at a corner spills over to the crosswalk, forcing pedestrians (e.g., by creating gaps in the street) to travel at their desired speed.

Split – The portion of the cycle length allocated to each phase or interval that may occur. In actuated control systems, split is the time in the cycle allocated to a phase—the sum of the green, yellow change, and red clearance intervals for a phase.

Split-diamond interchange – Diamond interchanges in which freeway entrance and exit ramps are separated at the street level, creating four intersections.

Stairway – A pedestrian facility that provides a grade change using a series of steps and landings.

Standee – A passenger standing in a transit vehicle.

Start-up lost time – The additional time consumed by the first few vehicles in a queue (above saturation flow headway) in excess of the normal headway because of the need to react to the initial display of the green phase and to accelerate.

Static flow model – A mathematical model in which the traffic flow rate and origin–destination volumes are constant.

Stochastic model – A mathematical model that uses random variables or probabilistic components to represent at least one parameter.

Stop rate – The ratio of total stops divided by the number of vehicles served.

Stop spacing – See *average stop spacing*.

Stopped delay – The amount of time that a vehicle is stopped. When calculated from vehicle trajectories, it equals the time the vehicle is in the stopped state. Time-step delays are calculated over all time steps in which the vehicle speed is in the stopped state (or at/below the stopped delay speed threshold).

Stopped state – A condition where a vehicle is traveling at less than 5 mi/h.

Storage length – The length of turn lane available for storing queued vehicles.

Street – See *roadway*.

Street corner – The area encompassed within the intersection of two sidewalks.

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Streetcar mode – A transit mode operated by vehicles that receive power from overhead wires and run on tracks. Compared with rapid rail, streetcars are generally shorter and narrower, are more likely to have unreserved fare collection, make more frequent stops, and are more likely to operate in mixed traffic.

Study period – See analysis period.

Subject approach – The approach under the study at a two-way and a one-way stop-controlled intersection.

Suburban street – A street with low-density driveway access on the periphery of an urban area.

Sustained spillback – A result of oversaturation, where queuing does not dissipate at the end of each cycle but remains present until the downstream capacity is increased or the upstream demand is reduced.

System – All the transportation facilities and modes within a particular region.

System elements – Components of a transportation system, including spirals, segments, facilities, terminals, and areas.

Taper area – An area characterized by a reduction or increase in pavement width to direct traffic.

Target speed – In a simulation tool, the speed at which a driver would prefer to travel, a difference from the free-flow speed in that most simulation tools apply a "driver aggressiveness" factor to the free-flow speed to determine a target speed.

Temporal variability – Variability in measured values, such as hourly traffic volumes. Traffic varies from day to day, month to month, and at a given location.

Terrain – See grade and terrain.

Three-level diamond interchange – A diamond interchange with two grade-separated levels of roadway facilities providing continuous through movements.

Through vehicles – All vehicles passing directly through a street segment and not turning.

Tight urban diamond interchange – A diamond interchange with a separation of less than 600 ft between the two intersections.

Time interval – See analysis period.

Time interval scale factor – The ratio of the total durable variance source to total facility variance.

Time mean speed – The average speed of vehicles at a point or over a segment of a highway.

Time gap – See gap.

Time space domain – A specification of the freeway corridor (or subject portion of the facility) and an identification of the time intervals for which the analysis is to be conducted.

Time step delay – The length of a time step minus the time it would have taken a vehicle to cover the distance traveled in the step at the target speed.

Time varying flow model – A simulator model in which flows change with time.

Tool – See traffic analysis tool.

Total lateral clearance (TLC) – The sum of the right-side and left-side lateral clearances at a single cross section of a highway.

Total lost time – See lost time.

Total ramp density – The average number of on-ramp, off-ramp, major merge, and major diverge segments per mile. It applies to a 10-segment freeway facility. See also boundary and influence area at the upstream end of the study segment.

Traffic analysis tool – A software product used for traffic analysis that includes, at a minimum, a computational engine and a user interface.

Traffic condition – A characteristic of traffic flow, its typical distributions of vehicle types in the traffic stream, directional distribution of traffic, time-of-day distribution of traffic, and type of driver population on a given facility.

Traffic control device – A sign, signal, marking, or other device used to regulate, warn, or guide traffic.

Traffic delay – The component of delay that can be attributed to the interaction of vehicles and causes drivers to reduce speed below the free-flow speed.

Traffic incidents – Occurrences, such as crashes, stalled cars, and debris in the roadway, that do not occur every day. These incidents reduce roadway capacity and create variation in day-to-day travel times along the roadway.

Traffic pressure – The display of aggressive driving behaviors by a large number of drivers during high-demand traffic.

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conditions. Under saturated conditions, a large number of drivers accept smaller headways than they would be comfortable with if they would prefer different accelerations.

Traffic signal delay – Delay experienced by a bus that arrives at a bus stop during the green indication, serves its passengers during portions of the green and red intervals, and then must wait for the traffic signal to turn green again before proceeding. See also control delay.

Traffic signal optimization tool – A tool primarily designed to develop optimal signal phasing and timing plans for isolated signalized intersections, arterials, networks, or signal networks.

Transit frequency – The number of transit vehicles that stop at or travel past a point during a specified time period.

Transit mode – A travel mode involving vehicles traveling between stations, terminals, and street networks along the roadway to pick up and discharge passengers.

Transit reliability – A measure of the time performance and the predictability of roadway between successive transit vehicles at the same stop, the amount of time passengers must wait at a transit stop as well as the consistency of a passenger's arrival time at a destination.

Transit signal preemption – The transfer of normal operation of a traffic signal to a special control mode serving a transit vehicle.

Transit signal priority – Adjustments to traffic signal timing to provide more favorable green time to a transit vehicle (bus, streetcar, light rail, and bus rapid transit).

Transitway – See busway/transitway.

Travel demand models – Models that forecast changes in future travel demand on the basis of current conditions and projected socioeconomic characteristics and changes in transportation system design.

Travel mode – 1. A category of roadway characterized by specific right-of-way, technology, and operational features. 2. A particular type of travel (for example, walking, bicycling, bus ride, automobile, or traveling by bus).

Travel speed – See average running speed.

Travel time – The average time spent by vehicles traversing a highway segment, including operational delay.

Travel time rate – The reciprocal of speed, expressed as time per unit distance traveled.

Travel time reliability – 1. The probability that a trip can be completed within a certain threshold time. 2. The variability in travel time for a given trip due to unforeseen causes such as weather, a crash, or an accident.

Traveler information systems – An integrated set of technologies that allow the general public to access real-time or near real-time data on traffic, transit services, incident conditions, travel time, and speed.

Traveler perception model – A model that estimates the average (or range of) response(s) that travelers would give for a given set of conditions (typically subjective or design in nature).

Trucks – A motor vehicle designed primarily for the transport of goods and materials or for the delivery of services other than public transportation.

Turn bay – See auxiliary turn lane.

Turnout – A short segment of a two-lane arterial or collector street, usually widened to the left, that is provided to allow vehicles traveling in the opposite direction to pass a slow-moving vehicle or to have room to safely stop and wait for a gap in traffic to enter.

Two-lane highway – A roadway with two lanes cross-sectionally, one lane for each direction of flow, on which passing maneuvers must be made in the opposing lane.

Two-phase pattern – A type of operation at an isolated intersection where drivers from opposing approaches enter the intersection at roughly the same time.

Two-sided weaving segment – A weaving segment in which all lane-changing weaving maneuvers require at least one lane change to be completed successfully and in which a single lane on each of two roadways followed by a single-lane off-ramp on the opposite side of the freeway.

Two-stage gap acceptance – A condition where a median refuge area is available for vehicles that desire to cross traffic that is separated by a median and that gaps in the near side and far side traffic streams, followed by gaps in the far side traffic stream.

Two-way left-turn lane – A lane in the median area that extends continuously along a street or highway and is marked by pavement markings on both sides and is open to the

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through-traffic stream, for vehicles traveling in another direction to make a left turn across all other conflicting traffic streams and driveways.

Two-way stop-controlled – The type of traffic control at an intersection where drivers on the minor street or driveway must wait for a gap in the major street traffic to complete a maneuver.

U

Uncertainty – The range within which a model's estimate of a value is statistically likely to vary from the actual value that

Uncontrolled – Lacking a traffic control device that interrupts traffic flow to give a traffic signal, STOP sign, or YIELD sign.

Understaturated flow – Traffic flow where (a) the arriving flow rate is less than the capacity of a point or segment, (b) no residual queue remains from a prior time period, and (c) traffic flow is unaffected by downstream conditions.

Uniform delay – The first term of the equation for lane group control delay assuming uniform arrival and departure rates during a given duration period.

Uninterrupted flow – Traffic flow on facilities that have no fixed causes of delay or interruption external to the traffic stream; examples include freeways and signalized sections of multilane and two-lane rural highways.

Unit extension – See *passage time*.

Unit width flow rate – The pedestrian flow rate normalized to pedestrians per minute per unit of walkway or crosswalk width.

Unmet demand – The number of vehicles or a specified lane group that cannot be served at any point in time as a result of operational problems (e.g., vehicle queues not cleared by the end of the green phase) or physical problems (e.g., excessive queue spillback from a downstream bottleneck).

Unsignalized intersection – An intersection not controlled by traffic signals.

Upstream – The direction from which traffic is flowing.

Urban – An area typified by high densities of development or concentrations of population, usually by people from several areas with a high degree

Urban street – A street with relatively high density of driveway access, related to an urban land use, and with traffic signals or interruptions by stop or yield signs no farther than 2 mi apart.

Urban street facilities – Extended sections of roadway or arterial streets that include the impacts of traffic signals or other traffic control along the road.

Urban street segment – A length of urban street connecting boundary intersections one end, including the upstream boundary intersection but excluding the downstream boundary intersection.

User perception variability – Variability in user responses that occurs when different drivers experiencing identical conditions are asked to rate the conditions.

Utility – A measure of the value a traveler places on a trip service.

V

Validation – The process by which the analyst checks the ability of a model to predict traffic performance for a stated road system against field measurements of traffic performance that were not used in the calibration process.

Variability – The day-to-day variation in travel demand and congestion within a transportation system.

Vehicle capacity – The maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic, and control conditions.

Vehicle trajectory analysis – The development of performance measures from the perspective of time-space paths of individual vehicles.

Verification – The process by which a software developer and other researchers check the accuracy of a software implementation of traffic-flow rationale theory.

Volume – The total number of vehicles or other roadway users that pass over a given point or roadway segment in both directions or in a given time interval, often 1 h.

Volume-to-capacity (v/c) ratio – The ratio of flow rate to capacity for a system element.

W

Walk interval – A signal display time intended to give pedestrians sufficient time to traverse the width

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indication and depart the curb before the pedestrian clearance interval begins.

Walkway – See pedestrian walkway.

Wave speed – The speed at which a shock wave travels upstream or downstream through traffic.

Weaving – The crossing of paths by two traffic streams traveling in the same direction along a significant length of highway, without the aid of traffic control devices (except for guide signs).

Weaving configuration – The organization and continuity of lanes in a weaving segment, which determines lane changing characteristics.

Weaving flow – The traffic movements in a weaving segment that are engaged in weaving movements.

Weaving length – See base length, maximum weaving length, and short length.

Weaving movement – A traffic flow within a weaving segment that requires a lane change to maintain its original path with no more than one lane change. A traffic flow which traverses the segment.

Weaving segment – See freeway weaving segment.

Weaving segment influence area – The base length of the weaving segment plus 500 ft upstream of the entry point to the weaving segment and 500 ft downstream of the exit point from the weaving segment. Entry and exit points are defined as the points where the appropriate edges of the merging and diverging lanes meet.

Weaving width – The total number of lanes between the entry and exit gore areas within a weaving segment, including the auxiliary lane, if present.

Work zone – A segment of highway in which maintenance or construction operations reduce the number of lanes available to traffic, or affect the operational characteristics of traffic flowing through the segment.

Y

Yellow change interval – The period of time that a yellow indication is displayed to alert drivers to the impending presentation of a red indication.

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2. LIST OF SYMBOLS

This section lists and defines the symbols and abbreviations used in the HCM, along with their units if applicable. If a symbol has more than one meaning, the chapter or chapters of the specific use are cited in parentheses after the definition.

%HV	percentage of heavy vehicles (decimal)
%OTP	percentage of segment with occupied on-highway parking
%R	percentage of traffic in peak direction
$\%HV_{ap}$	percentage of the total approach flow in the lane with the highest volume (decimal)
A	critical flow ratio for the arterial movements
a_i	passenger-car weighting factor
AADT	annual average daily traffic (veh/day)
A_b	adjusted passings per minute or mode by average bicycle
A_f	percent of free-flow speed (FFS)
A_p	adjusted passings per minute by the average bicycle during the peak 15 min
ATS_d	average travel speed in the analysis direction (mi/h)
ATS_f	average travel speed for the facility (mi/h)
ATS_i	average travel speed for directional segment i (mi/h)
ATS_{fd}	average travel speed in the analysis segment as affected by a passing lane (mi/h)
AWD	average width to nearest obstruction (ft)
b_d	destination adjustment factor
BFFS	base free-flow speed (mi/h)
b_f	platooning factor for lane group
BLOS	bicycle level of service score
b_p	origin adjustment factor
$PPTSF_d$	base percent time-spent-following in the analysis direction
c	base capacity
C	cycle length (s)
$c_{adj,i}$	capacity for lane i (pc/h)
C_m	cycle length (steps)
c_p	adjusted intersection capacity (veh/h)
c_p	average capacity (veh/h)
c_{pce}	available capacity of conversion lane, lane group with protected left-turn operation (veh/h)
c_p'	adjusted capacity in work zone consideration zone
c_{sh}	actual capacity of the shared lane (veh/h)
c_s	capacity of the bicycle lane (bicycle/h)
c_{shared}	capacity of the bypass lane, adjusted for heavy vehicles (pc/h)
c_{stat}	capacity in the analysis direction under prevailing conditions based on ATS (pc/h)
c_{stat}	capacity in the analysis direction under prevailing conditions based on PTSF (pc/h)

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C_{LT}	capacity of the left-turn lane, adjusted for heavy vehicles (pc/h)
C_{LTR}	capacity of the left-turn lane, adjusted for heavy vehicles (pc/h)
C_{RT}	capacity of the right-turn lane, adjusted for heavy vehicles (pc/h)
C_{Tf}	common green time with demand-actuated control (s)
CG_{Tf}	common green time between the upstream ramp green and the downstream arterial through green (s)
CG_{Tu}	common green time between the upstream through green and downstream through green (s)
CP	effective critical pause on the conflict path
c_{TR}	capacity of a shared lane (veh/h)
$c_{TR,x}$	capacity of a shared freeway segment with the same flow ratio as the subject lane group segment under equivalent ideal conditions, per lane (pc/h/ln)
$c_{TR,1}$	capacity of all lanes in the shared segment under ideal conditions (pc/h)
c_{TRS}	capacity of the shared segment under equivalent ideal conditions (pc/h/ln)
c_{TT}	capacity of a left-turn movement with permitted left-turn operation (veh/h)
$c_{TT,1}$	capacity of an exclusive left-turn lane group with permitted left-turn operation (veh/h)
$c_{TT,2}$	capacity of an exclusive two-lane left-turn group with permitted left-turn operation (veh/h)
$c_{TT,LT}$	capacity of the through and left-turn movements (veh/h)
$c_{TT,x}$	capacity of movement x
$c_{TT,1}$	capacity of movement 1 (veh/h)
$c_{TT,2}$	movement capacity of the two movements of the subject shared lane (veh/h)
C_{max}	maximum cycle length (s)
c_{max}	merge capacity (veh/h)
C_{min}	minimum cycle length (s)
c_{MT}	non-merge capacity in the inside lane (veh/h)
c_{MT1}	pedestal capacity of conflicting stream 1 (veh/h)
c_{MT2}	lane capacity adjusted for heavy vehicles (pc/h)
CT_i	change period (yellow change interval plus red clearance interval) for phase i (s)
c_{TR}	shared lane capacity for upstream right-turn traffic movement (veh/h)
c_R	capacity of the right-turn movement (veh/h)
$c_{r,1}$	capacity of movement 1 assuming random flow during the unblocked period
c_r	saturation capacity (veh/h)
c_{sr}	critical lane (veh/h)
c_{TT}	capacity of the lane if both storage areas were infinitely long (veh/h)
$c_{TT,1}$	capacity of the shared lane (veh/h)
$c_{TT,2}$	capacity of a shared lane lane group with permitted left-turn operation (veh/h)
c_{TT}	capacity for the exiting through movement (veh/h)
$c_{TT,1}$	capacity for the exiting turn movement (veh/h)
$c_{TT,2}$	critical phase flow rate (veh/h)
d	demand flow rate (veh/h, Chapter 17 control delay (s/veh, Chapter 17), interchange delay (s/veh, Chapter 22)
D	distance (pc/mi/ln, Chapter 17), distance between the two intersections of the interchange (ft, Chapter 22)
d_1	uniform delay (s/veh)

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d_1	baseline uniform delay (s/veh)
d_2	incremental delay (s/veh)
d_3	initial queue delay (s/veh)
d_A	control delay on the approach (s/veh)
d_I	arterial street bicycle intersection delay (s)
d_{ped}	average pedestrian delay per pedestrian (pedestrian)
d_R	adjusted volume per destination (veh/h)
d_{RA}	approach control delay for approach (s/veh)
d_{RI}	control delay at the upstream (s/veh)
d_{sl}	lower vehicle acceleration/deceleration delay due to a transit stop (s/veh)
d_T	delay due to turning right turns from the street into cross-street intersection (s/veh)
d_{TH}	through vehicle delay due to left turns (s/veh)
d_{TR}	through vehicle delay due to right turns (s/veh)
$d_{x,y,z}$	control delay for the approach (s/veh)
d_1	bicycle delay, 1-hour rate
D_1	distance to nearest signal-controlled crossing (ft)
D_2	Diversion distance (ft)
D_{adj}	Adjustment for progression adjustment factor
D_c	average density for the lane (pc/mi/ln)
d_p	average pedestrian gap delay (s)
$d_{p,i}$	average gap delay for pedestrians who have initiated delay
d_{ped}	pedestrian hours of delay, as explained in Chapter 21, Generalized Control Delay (pedestrian-hours, Chapter 18)
d_{ped}	vehicle demand on segment (veh), Chapter 21, control delay for lane (s/veh), Chapter 18)
d	intersection control delay (s/veh)
$d_{x,y,z,w,v}$	control delay for the entire intersection (s/veh)
D	distance for deceleration (ft/veh/h)
d	computed control delay for the lane group (s/veh)
$d_{adj,i}$	delay to major left-turning vehicles (s/veh)
D_{adj}	Density in the queue discharge illumination period, excluding approaching flows, lanes (pc/mi/ln)
d_{ped}	merge delay (s/veh)
d_{ped}	pedestrian delay for the inside lane (s/veh)
d_{ped}	delay due to vehicles moving along the route (s/veh)
D_1	phase duration (s)
d_1	average pedestrian delay (s)
$D_{1,1}$	phase duration for phase 1, which occurs just before phase 1 (s)
$D_{1,2}$	phase duration for phase 1, which occurs just after phase 1 (s)
d_{ped}	pedestrian delay when traversing Crosswalk X (s/p)
D_{p1}	phase duration for left-turn phase 1 (s)
$D_{p,ped}$	duration of the phase serving the pedestrian Shared Through movement (s)
$D_{p,1}$	phase duration for coordinated phase 1 (s)

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d_1	pedestrian delay when crossing the approach at a signalized intersection (s/p)
d_2	pedestrian diversion delay (s/p)
d_3	pedestrian delay (s/p)
d_4	pedestrian delay when walking parallel to the roadway (s/p)
d_5	transit vehicle delay due to serving passengers (s)
d_6	pedestrian waiting delay (s/p)
d_7	crossing delay (s/p)
d_{Q_1}	distance to the downstream point at the beginning of the upstream unblocked queue (ft)
d_{Q_2}	distance to the downstream queue at the beginning of the upstream queue in approach i (ft)
d_{Q_3}	distance to the downstream queue at the beginning of the upstream ramp queue (ft)
D_r	density in the ramp influence area (pc/mi/ln)
d_r	computed control delay for the right-turn movements (s/veh)
d_t	transit vehicle delay receiving the traffic stream from a transit stop (s/veh)
D_1	speed index for oversaturation
d_1	adjusted uniform delay (s/veh)
$d_{1,ln}$	uniform delay for the movement considered as a separate lane
$d_{1,i}$	uniform delay in shared (left-turn and through lane group (s/veh)
$d_{1,r}$	control delay in shared right-turn and through lane group (s/veh)
DSV	daily service volume
e_i	distance between stored vehicles (= 25 ft)
DSV_i	daily service volume for level of service i (veh/day)
d_i	control delay in exclusive through lane group (s/veh)
d_{i1}	average delay to through vehicles on the inside lane (s/veh)
d_i	total delay in analysis period (veh-h)
d'	through vehicle delay per right-turn vehicle (s/veh)
d_1	delay due to a transit vehicle stop for passenger pickup (s/veh/p)
D_{ij}	cumulative departures (veh)
$D_{ij,t}$	cumulative departures for phase (veh)
d_j	time headway per vehicle (s/veh)
dx_i	length of queue segment i (mi)
e	calibration factor with respect to changes in the travel time rate (Chapter 21), the extension of effective green time rate for clearance interval (s, Chapter 22)
E	weighted events per minute
E_1	equivalent number of through cars for a protected left-turning vehicle
$E_{1,ln}$	unadjusted through car equivalent for a protected left-turning vehicle
E_{11}	equivalent number of through cars for a permitted left-turning vehicle
$E_{11,ln}$	unadjusted through car equivalent for a permitted left-turning vehicle
E_{12}	equivalent number of through cars for a permitted left-turning vehicle when opposed by a queue on a single-lane approach
$E_{12,ln}$	unadjusted through car equivalent for a permitted left-turning vehicle when opposed by a queue on a single-lane approach
e_i	presumed extension of effective green (s)

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P_r	passenger car equivalent for recreational vehicles (Chapter 10); equivalent number of through cars for a protected right-turning vehicle (Chapter 18)
P_{RTOR}	equivalent number of through cars for a protected right-turning vehicle at an access point
P_{RT}	modified through-car equivalent for a protected right-turning vehicle
P_T	passenger car equivalent for trucks and buses
P_{TT}	passenger car equivalent for trucks operating at travel speed
p	total events on the path (events/h)
p_1	adjustment factor for area type (HCM, ATDM, LDB chapters)
p_2	adjustment for access points (unit/h)
p_3	proportion of transit vehicle stop acceleration/deceleration delay not due to traffic control
p_b	adjustment factor for blocking effect of local buses that stop within intersection area
p_c	indicator variable for boundary intersections (critical type: 1 [0] = signalized, 0 [1] = two-way stop-controlled)
p_d	median or two-way left-turn lane delay factor
p_f	adjustment for cross section (unit/h)
p_{ped}	pedestrian delay adjustment factor
p_{pk}	proportion of dwell time occurring during effective green
p_r	adjustment for the presence of turn bays, two-way, and two-way left-turn lanes (unit/h)
$PTSF$	free-flow speed (mi/h)
p_g	adjustment factor for approach grade
$p_{g,ATDM}$	grade adjustment factor
$p_{g,PTSF}$	grade adjustment factor for PTSF determination
p_{hv}	two-way left-turn lane factor
p_{hv}	heavy-vehicle adjustment factor
$p_{hv,ATDM}$	heavy-vehicle adjustment factor for average travel speed
$p_{hv,i}$	heavy-vehicle adjustment factor for the ith lane
$p_{hv,PTSF}$	heavy-vehicle adjustment factor for PTSF determination
p_i	signal-phasing adjustment factor
p_j	passenger load factor (passengers/seat)
p_k	adjustment for lateral clearance (unit/h)
p_{lc}	pedestrian-vehicle interaction factor for left-turn groups
p_{ls}	adjustment for lane and shoulder width (unit/h)
p_m	adjustment factor for left-turn vehicle presence in a lane group
p_{np}	adjustment factor for lane utilization
p_{rb}	adjustment for lane width (unit/h)
p_{rt}	adjustment for median type (unit/h)
p_s	number of passing events (events/h)
$p_{s,ATDM}$	adjustment factor for ATDM determination for the percentage of no-passing zones in the analysis direction
$p_{s,PTSF}$	adjustment to PTSF for the percentage of no-passing zones in the analysis segment
PO_4	base cut point for Phase 1 (s)
p^*	driver population factor

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L_p	number of passing or refuge lanes
f_p	pedestrian–vehicle adjustment factor
f_{pb}	pedestrian blockage factor for the proportion of time that one lane or an approach is blocked (unitless)
f_{pbx}	entire capacity adjustment factor for pedestrians
$f_{pbx,ped}$	adjustment factor for the effect of pedestrians on the exclusive pedestrian travel speed
$f_{pbx,veh}$	adjustment factor for the effect of a pedestrian on the percent time spent in leaving
f_{pr}	pedestrian–bicycle adjustment factor for right-turn groups
f_{rt}	adjustment for right-turning vehicle presence in the same group
f_s	motorized vehicle speed adjustment factor
f_w	sidewalk width coefficient
f_{wz}	time-in-service scale factor for time period i
f_z	pedestrian travel time factor
f	adjustment factor for traffic pressure
f_{ra}	motorized vehicle–bicycle adjustment factor
f_{rl}	adjustment factor for lane width
f_x	cross-section adjustment factor
g	effective green time (s)
G	green at grade (Chapter 17), green time (s) (Chapter 22)
$G_{ped,i}$	average green interval given that the phase is called by a pedestrian detection (s)
$G_{pv,i}$	average green interval given that the phase is called by a vehicle detection (s)
g'	effective green time adjusted for the presence of downstream queues (s)
G_i	green interval duration for phase i (s)
g_i	available effective green time (s)
g_{ini}	green interval for time-varying initial approach (s)
g_p	effective green time for the bicycle lane (s)
g_{PD}	green interval for the downstream signalized through movement (s)
g_{ps}	supplemental service time for shared-right-lane approaches (s)
g_s	green extension time (s)
g_t	time before the first left-turning vehicle arrives and blocks the shared lane (s)
g_{thru}	maximum time before the first left-turning vehicle arrives and with no vehicle delays are sufficient for through vehicles to depart at saturation flow rate (s)
g_u	effective green time for lane group u (s)
g	effective green time for left-turn phase (s)
G_{max}	maximum green setting (s)
G_{min}	minimum green setting (s)
g_{ns}	effective green time for permitted left-turn operation (s)
G_p	displayed green time associated with g_p (s)
$G_{ped,i}$	minimum green interval duration based on pedestrian crossing time (s)
g_{ped}	pedestrian service time (s)
$g_{ped,rt}$	pedestrian service time for the phase serving the major street through movement (s)
g_{ps}	queue service time during permitted left-turn operation (s)
g_q	upgrading queue service time (g_s for the opposing movement) (s)

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G'_i	displayed green interval corresponding to g_i (s)
GR	green interval for the left-turning (or pedestrian) flow (s)
g_s	queue service time (s)
g_u	duration of permitted left-turn green time that is not blocked by an opposing queue (s)
G_{ui}	unblocked green interval duration for a phase (s)
G_{Vi}	green interval for the opposing approach (s)
$h_{d,i,j}$	effective walk time for the phase serving the mixed-use movement (s)
h	average headway for each through lane
$h_{adj,HV}$	average headway of those heavy vehicles in A and N_i (s/veh)
H	maximum headway that the first through vehicle can have and still remain a queue (s/veh)
h_i	headway adjustment (s)
h_i	departure headway or average time between the departures of successive vehicles on a given approach (s)
$h_{adj,i}$	headway adjustment for heavy vehicles (s)
h_i	saturation headway for the subject through approach (s)
h_i	saturation headway or time between departures of successive vehicles on a given approach for a particular case (case i) (s)
$h_{adj,L}$	headway adjustment for left turns (s)
h_{adj}	full stop rate for the segment (stops/veh)
$h_{adj,R}$	headway adjustment for right turns (s)
HR_i	special stop rate for the segment (stops/veh)
i	crossing event index
I	adjustment factor for type, nature (s), and proximity of work activity (see Table Chapter 18 for pedestrian facility adjustment factors (Chapter 18)
$I_{a,i}$	automobile traveler perception score for segment
$I_{a,x}$	bicyclist perception score for intersection
$I_{b,w}$	bicycle perception score for link
$I_{b,i}$	bicyclist perception score for segment
$I_{b,x}$	bicycle perception score for signalized intersection
IO	intersection density, the number of intersections within 5 mi of the center of the subject segment, segment divided by 6 (unitless)
$I_{i,i}$	lane change intensity (C_{ch}/L_i) (veh/ft)
$I_{p,x}$	pedestrian perception score for intersection
$I_{p,w}$	pedestrian perception score for link
$I_{p,i}$	pedestrian perception score for segment
$I_{p,x}$	pedestrian perception score for signalized intersection
I_{pk}	indicator variable for on-street parking occupancy ($= 1$ if $p_{pk} > 20\%$)
I_i	interval between vehicle in queue (s/veh)
I_{sh}	indicator variable for shared lane ($= 1.0$ if the shared left-turn lane is in a shared lane, 0 if the subject left-turn lane is a separate lane)
I_{sp}	indicator variable ($= 1.0$ when equations are used to evaluate delay due to a split phase, 0.0000 when equations are used to evaluate delay due to simple phase)
$I_{t,i}$	transit passenger perception score for segment

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i	lane group associated with protected arrival time
k	incremental delay factor
K	proportion of AADT occurring in the peak hour (decimal)
k	density of riders or people (riders/mi)
k_{min}	minimum incremental delay factor
L	cycle lost time (s)
l_1	start-up lost time (s)
$l_{1,p}$	permitted start-up lost time (s)
l_2	clearance lost time (s)
L_a	available queue storage distance (ft/ln)
L_A	length of acceleration lane (ft)
$L_{a,lt}$	available queue storage distance for the combined lane movement (ft/ln)
$L_{a,lt}$	available queue storage distance for the left-turn movement (ft/ln)
$L_{a,th}$	available queue storage distance for the through movement (ft/ln)
$L_{a,rt}$	available queue storage distance for the turn movement (ft/ln)
L_B	base length of the segment, measured from the points at which the edges of the travel lanes of the merging and diverging roadways converge (ft)
LC_{ALL}	total rate of lane changing of all vehicles within the weaving segment (lc/h)
L_c	curb-to-curb crossing distance (ft)
LC_{FR}	minimum number of lane changes that a freeway-to-ramp weaving vehicle must make to complete the freeway-to-ramp movement successfully
LC_L	left-side lateral clearance (ft)
LC_{MIN}	minimum rate of lane changing that must exist for all weaving vehicles to complete their weaving maneuvers successfully (lc/h)
LC_{NW}	total rate of lane changing by nonweaving vehicles within the weaving segment (lc/h)
LC_R	right-side lateral clearance (ft)
LC_{RF}	minimum number of lane changes that a ramp-to-freeway weaving vehicle must make to complete the ramp-to-freeway movement successfully
LC_{RR}	minimum number of lane changes that must be made by one ramp-to-ramp vehicle to complete a weaving maneuver
LC_W	total rate of lane changing by weaving vehicles within the weaving segment (lc/h)
L_d	length of crosswalk (ft)
L_D	length of deceleration lane (ft)
$l_{de,A}$	lost time on the external arterial approach due to the presence of downstream queue (s)
L_{down}	distance between the subject ramp junction and the adjacent downstream ramp junction (ft)
$l_{de,R}$	lost time on the internal ramp approach due to the presence of downstream queue (s)
l_{ds}	additional lost time due to demand starvation (s)
L_{d}	length of the stop-line detection zone (ft)
$L_{d,lt}$	length of the stop-line detection zone in the left-turn lanes (ft)
$L_{d,rt}$	length of the stop-line detection zone in the right-turn lanes (ft)
$L_{d,th}$	length of the stop-line detection zone in the through lanes (ft)
$l_{de,u}$	lost time on the upstream approach due to the presence of a downstream queue (s)
L_{EQ}	equilibrium separation distance

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L_v	average vehicle spacing in queue (ft/veh)
L_{vg}	stored heavy-vehicle lane length = 40 (ft)
L_x	length of segment x (mi)
L_p	stored passenger-car lane length = 25 (ft)
L_{pc}	average passenger-car length (ft)
L_1	length of segment traversed by route in Lane 1 (ft)
L_2	distance between adjacent signalized intersections (ft)
L_s	short length of the segment, defined as the distance over which lane changing is not prohibited or discouraged by markings (ft)
L_t	total length of directional segment (mi)
L_u	unsignalized lane (s)
L_v	left-turn flow rate per cycle (veh/cycle)
L_{vv}	distance between the subject ramp junction and the adjacent upstream ramp junction (ft)
L_v	adjusted length of vehicle (ft)
L_{wa}	influence area of the weaving segment (ft)
$L_{x,max}$	maximum length of a queuing segment (ft)
M	pedestrian space (ft²/p)
M_c	meetings per minute of users already on path segment
MAH	maximum allowable headway (s/veh)
MAH^*	equivalent maximum allowable headway for the phase (s/veh)
MAH_c	maximum allowable headway for the concurrent phase that also ends at the barrier (s/veh)
MAH_{lpr}	maximum allowable headway for permitted left-turning vehicles in exclusive lane (s/veh)
$MAH_{l,s}$	maximum allowable headway for protected left-turning vehicles in exclusive lane (s/veh)
$MAH_{l,sh}$	maximum allowable headway for permitted left-turning vehicles in shared lane (s/veh)
MAH_{lsh}	maximum allowable headway for protected left-turning vehicles in shared lane (s/veh)
$MAH_{r,s}$	maximum allowable headway for protected right-turning vehicles in exclusive lane (s/veh)
MAH_{rsh}	maximum allowable headway for permitted right-turning vehicles in shared lane (s/veh)
MAH_{th}	maximum allowable headway for through vehicles (s/veh)
$M_{c,cir}$	corner circulation area per pedestrian (ft²/p)
M_{cw}	crosswalk circulation area per pedestrian (ft²/p)
m_l	set of Lanes available to vehicles that cross Crosswalk l
m_s	average speed of vehicles (mi/h)
m_t	number of lane groups on approach j
N_1	speed index for no-passing (tracing) zone
N_c	total number of expected meetings per minute during the peak 15 min
N_d	modified yield rate (decimal)
n_{15}	count of vehicles during the peak 15-min period (veh)
$n_{15,c}$	count of vehicles traveling on the major street during a 15-min period (veh/h)

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v_{ad}	total of vehicles entering the intersection (veh)
N_a	number of traffic signal cross-point approaches along the approach
N_{adj}	number of cross-point approaches on the right side of the opposing direction of travel (points)
N_{adj2}	number of cross-point approaches on the left side of the subject direction of travel (points)
$N_{approach}$	number of lanes in the approach or total through lanes (ln)
N_b	Bus stopping rate in the adjacent approach (buses/h)
N_c	total number of pedestrians in the crossing platoon (p)
N_{cl}	number of lanes in the combined movement (ln)
N_{cr}	number of lanes in the exclusive or shared right-turn lane (ln)
N_{cv}	number of pedestrians arriving at the corner during a cycle having crossed the major street (p)
N_{cw}	number of pedestrians arriving at the corner during a cycle having crossed the major street (p)
N_d	number of exclusive turn lanes in movement group (ln)
N_f	number of fully stopped vehicles (veh/h)
N_{fL}	number of fully stopped vehicles in shared left-turn and through lane group (veh/h)
N_{fR}	number of fully stopped vehicles in shared right-turn and through lane group (veh/h)
N_{fT}	number of fully stopped vehicles in exclusive through lane group (veh/h)
v_g	Arrival count during green (veh)
N_g	number of lane groups (one-way street = 1)
n	number of lanes serving phase movement (ln)
N	number of lanes in approach
N	number of lanes in exclusive left-turn lane group (ln)
N_L	number of lanes in shared left- and right-turn lane group (ln)
N_l	number of lanes in the left turn bay (ln)
N_l	parking maneuver rate adjacent to lane group (maneuvers/h)
n_{lane}	length of the storage area (ft) for the approach lane(s) under consideration (ft/ln)
N_l	number of other lanes in the form veh/h (total lanes, one freeway, 2 for multiple-lane freeway)
N_l	spatial distribution of pedestrians (cf. Chapter 13), number of parallel slopes (Chapter 30)
n_{ln}	number of overlapping pedestrians (p/ft)
N_{ln}	number of pedestrians crossing during an interval (p)
N_m	maximum number of approaching vehicles that could arrive after g_{min} before g_i (veh)
N_m	available queue storage (veh)
$N_{max,m}$	available queue storage for the conflicting movement (veh)
$N_{max,L}$	maximum queue storage for the left turn movement (veh)
$N_{max,T}$	maximum queue storage for the through movement (veh)
$N_{max,R}$	maximum queue storage for the right turn movement (veh)
N_o	number of lanes in exclusive/shared left-turn lane group (ln)
$N_{o,adj}$	number of lanes for the upstream ramp left-turning movement
N_{pR}	number of right-turn channelized pedestrian signals (see Chapter 18)
n_r	number of vehicles per cycle (= 2.0 veh/ln)

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N_{th}	number of lanes in shared lane or exclusive through lane group (thr)
N_{tr}	number of lanes in shared right-turn and through lane group (thr)
N_v	total number of vans
N_{vh}	number of through lanes (shared or exclusive) (lan)
N_{vh}	number of through lanes (shared or exclusive) (lan)
N_{vo}	total number of circulating pedestrians arriving on the walkway (ped)
N_w	number of lanes in a subject segment
N_{wo}	average number of lanes along the subject crosswalk (ln/pl)
N_{wo}	number of lanes in the intersection (ln)
N_x	number of weaving vehicles that cross the walk and pedestrian flow interval (ped)
N_{wb}	number of lanes from which a weaving maneuver may be completed with one lane change in the same direction
n_x	number of cells necessary to exhaust the green in one cycle
O_c	adjusted volume for origin (veh/h)
OCC_{bi}	bicycle occupancy
Occ_{ped}	pedestrian occupancy after the opposing queue clears
OCC_r	relevant conflicting vehicle occupancy
O_v	volume for origin (veh/h)
P	proportion of vehicles arriving during the green interval
P^*	adjustment to the major-street left-turn or major-street through impedance factor
P_{adj}	proportion of N_{wo} that can be assumed to be a left turn from the subject direction of travel
P_b	proportion of time blocked (decimal)
P_{bl}	proportion of time that the subject movement is blocked by the major-street platoon
$P_{bx,i}$	probability that an individual will respond with a score of B, C, D, E, or F
P_{cb}	proportion of slows on adjacent walk benches (decimal)
P_{cb}	probability of two blocked lanes in the opposing direction
P_{cb}	probability of two blocked lanes in the subject direction
$P_{curb,o}$	proportion of sidewalk length adjacent to a building or curb (decimal)
P	pavement condition rating
PC	pedestrian platooning ratio
$P_{d,i,x}$	probability that an individual will respond with a score of C, D, E, or F
$P_{d,o}$	proportion of segment with curb on the right-hand side (decimal)
$P_{dx,i}$	probability that an individual will respond with a score of D, E, or F
P_{fo}	probability of delayed passing in opposing direction
P_{fs}	probability of delayed passing in subject direction
P_{ix}	probability that an individual will respond with a score of E or F
P_{ix}	probability that an individual will respond with a score of F
P_{LD}	proportion of diverging traffic remaining in Lanes 1 and 2 immediately upstream of the deceleration lane
P_{LS}	proportion of sidewalk length adjacent to a fence or low wall (decimal)
P_{LT}	proportion of freeway vehicles remaining in Lanes 1 and 2 immediately upstream of the on-ramp deceleration area
PHF	peak hour factor

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P_{HV}	percentage of heavy vehicles in the corresponding movement group (%)
$P_{HV,o}$	adjusted percentage of heavy vehicles in the opposing shared lane demand flow rate (%)
p	probability for user group
p_i	seed proportion of volume from origin to destination i (decimal)
p_j	turning proportion for movement group (%)
P_L	proportion of left-turning vehicles in the shared lane
P_{LT}	probability of a vehicle moving from a left-turn lane to a through lane
P_o	proportion of left-turning vehicles in the subject approach (decimal)
P_{OL}	proportion of left-turning vehicles in the lane
$P_{OL,i-j}$	proportion of intersections with left-turn lanes (e.g., bay) on segment (decimal)
P_{OL}	proportion of left-turning vehicles in the opposing traffic stream
P_{pd}	probability of delayed passing for mode m
P_{pm}	probability of blocked lane in opposing direction
P_{pm}	probability of blocked lane in subject direction
P_R	proportion of heavy vehicles turning on red (decimal)
P_{RT}	probability of left-turn bay overflow (decimal)
P_{sp}	proportion of on-street parking occupied (decimal)
P_T	proportion of recreational vehicles in the traffic stream (Chapter 11), proportion of right-turning vehicles in the shared lane (Chapter 31)
P_{TR}	proportion of link length with restrictive median (decimal)
P_U	proportion of right-turning vehicles on the subject approach (decimal)
P_{UL}	proportion of right-turning vehicles in the lane
P_{UT}	proportion of drop-down gap cut with Cutler's (decimal)
P_v	proportion of buses and trucks in the traffic stream
PT	passage time setting (s)
P_{TH}	proportion of trucks operating at slow speed (decimal)
P_{TM}	total probability of delayed passing
PT_L	passage time setting for phase serving left-turning vehicles (s)
PT_R	passage time setting for phase serving right-turning vehicles (s)
$PTSF_a$	percent time-spent-following in the analysis direction (decimal)
$PTSF_b$	percent time-spent-following in the opposing direction (decimal)
$PTSF_{LT}$	percent time-spent-following for segment i (decimal)
$PTSF_p$	percent time-spent-following for segment as affected by the presence of a passing lane (decimal)
PT_T	passage time setting for phase serving through vehicles (s)
P_{UL}	proportion of turning vehicles in the shared lane L_1 or P_R (decimal)
$P_{walk,adj}$	proportion of sidewalk length adjacent to a window display (by decimal)
p_x	probability of phase termination by extension to the maximum green limit
q	demand flow rate = v/PHF (veh/h)
Q	back-of-queue size (veh/ln)
q^*	actual flow rate for the phase (veh/h)
q_{adj}	adjusted flow rate in time-space of upstream intersection (veh/h/ln) or v_o (veh/h/ln)
$q_{adj,i}$	departure flow rate in time-space of upstream intersection i (veh/h/ln)

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Q_1	first-term back-of-queue size (veh/ln)
Q_2	second-term back-of-queue size (veh/ln)
$Q_{2,T}$	second-term back-of-queue size for shared left-turn and through lane group (veh/ln)
$Q_{2,R}$	second-term back-of-queue size for shared right-turn and through lane group (veh/ln)
$Q_{2,T}$	second-term back-of-queue size for exclusive through lane group (veh/ln)
Q_3	back-of-queue size (veh/ln)
Q_3	third-term back-of-queue size (veh/ln)
$Q_{3,T}$	third-term back-of-queue size for shared left-turn and through lane group (veh/ln)
$Q_{3,R}$	third-term back-of-queue size for shared right-turn and through lane group (veh/ln)
Q_3	third-term back-of-queue size for exclusive through lane group (veh/ln)
Q_{95}	95th percentile queue (veh)
Q_a	estimated average per lane queue length for the through movement in the downstream (protected) link at the beginning of upstream critical Phase A (ft)
Q_b	initial queue at the start of the analysis period (veh)
$Q_{b,ini}$	initial queue for the unblocked movement (veh)
Q_c	arrival flow rate at downstream lane group (veh/s)
Q_e	queue at the end of the analysis period (veh)
Q_{e1}	queue at the end of the analysis period when $v = c_m$ and $Q_{e1} > 0$ (veh)
Q_e	queue size at the end of t_g (veh)
Q_g	arrival flow per during the effective green time (veh/s)
Q_i	lane adjusted saturation flow rate for lane group (passenger cars/h)
Q_i	queue size at the end of interval i (veh)
$Q_{max,n}$	length of the queue stored at the internal approach at the beginning of the last red during which the approach has a remaining observation interval
Q_o	outside lane flow rate = $v_o/3600$ (veh/s)
Q_p	bicycle demand in the opposing direction (bicycles/h)
Q_p	queue size at the end of permitted service time (veh)
Q_{pr}	queue size at the end of permitted service time t_{pr} adjusted for saturation (veh)
Q_r	queue size at the start of t_g (veh)
q_r	arrival flow rate during the effective red time (veh/s)
Q_r	queue size at the end of effective red time (t_r) (veh)
Q_s	estimated average per lane queue length for the through movement in the downstream (protected) link at the beginning of upstream critical Phase B (ft)
Q_{sh}	bicycle demand in the same direction (bicycles/h)
Q_{sq}	average queue length for the movement considered at the end of the cycle (veh)
Q_t	total hourly entering pedestrian volume (peds/h)
Q_{tw}	total time spent by pedestrians waiting to cross the major street during one cycle (p-s)
r	effective red time ($= C - g$) (s)
R	manual adjustment for on-ramps (veh/h, Chapter 10); radius of corner curb (Chapter 16); critical flow ratio for the exit ramp movement (Chapter 22)
R_1, R_2	intermediate calculation variables
r_a	deceleration rate = 3.5 (ft/s²)
r_d	transit vehicle deceleration rate (ft/s²)
R_r	red clearance interval (s)

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R_{pc}	pedestrian-vehicle conflict rate (ped/h)
s_a	adjusted saturation flow rate (pc/h/ln)
s_b	base saturation flow rate (pc/h/ln)
s_{bc}	base saturation flow rate for conflicting lane (pc/h/ln)
s_{bx}	base saturation flow rate for exclusive turn lane (pc/h/ln)
s_{bx1}	base saturation flow rate for exclusive left-turn lane (pc/h/ln)
s_{bx2}	base saturation flow rate for exclusive right-turn lane (pc/h/ln)
s_{bx12}	base saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{bx3}	base saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{bx4}	base saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_c	saturation flow rate for conflicting lane (pc/h/ln)
s_d	saturation flow rate for downstream segment (pc/h/ln)
s_{dx}	saturation flow rate for exclusive turn lane (pc/h/ln)
s_{dx1}	saturation flow rate for exclusive left-turn lane (pc/h/ln)
s_{dx2}	saturation flow rate for exclusive right-turn lane (pc/h/ln)
s_{dx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{dx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{dx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_f	saturation flow rate for subject approach (pc/h/ln)
s_{fx}	saturation flow rate for exclusive turn lane (pc/h/ln)
s_{fx1}	saturation flow rate for exclusive left-turn lane (pc/h/ln)
s_{fx2}	saturation flow rate for exclusive right-turn lane (pc/h/ln)
s_{fx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{fx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{fx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_g	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{gx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{gx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{gx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{gx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{gx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{gx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_h	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{hx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{hx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{hx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{hx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{hx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{hx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_i	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{ix}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ix1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ix2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{ix12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ix3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{ix4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_j	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{jx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{jx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{jx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{jx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{jx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{jx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_k	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{kx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{kx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{kx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{kx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{kx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{kx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_l	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{lx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{lx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{lx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{lx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{lx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{lx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_m	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{mx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{mx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{mx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{mx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{mx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{mx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_n	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{nx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{nx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{nx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{nx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{nx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{nx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_o	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{ox}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ox1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ox2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{ox12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ox3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{ox4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_p	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{px}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{px1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{px2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{px12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{px3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{px4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_q	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{qx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{qx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{qx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{qx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{qx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{qx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_r	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{rx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{rx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{rx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{rx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{rx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{rx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_s	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{sx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{sx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{sx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{sx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{sx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{sx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_t	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{tx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{tx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{tx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{tx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{tx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{tx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_u	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{ux}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ux1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ux2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{ux12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{ux3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{ux4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_v	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{vx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{vx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{vx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{vx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{vx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{vx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_w	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{wx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{wx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{wx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{wx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{wx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{wx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_x	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{xx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{xx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{xx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{xx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{xx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{xx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_y	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{yx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{yx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{yx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{yx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{yx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{yx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)
s_z	saturation flow rate for shared left- and right-turn lane group (pc/h/ln)
s_{zx}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{zx1}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{zx2}	saturation flow rate for exclusive right-turn lane with protected operation (pc/h/ln)
s_{zx12}	saturation flow rate for exclusive left-turn lane with protected operation (pc/h/ln)
s_{zx3}	saturation flow rate for exclusive left-turn lane with permitted operation (pc/h/ln)
s_{zx4}	saturation flow rate for exclusive left-turn lane group with permitted operation (pc/h/ln)

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$S_{p,i}$	pedestrian speed (mi/h)
S_{pb}	free-flow pedestrian walking speed (ft/s)
S_{pk}	peak speed (mi/h)
$s_{prot,pce}$	prevailing saturation flow rate for lane group (pc/h)
$s_{sh,i}$	shared lane discharge flow rate for upstream right-turn traffic movement (veh/h)
s_t	saturation flow rate for exclusive right-turn lane group with permitted operation (veh/h/ln)
v_p	average speed in the pedestrian circulation area (mi/h)
S_{pc}	adjusted free-flow bicycle running speed (mi/h)
N_{tr}	transit vehicle running speed (mi/h)
N_t	threshold speed for running or stopped vehicles (= 5.0 mi/h)
s_{tr}	saturation flow rate for shared left-turn and through lane group with permitted operation (veh/h/ln)
$s_{tr,pce}$	maximum saturation flow rate for shared left-turn and through lane group with permitted operation (pc/h/ln)
$s_{tr,1}$	saturation flow rate for shared left-turn and through lane group during Period 2 (veh/h/ln)
$S_{tr,v}$	average transit speed (mi/h)
s_{tr}	saturation flow rate for shared left-turn or right-turn and through lane group with permitted operation (veh/h/ln)
s_u	saturation flow rate for exclusive through lane group (veh/h/ln)
S_v	vehicle speed factor
$S_{v,th}$	travel speed of through vehicles for the segment (mi/h)
$S_{v,th,b}$	travel speed of through bicycles along the segment (mi/h)
s_v	saturation flow rate for an exclusive through lane (= base saturation flow rate adjusted for lane width, heavy vehicles, grade, parking, buses, and area type) (veh/h/ln)
$S_{v,th,p}$	travel speed of through pedestrians for the segment (ft/s)
$S_{v,tr,v}$	travel speed of transit vehicles on the segment (mi/h)
SV_i	service volume for LOS i (veh/h)
S_w	average speed of weaving vehicles within the weaving segment (mi/h)
s_{wt}	transit wait ride score
t	duration of unmet demand in the analysis period (= Chapter 16, path segment travel time for average analysis hour, Chapter 22)
T	analysis time period
t'	platoon arrival time (steps)
t_1	blocked period duration (steps)
t_2	segment running time (steps)
T_a	time at which a vehicle would have arrived at the stop line if it had been driving up at the reference speed
T_d	time at which a vehicle would have arrived at the stop line if it had been driving up at the running speed
T_e	time at which a vehicle is discharged at the stop line
t_{eq}	adjustment factor for intersection geometry
v_t	average duration of unmet demand in the analysis period (h)
v_u	adjusted duration of unmet demand in the analysis period (h)
v_{ur}	unmet demand rate (pc/h)

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T_{cp} base travel time rate = 60 for the central business district of a metropolitan area with 5 million persons or more; 25 increased 10 (min/mi)

t_d time until splitback (s)

t_g queue clearing time (Chapter 15, critical headway for a single protection; Chapter 14)

t_{go} base critical headway (s)

t_{hv} adjustment factor for grade (s)

t_{HV} adjustment factor for heavy vehicles (s)

t_c critical headway (i.e., the minimum time that allows intersection entry for one minor stream vehicle) for movement x (s)

t_f critical gap (s)

t_{fo} base follow-up time of the right-turn vehicle (s)

t_l overall time (s)

t_L duration of time interval during which the arrival flow rate and capacity flow rate are constant (h)

t_p average waiting time due to lateral gaps (s)

t_{pr} average waiting time due to lateral gaps (min/veh)

t_s follow-up headway (s, Chapter 21; service time for fully stopped vehicles (s, Chapter 30)

t_{sw} base follow-up headway (s)

t_{sw} adjustment factor for heavy vehicles (1.0 for major streets with one lane in each direction; 2.0 for major streets with two or three lanes in each direction)

t_t follow-up headway (i.e., the time between the departure of one vehicle from the intersection and the departure of the next vehicle under a continuous queue condition) for minor movement x (s)

t_{tv} follow-up headway (s)

t lost time for ith vehicle in queue (s, Chapter 4); duration of unmet demand for time period (h, Chapter 18)

t transit vehicle running time loss (sec/veh)

t_v lost time per phase (s)

t_x adjusted lost time (i.e., the time during which the separated intersections are not used effectively by any movement) (s)

t_x' adjusted lost time for the internal approaches (s)

t_{thr} threshold lane time = 30 (typical) (min)

t_v critical design headway = 3.2 (s)

t_{vt} total lateral clearance (ft)

T_{wk} crosswalk occupancy time (s)

U_p analysis time period

v_a pedestrian perception of signal indication and curb departure time (= 2.0 s)

v_p pedestrian walking speed (s)

v_{pa} passenger-car hourly lane rate (pcphpl)

v_r lane distribution of x (pcu)

v_s saturation flow rate (pcphpl)

v_{sh} segment hourly flow rate = [average] (veh/h)

V_{tp} total ramp demand (pcph/pln)

v_x segment hourly flow rate for x movement (veh)

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t_s	pedestrian start-up time and end clearance time (s; Chapter 19); service time or occupancy time spent by a vehicle in first position waiting to depart (s; Chapter 30)
TS_p	time-space available for travel by pedestrian (ped-s)
$TS_{p,ave}$	average crosswalk time-space (ped-s)
TS_p	available crosswalk time-space (ped-s)
TS_p'	effective available crosswalk time-space (ped-s)
ts_{tv}	time-space occupied by turning vehicles (ped-s)
t_t	duration of trapezoid or triangle in interval (s)
TT	total travel time of all vehicles in segment (veh-h)
TT_{av}	total travel time experienced by all vehicles traversing the subject segment during the 15-min analysis period (veh-h)
v	speed of average bicycle (mi/h)
v_c	constrained speed of the first through vehicle given that it is delayed (ft/s)
v_r	right-turn speed (ft/s)
v	service flow rate
V	demand volume under prevailing conditions (veh/h)
v	flow rate for the outside lane (veh/h/ln)
v_{12}	demand flow rate in Lanes 1 and 2 of the freeway immediately upstream of the ramp influence area (pc/h)
v_{15}	pedestrian flow rate during the peak 15 min (p/h)
V_{15}	volume during the peak 15 min of the analysis hour (veh/15 min)
v_a	flow rate in the adjacent through lane (veh/h/ln)
v_{av}	flow rate in Lane 3 of the freeway (pc/h/ln)
v_{ad}	adjusted arrival volume in the shared lane (veh/h)
v_{ca}	flow rate of pedestrians traveling through the corner from Sidewalk A to Sidewalk B, or vice versa (p/h)
v_{ch}	volume of flow rate for approach (veh/h)
v_c/N_c	arterial flow feeding the subject queue, divided by the respective number of lanes
$v_{c,T}$	average demand flow rate per through lane (upstream of any turn bays on the approach) (vehicle/lane)
$v_{c,up,T}$	upstream arterial through flow (v/h)
v_{cy}	bicycle flow rate (bicycles/h)
$v_{cy,g}$	bicycle flow rate during the green indication (bicycles/h)
v_d	conflicting flow rate
$v_{d,sh}$	shadow conflicting flow rate (veh/h), assumed to be 1,000N, where N is the number of through lanes per direction on the major street
$v_{d,x}$	conflicting flow rate (pc/h)
$v_{d,x}$	conflicting flow for movement x during the unblocked period (veh/h)
$v_{d,x}$	conflicting flow rate for movement x (veh/h)
v_{ped}	flow rate of pedestrians arriving at the corner to cross the minor street (p/h)
v_p	flow rate of pedestrians arriving at the corner to cross the minor street (p/h)
v_{pa}	flow rate on the adjacent downstream ramp (pc/h)
v_{pce}	demand flow rate for ATSIs for conflicting analysis lane (pc/h)
$v_{pce,av}$	demand flow rate in the analysis direction for estimation of FFS (pc/h)

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v_p	flow rate of pedestrians arriving at the corner to cross the major street (p/h)
v_{pb}	flow rate of pedestrians arriving at the corner to cross the major street (p/h)
$P_{v,15min}$	adjusted 15-min visit demand flow rate per parking configuration (veh/h)
v_p	entry flow rate
v_x	exit flow rate
$v_{x,y}$	conflicting opposing flow rate (pc/h)
$v_{x,y}$	flow rate on freeway immediately upstream of the ramp influence area under study (pc/h)
v_{FW}	freeway to freeway demand flow rate in the weaving segment (pc/h)
v_{FW}	flow rate on the freeway immediately downstream of the merge or diverge area (pc/h)
v_{FO}	freeway to ramp demand flow rate in the weaving segment (pc/h)
v_g	demand flow rate for movement group (veh/h)
v_{g1}	demand flow rate in the exclusive lane with the highest flow rate of all exclusive lanes in movement group (veh/h)
v_p	pedestrian demand during the analysis hour (p/h)
v_p	demand flow rate for movement i (pc/h, Chapter 19); planned volume for phase i (veh/h, Chapter 28)
v_i	demand volume for movement i (veh/h, Chapter 19); special pedestrian analysis (pc/h, Chapter 23)
v_i'	demand flow rate (veh/cycle/in)
v_{ll}	major street through vehicles in shared lane (veh/h)
v_{lr}	major street turning vehicles in shared lane (veh/h)
v_{LOS}	demand flow rate for LOS evaluation (pc/h)
v_{ij}	volume starting from origin i and exiting at destination j (veh/h)
$v_{ij,t}$	demand flow rate for movement i (pc/h)
v_{LOS}	demand flow rate for determination of PTSF (pc/h)
v_m	flow rate for movement m
v_{ll}	demand flow rate in exclusive left-turn lane (veh/h)
v_{lr}	major street through plus right-turn volume (veh/h)
v_{LT}	through and left-turn volume (veh/h)
v_{lr}	shared through and right-turn lane group (veh/h)
v_{lr}	shared left-turn demand flow rate (veh/h)
$v_{lr,sh}$	permitted left-turn demand flow rate (veh/h)
v_{lr}	median lane demand flow rate (pc/h) (for use in estimating the adjusted median lane flow rate)
v_{lr}	adjusted median lane demand flow rate (veh/h)
v_{lr}	merge flow rate (veh/h/ln)
VMT_i	vehicle miles traveled in segment i (veh-mi)
VMT_{all}	total vehicle miles traveled by all vehicles in directional segment during the 1-hour analysis period (veh-mi)
v_{lr}	flow rate for the outside lane (veh/h/ln)
$v_{lr,w}$	nonweaving demand flow rate in the weaving segment (pc/h)
v_{lr}	opposing demand flow rate (veh/h)
$v_{lr,sh}$	demand flow rate for ATS determination in the opposing direction (pc/h)
$v_{lr,LOS}$	demand flow rate in the opposing direction for calculation of PTSF (pc/h)

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v_{ao}	average per-vehicle demand flow rate on all lanes in the ramp influence area (pc/h) including flow in Lanes 1 and 2 (pc/h/ln)
$V_{c,p,t}$	15 min crossing count for ramp pedestrians and bicycles, location t (ped/h)
$v_{d,i}$	directional demand flow rate in the outside lane (veh/h)
$V_{d,p,t}$	15 min entering count for base period and entering location t (ped/h)
v_{ff}	demand flow rate under equivalent base conditions (pc/h/ln, Chapter 11); pedestrian flow per unit width (p/ft/min, Chapter 17)
v_{fo}	pedestrian flow rate (p/min/ft)
$v_{fo,i}$	pedestrian flow rate in the subject direction for base (ideal) hour (p/h)
$v_{fo,m}$	pedestrian flow rate during the pedestrian-service time (p/h)
v_{fo}	flow rate on the on-ramp or off-ramp (pc/h, Chapter 13); maximum value (veh/h, Chapter 14)
HV	volume ratio
$v_i = v_R$	ramp flow that leads the subject quarter, divided by the respective number of lanes
v_{12}	sum of the flow rates in Lanes 1 and 2 and the ramp flow rate for ramps only (pc/h)
$v_{av,y}$	upstream ramp-to-freeway flow (veh)
v_{ff}	ramp to freeway demand flow rate in the weaving segment (pc/h)
v_{fr}	freeway to ramp demand flow rate in the weaving segment (pc/h)
v_{fr}	right-turn demand flow rate (veh/h)
$v_{fr,m}$	right-turn maximum flow rate (veh/h)
v_{fr}	transit frequency for the segment (veh/h)
$v_{fr,m}$	flow rate for the two lanes (veh/h)
v_{fr}	demand flow rate in shared left-turn and through lane group (veh/h)
$v_{fr,s}$	left turn flow rate in shared lane group (veh/h/ln)
v_{fr}	demand flow rate in shared right-turn and through lane group (veh/h)
$v_{fr,s}$	right turn flow rate in shared lane group (veh/h/ln)
v_{fr}	demand flow rate in exclusive through lane group (veh/h/ln, Chapter 17); transit vehicle flow rate in pattern w (v, veh/h, Chapter 12)
v_{fr}	through demand flow rate (veh/h)
v_{fr}	total number of vehicles arriving during analysis period (veh)
v_{fr}	flow rate on the adjacent upstream roadway (pc/h)
v_{fr}	weaving demand flow rate in the weaving segment (pc/h)
v_{fr}	flow rate for one lane (veh/h)
v_{fr}	flow rate of the p movement in the subject shared lane (veh/h)
w	lane width of the lane that the corner movement is negotiating ratio (ft)
W	weaving adjacently factor (1 for W_{fr} = 6 ft); clear width of crosswalk (ft, Chapter 30)
W_{fr}	effective width of combined bicycle lane and shoulder (ft)
W	effective width of sidewalk A (ft)
W_{fr}	available sidewalk width (ft)
W_{fr}	adjusted available sidewalk width (ft)
W_{fr}	pedestrian walk setting (s)
W_{fr}	effective width of sidewalk B (ft)
W_{fr}	width of the bicycle lane (ft)
W_{fr}	buffer width between roadway and available sidewalk (ft)

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W_{cs}	curb-to-curb width of face-of-bus stop (ft)
W_e	effective width of crosswalk (ft)
W_i	average effective width of the outside through lane (ft)
W_{ov}	effective overlap width (ft)
W_s	width of signalized intersection approach measured along the segment centerline (ft)
W_{ss}	sum of fixed-object objection widths and lateral features shy distances for a given point along the walkway (ft)
W_{ssp}	adjusted fixed-object objection width on the left of sidewalk (ft)
$W_{ssp,s}$	adjusted roadside objection width on outside of sidewalk (ft)
W_t	width of the outside through lane (ft)
$W_{t,1}$	curb-side lane width (ft)
W_{ts}	width of paved outside shoulder (ft)
W_v	queue change rate (veh/h)
W_w	paved shoulder width (ft)
$W_{w,s}$	shy distance on inside of sidewalk (ft)
$W_{w,s}$	shy distance on outside of sidewalk (ft)
W_x	sum of the widths of the outside through lane, bicycle lane, and paved shoulder (ft)
W_z	total walkway width at a given point along the walkway (ft)
W_z	effective width as a function of traffic volume (ft)
x	degree of utilization
X	volume-to-capacity ratio
X_1	volume to capacity ratio in the shared lane
X_A	average volume-to-capacity ratio
X_c	critical intersection volume to capacity ratio
X_i	volume-to-capacity ratio for lane group i
X_m	weighted volume-to-capacity ratio for all upstream and conflicting pedestrian movements loading on the subject movement group
Y	yellow plus all-red change and clearance intervals (s)
Y_c	sum of the critical flow ratios
y_i	critical flow ratio for phase i
Y_{ped}	duration of the phase serving the minor-street through movement (s)
Y_{ped}	yield point for Phase 2 (s)
y_r	volume-to-saturation flow ratio for the concurrent phase when limited by travel time
h	headway of bunched (mobile stream (s/veh)
h^*	equivalent headway of bunched vehicle stream served by the phase (s/veh)
h_i	headway of bunched vehicle stream in lane group i (s/veh)
h_s	saturation headway (s/veh)
h^*	flow rate parameter for the phase (veh/s)
h_{ci}	flow rate parameter for lane group i served in the concurrent phase that is subject to the barrier (veh/s)
h_i	flow rate parameter for lane group i
h_{ij}	flow rate parameter for the exclusive left-turn lane group (veh/s)
h_{ij}	flow rate parameter for the exclusive right-turn lane group (veh/s)
h_{ij}	flow rate parameter for shared left-turn and through lane group (veh/s)

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s_0	flow rate parameter for shared right-turn and through lane group (veh/h)
s_t	flow rate parameter for exclusive through lane group (veh/h)
$s_{v/t}$	standard deviation of spot speeds (mi/h)
SV_i	sum of vehicle-to-space counts (veh)
v_i'	number of proportion of free (unblocked) vehicles for the phase
ψ	proportion of free (unblocked) vehicles in lane group i

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VOLUME 1 INDEX

The index to Volume 1 lists the text citations of the terms defined in the Glossary (Volume 1, Chapter 9). Volumes 1, 2, and 3 are separately indexed. In the index listings, the first number in each hyphenated pair of numbers indicates the chapter, and the number after the hyphen indicates the page within the chapter.

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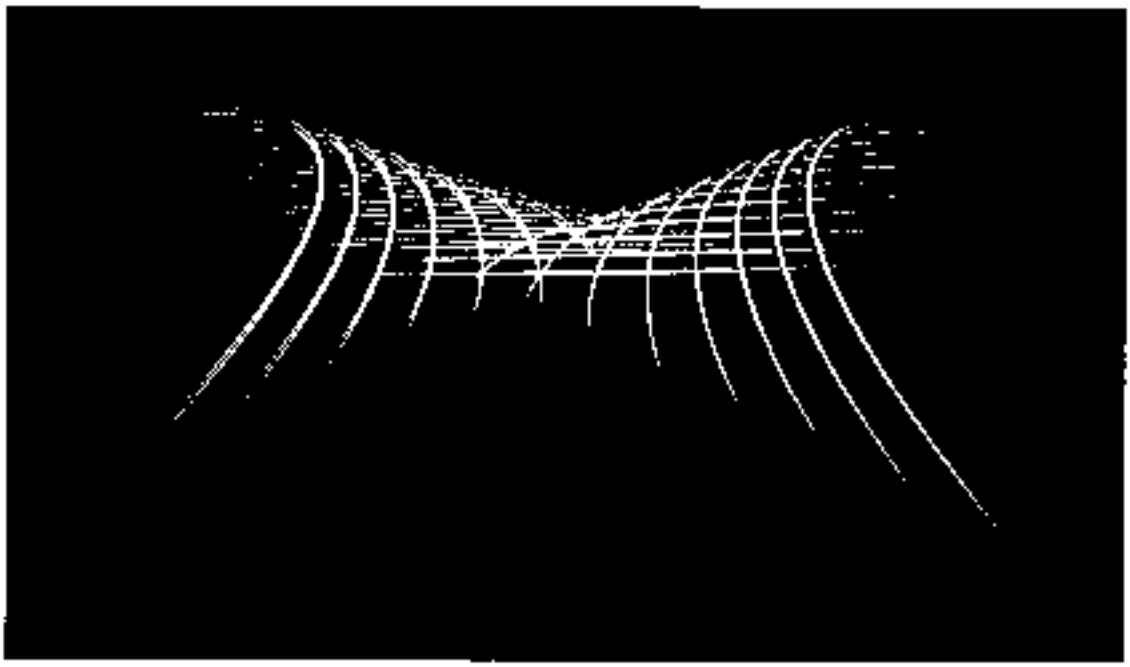

VOLUME 3: INTERRUPTED FLOW

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VOLUME 3
INTERRUPTED FLOW

OVERVIEW

Volume 3 of the *Highway Capacity Manual* (HCM) contains eight chapters that present analysis methods for interrupted-flow system elements—that is, roadways and pathways that have fixed causes of periodic delay or interruption to the traffic stream, such as traffic signals and stop signs. This volume addresses the following types of interrupted-flow system elements:

- *Urban street segments and facilities*, which are portions of roadways that have traffic signals, roundabouts, or stop-controlled intersections spaced less than 2 mi apart on average;
- *Interchanges*, consisting of signalized intersections, two-way stop-controlled intersections, all-way stop-controlled intersections, roundabouts, and interchange ramp terminals; and
- *Off-street pedestrian and bicycle facilities* that (a) are used only by nonmotorized modes and (b) are not considered part of an urban street or transit facility.

VOLUME ORGANIZATION

Vol 3 Ch 1 Interrupted Flow
Ch 16 Urban Street Facilities
Ch 17 Urban Street Segments
Ch 18 Signalized Intersections
Ch 19 TWSC Intersections
Ch 20 AWSC Intersections
Ch 21 Roundabouts
Ch 22 Interchange Ramp Terminals
Ch 23 Off-Street Pedestrian and Bicycle Facilities

Urban Street Segments and Facilities

Urban streets typically serve multiple travel modes, in particular the automobile, pedestrian, bicycle, and transit modes. Travelers associated with each of these modes perceive the service provided to them by the urban street in different ways. Any given operational decision that is intended to improve the service provided to one mode using an urban street can have both adverse and beneficial impacts on the service provided to other modes. The challenge for the analyst is to design and operate an urban street in such a way that all relevant travel modes are reasonably accommodated.

For the purpose of analysis, urban streets are separated into individual elements that are physically adjacent and operate as a single entity in serving travelers. A *node* represents the boundary between links and is represented by an intersection or ramp terminal. A *link* represents a length of roadway between two points. A link and its boundary points are referred to as a *segment*. Multiple contiguous segments can be combined into a single *facility*.

Chapter 17, Urban Street Segments, provides an integrated multimodal methodology for evaluating the quality of service provided to road users traveling along an urban street segment. **Chapter 16, Urban Street Facilities**, provides a similar methodology for evaluating extended lengths of urban streets. In both chapters, level of service (LOS) is reported separately for each mode and is not combined into a single overall LOS. This restriction recognizes that trip purpose, length, and expectation for each mode are different and that their

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combination does not produce a meaningful result. The integrated multimodal approach allows analysis of urban streets from a "complete streets" perspective.

Intersections

Five chapters in Volume 3 provide analysis methods for the different kinds of intersections that may be encountered along an urban street.

Chapter 18, Signalized Intersections, describes a methodology for evaluating the capacity and quality of service provided to road users traveling through a signalized intersection. The methodology calculates an array of performance measures describing intersection operation for multiple travel modes: automobile, pedestrian, and bicycle. These measures serve as clues for identifying the source of problems and provide insight into the development of effective improvement strategies. The analyst using this methodology is encouraged to consider the full range of measures.

Chapter 19, Two-Way STOP-Controlled Intersections, presents concepts and procedures for analyzing intersections where one street—the *major street*—is uncontrolled, while the other street—the *minor street*—is controlled by stop signs. These intersections typically occur in one of two configurations: three-leg, where the single minor-street approach is controlled by a STOP sign, and four-leg, where both minor-street approaches are controlled by STOP signs. The methodology is applicable to major streets with up to six lanes, three in each direction. Chapter 19 also provides a methodology for estimating pedestrian delay and LOS in the crossing of major streets at two-way STOP-controlled intersections and at unsignalized midblock crossings.

Chapter 20, All-Way STOP-Controlled Intersections, presents concepts and procedures for analyzing these types of intersections. All-way STOP-controlled intersections require every vehicle to stop at the intersection before proceeding. Because each driver must stop, the decision to proceed into the intersection is a function of traffic conditions on the other approaches. If no traffic is present on the other approaches, a driver can proceed immediately after stopping. If there is traffic on one or more of the other approaches, a driver proceeds only after determining that no vehicles are currently in the intersection and that it is the driver's turn to proceed.

Chapter 21, Roundabouts, presents concepts and procedures for analyzing modern roundabouts. Roundabouts are intersections with a generally circular shape, characterized by yield on entry and circulation around a central island (counterclockwise in the United States). The methodology can be used to assess the operational performance of existing or planned one-lane or two-lane roundabouts.

Chapter 22, Interchange Ramp Terminals, addresses interchanges with signalized intersections, interchanges with roundabouts, and the impact and operations of adjacent closely spaced intersections. Interchange ramp terminals provide the connection between various highway facilities (e.g., freeway–arterial, arterial–arterial), and thus their efficient operation is essential. In addition, they need to provide adequate capacity to avoid affecting the connecting facilities. The chapter's methodology can be applied to the operational and planning level

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analysis of a broad range of interchange types, including diamond, partial cloverleaf, and single-point urban interchanges.

Off-Street Pedestrian and Bicycle Facilities

Chapter 23, Off-Street Pedestrian and Bicycle Facilities, provides capacity and LOS estimation procedures for the following types of facilities:

- *Walkways*: paved paths, ramps, and plazas that are generally located more than 50 ft from an urban street as well as streets reserved for pedestrian traffic on a full- or part-time basis;
- *Stairways*: staircases that are part of a longer pedestrian facility;
- *Shared-use paths*: paths physically separated from highway traffic for the use of pedestrians, bicyclists, runners, in-line skaters, and other users of nonmotorized modes; and
- *Exclusive off-street bicycle paths*: paths physically separated from highway traffic for the exclusive use of bicycles.

On-street pedestrian and bicycle facilities are addressed in the other Volume 3 chapters, particularly Chapters 16–19.

RELATED CHAPTERS

Volume 1

The chapters in Volume 3 assume that the reader is already familiar with the concepts presented in the Volume 1 chapters, in particular the following:

- *Chapter 2, Applications*—types of HCM analysis, types of roadway system elements, and traffic flow characteristics;
- *Chapter 3, Modal Characteristics*—variations in demand, peak and analysis hours, K- and D-factors, facility types by mode, and interactions between modes;
- *Chapter 4, Traffic Flow and Capacity Concepts*—traffic flow parameters and factors that influence capacity; and
- *Chapter 5, Quality and Level of Service Concepts*—performance measures, service measures, and LOS.

Volume 2

Urban streets with two or more lanes in each direction that have traffic signals spaced 2 mi or more apart on average are treated as multilane highways. Chapter 14 provides analysis methods for two-lane highways. Two-lane roadways passing through moderately developed areas, such as small towns or developed recreational areas, are treated as Class II two-lane highways and can be analyzed with the methods given in Chapter 15.

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VOLUME 4: APPLICATIONS GUIDE
Methodological Details
29. Urban Street Facilities: Supplemental
30. Urban Street Segments: Supplemental
31. Signalized Intersections: Supplemental
32. Stop-Controlled Intersections: Supplemental
33. Roundabouts: Supplemental
34. Interchange Ramp Terminals: Supplemental
35. Active Traffic Management
Case Studies
Technical Reference Library

Access Volume 4 at www.HCM2010.org

Volume 4

Seven chapters in Volume 4 (accessible at www.HCM2010.org) provide additional information that supplements the material presented in Volume 3. These chapters are as follows:

- *Chapter 29, Urban Street Facilities: Supplemental*—examples of applying alternative tools to situations not addressed by the Chapter 16 method for urban street facilities;
- *Chapter 30, Urban Street Segments: Supplemental*—methods for adjusting traffic demand to account for capacity constraints and intersection turning movements, analyzing vehicular traffic flow on a segment bounded by signalized intersections, and estimating major-street delay due to midblock turns; a quick-estimation method for evaluating the operation of a coordinated street segment; a description of field measurement techniques; and documentation of the computational engine;
- *Chapter 31, Signalized Intersections: Supplemental*—descriptions of traffic signal controls; additional field measurement techniques; details of procedures for calculating capacity, phase duration, delay, and back-of-queue; a quick estimation method for determining an intersection's critical volume-to-capacity ratio, signal timing, and delay; documentation of the computational engine; and examples of applying alternative tools to situations not addressed by the Chapter 18 method for signalized intersections;
- *Chapter 32, Stop-Controlled Intersections: Supplemental*—methods for determining the potential capacity of two-way stop-controlled intersections; the operation of two-way stop-controlled intersections with pedestrian effects; and the operation of all-way stop-controlled intersections with three-lane approaches; and additional example problems;
- *Chapter 33, Roundabouts: Supplemental*—guidance on lane-use assignment and calibrating the Chapter 21 capacity model;
- *Chapter 34, Interchange Ramp Terminals: Supplemental*—complete solutions to the Chapter 22 example problems, along with additional example problems; and
- *Chapter 35, Active Traffic Management*—descriptions of active traffic management strategies; a discussion of the mechanisms by which they affect demand, capacity, and performance; and general guidance on possible evaluation methods for active traffic management techniques.

The *HCM Applications Guide* in Volume 4 provides three case studies on the analysis of interrupted-flow facilities:

- *Case Study No. 1* illustrates the process of applying HCM techniques to questions relating to the operational and control needs of an intersection located along a roadway in a university town;

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- Case Study No. 2 illustrates the process of applying HCM techniques to the analysis of unsignalized intersections, signalized intersections, and urban streets in the context of a traffic impact analysis; and
- Case Study No. 3 illustrates the consideration of nonmotorized modes as part of the evaluation of signalized and unsignalized intersections.

These case studies focus on the process of applying the HCM rather than on the details of performing calculations (which are addressed by the example problems in the Volume 3 and supplemental Volume 4 chapters). The case studies' computational results were developed by using HCM2000 methodologies and therefore may not match the results obtained from applying the HCM 2010. However, the process of application is the focus, not the specific computational results.

The Technical Reference Library in Volume 4 contains copies of (or links to) many of the documents referenced in Volume 3 and its supplemental chapters. The Technical Reference Library also provides computational engines (spreadsheets) to assist with the application of the urban streets, signalized intersections, all-way STOP-controlled intersections, and roundabouts methodologies.

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CHAPTER 16
URBAN STREET FACILITIES

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1. INTRODUCTION

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Chapter 16, Urban Street Facilities, describes an integrated multimodal methodology for evaluating the quality of service provided to road users traveling along an urban street. An urban street is unique among road types because it typically serves multiple travel modes. Four of the more common urban street travel modes include automobile, pedestrian, bicycle, and transit. Travelers associated with each of these modes use different criteria to evaluate the service provided to them when they travel along an urban street. This integrated multimodal approach allows analysts to analyze urban streets from a "complete streets" perspective.

Design or operational decisions that are intended to improve the service provided to one mode can sometimes have an adverse impact on the service provided to another mode. The challenge for the analyst is to design and operate the urban street in such a way that all relevant travel modes are reasonably accommodated. The methodology described in this chapter is intended to assist the analyst in this regard by providing a means to assess the performance of each urban street travel mode.

OVERVIEW OF THE METHODOLOGY

This chapter's methodology is applicable to an urban or suburban street. The street is classified as an arterial or collector with one-way or two-way vehicular traffic flow. The intersections along the street can be signalized or unsignalized.

Analysis Level

Analysis level describes the level of detail used in applying the methodology. Three levels are recognized:

- Operational,
- Design, and
- Planning and preliminary engineering.

The operational analysis is the most detailed application and requires the most information about the traffic, geometric, and signalization conditions. The design analysis also requires detailed information about the traffic conditions and the desired level of service (LOS) as well as information about either the geometric or signalization conditions. The design analysis then seeks to determine reasonable values for the conditions not provided. The planning and preliminary engineering analysis requires only the most fundamental types of information from the analyst. Default values are then used as substitutes for other input data. The subject of analysis level is discussed in more detail in the Applications section of this chapter.

Study Period and Analysis Period

The study period is the time interval represented by the performance evaluation. It consists of one or more consecutive analysis periods. An analysis period is the time interval evaluated by a single application of the methodology.

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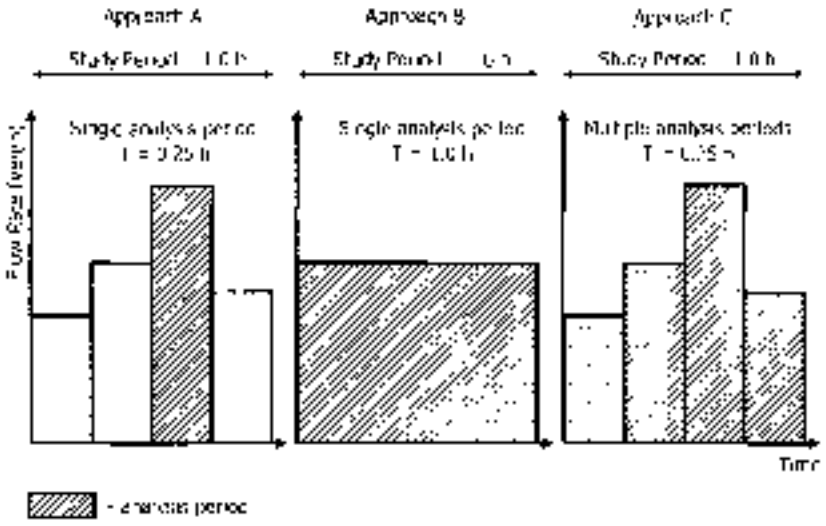
The methodology is based on the assumption that traffic conditions are steady during the analysis period (i.e., systematic change over time is negligible). For this reason, the duration of the analysis period is in the range of 0.25 to 1 h. The longer durations in the range are sometimes used for planning analyses. In general, the analyst should use caution with analysis periods that exceed 1 h because traffic conditions are not typically steady for long time periods and because the adverse impact of short peaks in traffic demand may not be detected in the evaluation.

If an analysis period of interest has a demand volume that exceeds capacity, then the study period should include an initial analysis period with no initial queue and a final analysis period with no residual queue. This approach provides a more accurate estimate of the delay associated with the congestion.

If evaluation of multiple analysis periods is determined to be important, then the performance estimates for each period should be separately reported. In this situation, reporting an average performance for the study period is not encouraged because it may obscure extreme values and suggest acceptable operation when in reality some analysis periods have unacceptable operation.

Exhibit 16-1 demonstrates three alternative approaches an analyst might use for a given evaluation. Note that other alternatives exist and that the study period can exceed 1 h. Approach A is the one that has traditionally been used and, unless otherwise justified, is the one that is recommended for use.

Exhibit 16-1
Three Alternative Study Approaches



Approach A is based on the evaluation of the peak 15-min period during the study period. The analysis period, T_A, is 0.25 h. The equivalent hourly flow rate in vehicles per hour (veh/h) used for the analysis is based on either a peak 15-min traffic count multiplied by four or a 1-h demand volume divided by the peak hour factor. The former option is preferred wherever traffic counts are available. The peak hour factor equals the hourly count of vehicles divided by four times the peak 15-min count for a common hour interval. It is provided by the analyst or operating agency.

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Approach B is based on the evaluation of one 1-h time period that is coincident with the study period. The analysis period, T, is 1.0 h. The flow rate used is equivalent to the 15-min demand volume (i.e., the peak hour factor is not used). This approach implicitly assumes that the arrival rate of vehicles is constant throughout the period of study. Therefore, the effects of peaking within the hour may not be identified, and the analyst risks underestimating the delay actually incurred.

Approach C uses a 1-h study period and divides it into four 0.25-h analysis periods. This approach accounts for systematic flow rate variation among analysis periods. It also accounts for queues that carry over to the next analysis period and produces a more accurate representation of delay.

Performance Measures

An urban street's performance is described by the use of one or more quantitative measures that characterize some aspect of the service provided to a specific road user group. Performance measures cited in this chapter include automobile travel speed, automobile stop rate, pedestrian space, pedestrian travel speed, pedestrian perception score, bicycle travel speed, bicycle perception score, transit travel speed, and transit passenger perception score.

LOS is also considered a performance measure. It is computed for the automobile, pedestrian, bicycle, and transit travel modes. It is useful for describing street performance to elected officials, policy makers, administrators, or the public. LOS is based on one or more of the performance measures listed in the previous paragraph.

Travel Modes

This chapter describes a separate methodology for evaluating urban street performance from the perspective of motorists, pedestrians, bicyclists, or transit passengers. These methodologies are referred to hereafter as the automobile methodology, pedestrian methodology, bicycle methodology, and transit methodology.

Each methodology consists of a set of procedures for computing the quality of service provided by one mode. Collectively, they can be used to evaluate urban street operation from a multimodal perspective.

Each methodology is focused on the evaluation of the urban street. A methodology for evaluating the segments that make up the street is described in Chapter 17, Urban Street Segments.

The four methodologies described in this chapter are based largely on the products of two National Cooperative Highway Research Program projects (1, 2).

The transit methodology described in this chapter is applicable to the evaluation of passenger service provided by local public transit vehicles operating in mixed traffic or exclusive lanes and stopping along the street. Nonlocal transit vehicle speed and delay are evaluated by using the automobile methodology.

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The phrase *automobile mode* as used in this chapter refers to travel by all motorized vehicles that can legally operate on the street, with the exception of local transit vehicles that stop to pick up passengers along the street. Unless explicitly stated otherwise, the word *vehicle* refers to motorized vehicles and includes a mixed stream of automobiles, motorcycles, trucks, and buses.

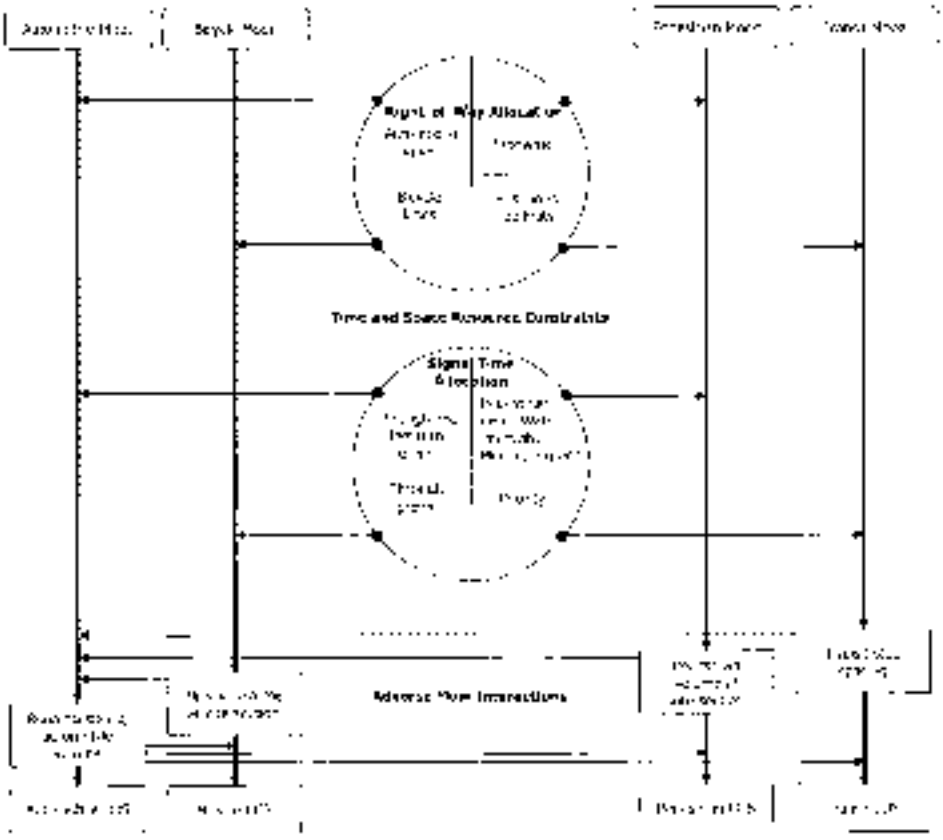
Multimodal Evaluation Framework

The urban street right-of-way is typically shared by multiple travel modes. Travelers associated with the more common modes include motorists, pedestrians, bicyclists, and transit passengers. The factors that influence the quality of service provided to these travelers vary by mode because each mode has a different trip purpose, length, and expectation.

The shared street right-of-way typically requires that the modes operate in close proximity to each other, sometimes even sharing the same portion of the cross section (e.g., a vehicular traffic lane). This arrangement may be workable when the modes are characterized by low demand volumes; however, acceptable operation for moderate to high volumes typically requires the spatial separation of the modes along the street and temporal (i.e., signal) separation at the intersections.

The integrated methodology described in Section 2 can be used to evaluate simultaneously the LOS provided to each travel mode on an urban street. A framework for this evaluation is shown in Exhibit 16-2.

Exhibit 16-2
Integrated Multimode Evaluation Framework



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The framework shown in Exhibit 16-2 illustrates the integrated multimodal evaluation approach supported by the methodology in Section 2. It is important to note that the LOS provided to each travel mode is separately evaluated. The relative importance given to each mode's LOS should be determined by the analyst (or operating agency) and reflect consideration of the subject street's functional class and purpose. The LOS for each mode should not be combined into one overall LOS for the street. This restriction recognizes that trip purposes, length, and expectation for each mode are different and that their combination does not produce a meaningful result.

Exhibit 16-2 illustrates how the travel modes compete for limited right of way along the street and at the intersections. They also compete for limited signal time at the intersections. For a given right of way, the allocation of space to one mode often requires a reduction (or elimination) of space for other modes and a corresponding reduction in their service quality.

The lower part of Exhibit 16-2 illustrates the potential adverse interactions between the automobile mode and the other modes. As the volume or speed of the automobile traffic stream increases, the LOS for the other modes may decrease. In contrast, if bicycle, pedestrian, or transit flows increase, then the LOS for the automobile traffic stream may decrease. In general, changes that alter resource allocation or flow interaction to improve the LOS for one mode may affect the other modes.

URBAN STREET FACILITY DEFINED

For the purpose of analysis, the urban street is separated into individual elements that are physically adjacent and operate as a single entity for the purpose of serving travelers. Two elements are commonly found in an urban street system: points and links. A *point* represents the boundary between links and is usually represented by an intersection or ramp terminal. A *link* represents a length of roadway between two points. A link and its boundary intersections are referred to as a segment. An urban street *facility* is a length of roadway that is composed of contiguous urban street segments and is typically functionally classified as an urban arterial or collector street.

Previous editions of this manual have allowed the evaluation of two directions of travel along a facility (even when it served two-way traffic). This approach is retained in this chapter for the analysis of bicycle and transit performance. For the analysis of pedestrian performance, this approach translates into the evaluation of sidewalk and street conditions on one side of the segment.

For the automobile methodology, a segment evaluation considers only one direction of travel (when the street is two-way flow).

For the analysis of automobile performance, an analysis of only one travel direction (when the street serves two-way traffic) does not adequately recognize the interactions between vehicles at the boundary intersections and their influence on segment operation. For example, the automobile methodology in this edition of the *Highway Capacity Manual* (HCM) explicitly models the platoon formed by the signal at one end of the segment and its influence on the operation of the signal at the other end of the segment. For these reasons, it is important to evaluate both travel directions on a two-way segment.

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Facility Length Considerations

Urban arterial and collector streets are designed to accommodate longer trips than local streets. They also have a significant mobility function and support the hierarchy of movement by connecting to streets of higher and lower functional class. An urban street facility with these attributes typically has a length of 3 mi or more in downtown areas and 2 mi or more in other areas. When an urban street facility meets or exceeds this length, average travel speed is a more meaningful indication of facility performance and LOS.

At least one intersection (or ramp terminal) along the facility must have a type of control that can impose on the through movement a legal requirement to stop or yield. A significant change in one or more facility characteristics may indicate the end of one facility and the start of a second facility. These characteristics include cross-section features (e.g., number of through lanes, median width, curb presence), annual average daily traffic volume, roadside development density and type, and vehicle speed. One or more of these characteristics will often change significantly when the street crosses an urban to suburban area boundary or intersects a freeway interchange.

If a facility assessment is desired for a given travel mode, the analyst will need to evaluate all of the segments that make up the facility for a common travel direction and aggregate the performance measures for each segment to obtain a facility performance estimate.

Facility Versus Segment Analysis Scope

The methodology described in Section 2 is used to evaluate an entire facility; however, for some specific conditions it may not be necessary to evaluate the entire facility. For these conditions, the appropriate segment or intersection chapter methodology may be used alone to evaluate selected segments or intersections. In general, it is up to the analyst to determine the scope of each analysis (i.e., one intersection, one segment, two segments, or all segments on the facility) on the basis of analysis objectives and agency directives.

One condition for which it may be acceptable to evaluate an individual segment or intersection occurs when the upstream intersection is considered to operate in isolation from nearby signalized intersections. A segment or intersection that is effectively isolated experiences negligible influence from upstream signalized intersections. Flow on an isolated segment or at an isolated intersection is effectively random over the cycle and without a discernible platoon pattern evident in the cyclic profile of arrivals. These characteristics are more likely to be found when (a) the nearest upstream signalized intersection is sufficiently distant from the subject segment or intersection and (b) the subject segment or intersection, if signalized, is not coordinated with the upstream signal.

A segment or intersection is sufficiently distant from the nearest upstream signal if an intermediate unsignalized intersection uses stop or yield control to regulate through traffic on the facility. If there is no intermediate STOP- or YIELD-controlled intersection, then Exhibit 16-3 can be used to obtain an indication of whether a segment or intersection is sufficiently distant from an upstream signal. If the

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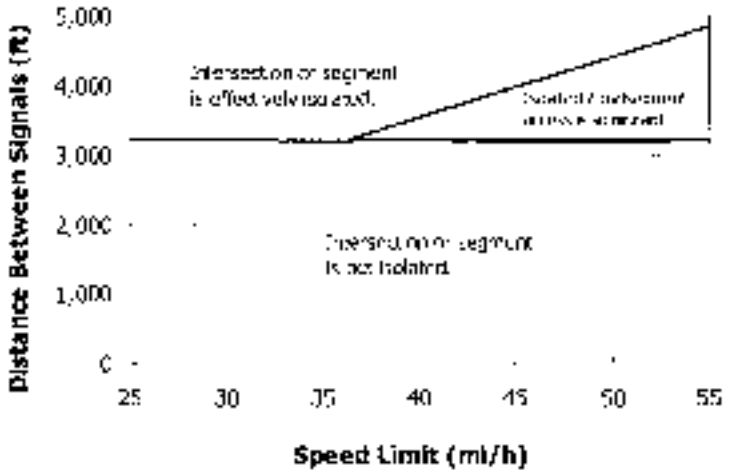
distance between signals is above the trend line, then the subject intersection or segment is likely to operate as effectively isolated (provided that it is not coordinated with the upstream signal).

LOS CRITERIA

This subsection describes the LOS criteria for the automobile, pedestrian, bicycle, and transit modes. The criteria for the automobile mode are different from the criteria used for the nonautomobile modes. Specifically, the automobile mode criteria are based on performance measures that are field-measurable and perceivable by travelers. The criteria for the pedestrian and bike modes are based on scores reported by travelers indicating their perception of service quality. The criteria for the transit mode are based on measured changes in transit patronage due to changes in service quality.

Exhibit 16-3
Signal Spacing Associated with Effectively Isolated Operation



Automobile Mode

All uses of the word "volume" in the phrase "volume to capacity ratio" in this chapter refer to demand volume to capacity ratio.

Through vehicle travel speed is used to characterize vehicular LOS for a given direction of travel along an urban street facility. This speed reflects the factors that influence running time along each link and the delay incurred by through vehicles at each boundary intersection. This performance measure indicates the degree of mobility provided by the facility. The following paragraphs characterize each service level.

LOS A describes primarily free-flow operation. Vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Control delay at the boundary intersections is minimal. The travel speed exceeds 85% of the base free-flow speed.

LOS B describes reasonably unimpeded operations. The ability to maneuver within the traffic stream is only slightly restricted and control delay at the boundary intersections is not significant. The travel speed is between 67% and 85% of the base free-flow speed.

LOS C describes stable operation. The ability to maneuver and change lanes at midsegment locations may be more restricted than at LOS B. Longer queues at

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the boundary intersections may contribute to lower travel speeds. The travel speed is between 50% and 67% of the base free-flow speed.

LOS D indicates a less stable condition in which small increases in flow may cause substantial increases in delay and decreases in travel speed. This operation may be due to adverse signal progression, high volumes, or inappropriate signal timing at the boundary intersections. The travel speed is between 40% and 50% of the base free-flow speed.

LOS E is characterized by unstable operation and significant delay. Such operations may be due to some combination of adverse progression, high volume, and inappropriate signal timing at the boundary intersections. The travel speed is between 30% and 40% of the base free-flow speed.

LOS F is characterized by flow at extremely low speed. Congestion is likely occurring at the boundary intersections, as indicated by high delay and extensive queuing. The travel speed is 30% or less of the base free-flow speed. Also, LOS F is assigned to the subject direction of travel if the through movement at one or more boundary intersections has a volume-to-capacity ratio greater than 1.0.

Exhibit 16-4 lists the LOS thresholds established for the automobile mode on urban streets.

Exhibit 16-4
LOS Criteria: Automobile Mode

Travel Speed as a Percentage of Base Free-Flow Speed (%)	LOS by Critical Volume-to-Capacity Ratio[a]	
	≤ 1.0	> 1.0
>67	A	F
>67–85	B	F
>50–67	C	F
>40–50	D	F
>30–40	E	F
≤30	F	F

Note: [a] The critical volume-to-capacity ratio is based on consideration of the through movement volume-to-capacity ratio at each boundary intersection in the subject direction of travel. The critical volume-to-capacity ratio is the largest ratio of those considered.

Nonautomobile Modes

Historically, this manual has used a single performance measure as the basis for defining LOS. However, research documented in Chapter 5, Quality and Level of Service Concepts, indicates that travelers consider a wide variety of factors in assessing the quality of service provided to them. Some of these factors can be described as performance measures (e.g., speed), and others can be described as basic descriptions of the urban street character (e.g., sidewalk width). The methodologies in Chapter 17, Urban Street Segments, and Chapter 18, Signalized Intersections, provide procedures for mathematically combining these factors into a score for the segment or intersection, respectively. This score is then used in this chapter to determine the LOS that is provided for a given direction of travel along a facility.

Exhibit 16-5 lists the range of scores associated with each LOS for the pedestrian travel mode. The LOS for this particular mode is determined by consideration of both the LOS score and the average pedestrian space on the sidewalk. The applicable LOS for an evaluation is determined from the table by

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finding the intersection of the row corresponding to the computed score value and the column corresponding to the computed space value.

The association between LOS score and LOS is based on traveler perception research. Travelers were asked to rate the quality of service associated with a specific trip along an urban street. The letter "A" was used to represent the "best" quality of service, and the letter "F" was used to represent the "worst" quality of service. "Best" and "worst" were left undefined, allowing respondents to identify the best and worst conditions on the basis of their traveling experience and perception of service quality.

Exhibit 16-5
LOS Criteria: Pedestrian Mode

Pedestrian LOS Score	LOS by Average Pedestrian Space (ft^2/p)					
	>60	>40–60	>24–40	>15–24	>8.0–15*	≤ 8.0*
≤2.00	A	B	C	D	E	F
>2.00–2.75	B	B	C	D	E	F
>2.75–3.50	C	C	C	D	E	F
>3.50–4.25	D	D	D	D	F	F
>4.25–5.00	E	E	F	F	E	F
>5.00	F	F	F	F	F	F

Note: * In cross-flow situations, the LOS E–F threshold is 11 ft/p.

Exhibit 16-6 lists the range of scores that are associated with each LOS for the bicycle and transit modes. This exhibit is also applicable for determining pedestrian LOS when a sidewalk is not available.

Exhibit 16-6
LOS Criteria: Bicycle and Transit Modes

LOS	LOS Score
A	≤2.00
B	>2.00–2.75
C	>2.75–3.50
D	>3.50–4.25
E	>4.25–5.00
F	>5.00

REQUIRED INPUT DATA

This subsection describes the required input data for the automobile, pedestrian, bicycle, and transit methodologies.

Automobile Mode

This part describes the input data needed for the automobile methodology. The data are listed in Exhibit 16-7 and are identified as "input data elements." For the subject travel direction, these elements must be provided for each segment and for the through movement group at each boundary intersection.

The last column in Exhibit 16-7 indicates whether the input data are needed for a movement group at a boundary intersection, the overall intersection, or the segment. The input data needed to evaluate the segment are identified in Chapter 17, Urban Street Segments. Similarly, the input data needed to evaluate the boundary intersections are identified in the appropriate chapter (i.e., Chapters 18 to 22).

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Exhibit 16-7
Input Data Requirements: Automobile Mode

Data Category	Location	Input Data Element	Basis
Geometric Design	Segment	Segment length	Segment
Other	Segment	Analysis period duration	Facility
Performance Measures	Boundary intersection	Volume-to-capacity ratio	Through-movement group
	Segment	Base free-flow speed	Segment
		Travel speed	Segment

Notes: Through-movement group = one value for the segment through movement at the downstream boundary intersection (inclusive of any turn movements in a shared lane). Segment = one value or condition for each segment and direction of travel on the facility. Facility = one value or condition for the facility.

Segment Length

Segment length represents the distance between the boundary intersections that define the segment. The point of measurement at each intersection is the stop line, the yield line, or the functional equivalent in the subject direction of travel. This length is measured along the centerline of the street. If it differs in the two travel directions, then an average length is used. One length is needed for each segment on the facility.

Analysis Period Duration

The analysis period is the time interval considered for the performance evaluation. Its duration is in the range of 15 min to 1 h, with longer durations in this range sometimes used for planning analyses. In general, the analyst should use caution in interpreting the results from an analysis period of 1 h or more because the adverse impact of short peaks in traffic demand may not be detected. Also, if the analysis period is other than 15 min, then the peak hour factor should not be used.

The methodology was developed to evaluate conditions in which queue spillback does not affect the performance of a segment or a boundary intersection during the analysis period. If spillback affects performance, the analyst should consider using an alternative analysis tool that is able to model the effect of spillback conditions.

Operational Analysis. A 15-min analysis period should be used for operational analyses. This duration will accurately capture the adverse effects of demand peaks. Any 15-min period of interest can be evaluated with the methodology, however, a complete evaluation should always include an analysis of conditions during the 15-min period that experiences the highest traffic demand during a 24-h period.

If traffic demand exceeds capacity for a given 15-min analysis period, then a multiple-period analysis should be conducted. This type of analysis consists of the calculation of several consecutive 15-min time periods. The periods analyzed would include an initial analysis period that has no initial queue, one or more periods in which demand exceeds capacity, and a final analysis period that has no residual queue.

When a multiple-period analysis is used, facility performance measures are computed for each analysis period. Averaging performance measures across

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multiple analysis periods is not encouraged because it may obscure extreme values.

If a multiple-period analysis is used and the boundary intersections are signalized, then the procedure described in Chapter 18 should be used to guide the evaluation. When a procedure for multiple period analysis is not provided in the chapter that corresponds to the boundary intersection configuration, the analyst should separately evaluate each period and use the residual queue from one period as the initial queue for the next period.

Planning Analysis. A 15-min analysis period is used for most planning analyses. However, hourly traffic demands are normally produced through the planning process. Thus, when 15-min forecast demands are not available for a 15 min analysis period, a peak hour factor must be used to estimate the 15-min demands for the analysis period. A 1-h analysis period can be used, if appropriate. Regardless of analysis period duration, a single-period analysis is typical for planning applications.

Volume-to-Capacity Ratio

The volume-to-capacity ratio is for the lane group serving the through movement that exits the segment at the downstream boundary intersection. With one exception, a procedure for computing this ratio is described in the appropriate intersection chapter (i.e., Chapters 18 to 22). Chapter 19, "Two-Way Stop-Controlled Intersections," does not provide a procedure for estimating the capacity of the uncontrolled through movement, but this capacity can be estimated by using Equation 16-1:

$$c_{th} = 1{,}800\,(N_{th} - 1 + p^*_{th}) \qquad \text{Equation 16-1}$$

Where

c_{th} = through movement capacity (veh/h),

N_{th} = number of through lanes (shared or exclusive) (in), and

p^*_{th} = probability that there will be no queue in the inside through lane.

The probability p^* is computed by using Equation 19-43 in Chapter 19. It is equal to 1.0 if a left-turn bay is provided for left turns from the major street.

One volume-to-capacity ratio is needed for the downstream boundary intersection of each segment on the facility.

Base Free Flow Speed

The base free-flow speed characterizes the traffic speed on the segment when low flow conditions exist and speed is unaffected by signal spacing. A procedure for determining this speed is described in Chapter 17. One speed is needed for each travel direction on each segment on the facility.

Travel Speed

Travel speed represents the ratio of segment length to through movement travel time. Travel time is computed as the sum of segment running time and through movement control delay at the downstream boundary intersection. A

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procedure for computing travel speed is described in Chapter 17. One speed is needed for each travel direction of each segment on the facility.

Nonautomobile Modes

This part describes the input data needed for the pedestrian, bicycle, and transit methodologies. The data are listed in Exhibit 16-8 and are identified as "input data elements." They must be separately specified for each direction of travel on the facility. Segment length is defined in the previous part.

Exhibit 16-8 categorizes each input data element by travel mode methodology. An "X" is used to indicate the association between a data element and methodology. A blank cell indicates that the data element is not used as input for the corresponding methodology.

Exhibit 16-8
Input Data Requirements: Nonautomobile Modes

Data Category	Location	Input Data Element	Pedestrian Mode	Bicycle Mode	Transit Mode
Geometric Design	Segment	Segment length	X	X	X
		Presence of a sidewalk	X		
Performance Measures	Segment	Pedestrian space	X		
		Pedestrian travel speed	X		
		Pedestrian LOS score for segment	X		
		Bicycle travel speed		X	
		Bicycle LOS score for segment		X	
		Transit travel speed			X
		Transit LOS score for segment			X

Presence of a Sidewalk

A sidewalk is a paved walkway that is provided at the side of the roadway. It is assumed that pedestrians will walk in the street if a sidewalk is not present. An indication of sidewalk presence is needed for each side of interest for each segment on the facility.

Pedestrian Space

Pedestrian space is a performance measure that describes the average circulation area available to each pedestrian traveling along the sidewalk. A procedure is described in Chapter 17 for estimating this quantity for a given sidewalk. One value is needed for each sidewalk of interest associated with each segment on the facility.

Pedestrian Travel Speed

Pedestrian travel speed represents the ratio of segment length to pedestrian travel time. Travel time is computed as the sum of segment walking time and control delay at the downstream boundary intersection. A procedure for computing this travel speed is described in Chapter 17. One speed is needed for each sidewalk of interest associated with each segment on the facility.

Pedestrian LOS Score for Segment

The pedestrian LOS score for the segment is used in the pedestrian methodology to determine facility LOS. It is obtained from the pedestrian

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methodology in Chapter 17. One score is needed for each direction of travel of interest for each segment on the facility.

Bicycle Travel Speed

Bicycle travel speed represents the ratio of segment length to bicycle travel time. Travel time is computed as the sum of segment running time and control delay at the downstream boundary intersection. This speed is computed only when a bicycle lane is present on the segment. A procedure for computing this travel speed is described in Chapter 17. One speed is needed for each direction of travel of interest for each segment on the facility.

Bicycle LOS Score for Segment

The bicycle LOS score for the segment is used in the bicycle methodology to estimate facility LOS. It is obtained from the bicycle methodology in Chapter 17. One score is needed for each direction of travel of interest for each segment on the facility.

Transit Travel Speed

Transit travel speed represents the ratio of segment length to transit travel time. Travel time is computed as the sum of segment running time and control delay at the downstream boundary intersection. A procedure for computing this travel speed is described in Chapter 17. One speed is needed for each direction of travel of interest for each segment on the facility.

Transit LOS Score for Segment

The transit LOS score for the segment is used in the transit methodology to estimate facility LOS. It is obtained from the transit methodology in Chapter 17. One score is needed for each direction of travel of interest for each segment on the facility.

SCOPE OF THE METHODOLOGY

Four methodologies are presented in this chapter. One methodology is provided for each of the automobile, pedestrian, bicycle, and transit modes. This section identifies the conditions for which each methodology is applicable.

- **Signalized and two-way stop-controlled boundary intersections.** All methodologies can be used to evaluate facility performance with signalized or two-way stop-controlled boundary intersections. In the latter case, the cross street is stop controlled. The automobile methodology can also be used to evaluate performance with all-way stop- or yield-controlled (e.g., roundabout) boundary intersections.
- **Arterial and collector streets.** The four methodologies were developed with a focus on arterial and collector street conditions. If a methodology is used to evaluate a local street, then the performance estimates should be carefully reviewed for accuracy.
- **Steady flow conditions.** The four methodologies are based on the analysis of steady traffic conditions and, as such, are not well suited to the

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evaluation of unsteady conditions (e.g., congestion, queue spillback, signal preemption).

- **Target road users.** Collectively, the four methodologies were developed to estimate the LOS perceived by automobile drivers, pedestrians, bicyclists, and transit passengers. They were not developed to provide an estimate of the LOS perceived by other road users (e.g., commercial vehicle drivers, automobile passengers, delivery truck drivers, or recreational vehicle drivers). However, it is likely that the perceptions of these other road users are reasonably well represented by the road users for whom the methodologies were developed.
- **Target travel modes.** The automobile methodology addresses mixed automobile, motorcycle, truck, and transit traffic streams in which the automobile represents the largest percentage of all vehicles. The pedestrian, bicycle, and transit methodologies address travel by walking, bicycle, and transit vehicle, respectively. The transit methodology is limited to the evaluation of public transit vehicles operating in mixed or exclusive traffic lanes and stopping along the street. The methodologies are not designed to evaluate the performance of other travel modes (e.g., grade separated rail transit, golf carts, or motorized bicycles).
- **Influences in the right-of-way.** A road user's perception of quality of service is influenced by many factors inside and outside of the urban street right of way. However, the methodologies in this chapter were specifically constructed to exclude factors that are outside of the right of way (e.g., buildings, parking lots, scenery, or landscaped yards) that might influence a traveler's perspective. This approach was followed because factors outside of the right-of-way are not under the direct control of the agency operating the street.
- **Mobility focus for automobile methodology.** The automobile methodology is intended to facilitate the evaluation of mobility. Accessibility to adjacent properties by way of automobile is not directly evaluated with this methodology. Regardless, a segment's accessibility should also be considered when its performance is evaluated, especially if the street is intended to provide such access. Oftentimes, factors that favor mobility reflect minimal levels of access and vice versa.
- **"Typical pedestrian" focus for pedestrian methodology.** The pedestrian methodology is not designed to reflect the perceptions of any particular pedestrian subgroup, such as pedestrians with disabilities. As such, the performance measures obtained from the methodology are not intended to be indicators of a sidewalk's compliance with U.S. Access Board guidelines related to the Americans with Disabilities Act requirements. For this reason, they should not be considered as a substitute for a formal compliance assessment of a pedestrian facility.

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LIMITATIONS OF THE METHODOLOGY

The urban street facility methodology uses the performance measures estimated by the segment and intersection methodologies in Chapters 17 to 22. As such, it incorporates the limitations of those methodologies (which are identified in the respective segment or intersection chapter).

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2. METHODOLOGY

OVERVIEW

This section describes four methodologies for evaluating the performance of an urban street facility. Each methodology addresses one possible travel mode within the street right-of-way. Analysts should choose the combination of methodologies that are appropriate for their analysis needs.

A complete evaluation of facility operation includes the separate examination of performance for all relevant travel modes for each travel direction. The performance measures associated with each mode and travel direction are assessed independently of one another. They are not mathematically combined into a single indicator of facility performance. This approach ensures that all performance impacts are considered on a mode-by-mode and direction-by-direction basis.

The focus of each methodology in this chapter is the facility. Methodologies for quantifying the performance of a segment or boundary intersection are described in other chapters (see Chapters 17 to 22).

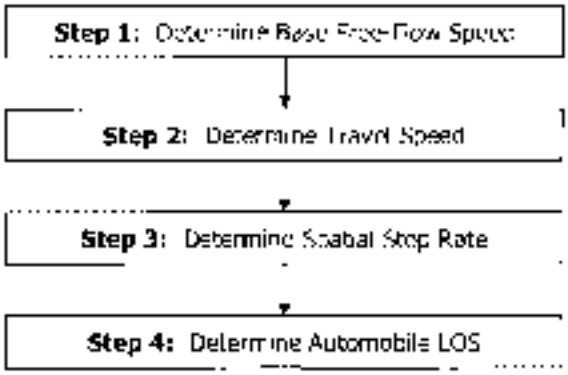
AUTOMOBILE MODE

This subsection provides an overview of the methodology for evaluating urban street facility performance from the motorist perspective. Each travel direction along the facility is separately evaluated. *Unless otherwise noted, all variables are specific to the subject direction of travel.*

The methodology is focused on the analysis of facilities with signalized, two-way stop, all-way stop, or roundabout boundary intersections. The signalized intersection can be an interchange ramp terminal.

Exhibit 16-9 illustrates the calculation framework of the automobile methodology. It identifies the sequence of calculations needed to estimate selected performance measures. The calculation process is shown to flow from top to bottom in the exhibit. The calculations are described more fully in the remainder of this subsection.

Exhibit 16-9
Automobile Methodology for Urban Street Facilities



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Step 1: Determine Base Free-Flow Speed

The base free-flow speed for the facility is the basis for LOS determination. It is determined for each segment by using the procedures described in Chapter 17, Urban Street Segments. The base free-flow speed for the facility is calculated by using Equation 16-2:

$$S_{f,0} = \frac{\sum_{i=1}^{m} L_i}{\sum_{i=1}^{m} \frac{L_i}{S_{fi,0}}} \quad \text{Equation 16-2}$$

where:

$S_{f,0}$ = base free-flow speed for the facility (mi/h),

L_i = length of segment i (ft),

m = number of segments on the facility, and

$S_{fi,0}$ = base free-flow speed for segment i (mi/h).

Step 2: Determine Travel Speed

The travel speed for the facility is the ratio of facility length to facility travel time. It represents an equivalent average speed for the through-vehicle traffic stream that reflects the running speed along the street for through vehicles and any delay they may incur at the boundary intersections. The travel speed for through vehicles is determined for each segment by using the procedures described in Chapter 17. The travel speed for the facility is calculated by using Equation 16-3:

$$S_{f,a} = \frac{\sum_{i=1}^{m} L_i}{\sum_{i=1}^{m} \frac{L_i}{S_{fi,a}}} \quad \text{Equation 16-3}$$

where $S_{f,a}$ is the travel speed for the facility (mi/h), $S_{fi,a}$ is the travel speed of through vehicles for segment i (mi/h), and other variables are as previously defined.

Step 3: Determine Spatial Stop Rate

The spatial stop rate for the facility is the ratio of stops (part to facility length). It relates the number of full stops incurred by the average through vehicle to the distance traveled. The spatial stop rate for through vehicles is determined for each segment by using the procedures described in Chapter 17. The spatial stop rate for the facility is calculated by using Equation 16-4:

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Equation 16-4

$$IT_s = \frac{\sum_{i=1}^{n} IT_{s,i} \cdot L_i}{\sum_{i=1}^{n} L_i}$$

where IT_s is the spatial stop rate for the facility (stops/mi), $IT_{s,i}$ is the spatial stop rate for segment i (stops/mi), and other variables are as previously defined.

The spatial stop rate from Equation 16-4 can be used to estimate an automobile traveler perception score for the facility if desired. The equations in Step 10 of Chapter 17 are used for this purpose. The value of IT_s would be substituted for IT_a in each equation. Similarly, the proportion of intersections with a left-turn lane (P_{LT}) would be calculated for the entire facility and this value would be used in each equation.

Step 4: Determine Automobile LOS

LOS is determined for both directions of travel along the facility. Exhibit 16-4 lists the LOS thresholds established for this purpose. As indicated in this exhibit, LOS is defined by travel speed, expressed as a percentage of the base free-flow speed. The base free-flow speed is computed in Step 1 and the travel speed is computed in Step 2.

The footnote to Exhibit 16-4 indicates that volume-to-capacity ratio for the through movement at the downstream boundary intersection is also relevant to the determination of facility LOS. This footnote indicates that LOS F is assigned to the subject direction of travel if a volume-to-capacity ratio greater than 1.0 exists for the through movements at one or more boundary intersections.

Facility LOS must be interpreted with caution. It can suggest acceptable operation of the facility when, in reality, certain segments are operating at an unacceptable LOS. For each travel direction, the analyst should always verify that each segment is providing acceptable operation and consider reporting the LOS for the poorest-performing segment as a means of providing context for the interpretation of facility LOS.

PEDESTRIAN MODE

This subsection describes the methodology for evaluating the performance of an urban street facility in terms of its service to pedestrians.

Urban street facility performance from a pedestrian perspective is separately evaluated for each side of the street. *Unless otherwise stated, all variables identified in this section are specific to the subject side of the street.*

The methodology is focused on the analysis of facilities with either signal-controlled or two-way STOP-controlled boundary intersections. This edition of the HCM does not include a procedure for evaluating a facility's performance when a boundary intersection is an all-way STOP-controlled intersection, a roundabout, or a signalized interchange ramp terminal.

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The pedestrian methodology is applied through a series of four steps that culminate in the determination of the facility LOS. These steps are illustrated in Exhibit 16-10.

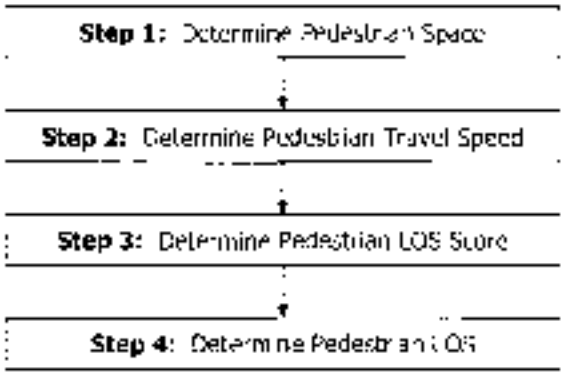

Exhibit 16-10
Pedestrian Methodology for Urban Street Facilities

Concepts

The methodology provides a variety of measures for evaluating facility performance in terms of its service to pedestrians. Each measure describes a different aspect of the pedestrian trip along the facility. One measure is the LOS score. This score is an indication of the typical pedestrian's perception of the overall facility travel experience. A second measure is the average speed of pedestrians traveling along the facility.

A third measure is based on the concept of "circulation area." It represents the average amount of sidewalk area available to each pedestrian walking along the facility. A larger area is more desirable from the pedestrian perspective. Exhibit 16-11 provides a qualitative description of pedestrian space that can be used to evaluate sidewalk performance from a circulation area perspective.

Pedestrian Space (ft²/p)		
Random Flow	Platoon Flow	Description
>60	>5.00	Ability to move in desired path, no need to alter movements
>40–60	>90–530	Occasional need to adjust path to avoid conflicts
>24–40	>40–90	Frequent need to adjust path to avoid conflicts
>15–24	>24–40	Speed and ability to pass slower pedestrians restricted
>8–15	>11–23	Speed restricted, very limited ability to pass slower pedestrians
≤ 8	≤ 11	Speed severely restricted, frequent contact with other users

Exhibit 16-11
Qualitative Description of Pedestrian Space

The first two columns in Exhibit 16-11 indicate a sensitivity to flow condition. Random pedestrian flow is typical of most facilities. Platoon flow is appropriate for facilities made up of shorter segments (e.g., in downtown areas with signalized boundary intersections).

Step 1: Determine Pedestrian Space

Pedestrians are sensitive to the amount of space separating them from other pedestrians and obstacles as they walk along a sidewalk. Average pedestrian space is an indicator of facility performance for travel in a sidewalk. This step is applicable only when the sidewalk exists on the subject side of the street.

AR0074127

The pedestrian space is determined for each segment by using the procedures described in Chapter 17, Urban Street Segments. The pedestrian space for the facility is calculated by using Equation 16-5:

Equation 16-5

$$A_{p,p} = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} \frac{L_i}{A_{p,i}}}$$

where

$A_{p,p}$ = pedestrian space for the facility (ft²/p),
L_i = length of segment i (ft),
n = number of segments on the facility, and
A_i = pedestrian space for segment i (ft²/p).

The pedestrian space for the facility reflects the space provided on the sidewalk along the segment. It does not consider the corner circulation area or the crosswalk circulation area at the intersections. Regardless, the analyst should verify that the intersection corners and crosswalks adequately accommodate pedestrians.

Step 2: Determine Pedestrian Travel Speed

The travel speed for the facility is the ratio of facility length to facility travel time. It represents an equivalent average speed of pedestrians that reflects their walking speed along the sidewalk and any delay they may incur at the boundary intersections. The travel speed for pedestrians is determined for each segment by using the procedures described in Chapter 17. The pedestrian travel speed for the facility is calculated by using Equation 16-6:

Equation 16–6

$$S_{p,p} = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} \frac{L_i}{S_{p,p,i}}}$$

where $S_{p,p}$ is the travel speed of through pedestrians for the facility (ft/s), $S_{p,p,i}$ is the travel speed of through pedestrians for segment i (ft/s), and other variables are as previously defined.

In general, a travel speed of 4.0 ft/s or more is considered desirable, and a speed of 2.0 ft/s or less is considered undesirable.

Step 3: Determine Pedestrian LOS Score

The pedestrian LOS score for the facility is computed in this step. It represents a length-weighted average of the pedestrian LOS scores for the individual segments that make up the facility. The segment scores are determined by using the procedures described in Chapter 17. The score for the facility is calculated by using Equation 16-7:

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$$I_{p,t} = \frac{\sum_{i=1}^{n} I_{p,i} \cdot L_i}{\sum_{i=1}^{n} L_i}$$

Equation 16-7

where

$I_{p,t}$ = pedestrian LOS score for the facility, and

$I_{p,i}$ = pedestrian LOS score for segment i.

Other variables are as previously defined.

Step 4: Determine Pedestrian LOS

The pedestrian LOS for the facility is determined by using the pedestrian LOS score from Step 3 and the average pedestrian space from Step 2. These two performance measures are compared with their respective thresholds in Exhibit 16-5 to determine the LOS for the specified direction of travel along the subject facility. If the sidewalk does not exist and pedestrians are relegated to walking in the street, then LOS is determined by using Exhibit 16-6 because the pedestrian space exception does not apply.

Facility LOS must be interpreted with caution. It can suggest acceptable operation of the facility when, in reality, certain segments are operating at an unacceptable LOS. For each travel direction, the analyst should always verify that each segment is providing acceptable operation and consider reporting the LOS for the poorest-performing segment as a means of providing context for the interpretation of facility LOS.

BICYCLE MODE

This subsection describes the methodology for evaluating the performance of an urban street facility in terms of its service to bicyclists.

Urban street facility performance from a bicyclist perspective is separately evaluated for each travel direction along the street. *Unless otherwise stated, all variables identified in this section are specific to the subject direction of travel.*

The methodology is focused on the analysis of a facility with either signal-controlled or two-way stop-controlled boundary intersections. This edition of the HCM does not include a procedure for evaluating a facility's performance when a boundary intersection is an all-way stop-controlled intersection, a roundabout, or a signalized interchange ramp terminal.

The bicycle methodology is applied through a series of three steps that culminate in the determination of the facility LOS. These steps are illustrated in Exhibit 16-12.

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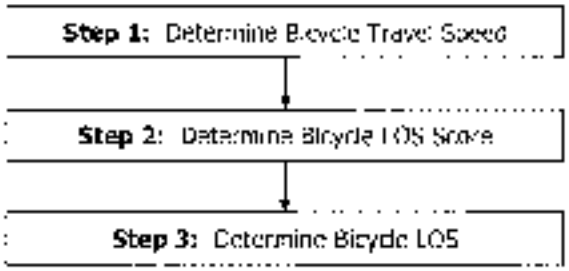
Exhibit 16-12
Bicycle Methodology for Urban Street Facilities



Step 1: Determine Bicycle Travel Speed

The travel speed for the facility is the ratio of facility length to facility travel time. It represents an equivalent average speed of bicycles that reflects their running speed along the street and any delay they may incur at the boundary intersections. The travel speed for bicycles is determined for each segment by using the procedures described in Chapter 17. The bicycle travel speed for the facility is calculated by using Equation 16-8:

Equation 16-8

$$S_{p,b} = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} \frac{L_i}{S_{p,b,i}}}$$

where

$S_{p,b}$ = travel speed of through bicycles for the facility (mi/h),
L_i = length of segment i (ft),
n = number of segments on the facility, and
$S_{p,b,i}$ = travel speed of through bicycles for segment i (mi/h).

Step 2: Determine Bicycle LOS Score

The bicycle LOS score for the facility is computed in this step. It represents a length-weighted average of the bicycle LOS scores for the individual segments that make up the facility. The segment scores are determined by using the procedures described in Chapter 17. The score for the facility is calculated by using Equation 16-9:

Equation 16-9

$$I_{b,f} = \frac{\sum_{i=1}^{n} I_{b,sg,i} \cdot L_i}{\sum_{i=1}^{n} L_i}$$

where $I_{b,f}$ is the bicycle LOS score for the facility, $I_{b,sg,i}$ is the bicycle LOS score for segment i, and other variables are as previously defined.

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Step 3: Determine Bicycle LOS

The bicycle LOS for the facility is determined by using the bicycle LOS score from Step 2. This performance measure is compared with the thresholds in Exhibit 16-9 to determine the LOS for the specified direction of travel along the subject facility.

Facility LOS must be interpreted with caution. It can suggest acceptable operation of the facility when, in reality, certain segments are operating at an unacceptable LOS. For each travel direction, the analyst should always verify that each segment is providing acceptable operation and consider reporting the LOS for the poorest-performing segment as a means of providing context for the interpretation of facility LOS.

TRANSIT MODE

This subsection describes the methodology for evaluating the performance of an urban street facility in terms of its service to transit passengers.

Urban street facility performance from a transit passenger perspective is separately evaluated for each travel direction along the street. *Unless otherwise stated, all variables identified in this section are specific to the subject direction of travel.*

The methodology is applicable to public transit vehicles operating in mixed traffic or exclusive lanes and stopping along the street. Procedures for estimating transit vehicle performance on grade separated or non-public-street rights-of-way, along with procedures for estimating origin–destination service quality, are provided in the *Transit Capacity and Quality of Service Manual* (3).

The transit methodology is applied through a series of three steps that culminate in the determination of facility LOS. These steps are illustrated in Exhibit 16-13. If multiple routes exist on the segment, then each route is evaluated by using a separate application of this methodology.

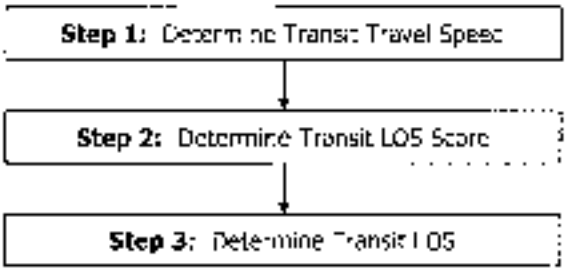

Exhibit 16-13
Transit Methodology for Urban Street Facilities

Step 1: Determine Transit Travel Speed

The travel speed for the facility is the ratio of facility length to facility travel time. It represents an equivalent average speed of transit vehicles that reflects their running speed along the street and any delay they may incur at the boundary intersection. The travel speed for a transit vehicle is determined on each segment by using the procedures described in Chapter 17. The transit travel speed for the facility is calculated by using Equation 16-16:

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Equation 16-10

$$S_{T,i} = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} \frac{L_i}{S_{m,avg,i}}}$$

where

$S_{T,i}$ = travel speed of transit vehicles for the facility (mi/h),

L_i = length of segment i (ft),

n = number of segments on the facility, and

$S_{m,avg,i}$ = travel speed of transit vehicles for segment i (mi/h).

Step 2: Determine Transit LOS Score

The transit LOS score for the facility is computed in this step. It represents a length-weighted average of the transit LOS score for the individual segments that make up the facility. The segment scores are determined by using the procedures described in Chapter 17. The score for the facility is calculated by using Equation 16-11:

Equation 16-11

$$I_{T,i} = \frac{\sum_{i=1}^{n} I_{m,avg,i} \cdot L_i}{\sum_{i=1}^{n} L_i}$$

where $I_{T,i}$ is the transit LOS score for the facility, $I_{m,avg,i}$ is the transit LOS score for segment i, and other variables are as previously defined.

Step 3: Determine Transit LOS

The transit LOS for the facility is determined by using the transit LOS score from Step 2. This performance measure is compared with the thresholds in Exhibit 16-6 to determine the LOS for the specified direction of travel along the subject facility.

Facility LOS must be interpreted with caution. It can suggest acceptable operation of the facility when, in reality, certain segments are operating at an unacceptable LOS. For each travel direction, the analyst should always verify that each segment is providing acceptable operation and consider reporting the LOS for the poorest performing segment as a means of providing context for the interpretation of facility LOS.

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3. APPLICATIONS

TYPES OF ANALYSIS

The automobile, pedestrian, bicycle, and transit methodologies described in this chapter can each be used in three types (or levels) of analysis. These analysis levels are described as operational, design, and planning and preliminary engineering. The characteristics of each analysis level are described in the subsequent parts of this subsection.

Operational Analysis

Each of the methodologies is most easily applied at an operational level of analysis. At this level, all traffic, geometric, and signalization conditions are specified as input variables by the analyst. These input variables are used in the methodology to compute various performance measures.

Design Analysis

The design level of analysis has two variations. Both variations require the specification of traffic conditions and target levels for a specified set of performance measures. One variation requires the additional specification of the signalization conditions. The methodology is then applied by using an iterative approach in which alternative geometric conditions are separately evaluated.

The second variation of the design level requires the additional specification of the geometric conditions. The methodology is then applied by using an iterative approach in which alternative signalization conditions are evaluated.

The objective of the design analysis is to identify the alternatives that operate at the target level of the specified performance measures (or provide a better level of performance). The analyst may then recommend the "best" design alternative after consideration of the full range of factors.

Planning and Preliminary Engineering Analysis

The planning and preliminary engineering level of analysis is intended to provide an estimate of the LOS for either a proposed facility or an existing facility in a future year. This level of analysis may also be used to size the overall geometries of a proposed facility.

The level of precision inherent in planning and preliminary engineering analyses is typically lower than for operational analyses. Therefore, default values are often substituted for field-measured values of many of the input variables. Recommended default values for this purpose are provided in Chapters 17 to 22.

USE OF ALTERNATIVE TOOLS

Chapter 39, Urban Street Facilities: Supplemental, includes a set of examples to illustrate the use of alternative tools to address the scope limitations of this chapter and Chapter 17, Urban Street Segments. Specifically, these examples are used to illustrate (a) the application of deterministic tools to optimize the signal

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timing, (b) the effect of using a roundabout as a segment boundary, (c) the effect of midsegment parking maneuvers on facility operation, and (d) the use of simulated vehicle trajectories to evaluate the proportion of time that the back of the queue on the minor-street approach to a two-way stop-controlled intersection exceeds a specified distance from the stop line.

GENERALIZED DAILY SERVICE VOLUMES FOR URBAN STREET FACILITIES

Generalized daily service volume tables provide a means to assess a large number of urban streets in a region or jurisdiction quickly to determine which facilities need to be assessed more carefully (by using operational analysis) to ameliorate existing or pending problems.

To build a generalized daily service volume table for urban street facilities, a number of simplifying assumptions must be made. The assumptions made here include the following:

- All segments of the facility have the same number of through lanes (one, two, or three) in each direction;
- Only traffic signal control is used along the facility (i.e., no roundabouts or all-way stop-controlled intersections exist);
- The traffic signals are coordinated and semi-actuated, the arrival type is 4, the traffic signal cycle time C is 120 s, and the weighted average green-to-cycle-length (g/C) ratio for through movements (defined below) is 0.46;
- Exclusive left-turn lanes with protected left-turn phasing and adequate queue storage are provided at each signalized intersection, and no excessive right-turn lanes are provided;
- At each traffic signal, 10% of the traffic on the urban street facility turns left and 10% turns right;
- The peak hour factor is 0.92;
- The facility length is 2 mi, and no restrictive medians exist along the facility; and
- The base saturation flow rate is 1,900 passenger cars per hour per lane (pc/h/ln).

The weighted average g/C ratio of an urban street is the average of the critical intersection through g/C ratio and the average of all the other g/C ratios for the urban street. For example, if there are four signals with a through g/C ratio of 0.50 and one signal with a through g/C ratio of 0.40, the weighted average g/C ratio for the urban street is 0.47. The weighted g/C ratio takes into account the adverse effect of the critical intersection and the overall quality of flow for the urban street.

Generalized daily service volumes are provided in Exhibit 16-11 for urban street facilities with posted speeds of 30 and 40 mi/h; two, four, or six lanes (both directions); and six combinations of the K factor and D factor. To use this table, analysts must select a combination of K and D appropriate for their locality.

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The 30-mi/h values further assume an average traffic signal spacing of 1,050 ft and 20 access points/mi, while the 45-mi/h values assume an average traffic signal spacing of 1,500 ft and 10 access points/mi.

Exhibit 16-14
Generalized Daily Service Volumes for Urban Street Facilities (1,000 veh/day)

K Factor	D Factor	Two-Lane Streets LOS B	LOS C	LOS D	LOS E	Four-Lane Streets LOS B	LOS C	LOS D	LOS E	Six-Lane Streets LOS B	LOS C	LOS D	LOS E
Posted Speed = 30 mi/h													
0.09	0.55	NA	5.9	15.4	19.9	NA	11.3	31.4	37.9	NA	16.3	46.4	54.3
	0.70	NA	5.4	14.1	18.3	NA	10.3	28.8	34.9	NA	15.2	42.5	49.8
0.10	0.55	NA	5.3	13.9	17.9	NA	10.1	28.2	34.1	NA	14.7	41.8	48.9
	0.60	NA	4.9	12.7	16.4	NA	9.3	25.9	31.3	NA	13.5	38.3	44.8
0.11	0.55	NA	4.8	12.6	16.3	NA	9.2	25.7	31.0	NA	13.4	38.0	44.5
	0.60	NA	4.4	11.5	14.9	NA	8.4	23.5	28.4	NA	12.2	34.9	40.9
Posted Speed = 45 mi/h													
0.09	0.55	NA	10.9	18.6	19.9	NA	21.1	37.2	37.9	NA	31.6	56.0	54.3
	0.60	NA	9.4	17.1	18.3	NA	19.6	34.1	34.8	NA	29.2	48.5	49.0
0.10	0.55	NA	9.3	16.0	17.9	NA	19.3	33.5	34.1	NA	28.7	48.6	48.9
	0.60	NA	8.5	15.4	16.4	NA	17.7	30.7	31.3	NA	26.3	44.5	44.8
0.11	0.55	NA	8.4	15.3	16.3	NA	17.5	30.5	31.0	NA	26.1	44.2	44.4
	0.60	NA	7.7	14.0	14.9	NA	16.1	27.9	28.4	NA	23.9	40.5	40.7

Notes: NA = not applicable; LOS cannot be achieved with the listed assumptions.
General assumptions include no roundabouts or freeway or controlled intersections along the facility, roadway and traffic characteristics typical of U.S. urban areas, pretimed signal control, protected left-turn phases, 0.94 weighted average g/C ratio, exclusive left-turn lanes with adequate queue storage provided at traffic signals, no exclusive right-turn lanes provided, no restrictive median, area facility type, 10% of traffic turning left and 10% turning right at each traffic signal, peak hour factor = 0.92, and base saturation flow rate = 1,900 pc/h/ln.
Additional assumptions for 30 mi/h facilities: signal spacing = 1,050 ft and 20 access points/mi.
Additional assumptions for 45 mi/h facilities: signal spacing = 1,500 ft and 10 access points/mi.

Exhibit 16-14 is provided for general planning use and should not be used to analyze any specific urban street facility or to make final decisions on important design features. A full operational analysis using this chapter's methodology is required for such specific applications.

The exhibit is useful, however, in evaluating the overall performance of a large number of urban streets within a jurisdiction, as a first pass to determine where problems might exist or arise, or to determine where improvements might be needed. Any urban street identified as likely to experience problems or need improvement, however, should then be subjected to a full operational analysis before any decisions on implementing specific improvements are made.

Daily service volumes are strongly affected by the *K*- and *D*-factors chosen as typical for the analyses. It is important that the values used for the facilities under study be reasonable. Also, if any characteristic is significantly different from the typical values used to develop Exhibit 16-14, particularly the weighted average g/C ratio and traffic signal spacing, the values taken from the exhibit will not be representative of the study facilities. In such cases, analysts are advised to develop their own generalized service volume tables by using representative local values or to proceed to a full operational analysis.

ACTIVE TRAFFIC MANAGEMENT STRATEGIES

Active traffic management (ATM) consists of the dynamic and continuous monitoring and control of traffic operations on a facility to improve facility performance. Examples of ATM measures on urban streets include congestion pricing zones, adaptive/responsive signal control, dynamic or metering, changeable

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message signs, incident response, and work zone management. ATM measures can influence both the nature of the demand for the facility and the ability of the facility to deliver the capacity tailored to serve the demand. ATM measures can boost facility performance to the same extent as adding a conventional lane of capacity.

Other advanced design and management measures not included in the definition of ATM can also significantly boost facility performance. These non-ATM measures include lane treatments (bus lanes, bus streets, and reversible lanes), advanced interchange and intersection designs (divergent diamond interchanges, single point urban interchanges, Michigan indirect left-turn intersections, and continuous flow intersections), and access management. These measures generally boost facility performance through the cost-effective addition of signal or lane capacity, or both in unconventional ways to the facility.

More information on ATM measures and methods for their evaluation can be found in Chapter 35, Active Traffic Management.

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4. EXAMPLE PROBLEMS

This part of the chapter describes the application of the automobile, pedestrian, bicycle, and transit methodologies through a series of example problems. Exhibit 16-15 provides an overview of these problems. The focus of the examples is to illustrate the multimodal facility evaluation process. An operational analysis level is used for all examples. The planning and preliminary engineering analysis level is identical to the operational analysis level in terms of the calculations except that default values are used when field-measured values are not available.

Exhibit 16-15
Example Problems

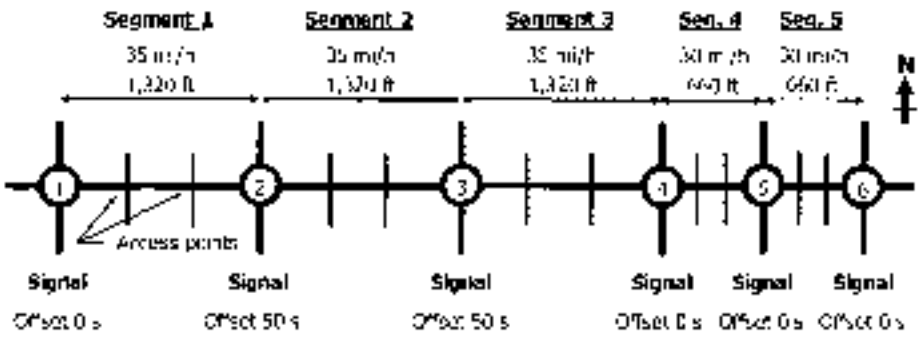
Problem Number	Description	Analysis Level
1	Auto-oriented urban street	Operational
2	Widen the sidewalks and add bicycle lanes on both sides of facility	Operational
3	Widen the sidewalks and add parking on both sides of facility	Operational

EXAMPLE PROBLEM 1: AUTO-ORIENTED URBAN STREET

The Urban Street Facility

A 1-mi urban street facility is shown in Exhibit 16-16. It is located in a downtown area and oriented in an east–west travel direction. The facility consists of five segments with a signalized boundary intersection for each segment. Segments 1, 2, and 3 are 1,320 ft long and have a speed limit of 35 mi/h. Segments 4 and 5 are 660 ft long and have a speed limit of 30 mi/h. Each segment has two access point intersections.

Exhibit 16-16
Example Problem 1: Urban Street Schematic



Segments 1, 2, and 3 pass through a mixture of office and strip commercial. Segments 4 and 5 are in a built-up shopping area.

The geometry of the typical street segment is shown in Exhibit 16-17. It is the same for each segment. The street has a curbed, four-lane cross section with two lanes in each direction. There's a 1.5-ft curb and gutter section on each side of the street. There are 200-ft left-turn bays on each approach to each signalized intersection. Right-turn vehicles share the outside lane with through vehicles on each intersection approach. A 6-ft sidewalk is provided on each side of the street adjacent to the curb. No fixed objects are located along the outside of the

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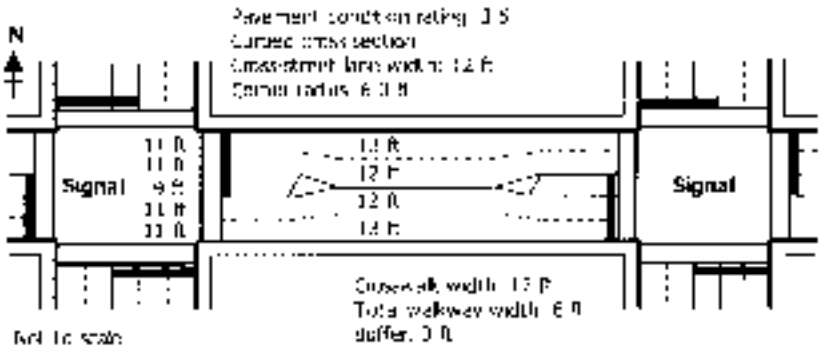
sidewalk. Mid-segment pedestrian crossings are legal. No bicycle lanes are provided on the facility or its cross streets. No parking is allowed along the street.

Exhibit 16-17
Example Problem 1: Segment Geometry



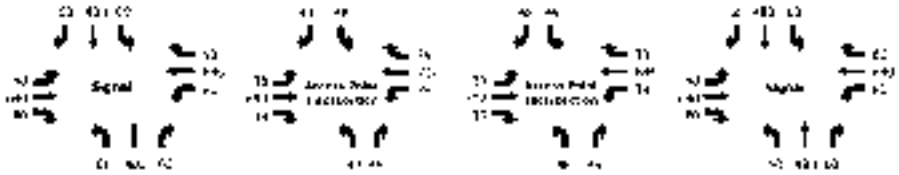
The Question

What are the travel speed and LOS of the automobile, pedestrian, bicycle, and transit modes in both directions of travel along the facility?

The Facts

The traffic counts for the one segment are shown in Exhibit 16-18. The counts are the same for all of the other segments. The counts were taken during the 15-min analysis period of interest. However, they have been converted to hourly flow rates.

Exhibit 16-18
Example Problem 1: Intersection Turn Movement Counts



The signalization conditions are shown in Exhibit 16-19. The conditions shown are identified as belonging to Signalized Intersection 1; however, they are the same for the other signalized intersections (with exception of offset). The signals operate with coordinated–actuated control. The left-turn movements on the northbound and southbound approaches operate under permitted control. The left-turn movements on the major street operate as protected–permitted in a lead–lead sequence.

Exhibit 16-19 indicates that the passage time for each phase is 2.0 s. The minimum green setting is 7 s for the major-street left-turn phases and 18 s for the cross-street phases. The offset to Phase 2 (the reference phase) end-of-green interval is 0.0 s. The offset for each of the other intersections is shown in Exhibit 16-16. A fixed-force mode is used to ensure coordination is maintained. The cycle length is 100 s.

Geometric conditions and traffic characteristics for Signalized Intersection 1 are shown in Exhibit 16-20. They are the same for the other signalized

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intersections. The movement numbers follow the numbering convention shown in Exhibit 18-2 of Chapter 18.

Exhibit 16-19
Example Problem 1: Signal Conditions for Intersection 1

Signalized Intersection 1								
General Information 19								
Cross Street: First Avenue				**Analysis Period:** AM peak				
Phase Sequence and Left-Turn Mode								
Major street sequence (movement numbers shown)	5 & 1 left leading			Cross street sequence (movement numbers shown)	No exclusive phase for 3 or 7			
Major street left-turn mode (movement numbers shown)	5/1 Protected+Permitted			Cross street left-turn mode (movement numbers shown)	3/7 Permitted			
Phase Settings								
Approach	Eastbound		Westbound		Northbound		Southbound	
Phase number	5	2	1	6		8		4
Movement	L	T+R	L	T+R		L+T+R		L+T+R
Lead/lag left-turn phase	Lead	--	Lead	--		--		--
Left-turn mode	Pr/Pm	--	Pr/Pm	--		Perm		Perm
Passage time, s	2.0	--	2.0	--		2.0		2.0
Minimum green, s	5	--	5	--		18		18
Yellow + red clear, s	4.0	4.0	4.0	4.0		4.0		4.0
Phase split, s	20	45	20	45		35		35
Recall	No	--	No	--	No	No	No	No
Dual entry	No	Yes	No	Yes	No	Yes	No	Yes
Ref. Phase 2	Offset, s:	0	Offset Ref.:	End of Green	Force Mode:	Fixed		
	Cycle, s:	100						
Enable Simultaneous Gap-Out? Phase Group 1,2,5,6: ☑	Phase Group 3,4,7,8: ☑		Enable Dallas Left-Turn Phasing? Phases 1,2,5,6: ☐	Phases 3,4,7,8: ☐				

Exhibit 16-20
Example Problem 1: Geometric Conditions and Traffic Characteristics for Signalized Intersection 1

The saturation flow rate is determined by using the procedure described in Chapter 18. All intersection movements include 3% heavy vehicles. The segment and intersection approaches are effectively level. No parking is allowed along the facility or its cross-street approaches. With a few exceptions (discussed below), local buses stop on the eastbound and westbound approaches to each signalized intersection at a rate of 3 buses/h.

Arrivals for all cross-street movements are effectively random, so a platoon ratio of 1.00 is used. The through movement arriving to the eastbound approach at Intersection 1 exhibits favorable progression from an upstream signal, so a platoon ratio of 1.33 is used. For similar reasons, a ratio of 1.33 is also used for the through movement arriving to the westbound approach at Intersection 6. Right-turn-on-red volume is estimated at 5.0% of the right-turn volume.

Each segment has a barrier curb along the outside of the street in each direction of travel. Allowing for the upstream signal width, the percentage of the segment length with curb is estimated at 94% for Segments 1, 2, and 3. It is estimated as 88% for Segments 4 and 5.

The traffic and lane assignment data for the two access point intersections for Segment 1 are shown in Exhibit 16-21. These data are the same for the other segments; however, the access point locations (shown in the first column) are

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reduced by one-half for Segments 4 and 5. The movement numbers follow the numbering convention shown in Exhibit 19-3 of Chapter 19, Two-Way STOP-Controlled Intersections. There are no turn bays on the segment at the two access point intersections.

Exhibit 16-21
Example Problem 1: Access Point Data

A low wall is located along about 25% of the sidewalk in Segments 1, 2, and 3. In contrast, 10% of the sidewalk along Segments 4 and 5 is adjacent to a low wall, 35% to a building face, and 15% to a window display.

Office and strip commercial activity along Segments 1, 2, and 3 generates a pedestrian volume of 100 p/h on the adjacent sidewalks and crosswalks. Shopping activity along Segments 4 and 5 generates a pedestrian volume of 300 p/h on the adjacent sidewalks and crosswalks. A lack of bicycle lanes has discouraged bicycle traffic on the facility and its cross streets; however, a bicycle volume of 1.0 bicycle/h is entered for each intersection approach.

Local buses stop on the eastbound and westbound approaches to each signalized intersection, with the exception of Intersection 5. There are no stops on either approach to Intersection 5. However, transit stops are provided along the facility at 0.25-mi intervals, so the service is considered to be local. As a result, the westbound transit frequency on Segment 5 and the eastbound transit frequency on Segment 4 are considered to be the same as for the adjacent segments (i.e., 3 buses/h). The bus dwell time at each stop averages 20 s. Buses arrive within 5 min of their scheduled time about 75% of the time and have a load factor of 0.80 passengers/seat. Each bus stop has a bench but no shelter.

Outline of Solution

This section outlines the results of the facility evaluation. To complete this evaluation, the automobile, pedestrian, and bicycle methodologies in Chapter 18 were used to evaluate each of the signalized intersections on the facility. The procedure in Chapter 19 was used to estimate pedestrian delay when crossing at a midsegment location. The automobile, pedestrian, bicycle, and transit methodologies in Chapter 17 were then used to evaluate both directions of travel on each segment. Finally, the methodologies described in Section 2 were used to evaluate all four travel modes in both directions of travel on the facility. The findings from each evaluation are summarized in the following three subparts.

Intersection Evaluation

The results of the evaluation of Intersection 1 (i.e., First Avenue) are shown in Exhibit 16-22. The results for Intersections 2, 3, and eastbound Intersection 4 are similar. In contrast, Intersections 5 and 6 are associated with a shorter segment length, lower speed limit, and higher pedestrian volume, so their operation is different from that of the other intersections. The results for Intersection 5 (i.e., Fifth Avenue) are shown in Exhibit 16-23. Intersection 6 and westbound Intersection 4 have similar results.

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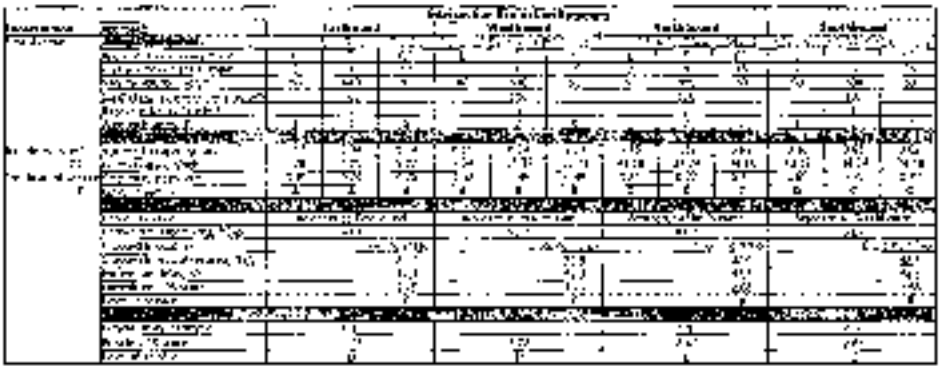

Exhibit 16-22
Example Problem 1: Intersection 1 Evaluation

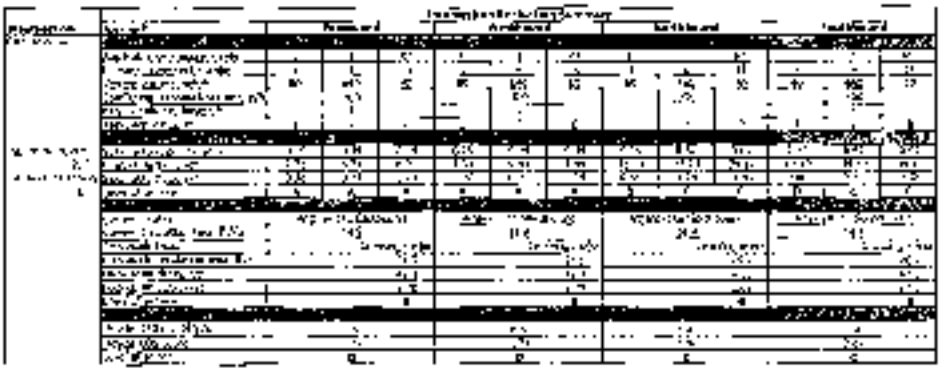

Exhibit 16-23
Example Problem 1: Intersection 5 Evaluation

Both exhibits indicate that the major-street vehicular through movements (i.e., eastbound Movement 2 and westbound Movement 6) operate with very low delay and few stops. The LOS is A and B for the eastbound and westbound through movements, respectively.

Pedestrian circulation area on the corners at Intersection 1 is generous, with pedestrians having the ability to move in their desired path without conflict. Corner circulation area at Intersection 5 is restricted, with pedestrians having very limited ability to pass slower pedestrians.

At Intersection 1, the low pedestrian volume results in generous crosswalk circulation area. Pedestrians rarely need to adjust their path to avoid conflicts. In contrast, the high pedestrian volume at Intersection 5 results in a constrained crosswalk circulation area. Pedestrians frequently adjust their path to avoid conflict. At each intersection, pedestrians experience an average wait of about 42 s at the corner to cross the street in any direction. This delay is lengthy, and some pedestrians may not comply with the signal indications. At Intersection 1, the pedestrian LOS is C for the major-street crossing and B for the minor-street crossing. At Intersection 5, the pedestrian LOS is B for the major-street and minor-street crossings.

Bicycle lanes are not provided at any intersection, so bicycle delay is not computed. The lack of a bicycle lane combined with a moderately high traffic volume results in a bicycle LOS D on the eastbound and westbound approaches of Intersection 1 and Intersection 5.

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Segment Evaluation

The results of the evaluation of Segment 1 (i.e., First Avenue to Second Avenue) are shown in Exhibit 16-24. The results for Segments 2 and 3 are similar. In contrast, Segments 4 and 5 are associated with a shorter segment length, lower speed limit, and higher pedestrian volume, so their operation is different from that of the other intersections. The results for Segment 5 (i.e., Fifth Avenue to Sixth Avenue) are shown on exhibit 16-25. Segment 4 has similar results.

Exhibit 16-24
Example Problem 1: Segment 1 Evaluation

Segment	Segment Evaluation Summary		
	Travel Direction	Eastbound	Westbound
First Avenue to Second Avenue	**Basic Description**		
	Speed limit, mi/h	35	35
	Vehicle volume, veh/h	503	502
	Through lanes, n	1	1
Segment length, ft: 1,320	**Vehicle Level of Service**		
	Base free-flow speed, FFS	40.0	40.0
	Travel speed, mi/h	27.5	28.2
	Spatial displacement, veh/mi	1.77	1.82
	Level of service	C	C
	Pedestrian Level of Service		
	Pedestrian space, ft²/p	593.9	593.9
	Pedestrian travel speed, ft/s	3.51	3.54
	Pedestrian LOS score	3.26	3.26
	Level of service	D	D
	Bicycle Level of Service		
	Bicycle travel speed, mi/h	No bicycle lane	No bicycle lane
	Bicycle LOS score	4.54	4.71
	Level of service	D	D
	Transit Level of Service		
	Transit base travel speed, mi/h	27	12.5
	Transit LOS score	3.04	3.71
	Level of service	C	C

Exhibit 16-25
Example Problem 1: Segment 5 Evaluation

Segment	Segment Evaluation Summary		
	Travel Direction	Eastbound	Westbound
Fifth Avenue to Sixth Avenue	**Basic Description**		
	Speed limit, mi/h	30	30
	Vehicle volume, veh/h	870	890
	Through lanes, n	1	1
Segment length, ft: 660	**Vehicle Level of Service**		
	Base free-flow speed, FFS	37.0	37.0
	Travel speed, mi/h	17.6	17.5
	Spatial displacement, veh/mi	2.48	2.50
	Level of service	D	D
	Pedestrian Level of Service		
	Pedestrian space, ft²/p	159.3	159.3
	Pedestrian travel speed, ft/s	3.39	3.39
	Pedestrian LOS score	3.67	3.67
	Level of service	D	D
	Bicycle Level of Service		
	Bicycle travel speed, mi/h	No bicycle lane	No bicycle lane
	Bicycle LOS score	5.08	5.46
	Level of service	E	E
	Transit Level of Service		
	Transit base travel speed, mi/h	7.7	7.7
	Transit LOS score	3.64	3.77
	Level of service	D	C

Exhibit 16-24 indicates that the vehicular through movements on Segment 1 in the eastbound and westbound travel directions have a travel speed of 24 and 23 mi/h, respectively (i.e., about 58% of the base free-flow speed). The LOS of each movement is C. In contrast, Exhibit 16-25 indicates that the through movements have a travel speed of only about 17 mi/h on Segment 5 (or 46% of the base free-flow speed), which is LOS D. Vehicles depart at a rate of about 1.8 stops/mi on Segment 1 and about 2.7 stops/mi on Segment 5.

Pedestrian space on the sidewalk along the segment is generous on Segment 1 and adequate on Segment 5. These characterizations are based on

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Exhibit 16-11 and an assumed dominance of platoon flow for Segments 4 and 5. Pedestrians on these sidewalks can walk freely without having to alter their path to accommodate other pedestrians. The segment travel speed (3.54 ft/s for Segment 1 and 3.15 ft/s for Segment 5) is inadequate, but would desirably exceed 4.0 ft/s. Nevertheless, the sidewalk is near the traffic lanes and crossing the street at a midsegment location can be difficult. As a result, the pedestrian LOS is D on all segments.

Bicycle lanes are not provided along the segment, so bicycle travel speed is not computed. The lack of a bicycle lane combined with a moderately high traffic volume results in a bicycle LOS D for both directions of travel on Segment 1. Bicycle service on Segment 5 is also poor. However, the short spacing between access points on Segment 5, as cited for Segment 1, further degrades service quality such that the bicycle LOS on Segment 5 is F.

Transit travel speed is about 12 mi/h on Segment 1 and corresponds to LOS C. On Segment 5, the travel speed is about 8 mi/h and 17 mi/h in the eastbound and westbound directions, respectively. The low speed for the eastbound direction results in LOS D. The higher speed for the westbound direction is due to the lack of a westbound transit stop on Segment 5. It results in LOS C for this direction.

Facility Evaluation

The methodology described in Section 2 is used to compute the aggregate performance measures for each travel direction along the facility. The results are shown in Exhibit 16-26. This exhibit indicates that the vehicle travel speed is about 22 mi/h in each travel direction (or 56% of the base free-flow speed). An overall LOS C applies to both vehicular movements on the facility; however, it is noted that LOS D applies to Segments 4 and 5. Vehicles incur stops along the facility at a rate of about 1.9 stops/mi.

	Facility Evaluation Summary		
	Travel Direction	Eastbound	Westbound
[illegible]	***Bicycle Level of Service***		
	Base free-flow speed, mi/h	39.7	39.7
	Travel speed, mi/h	37.1	37.1
	Spatial stop rate, stops/mi	1.96	1.91
	Level of service	E	E
	Percent of segment LOS	0	0
	Pedestrian Level of Service		
	Pedestrian space, ft²/p	431.0	291.0
	Pedestrian flow rate, p/15 min	161	161
	Pedestrian LOS score	3.53	3.53
	Level of service	D	D
	Percent of segment LOS	0	0
	Bicycle Level of Service		
	Bicycle flow rate, p/h	No bicycle flow	No bicycle flow
	Bicycle LOS score	4.32	4.30
	Level of service	F	F
	Percent of segment LOS	6	6
	Transit Level of Service		
	Travel time rate, min/mi	12.4	12.1
	Travel LOS score	1.15	2.16
	Level of service	C	C
	Percent of segment LOS	0	0

Exhibit 16-26
Example Problem 1: Facility Evaluation

Pedestrian space on the sidewalk along the facility is generous. Pedestrians on the sidewalks can walk freely without having to alter their path to accommodate other pedestrians. The facility travel speed of about 3.4 ft/s is

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adequate, but would generally exceed 400 ft/s. Nevertheless, the sidewalk is near the traffic lanes and crossing the street at a mid-segment location can be difficult. As a result, the pedestrian LOS is D for both directions of travel.

Bicycle lanes are not provided along the facility, so bicycle travel speed is not computed. The lack of a bicycle lane combined with a moderately high traffic volume results in an overall bicycle LOS F for both directions of travel.

Transit travel speed is about 12 mi/h on the facility in each direction of travel. An overall LOS C is assigned to each direction. The lower speed on westbound Segment 4 and eastbound Segment 5 is noted to result in LOS D for those segments.

EXAMPLE PROBLEM 2: PEDESTRIAN AND BICYCLE IMPROVEMENTS

The Urban Street Facility

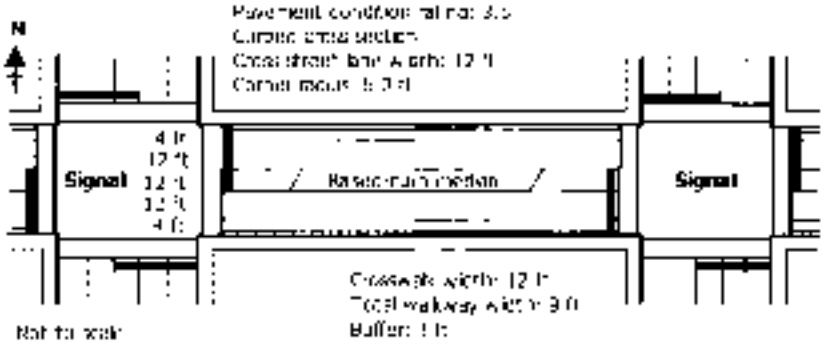
The 1-mi urban street facility shown in Exhibit 16-16 is being considered for geometric design modifications to improve pedestrian and bicycle service. The following changes to the facility are proposed:

- Eliminate one vehicle lane in each direction,
- Add a 12-ft raised-curb median,
- Add a 4-ft bicycle lane in each direction,
- Increase the total walkway width to 9 ft,
- Add a 3-ft buffer between the sidewalk and the curb, and
- Add bushes to the buffer using a 10-ft spacing.

No fixed objects are located along the outside of the sidewalk. The analysis for Example Problem 1 represents the existing condition, against which this alternative will be evaluated.

The geometry of the typical street segment is shown in Exhibit 16-27. It is the same for each segment. Additional segment details are provided in the discussion for Example Problem 1.

Exhibit 16-27
Example Problem 2
Segment Geometry



The Question

What are the travel speed and LOS of the automobile, pedestrian, bicycle, and transit modes in both directions of travel along the facility?

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The Facts

The traffic counts, signalization, and intersection geometry are listed in Exhibit 16-18 to Exhibit 16-21. They are unchanged from Example Problem 1.

Outline of Solution

This section outlines the results of the facility evaluation. To complete this evaluation, the automobile, pedestrian, and bicycle methodologies in Chapter 18 were used to evaluate each of the signalized intersections on the facility. The procedure in Chapter 19 was used to estimate pedestrian delay when crossing at a midsegment location. The automobile, pedestrian, bicycle, and transit methodologies in Chapter 17 were then used to evaluate both directions of travel on each segment. Finally, the methodologies described in Section 2 were used to evaluate all four travel modes in both directions of travel on the facility. The findings from each evaluation are summarized in the following three subparts.

Intersection Evaluation

The results of the evaluation of Intersection 1 (i.e., 1st Avenue) are shown in Exhibit 16-28. The results for Intersections 2, 3, and eastbound Intersection 4 are similar. In contrast, Intersections 5 and 6 are associated with a shorter segment length, lower speed limit, and higher pedestrian volume, so their operation is different from that of the other intersections. The results for Intersection 5 (i.e., Fifth Avenue) are shown in Exhibit 16-29. Intersection 6 and westbound Intersection 4 have similar results.

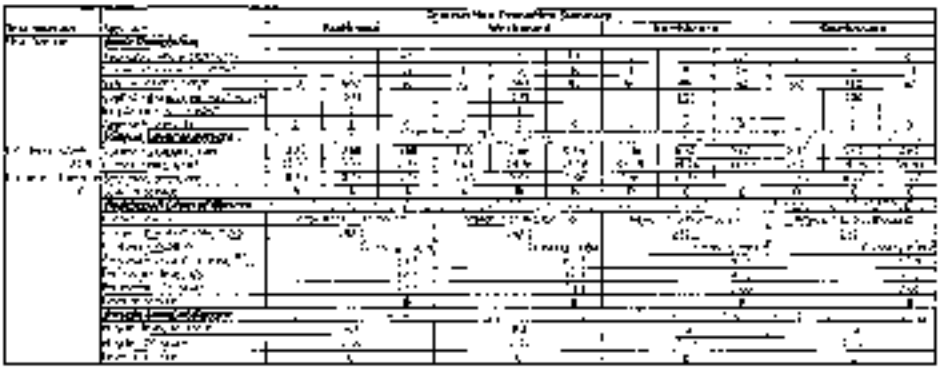

Exhibit 16-28
Example Problem 2: Intersection 1 Evaluation

Both exhibits indicate that the vehicular through movements on the facility (i.e., eastbound Movement 2 and westbound Movement 8) operate with low delay and few stops. For the eastbound through movement, the LOS is A at Intersection 1 and B at Intersection 5. The LOS is B for the westbound through movement at both intersections. Relative to Example Problem 1, the delay for the through movements has increased by a few seconds at Intersection 1 and by about 8 s at Intersection 5. This increase is sufficient to lower the LOS designation for the eastbound through movement at Intersection 5 (i.e., from A to B).

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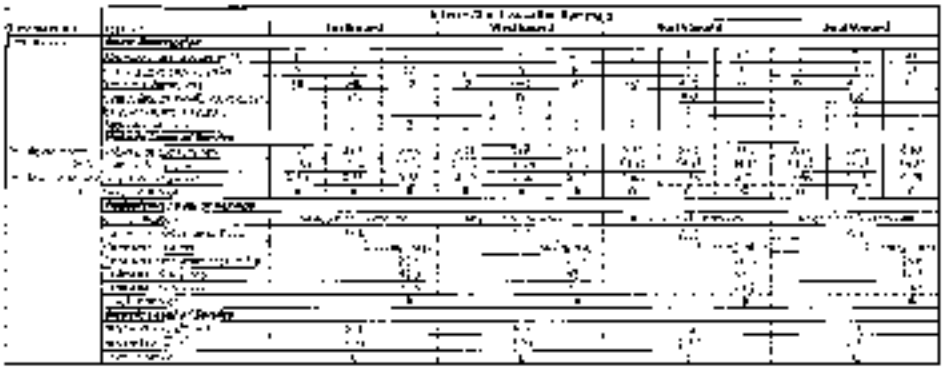
Exhibit 16-29
Example Problem 2:
Intersection 5 Evaluation



Pedestrian circulation area on the corners of Intersections 1 and 5 is generous, with few instances of conflict. This condition is greatly improved from Example Problem 1 and reflects the provision of wider sidewalks.

Relative to Example Problem 1, the reduction in through lanes has reduced the time provided to pedestrians to cross the major street. This reduction resulted in larger pedestrian groups using the crosswalk and a small reduction in crosswalk pedestrian space. At Intersection 1, pedestrian space is still generous, with few instances of conflict. At Intersection 5, the problem is amplified by a higher pedestrian demand. Pedestrian space in the crosswalks is constrained and pedestrians are likely to find that their ability to pass slower pedestrians is limited.

At each intersection, pedestrians experience an average wait of about 42 s at the corner to cross the street in any direction. This condition has not changed from Example Problem 1.

At both intersections, the pedestrian LOS is D for the major-street and minor-street crossings. Relative to Example Problem 1, the pedestrian LOS score has improved by about the same amount at all intersections. At Intersection 1, this change is sufficient to result in a change in service level (i.e., from C to D).

Bicyclists using the bicycle lanes are expected to see delayed about 8 s/bicycle on both the eastbound and westbound approaches to each intersection. This level of delay is desirably low. However, the bicycle lane is relatively narrow at 4 ft, which leads to LOS C on the eastbound and westbound approaches of both intersections. This LOS is noted to be an improvement over the LOS D identified in Example Problem 1.

Segment Evaluation

The results of the evaluation of Segment 1 (i.e., First Avenue to Second Avenue) are shown in Exhibit 16-30. The results for Segments 2 and 3 are similar. In contrast, Segments 4 and 5 are associated with a shorter segment length, lower speed limit, and higher pedestrian volume, so their operation is different from the other intersections. The results for Segment 5 (i.e., Fifth Avenue to Sixth Avenue) are shown in Exhibit 16-31. Segment 4 has similar results.

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Segment	Segment Evaluation Summary		
	Travel Direction	Eastbound	Westbound
First Avenue to Second Avenue	***Basic Description***		
	Speed limit, mi/h	35	35
	Vehicle volume, veh/h	970	910
	Through lanes, n	1	1
Segment length: 1,320 ft	***Vehicle Level of Service***		
	Base free-flow speed, mi/h	37.4	37.4
	Travel speed, mi/h	21.3	21.3
	Speed-change rate, stops/mi	2.63	2.87
	Level of service	C	C
	Pedestrian Level of Service		
	Pedestrian space, ft2/p	405.9	405.9
	Pedestrian flow speed, ft/s	4.4	4.4
	Pedestrian LOS score	2.24	2.21
	Level of service	B	B
	Bicycle Level of Service		
	Bicycle travel speed, mi/h	12.18	12.18
	Bicycle LOS score	1.27	1.27
	Level of service	D	D
	Transit Level of Service		
	Transit travel speed, mi/h	13.1	13.1
	Transit LOS score	1.42	1.42
	Level of service	C	C

Exhibit 16-30
Example Problem 2: Segment 1 Evaluation

Segment	Segment Evaluation Summary		
	Travel Direction	Eastbound	Westbound
Fifth Avenue to Sixth Avenue	***Basic Description***		
	Speed limit, mi/h	30	30
	Vehicle volume, veh/h	970	910
	Through lanes, n	1	1
Segment length: 660 ft	***Vehicle Level of Service***		
	Base free-flow speed, mi/h Travel speed, mi/h	29.5 15.7	29.5 15.7
	Speed-change rate, stops/mi	4.24	4.42
	Level of service	E	E
	Pedestrian Level of Service		
	Pedestrian space, ft2/p	220.4	220.4
	Pedestrian flow speed, ft/s	3.98	3.98
	Pedestrian LOS score Level of service	2.22 B	2.22 B
	Bicycle Level of Service		
	Bicycle travel speed, mi/h	11.25	11.25
	Bicycle LOS score	1.06	1.07
	Level of service	D	D
	Transit Level of Service		
	Transit travel speed, mi/h	13	13
	Transit LOS score Level of service	1.58 D	1.61 D

Exhibit 16-31
Example Problem 2: Segment 5 Evaluation

Exhibit 16-30 indicates that the vehicular through movements on Segment 1 in the eastbound and westbound travel directions have a travel speed of about 21 mi/h (i.e., about 57% of the base free-flow speed). LOS C applies to both movements. In contrast, Exhibit 16-31 indicates that the through movements have a travel speed of only about 15 mi/h on Segment 5 (i.e., 42% of the base free-flow speed), which is LOS E. Vehicles stop at a rate of about 2.8 stops/mi on Segment 1 and about 4.4 stops/mi on Segment 5. Relative to Example Problem 1, conditions have notably degraded for vehicles traveling along Segment 5.

Pedestrian space on the sidewalk along the segment is generous on Segment 1. Pedestrians can walk freely without having to alter their path to accommodate other pedestrians. Pedestrian space is adequate on Segment 5, with pedestrians in platoons occasionally needing to adjust their path to avoid conflict. These characterizations are based on Exhibit 16-31 and an assumed dominance of platoon flow for Segments 4 and 5. Relative to Example Problem 1, the sidewalks are more distant from the traffic lanes and crossing the street at a midsegment location is easier because of the paved curb median. As a result, the pedestrian LOS is B on all segments.

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bicyclists using the bicycle lanes experience a travel speed of 13 mi/h on Segment 1 and 12 mi/h on Segment 5. This travel speed is considered desirable. However, the bicycle lanes is relatively narrow at 4 ft, so a bicycle LOS D results for both directions of travel on each segment. While still poor, the bicycle LOS scores indicate that bicycle service has improved on both segments relative to that found in Example Problem 1. In fact, the bicycle LOS on Segment 5 has improved by one letter designation.

Transit travel speed is 10 mi/h on Segment 1 and corresponds to a LOS C. On Segment 5, the travel speed is about 5 mi/h and 13 mi/h in the eastbound and westbound directions, respectively. The low speed for the eastbound direction results in a LOS D. The higher speed for the westbound direction is due to the lack of a westbound transit stop on Segment 5. It results in a LOS C. Relative to Example Problem 1, the slower vehicular travel speed has increased the transit LOS scores, but not enough to change the designated service level.

Facility Evaluation

The methodology described in Section 2 is used to compute the aggregate performance measures for each travel direction along the facility. The results are shown in Exhibit 16-42. This exhibit indicates that the vehicle travel speed is about 26 mi/h in each travel direction (or 49% of the base free-flow speed). An overall LOS D applies to vehicle travel in each direction on the facility. It is noted that LOS E applies to Segments 4 and 5. Vehicles incur stops along the facility at a rate of about 2.6 stops/mi. Relative to Example Problem 1, vehicular travel speed has dropped about 4 mi/h, and LOS has degraded one level for this scenario.

Exhibit 16-32
Example Problem 2: Facility evaluation

	Facility Evaluation Summary		
	Travel Direction	Eastbound	Westbound
[illegible]	***Vehicle Level of Service***		
	Segment travel speed, mi/h	26.4	26.4
	Travel speed, mi/h	18.0	16.1
	Spatial stop rate, stops/mi	2.64	2.62
	Level of service	D	D
	Segment performance LOS	E	E
	Pedestrian Level of Service		
	Pedestrian space, ft²/p	422.2	422.2
	Pedestrian travel speed, mi/h	3.4	3.4
	Pedestrian flow rate, p/min/ft	2.64	2.64
	Level of service	B	B
	Segment performance LOS	B	B
	Bicycle Level of Service		
	Bicycle travel speed, mi/h	12.8	12.1
	Bicycle LOS score	3.61	3.93
	Level of service	D	D
	Segment performance LOS	D	D
	Transit Level of Service		
	Transit flow speed, mi/h	9.7	4.2
	Transit LOS score	1.48	3.44
	Level of service	C	E
	Segment performance LOS	C	E

Pedestrian space on the sidewalk along the facility is generous. Pedestrians on the sidewalks can walk freely without having to alter their path to accommodate other pedestrians. Increasing the separation between the sidewalk and traffic lanes and improving pedestrians' ability to cross the street at midsegment locations (by adding a raised-curb median) have resulted in an

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overall pedestrian LOS E for both directions of travel. This level compares favorably with the LOS D indicated in Example Problem 1.

Bicyclists within the bicycle lanes are estimated to experience an average travel speed of about 13 mi/h. This travel speed is considered desirable. However, the 4-ft bicycle lane is relatively narrow and produces LOS D. This level is one level improved over that found for Example Problem 1.

Transit travel speed is about 8 mi/h on the facility in each direction of travel. An overall LOS C is assigned to each direction. Relative to Example Problem 1, the LOS designation is unchanged, however, the transit speed is slower, and the transit LOS score indicates a small reduction in service.

EXAMPLE PROBLEM 3: PEDESTRIAN AND PARKING IMPROVEMENTS

The Urban Street Facility

The 1-mi urban street facility shown in Exhibit 16-16 is being considered for geometric design modifications to improve parking and pedestrian service. The following changes to the facility are proposed:

- Eliminate one vehicle lane in each direction,
- Add a 12-ft raised-curb median,
- Add a 9-ft parking lane in each direction, and
- Increase the total walkway width to 7 ft.

No fixed objects will be located along the outside of the sidewalk. The on-street parking is expected to be occupied 50% of the time. Parking maneuvers are estimated to cause 1.8 s/veh additional delay on Segments 1, 2, and 3. On Segments 4 and 5, these maneuvers are estimated to cause 0.3 s/veh additional delay. The analysis for Example Problem 3 represents the existing condition, against which this alternative will be evaluated.

The geometry of the typical street segment is shown in Exhibit 16-33. It is the same for each segment. Additional segment details are provided in the discussion for Example Problem 1.

The Question

What are the travel speed and LOS of the automobile, pedestrian, bicycle, and transit modes in both directions of travel along the facility?

The Facts

The traffic counts, signalization, and intersection geometry are listed in Exhibit 16-36 to Exhibit 16-37. They are unchanged from Example Problem 1.

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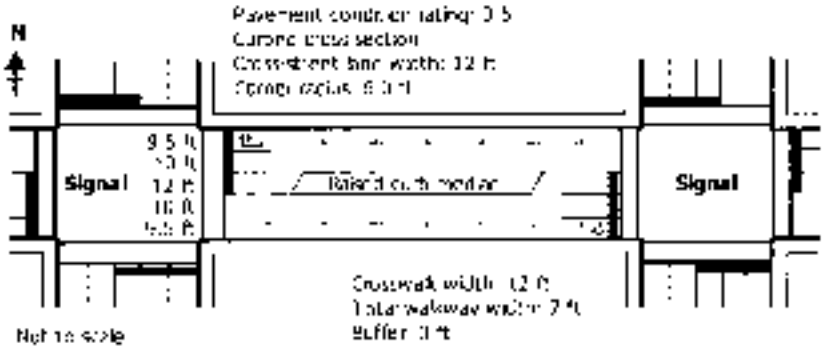
Exhibit 16-33
Example Problem 3:
Segment Geometry



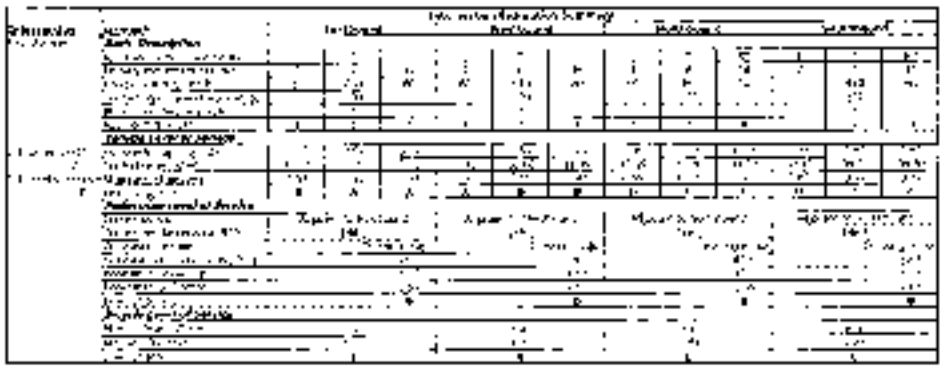
Outline of Solution

This section outlines the results of the facility evaluation. To complete this evaluation, the automobile, pedestrian, and bicycle methodologies in Chapter 18 were used to evaluate each of the signalized intersections on the facility. The procedure in Chapter 19 was used to estimate pedestrian delay when crossing at a midsegment location. The automobile, pedestrian, bicycle, and transit methodologies in Chapter 17 were then used to evaluate both directions of travel on each segment. Finally, the methodologies described in Section 2 were used to evaluate all four travel modes in both directions of travel on the facility. The findings from each evaluation are summarized in the following three subparts.

Intersection Evaluation

The results of the evaluation of Intersection 2 (i.e., First Avenue) are shown in Exhibit 16-34. The results for Intersections 2, 5, and eastbound Intersection 4 are similar. In contrast, Intersections 5 and 6 are associated with a shorter segment length, lower speed limit, and higher pedestrian volumes, so their operation is different from that of the other intersections. The results for Intersection 5 (i.e., Fifth Avenue) are shown in Exhibit 16-35. Intersection 6 and westbound Intersection 4 have similar results.

Exhibit 16-34
Example Problem 3:
Intersection 1 Evaluation



Both exhibits indicate that the vehicular through movements on the facility (i.e., eastbound Movement 2 and westbound Movement 6) operate with very low delay and few stops. For the eastbound through movement, the LOS is A at Intersection 1 and B at Intersection 5. The LOS is B for the westbound through movement at both intersections. Relative to Example Problem 1, the delay for the

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through movements has increased by a few seconds at both intersections. However, this increase is sufficient to lower the LOS designation for only the eastbound through movement at Intersection 5.

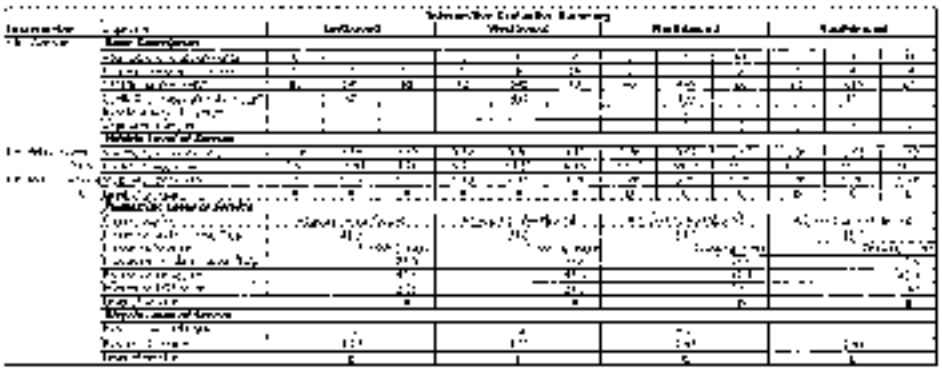

Exhibit 16-35
Example Problem 3: Intersection 5 Evaluation

Pedestrian circulation area on the corners of Intersection 1 is generous. However, corner circulation area at Intersection 5 is constrained, with pedestrians frequently needing to adjust their path to avoid slower pedestrians. Regardless, this condition is improved from Example Problem 1 and reflects the provision of wider sidewalks.

Relative to Example Problem 1, the reduction in lanes has reduced the time provided to pedestrians to cross the major street. This reduction resulted in larger pedestrian groups using the crosswalk and a slight reduction in crosswalk pedestrian space. At Intersection 1, pedestrian space is generous. However, pedestrian space is constrained at Intersection 5, with pedestrians having limited ability to pass slower pedestrians as they cross the street.

At each intersection, pedestrians experience an average wait of about 42 s at the corner to cross the street in any direction. At both intersections, the pedestrian LOS is D for the major-street crossing and the minor-street crossing. The LOS designation has improved at Intersection 1 by one letter, relative to Example Problem 1, and remains unchanged at Intersection 5.

Bicycle lanes are not provided at any intersection, so bicycle delay is not computed. The lack of a bicycle lane combined with a high traffic volume results in a bicycle LOS E on the eastbound and westbound approaches of Intersection 1 and Intersection 5. This level is rated to be worse than the LOS D identified in Example Problem 1 because the traffic volume per lane has doubled.

Segment Evaluation

The results of the evaluation of Segment 1 (i.e., First Avenue to Second Avenue) are shown in Exhibit 16-36. The results for Segments 2 and 3 are similar. In contrast, Segments 4 and 5 are associated with a shorter segment length, lower speed limit, and higher pedestrian volume, so their operation is different from that of the other intersections. The results for Segment 5 (i.e., Fifth Avenue to Sixth Avenue) are shown in Exhibit 16-37. Segment 4 has similar results.

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Exhibit 16-36
Example Problem 3: Segment 1 Evaluation

Segment	Segment Evaluation Summary Travel Direction	Eastbound	Westbound
1 (Arterial Segment Segment length, ft 1,320	***Basic Description***		
	Speed limit, mi/h	35	35
	Vehicle volume, veh/h	500	500
	Through lanes, n	1	1
	Vehicle Level of Service		
	Base free-flow speed, mi/h	37.4	37.4
	Free-flow speed, mi/h	29.8	29.8
	Spatial flow rate, veh/h/ln	2.46	2.46
	Level of service	E	E
	Pedestrian Level of Service		
	Pedestrian space, ft/p/min	11.5	11.5
	Pedestrian travel speed, mi/h	3.00	3.00
	Pedestrian LOS score	2.59	2.59
	Level of service	C	C
	Bicycle Level of Service		
	Bicycle flow rate, veh/h	No bicycle lane	No bicycle lane
	Bicycle LOS score	4.70	4.70
	Level of service	E	E
	Transit Level of Service		
	Transit travel speed, mi/h	13.5	13.5
	Transit LOS score	1.38	1.41
	Level of service	C	C

Exhibit 16-37
Example Problem 3: Segment 3 Evaluation

Segment	Segment Evaluation Summary Travel Direction	Eastbound	Westbound
Fifth Avenue North Avenue Segment length, ft 600	***Basic Description***		
	Speed limit, mi/h	35	35
	Vehicle volume, veh/h	500	500
	Through lanes, n	1	1
	Vehicle Level of Service		
	Base free-flow speed, mi/h	37.5	37.5
	Free-flow speed, mi/h	29.9	29.9
	Spatial flow rate, veh/h/ln	2.50	2.50
	Level of service	D	D
	Pedestrian Level of Service		
	Pedestrian space, ft/p/min	60.0	60.0
	Pedestrian travel speed, mi/h	3.00	3.00
	Pedestrian LOS score	1.27	1.27
	Level of service	C	C
	Bicycle Level of Service		
	Bicycle flow rate, veh/h	No bicycle lane	No bicycle lane
	Bicycle LOS score	4.94	4.94
	Level of service	E	E
	Transit Level of Service		
	Transit travel speed, mi/h	9.2	9.2
	Transit LOS score	1.04	1.01
	Level of service	D	C

Exhibit 16-36 indicates that the vehicular through movements on Segment 1 in the eastbound and westbound travel directions have a travel speed of about 30 mi/h (or, about 80% of the base free-flow speed). LOS C applies to both movements. In contrast, Exhibit 16-37 indicates that the through movements have a travel speed of only about 25 mi/h on Segment 3 (or 42 % of the base free-flow speed), which is LOS D. Vehicles stop at a rate of about 2.1 stops/mi on Segment 1 and about 3.5 stops/mi on Segment 3. Relative to Example Problem 2, conditions have degraded for vehicles traveling along these segments, but not enough to drop the LOS designation.

Pedestrian space on the sidewalk along the segment is generous on Segment 1 and adequate on Segment 3. These characterizations are based on Exhibit 16-11 and are assumed dominance of platoon flow for Segments 1 and 3. Pedestrians on these sidewalks can walk freely without having to alter their path to accommodate other pedestrians. Relative to Example Problem 1, the sidewalks are more distant from the traffic lanes, and crossing distances at a mid-segment location is easier because of the raised curb medians. As a result, the pedestrian LOS is improved on all segments (i.e., from LOS D to C).

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Bicycle lanes are not provided along the segment, so bicycle travel speed is not computed. The lack of a bicycle lane combined with a high traffic volume results in a bicycle LOS F for both directions of travel on Segment 1 and Segment 5. Relative to Example Problem 1, conditions have degraded for bicyclists on all segments, and the LOS for Segment 1 has dropped by one level. This reduction in service is due largely to the increased density of vehicles in the mixed traffic lanes.

Transit travel speed is about 10 mi/h on Segment 1 and corresponds to LOS C. On Segment 5, the travel speed is about 6 mi/h and 14 mi/h in the eastbound and westbound directions, respectively. The low speed for the eastbound direction results in LOS D. The higher speed for the westbound direction is due to the lack of a westbound transit stop on Segment 5. It results in LOS C. Relative to Example Problem 1 the slower travel speed has increased the transit LOS scores, but not enough to change the designated service level.

Facility Evaluation

The methodology described in Section 2 is used to compute the aggregate performance measures for each travel direction along the facility. The results are shown in Exhibit 16-38. This exhibit indicates that the vehicle travel speed is about 19 mi/h in each travel direction (or 70% of the base free-flow speed). An overall LOS C applies to both vehicular movements on the facility; however, it is noted that LOS D applies to Segments 4 and 5. Vehicles incur stops along the facility at a rate of about 2.3 stops/mi. Relative to Example Problem 1, vehicular LOS has degraded, but not enough to drop the LOS designation.

Exhibit 16-38
Example Problem 4: Facility Evaluation

Facility Evaluation Summary			
	Travel direction	Eastbound	Westbound
Facility length, ft (5,280)	Base free-flow speed, mi/h	27.0	25.8
	Travel speed, mi/h	18.7	19.5
	Signalized intersection density, int/mi	2.11	2.11
	Level of service	C	C
	Percent perf. segment LOS	D	D
	Pedestrian space, ft²/p	181.7	202.1
	Pedestrian travel speed, mi/h	3.9	4.1
	Pedestrian LOS score	2.68	2.48
	Level of service	C	C
	Percent perf. segment LOS	C	C
	Bicycle flow rate, veh/h	96 bicycles/h	56 bicycles/h
	Bicycle LOS score	4.76	4.75
	Level of service	F	F
	Percent perf. segment LOS	F	F
	Transit travel speed, mi/h	10.3	13.7
	Transit LOS score	3.07	2.38
	Level of service	C	C
	Percent perf. segment LOS	D	D

Pedestrian space on the sidewalk along the facility is generous. Pedestrians on the sidewalks can walk freely without having to alter their path to accommodate other pedestrians. Increasing the separation between the sidewalk and traffic lanes and improving pedestrians' ability to cross the street (by adding a raised-curb median) result in an overall pedestrian LOS C for both directions of travel. This level compares favorably with the LOS D indicated in Example Problem 1.

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Bicycle lanes are not provided along the facility, so bicycle travel speed is not computed. The lack of a bicycle lane, combined with a high traffic volume results in an overall bicycle LOS E for both directions of travel. Conditions have degraded slightly, relative to Example Problem 1, but not enough to drop the LOS designation.

Transit travel speed is about 10 mi/h on the facility in each direction of travel. An overall LOS C is assigned to each direction. Conditions have degraded slightly, relative to Example Problem 1, but not enough to drop the transit LOS designation.

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These references are available in the Technical Reference Library in volume 4.

1. Bonneson, J. A., M. P. Pratt, and M. A. Vandehey. *Predicting the Performance of Automobile Traffic on Urban Streets: Final Report*. National Cooperative Highway Research Program Project 3-79. Texas Transportation Institute, Texas A&M University, College Station, Jan. 2008.
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3. Kittelson & Associates, Inc.; KFH Group, Inc.; Parsons Brinckerhoff Quade and Douglass, Inc.; and K. Hunter-Zaworski. *TCRP Report 100: Transit Capacity and Quality of Service Manual*, 2nd ed. Transportation Research Board of the National Academies, Washington, D.C., 2003.

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CHAPTER 17
URBAN STREET SEGMENTS

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1. INTRODUCTION

VOLUME 2: UNINTERRUPTED FLOW
16. Urban Street Facilities
17. Urban Street Segments
18. Signalized Intersections
19. TWSC Intersections
20. AWSC Intersections
21. Roundabouts
22. Interchange Ramp Terminals
23. Off-Street Pedestrian and Bicycle Facilities

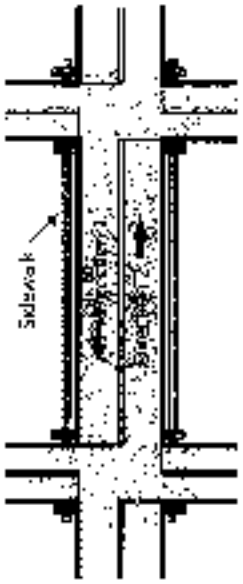
Chapter 17, Urban Street Segments, describes a methodology for evaluating the capacity and quality of service provided to road users traveling along an urban street segment. However, the methodology is much more than just a tool for evaluating capacity and quality of service. The methodology includes an array of performance measures that more fully describe segment operation for multiple travel modes. These measures serve as a basis in identifying the source of problems and provide insight into the development of effective improvement strategies. The analyst is encouraged to consider the full range of measures when using this methodology.

OVERVIEW OF THE METHODOLOGY

This chapter's methodology is applicable to an urban or suburban street segment. The segment can be part of an arterial or collector street with one-way or two-way vehicular traffic flow. The intersections on the segment can be signalized or unsignalized.

Analysis Boundaries

The segment analysis boundary is defined by the roadway right-of-way and the operational influence area of each boundary intersection. The influence area of a boundary intersection extends backward from the intersection on each intersection leg. The size of this area is location specific and includes the most distant extent of any intersection related queue expected to occur during the study period. For these reasons, the analysis boundaries should be established for each intersection on the basis of the conditions present during the analysis period. Practically speaking, the influence area should extend at least 250 ft back from the stop line on each intersection leg.



Analysis Level

Analysis level describes the level of detail used in applying the methodology. Three levels are recognized:

- Operational,
- Design, and
- Planning and preliminary engineering.

The operational analysis is the most detailed application and requires the most information about the traffic, geometric, and signalization conditions. The design analysis also requires detailed information about the traffic conditions and the desired level of service (LOS) as well as information about either the geometric or signalization conditions. The design analysis then seeks to determine reasonable values for the conditions not provided. The planning and preliminary engineering analysis requires only the most fundamental types of information from the analyst. Default values are then used as substitutes for other input data. The subject of analysis level is discussed in more detail in the Applications section of this chapter.

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Study Period and Analysis Period

The study period is the time interval represented by the performance evaluation. It consists of one or more consecutive analysis periods. An analysis period is the time interval evaluated by a single application of the methodology.

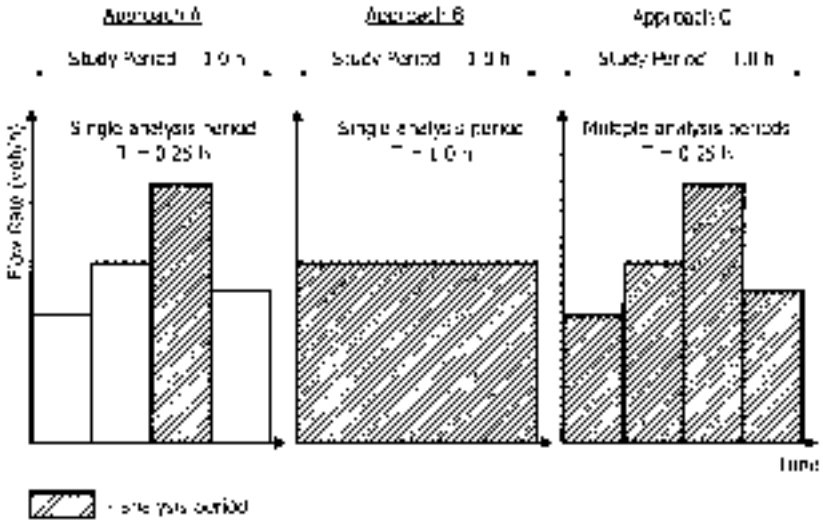
The methodology is based on the assumption that traffic conditions are steady during the analysis period (i.e., systematic change over time is negligible). For this reason, the duration of the analysis period is in the range of 0.25 to 1 h. The longer durations in this range are sometimes used for planning analyses. In general, the analyst should use caution with analysis periods that exceed 1 h because traffic conditions are not typically steady for long time periods and because the adverse impact of short peaks in traffic demand may not be detected in the evaluation.

If an analysis period of interest has a demand volume that exceeds capacity, then the study period should include an initial analysis period with no initial queue and a final analysis period with no residual queue. This approach provides a more accurate estimate of the delay associated with the congestion.

If evaluation of multiple analysis periods is determined to be important, then the performance estimates for each period should be separately reported. In this situation, reporting an average performance for the study period is not encouraged because it may obscure extreme values and suggest acceptable operation when actually some analysis periods have unacceptable operations.

Exhibit 17-1 demonstrates three alternative approaches an analyst might use for a given evaluation. Note that other alternatives exist and that the study period ran current 1 h. Approach A is the one that has traditionally been used and, unless otherwise justified, is the one that is recommended for use.

Exhibit 17-1
Three Alternative Study Approaches



Approach A is based on the evaluation of the peak 15-min period during the study period. The analysis period T is 0.25 h. The equivalent hourly flow rate used for the analysis is based on either a peak 15 min traffic count multiplied by four or a 1 h demand volume divided by the peak hour factor. The former option is preferred whenever traffic counts are available. The peak hour factor equals

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the hourly count of vehicles divided by four times the peak 15-min count for a common hour interval. It is provided by the analyst or operating agency.

Approach B is based on the evaluation of one 1-h analysis period that is coincident with the study period. The analysis period T is 1.0 h. The flow rate used is equivalent to the 1-h demand volume (i.e., the peak hour factor is not used). This approach implicitly assumes that the arrival rate of vehicles is constant throughout the period of study. Therefore, the effects of peaking within the hour may not be identified, and the analyst risks underestimating the delay actually incurred.

Approach C uses a 1-h study period and divides it into four 0.25-h analysis periods. This approach accounts for systematic flow rate variation among analysis periods. It also accounts for queues that carry over to the next analysis period and produces a more accurate representation of delay.

Performance Measures

A street segment's performance is described by the use of one or more quantitative measures that characterize some aspect of the service provided to a specific road user group. Performance measures cited in this chapter include automobile travel speed, automobile stop rate, automobile traveler perception score, pedestrian travel speed, pedestrian space, pedestrian perception score, bicycle travel speed, bicycle perception score, transit vehicle travel speed, transit walk-side score, and transit passenger perception score.

LOS is also considered a performance measure. It is computed for the automobile, pedestrian, bicycle, and transit travel modes. It is useful for describing segment performance to elected officials, policy makers, administrators, or the public. LOS is based on one or more of the performance measures listed in the previous paragraph.

Travel Modes

This chapter describes a separate methodology for evaluating urban street performance from the perspective of motorists, pedestrians, bicyclists, or transit passengers. These methodologies are referred to as the automobile methodology, pedestrian methodology, bicycle methodology, and transit methodology.

Each methodology consists of a set of procedures for computing the quality of service provided to one mode. Collectively, they can be used to evaluate the urban street segment operation from a multimodal perspective.

Each methodology is focused on the evaluation of a street segment, with consideration given to the intersections that bound it. The aggregation of segment performance measures to obtain an estimate of facility performance is described in Chapter 16, Urban Street Facilities. Methodologies for evaluating the intersections on the urban street are described in Chapters 18 to 22.

The four methodologies described in this chapter are based largely on the products of two National Cooperative Highway Research Program projects (1, 2). Contributions to the methodology from other research are referenced in the relevant sections.

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The transit methodology described in this chapter is applicable to the evaluation of passenger service provided by local public transit vehicles operating in mixed traffic or exclusive lanes and stopping along the street. Nonlocal transit vehicle speed and delay are evaluated by using the automobile methodology.

The phrase *automobile mode*, as used in this chapter, refers to travel by all motorized vehicles that can legally operate on the street, with the exception of local transit vehicles that stop to pick up passengers along the street. Unless explicitly stated otherwise, the word *vehicle* refers to motorized vehicles and includes a mixed stream of automobiles, motorcycles, trucks, and buses.

Lane Groups and Movement Groups

Lane group and *movement group* are phrases used to define combinations of intersection movements for the purpose of evaluating signalized intersection operation. These two terms are used extensively in Chapter 18, Signalized Intersections. They are also used in this chapter when the boundary intersection is signalized.

The automobile methodology in Chapter 18 is designed to evaluate the performance of designated lanes, groups of lanes, an intersection approach, and the entire intersection. A lane or group of lanes designated for separate analysis is referred to as a *lane group*. In general, a separate lane group is established for (*a*) each lane (or combination of adjacent lanes) that exclusively serves one movement and (*b*) each lane shared by two or more movements.

The concept of *movement groups* is also established to facilitate data entry. A separate movement group is established for (*a*) each turn movement with one or more exclusive turn lanes and (*b*) the through movement (inclusive of any turn movements that share a lane).

URBAN STREET SEGMENT DEFINED

For the purpose of analysis, the roadway is separated into individual elements that are physically adjacent and operate as a single entity in serving travelers. Two elements are commonly found on an urban street system: points and links. A *point* represents the boundary between links and is represented by an intersection or ramp terminal. A *link* represents a length of roadway between two points. A link and its boundary points are referred to as a *segment*.

Previous editions of this manual have allowed the evaluation of one direction of travel along a segment (even when it served two-way traffic). This approach is retained in this chapter for the analysis of bicycle and transit performance. For the analysis of pedestrian performance, this approach translates into the evaluation of sidewalk and street conditions on one side of the segment.

For the automobile methodology, a segment evaluation considers both directions of travel when the street serves two-way traffic.

For the analysis of automobile performance, an analysis of only one travel direction (when the street serves two-way traffic) does not adequately recognize the interactions between vehicles at the boundary intersections and their influence on segment operation. For example, the automobile methodology in this edition of the *Highway Capacity Manual* (HCM) explicitly models the platoon

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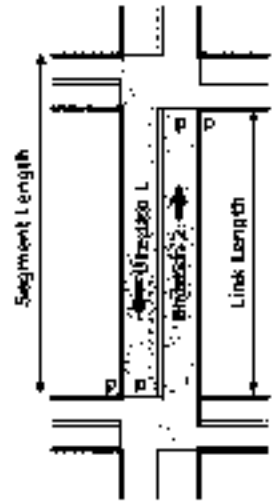
formed by the signal at one end of the segment and its influence on the operation of the signal at the other end of the segment. For these reasons, it is important to evaluate both travel directions on a two-way segment.

Points and Segments

The link and its boundary points must be evaluated together to provide an accurate indication of overall segment performance. For a given direction of travel along the segment, link and downstream point performance measures are combined to determine overall segment performance.

A segment performance measure considers link performance and point performance



If the subject segment is within a coordinated signal system, then the following rules apply when the segment boundaries are identified:

- A signalized intersection (or ramp terminal) is always used to define a segment boundary.
- Only intersections (or ramp terminals) at which the segment through movement is uncontrolled (e.g., a two-way stop-controlled intersection) can exist along the segment between the boundaries.

If the subject segment is not within a coordinated signal system, then the following rules apply when the segment boundaries are identified:

- An intersection (or ramp terminal) having a type of control that can impose on the segment through movement a legal requirement to stop or yield must always be used to define a segment boundary.
- An intersection (or ramp terminal) at which the segment through movement is uncontrolled (e.g., a two-way stop-controlled intersection) may be used to define a segment boundary, but it is typically not done.

A midsegment traffic control signal provided for the exclusive use of pedestrians should not be used to define a segment boundary. This restriction reflects the fact that the methodologies described here were derived for, and calibrated with data from, street segments bounded by an intersection.

An access point intersection is an unsignalized intersection with one or two access point approaches to the segment. The approach can be a driveway or a public street. The through movements on the segment are uncontrolled at an access point intersection.

Segment Length Considerations

When a segment has a "short" length, then the interaction between traffic movements and traffic control devices at the two boundary intersections is sufficiently complex that a separate analysis of each element will not provide an accurate estimation of urban street performance. This complication can occur regardless of the type of control present at the two boundary intersections; however, it is particularly complicated when the two intersections are signalized. The automobile methodology described in this chapter is not appropriate for the analysis of short segments. In contrast, the methodology described in Chapter 23, Interchange Ramp Terminals, is appropriate for the analysis of short segments at signalized interchanges.

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It is difficult to define specific conditions under which a segment is short. However, two general rules apply in making this determination. First, a segment is considered to be short if the queue frequently extends back from one intersection into the other intersection (i.e., spills back) during the analysis period. Second, a segment is considered to be short if the through signal phase duration at the downstream intersection is longer than that needed to serve all the vehicles that store on the segment plus any vehicles that can enter it from the upstream signalized intersection while the downstream phase is green. This situation results in "demand starvation." It leads to the inefficient use of the downstream through phase and the retention of unserved vehicles on the approaches to the upstream intersection. In general, segments that are bounded by signalized intersections and are shorter than 400 ft may experience one or both of these conditions.

Platoons formed at a signalized intersection are typically dispersed by the time they reach a point about 0.6 mi downstream of the signal. This distance can vary depending on the amount of access point activity along the street and the speed of the traffic stream. Regardless, the influence of platoons on urban street operation is very likely to be negligible when segment length exceeds 2 mi. Therefore, if a segment exceeds 2 mi in length and its boundary points are signalized, then the analyst should evaluate the segment as an uninterrupted-flow highway segment with isolated intersections.

LOS CRITERIA

This subsection describes the LOS criteria for the automobile, pedestrian, bicycle, and transit modes. The criteria for the automobile mode are different from the criteria used for the nonautomobile modes. Specifically, the automobile mode criteria are based on performance measures that are field measurable and perceivable by travelers. The criteria for the pedestrian and bicycle modes are based on scores reported by travelers indicating their perception of service quality. The criteria for the transit mode are based on measured changes in transit patronage due to changes in service quality.

Automobile Mode

All uses of the word "volume" in the phrase "volume-to-capacity ratio" in this chapter refer to demand volume or demand flow rate—capacity ratio.

Two performance measures are used to characterize vehicular LOS for a given direction of travel along an urban street segment. One measure is travel speed for through vehicles. This speed reflects the factors that influence running time along the link and the delay incurred by through vehicles at the boundary intersection. The second measure is the volume-to-capacity ratio for the through movement at the downstream boundary intersection. These performance measures indicate the degree of mobility provided by the segment. The following paragraphs characterize each LOS level.

LOS A describes primarily free-flow operation. Vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Control delay at the boundary intersection is minimal. The travel speed exceeds 85% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS B describes reasonably unimpeded operation. The ability to maneuver within the traffic stream is only slightly restricted, and control delay at the

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boundary intersection is not significant. The travel speed is between 67% and 85% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS C describes stable operation. The ability to maneuver and change lanes at mid-segment locations may be more restricted than at LOS B. Longer queues at the boundary intersection may contribute to lower travel speeds. The travel speed is between 50% and 67% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS D indicates a less stable condition in which small increases in flow may cause substantial increases in delay and decreases in travel speed. This operation may be due to adverse signal progression, high volume, or inappropriate signal timing at the boundary intersection. The travel speed is between 41% and 50% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS E is characterized by unstable operation and significant delay. Such operations may be due to some combination of adverse progression, high volumes, and inappropriate signal timing at the boundary intersection. The travel speed is between 30% and 40% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS F is characterized by flow at extremely low speed. Congestion is likely occurring at the boundary intersection, as indicated by high delay and extensive queuing. The travel speed is 30% or less of the base free-flow speed, or the volume-to-capacity ratio is greater than 1.0.

Exhibit 17-2 lists the LOS thresholds established for the automobile mode on urban streets.

Exhibit 17-2
LOS Criteria: Automobile Mode

Travel Speed as a Percentage of Base Free-Flow Speed (%)	LOS by Volume-to-Capacity Ratio[a]	
	≤1.0	> 1.0
>85	A	F
>67–85	B	F
>50–67	C	F
>40–50	D	F
>30–40	E	F
≤30	F	F

Note: [a]Volume-to-capacity ratio of through movement at downstream boundary intersection.

Nonautomobile Modes

Historically, this manual has used a single performance measure as the basis for defining LOS. However, research documented in Chapter 5, Quality and Level-of-Service Concepts, indicates that travelers consider a wide variety of factors when they assess the quality of service provided to them. Some of these factors can be described as performance measures (e.g., speed), and others can be described as basic descriptions of the urban street character (e.g., sidewalk width). The methodology for evaluating each mode provides a procedure for mathematically combining these factors into a score. This score is then used to determine the LOS that is provided for a given direction of travel along a segment.

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Exhibit 17-3 lists the scores associated with each LOS for the pedestrian travel mode. The LOS for this particular mode is determined by consideration of both the LOS score and the average pedestrian space on the sidewalk. The applicable LOS for an evaluation is determined from the table by finding the intersection of the row corresponding to the computed score value and the column corresponding to the computed space value.

Exhibit 17-3
LOS Criteria: Pedestrian Mode

Pedestrian LOS Score	LOS by Average Pedestrian Space (ft^2/p)					
	>60	>40–60	>24–40	>15–24	>8.0–15*	≤ 8.0*
≤2.00	A	B	C	D	L	F
>2.00–2.75	B	B	C	D	F	F
>2.75–3.50	C	C	C	D	E	F
>3.50–4.25	D	D	D	D	L	F
>4.25–5.00	E	E	E	E	E	F
>5.00	F	F	F	F	F	F

Note: *For crosswalk locations, the LOS F threshold is 15 ft²/p.

The association between LOS score and LOS is based on traveler perception research. Travelers were asked to rate the quality of service associated with a specific trip along an urban street. The letter "A" was used to represent the "best" quality of service, and the letter "F" was used to represent the "worst" quality of service. "Best" and "worst" were left undefined, allowing the respondents to identify the best and worst conditions on the basis of their traveling experience and perception of service quality.

Exhibit 17-4 lists the range of scores that are associated with each LOS for the bicycle and transit modes. This exhibit is also applicable for determining pedestrian LOS when a sidewalk is not available.

Exhibit 17-4
LOS Criteria: Bicycle and Transit Modes

LOS	LOS Score
A	≤2.00
B	>2.00–2.75
C	>2.75–3.50
D	>3.50–4.25
E	>4.25–5.00
F	>5.00

REQUIRED INPUT DATA

This subsection describes the required input data for the automobile, pedestrian, bicycle, and transit methodologies. Default values for some of these data are described in Section 3, Applications.

Automobile Mode

This part describes the input data needed for the automobile methodology. The data are listed in Exhibit 17-5 and are identified as "input data elements." They must be separately specified for each direction of travel on the segment and for each boundary intersection.

The last column in Exhibit 17-5 indicates whether the input data are needed for a movement group at a boundary intersection, the overall intersection, or the segment. The input data needed to evaluate the boundary intersections are identified in the appropriate chapter (i.e., Chapters 18 to 22).

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The data elements listed in Exhibit 17-5 do not include variables that are considered to represent calibration factors (e.g., acceleration rate). Default values are provided for these factors because they typically have a relatively narrow range of reasonable values or they have a small impact on the accuracy of the performance estimates. The recommended value for each calibration factor is identified at relevant points in the presentation of the methodology.

Exhibit 17-5
Input Data Requirements: Automobile Mode

Data Category	Location	Input Data Element	Basis
Traffic characteristics	Boundary intersection	Demand flow rate	Movement group
	Segment	Access point flow rate	Movement group
		Midsegment flow rate	Segment
Geometric design	Boundary intersection	Number of lanes	Movement group
		Upstream intersection width	Intersection
		Turn bay length	Segment approach
	Segment	Number of through lanes	Segment
		Number of lanes at access points	Segment approach
		Turn bay length at access points	Segment approach
		Segment length	Segment
		Restrictive median length	Segment
		Proportion of segment with curb	Segment
		Number of access point approaches	Segment
Other	Segment	Analysis period duration	Segment
		Speed limit	Segment
Performance measures	Boundary intersection	Through control delay	Through-movement group
		Through stopped vehicles	Through movement group
		2nd- and 3rd-term back-of-queue size	Through-movement group
		Capacity	Movement group
	Segment	Midsegment delay	Segment
		Midsegment stops	Segment

Notes: Movement group = one value for each turn movement with exclusive lanes and one value for the through movement (inclusive of any turn movements in a shared lane).
Through-movement group = one value for the segment through movement at the downstream boundary intersection (inclusive of any turn movements in a shared lane).
Segment = one value or condition for each direction of travel on the segment.
Segment approach = one value or condition for each intersection approach on the subject segment.

Traffic Characteristics Data

This subpart describes the traffic characteristics data listed in Exhibit 17-5. These data describe the motorized vehicle traffic stream traveling along the street during the analysis period.

Demand Flow Rate

The demand flow rate for an intersection traffic movement is defined as the count of vehicles arriving at the intersection during the analysis period, divided by the analysis period duration. It is expressed as an hourly flow rate, but it may be present for analysis periods shorter than 1 h. Guidance for estimating this rate is provided in the chapter that corresponds to the boundary intersection configuration (i.e., Chapters 18 to 22).

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Access Point Flow Rate

The access point flow rate is defined as the count of vehicles arriving at an access point intersection during the analysis period, divided by the analysis period duration. It is expressed as an hourly flow rate, but it may represent an analysis period shorter than 1 h. It should represent a demand flow rate. It is needed for all intersecting movements at each active access point intersection.

An access point approach is considered to be *active* if it has sufficient volume to have some impact on segment operations during the analysis period. As a rule of thumb, an access point approach is considered active if it has an entering flow rate of 10 vehicles per hour (veh/h) or more during the analysis period.

If the segment has many access point intersections that are considered inactive but collectively have some impact on traffic flow, these intersections can be combined into one equivalent active access point intersection. Each nonpriority movement at the equivalent access point intersection has a flow rate that is equal to the sum of the corresponding nonpriority movement flow rates of each of the individual inactive access points.

There is one exception to the aforementioned definition of access point flow rate. Specifically, if a planning analysis is being conducted in which (*a*) the projected demand coincides with a 1-h period and (*b*) an analysis of the peak 15 min period is desired, then each movement's hourly demand can be divided by the intersection peak hour factor to predict the flow rate during the peak 15-min period. The peak hour factor used should be based on local traffic peaking trends.

Midsegment Flow Rate

The midsegment flow rate is defined as the count of vehicles traveling along the segment during the analysis period, divided by the analysis period duration. It is expressed as an hourly flow rate, but it may represent an analysis period shorter than 1 h. This volume is specified separately for each direction of travel along the segment.

If one or more access point intersections exist along the segment, then the midsegment flow rate should be measured at a location between those intersections (or between an access point and boundary intersection). The location chosen should be representative in terms of its having a flow rate similar to other locations along the segment. If the flow rate is believed to vary significantly along the segment, then it should be measured at several locations and an average used in the methodology.

There is one exception to the aforementioned definition of midsegment flow rate. Specifically, if a planning analysis is being conducted in which (*a*) the projected demand coincides with a 1-h period and (*b*) an analysis of the peak 15 min period is desired, then each movement's hourly demand can be divided by the peak hour factor to predict the flow rate during the peak 15-min period. The peak hour factor used should be based on local traffic peaking trends.

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Geometric Design Data

This subpart describes the geometric design data listed in Exhibit 17-5. These data describe the geometric elements of the segment or intersections that are addressed in the automobile methodology.

Number of Lanes

The number of lanes at the boundary intersection represents the count of lanes that are provided for each intersection traffic movement. For a turn movement, this count represents the lanes reserved for the exclusive use of turning vehicles. Turn movement lanes include turn lanes that extend backward for the length of the segment and lanes in a turn bay. Lanes that are shared by two or more movements are included in the count of through lanes and are described as shared lanes. If no exclusive turn lanes are provided, then the turn movement is indicated to have 0 lanes.

Upstream Intersection Width

The intersection width applies to the upstream boundary intersection for a given direction of travel and represents the effective width of the cross street. On a two-way street, it represents the distance between the stop (or yield) line for the two opposing segment through movements at the boundary intersection, as measured along the centerline of the segment. On a one-way street, it represents the distance from the stop line to the far side of the most distant traffic lane on the cross street.

Turn Bay Length

Turn bay length represents the length of the bay at the boundary intersection for which the lanes have full width and at which queued vehicles can be stored. Bay length is measured parallel to the roadway centerline. If there are multiple lanes in the bay and they have differing lengths, then the length entered should be an average value.

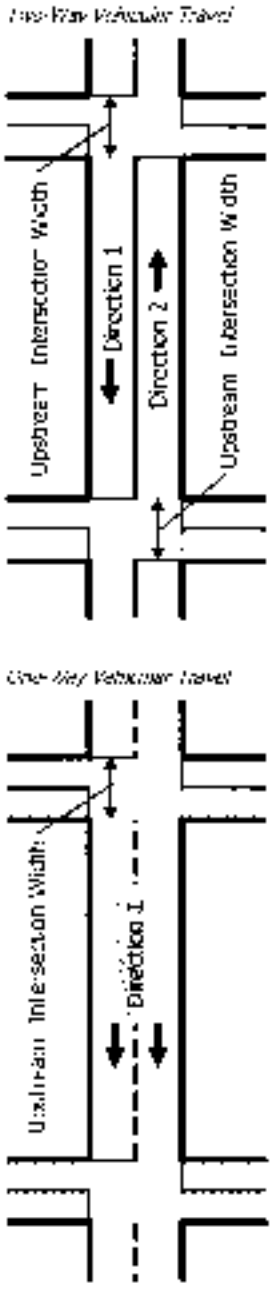
If a two-way left turn lane is provided for left turn vehicle storage and adjacent access points exist, then the bay length entered should represent the effective storage length available to the left turn movement. The determination of effective length is based on consideration of the adjacent access points and their associated left-turning vehicles that store in the two-way left-turn lane.

Number of Through Lanes

The number of through lanes on the segment represents the count of lanes that extend for the length of the segment and serve through vehicles (even if a lane is dropped or added at a boundary intersection). This count is specified separately for each direction of travel along the segment. A lane provided for the exclusive use of turning vehicles is not included in this count.

Number of Lanes at Access Points

The number of lanes at an access point intersection represents the count of lanes that are provided for each traffic movement at the intersection. The method



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for determining this number follows the same guidance provided in a previous paragraph for number of lanes at boundary intersections.

Turn Bay Length at Access Points

Turn bay length represents the length of the bay at the access point intersection for which the lanes have full width and in which queued vehicles can be stored. This length is needed by both segment approaches to the access point intersection. The method for determining this length follows the same guidance provided in a previous paragraph for turn bay length at boundary intersections.

Segment Length

Segment length represents the distance between the boundary intersections that define the segment. The point of measurement at each intersection is the stop line, the yield line, or the functional equivalent in the subject direction of travel. This length is measured along the centerline of the street. If it differs in the two travel directions, then an average length is used.

The *link length* is used in some calculations. It is computed as the segment length minus the width of the upstream boundary intersection.

Restrictive Median Length

The restrictive median length represents the length of street with a restrictive median (e.g., raised curb). This length is measured from median nose to median nose along the centerline of the street. It does not include the length of any median openings on the street.

Proportion of Segment with Curb

The proportion of the segment with curb represents that portion of the link length that has curb along the right side of the segment. This proportion is computed as the length of street with a curbed cross section divided by the link length. The length of street with a curbed cross section is measured from the start of the curbed cross section to the end of the curbed cross section on the link. The width of driveway openings is not deducted from this length. This value is input for each direction of travel along the segment.

Number of Access Point Approaches

The number of access point approaches along a segment represents the count of unsignalized driveway and public street approaches to the segment, regardless of the traffic demand entering the approach. This number is counted separately for each side of the segment. It must equal or exceed the number of active access points for which delay to segment through vehicles is computed. If the downstream boundary intersection is unsignalized, its cross-street approach on the right hand side (in the direction of travel) is included in the count.

Other Data and Performance Measures

This subpart describes the data listed in Exhibit 17-5 that are categorized as "other data" or "performance measures."

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Analysis Period Duration

The analysis period is the time interval considered for the performance evaluation. Its duration is in the range of 15 min to 1 h, with longer durations in this range sometimes used for planning analyses. In general, the analyst should use caution in interpreting the results from an analysis period of 1 h or more because the adverse impact of short peaks in traffic demand may not be detected. Also, if the analysis period is other than 15 min, then the peak hour factor should not be used.

The methodology was developed to evaluate conditions in which queue spillback does not affect the performance of the subject segment or other boundary intersection during the analysis period. If spillback affects performance, the analyst should consider using an alternative analysis tool that is able to model the effect of spillback conditions.

Operational Analysis. A 15-min analysis period should be used for operational analyses. This duration will accurately capture the adverse effects of demand peaks. Any 15-min period of interest can be evaluated with the methodology; however, a complete evaluation should always include an analysis of conditions during the 15-min period that experiences the highest traffic demand during a 24-h period.

If traffic demand exceeds capacity for a given 15-min analysis period, then a multiple-period analysis should be considered. This type of analysis consists of an evaluation of several consecutive 15-min periods. The periods analyzed would include an initial analysis period that has no initial queue, one or more periods in which demand exceeds capacity, and a final analysis period that has no residual queue.

When a multiple-period analysis is used, segment performance measures are computed for each analysis period. Averaging performance measures across multiple analysis periods is not encouraged because it may obscure extreme values.

If a multiple-period analysis is used and the boundary intersections are signalized, then the procedure described in Chapter 18 should be used to guide the evaluation. When a procedure for multiple-period analysis is not provided in the chapter that corresponds to the boundary intersection configuration, the analyst should separately evaluate each period and use the residual queue from one period as the initial queue for the next period.

Planning Analysis. A 15-min analysis period is used for most planning analyses. However, hourly traffic demands are normally produced through the planning process. Thus, when 15-min forecast demands are not available for a 15-min analysis period, a peak hour factor must be used to estimate the 15-min demands for the analysis period. A 1-h analysis period can be used if appropriate. Regardless of analysis-period duration, a single-period analysis is typical for planning applications.

Speed Limit

Average running speed is used in the methodology to evaluate segment performance. It is correlated with speed limit, where speed limit reflects the

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environmental and geometric factors that have an influence on driver speed choice. As such, speed limit represents a simple input variable that can be used as a convenient way to estimate running speed while limiting the need for numerous environmental and geometric input data.

The convenience of using speed limit as an input variable comes with a caution—the analyst must not infer a cause-and-effect relationship between the input speed limit and the estimated running speed. More specifically, the computed change in performance resulting from a change in the input speed limit is not likely to be indicative of performance changes that will actually be realized. Research indicates that a change in speed limit has a proportionally smaller effect on the actual average speed (7).

The methodology is based on the assumption that the posted speed limit is (*a*) consistent with that found on other streets in the vicinity of the subject segment and (*b*) consistent with agency policy regarding specification of speed limits. If it is known that the posted speed limit does not satisfy these assumptions, then the speed limit value that is input to the methodology should be adjusted such that it is consistent with the assumptions.

Through Control Delay

The through control delay represents the control delay for the through movement at the downstream boundary intersection. It is computed by using the appropriate procedure provided in one of Chapters 18 to 22, depending on the type of control used at the intersection.

If the intersection procedure provides delay by lane groups and the through movement is served in two or more lane groups, then the through-movement delay is computed as the weighted sum of the individual lane-group delays, where the weight for a lane group is its proportion of through vehicles.

Through Stopped Vehicles and Second- and Third-Term Back-of-Queue Size

These variables are needed for the calculation of stop rate. These variables are needed when the downstream boundary intersection is signalized. They apply to the through lane group at this intersection. A procedure for computing the number of fully stopped vehicles N_s, second-term back-of-queue size Q_2, and third-term back-of-queue size Q_3 is provided in Chapter 31, Signalized Intersections: Supplemental.

If the procedure provides the stop rate by lane groups and the through movement is served in two or more lane groups, then the through movement stop rate is computed as the weighted sum of the individual lane-group stop rates, where the weight for a lane group is its proportion of through vehicles.

Capacity

The capacity of a movement group represents the maximum number of vehicles that can discharge from a queue during the analysis period, divided by the analysis period duration. This value is needed for the movements entering the segment at the upstream boundary intersection and for the movements exiting the segment at the downstream boundary intersection. With one

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exception, it is computed by using the appropriate procedure provided in one of Chapters 18 to 22, depending on the type of control used at the intersection. Chapter 19, Two-Way Stop-Controlled Intersections, does not provide a procedure for estimating the capacity of the uncontrolled through movement, but this capacity can be estimated by using Equation 17-1.

$$c_{th} = 1{,}800\,(N_{th} - 1 - p^*_{sg}) \qquad \text{Equation 17-1}$$

where

c_{th} = through movement capacity (veh/h),

N_{th} = number of through lanes (shared or exclusive) (ln), and

p^*_{sg} = probability that there will be no queue in the inside through lane.

The probability p^*_{sg} is computed by using Equation 19-43 in Chapter 19. It is equal to 1.0 if a left-turn bay is provided for left turns from the major street.

If the procedure in Chapters 18 to 22 provides capacity by lane groups and the through movement is served in two or more lane groups, then the through-movement capacity is computed as the weighted sum of the individual lane-group capacities, where the weight for a lane group is its proportion of through vehicles. A similar approach is used to compute the capacity for a turn movement.

Midsegment Delay and Stops

Through vehicles traveling along a segment can encounter a variety of situations that cause them to slow slightly or even come to a stop. These encounters delay the through vehicles and cause their segment running time to increase. Situations that can cause this delay include

- Vehicles turning from the segment into an access point approach,
- Pedestrians crossing at a midsegment crosswalk,
- Vehicles maneuvering into or out of an on-street parking space,
- Double-parked vehicles blocking a lane, and
- Vehicles in a dropped lane that are merging into the adjacent lane.

A procedure is provided in the methodology for estimating the delay due to vehicles turning left or right into an access point approach. This edition of the HCM does not include procedures for estimating the delay or stops due to the other sources listed. If they exist on the subject segment, they must be estimated by the analyst and input to the methodology.

Nonautomobile Modes

This part describes the input data needed for the pedestrian, bicycle, and transit methodologies. The data are listed in Exhibit 17-6 and are identified as "input data elements." They must be separately specified for each direction of travel on the segment.

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Exhibit 17-6
Input Data Requirements: Nonautomobile Modes

Data Category	Location	Input Data Element	Pedestrian Mode	Bicycle Mode	Transit Mode
Traffic characteristics	Segment, transit	Dwell time			X
		Excess wait time			X
		Passenger trip length			X
		Transit frequency			X
		Passenger load factor			X
	Segment, other	Midsegment flow rate (motorized vehicles)	X	X	
		Percent heavy vehicles		X	
		Pedestrian flow rate	X		
		Prop. of on-street parking occupied	X	X	
Geometric design	Segment, roadway	Downstream intersection width	X		
		Segment length	X	X	X
		Number of through lanes	X	X	
		Width of outside through lane	X	X	
		Width of bicycle lane	X	X	
		Width of paved outside shoulder	X	X	
		Median type and curb presence	X	X	
		No. of access point approaches		X	
	Segment, sidewalk	Presence of a sidewalk	X		
		Total walkway width	X		
		Effective width of fixed objects	X		
		Buffer width	X		
		Spacing of objects in buffer	X		
Other	Segment	Area type			X
		Pavement condition rating		X	
		Distance to nearest signal-controlled crossing	X		
		Density of midsegment pedestrian crossing	X		
		Proportion of sidewalk adjacent to window, building, or fence	X		
	Transit stop	Transit stop location			X
		Transit stop position			X
		Proportion of stops with shelters			X
		Proportion of stops with benches			X
Performance measures	Segment	Motorized vehicle running speed	X	X	X
		Pedestrian LOS score for link			X
	Boundary intersection	Through control delay			X
		Reserve delay			X
		Effective green to cycle length ratio (if signalized)			X
		Volume-to-capacity ratio (if roundabout)			X
		Pedestrian delay	X		
		Bicycle delay		X	
		Pedestrian LOS score for intersection	X		
		Bicycle LOS score for intersection		X	

Exhibit 17-6 categorizes each input data element by travel mode methodology. An 'X' is used to indicate the association between a data element and methodology. A blank cell indicates that the data element is not used as input for the corresponding methodology.

The data elements listed in Exhibit 17-6 do not include variables that are considered to represent calibration factors. Default values are provided for these factors because they typically have a relatively narrow range of reasonable

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values or they have a small impact on the accuracy of the performance estimates. The recommended value for each calibration factor is identified at the relevant point during the presentation of the methodology.

Traffic Characteristics Data

This subpart describes the traffic characteristics data listed in Exhibit 17-6. These data describe the vehicle, pedestrian, and transit traffic streams traveling along the segment during the analysis period. If there are multiple transit routes on the segment, then the transit-related variables are needed for each route.

Dwell Time

Dwell time represents the time that the transit vehicle is stopped at the curb to serve passenger movements, including the time required to open and close the doors. It does not include time spent stopped after passenger movements have ceased (e.g., waiting for a traffic signal or waiting for a gap in traffic to reenter the travel lane). Dwell times are typically in the range of 10 to 60 s, depending on boarding and alighting demand. Procedures for measuring and estimating dwell time are provided in the *Transit Capacity and Quality of Service Manual* (3).

Excess Wait Time

The scheduled departure time from a stop and the scheduled travel time for a trip set the baseline for a passenger's expectations for how long a trip should take. If the transit vehicle departs late—or worse, departs before the scheduled time (i.e., before all the passengers planning to take that vehicle have arrived at the stop)—the trip will likely take longer than planned, which negatively affects a passenger's perceptions of the quality of service.

Transit reliability is measured by *excess wait time*, the average number of minutes passengers must wait at a stop past the scheduled departure time. It is measured in the field as the sum of the differences between the scheduled and actual departure times at the preceding time point, divided by the number of transit vehicle arrivals. Early departures from the preceding time point are treated as the transit vehicle being one headway late, as a passenger arriving at the stop by the scheduled departure time would have to wait one headway for the next transit vehicle. If time point–specific excess wait time information is not available, but on-time performance (e.g., percentage of departures from a time point 0 to 5 min late) data are available for a route, then Section 2, Methodology, provides a procedure for estimating excess wait time from on-time performance.

Passenger Trip Length

The impact of a late transit vehicle departure on the overall passenger speed for a trip (as measured by using scheduled departure time to actual arrival time) depends on the length of the passenger's trip. For example, a departure 5 min late has more of a speed impact on a 1-mi-long trip than on a 10-mi-long trip. Average passenger trip length is used to determine the impact of late departures on overall trip speed. For most purposes, the average trip length can be determined from National Transit Database data for the transit agency (4) by dividing total passenger miles by total unlinked trips. However, if an analyst has

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reason to believe that average trip length on a route is substantially different from the system average. A route-specific value can be determined from automatic passenger counter data or National Trans I Database count sheets for the route by dividing total passenger-miles by the total number of boarding passengers.

Transit Frequency

Transit frequency is defined as the count of scheduled fixed-route transit vehicles that stop on or near the segment during the analysis period. It is expressed in units of transit vehicles per hour.

Scheduled transit vehicles can be considered "local" or "nonlocal." Local transit vehicles make regular stops along the street (typically every 11 km or less), although they do not necessarily stop within the analysis segment when segment lengths are short or when stops alternate between the near and far sides of boundary intersections. They are always counted, regardless of whether they stop within the subject segment. Nonlocal transit vehicles operate on routes with longer stop spacing than local routes (e.g., limited-stop bus, rapid transit, or express routes). They are only counted when they stop within the subject segment.

Passenger Load Factor

The load factor represents the number of passengers occupying the transit vehicle divided by the number of seats on the vehicle. If the number of passengers equals the number of seats, then the load factor equals 1.0. This factor should be measured in the field or obtained from the agency serving the transit route. It is an average value for all of the scheduled fixed-route transit vehicles that travel along the segment during the analysis period.

Midsegment Flow Rate

The midsegment flow rate of motorized vehicles is equivalent to the midsegment flow rate defined previously for the automobile mode.

Percent Heavy Vehicles

A heavy vehicle is defined as any vehicle with more than four tires touching the pavement. Local buses that stop within the intersection area are not included in the count of heavy vehicles. The percentage of heavy vehicles represents the count of heavy vehicles that arrive during the analysis period divided by the total vehicle count for the same period. This percentage is provided for the same location on the segment as represented by the midsegment flow rate.

Pedestrian Flow Rate

The pedestrian flow rate is based on the count of pedestrians traveling along the outside of the subject segment during the analysis period. A separate count is taken for each direction of travel along the side of the segment. Each count is divided by the analysis period duration to yield a directional hourly flow rate. These rates are then added to obtain the pedestrian flow rate for that side.

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Proportion of On-Street Parking Occupied

This variable represents the proportion of the segment's right-hand curb lane on which parked vehicles are present during the analysis period. It is computed as the sum of the curb-lane lengths occupied by parked vehicles divided by the link length. Also, the use of pavement markings to delineate the parking lane should be noted.

If parking is not allowed on the segment, then the proportion equals 0.0. If parking is allowed along the segment but the spaces are not used during the analysis period, then the proportion equals 0.0. If parking is allowed along the full length of the segment but only one-half of the spaces are occupied during the analysis period, then the proportion equals 0.50.

Geometric Design Data

This subpart describes the geometric design data listed in Exhibit 17-6. These data describe the geometric elements that influence pedestrian, bicycle, or transit performance. All input data should be representative of the segment for its entire length. An average value should be used for each element that varies along the segment. Segment length, number of through lanes, and number of access point approaches are defined previously for the automobile mode.

Downstream Intersection Width

The intersection width applies to the downstream boundary intersection for a given direction of travel and represents the effective width of the cross street. On a two-way street, it represents the distance between the stop (or yield) line for the two opposing segment through movements at the boundary intersection, as measured along the centerline of the segment. On a one-way street, it represents the distance from the stop line to the far side of the most distant traffic lane on the cross street.

Width of Outside Through Lane, Bicycle Lane, and Paved Outside Shoulder

The widths of several individual elements of the cross section are considered input data. These elements include the outside lane that serves motorized vehicles traveling along the segment, the bicycle lane adjacent to the outside lane (if used), and the outside shoulder. The outside shoulder may be used for on-street parking. The widths of each of these elements is mutually exclusive because they are adjacent (i.e., not overlapped) in the cross section.

The outside lane width does not include the width of the gutter. If curb and gutter are present, then the width of the gutter is included in the shoulder width (i.e., shoulder width is measured to the curb face when a curb is present).

Median Type and Curb Presence

The median type is designated as undivided, nonrestrictive (e.g., two-way left-turn lane), or restrictive (e.g., raised curb). Whether the cross section has curb on the outside edge of the roadway should also be noted.

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Presence of a Sidewalk

A sidewalk is a paved walkway that is provided at the side of the roadway. It is assumed that pedestrians will walk in the street if a sidewalk is not present.

Total Walkway Width

Total walkway width is measured from the outside edge of the road pavement (or face of curb, if present) to the far edge of the sidewalk (as sometimes delineated by a building face or landscaping). It includes the width of any buffer (see below), if present. If this width varies along the segment, then an average value is used. A paved shoulder is not included in this width measurement.

Effective Width of Fixed Objects

Two input variables are used to describe fixed objects along the walkway. One variable represents the effective width of objects along the inside of the sidewalk. These objects include light poles, traffic signs, planter boxes, and so forth. Typical widths for these objects are provided in Chapter 23, Off-Street Pedestrian and Bicycle Facilities. All objects along the sidewalk should be considered and an average value for the length of the sidewalk input to the methodology.

The second variable represents the effective width of objects along the outside of the sidewalk. It is determined in the same manner as was the first variable.

Buffer Width and Spacing of Objects in Buffer

The buffer width represents the distance between the outside edge of the paved roadway (or face of curb, if present) and the near edge of the sidewalk. This element of the cross section is not designed for use by pedestrians or motorized vehicles. It may be unpaved or include various vertical objects that are continuous (e.g., barrier) or discontinuous (e.g., trees, bollards) to prevent pedestrian use. If vertical objects are in the buffer, then the average spacing of those objects that are 3 ft or more in height should also be recorded.

Other Data

This subpart describes the data listed in Exhibit 17-6 that are categorized as "other data."

Area Type

Area type describes the environment in which the subject segment is located. This data element is used in the transit methodology to set a baseline for passenger expectations of typical transit travel speeds. For this application, it is sufficient to indicate whether the area type is a "central business district or a metropolitan area with over 5 million persons" or "other."

Pavement Condition Rating

The pavement condition rating describes the road surface in terms of ride quality and surface defects. It is based on the Present Serviceability Rating, a

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subjective rating system based on a scale of 0 to 5 (5). Exhibit 17-7 provides a description of pavement conditions associated with various ratings.

Distance to Nearest Signal-Controlled Crossing

This input variable is needed if there is an identifiable pedestrian path (a) that intersects the segment and continues on beyond the segment and (b) on which most crossing pedestrians travel. This variable defines the distance pedestrians must travel along the segment should they divert from the path to cross the segment at the nearest signalized crossing. The crossing will typically be at a signalized intersection. However, it may also be at a signalized crosswalk provided at a midsegment location. If the crossing is at a signalized intersection, it will likely occur on the crosswalk on the side of the intersection that is nearest to the segment. Occasionally, it will be on the far side of the intersection because the near-side crosswalk is closed (or a crossing at this location is otherwise prohibited). This distance is measured along one side of the subject segment; the methodology accounts for the return distance once the pedestrian arrives at the other side of the segment.

Exhibit 17-7
Pavement Condition Rating

Pavement Condition Rating	Pavement Description	Motorized Vehicle Ride Quality and Traffic Speed
4.0 to 5.0	New or nearly new superior pavement. Some at cracks and patches.	Good ride
3.0 to 4.0	Flexible pavements may begin to show evidence of rutting and fine cracks. Rigid pavements may begin to show evidence of minor cracking.	Good ride
2.0 to 3.0	Flexible pavements may show rutting and extensive patching. Rigid pavements may have a few joint fractures, faulting, or cracking.	Acceptable ride for low-speed traffic, but badly deteriorated for high-speed traffic
1.0 to 2.0	Distress occurs over 50% or more of the surface. Flexible pavement may have large potholes and deep cracks. Rigid pavement distress includes joint spalling, patching, and cracking.	Pavement deterioration affects the speed of free-flow traffic. Ride quality not acceptable.
0.0 to 1.0	Distress occurs over 75% or more of the surface. Large potholes and deep cracks exist.	Passable only at reduced speed and considerable ride discomfort.

Legality of Midsegment Pedestrian Crossing

This input indicates whether a pedestrian can cross the segment at any point along its length, regardless of location. If it is illegal to make this crossing at any point, then the pedestrian is assumed to be required to divert to the nearest signalized intersection to cross the segment.

Proportion of Sidewalk Adjacent to Window, Building, or Fence

Three proportions are input for a sidewalk. One proportion represents the length of sidewalk adjacent to a fence or low wall (divided by the length of the link). The second proportion represents the length of the sidewalk adjacent to a building face (divided by the length of the link). The final proportion represents

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the length of the sidewalk adjacent to a window display divided by the length of the link.

Transit Stop Location

This input describes whether a transit stop is located on the near side of a boundary intersection or elsewhere. A portion of the time assumed to serve a near side transit stop at a boundary intersection may overlap with the control delay incurred at the intersection.

Transit Stop Position

Transit stops can be either *on line*, where the bus stops entirely or mostly in the travel lane and does not have to yield to other vehicles upon exiting the stop, or *off line*, where the bus pulls out of the travel lane to serve the stop and may have to yield to other vehicles upon reentry.

Proportion of Stops with Shelters and with Benches

These two input data describe the passenger amenities provided at a transit stop. A sheltered stop provides a structure with a roof and three enclosed sides that provides occupants from wind, rain, and sun. A shelter with a bench is counted twice, once as a shelter and a second time as a bench.

Performance Measures

This subpart describes the data listed in Exhibit 17-6 that are categorized as "performance measures." The through control delay variable was previously described for the automobile mode (in Exhibit 17-5).

Motorized Vehicle Running Speed

The motorized vehicle running speed is used in all of the nonautomobile methodologies. It is based on the segment running time obtained from the automobile methodology. The running speed is equal to the segment length divided by the segment running time.

Pedestrian LOS Score for Link

The pedestrian LOS score for the link is used in the transit methodology. It is obtained from the pedestrian methodology of this chapter.

Reentry Delay

The final component of transit vehicle stop delay is the reentry delay, the time (in seconds) a transit vehicle spends waiting for a gap to reenter the adjacent traffic stream. Reentry delay is estimated as follows (3):

- Reentry delay is zero at on-line stops.
- At off-line stops away from the influence of a signalized intersection queue, reentry delay is estimated from the procedures of Chapter 19, Two-Way Stop-Controlled Intersections, as if the bus were making a right turn onto the link, but a critical headway of 7 s is used to account for the slower acceleration of buses.

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- At an off-line bus stop located within the influence of a signalized intersection queue, reentry delay is estimated from the queue service time, g_s, by using the procedures of Chapter 18, Signalized Intersections.

Reentry delay can be reduced by the presence of yield-to-bus laws or placards (and motorist compliance with them), the existence of an acceleration lane or queue jump departing a stop, or a higher than normal degree of bus driver aggressiveness in hurling buses back into the traffic stream. Analyst judgment and local data can be used to make appropriate adjustments to reentry delay in these cases.

Effective Green-to-Cycle-Length Ratio

The effective green to cycle length ratio for the through movement is used in the transit methodology when the boundary intersection is a traffic signal and has a near-side transit stop. It is obtained from the Chapter 18 methodology.

Volume to Capacity Ratio (if Roundabout)

If the boundary intersection is a roundabout and it has a near-side transit stop, then the volume-to-capacity ratio for the upstream lane of the segment approach to the roundabout is needed. It is obtained from the Chapter 21 methodology.

Pedestrian Delay

Three pedestrian delay variables are needed. The first is the delay to pedestrians who travel through the boundary intersection along a path that is parallel to the segment centerline. The pedestrian movement of interest is traveling on the subject side of the street and heading in a direction that is "with" or "against" the motorized traffic stream. For a two-way stop-controlled boundary intersection, this delay is assumed to be negligible. For a signal-controlled boundary intersection, the procedure described in Chapter 18 is used to compute this delay.

The second delay variable needed describes the delay incurred by pedestrians who cross the subject segment at the nearby signal-controlled crossing. If the nearest crossing is at a signalized intersection, then the procedure described in Chapter 18 is used to compute this delay. If the nearest crossing is at a midsegment signalized crosswalk, then this delay should equal the pedestrian's average wait for service after pressing the pedestrian push button. This wait will depend on the signal settings and could range from 5 to 25 s/pedestrian (s/p).

The third delay variable needed is the pedestrian waiting delay. This delay is incurred when pedestrians wait at an uncontrolled crossing location. If this type of crossing is legal, then the pedestrian waiting delay is determined by using the procedure in Chapter 19, Two-Way Stop-Controlled Intersections. If it is illegal, then the pedestrian waiting delay does not need to be calculated.

Bicycle Delay

Bicycle delay is the delay to bicyclists who travel through the boundary intersection along a path that is parallel to the segment centerline. The bicycle-

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movement of interest is traveling on the subject side of the street and heading in the same direction as motorized vehicles. For a two-way stop-controlled boundary intersection, this delay is assumed to be negligible. For a signal-controlled boundary intersection, the procedure described in Chapter 18 is used to compute this delay.

Pedestrian LOS Score for Intersection

The pedestrian LOS score for the signalized intersection is used in the pedestrian methodology. It is obtained from the pedestrian methodology in Chapter 18.

Bicycle LOS Score for Intersection

The bicycle LOS score for the signalized intersection is used in the bicycle methodology. It is obtained from the bicycle methodology in Chapter 18.

SCOPE OF THE METHODOLOGY

Four methodologies are presented in this chapter. One methodology is provided for each of the automobile, pedestrian, bicycle, and transit modes. This section identifies the conditions for which each methodology is applicable.

- **Signalized and two-way STOP-controlled boundary intersections.** All methodologies can be used to evaluate segment performance with signalized or two-way stop-controlled boundary intersections. In the latter case, the cross street is stop controlled. The automobile methodology can also be used to evaluate performance with all-way stop- or yield-controlled (e.g., roundabout) boundary intersections.
- **Arterial and collector streets.** The four methodologies were developed with a focus on arterial and collector street conditions. If a methodology is used to evaluate a local street, then the performance estimates should be carefully reviewed for accuracy.
- **Steady flow conditions.** The four methodologies are based on the analysis of steady traffic conditions and, as such, are not well suited to the evaluation of unsteady conditions (e.g., congestion, queue spillback, signal preemption).
- **Target road users.** Collectively, the four methodologies were developed to estimate the LOS perceived by automobile drivers, pedestrians, bicyclists, and transit passengers. They were not developed to provide an estimate of the LOS perceived by other road users (e.g., commercial vehicle drivers, automobile passengers, delivery truck drivers, or recreational vehicle drivers). However, it is likely that the perceptions of these other road users are reasonably well represented by the road users for whom the methodologies were developed.
- **Target travel modes.** The automobile methodology addresses mixed automobile, motorcycle, truck, and transit traffic streams in which the automobile represents the largest percentage of all vehicles. The pedestrian, bicycle, and transit methodologies address travel by walking, bicycle, and transit vehicle, respectively. The transit methodology is

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limited to the evaluation of public transit vehicles operating in mixed or exclusive traffic lanes and stopping along the street. The methodologies are not designed to evaluate the performance of other travel means (e.g., grade-separated rail transit, golf carts, or motorized bicycles).

- **Influences in the right-of-way.** A road user's perception of quality of service is influenced by many factors inside and outside of the urban street right-of-way. However, the methodologies in this chapter were specifically constructed to exclude factors that are outside of the right-of-way (e.g., buildings, parking lots, scenery, or landscaped yards) that might influence a traveler's perspective. This approach was followed because factors outside of the right of way are not under the direct control of the agency operating the street.
- **Mobility focus for automobile methodology.** The automobile methodology is intended to facilitate the evaluation of mobility. Accessibility to adjacent properties by way of automobile is not directly evaluated with this methodology. Regardless, a segment's accessibility should also be considered in evaluating its performance, especially if the segment is intended to provide such access. Oftentimes, factors that favor mobility reflect minimal levels of access and vice versa.
- **"Typical pedestrian" focus for pedestrian methodology.** The pedestrian methodology is not designed to reflect the perceptions of any particular pedestrian subgroup, such as pedestrians with disabilities. As such, the performance measures obtained from the methodology are not intended to be indicators of a sidewalk's compliance with U.S. Access Board guidelines related to the Americans with Disabilities Act requirements. For this reason, they should not be considered as a substitute for a formal compliance assessment of a pedestrian facility.

LIMITATIONS OF THE METHODOLOGY

In general, the methodologies described in this chapter can be used to evaluate the performance of most traffic streams traveling along an urban street segment. However, the methodologies do not address all traffic conditions or types of control. The inability to replicate the influence of a condition or control type in the methodology represents a limitation. This subsection identifies the known limitations of the methodologies described in this chapter. If one or more of these limitations is believed to have an important influence on the performance of a specific street segment, then the analyst should consider using alternative methods or tools.

Automobile Modes

The automobile methodology does not directly account for the effect of the following conditions on street segment operation:

- On-street parking activity along the link (note that on-street parking activity on the approach to a signalized boundary intersection is addressed in Chapter 18, Signalized Intersections).
- Significant grade along the link.

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- Capacity constraints between intersections (e.g., narrow bridges).
- Queuing at the downstream boundary intersection consistently backing up to and interfering with the operation of the upstream intersection or an access point intersection.
- Stops incurred by segment through vehicles as a result of a vehicle ahead turning from the segment into an access point.
- Bicycles sharing a traffic lane with vehicular traffic, and
- Cross-street congestion or a railroad crossing that blocks through traffic.

In addition, any limitations associated with the methodologies used to evaluate the intersections that bound the urban street segment are shared with this methodology. These limitations are listed in Chapters 18 to 22.

Nonautomobile Modes

This part identifies the limitations of the pedestrian, bicycle, and transit methodologies. These methodologies are not able to model the presence of railroad crossings. In addition, the pedestrian methodology does not model the following conditions:

- Segments bounded by all-way stop-controlled intersections or roundabouts;
- Midsegment unsignalized crosswalks;
- Grades in excess of 2%;
- Pedestrian overcrossings for service across or along the segment;
- Points of high-volume pedestrian access to a sidewalk, such as a transit stop or a driveway from a large office building; and
- Points where a high volume of vehicles cross the sidewalk, such as a parking garage entrance.

In addition, the bicycle methodology is not able to model the following conditions:

- Segments bounded by all-way stop-controlled intersections or roundabouts, and
- Grades in excess of 2%.

With regard to the first bullet point in each of the two lists above, procedures have not been developed yet to address the effect of all-way STOP control or YIELD control on intersection performance from a pedestrian or bicyclist perspective.

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2. METHODOLOGY

OVERVIEW

This section describes four methodologies for evaluating the performance of an urban street segment. Each methodology addresses one possible travel mode within the street right-of-way. Analysts should choose the combination of methodologies that are appropriate for their analysis needs.

A complete evaluation of segment operation includes the separate examination of performance for all relevant travel modes for each travel direction. The performance measures associated with each mode and travel direction are assessed independently of one another. They are not mathematically combined into a single indicator of segment performance. This approach assumes that all performance inputs are considered on a mode-by-mode and direction-by-direction basis.

The focus of each methodology in this chapter is the segment. Methodologies for quantifying the performance of the downstream boundary intersection are described in other chapters (e.g., Chapters 19 to 22). The methodology described in Chapter 16, Urban Street Facilities, can be used to combine the performance measures for a specified travel mode for successive segments into an overall measure of facility performance for each mode and travel direction.

AUTOMOBILE MODE

This subsection provides an overview of the methodology for evaluating urban street segment performance from the motorist's perspective. The methodology is computationally intense and requires software to implement. The intensity stems from the need to model the traffic movements that enter or exit the segment in terms of their interaction with each other and with the traffic control elements of the boundary intersection. Default values are provided in Section 3, Applications, to support planning analyses for which the required input data are not available.

A Quick Estimation Method for evaluating segment performance at a planning level of analysis is provided in Chapter 30, Urban Street Segments: Supplemental. This method is not computationally intense and can be applied by using hand calculations.

The methodology is used to evaluate automobile performance on an urban street segment. Each travel direction along the segment is separately evaluated. *Unless otherwise stated, all variables are specific to a single direction of travel.*

The methodology has been developed to evaluate automobile performance for a street segment bounded by intersections that can have a variety of control types. The focus of the discussion in this subsection is on the use of the methodology to evaluate a coordinated signal system because this type of control is the most complex. However, as appropriate, the discussion is extended to describe how key elements of this methodology can be used to evaluate automobile performance at noncoordinated systems.

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Because of the intensity of the computations for coordinated-actuated control, the objective of this subsection is to introduce the analyst to the calculation process and to discuss the key analytic procedures. This objective is achieved by outlining the procedures that make up the methodology while highlighting important equations, concepts, and interpretations. A more detailed discussion of these procedures is provided in Chapter 30, Urban Street Segments: Supplemental.

The computational engine developed by the Transportation Research Board Committee on Highway Capacity and Quality of Service represents the most detailed description of this methodology. Additional information about this engine is provided in Chapter 31.

Framework

Exhibit 17-8 illustrates the calculation framework of the automobile methodology. It identifies the sequence of calculations needed to estimate selected performance measures. The calculation process is shown to flow from top to bottom in the exhibit. These calculations are described more fully in the remainder of this subsection.

The framework illustrates the calculation process as applied to two system types: coordinated and noncoordinated. The analysis of coordinated systems recognizes the influence of an upstream signalized intersection on the performance of the street segment. The analysis of noncoordinated systems is based on the assumption that arrivals to a boundary intersection are random.

The framework is further subdivided into the type of traffic control used at the intersections that bound the segment. This approach recognizes that a boundary intersection can be signalized, two-way STOP-controlled, all-way STOP-controlled, or a roundabout. Although not indicated in the exhibit, the boundary intersection could also be an interchange ramp terminal.

There is reference in Exhibit 17-8 to various procedures described in Chapters 18, 30, and 21. With regard to Chapter 18, the procedure for computing actuated phase duration is needed for the analysis of actuated intersections on both coordinated and noncoordinated segments. Also, the procedure for computing control delay in Chapter 18 is needed for the estimation of segment through-movement delay. The delay estimation procedure for roundabouts and all-way STOP-controlled intersections is needed from their respective chapters for the analysis of noncoordinated segments.

Performance measures estimated for each segment travel direction include:

- Travel speed,
- Stop rate, and
- Automobile traveler perception score.

The perception score is derived from traveler perception research and is an indication of travelers' relative satisfaction with service provided along the segment.

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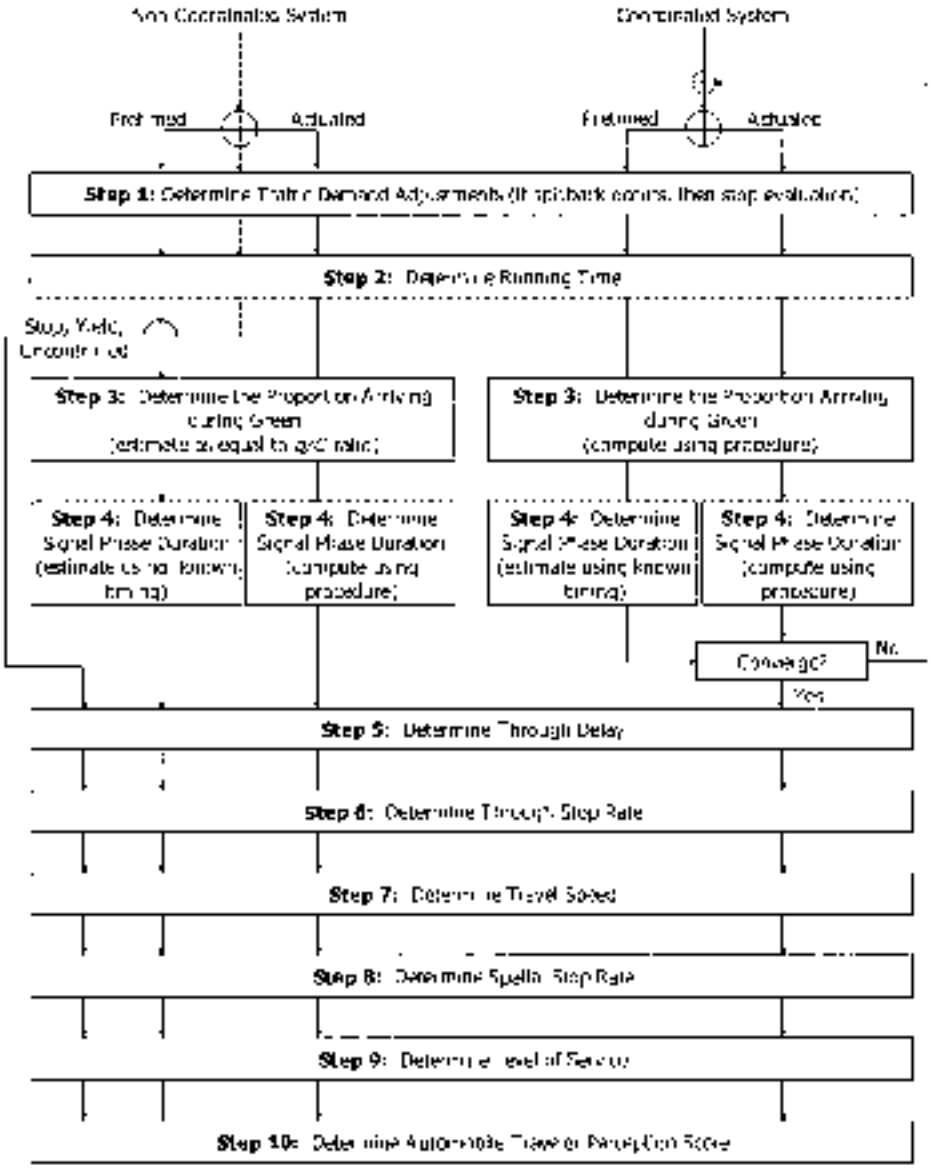

Exhibit 17-8
Automobile Methodology for Urban Street Segments

Step 1: Determine Traffic Demand Adjustments

During this step, various adjustments are undertaken to ensure the volumes evaluated accurately reflect segment traffic conditions. The adjustments include (a) limiting entry to the segment due to capacity constraint, (b) balancing the volumes entering and exiting the segment, and (c) mapping entry-to-exit flow paths by using an origin–destination matrix. Also during this step, a check is made for the occurrence of spillback from a turn bay or from one segment into another segment. As indicated in Exhibit 17-8, the methodology should not proceed if spillback occurs because the methodology does not address this condition.

The procedures for making these adjustments and checks are described in Chapter 30. These adjustments and checks are not typically used for planning and preliminary engineering analyses.

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Capacity Constraint

When the demand volume for an intersection traffic movement exceeds its capacity, the discharge volume from the intersection is restricted (or metered). When this metering occurs for a movement that enters the subject segment, the volume arriving at the downstream signal is reduced below the unrestricted value.

To determine whether metering occurs, the capacity of each upstream movement that discharges into the subject segment must be computed and then checked against the associated demand volume. If this volume exceeds movement capacity, then the volume entering the segment must be restricted to equal the movement capacity.

Volume Balance

Volume balance describes a condition in which the combined volume from all movements entering a segment equals the combined volume exiting the segment, in a given direction of travel. The segment is balanced when entering volume equals exit volume for both directions of travel. Unbalanced volumes often exist in turn movement counts when the count at one intersection is taken at a different time than the count at the adjacent intersection. They are also likely to exist when access point intersections exist but their volume is not counted.

The accuracy of the performance evaluation may be adversely affected if the volumes are not balanced. The extent of the impact is based on the degree to which the volumes are unequal. To balance the volumes, the methodology assumes that the volume for each movement entering the segment is correct and adjusts the volume for each movement exiting the segment in a proportional manner such that a balance is achieved. The exiting volumes computed in this manner represent a best estimate of the actual demand volumes, such that the adjustment process does not preclude the possibility of queue buildup by one or more exit movements at the downstream boundary intersection during the analysis period.

Origin–Destination Distribution

The volume of traffic that arrives at a downstream intersection for a given downstream movement represents the combined volume from each upstream point of entry weighted by its percentage contribution to the downstream movement. The distribution of these contribution percentages between each upstream and downstream pair is represented as an origin–destination distribution matrix.

The concept of an origin–destination distribution matrix is illustrated by example. Consider the segment shown in Exhibit 17-9. There are three entry volumes at upstream Intersection A that contribute to three exit volumes at downstream Intersection B. There is also an entrance and exit volume at the access point intersection located between the two intersections. It should be noted that 1,850 vehicles enter the segment and 1,981 vehicles exit the segment; thus there is volume balance for this example segment. The origin–destination distribution matrix for this sample street segment is shown in Exhibit 17-10.

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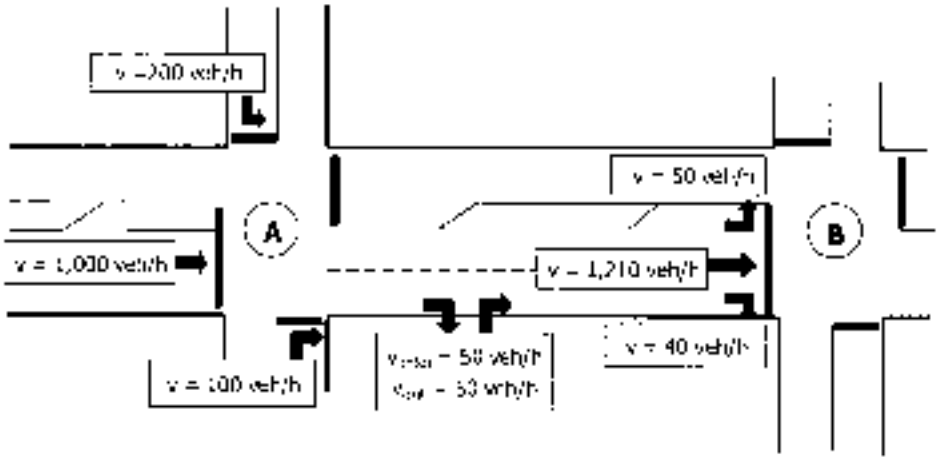

Exhibit 17-9
Entry and Exit Volume on Example Segment

Origin Volume by Movement (veh/h)				Destination Volume	
Left	Through	Right	Access Point	Movement	Total Volume (veh/h)
2	46	2	0	Left	50
189	877	95	50	Through	1,210
4	36	1	0	Right	40
7	41	2	0	Access Point	50
206	1,000	100	50		1,350

Exhibit 17-10
Example Origin–Destination Distribution Matrix

The column totals in the last row of Exhibit 17-10 correspond to the entry volumes shown in Exhibit 17-9. The row totals in the last column of Exhibit 17-10 indicate the exit volumes. The individual cell values indicate the volume contribution of each upstream movement to each downstream movement. For example, of the 1,000 through vehicles that enter the segment, 877 depart the segment as a through movement, 46 depart as a left-turn movement, and so on. The volumes in the individual cells are sometimes expressed as a proportion of the column total.

The automobile methodology computes one origin–destination matrix for movements between the upstream boundary intersection and a downstream location (i.e., either an access point or the downstream boundary intersection). When the boundary intersections are signalized, the matrix for movements between the upstream and downstream boundary intersections is used to compute the proportion of vehicles arriving during the green indication for each exit movement. The matrix for movements between the upstream boundary intersection and a downstream access point is used to compute the proportion of time that a platoon is passing through the access point and effectively blocking nonprotected movements from entering or crossing the street.

Spillback Occurrence

Segment spillback can be characterized as one of two types: cyclic and sustained. Cyclic spillback occurs when the downstream boundary intersection is signalized and its queue backs into the upstream intersection as a result of queue growth during the red indication. When the green indication is presented, the queue dissipates and spillback is no longer present for the remainder of the cycle.

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This type of spillback can occur on short street segments with relatively long signal cycle lengths.

Sustained spillback occurs at some point during the analysis period and is a result of oversaturation (i.e., more vehicles discharging from the upstream intersection than can be served at the subject downstream intersection). The queue does not dissipate at the end of each cycle. Rather, it remains present until the downstream capacity is increased or the upstream demand is reduced.

The preceding discussion has focused on segment spillback; however, the concepts are equally applicable to turn bay spillback. In this case, the queue of turning vehicles exceeds the bay storage and spills back into the adjacent lane that is used by other vehicular movements. The occurrence of both segment and bay spillback must be checked during this step.

Use of this methodology to evaluate segments (or intersection turn bays) with significant, sustained spillback is problematic because of the associated unsteady conditions and complex interactions. The procedure described in Chapter 30 is used in this step to compute the time when sustained spillback occurs, if it occurs. If this time of occurrence is shorter than the analysis period, then the methodology may not yield accurate performance estimates. In this situation, the analyst should consider either (*a*) reducing the analysis period such that it ends before spillback occurs or (*b*) using an alternative analysis tool that is able to model the effect of spillback conditions.

Step 2: Determine Running Time

A procedure for determining segment running time is described in this step. This procedure includes the calculation of free-flow speed, a vehicle proximity adjustment factor, and the additional running time due to mid-segment delay sources. Each calculation is discussed in the following subparts, which culminate with the calculation of segment running time.

A. Determine Free-Flow Speed

Free-flow speed represents the average running speed of through automobiles traveling along a segment under low volume conditions and not delayed by traffic control devices or other vehicles. It reflects the effect of the street environment on driver speed choice. Elements of the street environment that influence this choice under free-flow conditions include speed limit, access point density, median type, curb presence, and segment length.

The determination of free-flow speed is based on the calculation of base free-flow speed and an adjustment factor for signal spacing. These calculations are described in the next few paragraphs, which culminate in the calculation of free-flow speed.

Base Free-Flow Speed

The base free-flow speed is defined to be the free-flow speed on longer segments. It includes the influence of speed limit, access point density, median type, and curb presence. It is computed by using Equation 17-2. Alternatively, it can be measured in the field by using the technique described in Chapter 30.

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$$S_{fs} = S_o + f_{cs} + f_a$$

Equation 17-2

where

S_{fs} = base free-flow speed (mi/h),

S_o = speed constant (mi/h),

f_{cs} = adjustment for cross-section (mi/h), and

f_a = adjustment for access points (mi/h).

The speed constant and adjustment factors used in Equation 17-2 are listed in Exhibit 17-11. Equations provided in the table footnote can also be used to compute these adjustment factors.

Exhibit 17-11
Base Free-Flow Speed Adjustment Factors

Speed Limit (mi/h)	Speed Constant S_o (mi/h)[a]	Median Type	Percent with Restrictive Median (%)	Adjustment for Cross Section f_{cs} (mi/h)[b] No Curb	Curb
25	37.4	Restrictive	70	0.3	-0.9
30	39.7		40	0.6	-1.4
35	42.1		60	0.9	-1.8
40	44.4		80	1.2	-2.2
45	46.8		100	1.5	-2.7
50	49.1	Nonrestrictive	Not applicable	0.0	-0.5
55	51.5	No Median	Not applicable	0.0	-0.5

Access Density D_a (points/mi)	Adjustment for Access Points f_a by Lanes N_{as} (mi/h)[c] 1 Lane	2 Lanes	3 Lanes	4 Lanes
0	0.0	0.0	0.0	0.0
2	-0.2	0.1	-0.1	0.0
4	-0.3	-0.2	-0.1	-0.1
10	-0.9	-0.4	-0.3	-0.2
20	-1.6	-0.8	-0.5	-0.4
40	-3.1	-1.6	-1.0	-0.8
60	-4.7	-2.3	-1.6	-1.2

Notes: [a] $S_o = 25.6 + 0.47 S_p$ where S_p = posted speed limit (mi/h).
[b] $f_{cs} = 6.5 (p_{rm} - 0.5) + 3.7 (p_{cm} - 0.5)$ where p_{rm} = proportion of median length with restrictive median (decimal) and p_{cm} = proportion of segment with curb on the right-hand side (decimal).
[c] $f_a = -0.208 D_a / N_{as}$ with $D_a \leq 60$ ($N_{as} = N_{as1} + N_{as2}$) where D_a = access point density on segment (points/mi), N_{as} = number of through lanes on the signal to the subject direction of travel (ln), N_{as1} = number of access points (approaches on the right side in the subject direction of travel (points)), N_{as2} = number of access point approaches on the right side in the opposing direction of travel (points), and w = width of signalized intersection (ft).

Adjustment for Signal Spacing

Empirical evidence suggests that a shorter segment length (as best defined by signalized boundary intersections) tends to influence the driver's choice of free-flow speed (f). Shorter segments have been found to have a slower free-flow speed, all other factors being the same. Equation 17-3 is used to compute the value of an adjustment factor that accounts for this influence.

$$f_s = 1.02 - 4.7 \frac{S_{fs} - 19.5}{\max(L_s, 400)} \leq 1.0$$

Equation 17-3

where

f_s = signal spacing adjustment factor,

S_{fs} = base free-flow speed (mi/h), and

L_s = distance between adjacent signalized intersections (ft).

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Equation 17-3 was derived by using signalized boundary intersections. For more general applications, the definition of distance l_i is broadened such that it equals the distance between the two intersections that (a) bracket the subject segment and (b) each have a type of control that can impose on the subject through movement a legal requirement to stop or yield.

Free-Flow Speed

Free-flow speed is computed by using Equation 17-4 on the basis of estimates of base free-flow speed and the signal spacing adjustment factor. Alternatively, it can be entered directly by the analyst. It can also be measured in the field by using the technique described in Chapter 50.

Equation 17-4

$$S_f = S_0 f_s$$

where S_f equals the free-flow speed (mi/h) and other variables are as previously defined.

B. Compute Adjustment for Vehicle Proximity

The proximity adjustment factor adjusts the free-flow running time to account for the effect of traffic density. The adjustment results in an increase in running time (and corresponding reduction in speed) with an increase in volume. The reduction in speed is a result of shorter headways associated with the higher volume and drivers' propensity to be more cautious when headways are short. Equation 17-5 is used to compute the proximity adjustment factor.

Equation 17-5

$$f_x = \left[1 + \left(1 - \frac{v_m}{52.8\, N_m\, S_f}\right)^{2.001}\right]^{-1}$$

where

f_x = proximity adjustment factor,

v_m = mid-segment demand flow rate (veh/h),

N_m = number of through lanes on the segment in the subject direction of travel (ln), and

S_f = free-flow speed (mi/h).

The relationship between running speed [= (5,280 l_i)/(3,600 t_r)], where l_i is the segment length in feet and t_r is the segment running time in seconds] and volume for an urban street segment is shown in Exhibit 17-12. Trend lines are shown for three specific free-flow speeds. At a flow rate of 1,000 vehicles per hour per lane (veh/h/ln), each trend line shows a reduction of about 2.7 mi/h relative to the free flow speed. The trend lines extend beyond 1,000 veh/h/ln. However, it is unlikely that a volume in excess of this amount will be experienced on a segment bounded by intersections at which the through movement is regulated by a traffic control device.

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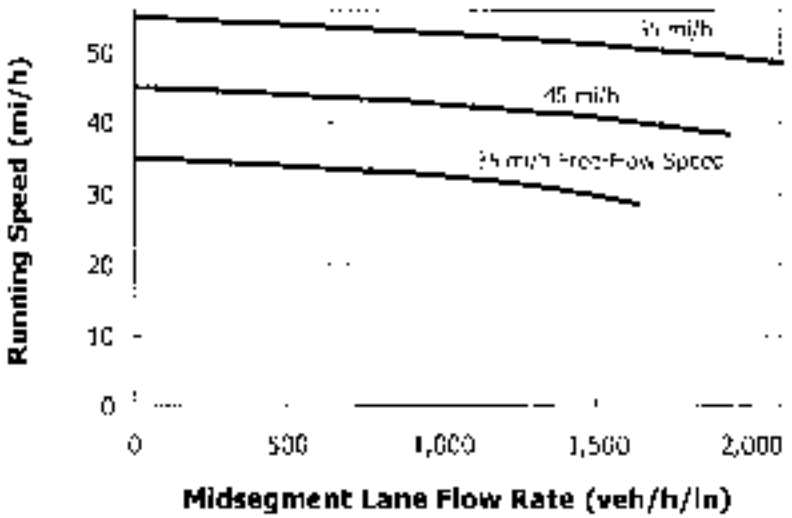

Exhibit 17-12
Speed–Flow Relationship for Urban Street Segments

C. Compute Delay due to Turning Vehicles

Vehicles turning from the subject street segment into an access point approach can cause a delay to following through vehicles. For right-turn vehicles, the delay results when the following vehicles' speed is reduced to accommodate the turning vehicle. For left-turn vehicles, the delay results when the following vehicles must wait in queue while a vehicle ahead executes a left-turn maneuver at the access point intersection. Delay due to left-turning vehicles occurs primarily on undivided streets; however, it can also occur on divided streets when the left-turn queue exceeds the available storage and spills back into the inside through lane. A procedure for computing this delay at each access point intersection is described in Chapter 30.

For planning and preliminary engineering analyses, Exhibit 17-13 can be used to estimate the delay due to turning vehicles at one representative access point intersection by using a midsegment volume that is typical for all such access points. The values in the exhibit represent the delay to through vehicles due to left and right turns at one access point intersection.[1] The selected value is multiplied by the number of access point intersections on the segment to estimate delay due to left and right turns ($\sum d_t$ in Equation 17-6).

Exhibit 17-13
Delay due to Turning Vehicles

Midsegment Volume (veh/h/ln)	Through Vehicle Delay (s/veh/pt) by Number of Through Lanes		
	1 Lane	2 Lanes	3 Lanes
200	0.04	0.04	0.05
300	0.08	0.08	0.09
400	0.12	0.13	0.13
500	0.18	0.25	0.15
600	0.27	0.41	0.19
700	0.50	0.77	0.15

The values listed in Exhibit 17-13 represent 10% left turns and 10% right turns from the segment at the access point intersection. If the actual turn percentages are less than 10%, then the delays can be reduced proportionally. For example, if the subject access point has 5% left turns and 5% right turns, then the values listed in the exhibit should be multiplied by 0.5 (= 5/10). Also, if a turn bay

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of adequate length is provided for one turn movement but not the other, then the values listed in the exhibit should be multiplied by 0.5. If both turn movements are provided a bay of adequate length, then the delay due to turns can be assumed to equal 0.0 seconds per vehicle per access point (s/veh/pt).

D. Estimate Delay due to Other Sources

Numerous other factors could cause a driver to reduce speed or to incur delay while traveling along a segment. For example, a vehicle that is completing a parallel parking maneuver may cause following vehicles to incur some delay. Also, vehicles that yield to pedestrians at a midsegment crosswalk may incur delay. Finally, bicyclists riding in a traffic lane or an adjacent bicycle lane may directly or indirectly cause vehicular traffic to adopt a lower speed.

Of the many sources for midsegment delay, the automobile methodology only includes procedures for estimating the delay due to turning vehicles. However, if the delay due to other sources is known or estimated by other means, then it can be included in the equation to compute running time.

E. Compute Segment Running Time

Equation 17-6 is used to compute segment running time based on consideration of through movement control at the boundary intersections, free-flow speed, vehicle proximity, and various midsegment delay sources.

Equation 17-6

$$t_r = \frac{6.0 - I}{0.0025\,L} f_A + \frac{3{,}600\,L}{5{,}280\,S_f} f_p + \sum_{i=1}^{N_a} d_{a,i} + d_{other}$$

with

Equation 17-7

$$f_A = \begin{cases} 1.00 & \text{(signalized or stop-controlled through movement)} \\ 0.00 & \text{(uncontrolled through movement)} \\ \min[v_d/c_t, 1.00] & \text{(YIELD-controlled through movement)} \end{cases}$$

where

t_r = segment running time (s);

I = start-up lost time = 2.0 if signalized, 2.5 if STOP or YIELD controlled (s);

L = segment length (ft);

f_p = control-type adjustment factor;

v_d = through-demand flow rate (veh/h);

c_t = through-movement capacity (veh/h);

$d_{a,i}$ = delay due to left and right turns from the street into access point or intersection i (s/veh);

N_a = number of influential access point approaches along the segment = $N_{a,1} + p_{a,2} N_{a,2}$ (points);

$N_{a,1}$ = number of access point approaches on the right side in the subject direction of travel (points);

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N_{apo} = number of access point approaches on the right side in the opposing direction of travel (points);

p_{pvl} = proportion of N_{apo} that can be accessed by a left turn from the subject direction of travel; and

d_{as} = delay due to other sources along the segment (e.g., curb parking or pedestrians) (s/veh).

Other variables are as previously defined. The variables l_1, l_2, v_m, and t_s used with the first term in Equation 17-6 apply to the through movement exiting the segment at the boundary intersection. This term accounts for the time required to accelerate to the running speed, less the start-up lost time. The divisor in this term is an empirical adjustment that minimizes the contribution of this term for longer segments. It partially reflects a tendency for drivers to offset this added time by adopting slightly higher midsegment speeds than reflected in the start-up lost time estimate.

Step 3: Determine the Proportion Arriving During Green

This step applies to the downstream boundary intersection when the operation of a signalized urban street segment is evaluated. If the downstream boundary intersection is not signalized, then this step is skipped.

The methodology includes a procedure for computing the proportion of vehicles that arrive during the effective green time for a phase serving a segment lane group (i.e., the lane groups "internal" to the segment). This procedure is described in this step. The procedure described in Chapter 18, Signalized Intersections, should be used for phases serving external lane groups.

If the upstream intersection is not signalized (or it is signalized but not coordinated with the downstream boundary intersection), then the proportion arriving during the green is equal to the effective green-to-cycle-length ratio and this step is completed. This relationship implies that arrivals are effectively uniform during the cycle when averaged over the analysis period.

If the boundary intersections are coordinated, then the remaining discussion in this step applies. The calculation of the proportion arriving during green is based on the signal timing of the upstream and downstream boundary intersections. However, if the signals are actuated, then the resulting estimate of the proportion arriving during green typically has an effect on signal timing and capacity. In fact, the process is circular and requires an iterative sequence of calculations to arrive at a convergence solution in which all computed variables are in agreement with their initially assumed values. This process is illustrated in Exhibit 17-8. That exhibit indicates that the calculation of average phase duration is added to this process when the intersection is actuated.

Typically, there are three signalized traffic movements that depart the upstream boundary intersection at different times during the signal cycle. They are the cross-street right turn, major-street through, and cross-street left turn. Traffic may also enter the segment at various access point intersections. The signalized movements often enter the segment as a platoon, but this platoon disperses as the vehicles move down the segment.

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A platoon dispersion model is used to predict the dispersed flow rate as a function of running time at any specified downstream location. The dispersed flow rates for the upstream intersection movement are combined with access point flow rates to predict an arrival flow profile at the downstream location. Exhibit 17-14 illustrates the predicted arrival flow profile at the stop line of the downstream intersection. This profile reflects the combination of the left-turn, through, and right-turn movements from the upstream intersection plus the turn movements at the access point intersection. The platoon dispersion model and the manner in which it is used to predict the dispersed flow rates for each of the individual movements are described in Chapter 30.

The gray shaded area in Exhibit 17-14 represents the arrival count during green, v_g. This count is computed by summing the flow rate for each time "step" (or interval) that occurs during the effective green period. The proportion of vehicles arriving during the effective green period for a specified lane group is computed by using Equation 17-8.

Equation 17-8

$$P = \frac{v_g}{q_v C}$$

where:

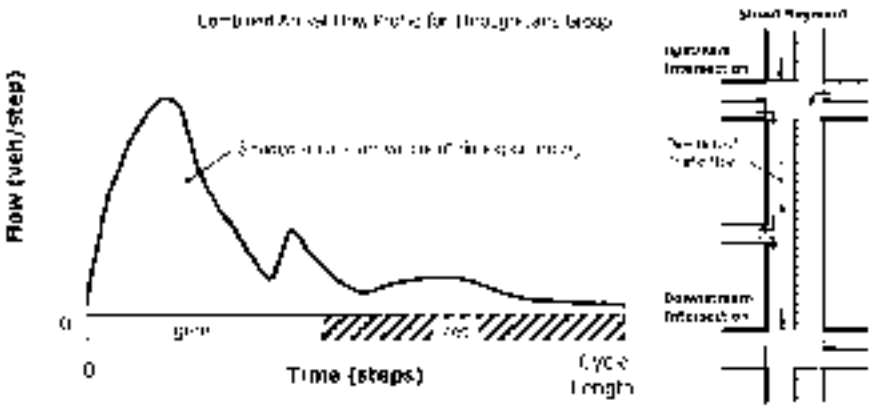
P = proportion of vehicles arriving during the green interval,

v_g = arrival count during green (veh),

q_v = arrival flow rate for downstream lane group (veh/s), and

C = cycle length (s).

Exhibit 17-14
Use of an Arrival Flow Profile to Estimate the Volume Arriving During Green



Step 4: Determine Signal Phase Duration

This step applies to the downstream boundary intersection when the operation of a signalized urban street segment is evaluated. If the downstream boundary intersection is not signalized, then this step is skipped.

If the downstream boundary intersection has pretimed signal control, then the signal phase duration is an input value. If this intersection has some form of actuated control, then the procedure described in Chapter 18 is used to estimate the average phase duration.

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Steps 3 to 5 are repeated until the duration of every phase at each signalized intersection converges to its steady-state value. Convergence is indicated when the estimate of phase duration on two successive repetitions is the same.

Step 5: Determine Through Delay

The delay incurred by through vehicles as they exit the segment is the basis for travel time estimation. In this context, a through vehicle is a vehicle that enters and exits the segment as a through vehicle. The nature of the delay models used in this manual makes it difficult to separate the delay to through vehicles from the delay to nonthrough vehicles. However, these models can provide a reasonable estimate of through delay whenever the through movement is the dominant movement on the segment.

Through delay represents the sum of two delay sources. One source is the delay due to the traffic control at the boundary intersection. It is called control delay. The other delay is that due to the negotiation of intersection geometry, such as curvature. It is called geometric delay.

Procedures for computing control delay are described in the following chapters of the manual:

- Signal control (Chapter 18 or 22),
- All-way stop control (Chapter 20), and
- Yield control at a roundabout intersection (Chapter 21).

The analyst should refer to the appropriate chapter for guidance in estimating the through control delay for the boundary intersection. If the through movement is uncontrolled at the boundary intersection, then the through control delay is 0.0 s/veh.

The geometric delay for conventional three-leg or four-leg intersections (i.e., nonroundabout intersections) is considered to be negligible. In contrast, the geometric delay for a circular intersection is not negligible and should be added to the control delay to obtain the necessary through delay. A procedure for estimating geometric delay for roundabout intersections is described in Chapter 33, Roundabouts: Supplemental.

If the segment is not in a coordinated system, the through delay estimate should be based on isolated operation. The methodologies in Chapters 18 to 21 can be used to provide this estimate.

If the segment is within a coordinated signal system, then the methodology in Chapter 18 or Chapter 22 is used to determine the through delay. The upstream filtering adjustment factor is used to account for the effect of the upstream signal on the variability in arrival volume at the downstream intersection. The procedure for calculating this factor is described in Section 3 of Chapter 18.

If the through movement shares one or more lanes at a signalized boundary intersection, then the through delay is computed by using Equation 17-5:

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Equation 17-9

$$d_t = \frac{d_{th} v_{th} N_{th} + d_{sh} v_{sh}(1 - P_L) + d_{sr} v_{sr}(1 - P_R)}{v_{th}}$$

where

d_t = through delay (s/veh),

v_{th} = through-demand flow rate (veh/h),

d_{th} = delay in exclusive through-lane group (s/veh),

v_{th} = demand flow rate in exclusive through-lane group (veh/h/ln),

N_{th} = number of lanes in exclusive through-lane group (ln),

d_{sh} = delay in shared left-turn and through lane group (s/veh),

v_{sh} = demand flow rate in shared left-turn and through-lane group (veh/h),

d_{sr} = delay in shared right-turn and through-lane group (s/veh),

v_{sr} = demand flow rate in shared right-turn and through-lane group (veh/h),

P_L = proportion of left-turning vehicles in the shared lane (decimal), and

P_R = proportion of right-turning vehicles in the shared lane (decimal).

The procedure described in Chapter 18, Signalized Intersections, is used to estimate the variables shown in Equation 17-9.

Step 6: Determine Through Stop Rate

As with control delay, through stop rate describes the stop rate of vehicles that enter and exit the segment as through vehicles. The nature of the stop rate models described in this step makes it difficult to separate the stops to through vehicles from those incurred by nonthrough vehicles. However, these models can provide a reasonable estimate of through stop rate whenever the through movement is the dominant movement on the segment.

Stop rate is defined as the average number of full stops per vehicle. A *full stop* is defined to occur at a signalized intersection when a vehicle slows to zero (or a crawl speed, if in queue) as a consequence of the change in signal indication from green to red, but not necessarily in direct response to the observed red indication. A *full stop* is defined to occur at an unsignalized intersection when a vehicle slows to zero (or a crawl speed, if in queue) as a consequence of the control device used to regulate the approach. For example, if a vehicle is in an overflow queue and requires three signal cycles to clear the intersection, then it is estimated to have three full stops (one stop for each cycle).

The stop rate for a STOP-controlled approach can be assumed to equal 1.0 stops/veh. The stop rate for an uncontrolled approach can be assumed to equal 0.0 stops/veh. The stop rate at a YIELD-controlled approach will vary with conflicting demand. It can be estimated (in stops per vehicle) as equal to the volume-to-capacity ratio of the through movement at the downstream intersection. This approach recognizes that YIELD control does not require drivers to come to a complete stop when there is no conflicting traffic.

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The through stop rate at a signalized boundary intersection is computed by using Equation 17-10.

$$h = 3{,}600\left(\frac{N_f}{\min(1, Q_{2,t})\, g\, s} + \frac{N_u\, Q_{2,t}}{v_u\, C}\right)^{0.9} \quad \text{Equation 17-10}$$

with

$$N_f = N_{f,t} + N_{f,sl}\left(1 - P_L\right) + N_{f,sr}\left(1 - P_R\right) \quad \text{Equation 17-11}$$

$$s = s_t N_t + s_{sl}\left(1 - \frac{P_L}{N_u}\right) + s_{sr}\left(1 - \frac{P_R}{N_u}\right) \quad \text{Equation 17-12}$$

$$Q_{2,t} = \frac{\left(Q_{2,t} - Q_{2,1}\right) N_t + \left(Q_{2,sl} - Q_{2,1}\right)\left(1 - P_L\right) + \left(Q_{2,sr} - Q_{2,1}\right)\left(1 - P_R\right)}{N_u} \quad \text{Equation 17-13}$$

where

h = full stop rate (stops/veh),

N_f = number of fully stopped vehicles (veh/ln),

g = effective green time (s),

s = adjusted saturation flow rate (veh/h/ln),

$Q_{2,t}$ = back-of-queue size (veh/ln),

N_t = number of fully stopped vehicles in exclusive through-lane group (veh/ln),

N_{sl} = number of fully stopped vehicles in shared left-turn and through-lane group (veh/ln),

N_{sr} = number of fully stopped vehicles in shared right-turn and through-lane group (veh/ln),

N_u = number of through lanes (shared or exclusive) (ln),

s_t = saturation flow rate in exclusive through-lane group (veh/h/ln),

s_{sl} = saturation flow rate in shared left-turn and through-lane group with permitted operation (veh/h/ln),

s_{sr} = saturation flow rate in shared right-turn and through-lane group with permitted operation (veh/h/ln),

$Q_{2,1}$ = second-term back-of-queue size for exclusive through-lane group (veh/ln),

$Q_{2,sl}$ = second-term back-of-queue size for shared left-turn and through-lane group (veh/ln),

$Q_{2,sr}$ = second-term back-of-queue size for shared right-turn and through-lane group (veh/ln),

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Q_t = third-term back-of-queue size for exclusive through lane group (veh/ln),

Q_{tL} = third-term back-of-queue size for shared left-turn and through-lane group (veh/ln), and

Q_{tR} = third-term back-of-queue size for shared right-turn and through lane group (veh/ln).

Other variables are as previously defined. The procedure for computing N_t, Q_t, and Q_{tL} is provided in Chapter 31, Signalized Intersections: Supplemental.

The first term in Equation 17-10 represents the proportion of vehicles stopped once by the signal. For some of the more complex arrival-departure polygons that include left-turn movements operating with the permitted mode, the queue may dissipate at two or more points during the cycle. If this occurs, then N_t is computed for each of the i periods between queue dissipation points. The value of N_t then equals the sum of the N_t values computed in this manner.

The second term in Equation 17-10 represents the additional stops that may occur during overflow (i.e., cycle failure) conditions. The contribution of this term becomes significant when the volume-to-capacity ratio exceeds about 0.8. The full stop rate typically varies from 0.4 stops/veh at low volume-to-capacity ratios to 2.0 stops/veh when the volume-to-capacity ratio is about 1.0.

Step 7: Determine Travel Speed

Equation 17-14 is used to compute the travel speed for the subject direction of travel along the segment.

Equation 17-14

$$S_{T,ex} = \frac{3{,}600\ L}{5{,}280\ (t_R + d_t)}$$

where

$S_{T,ex}$ = travel speed of through vehicles for the segment (mi/h),

L = segment length (ft),

t_R = segment running time (s), and

d_t = through delay (s/veh).

The control delay used in Equation 17-14 is that incurred by the through lane group at the downstream boundary intersection.

Step 8: Determine Spatial Stop Rate

Equation 17-15 is used to compute the spatial stop rate for the subject direction of travel along the segment.

Equation 17-15

$$H_{ex} = 5{,}280\ \frac{h + h_{adj}}{L}$$

where

H_{ex} = spatial stop rate for the segment (stops/mi),

h = full stop rate (stops/veh),

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h_{adj} = full stop rate due to other sources (stops/veh), and

L = segment length (ft).

The full stop rate based on Equation 17-15 is first incurred by the through lane group at the downstream boundary intersection. In some instances, stops may be incurred at midsegment locations due to pedestrian crosswalks, bus stops, or turns into access point approaches. If the full stop rate associated with these other stops can be estimated by the analyst, then it can be included in the calculation by using the variable h_{adj}.

Step 9: Determine LOS

LOS is determined for both directions of travel along the segment. Exhibit 17-2 lists the LOS thresholds established for this purpose. As indicated in this exhibit, LOS is defined by two performance measures. One measure is the travel speed for through vehicles, expressed as a percentage of the base free-flow speed. The second measure is the volume-to-capacity ratio for the through movement at the downstream boundary intersection.

The base free-flow speed was computed in Step 2 and the travel speed was computed in Step 7.

The volume-to-capacity ratio for the through movement at the boundary intersection is computed as the through volume divided by the through movement capacity. The capacity is an input variable to the methodology.

The LOS attributed to each direction of travel applies to the segment, which includes both the link and the downstream boundary intersection. Chapters 18 to 22 describe LOS thresholds for the boundary intersection. The automobile methodology does not assign a LOS indicator to the link portion of the segment.

LOS is probably more meaningful as an indicator of traffic performance along a facility rather than a single street segment. A procedure for estimating facility LOS is described in Chapter 16.

Step 10: Determine Automobile Traveler Perception Score

The automobile traveler perception score for urban street segments is provided as a useful performance measure. It indicates the traveler's perception of service quality. The score is computed by using Equation 17-16 to Equation 17-21.

$$I_{p,A} = 1 - P_{bicycle} \times P_{pedestrian} \times P_{transit} \times P_{LOS} \times P_V \quad \text{Equation 17-16}$$

with

$$P_{bicycle} = \left(1 + e^{-1.3466 + 0.0572 N_{bicycle} - 0.0748 v_{bicycle}}\right)^{-1} \quad \text{Equation 17-17}$$

$$P_{pedestrian} = \left(1 + e^{-0.6826 + 0.1546 N_{pedestrian} + 0.0419 v_{pedestrian}}\right)^{-1} \quad \text{Equation 17-18}$$

$$P_{transit} = \left(1 + e^{-1.0789 + 0.1038 N_{transit} + 0.0348 v_{transit}}\right)^{-1} \quad \text{Equation 17-19}$$

$$P_{LOS} = \left(1 + e^{-2.0381 + 0.2437 LOS + 0.0537 v_{thru}}\right)^{-1} \quad \text{Equation 17-20}$$

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Equation 17-21

$$P_i = \left(1 + e^{3.9811 - 0.5756 I_{a,s} - 3.0141 P_{LT,a,s}}\right)^{-1}$$

where

$I_{a,s}$ = automobile traveler perception score for segment;

$P_{i,BCDEF}$ = probability that an individual will respond with a rating of B, C, D, E, or F;

$P_{i,CDEF}$ = probability that an individual will respond with a rating of C, D, E, or F;

$P_{i,DEF}$ = probability that an individual will respond with a rating of D, E, or F;

$P_{i,EF}$ = probability that an individual will respond with a rating of E or F;

P_i = probability that an individual will respond with a rating of F; and

$P_{LT,a,s}$ = proportion of intersections with a left-turn lane (or bay) on the segment (decimal).

Other variables are as previously defined. The derivation of Equation 17-16 is based on the assignment of scores to each letter rating, in which a score of "1" is assigned to the rating of A (denoting "best"), "2" is assigned to B, and so on. The survey results were used to calibrate a set of models that collectively predicts the probability that a traveler will assign various rating combinations for a specified spatial stop rate and proportion of intersections with left-turn lanes. The score obtained from Equation 17-16 represents the expected (or long-run average) score for the population of travelers.

The proportion of intersections with left-turn lanes equals the number of left-turn lanes (or bays) encountered while driving along the segment divided by the number of intersections encountered. The signalized boundary intersection is counted (if it exists). All unsignalized intersections of public roads are counted. Private driveway intersections are not counted, unless they are signal controlled.

The score obtained from Equation 17-16 provides a useful indication of performance from the perspective of the traveler. Scores of 2.0 or less indicate the best perceived service, and values in excess of 5.0 indicate the worst perceived service. Although this score is closely tied to the concept of service quality, it is not used to determine LOS for the urban street segment.

PEDESTRIAN MODE

This subsection describes the methodology for evaluating the performance of an urban street segment in terms of its service to pedestrians.

Urban street segment performance from a pedestrian perspective is separately evaluated for each side of the street. *Unless otherwise stated, all variables identified in this section are specific to the subject side of the street.* If a sidewalk is not available for the subject side of the street, then it is assumed that pedestrians will walk on the street on that side (even if there is a sidewalk on the other side).

The methodology is focused on the analysis of a segment with either signal-controlled or two-way STOP-controlled boundary intersections. Chapter 18 describes a methodology for evaluating signalized intersection performance from

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a pedestrian perspective. No methodology exists for evaluating two-way stop-controlled intersection performance (with the cross street stop-controlled). However, it is assumed that this type of control has negligible influence on pedestrian service along the segment. This edition of the HCM does not include a procedure for evaluating a segment's performance when the boundary intersection is an all-way stop-controlled intersection, a roundabout, or a signalized interchange ramp terminal.

The pedestrian methodology is applied through a series of nine steps that culminate in the determination of the segment LOS. These steps are illustrated in Exhibit 17-15. Performance measures that are estimated include

- Pedestrian travel speed,
- Average pedestrian space, and
- Pedestrian LOS scores for the link and segment.

A methodology for evaluating off-street pedestrian facilities is provided in Chapter 23, Off-Street Pedestrian and Bicycle Facilities.

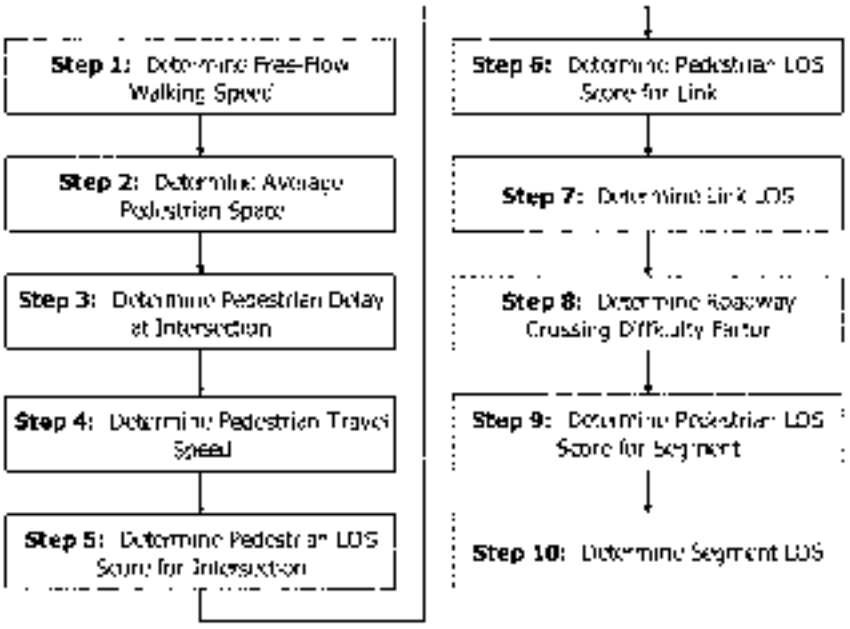

Exhibit 17-15
Pedestrian Methodology for Urban Street Segments

Link-Based Evaluation

Steps 6 and 7 of the pedestrian methodology can be used as a stand-alone procedure for link-based evaluation of pedestrian service. This approach is regularly used by local, regional, and state transportation agencies. It offers the advantage of being less data-intensive than the full, 10-step methodology and produces results that are generally reflective of pedestrian perceptions of service along the roadway. It can be especially attractive when agencies are performing a networkwide evaluation for a large number of roadway links.

The analyst should recognize that the resulting link LOS does not consider some aspects of pedestrian travel along a segment (e.g., crossing difficulty or intersection service). For this reason, the LOS score for the link should not be

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aggregated for the purpose of characterizing facility performance. The analyst should also be aware that this approach precludes an integrated multimodal evaluation because it does not fully reflect segment performance.

Concepts

The methodology provides a variety of measures for evaluating segment performance in terms of its service to pedestrians. Each measure describes a different aspect of the pedestrian trip along the segment. One measure is the LOS score. This score is an indication of the typical pedestrian's perception of the overall segment travel experience. A second measure is the average speed of pedestrians traveling along the segment.

A third measure is based on the concept of "circulation area." It represents the average amount of sidewalk area available to each pedestrian walking along the segment. A larger area is more desirable from the pedestrian perspective. Exhibit 17-16 provides a qualitative description of pedestrian space that can be used to evaluate sidewalk performance from a circulation-area perspective.

Exhibit 17-16
Qualitative Description of Pedestrian Space

Pedestrian Space (ft^2/p)		
Random Flow	Platoon Flow	Description
>60	>530	Ability to move in desired path, no need to alter movements
>40–60	>60–530	Occasional need to adjust path to avoid conflicts
>24–40	>40–90	Frequent need to adjust path to avoid conflicts
>15–24	>23–40	Speed and ability to pass slower pedestrians restricted
>8–15	>11–23	Speed restricted, very limited ability to pass slower pedestrians
≤8	≤11	Speed severely restricted, frequent contact with other users

The first two columns in Exhibit 17-16 indicate a sensitivity to flow condition. Random pedestrian flow is typical of most segments. Platoon flow is appropriate for shorter segments (e.g., in downtown areas) with signalized boundary intersections.

Step 1: Determine Free-Flow Walking Speed

The average free-flow pedestrian walking speed S_o is needed for the evaluation of urban street segment performance from a pedestrian perspective. This speed should reflect conditions in which there are negligible pedestrian-to-pedestrian conflicts and negligible adjustments in a pedestrian's desired walking path to avoid other pedestrians.

Research indicates that walking speed is influenced by pedestrian age and sidewalk grade (1). If 0% to 20% of pedestrians traveling along the subject segment are elderly (i.e., 65 years of age or older), an average free-flow walking speed of 4.4 ft/s is recommended for segment evaluation. If more than 20% of pedestrians are elderly, an average free-flow walking speed of 3.3 ft/s is recommended. In addition, an upgrade of 10% or greater reduces walking speed by 0.3 ft/s.

Step 2: Determine Average Pedestrian Space

Pedestrians are sensitive to the amount of space separating them from other pedestrians and obstacles as they walk along a sidewalk. Average pedestrian

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space is an indicator of segment performance for travel at a sidewalk. It depends on the effective sidewalk width, pedestrian flow rate, and walking speed. This step is not applicable when the sidewalk does not exist.

A. Compute Effective Sidewalk Width

The effective sidewalk width equals the total walkway width less the effective width of fixed objects located on the sidewalk and less any shy distance associated with the adjacent street or a vertical obstruction. Fixed objects can be continuous (e.g., a fence or a building face) or discontinuous (e.g., trees, poles, or benches).

The effective sidewalk width is an average value for the length of the link. It is computed by using Equation 17-22 to Equation 17-26.

$$W_e = W_t - W_{o,i} - W_{o,o} - W_{s,i} - W_{s,o} \geq 0.0 \quad \text{Equation 17-22}$$

with

$$W_{s,i} = \max(W_{in}, 1.5) \quad \text{Equation 17-23}$$

$$W_{s,o} = 3.0 p_{window} + 2.0 p_{building} + 1.5 p_{fence} \quad \text{Equation 17-24}$$

$$W_{o,i} = \omega_{o,i} \quad W_{s,i} \geq 0.0 \quad \text{Equation 17-25}$$

$$W_{o,o} = \omega_{o,o} \quad W_{s,o} \geq 0.0 \quad \text{Equation 17-26}$$

where

W_e = effective sidewalk width (ft),

W_t = total walkway width (ft),

$W_{o,i}$ = adjusted fixed-object effective width on inside of sidewalk (ft),

$W_{o,o}$ = adjusted fixed-object effective width on outside of sidewalk (ft),

$W_{s,i}$ = shy distance on inside (curb side) of sidewalk (ft),

$W_{s,o}$ = shy distance on outside of sidewalk (ft),

W_{in} = buffer width between roadway and sidewalk (ft),

p_{window} = proportion of sidewalk length adjacent to a window display (decimal),

$p_{building}$ = proportion of sidewalk length adjacent to a building face (decimal),

p_{fence} = proportion of sidewalk length adjacent to a fence or low wall (decimal),

$\omega_{o,i}$ = effective width of fixed objects on inside of sidewalk (ft), and

$\omega_{o,o}$ = effective width of fixed objects on outside of sidewalk (ft).

The relationship between the variables in these equations is illustrated in Exhibit 17-17.

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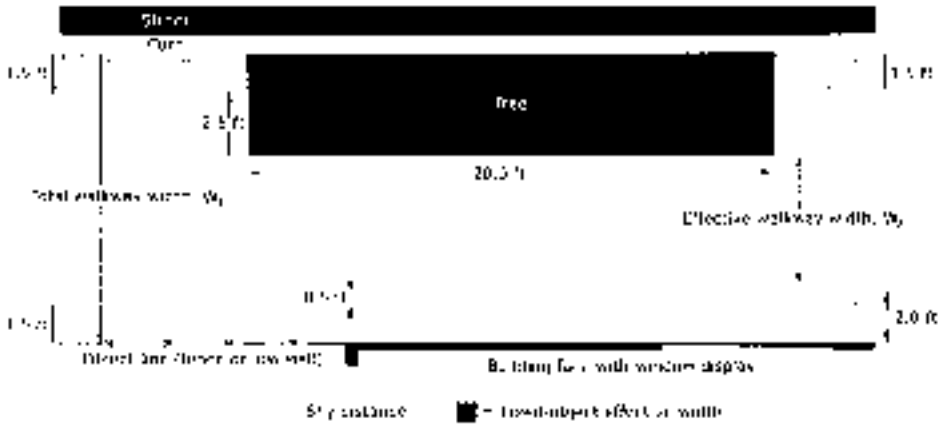
Exhibit 17-17
Width Adjustments for Point Objects



The variables W_p, $W_{p,o}$ (average, typical, or known pedestrian flow rate), and $v_{p,o}$ are input variables. They represent average, or typical, values for the length of the sidewalk. Chapter 25, Off-Street Pedestrian and Bicycle Facilities, provides guidance for estimating the effective width of many common fixed objects.

Typical shy distances are shown in Exhibit 17-17. Shy distance on the inside (curb side) of the sidewalk is measured from the outside edge of the paved roadway (or face of curb, if present). It is generally considered to equal 1.5 ft. Shy distance on the outside of the sidewalk is 1.5 ft if a fence or a low wall is present, 2.0 ft if a building is present, 3.0 ft if window display is present, and 0.0 ft otherwise.

B. Compute Pedestrian Flow Rate per Unit Width

The pedestrian flow per unit width of sidewalk is computed by using Equation 17-27 for the subject sidewalk. The variable $v_{p,o}$ is an input variable.

Equation 17-27

$$v_p = \frac{v_{p,o}}{60\ W_p}$$

where

v_p = pedestrian flow per unit width (p/ft/min),

$v_{p,o}$ = pedestrian flow rate in the subject sidewalk (walking in both directions) (p/h), and

W_p = effective sidewalk width (ft).

C. Compute Average Walking Speed

The average walking speed S_p is computed by using Equation 17-28. This equation is derived from the relationship between flow rate and average walking speed described in Exhibit 23-1 of Chapter 23.

Equation 17-28

$$S_p = (1 - 0.00078\ v_p)\ S_{p,0} \quad \geq 0.5\ S_{p,0}$$

where S_p = pedestrian walking speed (ft/s), $S_{p,0}$ = free-flow pedestrian walking speed (ft/s), and v_p = pedestrian flow per unit width (p/ft/min).

AR0074208

D. Compute Pedestrian Space

Finally, Equation 17-29 is used to compute average pedestrian space.

$$A_p = 60 \frac{S_p}{v_p}$$ Equation 17-29

where A_p is the pedestrian space (ft²/p) and other variables are as previously defined.

The pedestrian space obtained from Equation 17-29 can be compared with the ranges provided in Exhibit 17-16 to make some judgments about the performance of the subject intersection corner.

Step 3: Determine Pedestrian Delay at Intersection

Pedestrian delay at three locations along the segment is determined in this step. Each of these delays represents an input variable for the methodology and is described in Section 1, Required Input Data.

The first delay variable represents the delay incurred by pedestrians who travel through the boundary intersection along a path that is parallel to the segment centerline (d_p). The second delay variable represents the delay incurred by pedestrians who cross the segment at the nearest signal-controlled crossing (d_s). The third delay variable represents the delay incurred by pedestrians waiting for a gap to cross the segment at an uncontrolled location (d_u).

Step 4: Determine Pedestrian Travel Speed

Pedestrian travel speed represents an aggregate measure of speed along the segment. It combines the delay incurred at the downstream boundary intersection plus the time required to walk the length of the segment. As such, it is typically slower than the average walking speed. The pedestrian travel speed is computed by using Equation 17-30.

$$S_{p,ped} = \frac{l}{\frac{l}{S_p} + d_{ped}}$$ Equation 17-30

where:

$S_{p,ped}$ = travel speed of through pedestrians for the segment (ft/s),

l = segment length (ft),

S_p = pedestrian walking speed (ft/s), and

d_{ped} = pedestrian delay when walking parallel to the segment (s/p).

In general, a travel speed of 4.0 ft/s or more is considered desirable and a speed of 2.0 ft/s or less is considered undesirable.

Step 5: Determine Pedestrian LOS Score for Intersection

The pedestrian LOS score for the boundary intersection ($I_{p,int}$) is determined in this step. If the boundary intersection is signalized, then the pedestrian

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methodology described in Chapter 18 is used for this determination. If the boundary intersection is two-way STOP control, then the score is equal to 0.0.

Step 6: Determine Pedestrian LOS Score for Link

The pedestrian LOS score for the link $I_{p,ink}$ is calculated by using Equation 17-31.

Equation 17-31

$$I_{p,ink} = 6.0468 - I_{p} - F_{w} + F_{v}$$

with

Equation 17-32

$$F_{w} = 1.2276 \ln(W_{v} + 0.5 W_{t} + 50 p_{pk} + W_{bw} f_{b} + W_{s,a} f_{sw})$$

Equation 17-33

$$F_{v} = 0.0091 \left[\frac{v_{p}}{4 N_{ln}} \right]$$

Equation 17-34

$$F_{s} = 4 \left(\frac{S_{R}}{100} \right)^{2}$$

where

$I_{p,ink}$ = pedestrian LOS score for link;

I_{p} = cross-section adjustment factor;

F_{v} = motorized vehicle volume adjustment factor;

F_{s} = motorized vehicle speed adjustment factor;

$\ln(\cdot)$ = natural log of $\cdot$;

W_{t} = effective total width of outside through lane, bicycle lane, and shoulder as a function of traffic volume (see Exhibit 17-18) (ft);

W = effective width of combined bicycle lane and shoulder (see Exhibit 17-18) (ft);

p_{pk} = proportion of on-street parking occupied (decimal);

W_{bw} = border width between roadway and available sidewalk (= 0.0 if sidewalk does not exist) (ft);

f_{b} = buffer area coefficient = 5.37 for any continuous barrier at least 4 ft high that is located between the sidewalk and the outside edge of roadway; otherwise use 0.0;

W_{s} = available sidewalk width = 0.0 if sidewalk does not exist or $W_{s} = W_{s,a}$ if sidewalk exists (ft);

$W_{s,a}$ = adjusted available sidewalk width = min(W_{s}, 10) (ft);

f_{sw} = sidewalk width coefficient = 6.0 − 0.3 $W_{s,a}$;

v_{p} = mid-segment demand flow rate (direction nearest to the subject sidewalk) (veh/h);

N_{ln} = number of through lanes on the segment in the subject direction of travel (ln); and

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v_{av} = motorized vehicle running speed = 3,600 / [(5,280 r_g) (mi/h)

The value used for several of the variables in Equation 17-32 to Equation 17-34 is dependent on various conditions. These conditions are identified in Column 1 of Exhibit 17-18. If the condition is satisfied, then the equation in Column 2 is used to compute the variable value. If it is not satisfied, then the equation in Column 3 is used. The equations in the first two rows are considered in sequence to determine the effective width of the outside lane and shoulder W_e.

Exhibit 17-18
Variables for Pedestrian LOS Score for Urban Street Segments

Condition	Variable When Condition Is Satisfied	Variable When Condition Is Not Satisfied
p_{BL} = 0.0	$W_e = W_{OL} + W_{BL} + W_{OS}'$	$W_e = W_{OL} + W_{OS}$
v_{av} > 150 veh/h or street is divided	$W_e = W_t$	$W_e = W_t (2 - 0.005\ v_{av})$
p_{PK} < 0.25 or parking is striped	$W_t = W_e + W_{PK}'$	$W_t = 10$

Notes: W_e = total width of the outside through lane, bicycle lane, and paved shoulder (ft);
W_{OL} = width of the outside through lane (ft);
W_{OS}' = adjusted width of paved outside shoulder: if curb is present $W_{OS}' = W_{OS} - 1.5 > 0$, otherwise $W_{OS}' = W_{OS}$ (ft);
W_{OS} = width of paved outside shoulder (ft); and
W_{BL} = width of the bicycle lane = 0.0 if bicycle lane not striped (ft).

The buffer width coefficient determination is based on the presence of a continuous barrier in the buffer. In making this determination, repetitive vertical objects (e.g., trees or bollards) are considered to represent a continuous barrier if they are at least 3 ft high and have an average spacing of 20 ft or less. For example, the sidewalk shown in Exhibit 17-17 does not have a continuous buffer because the street trees adjacent to the curb are spaced at more than 20 ft.

The pedestrian LOS score is sensitive to the separation between pedestrians and moving vehicles. It is also sensitive to the speed and volume of those vehicles. Physical barriers and parked cars between moving vehicles and pedestrians effectively increase the separation distance and the perceived quality of service. Higher vehicle speeds or volumes lower the perceived quality of service.

If the sidewalk is not continuous for the length of the segment, then the segment should be subdivided into subsegments and each subsegment separately evaluated. For this application, a subsegment is defined to begin or end at each break in the sidewalk. Each subsegment is then separately evaluated by using Equation 17-31. Each equation variable is uniquely quantified to represent the subsegment to which it applies. The buffer width and the effective sidewalk width are each set to 0.0 ft for any subsegment without a sidewalk. The pedestrian LOS score $I_{p,ped}$ is then computed as a weighted average of the subsegment scores, where the weight assigned to each score equals the portion of the segment length represented by the corresponding subsegment.

The motorized vehicle running speed is computed by using the automobile methodology, as described in a previous subsection.

Step 7: Determine Link LOS

The pedestrian LOS for the link is determined by using the pedestrian LOS score from Step 6 and the average pedestrian space from Step 2. These two performance measures are compared with their respective thresholds in Exhibit

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17-3 to determine the LOS for the specified direction of travel along the subject link. If a sidewalk does not exist and pedestrians are relegated to walking in the street, then LOS is determined by using Exhibit 17-4 because the pedestrian space concept does not apply.

Step 8: Determine Roadway Crossing Difficulty Factor

The pedestrian roadway crossing difficulty factor measures the difficulty of crossing the street between boundary intersections. Segment performance from a pedestrian perspective is reduced if the crossing is perceived to be difficult.

The roadway crossing difficulty factor is based on the delay incurred by a pedestrian who crosses the subject segment. One crossing option the pedestrian may consider is to alter his or her travel path by diverting to the nearest signal-controlled crossing. This crossing location may be a midsegment signalized crosswalk or it may be a signalized intersection.

A second crossing option is to continue on the original travel path by completing a midsegment crossing at an uncontrolled location. If this type of crossing is legal along the subject segment, then the pedestrian crosses when there is an acceptable gap in the motorized vehicle stream.

Both of these two crossing options are considered in this step, with that option requiring the least delay used as the basis for computing the pedestrian roadway crossing difficulty factor. The time to walk across the segment is common to both options and therefore is not included in the delay estimate for either option.

A. Compute Diversion Delay

The delay incurred as a consequence of diverting to the nearest signal-controlled crossing is computed first. It includes the delay involved in walking to and from the midsegment crossing point to the nearest signal-controlled crossing and the delay waiting to cross at the signal. Hence, calculation of this delay requires knowledge of the distance to the nearest signalized crossing and its signal timing.

The distance to the nearest crossing location (l_d) is based on one of two approaches. The first approach is used if there is an identifiable pedestrian path (a) that intersects the segment and continues on beyond the segment and (b) on which most crossing pedestrians travel. The location of this path is shown for two cases in Exhibit 17-19. Exhibit 17-19(a) illustrates the distance l_d when the pedestrian diverts to the nearest signalized intersection. This distance is measured from the crossing location to the signalized intersection.

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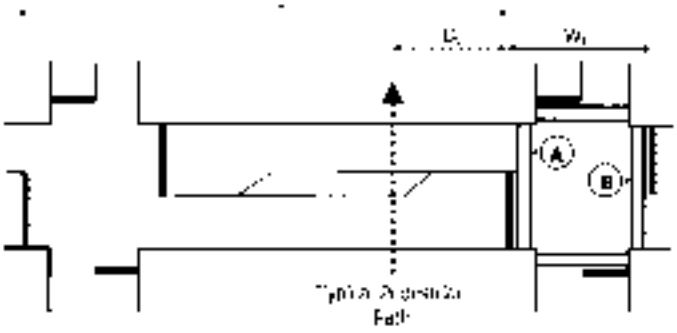
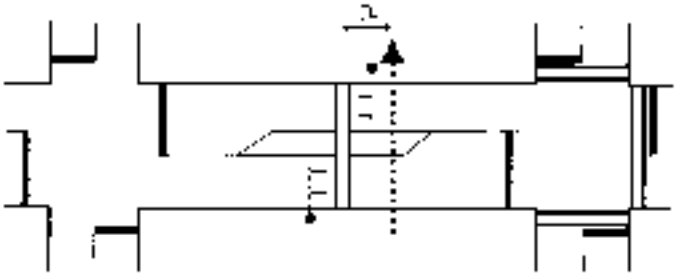


(a) Divert to Nearest Boundary Intersection



(b) Divert to Midsegment Signalized Crosswalk

Exhibit 17-19
Diversion Distance Components

Exhibit 17-19(b) illustrates the distance D_d when a signalized crosswalk is provided at a midsegment location. In this situation, the distance is measured from the pedestrian crossing location to the location of the signalized crosswalk. In either case, the distance D_d is an input value provided by the analyst.

The second approach is used if crossings occur somewhat uniformly along the length of the segment. In this situation the distance D_d can be assumed to equal one third of the distance between the nearest signal-controlled crossings that bracket the subject segment.

The diversion distance to the nearest crossing is computed by using Equation 17-35.

$$D_d = 2\,D_s \quad \text{Equation 17-35}$$

where

D_d = diversion distance (ft), and

D_s = distance to nearest signal-controlled crossing (ft).

If the nearest crossing location is at the signalized intersection and the crossing is at Location A in Exhibit 17-19(a), then Equation 17-35 applies directly. If the nearest crossing location is at the signalized intersection but the crossing is at Location B, then the distance obtained from Equation 17-35 should be increased by adding two increments of the intersection width W_e.

The delay incurred due to diversion is calculated by using Equation 17-36.

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Equation 17-36

$$d_{p,d} = \frac{D_d}{S_p} - d_{p,c}$$

where

$d_{p,d}$ = pedestrian diversion delay (s/p),

D_d = diversion distance (ft),

S_p = pedestrian walking speed (ft/s), and

$d_{p,c}$ = pedestrian delay when crossing the segment at the nearest signal-controlled crossing (s/p).

The pedestrian delay incurred when crossing at the nearest signal-controlled crossing was determined in Step 3.

8. Compute Roadway Crossing Difficulty Factor

The roadway crossing difficulty factor is computed by using Equation 17-37.

Equation 17-37

$$f_{cd} = 1.0 + \frac{0.10\, d_{p,c} \times (0.318\, I_{p,int} - 0.220\, I_{p,int} + 1.606)}{7.5}$$

where

f_{cd} = roadway crossing difficulty factor,

$d_{p,c}$ = crossing delay = min($d_{p,c}$, $d_{p,w}$, 60) (s/p),

$d_{p,d}$ = pedestrian diversion delay (s/p),

$d_{p,w}$ = pedestrian waiting delay (s/p),

$I_{p,int}$ = pedestrian LOS score for link, and

$I_{p,int}$ = pedestrian LOS score for intersection.

If the factor obtained from Equation 17-37 is less than 0.80, then it is set equal to 0.80. If the factor is greater than 1.20, then it is set equal to 1.20.

The pedestrian waiting delay was determined in Step 3. If a midsegment crossing is illegal, then the crossing delay determination does not include consideration of the pedestrian waiting delay [i.e., $d_{p,c} = \min(d_{p,c}, 60)$].

Step 9: Determine Pedestrian LOS Score for Segment

The pedestrian LOS score for the segment is computed by using Equation 17-38.

Equation 17-38

$$I_{p,s} = f_{cd}(0.318\, I_{p,int} - 0.220\, I_{p,int} - 1.606)$$

where $I_{p,s}$ is the pedestrian LOS score for the segment, and other variables are as previously defined.

Step 10: Determine Segment LOS

The pedestrian LOS for the segment is determined by using the pedestrian LOS score from Step 9 and the average pedestrian space from Step 7. These two performance measures are compared with their respective thresholds in Exhibit

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17-3 to determine the LOS for the specified direction of travel along the subject segment. If a sidewalk does not exist and pedestrians are relegated to walking in the street, then LOS is determined by using Exhibit 17-4 because the pedestrian space concept does not apply.

BICYCLE MODE

This subsection describes the methodology for evaluating the performance of an urban street segment in terms of its service to bicyclists.

Urban street segment performance from a bicyclist perspective is separately evaluated for each travel direction along the street. *Unless otherwise noted, all variables identified in this section are specific to the subject direction of travel.* The bicyclist is assumed to travel in the street (possibly in a bicycle lane) and in the same direction as adjacent motorized vehicles.

The methodology is focused on the analysis of a segment with either signal-controlled or two-way stop-controlled boundary intersections. Chapter 18 describes a methodology for evaluating signalized intersection performance from a bicyclist perspective. No methodology exists for evaluating two-way stop-controlled intersection performance (with the cross street stop-controlled). However, the influence of this type of control is incorporated in the methodology for evaluating segment performance. This edition of the HCM does not include a procedure for evaluating a segment's performance when the boundary intersection is an all-way stop-controlled intersection, a roundabout, or a signalized interchange ramp terminal.

The bicycle methodology is applied through a series of seven steps that culminate in the determination of the segment LOS. These steps are illustrated in Exhibit 17-20. Performance measures that are estimated include bicycle travel speed and LOS scores for the link and segment.

A methodology for evaluating off-street bicycle facilities is provided in Chapter 20, Off-Street Pedestrian and Bicycle Facilities.

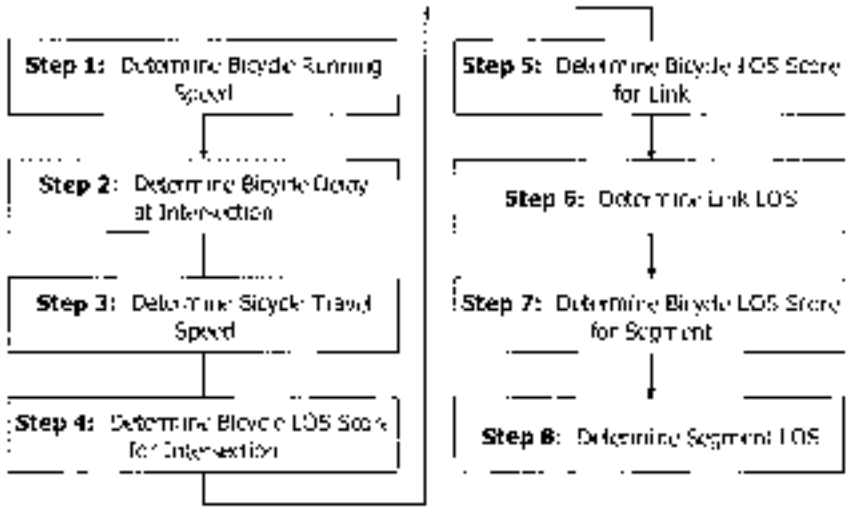

Exhibit 17-20
Bicycle Methodology for Urban Street Segments

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Link-Based Evaluation

Steps 5 and 6 of the bicycle methodology can be used as a stand-alone procedure for link-based evaluation of bicycle service. This approach is regularly used by local, regional, and state transportation agencies. It offers the advantage of being less data-intensive than the full, eight-step methodology and produces results that are generally reflective of bicyclist perceptions of service along the roadway. It can be especially attractive when agencies are performing a network-wide evaluation for a large number of roadway links.

The analyst should recognize that the resulting link LOS does not consider some aspects of bicycle travel along a segment (e.g., intersection service). For this reason, the LOS score for the link should not be aggregated for the purpose of characterizing facility performance. The analyst should also be aware that this approach precludes an integrated multimodal evaluation because it does not fully reflect segment performance.

Step 1: Determine Bicycle Running Speed

An estimate of the average bicycle running speed S_i is determined in this step. The best basis for this estimate is a field measurement of midsegment bicycle speed on representative streets in the vicinity of the subject street. In the absence of this information, it is recommended that the average running speed of bicycles be taken as 15 mi/h between signalized intersections (*7*). It is recognized that many factors might affect bicycle speed, including adjacent motor vehicle traffic, adjacent on-street parking activity, commercial and residential driveways, lateral obstructions, and significant grades. To date, research is not available to make any specific recommendations as to the effect of these factors on speed.

Step 2: Determine Bicycle Delay at Intersection

Bicycle delay at the boundary intersection d_i is computed in this step. This delay is incurred by bicyclists who travel through the intersection in the same lane as (or in a bicycle lane that is parallel to the lanes used by) segment through vehicles.

If the boundary intersection is two-way STOP controlled (where the subject approach is uncontrolled), then the delay is equal to 0.0 s/bicycle. If the boundary intersection is signalized, then the delay is computed by using the methodology described in Chapter 18, Signalized Intersections.

Step 3: Determine Bicycle Travel Speed

Bicycle travel speed represents an aggregate measure of speed along the segment. It combines the delay incurred at the downstream boundary intersection and the time required to ride the length of the segment. As such, it is typically slower than the average bicycle running speed. The average bicycle travel speed is computed by using Equation 17-39.

Equation 17-39

$$S_{p,ex} = \frac{3{,}600\,L}{5{,}280\,(t_{ip} - d_i)}$$

where

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$S_{BT,a}$ = travel speed of through bicycles along the segment (mi/h),

L = segment length (ft),

t_{BT} = segment running time of through bicycles $= (3,600)(L)/(5,280 S_a)$ (s),

S_a = bicycle running speed (mi/h), and

d_a = bicycle control delay (s/bicycle).

In general, a travel speed of 10.0 mi/h or more is considered desirable and a speed of 5.0 mi/h or less is considered undesirable.

Step 4: Determine Bicycle LOS Score for Intersection

The bicycle LOS score for the boundary intersection I_{int} is determined in this step. If the boundary intersection is signalized, then the bicycle methodology described in Chapter 18 is used for this determination. If the boundary intersection is two-way stop controlled, then the score is equal to 0.0.

Step 5: Determine Bicycle LOS Score for Link

The bicycle LOS score for the segment I_{link} is calculated by using Equation 17-40.

$$I_{link} = 0.760 + F_v + F_a - F_s + F_p \quad \text{Equation 17-40}$$

with:

$$F_v = -0.005 \, v_{ol}^2 \quad \text{Equation 17-41}$$

$$F_a = 0.507 \ln\left(\frac{v_{ol}}{4 N_{lo}}\right) \quad \text{Equation 17-42}$$

$$F_s = 0.199 \left[1 + 1.199 \ln(S_{ol} - 20) + 0.8103\right]\left(1 + 0.1038 \, P_{HV}\right)^2 \quad \text{Equation 17-43}$$

$$F_p = \frac{7.066}{W_e^2} \quad \text{Equation 17-44}$$

where

I_{link} = bicycle LOS score for link,

F_v = cross-section adjustment factor,

F_a = motorized vehicle volume adjustment factor,

F_s = motorized vehicle speed adjustment factor,

F_p = pavement condition adjustment factor,

$\ln(x)$ = natural log of x,

W_e = effective width of outside through lane (see Exhibit 17-21) (ft),

v_{ol} = adjusted mid-segment demand flow rate (see Exhibit 17-21) (veh/h),

N_{lo} = number of through lanes on the segment in the subject direction of travel (ln),

S_{ol} = adjusted motorized vehicle running speed (see Exhibit 17-21) (mi/h),

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$P_{HV,a}$ = adjusted percent heavy vehicles in midsegment demand flow rate (see Exhibit 17-21) (%), and

I_p = pavement condition rating (see Exhibit 17-7).

The value used for several of the variables in Equation 17-41 to Equation 17-44 is dependent on various conditions. These conditions are identified in Column 1 of Exhibit 17-21. If the condition is satisfied, then the equation in Column 2 is used to compute the variable value. If it is not satisfied, then the equation in Column 3 is used. The equations in the first three rows are considered in sequence to determine the effective width of the outside through lane W_v.

The motorized vehicle running speed is computed by using the automobile methodology described in a previous subsection.

Step 6: Determine Link LOS

The bicycle LOS for the link is determined by using the bicycle LOS score from Step 5. This performance measure is compared with the thresholds in Exhibit 17-4 to determine the LOS for the specified direction of travel along the subject link.

Exhibit 17-21
Variables for Bicycle LOS Score for Link

Condition	Variable When Condition Is Satisfied	Variable When Condition Is Not Satisfied
$f_{LW} = 0.0$	$W_v = W_t + W_{LT} + W_{adj}$	$W_v = W_t + W_{ol}$
$v_c > 150$ veh/h or street is divided	$W_v = W_t$	$W_v = W_t (2 - 0.0053 v_c)$
$W_{ol} + W_{adj} < 14$ ft	$W_v = W_t + 10 f_{PK} > 0.0$	$W_v = W_t + W_{ol} + W_{adj} - 10 f_{PK} > 0.0$
$v_c (1 - 0.01 P_{HV,a}) < 200$ veh/h and $P_{HV,a} > 50\%$	$f_{HV,a} = 0.096$	$f_{HV,a} = 0.0$
$S_r < 21$ mi/h	$S_a = 21$ mi/h	$S_a = S_r$
$v_c > 4 f_{HV,a}$	$f_{HV,a} = 0.0$	$v_{eq} = 4 f_{HV,a}$

Notes: W_t = total width of the outside through lane, bicycle lane, and paved shoulder (ft);
W_{LT} = width of outside through lane (ft);
W_{adj} = adjusted width of paved outside shoulder; 0 ft if curb present; $W_{adj} = 1.5 \times 0.6$, otherwise $W_{adj} = W_{sh}$ (ft);
W_{sh} = width of paved outside shoulder (ft);
W_{ol} = width of paved area = 0 if bicycle lane not provided (ft);
W_v = effective total width of outside through lane, bicycle lane, and shoulder as a function of traffic volume (ft);
f_{PK} = proportion of on-street parking occupied (decimal);
v_c = midsegment demand flow rate (veh/h);
$P_{HV,a}$ = percent of heavy vehicles in the subsegment demand flow rate (%), and
S_r = motorized vehicle running speed (mi/h).

Step 7: Determine Bicycle LOS Score for Segment

The bicycle LOS score for the segment is computed by using Equation 17-45.

Equation 17-45

$$I_{bike} = 0.760 I_{v,adj} + 0.011 P_{HV,a}^{0.911} - 0.035 \frac{N_{lane}^{0.911}}{(L_s / 5280)} + 2.86$$

where

I_{bike} = bicycle LOS score for segment,

$I_{v,adj}$ = bicycle LOS score for link,

N_{lane} = indicator variable for boundary intersection control type = 1.0 if signalized, 0.0 if two-way stop controlled;

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$I_{v,i}$ = bicycle LOS score for intersection, and

$N_{a,i}$ = number of access point approaches on the right side in the subject direction of travel (unitless).

The count of access point approaches used in Equation 17-45 includes both public street approaches and driveways on the right side of the segment in the subject direction of travel.

Step 8: Determine Segment LOS

The bicycle LOS for the segment is determined by using the segment bicycle LOS score from Step 7. This performance measure is compared with the thresholds in Exhibit 17-4 to determine the LOS for the specified direction of travel along the subject segment.

TRANSIT MODE

This subsection describes the methodology for evaluating the performance of an urban street segment in terms of its service to transit passengers.

Urban street segment performance from a transit-passenger perspective is separately evaluated for each travel direction along the street. *Unless otherwise stated, all variables identified in this section are specific to the subject direction of travel.*

The methodology is applicable to public transit vehicles operating in mixed traffic or exclusive lanes and stopping along the street. Procedures for estimating transit vehicle performance on grade-separated or non-public street rights of way, along with procedures for estimating origin–destination service quality, are provided in the *Transit Capacity and Quality of Service Manual* (3).

The transit methodology is applied through a series of six steps that culminate in the determination of segment LOS. These steps are illustrated in Exhibit 17-22. Performance measures that are estimated include transit travel speed along the street, transit wait-ride score, and a LOS score reflective of all transit service stopping within or near the segment.

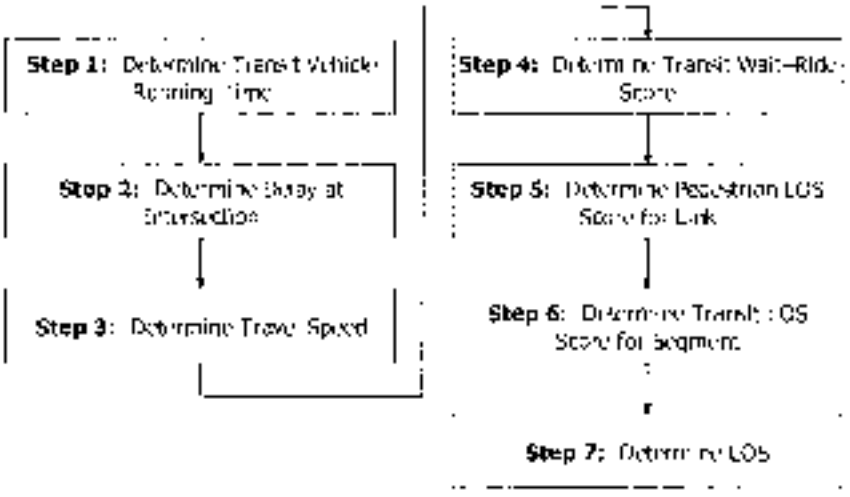

Exhibit 17-22
Transit Methodology for Urban Street Segments

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Step 1: Determine Transit Vehicle Running Time

There are two principal components of the transit vehicle's segment running time. One component represents the time required to travel the segment without stopping. (To allow direct comparison with automobile segment speeds, transit vehicles are treated as if they travel the entire segment, even if they join midblock.) The second component is the delay incurred at the transit stops that are provided on the link. The following subparts to this step describe procedures that are used to calculate these components. They culminate with a subpart that describes the calculation of transit vehicle segment running time.

A. Compute Segment Running Speed

Transit vehicle segment running speed represents the speed traveled by the vehicle when not influenced by the proximity of a transit stop or traffic control device. This speed can be computed by using Equation 17-46, which is derived from tables given in a Transit Cooperative Research Program report (8).

Equation 17-46

$$S_{av} = \min\left(S_R, \frac{61}{1 + e^{(3.97 - 0.805 S_a / 1.1)}}\right)$$

where

S_{av} = transit vehicle running speed (mi/h),

L = segment length (ft),

N_s = number of transit stops on the segment for the subject route (stops),

S_R = motorized vehicle running speed = $(3{,}600\ L)/(5{,}280\ r_s)$ (mi/h), and

r_s = segment running time (s).

The segment running time is computed by using Equation 17-6 in Step 2 of the automobile methodology.

B. Compute Delay due to a Stop

The delay due to a transit vehicle stop for passenger presumably includes the following components:

- Acceleration–deceleration delay,
- Delay due to serving passengers, and
- Reentry delay.

This procedure is applied once for each stop on the segment. The delay due to each stop is added (in a subsequent step) to compute the total delay due to all stops on the segment.

Acceleration–Deceleration Delay

Acceleration–deceleration delay represents the additional time required to decelerate to stop and then accelerate back to the transit vehicle running speed S_{av}. It is computed by using Equation 17-47 and Equation 17-48.

Equation 17-47

$$d_{ad} = \frac{5{,}280\ (S_{av})}{3{,}600 \times 2}\left(\frac{1}{a_d} - \frac{1}{a_a}\right) f_a$$

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with

$$f_{ss} = \begin{cases} 1.00 & \text{(stops not on the near side of a boundary intersection)} \\ 0.00 & \text{(near-side stops at all-way and major-street two-way STOP-controlled intersections)} \\ 1 - x & \text{(near-side stops at roundabouts)} \\ g/C & \text{(near-side stops at traffic signals)} \end{cases} \quad \text{Equation 17-48}$$

where

d_{at} = transit vehicle acceleration–deceleration delay due to a transit stop (s),

r_a = transit vehicle acceleration rate = 4.0 (ft/s²),

r_d = transit vehicle deceleration rate = 4.0 (ft/s²),

f_{ss} = proportion of transit vehicle stop acceleration–deceleration delay not due to traffic control,

x = volume-to-capacity ratio of the link's right-most lane on a roundabout approach,

g = effective green time (s), and

C = cycle length (s).

Acceleration–deceleration delay represents travel time that is in excess of that required to traverse the equivalent distance at the running speed. It is incurred when the transit vehicle stops solely because of a transit stop. When a transit stop is located on the near side of a boundary intersection, a transit vehicle might need to stop anyway due to the traffic control. In this situation, acceleration–deceleration delay is already included in the through delay estimate (addressed in a subsequent step) and should not be included in d_a. Equation 17-48 is used to determine the proportion of d_a incurred solely because of a transit stop.

If representative acceleration and deceleration rates are known, then they should be used in Equation 17-47. If these rates are unknown, then a rate of 4.0 ft/s² may be assumed for both acceleration and deceleration (5).

Delay due to Serving Passengers

The delay due to serving passengers is based on the average dwell time, which is an input to this procedure. At signalized intersections, a portion of the dwell time may overlap time the transit vehicle would have spent stopped anyway due to the traffic control. Equation 17-49 is used to compute the delay due to serving passengers.

$$d_{ps} = t_d f_{ts} \quad \text{Equation 17-49}$$

where

d_{ps} = transit vehicle delay due to serving passengers (s),

t_d = average dwell time (s), and

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f_b = proportion of dwell time occurring during effective green $t = g/C$ at near-side stops at signalized intersections and 1.00 otherwise, where g and C are as previously defined;

Reentry Delay

The final component of transit vehicle stop delay is the reentry delay d_r, which is an input to this procedure. Guidance for estimating reentry delay is provided in the Required Input Data subsection of Section 1, Introduction.

Delay due to a Stop

Delay due to a transit stop is the sum of acceleration, deceleration delay, passenger service time delay, and reentry delay. It is computed by using Equation 17-50:

Equation 17-50

$$d_{s,i} = d_{a,i} + d_{d,i} + d_r$$

where $d_{s,i}$ = delay due to a transit vehicle stop (s), d_r = reentry delay (s), and other variables are as previously defined.

C. Compute Segment Running Time

Equation 17-51 is used to compute transit vehicle running time, which is based on segment running speed and delay due to stops on the segment.

Equation 17-51

$$t_{ri} = \frac{3{,}600\, L_i}{5{,}280\, S_{ri}} + \sum_{i=1}^{N_i} d_{s,i}$$

where t_{ri} = segment running time of transit vehicle (s), $d_{s,i}$ = delay due to a transit vehicle stop for passenger pickup at stop i within the segment (s), and other variables are as previously defined.

If there are no stops on the segment, then the second term of Equation 17-51 equals zero.

Step 2: Determine Delay at Intersection

The through delay incurred at the boundary intersection is determined in this step. This delay is that incurred by the through movement that exits the segment at the downstream boundary intersection. Guidance for determining this delay is provided in Step 3 of the automobile methodology. Equation 17-52 can be used for a planning analysis to estimate the through delay due to a traffic signal (3).

Equation 17-52

$$d_t = t_i\, 60\left(\frac{L_i}{5{,}280}\right)$$

where

d_t = through delay (s/veh),

t_i = transit vehicle running time loss (min/mi), and

L_i = segment length (ft).

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The running time loss t_r used in Equation 17-52 is obtained from Exhibit 17-23.

Exhibit 17-23
Transit Vehicle Running Time Loss

Area Type	Transit Lane Allocation	Traffic Condition	Running Time Loss by Signal Condition (min/mi)		
			Typical	Signals Set for Transit	Signals More Frequent Than Transit Stops
Central business district	Exclusive	No right turns	1.2	0.6	1.5–2.0
		With right-turn delay	2.5	1.4	2.5–3.0
		Blocked by traffic	2.5–3.0	Not available	3.0–3.5
	Mixed traffic	Any	3.0	Not available	3.5–4.0
Other	Exclusive	Any	0.7 (0.5–1.0)	Not available	Not available
	Mixed traffic	Any	1.3 (0.7–1.5)	Not available	Not available

Source: St. Jacques and Koonce (8)

Step 3: Determine Travel Speed

Transit travel speed represents an aggregate measure of speed along the street. It combines the delay incurred at the downstream intersection with the segment running time. As such, it is typically slower than the running speed. The transit travel speed is computed by using Equation 17-53.

$$S_{t,av} = \frac{3{,}600\ L_i}{5{,}280\ (t_{ri} + d_i)} \quad \text{Equation 17-53}$$

where $S_{t,av}$ = travel speed of transit vehicles along the segment (mi/h), t_{ri} = segment running time of transit vehicle (s), and other variables are as previously defined.

Step 4: Determine Transit Wait–Ride Score

The transit wait–ride score is a performance measure that combines perceived time spent waiting for the transit vehicle and perceived travel time rate. If transit service is not provided for the subject characteristics of travel, then this score equals 0.0 and the analysis continues with Step 5.

The procedure for calculating the wait–ride score is described in this step. It consists of the separate calculation of the headway factor and the perceived travel time factor. The following subparts describe these two calculations, which culminate in the calculation of the wait–ride score.

A. Compute Headway Factor

The headway factor is the ratio of the estimated patronage at the prevailing average transit headway to the estimated patronage at a base headway of 60 min. The patronage values for the two headways (i.e., the input headway and the base headway of 60 min) are computed from an assumed set of patronage elasticities that relate the percentage change in ridership to the percentage change in headway. The headway factor is computed by using Equation 17-54.

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Equation 17-54

$$f_h = 4.00\,e^{-(0.157 \times v_t + 0.979)}$$

where

f_h = headway factor, and

v_t = transit frequency for the segment (veh/h)

The transit frequency v_t is an input to this procedure. Guidance for estimating this input is provided in the Required Input Data subsection.

5. Compute Perceived Travel Time Factor

Segment performance, as measured by the walk–ride score, is influenced by the travel time rate provided to transit passengers. The perceptibility of this rate is further influenced by the extent to which the transit vehicle is late, crowded, or both and whether the stop provides passenger amenities. In general, travel at a high rate is preferred, but travel at a lower rate may be nearly as acceptable if the transit vehicle is not late, the bus is fully loaded, and a shelter (with a bench) is provided at the transit stop.

The perceived travel time factor is based on the perceived travel time rate and the expected ridership elasticity with respect to changes in the perceived travel time rate. This factor is computed by using Equation 17-55.

Equation 17-55

$$f_{tt} = \frac{(e-1)\,T_{bb} - (e-1)\,T_{pt}}{(e-1)\,T_{pt} - (e+1)\,T_{bb}}$$

with

Equation 17-56

$$T_{pt} = \left(a_1 \frac{60}{S_{Loop}}\right) + (2\,T_t) - L_a$$

Equation 17-57

$$a_1 = \begin{cases} 1.00 & I \le 0.80 \\ 1 - \dfrac{(4)(I - 0.80)}{4.2} & 0.80 < I \le 1.00 \\ 1 - \dfrac{(4)(I - 0.80) - (I - 1.00)(6.5 + [(5)(I - 1.00)])}{4.2 \times I} & I > 1.00 \end{cases}$$

Equation 17-58

$$T_{bb} = \frac{1.3\,p_{0.25} + 0.2\,p_e}{L_{ct}}$$

where

f_{tt} = perceived travel time factor,

e = ridership elasticity with respect to changes in the travel time rate = -0.46,

T_{bb} = base travel time rate = 6.0 for the central business district of a metropolitan area with 5 million persons or more, otherwise = 4.0 (min/mi);

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PTR_{pv} = perceived travel time rate (min/mi);

ETR_w = excess wait time rate due to late arrivals (min/mi) = t_w/l_{sp};

t_w = excess wait time due to late arrivals (min);

TR_a = amenity time rate (min/mi);

w_l = passenger load weighting factor;

S_{tran} = travel speed of transit vehicles along the segment (mi/h);

P_l = average passenger load factor (passengers/seat);

l_{sp} = average passenger trip length = 3.7 typical (mi);

p_{sh} = proportion of stops on segment with shelters (decimal); and

p_b = proportion of stops on segment with benches (decimal).

The perceived travel time rate is estimated according to three components, as shown in Equation 17-58. The first component reflects the average travel speed of the transit service, adjusted for the degree of passenger loading. The second component reflects the average excess wait time for the transit vehicle (i.e., the amount of time spent waiting for a late arrival beyond the scheduled arrival time). The third component reflects the ability of passengers to tolerate longer travel time rates when there are amenities provided at the transit stops.

The first term in Equation 17-58 includes a factor that adjusts the transit vehicle travel time rate by using a passenger load weighting factor. This factor accounts for the decrease in passenger comfort when transit vehicles are crowded. Values of this factor range from 1.00 when the passenger load factor is less than 0.50 passengers/seat to 2.32 when the load factor is 1.6 passengers/seat.

The second term in Equation 17-58 represents the perceived excess wait time rate. It is based on the excess wait time t_w associated with late transit vehicles. The multiplier of 2 in Equation 17-58 is used to amplify the excess wait time rate because passengers perceive excess waiting time to be more onerous than actual travel time.

The excess wait time t_w reflects transit vehicle reliability. It is an input to this procedure. If excess wait time data are not available for a stop, but on-time performance data are available for routes using the stop, then Equation 17-59 may be used to estimate the average excess wait time.

$$t_w = [t_{th}(1 - p_{th})]^2 \quad \text{Equation 17-59}$$

where

t_w = excess wait time due to late arrivals (min);

t_{th} = threshold late time = 5.0 typical (min); and

p_{th} = proportion of transit vehicles arriving within the threshold late time (default = 0.75) (decimal).

The third term in Equation 17-58 represents the amenity time rate reduction. This rate is computed in Equation 17-60 as the equivalent time value of various

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transit stop improvements divided by the average passenger trip length. If multiple transit stops exist on the segment, an average amenity rate should be used for the segment, based on the average value for all stops in the segment.

The average passenger trip length is used to convert time values for excess wait time and amenities into distance-weighted travel time rates that adjust the perceived in-vehicle travel time rate. The shorter the trip, the greater the influence that late transit vehicles and stop amenities have on the overall perceived speed of the trip.

The average passenger trip length should be representative of transit routes using the subject segment. A value of 3.7 mi is considered to be nationally representative. More accurate local values can be obtained from the National Transit Database (4). Specifically, this database provides annual passenger miles and annual unlinked trips in the profile of most transit agencies. The average passenger trip length is computed as the annual passenger miles divided by the annual unlinked trips.

C. Compute Wait–Ride Score

The wait–ride score is computed by using Equation 17-60. A larger score corresponds to better performance.

Equation 17-60

$$s_w = f_h f_v$$

where

s_w = transit wait–ride score,

f_h = headway factor, and

f_v = perceived travel time factor.

Step 5: Determine Pedestrian LOS Score for Link

The pedestrian LOS score for the link $I_{p,ink}$ is computed by using the pedestrian methodology, as described in a previous subsection.

Step 6: Determine Transit LOS Score for Segment

The transit LOS score for the segment is computed by using Equation 17-61.

Equation 17-61

$$I_{p,trs} = 6.0 - 1.30\,s_{w,t} + 0.15\,I_{p,ink}$$

where $I_{p,trs}$ is the transit LOS score for the segment and other variables are as defined previously.

Step 7: Determine LOS

The transit LOS is determined by using the transit LOS score from Step 6. This performance measure is compared with the thresholds in Exhibit 17-4 to determine the LOS for the specified direction of travel along the subject street segment.

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3. APPLICATIONS

DEFAULT VALUES

Agencies that use the methodologies in this chapter are encouraged to develop a set of local default values based on field measurements on streets in their jurisdiction. Local default values provide the best means of ensuring accuracy in the analysis results. In the absence of local default values, the values identified in this subsection can be used if the analyst believes that they are reasonable for the street segment to which they are applied.

Exhibit 17-5 and Exhibit 17-6 identify the input data variables associated with the automobile, pedestrian, bicycle, and transit methodologies. These variables can be categorized as either (a) suitable for specification as a default value or (b) required input data. Those variables categorized as "suitable for specification as a default value" have a minor effect on performance estimates and tend to have a relatively narrow range of typical values used in practice. In contrast, required input variables have either a notable effect on performance estimates or a wide range of possible values. Variables suitable for default value specification are discussed in this subsection.

Required input variables typically represent fundamental segment and intersection geometric elements and demand flow rates. Values for these variables should be field measured whenever possible.

If field measurement of the input variables is not possible, then various options exist for determining an appropriate value for a required input variable. As a first choice, input values should be established through the use of local guidelines. If local guidelines do not address the desired variable, then some input values may be determined by considering the typical operation of (or conditions at) similar segments and intersections in the jurisdiction. As a last option, various authoritative national guideline documents are available and should be used to make informed decisions about design options and volume estimates. The use of simple rules of thumb or "ballpark" estimates for required input values is discouraged because this use is likely to lead to a significant cumulative error in the performance estimates.

Automobile Mode

The required input variables for the automobile methodology are identified in the following list. These variables represent the minimum basic input data that the analyst will need to provide for an analysis. These variables were previously defined in the text associated with Exhibit 17-5.

- Demand flow rate (at boundary intersection),
- Capacity (at boundary intersection),
- Number of lanes (at boundary intersection),
- Upstream intersection width (at boundary intersection),
- Turn bay length (at boundary intersection), and
- Number of through lanes.

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- Segment length,
- Restrictive median length (if present),
- Speed limit,
- Through control delay (at boundary intersection),
- Through stopped vehicles (at boundary intersection), and
- Second- and third-term back of queue (at boundary intersection).

Several authoritative reference documents (*1–11*) provide useful guidelines for selecting the type of signal control at the boundary intersections and determining the appropriate traffic control for the segment.

Exhibit 17-24 lists default values for the automobile methodology. Some of the values listed may also be useful for the pedestrian, bicycle, or transit methodologies. The last column of this exhibit indicates "See discussion" for one variable. In this situation, the default value is described in the discussion provided in this subsection.

Exhibit 17-24
Default Values: Automobile Mode

Data Category	Input Data Element	Default Values
Traffic characteristics	Access point flow rate	See discussion
	Midsegment flow rate	Estimate by using demand flow rate at the downstream boundary intersection approach
Geometric design	Number of lanes at access points	Signalized Approach: If median is present, one left-turn lane/approach If no median is present, no left-turn lanes. No right-turn lanes. Through lanes are the same as N_{th} Access Point Approach: One left-turn lane and one right-turn lane
	Turn bay length at access points	40% of the access point spacing, where spacing result: $2 (5,280) / D_{ap}$ in feet. Computed bay length should not exceed 400 ft or be less than 50 ft
	Proportion of segment with curb	1.0 (curb present on both sides of segment)
	Number of access point approaches	Estimated for each segment side by multiplying default access point density by 1/2 segment length (i.e., $N_{ap} = 0.5 D_{ap} / 5,280$): Urban arterial D_{ap} = 24 points/mi Suburban arterial D_{ap} = 21 points/mi Urban collector D_{ap} = 31 points/mi Suburban collector D_{ap} = 46 points/mi
Other	Analysis period duration	0.25 h
Performance measures	Midsegment delay	0.0 s/veh
	Midsegment stops	0.0 stops/veh

Note: D_{ap} = access point density on segment (points/mi), N_{ap} = number of access point approaches on the right side of the subject direction of travel (points), L = segment length (ft), and N_{th} = number of through lanes on the segment in the subject direction of travel (-).

The default access point flow rate can be estimated from the midsegment flow rate by using default turn proportions. These proportions are shown in Exhibit 17-25 for a typical access point intersection on an arterial street. The proportion of 0.05 for the left turn movements can be reduced to 0.01 for a typical access point on a collector street. These proportions are appropriate for

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segments with an access point density consistent with the default densities in Exhibit 17-24 and are applicable to access points serving any public-oriented land use (this excludes single family residential land use and undeveloped property).

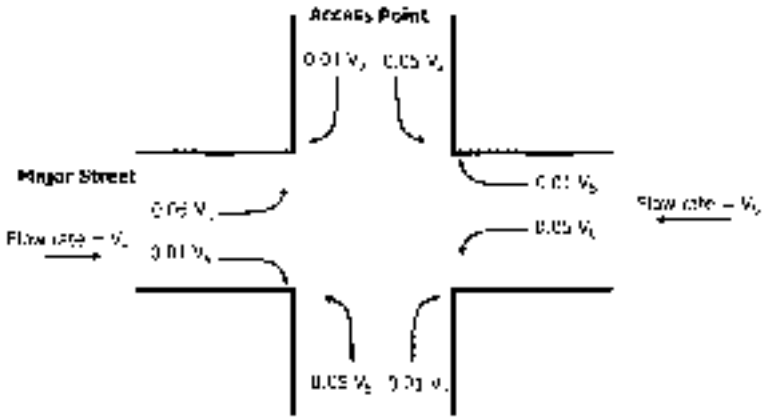

Exhibit 17-25
Default Turn Proportions for Access Point Intersections

If one of the movements shown in Exhibit 17-25 does not exist at a particular access point intersection, then its volume is not computed (its omission has no effect on the proportions used for the other movement flow rates). The flow rate for the crossing movements at an access point intersection is not needed for the automobile methodology. The left turn proportions shown are larger than the right-turn proportions because right-turn opportunities are typically more frequent than left-turn opportunities along an arterial street.

Nonautomobile Modes

The required input variables for the pedestrian, bicycle, and transit methodologies are identified in the list below. These variables represent the minimum basic input data that the analyst will need to provide for an analysis. These variables were previously defined in the text associated with Exhibit 17-6.

Pedestrian Methodology

- Midsegment flow rate
- Pedestrian flow rate
- Downstream intersection width (at boundary intersection)
- Segment length
- Number of through lanes
- Median type and curb presence
- Spacing of objects in buffer
- Quality of midsegment pedestrian crossing
- Proportion of segment adjacent to window display
- Proportion of segment adjacent to building face
- Proportion of segment adjacent to low wall or fence
- Motorized vehicle running speed
- Pedestrian delay

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- Pedestrian LOS score for intersection

Bicycle Methodology

- Midsegment flow rate
- Segment length
- Number of through lanes
- Median type and curb presence
- Motorized vehicle running speed
- Bicycle delay (at boundary intersection)
- Bicycle LOS score for intersection

Transit Methodology

- Excess wait time (or arc time performance)
- Transit frequency
- Segment length
- Area type
- Transit stop location
- Transit stop position
- Proportion of stops with shelters
- Proportion of stops with benches
- Motorized vehicle running speed
- Pedestrian LOS score for link
- Through vehicle delay (at boundary intersection)
- Reentry delay
- Effective green-to-cycle-length ratio (at boundary intersection)
- Volume-to-capacity ratio (at roundabout boundary intersection)

Exhibit 17-26 lists the default values for the pedestrian, bicycle, and transit methodologies (2, 12).

TYPES OF ANALYSIS

The automobile, pedestrian, bicycle, and transit methodologies described in this chapter can each be used in three types (or levels) of analysis. These analysis levels are described as operational, design, and planning and preliminary engineering. The characteristics of each analysis level are described in the subsequent parts of this subsection.

Operational Analysis

Each of the methodologies is most easily applied at an operational level of analysis. At this level, all traffic, geometric, and signalization conditions are specified as input variables by the analyst. These input variables are used in the methodology to compute various performance measures.

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Exhibit 17-26
Default Values, Nonmotorized Modes

Data Category	Input Data Element	Default Value
Traffic characteristics	Dwell time	Downtown stop, transit center, major on-line transfer point, major park-and-ride stop: 60 s Major outlying stop: 30 s Typical outlying stop: 15 s
	Passenger trip length	3.7 mi
	Passenger load factor	0.80 passengers/seat
	Percent heavy vehicles	3%
	Proportion of on-street parking occupied	0.50 (if parking lane present)
Geometric design	Width of outside through lane	12 ft
	Width of bicycle lane	5.0 ft (if provided)
	Width of paved outside shoulder	No parking lane: 1.5 ft (curb and gutter width) Parking lane present: 8.0 ft
	Number of access point approaches	Estimated for each segment side by multiplying default access point density by segment length (i.e., $N_{ap} = 0.5 \cdot D_{ap} \cdot L / 5{,}280$) Urban arterial D_{ap} = 34 points/mi Suburban arterial D_{ap} = 20 points/mi Urban collector D_{ap} = 60 points/mi Suburban collector D_{ap} = 48 points/mi
	Total walkway width	Business or office land use: 9.0 ft Residential or industrial land use: 11.0 ft
	Effective width of fixed objects	Business or office land use: 2.0 ft (near), 2.0 ft (outside) Residential or industrial land use: 0.0 ft (near), 0.0 ft (outside)
	Buffer width	Business or office land use: 0.0 ft Residential or industrial land use: 6.0 ft
Other	Pavement condition rating	3.5
	Distance to nearest signal-controlled crossing	Use half the distance between signal controlled crossings that bracket the segment
Performance measures	Delay at midsegment signalized crosswalk	40 s/p

Note: D_{ap} = access point density on segment (points/mi); N_{ap} = number of access point approaches on the right side of the subject direction of travel (points); L = segment length (ft); and N_{cl} = number of through lanes in the segment in the subject direction of travel (ln).

Design Analysis

The nature of the design analysis varies depending on whether the boundary intersections are unsignalized or signalized. When the segment has unsignalized boundary intersections, the analyst specifies traffic conditions and target levels for a specified set of performance measures. The methodology is then applied by using an iterative approach in which alternative geometric conditions are separately evaluated.

When the segment has signalized boundary intersections, the design level of analysis has two variations. Both variations require the specification of traffic conditions and target levels for a specified set of performance measures. One variation requires the additional specification of the signalization conditions. The methodology is then applied by using an iterative approach in which alternative geometric conditions are separately evaluated.

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The second variation of the design level requires the additional specification of the geometric conditions. The methodology is then applied by using an iterative approach in which alternative signalization conditions are evaluated.

The objective of the design analysis is to identify the alternatives that operate at the target level of the specified performance measures (or provide a better level of performance). The analyst may then recommend the "best" design alternative after consideration of the full range of factors.

Planning and Preliminary Engineering Analysis

The planning and preliminary engineering level of analysis is intended to provide an estimate of the LOS for either a proposed segment or an existing segment in a future year. This level of analysis may also be used to size the overall geometrics of a proposed segment.

The level of pavement interest in planning and preliminary engineering analyses is typically lower than for operational analyses. Therefore, default values are often adequate for field-measured values of many of the input variables. Recommended default values for this purpose were described previously in this section.

The requirement for a complete description of the signal timing plan can be a burden for some planning analyses involving signalized intersections, especially when the signal control is pretimed or coordinated-actuated. The Intersection Quick Estimation Method described in Chapter 31, Signalized Intersections: Supplemental, can be used to estimate a reasonable timing plan, in conjunction with the aforementioned default values.

For some planning and preliminary engineering analyses, the segment Quick Estimation Method described in Chapter 30, Urban Street Segments: Supplemental, may provide a better balance between accuracy and analysis effort in the evaluation of vehicle LOS.

USE OF ALTERNATIVE TOOLS

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools, and Chapter 7, Interpreting HCM and Alternative Tool Results. This section contains specific guidance for the application of alternative tools to the analysis of urban street segments. The tools are described as either simulation or deterministic, in reference to their traffic modeling approach. Additional information on this topic is provided in Volume 4. The focus of this section is the application of alternative tools to evaluate automobile operations.

Strengths of the Automobile Methodology

The automobile methodology described in Section 2 models the driver–vehicle–road system with reasonable accuracy for most applications. It accounts for passenger-car speed variations due to traffic and geometric conditions. Alternative tools offer a more detailed treatment of the arrival and departure of vehicles, as well as the interaction between the vehicle, the roadway, and the

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control system. As such, some tools can model the driver–vehicle–road system more accurately for some applications.

The automobile methodology offers several advantages over alternative analysis tools. One advantage is that it has an empirically calibrated procedure for estimating saturation flow rate. Alternative tools often require saturation flow rate as an input variable. A second advantage is that it produces a direct estimate of capacity and volume-to-capacity ratio. These measures are not directly available from simulation tools. A third advantage is that it produces an expected value for each of a wide variety of data outputs in a single application. Many alternative tools operate as a "black box," providing little detail describing the intermediate calculations. Moreover, simulation tools require multiple runs and manual calculations to obtain expected values for the output data.

Identified Limitations of the Automobile Methodology

The limitations of the automobile methodology are identified in Section 1. If any of these limitations apply to a particular situation, then alternative tools may produce more credible performance estimates. Limitations involving consideration of the impact of progression on performance are a special case that is discussed in more detail in Chapter 16, Urban Street Facilities.

Features and Performance Measures Available from Alternative Tools

Both deterministic tools and simulation tools are in common use as alternatives to the procedures offered in this chapter. Deterministic tools are used to a greater extent for the analysis of urban street segments than for most of the other transportation elements represented in this manual. The main reasons for their popularity are found in the user interface, optimization options, and output presentation features. Some also offer additional performance measures such as fuel consumption, air quality, and operating cost.

Development of HCM-Compatible Performance Measures Using Alternative Tools

The LOS assessment for the automobile mode on urban street segments is based on the average travel speed over the segment. The average travel speed is computed by dividing the segment length by the total time required to travel the segment, taking into account all intersection and nonintersection delays.

Alternative tools generally define the travel speed in the same way that it is defined in this chapter. However, these tools may not compute delay and running speed by using the procedures presented in Section 2. Therefore, some care must be taken when using speed and delay estimates from other tools. Issues related to speed and delay comparison among different tools are discussed in more detail in Chapter 7. In general, the travel speed from an alternative tool should not be used for LOS assessment unless the tool is confirmed to apply the procedures described in Section 2.

Conceptual Differences That Preclude Direct Comparison of Results

Alternative deterministic tools apply traffic models that are conceptually similar to those described in this chapter. While their computational details will

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usually produce different numerical results, there are few major conceptual differences that would preclude comparison in terms of relative magnitude.

Simulation tools, on the other hand, are based on entirely different modeling concepts. A general discussion of the conceptual differences is presented in Chapters 6 and 7. Some specific examples for signalized intersections, which also apply to urban street segments, are presented in Chapter 18.

One phenomenon that makes comparison difficult is the propagation of platoons along a segment. Deterministic tools, including the model presented in this chapter, apply equations that spread out a platoon as it progresses downstream. Simulation tools create platoon dispersion implicitly from a distribution of desired speeds among drivers. Both approaches will produce platoon dispersion, but the amount of dispersion will differ among tools.

Similar to tools may also exhibit platoon compression because of the effect of slower-moving vehicles that cause platoons to regenerate. For this and other reasons, it is difficult to achieve comparability of platoon representation along a segment between these tools and the automobile methodology.

Adjustment of Alternative Tool Parameters

For applications in which either an alternative tool or the automobile methodology can be used, some adjustment will generally be required for the alternative tool if some consistency with the automobile methodology is desired. For example, the parameters that determine the capacity of a signalized approach (e.g., saturation flow rate and start-up lost time) should be adjusted to ensure that the same ranges for approach capacities match those estimated by the automobile methodology.

It might also be necessary to adjust the parameters that affect the travel time along the segment to produce comparable results. The automobile methodology is based on a free-flow speed that is computed as a function of demand flow rate, median type, access point density, and speed limit. Most alternative tools typically require a user-specified free-flow speed, which could be obtained from the automobile methodology to maintain comparability. It may be more difficult to adjust the platoon modeling parameters. So, if comparability is desired in representing the platoon effect, it is preferable to adjust the free-flow speed specified for simulation such that the actual travel speeds are similar to those obtained from the automobile methodology.

Step-by-Step Recommendations for Applying Alternative Tools

A set of step-by-step recommendations for signalized intersection evaluation with alternative tools is presented in Chapter 18. The recommendations in that chapter also apply to the evaluation of urban street segments.

Sample Calculations Illustrating Alternative Tool Applications

The most useful examples of the application of alternative tools involve multiple-segment facilities. Chapter 29, Urban Street Facilities: Supplemental, includes a set of examples to illustrate the use of alternative tools to address the stated limitations of this chapter and Chapter 16, Urban Street Facilities.

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Specifically, these examples illustrate (a) the application of deterministic tools to optimize signal timing, (b) the effect of using a roundabout as a segment boundary, (c) the effect of midsegment parking maneuvers on facility operations, and (d) the use of simulated vehicle trajectories to evaluate the proportion of time that the back of the queue on the minor-street approach to a two-way stop-controlled intersection exceeds a specified distance from the stop line.

Chapter 31, Signalized Intersections: Supplemental, includes example problems that address left-turn storage bay overflow, right-turn-on-red operation, short through lanes, and closely spaced intersections.

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4. EXAMPLE PROBLEMS

This part of the chapter describes the application of each of the automobile, pedestrian, bicycle, and transit methodologies through the use of example problems. Exhibit 17-27 provides an overview of these problems. The focus of the examples is on the operational analysis level. The planning and preliminary engineering analysis level is identical to the operational analysis level in terms of the calculations, except that default values are used when field-measured values are not available.

Exhibit 17-27
Example Problems

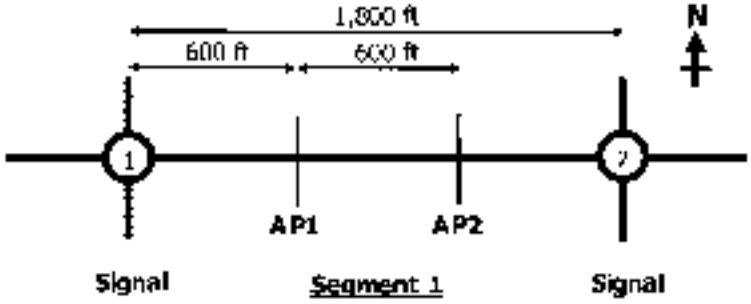
Problem Number	Description	Analysis Level
1	Automobile LOS	Operational
2	Pedestrian LOS	Operational
3	Bicycle LOS	Operational
4	Transit LOS	Operational

EXAMPLE PROBLEM 1: AUTOMOBILE LOS

The Urban Street Segment

The total length of an undivided urban street segment is 1,800 ft. It is shown in Exhibit 17-28. Both of the boundary intersections are signalized. The street has a four-lane cross section with two lanes in each direction. There are left-turn bays on the subject segment at each signalized intersection.

Exhibit 17-28
Example Problem 1: Urban Street Segment Schematic



The segment has two access point intersections, shown in the exhibit as AP1 and AP2. Each intersection has two STOP-controlled side-street approaches. The segment has some additional driveways on each side of the street; however, their turn movement volumes are too low during the analysis period for them to be considered "active." So, the few vehicles that do turn at these locations during the analysis period have been added to the appropriate flow rates at the two access point intersections.

The Question

What are the travel speed, spatial stop rate, and LOS during the analysis period for the segment through movement in both directions of travel?

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The Facts

The segment's traffic counts are listed in Exhibit 17-29. The counts were taken during the 15-min analysis period of interest. However, they have been converted to hourly flow rates. It is noted that the volumes leaving the signalized intersections do not add to equal the volume arriving at the downstream access point intersection.

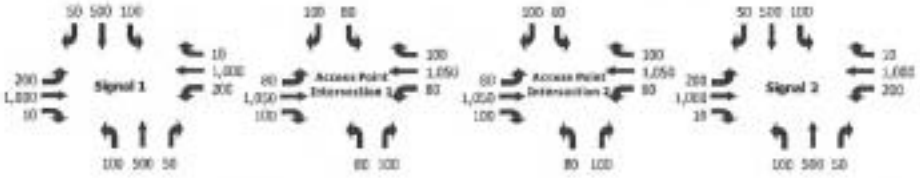

Exhibit 17-29
Example Problem 1: Intersection Turn Movement Counts

The signalization conditions are shown in Exhibit 17-30. The conditions shown are identified as belonging to Signalized Intersection 1; however, they are the same for Signalized Intersection 2. The signals operate with coordinated–actuated control. The left-turn movements on the northbound and southbound approaches operate under protected–permitted control and lead the opposing through movements (i.e., a lead–lead phase sequence). The left-turn movements on the major street operate as protected-only in a lead–lead sequence.

Signalized Intersection 1

General Information								
Cross Street:	First Avenue				**Analysis Period:**	7:15 am to 7:30 am		
Phase Sequence and Left-Turn Mode								
Major street sequence (movement numbers shown)	5 & 1 left leading				Cross street sequence (movement numbers shown)	3 & 7 left leading		
Major street left-turn mode (movement numbers shown)	5/1 Protected-Only				Cross street left-turn mode (movement numbers shown)	3/7 Protected+Permitted		
Phase Settings								
Approach	Eastbound		Westbound		Northbound		Southbound	
Phase number	5	2	1	6	3	8	7	4
Movement	L	T+R	L	T+R	L	T+R	L	T+R
Lead/lag left-turn phase	Lead	–	Lead	–	Lead	–	Lead	–
Left-turn mode	Prot.	–	Prot.	–	Pr/Pm	–	Pr/Pm	–
Passage time, s	2.0	–	2.0	–	2.0	2.0	2.0	2.0
Minimum green, s	5	–	5	–	5	5	5	5
Yellow + red clear, s	3.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
Phase split, s	20	35	20	35	20	25	20	25
Recall	No	–	No	–	No	No	No	No
Dual entry	No	Yes	No	Yes	No	Yes	No	Yes
Ref. Phase: 2	Offset, s:	0	Offset Ref.:	End of Green	Force Mode:	Fixed		
	Cycle, s:	100						
Enable Simultaneous Gap-Out? Phase Group 1,2,5,6: ☑ Phase Group 3,4,7,8: ☑			Enable Dallas Left-Turn Phasing? Phases 1,2,5,6: ☐ Phases 3,4,7,8: ☐					

Exhibit 17-30
Example Problem 1: Signal Conditions for Intersection 1

Exhibit 17-30 indicates that the passage time for each phase is 2.0 s. The minimum green setting is 5 s for each phase. The offset to Phase 2 (the reference phase) end-of-green interval is 0.0 s. A fixed-force mode is used to ensure that coordination is maintained. The cycle length is 100 s.

Geometric conditions and traffic characteristics for Signalized Intersection 1 are shown in Exhibit 17-31. They are the same for Signalized Intersection 2. The

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movement numbers follow the numbering convention shown in Exhibit 18-2 of Chapter 18.

Exhibit 17-31
Example Problem 1: Geometric Conditions and Traffic Characteristics for Signalized Intersection 1

Signalized Intersection 1														
	Approach	Eastbound			Westbound			Northbound			Southbound			
	Movement	L	T	R	L	T	R	L	T	R	L	T	R	
	Movement number	5	2	12	1	6	16	3	8	18	7	4	14	
	Volume, veh/h	100	1,000	50	200	1,000	50	100	100	50	100	100	50	
	Lanes	1	2	1	1	2	1	1	2	1	1	2	1	
	Turn bay length, ft	200		200	200		200	200			200			
	Sat. flow rate, veh/h/ln	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800		1,800	1,800		
	Platoon ratio	1.00	1.33	1.00	1.00	1.33	1.00	1.00	1.00		1.00	1.00		
	Critical speed, mi/h	35	35	35	35	35	35	35	35	35	35	35	35	
	Speed limit, mi/h	35	35	35	35	35	35	35	35	35	35	35	35	
	Stop line dist. length, ft	40			40			40	40		40	40		
	Max. allow. headway, s/veh	3.0			3.0			3.0	3.0		3.0	3.0		

All signalized intersection approaches have a 200-ft left-turn bay and two through lanes. The east–west approaches have a 200-ft right-turn lane. The north–south approaches have a shared through and right-turn lane. The saturation flow rate is determined by using the procedure described in Chapter 18.

The platoon ratio is entered for all movements associated with an external approach to the segment. The eastbound through movement at Signalized Intersection 1 is coordinated with the upstream intersection such that favorable progression occurs, as described by a platoon ratio of 1.33. The westbound through movement at Signalized Intersection 2 is also coordinated with its upstream intersection, and arrivals are described by a platoon ratio of 1.33. Arrivals to all other movements are characterized as "random" and are described with a platoon ratio of 1.00. The movements for the westbound approach at Signalized Intersection 1 (and eastbound approach at Signalized Intersection 2) are internal movements, so the input platoon ratios shown will only be used for the first iteration of calculations. More accurate values are computed during subsequent iterations by using a procedure provided in the methodology.

The speed limit on the segment and on the cross-street approaches is 35 mi/h. A 40-ft detection zone is located just upstream of the stop line in each traffic lane at the two signalized intersections.

The geometric conditions that describe the segment are shown in Exhibit 17-32. These data are used to compute the free-flow speed for the segment.

The traffic and lane assignment data for the two access point intersections are shown in Exhibit 17-33. The movement numbers follow the numbering convention shown in Exhibit 19-3 of Chapter 19, Two-Way STOP-Controlled Intersections. There are no turn bays on the segment at the two access point intersections.

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Segment 1		
Free-Flow Speed Computation		
Input Data		
	EB	WB
Basic Segment Data		
Number of through lanes that extend the length of the segment:	2	2
Speed limit, mph	35	35
Segment Length Data		
Length of segment (measured stopline to stopline), ft	1,800	1,800
Width of upstream signalized intersection, ft	50	50
Adjusted segment length, ft	1,750	1,750
Length of segment with a restrictive median (e.g. raised-curb), ft	0	0
Length of segment with a non-restrictive median (e.g. two-way left-turn lane), ft	0	0
Length of segment with no median, ft	1,750	1,750
Percentage of segment length with restrictive median, %	0	0
Access Data		
Percentage of street with curb on right-hand side (in direction of travel), %	70	70
Number of access points on right-hand side of street (in direction of travel)	4	4
Access point density, access points/mi	24	24

Exhibit 17-32
Example Problem 1: Segment Data

Access Point Input Data

Access Point	Approach	Eastbound			Westbound			Northbound			Southbound		
	Movement	L	T	R	L	T	R	L	T	R	L	T	R
Location	Movement number	1	2	3	4	5	6	7	8	9	10	11	12
300	Volume, veh/h	38	1,818	308	93	1,818	238	90	8	308	90	8	180
West end	Lanes	1	2	0	1	2	0	1	1	1	1	1	1
1,800	Volume, veh/h	90	1,818	308	68	1,818	238	90	8	308	90	8	180
	Lanes	1	2	0	1	2	0	1	1	1	1	1	1

Exhibit 17-33
Example Problem 1: Access Point Data

Outline of Solution

Movement-Based Data

Exhibit 17-34 provides a summary of the analysis of the individual traffic movements at Signalized Intersection 1.

INTERSECTION 1	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
	L	T	R	L	T	R	L	T	R	L	T	R
Movement:	5	2	12	1	6	16	3	8	18	7	4	14
Volume, veh/h	209	1,000	33	134	966	55	139	500	58	180	500	90
Lanes	1	2	1	1	2	1	1	2	0	1	2	0
Bay Length, ft	200	0	200	200	0	200	300	0	0	200	0	0
Saturation Flow Rate, veh/h/ln	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Flareon Ratio	1.00	1.33	1.00	1.00	1.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Initial Queue, veh	0	0	0	0	0	0	0	0	0	0	0	0
Speed Limit, mph	35	35	35	35	35	35	35	35	35	35	35	35
Detector Length, ft	40	0	0	40	0	0	40	40	40	40	40	40
Capacity, veh/h	234	1,783	724	250	1,695	720	213	689	61	213	689	61
Discharge Volume, veh/h	0	1,000	0	0	0	0	0	0	58	180	0	0
Proportion Arriving On Green	0.137	0.620	0.473	0.076	0.458	0.480	0.060	0.389	0.389	0.083	0.389	0.389
Approach Volume, veh/h		1,210			1,172			650			650	
Approach Delay, s/veh		19.4			24.6			18.4			29.4	
Approach Stop Rate, stops/veh		0.47			0.668			1.050			0.898	

Exhibit 17-34
Example Problem 1: Movement-Based Output Data

With one exception, the first eight rows of data in Exhibit 17-34 are an "echo" of the input data. The remaining rows list variables that are computed by using these input data. The volumes shown in Exhibit 17-34 for the eastbound (EB), northbound (NB), and southbound (SB) movements are identical to the input volumes. The westbound (WB) volumes were reduced from the input volumes during Step 1: Determine Traffic Demand Adjustments. This reduction occurred because the westbound volume input for this intersection exceeded the volume departing the upstream access point intersection (i.e., AP1).

Capacity for a movement is computed by using the movement volume proportion in each approach lane group, lane group saturation flow rate, and corresponding phase duration. This variable represents the capacity of the movement, regardless of whether it is served in an exclusive lane or a shared lane. If the movement is served in a shared lane, then the movement capacity represents the portion of the lane group capacity available to the movement, as distributed in proportion to the flow rate of the movements served by the associated lane group.

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Discharge volume is computed for those movements that enter a segment during Step 1: Determine Traffic Demand Adjustments. At Signalized Intersection 1, the movements entering the segment are the eastbound through movement, northbound right-turn movement, and southbound left-turn movement. A value of 0.0 veh/h is shown for all other movements and indicates that they are not relevant to this calculation. If volume exceeds capacity for any given movement, then the discharge volume is set equal to the capacity. Otherwise, the discharge volume is equal to the movement volume.

The proportion arriving during green P is computed for internal movements during Step 3: Determine the Proportion Arriving During Green. In contrast, it is computed from the input platoon ratio for external movements.

The last three rows in Exhibit 17-34 represent summary statistics for the approach. The approach volume represents the sum of the three movement volumes. Approach delay and approach stop rate are computed as volume-weighted averages for the lane groups served on an intersection approach.

Timer-Based Phase Data

Exhibit 17-35 provides a summary of the output data for Signalized Intersection 1 using a signal controller perspective. The controller has eight timing functions (or timers), with Timers 1 to 4 representing Ring 1 and Timers 5 to 8 representing Ring 2. The ring structure and phase assignments are described in Chapter 18. Timers 1, 2, 5, and 6 are used to control the east–west traffic movements on the segment. Timers 3, 4, 7, and 8 are used to control the north–south movements that cross the segment.

Exhibit 17-35
Example Problem 1: Timer-Based Phase Output Data

Timer Data

Timer:	1 WB L	2 EB T,R	3 NB L	4 SB T,T+R	5 EB L	6 WB T,R	7 SB L	8 NB T,T+R
Assigned Phase	1	2	3	4	5	6	7	8
Case No	2	3	1	4	2	3	1	4
Phase Duration (G+Y+Rc), s	16.48	51.29	9.32	22.90	16.69	51.09	9.32	22.90
Change Period (Y+Rc), s	3.00	4.00	3.00	4.00	3.00	4.00	3.00	4.00
Phase Start Time, s	36.22	52.70	4.00	13.32	36.22	52.92	4.00	13.32
Phase End Time, s	52.70	4.00	13.32	36.22	52.92	4.00	13.32	36.22
Max. Allowable Headway (MAH), s	3.13	0.00	3.13	3.06	3.13	0.00	3.13	3.06
Equivalent Maximum Green (Gmax), s	29.78	0.00	17.00	31.68	29.78	0.00	17.00	31.68
Max. Queue Clearance Time (g_c+I1),	13.238	0.000	6.644	16.955	13.432	0.000	6.644	16.955
Green Extension Time (g_e), s	0.302	0.000	0.098	1.946	0.313	0.000	0.098	1.946
Probability of Phase Call (p_c)	0.995	0.000	0.938	1.000	0.996	0.000	0.938	1.000
Probability of Max Out (p_x)	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.023

Cycle Length, s: 100

The timing function construct is essential to the modeling of a ring-based signal controller. *Timers* always occur in the same numeric sequence (i.e., 1 then 2 then 3 then 4 in Ring 1; 5 then 6 then 7 then 8 in Ring 2). The practice of associating movements with phases (e.g., the major-street through movement to Phase 2), coupled with the occasional need for lagging left-turn phases and split phasing, creates the situation in which *phases* do not always time in sequence. For example, with a lagging left-turn phase sequence, major-street through Phase 2 times first and then major-street left-turn Phase 1 times second.

The modern controller accommodates the assignment of phases to timing functions by allowing the ring structure to be redefined manually or by time-of-

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day settings. Specification of this structure is automated in the computational engine by the assignment of phases to timers.

The methodology is based on modeling *timers*, not by directly modeling movements or phases. The methodology converts movement and phase input data into timer input data. It then models controller response to these inputs and computes timer duration and related performance measures.

The two signalized intersections in this example problem have lead–lead left-turn sequences. Hence, the timer number is equal to the phase number (e.g., the westbound movement is associated with Phase 1, which is assigned to Timer 1).

The case number shown in Exhibit 17-35 is used as a single variable descriptor of each possible combination of left-turn mode and lane group type (i.e., shared or exclusive). An understanding of this variable is not needed to interpret the output data.

The phase duration shown in Exhibit 17-35 represents the estimated average phase duration during the analysis period. It represents the sum of the green, yellow change, and red clearance intervals. For Timer 2 (i.e., Phase 2), the average green interval duration can be computed as 47.29 s (= 51.29 − 4.00).

The phase start time represents the time the timer (and phase) starts, relative to system time 0.0. For Phase 2, the start time is 52.71 s. The end of the green interval associated with this phase is 100.0 s (= 52.71 + 47.29). This time is equal to the cycle length, so the end of green actually occurs at 0.0 s. This result is expected because Phase 2 is the coordinated phase and the offset to the end of Phase 2 (relative to system time 0.0) was input as 0.0 s.

The phase end time represents the time the timer (and phase) ends relative to system time 0.0. For Phase 2, the end of the green interval occurs at 0.0 s and the end of the phase occurs 4.0 s later (i.e., the change period duration).

The remaining variables in Exhibit 17-35 apply to the noncoordinated phases (i.e., the actuated phases). These variables describe the phase timing and operation. They are described in more detail in Chapter 18.

Timer-Based Movement Data

Exhibit 17-36 summarizes the output for Signalized Intersection 1 as it relates to the movements assigned to each timer. Separate sections of output are shown in the exhibit for the left-turn, thru-ugh, and right-turn movements. The assigned movement row identifies the movement (previously identified in Exhibit 17-34) assigned to each timer.

The saturation flow rate shown in Exhibit 17-36 represents the saturation flow rate for the movement. The procedure for calculating these rates is described in Chapter 18. In general, the rate for a movement is the same as for a lane group when the lane group serves one movement. The rate is split between the movements when the lane group is shared by two or more movements.

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Exhibit 17-36
Example Problem 1: Timer-Based Movement Output Data

Timer Data								
Timer:	1 WB L	4 EB T,R	5 NB L	8 SB T,T+R	9 EB L	6 WB T,R	7 SB L	8 NB T,T+R
Left-Turn Movement Data								
Average Movement	1		5		9		7	
Mean Split (sec/veh)	[illegible]		[illegible]		[illegible]		[illegible]	
Through Movement Data								
Average Movement		2		1		6		8
Mean Split (sec/veh)		[illegible]		[illegible]		[illegible]		[illegible]
Right Turn Movement Data								
Average Movement		12		11		16		18
Mean Split (sec/veh)		[illegible]		[illegible]		[illegible]		[illegible]

Timer-Based Lane Group Data

The methodology described in Chapter 18 computes a variety of output data that describe the operation of each intersection lane group. The example problem in Chapter 18 illustrates these data and discusses their interpretation. The output data for the individual lane groups are not repeated in this chapter. Instead, the focus of the remaining discussion is on the access point output and the performance measures computed for the two segment through movements.

Access Point Data

Exhibit 17-37 illustrates the output statistics for the two access point intersections located on the segment. The first six rows listed in the exhibit correspond to Access Point Intersection 1 (AP1), and the second six rows correspond to Access Point Intersection 2 (AP2). Additional sets of six rows would be provided in this table if additional access point intersections were evaluated.

Exhibit 17-37
Example Problem 1: Movement-Based Access-Point Output Data

Access Point Data Segment: 1 Movement:	EB 1 L	EB 2 T	WB 3 R	WB 4 L	WB 5 T	NB 6 L	NB 7 T	NB 8 R	SB 9 L	SB 10 T	SB 11 R
Access Point Intersection No. 1											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Access Point Intersection No. 2											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The eastbound and westbound volumes listed in Exhibit 17-37 are not equal to the input volumes. These volumes were adjusted during Step 1: Determine Traffic Demand Adjustments such that they equal the volume discharging from the upstream intersection. This routine achieves balance between all junction pairs (e.g., between Signalized Intersection 1 and Access Point Intersection 1, between Access Point Intersection 1 and Access Point Intersection 2, and so forth).

The proportion of time blocked is computed during Step 3: Determine the Proportion Arriving During Green. It represents the proportion of time during the cycle that the associated access point movement is blocked by the presence of a platoon passing through the intersection. For major-street left turns, the platoon of concern approaches from the opposing direction. For the minor-street left turn, platoons can approach from either direction and can combine to block this left turn for extended time periods. This trend can be seen by comparing the

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proportion of time blocked for the eastbound (major-street) left turn (v_o = 0.17) with that for the northbound (minor-street) left turn (v_o = 0.20) at Access Point/Intersection 1.

The delay to through vehicles is computed during Step 3: Determine Running Time. It represents the sum of the delay due to vehicles turning left from the major street and the delay due to vehicles turning right from the major street. This delay tends to be small compared with typical signalized intersection delay values. But it can influence travel speed if there are several high-volume access points on a street and only one or two through lanes in each direction of travel.

The probability of the curbside through lane being blocked is also computed during Step 3: Determine Running Time as part of the delay to through vehicles procedure. This variable indicates the probability that the left-turn bay at an access point will overflow into the inside through lane on the street segment. Hence, it indicates the potential for a through vehicle to be delayed by a left-turn maneuver. The segment being evaluated has an undivided cross section, and no left-turn bays are provided at the access point intersections. In this situation, the probability of overflow is 0.10, indicating that the inside lane is blocked about 10 % of the time.

Results

Exhibit 17-38 summarizes the performance measures for the segment. Also shown are the results from the spillback check conducted during Step 1: Determine Traffic Demand Adjustments. The movements indicated in the column heading represent the movements exiting the segment at a boundary intersection. Thus, the westbound movements on Segment 1 are those that occur at Signalized Intersection 1. Similarly, the eastbound movements on Segment 1 are those that occur at Signalized Intersection 2.

Segment Summary	EB	EB	EB	WB	WB	WB
	L	T	R	L	T	R
Seg.No. Movement:	5	2	12	1	6	16
1 Bay/Lane Spillback Time, h	never	never	never	never	never	never
1 Shd/Lane Spillback Time, h	never	never	never	never	never	never
1 Base Free-flow Speed, mph		40.78			40.78	
1 Running Time, s		33.48			33.48	
1 Running Speed, mph		36.65			36.65	
1 Through Delay, sveh		20.862			20.862	
1 Travel Speed, mph		22.58			22.58	
1 Stop Rate, stops/veh		0.608			0.608	
1 Signal Stop Rate, stops/mi		1.70			1.70	
1 Through v/c(cap) ratio		0.57			0.57	
1 Percent of Base LOS		55.4			55.4	
1 Level of Service		C			C	
1 Protection for Lanes		0.33			0.33	
1 Auto Traveler Perception Score		2.56			2.56	

SPILLBACK TIME, h: none

Exhibit 17-38
Example Problem 1: Performance Measure Summary

The spillback check procedure computes the time of spillback for each of the internal movements. For turn movements, the bay/lane spillback time represents the time before the turn bay overflows. For through movements, the bay/lane spillback time represents the time before the through lane overflows due only to

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through demand. If a turn bay exists and it overflows, then the turn volume will spill to the adjacent through lane. For this scenario, the shared-lane spillback time is computed and used instead of the bay/lane spillback time. If several movements experience spillback, then the time of first spillback is reported at the bottom of Exhibit 17-38.

The output data for the two through movements are listed in Exhibit 17-38, starting with the third row. The base free-flow speed (FFS) and running time statistics are computed during Step 2: To determine Running Time. The through delay listed is computed during Step 5: Determine Through Control Delay. It represents a weighted average delay for the lane groups serving through movements at the downstream boundary intersection. The weight used in this average is the volume of through vehicles served by the lane group.

The percent of base free-flow speed equals the travel speed divided by the base free-flow speed. It and the through movement volume-to-capacity ratio are used with Exhibit 17-2 to determine that the segment is operating at LOS C in both travel directions.

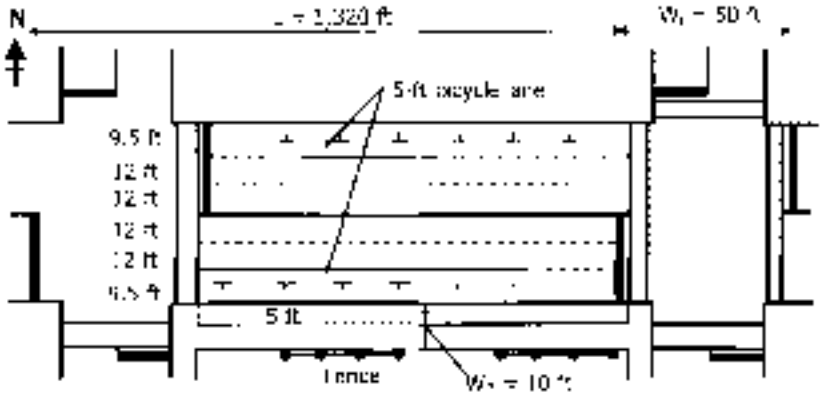
Each travel direction has one left-turn bay and three intersections. Thus, the proportion of intersections with left-turn lanes is 0.33. This proportion is used in Step 10: Determine Automobile Travel or Perception Score to compute the score of 2.56, which suggests that most automobile travelers would find segment service to be very good.

EXAMPLE PROBLEM 2: PEDESTRIAN LOS

The Segment

The sidewalk of interest is located along a 1,320-ft urban street segment. The segment is part of a collector street located near a community college. It is shown in Exhibit 17-39. Sidewalk is only shown for the south side of the segment for the convenience of illustration. It also exists on the north side of the segment.

Exhibit 17-39
Example Problem 2
Segment Geometry



The Question

What is the pedestrian LOS for the sidewalk on the south side of the segment?

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The Facts

The geometric details of the sidewalk and street cross section are shown in Exhibit 17-34. Both boundary intersections are signalized. It is legal to cross the segment at uncontrolled, midsegment locations. The following additional information is known about the sidewalk and street segment:

Traffic Characteristics

Midsegment flow rate in restricted direction: 960 veh/h

Pedestrian flow rate in south sidewalk (walking in both directions): 2,000 p/h

Proportion of on-street parking occupied during analysis period: 0.70

Geometric Characteristics

Shoulder width consists of 8.0 ft for parking and 1.5 ft for gutter pan.

Cross section has raised curb along outside edge of roadway.

Effective width of fixed objects on sidewalk: 0.0 ft (no objects present)

Presence of trees, bushes, or other vertical objects in buffer: No

Other Data

Pedestrians can cross the segment legally and do so somewhat uniformly along its length.

Proportion of sidewalk adjacent to window display: 0.0

Proportion of sidewalk adjacent to building face: 0.0

Proportion of sidewalk adjacent to fence: 0.50

Performance Measures Obtained from Supporting Methodologies

Motorized vehicle running speed: 33 mi/h

Pedestrian delay when walking parallel to the segment: 40 s/p

Pedestrian delay when crossing the segment at the nearest signal-controlled crossing: 80 s/p

Pedestrian waiting delay: 740 s/p

Pedestrian LOS score for the downstream intersection: 3.6

Outline of Solution

First, the pedestrian space will be calculated for the sidewalk. This measure will then be compared with the qualitative descriptions of pedestrian space listed in Exhibit 17-16. Next, the pedestrian travel speed along the sidewalk will be calculated. Finally, LOS for the crossing will be determined by using the computed pedestrian LOS score and pedestrian space variables with Exhibit 17-3.

Computational Steps

Step 1: Determine Free-Flow Walking Speed

The average free-flow walking speed is estimated to be 4.4 ft/s on the basis of the guidance provided.

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Step 2: Determine Average Pedestrian Space

The shy distance on the inside of the sidewalk is computed by using Equation 17-23.

$$W_{s,i} = \max(W_{os,i}, 1.5)$$

$$W_{s,i} = \max(5.0, 1.5)$$

$$W_{s,i} = 5.0 \text{ ft}$$

The shy distance on the outside of the sidewalk is computed by using Equation 17-24.

$$W_{s,o} = 3.0 P_{curb} + 2.0 P_{curbg} + 1.5 P_{bus}$$

$$W_{s,o} = 3.0(0.0) + 2.0(0.0) + 1.5(0.50)$$

$$W_{s,o} = 0.75 \text{ ft}$$

There are no fixed objects present on the sidewalk, so the adjusted fixed-object effective widths for the inside and outside of the sidewalk are both equal to 0.0 ft. The effective sidewalk width is computed by using Equation 17-22.

$$W_e = W_T - W_{fo,i} - W_{fo,o} - W_{s,i} - W_{s,o} \geq 0.0$$

$$W_e = 10 - 0.0 - 0.0 - 5.0 - 0.75$$

$$W_e = 4.25 \text{ ft}$$

The pedestrian flow per unit width of sidewalk is computed by using Equation 17-27 for the subject sidewalk.

$$v_p = \frac{v_{15}}{60 W_e}$$

$$v_p = \frac{2,000}{60(4.25)}$$

$$v_p = 7.84 \text{ p/ft/min}$$

The average walking speed S_p is computed by using Equation 17-28.

$$S_p = (1 - 0.00078 v_p) S_o \geq 0.5 S_o$$

$$S_p = (1 - 0.00078 \times 7.84) \times 4.4$$

$$S_p = 4.19 \text{ ft/s}$$

Finally, Equation 17-29 is used to compute average pedestrian space.

$$A_p = 60 \frac{S_p}{v_p}$$

$$A_p = 60 \frac{4.19}{7.84}$$

$$A_p = 32.0 \text{ ft}^2/\text{p}$$

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The pedestrian space can be compared with the ranges provided in Exhibit 17-16 to make some judgments about the performance of the subject intersection corner. The criteria for platoon flow are considered applicable given the influence of the signalized intersections. According to the qualitative descriptions provided in this exhibit, walking speed will be restricted as will the ability to pass slower pedestrians.

Step 3: Determine Pedestrian Delay at Intersection

The pedestrian methodology in Chapter 18, Signalized Intersections, was used to estimate two pedestrian delay values. One value is the pedestrian delay at the boundary intersection when walking parallel to segment d_{p1}. This delay was computed to be 40 s/p. The second value is the pedestrian delay when crossing the segment at the nearest signal-controlled crossing d_{p2}. This delay was computed to be 60 s/p.

The pedestrian methodology in Chapter 19, Two-Way Stop-Controlled Intersections, was used to estimate the delay incurred while waiting for an acceptable gap in traffic d_{p3}. This delay was computed to be 7.10 s/p.

Step 4: Determine Pedestrian Travel Speed

The pedestrian travel speed is computed by using Equation 17-70.

$$S_{p,ms} = \frac{L_s}{\frac{L_s}{S_p} - d_p}$$

$$S_{p,ms} = \frac{1{,}320}{\frac{1{,}320}{4.19} + 40}$$

$$S_{p,ms} = 3.72 \text{ ft/s}$$

This walking speed is slightly less than 4.0 ft/s and is considered acceptable, but a higher speed is desirable.

Step 5: Determine Pedestrian LOS Score for Intersection

The pedestrian methodology in Chapter 18 was used to determine the pedestrian LOS score for the downstream boundary intersection $I_{p,o}$. It was computed to be 3.60.

Step 6: Determine Pedestrian LOS Score for Link

The pedestrian LOS score for the link is computed from three factors. However, before these factors can be calculated, several cross-section variables need to be adjusted and several coefficients need to be calculated. These variables and coefficients are calculated first. Then, the three factors are computed. Finally, they are combined to determine the desired score.

The total width of the outside through lane, bicycle lane, and paved shoulder W_v is computed as

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$$W_t = W_d + W_{ol}$$

$$W_t = 12 - 5$$

$$W_t = 17 \text{ ft}$$

In fact, the variable W_t does not include the width of the paved outside shoulder in this instance because the proportion of occupied on-street parking exceeds 0.0.

The effective total width of the outside through lane, bicycle lane, and shoulder as a function of traffic volume W_v is equal to W_t because the midsegment flow rate is greater than 360 veh/h.

The street cross section is curbed, so the adjusted width of paved outside shoulder W_s is 5.0 ft ($= 0.5 - 1.5$).

Because the proportion of occupied on-street parking is less than 0.25, the effective width of the combined bicycle lane and shoulder W_l is computed as

$$W_l = W_{bl} + W_s$$

$$W_l = 5 + 8$$

$$W_l = 13 \text{ ft}$$

The adjusted available sidewalk width W_{as} is computed as

$$W_{as} = \min(W_{os} - W_{ds}, 10)$$

$$W_{as} = \min(10 - 5, 10)$$

$$W_{as} = 5.0 \text{ ft}$$

The sidewalk width coefficient f_{sw} is computed as

$$f_{sw} = 6.0 - 0.3\,W_{as}$$

$$f_{sw} = 6.0 - 0.3(5.0)$$

$$f_{sw} = 4.5 \text{ ft}$$

The buffer area coefficient f_b is equal to 1.0 because there is no continuous barrier at least 3.0 ft high located in the buffer area.

The automobile methodology described in Section 2 was used to determine the motorized vehicle running speed S_r for the subject segment. This speed was computed to be 53.0 mi/h.

The cross-section adjustment factor is computed by using Equation 17-32:

$$I_x = -1.2276 \ln(W_t + 0.5\,W_l + 50\,p_{pl} + W_{as}\,f_b + W_{sw}\,f_{sw})$$

$$I_x = -1.2276 \ln(17 + 0.5(13) - 50(0.20) - 5.0(1.0) - 5.0(4.5))$$

$$I_x = -5.05$$

The motorized vehicle volume adjustment factor is computed by using Equation 17-33:

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$$F_p = 0.0091 \frac{v_p}{4 N_w}$$

$$F_p = 0.0091 \frac{940}{4 (2)}$$

$$F_p = 1.07$$

The motorized vehicle speed adjustment factor is computed by using Equation 17-34.

$$F_s = 4 \left(\frac{S_a}{100} \right)^2$$

$$F_s = 4 \left(\frac{33.0}{100} \right)^2$$

$$F_s = 0.44$$

Finally, the pedestrian LOS score for the link $I_{p,ink}$ is calculated by using Equation 17-31.

$$I_{p,ink} = 6.0468 + F_w + F_p + F_s$$

$$I_{p,ink} = 6.0468 + (-5.05) + 1.07 + 0.44$$

$$I_{p,ink} = 2.51$$

Step 7: Determine Link LOS

The pedestrian LOS for the link is determined by using the pedestrian LOS score from Step 6 and the average pedestrian space from Step 2. These two performance measures are compared with their respective thresholds in Exhibit 17-3 to determine that the LOS for the specified direction of travel along the subject link is C.

Step 8: Determine Roadway Crossing Difficulty Factor

Crossings occur somewhat uniformly along the length of the segment and the segment is bounded by two signalized intersections. Thus, the distance D_i is assumed to equal one-third of the segment length, or 440 ft (= 1,320/3), and the diversion distance D_d is computed as 880 ft (= 2 × 440 ft).

The delay incurred due to diversion is calculated by using Equation 17-36.

$$d_{ped} = \frac{D_d}{S_p} + d_s$$

$$d_{ped} = \frac{880}{4.19} + 80$$

$$d_{ped} = 290 \text{ s/p}$$

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The crossing delay used to estimate the roadway crossing difficulty factor is computed as

$$d_{cx} = \min(d_{cx}, d_{px}, 60)$$

$$d_{cx} = \min(299, 740, 60)$$

$$d_{cx} = 60 \text{ s/p}$$

The roadway crossing difficulty factor is computed by using Equation 17-37.

$$f_{cx} = 1.0 + \frac{0.10\, d_{cx} - (0.318\, I_{p,ins} + 0.220\, I_{p,ou} + 1.606)}{7.5} \leq 1.20$$

$$f_{cx} = 1.0 + \frac{0.10\,(60) - (0.318\,[2.51] + 0.220\,[3.60] + 1.606)}{7.5}$$

$$f_{cx} = 1.20$$

Step 9: Determine Pedestrian LOS Score for Segment

The pedestrian LOS score for the segment is computed by using Equation 17-38.

$$I_{p,ped} = f_{cx}(0.318\, I_{p,ins} + 0.220\, I_{p,ou} + 1.606)$$

$$I_{p,ped} = 1.20\,(0.318\,[2.51] + 0.220\,[3.60] + 1.606)$$

$$I_{p,ped} = 3.83$$

Step 10: Determine Segment LOS

The pedestrian LOS for the segment is determined by using the pedestrian LOS score from Step 9 and the average pedestrian space from Step 2. These two performance measures are compared with their respective thresholds in Exhibit 17-3 to determine that the LOS for the specified direction of travel along the subject segment is D.

EXAMPLE PROBLEM 3: BICYCLE LOS

The Segment

The bicycle lane of interest is located along a 1,320-ft urban street segment. The segment is part of a collector street located near a community college. The bicycle lane is provided for the eastbound direction of travel, as shown in Exhibit 17-40.

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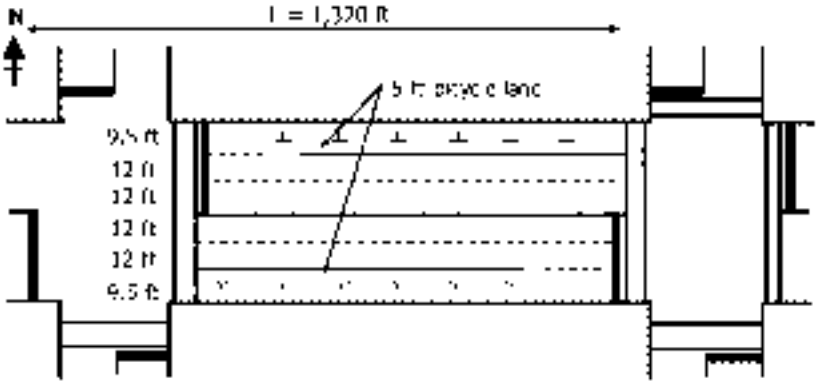

Exhibit 17-40
Example Problem 3: Segment Geometry

The Question

What is the bicycle LOS for the eastbound bicycle lane?

The Facts

The geometric details of the street cross section are shown in Exhibit 17-40. Both boundary intersections are signalized. The following additional information is known about the street segment:

Traffic Characteristics

Midsegment flow rate in eastbound direction: 940 veh/h

Percent heavy vehicles: 8.0%

Proportion of on-street parking occupied during analysis period: 0.20

Geometric Characteristics

Shoulder width consists of 8.0 ft for parking and 1.5 ft for gutter pan.

Cross section has raised curb along outside edge of roadway.

Number of access point approaches on right side of segment in subject travel direction: 4

Other Data

Pavement condition rating: 2.0

Performance Measures Obtained from Supporting Methodologies

Motorized vehicle running speed: 35 mi/h

Bicycle control delay: 40 s/bicycle

Bicycle LOS score for the downstream intersection: 0.08

Outline of Solution

First, the bicycle delay at the boundary intersection will be computed. This delay will then be used to compute the bicycle travel speed. Next, a bicycle LOS score will be computed for the link. It will then be combined with a similar score for the boundary intersection and used to compute the bicycle LOS score for the segment. Finally, LOS for the segment will be determined by using the computed score and the thresholds in Exhibit 17-4.

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Computational Steps

Step 1: Determine Bicycle Running Speed

The average bicycle running speed S_o could not be determined from field data. Therefore, it was estimated to be 15 mi/h on the basis of the guidance provided.

Step 2: Determine Bicycle Delay at Intersection

The methodology in Chapter 18, Signalized Intersections, was used to estimate the bicycle delay at the boundary intersection d_i. This delay was computed to be 49.0 s/bicycle.

Step 3: Determine Bicycle Travel Speed

The segment running time of through bicycles is computed as

$$t_{rs} = \frac{3{,}600\ L_s}{5{,}280\ S_o}$$

$$t_{rs} = \frac{3{,}600\ (1{,}320)}{5{,}280\ (15)}$$

$$t_{rs} = 60.0\ \text{s}$$

The average bicycle travel speed is computed by using Equation 17-39.

$$S_{bw,ex} = \frac{3{,}600\ L_s}{5{,}280\ (t_{rs} + d_i)}$$

$$S_{bw,ex} = \frac{3{,}600\ (1{,}320)}{5{,}280\ (60.0 + 49.0)}$$

$$S_{bw,ex} = 9.0\ \text{mi/h}$$

This travel speed is adequate, but a speed of 10 mi/h or more is considered desirable.

Step 4: Determine Bicycle LOS Score for Intersection

The bicycle methodology in Chapter 18 was used to determine the bicycle LOS score for the boundary intersection $I_{v,int}$. It was computed to be 0.06.

Step 5: Determine Bicycle LOS Score for Link

The bicycle LOS score is computed from four factors. However, before these factors can be calculated, several cross-section variables need to be adjusted. These variables are calculated first, and then the four factors are computed. Finally, they are combined to determine the desired score.

The total width of the outside through lane, bicycle lane, and paved shoulder W_v is computed as

$$W_v = W_w + W_s$$

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$$W_v = 12 - 5$$

$$W_v = 17 \text{ ft}$$

In fact, the variable W_v does not include the width of the paved outside shoulder in this instance because the proportion of occupied on-street parking exceeds 0.0.

The effective total width of the outside through lane, bicycle lane, and shoulder as a function of traffic volume W_t is equal to W_v because the midsegment flow rate is greater than 100 veh/h.

The street cross section is curbed, so the adjusted width of paved outside shoulder W_s' is 8.0 ft (= 9.5 − 1.5).

Because the combined bicycle lane and adjusted shoulder width exceed 4.0 ft, the effective width of the outside through lane is computed as

$$W_e = W_t + W_s - W_s' - 20\,p_{a1} \quad \geq 0.0$$

$$W_e = 17 + 5 + 8 - 20\,(0.20)$$

$$W_e = 26 \text{ ft}$$

The percent heavy vehicles is less than 5%, so the adjusted percent heavy vehicles P_{HV} is equal to the input percent heavy vehicles P_{HV} of 3.0%.

The automobile methodology described in Section 2 was used to determine the undersized vehicle running speed S_t for the subject segment. This speed was computed to be 34.0 mi/h. This speed exceeds 21 mi/h, so the adjusted motorized vehicle speed S_{av} is also equal to 34.0 mi/h.

The midsegment demand flow rate is greater than 8 veh/h ($> 4\,N_{ln}$), so the adjusted midsegment demand flow rate v_{av} is equal to the input demand flow rate of 940 veh/h.

The cross-section adjustment factor is computed by using Equation 17-41.

$$f_v = -0.005\,W_e^2$$

$$f_v = -0.005\,(26)^2$$

$$f_v = -3.38$$

The motorized vehicle volume adjustment factor comes from Equation 17-42

$$F_v = 0.507 \ln\left(\frac{v_{av}}{4\,N_{ln}}\right)$$

$$F_v = 0.507 \ln\left(\frac{940}{4\,(2)}\right)$$

$$F_v = 2.42$$

The motorized vehicle speed adjustment factor is computed by using Equation 17-43

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$$C_v = 0.199\left[1.1199\ln(S_{av} - 20) - 0.8103\right](1 + 0.1038\,P_{HV})^2$$

$$C_v = 0.199\left[1.1199\ln(33.0 - 20) - 0.8103\right](1 + 0.1038\,(8.0))^2$$

$$C_v = 2.46$$

The pavement condition adjustment factor is computed by using Equation 17-44.

$$F_c = \frac{7.066}{PCI^2}$$

$$F_c = \frac{7.066}{2.0^2}$$

$$F_c = 1.77$$

Finally, the bicycle LOS score for the link $I_{v,ost}$ is calculated by using Equation 17-40.

$$I_{v,ost} = 0.760 + F_v + I_w + F_c + C_v$$

$$I_{v,ost} = 0.760 - 3.38 + 2.42 + 2.46 + 1.77$$

$$I_{v,ost} = 4.02$$

Step 6: Determine Link LOS

The bicycle LOS for the link is determined by using the bicycle LOS score from Step 5. This performance measure is compared with the thresholds in Exhibit 17-4 to determine that the LOS for the specified direction of travel along the subject link is D.

Step 7: Determine Bicycle LOS Score for Segment

The bicycle LOS score for the segment is computed by using Equation 17-45.

$$I_{v,seg} = 0.260\,I_{v,ost} + 0.011\,F_v\,e^{1.38\,I_{v,ost}} + 0.035\,\frac{N_{v,av}}{(L/5{,}280)} + 2.85$$

$$I_{v,seg} = 0.260\,(4.02) + 0.011\,(1)\,e^{1.38(4.02)} + 0.035\,\frac{3}{(1{,}320/5{,}280)} - 2.85$$

$$I_{v,seg} = 3.92$$

Step 8: Determine Segment LOS

The bicycle LOS for the segment is determined by using the bicycle LOS score from Step 7. This performance measure is compared with the thresholds in Exhibit 17-4 to determine that the LOS for the specified direction of travel along the subject segment is D.

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EXAMPLE PROBLEM 4: TRANSIT LOS

The Segment

The transit route of interest travels east along a 1,320-ft urban street segment. The segment is part of a collector street located near a community college. It is shown in Exhibit 17-41. A bus stop is provided on the south side of the segment for the subject route.

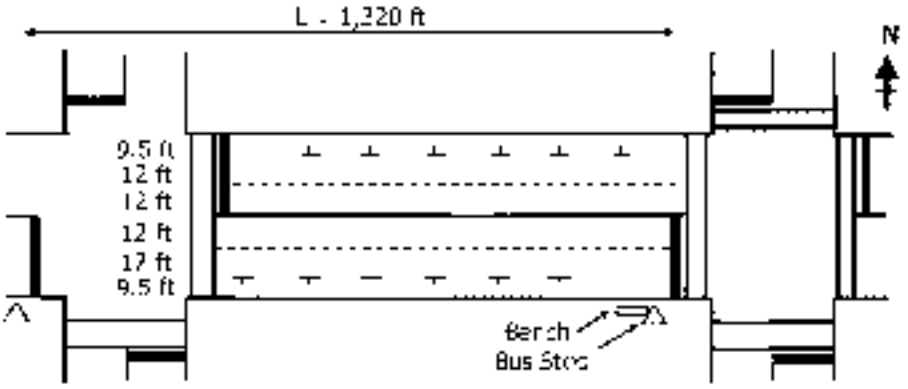

Exhibit 17-41
Example Problem 4: Segment Geometry

The Question

What is the transit LOS for the eastbound bus route while traveling the subject segment?

The Facts

The geometric details of the segment are shown in Exhibit 17-41. Both boundary intersections are signalized. There is one stop in the segment for the eastbound route. The following additional information is known about the bus stop and street segment:

Transit Characteristics

Dwell time: 20.0 s

Transit frequency: 4 veh/h

Excess wait time data are not available for the stop, but the on-time performance of the route (based on a standard of up to 5 min late being considered "on time") at the previous time point is known (92%).

Passenger load factor: 0.83 passengers/seat

Other Data

Area type: not in a central business district

The bus stop in the segment has a bench, but no shelter.

Number of routes serving the segment: 1

The bus stop is accessed from the right-turn lane (i.e., the stop is off-line). Buses are exempt from the requirement to turn right but have no other traffic priority.

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Performance Measures Obtained from Supporting Methodologies

Motorized vehicle running speed: 33 mi/h

Pedestrian LOS score for the link: 3.33

Through control delay at downstream boundary intersection: 20.9 s/veh

Reentry delay: 16.17 s

g/C ratio at downstream boundary intersection: 0.4729

Outline of Solution

First, the transit vehicle segment running time will be computed. Next, the control delay at the boundary intersection will be obtained and used to compute the transit vehicle segment travel speed. Then, the transit wait time score will be computed. This score will be combined with the pedestrian LOS score for the link to compute the transit LOS score for the segment. Finally, LOS for the segment will be determined by comparing the computed score with the thresholds identified in Exhibit 17-4.

Computational Steps

Step 1: Determine Transit Vehicle Running Time

The transit vehicle running time is based on the segment running speed and delay due to a transit vehicle stop. These components are calculated first, and then running time is calculated.

Transit vehicle segment running speed can be computed by using Equation 17-46.

$$S_{x1} = \min\left(S_{FF},\ \frac{61}{1 + e^{1.20(1.68 - \ln(v_{x1}/2))}}\right)$$

$$S_{x1} = \min\left(33.0,\ \frac{61}{1 + e^{1.20(1.68 - \ln(1{,}200))}}\right)$$

$$S_{x1} = 32.1 \text{ mi/h}$$

The acceleration and deceleration rates are unknown, so they are assumed to equal 4.0 ft/s².

The bus stop is located on the near side of a signalized intersection. From Equation 17-48, the average proportion of bus stop acceleration–deceleration delay not due to the intersection's traffic control f_{x1} is equal to the g/C ratio for the through movement on the bus's direction of travel (in this case, eastbound). The effective green time g is 47.29 s (calculated as the phase duration minus the change period), and the cycle length is 100 s. Therefore, f_{x1} is 0.4729.

Equation 17-47 can now be used to compute the portion of bus stop delay due to acceleration and deceleration.

$$d_{x1} = \frac{5{,}280}{3{,}600}\left(\frac{S_{x1}}{2}\right)\left(\frac{1}{r_{x1}} - \frac{1}{r_{x2}}\right)f_{x1}$$

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$$d_{as} = \frac{5,280}{3,600}\left(\frac{33.0}{2}\right)\left(\frac{1}{4.0} + \frac{1}{4.0}\right)(0.4729)$$

$$d_{as} = 5.36 \text{ s}$$

Equation 17-49 is used to compute the portion of bus stop delay due to serving passengers, using the input average dwell time of 20.0 s and an f_c value of 0.4729, based on the stop's near-side location at a traffic signal and the g/C ratio computed in a previous step. The f_c factor is used to avoid double-counting the portion of passenger service time that occurs during the signal's red indication and is therefore included as part of control delay.

$$d_{ps} = t_s f_c$$

$$d_{ps} = (20.0)(0.4729)$$

$$d_{ps} = 9.46 \text{ s}$$

The bus stop is located in the right turn lane; therefore, the bus is subject to reentry delay upon leaving the stop. On the basis of the guidance for reentry delay for a near-side stop at a traffic signal, the reentry delay d_r is equal to the queue service time g_s. By following the procedures given in Chapter 18, Signalized Intersections, this time is calculated to be 16.17 s.

Equation 17-50 is used to compute the total delay due to the transit stop.

$$d_s = d_{as} + d_{ps} - d_r$$

$$d_s = 5.36 + 9.46 - 16.17 = 31.19 \text{ s}$$

Equation 17-51 is used to compute transit vehicle running time on the basis of the previously computed components.

$$t_R = \frac{3,600\, L}{5,280\, S_R} + \sum_{i=1}^{N_s} d_{s,i}$$

$$t_R = \frac{3,600\,(1,320)}{5,280\,(32.1)} + 31.19$$

$$t_R = 59.3 \text{ s}$$

Step 2: Determine Delay at Intersection

The automobile control delay d at the boundary intersection was computed to be 20.9 s/veh.

Step 3: Determine Travel Speed

The average transit travel speed is computed by using Equation 17-53.

$$S_{p,tr} = \frac{3,600\, L}{5,280\,(t_R - d)}$$

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$$S_{a,veh} = \frac{3{,}600\,(1{,}320)}{5{,}280\,(59.3 + 20.9)}$$

$$S_{a,veh} = 11.2\ \text{mi/h}$$

Step 4: Determine Transit Wait–Ride Score

The wait–ride score is based on the headway factor and the perceived travel time factor. Each of these components is calculated separately. The wait–ride score is then calculated.

The input data indicate that there is one route on the segment, and its frequency is 4 veh/h. The headway factor is computed by using Equation 17-54.

$$F_h = 4.00\,e^{-1.4\,A_{pbs}\,+\,0.01\,f_{pbs}}$$

$$F_h = 4.00\,e^{-1.4\,(0.0)\,+\,0.01\,(4.00)}$$

$$F_h = 2.80$$

The perceived travel time factor is based on several intermediate variables that need to be calculated first. The first of these calculations is the amenity time rate. It is calculated by using Equation 17-58. A default passenger trip length of 3.7 mi is used in the absence of other information.

$$T_a = \frac{1.3\,p_{sh} + 0.2\,p_{sb}}{L_p}$$

$$T_a = \frac{1.3\,(0.0) + 0.2\,(1.0)}{3.7} = 0.054\ \text{min/mi}$$

Since no information is available for actual excess wait time, but on-time performance information is available for the route, Equation 17-59 is used to estimate excess wait time.

$$t_e = [t_{pbs}\,(1 - p_{ot})]^2$$

$$t_e = [5.0\,(1 - 0.92)]^2$$

$$t_e = 0.16\ \text{min}$$

The excess wait time rate T_e is then the excess wait time t_e divided by the average passenger trip length L_p: 0.16/3.7 = 0.043 min/mi.

The passenger load warning factor is computed by using Equation 17-57.

$$a_1 = 1 + \frac{(4)(F_h - 0.80)}{4.2}$$

$$a_1 = 1 + \frac{(4)(0.83 - 0.80)}{4.2}$$

$$a_1 = 1.03$$

The perceived travel time rate is computed by using Equation 17-56.

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$$T_{pt} = \left(a_1 \frac{60}{S_{TVA}}\right) - (2\,T_v) - T_a$$

$$T_{pt} = \left(1.03 \frac{60}{21.2}\right) - (2\,[0.043]) - 0.054$$

$$T_{pt} = 5.53 \text{ min/mi}$$

The segment is not located in a central business district of a metropolitan area with a population of 5 million or more, so the base travel time rate T_{ta} is equal to 4.0 min/mi. The perceived travel time factor is computed by using Equation 17-55:

$$F_t = \frac{(e-1)\,T_{ta} - (e-1)\,T_{pt}}{(e-1)\,T_{pt} - (e+1)\,T_{ta}}$$

$$F_t = \frac{(-0.40-1)\,(4.0) - (-0.40+1)(5.53)}{(-0.40-1)\,(5.53) - (-0.40+1)\,(4.0)}$$

$$F_t = 0.88$$

Finally, the transit walk mode score is computed by using Equation 17-60:

$$I_{w,t} = I_w\,F_t$$

$$I_{w,t} = (2.80)(0.88)$$

$$I_{w,t} = 2.46$$

Step 5: Determine Pedestrian LOS Score for Link

The pedestrian methodology described in Section 7 was used to determine the pedestrian LOS score for the link $I_{p,a}$. This score was computed to be 3.53.

Step 6: Determine Transit LOS Score for Segment

The transit LOS score for the segment is computed by using equation 17-61:

$$I_{t,s} = 6.0 - 1.50\,I_{w,t} - 0.15\,I_{p,ato}$$

$$I_{t,s} = 6.0 - 1.50\,(2.46) - 0.15\,(3.53)$$

$$I_{t,s} = 2.84$$

Step 7: Determine LOS

The transit LOS is determined by using the transit LOS score from Step 6. The performance measure is compared with the thresholds in Exhibit 17-4 to determine that the LOS for the specified bus route is C.

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CHAPTER 18
SIGNALIZED INTERSECTIONS

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1. INTRODUCTION

16. Urban Street Facilities
17. Urban Street Segments
18. Signalized Intersections
19. TWSC Intersections
20. AWSC Intersections
21. Roundabouts
22. Freeway Ramp Terminals
23. Off-Street Pedestrian and Bicycle Facilities

Chapter 18, Signalized Intersections, describes a methodology for evaluating the capacity and quality of service provided to road users traveling through a signalized intersection. However, the methodology is much more than just a tool for evaluating capacity and quality of service. It includes an array of performance measures that describe intersection operation for multiple travel modes. These measures serve as clues for identifying the source of problems and provide insight into the development of effective improvement strategies. The analyst using this methodology is encouraged to consider the full range of measures.

OVERVIEW OF THE METHODOLOGY

This chapter's methodology applies to three- and four-leg intersections of two streets or highways where the signalization operates in isolation from nearby intersections.

The influence of an upstream signalized intersection on the subject intersection's operation is addressed by input variables that describe platoon structure and the uniformity of arrivals on a cyclic basis. Chapter 17, Urban Street Segments, describes a methodology for evaluating an intersection that is part of a coordinated signal system.

Analysis Boundaries

The intersection analysis boundaries are not defined at a fixed distance for all intersections. Rather, they are dynamic and extend backward from the intersection a sufficient distance to indicate the operational influence area on each intersection leg. The size of this area is leg specific and includes the most distant extent of any intersection-related queue expected to occur during the study period. For these reasons, the analysis boundaries should be established for each intersection according to conditions during the analysis period. The influence area should extend at least 250 ft back from the stop line on each intersection leg.

Analysis Level

Analysis level describes the level of detail used when the methodology is applied. Three levels are recognized:

- Operational,
- Design, and
- Planning and preliminary engineering.

The operational analysis is the most detailed application and requires the most information about traffic, geometric, and signalization conditions. The design analysis also requires detailed information about traffic conditions and the desired level of service (LOS) as well as information about geometric or signalization conditions. The design analysis then seeks to determine reasonable values for the conditions not provided. The planning and preliminary engineering analysis requires only the most fundamental types of information

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from the analyst. Default values are then used as substitutes for other input data. Analysis levels are discussed in more detail in the applications section of this chapter.

Study Period and Analysis Period

The study period is the time interval represented by the performance evaluation. It consists of one or more consecutive analysis periods. An analysis period is the time interval evaluated by a single application of the methodology.

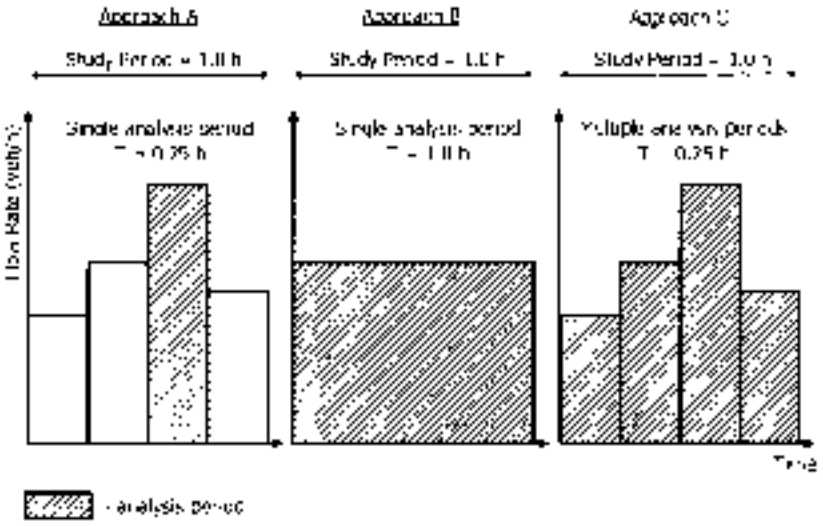
The methodology is based on the assumption that traffic conditions are steady during the analysis period (i.e., systematic change over time is negligible). For this reason, the analysis period ranges from 0.25 to 1 h. The longer durations are sometimes used for planning analyses. In general, the analyst should use caution with analysis periods that exceed 1 h because traffic conditions typically are not steady for long time periods and because the adverse impact of short peaks in traffic demand may not be detected in the evaluation.

If an analysis period of interest has a demand volume that exceeds capacity, then the study period should include an initial analysis period with no initial queue and a final analysis period with no residual queue. This approach provides a more accurate estimate of the delay associated with the congestion.

If evaluation of multiple analysis periods is determined to be important, then the performance estimates for each period should be reported separately. In this situation, reporting an average performance for the study period is not encouraged because it may obscure extreme values and suggest acceptable operation when some analysis periods have unacceptable operation.

Exhibit 18-1 demonstrates three alternative approaches an analyst might use for a given evaluation. Other alternatives exist, and the study period can exceed 1 h. Approach A has traditionally been used and, unless otherwise justified, is the one recommended for use.

Exhibit 18-1
Three Alternative Study Approaches



Approach A is based on evaluation of the peak 15-min period during the study period. The analysis period $T = 0.25$ h. The equivalent hourly flow rate is

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vehicles per hour (veh/h) used for the analysis is based on either a peak 15-min traffic count multiplied by four or a 1-h demand volume divided by the peak hour factor. The former option is preferred when traffic counts are available. Additional discussion on use of the peak hour factor is provided in the required input data subsection.

Approach B is based on evaluation of one 1-h analysis period that is coincident with the study period. The analysis period F is 1.0 h. The flow rate used is equivalent to the 1-h demand volume (i.e., the peak hour factor is not used). This approach implicitly assumes that the arrival rate of vehicles is constant throughout the period of study. Therefore, the effects of peaking within the hour may not be identified and the analyst risks underestimating the delay actually incurred.

Approach C uses a 1-h study period and divides it into four 0.25-h analysis periods. This approach accounts for systematic flow rate variation among analysis periods. It also accounts for queues that carry over to the next analysis period and produces a more accurate representation of delay.

Performance Measures

An intersection's performance is described by the use of one or more quantitative measures that characterize some aspect of the service provided to a specific road user group. Performance measures cited in this chapter include automobile volume-to-capacity ratio, automobile delay, queue storage ratio, pedestrian delay, pedestrian circulation area, pedestrian perception score, bicycle delay, and bicycle perception score.

LOS is also considered a performance measure. It is computed for the automobile, pedestrian, and bicycle travel modes. It is useful for describing intersection performance to elected officials, policy makers, administrators, and the public. LOS is based on one or more of the performance measures listed in the preceding paragraph.

Travel Modes

This chapter describes three methodologies that can be used to evaluate intersection performance from the perspective of motorists, pedestrians, and bicyclists. They are referred to as the automobile methodology, the pedestrian methodology, and the bicycle methodology.

The automobile methodology has evolved and reflects the findings from a large body of research. It was originally based, in part, on the results of a National Cooperative Highway Research Program (NCHRP) study (*1*, *2*) that formalized the critical movement analysis procedure and the automobile delay estimation procedure. The critical movement analysis procedure was developed in the United States (*3*, *4*), Australia (*5*), Great Britain (*6*), and Sweden (*7*). The automobile delay estimation procedure was developed in Great Britain (*8*), Australia (*9*), and the United States (*10*). Updates to the original methodology were developed in a series of research projects (*11*–*24*). The procedures for evaluating pedestrian and bicyclist perception of LOS are documented in an NCHRP report (*25*). The procedures for evaluating pedestrian delay, pedestrian

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circulation area, and bicyclist delay are documented in two Federal Highway Administration reports (26, 27).

The phrase *automobile mode*, as used in this chapter, refers to travel by all motorized vehicles that can legally operate on the street, with the exception of local transit vehicles that stop to pick up passengers at the intersection. Unless explicitly stated otherwise, the word *vehicles* refers to motorized vehicles and includes a mixed stream of automobiles, motorcycles, trucks, and buses.

Lane Groups and Movement Groups

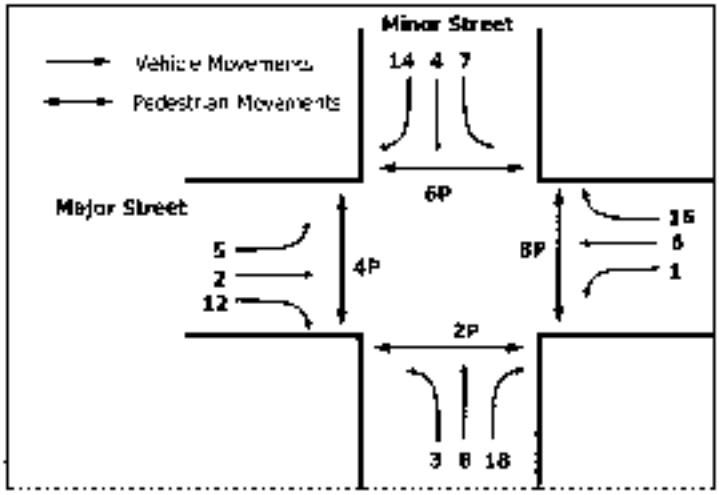
The automobile methodology is designed to evaluate the performance of designated lanes, groups of lanes, an intersection approach, and the entire intersection. A lane or group of lanes designated for separate analysis is referred to as a *lane group*. In general, a separate lane group is established for (*a*) each lane (or combination of adjacent lanes) that exclusively serves one movement and (*b*) each lane shared by two or more movements. Guidelines for establishing lane groups are described in Section 2, Methodology.

The concept of *movement groups* is also established to facilitate data entry. A separate movement group is established for (*a*) each turn movement with one or more exclusive turn lanes and (*b*) the through movement (inclusive of any turn movements that share a lane).

Movement and Phase Numbering

Exhibit 18-2 illustrates the vehicle and pedestrian traffic movements at a four-leg intersection. Three vehicular traffic movements and one pedestrian traffic movement are shown for each intersection approach. To facilitate the discussion in this chapter, each movement is assigned a unique number or a number and letter combination. The letter P denotes a pedestrian movement.

Exhibit 18-2
Intersection Traffic Movements and Numbering Scheme



Modern actuated controllers implement signal phasing by using a dual-ring structure that allows for the concurrent presentation of a green indication to two phases. Each phase serves one or more movements that do not conflict with each other. The commonly used eight-phase dual-ring structure is shown in Exhibit

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18.1. The symbol Φ shown in this exhibit represents the word "phase," and the number following the symbol represents the phase number.

Exhibit 18-3 shows one way that traffic movements can be assigned to each of the eight phases. These assignments are illustrative, but they are not uncommon. Each left-turn movement is assigned to an exclusive phase. During this phase, the left-turn movement is "protected" so that it receives a green arrow indication. Each through, right-turn, and pedestrian movement combination is also assigned to an exclusive phase. The dashed arrows indicate turn movements that are served in a "permitted" manner so that the turn can be completed only after yielding the right-of-way to conflicting movements. Additional information about traffic signal controller operation is provided in Chapter 31, Signalized Intersections: Supplemental.

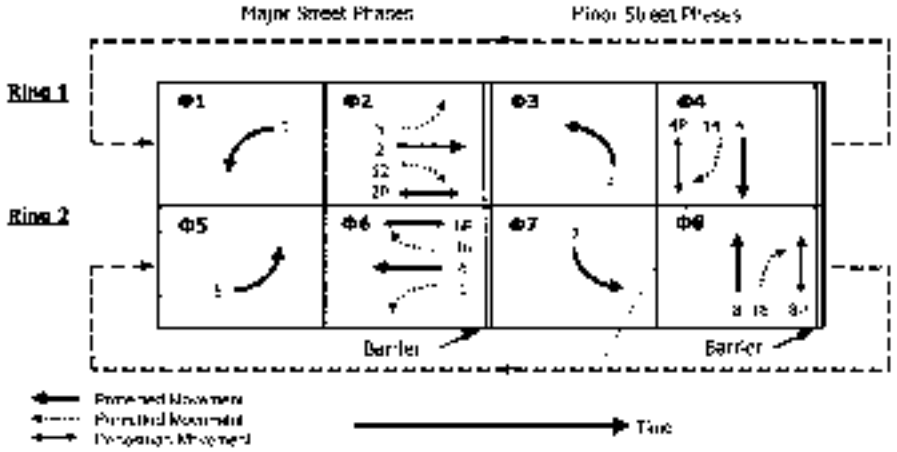

Exhibit 18-3
Dual-Ring Structure with Illustrative Movement Assignments

LOS CRITERIA

This subsection describes the LOS criteria for the automobile, pedestrian, and bicycle modes. The criteria for the automobile mode are different from those for the nonautomobile modes. Specifically, the automobile-mode criteria are based on performance measures that are field measurable and perceivable by travelers. The criteria for the nonautomobile modes are based on scores reported by travelers indicating their perception of service quality.

Automobile Mode

All uses of the word "volume" or the phrase "volume to capacity ratio" in this chapter refer to demand volume or demand-volume-to-capacity ratio.

LOS can be characterized for the entire intersection, each intersection approach, and each lane group. Control delay alone is used to characterize LOS for the entire intersection or an approach. Control delay and volume to capacity ratio are used to characterize LOS for a lane group. Delay quantifies the increase in travel time due to traffic signal control. It is also a surrogate measure of driver discomfort and fuel consumption. The volume-to-capacity ratio quantifies the degree to which a phase's capacity is utilized by a lane group. The following paragraphs describe each LOS.

LOS A describes operations with a control delay of 10 s/veh or less and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is low and either progression is exceptionally

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favorable or the cycle length is very short. It is due to favorable progression, most vehicles arrive during the green indication and travel through the intersection without stopping.

LOS B describes operations with control delay between 10 and 20 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is low and either progression is highly favorable or the cycle length is short. More vehicles stop than with LOS A.

LOS C describes operations with control delay between 20 and 35 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when progression is favorable or the cycle length is moderate. Individual cycle failures (i.e., one or more queued vehicles are not able to depart as a result of insufficient capacity during the cycle) may begin to appear at this level. The number of vehicles stopping is significant, although many vehicles still pass through the intersection without stopping.

LOS D describes operations with control delay between 35 and 55 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is high and either progression is ineffective or the cycle length is long. Many vehicles stop and individual cycle failures are noticeable.

LOS E describes operations with control delay between 55 and 80 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is high, progression is unfavorable, and the cycle length is long. Individual cycle failures are frequent.

LOS F describes operations with control delay exceeding 80 s/veh or a volume-to-capacity ratio greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is very high, progression is very poor, and the cycle length is long. Most cycles fail to clear the queue.

A lane group can incur a delay less than 80 s/veh when the volume-to-capacity ratio exceeds 1.0. This condition typically occurs when the cycle length is short, the signal progression is favorable, or both. As a result, both the delay and volume-to-capacity ratio are considered when lane group LOS is established. A ratio of 1.0 or more indicates that cycle capacity is fully utilized and represents failure from a capacity perspective (just as delay in excess of 80 s/veh represents failure from a delay perspective).

Exhibit 18-4 lists the LOS thresholds established for the automobile mode at a signalized intersection.

Exhibit 18-4
LOS Criteria: Automobile Mode

Control Delay (s/veh)	LOS by Volume-to-Capacity Ratio[a]	
	≤1.0	>1.0
≤10	A	F
>10–20	B	F
>20–35	C	F
>35–55	D	F
>55–80	E	F
>80	F	F

Note: [a] For approach-based and intersection delay assessments, LOS is defined solely by control delay.

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Nonautomobile Modes

Historically, the HCM has used a single performance measure as the basis for defining LOS. However, research documented in Chapter 5, Quality and Level-of-Service Concepts, indicates that travelers consider a wide variety of factors in assessing the quality of service provided to them. Some of these factors can be described as performance measures (e.g., speed) and others can be described as basic descriptors of the intersection character (e.g., crosswalk width). The methodology for evaluating each mode provides a procedure for mathematically combining these factors into a score. This score is then used to determine the LOS that is provided.

Exhibit 18-5 lists the range of scores associated with each LOS for the pedestrian and bicycle travel modes. The association between score value and LOS is based on traveler perception research. Travelers were asked to rate the quality of service associated with a specific trip through a signalized intersection. The letter A was used to represent the best quality of service, and the letter F was used to represent the worst quality of service. "Best" and "worst" were left undefined, allowing respondents to identify the best and worst conditions on the basis of their traveling experience and perception of service quality.

Exhibit 18-5
LOS Criteria: Pedestrian and Bicycle Modes

LOS	LOS Score
A	≤2.00
B	>2.00–2.75
C	>2.75–3.50
D	>3.50–4.25
E	>4.25–5.00
F	>5.00

REQUIRED INPUT DATA

This subsection describes the required input data for the automobile, pedestrian, and bicycle methodologies. Default values for some of these data are provided in Section 3, Applications.

Automobile Mode

This part describes the input data needed for the automobile methodology. The data needed for fully or semiactuated signal control are listed in Exhibit 18-6. The additional data needed for coordinated actuated control are listed in Exhibit 18-7.

The last column of Exhibit 18-6 and Exhibit 18-7 indicates whether the input data are needed for each traffic movement, a specific movement group, each signal phase, each intersection approach, or the intersection as a whole.

The data elements listed in Exhibit 18-6 and Exhibit 18-7 do not include variables that are considered to represent calibration factors (e.g., start-up lost time). Default values are provided for these factors because they typically have a relatively narrow range of reasonable values or they have a small impact on the accuracy of the performance estimates. The recommended value for each calibration factor is identified at relevant points in the presentation of the methodology.

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Exhibit 18–6
Input Data Requirements: Automobile Mode with Pretimed, Fully Actuated, or Semiactuated Signal Control

Data Category	Input Data Element	Basis
Traffic characteristics	Demand flow rate	Movement
	Right-turn-on-red flow rate	Approach
	Percent heavy vehicles	Movement group
	Intersection peak hour factor	Intersection
	Platoon ratio	Movement group
	Upstream filtering adjustment factor	Movement group
	Initial queue	Movement group
	Base saturation flow rate	Movement group
	Lane utilization adjustment factor	Movement group
	Pedestrian flow rate	Approach
	Bicycle flow rate	Approach
	On-street parking maneuver rate	Movement group
	Local bus stopping rate	Approach
Geometric design	Number of lanes	Movement group
	Average lane width	Movement group
	Number of receiving lanes	Approach
	Turn bay length	Movement group
	Presence of on-street parking	Movement group
	Approach grade	Approach
Signal control	Type of signal control	Intersection
	Phase sequence	Intersection
	Left-turn operational mode	Approach
	Dallas left-turn phasing option	Approach
	Passage time (if actuated)	Phase
	Maximum green (or green duration if pretimed)	Phase
	Minimum green	Phase
	Yellow change	Phase
	Red clearance	Phase
	Walk	Phase
	Pedestrian clear	Phase
	Phase recall	Phase
	Dual entry (if actuated)	Phase
	Simultaneous gap-out (if actuated)	Approach
Other	Analysis period duration	Intersection
	Speed limit	Approach
	Stop line detector length and detection mode	Movement group
	Area type	Intersection

Notes: Movement = one value for each left-turn, through, or right-turn movement.
Movement group = one value for each left-turn movement (although two lanes and one value for the through movement, inclusive of any turn movements in a shared lane).
Approach = one value or condition for the intersection approach.
Intersection = one value or condition for the intersection.
Phase = one value or condition for each signal phase.

Exhibit 18–7
Input Data Requirements: Automobile Mode with Coordinated-Actuated Signal Control

Data Category	Input Data Element	Basis
Signal control	Cycle length	Intersection
	Phase splits	Phase
	Offset	Intersection
	Offset reference point	Intersection
	Force mode	Intersection

Notes: Intersection = one value or condition for the intersection.
Phase = one value or condition for each signal phase.

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Traffic Characteristics Data

This subpart describes the traffic characteristics data listed in Exhibit 18-6. These data describe the motorized vehicle traffic stream that travels through the intersection during the study period.

Demand Flow Rate

The demand flow rate for an intersection traffic movement is defined as the count of vehicles arriving at the intersection during the analysis period divided by the analysis period duration. It is expressed as an hourly flow rate but may represent an analysis period shorter than 1 h. Demand flow rate represents the flow rate of vehicles arriving at the intersection. When measured in the field, this flow rate is based on a traffic count taken upstream of the queue associated with the subject intersection. This distinction is important for counts during congested periods because the count of vehicles departing from a congested approach will produce a demand flow rate that is lower than the true rate.

There is one exception to the aforementioned definition of demand flow rate. Specifically, if a planning analysis is being conducted where (*a*) the projected demand flow rate coincides with a 1-h period and (*b*) an analysis of the peak 15-min period is desired, then each movement's hourly demand can be divided by the intersection peak hour factor to predict the flow rate during the peak 15 min period. The peak hour factor should be based on local traffic peaking trends. If a local factor is not available, then the default value provided in Section 3 can be used.

In summary, demand flow rate for the analysis period is an input to the methodology. This rate is computed as the count of vehicles arriving during the period divided by the length of the period, expressed as an hourly flow rate, and without the use of a peak hour factor. If a peak hour factor is used, it must be used to recompute the hourly flow rate that is input to the methodology.

If intersection operation is being evaluated during multiple sequential analysis periods, then the count of vehicles arriving during each analysis period should be provided for each movement.

The methodology includes a procedure for determining the distribution of flow among the available lanes on an approach with one or more shared lanes. The procedure is based on an assumed desire by drivers to choose the lane that minimizes their service time at the intersection, where the lane volume-to-saturation flow ratio is used to estimate relative differences in this time among lanes. This assumption may not always hold for situations in which drivers choose a lane so that they are prepositioned for a turn at the downstream intersection. In this situation, the analyst needs to provide the flow rate for each lane on the approach and then combine these rates to define explicitly the flow rate for each lane group.

Only right turns that are controlled by the signal should be represented in the right-turn volume input to the automobile methodology.

If a right-turn movement is allowed to turn right on the red indication, the analyst may reduce the right-turn flow rate by the flow rate of right-turn-on-red

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(RTOR) vehicles. This topic is discussed in more detail in the next few paragraphs.

Right-Turn-on-Red Flow Rate

The RTOR flow rate is defined as the count of vehicles that turn right at the intersection when the controlling signal indication is red, divided by the analysis period duration. It is expressed as an hourly flow rate but may represent an analysis period shorter than 1 h.

It is difficult to predict the RTOR flow rate because it is based on many factors that vary widely from intersection to intersection. These factors include the following:

- Approach lane allocation (shared or exclusive right-turn lane),
- Right-turn flow rate,
- Sight distance available to right-turning drivers,
- Volume-to-capacity ratio for conflicting movements,
- Arrival patterns of right-turning vehicles during the signal cycle,
- Departure patterns of conflicting movements,
- Left-turn signal phasing on the conflicting street, and
- Conflicts with pedestrians.

Given the difficulty of estimating the RTOR flow rate, it should be measured in the field when possible. If the analysis is dealing with future conditions or if the RTOR flow rate is not known from field data, then the RTOR flow rate for each right-turn movement should be assumed to equal 0 veh/h. This assumption is conservative because it yields a slightly larger estimate of delay than may actually be incurred by intersection movements.

If the right-turn movement is served by an exclusive lane and a complementary left-turn phase exists on the cross street, then the right-turn volume for analysis can be reduced by the number of shadowed left turners (with both movements being considered on an equivalent, per-lane basis).

Percent Heavy Vehicles

A heavy vehicle is defined as any vehicle with more than four tires touching the pavement. Local buses that stop within the intersection area are not included in the count of heavy vehicles. The percentage of heavy vehicles represents the count of heavy vehicles that arrive during the analysis period divided by the total vehicle count for the same period. This percentage is provided for each intersection traffic movement; however, one representative value for all movements may be used for a planning analysis.

Intersection Peak Hour Factor

One peak hour factor for the entire intersection is computed with the following equation:

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$$PHF = \frac{v_{60}}{4 \times v_{15}}$$

Equation 18-1

where

PHF = peak hour factor,

v_{60} = count of vehicles during a 1-h period (veh), and

v_{15} = count of vehicles during the peak 15-min period (veh).

The count used in the denominator of Equation 18-1 must be taken during a 15-min period that occurs within the 1-h period represented by the variable in the numerator. Both variables in this equation represent the total number of vehicles entering the intersection during their respective time period. As such, one peak hour factor is computed for the intersection. This factor is then applied individually to each traffic movement. Values of this factor typically range from 0.80 to 0.98.

As noted previously, the peak hour factor is used primarily for a planning analysis when a forecast hourly volume is provided and an analysis of the peak 15 min period is sought. Normally, the demand flow rate is computed as the count of vehicles arriving during the period divided by the length of the period, expressed as an hourly flow rate, and without the use of a peak hour factor.

The use of a single peak hour factor for the entire intersection is intended to avoid the likelihood of creating demand scenarios with conflicting volumes that are disproportionate to the actual volumes during the 15 min analysis period. If peak hour factors for each individual approach or movement are used, they are likely to generate demand volumes from one 15 min period that are in apparent conflict with demand volumes from another 15 min period, whereas in reality these peak volumes do not occur at the same time. Furthermore, to determine individual approach or movement peak hour factors, actual 15-min count data are likely available, permitting the determination of actual 15-min demand and avoiding the need to use a peak hour factor. In the event that individual approaches or movements are known to peak at different times, several 15 min analysis periods that encompass all the peaking should be considered instead of a single analysis in which all the peak hour factors are used together, as if the peaks they represent also occurred together.

Platoon Ratio

Platoon ratio is used to describe the quality of signal progression for the corresponding movement group. It is computed as the demand flow rate during the given indication divided by the average demand flow rate. Values for the platoon ratio typically range from 0.33 to 2.0. Exhibit 18-8 provides an indication of the quality of progression associated with selected platoon ratio values.

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Exhibit 18-8
Relationship Between Arrival Type and Progression Quality

Platoon Ratio	Arrival Type	Progression Quality
0.33	1	Very poor
0.57	2	Unfavorable
1.00	3	Random arrivals
1.33	4	Favorable
1.67	5	Highly favorable
2.00	6	Exceptionally favorable

For protected or protected-permitted left-turn movements operating in an exclusive lane, platoon ratio is used to describe progression quality during the associated turn phase (i.e., the protected period). Hence, the platoon ratio is based on the flow rate during the green indication of the left-turn phase.

For permitted left-turn movements operating in an exclusive lane, platoon ratio is used to describe progression quality during the permitted period. Hence, the platoon ratio is based on the left-turn flow rate during the green indication of the phase providing the permitted operation.

For permitted or protected-permitted right-turn movements operating in an exclusive lane, platoon ratio is used to describe progression quality during the permitted *period* (even if a protected right-turn operation is provided during the complementary left-turn phase on the cross street). Hence, the platoon ratio is based on the right-turn flow rate during the green indication of the phase providing the permitted operation.

For through movements served by exclusive lanes (or shared lanes on the approach), the platoon ratio for the through movement group is based on the through flow rate during the green indication of the associated phase.

For all movements served by split phasing, the platoon ratio for a movement group is based on its flow rate during the green indication of the common phase.

For intersection approaches with one or more shared lanes, one platoon ratio is computed for the shared movement group on the basis of the flow rate of all shared lanes (plus that of any exclusive through lanes that are also served) during the green indication of the common phase.

The platoon ratio for a movement group can be estimated from field data with the following equation:

Equation 18-2

$$R_p = \frac{P}{(g/C)}$$

where:

R_p = platoon ratio,

P = proportion of vehicles arriving during the green indication (decimal),

g = effective green time (s), and

C = cycle length (s).

The "proportion of vehicles arriving during the green indication" P is computed as the count of vehicles that arrive during the green indication divided by the count of vehicles that arrive during the entire signal cycle. It is an average value representing conditions during the analysis period.

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If the subject intersection is part of a signal system, then the procedure in Chapter 17, Urban Street Segments, can be used to estimate the arrival flow profile for any approach that is evaluated as part of an urban street segment. The procedure uses the profile to compute the proportion of arrivals during the green indication. If this procedure is used, then platoon ratio is not an input for the traffic movements on the subject approach.

If the subject intersection is not part of a signal system and an existing intersection is being evaluated, then it is recommended that analysts use field-measured values for the variables in Equation 18-2 in estimating the platoon ratio.

If the subject intersection is not part of a signal system and the analysis is dealing with future conditions, or if the variables in Equation 18-2 are not known from field data, then the platoon ratio can be judged from Exhibit 18-8 by using the arrival type designation. Values of arrival type range from 1 to 6. A description of each arrival type is provided in the following paragraphs to help the analyst make a selection.

Arrival Type 1 is characterized by a dense platoon of more than 80% of the movement group volume arriving at the start of the red interval. This arrival type is often associated with short segments with very poor progression in the subject direction of travel (and possibly good progression for the other direction).

Arrival Type 2 is characterized by a moderately dense platoon arriving in the middle of the red interval or a dispersed platoon containing 60% to 80% of the movement group volume arriving throughout the red interval. This arrival type is often associated with segments of average length with unfavorable progression in the subject direction of travel.

Arrival Type 3 describes one of two conditions. If the signals bounding the segment are coordinated, then this arrival type is characterized by a platoon containing less than 40% of the movement group volume arriving partly during the red interval, and partly during the green interval. If the signals are not coordinated, then this arrival type is characterized by platoons arriving at the subject intersection at different points in time over the course of the analysis period so that arrivals are effectively random.

Arrival Type 4 is characterized by a moderately dense platoon arriving in the middle of the green interval or a dispersed platoon containing 40% to 60% of the movement group volume arriving throughout the green interval. This arrival type is often associated with segments of average length with favorable progression in the subject direction of travel.

Arrival Type 5 is characterized by a dense platoon of more than 80% of the movement group volume arriving at the start of the green interval. This arrival type is often associated with short segments with highly favorable progression in the subject direction of travel and a low-to-moderate number of side street turns.

Arrival Type 6 is characterized by a dense platoon of more than 80% of the movement group volume arriving at the start of the green interval. This arrival type occurs only on very short segments with exceptionally favorable

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progression in the subject direction of travel and negligible side street entries. It is reserved for routes in dense signal networks, possibly with one-way streets.

Upstream Filtering Adjustment Factor

The upstream filtering adjustment factor *I* accounts for the effect of an upstream signal on vehicle arrivals to the subject movement group. Specifically, this factor reflects the way an upstream signal changes the variance in the number of arrivals per cycle. The variance decreases with increasing volume-to-capacity ratio, which can reduce cycle failure frequency and resulting delay.

The filtering adjustment factor varies from 0.09 to 1.0. A value of 1.0 is appropriate for an isolated intersection (i.e., one that is 0.6 mi or more from the nearest upstream signalized intersection). A value of less than 1.0 is appropriate for nonisolated intersections. The following equation is used to compute *I* for nonisolated intersections:

Equation 18-3

$$I = 1.0 - 0.91 \cdot X_u^{2.68} \quad \geq 0.090$$

where

I = upstream filtering adjustment factor, and

X_u = weighted volume-to-capacity ratio for all upstream movements contributing to the volume in the subject movement group.

The variable X_u is computed as the weighted volume-to-capacity ratio of all upstream movements contributing to the volume in the subject movement group. This ratio is computed as a weighted average with the volume-to-capacity ratio of each contributing upstream movement weighted by its discharge volume. For planning and design analyses, X_u can be approximated as the volume-to-capacity ratio of the contributing through movement at the upstream signalized intersection. The value of X_u used in Equation 18-3 cannot exceed 1.0.

Initial Queue

The initial queue represents the queue present at the start of the subject analysis period for the subject movement group. This queue is created when over saturation is sustained for an extended time. The initial queue can be estimated by monitoring queue count continuously during each of the three consecutive cycles that occur just before the start of the analysis period. The smallest count observed during each cycle is recorded. The initial queue estimate equals the average of the three counts. The initial queue estimate should not include vehicles in the queue due to random, cycle-by-cycle fluctuations.

Base Saturation Flow Rate

The saturation flow rate represents the maximum rate of flow for a traffic lane, as measured at the stop line during the green indication. The base saturation flow rate represents the saturation flow rate for a traffic lane that is 12 ft wide and has no heavy vehicles, a flat grade, no parking, no buses that stop at the intersection, even lane utilization, and no turning vehicles. Typically, one base rate is selected to represent all signalized intersections in the jurisdiction (or area) within which the subject intersection is located. It has units of passenger

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cars per hour per lane (pc/h/ln). Chapter 31, Signalized Intersections: Supplemental, describes a field measurement technique for quantifying the local base saturation flow rate.

Lane Utilization Adjustment Factor

The lane utilization adjustment factor accounts for the unequal distribution of traffic among the lanes in those movement groups with more than one exclusive lane. This factor provides an adjustment to the base saturation flow rate to account for unevenness of the lanes. It is not used unless a movement group has more than one exclusive lane. It is calculated with Equation 18-4.

$$f_{LU} = \frac{v_g}{N \cdot v_{g1}}$$

Equation 18-4

where:

f_{LU} = adjustment factor for lane utilization,

v_g = demand flow rate for movement group (veh/h),

v_{g1} = demand flow rate on the single exclusive lane with the highest flow rate of all exclusive lanes on movement group (veh/h/ln), and

N = number of exclusive lanes in movement group (ln).

Lane flow rates measured in the field can be used with Equation 18-4 to establish local default values of the lane utilization adjustment factor.

A lane utilization factor of 1.0 is used when a uniform traffic distribution can be assumed across all exclusive lanes in the movement group or when a movement group has only one lane. Values less than 1.0 apply when traffic is not uniformly distributed. As demand approaches capacity, the lane utilization factor is often closer to 1.0 because drivers have less opportunity to select their lane.

At some intersections, drivers may choose one through lane over another lane in each group of a turn at a downstream intersection. When this type of "prepositioning" occurs, a more accurate evaluation will be obtained when the actual flow rate for each approach lane is measured in the field and provided as an input to the methodology.

Pedestrian Flow Rate

The pedestrian flow rate is based on the count of pedestrians traveling in the crosswalk that is crossed by vehicles turning right from the subject approach during the analysis period. For example, the pedestrian flow rate for the westbound approach describes the pedestrian flow at the crosswalk on the north leg. A separate count is taken for each direction of travel in the crosswalk. Each count is divided by the analysis period duration to yield a directional hourly flow rate. These rates are then added to obtain the pedestrian flow rate.

Bicycle Flow Rate

The bicycle flow rate is based on the count of bicycles whose travel path is crossed by vehicles turning right from the subject approach during the analysis

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period. These bicycles may travel on the shoulder or in a bike lane. Any bicycle traffic operating in the right lane with automobile traffic should not be included in the count. This interaction is not modeled by the methodology. The count is divided by the analysis period duration to yield an hourly flow rate.

On-Street Parking Maneuver Rate

The parking maneuver rate represents the count of *influential* parking maneuvers that occur on an intersection leg, as measured during the analysis period. An influential maneuver occurs directly adjacent to a movement group within a zone that extends from the stop line to a point 250 ft upstream of it. A maneuver occurs when a vehicle enters or exits a parking stall. If more than 180 maneuvers/h exist, then a practical limit of 180 should be used. On a two-way leg, maneuvers are counted for just the right side of the leg. On a one-way leg, maneuvers are separately counted for each side of the leg. The count is divided by the analysis period duration to yield an hourly flow rate.

Local Bus Stopping Rate

The bus stopping rate represents the number of local buses that stop and block traffic flow in a movement group within 250 ft of the stop line (upstream or downstream), as measured during the analysis period. A *local bus* is a bus that stops to discharge or pick up passengers at a bus stop. The stop can be on the near side or the far side of the intersection. If more than 250 buses/h exist, then a practical limit of 250 should be used. The count is divided by the analysis period duration to yield an hourly flow rate.

Geometric Design Data

This subpart describes the geometric design data listed in Exhibit 18-6. These data describe the geometric elements of the intersection that influence traffic operations.

Number of Lanes

The number of lanes represents the count of lanes provided for each intersection traffic movement. For a turn movement, this count represents the lanes reserved for the exclusive use of turning vehicles. Turn movement lanes include turn lanes that extend backward for the length of the segment and lanes in a turn bay. Lanes that are shared by two or more movements are included in the count of through lanes and are described as *shared lanes*. If no exclusive turn lanes are provided, then the turn movement is indicated to have 0 lanes.

Average Lane Width

The average lane width represents the average width of the lanes represented in a movement group. The minimum average lane width is 8 ft. Standard lane widths are 12 ft. Lane widths greater than 16 ft can be entered; however, the analyst should consider whether the wide lane actually operates as two narrow lanes. The analyst should reflect the way in which the lane width is actually used or expected to be used.

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Number of Receiving Lanes

The number of receiving lanes represents the count of lanes departing the intersection. This number should be separately determined for each left-turn and right-turn movement. Experience indicates that protected turning cannot be executed at some intersections because a receiving lane is frequently blocked by double-parked vehicles. For this reason, the number of receiving lanes should be determined from field observation when possible.

Turn Bay Length

Turn bay length represents the length of the bay for which the lanes have full width and in which queued vehicles can be stored. Bay length is measured parallel to the roadway centerline. If there are multiple lanes in the bay and they have different lengths, then the length entered should be an average value.

If a two-way left-turn lane is provided for left-turn vehicle storage and adjacent access points exist, then the bay length entered should represent the "effective" storage length available to the left turn movement. The determination of effective length is based on consideration of the adjacent access points and the associated left turning vehicles that store in the two-way left-turn lane.

Presence of On-Street Parking

This input indicates whether on-street parking is allowed along the curb lane adjacent to a convenient group (at least within 250 ft upstream of the stop line during the analysis period. On a two-way street, the presence of parking is noted for just the right side of the street. On a one-way street, the presence of on-street parking is separately noted for each side of the street.

Approach Grade

Approach grade defines the average grade along the approach, as measured from the stop line to a point 100 ft upstream of the stop line along a line parallel to the direction of travel. An uphill condition has a positive grade, and a downhill condition has a negative grade.

Signal Control Data

This subpart describes the signal control data listed in Exhibit 18-6 and Exhibit 18-7. They are specific to an actuated traffic signal controller that is operated in a pretimed, semiactuated, fully actuated, or coordinated-actuated manner.

Type of Signal Control

The methodology is based on the operation of a fully actuated controller. However, semiactuated, pretimed, and coordinated-actuated control can be achieved through proper specification of the controller inputs.

Semiactuated control is achieved by using the following settings for unactuated phases:

- Maximum green is set to an appropriate value, and
- Maximum recall is invoked.

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An equivalent pretimed control is achieved by using the following two settings for each signal phase:

- Maximum green is set to the desired pretimed green interval duration, and
- Maximum recall is invoked.

Settings used for coordinated-actuated control are described later in this subpart and are used in Chapter 17.

The automobile methodology is based on the latest controller functions defined in the National Transportation Communications for ITS Protocol Standard 1202. It is incumbent on the analyst to become familiar with these functions and adapt them, if needed, to the functionality of the controller that is used at the subject intersection. Chapter 31 provides additional information about traffic signal controller operation.

Phase Sequence

In a lexical context, phase sequence describes the sequence of service provided to each traffic movement. This definition is narrowed here to limit phase sequence to a description of the order in which the left-turn movements are served, relative to the through movements. The sequence options addressed in the methodology include no left-turn phase, leading left-turn phase, lagging left-turn phase, and split phasing.

Left Turn Operational Mode

The left-turn operational mode describes how the left-turn movement is served by the controller. It can be described as permitted, protected, or protected-permitted.

Dallas Left-Turn Phasing Option

This option allows the left-turn movements to operate in the protected-permitted mode without causing a "yellow trap" safety concern. It effectively ties the left turn's permitted period signal indication to the opposing through movement signal indication. This phasing option is also used with a flashing yellow arrow left-turn signal display.

Passage Time

Passage time is the maximum amount of time one vehicle actuation can extend the green interval while green is displayed. It is input for each actuated signal phase. It is also referred to as vehicle interval, extension interval, extension, or unit extension.

Passage time values are typically based on detection zone length, detection zone location (relative to the stop line), number of lanes served by the phase, and vehicle speed. Longer passage times are often used with shorter detection zones, greater distance between the zone and stop line, fewer lanes, and slower speeds.

The objective in determining the passage time value is to make it large enough to ensure that all queued vehicles are served but not so large that it extends for randomly arriving traffic. On high-speed approaches, this objective is broadened to include not making the passage time so long that the phase

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frequently extends to its maximum setting (i.e., maxes out) so that safe phase termination is compromised.

Maximum Green

The maximum green setting defines the maximum amount of time that a green signal indication can be displayed in the presence of conflicting demand. Typical maximum green values for left-turn phases range from 15 to 30 s. Typical values for through phases serving the minor-street approach range from 20 to 40 s, and those for through phases serving the major-street approach range from 30 to 60 s.

For an operational analysis of optimal operation, the maximum green setting for each phase should equal the desired green interval duration and the recall mode should be set to "maximum." These settings also apply to the major-street through movement phases for semiactuated operation.

For an analysis of coordinated actuated operation, the maximum green is disabled through the inhibit mode and the phase splits are used to determine the maximum length of the actuated phases.

Minimum Green

The minimum green setting represents the least amount of time a green signal indication is displayed when a signal phase is activated. Its duration is based on consideration of driver reaction time, queue size, and driver expectancy. Minimum green typically ranges from 4 to 15 s, with shorter values in this range used for phases serving turn movements and lower-volume through movements. For intersections without pedestrian push buttons, the minimum green setting may also need to be long enough to allow time for pedestrians to react to the signal indication and cross the street.

Yellow Change and Red Clearance

The yellow change and the red clearance settings are input for each signal phase. The yellow change interval is intended to alert a driver to the impending presentation of a red indication. It ranges from 3 to 6 s, with longer values in this range used with phases serving high-speed movements. The red clearance interval can be used to allow a brief time to elapse after the yellow indication, during which the signal heads associated with the ending phase and all conflicting phases display a red indication. If used, the red clearance interval is typically 1 or 2 s.

Walk

The walk interval is intended to give pedestrians adequate time to perceive the WALK indication and depart the curb before the pedestrian clearance interval begins.

For an actuated or a run-coordinated phase, the walk interval is typically set at the minimum value needed for pedestrian detection and curb departure. Many agencies consider this value to be 7 s. However, some agencies use as little as 4 s. Longer walk durations should be considered in school zones and areas with large numbers of elderly pedestrians. In the methodology, it is assumed that

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the rest-in-walk mode is not enabled for actuated phases and noncoordinated phases.

For a permitted phase, the walk interval is often set at a value equal to the green interval duration needed for vehicle service less the pedestrian clear setting (provided that the resulting interval exceeds the minimum time needed for pedestrian perception and curb departure).

For a coordinated phase, the controller is sometimes set to use a coordination mode that extends the walk interval for most of the green interval duration. This functionality is not explicitly modeled in the automobile methodology, but it can be approximated by setting the walk interval to a value equal to the phase split minus the sum of the pedestrian clear, yellow change, and red clearance intervals.

If the walk and pedestrian clear settings are provided for a phase, then it is assumed that a pedestrian signal head is also provided. If these settings are not used, then it is assumed that any pedestrian accommodation needed is provided in the minimum green setting.

Pedestrian Clear

The pedestrian clear interval (also referred to as the pedestrian change interval) is intended to provide time for pedestrians who depart the curb during the WALK indication to reach the opposite curb (or the median). Some agencies set the pedestrian clear equal to the "crossing time," where crossing time equals the curb-to-curb crossing distance divided by the pedestrian walking speed of 3.5 ft/s. Other agencies set the pedestrian clear equal to the crossing time less the vehicle change period (i.e., the combined yellow change and red clearance intervals). This choice depends on agency policy and practice. A flashing DON'T WALK indication is displayed during this interval.

Phase Recall

If used, recall causes the controller to place a call for a specified phase each time the controller is serving a conflicting phase. It is input for each signal phase. Three types of recalls are modeled in the automobile methodology: minimum recall, maximum recall, and pedestrian recall.

Invoking minimum recall causes the controller to place a continuous call for vehicle service on the phase and then service the phase until its minimum green interval times out. The phase can be extended if actuations are received.

Invoking maximum recall causes the controller to place a continuous call for vehicle service on the phase. It results in presentation of the green indication for its maximum duration every cycle. Using maximum recall on all phases yields an equivalent pretimed operation.

Invoking pedestrian recall causes the controller to place a continuous call for pedestrian service on the phase and then service the phase for at least an amount of time equal to its walk and pedestrian clear intervals (longer if vehicle detections are received). Pedestrian recall is used for phases that have a high probability of pedestrian demand every cycle and no pedestrian detection.

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Dual Entry

The entry mode is used in dual ring operation to specify whether a phase is to be activated (green) even though it has not received a call for service. Two entry modes are possible: dual entry and single entry. This mode is input for each actuated signal phase.

A phase operating in dual entry is available to be called by the controller, even if no actuations have been received for this phase. A phase operating in single entry will be called only if actuations have been received.

During the timing of a cycle, a point is reached where the next phase (or phases) to be timed is on the other side of a barrier. At this point, the controller will check the phases in each ring and determine which phase to activate. If a call does not exist in a ring, the controller will activate a phase designated as dual entry in that ring. If two phases are designated as dual entry in the ring, then the first phase to occur in the phase sequence is activated.

Simultaneous Gap Out

The simultaneous gap out mode affects the way actuated phases are terminated before the barrier can be crossed to serve a conflicting call. This mode can be enabled or disabled. It is a phase-specific setting; however, it is typically set the same for all phases that serve the same street. This mode is input for each actuated signal phase.

Simultaneous gap-out dictates controller operation when a barrier must be crossed to serve the next call and one phase is active in each ring. If simultaneous gap-out is enabled, it requires that both phases reach a point of being committed to terminate (via gap out, max out, or force off) at the same time. If one phase is able to terminate because it has gapped out, but the other phase is not able to terminate, then the gapped out phase will reset its extension timer and restart the process of timing down to gap-out.

If the simultaneous gap-out feature is disabled, then each phase can reach a point of termination independently. In this situation, the first phase to attain its termination maintains its active status while waiting for the other phase to attain its termination. Regardless of which mode is in effect, the barrier is not crossed until both phases are committed to terminate.

Cycle Length (Coordinated-Actuated Operation)

Cycle length is the time elapsed between the endings of two sequential presentations of a coordinated phase green interval.

Phase Splits (Coordinated-Actuated Operation)

Each coordinated phase is provided a "split" time. This time represents the sum of the green, yellow change, and red clearance intervals for the phase. The rationale for determining the green interval duration varies among agencies; however, it is often related to the "optimum" pretimed green interval duration. Chapter 31 describes a procedure for determining pretimed phase duration.

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Offset and Offset Reference Point (Coordinated-Actuated Operation)

The reference phase is specified to be one of the two coordinated phases (i.e., Phase 2 or 6). The offset entered in the controller represents the time that the reference phase begins (or ends) relative to the system master time zero. The offset must be specified as being referenced to the beginning, or the end, of the green interval of the reference phase. The offset reference point is typically the same at all intersections in a given signal system.

Force Mode (Coordinated-Actuated Operation)

This mode is a controller-specific setting. It is set to "fixed" or "floating." The controller calculates the phase force-off point for each noncoordinated phase on the basis of the force mode and the phase splits. When set to the fixed mode, each noncoordinated phase has its force-off point set at a fixed time in the cycle, relative to time zero on the system master. This operation allows unused split time to revert to the following phase. When set to the floating mode, each noncoordinated phase has its force off point set at the split time after the phase first becomes active. This operation allows unused split time to revert to the coordinated phase (referred to as an "early return to green").

Other Data

This subpart describes the data listed at Exhibit 18-6 that are categorized as "other" data.

Analysis Period Duration

The analysis period is the time interval considered for the performance evaluation. It ranges from 15 min to 1 h, with longer durations in this range sometimes used for planning analyses. In general, the analyst should interpret the results from an analysis period of 1 h or more with caution because the adverse impact of short peaks in traffic demand may not be detected. Also, if the analysis period is other than 15 min, then the peak hour factor should not be used.

The methodology was developed to evaluate conditions in which queue spillback does not affect the performance of the subject intersection or any upstream intersection during the analysis period. If spillback affects intersection performance, the analyst should consider use of an alternative analysis tool that is able to model the effect of spillback conditions.

Operational Analysis. A 15-min analysis period should be used for operational analyses. This duration will accurately capture the adverse effects of demand peaks. Any 15-min period of interest can be evaluated with the methodology. However, a complete evaluation should always include an analysis of conditions during the 15-min period that experiences the highest traffic demand during a 24-h period.

If traffic demand exceeds capacity for a given 15-min analysis period, then a multiple-period analysis should be conducted. This type of analysis consists of an evaluation of several consecutive 15-min time periods. The periods analyzed would include an initial analysis period that has no initial queue, one or more

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cars per hour per lane (veh/h/ln). Chapter 31, Signalized Intersections: Supplemental, describes a field measurement technique for quantifying the local base saturation flow rate.

Lane Utilization Adjustment Factor

The lane utilization adjustment factor accounts for the unequal distribution of traffic among the lanes in those movement groups with more than one exclusive lane. This factor provides an adjustment to the base saturation flow rate to account for uneven use of the lanes. It is not used unless a movement group has more than one exclusive lane. It is calculated with Equation 18-4.

$$f_{LU} = \frac{v}{N_e v_e}$$

Equation 18-4

where

f_{LU} = adjustment factor for lane utilization,

v = demand flow rate for movement group (veh/h),

v_e = demand flow rate in the single exclusive lane with the highest flow rate of all exclusive lanes in movement group (veh/h/ln), and

N_e = number of exclusive lanes in movement group (ln).

Lane flow rates measured in the field can be used with Equation 18-4 to establish local default values of the lane utilization adjustment factor.

A lane utilization factor of 1.0 is used when a uniform traffic distribution can be assumed across all exclusive lanes in the movement group or when a movement group has only one lane. Values less than 1.0 apply when traffic is not uniformly distributed. As demand approaches capacity, the lane utilization factor is often closer to 1.0 because drivers have less opportunity to select their lane.

At some intersections, drivers may choose one through lane over another lane in anticipation of a turn at a downstream intersection. When this type of "prepositioning" occurs, a more accurate evaluation will be obtained when the actual flow rate for each approach lane is measured in the field and provided as an input to the methodology.

Pedestrian Flow Rate

The pedestrian flow rate is based on the count of pedestrians traveling in the crosswalk that is crossed by vehicles turning right from the subject approach during the analysis period. For example, the pedestrian flow rate for the westbound approach describes the pedestrian flow in the crosswalk on the north leg. A separate count is taken for each direction of travel in the crosswalk. Each count is divided by the analysis period duration to yield a directional hourly flow rate. These rates are then added to obtain the pedestrian flow rate.

Bicycle Flow Rate

The bicycle flow rate is based on the count of bicycles whose travel path is crossed by vehicles turning right from the subject approach during the analysis

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period. These bicycles may travel on the shoulder or in a bike lane. Any bicycle traffic operating in the right lane with automobile traffic should not be included in this count. This interaction is not modeled by the methodology. The count is divided by the analysis period duration to yield an hourly flow rate.

On-Street Parking Maneuver Rate

The parking maneuver rate represents the count of *influential* parking maneuvers that occur on an intersection leg, as measured during the analysis period. An influential maneuver occurs directly adjacent to a movement group, within a zone that extends from the stop line to a point 250 ft upstream of it. A maneuver occurs when a vehicle enters or exits a parking stall. If more than 180 maneuvers/h exist, then a practical limit of 180 should be used. On a two-way leg, maneuvers are counted for just the right side of the leg. On a one-way leg, maneuvers are separately counted for each side of the leg. The count is divided by the analysis period duration to yield an hourly flow rate.

Local Bus Stopping Rate

The bus stopping rate represents the number of local buses that stop and block traffic flow in a movement group within 250 ft of the stop line (upstream or downstream), as measured during the analysis period. A *local bus* is a bus that stops to discharge or pick up passengers at a bus stop. The stop can be on the near side or the far side of the intersection. If more than 250 buses/h exist, then a practical limit of 250 should be used. The count is divided by the analysis period duration to yield an hourly flow rate.

Geometric Design Data

The subpart describes the geometric design data listed in Exhibit 18-6. These data describe the geometric elements of the intersection that influence traffic operation.

Number of Lanes

The number of lanes represents the count of lanes provided for each intersection traffic movement. For a turn movement, this count represents the lanes reserved for the exclusive use of turning vehicles. Turn movement lanes include turn lanes that extend backward for the length of the upstream and lanes in a turn bay. Lanes that are shared by two or more movements are included in the count of through lanes and are described as *shared lanes*. If no exclusive turn lanes are provided, then the turn movement is indicated to have 0 lanes.

Average Lane Width

The average lane width represents the average width of the lanes represented in a movement group. The minimum average lane width is 8 ft. Standard lane widths are 12 ft. Lane widths greater than 16 ft can be excluded; however, the analyst should consider whether the wide lane actually operates as two narrow lanes. The analysis should reflect the way in which the lane width is actually used or expected to be used.

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Number of Receiving Lanes

The number of receiving lanes represents the count of lanes departing the intersection. This number should be separately determined for each left-turn and right-turn movement. Experience indicates that proper turning cannot be executed at some intersections because a receiving lane is frequently blocked by double-parked vehicles. For this reason, the number of receiving lanes should be determined from field observation when possible.

Turn Bay Length

Turn bay length represents the length of the bay for which the lanes have full width and in which queued vehicles can be stored. Bay length is measured parallel to the roadway centerline. If there are multiple lanes in the bay and they have different lengths, then the length entered should be an average value.

If a two-way left-turn lane is provided for left-turn vehicle storage and adjacent access points exist, then the bay length entered should represent the "effective" storage length available to the left-turn movement. The determination of effective length is based on consideration of the adjacent access points and the associated left-turning vehicles that store in the two-way left-turn lane.

Presence of On-Street Parking

This input indicates whether on-street parking is allowed along the curb line adjacent to a movement group and within 250 ft upstream of the stop line during the analysis period. On a two-way street, the presence of parking is noted for just the right side of the street. On a one-way street, the presence of on-street parking is separately noted for each side of the street.

Approach Grade

Approach grade defines the average grade along the approach, as measured from the stop line to a point 100 ft upstream of the stop line along a line parallel to the direction of travel. An uphill condition has a positive grade, and a downhill condition has a negative grade.

Signal Control Data

This subpart describes the signal control data listed in Exhibit 18-6 and Exhibit 18-7. They are specific to an actuated traffic signal controller that is operated in a pretimed, semiactuated, fully actuated, or coordinated-actuated manner.

Type of Signal Control

The methodology is based on the operation of a fully actuated controller. However, semiactuated, pretimed, and coordinated actuated control can be achieved through proper specification of the controller inputs.

Semiactuated control is achieved by using the following settings for nonactuated phases:

- Maximum green is set to an appropriate value, and
- Maximum recall is invoked.

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An equivalent pretimed control is achieved by using the following two settings for each signal phase:

- Maximum green is set to the desired pretimed green interval duration, and
- Maximum recall is invoked.

Settings used for coordinated-actuated control are described later in this subpart and are used in Chapter 17.

The actuated-control methodology is based on the latest controller functions defined in the National Transportation Communications for ITS Protocol Standard 1202. It is incumbent on the analyst to become familiar with these functions and adapt them, if needed, to the functionality of the controller that is used at the subject intersection. Chapter 31 provides additional information about traffic signal controller operation.

Phase Sequence

In a broad context, phase sequence describes the sequence of service provided to each traffic movement. This definition is narrowed here to limit phase sequence to a description of the order in which the left-turn movements are served, relative to the through movements. The sequence options addressed in the methodology include no left-turn phase, leading left-turn phase, lagging left-turn phase, and split phasing.

Left-Turn Operational Mode

The left-turn operational mode describes how the left-turn movement is served by the controller. It can be described as permitted, protected, or protected-permitted.

Dallas Left-Turn Phasing Option

This option allows the left-turn movements to operate in the protected-permitted mode without causing a "yellow trap" safety concern. It effectively ties the left turn's permitted period signal indication to the opposing through movement signal indication. This phasing option is also used with a flashing yellow arrow left-turn signal display.

Passage Time

Passage time is the maximum amount of time one vehicle at a time can extend the green interval while green is displayed. It is input for each actuated signal phase. It is also referred to as vehicle interval, extension interval, extension, or unit extension.

Passage time values are typically based on detection zone length, detection zone location (relative to the stop line), number of lanes served by the phase, and vehicle speed. Longer passage times are often used with shorter detection zones, greater distance between the zone and stop line, fewer lanes, and slower speeds.

The objective in determining the passage time value is to make it large enough to ensure that all queued vehicles are served but not so large that it extends for randomly arriving traffic. On high-speed approaches, this objective is hastened to reduce p0, making the passage time so long that the phase

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frequently extends to its maximum setting (i.e., maxes out) so that safe phase termination is compromised.

Maximum Green

The maximum green setting defines the maximum amount of time that a green signal indication can be displayed in the presence of conflicting demand. Typical maximum green values for left-turn phases range from 15 to 30 s. Typical values for through phases serving the minor street approach range from 20 to 40 s, and those for through phases serving the major-street approach range from 30 to 60 s.

For an operational analysis of pretimed operation, the maximum green setting for each phase should equal the desired green interval duration and the recall mode should be set to "maximum." These settings also apply to the major-street through-movement phases for semiactuated operation.

For an analysis of coordinated-actuated operation, the maximum green is disabled through the inhibit mode and the phase split times used to determine the maximum length of the actuated phases.

Minimum Green

The minimum green setting represents the least amount of time a green signal indication is displayed when a signal phase is activated. Its duration is based on consideration of driver reaction time, queue size, and driver expectancy. Minimum green typically ranges from 4 to 15 s, with shorter values in this range used for phases serving turn movements and lower volume through movements. For intersections without pedestrian push buttons, the minimum green setting may also need to be long enough to allow time for pedestrians to react to the signal indication and cross the street.

Yellow Change and Red Clearance

The yellow change and the red clearance settings are input for each signal phase. The yellow change interval is intended to alert a driver to the impending presentation of a red indication. It ranges from 3 to 6 s, with longer values in this range used with phases serving high-speed movements. The red clearance interval can be used to allow a brief time to elapse after the yellow indication, during which the signal heads associated with the ending phase and all conflicting phases display a red indication. If used, the red clearance interval is typically 1 or 2 s.

Walk

The walk interval is intended to give pedestrians adequate time to perceive the walk indication and depart the curb before the pedestrian clear interval begins.

For an actuated or a coordinated-actuated phase, the walk interval is typically set at the minimum value needed for pedestrian perception and curb departure. Many agencies consider this value to be 7 s, however, some agencies use 5 or as few as 4 s. Longer walk durations should be considered in school zones and areas with large numbers of elderly pedestrians. In the methodology, it is assumed that

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the rest-in-walk mode is not enabled for actuated phases and noncoordinated phases.

For a pretimed phase, the walk interval is often set at a value equal to the green interval duration needed for vehicle service less the pedestrian clear setting (provided that the resulting interval exceeds the minimum time needed for pedestrian perception and curb departure).

For a coordinated phase, the controller is sometimes set to use a coordination mode that extends the walk interval for most of the green interval duration. This functionality is not explicitly modeled in the automobile methodology, but it can be approximated by setting the walk interval to a value equal to the phase split minus the sum of the pedestrian clear, yellow change, and red clearance intervals.

If the walk and pedestrian clear settings are provided for a phase, then it is assumed that a pedestrian signal head is also provided. If these settings are not used, then it is assumed that any pedestrian accommodation needed is provided at the minimum green setting.

Pedestrian Clear

The pedestrian clear interval (also referred to as the pedestrian change interval) is intended to provide time for pedestrians who depart the curb during the WALK indication to reach the opposite curb (or the median). Some agencies set the pedestrian clear equal to the "crossing time," where crossing time equals the curb-to-curb crossing distance divided by the pedestrian walking speed or 3.5 ft/s. Other agencies set the pedestrian clear equal to the crossing time less the vehicle change period (i.e., the combined yellow change and red clearance intervals). This choice depends on agency policy and practice. A flashing DON'T WALK indication is displayed during this interval.

Phase Recall

If used, recall causes the controller to place a call for a specified phase each time the controller is servicing a conflicting phase. It is input for each signal phase. Three types of recalls are modeled in the automobile methodology: minimum recall, maximum recall, and pedestrian recall.

Invoking minimum recall causes the controller to place a continuous call for vehicle service on the phase and then service the phase until its minimum green interval times out. The phase can be extended if actuations are received.

Invoking maximum recall causes the controller to place a continuous call for vehicle service on the phase. It results in presentation of the green indication for its maximum duration every cycle. Using maximum recall on all phases yields an equivalent pretimed operation.

Invoking pedestrian recall causes the controller to place a continuous call for pedestrian service on the phase and then service the phase for at least an amount of time equal to its walk and pedestrian clear intervals (longer if vehicle detections are received). Pedestrian recall is used for phases that have a high probability of pedestrian demand every cycle and no pedestrian detection.

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Dual Entry

The entry mode is used in dual-ring operation to specify whether a phase is to be activated (green) even though it has not received a call for service. Two entry modes are possible: dual entry and single entry. This mode is input for each actuated signal phase.

A phase operating in dual entry is available to be called by the controller, even if no actuations have been received for this phase. A phase operating in single entry will be called only if actuations have been received.

During the timing of a cycle, a point is reached where the next phase (or phases) to be timed is on the other side of a barrier. At this point, the controller will check the phases in each ring and determine which phase to activate. If a call does not exist in a ring, the controller will activate a phase designated as dual entry in that ring. If two phases are designated as dual entry in the ring, then the first phase to occur in the phase sequence is activated.

Simultaneous Gap-Out

The simultaneous gap-out mode affects the way actuated phases are terminated before the barrier can be crossed to serve a conflicting call. This mode can be enabled or disabled. It is a phase-specific setting; however, it is typically set the same for all phases that serve the same street. This mode is input for each actuated signal phase.

Simultaneous gap out dictates controller operation when a barrier may be crossed to serve the next call and one phase is active in each ring. If simultaneous gap-out is enabled, it requires that both phases reach a point of being committed to terminate (via gap out, max out, or force-off) at the same time. If one phase is able to terminate because it has gapped out, but the other phase is not able to terminate, then the gapped-out phase will reset its extension timer and restart the process of timing down to gap-out.

If the simultaneous gap-out feature is disabled, then each phase can reach a point of termination independently. In this situation, the first phase to commit to termination maintains its active status while waiting for the other phase to commit to termination. Regardless of which mode is in effect, the barrier is not crossed until both phases are committed to terminate.

Cycle Length (Coordinated-Actuated Operation)

Cycle length is the time elapsed between the endings of two sequential presentations of a coordinated phase green interval.

Phase Splits (Coordinated-Actuated Operation)

Each noncoordinated phase is provided a "split" time. This time represents the sum of the green, yellow change, and red clearance intervals for the phase. The rationale for determining the green interval duration varies among agencies; however, it is often related to the "optimum" pretimed green interval duration. Chapter 31 describes a procedure for determining pretimed phase duration.

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Offset and Offset Reference Point (Coordinated-Actuated Operation)

The reference phase is specified to be one of the two coordinated phases (i.e., Phase 2 or 6). The offset entered in the controller represents the time that the reference phase begins (or ends) relative to the system master time zero. The offset must be specified as being referenced to the beginning, or the end, of the green interval of the reference phase. The offset reference point is typically the same at all intersections in a given signal system.

Force Mode (Coordinated-Actuated Operation)

This mode is a controller-specific setting. It is set to "fixed" or "floating." The controller calculates the phase force-off point for each noncoordinated phase on the basis of the force mode and the phase splits. When set to the fixed mode, each noncoordinated phase has its force-off point set at a fixed time in the cycle, relative to time zero on the system master. This operation allows unused split time to revert to the following phase. When set to the floating mode, each noncoordinated phase has its force-off point set at the split time after the phase first becomes active. This operation allows unused split time to revert to the coordinated phase (referred to as an "early return to green").

Other Data

This subpart describes the data listed in Exhibit 18-6 that are categorized as "other" data.

Analysis Period Duration

The analysis period is the time interval considered for the performance evaluation. It ranges from 15 min to 1 h, with longer durations in this range sometimes used for planning analyses. In general, the analyst should interpret the results from an analysis period of 1 h or more with caution because the adverse impact of short peaks in traffic demand may not be detected. Also, if the analysis period is other than 15 min, then the peak hour factor should not be used.

The methodology was developed to evaluate conditions in which queue spillback does not affect the performance of the subject intersection or any upstream intersection during the analysis period. If spillback affects intersection performance, the analyst should consider use of an alternative analysis tool that is able to model the effect of spillback conditions.

Operational Analysis. A 15-min analysis period should be used for operational analyses. This duration will accurately capture the adverse effects of demand peaks. Any 15-min period of interest can be evaluated with the methodology; however, a complete evaluation should always include an analysis of conditions during the 15-min period that experiences the highest traffic demand during a 24-h period.

If traffic demand exceeds capacity for a given 15-min analysis period, then a multiple-period analysis should be conducted. This type of analysis consists of an evaluation of several consecutive 15-min time periods. The periods analyzed would include an initial analysis period that has no initial queue, one or more

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2. METHODOLOGY

OVERVIEW

This section describes three methodologies for evaluating the performance of a signalized intersection. Each methodology addresses one possible travel mode through the intersection. Analysts should choose the combination of methodologies that are appropriate for their analysis needs.

A complete evaluation of intersection operation includes the separate examination of performance for all relevant travel modes. The performance measures associated with each mode are assessed independently of one another. They are not mathematically combined into a single indicator of intersection performance. This approach ensures that all performance impacts are considered on a mode-by-mode basis.

The focus of each methodology in this chapter is the signalized intersection. Chapter 17, Urban Street Segments, provides a methodology for quantifying the performance of an urban street segment. The methodology described in Chapter 16, Urban Street Facilities, can be used to combine the performance measures (for a specified travel mode) on successive segments into an overall measure of facility performance for that mode.

AUTOMOBILE MODE

This subsection provides an overview of the methodology for evaluating signalized intersection performance from the motorist perspective. The methodology is computationally intense and requires software to implement. The intensity stems partly from the need to model traffic-actuated signal operation. Default values are provided in Section 3, Applications, to support planning analyses for which the required input data are not available.

A quick estimation method for evaluating intersection performance at a planning level of analysis is provided in Chapter 31, Signalized Intersections: Supplemental. This method is not computationally intense and can be applied by using hand calculations.

Because of the intensity of the computations, the objective of this subsection is to introduce the analyst to the calculation process and discuss the key analytic procedures. This objective is achieved by focusing the discussion on lane groups that serve one traffic movement with protected control and for which there are no permitted or protected-permitted left-turn movements. Details on evaluation of actuated control, shared-lane lane groups, and intersections with permitted or protected-permitted left-turn operation are provided in Chapter 31.

The computational engine developed by the Transportation Research Board Committee on Highway Capacity and Quality of Service represents the most detailed description of this methodology. Additional information about this engine is provided in Chapter 31.

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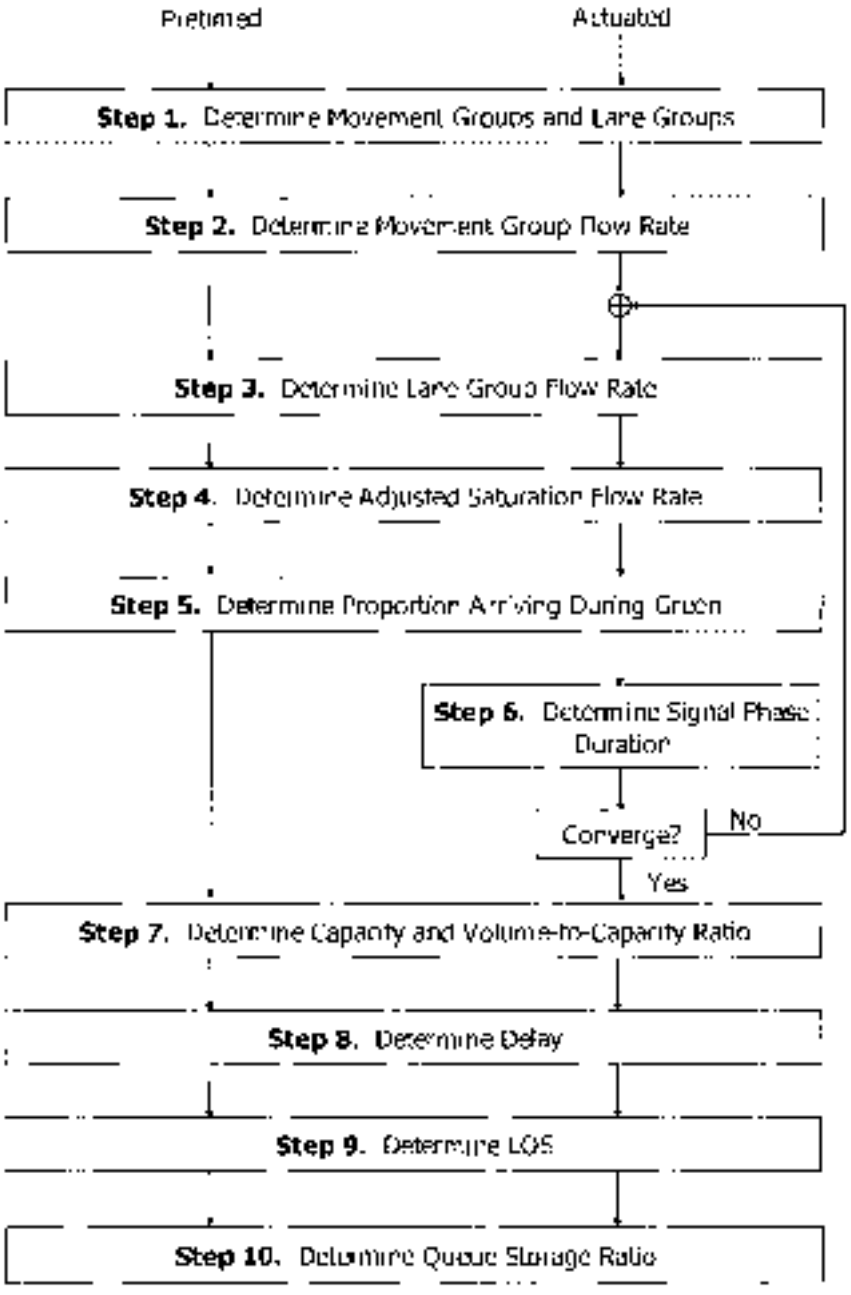
Framework

Exhibit 18-11 illustrates the calculation framework of the automobile methodology. It identifies the sequence of calculations needed to estimate selected performance measures. The calculation process is shown to flow from top to bottom in the exhibit. These calculations are described more fully in the remainder of this subsection.

Exhibit 18-11
Automobile Methodology for Signalized Intersections



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Step 1: Determine Movement Groups and Lane Groups

The methodology for signalized intersections uses the concept of movement groups and lane groups to describe and evaluate intersection operation. These two group designations are very similar in meaning. In fact, their differences emerge only when a shared lane is present on an approach with two or more lanes. Each designation is defined in the following paragraphs. The movement-group designation is a useful construct for specifying input data. In contrast, the lane group designation is a useful construct for describing the calculations associated with the methodology.

The following rules are used to determine movement groups for an intersection approach.

- A turn movement that is served by one or more exclusive lanes and no shared lanes should be designated as a movement group.
- Any lanes not assigned to a group by the previous rule should be combined into one movement group.

These rules result in the designation of one to three movement groups for each approach.

The concept of lane groups is useful when a shared lane is present on an approach that has two or more lanes. Several procedures in the methodology require some indication of whether the shared lane serves a mix of vehicles or functions as an exclusive turn lane. This issue cannot be resolved until the proportion of turns in the shared lane has been computed. If the computed proportion of turns in the shared lane equals 1.0 (i.e., 100%), the shared lane is considered to operate as an exclusive turn lane.

The following rules are used to determine lane groups for an intersection approach:

- An exclusive left-turn lane or lanes should be designated as a separate lane group. The same is true of an exclusive right-turn lane.
- Any shared lane should be designated as a separate lane group.
- Any lanes that are not exclusive turn lanes or shared lanes should be combined into one lane group.

These rules result in the designation of one or more of the following lane group possibilities for an intersection approach:

- Exclusive left-turn lane (or lanes),
- Exclusive through lane (or lanes),
- Exclusive right-turn lane (or lanes),
- Shared left-turn and through lane,
- Shared left-turn and right-turn lane,
- Shared right-turn and through lane, and
- Shared left-turn, through, and right-turn lane.

The methodology can be applied to any logical combination of these lane groups. Exhibit 18-12 shows some common movement groups and lane groups.

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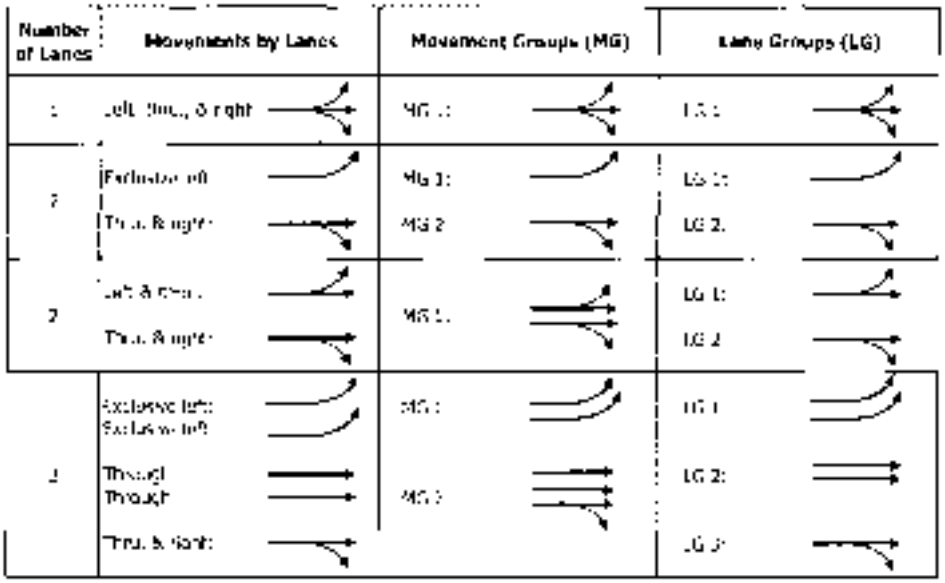
Exhibit 18-12
Typical Lane Groups for Analysis



Step 2: Determine Movement Group Flow Rate

The flow rate for each movement group is determined in this step. If a turn movement is served by one or more exclusive lanes and no shared lanes, then that movement's flow rate is assigned to a movement group. Any of the approach flow that is yet to be assigned to a movement group (following application of the guidance in the previous sentence) is assigned to one movement group.

The RTOR flow rate is subtracted from the right-turn flow rate, regardless of whether the right turn occurs from a shared or an exclusive lane. At an existing intersection, the number of RTORs should be determined by field observation.

Step 3: Determine Lane Group Flow Rate

The lane group flow rate is determined in this step. If there are no shared lanes on the intersection approach or the approach has only one lane, there is a one-to-one correspondence between lane groups and movement groups. In this situation, the lane group flow rate equals the movement group flow rate.

If there are one or more shared lanes on the approach and two or more lanes, then the lane group flow rate is computed by the procedure described in Chapter 31. This procedure is based on an assumed desire by drivers to choose the lane that minimizes their service time at the intersection, where the lane volume-to-saturation flow ratio is used to estimate relative differences in the time among lanes. This assumption may not always hold for situations in which drivers choose a lane on the subject approach so that they are properly positioned for a turn at a downstream intersection. In this situation, the analyst needs to provide as input the desired flow rate for each lane on the approach and aggregate them as appropriate to define the lane group flow rate.

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Step 4: Determine Adjusted Saturation Flow Rate

The adjusted saturation flow rate for each lane of each lane group is computed in this step. The base saturation flow rate provided as an input variable is used in this computation.

The computed saturation flow rate is referred to as the "adjusted" saturation flow rate because it reflects the application of various factors that adjust the base saturation flow rate to the specific conditions present on the subject intersection approach.

The procedure described in this step applies to lane groups that consist of an exclusive lane (or lanes) operating in a protected-plus-permitted mode and without pedestrian or bicycle interaction. When these conditions do not hold, the supplemental procedures described in Chapter 31 should be combined with those in this step to compute the adjusted saturation flow rate.

Equation 18-5 is used to compute the adjusted saturation flow rate per lane for the subject lane group:

$$s = s_o \cdot f_w \cdot f_{HV} \cdot f_g \cdot f_p \cdot f_{bb} \cdot f_a \cdot f_{LU} \cdot f_{LT} \cdot f_{RT} \cdot f_{Lpb} \cdot f_{Rpb} \quad \text{Equation 18-5}$$

where

- s = adjusted saturation flow rate (veh/h/ln),
- s_o = base saturation flow rate (pc/h/ln),
- f_w = adjustment factor for lane width,
- f_{HV} = adjustment factor for heavy vehicles in traffic stream,
- f_g = adjustment factor for approach grade,
- f_p = adjustment factor for existence of a parking lane and parking activity adjacent to lane group,
- f_{bb} = adjustment factor for blocking effect of local buses that stop within intersection area,
- f_a = adjustment factor for area type,
- f_{LU} = adjustment factor for lane utilization,
- f_{LT} = adjustment factor for left-turn vehicle presence in a lane group,
- f_{RT} = adjustment factor for right-turn vehicle presence in a lane group,
- f_{Lpb} = pedestrian adjustment factor for left-turn groups, and
- f_{Rpb} = pedestrian–bicycle adjustment factor for right-turn groups.

The adjustment factors in the list above are described in the following subparts.

Base Saturation Flow Rate

Computations begin with selection of a base saturation flow rate. This base rate represents the expected average flow rate for a through-traffic lane having geometric and traffic conditions that correspond to a value of 1.0 for each adjustment factor. Typically, one base rate is selected to represent all signalized

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intersections in the jurisdiction (or area) within which the subject intersection is located. Default values for this rate are provided in Section 3, Applications.

Adjustment for Lane Width

The lane width adjustment factor f_w accounts for the negative impact of narrow lanes on saturation flow rate and allows for an increased flow rate on wide lanes. Values of this factor are listed in Exhibit 18-13.

Exhibit 18-13
Lane Width Adjustment Factor

Average Lane Width (ft)	Adjustment Factor (f_w)
<10.0[a]	0.96
10.0–12.9	1.00
≥13.0	1.04

Note: [a]Factors apply to average lane widths of 8.0 ft or more.

Standard lanes are 12 ft wide. The lane width factor may be used with caution for lane widths greater than 16 ft, or an analysis with two narrow lanes may be conducted. Use of two narrow lanes will always result in a higher saturation flow rate than a single wide lane, but, in either case, the analysis should reflect the way the width is actually used or expected to be used. In no case should this factor be used to estimate the saturation flow rate of a lane group with an average lane width that is less than 8.0 ft.

Adjustment for Heavy Vehicles

The heavy-vehicle adjustment factor f_{hv} accounts for the additional space occupied by heavy vehicles and for the difference in their operating capabilities, compared with passenger cars. This factor does not address local buses that stop in the intersection area. Values of this factor are computed with Equation 18-6.

Equation 18-6

$$f_{hv} = \frac{100}{100 + P_{hv}(E_T - 1)}$$

where

P_{hv} = percent heavy vehicles in the corresponding movement group (%), and

E_T = equivalent number of through cars for each heavy vehicle = 2.0

Adjustment for Grade

The grade adjustment factor f_g accounts for the effects of approach grade on vehicle performance. Values of this factor are computed with Equation 18-7.

Equation 18-7

$$f_g = 1 - \frac{P_g}{200}$$

where P_g is the approach grade for the corresponding movement group (%).

This factor applies to grades ranging from −6.0% to +10.0%. An uphill grade has a positive value and a downhill grade has a negative value.

Adjustment for Parking

The parking adjustment factor f_p accounts for the frictional effect of a parking lane or flow in the lane group adjacent to the parking lane. It also accounts for the occasional blocking of an adjacent lane by vehicles moving in and out of

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parking spaces. If no parking is present, then this factor has a value of 1.00. If parking is present, then the value of this factor is computed with Equation 18-8.

$$f_p = \frac{N - 0.1 - \frac{18N_m}{3{,}600}}{N} \geq 0.050 \qquad \text{Equation 18-8}$$

where

N_m = parking maneuver rate adjacent to lane group (maneuvers/h), and

N = number of lanes in lane group (in).

The parking maneuver rate corresponds to parking areas directly adjacent to the lane group and within 250 ft upstream of the stop line. A practical upper limit of 180 maneuvers/h should be maintained with Equation 18-8. A minimum value of f_p from this equation is 0.050. Each maneuver (either in or out) is assumed to block traffic in the lane next to the parking maneuver for an average of 18 s.

The factor applies only to the lane group that is adjacent to the parking. On a one-way street with a single lane lane group, the number of maneuvers used is the total for both sides of the lane group. On a one-way street with two or more lane groups, the factor is calculated separately for each lane group and is based on the number of maneuvers adjacent to the group. Parking conditions with zero maneuvers have an impact different from that of a no-parking situation.

Adjustment for Bus Blockage

The bus blockage adjustment factor f_{bb} accounts for the impact of local transit buses that stop to discharge or pick up passengers at a near-side or far-side bus stop within 250 ft of the stop line (upstream or downstream). Values of this factor are computed with Equation 18-9.

$$f_{bb} = \frac{N - \frac{14.4N_b}{3{,}600}}{N} \geq 0.050 \qquad \text{Equation 18-9}$$

where N is the number of lanes in lane group (ln) and N_b is the bus stopping rate on the subject approach (buses/h).

This factor should be used only when stopping buses block traffic flow in the subject lane group. A practical upper limit of 250 buses/h should be maintained with Equation 18-9. A minimum value of f_{bb} from this equation is 0.050. The factor used here assumes an average blockage time of 14.4 s during a green indication.

Adjustment for Area Type

The area type adjustment factor f_a accounts for the inefficiency of intersections in CBDs relative to those in other locations. When used, it has a value of 0.90.

Use of this factor should be determined on a case-by-case basis. This factor is not limited to designated CBD areas, nor does it need to be used for all CBD areas. Instead, it should be used in areas where the geometric design and the

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traffic or pedestrian flows, or both, are such that the vehicle headways are significantly increased.

Adjustment for Lane Utilization

The input lane utilization adjustment factor is used to estimate saturation flow rate for a lane group with more than one exclusive lane. If the lane group has one shared lane or one exclusive lane, then this factor is 1.0.

Adjustment for Right Turns

The right-turn adjustment factor f_{RT} is intended primarily to reflect the effect of right-turn path geometry on saturation flow rate. The value of this adjustment factor is computed with Equation 18-10.

Equation 18-10

$$f_{RT} = \frac{1}{E_R}$$

where E_R is the equivalent number of through cars for a protected right-turning vehicle (= 1.18).

If the right-turn movement shares a lane with another movement or has permitted operation, then the procedure described in Chapter 31 should be used to compute the adjusted saturation flow rate for the shared-lane lane group. The effect of pedestrians and bicycles on right-turn saturation flow rate is considered in a separate adjustment factor.

Adjustment for Left Turns

The left-turn adjustment factor f_{LT} is intended primarily to reflect the effect of left-turn path geometry on saturation flow rate. The value of this adjustment factor is computed with Equation 18-11.

Equation 18-11

$$f_{LT} = \frac{1}{E_L}$$

where E_L is the equivalent number of through cars for a protected left-turning vehicle (= 1.05).

If the left-turn movement shares a lane with another movement or has permitted operation, then the procedure described in Chapter 31 should be used to compute the adjusted saturation flow rate for the shared-lane lane group. The effect of pedestrians on left-turn saturation flow rate is considered in a separate adjustment factor.

Adjustment for Pedestrians and Bicycles

The procedure to determine the left-turn pedestrian-bicycle adjustment factor f_{Lpb} and the right-turn pedestrian-bicycle adjustment factor f_{Rpb} is based on the concept of conflict zone occupancy, which accounts for the conflict between turning vehicles, pedestrians, and bicycles. Relevant conflict zone occupancy takes into account whether the opposing vehicle flow is also in conflict with the left-turn movement. The proportion of green time in which the conflict zone is occupied is determined as a function of the relevant occupancy and the number

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of receiving lanes for the turning vehicles. A procedure for computing these factors is provided in Chapter 31.

Step 5: Determine Proportion Arriving During Green

Control delay and queue size at a signalized intersection are highly dependent on the proportion of vehicles that arrive during the green and red signal indications. Delay and queue size are smaller when a larger proportion of vehicles arrive during the green indication. Equation 18-12 is used to compute this proportion for each lane group.

$$P = R_p(g/C) \quad \text{Equation 18-12}$$

All variables are as previously defined. This equation requires knowledge of the effective green time g and cycle length C. These values are known for pretimed operation. If the intersection is not pretimed, then the average phase time and cycle length must be calculated by the procedures described in the next step.

The procedure in Chapter 17 can be used to estimate the arrival flow profile for an intersection approach when this approach is coordinated as part of an urban street segment. The procedure uses the profile to compute the proportion of arrivals during the green indication.

Step 6: Determine Signal Phase Duration

The duration of a signal phase depends on the type of control used at the subject intersection. If the intersection has pretimed control, then the phase duration is an input and this step is skipped. If the phase duration is unknown, then the pretimed phase duration procedure in Section 7 of Chapter 31 can be used to estimate the pretimed phase duration.

If the intersection has actuated control, then the actuated phase duration procedure in Section 7 of Chapter 31 is used in this step to estimate the average duration of an actuated phase. It distinguishes between actuated, uncoordinated, and coordinated phase types.

It is useful at this point to define the various terms that define phase duration. Some terms are specific to actuated operation; however, most constructs are equally applicable to pretimed operation.

The duration of an actuated phase is composed of five time periods. The first period represents the time lost while the queue reacts to the signal indication changing to green. The second interval represents the time required to clear the queue of vehicles. The third period represents the time the green indication is extended by randomly arriving vehicles. It ends when there is a gap in traffic (i.e., gap out) or the green extends to the maximum limit (i.e., max out). The fourth period represents the yellow change interval, and the fifth period represents the red clearance interval. The duration of an actuated phase is defined by Equation 18-13.

$$D_p = l_1 + g_s + g_e + Y + R_c \quad \text{Equation 18-13}$$

where

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D_p = phase duration (s),

l_1 = start-up lost time = 2.0 (s),

g_s = queue service time (s),

g_e = green extension time (s),

$Y + R_c$ = yellow change interval (s), and

R_c = red clearance interval (s).

The relationship between the variables in Equation 18-13 is shown in Exhibit 18-14 by using a queue accumulation polygon.

Exhibit 18-14
Time Intervals Influencing Actuated Phase Duration

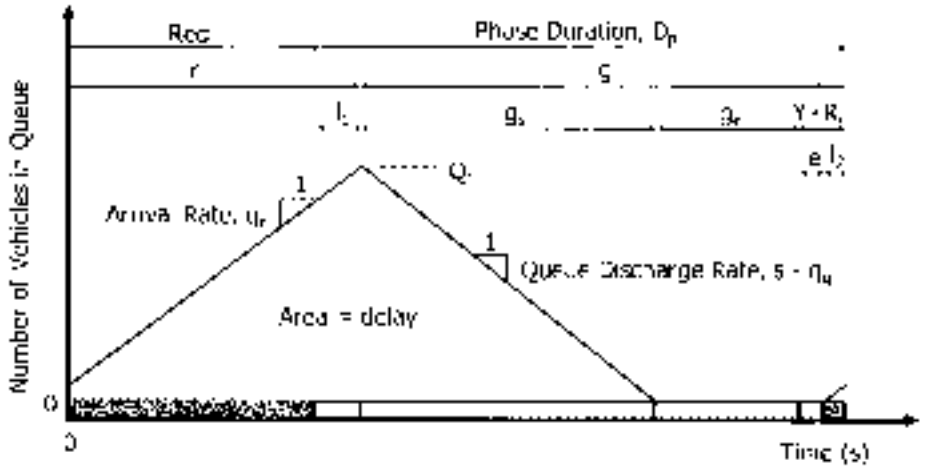

Exhibit 18-14 shows the relationship between phase duration and queue size for the average signal cycle. During the red interval, vehicles arrive at a rate of q_r and form a queue. The queue reaches its maximum size l_2 seconds after the red interval ends. At this time, the queue begins to discharge at a rate equal to the saturation flow rate s less the arrival rate during green q_a. The queue clears g_s seconds after it first begins to discharge. Thereafter, random vehicle arrivals are detected and cause the green interval to be extended. Eventually, a gap occurs in traffic (or the maximum green limit is reached) and the green interval ends. The end of the green interval coincides with the end of the extension time g_e.

The effective green time for the phase is computed with the following equation:

Equation 18-14

$$g = D_p - l_1 - l_2 - g_s + g_e + e \quad (18\text{-}14)$$

where

l_2 = clearance lost time = $Y + R_c - e$ (s),

e = extension of effective green = 2.0 (s), and

all other variables are as previously defined.

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Step 7: Determine Capacity and Volume-to-Capacity Ratio

Lane Group Volume-to-Capacity Ratio

The capacity of a given lane group serving one traffic movement, and for which there are no permitted left-turn movements, is defined by Equation 18-15.

$$c = N\, s \frac{g}{C} \qquad \text{Equation 18-15}$$

where c is the capacity (veh/h) and other variables are as previously defined. This equation cannot be used to calculate the capacity of a shared-lane lane group or a lane group with permitted left-turn operation because these lane groups have other factors that affect their capacity. Chapter 31 provides a procedure for estimating the capacity of these types of lane groups.

The volume-to-capacity ratio for a lane group is defined as the ratio of the lane group volume and its capacity. It is computed using Equation 18-16.

$$X = \frac{v}{c} \qquad \text{Equation 18-16}$$

where

X = volume-to-capacity ratio,
v = demand flow rate (veh/h), and
c = capacity (veh/h).

Critical Intersection Volume to Capacity Ratio

Another concept used for analyzing signalized intersections is the critical volume to capacity ratio X_c. This ratio is computed by using Equation 18-17 with Equation 18-18.

$$X_c = \left(\frac{C}{C - L}\right) \sum_{i \in CI} y_{ci} \qquad \text{Equation 18-17}$$

with

$$L = \sum_{i \in CI} l_{ci} \qquad \text{Equation 18-18}$$

where

X_c = critical intersection volume-to-capacity ratio,
C = cycle length (s),
y_{ci} = critical flow ratio for phase $i = v/(Ns)$,
l_{ci} = phase i lost time = $l_1 + l_2$ (s),
CI = set of critical phases on the critical path, and
L = cycle lost time (s).

The summation term in each of these equations represents the sum of a specific variable for the set of critical phases. A critical phase is one phase of a set of phases that occur in sequence and whose combined flow ratio is the largest for

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the signal cycle. The critical path and critical phases are identified by mapping traffic movements to a dual-ring phase diagram, as shown in Exhibit 18-3.

Equation 18-17 is based on the assumption that each critical phase has the same volume-to-capacity ratio and that this ratio is equal to the critical intersection volume-to-capacity ratio. This assumption is valid when the effective green duration for each critical phase i is proportional to $g_i/(g_i + l_i)$. When this assumption holds, the volume-to-capacity ratio for each noncritical phase is less than or equal to the critical intersection volume-to-capacity ratio.

Identifying Critical Lane Groups and Critical Flow Ratios

Calculation of the critical intersection volume-to-capacity ratio requires identification of the critical phases. This identification begins by mapping all traffic movements to a dual-ring diagram.

Next, the lane group flow ratio is computed for each lane group served by the phase. If a lane group is served only during one protected phase, then its flow ratio is computed as the lane group flow rate (per lane) divided by the lane group saturation flow rate [i.e., $v/(Ns)$]. If a lane group is served during multiple protected phases, then a flow ratio is computed for each phase. Specifically, the demand flow rate and saturation flow rate that occur during a given phase are used to compute the lane group flow ratio for that phase. For actuated phases, the flow ratio is computed only for those lane group and phase combinations in which the group's detectors actively extend the phase.

Next, the phase flow ratio is determined from the flow ratio of each lane group served during the phase. The phase flow ratio represents the largest flow ratio of all lane groups served.

Next, the diagram is evaluated to identify the critical phases. The phases that occur between one barrier pair are collectively evaluated to determine the critical phases. This evaluation begins with the pair in Ring 1 and proceeds to the pair in Ring 2. Each ring represents one possible critical path. The phase flow ratios are added for each phase pair in each ring. The larger of the two ring totals represents the critical path, and the corresponding phases represent the critical phases for the barrier pair.

Finally, the process is repeated for the phases between the other barrier pair. One critical flow rate is defined for each barrier pair by this process. These two values are then added to obtain the sum of the critical flow ratios used in Equation 18-17. The lost time associated with each of the critical phases is added to yield the cycle lost time L.

This procedure for the basic intersection case is explained in the next few paragraphs by using an example intersection. A variation of this procedure applies when protected-permitted left-turn operation is used with pretimed control. This variation is described after the basic case is described.

Basic Case

Consider a pretimed intersection with a lead-lag phase sequence on the major street and a permitted-only sequence on the minor street, as shown in Exhibit 18-15. The curbside right turn is provided an exclusive lane and a

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green arrow indication that displays concurrently with the complementary left-turn phase on the major street. Each of the left-turn movements on the major street is served with a protected phase.

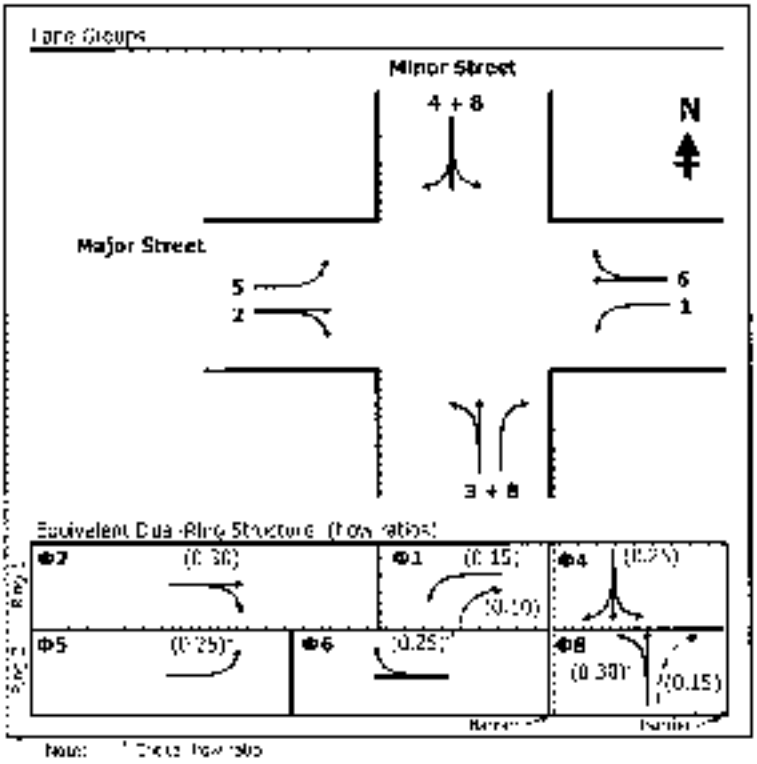

Exhibit 18-15
Critical Path Determination with Protected Left-Turn Phases

Phases 4 and 8 represent the only phases between the barrier pair serving the minor-street movements. Inspection of the flow ratios provided in the exhibit indicates that Phase 8 has two lane-group flow rates. The larger flow rate corresponds to the shared left-turn and through movement. Thus, the phase flow ratio for Phase 8 is 0.30. The phase flow ratio for Phase 4 is 0.25. Of the two phases, the largest phase flow ratio is that associated with Phase 8 (= 0.30), so it represents the critical phase for this barrier pair.

Phases 1, 2, 5, and 6 represent the phases between the other barrier pair. They serve the major-street approaches. A flow ratio is shown for the right-turn lane group in Phase 1 because the intersection has pretimed control. If the intersection was actuated, it is unlikely that the right-turn detection would be used to extend Phase 1, and the flow ratio for the right-turn lane group would not be considered in defining the phase flow rate for Phase 1. Regardless, the phase flow ratio of Phase 1 is 0.15, on the basis of the left-turn lane group flow rate.

There are two possible critical paths through the major-street phase sequence—one path is associated with Phases 1 and 2 (i.e., Ring 1), and the other path is associated with Phases 5 and 6 (i.e., Ring 2). The total phase flow ratio for the Ring 1 path is 0.30 + 0.15, or 0.45. The total phase flow ratio for the Ring 2 path is 0.25 + 0.25 = 0.50. The latter total is larger and, hence, represents the

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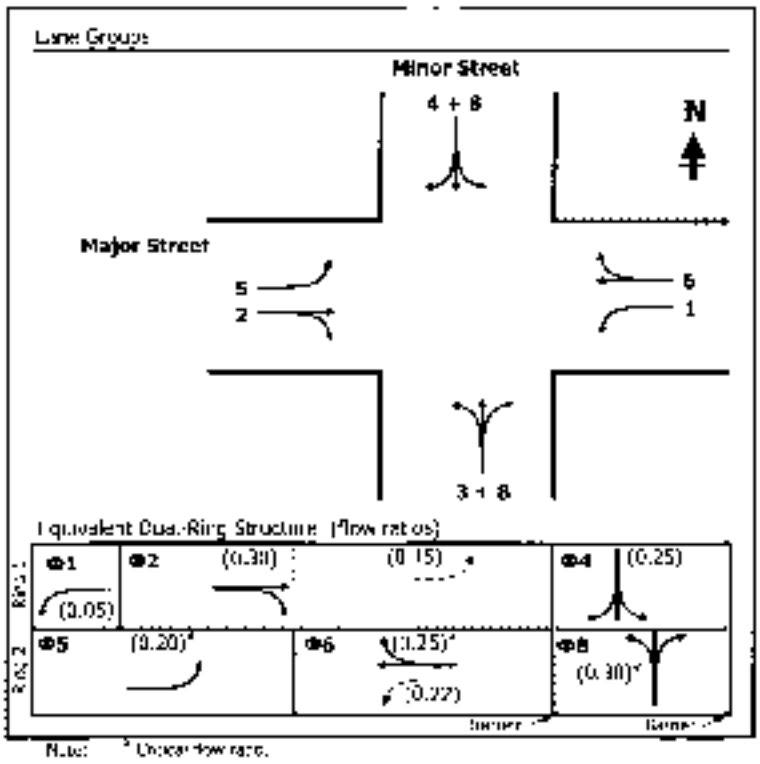
critical path. It identifies Phases 5 and 6 as the critical phases. Thus, the sum of critical flow ratios for the cycle is 0.50 (= 0.30 + 0.50).

One increment of phase lost time l_i is associated with each phase on the critical path. Thus, the cycle lost time L is computed as the sum of the lost time for each of Phases 5, 6, and 8.

Special Case: Prelimed Protected-Permitted Left-Turn Operation

Consider a pretimed intersection with a lead–lead phase sequence on the major street and a permitted-only sequence on the minor street, as shown in Exhibit 18-16. The left-turn movements on the major street operate in the protected-permitted mode. Phases 4 and 8 represent the only phases between one barrier pair. They serve the minor street lane groups. By inspection of the flow ratios provided in the exhibit, Phase 8 has the highest flow ratio (= 0.30) of the two phases and represents the critical phase for this barrier pair.

Exhibit 18-16
Critical Path Determination with Protected-Permitted Left-Turn Operation



Phases 1, 2, 5, and 6 represent the phases between the other barrier pair. They serve the major-street approaches. Each left-turn lane group is shown to be served during two phases—once during the left-turn phase and once during the phase serving the adjacent through movement. The flow ratio for each of the four left-turn service periods is shown in Exhibit 18-16. The following rules define the possible critical paths through this phase sequence:

1. One path is associated with Phases 1 and 2 in Ring 1 (0.35 = 0.05 + 0.30).
2. One path is associated with Phases 5 and 6 in Ring 2 (0.45 = 0.20 + 0.25).

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3. If a lead–lead or lag–lag phase sequence is used, then one path is associated with (a) the left-turn phase with the larger flow ratio and (b) the through phase that permissively serves the same left turn lane group. Sum the protected and permitted left-turn flow ratios on this path (0.35 + 0.20 = 0.15).
4. If a lead–lag phase sequence is used, then one path is associated with (a) the leading left-turn phase, (b) the lagging left-turn phase, and (c) the controlling through phase (see discussion to follow). Sum the two protected left-turn flow ratios and the one controlling permitted left-turn flow ratio on this path.

If a lead–lag phase sequence is used, each of the through phases that permissively serves a left-turn lane group is considered in determining the controlling through phase. If both through phases have a permitted period, then there are two through phases to consider. The controlling through phase is that phase with the larger permitted left turn flow ratio. For example, if Phase 1 were shown to lag Phase 2 in Exhibit 18-15, then Phase 6 would be the controlling through phase because the permitted left-turn flow rate of 0.22 exceeds 0.15. The critical path for this phase sequence would be 0.47 (= 0.20 + 0.22 + 0.05).

The first three rules in the preceding list apply to the example intersection. The calculations are shown for each path in parentheses in the previous list of rules. The total flow ratio for the path in Ring 2 is largest (= 0.45) and, hence, represents the critical path. It identifies Phases 5 and 6 as the critical phases. Thus, the sum of critical flow ratios for the cycle is 0.75 (= 0.30 + 0.45).

If Rule 3 in the preceding list applies, then the only lost time incurred is the start up lost time l_1 associated with the first critical phase and the clearance lost time l_2 associated with the second critical phase. If Rule 1, 2, or 4 applies, then one increment of phase lost time l is associated with each critical phase. Rule 2 applies for the example, so the cycle lost time L is computed as the sum of the lost time for each of Phases 5, 6, and 8.

Two flow ratios are associated with Phase 6 in this example. Both flow ratios are shown possibly to dictate the duration of Phase 6 (this condition does not hold for Phase 2 because of the timing of the left turn phases). This condition is similar to that for the northbound right-turn movement in Phase 1 of Exhibit 18-15 and the treatment is the same. That is, both flow ratios are considered in defining the phase flow ratio for Phase 6.

This example is specific to pre-timed control. If actuated control were used, then it is unlikely that the left-turn detection on the major street would be used to extend the through phases. In this situation, the flow ratio for the permitted left-turn lane group would not be considered in defining the phase flow ratio for the through phases (i.e., only the first two rules in the previous list would apply). In short, the analysis of protected–permitted left-turn operation with actuated control defaults to the basic case previously described.

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Step 6: Determine Delay

The delay calculated in this step represents the average control delay experienced by all vehicles that arrive during the analysis period. It includes any delay incurred by these vehicles that are still in queue after the analysis period ends. The control delay for a given lane group is computed by using Equation 18-19.

Equation 18-19

$$d = d_1 + d_2 + d_3$$

where

d = control delay (s/veh),
d_1 = uniform delay (s/veh),
d_2 = incremental delay (s/veh), and
d_3 = initial queue delay (s/veh).

Concepts

Uniform Delay

Equation 18-20 represents one way to compute delay when arrivals are assumed to be random throughout the cycle. It also assumes one effective green period during the cycle and one saturation flow rate during this period. It is based on the first term of a delay equation presented elsewhere (*1*).

Equation 18-20

$$d_1 = \frac{0.5\,C\,(1 - g/C)^2}{1 - [\min(1, X)\,g/C]}$$

All variables are as previously defined. The delay calculation procedure used in this methodology is consistent with Equation 18-20. However, it removes the aforementioned assumptions to allow more accurate uniform delay estimates for progressed traffic movements, movements with multiple green periods, and movements with multiple saturation flow rates (e.g., protected-permitted turn movements). It is called the "incremental queue accumulation" procedure (*21*, *22*).

The incremental queue accumulation procedure models arrivals and departures as they occur during the average cycle. Specifically, it considers arrival rates and departure rates as they may occur during one or more effective green periods. The rates and resulting queue size can be shown in a queue accumulation polygon, such as that shown previously in Exhibit 18-14. The procedure decomposes the resulting polygon into an equivalent set of trapezoids or triangles for the purpose of delay estimation.

The key criterion for constructing a trapezoid or triangle is that the arrival and departure rates must be effectively constant during the associated time period. This process is illustrated in Exhibit 18-17 for a lane group having two different departure rates during the effective green period.

The delay associated with the cycle is determined by summing the area of the trapezoids or triangles that compose the polygon. The area of a given trapezoid or triangle is determined by first knowing the queue at the start of the

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interval and then adding the number of arrivals and subtracting the number of departures during the specified time interval. The result of this calculation yields the number of vehicles in queue at the end of the interval. Equation 18-21 illustrates this calculation for interval i.

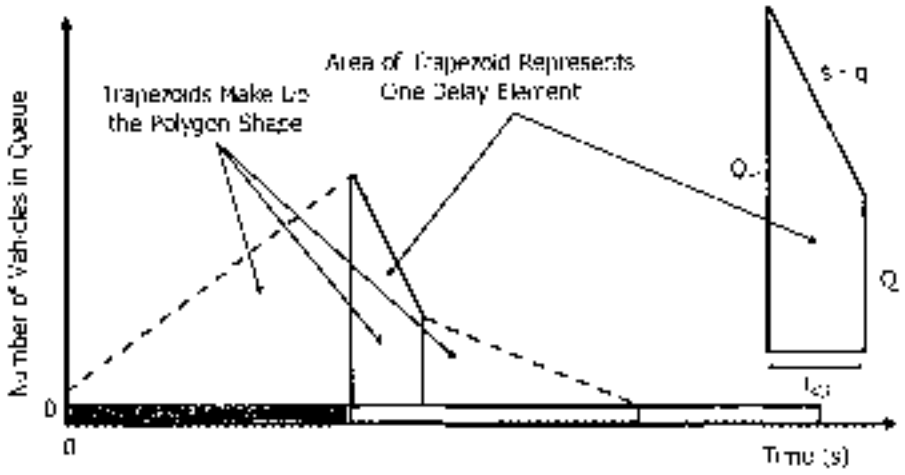

Exhibit 18-17
Decomposition of Queue Accumulation Polygon

$$Q_i = Q_{i-1} + (s/3{,}600 - q/N)\, t_{g,i} \quad \geq 0.0$$

Equation 18-21

where

Q_i = queue size at the end of interval i (veh),

q = arrival flow rate = $v/3{,}600$ (veh/s),

$t_{g,i}$ = duration of time interval i during which the arrival flow rate and saturation flow rate are constant (s), and

all other variables as previously defined.

Construction of the queue accumulation polygon requires converting all flow rate variables to common units of vehicles per second per lane. This conversion is implicit for all flow rate variables shown in exhibits here that depict a queue accumulation polygon.

Equation 18-22 is used to compute the *total* delay associated with a given trapezoid or triangle.

$$d_{t,i} = 0.5\,(Q_{i-1} + Q_i)\, t_{g,i}$$

Equation 18-22

where $d_{t,i}$ is the total delay associated with interval i (veh-s) and other variables are as previously defined. Total delay is computed for all intervals, added together, and the sum divided by the number of arrivals during the cycle ($= qC$) to estimate uniform delay in seconds per vehicle.

Construction of the queue accumulation polygon requires that the arrival flow rate not exceed the phase capacity. If the arrival flow rate exceeds capacity, then it is set to equal the capacity for the purpose of constructing the polygon. The queue can be assumed to equal zero at the end of the protected phase, and the polygon construction process begins at this point in the cycle. Once constructed, this assumption must be checked and, if the ending queue is not

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zero, then a second polygon is constructed with this ending queue as the starting queue for the first interval.

Polygon construction requires identifying points in the cycle where one of the following two conditions applies.

- The departure rate changes (e.g., due to the start or end of effective green, a change in the saturation flow rate, depletion of the subject queue, depletion of the opposing queue, spillback/spillback).
- The arrival rate changes (e.g., when a platoon arrival condition changes).

During the intervals of time between these points, the saturation flow rate and arrival flow rate are constant.

The determination of flow-rate change points may require an iterative calculation process when the approach has shared lanes. For example, an analysis of the opposing through movement must be completed to determine the time this movement's queue clears and the subject left-turn lane group can begin its service period. This service period may, in turn, dictate when the permitted left-turn movements on the opposing approach may depart.

The procedure is based on defining arrival rate as having one of two flow states, an arrival rate during the green indication and an arrival rate during the red indication. Further information about when each of these rates applies is described in the discussion for platoon ratio in the required input data subsection. The proportion of vehicles arriving during the green indication P is used to compute the arrival flow rate during each flow state. The following equations can be used to compute these rates:

Equation 18-23

$$q_g = \frac{q\,P}{g/C}$$

and

Equation 18-24

$$q_r = \frac{q\,(1 - P)}{1 - g/C}$$

where

q_g = arrival flow rate during the effective green time (veh/s),

q_r = arrival flow rate during the effective red time (veh/s), and

all other variables as previously defined.

A more detailed description of the procedure for constructing a queue accumulation polygon for lane groups with various lane allocations and operating modes is provided in Chapter 31.

Incremental Delay

Incremental delay consists of two delay components. One component accounts for delay due to the effect of random, cycle-by-cycle fluctuations in demand that occasionally exceed capacity. This delay is evidenced by the occasional overflow queue at the end of the green interval (i.e., cycle failure). The second component accounts for delay due to a sustained oversaturation during

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the analysis period. This delay occurs when aggregate demand during the analysis period exceeds aggregate capacity. It is sometimes referred to as the "deterministic" delay component and is shown as variable d_{D1} in Exhibit 18-18.

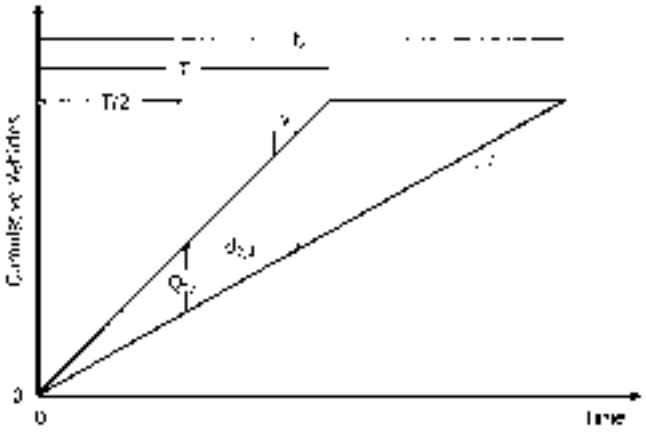

Exhibit 18-18
Cumulative Arrivals and Departures During an Oversaturated Analysis Period

Exhibit 18-18 illustrates the queue growth that occurs as vehicles arrive at a demand flow rate of v during analysis period T, which has capacity c. The deterministic delay component is represented by the triangular area bounded by the thick line and is associated with an average delay per vehicle represented by the variable d_{D1}. The last vehicle to arrive during the analysis period is shown to clear the queue t_f hours after the start of the analysis period. The average queue size associated with this delay is also shown in the exhibit as Q_{D1}. The queue present at the end of the analysis period [T ($v - c$)] is referred to as the *residual queue*.

Initial Queue Delay

The equation used to estimate incremental delay is based on the assumption that no initial queue is present at the start of the analysis period. The initial queue delay term accounts for the additional delay incurred due to an initial queue. This queue is a result of unmet demand in the previous time period. It does not include any vehicles that may be in queue due to random, cycle-by-cycle fluctuations in demand that occasionally exceed capacity. When a multiple-period analysis is undertaken, the initial queue for the second and subsequent analysis periods is equal to the residual queue from the previous analysis period.

Exhibit 18-19 illustrates the delay due to an initial queue as a trapezoid shape bounded by thick lines. The average delay per vehicle is represented by the variable d_2. The initial queue size is shown as Q_b vehicles. The duration of time during the analysis period for which the effect of the initial queue is still present is represented by the variable t. This duration is shown to equal the analysis period in Exhibit 18-19. However, it can be less than the analysis period duration for some lower-volume conditions.

Exhibit 18-19 illustrates the case in which the demand flow rate v exceeds the capacity c during the analysis period. In contrast, Exhibit 18-20 and Exhibit 18-21 illustrate alternative cases in which the demand flow rate is less than the capacity.

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Exhibit 18-19
Initial Queue Delay with Increasing Queue Size

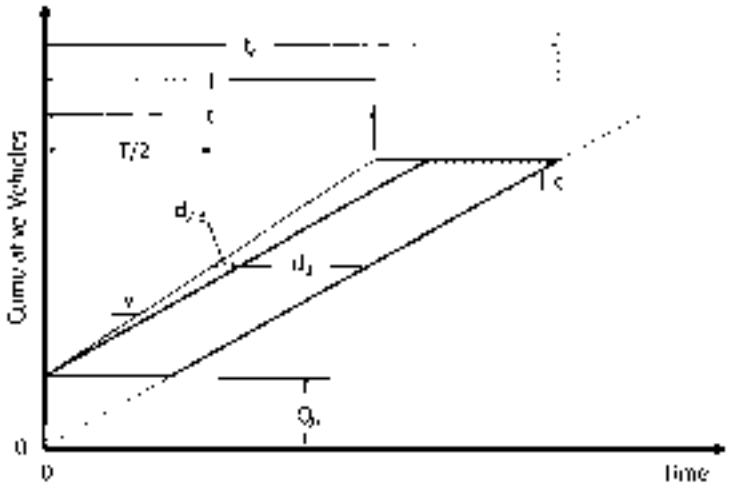


Exhibit 18-20
Initial Queue Delay with Decreasing Queue Size

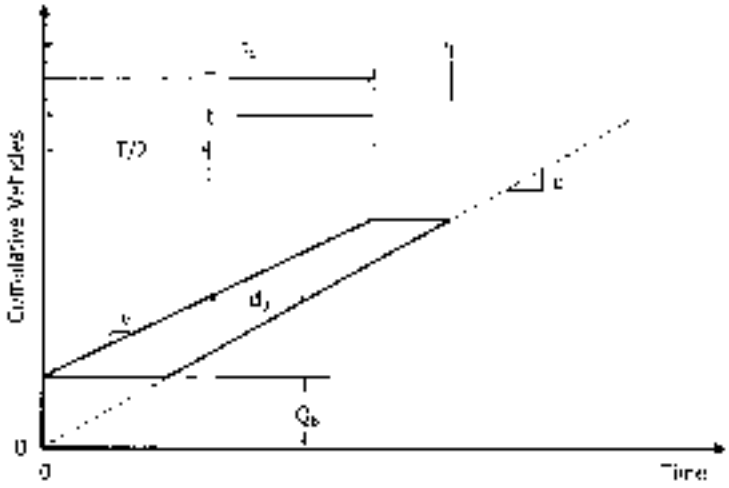
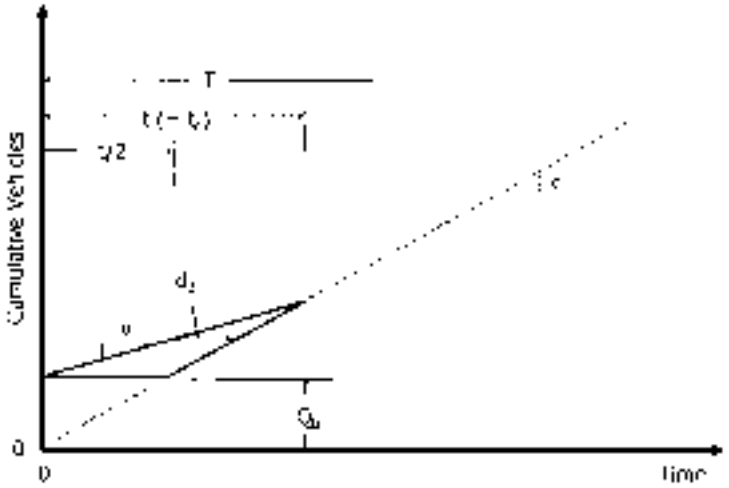


Exhibit 18-21
Initial Queue Delay with Queue Clearing



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In this chapter, the phrase *initial queue* is always used as reference to the initial queue due to unmet demand in the previous time period. It never refers to vehicles in queue due to random, cycle by cycle fluctuations in demand.

The remainder of this step describes the procedure for computing the control delay for a lane group during a given analysis period. Chapter 31 describes a technique for measuring control delay in the field.

A. Compute Baseline Uniform Delay

Exhibit 18-14 was previously provided to illustrate a simple polygon for a lane group serving one traffic movement and for which there are no permitted or protected-permitted left-turn movements. Exhibit 18-22 is provided to illustrate delay calculation for a more complicated polygon shape. This particular polygon describes permitted left-turn operation from a shared lane for a specific combination of timing and volume conditions.

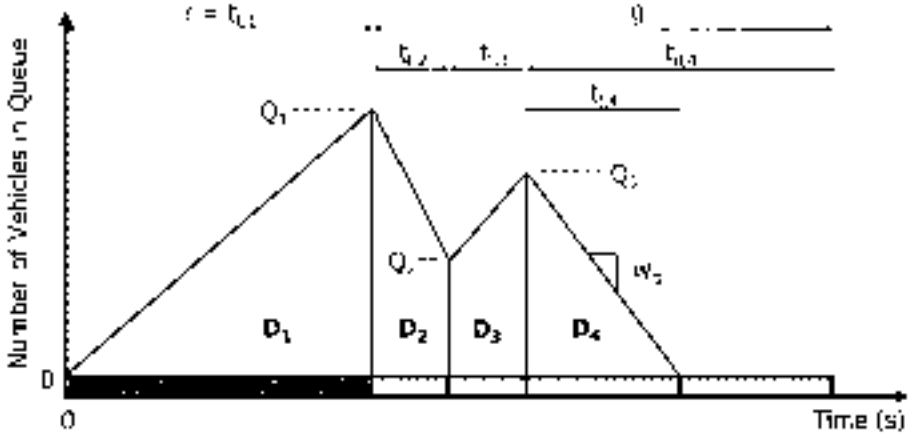

Exhibit 18-22
Polygon for Uniform Delay Calculation

The area bounded by the polygon represents the total delay incurred during the average cycle. The total delay is then divided by the number of arrivals per cycle to estimate the average uniform delay. These calculations are summarized in Equation 18-25, with Equation 18-26.

$$d_{u1} = \frac{0.5\sum_{i} (Q_{i-1} + Q_i) t_{r,i}}{q C} \qquad \text{Equation 18-25}$$

with

$$t_{r,i} = \min(t_{a,i}, Q_{i-1}/w_{2,i}) \qquad \text{Equation 18-26}$$

where

d_{u1} = baseline uniform delay (s/veh),

$t_{r,i}$ = duration of trapezoid or triangle in interval i (s),

$w_{2,i}$ = queue discharge rate (i.e., slope of the upper boundary of the trapezoid or triangle) (veh/s), and

all other variables as previously defined.

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The summation term in Equation 18-25 includes all intervals for which there is a nonzero queue. In general, t_i will equal the duration of the corresponding interval. However, during some intervals, the queue was dissipated and t_i will only be as long as the time required for the queue to dissipate ($= Q_i / \mu_i$). This condition is shown to occur during Time Interval 4 in Exhibit 18-22.

The delay computed in this step is referred to as the *baseline uniform delay*. It may be adjusted in Step C1 if there is an initial queue that dissipates during the analysis period. The uniform delay to be used in Equation 18-19 is determined in this subsequent step.

B. Initial Queue Analysis

If an initial queue is present for any lane group at the intersection, then a second set of polygons needs to be constructed for each intersection lane group (in addition to those constructed for Step A). If no lane group has an initial queue, then this step is skipped.

At the start of this step, the initial queue that was input for each movement group needs to be converted to an initial queue for each lane group. When there is a one-to-one correlation between the movement group and the lane group, then the initial queue for the lane group equals the input initial queue for the movement group. When there is a shared lane on an approach that has another shared lane or additional through lanes, then the input initial queue needs to be distributed among the lane groups that serve the movements sharing the lane. Specifically, the initial queue for each lane group is estimated as being equal to the input initial queue multiplied by the number of lanes in the lane group and divided by the total number of shared and through lanes.

When the polygons are constructed in this step, lane groups with an initial queue will have their arrival flow rate set to equal the lane group capacity, regardless of their input arrival rate. The remaining lane groups will have their arrival flow rate set to equal the smaller of the input demand flow rate or the capacity. One polygon is constructed for each lane group, regardless of whether it has an initial queue.

The need for a second set of polygons stems from the influence one lane group often has on the operation of other lane groups. This influence is notably adverse when one or more lane groups are operating in a saturated state for a portion of the analysis period. If the saturated lane group represents a conflicting movement to a lane group that includes a permitted left-turn operation, then the left-turn lane group's operation will also be adversely affected for the same time period. Moreover, if the phase serving the lane group is actuated, then its capacity during the saturated state will be different from that of the subsequent unsaturated state. The following procedure is used to address this situation.

The duration of unmet demand is calculated in this step for each lane group with Equation 18-27 or Equation 18-28.

If $x \geq 1$, then

Equation 18-27

$$t_d = T$$

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If $v < c$, then

$$t = Q_0 / (c - v) < T \quad \text{Equation 18-28}$$

where

t = duration of unmet demand in the analysis period (h),
T = analysis period duration (h),
Q_0 = initial queue at the start of the analysis period (veh),
v = demand flow rate (veh/h), and
c = saturated capacity (veh/h).

For this calculation, the saturated capacity c is equal to that obtained from the polygon constructed in this step and is reflective of the phase duration that is associated with saturated operation (due to the initial queue).

Next, the average duration of unmet demand is calculated with Equation 18-29.

$$t_a = \frac{1}{N_v} \sum_{N_v} t \quad \text{Equation 18-29}$$

where

t_a = average duration of unmet demand in the analysis period (h), and
N_v = number of lane groups for which t exceeds 0.0 h.

The summation term in Equation 18-29 represents the sum of the t values for only those lane groups that have a value of t that exceeds 0.0 h. The average duration t_a is considered as a single representative value of t for all lane groups that do not have an initial queue.

The procedure described in Step A is repeated in this step to estimate the saturated uniform delay d_1 for each lane group.

C. Compute Uniform Delay

If no lane group has an initial queue, then the uniform delay is equal to that computed in Step A (i.e., $d_1 = d_{1,1}$). If an initial queue is present in any lane group at the intersection, then Equation 18-30 or Equation 18-31 is used to compute the uniform delay for each lane group.

If lane group i has an initial queue, then

$$d_1 = d_{1,1} \frac{t_a}{T} + d_{1,1} \frac{(T - t_a)}{T} \quad \text{Equation 18-30}$$

If lane group i does not have an initial queue, then

$$d_1 = d_{1,1} \frac{t_a}{T} + d_{1,1} \frac{(T - t_a)}{T} \quad \text{Equation 18-31}$$

where d_1 is the saturated uniform delay (s/veh), t is the duration of unmet demand for lane group i in the analysis period (h), and other variables are as previously defined.

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D. Compute Average Capacity

If no lane group has an initial queue, then the average lane group capacity c_A is equal to that computed in Step 7 (i.e., $c_A = c$). If an initial queue is present for any lane group at the intersection, then Equation 18-32 and Equation 18-33 are used to compute the average capacity for each lane group.

If lane group i has an initial queue, then

Equation 18-32

$$c_{A,i} = c_{i,1}\frac{t_1}{T} + c_i\frac{(T - t_1)}{T}$$

If lane group i does not have an initial queue, then

Equation 18-33

$$c_{A,i} = c_{i,1}\frac{t_1}{T} + c_i\frac{(T - t_1)}{T}$$

where c_i is the average capacity (veh/h) and other variables are as previously defined.

E. Compute Initial Queue Delay

If no lane group has an initial queue, then the initial queue delay d_1 is equal to 0.0 s/veh. If an initial queue is present for any lane group at the intersection, then Equation 18-34 through Equation 18-39 are used to compute the initial queue delay for each lane group.

Equation 18-34

$$d_1 = \frac{3{,}600}{vT}\left[t_A Q_1 + Q_2\frac{Q_{e2}}{2} - \frac{Q_1^2 - Q_{e1}^2}{2c_{i,1}} - \frac{Q_{e2}^2}{2c_{i,1}}\right]$$

with

Equation 18-35

$$Q_{e1} = Q_b - t_A(v - c_{i,1})$$

If $v \geq c_{i,1}$, then

Equation 18-36

$$Q_{e2} = T(v - c_{i,1})$$

Equation 18-37

$$t_A = T$$

If $v < c_{i,1}$, then

Equation 18-38

$$Q_{e2} = 0.0 \text{ veh}$$

Equation 18-39

$$t_A = Q_b/(c_{i,1} - v) \quad < T$$

where

t_A = adjusted duration of unmet demand in the analysis period (h),

Q_1 = queue at the end of the analysis period (veh),

Q_{e2} = queue at the end of the analysis period when $v \geq c_{i,1}$ and $Q_{e2} = 0.0$ (veh), and

other variables as previously defined.

The last vehicle that arrives to an overflow queue during the analysis period will clear the intersection at the time obtained with the following equations.

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$$t_c = t_0 + Q_b / c_a$$ **Equation 18-40**

where t_c is the queue clearing time (h) and other variables are as previously defined.

The queue clearing time is measured from the start of the analysis period to the time the last arriving vehicle clears the intersection.

F. Compute Incremental Delay Factor

The equation for computing incremental delay includes a variable that accounts for the effect of controller type on delay. This variable is referred to as the incremental delay factor *k*. It varies in value from 0.04 to 0.50. A factor value of 0.50 is recommended for pretimed phases, coordinated phases, and phases set to "recall-to-maximum."

An actuated phase has the ability to adapt its green interval duration to serve the demand on a cycle-by-cycle basis and, thereby, to minimize the frequency of cycle failure. Only when the green is extended to its maximum time is this capability curtailed. This influence of actuated operation on delay is accounted for in Equation 18-41 through Equation 18-44.

$$k = (1 - 2k_{opt})(v/c_1 - 1.5) + k_{opt} \quad \leq 0.50$$ **Equation 18-41**

with

$$k_{opt} = 0.375 - 0.354\,PT \quad (0.0910\,PT^2 - 0.00889\,PT^3) \quad > 0.04$$ **Equation 18-42**

$$c_a = 3{,}600\,\frac{g_e \cdot s/N}{C}$$ **Equation 18-43**

$$g_e = G_{max} - Y - R_c - I_1 - I_2$$ **Equation 18-44**

where

k = incremental delay factor,

c_a = available capacity for a lane group served by an actuated phase (veh/h),

k_{opt} = optimum incremental delay factor, and

g_e = available effective green time (s).

All other variables are as previously defined. As indicated by this series of equations, the factor value depends on the maximum green setting and the passage time setting for the phase that controls the subject lane group. Research indicates that shorter passage times result in a lower value of *k* (and lower delay), provided that the passage time is not so short that the phase terminates before the queue is served (*17*).

G. Compute Incremental Delay

The incremental delay term accounts for delay due to random variation in the number of arrivals on a cycle by cycle basis. It also accounts for delay caused by demand exceeding capacity during the analysis period. The amount by which demand exceeds capacity during the analysis period is referred to here as unmet demand. The incremental delay equation was derived by using an assumption of

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no initial queue due to unmet demand in the preceding analysis period. Equation 18-45, with Equation 18-46, is used to compute incremental delay.

Equation 18-45

$$d_2 = 900\,T\left[(X_A - 1) + \sqrt{(X_A - 1)^2 + \frac{8\,k\,I\,X_A}{c_A T}}\right]$$

with

Equation 18-46

$$X_A = v/c_A$$

where X_A is the average volume-to-capacity ratio and other variables are as previously defined. The incremental delay term is valid for all values of X_A, including highly oversaturated lane groups.

H. Compute Lane Group Control Delay

The uniform delay, incremental delay, and initial queue delay values computed in the previous steps are added (see Equation 18-19) to estimate the control delay for the subject lane group.

I. Compute Aggregated Delay Estimates

It is often desirable to compute the average control delay for the intersection approach. This aggregated delay represents a weighted average delay, where each lane group delay is weighted by the lane group demand flow rate. The approach control delay is computed with Equation 18-47.

Equation 18-47

$$d_A = \frac{\sum_{i=1}^{m_A} d_i v_i}{\sum_{i=1}^{m_A} v_i}$$

where

d_A = approach control delay for approach j (s/veh),

d_i = control delay for lane group i (s/veh), and

m_A = number of lane groups on approach j.

All other variables are as previously defined. The summation terms in Equation 18-47 represent the sum over all lane groups on the subject approach.

Similarly, intersection control delay is computed with Equation 18-48.

Equation 18-48

$$d_I = \frac{\sum d_i v_i}{\sum v_i}$$

where d_I is the intersection control delay (s/veh) and all other variables are as previously defined. The summation terms in Equation 18-48 represent the sum over all lane groups at the subject intersection.

Step 9: Determine LOS

Exhibit 18-4 is used to determine the LOS for each lane group, each approach, and the intersection as a whole. LOS is an indication of the

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acceptability of delay levels to motorists at the intersection. It can also indicate an unacceptable oversaturated operation for individual lane groups.

Step 10. Determine Queue Storage Ratio

A procedure is described in Chapter 31 for estimating the back-of-queue size and the queue storage ratio. The back of queue is the position of the vehicle stopped farthest from the stop line during the cycle as a consequence of the display of a red signal indication. The back of queue size depends on the arrival pattern of vehicles and on the number of vehicles that do not clear the intersection during the previous cycle.

The queue storage ratio represents the proportion of the available queue storage distance that is occupied at the point in the cycle when the back-of-queue position is reached. If this ratio exceeds 1.0, then the storage space will overflow and queued vehicles may block other vehicles from moving forward.

Extension to Multiple Time Periods

The 10-step sequence can be extended to analysis of consecutive time periods, each of duration T, and each having a fixed demand flow rate. The analysis is performed for each analysis period in sequence, as they occur in time. The initial queue Q_1 for the second and subsequent periods is equal to the final queue Q_2 from the previous period.

Typically, a multiple-time-period analysis would start with an undersaturated time period, desirably one when there is no initial queue for any intersection movement group. The demand flow rate for each period is a required input.

Interpretation of Results

The computations discussed in the previous steps result in the estimation of control delay and LOS for each lane group, for each approach, and for the intersection as a whole. They also produce a volume-to-capacity ratio for each lane group and a critical intersection volume-to-capacity ratio. This part provides some useful interpretations of these performance measures.

Level of Service

In general, LOS is an indication of the *general* acceptability of delay to drivers. In this regard, it should be remembered that what might be acceptable in a large city is not necessarily acceptable in a smaller city or rural area.

Intersection LOS must be interpreted with caution. It can suggest acceptable operation of the intersection when in reality certain lane groups (particularly those with lower volumes) are operating at an unacceptable LOS but are masked at the intersection level by the acceptable performance of higher volume lane groups. The analyst should always verify that each lane group is providing acceptable operation and consider reporting the LOS for the poorest-performing lane group as a means of providing context to the interpretation of intersection LOS.

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Volume-to-Capacity Ratio

In general, a volume-to-capacity ratio greater than 1.0 is an indication of actual or potential breakdown. In such cases, a multiple-period analysis is necessary for this condition. This analysis would encompass all consecutive periods in which a residual queue is present.

The critical intersection volume-to-capacity ratio from Equation 18-17 is useful in evaluating the intersection from a capacity-only perspective. It is possible to have a critical intersection volume-to-capacity ratio of less than 1.0 and still have individual movements oversaturated within the signal cycle. If this situation occurs, then the cycle time is generally not appropriately balanced among the phases. Reallocation of the cycle time should be considered, where additional time is given to the phases serving those lane groups with a volume-to-capacity ratio greater than 1.0.

A critical intersection volume-to-capacity ratio greater than 1.0 indicates that the overall signal timing and geometric design provide inadequate capacity for the given demand flows. Improvements that might be considered include the following:

- Basic changes in intersection geometry (i.e., change in the number or use of lanes),
- Increase in signal cycle length, if it is determined to be too short, and
- Changes in signal phase sequence or timing.

Local guidelines should always be consulted before potential improvements are developed.

Fully actuated control is intended to allocate cycle time dynamically to movements on the basis of demand and, thereby, maintain efficient operation on a cycle-by-cycle basis. The critical intersection volume-to-capacity ratio can provide an indication of this efficiency. In general, this ratio will vary between 0.85 and 0.95 for most actuated intersections, with lower values in this range more common for intersections having multiple detectors in the through traffic lanes. A ratio less than 0.85 may be an indication of excessive green extension by random arrivals, and the analyst may consider reducing passage time, minimum green, or both. A ratio that is more than 0.95 may be an indication of frequent phase termination by maximum and limited ability of the controller to reallocate cycle time dynamically on the basis of detected demand. Increasing the maximum green may improve operation in some instances; however, it may also degrade operation when phase flow rates vary widely (because green extension is based on total flow rate served by the phase, not flow rate per lane).

For semi-actuated and coordinated actuated control, the critical intersection volume-to-capacity ratio can vary widely because of the non-actuated nature of some phases. The duration of these phases may not be directly related to their associated demand; instead, it may be dictated by coordination timing or the demand for the other phases. A critical intersection volume-to-capacity ratio that exceeds 0.95 has the same interpretation as offered previously for fully actuated control.

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The critical intersection volume-to-capacity ratio can be misleading when it is used to evaluate the overall sufficiency of the intersection geometry, as is often required in planning applications. The problem is that low flow rates dictate the need for short cycle lengths to minimize delay. Yet, equation 18-17 indicates that the desired shorter cycle length produces a higher volume to capacity ratio. Therefore, a relatively large value of X_c (provided that it is less than 1.0) is not a cause for an indication of poor operation. Rather, it means that closer attention must be paid to the adequacy of phase duration and queue size, especially for the critical phases.

Volume-to-Capacity Ratio and Delay Combinations

In some cases, delay is high even when the volume-to-capacity ratio is low. In these situations, poor progression, a notably long cycle length, or an inefficient phase plan is generally the cause. When the intersection is part of a coordinated system, the cycle length is determined by system considerations, and alterations at individual intersections may not be practical.

It is possible that delay is at acceptable levels even when the volume-to-capacity ratio is high. This situation can occur when some combination of the following conditions exists: the cycle length is relatively short, the analysis period is short, the lane group capacity is high, and there is no initial queue. If a residual queue is created in this scenario, then the conduct of a multiple period analysis is necessary to gain a true picture of the delay.

When both delay levels and volume-to-capacity ratios are unacceptably high, the situation is critical. In such situations, the delay may increase rapidly with small changes in demand. The full range of potential geometric and signal design changes should be considered in the search for improvements.

In summary, unacceptable delay can exist when capacity is a problem as well as when capacity is adequate. Further, acceptable delay levels do not automatically ensure that capacity is sufficient. Delay and capacity are complex variables that are influenced by a wide range of traffic, roadway, and signalization conditions. The methodology presented here can be used to estimate these performance measures, identify possible problems, and assist in developing alternative improvements.

PEDESTRIAN MODE

This subsection describes the methodology for evaluating the performance of a signalized intersection in terms of its service to pedestrians.

Intersection performance is separately evaluated for each crosswalk and intersection corner with this methodology. *Unless otherwise stated, all variables identified in this subsection are specific to one crosswalk and one corner.* A crosswalk is assumed to exist across each intersection leg, unless crossing is specifically prohibited by local ordinance (and signed as this effect).

The methodology is focused on the analysis of signalized intersection performance. Chapter 17, Urban Street Segments, and Chapter 19, Two-Way Stop-Controlled Intersections, describe methodologies for evaluating the performance of these system elements with respect to the pedestrian mode.

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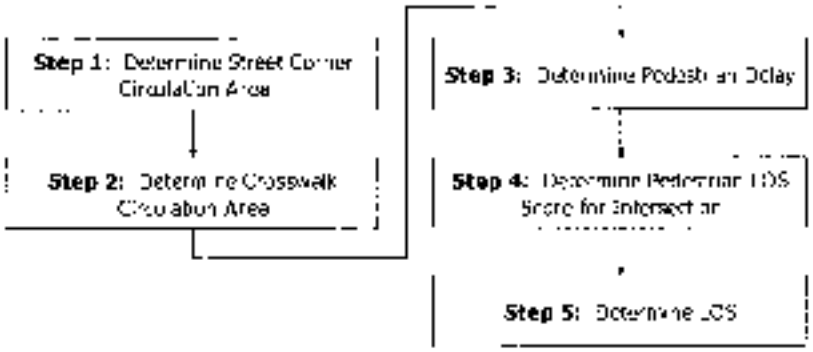
The pedestrian methodology is applied through a series of five steps that determine the pedestrian LOS for a crosswalk and associated corners. These steps are illustrated in Exhibit 18-23.

Exhibit 18-23
Pedestrian Methodology for Signalized Intersections



Concepts

Performance Measures

The methodology provides a variety of measures for evaluating intersection performance in terms of its service to pedestrians. Each measure describes a different aspect of the pedestrian trip through the intersection. Performance measures that are estimated include the following:

- Corner circulation area,
- Crosswalk circulation area,
- Pedestrian delay, and
- Pedestrian LOS score.

The first two performance measures listed are based on the concept of "circulation area." One measure is used to evaluate the circulation area provided to pedestrians while they wait at the corner. Another measure is used to evaluate the area provided while the pedestrian is crossing in the crosswalk. Circulation area describes the space available to the average pedestrian. A larger area is more desirable from the pedestrian perspective. Exhibit 18-24 can be used to evaluate intersection performance from a circulation-area perspective.

Exhibit 18-24
Qualitative Description of Pedestrian Space

Pedestrian Space (ft^2/p)	Description
>60	Ability to move in desired path, no need to alter movements
>40–60	Occasional need to adjust path to avoid conflicts
>24–40	Frequent need to adjust path to avoid conflicts
>15–24	Speed and ability to pass slower pedestrians restricted
>8–15	Speed restricted, very limited ability to pass slower pedestrians
≤8	Speed severely restricted, frequent contact with other users

Pedestrian delay represents the average time a pedestrian waits for a legal opportunity to cross an intersection leg. The LOS score is an indication of the typical pedestrian's perception of the overall crossing experience.

Flow Conditions

Exhibit 18-25 and Exhibit 18-26 show the variables considered when one corner and its two crosswalks are evaluated. Two flow conditions are illustrated.

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Condition 1 corresponds to the minor-street crossing that occurs during the major-street through phase. The pedestrians who desire to cross the major street must wait at the corner. Condition 2 corresponds to the major-street crossing that occurs during the minor street through phase. For this condition, the pedestrians who desire to cross the minor street wait at the corner.

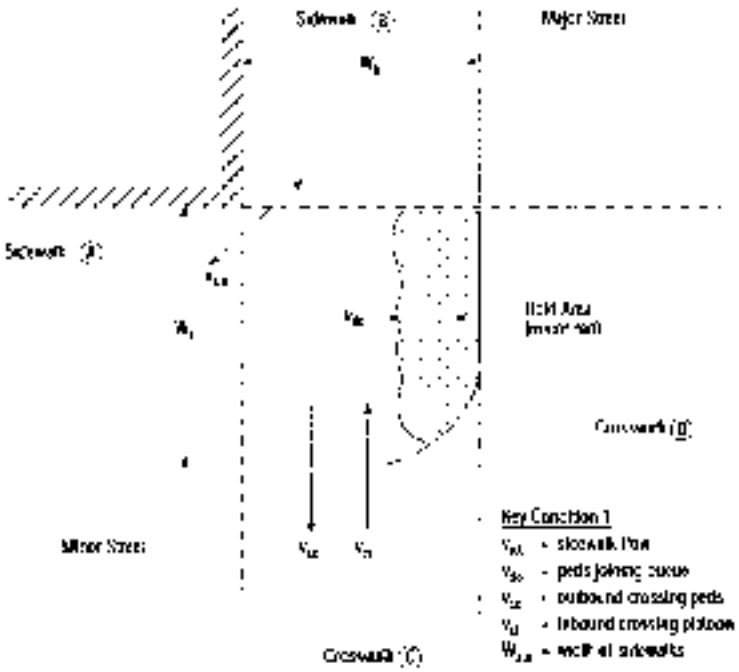

Exhibit 18-25
Condition 1: Minor Street Crossing

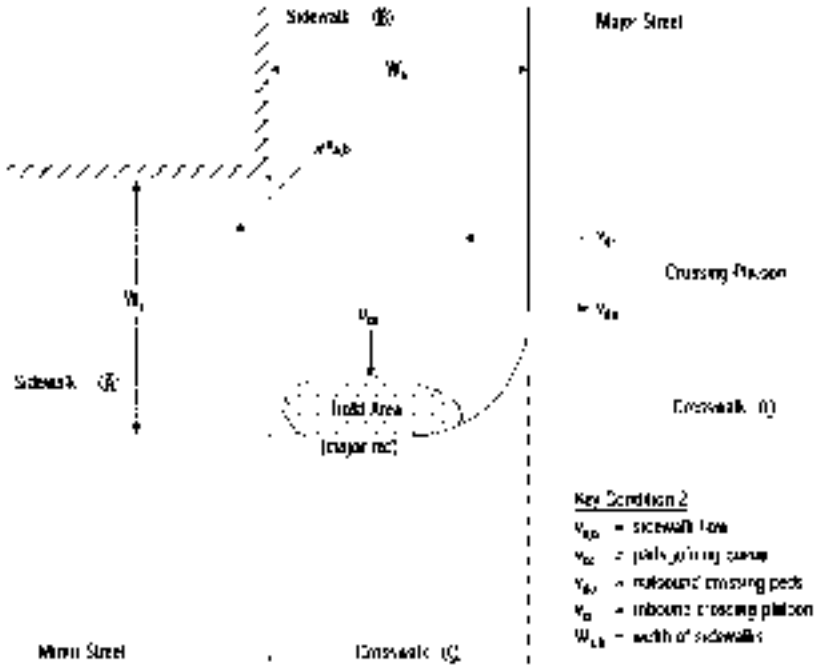

Exhibit 18-26
Condition 2: Major-Street Crossing

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Effective Walk Time

Research indicates that, at intersections with pedestrian signal heads, pedestrians typically continue to enter the intersection during the first few seconds of the pedestrian clear interval (26, 28). This behavior effectively increases the effective walk time available to pedestrians. A conservative estimate of this additional walk time is 4.0 s (26). A maximum value for this additional time implies that some pedestrians are initiating their crossing during the flashing DON'T WALK indication.

The following guidance is provided to estimate the effective walk time on the basis of the above-mentioned research findings. If the phase providing service to the pedestrians is either (a) actuated with a pedestrian signal head and rest-in-walk *not* enabled or (b) pretimed with a pedestrian signal head, then

Equation 18-49

$$g_{ped} = Walk + 4.0$$

If the phase providing service to the pedestrians is actuated with a pedestrian signal head and rest-in-walk enabled, then

Equation 18-50

$$g_{ped} = D_p - Y - R_c - PC - 4.0$$

Otherwise (i.e., no pedestrian signal head)

Equation 18-51

$$g_{ped} = D_p - Y - R_c$$

where

g_{ped} = effective walk time (s),
$Walk$ = pedestrian walk setting (s),
PC = pedestrian clear setting (s),
D_p = phase duration (s),
Y = yellow change interval (s), and
R_c = red clearance interval (s).

The above-mentioned research indicates that the effective walk time estimated with Equation 18-49 or Equation 18-50 can vary widely among intersections. At a given intersection, the additional walk time can vary from 0.0 s to an amount equal to the pedestrian clear interval. The amount of additional walk time used by pedestrians depends on many factors, including the extent of pedestrian delay, vehicular volume, level of enforcement, and presence of countdown pedestrian signal heads.

The effective walk time estimated with Equation 18-49 or Equation 18-50 is considered to be directly applicable to design or planning analyses because it is conservative in the amount of additional walk time that it includes. A larger value of effective walk time may be applicable to an operational analysis if (a) field observation or experience indicates such a value would be consistent with actual pedestrian use of the flashing DON'T WALK indication; (b) an accurate estimate of pedestrian delay or queue size is desired; and (c) the predicted performance estimates are understood to reflect some illegal pedestrian behavior, possibly in response to constrained spaces or inadequate signal timing.

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Step 1: Determine Street Corner Circulation Area

This step describes a procedure for evaluating the performance of one intersection corner. It is repeated for each intersection corner of interest.

The analysis of circulation area at the street corners and in the crosswalks compares available time and space with pedestrian demand. The product of time and space is the critical parameter. It combines the constraints of physical design (which limits available space) and signal operation (which limits available time). This parameter is hereafter referred to as "time–space."

A. Compute Available Time–Space

The total time–space available for circulation and queuing in the intersection corner equals the product of the net corner area and the cycle length C. Equation 18-52 is used to compute time–space available at an intersection corner. Exhibit 18-10 identifies the variables used in the equation.

$$TS_{corner} = C\,(W_a W_b - 0.215\,R^2) \qquad \text{Equation 18-52}$$

where

TS_{corner} = available corner time–space (ft-s),

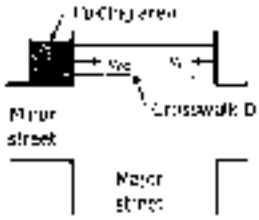
C = cycle length (s),

W_a = total walkway width of Sidewalk A (ft),

W_b = total walkway width of Sidewalk B (ft), and

R = radius of corner curb (ft).

If the corner curb radius is larger than either W_a or W_b, then the variable R in Equation 18-52 should equal the smaller of W_a or W_b.



B. Compute Holding-Area Waiting Time

The average pedestrian holding time represents the average time that pedestrians wait to cross the street when departing from the subject corner. The equation for computing this time is based on the assumption that pedestrian arrivals are uniformly distributed during the cycle. For Condition 1, as shown in Exhibit 18-23, Equation 18-53 and Equation 18-54 are used to compute holding-area time for pedestrians waiting to cross the major street.

$$Q_{p2} = \frac{N_{ped}\,(C - g_{walk,ped})^2}{2C} \qquad \text{Equation 18-53}$$

with

$$N_{ped} = \frac{v_{ped}}{3{,}600}\,C \qquad \text{Equation 18-54}$$

where

Q_{p2} = total time spent by pedestrians waiting to cross the major street during one cycle (p-s),

N_{ped} = number of pedestrians arriving at the corner each cycle to cross the major street (p),

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$g_{walk,ae}$ = effective walk time for the phase serving the minor street through movement (s),

C = cycle length (s), and

v_{ci} = flow rate of pedestrians arriving at the corner to cross the major street (p/h).

If the phase providing service to the pedestrians is either (*a*) actuated with a pedestrian signal head and rest-in-walk *not* enabled or (*b*) pretimed with a pedestrian signal head, then

Equation 18-55

$$g_{walk,ae} = Walk_{ae} + 4.0$$

If the phase providing service to the pedestrians is actuated with a pedestrian signal head and rest-in-walk enabled, then

Equation 18-56

$$g_{walk,ae} = D_{p,ae} - Y_{ae} - R_{c,ae} - PC_{ae} - 4.0$$

Otherwise (i.e., no pedestrian signal head)

Equation 18-57

$$g_{walk,ae} = D_{p,ae} - Y_{ae} - R_{c,ae}$$

where

$g_{walk,ae}$ = effective walk time for the phase serving the minor-street through movement (s),

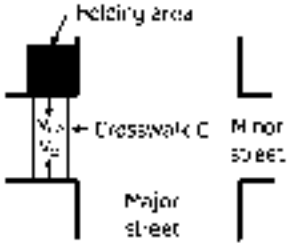
$Walk_{ae}$ = pedestrian walk setting for the phase serving the minor-street through movement (s),

PC_{ae} = pedestrian clear setting for the phase serving the minor-street through movement (s),

$D_{p,ae}$ = duration of the phase serving the minor-street through movement (s),

Y_{ae} = yellow change interval of the phase serving the minor-street through movement (s), and

$R_{c,ae}$ = red clearance interval of the phase serving the minor-street through movement (s).



For Condition 2, the previous three equations are repeated to compute the holding-area time for pedestrians waiting to cross the minor street Q_{cw}. For this application, the subscript letters "*ae*" are replaced with the letters "*cw*" to denote the pedestrians arriving at the corner to cross in Crosswalk C. Similarly, the subscript letters "*ae*" are replaced with "*ve*" to denote signal timing variables associated with the phase serving the major-street through movement.

C. Compute Circulation Time–Space

The time–space available for circulating pedestrians equals the total available time–space minus the time–space occupied by the pedestrians waiting to cross. The latter value equals the product of the total waiting time and the area used by waiting pedestrians (3.0 ft²/p). Equation 18-58 is used to compute the time–space available for circulating pedestrians.

Equation 18-58

$$TS_c = TS_{corner} - [5.0 (Q_{cw} + Q_{ce})]$$

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where TS_c is the time–space available for circulating pedestrians (ft²-s) and other variables are as previously defined.

D. Compute Pedestrian Corner Circulation Area

The space required for circulating pedestrians is computed by dividing the time–space available for circulating pedestrians by the time that pedestrians consume walking through the corner area. The latter quantity equals the total circulation volume multiplied by the assumed average circulation time (= 4.0 s). Equation 18-59, with Equation 18-60, is used to compute corner circulation area.

$$M_{corner} = \frac{TS_c}{4.0\,N_{ca}} \quad \text{Equation 18-59}$$

with

$$N_{ca} = \frac{(v_{ci} + v_{cr} + v_{di} + v_{dr} + v_{si})\,C}{3{,}600} \quad \text{Equation 18-60}$$

where

M_{corner} = corner circulation area per pedestrian (ft²/p),

N_{ca} = total number of circulating pedestrians that arrive each cycle (p),

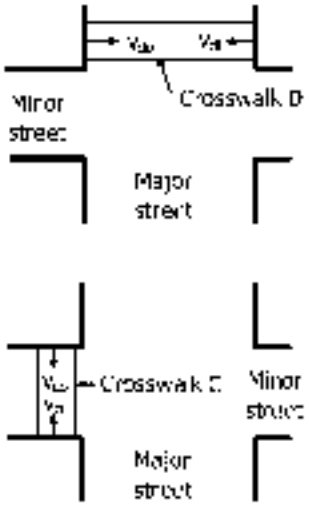
v_{ci} = flow rate of pedestrians arriving at the corner after crossing the minor street (p/h),

v_{cr} = flow rate of pedestrians arriving at the corner to cross the minor street (p/h),

v_{di} = flow rate of pedestrians arriving at the corner after crossing the major street (p/h), and

v_{si} = flow rate of pedestrians traveling through the corner from Sidewalk A to Sidewalk B, or vice versa (p/h).

Other variables are as previously defined. The circulation area obtained from Equation 18-59 can be compared with the ranges provided in Exhibit 18-24 to make some judgments about the performance of the subject intersection corner.



Step 2: Determine Crosswalk Circulation Area

This step describes a procedure for evaluating the performance of one crosswalk. It is repeated for each crosswalk of interest.

The procedure to follow describes the evaluation of Crosswalk D in Exhibit 18-25 (i.e., a crosswalk across the major street). The procedure is repeated to evaluate Crosswalk C in Exhibit 18-25. For the second application, the subscript letters "di" and "dr" are replaced with the letters "ci" and "cr," respectively, to denote the pedestrians associated with Crosswalk C. Similarly, the subscript letter "d" is replaced with the letter "c" to denote the length and width of Crosswalk C. Also, the subscript letters "ni" are replaced with "ri" to denote signal timing variables associated with the phase serving the major-street through movement.

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The recommended walking speed, called average (50th percentile) walking speed, for the purposes of calculating LOS. Traffic signal timing for pedestrians is typically based on a 15th percentile walking speed.

A. Establish Walking Speed

The average pedestrian walking speed S_p is needed to evaluate corner and crosswalk performance. Research indicates that the walking speed is influenced by pedestrian age and sidewalk grade (26). If 0% to 20% of pedestrians traveling along the subject segment are elderly (i.e., 65 years of age or older), an average walking speed of 4.0 ft/s is recommended for intersection evaluations. If more than 20% of all pedestrians are elderly, an average walking speed of 3.5 ft/s is recommended. In addition, an upgrade of 10% or greater reduces walking speed by 0.8 ft/s.

B. Compute Available Time–Space

Equation 18-61 is used to compute the time–space available in the crosswalk.

Equation 18-61

$$TS_c = L_c W_e g_{walk,ns}$$

where

TS_c = available crosswalk time–space (ft²-s),

L_c = length of Crosswalk 1 (ft),

W_e = effective width of Crosswalk 1 (ft), and

$g_{walk,ns}$ = effective walk time for the phase serving the major-street through movement (s).

C. Compute Effective Available Time–Space

The available crosswalk time–space is adjusted in this step to account for the effect turning vehicles have on pedestrians. This adjustment is based on the assumed occupancy of a vehicle in the crosswalk. The vehicle occupancy is computed as the product of vehicle swept path, crosswalk width, and the time the vehicle preempts this space. Equation 18-62 through Equation 18-64 are used for this purpose.

Equation 18-62

$$TS_c' = TS_c - TS_v$$

with

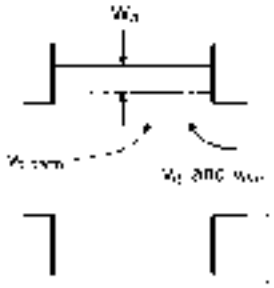
Equation 18-63

$$TS_v = 10\,N_v W_e$$

Equation 18-64

$$N_v = \frac{v_{lt,perm} + v_{rt} + v_{rtor}}{3{,}600} C$$

where



TS_c' = effective available crosswalk time–space (ft²-s),

TS_v = time–space occupied by turning vehicles (ft²-s),

N_v = number of turning vehicles during the walk and pedestrian clear intervals (veh),

$v_{lt,perm}$ = permitted left-turn demand flow rate (veh/h),

v_{rt} = right turn demand flow rate (veh/h), and

v_{rtor} = right turn on red flow rate (veh/h).

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Other variables are as previously defined. The constant 40 in Equation 18-65 represents the product of the swept-path for most vehicles (= 8 ft) and the time that a turning vehicle occupies the crosswalk (= 5 s). The left-turn and right-turn flow rates used in Equation 18-64 are those associated with movements that receive a green indication concurrently with the subject pedestrian crossing and turn across the subject crosswalk.

D. Compute Pedestrian Service Time

Total service time is computed with either Equation 18-65 or Equation 18-66, depending on the crosswalk width, along with Equation 18-67. This time represents the elapsed time starting with the first pedestrian's departure from the corner to the last pedestrian's arrival at the far side of the crosswalk. In this manner, it accounts for platoon size in the service time (20).

If crosswalk width W_c is greater than 10 ft, then

$$t_{ped} = 3.2 + \frac{L_c}{S_p} + 2.7\,\frac{N_{ped,do}}{W_e} \qquad \text{Equation 18-65}$$

If crosswalk width W_c is less than or equal to 10 ft, then

$$t_{ped} = 3.2 + \frac{L_c}{S_p} + 0.27\,N_{ped,do} \qquad \text{Equation 18-66}$$

with

$$N_{ped,do} = N_{do}\,\frac{C}{C}\,\frac{g_{Walk,do}}{C} \qquad \text{Equation 18-67}$$

where

t_{ped} = service time for pedestrians that arrive at the corner to cross the major street (s),

$N_{do,k}$ = number of pedestrians waiting at the corner to cross the major street (p), and

other variables are as previously defined.

Equation 18-67 provides an estimate of the number of pedestrians who cross as a group following the presentation of the WALK indication (or green indication, if pedestrian signal heads are not provided). It is also used to compute N_{ped} for the other travel direction on the same crosswalk (using N_{do} as defined below). Finally, Equation 18-65 or Equation 18-66 is used to compute the service time for pedestrians who arrive at the subject corner having waited on the other corner before crossing the major street (t_{ped} using $N_{ped,do}$).

E. Compute Crosswalk Occupancy Time

The total crosswalk occupancy time is computed as a product of the pedestrian service time and the number of pedestrians using the crosswalk during one signal cycle. Equation 18-68 is used, with Equation 18-69 and results from previous steps, for the computation.

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Equation 18-68

$$T_{occ} = t_{c,ab} N_{ab} + t_{c,ba} N_{ba}$$

with

Equation 18-69

$$N_a = \frac{v_a}{3{,}600} C$$

where

T_{occ} = crosswalk occupancy time (p=s), and

N_a = number of pedestrians arriving at the corner each cycle having crossed the major street (p)

Other variables are as previously defined.

F. Compute Pedestrian Crosswalk Circulation Area

The circulation space provided for each pedestrian is determined by dividing the time space available for crossing by the total occupancy time, as shown in Equation 18-70.

Equation 18-70

$$M_{cr} = \frac{TS_{cw}}{T_{occ}}$$

where M_{cr} is the crosswalk circulation area per pedestrian (ft²/p) and other variables are as previously defined.

The circulation area obtained from Equation 18-70 can be compared with the ranges provided in Exhibit 18-24 to make some judgments about the performance of the subject intersection crosswalk (for the specified direction of travel). For a complete picture of the subject crosswalk's performance, the procedure described in this step should be repeated for the other direction of travel along the crosswalk (i.e., by using the other corner associated with the crosswalk as the point of reference).

Step 3: Determine Pedestrian Delay

This step describes a procedure for evaluating the performance of a crosswalk at the intersection. It is repeated for each crosswalk of interest.

The discussion that follows describes the evaluation of Crosswalk D shown in Exhibit 18-2. The procedure is applied again to evaluate Crosswalk C shown in Exhibit 18-23. For the second application, the subscript letters "wi" are replaced with "ap" to denote signal timing variables associated with the phase serving the major-street through movement.

The pedestrian delay while waiting to cross the major street is computed with Equation 18-71.

Equation 18-71

$$d_p = \frac{(C - g_{walk,wi})^2}{2C}$$

where d_p is pedestrian delay (s/p) and other variables are as previously defined.

The delay obtained from Equation 18-71 applies equally to both directions of travel along the crosswalk.

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Research indicates that average pedestrian delay at signalized intersection crossings is not constrained by capacity, even when pedestrian flow rates reach 5,000 p/h (26). For this reason, delay due to oversaturated conditions is not included in the value obtained from Equation 18-71.

If the subject crosswalk is crossed, then the pedestrian delay d_p is estimated as the value obtained from Equation 18-71 for the subject crosswalk, plus two increments of the delay from this equation when applied to the perpendicular crosswalk. This adjustment reflects the additional delay pedestrians incur when crossing the other three legs of the intersection so that they can continue walking in the desired direction.

The pedestrian delay computed in this step can be used to make some judgment about pedestrian compliance. In general, pedestrians become impatient when they experience delays in excess of 30 s/p, and there is a high likelihood of their not complying with the signal indication (30). In contrast, pedestrians are very likely to comply with the signal indication if their expected delay is less than 10 s/p.

Step 4: Determine Pedestrian LOS Score for Intersection

This step describes a procedure for evaluating the performance of one crosswalk. It is repeated for each crosswalk of interest.

The procedure to follow describes the evaluation of Crosswalk D in Exhibit 18-26. The procedure is repeated to evaluate Crosswalk C in Exhibit 18-25. For the second application, the subscript letter "d" is replaced with the letter "c" to denote the length and width of Crosswalk C. Also, the subscript letters "om" are replaced with "os" to denote variables associated with the minor street.

The pedestrian LOS score for the intersection $I_{p,int}$ is calculated by using Equation 18-72 through Equation 18-77.

$$I_{p,int} = 0.5997 - F_w + F_c + F_s + F_{delay} \quad \text{Equation 18-72}$$

with

$$F_w = 0.681\left(N_d\right)^{0.514} \quad \text{Equation 18-73}$$

$$F_c = 0.00569\left(\frac{v_{d,ae} + v_{d,pae}}{4}\right) - N_{om,d}\left(0.0027\, v_{15,om} - 0.1946\right) \quad \text{Equation 18-74}$$

$$F_s = 0.00013\, v_{15,os}\, S_{os,ft} \quad \text{Equation 18-75}$$

$$F_{delay} = 0.0401\, \ln(d_{p,d}) \quad \text{Equation 18-76}$$

$$v_{d,ae} = \frac{0.25}{N_d} \sum_{i=1}^{N_d} v_i \quad \text{Equation 18-77}$$

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where

$I_{p,int}$ = pedestrian LOS score for intersection,

F_w = cross section adjustment factor,

f_v = motorized vehicle volume adjustment factor,

f_s = motorized vehicle speed adjustment factor,

F_{delay} = pedestrian delay adjustment factor,

$\ln(x)$ = natural logarithm of x,

N_l = number of traffic lanes crossed when traversing Crosswalk D (lc),

N_{crossi} = number of right-turn channelizing islands along Crosswalk D,

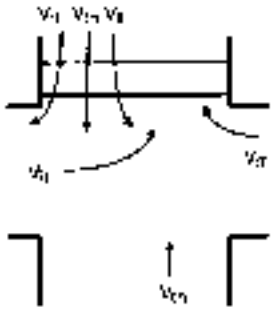
$v_{l,m}$ = count of vehicles traveling on the major street during a 15-min period (veh/ln),

$S_{85,m}$ = 85th percentile speed at a midsegment location on the major street (mi/h),

d_p = pedestrian delay when traversing Crosswalk D (s/p),

v_i = demand flow rate for movement i (veh/h), and

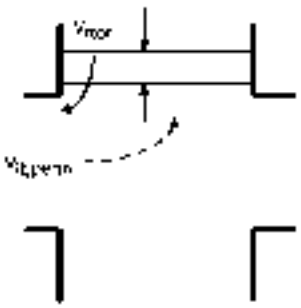
m_i = set of all automobile movements that cross Crosswalk D (see figure in margin).



The left-turn flow rate $v_{lt,p}$ used in Equation 18-74 is that associated with the left-turn movement that receives a green indication concurrently with the subject pedestrian crossing and turns across the subject crosswalk. The RTOR flow rate $v_{rt,p}$ is that associated with the approach being crossed and that turns across the subject crosswalk. It is not the same v_{rt} used in Equation 18-64.

The pedestrian LOS score obtained from this equation applies equally to both directions of travel along the crosswalk.

The variable for "number of right-turn channelizing islands" N_{ci} is an integer with a value of 0, 1, or 2.



Step 5: Determine LOS

This step describes a process for determining the LOS of one crosswalk. It is repeated for each crosswalk of interest.

The pedestrian LOS is determined by using the pedestrian LOS score from Step 4. This performance measure is compared with the thresholds in Exhibit 18-5 to determine the LOS for the subject crosswalk.

BICYCLE MODE

This subsection describes the methodology for evaluating the performance of a signalized intersection in terms of its service to bicyclists.

Intersection performance is evaluated separately for each intersection approach. *Unless otherwise noted, all variables identified in this subsection are specific to one subject approach.* The bicyclist is assumed to travel in the street (possibly in a bicycle lane) and in the same direction as adjacent motorized vehicles.

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The methodology is focused on analyzing signalized intersection performance from the bicyclist point of view. Chapter 17, Urban Street Segments, describes a methodology for evaluating urban street performance.

The bicycle methodology is applied through a series of three steps that determine the bicycle LOS for an intersection approach. These steps are illustrated in Exhibit 18-27. Performance measures that are estimated include bicycle delay and a bicycle LOS score.

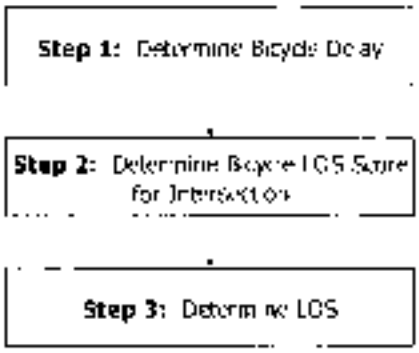

Exhibit 18-27
Bicycle Methodology for Signalized Intersections

Step 1: Determine Bicycle Delay

This step describes a procedure for evaluating the performance of one intersection approach. It is repeated for each approach of interest. Bicycle delay can be calculated only for intersection approaches that have an on-street bicycle lane or a shoulder that can be used by bicyclists as a bicycle lane. Bicyclists who share a lane with automobile traffic will incur the same delay as the automobiles.

A. Compute Bicycle Lane Capacity

A wide range of capacities and saturation flow rates have been reported by many countries for bicycle lanes at intersections. Research indicates that the base saturation flow rate may be as high as 2,630 bicycles/h (37). However, few intersections provide base conditions for bicyclists, and current information is insufficient to calibrate a series of appropriate saturation flow adjustment factors. Until such factors are developed, it is recommended that a saturation flow rate of 2,000 bicycles/h be used as an average value achievable at most intersections.

A saturation flow rate of 2,000 bicycles/h assumes that right-turning motor vehicles yield the right-of-way to through bicyclists. Where aggressive right-turning traffic exists, 2,000 bicycles/h may not be achievable. Local observations to determine a saturation flow rate are recommended in such cases.

The capacity of the bicycle lane at a signalized intersection may be computed with Equation 18-78.

$$c_l = s_l \frac{g_l}{C} \quad \text{Equation 18-78}$$

where

c_l = capacity of the bicycle lane (bicycles/h),

s_l = saturation flow rate of the bicycle lane = 2,000 (bicycles/h),

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g_b = effective green time for the bicycle lane (s), and

C = cycle length (s).

The effective green time for the bicycle lane can be assumed to equal that for the adjacent motor-vehicle traffic stream that is served concurrently with the subject bicycle lane (i.e., $g_b = D_p - I_b - l_1$).

b. Compute Bicycle Delay

Bicycle delay is computed with Equation 18-79.

Equation 18-79

$$d_b = \frac{0.5C(1 - g_b/C)^2}{1 - \min\left(\frac{v_{bo}}{c_b}, 1.0\right)\frac{g_b}{C}}$$

where d_b is bicycle delay (s/bicycle), v_{bo} is bicycle flow rate (bicycles/h), and other variables are as previously defined.

This delay equation is based on the assumption that there is no bicycle incremental delay or initial queue delay. Bicyclists will not normally tolerate an oversaturated condition and will select other routes or ignore traffic regulations to avoid the associated delays.

At most signalized intersections, the only delay to through bicycles is caused by the signal, because bicycles have the right-of-way over right-turning vehicles during the green indication. Bicycle delay could be longer than that obtained from Equation 18-79 when (*a*) bicycles are forced to weave with right-turning traffic during the green indication, or (*b*) drivers do not acknowledge the bicycle right-of-way because of high flows of right-turning vehicles.

The delay obtained from Equation 18-79 can be used to make some judgment about intersection performance. Bicyclists tend to have about the same tolerance for delay as pedestrians. They tend to become impatient when they experience a delay in excess of 30 s/bicycle. In contrast, they are very likely to comply with the signal indication if their expected delay is less than 10 s/bicycle.

Step 2: Determine Bicycle LOS Score for Intersection

This step describes a procedure for evaluating the performance of one intersection approach. It is repeated for each approach of interest. The bicycle LOS score can be calculated for any intersection approach, regardless of whether it has an on-street bicycle lane.

The bicycle LOS score for the intersection $I_{b,int}$ is calculated by using Equation 18-80 through Equation 18-83.

Equation 18-80

$$I_{b,int} = 4.1324 \cdot F_v \cdot F_s$$

with

Equation 18-81

$$F_v = 0.0153\,W_{ev} - 0.2144\,W_v$$

Equation 18-82

$$F_s = 0.0066\,\frac{v_o + v_{lo} \cdot v_{ro}}{4\,N_{lo}}$$

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$$W_t = W_v + W_{bl} + I_{pl} W_{pl}^{*}$$

Equation 18-83

where:

$I_{bi,t}$ = bicycle LOS score for intersection,

W_{cs} = curb-to-curb width of the cross street (ft),

W_t = total width of the outside through lane, bicycle lane, and paved shoulder (ft);

v_l = left-turn demand flow rate (veh/h);

v_t = through demand flow rate (veh/h);

v_r = right-turn demand flow rate (veh/h);

N_{tl} = number of through lanes (shared or exclusive) (in);

W_v = width of the curbside through lane (ft),

W_{bl} = width of the bicycle lane = 0.0 if bicycle lane not provided (ft);

I_{pl} = indicator variable for on-street parking occupancy = 0 if $p_{pl} > 0.0$, 1 otherwise;

p_{pl} = proportion of on-street parking occupied (decimal);

W_s = width of paved outside shoulder (ft); and

W_{pl}^{*} = adjusted width of paved outside shoulder, if curb is present $W_{pl}^{*} = W_s - 1.5 \geq 0.0$, otherwise $W_{pl}^{*} = W_s$ (ft).

The variable "proportion of on-street parking occupied" is used to describe the presence of on-street parking and activity on the approach and departure legs of the intersection that are used by the subject bicycle movement.

Step 3: Determine LOS

This step describes a process for determining the LOS of one intersection approach. It is repeated for each approach of interest.

The bicycle LOS is determined by using the bicycle LOS score from Step 2. This performance measure is compared with the thresholds in Exhibit 18-5 to determine the LOS for the subject approach.

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3. APPLICATIONS

DEFAULT VALUES

Agencies that use the methodologies in this chapter are encouraged to develop a set of local default values based on field measurements at intersections in their jurisdiction. Local default values provide the best means of ensuring accuracy in the analysis results. In the absence of local default values, the values identified in this subsection can be used if the analyst believes they are reasonable for the intersection to which they are applied.

Exhibit 18-6, Exhibit 18-7, and Exhibit 18-9 identify the input data variables associated with the automobile, pedestrian, and bicycle methodologies. These variables can be categorized as (a) suitable for specification as a default value or (b) required input data. Those variables categorized as "suitable for specification as a default value" have a minor effect on performance estimates and tend to have a relatively narrow range of typical values used in practice. In contrast, required input variables have either a notable effect on performance estimates or a wide range of possible values.

Required input variables typically represent fundamental intersection geometric elements and demand flow rates. Values for these variables should be field measured where possible.

If field measurement of the input variables is not possible, then various options exist for determining an appropriate value for a required input variable. As a first choice, input values should be established through the use of local guidelines. If local guidelines do not address the desired variable, then some input values may be determined by considering the typical operation of (or conditions at) similar intersections in the jurisdiction. As a last option, various authoritative national guideline documents are available and should be used to make informed decisions about design options and volume estimates. The use of simple rules of thumb or "ballpark" estimates for required input values is discouraged because this use is likely to lead to a significant cumulative error in performance estimates.

Automobile Mode

The required input variables for the automobile methodology are identified in the following list. These variables represent the minimum basic input data the analyst will need to provide for an analysis and were previously defined in the text associated with Exhibit 18-6:

- Demand flow rate,
- Initial queue,
- Pedestrian flow rate,
- Bicycle flow rate,
- Number of lanes,
- Number of receiving lanes,
- Turn bay length,

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- Presence of on-street parking,
- Type of signal control,
- Phase sequence,
- Left-turn operational mode,
- Speed limit, and
- Area type.

Initial queue has a significant effect on delay and can vary widely among intersections and traffic movements. If it is not possible to obtain an initial queue estimate, then the analysis period should be established so that the previous period is known to have demand less than capacity and no residual queue. A multiple-period analysis may be appropriate when the duration of congestion exceeds 15 min (i.e., 0.25 h).

Several authoritative reference documents (37–44) provide useful guidelines for selecting the type of signal control, designing the phase sequence, and selecting the left-turn operational mode (i.e., permitted, protected, or protected-permitted).

Exhibit 18-28 lists default values for the automobile methodology based on national research (25). Some of the values listed may also be useful for the pedestrian or bicycle methodologies. The last column of this exhibit indicates "see discussion" for some variables. In these situations, the default value is described in the discussion provided in this subsection.

Many of the controller settings are specific to an actuated phase and fully actuated signal control. If pretimed control is used and the phase durations are known, the cycle length and phase durations are set to equal the known values. If pretimed control is used and the phase durations are not known, then the quick estimation method described in Chapter 32, Signalized Intersections: Supplemental, should be used to estimate the cycle length and the duration of each phase. For semiactuated control, phases with a fixed duration should have their recall mode set to "recall to maximum" and their maximum green limit set to the known green interval duration.

Platoon Ratio

A default value for platoon ratio can be determined from arrival type. Once the default arrival type is determined, Exhibit 18-8 is consulted to determine the equivalent default platoon ratio for input to the methodology.

In the absence of more detailed information from Chapter 17 or field measurements, a default arrival type of 3 is used for uncoordinated through movements and a default value of 4 is used for coordinated through movements. Exhibit 18-29 provides further guidance on the relationship between arrival type, street segment length, and the provision of signal coordination for through movements.

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Exhibit 18-28
Default Values: Automobile Mode with Fully or Semiactuated Signal Control

Data Category	Input Data Element	Default Values
Traffic characteristics	Right-turn-on-red flow rate	0.0 veh/h
	Percent heavy vehicles	3%
	Intersection peak hour factor	If analysis period is 0.25 h and hourly rates are used. Total entering volume ≥ 1,000 veh/h: 0.92 Total entering volume < 1,000 veh/h: 0.90 Otherwise: 1.00
	Platoon ratio	See discussion
	Upstream filtering adjustment factor	1.0
	Base saturation flow rate	Metropolitan area with population ≥ 250,000: 1,900 pc/h/ln Otherwise: 1,750 pc/h/ln
	Lane utilization adjustment factor	See discussion
	On-street parking maneuver rate	See discussion
	Local bus stopping rate	When buses expected to stop: Central business district: 12 buses/h Non-central business district: 2 buses/h When buses not expected to stop: 0
Geometric design	Average lane width	12 ft
	Approach grade (negative for downhill conditions)	Flat approach: 0% Moderate grade on approach: 3% Steep grade on approach: 6%
Controller settings	Dallas left-turn phasing option	Dictated by local use
	Passage time	2.0 s (presence detection)
	Maximum green	Major-street through movement: 50 s Minor-street through movement: 30 s Left-turn movement: 20 s
	Minimum green	Major-street through movement: 10 s Minor-street through movement: 8 s Left-turn movement: 5 s
	Yellow change + red clearance[a]	4.0 s
	Walk	Actuated: 7.0 s Pretimed: green interval minus pedestrian clear
	Pedestrian clear	Based on 3.5-ft/s walking speed
	Phase recall	Actuated phase: No Pretimed phase: Recall to maximum
	Dual entry	Not enabled (i.e., use single entry)
	Simultaneous gap-out	Enable
Other	Analysis period duration	0.25 h
	Stop-line detector length	40 ft (presence detection)

Note: [a]Specific values of yellow change and red clearance should be determined by local guidelines or practice.

In the absence of more detailed information from Chapter 17 or field measurements, Arrival Type 3 is used for turn movements because they are typically not coordinated.

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Arrival Type	Progression Quality	Signal Spacing (ft)	Conditions Under Which Arrival Type Is Likely to Occur
1	Very poor	≤1,600	Coordinated operation on a two-way street where the subject direction does not receive good progression
2	Unfavorable	>1,600–3,200	A less extreme version of Arrival Type 1
3	Random arrivals	>3,200	Isolated signals or widely spaced coordinated signals
4	Favorable	>1,600–3,200	Coordinated operation on a two-way street where the subject direction receives good progression
5	Highly favorable	≤1,600	Coordinated operation on a two-way street where the subject direction receives good progression
6	Exceptional	≤600	Coordinated operation on a one-way street in dense networks and central business districts

Exhibit 18-29
Progression Quality and Arrival Type

Lane Utilization Adjustment Factor

The default lane utilization factors described in this subpart apply to situations in which drivers randomly choose among the exclusive use lanes on the intersection approach. The factors do not apply to special conditions (such as short lane drops or a downstream freeway on ramp) that might cause drivers intentionally to choose their lane position on the basis of an anticipated downstream maneuver. Exhibit 18-30 provides a summary of lane utilization adjustment factors for different lane group movements and numbers of lanes.

Lane Group Movement	Number of Lanes in Lane Group (n)	Traffic in Most Heavily Traveled Lane (%)	Lane Utilization Adjustment Factor f_{LU}
Exclusive through	1	100.0	1.000
	2	52.5	0.952
	3*	36.7	0.908
Exclusive left turn	1	100.0	1.000
	2*	51.5	0.971
Exclusive right turn	1	100.0	1.000
	2*	56.5	0.885

Note: *If a lane group has more lanes than shown in this exhibit, it is recommended that field surveys be conducted or the smallest f_{LU} value shown for that type of lane group be used.

Exhibit 18-30
Default Lane Utilization Adjustment Factors

As demand approaches capacity, the analyst may use lane utilization factors that are closer to 1.0 than those offered in Exhibit 18-30. This refinement in the factor value recognizes that a high volume to capacity ratio is associated with a more uniform use of the available lanes because of reduced opportunity for drivers to select their lane freely.

On-Street Parking Maneuver Rate

Exhibit 18-31 gives default values for the parking maneuver rate on an intersection approach with no stall of parking. It is estimated for a distance of 250 ft back from the stop line. The calculations assume 25 ft per parking space and 80% occupancy. Each turnover (one car leaving and one car arriving) generates two parking maneuvers.

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Exhibit 18-31
Default Parking Maneuver Rate

Street Type	Number of Spaces in 250 ft	Parking Time Limit (h)	Turnover Rate (veh/h)	Maneuver Rate (maneuvers/h)
Two-way	10	1 2	1.0 0.5	16 8
One-way	20	1 2	1.0 0.5	32 16

Automobile Mode (Coordinated-Actuated Operation)

Exhibit 18-32 lists the default values for evaluating signalized intersections that are part of a coordinated-actuated signal system. The text "see discussion" in the last column of this exhibit indicates that the default value is described in the discussion provided in this part.

Exhibit 18-32
Default Values: Automobile Mode with Coordinated-Actuated Signal Control

Data Category	Input Data Element	Default Value
Controller settings	Cycle length	See discussion
	Phase splits	See discussion
	Offset	Equal to travel time of Phase 2 direction[a]
	Offset reference	End of green for Phase 2[a]
	Force mode	Fixed

Note: [a] Assumes that Phase 2 is the reference phase. Substitute 6 if Phase 6 is the reference phase.

Cycle Length

The cycle length used for a coordinated signal system often represents a compromise value based on intersection capacity, queue size, phase sequence, segment length, speed, and progression quality. Consideration of these factors leads to the default cycle lengths shown in Exhibit 18-33.

Exhibit 18-33
Default System Cycle Length

Average Segment Length (ft)[a]	Cycle Length by Street Class and Left-Turn Phasing (s)[b]					
	Major Arterial Street			Minor Arterial Street or Grid Network		
	No Left-Turn Phases	Left-Turn Phases on One Street	Left-Turn Phases on Both Streets	No Left-Turn Phases	Left-Turn Phases on One Street	Left-Turn Phases on Both Streets
1,300	90	120	150	80	100	120
2,600	90	120	150	100	100	120
3,900	110	120	150			

Notes: [a] Average length based on all street segments in the signal system.
[b] Selected left-turn phasing scheme should describe the phase sequence at the high-volume intersections in the system.

Phase Splits

If the phase splits are not known, they can be estimated by using the quick estimation method described in Chapter 31. The method can be used to estimate the effective green time for each phase on the basis of the established system cycle length. The phase split D_i is then computed by adding 4 s of lost time to the estimated effective green time (i.e., $D_i = g_i + 4.0$).

Nonautomobile Modes

The required input variables for the pedestrian and bicycle methodologies are identified in the following list. These variables represent the minimum basic input data the analyst will need to provide for an analysis. These variables were previously defined in the text associated with Exhibit 18-9.

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- Demand flow rate of motorized vehicles,
- RTOR flow rate (pedestrian mode only),
- Permitted left-turn flow rate (pedestrian mode only),
- Pedestrian flow rate (pedestrian mode only),
- Bicycle flow rate (bicycle mode only),
- Number of lanes,
- Crosswalk length (pedestrian mode only), and
- Pedestrian signal head presence (pedestrian mode only).

The RTOR flow rate does not have a default value for application of the pedestrian methodology. This flow rate has both a notable effect on performance estimates and a wide range of possible values. The analyst is encouraged to conduct measurements at intersections for the purpose of developing local defaults for this variable.

The permitted left-turn flow rate for movements served by the permitted mode is equal to the left-turn demand flow rate. The permitted left-turn flow rate for movements served by the protected-permitted mode does not have a default value. This flow rate has both a notable effect on performance estimates and a wide range of possible values. It should be measured in the field if possible. If the analysis is dealing with future conditions or if the permitted left-turn flow rate is not known from field data, its value can be approximated as the left-turn arrival rate during the permitted period of the protected-permitted operation. This rate should equal the left-turn arrival rate during the effective red time [i.e., $v_{o,i} = (1 - P_{thru}) v_i$].

The pedestrian flow rate data consist of count data for each of five pedestrian movements at each intersection corner. These variables are shown as v_{p1}, v_{p2}, v_{p3}, v_{p4}, and v_{p5} in Exhibit 18-10.

Exhibit 18-34 lists the default values for the pedestrian and bicycle methodologies (25–27).

TYPES OF ANALYSIS

The automobile, pedestrian, and bicycle methodologies described in this chapter can each be used at three types (or levels) of analysis. These analysis levels are described as operational, design, and planning and preliminary engineering. The characteristics of each analysis level are described in later parts of this subsection.

Operational Analysis

Each of the methodologies is most easily applied at an operational level of analysis. At this level, all traffic, geometric, and signalization conditions are specified as input variables by the analyst. These input variables are used in the methodology to compute various performance measures.

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Exhibit 18-34
Default Values: Nonautomobile Modes

Data Category	Input Data Element	Default Value
Traffic characteristics	Intersection peak hour factor (motorized vehicles)	If analysis period is 0.25 h and hourly data are used: Total entering volume ≥ 1,000 veh/h: 0.92 Total entering volume < 1,000 veh/h: 0.90 Otherwise: 1.00
	Midsegment 85th percentile speed	Speed limit (mi/h)
	Proportion of on-street parking occupied	0.50 (if parking lane present)
Geometric design	Street width	Based on a 12-ft lane width
	Number of right-turn islands	None
	Width of outside through lane	12 ft
	Width of bicycle lane	5.0 ft (if provided)
	Width of paved outside shoulder	No parking lane: 2.0 ft (curb and gutter width) Parking lane present: 8.0 ft
	Total walkway width	Business or office land use: 9.0 ft Residential or industrial land use: 11.0 ft
	Crosswalk width	12 ft
	Corner radius	Trucks and buses in turn volume: 45 ft No trucks or buses in turn volume: 25 ft
Signal control	Walk	Actuated: 7 s Pretimed: green interval minus pedestrian clear
	Pedestrian clear	Based on 3.5 ft/s walking speed
	Rest in walk	Not enabled
	Cycle length	Based on default values determined for automobile mode
	Yellow change and red clearance[a]	4 s
	Duration of phases serving pedestrians and bicycles	Based on default values determined for automobile mode
Other	Analysis period duration	0.25 h

Note: [a] Specific values of yellow change and red clearance should be determined by local guidelines or practice.

Design Analysis

The design level of analysis has two variations. Both variations require specifying (*a*) traffic conditions and (*b*) target levels for a specified set of performance measures. One variation requires the additional specification of the signalization conditions. The methodology is then applied by using an iterative approach in which alternative geometric conditions are separately evaluated.

The second variation of the design level requires the additional specification of geometric conditions. The methodology is then applied by using an iterative approach in which alternative signalization conditions are separately evaluated.

The objective with either variation is to identify alternatives that operate at the target level of the specified performance measures (or provide a better level of performance). The analyst may then recommend the "best" alternative based on consideration of the full range of factors.

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Planning and Preliminary Engineering Analysis

The planning and preliminary engineering level of analysis is intended to provide an estimate of the LOS for either a proposed intersection or an existing intersection in a future year. This level of analysis may also be used for a preliminary engineering activity to size the overall geometrics of a proposed intersection.

The level of precision inherent in planning and preliminary engineering analyses is typically lower than for operational analyses. Therefore, default values are often substituted for field-measured values of many of the input variables. Recommended default values for this purpose were described previously in this section.

The requirement for a complete description of the signal timing plan can be a burden for some planning analyses, especially when the signal control is pretimed or coordinated-actuated. The quick estimation method described in Chapter 31 can be used to estimate a reasonable timing plan in conjunction with the aforementioned default values.

USE OF ALTERNATIVE TOOLS

General alternative tool guidance is provided in Chapters 6 and 7.

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools, and Chapter 7, Interpreting HCM and Alternative Tool Results. This section contains specific guidance for applying alternative tools to the analyses of signalized intersections. Additional information on this topic may be found in the Technical Reference Library in Volume 4.

Strengths of the Automobile Methodology

The automobile methodology described in Section 2 offers a comprehensive procedure for analyzing the performance of a signalized intersection. It models the driver–vehicle–road–signal system with reasonable accuracy for most applications. Simulation-based traffic analysis tools offer a more detailed treatment of the arrival and departure of vehicles and their interaction with the roadway and the control system. As such, some simulation tools can model the driver–vehicle–road–signal system more accurately for some applications.

The automobile methodology offers the following advantages over the use of simulation-based analysis tools:

- Its empirically calibrated saturation flow rate adjustment factors can produce an accurate estimate of saturation flow rate (simulation tools require saturation flow rate as an input variable).
- It produces a direct estimate of capacity and volume-to-capacity ratio (these measures are much more difficult to quantify with simulation).
- It produces an estimate of expected, long-run performance for a variety of measures (multiple runs and supplemental calculations are required to obtain this type of estimate with a simulation tool).

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Identified Limitations of the Automobile Methodology

The limitations of the automobile methodology are identified near the end of Section 1. If any of these limitations applies to a particular situation, then alternative tools may produce more reliable performance estimates. Limitations involving consideration of the impact of progression on performance are a special case that is discussed in more detail in Chapter 16, Urban Street Facilities.

Features and Performance Measures Available from Alternative Tools

This chapter provides a methodology for estimating the capacity, control delay, LOS, and back of queue associated with lane groups at a signalized intersection. Alternative tools often offer additional performance measures such as number of stops, fuel consumption, air quality, and operating costs.

Development of HCM-Compatible Performance Measures Using Alternative Tools

The LOS assessment for signalized intersections is based on control delay, which is defined as the excess travel time caused by the action of the control device (in this case, the signal).

Simulation-based analysis tools often use a definition of delay that is different from that used in the automobile methodology, especially for movements that are oversaturated at some point during the analysis. Therefore, some care must be taken in the determination of LOS when simulation-based delay estimates are used. Delay comparison among different tools is discussed in more detail in Chapter 7.

An accurate estimate of control delay may be obtained from a simulation tool by performing simulation runs with and without the control device(s) in place. The segment delay reported with no control is the delay due to geometry and interaction between vehicles. The additional delay reported in the run with the control in place is, by definition, the control delay.

Conceptual Differences That Preclude Direct Comparison of Results

Conceptual differences in modeling approach may preclude the direct comparison of performance measures from the automobile methodology with those from alternative tools. The treatment of random arrivals is a case in point. There is a common misconception among analysts that alternative tools treat random arrivals in a similar manner.

A simple case is used to demonstrate the different ways alternative tools model random arrivals. Consider an isolated intersection with a two-phase sequence. The subject intersection approach serves only a through movement: there are no turning movements from upstream intersections or driveways. The only parameter that is allowed to vary in this example is the cycle length (all other variables are held constant).

The results of this experiment are shown in Exhibit 18-35. The two solid lines represent delay estimates obtained from the automobile methodology. Uniform delay is shown to increase linearly with cycle length. Incremental delay is constant with respect to cycle length because the volume-to-capacity ratio is

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constant. As a result, control delay (being the sum of the uniform and incremental delay) is also shown to increase linearly with cycle length.

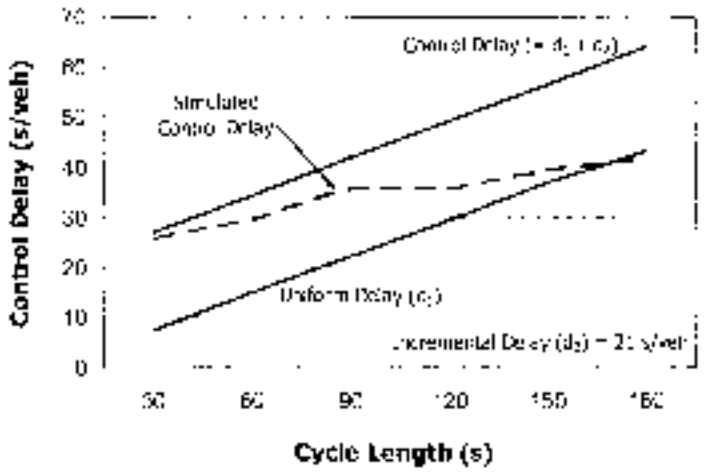

Exhibit 18-35
Effect of Cycle Length on Delay

The dashed line represents the control delay estimate obtained from a simulation-based analysis tool. The simulation-based tool shows close agreement with the automobile methodology for short cycles but deviates for longer cycles. There are likely to be explainable reasons for this difference; however, the point is that such differences are likely to exist among tools. The analyst should understand the underlying modeling assumptions and limitations inherent in any tool (including the automobile methodology) when it is used. Moreover, the analyst should fully understand the definition of any performance measure used so as to interpret the results and observed trends properly.

Adjustment of Alternative Tool Parameters

For applications in which either an alternative tool or the automobile methodology can be used, some adjustment is generally required for the alternative tool if some consistency with the automobile methodology is desired. For example, the parameters that determine the capacity of a signalized approach (e.g., saturation flow rate and start-up lost time) should be adjusted to ensure that the simulated lane group (or approach) capacities match those estimated by the automobile methodology.

Step-by-Step Recommendations for Applying Alternative Tools

This part provides recommendations specifically for signalized intersection evaluation. The following steps should be taken to apply an alternative tool for signalized intersection analysis:

1. Determine whether the automobile methodology can provide a realistic assessment of the capacity and control delay for the signalized approaches of interest. The limitations stated at the end of Section 1 provide a good starting point for this assessment. If there are no conditions outside these limitations, then it should not be necessary to consider alternative tools. Otherwise, proceed with the remaining steps.

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2. Select the appropriate tool in accordance with the general guidelines presented in Chapter 7.
3. Enter all available input characteristics and parameters.
4. Use the tool to evaluate the intersection. Be careful to observe the guidance provided in Chapter 7 regarding self-aggravating conditions that occur near capacity. If the tool is simulation based, then estimate the required number of runs so that the comparison is statistically valid.
5. If the documented delay definition and computational methodology used by the tool conform to the specifications set forth in Chapter 7 of this manual, then the delay estimates should be suitable for estimating the LOS. Otherwise, no such estimate should be attempted.

Sample Calculations Illustrating Alternative Tool Applications

Chapter 31 includes example problems that address the following conditions.

- Left-turn storage bay overflow,
- RTOR operation,
- Short through lanes, and
- Closely spaced intersections.

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4. EXAMPLE PROBLEMS

INTRODUCTION

This part of the chapter describes the application of each of the automobile, pedestrian, and bicycle methodologies through the use of example problems. Exhibit 18-36 provides an overview of these problems. The examples focus on the operational analysis level. The planning and preliminary engineering analysis level is identical to the operational analysis level in terms of the calculations, except that default values are used when field-measured values are not available.

Problem Number	Description	Analysis Level
1	Automobile LOS	Operational
2	Pedestrian LOS	Operational
3	Bicycle LOS	Operational

Exhibit 18-36
Example Problems

EXAMPLE PROBLEM 1: AUTOMOBILE LOS

The Intersection

The intersection of 5th Avenue and 12th Street is an intersection of two urban arterial streets. It is shown in Exhibit 18-37.

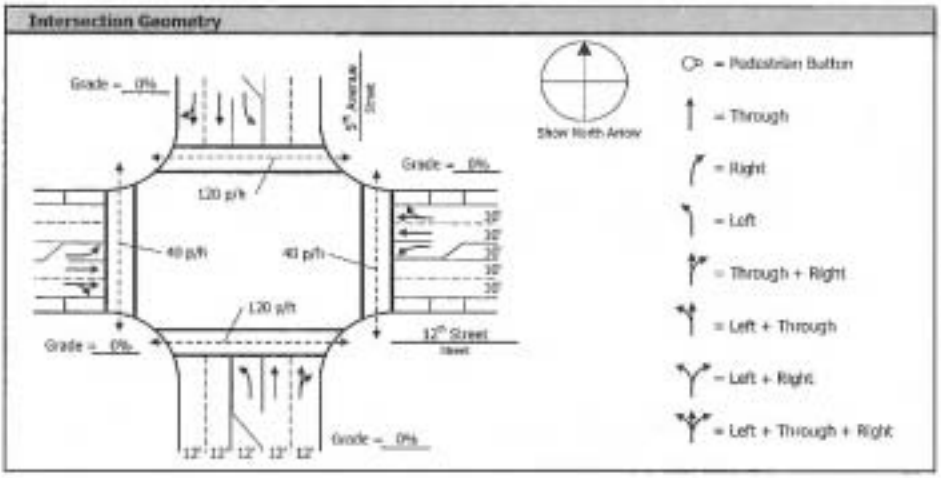

Exhibit 18-37
Example Problem 1: Intersection Plan View

The Question

What is the motorist delay and LOS during the analysis period for each lane group and the intersection as a whole?

The Facts

The intersection's traffic, geometric, and signalization conditions are listed in Exhibit 18-38 and Exhibit 18-39.

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Exhibit 18-38
Example Problem 1: Signal Conditions

Controller Data Worksheet

General Information								
Analyst:	BR			Intersection:	9th Avenue/12th Street			
Agency or Company:				Area Type:	CBD		Phase 2:	EB
Date Performed:	2/11/2010							
Analysis Time Period:	5:30 pm to 5:45 pm			Analysis Year:	2010			
File Name:	C:\Documents and Settings\Texas\EX3							

Phase Sequence and Left-Turn Mode			
WB left (1) with WB thru (6)	EB left (2) with EB thru (5)	NB left (3) before EB thru (4)	SB left (7) before NB thru (8)
WB left permitted	EB left permitted	NB left (3) prot-perm	SB left (7) prot-perm

Phase Settings								
Approach	Eastbound		Westbound		Northbound		Southbound	
Phase number		2		6	3	8	7	4
Movement		L+T+R		L+T+R	L	T+R	L	T+R
Lead/lag left-turn phase		--		--	Lead	--	Lead	--
Left-turn mode		Perm.		Perm.	Pr/Pm	--	Pr/Pm	--
Passage time, s		2.0		2.0	2.0	2.0	2.0	2.0
Maximum green, s		30		30	25	50	25	50
Minimum green, s		5		5	5	5	5	5
Yellow change, s		4.0		4.0	4.0	4.0	4.0	4.0
Red clearance, s		0.0		0.0	0.0	0.0	0.0	0.0
Walk+ ped. clear, s		19		19		21		21
Recall?:	No	No	No	No	No	No	No	No
Dual entry	No	Yes	No	Yes	No	Yes	No	Yes

Enable Simultaneous Gap-Out (check = Yes)? Phase Group 1,2,5,6: ☑ Phase Group 3,4,7,8: ☑					Enable Dallas Left-Turn Phasing? Phases 1,2,5,6: ☐ Phases 3,4,7,8: ☐			
Protected right-turn with left-turn phase?	n.a.		n.a.		Eastbd. right		Westbd. right	
	No		No		No		No	
Phase number assignment to timers (by ring):					Controller timer ring structure:			
Ring 1:	0	2	3	4	Ring 1:	Timer 1	Timer 2	Timer 3	Timer 4
Ring 2:	0	6	7	8	Ring 2:	Timer 5	Timer 6	Timer 7	Timer 8

Exhibit 18-39
Example Problem 1: Traffic and Geometric Conditions

Movement-Specific Intersection Data Worksheet

Approach	Eastbound			Westbound			Northbound			Southbound		
Movement	L	T	R	L	T	R	L	T	R	L	T	R
Movement number	5	2	12	1	6	16	3	8	18	7	4	14
Traffic Characteristics (please fill volume data in all columns, even if all zeros; volumes only if turn pocket exists)												
Volume, veh/h	71	595	103	118	808	74	183	1,444	171	198	988	111
Right-turn-in-lane volume, veh/h			0			0			22			33
Percent heavy vehicles, %	5	5		5	5		2	2		2	2	
Lane utilization adjustment factor	1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000	
Peak hour factor 1.00	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Start-up lost time, s	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Extension of eff. green time, s	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
Ped/bicycle/grade adjustment factor	1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000	
Downstream metering factor	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking/bus volume, veh/h		120			108			60			40	
Bicycle volume, bicycles/h		0			0			0			0	
Other vol.												
Initial queue, veh	0	0		0	0		0	0		0	0	
Lane width, ft/m	11	11	11	11	11	11	11	11	11	11	11	11
Other vol.												
Multiple Period Analysis Counts (if all cell values = 0, then values in the Volume row above will be used for a single-period analysis)												
Period 1 traffic count, veh												
Period 2 traffic count, veh												
Period 3 traffic count, veh												
Period 4 traffic count, veh												
Lane Characteristics (Approach/Movement) (Only the number of lanes for all approaches, lane assignments, and if there are pocket lanes)												
Number of lanes	1	2	0	1	2	0	1	2	0	1	2	0
Lane assignment	L	TR	n.a.	L	TR	n.a.	L	TR	n.a.	L	TR	n.a.
Average lane width, ft	10.0	10.0		10.0	10.0		12.0	12.0		12.0	12.0	
Number of receiving lanes		2			2			2			2	
Turn bay or segment length, ft	200	100		200	100		200	100		200	100	
Approach Data	Left Turn	Right Turn		Left Turn	Right Turn		Left Turn	Right Turn		Left Turn	Right Turn	
Parking present?	No			No			No			No		
Parking maneuvers, maneuvers/h	0			0			0			0		
Bus stopping rate, buses/h												
Blockage rate, %	0			0			0			0		
Detection Data (please provide only if you will not be using the default values)												
Approach detector length, ft	40	40	n.a.	40	40	n.a.	40	40	n.a.	40	40	n.a.
Other vol.												

The intersection is located in a central business district–type environment. Adjacent signals are somewhat distant so the intersection is operated by using fully actuated control. Vehicle arrivals to each approach are characterized as "random" and are described by using a platoon ratio of 1.0.

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The left-turn movements on the north–south street operate under protected permitted control and lead the opposing through movements (i.e., a lead–lead phase sequence). The left-turn movements on the east–west street operate as permitted.

All intersection approaches have a 200-ft left-turn bay, an exclusive through lane, and a shared through and right-turn lane. The average width of the traffic lanes on the east–west street is 12 ft. The average width of the traffic lanes on the north–south street is 12 ft.

Crosswalks are provided on each intersection leg. A two-way flow rate of 120 p/h is estimated to use each of the east–west crosswalks and a two-way flow rate of 40 p/h is estimated to use each of the north–south crosswalks.

On-street parking is present on the east–west street. It is estimated that parking maneuvers on each intersection approach occur at a rate of 3 maneuvers/h during the analysis period.

The speed limit is 35 mi/h on each intersection approach. The analysis period is 0.25 h. There is no initial queue for any movement.

As noted in the next section, none of the lane groups at the intersection has two or more exclusive lanes. For this reason, the saturation flow rate adjustment factor for lane utilization is equal to 1.0 for all approaches. Any unequal lane use that may occur due to the shared through and right-turn lane groups will be accounted for in the lane group flow rate calculation, as described in Chapter 31.

Outline of Solution

Movement-Based Data

Exhibit 18-40 provides a summary of the analysis of the individual traffic movements at the intersection. The movement numbers shown follow the numbering convention in Exhibit 18-2.

Exhibit 18-40
Example Problem 1: Movement-Based Output Data

Two saturation flow rate adjustment factors are shown in Exhibit 18-40. One factor is the pedestrian–bicycle adjustment factor. This factor is used to estimate the saturation flow rate for the turn movement in a lane group. The "parking, bus adjustment factor" represents the product of the parking adjustment factor and the bus blockage adjustment factor. This combined factor is computed separately for the lane group that is adjacent to the parking or bus stop.

The adjusted saturation flow rate represents the saturation flow rate for all lane groups on the approach. It reflects the combined effect of lane width, heavy-vehicle presence, grade, and area type. The effect of pedestrians, bicycles, parking, bus blockage, lane utilization, right-turn maneuvers, and left-turn

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movements is calculated separately at a later stage of the analysis because their values are influenced by signal timing, lane group demand flow rate, and lane group location (adjacent to parking or not, etc.). As such, these factors are internal to the iterative sequence of calculations used to estimate signal phase duration.

Capacity for a movement is computed by using the movement volume proportion in the lane group, lane group saturation flow rate, and corresponding phase duration. This variable represents the capacity of the movement, regardless of whether it is served in an exclusive lane or in a shared lane. If the movement is served in a shared lane, then the movement capacity represents the portion of the lane group capacity available to the movement, as distributed in proportion to the flow rate of the movements served by the associated lane group.

The last two rows in Exhibit 18-40 represent summary statistics for the approach. The approach volume represents the sum of the three movement volumes. Approach delay is computed as a volume-weighted average for the lane groups served on an intersection approach.

Timer Based Phase Data

Exhibit 18-41 provides a summary of the output data by using a signal controller perspective. The controller has eight timing functions (or timers), with Timers 1 to 4 representing Ring 1 and Timers 5 to 8 representing Ring 2. The ring structure and phase assignments were previously shown at the bottom of Exhibit 18-38. Timers 1 and 5 are not used at this intersection.

Exhibit 18-41
Example Problem 1: Timer Based Phase Output Data

Timer Data Timer	1	2 EB L,T,TR	3 NB L	4 SB T,R+A	5	6 WB L,T,TR	7 SB L	8 NB T,TR
Assigned Phase		2	3	4		6	7	8
Case No		6	1	6		6	1	6
Phase Duration (G+Y+Rc), s		36.70	17.21	32.09		36.70	17.17	14.11
Change Period (Y+Rc), s		4.70	4.00	4.00		4.70	4.00	4.00
Max Allowed Headway (MAH), s		3.44	3.11	3.06		3.44	3.13	3.06
Maximum Green, s		32.00	13.00	28.00		32.00	13.00	10.00
Max Queue Clearance Time (gc+I1), s		31.29	9.16	27.35		29.11	9.21	12.20
Green Extension Time (ge), s		0.00	0.09	0.00		0.00	0.00	0.00
Probability of Phase Call (pc)		1.00	0.97	1.00		1.00	0.95	1.00
Probability of Max Out (pm)		1.00	1.00	0.00		1.00	0.00	1.00
Equilibrium Cycle Length, s: 102								

The timing function construct is essential in modeling a ring-based signal controller. Timers always occur in the same numeric sequence (i.e., Timer 1 then 2 then 3 then 4 in Ring 1, 5 then 6 then 7 then 8 in Ring 2). The practice of associating movements to phases (e.g., the major-street through movement to Phase 2) coupled with the occasional need for lagging left-turn phases and split phasing creates the situation in which phases do not always occur in sequence. For example, with a lagging left-turn phase sequence, major street through Phase 2 times first and then major-street left-turn Phase 1 times second.

The modern controller accommodates the assignment of phases to timing functions by allowing the ring structure to be redefined manually or by time-of-day settings. Specification of this structure is automated in the computational engine by assigning phases to timers.

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The methodology is based on modeling timers, not by directly modeling movements or phases. The methodology converts movement and phase input data into timer input data. It then models controller response to these inputs and computes timer duration and related performance measures.

The signalized intersection in this example problem has a lead–lead left-turn phase sequence on the north–south street. Hence, the timer numbers for this street are the same as the phase numbers, which are the same as the movement numbers (e.g., the northbound left-turn Movement 3 is associated with Phase 3, which is assigned to Timer 3). In contrast, the east–west street does not have left-turn phases, so one timer and one phase are used to serve all movements on a given approach.

The case number shown in Exhibit 18-41 is used as a single variable descriptor of each possible combination of left-turn mode and lane group type (i.e., shared or exclusive). An understanding of this variable is not needed to interpret the output data.

The phase duration shown in the exhibit represents the estimated average phase duration during the analysis period. It represents the sum of the green, yellow change, and red clearance intervals. For Timer 2 (i.e., Phase 2), the average green interval duration is 30 s (= 34.00 – 4.00).

The durations of Phases 2, 3, and 4 add to the average cycle length of 101.67 s (= 34.00 + 10.21 + 57.66). Similarly, the durations of Phases 6, 7, and 8 add to the cycle length.

The cycle length is described in Exhibit 18-41 to be the "equilibrium" cycle length. The equilibrium cycle length is the average cycle length when all phase durations are dictated by traffic demand. However, the duration of several phases at this intersection is constrained by their maximum green limit. As such, the cycle length shown is not truly an equilibrium cycle length for this particular intersection.

The maximum green setting is input by the analyst. If the intersection were operated as coordinated-actuated, the "operational" maximum green setting would be shown here. It would be computed from the input phase splits and would reflect the specified force mode.

The maximum queue clearance time represents the largest queue clearance time of all lane groups served by the phase. Queue clearance time represents the time between the start of the green interval and the end of the queue service period. It is determined from the queue accumulation polygon. It includes the start-up lost time.

The maximum allowable headway, maximum green, and maximum queue clearance time apply only to actuated phases. They are not relevant to calculation of coordinated phase duration.

The green extension time represents the time the green interval is extended by arriving vehicles. This value is 0.0 s for two timers because they terminate by extension to their maximum limit (i.e., max-out).

The probability of a phase call represents the probability that one or more vehicles will place a call for service on the associated timer. The probability of

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max out represents the probability that the phase will extend to the maximum green setting and terminate, perhaps leaving some unserved vehicles on the intersection approach.

Timer-Based Movement Data

Exhibit 18-42 summarizes the output for the vehicle movements assigned to each timer. Separate sections of output are shown in the exhibit for the left-turn, through, and right-turn movements. The assigned movement row identifies the movement (previously identified in Exhibit 18-40) assigned to each timer.

Exhibit 18-42
Example Problem 1: Timer-Based Movement Output Data

Timer Data								
Timer	1	2 EB L,T,T+R	3 NB L	4 SB T,T+R	5	6 WB L,T,T+R	7 SB L	8 NB T,T+R
Left-Turn Movement Data								
Assigned Movement		5	2			1	7	
Yield Sat Flow, veh/h		956.73	1,597.65			518.58	1,597.65	
Through Movement Data								
Assigned Movements		2		4		6		8
Yield Sat Flow, veh/h		2,130.72		3,046.23		2,609.91		3,179.25
Right-Turn Movement Data								
Assigned Movement		12		14		16		18
Yield Sat Flow, veh/h		1,110.79		751.57		1,025....		810.1

The saturation flow rate shown in Exhibit 18-42 represents the saturation flow rate computed for the movement. For through movements in exclusive lanes, the movement saturation flow rate is equal to the number of through lanes times the adjusted saturation flow rate, times the pedestrian–bicycle adjustment factor, times the combined parking/bus blockage adjustment factor. For turn movements in exclusive lanes, the calculation is similar except that the left-turn (or right-turn) adjustment factor is also applied.

For turn movements that share a lane with a through movement, the saturation flow rate for the lane group is computed by using the procedure described in Chapter 31. The movement saturation flow rate represents the portion of the lane group saturation flow rate available to the movement, as distributed in proportion to the flow rate of the movements served by the lane group. To illustrate this point, consider Timer 4. It has a shared-lane lane group with 15.7% right-turning vehicles, 84.3% through vehicles, and a saturation flow rate of 1,624.5 veh/h/ln. The turn movement saturation flow rate is 254.67 veh/h/ln (= 0.157 × 1,624.5). The through movement saturation flow rate in this shared lane is 1,369.8 veh/h (= 0.843 × 1,624.5). The through movement is also served by one exclusive through lane with a saturation flow rate of 1,676.5 veh/h. Thus, the total through-movement saturation flow rate is 3,046.3 veh/h (= 1,369.8 + 1,676.5). The individual lane group saturation flow rates used in this example were obtained from the lane group data described in the next few sections.

Timer-Based Left Lane Group Data

Exhibit 18-43 summarizes the output for the "left" lane group associated with an intersection approach. Each left lane group includes the left-turn movements when they exist on an intersection approach. A left lane group will also contain all the output data for a single-lane approach, regardless of whether a left-turn movement exists.

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The "lane assignment" row indicates the lane groups served by the timer (e.g., L, left turn; T, through; R, right turn). The letter "L" is shown for Timers 2 and 6 as a reminder that the timer is serving a left-turn lane group. Other letter combinations are possible. For example, "L+T" indicates the timer is serving a lane group consisting of a shared lane serving left-turn and through movements. A "L+T+R" sequence indicates a single-lane approach serving all movements.

Exhibit 18-43
Example Problem 1: Timer Based Left Lane Group Output Data

Timer Data								
Timer	1	2 EB L,T,T+R	3 NB L	4 SB T,T+R	5	6 WB L,T,T+R	7 SB L	8 NB T,T+R
Left Lane Group Data								
Assigned Movement		5	2			1	7	
Lane Assignment		LTR/Pm*				LTR/Pm*		
Lanes in Group		1	1			1	1	
Group Volume (v), veh/h		70.0	53.0			113.0	13.0	
Group Saturation Flow (s), veh/h		1767	1.0921			1814	1.921	
Queue Service Time (g_s), s		17.2	4.1			14.1	2.6	
Cycle Queue Clearance Time (g_c), s		25.2	4.1			27.5	2.6	
Green Extension Time (g_e), s		0.0	0.0			0.0	0.0	
Phase Call Probability		1.00	1.00			1.00	1.00	
Max Out Probability		0.00	0.00			0.00	0.00	
Left-Turn Saturation Flow Rate, veh/h		1767	1.0921			1814	1.921	
Left-Turn Capacity, veh/h		1767	1.0921			1814	1.921	
Left-Turn Queue Size, veh		17.2	4.1			14.1	2.6	
Left-Turn Control Delay, s/veh		17.1	220.5			20.8	225.1	
Left-Turn Control Delay, s/veh		0.410	0.497			0.771	0.862	
Adjusted Capacity, veh/h		1152	1207			1269	1411	
Operational Delay Factor, I		1.000	1.000			1.000	1.000	
Uniform Delay, d_1, s/veh		16.536	102.13			41.881	99.229	
Incremental Delay, d_2, s/veh		0.510	1.304			2.196	5.751	
Delay Queue Size, d_3, s/veh		0.000	0.000			0.000	0.000	
Control Delay, d, s/veh		16.546	103.447			43.979	104.980	
Lane Group Queue Size, veh		0.0	0.0			0.0	0.0	
Average Lane Queue Size, veh		0.14	0.08			0.14	0.04	
1-Hr Lane Queue Size, veh		0.00	0.00			0.00	0.00	
Percent Blocking Time, %		0.00	0.00			0.00	0.00	
Percentile Back of Queue Size, veh		1.45	1.42			2.47	0.67	
Percentile Storage Ratio, %		0.272	0.141			0.765	0.405	
1-Hr Queue, veh		0.0	0.0			0.0	0.0	
1-Hr Back-of-Queue, veh		0.0	0.0			0.0	0.0	
Incremental Delay, d_2, s/veh		0.000	0.000			0.000	0.000	
Saturated Queue, veh		0.00	0.00			0.00	0.00	
Saturated Capacity, veh/h		0.0	0.0			0.0	0.0	
Total Queue Clearance Time (g_c), s		0.00	0.00			0.00	0.00	

The lane assignment row also indicates the operational mode for the left-turn movements. "Prot" indicates a protected left-turn mode. "Pe/Pm" indicates a protected-permitted left-turn mode. Other designations with the letter "L" indicate either a permitted left-turn mode or split phasing.

The rows listed in Exhibit 18-43 that start with "queue service time" and end with "uniform delay" correspond to variables that are computed from the queue accumulation polygon.

The permitted left-turn saturation flow rate represents the filtering flow rate of a permitted left-turn movement. Equations for computing this flow rate and the other variables identified with an asterisk (*) are described in Chapter 31.

The shared left-turn saturation flow rate is the saturation flow rate of a shared left-turn and through lane during the period after the final blocking left-turning vehicle arrives but before the queue service ends. This flow rate is applicable only when the opposing approach has one traffic lane. It reflects the opportunities to serve the subject approach that are created by left-turning vehicles in the opposing lane.

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The permitted left-turn effective green time represents the time available for permitted left-turn movement. In general, it is the time in the opposing through movement phase that is associated with a permissive green ball signal indication. Its duration can vary with phase sequence and timing.

The permitted left-turn service time represents the time required to serve the left turn queue. This time occurs during the permitted left-turn effective green time but after the conflicting queue clears. It exists for phases that operate in the permitted mode or in the protected-permitted mode.

The time to first block applies to a lane group with a shared lane and a left-turn movement that operates in the permitted or protected-permitted mode. It represents the time from the start of the through phase until the first left-turning vehicle arrives at the stop line and stops to wait for an acceptable gap in oncoming traffic.

The queue service time before the first block (i.e., serve time pre blk) represents the queue service time for a stream of through movements at a shared left-turn and through lane. If the left-turn flow rate is low, the time to first block may occur well into the phase. In this case, it is possible that the queue of through vehicles in the shared lane will be served before the first left-turning vehicle arrives. This variable applies only to lane groups with a shared left-turn lane.

The proportion of left-turning vehicles in the inside lane represents the distribution of vehicles in the left-lane group. If a left-turn bay exists, then the proportion equals 1.0. If the lane group is shared by left-turn and through movements, then the proportion can vary between 0.0 and 1.0. If it is 1.0, then the shared lane operates as an exclusive left-turn lane.

Uniform delay represents the area under the queue accumulation polygon. This polygon is based on an average arrival rate during the green indication and an average arrival rate during the red indication. As such, it reflects the effect of progression on the delay estimate.

The available capacity is computed for all actuated phases and noncoordinated phases. It is computed by using the maximum green setting for the phase. For coordinated phases, the available capacity is computed by using the average effective green time.

The incremental delay is computed by using the incremental delay equation. For actuated phases, it uses available capacity to estimate the incremental delay factor, *k*. For coordinated phases and phases set to "recall-to-maximum," it uses a factor of 0.50.

The first-term queue is a back-of-queue estimate that is obtained from an arrival–departure polygon. This polygon is based on the specification of arrival rates during the red and green intervals. As such, it reflects the effect of progression on first-term queue size. The procedure for developing this polygon is described in Chapter 31.

The second-term queue is computed as a derivative of the incremental delay estimate. It represents the average number of vehicles in queue each cycle due to

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random variation in arrivals plus those vehicles in queue due to oversaturation during the analysis period.

The queue storage ratio represents the ratio of the back-of-queue size to the available storage length. In general, this ratio can be computed for turn bays and through lanes; however, it is computed only for the left turn bays in this example. A value of 0.00 indicates that no turn vehicles are queued in the bay. A value of 1.0 or more indicates that the queue completely fills the bay at some point during the cycle.

The initial queue reflects the input initial queue value when a single analysis period is evaluated. In contrast, it reflects the residual queue from the previous analysis period for the second and subsequent analysis periods of a multiple-period analysis.

The saturated delay, queue, and capacity data reflect the output from a complete (and separately computed) intersection analysis. For this separate analysis, lane groups with an initial queue will have their demand flow rate adjusted so that volume equals lane group capacity. The saturated delay equals the uniform delay computed for this "saturated" condition. Similarly, the "saturated" queue equals the first-term queue for the saturated condition.

The initial queue clear time indicates the time when the last vehicle that arrives at an overflow queue during the analysis period clears the intersection (measured from the start of the analysis period).

Timer-Based Middle Lane Group Data

Exhibit 18-44 provides a summary of the output for the "middle" lane group associated with an intersection approach. This lane group is used when one or more exclusive lanes serve through vehicles on an intersection approach. The explanation of the various output statistics is the same as that previously given for the left lane groups.

In Exhibit 18-41, the exclusive through lane served by Timer B has a volume-to-capacity ratio that slightly exceeds 1.0. This condition results in a large value of control delay (= 73.6 s/veh) and a final (i.e., residual) queue size of 11.5 veh. The last vehicle to arrive at this queue during the analysis period will depart the intersection 0.294 h after the *start* of the 0.25-h analysis period.

Timer-Based Right Lane Group Data

Exhibit 18-45 summarizes the output for the "right" lane group associated with an intersection approach. This lane group is used when there are two or more lanes on an intersection approach and a through or right turn movement is present. A lane that is shared by the right turn and through movements is always shown in the right lane group. The explanation of the various output statistics is the same as that previously given for the left lane groups.

The protected right-turn saturation flow rate row is used when the right-turn movement is provided a green arrow indication concurrently with its complementary left-turn phase on the cross street. This flow rate represents the saturation flow rate during the green arrow. Similarly, the protected right-turn effective green time equals the effective green time coincident with the green

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arrow indication. This operation is not provided at the subject intersection, so the values for these two variables equal 0.0.

Exhibit 18-44
Example Problem 1: Timer-Based Middle Lane Group Output Data

Timer:	1	2 EB L T T+R	3 NB L	4 SB T T+R	5	6 WB L T T+R	7 EB L	8 NB T T+R
Middle Lane Group Data								
Assigned Movement		2		4		6		8
Lane Assignment		T		T		T		T
Lane Group		1		1		1		1
Green Extension Time, g_e (s)		2.4		0.0		0.0		0.0
Green Ratio, g/C		0.286		0.643		0.429		0.429
Queue Service Time, g_s (s)		11.0		21.4		13.4		29.0
Cycle Queue Clearance Time, g_c (s)		13.4		21.4		13.4		29.0
Green-Up Lost Time, l_1 (s)		4.0		0.0		0.0		0.0
Yellow Plus Lost Time, l_2 (s)		4.0		0.0		0.0		0.0
Available Capacity, c_a (veh/h)		474		1010		706		577
Upstream Filter Factor, I		1.00		1.00		1.00		1.00
Uniform Delay (d_1), s/veh		36.0		16.4		31.4		37.5
Incremental Delay (d_2), s/veh		1.4		0.4		0.4		47.4
Initial Queue Delay, d_3, s/veh		0.0		0.0		0.0		0.0
Control Delay (d), s/veh		37.5		16.8		31.8		84.9
Initial Queue (Q_b), veh		0.0		0.0		0.0		0.0
Average Queue (Q), veh/ln		4.0		7.6		4.7		17.6
Second-Term Queue (Q_2), veh/ln		3.9		6.9		4.5		15.9
Third-Term Queue (Q_3), veh/ln		0.0		0.0		0.0		0.0
Percentile Queue Factor, P_f		1.00		1.00		1.00		1.00
Percentile Queue (Q_p), veh/ln		4.0		7.7		4.7		17.6
Queue Storage Ratio (RQ), veh/ln		0.14		0.08		0.07		0.17
Initial Queue (Q_b), veh		0.0		0.0		0.0		0.0
Time-Dependent Queue (Q_t), veh		0.0		0.0		0.0		0.0
Spillback Ratio (R_b), veh/ln		0.00		0.00		0.00		0.00
Saturated Queue (Q_s), veh/ln		0.04		0.00		0.01		0.00
Saturated Queue Ratio (RQ_s), veh/ln		0.1		0.0		0.1		0.0
Total Queue (Q_t), veh/ln		0.0		0.0		0.0		0.0

Exhibit 18-45
Example Problem 1: Timer-Based Right Lane Group Output Data

Timer:	1	2 EB L T T+R	3 NB L	4 SB T T+R	5	6 WB L T T+R	7 EB L	8 NB T T+R
Right Lane Group Data								
Assigned Movement		12		14		16		18
Lane Assignment		T+R		T+R		T+R		T+R
Lanes in Group		1		1		1		1
Group Capacity, c (veh/h)		1576		2026		2021		1829
Adjusted Flow Rate, v (veh/h)		1,012		1,644		1,147		1,642
Queue Service Time, g_s (s)		11.0		21.4		13.4		29.0
Cycle Queue Clearance Time, g_c (s)		13.4		21.4		13.4		29.0
Prop. RT in Free Lane (P_{RT})		1.00		0.00		0.00		0.00
Prop. RT in Lane Group (P_R)		1.00		0.00		0.00		0.00
Right-Turn RT Service Time ($g_{s,RT}$)		11.0		0.0		0.0		0.0
Adj. Saturation Flow Rate (s_{adj})		1900		1900		1900		1900
Adj. Saturation Flow Rate (s)		1576		2026		2021		1829
Right-Turn Capacity (c_{RT})		1576		2026		2021		1829
Left-Turn Adjustment ($P_{LT,adj}$)		1.00		1.00		1.00		1.00
Right-Turn Adjustment ($P_{RT,adj}$)		0.86		1.00		0.86		0.86
Arrival Type		3		3		3		3
Approach Delay (d_A), s/veh		37.5		16.8		31.8		84.9
Intersection Delay (d_I), s/veh		39.9						
Intersection LOS		D						
Approach Delay (d_A), s/veh		37.5		16.8		31.8		84.9
Approach LOS		D		B		C		F
Lane Group Capacity, Control Delay, and LOS Determination								
Adjusted Flow Rate, v (veh/h)		1012		1644		1147		1642
Lane Group Capacity, c (veh/h)		1576		2026		2021		1829
v/c Ratio, X		0.642		0.811		0.568		0.898
Green Ratio, g/C		0.286		0.643		0.429		0.429
Uniform Delay Factor, k		0.500		0.500		0.500		0.500
Incremental Delay Factor, I		1.000		1.000		1.000		1.000
Uniform Delay (d_1), s/veh		36.0		16.4		31.4		37.5
Incremental Delay (d_2), s/veh		1.4		0.4		0.4		47.4
Initial Queue Delay, d_3, s/veh		0.0		0.0		0.0		0.0
Control Delay (d), s/veh		37.5		16.8		31.8		84.9
Initial Queue (Q_b), veh		0.0		0.0		0.0		0.0
Average Queue (Q), veh/ln		4.0		7.6		4.7		17.6
Second-Term Queue (Q_2), veh/ln		3.9		6.9		4.5		15.9
Third-Term Queue (Q_3), veh/ln		0.0		0.0		0.0		0.0
Percentile Queue Factor, P_f		1.00		1.00		1.00		1.00
Percentile Queue (Q_p), veh/ln		4.0		7.7		4.7		17.6
Queue Storage Ratio (RQ), veh/ln		0.14		0.08		0.07		0.17
Initial Queue (Q_b), veh		0.0		0.0		0.0		0.0
Time-Dependent Queue (Q_t), veh		0.0		0.0		0.0		0.0
Spillback Ratio (R_b), veh/ln		0.00		0.00		0.00		0.00
Saturated Queue (Q_s), veh/ln		0.04		0.00		0.01		0.00
Saturated Queue Ratio (RQ_s), veh/ln		0.1		0.0		0.1		0.0
Total Queue (Q_t), veh/ln		0.0		0.0		0.0		0.0

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Results

A comparison of the lane-group volumes in Exhibit 18-43, Exhibit 18-44, and Exhibit 18-45 indicates the extent to which drivers are expected to distribute themselves among the lane groups on each intersection approach. For example, Timer 2 serves three lane groups on the eastbound approach. The left lane group is an exclusive lane and serves all left-turn movements. The middle lane group serves 239 veh/h of the 318 veh/h of the through movement (i.e., about 75%). The right lane group serves the remaining through vehicles (i.e., 79 veh/h) and the right-turning vehicles (106 veh/h) for a total flow rate of 185 veh/h. There are fewer vehicles in the right lane group (i.e., 185 versus 239) because some through drivers choose the middle lane to avoid any possible delay that might be incurred by the presence of right-turning vehicles in the outside lane.

Exhibit 18-46 summarizes the delay for each lane group, approach, and the intersection as a whole. It also provides the volume-to-capacity ratio and LOS for each lane group. The delay varies widely among lane groups, as does the LOS. The northbound through and right-turn movements have the highest delay and a LOS F condition.

Exhibit 18-46
Example Problem 1: Performance Measure Summary

The fact that several phases are terminating by maximal and that the northbound through and right-turn movements are congested (i.e., Timer 4) suggests that some improvements could be made at this intersection. Simply increasing the maximum green settings is not a solution and, in fact, increases the overall delay and queue size for most lane groups. Physical changes to the intersection geometry to increase capacity could be considered.

EXAMPLE PROBLEM 2: PEDESTRIAN LOS

The Intersection

The pedestrian crossing of interest crosses the north leg at a signalized intersection. The north–south street is the minor street and the east–west street is the major street. The intersection serves all north–south traffic concurrently (i.e., no left-turn phases) and all east–west traffic concurrently. The signal has an 80-s cycle length. The crosswalk and intersection corners that are the subject of this example problem are shown in Exhibit 18-47.

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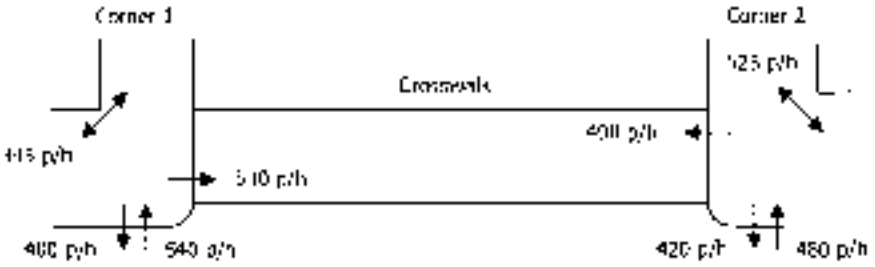
Exhibit 18-47
Example Problem 2: Pedestrian Flow Rates



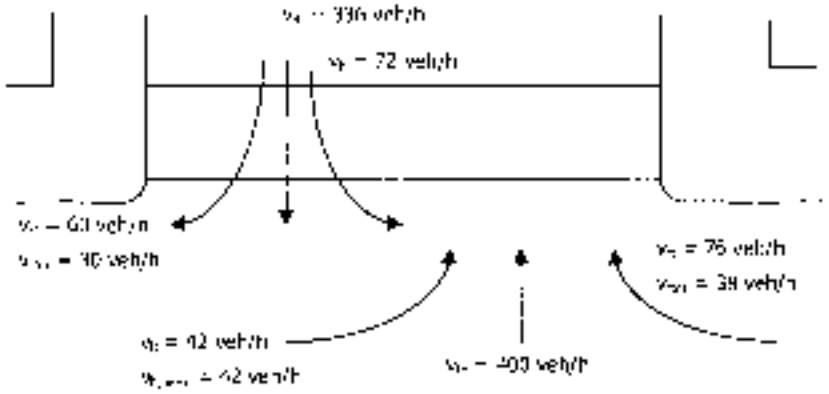
The Question

What is the pedestrian LOS for the crossing?

The Facts

Pedestrian flow rates are shown in Exhibit 18-47. Vehicular flow rates are shown in Exhibit 18-48.

Exhibit 18-48
Example Problem 2: Vehicular Demand Flow Rates



In addition, the following facts are known about the crosswalk and the intersection corners:

Major street:
- Phase duration, D_{ped} = 48 s
- Yellow change interval, Y_{ped} = 4 s
- Red clearance interval, R_{ped} = 1 s
- Walk setting, $Walk_{ped}$ = 7 s
- Pedestrian clear setting, PC_{ped} = 8 s
- Four traffic lanes (no turn bays)

Minor street:
- Phase duration, D_{ped} = 32 s
- Yellow change interval, Y_{ped} = 4 s
- Red clearance interval, R_{ped} = 1 s
- Walk setting, $Walk_{ped}$ = 7 s
- Pedestrian clear setting, PC_{ped} = 13 s
- Two traffic lanes (no turn bays)
- 85th percentile speed at a midsegment location, S_{85} = 35 mi/h

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Corner 1:	Total walkway width, W_c = W_s = 16 ft
	Corner radius, R = 15 ft
Corner 2:	Total walkway width, W_c = W_s = 16 ft
	Corner radius, R = 15 ft
Other data:	No right-turn channelizing islands provided on any corner
	Effective crosswalk width, W_c = 16 ft
	Crosswalk length, L_c = 25 ft
	Walking speed, S_p = 4 ft/s
	Pedestrian signal indications are provided for each crosswalk.
	Rest-in-walk mode is not used for any phase.

Comments

On the basis of the variable notation in Exhibit 18-25, the subject crosswalk is "Crosswalk C" because it crosses the minor street. The outbound pedestrian flow rate v_o at Corner 1 equals inbound flow rate v_i at Corner 2, and the inbound flow rate v_i at Corner 1 equals the outbound flow rate v_o at Corner 2.

Outline of Solution

First, the circulation area is calculated for both corners. Next, the circulation area is calculated for the crosswalk. The street corner and crosswalk circulation areas are then compared with the qualitative descriptions of pedestrian space listed in Exhibit 18-24.

Pedestrian delay and the pedestrian LOS score are then calculated for the crossing. Finally, LOS for the crossing is determined on the basis of the computed score and the threshold values in Exhibit 18-5.

Computational Steps

Step 1: Determine Street Corner Circulation Area

A. Compute Available Time Space

For Corner 1, the available time space is computed with Equation 18-52.

$$TS_{corner} = C(W_c W_s - 0.215R^2)$$

$$TS_{corner} = (80)[(16)(16) - 0.215(15)^2]$$

$$TS_{corner} = 16{,}610 \text{ ft}^2\text{-s}$$

B. Compute Holding-Area Waiting Time

Because pedestrian signal indications are provided and rest-in-walk is not enabled, the effective walk time for the phase serving the major street is computed with Equation 18-49.

$$g_{walk,eff} = Walk_{ped} - 4.0$$

$$g_{walk,eff} = 7.0 + 4.0 = 11 \text{ s}$$

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The number of pedestrians arriving at the corner during each cycle to cross the minor street is computed with Equation 18-54.

$$N_{ped} = \frac{v_{ped}}{3{,}600} C$$

$$N_{ped} = \frac{530}{3{,}600}(80) = 11.8 \text{ p}$$

The total time spent by pedestrians waiting to cross the minor street during one cycle is then calculated with Equation 18-53.

$$Q_{ped} = \frac{N_{ped}(C - g_{walk,eq})^2}{2C}$$

$$Q_{ped} = \frac{(11.8)(80 - 12)^2}{2(80)} = 350.5 \text{ p-s}$$

By the same procedure, the total time spent by pedestrians waiting to cross the major street during one cycle (Q_{ped}) is found to be 264.5 p-s.

C. Compute Circulation Time–Space

The circulation time–space is found by using Equation 18-58.

$$TS = TS_{corner} - [5.0(Q_{ped} + Q_{ped})]$$

$$TS_c = 26{,}610 - [5.0(350.5 + 264.5)] = 13{,}535 \text{ ft}^2\text{-s}$$

D. Compute Pedestrian Corner Circulation Area

The total number of circulating pedestrians is computed with Equation 18-60.

$$N_{ped} = \frac{v_{p1} + v_{p2} - v_{p3} + v_{p4} + v_{p5}}{3{,}600} C$$

$$N_{ped} = \frac{490 - 530 + 540 + 400 + 345}{3{,}600}(80) = 51.2 \text{ p}$$

Finally, the corner circulation area per pedestrian is calculated with Equation 18-59.

$$M_{corner} = \frac{TS_c}{4.0 N_{ped}}$$

$$M_{corner} = \frac{13{,}535}{4.0(51.2)} = 66.1 \text{ ft}^2\text{/p}$$

By following the same procedure, the corner circulation area per pedestrian for Corner 2 is found to be 87.6 ft²/p. According to the qualitative descriptions provided in Exhibit 18-24, pedestrians at both corners will have the ability to move in the desired path, with no need to alter their movements to avoid conflicts.

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Step 2: Determine Crosswalk Circulation Area

The analysis conducted in this step describes the circulation area for pedestrians in the subject crosswalk.

A. Establish Walking Speed

As given in the "Facts" section, the average walking speed is determined to be 4.0 ft/s.

B. Compute Available Time-Space

Rest in walk is not enabled, so the pedestrian service time g_p is estimated to equal the sum of the walk and pedestrian clear settings. The time–space available in the crosswalk is found with Equation 18-63.

$$TS_w = L_c W_c (g_{walk,ad})$$

$$TS_w = (28)(16)(11) = 4{,}928 \text{ ft}^2\text{-s}$$

C. Compute Effective Available Time–Space

The number of turning vehicles during the walk and pedestrian clear intervals is calculated with Equation 18-64.

$$N_{tv} = \frac{v_{lt,opp} + v_{rt} + v_{o,ped}}{3{,}600} C$$

$$N_{tv} = \frac{42 + 76 + 38}{3{,}600}(80) = 1.8 \text{ veh}$$

The time–space occupied by turning vehicles can then be computed with Equation 18-65.

$$TS_v = 40 N_{tv} W_c$$

$$TS_v = 40(1.8)(16) = 1{,}138 \text{ ft}^2\text{-s}$$

The effective available crosswalk time–space TS_e is found by subtracting the total available cross-walk time–space TS_w from the time–space occupied by turning vehicles.

$$TS_e = TS_w - TS_v$$

$$TS_e = 4{,}928 - 1{,}138 = 3{,}790 \text{ ft}^2\text{-s}$$

D. Compute Pedestrian Service Time

The number of pedestrians exiting the curb when the WALK indication is presented is as follows:

$$N_{ped,w} = N_v \frac{C - g_{walk,ad}}{C}$$

$$N_{ped,w} = (11.8)\frac{80 - 11}{80} = 10.2 \text{ p}$$

Because the crosswalk width is greater than 10 ft, the pedestrian service time is computed as follows:

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$$t_{p,ped} = 3.2 + \frac{L}{S_p} - 2.7\frac{N_{ped,o}}{W_e}$$

$$t_{p,ped} = 3.2 + \frac{28}{4.0} + 2.7\left(\frac{10.2}{16}\right) = 13.9 \text{ s}$$

The other travel direction in the crosswalk is analyzed next. The number of pedestrians arriving at Corner I each cycle by crossing the minor street is as follows:

$$N_c = \frac{v_{ped} C}{3{,}600}$$

$$N_c = \frac{490}{3{,}600}(80) = 10.9 \text{ p}$$

The sequence of calculations is repeated for this second travel direction in the subject crosswalk to indicate that $N_{ped,o}$ is equal to 9.4 p and $t_{p,o}$ is 11.8.

E. Compute Crosswalk Occupancy Time

The crosswalk occupancy time for the crosswalk is computed as follows:

$$T_{cw} = t_{p,o} N_{ped,o} + t_{p,ped} N_c$$

$$T_{cw} = 13.9\,(11.8) + 11.8\,(10.9) = 268.6 \text{ p-s}$$

F. Compute Pedestrian Crosswalk Circulation Area

Finally, the crosswalk circulation area per pedestrian for the crosswalk is computed as follows:

$$M_{cw} = \frac{WS_{cw}}{T_{cw}}$$

$$M_{cw} = \frac{3{,}790}{268.6} = 14.1 \text{ ft}^2/\text{p}$$

The crosswalk circulation area is found to be 14.1 ft²/p. According to the qualitative descriptions provided in Exhibit 18-24, pedestrians will find that their walking speed is restricted, with very limited ability to pass slower pedestrians. Improvements to the crosswalk should be considered and may include a wider crosswalk or a longer walk interval.

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Step 3: Determine Pedestrian Delay

The pedestrian delay is calculated as follows.

$$d_p = \frac{(C - g_{walk,ad})^2}{2C}$$

$$d_p = \frac{(80 - 12)^2}{2(80)} = 29.8 \text{ s/p}$$

Step 4: Determine Pedestrian LOS Score for Intersection

The number of vehicles traveling on the minor street during a 15-min period is computed as follows:

$$v_{15,m} = \frac{0.25}{N_t} \sum v_i$$

$$v_{15,m} = \frac{0.25}{2}(72 + 336 + 60 - 42 + 400 + 76) = 123.3 \text{ veh/ln}$$

The cross-section adjustment factor is calculated as follows:

$$F_w = 0.681(N)^{0.314}$$

$$F_w = 0.681(2)^{0.314} = 0.972$$

The motorized vehicle adjustment factor is computed as follows.

$$F_v = 0.00569\left(\frac{v_{15,m} + v_{15,prot}}{4}\right) - N_{ped}(0.0027 v_{15,m} - 0.1946)$$

$$F_v = 0.00569\left(\frac{30 - 42}{4}\right) - (0)[0.0027(123.3) - 0.2946] = 0.102$$

The motorized vehicle speed adjustment factor is then computed:

$$F_s = 0.00013\, v_{15,m} S_{prot}$$

$$F_s = 0.00013(123.3)(35) = 0.561$$

The pedestrian delay adjustment factor is calculated as follows:

$$F_{delay} = 0.0401 \ln(d_{ped})$$

$$F_{delay} = 0.0401 \ln(29.8) \quad 0.136$$

The pedestrian LOS score for the intersection $I_{p,int}$ is then computed as follows:

$$I_{p,int} = 0.5997 + F_w + F_v - F_s - F_{delay}$$

$$I_{p,int} = 0.5997 + 0.972 + 0.102 - 0.561 + 0.136 = 2.37$$

For this crosswalk, $I_{p,int}$ is found to be 2.37.

Step 5: Determine LOS

According to Exhibit 18-5, the crosswalk operates at LOS B.

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Discussion

The crosswalk was found to operate at LOS D in Step 5. It was determined in Step 1 that the pedestrians at both corners have adequate space to allow freedom of movement. Crosswalk circulation area was found to be restricted in Step 2 and improvements are probably justified. Moreover, the pedestrian delay computed in Step 3 was found to be slightly less than 50 s/p. With this much delay, some pedestrians may not comply with the signal indication.

EXAMPLE PROBLEM 3: BICYCLE LOS

The Intersection

A 5 ft wide bicycle lane is provided at a signalized intersection.

The Question

What is the LOS of this bicycle lane?

The Facts

Saturation flow rate for bicycles = 2,000 bicycles/h

Effective green time = 48 s

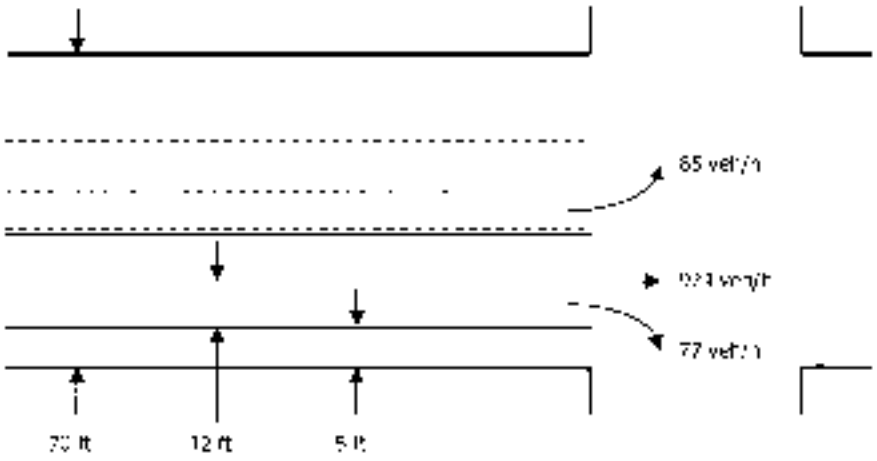
Cycle length = 120 s

Bicycle flow rate = 120 bicycles/h

No on-street parking.

The vehicular flow rates and street cross-section element widths are as shown in Exhibit 18-49.

Exhibit 18-49
Example Problem 3: Vehicular Demand Flow Rates and Cross-Section Element Widths



Outline of Solution

Bicycle delay and the bicycle LOS score will be computed. LOS is then determined on the basis of the computed score and the threshold values in Exhibit 18-5.

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Computational Steps

Step 1: Determine Bicycle Delay

A. Compute Bicycle Lane Capacity

The capacity of the bicycle lane is calculated with Equation 18-78:

$$c_b = s_b \frac{g_b}{C}$$

$$c_b = (2{,}000)\frac{48}{120} = 800 \text{ bicycles/h}$$

B. Compute Bicycle Delay

Bicycle delay is computed with Equation 18-79:

$$d_b = \frac{0.5C(1 - g_b/C)^2}{1 - \frac{N_b}{C}\text{Min}\left[\frac{v_b}{c_b}, 1.0\right]}$$

$$d_b = \frac{0.5(120)(1 - 48/120)^2}{1 - \frac{48}{120}\text{Min}\left[\frac{120}{800}, 1.0\right]} = 23.0 \text{ s/bicycle}$$

Step 2: Determine Bicycle LOS Score for Intersection

As shown in Exhibit 18-49, the total width of the outside through lane, bicycle lane, and paved shoulder is 17 ft (= 12 + 5 + 0). The cross section adjustment factor can then be calculated with Equation 18-81:

$$F_v = 0.0153W_e - 0.2144W_t$$

$$F_v = 0.0153(70) - 0.2144(17) = -2.57$$

The motor-vehicle volume adjustment factor must also be calculated, by using Equation 18-82.

$$F_t = 0.0066\frac{v_{lt} + v_{rt} + v_o}{4N_{ln}}$$

$$F_t = 0.0066\frac{85 + 924 + 77}{4(2)} = 0.90$$

The bicycle LOS score can now be computed with Equation 18-80:

$$I_{b,int} = 4.1324 - F_v + F_t$$

$$I_{b,int} = 4.1324 - 2.57 + 0.90 = 2.45$$

Step 3: Determine LOS

According to Exhibit 18-5, this bicycle lane would operate at LOS B through the signalized intersection.

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Discussion

The bicycle lane was found to operate at LOS B. The bicycle delay was found to be 23.0 s/bicycle, which is low enough that most bicyclists are not likely to be impatient. However, if the signal timing at the intersection were to be changed, the bicycle delay would need to be computed again to verify that it does not rise above 30 s/bicycle.

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CHAPTER 19
TWO-WAY STOP-CONTROLLED INTERSECTIONS

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1. INTRODUCTION

Two-way STOP-controlled (TWSC) intersections are common in the United States. One typical configuration is a four-leg intersection, where one street—the *major street*—is uncontrolled, while the other street—the *minor street*—is controlled by stop signs. The other typical configuration is a three-leg intersection, where the single minor-street approach (i.e., the stem of the T configuration) is controlled by a STOP sign. Minor street approaches can be public streets or private driveways. **Chapter 19, Two-Way STOP-Controlled Intersections,** presents concepts and procedures for analyzing these types of intersections. Chapter 9 provides a glossary and list of symbols, including those used for TWSC intersections.

Capacity analysis of TWSC intersections requires a clear description and understanding of the interaction between travelers on the minor, or stop-controlled, approach with travelers on the major street. Both gap acceptance and empirical models have been developed to describe this interaction. Procedures described in this chapter rely primarily on field measurements of TWSC performance in the United States (*1*) that have been applied to a gap acceptance model developed and refined in Germany (*2*).

INTERSECTION ANALYSIS BOUNDARIES AND TRAVEL MODES

The intersection boundaries for a TWSC intersection analysis are assumed to be those of an isolated intersection (i.e., not affected by upstream or downstream intersections), with the exception of TWSC intersections that are located within 0.25 mi of a signalized intersection (for the major-street approaches). This chapter presents methodologies to assess TWSC intersections for both pedestrians and motor vehicles. A discussion of how the procedures for motor vehicles could potentially apply to an analysis of bicycle movements is also provided.

LEVEL-OF-SERVICE CRITERIA

Level of service (LOS) for a TWSC intersection is determined by the computed or measured control delay. For motor vehicles, LOS is determined for each minor-street movement (or shared movement) as well as major-street left turns by using criteria given in Exhibit 19-1. LOS is not defined for the intersection as a whole or for major-street approaches for three primary reasons: (a) major-street through vehicles are assumed to experience zero delay; (b) the disproportionate number of major-street through vehicles at a typical TWSC intersection skews the weighted average of all movements, resulting in a very low overall average delay for all vehicles; and (c) the resulting low delay can mask important LOS deficiencies for minor movements. As Exhibit 19-1 notes, LOS F is assigned to the movement if the volume-to-capacity ratio for the movement exceeds 1.0, regardless of the control delay.

The LOS criteria for TWSC intersections are somewhat different from the criteria used in Chapter 18 for signalized intersections, primarily because user perceptions differ among transportation facility types. The expectation is that a signalized intersection is designed to carry higher traffic volumes and will

SIGNALIZED INTERSECTIONS
15. Urban Street Facilities
17. Urban Street Segments
18. Signalized Intersections
19. TWSC Intersections
20. AWSC Intersections
21. Roundabouts
22. Freeway Ramp Terminals
23. Off-Street Pedestrian and Bicycle Facilities

Two-way intersections are considered a standard type of TWSC intersection, when the stem of the T is controlled by a stop sign.

LOS is not defined for the major-street approaches or for the overall intersection, as major-street through vehicles are assumed to experience no delay.

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present greater delay than an unsignalized intersection. Unsignalized intersections are also associated with more uncertainty for users, as delays are less predictable than they are at signals, which can reduce users' delay tolerance.

Exhibit 19-1
Level of Service Criteria: Automobile Mode

Control Delay (s/vehicle)	LOS by Volume-to-Capacity Ratio	
	v/c ≤ 1.0	v/c > 1.0
0–10	A	F
>10–15	B	F
>15–25	C	F
>25–35	D	F
>35–50	E	F
>50	F	F

Note: The LOS criteria apply to each lane on a given approach and to each approach on the minor street. LOS is not calculated for major street approaches or for the intersection as a whole.

Pedestrian LOS at TWSC intersections is defined for pedestrians crossing a traffic stream not controlled by a STOP sign. It also applies to midblock pedestrian crossings. LOS criteria for pedestrians are given in Exhibit 19-2.

Exhibit 19-2
Level-of-Service Criteria: Pedestrian Mode

LOS	Control Delay (s/pedestrian)	Comments
A	0–5	Delay as for conflicting traffic
B	5–10	Occasionally some delay due to conflicting traffic
C	10–20	Delay noticeable to pedestrians, but not inconveniencing
D	20–30	Delay noticeable and irritating, increased likelihood of risk taking
E	30–45	Delay approaches tolerance level, risk-taking behavior likely
F	>45	Delay exceeds tolerance level; high likelihood of pedestrian risk taking

Note: Control delay may be interpreted as a pedestrian group if a mix of pedestrians with a mixture of crossing individual pedestrians.

LOS F for pedestrians occurs when there are not enough gaps of suitable size to allow waiting pedestrians to cross through traffic on the major street safely. This situation is typically evident from extremely long control delays. The method is based on a constant critical headway. In the field, however, LOS F may also appear in the form of crossing pedestrians selecting smaller-than-usual gaps. In such cases, safety could be a concern that warrants further study.

REQUIRED INPUT DATA

Analysis of a TWSC intersection requires the following data:

1. Number and configuration of lanes on each approach;
2. Percentage of heavy vehicles for each movement;
3. Either of the following:
   a. Demand flow rate for each entering vehicular movement and each pedestrian crossing movement during the peak 15 min, or
   b. Demand flow rate for each entering vehicular movement and each pedestrian crossing movement during the peak hour and a peak hour factor for the hour;
4. Special geometric factors such as
   a. Unique channelization aspects,
   b. Existence of a two-way left-turn lane or raised or striped median storage (or both),

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c. Approach grades,

d. Existence of flared approaches on the minor street, and

e. Existence of upstream signals;

5. The rate at which motorists yield to pedestrians and the degree of pedestrian platooning (for pedestrian LOS analysis); and

6. Length of analysis period, generally a peak 15-min period within the peak hour.

SCOPE OF THE METHODOLOGY

This chapter focuses on TWSC intersection operations. This version of the TWSC intersection analysis procedures is primarily based on studies conducted by National Cooperative Highway Research Program Project 3-60 (1).

LIMITATIONS OF THE METHODOLOGY

Automobile Mode

The methodologies in this chapter apply to TWSC intersections with up to three through lanes (either shared or exclusive) on the major street approaches and up to three lanes on the minor street approaches (with no more than one exclusive lane for each movement on the minor street approach). Effects from other intersections are accounted for only in situations in which a TWSC intersection is located on an urban street segment between coordinated signalized intersections. In this situation, the intersection can be analyzed by using the procedures in Chapter 17, Urban Street Segments. The methodologies do not apply to TWSC intersections with more than four approaches.

The methodologies do not include a detailed method for estimating delay at yield-controlled intersections; however, with appropriate changes in the values of key parameters (e.g., critical headway and follow-up headway), the analyst could apply the TWSC method to yield-controlled intersections.

With appropriate changes in the values of critical headway and follow-up headway, the analyst could apply the TWSC method to yield-controlled intersections.

All the methods are for steady-state conditions (i.e., the demand and capacity conditions are constant during the analysis period); the methods are not designed to evaluate how fast or how often the facility transitions from one demand or capacity state to another. Analysts interested in that kind of information should consider applying alternative tools, as discussed later in this chapter.

Pedestrian Mode

The limitations of the pedestrian methodologies are somewhat different from those of the automobile mode, as the methods were developed in separate research efforts. In this chapter, pedestrian methodologies apply to TWSC intersections and midblock crossings where pedestrians cross up to four through lanes on the major street. The analysis procedure does not apply to undivided streets with more than four lanes, although it can accommodate up to four lanes in each direction separated by a median. The methodologies do not account for interaction effects of upstream signalized intersections. The analysis procedure assumes random arrivals on the major street and critical directional and lane

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distribution on the major street. It does not account for the effects of upstream signals.

The analysis procedure does not take into account pedestrian cross flows (i.e., pedestrian flows approximately perpendicular to and crossing another pedestrian stream) and assumes that the pedestrian will reach the crossing without delay from pedestrians traveling parallel to the major street. Under high pedestrian volumes, this assumption may not be reasonable.

All the methods are for steady-state conditions (i.e., the demand and capacity conditions are constant during the analysis period); the methods are not designed to evaluate how fast or how often the facility transitions from one demand or capacity state to another.

Bicycle Mode

At the time of publication of this edition of the HCM, the current methodologies for analyzing LOS and delay at TWSC intersections apply to bicycles in limited situations that are not supported by research. As such, there are no established LOS standards for bicycles at TWSC intersections. Additional research on bicycle behavior and operations at TWSC intersections needs to be done before procedures that adequately address these issues can be developed. A discussion of qualitative effects is included in the methodology section of this chapter.

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2. METHODOLOGY

OVERVIEW

TWSC intersections require only drivers on the minor street approaches to stop before proceeding into the intersection. Left turning drivers from the major street may have to yield to oncoming major street through or right-turning traffic but are not required to stop in the absence of oncoming traffic.

The methodologies presented rely on the acquired input data listed previously to compute the potential capacity of each minor movement, which is ultimately adjusted, if appropriate, to compute a movement capacity for each movement. The movement capacity can be used to estimate the control delay by movement, by approach, and for the intersection as a whole. Queue lengths can also be estimated once movement capacities are determined.

The capacity of the controlled legs is based primarily on three factors: the distribution of gaps in the major stream, driver judgment in selecting the gaps, and the follow-up headways required by each driver in a queue.

At TWSC intersections, drivers on the stop controlled approaches are required to select gaps in the major-street flow in order to execute crossing or turning maneuvers. In the presence of a queue, each driver on the controlled approach must also use some time to move into the front-of-queue position and prepare to evaluate gaps in the major-street flow. Thus, the capacity of the controlled legs is based primarily on three factors: the distribution of gaps in the major street traffic stream, driver judgment in selecting gaps through which to execute the desired maneuvers, and the follow up headways required by each driver in a queue.

The basic capacity model assumes that gaps in the conflicting movements are randomly distributed. When traffic signals on the major street are within 0.25 mi of the subject intersection, flows may not be random but will likely have some platoon structure.

For the automobile mode analysis, the methodology addresses a number of special circumstances that may exist at TWSC intersections, including the following:

- Two-stage gap acceptance,
- Approaches with shared lanes,
- The presence of upstream traffic signals, and
- Paired approaches for minor street right-turning vehicles.

THEORETICAL BASIS

Gap-acceptance models begin with the recognition that TWSC intersections give no positive indication or control to the driver on the minor street as to when it is appropriate to leave the stop line and enter the major street. The driver must determine when a gap on the major street is large enough to permit entry and when to enter, on the basis of the relative priority of the competing movements. This decision-making process has been formalized analytically into what is commonly known as gap acceptance theory. Gap-acceptance theory includes three basic elements: the size and distribution (availability) of gaps on the major

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street, the usefulness of these gaps to the minor-street drivers, and the relative priority of the various movements at the intersection.

Availability of Gaps

The first element to consider is the proportion of gaps of a particular size on the major street offered to the driver entering from the minor street as well as the pattern of arrival times of vehicles. The distribution of gaps between the vehicles in the different streams has a major effect on the performance of the intersection.

Usefulness of Gaps

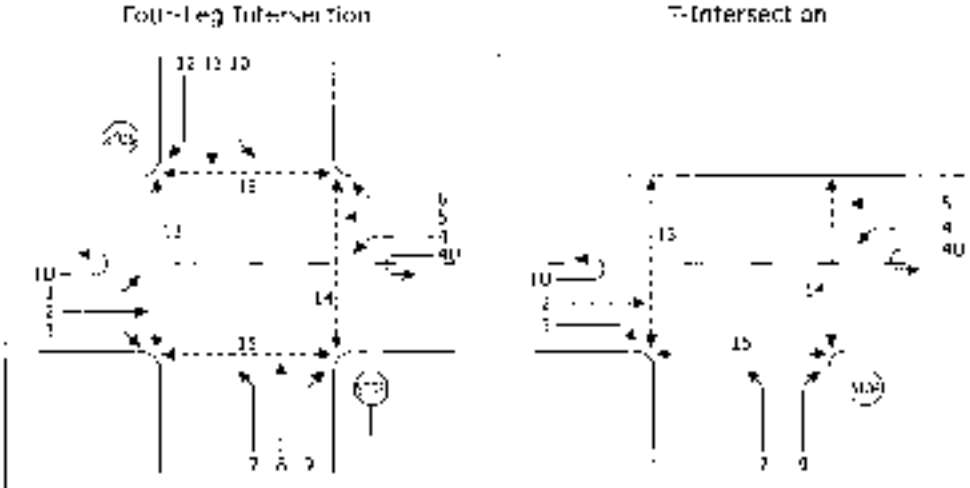
The second element to consider is the extent to which drivers find gaps of a particular size useful when they attempt to enter the intersection. It is generally assumed in gap-acceptance theory that drivers are both consistent and homogeneous. This assumption is not entirely correct. Studies have demonstrated that different drivers have different gap acceptance thresholds and even that the gap-acceptance threshold of an individual driver often changes over time (3). In this manual, the critical headways and follow-up headways are considered representative of a statistical average of the driver population in the United States.

Relative Priority of Various Movements at the Intersection

Each movement has a different ranking in a priority hierarchy. The gap acceptance process evaluates them with impedance given through the order of departures. Typically, gap-acceptance processes assume that drivers on the major street are unaffected by the minor-street movements. If this assumption is not the case, the gap-acceptance process has to be modified.

In using the TWSC intersection methodology, the priority or right of way given to each movement must be identified. Some movements have absolute priority, while others have to give way or yield to higher-order movements. Exhibit 19-3 shows the assumed numbering of movements at both T- and four-leg intersections.

Exhibit 19-3
Vehicular and Pedestrian Movements at a TWSC Intersection



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Movements can be categorized by right-of-way priority as follows:

- Movements of Rank 1 include through traffic on the major street, right-turning traffic from the major street, and pedestrian movements crossing the minor street.
- Movements of Rank 2 (subordinate to Rank 1) include left-turning and U-turning traffic from the major street, right-turning traffic onto the minor street, and pedestrian movements crossing the major street (assumed for this procedure).
- Movements of Rank 3 (subordinate to Ranks 1 and 2) include through traffic on the minor street (in the case of a four-leg intersection) and left-turning traffic from the minor street (in the case of a T-intersection).
- Movements of Rank 4 (subordinate to all others) include left-turning traffic from the minor street. Rank 4 movements occur only at four-leg intersections.

The minor-street left-turn movement is assigned Rank 3 priority at a T intersection and Rank 4 priority at a four-leg intersection.

As an example of application of the priority of right-of-way, assume the situation of a left-turning vehicle on the major street and a through vehicle from the minor street waiting to cross the major traffic stream. The first available gap of acceptable size would be taken by the left-turning vehicle. The minor-street through vehicle must wait for the second available gap. In aggregate terms, a large number of such left-turning vehicles could use up so many of the available gaps that minor-street through vehicles would be severely impeded or unable to make safe crossing movements.

Critical Headway and Follow-Up Headway

Critical headway defined.

The *critical headway* (t_c) is defined as the minimum time interval in the major-street traffic stream that allows intersection entry for one minor-street vehicle (4). Thus, the driver's critical headway is the minimum headway that would be acceptable. A particular driver would reject headways less than the critical headway and would accept headways greater than or equal to the critical headway. Critical headway can be estimated on the basis of observations of the largest rejected and smallest accepted headway for a given intersection.

Follow-up headway defined.

The time between the departure of one vehicle from the minor street and the departure of the next vehicle using the same major-street headway, under a condition of continuous queuing on the minor street, is called the *follow-up headway* (t_f). Thus, t_f is the headway that defines the saturation flow rate for the approach if there were no conflicting vehicles on movements of higher rank.

AUTOMOBILE MODE

The TWSC intersection methodology for the automobile mode is applied through a series of steps that require input data to afford movement flow information and geometric conditions, prioritization of movements, computation of potential capacities and incorporation of adjustments to compute movement capacities, and estimation of control delays and queue lengths. These steps are illustrated in Exhibit 19-4.

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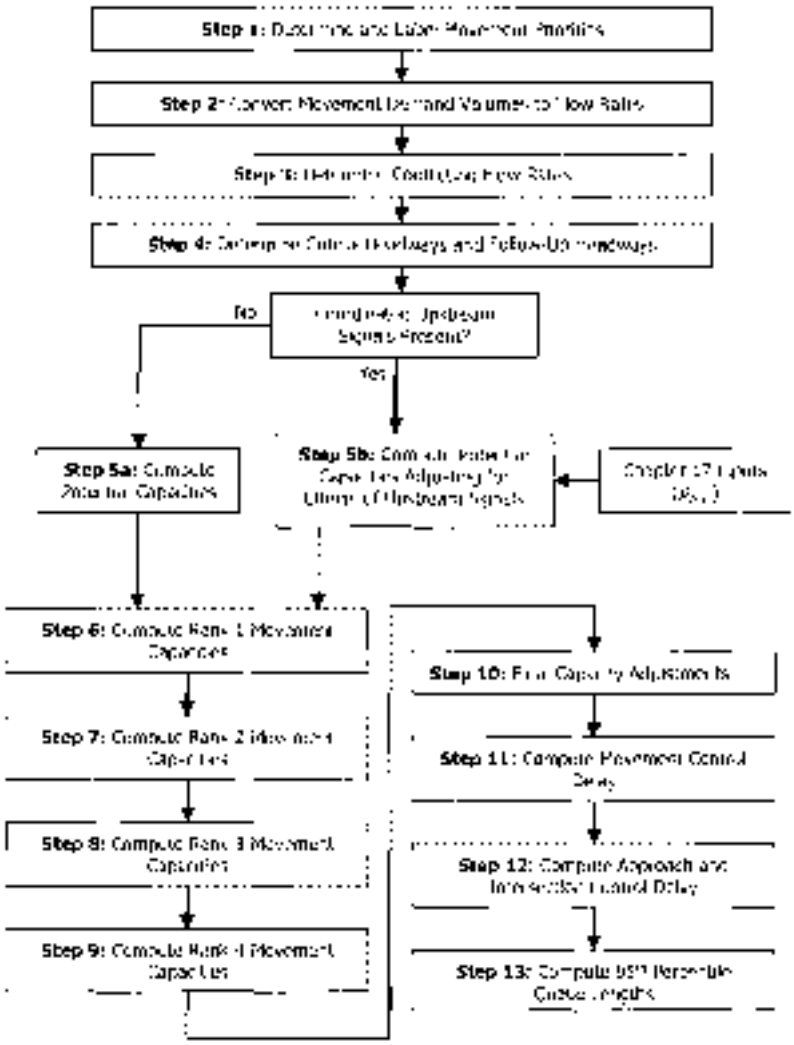
Exhibit 19-4
TWSC Intersection Methodology



Step 1: Determine and Label Movement Priorities

The priority for each movement at a TWSC intersection must be identified to designate the appropriate rank of each movement for future steps in the analysis process. The process of this step also identifies for the analyst the sequence in which capacity computations will be completed. Because the methodology is based on prioritized use of gaps by vehicles at a TWSC intersection, it is important that the subsequent computations in the methodology be made in a precise order. The computational sequence is the same as the priority of gap use, and movements are considered in the following order:

1. Left turns from the major street,
2. Right turns from the minor street,
3. U-turns from the major street,
4. Through movements from the minor street, and
5. Left turns from the minor street.

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Step 2: Convert Movement Demand Volumes to Flow Rates

For analyses of existing conditions where the peak 15 min period can be measured in the field, the volumes for the peak 15-min period are converted to a peak 15-min demand flow rate by multiplying the peak 15-min volumes by 4.

For analysis of projected conditions or when 15-min data are not available, hourly demand volumes for each movement are converted to peak 15-min demand flow rates in vehicles per hour, as shown in Equation 19-1, through use of the peak hour factor for the intersection.

$$v_i = \frac{V_i}{PHF}$$ **Equation 19-1**

where

v_i = demand flow rate for movement i (veh/h),

V_i = demand volume for movement i (veh/h), and

PHF = peak hour factor.

Step 3: Determine Conflicting Flow Rates

Each movement at a TWSC intersection faces a different set of conflicts that are directly related to the nature of the subject movement. The following subsections provide an illustration of the set of conflicts facing each minor movement (Rank 2 through Rank 4) at a TWSC intersection. These exhibits illustrate the computation of the parameter v_c, the conflicting flow rate for movement x—that is, the total flow rate (in vehicles per hour [veh/h]) that conflicts with movement x.

Pedestrians may also conflict with vehicular movements. Pedestrian flow rates, also defined as v_c, with x noting the leg of the intersection being crossed, should be included as part of the conflicting flow rates. Pedestrian flows are included because they define the beginning or ending of a gap that may be used by a minor-street movement. Although it recognizes some peculiarities associated with pedestrian movements, this method takes a uniform approach to vehicular and pedestrian movements.

Major-Street Left-Turn Movements (Rank 2—Movements 1 and 4)

Exhibit 19-5 illustrates the conflicting movements, while Equation 19-2 and Equation 19-3 compute the conflicting flow encountered by major street left-turning drivers. The left-turn movement from the major street is in conflict with the total opposing through and right-turn flow, because those vehicles must cross the opposing through movement and merge with the right-turning vehicles. The method does not differentiate between crossing and merging conflicts. Left-turning vehicles from the major street and the opposing right turns from the major street are considered to merge, regardless of the number of lanes provided in the exit roadway.

AR0074383

Exhibit 19-5
Definition of Conflicting Movements for Major Street Left-Turn Movements

Equation 19-2

$$v_{c,1} = v_1 - v_5 + v_{12}$$

Equation 19-3

$$v_{c,2} = v_2 + v_{11} + v_{12}$$

If the major-street right turn is separated by a triangular island and has to comply with a YIELD or STOP sign, the v_{11} and v_{12} terms in Equation 19-2 and Equation 19-3, respectively, may be assumed to be zero.

Minor-Street Right-Turn Movements (Rank 2—Movements 9 and 12)

Exhibit 19-6 illustrates the conflicting movements encountered by minor street right-turning drivers. The right-turn movement from the minor street is assumed to be in conflict with only a portion of the major-street through movement where more than one major-street lane is present. Also, one-half of each right-turn movement from the major street is considered to conflict with the minor-street right-turn movement, as some of these vehicles tend to encroach the subject movement. Because right-turning vehicles from the minor street commonly merge into gaps in the right-hand lane of the stream into which they turn, they typically do not require a gap across all lanes of the conflicting stream (this situation may not be true for some trucks and vans with long wheelbases that encroach on more than one lane in making their turn). Furthermore, a gap in the overall major-street traffic could be used simultaneously by another vehicle, such as a major-street left-turning vehicle. Exhibit 19-6 does not include major-street U-turns as conflicting vehicles. While these conflicts may be observed in practice, they are not assumed to be conflicts in this methodology.

Exhibit 19-6
Definition of Conflicting Movements for Minor Street Right-Turn Movements

Equation 19-4 and Equation 19-5 compute the conflicting flow rate for minor-street right-turn movements entering two-lane major streets. Equation 19-6 and Equation 19-7 are used for four-lane major streets, and Equation 19-8 and Equation 19-9 are used for six-lane major streets. If the major street right turn has its own lane, the corresponding v_{11} or v_{12} term in these equations may be assumed to be zero. Users may supply different lane distributions for the v_{11} and v_{12} terms in the equations for four- and six-lane major streets, when supported by field data.

AR0074384

Two-lane major streets:

$$v_{c,9} = v_2 + 0.5v_3 + v_{14} + v_{15}$$ Equation 19-4

$$v_{c,12} = v_5 + 0.5v_6 + v_{15} + v_{16}$$ Equation 19-5

Four-lane major streets:

$$v_{c,9} = 0.5v_2 + 0.5v_3 + v_{14} + v_{15}$$ Equation 19-6

$$v_{c,12} = 0.5v_5 + 0.5v_6 + v_{15} + v_{16}$$ Equation 19-7

Six-lane major streets:

$$v_{c,9} = 0.5v_2 + 0.5v_3 + v_{14} + v_{15}$$ Equation 19-8

$$v_{c,12} = 0.5v_5 + 0.5v_6 + v_{15} + v_{16}$$ Equation 19-9

Major-Street U-Turn Movements (Rank 2—Movements 1U and 4U)

Exhibit 19-7 illustrates the conflicting movements encountered by major-street U-turning drivers. The U-turn movement from the major street is in conflict with the total opposing through and right-turn flow, similar to the major-street left-turn movement. Research found that the presence of minor-street right-turning vehicles significantly affects the capacity of major-street U-turns (*9*). The methodology accounts for this effect in the impedance calculation rather than here in the calculation of conflicting flow. If a different priority order is desired (e.g., minor-street right turns yield to major-street U-turns), the analyst should adjust the computation procedure accordingly to replicate observed conditions.

Exhibit 19-7
Definition of Conflicting Movements for Major-Street U-Turn Movements

Equation 19-10 and Equation 19-11 compute the conflicting flow rates for major-street U-turns where the major street has four lanes. Equation 19-12 and Equation 19-13 compute the conflicting flow rates for major-street U-turns on six-lane major streets. (No field data are available for U-turns on major streets with fewer than four lanes.) If a major-street right turn has its own lane, the corresponding v_2 or v_5 term in these equations should be assumed to be zero.

Four-lane major streets:

$$v_{c,1U} = v_5 + v_6$$ Equation 19-10

$$v_{c,4U} = v_2 + v_3$$ Equation 19-11

Six-lane major streets:

$$v_{c,1U} = 0.73v_5 + 0.73v_6$$ Equation 19-12

$$v_{c,4U} = 0.73v_2 + 0.73v_3$$ Equation 19-13

AR0074385

Minor-Street Pedestrian Movements (Rank 2 – Movements 13 and 14)

Minor-street pedestrian movements (those pedestrians crossing the major street) are in direct conflict with all vehicular movements on the major street except the right-turn and left-turn movements on the major street approaching from the far side of the intersection. The volume of minor street pedestrians is an input parameter in the computation of the conflicting flow rates for all Rank 3 and Rank 4 movements.

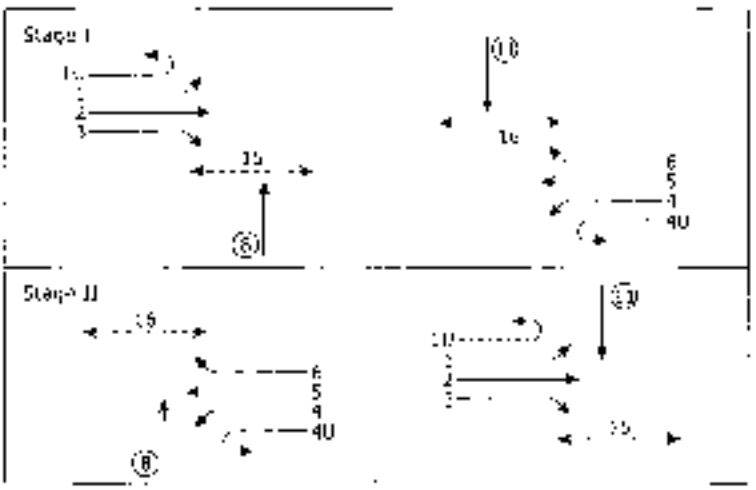
Minor-Street Through Movements (Rank 3 – Movements 8 and 11)

Minor-street through movements have a direct crossing or merging conflict with all movements on the major street except the right turn into the subject approach. Similar to the minor-street right turn movement, one half of each right-turn movement from the major street is considered to conflict with the minor-street through movement. In addition, field research (1) has shown that the effect of left-turning vehicles is approximately twice their actual number.

Minor-street through movements may complete their maneuver in one or two stages. Single-stage gap acceptance assumes no median refuge area is available for minor street drivers to store in and that the minor street drivers will be evaluating gaps in both major-street directions simultaneously. Conversely, the two-stage gap-acceptance scenario assumes that a median refuge area is available for minor-street drivers. During Stage I, minor-street drivers evaluate major-street gaps in the near-side traffic stream (conflicting traffic from the left); during Stage II, minor-street drivers evaluate major-street gaps in the far-side traffic stream (conflicting traffic from the right). For one-stage crossings, the conflicting flows for Stage I and Stage II are combined; for two-stage crossings, the conflicting flows are considered separately.

Exhibit 19-8 illustrates the conflicting movements encountered by minor street through-movement drivers.

Exhibit 19-8
Definition of Conflicting Movements for Minor-Street Through Movements



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Equation 19-14 and Equation 19-15 compute the conflicting flow encountered by minor-street through-movement drivers during Stage I. If there is a right-turn lane on the major street, the corresponding v_6 or v_{12} term in these equations may be assumed to be zero.

$$v_{c,x,I} = 2(v_1 + v_{10}) + v_2 + 0.5v_3 + v_5$$ **Equation 19-14**

$$v_{c,x,II} = 2(v_4 + v_{11}) + v_5 + 0.5v_6 + v_{12}$$ **Equation 19-15**

Equation 19-16 and Equation 19-17 compute the conflicting flow encountered by minor-street through-movement drivers during Stage II. If the major-street right turn is separated by a triangular island and has to comply with a YIELD or STOP sign, the corresponding v_5 or v_{12} term in these equations may be assumed to be zero.

$$v_{c,x,I} = 2(v_4 + v_{11}) + v_6 + v_{12}$$ **Equation 19-16**

$$v_{c,x,II} = 2(v_1 + v_{10}) + v_2 + v_3 + v_5$$ **Equation 19-17**

Minor-Street Left-Turn Movements (Rank 4—Movements 7 and 10)

The left-turn movement from the minor street is the most difficult maneuver to execute at a TWSC intersection, and it faces the most complex set of conflicting movements, which include all major-street movements in addition to the opposing right turn and through movements on the minor street. Only one half of the opposing right-turn and through-movement flow rate is included as conflicting flow rate because both movements are STOP-controlled, which diminishes their effect on left turns. The additional capacity impedance effects of the opposing right-turn and through-movement flow rates are taken into account elsewhere in the procedure.

Similar to minor-street through movements, minor-street left-turn movements may be completed in one or two stages. Exhibit 19-9 illustrates the conflicting movements encountered by minor-street left-turning drivers.

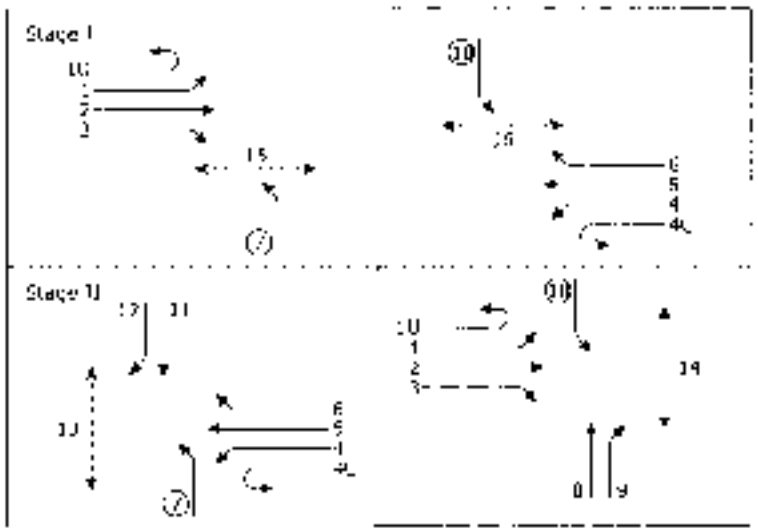

Exhibit 19-9
Conflicting Movements for Minor-Street Left-Turn Movements

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During Stage I, Equation 19-18 and Equation 19-19 compute the conflicting flow rate for minor street left-turn movements entering two-lane major streets, while Equation 19-20 and Equation 19-21 are used for four-lane major streets, and Equation 19-22 and Equation 19-23 are used for six-lane major streets. If a right-turn lane exists on the major street, the corresponding v_1 or v_6 term in these equations may be assumed to be zero.

Two-lane major streets

Equation 19-18
$$v_{c,I,2} = 2v_1 + v_2 + 0.5v_3 + v_{10}$$

Equation 19-19
$$v_{c,I,1} = 2v_1 + v_2 + 0.5v_3 + v_{11}$$

Four-lane major streets

Equation 19-20
$$v_{c,I,2} = 2(v_1 + v_{20}) + v_2 + 0.5v_3 + v_{10}$$

Equation 19-21
$$v_{c,I,1} = 2(v_2 + v_{21}) + v_1 + 0.5v_3 + v_{11}$$

Six-lane major streets:

Equation 19-22
$$v_{c,I,2} = 2(v_1 + v_{30}) + v_2 + 0.5v_3 + v_{10}$$

Equation 19-23
$$v_{c,I,1} = 2(v_2 + v_{31}) + v_1 + 0.5v_3 + v_{11}$$

During Stage II, Equation 19-24 and Equation 19-25 compute the conflicting flow rate for minor street left-turn movements entering two-lane major streets, while Equation 19-26 and Equation 19-27 are used for four-lane major streets, and Equation 19-28 and Equation 19-29 are used for six-lane major streets. If the minor-street right turn is separated by a triangular island and has to comply with a YIELD or STOP sign, the corresponding v_{12} or v_{13} term in these equations may be assumed to be zero.

Two-lane major streets

Equation 19-24
$$v_{c,II,2} = 2v_1 + v_2 + 0.5v_3 + 0.5v_{12} + 0.5v_{13} + v_{11}$$

Equation 19-25
$$v_{c,II,1} = 2v_1 + v_2 + 0.5v_3 + 0.5v_{12} + 0.5v_{13} + v_{10}$$

Four-lane major streets

Equation 19-26
$$v_{c,II,2} = 2(v_1 + v_{20}) + 0.5v_3 + 0.5v_{12} + v_{13}$$

Equation 19-27
$$v_{c,II,1} = 2(v_2 + v_{21}) + 0.5v_3 + 0.5v_{13} + v_{12}$$

Six-lane major streets:

Equation 19-28
$$v_{c,II,2} = 2(v_2 + v_{30}) + 0.4v_3 + 0.5v_{12} + v_{13}$$

Equation 19-29
$$v_{c,II,1} = 2(v_1 + v_{31}) + 0.4v_3 + 0.5v_{13} + v_{12}$$

AR0074388

Step 4: Determine Critical Headways and Follow-Up Headways

The critical headways (t_c) and follow-up headways (t_f) must be determined for the major street left turns ($t_{c,1}$ and $t_{f,1}$), the minor-street right turns ($t_{c,4}$ and $t_{f,4}$), the major street U turns ($t_{c,12}$ and $t_{f,12}$), the minor-street through movements ($t_{c,2}$ and $t_{f,2}$) and the minor-street left turns ($t_{c,3}$ and $t_{f,3}$) as they occur at a TWSC intersection.

To compute the critical headways for each movement, the analyst begins with the base critical headway given in Exhibit 19-10 and makes movement-specific adjustments relating to the percentage of heavy vehicles, the grade encountered, and a three-leg versus four-leg intersection, as shown in Equation 19-30:

$$t_{c,x} = t_{c,base} + t_{c,HV} P_{HV,x} - t_{c,G} G - t_{c,T} \quad \text{Equation 19-30}$$

where

$t_{c,x}$ = critical headway for movement x (s),

$t_{c,base}$ = base critical headway from Exhibit 19-10 (s),

$t_{c,HV}$ = adjustment factor for heavy vehicles (2.0 for major streets with one lane in each direction; 2.0 for major streets with two or three lanes in each direction) (s),

$P_{HV,x}$ = proportion of heavy vehicles for movement (expressed as a decimal; e.g., $P_{HV} = 0.02$ for 2% heavy vehicles),

$t_{c,G}$ = adjustment factor for grade (0.1 for Movements 9 and 12; 0.2 for Movements 7, 8, 10, and 11) (s),

G = percent grade (expressed as an integer; e.g., $G = -2$ for a 2% downhill grade), and

$t_{c,T}$ = adjustment factor for intersection geometry (0.7 for minor-street left turn movement at three-leg intersections; 0.0 otherwise) (s).

$t_{c,T}$ is applicable to Movements 2, 6, 10, and 11.

Exhibit 19-10
Base Critical Headways for TWSC Intersections

Vehicle Movement	Base Critical Headway, $t_{c,base}$ (s)		
	Two Lanes	Four Lanes	Six Lanes
Left turn from major	4.1	4.1	5.3
U turn from major	N/A	6.4 (wide) 6.9 (narrow)	5.6
Right turn from minor	5.2	6.9	7.1
Through traffic on minor	1-stage: 6.5 2-stage, Stage I: 5.5 2-stage, Stage II: 5.5	1-stage: 6.5 2-stage, Stage I: 5.5 2-stage, Stage II: 5.5	1-stage: 6.5* 2-stage, Stage I: 5.5* 2-stage, Stage II: 5.5*
Left turn from minor	1-stage: 7.1 2-stage, Stage I: 6.1 2-stage, Stage II: 6.1	1-stage: 7.5 2-stage, Stage I: 6.5 2-stage, Stage II: 6.5	1-stage: 6.4 2-stage, Stage I: 7.3 2-stage, Stage II: 6.7

* = No default value is provided.

The critical headway data for four- and six-lane sites account for the actual lane distribution of traffic flows measured at each site. For six-lane sites, minor-street left turns were commonly observed beginning their movement while apparently conflicting vehicles in the far-side major street through stream pass. The values for critical headway for minor street through movements at six lane streets are estimated, as the movement is not frequently observed in the field.

AR0074389

Similar to the computation of critical headways, the analyst begins the computation of follow-up headways with the base follow-up headways given in Exhibit 19-11. The analyst then makes movement-specific adjustments to the base follow-up headways with information gathered on heavy vehicles and the geometrics of the major street per the adjustment factors given in Equation 19-31.

Equation 19-31

$$t_{f,x} = t_{f,base} + f_{HV} P_{HV}$$

where

$t_{f,x}$ = follow-up headway for movement x (s),

$t_{f,base}$ = base follow-up headway from Exhibit 19-11 (s),

f_{HV} = adjustment factor for heavy vehicles (0.9 for major streets with one lane in each direction, 1.0 for major streets with two or three lanes in each direction), and

P_{HV} = proportion of heavy vehicles for movement (expressed as a decimal, e.g., P_{HV} = 0.02 for 2% heavy vehicles).

Exhibit 19-11
Base Follow-Up Headways for TWSC Intersections

Vehicle Movement	Base Follow-Up Headway, $t_{f,base}$ (s)		
	Two Lanes	Four Lanes	Six Lanes
Left turn from major	2.2	2.2	3.1
U-turn from major	N/A	2.5 (wide) 3.2 (narrow)	3.5
Right turn from minor	3.3	3.3	3.5
Through traffic on minor	4.0	4.0	4.0
Left turn from minor	3.5	3.5	3.8

Values from Exhibit 19-10 and Exhibit 19-11 are based on studies throughout the United States and are representative of a broad range of conditions. If smaller values for t_c and t_f are observed, capacity will be increased. If larger values for t_c and t_f are used, capacity will be decreased.

Step 5: Compute Potential Capacities

Step 5a: Potential Capacity If No Upstream Signal Effects Are Present

The potential capacity $c_{p,x}$ of a movement is computed according to the gap-acceptance model provided in Equation 19-32 (6). This model requires the analyst to input the conflicting flow rate $v_{c,x}$, the critical headway $t_{c,x}$, and the follow-up headway $t_{f,x}$ for movement x.

Equation 19-32

$$c_{p,x} = v_{c,x} \frac{e^{-v_{c,x} t_{c,x}/3600}}{1 - e^{-v_{c,x} t_{f,x}/3600}}$$

where

$c_{p,x}$ = potential capacity of movement x (veh/h),

$v_{c,x}$ = conflicting flow rate for movement x (veh/h),

$t_{c,x}$ = critical headway for minor movement x (s), and

$t_{f,x}$ = follow-up headway for minor movement x (s).

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For two-stage Ranks 3 or 4 movements, the potential capacity is computed three times: (a) assuming one-stage operation, $c_{p,x}$ for Stage I, and $c_{p,xy}$ for Stage II. The conflicting flow definitions for each calculation are as provided in Step 4.

Step 5b: Potential Capacity If Upstream Signal Effects Are Present

To evaluate the impact of coordinated upstream signals, the urban street segments methodology (Chapter 17) is used to estimate the proportion of time that each Rank 2 or lower movement will be effectively blocked by a platoon. The proportion of time blocked is denoted by $p_{x,u}$, where x is the movement using the movement conventions provided in Exhibit 19-8.

With these values, the proportion of the analysis period that is blocked for each major movement can be computed by using Exhibit 19-12:

Exhibit 19-12
Proportion of Analysis Period Blocked for Each Movement

Movement(s) x	Proportion Blocked for Movement, $p_{x,u}$		
		Two-Stage Movements	
	One-Stage Movements	Stage I	Stage II
1, 10	$p_{1,u}$	N/A	N/A
4, 40	$p_{4,u}$	N/A	N/A
7	$p_{7,u}$	$p_{7,u}$	$p_{7,u}$
8	$p_{8,u}$	$p_{8,u}$	$p_{8,u}$
9	$p_{9,u}$	N/A	N/A
10	$p_{10,u}$	$p_{10,u}$	$p_{10,u}$
11	$p_{11,u}$	$p_{11,u}$	$p_{11,u}$
12	$p_{12,u}$	N/A	N/A

The flow for the unblocked period (no platoons) is determined in this step. This flow becomes the conflicting flow for the subject movement and is used to compute the capacity for this movement. The minimum platooned flow rate $v_{c,min}$ is approximately 1,000N, where N is the number of through lanes per direction on the major street (7).

The conflicting flow for movement x during the unblocked period is given by Equation 19-33:

$$v_{c,u,x} = \begin{cases} \dfrac{v_{c,x} - 1.5v_{c,min}p_{x,u}}{1 - p_{x,u}} & \text{if } v_{c,x} > 1.5v_{c,min}p_{x,u} \\ 0 & \text{otherwise} \end{cases}$$

Equation 19-33

where

$v_{c,u,x}$ = conflicting flow for movement x during the unblocked period (veh/h),

$v_{c,x}$ = total conflicting flow for movement x as determined from Step 3 (veh/h),

$v_{c,min}$ = minimum platooned flow rate (veh/h), assumed to be 1,000N, where N is the number of through lanes per direction on the major street, and

$p_{x,u}$ = proportion of time the subject movement x is blocked by the major-street platoon, which is determined from Exhibit 19-12.

The potential capacity of the subject movement x, accounting for the effect of platooning, is given by Equation 19-34 and Equation 19-35:

AR0074391

Equation 19-34

$$c_{x,p} = (1 - p_x)v_x$$

Equation 19-35

$$c_{x,r} = v_x e^{-v_{c,x}(t_{f,x}/3600)}$$

where

$c_{x,p}$ = potential capacity of movement x (veh/h),

p_x = proportion of time that movement x is blocked by a platoon, and

v_x = capacity of movement x assuming random flow during the unblocked period.

This equation uses the same critical headway and follow-up headway inputs as does a normal calculation but uses only the conflicting flow during the unblocked period.

Steps 6–9: Compute Movement Capacities

For clarity, these steps assume that pedestrian impedance effects can be neglected, and in many cases this is a reasonable assumption. However, pedestrians can be accounted for in the analysis of the automobile mode by replacing these steps with those provided in Chapter 22, Street Corridors and Systems Supplemental, that incorporate the effects of pedestrian impedance.

Step 6: Rank 1 Movement Capacity

Rank 1 major-street movements are assumed to be unimpeded by any movements of lower rank. This rank also implies that major-street movements of Rank 1 are not expected to incur delay or slowing as they travel through the TWSC intersection. Empirical observations have shown that such delays do occasionally occur, and they are accounted for by using adjustments provided later in this procedure.

Step 7: Rank 2 Movement Capacity

Movements of Rank 2 (left turns and U-turns from the major street and right turns from the minor street) must yield to conflicting major-street through and right-turning vehicular movements of Rank 1. Minor-street right turns are assumed to yield to major-street U-turns, although sometimes the reverse occurs.

Step 7a: Movement Capacity for Major-Street Left-Turn Movement

The movement capacity of each Rank 2 major-street left-turn movement (1 and 4) is equal to its potential capacity, as shown in Equation 19-36.

Equation 19-36

$$c_{x,r} = c_x$$

Step 7b: Movement Capacity for Minor-Street Right-Turn Movements

The movement capacity, $c_{x,r}$, for Rank 2 minor-street right-turn movements (9 and 12) is equal to its potential capacity, as shown in Equation 19-37.

Equation 19-37

$$c_{x,r} = c_x$$

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Step 7c: Movement Capacity for Major-Street U-turn Movements

The movement capacity, $c_{u,2}$ for Rank 2 major-street U-turn movements (1L and 4L) is found by first computing a capacity adjustment factor that accounts for the impeding effects of higher ranked movements. Field observations are mixed in terms of the degree to which major-street U-turn movements yield to minor-street right-turn movements and vice versa (7). It is assumed that the presence of minor-street right-turning vehicles will impede U-turning vehicles from accepting gaps in the major-street traffic stream; therefore, the capacity of the U-turn movement is affected by the probability that the minor street right turning traffic will operate in a queue free state. The capacity adjustment factors are denoted by f_{1u} and f_{4u} for the major street U-turn movements 1L and 4L respectively, and are given by Equation 19-38 and Equation 19-39, respectively

$$f_{1u} = p_{9,12} = 1 - \frac{v_{9,12}}{c_{9,12}}$$ **Equation 19-38**

$$f_{4u} = p_{3,6} = 1 - \frac{v_{3,6}}{c_{3,6}}$$ **Equation 19-39**

where

f_{1u}, f_{4u} = capacity adjustment factor for Rank 2 major-street U-turn movements 1 and 4, respectively;

p_j = probability that conflicting Rank 2 minor-street right-turn movement j will operate in a queue-free state;

v_j = flow rate of movement j;

c_j = capacity of movement j; and

j = 9 and 12 (minor-street right-turn movements of Rank 2).

The movement capacity for major-street U-turn movements is then computed with Equation 19-40:

$$c_{u,1} = (c_{1,0})f_{1u}$$ **Equation 19-40**

where

$c_{u,1}$ = movement capacity for Movements 1L and 4L,

$c_{1,1}$ = potential capacity for Movements 1L and 4L (from Step 3), and

f_{1u} = capacity adjustment factor for Movements 1L and 4L.

In almost all cases, major-street left-turning vehicles share a lane with U-turning vehicles. Therefore, if Rank 2 major street U-turn movements are present in a signalized region, then Equation 19-41 should be used to compute the shared-lane capacity.

Since the left-turn and U-turn movements are typically conducted from the same lane, their shared-lane capacity is computed with Equation 19-41:

$$c_{sh} = \frac{\sum_i v_i}{\sum_i \left(\frac{v_i}{c_{i,1}} \right)}$$ **Equation 19-41**

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where

c_{sh} = capacity of the shared lane (veh/h),

v_y = flow rate of the y movement in the subject shared lane (veh/h), and

$c_{m,y}$ = movement capacity of the y movement in the subject shared lane (veh/h).

Step 7d: Effect of Major-Street Shared Through and Left-Turn Lane

The probability that the major-street left-turning traffic will operate in a queue-free state is expressed by Equation 19-43:

Equation 19-42

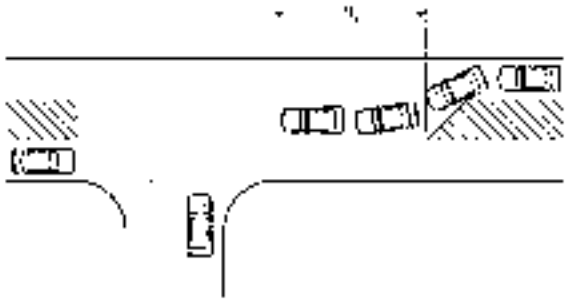
$$p_{x,y} = 1 - \frac{v_y}{c_{m,y}}$$

If major-street through and left-turn movements are shared, use Equation 19-42. Also, use Equation 19-42 to compute the probability of a queue-free state for Rank 1 movements.

where y = 1 and 4 (major-street left-turn and U-turn movements of Rank 2, using shared volume and capacity as appropriate).

If, however, a shared left-turn lane or a short left-turn pocket is present on a major-street approach (as in Exhibit 19-13), the analyst accounts for this occurrence by computing the probability that there will be no queue in the major-street shared lane, $p'_{x,y}$, according to Equation 19-43. This probability is then used by the analyst in lieu of $p_{x,y}$ (as computed by Equation 19-42).

Exhibit 19-13
Short Left-Turn Pocket



The methodology implicitly assumes that an exclusive lane is provided to all left-turning traffic from the major street. If a left-turn lane is not provided or the left-turn pocket is not long enough to accommodate all queuing left-turn and U-turn vehicles, major-street through (and possibly right-turning) traffic could be delayed by left-turning vehicles waiting for an acceptable gap in opposing major-street through traffic. To account for this occurrence, the factors $p'_{x,y}$ and $p'_{x,z}$ may be computed according to Equation 19-43 and Equation 19-44 as an indication of the probability that there will be no queue in the respective major-street shared or short lanes (Y).

Equation 19-43

$$p'_{x,y} = 1 - \left(1 - p_{x,y}\right)\left[\left(v_{sh}/s_{sh}\right)\sqrt{1 + \frac{2\left(c_{m,y} - v_y\right)}{1 - v_{sh}/s_{sh}}}\right]$$

Equation 19-44

$$v_{sh} = \frac{v_{sh1}}{s_{sh1}} + \frac{v_{sh2}}{s_{sh2}}$$

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where

p_j = probability of queue-free state for movement j assuming an exclusive left-turn lane on the major street (per Equation 19-42);

j = 1 and 4 (major-street left-turning vehicular movements);

When $j = 1$, $i1 = 2$ and $i2 = 3$; when $j = 4$, $i1 = 5$ and $i2 = 6$.

$i1$ = 2 and 5 (major-street through vehicular movements);

$i2$ = 3 and 6 (major-street right-turning vehicular movements);

$v_{c,i2}$ = combined degree of saturation for the major street through and right turn movements;

s_1 = saturation flow rate for the major street through movements (default assumed to be 1,900 veh/h; however, this parameter can be measured in the field);

s_r = saturation flow rate for the major-street right-turn movements (default assumed to be 1,500 veh/h; however, this parameter can be measured in the field);

v_{i1} = major-street through-movement flow rate (veh/h);

v_r = major-street right-turn flow rate (veh/h) (0 if an exclusive right-turn lane is provided); and

n_{st} = storage places in the left turn pocket (see Exhibit 19-13).

For the special situation of shared lanes ($n_{st} = 0$), Equation 19-43 becomes Equation 19-45 as follows:

$$p'_{x,j} = p_{x,j} \frac{1 - p_{0,i1}}{1 - x_{c,i2}} \quad \text{Equation 19-45}$$

where all terms are as previously defined.

By using $p'_{x,j}$ and $p'_{x,4}$ in lieu of $p_{x,j}$ and $p_{x,4}$ (as computed by Equation 19-42), the potential for queues on a major street with shared or short left-turn lanes may be taken into account.

Step 6: Compute Movement Capacities for Rank 3 Movements

Rank 3 minor-street traffic movements (minor-street through movements at four-leg intersections and minor-street left turns at three-leg intersections) must yield to conflicting Rank 1 and Rank 2 movements. Not all gaps of acceptable length that pass through the intersection will normally be available for use by Rank 3 movements, because some of these gaps are likely to be used by Rank 2 movements.

If the Rank 3 movement is a two-stage movement, the movement capacity for the one-stage movement is computed as an input to the two-stage calculation.

Step 6a: Rank 3 Movement Capacity for One-Stage Movements

For Rank 3 movements, the magnitude of vehicle impedance depends on the probability that major-street left-turning vehicles will be waiting for an acceptable gap at the same time as vehicles of Rank 1. A higher probability that

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this situation will occur means greater capacity reducing effects of the major street left turning traffic on all Rank 3 movements.

The movement capacity $c_{x,y}$ for all Rank 3 movements is found by first computing a capacity adjustment factor that accounts for the impeding effects of higher-ranked movements. The capacity adjustment factor is denoted by f_i for all movements k and for all Rank 3 movements and is given by Equation 19-46:

Equation 19-46

$$f_i = \prod_{k} p_{0,k}$$

where

$p_{0,k}$ = probability that conflicting Rank 2 movement j will operate in a queue free state, and

k = Rank 3 movements.

The movement capacity for Rank 3 minor-street movements is computed with Equation 19-47, where f_i is the capacity adjustment factor that accounts for the impeding effects of higher-ranked movements computed according to Equation 19-46.

Equation 19-47

$$c_{m,x} = (c_{g,x})\, f_i$$

Step 8b: Rank 3 Capacity for Two-Stage Movements

If the Rank 3 movement is a two-stage movement, the procedure for computing the total movement capacity for the subject movement considering the two-stage gap-acceptance process is as follows. An adjustment factor α and an intermediate variable γ are computed with Equation 19-48 and Equation 19-49, respectively.

Equation 19-48

$$\alpha = \begin{cases} 1 & \text{for } n_{st} = 0 \\ 0.32e^{-0.12\sqrt{n_{st}}} & \text{for } n_{st} > 0 \end{cases}$$

Equation 19-49

$$\gamma = \frac{v_{g1} - c_{m,x}}{v_{g2} + v_{g1} - c_{m,x}}$$

where

n_{st} = number of storage spaces in the median,

v_{g1} = movement capacity for the Stage I process (veh/h),

v_{g2} = movement capacity for the Stage II process (veh/h),

v_{c1} = major left turn or U-turn flow rate, either v_{12} or $v_{11} + v_{13}$ (veh/h), and

$c_{m,x}$ = capacity of subject movement, considering the total conflicting flow rate for both stages of a two-stage gap acceptance process (from Step 8a).

The total capacity c_x for the subject movement, considering the two-stage gap-acceptance process, is computed by using Equation 19-50 and Equation 19-51 and incorporating the adjustment factors derived from Equation 19-48 and Equation 19-49.

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For $v > 1$:

$$c_T = \frac{A}{y^{v-1} - 1}\left[y(y^{v-1} - 1)(c_p - c_L) - (y - 1)c_{v,r}\right]$$ **Equation 19-50**

For $v = 1$:

$$c_T = \frac{A}{y_a - 1}\left[y_a(c_p - c_L) - c_{v,r}\right]$$ **Equation 19-51**

Step 9: Compute Movement Capacities for Rank 4 Movements

Rank 4 movements occur only at four-leg intersections. Rank 4 movements (i.e., only the minor-street left turns at a four-leg intersection) can be impeded by all higher-ranked movements (Ranks 1, 2, and 3).

Step 9a: Rank 4 Capacity for One-Stage Movements

The probability that higher-ranked traffic movements will operate in a queue-free state is central to determining their overall impeding effects on the minor-street left-turn movement. At the same time, it must be recognized that not all these probabilities are independent of each other. Specifically, queuing in the major-street left-turning movement affects the probability of a queue-free state in the minor-street crossing movement. Applying the simple product of these two probabilities would likely overestimate the impeding effects on the minor-street left-turning traffic.

Exhibit 19-14 can be used to adjust for the overestimate caused by the statistical dependence between queues in streams of Ranks 2 and 3. The mathematical representation of this curve is determined with Equation 19-52.

$$p' = 0.6 + 0.6\sqrt{p^{v}} - \frac{p^{v}}{p^{v} + 3}$$ **Equation 19-52**

where

p' = adjustment to the major street left, minor-street through impedance factor;

p^{v} = $(p_1)(p_{2,3})$;

$p_{1,}$ = probability of a queue-free state for the conflicting major-street left-turning traffic; and

$p_{2,3}$ = probability of a queue-free state for the conflicting minor-street crossing traffic.

When determining p' for Rank 4 Movement 7 in Equation 19-53, $p^{v} = (p_1)(p_{2,3})(p_{5,6})$. Likewise, when determining p' for Rank 4 Movement 10, $p^{v} = (p_1)(p_{5,6})(p_{8,9})$.

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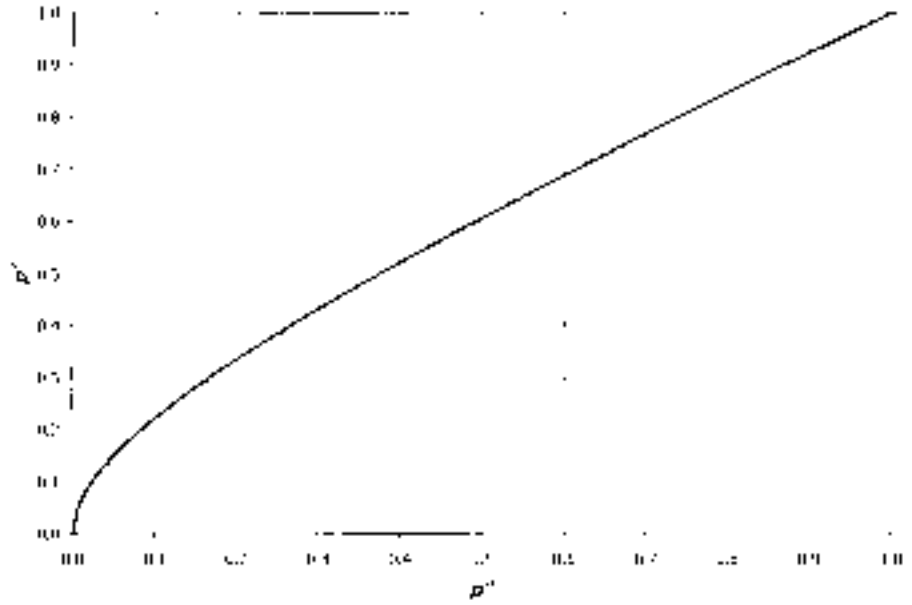
Exhibit 19-14
Adjustment to Impedance Factors for Major Left-Turn Movement and Minor Crossing Movement



The movement capacity c_x for all Rank 4 movements is found by first computing a capacity adjustment factor that accounts for the impeding effects of higher-ranked movements. The capacity adjustment factor for the Rank 4 minor-street left-turn movement can be computed with Equation 19-53:

Equation 19-53

$$f_{x,z} = (p^{\prime})(p_{y,z})$$

where

x = minor-street left-turn movement of Rank 4 (Movements 7 and 10 in Exhibit 19-3), and

y = conflicting Rank 2 minor-street right-turn movement (Movements 9 and 12 in Exhibit 19-3).

Finally, the movement capacity for the minor-street left-turn movements of Rank 4 is determined with Equation 19-54, where $f_{x,z}$ is the capacity adjustment factor that accounts for the impeding effects of higher-ranked movements.

Equation 19-54

$$c_{x,z} = (c_{x,0})\,f_{x,z}$$

Step 9b: Rank 4 Capacity for Two-Stage Movements

The procedure for computing the total movement capacity for the subject movement considering the two-stage gap-acceptance process is as follows. An adjustment factor a and an intermediate variable g are computed with Equation 19-55 and Equation 19-56, respectively:

Equation 19-55

$$a = 1 - 0.32e^{-1.3(v_{x,2}/1000)} \text{ for } v_{x,2} > 0$$

Equation 19-56

$$g = \frac{c_x - c_{x,z}}{c_x - v_{x,2} - c_{x,z}}$$

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where

n_s = number of storage spaces in the median,

c_f = movement capacity for the Stage I process (veh/h),

c_g = movement capacity for the Stage II process (veh/h),

v_i = major left-turn or U-turn flow rate, either $v_{13} + v_{16}$ or $v_{14} + v_{15}$ (veh/h), and

c_{ii} = capacity of subject movement, including the total conflicting flow rate for both stages of a two-stage gap-acceptance process (from Step 9a).

The total capacity c_i for the subject movement considering the two-stage gap-acceptance process is computed by using Equation 19-57 and Equation 19-58 and incorporating the adjustment factors computed in Equation 19-55 and Equation 19-56.

For $y \neq 1$:

$$c_i = \frac{a}{y^{n_s+1}-1}\left[y\left(y^{n_s}-1\right)\left(c_g - v_i\right) - (y-1)\,c_{ii}\right] \qquad \textbf{Equation 19-57}$$

For $y = 1$:

$$c_i = \frac{a}{n_s+1}\left[n_s\left(c_g - v_i\right) + c_{ii}\right] \qquad \textbf{Equation 19-58}$$

Step 10: Final Capacity Adjustments

Step 10a: Shared-Lane Capacity of Minor-Street Approaches

Where several movements share the same lane and cannot stop side by side at the stop line, Equation 19-59 is used to compute shared-lane capacity.

$$c_{SH} = \frac{\sum_y v_y}{\sum_y \left(\frac{v_y}{c_{SH,y}}\right)} \qquad \textbf{Equation 19-59}$$

where

c_{SH} = capacity of the shared lane (veh/h),

v_y = flow rate of the y movement in the subject shared lane (veh/h), and

$c_{SH,y}$ = movement capacity of the y movement in the subject shared lane (veh/h).

Step 10b: Compute Flared Minor-Street Lane Effects

To estimate the capacity of a flared right-turn lane (as in Exhibit 19-15), the average queue length for each movement sharing the right lane on the minor-street approach must first be computed with Equation 19-60. This computation assumes that the right-turn movement operates in one lane and that the other traffic in the right lane (upstream of the flare) operates in another, separate lane.

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Equation 19–60

$$Q_T = \frac{d_{r,g} v_{r,g}}{3{,}600}$$

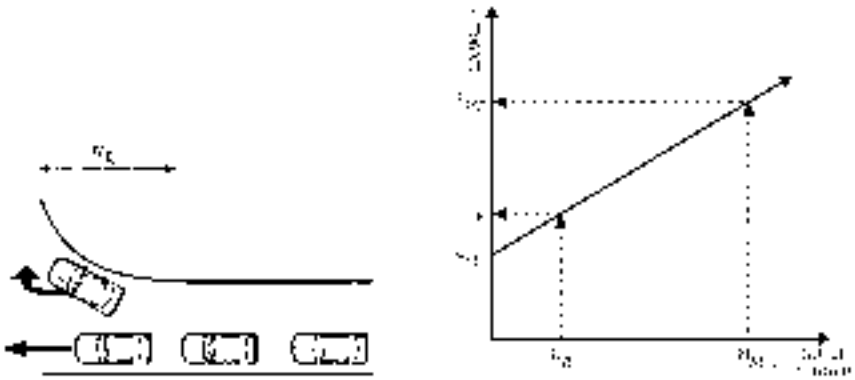
where

$Q_{r,g}$ = average queue length for the movement considered as a separate lane (veh);

$d_{r,g}$ = control delay for the movement considered as a separate lane (as described in Step 11), and

$v_{r,g}$ = flow rate for the movement (veh/h).

Exhibit 19–15
Capacity of a Flare-Lane Approach



Next, the required length of the storage area such that the approach would operate effectively as separate lanes is computed with Equation 19-61. This is the maximum value of the queue lengths computed for each separate movement plus one vehicle.

Equation 19–61

$$v_{R,t} = \text{Max}\left[\text{round}(Q_{r,t} - 1)\right]$$

where

$Q_{r,t}$ = average queue length for movement t considered as a separate lane

round = round-off operator, rounding the quantity in parentheses to the nearest integer; and

$v_{R,t}$ = length of the storage area such that the approach would operate as separate lanes.

Next, the capacity of a separate lane condition $c_{s,g}$ must be computed and is assumed to be the capacity of right-turning traffic operating as a separate lane and the capacity of the other traffic in the right lane (upstream of the flare) operating as a separate lane. The capacity of a separate lane condition is calculated according to Equation 19-62, as shown:

Equation 19–62

$$c_{s,g} = \text{Min}\left[c_g\left(1 + \frac{v_{r,t,g}}{v_g}\right), c_{r,t,g}\left(1 - \frac{v_g}{2{,}700}\right)\right]$$

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where

$c_{sh,r}$ = set of the capacities of the right-turning traffic operating as a separate lane and the capacity of the other traffic in the right lane (upstream of the flare) operating in a separate lane (veh/h),

c_r = capacity of the right-turn movement (veh/h),

$c_{sh,tr}$ = capacity of the through and left-turn movements as a shared lane (veh/h),

v_r = right-turn movement flow rate (veh/h), and

$v_{sh,tr}$ = through and left-turn movement combined flow rate (veh/h).

Finally, the capacity of the lane is computed, taking into account the flare. The capacity is interpolated as shown in Exhibit 19-15. A straight line is established by using values at two points: $(c_{sh,r}, v_{sh,r})$ and $(c_{sh,tr}, 0)$. The interpolated value of the actual value of the flared-lane capacity c_r is computed with Equation 19-63.

$$c_r = \begin{cases} \left(c_{sh,tr} - c_{sh,r}\right)\dfrac{v_r}{v_{sh,r}} + c_{sh,r} & \text{if } v_r < v_{sh,r} \\ c_{sh,tr} & \text{if } v_r \geq v_{sh,r} \end{cases} \qquad \text{Equation 19-63}$$

where

c_r = actual capacity of the flared lane (veh/h),

$c_{sh,tr}$ = capacity of the lane if both storage areas were infinitely long (refer to Equation 19-62) (veh/h),

$c_{sh,r}$ = capacity of the lane when all traffic is sharing one lane (veh/h), and

v_r = actual storage area for right-turning vehicles as defined in Exhibit 19-15.

The actual capacity c_r must be greater than $c_{sh,r}$ but less than or equal to $c_{sh,tr}$.

Step 11: Compute Movement Control Delay

The delay experienced by a motorist is made up of a number of factors that relate to control type, geometrics, traffic, and incidents. In the TWSC intersection methodology, only that portion of delay attributed to the stop-control aspect of the intersection, referred to as control delay, is quantified.

Control delay includes delay due to deceleration to a stop at the back of the queue from free-flow speed, move-up time within the queue, stopped delay at the front of the queue, and delay due to acceleration back to free-flow speed. With respect to field measurements, control delay is defined as the total time that elapses from the time a vehicle stops at the end of the queue to the time the vehicle departs from the stop line. This total elapsed time includes the time required for the vehicle to travel from the last-in-queue position to the first-in-queue position, including deceleration of vehicles from free-flow speed to the speed of vehicles in queue.

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Step 11a: Compute Control Delay to Rank 2 Through Rank 4 Movements

Average control delay for any particular minor movement is a function of the capacity of the approach and the degree of saturation. The analytical model used to estimate control delay (Equation 19-64) assumes that demand is less than capacity for the period of analysis. If the degree of saturation is greater than about 0.9, average control delay is significantly affected by the length of the analysis period. In most cases, the recommended analysis period is 15 min. If demand exceeds capacity during a 15-min period, the delay results computed by the procedure may not be accurate. In this case, the period of analysis should be lengthened to include the period of oversaturation.

Equation 19-64

$$d = \frac{3600}{c_{x,1}} \cdot 900T \left[\frac{v_x}{c_{x,1}} - 1 - \sqrt{\left(\frac{v_x}{c_{x,1}} - 1 \right)^2 + \frac{\left(\frac{3600}{c_{x,1}} \right)\left(\frac{v_x}{c_{x,1}} \right)}{450T}} \right] + 5$$

where

d = control delay (s/veh),

v_x = flow rate for movement x (veh/h),

$c_{x,1}$ = capacity of movement x (veh/h), and

T = analysis time period (equals 0.25 h for a 15-min period).

A constant value of 5 s/veh is used to reflect delay during deceleration to and acceleration from a stop.

The constant 5 s/veh is included in Equation 19-64 to account for the deceleration of vehicles from free-flow speed to the speed of vehicles in queue and the acceleration of vehicles from the stop line to free-flow speed.

Step 11b: Compute Control Delay to Rank 1 Movements

The effect of a shared lane on the major street approach where left-turning vehicles may block Rank 1 through or right-turning vehicles can be significant. If no exclusive left-turn pocket is provided on the major street, a delayed left-turning vehicle may block the Rank 1 vehicles behind it. This will delay not only Rank 1 vehicles but also lower-ranked movements. While the delayed Rank 1 vehicles are discharging from the queue formed behind a left-turning vehicle, they impede lower-ranked conflicting movements.

Field observations have shown that such a blockage effect is usually very small, because the major street usually provides enough space for the blocked Rank 1 vehicle to sneak by or bypass the left-turning vehicle. At a minimum, incorporating this effect requires estimating the proportion of Rank 1 vehicles being blocked and computing the average delay to the major street left-turning vehicles that are blocking through vehicles.

In the simplest procedure, the proportion of Rank 1 major-street vehicles not being blocked (i.e., in a queue-free state) is given by p'_0 in Equation 19-13 (p'_0 should be substituted for the main left-turn factor p_0 in Equation 19-43 in computing the capacity of lower-ranked movements that conflict). Therefore, the proportion of Rank 1 vehicles being blocked is $1 - p'_0$.

The average delay to Rank 1 vehicles is computed with Equation 19-65.

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$$d_{1,sr} = \begin{cases} (1 - p_{1,t}')\, d_{1,t,sr}\left(\frac{v_{1,t}}{N}\right) & N > 1 \\ v_{1,t} + v_{1,r} & \\ (1 - p_{1,t}')\, d_{1,t,sr} & N = 1 \end{cases}$$

Equation 19-65

where

$d_{1,sr}$ = delay to Rank 1 vehicles (s/veh),

N = number of through lanes per direction on the major street,

$p_{1,t}'$ = proportion of Rank 1 vehicles not blocked, from Equation 19-43,

$d_{1,t,sr}$ = delay to major left-turning vehicles, from Equation 19-64 (s/veh),

$v_{1,t}$ = major-street through vehicles in shared lane (veh/h), and

$v_{1,r}$ = major-street turning vehicles in shared lane (veh/h).

On a multilane road, only the major-street volumes in the lane that may be blocked should be used in the computation as $v_{1,t}$ and $v_{1,r}$. On multilane roads, if it is assumed that blocked Rank 1 vehicles do not bypass the blockage by moving into other through lanes (a reasonable assumption under conditions of high major-street flows), then $v_{1,t} = v_t/N$. Because of the unique characteristics associated with each site, the decision on whether to account for this effect is left to the analyst.

Step 12: Compute Approach and Intersection Control Delay

The control delay for all vehicles on a particular approach can be computed as the weighted average of the control delay estimates for each movement on the approach. Equation 19-66 is used for the computation.

$$d_A = \frac{d_R v_R + d_T v_T + d_L v_L}{v_R + v_T + v_L}$$

Equation 19-66

where

d_A = control delay on the approach (s/veh),

d_R, d_T, d_L = computed control delay for the right-turn, through, and left-turn movements, respectively (s/veh), and

v_R, v_T, v_L = volume or flow rate of right-turn, through, and left-turn traffic on the approach, respectively (veh/h).

Similarly, the intersection control delay can be computed with

$$d_I = \frac{d_A v_{A,1} + d_{A,2} v_{A,2} + d_{A,3} v_{A,3} + d_{A,4} v_{A,4}}{v_{A,1} + v_{A,2} + v_{A,3} + v_{A,4}}$$

Equation 19-67

where

d_A = control delay on approach x (s/veh), and

v_A = volume or flow rate on approach x (veh/h).

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In applying Equation 19-66 and Equation 19-67, the delay for all Rank 1 major-street movements is assumed to be 0 s/veh. LOS is not deemed for an overall intersection because major-street movements with 0 s of delay typically result in a weighted average delay that is extremely low. As such, total intersection control delay calculations are typically used only when comparing control delay among different types of traffic control, such as two-way STOP control versus all-way STOP control.

Step 13: Compute 95th Percentile Queue Lengths

Queue length is an important consideration at unsignalized intersections. Theoretical studies and empirical observations have demonstrated that the probability distribution of queue lengths for any minor movement at an unsignalized intersection is a function of the capacity of the movement and the volume of traffic being served during the analysis period. Equation 19-68 can be used to estimate the 95th percentile queue length for any minor movement at an unsignalized intersection during the peak 15-min period on the basis of these two parameters as follows (9).

Equation 19-68

$$Q_{95} = 900T\left(\frac{v_x}{c_{m,x}} - 1\right) + \sqrt{\left(\frac{v_x}{c_{m,x}} - 1\right)^2 + \left(\frac{3{,}600}{c_{m,x}}\right)\left(\frac{v_x}{1500T}\right)\left(\frac{c_{m,x}}{3{,}600}\right)}$$

where

Q_{95} = 95th percentile queue (veh),

v_x = flow rate for movement x (veh/h),

$c_{m,x}$ = capacity of movement x (veh/h), and

T = analysis time period (0.25 h for a 15-min period) (h).

The mean queue length is computed as the product of the average delay per vehicle and the flow rate for the movement of interest. The expected total delay (vehicle hours per hour) equals the expected number of vehicles in the average queue; that is, the total hourly delay and the average queue are numerically identical. For example, four vehicle hours per hour of delay can be used interchangeably with an average queue length of four vehicles during the hour.

PEDESTRIAN MODE

The TWSC intersection methodology for the pedestrian mode is applied through a series of steps preparing input data related to vehicle and pedestrian volumes, geometric conditions, and motorist yield rates to pedestrians. These data are used to calculate the average pedestrian delay associated with pedestrian crossings of unsignalized and non-stop-controlled roadways. The required steps are illustrated in Exhibit 19-16.

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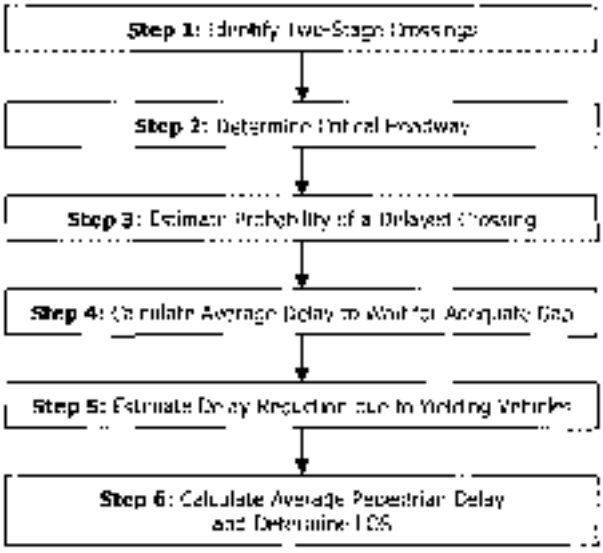

Exhibit 19-16
TWSC Pedestrian Methodology

Step 1: Identify Two-Stage Crossings

When a raised pedestrian-median refuge island is available, pedestrians typically cross in two stages, similar to the two-stage gap-acceptance described for automobiles earlier in this chapter. Determination of whether a pedestrian median refuge exists may require engineering judgment. The main issue to determine is whether pedestrians cross the traffic streams in one or two stages. When pedestrians cross in two stages, pedestrian delay should be estimated separately for each stage of the crossing by using the procedures described in Steps 2 to 6. To determine pedestrian LOS, the pedestrian delay for each stage should be summed to establish the average pedestrian delay associated with the entire crossing. This service measure is used to determine pedestrian LOS for a TWSC intersection with two-stage crossings.

Step 2: Determine Critical Headway

Critical headway for pedestrians.

The procedure for estimating the critical headway is similar to that described for automobiles. The critical headway is the time in seconds below which a pedestrian will not attempt to begin crossing the street. Pedestrians use their judgment to determine whether the available headway between conflicting vehicles is long enough for a safe crossing. If the available headway is greater than the critical headway, it is assumed that the pedestrian will cross, but if the available headway is less than the critical headway, it is assumed that the pedestrian will not cross.

For a single pedestrian, critical headway is computed with Equation 19-69:

$$t_c = \frac{I}{S_p} - l$$

Equation 19-69

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where

t_c = critical headway for a single pedestrian (s),

S_p = average pedestrian walking speed (ft/s),

L = crosswalk length (ft), and

t_s = pedestrian start-up time and end clearance time (s).

Pedestrian platooning

If pedestrian platooning is observed in the field, then the spatial distribution of pedestrians should be computed with Equation 19-70. If no platooning is observed, the spatial distribution of pedestrians is assumed to be 1.

Equation 19-70

$$N_s = \text{Int}\left[\frac{8.0(N_p - 1)}{W_c}\right] + 1$$

where

N_s = spatial distribution of pedestrians (ped),

N_p = total number of pedestrians in the crossing platoon, from Equation 19-71 (ped),

W_c = crosswalk width (ft), and

8.0 = default clear effective width used by a single pedestrian to avoid interference when passing other pedestrians (ft).

To compute spatial distribution, the analyst must make field observations or estimate the platoon size by using Equation 19-71:

Equation 19-71

$$N_p = \frac{v_p e^{(v_c t_c / 3600)} + v_p - 1}{(v_p + v_c)e^{(v_c t_c / 3600)} - v_c}$$

where

N_p = total number of pedestrians in the crossing platoon (ped),

v_p = pedestrian flow rate (ped/s),

v_c = vehicular flow rate (veh/s), and

t_c = single pedestrian critical headway (s).

Group critical headway is determined with Equation 19-72:

Equation 19-72

$$t_{c,g} = t_c + 2(N_p - 1)$$

where

$t_{c,g}$ = group critical headway (s),

t_c = critical headway for a single pedestrian (s), and

N_p = spatial distribution of pedestrians (ped).

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Step 3: Estimate Probability of a Delayed Crossing

On the basis of calculation of the critical headway t_c, the probability that a pedestrian will not incur any crossing delay is equal to the likelihood that a pedestrian will encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection.

Assuming random arrivals of vehicles on the major street, and equal distribution of vehicles among all through lanes on the major street, the probability of encountering a headway exceeding the critical headway in any given lane can be estimated by using a Poisson distribution. The likelihood that a gap in a given lane does not exceed the critical headway is thus the complement as shown in Equation 19-73. Because traffic is assumed to be distributed independently in each through lane, Equation 19-74 shows the probability that a pedestrian incurs nonzero delay at a TWSC crossing.

$$P_1 = 1 - e^{-\frac{v_{c,g} t_c}{3600}} \quad \text{Equation 19-73}$$

$$P_2 = 1 - (1 - P_1)^n \quad \text{Equation 19-74}$$

where

P_1 = probability of a blocked lane,
P_2 = probability of a delayed crossing,
n = number of through lanes crossed,
t_c = critical headway (s), and
$v_{c,g}$ = vehicular flow rate (veh/h).

Step 4: Calculate Average Delay to Wait for Adequate Gap

Research indicates that average delay to pedestrians at unsignalized crossings, assuming that no motor vehicles yield and the pedestrian is forced to wait for an adequate gap, depends on the critical headway, the vehicular flow rate of the subject crossing, and the mean vehicle headway ($1/f$). The average delay per pedestrian to wait for an adequate gap is given by Equation 19-75.

$$d_{p,g} = \frac{1}{f}\left(e^{\frac{v_{c,g} t_c}{3600}} - \frac{v_{c,g} t_c}{3600} - 1\right) \quad \text{Equation 19-75}$$

where

$d_{p,g}$ = average pedestrian gap delay (s),
t_c = critical headway (s), and
$v_{c,g}$ = vehicular flow rate (veh/h).

The average delay for any pedestrian who is unable to cross immediately upon reaching the intersection (e.g., any pedestrian experiencing nonzero delay) is equal to a function of P_2 and $d_{p,g}$ as shown in Equation 19-76.

$$d_{p,ng} = \frac{d_{p,g}}{P_2} \quad \text{Equation 19-76}$$

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where

d_{gi} = average gap delay for pedestrians who incur nonzero delay,

d_g = average pedestrian gap delay (s), and

P_t = probability of a delayed crossing.

Step 5: Estimate Delay Reduction due to Yielding Vehicles

When a pedestrian arrives at a crossing and finds an inadequate gap, that pedestrian is delayed until one of two situations occurs: (a) a gap greater than the critical headway is available, or (b) motor vehicles yield and allow the pedestrian to cross. Equation 19-75 estimates pedestrian delay when motorists on the major approaches do not yield to pedestrians. Where motorist yield rates are significantly higher than zero, pedestrians will experience considerably less delay than that estimated by Equation 19-75.

In the United States, motorists are legally required to yield to pedestrians, under most circumstances, at both marked and unmarked crosswalks. However, actual motorist yielding behavior varies considerably. Motorist yield rates are influenced by a range of factors, including roadway geometry, travel speeds, pedestrian crossing treatments, local culture, and law enforcement practices.

Research (11, 12) provides information on motorist responses to typical pedestrian crossing treatments, as shown in Exhibit 19-17. The exhibit shows results from two separate data collection methods. Staged data were collected with pedestrians trained by the research team to maintain consistent posturing, stance, and aggressiveness in crossing attempts. Unstaged data were collected through video recording of the general population. The values shown in Exhibit 19-17 are based on a limited number of sites and do not encompass the full range of available crossing treatments. As always, practitioners should supplement these values with local knowledge and engineering judgment.

Exhibit 19-17
Effect of Pedestrian Crossing Treatments on Motorist Yield Rates

Crossing Treatment	Staged Pedestrians		Unstaged Pedestrians	
	Number of Sites	Mean Yield Rate, %	Number of Sites	Mean Yield Rate, %
Overhead flashing beacon (push button activation)	3	47	4	49
Overhead flashing beacon (passive activation)	3	52	4	67
Pedestrian crossing flags	5	65	4	74
In-street crossing signs (25–30 mi/h)	3	87	3	90
Nonvisibility signs and markings (35 mi/h)	2	17	2	20
Nonvisibility signs and markings (25 mi/h)	1	62	1	91
Rectangular rapid-flash beacon	N/A	N/A	17	81

Source: Fitzpatrick et al. (12) and Shurbutt et al. (11).

Knowledge of the crossing treatment and other factors influence motorist behavior fairly significantly.

It is possible for pedestrians to incur less actual delay than d_g because of yielding vehicles. The likelihood of this situation occurring is a function of vehicle volumes, motorist yield rates, and number of through lanes on the major street. Consider a pedestrian waiting for a crossing opportunity at a TWSC intersection, with vehicles in each conflicting through lane arriving every h seconds. On average, a potential yielding event will occur every h seconds, where $P(Y)$ represents the probability of motorists yielding for a given event. As

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vehicles are assumed to arrive randomly, each potential yielding event is considered to be independent.

For any given yielding event, each through lane is in one of two states:

1. Clear—no vehicles are arriving within the critical headway window, or
2. Blocked—a vehicle is arriving within the critical headway window. The pedestrian may cross only if vehicles in each blocked lane choose to yield.

If not, the pedestrian must wait an additional h seconds for the next yielding event. On average, this process will be repeated until the wait exceeds t_d, the expected delay required for an adequate gap in traffic (d_a), at which point the average pedestrian will receive an adequate gap in traffic and will be able to cross the street without having to depend on yielding motorists.

Thus, average pedestrian delay can be calculated with Equation 19-77, where the first term in the equation represents expected delay from crossings occurring when motorists yield, and the second term represents expected delay from crossings where pedestrians wait for an adequate gap.

$$d_p = \sum_{i=1}^{n} h(i - 0.5)P(Y_i) + \left(P_a - \sum_{i=1}^{n} P(Y_i)\right)d_{ta} \quad \text{Equation 19-77}$$

where

d_p = average pedestrian delay (s),
i = crossing event ($i = 1$ to n),
h = average headway for each through lane,
$P(Y_i)$ = probability that motorists yield to pedestrian on crossing event i, and
n = $\text{Int}(t_d/h)$, average number of crossing events before an adequate gap is available.

Equation 19-77 requires the calculation of $P(Y_i)$. The probabilities $P(Y_i)$ that motorists will yield for a given crossing event are considered below for pedestrian crossings of one, two, three, and four through lanes.

One-Lane Crossing

Under the scenario in which a pedestrian crosses one through lane, $P(Y_i)$ is found simply. When $i = 1$, $P(Y_i)$ is equal to the probability of a delayed crossing, P_a, multiplied by the motorist yield rate, M_r, but $i = 2$, $P(Y_i)$ is equal to M_r multiplied by the probability that the second yielding event occurs (i.e., that the pedestrian did not cross on the first yielding event), $P(1 - M_r)$. Equation 19-78 gives $P(Y_i)$ for any i.

$$P(Y_i) = P_a M_r (1 - M_r)^{i-1} \quad \text{Equation 19-78}$$

where

M_r = motorist yield rate (decimal), and
i = crossing event ($i = 1$ to n).

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Two-Lane Crossing

For a two-lane pedestrian crossing at a TWSC intersection, $P(Y_i)$ requires either (*a*) motorists in both lanes to yield simultaneously if both lanes are blocked, or (*b*) a single motorist to yield if only one lane is blocked. Because these cases are mutually exclusive, where $i = 1$, $P(Y_i)$ is equal to Equation 19-79.

Equation 19-79

$$P(Y_i) = 2P_i(1 - P_i)M_{i-1} + P_i^2 M_{i-2}$$

Equation 19-80 shows $P(Y_i)$ where i is greater than 1. Equation 19-80 is equivalent to Equation 19-79 if $P(Y_0)$ is set to equal 0.

Equation 19-80

$$P(Y_i) = \left[P_i - \sum_{j=0}^{i-1} P(Y_j)\right]\left[(2P_i(1 - P_i)M_{i-1}) + (P_i^2 M_{i-2})\right]$$

Three Lane Crossing

A three-lane crossing follows the same principles as a two-lane crossing. Equation 19-81 shows the calculation for $P(Y_i)$:

Equation 19-81

$$P(Y_i) = \left[P_i - \sum_{j=0}^{i-1} P(Y_j)\right] \times \left[\frac{P_i^3 M_{i-3} + 3P_i^2(1 - P_i)M_{i-2} + 3P_i(1 - P_i)^2 M_{i-1}}{P_i}\right]$$

where $P(Y_0) = 1$.

Four-Lane Crossing

A four-lane crossing follows the same principles as above. Equation 19-82 shows the calculations for $P(Y_i)$.

Equation 19-82

$$P(Y_i) = \left[P_i - \sum_{j=0}^{i-1} P(Y_j)\right] \times \left[\frac{P_i^4 M_{i-4} + 4P_i^3(1 - P_i)M_{i-3} + 6P_i^2(1 - P_i)^2 M_{i-2} + 4P_i(1 - P_i^3)M_{i-1}}{P_i}\right]$$

where $P(Y_0) = 1$.

Step 6: Calculate Average Pedestrian Delay and Determine LOS

The delay experienced by a pedestrian is the service measure. Exhibit 19-2 lists LOS criteria for pedestrians at TWSC intersections based on pedestrian delay. Pedestrian delay at TWSC intersections with two-stage crossings is equal to the sum of the delay for each stage of the crossing.

BICYCLE MODE

As of the publication date of this edition of the HCM, no methodology specific to bicyclists has been developed to assess the performance of bicyclists at TWSC intersections, as few data are available in the United States to support model calibration or LOS definitions. Depending on individual comfort level, ability, geometric conditions, and traffic conditions, bicyclists may travel through the intersection as a motor vehicle or as a pedestrian. Critical headway

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distributions have been identified in the research (13, 14) for bicycles crossing two-lane major streets. Data on critical headways for bicycles under many circumstances are not readily available, however. Bicycles also differ from motor vehicles in that they normally do not queue linearly at a STOP sign. Instead, multiple bicycles often use the same gap in the vehicular traffic stream. This fact probably affects the determination of bicycle follow-up time. This phenomenon and others described in this section have not been adequately researched and are not explicitly included in the methodology.

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3. APPLICATIONS

DEFAULT VALUES

A comprehensive presentation of potential default values for interrupted flow facilities is provided elsewhere (1b), with specific recommendations summarized in its Chapter 3, Recommended Default Values. These defaults cover the key characteristics of PHF and percent heavy vehicles (%HV). Recommendations are based on geographic region, population, and time of day. All general default values for interrupted flow facilities may be applied to the analysis of TWSC intersections in the absence of field data or project conditions.

The following general default values may be applied to a TWSC intersection analysis:

- $PHF = 0.92$
- %HV = 3

Additional default values are sometimes required. For the analysis of shared or short major-street left-turn lanes, the following assumed default values may be applied for the saturation flow rates of the major-street through and right-turn movements:

- Major-street through movement, $s_T = 1,800$ veh/h
- Major-street right-turn movement, $s_T = 1,700$ veh/h

For analysis of pedestrians at TWSC intersections, the following default values may be applied:

- Average pedestrian walking speed, $S_p = 3.5$ ft/s
- Pedestrian start-up time and end clearance time, $t_s = 3$ s

As the number of default values used in any analysis increases, its accuracy becomes more approximate, and the result may be significantly different from the actual outcome, depending on local conditions.

ESTABLISH INTERSECTION BOUNDARIES

This methodology assumes that the TWSC intersection under investigation is isolated, with the exception of a TWSC intersection that is located within 0.25 mi of a signalized intersection (for the major-street approaches). When interaction effects are likely between the subject TWSC intersection and other intersections (e.g., queue spillback, demand starvation), the use of alternative tools may result in more accurate analysis. Analysis boundaries may also include different demand scenarios related to the time of day or to different development scenarios that produce various demand flow rates.

TYPES OF ANALYSIS

The methodology of this chapter can be used in three types of analysis: operational analysis, design analysis, and planning and preliminary engineering analysis.

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Operational Analysis

The methodology is most easily applied in the operational analysis mode. In operational analysis, all traffic and geometric characteristics of the analysis segment must be specified, including analysis-hour demand volumes for each turning movement in vehicles per hour, *SHV* for each approach, *PHF* for all demand volumes, lane configurations, specific geometric conditions, and upstream signal information. The outputs of an operational analysis are estimates of capacity, control delay, and queue lengths. The steps of the methodology, described in this chapter's methodology section, are followed directly without modification.

Design Analysis

The operational analysis described earlier in this chapter can be used for design purposes by using a given set of traffic flow data and iteratively determining the number and configuration of lanes that would be required to produce a given LOS.

Planning and Preliminary Engineering Analysis

The operational analysis method described earlier in this chapter provides a detailed procedure for evaluating the performance of a TWSC intersection. To estimate LOS for a future time horizon, a planning analysis based on the operational method is used. The planning method uses all the geometric and traffic flow data required for an operational analysis, and the computations are identical. However, input variables for *SHV* and *PHF* are typically estimated (or defaults are used) when planning applications are performed.

Interpreting Results

Analysis of TWSC intersections is commonly performed to determine whether an existing intersection or driveway can remain as a TWSC intersection or whether additional treatments are necessary. These treatments, including geometric modifications and changes in traffic control, are discussed in other references, including the presentation of traffic signal warrants in the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD; 16). This section discusses two common situations and issues for the analysis of shared versus separate lanes and the interpretation of LOS F.

Interpretation of the effects of shared lanes should take into account both delay associated with individual movements and delay associated with all vehicles on a given approach.

Some movements, most often left-turn movements, can sometimes have a poorer LOS when given a separate lane than when they share a lane with another movement (usually a through movement). This is not incongruent in terms of the control criteria. Left-turn movements will generally experience longer control delays than other movements because of the nature and priority of the movement. If left turns are placed in a shared lane, the control delay for vehicles in that lane may be less than the control delay for left turns in a separate lane. However, if delay for all vehicles on the approach or at the intersection is considered, providing separate lanes will result in lower total delay.

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PERFORMANCE MEASURES

LOS F occurs when there are not enough gaps of suitable size to allow minor-street vehicles to enter or cross through traffic on the major street, resulting in long average control delays (greater than 50 s/veh). Depending on the demand on the approach, long queues on the minor approaches may result. The method, however, is based on a constant critical headway.

LOS F may also appear in the form of drivers on the minor street selecting smaller-than-usual gaps. In such cases, safety issues may occur, and some disruption to the major traffic stream may result. With lower demands, LOS F may not always result in long queues.

At TWSC intersections, the critical movement, often the minor-street left turn, may control the overall performance of the intersection. The lower threshold for LOS F is set at 50 s of delay per vehicle. In some cases, the delay equations will predict delays greater than 50 s for minor-street movements under very low-volume conditions on the minor street (fewer than 25 veh/h). On the basis of the first term of the delay equation, the LOS F threshold is reached with a movement capacity of approximately 85 veh/h or less, regardless of the minor-street movement volume.

This analysis procedure assumes random arrivals on the major street. For a typical major street with two lanes in each direction and an average traffic volume in the range of 15,000 to 20,000 veh/day (roughly equivalent to a peak hour flow rate of 1,500 to 2,000 veh/h), the delay equation will predict greater than 50 s of delay (LOS F) for many urban TWSC intersections that allow minor-street left-turn movements. LOS F will be predicted regardless of the volume of minor-street left-turning traffic. Even with an LOS F estimate, most low-volume minor-street approaches would not meet any of the MUTCD volume or delay warrants for signalization. As a result, analysts who use the HCM LOS thresholds to determine the design adequacy of TWSC intersections should do so with caution.

In evaluating the overall performance of TWSC intersections, it is important to consider measures of effectiveness in addition to delay, such as volume to capacity (v/c) ratios for individual movements, average queue lengths, and 95th percentile queue lengths. By focusing on a single measure of effectiveness for the worst movement only, such as delay for the minor-street left turn, users may make less effective traffic control decisions.

USE OF ALTERNATIVE TOOLS

Strengths of the HCM Procedure

This chapter offers a set of comprehensive procedures for analyzing the performance of an intersection under two ways of control. Simulation-based tools offer a more detailed treatment of the arrival and departure of vehicles and their interaction with the roadway and the control system, but for most purposes the HCM procedure produces an acceptable approximation.

The HCM procedure offers the advantage of a deterministic evaluation of a TWSC intersection, the results of which have been accepted by a broad

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consensus of international experts. The HCM procedure also considers advanced concepts such as two-stage gap acceptance and flared approaches based on empirical evidence of their effects.

Limitations of the HCM Procedures That Might Be Addressed by Alternative Tools

The identified limitations for this chapter are shown in Exhibit 19-18, along with the potential for improved treatment by alternative tools.

Exhibit 19-18
Limitations of the HCM Signalized Intersection Procedure

Limitation	Potential for Improved Treatment by Alternative Tools
Effects of upstream intersections	Simulation tools can include an upstream intersection explicitly within a signalized arterial or network.
Yield-controlled intersection operations	Treated explicitly by some tools. Can be approximated by varying the gap acceptance parameters.
Non-steady-state conditions for demand and capacity	Most alternative tools provide for multiperiod variation of demand and, in some cases, capacity.
Macroscopic treatment of pedestrians and bicycles	Some simulation tools offer a microscopic modeling approach that provides explicit treatment of pedestrians and bicycles.

The most common application of alternative tools for HCM analysis is an oversaturated intersection within a signalized arterial system.

Most analyses for isolated unsignalized intersections are intended to determine whether TWSC is a viable control alternative. Analyses of this type are handled adequately by the procedures described in this chapter. The main application for alternative tools at TWSC intersections involves coordinated arterial systems. Most intersections (i.e., those that are between the signals) operate under TWSC. These intersections tend to be ignored in the analysis of the system because their effect on the system operation is minimal. Occasionally, it is necessary to examine a TWSC intersection as a part of the arterial system. While the procedures in this chapter provide a method for approximating the operation of a TWSC intersection with an upstream signal, the operation of such an intersection is arguably best handled by including it in a complete simulation of the full arterial system. For example, queue backup from a downstream signal that blocks entry from the cross street for a portion of the cycle is not treated explicitly by the procedures contained in this chapter.

Development of HCM-Compatible Performance Measures Using Alternative Tools

The performance measure that determines LOS for unsignalized intersections is *control delay*, defined as that portion of the delay that is due to the existence of the control device—in this case, a STOP sign. Most simulation tools do not produce explicit estimates of control delay.

The best way to determine control delay at a STOP sign from simulation is to perform simulation runs with and without the control device(s) in place. The segment delays reported with no control represent the delays due to geometrics and interaction between vehicles. The additional delay reported in the run with the control in place is, by definition, the control delay.

Chapter 7, Interpreting HCM and Alternative Tool Results, discusses performance measures from various tools in more detail, and Chapter 24, Concepts Supplemental, provides recommendations on how individual vehicle trajectories should be interpreted to produce specific performance measures. Of

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Delay and LOS should be recalculated only by using alternative tools that conform to these definitions and computation of queue delay as given in this chapter.

particular interest to TWSC operation is the definition of a "queued" state and the development of queue delay from that definition. For alternative tools that conform to the queue delay definitions and computations presented in this manual, the queue delay will provide the best estimate of control delay for TWSC intersections. Delay and LOS should not be estimated by using alternative tools that do not conform to these definitions and computations.

Conceptual Differences Between the HCM and Simulation Modeling That Preclude Direct Comparison of Results

Deterministic tools and simulation tools both model TWSC operations as a gap-acceptance process that follows the rules of the road to determine the right-of-way hierarchy. To this extent, they are dealing in the same conceptual framework. Deterministic tools such as the HCM base their estimates of capacity and delay on expected values computed from analytical formulations that have been mathematically derived. Simulation tools take a more microscopic view, treating each vehicle as an independent object that is subject to the rules of the road as well as interaction with other vehicles. Differences in the treatment of randomness also exist, as explained in the Chapter 18, Signalized Intersections, guidance.

When the opposing movement volumes are very high, there is minimal opportunity for the stop-controlled movements to accept gaps and these movements often have little or no capacity. Simulation tends to produce slightly higher capacities under these conditions because of overriding logic that limits the amount of time any driver is willing to wait for a gap. The overriding logic is somewhat tool specific.

In general, the simulation results for a specific TWSC intersection problem should be close to the results obtained from the procedures in this chapter. Some differences may, however, be expected among all the analysis tools.

Adjustment of Simulation Parameters to the HCM Parameters

The critical headways and follow-up headways are common to both deterministic and simulation models. It is therefore desirable that similar values be used for these parameters.

Sample Calculations Illustrating Alternative Tool Applications

It was mentioned previously that the most common application for TWSC simulation involves closely spaced intersections within a signalized arterial system. An example of this situation is presented in Chapter 29, Urban Street Facilities: Supplemental. An additional example involving blockage of a cross-street approach with STOP control by a queue from a nearby diamond interchange is presented in Chapter 36, Interchange Ramp Terminals: Supplemental.

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4. EXAMPLE PROBLEMS

Example Problem	Title	Type of Analysis
1	TWSC T-intersection	Operational analysis
2	TWSC pedestrian crossing	Operational analysis

Exhibit 19-19
List of Example Problems

EXAMPLE PROBLEM 1: TWSC T-INTERSECTION

The Facts

The following data are available to describe the traffic and geometric characteristics of this location.

- T-intersection,
- Major street with one lane in each direction,
- Minor street with one lane in each direction and stop-controlled on the minor-street approach,
- Level grade on all approaches,
- Percent heavy vehicles on all approaches = 10 %,
- No other unique geometric considerations or upstream signal considerations,
- No pedestrians,
- Length of analysis period = 0.25 h, and
- Volumes during the peak 15-min period and lane configurations as shown in Exhibit 19-20.

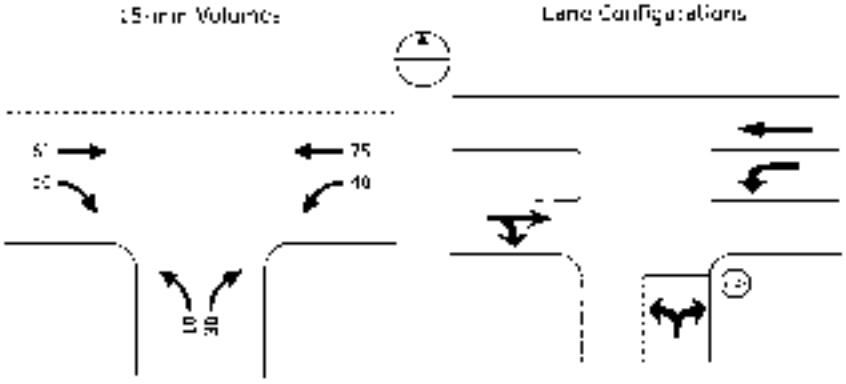

Exhibit 19-20
Example Problem 1: Movement Priorities, Lane Configurations, and Volumes

Comments

All input parameters are known, so no default values are needed or used.

Steps 1 and 2: Convert Movement Demand Volumes to Flow Rates and Label Movement Priorities

Because peak 15-min volumes have been provided, each volume is multiplied by 4 to determine a peak 15-min flow rate (in veh/h) for each

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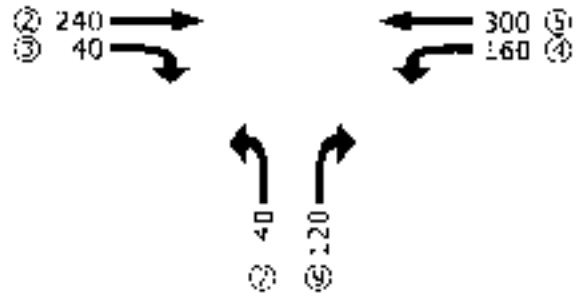
movement. These values, along with the associated movement numbers, are shown in Exhibit 19-21.

Exhibit 19-21
Example Problem 1: Calculation of Peak 15-min Flow Rates



Step 3: Compute Conflicting Flow Rates

The conflicting flow rates for each minor movement at the intersection are computed according to Equation 19-3, Equation 19-4, Equation 19-18, and Equation 19-24. The conflicting flow for the major-street left-turn v_{c1} is computed as follows:

$$v_{c1} = v_2 + v_3 + v_{18}$$

$$v_{c1} = 240 + 40 + 0 = 280 \text{ veh/h}$$

The conflicting flow for the minor-street right-turn movement v_{c9} is computed as follows:

$$v_{c9} = v_2 + 0.5v_3 + v_{16} + v_{17}$$

$$v_{c9} = 240 + 0.5(40) + 0 + 0 = 260 \text{ veh/h}$$

Finally, the conflicting flow for the minor-street left-turn movement v_{c7} is computed. Because two-stage gap acceptance is not present at this intersection, the conflicting flow rates shown in Stage I (Equation 19-18) and Stage II (Equation 19-24) are added together and considered as one conflicting flow rate. The conflicting flow for v_{c7} is computed as follows:

$$v_{c7} = 2v_1 + v_2 + 0.5v_3 + v_{16} + 2v_4 + v_5 + 0.5v_6 + 0.5v_{15} + 0.5v_{17} + v_{18}$$

$$v_{c7} = 2(0) + 240 + 0.5(40) + 0 + 2(160) + 300 + 0.5(0) + 0.5(0) + 0.5(0) + 0 = 880 \text{ veh/h}$$

Step 4: Determine Critical Headways and Follow-Up Headways

The critical headway for each minor movement is computed beginning with the base critical headway given in Exhibit 19-10. The base critical headway for each movement is then adjusted according to Equation 19-30. The critical headway for the major-street left-turn t_{c1} is computed as follows:

$$t_{c1} = t_{c,base} + t_{c,HV}P_{HV} + t_{c,G} - t_{c,T}$$

$$t_{c1} = 4.1 + 1.0(0.1) - 0(0) - 0 = 4.2 \text{ s}$$

Similarly, the critical headway for the minor-street right-turn t_{c9} is computed as follows:

$$t_{c9} = 6.2 + 1.0(0.1) + 0.1(0) - 0 = 6.3 \text{ s}$$

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Finally, the critical headway for the minor-street left-turn $t_{c,y}$ is computed as follows:

$$t_{c,y} = 7.1 + 1.0(0.1) + 0.2(0) - 0.7 = 6.5 \text{ s}$$

The follow-up headway for each minor movement is computed beginning with the base follow-up headway given in Exhibit 19-11. The base follow-up headway for each movement is then adjusted according to Equation 19-31. The follow-up headway for the major-street left-turn $t_{f,2}$ is computed as follows:

$$t_{f,x} = t_{f,base} + f_{HV} P_{HV}$$

$$t_{f,2} = 2.2 + 0.9(0.1) = 2.29 \text{ s}$$

Similarly, the follow-up headway for the minor-street right turn $t_{f,9}$ is computed as follows:

$$t_{f,9} = 3.3 - 0.9(0.1) = 3.39 \text{ s}$$

Finally, the follow-up headway for the minor-street left-turn $t_{f,y}$ is computed as follows:

$$t_{f,y} = 3.5 + 0.9(0.1) = 3.59 \text{ s}$$

Step 5: Compute Potential Capacities

The computation of a potential capacity for each movement provides the analyst with a definition of capacity under the assumed base conditions. The potential capacity will be adjusted in later steps to estimate the movement capacity for each movement. The potential capacity for each movement is a function of the conflicting flow rate, critical headway, and follow-up headway computed in the previous steps. The potential capacity for the major-street left turn $c_{p,2}$ is computed as follows:

$$c_{p,2} = 720 \frac{e^{-5.5(1{,}000)/1{,}500}}{1 - e^{-5.5(1{,}000)/3{,}600}} = 280 \frac{e^{-(250)(6.2)/3{,}600}}{1 - e^{-(250)(3.2)/3{,}600}} = 1{,}238 \text{ veh/h}$$

Similarly, the potential capacity for the minor-street right-turn movement $c_{p,9}$ is computed as follows:

$$c_{p,9} = 260 \frac{e^{-(1{,}000+500)(3.9)/3{,}600}}{1 - e^{-(1{,}000+500)(3.9)/3{,}600}} = 760 \text{ veh/h}$$

Finally, the potential capacity for the minor-street left-turn movement $c_{p,7}$ is computed as follows:

$$c_{p,7} = 880 \frac{e^{-(1{,}000+500)(6.5)/3{,}600}}{1 - e^{-(1{,}000+500)(3.5)/3{,}600}} = 308 \text{ veh/h}$$

There are no upstream signals, so the adjustments for upstream signals are ignored.

Step 6: Compute Movement Capacities for Rank 1 Movements

There are no pedestrians at the intersection; therefore, all pedestrian impedance factors are equal to 1.0 and this step can be ignored.

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Step 7: Compute Movement Capacities for Rank 2 Movements

The movement capacity for the major-street left-turn movement (Rank 2) $c_{u,1}$ is computed as follows:

$$c_{u,1} = (c_{p,1}) = 1{,}238 \text{ veh/h}$$

Similarly, the movement capacity for the minor-street right-turn movement (Rank 2) $c_{u,3}$ is computed as follows:

$$c_{u,3} \quad (c_{p,3}) \quad 760 \text{ veh/h}$$

Step 8: Compute Movement Capacities for Rank 3 Movements

The computation of vehicle impedance effects accounts for the reduction in potential capacity due to the impacts of the congestion of a high-priority movement on lower-priority movements.

Major-street movements of Rank 1 and Rank 2 are assumed to be unimpeded by other vehicular movements. Minor-street movements of Rank 3 can be impeded by major street left-turn movements due to a major-street left-turning vehicle waiting for an acceptable gap at the same time as vehicles of Rank 3. The magnitude of this impedance depends on the probability that major-street left turning vehicles will be waiting for an acceptable gap at the same time as vehicles of Rank 3. In this example, only the minor-street left-turn movement is defined as a Rank 3 movement. Therefore, the probability of the major-street left-turn operating in a queue-free state, $p_{x,1}$ is computed as follows:

$$p_{x,1} = 1 \quad \frac{v_1}{c_{u,1}} = 1 \quad \frac{160}{1{,}238} = 0.871$$

The movement capacity for the minor-street left-turn movement (Rank 3), $c_{p,2}$ is found by first computing a capacity adjustment factor that accounts for the impeding effects of higher-ranked movements. The capacity adjustment factor for the minor-street left-turn movement f_2 is computed with Equation 19-4a as follows:

$$f_2 = \prod_j p_{x,j} = 0.871$$

The movement capacity for the minor street left-turn movement (Rank 3) $c_{p,2}$ is computed as follows:

$$c_{p,2} = (c_{p,2}) f_2 = (308)0.871 = 268 \text{ veh/h}$$

Step 9: Compute Movement Capacities for Rank 4 Movements

There are no Rank 4 movements in this example problem, so this step does not apply.

Step 10: Compute Capacity Adjustment Factors

In this example, the minor-street approach is a single lane shared by right-turn and left-turn movements; therefore, the capacity of these two movements must be adjusted to compute an approach capacity based on shared-lane effects.

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The shared-lane capacity for the northbound major-street approach $c_{sh,NB}$ is computed as follows:

$$c_{sh,NB} = \frac{\sum v_i}{\sum \left(\frac{v_i}{c_{m,i}}\right)} = \frac{v_T + v_R}{\frac{v_T}{c_{m,T}} + \frac{v_R}{c_{m,R}}} = \frac{40 + 120}{\frac{40}{368} + \frac{120}{760}} = 521 \text{ veh/h}$$

No other adjustments apply.

Step 11: Compute Control Delay

The control-delay computation for any movement includes initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay.

Step 11a: Compute Control Delay to Rank 2 Through Rank 4 Movements

The control delay for the major street left-turn movement (Rank 2) d_4 is computed as follows:

$$d_4 = \frac{3600}{c_{m,4}} + 900T\left[\frac{v_4}{c_{m,4}} - 1 + \sqrt{\left(\frac{v_4}{c_{m,4}} - 1\right)^2 + \frac{\left(\frac{3,600}{c_{m,4}}\right)\left(\frac{v_4}{c_{m,4}}\right)}{450T}}\right] + 5$$

$$d_4 = \frac{3,600}{1,238} + 900(.25)\left[\frac{160}{1,238} - 1 + \sqrt{\left(\frac{160}{1,238} - 1\right)^2 + \frac{\left(\frac{3,600}{1,238}\right)\left(\frac{160}{1,238}\right)}{450(0.25)}}\right] + 5 = 8.3 \text{ s}$$

On the basis of Exhibit 19-7, the westbound left-turn movement is assigned LOS A.

The control delay for the minor-street right-turn and left-turn movements is computed by using the same formula; however, one significant difference from the major-street left-turn computation of control delay is that these movements share the same lane. Therefore, the control delay is computed for the approach as a whole and the shared-lane volume and shared-lane capacity must be used as follows:

$$d_{sh,NB} = \frac{3,600}{521} - 900(0.25)\frac{160}{521} + 1 + \sqrt{\left(\frac{160}{521} - 1\right)^2 + \frac{\left(\frac{3,600}{521}\right)\left(\frac{160}{521}\right)}{450(0.25)}} + 5 = 14.9 \text{ s}$$

On the basis of Exhibit 19-7, the northbound approach is assigned LOS B.

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Step 11b: Compute Control Delay to Rank 1 Movements

This step is not applicable as the westbound major-street through movement v_2 and westbound major-street left-turn movement v_1 have exclusive lanes at this intersection. It is assumed that the eastbound through movement v_5 and eastbound major-street right-turn movement v_6 do not incur any delay at this intersection.

Step 11c: Compute Approach and Intersection Control Delay

The control delays to all vehicles on the eastbound approach are assumed to be negligible as described in Step 11b. The control delay for the westbound approach $d_{A,WB}$ is computed as follows:

$$d_{A,WB} = \frac{d_1 v_1 + d_2 v_2 + d_3 v_3}{v_1 + v_2 + v_3}$$

$$d_{A,WB} = \frac{0(0) + 0(300) + 8.3(160)}{0 + 300 + 160} = 2.9 \text{ s}$$

It is assumed that the westbound through movement incurs no control delay at this intersection. The control delay for the northbound approach was computed in Step 11a as $d_{A,NB}$.

The intersection delay d_I is computed as follows:

$$d_I = \frac{d_{A,NB} v_{A,NB} + d_{A,WB} v_{A,WB} + d_{A,EB} v_{A,EB}}{v_{A,NB} + v_{A,WB} + v_{A,EB}}$$

$$d_I = \frac{0(280) + 2.9(460) + 14.9(160)}{280 + 460 + 160} = 4.1 \text{ s}$$

As noted previously, neither major street approach LOS nor intersection LOS is defined.

Step 12: Compute 95th Percentile Queue Lengths

The 95th percentile queue length for the major-street westbound left-turn movement, $Q_{95,1}$, is computed as follows:

$$Q_{95,1} = 900T\left[\frac{v_1}{c_{m,1}} - 1 + \sqrt{\left(\frac{v_1}{c_{m,1}} - 1\right)^2 + \frac{\left(\frac{3600}{c_{m,1}}\right)\left(\frac{v_1}{c_{m,1}}\right)}{150T}}\right]\left(\frac{c_{m,1}}{3600}\right)$$

$$Q_{95,1} = 900(0.25)\left[\frac{160}{1238} - 1 + \sqrt{\left(\frac{160}{1238} - 1\right)^2 + \frac{\left(\frac{3600}{1238}\right)\left(\frac{160}{1238}\right)}{150(0.25)}}\right]\left(\frac{1238}{3600}\right) = 0.4 \text{ veh}$$

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The result of 0.4 veh for the 95th percentile queue indicates that a queue of more than one vehicle will occur very infrequently for the major street left turn movement.

The 95th percentile queue length for the northbound approach is computed by using the same formula. Similar to the control-delay computation, the shared-lane volume and shared-lane capacity must be used as shown:

$$Q_{95,NB} = 900(0.25)\left[\frac{160}{521} + 1 - \sqrt{\left(\frac{160}{521} - 1\right)^2 + \frac{3{,}600}{150(0.25)}\left(\frac{160}{521}\right) - \left(\frac{521}{3{,}600}\right)}\right] = 1.3 \text{ veh}$$

The result suggests that a queue of more than one vehicle will occur only occasionally for the northbound approach.

Discussion

Overall, the results indicate that the three-leg TWSC intersection will operate well with small delays and little queuing for all minor movements.

EXAMPLE PROBLEM 2: TWSC PEDESTRIAN CROSSING

Calculate the pedestrian LOS of a pedestrian crossing of a major street at a TWSC intersection under the following circumstances:

- Scenario A: Unmarked crosswalk, no median refuge island;
- Scenario B: Unmarked crosswalk, median refuge island; and
- Scenario C: Marked crosswalk with high-visibility treatments, median refuge is and

The Facts

The following data are available to describe the traffic and geometric characteristics of this location:

- Four-lane major street;
- 1,700 peak hour vehicles, bidirectional;
- Crosswalk length without median = 46 ft;
- Crosswalk length with median = 40 ft;
- Observed pedestrian walking speed = 4.0 ft/s;
- Pedestrian start-up time = 3 s; and
- No pedestrian platooning.

Comments

In addition to the input data listed above, information is required on motor vehicle yield rates under the various scenarios. On the basis of an engineering study of similar intersections in the vicinity, it is determined that motor vehicle yield rates are 0% with unmarked crosswalks and 50% with high-visibility marked crosswalks.

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Step 1: Identify Two-Stage Crossings

Scenario A does not have two-stage pedestrian crossings, as no median refuge is available. Analysis for Scenarios B and C does assume two-stage crossings. Thus, analysis for Scenarios B and C will combine two equidistant pedestrian crossings in 2011 to determine the total delay.

Step 2: Determine Critical Headway

Because there is no pedestrian platooning, the critical headway is determined using Equation 19-69:

Scenario A: $t_{c,g}$ = (4.6 s/4 ft/s) + 3 s = 14.5 s

Scenario B: $t_{c,g}$ = (20 ft/4 ft/s) + 3 s = 8 s

Scenario C: $t_{c,g}$ = (20 ft/4 ft/s) + 3 s = 8 s

Step 3: Estimate Probability of a Delayed Crossing

Equation 19-73 and Equation 19-74 are used to calculate P_b, the probability of a blocked lane, and P_d, the probability of a blocked crossing, respectively. In the case of Scenario A, the crossing consists of four lanes. Scenarios B and C have only two lanes, given the two-stage crossing opportunity.

$$P_b = 1 - e^{-v_c \cdot t_{c,g}}$$

$$P_d = 1 - (1 - P_b)^n$$

where

P_b = probability of a blocked lane,

P_d = probability of a delayed crossing,

n = number of through lanes crossed,

$t_{c,g}$ = group critical headway (s), and

v_c = vehicular flow rate (veh/s).

For the single-stage crossing, v_c is (1,700 veh/h)/(3,600 s/h) = 0.47 veh/s.

For the two-stage crossing, without any information on directional flows, one-half the volume is used, and v_c is therefore (570 veh/h)/(3,600 s/h) = 0.24 veh/s.

Scenario A:

$$P_b = 1 - e^{-0.24 \cdot 14.5} = 0.82$$

$$P_d = 1 - (0.18)^4 = 0.999$$

Scenario B:

$$P_b = 1 - e^{-0.24 \cdot 8} = 0.61$$

$$P_d = 1 - (0.39)^2 = 0.85$$

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Scenario C:

$$P_c = 1 - e^{-\frac{s \cdot t_c}{3600}} = 0.61$$

$$P_{c,adj} = 1 - (0.39)^3 = 0.85$$

Step 4: Calculate Average Delay to Wait for Adequate Gap

Average gap delay d_g and average gap delay when delay is nonzero $d_{g,adj}$ are calculated by Equation 19-75 and Equation 19-76.

Scenario A:

$$d_g = \frac{1}{0.47} \times \left(e^{0.47 \times 14.5} - 0.47 \times 14.5 - 1\right) = 1.977 \text{ s}$$

$$d_{g,adj} = \frac{1.977}{0.099} = 19.9 \text{ s}$$

Scenario B:

$$d_g = \frac{1}{0.24}\left(e^{0.24 \times 8} - 0.24 \times 8 - 1\right) = 15.8 \text{ s}$$

$$d_{g,adj} = \frac{15.8}{0.85} = 18.6 \text{ s}$$

Scenario C:

$$d_g = \frac{1}{0.24}\left(e^{0.24 \times 8} - 0.24 \times 8 - 1\right) = 15.8 \text{ s}$$

$$d_{g,adj} = \frac{15.8}{0.85} = 18.6 \text{ s}$$

Step 5: Estimate Delay Reduction due to Yielding Vehicles

Under Scenarios A and B, the motorist yield rates are approximately 0%. Therefore, there is no reduction in delay due to yielding vehicles, and average delay is the same as that shown in Step 4. Under Scenario C, motorist yield rates are 50%. Because of the two-stage crossing, use Equation 19-80 to determine $P(Y_1)$:

$$P(Y_1) = [0.85 - 0] \left[\frac{(2 \times 0.61(1 - 0.61)0.50) + (0.61^2 0.50^2)}{0.85}\right] = 0.33$$

$$P(Y_2) = [0.85 - 0.33] \left[\frac{(2 \times 0.61(1 - 0.61)0.50) + (0.61^2 0.50^2)}{0.85}\right] = 0.20$$

The results of Equation 19-80 can be substituted into Equation 19-77 to determine average pedestrian delay.

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$$d_p = \sum_{i=1}^{2} 8.5(i-0.5)P(X_i) + \left(0.85 - \sum_{i=1}^{2} P(X_i)\right)18.6 = 9.8 \text{ s}$$

Step 6: Calculate LOS

Average pedestrian delays and pedestrian LOS under each of the three scenarios are as follows:

Scenario A = 2,979 s = LOS F

Scenario B = 2 × 15.8 s = 31.6 s = LOS D

Scenario C = 2 × 9.8 s = 19.6 s = LOS C

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CHAPTER 20
ALL-WAY STOP-CONTROLLED INTERSECTIONS

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1. INTRODUCTION

VOLUME 3: INTERRUPTED FLOW
16. Urban Street Facilities
17. Urban Street Segments
18. Signalized Intersections
19. TWSC Intersections
20. AWSC Intersections
21. Roundabouts
22. Interchange Ramp Terminals
23. Off-Street Pedestrian and Bicycle Facilities

Chapter 20, All-Way STOP-Controlled Intersections, presents concepts and procedures for analyzing these types of intersections (*1*). A glossary and list of symbols, including those used for all-way STOP-controlled (AWSC) intersections, is provided in Chapter 9.

AWSC intersections require every vehicle to stop at the intersection before proceeding. Because each driver must stop, the decision to proceed into the intersection is a function of traffic conditions on the other approaches. If no traffic is present on the other approaches, a driver can proceed immediately after stopping. If there is traffic on one or more of the other approaches, a driver proceeds only after determining that no vehicles are currently in the intersection and that it is the driver's turn to proceed.

Field observations indicate that standard four-leg AWSC intersections operate in either a two-phase or a four-phase pattern, based primarily on the complexity of the intersection geometry. Flows are determined by a consensus of right-of-way that alternates between the north–south and east–west streams (for a single-lane approach) or proceeds in turn to each intersection approach (for a multilane approach intersection).

If traffic is present on the subject approach only, vehicles depart as rapidly as individual drivers can safely accelerate into and clear the intersection. This case is illustrated as Case 1 in Exhibit 20-1.

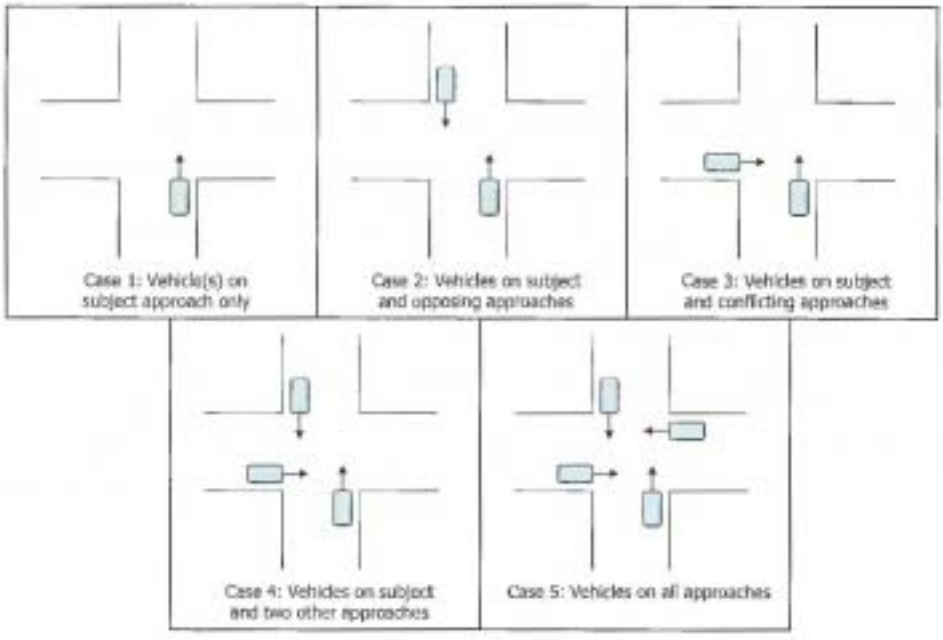

Exhibit 20-1
Analysis Cases for AWSC Intersections

If traffic is present on the other approaches, as well as on the subject approach, the saturation headway (the time between subsequent vehicle departures) on the subject approach will increase somewhat, depending on the degree of conflict that results between the subject approach vehicles and the

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vehicles on the other approaches. In Case 2, some uncertainty is introduced with a vehicle on the opposing approach, and thus the saturation headway will be greater than for Case 1. In Case 3, vehicles on one of the conflicting approaches further restrict the departure rate of vehicles on the subject approach, and the saturation headway will be longer than for Case 1 or Case 2. In Case 4, two vehicles are waiting on opposing or conflicting approaches, and saturation headways are even longer. When vehicles are present on all approaches, as in Case 5, saturation headways are the longest of any of the cases because the potential for conflict between vehicles is greatest. The increasing degree of potential conflict translates directly into longer driver decision times and longer saturation headways. Because no traffic signal controls the stream movement or allocates the right-of-way to each conflicting traffic stream, the rate of departure is controlled by the interactions between the traffic streams.

Capacity of an AWSC can be described by saturation headway, departure headway, and service time.

Therefore, the operation at an AWSC intersection can be described numerically by a few key time-based terms:

- The saturation headway, h_{si}, is the time between departures of successive vehicles on a given approach for a particular case (case i), as described above, assuming a continuous queue.
- The departure headway, h_d, is the average time between departures of successive vehicles on a given approach accounting for the probability of each possible case.
- The service time, t_s, is the average time spent by a vehicle in first position waiting to depart. It is equal to the departure headway minus the time it takes a vehicle to move from second position into first position (the move-up time, m).

INTERSECTION ANALYSIS BOUNDARIES AND TRAVEL MODES

The intersection analysis boundaries for an AWSC analysis are assumed to be those of an isolated intersection; that is, no upstream or downstream effects are accounted for in the analysis. The present methodology is limited to motor vehicles.

LEVEL-OF-SERVICE CRITERIA

The level-of-service (LOS) criteria for AWSC intersections are given in Exhibit 20-2. As the exhibit notes, LOS F is assigned if the volume-to-capacity (v/c) ratio of a lane exceeds 1.0, regardless of the control delay. For assessment of LOS at the approach and intersection levels, LOS is based solely on control delay.

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Control Delay (s/veh)	LOS by Volume-to-Capacity Ratio*	
	v/c ≤ 1.0	v/c > 1.0
≤ 10	A	F
>10–15	B	F
>15–25	C	F
>25–35	D	F
>35–50	E	F
>50	F	F

Note: * For approaches and intersection as a whole. LOS is defined solely by control delay.

Exhibit 20-2
LOS Criteria: Automobile Mode

REQUIRED INPUT DATA

Analysis of an AWSC intersection requires the following data.

1. Number and configuration of lanes on each approach,
2. Percentage of heavy vehicles,
3. Turning movement demand flow rate for each entering lane or, alternatively, hourly demand volume and peak hour factor, and
4. Length of analysis period – generally a peak 15-min period within the peak hour, although any 15-min period can be analyzed.

SCOPE OF THE METHODOLOGY

This chapter focuses on the operation of AWSC intersections. This version of the AWSC intersection analysis procedures is primarily a result of studies conducted by National Cooperative Highway Research Program Project 3-46 (*1*).

LIMITATIONS OF THE METHODOLOGY

Automobile Mode

The methodologies in this chapter apply to isolated AWSC intersections with up to three lanes on each approach. They do not account for interaction effects with other intersections. The methodologies do not apply to AWSC intersections with more than four approaches. In addition, the effect of conflicting pedestrians on automobiles is not considered in this procedure. Conflicting pedestrian movements are likely to increase the saturation headway of affected vehicular movements, but the magnitude of this effect is unknown as of the publication of this edition of the HCM.

Pedestrian and Bicycle Modes

The current methodologies for analyzing LOS and delay at AWSC intersections do not extend to pedestrians and apply to bicycles only in limited situations that are not supported by research at the time of publication of this edition. As such, there are no set LOS standards that apply to pedestrians or bicycles at AWSC intersections, nor can pedestrian or bicycle delay, capacity, or quality of service be quantitatively assessed by using the procedures described in this chapter. Additional research on pedestrian and bicyclist behavior and operations at AWSC intersections needs to be done before procedures can be developed that adequately address these issues. A discussion of qualitative effects is included in the methodology section of this chapter.

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2. METHODOLOGY

OVERVIEW

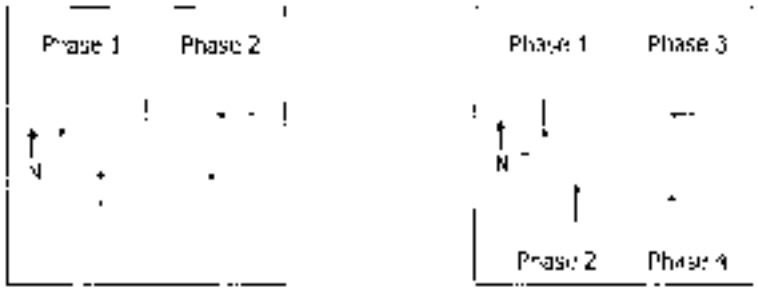
AWSC intersections require drivers on all approaches to stop before proceeding into the intersection. While giving priority to the driver on the right is a recognized rule in some areas, it is not a good description of actual intersection operations. What happens is the development of a consensus of right-of-way that alternates between the drivers on the intersection approaches, a consensus that depends primarily on the intersection geometry and the arrival patterns at the stop line.

The methodology analyzes each intersection approach independently. The approach under study is called the subject approach. The opposing approach and the conflicting approaches create conflicts with vehicles on the subject approach.

Phase Patterns

A two-phase pattern, as shown in Exhibit 20-3(a), is observed at a standard four-leg AWSC intersection (one approach lane on each leg), where drivers from opposing approaches enter the intersection at roughly the same time. Some interruption of this pattern occurs when there are conflicts between certain turning maneuvers (such as a northbound left-turning vehicle and a southbound through vehicle), but generally the north–south streams alternate right-of-way with the east–west streams. A four-phase pattern, as shown in Exhibit 20-3(b), emerges at multilane four-leg intersections, where development of the right-of-way consensus is more difficult. Here drivers from each approach enter the intersection together as right-of-way passes from one approach to the next and each is served in turn. A similar three-phase pattern emerges at multilane three-leg intersections.

Exhibit 20-3
Operation Patterns at AWSC Intersections



(a) Two-phase (single-lane approaches) (b) Four-phase (multiple approaches)

Two cases for departure headways

The headways of vehicles departing from the subject approach fall into one of two cases. If there are no vehicles on any of the other approaches, subject approach vehicles can enter the intersection immediately after stopping. However, if vehicles are waiting on a conflicting approach, a vehicle from the subject approach must wait for consensus with the next conflicting vehicle. The headways between consecutively departing subject approach vehicles will be shorter in the first case than in the second case. Thus, the headway for a departing subject approach vehicle depends on the degree of conflict experienced

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with vehicles on the other intersection approaches. The degree of conflict increases with two factors: the number of vehicles on the other approaches and the complexity of the intersection geometry.

Vehicle type and turning movement affect departure headway. These effects are captured implicitly in the method.

Two other factors affect the departure headway of a subject approach vehicle: vehicle type and turning movement. The headway for a heavy vehicle will be longer than that for a passenger car. Furthermore, the headway for a left-turning vehicle will be longer than that for a through vehicle, which in turn will be longer than that for a right-turning vehicle.

In summary:

1. Standard four-leg AWSC intersections operate in either two phase or four phase patterns, based primarily on the complexity of the intersection geometry. Flows are determined by a consensus of right-of-way that alternates between the north–south and east–west streams (for a single-lane approach) or proceeds in turn to each intersection approach (for a multilane approach).
2. The headways between consecutively departing subject approach vehicles depend on the degree of conflict between those vehicles and the vehicles on the other intersection approaches. The degree of conflict is a function of the number of vehicles faced by the subject approach vehicle and of the number of lanes on the intersection approaches.
3. The headway of a subject approach vehicle also depends on its vehicle type and its turning maneuver (if any).

Capacity Concepts

Capacity defined.

Capacity is defined as the maximum throughput on an approach given the flow rates on the other intersection approaches. The capacity model described here is an expansion of earlier work (*2*). The model is described for four increasingly complex cases: the intersection of two one-way streets with no turning movements, the intersection of two two-way streets with no turning movements, a generalized model for single-lane sites, and a generalized model for multilane sites. The methodology described later in this chapter is an implementation of the latter and most general case.

Intersection of Two One-Way Streets

The impact of turning movements is considered later, as part of the generalized model.

The first formulation of the model is based on the intersection of two one-way streets, each stop controlled. In this basic model, vehicles on either approach travel only straight through the intersection, as shown in Exhibit 20-4.

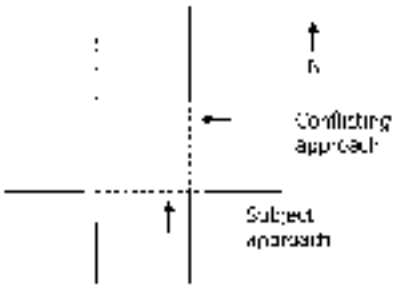

Exhibit 20-4
AWSC Configuration: Formulation 1

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The saturation headway for a vehicle assumes one of two values. h_{s1} is the saturation headway if no vehicle is waiting on the conflicting approach, and h_{s2} is the saturation headway if the conflicting approach is occupied. The departure headway for vehicles on an approach is the expected value of this bivalued distribution. For the eastbound approach, the mean service time is computed by Equation 20-1:

Equation 20-1

$$h_{d,E} = h_{s1}(1 - x_W) + h_{s2}x_W$$

where x_W is the degree of utilization of the westbound approach and is equal to the probability of finding at least one vehicle on that approach. Thus, $1 - x_W$ is the probability of finding no vehicle on the westbound approach.

By symmetry, the mean service time for the westbound approach is given by Equation 20-2:

Equation 20-2

$$h_{d,W} = h_{s1}(1 - x_E) + h_{s2}x_E$$

Since the degree of utilization x is the product of the arrival rate λ and the mean departure headway h_d, the departure headways for each approach can be expressed in terms of the bivalued saturation headways and the arrival rates on each approach, as in Equation 20-3 and Equation 20-4.

Equation 20-3

$$h_{d,E} = \frac{h_{s1}[1 + \lambda_W(h_{s2} - h_{s1})]}{1 - \lambda_E\lambda_W(h_{s2} - h_{s1})}$$

Equation 20-4

$$h_{d,W} = \frac{h_{s1}[1 + \lambda_E(h_{s2} - h_{s1})]}{1 - \lambda_E\lambda_W(h_{s2} - h_{s1})}$$

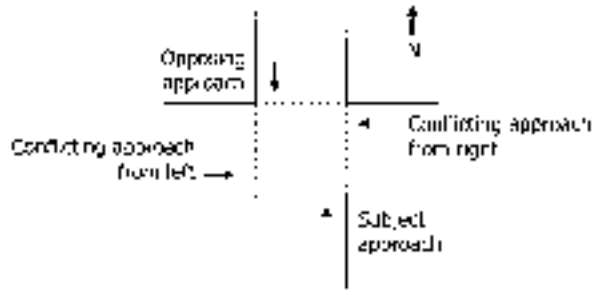
Intersection of Two Two-Way Streets

In this simplified model, the saturation headway for a vehicle assumes one of two values, h_{s1} or h_{s2}, because vehicles are again assumed to pass straight through the intersection. The departure headway for vehicles on an approach is the expected value of this bivalued distribution. A northbound vehicle will have a saturation headway of h_{s1} if the eastbound and westbound approaches are empty simultaneously. The probability of this event is the product of the probability of an empty westbound approach and the probability of an empty eastbound approach. The departure headway for the northbound vehicle is computed with Equation 20-5. See Exhibit 20-5.

Equation 20-5

$$h_{d,N} = h_{s1}(1 - x_E)(1 - x_W) + h_{s2}[1 - (1 - x_E)(1 - x_W)]$$

Exhibit 20-5
AWSC Configuration for Equation 2



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Unlike Formulation 1, it is not possible to solve directly for the departure headway in terms of a combination of arrival rates and the base saturation headways. The departure headway on any approach depends on, or is directly coupled with, the traffic intensity on the two conflicting approaches. This coupling prevents a direct solution. However, it is possible to solve for the departure headway on each approach in an iterative manner, by using a system of equations similar in form to Equation 20-5.

Generalized Model for Single-Lane Sites

Capacity is determined by an iterative procedure.

The generalized model is based on five saturation headway values, each reflecting a different level or degree of conflict faced by the subject approach driver. Exhibit 20-6 specifies the conditions for each case and the probability of occurrence of each. The probability of occurrence is based on the degree of utilization on the opposing and conflicting approaches. The essence of the model, and its complexity, is evident when one realizes that the traffic intensity on one approach is computed from its capacity, which in turn depends on the traffic intensity on the other approaches. The interdependence of the traffic flow on all intersection approaches creates the need for iterative calculations to obtain stable estimates of departure headway and service time and thus capacity.

Exhibit 20-6
Probability of Degree-of-Conflict Case

Degree-of-Conflict Case	Approach			Probability of Occurrence
	Opp	Con-L	Con-R	
1	N	N	N	$(1 - x_o)(1 - x_{cl})(1 - x_{cr})$
2	Y	N	N	$(x_o)(1 - x_{cl})(1 - x_{cr})$
3	N	Y	N	$(1 - x_o)(x_{cl})(1 - x_{cr})$
3	N	N	Y	$(1 - x_o)(1 - x_{cl})(x_{cr})$
4	Y	N	Y	$(x_o)(1 - x_{cl})(x_{cr})$
4	Y	Y	N	$(x_o)(x_{cl})(1 - x_{cr})$
4	N	Y	Y	$(1 - x_o)(x_{cl})(x_{cr})$
5	Y	Y	Y	$(x_o)(x_{cl})(x_{cr})$

Note: Opp = opposing approach, Con-L = conflicting approach from the left, Con-R = conflicting approach from the right, N = no, Y = yes.

The probability, $P(C_i)$, for each degree-of-conflict case given in Exhibit 20-6 can be computed with Equation 20-6 through Equation 20-10. The degrees of utilization on the opposing approach, the conflicting approach from the left, and the conflicting approach from the right are given by x_o, x_{cl}, and x_{cr}, respectively.

$$P(C_1) = (1 - x_o)(1 - x_{cl})(1 - x_{cr}) \quad \text{Equation 20-6}$$

$$P(C_2) = (x_o)(1 - x_{cl})(1 - x_{cr}) \quad \text{Equation 20-7}$$

$$P(C_3) = (1 - x_o)(x_{cl})(1 - x_{cr}) + (1 - x_o)(1 - x_{cl})(x_{cr}) \quad \text{Equation 20-8}$$

$$P(C_4) = (x_o)(1 - x_{cl})(x_{cr}) + (x_o)(x_{cl})(1 - x_{cr}) + (1 - x_o)(x_{cl})(x_{cr}) \quad \text{Equation 20-9}$$

$$P(C_5) = (x_o)(x_{cl})(x_{cr}) \quad \text{Equation 20-10}$$

The departure headway for an approach is the expected value of the saturation headway distribution, computed by Equation 20-11.

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Equation 20-11

$$h_g = \sum_i P(C_i) h_{g_i}$$

where $P(C_i)$ is the probability of the degree-of-conflict case C_i and h_{g_i} is the saturation headway for that case, given the traffic stream and geometric conditions of the intersection approach.

Capacity is determined by opposing volume on the subject approach and v > 1,0.

The capacity is computed by incrementally increasing the volume on the subject approach until the degree of utilization exceeds 1.0. This flow rate is the maximum possible flow or throughput on the subject approach under the conditions used as input to the analysis.

Generalized Model for Multilane Sites

Saturation headways at multilane sites are typically longer than at single-lane sites, all other conditions being equal. This situation is the result of two factors:

- A larger intersection (i.e., greater number of lanes) requires more travel time through the intersection, thus increasing the saturation headway; and
- Additional lanes also result in an increasing degree of conflict with opposing and conflicting vehicles, again increasing driver decision time and the saturation headway.

By contrast, some movements may not conflict with each other as readily at multilane sites as at single-lane sites. For example, a northbound vehicle turning right may be able to depart simultaneously with an eastbound through movement if the two vehicles are able to occupy separate receiving lanes when departing to the east. Consequently, in some cases, the saturation headway may be lower at multilane sites.

The theory described earlier proposed that the saturation headway is a function of the directional movement of the vehicle, the vehicle type, and the degree of conflict faced by the subject vehicle. This theory is extended here for multilane sites with respect to the concept of degree of conflict. saturation headway is affected to a large extent by the number of opposing and conflicting vehicles faced by the subject driver. For example, in degree-of-conflict Case 2, a subject vehicle is faced only by a vehicle on the opposing approach. At a two-lane approach, however, there can be either one or two vehicles on the opposing approach. Each degree-of-conflict case is expanded to consider the number of vehicles present in each of the opposing and conflicting approaches. The cases are defined in Exhibit 20-7 and Exhibit 20-8 for two-lane and three-lane approaches, respectively.

For multilane sites, separate saturation headway values are computed for the number of vehicles faced by the subject vehicle for each degree-of-conflict case. This calculation requires a further extension of the service time model to account for the increased number of subcases. These combinations can be further subdivided if a vehicle can be present on any lane on a given approach.

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Degree-of-Conflict Case	Approaches with Vehicles			Number of Opposing and Conflicting Vehicles
	Opposing	Conflicting Left	Conflicting Right	
1				0
2	x			1, 2
3		x		1, 2
			x	
4	x	x		2, 3, 4
	x		x	
		x	x	
5	x	x	x	3, 4, 5, 6

Exhibit 20-7
Degree of Conflict Cases for Two-Lane Approaches

Degree-of-Conflict Case	Approaches with Vehicles			Number of Opposing and Conflicting Vehicles
	Opposing	Conflicting Left	Conflicting Right	
1				0
2	x			1, 2, 3
3		x		1, 2, 3
			x	
4	x	x		2, 3, 4, 5, 6
	x		x	
		x	x	
5	x	x	x	3, 4, 5, 6, 7, 8, 9

Exhibit 20-8
Degree-of-Conflict Cases for Three-Lane Approaches

The probability of a vehicle being at the stop line in a given lane is the degree of utilization. The product of the six degrees of saturation encompassing each of the six lanes on the opposing or conflicting approaches (two lanes on the opposing approach and two lanes on each of the conflicting approaches), gives the probability of any particular combination occurring.

The iterative procedure to compute the departure headways and capacities for each approach as a function of the departure headways on the other approaches is the same as described earlier. However, the additional subcases greatly increase the complexity of this computation.

AUTOMOBILE MODE

The AWSC intersection methodology for the automobile mode is applied through a series of steps that relate to input data, saturation headways, departure headways, service time, capacity, and LOS. They are illustrated in Exhibit 20-9.

Step 1: Convert Movement Demand Volumes to Flow Rates

Flow rates for each turning movement at the intersection must be converted from hourly volumes in vehicles per hour (veh/h) to peak 15-min flow rates in vehicles per hour as given in Equation 20-12.

$$v_i = \frac{V_i}{PHF}$$

Equation 20-12

where

v_i = demand flow rate for movement i (veh/h),

V_i = demand volume for movement i (veh/h), and

PHF = peak hour factor.

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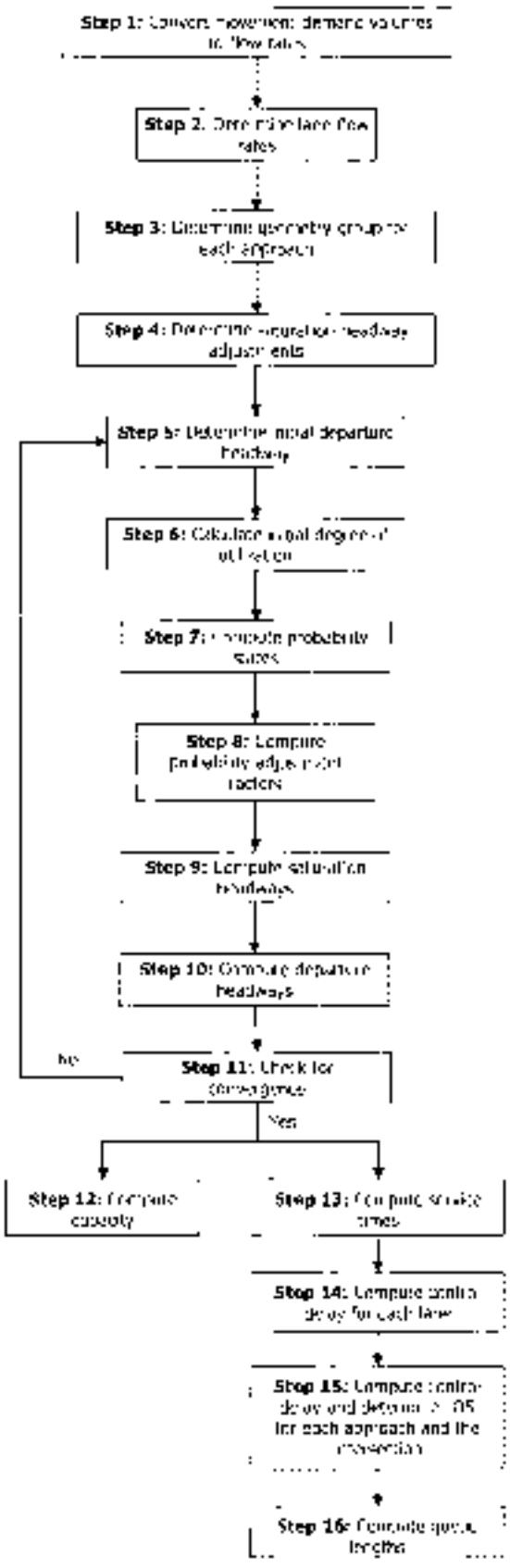
Exhibit 20-9
AWSC Intersection Methodology



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Step 2: Determine Lane Flow Rates

For multiple-lane approaches, the flow rate for each lane by movement is determined. If a certain movement can use more than one lane and its traffic volume distribution per lane is unknown, an equal distribution of volume among the lanes can be assumed.

Step 3: Determine Geometry Group for Each Approach

Exhibit 20-10 is provided to determine the geometry group for each approach. The geometry group is needed to look up base saturation headways and headway adjustment factors.

Exhibit 20-10
Geometry Groups

Intersection Configuration	Number of Lanes: Subject Approach	Opposing Approach	Conflicting Approaches[a]	Geometry Group
Four leg or T	1	0 or 1	1	1
Four leg or T	1	0 or 1	2	2
Four leg or T	1	2	1	3a/4a
T	1	2	2	3a
Four leg	1	2	2	4a
Four leg or T	1	0 or 1	3	5
	1	3	1	
	2	0, 1, or 2	1 or 2	
	3	0 or 1	1	
	3	0 or 1	2 or 3	
	2	2 or 3	1	
Four leg or T	1	3	2	6
	1	2	3	
	1	3	3	
	2	3	1, 2, or 3	
	2	0, 1, 2 or 3	3	
	3	2 or 3	2 or 3	

Note: [a] If the number of lanes on conflicting approaches is different, the higher of the two values should be used.

Step 4: Determine Saturation Headway Adjustments

The headway adjustment for each lane is computed by Equation 20-13. Saturation headway adjustments for left turns, right turns, and heavy vehicles are given in Exhibit 20-11.

$$h_{adj} = h_{adj,LT} P_{LT} + h_{adj,RT} P_{RT} + h_{adj,HV} P_{HV}$$

Equation 20-13

where

h_{adj} = headway adjustment (s),

$h_{adj,LT}$ = headway adjustment for left turns (see Exhibit 20-11) (s),

$h_{adj,RT}$ = headway adjustment for right turns (see Exhibit 20-11) (s),

$h_{adj,HV}$ = headway adjustment for heavy vehicles (see Exhibit 20-11) (s),

P_{LT} = proportion of left-turning vehicles in the lane,

P_{RT} = proportion of right-turning vehicles in the lane, and

P_{HV} = proportion of heavy vehicles in the lane.

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Exhibit 20-11
Saturation Headway Adjustments by Geometry Group

	Saturation Headway Adjustment (s)							
Factor	Group 1	Group 2	Group 3a	Group 3b	Group 4a	Group 4b	Group 5	Group 6
LT	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.5
RT	−0.6	−0.6	−0.6	−0.6	−0.6	−0.6	−0.7	−0.7
HV	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7

Note: LT = left turns, RT = right turns, HV = heavy vehicles.

Step 5: Determine Initial Departure Headway

The process of determining departure headways (and thus service times) for each of the lanes on each of the approaches is iterative. For the first iteration, an initial departure headway of 3.2 s would be assumed. For subsequent iterations, the calculated values of departure headway from the previous iteration should be used if the calculation has not converged (see Step 10).

Step 6: Calculate Initial Degree of Utilization

By using the lane flow rates from Step 2 and the assumed initial departure headway from Step 5, the initial degree of utilization, x_i, is computed with Equation 20-14. If it is not the final iteration and the degree of utilization exceeds 1, then the degree of utilization should be reset to 1.

Equation 20-14

$$x = \frac{vh_d}{3{,}600}$$

Step 7: Compute Probability States

The probability state of each combination i is found with Equation 20-15.

Equation 20-15

$$P(i) = \prod_j P(a_j)$$

where

j = O1 (opposing approach, Lane 1), O2 (opposing approach, Lane 2), C1L (conflicting left approach, Lane 1), C2L (conflicting left approach, Lane 2), C1R (conflicting right approach, Lane 1), and C2R (conflicting right approach, Lane 2) for a two-lane, two-way AWSC intersection;

$P(a_j)$ = probability of a_j computed on the basis of Exhibit 20-12, where V_j is the lane flow rate; and

a_j = 1 (indicating a vehicle present) or 0 (indicating no vehicle present in the lane) values of a_j for each lane in each combination are listed in Exhibit 20-13.

Exhibit 20-12
Probability of a_j

a_j	V_j	$P(a_j)$
1	0	0
0	0	1
1	> 0	x_j
0	> 0	$1 - x_j$

Note: x_j is the degree of utilization defined in Equation 20-14.

Tables for three-lane approaches are given in Chapter 32, Two-Controlled Intersections: Supplemental.

Exhibit 20-13 provides the 64 possible combinations when alternative lane occupancies are considered for two-lane approaches. A 1 indicates that a vehicle is in the lane, and a 0 indicates that a vehicle is not in the lane. A similar table for three lanes on each approach is provided in Chapter 32 in Volume 4.

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Exhibit 20-13
Probability of Degree-of-Conflict Case for Intersection AWSC Intersections (Two-Lane Approaches, by Lane)

J	DOC Case	Number of Vehicles	Opposing Approach L1	Opposing Approach L2	Conflicting Left Approach L1	Conflicting Left Approach L2	Conflicting Right Approach L1	Conflicting Right Approach L2
1	1	0	0	0	0	0	0	0
2	2	1	1	0	0	1	0	0
3			0	1	0	0	0	0
4		2	1	1	0	0	0	0
5	3	1	0	0	1	0	0	0
6			0	0	0	1	0	0
7			0	0	0	0	1	0
8			0	1	0	0	0	1
9		2	0	0	1	1	0	0
10			0	0	0	0	1	1
11	4	2	0	0	0	1	0	1
12			0	0	1	0	0	1
13			1	1	1	1	1	0
14			0	1	0	1	1	0
15			0	1	0	1	0	0
16			1	0	1	0	0	0
17			0	1	0	1	0	0
18			1	1	0	1	0	0
19			0	1	1	0	0	0
20			0	1	0	0	0	1
21			1	0	0	0	1	0
22			1	0	0	0	0	1
23		3	0	0	0	1	1	1
24			0	0	1	1	0	1
25			0	0	1	1	1	0
26			1	0	1	1	0	0
27			1	1	1	0	0	0
28			1	1	0	1	1	0
29			1	1	0	1	0	1
30			0	1	1	1	0	0
31			1	0	0	0	1	1
32			0	0	1	0	1	1
33			1	1	0	1	0	0
34			0	1	0	1	1	1
35		4	1	1	0	0	1	1
36			0	0	1	1	1	1
37			1	1	1	1	0	0
38	5	3	0	1	0	1	0	1
39			1	0	0	1	1	0
40			0	1	1	0	1	0
41			0	1	0	1	1	0
42			0	1	1	0	0	1
43			1	0	1	1	0	1
44			1	1	0	1	0	1
45			1	1	1	0	1	0
46		4	1	0	0	1	1	1
47			0	1	1	1	1	0
48			0	1	1	1	0	1
49			1	1	1	1	1	1
50			1	0	1	1	1	0
51			0	1	0	1	1	1
52			1	1	1	0	0	1
53			1	0	1	1	0	1
54			1	1	1	1	1	1
55			1	1	0	1	1	0
56			1	1	0	1	0	1
57			1	1	1	0	1	0
58	6	5	1	0	1	1	1	1
59			1	1	0	1	1	1
60			1	1	1	1	1	1
61			0	1	1	1	1	1
62			1	1	1	1	1	0
63			1	1	1	1	0	1
64		6	1	1	1	1	1	1

Note: DOC case is the degree-of-conflict case, number of vehicles is the total number of vehicles on the opposing and conflicting approaches. L1 is Lane 1, and L2 is Lane 2.

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Step 8: Compute Probability Adjustment Factors

The probability adjustment is computed with Equation 20-16 through Equation 20-20 to account for the serial correlation in the previous probability computation. First, the probability of each degree-of-conflict case must be determined (assuming the 64 cases presented in Exhibit 20-13).

Equation 20-16
$$P(C_1) = P(1)$$

Equation 20-17
$$P(C_2) = \sum_{i=2}^{4} P(i)$$

Equation 20-18
$$P(C_3) = \sum_{i=5}^{10} P(i)$$

Equation 20-19
$$P(C_4) = \sum_{i=11}^{36} P(i)$$

Equation 20-20
$$P(C_5) = \sum_{i=37}^{64} P(i)$$

The probability adjustment factors are then computed with Equation 20-21 through Equation 20-25.

Equation 20-21
$$Adj P(1) = \alpha[P(C_2) + 2P(C_3) + 3P(C_4) + 4P(C_5)]/3$$

Equation 20-22
$$Adj P(2) \text{ through } Adj P(4) = \alpha[P(C_2) + 2P(C_3) - 3P(C_4) - P(C_5)]/3$$

Equation 20-23
$$Adj P(5) \text{ through } Adj P(10) = \alpha[P(C_3) - 2P(C_4) - 3P(C_5)]/6$$

Equation 20-24
$$Adj P(11) \text{ through } Adj P(37) = \alpha[P(C_4) - 6P(C_5)]/27$$

Equation 20-25
$$Adj P(38) \text{ through } Adj P(64) = \alpha[10P(C_5)]/27$$

where α equals 0.01 (or 0.00 if correlation among saturation headways is not taken into account).

The adjusted probability $P'(i)$ for each combination is simply the sum of $P(i)$ and $Adj P(i)$, as given by Equation 20-26.

Equation 20-26
$$P'(i) = P(i) + Adj P(i)$$

Step 9: Compute Saturation Headways

The saturation headway h_{ij} is the sum of the base saturation headway as presented in Exhibit 20-14 and the saturation headway adjustment factor from Step 4. It is shown in Equation 20-27.

Equation 20-27
$$h_{ij} = h_{base} + h_{adj}$$

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Case	No. of Veh.	Base Saturation Headway (s) Group 1	Group 2	Group 3a	Group 3b	Group 4a	Group 4b	Group 5	Group 6
1	0	3.9	3.9	4.0	4.0	4.0	4.0	4.5	4.5
2	1	4.7	4.7	4.8	5.1	4.8	5.3	5.0	6.0
	2							6.2	6.8
	≥3								7.4
3	1	5.8	5.8	5.9	6.2	5.9	6.4	6.4	6.6
	2							7.2	7.3
	≥3								7.8
4	2	7.0	7.0	7.1	7.4	7.1	7.5	7.6	8.1
	3							7.8	8.7
	4							9.0	9.6
	≥5								12.0
5	3	9.6	9.6	9.7	10.0	9.7	10.2	9.7	10.6
	4							9.7	11.1
	5							10.6	11.4
	≥6							11.5	13.3

Exhibit 20-14
Saturation Headway Values by Case and Geometry Group

Step 10: Compute Departure Headways

The departure headway of the approach is the expected value of the saturation headway distribution, given by Equation 20-28.

$$h_d = \sum_{i=1}^{6} P(i) h_{s,i} \qquad \text{Equation 20-28}$$

where i represents each combination of the five degree of conflict cases and $h_{s,i}$ is the saturation headway for that combination.

Step 11: Check for Convergence

The calculated values of h_d are checked against the initial values assumed for h_d. If the values change by more than 0.1 s (for a more precise measure of convergence), Steps 5 through 10 are repeated until the values of departure headway for each lane do not change significantly.

Step 12: Compute Capacity

Capacity is estimated for a stable set of opposing and conflicting volumes.

The capacity of each approach is computed under the assumption that the flows on the opposing and conflicting approaches are constant. The given flow rate on the subject lane is increased and the departure headways are computed for each approach until the degree of utilization for the subject lane reaches 1. When this occurs, the final value of the subject approach flow rate is the maximum possible throughput or capacity of this lane.

Step 13: Compute Service Times

The service time required to calculate control delay is computed on the basis of the final calculated departure headway and the move-up time with Equation 20-29.

$$t_s = h_d - m \qquad \text{Equation 20-29}$$

where t_s is the service time, h_d is the departure headway, and m is the move-up time (2.0 s for Geometry Groups 1 through 4, 2.3 s for Geometry Groups 5 and 6).

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Step 14: Compute Control Delay for Each Lane

The delay experienced by a motorist is made up of a number of factors that relate to control, geometrics, traffic, and incidents. Control delay is the difference between the travel time that is actually experienced and the reference travel time that would result during conditions in the absence of traffic control or conflicting traffic.

Equation 20-30 can be used to compute control delay for each lane.

Equation 20-30

$$d = t_s + 900T\left[(x-1) + \sqrt{(x-1)^2 + \frac{kx}{450T}}\right] + 5$$

where

d = average control delay (s/veh),

x = $vt_s/3{,}600$ = degree of utilization,

t_s = service time (s),

k = departure headway (s), and

T = length of analysis period (h).

Step 15: Compute Control Delay and Determine LOS for Each Approach and the Intersection

The control delay for an approach is calculated by computing a weighted average of the delay for each lane on the approach, weighted by the volume in each lane. The calculation is shown in Equation 20-31.

Equation 20-31

$$d_{approach} = \frac{\sum d_i v_i}{\sum v_i}$$

where

$d_{approach}$ = control delay for the approach (s/veh),

d_i = control delay for lane i (s/veh), and

v_i = flow rate for lane i (veh/h).

The control delay for the intersection as a whole is similarly calculated by computing a weighted average of the delay for each approach, weighted by the volume on each approach. It is shown in Equation 20-32.

Equation 20-32

$$d_{intersection} = \frac{\sum d_i v_i}{\sum v_i}$$

where

$d_{intersection}$ = control delay for the entire intersection (s/veh),

d_i = control delay for approach i (s/veh), and

v_i = flow rate for approach i (veh/h).

The LOS for each approach and for the intersection are determined with Exhibit 20-2 and the computed values of control delay.

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Step 16: Compute Queue Lengths

Research (*3*) has determined that the methodology for predicting queues at TWSC intersections can be applied to AWSC intersections. As such, the mean queue length is computed as the product of the average delay per vehicle and the flow rate for the movement of interest.

Equation 20-33 can be used to calculate the 95th percentile queue for each approach lane.

$$Q_{95} = \frac{900T}{t_d}\left[(x-1)+\sqrt{(x-1)^2+\frac{t_d x}{150T}}\right] \quad \text{Equation 20-33}$$

where

Q_{95} = 95th percentile queue (veh),

x = $v t_d/3{,}600$ = degree of utilization,

t_d = departure headway (s), and

T = length of analysis period (h).

PEDESTRIAN MODE

Data collection and research are needed to determine an appropriate LOS methodology for pedestrians at AWSC intersections.

Applying the LOS procedures used to determine pedestrian delay at TWSC intersections to AWSC intersections does not produce intuitive or usable results. The TWSC delay calculations apply only for crossings where conflicting traffic is not stop-controlled (i.e., pedestrians crossing the major street at a TWSC intersection). Approaches where conflicting traffic is stop-controlled (i.e., pedestrians crossing the minor street at a TWSC intersection) are assumed to result in negligible delay for pedestrians, as vehicles are required to stop and wait for conflicting vehicle and pedestrian traffic before proceeding.

As such, applying the TWSC methodology to pedestrians at AWSC intersections results in negligible delay for all pedestrians at all approaches. The reality of AWSC intersection operations for pedestrians is much different, however, and generally results in at least some delay for pedestrians. The amount of delay incurred will depend on a number of operating and geometric characteristics of the intersection in question. While no quantitative methodology accounting for these factors is available, several of the most important factors are discussed qualitatively below.

The operational characteristics of AWSC intersections for pedestrians largely depend on driver behavior. In most cases, drivers are legally required to yield to pedestrians crossing or preparing to cross AWSC intersections. However, it should be expected that operations differ significantly depending on enforcement levels, region of the country, and location (e.g., urban, suburban, or rural).

Traffic Volumes

At intersections with relatively low traffic volumes, there are generally no standing queues of vehicles at AWSC approaches. In these cases, pedestrians attempting to cross an approach of the intersection will typically experience little

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or no delay, as they will be able to proceed almost immediately after reaching the intersection.

At AWSC intersections with higher volumes, there are typically standing queues of motor vehicles on each approach. These intersections operate on a two-phase or four-phase sequence, as described earlier and depicted in Exhibit 20-3. In these situations, the arrival of a pedestrian does not typically disrupt the normal phase operations of the intersection. Rather, the pedestrian is often forced to wait until the phase arrives for vehicles in the approach moving adjacent to the pedestrian.

Under a scenario in which the intersection functions under the operations described above for pedestrians, average pedestrian delay might be expected to be half of the time needed to cycle through all phases for the particular intersection, assuming random arrival of pedestrians. However, several other factors may also affect pedestrian delay and operations at AWSC intersections, as described below.

Number of Approach Lanes

As the number of approach lanes at AWSC intersections increases, pedestrian crossing distance increases proportionally, resulting in significantly longer pedestrian crossing times compared with single-lane intersections. In addition, vehicles already in the intersection or about to enter the intersection take longer to complete their movement. As a result, pedestrians at multilane AWSC intersections may wait longer before taking their turn to cross.

Proportion of Turning Traffic

The ability of a pedestrian to cross at an AWSC intersection may also depend on the proportion of through motor vehicle traffic to turning motor vehicle traffic. As described above, pedestrians may often cross during the phase in which adjacent motor vehicle traffic traverses the intersection. However, when an adjacent motor vehicle is turning, that vehicle will conflict with pedestrians attempting to cross. Because of the additional conflicts with pedestrians created by turning vehicles at AWSC intersections, pedestrian delay may be expected to rise as the proportion of turning vehicles increases, similar to the effect that turning proportion has on vehicular delay.

Pedestrian Volumes

Under most circumstances, there is adequate capacity for all pedestrians queued for a given movement at an AWSC intersection to cross simultaneously with adjacent motor vehicle traffic. However, in locations with very high pedestrian volumes, this may not be the case. The total pedestrian capacity of a particular AWSC intersection phase is limited by both the width of the crosswalk (how many pedestrians can cross simultaneously) and driver behavior.

In situations in which not all queued pedestrians may cross during a particular phase, pedestrian delay will increase, as some pedestrians will be forced to wait through an additional cycle of intersection phases before crossing. However, pedestrian volumes in this range are unlikely to occur often; rather,

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intersections with pedestrian volumes high enough to cause significant delay are typically signalized.

BICYCLE MODE

Where bicycles queue with motor vehicles on AWSC approaches, the procedures described to estimate motor vehicle delay can be applied to bicycles. However, bicycles differ from motor vehicles in that they do not queue evenly at STOP signs. Instead, multiple bicycles often cross at the same time as the adjacent vehicular traffic stream. This phenomenon has not been researched as of the time of publication of this edition of the HCM and is not explicitly included in the methodology.

Where an AWSC approach provides a bicycle lane, bicycle delay will be significantly different and, in general, lower than motor vehicle delay. The exception is bicycles intending to turn left. These cyclists will typically queue with motor vehicles. Where bicycle lanes are available, bicycles are able to move unimpeded until reaching the stop line, as the bike lane allows the cyclist to pass any queued motor vehicles on the right. In this situation, bicycles will still incur delay upon reaching the intersection.

In most cases, bicycles will be able to travel through the intersection concurrently with adjacent motor vehicle traffic. This, in effect, results in multilane operations, with the bike lane serving as the curb lane, meaning that bicycles will be delayed from the time of arrival at the intersection until the adjacent motor vehicle phase ceases. As noted above, multiple bicycles will likely be able to cross simultaneously through the intersection. Finally, even where bicycle lanes are not available, many cyclists still pass queued motor vehicles on the right, resulting in lower effective bicycle delay compared with motor vehicle delay.

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3. APPLICATIONS

DEFAULT VALUES

A comprehensive presentation of potential default values for interrupted-flow facilities is available elsewhere (4). These defaults cover the key characteristics of peak hour factor (*PHF*) and percent heavy vehicles (%HV). Recommendations are based on geographic region, population, and time of day. All general default values for interrupted-flow facilities may be applied to analysis of AWSC intersections in the absence of field data or projections of conditions.

Both demand volumes and the number and configuration of lanes at the intersection are site specific and do not lend themselves to default values. The following default values may be applied to an AWSC intersection analysis:

- Peak hour factor (*PHF*) = 0.92
- Percent heavy vehicles (%HV) = 3%

As the number of default values used in any analysis increases, the accuracy of the result becomes more approximate and may differ significantly from the actual outcome, depending on local conditions.

ESTABLISH INTERSECTION ANALYSIS BOUNDARIES

This methodology assumes that the AWSC intersection under investigation is isolated. When interaction effects are likely between the subject AWSC intersection and other intersections (e.g., queue spillback, demand starvation), the use of alternative tools may result in a more accurate analysis. Analysis boundaries may also include different demand scenarios related to time of day or to different development scenarios that produce different demand flow rates.

TYPES OF ANALYSIS

The methodology of this chapter can be used in three types of analysis: operational analysis, design analysis, and planning and preliminary design analysis.

Operational Analysis

The methodology is most easily applied in the operational analysis mode. In operational analysis, all traffic and geometric characteristics of the analysis segment must be specified, including analysis-hour demand volumes for each turning movement (veh/h), heavy vehicle percentages for each approach, peak hour factor for all demand volumes, and lane configuration. The outputs of an operational analysis are estimates of capacity and control delay. The steps of the methodology, described in the Methodology section, are followed directly without modification.

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Design Analysis

The operational analysis described earlier in this chapter can be used for design purposes by using a given set of traffic flow data and iteratively determining the number and configuration of lanes that would be required to produce a given LOS.

The operational analysis methodology for AWSC intersections can also be used for design analysis and planning and preliminary engineering analysis.

Planning and Preliminary Engineering Analysis

The operational analysis method described earlier in this chapter provides a detailed procedure for evaluating the performance of an AWSC intersection. To estimate LOS for a future time horizon, a planning analysis based on the operational method is used. The planning method uses all the geometric and traffic flow data required for an operational analysis, and the computations are identical. However, input variables for heavy vehicle percentage and peak hour factor are typically estimated (or defaults used) when planning applications are performed.

USE OF ALTERNATIVE TOOLS

Except for the effects of interaction with other intersections, the limitations of the methodology that were stated earlier in this chapter have minimal potential to be addressed by alternative tools. Therefore, sufficient experience with alternative tools is available as of the time of publication of this edition of the HCM to support the development of useful guidance for their application to AWSC intersections.

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4. EXAMPLE PROBLEM

An additional AMSC example problem is provided in Chapter 33, Stop-Controlled Intersections: Supplemental.

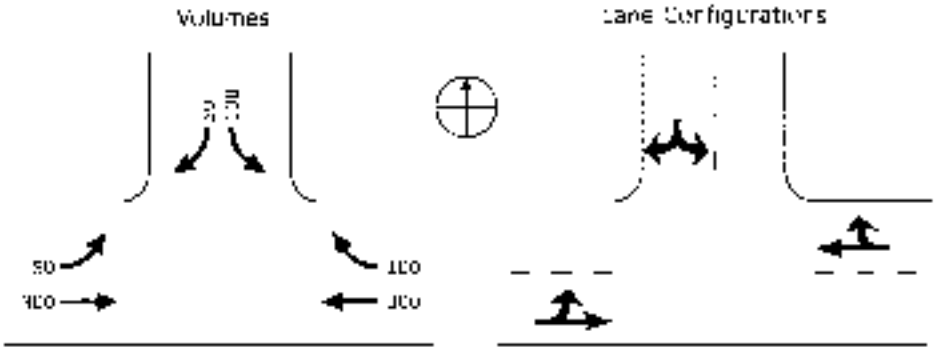
EXAMPLE PROBLEM 1: SINGLE-LANE, T-INTERSECTION

The Facts

The following describes the location's traffic and geometric characteristics.

- Three legs (T intersection).
- One-lane entries on each leg.
- Percent heavy vehicles on all approaches = 2%.
- Peak hour factor = 0.95, and
- Volumes and lane configurations as shown below (Exhibit 20-15).

Exhibit 20-15
Volumes and Lane Configurations for Example Problem 1



Comments

The use of a spreadsheet or software for AMSC intersection analysis is recommended because of the iterative and iterative computations required.

All input parameters are known so no default values are needed or used. The use of a spreadsheet or software is recommended because of the repetitive computations required. Slight differences in reported values may result from rounding differences between manual and software computations.

Step 1: Convert Movement Demand Volumes to Flow Rates

Peak 15-min flow rates for each turning movement at the intersection are equal to the hourly volumes divided by *PHF*. For example, the peak 15-min flow rate for the eastbound through movement is as follows:

$$v_{EBT} = \frac{V_{EBT}}{PHF} = \frac{300}{0.95} = 316 \text{ veh/h}$$

Step 2: Determine Lane Flow Rates

This step does not apply because the intersection has one lane approaches on all legs.

Step 3: Determine Geometry Group for Each Approach

Exhibit 20-16 shows that each approach should be assigned to Geometry Group 1.

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Step 4: Determine Saturation Headway Adjustments

Exhibit 20-17 shows that the headway adjustments for left turns, right turns, and heavy vehicles are 0.2, −0.6, and 1.7, respectively. These values apply to all approaches because all are assigned Geometry Group 3. Therefore, the saturation headway adjustment for the eastbound approach is as follows.

$$h_{s,i} = h_{s,LT} P_{LT,i} + h_{s,RT} P_{RT,i} + h_{s,HV} P_{HV,i}$$

$$h_{s,i} = 0.2 \frac{53}{53 + 316} - 0.6(0) + 1.7(0.021) = 0.063$$

Similarly, the saturation headway adjustment for the westbound approach is as follows:

$$h_{s,i} = 0.2(0) - 0.6 \frac{105}{105 + 316} + 1.7(0.02) = -0.116$$

Finally, the saturation headway adjustment for the southbound approach is as follows:

$$h_{s,i} = 0.2 \frac{105}{105 + 53} - 0.6 \frac{53}{105 + 53} + 1.7(0.02) = -0.034$$

Steps 5 Through 11: Determine Departure Headway

These steps are iterative. The following narrative highlights some of the key calculations using the eastbound approach for Iteration 1 but does not attempt to reproduce all calculations for all iterations. Full documentation of the example problem is included in Chapter 32, Stop-Controlled Intersections: Supplemental.

Step 6: Calculate Initial Degree of Utilization

By using the lane flow rates from Step 2 and the assumed initial departure headway from Step 5, the initial degree of utilization, x, for the eastbound approach is computed as follows:

$$x_i EB = \frac{vh_d}{3{,}600} = \frac{(368)(3.2)}{3{,}600} = 0.327$$

$$x_i WB = \frac{(421)(3.2)}{3{,}600} = 0.374$$

$$x_i NB = \frac{vh_d}{3{,}600} = \frac{(158)(3.2)}{3{,}600} = 0.140$$

Step 7: Compute Probability States

The probability state of each combination is determined with Equation 20-18.

$$P(i) = \prod_j P(s_j) = P(a_{1,i}) P(a_{2,i}) P(a_{3,i})$$

For an intersection with single-lane approaches, only those eight cases from Exhibit 20-13 apply:

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i	DOC Case	Number of Vehicles	Opposing Approach	Conflicting Left Approach	Conflicting Right Approach
1	1	0	0	0	0
2	2	1	1	0	0
5	3	1	0	1	0
7	3	1	0	0	1
13	4	2	0	1	1
16	4	2	1	1	0
21	4	2	1	0	1
45	5	2	1	1	1

For example, the probability state for the eastbound left under the condition of no opposing vehicles on the other approaches (degree of conflict Case 1, $i = 1$) is as follows (using Exhibit 20-6).

$P(a_{1,1}) = 1 - x_{v_o} = 1 - 0.374 = 0.626$ (no opposing present)

$P(a_{1,2}) = 1 - x_{v_l} = 1 - 0.140 = 0.860$ (no conflicting from left present)

$P(a_{1,3}) = 1$ (no approach conflicting from right)

Therefore,

$$P(1) = P(a_{1,1})P(a_{1,2})P(a_{1,3}) = (0.626)(0.860)(1) = 0.538$$

Similarly,

$$P(2) = (0.374)(0.860)(1) = 0.322$$

$$P(5) = (0.626)(0.140)(1) = 0.088$$

$$P(7) = (0.626)(0.860)(0) = 0$$

$$P(13) = (0.626)(0.140)(0) = 0$$

$$P(16) = (0.374)(0.140)(1) = 0.052$$

$$P(21) = (0.374)(0.860)(0) = 0$$

$$P(45) = (0.374)(0.140)(0) = 0$$

Step 8: Compute Probability Adjustment Factors

The probability adjustment is computed as follows:

$$P(C_1) = P(1) = 0.538$$

$$P(C_2) = P(2) = 0.322$$

$$P(C_3) = P(5) + P(7) = 0.088 + 0 = 0.088$$

$$P(C_4) = P(13) + P(16) + P(21) = 0 + 0.052 + 0 = 0.052$$

$$P(C_5) = P(45) = 0$$

The probability adjustment factors for the nonzero cases are as follows:

$$Adj P(1) = 0.01[0.322 + 2(0.088) + 3(0.052) + 0]/1 = 0.0065$$

$$Adj P(2) = 0.01[(0.088) + 2(0.052) + 0 - 0.322]/3 = 0.0004$$

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$$AdjP(5) = 0.01[(0.052) + 2(0) - 3(0.088)]/6 = -0.0004$$

$$AdjP(16) = 0.01[0 - 6(0.052)]/27 = -0.0001$$

Therefore, the adjusted probability for Combination 1, for example, is as follows:

$$P'(1) = 0.538 + 0.0065 = 0.5445$$

Step 9: Compute Saturation Headways

The base saturation headways for each combination can be determined with Exhibit 20-14. They are adjusted by using the adjustment factors calculated in Step 4 and added to the base saturation headways to determine saturation headways as follows (eastbound illustrated):

i	h_{base}	h_{adj}	h_{si}
1	3.9	0.063	3.963
2	4.7	0.063	4.763
5	5.8	0.063	5.863
7	7.0	0.063	7.063

Step 10: Compute Departure Headways

The departure headway of the approach is the sum of the products of the adjusted probabilities and the saturation headways as follows (eastbound illustrated):

$$h_d = (0.5445)(3.963) + (0.3213)(4.763) + (0.0875)(5.863) + (0.0524)(7.063) = 4.57$$

Step 11: Check for Convergence

The calculated values of h_d are checked against the initial values assumed for h_d. After one iteration, each calculated headway differs from the initial value by more than 0.1 s. Therefore, the new calculated headway values are used as initial values in a second iteration. For this problem, four iterations are required for convergence.

	EB L1	EB L2	WB L1	WB L2	NB L1	NB L2	SB L1	SB L2
Total Lane Flow Rate	368		421				158	
hd, initial value, iteration 1	3.2		3.2				3.2	
x, initial, iteration 1	0.327		0.374				0.140	
hd, computed value, iteration 1	4.57		4.35				5.14	
Convergence?	N		N				N	
hd, initial value, iteration 2	4.57		4.35				5.14	
x, initial, iteration 2	0.468		0.509				0.225	
hd, computed value, iteration 2	4.88		4.66				5.59	
Convergence?	N		N				N	
hd, initial value, iteration 3	4.88		4.66				5.59	
x, initial, iteration 3	0.499		0.545				0.245	
hd, computed value, iteration 3	4.95		4.73				5.70	
Convergence?	Y		Y				N	
hd, initial value, iteration 4	4.88		4.66				5.70	
x, initial, iteration 4	0.499		0.545				0.250	
hd, computed value, iteration 4	4.97		4.74				5.70	
Convergence?	Y		Y				Y	

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Step 12: Compute Capacity

The capacity of each approach is computed by increasing the given flow rate on the subject lane (assuming the flows on the opposing and conflicting approaches are constant) until the degree of utilization for the subject lane reaches 1. This level of calculation requires running an iterative procedure many times, which is practical for a spreadsheet or software implementation.

Here, the eastbound approach capacity is approximately 720 veh/h, which is lower than the value that could be estimated by dividing the approach volume by the degree of utilization (368/0.492 = 748 veh/h). The difference is due to the interaction effects among the approaches: increases in eastbound traffic volume increase the departure headways of the other approaches, which in turn increases the departure headway of the subject approach.

Step 13: Compute Service Times

The service time required to calculate control delay is computed on the basis of the final calculated departure headway and the move-up time by using Equation 20-29. For the eastbound approach (using a value for m of 2.0 for Geometry Group 1), the calculation is as follows:

$$t_s = h_d - m = 4.97 - 2.0 = 2.97$$

Step 14: Compute Control Delay

The control delay for each approach is computed with Equation 20-30 as follows (eastbound approach illustrated):

$$d = 2.97 + 900(0.25)\left[(0.508-1)+\sqrt{(0.508-1)^2+\frac{4.97(0.508)}{450(0.25)}}\right]+5 = 13.0\text{ s}$$

By using Exhibit 20-2, the eastbound approach is assigned LOS B. A similar calculation for the westbound and southbound approaches yields 13.5 and 10.6 s, respectively.

The control delays for the approaches can be combined into an intersection control delay by using a weighted average as follows:

$$d = \frac{(13.0)(368)+(13.5)(421)+(10.6)(158)}{368+421+158} = 12.8\text{ s}$$

This value of delay is assigned LOS B.

Step 15: Compute Queue Length

The 95th percentile queue for each lane is computed with Equation 20-33 as follows (eastbound approach illustrated):

$$Q_{95} \approx \frac{900(0.25)}{4.97}\left[(0.508-1)+\sqrt{(0.508-1)^2+\frac{4.97(0.508)}{150(0.25)}}\right] = 2.9\text{ veh}$$

This queue length would be reported as 3 vehicles.

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Discussion

The results indicate that the intersection operates well with low delays.

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5. REFERENCES

These references are available in the Technical Reference Library on Volume 4.

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CHAPTER 21
ROUNDABOUTS

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1. INTRODUCTION

20. [OMITTED CHAPTER 20]
16. Urban Street Facilities
17. Urban Street Segments
18. Signalized Intersections
19. TWSC Intersections
20. AWSC Intersections
21. Roundabouts
22. Interchange Ramp Terminals
23. Chapter 23 Pedestrian and Bicycle Facilities

Roundabouts are intersections with a generally circular shape, characterized by yield-at-entry and circulation around a central island (counterclockwise in the United States). Roundabouts have been used successfully throughout the world and are being used increasingly in the United States, especially since 1990.

Chapter 21, Roundabouts, presents concepts and procedures for analyzing these intersections. National Cooperative Highway Research Program Project 3-65 (*1*) provided a comprehensive database of roundabout operations for U.S. conditions on the basis of a study of 31 sites. The procedures that follow are largely founded on that study's recommendations. These procedures allow the analyst to assess the operational performance of an existing or planned one-lane or two-lane roundabout given traffic demand levels.

INTERSECTION ANALYSIS BOUNDARIES AND TRAVEL MODES

The analytical procedure presented in this chapter assumes that the analysis boundaries are the roundabout itself, including associated pedestrian crosswalks. Alternative tools discussed in this chapter can, in some cases, expand the analysis boundaries to include adjacent intersections. The methodology presented here includes discussion of motor vehicles, pedestrians, and bicycles.

LEVEL OF SERVICE CRITERIA

The level of service (LOS) criteria for automobiles in roundabouts are given in Exhibit 21-1. As the table notes, LOS F is assigned if the volume-to-capacity ratio of a lane exceeds 1.0 regardless of the control delay. For assessment of LOS at the approach and intersection levels, LOS is based solely on control delay.

The thresholds in Exhibit 21-1 are based on the consulted judgment of the Transportation Research Board Committee on Highway Capacity and Quality of Service. As discussed later in this chapter, roundabouts share the same basic control delay formulation with two-way and all-way STOP-controlled intersections, adjusting for the effect of YIELD control. However, at the time of publication of this edition of the *Highway Capacity Manual* (HCM), no research was available on traveler perception of quality of service at roundabouts. In the absence of such research, the service measure and thresholds have been made consistent with those for other unsignalized intersections, primarily on the basis of this similar control delay formulation.

Exhibit 21-1
LOS Criteria: Automobile Mode

Control Delay (s/veh)	LOS by Volume-to-Capacity Ratio[a]	
	v/c ≤ 1.0	v/c >1.0
≤ 10	A	F
>10–15	B	F
>15–25	C	F
>25–35	D	F
>35–50	E	F
>50	F	F

Note: [a] For approaches and intersection as a whole, LOS is determined solely by control delay.

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REQUIRED INPUT DATA

The following data are required to analyze a roundabout:

1. Number and configuration of lanes on each approach;
2. Either of the following:
   a. Demand volume for each entering vehicular movement and each pedestrian crossing movement during the peak 15 min, or
   b. Demand volume for each entering vehicular movement and each pedestrian crossing movement during the peak hour and a peak hour factor for the hour;
3. Percentage of heavy vehicles;
4. Volume distribution across lanes for multilane entries; and
5. Length of analysis period, generally a peak 15-min period within the peak hour. Any 15-min period can be analyzed, however.

SCOPE OF THE METHODOLOGY

The methodology presented in this chapter focuses on the operation of roundabouts. The methodology does not account for the effects of adjacent traffic control devices, such as nearby traffic signals or signalized pedestrian crossings. This version of the roundabout analysis procedures results primarily from studies conducted by National Cooperative Highway Research Program Project 3-65 (*1*). The chapter also includes a discussion of alternative tools that can model situations beyond the scope of the analytical methodology presented in this chapter.

The methodology does not necessarily apply to other types of circular intersections such as rotaries, neighborhood traffic circles, or signalized traffic circles, because these types of circular intersections usually have geometric or traffic control elements that deviate from those used in roundabouts. As a result, their operational performance may be significantly different from that experienced at roundabouts and thus cannot be accurately modeled by using the procedures in this chapter. More detail on the differentiation between roundabouts and other circular intersections can be found elsewhere (*2*, *3*).

This chapter's methodology applies to isolated roundabouts with up to two entry lanes and up to one bypass lane per approach.

LIMITATIONS OF THE METHODOLOGY

While the database on which these procedures are based is the most comprehensive developed for U.S. conditions, it does not cover all situations that may be encountered in practice. The chapter's methodology applies to isolated roundabouts with up to two entry lanes and up to one bypass lane per approach.

Automobile Mode

The methodology presented for automobiles covers typical roundabout facilities quite well, but it lacks examples of situations in which

- Upstream or downstream signals (including, but not limited to, pedestrian signals) significantly influence the performance of the roundabout;

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- Priority reversal occurs, such as unusual forced entry conditions under extremely high flows,
- A high level of pedestrian or bicycle activity is present;
- The roundabout is in close proximity to one or more other roundabouts,
- More than two entry lanes are present on one or more approaches, or
- One or more entry lanes are of limited, or short, length (a flared design).

Priority reversal can occur when entering traffic dominates an entry, causing circulating traffic to yield

A typical flared entry is one that widens from one approach lane to two entry lanes. Other flaring configurations, including flares of zero width, are possible

Pedestrian Mode

Research on the operational performance of pedestrians at roundabouts is limited, in terms of the effect of both motor vehicles on pedestrians and pedestrians on motor vehicles. This chapter's methodologies include international models and analytical tools that have not been validated by research in the United States at the time of publication of this edition of the HCM. Additional research on pedestrian operations at roundabouts is needed to develop national design procedures that adequately address these issues.

Bicycle Mode

Current methodologies to analyze LOS and delay at roundabouts only apply to bicycles in limited situations and have not been validated by research in the United States at the time of publication of this edition of the HCM. Additional research on bicycle behavior and operations at roundabouts is needed to develop procedures that adequately address these issues.

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2. METHODOLOGY

OVERVIEW

This chapter presents procedures for analyzing roundabouts, introduces the unique characteristics of roundabout capacity, and presents terminology specific to roundabouts. For ease of reference, the following terms are defined:

- v_e = entry flow rate,
- v_c = conflicting flow rate, and
- v_x = exit flow rate.

Intersection analysis models generally fall into two categories. Regression models use field data to develop statistically derived relationships between geometric features and performance measures such as capacity and delay. Analytical models are based on traffic flow theory combined with the use of field measures of driver behavior, resulting in an analytic formulation of the relationship between those field measures and performance measures such as capacity and delay.

The procedure in this chapter uses a combination of regression and analytical models.

Both of these types of models are applicable to roundabouts. Gap-acceptance models are an example of an analytical model and are commonly applied for analyzing unsignalized intersections because they capture driver behavior characteristics directly and can be made site-specific by custom-tuning the values used for those parameters. However, simple gap-acceptance models may not capture all of the observed behavior, and more complex gap acceptance models that account for limited priority or reverse priority are difficult to calibrate. Regression models are often used in those cases in which an understanding of driver behavior characteristics is incomplete. On the basis of recent analyses of U.S. field data, the procedure presented in this chapter incorporates a combination of simple, lane-based regression and gap acceptance models for both single-lane and double-lane roundabouts.

CAPACITY CONCEPTS

The capacity of a roundabout approach is directly influenced by flow patterns. The three flows of interest, the circulating flow, the conflicting flow, and the exiting flow, are shown in Exhibit 21-2.

The capacity of a roundabout approach decreases as the conflicting flow increases.

The capacity of an approach decreases as the conflicting flow increases. In general, the primary conflicting flow is the circulating flow that passes directly in front of the subject entry. While the circulating flow directly conflicts with the entry flow, the exiting flow may also affect a driver's decision to enter the roundabout. This phenomenon is similar to the effect of the right-turning stream approaching from the left side of a two-way stop-controlled intersection. Until those drivers complete their exit maneuver or right turn, there may be some uncertainty in the mind of the driver at the yield or stop line about the intentions of the exiting or turning vehicle. However, even though it may have an influence in some cases, including this effect did not significantly improve the overall fit of the capacity models to the data [7] and therefore is not included in this chapter's models.

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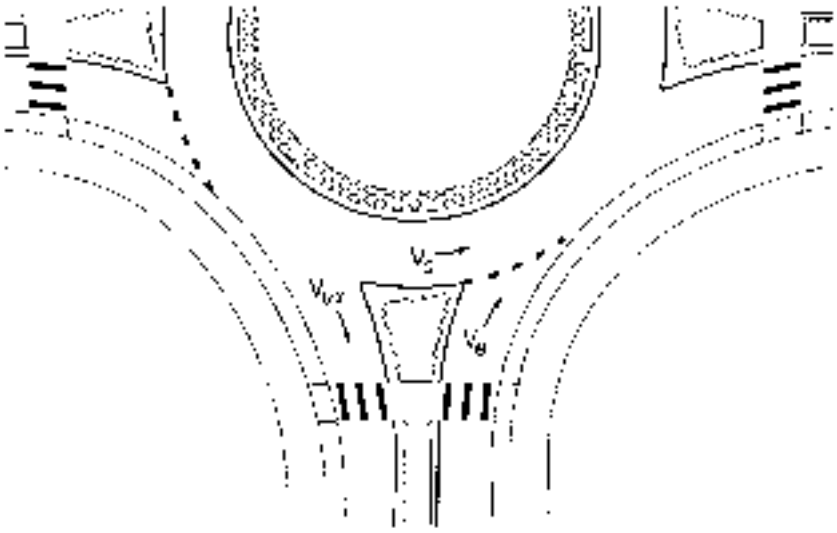

Exhibit 21-2
Analysis on One Roundabout Leg

When the conflicting flow approximates zero, the maximum entry flow is given by 3,600 s/h divided by the follow-up headway, which is analogous to the saturation flow rate for a movement receiving a green indication at a signalized intersection. At high levels of both entering and conflicting flow, limited practice (in which circulating traffic adjusts its headways to allow entering vehicles to enter), priority reversal (in which entering traffic forces circulating traffic to yield), and other behaviors may occur. In these cases, more complex analytical models or regression models, such as those incorporated into some of the alternative tools discussed later in this chapter, may give more realistic results.

When an approach operates over capacity during the analysis period, a condition known as *capacity constraint* may occur. During this condition, the actual circulating flow downstream of the constrained entry will be less than demand. The reduction in actual circulating flow may therefore increase the capacity of the affected downstream entries during this condition.

In addition, it has been suggested that origin–destination patterns have an influence on the capacity of a given entry (f_c, %). This effect was not identified in a recent study (1) and has not been incorporated into this chapter's models.

Both roundabout design practices and the public's use of roundabouts are still maturing in the United States. Many of the sites that formed the database for this chapter were less than 5 years old when the data were collected. Although the available data were insufficient to definitively answer the question of whether capacity increases with driver familiarity, anecdotal observations suggest that this may well be the case. At this early stage of their introduction to roundabouts, American drivers seem to be displaying more hesitation and caution in the use of roundabouts than their international counterparts, which in turn has resulted in a lower observed capacity than might be ultimately achievable. It is therefore likely that capacity (and volumes) will increase in the years to come as more roundabouts are constructed in the United States and as user familiarity grows. Such an increase in capacity over time would be consistent with the historically observed trends in capacity for freeway facilities and signalized intersections, for example. On the other hand, capacities in the

U.S. drivers presently seem to display more hesitation and caution in using roundabouts than drivers in other countries, which results in lower observed capacities. It is likely that capacities will increase in the future as U.S. drivers become more familiar with roundabouts.

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United States over time may still be fundamentally different from those observed in other countries due to a variety of factors. These include limited use of turn indicators at roundabout exits by American drivers, differences in vehicle types, and the effect that the common use of STOP-controlled intersections (versus YIELD-controlled intersections) has had on drivers in the United States.

Single-Lane Roundabouts

The capacity of a single entry lane conflicted by one circulating lane (e.g., a single-lane roundabout, illustrated in Exhibit 21-3) is based on the conflicting flow. The equation for estimating the capacity is given as Equation 21-1:

Equation 21-1

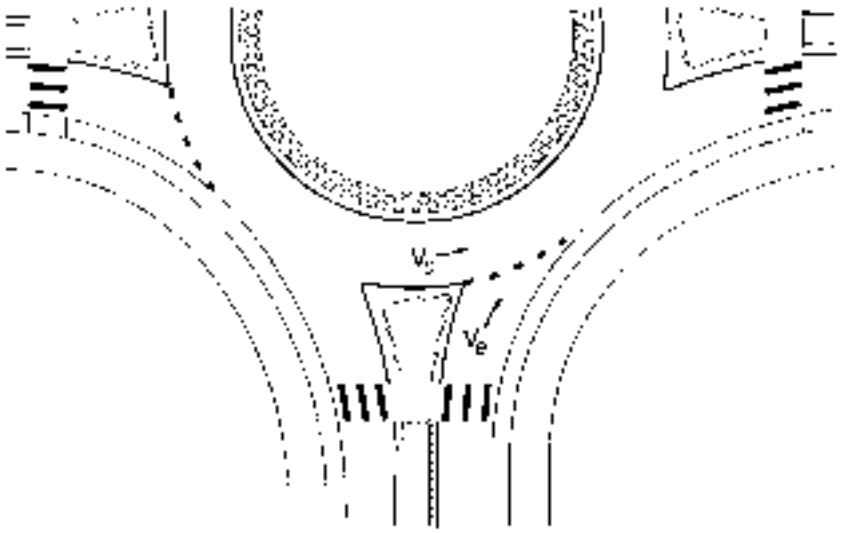
$$c_{e,pc} = 1{,}130e^{(-1.3 \times 10^{-3} \times v_c)}$$

where

$c_{e,pc}$ = lane capacity, adjusted for heavy vehicles (pc/h), and

$v_{c,pc}$ = conflicting flow rate (pc/h)

Exhibit 21-3
Example of One-Lane Entry Conflicted by One Circulating Lane



The capacity model given above reflects observations made at U.S. roundabouts in 2005. As noted previously, it is probable that U.S. roundabout capacity will increase to some degree with increased driver familiarity. In addition, communities with higher densities of roundabouts or generally more aggressive drivers may experience higher capacities. Therefore, local calibration of the capacity model is recommended to best reflect local driver behavior. This topic is discussed later in this chapter.

Multilane Roundabouts

Multilane roundabouts have more than one lane on at least one entry and at least part of the circulatory roadway. The number of entry, circulating, and exiting lanes may vary throughout the intersection. Because of the many possible variations, the computational complexity is higher than for single-lane roundabouts.

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The definition of headways and gaps for multilane facilities is more complicated than for single-lane facilities. If the circulating roadway truly functions as a multilane facility, then motorists at the entry perceive gaps in both the inside and outside lanes in some integrated fashion. Some drivers who choose to enter the roundabout via the right entry lane will yield to all traffic in the circulatory roadway due to their uncertainty about the path of the circulating vehicles. This uncertainty is more pronounced at roundabouts than at other unsignalized intersections due to the curvature of the circulatory roadway. However, some drivers in the right entry lane will enter next to a vehicle circulating in the inside lane of the circulating vehicles is not perceived to conflict. In addition, the behavior of circulating vehicles may be affected by the presence or absence of lane markings within the circulatory roadway. As a result, the gap acceptance behavior of the right entry lane, in particular, is imperfect and difficult to quantify with a simple gap-acceptance model. This leads to an inclination toward using a regression-based model that implicitly accounts for these factors. More detail on the nuances of geometric design, pavement markings, and their relationship with operational performance can be found elsewhere (*9*, *8*).

For roundabouts with up to two circulating lanes, which is the only type of multilane roundabout addressed by the analytical methodology in this chapter, the entries and exits can be either one or two lanes wide (plus a possible right turn bypass lane). The capacity model given above reflects observations made at a limited number of U.S. roundabouts in 2000. As discussed previously with single-lane roundabouts, local calibration of the capacity models (presented later in this chapter) is recommended to best reflect local driver behavior.

Capacity for Two-Lane Entries Conflicted by One Circulating Lane

Equation 21-2 gives the capacity of each entry lane conflicted by one circulating lane (illustrated in Exhibit 21-4) as follows:

$$c_{e,pce} = 1{,}130e^{-1.0\times10^{-3}\times v_c} \quad \text{Equation 21-2}$$

where all variables are as defined previously.

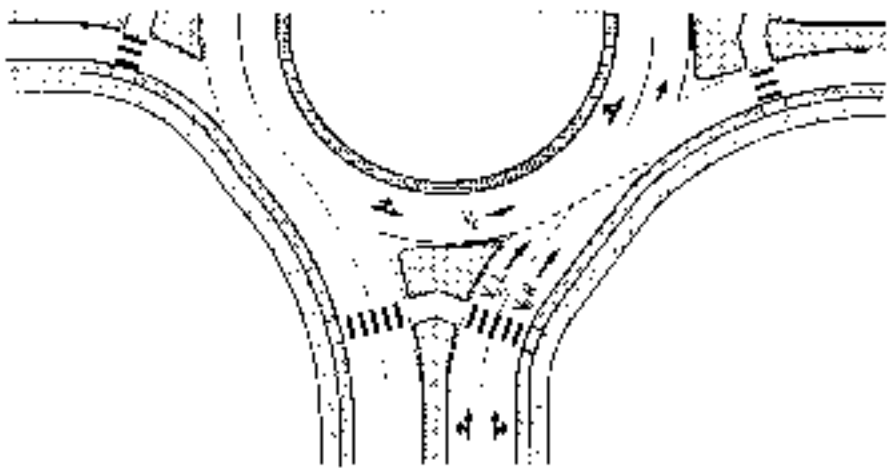

Exhibit 21-4
Example of Two-Lane Entry Conflicted by One Circulating Lane

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Capacity for One-Lane Entries Conflicted by Two Circulating Lanes

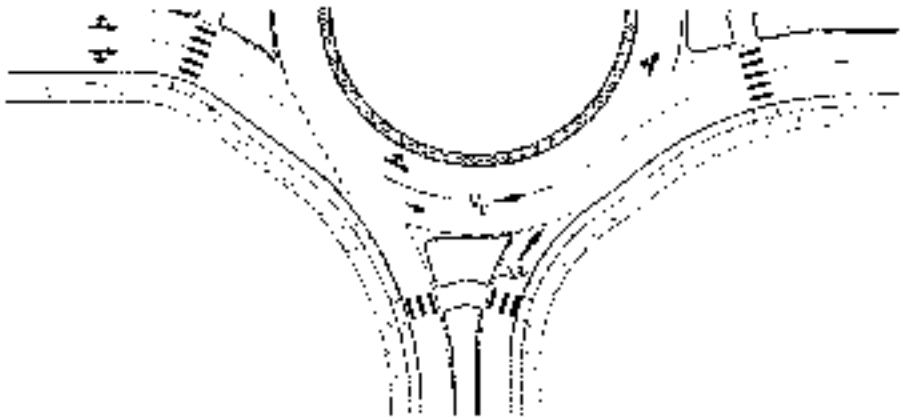
Equation 21-3 gives the capacity of a one-lane roundabout entry conflicted by two circulating lanes (illustrated in Exhibit 21-5) as follows:

Equation 21-3

$$c_{pce} = 1{,}130e^{(-1.0 \times 10^{-3} \times v_c)}$$

where all variables are as defined previously (v_c is the total of both lanes).

Exhibit 21-5
Example of One-Lane Entry Conflicted by Two Circulating Lanes



Capacity for Two-Lane Entries Conflicted by Two Circulating Lanes

Equation 21-4 and Equation 21-5 give the capacity of the right and left lanes, respectively, of a two-lane roundabout entry conflicted by two circulating lanes (illustrated in Exhibit 21-6):

Equation 21-4

$$c_{r,pce} = 1{,}130e^{(-1.0 \times 10^{-3} \times v_c)}$$

Equation 21-5

$$c_{l,pce} = 1{,}130e^{(-1.0 \times 10^{-3} \times v_c)}$$

where

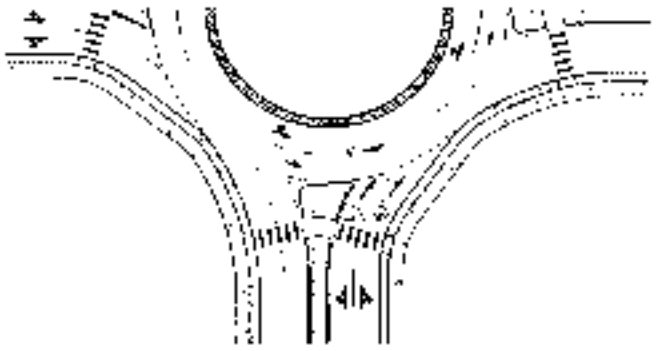
The capacity of the left lane of a roundabout approach is lower than the capacity of the right lane.

$c_{r,pce}$ = capacity of the right entry lane, adjusted for heavy vehicles (pc/h),

$c_{l,pce}$ = capacity of the left entry lane, adjusted for heavy vehicles (pc/h), and

v_c = conflicting flow rate (total of both lanes) (pc/h).

Exhibit 21-6
Example of Two-Lane Entry Conflicted by Two Circulating Lanes



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Field data (1) have found that drivers in the left lane have longer critical headways than drivers in the right lane. As a result, the capacity of the left lane is lower. Note that this research was able to observe sustained queue conditions for only the right lane. Equation 21-4 represents a regression best fit that is also consistent with observed critical headways. The left-lane capacity given in Equation 21-5 is based on observed critical headways under both queued and nonqueued conditions.

The calculated capacities for each lane in passenger car equivalents per hour will be adjusted back to vehicles per hour, as described later in this section.

Exhibit 21-7 presents a plot showing Equation 21-1, Equation 21-4, and Equation 21-5. The dashed lines represent portions of the curves that lie outside the range of observed field data.

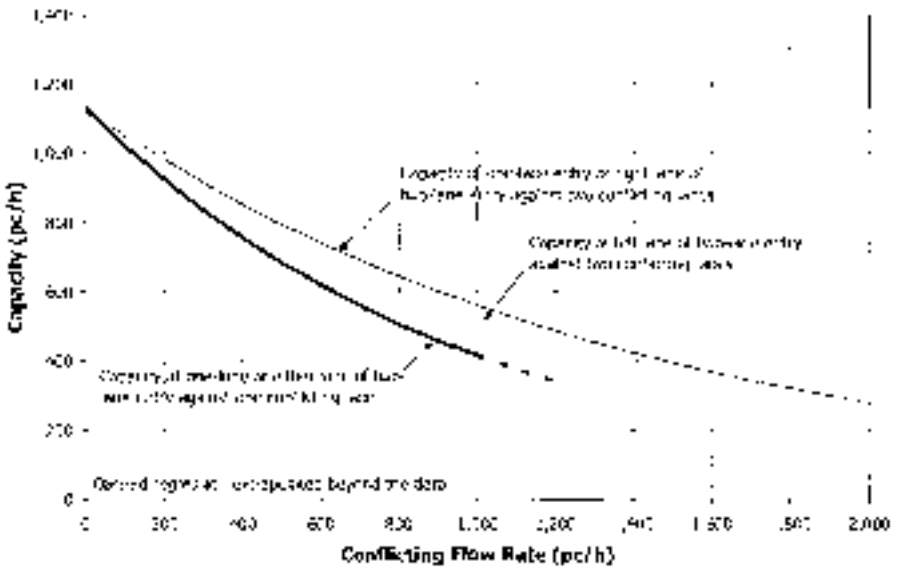

Exhibit 21-7
Capacity of Single-Lane and Multilane Entries

Right-Turn Bypass Lanes

Two common types of right-turn bypass lanes are used at both single-lane and multilane roundabouts. These are illustrated in Exhibit 21-8.

The following sections describe each type of bypass lane. Note that in the United States, drivers in both types of bypass lane would generally be required to yield to pedestrians crossing the bypass lane. The capacity effect of drivers yielding to pedestrians was not been included in this analysis procedure.

The bypass lane capacity procedure does not include the effect of drivers yielding to pedestrians.

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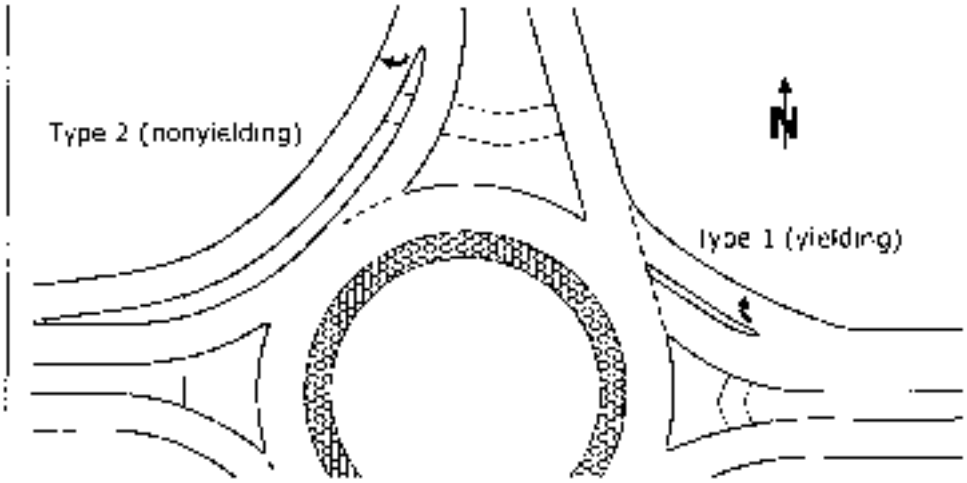
Exhibit 21-8
Right-Turn Bypass Lanes



Type 1 (Yielding Bypass Lane)

A Type 1 bypass lane terminates at a high angle, with right-turning traffic yielding to exiting traffic. Right-turn bypass lanes were not explicitly included in the recent national research. However, the capacity of a yield bypass lane may be approximated by using one of the capacity formulas given previously by treating the exiting flow from the roundabout as the circulating flow and treating the flow in the right-turn bypass lane as the entry flow.

The capacity for a bypass lane opposed by one exiting lane can be approximated by using Equation 21-6.

Equation 21-6

$$c_{bypass,1v} = 1{,}130e^{(-1.0 \times 10^{-3} \times v_{c,bypass})}$$

The capacity for a bypass lane opposed by two exiting lanes can be approximated by using Equation 21-7.

Equation 21-7

$$c_{bypass,2v} = 1{,}130e^{(-0.708 \times 10^{-3} \times v_{c,bypass})}$$

where

c_{bypass} = capacity of the bypass lane, adjusted for heavy vehicles (pc/h); and

$v_{c,bypass}$ = conflicting exiting flow rate (pc/h).

Type 2 (Nonyielding Bypass Lane)

A Type 2 bypass lane merges at a low angle with exiting traffic or forms a new lane adjacent to exiting traffic. The capacity of a merging bypass lane has not been assessed in the United States. Its capacity is expected to be relatively high due to a merging operation between two traffic streams at similar speeds.

Exit Capacity

German research (9) has suggested that the capacity of an exit lane, accounting for pedestrian and bicycle traffic in a typical urban area, is in the range of 1,200 to 1,300 vehicles per hour (veh/h). A Federal Highway Administration document used this information to provide guidance that exit flows exceeding 1,200 veh/h may indicate the need for a double-lane exit (2).

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However, the analyst is cautioned to also evaluate exit lane requirements on the basis of vehicular lane numbers and arrangements. For example, a double-lane exit might be required to receive two through lanes in order to provide basic lane continuity along a corridor, regardless of the volume at the exit. Further guidance can be found elsewhere (2).

AUTOMOBILE MODE

The capacity of a given approach is computed by using the process illustrated in Exhibit 21-9.

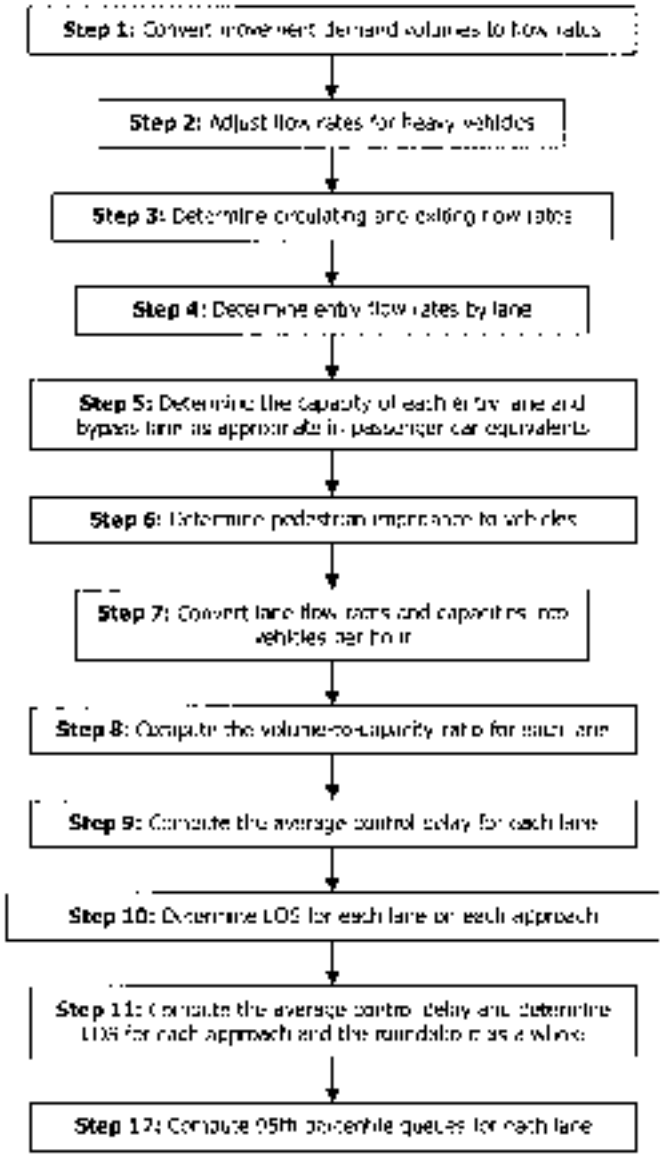

Exhibit 21-9
Roundabout Analysis Methodology

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Step 1: Convert Movement Demand Volumes to Flow Rates

For an analysis of existing conditions in which the peak 15-min period can be measured in the field, the volumes for the peak 15-min period are converted to a peak 15-min demand flow rate by multiplying the peak 15-min volumes by 4.

For analysis of projected conditions or when 15-min data are not available, hourly demand volumes for each movement are converted to peak 15-min demand flow rates in vehicles per hour, as shown in Equation 21-8, through the use of a peak hour factor for the intersection:

Equation 21-8

$$v_i = \frac{V_i}{PHF}$$

where

v_i = demand flow rate for movement i (veh/h),

V_i = demand volume for movement i (veh/h), and

PHF = peak hour factor.

Step 2: Adjust Flow Rates for Heavy Vehicles

The flow rate for each movement may be adjusted to account for vehicle stream characteristics by using factors given in Exhibit 21-10.

Exhibit 21-10
Passenger Car Equivalencies

Vehicle Type	Passenger Car Equivalent, E_T
Passenger car	1.0
Heavy vehicle	2.0

The calculation to incorporate these values is given in Equation 21-9 and Equation 21-10.

Equation 21-9

$$v_{i,hv} = \frac{v_i}{f_{hv}}$$

Equation 21-10

$$f_{hv} = \frac{1}{1 + P_T (E_T - 1)}$$

where

$v_{i,hv}$ = demand flow rate for movement i (pc/h),

v_i = demand flow rate for movement i (veh/h),

f_{hv} = heavy-vehicle adjustment factor,

P_T = proportion of demand volume that consists of heavy vehicles, and

E_T = passenger car equivalent for heavy vehicles.

Step 3: Determine Circulating and Exiting Flow Rates

Circulating and exiting flow rates are calculated for each roundabout leg. Although the following sections present a numerical methodology for a four-leg roundabout, this methodology can be extended to any number of legs.

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Circulating Flow Rate

The circulating flow opposing a given entry is defined as the flow conflicting with the entry flow (i.e., the flow passing in front of the splitter island next to the subject entry). The circulating flow rate calculation for the northbound circulating flow rate is illustrated in Exhibit 21-11 and numerically in Equation 21-11. All flows are in passenger car equivalents.

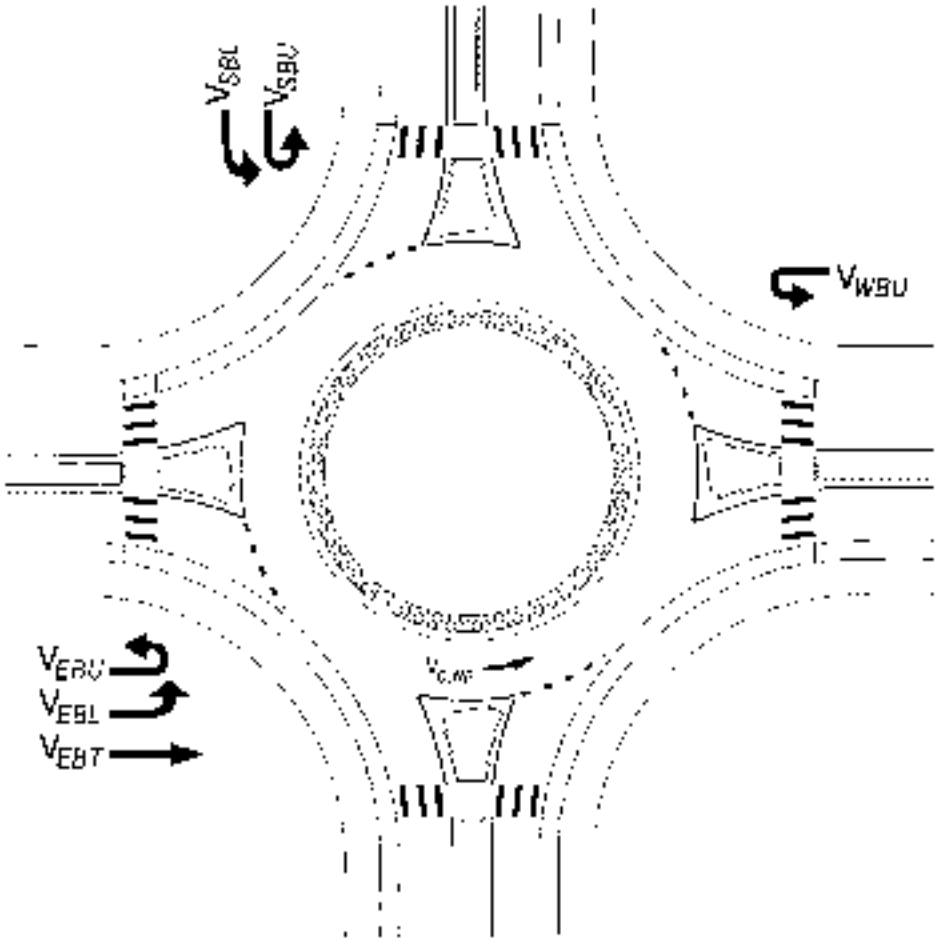

Exhibit 21-11
Calculation of Circulating Flow

$$V_{c,SB,pce} = V_{WBU,pce} + V_{NBL,pce} + V_{NBT,pce} + V_{EBLR,pce} + V_{EBU,pce} + V_{EBL,pce}$$

Equation 21-11

Exiting Flow Rate

The exiting flow rate for a given leg is used primarily in the calculation of conflicting flow for right-turn bypass lanes. The exiting flow calculation for the southbound exit is illustrated in Exhibit 21-12 and numerically in Equation 21-12. If a bypass lane is present on the immediate upstream entry, the right-turning flow using the bypass lane is deducted from the exiting flow. All flows are in passenger car equivalents.

If a bypass lane is present on the immediate upstream entry, the right-turning flow using the bypass lane is deducted from the exiting flow.

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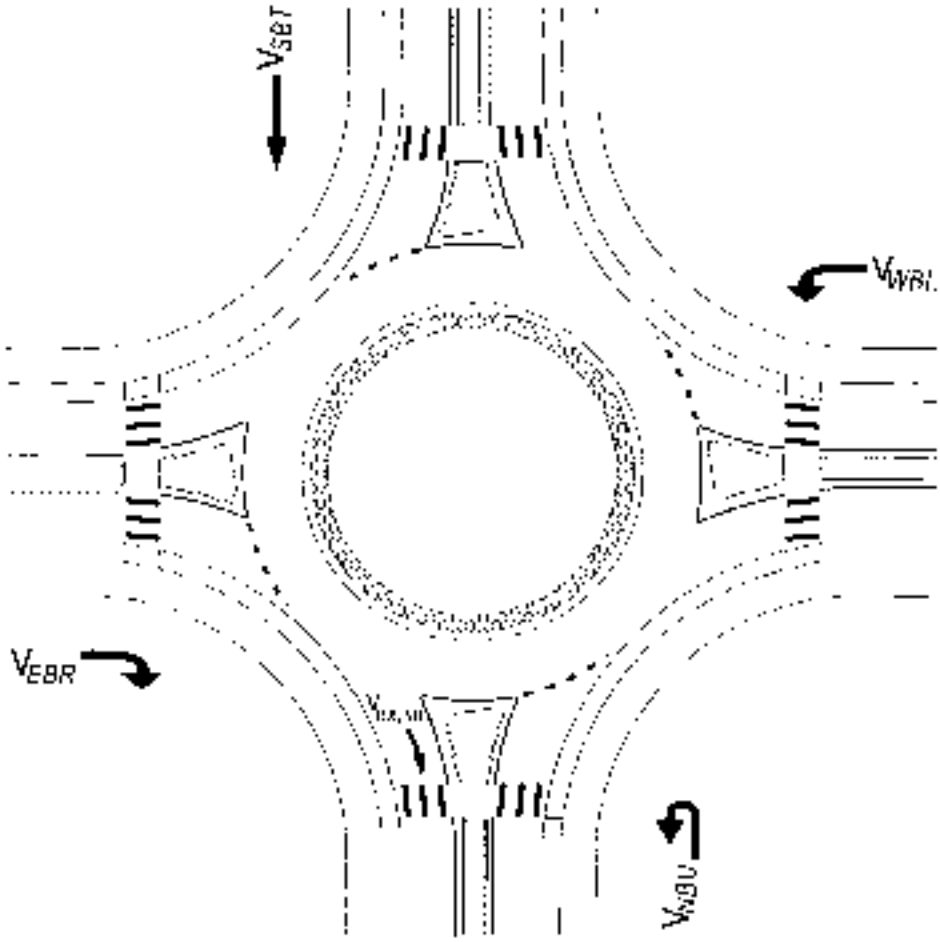
Exhibit 21-12
Calculation of Exiting Flow



Equation 21-12

$$v_{exit,i} = v_{NBT,pe} + v_{NBL,pe} + v_{EBT,pe} + v_{EBR,pe} - v_{EBR,bypass}$$

Step 4: Determine Entry Flow Rates by Lane

For single-lane entries, the entry flow rate is the sum of all movement flow rates using that entry. For multilane entries or entries with bypass lanes, or both, the following procedure may be used to assign flows to each lane:

1. If a right-turn bypass lane is provided, the flow using the bypass lane is removed from the calculation of the roundabout entry flows.
2. If only one lane is available for a given movement, the flow for that movement is assigned only to that lane.
3. The remaining flows are assumed to be distributed across all lanes, subject to the constraints imposed by any designated or de facto lane assignments and any observed or estimated lane utilization imbalances.

A de facto lane is one designated for multiple movements but that may operate as an exclusive lane due to a dominant movement demand. A common example is a left through lane with a left-turn flow rate that greatly exceeds the through flow rate.

Even generalized multilane cases may be analyzed with this procedure. For cases in which a movement may use more than one lane, a check should first be made to determine what the assumed lane configuration may be. This may differ from the designated lane assignment based on the specific turning movement patterns being analyzed. These assumed lane assignments are given in Exhibit

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21-13. For intersections with a different number of legs, the analyst should exercise reasonable judgment in assigning volumes to each lane.

Exhibit 21-13
Assumed (de facto) Lane Assignments

Designated Lane Assignment	Assumed Lane Assignment
LT, TR	If $v_{o1} + v_{o2} > v_{o3}$: L, TR (de facto left-turn lane) If $v_{o1} + v_{o2} \leq v_{o3}$: LT, R (de facto right-turn lane) Else LT, TR
L, LTR	If $v_{o1} + v_{o2} > v_{o3} + v_{o4}$: L, TR (de facto through–right lane) Else L, LTR
LTR, R	If $v_{o1} + v_{o2} + v_{o3} > v_{o4}$: LT, R (de facto left-through lane) Else LTR, R

Notes: v_{o1}, v_{o2}, v_{o3}, and v_{o4} are the U-turn, left-turn, through, and right-turn flow rates using a given entry, respectively.
L = left, LT = left-through, TR = through-right, LTR = left-through-right, and R = right.

On the basis of the assumed lane assignments for the entry and the lane utilization effect described above, flow rates can be assigned to each lane by using the formulas given in Exhibit 21-14. In this exhibit, %*R*/ is the percentage of entry traffic using the right lane, %*L*/ is the percentage of entry traffic using the left lane, and %*L*/ + %*R*/ = 1.

Exhibit 21-14
Volume Assignments for Two-Lane Entries

Case	Assumed Lane Assignment	Left Lane	Right Lane
1	L, TR	$v_{o1} + v_{o2}$	$v_{o3} + v_{o4}$
2	LT, R	$v_{o1} + v_{o2} + v_{o3}$	v_{o4}
3	LT, TR	%*L*/ $(v_{o1} + v_{o2} + v_{o3})$	%*R*/ $(v_{o1} + v_{o2} + v_{o3})$
4	L, LTR	%*L*/ $(v_{o1} + v_{o2} + v_{o3} + v_{o4})$	%*R*/ $(v_{o1} + v_{o2} + v_{o3} + v_{o4})$
5	LTR, R	%*L*/ $(v_{o1} + v_{o2} + v_{o3} + v_{o4})$	%*R*/ $(v_{o1} + v_{o2} + v_{o3} + v_{o4})$

Notes: v_{o1}, v_{o2}, v_{o3}, and v_{o4} are the U-turn, left-turn, through, and right-turn flow rates using a given entry, respectively.
L = left, LT = left-through, TR = through-right, LTR = left-through-right, and R = right.

Further discussion of lane use at multilane roundabouts, including conditions that may create unequal lane use, can be found in Chapter 33, Roundabouts: Supplemental, located in HCM Volume 4.

Step 5: Determine the Capacity of Each Entry Lane and Bypass Lane as Appropriate in Passenger Car Equivalents

The capacity of each entry lane and bypass lane is calculated by using the capacity equations discussed previously. Capacity equations for entry lanes are summarized in Exhibit 21-15; capacity equations for bypass lanes are summarized in Exhibit 21-16.

Exhibit 21-15
Capacity Equations for Entry Lanes

Entering Lanes	Conflicting Circulating Lanes	Capacity Equation
1	1	Equation 21-1
2	1	Each lane: Equation 21-2
1	2	Equation 21-4
2	2	Right lane: Equation 21-4, left lane: Equation 21-5

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Exhibit 21-16
Capacity Equations for Bypass Lanes

Conflicting Exiting Lanes	Capacity Equation
1	Equation 21-6
2	Equation 21-7

Step 6: Determine Pedestrian Impedance to Vehicles

Pedestrian traffic can reduce the vehicular capacity of a roundabout entry if sufficient pedestrians are present and they assert the right-of-way typically granted pedestrians in most jurisdictions. Under high vehicular conflicting flows, pedestrians typically pass between queued vehicles on entry and have more negligible additional impact on vehicular entry capacity. However, under low vehicular conflicting flows, pedestrians can effectively turn into additional conflicting vehicles and thus reduce the vehicular capacity at the entry. The effect of pedestrians is more pronounced with increased pedestrian volume.

For one-lane roundabout entries, the model shown in Exhibit 21-17 can be used to approximate this effect (6). These equations are illustrated in Exhibit 21-18 and are based on the assumption that pedestrians have absolute priority.

Exhibit 21-17
Model of Entry Capacity Adjustment Factor for Pedestrians Crossing a One-Lane Entry (Assuming Pedestrian Priority)

Case	One-Lane Entry Capacity Adjustment Factor for Pedestrians
If $v_{c,ped} > 881$	$f_{ped} = 1$
Else if $v_{ped} \leq 101$	$f_{ped} = 1 - 0.000137 v_{ped}$
Else	$f_{ped} = \frac{1{,}119.5 - 0.715 v_{c,ped} - 0.614 v_{ped} + 0.000732 v_{c,ped} v_{ped}}{1{,}068.6 - 0.654 v_{c,ped}}$

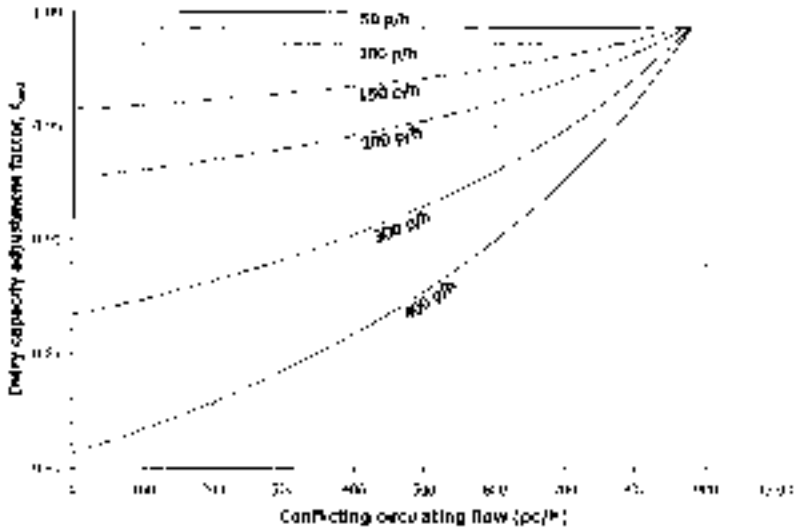
where

f_{ped} = entry capacity adjustment factor for pedestrians,

v_{ped} = number of conflicting pedestrians per hour (p/h), and

$v_{c,ped}$ = conflicting vehicular flow rate in the circulatory roadway, pc/h.

Exhibit 21-18
Illustration of Entry Capacity Adjustment Factor for Pedestrians Crossing a One-Lane Entry (Assuming Pedestrian Priority)



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For two-lane entries, the model shown in Exhibit 21-19 can be used to approximate this effect (6). These equations are illustrated in Exhibit 21-20 and share the assumption as before that pedestrians have absolute priority.

Case	Two-Lane Entry Capacity Adjustment Factor for Pedestrians
$v_{ped} < 100$	$f_{ped} = \min\left[1 - \frac{v_{ped}}{100}\left(1 - \frac{1{,}260.6 - 0.329v_{c,ped} - 0.381 \times 100}{1{,}380 - 0.5v_{c,ped}}\right), 1\right]$
Else	$f_{ped} = \min\left[\frac{1{,}260.6 - 0.329v_{c,ped} - 0.381v_{ped}}{1{,}380 - 0.5v_{c,ped}}, 1\right]$

Exhibit 21-19
Model of Entry Capacity Adjustment Factor for Pedestrians Crossing a Two-Lane Entry (Assuming Pedestrian Priority)

where

f_{ped} = entry capacity adjustment factor for pedestrians,

v_{ped} = number of conflicting pedestrians (p/h), and

$v_{c,ped}$ = conflicting vehicular flow rate in the circulatory roadway (pc/h).

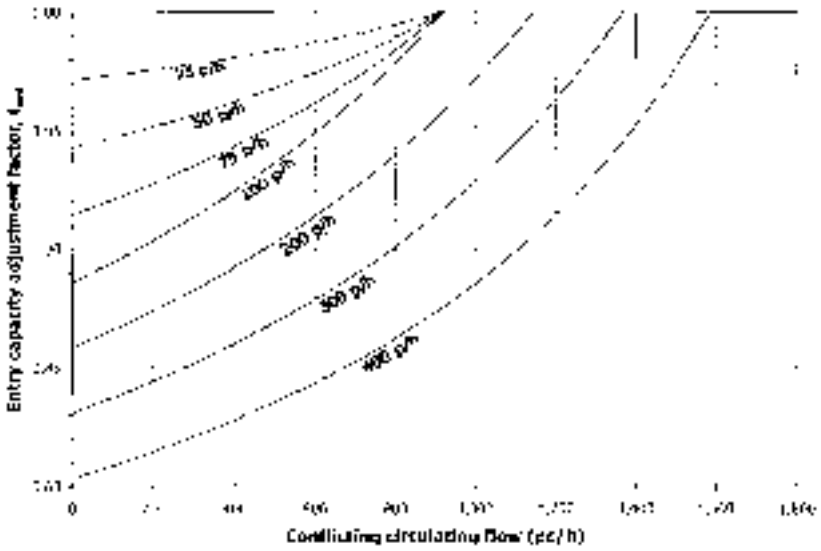

Exhibit 21-20
Illustration of Entry Capacity Adjustment Factor for Pedestrians Crossing a Two-Lane Entry (Assuming Pedestrian Priority)

Step 7: Convert Lane Flow Rates and Capacities into Vehicles per Hour

The flow rate for a given lane is converted back to vehicles per hour by multiplying the passenger car-equivalent flow rate computed in the previous step by the heavy-vehicle factor for the lane as shown in Equation 21-13:

$$v_i = v_{i,pc} f_{HV,i} \quad \text{Equation 21-13}$$

where

v_i = flow rate for lane i (veh/h),

$v_{i,pc}$ = flow rate for lane i (pc/h), and

$f_{HV,i}$ = heavy-vehicle adjustment factor for the lane (see below).

Similarly, the capacity for a given lane is converted back to vehicles per hour as shown in Equation 21-14.

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Equation 21-14

$$c_i = c_{g,i} f_{HV,i} f_{ped}$$

where

c_i = capacity for lane i (veh/h),

$c_{g,i}$ = capacity for lane i (pc/h),

$f_{HV,i}$ = heavy-vehicle adjustment factor for the lane (see below), and

f_{ped} = pedestrian impedance factor.

The heavy-vehicle adjustment factor for each entry lane can be approximated by taking a weighted average of the heavy-vehicle adjustment factors for each movement entering the roundabout (excluding a bypass lane if present) weighted by flow rate, as shown in Equation 21-15.

Equation 21-15

$$f_{HV,i} = \frac{f_{HV,1} v_{i,1} + f_{HV,2} v_{i,2} + f_{HV,3} v_{i,3} + f_{HV,4} v_{i,4}}{v_{i,1} + v_{i,2} + v_{i,3} + v_{i,4}}$$

where

$f_{HV,i}$ = heavy-vehicle adjustment factor for the entry lane,

$f_{HV,j}$ = heavy-vehicle adjustment factor for movement j, and

$v_{i,j}$ = demand flow rate for movement j (pc/h).

If specific lane-use assignment by heavy vehicles is known, heavy-vehicle adjustment factors can be calculated separately for each lane.

Pedestrian impedance is discussed later in this chapter.

Step 8: Compute the Volume-to-Capacity Ratio for Each Lane

For a given lane, the volume-to-capacity ratio x is calculated by dividing the lane's calculated capacity into its demand flow rate, as shown in Equation 21-16. Both input values are in vehicles per hour.

Equation 21-16

$$x_i = \frac{v_i}{c_i}$$

where

x_i = volume-to-capacity ratio of the subject lane i,

v_i = demand flow rate of the subject lane i (veh/h), and

c_i = capacity of the subject lane i (veh/h).

Step 9: Compute the Average Control Delay for Each Lane

Delay data collected for roundabouts in the United States suggest that control delays can be predicted in a manner generally similar to that used for other unsignalized intersections. Equation 21-17 shows the model that should be used to estimate average control delay for each lane of a roundabout approach.

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$$d = \frac{3{,}600}{c} + 900T\left[(x-1) + \sqrt{(x-1)^2 + \frac{(3{,}600/c)x}{450T}}\right] + 5 \times \min[x,1]$$

Equation 21-17

The final term of this equation uses the calculated volume-to-capacity ratio or 1, whichever is less.

where

d = average control delay (s/veh),

x = volume-to-capacity ratio of the subject lane,

c = capacity of the subject lane (veh/h), and

T = time period (h) ($T = 0.25$ h for a 15-min analysis).

Equation 21-17 is the same as that for stop-controlled intersections except that the "+ 5" term has been modified. This modification is necessary to account for the yield control on the subject entry, which does not require drivers to come to a complete stop when there is no conflicting traffic. At higher volume-to-capacity ratios, the likelihood of coming to a complete stop increases, thus causing behavior to resemble stop control more closely.

Average control delay for a given lane is a function of the lane's capacity and degree of saturation. The analytical model used above to estimate average control delay assumes that there is no residual queue at the start of the analysis period. If the degree of saturation is greater than about 0.9, average control delay is significantly affected by the length of the analysis period. In most cases, the recommended analysis period is 15 min. If demand exceeds capacity during a 15-min period, the delay results calculated by the procedure may not be accurate due to the likely presence of a queue at the start of the time period. In addition, the conflicting demand for movements downstream of the movement operating over capacity may not be fully realized (in other words, the flow cannot get past the oversaturated entry and thus cannot conflict with a downstream entry). In these cases, an iterative approach that accounts for this effect and the carryover of queues from one time period to the next may be considered, as discussed elsewhere (7).

Step 10: Determine LOS for Each Lane on Each Approach

The LOS for each lane on each approach is determined by using Exhibit 21-1 and the computed or measured values of control delay.

Step 11: Compute the Average Control Delay and Determine LOS for Each Approach and the Roundabout as a Whole

The control delay for an approach is calculated by computing a weighted average of the delay for each lane on the approach, weighted by the volume in each lane. The calculation is shown in Equation 21-18. Note that the volume in the bypass lane should be included in the delay calculations for the approach. The LOS for each approach is determined by using Exhibit 21-1 and the computed or measured values of control delay.

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Equation 21-18

$$d_{approach} = \frac{d_1 v_{1,i} + d_2 v_{2,i} + d_{exp,i} v_{exp,i}}{v_{1,i} + v_{2,i} + v_{exp,i}}$$

The control delay for the intersection as a whole is similarly calculated by computing a weighted average of the delay for each approach, weighted by the volume on each approach. This is shown in Equation 21-19. The LOS for the intersection is determined by using Exhibit 21-1 and the computed or measured values of control delay.

Equation 21-19

$$d_{intersection} = \frac{\sum d_i v_i}{\sum v_i}$$

where

$d_{intersection}$ = control delay for the entire intersection (s/veh),

d_i = control delay for approach i (s/veh), and

v_i = flow rate for approach i (veh/h).

Step 12: Compute 95th Percentile Queues for Each Lane

The 95th percentile queue for a given lane on an approach is calculated by using Equation 21-20.

Equation 21-20

$$Q_{95} = 900T\left(X - 1 + \sqrt{(1 - X)^2 + \left(\frac{3{,}600}{cT}\right)X}\right)$$

where

Q_{95} = 95th percentile queue (veh),

X = volume-to-capacity ratio of the subject lane,

c = capacity of the subject lane (veh/h), and

T = time period (h) ($T = 1$ for a 1-h analysis, $T = 0.25$ for a 15-min analysis).

The queue length calculated for each lane should be checked against the available storage. The queue in each lane may interact with adjacent lanes in one or more ways:

- If queues in adjacent lanes exceed the available storage, the queue in the subject lane may be longer than anticipated due to additional queuing from the adjacent lane.
- If queues in the subject lane exceed the available storage for adjacent lanes, the adjacent lane may be starved by the queue in the subject lane.

Should one or more of these conditions occur, a sensitivity analysis can be conducted with the methodology by varying the demand in each lane. The analyst may also use an alternative tool that is sensitive to lane-by-lane effects, as discussed in this chapter's Applications section.

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PEDESTRIAN MODE

Limited research has been performed to date in the United States on the operational impacts of vehicular traffic on pedestrians at roundabouts. In the United States, pedestrians have the right-of-way either after entering a crosswalk or as they are about to enter the crosswalk, depending on specific state law. This is somewhat different from other countries that may establish absolute pedestrian right-of-way in some situations (typically urban) and absolute vehicular right-of-way in others (typically rural).

Much of the recent research focus on pedestrians in the United States has been in the area of assessing accessibility for pedestrians with vision disabilities. Research has found that some roundabouts present a challenge for blind and visually impaired pedestrians relative to sighted pedestrians, thus potentially bringing them out of compliance with the Americans with Disabilities Act (8). A variety of treatments has been or is being considered to improve roundabouts' accessibility to this group of pedestrians, including various types of signalization of pedestrian crossings. The analysis of these treatments can in some cases be performed by simple analytical methods presented in the HCM (e.g., the analysis procedure for the pedestrian mode in Chapter 19). However, in many cases, alternative tools will produce more accurate results. These are discussed later in this chapter.

Techniques to analyze the operational performance of pedestrians as provided in Chapter 19, Two-Way STOP-Controlled Intersections, can be applied with care at roundabouts. As noted in that chapter, vehicular yielding rates vary depending on crossing treatment, number of lanes, posted speed limit, and within individual sites (9). This makes modeling of pedestrian interactions imprecise. As a result, models to analyze vehicular effects on pedestrian travel should be applied with caution.

BICYCLE MODE

As of the publication date of this edition of the HCM, no methodology specific to bicyclists has been developed to assess the performance of bicyclists at roundabouts, as few data are available in the United States to support model calibration. Depending on individual motion level, ability, geometric conditions, and traffic conditions, bicyclists may either circulate as a motor vehicle or as a pedestrian. If bicyclists are circulating as motor vehicles, their effect can be approximated by combining bicyclist flow rates with other vehicles by using a passenger-car equivalent factor of 2.5 (2). If bicyclists are circulating as pedestrians, their effect can be analyzed by using the methodology described previously for pedestrians. Further guidance on accommodating bicyclists at roundabouts can be found elsewhere (2).

Use a passenger-car equivalent factor of 2.5 for bicycles when treating them as motor vehicles.

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3. APPLICATIONS

DEFAULT VALUES

No default values have been developed specifically for roundabouts. However, a comprehensive presentation of potential default values for interrupted-flow facilities is available (*19*), with specific recommendations summarized in the Chapter 3, Recommended Default Values. These defaults cover the key characteristics of peak hour factor and percent heavy vehicles. Recommendations are based on geographical region, population, and time of day. All general default values for interrupted flow facilities may be applied to the analysis of roundabouts in the absence of field data or projections of conditions.

Demand volumes as well as the number and configuration of lanes at a roundabout are site-specific and thus do not lend themselves to default values. The following default values may be applied to a roundabout analysis.

- Peak hour factor = 0.92, and
- Percent heavy vehicles = 3%.

Default values for lane utilization on two-lane roundabout approaches are not provided in the above reference (*19*). In these cases, in the absence of field data, the effect of lane utilization imbalance can be approximated by using the assumed values given in Exhibit 21-21.

Exhibit 21-21
Assumed Default Values for Lane Utilization for Two-Lane Approaches

Lane Configuration	% Traffic in Left Lane[a]	% Traffic in Right Lane[a]
Left, through + through-right	0.47	0.53
Left + through-right, right	0.47	0.53
Left + left, through, right	0.53	0.47

Note: [a] These values are generally consistent with observed lanes for through movements at signalized intersections. These values should be applied with care, particularly under conditions expected to be near capacity.

Obviously, as the number of default values used in any analysis increases, the analysis result becomes more approximate and may be significantly different from the actual outcome, depending on local conditions.

TYPES OF ANALYSIS

The methodology of this chapter can be used in three types of analysis: operational analysis, design analysis, and planning and preliminary engineering analysis.

Operational Analysis

Operational analysis takes traffic flow data and geometric configurations as input to determine operational performance.

The methodology is most easily applied in the operational analysis mode. In operational analysis, all traffic and geometric characteristics of the analysis segment must be specified, including analysis-hour demand volumes for each turning movement (in vehicles per hour), heavy-vehicle percentages for each approach, peak hour factor for all hourly demand volumes (if not provided as 15-min volumes), and lane configuration. The outputs of an operational analysis will be estimates of capacity and control delay. The steps of the methodology,

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described in the Methodology section, are followed directly without modification.

Design Analysis

Design analysis is used to determine the geometric configuration of a roundabout to produce a desired operational performance.

The operational analysis methodology described earlier in this chapter can be used for design purposes by using a given set of traffic flow data to determine iteratively the number and configuration of lanes that would be required to produce a given LOS.

Planning and Preliminary Engineering Analysis

Planning and preliminary engineering analysis is used to evaluate future conditions for which assumptions and estimates must be made.

The operational analysis method described earlier in this chapter provides a detailed procedure for evaluating the performance of a roundabout. To estimate LOS for a future time horizon, a planning analysis based on the operational method is used. The planning method uses all the geometric and traffic flow data required for an operational analysis, and the computations are identical. However, input variables for percent heavy vehicles and peak hour factor are typically estimated (or defaults used) when planning applications are performed.

CALIBRATION OF CAPACITY MODEL

The capacity models presented previously can be generalized by using the expressions in Equation 21-21 through Equation 21-23 as follows:

$$c_{pr} = Ae^{-B v_c} \quad \text{Equation 21-21}$$

$$A = \frac{3{,}600}{t_f} \quad \text{Equation 21-22}$$

$$B = \frac{t_c - (t_f/2)}{3{,}600} \quad \text{Equation 21-23}$$

Field measures of critical headway and follow-up headway can be used to calibrate the capacity models.

where

c_{pr} = lane capacity, adjusted for heavy vehicles (pc/h),

v_c = conflicting flow (pc/h),

t_c = critical headway (s), and

t_f = follow-up headway (s).

Therefore, the capacity model can be calibrated by using two parameters: the critical headway t_c and the follow-up headway t_f. An example illustrating this procedure is provided in Chapter 33, Roundabouts: Supplemental.

USE OF ALTERNATIVE TOOLS

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools, and Chapter 7, Interpreting HCM and Alternative Tool Results. This section contains specific guidance for the application of alternative tools to the analysis of roundabouts. The reader should also be familiar with the information and guidance on the design and evaluation of roundabouts (2, 3).

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Two modeling approaches are used in the types of alternative tools commonly applied:

- *Deterministic intersection models.* These models represent vehicle flows as flow rates and are sensitive to various flow and geometric features of the roundabout, including lane numbers and arrangements or specific geometric dimensions (e.g., entry width, inscribed circle diameter), or both. The majority of these models are anchored in research conducted outside the United States (e.g., [1–4]). Some software implementations may include more than one model or employ extensions beyond the original fundamental research conducted within a particular country. Some deterministic models can model an entire network of intersections but generally assume no interaction effects between intersections, thus potentially limiting their application.
- *Stochastic network models.* These models represent vehicle flows by simulating individual vehicles and their car-following, lane-choice, and gap-acceptance decisions. The models are based on a variety of fundamental research studies on driver behavior (e.g., [5, 6]). By their nature, most stochastic models used for roundabouts can model an entire network of intersections, thus making them capable of modeling a broader range of problems. However, their data requirements are typically more intensive than for the deterministic intersection models. Most stochastic models are implemented in microsimulation tools.

Strengths of the HCM Procedure

The procedures in this chapter were based on extensive research supported by a significant quantity of field data. They have evolved over several years and represent a body of expert consensus. They produce unique deterministic results for a given set of inputs, and the capacity of each approach is an explicit part of the results. Alternative tools based on deterministic intersection models also produce a unique set of results, including capacities, for a given set of inputs, while those based on simulation may produce different results based on different random number sequences. Unique results from an analysis tool are important for some purposes such as development impact review.

Limitations of the HCM Procedures That Might Be Addressed by Alternative Tools

The procedures presented in this chapter cover many of the typical situations that a user may encounter in practice. However, there are sometimes applications for which alternative tools can produce a more accurate analysis. The following limitations, stated earlier in this chapter, may be addressed by using available simulation tools. The conditions beyond the scope of this chapter that are treated explicitly by alternative tools include:

- Adjacent signals or roundabouts,
- Priority reversal under extremely high flows,
- High pedestrian or bicycle activity levels,
- More than two entry lanes on an approach, or

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- Flared entry lanes

A few of the more common applications of alternative tools to overcome the limitations of the procedures presented in this chapter will now be discussed.

Interaction Effects with Other Traffic Control Devices

Several common situations can be modeled with alternative tools.

- *Pedestrian signals or hybrid beacons at roundabout crosswalks.* These devices, described in detail in the *Manual on Uniform Traffic Control Devices for Streets and Highways* (17), can be used in a variety of applications, including the following:
  - High vehicle flows in which naturally occurring gaps in vehicle traffic or vehicular yielding for pedestrians is insufficient;
  - High pedestrian flows in which unrestricted pedestrian crossing activity may create insufficient capacity for motor vehicles; and
  - Crossing situations in which pedestrians with vision or other impairments may not receive equivalent access to the crossing. This is a legal requirement in the United States under the Americans with Disabilities Act and is regulated by the U.S. Access Board (9).
- *Metering signals on roundabout approaches.* These signals are sometimes used in applications in which a dominant entering flow reduces downstream entry capacity to zero or nearly zero. A metering signal can create gaps in the dominant flow at regular intervals or as dictated by queuing at the downstream entry.
- *Signals used to give priority to other uses.* These applications include at-grade rail crossings, emergency vehicle signals, and others.
- *Nearby intersections or traffic control devices at approaches or lane use effects internal.* These nearby intersections can have any type of control, including signalization, stop control, or YIELD control (as at another roundabout). Applications could also include nonintersection treatments such as freeway ramp meters.

While some deterministic intersection tools can model these situations, they are often treated more satisfactorily by using stochastic network models.

Flared Entries or Short-Lane Applications

Flared entries or short-lane applications are sometimes used at roundabouts to add capacity at the entry without substantially widening the approach upstream of the entry. Common applications include flaring from one lane to two lanes at the entry or from two lanes to three lanes, although some international research has found capacity sensitivity to flaring in sub-lane-width increments (11).

The methodology presented in this chapter provides a mechanism for flagging conditions under which queues for a given lane may exceed available storage or block access to adjacent lanes. Alternative tools may provide more accurate modeling of these situations.

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Three-Lane Roundabouts

Three-lane roundabouts are not included in the methodology described in this chapter but can be analyzed by a number of alternative tools. Note that no data for three-lane roundabouts are available in the source material (1) for this chapter's methodology, so the analyst should use care in estimating calibration parameters.

Adjustment of Simulation Parameters to the HCM Results

Calibration of any model used to analyze roundabouts is essential to producing realistic results that are consistent with field data. Ideally, field data should be used for calibration. For situations involving the assessment of hypothetical or proposed alternatives for which no field data exist, alternative tool results may be made more comparable with HCM results by adjusting alternative tool parameters to obtain a better match with the results obtained from the HCM procedures as follows:

- *Deterministic gap-acceptance models.* Typical calibration parameters for deterministic models include global adjustment factors that shift or shape the capacity model used by the model. These include adjustments to the intercept and slope of Tanner models or other shaping parameters of more complex analytical forms.
- *Stochastic gap-acceptance models.* Calibration of stochastic models is more challenging than for deterministic models because some calibration factors, such as factors related to driver aggressiveness, often apply globally to all elements of the network and not just to roundabouts. In other cases, the specific coding of the model can be fine-tuned to reflect localized driver behavior, including look-ahead points for gap acceptance and locations for discretionary and mandatory lane changes.

Step-by-Step Recommendations for Applying Alternative Tools

The following steps should be taken in applying an alternative tool to the analysis of roundabouts:

1. Identify the limitations of the HCM procedures that dictate the use of alternative tools.
2. Decide between a microscopic and a macroscopic modeling approach.
3. If possible, develop a simple configuration that can be analyzed by the HCM procedures. Analyze the simple configuration by using both the HCM and the selected alternative tool. Make adjustments to the alternative tool parameters to obtain a better match with the HCM results.
4. Perform the analysis of the full configuration by using the alternative tool.
5. Interpret and present the results.

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Sample Calculations Illustrating Alternative Tool Applications

Chapter 29, Urban Street Facilities: Supplemental, includes an example of the application of a simulation tool to assess the effect of using a roundabout within a coordinated arterial signal system. The interactions between the roundabout and the arterial system are examined by using signal timing plans with different progression characteristics.

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4. EXAMPLE PROBLEMS

Exhibit 21-22
List of Example Problems

Example Problem	Description	Application
1	Single-lane roundabout with bypass lanes	Operational analysis
2	Multilane roundabout	Operational analysis

EXAMPLE PROBLEM 1: SINGLE-LANE ROUNDABOUT WITH BYPASS LANES

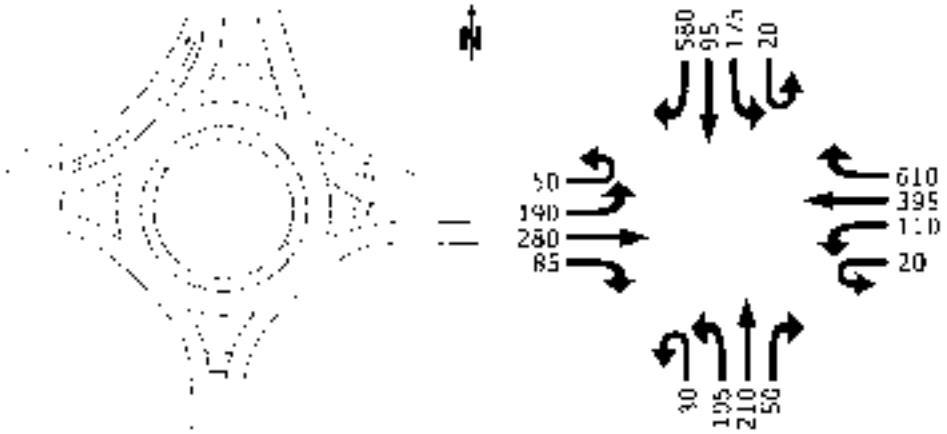
This is an example of an operational analysis. It uses traffic data and geometric characteristics to determine capacities, control delay, and LOS.

The Facts

The following data are available to describe the traffic and geometric characteristics of this location.

- Four legs,
- One-lane entries on each leg,
- A westbound right-turn bypass lane that yields to exiting vehicles,
- A southbound right-turn bypass lane that forms its own lane adjacent to exiting vehicles,
- Percent heavy vehicles for all movements = 2%,
- Peak hour factor = 0.94,
- Demand volumes and lane configurations as shown in Exhibit 21-23, and
- 50 pph across the south leg and negligible pedestrian activity across the other three legs.

Exhibit 21-23
Demand Volumes and Lane Configurations for Example Problem 1



Comments

All input parameters are known, so no default values are needed or used.

Step 1: Convert Movement Demand Volumes to Flow Rates

Each turning-movement volume given in the problem is converted to a demand flow rate by dividing by the peak hour factor. As an example, the northbound left-turn volume is converted to a flow rate as follows:

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$$v_{NB,pc} = \frac{V_{NB,pc}}{PHF} = \frac{105}{0.94} = 112 \text{ pc/h}$$

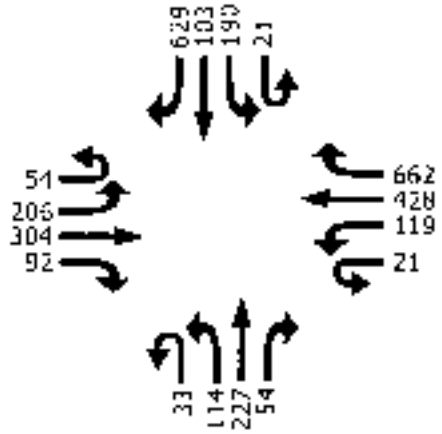
Step 2: Adjust Flow Rates for Heavy Vehicles

The flow rate for each movement may be adjusted to account for vehicle stream characteristics as follows (northbound left turn illustrated):

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} = \frac{1}{1 + 0.02(2 - 1)} = 0.980$$

$$v_{NB,pc,HV} = \frac{v_{NB,pc}}{f_{HV}} = \frac{112}{0.980} = 114 \text{ pc/h}$$

The resulting adjusted flow rates for all movements accounting for Steps 1 and 2 are therefore computed as follows:



Step 3: Determine Circulating and Exiting Flow Rates

The circulating and exiting flows are calculated for each leg. For the south leg (northbound entry), the circulating flow is calculated as follows:

$$v_{c,SB,pc} = v_{EBT,pc} + v_{WBL,pc} + v_{NBTA,pc} + v_{NBT,pc} + v_{NBR,pc} + v_{SBU,pc}$$

$$v_{c,SB,pc} = 21 + 190 + 21 + 304 + 206 + 54 = 796 \text{ pc/h}$$

Similarly, $v_{c,EB,pc} = 769$ pc/h, $v_{c,WB,pc} = 487$ pc/h, and $v_{c,NB,pc} = 666$ pc/h.

For this problem, one exit flow rate is needed: the northbound exit flow rate, which serves as the conflicting flow for the westbound bypass lane. Because all westbound right turns are assumed to use the bypass lane, they are excluded from the conflicting exit flow as follows:

$$v_{ex,pc,NB} = v_{NBTA,pc} + v_{EBT,pc} + v_{NBT,pc} - v_{NBU,pc}$$

$$v_{ex,pc,NB} = 21 + 206 + 227 + 0 = 454 \text{ pc/h}$$

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Step 4: Determine Entry Flow Rates by Lane

The entry flow rate is calculated by summing the movement flow rates that enter the roundabout (without using a bypass lane). Because this is a single-lane roundabout, no lane-use calculations are needed.

The entry flow rates are calculated as follows, assuming that all right-turn volumes on the westbound and southbound approaches use the bypass lane provided and not the entry.

$$v_{e,WB} = v_{WB,LT} + v_{WB,TH} + v_{WB,RT} + v_{WB,U} = 33 + 114 + 227 + 54 = 428 \text{ pc/h}$$

$$v_{e,SB} = v_{SB,LT} + v_{SB,TH} + v_{SB,RT} + v_{SB,U} = 21 + 191 + 103 + 0 = 314 \text{ pc/h}$$

$$v_{e,EB} = v_{EB,LT} + v_{EB,TH} + v_{EB,RT} + v_{EB,U} = 54 + 208 + 304 + 92 = 656 \text{ pc/h}$$

$$v_{e,NB} = v_{NB,LT} + v_{NB,TH} + v_{NB,RT} + v_{NB,U} = 21 + 119 + 428 + 0 = 568 \text{ pc/h}$$

Step 5: Determine the Capacity of Each Entry Lane and Bypass Lane as Appropriate in Passenger Car Equivalents

By using the single-lane capacity equation (Equation 21-1), the capacity for each entry lane is given as follows:

$$c_{pe,WB} = 1{,}130e^{(-1.0 \times 10^{-3})(v_{c,WB})} = 1{,}130e^{(-1.0 \times 10^{-3})(634)} = 510 \text{ pc/h}$$

$$c_{pe,SB} = 1{,}130e^{(-1.0 \times 10^{-3})(v_{c,SB})} = 1{,}130e^{(-1.0 \times 10^{-3})(746)} = 524 \text{ pc/h}$$

$$c_{pe,EB} = 1{,}130e^{(-1.0 \times 10^{-3})(v_{c,EB})} = 1{,}130e^{(-1.0 \times 10^{-3})(460)} = 691 \text{ pc/h}$$

$$c_{pe,NB} = 1{,}130e^{(-1.0 \times 10^{-3})(v_{c,NB})} = 1{,}130e^{(-1.0 \times 10^{-3})(729)} = 587 \text{ pc/h}$$

By using the equation for a bypass lane opposed by a single exit lane (Equation 21-6), the capacity for the westbound bypass lane is given as follows:

$$c_{bypass,pe,WB} = 1{,}130e^{(-1.0 \times 10^{-3})(v_{c,WB})} = 1{,}130e^{(-1.0 \times 10^{-3})(634)} = 718 \text{ pc/h}$$

Step 6: Determine Pedestrian Impedance to Vehicles

The south leg (northbound entry) has a conflicting pedestrian flow rate, v_{ped}, of 50 p/h. Therefore, the pedestrian impedance factor is calculated by using Exhibit 21-17 as follows:

$$f_{ped} = 1 - 0.001337 v_{ped} = 1 - 0.001337(50) = 0.993$$

The other legs have negligible pedestrian activity and therefore have $f_{ped} = 1$.

Step 7: Convert Lane Flow Rates and Capacities into Vehicles per Hour

The capacity for a given lane is converted back to vehicles by first determining the heavy-vehicle adjustment factor for the lane and then multiplying it by the capacity in passenger car equivalents. For this example, since all turning movements on each entry have the same f_{HV}, each entry will also have the same f_{HV}: 0.980.

$$c_{veh} = c_{pe,lane} f_{HV,lane} f_{ped} = (510)(0.980)(0.993) = 497 \text{ veh/h}$$

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$$c_{NR} = c_{sat,NR} f_{HV,NR} f_{PA} = (524)(0.980)(1) = 514 \text{ veh/h}$$

$$c_{TR} = c_{sat,TR} f_{HV,TR} f_{PA} = (694)(0.980)(1) = 680 \text{ veh/h}$$

$$c_{SHR} = c_{sat,SHR} f_{HV,SHR} f_{PA} = (587)(0.980)(1) = 575 \text{ veh/h}$$

$$c_{bypass,SR} = c_{sat,bypass,SR} f_{HV,bypass} f_{PA} = (718)(0.980)(1) = 704 \text{ veh/h}$$

Calculations for the entry flow rates are as follows.

$$v_{NR} = v_{pce,NR} f_{HV,NR} = (428)(0.980) = 420 \text{ veh/h}$$

$$v_{TR} = v_{pce,TR} f_{HV,TR} = (314)(0.980) = 308 \text{ veh/h}$$

$$v_{LR} = v_{pce,LR} f_{HV,LR} = (656)(0.980) = 643 \text{ veh/h}$$

$$v_{SHR} = v_{pce,SHR} f_{HV,SHR} = (568)(0.980) = 557 \text{ veh/h}$$

$$v_{bypass,SR} = v_{pce,bypass,SR} f_{HV,bypass} f_{PA} = (662)(0.980) = 649 \text{ veh/h}$$

Step 8: Compute the Volume-to-Capacity Ratio for Each Lane

The volume-to-capacity ratios for each entry lane are calculated as follows:

$$x_{NR} = \frac{420}{497} = 0.85$$

$$x_{TR} = \frac{308}{514} = 0.60$$

$$x_{LR} = \frac{643}{680} = 0.95$$

$$x_{SHR} = \frac{557}{575} = 0.97$$

$$x_{bypass,SR} = \frac{649}{704} = 0.92$$

Step 9: Compute the Average Control Delay for Each Lane

The control delay for the rightmost entry lane is computed as follows:

$$d_{NR} = \frac{3{,}600}{497} + 900(0.25)\left[0.85 - 1 + \sqrt{(0.85-1)^2 + \left(\frac{3{,}600}{497}\right)\frac{0.85}{450(0.25)}}\right]$$

$$+ 5 \times \min[0.85, 1] = 39.6 \text{ s/veh (assuming no rounding of } x)$$

Similarly, $d_{TR} = 19.5$ s, $d_{bypass,SR} = 0$ s (assumed), $d_{LR} = 40.7$ s, $d_{SHR} = 36.5$ s, and $d_{bypass,SR} = 41.5$ s.

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Step 10: Determine LOS for Each Lane on Each Approach

Using Exhibit 21-1, the LOS for each lane is determined as follows:

Lane	Control Delay (s/veh)	LOS
Northbound entry	39.0	E
Southbound entry	19.9	C
Southbound bypass lane	0 (assumed)	A
Eastbound entry	46.7	E
Westbound entry	56.5	F
Westbound bypass lane	41.5	E

Step 11: Compute the Average Control Delay and Determine LOS for Each Approach and the Roundabout as a Whole

The control delays for the northbound and eastbound approaches are equal to the control delay for the entry lanes, as both of these approaches have only one lane. On the basis of Exhibit 21-1, these approaches are both assigned LOS F.

The control delay calculations for the westbound and southbound approaches include the effects of their bypass lanes as follows:

$$d_{WB} = \frac{(56.5)(557) + (41.5)(649)}{557 + 649} = 48.4 \text{ s/veh}$$

$$d_{SB} = \frac{(19.9)(308) + (0.0)(617)}{308 + 617} = 6.6 \text{ s/veh}$$

On the basis of Exhibit 21-1, these approaches are respectively assigned LOS E and LOS A.

Similarly, intersection control delay is computed as follows:

$$d_{intersection} = \frac{(39.6)(420) + (0.6)(925) + (46.7)(613) + (48.4)(1206)}{420 + 925 + 649 + 1206} = 34.8 \text{ s/veh}$$

On the basis of Exhibit 21-1, the intersection is assigned LOS D.

Step 12: Compute 95th Percentile Queues for Each Lane

The 95th percentile queue is computed for each lane. An example calculation for the northbound entry is given as follows:

$$Q_{95,NB} = 900(0.25)\left[0.85 - 1 + \sqrt{(1-0.85)^2 + \frac{(2,600)^{0.85}}{497} + \frac{150(0.25)}{2,600}}\right] = 8.6 \text{ veh}$$

For design purposes, this value is typically rounded up to the nearest vehicle, which for this case would be 9 veh.

Similarly, $Q_{95,EB} = 3.9$ veh, $Q_{95,WB} = 13.4$ veh, $Q_{95,SB} = 3.3$ veh, and $Q_{95,bypass} = 12.5$ veh.

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Discussion

The results indicate that the overall roundabout is operating at LOS D based on a control delay very close to the boundary between LOS D and LOS E. However, three approaches (northbound, eastbound, and westbound) are operating at LOS E, and one lane (westbound entry) is operating at LOS F (based on control delay). In addition, two of the four entries have volume-to-capacity ratios exceeding 0.85 during the peak 15 min of the hour analyzed. If the performance standard for this intersection were LOS D, these approaches would not meet the standard, even though the overall intersection meets the standard. For these reasons, the analyst should report volume-to-capacity ratios, control delay, and queue lengths for each lane, in addition to the aggregated measures, for a more complete picture of operational performance.

The analyst should be careful not to mask key operational performance issues by reporting overall intersection measures without also reporting the performance of each lane, or at least the most constraining lane.

EXAMPLE PROBLEM 2: MULTILANE ROUNDABOUT

The Facts

The following data are available to describe the traffic and geometric characteristics of this location:

- Percent heavy vehicles for eastbound and westbound movements = 5%,
- Percent heavy vehicles for northbound and southbound movements = 2%,
- Peak hour factor = 0.95,
- Negligible pedestrian activity, and
- Volumes and lane configurations as shown in Exhibit 21-74.

This is also an example of an operational analysis, despite the fact that lane utilization data are unknown and must be assumed.

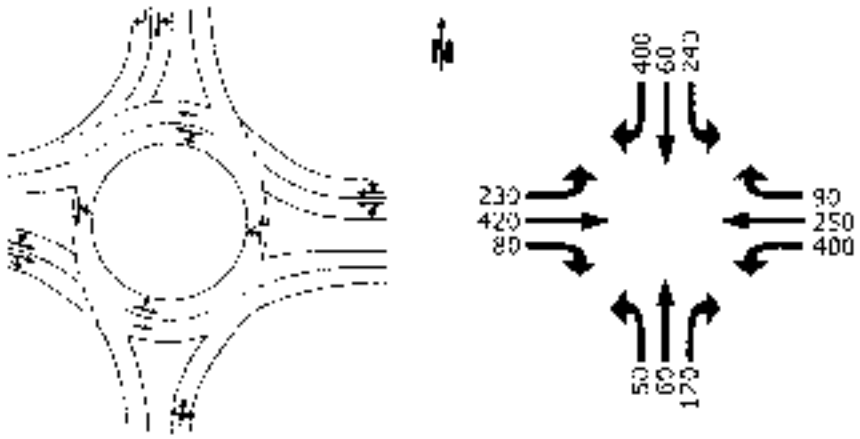

Exhibit 21-74
Demand Volumes and Lane Configurations for Example Problem 2

Comments

Lane use is not specified for the eastbound and westbound approaches. Therefore, the percentage flow in the right lane is assumed to be 55%, per Exhibit 21-21.

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Step 1: Convert Movement Demand Volumes to Flow Rates

Each turning movement demand volume given in the problem is converted to a demand flow rate by dividing by the peak hour factor. As an example, the eastbound left demand volume is converted to a demand flow rate as follows:

$$v_{EBL} = \frac{V_{EBL}}{PHF} = \frac{230}{0.95} = 242 \text{ veh/h}$$

Step 2: Adjust Flow Rates for Heavy Vehicles

The heavy-vehicle adjustment factor for the eastbound and westbound movements is calculated as follows:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} = \frac{1}{1 + 0.05(2 - 1)} = 0.952$$

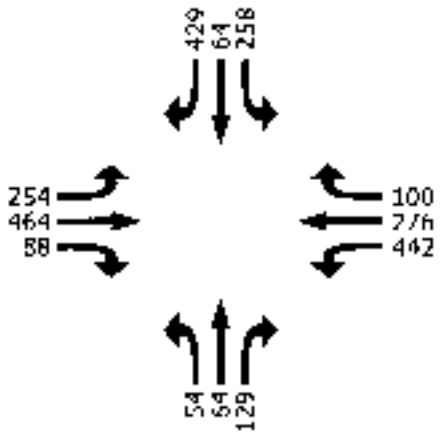
Similarly, the heavy-vehicle adjustment factor for the northbound and southbound movements is calculated as follows:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} = \frac{1}{1 + 0.02(2 - 1)} = 0.980$$

This is applied to each movement as follows (eastbound left turn illustrated):

$$v_{EBL,pc} = \frac{v_{EBL}}{f_{HV}} = \frac{242}{0.952} = 254 \text{ pc/h}$$

The resulting adjusted flow rates for all movements, accounting for Steps 1 and 2, are therefore as follows:



Step 3: Determine Circulating and Exiting Flow Rates

For this problem, only circulating flows need to be calculated for each leg. For the west leg (eastbound entry), the circulating flow is calculated as follows:

$$v_{c,EB,pc} = v_{NBT,pc} + v_{NBR,pc} + v_{WBL,pc} + v_{SBT,pc} + v_{SBR,pc}$$

$$v_{c,EB,pc} = 0 + 442 + 0 + 64 + 258 + 0 = 764 \text{ pc/h}$$

Similarly, $v_{c,NB,pc} = 372$ pc/h, $v_{c,WB,pc} = 970$ pc/h, and $v_{c,SB,pc} = 777$ pc/h.

AR0074494

Step 4: Determine Entry Flow Rates by Lane

The entry flow rate is calculated by summing up the movement flow rates that enter the roundabout. This step presents four unique cases:

- *Northbound:* The northbound entry has only one lane. Therefore, the entry flow is simply the sum of two movements, or 54 + 64 = 729 = 847 pc/h.
- *Southbound:* The southbound entry has two lanes: a shared through–left lane and a right-turn-only lane. Therefore, the flow rate in the right lane is simply the right-turn movement flow, or 420 pc/h, and the flow rate in the left lane is the sum of the left-turn and through movements, or 258 + 64 = 322 pc/h.
- *Eastbound:* The eastbound entry has shared left–through and through–right lanes. A check is needed to determine whether any de facto lanes are in effect. These checks are as follows:
  - *Left lane:* The left-turn flow rate, 254 pc/h, is less than the sum of the through and right-turn flow rates, 404 + 88 = 532 pc/h. Therefore, some of the through volume is assumed to use the left lane, and no de facto left-turn lane condition is present.
  - *Right lane:* The right-turn flow rate, 88 pc/h, is less than the sum of the left-turn and through flow rates, 254 + 464 = 718 pc/h. Therefore, some of the through volume is assumed to use the right lane, and no de facto right turn lane condition is present.
  - The total entry flow (254 + 464 + 88 = 806 pc/h) is therefore distributed over the two lanes, with flow biased to the right lane using the assumed lane use factor identified previously:
    - Right lane: (806)(0.53) = 427 pc/h
    - Left lane: 806 – 427 = 379 pc/h
- *Westbound:* The westbound entry also has shared left–through and through–right lanes, and so a similar check is needed for de facto lanes. The left-turn flow rate, 462 pc/h, is greater than the sum of the through and right-turn flow rates, 276 + 100 = 376 pc/h. Therefore, the left lane is assumed to operate as a de facto left-turn lane. Therefore, the left-lane flow rate is equal to the left turn flow rate, or 462 pc/h, and the right lane flow rate is equal to the sum of the through and right turn movement flow rates, or 376 pc/h.

Step 5: Determine the Capacity of Each Entry Lane and Bypass Lane as Appropriate in Passenger Car Equivalents

The capacity calculations for each approach are calculated as follows:

- *Northbound:* The northbound entry is a single-lane entry opposed by two circulating lanes. Therefore, Equation 21-5 is used as follows:

$$c_{pce,NB} = 1{,}130e^{(-1.0 \times 10^{-3} \times 1{,}129)} = 571 \text{ pc/h}$$

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- *Southbound:* The southbound entry is a two-lane entry opposed by two circulating lanes. Therefore, Equation 21-4 is used for the right lane, and Equation 21-5 is used for the left lane:

$$c_{pce,SB,R} = 1{,}130e^{(-1.3\times10^{-3})(v_{c2})} = 658 \text{ pc/h}$$

$$c_{pce,SB,L} = 1{,}130e^{(-1.3\times10^{-3})(v_{c1})} = 633 \text{ pc/h}$$

- *Eastbound:* The eastbound entry is a two-lane entry opposed by one circulating lane. Therefore, the capacity for each lane is calculated by using Equation 21-2 as follows:

$$c_{pce,EB} = 1{,}130e^{(-1.0\times10^{-3})(v_{c3})} = 526 \text{ pc/h}$$

- *Westbound:* The westbound entry is also a two-lane entry opposed by one circulating lane, so its capacity calculation is similar to that for the eastbound entry:

$$c_{pce,WB} = 1{,}130e^{(-1.0\times10^{-3})(v_{c4})} = 779 \text{ pc/h}$$

Step 6: Determine Pedestrian Impedance to Vehicles

For this problem pedestrians have been assumed to be negligible, so no impedance calculations are performed.

Step 7: Convert Lane Flow Rates and Capacities into Vehicles per Hour

The capacity for a given lane is converted back to vehicles by first determining the heavy vehicle adjustment factor for the lane and then multiplying it by the capacity in passenger car equivalents. For this example, since all turning movements on the eastbound and westbound entries have the same f_{HV}, each of the lanes on the eastbound and westbound entries can be assumed to have the same f_{HV} of 0.952.

$$c_{veh,L} = c_{pce,EB,R} f_{HV,EB} = (526)(0.952) = 501 \text{ veh/h}$$

Similarly, $c_{veh,L}$ = 501 veh/h, $c_{veh,T}$ = 742 veh/h, and $c_{veh,R}$ = 742 veh/h.

Since all turning movements on the northbound and southbound entries have the same f_{pce}, each of the lanes on those entries can be assumed to have the same f_{HV} of 0.980.

$$c_{veh} = c_{pce,WB} f_{HV,WB} = (571)(0.980) = 560 \text{ veh/h}$$

Similarly, $c_{veh,T}$ = 621 veh/h and $c_{veh,R}$ = 947 veh/h.

Calculations for the entry flow rates are as follows:

$$v_{veh,L} = v_{pce,EB,R} f_{HV,EB} = (427)(0.952) = 407 \text{ veh/h}$$

$$v_{veh} = v_{pce,WB} f_{HV,WB} = (247)(0.980) = 242 \text{ veh/h}$$

Similarly, $v_{veh,T}$ = 361 veh/h, $v_{veh,R}$ = 421 veh/h, $v_{veh,L}$ = 358 veh/h, $v_{veh,T}$ = 316 veh/h, and $v_{veh,R}$ = 421 veh/h.

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Step 8: Compute the Volume-to-Capacity Ratio for Each Lane

The volume-to-capacity ratio for each lane is calculated as follows:

$$x_{NB} = 242/560 = 0.43$$

$$x_{SB,L} = 316/621 = 0.51$$

$$x_{SB,R} = 421/645 = 0.65$$

$$x_{EB,T} = 361/501 = 0.72$$

$$x_{EB,R} = 407/501 = 0.81$$

$$x_{WB,L} = 421/742 = 0.57$$

$$x_{WB,R} = 358/742 = 0.48$$

Step 9: Compute the Average Control Delay for Each Lane

The control delay for the northbound entry lane is computed as follows:

$$d_{NB} = \frac{3,600}{560} - 900(0.25)\left[\frac{242}{560} - 1 - \sqrt{\left(\frac{242}{560} - 1\right)^2 - \left(\frac{3,600}{560}\right)\frac{242}{560}}{450(0.25)}\right] + 5 \times \min\left[\frac{242}{560}, 1\right] = 13.4 \text{ s/veh}$$

Similarly, $d_{SB,L} = 14.2$ s, $d_{SB,R} = 18.7$ s, $d_{EB,T} = 27.2$ s, $d_{EB,R} = 35.4$ s, $d_{WB,L} = 13.9$ s, and $d_{WB,R} = 11.7$ s.

Step 10: Determine LOS for Each Lane on Each Approach

On the basis of Exhibit 21-1, the LOS for each lane is determined as follows:

Critical Lane	Control Delay (s/veh)	LOS
Northbound entry	13.4	B
Southbound left lane	14.2	B
Southbound right lane	18.7	C
Eastbound left lane	27.2	D
Eastbound right lane	35.4	E
Westbound left lane	13.9	B
Westbound right lane	11.7	B

Step 11: Compute the Average Control Delay and Determine LOS for Each Approach and the Roundabout as a Whole

The control delay for the northbound approaches is equal to the control delay for the entry lane, 13.4 s, as the approach has only one lane. The control delays for the other approaches are as follows:

$$d_{SB} = \frac{(14.2)(316) + (18.7)(421)}{316 + 421} = 16.8 \text{ s/veh}$$

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$$d_{wb} = \frac{(27.2)(361) + (35.4)(407)}{361 + 407} = 31.5 \text{ s/veh}$$

$$d_{sb} = \frac{(13.9)(421) + (11.7)(358)}{421 + 358} = 12.9 \text{ s/veh}$$

On the basis of Exhibit 21-1, these approaches are respectively assigned LOS D, LOS C, LOS D, and LOS B.

Similarly, control delay for the intersection is computed as follows:

$$d_{intersection} = \frac{(13.4)(242) + (16.8)(736) + (31.5)(768) + (12.9)(779)}{242 + 736 + 768 + 779} = 19.7 \text{ s/veh}$$

On the basis of Exhibit 21-2, the intersection is assigned LOS C.

Step 12: Compute 95th Percentile Queues for Each Lane

The 95th percentile queue is computed for each lane. An example calculation for the northbound entry is given as follows:

$$Q_{95,nb} = 900(0.25)\left[\frac{242}{560}\right] + 1 + \sqrt{\left[\frac{242}{560}\right]^2 + \frac{3{,}600\left(\frac{242}{560}\right)}{150(0.25)}}\left\{\frac{560}{3{,}600}\right\} = 2.2 \text{ veh}$$

For design purposes, this value is typically rounded up to the nearest vehicle, in this case 3 veh.

Discussion

The results indicate that the intersection as a whole operates at LOS C on the basis of control delay during the peak 15 min of the analysis hour. However, the eastbound approach operates at LOS D, and the right lane of that approach operates at LOS E (with a control delay very close to the boundary of LOS D and LOS E) and with a volume-to-capacity ratio of 0.8. The analyst should report both the overall performance and those of the individual lanes to provide a more complete picture of operational performance.

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INTERCHANGE RAMP TERMINALS

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1. INTRODUCTION

VOLUME 3: INTERRUPTED FLOW
18. Urban Street Facilities
19. Urban Street Segments
20. Signalized Intersections
21. TWSC Intersections
22. AWSC Intersections
23. Roundabouts
24. Interchange Ramp Terminals
25. On-Street Pedestrian and Bicycle Facilities

Interchange ramp terminals are critical components of the highway network. They provide the connection between various highway facilities (i.e., freeway–arterial, arterial–arterial, etc.), and thus their efficient operation is essential. Interchanges have to be designed to work in harmony with the freeway, the ramps, and the arterials. In addition, they need to provide adequate capacity to avoid affecting the connecting facilities.

SCOPE OF THE CHAPTER

Chapter 22, Interchange Ramp Terminals, presents the methodology for the analysis of interchanges involving freeways and surface streets (i.e., service interchanges), and it was developed primarily on the basis of research conducted through the National Cooperative Highway Research Program (*1–3*) and elsewhere (*4*).

The methodology addresses interchanges with signalized intersections, interchanges with roundabouts, and the impact and operations of adjacent closely spaced intersections. Interchanges with two-way stop-controlled intersections or interchanges consisting of a signalized intersection and a roundabout cannot be evaluated with the procedures of this chapter. Traffic circles (e.g., intersections with a circular island in the middle and signals at the approaches) are not considered in this chapter. The scope of this chapter includes the operational analysis for a full range of service interchange types, including diamond, partial cloverleaf (parclo), and single-point urban interchanges (SPUIs). It also includes a methodology for assessing the operational performance of various types of interchanges for purposes of interchange type selection. The chapter can be used to obtain guidance for assessing various interchange types with respect to their operational performance; it does not provide guidance for selecting an appropriate interchange type with respect to economic, environmental, land use, and other such concerns. The methodology addresses at-grade intersections, not including the freeway proper, and focuses on surface streets; it does not analyze freeway-to-freeway interchanges.

LIMITATIONS OF THE METHODOLOGY

The methodology does not address oversaturated conditions, particularly cases when the downstream queue spills back into the upstream intersection (i.e., when the internal queue exceeds the available storage of the link). It does not address spillback from inadequate turning pocket length. It does not explicitly evaluate the impact of spillback on freeway operations; however, it does estimate the expected queue on the ramps. It does not consider the impacts of ramp metering and spillback from the freeway into the interchange. The method does not estimate lane utilizations for cases when one or both intersections contain an approach that is not part of the prescribed interchange configuration given in the Types of Interchanges section; however, guidance is provided for addressing those cases. The methodology does not specifically address diverging interchanges or continuous flow interchanges (there is limited information with

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regard to the operation of these emerging interchange types, but it is likely that future research will focus on developing methods for evaluating their operational performance). The methodology provides delay estimates but does not provide link travel times and speeds.

In cases where the user is interested in the analysis of conditions that fall under the above methodological limitations or in the investigation of dynamic traffic operations (i.e., those that evolve in time and space), the use of another analysis tool, such as simulation modeling, is advised. Section 3 includes information on the use of alternative tools for the analysis of interchange ramp terminals.

The operational analysis is only one factor to be considered in the design or redesign of an interchange ramp terminal. Other important factors include right-of-way availability and economic and environmental constraints. The scope of this chapter does not include such considerations; the chapter focuses only on the traffic operational performance of signalized interchanges.

TYPES OF INTERCHANGES

A number of different types of interchanges are recognized in the literature. *A Policy on Geometric Design of Highways and Streets* (1) provides extensive information on interchange designs and their characteristics. This section illustrates and discusses the interchange designs considered in this chapter, namely diamond interchanges, parclos, SPUIs, and interchanges with roundabouts.

Diamond Interchanges

Most forms of diamond interchanges result in two or more closely spaced surface intersections, as illustrated in Exhibit 22-1. On a diamond interchange, only one connection is made for each freeway entry and exit, with one connection per quadrant. Left- and right-turning movements are used for entry to or exit from the two directions of the surface facility, which necessitates left-turning movements. When demands are low (generally in rural areas), the junction of diamond interchange ramps with the surface facility is typically controlled by stop or yield signs. If traffic demands are sufficiently high, signalization becomes necessary.

There are many variations of the diamond interchange. The typical diamond configuration has three subcategories defined by the spacing of the intersections formed by the ramp–street connections. Conventional diamond interchanges provide a separation of 800 ft or more between the two intersections. Compressed diamond interchanges have intersections spaced between 400 and 800 ft, and tight urban diamond interchanges feature spacing of less than 400 ft. Because of right-of-way constraints, compressed diamonds are more likely to be used in urban areas, while conventional diamond interchanges are more likely to be used in rural or suburban settings.

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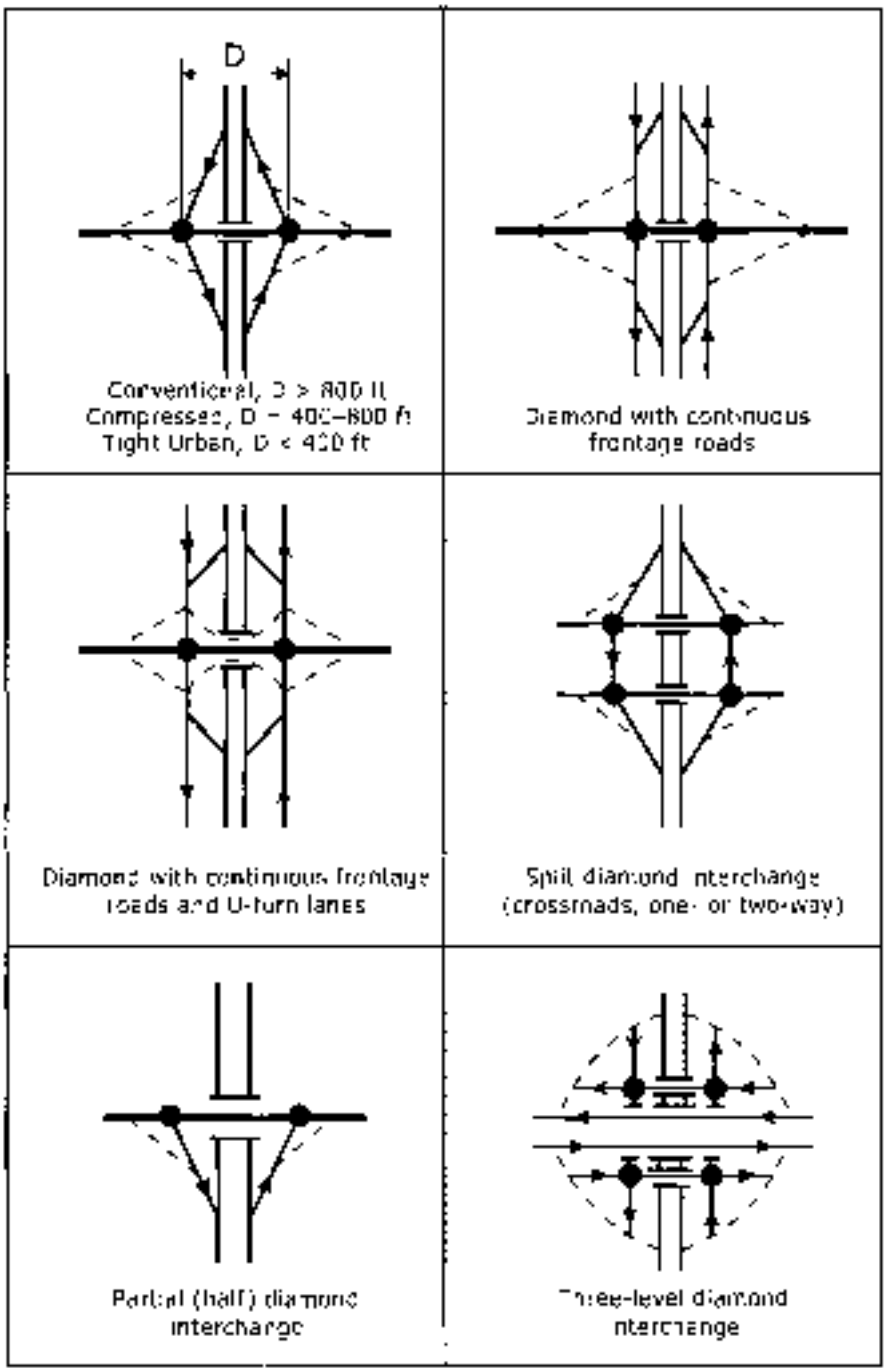

Exhibit 22-1
Types of Diamond Interchanges

Note: — Possible alternative configuration of signal bypasses operating as unsignalized movements; these are movements that do not stop at the ramp terminals.

Split diamond interchanges have freeway entry and exit ramps separated at the street level, creating four intersections. Diamond configurations also can be combined with continuous one-way frontage roads. The frontage roads become one-way arterials, and turning movements at the intersections created by the diamond interchange become even more complex. Separated U-turn roadways may be added, removing U-turns from the signal scheme, if there is a signal. A

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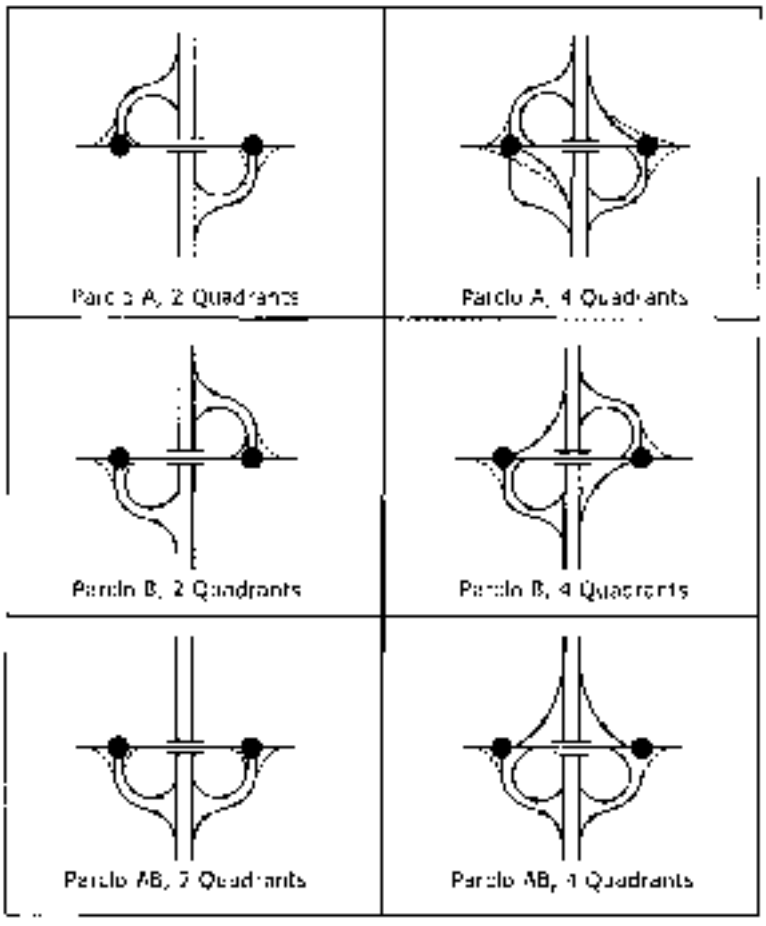
partial diamond interchange has fewer than four ramps, and not all freeway–street or street–freeway movements are served. A three-level diamond interchange features two divided levels so that ramps are necessary on both facilities to allow continuous through movements.

All these forms of diamond interchanges are depicted in Exhibit 22-1. The methodology in this chapter is applicable to all diamond interchange forms except the split diamond and the three-level diamond. The methodology addresses interchanges where both terminals are signalized or both terminals are roundabouts.

Parclo Interchanges

Parclo interchanges are depicted in Exhibit 22-2. A variety of parclo interchanges can be created with one or two loop ramps. In such cases, one or two of the outer ramps take the form of a diamond ramp, allowing a movement to take place by means of a right turn. In some parclo configurations, left turns also may be made onto or off of a loop ramp. The methodology in this chapter is applicable to parclo interchanges where both terminals are signalized or both terminals are roundabouts.

Exhibit 22-2
Types of Parclo Interchanges



Note: - - - - Possible alternative configuration of ramp. Dynamic operation of unsignalized movements may be necessary to avoid overlapping the ramp terminals.

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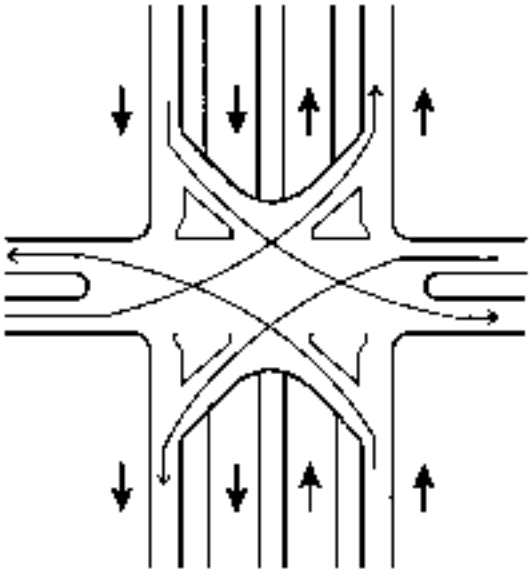
Single-Point Urban Interchanges

A SPUI combines all the ramp movements into a single signalized intersection and has the advantage of operating as such. The design eliminates the critical issue of coordinating the operation of two closely spaced intersections. The SPUI is depicted in Exhibit 22-3.

Exhibit 22-3
Single-Point Urban Interchange



Interchanges with Roundabouts

Roundabout intersections can replace signalized or stop-controlled intersections at interchange ramp terminals. Three types of roundabout intersection designs are typically used in the United States and are illustrated in Exhibit 22-4. The first design consists of two traditional roundabouts at the two nodes of the interchange. The second design is called the raindrop roundabout interchange, and it restricts certain movements within each roundabout by creating raindrop-shaped central islands. The two designs are essentially the same, except that the first should be provided when U-turns are allowed or when there is an additional approach to the roundabout. The last design consists of a single roundabout spanning both sides of the freeway via overpass or underpasses.

These three designs are applicable to both diamond and parclo interchanges. Their major advantage is that they can reduce the number of lanes needed between terminals, thereby significantly reducing structure-related costs. They also eliminate the need for coordinating signal operations at the two closely spaced intersections. A potential disadvantage of using roundabouts is that spillback from a downstream facility into the roundabout may result in gridlock for all movements at the roundabout, since all movements must use the circulating roadway.

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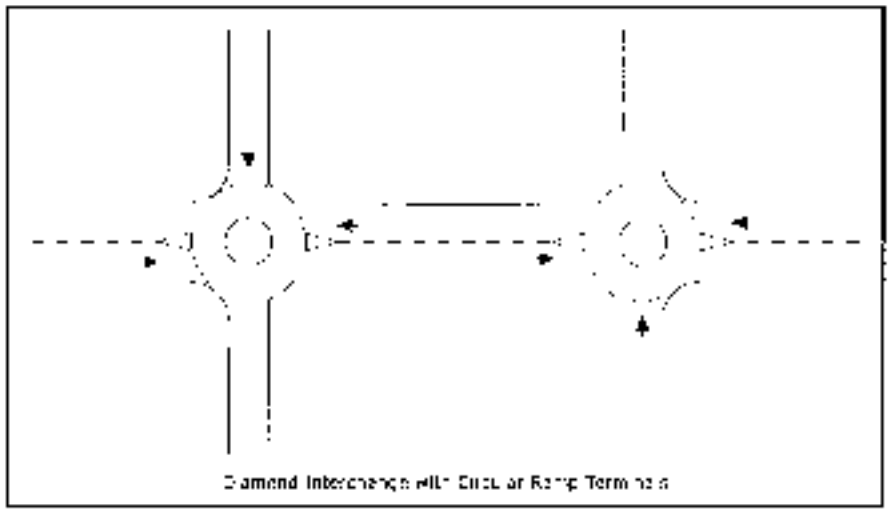
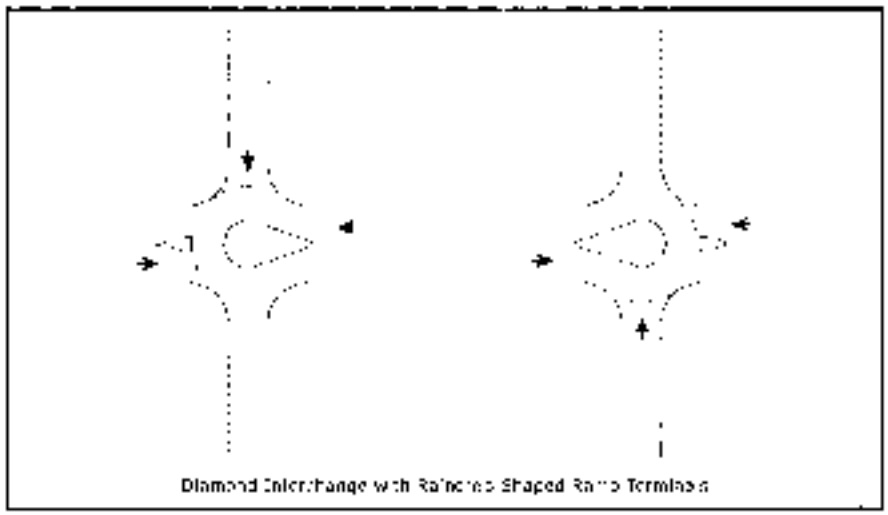
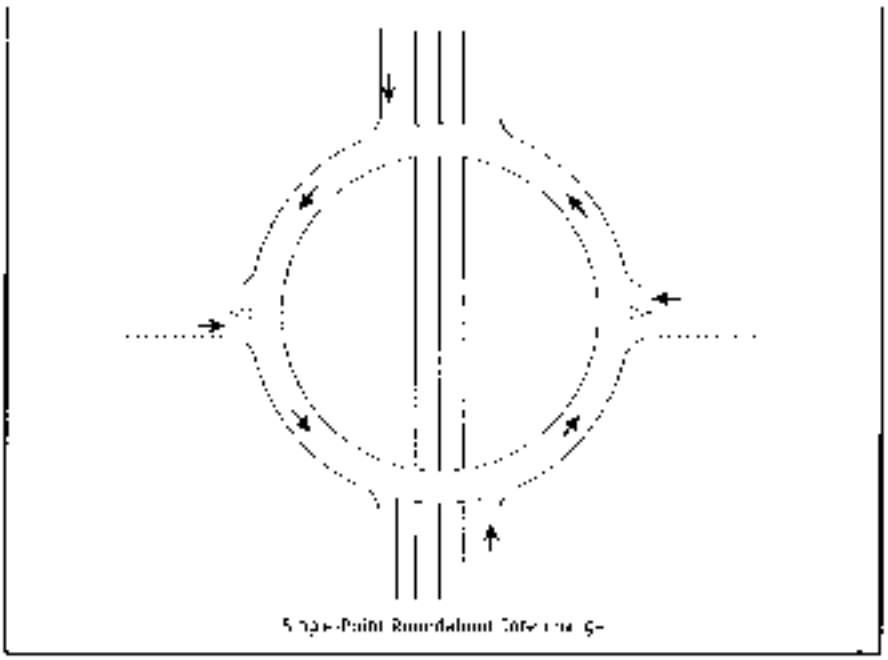
Exhibit 22-4
Interchanges with Roundabouts







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UNIQUE OPERATIONAL CHARACTERISTICS OF INTERCHANGES

Influence of Interchange Type on Turning Movements

The type of interchange has a major influence on turning movements. Movements that involve a right-side merge in one configuration become left turns in another. Movements approaching the interchange on the surface facility are also affected by the interchange type, depending on whether the ramp movements involve left or right turns. Thus, the identification of the external approaches to the interchange varies as a function of the type of interchange and the relative proportion of the turning movements at the downstream intersection.

In selecting an appropriate type of interchange, the impacts on the turning movements should be considered. Left-turning movements are always the most difficult in terms of efficiency of operation, and high-volume left-turning movements should be avoided, if possible. By selecting a type of interchange that requires left turns only for low-demand movements, the overall operation can be enhanced significantly. However, it is not always possible to accomplish this. Right-of-way limitations or agency policies may preclude the use of loop ramps, and economic and environmental constraints may make multilevel structures undesirable.

Because of the influence of interchange type on turning movements, and to be able to compare various interchange types, their level of service (LOS) is based on origin–destination (O-D) demands through the interchange, which are identical regardless of the interchange type. The methodology in this chapter uses both O-D demands and turning movement demands; one set of demands can be derived from the other. Exhibit 22-5 illustrates the O-D demands of an interchange and gives their respective notation. To simplify the mapping process, it is assumed that the freeway is oriented north–south (N-S) and the surface arterial east–west (E-W). Note that Demands K and L indicate the through movement that travels across the surface street, not the freeway through traffic. These demands are expected to be minimal; however, they are included in the methodology because they constitute allowable movements through the interchange. Exhibit 22-6 illustrates the routing of all demands through a diamond interchange, while Exhibit 22-7 illustrates their routing through a Parclo AB-2Q. As shown, the O-D Demand E, eastbound from the arterial and northbound into the freeway, is a left turn in the diamond configuration, while it becomes a right turn in Parclo AB-2Q.

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Exhibit 22-5
Illustration and Notation of O-D Demands at an Interchange

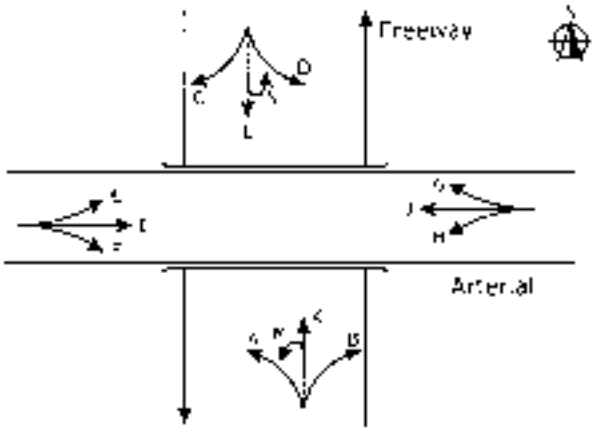


Exhibit 22-6
Illustration and Notation of O-D Demands at a Diamond Interchange

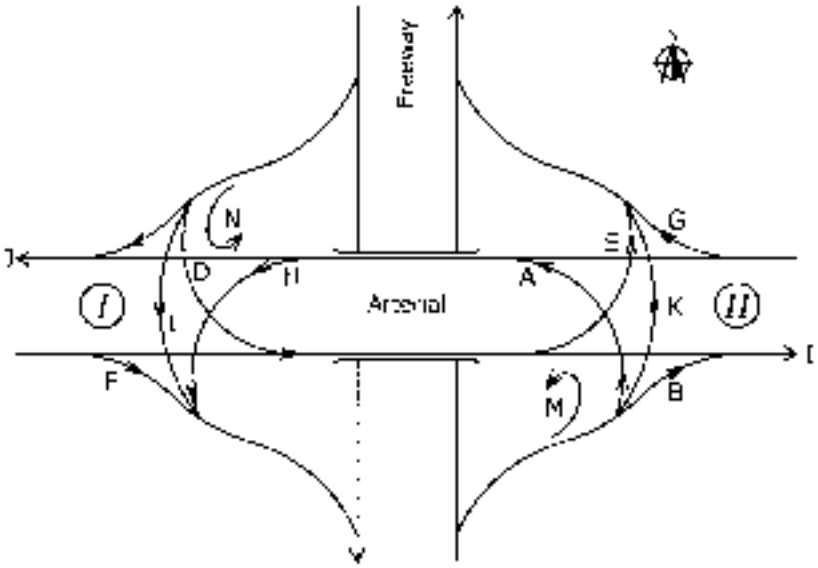
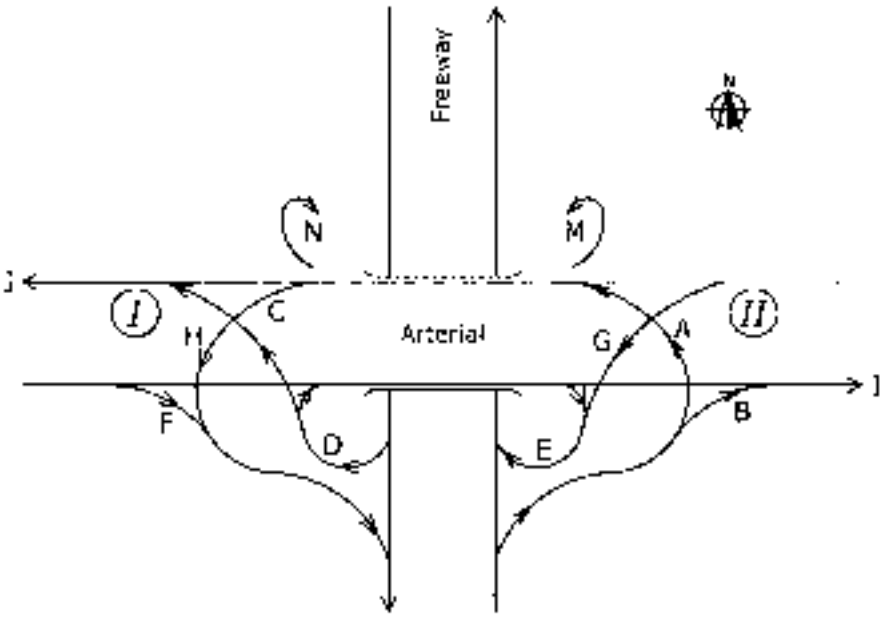


Exhibit 22-7
Illustration of O-D Demands Through a Parclo A5-2Q Interchange



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Operational Effects of the Intersection Spacing

These configurations with two closely spaced signalized intersections present unique challenges because the two intersections do not operate in isolation. Examples of such configurations include the diamond interchange and two quadrant parcles. The distance separating the two intersections limits the amount of storage available for queued vehicles. Also, the presence of a downstream queue may reduce or completely block the discharge from the upstream intersection.

Queuing at the downstream intersection can have one of the following two impacts on the discharge from the upstream intersection:

1. Queuing conditions at the downstream intersection are not severe enough to affect the upstream intersection; or
2. Queues at the downstream intersection reduce the rate of discharge upstream because of proximity of the back of the queue. When that occurs, portions of the upstream green cannot be used because of downstream blockage.

Queued vehicles within a short segment (or link) limit the effective length of the link, and vehicles can travel freely only from the upstream stop line to the back of the downstream queue. Because this distance may be small, the impact on the upstream discharge rates significant. In this methodology, the effects of the presence of a queue at the downstream link are considered by estimating the amount of additional lost time experienced at the upstream intersection. The additional lost time is calculated as a function of the distance to the downstream queue at the beginning of the green for each of the upstream phases.

The extent of queuing at the downstream intersection depends on several factors, including the signal control at the upstream and downstream signals, the number and use of lanes at both intersections, and the upstream flow rates that feed the downstream intersection.

Some of these effects may also occur at locations where signalized intersections are closely spaced, particularly where heavy left-turn movements exist. This chapter addresses the interactions of interchange operations with those of adjacent closely spaced signalized intersections. Furthermore, the principles described in this chapter may be applied to similar situations in which closely spaced signalized intersections (other than those at interchanges) interact.

Similar issues may exist at interchanges with roundabouts that are near signalized intersections. When the queue from the signalized intersection reaches the roundabout, it might cause complete gridlock. Some of movements through the roundabout must use the circulating roadway.

Lane Utilization for the External Through Movements

For two-intersection signalized interchanges, the lane utilization for the external through movements approaching the interchange on the surface facility is significantly affected by the distribution and demand of the turning movements at the downstream intersection. As shown in Exhibit 22-6, high-volume downstream left turns will gravitate toward the left-side lanes at the upstream

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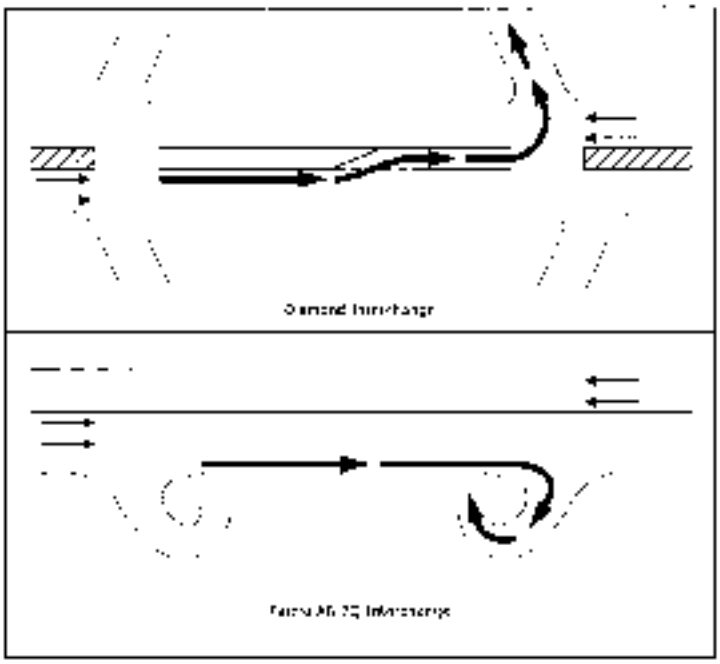
intersection, while the remaining through and right-turning vehicles will tend toward the right. Conversely, heavy-volume downstream right turns will gravitate toward the right side at the upstream intersection. This can create lane-use imbalances that extend far at single-intersections.

The methodology in this chapter identifies the highest utilization level at each of the upstream external through movements as a function of the interchange type, the number of through lanes, the distance between the two intersections, and the O-D demands.

Exhibit 22-8
Impact of Interchange Type on Lane Utilization



How the upstream intersections distribute the lane utilization of the arterial approaches at intersections adjacent to the interchange. Lane utilization at these intersections may be affected by turning movement demands at the interchange.

Demand Starvation

Demand starvation occurs when a signalized approach has adequate capacity but a significant portion of the traffic demand is held upstream because of the signalization pattern. For two-intersection signalized interchanges, demand starvation occurs when a portion of the green at the downstream intersection is not used because the upstream intersection signalization prevents vehicles from reaching the stop line. Thus, portions of the downstream green are unused while demand is stuck at the upstream intersection. Exhibit 22-9 illustrates the concept of demand starvation for an interchange. As shown, the internal left turn in the eastbound direction is green, blocking all westbound vehicles from reaching the westbound internal link/green. Thus, demand starvation is experienced by the external westbound through movement, where the signal is green, while the demand for it is blocked upstream.

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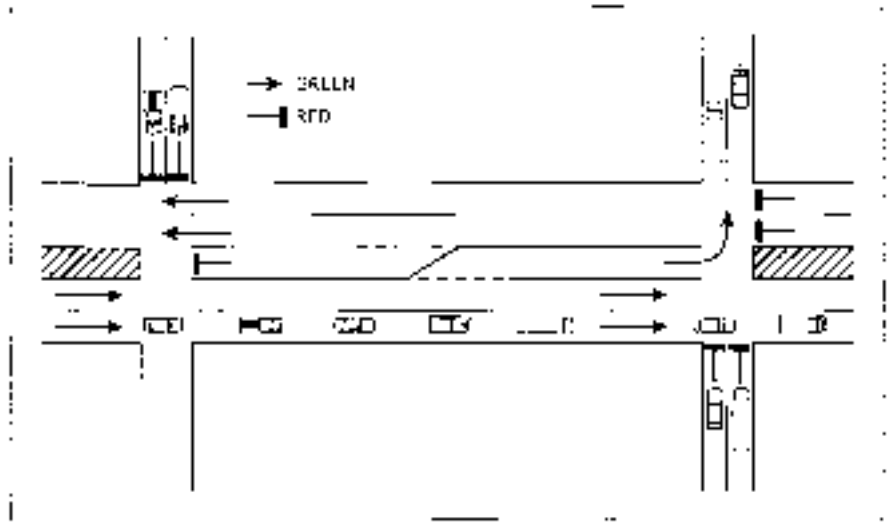

Exhibit 22-9
Demand Starvation at the Internal Link of a Diamond Interchange

LOS FRAMEWORK

Signalized Interchanges

The LOS designation is based on the operational performance of O-D demands (shown in Exhibit 22-5) through the interchange. The LOS for each O-D is based on the total average control delay experienced by that demand as it travels through the interchange. For example, for the diamond interchange shown in Exhibit 22-10, the delay for the O-D Movement H is equal to the sum of the average control delays (d_{EBT}, d_{WBT}) at each of the lane group flows (v_{EBT}, v_{WBT}) along its path. Thus, the delay d_H for O-D H is as follows:

$$d_H = d_{EBT} + d_{WBT} \quad \text{Equation 22-1}$$

where d_{EBT} is average control delay of the external westbound through movement (seven) and d_{WBT} is average control delay of the internal westbound left movement (seven).

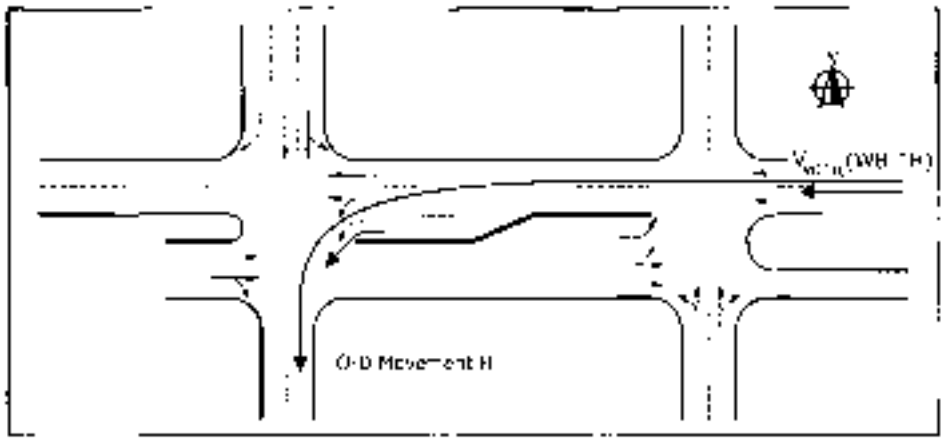

Exhibit 22-10
Illustration of the LOS Concept at a Diamond Interchange

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Furthermore, LOS F is defined to occur when either the volume-to-capacity ratio (v/c) or the average queue-to-storage ratio (R_Q) for any of the lane groups that contain this O-D exceed 1, where R_Q refers to the average per lane queue storage ratio within the lane group. Storage is defined as the distance available for queued vehicles on a particular movement, and it is provided on a per lane basis. For example, if the left-turning lane group shown in Exhibit 22-10 has $v/c > 1$, then the LOS for the entire O-D Movement 11 will be LOS F. If a particular lane group has $v/c > 1$, then all O-Ds that travel through this lane group will operate in LOS F, regardless of their delay. Similarly, if the average per lane queue in a particular lane group exceeds its available storage, then all O-Ds traveling through this lane group will operate in LOS F, regardless of their delay.

Exhibit 22-11 summarizes the LOS criteria for each O-D of an interchange. The values presented in Exhibit 22-11 are greater than those for signalized intersections by a factor of 1.5 to reflect the fact that some of the O-D movements would travel through two intersections, while others would travel through only one.

Exhibit 22-11
LOS Criteria for Each O-D of a Signalized Interchange

Control Delay (s/veh)	O-D LOS $v/c < 1$ and $R_Q < 1$ for Every Lane Group	 $v/c > 1$ for Any Lane Group	 $R_Q > 1$ for Any Lane Group
≤15	A	F	F
>15–30	B	F	F
>30–55	C	F	F
>55–85	D	F	F
>85–120	E	F	F
>120	F	F	F

Interchanges with Roundabouts

Similar to signalized interchanges, the LOS computation for interchanges with roundabouts is based on the operational performance of O-D demands through the interchange. The LOS for each O-D is based on the total average control delay experienced by that demand as it travels through the interchange. For example, for the interchange shown in Exhibit 22-12, the delay for the O-D Movement 11 is equal to the sum of the average control delays (d_1, d_2, d_3) at each of the approach flows (v_1, v_2, v_3) along its path. Furthermore, LOS F is defined to occur when either the v/c ratio or the average R_Q for any of the lane groups that contain this O-D exceeds 1, where R_Q refers to the average per lane queue storage ratio within the lane group.

Exhibit 22-12
Illustration of the LOS Concept at an Interchange with Roundabouts

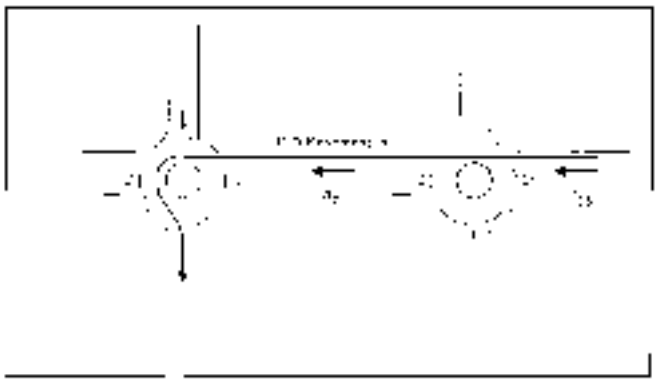

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Exhibit 22-13 summarizes the LOS criteria for each O-D of an interchange with one or two roundabouts. The values presented in Exhibit 22-13 are greater than those for noninterchange roundabouts to reflect the fact that some of the O-D movements might travel through two roundabouts while others might travel through only one. The values are also generally lower than the respective ones for signalized interchanges, since drivers would likely expect lower delays at roundabouts.

Exhibit 22-13
LOS Criteria for Interchanges with Roundabouts

Control Delay (s/veh)	O-D LOS $v/c < 1$ and $R_Q < 1$ for All Approaches	$v/c > 1$ for Any Approach	$R_Q > 1$ for Any Approach
≤15	A	F	F
>15–25	B	F	F
>25–35	C	F	F
>35–50	D	F	F
>50–70	E	F	F
>70	F	F	F

Other Interchange Types

Interchange types and control not explicitly included in this chapter (e.g., two-way STOP-controlled diamond interchanges) do not have LOS criteria defined on an O-D basis. In the absence of such LOS criteria, analyses of these interchange types and comparisons with other interchange types can be made by using control delay for each O-D and other applicable performance measures. These performance measures can be determined with procedures in this and other *Highway Capacity Manual* (HCM) chapters, alternative tools, or both, aggregated as appropriate into O-D performance measures by using the techniques in this chapter.

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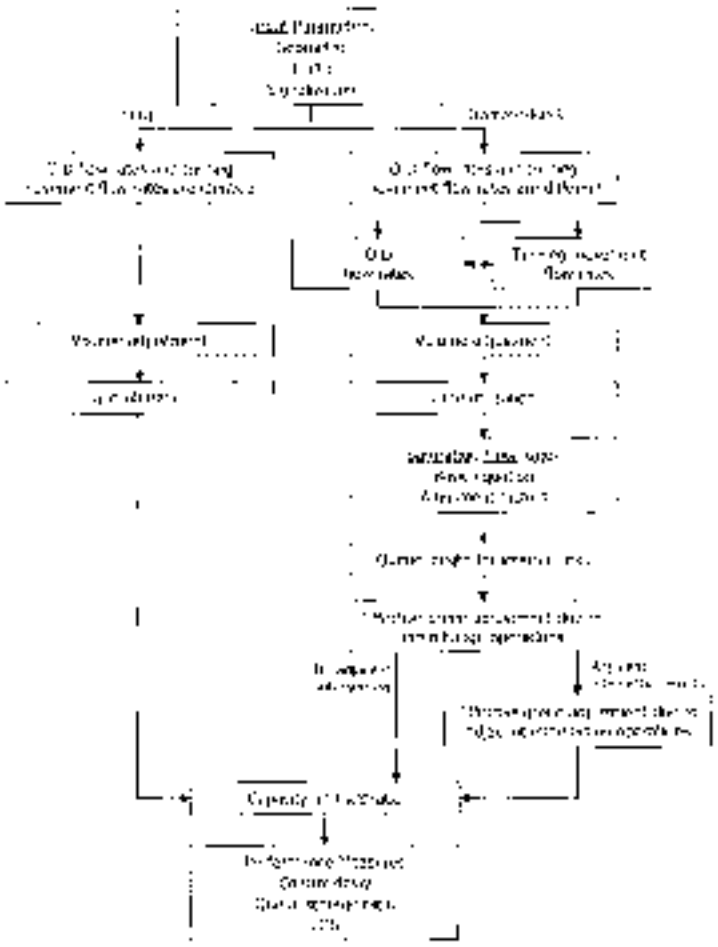
2. METHODOLOGIES

There are two general types of analysis for signalized interchange ramp terminals: (a) final design and traffic operational analysis and (b) operational analysis for interchange type selection. The methodology for final design and traffic operational analysis for signalized interchanges is presented first. The next section presents the methodology for analyzing interchanges with roundabouts and is followed by a brief discussion of operations at interchanges with unsignalized intersections. The last section presents the methodology used in interchange type selection.

FINAL DESIGN AND OPERATIONAL ANALYSIS FOR SIGNALIZED INTERCHANGES

Exhibit 22-14 summarizes the basic methodology for the final design and operational analysis of signalized interchange ramp terminals. The methodology is similar to that of Chapter 18, Signalized Intersections, with additional consideration for unbalanced lane utilizations, additional lost times due to downstream queues, demand starvation, and additional lost times due to intersections with closely spaced interconnections.

Exhibit 22-14
Interchange Ramp Terminals Methodology: Final Design and Operational Analysis for Signalized Interchanges



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The analysis of SPUIs is outlined on the left part of the graph. The graph highlights only the components added to the signalized intersection methodology for analyzing SPUIs. The right part of the graph highlights the components added to the signalized intersection methodology for analyzing diamond and parclo interchanges. Each of the steps outlined in Exhibit 22-14 is explained and discussed below.

The analysis begins with the assembly of all pertinent input data, such as geometric characteristics, traffic demands, and signalization information. Exhibit 22-15 provides a summary of all input data required to conduct an operational analysis for interchange ramp terminals.

Exhibit 22-15
Summary of Required Input Data for Final Design and Operational Analysis of Signalized Interchanges

Type of Condition	Parameter
Geometric conditions	Area type Number of lanes (N) Average lane width (w, ft) Grade (G, %) Presence of exclusive left- or right-turn lanes Length of storage for each lane group (L_s, ft) Distance corresponding to the internal storage between the two intersections in the interchange (D, ft) Distances corresponding to the internal storage between interchange intersections and adjacent closely spaced intersections (D, ft) Turning radii for all turning movements (ft)
Traffic conditions	Demand volume by O-D or turning movement (v, veh/h) Right-turn-on-red flow rates Base saturation flow rate (s_0, pc/h/ln) Peak hour factor (*PHF*) Percent heavy vehicles (*%HV*, %) Approach pedestrian flow rates (v_{ped}, ped/h) Approach bicycle flow rates (v_b, bicycles/h) Local bus stopping rate (N_b, buses/h) Parking activity (N_m, maneuvers/h) Arrival type (*AT*) Upstream filtering adjustment factor Approach speed (S_A, mi/h)
Signalization conditions	Type of signal control Phase sequence Cycle length (if appropriate) (C, s) Green times (if appropriate) (G, s) Yellow-plus-all-red change-and-clearance interval (intergreen) (Y, s) Offset (if appropriate) Maximum, minimum green, passage times, phase recall (for actuated control) Pedestrian push button Minimum pedestrian green (G_p, s) Phase plan

O-D Demands and Movement Demands

The analyst may have either O-D demands or intersection turning movements available for the study interchange. Since both are needed in the analysis, the first step in the methodology consists of calculating either the turning movements by using the O-D demands or the O-D demands by using the turning movements. If the interchange is a SPUI (i.e., only has one intersection), the O-D demands and the turning movement demands are the same, and the analysis proceeds similarly to the methodology of Chapter 18, Signalized Intersections, to estimate capacity, v/c, delay, and queue storage ratios. The

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Applications section of this chapter provides guidance on converting O-D movements to turning movements and vice versa for each type of interchange configuration addressed in this methodology.

Lane Group Determination

As in the case of signalized interchanges, the methodology for interchange ramp terminals is disaggregate, that is, it is designed to consider individual intersection approaches and individual lane groups within approaches. The segmentation of the interchange into lane groups generally follows the same guidelines that apply for the analysis of signalized intersections.

Lane Utilization

Vehicles at interchanges do not distribute evenly among lanes in a lane group, and their lane selection is highly affected by their ultimate destination. For example, for two-intersection interchanges, when there is a high-volume left turn at the downstream intersection, traffic at the upstream intersection will gravitate toward the left lanes, while through and right-turning vehicles will tend toward the right. While this may occur at any intersection, because the internal link is generally short and because turning movements are typically high, there is generally greater variation in lane distribution and the adjustment factors that result from this segregation at the upstream intersection may occur by driver selection or by designated signing and striping.

To account for these phenomena, lane utilization models have been developed specifically for the external through approaches (surface streets) at two-intersection interchanges. The lane utilization factors for all other interchange approaches (freeway ramps, internal approaches, and SPUI approaches) are estimated by using the procedures of Chapter 18. These lane utilization factors are then used to adjust the saturation flow rates for each lane group.

Adjustment for Lane Utilization

The lane utilization factor accounts for the unequal distribution of traffic among the lanes in a lane group with more than one lane. The factor provides an adjustment to the base saturation flow rate. The adjustment factor is based on the flow in the lane with the highest volume and is calculated by Equation 22-2.

Equation 22-2

$$f_{LU} = \frac{1}{\%V_{1,max} \times N}$$

where

f_{LU} = adjustment factor for lane utilization,

$\%V_{1,max}$ = percent of the total approach flow in the lane with the highest volume, expressed as a decimal, and

N = number of lanes in lane group.

A series of models have been developed to predict $\%V_{1,max}$ for the external arterial approaches of two-intersection interchanges as a function of the downstream turning movements. The remaining approaches should use lane

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utilization factors based on either field data or default values obtained from Exhibit 18-30.

Exhibit 22-16 through Exhibit 22-20 provide the models developed for each type of interchange configuration and for two-, three-, and four-lane arterials. In these exhibits, L1 represents the leftmost lane, L2 represents the second lane from the left, and so forth. The notation used in these exhibits is provided immediately after Exhibit 22-20.

The models estimate the percent of traffic expected to use each through lane as a function of the O-D demands in the subject approach. These models predict, for the external arterial approaches, the percent of traffic that is expected to use a particular lane as a function of the downstream turning movements. These turning movements are expressed in terms of their respective O-D flows. O-D flows (A through N) are shown in Exhibit 22-21 for each configuration type. When the patterns of the eastbound and westbound approaches are symmetrical, the calibration parameters for the eastbound and the westbound directions are identical, and only the O-D flows differ. Interchange approaches with identical turning movement patterns in the subject direction (eastbound or westbound) are grouped together, and the models developed apply to all configurations in the group. For example, the Parclo B-2Q, B-4Q, and AB-4Q westbound approach are grouped together, and their lane utilization models are presented in Exhibit 22-16.

In Exhibit 22-16, Exhibit 22-18, and Exhibit 22-19, when an external approach has an exclusive right-turning lane, the O-D for that movement (v_{ij} or v_{ji}) should be assumed to be zero in the respective equation. In Exhibit 22-17, Exhibit 22-18, Exhibit 22-19, and Exhibit 22-20, when there is an additional leg at the upstream intersection, the analyst should use the lane utilization factors of Chapter 18. The models shown in these exhibits are valid for values of D less than 500 ft. The empirical models shown in Exhibit 22-16 through Exhibit 22-20 did not consider configurations with longer distances; for these longer distances between the two intersections vehicles tend not to perpositure themselves in anticipation of a downstream turn. In those cases, and in the absence of field data, it is recommended that the default values of Exhibit 18-30 be used. In cases when the internal link contains dual left turns extending to the upstream approach, the volume in the most heavily traveled left-turning lane can be approximated as follows:

1. Use the model with number of lanes N + 1, where N is the number of lanes of the subject external approach;
2. Estimate the leftmost lane volume; and
3. Multiply by 0.535.

Research has shown that as operations approach congested conditions, the lane utilization factor tends to approach 1 (i.e., traffic becomes more uniformly distributed).

Actual lane volume distributions observed in the field should be used, if available, because these distributions are highly dependent on the existing land uses and access points in the vicinity of the interchange. A lane utilization factor

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of 1.0 can be used when uniform traffic distribution can be assumed across all lanes in the lane group or when a lane group comprises a single lane. The lane utilization factors are used in the next step of the methodology to adjust the saturation flow rates for each lane group of the interchange.

Exhibit 22-16
Lane Utilization Models for the External Arterial Approaches of Diamond Interchanges

TWO LANES IN THE LANE GROUP	
Eastbound Leftmost lane ($\%LU_{EB,1}$)	$\%LU_{EB,1} = \frac{1}{2}\left(1.04 + \frac{v_{EBL}}{v_{EBL} + v_{EBT}}\right)\left(1 - \frac{v_{EBL}}{v_{EBL} + v_{EBT}}\right)^{0.154} \geq \max\left(\frac{v_{EBL}}{v_{EBL} + v_{EBT}}, 0.5\right)$
Eastbound Right lane ($\%LU_{EB,2}$)	$\%LU_{EB,2} = 1 - \%LU_{EB,1}$
Westbound Leftmost lane ($\%LU_{WB,1}$)	$\%LU_{WB,1} = \frac{1}{2}\left(1.04 + \frac{v_{WBL}}{v_{WBL} + v_{WBT}}\right)\left(1 - \frac{v_{WBL}}{v_{WBL} + v_{WBT}}\right)^{0.154} \geq \max\left(\frac{v_{WBL}}{v_{WBL} + v_{WBT}}, 0.5\right)$
Westbound Right lane ($\%LU_{WB,2}$)	$\%LU_{WB,2} = 1 - \%LU_{WB,1}$
THREE LANES IN THE LANE GROUP	
Eastbound Leftmost lane ($\%LU_{EB,1}$)	$\%LU_{EB,1} = \frac{1}{3}\left(0.93 + 0.15\frac{v_{EBL}}{v_{EBL} + v_{EBT}}\right)\left(1 - \frac{v_{EBL}}{v_{EBL} + v_{EBT}}\right)^{0.16} \geq \max\left(\frac{v_{EBL}}{v_{EBL} + v_{EBT}}, 0.33\right)$
Eastbound Middle lane ($\%LU_{EB,2}$)	$\%LU_{EB,2} = 1 - \%LU_{EB,1} - \%LU_{EB,3}$
Eastbound Right lane ($\%LU_{EB,3}$)	$\%LU_{EB,3} = \frac{1}{3}\left(1.07 + 0.15\frac{v_{EBR}}{v_{EBR} + v_{EBT}}\right)\left(1 - \frac{v_{EBR}}{v_{EBR} + v_{EBT}}\right)^{0.16} \geq 0.33\left(\frac{v_{EBR}}{v_{EBR} + v_{EBT}}\right)$
Westbound Leftmost lane ($\%LU_{WB,1}$)	$\%LU_{WB,1} = \frac{1}{3}\left(0.93 + 0.15\frac{v_{WBL}}{v_{WBL} + v_{WBT}}\right)\left(1 - \frac{v_{WBL}}{v_{WBL} + v_{WBT}}\right)^{0.16} \geq \max\left(\frac{v_{WBL}}{v_{WBL} + v_{WBT}}, 0.33\right)$
Westbound Middle lane ($\%LU_{WB,2}$)	$\%LU_{WB,2} = 1 - \%LU_{WB,1} - \%LU_{WB,3}$
Westbound Right lane ($\%LU_{WB,3}$)	$\%LU_{WB,3} = \frac{1}{3}\left(1.07 + 0.15\frac{v_{WBR}}{v_{WBR} + v_{WBT}}\right)\left(1 - \frac{v_{WBR}}{v_{WBR} + v_{WBT}}\right)^{0.16} \geq 0.33\left(\frac{v_{WBR}}{v_{WBR} + v_{WBT}}\right)$
FOUR LANES IN THE LANE GROUP	
Eastbound Leftmost lane ($\%LU_{EB,1}$)	$\%LU_{EB,1} = \frac{1}{4}\left(0.93 + 0.15\frac{v_{EBL}}{v_{EBL} + v_{EBT}}\right)\left(1 - \frac{v_{EBL}}{v_{EBL} + v_{EBT}}\right)^{0.16} \geq \max\left(\frac{v_{EBL}}{v_{EBL} + v_{EBT}}, 0.25\right)$
Eastbound Middle lanes ($\%LU_{EB,2}$, $\%LU_{EB,3}$)	$\%LU_{EB,2} = \%LU_{EB,3} = \left(1 - \%LU_{EB,1} - \%LU_{EB,4}\right)/2$
Eastbound Right lane ($\%LU_{EB,4}$)	$\%LU_{EB,4} = \frac{1}{4}\left(1.04 + 0.15\frac{v_{EBR}}{v_{EBR} + v_{EBT}}\right)\left(1 - \frac{v_{EBR}}{v_{EBR} + v_{EBT}}\right)^{0.16} \geq \max\left(\frac{v_{EBR}}{v_{EBR} + v_{EBT}}, 0.25\right)$
Westbound Leftmost lane ($\%LU_{WB,1}$)	$\%LU_{WB,1} = \frac{1}{4}\left(0.93 + 0.15\frac{v_{WBL}}{v_{WBL} + v_{WBT}}\right)\left(1 - \frac{v_{WBL}}{v_{WBL} + v_{WBT}}\right)^{0.16} \geq \max\left(\frac{v_{WBL}}{v_{WBL} + v_{WBT}}, 0.25\right)$
Westbound Middle lanes ($\%LU_{WB,2}$, $\%LU_{WB,3}$)	$\%LU_{WB,2} = \%LU_{WB,3} = \left(1 - \%LU_{WB,1} - \%LU_{WB,4}\right)/2$
Westbound Right lane ($\%LU_{WB,4}$)	$\%LU_{WB,4} = \frac{1}{4}\left(1.04 + 0.15\frac{v_{WBR}}{v_{WBR} + v_{WBT}}\right)\left(1 - \frac{v_{WBR}}{v_{WBR} + v_{WBT}}\right)^{0.16} \geq \max\left(\frac{v_{WBR}}{v_{WBR} + v_{WBT}}, 0.25\right)$

Notes: Definitions of variables are provided in Exhibit 22-20.

a. If there is an exclusive right-turn lane on the external approach, then the respective O-D demand (v_{EBR} or v_{WBR}) should be zero in the respective equation.

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Exhibit 22-17
Lane Utilization Models for the External Arterial Approaches of Peripheral Quadrants

TWO LANES IN THE LANE GROUP	
Eastbound Leftmost Lane ($\%V_{EB,L}$)	$\%V_{EB,L} = \frac{1}{2}\left[1 + \frac{v_{EB,R} - v_{EB,L}}{v_{EB,R} + v_{EB,L}}\right]$
Eastbound Right Lane ($\%V_{EB,R}$)	$\%V_{EB,R} = 1 - \%V_{EB,L}$
Westbound Leftmost Lane ($\%V_{WB,L}$)	$\%V_{WB,L} = \frac{1}{2}\left[1 + \frac{v_{WB,R} - v_{WB,L}}{v_{WB,R} + v_{WB,L}}\right]$
Westbound Right Lane ($\%V_{WB,R}$)	$\%V_{WB,R} = 1 - \%V_{WB,L}$
THREE LANES IN THE LANE GROUP	
Eastbound Leftmost Lane ($\%V_{EB,L}$)	$\%V_{EB,L} = \frac{1}{3}\left[1 + \frac{v_{EB,R} - v_{EB,L}}{v_{EB,R} + v_{EB,L}}\right]$
Eastbound Middle Lane ($\%V_{EB,M}$)	$\%V_{EB,M} = 1 - \%V_{EB,L} - \%V_{EB,R}$
Eastbound Right Lane ($\%V_{EB,R}$)	$\%V_{EB,R} = \frac{1}{3}\left[1 + \frac{v_{EB,R} - v_{EB,L}}{v_{EB,R} + v_{EB,L}}\right]$
Westbound Leftmost Lane ($\%V_{WB,L}$)	$\%V_{WB,L} = \frac{1}{3}\left[1 + \frac{v_{WB,R} - v_{WB,L}}{v_{WB,R} + v_{WB,L}}\right]$
Westbound Middle Lane ($\%V_{WB,M}$)	$\%V_{WB,M} = 1 - \%V_{WB,L} - \%V_{WB,R}$
Westbound Right Lane ($\%V_{WB,R}$)	$\%V_{WB,R} = \frac{1}{3}\left[1 + \frac{v_{WB,R} - v_{WB,L}}{v_{WB,R} + v_{WB,L}}\right]$
FOUR LANES IN THE LANE GROUP	
Eastbound Leftmost Lane ($\%V_{EB,L}$)	$\%V_{EB,L} = \frac{1}{4}\left[1 + \frac{v_{EB,R} - v_{EB,L}}{v_{EB,R} + v_{EB,L}}\right]$
Eastbound Middle lanes ($\%V_{EB,1}$, $\%V_{EB,2}$)	$\%V_{EB,1} = (1 - \%V_{EB,L} - \%V_{EB,R})/2$ $\%V_{EB,2} = (1 - \%V_{EB,L} - \%V_{EB,R})/2$
Eastbound Right Lane ($\%V_{EB,R}$)	$\%V_{EB,R} = \frac{1}{4}\left[1 + \frac{v_{EB,R} - v_{EB,L}}{v_{EB,R} + v_{EB,L}}\right]$
Westbound Leftmost Lane ($\%V_{WB,L}$)	$\%V_{WB,L} = \frac{1}{4}\left[1 + \frac{v_{WB,R} - v_{WB,L}}{v_{WB,R} + v_{WB,L}}\right]$
Westbound Middle lanes ($\%V_{WB,1}$, $\%V_{WB,2}$)	$\%V_{WB,1} = (1 - \%V_{WB,L} - \%V_{WB,R})/2$ $\%V_{WB,2} = (1 - \%V_{WB,L} - \%V_{WB,R})/2$
Westbound Right Lane ($\%V_{WB,R}$)	$\%V_{WB,R} = \frac{1}{4}\left[1 + \frac{v_{WB,R} - v_{WB,L}}{v_{WB,R} + v_{WB,L}}\right]$

Notes: Definitions of variables are provided after Exhibit 22-20.

If the intersection for which lane utilizations are being estimated has an acronym (e.g., the analyst should not use the equations of this exhibit. The procedures of Chapter 18 should be used instead.

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Exhibit 22-18
Lane Utilization Models for the External Arterial Approaches of Ramp B-2Q, B-4Q, and AB-4Q (Westbound Only)

TWO LANES IN THE LANE GROUP	
Eastbound Leftmost lane ($\%LU_1$)	$\%LU_1 = \frac{1}{2}\left(1 + 0.392 \times \left(\frac{v_1}{v_1 + v_2 + v_{r1}}\right) - 0.392 \times \left(\frac{v_{r1}}{v_1 + v_2 + v_{r1}}\right)\right)$
Eastbound Right lane ($\%LU_2$)	$\%LU_2 = 1 - \%LU_1$
Westbound Leftmost lane ($\%LU_1$)	$\%LU_1 = \frac{1}{2}\left(1 + 0.392 \times \left(\frac{v_1}{v_1 + v_2 + v_{r1}}\right) - 0.392 \times \left(\frac{v_{r1}}{v_1 + v_2 + v_{r1}}\right)\right)$
Westbound Right lane ($\%LU_2$)	$\%LU_2 = 1 - \%LU_1$
THREE LANES IN THE LANE GROUP	
Eastbound Leftmost lane ($\%LU_1$)	$\%LU_1 = \frac{1}{3}\left(1 + 0.55 \times \left(\frac{v_1}{v_1 + v_2 + v_{r1}}\right) - 0.218 \times \left(\frac{v_{r1}}{v_2 + v_{r1} + v_{r2}}\right)\right)$
Eastbound Middle lane ($\%LU_2$)	$\%LU_2 = 1 - \%LU_1 - \%LU_3$
Eastbound Right lane ($\%LU_3$)	$\%LU_3 = \frac{1}{3}\left(1 + 0.218 \times \left(\frac{v_1}{v_1 + v_2 + v_{r1}}\right) - 0.655 \times \left(\frac{v_{r1}}{v_2 + v_{r1} + v_{r2}}\right)\right)$
Westbound Leftmost lane ($\%LU_1$)	$\%LU_1 = \frac{1}{3}\left(1 + 0.55 \times \left(\frac{v_{r1}}{v_{r1} + v_2 + v_1}\right) - 0.218 \times \left(\frac{v_1}{v_{r1} + v_{r2} + v_2}\right)\right)$
Westbound Middle lane ($\%LU_2$)	$\%LU_2 = 1 - \%LU_1 - \%LU_3$
Westbound Right lane ($\%LU_3$)	$\%LU_3 = \frac{1}{3}\left(1 + 0.218 \times \left(\frac{v_{r1}}{v_{r1} + v_2 + v_1}\right) - 0.655 \times \left(\frac{v_{r1}}{v_{r1} + v_{r2} + v_2}\right)\right)$
FOUR LANES IN THE LANE GROUP	
Eastbound Leftmost lane ($\%LU_1$)	$\%LU_1 = \frac{1}{4}\left(1 + 0.615 \times \left(\frac{v_1}{v_1 + v_2 + v_{r1}}\right) - 0.308 \times \left(\frac{v_{r1}}{v_2 + v_{r1} + v_{r2}}\right)\right)$
Eastbound Middle lanes ($\%LU_2$, $\%LU_3$)	$\%LU_2 = (1 - \%LU_1 - \%LU_4)/2$ $\%LU_3 = (1 - \%LU_1 - \%LU_4)/2$
Eastbound Right lane ($\%LU_4$)	$\%LU_4 = \frac{1}{4}\left(1 + 0.308 \times \left(\frac{v_1}{v_1 + v_2 + v_{r1}}\right) - 0.615 \times \left(\frac{v_{r1}}{v_2 + v_{r1} + v_{r2}}\right)\right)$
Westbound Leftmost lane ($\%LU_1$)	$\%LU_1 = \frac{1}{4}\left(1 + 0.615 \times \left(\frac{v_{r1}}{v_{r1} + v_2 + v_1}\right) - 0.308 \times \left(\frac{v_1}{v_{r1} + v_{r2} + v_2}\right)\right)$
Westbound Middle lanes ($\%LU_2$, $\%LU_3$)	$\%LU_2 = (1 - \%LU_1 - \%LU_4)/2$ $\%LU_3 = (1 - \%LU_1 - \%LU_4)/2$
Westbound Right lane ($\%LU_4$)	$\%LU_4 = \frac{1}{4}\left(1 + 0.308 \times \left(\frac{v_{r1}}{v_{r1} + v_2 + v_1}\right) - 0.615 \times \left(\frac{v_{r1}}{v_{r1} + v_{r2} + v_2}\right)\right)$

Notes: Definitions of variables are provided after Exhibit 22-20.

[1] There is an exclusive right-turn lane on the external approach; thus the respective O-D demand (v_r or v_{r1}) should be zero in the respective equation.

[2] The intersection for which lane utilizations are being determined has an additional eq. the sum of the corresponding equations (Exhibit 31). The procedure of Chapter 18 should be used instead.

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TWO LANES IN THE LANE GROUP	
Eastbound Leftmost lane (%V_{L1})	$\%V_{L1} = \frac{1}{2} \cdot 0.316 \cdot \left(\frac{V_{L1}}{v_{L1} + v_{T1} + v_{R1}}\right) + 0.684 \cdot \left(\frac{V_{T1}}{v_{L1} + v_{T1} + v_{R1}}\right)$
Eastbound Right lane (%V_{R1})	$\%V_{R1} = 1 - \%V_{L1}$
Westbound Leftmost lane (%V_{L2})	$\%V_{L2} = \frac{1}{2} \cdot 0.316 \cdot \left(\frac{V_{L2}}{v_{L2} + v_{T2} + v_{R2}}\right) + 0.684 \cdot \left(\frac{V_{T2}}{v_{L2} + v_{T2} + v_{R2}}\right)$
Westbound Right lane (%V_{R2})	$\%V_{R2} = 1 - \%V_{L2}$
THREE LANES IN THE LANE GROUP	
Eastbound Leftmost lane (%V_{L1})	$\%V_{L1} = \frac{1}{3} \cdot 0.533 \cdot \left(\frac{V_{L1}}{v_{L1} + v_{T1} + v_{R1}}\right) + 0.284 \cdot \left(\frac{V_{T1}}{v_{L1} + v_{T1} + v_{R1}}\right)$
Eastbound Middle lane (%V_{T1})	$\%V_{T1} = 1 - \%V_{L1} - \%V_{R1}$
Eastbound Right lane (%V_{R1})	$\%V_{R1} = \frac{1}{3} \cdot 0.533 \cdot \left(\frac{V_{R1}}{v_{L1} + v_{T1} + v_{R1}}\right) + 0.428 \cdot \left(\frac{V_{T1}}{v_{L1} + v_{T1} + v_{R1}}\right)$
Westbound Leftmost lane (%V_{L2})	$\%V_{L2} = \frac{1}{3} \cdot 0.533 \cdot \left(\frac{V_{L2}}{v_{L2} + v_{T2} + v_{R2}}\right) + 0.284 \cdot \left(\frac{V_{T2}}{v_{L2} + v_{T2} + v_{R2}}\right)$
Westbound Middle lane (%V_{T2})	$\%V_{T2} = 1 - \%V_{L2} - \%V_{R2}$
Westbound Right lane (%V_{R2})	$\%V_{R2} = \frac{1}{3} \cdot 0.533 \cdot \left(\frac{V_{R2}}{v_{L2} + v_{T2} + v_{R2}}\right) + 0.428 \cdot \left(\frac{V_{T2}}{v_{L2} + v_{T2} + v_{R2}}\right)$
FOUR LANES IN THE LANE GROUP	
Eastbound Leftmost lane (%V_{L1})	$\%V_{L1} = \frac{1}{4} \cdot 0.233 \cdot \left(\frac{V_{L1}}{v_{L1} + v_{T1} + v_{R1}}\right) + 0.267 \cdot \left(\frac{V_{T1}}{v_{L1} + v_{T1} + v_{R1}}\right)$
Eastbound Middle lanes (%V_{T1}, %V_{R1})	$\%V_{T1} = (1 - \%V_{L1} - \%V_{R1}) \cdot \%V_{T1}/2$ $\%V_{R1} = (1 - \%V_{L1} - \%V_{R1}) \cdot \%V_{T1}/2$
Eastbound Right lane (%V_{R1})	$\%V_{R1} = \frac{1}{4} \cdot 0.233 \cdot \left(\frac{V_{R1}}{v_{L1} + v_{T1} + v_{R1}}\right) + 0.767 \cdot \left(\frac{V_{T1}}{v_{L1} + v_{T1} + v_{R1}}\right)$
Westbound Leftmost lane (%V_{L2})	$\%V_{L2} = \frac{1}{4} \cdot 0.233 \cdot \left(\frac{V_{L2}}{v_{L2} + v_{T2} + v_{R2}}\right) + 0.267 \cdot \left(\frac{V_{T2}}{v_{L2} + v_{T2} + v_{R2}}\right)$
Westbound Middle lanes (%V_{T2}, %V_{R2})	$\%V_{T2} = (1 - \%V_{L2} - \%V_{R2}) \cdot \%V_{T2}/2$ $\%V_{R2} = (1 - \%V_{L2} - \%V_{R2}) \cdot \%V_{T2}/2$
Westbound Right lane (%V_{R2})	$\%V_{R2} = \frac{1}{4} \cdot 0.233 \cdot \left(\frac{V_{R2}}{v_{L2} + v_{T2} + v_{R2}}\right) + 0.767 \cdot \left(\frac{V_{T2}}{v_{L2} + v_{T2} + v_{R2}}\right)$

Notes: Definitions of variables are provided after Exhibit 22-23.

If there is an exclusive right-turn lane on the external approach, then the respective O-D demands (v_{R1} or v_{R2}) should be zero in the respective equation.

If the intersection for which lane utilizations are being estimated has an additional leg, the analyst should use the four-leg version of the equations. The procedures of Chapter 18, Urban Street Segments, should be used to estimate the lane utilization for the additional leg.

Exhibit 22-19
Lane Utilization Models for the External Arterial Approaches of Pardo A-4Q, AB-2Q (Eastbound Only), and AB-4Q (Eastbound Only)

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Exhibit 22-20
Lane Utilization Models for the External Arterial Approaches of Paclo AB (Q (Westbound Only) Interchange

TWO LANES IN THE LANE GROUP	
Westbound Leftmost lane (% V_1)	$\%V_1 = \frac{1}{1+0.864\left(\frac{v_2}{v_1}\right)^{1.1}}$
Westbound Right lane (% V_2)	$\%V_2 = 1 - \%V_1$
THREE LANES IN THE LANE GROUP	
Westbound Leftmost lane (% V_1)	$\%V_1 = \frac{1}{1+0.775\left(\frac{v_2}{v_1}\right)^{1.1}}$
Westbound Middle lane (% V_2)	$\%V_2 = 1 - \%V_1 - \%V_3$
Westbound Right lane (% V_3)	$\%V_3 = \frac{1}{1+0.775\left(\frac{v_2}{v_3}\right)^{1.1}}$
FOUR LANES IN THE LANE GROUP	
Westbound Leftmost lane (% V_1)	$\%V_1 = \frac{1}{1+0.775\left(\frac{v_2}{v_1}\right)^{1.1}}$
Westbound Middle lanes (% V_2, % V_3)	$\%V_2 = (1 - \%V_1 - \%V_4)/2$ $\%V_3 = (1 - \%V_1 - \%V_4)/2$
Westbound Right lane (% V_4)	$\%V_4 = \frac{1}{1+0.775\left(\frac{v_3}{v_4}\right)^{1.1}}$

Note: Definitions of variables are provided after Exhibit 22-20.

If the intersection where lane utilization is estimated has an additional leg, the analyst should not use the equations of this exhibit. The procedures of Chapter 18 should be used instead.

Definitions of variables used in Exhibit 22-20 through Exhibit 22-27 are as follows:

- $\%V_i$ = percent of traffic present in lane i, where 1 represents the leftmost lane, 12 represents the second lane from the left, and so forth;
- D = distance between the two intersections of the interchange (ft), and
- v_i = O-D demand flow rates for movement i (veh/h), as illustrated in Exhibit 22-21 for each interchange type.

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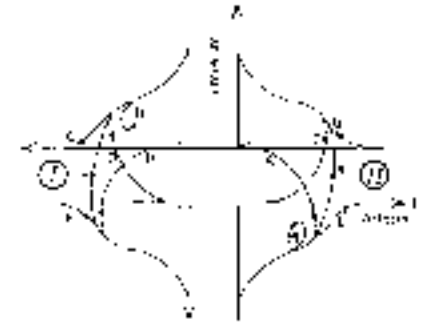
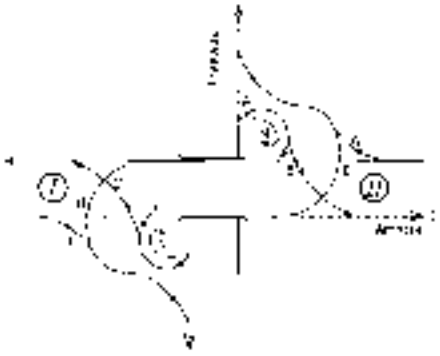
Exhibit 22-21
D-D Flows for Each Interchange Configuration

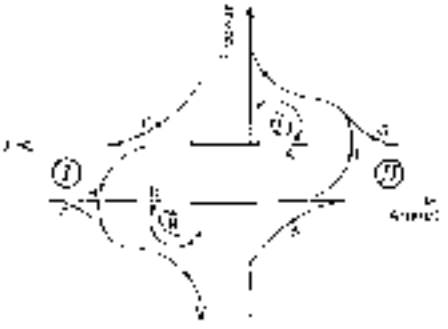


(a) Diamond Interchange

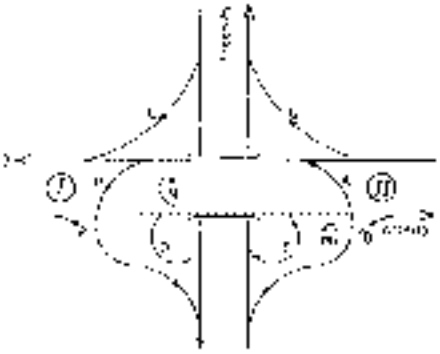
(b) Parclo A-2Q



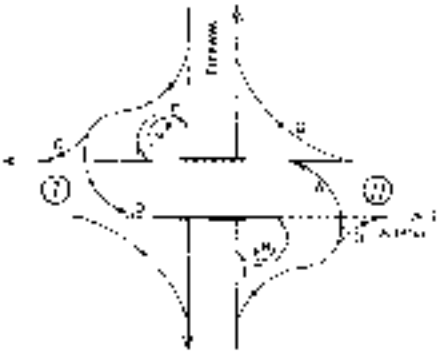
(c) Parclo B-2Q



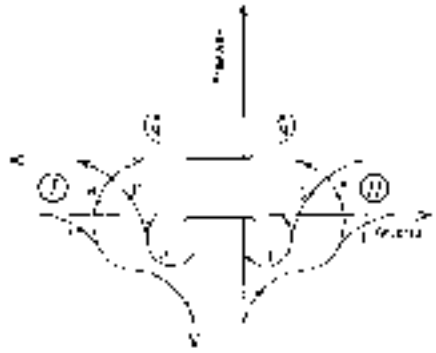
(d) Parclo B-4Q



(e) Parclo AB-4Q



(f) Parclo A-4Q



(g) Parclo AB-2Q

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Saturation Flow Rates

The saturation flow rate for each lane group can either be measured in the field or estimated with the following equation:

Equation 22-3

$$s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb} f_{LU} f_T$$

where

- s = adjusted saturation flow rate (vphpl),
- s_o = base saturation flow rate per lane (1,900 pc/h/ln),
- N = number of lanes in the lane group,
- f_w = adjustment factor for lane width (from Chapter 18),
- f_{HV} = adjustment factor for heavy-vehicle presence (from Chapter 18),
- f_g = adjustment factor for approach grade (from Chapter 18),
- f_p = adjustment factor for existence of a parking lane and parking activity adjacent to the lane group (from Chapter 18),
- f_{bb} = adjustment factor for local bus blockage (from Chapter 18),
- f_a = adjustment factor for the area type (from Chapter 18),
- f_{LU} = adjustment for right-turning vehicle presence in the lane group (from Chapter 18),
- f_{LT} = adjustment for left-turning vehicle presence in the lane group (from Chapter 18),
- f_{Lpb} = pedestrian adjustment factor for left turns (from Chapter 19),
- f_{Rpb} = pedestrian–bicycle adjustment factor for right turns (from Chapter 18),
- f_{LU} = adjustment factor for lane utilization (from Equation 22-2 and Exhibit 22-16 to Exhibit 22-20, as discussed in the previous section), and
- f_T = adjustment for traffic pressure (from Exhibit 22-22).

All factors in Equation 22-3 are obtained from Chapter 18, Signalized Intersections, except the last two. A third adjustment factor, f_R, which quantifies the effect of turn radius on the saturation flow rate of a left- or right-turn movement, is used to modify the adjustment factors for protected turn movements provided in Chapter 18. The lane utilization factor was discussed in the previous section, while the other two are discussed below.

Adjustment for Traffic Pressure

Saturation flow rates have generally been found to be higher during peak traffic demand periods than during off-peak periods (4). Traffic pressure reflects the display of aggressive driving behavior for a large number of drivers during high-demand traffic conditions. Under such conditions, a large number of drivers accept shorter headways during queue discharge than they would under different circumstances.

The effect of traffic pressure has been found to vary by traffic movement. The left-turn movements tend to be more affected by traffic pressure than through or right movements. To account for this phenomenon, the saturation flow rates at

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interchange approaches are adjusted by using the traffic pressure factor. This factor is computed with the following equation:

$$f_v = \begin{cases} \dfrac{1}{1.07 - 0.00672v_i} & \text{(left turn)} \\ \dfrac{1}{1.07 - 0.00486v_i} & \text{(through or right turn)} \end{cases}$$

Equation 22-4

where f_v is the adjustment factor for traffic pressure and v_i is demand flow rate per cycle per lane (veh/cycle/ln).

For values of v_i higher than 30 veh/cycle/ln, 30 veh/cycle/ln should be used, since the effects of demands higher than that value are not known.

Exhibit 22-22 tabulates the results of Equation 22-4 for various demands and for each turning movement type.

Exhibit 22-22
Adjustment Factor for Traffic Pressure (f_v)

Demand Flow Rate v_i (veh/cycle/ln)	Movement Type	
	Left Turn	Through and Right Turn
3.0	0.953	0.947
6.0	0.971	0.961
9.0	0.991	0.974
12.0	1.011	0.988
15.0	1.032	1.003
18.0	1.054	1.018
21.0	1.077	1.034
24.0	1.100	1.049

When the lane group is shared by several movements, the adjustment factor for traffic pressure is estimated as the weighted (on the basis of the respective flows) average of the respective movements.

Adjustment for Turn Radius Effects on Left- or Right-Turning Movements

Traffic movements that discharge along a curved travel path do so at rates lower than those of through movements (3). The turning radius has been found to have a unique effect on saturation flows for turning movements at interchanges (3). The adjustment factor to account for the effects of travel path radius, f_R, is calculated with the following equation:

$$f_R = \frac{1}{1 + \dfrac{5.61}{R}}$$

Equation 22-5

where R is the radius of curvature of the left- or right-turning path (at the center of the path), in feet.

The turning radius adjustment factor f_R is used to revise the adjustment factors for protected turn movements provided in Chapter 28. The revised left- and right-turn adjustment factors are as follows:

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For protected, exclusive left-turn lanes:

Equation 22-6

$$f_{LT} = f_R$$

For protected, shared left-turn lanes:

Equation 22-7

$$f_{LT} = \frac{1}{1 - P_{LT}\left(\frac{1}{f_R} - 1\right)}$$

For protected, exclusive right-turn lanes:

Equation 22-8

$$f_{RT} = f_R$$

For protected, shared right-turn lanes:

Equation 22-9

$$f_{RT} = \frac{1}{1 + P_{RT}\left(\frac{1}{f_R} - 1\right)}$$

Exhibit 22-23 tabulates the adjustment factor for turn radius for several radii.

Exhibit 22-23
Adjustment Factor for Turn Radius (f_R)

Radius of the Travel Path (ft)	Movement Type	
	Left and Right Turn	Through
25	0.917	1.00
50	0.959	1.00
100	0.947	1.00
150	0.964	1.00
200	0.973	1.00
250	0.978	1.00
300	0.982	1.00
350	0.984	1.00

When the lane group is shared by several movements, the adjustment factor for turn radii is estimated as the weighted (on the basis of the respective flows) average of the respective movements. The adjustment factors for permissive phasing are estimated by using the procedures of Chapter 18.

Additional Lost Time for the Upstream Approaches due to the Presence of a Downstream (Internal) Link Queue

The presence of a downstream queue may restrict or block the discharge of the upstream movements, increasing the amount of lost time for the upstream phases. In the analysis of interchange ramp terminals, the effects of the presence of a queue at the downstream link (through movement) are considered by estimating the amount of additional lost time experienced at the upstream intersection. The methodology takes into consideration the duration of common green times between various phases at the two intersections. In this chapter common green time between Phase A in Intersection I and Phase B in Intersection II is defined as the amount of time (in seconds) during which both phases have a green indication. Exhibit 22-24 provides an illustrative example of common green times between the upstream and downstream through phases (tG_{uu}) and between the upstream ramp and the downstream through phases (tG_{ru}).

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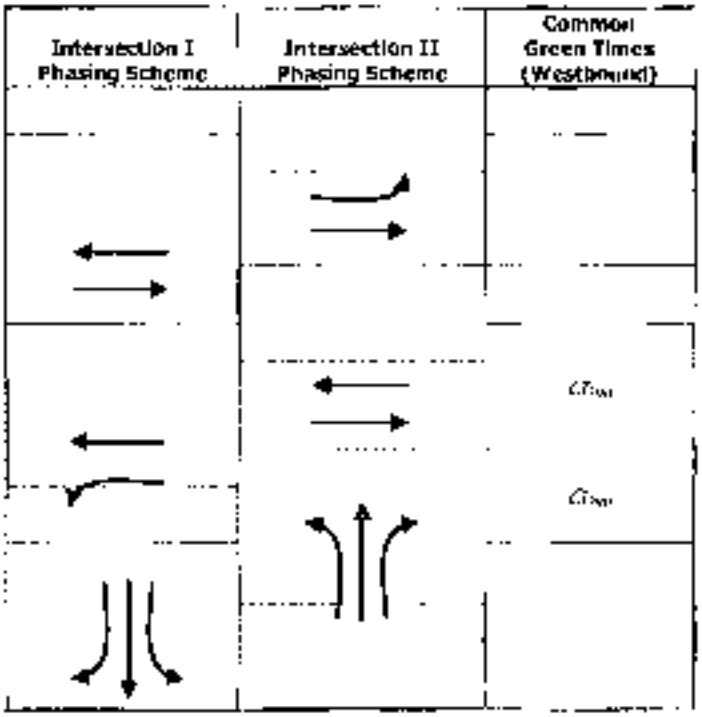

Exhibit 22-24
Illustration of Common Green Times

The additional lost time due to the presence of a downstream queue in the internal through movement is calculated for each of the upstream approaches with the following equations.

Additional lost time on the external arterial approach:

$$l_{p,a} = G_a - 0.106 \times DQ_a - 5.39 \times \frac{CG_{EW}}{C}$$

Equation 22-10

Additional lost time on the ramp approach:

$$l_{p,r} = G_r - 0.106 \times DQ_r - 5.39 \times \frac{CG_{EW}}{C}$$

Equation 22-11

where

$l_{p,a}$ = lost time on external arterial approach due to presence of downstream queue (s),

$l_{p,r}$ = lost time on external ramp approach due to presence of downstream queue (s),

G_a = green interval for external arterial approach (s),

G_r = green interval for left-turning ramp movement (s),

DQ_a = distance to downstream queue at beginning of upstream arterial green (ft),

DQ_r = distance to downstream queue at beginning of upstream ramp green (ft),

CG_{EW} = common green time between upstream and downstream arterial through green (s).

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CG_{ut} = common green time between upstream ramp green and downstream arterial through green (s), and

C = cycle length (s).

If Equation 22-10 or Equation 22-11 results in negative values, then the respective lost times $l_{1,y}$ or $l_{1,x}$ are zero. Furthermore, if DQ_A or DQ_B exceeds 200 ft, then the lost time will be zero.

DQ_A and DQ_B are calculated as follows:

Equation 22-12
$$DQ_A = D - Q_A$$

Equation 22-13
$$DQ_B = D - Q_B$$

where

D = distance corresponding to storage space between the two intersections of the interchange (ft),

Q_A = estimated average per lane queue length for through movement on downstream (internal) link at beginning of upstream arterial Phase A (ft), and

Q_B = estimated average per lane queue length for through movement on downstream (internal) link at beginning of upstream ramp Phase B (ft).

The downstream queue length (averaged across all through lanes) at the beginning of each upstream phase is calculated with the following equations.

Queue at the beginning of the upstream arterial Phase A:

Equation 22-14
$$Q_A = \left[0.0107 \frac{v_r}{N_r} - 7.96 \times \frac{G_{1r}}{C} - 0.0820 G_{ut} + 7.96 \frac{G_a}{C} \right] \times L_r$$

Queue at the beginning of the upstream ramp Phase B:

Equation 22-15
$$Q_B = \left[0.0107 \frac{v_a}{N_a} - 7.96 \times \frac{G_{1r}}{C} - 0.0820 G_{ut} + 7.96 \frac{G_a}{C} \right] \times L_r$$

where

Q_A = queue at the beginning of upstream arterial Phase A (ft),

Q_B = queue at the beginning of upstream ramp Phase B (ft),

v_r = ramp flow feeding subject queue (veh/h),

v_a = arterial flow feeding subject queue (veh/h),

N_r = number of ramp lanes feeding the subject queue,

N_a = number of arterial lanes feeding the subject queue,

G_{1r} = green interval for upstream left ramp movement (s),

G_a = green interval for upstream arterial through movement (s),

G_{2r} = green interval for downstream arterial through movement (s),

CG_{ut} = common green time between upstream arterial green and downstream through green (s),

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CG_{ds} = common green time between upstream ramp green and downstream through green (s);

l_s = average queue spacing in a stationary queue, measured from front bumper to front bumper between successive vehicles (ft/veh), and

C = cycle length (s).

The variables v_a, N_a, v_d, and N_d refer to the movement flows that feed the subject queue. For example, for the diamond interchange, v_a is the left-turning flow from the ramp, and the variable becomes $v_{left,a}$. For actuated signals, the analyst should first determine the equivalent protected signal timing plan on the basis of the average duration of each phase during the study hour and estimate the parameters described above on the basis of that plan.

If Q_a or Q_d is calculated to be less than zero, then the expected queue is zero, and no additional lost time due to the presence of a downstream queue will be experienced. Similarly, if the lost times L_a or L_{ds} are estimated to be negative, then the expected lost time will be zero for the respective approach. Conversely, if Q_a or Q_d exceeds the available storage, its value should be set equal to that storage, and the respective distance to the downstream queue, DQ_a or DQ_d, should be set to zero.

Additional Lost Time for the Downstream (Internal) Approaches due to Demand Starvation

This methodology accounts for the effects of demand starvation in interchange operations by computing the lost time experienced at the downstream intersection that results from demand starvation. Lost time due to demand starvation (L_{ds}) is defined as the amount of green time during which there is no queue present to be discharged from the internal link *and* there are no arrivals from either of the upstream approaches due to signalization. The common green time between two phases that may lead to demand starvation is called *common green time with demand starvation potential* (CG_{ds}). Exhibit 22-25 provides an illustrative example of an interval with demand starvation potential. In that example, there is potential for demand starvation for the westbound internal through movement of the interchange.

The following equation is used to estimate lost time due to demand starvation:

$$L_{ds} = CG_{ds} - Q_{storage} \times h_i \qquad \text{Equation 22-16}$$

where

L_{ds} = additional lost time due to demand starvation (s);

CG_{ds} = common green time with demand starvation potential (s);

h_i = saturation headway for internal through approach [= 3,600/saturation flow per lane] (s); and

$Q_{storage}$ = length of queue stored at internal approach at beginning of interval during which this approach has demand starvation potential, calculated from Equation 22-17.

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Equation 22-17

$$Q_{demand} = \left(\frac{v_{upstream\,L} \times C}{3{,}600 \times N_{upstream\,L}} - \frac{(CG_{up} - L)}{h_d}\right) + \left(\frac{v_{upstream\,T} \times C}{3{,}600 \times N_{upstream\,T}} - \frac{(CG_{up} - L)}{h_d}\right)$$

where

$v_{upstream\,L}$ = upstream ramp left-turning flow (veh),

$v_{upstream\,T}$ = upstream arterial through flow (veh),

C = cycle length (s),

$N_{upstream\,L}$ = number of lanes for upstream ramp left-turning movement,

$N_{upstream\,T}$ = number of lanes for upstream arterial through movement,

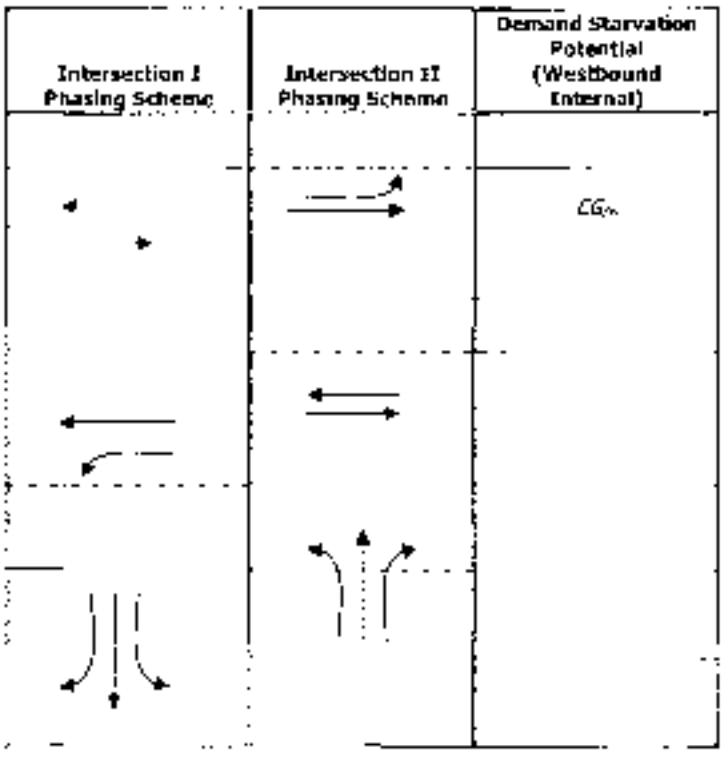
CG_{up} = common green time between upstream ramp and downstream through green phase (s),

CG_{up} = common green time between upstream through and downstream through green phase (s),

h_d = saturation headway for internal through approach (= 3,600/saturation flow per lane) (s), and

L = lost time per phase (s).

Exhibit 22-25
Illustration of Internal Link Demand Starvation Potential



Equation 22-16 calculates the amount of time that would not be used because the internal link queue has completely discharged and the upstream demand is blocked and cannot arrive to the internal link stop line. The initial queue at the beginning of the demand starvation interval is estimated as a function of the demands of the upstream approaches and of the respective common intervals between the upstream and downstream green.

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Equation 22-17 is valid for values of CG_{ex} and $CG_{in} > t_s$. If CG_{in} or $CG_{ex} < t_s$, the analyst should assume that CG_{ex} or $CG_{in} = t_s$. Also, in applying Equation 22-17 it is assumed that no vehicles will have to wait for more than one cycle (i.e., none of the approaches is oversaturated). If the time required to discharge the queue is equal to or larger than the CG_{ex}, the lost time due to demand starvation will be zero. The model for estimating lost time due to demand starvation assumes uniform arrivals and departures and assumes that operations at the interchange are not oversaturated.

Effective Green Adjustments

The effective green adjustment involves two components: (a) adjustment in the effective green of the upstream approaches due to the presence of a downstream queue and (b) adjustment in the effective green of the downstream (internal) approaches due to demand starvation.

The adjusted lost time t_L' for the arterial approaches and for the ramp approaches is estimated as follows:

Arterial approaches:

$$t_L' = t_L + t_{ex,q} + Y - e \quad \text{Equation 22-18}$$

Ramp approaches:

$$t_L' = t_L + t_{ex,q} + Y - e \quad \text{Equation 22-19}$$

where

t_L' = adjusted lost time (i.e., time when the signalized intersection is not used effectively by any movement) (s),

t_L = start-up lost time (s),

$t_{ex,q}$ = lost time on external arterial approach due to presence of a downstream queue (s),

$t_{r,q}$ = lost time on external ramp approach due to presence of a downstream queue (s),

Y = yellow-plus-all-red change and clearance intervals (s), and

e = extension of effective green time into the clearance interval (s).

The adjusted lost time t_L' for the internal approaches is estimated as follows:

$$t_L' = t_L + t_{in,s} - Y - e \quad \text{Equation 22-20}$$

where $t_{in,s}$ is the additional lost time due to demand starvation (s).

The effective green time adjusted due to the presence of a downstream queue is then calculated for the external approaches by using the following equation:

$$g' = G + Y - t_L' \quad \text{Equation 22-21}$$

where g' is the effective green time adjusted due to presence of a downstream queue (s), G is the green time (s), and t_L' is the adjusted lost time for external approaches (s).

Similarly, the effective green time adjusted due to demand starvation is calculated for the internal approaches as follows:

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Equation 22-22

$$g' = G - Y + t_l'$$

where g' is the effective green time adjusted due to demand starvation (s), G is the green time (s), and t_l' is the adjusted lost time for the internal approaches (s).

Closely Spaced Adjacent Intersections

The presence of closely spaced signalized intersections in the vicinity of an interchange may affect the operations of the entire interchange system and can present unique operational challenges. First, the lane utilizations of the arterial approaches would be affected by the presence of the interchange as vehicles position themselves to make a turn downstream or as they enter the arterial from the interchange. Queuing from the adjacent intersections could affect the discharge rate of the upstream (internal) link of the interchange. Furthermore, demand starvation in the internal link can coexist with queues upstream, at the external approaches of the interchange. If this external link is short, queue spillback may affect the adjacent intersections and have a significant and long-lasting impact throughout the interchange area. Generally, closely spaced signalized intersections whose traffic signals are poorly timed can create flow blockages on the next upstream link due to queue spillback, even during normally undersaturated conditions.

In the analysis of interchange ramp terminals, the effects of the presence of closely spaced intersections are considered by adjusting the lane utilizations of the intersections' arterial approaches, by estimating the amount of additional lost time experienced at the upstream intersection due to the presence of the downstream queue, and by estimating the additional lost time due to demand starvation.

The lane utilization factors for the through approaches of closely spaced intersections should be estimated by subtracting 0.03 from the lane utilization factors obtained from Exhibit 18-30. Research has shown that those lane utilization factors are generally lower than those at a typical intersection approach.

The additional lost times experienced at the approaches to closely spaced intersections are estimated as discussed in the previous section. A brief overview is provided here for convenience.

Additional lost time may be experienced at any of the upstream approaches to the closely spaced intersections. The additional lost time due to the presence of the downstream queue is calculated for each of the upstream approaches i by using the following equation:

Equation 22-23

$$L_{d,i} = G_i - 0.106 \times DQ_i - 5.39 \times \frac{CG_{q,i}}{C}$$

where

$L_{d,i}$ = lost time for upstream approach i due to presence of a downstream queue (s),

G_i = green interval for upstream approach i (s),

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DQ_i = distance to downstream queue at beginning of upstream green for approach i (ft), and

CG_{is} = common green time between upstream approach i and downstream through green (s).

The distance to the downstream queue at the beginning of the upstream green is calculated on the basis of the estimated average per lane queue length (in feet) for the through movement in the downstream link at the beginning of the respective upstream phase with Equation 22-12 through Equation 22-15.

When a significant portion of the traffic demand is held at the upstream adjacent intersection, demand starvation can occur on the external approaches to the interchange. The lost time caused by demand starvation on the external approaches to the interchange is estimated with the following equation:

$$t_{ds} = CG_{ds} - Q_{ini\_ds} \times h_i \quad \text{Equation 22-24}$$

where

t_{ds} = additional lost time due to demand starvation (s),

CG_{ds} = common green time with demand starvation potential (s),

h_i = saturation headway for through approach i (3,600/saturation flow per lane) (s), and

Q_{ini_ds} = initial queue length at beginning of interval with demand starvation potential.

When the operations of adjacent closely spaced intersections affect and are affected by operations at the interchange, the external and internal approaches of the interchange could experience both lost time due to a downstream queue and demand starvation. For example, the internal approach of a diamond interchange may experience lost time due to a downstream queue created at the downstream intersection, and at the same time may experience demand starvation. In these cases, the procedures of this chapter should not be applied; simulation or other alternative tools should be used instead.

LOS Determination

The determination of LOS for each O-D in the interchange involves the calculation of three performance measures: the queue storage ratio (R_s), the v/c ratios, and the average control delays. First, the queue storage ratios and v/c ratios for each lane group are estimated. If for any given lane group one or both of these variables exceed 1.0, then the LOS for every O-D that travels through this particular lane group will be F. Next, the average control delay for each lane group is estimated. Finally, the average control delay for each O-D is estimated as the sum of the control delays for each lane group through which the O-D travels.

Queue Storage Ratio Estimation

The procedure to estimate the queue storage ratio (R_s) is described in detail in Chapter 31, Signalized Intersections: Supplemental.

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v/c Ratio Estimation

For a given lane group *i*, X_i is computed with the following equation:

Equation 22-25

$$X_i = \frac{v_i}{s_i\left(\frac{g_i}{C}\right)} \quad v_i C \quad s_i g_i$$

where

X_i = (v/c) ratio for lane group *i*,

v_i = actual or projected demand flow rate for lane group *i* (veh/h),

s_i = saturation flow rate for lane group *i* (veh/h),

g_i = effective green time for lane group *i* (s), and

C = cycle length (s).

Note that the effective green time g_i should be replaced by the adjusted green time g_i' if there is additional lost time due to a downstream queue and by the adjusted green time g_i'' if there is lost time due to demand starvation.

Average Control Delay Estimation for Each O-D

The average control delay for each lane group and movement is estimated by using the procedures provided in Chapter 18, Signalized Intersections. The average control delay for each O-D is estimated as the total delay experienced by that O-D. If the O-D travels only through one intersection, then its average control delay is equal to the average control delay of the respective lane group. If the O-D travels through both intersections, then its average control delay is the sum of the delays experienced at each of the lane groups along its path.

Operations at the closely spaced intersections are generally assessed by using the procedures of Chapter 18. The additional lost time estimation, which is computed with the procedures of that chapter, is used to determine the adjusted effective green time for all affected approaches.

FINAL DESIGN AND OPERATIONAL ANALYSIS FOR INTERCHANGES WITH ROUNDABOUTS

Roundabouts are generally analyzed with the procedures of Chapter 21 of the HCM. This chapter provides guidance for translating O-D demands into movement demands at a roundabout to apply the procedures of Chapter 21.

Exhibit 22-26 defines the movements traveling through an interchange with two roundabouts, while Exhibit 22-27 lists the O-D demands contributing to each of these movements. For example, for diamond interchanges, O-D Movements G, H, and J constitute Movement 15 in Exhibit 22-26.

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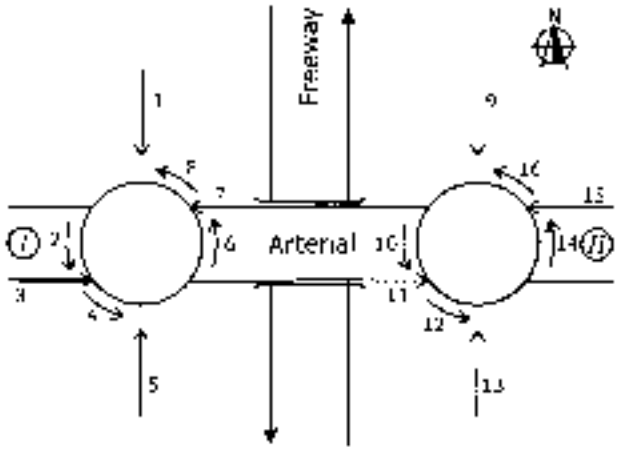

Exhibit 22-26
Illustration and Notation of O-D Demands at an Interchange with Roundabouts

Movement	Diamond	Parclo A-2Q	Parclo B-2Q	Parclo B-4Q
1	D, G, L, N	C, G, N	-	C
2	D, F, L, M, N	D, N	H, M, N	M, M
3	C, F, L	E, F	F, F, I	F, F, I
4	D, E, F, H, I, L, M, N	D, E, F, I, N	E, F, H, I, M	E, F, H, I, M
5	--	--	C	D, N
6		F	C	--
7	A, H, J, M	A, H, J, M	A, H, J, M	A, H, J, M
8	J, M	A, F, H, J, M	A, C, F, J, M	A, H, J, M
9		--	A, B, M	A, M
10	--	G	D	-
11	D, F, L, N	D, F, I, N	D, F, I, N	D, F, I, N
12	D, E, L, N	D, E, G, I, N	B, D, E	D, E, I, N
13	A, B, K, M	A, B, M	-	B
14	A, F, K, M, N	A, M	E, N	E, N
15	G, H, J	G, H, J	G, H, J	G, H, J
16	A, E, G, K, L, K, M, N	A, G, H, J, M	F, G, H, I, N	F, G, H, J, N
Movement	**SPUI**	**Parclo AB-4Q**	**Parclo A-4Q**	**Parclo AB-2Q**
1	C, D, L, N	C	C, D, N	--
2	D, M, L, M, N	F, M	D, N	F, M
3	E, F, L	E, F, I	E, F, J	E, F, I
4	D, F, L, N	F, F, H, I, M	D, F, F, I, N	F, F, H, I, M
5	A, B, K, M	D, N	--	C, D, N
6	A, E, K, M, N	--		C
7	G, H, J	A, H, J, M	A, H, J, M	A, H, J, M
8	A, H, J, M	A, H, J, M	A, H, J, M	A, C, H, J, M
9	-	--	-	-
10			--	G
11	--	D, L, I, N	D, E, J, N	D, E, I, N
12	--	D, F, I, N	D, F, I, N	D, F, G, I, N
13		A, B, M	A, B, M	A, B, M
14	--	A, M	A, M	A, M
15		G, H, J	G, H, J	G, H, J
16	--	A, G, H, J, M	A, G, H, J, M	A, G, H, J, M

Note: -- indicates movement is not allowed (or not likely) for a given interchange form.

Exhibit 22-27
Notation of O-D Demands at Interchanges with Roundabouts

In analyzing interchanges with roundabouts, Exhibit 22-26 and Exhibit 22-27 should be used to establish the roundabout movements. The procedures of Chapter 21 should then be applied to estimate the capacity and delay for each roundabout approach. Finally, Exhibit 22-13 should be used to determine the LOS for each O-D demand through the interchange.

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INTERCHANGES WITH UNSIGNALIZED INTERSECTIONS

Interchanges with unsignalized intersections cannot be evaluated with the procedures of this chapter, since research has not yet been done on the operation of two closely spaced unsignalized intersections. In the absence of research, the intersections of such interchanges can be analyzed individually with the procedures of Chapter 19, Two-Way STOP-Controlled Intersections, or Chapter 20, All-Way Stop-Controlled Intersections.

OPERATIONAL ANALYSIS FOR INTERCHANGE TYPE SELECTION

The operational analysis for interchange type selection can be used to evaluate the operational performance of various interchange types. It allows the user to compare eight fundamental types of interchanges for a given set of demand flows. The eight signalized interchange types covered by the interchange type selection analysis methodology are as follows:

1. SPUI,
2. Tight urban diamond interchange (TUDI),
3. Compressed urban diamond interchange (CUDI),
4. Conventional diamond interchange (CDI),
5. Parclo A—four quadrants (Parclo A-4Q),
6. Parclo A—two quadrants (Parclo A-2Q),
7. Parclo B—four quadrants (Parclo B-4Q), and
8. Parclo B—two quadrants (Parclo B-2Q).

Other types of signalized interchanges cannot be investigated with this interchange type selection analysis methodology. Also, the operational analysis methodology does not distinguish between the TUDI, CUDI, and CDI types. In general, the interchange type selection analysis methodology categorizes diamond interchanges by the distance between the centerlines of the ramp roadways that form the signalized intersections. This distance is generally between 200 and 400 ft for the TUDI, between 600 and 800 ft for the CUDI, and between 1,000 and 1,200 ft for the CDI.

The method is based on research (*4*). The research also provides a methodology for selecting unsignalized interchanges. Since unsignalized interchanges are not covered by this chapter, users should consult the original source for this information.

The methodology is based on the estimation of the sums of critical flow ratios through the interchange and then use to estimate interchange delay. A combination of simulation and field data was used in development of relationships for the methodology.

The sum of critical flow ratios is based on an identification of all flows served during a particular signal phase and the determination of maximum flow ratios among the movements served by that phase. The models are similar to those used in Chapter 18 for signalized intersections; they are modified to take into account the fact that each signal phase involves two signalized intersections. Interchange delay is defined as the total of all control delays experienced by all

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interchange movements involved in signalized ramp terminal movements divided by the sum of all external movement flows. Additional information is available in the source report (4).

Because signalization is not specified for an interchange type selection analysis, it is assumed that the following interchange types are operated by a single signal controller: SPUI, TUDI, and CUDI. All other types are assumed to be operated by separate controllers at each signalized ramp terminal. In all cases, optimal signal timing and phasing are assumed.

Inputs and Applications

This interchange type selection analysis methodology can be used in several ways:

1. For a given set of O-D interchange movements, eight basic types of signalized interchanges may be compared on the basis of intersection delay;
2. For a given type of interchange, the impact of intersection spacing on interchange delay can be examined (within the range of applicability for each interchange type); and
3. For a given type of interchange, the impact of the number of lanes on ramp and surface arterial approaches and the movements assigned to these lanes can be examined, again by using interchange delay as the measure of effectiveness.

For any of these applications, all interchange O-D movements must be specified, generally by using full peak hour volumes. The interchange type selection methodology is not detailed enough to use flow rates or to consider such factors as the presence of heavy vehicles.

In addition, for any given computation, it is necessary to specify the number of lanes assigned to each phase movement and to specify the distance between the centerlines of the two ramps, measured along the surface arterial.

Saturation Flow Rates

Implementation of the interchange type selection methodology requires the adoption of default values for saturation flow rate. Research (4) suggests the use of 1,900 veh/hg/ln for some basic cases. This is, however, based on a suggested base saturation flow rate of 2,000 pc/hg/ln, which is higher than the default values suggested in Chapter 18, Signalized Intersections. For consistency with the base saturation flow rate of 1,900 pc/hg/ln specified in Chapter 18, and to recognize the impact of various movements on saturation flow rate, it is recommended that the default values shown in Exhibit 22-28 be used in connection with the interchange type selection methodology. Alternatively, and if more relevant information is available, the default values provided in Chapter 18, Signalized Intersections (Exhibit 18-28), may be used.

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Exhibit 22-28
Default Values of Saturation Flow Rate for Use with the Operational Analysis for Interchange Type Selection

Interchange Type	Default Saturation Flow Rate (veh/hg/ln)		
	Left Turns	Through	Right Turns
SPUI	1,600	1,800	1,800
TUDI	1,700	1,800	1,800
CUDI	1,700	1,800	1,800
CDI	1,700	1,800	1,800
Parclo A-4Q	1,700	1,800	1,800
Parclo A-2Q	1,700	1,800	1,800
Parclo B-4Q	1,700	1,800	1,800
Parclo B-2Q	1,700	1,800	1,800

Where turning movements are in shared lanes, the "through" saturation flow rates should be used for analysis.

Step 1: Mapping O-D Flows into Interchange Movements

Since the primary objective of an interchange type selection analysis is to compare up to eight interchange types against a given set of design volumes, it is necessary first to convert a given set of design origin and destination volumes to movement flows through the signalized interchange. The methodology identifies volumes by signal phase by using the standard National Electrical Manufacturers Association (NEMA) numbering sequence for interchange phasing. Thus, movements are numbered 1 through 8 on the basis of their goal phase that accommodates the movement. Not all configurations and signalizations include all eight NEMA phases, and for some interchange forms some movements are not signalized and do not, therefore, contribute to interchange delay.

As for the operational analysis methodology, to simplify the mapping process, it is assumed that the freeway is oriented north-south and the surface arterial east-west. If the freeway is oriented in the east-west direction, rotate the interchange drawing or diagram clockwise until the freeway is in the north-south direction. In rotating clockwise, the westbound freeway direction becomes northbound and the eastbound freeway direction becomes southbound; the northbound arterial direction becomes eastbound and the southbound arterial direction becomes westbound. The methodology allows for separate consideration of freeway U-turn movements through the interchange. Thus, there are 14 basic movements that must be mapped for each interchange type.

For interchange types using two controllers, phase movements through the left (intersection I) and right (intersection II) intersections of the interchange are separately mapped and used in the procedure.

Exhibit 22-29 indicates the appropriate mapping of O-D demand volumes into phase movement volumes for the eight covered interchange types. The designation of the O-D demands is shown in Exhibit 22-21. The mapped phase movement volumes are then used in Step 2 to compute critical flow ratios.

Step 2: Computation of Critical Flow Ratios

The subsections that follow detail the computation of the critical flow ratio Y_c for the interchange for the eight basic configurations covered by this methodology.

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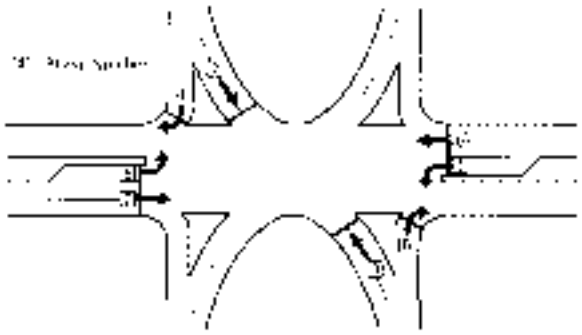
Interchange Type	NEMA Phase Movement Number							
	1	2	3	4	5	6	7	8
SPUI	H	I+F	A+M	C	K	J+G	D+N	B
TUDI/CUDI	K+M	E+I+F	--	D+C+N	E+N	H+J+G		A+M+B
CDI (I)	H+M	C+J+F	--	D+C+N	--	J+A	--	--
CDI (II)		I+J		--	E+N	H+J+G	--	A+M+B
Parclo A-4Q (I)	--	E+I	--	D+N+C	--	J+A+M+N		
Parclo A-4Q (II)	--	I+J+N+E	--	--	--	J+H	--	A+M+B
Parclo A-2Q (I)		E+I		D+N+C	F	J+A+H+M		
Parclo A-2Q (II)	G	I+J+E+N	--	--	--	M+J	--	A+M+B
Parclo B-4Q (I)	A+M	J+H+F			K	J+A		
Parclo B-4Q (II)	--	I+J	--	--	E+N	H+J+G	--	--
Parclo B-2Q (I)	K+M	K+H+F	--	--	--	I+A	--	C
Parclo B-2Q (II)	--	I+J	--	B	E+N	H+J+G		

Notes: -- indicates that a movement does not exist for this interchange configuration.
Bold indicates movements that change when only ramp terminal traffic control is changed.

Exhibit 22-29
Mapping of Interchange Origins and Destinations into Phase Movements for Operational Interchange Type Selection Analysis

Single-Point Urban Interchange

The phase movements in a SPUI are illustrated in Exhibit 22-30.



Source: Reprinted with permission from Traffic Control Systems Handbook (4).

Exhibit 22-30
Phase Movements in a SPUI

The sum of critical flow ratios is estimated as follows:

$$Y_c = A + R$$

$$A = \max\left[\left(\frac{v_1}{s_1 n_1}, \frac{v_2}{s_2 n_2}\right)\left(\frac{v_5}{s_5 n_5} + \frac{v_6}{s_6 n}\right)\right]$$

$$R = \max\left[\left(\frac{v_3}{s_3 n_3} - \frac{v_4}{s_4 n_4}\right)\left(\frac{v_7}{s_7 n_7}, \frac{v_8}{s_8 n_8}\right)\right]$$

Equation 22-26

where

Y_c = sum of the critical flow ratios,
v_i = phase movement volume for phase i (veh/h),
n_i = number of lanes serving phase movement i,
s_i = saturation flow rate for phase movement i (veh/h/ln),
A = critical flow ratio for the arterial movements, and
R = critical flow ratio for the external movements.

Tight Urban Diamond Interchange

Phase movements in a TUDI are illustrated in Exhibit 22-31.

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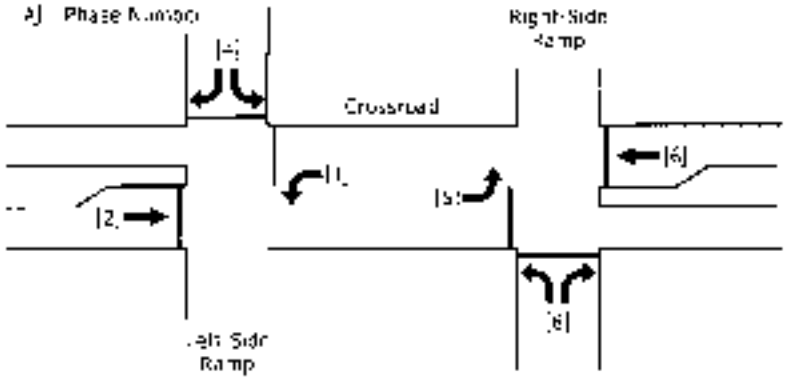
Exhibit 22-31
Phase Movements in a Tight Urban or Compressed Urban Diamond Interchange



Source: Reproduced at (4).

The sum of critical flow ratios is computed as follows:

$$Y_c = A + R$$

$$A = \max\left[\left(\frac{v_2}{s_2 n_2} + \frac{v_4}{s_4 n_4}\right) y_1 \;\middle|\; \left(\frac{v_5}{s_5 n_5} + y_2\right)\right]$$

$$R = \max\left[\left(\frac{v_1}{s_1 n_1} + y_1\right) \;\middle|\; \left(\frac{v_3}{s_3 n_3} + \frac{v_6}{s_6 n_6}\right) y_2\right]$$

$$y_1 = \min\left[\frac{v_4}{s_4 n_4}; y_1\right]$$

$$y_2 = \min\left[\frac{v_4}{s_5 n_5}; y_2\right]$$

Equation 22-27

where y_1 and y_2 are the effective flow ratios for concurrent (or transition) Phases 4 and 7, respectively; y_2 is the effective flow ratio for the concurrent phase when dictated by travel time, and other variables are as previously denoted.

For preliminary design applications, the default values of Exhibit 22-32 are recommended for y_2. The distance between the two intersections is measured from the centerline of the left ramp roadway to the centerline of the right ramp roadway.

Exhibit 22-32
Default Values for y_2

Distance Between Intersections D'	Default Value for y_2
200 ft	0.050
300 ft	0.070
400 ft	0.095

For Phase Movements 2 and 6, the number of assigned lanes (n_2 and n_6) is related to the arterial left-turn bay design. If the left-turn bay extends back to the external approach to the interchange, then the number of lanes on these external approaches is the total number of approaching lanes, including the left-turn bay. If the left-turn bay is provided only on the internal arterial link, n_2 or n_6 or both, would not include this lane.

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Compressed Urban Diamond Interchange

Exhibit 22-31 illustrates the phase movement volumes for a CUDI. They are the same as for a TUDI. The sum of critical flow ratios is computed as follows:

$$Y_c = A + R$$

$$A = \max\left[\left(\frac{v_1}{s_1 n_1} + y_2\right)\left(\frac{v_3}{s_3 n_3} + y_6\right)\right]$$

$$R = \max\left[\left(\frac{v_4}{s_4 n_4}\right)\left(\frac{v_5}{s_5 n_5}\right)\right]$$

$$y_2 = \max\left[\left(\frac{v_7}{s_7 n_7}\right)\left(\frac{v_8}{s_8}\right)\right]$$

$$y_6 = \max\left[\left(\frac{v_8}{s_8 n_8}\right)\left(\frac{v_3}{s_6}\right)\right]$$

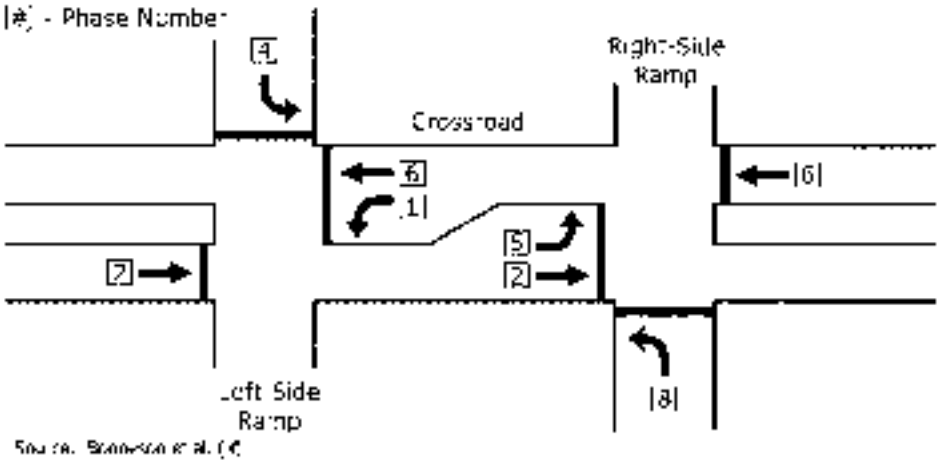
Equation 22-28

where y_2 and y_6 are the flow ratios for Phases 2 and 6, respectively, with consideration of prepositioning, and all other variables are as previously defined.

All Interchanges with Two Signalized Intersections and Separate Controllers

These interchange types include CDI, Parclo A-4Q, Parclo A-2Q, Parclo B-4Q, and Parclo B-2Q. The computation of the maximum sum of critical volumes is the same for each. Each has two signalized intersections, and each is generally operated with two controllers.

While the equations for estimating the maximum sum of critical volumes are the same, the phase movement volumes differ for each type of interchange, as was indicated in Exhibit 22-29. Exhibit 22-30 through Exhibit 22-35 illustrate the phase movements for each of these interchange types.



Source: Stanovich et al. (4)

Exhibit 22-33
Phase Movements in a CDI

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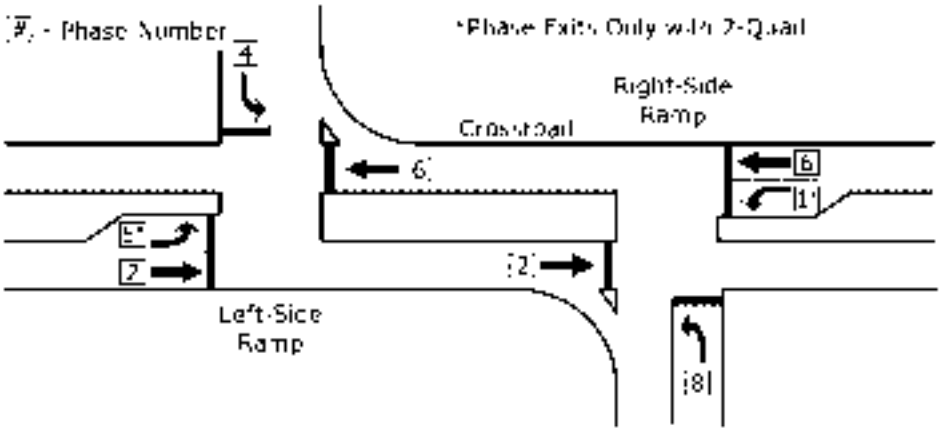
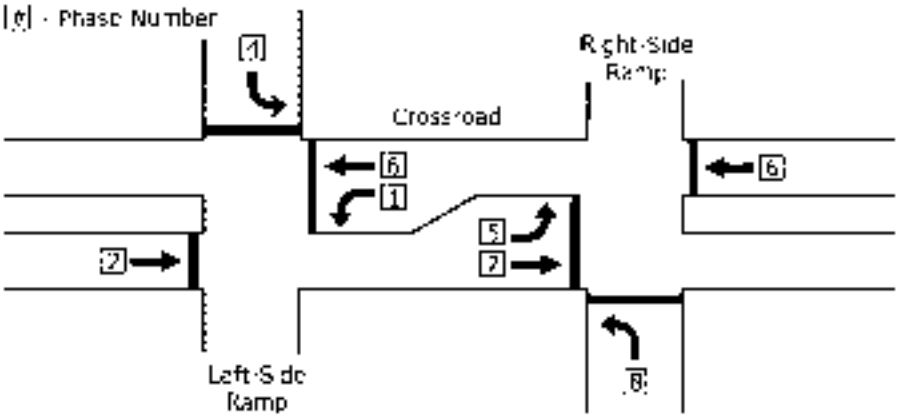
Exhibit 22-34
Phase Movements in Parclo A-2Q and A-4Q Interchanges



Source: Messer and Bonneson (9)

Exhibit 22-35
Phase Movements in Parclo B-2Q and B-4Q Interchanges



Source: Messer and Bonneson (9)

For all conventional diamond, Parclo A, and Parclo B interchanges, the sum of critical flow ratios is computed as follows:

$$Y_{sum} = \max[Y_{1,2}, Y_{3,4}]$$

$$Y_{1,2} = A_1 + R_1$$

$$Y_{3,4} = A_2 + R_2$$

Equation 22-29

$$A_{1,2} = \max\left[\left(\frac{v_1}{s_1 N_1}\right) + \left(\frac{v_2}{s_2 N_{2,1}}\right), \left(\frac{v_5}{s_5 N_5}\right) + \left(\frac{v_6}{s_6 N_6}\right)\right]$$

$$R_{1,2} = \max\left[\left(\frac{v_4}{s_4 N_4}\right), \left(\frac{v_8}{s_8 N_8}\right)\right]$$

where all variables are as previously defined.

Note that when values of A_1, A_2, R_1, and R_2 are computed, the movement volumes vary for the intersections I and II, even though the phase movement designations are the same (Exhibit 22-29).

Some of the phase movement volumes do not exist at either intersection I or II. A value of 0 is used for the volume in each case where this occurs.

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Step 3: Estimation of Interchange Delay

Interchange delay for each interchange type or design is estimated by using regression models that were developed primarily from simulation output but validated with a limited account of field data (4). In each case, two delay estimates are provided on the basis of the control of the off-ramp right-turn movements.

- Case A: Used where the right-turn movements from freeway off-ramps are controlled by the signal.
- Case B: Used where the right-turn movements from freeway off-ramps have a separate lane or lanes that are either free (uncontrolled) or controlled by a YIELD sign.

For SPUIs, a third condition is added. Where the right turns from the freeway ramps are controlled by a signal and right-turn-on-red is allowed, both cases are used, and the results are weighted on the proportions of right turns made during the red and green indications. Since the signal timing is unknown for an interchange type selection application, it is recommended that a 50%/50% split be assumed.

This modification, applied only to SPUIs, is necessary due to difficulties experienced in simulating right-turn-on-red at these interchanges.

Exhibit 22-36 gives the delay equations used to estimate interchange delay for the eight interchange types covered by the interchange type selection procedure. In each case, the variables used are defined as follows:

d = interchange delay (s/veh);

V_c = critical or controlling flow ratio from Step 1; and

D = distance between the two intersections, measured between the centerlines of the two ramp roadways along the surface arterial (ft).

Exhibit 22-36 also shows the ranges of D over which these equations are valid. They generally represent the normal design range for these interchange types. These equations should be used with great caution beyond these ranges.

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Exhibit 22-36
Estimation of Interchange Delay for Eight Basic Interchange Types

Interchange Type	Valid Range of D^{I} (ft)	Interchange Delay (d_I) CASE A: Right Turns Signalized	CASE B: Right Turns Free or Yield-Controlled
SPUI	150–400	[illegible]	[illegible]
TUDI	200–400	[illegible]	[illegible]
CUDI	600–800	[illegible]	[illegible]
CDI	900–1,300	[illegible]	[illegible]
Parclo A-4Q	700–1,000	[illegible]	[illegible]
Parclo A-2Q	700–1,000	[illegible]	[illegible]
Parclo B-4Q	1,000–1,420	[illegible]	[illegible]
Parclo B-2Q	1,000–1,420	[illegible]	[illegible]

Delay estimates can be related to LOS. For consistency, the same criteria as used for the operational analysis methodology (Exhibit 22-11) are applied. Because LOS F is based on a v/c ratio greater than 1.00 or a queue storage ratio greater than 1.00, this interchange type selection methodology will never predict LOS F, because it does not predict these ratios. Users should be accordingly cautious of results where interchange delay exceeds 85 to 90 s/veh.

In evaluating alternative interchange types, the exact distance, D^{I}, may not be known for each of the alternatives. It is recommended that all lengths be selected at the midpoint of the range shown in Exhibit 22-36 for this level of analysis.

Interpretation of Results

The output of the interchange type selection procedure for signalized interchanges is a set of delay predictions for (a) various interchange types, (b) various distances D^{I} between the two intersections, or (c) various numbers and assignments of lanes on ramps and the surface arterials.

While, in general, the lower the interchange delay the better, a final choice must consider a number of other criteria that are not part of this methodology, including the following:

- Availability of right of way,
- Environmental impacts,
- Social impacts,
- Construction cost, and
- Benefit–cost analyses.

This methodology provides valuable information that can be used, in conjunction with other analyses, in making an appropriate choice of an interchange type and some of the primary design parameters. The final design,

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however, will be based on any other criteria in addition to the output of this methodology.

Users are also cautioned that while the definition of interchange delay is similar for both the interchange type selection methodology and the operational analysis methodology, different modeling approaches to delay prediction were taken, and there is no guarantee that the results of the two methodologies will be consistent.

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3. APPLICATIONS

DEFAULT VALUES

Agencies that use the methodologies of this chapter are encouraged to develop a set of local default values based on measurements at interchanges in their jurisdiction. Local default values provide the best means of ensuring reasonable accuracy in the analysis results. In the absence of local default values, the values provided in Chapter 18, Signalized Intersections, can be used if appropriate.

TYPES OF ANALYSIS

There are two general types of analysis for signalized interchange ramp terminals: (a) final design and traffic operational analysis and (b) operational analysis for interchange type selection. Planning applications, as defined in other methodological chapters in the HCM, are not included in this chapter, because signal timing is a critical input in the procedure and is typically not known in the planning stages of a project.

In a final design and operational analysis the interchange configuration is given and detailed traffic control information is available. During the planning and preliminary design analysis stage, however, the engineer typically considers several configurations (e.g., SPUI, diamond), with limited input information available (for example, demand or no traffic control information). At that stage, the interchange type selection analysis should be used to determine which interchange configurations would be preferable from an operational perspective. These two general types of analyses have different objectives, different requirements, and different levels of required input, and each of them is defined and discussed below.

Final Design and Operational Analysis

Final design and operational analysis for signalized interchanges is to be conducted when the type of interchange is known. The objective is either to provide final design details for LOS or to assess the interchange and provide LOS and other performance measures. Two analysis types are distinguished: (a) design analysis (where the input is the desired LOS and the outputs are design element(s) and (b) operational analysis (where the input is complete design and the output is LOS).

Design analyses include highway design and signal design and are concerned with the physical, geometric, and signal control characteristics of the facility so that it operates at a desired LOS. For these types of analysis, the evaluation is conducted iteratively. The input data typically required for design analysis are fairly detailed and based substantially on design attributes that are being proposed. The objective of the interchange design analysis is to recommend geometric elements such as the number of lanes and storage bay length, or a signal control scheme, to maintain a given LOS. The principal inputs for design analysis are the design hourly volumes and the desired LOS for a given interchange configuration.

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The objective of operational analysis is to obtain the LOS of a facility under given traffic, design, and signal control conditions. As in design analysis, the operational analysis is conducted for a given interchange configuration, where the input data include the turning movement demands, number of lanes and their respective lengths and channelization, and traffic control information.

Operational Analysis for Interchange Type Selection

This type of analysis should be used when the type of interchange is not known yet and the engineer is interested in assessing the traffic operations of various alternatives. Detailed information is not known (e.g., signalization information, design details). The principal inputs for an interchange type selection analysis are O-D demands and a list of feasible configurations that can be tested according to site physical and right-of-way conditions. This type of analysis considers signalized interchanges but does not consider unsignalized interchanges or interchanges with roundabouts.

O-D and Turning Movements

Exhibit 22-37 through Exhibit 22-44 illustrate how O-D movements can be obtained from turning movements for each type of interchange considered in this methodology. Exhibit 22-45 through Exhibit 22-52 provide the corresponding calculations for obtaining turning movements from O-D movements.

Input					Output	
Approach	Intersection I Turning Movement	Volume (veh/h)	Intersection II Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	LT+LT RT EXT+TH		LT INT RT EXT+TH		A = (EB LT) + (NB LT) B = NB RT C = SB RT	
Westbound (WB)	LT EXT+RT INT TH		EXT+LT RT EXT TH		D = (EB LT) + (SB UT) E = (EB INT RT) + (SB UT) F = EB EXT LT	
Northbound (NB)	LT RT TH LT		LT RT TH LT		G = WB EXT-LT H = (WB EXT+RT) + (NB UT) I = (EB INT TH) + (SB LT) + (SB UT) J = (WB INT TH) + (NB LT) + (WB UT) K = [illegible] L = NB LT M = SB UT	
Southbound (SB)	LT RT TH LT		LT RT TH UT			

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
The move of the left U-turn vehicles from the freeway (EB LT and SB UT) are two types of left turning indicates movements that do not occur in this interchange form.

Exhibit 22-37
Worksheet for Obtaining O-D Movements from Turning Movements for Partial A-AQ Interchanges

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Exhibit 22-38
Worksheet for Obtaining O-D Movements from Turning Movements for Partial A-4Q Interchanges

Input					Output	
	Intersection I		Intersection II			
Approach	Turning Movement	Volume (veh/h)	Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	LT EXT-RT EXT-TH		LT EXT-RT EXT-TH		A = (NB LT) + (NB UT) B = NB RT C = SB RT	
Westbound (WB)	LT INT-RT INT-TH		LT EXT-RT EXT-TH		D = (SB LT) + (SB UT) E = (EB INT RT) + (NB UT) F = EB EXT-RT G = WB EXT-RT H = (WB INT-RT) + (NB LT) I = (EB INT TH) + (SB UT) + (SB LT) J = (WB INT-TH) + (SB LT) + (NB UT) K L M = NB UT N = SB LT	
Northbound (NB)	LT RT TH UT		LT RT TH UT			
Southbound (SB)	LT RT TH UT		LT RT TH UT			

Notes: LT = left turn, RT = right turn, UT = u-turn, TH = through, INT = internal, EXT = external.
The flows of the two U-turn movements from the freeway (SB UT and NB UT) are user-specified placeholder movements that do not occur in the interchange form.

Exhibit 22-39
Worksheet for Obtaining O-D Movements from Turning Movements for Partial A8-2Q Interchanges

Input					Output	
	Intersection I		Intersection II			
Approach	Turning Movement	Volume (veh/h)	Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	LT EXT-RT EXT-TH		LT INT-RT INT-TH		A = (NB LT) + (NB UT) B = NB RT C = NB TH D = (NB RT) + (NB UT) E = (EB INT RT) + (NB UT) F = EB EXT-RT G = NB EXT-LT H = (WB INT-LT) + (NB UT) I = (EB INT TH) + (NB TH) + (NB LT) J = (WB INT-TH) + (NB LT) + (SB UT) K L M = NB UT N = NB LT	
Westbound (WB)	INT-LT RT INT-TH		LT RT EXT-TH			
Northbound (NB)	LT RT TH UT		LT RT TH UT			
Southbound (SB)	LT RT TH UT		LT RT TH UT			

Notes: LT = left turn, RT = right turn, UT = u-turn, TH = through, INT = internal, EXT = external.
The flows of the two U-turn movements from the freeway (NB UT and NB LT) are user-specified placeholder movements that do not occur in the interchange form.

Exhibit 22-40
Worksheet for Obtaining O-D Movements from Turning Movements for Partial A8-4Q Interchanges

Input					Output	
	Intersection I		Intersection II			
Approach	Turning Movement	Volume (veh/h)	Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	LT EXT-RT EXT-TH		LT INT-RT INT-TH		A = (NB LT) + (NB UT) B = NB RT C = NB TH D = (NB RT) + (NB UT) E = (EB INT RT) + (NB UT) F = EB EXT-RT G = NB EXT-LT H = (WB INT-LT) + (NB UT) I = (EB INT TH) + (NB TH) + (NB LT) J = (WB INT-TH) + (NB LT) + (SB UT) K L M = NB UT N = NB LT	
Westbound (WB)	INT-LT RT INT-TH		LT EXT-RT EXT-TH			
Northbound (NB)	LT RT TH UT		LT RT TH UT			
Southbound (SB)	LT RT TH UT		LT RT TH UT			

Notes: LT = left turn, RT = right turn, UT = u-turn, TH = through, INT = internal, EXT = external.
The flows of the two U-turn movements from the freeway (NB UT and NB LT) are user-specified placeholder movements that do not occur in the interchange form.

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Input					Output	
	Intersection I		Intersection II			
Approach	Turning Movement	Volume (veh/h)	Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	LT EXT-RT EXT-TH		INT-LT RT EXT-TH		A = (SB RT) − (SB LT) B = SB LT C = NB LT	
Westbound (WB)	EXT-LT RT EXT-TH		LT EXT-RT EXT-TH		D = (NB RT) − (NB LT) E = (EB EXT-LT) − (NB LT) F = (EB EXT-RT)	
Northbound (NB)	LT RT TH UT		LT RT TH UT		G = (WB EXT-RT) H = (WB INT-LT) + (SB UT) I = (LB EXT-TH) + (NB RT) + (NB UT) J = (WB INT-TH) + (SB RT) + (SB UT) K L M = SB LT N = NB UT	
Southbound (SB)	LT RT TH UT		LT RT TH UT			

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
The flows of the two U-turn movements from the freeway (NB UT and SB UT) are user specified.
Shading indicates movements that do not occur in this interchange form.

Exhibit 22-41
Worksheet for Obtaining O-D Movements from Turning Movements for Partial Cloverleaf Interchanges

Input					Output	
	Intersection I		Intersection II			
Approach	Turning Movement	Volume (veh/h)	Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	LT EXT-RT EXT-TH		INT-LT RT EXT-TH		A = (SB RT) − (SB LT) B = NB RT − (SB LT) C = SB RT	
Westbound (WB)	EXT-LT RT EXT-TH		LT EXT-RT EXT-TH		D = (NB RT) − (NB LT) E = (EB EXT-LT) − (NB LT) F = EB EXT-RT	
Northbound (NB)	LT RT(I) TH UT		LT RT(I) TH UT		G = WB EXT-RT H = (WB INT-LT) − (SB UT) I = (EB EXT-TH) − (NB RT(I)) − (NB UT) J = (WB INT-TH) − (SB RT(I)) − (SB UT) K L M = SB UT N = NB UT	
Southbound (SB)	LT RT(I) TH UT		LT RT(I) TH UT			

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
The flows of the two U-turn movements from the freeway (NB UT and SB UT) are user specified.
Shading indicates movements that do not occur in this interchange form.

Exhibit 22-42
Worksheet for Obtaining O-D Movements from Turning Movements for Partial Cloverleaf Interchanges

Input					Output	
	Intersection I		Intersection II			
Approach	Turning Movement	Volume (veh/h)	Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	LT EXT-RT EXT-TH		INT-LT RT EXT-TH		A = (SB RT(I)) − (SB LT) B = NB RT(I) C = SB RT(I)	
Westbound (WB)	EXT-LT RT EXT-TH		LT EXT-RT EXT-TH		D = (NB RT(I)) − (NB LT) L = (EB EXT-LT) − (NB UT) F = EB EXT-RT	
Northbound (NB)	LT RT(I) TH UT		LT RT(I) TH UT		G = WB EXT-RT H = (WB INT-LT) − (SB UT) I = (EB EXT-TH) − (NB RT(I)) − (NB UT) J = (WB INT-TH) − (SB RT(I)) − (SB UT) K L M = SB UT N = NB UT	
Southbound (SB)	LT RT(I) TH UT		LT RT(I) TH UT			

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
The flows of the two U-turn movements from the freeway (NB UT and SB UT) are user specified.
Shading indicates movements that do not occur in this interchange form.

Exhibit 22-43
Worksheet for Obtaining O-D Movements from Turning Movements for Diamond Interchanges

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Exhibit 22-44
Worksheet for Obtaining O-D Movements from Turning Movements for SPUIs

Input			Output	
Approach	Turning Movement	Volume (veh/h)	O-D Movement Calculation	Volume (veh/h)
Eastbound (EB)	L		A = NB LT	
	RT		B = NB RT	
	TH		C = NB TH	
Westbound (WB)	LT		D = SB LT	
	RT		E = EB LT	
	TH		F = EB RT	
Northbound (NB)	LT		G = NB RT	
	RT		H = NB LT	
	TH		I = EB TH	
	UT		J = NB TH	
Southbound (SB)	LT		K = NB TH	
	RT		L = SB TH	
	TH		M	
	UT		N	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through.
The flow of the two U-turn movements from the freeway (NB UT and SB UT) is user specified.
Shading indicates movements that do not occur in this interchange form.

Exhibit 22-45
Worksheet for Obtaining Turning Movements from O-D Movements for Parclo A-2Q Interchanges

Input		Output				
O-D Movement	Volume (veh/h)	Approach	Intersection I Turning Movement Calculation	Intersection I Volume (veh/h)	Intersection II Turning Movement Calculation	Intersection II Volume (veh/h)
A		Eastbound (EB)	EXT-LT = F		LT	
B			RT		INT-RT = I+N	
C			EXT-TH = I+L		EXT-TH = I+P	
D		Westbound (WB)	LT		EXT-LT = G	
E			INT-RT = H+M		RT	
F			INT-TH = J+A		EXT-TH = J+H	
G		Northbound (NB)	LT		LT = A+M	
H			RT		RT = G	
I			TH		TH = B	
J			UT		UT = M	
K		Southbound (SB)	LT = D+N		LT = D+N	
L			RT = C		RT = C	
M			TH = E		TH = E	
N			UT = N		UT = N	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
Shading indicates movements that do not occur in this interchange form.

Exhibit 22-46
Worksheet for Obtaining Turning Movements from O-D Movements for Parclo A-4Q Interchanges

Input		Output				
O-D Movement	Volume (veh/h)	Approach	Intersection I Turning Movement Calculation	Intersection I Volume (veh/h)	Intersection II Turning Movement Calculation	Intersection II Volume (veh/h)
A		Eastbound (EB)	EXT-LT = F		LT	
B			RT		INT-RT = L+N	
C			EXT-TH = I+L		INT-TH = J+P	
D		Westbound (WB)	LT		EXT-LT = G	
E			INT-RT = H+M		RT	
F			INT-TH = J+A		EXT-TH = J+H	
G		Northbound (NB)	LT		LT = A+M	
H			RT		RT = B	
I			TH		TH = G	
J			UT		UT = M	
K		Southbound (SB)	LT = D+N		LT	
L			RT = C		RT	
M			TH		TH	
N			UT = N		UT	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
Shading indicates movements that do not occur in this interchange form.

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Input		Output					
O-D Movement	Volume (veh/h)	Approach	Intersection I Turning Movement Calculation	Volume (veh/h)	Intersection II Turning Movement Calculation	Volume (veh/h)
A		Eastbound (EB)	LT		LT	
B			EXT RT = I		INT RT = D–N	
C			EXT TH = J+L		INT TH = C+O	
D		Westbound (WB)	INT LT = H+M		EXT LT = G	
E			RT		RT	
F			INT TH = J+A		EXT TH = J+H	
G		Northbound (NB)	LT(I) = C		LT(II) = A+M	
H			RT(I) = D+N		RT(II) = B	
I			TH =		TH =	
J			LT(I) = B		LT(II) = M	
K		Southbound (SB)	LT		LT	
L			RT		RT	
M			TH		TH	
N			UT		UT	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
Shading indicates movements that do not occur at this interchange form.

Exhibit 22-47
Worksheet for Obtaining Turning Movements from O-D Movements for Parclo AB 2Q Interchanges

Input		Output					
O-D Movement	Volume (veh/h)	Approach	Intersection I Turning Movement Calculation	Volume (veh/h)	Intersection II Turning Movement Calculation	Volume (veh/h)
A		Eastbound (EB)	LT		LT	
B			EXT RT = I		INT RT = D–N	
C			EXT TH = J+L		INT TH = C+O	
D		Westbound (WB)	INT LT = H+M		EXT LT = G	
E			RT		RT	
F			INT TH = J+A		EXT TH = J+H	
G		Northbound (NB)	LT		LT(II) = A+M	
H			RT(I) = D+N		RT(II) = B	
I			TH		TH(II) = M	
J			LT(I) = B			
K		Southbound (SB)	LT		LT	
L			RT(I) = L		RT	
M			TH		TH	
N			UT		UT	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
Shading indicates movements that do not occur at this interchange form.

Exhibit 22-48
Worksheet for Obtaining Turning Movements from O-D Movements for Parclo AB-1Q Interchanges

Input		Output					
O-D Movement	Volume (veh/h)	Approach	Intersection I Turning Movement Calculation	Volume (veh/h)	Intersection II Turning Movement Calculation	Volume (veh/h)
A		Eastbound (EB)	T		RT	
B			EXT RT = I		INT-RT = D–N	
C			EXT TH = J+L		INT TH = C+O	
D		Westbound (WB)	INT LT = H+M		LT	
E			RT		EXT RT = G	
F			INT TH = J+A		EXT TH = J+H	
G		Northbound (NB)	LT = C		LT	
H			RT = D–N		RT	
I			TH		TH	
J			UT = B		UT	
K		Southbound (SB)	T		L = G	
L			RT		RT = A+M	
M			TH		TH	
N			U		UT = B	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
Shading indicates movements that do not occur at this interchange form.

Exhibit 22-49
Worksheet for Obtaining Turning Movements from O-D Movements for Parclo B-2Q Interchanges

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Exhibit 22-50
Worksheet for Obtaining Turning Movements from O-D Movements for Parclo B-4Q Interchanges

Input		Output				
O-D Movement	Volume (veh/h)	Approach	Intersection I Turning Movement Calculation	Intersection I Volume (veh/h)	Intersection II Turning Movement Calculation	Intersection II Volume (veh/h)
A		Eastbound (EB)	LT		INT-LT = L+N	
B			EXT-RT = C		RT	
C			EXT-TH = D+E		INT-TH = I+O	
D		Westbound (WB)	INT-LT = H+M		LT	
E			RT		EXT-RT = G	
F			INT-TH = J+A		EXT-TH = J+A	
G		Northbound (NB)	LT		LT	
H			RT(I) = O+N		RT(II) = B	
I			TH		TH	
J			LT = M		UT	
K		Southbound (SB)	LT		LT	
L			RT(I) = A		RT(II) = A+M	
M			TH		TH	
N			UT		UT = N	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external
Shading indicates movements that do not occur in this interchange form.

Exhibit 22-51
Worksheet for Obtaining Turning Movements from O-D Movements for Diamond Interchanges

Input		Output				
O-D Movement	Volume (veh/h)	Approach	Intersection I Turning Movement Calculation	Intersection I Volume (veh/h)	Intersection II Turning Movement Calculation	Intersection II Volume (veh/h)
A		Eastbound (EB)	LT		INT-LT = I+N	
B			EXT-RT = F		RT	
C			EXT-TH = I+O		INT-TH = I+D	
D		Westbound (WB)	INT-LT = H+M		LT	
F			RT		EXT-RT = G	
I			INT-TH = J+A		EXT-TH = J+H	
G		Northbound (NB)	LT		LT = A+M	
H			RT		TH = B	
J			TH		RT = K	
K			LT = N		UT = H	
L		Southbound (SB)	LT = M+A		LT	
M			RT = C		RT	
N			TH = I		TH	
			UT = N		LT = O	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external
Shading indicates movements that do not occur in this interchange form.

Exhibit 22-52
Worksheet for Obtaining Turning Movements from O-D Movements for SPUIs

Input		Output		
O-D Movement	Volume (veh/h)	Approach	Turning Movement Calculation	Volume (veh/h)
A		Eastbound (EB)	LT = F	
B			TH = I	
C			RT = I	
D		Westbound (WB)	LT = H	
F			TH = G	
I			RT = J	
G		Northbound (NB)	LT = A	
H			TH = B	
I			RT = K	
J			UT = M	
K		Southbound (SB)	LT = O	
L			RT = C	
M			TH = L	
N			UT = N	

Notes: LT = left turn, RT = right turn, UT = U-turn, TH = through, INT = internal, EXT = external.
Shading indicates movements that do not occur in this interchange form.

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USE OF ALTERNATIVE TOOLS

General guidance on alternative tools is provided in Chapters 6 and 7.

General guidance for the use of alternative traffic analysis tools for capacity and LOS analysis is provided in Chapter 6, HCM and Alternative Analysis Tools, and Chapter 7, Interpreting HCM and Alternative Tool Results. This section contains specific guidance for the application of alternative tools to the analysis of interchange ramp terminals. Chapter 34, Interchange Ramp Terminals, Supplemental, contains supplemental examples illustrating the use of alternative tools for interchange analysis. Additional information on this topic may be found in the Technical Reference Library in Volume 4.

As indicated in Chapter 6, traffic models may be classified in several ways (e.g., deterministic versus stochastic, macroscopic versus microscopic). The alternative tools used for interchange analysis are generally based on models that are microscopic and stochastic in nature. Therefore, the discussion in this section will be limited to microsimulation tools.

Strengths of the HCM Procedure

This chapter offers a comprehensive procedure for analyzing the performance of several types of interchanges. Simulation-based tools offer a more detailed treatment of the arrival and departure of individual vehicles and features of the signal control system, but for most purposes, the HCM procedure produces an acceptable approximation. The HCM procedure offers several advantages over the simulation approach:

- The HCM provides saturation flow rate adjustment factors based on extensive field studies.
- The HCM produces direct estimates of capacity and service volume. These measures are much more elusive to simulation.
- The HCM provides LOS by O-D, which facilitates the comparison of operational performance for different interchange configurations.
- It provides deterministic estimates of the measures of effectiveness, which is important for some purposes such as development impact reviews.
- Simulation tools use definitions of delay (and therefore LOS) different from those of the HCM, especially for movements that are oversaturated at some point during the analysis. Great care must therefore be taken in producing LOS estimates directly from simulation. Chapter 7 discusses simulation-based performance measures in more detail.

Identified Limitations of the HCM Procedure

The identified limitations of the HCM procedure for this chapter cover a number of conditions that are not evaluated explicitly, including the following:

- Oversaturated conditions, particularly cases when the downstream queue spills back into the upstream intersection for long periods of time,
- The impact of spillback on freeway operations (however, the method does estimate the expected queue storage ratio for the ramp approaches),
- Ramp metering and its resulting spillback of vehicles into the interchange, and

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- Impacts of the interchange operations on arterial operations and the extended surface street network;
- Lane utilization for interchanges with additional approaches that are not part of the prescribed interchange configuration; and
- Full freeway interchanges (freeway-to-freeway or system interchanges), since the scope of the chapter is limited to service interchanges (e.g., freeway-to-arterial interchanges).

If any of these conditions apply to a particular situation, then alternative tools that recognize them explicitly should be considered to supplement or replace the methodology described in this chapter.

Additional Features and Performance Measures Available From Alternative Tools

This chapter provides a methodology for estimating the capacity, control delay, queue storage ratio, and LOS associated with a given set of traffic, control, and design conditions at an interchange. As with most other procedural chapters in this manual, simulation outputs, especially graphics-based presentations, can provide details on problems at specific elements of the interchange that might otherwise go unnoticed with a macroscopic analysis. For example, problems associated with turn bay overflow or blockage of access to turn bays can be better observed by using microscopic simulation tools. Alternative tools offer additional performance measures such as number of stops, fuel consumption, and pollution. The animated graphics displays offered by many simulation tools are especially useful for observing network operations and identifying problems at specific elements.

Development of HCM-Compatible Performance Measures Using Alternative Tools

Simulation tools provide a wealth of information with regard to performance measures, including queue length, travel time, emissions, and so forth. However, simulation tools often have different definitions for each of these performance measures. General guidance on developing compatible performance measures based on the analysis of individual vehicle trajectories is provided in Chapter 7, with supplemental examples provided in Chapter 31, Concepts Supplemental. Chapter 18, Signalized Intersections, provides some specific guidance on performance measures for signalized approaches that also applies to this chapter. To obtain LOS for a specific O-D, the analyst will need to obtain the performance measures for the specific approaches using that particular O-D and aggregate them as indicated in the methodology section of this chapter.

Conceptual Differences Between the HCM and Simulation Modeling That Preclude Direct Comparison of Results

For interchanges, the definitions of delay and queuing are the most significant conceptual differences between the HCM and simulation modeling. Both are measures of effectiveness used to obtain LOS for each O-D, and simulated estimates of them would produce results inherently different from those obtained by the analytical method described in this chapter.

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Lane utilization is also treated differently. Simulation tools derive lane distributions and utilization implicitly from driver behavior modeling, while the deterministic model used in this chapter develops lane distributions from empirical models. Differences in the treatment of random arrivals are also an issue in the comparison of performance measures. This topic was discussed in detail in Chapter 18, and the same phenomena apply to this chapter.

In some cases, and when saturation flow rate is not an input, simulation tools do not explicitly account for differences between left turning, through, and right turning movements and all three have very similar saturation headway values. Thus, the left- and right-turn lane capacity would likely be overestimated in these types of tools.

Adjustment of Simulation Parameters to Match the HCM Parameters

Some adjustments will generally be required before an alternative tool can be used effectively to supplement or replace the procedures described in this chapter. For example, the parameters that determine the capacity of a signalized approach (e.g., steady-state headway and start-up lost time) should be adjusted to ensure that the simulated approach capacities match the HCM values.

One parameter outside to this chapter is the lane utilization on the approaches within the interchange. Driver behavior model parameters that affect lane choice should be examined closely and modified if necessary to produce better agreement with the lane distributions estimated by the procedures in this chapter.

Simulation tools do not produce explicit capacity estimates. The accepted method of determining the capacity of a signalized approach by simulation is to perform the simulation run(s) with a demand in excess of the computed capacity and use the throughput as an indication of capacity. Chapter 7 provides additional guidance on the determination of capacity in this manner. The Chapter 7 discussion points out the complexities that can arise when self-aggravating phenomena occur as the operation approaches capacity. Because of the interaction of traffic movements within an interchange, the potential for self-aggravating situations is especially high.

In complex situations, conceptual differences between the deterministic procedures in this chapter and those of simulation tools may exist such that the production of comparable capacity estimates is not possible. In such cases, the capacity differences should be noted.

Step-by-Step Recommendations for Applying Alternative Tools

General guidance on selecting and applying alternative tools is provided in Chapters 6 and 7. Chapter 18 provides recommendations specifically for signalized intersections that also apply to interchange ramp terminals.

One step that is specific to this chapter is the emulation of the traffic control hardware. Generally, simulation tools provide great flexibility in emulating actuated control, particularly in the type and location of detectors. In most cases, simulation tools attach a controller to each intersection (or node) in the network. This creates problems for some interchange operations in which a controller at

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one node must be connected to an approach to another node. A diamond interchange operating with one controller is an example of the complexities that can arise in the emulation of the traffic control scheme.

Some tools are able to accommodate complex schemes more flexibly than others. The ability to emulate the desired traffic control scheme is an important consideration in the selection of a tool for interchange analysis.

Sample Calculations Illustrating Alternative Tool Applications

Supplemental problems involving the use of alternative tools for signalized intersection analysis are presented in Chapter 34.

Example Problem 1 in this chapter involves a diamond interchange that offers the potential for illustrating the use of alternative tools. There are no limitations in this example that suggest the need for alternative tools. It is possible, however, to emulate situations in which alternative tools might be needed for a proper assessment of performance.

Chapter 34 includes supplemental examples that apply alternative tools to deal with conditions that are beyond the scope of the procedures presented in this chapter.

1. A two-way STOP-controlled intersection in close proximity to the diamond interchange and
2. Ramp metering on one of the freeway entrance ramps connected to the interchange.

In both cases, the demand volumes are varied to examine the oversaturation-aggravating effects on the operation of the facility.

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4. EXAMPLE PROBLEMS

INTRODUCTION

This part of the chapter describes the application of each of the final design, operational analysis for interchange type selection, and roundabouts analysis methods through the use of example problems. Exhibit 22-53 describes each of the three example problems included in this chapter and indicates the methodology applied. Additional example problems are provided in Chapter 34, Interchange Ramp Terminals: Supplemental.

Exhibit 22-53
Example Problem Descriptions

Problem Number	Description	Application
1	Find the control delay, queue storage ratio, and LOS of a diamond interchange.	Operational analysis
2	Find the control delay, queue storage ratio, and LOS of a Parclo A-2Q interchange.	Operational analysis
3	Compare eight types of signalized interchanges.	Operational analysis for interchange type selection

EXAMPLE PROBLEM 1: DIAMOND INTERCHANGE

The Interchange

The interchange of I-99 (northbound/southbound, N/SB) and University Drive (eastbound/westbound, E/WB) is a diamond interchange. Exhibit 22-54 provides the interchange volumes and channelization, while Exhibit 22-55 provides the signalization information.

Exhibit 22-54
Example Problem 1: Interchange Volumes and Channelization

Exhibit 22-55
Example Problem 1: Signalization Information

Phase	Intersection I			Intersection II		
	1	2	3	1	2	3
NEMA	Φ (4+8)	Φ (4+7)	Φ (2+5)	Φ (4+8)	Φ (1+6)	Φ (3+8)
Green time (s)	60	40	36	60	53	29
Yellow + all red (s)	5	5	5	5	5	5
Offset (s)		19			9	

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The Question

What are the control delay, queue storage ratio, and LOS for this interchange?

The Facts

There are no closely spaced intersections to this interchange, and it operates as a pretimed signal with no right-turns-on-red allowed. Travel path radii are 50 ft for all right-turning movements and 75 ft for all left-turning movements. Arrival Type 4 is assumed for all arterial movements and Arrival Type 3 for all other movements.

There are 5% heavy vehicles on both the external and internal through movements, and the peak hour factor (PHF) for the interchange is estimated to be 0.90. Start-up lost time and extension of effective green are both 2 s for all approaches. During the analysis period there is no parking and no buses, bicycles, or pedestrians utilize the interchange.

Outline of Solution

Calculation of O-Ds

O-Ds through this diamond interchange are calculated on the basis of Exhibit 22-21(a). Since all movements utilize the signal and no right-turns-on-red are allowed, O-Ds can be calculated directly from the turning movements at the two intersections. The results of these calculations and the resulting PHF-adjusted values are presented in Exhibit 22-56.

Exhibit 22-56
Example Problem 1: Adjusted O-D Table

O-D Movement	Demand (veh/h)	PHF-Adjusted Demand (veh/h)
A	210	233
B	204	227
C	156	173
D	185	206
E	96	107
F	80	89
G	135	150
H	212	236
I	685	761
J	585	650
K	0	0
L	0	0
M	0	0
N	0	0

Lane Utilization and Saturation Flow Rate Calculations

Both external approaches to this interchange consist of a two-lane shared right and through lane group. Use of the two-lane model of Exhibit 22-10 results in the predicted lane utilization percentages for the external through approaches that are presented in Exhibit 22-57.

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Approach	V_1	V_2	Maximum Lane Utilization	Lane Utilization Factor
Eastbound external	0.5056	0.4344	0.5056	0.3590
Westbound external	0.5161	0.4839	0.5161	0.3661

Exhibit 22-57
Example Problem 1: Lane Utilization Adjustment Calculations

Saturation flow rates are calculated on the basis of reductions to the base saturation flow rate of 1,900 pc/h/ln by using Equation 22-3. The lane utilization of the approaches external to the interchange is obtained as shown above in Exhibit 22-57. Traffic pressure is calculated by using Equation 22-4. The left- and right-turn adjustment factors are estimated by using Equation 22-6 through Equation 22-9. These equations use an adjustment factor for travel path radius calculated by Equation 22-5. The remaining adjustment factors are calculated as indicated in Chapter 18, Signalized Intersections. The estimated saturation flow rates for the eastbound approaches are shown in Exhibit 22-58.

Calculation of Common Green and Lost Time due to Downstream Queue and Demand Starvation

The duration of common green between various movements is calculated next. Exhibit 22-59 provides the beginning and end of each phase for the two intersections, as well as the calculations of common green between various movements at the two intersections.

	Eastbound Turning Movements		
	EXT-TH, EXT-RT	INT-TH	INT-LT
Base saturation flow (s_o, in pc/h/ln)	1,900	1,900	1,900
Number of lanes (N)	2	2	1
Lane width adjustment (f_w)	1.000	1.000	1.000
Heavy-vehicle adjustment (f_{HV})	0.952	0.952	1.000
Grade adjustment (f_g)	1.000	1.000	1.000
Parking adjustment (f_p)	1.000	1.000	1.000
Bus blockage adjustment (f_{bb})	1.000	1.000	1.000
Area type adjustment (f_a)	1.000	1.000	1.000
Lane utilization adjustment (f_{lu})	0.989	0.952	1.000
Left-turn adjustment (f_{LT})	1.000	1.000	0.950
Right-turn adjustment (f_{RT})	0.999	1.000	1.000
Left-turn pedestrian–bicycle adjustment (f_{Lpb})	1.000	1.000	1.000
Right-turn pedestrian–bicycle adjustment (f_{Rpb})	1.000	1.000	1.000
Turn radius adjustment for lane group (f_r)	0.991	1.000	0.970
Traffic pressure adjustment for lane group (f_t)	1.054	1.026	0.960
Adjusted saturation flow (s_i, in veh/h/ln)	3,708	3,568	1,703

Note: LT = left turn, RT = right turn, TH = through, INT = internal, EXT = external.

Exhibit 22-58
Example Problem 1: Calculation of Saturation Flow Rate for Eastbound Approaches

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Exhibit 22-59
Example Problem 1: Common Green Calculations

Phase	Intersection I Phase Begin	Intersection I Phase End	Intersection II Phase Begin	Intersection II Phase End
Phase 1	0	60	150	53
Phase 2	68	111	58	111
Phase 3	116	155	116	145

Movement	1st Green Time of Cycle Begin	1st Green Time of Cycle End	2nd Green Time of Cycle Begin	2nd Green Time of Cycle End	Overlap
EB EXT-TH	0	60			53
EB INT-TH	150	53	116	150	
WB EXT-TH	150	53			53
WB INT-TH	0	111			
SB RAMP	116	155			14
EB INT-TH	150	53	116	150	
NB RAMP	58	111			53
WB INT-TH	0	111			
WB INT-LT	58	111			0
EB INT-TH	150	53			
SB INT-LT	116	145			0
WB INT-TH	0	111			

Note: NB = northbound, SB = southbound, EB = eastbound, WB = westbound, LT = left turn, TH = through, INT = internal, EXT = external.

The next step involves the calculation of lost time due to downstream queues. First, the queue at the beginning of the upstream arterial phase and at the beginning of the upstream ramp phase must be calculated by using Equation 22-14 and Equation 22-15, respectively. These numbers are then subtracted from the internal link storage length to determine the storage available at the beginning of the respective upstream phase. Exhibit 22-60 presents the calculation of the downstream queues followed by the calculation of the respective lost time due to those downstream queues.

Exhibit 22-60
Example Problem 1: Calculation of Lost Time due to Downstream Queues

	EB EXT-TH	SB-LT	WB EXT-TH	NB-LT
v_i or v_d (veh/h)	206	986	210	686
N_{ui} or N_d	1	2	1	2
G_i or G_d (s)	39	83	53	83
G_p (s)	97	97	111	111
C (s)	160	160	160	160
CG_{ui} or CG_{ud} (s)	53	34	53	53
Queue length (Q_1 or Q_2) (ft)	0.0	4.1	0.0	0.0
G_i or G_d (s)	53	39	63	53
C (s)	160	160	160	160
Q_{ui} or Q_{ud} (ft)	500	496	500	500
CG_{ui} or CG_{ud} (s)	53	34	53	53
Additional lost time ($t_{L,ui}$ or $t_{L,ud}$) (s)	0.0	0.0	0.0	0.0
Total lost time t_L (s)	5.0	5.0	5.0	5.0
Effective green time g' (s)	63.0	39.0	63.0	53.0

Note: NB = northbound, SB = southbound, EB = eastbound, WB = westbound, LT = left turn, TH = through, EXT = external.

Calculation of lost time due to demand starvation begins by determining the queue storage length at the beginning of an interval with demand starvation potential by using Equation 22-17. The lost time due to demand starvation is then calculated by using Equation 22-16. The respective calculations are presented in Exhibit 22-61.

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	EB INT-TH	WB INT-TH
$v_{EB,T}$ (veh/h)	226	253
$v_{EB,R}$ (veh/h)	868	896
C (s)	150	150
$N_{EB,T}$	1	1
$N_{EB,R}$	2	2
$CS_{EB,T}$ (s)	34	55
$CS_{EB,R}$ (s)	53	53
v_o	0.02	0.04
$Q_{EB,T}$ (F)	0	0
$CS_{EB,T}$ (s)	0	0
$t_{EB,T}$ (s)	0	0
t_o (s)	5	5
Effective green time g^{EB} (s)	97	111

Note: EB = eastbound, WB = westbound, TH = through, INT = internal.

Exhibit 22-61
Example Problem 1: Calculation of Lost Time due to Demand Starvation

Queue Storage and Control Delay

The queue storage ratio is estimated as the ratio of the average maximum queue divided by the available queue storage by using Equation 31-91. Exhibit 22-62 presents the calculation of the queue storage ratio for all eastbound movements in Example Problem 1. Control delay for each movement is calculated according to Equation 18-47. Exhibit 22-63 provides the control delay for each eastbound movement of the interchange.

	EXT-TH, EXT-RT	INT-LT	INT-TH
Q_1 (F)	0.0	0.0	0.0
v (veh/h/n group)	967	107	567
s (veh/h/ln)	1850	1703	1784
g (s)	63	29	37
g/C	0.39	0.19	0.61
f	1.00	0.71	0.71
c (veh/h/n group)	1455	309	2163
$X = v/c$	0.66	0.35	0.45
c_a (veh/ft)	3.5	3.5	3.5
s_a (ft/s)	4.0	4.0	4.0
A_c (mi/h)	5	5	5
S_{ff} (mi/h)	40	40	40
S_a (mi/h)	39.96	39.96	39.96
D_a (s)	12.04	12.04	12.04
Re	1.000	1.333	1.333
n	0.49	0.79	0.61
r (s)	97	131	53
t_r (s)	0.01	0.00	0.00
n (veh/s)	0.27	0.03	0.27
n_r (veh/s)	0.27	0.04	0.30
n_r (veh-s)	0.27	0.03	0.14
Q (veh)	15.22	3.47	3.64
Q_1 (veh)	0.93	0.34	1.37
F	11.25	0.75	0.25
Q_2 (veh)	0.00	0.00	0.00
n_r	0	0	0
Q_3 (veh)	0.00	0.00	0.00
Q_4 (veh)	0.00	0.00	0.00
Q_5 (veh)	0.00	0.00	0.00
Q (veh)	16.15	3.65	3.88
l_1 (ft)	25.01	25.00	25.01
L_a (ft)	600	200	500
X_a	0.67	0.46	0.20

Note: LT = left turn, RT = right turn, TH = through, INT = internal, EXT = external.

Exhibit 22-62
Example Problem 1: Queue Storage Ratio Calculations for Eastbound Movements

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Exhibit 22-63
Example Problem 1: Calculation of Control Delay for Eastbound Movements

	EXT-TH, EXT-RT	INT-LT	INT-TH
g_i (s)	NA	29	97
g_i/C	0.20	0.48	0.61
c_i (veh/h)	1459	309	2152
$1 - g_i/C$	0.80	0.52	0.39
d_1 (s/veh)	39.6	52.3	7.3
k	0.5	0.5	0.5
d_2 (s/veh)	4.8	2.2	0.5
d_3 (s/veh)	0.0	0.0	0.0
k_{adj}	0.04	0.04	0.04
n	0	0	0
I	0	0	0
d_i (s/veh)	44.4	55.0	7.9

Note: LT = left turn, RT = right turn, TH = through, INT = inside, EXT = exterior, NA = not applicable.

Results

This section discusses the estimation of the delay experienced by each O-D movement and provides the resulting LOS. Delay for each O-D is estimated as a sum of the movement delays for each movement utilized by the O-D, as shown in Equation 22-1. Next, the v/c and queue storage ratios must be checked. If either of these parameters exceeds 1, the LOS for all O-Ds that utilize that movement will be F. Exhibit 22-64 presents a summary of the results for all O-D movements at this interchange. As shown, neither v/c nor R_p exceed 1, and all movements have LOS E or better. The LOS is determined by using Exhibit 22-11.

Exhibit 22-64
Example Problem 1: O-D Movement LOS

O-D Movement	Delay (s)	$v/c > 1$?	$R_p > 1$?	LOS
A	45.6	No	No	C
B	43.7	No	No	C
C	54.6	No	No	C
D	63.6	No	No	D
E	99.2	No	No	E
F	44.2	No	No	C
G	37.5	No	No	C
H	62.7	No	No	D
I	52.8	No	No	C
J	35.8	No	No	C

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EXAMPLE PROBLEM 2: PARCLO A-2Q INTERCHANGE

The Interchange

The interchange of I-75 (NB/SB) and Newberry Avenue (EB/WB) is a Parclo A-2Q interchange. Exhibit 22-65 provides the interchange volumes and channelization, while Exhibit 22-66 provides the signalization information.

Exhibit 22-65
Example Problem 2: Intersection Plan View

Phase	Intersection I			Intersection II		
	1	2	3	1	2	3
NEMA	Φ (3+8)	Φ (4+8)	Φ (2+5)	Φ (4+7)	Φ (1+6)	Φ (4+8)
Green time (s)	25	60	90	25	85	65
Yellow + all-red (s)	5	5	5	5	5	5
Offset (s)		0			0	

Exhibit 22-66
Example Problem 2: Signalization Information

The Question

What are the control delay, queue storage ratio, and LOS for this interchange?

The Facts

There are no closely spaced intersections to this interchange, and it operates as a pretimed signal with no right turns-on-red allowed. The eastbound and westbound left-turn radii are 80 ft, while all remaining turning movements have radii of 50 ft. The arrival type is assumed to be 4 for arterial movements and 3 for all other movements.

There are 10% heavy vehicles on both the external and internal through movements, and the PHF for the interchange is estimated to be 0.95. Start-up lost time is 3 s for all approaches, while the extension of effective green is 2 s for all approaches. During the analysis period there is no parking and no buses, bicycles, or pedestrians utilize the interchange.

Outline of Solution

Calculation of d-D

d-D's through this interchange are calculated on the basis of Exhibit 22-21(e). Since all movements utilize the signal and no right-turns-on-red are allowed,

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O-Ds can be calculated directly from the turning movements at the two intersections. The results of these calculations and the resulting PHF-adjusted values are presented in Exhibit 22-67.

Exhibit 22-67
Example Problem 7: Adjusted O-D Table

O-D Movement	Demand (veh/h)	PHF-Adjusted Demand (veh/h)
A	216	229
B	250	263
C	120	126
D	275	289
E	186	194
F	900	916
G	165	174
H	850	868
I	825	868
J	837	881
K	0	0
L	0	0
M	0	0
N	0	0

Lane Utilization and Saturation Flow Rate Calculations

The external approaches to this interchange consist of a three-lane through lane group for the external approaches. Use of the three-lane model from Exhibit 22-17 results in the prediction of lane utilization percentages for the external through approaches presented in exhibit 22-68.

Exhibit 22-68
Example Problem 7: Lane Utilization Adjustment Calculations

Approach	V_1	V_2	V_3	Maximum Lane Utilization	Lane Utilization Factor
Eastbound	0.2660	0.2791	0.4549	0.4549	0.7329
Westbound	0.2969	0.2472	0.5305	0.5305	0.6332

Saturation flow rates are calculated on the basis of reductions to the base saturation flow rate of 1,900 pc/h/ln by using equation 22-5. The lane utilization of the external approaches is obtained as shown above in Exhibit 22-68. Traffic pressure is calculated by using Equation 22-4. The left- and right-turn adjustment factors are estimated by using Equation 22-6 through Equation 22-9. These equations use an adjustment factor for travel path radius calculated by Equation 22-5. The remaining adjustment factors are calculated according to Chapter 18. The results of these calculations on the eastbound approaches are presented in Exhibit 22-69.

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	EXT-TH	EXT-LT	INT-TH, INT-RT
Base saturation flow (s_o, in pchg/ln)	1,900	1,900	1,900
Number of lanes (N)	2	1	3
Lane width adjustment (f_w)	1.000	1.000	1.000
Heavy vehicle adjustment (f_{hv})	0.909	1.000	0.909
Grade adjustment (f_g)	1.000	1.000	1.000
Parking adjustment (f_p)	1.000	1.000	1.000
Bus blockage adjustment (f_{bb})	1.000	1.000	1.000
Area type adjustment (f_a)	1.000	1.000	1.000
Lane utilization adjustment (f_{lu})	0.733	1.000	1.000
Left-turn adjustment (f_{lt})	1.000	0.914	1.000
Right-turn adjustment (f_{rt})	1.000	1.000	0.998
Left-turn pedestrian-bicycle adjustment (f_{lpb})	1.000	1.000	1.000
Right-turn pedestrian-bicycle adjustment (f_{rpb})	1.000	1.000	1.000
Turn radius adjustment for lane group (f_R)	1.000	0.934	0.985
Traffic pressure adjustment for lane group (f_t)	0.997	1.011	1.010
Adjusted saturation flow (s_i, in veh/hg/ln)	1,656	1,968	5,253

Note: LT = left turn, RT = right turn, TH = through, INT = interna, EXT = external.

Exhibit 22-69
Example Problem 2: Calculation of Saturation Flow Rates for Eastbound Approaches

Calculation of Common Green and Lost Time due to Downstream Queue

The duration of common green between various movements is calculated next. Exhibit 22-70 presents the beginning and ending of each phase at the two intersections and the calculations of common green between various movements at the two intersections.

Phase	Intersection I Phase Begin	Intersection I Phase End	Intersection II Phase Begin	Intersection II Phase End
Phase 1	0	25	0	25
Phase 2	30	90	30	65
Phase 3	95	135	70	135

Movement	1st Green Time of Cycle Begin	1st Green Time of Cycle End	2nd Green Time of Cycle Begin	2nd Green Time of Cycle End	Overlap
EB EXT-TH	0	90			20
EB INT-TH	70	135			
WB EXT-TH	0	25	70	135	20
WB INT-TH	30	90			
SB RAMP	95	135			40
EB INT TH	70	135			
NB RAMP	30	65			35
WB INT TH	30	90			

Note: NB = northbound, SB = southbound, EB = eastbound, WB = westbound, TH = through, INT = interna, EXT = external.

Exhibit 22-70
Example Problem 2: Common Green Calculations

The next step involves the calculation of lost time due to downstream queues. First, the queues at the beginning of the upstream arterial phase and at the beginning of the upstream ramp phase must be calculated by using Equation 22-14 and Equation 22-15, respectively. These numbers are then subtracted from the internal link storage length to determine the storage at the beginning of the respective upstream phase. Exhibit 22-71 presents the calculation of the downstream queues followed by the calculation of the respective lost times due to those downstream queues.

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Exhibit 22-71
Example Problem 2: Calculation of Lost Time due to Downstream Queues

	EB EXT-TH	SB-LT	WB EXT-TH	NB-LT
Lane V_o (veh/h)	289	1165	229	1249
N_o or N	1	3	1	3
G_o or G_s (s)	40	60	35	35
G_s (s)	65	65	60	60
C (s)	140	140	140	140
GG_o or GG_s (s)	20	40	20	35
Queue length (Q_4 or Q_5) (ft)	0.9	48.6	0.0	89.4
G_o or G_s (s)	50	40	35	35
C (s)	140	140	140	140
Q_{ps} or Q_{os} (ft)	700	750	800	700
GG_o or GG_s (s)	20	40	20	35
Additional lost time (l_{p1} or l_{p2}) (s)	0	0	0	0
Total lost time t_l (s)	6	6	6	6
Effective green time g' (s)	89	79	94	74

Note: NB = northbound, SB = southbound, EB = eastbound, WB = westbound, LT = left turn, TH = through, EXT = external.

Queue Storage and Control Delay

The queue storage ratio is estimated as the ratio of the average maximum queue divided by the available queue storage by using Equation 31-91. Exhibit 22-72 presents the calculations of queue storage for all eastbound movements. Control delay for each movement is calculated according to Equation 18-47. Exhibit 22-73 provides the control delay for each eastbound movement of this interchange.

Exhibit 22-72
Example Problem 2: Queue Storage Ratio Calculations for Eastbound Movements

	EXT-TH	EXT-LT	INT-TH, INT-RT
Q_{ra} (ft)	0.0	0.0	0.0
v (veh/h/ln group)	1066	316	1232
s (veh/h/ln)	1262	1738	1751
g' (s)	89	74	84
g/C	0.64	0.47	0.46
f	1.00	1.00	0.93
c (veh/h/ln group)	2407	808	2401
$X = v/c$	0.44	1.02	0.54
s_a (ft/s²)	3.5	3.5	3.5
a (ft/s²)	4.0	4.0	4.0
S_i (mi/h)	5	5	5
S_o (mi/h)	40	40	40
S_s (mi/h)	39.96	39.96	39.96
d_1 (s)	17.04	17.04	17.04
Rp	1.001	1.300	1.333
P	0.64	0.17	0.61
I (s)	51	216	76
t_c (s)	0.00	0.03	0.00
q (veh/s)	0.30	0.09	0.38
Q_1 (veh/s)	0.91	0.09	0.91
Q_2 (veh/s)	0.30	0.09	0.27
Q_1 (veh)	5.36	10.75	5.91
Q_2 (veh)	0.13	4.04	0.33
T	0.25	0.25	0.25
Q_{ra} (veh)	0.00	0.00	0.00
L	0	0	0
Q_3 (veh)	0.00	0.00	0.00
Q_4 (veh)	0.00	0.00	0.00
Q_5 (veh)	0.00	0.00	0.00
Q (veh)	5.49	15.99	7.24
d_2 (s)	25.02	25.02	25.02
d_3 (s)	800	200	800
R_q	0.17	1.96	0.23

Note: LT = left turn, RT = right turn, TH = through, INT = internal, EXT = external.

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	EXT-TH	INT-LT	INT-TH, INT-RT
c (s)	NA	24	64
g (s)	80	NA	NA
g/C or g/C	0.64	0.17	0.46
s (veh/h)	2407	406	2401
$X = v/C$	0.44	1.02	0.56
d_1 (s/veh)	12.9	58.0	18.01
k	0.5	0.5	0.5
d_2 (s/veh)	0.6	57.7	1.53
d_3 (s/veh)	0.0	0.0	0.0
d_{avg}	0.04	0.04	0.04
v	0	2	0
f	0	2	0
d (s/veh)	13.5	115.7	20.34

Note: LT = left turn, TH = through, RT = right turn, EXT = external, INT = internal, NA = not applicable

Exhibit 22-73
Example Problem 2: Control Delay for Eastbound Movements

Results

This section discusses the estimation of delay experienced by each O-D movement and provides the resulting LOS. Delay for each O-D is estimated as a sum of the movement delays for each movement utilized by the O-D, as shown in Equation 22-3. Next, the v/c and queue storage ratios are checked. If either of these parameters exceeds 1, the LOS for all O-Ds that utilize that movement will be F. Exhibit 22-74 presents the resulting delay, v/c, and R_Q for each O-D movement. As shown, O-D Movement F has a v/c and R_Q ratio greater than 1, resulting in a LOS of F.

O-D Movement	Delay (s)	$v/c > 1$?	$R_Q > 1$?	LOS
A	26.9	No	No	D
B	35.7	No	No	D
C	21.1	No	No	C
D	26.3	No	No	D
E	33.9	No	No	C
F	115.7	Yes	Yes	F
G	61.6	No	No	D
H	23.0	No	No	C
I	33.9	No	No	C
J	30.9	No	No	C

Exhibit 22-74
Example Problem 2: O-D Movement LOS

EXAMPLE PROBLEM 3: OPERATIONAL ANALYSIS FOR INTERCHANGE TYPE SELECTION

The Interchange

An interchange is to be built at the junction of I-83 (NB/SB) and Archer Road (EB/WB) in an urban area. The interchange type selection methodology is used.

The Question

Which interchange type is likely to operate better under the given demands?

The Facts

This interchange will have two-lane approaches with single left-turn lanes on the arterial approaches. Freeway ramps will consist of two-lane approaches with channelized right turns in addition to the main ramp lanes. Default saturation flow rates for use in the interchange type selection analysis are given in Exhibit 22-28. The O-Ds of traffic through this interchange are shown in Exhibit 22-73.

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Exhibit 22-75
Example Problem 3: O-D Demand Information for the Interchange

O-D Movement	Volume (veh/h)
A	400
B	300
C	400
D	550
E	150
F	200
G	225
H	195
I	600
J	800
K	2,500
L	3,200
M	0
N	10

Outline of Solution

Mapping O-D Flows into Interchange Movements

The primary objective of this example is to compare up to eight interchange types against a given set of design volumes. The first step is to convert these O-D flows into movement flows through the signalized interchange. The interchange type methodology uses the standard NEMA numbering sequence for interchange phasing, and Exhibit 22-29 demonstrates which O-Ds make up each NEMA phase at the eight interchange types. Exhibit 22-76 shows the corresponding volumes for this example on the basis of the O-Ds from Exhibit 22-75. Since this interchange has channelized right turns, Exhibit 22-77 shows only the NEMA phasing volumes utilizing the signals.

Exhibit 22-76
Example Problem 3: NEMA Flows (veh/h) for the Interchange

Interchange Type	NEMA Phase Movement Number							
	1	2	3	4	5	6	7	8
SPUI	185	800	400	400	150	1,025	550	350
Tight SPUI	185	850	--	900	160	1,210	-	750
CDI (I)	185	350	--	860	-	1,200	--	--
CDI (II)	--	1,150	--	--	160	1,210		750
Parclo A-4Q (I)	--	750	--	960	--	1,385	--	--
Parclo A-4Q (II)		1,310				865	--	750
Parclo A-2Q (I)	--	750	--	960	200	1,385	--	--
Parclo A-2Q (II)	225	1,410	--		--	985	--	750
Parclo B-4Q (I)	185	950	--	--	--	1,200		
Parclo B-4Q (II)	-	1,150	--	--	160	1,210	--	--
Parclo B-2Q (I)	185	950				1,200	--	400
Parclo B-2Q (II)	--	1,150	--	350	160	1,210		

Note: (I) and (II) indicate the intersections within the interchange type. -- indicates that the movement does not exist in the interchange type.

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Interchange Type	NEMA Phase Movement Number							
	1	2	3	4	5	6	7	8
SPUI	285	600	400	0	160	1,045	568	360
TUDI/CUDI	285	750	--	550	160	1,210	--	750
CDI (I)	185	750	--	550	--	1,700	--	--
CDI (II)		1,150		--	160	1,210		750
Parclo A-4Q (I)	--	750	--	550	--	1,385	--	--
Parclo A-4Q (II)	--	1,150	--	--	--	985	--	760
Parclo A-2Q (I)		750	--	550	200	1,385		
Parclo A-2Q (II)	225	1,150		--	--	985	--	760
Parclo B-4Q (I)	285	750	--		--	1,200	--	--
Parclo B-4Q (II)	--	1,150	--	--	160	1,210	--	--
Parclo B-2Q (I)	185	750	-	--	--	1,200	-	400
Parclo B-2Q (II)		1,150	--	550	160	1,210	--	--

Exhibit 22-77
Example Problem 3: NEMA Flows for the Interchange Without Channelized Right Turns

Computation of Critical Flow Ratios

Comparison between the eight intersection types begins with computation of the critical flow ratio at each interchange type. The first intersection type to be calculated is the SPUI by using Equation 22-26. On the basis of the default saturation flow rate for a SPUI and the values for the NEMA phases, Exhibit 22-78 shows the output from these calculations for a SPUI.

	Signalized Right Turns	Channelized Right Turns
Critical flow ratio for the arterial movements, *A*	0.388	0.306
Critical flow ratio for the ramp movements, *B*	0.350	0.156
Sum of critical flow ratios, *Y*	0.738	0.462

Exhibit 22-78
Example Problem 3: SPUI Critical Flow Ratio Calculations

The TUDI critical flow ratios are calculated by using Equation 22-27. Exhibit 22-79 shows these calculations for a 300-ft distance between the two TUDI intersections.

	Signalized Right Turns	Channelized Right Turns
Effective flow ratio for concurrent phase when dictated by travel time, *y*	0.070	0.070
Effective flow ratio for concurrent Phase 3, *y*	0.070	0.070
Effective flow ratio for concurrent Phase 7, *y*	0.070	0.070
Critical flow ratio for the arterial movements, *A*	0.491	0.294
Critical flow ratio for the ramp movements, *B*	0.479	0.315
Sum of critical flow ratios, *Y*	0.970	0.609

Exhibit 22-79
Example Problem 3: TUDI Critical Flow Ratio Calculations

The CUDI critical flow ratios are calculated by using Equation 22-28. Exhibit 22-80 shows these calculations for a CUDI with the given O-D flows.

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Exhibit 22-80
Example Problem 3: DDI Critical Flow Ratio Calculations

	Signalized Right Turns	Channelized Right Turns
Flow ratio for Phase 2 with consideration of proposition ng, y_2	0.264	0.208
Flow ratio for Phase 6 with consideration of proposition ng, y_6	0.209	0.208
Critical flow ratio for the arterial movements, A	0.474	0.337
Critical flow ratio for the ramp movements, R	0.207	0.156
Sum of critical flow ratios, K_i	0.640	0.486

The CDI, Parclo A-1Q, Parclo A-2Q, Parclo B-4Q, and Parclo B-2Q all use separate controllers. For these interchanges the critical flow ratios are calculated for each intersection, and then the maximum is taken for the overall interchange critical flow ratio. These numbers are all calculated by using Equations 22-29 and the default saturation flows. Exhibit 22-81 through Exhibit 22-85 show the calculations for these interchanges utilizing two controllers.

Exhibit 22-81
Example Problem 3: CDI Critical Flow Ratio Calculations

	Signalized Right Turns	Channelized Right Turns
Critical flow ratio for the arterial movements at Intersection 1, A_1	0.474	0.337
Critical flow ratio for the ramp movements at Intersection 1, R_1	0.202	0.165
Sum of critical flow ratios at Intersection 1, K_{i1}	0.655	0.486
Critical flow ratio for the arterial movements at Intersection 2, A_2	0.490	0.368
Critical flow ratio for the ramp movements at Intersection 2, R_2	0.221	0.118
Sum of critical flow ratios at Intersection 2, K_{i2}	0.651	0.486
Maximum sum of critical flow ratios, K_i	0.655	0.486

Exhibit 22-82
Example Problem 3: Parclo B-4Q Critical Flow Ratio Calculations

	Signalized Right Turns	Channelized Right Turns
Critical flow ratio for the arterial movements at Intersection 1, A_1	0.345	0.331
Critical flow ratio for the ramp movements at Intersection 1, R_1	0.282	0.282
Sum of critical flow ratios at Intersection 1, K_{i1}	0.657	0.615
Critical flow ratio for the arterial movements at Intersection 2, A_2	0.364	0.334
Critical flow ratio for the ramp movements at Intersection 2, R_2	0.208	0.111
Sum of critical flow ratios at Intersection 2, K_{i2}	0.572	0.444
Maximum sum of critical flow ratios, K_i	0.667	0.615

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Exhibit 22-83
Example Problem 3: Peak A.M.
Critical Flow Ratio Calculations

	Signalized Right Turns	Channelized Right Turns
Critical flow ratio for the arterial movements at Intersection I, A_I	0.500	0.451
Critical flow ratio for the ramp movements at Intersection I, R_I	0.282	0.165
Sum of critical flow ratios at Intersection I, Y_I	0.784	0.616
Critical flow ratio for the arterial movements at Intersection II, A_{II}	0.430	0.452
Critical flow ratio for the ramp movements at Intersection II, R_{II}	0.221	0.111
Sum of critical flow ratios at Intersection II, Y_{II}	0.651	0.563
Maximum sum of critical flow ratios, Y	0.784	0.616

Exhibit 22-84
Example Problem 3: Peak P.M.
Critical Flow Ratio Calculations

	Signalized Right Turns	Channelized Right Turns
Critical flow ratio for the arterial movements at Intersection I, A_I	0.373	0.333
Critical flow ratio for the ramp movements at Intersection I, R_I	0.000	0.000
Sum of critical flow ratios at Intersection I, Y_I	0.373	0.333
Critical flow ratio for the arterial movements at Intersection II, A_{II}	0.450	0.368
Critical flow ratio for the ramp movements at Intersection II, R_{II}	0.000	0.000
Sum of critical flow ratios at Intersection II, Y_{II}	0.450	0.368
Maximum sum of critical flow ratios, Y	0.450	0.368

Exhibit 22-85
Example Problem 4: Peak P.M.
Critical Flow Ratio Calculations

	Signalized Right Turns	Channelized Right Turns
Critical flow ratio for the arterial movements at Intersection I, A_I	0.373	0.333
Critical flow ratio for the ramp movements at Intersection I, R_I	0.111	0.111
Sum of critical flow ratios at Intersection I, Y_I	0.484	0.444
Critical flow ratio for the arterial movements at Intersection II, A_{II}	0.430	0.369
Critical flow ratio for the ramp movements at Intersection II, R_{II}	0.103	0.103
Sum of critical flow ratios at Intersection II, Y_{II}	0.533	0.471
Maximum sum of critical flow ratios, Y	0.535	0.471

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Estimation of Interchange Delay

Estimation of interchange delay is the final step when interchange types are compared. On the basis of the critical flow ratios calculated previously, Exhibit 22-76 can be used to calculate the delay at the eight interchange types. Exhibit 22-86 shows the solutions to these calculations.

Exhibit 22-86
Example Problem 2: Interchange Delay for the Eight Interchange Types

Intersection Type	Interchange Delay d_I (s) Right Turns Signalized	Interchange Delay d_I (s) Right Turns Free or YIELD-controlled
SPUI	60.9	22.0
TUDI	217.7	33.9
CUDI	35.9	27.4
CDI	26.6	21.9
Parclo A-4Q	26.2	21.6
Parclo A-2Q	47.4	29.8
Parclo B-4Q	31.9	15.3
Parclo B-2Q	30.7	29.2

Results

As demonstrated by exhibit 22-86, a Parclo B-4Q would be the best interchange type to select in terms of operational performance for the given O-D flows at this interchange. For the final interchange type selection, however, additional criteria should be considered, including those related to economic, environmental, and land use concerns.

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5. REFERENCES

Some of these references can be found in the Technical Reference Library in Volume 4

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3. Messer, C. J., and J. A. Bonneson. *Capacity of Interchange Ramp Terminals*. Final Report. National Cooperative Highway Research Program. Project 3-47. Texas A&M Research Foundation, College Station. April 1997.
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CHAPTER 23
OFF-STREET PEDESTRIAN AND BICYCLE FACILITIES

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1. INTRODUCTION

OVERVIEW

Off-street pedestrian and bicycle facilities are facilities that (a) are used only by nonmotorized modes and (b) are not considered part of an urban street or transit facility. The second part of this definition excludes facilities located directly along an urban street (e.g., bicycle lanes or sidewalks). In general, off-street facilities include those for which the characteristics of motor vehicle traffic do not play a strong role in determining the quality of service from the perspective of bicyclists and pedestrians. Thus, a shared-use path only 10 ft from a roadway but separated by a secure barrier may be considered an off-street facility, whereas a sidepath with a 10-ft planted buffer separating it from the roadway would generally be considered an on-street facility.

In general, facilities located within approximately 35 ft of an urban street are not considered off-street, although the precise definition of "off-street" varies by facility as described earlier. These types of pedestrian and bicycle facilities are covered in Chapter 16, Urban Street Facilities, and Chapter 17, Urban Street Segments. The definition also excludes crosswalks and queuing areas; these are addressed in each of the chapters on intersections (Chapters 15–21). Pedestrian components of transit facilities are addressed in the *Transit Capacity and Quality of Service Manual* (*1*). The 27-ft threshold is based on studies of pedestrian and bicycle facilities (*2–4*) in which it was found that motor vehicle traffic influenced pedestrian and bicycle quality of service on facilities located within at least this distance of the roadway.

Chapter 23, Off-Street Pedestrian and Bicycle Facilities, provides capacity and level-of-service (LOS) estimation procedures for the types of facilities shown below. Examples of each of the following facility types can be found in Chapter 3, Modal Characteristics:

- Walkways: paved paths, ramps, and plazas that are generally located more than 35 ft from an urban street as well as streets reserved for pedestrian traffic on a full- or part-time basis;
- Stairways: staircases that are part of a longer pedestrian facility;
- Shared-use paths: paths physically separated from highway traffic for the use of pedestrians, bicyclists, runners, inline skaters, and other users of nonmotorized modes; and
- Exclusive off-street bicycle paths: paths physically separated from highway traffic for the exclusive use of bicycles.

VOLUME 2: UNINTERRUPTED FLOW
16: Urban Street Facilities
17: Urban Street Segments
18: Signalized Intersections
19: TWSC Intersections
20: AWSC Intersections
21: Roundabouts
22: Interchange Ramp Terminals
23: Off-Street Pedestrian and Bicycle Facilities

Pedestrian capacity concepts are the same across facility types (i.e., exclusive off-street facilities, on-street facilities, and transit facilities). However, LOS thresholds for transit facilities allow higher levels of crowding for a given LOS than do the thresholds for nonmotorized facilities.

Off-street facilities are those generally located more than 35 ft from a roadway, although the exact distance may vary on the basis of the local context.

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ANALYSIS BOUNDARIES

The analysis of on-street pedestrian and bicycle facilities occurs at the segment level. A segment ends and a new segment begins when any of the following occur:

- There is a street crossing;
- The width of the facility changes significantly;
- There is an intersection with another exclusive pedestrian or bicycle facility, where user volumes change significantly or cross flows are created; or
- The type of facility changes (e.g., where a walkway becomes a stairway).

LOS CRITERIA

The LOS thresholds defined for each of the on-street pedestrian and bicycle facilities are presented in this section. Three types of service measures are defined:

- For pedestrians on exclusive pedestrian facilities, *pedestrian space* (square feet per pedestrian);
- For pedestrians on facilities shared by pedestrians and bicycles, the number of *bicycle meetings and passing events per hour*; and
- For bicycles on both shared-use and exclusive paths, a *bicycle* LOS score incorporating meetings per minute, active passings per minute, presence of a centerline, path width, and delayed passings.

Exhibit 23-1 through Exhibit 23-5 provide five LOS tables: four for pedestrian facilities and one for bicycle facilities. As described in Chapter 1, Traffic Flow and Capacity Concepts, pedestrian flow rates and speeds are directly related to the average space occupied by a pedestrian. These values are given for reference in the space-based LOS tables along with the corresponding range of volume-to-capacity (v/c) ratios; however, the actual LOS in those tables are based on space per pedestrian.

LOS does not reflect whether a facility complies with the ADA or other standards.

The LOS thresholds are based on user perception research where available and in other cases on expert judgment. LOS does not reflect whether a facility complies with the Americans with Disabilities Act (ADA) or other standards.

Walkways

The walkway LOS tables apply to paved pedestrian paths, pedestrian zones (exclusive pedestrian streets), walkways and ramps with up to a 5% grade, and pedestrian walking zones through plaza areas. Exhibit 23-1 applies when pedestrian flow along the facility is random. Exhibit 23-2 applies when platoons of pedestrians form along the facility, for example, when a signalized crosswalk is located at one end of the portion of the facility being analyzed.

Cross flows occur at the intersection of two approximately perpendicular pedestrian streams (e.g., where two walkways intersect or at a building entrance). Because of the increased number of conflicts that occur between pedestrians, walkway capacity is lower in a cross-flow situation than along other

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parts of the walkway. In cross-flow locations, the LOS F threshold is 13 ft²/p, as indicated in the notes for Exhibit 23-1 and Exhibit 23-2.

Exhibit 23-1
Average Flow LOS Criteria for Walkways

LOS	Average Space (ft²/p)	Related Measures: Flow Rate (p/min/ft)[a]	Related Measures: Average Speed (ft/s)	Related Measures: v/c Ratio[b]	Comments
A	>60	≤5	>4.25	≤0.21	Ability to move in desired path, no need to alter movements
B	>40–60	>5–7	>4.17–4.25	>0.21–0.31	Occasional need to adjust path to avoid conflicts
C	>24–40	>7–10	>4.00–4.17	>0.31–0.44	Frequent need to adjust path to avoid conflicts
D	>15–24	>10–15	>3.75–4.00	>0.44–0.64	Speed and ability to pass slower pedestrians restricted
E	>8–15	>15–23	>2.50–3.75	>0.65–1.00	Speed restricted, very limited ability to pass slower pedestrians
F	≤8[c]	Variable	≤2.50	Variable	Speeds severely restricted, frequent contact with other users

Notes: Exhibit 23-1 does not apply to walkways with steep grades (>5%). See the Special Cases section for further discussion.
[a] Pedestrians per minute per foot of walkway width.
[b] v/c ratio = flow rate/23.0; 23.0 is speed at average 4 ft²/p per pedestrian.
[c] In cross-flow situations, the LOS E–F threshold is 13 ft²/p.

Exhibit 23-2
Platoon-Adjusted LOS Criteria for Walkways

LOS	Average Space (ft²/p)	Related Measure: Flow Rate[a] (p/min/ft)[b]	Comments
A	>530	≤0.5	Ability to move in desired path, no need to alter movements
B	>90–530	>0.5–3	Occasional need to adjust path to avoid conflicts
C	>40–90	>3–5	Frequent need to adjust path to avoid conflicts
D	>24–40	>5–11	Speed and ability to pass slower pedestrians restricted
E	>11–22[c]	>11–18	Speed restricted, very limited ability to pass slower pedestrians
F	≤11[c]	>18	Speeds severely restricted, frequent contact with other users

Notes: [a] Rates in the table represent average flow rates over a 5-min period. Flow rate is linearly related to space; however, LOS is based on average space per pedestrian.
[b] Pedestrians per minute per foot of walkway width.
[c] In cross-flow situations, the LOS E–F threshold is 13 ft²/p.

Stairways

Exhibit 23-3 provides the LOS criteria for stairways.

Exhibit 23-3
LOS Criteria for Stairways

LOS	Average Space (ft²/p)	Related Measures: Flow Rate (p/min/ft)[a]	Related Measures: v/c Ratio[b]	Comments
A	>20	≤5	≤0.33	No need to alter movements
B	>17–20	>5–6	>0.33–0.41	Occasional need to adjust path to avoid conflicts
C	>12–17	>6–8	>0.41–0.53	Frequent need to adjust path to avoid conflicts
D	>9–12	>8–11	>0.53–0.73	Limited ability to pass slower pedestrians
E	>5–9	>11–15	>0.73–1.00	Very limited ability to pass slower pedestrians
F	≤5	Variable	Variable	Speeds severely restricted, frequent contact with other users

Notes: [a] Pedestrians per minute per foot of walkway width.
[b] v/c ratio = flow rate/15; LOS is based on average space per pedestrian.

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Pedestrians on Shared-Use Paths

Exhibit 23-4 shows LOS criteria for paths shared between pedestrians and bicycles.

Exhibit 23-4
Pedestrian LOS Criteria for Shared Use Paths

LOS	Weighted Event Rate/h	Related Measure Bicycle Service Flow Rate per Direction (bicycles/h)	Comments
A	≤36	≤28	Optimum conditions, conflicts with bicycles rare
B	>36–60	>28–44	Good conditions, few conflicts with bicycles
C	>60–103	>44–79	Difficult to walk two abreast
D	>103–144	>79–105	Frequent conflicts with cyclists
E	>144–180	>105–131	Conflicts with cyclists frequent and disruptive
F	>180	>131	Significant user conflicts, diminished experience

Notes: An "event" is a bicycle meeting or passing a pedestrian.
Bicycle service volumes are shown for reference and are based on a 50/50 directional split of events. LOS is based on number of events per hour and applies to any directional flow.

Exclusive and Shared Bicycle Facilities

Exhibit 23-5 provides LOS criteria for bicyclists on both shared-use and exclusive off-street paths.

Exhibit 23-5
LOS Criteria for Bicycles on Shared-Use and Exclusive Paths

LOS	Bicycle LOS Score	Comments
A	>4.0	Optimum conditions, ample ability to absorb more riders
B	>3.5–4.0	Good conditions, some ability to absorb more riders
C	>3.0–3.5	Meets current demand, marginal ability to absorb more riders
D	>2.5–3.0	Many conflicts, some reduction in bicycle travel speed
E	>2.0–2.5	Very crowded, with significantly reduced bicycle travel speed
F	≤2.0	Significant user conflicts and diminished experience

REQUIRED INPUT DATA

The input data required to perform an analysis differ depending on the type of facility and user being analyzed. Exhibit 23-6 shows the required input data for each of the facility types addressed in this chapter.

Exhibit 23-6
Required Input Data by Exclusive Pedestrian and Bicycle Facility Type

Pedestrian/Bicycle Facility	Required Input Data	Symbol
Walkways, stairways	Effective walkway width	W_E
	Peak 15-min pedestrian volume	$v_{p,15}$
	Directional hourly bicycle volumes	Q_i
Pedestrians on shared-use paths	Mean pedestrian speed	S_p
	Mean bicycle speed	S_b
	Directional hourly path volumes	Q_i
	Path mode split by user group	p_i
	Path peak hour factor	PHF
Bicycles on shared-use and exclusive paths	Mean and standard deviation of speed by user group	μ_i, σ_i
	Path width	W_t
	Presence of center line on path	CL
	Proportion of users blocking two lanes by user group (three- and four-lane paths only)	$P_{b,i}$

SCOPE OF THE METHODOLOGY

Methodologies are described here for evaluating the LOS of pedestrian and bicycle facilities that are separate from, and unaffected by, motor vehicle traffic. Other chapters in Volumes 2 and 3 provide methodologies for determining pedestrian and bicycle LOS on roadway system elements with motor vehicle traffic. The procedures may be applied in an approximate manner to pedestrian

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zones (exclusive pedestrian streets), plazas, and ramps with grades exceeding 5%, as described later in the Special Cases section.

The analysis methodologies are based solely on facility characteristics and do not consider external factors that may also affect quality of service, such as weather, landscaping, adjacent land uses, and lighting conditions, which may also affect users' perceptions of a facility.

Much of the material in this chapter is the result of research sponsored by the Federal Highway Administration (6, 7). Both commuter and recreational bicyclists were included in the off-street bicycle path research (7).

LIMITATIONS OF THE METHODOLOGY

In this chapter each of the facilities is treated from the point of view of pedestrians or bicyclists. Procedures for assessing the impact of pedestrians and bicyclists on other facility users (e.g., inline skaters) are not considered. Additional information on other users may be found elsewhere (*8*). The methodology does not address LOS for pedestrians with disabilities, including vision or mobility impairments. The reader is encouraged to consult material published by the United States Access Board to ensure compliance with the ADA.

The methodology does not address the impact of roadway crossings on the LOS of off-street paths.

The analysis methodologies presented here do not consider the continuity of walkways, sidewalks, and shared-use paths or contemplate the LOS. Facilities that are interrupted with frequent roadway crossings will provide lower capacities and travel speeds than facilities with long, uninterrupted stretches. In addition, roadway crossings, especially crossings of high-volume or high-speed facilities, may negatively affect the pedestrian and bicycle environment and user perceptions of quality of service. However, the methodologies described here only consider discrete, uninterrupted facilities and do not assess the impact of intersections with other facilities.

Pedestrian Facilities

The capacity of pedestrian facilities is based on research conducted on constrained facilities (e.g., bridges and underground passageways), where there is no opportunity for pedestrians to walk outside the designated area. Off-street pedestrian facilities, in contrast, typically have no barriers keeping pedestrians to the designated path. As a result, these facilities reach effective failure (i.e., pedestrian spillover) at densities less than their capacity. For this reason, in combination with considerations of general pedestrian comfort, off-street walkways are desirably designed to achieve LOS C or better, based on pedestrian space, rather than for capacity conditions. The methodologies are generally appropriate regardless of the type of surface used for the pedestrian facility.

When the pedestrian width, pedestrian and speed are outside the ranges of a walkway, consider other aspects.

Exclusive Bicycle Facilities

The methodology for exclusive bicycle facilities is based on research conducted only on paved surfaces and may not be applicable to surfaces such as gravel, dirt, or wood chips.

The exclusive bicycle facility methodology may not be applicable to facilities with soft surfaces.

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The pedestrian shared-use path methodology does not account for the effect of nonbicyclist users of the path on pedestrian LOS.

Shared-Use Paths

The methodology for shared-use paths does not account for the effect on pedestrian LOS of path width or the impact of meeting and passing events. No credible data were found on fixed objects and their effects on users of these types of facilities. The methodology also does not account for the effect of nonbicyclist users of the path (e.g., skateboarders, inline skaters) on pedestrians. However, it is expected that pedestrians will often encounter these users on shared-use paths and that because of their higher speeds, these users can have a negative effect on pedestrian LOS.

The methodology for bicycle LOS on shared-use paths incorporates the effects of five user groups: bicyclists, pedestrians, runners, inline skaters, and child bicyclists. However, several path user groups that may be a part of the mix on some trails are not incorporated, including push scooter users, wheelchair users, equestrians, cross-country skiers, and users of electric vehicles. The methodology is based on research conducted only on paved surfaces and may not be applicable to soft surfaces such as gravel, dirt, or wood chips. The methodology is not applicable for paths wider than 20 ft. This methodology was developed from data collected on two-way paths but may be applied to one-way paths by setting opposing volumes equal to zero.

Some shared-use paths are signed or striped, or both, to segregate pedestrian and bicycle traffic. The research that developed the shared-use path methodology did not address those kinds of paths; guidance on such paths may be found in the Special Cases section.

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2. METHODOLOGY

OVERVIEW

Off-street pedestrian and bicycle facilities serve only nonmotorized traffic and are separated from motor vehicle traffic to the extent that such traffic does not affect their quality of service. Thus, although sidewalks primarily serve only pedestrians, they are not addressed in this chapter—the quality of service afforded to pedestrians on sidewalks depends in part on the presence and characteristics of the adjacent motor vehicle traffic.

Sidewalk and bicycle facilities along urban streets are addressed in Chapter 17, Urban Street Segments.

Bicycle facilities on multiuse and one-lane roadways are addressed in Chapters 14 and 15, respectively.

Procedures for estimating LOS are separated into three main categories: exclusive pedestrian facilities, exclusive bicycle facilities, and shared pedestrian and bicycle facilities. Separate methodologies are presented to assess pedestrian and bicycle LOS on shared facilities.

There are three general categories of exclusive pedestrian facilities: walkways, cross-flow areas, and stairways. The LOS thresholds for each category are different, but all are based on the concept of space per pedestrian, which is a measure of pedestrian comfort and mobility. Exhibit 23-7 illustrates the steps taken to determine the LOS of exclusive off-street pedestrian facilities.

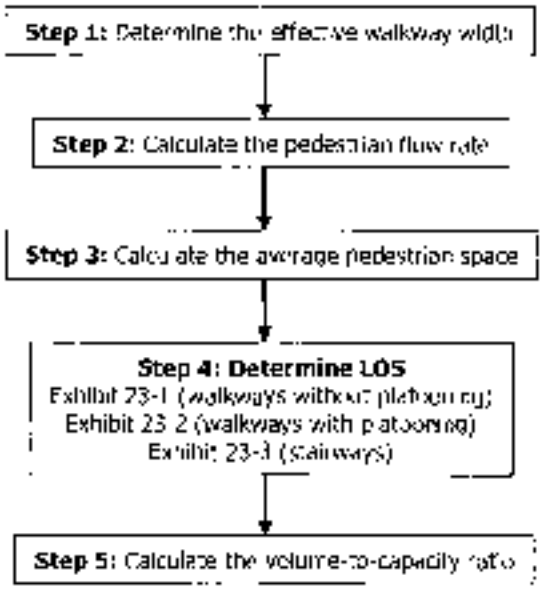

Exhibit 23-7
Flowchart for Analysis of Exclusive Off-Street Pedestrian Facilities

LOS for pedestrians on shared off-street bicycle and pedestrian facilities is based on the number of events during which a pedestrian either meets an oncoming bicyclist or is passed by a bicyclist. As the number of events increases, the pedestrian LOS decreases because of reduced comfort. Exhibit 23-8 shows the steps taken to determine shared-facility LOS.

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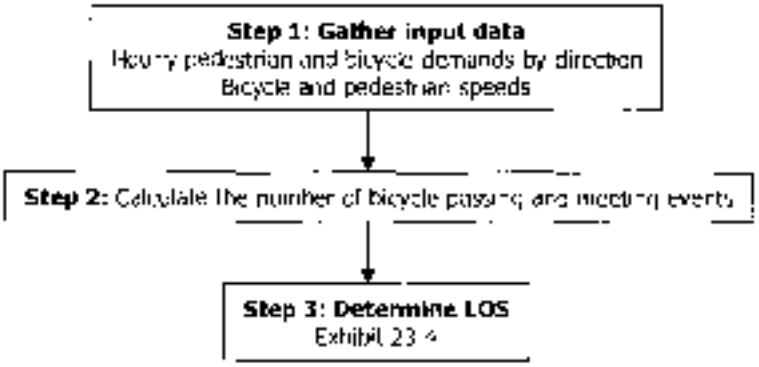
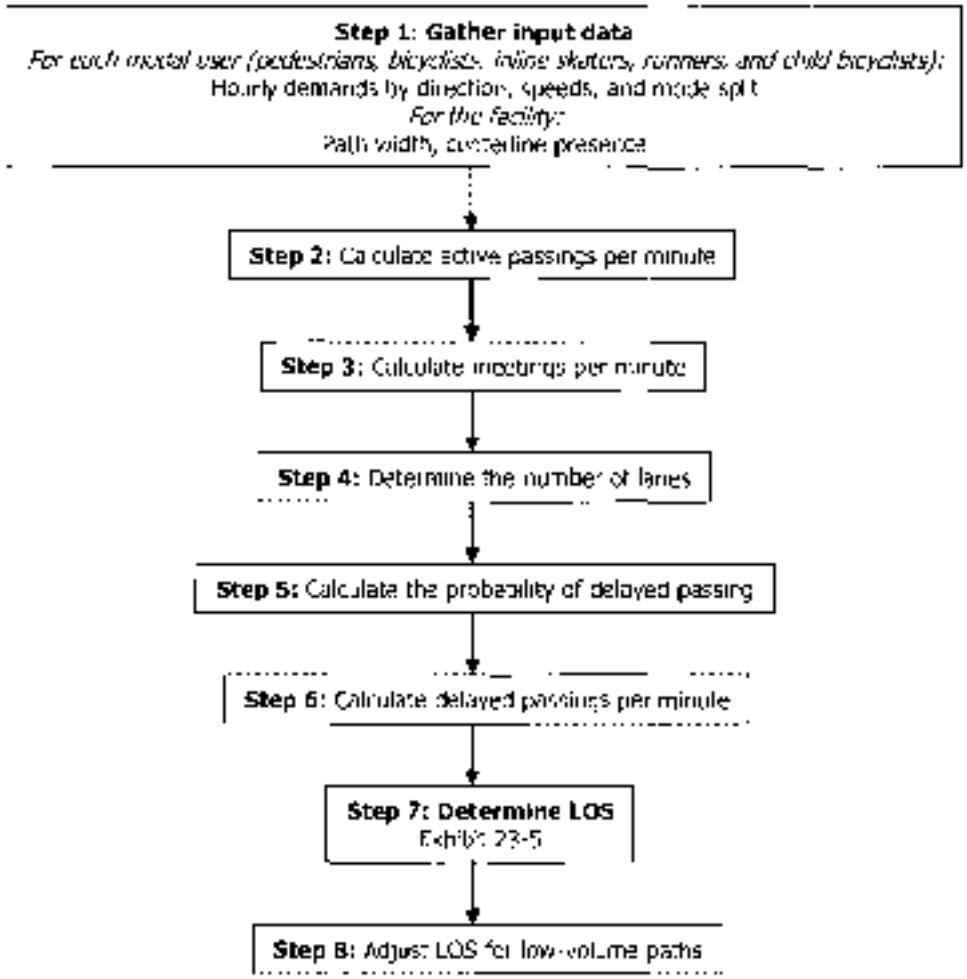
Exhibit 23-8
Flowchart for Analysis of Pedestrian LOS on Shared Off-Street Facilities



Bicycle LOS on exclusive and shared-use off-street bicycle facilities is based on user perceptions of how the LOS of shared-use paths changes according to several different factors. These factors are combined into a single bicycle LOS score. LOS thresholds relate to a specific range of LOS score values. Exhibit 23-9 shows the steps taken to determine the LOS of off-street bicycle facilities.

Exhibit 23-9
Flowchart for Analysis of Bicycle LOS on Off-Street Facilities



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EXCLUSIVE OFF-STREET PEDESTRIAN FACILITIES

Step 1: Determine Effective Walkway Width

Walkways and Cross-Flow Areas

Effective walkway width is the portion of a walkway that can be used effectively by pedestrians. Various types of obstructions and linear features, discussed below, reduce the walkway area that can be effectively used by pedestrians. The effective walkway width at a given point along the walkway is computed as follows:

$$W_E = W_T - W_O \quad \text{Equation 23-1}$$

where

W_E = effective walkway width (ft),

W_T = total walkway width at a given point along walkway (ft), and

W_O = sum of fixed-object effective widths and linear-feature shy distances at a given point along walkway (ft).

Exhibit 23-10 illustrates a portion of a sidewalk or walkway. The general concepts shown are applicable both to sidewalks along urban streets and to exclusive off-street paths not located adjacent to a street. Linear features such as the street curb, the low wall, and the building face each have associated shy distances. The *shy distance* is the buffer that pedestrians give themselves to avoid accidentally stepping off the curb, brushing against a building face, or getting too close to other pedestrians standing under awnings or window shopping. Fixed objects, such as the tree, have effective widths associated with them. The *fixed-object effective width* includes the object's physical width, any functionally unusable space (e.g., the space between a parking meter and the curb or the space in front of a bench occupied by people's legs and belongings), and the buffer given the object by pedestrians.

Shy distance is a buffer that pedestrians leave between themselves and linear objects along a walkway, such as curbs and building faces.

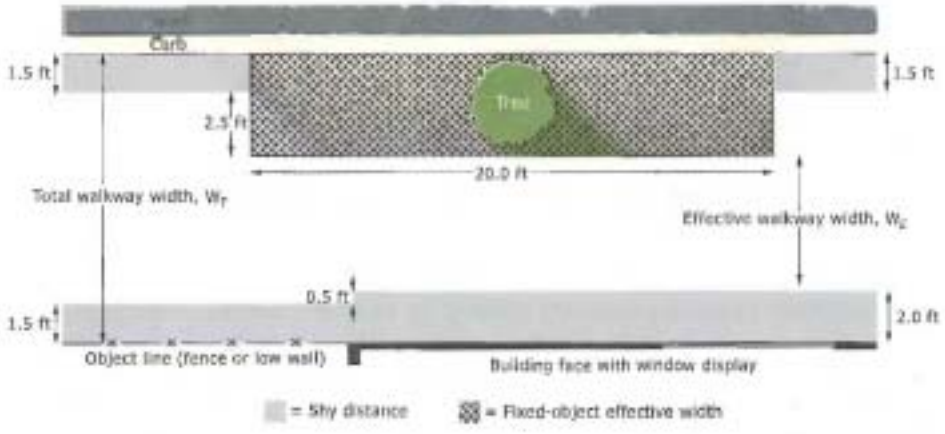

Exhibit 23-10
Width Adjustments for Fixed Obstacles

The concept of effective width applies to both on-street and off-street facilities. Because of the proximity of the street in Exhibit 23-10, the sidewalk here would be considered an on-street pedestrian facility.

The street is shown so that all factors that can influence the effective width of walkways can be depicted in one place.

Exhibit 23-10 also shows that the effective width of a fixed object extends over an effective length that is considerably longer than the object's physical length. The effective length represents the portion of the walkway that is functionally unusable because pedestrians need to move to one side ahead of

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time to get around a fixed object. The effective length of a fixed object is assumed to be five times the object's effective width.

Typically, a walkway operational analysis evaluates the portion of the walkway with the narrowest effective width, since this section forms the constraint on pedestrian flow. A design analysis identifies the minimum effective width that must be maintained along the length of the walkway to avoid pedestrian queuing or spillover.

Exhibit 23-11 gives the effective widths of a variety of typical fixed objects found along on- and off-street pedestrian facilities. The values in Exhibit 23-11 can be used when specific walkway configurations are not available.

Exhibit 23-11
Typical Fixed-Object Effective Widths

Fixed Object	Effective Width (ft)
Street Furniture	
Light pole	2.5–3.5
Traffic signal poles and boxes	3.0–4.0
Fire alarm boxes	2.5–3.5
Fire hydrants	2.5–3.0
Traffic signs	2.0–2.5
Parking meters	2.0
Mail boxes (1.7 ft x 1.7 ft)	3.2–3.7
Telephone booths (2.7 ft x 2.7 ft)	4.0
Trash cans (1.8 ft diameter)	3.0
Benches	5.0
Bus shelters (on sidewalk)	6.0–7.0
Public Underground Access	
Subway stairs	5.5–7.0
Subway ventilation gratings (raised)	6.0+
Transformer vault ventilation gratings (raised)	6.0+
Landscaping	
Trees	3.0–4.0
Planter boxes	5.0
Commercial Uses	
Newsstands	4.0–13.0
Vending stands	Variable
Advertising and store displays	Variable
Sidewalk cafés (two rows of tables)	7.0
Building Protrusions	
Columns	2.5–3.0
Stoops	2.0–6.0
Cellar doors	5.0–7.0
Standpipe connections	1.0
Awning poles	2.5
Truck docks (trucks protruding)	Variable
Garage entrance/exit	Variable
Driveways	Variable

Source: Pushkarev and Zupan (9).

See Exhibit 23-10 for shy distances associated with curbs and building faces.

Stairways

Pedestrians tend to walk in lines or lanes on stairways; thus, meaningful increases in capacity are related to the number of pedestrian lanes available.

A stairway's capacity is largely affected by its width. Unlike walking on a level surface, traversing stairs tends to make people walk in lines or lanes. The width of a stairway determines both the number of distinct lines that can traverse the stair and the side-to-side spacing between them, affecting both the ability of faster pedestrians to pass slower-moving pedestrians and the level of interference between adjacent lines of people. The consequence is that meaningful increases in capacity are not linearly proportional to the width but occur in increments of about 30 in. (1).

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On stairways (in contrast to walkways), a minor pedestrian flow in the opposing direction can result in reduced capacity disproportionate to the magnitude of the reverse flow. As a result, a small reverse flow should be assumed to occupy one pedestrian lane or 20 in. of the stair's width. For a stairway with an effective width of 60 in. (5 ft), a small reverse flow could consume half its capacity (1). The allowance for small reverse flows, when used, is included as part of the 0% term in Equation 23-1.

Small reverse flows on stairways should be assumed to use one pedestrian lane (20 in.) of width.

Step 2: Calculate Pedestrian Flow Rate

Walkways and Cross-Flow Areas

Hourly pedestrian demand is used as an input to the analysis. Consistent with the general analysis procedures used throughout the HCM, hourly demand is usually converted into peak 15-min flows, so that LOS is based on the busiest 15 consecutive minutes during an hour:

$$v_{15} = \frac{v_h}{4 \times PHF} \quad \text{Equation 23-2}$$

where

v_{15} = pedestrian flow rate during peak 15 min (p/h),
v_h = pedestrian demand during analysis hour (p/h), and
PHF = peak hour factor.

However, if peak-15-min pedestrian volumes are available, the highest 15-min volume can be used directly without the application of a peak hour factor.

Next, the peak 15-min flow is converted into a unit flow rate (pedestrians per minute per foot of effective path width):

$$v_p = \frac{v_{15}}{15 \times W_e} \quad \text{Equation 23-3}$$

where v_p is pedestrian flow per unit width (p/ft/min) and all other variables are as previously defined.

Stairways

Because pedestrians use more energy to ascend stairs than to descend them, lower flow rates typically occur in the ascending direction. For this reason, when stairs serve both directions simultaneously or when the same stairway will be used primarily in the up direction during some time periods and primarily in the down direction during other time periods, the upward flow rate should be used for analysis and design (1). The calculation of pedestrian flow rate for stairways is otherwise the same as that described for walkways and cross-flow areas.

Typical pedestrian flows on stairs occur in the up direction.

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Space = $\frac{1}{\text{density}}$

Step 3: Calculate Average Pedestrian Space

The service measure for walkways is *pedestrian space*, the inverse of density. Pedestrian space can be directly observed in the field by measuring a sample area of the facility and determining the maximum number of pedestrians at a given time in that area. The pedestrian unit flow rate is related to pedestrian space and speed.

Equation 23-4

$$A_p = \frac{S_p}{v_p}$$

where

A_p = pedestrian space (ft²/p),

S_p = pedestrian speed (ft/min), and

v_p = pedestrian flow per unit width (p/ft/min).

Step 4: Determine LOS

Walkways with Random Pedestrian Flow

Where pedestrian flow on the path is not influenced by platooning (see next subsection), Exhibit 23-3 should be used to determine pedestrian LOS.

Ramps with grades of 5% or less can be treated as walkways for the purpose of determining LOS

Research (*9, 11*) has shown that pedestrian speeds on ramps with grades up to 5% are not significantly different from speeds on level walkways but that speeds decrease at higher grades. Therefore, the walkway LOS values are also applicable to ramps with grades of 5% or less. Ramps with steeper grades are discussed later in this chapter in the Special Cases section. The walkway LOS values can also be adapted to pedestrian plazas and pedestrian zones (exclusive pedestrian streets), as discussed in the Special Cases section.

Walkways with Platoon Flow

Platooning on walkways.

It is important for the analyst to determine whether platooning alters the underlying assumptions of random flow in the LOS calculation. Platoons can arise, for example, if entry to a walkway segment is controlled by a traffic signal at a street crossing or if pedestrians arrive at intervals on transit services.

Where platooning occurs, the pedestrian flow is concentrated over short time periods rather than being distributed evenly throughout the peak 15 min analysis period. The available space for the typical pedestrian under these circumstances is much more constrained than the average space available with random arrival would indicate. There is no strict definition for what constitutes platooning rather than random flow; observations of local conditions and engineering judgment should be used to determine the most relevant design criteria (i.e., platoons versus random flow).

If platooning occurs, Exhibit 23-2 should be used to determine LOS. Research (*9*) indicates that impeded flow starts at 530 p/h/p, which is equivalent to a flow rate of 0.5 p/min/ft. This value is used as the LOS A–B threshold. The same research shows that jammed flow in platoons starts at 11 p/h/p, which is equivalent to 18 p/min/ft. This value is used as the LOS E–F threshold.

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Cross-Flow Areas

A cross flow is a pedestrian flow that is approximately perpendicular to and crosses another pedestrian stream, for example, at the intersection of two walkways or at a building entrance. In general, the lesser of the two flows is referred to as the cross-flow condition. The same procedure used to estimate walkway space is used to analyze pedestrian facilities with cross flows. As shown in the footnotes to Exhibit 23-1 and Exhibit 23-2, the LOS F threshold (i.e., capacity) in cross flow situations occurs at a lower density than that for walkways without cross flows (*2*).

Cross-flow LOS thresholds are identical to those for walkways, except for the LOS F threshold.

Stairways

Research (*2*) has developed LOS thresholds based on the Institute of Transportation Engineers stairway standards, which provide the space and flow values given in Exhibit 23-3. As with walkways, stairway LOS is described by the service measure of pedestrian space, expressed as square feet per pedestrian.

Step 5: Calculate Volume-to-Capacity Ratio

The volume-to-capacity (v/c) ratio can be computed by using the following values of capacity for various exclusive pedestrian facilities:

- Walkways with random flow: 23 p/min/ft,
- Walkways with platoon flow (average over 5 min): 18 p/min/ft,
- Cross-flow areas: 17 p/min/ft (sum of both flows), and
- Stairways (up direction): 16 p/ft/min/ft in the ascending direction.

SHARED-USE PATHS

Shared-use pedestrian–bicycle paths typically are open to users of nonmotorized modes such as bicyclists, skateboarders, and wheelchair users. Shared-use paths are often constructed to serve areas without city streets and to provide recreational opportunities for the public. These paths are also common on university campuses, where motor vehicle traffic and parking are often restricted. In the United States, there are few paths exclusively for pedestrians; most off-street paths are for shared use.

Bicycles—because of their markedly higher speeds—have a negative effect on pedestrian capacity and LOS on shared-use paths. However, it is difficult to establish a bicycle–pedestrian equivalent because the relationship between the two differs depending on their respective flows and directional splits, among other factors. This section covers pedestrian LOS on shared-use paths. Bicyclists have a different perspective, as discussed in the following section.

Step 1: Gather Input Data

The following input data are required for the analysis:

- Hourly pedestrian and bicycle demands by direction, and
- Average pedestrian and bicycle speeds.

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Step 2: Calculate Number of Bicycle Passing and Meeting Events

LOS is based on the overtaking of pedestrians by bicyclists. Interaction in pedestrian conflation is typically negligible.

LOS for shared-use paths is based on hindrance. Research (*14*) has established LOS thresholds for pedestrians based on the frequency of passing (in the same direction) and of meeting (in the opposite direction) other users. Because pedestrians seldom overtake other pedestrians, pedestrian LOS on a shared-use path depends on the frequency with which the average pedestrian is met and overtaken by bicyclists (*14*). However, the analyst should observe pedestrian behavior in the field before assuming that pedestrian-to-pedestrian interaction is negligible. The shared-use-path methodology does not account for events with users other than bicyclists (e.g., inline skaters).

The average number of passing and meeting events per hour is calculated by Equation 23-5 and Equation 23-6. These equations do not account for the range of bicycle speeds encountered in practice; however, because of the limited degree of overlap between the speed distributions of bicycles and pedestrians, the resulting difference is practically insignificant.

For one-way paths, there are no meeting events, so only F_p, the number of passing events, needs to be calculated. Paths 25 ft or more in width may effectively operate as two adjacent one-way facilities, in which case F_o may be set to zero.

Equation 23-5

$$F_p = \frac{Q_s}{PHF}\left(1 - \frac{S_p}{S_c}\right)$$

Equation 23-6

$$F_o = \frac{Q_{so}}{PHF}\left(1 + \frac{S_p}{S_c}\right)$$

where

F_p = number of passing events (events/h),
F_o = number of meeting events (events/h),
Q_s = bicycle demand in same direction (bicycles/h),
Q_{so} = bicycle demand in opposing direction (bicycles/h),
PHF = peak hour factor,
S_p = mean pedestrian speed on path (mi/h), and
S_c = mean bicycle speed on path (mi/h).

Meeting events create less hindrance than overtaking events.

Meeting events allow direct visual contact, so opposing-direction bicycles tend to cause less hindrance to pedestrians. To account for the reduced hindrance, a factor of 0.6 is applied to the meeting events on the basis of theoretical considerations (*14*). Where sufficient data are available on the relative effects of meetings and passings on hindrance, this factor can be calibrated to local conditions. Because the number of events calculated in the previous step was based on hourly demand, a peak hour factor must be applied to convert them to the equivalent demand based on peak 15-min conditions. The total number of events is

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$$F = (F_o + 0.5F_c)$$

Equation 23-7

where F is the total events on the path in events per hour and the other variables are as defined previously.

Step 3: Determine LOS

Exhibit 23-4 is used to determine shared-use path pedestrian LOS based on the total events per hour calculated in Step 2. Unlike the case for exclusive pedestrian facilities, the LOS F–F threshold does not reflect the capacity of a shared-use path but rather a point at which the number of bicycle meeting and passing events results in a severely diminished experience for the pedestrians sharing the path.

OFF-STREET BICYCLE FACILITIES

The methodology for bicycle facility analysis is based on several factors that affect user perception.

On shared-use paths, the presence of other bicyclists and other path users can be detrimental to bicyclists by increasing bicycle delay, decreasing bicycle capacity, and reducing bicyclists' freedom of movement. Research (7) correlating user perceptions of comfort and enjoyment of path facilities with an objective measure of path and user characteristics serves as the basis for the LOS thresholds and methodology described in this section. The following key criteria are considered through this methodology:

- The ability of a bicyclist to maintain an optimum speed,
- The number of times that bicyclists meet or pass other path users, and
- The bicyclist's freedom to maneuver.

The results of a perception survey were used to fit a linear regression model in which the survey results served as the dependent variable. The methodology incorporates the effects of five path modes that may affect bicycle LOS: other bicyclists, pedestrians, runners, inline skaters, and child bicyclists. Five variables – meetings per minute, active passings per minute, path width, presence of a centerline, and delayed passings – are used in the model. In the special case of an exclusive off-street bicycle facility, the volume for all nonbicycle modes is assumed to be zero, and the number of passings and meetings is determined solely by the volume of bicycles.

On exclusive off-street bicycle facilities the number of passings and meetings is determined solely by the bicycle volume.

The following sections describe the steps to be taken to calculate bicycle LOS for an off-street facility.

Step 1: Gather Input Data

The methodology addresses five types of path users, or mode groups: bicyclists, pedestrians, runners, inline skaters, and child bicyclists. The following input data are required for each mode group:

- Hourly demand by direction in modal users per hour,
- Average mode group speed in miles per hour, and
- Proportion of all path users represented by a particular mode group (i.e., mode split).

In addition, the following data are required for the facility:

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- Path width in feet, and
- Presence of a centerline stripe (yes or no).

With the hourly directional demand for the path and the path mode split, the hourly directional flow rate on the path is calculated for each of the five modes:

Equation 23-8

$$q_i = \frac{Q_D \times p_i}{PHF}$$

where

q_i = hourly directional path flow rate for user group i (modal users/h),
Q_D = total hourly directional path demand (modal users/h),
p_i = path mode split for user group i, and
PHF = peak hour factor.

Step 2: Calculate Active Passings per Minute

Active passings are defined as the number of other path users traveling in the same direction as an average bicyclist (i.e., a bicyclist traveling at the average speed of all bicyclists) who are passed by that bicyclist. The average bicyclist is assumed to move at a constant speed U. The value of U should be set to the average speed of bicyclists on the facility in question, where local data are not available, the default average bicyclist speed of 12.8 mi/h may be used. The methodology for determining active passings incorporates separately the effects of each of the five mode groups described in Step 1. The speeds of path users of each mode group are assumed to be normally distributed with a mean s_i and standard deviation σ_i, where i represents mode.

The average bicyclist passes only those users who (a) are present on the path segment when the average bicyclist enters and (b) exit the segment after the average bicyclist does. Thus, for a given modal user in the path when the average bicyclist enters, the probability of being passed is expressed by:

Equation 23-9

$$P(e_i) = P[s_i < U(1 - \frac{x}{L})]$$

where

$P(e_i)$ = probability of passing user of mode i,
U = speed of average bicyclist (mi/h),
s_i = speed of path user of mode i (mi/h),
L = length of path segment (mi), and
x = distance from average bicyclist to user (mi).

Exhibit 23-12 provides a schematic of active passing events.

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Exhibit 23-12
Schematic of Active Passing Events

Since v_i is distributed normally, the probability in Equation 23-9 can be calculated from the integral under the standard normal curve. By dividing the total length of the path L into a small number of discrete pieces each of length dx, the average probability of passing within each piece x can be estimated as the average of the probabilities at the start and end of each piece:

$$P(x_i) = 0.5[F(x - dx) + F(x)] \quad \text{Equation 23-10}$$

where $F(x)$ is the cumulative probability of normal distribution, and the other variables are as defined previously.

The expected number of times that the average bicyclist passes users of mode i over the entire path segment is then determined by multiplying $P(x_i)$ by the density of users of mode i and summing over all portions of the segment. The number of passings per minute is then obtained by dividing the result by the number of minutes required for the bicyclist to traverse the path segment:

$$A_i = \sum_{x=1}^{L} P(x_i) \times \frac{q_i}{\mu_i} \times \frac{1}{t} dx_i \quad \text{Equation 23-11}$$

where

A_i = expected passings per minute of mode i by average bicyclist,
q_i = directional hourly flow rate of mode i (modal users/h),
μ_i = average speed of mode i (mi/h),
t = path segment travel time for average bicyclist (min), and
dx = length of discrete segment x (mi).

The other variables are as previously defined.

Research (7) found that setting dx equal to 0.01 mi is appropriate for the purposes of the calculations shown in Equation 23-11 and below.

Equation 23-11 provides expected passings by the average bicyclist for mode i. To determine total active passings of all modes, Equation 23-11 must be repeated for each individual mode and then summed:

$$A_T = \sum_i A_i \quad \text{Equation 23-12}$$

where A_T is the expected active passings per minute by the average bicyclist during the peak 15 min, and the other variables are as defined previously.

Step 3: Calculate Meetings per Minute

Meetings are defined as the number of path users traveling in the opposing direction to the average bicyclist that the average bicyclist passes on the path segment. All users present on the path when the average bicyclist enters will be

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passed by the average bicyclist, assuming that no user enters or exits the path at an intermediate point:

Equation 23-13

$$M_1 = \frac{U}{3600} \sum_i \mu_i$$

where M_1 is the meetings per minute of users already on the path segment and U is the speed of the average bicyclist in miles per hour. The other variables are as previously defined.

In addition to users already on the path segment, a number of users will have yet to enter the segment will meet the average bicyclist within the segment. The probability of this occurrence is

Equation 23-14

$$P(e_{1,i}) = P(v_i > X \frac{U}{L})$$

where

$P(e_{1,i})$ = probability of meeting opposing user of mode i,

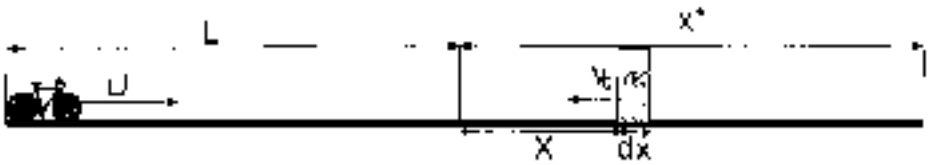
v_i = speed of path user of mode i (mi/h),

X = distance of user beyond end of path segment (mi), and

U = speed of average bicyclist (mi/h).

Since v_i is distributed normally, the probability in Equation 23-14 can be readily calculated from the area under the standard normal curve. The length of path beyond the analysis segment that may supply users who will be met by the average bicyclist is defined as x^*. By dividing x^* into small distinct pieces, each of length dx, the average probability of meeting a mode i user from each piece can be estimated by Equation 23-10. Although some meetings will occur with very fast path users located greater than L distance beyond the end of the segment when the average bicyclist enters, setting x^* equal to L is sufficient to guarantee that at least 99% of meetings will be captured (7). Exhibit 23-13 provides a schematic of meeting events.

Exhibit 23-13
Schematic of Meeting Events



Similar to the process for calculating number of active passings (Equation 23-11), the estimation of number of meetings with users from a particular mode group that exit the path segment when the average bicyclist enters is

Equation 23-15

$$M_{2,i} = \sum_{x=0}^{x^*} P(e_{1,i}) \times \frac{U}{\mu_i} \times \frac{1}{L} dx_i$$

where $M_{2,i}$ is the expected meetings per minute of users of mode i located beyond the end of the path segment at the time the average bicycle enters the segment, and the other variables are as previously defined.

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Finally, the total number of expected meetings per minute during the peak 15 min M_t is determined by adding M_o to the sum of M_{ij} across all mode groups:

$$M_t = (M_1 - \sum M_{ij}) \quad \text{Equation 23-16}$$

All variables are as previously defined.

In the special case of a one-way path, there are no opposing users to meet; therefore, M_o is zero.

Step 4: Determine Number of Lanes

The effective number of lanes on a shared-use path affects the number of delayed passings: as the number of lanes increases, delayed passings decrease. Even paths without painted lane markings will operate with a de facto number of lanes. The relationship between path width and the number of effective operational lanes is shown in Exhibit 23-14.

Exhibit 23-14
Effective Lanes by Path Width

Path Width (ft)	Lanes
8.0–10.5	2
11.0–14.5	3
15.0–20.0	4

Source: Hummer et al. (7)

Step 5: Calculate Probability of Delayed Passing

Delayed passing maneuvers occur when there is a path user ahead of the overtaking average bicyclist in the subject direction and another path user in the opposing direction, such that the average bicyclist cannot immediately make the passing maneuver. The probability of a delayed passing depends on the passing distance required, which in turn depends on both the overtaking mode and the mode of the user being passed. The passing distances that bicyclists require to pass other user modes are shown in Exhibit 23-15.

Exhibit 23-15
Required Bicycle Passing Distance

Overtaking Mode	Mode Passed	Required Passing Distance (ft)
Bicycle	Bicyclist	100
Bicycle	Pedestrian	60
Bicycle	Inline skater	100
Bicycle	Runner	70
Bicycle	Child bicyclist	70

Source: Hummer et al. (7)

With the values in Exhibit 23-15, the probability that a given section will be vacant of a given mode for at least the required passing distance p can be calculated by using a Poisson distribution. The probability of observing at least one modal user in the passing section is the complement of the probability of observing a vacant section. The probability P_{bi} of observing a blocked passing section for mode i is

$$P_{bi} = 1 - e^{-V_i p} \quad \text{Equation 23-17}$$

where

P_{bi} = probability of passing section's being blocked by mode i,

p = distance required to pass mode i (mi), and

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λ_v = density of users of mode v (users/mi)

Equation 23-17 is applicable to both the subject and opposing directions.

Two-Lane Paths

On a two-lane path, delayed passing occurs when, within the distance required to complete a pass, the average bicyclist encounters one of the following: traffic in both directions, each blocking a single lane, or the traffic in the subject direction in conjunction with traffic in the opposing direction that is being overtaken by an opposing bicyclist. Note that these situations are mutually exclusive. The delayed passing probabilities in the subject and opposing directions are

Equation 23-18

$$P_{d1} = P_{o1}P_{o2} + P_{o1}(1 - P_{o2})(1 - P_{g2})$$

Equation 23-19

$$P_{d2} = P_{g2}P_{o1} + P_{g2}(1 - P_{o1})(1 - P_{d1})$$

where

P_{d1} = probability of delayed passing in subject direction,

P_{d2} = probability of delayed passing in opposing direction,

P_{o1} = probability of blocked lane in opposing direction, and

P_{g1} = probability of blocked lane in subject direction.

Solving Equation 23-18 and Equation 23-19 for P_{g2} results in

Equation 23-20

$$P_{g2} = \frac{P_{o1}P_{o2} + P_{d2}(1 - P_{o2})}{1 + P_{o1}P_{o2}(1 - P_{o2})(1 - P_{d1})}$$

Since P_{d2} and P_{o1} are calculated using Equation 23-17, Equation 23-20 can be readily solved for P_{g2}.

Three-Lane Paths

The operations of three-lane paths are more complicated than those of two-lane paths, since there is a greater variety of possible scenarios that may occur. The methodology includes several limiting assumptions regarding user behavior:

- Bicyclists in the subject direction use only the two rightmost lanes,
- Bicyclists in the opposing direction use only the two leftmost lanes,
- Passing maneuvers occur only in the middle lane and never in the left lane, and
- Groups of users may sometimes block the two lanes allocated to that direction but cannot block all three lanes.

As a result, a delayed passing occurs in two cases: (*a*) traffic in the subject direction is blocking the rightmost lane in conjunction with opposing traffic occupying the other two lanes, or (*b*) side-by-side users are blocking the two rightmost lanes in the subject direction. The probabilities of the occurrence of a delayed passing in the subject and opposing directions are given by

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$$P_{o,} = P_{so}[P_{so} + P_{so}(1 - P_{o})] + P_{o} \quad \text{Equation 23-21}$$

$$P_{s,} = P_{so}[P_{o} + P_{o}(1 - P_{o})] + P_{s} \quad \text{Equation 23-22}$$

where P_{o} is the probability of two blocked lanes in the opposing direction, P_{s} is the probability of two blocked lanes in the subject direction, and all other variables are as previously defined.

Equation 23-21 and Equation 23-22 are simultaneous equations with two unknowns, P_{o} and P_{s}. Denoting D as $P_{o} - P_{s}$ gives the following equation.

$$D = [(P_{o} - P_{s}) + (P_{o}P_{so} - P_{so}P_{o})]/(1 - P_{so}P_{so}) \quad \text{Equation 23-23}$$

Substituting Equation 23-23 into Equation 23-21 results in

$$P_{o} = [P_{o}(P_{so} + P_{so}(1 + D)) + P_{o}]/(1 + P_{so}P_{so}) \quad \text{Equation 23-24}$$

This model requires determining four probability parameters, specifically, P_{o} and P_{s} in each direction. Calculating these parameters requires estimating the frequency of all events in which both lanes are blocked. These parameters were established through research [7] in which video data of more than 4,000 path users on U.S. shared-use paths were observed. Exhibit 23-16 shows the blocking frequencies by mode.

Exhibit 23-16
Frequency of Blocking of Two Lanes

Mode	Frequency of Blocking (%)
Bicycle	5
Pedestrian	26
Inline skater	8
Runner	13
Child bicyclist	1

Source: Hummer et al. [7].

Therefore, P_{so} and P_{so}, the probabilities that a user of mode i will block two lanes in the opposing and subject directions, respectively, are found by multiplying the frequency of blocking two lanes by a particular user of mode i (Exhibit 23-16) by the probability that a user of mode i will be encountered, which was given by Equation 23-17. This process results in

$$P_{so} = F_{i} \times P_{so} \quad \text{Equation 23-25}$$

$$P_{so} = F_{i} \times P_{so} \quad \text{Equation 23-26}$$

where F is the frequency with which mode i will block two lanes, from Exhibit 23-16, and all other variables are as previously defined. The probability that a user of any mode will block two lanes is thus given by

$$P_{so} = \sum_{i} P_{so} \quad \text{Equation 23-27}$$

$$P_{so} = \sum_{i} P_{so} \quad \text{Equation 23-28}$$

The probabilities that only a single lane will be blocked by a user of a given mode, P_{so} and P_{so}, are then derived from the probability that at least one lane will be blocked (from Equation 23-17) minus the probability that two lanes will be blocked (from Equation 23-25 and Equation 23-26). These probabilities are

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Equation 23-29

$$P_{bs} = 1 - e^{-v_s} \quad P_{ps}$$

Equation 23-30

$$P_{b,i} = 2 - e^{-(v_s + v_o)} \cdot P_{ss}$$

where v_s and v_o are the densities of users of mode i in users per min/ft in the subject and opposing direction, respectively, and all other variables are as previously defined.

The probabilities that a user of any mode will block a single lane are then given by

Equation 23-31

$$P_s = \sum_i P_{bs}$$

Equation 23-32

$$P_o = \sum P_{bo}$$

The values of P_s and P_o from Equation 23-27 and Equation 23-28, and the values of P_{bs} and P_{bo} from Equation 23-31 and Equation 23-32 can now be substituted into Equation 23-23 and Equation 23-24 to determine the probability of delayed passing, P_{ps}. This delayed passing factor was calculated by using peak hour volumes, rather than peak 15-min volumes. Therefore, a peak hour factor is applied to convert A_i from peak 15-min flow rate conditions back to hourly conditions.

Four-Lane Paths

On four-lane paths, the methodology assumes that the path operates similarly to a divided four-lane highway, such that the probability of delayed passing is independent of opposing users, since no passing occurs in the leftmost lanes. Thus, the probability of delayed passing P_s is equivalent to the probability that both subject lanes will be blocked P_{bs}, which can be found by using Equation 23-25 and Equation 23-27.

Step 6: Calculate Delayed Passings per Minute

The probability of delayed passing P_{ps} described earlier, applies only to a single pair of modal path users (e.g., a bicyclist passing a pedestrian and opposed by a runner). The total probability of delayed passing P_{ps} must be calculated from all modal pairs. Since there are five modes, there are five times five (25) total modal pairs that require calculation. The total probability of delayed passing is found by using

Equation 23-33

$$P_{ps} = 1 - \prod_n (1 - P_{ps,n})$$

where P_{ps} is the total probability of delayed passing and $P_{ps,n}$ is the probability of delayed passing for mode n. The operator $\prod$ in Equation 23-33 indicates the product of a series of variables.

Finally, delayed passings per minute are simply the active passings per minute A_i multiplied by the total probability of delayed passing P_{ps}:

Equation 23-34

$$\text{Delayed Passings per Minute} = A_i \times P_{ps} \times PHF$$

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This delayed passing factor was calibrated by using peak hour volumes rather than peak 15-min volumes. Therefore, a peak hour factor is applied to convert v_p from peak 15-min flow rate conditions back to hourly conditions.

Step 7: Determine LOS

The bicycle LOS score (Equation 23-35) uses inputs from Steps 2, 5, and 6 plus facility data gathered in Step 1. The equation was developed from a regression model of user responses to video clips depicting a variety of off-street bicycle facilities (7). The LOS C–D threshold represents the midpoint of the response scale used in the survey.

$$\text{Bicycle LOS Score} = 3.646 + 0.0076(E) + 1.376(RW) - 0.267(CL) + 0.548(DP) \quad \text{Equation 23-35}$$

where

E = weighted events per minute = meetings per minute + 10 × (active passings per minute);

RW = reciprocal of path width = 1/path width (ft);

CL = 1 if trail has centerline, 0 if no centerline; and

DP = min (delayed passups per minute, 1.5).

With the exception of the special cases discussed in Step 8 below, the bicyclist perception index is used directly with Exhibit 23-5 to determine bicyclist LOS on off-street facilities. As was the case with shared pedestrian facilities, the LOS F threshold does not reflect the capacity of an off-street bicycle facility, but rather a point at which the number of meeting and passing events results in a severely diminished experience for bicyclists using the path.

Step 8: Adjust LOS for Low-Volume Paths

For narrow paths (i.e., 8 ft in width), it is not possible to achieve LOS A or B by using Equation 23-35. Since paths with very low volumes would be expected to result in a high perceived quality of service, the following adjustments are made to the LOS results:

- All paths with five or fewer weighted events per minute are assigned LOS A.
- All paths with >5 to 10 weighted events per minute are assigned LOS B, unless Equation 23-37 would result in LOS A.

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3. APPLICATIONS

This chapter's methodologies evaluate the LOS of exclusive pedestrian and bicycle facilities. The analyst must address two fundamental issues. First, the primary outputs must be identified. These may include LOS, effective width W_e, or achievable path flow rate Q. Second, any necessary default or estimated values must be identified. There are three basic sources of input data:

1. Default values provided in the HCM;
2. Estimates or locally derived default values developed by the user; and
3. Values derived from field measurements and observation.

When it is possible to obtain them, field measurements are preferable to default values.

DEFAULT VALUES

For pedestrians on off-street paths, a default average speed of 3.4 mi/h for pedestrians and 12.8 mi/h for bicycles can be applied in the absence of local data (7). Default values for off-street bicycle facilities are summarized in Exhibit 23-17.

Exhibit 23-17
Default Values for Exclusive Off-Street Bicycle Facilities

Variable	User Group	Default Value
Mode split	Bicycle	70%
	Pedestrian	20%
	Runner	10%
	Inline skater	10%
	Child bicyclist	5%
Mean speed by mode	Bicycle	12.8 mi/h
	Pedestrian	3.4 mi/h
	Runner	6.5 mi/h
	Inline skater	10.1 mi/h
	Child bicyclist	7.9 mi/h
Standard deviation of speed by mode	Bicycle	3.4 mi/h
	Pedestrian	0.6 mi/h
	Runner	1.2 mi/h
	Inline skater	2.7 mi/h
	Child bicyclist	1.9 mi/h
Proportion of users passing two lanes by mode	Bicycle	5%
	Pedestrian	30%
	Runner	12%
	Inline skater	8%
	Child bicyclist	1%
Peak hour factor	N/A	0.85

Source: Rummel et al. (7)

ANALYSIS BOUNDARIES

As stated in this chapter's introduction, exclusive pedestrian and bicycle facilities are analyzed at the segment level, with segment endpoints being defined by street crossing locations, changes in path width, intersections with other paths that create cross flows or change path demand, and transition points to other types of facilities (e.g., from path to ramp). In most cases, the minimum segment length will be around 0.25 mi, and the maximum segment length will be 2 to 3 mi (7). Certain kinds of facilities, such as stairways, cross flow areas, and pedestrian plazas, will have shorter segment lengths.

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TYPES OF ANALYSIS

Operational Analysis

A common application of operational analysis is to compute the LOS of a facility under existing or future demand. The effective width of the facility is an input to the calculation and LOS is an output.

Design Analysis

Designing for an effective width.

Design applications require that an LOS goal be established, with the primary output being the facility design characteristics required or the maximum user volumes allowable for the LOS goal. For instance, a design analysis for a pedestrian walkway may estimate the minimum effective width W_E needed to achieve a design LOS value. In this case, the maximum pedestrian unit flow rate for the desired service level would be determined from Exhibit 23-1 or Exhibit 23-2. The effective width would be computed by solving the pedestrian unit flow-rate equation backward. To avoid pedestrian spillover, it is desirable to design a walkway to achieve LOS C or better (i.e., a maximum of 10 p/min/ft). Stairways are desirably designed to achieve LOS C or D.

Determining service volumes.

Similarly, the achievable path flow rate Q_T can be solved as the primary output. For exclusive bicycle facilities, the minimum LOS perception score for the design LOS would be determined from Exhibit 23-5. By holding all but one path user group's demand constant and solving the events equation backward, the service volume for the user group of interest can be computed.

Planning and Preliminary Engineering Analyses

Planning and preliminary engineering analyses use estimates, HCM default values, or local default values as inputs and determine LOS, bicycle flow rate, effective width, or all three, as outputs. The difference between a planning analysis and an operational or design analysis is that most or all of the input values in planning come from estimates or default values, whereas operational and design analyses tend to use field measurements or known values for most or all of the input variables.

SPECIAL CASES

Pedestrian Plazas

Pedestrian plazas are large, paved areas that serve multiple functions, including pedestrian circulation, special events, and seating. The circulation function is of interest here, although the design of a plaza must consider how all of the functions interact. For example, queues from areas designated for food vendors may intrude into a pedestrian circulation route, reducing the route's effective width, or two circulation routes may intersect each other, creating a cross-flow area. In addition, research has shown that the circulation and amenity functions of a plaza sometimes conflict, since people tend to linger longer in plazas that do not act as thoroughfares (9).

The exclusive pedestrian walkway methodology can be used to analyze pedestrian circulation routes through pedestrian plazas. The methodology does

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not address the need or desire to have space for amenities within a pedestrian plaza. The effective width of such a route is not as easily identified as that of a walkway, because the edges of the circulation area are often undefined. However, pedestrians will tend to take the shortest available route across the plaza, as illustrated in Exhibit 23-18.

Exhibit 23-18
Pedestrian Circulation Space in a Pedestrian Plaza

The effective width of a circulation route is influenced by the widths of the entrance and exit points to the plaza and by the presence of obstacles (e.g., walls, poles, signs, benches). Effective width may also be influenced by whether a change in texture is used to mark the transition between circulation and amenity space. Between 30% and 60% of pedestrians will use plaza space that is flush with a sidewalk, with the higher percentages applying to wider plazas and those that help cut a corner and the lower percentages applying to narrower plazas and those with obstacles (9).

For design applications, peak pedestrian demands through the plaza would need to be estimated. Given this information and a design LOS, a minimum effective width could be determined for each circulation route. Multiplying the width of the route by the length of the route and summing for all routes results in the space required for pedestrian circulation. Space requirements for sitting areas and other plaza functions are added to the circulation space to determine the total plaza space required.

For operational applications, an average effective width can be determined through field observation of the space occupied by pedestrians on a circulation route during peak times. Dividing an average per minute pedestrian volume by the effective width gives the pedestrian flow rate for the circulation route, from which LOS can be determined.

Pedestrian Zones

Pedestrian zones are streets dedicated to exclusive pedestrian use on a full- or part-time basis. These zones can be analyzed from an operational standpoint by using the exclusive pedestrian walkway methodology, as long as the kinds of obstructions listed in Exhibit 23-11, such as sidewalk café tables, are taken into account. Other performance measures may be considered that assess the street's attractiveness to pedestrians, since a successful pedestrian zone is expected to be relatively crowded (i.e., to have a lower LOS). Although an uncrowded zone would have a high LOS, it could be perceived by pedestrians as being a potential personal security risk, because of the lack of other users.

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The HCM methodology is not suitable for pedestrian zones during times when delivery vehicles are allowed to use the street. The HCM methodology is also not applicable to the analysis of a low-speed street (e.g., a Dutch *woonerf*) shared by pedestrians, bicycles, and automobiles.

Walkways with Grades over 5%

Research (*9–11*) has shown no appreciable impact on pedestrian speed for grades up to 5%. As shown in Exhibit 23-19, above a 5% grade, walking speeds drop as grade increases, with travel on a 12% grade being about 30% slower than travel on a level surface. Grade may not have an appreciable impact on capacity, however, since the reduction in pedestrian speed is offset by closer pedestrian spacing (*9*). The stairway LOS table (Exhibit 23-3) would provide a conservative estimate of pedestrian LOS on steeper walkways.

Consult the latest version of the ADA Accessibility Guidelines for guidance on the maximum slope allowed on an accessible route.

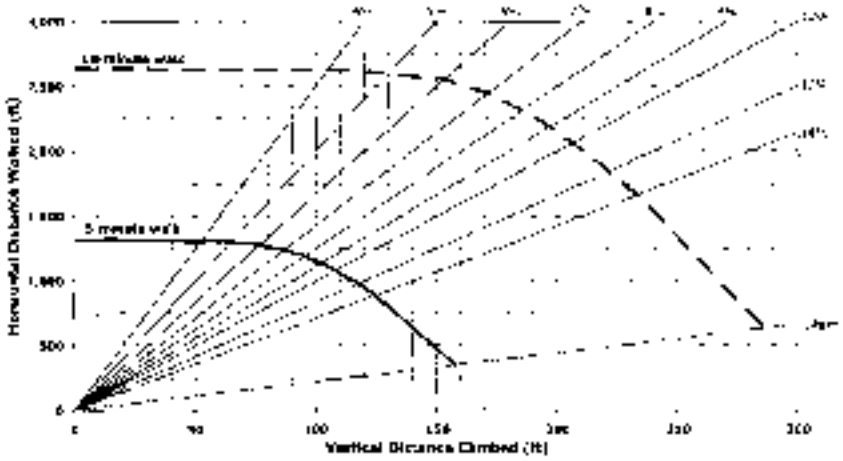

Exhibit 23-19
Effect of Vertical Climb on Horizontal Distance Walked

Source: Montreal Planning Association (*10*).

Paths Segregating Pedestrians and Bicyclists

Some paths are signed or striped, or both, to segregate bicyclists from pedestrians. Where field observation on the path (or similar paths in the same region) indicates that path users generally comply with the regulations, up to all of the bicycle–pedestrian passing events could be converted to meeting events in proportion to the path users' compliance rate, resulting in an improved LOS. Where sufficient physical segregation of bicyclists and pedestrians occurs, it may be appropriate to treat the path as two separate facilities.

USE OF ALTERNATIVE TOOLS

To date, there is no widely used computer simulation software in the United States that is capable of describing user interactions on shared-use paths in a realistic manner. Microsimulation has been used to model pedestrian interactions on off-street pedestrian facilities. In many cases, these models were developed to model pedestrian movements within airports or transit facilities.

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4. EXAMPLE PROBLEMS

Exhibit 23-20
List of Example Problems

Example Problem	Description	Application
1	Pedestrian LOS on shared-use and exclusive paths	Operational analysis
2	Bicycle LOS on a shared-use path	Planning analysis

EXAMPLE PROBLEM 1: PEDESTRIAN LOS ON SHARED-USE AND EXCLUSIVE PATHS

The Facts

The following information was collected in the field for this path:

- Q_b = bicycle volume in same direction = 300 bicycles/h;
- Q_o = bicycle volume in opposing direction = 100 bicycles/h;
- v_{15} = peak 15-min pedestrian volume = 180 pedestrians;
- PHF = peak hour factor = 0.83;
- S_p = average pedestrian speed = 4.0 ft/s (2.7 mi/h);
- S_b = average bicycle speed = 16.0 ft/s (10.9 mi/h), and
- No pedestrian platooning was observed.

Step 1: Gather Input Data

The shared-use-path pedestrian LOS methodology requires pedestrian and bicycle speeds and bicycle demand, all of which are available from the field measurements just given.

Step 2: Calculate Number of Bicycle Passing and Meeting Events

The number of passing events F_p is determined from Equation 23-5:

$$F_p = \frac{Q_o}{PHF}\left(1 - \frac{S_p}{S_b}\right)$$

$$F_p = \frac{100 \text{ bicycles/h}}{0.83}\left(1 - \frac{4.0 \text{ ft/s}}{16.0 \text{ ft/s}}\right)$$

$$F_p = 90 \text{ events/h}$$

The number of meeting events F_m is determined from Equation 23-6:

$$F_m = \frac{Q_{os}}{PHF}\left(1 + \frac{S_p}{S_b}\right)$$

$$F_m = \frac{100 \text{ bicycles/h}}{0.83}\left(1 + \frac{4.0 \text{ ft/s}}{16.0 \text{ ft/s}}\right)$$

$$F_m = 150 \text{ events/h}$$

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The total number of events is calculated from Equation 23-7:

$$E = (E_p + 0.5E_o)$$

$$E = [90 \text{ events/h} + (0.5)(150 \text{ events/h})]$$

$$E = 165 \text{ events/h}$$

Step 3: Determine Shared-Use-Path Pedestrian LOS

The shared-use path LOS is determined from Exhibit 23-4. The value of E_p 165 events/h, falls into the LOS E range. Since this value is rather low, what would happen if a parallel, 5-ft-wide, pedestrian-only path were provided?

Step 4: Compare Exclusive-Path Pedestrian LOS

Step 4.1: Determine Effective Walkway Width

Assuming that no obstacles exist on or immediately adjacent to the path, the effective width would be the same as the actual width, or 5 ft. Common amenities located along pedestrian walkways include trash cans and benches. From Exhibit 23-11, these should be located at least 3.0 ft and 5.0 ft, respectively, from the edge of the path to avoid affecting the effective width.

Step 4.2: Calculate Pedestrian Flow Rate

Since a peak-15-min pedestrian volume was measured in the field, it is not necessary to use Equation 23-2 to determine v_{15}. The unit flow rate for the walkway v_p is determined from Equation 23-3 as follows:

$$v_p = \frac{v_{15}}{15 \times W_E}$$

$$v_p = \frac{100 \text{ p}}{15 \times 5 \text{ ft}}$$

$$v_p = 1.3 \text{ p/ft/min}$$

Step 4.3: Calculate Average Pedestrian Space

Average pedestrian space is determined by rearranging Equation 23-4:

$$A_p = S_p / v_p$$

$$A_p = (4.0 \text{ ft/s})(60 \text{ s/min})/(1.3 \text{ p/ft/min})$$

$$A_p = 185 \text{ ft}^2/\text{p}$$

Step 4.4: Determine LOS

Since no pedestrian platooning was observed, Exhibit 23-4 should be used to determine the LOS. A value of 185 ft²/p corresponds to LOS A.

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Discussion

The existing mixed-use path operates at LOS E for pedestrians. Pedestrian LOS would increase to LOS A if a parallel, 6-ft-wide pedestrian path were provided.

EXAMPLE PROBLEM 2: BICYCLE LOS ON A SHARED-USE PATH

The Facts

A new shared-use path is being planned. On the basis of data from a similar facility in the region, it is estimated that the path will have a peak-hour volume of 340 users, a peak hour factor of 0.90, and a 50/50 directional split. The path will be 10 ft wide, with no obstacles, and will not have a centerline. The segment analyzed here is 3 mi long.

Step 1: Gather Input Data

Facility and overall demand data are available but not the mode split of users or the average mode group speed. Those values will need to be defaulted by using Exhibit 23-17. On the basis of the default mode split and the estimated directional split, the directional hourly volume by mode is as follows:

- Directional bicycle flow rate = 340 users/h × 0.5 × 0.56/0.90 = 104 bicycles/h;
- Directional pedestrian flow rate = 340 × 0.5 × 0.20/0.90 = 38 p/h;
- Directional runner flow rate = 340 × 0.5 × 0.10/0.90 = 19 runners/h;
- Directional inline skater flow rate = 340 × 0.5 × 0.10/0.90 = 19 skaters/h; and
- Directional child bicyclist volume = 340 × 0.5 × 0.05/0.90 = 9 child bicyclists/h.

From Exhibit 23-17, average mode group speeds and standard deviations are as follows:

- Bicycle: average speed = 12.8 mi/h, standard deviation = 3.4 mi/h;
- Pedestrian: average speed = 3.4 mi/h, standard deviation = 0.6 mi/h;
- Runner: average speed = 6.5 mi/h, standard deviation = 1.2 mi/h;
- Inline skater: average speed = 10.1 mi/h, standard deviation = 2.7 mi/h; and
- Child bicyclist: average speed = 7.9 mi/h, standard deviation = 1.9 mi/h.

Step 2: Calculate Active Passings per Minute

Active passings per minute must be calculated separately for each mode, by using Equation 23-9 through Equation 23-11. For the number of bicycles passed per minute, the path is considered as broken into n slices, each of which has a length l_i of 0.05 mi, and a total path segment length L of 3 mi. Then, for the first slice, from Equation 23-9:

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$$P(v_i) = P[v_i < U(1 - \frac{x}{L})]$$

$$P(x) \quad P[v_i < 12.8(1 \quad \frac{0.01}{3})] \quad P[v_i < 12.76] \quad 0.4949$$

$$P(x \quad dx) \quad P[v_i < 12.8(1 \quad \frac{0}{3})] = P[v_i < 12.80] \quad 0.5000$$

Applying Equation 25-20 and Equation 24-11 then gives the following probability of passing for the first slice:

$$P(v_i) = 0.5[P(v_i - dv) + P(v_i)]$$

$$P(v_i) = 0.5[0.5000 + 0.4949] = 0.4975$$

$$A_i = \sum_{v_i}^{v_i} P(v_i) \times \frac{q_i}{\mu_i} \times \frac{1}{L} dx_i$$

$$A_{i1} = 0.4975 \times \frac{104}{12.8} \times \frac{1}{14}(0.01) = 0.0029$$

Repeating this procedure for all slices from 1 to *n* and summing the results yields

$$\text{Passings of bicycles per minute} = (0.0029 + A_{i2} + \ldots + A_{in}) = 0.19$$

With the same methodology for each mode, the following active passings per minute are found for the other modes:

- Pedestrians, 1.74;
- Runners, 0.30;
- Inline skaters, 0.09; and
- Child bicyclists, 0.10.

Total active passings are then determined by using Equation 23-12:

$$A_i \quad \sum_i A_i$$

$$\text{Total passings per minute} = (0.19 + 1.74 + 0.30 + 0.09 + 0.10) = 2.42$$

Step 3: Calculate Meetings per Minute

Meetings per minute of users already on the path segment M_i are calculated for each mode with Equation 23-13:

$$M_i = \frac{U}{60} \sum_i \frac{q_i}{\mu_i}$$

$$M_i = (12.8/60) \times [(104/12.8) + (48/9.4) + (9/6.6) + (1/10.3) + (1/7.9)] = 5.3$$

Meetings per minute of users not yet on the path segment must be calculated separately for each mode. For the number of bicycles passed per minute, the section of path beyond the study segment is considered as broken into *n* slices, each of which has length $dx = 0.01$ mi, and a total segment length X equivalent to 1 (3 mi). Then, for the first slice, from Equation 23-14:

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$$P(v_p) = P(v_i > X\frac{U}{L})$$

$$P(x) = P[v_i > 0.01 \times \frac{12.8}{3}] = P[v_i > 0.4267] = 0.9999$$

$$P(x) = P[v_i > 0 \times \frac{12.8}{3}] = P[v_i > 0] = 1.0000$$

Applying Equation 23-10 and Equation 23-15 then gives the probability of passing at the first slice.

$$P(v_i) = 0.5[P(x - dx) + P(x)]$$

$$P(v_i) = 0.5\,[0.99992 + 1.0000] = 0.99996$$

$$M_{p_i} = \sum_{i=1}^{n} P(v_{p_i}) \times \frac{v_i}{R_i} \times \frac{1}{l} dx_i$$

$$M_{p_1} = 0.99996 \times (104/12.8) \times (1/14) \times 0.01 = 0.0058$$

Repeating this procedure for all slices from 1 to n and summing the results yields

M_{p_i} = meetings of bicycles per minute = $0.0058 + M_{p_2} + \ldots + M_{p_n} = 1.54$

Repeating the foregoing procedure for the other modes, the following meetings per minute are found for each mode:

- Pedestrians, 0.68;
- Runners, 0.31;
- Inline skaters, 0.31; and
- Child bicyclists, 0.16.

Total meetings are then determined by using Equation 23-16.

$$M_t = (M_i + \sum_i M_{x_i})$$

Total meetings per minute = [5.36 + 1.54 + 0.68 + 0.31 + 0.31 + 0.16] = 8.36

Step 4: Determine the Number of Lanes

From Exhibit 23-14, a 10-ft wide path has two effective lanes.

Step 5: Calculate the Probability of Delayed Passing

From Step 4, it is clear that a path with a width of 10 ft will operate as two lanes. Therefore, delayed passings per minute must be calculated separately for each of the 25 modal pairs, by using Equation 23-17 and Equation 23-20. For instance, considering the probability of a delayed passing of a bicyclist as a result of an opposing bicyclist's overtaking a pedestrian gives the following:

$$P_d = 1 - e^{-Mt}$$

$$P_{d_1} = 1 - \exp[-(100/5280) \times (1/0.90)(104/12.8)] = 1 - 0.858 = 0.142$$

$$P_{d_2} = 1 - \exp[-(100/5280) \times (1/0.90)(36/3.4)] = 1 - 0.810 = 0.190$$

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Substituting into Equation 23-20 then yields P_{ds}:

$$P_{ds} = \frac{P_{ss}P_{sq} + P_{sq}(1 - P_{ss})^{n}}{1 - P_{ss}P_{sq}(1 - P_{ss})(1 - P_{sq})}$$

$$P_{ds} = \frac{0.190 \times 0.142 - 0.190(1 - 0.142)^{1}}{1 - 0.190 \times 0.142(1 - 0.190)(1 - 0.142)} = 0.1698$$

Performing the foregoing procedures for each of the 23 modal pairs and applying Equation 23-33 gives the total probability of delayed passing:

$$P_{total} = 1 - \prod_{m}(1 - P_{dsm})$$

$$P_{total} = 1 - (1 - 0.1698)(1 - P_{ds2}) \ldots (1 - P_{ds23}) = 0.8334$$

Thus, the probability of delayed passing is 83.34%.

Step 6: Determine Delayed Passings per Minute

Equation 23-34 is used to determine the total number of delayed passings per minute:

$$\text{Delayed passings per minute} = V_{ped} \times P_{total} \times PHF$$

$$\text{Total delayed passings per minute} = 0.8334 \times 2.42 \times 0.90 = 1.82$$

The delayed passing factor has a maximum of 3. The total delayed passings per minute (1.82) is less than 3. Therefore the delayed passing factor is set to 1.82.

Step 7: Calculate LOS

Equation 23-37 is used to determine the bicycle LOS score for the path:

$$\text{Bicycle LOS Score} = 3.446 - 0.00809[8.98 + (10 \times 2.03)] - 1.986(1/10) - 0.256(10) - 0.5(1.82) = 2.09$$

Because the bicyclist perception index is between 2.5 and 3.0, the facility operates at LOS D according to Exhibit 23-5.

Results

The results indicate that the path would operate close to its theoretical capacity. A slightly wider path would provide three effective lanes and a better LOS.

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Most of these references can be found in the Technical Reference Library in Volume 4

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VOLUME 3 INDEX

The Index to Volume 3 lists the text citations of the terms defined in the Glossary (Volume 1, Chapter 9). Volumes 1, 2, and 3 are separately indexed. In the index listings, the first number in each hyphenated pair of numbers indicates the chapter, and the number after the hyphen indicates the page within the chapter.

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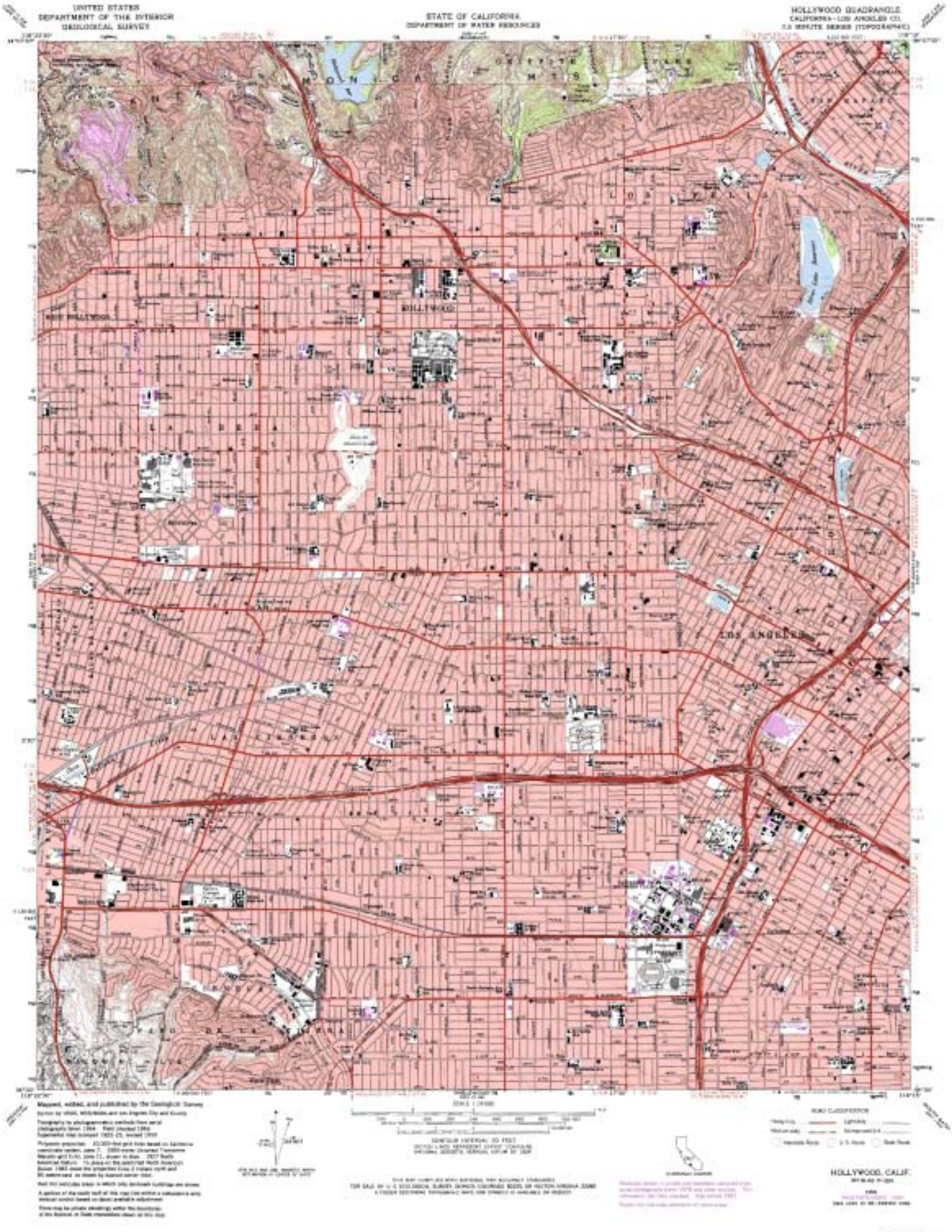
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
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7.5 MINUTE SERIES (TOPOGRAPHIC)
SANTA MONICA MTS.
HOLLYWOOD
WEST HOLLYWOOD
LOS ANGELES
HOLLYWOOD, CALIF.

AR0074027

Upper Los Angeles River Area Watermaster

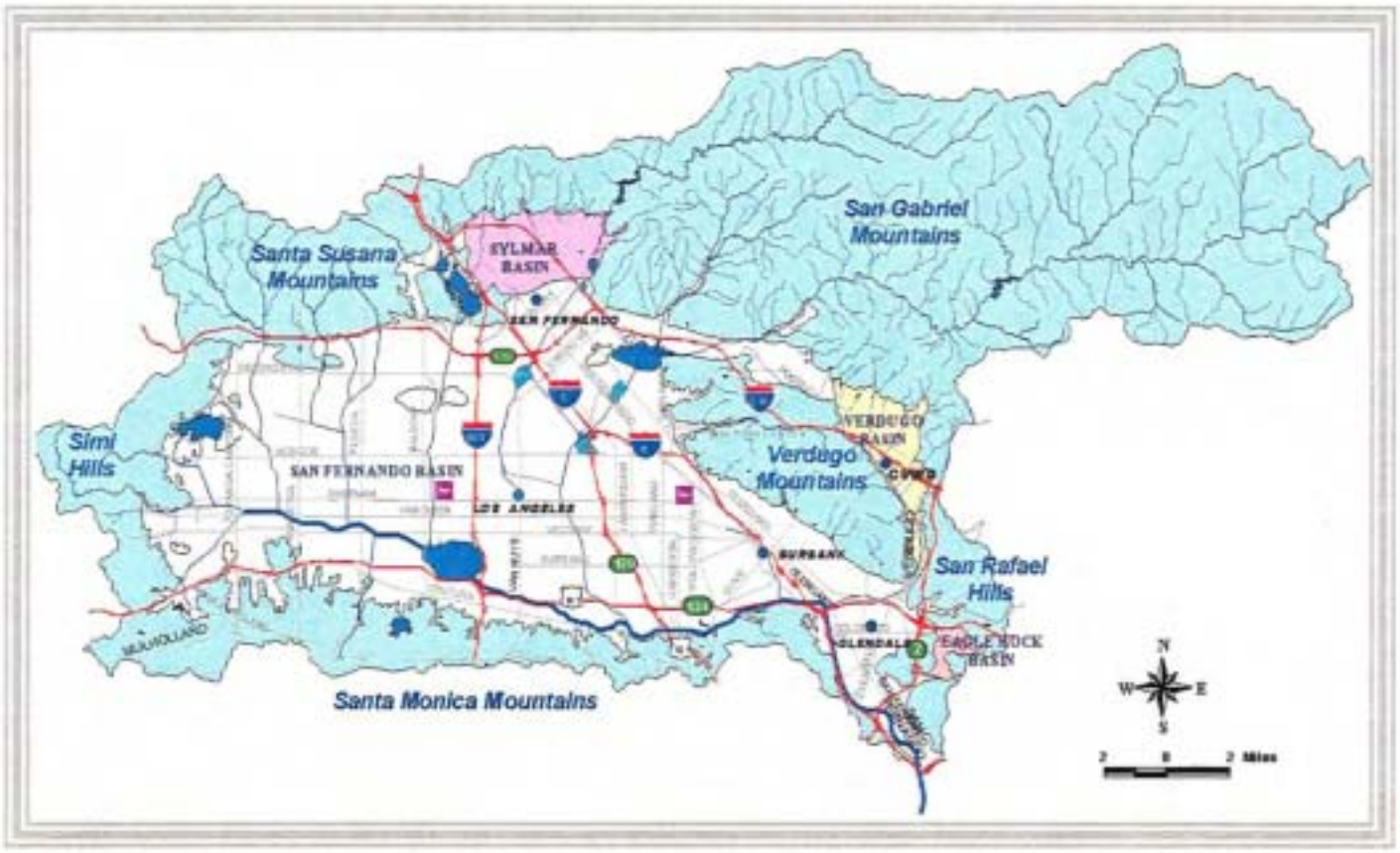
City of Los Angeles vs. City of San Fernando, et al.

Case No. 650079 – County of Los Angeles

WATERMASTER SERVICE
IN THE
UPPER LOS ANGELES RIVER AREA
LOS ANGELES COUNTY, CALIFORNIA

2004-05 WATER YEAR

OCTOBER 1, 2004 – SEPTEMBER 30, 2005



MAY 2006

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UPPER LOS ANGELES RIVER AREA WATERMASTER

CITY OF LOS ANGELES VS. CITY OF SAN FERNANDO, ET AL.
CASE NO. 650079 - COUNTY OF LOS ANGELES

WATERMASTER SERVICE IN THE UPPER LOS ANGELES RIVER AREA LOS ANGELES COUNTY

2004-2005 WATER YEAR
OCTOBER 1, 2004 - SEPTEMBER 30, 2005

ULARA WATERMASTER
Mark Mackowski

ASSISTANT WATERMASTER
Patricia Kuechler

CONSULTANT TO THE WATERMASTER
Melvin L. Blevins, P.E.

GROUNDWATER HYDROLOGY/MODELING CONSULTANT
Hadi Jonny, P.E.

WATERMASTER STAFF

Andy Agra, P.E.	Water Resources Engineer
Vahe Dabbaghian	Water Resources Engineer
Michael Hedvig	Management Assistant
Billie Washington	Clerk Typist

SPECIAL COUNSEL
Frederic A. Fudacz
Alfred E. Smith
of Nossaman, Guthner, Knox, & Elliott, LLP

Copies of this report may purchased for $40.00 (including shipping).
P.O. Box 51111, Room 1450
Los Angeles, CA 90051-0100
213/367-0921 or 213/367-0896

MAY 2006

FORWARD

I am pleased to submit this annual Watermaster Report for the 2004-2005 Water Year in accordance with the provisions of the Final Judgment signed by the Los Angeles Superior Court on January 26, 1979.

This report describes the water rights in each basin, and indicates the water in storage to the credit of each party as of October 1, 2005. In addition, this report includes background information on the history of the San Fernando Case; information regarding each basin in ULARA with respect to water supply, groundwater extractions, groundwater levels, quantities of imported water use, recharge operations, and water quality conditions; and other pertinent information occurring during the 2004-05 Water Year.

Updates on the development of "Significant Events" through April 2006 are discussed in Section 1.5. These include chromium and other emerging contaminants in the San Fernando Basin, and the challenges and opportunities presented by urban runoff. We are also happy to announce our new internet web site at www.ularawatermaster.com.

Our most significant long-term challenges continue to be the contamination of groundwater in the San Fernando Basin (SFB); and the decline in stored groundwater in the SFB and Verdugo Basins.

In partnership with the United States Environmental Protection Agency (USEPA) and the Los Angeles Regional Water Quality Control Board (RWQCB), the Cities of Los Angeles, Burbank, and Glendale continue their efforts to remediate groundwater contaminated with volatile organic compounds (VOCs) and hexavalent chromium, and identify the responsible parties. The City of Glendale continues its groundbreaking study of ion exchange technology to remove hexavalent chromium from groundwater in the SFB, and hopes to install a wellhead treatment system within the next year.

The Crescenta Valley Water District (CVWD) has taken the lead on a study of the Verdugo Basin that includes groundwater modeling and geophysical mapping. This study will give us a better understanding of basin geology and hydrology, and will provide guidance to CVWD and the City of Glendale for the location of future recharge and extraction facilities. The Watermaster and the Cities of Los Angeles, Glendale, and Burbank have begun discussions regarding the cause and effect of a decline in stored groundwater and the accumulation of a large amount of Stored Water Credits in the SFB. I am hopeful that this process will lead to improved basin management and long-term sustainability of water resources in the SFB.

To provide groundwater management for the ULARA basins, the Watermaster and Administrative Committee met on a quarterly basis during 2004-2005. As provided in Section 5.4 of the ULARA Policies and Procedures, the eleventh ULARA Groundwater Pumping and Spreading Plan was completed and filed with the Court in July 2005.

We welcome the new members to the Administrative Committee from the City of San Fernando: Mr. Ron Ruiz, Director of Public Works, and Mr. Daniel Wall, City Engineer. We also welcome Mr. Raul Garibay for the City of Burbank.

I thank the Court and the Administrative Committee for their continued confidence and support. I also wish to acknowledge and express appreciation to all the parties who have provided information and data that were essential to the completion of this report.

MARK G. MACKOWSKI
ULARA Watermaster

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I. INTRODUCTION

1. INTRODUCTION

1.1 Background

The Upper Los Angeles River Area (ULARA) encompasses the entire watershed of the Los Angeles River and its tributaries above a point in the river designated as Los Angeles County Department of Public Works (LACDPW) Gaging Station F-57C-R, near the junction of the Los Angeles River and the Arroyo Seco (Plates 1 and 5). ULARA encompasses 328,500 acres, composed of 122,800 acres of valley fill, referred to as the groundwater basins, and 205,700 acres of tributary hills and mountains. ULARA is bounded on the north and northwest by the Santa Susana Mountains; on the north and northeast by the San Gabriel Mountains; on the east by the San Rafael Hills, which separate it from the San Gabriel Basin; on the south by the Santa Monica Mountains, which separate it from the Los Angeles Coastal Plain; and on the west by the Simi Hills.

ULARA has four distinct groundwater basins. The water supplies of these basins are separate and are replenished by deep percolation from rainfall, surface runoff and from a portion of the water that is delivered for use within these basins. The four groundwater basins in ULARA are the San Fernando, Sylmar, Verdugo, and Eagle Rock Basins.

THE SAN FERNANDO BASIN (SFB), the largest of the four basins, consists of 112,000 acres and comprises 91.2 percent of the total valley fill. It is bounded on the east and northeast by the San Rafael Hills, Verdugo Mountains, and San Gabriel Mountains; on the north by the San Gabriel Mountains and the eroded south limb of the Little Tujunga Syncline which separates it from the Sylmar Basin; on the northwest and west by the Santa Susana Mountains and Simi Hills, and on the south by the Santa Monica Mountains.

THE SYLMAR BASIN, in the northerly part of ULARA, consists of 5,600 acres and comprises 4.6 percent of the total valley fill. It is bounded on the north and east by the San Gabriel Mountains; on the west by a topographic divide in the valley fill between the Mission Hills and the San Gabriel Mountains; on the southwest by the Mission Hills; on the east by the bedrock of Saugus Formation along the east bank of the Pacoima Wash; and on the south by the eroded south limb of the Little Tujunga Syncline, which separates it from the SFB.

THE VERDUGO BASIN, north and east of the Verdugo Mountains, consists of 4,400 acres and comprises 3.6 percent of the total valley fill. It is bounded on the north by the San

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Gabriel Mountains; on the east by a groundwater divide separating it from the Monk Hill Subarea of the Raymond Basin; on the southeast by the San Rafael Hills; and on the south and southwest by the Verdugo Mountains.

THE EAGLE ROCK BASIN, the smallest of the four basins, is in the extreme southeast corner of ULARA. It consists of 800 acres and comprises 0.6 percent of the total valley fill.

1.2 History of Adjudication

The water rights in ULARA were established by the JUDGMENT AFTER TRIAL BY COURT in Superior Court Case No. 650079, entitled The City of Los Angeles, a Municipal Corporation, Plaintiff, vs. City of San Fernando, et al., Defendants, signed March 14, 1968, by the Honorable Edmund M. Moor, Judge of the Superior Court. Numerous pretrial conferences were held subsequent to the filing of the action by the City of Los Angeles in 1955 and before the trial commenced on March 1, 1966.

On March 19, 1958, an Interim Order of Reference was entered by the Court directing the State Water Rights Board, now known as the State Water Resources Control Board (SWRCB), to study the availability of all public and private records, documents, reports, and data relating to a proposed order of reference in the case. The Court subsequently entered an "Order of Reference to State Water Rights Board to Investigate and Report upon the Physical Facts (Section 2001, Water Code)" on June 11, 1958.

A final Report of Referee was approved on July 27, 1962 and filed with the Court. The Report of Referee made a complete study of the geology, insofar as it affects the occurrence and movement of groundwater and the surface and groundwater hydrology of the area. In addition, investigations were made of the history of channels of the Los Angeles River and its tributaries; the areas, limits, and directions of flow of all groundwater within the area; the historic extractions of groundwater in the basin and their quality; and all sources of water, whether they be diverted, extracted, imported, etc. The Report of Referee served as the principal basis for geological and hydrological facts for the original Trial Court Judgment in 1968, the Decision of the Supreme Court in 1975 (14 Cal 3d 199, 123 Cal Rept 1), and the Trial Court Final Judgment on remand on January 26, 1979.

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The Trial Court issued its opinion on March 15, 1968. The City of Los Angeles filed an appeal from the Judgment of the Trial Court with the Court of Appeal, which held a hearing on November 9, 1972, and issued its opinion on November 22, 1972. The opinion, prepared by Judge Compton and concurred in by Judges Roth and Fleming, reversed, with direction, the original judgment handed down by Judge Moor. In essence, the City of Los Angeles was given rights to all water in ULARA, including the use of the underground basins with some limited entitlements to others. The defendants, however, were given the right to capture "return water", which is water purchased from the Metropolitan Water District of Southern California (MWD) that percolates into the basin.

A petition for rehearing was filed on December 7, 1972, but was denied by the Court of Appeal. On January 2, 1973, the defendants filed a petition for hearing with the State Supreme Court. The Court on March 7, 1973 advised the parties it would hear the case. The hearing began on January 14, 1975.

On May 12, 1975, the California Supreme Court filed its opinion on the 20-year San Fernando Valley water litigation. This opinion, which became final on August 1, 1975, upheld the Pueblo Water Rights of the City of Los Angeles to all groundwater in the SFB derived from precipitation within ULARA. The City of Los Angeles' Pueblo Water Rights were not allowed to extend to the groundwaters of the Sylmar and Verdugo Basins. However, all surface and groundwater underflows from these basins are a part of the Pueblo Waters.

The City of Los Angeles was also given rights to all SFB groundwater derived from water imported by it from outside ULARA and either spread or delivered within the SFB. The Cities of Glendale and Burbank were also given rights to all SFB groundwater derived from water that each imports from outside ULARA and delivered within ULARA. San Fernando was not a member of MWD until the end of 1971, and had never prior thereto imported any water from outside ULARA. San Fernando has no return flow rights based on a stipulation between Los Angeles and San Fernando in the March 22, 1984 amendment to the Final Judgment.

The Supreme Court reversed the principal judgment of the Trial Court and remanded the case back to the Superior Court for further proceedings consistent with the Supreme Court's opinion. On remand the case was assigned to the Honorable Harry L. Hupp, Judge of the Superior Court of Los Angeles County.

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The Final Judgment (Judgment), signed by the Honorable Harry L. Hupp, was entered on January 26, 1979. (Copies of the Judgment are available from the ULARA Watermaster Office.) The water rights set forth in the Judgment are consistent with the opinion of the Supreme Court described above. In addition, the Judgment includes provisions and stipulations regarding water rights, the calculation of imported return water credit, storage of water, stored water credit, and arrangements for physical solution water for certain parties as recommended by the Supreme Court. A separate stipulation was filed in Superior Court on January 26, 1979 appointing Melvin L. Blevins as Watermaster under the Judgment in this case. On September 1, 2003 Mark G. Mackowski was appointed Watermaster by the Superior Court, succeeding Mr. Blevins after 24 years of service as Watermaster.

On August 26, 1983, the Watermaster reported to the Court pursuant to Section 10.2 of the Judgment that the Sylmar Basin was in a condition of overdraft. In response to the Watermaster's letter and a Minute Order of the Court, the Cities of Los Angeles and San Fernando responded by letter to the Court, agreeing with the Watermaster's report on overcraft. On March 22, 1984, Judge Harry L. Hupp signed a stipulation ordering, effective October 1, 1984, that the Cities of Los Angeles and San Fernando would be limited in their pumping to bring the total pumping within the safe yield of the basin, including any rights exercised by private parties.

The following table lists the judges who have succeeded Judge Hupp as Judge of Record for the San Fernando Judgment.

TABLE 1-1: JUDGES OF RECORD

Judge	Date Appointed
Susan Bryant-Deason	January 1, 1999
Ricardo A. Torres	January 1, 1993
Gary Klausner	December 9, 1991
Jerold A. Krieger	April 16, 1991
Sally Disco	May 25, 1990
Miriam Vogel	January 16, 1990
Vernon G. Foster	April 30, 1985

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1.3 Extraction Rights

The extraction rights under the Judgment and Sylmar Basin Stipulation are as follows:

San Fernando Basin

Native Water

Los Angeles has an exclusive right to extract and utilize all the native safe yield water that has been determined to be an average of 43,660 acre-feet per year (AFY). This represents Los Angeles' Pueblo Water Right under the Judgment.

Import Return Water

Los Angeles, Glendale, and Burbank each have a right to extract the following amounts of groundwater from the San Fernando Basin.

Los Angeles: 20.6 percent of all delivered water, including reclaimed water, to valley fill lands of the SFB.

Burbank: 20.0 percent of all delivered water, including reclaimed water, to the SFB and its tributary hill and mountain areas.

Glendale: 20.0 percent of all delivered water, including reclaimed water, to the SFB and its tributary hill and mountain areas.

Physical Solution Water

Several parties are granted limited entitlement to extract groundwater chargeable to the rights of others upon payment of specified charges. Table 1-2 lists the parties and their maximum physical solution quantities.

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TABLE 1-2: PHYSICAL SOLUTION PARTIES

Chargeable Party	Pumping Party	Allowable Pumping (acre-feet)
City of Los Angeles	City of Glendale	5,500
	City of Burbank	4,200
	Middle Ranch	50
	Hathaway	60
	Van de Kamp[1]	120
	Toluca Lake	100
	Sportsmen's Lodge	25
	Water Licenses	83
City of Glendale	Forest Lawn	400
	Angelica Healthcare[2]	75
City of Burbank	Valhalla	300
	Lockheed-Martin	25

1 Van de Kamp has never pumped its physical solution right.

2 Angelica Healthcare no longer pumps its physical solution rights.

Stored Water

Los Angeles, Glendale, and Burbank each have a right to store groundwater and the right to extract equivalent amounts.

Sylmar Basin

Native Water

The March 22, 1984 Stipulation assigned Los Angeles and San Fernando equal rights to the safe yield of the Sylmar Basin. On the recommendation of the Watermaster, on July 16, 1996, the Administrative Committee approved a temporary increase in the safe yield of the basin from 6,210 AF/Y to 6,510 AF/Y. The 10-year period ended on October 1, 2005, triggering a re-evaluation of the safe yield. The results of this re-evaluation will be discussed in the 2007 Watermaster Report; however, for the 2005-06 Water Year, the safe yield will be 6,510 AF.

The only potentially active private party with overlying rights within the Sylmar Basin is Santiago Estates, a successor to Meurer Engineering, M.H.C. Inc.

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Santiago Estates' pumping is deducted from the safe yield and the two cities divide the remainder. Santiago Estates has not pumped since the 1998-99 Water Year.

Stored Water

Los Angeles and San Fernando each have a right to store groundwater by in-lieu practices and the right to extract equivalent amounts.

Verdugo Basin

Native Water

Glendale and the Crescenta Valley Water District (CVWD) have appropriative and prescriptive rights to extract 3,856 and 3,294 AF/Y, respectively.

Stored Water

There are no storage rights in the Verdugo Basin.

Eagle Rock Basin

Native Water

The Eagle Rock Basin has a small native safe yield.

Imported Return Water

Los Angeles delivers imported water to lands overlying the basin, and return flow from this delivered water constitutes the majority of the safe yield of the basin. Los Angeles has the right to extract or allow to be extracted the safe yield of the basin.

Physical Solution Water

DS Waters (successor to Soarkletts and Deep Rock) has physical solution rights to extract groundwater pursuant to a stipulation with the City of Los Angeles, and as provided in Section 9.2.1 of the Judgment.

Stored Water

There are no storage rights in the Eagle Rock Basin.

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1.4 Watermaster Service and Administrative Committee

In preparing the annual Watermaster Report, the Watermaster collected and reported all information affecting and relating to the water supply, water use and disposal, groundwater levels, water quality, and ownership and location of new wells within ULARA. Groundwater pumpers report their extractions monthly to the Watermaster. This makes it possible to update the Watermaster Water Production Accounts on a monthly basis and determine the allowable pumping for the remainder of the year.

Section 8.3 of the Judgment established an Administrative Committee for the purpose of advising the Watermaster in the administration of his duties. The duly appointed members of the Committee, as of May 1, 2006, are:

BURBANK, CITY OF
Bill Mace (Vice-President)
Raul Garibay (Alternate)

GLENDALE, CITY OF
Peter Kavounas (President)
Raja Takidin (Alternate)

SAN FERNANDO, CITY OF
Ron Ruiz
Daniel Wall (Alternate)

LOS ANGELES, CITY OF
Thomas Erb
Mario Acevedo (Alternate)

CRESCENTA VALLEY WATER DISTRICT
Dennis Erdman
David Gould (Alternate)

The Watermaster may convene the Administrative Committee at any time in order to seek its advice. Each year the Committee is responsible for reviewing and approving with the Watermaster the proposed annual report. The Committee met in October, December, February, and April of the 2004-05 Water Year. The Committee approved the 2004-05 Watermaster Report on April 26, 2006.

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1.5 Significant Events through April 2006

Burbank Operable Unit (BOU)

The BOU, operated by Burbank under a contract with ECO Resources, Inc., and funded by Lockheed-Martin, removes volatile organic compounds (VOCs) from elevated nitrate groundwater and then blends it with water from MWD for delivery to the City of Burbank. The City of Burbank, in cooperation with the USEPA and Lockheed-Martin, continued to make design and operational changes in an attempt to bring the facility up to the design capacity of 9,000 gallons per minute (gpm), or 14,000 acre-feet (AF) annually. During the 2004-05 Water Year 6,399 AF of groundwater were treated at the facility. Burbank is also reducing the levels of chromium in its groundwater supply by blending with imported supplies from MWD before delivery to the City of Burbank.

Montgomery Watson Harza (MWH) was hired by Burbank to perform a Well Field Performance Attainment Study that evaluated the well field and appurtenant facilities in an effort to bring production up to 9,000 gpm. Recommendations include drilling more wells and deflating the well packers in the existing wells. The USEPA is reviewing the study. In 2004-05 the USEPA gave conceptual approval for the redesign of screens used in the air-phase granular activated carbon (GAC) vessels.

Glendale Operable Unit (GOU)

The GOU removes VOCs and has the capability of treating up to 5,000 gpm from the Glendale North and South OU Well Fields. Treated water is blended with imported MWD supplies to reduce nitrate and hexavalent chromium levels. The GOU treated 7,541 AF during the 2004-05 Water Year.

The USEPA has accepted Glendale's interim pumping plan in an effort to control chromium levels in the blended plant effluent and to accommodate the loss of pumping from GN-3 which remains non-operational due to a damaged well screen. A repair recommendation is pending. The over-all pumping plan varies from the original Consent Decree pumping pattern, and calls for reduced pumping from higher chromium wells and increased pumping from wells lower in chromium.

Glendale, in cooperation with the cities of Los Angeles, Burbank, San Fernando, and the American Water Works Association Research Foundation (AWWARF) is continuing to perform studies for the large-scale removal of chromium from drinking water. McGuire

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Malcolm Pirnie has identified weak-base anion exchange as a promising chromium removal technology. Unit cost of this technology is currently being evaluated, and wellhead demonstration-scale testing will be initiated when funding is secured.

North Hollywood Operable Unit (NHOU)

LADWP's NHOU, funded in part by a USEPA Consent Decree, is designed to remove VOCs at a rate of 2,000 gpm using a system of seven extraction wells and an air-stripping tower. The 15-year Consent Decree expired on December 31, 2004. The USEPA has stated that there are sufficient funds to continue operation and maintenance of the NHOU into 2008. However, the remedy did not perform as expected, and some VOCs have been detected at nearby LADWP well fields. The USEPA, LADWP, and the Watermaster are currently evaluating additional treatment and funding alternatives. A total of 1,042 AF were treated during the 2004-05 Water Year.

Pollock Wells Treatment Plant

LADWP's Pollock Wells Treatment Plant uses three wells and four liquid-phase GAC vessels to remove VOCs at a design rate of 3,000 gpm. The primary purpose of the facility is to prevent the loss of groundwater through the Los Angeles River Narrows due to rising groundwater outflow. An evaluation of the Pollock area was performed in 1990 that showed approximately 2,000 AF/Y of excess rising groundwater occurring in the Los Angeles river Narrows as a result of delivered water, precipitation, and percolation along the unlined portion of the river upstream of the Narrows. This is part of Los Angeles' water right, and it is lost from the SFB in the absence of pumping at the Pollock Wells.

During Water Year 2004-05 a total of 1,752 AF of groundwater was pumped and treated. As a result of excess rising groundwater, the Watermaster debited Los Angeles 217.56 AF (Appendix F).

Verdugo Park Water Treatment Plant

The City of Glendale Verdugo Park Water Treatment Plant treats groundwater from the Verdugo Basin for turbidity and bacteria, and is operating at 500 gpm instead of the expected 700 gpm. Methods to increase the efficiency of the groundwater collection system are being investigated. A total of 700 AF were treated in the 2004-05 Water Year.

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Glenwood Nitrate Removal Plant

CVWD's Glenwood Nitrate Removal Plant treated 782 AF during the 2004-05 Water Year. The amount of treated water is more than three times the previous year due to the higher water table in the Verdugo Basin, which enabled CVWD to increase its pumping.

Verdugo Basin Evaluation

In June 2003 CVWD obtained an AB 303 grant to determine the cause(s) of the decline in Verdugo Basin groundwater levels, develop alternatives to reverse the decline, enhance conjunctive use of the basin, and reduce CVWD's reliance on imported supplies. The Watermaster and the City of Glendale serve on the Technical Advisory Committee. A final report was completed in May 2005 that identified several possible sites at which storm water recharge can be maximized. In October 2005 CVWD began the Verdugo Basin Geophysical Evaluation Project to guide CVWD in the selection of sites for future supply wells and recharge facilities. Both studies have been funded with AB 303 grants.

CVWD Over-Pumping in the Verdugo Basin

During the 2004-05 Water Year CVWD pumped a total of 3,310 AF, which was 16 AF (0.5%) above its adjudicated right of 3,294 AF/Y. Glendale pumped a total of 2,358 AF, which was 61% of its adjudicated right of 3,856 AF/Y.

In September 2005, prior to the end of the 2004-05 Water Year, CVWD alerted the Watermaster that it would exceed its adjudicated right by about 50 AF. The Watermaster suggested that CVWD contact Glendale regarding pumping Glendale's right, as Glendale had not yet pumped its full adjudicated right in 2004-05. CVWD contacted Glendale regarding this issue and Glendale requested that CVWD pay Glendale for pumping the unused portion of Glendale's right. No agreement was reached.

The San Fernando Judgment (Sections 6.4 and 6.7) enjoins both CVWD and Glendale from over-pumping in excess of their adjudicated rights in the Verdugo Basin. The Watermaster's Policies and Procedures dated February 1998 (Section 2.3.4) permit pumping of any unused portion of the other party's rights, but only with the Watermaster's approval. CVWD neither requested, nor received the Watermaster's approval prior to the close of the 2004-05 Water Year.

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Due to a combination of lack of available supply, and low water levels, Glendale has never pumped its full adjudication of 3,656 AF/Y. Glendale has expressed its intention to increase its production capacity in the Verdugo Basin and anticipates utilizing its full adjudicated right in the near future. Although there are no Stored Water Credits in the Verdugo Basin, Glendale believes that any over-pumping by CVWD may impair Glendale's ability to pump the full quantity of its right in the future.

On February 21, 2006, after failing to reach agreement with Glendale, CVWD formally requested the Watermaster's retroactive approval for its 2004-05 over-pumping. The Watermaster has not yet acted on CVWD's request. The Watermaster has requested that CVWD and Glendale continue to attempt to reach agreement regarding the over-pumping.

Glendale and CVWD have initiated discussions with respect to CVWD's 2004-05 over-pumping and any proposed over-pumping in the future. CVWD and Glendale have agreed in concept to perform a joint study that will utilize the Verdugo Basin Groundwater Model and data obtained from the Verdugo Basin Geophysical Study to assist in managing the basin and optimizing pumping strategies for each agency.

Reclamation Projects in the San Fernando Valley

LADWP has plans to connect large recycled water customers over the next three years including the Hansen Dam Recreation Area, Valley Generating Station and Angeles National Golf Course in the eastern portion of the Valley, and the Sepulveda Basin and Pierce College in the southern portion of the Valley. Smaller users in the vicinity of these pipelines will also be connected over time with the present goal of fully utilizing the 10,000 AF/Y originally intended for groundwater recharge as part of the East Valley Water Recycling Project.

Hansen Area Water Reclamation Project Phase I consists of approximately one-half mile of 30-inch pipeline and a 7-million gallon storage tank. The primary purpose of this project is to deliver recycled water to the Valley Generating Station for cooling tower and other industrial uses. The project is scheduled to be in service in 2006.

The Hansen Area Water Reclamation Project Phase II will consist of a booster pumping station adjacent to the proposed 7-million gallon recycled water storage tank at the

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Valley Generating Station, and a pipeline extending to the Hansen Dam Recreation Area and other areas.

The Sepulveda Basin Water Recycling project is designed to provide recycled water for irrigation throughout the Sepulveda Basin Recreation Area including Woodley Golf Course, Lake Balboa Recreation Area, Wildlife Area, Balboa and Encino Golf Courses, Balboa Sports Center, and Hjelte Park. The Woodley Park, West Valley Youth Baseball, and the proposed Sports Concession will be connected to the South Valley Water Recycling Project pipeline scheduled to be in service late 2007 or early 2008. Delivery to Woodley Golf Course is scheduled to begin in 2006 as soon as regulatory permitting issues are resolved.

The South Valley Water Reclamation Project includes construction of a 13-mile long pipeline from Warner Center to North Hollywood to deliver recycled water to serve irrigation and industrial users near the pipeline route including Pierce College, the Metropolitan Transportation Authority bus way currently under construction, and various park facilities.

Headworks

The Headworks Spreading Grounds is the site of multi-objective projects to improve water quality and storage, and to provide the community with an opportunity for passive recreation. LADWP has completed the preliminary design and is in the process of completing the Environmental Impact Report for the Silver Lake Reservoir Complex Storage Replacement Project in order to comply with the Stage 2 Disinfection By-Products Rule and the Long-Term 2 Enhanced Surface Water Treatment Rule. The project will remove Silver Lake and Ivanhoe Reservoirs from service as potable water reservoirs, provide potable water storage in a buried 110 million gallon reservoir located at the Headworks Spreading Grounds, and provide for hydropower generation.

The other Headworks component is the proposed wetlands project that is a joint effort between LADWP and the Army Corps of Engineers. A feasibility study for the wetlands habitat is currently underway.

Tujunga Spreading Grounds Task Force

The Watermaster initiated the Tujunga Spreading Grounds Task Force in May 1998. The use of the Tujunga Spreading Grounds has been significantly reduced in above-

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normal runoff years because of environmental issues associated with methane gas migration from the nearby Sheldon-Arleta Landfill. The purpose of the task force is to restore the historic recharge capacity; enhance methane gas control and monitoring; and improve storm water management. The task force consists of representatives of the Los Angeles County Department of Public Works (LACDPW), Los Angeles Bureau of Sanitation, LADWP, and the Watermaster Office. During a study in May 2003, a consultant analyzed the impact of a controlled release of native water from the Big Tujunga Dam to test the gas collection system at the Sheldon-Arleta Landfill. Preliminary results suggested that a release of 100 cubic feet per second (cfs) into the spreading grounds over a one week period has no negative impact on the methane gas movement. Heavy storms in January 2005 confirmed that spreading in excess of 100 cfs caused methane migration from the landfill. Future planned modifications include installing additional methane collection wells. A methane gas collection system has been designed and bids accepted for construction. The bids came in much higher than estimated and have been rejected. A re-advertisement of the project is pending with a new award date anticipated in August 2006. The goal is to restore recharge capacity at the Tujunga Spreading Grounds to 250 cfs.

San Fernando Basin Recharge Task Force

In 2004 the Watermaster formed the San Fernando Basin Recharge Task Force in an effort to increase spreading of native water in the SFB. The Task Force includes LADWP, LACDPW, and Watermaster. The goal of the task force is to identify ways to capture and infiltrate more rainfall runoff.

Above-normal rainfall during the 2004-05 Water Year resulted in spreading more than 74,000 AF of runoff by LACDPW. However, artificial recharge at Hansen Spreading Grounds was curtailed in January 2005 when seepage was observed on the face of a 200'-high cut slope in the adjacent Boulevard Pit, which is owned and operated by Vulcan Materials Company as a source of sand and gravel. There was concern that this spreading-related seepage could destabilize the slope, so LACDPW confined spreading for several months to the basins furthest from Boulevard Pit. The reduced spreading resulted in a lost opportunity for LACDPW to conserve additional runoff, which benefits the City of Los Angeles under its Pueblo right.

Over the next several months, Vulcan submitted geotechnical reports to the City of Los Angeles Department of Building and Safety (LADBS) related to the stability of the slope

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in the Boulevard Pit. On February 2, 2006 LADBS issued a letter stating that the slope was stable and that no additional work was necessary. During a Task Force meeting on March 9, 2006 LACDPW agreed to resume full spreading at Hansen Spreading Grounds as runoff becomes available.

Big Tujunga Dam Seismic Rehabilitation

The Big Tujunga Dam Retrofit Proposal Planning and Coordination Task Force has been meeting for several years to discuss the operation of the dam during seismic retrofit construction and after the retrofit completion. The task force includes representatives from the Federal Emergency Management Agency (FEMA), United States Forest Service (USFS), United States Fish and Wildlife Service (USFWS), California Department of Fish and Game, LACDPW, LADWP, and the Watermaster Office.

The USFS and USFWS are mandated to protect the Santa Ana Sucker (SAS) under the Endangered Species Act. They view the dam retrofit as an opportunity to reduce peak flows during the winter to prevent damage to the SAS and its habitat, and to provide low flows during the dry summer season to prevent the stream bed from drying out and adversely impacting the population of SAS.

The LACDPW is required by law to operate the dam to protect life and property from flooding. Furthermore, the LACDPW, LADWP, and Watermaster view the retrofit as an opportunity to conserve more native water, which belongs to the City of Los Angeles under its Pueblo Right.

If large controlled releases are not allowed during the winter storm season, the limited storage capacity of the reservoir could cause uncontrolled releases over the dam spillway, resulting in flood damage to property and SAS habitat along Tujunga Wash. If small releases from the dam are required during the dry summer months, this water may not reach the spreading grounds where it recharges the SFB. Small releases from the dam percolating into the stream channel alluvium will be delayed many years before reaching the SFB and becoming available to pump at the production well fields.

In November 2004 FEMA terminated its OES/FEMA Hazard Mitigation Grant of $5.4 million for the seismic retrofit project, citing a 10-year period during which the project was not constructed and the probability of further delays. Without FEMA funding the

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project will probably not go forward. LACDPW appealed the FEMA decision with supporting letters from the Watermaster and other agencies.

In April 2005 LACDPW was informed that FEMA had reinstated the grant funding. However, in the meantime the project cost had risen to approximately $78 million due to increased material costs, high demand for large-scale civil construction contractors, and for additional project scope (left abutment stabilization).

To date, a total of $12 million has been secured, and LACDPW has requested additional funding from the California Department of Water Resources and from the City of Los Angeles Proposition O funds.

Due to significantly higher construction costs there is some uncertainty whether this project will be built unless additional outside funding can be secured. The project is tentatively scheduled to begin construction in summer 2006 and would be completed in about three years

Standard Urban Stormwater Mitigation Plan (SUSMP)

The RWQCB adopted SUSMP on March 8, 2000. It requires some new developments and redevelopments to contain or treat the first ¾-inch of rainfall runoff from every storm, and encourages on-site infiltration. The Watermaster placed a temporary moratorium on urban stormwater infiltration in the San Fernando Basin due to concerns over potential impacts on groundwater quality. For the past several years we have been monitoring water quality data from several demonstration sites, and have determined that infiltration in residential and light commercial areas can be safely accomplished under certain conditions. The Watermaster is currently working with the City of Los Angeles' Watershed Protection Division to allow infiltration if those criteria are met.

Sun Valley Watershed Committee

The Watermaster Office is a stakeholder on the Sun Valley Watershed Committee. The objective of the group is to identify alternative ways to solve the local flooding problems in the Sun Valley area. These alternatives could replace or augment the traditional approach of an improved storm drain system. Some of the alternatives include on-site infiltration of storm runoff and the acquisition of gravel pits for conversion into spreading basins. The storm runoff contains contaminants that are potentially adverse to water quality in the basin. The Watermaster is concerned about potential impacts to

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groundwater quality as well as conflicts with established water rights, but is working closely with the committee to resolve these issues. The Sun Valley Watershed Project Environmental Impact Report was approved by the Los Angeles County Board of Supervisors on June 29, 2004. An infiltration gallery at Sun Valley Park is currently under construction, and additional infiltration demonstration projects are being planned or are in the design phase including the stormwater project at the LADWP Valley Generating Station.

Water Augmentation Study (WAS)

The Los Angeles and San Gabriel Rivers Watershed Council has developed a WAS to determine the feasibility of infiltrating urban runoff to reduce local flooding, recharge groundwater, and reduce surface water pollution. The Watermaster serves on the Technical Advisory Committee and provides guidance with respect to water quality and water rights within ULARA. The WAS now has six sites throughout the greater Los Angeles area where it infiltrates urban stormwater and monitors the effects on underlying groundwater. These demonstration sites have given us a better understanding of the effects on groundwater quality, and an increased level of confidence in the use of urban runoff to augment recharge of our local aquifers.

Integrated Resources Plan (IRP)

The IRP is Los Angeles' plan to integrate its wastewater, storm water, potable water, and reclaimed water programs for the next 20 years. Phase I, the Integrated Plan for Wastewater Program, emphasized community outreach to help direct the program and was completed in 2001. The goal of Phase II is to develop and implement the program. The IRP uses a broader "watershed" approach to promote more efficient use of all water within the City. The Watermaster serves on the Management Advisory Committee and guides the process with respect to water rights and water quality within ULARA. The draft Environmental Impact Report has been written and distributed for public review.

The Los Angeles Unified School District IRP has been formed to ensure that new and retrofitted schools conform to the overall goals of the City's IRP.

Los Angeles River Revitalization Master Plan

In 2002, Councilman Ed Reyes led efforts to establish the Los Angeles City Council Ad Hoc Committee on the Los Angeles River to function as a clearinghouse for Los Angeles

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River projects, to encourage community involvement in Los Angeles River improvements, and to help coordinate Los Angeles River-related projects within the City.

One of the most exciting initiatives started over the last three years by the Ad Hoc River Committee is the Los Angeles River Revitalization Master Plan. As a result of the Ad Hoc River Committee's efforts, and with funding from the Los Angeles Department of Water and Power, the City of Los Angeles' Department of Public Works-Bureau of Engineering issued a Request for Proposals in 2005 for the preparation of a Revitalization Master Plan which would identify proposals that would make the Los Angeles river a "front door" to the City, and support a multitude of civic activities.

The 18-month Revitalization planning process will look at improvements along the project area all aimed towards celebrating neighborhoods, protecting wildlife, promoting the health of the river, and leveraging economic development. By the end of the planning process, a 20-year blueprint for development and management of the Los Angeles River will be developed for implementation by the City of Los Angeles.

To learn more about this effort and how you can participate please visit www.lariverrmp.org.

Integrated Regional Water Management Plan (IRWMP)

The County of Los Angeles has been organized into five sub-regions to more efficiently and effectively develop proposals to request Proposition 50 funds for the region. The sub-regional districts are: North Santa Monica Bay Watersheds; Upper San Gabriel River and Rio Hondo River Watersheds; Upper Los Angeles River Watershed; Lower San Gabriel and Los Angeles River Watersheds; and South Bay Watersheds. The sub-regions have until January 1, 2007 to develop proposals that are integrated to maximize regional benefits, prioritize project approaches, select priority projects, hold public hearings, and finalize and adopt the IRWMP for submission to the State.

Dewaterers

The groundwater table in parts of the SFB is near the ground surface. Dewatering is occasionally required to maintain subsurface structures. If dewatering is needed, the dewaterer is required to meter the discharge and enter into an agreement with the

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affected party for payment for the pumped water. The Watermaster Office currently receives reports from several dewaterers in the SFB.

Water Licenses

Portions of ULARA located in unincorporated Los Angeles County are without water service. Working in cooperation with the County Department of Health Services and County Planning, the Watermaster and LADWP have developed a process to identify and monitor water usage through a water license agreement. The agreements allow the use of groundwater on overlying property until a water service becomes available, establish maximum annual groundwater usage, and require the monthly reporting of groundwater production to the Watermaster Office and annual payment to the City of Los Angeles

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1.6 Summary of Water Supply, Operations, and Hydrologic Conditions

Highlights of operations for the 2003-04 and 2004-05 Water Years are summarized in Table 1-3. Details of the 2004-05 Water Year operations and hydrologic conditions are provided in Section 2. Locations of the groundwater basins, water service areas of the parties and individual producers, and other pertinent hydrologic facilities are shown on Plates 2 through 8.

Average Rainfall

Precipitation on the valley floor area during the 2004-05 Water Year was 42.64 inches, 259 percent of the calculated 100-year mean (16.48 inches). Precipitation in the mountain areas was 47.54 inches, 218 percent of the calculated 100-year mean (21.76 inches). The weighted average of 45.66 inches is 232 percent of the 100-year mean (21.22 inches).

Spreading Operations

A total of 74,198 AF of water were spread. This represents a significant increase from the average annual spreading of native water for the 1968-2005 period of 26,294 AF.

Extractions

Total extractions amounted to 77,995 AF. This is a decrease of 22,761 AF from 2003-04, and less than the 1968-2005 average of 97,439 AF. Of the total for the 2004-05 Water Year, 3,352 AF were for non-consumptive use. Appendix A contains a summary of groundwater extractions for the 2004-05 Water Year.

Imports

Gross imports (including pass-through water) totaled 551,007 AF, a decrease of 52,370 AF from 2003-04. Net imports used within ULARA amounted to 311,988 AF, a 18,899 AF decrease from 2003-04.

Exports

A total of 284,178 AF were exported from ULARA. Of the 284,178 AF exported, 45,159 AF were from groundwater extractions, and 239,019 AF were from imported supplies (pass-through).

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Treated Wastewater

A total of 87,498 AF of wastewater were treated in ULARA. The majority of the treated water was discharged to the Los Angeles River, a portion was delivered to the Hyperion Treatment Plant, and approximately 6 percent was used as recycled water.

Recycled Water

Total recycled water used in ULARA was 5,643 AF, a 1,756 AF decrease from last year. The recycled water is used for landscape irrigation, in-plant use, power plant use (i.e. cooling), and other industrial uses.

Sewage Export

Sewage export was estimated at 104,768 AF; this was the amount of untreated sewage delivered by pipeline to the Hyperion Treatment Plant. The estimate does not include treated wastewater discharged to the Los Angeles River that leaves ULARA as surface flow.

Groundwater Storage

Groundwater storage in the SFB during 2004-05 increased by 66,476 AF with the total cumulative increase in groundwater storage since October 1, 1968 of 150,895 AF. The 2004-05 change in storage increased due primarily to the effect of the near historic high rainfall, a significant increase in spread water, and reduced pumping by the City of Los Angeles. The calculated change in groundwater storage for the Sylmar, Verdugo, and Eagle Rock Basins was +6,694, +9,638, and +169 AF, respectively.

Wells

During the 2004-2005 Water Year no new municipal wells were drilled or destroyed. Forest Lawn Cemetery destroyed Well No. 2 (3947A) and drilled replacement Well No. 8 (3947M).

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TABLE 1-3: SUMMARY OF OPERATIONS IN ULARA

Item	Water Year 2003-04	Water Year 2004-05
Active Pumpers (parties and nonparties)	30	31
Inactive Pumpers (parties)[1]	6	7
Valley Rainfall, in inches		
Valley Floor	9.52	42.64
Mountain Area	13.04	47.54
Weighted Average	12.2[illegible]	45.66
Spreading Operations, in acre-feet	16,065	74,198
Extractions, in acre-feet		
Used in ULARA	34,675	32,836
Exported from ULARA	66,08[illegible]	45,159
Total	**100,758**	**77,995**
Gross Imports, in acre-feet		
Los Angeles Aqueduct Water	212,805	335,617
MWD Water	390,572	215,390
Total	**603,377**	**551,007**
Exports, in acre-feet		
Los Angeles Aqueduct Water	97,545	168,898
MWD Water	[illegible]74,944	70,121
Groundwater	66,081	45,159
Total	**338,571**	**284,178**
Net Imports Used in ULARA, in acre-feet	330,887	311,988
Recycled Water Use, in acre-feet	7,399	5,643
Total Water Use in ULARA, in acre-feet[2]	372,961	350,467
Treated Wastewater, in acre-foot[3]	90,546	87,498
Sewage Export to Hyperion, in acre-feet[4]	103,744	104,768

1. The seven inactive pumpers are Van de Kamp, Disney, Angelica, Santiago Estates, Greef, Sears, Waste Management
2. Extractions used in ULARA plus Net Imports and Recycled Water.
3. Most treated wastewater flows to LAR, a portion to Hyperion (see T2-7), and for recycled water
4. Sewage outflow includes estimates of outflow from each of the four basins, and discharges to Hyperion from the Tillman and Los Angeles-Glendale Water Reclamation Plants

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1.7 Allowable Pumping for the 2005-06 Water Year

Table 1-4 shows a summary of extraction rights for the 2005-06 Water Year and stored water credit as of October 1, 2005, for the Cities of Los Angeles, Burbank, Glendale, San Fernando, and the CVWD. The calculation of these values is shown in more detail in Section 2.

TABLE 1-4: ALLOWABLE PUMPING 2005-06 WATER YEAR

(acre-feet)

	Native Safe Yield Credit [1]	Import Return Credit [2]	Total Native + Import	Stored Water Credit [3] (as of Oct. 1, 2005)	Allowable Pumping 2005-06 Water Year
San Fernando Basin					
City of Los Angeles	43,650	43,291	86,941	325,739	412,680
City of Burbank	--	4,350	4,350	20,191	24,541
City of Glendale	--	5,547	5,547	64,103	69,650
Total	43,650	53,175	96,838	410,033	506,871
Sylmar Basin					
City of Los Angeles	3,255	--	3,255	9,448	11,703
City of San Fernando	3,255	--	3,255	339	3,594
Total	6,510	--	6,510	9,787	15,297
Verdugo Basin					
CVWD	3,294	--	3,294	--	3,294
City of Glendale	3,856	--	3,856	--	3,856
Total	7,150	--	7,150	--	7,150

1) Native Safe Yield extraction right per Judgment, page 11
2) Import Return extraction right per Judgment, page 17.
3) There is no Stored Credit assigned in Verdugo Basin

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2. WATER SUPPLY, OPERATIONS, AND HYDROLOGIC CONDITIONS

2. WATER SUPPLY, OPERATIONS, AND HYDROLOGIC CONDITIONS

2.1 Precipitation

Precipitation varies considerably throughout ULARA depending on topography and elevation. Mean seasonal precipitation ranges from about 14 inches at the western end of the San Fernando Valley to 33 inches in the San Gabriel Mountains. Approximately 50 percent of the annual rainfall occurs from December through March.

In the 2004-05 Water Year the valley floor received 42.64 inches of rain (259 percent of the 100-year mean), while the mountain area received 47.54 inches (218 percent of the 100-year mean). Figure 2-1 shows monthly valley floor and mountain area rainfall in Ul ARA. The weighted average of both valley and mountain areas was 45.66 inches (232 percent of the 100-year mean). Table 2-1 shows a record of rainfall at the valley and mountain precipitation stations, and Plate 5 shows their locations.

FIGURE 2-1: MONTHLY RAINFALL

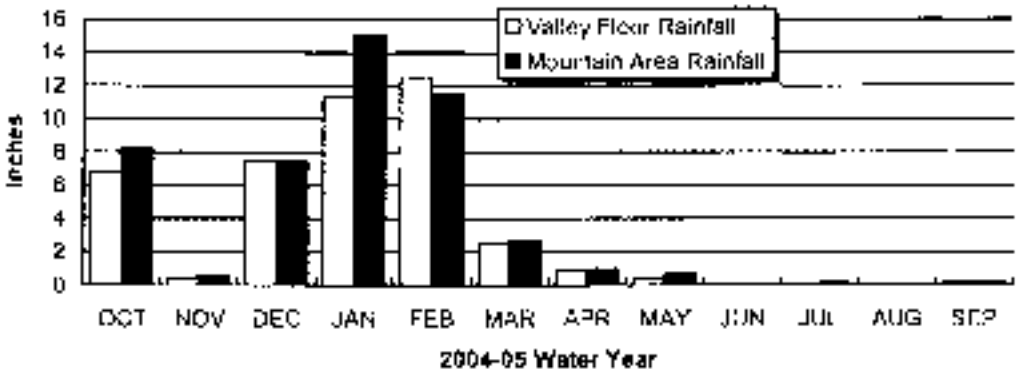

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TABLE 2-1: 2004-2005 PRECIPITATION

(inches)

LACDPW Rain Gage Stations No.	Name	2004-05 Precipitation	100-Year Mean (1881-1981)	Percent of 100-Year Mean
	Valley Stations			
13C	North Hollywood-Lakeside	51.97	16.63	313%
1067D	Green Verdugo Pumping Plant	45.93	14.98	307%
465C	Sepulveda Dam	38.65	15.30	253%
21B	Woodland Hills	38.71	14.60	265%
23B	Chatsworth Reservoir	30.92	15.19	204%
25C	Northridge-LADWP	34.43	15.16	227%
251C	La Crescenta	53.74	23.31	231%
293B	Los Angeles Reservoir	42.28	17.32	244%
	Weighted Average[1]	**42.64**	**16.46**	**259%**
	Mountain Stations			
11D	Upper Franklin Canyon Reservoir	54.11	16.50	292%
17	Sepulveda Canyon at Mulholland	55.30	16.84	328%
33A	Pacoima Dam	46.90	19.64	239%
47D	Clear Creek - City School	77.80	33.01	236%
53D	Monte Cristo Ranger Station	37.08	29.04	128%
54C	Loomis Ranch-Alder Creek	44.46	18.62	239%
210C	Brand Parks	40.60	19.97	203%
797	DeSoto Reservoir	31.36	17.52	179%
1074	Little Gleason	49.84	21.79	229%
	Weighted Average[1]	**47.54**	**21.76**	**218%**
	Weighted Average Valley/Mountain Areas[1]	**45.66**	**19.64**	**232%**

1. Weighted Average calculations performed according to Report of Referee-7/82. Mountain Station Weighted Average estimated due to incomplete data.

2.2 Runoff and Outflow from ULARA

The watershed of ULARA contains 328,500 acres, of which 205,700 acres are hills and mountains. The drainage system is made up of the Los Angeles River and its tributaries. Surface and sub-surface flow originates as runoff from the hills and mountains, runoff from the impervious areas of the valley, industrial and sanitary waste discharges, domestic irrigation runoff, and rising groundwater.

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A number of stream-gaging stations are maintained throughout ULARA, either by the LACDPW or the United States Geological Survey (USGS). The Watermaster has selected six key gaging stations which record runoff from the main hydrologic areas in ULARA (Plate 5 shows the location of the stations). The six gaging stations are as follows:

1. Station F-57C-R registers all surface outflow from ULARA.

2. Station F-252-R registers flow from Verdugo Canyon which includes flows from Dunsmore and Pickens Canyons.

3. Station E-285-R registers flow from the westerly slopes of the Verdugo Mountains and some flow from east of Lankershim Boulevard. It also records any releases of reclaimed wastewater discharged by the City of Burbank.

4. Station F-300-R registers all flow east of Lankershim Boulevard plus the portion of outflow from Hansen Dam which is not spread. These records also include flow through the Sepulveda Dam.

5. Station F-168-R registers all releases from Big Tujunga Dam, which collects runoff from the watershed to the northeast. Runoff below this point flows to Hansen Dam.

6. Station F-118B-R registers all releases from Pacoima Dam. Runoff below this point flows to the Los Angeles River through lined channels, or can be diverted to the Lopez and Pacoima Spreading Grounds.

Table 2-2 summarizes the 2003-04 and 2004-05 monthly runoff for these stations. The high runoff in 2004-05 is related to the historic high rainfall. The mean daily discharge rates for these six stations during 2004-05 are summarized in Appendix B.

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TABLE 2-2: MONTHLY RUNOFF AT SELECTED GAGING STATIONS

(acre-feet)

Station	Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
F-57C-R	2004-05	35,240	7,550	58,230	162,650	143,450	45,620	15,550	7,410	6,140	5,410	5,700	5,120	503,430
L.A. River Arroyo Seco	2003-04	15,120	2,550	15,450	3,940	33,510	9,180	5,430	1,510	1,650	1,460	1,250	1,190	135,860
F-202-R	2004-05	3,050	512	3,400	9,150	17,570	3,705	1,210	830	721	568	527	288	37,032
Verdugo Wash	2003-04	247	250	750	250	1,840	452	225	107	156	264	214	316	5,319
F-218-R	2004-05	3,100	517	3,582	7,120	5,210	2,340	1,240	839	1,450	1,120	1,070	1,146	32,836
Burbank Storm Drain	2003-04	505	500	812	911	2,240	772	926	456	585	468	392	806	8,334
F-30C-R	2004-05	23,430	5,650	40,380	142,620	125,720	41,630	13,250	6,140	6,840	4,420	5,000	5,000	421,630
L.A. River Tujunga Ave	2003-04	5,890	5,380	8,280	6,350	22,900	8,310	4,790	3,770	3,500	3,550	3,580	3,180	80,750
F-16E-R	2004-05	1,310	2,420	8,460	45,480	28,710	31,810	7,130	4,160	3,680	2,960	1,230	356	137,386
Big Tujunga Dam	2003-04	116	0	287	2	479	1,260	121	22	0	7	9	3	2,315
F-11B-R	2004-05	3	764	235	5,930	4,310	6,320	1,240	2,160	1,610	1,150	0	0	25,357
Pacoima Dam	2003-04	10	693	20	1	0	497	221	0	3	0	0	0	1,315

2.3 Components of Surface Flow

The surface flow of the Los Angeles River at Gaging Station F-57C-R consists of:

1. Storm flows;
2. Treated wastewater from the Tillman, Burbank, and Los Angeles-Glendale Water Reclamation Plants;
3. Industrial discharges and domestic irrigation runoff; and,
4. Rising groundwater.

In the Report of Referee (Volume II, Appendix O), procedures were developed for the calculation of rising groundwater for the period 1928-1958. Some of the important factors of that study are no longer significant - releases of Owens River water, operation of the Chatsworth Reservoir, and operation of the Headworks Spreading Grounds. As shown on Figure O-2 of the Report of Referee, excess rising groundwater was considered to have fallen to zero by the late 1950s. The January 1993 report by Brown and Caldwell, "Potential Infiltration of Chlorides from the Los Angeles River Narrows into the Groundwater Aquifer" studied groundwater levels along the course of the Los Angeles River. The Watermaster provided the insight and data for this evaluation. As of the end of the drought period in 1977, groundwater levels in the Los Angeles River Narrows were very low, with very little potential for excess rising groundwater. Heavy runoff occurred during the 1978-83 period, which, combined

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with reduced pumping in the Crystal Springs, Grandview, and Pollock Well Fields, caused large recoveries of groundwater levels in the Los Angeles River Narrows

An even greater factor effecting hydrologic conditions in the Los Angeles River Narrows has been the increasing releases of treated wastewater. Releases from the Los Angeles-Glendale Plant began in 1976-77 and from the Tillman Plant in 1985-86. These large year-round releases tend to keep the alluvium of the Los Angeles River Narrows saturated, even in dry years. Nevertheless, there is some opportunity for continuing percolation in the unlined reach, both upstream and downstream of the lined section near the confluence of the Verdugo Wash and the Los Angeles River. Water percolating in the unlined reach is believed to circulate through shallow zones and re-appears as rising groundwater downstream from Los Feliz Boulevard. Also, there is up to 3,000 AF of recharge from delivered water within the Los Angeles Narrows-Pollock Well Field area that adds to the rising groundwater conditions.

Rising groundwater also occurs above the Verdugo Wash Narrows, and in the unlined reach of the Los Angeles River upgradient from Gage F-57C-R. During dry periods, conditions in the unlined reach are stabilized with regard to percolation and rising water by releases of treated water. In above-normal rainfall years, rising groundwater values at Gage F-57C-R are closely related to increased rising groundwater leaving the Verdugo Basin past Gage F-252-R (Table 2-3). In 2004-05 flows of rising water at Gage F-252-R were estimated at 5,198 AF. For 2004-05 the total rising groundwater flow at Gage F-57C-R was estimated at 6,309 AF.

Field inspection during 1998-99 confirmed significant year-round unmetered flows of domestic irrigation runoff from residences, golf courses and other sites through the Sycamore Channel and several other storm drains north of Gage F-57C-R.

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TABLE 2-3: ESTIMATED SEPARATION OF SURFACE FLOW AT STATIONS F-57C-R & F-252-R

(acre-feet)

Water Year	F-57C-R Rising Groundwater*	F-57C-R Waste Discharge	F-57C-R Storm Runoff	F-57C-R Total Outflow	F-252-R Rising Groundwater	F-252-R Storm Runoff	F-252-R Total Outflow
2004-05	6,309	76,828	423,293	506,430	5,198	31,974	37,972
2003-04	3,330	90,377	42,153	135,860	2,468	2,851	5,319
2002-03	3,669	75,159	106,862	185,690	3,167	5,183	8,350
2001-02	2,126	74,737	43,937	120,800	1,810	5,731	7,540
2000-01	3,000	87,795	94,065	188,860	1,500	6,370	7,870
1999-00	1,992	78,009	62,202	142,180	924	4,243	6,470
1998-99	2,030	72,790	39,110	113,900	1,300	2,534	7,250
1997-98	4,000	97,881	245,079	346,720	4,300	12,140	16,140
1996-97	3,030	75,827	76,485	155,312	3,300	13,650	16,950
1995-96	3,941	86,127	61,198	151,166	2,577	10,946	13,523
1994-95	4,900	86,209	367,456	438,587	4,809	28,851	33,656
1993-94	2,952	60,504	73,149	136,696	1,387	6,156	7,543
1992-93	4,900	77,000	478,123	560,023	3,335	20,185	23,520
1991-92	3,000	120,789	197,040	320,829	1,412	13,209	14,671
1990-91	3,203	75,647	117,779	196,629	1,157	6,865	8,022
1989-90	3,000	78,769	55,811	167,639	1,182	2,938	4,120
1988-89	3,000	80,520	56,535	136,843	1,995	4,453	6,448
1987-88	3,030	81,520	74,071	158,701	3,548	10,493	14,041
1986-87	3,030	64,125	16,060	83,285	2,100	1,690	3,790
1985-86	3,880	46,370	102,840	155,090	2,470	6,270	8,740
1984-85	3,750	21,600	46,330	71,160	2,710	3,970	6,680
1983-84	3,000	17,760	48,080	69,870	4,000	n/a	n/a
1982-83	3,460	17,610	384,620	405,690	5,330	21,364	26,714
1981-82	1,280	16,180	82,030	99,460	3,710	5,367	9,077
1980-81	4,710	19,560	51,940	76,200	5,700	2,917	8,697
1979-80	5,500	16,500	n/a	n/a	5,150	7,752	12,902
1978-79	2,840	16,450	119,810	139,100	2,470	n/a	n/a
1977-78	1,301	7,449	357,803	366,663	1,108	23,571	24,709
1976-77	839	7,128	58,046	66,013	1,583	2,635	4,318
1975-76	281	6,741	32,723	39,725	2,170	2,380	4,550
1974-75	427	7,319	56,390	64,141	1,333	4,255	5,588
1973-74	2,634	6,366	79,587	88,878	1,772	5,913	7,385
1972-73	4,596	8,776	103,587	116,959	1,706	7,702	9,408
1971-72	---	---	---	---	2,050	2,513	4,563

*Includes unaccounted water and the influence of treated waste water

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2.4 Groundwater Recharge

Precipitation has a marked influence on groundwater recharge and, with some delay, groundwater storage. Urban development in ULARA has resulted in a significant portion of the rainfall being collected and routed into lined channels that discharge into the Los Angeles River. To partially offset the increased runoff due to urbanization, Pacoima, Big Tujunga and Hansen Dams, originally built for flood control, are utilized to regulate storm flows and allow recapture of the flow in downstream spreading basins operated by the LACDPW and the City of Los Angeles.

The LACDPW operates the Branford, Hansen, Lopez, and Pacoima Spreading Grounds. The LACDPW, in cooperation with the City of Los Angeles, operates the Tujunga Spreading Grounds. The spreading grounds are primarily used for spreading native and imported water. Table 2-4 summarizes the spreading operations for the 2004-05 Water Year, Table 2-4A summarizes recharge since 1968-69 Water Year, and Plate 8 shows the locations of the spreading grounds.

TABLE 2-4: 2004-2005 SPREADING OPERATIONS IN THE SAN FERNANDO BASIN
(acre-feet)

Agency	Spreading Facility	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
LACDPW														
	Branford	128	25	136	532	240	120	90	61	46	41	14	11	1,448
	Hansen	2,048	1,240	2,450	6,750	3,960	5,020	5,570	2,529	11	1,100	1,650	1,260	33,307
	Lopez	0	318	2	30	38	260	0	200	52	34	0	0	940
	Pacoima	640	15	584	4,170	2,620	5,020	930	1,000	822	758	0	0	17,164
	Tujunga	542	0	498	3,769	961	3,570	3,730	3,240	4,130	452	0	0	21,112
	Total	3,400	1,593	3,950	14,251	7,820	14,830	10,315	7,527	5,062	2,585	1,664	1,271	74,198
City of Los Angeles														
	Tujunga	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hansen	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0	0	0
Basin Total		3,400	1,593	3,950	14,251	7,820	14,830	10,315	7,527	5,062	2,585	1,664	1,271	74,198

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TABLE 2-4A ANNUAL SPREADING OPERATIONS IN THE SAN FERNANDO BASIN
1968-69 through 2004-05
(acre-feet)

Water Year	Los Angeles County Department of Public Works (Narrows)						City of Los Angeles (Reported)			GRAND TOTAL	Rainfall Weighted Average Valley Mins
	Branford	Hansen	Lopez	Pacoima	Tujunga	TOTAL	Headworks	Tujunga	TOTAL		
2004-05	1,448	33,921	940	17,394	21,315	74,198	0	0	0	74,198	45.65
2003-04	444	6,429	144	1731	1322	10,066	0	0	0	10,066	12.21
2002-03	932	9,427	518	3,505	1,514	15,230	0	0	0	15,230	21.22
2001-02	460	1,342	0	761	121	2,564	0	0	0	2,564	8.64
2000-01	552	11,654	172	3,826	1,685	17,889	0	0	0	17,889	22.49
1999-00	456	7,487	578	2,609	2,664	14,106	0	0	0	14,106	16.77
1998-99	541	8,949	536	586	3,934	14,562	0	0	0	14,562	15.85
1997-98	641	28,139	578	20,714	1,160	51,242	0	77	77	51,319	36.51
1996-97	416	9,808	724	5,768	6,406	23,121	0	51	51	23,172	17.65
1995-96	345	8,232	363	4,532	7,767	21,239	0	0	0	21,239	14.46
1994-95	550	35,137	1,066	14,264	18,236	69,108	0	0	0	69,108	33.05
1993-94	462	12,052	182	3,156	4,129	19,981	0	0	0	19,981	11.96
1992-93	389	26,136	1,312	17,207	19,655	64,544	114	0	114	64,658	41.25
1991-92	653	15,461	1,091	12,214	9,272	38,394	230	0	230	38,624	32.39
1990-91	508	11,429	241	3,240	2,487	18,566	52	0	52	18,718	7.59
1989-90	327	2,029	80	1,708	0	4,154	0	0	0	4,154	9.56
1988-89	755	3,644	308	1,306	0	5,713	0	0	0	5,713	9.12
1987-88	152	17,252	1,037	4,520	0	23,161	0	0	0	23,161	21.35
1986-87	0	7,311	141	467	0	7,919	0	33	33	7,952	7.10
1985-86	280	18,158	1,735	5,704	0	25,917	0	1,433	1,433	28,350	23.27
1984-85	744	13,274	104	3,375	0	15,997	0	5,456	5,456	22,453	15.31
1983-84	213	10,410	0	3,545	0	14,168	0	24,115	24,115	38,283	11.16
1982-83	583	25,157	1,067	27,972	10,550	70,329	10	32,237	32,247	102,925	46.07
1981-82	345	14,317	241	5,495	0	20,400	3,853	0	3,853	24,253	20.15
1980-81	243	14,470	335	3,161	0	18,210	4,052	9,020	13,072	31,851	12.29
1979-80	397	31,267	1,097	15,583	0	48,164	1,446	19,527	25,279	73,643	33.65
1978-79	715	24,597	1,013	12,036	0	38,245	2,483	31,945	34,428	72,454	24.07
1977-78	2,142	25,123	445	20,472	12,821	54,303	3,200	18,247	21,447	85,450	44.54
1976-77	317	7,356	63	1,941	0	9,677	2,142	16	3,158	8,157	16.07
1975-76	440	3,128	662	1,308	0	5,488	3,837	5,502	9,337	14,825	14.20
1974-75	601	5,423	913	2,470	0	9,495	4,070	9,221	12,291	22,786	---
1973-74	672	6,257	948	2,378	0	10,260	6,205	0	6,226	16,486	---
1972-73	1,271	9,272	0	6,343	2,274	19,160	5,182	0	5,182	24,342	---
1971-72	161	1,952	0	1,113	0	3,206	7,383	0	7,383	10,589	---
1970-71	507	11,657	127	4,249	0	16,540	6,804	399	7,203	24,143	---
1969-70	674	11,327	0	1,577	2,980	16,558	11,021	0	11,021	27,579	---
1968-69	461	32,464	893	14,262	10,052	61,132	6,892	3,676	10,374	71,506	---
AVG	544	14,326	540	5,750	4,134	25,294	2,010	4,562	6,572	32,866	

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2.5 Groundwater Extractions

The original Trial Court adjudication of groundwater rights in ULARA restricted all groundwater extractions, effective October 1, 1968. On that date, total extractions in ULARA were restricted to approximately 104,040 AF/Y. This amounted to a reduction of approximately 50,000 AF from the previous six-year average. The State Supreme Court's opinion, as implemented on remand in the Judgment dated on January 26, 1979, restricts groundwater pumping within each basin, and by each party within each basin.

Figure 2.2 illustrates the imported water used in ULARA and annual groundwater extractions, beginning with the 1954-55 Water Year. It can be noted that for the 14 years prior to pumping restrictions (1954-55 to 1967-68), imports exceeded extractions by 50,000 to 90,000 AF/Y, in contrast to the past 37 years (1968-69 to 2004-05) where imports have exceeded extractions by 110,000 to 250,000 AF/Y.

A total of 77,995 AF were pumped from ULARA during the 2004-05 Water Year: 67,865 AF from the SFB, 4,253 AF from the Sylmar Basin, 5,669 AF from the Verdugo Basin, and 208 AF from the Eagle Rock Basin. The respective extraction rights for the 2004-05 Water Year were 99,709 AF (Native Safe Yield of 43,660 plus an Import return credit of 56,049 AF) for the SFB; 6,510 AF for the Sylmar Basin; and 7,150 AF for the Verdugo Basin. Appendix A contains a summary of groundwater extractions for the 2004-05 Water Year, Plate 6 shows the locations of the well fields, and Plate 11 illustrates the pattern of groundwater extractions.

Of the total amount pumped in the SFB (67,865 AF), 63,275 AF constitutes extractions by Parties to the Judgment; 2,352 AF constitutes nonconsumptive use; and 1,238 AF were used for physical solutions, groundwater cleanup, testing/well development, and dewatering parties (Appendix E). Table 2-5 summarizes 2004-05 private party pumping in the SFB, and Plate 3 shows the locations of the individual producers.

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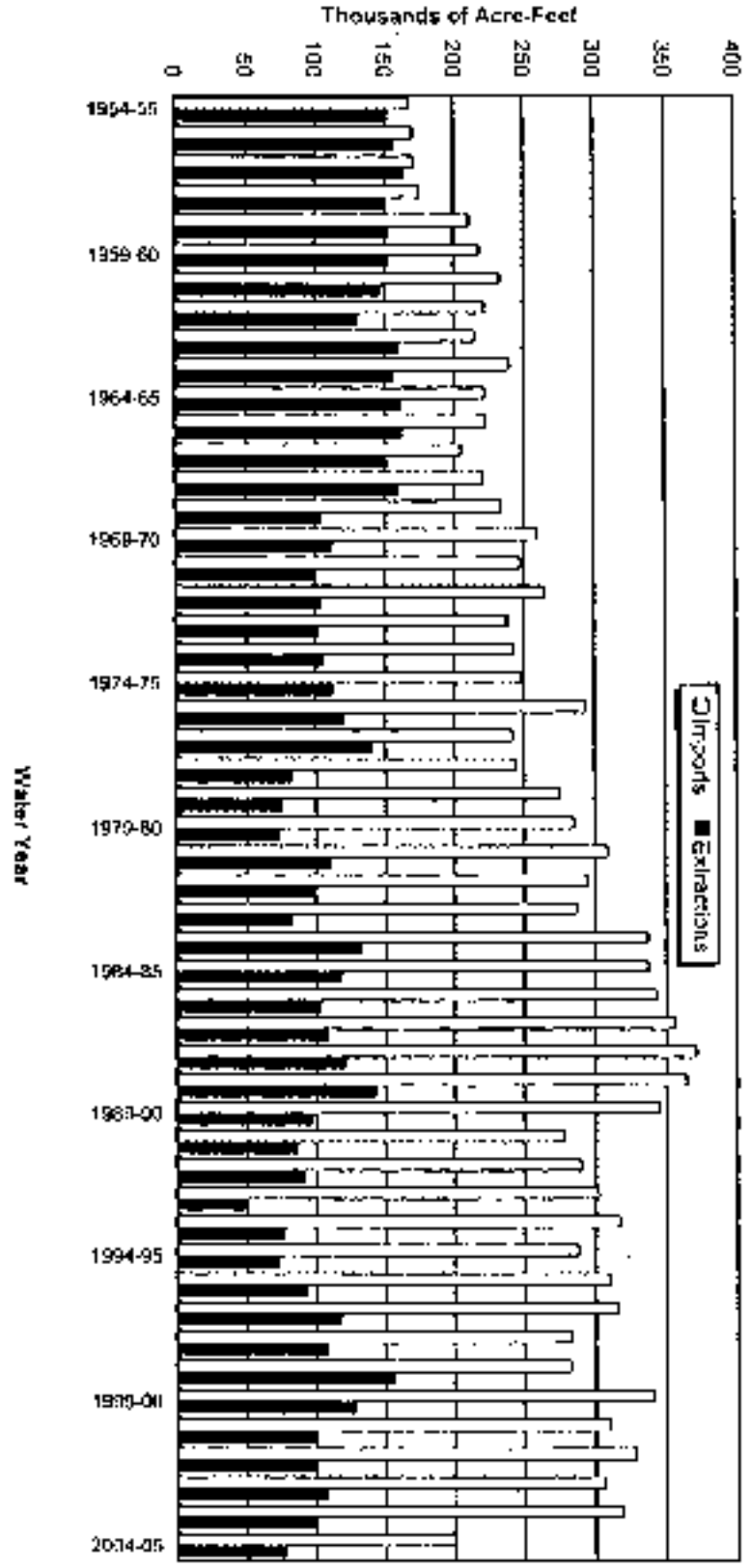

FIGURE 2.2 - YEARLY IMPORTS USED IN ULARA AND TOTAL ULARA EXTRACTIONS

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TABLE 2-5: 2004-05 PRIVATE PARTY PUMPING - SAN FERNANDO BASIN
(acre-feet)

Nonconsumptive Use or Minimal Consumption		Groundwater Dewatering	
CalMat	3,351.41	Aulo Stiegler	6.22
(Gravel washing)		(Charged to Los Angeles water rights)	
Sears, Roebuck and Company	0	First Financial Plaza Site	75.09
(Air Conditioning well disconnected 2000)		(Charged to Los Angeles' water rights)	
Sportsmens' Lodge	0.03	Trillium Corporation	26.45
Toluca Lake Property Owners	0.83	(Charged to Los Angeles' water rights)	
Walt Disney Productions	0	Metropolitan Transportation Agency	69.23
(2 wells inactive/ Not abandoned)		(Charged to Los Angeles water rights)	
		Metropolitan Water Dist of SWD	193.90
		(Charged to Los Angeles' water rights)	
		North East Interceptor Sewer	0.84
		(Charged to Los Angeles' water rights)	
		Warner Properties Plaza 6 and 3	31.51
		(Charged to Los Angeles' water rights)	
Total	**3,352.27**	**Total**	**403.04**

Groundwater Cleanup		Physical Solution	
Boeing Santa Susana Field Lab	7.20	Forest Lawn Cemetery Assn.	311.90
(Charged to Los Angeles water rights)		(Charged to Glendale's water rights)	
Raytheon (Hughes)	2.07	Halhaway (deMille)	43.46
(Charged to Los Angeles water rights)		(Charged to Los Angeles' water rights)	
B.F.Goodrich (Menasco/Collec)	0.43	Middle Ranch (deMille)	7.56
(Charged to Los Angeles' water rights)		(Charged to Los Angeles' water rights)	
Micro Matics USA, Inc.	3.57	Toluca Lake Property Owners	30.00
(Charged to Los Angeles' water rights)		(Charged to Los Angeles' water rights)	
Mobil Oil Corporation	0.58	Valhalla Memorial Park	295.35
(Charged to Los Angeles' water rights)		(Charged to Burbank's water rights)	
3M-Pharmaceutical	61.70	Waterworks District No. 21	43.53
(Charged to Los Angeles' water rights)		(Charged to Los Angeles' water rights)	
Tesoro	20.54	Water Licenses	0.76
(Charged to Los Angeles' water rights)		(Charged to Los Angeles' water rights)	
		Wildlife Waystation	5.84
		(Charged to Los Angeles' water rights)	
Total	**96.09**	**Total**	**738.40**
Total Extractions	**4,590**		

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2.6 Imports and Exports of Water

Residential, commercial, and industrial expansions in ULARA have required the importation of additional water supplies to supplement that provided by the groundwater basins.

The imported supplies to ULARA are from the Los Angeles Aqueducts and the MWD. Los Angeles Aqueduct water consists of runoff from the Eastern Sierra Nevada and groundwater from Owens Valley. The MWD supplies consist of State Water Project and Colorado River Aqueduct waters.

Exports from ULARA include imported Los Angeles Aqueduct and MWD water (pass-through), and groundwater from the SFB. Exports of wastewater are by pipeline to Hyperion Treatment Plant.

Table 2-6 summarizes the imports and exports from ULARA during the 2003-04 and 2004-05 Water Years, and Figure 2.3 shows the monthly extractions and imports.

FIGURE 2.3 - TOTAL MONTHLY EXTRACTIONS AND GROSS IMPORTS

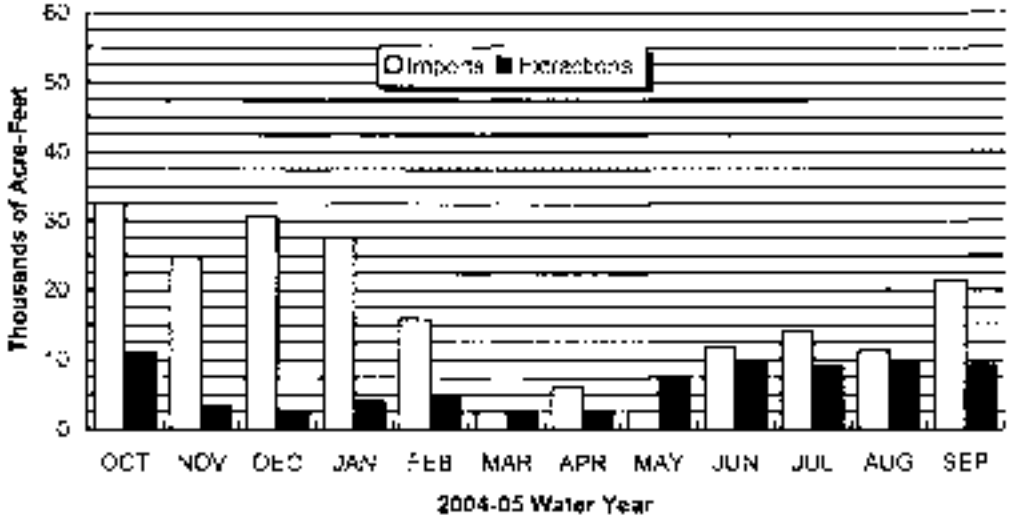

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TABLE 2-6: ULARA WATER IMPORTS AND EXPORTS

(acre-feet)

Source and Agency	Water Year 2003-04	2004-05
Gross Imported Water		
Los Angeles Aqueduct		
City of Los Angeles	212,805	335,617
MWD Water		
City of Burbank	13,751	14,415
Crescenta Valley Water District	3,298	1,909
City of Glendale	24,540	21,233
City of Los Angeles [1]	338,529	168,687
La Canada Irrigation District [1]	1,408	1,197
Las Virgenes Municipal Water District [1]	8,532	7,449
City of San Fernando	508	500
MWD Total	**390,572**	**215,390**
Grand Total	**603,377**	**551,007**
Exported Water (Pass-Through)		
Los Angeles Aqueduct		
City of Los Angeles	97,546	168,898
MWD Water		
City of Los Angeles	174,944	70,121
Total	**272,490**	**239,019**
Net Imported Water	**330,887**	**311,988**

1. Deliveries to those portions of these agency service areas that are within ULARA.

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2.7 Water Recycling

Water recycling presently provides a source of water for irrigation, industrial, and recreational uses. In the future, water recycling may provide water for groundwater recharge. Four wastewater reclamation plants are in operation in ULARA. The Las Virgenes Municipal Water District operates a water recycling facility outside ULARA but uses part of the treated water in ULARA. Table 2-7 summarizes the 2004-05 reclamation plant operations, and Plate 5 shows their locations.

TABLE 2-7: 2004-05 WASTEWATER RECYCLING OPERATIONS

(acre-feet)

Plant/Agency	Treated Water	Recycled Water Use	Recycled Water Use (%)	Recycled Water Delivered to SFB
City of Burbank	8,800	681 [1]	8%	681
Los Angeles Glendale	16,321	2,899 [2]	18%	
Los Angeles		1,868		19
Glendale		1,119		939
Donald C. Tillman	62,377	816 [3]	1%	0
The Independent Order of Foresters	NR	NR [4]		
Las Virgenes MWD		1,347		1,347
Total	**87,498**	**5,643**		**2,986**

1. Of the total recycled water (680.85 AF), 80.75 AF was delivered to the Burbank power plant. 600.1 AF was used by CalTrans, DeBell Golf Course and other landscape irrigation.
2. Of the total recycled water (2,899 AF), 1,111 AF was delivered to Glendale for use in Glendale's Power Plant and for irrigation water for the Trains, Forest Lawn and Brand Park; 917 AF was for in plant use; 655 AF was delivered to Griffith Park by Los Angeles for irrigation; and 1,232 AF was used by CalTrans, Lake Side, Mt. Sinai Memorial Park, Forest Lawn 2, and Universal City MCA for irrigation.
3. Recycled water was for in plant use and then discharged to the Los Angeles River.
4. Recycled water is used for irrigation. NR no response for 2004-05.

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2.8 Water Level Elevations

The 2005 contour maps for the Spring (April) and the Fall (September) were produced by using the SFB Groundwater Flow Model. The SFB model was initially developed during the Remedial Investigation (RI) study of groundwater contamination in the San Fernando Valley. The RI study was funded through the EPA's Superfund program.

The model is comprised of up to four layers in the deepest portion of the eastern SFB, and includes 22,016 cells, ranging in size from 1,000 by 1,000 feet to 3,000 by 3,000 feet. The model parameters were calibrated by matching the simulated hydraulic-head fluctuations with the historical water level fluctuations measured at selected key monitoring wells for a 10-year period. The 2005 contours were simulated by incorporating the estimated monthly recharge (e.g. spread water, precipitation, etc.) and discharge (groundwater extractions, rising groundwater, etc.) values for the 2004-05 Water Year. The model was then run for twelve consecutive monthly stress periods beginning October 2004 through September 2005. The simulated head values at the end of the April and September 2005 stress periods were then plotted by utilizing groundwater contouring software.

The simulated Spring and Fall 2005 Groundwater Contour Maps are shown as Plates 9 and 10. These contours are intended to depict the general trend of groundwater flow for April and September 2005. Up-to-date groundwater elevations for specific locations can be obtained by contacting the Watermaster's Office at (213) 367-0921.

Plate 11 exhibits the change in groundwater elevation from the Fall of 2004 to the Fall of 2005. The increase in groundwater levels in the north portion of the SFB, specifically near the Hansen Spreading Grounds, is attributed to the increased volume of Native Runoff water spread at Hansen, 33,301 AF compared to the previous year of 2003-04 when 6,424 AF were spread. The groundwater levels in the vicinity of Pacoima Spreading Grounds increased by about 50 feet from the previous year. The water spread at Pacoima increased by about 15,663 AF compared to the 2003-04 Water Year.

The 30-44 foot recovery in groundwater levels near the Rinaldi-Toluca and North Hollywood Well Field areas is primarily attributed to increased recharge in upgradient spreading grounds and decreased groundwater extractions. Extractions for these two well fields decreased by 44 percent from 2003-04 to 2004-05 (40,652 AF to 22,972 AF). The area near the Tujunga Well Field shows an increase in groundwater levels, as much as 50 feet, due to an increase in recharge in upgradient spreading grounds and specifically at the nearby Tujunga Spreading

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Grounds (TSG) where the recharge of TSG increased by about 20,851 AF between 2003-04 and 2004-05 (264 AF to 21,115 AF) and also due to reduced pumping at the Tujunga Well Field by about 1,503 AF from 2003-04 to 2004-05 (17,310 AF to 15,807 AF). The vicinity of the Burbank Operable Unit (BOU) shows an increase in groundwater levels of approximately 16 feet as a result of increased recharge in the basin and reduced pumping at BOU. Extraction from this well field decreased by about 34 percent between 2003-04 and 2004-05 (9,660 AF to 6,398 AF). In general, the SFB shows a rebound in groundwater levels as a result of low pumping, high artificial recharge, and high precipitation.

Figure 2.4 shows historic well hydrographs of wells throughout ULARA and their locations.

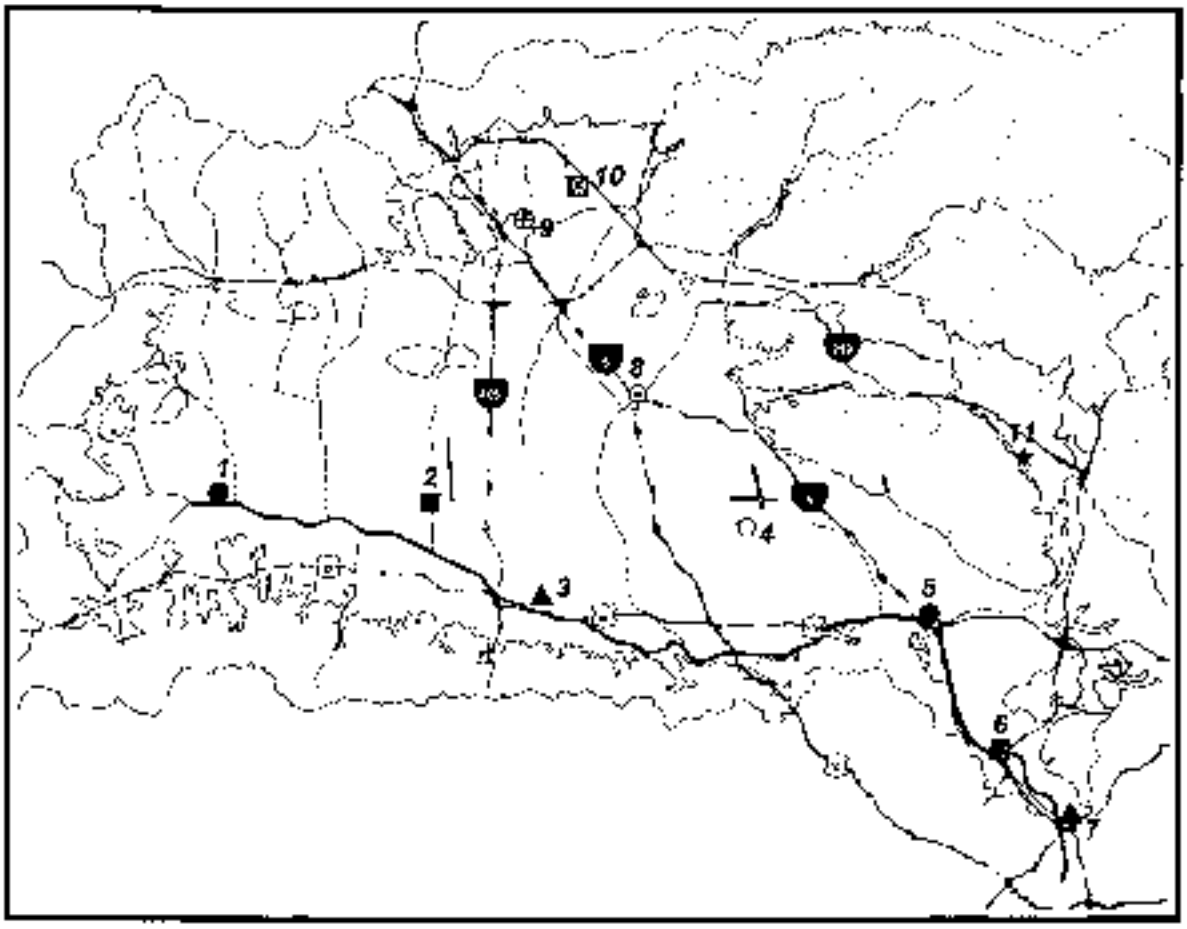

FIGURE 2.4 HYDROGRAPHS AND LOCATIONS OF WELLS THROUGHOUT ULARA

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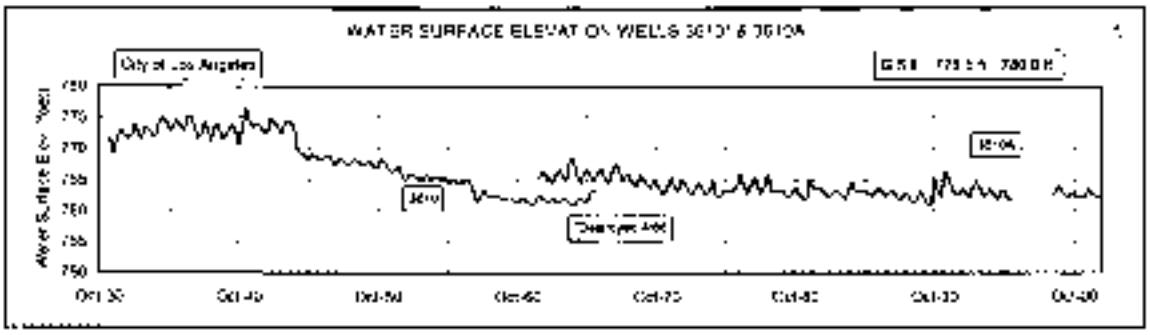
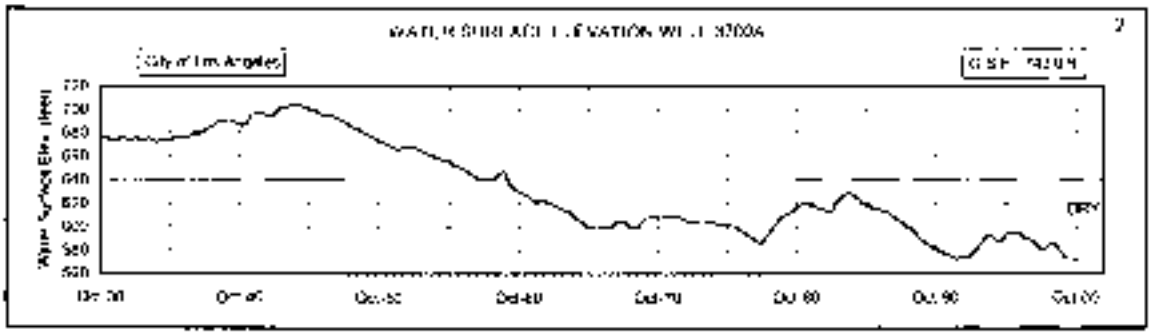
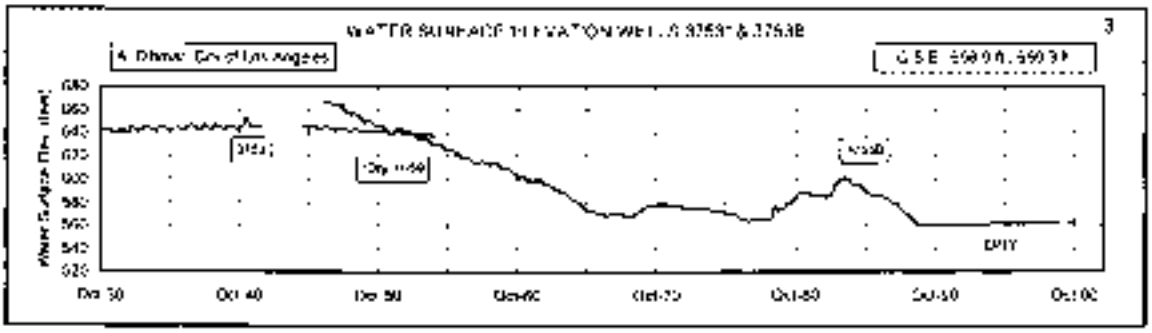
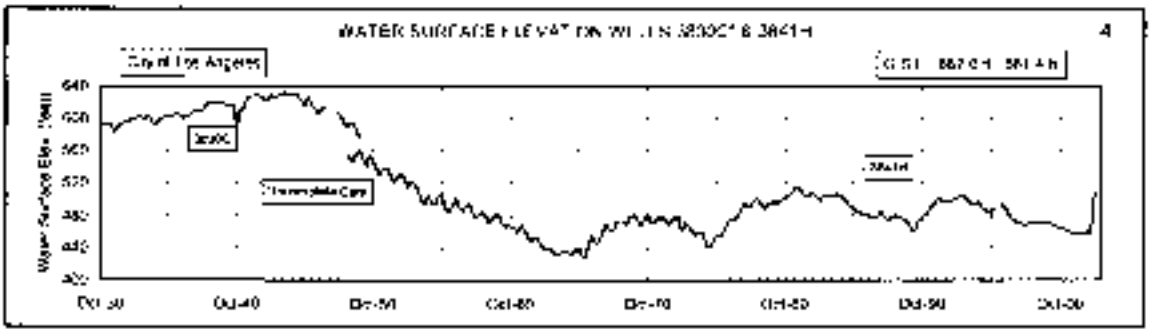
SAN FERNANDO BASIN









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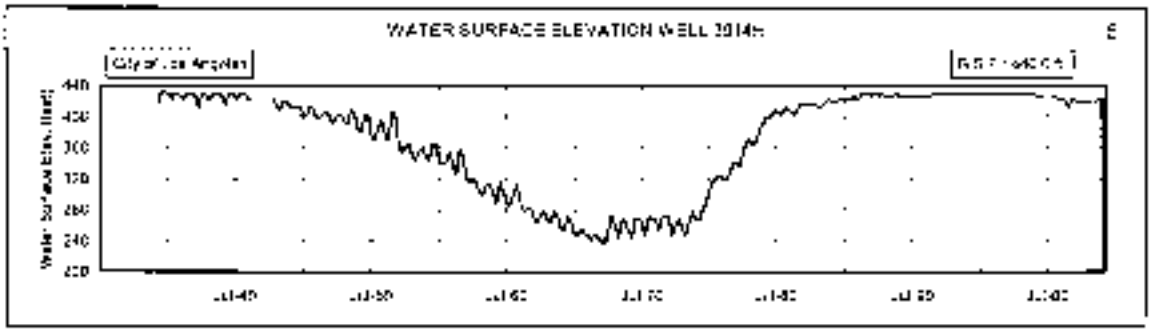
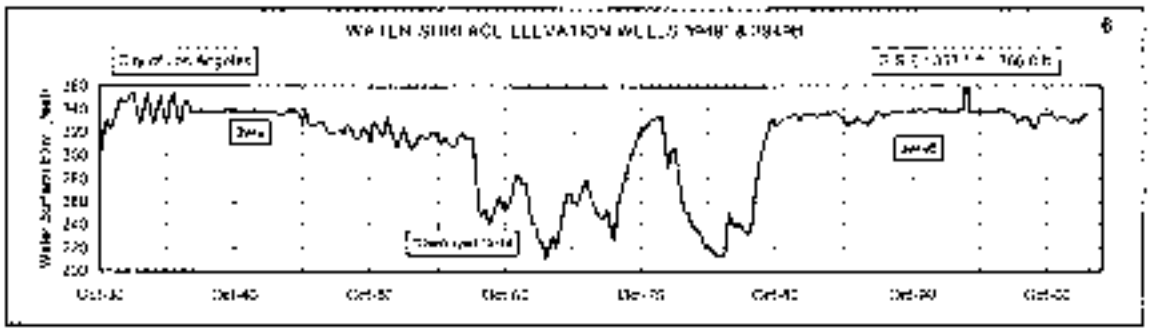
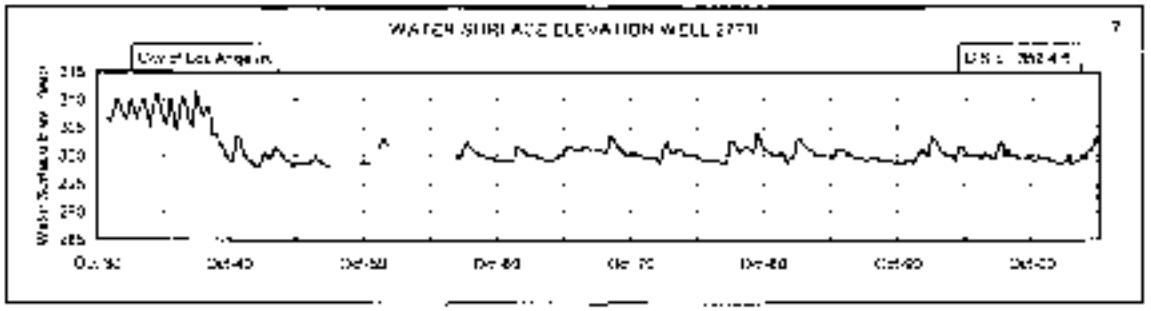
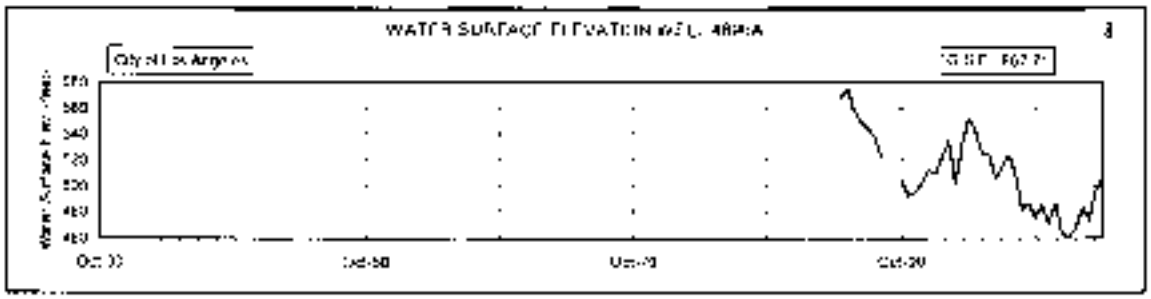
SAN FERNANDO BASIN









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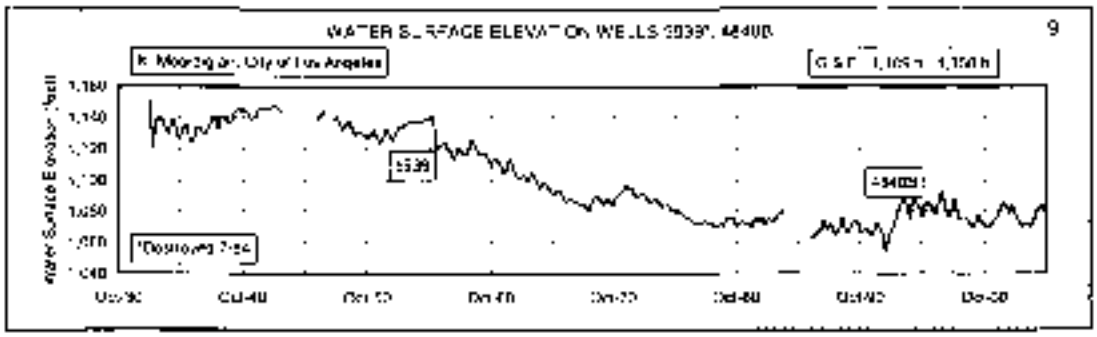
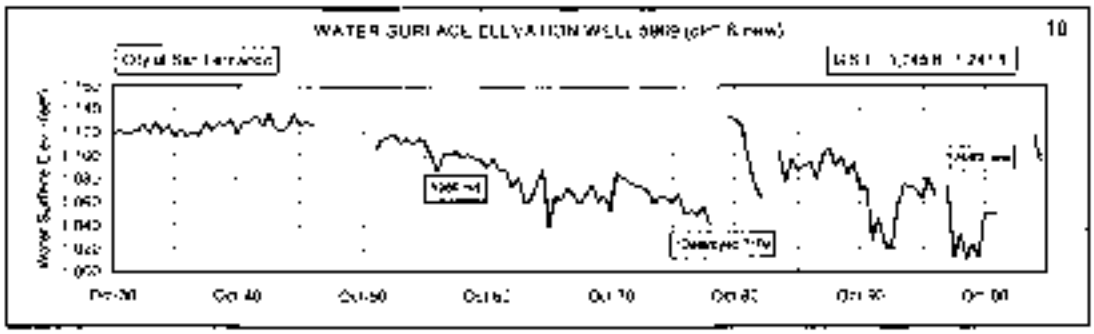
SYLMAR BASIN





VERDUGO BASIN

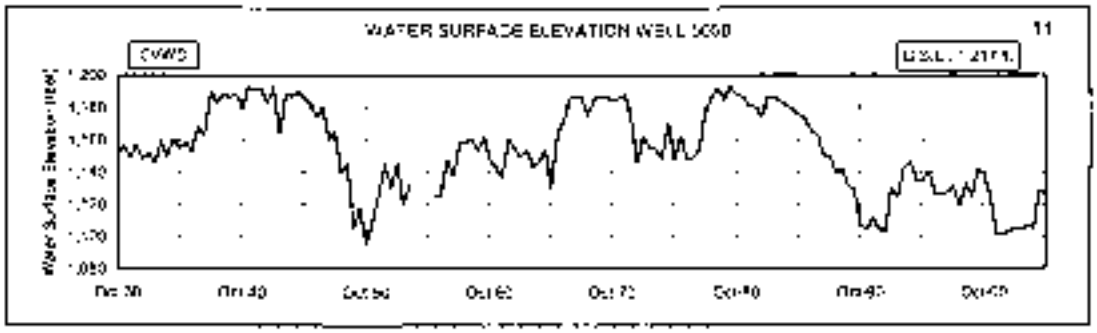


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TABLE 2-8: CHANGE IN GROUNDWATER STORAGE SAN FERNANDO BASIN

Water Year	Valley Floor Precipitation (in)	Artificial Recharge (acre-feet)	Change in Storage (acre-feet)	Cumulative Change In Storage (acre-feet)	Pumping (acre-feet)
2004-05	42.84	74,190	66,470	150,055	67,865
2003-04	5.52	10,065	(22,307)	84,419	89,346
2002-03	19.41	18,332	(15,835)	106,766	55,431
2001-02	6.96	2,664	(27,094)	122,551	87,592
2000-01	19.52	17,935	(6,930)	146,715	86,946
1999-00	14.84	14,105	(31,044)	153,545	116,357
1998-99	6.91	14,662	(82,673)	187,689	141,757
1997-98	27.04	61,115	44,013	270,362	54,982
1996-97	15.17	23,172	(35,737)	226,249	105,899
1995-96	12.03	21,233	(49,223)	261,986	82,962
1994-95	33.36	69,109	79,132	311,209	56,121
1993-94	10.19	15,981	(22,238)	232,077	62,593
1992-93	36.82	64,658	106,317	254,315	36,419
1991-92	30.05	39,624	411	147,998	76,213
1990-91	14.28	18,710	(14,123)	147,587	71,065
1989-90	8.20	4,154	(29,941)	161,709	81,496
1988-89	9.12	5,713	(32,565)	191,650	127,573
1987-88	18.67	23,161	(5,005)	223,200	105,470
1986-87	5.96	7,952	(31,948)	227,200	51,932
1985-86	20.27	28,355	(7,960)	259,140	86,504
1984-85	11.00	22,499	(31,690)	267,100	101,591
1983-84	9.97	38,283	(63,180)	298,810	115,511
1982-83	39.64	102,925	121,090	361,990	66,394
1981-82	17.16	24,253	(535)	240,900	84,962
1980-81	11.04	31,891	(32,568)	241,430	82,791
1979-80	30.25	73,542	99,975	273,998	56,915
1978-79	21.76	72,454	78,080	174,020	59,043
1977-78	35.45	65,455	136,150	95,940	69,314
1976-77	14.10	8,197	(50,495)	(40,210)	126,445
1975-76	9.90	14,605	(30,005)	10,280	103,740
1974-75	14.74	22,785	(22,585)	40,370	85,930
1973-74	15.75	16,488	(21,820)	62,950	88,317
1972-73	20.65	24,342	17,020	84,770	82,004
1971-72	8.10	10,595	(17,090)	67,750	84,140
1970-71	15.67	24,149	15,340	84,840	79,210
1969-70	10.50	27,579	(9,740)	69,500	88,856
1968-69	29.00	71,505	79,240	79,240	84,185
37 Year Average	**18.58**	**32666**	**4078**		**67,750**

1 Accumulation of storage began as of October 1, 1968

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2.8 Groundwater Storage

San Fernando Basin

The total groundwater storage capacity of the SFB was calculated by the State Water Rights Board in the Report of Referee to be approximately 3.2 million AF.

Each year, the change in storage is evaluated in three ways – between the most recent and the previous water year; for the cumulative change since Safe Yield Operation began in 1968; and, for the cumulative change since the beginning year of 1928.

In Fall 1968, following the Trial Court Judgment, Safe Yield Operation was instituted to halt the overdraft in groundwater levels that began in 1964 (Plate 13). Methodology established by the State Water Rights Board was used to derive a regulatory storage requirement of 360,000 AF for the SFB that considered normal wet-dry cycles, operational flexibility, and pumping based on the calculated safe yield. The upper boundary of 210,000 AF above the 1954 level was based on the need to prevent excess rising groundwater from leaving the basin, and the lower boundary of 150,000 AF below the 1954 level provided storage space for wet years. Ideally, the basin should be operated between the upper and lower boundaries of the regulatory storage range.

Plate 13 illustrates a 25-year overall decline in storage below the regulatory storage range beginning in approximately 1980. The trend becomes clearer when the temporary effects of above-normal rainfall years of 1982-83, 1992-93, 1994-95, 1997-98, and 2004-05 are excluded. Probable causes of this decline include increased urbanization and runoff leaving the SFB, reduced artificial recharge, and pumping in excess of long-term recharge.

The calculated change in storage in the SFB between 2003-04 and 2004-05 is +55,476 AF (Table 2-8). As indicated by the blue line on Plate 13, there has been an increase in storage of 150,895 AF since 1968, but an overall decline in storage of 504,475 AF since 1928.

In addition, since Fall 1978 there has been an accumulation of 410,033 AF of Stored Water Credits by the Cities of Los Angeles, Glendale, and Burbank through in-lieu activities (leaving groundwater in storage rather than pumping it). Stored groundwater can be extracted by the parties in excess of annual pumping rights with the approval of the Watermaster. If this groundwater had been pumped instead of stored, the cumulative change in storage since 1928 would be -914,508 AF. As indicated by the red line on Plate 13, the basin would be below the

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beginning of Safe Yield Operation that began in 1968. Clearly, groundwater recharge in the SFB is not keeping pace with pumping rights.

The Watermaster is required to continue evaluating the change in groundwater storage and the safe yield within ULARA, to notify the parties and the Court of significant changes, and to consider corrective measures for the future if the imbalance continues. In accordance with his duties, the Watermaster has begun discussions with the Cities regarding this imbalance, and informed the Court on February 13, 2006 (Appendix G).

On a positive note, there is more than 500,000 AF of storage space available in the SFB. This storage can be used to capture additional native water or imported supplies during wet years. Basin storage space is a valuable resource, and the Watermaster Office supports its wise use for the benefit of the public.

Sylmar Basin

The groundwater storage capacity of the Sylmar Basin is approximately 310,000 AF. The estimated change in storage from 2003-04 to 2004-05 is +6,694 AF, and the cumulative change in storage from 1968-69 through 2004-05 is +2,895 AF.

Verdugo Basin

The groundwater storage capacity of the Verdugo Basin is approximately 160,000 AF. The estimated change in storage for 2004-05 compared to 2003-04 is +9,838 AF, and the cumulative change in storage from 1968-69 through 2004-05 is -8,551 AF.

The long-term decline in Verdugo Basin groundwater was partially reversed by the heavy rains of 2004-05. It will not be known until next year's calculations how long the increase will last. The probable causes of the decline seen in the past years include increased urbanization and runoff leaving the basin, and a significant reduction in groundwater recharge from cesspools and septic systems following the installation of sewers beginning in the 1980s. An evaluation of the basin is currently underway. The study on stormwater storage and conjunctive use was completed in May 2005 and the geophysical study is in progress.

Eagle Rock Basin

The estimated change in storage from 2003-04 to 2004-05 is +189 AF.

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2.10 Water Supply and Disposal - Basin Summaries

Tables 2-9A, 2-9B, 2-9C, and 2-9D summarize water supply and disposal in the San Fernando, Sylmar, Verdugo, and Eagle Rock basins, respectively. Outflows are based on computations made by the State Water Rights Board in the Report of Referee.

2.11 Extraction Rights and Stored Water Credit - Basin Summaries

San Fernando Basin

Tables 2-10A and 2-11A show the calculation of SFB extraction rights for the 2004-05 Water Year and Stored Water Credit (as of October 1, 2004) for the Cities of Burbank, Glendale, and Los Angeles. All rights are based on the City of Los Angeles vs. City of San Fernando, et al., Judgment, dated January 26, 1979.

Sylmar Basin

Tables 2-10B and 2-11B show the calculation of Sylmar Basin extraction rights for the 2004-05 Water Year and Stored Water Credit (as of October 1, 2005) for the Cities of Los Angeles and San Fernando. All rights are based on the March 22, 1984 stipulation between the City of San Fernando and the City of Los Angeles and the action by the Administrative Committee on July 16, 1996 to temporarily increase the safe yield from 6,210 AF/Y to 6,510 AF/Y. The temporary increase has expired and is being re-evaluated.

Verdugo Basin

Glendale and CVWD have rights to extract 3,856 and 3,294 AF/Y respectively. Glendale has not pumped its full right since the Judgment was entered. In the past, CVWD has extracted in excess of its right with the permission of Glendale and the approval of the Watermaster. During the 2004-05 Water Year, CVWD unexpectedly pumped 16 AF above its adjudicated right without Glendale's consent or approval by the Watermaster. CVWD, Glendale, and the Watermaster are working to resolve the issue

Los Angeles has a right to extract its Import Return Flows in the Verdugo Basin, but has never exercised its right.

There are no Stored Water Credits in the Verdugo Basin

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Eagle Rock

Los Angeles has the right to extract, or cause to be extracted, the entire safe yield of the basin that consists mostly of return flows of delivered water by Los Angeles. Los Angeles does not pump groundwater from the Eagle Rock Basin. DS Waters, as successor to Sparkletts and Deep Rock, has a physical solution right to extract groundwater to supply its bottled drinking water facility. DS Waters pumped 208 AF for the 2004-05 Water Year.

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TABLE 2-9A: SUMMARY OF 2004-05 WATER SUPPLY AND DISPOSAL SAN FERNANDO BASIN

(acre-feet)

Water Source and Use	City of Burbank	City of Glendale	City of Los Angeles	City of San Fernando	All Others	Total
Extractions						
Municipal Use	6,359	7,792	49,085	---	0	63,270
Basin Account		0	0	---	0 [1]	0
Physical Solution	295 [2]	312 [2]	38	---	94 [3]	738
Cleanup/Dewatering	---	---	459	---	---	459
Non consumptive Use	---	---	---	---	3,352	3,352
Total	6,654	8,104	49,622	0	3,446	67,865
Imports						
LA Aqueduct Water	---	---	335,617	---		335,617
MWD Water	14,415	21,233	141,572	455	7,449 [3]	185,125
MWD Water (LA 17)			23,484			23,484
Groundwater from						
Sylmar Basin	---	---	1,110	2,860	---	3,970
Verdugo Basin		700				700
Total	14,415	21,933	501,783	3,315	7,449	548,894
Delivered Reclaimed Water	681	939	19 [4]	0	1,347 [5]	2,986
Exports						
LA Aqueduct Water						
out of ULARA	---	---	168,898	---	---	168,898
to Verdugo Basin			514			514
to Sylmar Basin			7,157			7,157
to Eagle Rock Basin		---	314			314
MWD Water						
out of ULARA	---		70,121	---	---	70,121
to Verdugo Basin	---	2,916	220	---	---	3,136
to Sylmar Basin	---	---	3,067	---	---	3,067
to Eagle Rock Basin			135			135
Groundwater	41 [6]	325 [7]	44,586	---	---	44,951
Total	41	3,240	295,011	0	0	298,292
Delivered Water						
Hill & Mountain Areas		---	48,330			48,330
Total - All Areas	21,749	27,735	258,412	3,315	12,242	321,453
Water Outflow						
Storm Runoff (Sta. F-57					420,293	420,293
Subsurface	---	---	---	---	407	407
Sewage	2,824	16,031	76,275	2,537	---	99,467
Reclaimed Water to						
the LA River	8,119	324	49,313	---	---	57,756
Tujunga		521 [6]	20,260 [6]			20,881
Total	10,743	16,976	146,848	2,537	420,700	601,804

1. Basin Account water for Burbank
2. Includes Valhalla (Burbank) and Forest Lawn (Glendale)
3. Las Virgenes Municipal Water District
4. LA total reclaimed water is 1,888 AF of which 19 AF were delivered to valley fill and 1,868 delivered to hillmountains.
5. Glendale OU and Burbank OU treated groundwater discharged to Los Angeles River
6. Water discharged from Tujunga and LA-Glendale plants. Annual citiesí portion from LAG based on proportion of reclaimed water
7. Pumping from Hill and Mountain areas tributary to SFB

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TABLE 2-9B: SUMMARY OF 2004-05 WATER SUPPLY AND DISPOSAL SYLMAR BASIN

(acre-feet)

Water Source and Use	City of Los Angeles	City of San Fernando	All Others	Total
Total Extractions	1,110	3,143	0 [1]	4,253
Imports				
LA Aqueduct Water	7,157		--	7,157
MWD Water	3,067	45	--	3,112
Total	10,225	45	0	10,270
Exports - Groundwater				
to San Fernando Basin	1,110	2,860	0	3,970
Total Delivered Water	10,225	329	0	10,553
Water Outflow				
Storm Runoff	5,000 [2]			5,000
Subsurface	560 [3]		--	560
Sewage	830 [3]	45	--	875
Total	6,390	45	0	6,435

1. Pumping for landscape irrigation by Santiago Estates. This well was capped in 1998.
2. Surface outflow is not measured. Estimate based on Mr. F. Laverty – SF Exhibits 57 and 64.
3. Estimates in the Report of Referee.

TABLE 2-9C: SUMMARY OF 2004-05 WATER SUPPLY AND DISPOSAL VERDUGO BASIN

(acre-feet)

Water Source and Use	Crescenta Valley Water District	City of Glendale	La Canada Irrigation District	City of Los Angeles	Other	Total
Total Extractions	3,302	2,359	---	-	9 [1]	5,669
Imports						
LA Aqueduct Water		-		514		514
MWD Water	1,909	2,919	1,197	220		6,242
Total	1,909	2,919	1,197	734		6,756
Exports to San Fernando Basin	0	700	0	0		700
Delivered Reclaimed Water		180				180
Total Delivered Water	5,212	4,758	1,197	734	9	11,905
Water Outflow						
Storm Runoff (Sta. F 292) [2]					37,072	37,072
Subsurface to						
Monk Hill Basin				---	300	300 [2]
San Fernando Basin	---	---	---	---	80	80 [2]
Sewage	692	1,321	0	472		2,485
Total	692	1,321	0	473	37,452	39,938

1. Private party extractions.
2. Estimated
3. Includes using groundwater

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TABLE 2-9D: SUMMARY OF 2004-05 WATER SUPPLY AND DISPOSAL EAGLE ROCK BASIN

(acre-feet)

Water Source and Use	City of Los Angeles	DS Waters	Total
Total Extractions	0	208 [1]	208
Imports			
LA Aqueduct Water from SFB	314	--	314
MWD Water (26+35) from SFB	135		135
MWD Water (17)	27,115		27,115
Groundwater from SFB	0	--	0
Total	**27,564**	**0**	**27,564**
Exports			
MWD Water (17) to SFB	23,484		23,484
Groundwater	0	208	208
Total	**23,484**	**208**	**23,692**
Total Delivered Water	4,080	0	4,080
Water Outflow			
Storm Runoff	--	--	-- [4]
Subsurface	50 [2]	--	50
Sewage	1,940 [3]	0	1,940
Total	**1,990**	**0**	**1,990**

1 DS Waters (formed by the merger of Suntory/Deep Rock Water Co. and McKesson/Danone Water Products) is allowed to pump as successor to Deep Rock and Sparkletts, under a stipulated agreement with the City of Los Angeles and export equivalent amounts.

2 Estimated in Supplement No. 2 to Report of Referee

3 Estimated.

4. Not quantified

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TABLE 2-10A: CALCULATION OF 2005-06 EXTRACTION RIGHTS SAN FERNANDO BASIN

(acre-feet)

	City of Burbank	City of Glendale	City of Los Angeles
Total Delivered Water, 2004-05	21,749	27,735	256,412
Water Delivered to Hill and Mountain Areas, 2004-2005		—	48,330
Water Delivered to Valley Fill, 2004-2005	21,749	27,735	208,082
Percent Recharge Credit	20.0%	20.0%	20.8%
Return Water Extraction Right	4,350	5,547	43,281
Native Safe Yield Credit	—	—	43,660
Total Extraction Right for the 2005-2006 Water Year[1]	**4,350**	**5,547**	**86,941**

1 Does not include Stored Water Credit and Physical Solution

TABLE 2-10B: CALCULATION OF 2005-06 EXTRACTION RIGHTS SYLMAR BASIN

(acre-feet)

	City of Los Angeles	City of San Fernando	All Others
Extraction Right for the 2005-2006 Water Year[1]	3,255	3,255	— [2]

1 Does not include Stored Water Credit. The safe yield of the Sylmar Basin was increased to 6,510 AF/YR effective 7/15/1986. Effective October 1, 1994 safe yield less pumping by Santiago Estates is equally shared by Los Angeles and San Fernando.

2 Santiago Estates Home Owners Group stopped pumping in 1989.

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TABLE 2-11A: CALCULATION OF STORED WATER CREDIT SAN FERNANDO BASIN

(acre-feet)

	City of Burbank	City of Glendale	City of Los Angeles
1. Stored Water Credit (as of October 1, 2004)	22,038	66,201	286,846
1a. Credits and debits.			(248) [1]
2. Extraction Right for the 2004-05 Water Year	4,847	6,006	88,856
3. 2004-05 Extractions			
Party Extractions	6,389	7,707	49,085
Physical Solution Extractions	295	312	131
Clean-up/Dewaterers			499
Total	6,694	8,104	49,715
4. Total 2004-05 Spread Water	0	0	0
5. Stored Water Credit [2] (as of October 1, 2005)	**20,191**	**64,103**	**325,739**

1. City of Los Angeles debited for loss of rising water at Pollock. See Appendix H.
2. Item 5 = 1 +1a + 2 - 3 + 4.

TABLE 2-11B: CALCULATION OF STORED WATER CREDIT SYLMAR BASIN

(acre-feet)

	City of Los Angeles	City of San Fernando
1. Stored Water Credit (as of October 1, 2004)	6,303	227
2. Extraction Right for the 2004-05 Water Year [1]	3,255	3,255
3. Total 2004-05 Extractions	1,110	3,143
Santiago Estates [2]	0.0	0.0
4. Stored Water Credit [3] (as of October 1, 2005)	**8,448**	**339**

1. The safe yield of the Sylmar Basin was increased to 6,510 AF/YR as of 7/15/1996.
2. Santiago Estates pumping is equally taken from the rights of San Fernando and Los Angeles. Santiago Estates capped well in 1998.
3. Item 4 = 1 + 2 - 3

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3. WATER QUALITY, TREATMENT, AND REMEDIAL INVESTIGATION ACTIVITIES

3. WATER QUALITY, TREATMENT, AND REMEDIAL INVESTIGATION ACTIVITIES

3.1 Water Quality

Imported Water

1. *LOS ANGELES AQUEDUCT* water is sodium bicarbonate in character and is the highest quality water available to ULARA. Its Total Dissolved Solids (TDS) concentration averaged about 210 parts per million (ppm) for 30 years before 1969. The highest on record was 320 ppm on April 1, 1946. TDS concentration on May 17, 2005 was 267 ppm.

2. *COLORADO RIVER* water is predominantly sodium-calcium sulfate in character, changing to sodium sulfate after treatment to reduce total hardness. Samples taken at the Burbank turnout between 1941 and 1975 indicated a high TDS concentration of 875 ppm in August 1955 and a low of 625 ppm in April 1959. The average TDS concentration over the 34-year period was approximately 740 ppm. Tests conducted at Lake Matthews showed an average TDS concentration of 625 ppm for Fiscal Year 2005.

3. *NORTHERN CALIFORNIA* water (State Water Project) is sodium bicarbonate-sulfate in character. It generally contains less TDS and is softer than local and Colorado River water. Since its arrival in Southern California in April 1972, the water has had a high TDS concentration of 410 ppm and a low of 247 ppm. Tests conducted at the Joseph Jensen Filtration Plant showed an average TDS concentration of 267 ppm during Fiscal Year 2005.

4. *COLORADO RIVER/NORTHERN CALIFORNIA* water were first blended at the Weymouth Plant in May 1975. Blending ratios vary, and tests are taken from the effluent. Tests conducted at the Weymouth Plant showed an average TDS concentration of 467 ppm during Fiscal Year 2005.

Surface Water

Surface runoff contains salts dissolved from rocks in the tributary areas and is sodium-calcium, sulfate-bicarbonate in character. The most recent tests taken in September 1995 from flows in the Los Angeles River at the Arroyo Seco showed a TDS concentration of 666 ppm and a total

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hardness of 270 ppm. These values also reflect the inclusion of rising groundwater in the Los Angeles River between Los Feliz Blvd. and Gage F-57C-R.

Chlorides in Surface Water

In 1997 the RWQCB Amended Resolution No. 90-04 was rescinded by Resolution No. 97-02 on chlorides. Water quality objectives for chloride for certain surface waters were revised to accommodate fluctuations in chloride concentrations that may be caused by future droughts. The Amendment to the Water Quality Control Plan to Incorporate a Policy for Addressing Levels of Chloride in Discharges of Wastewaters for ULARA in the Waterbody – Los Angeles River - between Sepulveda Flood Control Basin and Figueroa Street (including Burbank Western Channel only) currently has a maximum of 190 ppm. Chloride levels are reported in Appendix D.

Nitrogen in Surface Water

The Regional Board has ordered the cities of Burbank and Los Angeles as part of a TMDL program to determine the source of nitrogen in the Los Angeles River either from stormwater or rising groundwater entering the river. The Los Angeles City Bureau of Sanitation and the City of Burbank have contracted with a consultant to conduct the first phase of the study.

Groundwater

Groundwater in ULARA is moderately hard to very hard. The character of groundwater from the major water-bearing formations is of two general types, each reflecting the composition of the surface runoff in the area. In the western part of ULARA, it is calcium sulfate-bicarbonate in character, while in the eastern part, including Sylmar and Verdugo Basins, it is calcium bicarbonate in character.

Groundwater is generally within the recommended limits of the California Title 22 Drinking Water Standards, except for: 1) areas of the eastern SFB where high concentrations of Trichloroethylene (TCE), Tetrachloroethylene (PCE), Hexavalent Chromium, and nitrates are present; 2) areas in the western end of the SFB having excess concentrations of sulfate and TDS; and 3) areas within the Verdugo Basin that have high concentrations of nitrate. In each area the groundwater delivered is either being treated or blended to meet State Drinking Water Standards

A history of the TDS content and mineral analyses of imported, surface, and groundwater is contained in Appendix D.

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3.2 Groundwater Quality Management Plan

During the 2004-05 Water Year, the Interagency Coordinating Committee continued to implement the recommendations of the "Groundwater Quality Management Plan - San Fernando Valley Basins" issued in July 1983. The objective of this effort is to protect and improve the quality of stored water held in ULARA. Special emphasis is placed on monitoring and removing the organic contaminants TCE and PCE found in the groundwater. Table 3-1 summarizes the number of ULARA wells that are contaminated at the indicated levels above the Maximum Contaminant Level (MCL) of the California Drinking Water Standards of 5 parts per billion (ppb) for TCE and 5 ppb for PCE.

TABLE 3-1: 2004-05 NUMBERS OF WELLS IN THE ULARA WELL FIELDS EXCEEDING STATE MCL FOR TCE AND PCE

	Number of Wells													
	City of Los Angeles[3]									Sub-	Others[3]			Grand
Total Number of	NH	RT	P	HW	E	W	TJ	V	AE	Total	B	G	C	Total
Wells in Well Field[2]	35	15	3	4	7	8	12	5	7	96	16	13	12	137
	Number of Wells Exceeding Contaminant Level[1]													
TCE Levels ppb														
5-20	0	5	1	-	0	3	7	0	1	17	0	0	0	17
20-100	0	0	0	-	0	0	3	0	4	7	7	3	0	17
>100	0	0	0	-	0	0	0	0	2	2	8	4	0	14
Total	0	5	1	-	0	3	10	0	7	26	15	7	0	48
PCE Levels ppb														
5-20	1	4	1	-	0	2	6	0	5	19	1	3	0	23
20-100	0	0	0	-	0	0	0	0	2	2	3	3	0	8
>100	0	0	0	-	0	0	0	0	0	0	11	1	0	12
Total	1	4	1	-	0	2	6	0	7	21	15	7	0	43

1 Wells are categorized based upon maximum TCE and PCE values measured during the 2004-05 Water Year. No data was available for some old inactive wells.

2 Includes active, inactive, and stand-by wells.

3 Well Fields. NH - North Hollywood; P - Pollock; HW - Headworks; E - Erwin; W - Whitnall; TJ - Tujunga; V - Verdugo; AE - LADWP Aeration Tower Wells; B - City of Burbank; G - City of Glendale; C - Crescenta Valley Water District

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3.3 Underground Tanks, Sumps, and Pipelines

The City of Los Angeles Fire Department (LAFD) continues to implement the State-mandated Underground Storage Tank (UST) Program and is actively conducting a program to bring the large number of underground tanks in the San Fernando Valley into compliance with current law. During the 2004-05 Water Year, a total of 32 sites were remediated under the direction of the LAFD. Currently, the Environmental Unit of the LAFD is monitoring the remediation of 74 sites.

The main focus of the LAFD UST Program in ULARA has been the monitoring and removal of gasoline, diesel, and their related constituents from the soil, to prevent contamination of the underlying groundwater. If a site investigation indicates groundwater contamination, the site is referred to the RWQCB for further action. Since October 1, 2004, 15 sites have been assigned to the Underground Tank Plan Check Unit.

3.4 Private Sewage Disposal Systems (PSDS)

In order to eliminate existing commercial and industrial PSDS and their discharges of nitrates to the SFB, a sanitary sewer construction program has been in progress for many years. This program is continuing to systematically install sanitary sewers in eighteen Groundwater Improvement Districts (GIDs) throughout the San Fernando Valley. To date, a total of twelve areas have had construction completed, and six areas are in various stages of right-of-way acquisition and processing. Plate 7 shows the locations of these six GIDs.

The sewer construction program ordered by the City Council required project design and construction to be funded though Assessment Act provisions. Proposition 218, approved by the electorate on November 5, 1996, now requires that a majority of mail-in ballots of property owners approve any new or increased assessments, in order to proceed with funding the projects through the Assessment Program. The passage of Proposition 218 and continued downsizing of the workforce of the City of Los Angeles has impeded the sewer construction program for the remaining six GIDs.

Toward the end of the 1998-99 Water Year, inquiries by the Watermaster regarding scheduling for the completion of the remaining six GIDs led to the revision and re-estimation of construction plans for those improvements. Those projects were reactivated with the intent of facilitating the construction through the Assessment Program. The previously completed plans

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were revised as necessary and a revised construction cost estimate was prepared for each project. Those anticipated construction costs and project incidental costs were spread among the owners of benefiting property within the individual districts and the owners were notified of their proportionate share of the assessable costs for the projects.

The majority of the responding owners of each of the following five GIDs: GID No. 3 (Raymer St. Nr. Fulton Ave.), GID No. 17 (Glenoaks Blvd. Nr. Roxford St.), GID No. 19 (Sherman Way Nr. Balboa Blvd.), and GID No. 5 (Chandler Blvd. Nr. Lankershim Blvd.) and GID No. 12 (San Fernando Rd. Nr. Brazil St.) voted against construction of the assessment projects. These projects are now defunct Assessment Projects. 61 percent of the responding owners serviced by GID No. 4 (San Fernando Rd. Nr. Keswick St.) voted in favor of the project. Right-of-way acquisition for that project is pending arbitration in court to reduce the aquired right-of-way easement.

Work on the five postponed projects has been deferred because of the fiscal impact to the City of Los Angeles for right-of-way acquisition and construction. The City Council will be notified of the current impasse regarding these projects. Further work on the projects will be contingent upon direction from the City Council and authorization for alternative financing of the projects.

In order to determine the number of properties not connected to a sewer, the Bureau of Sanitation updated the database for water users not being billed for sewer usage. The analysis initially revealed that in the San Fernando Basin approximately 5,700 of these properties are located within 50 feet of an existing sewer, and 7,700 of these properties are more than 50 feet from an existing sewer. The Bureau of Sanitation has prepared a map that covers the unsewered properties and municipal water supply wells within ULARA. The map will assist Bureau of Sanitation in prioritizing field inspections, beginning with unsewered properties within 1,000 feet of a production well.

The Bureau of Sanitation field checked hundreds of addresses in the past year. Most sites have been found to be connected to a sewer but are not being billed. Other addresses have two water meters – one for irrigation and a second for residential use. Some are on septic tanks in areas were there are no sewers.

City Councilman Alex Padilla, Council District 7, obtained federal funds to subsidize sewer installation for lower-income families in the northeast San Fernando Valley. Funding applications, which became available in March 2001, are currently being processed only for

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properties that have an existing available sewer to which connections can be made without construction of new public sewers.

In 2004 a settlement was reached between Santa Monica Baykeeper et al., Plaintiff, and the City of Los Angeles Bureau of Sanitation to reduce or eliminate sewage releases to surface waters. The settlement will reduce nitrate levels in the SFB only indirectly as a result of the effort to reduce sewer overflows through increased sewer inspection, maintenance, cleaning, replacement, etc. This Capital Improvement Program is expected to cost approximately $2 billion over a 10-year period.

The Industrial Waste Management Division (IWMD) of the Bureau of Sanitation continued to pursue the enforcement provisions of the PSDS elimination program.

3.5 Landfills

The Solid Waste Assessment Test (SWAT) reports for major SWAT Rank 1 to 4 landfills in the Los Angeles area have been completed and submitted to the RWQCB for approval. The reports reviewed by the RWQCB are listed in Table 3-2. As stipulated by Article 5 of Title 27, a follow-up sampling program under an Evaluation Monitoring Plan was required for some landfills due to the presence of VOCs in the underlying groundwater. Further updates to the SWAT would be triggered by post closure land use.

An application to increase the trash height at Bradley West Landfill is pending. The public comment period for the draft EIR to increase the landfill by 43 feet vertically will close April 2006. The date of closure for the landfill is April 2007.

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TABLE 3-2: LANDFILLS WITH SWAT INVESTIGATIONS

(reported to Interagency Coordinating Committee)

Name	Rank	Status	Current Owner	Location	SWAT Report Completed	Final SWAT Submitted	Phase II SWAT Req.	Approved by RWQCB	Site Task (1)	Type of Emission (2)	Further Monitoring
Bradley West	1	Open	MWDSC	Sun Valley, SE of Glenoaks Blvd & Stetson St	5/97	11/97		4/98	G	NHA (LO)	3
Shelburn-Arleta	1	Closed	City of Los Angeles Bureau of Sanitation	Sun Valley, Penrose Ave. between N. Gaffey Street & Keystone	5/97	8/97		7/98	G	MSW	4, 7
Ashby Canyon	1	Open	City of Glendale	San Rafael Hills, 1 mile West of Rose Bowl	7/97	4/98		9/98	G	NHA (LO)	3
Scholl Canyon	2	Closed	City of Glendale	San Rafael Hills, 1 mile West of Rose Bowl	7/97	9/98		12/98	G	NHA	5
Bradley East	2	Closed	MWDSC	SE of Glenoaks Blvd & Stetson St	9/97	11/98		4/99	G	NHA (LO)	4, 5
Bradley West Extension	3	Open	MWDSC	Near Glenoaks Blvd & Stetson St	7/98	7/99		4/99	G	MSW	3, 5
Sunshine Canyon City	2	Closed	Browning-Ferris Industries	SE Santa Susana Mtns W of Ronald Reagan Fwy	7/98	7/99		4/99	G	MSW	6
Sunshine Canyon LA County	2	Open	Browning-Ferris Industries	SE Santa Susana Mtns W of Ronald Reagan Fwy	7/98	7/99		4/99		MSW	6
Gregg Pollution	2	Closed	CalMat Properties	Between Hewitt and Gale St & Tujunga Ave	7/98	7/99		9/99	G	NHA	4
Branford	2	Closed	City of Los Angeles Bureau of Sanitation	Sun Valley District, W of Tujunga Wash	7/98	10/98	A	5/99		MSW	4, 7
CalMat Sun Valley #31	2	Open	CalMat Properties	Sun Valley District, NE of Glenoaks Blvd	7/98	11/99		5/00	N	Inert Fill	N 7
Tujunga Canyon	2	Closed	City of Los Angeles Bureau of Sanitation	N of Hansen Dam near Lopez and Kagel Cyn	6/98	6/98	A				A
Toyon Canyon	2	Closed	City of Los Angeles Bureau of Sanitation	Griffith Park	6/98	7/98		4/99	L	NHA (LO) MSW	3
Turk 2 Pit	2	Closed	Austin Bros. (CA By Products Co.)	Sun Valley District, SW of Glenoaks Blvd & Tujunga Ave	6/98	12/98		5/99		MSW	4, 8, 9
Penrose	2	Closed	Los Angeles (CA By Products Co.)	N of Strathern St & Tujunga Ave	6/98	7/99		5/99	G	NHA (LO)	4
Newberry	3	Closed	Los Angeles (CA By Products Co.)	N of Strathern St & Tujunga Ave	6/98	7/99		5/00	G	NHA (LO)	4
Hewitt Pit	2	Closed	CalMat Properties	North Hollywood District, Hollywood Fwy, Lauren	6/98	7/99		9/99	G	NHS (I)	5
Pendleton St.	4	Closed	City of Los Angeles Bureau of Sanitation	Sun Valley, Pendleton St. & Glenoaks Blvd	7/98	9/99		5/00	N	Inert Soil	5
Brough Park	2	Open	City of Burbank	Bel Air Drive & Cambridge Drive	6/98	10/98		4/99	G	NHA Inert Soil	3
Stadium			Newly constructed Apx. Year 2004	Stadium St. & Tujunga Ave							10

1 G = Gas, L = Leak

2 NHA = Non-Hazardous but above state or local groundwater regulatory levels
NHS = Non-Hazardous but below state and local groundwater regulatory levels
I = Inorganic, O = Organic, N = No, Y = Yes

MSW = Municipal Solid Waste

3 Under Title 27 Corrective Action Program (CAP) after completion of EMP

4 Closed landfills with groundwater monitoring required under Title 27. Monitoring results are submitted to the Regional Board periodically

5 Subject to SWAT requirements. Further monitoring may be required under Title 27

6 All open landfills are required to have groundwater monitoring under Title 27. Monitoring results are submitted to the Regional Board quarterly or semi-annually

7 Semi-annual groundwater monitoring

8 Groundwater Contamination Evaluation Monitoring Program (EMP) required under Title 27

9 EPA Federal Investigation

10 Under construction (Inert Landfill)

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3.6 San Fernando Valley Remedial Investigation Activities

A remedial investigation (RI) of groundwater contamination in the San Fernando Valley was initiated in July 1987 by the USEPA to characterize the San Fernando Basin and the Verdugo Basin and their contamination with TCE and PCE. The LADWP was selected by the USEPA to serve as the lead agency in conducting the RI and entered into a cooperative agreement that has provided over $22 million in federal funding to LADWP beginning July 1987. In August 1987, the LADWP selected James M. Montgomery, Consulting Engineers, Incorporated to serve as its consultant to perform various RI tasks.

The report, "Remedial Investigation of Groundwater Contamination in the San Fernando Valley," was completed in December 1992 and is a comprehensive, five-volume report that presents the findings and characterizations of the SFB and the Verdugo Basin with regard to their geology, hydrogeology, and nature and extent of contamination. The RI report also provides a description and the documentation of the SFB Groundwater Flow Model, summarizes the RI field investigation activities, and evaluates potential risks to human health and the environment.

The SFB Groundwater Flow Model was developed as a part of the San Fernando Valley Remedial Investigation and is a comprehensive, three-dimensional, regional-scale model. A three-dimensional mass transport model has also been developed for the SFB. The model has been utilized for various groundwater projects to analyze the storage and physical characteristics of groundwater in the SFB.

USEPA's consultant, CH2M HILL, continues to periodically sample the 87 groundwater monitoring wells that were installed as part of the RI. CH2M HILL also obtains groundwater quality and groundwater elevation data from the municipalities and various agencies and facilities in the San Fernando Valley to update the SFB database. CH2M HILL utilizes the data to produce contaminant plume maps.

The RI Report and semi-annual sampling reports are available for public use at the Superfund Primary Information Repositories, which are located in the following libraries: City of Glendale, City of Burbank, LADWP, California State University-Northridge, and the University of California - Los Angeles.

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The LADWP also maintains a current SFB database for use with the SFB flow model and generation of groundwater contour maps and contaminant plume maps. CH2M HILL forwards current groundwater quality data for incorporation into the LADWP database.

3.7 Water Treatment

USEPA Operable Units

The USEPA is proceeding with enforcement actions against Potentially Responsible Parties (PRPs) for the North Hollywood, Burbank, and Glendale North and South Operable Units (OUs), which are part of the USEPA's overall, long term groundwater remediation activities in the SFB. The OUs are described below.

1. *North Hollywood OU* - The North Hollywood OU (NHOU) construction was funded by the USEPA, DHS, and LADWP. The NHOU Operations and Maintenance is funded by the USEPA and LADWP. The NHOU removes VOCs by air-stripping. In 2004-05, 339 million gallons (1,042 AF) of groundwater were treated. This represents 107 AF less than the 2003-04 Water Year

   Air discharged to the atmosphere was monitored for VOCs on a quarterly basis. All four quarters of VOC monitoring data were in conformance with permit requirements of the South Coast Air Quality Management District.

   Production at NHOU continues to be limited due to declining groundwater levels in the SFB. Although the 15-year NHOU Consent Decree expired on December 31, 2004, the VOC plume has not been fully remediated. In addition, a hexavalent chromium groundwater plume has been identified nearby, adding to the complexity of the problem. If production capacity of the NHOU is increased it might also capture the hexavalent chromium, which the NHOU is not designed to remove. The USEPA has begun a Focused Feasibility Study to evaluate the NHOU.

2. *Burbank OU* - The Burbank OU, funded by Lockheed-Martin under a USEPA Consent Decree and operated by Burbank, uses aeration and liquid-phase

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GAC to remove VOCs from high nitrate groundwater and then blends it with water from the Metropolitan Water District (MWD) for delivery to the City of Burbank.

Burbank assumed operation and maintenance of the BOU in 2001. Since that time, the facility has been unable to sustain operation at the designed treatment rate of 9,000 gpm. Burbank, Lockheed-Martin, USEPA, and the Watermaster Office have been cooperating in an effort to determine the cause(s) of the reduced treatment capacity. As a result, several modifications were found to be needed to the liquid-phase and vapor-phase GAC vessels. The modification of the liquid-phase GAC vessels is complete, and the vapor-phase mocification is pending. In addition, the study showed that additional well capacity may be required to sustain operation at 9,000 gpm.

In order to further explore ways to increase production, Burbank selected Montgomery Watson Harza to conduct a Well Field Performance Attainment Study which is currently being evaluated by the USEPA. Options to increase production include deflating well packers from existing wells, drilling additional wells, and building a pipeline to blend MWD water with high chromium groundwater from the Lake Street wells.

Burbank is also concerned about hexavalent chromium in water produced at the BOU and has been blending with imported water to keep the level of hexavalent chromium at, or below, 5 ppb. The BOU was not designed to treat chromium.

A total of 6,398 AF were treated in the 2004-05 Water Year.

3. *GLENDALE NORTH AND SOUTH OUS.* Construction of the Glendale North and South Operable Units was completed and treated water was ready for delivery on September 26, 2000. The system includes four Glendale North OU extraction wells with a capacity of 3,300 gpm and four Glendale South OU extraction wells with a capacity of 1,700 gpm. The process uses aeration and liquid-phase GAC to treat groundwater contaminated with VOCs and

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then blends it with MWD water at the refurbished Grandview Pump Station. A total of 7,541 AF were treated in 2004-05.

In 2004 the USEPA approved Glendale's temporary pumping plan to minimize chromium levels by reducing pumping in wells with elevated levels of chromium and increasing the pumping rate from the other wells.

Other Treatment Facilities

1. *Verdugo Park Water Treatment Plant (VPWTP)* – Glendale's VPWTP produces about 500 gpm and serves as a chlorination and turbidity treatment facility. A total of 700 AF were treated in 2004-05.

2. *Glenwood Nitrate Water Treatment Plant* - CVWD's Glenwood Nitrate Water Treatment Plant, which uses an ion-exchange process for nitrate removal, continued to operate satisfactorily during the 2004-05 Water Year. A total of 255 million gallons (782 AF) of water were treated. The 375 percent increase in the amount of treated water is due to the historic rainfall that raised the water table significantly in the Verdugo Basin. In addition, nitrate levels in the groundwater have declined during the past several years.

3. *Pollock Wells Treatment Plant* (PWTP) – The 3,000-gpm PWTP was dedicated on March 17, 1999. The treatment plant uses four GAC vessels to remove VOCs from Pollock Wells No. 4 and No. 6 to operation. The operation of these production wells reduces groundwater discharge to the Los Angeles River due to excess rising groundwater in the area. The treated water is chlorinated before distribution in the water system. A total of 1,752 AF of groundwater were treated during the year. This is a 54 percent increase over the historic low of 2003-04. The 248 AF lost as excess rising water has been deducted from Los Angeles' stored credit (Appendix F).

4. *Burbank GAC Treatment Plant* - The City of Burbank GAC system (Lake St. wells) was shut down in March 2001 due to the levels of hexavalent chromium in the groundwater and remained out of service during the 2004-05 Water Year. The City of Burbank has a goal of accepting a maximum of 5 ppb of hexavalent chromium after blending for distribution to its water system. If the plant is returned to service, production may be considered as

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part of the designated average pumping goal of 9,000 gpm for the Burbank OU.

3.8 Groundwater Quality Investigations

There are several ongoing groundwater quality investigations in the San Fernando Basin. Some of the major sites and related activities are summarized below.

Boeing/Rocketdyne Santa Susana Field Lab, Simi Hills

This facility, located in the hills at the western end of the San Fernando Valley, was the site of rocket testing until the 1980s. As a result, soil and groundwater became contaminated with TCE and perchlorate. Several hundred monitoring wells have been installed and are being sampled and tested. Contaminated soil and groundwater are being remediated at selected locations.

CVWD-MTBE Investigation

In February 2004, methyl-tert-butyl-ether (MTBE) was discovered by CVWD in Well #5 during its annual VOC water quality sampling. DHS directed CVWD to continue monitoring Well #5 on a quarterly basis. MTBE continued to be detected through 2005. CVWD retained McGuire Malcolm Pirnie Environmental Consultants (McGuire) to perform a "Preliminary Evaluation of MTBE Contamination Sources at CVWD Well #5". In addition, the Watermaster requested the RWQCB to perform an investigation into potential sources of MTBE. RWQCB met with CVWD in 2005, and has begun the investigation. In March 2006 the McGuire report was completed and forwarded to RWQCB. The report identified several potential source sites. RWQCB will continue the investigation and forward their findings to CVWD and the Watermaster.

DriLube, 711 W. Broadway and 718 W. Wilson, Glendale

DriLube Company, a plating facility located in Glendale, was issued a Cleanup and Abatement Order (CAO) by the RWQCB on March 29, 2002. Two additional property owners have been identified and will be added to the CAO, which is now being revised. DriLube was named a Responsible Party by the USEPA for discharging contaminants to the Glendale South Operable Unit from its site. The results of subsurface investigations have detected soil and groundwater contaminated with chlorinated solvents, petroleum hydrocarbons, PCBs, and heavy metals including chromium. On November 15, 2002 a fire at the DriLube Company totally destroyed the Plant 1 facility and records.

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PRC-DeSoto (formerly Courtaulds Aerospace), 5430 San Fernando Road, Glendale

The RWQCB issued a CAO to PRC-DeSoto (formerly Courtaulds Aerospace) on August 22, 2002. This facility has been named a responsible party by USEPA for releasing chlorinated organic solvents within the Glendale South Operable Unit. The facility's principal industrial activities involve chemical formulation of adhesives and sealants used by the U.S Department of Defense for various aerospace applications. Periodic groundwater monitoring and reporting has been conducted at the site since 1994. Trichloroethane (1,1,1-TCA), dichloroethane (DCE), TCE, PCE, chromium, hexavalent chromium, and nickel have been found in soil and groundwater beneath the site. The third quarter 2005 sampling indicated chromium and hexavalent chromium concentrations of 580 ppb and 79.9 ppb, respectively, in groundwater beneath the site. Groundwater monitoring will begin in 2006. Three down-gradient wells will be added. PRC-DeSoto has submitted a Remedial Action Plan (RAP) for the reduction of hexavalent chromium that is under review by the RWQCB.

Excello Plating, 4057 Goodwin Ave., Los Angeles

The RWQCB issued a CAO to Excello Plating on June 20, 2003. The CAO was revised and submitted on June 2, 2005 to the property owners. This facility has been named a responsible party for releasing volatile organic compounds, chromium, hexavalent chromium, nickel, cadmium, zinc and lead. The purpose of this CAO is to ensure that Excello Plating completes the on-site and off-site assessment to delineate the lateral and vertical extent of heavy metal contaminants (specifically chromium) and, as necessary, undertake remediation of the affected soil and groundwater, on-site and off-site. Groundwater samples from the Glendale South Operable Unit wells adjacent to the Excello site in 2002 indicated levels of hexavalent chromium above 54 ppb.

On September 23, 2004 the Los Angeles City Attorney charged Excello with a violation of the federal Clean Water Act for failure to comply in a timely manner with the CAO. This criminal citation has corresponding financial penalties including fines of $50,000 per day. The firm submitted to the RWQCB a workplan for review in October 2004. Field work began in February 2005. Three new monitoring wells and 16 borings have been drilled at the site to provide additional data. Excello completed a round of groundwater sampling in February 2006.

Goodrich (formerly Menasco/Coltec Industries, Inc.), 100 E. Cedar Ave., Burbank

The RWQCB issued a CAO to Coltec Industries, Inc. on July 5, 2002. This facility has been named a Responsible Party by the USEPA for discharging contaminants to the Glendale North

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Operable Unit. The facility's former industrial activities involve machining, manufacturing, metal plating and anodizing of parts and equipment used by the U.S. Department of Defense for various aerospace applications. TCE, PCE, DCE, 1,1,1-TCA and hexavalent chromium have been detected on this site. The third quarter 2005 sampling indicated maximum hexavalent chromium concentrations of 720 ppb in groundwater. Recently constructed offsite groundwater monitoring wells are being sampled quarterly.

ITT/Home Depot, 1200 S. Flower St., Burbank

Home Depot has completed construction of a store and parking lot on part of the former ITT Aerospace Controls site. ITT Aerospace Controls manufactured parts, and conducted metal finishing and plating. Groundwater contamination at the site consists of VOCs, petroleum hydrocarbons, nickel, and hexavalent chromium. In 2004 Home Depot built a slurry wall under the site to prevent lateral migration of contamination. A naturally occurring low-permeability zone located 50 feet below the ground surface is expected to prevent vertical migration of the contaminants. In preparation for the Remedial Action Plan implementation and in accordance with the mitigation measures set forth in the EIR, in late 2003, Home Depot installed four groundwater monitoring wells outside of the planned location of the slurry wall to monitor the baseline condition. In February 2006 Home Depot began a testing of a pump and treat system for the site with 16 dual-phase extraction wells. ITT, the firm responsible for the contamination of the site, has drilled additional off-site multi-level wells and is responsible for cleanup of the regional area surrounding and below Home Depot's slurry wall barrier. The Regional Board has approved the ITT Work Plan for the construction of additional offsite groundwater monitoring wells.

Brenntag (formerly Holchem) and Paxton Street LLC (formerly Price Pfister) - Pacoima Area Groundwater Investigation

Progress has been made in the Pacoima Area investigation by a coordinated effort between Cal-EPA DTSC, the RWQCB, LADWP, and the Watermaster Office. A VOC contaminant plume was identified in the Pacoima area near the intersection of the Simi Valley Freeway (118 Freeway) and San Fernando Road. This site is approximately 2.5 miles upgradient of LADWP's Tujunga Well Field, which can supply up to 120 cfs of groundwater. LADWP installed two monitoring wells downgradient of the contaminant plume. Under DTSC guidance, Brenntag has installed a soil vapor extraction system (SVE). Brenntag installed two new wells along Sutter Avenue to the southeast of the site in spring 2003. Brenntag now has 16 monitoring wells - nine on-site and seven off-site. Since start up in January 2003 through

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fourth quarter 2005, more than 27,683 lbs. of VOCs have been removed from the subsurface by the SVE.

The Paxton Street site (formerly Price Pfister), located southeast of Brenntag, has been directed to delineate the extent of VOC contamination with on-site and off-site monitoring wells. The RWQCB is the lead agency in enforcing cleanup of this site. Soil vapor extraction began in September 2002 and air sparging began in June 2003. Both systems were turned off in April 2004 to prevent damage while buildings were being demolished. The soil excavation from all source areas in the northern part of the site (approximately 2/3 of the total 25 acres) has been completed. Groundwater monitoring is on-going including replacement of two groundwater monitoring wells that will be installed soon. Recent sampling in February 2006 of two monitoring wells detected hexavalent chromium concentrations of 109 ppb and 780 ppb.

A series of community meetings were held in the Pacoima Area in 2004-2005 chaired by Los Angeles Councilmember Alex Padilla to address issues regarding the development of the Price Pfister site as a Lowe's Home Center. The contamination investigation and cleanup will continue during and after the construction development.

Honeywell (formerly Allied Signal/Bendix) 11600 Sherman Way, North Hollywood

Honeywell was issued a Clean Up and Abatement Order February 21, 2003 and an amended Clean Up and Abatement Order in September 2004. The firm was directed to prepare a workplan for additional on-site and off-site subsurface assessment of soil and groundwater. Honeywell has also provided previously unreported monitoring data from on-site wells between 1997 and 2003 that indicate TCE levels of 610 ppb in June 2003. Beginning in February 2005 four additional off-site wells were drilled. Samples from all existing wells were provided to the USEPA in December 2004. MWH, consultant for Honeywell, has completed bench-scale testing for treatment of hexavalent chromium and VOCs and is ready to present its findings. The RWQCB is reviewing the Waste Discharge Requirements application.

General Electric (formerly Pacific Airmotive), 2940 North Hollywood Way, Burbank

RWQCB has identified an apparent continuing source of VOCs at the former site of Pacific Airmotive property that is currently owned by General Electric. The soil vapor extraction system has been removing PCE vapor from underneath the adjacent property (2960 No. Hollywood Way). The cumulative PCE removal since January 2002 is approximately 6,500 gallons.

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Raytheon (formerly Hughes Missile Systems Company), 8433 Fallbrook Avenue, Canoga Park

The most prominent contaminant has been 1,1-DCE with lesser amounts of TCE, PCE, TCA, BTEX and 1,1-DCA. TDS is in excess of the Basin Plan objectives, so the treated water may not be discharged to the Los Angeles River even though the origin of the high TDS is related to the naturally occurring groundwater. As a result of the high TDS, the treatment plant effluent is stored in holding tanks, and used for on-site irrigation.

Due to significant decreases in contaminant concentrations, the RWQCB has approved groundwater sampling and analyses on a semiannual basis. The remediation system has reduced the extent of the plume by more than 50 percent. A work plan submitted to the RWQCB to perform a pilot test for the effectiveness of enhanced in-situ bioremediation (EISB) was approved by the RWQCB and initial fieldwork began in September 2003. A work plan for fullscale implementation of EISB was approved with associated permitting in September 2005 and injections in two of the four proposed areas completed in October 2005. The remaining two areas will be completed in Spring 2006. Although the property is now owned by other entities, Raytheon is the current operator of the soil and groundwater treatment system.

3M (formerly Riker Lab), 19901 Nordhoff, Northridge

Contaminants at this site include chloroform, 1,2-DCE, 1,2-DCA, and Freon 1[illegible]. There has been a groundwater treatment system in operation since 1997. There are currently 15 groundwater extraction wells and two air-stripping towers in series capable of treating 60,000 gallons per day. Until recently, some of the treated groundwater was used on-site for roloclones (dust collectors), biofilters, and cooling towers, and the balance was discharged to the stormdrain under a NPDES permit. In March 2005, 3M and its consultant, Weston Solutions, Inc. completed installation of a system to re-use the discharged portion of the groundwater for landscape irrigation. All of the treated groundwater is now beneficially used on-site.

3M has obtained a license from the National Aeronautics and Space Administration for a proprietary technology that 3M has used successfully at other sites. Nanometer-size iron particles are suspended in an emulsion of vegetable oil which is injected into the contaminated groundwater. The iron particles strip the chlorine from the VOC molecules. The remaining hydrocarbon is then cometabolized by naturally-occurring bacteria in the soil and groundwater, which use the vegetable oil as a food source. 3M is evaluating whether the conditions at the Northridge site are compatible with this technology.

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Micro Matics, 19791 Bahama St., Northridge

The Micro Matics site is located adjacent to 3M. The soil and groundwater beneath a portion of the property are contaminated with PCE and 1,1,1-TCA. The plume has also moved off-site to the west beneath a portion of the former 3M property, and a so to the south beneath Bahama Street. The 3M parcel contaminated by Micro Matics was sold to a developer, Northoff Industrial, in December 2004. Preparation and submittal of a groundwater remedial action plan will follow review of the HRC pilot test data.

Treatment currently consists of pumping contaminated groundwater and treating it with liquid-phase GAC. A plan has recently been approved by the RWQCB to inject a hydrogen donating compound into the aquifer to degrade the VOCs in-situ. The first phase of the HRC™ in-situ groundwater remediation pilot test has been implemented and initial results indicate a reduction in the perchloroethylene (PCE) concentration. The second phase of the pilot test that includes injection of HRC-X™ was implemented in July 2005.

Tesoro Petroleum (former Fast Fuel, 11051 Victory Blvd., N. Hollywood)

Tesoro Petroleum is the owner of a gasoline station site in North Hollywood. A leaking underground tank caused a plume of gasoline hydrocarbons and MTBE that has migrated off-site toward several wells in LADWP's Whitnall Well Field. Tesoro, and its consultants Haley & Aldrich and Miller Brooks Environmental, have been performing soil remediation using soil vapor extraction. Working with its consultants, LADWP, RWQCB, and the Watermaster, Tesoro has implemented a groundwater cleanup plan that features ex-situ bioremediation and re-injection of the treated groundwater. Full-scale re-injection began in October 2005. During that month, a total of 1,194,735 gallons were treated of which 1,164,050 gallons were re-injected back into the aquifer. In July 2005 the National Ground Water Association (NGWA) selected this project for its 2005 NGWA Outstanding Ground Water Project Award.

Taylor Yard (Los Angeles River Narrows Area)

The remediation of the Taylor Yard of the Union Pacific Railroad Company is under the jurisdiction of the Cal-EPA DTSC. The Taylor Yard has been divided into two parts - active yard and sale parcel.

The Union Pacific Railroad originally owned this entire large parcel along the Los Angeles River Narrows. It has attracted the interest of many stakeholders including the State Parks

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Department and the California State Coastal Conservancy as a potential site for habitat restoration and recreation. There is significant soil and groundwater contamination at the site, and potential issues involving water rights. The Watermaster Office is working with the stakeholders to resolve these issues. A final feasibility study was issued in June 2002, and is available through the Coastal Conservancy.

The 25-acre active yard is contaminated with VOCs, SVOCs, fuel hydrocarbons, and metals. Three soil vapor extraction systems have removed a total of 2,318 pounds of VOCs . There are currently 38 groundwater wells in the monitoring program, eight of which are sampled quarterly and 21 are sampled semi-annually. Two of the SVE systems have been shut down since June 2004 to allow for soil-gas sampling in support of the Focused Remedial Investigation. The systems will remain shut down pending the outcome of the review of the Interim Remedial Measure Closure Report due approximately March 31, 2006.

Chromium

In January 2003 the ULARA Watermaster published a report on hexavalent chromium contamination in the SFB. The RWQCB published a report of its four-year investigation of hexavalent chromium in December 2002. The presence of this contaminant threatens the use of SFB groundwater as a reliable source of water for Burbank, Glendale, and Los Angeles, and jeopardizes the Operable Units constructed with funding from the USEPA to clean up VOCs on a regional basis. The Operable Units that treat VOCs in the groundwater were not designed to treat chromium.

Total chromium is comprised of hexavalent chromium and trivalent chromium. Hexavalent chromium is a carcinogen when inhaled, but the effects when ingested are a subject of continuing debate. Trivalent chromium is a nutrient when ingested in small amounts.

A National Toxicology Program study is underway to determine a safe federal Maximum Contaminant Level (MCL) for hexavalent chromium, and should be completed in 2006 or 2007. The federal and state drinking water MCLs for total chromium are 100 ppb and 50 ppb, respectively. There are no separate standards for hexavalent chromium. Until hexavalent standards are developed, the total chromium standards will continue to be used.

At the State level, the Governor approved State Senate Bill 2127 in November 2000. This bill requires the DHS to determine the levels of chromium in the drinking water supplied by public water systems from the SFB aquifer and, in consultation with OEHHA, to assess the exposures

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and risks to the public. The report was due January 1, 2002 but has not been published as of this writing

The Consent Decrees between the USEPA and the responsible parties require that certain pumping rates be maintained in the OUs to control VOC plume migration and provide contaminant removal. As these wells are pumped, the chromium plumes also migrate toward the wells, albeit at a slower rate than the VOCs. Hexavalent chromium has now appeared in all of the OUs in the SFB. Fortunately, the levels are currently low enough to allow blending with imported water to levels that meet all drinking water standards. However, should the levels become too high to allow blending to reduce chromium to acceptable level, the operation of the OUs would become compromised.

The RWQCB, with assistance from the USEPA and the cities of Burbank, Glendale, and Los Angeles has received temporary staff support to expedite investigation of possible hexavalent chromium contaminated sites. The focus is on the several sites identified last year by the RWQCB with the highest reported levels of hexavalent chromium and the greatest potential impact on the three cities' OUs and well fields. Additional suspect sites were uncovered during the investigation and these new sites have been transferred to the jurisdiction of the Cal EPA-Department of Toxic Substance Control.

A study is underway by McGuire Malcolm Pirnie Environmental Consultants to identify a cost-effective technology to remove chromium to very low levels. The USEPA, American Water Works Research Foundation, and the cities of Glendale, Los Angeles, and Burbank are funding the project. Weak base anion exchange has been identified as a promising treatment technology. When additional funding is secured the City of Glendale intends to install a treatment system on at least one of its high-chromium OU wells.

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3. WATER QUALITY, TREATMENT, AND REMEDIAL INVESTIGATION ACTIVITIES

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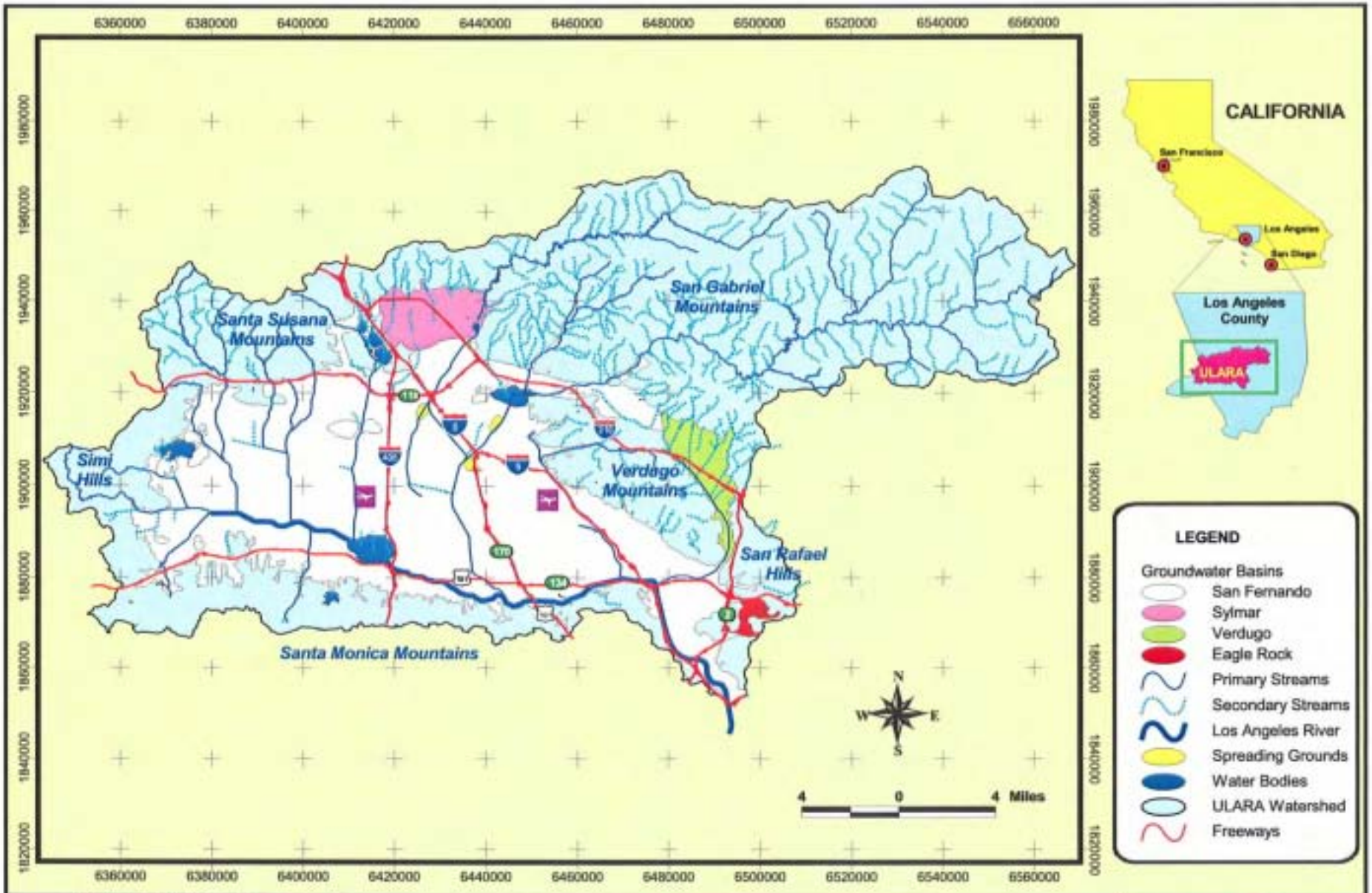
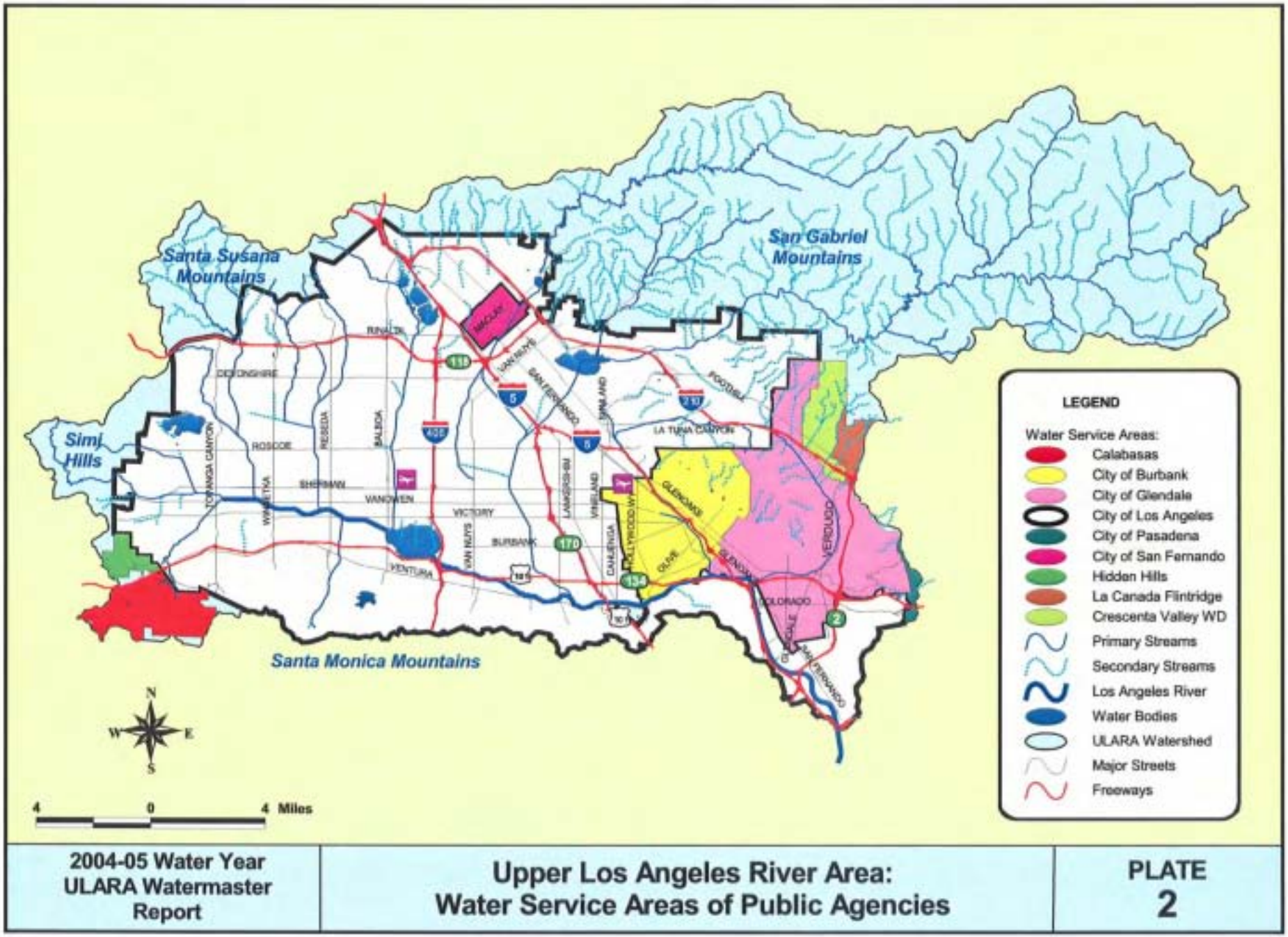
PLATES



2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Vicinity and Location Map	PLATE 1



2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Water Service Areas of Public Agencies	PLATE 2

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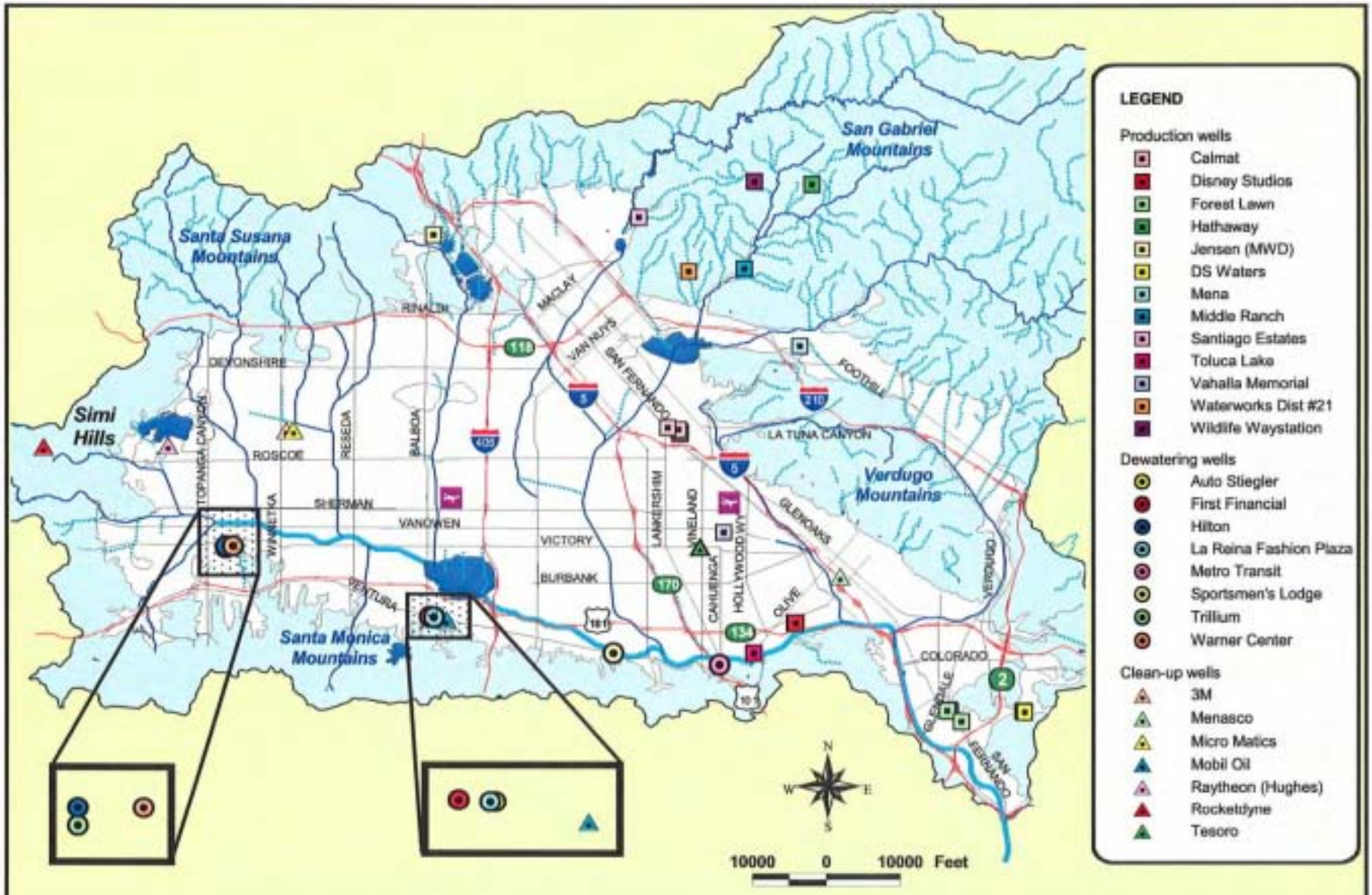
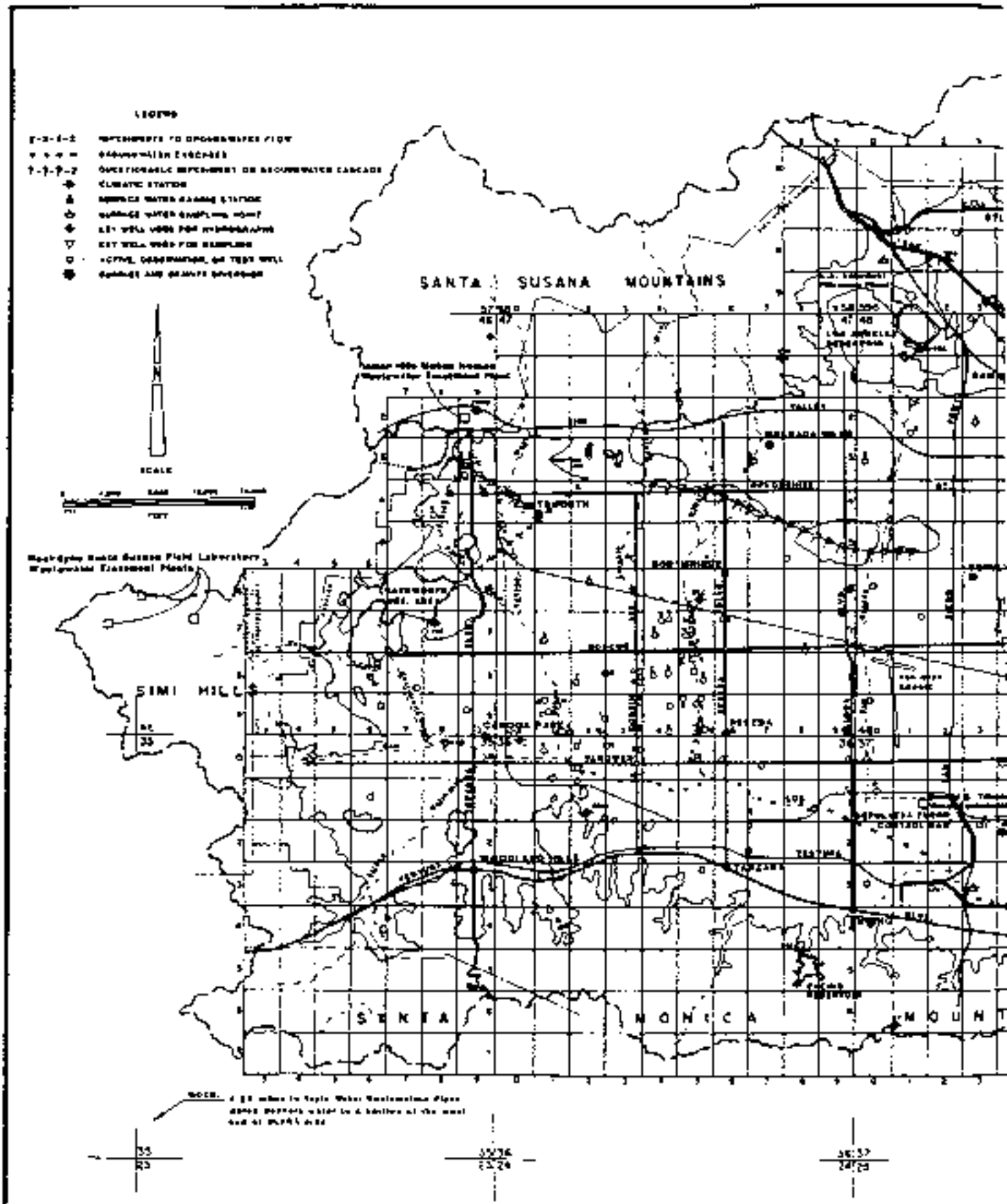


2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Location of Individual Producers	PLATE 3



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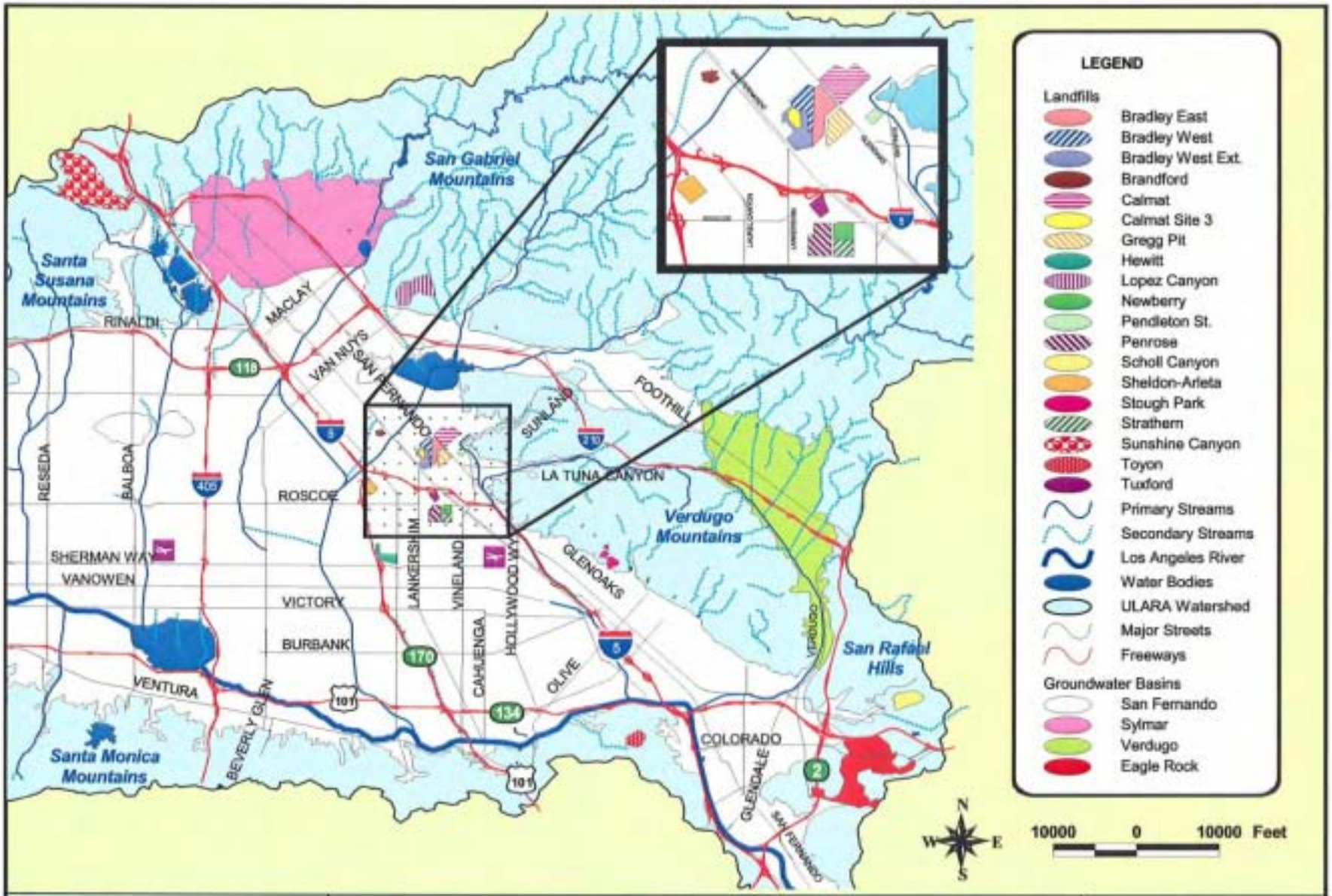
2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Water Reclamation Plants and Rain-Runoff Gages	PLATE 5



2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Landfill Locations	PLATE 6

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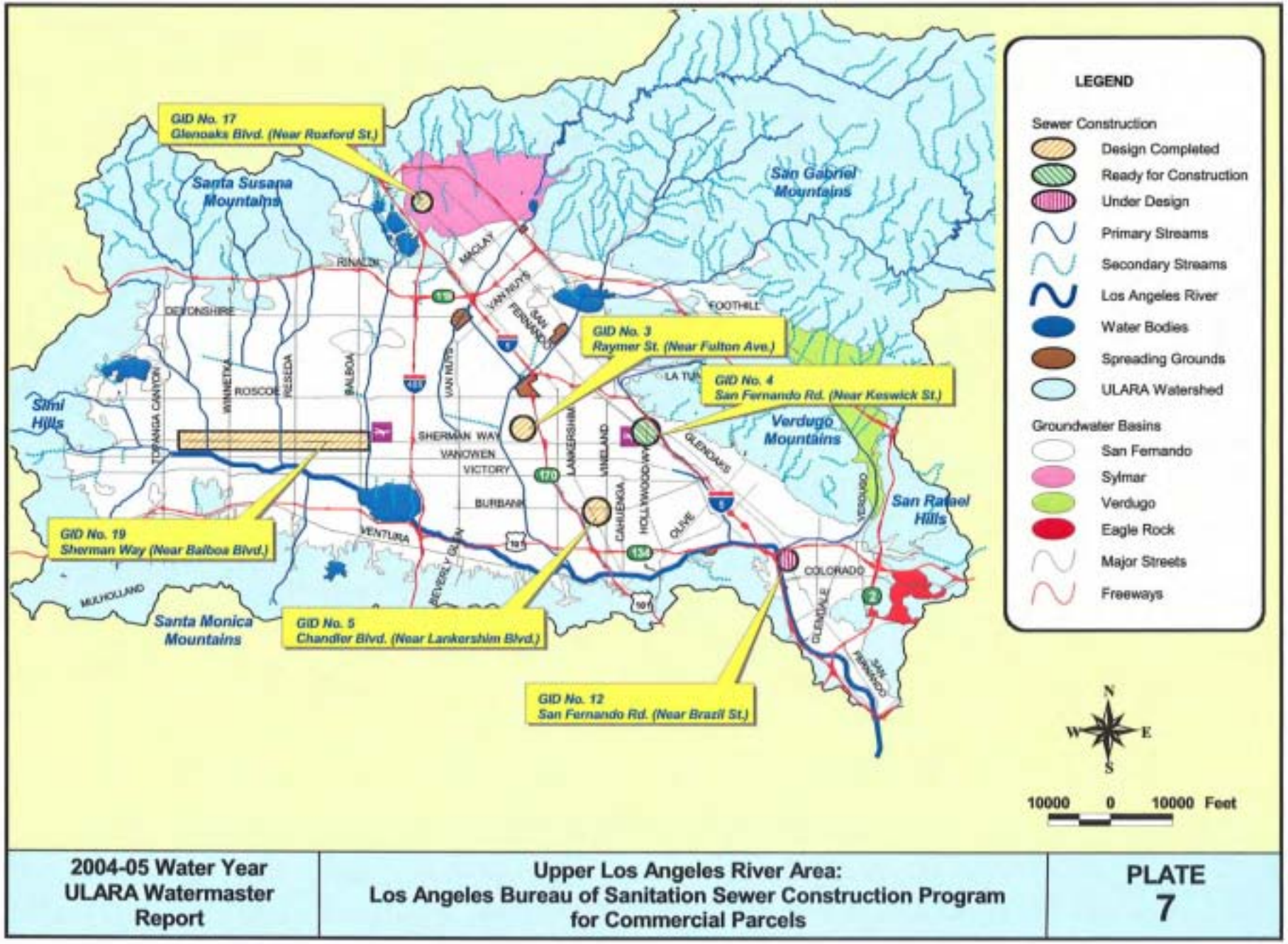
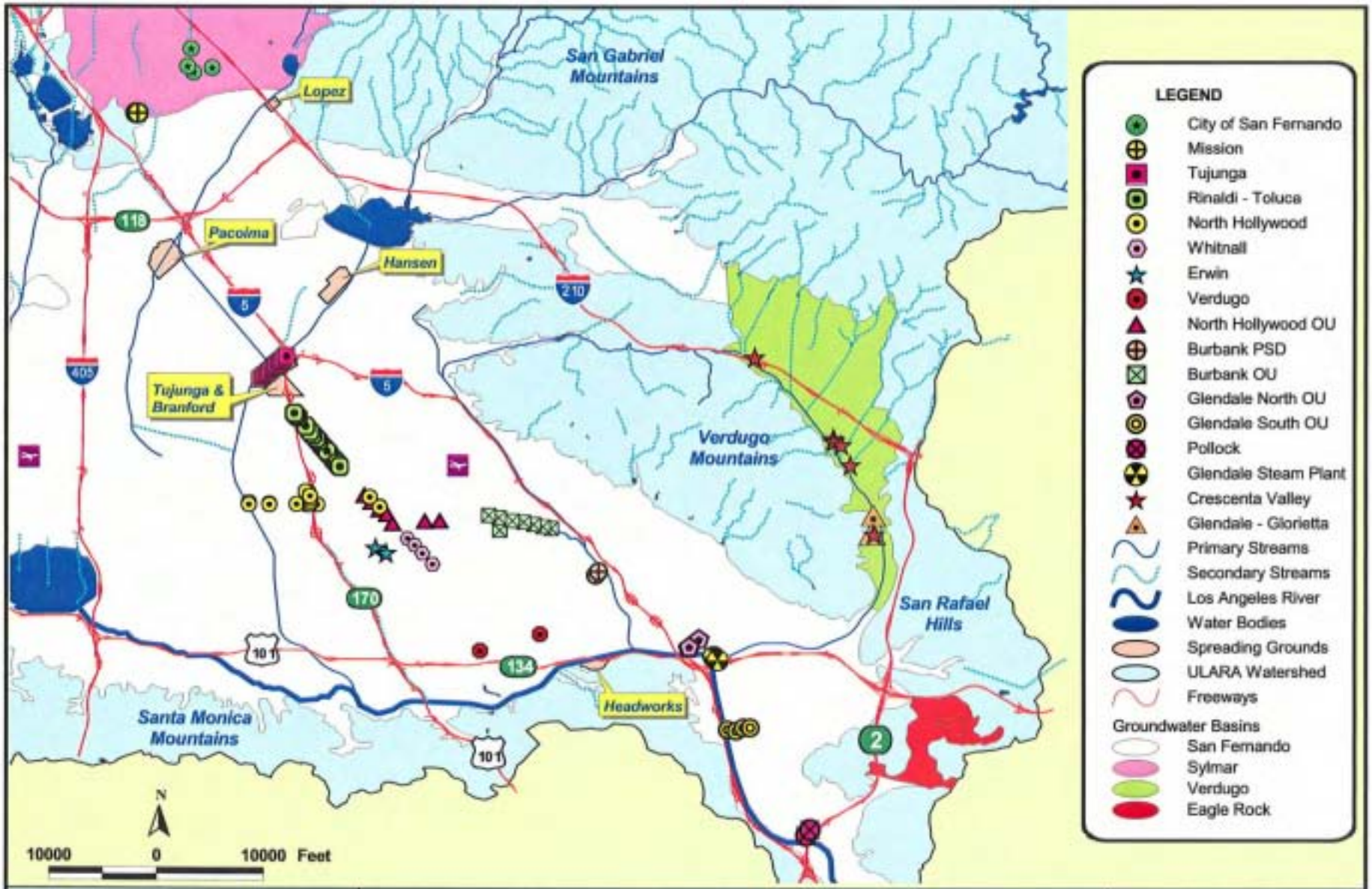


2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Los Angeles Bureau of Sanitation Sewer Construction Program for Commercial Parcels	PLATE 7



2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Major Well Fields and Spreading Grounds	PLATE 8

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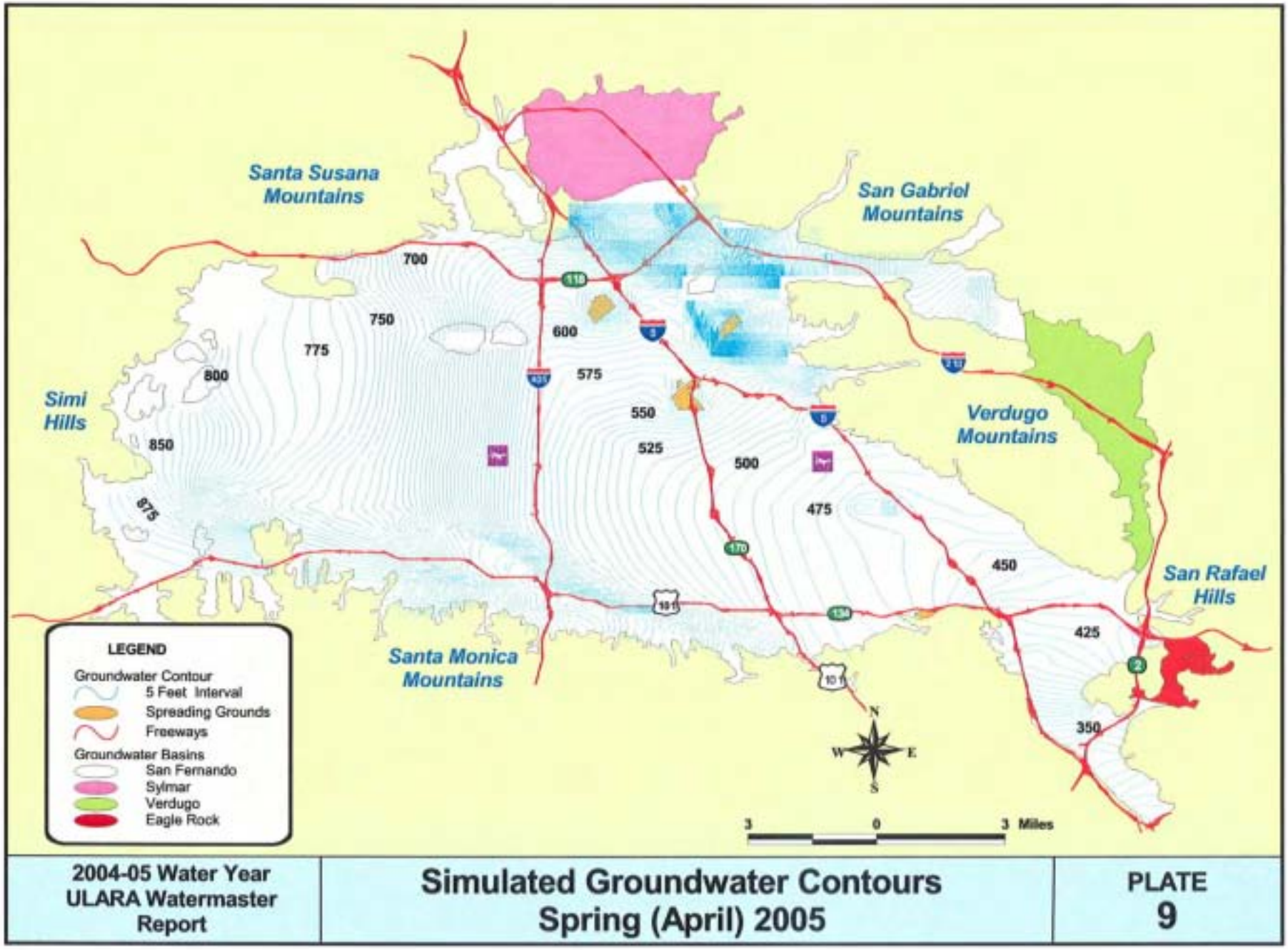

2004-05 Water Year ULARA Watermaster Report	Simulated Groundwater Contours Spring (April) 2005	PLATE 9

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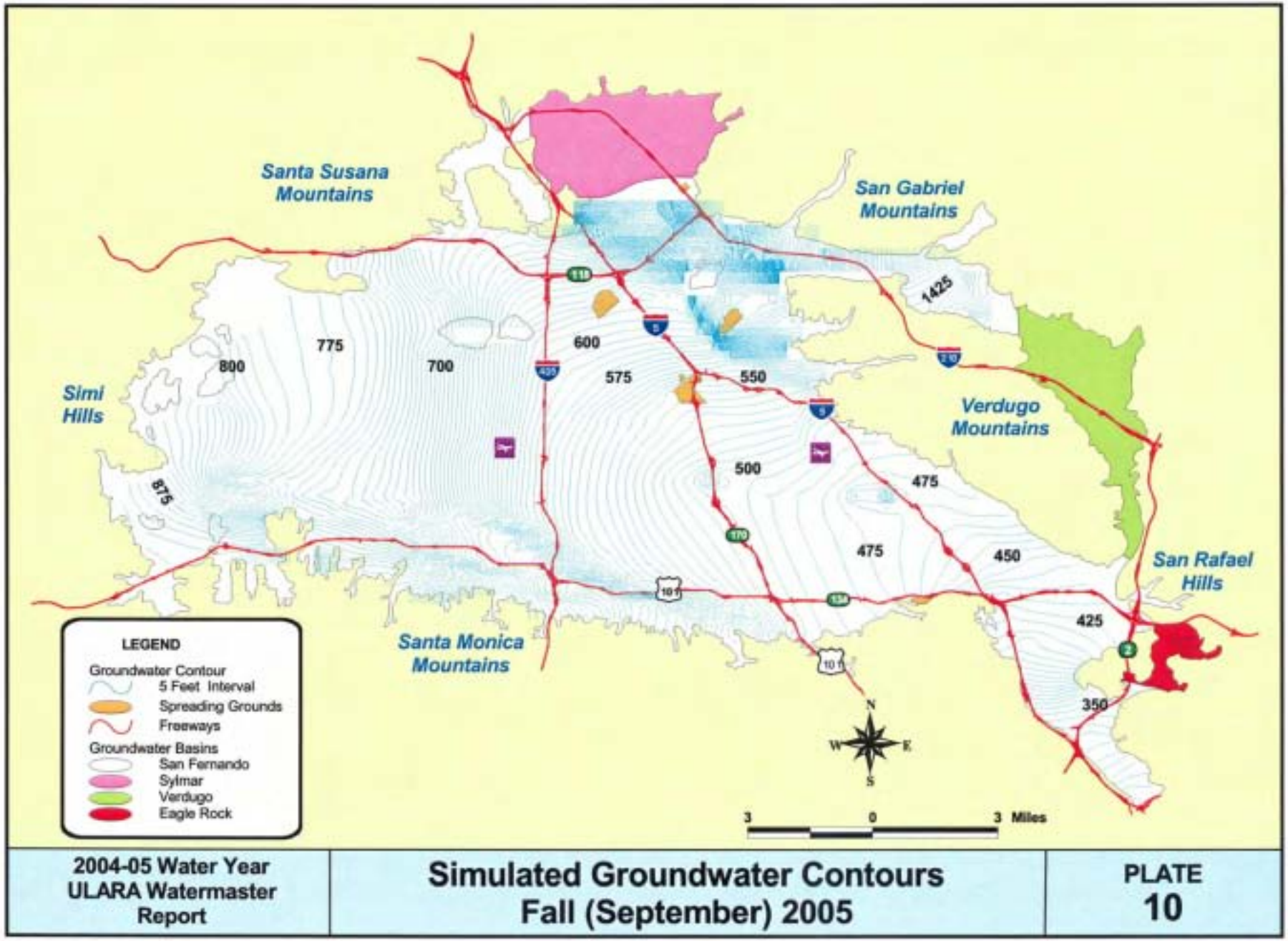

2004-05 Water Year ULARA Watermaster Report	Simulated Groundwater Contours Fall (September) 2005	PLATE 10

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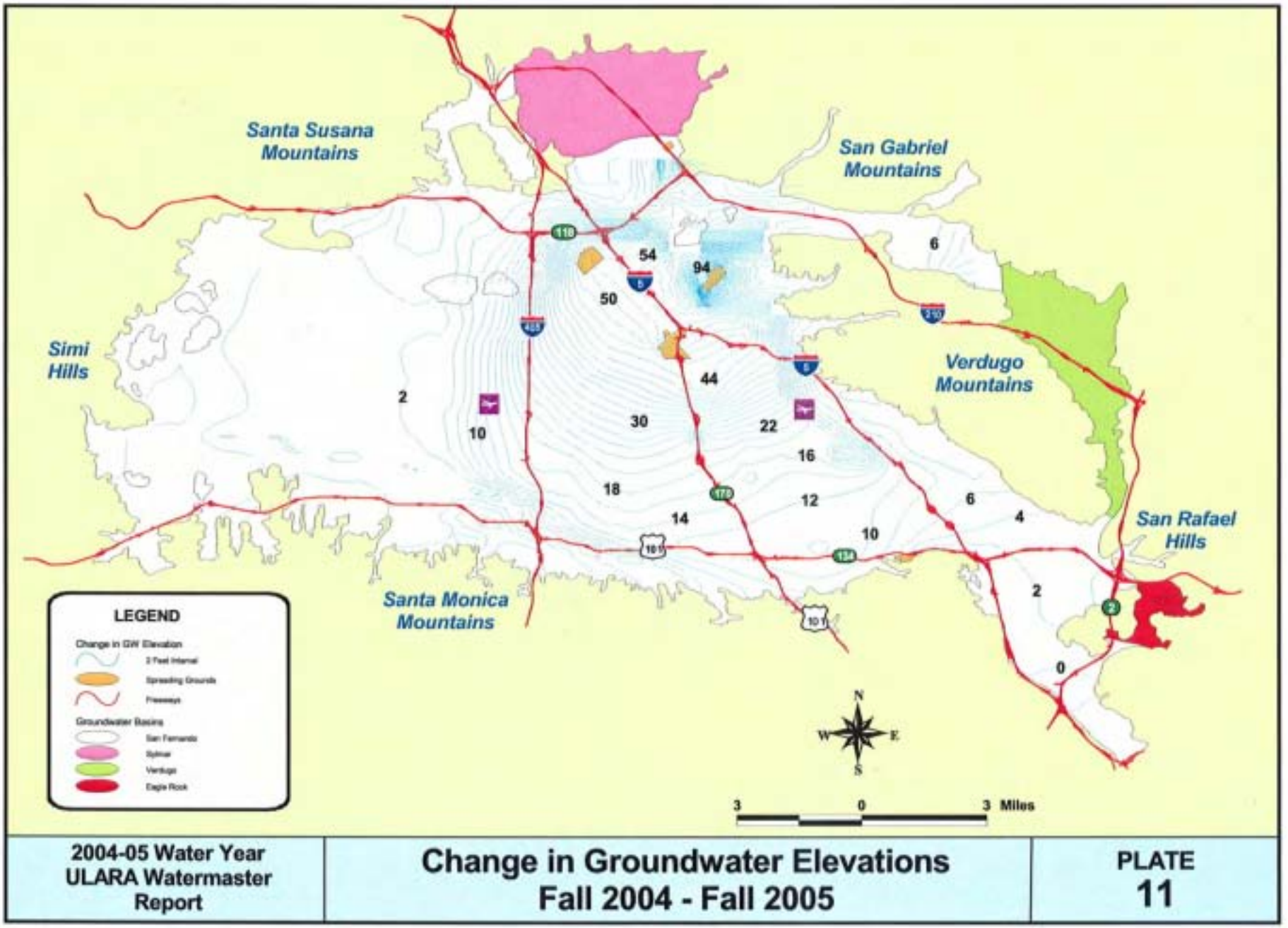

2004-05 Water Year ULARA Watermaster Report	Change in Groundwater Elevations Fall 2004 - Fall 2005	PLATE 11

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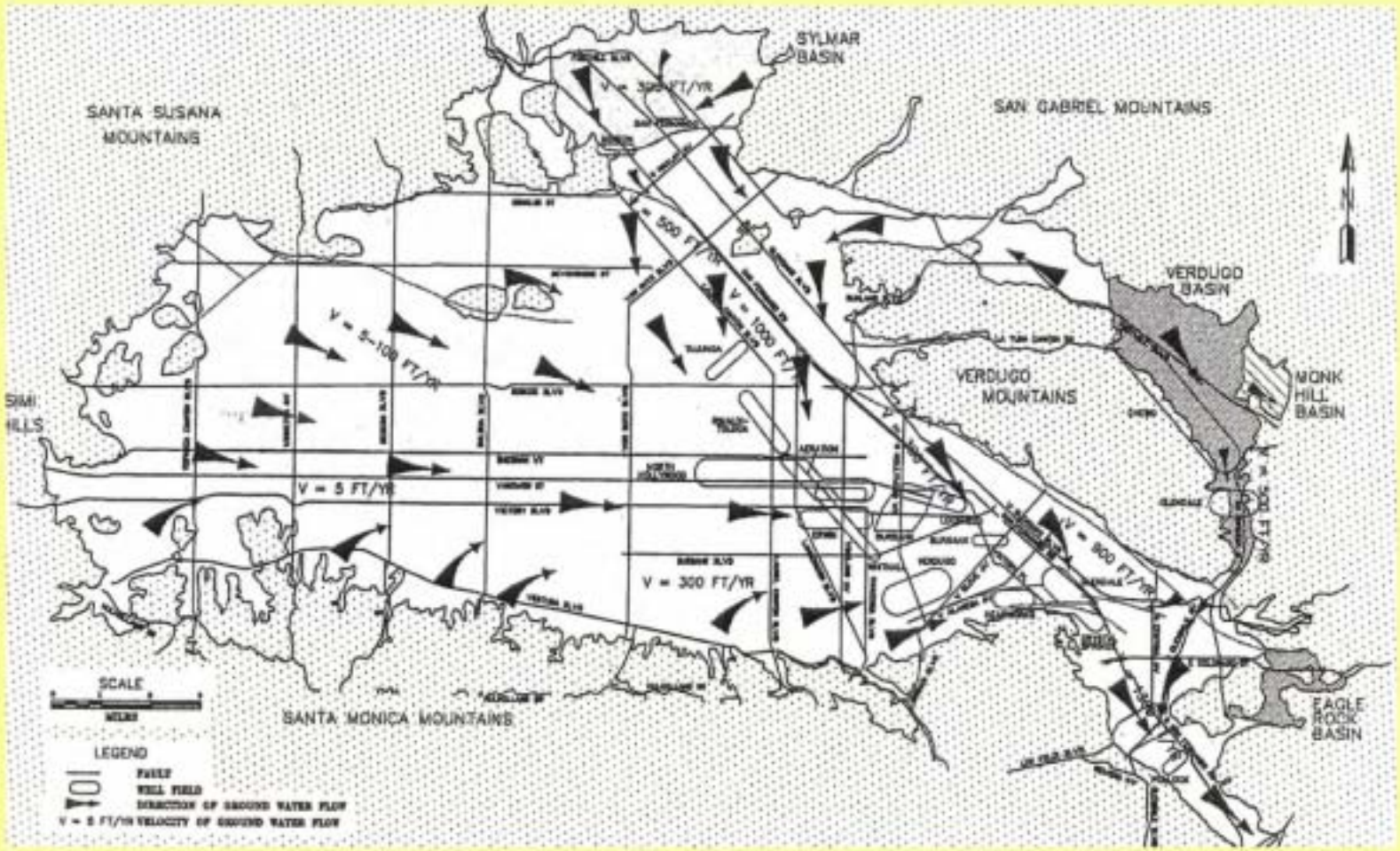
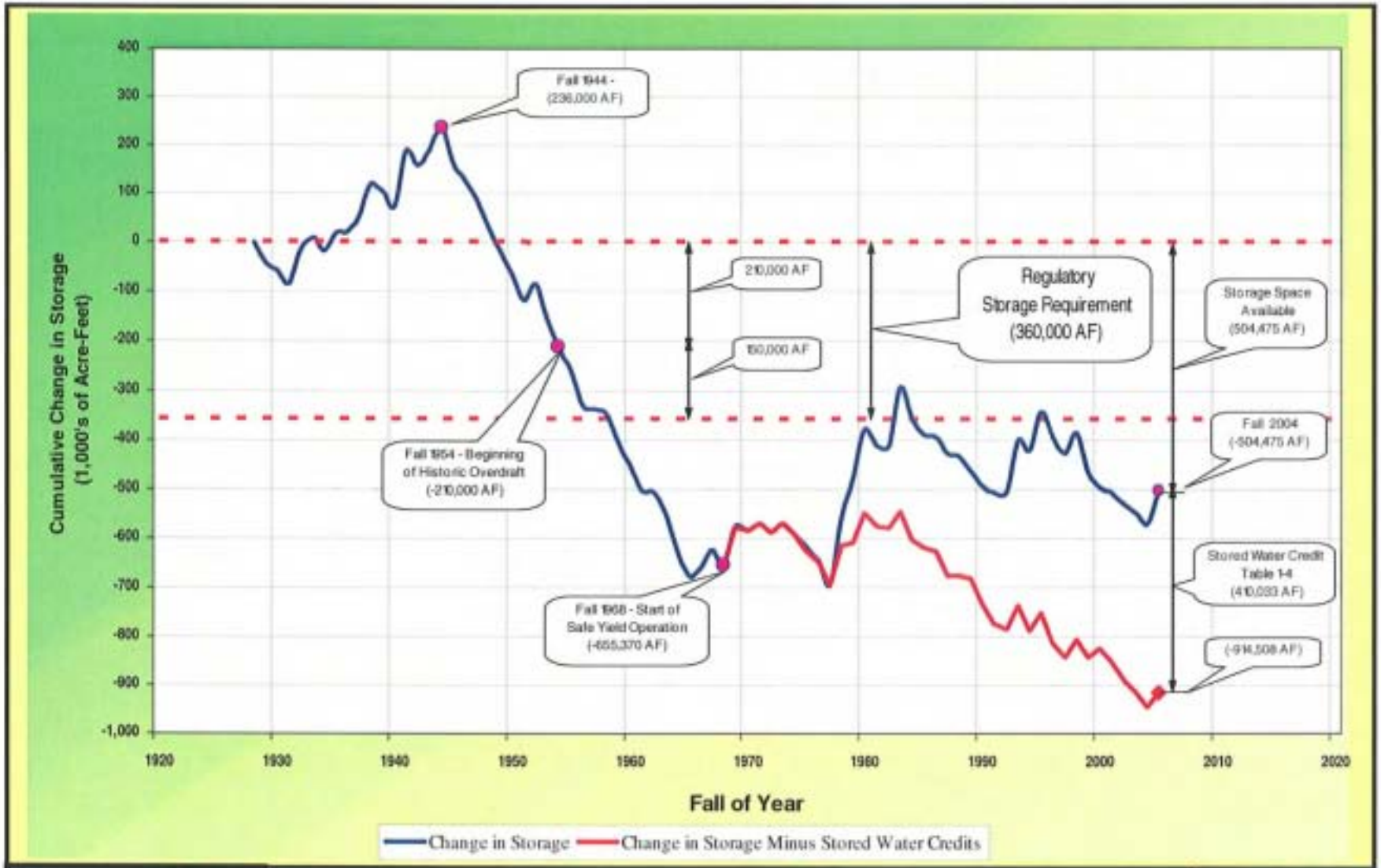


2004-05 Water Year ULARA Watermaster Report	**Upper Los Angeles River Area: Estimated Directions and Velocities of Groundwater**	PLATE **12**



2004-05 Water Year ULARA Watermaster Report	**San Fernando Basin:** **Cumulative Change in Groundwater Storage**	PLATE **13**

PLATE 13 B - ULARA WATERMASTER REPORT

SAN FERNANDO BASIN
CUMULATIVE CHANGE IN GROUNDWATER STORAGE
(acre-feet)

Fall of Year	Change in Storage	Cumulative Chg. in Storage (1928)	Cumulative Chg in Storage 1,000 AF	Cumulative Chg in Storage (1944)	Cumulative Chg in Storage 1,000 AF
1928	0	0	0		
1929	-41,510	41,510	-42		
1930	15,690	-57,200	-57		
1931	-26,320	-83,520	-84		
1932	67,030	-16,490	16		
1933	26,640	10,150	10		
1934	-28,560	-18,410	-18		
1935	38,040	19,630	20		
1936	1,000	20,630	21		
1937	30,660	51,290	51		
1938	66,420	117,710	118		
1939	-12,540	105,170	105		
1940	-32,650	72,520	73		
1941	116,850	189,370	189		
1942	-31,230	158,140	158		
1943	31,030	189,170	189		
1944	47,200	236,370	236	0	0
1945	-74,180	162,190	162	-74,180	-74
1946	-33,300	128,890	129	107,480	-107
1947	-41,200	87,690	88	-148,680	-149
1948	-52,770	34,920	35	-201,450	-201
1949	-56,360	-21,440	-21	-257,810	-258
1950	-43,390	-64,830	-65	-301,200	-301
1951	-53,290	-118,120	-118	-354,490	-354
1952	33,720	-84,400	-84	-320,770	321
1953	-68,280	152,680	153	-389,050	-389
1954	-56,770	-209,450	-209	-445,820	-446
1955	-51,370	-260,820	-261	-497,190	-497
1956	-71,390	-332,210	-332	-568,580	-569
1957	-6,280	-338,490	-338	574,860	-575
1958	-9,150	-347,650	-348	-584,020	-584
1959	-52,160	-399,810	-400	-636,180	-636
1960	53,080	-452,890	-453	689,260	-689
1961	-50,770	-503,660	-504	-740,030	-740
1962	-3,590	-507,250	-507	-743,620	-744
1963	-40,395	-547,640	-548	784,010	-784
1964	-70,220	-617,860	-618	-854,230	-854
1965	57,850	-675,710	676	-912,080	-912
1966	14,970	-660,740	-661	-897,110	-897
1967	36,720	-624,020	-624	-860,390	-860
1968	-31,350	-655,370	-655	891,740	892
1969	79,240	-576,130	-576	-812,500	-813

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SAN FERNANDO BASIN
CUMULATIVE CHANGE IN GROUNDWATER STORAGE
(acre-feet)

Fall of Year	Change in Storage	Cumulative Chg. in Storage (1929)	Cumulative Chg. in Storage 1,000 AF	Cumulative Chg. in Storage (1944)	Cumulative Chg. in Storage 1,000 AF
1970	-5,740	-585,870	-586	-822,240	-822
1971	15,340	-570,530	-571	-806,900	-807
1972	-17,090	-587,620	-588	-823,990	-824
1973	17,020	-570,600	-571	-806,970	-807
1974	-21,820	-592,420	-592	-828,790	-829
1975	-22,580	-615,000	-615	-851,370	-851
1976	-30,090	-645,090	-645	-881,460	-881
1977	-50,490	-695,580	-696	-931,950	-932
1978	136,150	-559,430	-559	-795,800	-796
1979	78,080	-481,350	-481	-717,720	-718
1980	99,970	-381,380	-381	-617,750	-618
1981	-32,560	-413,940	-414	-650,310	-650
1982	530	-414,470	-414	-650,840	-651
1983	121,090	-293,380	-293	-529,750	-530
1984	-63,180	-356,560	-357	-592,930	-593
1985	31,690	-388,250	-388	-624,620	-625
1986	-7,980	-396,230	-396	-632,600	-633
1987	-31,940	-428,170	-428	-664,540	-665
1988	-5,000	-433,170	-433	-669,540	-670
1989	-30,550	-463,720	-464	-700,090	-700
1990	-29,941	-493,661	-494	-730,031	-730
1991	-14,122	-507,783	-508	-744,153	-744
1992	411	-507,372	-507	-743,742	-744
1993	106,317	-401,055	-401	-637,425	-637
1994	-22,238	-423,293	-423	-659,663	-660
1995	79,132	-344,161	-344	-580,531	-581
1996	49,723	-393,384	-393	-629,754	-630
1997	-35,737	-429,121	-429	-665,491	-665
1998	44113	-385,008	-385	-621,378	-621
1999	-82673	-467,681	-468	-704,051	-704
2000	-31,044	-498,725	-499	-735,095	-735
2001	-6,930	-505,655	-506	-742,025	-742
2002	-27,094	-532,749	-533	-769,119	-769
2003	-15,835	-548,584	-549	-784,954	-785
2004	-22,367	-570,951	-571	-807,321	-807
2005	66,476	-504,475	-504	-740,845	-741

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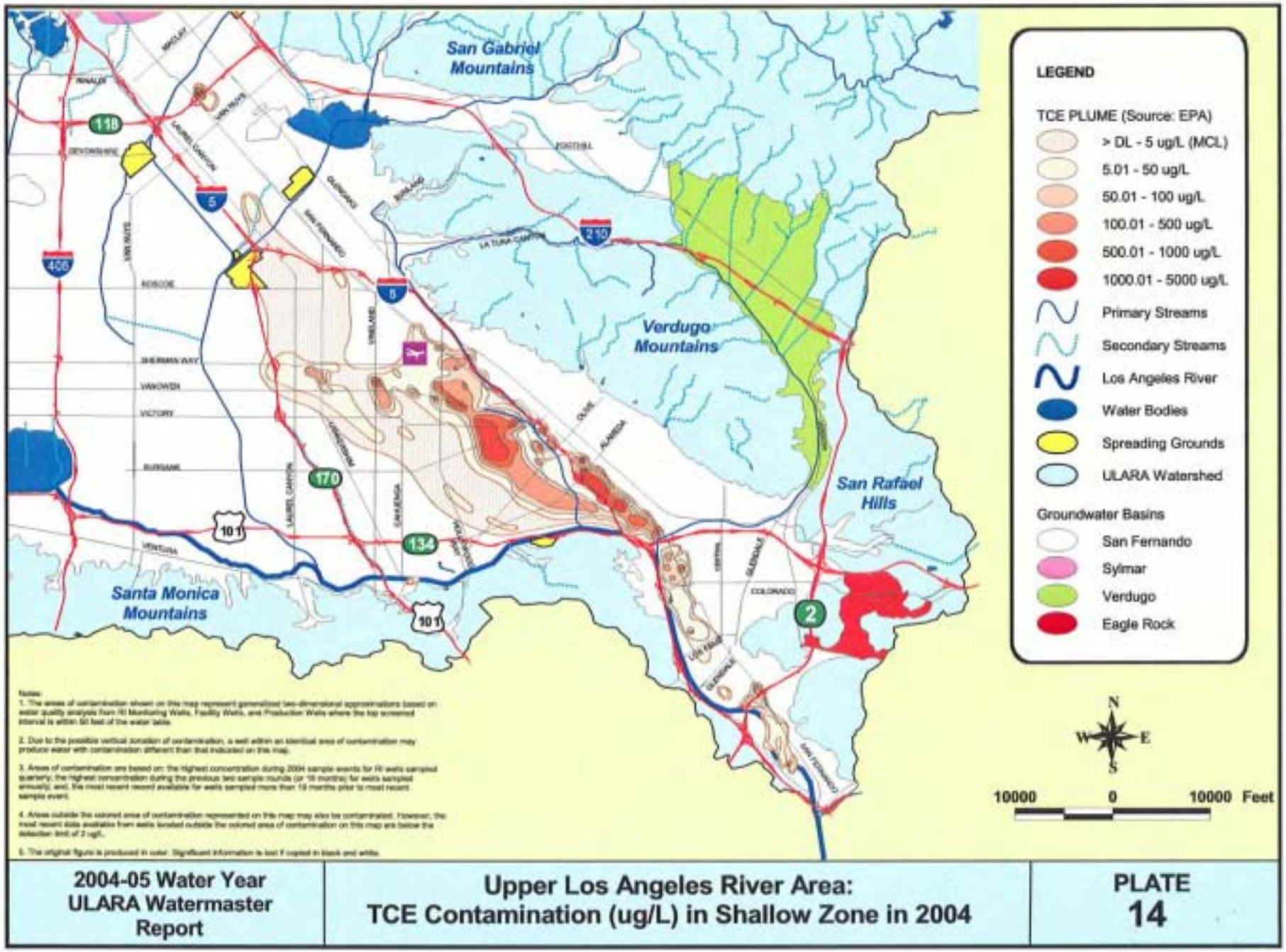
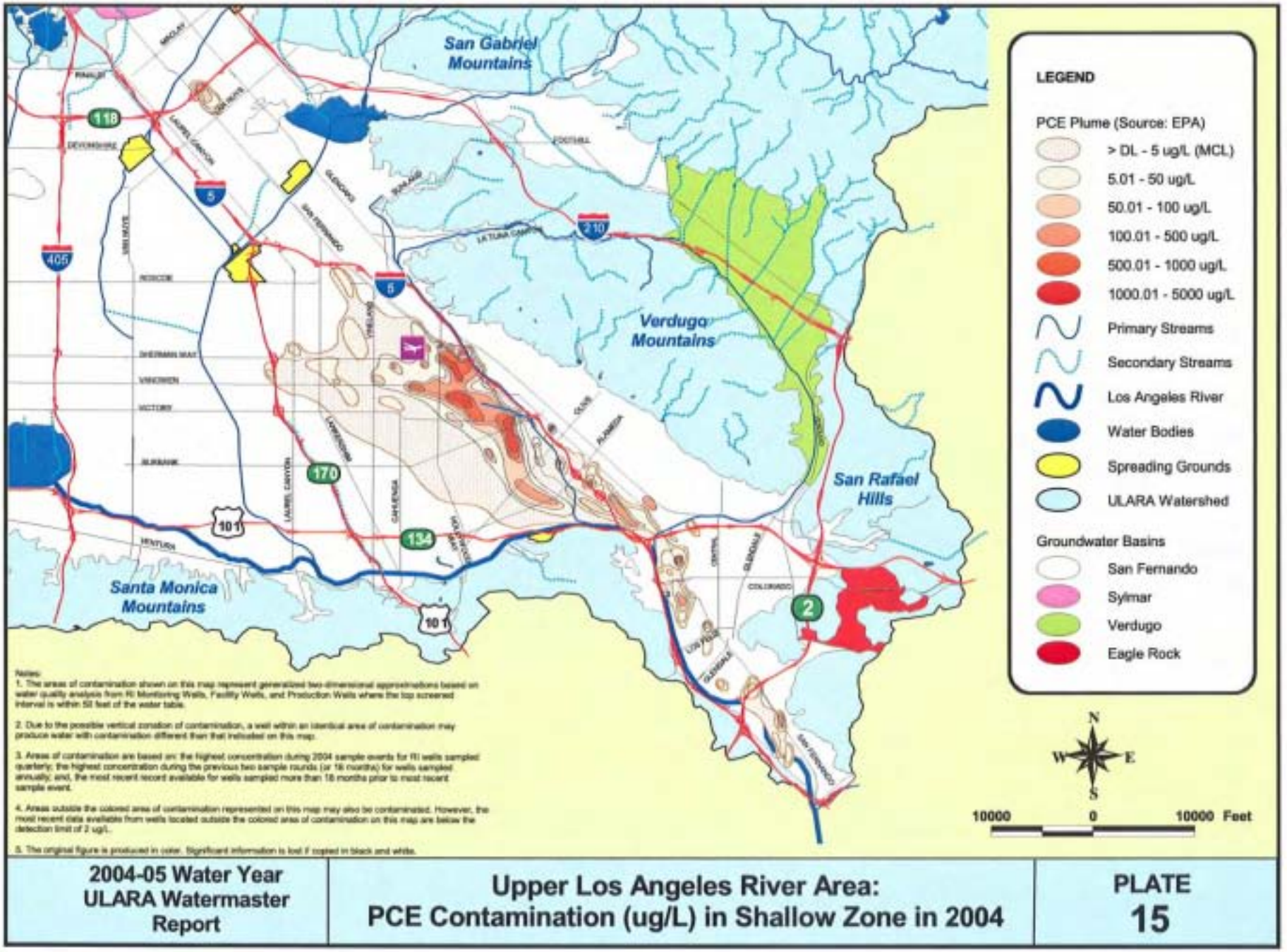
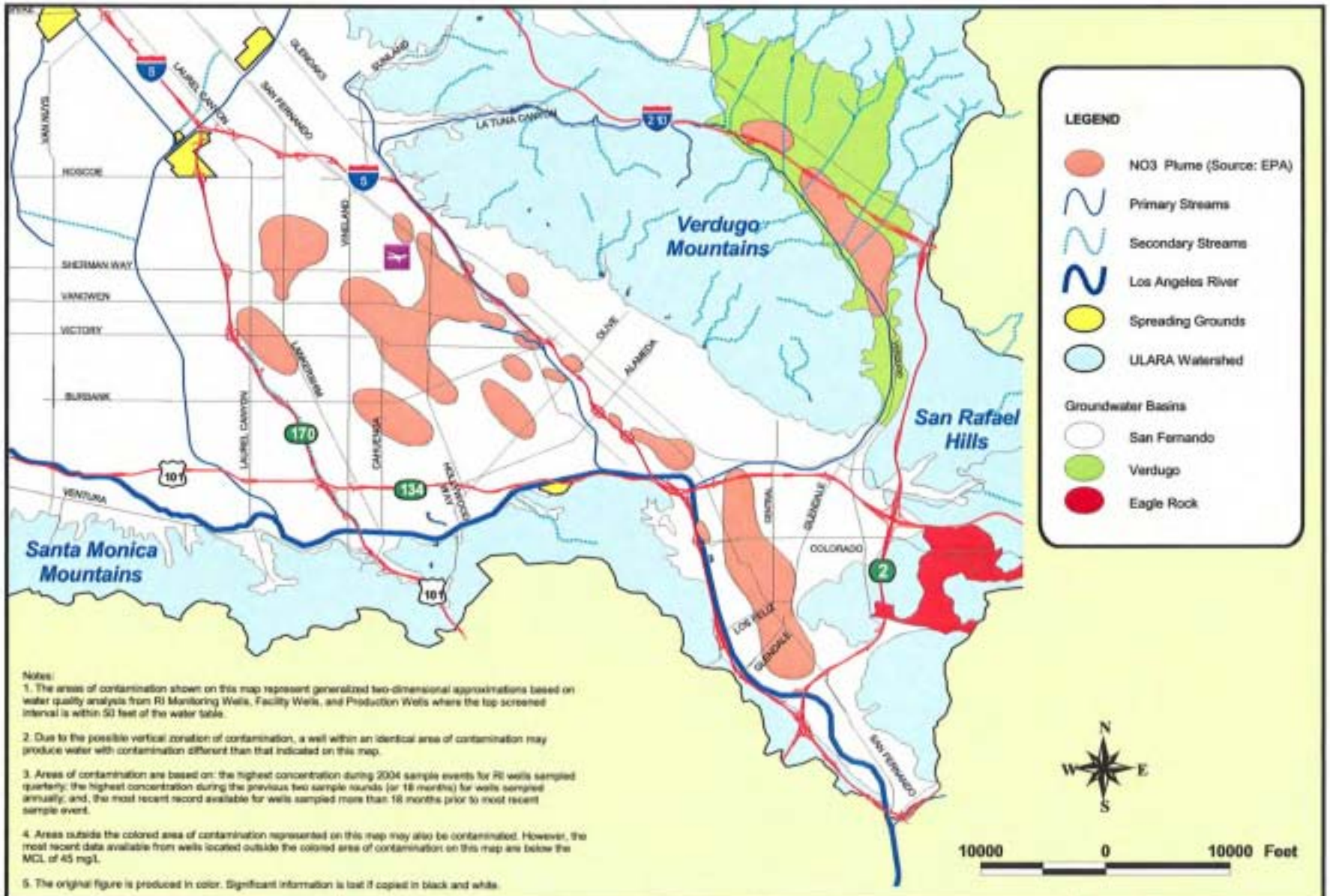


2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: TCE Contamination (ug/L) in Shallow Zone in 2004	PLATE 14



2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: PCE Contamination (ug/L) in Shallow Zone in 2004	PLATE 15

AR0074737



Notes:
1. The areas of contamination shown on this map represent generalized two-dimensional approximations based on water quality analysis from RI Monitoring Wells, Facility Wells, and Production Wells where the top screened interval is within 50 feet of the water table.

2. Due to the possible vertical zonation of contamination, a well within an identical area of contamination may produce water with contamination different than that indicated on this map.

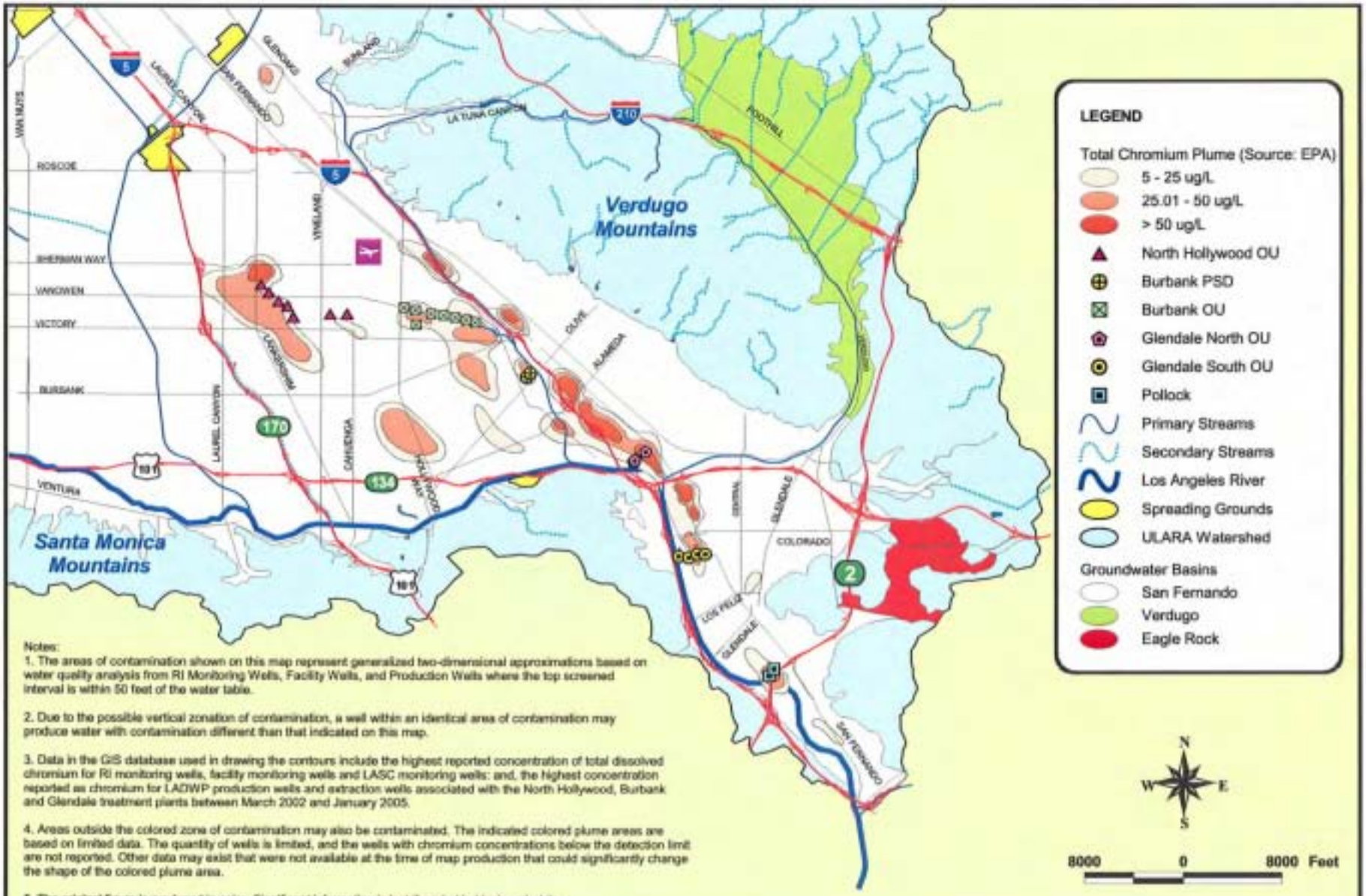
3. Areas of contamination are based on: the highest concentration during 2004 sample events for RI wells sampled quarterly; the highest concentration during the previous two sample rounds (or 18 months) for wells sampled annually; and, the most recent record available for wells sampled more than 18 months prior to most recent sample event.

4. Areas outside the colored area of contamination represented on this map may also be contaminated. However, the most recent data available from wells located outside the colored area of contamination on this map are below the MCL of 45 mg/L.

5. The original figure is produced in color. Significant information is lost if copied in black and white.

2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: NO3 Contamination (mg/L) in Shallow Zone in 2004	PLATE 16

AR0074738



Notes:
1. The areas of contamination shown on this map represent generalized two-dimensional approximations based on water quality analysis from RI Monitoring Wells, Facility Wells, and Production Wells where the top screened interval is within 50 feet of the water table.

2. Due to the possible vertical zonation of contamination, a well within an identical area of contamination may produce water with contamination different than that indicated on this map.

3. Data in the GIS database used in drawing the contours include the highest reported concentration of total dissolved chromium for RI monitoring wells, facility monitoring wells and LASC monitoring wells; and, the highest concentration reported as chromium for LADWP production wells and extraction wells associated with the North Hollywood, Burbank and Glendale treatment plants between March 2002 and January 2005.

4. Areas outside the colored zone of contamination may also be contaminated. The indicated colored plume areas are based on limited data. The quantity of wells is limited, and the wells with chromium concentrations below the detection limit are not reported. Other data may exist that were not available at the time of map production that could significantly change the shape of the colored plume area.

5. The original figure is produced in color. Significant information is lost if copied in black and white.

2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Total Dissolved Chromium Contamination (ug/L) in Shallow Zone in 2004	PLATE 17

AR0074739

APPENDIX A
GROUNDWATER EXTRACTIONS

2004-2005 Water Year
(acre feet)

LACDPW Well No	Owner Well No	2004 Oct	Nov.	Dec.	2005 Jan	Feb	Mar.	Apr.	May	June	July	Aug	Sept	TOTAL
						San Fernando Basin								
A. W. Warner Properties														
Plaza Six		0.92	1.23	1.08	1.57	1.15	1.47	1.81	1.78	1.30	1.56	1.42	1.19	17.08
A. W. Warner Properties														
Plaza Tower		0.78	0.84	0.87	1.10	1.14	1.51	1.59	1.76	1.11	1.75	1.50	1.04	13.51
Angelica Healthcare Services		(Formerly CPC)												
V-34A	M050A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apple Dodger														
---	---	0.74	0.91	0.00	0.83	0.65	0.78	0.00	1.50	0.40	0.93	1.78	1.36	9.22
Boeing (Rocketdyne International. No further pumping until 2006)														
---	P-1 to P-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boeing Santa Susana Field Laboratory														
Delta	WS-05A	0.74	0.85	1.45	0.00	0.00	0.26	0.8	.02	1.21	0.95	0.80	0.00	5.06
	RD-14	0.11	0.22	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
	Total	0.85	0.9	1.80	0.00	0.00	0.26	0.91	1.02	1.21	0.95	0.80	0.00	5.20
Burbank, City of														
3811C	6A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3812F	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3811F	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3811K	12A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3812J	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3811H	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Burbank Operable Unit														
3457L	VO-1	7.34	37.26	68.22	8.31	8.17	11.26	56.30	0.00	1.41	18.46	24.58	74.75	495.49
3810G	VO-2	75.76	124.5	1.26	126.67	52.24	50.76	55.06	0.00	26.56	141.49	44.52	106.28	1,026.56
3460N	VO-3	112.61	90.19	118.56	17.27	5.06	22.39	1.36	0.00	25.76	80.72	0.00	37.95	542.18
3861L	VO-4	65.20	106.91	122.77	15.50	31.26	54.29	34.61	0.00	0.00	0.00	7.18	107.83	596.75
3815N	VO-5	78.59	0.15	10.53	0.00	0.00	0.00	119.45	0.00	0.00	0.00	0.00	19.29	228.11
3850L	VO-6	103.22	0.10	0.00	0.00	0.00	0.00	0.00	0.27	93.97	191.81	128.85	93.72	612.07
3850A/B	VO-7	101.84	122.9	122.48	119.22	52.9	140.22	103.1	0.00	24.30	129.62	60.43	0.00	1,029.16
3851K	VO-8	136.95	164.23	164.05	139.41	19.18	157.76	171.22	0.00	186.21	195.69	189.54	182.23	1,716.96
	Total	784.51	651.46	708.71	566.68	324.61	446.34	601.8	0.00	542.37	969.78	927.80	666.05	6,378.67
CalMat														
4916A	2	28.64	7.3	19.53	24.30	33.07	32.07	13.61	0.00	32.56	0.00	0.04	0.00	213.09
4916	1	46.20	50.42	41.59	47.20	63.06	63.90	60.14	31.35	7.10	41.78	56.22	39.50	527.47
4916(a)	1	29.64	84.39	88.10	90.20	122.64	122.00	26.66	2.31	124.26	82.15	121.25	57.41	1,049.99
vacation Pond		148.54	111.88	147.93	101.14	32.12	32.12	258.88	143.11	121.47	148.93	152.11	128.06	1,447.30
	Total	253.02	254.00	297.64	262.84	250.89	250.09	359.29	177.77	285.39	272.86	329.62	224.97	3,237.85
First Financial Plaza Site														
N/A	LLPS	2.82	7.75	3.42	12.29	13.43	14.48	9.71	9.16	4.21	3.29	3.12	2.64	75.01

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2004-2005 Water Year
(acre-feet)

LACDPW Well No.	Owner Well No.	2004 Oct	Nov	Dec	2005 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	2005 Total
San Fernando Basin (cont'd)														
Forest Lawn Memorial Park														
1943A	2	6.45	7.86	1.32	1.32	1.07	1.81	1.57	0.00	0.00	0.00	0.00	0.00	20.43
1943B	5	6.57	7.80	1.32	1.64	.09	1.85	14.21	25.8	27.15	29.5	13.28	22.45	92.07
1943C	6	1.05	2.47	1.29	0.5	1.05	1.82	12.06	23.42	25.25	27.85	13.38	26.45	141.41
1943K	7	0.00	0.00	0.00	0.00	0.00	0.07	0.27	0.00	0.00	0.00	0.00	0.00	0.00
1943M	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	13.07	8.00	4.33	3.37	2.21	5.73	31.05	49.2	49.90	57.35	31.66	53.5	253.90
Glendale, City of														
1924S	STP 1	5.73	0.00	0.00	0.00	10.24	1.23	0.15	1.00	0.00	41.28	35.33	5.05	211.25
1924R	STP 2	2.31	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	8.62	11.27	0.00	19.45
GVPW1	GV#2 WT	0.31	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
	Total	5.29	0.00	0.00	0.00	20.28	1.23	0.15	0.00	0.00	49.9	47.06	5.05	230.69
Glendale North/South														
	GN-1	94.09	92.26	94.82	43.15	84.42	94.46	69.80	51.46	91.21	87.22	93.51	91.60	1,066.93
	GN-2	87.65	93.65	93.16	85.98	78.17	95.50	90.53	91.42	83.25	75.12	78.17	64.16	926.91
	GN-3	58.09	62.55	92.90	91.5	0.00	0.00	0.00	.00	0.00	0.00	0.00	0.00	175.19
	GN-4	218.97	212.55	214.78	213.2	145.65	214.23	224.91	212.81	224.1	214.45	212.46	22.29	2,564.58
	GS-1	94.25	93.52	92.90	5.25	14.12	93.11	93.43	47.58	44.91	44.74	44.17	72.86	582.82
	GS-2	47.26	39.16	87.94	74.64	43.43	45.16	26.4	58.84	79.26	74.44	21.80	65.61	588.36
	GS-3	39.26	45.13	44.65	46.03	8.81	46.14	45.1	47.9	47.84	11.36	31.46	78.46	472.41
	GS-4	93.15	93.18	93.87	1.62	62.3	93.05	65.26	63.24	64.11	60.14	34.77	90.01	695.93
	Total:	931.47	931.19	932.02	651.29	474.29	866.79	683.28	573.54	646.51	634.01	553.36	589.53	7,316.18
Gravel Fabrics														
---	---	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanson Aggregates (formerly Mitic)														
---	1	1.15	0.13	1.09	0.43	0.64	0.00	0.00	1.65	2.42	2.64	2.34	2.47	13.74
	2	1.81	1.45	0.98	1.35	1.14	1.45	1.20	1.35	2.22	1.79	1.25	2.42	2.36
	3	1.54	0.54	0.16	0.00	0.00	0.24	0.54	0.00	0.00	0.16	0.00	0.00	4.87
	Total:	4.50	1.13	2.23	2.12	1.48	1.69	2.74	3.47	4.64	4.66	4.01	4.72	43.46
Rose Dias														
---		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metalcraw/Calgro Stor														
---		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metropolitan Transportation Authority														
---	1005	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
---	1025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
---	1110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
---	1140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
---	1150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
---	1010	2.12	1.36	2.97	3.54	3.08	3.80	4.55	6.88	6.42	6.49	8.81	11.10	62.45
---	1135	0.00	0.00	0.00	0.00	0.00	1.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	2.12	1.36	2.97	3.54	3.08	5.42	4.55	6.88	6.42	6.49	8.81	11.10	62.45

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2004-2005 Water Year
(acre-feet)

LACDPW Well No.	Owner Well No.	2004 Oct.	Nov.	Dec.	2005 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	TOTAL
					San Fernando Basin (cont'd)									
Metropolitan Water District														
	Jensen	15.30	15.30	3.45	3.30	16.51	12.10	11.00	18.15	15.91	18.2	19.1	18.20	161.93
Middle Ranch (Successor to deMille)														
4911-1	3	0.00	.00	0.01	0.00	2.99	0.00	0.2	0.00	0.15	0.00	7.00	2.99	0.35
4940-1	4	0.00	2.00	0.00	0.00	2.99	0.00	0.25	.00	0.15	0.00	2.99	2.99	0.35
new	5	0.00	2.00	0.01	0.00	2.01	0.01	0.25	01	0.04	0.05	2.01	2.96	0.33
4910-1	6	0.00	2.00	0.01	0.01	2.07	0.01	0.25	0.00	0.07	0.99	2.99	2.94	2.32
4910-2	7	0.46	2.99	0.21	0.44	2.08	2.09	0.99	2.11	0.78	0.05	2.02	2.00	5.57
new	8	0.00	2.00	0.00	0.00	2.00	2.00	0.00	2.00	0.01	0.14	2.14	2.01	0.58
	Spring 1&2	0.00	2.01	0.00	0.00	2.01	2.01	0.05	2.05	0.01	0.05	2.05	2.05	0.32
	Total	0.52	2.46	0.25	0.47	0.17	2.18	2.46	0.19	1.24	1.21	1.21	2.65	7.55
Micro Matic														
4TW	1	0.25	0.21	0.18	0.15	0.00	2.00	2.00	0.06	0.17	0.21	2.11	2.55	1.41
2RW	2	0.24	2.06	0.16	0.25	0.00	2.00	2.00	0.05	0.1	0.01	2.00	2.07	0.25
RMW	10	0.11	2.10	0.29	1.05	0.00	0.00	2.00	0.00	0.15	0.21	0.15	2.07	0.44
	Total	0.41	2.43	0.51	2.25	0.00	0.00	2.00	0.50	0.53	0.51	0.44	2.47	5.57
Mobil Oil Corporation														
---	--	0.1	2.02	0.02	1.06	0.16	0.11	0.16	0.26	0.00	0.01	0.00	2.00	0.59
(NEW) Northeast Interceptor Sewer (Trunk L.A. BOS)														
---	---	0.44												0.44
Northern Farmers Rubber Muzzle Systems														
--	-----	0.24	2.21	0.15	1.30	0.17	0.10	0.16	0.28	0.02	0.21	0.12	10	2.27
Oceanside #10004														
----	--								0.35	2.00	0.00	0.00	2.00	0.35
Sears Roebuck & Co. (Well disconnected 10/2000)														
5445	1945	0.00	0.00	0.15	2.01	0.00	0.00	0.00	0.00	2.00	0.00	0.00	2.00	0.16
Sportsmen's Lodge														
5385A	2	0.2	2.00	0.00	2.00	0.31	0.2	0.21	0.00	2.01	0.21	0.1	2.00	0.73
SM-Pharmaceuticals														
	---	4.52	4.01	4.36	5.08	4.48	4.12	4.87	4.59	3.72	2.34	1.53	5.42	5.20
Tesoro Petroleum Corporation														
--	MW-15	1.22	2.93	0.94	2.20	1.72	2.03	2.12	2.96	2.26	1.93	1.84	2.47	22.54
Toluca Lake Property Owners Association														
28455*	28455	2.44	2.98	1.90	0.16	2.00	2.00	2.48	3.11	5.01	5.04	4.41	5.19	0.80
Trillium Corporation														
Well #1	-	1.11	1.29	1.31	1.44	1.10	1.08	1.10	0.16	1.17	1.22	1.27	1.77	15.02
Well #2	---	0.25	0.26	2.06	2.05	2.27	0.19	2.08	0.09	0.16	2.06	0.05	0.16	7.81
	Total*	2.34	1.55	1.81	4.54	3.7	2.27	1.20	0.20	2.13	2.28	2.32	2.21	24.83
Valhalla Memorial Park and Mortuary														
5945-A	4	11.61	4.82	4.38	0.2	0.00	0.00	0.15	5.48	53.42	49.26	48.74	47.51	351.55
Waste Management Disposal Services of Calif.														
4915-D		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.00	2.00	0.00	0.00

AR0074744

2004-2005 Water Year
(in acre-feet)

LACDPW Well No.	Owner Well No.	2004 Oct.	Nov.	Dec.	2005 Jan.	Feb.	Mar.	Apr	May	June	July	Aug.	Sept.	TOTAL
						San Fernando Basin (cont'd)								
Walt Disney Pictures and Television														
16741	EAST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16741	WEST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16741	NORTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Walt Disney Riverside Building														
-	---	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waterworks District No. 21														
	---	4.51	2.08	4.47	3.58	3.21	4.10	3.10	3.20	3.36	3.35	3.61	3.40	40.41
Wildlife Waystation														
Kelsch Canyon		0.17	0.29	0.23	0.41	0.43	0.64	0.59	0.53	0.43	0.35	0.41	0.49	5.14
Sorenson Hill spring		0.02	0.00	0.00	0.00	0.02	0.04	0.03	0.02	0.02	0.0	0.01	0.01	0.12
	Total:	0.19	0.29	0.23	0.41	0.45	0.68	0.62	0.55	0.45	0.45	0.42	0.50	5.26
Los Angeles, City of														
Aeration (A)														
3800E	A-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3800W	A-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810W	A-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810W	A-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820H	A-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820J	A-6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820P	A-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3831K	A-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	A Total:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Erwin (E)														
3815 II	E-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3821T	E-2A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3815G	E-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3821F	E-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810F	E-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3821G	E-6	141.06	135.56	98.29	136.54	231.90	5.15	0.00	261.09	134.45	58.51	0.00	0.00	1,264.55
3821F	E-10	0.00	4.32	15.95	101.11	145.58	3.11	0.00	28.17	76.74	69.51	112.56	159.21	865.26
	E Total:	141.06	139.88	114.24	237.65	377.47	8.26	0.00	289.26	211.19	128.02	112.56	159.21	2,129.81
Headworks (H)		Inactive Well Field												
3853Q	H-27A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3853R	H-28A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3853S	H-29A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3853T	H-30A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	H Total:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

AR0074745

2004-2005 Water Year

(acre-feet)

Calculated Well No.	Owner Well No.	2004 Oct	2004 Nov	2004 Dec	2005 Jan.	2005 Feb	2005 May	2005 Apr.	2005 May	2005 June	2005 July	2005 Aug	2005 Sept	TOTAL
						San Fernando Basin (cont'd)								
North Hollywood (NH)														
3802	NH-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3802A	NH-4	0.00	0.00	0.00	29.09	91.00	158.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3802S	NH-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3720	NH-7	61.54	25.03	0.14	17.22	12.90	1.74	0.05	35.55	67.83	42.24	12.67	16.15	322.62
3810	NH-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810A	NH-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810S	NH-14A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3790Q	NH-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820U	NH-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820T	NH-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820W	NH-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820D	NH-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820X	NH-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3820B	NH-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3790C	NH-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3790D	NH-24	285.15	97.27	0.44	0.00	0.16	0.16	0.18	255.00	159.76	174.55	109.22	146.24	1,234.53
3840C	NH-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3790F	NH-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3790G	NH-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3790H	NH-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810X	NH-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810Z	NH-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3840G	NH-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810T	NH-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3770C	NH-32	140.76	42.50	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.98	234.34	527.11
3780F	NH-33	220.26	65.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.69	51.24	796.32
3790C	NH-34	417.29	21.69	0.41	0.00	0.18	0.64	0.29	302.8	431.54	0.00	57.11	0.41	1,233.01
3820V	NH-35	0.00	0.00	0.00	0.00	97.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	97.47
3790U	NH-36	340.71	26.17	0.41	0.00	0.00	84.57	0.00	206.87	151.56	262.17	234.99	291	1,727.18
3790J	NH-37	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41
3810M	NH-38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810N	NH-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810P	NH-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810Q	NH-41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3810R	NH-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3740K	NH-43A	402.75	32.44	0.55	61.19	27.15	34.00	0.00	275.67	213.62	97.52	11.62	0.37	1,156.58
3790L	NH-44	305.1	21.17	0.55	0.00	21	31.83	0.12	254.91	351.51	173.00	13.43	370.86	1,577.46
3790M	NH-45	332.21	24.55	0.00	0.00	0.00	41.11	0.00	353.45	485.76	239.55	412.54	109.16	2,018.33
	NH Total:	2,335.59	596.36	2.53	109.51	312.09	0.6	0.76	1,821.25	2,261.37	1,318.90	2,221.22	1,343.66	14,063.44

AR0074746

2004-2005 Water Year
(acre-feet)

LAC DPW Well No.	Owner Well No	2004 Oct	Nov.	Dec	2005 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	TOTAL
San Fernando Basin (cont'd)														
Pollock (P)														
3959E	P-4	1.84	0.00	5.90	0.00	0.00	89.53	12.54	48.76	1.51	.00	0.00	0.00	484.08
3959E	P-6	122.54	55.03	59.86	147.29	304.33	65.75	0.00	0.29	191.80	99.72	244.46	61.44	1,268.26
3959H	P-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P Total:	124.38	55.03	97.86	147.29	304.33	155.28	12.54	49.05	193.31	99.72	244.46	61.44	1,752.44
Rinaldi Toluca (RT)														
4960F	RT-1	0.31	0.00	0.18	0.00	14.67	25.44	0.00	0.31	0.00	0.25	0.35	0.39	42.11
4960A	RT-2	1.21.14	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	1.39	26.28
4960N	RT-3	478.26	42.36	0.28	74.13	241.45	11.52	0.00	0.47	0.00	0.35	0.00	0.35	856.05
4960C	RT-4	419.72	17.92	0.00	47.08	221.92	26.58	0.00	0.25	0.00	.25	12.56	0.00	845.96
4960H	RT-5	287.13	26.58	0.00	0.00	0.37	20.46	0.00	0.55	0.00	151.61	427.63	35.59	981.99
4960F	RT-6	424.74	18.29	.12	0.00	12.23	30.22	0.00	182.41	306.24	96.50	114.26	39.13	1,224.35
4960F	RT-7	23.32	11.21	0.07	0.7	15.19	5.91	0.00	0.51	0.00	39.41	23.59	1.39	164.50
4960U	RT-8	7.16	0.00	0.00	0.00	21.99	0.55	0.00	135.15	152.64	66.4	355.64	355.52	1,146.22
4960H	RT-9	454.86	12.24	0.00	0.00	0.62	0.00	0.00	1.05	0.00	3.85	4.23.54	1.18.00	1,019.9
4960G	RT-10	0.46	0.00	0.00	10.59	1.46.24	0.00	0.00	0.76	0.00	0.28	0	0.47	251.00
4960K	RT-11	0.32	0.00	0.00	0.00	0.67	0.00	0.00	0.51	0.00	0.41	0.31	0.50	3.40
4960H	RT-12	0.46	0.00	0.00	0.00	0.54	0.00	0.00	0.69	0.00	0.00	0.00	0.00	3.21
4960J	RT-13	0.26	0.00	0.00	0.00	1.39	0.00	0.00	1.75	0.00	0.21	0.47	0.00	4.84
4960L	RT-14	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
4960M	RT-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	RT Total:	2,472.80	1,91.61	4.60	282.45	684.55	1.50.71	0.00	327.69	559.28	416.17	1,828.56	1,028.28	7,956.33
Tujunga (T)														
4987C	T-1	1.1.41	0.00	0.02	84.62	2.5.83	20.14	0.02	484.62	445.62	606.12	5.9.14	7.5.15	3,468.34
4987D	T-2	346.09	0.00	0.00	78.47	2.0.36	44.45	0.15	1.53.72	462.47	0.00	0.15	421.89	1,896.27
4987F	T-3	414.93	0.00	0.00	0.62	0.34	0.00	0.00	0.15	1.7.34	662.42	5.8.01	5.1.37	2,1.3.28
4987F	T-4	3.2.08	0.00	0.57	85.66	2.1.20	21.62	0.15	3.69.70	64.72	583.86	3.2.30	0.00	2,0.5.57
4987K	T-5	2.5.93	0.00	0.64	0.00	0.85	24.52	0.64	1.91.19	4.1.39	0.00	0.10	0.37	1,0.0.73
4987H	T-6	0.21	0.00	0.71	0.73	0.79	0.16	0.71	0.51	0.54	0.00	1.27	.07	4.24
4987L	T-7	0.73	0.00	0.84	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.42
4987K	T-8	0.47	0.00	1.15	0.46	0.39	0.00	0.51	0.05	1.06	0.00	0.26	.05	3.3
4987G	T-9	0.00	0.00	0.00	0.00	1.19	0.00	0.54	0.00	1.74.75	6.0.21	3.2.11	0.28	1,1.9.46
4987C	T-10	.4.41	0.00	2.39	88.64	2.2.26	2.82	0.57	4.5.22	4.7.22	0.00	0.12	0.00	1,2.0.93
4987D	T-11	0.63	0.00	1.95	0.49	1.00	0.00	0.32	0.00	0.44	0.37	0.30	0.00	4.67
4987J	T-12	0.47	0.00	2.29	0.46	1.36	0.00	0.51	0.25	2.1.91	6.0.22	3.5.52	1.9.31	1,2.0.27
	T Total:	1,911.49	0.00	1.2.1	44.16	884.41	1.4.52	4.45	1,.44.39	1,2.1.49	1,.09.44	1,2.2.17	1,.58.64	11,.2.1.97

AR0074747

2004-2005 Water Year
(acre-feet)

LAU DPW Well No.	Owner Well No.	2004 Oct	Nov.	Dec.	2005 Jan	Feb.	Mar	Apr.	May	June	July	Aug.	Sept	TOTAL
San Fernando Basin (cont'd)														
Verdugo (V)														
3900S	V-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3900T	V-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3900U	V-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3900V	V-7	86.18	145.97	109.74	0.00	279.16	0.00	0.00	227.99	0.00	0.00	0.00	0.00	1,112.92
3853G	V-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3853H	V-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3844R	V-24	279.12	210.26	144.19	257.13	584.18	8.01	1.00	0.27	0.00	75.85	0.19	0.05	1,560.25
	V Total	449.51	356.38	253.93	457.34	864.17	14.53	0.00	227.76	0.00	75.85	0.19	0.05	2,699.81
Whitnall (W)														
3830F	W-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3821B	W-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3821C	W-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3821D	W-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3821E	W-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3830J	W-6A	224.64	109.56	134.41	254.60	320.24	1.00	0.00	264.07	151.40	264.24	141.43	114.26	1,974.05
3853K	W-7	1.00	0.44	0.07	0.00	1.00	0.00	0.00	207.47	0.00	144.65	77.64	60.66	575.93
3853L	W-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3853M	W-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3844S	W-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	W Total	224.64	109.99	134.48	254.60	321.24	1.00	0.00	471.54	151.40	408.89	219.07	174.92	2,549.98
Los Angeles, City of Total		5,662.40	1,219.55	518.14	2,023.28	1,455.77	700.74	140.56	5,314.22	6,391.71	5,992.11	7,023.49	6,451.72	47,084.63
San Fernando Basin Total:		9,854.28	2,964.84	2,129.74	3,991.18	6,472.14	3,211.97	1,991.99	8,659.15	8,868.54	9,992.45	8,822.10	7,899.14	67,855.19

Sylmar Basin														
Los Angeles, City of														
Plan	Mission													00
4440J	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4440K	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.04	0.00	53.00	127.00	317.00	521.04
4440S	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.02	0.00	72.00	135.00	0.00	585.96
		0.00	0.00	0.00	0.00	0.00	0.00	1.24	246.00	0.00	174.00	371.00	1,161.00	1,953.24
Santiago Lateral														
4440F	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

AR0074748

2004-2005 Water Year

(acre-feet)

LACDPW Well No.	Owner Well No.	2004 Oct	Nov.	Dec.	2005 Jan.	Feb	Mar.	Apr	May	June	July	Aug.	Sept	TOTAL
Sylmar Basin (cont'd)														
San Fernando, City of														
5959H1	2A	158.46	5.00	2.43	101.22	16.89	92.11	107.12	136.3	75.21	200.73	200.38	182.79	1,314.43
5959	3	81.49	.66	5.07	72.83	71.19	76.94	72.47	82.59	93.65	63.76	66.37	62.33	853.45
5959	4	14.67	1.01	1.47	9.35	13.32	20.46	19.18	7.86	18.97	23.41	23.41	22.81	22.06
5959	2A	51.92	2.81	4.47	41.5	43.62	46.46	52.26	62.02	59.2	56.76	66.31	65.87	57.06
	Total	408.54	10.99	7.84	312.11	216.72	235.19	251.52	330.47	245.50	417.66	357.03	361.69	3,144.03
	Sylmar Basin Total:	408.54	10.99	21.14	297.11	216.72	217.75	232.96	322.11	148.41	526.12	299.33	326.83	4,278.27

LACDPW Well No.	Owner Well No.	Oct	Nov.	Dec.	Jan.	Feb	Mar.	Apr	May	June	July	Aug.	Sept	TOTAL
Verdugo Basin														
Crescenta Valley County Water District														
5959H	1	37.25	23.82	26.18	16.54	11.14	21.77	46.39	42.01	45.58	44.69	46.12	45.34	351.93
5959A	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5959H	5	53.44	56.97	69.46	59.56	32.82	21.86	45.49	57.36	52.12	55.64	71.28	42.11	568.64
5959	6	9.43	5.96	2.61	1.39	5.51	7.34	9.35	9.71	2.39	9.82	9.89	10.53	74.10
5959H	7	2.76	0.76	0.00	2.62	21.21	19.76	19.18	10.28	20.12	18.93	18.62	5.40	139.74
5959G	8	31.82	32.10	31.40	31.86	29.90	22.56	0.00	33.68	33.14	42.11	44.20	35.61	362.91
5959H	9	17.49	18.36	19.46	19.21	22.22	22.04	9.55	18.42	23.45	18.11	23.23	23.65	157.39
5959H	17	5.26	17.14	16.23	7.16	1.99	15.26	39.13	50.67	62.94	54.68	63.73	36.45	368.78
5959H	11	14.11	19.87	16.69	20.05	7.82	24.78	44.82	21.35	30.45	32.03	29.16	21.10	274.89
5959J	12	19.92	13.07	18.67	19.96	19.60	18.22	0.00	0.00	2.05	0.25	14.17	23.60	150.4
5959H	14	36.46	36.09	35.20	35.88	32.50	36.04	41.25	47.98	40.12	40.60	39.18	49.52	454.93
	15 PCR(EH) (CWD)	6.18	3.51	3.67	3.09	5.42	6.80	7.25	5.42	7.60	7.12	5.90	5.78	63.56
		3.56	3.21	3.67	3.22	5.84	5.71	4.88	5.48	5.12	5.15	4.21	4.26	54.05
	Total	240.18	231.45	234.63	221.06	211.16	244.21	274.34	332.16	335.27	348.24	371.57	316.51	3,122.22
Burbank														
	PUMPING	0.89	0.66	0.46	0.09	0.67	0.61	2.66	0.53	0.96	0.53	0.96	0.21	9.41
Glendale, City of														
5961-5971	GL 3-4	58.40	26.81	17.79	24.51	35.20	66.04	73.53	106.82	124.34	210.64	24.80	102.35	1,039.59
5970	GL 5	41.69	46.73	36.86	48.06	48.69	64.31	69.71	74.05	69.84	75.05	20.15	0.00	615.47
---	VPCKP	5.76	23.32	50.72	34.55	55.79	60.12	74.86	75.61	77.88	75.91	75.10	52.28	695.92
-	MW-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total:	155.81	98.16	141.42	91.96	129.68	191.55	220.83	256.48	241.10	270.84	232.73	162.77	2,351.89
	Verdugo Basin Total:	396.43	330.27	407.04	335.21	341.52	436.41	497.83	589.17	581.83	619.85	605.26	480.33	5,568.5

AR0074749

2004-2005 Water Year
(acre-feet)

LACDPW Well No.	Owner Well No.	2004 Oct.	Nov.	Dec	2005 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	TOTAL
Eagle Rock Basin														
Stonehurst														
1967A	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1967B	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1967C	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1967D	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Eagle Rock Basin Total:		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SGVBA Total:		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

AR0074750

APPENDIX B
KEY GAGING STATIONS OF SURFACE RUNOFF

Summary Report

Site: F57C Los Angeles River Above Arroyo Seco
USGS #:
Beginning Date: 10/01/2004
Ending Date: 09/30/2005

Daily Mean Discharge in Cubic feet/second Water Year Oct 2004 to Sep 2005

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	117	90.2	102	493	232	863	407	104	120	171	97.7	91.7
2	116	91.8	105	990	224	791	383	105	128	145	91.7	92.0
3	116	94.6	104	6240	222	1010	359	111	125	147	93.5	88.8
4	121	96.5	103	488	231	3370	337	108	132	136	87.5	90.0
5	112	102	799	361	214	1090	316	949	132	128	86.1	91.4
6	123	104	146	386	231	1090	296	156	119	123	87.5	89.0
7	133	107	103	1950	169	964	277	104	130	105	87.1	88.9
8	131	101	259	4730	164	680	259	109	171	117	81.6	85.7
9	124	114	116	17500	143	815	243	194	134	121	81.4	86.5
10	117	111	106	16500	144	811	228	107	129	129	81.6	85.6
11	111	112	101	9550	5780	664	215	102	131	120	81.7	84.3
12	115	113	106	5710	931	615	198	97.9	131	121	88.9	78.8
13	111	110	102	2470	382	613	185	98.9	130	115	91.7	78.0
14	125	111	105	1510	363	646	173	105	131	136	96.7	76.1
15	143	115	107	1470	301	619	161	105	131	138	111	75.7
16	144	112	114	1210	280	619	150	107	203	114	80.9	82.8
17	1910	114	115	1110	1080	639	140	116	132	115	80.3	80.8
18	601	113	111	1110	4160	678	132	106	125	116	80.9	81.5
19	2210	121	112	1090	3500	915	124	108	128	122	78.5	82.5
20	5210	158	119	1090	8310	654	117	105	131	118	84.9	250
21	122	540	127	1040	14700	645	115	105	145	122	91.5	78.5
22	99.4	101	126	425	7420	2580	116	110	360	123	92.0	74.1
23	90.5	100	126	451	5490	813	116	115	168	127	94.9	73.3
24	88.6	104	119	415	3600	528	126	106	151	132	93.9	74.1
25	91.9	105	121	383	3000	502	118	106	161	121	102	73.3
26	2810	96.4	125	396	2430	471	109	107	157	119	103	71.1
27	2670	219	910	812	1210	441	104	131	143	120	105	76.7
28	180	118	11000	1070	1570	427	2110	130	135	116	109	78.3
29	104	103	6080	442	------	405	117	104	131	111	103	75.0
30	97.9	103	984	419	------	420	106	107	139	107	101	80.8
31	89.3	-----	3620	368	------	420	------	130	-	102	96.9	-- --
Total	17768.7	3824.6	26385	81960	72533	25017	7842	3735.3	4195	3736	2851.3	2579.6
Mean	573	128	850	2644	2591	807	261	121	117	121	91.9	86.0
Max	5210	540	11500	17500	14700	2580	2110	949	359	347	121	250
Min	88.6	90.2	102	166	141	420	106	93.0	111	102	78.5	73.1
Acre-Ft	35240	7590	52330	162600	143850	49620	15550	7410	8320	7410	5660	5120

Wat Year 2005	Total	251307.3	Mean	691	Max	17500	Min	73.1	Acre-Ft	500400
Cal Year 2004	Total	35745.2	Mean	273	Max	11000	Min	88.6	Acre-Ft	195600

AR0074754

Los Angeles County Dept of Public Works WinDAY V4.5 Output 10/06/2005

Summary Report

Site: F110B Pacoima Creek Flows Below Pacoima Dam
USGS #:
Beginning Date: 10/01/2004
Ending Date: 09/30/2005

Daily Mean Discharge in Cubic Feet/second Water Year Oct 2004 to Sep 2005

DW 10/13/05

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0	0	0	141	74.0	156	89.2	0	14%	0	0	0
2	0	15.1	0	140	94.5	162	0	0	19 3	0	0	0
3	0	24.0	0	140	103	131	0	0	0	0	0	0
4	0	25.8	0	135	34 8	116	51.3	0	.64	0	0	0
5	0	21.6	0	129	0	116	120	0	5.79	3 42	0	0
6	0	21.5	0	138	0	117	126	216	28.5	2 71	0	0
7	0	21.4	0	157	74 5	117	46 8	245	13.2	.25	0	0
8	0	21.2	0	187	119	119	0	0	28.8	0	0	0
9	0	22.9	0		111	117	0	0	15.8	0	0	0
10	0	24.1	0	0	109	105	0	0	1.44	0	0	0
11	0	0	0	0	58.7	90.0	88 8	0	4.66	0	0	0
12	0	0	0	0	0	90.1	64 5	0	2.98	214	0	0
13	0	0	0	0	0	89.9	0	0	1 30	93 8	0	0
14	0	0	0	0	130	88.9	0	0	161	0	0	0
15	0	0	0	0	159	87.4	0	0	54.5	0	0	0
16	0	0	0	0	97.3	86.1	0	0	2.11	0	0	0
17	0	0	0	0	50 9	86.3	0	263	8.33	0	0	0
18	0	0	0	0	0	86.1	0	203	6.70	.84	0	0
19	1.34	0	0	0	442	86.1	0	0	5.25	0	0	0
20	0	0	0	0		85 3	0	0	13.5	0	0	0
21	0	0	0	163		85 5	0	0	14.5	0	0	0
22	0	0	0	241		85.8	0	0	17 1	0	0	0
23	0	0	0	240		85.8	0	0	19 7	0	0	0
24	0	0	0	236		85.4	0	0	22 6	0	0	0
25	0	0	0	232	559	84.3	0	0	25 5	0	0	0
26	0	0	0	129	411	84.5	0	0	28.5	192	0	0
27	0	0	0	78.3	414	84.9	0	0	11.5	74.9	0	0
28	0	0	0	77.5	259	83.5	02	0	38.5	0	0	0
29	0	0	9 13	76.8	------	77 8	0	0	37.5	0	0	0
30	0	0	15.4	76.6	------	115	0	0	19 5	0	0	0
31	0	-----	71.7	76.3	------	142	- -	174	------	0	0	--- --
Total	1 34	193.6	116.23	2987 5	3275.7	3385.1	427.02	1101	811 80	581.32	1	0
Mean	.043	6.45	3.82	96.6	142	109	20.3	35 5	27.1	18 8	0	0
Max	1.34	24 0	71.7	381	559	142	128	263	165	214	1	0
Min	0	0	0	0	0	77.8	0	0	0	0	1	0
Acre-Ft	3 7	384	235	5910	6500	6710	1240	2183	1610	1152	1	0 ✓

Wtr Year 2005	Total	12881.41	Mean	35 9	Max	559	Min	1 Acre Ft 25550
Cal Year 2004	Total	564 90	Mean	1 54	Max	71 7	Min	1 Acre-Ft 1120

AR0074755

Los Angeles County Dept of Public Works — CDORT V4.1 Output 10/06/2005

Summary Report

Site: F16B Big Tujunga Creek Below Big Tujunga Dam
COOP #:
Beginning Date: 10/01/2004
Ending Date: 09/30/2005

Daily Mean Discharge in Cubic Feet/second Water Year Oct 2004 to Sep 2005

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	35.5	47.5	537	119	566	170	94.4	94.6	40.4	45.6	7.65
2	.00	54.7	47.5	415	113	581	161	103	105	35.9	45.5	7.57
3	.00	80.3	47.5	538	311	411	149	101	104	35.0	45.9	5.90
4	.10	84.3	47.5	379	308	421	123	103	104	34.9	46.0	6.63
5	.03	75.5	48.4	374	305	533	105	103	104	48.9	46.0	6.36
6	.09	114	48.3	357	304	159	98.6	83.9	103	51.7	46.0	4.73
7	.09	112	48.3	355	303	360	153	99.5	102	51.7	46.0	1.52
8	.09	108	48.3	1050	98.6	350	142	101	76.6	51.7	46.1	94
9	.09	72.5	48.3	3650	99.3	350	136	111	74.5	51.5	46.9	00
10	.10	45.7	48.3	3720	95.3	357	135	118	75.1	51.1	44.1	00
11	.11	45.8	48.3	3200	127	365	109	103	75.3	50.8	43.7	82
12	.10	45.5	48.3	1210	420	365	105	56.4	75.0	50.4	43.6	.78
13	.10	45.4	48.3	366	449	350	123	26.4	74.8	50.6	43.6	79
14	.10	45.7	48.3	841	276	357	103	25.5	94.9	55.7	43.6	80
15	.11	46.2	48.3	814	258	355	115	25.3	94.7	50.7	45.8	.79
16	.15	46.8	48.1	777	178	340	114	25.4	87.5	50.7	17.8	10.4
17	.30	46.5	48.3	731	161	149	113	25.3	123	50.7	17.1	25.4
18	.26	46.5	48.3	408	183	339	113	25.3	121	46.8	17.4	24.5
19	.88	46.5	48.1	355	545	333	111	25.3	121	44.7	17.4	9.73
20	103	47.9	48.8	295	781	327	110	40.1	114	44.8	17.5	3.69
21	166	48.1	45.9	196	2310	331	110	48.5	117	44.8	58.1	1.20
22	43.1	48.1	49.8	141	1490	314	108	48.9	115	44.8	37.0	1.00
23	39.8	48.1	49.9	322	1130	311	109	56.9	114	44.9	36.8	.92
24	78.1	48.1	49.8	193	1130	305	109	59.1	112	45.1	31.2	.91
25	16.5	48.9	49.9	88.1	914	297	106	66.1	110	45.2	26.9	92
26	33.2	48.1	49.5	154	760	287	104	69.1	108	45.3	22.4	.89
27	30.5	48.7	50.5	209	655	286	103	69.1	75.4	45.2	19.4	.91
28	29.9	47.4	136	109	571	243	101	69.1	69.8	46.2	16.0	.85
29	29.4	47.5	1420	154	------	161	120	69.1	60.5	45.8	13.7	.84
30	29.1	47.5	558	192	------	145	117	69.1	60.8	45.4	11.1	57
31	28.6	------	494	123		147	------	69.1		45.4	8.89	------
Total	808.69	1710.0	4275.2	23436.1	14209.3	10498	3394.6	2295.5	2861.6	1435.2	1121.23	129.30
Mean	19.6	57.3	138	756	507	355	120	67.6	95.5	46.2	36.2	4.31
Max	166	114	1420	3720	2230	631	170	118	123	51.7	46.4	25.4
Min	.09	35.5	47.5	88.1	95.3	145	98.6	25.2	40.8	34.9	8.89	.73
Acre-Ft	1605	3390	8480	46480	28175	21810	7130	4550	5680	2960	2225	256

Wtr Year 2005	Total	66543.06	Mean	182	Max	3720	Min	09	Acre-Ft	131980
Cal Year 2004	Total	9410.79	Mean	20.4	Max	1420	Min	0	Acre-Ft	18020

AR0074756

Los Angeles County Dept of Public Works CSUSY V43 Output 11/06/2015

Summary Report

Site: F252 Verdugo Wash At Eagle Avenue
USGS #
Beginning Date: 10/01/2004
Ending Date: 09/30/2005

Daily Mean Discharge in Cubic feet/second Water Year Oct 2004 to Sep 2005

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	5.42	7.29	11.1	19.8	16.3	48.5	20.1	14.7	11.9	15.6	14.3	15.4
2	5.42	7.01	10.9	70.0	15.7	43.5	20.1	14.5	11.4	15.6	14.2	12.1
3	5.42	7.95	8.13	159	15.3	41.9	20.1	15.2	11.8	15.8	14.1	11.7
4	5.43	7.11	7.16	38.4	15.3	345	19.4	15.0	11.4	15.6	14.5	11.3
5	5.43	7.19	24.8	19.8	15.1	180	18.5	23.3	11.5	15.9	14.5	10.7
6	5.42	6.96	7.59	16.8	15.3	52.6	17.7	13.7	10.9	16.1	12.8	11.2
7	5.43	6.94	7.19	364	15.3	40.3	17.7	14.5	10.9	16.5	12.5	10.4
8	5.43	7.44	8.91	848	14.9	34.3	17.7	13.2	11.3	16.1	15.5	11.4
9	5.42	7.14	7.56	1350	14.0	31.6	17.7	14.7	12.0	17.5	15.4	12.4
10	5.42	7.41	6.94	957	13.1	29.8	17.3	13.1	12.0	16.8	14.5	12.9
11	5.42	7.16	6.74	494	459	28.4	16.5	12.3	12.0	16.4	15.3	13.5
12	5.42	7.32	6.82	178	254	28.2	16.5	12.3	12.0	16.7	14.0	12.8
13	5.42	6.78	6.97	87.5	67.1	26.8	16.5	12.5	11.5	16.8	16.1	11.4
14	5.42	6.60	7.24	49.0	31.5	26.8	16.5	12.8	12.3	16.9	15.3	12.6
15	5.42	6.62	7.57	43.3	22.4	25.4	16.5	12.8	12.4	16.7	13.7	13.1
16	5.55	6.58	6.34	16.1	17.8	23.7	15.9	13.1	11.1	16.1	12.7	12.2
17	38.6	6.66	6.43	31.7	23.5	22.7	15.3	13.1	12.0	16.0	13.5	11.3
18	29.5	7.26	6.35	28.4	231	21.1	15.3	13.3	11.2	16.0	11.8	12.5
19	210	7.29	6.21	27.4	679	24.1	16.1	12.8	13.5	15.9	12.6	13.4
20	538	24.1	7.03	24.8	761	23.9	16.5	12.7	12.8	16.1	12.6	36.8
21	21.7	15.4	6.79	22.7	1060	22.7	15.5	13.6	13.6	16.5	12.4	15.8
22	7.58	7.40	7.27	21.7	570	231	15.7	13.1	15.2	15.9	13.9	14.1
23	7.10	6.85	6.68	21.4	513	265	16.8	13.6	25.2	14.3	12.7	12.7
24	7.05	7.16	6.47	19.7	156	56.5	17.2	13.8	15.3	16.7	13.8	12.2
25	6.61	7.12	6.31	17.9	170	34.5	16.8	13.9	16.9	13.8	13.1	13.5
26	214	7.14	6.53	19.2	115	28.8	15.9	13.3	16.8	15.1	13.8	11.4
27	514	21.5	48.9	25.6	72.5	25.1	15.1	11.5	15.3	12.8	13.6	10.1
28	51.6	8.04	805	30.8	54.4	23.8	115	10.7	15.2	15.1	13.8	19.6
29	14.1	6.16	464	25.8	------	22.6	16.3	11.4	15.2	13.4	12.6	10.6
30	8.23	5.98	24.5	18.2	------	21.4	15.4	11.2	15.3	13.7	11.6	11.8
31	7.33	------	151	17.2	------	21.4	------	11.5	------	14.0	12.0	------
Total	1842.05	358.32	1712.74	4766.5	5533.7	1864.8	609.4	421.4	388.7	483.8	416.7	396.5
Mean	59.4	8.41	55.2	154	198	60.2	20.1	13.6	13.0	15.6	13.4	13.2
Max	538	24.1	805	1350	1060	345	115	25.3	15.6	17.1	16.1	36.8
Min	5.42	6.16	6.21	16.8	13.1	21.4	15.1	10.7	10.9	12.8	11.7	10.1
Acre-Ft	3650	712	3400	9450	10970	3700	1210	836	771	960	827	786

Wtr Year 2005 Total 18692.43 Mean 51.2 Max 1350 Min 5.42 Acre Ft 37080
Cal Year 2004 Total 5841.52 Mean 16.0 Max 805 Min 1.42 Acre-Ft 11590

AR0074757

Los Angeles County Dept of Public Works HYDRAT V43 Output 10/26/2005

Summary Report

Site: X285 Harbor-Western Storm Drain
USGS #:
Beginning Date: 10/01/2004
Ending Date: 09/30/2005

Daily Mean Discharge in Cubic feet/second Water Year Oct 2004 to Sep 2005

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	16.7	12.9	15.7	42.9	38.7	45.5	19.8	17.3	37.4	34.1	23.4	38.5
2	16.7	12.2	14.5	58.4	32.2	35.3	19.7	12.6	19.2	34.5	37.4	36.6
3	16.7	12.4	13.7	290	27.4	28.3	19.7	12.9	18.4	34.8	37.4	36.3
4	17.0	12.3	14.8	93.0	24.3	139	18.4	13.4	19.1	31.3	36.8	35.7
5	16.6	12.4	23.9	49.1	23.1	69.4	18.2	26.9	17.8	28.6	29.6	16.8
6	15.9	13.2	21.0	38.9	22.7	32.7	18.2	13.1	19.8	28.5	16.3	17.6
7	15.5	13.7	15.1	192	20.2	28.4	17.5	12.6	25.0	29.6	17.6	18.3
8	15.7	14.8	13.5	262	19.0	29.9	16.8	12.7	30.2	28.5	17.6	18.0
9	15.1	13.1	13.1	725	18.3	28.7	16.8	14.1	20.9	28.0	17.7	18.4
10	16.5	12.9	13.6	467	18.2	28.2	16.5	13.0	20.3	29.5	18.0	20.0
11	15.6	12.8	13.4	224	124	27.1	15.3	17.5	21.8	29.3	18.0	20.9
12	15.5	13.1	13.6	157	98.3	26.8	15.4	13.0	24.7	29.6	19.8	18.1
13	15.4	14.2	13.7	119	41.2	26.8	15.4	11.9	24.8	27.4	19.3	19.1
14	16.1	14.5	13.8	91.9	33.5	26.8	14.4	12.1	22.7	27.3	25.3	18.7
15	15.6	15.6	13.9	79.8	30.0	25.9	14.2	11.9	21.8	27.9	27.3	19.4
16	17.7	10.5	12.2	68.5	29.7	25.4	14.1	12.4	20.7	28.3	25.7	21.1
17	70.6	8.39	11.5	58.8	75.5	25.9	14.1	12.4	21.4	28.3	25.5	20.3
18	52.9	7.50	11.7	41.3	566	25.4	14.1	12.4	21.6	26.7	25.8	20.2
19	254	7.44	11.1	37.0	554	25.4	13.9	11.9	22.5	25.7	26.7	20.5
20	765	18.9	11.4	36.4	546	24.5	14.2	21.3	22.8	24.5	27.3	23.6
21	23.4	21.6	11.5	34.7	527	24.1	12.8	11.2	35.5	25.2	17.8	19.1
22	13.8	19.1	11.5	29.2	333	224	13.1	12.1	37.2	26.1	18.4	14.1
23	13.0	13.6	12.3	26.2	289	185	12.9	13.8	34.8	26.5	17.7	13.6
24	13.1	13.9	14.1	25.6	167	65.1	13.2	13.7	33.4	25.5	18.1	14.1
25	13.1	13.5	14.1	25.2	111	44.0	13.7	13.9	31.4	23.9	16.9	13.0
26	258	13.8	13.1	25.2	54.5	28.1	12.7	14.0	14.9	15.1	16.1	14.2
27	166	16.5	83.6	25.2	43.8	25.2	12.8	14.1	15.3	16.4	16.4	12.9
28	91.5	16.4	765	89.5	41.0	24.2	781	14.3	32.4	13.8	17.0	13.4
29	14.6	14.8	442	84.9	------	23.1	12.7	15.3	31.1	13.9	17.7	13.2
30	13.9	16.0	96.6	54.1		22.1	12.5	35.7	34.8	13.4	18.4	13.2
31	13.1	------	207	44.5	---- .	21.2	------	35.8	------	18.6	18.2	----
Total	1494.8	442.23	1964.2	3577.2	4169.4	1178.6	526.2	422.9	831.7	684.4	539.4	525.3
Mean	51.4	15.4	63.3	115	149	38.0	20.9	13.6	27.7	21.4	27.4	17.5
Max	765	73.6	765	725	637	204	781	26.9	37.2	35.1	37.4	33.5
Min	13.0	7.44	11.1	25.2	18.3	14.1	12.5	11.8	17.8	13.4	11.6	12.9
Acre-Ft	3150	917	3890	7100	8270	2340	1240	839	1650	1360	1070	1040

Wtr Year 2005	Total	16344.13	Mean	45.1	Max	765	Min	7.44	Acre-Ft	32810
Cal Year 2004	Total	7596.84	Mean	20.8	Max	765	Min	1.58	Acre Ft	15070

AR0074758

Los Angeles County Dept of Public Works

DSSAY V4s Output 10/06/2005

Summary Report

Site: F300 Los Angeles River at Tujunga Avenue
USGS #:
Beginning Date: 10/01/2004
Ending Date 09/30/2005

Daily Mean Discharge in Cubic Feet/second Water Year Oct 2004 to Sep 2005

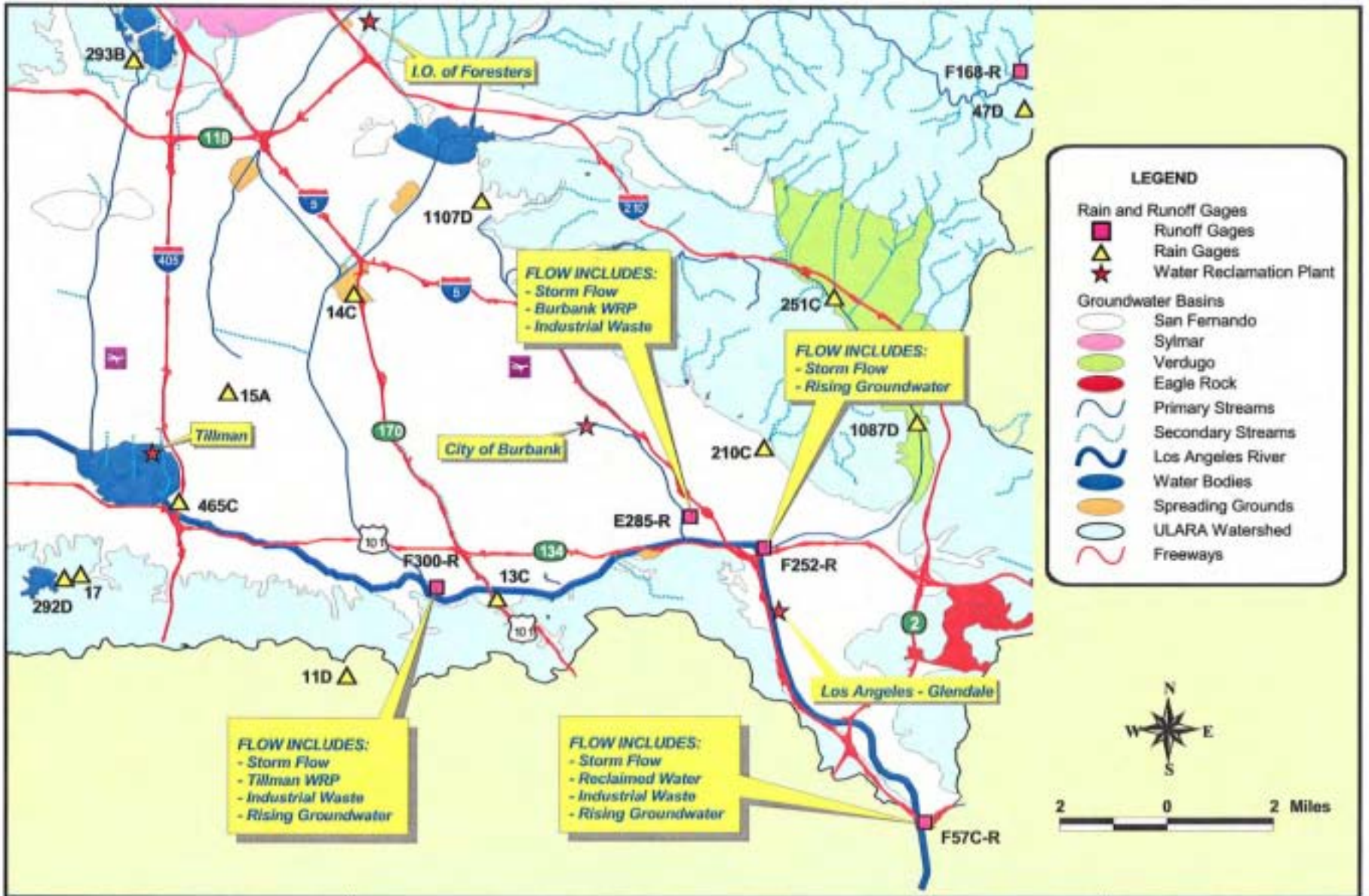
Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	57 1	81.9	94.0	513	187	865	182	111	84.1	90.9	62.1	83.1
2	75.6	82.1	92.0	758	174	925	151	110	88.8	90.8	61.7	82.9
3	56.4	84.6	90.5	5460	164	955	145	102	78.1	90.2	57.9	82.7
4	56.1	86.2	87.9	620	156	2330	141	92.5	72.9	90.1	85.2	82.5
5	56 5	92.7	592	497	151	954	136	102	76.4	90.0	86.2	82.7
6	57 0	88.8	190	505	151	887	131	150	107	85 7	86.0	82.7
7	57.9	93.2	217	1940	151	810	131	78 8	249	76 5	87 4	82 7
8	49 6	130	207	1450	152	633	131	67.8	250	71.7	84.1	82.4
9	56.3	97.5	85 6	14400	145	562	130	110	146	73 1	86.4	82 6
10	58.4	98.8	87.6	15600	145	552	126	89 1	142	74.1	86 7	81.9
11	59.6	94.3	80.7	9060	4840	571	128	55 1	138	75 7	84 9	81.7
12	54.3	91.7	82.2	1560	823	568	138	42 8	133	79 3	84.9	81.8
13	61.4	85 6	87 4	1230	612	568	127	38 4	129	81 1	84.7	81.5
14	78.8	91.5	73 8	1110	608	568	116	40.1	127	72 4	85.1	81.9
15	79.0	92.4	80.4	1180	594	568	101	42.9	125	73 3	108	80.4
16	90.4	94.7	81 5	1020	588	568	101	42 7	176	72.7	82.4	80.6
17	935	178	78 8	940	1080	568	101	46 5	174	73 8	79.1	79.7
18	391	108	76.8	722	4130	671	93.7*	48.1	234	66 0	75 0	80.5
19	1840	105	76.4	576	7301	675	109	45.8	120	68 4	68 9	79 7
20	2890	472	82 1	548	886C	571	268	48.3	115	69.3	15.6	277
21	100	520	83.3	539	11301	562	231	67.9	108	68.5	80 3	79.4
22	95.4	290	82.5	522	7591	2230	209	47.5	107	68.8	79 0	71 7
23	75.1	172	74.5	531	4845	681	181	47 4	115	68 7	85.0	72.4
24	76.9	99.7	80.8	528	2710	570	172	47 0	112	62 1	83 5	80.7
25	82.7	89.9	76.2	492	2430	568	159	47.1	107	62 1	83.8	68.9
26	2480	85.9	77 1	456	1820	568	145	41 5	106	62 2	81.1	74.5
27	1530	181	975	417	1650	568	131	47.0	101	62 4	81 6	68.6
28	181	211	8150	804	1200	541	2340	46.4	98.0	62.2	82 6	80.9
29	93.5	99.6	4090	457	-------	543	371	51.5	95.0	62.1	83 3	61.6
30	81 0	97 8	1080	266	- --	234	160	54.2	92.7	62.1	84.0	63 9
31	78.4	------	3070	204	-	187	------	58 0	------	62.4	83.1	- ----
Total	11810 1	4150.9	20361.8	71908	63189	33987	6681 7	2045.5	3451.0	2220.6	2520 3	2520 4
Mean	381	145	657	2320	2264	617	223	67.3	115	72.0	81.3	84.0
Max	2890	520	8150	15600	12300	2230	2340	262	174	90.9	108	277
Min	49.6	84 7	73.8	204	145	187	93.7	38.4	84 3	62.4	57.9	68 9
Acre-Ft	23419	8010	40380	142610	125300	41610	13250	4160	6840	4420	5000	5000

Wtr Year 2005 Total 212257.1 Mean 582 Max 15600 Min 15.6 Acre-Ft 421100
Cal Year 2004 Total 66620 9 Mean 182 Max 8150 Min 32.8 Acre-Ft 132150

AR0074759

APPENDIX C
COMPONENTS OF LOS ANGELES RIVER FLOW

AR0074761



2004-05 Water Year ULARA Watermaster Report	Upper Los Angeles River Area: Components of Los Angeles River	PLATE C.1

AR0074762

UPPER LOS ANGELES RIVER AREA: COMPONENTS OF LOS ANGELES RIVER FLOW

2004-05 WATER YEAR

TOTAL FLOW AT GAGE F-57C-R

Total:	500,436	

F-57C-R: Storm, Reclaimed, Industrial, Rising Ground
F300-R: Storm, Tillman, Industrial Waste, and Rising
F285-R :Storm, Burbank WRP, Industrial Waste
F252-R: Storm, Rising Water

I. RECLAIMED WATER DISCHARGED TO L.A. RIVER IN ULARA

Tillman:	49145	Record
L.A.-Glendale:	12378	Record
Burbank WRP	8119	Record
Total:	61642	

II. INDUSTRIAL WATER and STORM FLOWS DISCHARGED TO L.A. RIVER IN ULARA

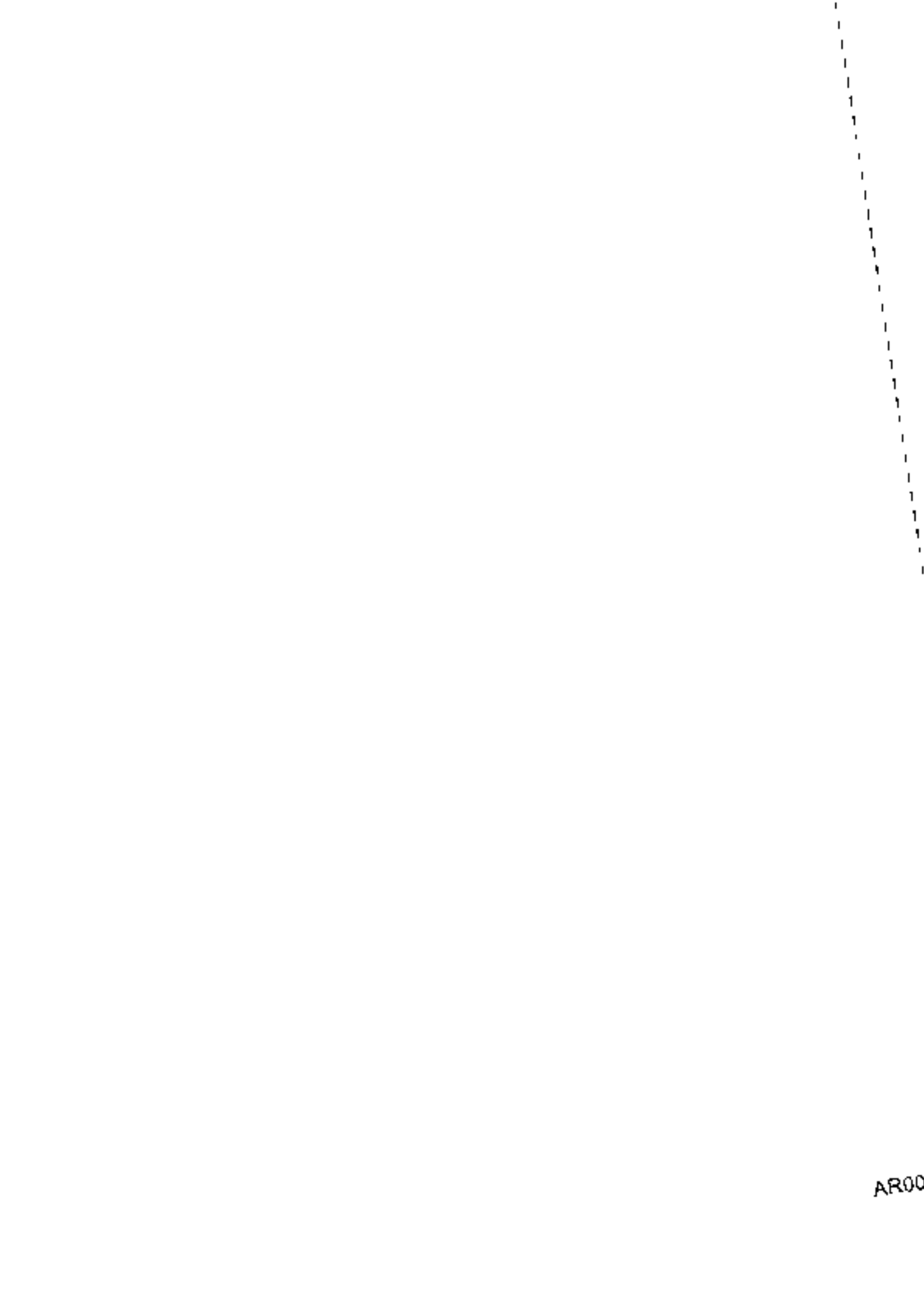
Upstream of F300-R		
Industrial Water	322	From F300-R separation of flow
F168	121986	
F118	25552	
Storm Flows @300	211600	Storm flows less F168 and F118
	369460	
Between F300-R and E-285		
Burbank OU	41	Burbank Operable Unit
MTA: Storm Drains and Unaccounted water	69 4620	6.4 cfs assumes 4,620
Headworks:	0	pilot project record
Western Drain	2780	From E285-R separation of flow
Storm Flows @285	16088	
	23598	
Between E-285 and F57C-R		
Storm Flows@ 252	30780	
Irrigation and Industry Flows	2871	From F252-R separation of flow
Glendale Operable Unit	325	
Eagle Rock Blow Off	2000	
Pollock Treatment	200	
Sycamore Canyon	1100	Estimated from historic flows
Storm Drains and Unaccounted water	2145	3.0 cfs assumes 1,245 from F57C-R separation of flows
	39421	
Total Part II	432479	

III. RISING WATER IN L.A. RIVER IN ULARA

Total:	6109	See Section 2.3 of the Watermaster's Report

FLOSEP03;2/[illegible]/2006

AR0074763



APPENDIX D
WATER QUALITY DATA

AR007

REPRESENTATIVE MINERAL ANALYSES OF WATER

Well Number or Source	Date Sampled	Spec. Cond. (µmhos)	Mineral Constituents, in milligrams per liter (mg/L)												TDS mg/L	Hardness as $CaCO_3$ mg/L
			pH	Ca	Mg	Na	K	CO_3	HCO_3	NH_4	Cl	NO_3	F	B		
Imported Water																
Colorado River Water @																
Eagle Rock Reservoir	2/08/05	789	8.3	43	20	85	2.8	0	130	194	82	2.4	0.16	0.13	482	190
LA Aqueduct No 1 @ Foothill	5/12/2005	883	8.3	22.1	4.3	40.2	4.9	0	132	148	29.1	ND	0.61	0.41	287	82.8
LA Aqueduct																
Filtration Plant Influent	11/1/2005	449	8.1	29	6.9	35.5	4.1	8.4	121	19.5	19.5	ND	0.65	0.32	213	87.0
State Water Project @																
Joseph Jensen Filtration Plant Influent	2005/Yr	436	7.9	27	11.5	45	2.8	0	101	33	57	2.2	0.16	0.16	267	113
Surface Water																
Tillman Res. Plant																
Discharge to LA River	2005/Yr	-		-	-	-	-	-	-	141	121	2.75	0.84	0.3	549	207
Los Angeles River																
@ Arroyo Seco	5/05	991	8.0	66.1	24.5	96.5	9.75	ND	171	191	106	2.4	0.5	0.56	666	270
LA Glendale Res. Plant																
Discharge to LA River	2005/Yr	-	7.7	-	-	-	-	-	-	146	140	51	0.5	0.4	826	240
Ground Water																
(San Fernando Basin - Western Portion)																
4352C																
(Reseda No. 6)	10/23/63	944	7.8	115	21	41	2.1	-	301	297	23	2.6	0.61	0.24	595	415
(San Fernando Basin - Eastern Portion)																
5400																
(No. Hollywood No. 11)	9/19/2004	1150	7.8	80.5	23.4	122	3.9	-	300	320	63.2	3.06	0.45	0.56	775	321
3821C																
Well Burbank No. 10	4/30/04	-	7.5	-	-	-	-	ND	266		56.5	22.7	-		443	314
Glendale OU																
C-5-1	4/6/2004	777	7.2	120	31	44	5.1	0.15	418	195	58	8.7	0.52	0.16	605	361
(San Fernando Basin - L.A. Narrows)																
3939F																
(Pollock No. 1)	5/19/2004	995	7.2	91	19.4	127.9	2.55	11	262	125	75.8	42.4	0.26	0.25	551	347
(Sylmar Basin)																
4840J																
(Mission No. 5)	6/17/2002	577	7.7	74.8	17.1	78.4	1.69	11	256	46.4	45.3	38.7	0.11	-	396	287
3989																
(San Fernando No. 4A)	5/24/2005	449	7.8	46	9.5	27	4.1	0.75	135	47	15	13.4	0.21	-	280	158
(Verdugo Basin)																
3931																
(Glenoaks No. 1)	3/20/2005	1045	6.8	111	38.1	41.8	5.69	-	-	151	125	79.2	34.7	-	546	396
4009F																
(GVWD No. 14)	2005	762	7.1	175	19	33	2.7	ND	250	110	54	41	0.28	ND	5.0	520

AR0074767

APPENDIX E
DEWATERING AND REMEDIATION PROJECTS

AR0074770

DEWATERING PROJECTS

No.	Company	Contact	Address	ID	Start Date
1	Danalex Engineering Corp.	Krell, Alex	11239 Ventura Blvd	P	
2		Henkin, Doug	5806 Etiwanda Ave.	P	
3	Delta Tech Engineering	Abbasi, Z. A	12680 Ventura Blvd.	P	
4	Commercial Project	Hellman, Haloosim & Assoc. Varadi, Ivan	5550 Topanga Canyon	D	Jun 19, 1989
5	Interne Spectrum Project	Hellman, Haloosim & Assoc. Varadi, Ivan	15503 Ventura Blvd.	D	Jun 14, 1989
6	Home Savings of America	Eli Stein & Associates	13949 Ventura Blvd.	D	Jun 14, 1989
7	Warner Center Ent. Complex	Tsuchiyama and Kaino	5955 Owensmouth Ave.	D	Jun 26, 1989
8	T. Viola Construction Company	Viola, Tan, Jr	15840 Ventura Blvd.	P	
9		Eccleston, C. W	22020 Clerendon St.	P	
10		Mares, Ronald	5348 Topanga Canyon	P	
11	Hellman, Haloosim & Assoc.	Varadi, Ivan	21820 Burbank Blvd	P	
12	Park Hill Medical Plaza	Anjomshoaa, Mahmoud	7203 Medical Center Dr.	D	Dec 27, 1989
13	Danalex Engineering		12050 Ventura Blvd	P	
14	Ellis Plumbing Co.	Ellis, Chris	4235 Mary Ellen Ave.	P	
15	Tarzana Office Plaza	Varadi Engineering	18701 Burbank Ave.	P	
16	Hellman, Haloosim & Associates	Varadi, Ivan	5350 White Oak Ave	P	
17	First Financial Plaza Site	Slade, Richard	16820 Ventura Blvd	D	Oct 9, 1987
18	TriRism	Arnold, Daryl	6310 Canoga Ave.	D	Apr 27, 1988
19	LAMCO	O'Neil, John	21301 Victory Blvd.	D	Apr 27, 1988
20	La Reina Fashion Plaza	Blumenfeld, Dolores	14622 Ventura Blvd.	D	Apr 27, 1988
21	Aldo Stiegler	Stiegler, John	16721 Ventura Blvd.	D	Oct 31, 1987
22	Sherway Properties	Vasquez, Rodney	4477 Woodman Ave.	P	
23	Ellis Plumbing Co.	Ellis, Chris	19951 Roscoe Blvd	P	
24	Metropolitan Transportation Authority	Laury, Victor	Metro Red Line	D	April 1, 1995
25		Carter, Dennis	4547 Murietta Ave	P	Jan 16, 1997
26	MWD Sepulveda Feeder PipeLine Cons	David Dean	Jensen Plant	TD	August 1, 1998
27	A 31 Warner Properties Plaza 5	Bernier, Dave	21650 Oxnard	D	June 4, 1997
28	A 31 Warner Properties Plaza 6	Bernier, Dave	21700 Oxnard	D	June 4, 1997
29	Boren & Miller	Boren, Stanley	4328 Mammoth Ave	D	January 13, 2000
30	Northeast Interceptor Sewer	Nick Demos	Bureau of Engineering	TD	October 1, 2001
31	MTA Underground Pedestrian Crossing	Tim Lindholm	MTA	TD	November 1, 2001

Notes:

1) ID - Refers to the type of project:

D: Permanent dewatering required

P: No dewatering required presently, however there is potential for dewatering in the future

TD: Temporary Dewatering

2) Start Date - Date project was brought to the attention of the LLARA Watermaster.

REMEDIATION PROJECTS

No.	Company	Contact	Address	ID	Start Date
1	Mobil Oil	Alton Geoscience	16461 Ventura Blvd.	R	May 11, 1989
2	Thrifty Oil	Delta Tech. Eng.	18226 Ventura Blvd.	R	Feb 2, 1990
3	Boeing (Rockwell International)	LaFlam, S. R.	6633 Canoga Park Ave	R	Jan 16, 1990
4	Lockheed	Gene Matsushita	N. Hollywood Way	R	Jan 5, 1989
5	3M Pharmaceutical	Bob Paschke	1900 Nordhoff St.	R	Feb 8, 1989
6	Philips Components	Wade Smith	4561 Colorado St	R	Jul 14, 1987
7	Raytheon (Hughes)	Tim Garvey	Canoga Park, CA	R	February 1995
8	Balchem	Cuthbert, Andrew	Pacoima, CA	R	February 7, 2000
9	Micro Matic USA Inc.	Reinhard Kuhnke	Northridge CA	R	April, 1999
10	Menasco	George Pianka	Burbank, CA	R	October 31, 2001
11	Home Depot	Karen Arteaga	Burbank, CA	R	March 15, 2001
12	DriLube	Artik Avanessians	Glendale, CA	R	March 29, 2002
13	PRC-Desoto (Courtaldi	Christer Sorensen	Glendale, CA	R	August 22, 2002
14	Honeywell (Allied Signal)	Benny Dehghi	No.Hollywood, CA	R	February 21, 2003
15	Excello Plating	Glen Harleman	Los Angeles, CA	R	June 20, 2003
16	Tesoro	Peter Stumpf	No. Hollywood,CA	R	May 8, 2004
17	ITT	Teresa Olmstead	Burbank, CA	R	June 9, 2004

Notes:

1) ID - Refers to the type of project:
R: Ground water remediation site

2) Start Date - Date project was brought to the attention of the ULARA Watermaster.

APPENDIX F
POLLOCK WELL FIELD REMEDIATION PROJECT
PRODUCTION

AR007477

UPPER LOS ANGELES RIVER AREA WATERMASTER

CITY OF LOS ANGELES VS. CITY OF SAN FERNANDO, ET AL
CASE NO. 650079 -- COUNTY OF LOS ANGELES

MARK G. MACKOWSKI -- WATERMASTER

OFFICE LOCATION:
111 North Hope Street, Room 1450
Los Angeles, CA 90012
TELEPHONE: (213) 367-0856
FAX: (213) 367-0939

MAILING ADDRESS:
ULARA WATERMASTER
P.O. Box 51111, Room 1450
Los Angeles, CA 90051-0100

January 5, 2006

Mr. Thomas Erb
Director of Water Resources
Los Angeles Department of Water and Power
111 N. Hope Street, Room 1460
Los Angeles, CA 90012

Dear Mr. Erb:

Subject: Pollock Well Field Remediation Project

The Pollock Well Field Remediation Project (Pollock) was constructed primarily to reduce or eliminate excess rising groundwater from entering the Los Angeles River, leaving the San Fernando Basin (SFB) as surface flow, and wasting to the ocean. This groundwater belongs to Los Angeles under its Pueblo and import return water rights.

The 1994 Project Description and California Environmental Quality Act (CEQA) Negative Declaration for Pollock acknowledge the need to eliminate this excess rising groundwater. In addition, a letter dated November 8, 1994 from the Los Angeles Department of Water and Power (LADWP) to the Los Angeles Regional Water Quality Control Board requested a National Pollutant Discharge Elimination System (NPDES) permit for Pollock so that this excess rising groundwater can be minimized. According to these and other documents, the facility was designed to operate at approximately 2,300 acre-feet per year (AF/yr.) to preserve Los Angeles' water rights in the SFB.

Since the 1998-1999 Water Year, annual pumping at Pollock has been as follows:

Water Year	Annual Pumping (AF)
1998-1999	1,512.98
1999-2000	1,851.37
2000-2001	1,255.98
2001-2002	1,642.55
2002-2003	1,720.41
2003-2004	1,137.16
2004-2005	1,752.44

LADWP's July 26, 2001 letter to the Watermaster states, "...LADWP respects the need to operate the Pollock Wells for approximately six months per year to achieve a long-

term average of 2,400 AF/yr. of groundwater pumping." And, "Year-to-year fluctuations In the date of operation commencing for the Pollock Plant do not inhibit LADWP's effectiveness in addressing the excess rising groundwater discharges to the Los Angeles River so long as the long-term average of 2,400 AF/yr. of Pollock Plant operation is satisfied. In satisfying the long-term average of Pollock Plant operation, the City of Los Angeles is able to maintain its SFB water right."

On August 2, 2001, the Watermaster Office sent you a letter reducing the required baseline extraction rate to 2,000 AF/yr. in an effort to help Los Angeles preserve its water rights. Based on the data in the above table, pumping has never reached 2,000 AF/yr. for a single year, nor has it achieved 2,400 AF/yr. on a long-term average. The long-term average pumping is 1,553 AF/yr.

Pumping during the 2004-2005 Water Year again failed to meet the required 2,000 AF/yr. baseline by 247.56 AF. Therefore, we will be debiting 247.56 AF from Los Angeles' pumping credits. This debit is necessary to account for losses of groundwater from the SFB and to provide a realistic view of actual water in storage.

We hope that pumping in the current and future years can be increased to at least 2,000 AF/yr. to preserve Los Angeles' water rights in the SFB.

Sincerely,

Mark G. Mackowski
ULARA Watermaster

MGM:bw
A:\Pollock 2004-05\MGM02
c: Administrative Committee Members
Mr. William Mace, City of Burbank
Mr. Ronald Rulz, City of San Fernando
Mr. Dennis Erdman, Crescenta Valley Water District
Mr. Peter Kavounas, City of Glendale

Watermaster Office
Mr. Mark G. Mackowski, Watermaster
Mr. Frederic A. Fudacz, Special Counsel
Mr. Melvin L. Blevins, Consultant to the Watermaster
Ms. Patricia T. Kiechler, Assistant Watermaster

bc: FileNet

APPENDIX G
COURT NOTIFICATION re: DECLINING WATER TABLE

UPPER LOS ANGELES RIVER AREA WATERMASTER

CITY OF LOS ANGELES VS. CITY OF SAN FERNANDO, ET AL
CASE NO. 650079 – COUNTY OF LOS ANGELES

MARK G. MACKOWSKI – WATERMASTER

OFFICE LOCATION:
111 North Hope Street, Room 1450
Los Angeles, CA 90012
TELEPHONE: (213) 367-0896
FAX: (213) 367-0939

MAILING ADDRESS:
ULARA WATERMASTER
P.O. Box 51111, Room 1450
Los Angeles, CA 90051-0100

February 13, 2006

The Honorable Susan Bryant-Deason
Judge of the Los Angeles Superior Court
111 North Hill Street, Department 52
Los Angeles, CA 90012

Dear Judge Bryant-Deason:

Subject: Decline in Storage in the San Fernando Basin

You may recall from our periodic status conferences that I have been concerned for some time over a general decline in stored groundwater in the San Fernando Basin. During our last meeting on December 5, 2005, I provided you a graph (Plate 99 enclosed) that illustrates my concern.

The blue line clearly shows an overall decline in stored groundwater beginning in approximately 1963. In addition, the red line illustrates the effect on stored groundwater if the Cities of Los Angeles, Glendale, and Burbank (Cities) had pumped their full adjudicated water rights each year instead of accumulating Stored Water Credits beginning in 1968.

The problem is, therefore, twofold: a decline in actual groundwater stored in the San Fernando Basin, and groundwater pumping rights that exceed long-term recharge.

I met with the Cities on January 19, 2006 to discuss my concerns. There was a general consensus on the main issues, although the Cities have requested additional information and background. Therefore, the Watermaster Office is coordinating a workshop with the Cities to provide technical background on the original calculations of Safe Yield, Return Flow Credits, and other relevant data and information. This is an important first step in developing a common understanding of the issues.

In my opinion, the San Fernando Basin is experiencing a continuing decline in stored groundwater and an accumulation of Stored Water Credits that must be addressed. I want to assure the Court that the Watermaster Office is working with the Cities to develop a plan that returns the San Fernando Basin to long-term sustainability.

The Watermaster Office will continue to keep the Court informed of our progress toward this goal. If you have any questions, please call me at (213) 367-0896.

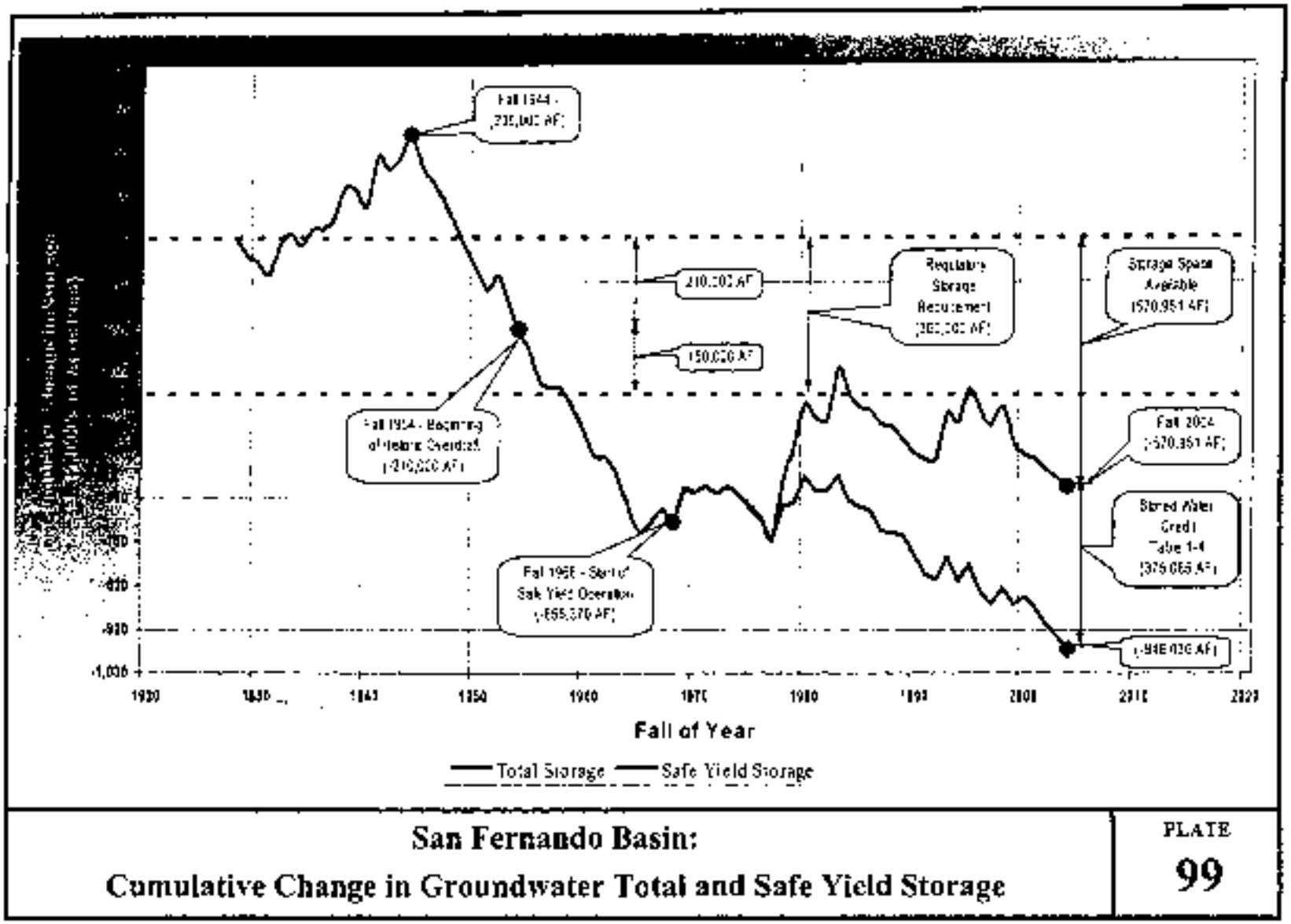
Sincerely,

Mark G. Mackowski
ULARA Watermaster

MGM:bw
Enclosure
A:\SFB Decline in Storage\MGM02
c: Administrative Committee
Mr. William Mace, City of Burbank
Mr. Peter Kavounas, City of Glendale
Mr. Ronald Ruiz, City of San Fernando
Mr. Dennis Erdman, Crescenta Valley Water District
Mr. Thomas M. Erb, City of Los Angeles

Watermaster Staff
Mr. Frederic A. Fudacz, Special Counsel
Mr. Melvin L. Blevins, Consultant
Ms. Patricia T. Kiechler, Assistant Watermaster

bc: FileNet



San Fernando Basin:

Cumulative Change in Groundwater Total and Safe Yield Storage

PLATE

99

APPENDIX H
WELLS DRILLED OR ABANDONED

WELLS DRILLED OR ABANDONED

2004-05 WATER YEAR

Forest Lawn

Forest Lawn, a party to the Judgment, destroyed Well No. 2 (3947A) and replaced it with newly drilled Well No. 8 (3947M).

APPENDIX I
ACTION ITEMS 2005-06

ACTION ITEMS

WATERMASTER ACTIVITIES FOR 2005-06 WATER YEAR

- Support the parties in their efforts to deal with increasingly stringent stormwater discharge requirements.
- Continue to keep the parties informed regarding current and emerging water quality issues, such as chromium, perchlorate, 1,4-Dioxane, and 1,2,3 TCP.
- Continue to attend meetings of public interest groups, such as the Los Angeles and San Gabriel Rivers Watershed Council, the Sun Valley Watershed Committee, Bureau of Sanitation Integrated Resources Plan Committee, the Los Angeles City Ad Hoc Committee on the Los Angeles River, and others to support and promote the goals of the parties and the overall health of the basins within ULARA.
- Continue to attend meetings of technical groups, such as the Association of Groundwater Agencies (AGWA), Groundwater Resources Association (GRA), and others to exchange ideas and information regarding water quality and basin management.
- Explore ways to maximize the spreading of native water and increase the infiltration of urban runoff in the SFB.
- Continue to support the ongoing Verdugo Basin Groundwater Evaluation, and investigate ways to maximize conjunctive use in the Verdugo Basin.
- Continue exploring ways to maximize spreading at the Tujunga and Hansen Spreading Grounds.
- Continue to investigate the unauthorized use of groundwater in unincorporated areas of ULARA and develop processes to expedite water license agreements and access to well drilling permits for property owners.
- Continue to work with the U.S. Forest Service, U.S. Fish and Wildlife Service, LACDPW, and LADWP to support the seismic retrofit of Big Tujunga Dam, with the goal of providing maximum water conservation, protection against flood damage, preservation of habitat for endangered species, and protection of Los Angeles' Pueblo water right.
- Continue to support the City of Burbank in its effort to purchase imported supplies from MWD for spreading and recharging in the SFB.
- Participate in the IRWMP process to increase the amount of grant support for water projects in the Greater Los Angeles Region.

APPENDIX J
WATER EQUIVALENTS

Water Equivalents

Volume

1 gallon* = 3.7854 liters (L) = 231** cubic inches (in^3)
= 0.003785 cubic meters (m^3) = 0.132475 cubic feet (ft^3)

100 cubic feet (HCF)**** = 748 gallons (gal) = 2.83317 cubic meters (m^3)
= 2,832 liters (L) = 3.70386 cubic yards (yd^3)
= 6,230.8 pounds of water (lb) = 2,826.24 kilograms (kg)

1 acre-foot (AF)*** = 43,560** cubic feet (ft^3) = 1233.5 cubic meters (m^3)
= 325,851 gallons (gal) 1,233,476.3754 liters (L)
= the average amount of water used by two families for one year

Flow

1 cubic foot per
second(cfs) = 448.83 gallons per minute (gpm) = 0.028317 cubic meters/sec (m^3/s)
= 646.317 gallons per day (gal/day) = 1.70 cubic meters/min
= 1.98 AF/day = 2446.6 cubic meters/day

1,000 gallons per
minute(gpm) = 2.23 cubic feet per second (cfs) = 0.063 cubic meters/sec (m^3/s)
= 4.42 AF/day 5452.6 cubic meters/day
11,613.01 AF/year = 1.99 million cubic meters/yr

1 million gallons per
day (mgd) = 3.07 AF/day =3785 cubic meters/day
= 1,120.14 AF/year =1.38 million cubic meters/yr.

Concentration

1.0 milligrams per liter (mg/L) = 1.0 parts per million (ppm)

1.0 micrograms per liter (µg/L) = 1.0 parts per billion (ppb)

* U.S. gallons
** Exact Value
*** An acre foot covers one acre of land one foot deep
**** This is a billing unit of DWP

AR0074787

APPENDIX K
LIST OF ABBREVIATIONS

List of Abbreviations

AF	Acre-feet
BOU	Burbank Operable Unit
BTEX	Benzene, toluene ethylbenzene, and total xylene
CVWD	Crescenta Valley Water District
Cal-EPA	California Environmental Protection Agency
DCA	Dichloroethane
DCE	Dichloroethylene
DHS	California Department of Health Services
DTSC	California Department of Toxic Substances Control
DWP	Department of Water and Power (see also LADWP)
EPA	Environmental Protection Agency (see also USEPA)
EVWRP	East Valley Water Recycling Project
LAFD	Los Angeles Fire Department
GAC	Granular Activated Carbon
gpm	Gallons Per Minute
LACDPW	Los Angeles County Department of Public Works
LADWP	Los Angeles Department of Water and Power
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
MTA	Metropolitan Transportation Authority
MWD	Metropolitan Water District
OEHHA	Office of Environmental Health Hazard Assessment
OU	Operable Unit
PCE	Tetrachloroethylene
PHG	Public Health Goal
PSDS	Private Sewage Disposal Systems
RAW	Removal Action Workplan
RI	Remedial Investigation
RWQCB	Regional Water Quality Control Board
SFB	San Fernando Basin
SUSMP	Standard Urban Stormwater Mitigation Plan
SWCRB	State Water Resources Control Board
SWAT	Solid Waste Assessment Test
TCA	1,1,1- Trichloroethane
TCE	Trichloroethylene
TDS	Total Dissolved Solids
ug/L	Micrograms per Liter
ULARA	Upper Los Angeles River Area
UST	Underground Storage Tank
VOC	Volatile Organic Compound
VPWTP	Glendale-Verdugo Park Water Treatment Plant
USGS	United States Geological Survey

City of Los Angeles
Department of City Planning

PARCEL PROFILE REPORT

PROPERTY ADDRESSES	**Address/Legal Information**	
1615 N VINE ST	PIN Number	150A187 [illegible]
1601 N VINE ST	Lot/Parcel Area (Calculated)	17,720.7 (sq ft)
6308 W YUCCA ST	Thomas Brothers Grid	PAGE 593 - GRID F4
6309 W YUCCA ST	Assessor Parcel No. (APN)	5546022015
6301 W YUCCA ST	Tract	TR 20238
6307 W YUCCA ST	Map Reference	M B 861-31/32
6313 W YUCCA ST	Block	None
6311 W YUCCA ST	Lot	11
6305 W YUCCA ST	Arb (Lot Cut Reference)	None
6315 W YUCCA ST	Map Sheet	150A187
6317 W YUCCA ST	**Jurisdictional Information**	
	Community Plan Area	Hollywood
ZIP CODES	Area Planning Commission	Central
90028	Neighborhood Council	Hollywood United
	Council District	CD 13 - Mitch O'Farrell
RECENT ACTIVITY	Census Tract #	1870.01
Adaptive Reuse Ordinance Spec. Plan Ord. 175038	LADBS District Office	Los Angeles Metro
Hollywood Signage Supp.	**Planning and Zoning Information**	
	Special Notes	None
CASE NUMBERS	Zoning	C4-2D-SN
CPC-2000-5288-SA	Zoning Information (ZI)	ZI-1352 Hollywood Redevelopment Project
CPC-2003-2115-CWA		ZI-2277 Hollywood Redevelopment Project
CPC-2002-4175-GDO		ZI-1612
CPC-1999-326-ICO		ZI-2331 Hollywood CRA Area
CPC-1988-2281-ICO		ZI-2427 Freeway Adjacent Advisory Notice for Sensitive Uses
CPC-1986-835-GPA		ZI-2435 Preliminary Hollywood East Study Area
ORD-167940		ZI-2452 Hollywood Community Plan Injunction
ORD-170172		ZI-2374 LOS ANGELES STATE HISTORIC PARK ZONE
ORD-173382	General Plan Land Use	Regional Center Commercial
ORD-176445-SA248	General Plan Footnote(s)	Yes
ZA-2547	Hillside Area (Zoning Code)	No
PKG-2092-1377-WDB	Baseline Hillside Ordinance	No
	Baseline Mansionization Ordinance	No
	Specific Plan Area	None
	Special Land Use / Zoning	None
	Design Review Board	No
	Historic Preservation Review	No
	Historic Preservation Overlay Zone	None
	Other Historic Designations	None
	Other Historic Survey Information	None
	Mills Act Contract	None
	POD - Pedestrian Oriented Districts	None
	CDO - Community Design Overlay	None
	NSO - Neighborhood Stabilization Overlay	No
	Streetscape	No
	Sign District	Hollywood (CRA Area)

The Hillside Area (Zoning Code) Ordinance is subject to modification. For more details, please refer to the Interim Control Ordinance Map and the Los Angeles Municipal Code Section 12.21.1 A.1. Flood Zone data is from the Los Angeles County Flood Control District. Seismic Hazard Zone data is from the California State Seismic Hazard Zone Maps.

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Adaptive Reuse Incentive Area	Adaptive Reuse Incentive Areas
CRA - Community Redevelopment Agency	Hollywood Redevelopment Project
Central City Parking	No
Downtown Parking	No
Building Line	None
500 Ft School Zone	No
500 Ft Park Zone	No
Assessor Information	
Assessor Parcel No. (APN)	5546003016
APN Area (Co. Public Works)*	0.256 (ac)
Use Code	1200 - Store and Office Combination
Assessed Land Val	$1,352,904
Assessed Improvement Val	$4,929,291
Last Owner Change	04/1905
Last Sale Amount	$0
Tax Rate Area	200
Deed Ref No. (City Clerk)	8 531
	2017
	1888 108
Building 1	
Year Built	1926
Building Class	CD0
Number of Units	3
Number of Bedrooms	0
Number of Bathrooms	3
Building Square Footage	35,462.0 (sq ft)
Building 2	No data for building 2
Building 3	No data for building 3
Building 4	No data for building 4
Building 5	No data for building 5
Additional Information	
Airport Hazard	None
Coastal Zone	None
Farmland	Area Not Mapped
Very High Fire Hazard Severity Zone	No
Fire District No. 1	No
Flood Zone	None
Watercourse	No
Hazardous Waste / Border Zone Properties	No
Methane Hazard Site	None
High Wind Velocity Areas	No
Special Grading Area (BOE Basic Grid Map A-13372)	Yes
Oil Wells	None
Seismic Hazards	
Active Fault Near-Source Zone	
Nearest Fault (Distance in Km)	5.4390659
Nearest Fault (Name)	Hollywood Fault
Region	Transverse Ranges and Los Angeles Basin
Fault Type	B
Slip Rate (mm/year)	1.0000000
Slip Geometry	Reverse - Oblique
Slip Type	Poorly Constrained
Down Dip Width (km)	14.0000000
Rupture Top	0.0000000

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(*) APN Area is provided "as is" from the Los Angeles County Public Works Digital Cadastre Parcels Layer.

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Radiate Section	[illegible]
Dist Adv Flag Area	[illegible]
Mexican Disparate	[illegible]
Almost-Hist-Pl Flood Zone	No
Landslide	No
Liquefaction	No
Tsunami Inundation Zone	No
Economic Development Areas	
Business Improvement District	HOLLYWOOD ENTERTAINMENT DISTRICT
Business Community	No
Revitalization Area	Central City
State Enterprise Zone	LOS ANGELES STATE ENTERPRISE ZONE
State Enterprise Zone Adjacency	No
Targeted Neighborhood Initiative	None
Public Safety	
Police Information	
Bureau	West
Division / Station	Hollywood
Reporting District	638
Fire Information	
Basic	1
Battalion	5
District / Fire Station	27
Red Flag Restricted Parking	No

[illegible] zimas.lacity.org | cityplanning.lacity.org

AR0074792

CASE SUMMARIES

Note: Information for case summaries is retrieved from the Planning Department's Plan Case Tracking System (PCTS) database.

Case Number:	CPC-2007-4838-SN
Required Action(s):	SN: SIGN DISTRICT
Project Description(s):	ESTABLISHMENT OF SIGN SUPPLEMENTAL
Case Number:	CPC-2003-2115-CRA
Required Action(s):	CRA-COMMUNITY REDEVELOPMENT AGENCY
Project Description(s):	Transfer agreement for the Hollywood Redevelopment Plan
Case Number:	CPC-2002-4172-SUD
Required Action(s):	SUD-SUPPLEMENTAL USE DISTRICT (PROPERTY OWNER INITIATED)
Project Description(s):	Data Not Available
Case Number:	CPC-1998-324-CO
Required Action(s):	CO-INTERIM CONTROL ORDINANCE
Project Description(s):	
Case Number:	CPC-1998-2998-CO
Required Action(s):	CO-INTERIM CONTROL ORDINANCE
Project Description(s):	INTERIM CONTROL ORDINANCE
Case Number:	CPC-1986-835-GPA-C
Required Action(s):	GPA-GENERAL PLAN/ZONING CONSISTENCY (ZI 2383)
Project Description(s):	PLAN AMENDMENTS AND ZONE CHANGES FOR THE HOLLYWOOD COMMUNITY PLAN PER LA CITY COUNCIL ACTION NO. CONSISTENCY PROGRAM
Case Number:	ENV-2009-1577-MND
Required Action(s):	MND-MITIGATED NEGATIVE DECLARATION
Project Description(s):	Approval of a proposed Sign Supplemental Use District pursuant to Section 13.11 of the LAMC for the Hollywood Redevelopment Project Area

DATA NOT AVAILABLE

ORD-97540

ORD-179172

ORD-173682

ORD-165660-SA40

ZA 2047

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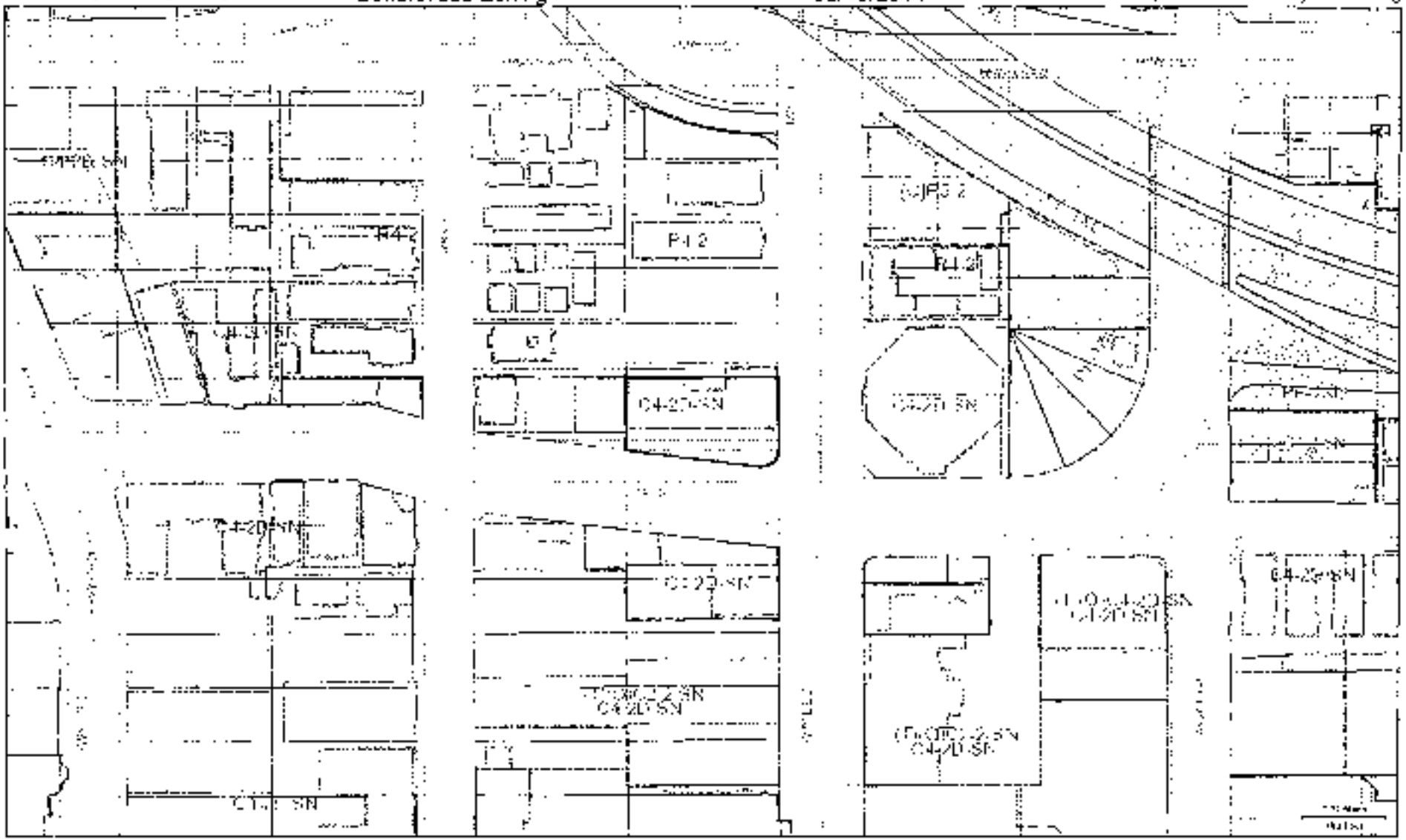
This map was created by the City of Los Angeles Department of City Planning - GIS Section. (800) 824-7488.

ZIMAS PUBLIC

Generalized Zoning

08/15/2014

City of Los Angeles
Department of City Planning


R4-2
R4-2-SN
P-1-2
C4-2D-SN
C4-2D-SN
C4-2D-SN

LEGEND

GENERALIZED ZONING

OS, GW

A, RA

RE, RS, R1, RU, RZ, RW1

R2, RD, RW2, R3, RAS, R4, R5

CR, C1, C1.5, C2, C4, CM, CW, ADP, LASED, PTC, USC, PVSP

CV, MR, WC, CCS, JW, LAX, JC, M1, M2, LAX, M3, SL

PB

PF

RMPD

GENERAL PLAN LAND USE

LAND USE

RESIDENTIAL

Minimum Residential

Very Low / Very Low I Residential

Very Low II Residential

Low / Low I Residential

Low II Residential

Low Medium / Low Medium I Residential

Low Medium II Residential

Medium Residential

High Medium Residential

High Density Residential

Very High Medium Residential

COMMERCIAL

Limited Commercial

Limited Commercial - Mixed Medium Residential

Highway Oriented Commercial

Highway Oriented and Limited Commercial

Highway Oriented Commercial - Mixed Medium Residential

Neighborhood Office Commercial

Community Commercial

Community Commercial - Mixed High Residential

Regional Center Commercial

INDUSTRIAL

Commercial Manufacturing

Limited Manufacturing

Light Manufacturing

Heavy Manufacturing

Hybrid Industrial

PARKING

Parking Buffer

PORT OF LOS ANGELES

General / Bulk Cargo - Non-Hazardous (Multi-User) / Commercial Fishing

General / Bulk Cargo - Hazardous

Commercial Fishing

Recreational and Commercial

Intermodal Container Transfer Facility Site

LOS ANGELES INTERNATIONAL AIRPORT

Airport Landside

Airport Airside

Airport Northside

OPEN SPACE / PUBLIC FACILITIES

Open Space

Public / Open Space

Public / Quasi-Public Open Space

Other Public Open Space

Public Facilities

FRAMEWORK

COMMERCIAL

Neighborhood Commercial

General Commercial

Community Commercial

Regional Mixed Commercial

INDUSTRIAL

Limited Industrial

Light Industrial

CIRCULATION

STREET

- Arterial Mountain Road
- Collector Scenic Street
- Collector Street
- Collector Street (Modified)
- Collector Street (Proposed)
- Country Road
- Divided Major Highway
- Divided Secondary Scenic Highway
- Local Scenic Road
- Local Street
- Major Highway (Modified)
- Major Highway
- Major Highway I
- Major Highway II (Modified)
- Major Scenic Highway
- Major Scenic Highway (Modified)
- Major Scenic Highway II
- Mountain Collector Street
- Park Road
- Parkway
- Principal Major Highway
- Private Street
- Scenic Divided Major Highway I
- Scenic Park
- Scenic Parkway
- Secondary Highway
- Secondary Highway (Modified)
- Secondary Scenic Highway
- Special Collector Street
- Super Major Highway

FREEWAYS

- Freeway
- Interchange
- On Ramp / Off Ramp
- Railroad
- Scenic Freeway Highway

MISC. LINES

- Airport Boundary
- Bus Line
- Coastal Zone Boundary
- Coastline Boundary
- Collector Scenic Street (Proposed)
- Commercial Areas
- Commercial Center
- Community Redevelopment Project Area
- Country Road
- DWP Power Lines
- Desirable Open Space
- Detached Single Family House
- Endangered Ridgeline
- Equestrian and/or Hiking Trail
- Hiking Trail
- Historical Preservation
- Horsekeeping Area
- Local Street
- MRCA Desirable Open Space
- Major Scenic Controls
- Multi Purpose Trail
- Natural Resource Reserve
- Open Road
- Park Road (Proposed)
- Quasi-Public
- Rapid Transit Line
- Recreational Planned Development
- Scenic Highway (Obsolete)
- Secondary Scenic Corridors
- Secondary Scenic Highway (Proposed)
- Side Boundary
- Southern California Edison Power
- Special Study Area
- Specific Plan Area
- Stagecoach Line
- Wildlife Corridor

AR0074796

POINTS OF INTEREST

- Alternative Youth Hostel (Proposed)
- Animal Shelter
- Area Library
- Area Library (Proposed)
- Bridge
- Campground
- Campground (Proposed)
- Cemetery
- Church
- City Hall
- Community Center
- Community Library
- Community Library (Proposed Expansion)
- Community Library (Proposed)
- Community Park
- Community Park (Proposed Expansion)
- Community Park (Proposed)
- Community Transit Center
- Convalescent Hospital
- Correctional Facility
- Cultural / Historic Site (Proposed)
- Cultural / Historical Site
- Cultural Arts Center
- DMV Office
- DWP
- DWP Pumping Station
- Equestrian Center
- Fire Department Headquarters
- Fire Station
- Fire Station (Proposed Expansion)
- Fire Station (Proposed)
- Fire Supply & Maintenance
- Fire Training Site
- FireBoat Station
- Health Center / Medical Facility
- Helistop
- Historic Monument
- Historical / Cultural Monument
- Horsekeeping Area
- Horsekeeping Area (Proposed)
- Horticultural Center
- Hospital
- Hospital (Proposed)
- HW House of Worship
- Important Ecological Area
- Important Ecological Area (Proposed)
- Interpretive Center (Proposed)
- JC Junior College
- MTA / Metrolink Station
- MTA Station
- MTA Stop
- MWD Headquarters
- Maintenance Yard
- Municipal Office Building
- Municipal Parking lot
- Neighborhood Park
- Neighborhood Park (Proposed Expansion)
- Neighborhood Park (Proposed)
- OT Collection Center
- Parking Enforcement
- Police Headquarters
- Police Station
- Police Station (Proposed Expansion)
- Police Station (Proposed)
- Police Training Site
- PO Post Office
- Power Distribution Station
- Power Distribution Station (Proposed)
- Power Receiving Station
- Power Receiving Station (Proposed)
- Private College
- Private Elementary School
- Private Golf Course
- Private Golf Course (Proposed)
- JH Private Junior High School
- PS Private Pre-School
- Private Recreation & Cultural Facility
- SH Private Senior High School
- SF Private Special School
- Public Elementary (Proposed Expansion)
- Public Elementary School
- Public Elementary School (Proposed)
- Public Golf Course
- Public Golf Course (Proposed)
- Public Housing
- Public Housing (Proposed Expansion)
- Public Junior High School
- Public Junior High School (Proposed)
- MS Public Middle School
- Public Senior High School
- Public Senior High School (Proposed)
- Pumping Station
- Pumping Station (Proposed)
- Refuse Collection Center
- Regional Library
- Regional Library (Proposed Expansion)
- Regional Library (Proposed)
- Regional Park
- Regional Park (Proposed)
- RPD Residential Plan Development
- Scenic View Site
- Scenic View Site (Proposed)
- School District Headquarters
- School Junior Red Tag/Type (Proposed)
- Skill Center
- Social Services
- Special Feature
- Special Recreation (s)
- Special School Facility
- Special School Facility (Proposed)
- Steam Plant
- SMI Surface Mining
- Trail & Assembly Area
- Trail & Assembly Area (Proposed)
- UTL Utility yard
- Water Tank Reservoir
- Wildlife Migration Corridor
- Wildlife Preserve Gate

AR0074797

SCHOOLS/PARKS WITH 500 FT. BUFFER

Existing School/Park Site

Planned School/Park Site

Inside 500 Ft. Buffer

Aquatic Facilities

Beaches

Charter School

Child Care Centers

Elementary School

Golf Course

High School

Historic Sites

Horticulture/Gardens

Middle School

Opportunity School

Other Facilities

Park / Recreation Centers

Parks

Performing / Visual Arts Centers

Recreation Centers

Span School

Special Education School

Senior Citizen Centers

Skate Park

OTHER SYMBOLS

Lot Line

Tract Line

Lot Cut

Easement

Zone Boundary

Building Line

Lot Split

Common Driveway

Tract Map

Parcel Map

Lot Ties

Building Outlines

Airport Hazard Zone

Census Tract

Coastal Zone

Council District

LADBS District Office

Downtown Parking

Fault Zone

Fire District No. 1

Flood Zone

Hazardous Waste

High Wind Zone

Hillside Grading

Historic Preservation Overlay Zone

Specific Plan Area

Very High Fire Hazard Severity Zone

Oil Wells

City of Los Angeles
Department of City Planning

PARCEL PROFILE REPORT

PROPERTY ADDRESSES
1777 N VINE ST

ZIP CODES
90028

RECENT ACTIVITY
Adaptive Reuse Incentive Spec. Plan Unit (ARIA)
Hollywood Signage SUD

CASE NUMBERS
CPC-2014-668-CPU
CPC-2007-8858-CA
CPC-2005-0082-CPU
CPC-2004-2115-CRA
ORD-172002-SA1
CPC-1988-824-GPA
CPC-1988-823-GPA
ORD-182760
ORD-182178-SA63
ORD-176248
ORD-176172
ORD-173692
ORD-164564-SA192
ORD-129944
PKG-2014-677-SE
ENV-2005-0156-EIR
ENV-2004-1377-MND
AFF-22208

Address/Legal Information

PIN Number	150A197 370
Lot/Parcel Area (Calculated)	1,725.7 (sq. ft.)
Thomas Brothers Grid	PAGE 593 - GRID J4
Assessor Parcel No. (APN)	5546024027
Tract	HOLLYWOOD
Map Reference	M R 28 54/55
Block	2
Lot	FR 23
Arb (Lot Cut Reference)	-
Map Sheet	150A197

Jurisdictional Information

Community Plan Area	Hollywood
Area Planning Commission	Central
Neighborhood Council	Hollywood United
Council District	CD 13 - Mitch O'Farrell
Census Tract #	1902.01
LADBS District Office	Los Angeles Metro

Planning and Zoning Information

Special Notes	None
Zoning	C4-2D-SN
Zoning Information (ZI)	ZI-2272 Hollywood Redevelopment Project
	ZI-1352 Hollywood Redevelopment Project
	ZI-2374 Hollywood CRA Area
	ZI-2427 Freeway Adjacent Advisory Notice for Sensitive Uses
	ZI-2452 Hollywood Community Plan Implementation
	ZI-2438 Preliminary Hollywood Fault Study Area
	ZI-2374-1 CALIFORNIA STATE ENTERPRISE ZONE
General Plan Land Use	Regional Center Commercial
General Plan Footnote(s)	Yes
Hillside Area (Zoning Code)	No
Baseline Hillside Ordinance	No
Baseline Mansionization Ordinance	No
Specific Plan Area	None
Special Land Use / Zoning	None
Design Review Board	No
Historic Preservation Review	Yes
Historic Preservation Overlay Zone	None
Other Historic Designations	None
Other Historic Survey Information	None
Mills Act Contract	None
CDO - Community Design Overlay	None
NSO - Neighborhood Stabilization Overlay	No
Streetscape	No
Sign District	Hollywood (CRA Area)
Adaptive Reuse Incentive Area	Adaptive Reuse Incentive Areas

The reported data is based upon the following sources as applicable for the property. Information should be verified with the respective City or County Departments. Thomas Bros. Maps is a registered trademark of Thomas Bros. Maps. (T-ARN Area is provided "as is" from the Los Angeles County Public Works Flood Control District.)

CRA - Community Redevelopment Agency	Hollywood Redevelopment Project
Central City Parking	No
Downtown Parking	No
Building Line	None
Split Lot	No
Special School Zone	No
Special Park Zone	No

Assessor Information

Assessor Parcel No. (APN)	5546004027
APN Area (Co. Public Work)	0.265 (ac)
Use Code	1300 - Office Building
Assessed Land Val	$1,967,206
Assessed Improvement Val	$4,023,124
Last Owner Change	07/01/13
Last Sale Amount	$12,625,125
Tax Rate Area	700
Deed Ref No. (City Clerk)	5501647
	0268274A
	0268278
	490,032
	0548179

Building 1

Year Built	0
Building Class	DX
Number of Units	0
Number of Bedrooms	0
Number of Bathrooms	0
Building Square Footage	36,248.0 (sq ft)

Building 2	No data for building 2
Building 3	No data for building 3
Building 4	No data for building 4
Building 5	No data for building 5

Additional Information

Airport Hazard	None
Coastal Zone	None
Farmland	Area Not Mapped
Very High Fire Hazard Severity Zone	No
Fire District No. 1	Yes
Flood Zone	None
Watercourse	No
Hazardous Waste / Border Zone Properties	No
Methane Hazard Site	None
High Wind Velocity Area	No
Special Grading Area (BOE Basic Grid Map A-13372)	Yes
Oil Wells	None

Seismic Hazards

Active Fault Near-Source Zone

Nearest Fault (Deterministic)	0.5081996
Nearest Fault Name	Hollywood Fault
Region	Transverse Ranges and Los Angeles Basin
Fault Type	B
Slip Rate (mm/year)	1.0000000
Slip Geometry	Left Lateral - Reverse - Oblique
Slip Type	Poorly Constrained
Down Dip Width (km)	14.0000000

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ZIMAS Help | Disclaimer | Privacy Policy | Terms of Use

Rupture Top	3.0000000
Rupture Bottom	13.0000000
Dip Angle (degrees)	70.0000000
Maximum Magnitude	6.4000000
Alquist-Priolo Fault Zone	No
Landslide	No
Liquefaction	No
Tsunami Inundation Zone	No

Economic Development Areas

Business Improvement District	HOLLYWOOD ENTERTAINMENT DISTRICT
Redevelopment Project Area	No
Revitalization Zone	Central City
State Enterprise Zone	LOS ANGELES STATE ENTERPRISE ZONE
State Enterprise Zone Adjacency	No
Targeted Neighborhood Initiative	None

Public Safety

Police Information

Bureau	West
Division / Station	Hollywood
Reporting District	638

Fire Information

Battalion	2
Battalion	6
District / Fire Station	27
Red Flag Restricted Parking	No

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CASE SUMMARIES

Note: Information for case summaries is retrieved from the Planning Department's Case Tracking System (CTS) database.

Case Number:	CPC-2014-665-CPU
Required Action(s):	CPU COMMUNITY PLAN UPDATE
Project Description(s):	COMMUNITY PLAN UPDATE/GENERAL PLAN AMENDMENT
Case Number:	CPC-2007-5086-SN
Required Action(s):	SN SIGN DISTRICT
Project Description(s):	HOLLYWOOD SIGN SUD AMENDMENT
Case Number:	CPC-2005-5082-CPU
Required Action(s):	CPU COMMUNITY PLAN UPDATE
Project Description(s):	Data Not Available
Case Number:	CPC-2003-2115-DRA
Required Action(s):	DRA COMMUNITY REDEVELOPMENT AGENCY
Project Description(s):	Final Amendment to the Hollywood Redevelopment Plan
Case Number:	CPC-2002-4173-SUD
Required Action(s):	SUD SUPPLEMENTAL USE DISTRICT (SUPERSTITION DISTRICT, ETC.)
Project Description(s):	Data Not Available
Case Number:	CPC-1999-224-ICO
Required Action(s):	ICO-INTERIM CONTROL ORDINANCE
Project Description(s):	
Case Number:	CPC-1999-2053-ICO
Required Action(s):	ICO-INTERIM CONTROL ORDINANCE
Project Description(s):	INTERIM CONTROL ORDINANCE
Case Number:	CPC-1997-10-CPU
Required Action(s):	CPU-COMMUNITY PLAN UPDATE
Project Description(s):	COMMUNITY PLAN UPDATE FOR HOLLYWOOD WITH AMENDMENTS AND REDEFINITION, UPDATED LAND USE ISSUES AND INCONSISTENT ZONING, REVIEWS POLICIES AND PROGRAMS, AS WELL AS REVISING AND UPDATING THE PLAN MAP AND TEXT
Case Number:	CPC-1986-835-CPC
Required Action(s):	CPC-GENERAL PLAN/ZONING CONSISTENCY (AB283)
Project Description(s):	PLAN AMENDMENTS AND ZONE CHANGES FOR THE HOLLYWOOD COMMUNITY PLAN REVISION/ZONE CONSISTENCY PROGRAM
Case Number:	ENV-2014-670-EIR
Required Action(s):	STATUTORY EXEMPTIONS
Project Description:	COMMUNITY PLAN UPDATE/GENERAL PLAN AMENDMENT
Case Number:	ENV-2005-2159-EIR
Required Action(s):	EIR-ENVIRONMENTAL IMPACT REPORT
Project Description:	COMMUNITY PLAN UPDATE FOR HOLLYWOOD WHICH ESTABLISHES ANG REDEFINES OUTDATED LAND USE ISSUES AND INCONSISTENCIES, REVIEWS POLICIES AND PROGRAMS AS WELL AS REVISING AND UPDATING THE PLAN MAP AND TEXT
Case Number:	ENV-2003-1077-MND
Required Action(s):	MND-MITIGATED NEGATIVE DECLARATION
Project Description(s):	Approval of a proposed Sign Supplemental Use District pursuant to Section 13.11 of the LAMC for the Hollywood Redevelopment Project Area

DATA NOT AVAILABLE

ORD-182868

ORD-182172-SA12

ORD-181343

ORD-176172

ORD-175562

ORD-180078-SA15

ORD-179814

ENV-2008

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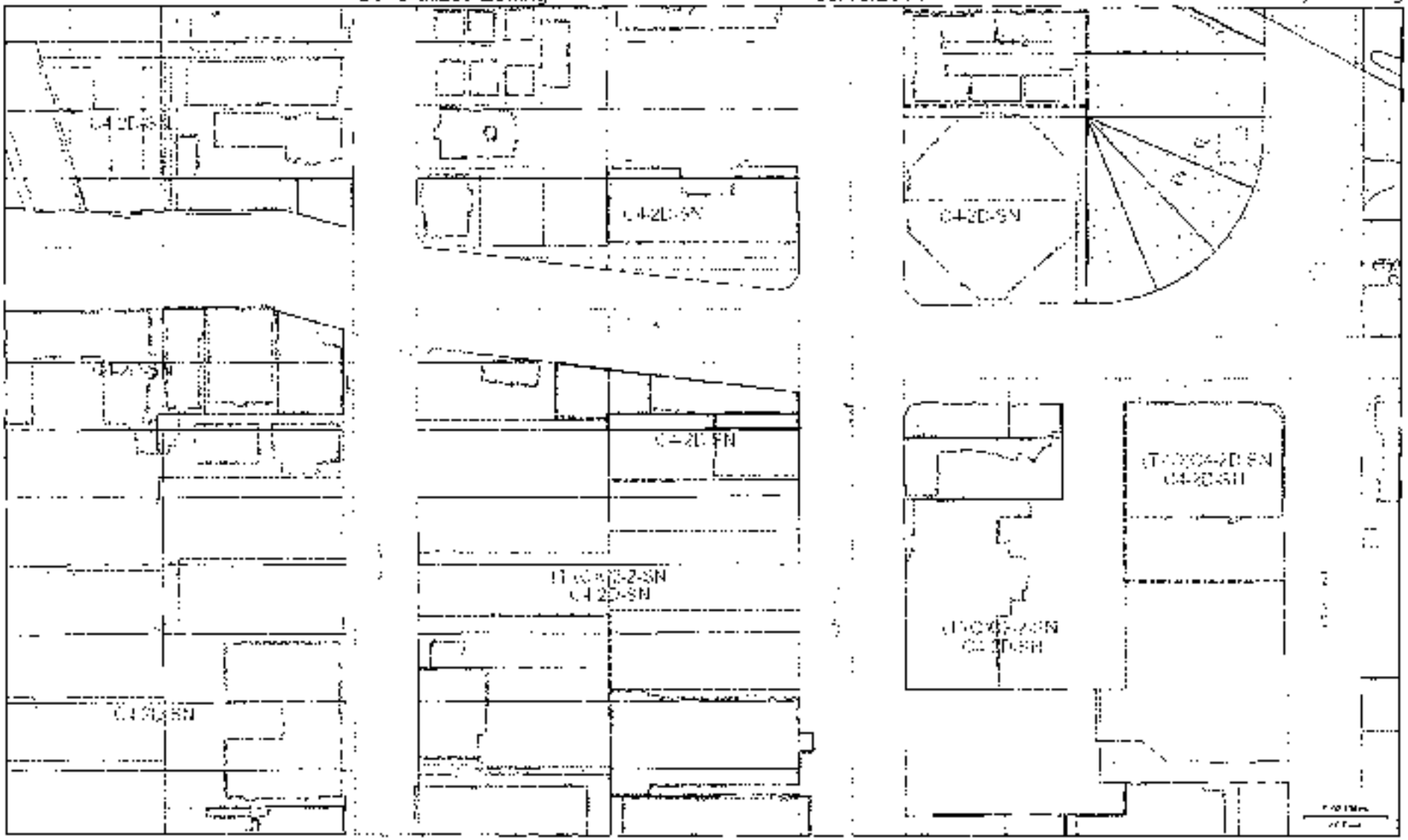
ZIMAS PUBLIC

Generalized Zoning

08/15/2014

City of Los Angeles
Department of City Planning



Address: 1777 N VINE ST
APN: 5546024027
PIN #: 150A187 376

Tract: HOLLYWOOD
Block: 21
Lot: FR 23
Arb: 1

Zoning: C4-2D-SN
General Plan: Regional Center Commercial

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AR0074803

LEGEND

GENERALIZED ZONING

OS, GW

A, RA

RE, RS, R1, RU, RZ, RW1

R2, RD, RW2, R3, R4, R5, RAS, R4, R5

CR, C1, C1.5, C2, C4, C5, CW, ADP, LASED, CEC, USC, PVSP

MR, M1, M2, LAX, M3, S

P, PB

PF

GENERAL PLAN LAND USE

LAND USE

RESIDENTIAL

- Minimum Residential
- Very Low / Very Low I Residential
- Very Low II Residential
- Low / Low I Residential
- Low II Residential
- Low Medium / Low Medium I Residential
- Low Medium II Residential
- Medium Residential
- High Medium Residential
- High Density Residential
- Very High Medium Residential

COMMERCIAL

- Limited Commercial
- Limited Commercial - Mixed Medium Residential
- Highway Oriented Commercial
- Highway Oriented and Limited Commercial
- Highway Oriented Commercial - Mixed Medium Residential
- Neighborhood Office Commercial
- Community Commercial
- Community Commercial - Mixed High Residential
- Regional Center Commercial

INDUSTRIAL

- Commercial Manufacturing
- Limited Manufacturing
- Light Manufacturing
- Heavy Manufacturing
- Hybrid Industrial

PARKING

- Parking Buffer

PORT OF LOS ANGELES

- General / Bulk Cargo - Non-Hazardous (Industry / Commercial)
- General / Bulk Cargo - Hazard
- Commercial Fishing
- Recreation and Commercial
- Intermodal Container Transfer Facility Site

LOS ANGELES INTERNATIONAL AIRPORT

- Airport Landside
- Airport Airside
- Airport Northside

OPEN SPACE / PUBLIC FACILITIES

- Open Space
- Public / Open Space
- Public / Quasi-Public Open Space
- Other Public Open Space
- Public Facilities

FRAMEWORK

COMMERCIAL

- Neighborhood Commercial
- General Commercial
- Community Commercial
- Regional Mixed Commerce

INDUSTRIAL

- Limited Industrial
- Light Industrial

CIRCULATION

STREET

- Arterial Mountain Road
- Collector Scenic Street
- Collector Street
- Collector Street (Hillside)
- Collector Street (Modified)
- Collector Street (Proposed)
- Country Road
- Divided Major Highway II
- Divided Secondary Scenic Highway
- Local Scenic Road
- Local Street
- Major Highway II (Modified)
- Major Highway I
- Major Highway I
- Major Highway I (Modified)
- Major Scenic Highway
- Major Scenic Highway (Modified)
- Major Scenic Highway I
- Mountain Collector Street
- Park Road
- Parkway
- Principal Major Highway
- Private Street
- Scenic Divided Major Highway
- Scenic Park
- Scenic Parkway
- Secondary Highway
- Secondary Highway (Modified)
- Secondary Scenic Highway
- Special Collector Street
- Super Major Highway

FREEWAYS

- Freeway
- Interchange
- On-Ramp / Off-Ramp
- Railroad
- Scenic Freeway Highway

MISC. LINES

- Airport Boundary
- Bus Line
- Coastal Zone Boundary
- Coastline Boundary
- Collector Scenic Street (Proposed)
- Commercial Area
- Commercial Center
- Community Redevelopment Project Area
- Country Road
- DWP Power Lines
- Desirable Open Space
- Detached Single Family House
- Ecotone or Ridgeline
- Equestrian and/or Hiking Trail
- Hiking Trail
- Historical Preservation
- Horsekeeping Area
- Local Street
- MRA Desirable Open Space
- Major Scenic Controls
- Multi Purpose Trail
- Natural Resource Reserve
- Park Road
- Park Road (Proposed)
- Quasi-Public
- Rapid Transit Line
- Residential Planned Development
- Scenic Highway (Obsolete)
- Secondary Scenic Controls
- Secondary Scenic Highway (Proposed)
- Site Boundary
- Southern California Edison Power
- Special Study Area
- Specific Plan Area
- Stagecoach Line
- Wildlife Corridor

AR0074805

POINTS OF INTEREST

- Alternative Youth Hostel (Proposed)
- Animal Shelter
- Area Library
- Area Library (Proposed)
- Bridge
- Campground
- Campground (Proposed)
- Cemetery
- Church
- City Hall
- Community Center
- Community Library
- Community Library (Proposed Expansion)
- Community Library (Proposed)
- Community Park
- Community Park (Proposed Expansion)
- Community Park (Proposed)
- Community Transit Center
- Convalescent Hospital
- Correctional Facility
- Cultural / Historic Site (Proposed)
- Cultural / Historical Site
- Cultural Arts Center
- DMV Office
- DWP
- DWP Pumping Station
- Equestrian Center
- Fire Department Headquarters
- Fire Station
- Fire Station (Proposed Expansion)
- Fire Station (Proposed)
- Fire Supply & Maintenance
- Fire Training Site
- Fireboat Station
- Health Center / Medical Facility
- Helistop
- Historic Monument
- Historical / Cultural Monument
- Horsekeeping Area
- Horsekeeping Area (Proposed)
- Horticultural Center
- Hospital
- Hospital (Proposed)
- House of Worship
- Important Ecological Area
- Important Ecological Area (Proposed)
- Interpretive Center (Proposed)
- Junior College
- MTA / Metrolink Station
- MTA Station
- MTA Stop
- MWD Headquarters
- Maintenance Yard
- Municipal Office Building
- Municipal Parking lot
- Neighborhood Park
- Neighborhood Park (Proposed Expansion)
- Neighborhood Park (Proposed)
- Oil Collection Center
- Parking Enforcement
- Police Headquarters
- Police Station
- Police Station (Proposed Expansion)
- Police Station (Proposed)
- Police Training Site
- Post Office
- Power Distribution Station
- Power Distribution Station (Proposed)
- Power Receiving Station
- Power Receiving Station (Proposed)
- Private College
- Private Elementary School
- Private Golf Course
- Private Golf Course (Proposed)
- Private Junior High School
- Private Pre School
- Private Recreation & Cultural Facility
- Private Senior High School
- Private Special School
- Public Elementary (Proposed Expansion)
- Public Elementary School
- Public Elementary School (Proposed)
- Public Golf Course
- Public Golf Course (Proposed)
- Public Housing
- Public Housing (Proposed Expansion)
- Public Junior High School
- Public Junior High School (Proposed)
- Public Middle School
- Public Senior High School
- Public Senior High School (Proposed)
- Pumping Station
- Pumping Station (Proposed)
- Refuse Collection Center
- Regional Library
- Regional Library (Proposed Expansion)
- Regional Library (Proposed)
- Regional Park
- Regional Park (Proposed)
- Residential Plan Development
- Scenic View Site
- Scenic View Site (Proposed)
- School District Headquarters
- School Unspecified Loc/Type (Proposed)
- Skill Center
- Social Services
- Special Feature
- Special Recreation Ctr
- Special School Facility
- Special School Facility (Proposed)
- Steam Plant
- Surface Mining
- Trail & Assembly Area
- Trail & Assembly Area (Proposed)
- Utility Yard
- Water Tank Reservoir
- Wildlife Migration Corridor
- Wildlife Preserve Gate

SCHOOLS/PARKS WITH 500 FT. BUFFER

Existing School/Park Site

Planned School/Park Site

Inside 500 Ft. Buffer

- Aquatic Facilities
- Beaches
- Charter School
- Child Care Centers
- Elementary school
- Golf Course
- High School
- Historic Sites
- Joint Use/Agencies
- Middle School
- Opportunity School
- Other Facilities
- Parks/Recreation Centers
- Parks
- Performing / Visual Arts Centers
- Recreation Centers
- Senior High
- Special Education School
- Senior Citizen Centers
- Skate Parks

OTHER SYMBOLS

- Lot Line
- Tract Line
- Lot Cut
- Easement
- Zone Boundary
- Building Line
- Lot Split
- Community Driveway
- Tract Map
- Parcel Map
- Lot Ties
- Surveying Outlines
- Airport Hazard Zone
- Census Tract
- Coastal Zone
- Council District
- LADBS District Office
- Downtown Parking
- Fault Zone
- Fire District No. 1
- Flood Zone
- Hazardous Waste
- High Wind Zone
- Hillside Grading
- Historic Preservation Overlay Zone
- Specific Plan Area
- Very High Fire Hazard Severity Zone
- Oil Wells

[illegible]

- -

[illegible]

[illegible]

[illegible]

- -

[illegible]

[illegible]

[illegible]

AR0074809

INDEX

[illegible] ... [illegible] ... VI"
[illegible] ... [illegible] ...
Navigator Agreement, approved ...

Motion to [illegible] ... [illegible] ... 9:6
proceed [illegible] ... [illegible] ...
Prohibition [illegible] ... [illegible] ...
Upon [illegible]

AR0074810

[illegible]

[illegible]

[illegible]

AR0074812

[illegible] will not, without the [illegible] a bill. We will have [illegible] with, who will help [illegible] [illegible] to vote [illegible]. We'll have [illegible] [illegible] [illegible]

AR0074814

[illegible]

[illegible]

[illegible]

[illegible] will be [illegible] year's [illegible].

[illegible] the [illegible] [illegible] [illegible]

AR0074818

AR0074819

[illegible] for [illegible] area.

Air quality [illegible] the [illegible] [illegible] and [illegible] [illegible] [illegible]

AR0074822

AR0074823

AR0074824

[illegible]

[illegible]

[illegible]

[illegible] Deputy, do you see the publication year on the publication given right, and will you be able to provide a reliable estimate, such that the Virgin Islands Bureau of Motor Vehicles will be protected and satisfied, as to publication year, the reason why, and that explanation to be valid, how will we provide publication year with reasonable certainty.

MR. HERMAN: [illegible] -- let's start by discussing it for the [illegible].

MR. [illegible]: It is a problem in the industry that [illegible] information [illegible] publication.

MR. HERMAN: I hear you.

DR. [illegible]: [illegible] publication [illegible] of the [illegible] and will [illegible] publication [illegible] -- well, we'll go back [illegible] to [illegible].

MR. HERMAN: [illegible]

AR0074826

AR0074827

[illegible]

[illegible]

[illegible]

[illegible] with FDA approval.

Now, this is not FDA approved. It's [illegible] general recognition, this was [illegible] manual [illegible], what guarantees that this will be true [illegible] with your experience.

Other [illegible] consistency [illegible]. Now, one of the appeal issues that this person has is, since [illegible] and now it's not, is it [illegible] that's an [illegible] that we can't [illegible] CO2, it's 1, 2, 3, 4, 5 [illegible].

Now this is [illegible] consistency [illegible] that's [illegible] to the side of [illegible] property, you [illegible] [illegible] [illegible] [illegible] [illegible].

And you've also had [illegible] [illegible] [illegible] [illegible].

AR0074830

[illegible] morning,
[illegible]. I'm [illegible] here
[illegible] and I'm going to
[illegible] [illegible] the data
[illegible] [illegible] my [illegible], but
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

[illegible] [illegible], [illegible]
[illegible] [illegible] [illegible].
[illegible]'s a [illegible] and a [illegible]
[illegible], and [illegible] [illegible] [illegible]
[illegible] [illegible].

[illegible] [illegible], [illegible] [illegible]
[illegible] [illegible], [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible]. [illegible] [illegible], [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible].

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

[illegible] [illegible] [illegible] [illegible]

AR0074831

[illegible] Riverside Building and the Main [illegible] that was on the 9th floor of the [illegible] Riverside Building, is this [illegible] the Multicultural Magazine, Miss [illegible] Have you ever been in the [illegible] Riverside Building?

[illegible] I'm [illegible] Building [illegible] Riverside Building, [illegible] Building, [illegible] Riverside Building, [illegible] Building, [illegible] Riverside Building, [illegible] Building,

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [

AR0074834

[illegible] Miss Williams to [illegible] your [illegible] [illegible] [illegible]

AR0074836

AR0074837

AR0074838

approximately [illegible]. Because you see, there's a
[illegible] that [illegible] that [illegible]
life [illegible]. The Bill [illegible] in life,
[illegible]. They [illegible] in life [illegible], but
we [illegible], we [illegible] [illegible] our
[illegible] [illegible] [illegible] [illegible] that [illegible]
[illegible]. They [illegible] [illegible] life [illegible], but we
don't [illegible] [illegible] [illegible] [illegible] appropriation,
we [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible].

And [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]. We [illegible]
[illegible], you [illegible] [illegible] -- you [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible]. You [illegible] [illegible] [illegible] [illegible]
[illegible]. [illegible] [illegible] [illegible], [illegible]
[illegible] [illegible]. And [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

You [illegible] [illegible] [illegible] [illegible]
should [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible]. So [illegible] [illegible], you
[illegible] [illegible] [illegible] [illegible]. It [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible], and
[illegible] [illegible] [illegible] [illegible] [illegible].

AR0074839

[illegible] that would [illegible] that it
[illegible] and [illegible] a [illegible]
[illegible], and I [illegible] personally
[illegible] relationship.

[illegible] important to [illegible] that
[illegible], they [illegible]
[illegible] and they [illegible] in
[illegible] bridge [illegible] that [illegible].

And [illegible] to [illegible] the
[illegible] Capitol [illegible], I'm
[illegible] that [illegible]
[illegible], and they
[illegible] that [illegible]
[illegible].

And [illegible], you have a
[illegible] problem [illegible], but
[illegible] to [illegible]
[illegible]. And you [illegible]
[illegible], and [illegible] to be [illegible]
[illegible], and [illegible] differentiate
[illegible] -- that [illegible]
[illegible].

And I'd [illegible] [illegible] the
[illegible] [illegible] to [illegible].

AR0074840

religion. As you can see, it increases.

And this is an example of a

multiply-connected passageway. In

this -- screen that I'm sure you can't read

or this screen, and I'm sure I'm pronouncing

that wrong, but I'm trying. This screen is

Arroyo Seco Loop. And these are examples

of my recent sponsor activities, which

include a total of twenty feet, and the

overall power requirement is for

illumination, power consumption, and

cooling, and this productivity.

And it really starts to create a collective

network of activities, which

create a sense of belonging, and

I'm very proud to be working a

combination of art, and potentially

integrating it with science, which is

very, very important, and it starts to

relate to the ground. And I, I mean I

like to work, like to be outside in

green industry-type activities and

hospitality, as well. So this is fun, I

-- I'm very excited, and I'm sure you're

very excited.

AR0074842

[illegible] the way you came up with these
[illegible] conversation [illegible]. So it
[illegible] hypothetical [illegible] with
[illegible] [illegible] [illegible] and
your other [illegible] that
[illegible] [illegible] [illegible]. So
[illegible] you [illegible] [illegible]
[illegible] in the Bible.

And [illegible] [illegible] [illegible]
[illegible] [illegible].

MR. [illegible]: I'm just [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible].

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [

[illegible] applications, [illegible] applicant [illegible] registration [illegible] [illegible].

With that said, [illegible] [illegible] [illegible]

AR0074845

[illegible] associated with the construction, including [illegible] [illegible] [illegible]

AR0074847

THE CLERK: Thank you. Ms. [illegible] Norman, Mr. Anderson, and Mary Hatch. [illegible] Mr. Chairman, if you're ready, you may proceed.

DR. CHAIRMAN: Fine, we will entertain [illegible] from [illegible].

MS. NORMAN: Mr. Chairman, -- Mr. Chairman, may I have a moment to [illegible] [illegible] [illegible] [illegible]

THE CLERK: We can't hear you. Your [illegible] [illegible], please, and [illegible], Ms. Norman, please.

MS. NORMAN: Thank you. [illegible] [illegible], I may [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [

[illegible] industrial [illegible] of the world's most [illegible] biodiversity, [illegible] virus.

[illegible] was also to [illegible] a [illegible] of development [illegible] [illegible] of [illegible], [illegible], vulnerability, and [illegible] [illegible]. [illegible] this project [illegible] [illegible] [illegible] [illegible] of the [illegible] will [illegible] from [illegible].

[illegible] in a [illegible] [illegible] [illegible] [illegible] [illegible] by the [illegible] [illegible] [illegible] [illegible], [illegible] [illegible], [illegible] [illegible] [illegible], we [illegible] to [illegible] a [illegible] and a [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible], [illegible], [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] department's [illegible]
privilege, it does not [illegible]
[illegible], but [illegible] [illegible]
[illegible] the [illegible]
[illegible], and [illegible] [illegible]
[illegible], [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible], [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible]

[illegible] [illegible] [illegible] [

AR0074854

[illegible] opportunity [illegible] a
major [illegible] of [illegible] property [illegible]
[illegible], where [illegible] of [illegible] [illegible]
will be [illegible] and [illegible]
[illegible].

We [illegible] [illegible] [illegible] a
variety of [illegible]. We will [illegible] a
variety of [illegible] [illegible] of [illegible]
sizes, which [illegible] will be available
at [illegible] and [illegible] [illegible]
of [illegible], in addition, we
[illegible] will [illegible] [illegible]
[illegible] to [illegible], a [illegible]
personal [illegible] of [illegible], which [illegible]
we have [illegible] at [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] payment [illegible]
the [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible]

AR0074856

AR0074857

Article, as was contemplated by, and
expressly, to avoid [illegible] that
[illegible] of the Little Rock Port.

As you Exhibit, the attorneys of the
Naptown Business Park Authority, acting in
[illegible] have, this Board, to provide
[illegible] over any [illegible]
[illegible] in the [illegible] by Little
Rock [illegible]. And additional expenses,
[illegible], should [illegible] the
[illegible] [illegible] [illegible] of
[illegible] [illegible].

In [illegible], as you have [illegible]
in, the [illegible] [illegible] [illegible]
[illegible] [illegible], [illegible] in the
[illegible] [illegible], as [illegible] of
[illegible] [illegible]. The [illegible]
[illegible] by [illegible] [illegible], the
[illegible], [illegible] of [illegible]
the [illegible] [illegible] [illegible]
[illegible] [illegible].

In [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] of
[illegible] [illegible] [illegible].

AR0074858

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [

AR0074861

Next,

And this time, I would be on your [illegible] that people also weigh, be very [illegible], because of the [illegible] implications of the decision we [illegible], especially, as it [illegible], which really was the only aspect of this [illegible] we had any [illegible] on -- by -- and we [illegible] matters.

And then [illegible] your [illegible], there [illegible] which [illegible] [illegible] [illegible], this [illegible], and the [illegible] weight, with the understanding of course [illegible] [illegible] that [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

Next.

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

Next.

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

Next.

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

AR0074864

[illegible] [illegible]

[illegible]

Next.

[illegible] [illegible]

[illegible]

[illegible]

[illegible]

Next.

[illegible]

[illegible]

[illegible]

[illegible]

Next.

[illegible]

[illegible]

[illegible]

AR0074865

[illegible] Secretary Carson, and which [illegible] Secretary [illegible] Department of [illegible] -- I would be part of what is [illegible] willing to [illegible] of public upon opinions.

[illegible] Secretary Carson [illegible] the [illegible] of the [illegible] Department, and [illegible] Secretary [illegible] create a [illegible] [illegible] [illegible] the [illegible] of [illegible], [illegible] [illegible] [illegible] [illegible] and [illegible], and [illegible], you [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] individual [illegible] [illegible].

Next.

[illegible] [illegible] [illegible] [illegible]. And [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

AR0074869

[illegible]

Next.

-- [illegible] and [illegible] the [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

[illegible] from their [illegible] and any
[illegible] supervision [illegible] the [illegible].

[illegible], we have [illegible] an [illegible]
and [illegible] of [illegible] in [illegible] in [illegible]
as a [illegible] other [illegible] and [illegible],
and [illegible] to the [illegible] of [illegible], in a
[illegible] [illegible], which [illegible] of
[illegible] [illegible].

In short, [illegible] with [illegible] staff,
we have [illegible] as a [illegible] to
[illegible] [illegible] [illegible] [illegible],
[illegible] to [illegible], but [illegible] with a
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

I [illegible] already [illegible] a [illegible] in
[illegible] [illegible], in [illegible] to
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

[illegible], we [illegible] [illegible] to
[illegible] [illegible] and [illegible] [illegible]
[illegible] [illegible] --
[illegible], and [illegible]
[illegible] [illegible].

[illegible] [illegible] [illegible] [illegible]

AR0074873

[illegible]

[illegible]

[illegible]

[illegible] [illegible] [illegible] [

[illegible] for your [illegible] efforts [illegible].

We have a few questions. We would require [illegible] with this to be a clear difficulty, and as you [illegible] would expect, we have to [illegible]. We would want [illegible] a minimum of [illegible] years to [illegible] the [illegible] would [illegible] [illegible] square [illegible] and [illegible] [illegible] [illegible]

AR0074878

AR0074879

AR0074880

[illegible]

AR0074881

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

AR0074884

material, if you give me the certainties
I may not have the most accurate information,
I'm applying this argument, however,
in isolation, and hedge risks in dealing.
Some of the parameters you invoke may
not be the most optimal approach, and
yet, you're not really getting into
counterproductive territory. There is a
better investigative model, you must
realize that's obvious.

Based on a recorded note, it's not
until about the 1960's picture. Any
unusual conflict of 1941, a investment issue,
in that event it disqualify for a number of
a variable value in financial interest
in a per hour, the disqualification
applies for the entire portion. So,
I would, I say hypothesize, is not merely a
penalty for the novel approach somewhere. The
[illegible] the approach, the Supreme Court, but
this, this disqualifying interest applies
to the particular to be, of the
circumstance. And, therefore, it
alternatives rule reasonable. Is that an
entire rule by you would

AR0074885

[illegible] [illegible] immediately.

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

[illegible] Yes, but you did not provide that to the public prior to [illegible]. And I'm not [illegible] that.

MS. [illegible]: Mr. [illegible], we provided [illegible] to the public and [illegible] other documents that are [illegible] of the [illegible]. It may [illegible] --

[illegible]: Well, I submitted a [illegible] to [illegible] this, [illegible]. That's what I'm [illegible].

THE [illegible]: Please proceed.

MS. [illegible]: I hope [illegible] "Guard" [illegible] [illegible], Mississippi Democrats.

Also, [illegible] [illegible] [illegible]

AR0074888

[illegible] your life [illegible]
[illegible] [illegible].

What will [illegible]? Will it
[illegible] [illegible]? Will
[illegible]? Will [illegible]
[illegible]? [illegible], [illegible]
[illegible]? Will [illegible],
[illegible], [illegible]
[illegible], [illegible] [illegible]
[illegible] [illegible]? [illegible]
[illegible], [illegible]
[illegible], [illegible]
[illegible], [illegible]
[illegible]?

Will [illegible] [illegible]
[illegible], [illegible],
[illegible] [illegible]
[illegible]. [illegible]
[illegible]. [illegible]
[illegible], [illegible]
[illegible]. [illegible]
[illegible] [illegible]
[illegible], [illegible]
[illegible]?

AR0074889

AR0074890

[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [

[illegible] in certain cases.

Our approval also provides that the [illegible] authority to provide [illegible] the Delaware River Basin Commission [illegible] review and approval [illegible] Administrative Manual [illegible] Basin Regulations [illegible] Flexible Hose [illegible] Natural Gas [illegible] Pipeline [illegible] Pipeline [illegible] Pipeline

[illegible] in this city, and while [illegible] was in the city [illegible] of [illegible] [illegible] [illegible]

[illegible] Station Road, [illegible]
[illegible], [illegible] Regional Hospital,
[illegible] Associates. Simply, [illegible]
Mutual, [illegible] Drive in [illegible],
and for those present, you should find that
this is [illegible].

Finally, the earlier [illegible]
[illegible] Millennium [illegible] Project
[illegible] Partnership Plan [illegible]
[illegible] by the City. That plan is
currently -- [illegible] Wellington II, [illegible] by the
Preservation Land Trust, [illegible] the
[illegible] [illegible] and [illegible] of the
[illegible] people [illegible] [illegible]
[illegible] [illegible] -- part of the [illegible] [illegible]
[illegible].

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible],
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

AR0074895

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

[illegible] [illegible] [illegible] [

[illegible] to [illegible] arrive. Then, the [illegible] to [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

AR0074902

[illegible] [illegible] [illegible] [

[illegible]

[illegible]

[illegible]

[illegible] build a new plant anywhere in
[illegible] community.

[illegible] is very clear about that. We
[illegible] to be very clear about that. We
[illegible] community owned space and the [illegible]
[illegible], and the overall [illegible]
[illegible] community. But we are [illegible] by
[illegible] [illegible] of [illegible]
[illegible], which is what [illegible]
[illegible] moved to us.

[illegible] the [illegible], the [illegible] would
[illegible] [illegible] a world [illegible]. [illegible]
[illegible] a way [illegible] [illegible]
[illegible] [illegible]. "Will [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible]-[illegible] [illegible], [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible], [illegible],
[illegible], [illegible] [illegible] [illegible]
[illegible]."

[illegible] [illegible], [illegible]
[illegible], [illegible] [illegible]
[illegible] [illegible].

[illegible] [illegible], [illegible]

AR0074905

AR0074906

AR0074908

AR0074909

AR0074910

[illegible]

AR0074912

AR0074913

AR0074916

[illegible]

[illegible]

[illegible]

AR0074920

AR0074921

[illegible] Williamsburg. We have a [illegible] relationship [illegible] Historic Triangle [illegible] Association, [illegible] Virginia Tourism Corporation, [illegible] Virginia Beach, [illegible] Norfolk, [illegible] Virginia Beach, [illegible] Norfolk, [illegible] Virginia Beach, [illegible] Norfolk

AR0074924

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AR0074939

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AR0074941

[illegible]

AR0074942

[illegible] take advantage of it, and I'm sure they're
busy, but I'm not getting that busy, but when
[illegible] I'm [illegible], particularly,
[illegible]. And I think that's the
[illegible] environment that has
[illegible] and also I'm
[illegible], and you can also maintain
[illegible]. It's certainly [illegible]
[illegible] environment that has public
[illegible]'s well taken, [illegible] that
[illegible] A competitive employ
[illegible] in the community and private [illegible],
[illegible], I think you're
[illegible] this position.

Thank you.

MR. [illegible]: Mr. Chairman,
[illegible]. My name is [illegible],
I'm the Business Manager for [illegible]
[illegible], and I'm a [illegible] of
the [illegible] Nation.

The Milwaukee Area Project [illegible]
[illegible] with [illegible] that Native
[illegible] [illegible].

AR0074943

AR0074944

[illegible]

[illegible]

[illegible]

[illegible] years. Your
[illegible] service, what's the [illegible]
of the [illegible] that all have
already been stated. I think it's a
[illegible] privilege, it's also [illegible]
[illegible] over [illegible] the [illegible]
and similar buildings, [illegible] and
[illegible] that. It will [illegible] the
[illegible] that multiplied and [illegible]
at [illegible].

[illegible]

Yes, [illegible] like to [illegible],
[illegible].

Mr. [illegible], my name is [illegible].
I'm [illegible]. I have [illegible] and live in
[illegible] over [illegible] years. I'm a
[illegible] [illegible] [illegible], and
[illegible] by [illegible] have been very
[illegible] and [illegible] [illegible]
[illegible].

I'm [illegible] than [illegible] and
[illegible]. I [illegible]
[illegible] of the
[illegible] of [illegible]
[illegible], [illegible] [illegible], [illegible]

AR0074946

to audit, from time to time, the use and the
[illegible] of [illegible]. Our primary,
[illegible] is to [illegible] it,
and it's [illegible] to [illegible] community.

[illegible] -- I [illegible] support them. We have a huge
[illegible] of our [illegible]. And I'm a [illegible]
[illegible], so much so that [illegible] my
[illegible], we [illegible] the [illegible]
[illegible], to [illegible] [illegible].
Thanks, I [illegible].

We, [illegible],
[illegible]. We have [illegible].
I'm [illegible] [illegible]. Many [illegible]
[illegible], [illegible] [illegible]
[illegible] [illegible].

We [illegible] [illegible],
[illegible], [illegible], [illegible]
[illegible] [illegible].

We're [illegible] [illegible].
We believe [illegible]. We believe
it's a [illegible], and we'd
like you to [illegible].

AR0074947

Thank you.

[illegible] Thank you very much,

[illegible]. My name is [illegible]

[illegible]. I'm originally from [illegible].

[illegible] Polytechnic University, and I'm

[illegible] of the [illegible], which is

[illegible] of [illegible].

[illegible] I'm very proud to [illegible]

[illegible] of this work, and I would like to [illegible]

[illegible] services, [illegible] the [illegible] of

[illegible] FAA, [illegible] and [illegible]

[illegible], [illegible] [illegible] to [illegible]

[illegible] and other people that [illegible]

[illegible] with the [illegible] to [illegible]

[illegible] and [illegible].

We have had a [illegible], and [illegible]

[illegible] of the [illegible] of this [illegible]

[illegible] the [illegible], and [illegible] are a [illegible]

[illegible] that I want to [illegible].

[illegible] I'm [illegible] a [illegible] at the

[illegible] of [illegible]. And [illegible] to [illegible]

[illegible] from [illegible] of [illegible]

[illegible] [illegible] to [illegible] and

[illegible] [illegible] and a [illegible] to [illegible]

[illegible] for [illegible] and [illegible].

AR0074948

AR0074949

AR0074950

[illegible]

AR0074952

[illegible]

[illegible]

[illegible]

AR0074954

[illegible] and in many cases, we visit those [illegible] and we have [illegible], any [illegible] [illegible] [illegible]

AR0074956

AR0074957

Thank you very much.

Mr. WILLIAMS: Thank you, Mr. Chairman.

Mr. Chairman, Ranking Member Cummings, and distinguished members of the committee, I'm a retired senior executive with 30 years of service in the Department of Defense. I'm also a veteran of the Vietnam War, and I'm honored to testify before you today on the subject of the Department of Defense's Military Whistleblower Reprisal Program.

The Department of Defense Inspector General's office is responsible for investigating allegations of reprisal against members of the Armed Forces, DOD contractor employees, and DOD nonappropriated fund employees. We receive approximately 1,000 complaints annually.

Our investigations show that the Department's military whistleblower reprisal program is broken. Complainants are frustrated by the length of time it takes to complete investigations. Many times, it takes more than a year to complete an investigation. Many times, it takes more than two years to complete an investigation. Many times, it takes more than three years to complete an investigation. Many times, it takes more than four years to complete an investigation. Many times, it takes more than five years to complete an investigation.

I've been told that there is a plan to reduce the timeliness requirements. They are not going to be reduced, but they are going to be changed, and they will be changed.

AR0074958

AR0074959

[illegible] to the Navajo Nation, as a result of the [illegible] and visitors.

The proposed [illegible] of the Navajo Nation [illegible] the [illegible] and [illegible] and [illegible] and

AR0074962

AR0074963

[illegible] Libya.

[illegible] Libya, [illegible] Libya [illegible] Libya [illegible] Libya

[illegible] Hive is a threat. You poor [illegible] very well.

Q. Under the Law of Diversity, the [illegible], was a victim related to the Hydra, Hellyarnold's world. In the game, [illegible] they don't exist [illegible], they make room in order to survive. They must destroy in order to [illegible]. Hellyarnold's world is like this, [illegible] you're trying to [illegible] right?

A. Right.

Q. Please explain to [illegible] what a [illegible] is, [illegible] Hydra, alright. [illegible] Hydra, [illegible] Hydra is [illegible] until Hellyarnold and Bloodlust [illegible]. It was [illegible] and [illegible] Hydra. [illegible] Hydra, Hydra [illegible] said it all, and that if you [illegible] Hydra, it's only going to [illegible] Hydra, [illegible] [illegible], [illegible] it will be [illegible]. It is [illegible], you [illegible]. You [illegible] Hydra, you [illegible], you [illegible]. But you've got [illegible] Hydra [illegible] Hydra [illegible].

AR0074965

AR0074966

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

AR0074969

AR0074970

AR0074971

AR0074972

[illegible] Wisconsin, but I'm committed to
[illegible] Wisconsin Employers.

Please continue if you're [illegible].

Thank you.

MR. BARRY: Good afternoon, Mr. Chairman, Members of the Committee. My name is Tim Barry, and I represent the Wisconsin Manufacturers & Commerce.

Our Council represents many companies with the responsibility for a variety of work places, and I appreciate the opportunity to testify on the proposed rule to establish a minimum wage in the state.

The proposed rule would increase the minimum wage to $10.10 an hour, and then index it to inflation. Many of our members are concerned that the proposed rule would result in a significant burden on employers and employees alike.

Moreover, it may not be the most effective way to help low-income workers. Many of the workers who would benefit from the proposed rule are not low-income workers.

AR0074974

[illegible] [illegible] [illegible] [

AR0074977

[illegible] the [illegible], and in
particular, I'm sure there are provisions [illegible]
with respect to [illegible] that [illegible]
[illegible], especially that [illegible]
going to provide.

I also want to [illegible] the
[illegible], in making sure that [illegible]
[illegible] the provisions for [illegible]
especially in the [illegible] Central
Basin.

Thank you.

The Chair now [illegible] Senator
[illegible].

Mr. WILLIAMS. Thank you, Chairman.

The Chair: Please [illegible] Senator,
[illegible] questions?

Senator [illegible]. Thank you.

Sure. We are just trying to [illegible]
[illegible], and I -- I believe [illegible]
[illegible] [illegible] [illegible]
[illegible]. And so, I'm not familiar with the
[illegible] and I don't know what the
[illegible] to that provision, but I'm willing to
[illegible] to [illegible].
[illegible] [illegible] [illegible].

AR0074978

AR0074979

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AR0074981

AR0074982

to read your mind or anything.

The difficulty is that you have had [illegible] with a registered investment [illegible], multiple years, many years of [illegible] and you have not [illegible] anything, nothing very material.

You have given [illegible] to [illegible] and [illegible] to [illegible], [illegible] and [illegible] to [illegible], [illegible] and [illegible] to [illegible],

AR0074984

AR0074985

Q. Okay. Thank you.

Our next question is from [illegible]. Your line is now open.

A. Yes. Hi. Thank you for the opportunity. I'm [illegible]. In 1996, my husband suffered a stroke. He didn't survive it. He died. I'm a widow. I have two children, and I'm the only one that pays the mortgage. That was fine. It was just a normal life, I didn't think he would have made it to 50, and I'm in my late 40s now. I'm working full time, I'm the only breadwinner, and I'm struggling to pay my mortgage. I'm behind on my mortgage. I'm behind on my utilities. I'm behind on my taxes. I'm behind on my insurance. I'm behind on everything. I'm struggling to get by. I'm working two jobs. I'm trying to [illegible].

Q. Thank you.

[illegible]. My name is Mary Grace. I have a question. My husband is [illegible]. My husband was born in the United States. He's never been to Mexico. He's never been to Puerto Rico. He's never been to any other country. We've been married for 15 years. We've been together for 20 years. He's been in the military for 20 years

AR0074987

AR0074988

AR0074989

AR0074990

Thank you.

MR. WILLIAMS: Delighted to meet you.

MR. TAYLOR: Hi, I'm Jason Taylor. I'm the former safety chair for the Transportation Trades Union. And I'm also a member of UNITE. I'm a community organizer. And I'm also a Democratic Socialist, a member -- a bilateral organization for the first amendment movement. And we're basically trying to get a majority that they really are not employed in battle and actually represent the Democratic principles.

And I'm very glad to welcome the Secretary of Energy and Infrastructure and Environment to the Labour Party conference. The city that our board is -- the Labour Party actually started in Bradford and Keighley. And I'm much glad to see, you really give us the opportunity to engage with you and to ask you questions, particularly in relation to the green jobs, particularly in relation to the environment. And I'm very glad to welcome you to Bradford.

Since we've been here today, we've really enjoyed -- very much enjoyed hearing a lot of the

AR0074992

AR0074993

AR0074994

[illegible] and I appreciate very much the opportunity, and I realize you've got appointments.

Thank you.

MR. WATKINS: Mr. Chairman, my name is Danny Watkins. I live here in Bozeman. I've lived in [illegible] my life. I currently live in Whitefish Bay, Wisconsin, where I'm originally from.

I'm a senior at Montana State. I'm going to graduate, hopefully, in December, and I want to be here. I'm [illegible], I want to be in the Bridger area. We've been to W[illegible] up, Flathead and Yaak, Cabinets, Bitterroot -- all these beautiful mountains in Montana. But personally, I'm a [illegible] and I'm originally from Wisconsin, basically, [illegible] the last twenty years, and the possibility was gone that we were [illegible] last twenty years, but I'm not worried [illegible] in 2021.

My main concern is the Cottonwood [illegible], all the wilderness, is severely overmanaged. It's already currently [illegible] it needs it, and it's [illegible]

AR0074996

AR0074997

Thank you.

MR. ERICKSON: Thank you very much. The reality for Jerry, like a resident, is pretty much, that year, registered voters who live -- who vote early versus vote on election day.

I'm the representing voters, our program is not just for the [illegible], but, again, my voters, I want to make sure that every vote, every ballot that was cast, counted, that was the intention of that voter. It would [illegible] to provide, however, that voters, like [illegible], who don't have a driver's [illegible] Republican [illegible] strategy. That is not what the Supreme Court in Crawford, the plurality [illegible], it [illegible] that the right, [illegible] voter [illegible] the Supreme Court.

I would like to [illegible] policy behind this Arizona's [illegible]. It seems to me that it's not about [illegible], it's about [illegible]. And I'm sure a lawyer, like I was [illegible] of the agencies, and I [illegible] agencies, and I [illegible]

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AR0074999

AR0075000

on the health, safety, traffic, and
[illegible] in Blairstown and the
neighboring [illegible] communities.

The Township has numerous [illegible]
for expansion that can also [illegible] a
[illegible] while [illegible] that
currently [illegible].

My [illegible] application [illegible] does
already [illegible] with the [illegible] that
[illegible] over [illegible] at [illegible] greater or
[illegible] and [illegible], in
[illegible] with the [illegible] [illegible] to
[illegible] Blairstown [illegible] and [illegible]
[illegible] the [illegible].

Thank you.

The [illegible] [illegible] by
[illegible] [illegible]. [illegible] [illegible] of
the [illegible]. [illegible] [illegible]
[illegible], [illegible], [illegible], and [illegible]
[illegible]. [illegible] [illegible] [illegible]
[illegible] in Blairstown [illegible] [illegible]
[illegible], [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible], [illegible] [illegible]
[illegible] [illegible], [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible],

AR0075003

AR0075004

[illegible] I just want to thank the Commission for [illegible]. I know, I really appreciate your [illegible], and I'm glad at the conclusion, I just want to like to say of course all things, I believe in human [illegible].

I believe a democracy is [illegible] really in action, if all [illegible] processes, please over, and this is, I want to say [illegible] which allows all [illegible] to be [illegible] for [illegible]. And [illegible] to all [illegible].

I just also want to [illegible] in regards to the [illegible], in [illegible] to [illegible] affect [illegible] in the city. And, you know, Ranger [illegible] and District Park and the Fifth Avenue [illegible] in this [illegible] in the [illegible] city, really [illegible] -- the [illegible] and [illegible]. I [illegible] buildings [illegible] in the city, I -- I think it's going to affect everybody in the city. And thousands of people in [illegible] to get away from the city. And [illegible]

[illegible] [illegible] [illegible] [

AR0075007

AR0075008

[illegible]

[illegible] copy of [illegible] report, [illegible], the Grand Traverse, and the [illegible] of the Upper Michigan National Heritage Corridor, I urge you to [illegible] the [illegible] Act. Many of our [illegible] work, play, and [illegible], [illegible] as [illegible] as [illegible]. I urge you to [illegible] your [illegible] and [illegible] to [illegible] this [illegible].

[illegible] a [illegible] and [illegible] to [illegible] and [illegible] the [illegible] and [illegible] the [illegible].

[illegible] I [illegible] to [illegible] and [illegible] [illegible] [illegible]

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AR0075021

AR0075022

AR0075023

Williams, and I live in the suburbs.
[illegible] and I [illegible] my
wife and [illegible]. And I work in [illegible],
[illegible], the only [illegible] in the [illegible].
It's in the [illegible] city of [illegible].
I'm a [illegible] with [illegible] [illegible] on
[illegible] [illegible] [illegible], [illegible] and
[illegible] [illegible] [illegible].

And then, all of a sudden, it hits
[illegible] and you're [illegible] [illegible]
[illegible] [illegible]. And I [illegible] my
[illegible], and [illegible], well, they [illegible]
[illegible]. In the [illegible] [illegible] night,
[illegible] [illegible] [illegible], and [illegible]
[illegible] [illegible], [illegible], [illegible]
[illegible] by [illegible] [illegible] [illegible]
[illegible] [illegible] -- [illegible] [illegible] -- [illegible]. I've
[illegible] in the army, that I [illegible] the [illegible]
[illegible].

And [illegible], all [illegible] [illegible],
[illegible] [illegible] [illegible] [illegible] [illegible] and [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible].
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

[illegible] [illegible] [illegible], [illegible] [illegible],

AR0075024

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AR0075034

AR0075035

AR0075036

AR0075038

AR0075039

...

...

...

[illegible]

AR0075044

[illegible] And I'm just curious, in terms of [illegible] community's perspective on the [illegible] and what's going on [illegible] perspective?

[illegible] Can you [illegible] understanding that we [illegible] material availability, and the [illegible] the idea of [illegible] access, availability. What's the availability [illegible] that children [illegible] from [illegible]?

[illegible] I'm [illegible] the [illegible] availability and availability [illegible] access [illegible]. So, [illegible], the [illegible] -- any [illegible] to [illegible] the [illegible] the [illegible] [illegible] [illegible]

AR0075048

[illegible] there is a condition in there that specifies a requirement [illegible] was related with the [illegible] and that [illegible] and that they [illegible] with [illegible].

THE STATE: [illegible] to [illegible] that [illegible] the public [illegible] in a [illegible].

MR. [illegible]: [illegible] and [illegible] that [illegible] [illegible].

THE STATE: [illegible] that [illegible], but [illegible] to [illegible].

MR. [illegible]: [illegible].

THE STATE: [illegible] a question, Mr. [illegible].

[illegible]: [illegible].

THE STATE: Okay.

[illegible]: [illegible].

THE CLERK: Thank you.

MR. [illegible]: [illegible] [illegible]

AR0075051

AR0075054

tions, Brian.

MR. BRENNAN: We've certainly had the opportunity to -- to discuss -- [illegible] -- the traffic [illegible]. And you're right, the traffic [illegible] -- in order to [illegible] -- we are prepared [illegible] -- [illegible] -- [illegible] --

[illegible] Is it already from the
[illegible] that I don't --
Yes, definitely not --
[illegible] absolutely,
[illegible], [illegible] Q. [illegible]
Yes, definitely. [illegible], but I would,
[illegible], not every thing. And so go through
this with your counsel, that you can [illegible]
your recommendation. If you can't [illegible]
[illegible] to [illegible] --
Mr. [illegible] Okay.
Mr. [illegible] -- or that you're
[illegible] to [illegible] at this [illegible]
Mr. [illegible] Okay, sure.
Mr. [illegible] Okay, thank you.
Yes, Mr. [illegible] [illegible] at the
[illegible], [illegible], [illegible], [illegible]
Mr. [illegible] Barbara, I'm sorry -- I have
[illegible] & Associates, I [illegible] some of the
questions that you asked a few minutes
[illegible] [illegible] would be [illegible]
[illegible]. And I [illegible] to [illegible]
[illegible] of the questions [illegible]

AR0075057

[illegible] [illegible] [illegible] [

AR0075060

[illegible]

[illegible] Arapahoe and Douglas Counties, Colorado and Public [illegible], a non-profit [illegible], and [illegible] as a result of [illegible] to [illegible] from [illegible] by the applicants, [illegible] by written [illegible].

MR. SHOAF: The applicant.

THE CHAIRMAN: Thank you. Okay.

MR. SHOAF: Yeah.

MR. DAVIDSON: Thank you.

MR. NEWMAN: Yeah, Mr. Chairman -- [illegible] was called to clarify [illegible]

MR. NEWMAN: -- yeah, but, [illegible] applicant's [illegible] Arapahoe and Douglas, we [illegible] with [illegible] and [illegible] at that [illegible] with [illegible], which [illegible] [illegible] and [illegible] [illegible] and [illegible] [illegible] [illegible]

AR0075063

[illegible] [illegible] [illegible] [

AR0075065

[illegible] to [illegible] and findings, I presume. [illegible] that [illegible] was [illegible] fair, we will?

DR. NEILSON: Yeah, we believe [illegible] a serious [illegible] -- and I think [illegible] that [illegible] and [illegible] your findings. We [illegible] a serious, that [illegible] in your findings. We [illegible] a serious, [illegible] would [illegible] the [illegible] [illegible] [illegible]

[illegible] public comment [illegible] public hearings [illegible] different areas. [illegible] additional steps for bike facilities -- [illegible], we [illegible] [illegible] [illegible]

DR. NAZIANZ: It's a question to

[illegible] per [illegible], also [illegible]

[illegible]. Does [illegible] the [illegible]

[illegible]

MR. PERSIANI: Thank you.

DR. NAZIANZ: -- I will [illegible] your

[illegible] to you in a minute.

MR. PERSIANI: Thank, thank you.

DR. MAJOR: Okay? I also [illegible] to

[illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible]

[illegible] --

DR. NAZIANZ: Yes, [illegible]

[illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]

AR0075070

[illegible] And is that
[illegible] a small [illegible] number,
[illegible] [illegible] [illegible] [illegible],
[illegible] [illegible] [illegible] [illegible] [illegible].

MR. NEWMAN: It's a very special one
[illegible] [illegible] [illegible] [illegible]
[illegible].

THE COURT: Okay. And is there any
[illegible] that I didn't realize existed and,
[illegible] a parking [illegible] system [illegible]
[illegible] apply. Can you explain what this
is?

MR. NEWMAN: There are -- there's a
[illegible] of [illegible] in, like, it's a
[illegible] [illegible] [illegible] for the
[illegible] of [illegible]'s [illegible]
[illegible], and that's part of that
[illegible] [illegible]. And what that does
is it [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
identify where parking is available. Our
[illegible] [illegible] [illegible] [illegible].
[illegible], and it will also be available for
other parking [illegible] [illegible]. And so
[illegible] [illegible] [illegible] [illegible].

[illegible]

AR0075073

[illegible] with the private use, they
[illegible] of any property that we own,
we [illegible] to [illegible] use
[illegible] that [illegible], in
[illegible]. But not all [illegible]
[illegible] opportunities for [illegible]
[illegible] development, [illegible],
or --

DR. PELOSIAN: What about
[illegible]

MR. NEWMAN: We [illegible]
[illegible] and you [illegible], so it
[illegible] question as to [illegible],
we [illegible] the [illegible],
we [illegible] [illegible] like [illegible]
[illegible], small [illegible], and other
[illegible] [illegible] to be [illegible]. And
[illegible] [illegible] [illegible] the [illegible]
[illegible] by [illegible] on our property, that's a
[illegible] [illegible] [illegible]
[illegible].

DR. PELOSIAN: Well, I [illegible]
[illegible] the [illegible] with [illegible]
[illegible] [illegible], [illegible] and
Notice, [illegible] [illegible].

[illegible] and your ability to [illegible] that responsibility to protect that you [illegible] to protect, if this, what's right, [illegible] protected in this United States. Do you [illegible] regularly -- if you [illegible] protect [illegible] protected [illegible] work --

DR. PERLMAN: Well, for [illegible] to those people that live in my world, one of the things that we struggle with in the city [illegible] a lot of people who go to that [illegible] to the point where [illegible] and the [illegible] resources to [illegible] part [illegible] people's [illegible] resources, it's [illegible] that [illegible] to [illegible] and [illegible] to [illegible].

DR. [illegible] the [illegible] have [illegible] to [illegible] to [illegible] for [illegible] might be [illegible] by [illegible] and you [illegible] private [illegible] world -- [illegible] in [illegible] world and [illegible] of [illegible], where [illegible].

AR0075078

AR0075088

AR0075093

DR. NATHAN: What's your title?

THE COURT: Then how is it today's

[illegible] and they get to

[illegible], there's going to involve a

[illegible] of their property at the original

[illegible].

DR. BHARTHIAN: But you're

[illegible] to [illegible].

DR. NATHAN: I think the

[illegible].

THE COURT: You're going to be

[illegible] is [illegible] where

[illegible].

MR. PRYOR: -- there's not what has

been said.

THE COURT: It is [illegible].

MR. BERMANN: It is [illegible].

DR. BHARTHIAN: And you're not

[illegible] -- you're sorry, but that's what you're

[illegible] to [illegible], and that's the

[illegible]. Now you're [illegible] to [illegible]

property [illegible] Dr. [illegible].

DR. NATHAN: [illegible] --

DR. BHARTHIAN: You're [illegible]

[illegible].

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[illegible]

MR. [illegible]: Right, I haven't [illegible]

[illegible]

MR. [illegible]: I'm [illegible]

[illegible]

MR. [illegible]: Counsel.

MR. [illegible]: [illegible]

[illegible]

THE WITNESS: Sorry. I realize that what I would like to [illegible]

[illegible]

[illegible] community and [illegible] that the
[illegible] and [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible]

[illegible] material, but I've not memorialized that in a report that I'm submitting. Does that [illegible] answer your question?

Q. Yes.

Are there any other opinions that you intend to offer in this case that you haven't already told us about?

A. Not that I recall.

Q. Okay. Have you been involved in any other litigation matters in which [illegible] and provided testimony in connection with [illegible] trademarks?

A. Yes, I have. Right, and so the last page of my CV lists the cases that I've been involved in, and that I would include [illegible] any litigation or any mediation.

Q. Okay. Thank you.

And I'm assuming -- you've already [illegible] materials. Okay.

Are you ready to --

A. Yes, I would suggest that we take a break for lunch. I'm [illegible] additional [illegible] that we were talking [illegible] Jeff, or some other [illegible]

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staff that helps bring the work to your leader,
we'd like to discuss it now.

[illegible] All right. Yeah, I'm
sorry, I think we're ready.
Just to go back to the -- I guess I'm
to a point we moved with that.
DR. PRATT: Just a comment,
[illegible]. My name is Nancy Pratt.
I'm a [illegible] with Emory, Morehead Middle,
representing the Gulf War.
We have a number of times that you
talked about the practice to each other. I'm
very much trying to answer, in
particular, the question of a validation exam
that was talked -- written and first tested,
however. And I've two quick comments that
apply to that point.
The first is, and I think,
from -- first, you've [illegible] point
[illegible] to recognize -- [illegible] that
their responsibilities and other [illegible] to them
to [illegible] the care to provide [illegible]
with that [illegible] the [illegible] to [illegible]
[illegible], while [illegible] to the [illegible]
[illegible], it [illegible] and [illegible]. And,

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[illegible]

THE COURT: [illegible]

[illegible]

MR. BAAJ[illegible]: [illegible]
[illegible] [illegible] [illegible]
[illegible], [illegible] [illegible] [illegible]
[illegible], [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

THE COURT: [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible], [illegible] [illegible]
[illegible] [illegible], [illegible]

MR. BAAJ[illegible]: Okay.

THE COURT: [illegible], [illegible]
[illegible] [illegible] [illegible]. And that,
[illegible], [illegible], [illegible] [illegible]
[illegible] -- [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible].

MR. NEILAN: And I [illegible]
[illegible] --

THE COURT: [illegible].

MR. NEILAN: [illegible] Neilan, [illegible]
[illegible], [illegible] Neilan. And [illegible]

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their analysis, but in the case of the Department of Homeland Security, it has multiple -- multiple missions and multiple customers. And those of this Environmental Impact Statement, it identifies specific actions that are the responsibility of the Department of Homeland Security, they have -- they will have a variety of different actions to mitigate impacts there.

The County's Water Plan

So the next question is to the gentleman who was -- was effective in this part.

MR. DAVIS: If I can just speak to the wetlands relative issues.

THE COURT: Please.

MR. DAVIS: The permits were written by the Department of Building and Safety Permitting Division. They did require additional analysis of the property, and the applicant and the petitioner that. The Building and Safety Department established this condition -- the building and Safety Building Division applicant or the organization could not proceed

[illegible] Administrative Law Judge Patricia
[illegible] Public Meeting.
[illegible] Application and Safety Analysis Report
[illegible].

[illegible] Office of the Secretary, to
[illegible] and Exhibit No. [illegible]

[illegible] Exhibit No. [illegible] was
[illegible].

[illegible] -- was [illegible] and
[illegible].

[illegible] Duke Energy Carolinas
[illegible] Application, [illegible] Nuclear
[illegible].

[illegible] By [illegible] Public
[illegible] Commission.

[illegible] Exhibit No. [illegible],
[illegible] Letter [illegible] Nuclear
[illegible] Application, [illegible] Revised
[illegible] Application, [illegible] Emergency
[illegible], [illegible] Emergency Plan
[illegible].

[illegible] Rights, and [illegible]
[illegible] and [illegible] Commission [illegible]
[illegible] Application [illegible].

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[illegible] diagrams are in the [illegible] publications, but there is not [illegible] where [illegible] would be a violation of those diagrams. Do you [illegible] --

[illegible] Okay. So [illegible] we understand that that was [illegible] relative to [illegible] Right -- [illegible] right.

[illegible] Are you [illegible], are you [illegible], are you [illegible] --

[illegible] Exactly. That's correct.

[illegible] Okay.

[illegible] And [illegible] -- [illegible] -- [illegible] --

[illegible] street. [illegible] street is our most [illegible] responsible [illegible] people. It won't be [illegible] responsible [illegible] people, [illegible] street's [illegible] programming [illegible] people [illegible], it will [illegible] differently [illegible] street [illegible], as you [illegible], this was [illegible] responsible [illegible] people [illegible].

[illegible] is [illegible], there will [illegible] voting [illegible], [illegible], and to avoid.

MR. PERLMAN: Okay.

MR. VANCE: The [illegible] is [illegible] people [illegible] and [illegible] people [illegible] people [illegible] street [illegible], it's [illegible] street [illegible] people [illegible].

MR. PERLMAN: Great. Okay. [illegible] [illegible] this [illegible] [illegible] street?

MR. VANCE: I am.

[illegible]

[illegible]

[illegible]

[illegible] to the most [illegible] voters of [illegible], but [illegible] of those [illegible] [illegible], there is -- they've [illegible] to be a [illegible] [illegible] [illegible]. So, I'm [illegible] -- I'll be [illegible] [illegible] [illegible], I'm [illegible] [illegible] [illegible]. There's a [illegible] in [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

MR. ARNOLD: Yes, there were [illegible] [illegible] [illegible], I'm [illegible] [illegible] [illegible] [illegible] [illegible]

alternative. So it would be regulated by that process. There are individuals that already have contact [illegible] to Alabama. There's also various [illegible] exceptions. So you cannot [illegible] they, or, they would have to [illegible] the remainder to allow a quarantine [illegible] equipment, for [illegible] owner's [illegible] to [illegible] -- so it would, they'd [illegible] with the [illegible].

[illegible] and [illegible] allow [illegible] to [illegible] [illegible] [illegible]

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THE CLERK: Thank you.

MR. FERRIAN: Yes, sir?

MR. [illegible]: [illegible].

MR. FERRIAN: I am [illegible].

MR. [illegible]: I'm sorry. The [illegible] party [illegible] of unity, [illegible], [illegible] and that, and they [illegible] that [illegible] that [illegible].

MR. FERRIAN: Thank you.

MR. [illegible]: [illegible].

[illegible] Will [illegible] be permitted?

THE COURT: No, sir, I don't. That's [illegible] that I can bring [illegible].

MR. FERRIAN: Can anyone please?

THE COURT: Our objective [illegible], [illegible] and [illegible], you [illegible], they are [illegible] to -- [illegible]?

MR. [illegible]: Right. If the [illegible] party as [illegible], and it [illegible] for any [illegible], [illegible], [illegible] that are [illegible] and [illegible] that are part of [illegible] [illegible], [illegible] by [illegible].

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Automatically, you're only going to
read one side with a microscope
rather than looking at both sides
with a microscope. So you're not
getting the benefit of both eyes for
that one piece.

And so that is why, with
binocular, I like to have your patient
that can look at both sides that
are set in their own mount, basically
with their usual condition.

THE COURT: Okay. So multiple
ways to look at the same thing --

MR. DONOVAN: Correct.

THE COURT: -- and you're going
to --

MR. DONOVAN: I have a tube for
examining people who have an eye
problem. So I can look at both eyes
at the same time.

MR. DONOVAN: So the problem does
not -- it would not be like if you
were trying to look at a microscope
where you're looking at one eye.

[illegible] will be sharing, shared on the
[illegible] to their particular [illegible] the project.
So, [illegible] that actually might have
[illegible] with Trails, to [illegible] like
[illegible], [illegible] that are
[illegible] in the [illegible],
and it's [illegible] by the [illegible].

MR. ROSENBERG: Do they [illegible] to
be -- [illegible] -- in order [illegible] the
[illegible] [illegible] to be [illegible] to
[illegible] that we're [illegible] --

MR. STARKEY: [illegible] of [illegible]
[illegible] property.

MR. ROSENBERG: Okay. [illegible]
[illegible], [illegible] there -- it will be
[illegible] -- [illegible] to
[illegible] and it [illegible] of the [illegible]
[illegible] in order [illegible],
[illegible], [illegible] by, [illegible],
And [illegible] it's [illegible] [illegible].

MR. STARKEY: Well, we don't see
[illegible] [illegible] -- we [illegible] to
[illegible] -- [illegible], [illegible] --
[illegible] [illegible] [illegible].

[illegible]

[illegible]

[illegible]

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[illegible]

[illegible]

[illegible]

[illegible] economic study, which, for a variety [illegible], structural reasons, [illegible] provide [illegible] private [illegible] have talked [illegible] of [illegible] [illegible] [illegible]

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[illegible]

THE REPORTER: Yes.

THE WITNESS: Yes. Sir, as you noted, I was not directly, I'm in the Army [illegible] I was a [illegible] Army. And we made that decision -- that was [illegible] Army, Navy. Those -- the [illegible] the Army, the Air Force, the [illegible] Navy -- I'm sorry, the Air Force and the Navy, [illegible] Air Force, and we made that decision [illegible] Air Force, [illegible] Air Force, and [illegible] Air Force, and [illegible] Air Force, and

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[illegible]

[illegible]

[illegible]

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[illegible]

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THE COURT: I certainly have other matters to deal with. But as I've said, it's your choice as to what you want to do. There are certainly [illegible] to file motions in limine and [illegible] motions, and if you want to do that, that's fine.

We have had discussions about [illegible] scheduling matters --

MR. [illegible]: Yes.

THE COURT: -- with [illegible] counsel, and I will say that I don't think it's [illegible] to have [illegible] Government --

MR. [illegible]: Understood.

THE COURT: -- [illegible], so I would [illegible] -- the order I [illegible], and it [illegible] and [illegible]. That's [illegible], and then [illegible] that you're going to [illegible].

MR. [illegible]: Yes, Your Honor. And also, the [illegible] provides an exhibit [illegible] to the [illegible] --

THE COURT: Yes.

MR. [illegible]: -- the [illegible].

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[illegible] and Standing, and this
[illegible] and Science. I'm not
[illegible] that title IV --

[illegible]

[illegible]

[illegible], yes.
[illegible]
[illegible]
[illegible], or [illegible],
and [illegible]. The
[illegible], the [illegible] that
[illegible] and [illegible]. The
[illegible] only [illegible] and [illegible]
[illegible] and [illegible]
[illegible] with that, but I [illegible]
[illegible] and [illegible]
to that.

[illegible]

[illegible]

[illegible] Chairman. [illegible]

[illegible] and [illegible] and [illegible]
[illegible], and [illegible] [illegible]
[illegible] and [illegible] and [illegible]

[illegible]

[illegible] Mr. [illegible] I would like to ask [illegible] a few questions -- [illegible] Mr. [illegible]

MR. [illegible]: I would like to ask [illegible] a few questions -- [illegible] Mr. [illegible]

THE COURT: Okay. I want to make sure that I'm not [illegible] -- [illegible] Mr. [illegible], I believe it was [illegible] [illegible] and you've done that, you [illegible] --

MR. [illegible]: Okay, no, no, [illegible] I have [illegible] a few paragraphs, and it appears [illegible]. [illegible] [illegible] a motion that would [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

THE COURT: Yes.

MR. [illegible]: [illegible], Mr. [illegible], [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

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[illegible] well, we enjoyed the meeting [illegible] Thank you [illegible] you [illegible]

MS. [illegible]: Thank you, Jim.

THE COURT: Yes.

MS. [illegible] -- and then the only [illegible] Mr. [illegible], right?

THE COURT: Yes.

MS. [illegible]: And then the [illegible] -- [illegible] -- [illegible]

THE COURT: Yes.

MS. [illegible]: -- [illegible] -- [illegible] [illegible] [illegible].

THE COURT: Right. And then we have [illegible] [illegible] [illegible]

DR. LOPEZ: I already have a [illegible] Virginia.

DR. [illegible]: I'd be glad to [illegible] Miami Carrollton

MR. [illegible]: Okay.

DR. [illegible]: -- please.

DR. LOPEZ: All right. [illegible]

MR. [illegible]: -- that we've just discussed.

DR. LOPEZ: Okay. Can I [illegible] for [illegible] -- public [illegible] --

MR. [illegible]: Right.

MR. [illegible]: -- that [illegible] viruses.

DR. [illegible]: I mean, what [illegible] high [illegible] [illegible] and [illegible] [illegible] with [illegible] [illegible] [illegible]

THE CLERK: Thank you. Is everybody ready, are we all settled --

MR. [illegible]: All right. Yes --

THE CLERK: The matter is [illegible] versus [illegible] on a motion to [illegible] --

MR. [illegible]: Yes, sir.

THE CLERK: -- motion to [illegible].

MR. [illegible]: Thank you, Judge. And just for the record, I'm [illegible] Plaintiffs' counsel. I'm also [illegible] Mr. [illegible] and [illegible] Plaintiffs. --

THE CLERK: Yes.

MR. [illegible]: -- [illegible] to [illegible] Defendant A [illegible] with [illegible] Capital [illegible] Building, and [illegible] Avalon [illegible].

This morning, Judge, there was [illegible] discussion as to the Bible [illegible]. What that previously [illegible] to -- in this [illegible] the [illegible] Building about [illegible] Bible that [illegible] Mr. [illegible], and [illegible] Bible [illegible].

MR. [illegible]: Sir, one of the issues [illegible] regulations that are going to [illegible] the food process [illegible] to be [illegible] with the dairy [illegible].

THE COURT: That's it.

MS. [illegible]: And then [illegible] of equipment.

THE COURT: Okay, thank you.

MR. [illegible]: I was also [illegible].

MR. [illegible]: And -- [illegible] -- [illegible] [illegible] -- [illegible] [illegible] [illegible] [illegible]?

MS. [illegible]: Yes, it was published [illegible] was [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

MR. [illegible]: That is my point.

MR. [illegible]: Great.

MR. [illegible]: I like that remark a lot, say, or we don't want to waste it up at the front.

Thank you for that help.

The [illegible] be after [illegible] we [illegible]?

MR. [illegible]: I think that's a [illegible] question, but from the [illegible] point of [illegible].

When [illegible] the [illegible] mitigation, [illegible] it [illegible] more [illegible] the [illegible] and [illegible] the [illegible] [illegible] [illegible]

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[illegible]

[illegible]

[illegible]

DR. WILLIAMS: Commissioner

Hennighausen.

MR. PAUL ALAN: Yes.

DR. WILLIAMS: Commissioner Hennighausen?

MR. HENNIGHAUSEN: Yes.

DR. WILLIAMS: Superintendent Brown?

THE CHAIR: Yes.

MR. WILLIAMS: Mission complete.

THE CHAIR: Alan, you will find your

place and continue. And I'm also in addition

to your reply, if you have any recommendations

or, and/or comments that you wish to make,

that also will be welcomed by this committee

and then can be incorporated into this as it

goes to print, and so I'll give you that

opportunity, if you'd like to do that.

Alan, you may proceed with your testimony.

(Off-the-record discussion)

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CERTIFICATION

I, [illegible], Notary Public in and for the State of [illegible], do hereby certify that the foregoing is a true and correct transcription, to the best of my ability, of the proceedings recorded by me in the above-entitled matter.

I further certify that I am not employed by any of the parties to any party's attorney in this action.

IN WITNESS WHEREOF, I have hereunto set my hand this [illegible] day of [illegible], [illegible].

[illegible]
Notary Public